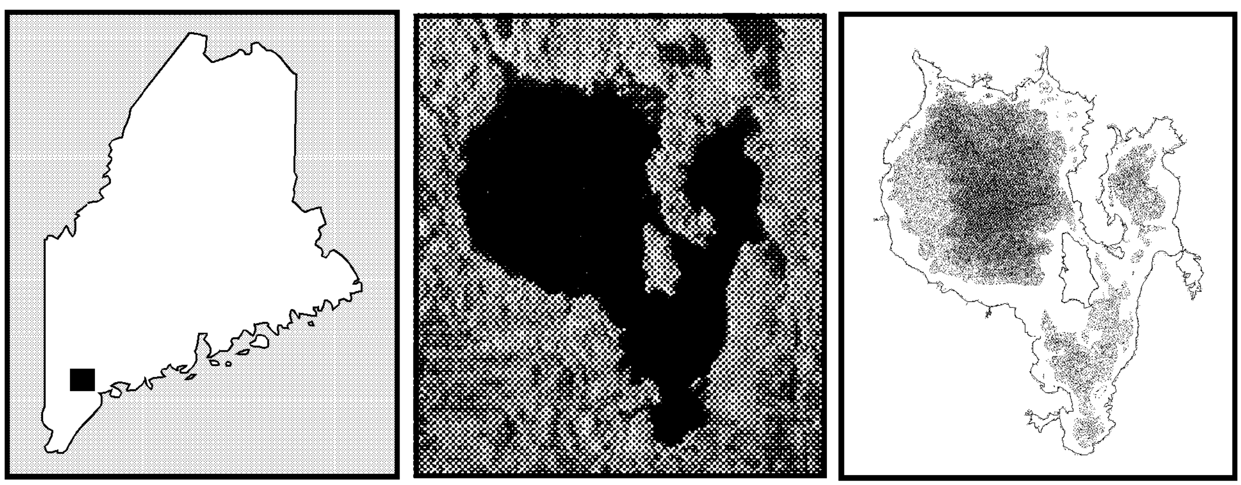
Beach Dynamics of Sebago Lake

A Report on the Results of Beach Profiling



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Maine Geological Survey
Natural Resources Information and Mapping Center
DEPARTMENT OF CONSERVATION
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Related Publications

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Johnston, R. A., 1998, Shoreline classification of Sebago Lake, Maine: Maine Geological Survey, Open-File Map 98-123, scale 1:24,000.

Lewis, E. B., and Johnston, R. A., 1998, Slope stability / shoreline classification map of the Songo River, Maine: Maine Geological Survey, Open-File Map 98-124, scale 1:4,000.

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ABSTRACT

Sebago Lake, located in southwestern Maine, is the site of this shoreline change study. This study follows up on a previous investigation (Dickson and Johnston, 1994) that reported on three years of beach profiling at the north end of Sebago Lake. This report includes an additional three years of beach profiling data at those sites and describes three years of beach profiling at 12 more sites at 6 beaches around the perimeter of the lake. The additional sites cover a variety of compass-facing directions. In addition to beach profiling, a shoreline classification and mapping project was completed to determine the types and extents of different shoreline environments around the lake; and a monitoring program for eroding bluffs was initiated.

Mapping for the shoreline classification project was done by boat and tape measure using 7.5 minute topographic maps as a base. The results show the following types of surficial materials around the perimeter of the lake: till (a mixture of sand, silt, and clay), glacial outwash (sand and gravel), silt, clay, and wetland deposits (silt and decaying plant material). The shoreline environment classes mapped are marsh, sandy environments (sand beach, seawall behind sand beach, groins with sand in between rip rap, bluffs behind sand beach, and sand beach with boulders present), till, artificial fill, and bedrock. Till is the dominant environment mapped, followed by sand beaches. Two maps present the results of the study: a shoreline classification map of Sebago Lake (Johnston, 1998), and a similar shoreline classification map showing the Songo River from the Songo Lock to Sebago Lake (Lewis and Johnston, 1998).

The bluff erosion monitoring program began in the summer of 1996, on six eroding bluffs. Permanent markers (steel pins) placed at measured distances along the bluffs were surveyed with a total station and data was collected through the spring of 1997. This program documented minor erosion over this short time period, and further monitoring of these sites is recommended because bluffs tend to recede episodically.

Results of beach profiling showed that most beach changes are transient seasonal changes related to ice processes and water level fluctuations. Beaches were stable over the study period until the fall of 1996, when the south-facing beaches and one east-facing beach experienced catastrophic erosion as a result of a combination of weather events that raised the lake levels to their maximum and later brought high winds out of the south with associated high waves. These large-scale changes are expected to be long-lasting. Minor erosion events occurred during spring high water in two years, but were not long-lasting. Erosion events that occurred in the fall of 1992 and 1995, although they involved large volumes of material, were restored within a year.

A picture of beach dynamics emerges in which long-term stability is punctuated by sudden large, long-lasting changes caused by storms during high water periods.

INTRODUCTION

Purpose

The Maine Geological Survey, F. M. Beck, Inc., and Portland Water District undertook studies to evaluate the erosion potential of specific sedimentary environments at Sebago Lake, Maine. The work determined types of materials, their erodability, whether or not erosion or accretion has occurred at a variety of sites, and the influence of water levels and other environmental factors on the shoreline of the lake. These other factors include ice action, weather, human influences, and currents.

Sebago Lake, Maine's second largest lake, is located approximately 20 miles northwest of Portland (Figure 1). The lake covers a surface area of approximately 47.5 square miles and is 316 feet deep. It is the deepest lake in Maine. Sebago Lake serves as a public water supply for approximately 160,000 people in the Portland area. Erosion of sand bank sediments due to water level changes may affect water quality in the lake.

The Sebago Lake environments studied include river banks, lake beaches, and bluffs. Bottom sediment studies are in progress (Johnston and others, 1994). The first step was development of a shoreline classification map for Sebago Lake to identify sites for further study (Johnston, 1998). Based on this map, beach and bluff sites were chosen for profile location. The study examined up to seven years of sand beach profiles to determine the cause and extent of erosion and accretion at the sand beaches around Sebago Lake. Beginning in 1996, six eroding bluffs on the lake were studied to determine the seasonal patterns of bluff erosion and its controls (Smith, 1997). In 1996 the Songo River banks were classified according to their erosion potential (Lewis and Johnston, 1998). Both the beach and bluff studies were a cooperative effort between the Portland Water District (PWD), the Maine Geological Survey (MGS), and F. M. Beck, Inc. of Yarmouth, Maine.

Artificial management of lake levels at Sebago Lake began in 1830 when the Basin Dam was first built by the Cumberland and Oxford Canal Company (Wheeler, 1994). The dam was originally constructed to provide for better navigation and to divert water to a newly constructed canal. The present full pool elevation is 266.65 feet above mean sea level. At the present time the water levels in the lake are governed by a water level management plan developed by S. D. Warren, the Federal Energy Regulatory Agency, the Portland Water District, various state agencies, and local citizen groups.

Shoreline erosion became a concern at Sebago Lake in the mid 1980’s when the S. D. Warren Paper Company, the owner of the dam, changed their water level management plan. Before 1986 there was no specific rule curve for the water levels. In 1986, S. D. Warren began to hold more water in the lake during the fall and winter months in order to obtain more cost effective electric rates. This raising of the water levels brought on an increase in the number of complaints about their management of the lake level. At a number of places around the lake, erosion of the sand beaches was reported due to the higher water levels.

Beginning in 1990, the Maine Department of Conservation, Bureau of Parks and Recreation, raised concerns that S. D. Warren’s water level management plan was increasing erosion at Sebago Lake State Park. In the late 1980's tree roots were exposed along Songo Beach (Figure 2). The exposed roots suggested that sand had been lost from the upper beach due to the higher water levels. The Bureau of Parks and Recreation asked the Maine Geological Survey (both agencies are in the Department of Conservation) to look at the erosion problem. As a result, the Survey established a network of beach profile stations along the sand beaches in the park. Ten stations were established in the fall of 1990 on Cub Cove, Songo, Naples, and Witch Cove beaches (Figure 3). In the summer of 1991, two more sites were added at Halls (Tasseltop) Beach, just south of Browns Point in Raymond (Figure 3). Dickson and Johnston (1994) published an open-file report based on the monitoring of these twelve sites during the open-water season.

Due to the increasing concerns about shoreline erosion, Maine Geological Survey and Portland Water District staff, with assistance from the Friends of Sebago Lake (a local citizen’s group), initiated beach profile training during the fall of 1993. Another 34 sites were started in the fall of 1993 and four more sites were added on the sand beach at the southern end of Frye Island. This brought the total number of sites around the lake to 50 (Figure 3) and expanded beach profiling from the north end of the big basin and Jordan Bay to cover most of the sand beaches on the lake. Since their initiation, most of these sites have been profiled on a monthly basis during the open-water season, however some of the sites have been profiled only occasionally. The bluff sites were initiated in 1996, when six eroding bluffs around the lake were selected for profiling (Smith, 1997).

The main purpose of this study is to evaluate sand beach profiles to determine if erosion or accretion has occurred during the past seven years and to examine the processes that cause sand to move on and off the beaches. The authors examined over 466 sand beach profiles through December of 1996 and 23 bluff profiles (1996 and 1997) for indications of accretion or erosion. They considered weather, lake levels, and ice action when analyzing beach and bluff trends. Smith (1997) reported bluff erosion results. Refer to the section on Methods for detailed information on the methods used.

Geology of Sebago Lake

Sebago Lake is located along the boundary between the coastal lowland and central highlands of New England (Denny, 1982). Topographic relief in the region is low to moderate, with elevations ranging from 200 feet at the southern and eastern sides to 1300 feet to the northwest. North of Indian Island, the lake is underlain by the Sebago batholith, a Late Carboniferous - Early Permian intrusion of muscovite-biotite granite and pegmatite with an estimated age of approximately 290 million years (Hussey, 1996). The southern portion of the lake, below Indian Island, is underlain by Silurian metapelitic rocks of the Rindgemere Formation. These rocks consist of rusty and non-rusty gray to silvery muscovite-biotite-quartz schist (Hussey, 1996). The lake lies in a glacially eroded basin. Differential erosion of the two bedrock types developed a larger and deeper basin to the northwest where the lake is underlain by the granitic rocks, while the shallow and smaller basin to the south is underlain by the more resistant metamorphic rocks.

Continental glaciation strongly influenced the lake and the surrounding landscape. The remnants of the continental ice sheet left the Sebago Lake area thirteen to fourteen thousand years ago. When the area was depressed under the weight of the continental ice sheet, the ocean was in contact with the retreating edge of the ice sheet. Sebago Lake, and much of the surrounding landscape, was submerged below sea level. The inland marine limit during the most recent glaciation, approximately 13,000 years before present (Bloom, 1960), was in the vicinity of the Sebago Lake basin. That inland limit of the ocean has been identified on the Surficial Geologic Map of Maine (Thompson and Borns, 1985) based on the exposure of marine clay (called the Presumpscot Formation) along the shoreline near Whites Bridge and at the northern end of Jordan Bay (Bolduc and others, 1994). The Presumpscot Formation is not found along the shoreline of the big basin or on land north of the mapped marine limit (Thompson, 1976; Thompson and Smith, 1977). Surficial deposits presently exposed in the region include till, glacial outwash (sand and gravel), silt and clay, and wetland materials (Thompson and Smith, 1977). The age of Sebago Lake can be estimated to be approximately 13,000 years, a time when the ocean retreated from the area due to the isostatic rebound of the earth's crust after the retreat of the last continental ice sheet.

The Holocene epoch, the warm time period in which we live, began about 10,000 years ago. Since the beginning of the Holocene, only minor changes have occurred to the sediments in the Sebago Lake basin. The large sand deposits of the Songo and Northwest River deltas (Bloom, 1959) are evidence of the reworking of glacial deposits by fluvial processes. Rivers and streams deposited material in the lake basin forming thick deposits of sandy delta sediments. Sediments deposited along the shore and at the bottom of the lake are the result of erosion of materials exposed along the shoreline of the lake, at various levels throughout the Holocene. Processes acting on those exposed deposits of clay, sand and gravel, and bedrock include frost action and ice, wind and waves, longshore drift, and other fluvial processes.

Shoreline Processes

The sand beach and bluff ecosystems are the most dynamic of all the geologic environments at Sebago Lake. Important agents of shoreline change that affect those ecosystems are as follows: waves, wind, lake levels, storms, ice action, human interaction, and currents.

Waves. Wind and waves are the most important agents of shoreline change at Sebago Lake. Wind forms waves and their size depends on the strength and duration of the wind, as well as the distance the wave travels (fetch). The stronger the wind, the longer the wind duration, and the longer the fetch, the larger the wave. Waves created by boat wakes were not considered in this report, although in certain constricted areas of the lake they may play an important role.

In this report we consider the beach environment (Figure 4) to be the zone of modern, unconsolidated granular sediment that extends from the uppermost limit of wave action to the deepest water depth agitated beneath waves or "wave base." Wave base is a depth equal to 25% of the deep water wavelength (Komar, 1976). Beach profiles measured in this study typically extend underwater, but not far enough offshore to reach wave base. We estimate wave base to be approximately 24 feet (based on estimates below). Hence, sand exchange in the beach environment by waves can include the offshore lakebed beyond the limits profiled and illustrated in this report.

Wave action is a primary influence on the movement of beach sand (Komar, 1976). Waves that approach the beach at an angle cause sand movement along the shore called longshore drift. The direction of wave approach is controlled by the wind direction and wave refraction in shallow water. In addition, there may be seasonality in the wind speed or direction that may determine the volume of sand transported by longshore currents. In a study by Lorang and others (1993) in a Montana lake, the redistribution of annual wave energy (from that experienced by a natural lake) due to regulated lake levels caused increased beach erosion. In Montana, higher lake levels caused erosion in the stormy fall season when wave energy was greatest. Fall storms may play an important role in moving sand onshore or offshore or along the beaches at Sebago Lake.

In general, lake level restricted to one elevation (high or low) limits wave action to a relatively narrow part of the beach profile. A prolonged episode of single period wave action on a beach should produce a profile of "equilibrium." In reality, however, levels fluctuate due to precipitation, wind, barometric pressure, dams, etc. These fluctuating lake levels and wave heights will influence a wider range of the beach profile than a lake with a constant or narrow range of levels. Idealized profile adjustments due to lake level changes are shown in Figure 5. Unlike this ideal situation, waves are of various heights and periods and can arrive from different directions. These conditions vary seasonally, further complicating predictions of profile variation due to lake level changes. Consequently, an equilibrium profile, in the strictest sense, is never established. Instead, sand is always shifting in response to existing conditions. Extreme conditions, such as storm waves, can cause large changes that may take weeks or months to erase. A beach profile then, is the complex result of past events and includes episodes of both erosion and deposition.

Waves can be either constructive (depositional) or destructive (erosional) to a beach profile. Wave characteristics such as height and length as well as beach slope and grain size determine how sand will move under certain conditions. The process of landward movement of sand beneath shoaling waves is well understood and documented. The process called Stokes Drift (Komar, 1976) results from wave orbital friction and speed differences below wave crests and troughs. Sands on the outer part of the beach profile experience an oscillatory (onshore-offshore) motion below a passing wave. Smaller, constructive waves produce a stronger landward velocity which results in sand shifting landward beneath shoaling waves. Consequently, not all waves are detrimental to the beach. In fact, this landward motion of sand by Stokes Drift causes sand accumulation along the upper part of beach profiles and almost certainly helps maintain Sebago Lake beaches.

Sand can also be carried into deeper water where it would build up the offshore portion of a profile. This offshore shift in sand results in a lower-sloping profile with apparent erosion of the subaerial beach. The sand can be returned landward by a different wave type or by lowering the lake level. When the lake level is lowered, sand can be reworked back ashore (even by small waves) onto the upper part of the beach profile. Sand carried ashore leads to a steeper beach profile. As a result of profile steepening, high waves can travel closer to shore before breaking. This condition allows for greater scour near the waterline and erosion back to a flatter profile. In short, the profile response to waves and lake level continually changes (Figure 5).

Because no observational wave data were available for this study, a specific investigation has not been made of wave height and periods at the Sebago Lake profile sites. Such a study would help determine which wave conditions are constructional and which are erosional. Predicted wave heights were calculated in the Environmental Impact Statement on the relicensing of the Eel Weir Hydroelectric Project Dam (FERC, 1997). If lake levels remain high during periods of high waves then it is possible that erosion could occur in the upper portion of the beach profile. If lake levels were low during periods of high waves, then the lower portion of a beach profile would be eroded.

Beaches exist because of a balance between sediment supply and loss in directions both parallel and perpendicular to the shore. Shallow waters with sandy lakebeds can supply sand to beaches. The delta of the Songo River may be a sand source for Songo Beach. During periods of low lake level, the delta surface may be reworked more vigorously by waves and additional sand may be carried toward the beach. Similarly, deeper portions of the beach profile may be a source of sand to the beach. At times of low lake level, waves may rework the lower beach area and carry sand onshore or offshore.

In summary, wind-generated waves affect the shore, the swash zone, and the lakebed above wave base. Changing wave conditions and lake levels result in dynamic beach profiles that never reach a stable equilibrium. Wave size depends on fetch (distance of travel across the lake), duration of wind, wind direction, wind speed, and water depth.

Wind. The study of wind direction and occurrence in Dickson and Johnston (1994) showed that most of Maine's winds are influenced by prevailing westerlies (Tables 3-6 and Figures 9 and 10 in Dickson and Johnston, 1994). Winter winds have a strong northwesterly component, while spring winds have a southerly component. Summer winds also show a strong southerly component, while fall winds show a distribution from north to south (Dickson and Johnston, 1994). The strongest winds occur in the winter and spring, while the calmest winds are in the summer.

Another wind variable affecting wave heights is fetch. Fetch varies with direction from Sebago Lake beaches and ranges from 3.1 miles at Harmon Beach (Figure 19) to 9.1 miles at Rockwall Beach (Figure 16). The remaining fetches range from 4.2 to 7.1 miles (Figures 13-20). Larger waves can be built over larger fetches so the largest waves breaking on Sebago Lake beaches should come from the northwest onto Rockwall Beach (Figure 16).

Using a theoretical approach, the height of waves reaching Sebago Lake beaches can be approximated (Dickson and Johnston, 1994). Wave heights can be estimated graphically from nomograms based on wind speed and fetch (U.S. Army Corps of Engineers, 1984, p. 3-50). A maximum significant wave height for Songo Beach is 4.4 feet and period is 4.3 seconds and results from SSE gale force winds (winds 32 mph or greater). A gale will produce a 3.4 foot wave over a 6 mile fetch and a 2.4 foot wave over a 3 mile fetch.

At Halls Beach the maximum significant wave height for a SSW gale is 3.5 feet and wave period is 3.7 seconds. In the case of either the state park or Halls Beach, fully-developed ("deep water") waves can be created in as little as two hours. The significant wave height is the average height of the highest one-third of the waves (Komar, 1976). For Sebago Lake, wind duration and water depth do not restrict the maximum size of waves. Wind speed and direction (and hence fetch) are the two factors controlling maximum wave heights at the sand beaches. Gale force winds last for only a few hours each year, but could create significant wave heights in excess of 4 feet at Sebago Lake beaches. Waves will affect the beach in all seasons, but are reduced in importance in winter due to ice cover. Significant wave heights for the other sites are calculated in an environmental impact statement by FERC (1997).

Storms. Two types of storm systems have an impact on the Sebago Lake region: low pressure systems and tropical storms or hurricanes. The most common type of storm is the extratropical low pressure system which generally tracks in a southwest to northeast direction. When a low pressure system tracks to the east of the lake basin, close to or out over the Gulf of Maine, the winds tend to blow from a northeasterly direction (a "nor'easter"). When a low pressure system tracks well to the west of the lake basin (for example, up the St. Lawrence River valley) winds blow from a southerly direction on the lake. When a extratropical low pressure system tracks over the lake basin, storm winds blow from an easterly direction.

Hurricanes occur infrequently in Maine, but can produce significant size waves on the lake. These tropical systems originate in the low latitudes over warm ocean areas in summer and fall. Hurricane Bob tracked just east of Portland in August of 1991 with north winds of over 40 mph and gusts greater that 60 mph. However, since there were no established profile sites on any of Sebago Lake's north-facing beaches, no erosion was recorded.

Lake Levels. Lake levels, partially controlled by a dam, fluctuate up to five feet annually (Figures 6 - 12). Water levels determine where, and for how long, waves have an impact on the beach. Sebago Lake's normal maximum water level is 266.65 feet above mean sea level. Water levels above that elevation spill out over the Eel Weir Dam in Windham. The lake is usually at its highest level in May or June, and usually reaches its lowest levels in November. The months of November through mid-March generally show a water level between 262 and 263 feet above sea level, with a gradual rise in late-March through April to the 266.65 level in May or June.

Water levels have been a contentious issue in the lake basin since the mid 1980's when S. D. Warren changed their water level management plan. Reported cases of erosion increased at about that time. Beginning in 1994, the Federal Energy Regulatory Commission (FERC) reviewed environmental concerns in response to complaints about S. D. Warren's management of water levels. FERC (1997) prepared a final environmental impact statement which addressed water level management and beach erosion around Sebago Lake.

The water level management plan now in effect is the 1996 State of Maine Compromise Sebago Lake Water Level Plan (Figure 23). It lists five recommendations: (1) earliest full pond date - May 1; (2) maximum full pond duration - 3 weeks (between May 1 and the second week of June); (3) target level for August 1 - 265.17 feet; (4) target level for November 1 - 262.5 feet; and (5) target level for November 1 - January 1 period: 261.0 feet msl or lower two times in nine years. These recommendations were made in order to minimize erosion during early spring high water, to have ample water available for boat traffic during the summer boating season, and to allow, during the two out of nine low years, enough water level rise to bring sand up the profile onto the upper beach.

Ice. Ice covers Sebago Lake for approximately three months each winter when strong winds are predicted on the lake. Since winter wave action is reduced by ice, beach erosion by waves on the lake should also be reduced in the winter. However, another process that affects sand transport is ice action. Wind stress on the ice causes it to move across the lake and pile up along the shore. On the Ohio shore of Lake Erie, ice is suspected of causing beach erosion (Barnes and others, 1993). In the St. Lawrence River estuary ice may deposit sand along the shoreline (Dionne, 1993). Consequently, ice can have both erosional and depositional effects on a beach. Sebago Lake ice frequently incorporates and carries sand (Figure 21). In addition, ice physically plows frozen sand shoreward onto the subaerial beach.

Human Influences. Human influences on Sebago Lake's shorelines include foot traffic in sensitive areas, boat wakes, dredging, sea wall and groin construction, and recreational vehicle tracks. Foot traffic is noticeable on Songo, Halls and Harmon Beaches. Boat wakes cause problems when boaters create waves when exiting narrow channels such as along the Songo River in Naples. Dredging and groin construction in some areas cause the interruption of the natural movement of sand along the shoreline. Recreational vehicle tracks were occasionally visible on the beach at the south end of Frye Island and at the Standish sites.

Currents and Longshore Drift. Sebago Lake currents and longshore drift were studied by Charlie Page at Bates College (Page, 1996). His work showed that, depending on which direction the wind was blowing, sand would move in either direction along Songo Beach in Sebago Lake State Park. Much of the spit at Songo Beach appears to have been built by longshore drift and the movement of sand by currents. Lisius and others (1990) studied circulation in the lake at different water depths in the late 1980's and early 1990's. Their report showed that currents in the Lower Bay move in a counterclockwise direction. This result may affect the movement of sediment along the southern lake shoreline.

METHODS

Shoreline Classification

A field investigation of the Sebago Lake shoreline began in the late spring of 1992. By boat, the various shoreline sediment typeswere identified. Navigation was by compass, and the data was logged onto USGS 7.5' topographic maps. Three days were needed to traverse the entire 105 mile shoreline of the lake. In the office, cartographers digitized the 7.5' topo maps using the ARC/INFO geographic information system (Johnston, 1998).

In the spring and summer of 1996, a shoreline classification map was constructed for the Songo River (Lewis and Johnston, 1998). Methods used were similar to the Sebago Lake shoreline classification, but archive aerial photography was used to note historic riverbank positions.

Beach Profile Sites

Eighteen profile sites on eight beaches were selected for inclusion in this study. Table 1 presents descriptive information on each profile site. The grain size of the beaches ranges from medium to very coarse sand (Table 1). The beaches range in length from about 530 feet at Rockwall to over 3900 feet at Songo Beach. Beach profile sites were chosen on the basis of access, reported erosion, and facing direction. The beaches chosen for

TABLE 1. BEACH PROFILE SITES

Location	Site	Beach Length (feet)	Slope	Average Phi Size	Fetch Direction	Fetch Length (miles)
Frye Island.	Site 2	1370	1:10.2	(cs)	S	4.2
	Site 3	1370	1:10.1	(cs)	S	4.2
Halls Beach	Site 11	1510	NC	- (vcs)	SSW	7.1
	Site 12	1510	1:8.3	- (vcs)	SSW	7.1
Harmon Beach.	Barton residence	2840	NC	(ms)	ENE	3.1
	Banks residence	2840	NC	(cs)	ENE	3.1
	Straw residence #2	2840	1:9.0	(cs)	ENE	3.1
Long Point Beach . . .	Thompson residence	3175	1:7.8	- (vcs)	NE	6.2
	Sunningdale residence	3175	NC	NC	NE	6.2
Rockwall Beach	Site 7	530	1:10.0	- (vcs)	NW	9.1
	Site 8	530	1:10.1	- (vcs)	NW	9.1
Sandbar Beach.	Site 10	1895	NC	(cs)	NE	4.4
	Site 12	1895	1:8.3	(cs)	NE	4.4
Songo Beach.	Site 3	3935	1:10.5	(cs)	S	6.0
	Site 4	3935	NC	(cs)	S	6.0
	Site 5	3935	1:10.9	(cs)	S	6.0
	Site 7	3935	NC	(cs)	S	6.0
Standish Boat Launch .	Site 1	3555	NC	(cs)	N	4.2
	Site 3	3555	1:8.8	(cs)	N	4.2

Notes: NC = not calculated
vcs = very coarse sand, cs = coarse sand, ms = medium sand (Folk, 1974)

detailed analysis in this study were those that represented a variety of environmental factors including wind direction, fetch, location, the number of profiles taken, and remoteness. Some of the sites were chosen because of the lack of human influence. Baseline data on beach slope and grain size were collected at each of the eighteen sites for future comparisons. Multiple profiles were established along each beach in order to evaluate longshore shifts in sand (e.g., erosion at one end and deposition at the other). Profile locations are shown in Figure 3.

Beach slope was calculated with a simple linear regression of profile data points. Data points used in the regression were from the highest point closest to the reference pin to a point marking the average profile distance offshore for that site.

Songo Beach is a mainland beach located in the day-use area at Sebago Lake State Park (Figure 13). The main beach (excluding the sand spit) is about 2000 feet long and has an average slope of about 1:11, based on all of the profile data. Sites profiled on Songo Beach include Songo 3, 4, 5, and 7. Profiling began at these sites in the fall of 1990. This beach faces south with fetch lengths of up to 6.2 miles. At the western end of Songo Beach a spit continues away from the mainland for a distance of about 2000 feet. This is the location of Songo 7. Slopes on the spit beach were not calculated with the newer profile data, but its slope in 1994 was calculated to range from 1:7 to as low as 1:17 (Dickson and Johnston, 1994). Profiling responsibility here belongs to the Maine Geological Survey.

Halls Beach (also called Tasseltop Beach or Tasseltop Park) is located well away from the state park beaches and is in Jordan Bay (Figure 3, 14). This mainland beach is 1500 feet or more in length and at the profile sites, near the center of the beach, the slope is in the range of 1:8. Profiling began at these sites in July of 1991 and is the responsibility of the Maine Geological Survey.

The south-facing beach at the southern end of Frye Island initially had four beach profile sites (Figure 15). Site 4 was destroyed in the fall of 1996 during construction of the new marina entrance. Sites 1 and 3 are included in our analysis. This beach is approximately 1400 feet long and has a maximum fetch length of 4.2 miles in a south-facing direction. Profiling began on Frye Island in the fall of 1993 and is the responsibility of the Maine Geological Survey.

Rockwall Beach, located on Portland Water District property, is a northwest-facing beach with a fetch distance of 9.1 miles to the northwest (Figure 16). This beach is approximately 500 feet long and has an average slope of approximately 1:10. The two profile sites located on this beach are in a remote section of the lake that sees little human interference (swimming is prohibited). Profile sites were established here in October of 1993, and profiling responsibility belongs to the Portland Water District.

The two Standish profile sites used in this study are located at the southern limit of the lake along a 3500 foot sand beach (Figure 17). No swimming is allowed at this site so foot traffic is at a minimum along the beach. However, evidence of recreational vehicle traffic has been noted. The beach faces north and has a fetch distance in that direction of 4.2 miles. Profiling began on this beach in October of 1993 and is the responsibility of the Portland Water District.

Sandbar Beach is a northeast-facing beach located along the western edge of Lower Bay (Figure 18). It is almost 2000 feet in length and has its longest fetch distance to the northeast at 4.4 miles. Profiling responsibility here belongs to the Portland Water District and began in October of 1993. This site experiences a great deal of boat traffic.

Harmon Beach is an 2800 feet east-facing sand beach that is heavily developed with summer cottages (Figure 19). The fetch distance to the east-northeast is 3.1 miles. Profilers noted evidence of human influence with foot traffic, boat traffic, and seawalls and docks. Profiling responsibility here belongs to the Maine Geological Survey and began in September of 1993.

Long Point is a north-facing beach on the southern edge of the Big Basin (Figure 20). Sites profiled here include Thompson (where the grain size data sample was collected) and Sunningdale. The Thompson site has the steepest profile among all the sites on the lake at 1:7.8. Profiling responsibility here belongs with the Friends of Sebago Lake and began in September of 1993. The beach is over 3000 feet long. Profile sites on Long Beach (west of Long Point) were not included in this report due to the infrequency of profiling.

Grain Size Data

Grain size data was collected for all eighteen of the beach profile sites analyzed in this study (Table 1). The samples, except those from Songo Beach, were collected on November 22, 1996 at the water line when the water level was approximately 265.8 feet above mean sea level. The Songo Beach samples were collected on August 10, 1995 at the water line, with a water level of approximately 263.8 feet (Page, 1996). All samples were analyzed in the Sediment Lab at Bates College in Lewiston, Maine. Methods used to obtain the median grain size are discussed in detail in Folk (1974). Percent gravel, percent sand, and percent silt and clay were calculated for each sample. Also, the median phi size was determined from the weight of sediment in each phi size using the cumulative curve, arithmetic ordinate method (Folk, 1974). Phi( ) is a logarithmic scale used in analyzing sedimentological data. This scale defines the size of particles ($= -\log_2 S$, where S = grain size in millimeters). The larger the unit, the smaller the particle. Grain size data was also collected on the six bluff sites and is presented in Smith (1997).

Emery Method of Beach Profiling

Beach profiles are lines surveyed perpendicular to the shoreline that record the shape of the beach at the time of measurement. In this report a series of profiles record changes in beach shape over a period of seven years providing insight into the processes that shape Sebago Lake's beaches. Waves, currents, lake levels, sediment size, ice action, and human influences affect these processes. From the time series of profiles, the erosional and accretional history of the beaches can be determined, and the coastal processes that shape the landforms can be studied.

K. O. Emery (1961) developed the "visual method" of beach profiling which involves measuring the vertical distance between the tops of two graduated poles of equal length by leveling on the horizon. Dickson and Johnston (1994) outlined the steps used in measuring and recording profiles in this study. Data were entered into a computer spreadsheet program, and cumulative horizontal distances and differences in elevation calculated. Data were edited to correct recording errors (see Data Analysis section below).

Plots of Beach Profiles

Beach profiles were plotted using Techbase software. A large vertical exaggeration of approximately 20:1 accentuated changes in the elevation of the beach. A plot of all the profiles at each location defined the vertical envelope that the beach occupied during the study period. The outermost points that delimit this envelope define a "sweep zone" (Barnes and King, 1955). Analysis of the sweep zone helps to define the overall variability of a given beach profile location which can then be compared to individual changes seen between months, seasons, or years. In addition to sweep zone plots for each site, plots were made of each profile, usually three to a page, with separate pages for spring, summer, and fall plots. Where sufficient data were available, plots were made showing all of the late summer profiles at a site. These plots helped define interannual and long term trends at the profile sites. Additional plots were made for some sites, comparing the last fall profile of one year to the first spring profile of the next year, all fall profiles at a site, and other combinations. A light table was used to compare profiles that were not on the same page.

Data Analysis and Error Estimates

Data for each profile site was examined chronologically to look for events, episodes, or trends affecting the beach. The full data set (sweep plot) was used to assess total profile variability over the study period. Profile trends by month and season were analyzed to compare seasonal changes. Late summer or fall profiles, when water levels are lowest and the longest profiles are generally collected, were used to assess interannual changes and long term trends.

Since there is a large variation in the amount of data collected for different sites (7 profiles collected over 3 years at Frye Island compared to 50 collected over 7 years at Songo 5), the degree of our understanding of processes and our ability to recognize trends is different for different sites. Those sites with the highest number of profiles over the longest time period are the best understood.

Measurement precision is estimated at less than 3 inches vertically and a foot horizontally at each data point on the profile. In the Emery method an error at any measurement location is carried through the rest of the profile. Large errors, therefore, result in profiles that are outliers to the sweep zone. All outlier profiles were scrutinized for possible recording or measurement errors and corrected where possible. Smaller random errors are assumed to cancel each other out. Systematic errors would lead to greater imprecision in the outer portions of profiles.

Use of the Emery method introduces some very small systematic errors into the vertical elevation data. These errors arise because the opposite shoreline of the lake is used as a horizon for leveling the tops of the survey stakes. These errors result in a very slight underestimation of the downward-sloping portions of profiles and a very slight overestimation of the upward-sloping portions.

Where the distance to the horizon or lake shoreline is a mile or greater, the error introduced for a typical measurement is approximately +/- 0.01 foot or less (negative for downward sloping readings, positive for upward sloping or flat increments) for each measurement taken. Fetch maps for each site (Figures 13-20) show the distance to the opposite shoreline. According to these figures, the Halls beach sites (Tasseltop Park) have the shortest distance (1.9 miles) to the opposite shoreline on Raymond Neck. The resulting error for a typical measurement would therefore be less than 0.01 foot, or less than 0.1 foot over a 100-foot profile measured at 10-foot intervals. The error increases with increasing size of horizontal intervals and with closeness of the horizon. Intervals greater than 10 feet are not used in these beach profiles. In any case, these systematic errors do not affect the detection or analysis of *changes* in profiles over time, which is the focus of this beach profiling study.

Data Corrections

Corrections to the data set were made when obvious recording errors were noted in plots of profiles. These errors included sign switches (+/-), decimal place errors and others. The position of the water level recorded on the profile served as a tool to check reasonableness of the corrected profiles. These types of corrections were made to the following profiles: Halls 12, July 8 1994 (at 25.5 feet from pin, -1.75 changed to -0.75); Songo 7, September 1, 1995 (sign change in vertical increment at 60 feet from pin), April 6, 1996 (vertical increments adjusted in first two readings to make them fit in sweep). Recording errors are suspected in a few other profiles (Songo 7, July 5, 1995; Standish 3, August 5, 1994; Sandbar 10, November 8, 1993 and December 17, 1993; Straw #2, October 18, 1993) which could not easily be corrected. No corrections were made in those cases, and data were not included in the analysis.

Changes in profile starting locations required adjustments to some data at the Harmon Beach, Banks and Barton residences. At the Barton residence, two profiles which started at the corner of the house could not be reconciled with the others, and were omitted from analysis.

Dickson and Johnston (1994) describe data corrections made to the 1990 through 1993 data for Songo Beach and Halls Beach profile locations.

Weather

Weather information was obtained from the National Weather Service office in Gray. Monthly summaries of local climatological data for Portland, Maine were used as a source of wind speed and direction. Sebago Lake weather differs from that of Portland mostly in the summer when the lake region experiences less of a sea breeze. The Sebago Lake region also experiences more extreme temperatures than Portland due to its distance from the milder ocean. Additional weather data was collected and analyzed from the Portland Water District weather station in Standish. Only 1995 and 1996 wind data were available from this lakeside site (see Smith, 1997). In both weather data sets sustained winds were analyzed rather than wind gusts. Wave-building winds are the longer duration events, not the gusts.

Ice Action

Ice may cover the lake for up to five months each year. In shallow water sand is frozen onto the ice and is redistributed by ice-push and ice-rafting. In order to determine the role of ice on the beaches at Sebago Lake, profiles were compared from the late fall and early spring. Beaches were visited during early spring to look for evidence of ice action, and photographs were taken of the beach to document its impact on the sand budget.

RESULTS

Shoreline Classification Map

Surficial materials found in the Sebago Lake region include till, a mixture of sand, silt, and clay; glacial outwash, sand and gravel; silt and clay; and wetland deposits, a mixture of silts and decaying plant material. A shoreline classification map of Sebago Lake (Johnston, 1998) identifies the sediment types exposed along the shore of the lake (see Table 2).

Till, a mixture of sand, silt and clay, is the dominant sediment type found along the lake shore. The second most common sediment type is the sand beach. Till and sand were deposited either directly or indirectly from the late Wisconsinan glaciation. Till was deposited in direct contact with glacial ice while sand

Table 2.

Shoreline Type (yards)	Length
Marsh	7,240
Sand beach	26,030
Seawall behind beach	8,370
Groins with sand in between	4,690
Bluff behind sand beach	7,470
Sand beach with boulders	3,820
Till (sand, silt and clay)	100,750
Artificial fill	10,100
Bedrock	6,920

was deposited by flowing water out in front of the ice. The large volumes of sediment available from local glacial deposits have provided much of the material for the sand beaches around the lake. Fluvial and lacustrine processes have moved the glacial materials to their present position. Both the Songo River delta and the Northwest River delta were formed by fluvial processes since glacial time and comprise the largest volumes of sand around the lake. Bloom (1959) suggested that waves reworked the delta sand along shore to create Cub Cove, Songo, Naples, and Witches Cove beaches at the state park.

Shorelines modified by human action make up the third most prevalent type. These include sand beaches with a seawall behind, groins with sand in between, and artificial fill. Bedrock is exposed along almost 4 miles of lake shore. When added together, all sediment types that include sand make up almost 28 miles of shoreline. Total length of shoreline at Sebago Lake is approximately 105 miles. The till-and bedrock-lined shorelines are the most resistant to erosion, while the sand, gravel and mud shorelines are easily reworked by wave action.

Analysis of Profiles

This section describes events and processes documented at each profile site. The appendix contains plots of the profiles referred to in the text, where they are arranged by beach and site, in clockwise order around the lake. Within the profile set for each site, profiles are arranged in chronological order by season, with any additional profiles (comparison of all fall profiles, for example) at the end. Figure 3 shows locations of the profile stations. Other data referred to in the following descriptions is contained in Figures 6-12 (lake level curves for 1990-1996), Figure 4 (beach and wave terminology) and Figure 5 (cartoon of idealized beach changes due to changing lake levels). These figures are placed at the end of the text.

For convenience, the magnitude of changes are generally described in their horizontal dimension, and referenced to a vertical position below the survey marker or pin. For example, "accretion of 5 feet horizontally at 3 feet vertically below the pin" describes the change along a horizontal line through the profile at a vertical position 3 feet below the pin. The change, depending on the slope of that portion of the beach, could have resulted from the addition of a layer of sand a few inches to over a foot thick. The relative significance of these changes is evident from examination of the profiles.

Songo Beach, Site 3. A total of 49 profiles, collected between December 1990 and May 1997, were analyzed for this study. Profiles of Songo 3 document the following events and processes:

Offshore-onshore profile shifts in response to falling and rising lake levels (see, for example, Summer 1994, and Figure 5), accreting up to 5 feet horizontally to the dry beach as water levels drop in the fall, and eroding the underwater portion of the profile;

Ice-push ridges (see Spring 1995 and 1996 profiles).

A major but transient erosion episode affecting the outer beach between September 1 and October 3, 1995 during record low water levels (Figure 11). The outer beach profile returned to approximate pre-erosion levels by October 11, 1996 (shown on Sweep Zone and Fall 1996 plots).

A catastrophic erosion event during early November of 1996, and extremely high water levels, steepened the profile considerably in the upper beach. Erosion of up to 10 feet (horizontally) at 3 to 4 feet (vertically) below the pin, and up to 3 feet (horizontally) 1.5 feet below the pin, with deposition of this material in the outer part of the profile (see Fall 1996 profiles). This erosion episode resulted in a zone of exposed tree roots, left a cobble layer along the beach, and toppled some large trees (Figure 2). By May 16, 1997 there was no evidence of recovery, and there was additional loss of sand from the mid and outer beach areas on that date.

Songo Beach, Site 4. A total of 44 profiles, collected between December 1990 and May 1997, were analyzed for this study. This site was not profiled during the summer and early fall of 1996. The following observations were made from profile data collected at Songo 4:

Offshore-onshore shifts in the profile with changing water levels. For example, an offshore shift in the profile occurred in response to falling water levels between September 1 and October 3, 1995, with progradation of the dry beach 8 to 10 feet (horizontally) at 5 feet (vertically) below the pin. Rising water levels in the spring shifted the profile back (see April 6, 1996 profile).

A ridge runnel system was present at this site in the spring and late fall of 1996 (see Figure 4, and Spring and Fall 1996 profiles).

A large ice-push ridge was present in the spring of 1997 (see April 9, 1997 profile, and Figure 22). The long, sinuous ridge extended discontinuously for most of the length of Songo Beach on that date.

A catastrophic erosion event in November 1996, during extremely high water levels, steepened the profile considerably. Considerable erosion also occurred between April and May 1997. By December 1996 the profile had lost 5 feet horizontally in a zone from 1 to 3 feet below the pin. By May the loss had been increased to 11 feet horizontally 3 feet below the pin (see Fall 1996 through Spring 1997 profiles).

Songo Beach, Site 5. A total of 50 profiles, collected between December 1990 and May 1997, were analyzed for this study. The Songo 5 profile passes between two stumps, with roots exposed on the side facing the lake, 20 feet from the survey pin. Some of the profile variability at this distance from the pin is due to variable placement of the survey rod on the stumps or down between the roots to the sand below. Since the erosion event of November 1996, these stumps have been undermined considerably. Profiles of Songo 5 show a progressive loss of sand from the outer beach over two consecutive years, a major erosion event affecting the upper beach during November 1996, and other smaller or more transient features. These are described below:

The sweep zone plot for Songo 5 shows a progressive loss of sand from the outer beach, beyond approximately 90 feet from the pin. This loss occurred between July 1995 and October 1996. Profiles from earlier years do not go beyond 90 or 100 feet from the pin, but some from 1992 and 1993 suggest the outer beach may have been at a higher level. The profile of December 1996 shows a reversal of the trend, when a major erosion event affecting the upper beach dumped sand onto the outer beach. Future profiles will show whether or not this reversal is temporary.

The erosion event of November 1996 that affected other south-facing beaches also affected Songo 5. The upper to middle beach lost up to 10 feet (horizontal) of sand between the November 6 and December 3 profiles (at 3 feet vertically below the pin). The outer beach gained approximately the same amount at that time. A ridge and runnel developed. The profile remained relatively stable over the winter, but between April and May of 1997 the upper beach eroded another 4 to 5 feet horizontally at 1.5 feet below the pin. The sand was deposited in the runnel of the mid beach, smoothing it out.

A small ridge and runnel were present on April 6 and were gone by April 18, 1996.

An ice push ridge was documented on April 6, 1996 and was reworked by April 18 (Figure 22).

During a period of relatively stable water levels in the fall of 1994, the mid beach prograded 10 feet in the vicinity of the water line (4 feet vertically below the pin). The submerged beach eroded during this time. This gain was gradually lost over the following spring.

Transient changes related to rising and falling lake levels.

Minor erosion affecting mid beach during rising water levels, Spring 1996 (see Songo 7, also).

Songo Beach, Site 7. A total of 48 profiles, collected between December 1990 and May 1997, were analyzed for this study. This profile location, at the far west end of Songo Beach on the spit, shows a high degree of variability compared to other sites included in the study, with a sweep zone around 20 feet wide in the mid beach. Elements of some of this variability are as follows:

Progradation of the beach face accompanying rising water level, from deposition of sand above the water line, as documented in Figure 30 in Dickson and Johnston (1994), during Spring 1992. This is also seen in Spring 1994 (May 3 to May 31); October 1994, extending through July 5, 1995; and Spring 1996 (April 6 to June 6).

Beach progradation accompanying falling water level. Sand is deposited in the swash zone as the water line recedes. This is seen between August 3 and September 9, 1994, and between July 18 and August 13, 1996.

Erosion of the beach face occurred between June 6 and July 18, 1996, with a slight increase in water level. There were several days of high winds during that time period.

Accretion of almost 1/2 foot of sand to the top of the spit occurred during the very high water levels of late October and early November, 1996. The lower beach face also prograded approximately 5 feet. By early December 1996 the top of the spit had reached its highest point since profiling began at this site in fall 1990, but the spit had also eroded horizontally some 10 feet in the upper beach face, a result of the high winds of November 8-9, 1996. This eroded material was redeposited in the remainder of the profile, creating a stranded ridge and runnel (or longshore bar and trough) as the water fell, and causing considerable progradation of the outer beach.

The low slope terrace in the outer portion of the profile appears to oscillate slowly between 3 and 4 feet (vertically) below the pin. In Fall 1992 and 1993 it appears to have been positioned around -3.25 feet. By Fall 1994 it had moved down to around -3.5 feet. In Spring 1995 it moved down further, approaching -4 feet. Since then it has been rising.

Halls Beach, Site 11, Tasseltop Park. A total of 36 profiles, collected between July 1991 and May 1997, were analyzed for this study. Some of the variability at this site is due to a large driftwood log approximately 10 feet from the pin, a large boulder at approximately 30 feet, and vandalism (removal) of the pin in 1993. Profilers have variably placed the profile rods on top of, in front or in back of, or to the side of the log and rock, creating a considerable spread in the data at these locations. Some of the outliers on the sweep zone are due to vandalism (removal) of the pin during Spring 1993. Despite vandalism and lack of horizontal control, the site is fairly stable.

Most profile changes at the site are transient adjustments to rising and falling water levels. For example:

- Erosion of outer beach with falling water level in Summer 1994 (offshore profile shift).
- Accretion of sand to dry beach during falling water level, Summer 1995 (offshore profile shift).
- Accretion above water line, erosion below, with rising lake level, Spring 1996 (onshore profile shift).
- Accretion at water level and erosion below also occurred with stable water level in Fall 1994.

An erosion event removed 6 feet of sand from the mid-beach between May 3 and 31, 1994. Climatological data show average winds exceeding 10 mph out of the south and southwest on May 7, 9, and 11-13. The profile had recovered by July 1994.

Prominent ice-push ridges were present in April 1992 and 1995.

Accretion of 5 to 6 (horizontal) feet of sand to the mid and outer beach areas between Fall 1995 and Spring 1996, perhaps related to very low water levels of 1995 followed by water level rise in Spring 1996.

Slight erosion following October 20-22 rains followed by accretion above and below water level during November 1996; at a time when south-facing beaches suffered major erosion during high water, with winds from the south. Following the October 20-22 rain storm, profilers observed channels cut through the beach forming small deltas out in the lake. The heavy rains had flooded a low-lying area behind the vegetated berm (east of it). The flood waters had broken through the berm, creating the channels across the beach. The early November profile did not cross any part of the small delta nearby. The early December accretion resulted from reworking of the delta sands. November field notes indicate the channels were being filled in by the accreting sand.

The May 1997 profile shows development of a runnel/ridge or longshore bar/trough feature.

Halls Beach, Site 12, Tasseltop Park. A total of 37 profiles, collected between July 1991 and May 1997 were analyzed for this study. As at site 11, this profile is relatively stable, with most beach changes related to onshore-offshore profile shifts that accompany rising and falling lake levels. Some examples of these shifts, and other features of the profiles are described here:

Some examples of the onshore-offshore shifts with rising and falling lake levels are:

- Accretion above the shoreline, erosion below with falling lake levels, resulting in an offshore profile shift, between late July and September 1995.
- An onshore shift occurred between the April and May profiles, 1996.
- Accretion and erosion occurred with stable water level in the fall of 1994, prograding the beach at the water level and eroding it below.

Ice push ridges were present in the spring of 1992 and 1995.

Dickson and Johnston (1994) noted the development of notches and erosion of 5 feet (horizontal) of sand from the beach face in the fall and winter of 1992-1993, with return of the profile to its original shape by May 1993.

A significant accretion event occurred between the August 13 and October 30, 1996 profile dates. The middle to outer beach area was extended by 5 to 7 feet (horizontal). Some of this material was reworked and redeposited higher on the profile, above the water level, by the next profile date, November 22, 1996. On October 30, beach profilers observed channels cut in the beach and small deltas, as described for the Halls 11 site. This profile may have crossed the edge of one of these small deltas.

Comparison of a sweep plot of the 1991 to 1993 data with a sweep plot of the 1994 to 1997 data suggests a steepening of the profile has occurred in the upper beach area. This trend may have been reversed, at least temporarily, by the events of Fall 1996.

Frye Island, Site 2. A total of 7 profiles, collected between October 1993 and November 1996 were analyzed for this study. Significant features of this profile site are :

An ATV track present in the upper beach, October 1995; accretion of 13 feet (horizontal) below the water level, in the outer beach, between October 1993 and October 1995.

Erosion from upper, mid, and outer beach areas. Loss of up to 12 feet (horizontal) of sand from most of the central portion of the profile, and development of an erosional notch between October 1995 and by Spring 1996. The notch most likely formed in the fall of 1995 during the long period of low lake levels.

An erosion event in the fall of 1996, with development of a notch and loss of up to 5 feet of beach (horizontal) within 15 feet (horizontal) of the pin; and deposition of the material in the mid and outer profile, resulting in up to 8 feet of accretion there. This event occurred between October 30, 1996 and November 22, 1996, during very high water levels, most probably during the episode of high winds out of the south in early November that affected other south-facing beaches. Some of the erosional notch in the upper profile had filled in by May 1997, but the accretion in the mid and outer profile had been eroded to beyond the profile limits.

Frye Island, Site 3. A total of 7 profiles, collected between October 1993 and November 1996, were analyzed for this study. This site shows the following features:

A net gain of sand in the outer beach, with a gain of up to 13 feet of beach (horizontal), at 7 feet below the pin from October 15, 1993 to October 4, 1996.

Similar to Frye Island 2, it also shows the Fall 1996 erosion event with development of a notch and loss of approximately 5 feet of beach (horizontal) within 15 feet (horizontal) of the pin. The eroded material was deposited in the mid beach area, resulting in some minor accretion there. Like site 2, some of the erosional notch in the upper profile had filled in by May 1997, but the accretion in the mid profile area had been eroded to beyond the profile limits. Up to 10 feet (horizontal) of beach was lost from the mid beach section of the profile.

Rockwall Beach, Site 7. A total of 23 profiles collected between October 1993 and November 1996 were analyzed for this study. The sweep zone contains two sets of notches, and an outlier on either side of the main sweep in the mid beach area. The major profile changes at this site are:

Notches in Fall 1993. It is not clear whether the Fall 1993 notches are erosional features, or depositional features since these were the first profiles collected. They were filled in by June 1994.

Summer 1994 profiles show erosion of the outer beach between the July and August profiles, followed by accretion in the same portion of the profile between August and September. New "notches" that first appeared in the September 1994 profile and persisted through the spring of 1995 are actually the result of accretion of a flat-topped layer of sand or berm up to 8 feet wide (horizontal). Both erosion and accretion occurred during falling lake levels in the summer of 1994. This was followed by further accretion and smoothing of the profile between May and June 1995 when water levels rose slightly.

Other profile changes are smaller and more transient responses to lake level changes.

Rockwall Beach, Site 8. A total of 23 profiles collected between October 1993 and November 1996 were analyzed for this study. The sweep of this site shows a compact zone near the pin that expands slightly with distance from the pin. There are no outliers. Offshore-onshore profile shifts with falling and rising lake levels account for most of the profile changes at this site. The major profile changes at this site are:

Summer 1994, 1995, and 1996 show accretion to the mid beach area between the August and September profiles, with falling lake levels. The accretion is most significant in 1994, when 8 feet (horizontal) of beach was added to the profile.

By October 1994 a strong erosional notch had developed in the newly accreted beach at 3.5 feet (vertical) below the pin.

By Spring 1994 and Spring 1995, most of the sand gained during the previous summers had been eroded. This is consistent with wind data for the Sebago area (Portland Jetport) that shows strong winds out of the north and west are typical in the spring.

Standish Boat Launch, Site 1. A total of 24 profiles, collected between October 1993 and November 1996, were analyzed for this study. The Standish 1 profiling location experienced alternating accretion and erosion of up to 10 feet (horizontal) in the mid-beach area over the study period. The sweep zone is compact, 10 feet wide in the mid beach area and up to 15 feet wide at the outer limits of profiling. The major profile changes at this site are:

The beach prograded 10 feet during predominantly stable and rising water levels during Fall 1993 and Spring 1994, and was stable until the September 1994 profile, when up to 10 feet was lost from the upper, middle, and outer beach areas (NWS data show winds out of the north between 13 and 20 mph for 21 hours on August 5-6, and again out of the north between 9 and 14 mph for 15 hours on August 23, 1994). The eroded profile remained stable through the fall.

By the spring (May) of 1995 the mid and outer beach had prograded again 10 feet, during stable to slowly rising lake levels. These gains were lost during the summer, regained in the outer beach (September 1995 profile), and then lost again (October 1995 profile). The beach then remained stable, with only minor changes near the shoreline, until Fall 1996.

Some erosion (4 feet, horizontal) in the mid beach area is documented between the October 1 and November 5, 1996 profiles. During this time period, the lake level rose 2.5 feet due to an 8- to 12-inch rainfall on October 20-21.

Standish Boat Launch, Site 3. A total of 23 profiles, collected between November 1993 and November 1996, were analyzed for this study. The Standish 3 site was very stable over the study period. The sweep zone is straight and compact, up to 7 feet wide for most of its length, if a single outlier (suspected recording error) is ignored. The major profile changes at this site are:

Beach profiles were straight and stable from November 1993 through Fall 1994, except for a small amount of erosion from the outer beach (September to October), and accretion just above the water level (offshore shift of profile with falling water level). A recording error is suspected in the August 1994 profile and the large amount of accretion shown there may not be real. The profile remained stable over the winter.

As water levels rose slightly in the spring of 1995 (May to June) the entire beach prograded up to 6 feet, and the profile was smoothed. It then remained stable, with only a suggestion of offshore-onshore shifts with falling and rising lake levels for the remainder of the study period.

Sandbar Beach, Site 10. A total of 24 profiles collected between October 1993 and November 1996 were analyzed for this study. This site has an S-shaped profile that is relatively stable. All variations are minor, transient onshore-offshore shifts related to lake level rising and falling (There may be recording errors in profiles B and C).

Sandbar Beach, Site 12. A total of 24 profiles collected between October 1993 and November 1996 were analyzed for this study. This site has been extremely stable over the study period. The sweep zone is compact and straight. The stability of this site and Sandbar 10 may be due to their protected location. The only wind direction capable of generating significant waves is northeast. During the study period, there have not been many large storms with strong winds out of the northeast.

Harmon Beach, Barton Residence. A total of 12 profiles collected between September 1993 and May 1997 were analyzed for this study. In contrast to the other sites profiled at Harmon Beach, this one showed quite a bit of variation, especially in 1996. Confusion about the starting location of profiles for this profile location led to use of two different starting points, the northeast corner of the house, and a steel pipe east of the house. Profiles which started at the northeast corner of the house, but did not reference the pipe in the field notes, have not been used. The major profile changes at this site are:

This site was stable through the September 1995 profile. The next usable profile, in August 1996, showed erosion from all areas of the profile. Maximum erosion was at the end of the profile, where 18 feet (horizontal) of sand were lost. By October 1996 sand had returned to the outer portion of the profile.

Between November 6 and December 3, 1996 a major erosion event affected the upper part of the profile, exposing an additional foot (vertical) of the steel pipe that serves as the profile starting point. The eroded material was redeposited in the outer portion of the profile, where a gain of approximately 15 feet (horizontal) occurred. By Spring 1996 this material had been removed from the outer profile area, and a small amount of sand had returned to the upper part of the profile. The November summary of Local Climatological Data for Portland, Maine, and Portland Water District wind data were scanned for high wind occurrences from fetch directions affecting Harmon Beach during this time period. The Portland data shows one reading (3-hourly readings) on each of November 6, 7, and 9 of moderate to high winds, from a direction that could reach Harmon Beach. These times bracket the time of high southerly winds of November 8 and 9, that affected the south-facing beaches. The Portland Water District weather data, collected in their station in Standish, show a few hourly ranges exceeding 8 mph from the appropriate directions. None of these wind records show sustained high winds capable of producing the major erosion seen in this profile. This suggests that winds from other directions generate waves that are refracted into the north end of Harmon Beach, causing the erosion observed at the Barton residence.

Harmon Beach, Banks Residence. A total of 12 profiles collected between September 1993 and May 1997 were analyzed for this study. Over the study period this beach was relatively stable, with an S-shaped profile. Notable features are an erosional episode shown in the August 1994 profile, a significant but short-lived erosional event shown in the December 1996 profile, and a pronounced ice-push ridge in the May 1997 profile. All of these features were transient.

Harmon Beach, Straw Residence #2. A total of 12 profiles, collected between September 1993 and May 1997, were analyzed for this study. The beach has an S-shaped profile with a fairly narrow sweep zone. Variability is due to:

Erosion (approximately 7 feet, horizontal) between the August 1994 and September 1995 profiles (October 1993 profile eliminated from analysis due to suspected recording error). By May 1996, it appears some of this sand had returned.

During the spring of 1996 (May to June), approximately 4 feet (horizontal) of erosion occurred just below the water line, at 3 feet below the pin (vertically). As water levels fell in the summer and fall, accretion and erosion occurred, shifting the profile offshore slightly. The rapid rise in water level of October 1996 resulted in progradation of the outer beach, restoring it to its position of the fall of 1993 and 1994.

Long Point Beach, Sunningdale Residence. A total of 11 profiles, collected between September 1993 and July 1995, were analyzed for this study. The sweep zone for this site is gently S-shaped, compact in the upper beach, spreading gradually to 8 feet wide at 10 feet below the pin, in the mid portion of the profile; to about 15 feet in the outer beach. Sources of variation are:

Approximately 5 feet of progradation with falling water level in Fall 1993.

Transient changes that are not clearly related to water levels, in 1994 and 1995.

Interannual Trends

Over most of the time period studied (3 to 6 years between 1990 and 1996), most beaches were stable. The exceptions are described below (Large Changes, Fall 1996). Most of the changes observed can be characterized as transient sand movement resulting in onshore and offshore profile shifts (Figure 5), in response to rising and falling lake levels. Other changes documented include sand ridges and piles in the upper beach that were bulldozed or deposited by wind-blown slabs of ice as they melted in spring; and erosion of the outer beach with development of erosional notches at two sites during very low lake levels in 1995. Similar erosion and notching were observed in the fall of 1992 (Dickson and Johnston, 1994). Although some of these changes involved relatively large volumes of sand, none of them persisted longer than a year.

The stability of most profile sites is seen from the narrowness and compactness of the sweep zone plots, especially the upper beach sections near the pins; and from the lack of directional change, or long term trends in the beach profile plots. Evidence of stability of the beaches can also be seen in the plots that show all August, or other late summer or fall profiles for each site. These are collected at a time when lake levels are near their low for the year, so profiles are long, and are generally free from the effects of any recent storms.

While most beaches were stable over the study period, a few beaches showed evidence of gradual, long term change. These interannual changes were observed by comparing yearly late-summer profiles. Sites which showed progressive sand gain or loss over the study period are described here:

Songo 5 appears to show a progressive sand loss from the outer beach profile. Coverage of the outer beach is better in more recent profiles. The profiles from 1992 and 1993 seem to suggest the outer beach may have been at a higher level then. Profiles between July 1995 and October 1996 clearly show the trend of sand loss from the outer beach. The trend was reversed by the December 1996 profile due to the erosion event in November, in which material eroded from the upper beach was deposited on the outer beach. Future profiling will show whether sand loss from the outer beach resumes following this event.

The low slope terrace in the outer portion of the profile of Songo 7 gained sand during 1995 and 1996. Prior to that it may have lost sand for a few years in a row, although these earlier profiles are more difficult to interpret because they are not as long as the more recent profiles. The sand loss at Site 5 (1995-1996) and sand gain at Site 7 (1995-1996) suggest a longshore current may be transporting sand to the west.

Frye Island 3 shows net gain of sand in the outer beach over the three-year study period (October 1993 to October 1996). Site 2 at Frye Island does not show any clear trend. Collection of data over a longer time period, and examination of data from the other two Frye Island sites not included in this study, might confirm this trend and show whether accretion or erosion is occurring at the other Frye Island sites.

Separate sweep plots of 1991 to 1993, and 1994 to 1997 data for Halls 12 show the profile is steeper in the upper beach in the more recent data. The mid and outer beach portions of the sweep plots over the same time period do not show the same trend. The upper beach portion of Halls 11 is more variable, due to a large driftwood log and a large boulder that the profile passes over. A trend showing a steepening of the upper beach would be more difficult to recognize at Halls 11.

Long-term gradual changes suggested here, especially at Frye Island, need confirmation from additional profiling.

Large Changes, Fall 1996

The south-facing beaches (Songo and Frye Island) and one east-facing profile site (Barton Residence at Harmon Beach) experienced significant erosion to the upper beach areas during the fall of 1996. This erosion occurred after several years of stability or gradual change. At the same time, the Halls 12 site (southwest-facing) experienced a significant amount of accretion. The northern Halls beach site experienced moderate erosion, followed by accretion.

A combination of events led to this major episode of shoreline change. On October 20-22, 1996 a major precipitation event occurred in southern Maine. Precipitation in the form of rain fell in excess of 8 inches in the Sebago Lake basin over a period of about 12 hours (FEMA, 1996). This record-breaking rainfall resulted from a blocked northeaster over southern Maine being fed tropical moisture from hurricane Lili, located 900 miles southeast of Portland. A strong high pressure system over Labrador kept the low pressure system from moving out of the region. The Sebago Lake water level rose 2 feet from October 16th through October 23rd. The overall rise in lake level from October 16th through November 12th was 3.6 feet.

While lake levels were at or near this full pond level, a low pressure system tracking up the St. Lawrence River valley brought strong southerly winds to the lake on November 8th and 9th (FEMA, 1996). The combination of the strong southerly winds and a high lake level allowed waves to reach and erode the upper beach areas, exposing tree roots and toppling trees along the shoreline at the Songo and Frye Island sites (Figure 2).

The steepening of upper portions of profiles that occurred at the Songo sites in the fall of 1996 continued into the spring of 1997, when further erosion occurred on these beaches. Exposure of tree roots at Songo and Frye Island beaches, and loss of the front line of trees along Songo beach, suggest that further changes in the profiles are likely before a new equilibrium profile is reached. Because the erosion occurred so high up on the beaches, it is not likely that sand will be returned to the eroded upper profile. Continued profiling at these sites will show the extent of erosion that eventually will result from the weather events of October and November 1996.

The accretion event documented at the Halls 12 site appeared to be a result primarily of the rain storm. Field evidence suggested the accretion was the result of erosion from channels cut into the beach and deposition of the sand in small deltas, which profile 12 crossed. Subsequent accretion at Halls 11 could have resulted from redistribution and longshore transport of material from site 12 to the south to site 11 to the north.

The major erosion documented at the Barton Residence at Harmon Beach between November 6 and December 3, 1996 was unexpected. The beach facing direction is east, the winds associated with the low pressure system of November 8-9 were out of the south, and there was an apparent lack of significant wind from the east, northeast, or southeast during the profile month. Wave refraction may play a role at this site, allowing waves from other directions to reach the north end of Harmon Beach, causing the erosion observed at the Barton residence. In addition to the southerly winds, there was over a day of continuous moderately high wind out of the north on November 26-27. The northerly winds would have had a long fetch.

The records of stability at these sites, followed by the sudden large changes associated with these fall storms, suggest that large, permanent shifts in profiles are not the norm, but are the result of extreme events that occur infrequently.

Seasonal Patterns

Early spring observations and beach profiles have shown ice-deposited accumulations of sand on the dry beach and in shallow water at several beaches. These sand ridges have been observed at Songo, Halls, Harmon, and Long Point beaches. A striking example of an ice-deposited sand ridge was profiled and photographed at Songo beach in 1997 (Figure 22). During the winter of 1997, a spectacular wind-blown ice pile developed in front of a residence at Wards Cove. Ice-related sand deposits are quickly reworked with rising water levels in the spring.

Beaches generally experienced accretion during mid and late spring when lake levels rose. The combination of rising water level and average waves moved sand onshore from farther out in the profile (Halls 11, Last Profile 1995, First Profile 1996; Songo 7, Spring 1994, for example), and accreted it to the beach face. Rising water levels also rearranged the sand, eroding it from just below the water line and depositing it just above the water line (Halls 11, Spring 1996), creating an onshore shift in the profile, and progradation of the dry beach. In some cases the rearranging and accretion go on simultaneously (Songo 7, Spring 1992, Figure 30, Dickson and Johnston, 1994).

Erosion was also observed during rising water levels in the spring at some beaches. Some examples are seen in Spring 1996 at Songo 5 and 7, and Spring 1995, Songo 4. The erosion at Songo 4 and 5 was minor. At Songo 7 approximately 10 feet (horizontal) was lost 1 foot below the pin. High winds may have played a role in the springtime erosion. There were some days on which higher than average southerly winds were recorded during the month in question.

Most beaches prograded as lake levels fell during summer, and profiles shifted lake ward (Rockwall 8, Summer 1994). Progradation of the dry beach was sometimes accompanied by erosion of the underwater portion of the profile, as at Songo 3, Summer 1994. Falling water levels also swept sand offshore, in a reverse of the spring beach-building process (Halls 11, Summer 1994).

Erosion and development of erosional notches were observed in some late summer and fall profiles. Summer and fall of 1995 was a time of prolonged low lake levels (Figure 11). Songo 3 developed an erosional notch, and suffered a major erosion episode to the outer profile between the September 1 and October 3 profiles. This outer, low-slope portion of the profile lost 1 to 1.5 feet vertically (60 feet horizontally, at 8.5 feet below the pin) during this month. This erosion turned out to be temporary. The sand gradually returned over the next year, returning almost to its previous position by October 11, 1996.

Also during the 1995 low lake levels (between October 13, 1995 and May 8, 1996 profiles), Frye Island 2 developed an erosional notch at the position of the low water level in the fall.

Lake levels sometimes become stable for a period of a few months, especially in the fall. When this happens, progradation of the dry beach just above the water line, and erosion just below often occur. Examples of this are seen in the following profiles: Songo 5 and 7, Halls 11 and 12, profiles of October 5, October 25, and December 6, 1994.

Except for the development of temporary ice-related features, profiles do not change much over the winter when the lake is frozen (see Songo 3 and 5, Last Profile 1996, First Profile 1997).

All of these seasonal effects observed were transient, persisting for a year at most.

Beach Facing Direction

This study included beaches around the entire perimeter of the lake, so that all facing directions could be evaluated. Sites from all facing directions can be characterized as predominantly stable, with transient changes related to water levels. The northwest-facing Rockwall sites showed a large amount of accretion with falling water levels in the late summer, and loss of the accreted sand by the following spring (May) profiles. The prevailing westerlies may play a role in the strong summer and early fall accretion at this site. Strong northwest winds in the early spring may play a role in the subsequent loss of the accreted material (Figure 10 and Table 1 in Dickson and Johnston, 1994).

Ice depositional features have been observed in the field at all beaches except Rockwall, Sandbar, and Standish. These sites may not have been profiled early enough in the spring to document ice features. Ice features are expected to occur at all sites to some degree, but are also dependent on wind direction during the time of ice break-up.

The largest changes documented in this study were associated with a low pressure system moving up the St. Lawrence valley, bringing southerly winds during a time of high lake levels in the fall of 1996. It affected primarily south-facing beaches. A northeaster during high water levels could have caused erosion of the same magnitude at beaches on the western shores of the lake. A longer period of data collection may document such an event in the future. Water levels in the lake are not anticipated to be that high during the storm season with the new lake level rule curve (FERC, 1996).

The study is biased with respect to facing direction in that the most data has been collected over the longest time period on the south-facing Songo sites and the southwest-facing Halls beach sites.

Lake currents

Multiple profile sites are included at each beach studied so that changes along a beach can be documented. Evidence of possible longshore currents were seen between Songo 5 and 7, and Halls 11 and 12. The profile changes that suggest the action of longshore currents, loss of sand from a portion of the profile at one site and gain at another, are subtle and have not been documented over long time periods. More profiling data is needed to evaluate the role of longshore currents.

Beach dynamics

The lake freezes over each winter for about 3 months of the year, from January through March. While frozen, the shoreline is protected from battering by winter storm waves. Slabs of ice, however, can be blown by winds up onto the shore, plowing sand in front of them. Melting ice piles along the shoreline can leave ridges of sand as they melt in the spring, both from the sand plowed up, and from sand that is frozen into the ice and released during melting. These features were observed in several years, but striking examples were seen in the spring of 1997 at Songo Beach (Figure 22). During the winter of 1997, a spectacular ice pile developed at Wards Cove (not a profile site in this study).

As the spring thaw occurs, the lake level rises between 2.5 and 5 feet, reaching an annual maximum usually in May. As the lake level rises, ice push features are quickly reworked; rising lake level sweeps sand onshore (Halls 11, Last Profile 1995, First Profile 1996), accreting it to the beach face; and the sand in the profile is rearranged by erosion from just below the water line and deposition just above the water line (Halls 11, Spring 1996). This results in an onshore shift of sand on the beach profile. In some cases, the rearrangement and accretion go on simultaneously (Songo 7, Spring 1992). Erosion can also occur during spring high water, in combination with high winds (Songo 5 and 7, Spring 1996).

After reaching its maximum in spring, the lake level begins to drop, reaching an annual minimum around the first of November. The falling lake levels cause accretion of sand to the dry beach as the swash zone moves down the beach, piling up sand just above the water level as it goes (Rockwall 8, Summer 1994). This is often accompanied by erosion of the underwater portion of the profile (Songo 3, Summer 1994). The net effect is an offshore shift in the profile immediately around the water level. Falling water levels can also sweep sand offshore, in a reverse of the spring beach-building process (Halls 11, Summer 1994).

The lowered lake levels of fall expose the outer portions of beach profiles to the effects of waves, sometimes resulting in erosion of the outer beach and development of notches in the profiles (Fall 1992, Songo and Halls beaches, Dickson and Johnston, 1994; Fall 1995, Songo 3; Frye Island 2, Fall 1995). Songo 3 experienced a loss of over a foot of sand (vertically) from the outer beach during late summer to Fall 1995, but had nearly regained it a year later.

Lake levels sometimes rise slightly in the late fall to early winter before the lake freezes. Except for ice-related features, profiles do not change much over the winter when the lake is frozen.

All of these seasonal effects, including fall erosion and development of notches, are transient, and rarely persist beyond a year. Most locations have a balanced sweep zone that exhibits seasonal dynamics with an interannual stability.

In contrast to the regular seasonal oscillations, storms can produce larger long-lasting changes in beach profiles. A storm occurring during high water gives storm waves access to the upper beach, contributes new material to the active beach, steepens the upper beach profile, and leads to further changes in the profile until a new equilibrium profile is reached.

CONCLUSIONS

Beaches were stable over the study period until the Songo and Barton beaches experienced catastrophic changes in the fall of 1996. These changes were the result of an unusual combination of weather events, but illustrate the role of high lake levels in providing storm waves access to new ground. Although this event took place in the fall, comparable damage could occur at any time lake levels are high and on any beach where the combination of wind direction, speed, and fetch allow development of storm waves. Relatively minor erosion events were documented during Spring 1994, and the late spring/early summer of 1995; both events at times of high water and strong winds.

Erosion that occurs at low lake levels, even of large volumes of sand, does not result in permanent change to the profile. Significant erosion events occurred in the fall of 1992 and 1995, at low lake levels. One of the largest changes documented in the six years of beach profiling is an erosion event at Songo 3 between September 1 and October 3, 1995, a time of low water. The sand lost was restored within a year. Low lake levels, therefore, do not pose the same risk of long term change to beaches as high lake levels.

Overall, the beach profile data present an emerging picture of beach dynamics in which long term stability is punctuated by sudden large, long-lasting, and irreversible changes caused by storms during high water. Only one such catastrophic event was observed, in the fall of 1996, during the six years of profiling this study covered. Predictions are made of its long-lasting effects based on the loss of large trees along the shoreline, and exposure of the roots of many other trees.

The shoreline classification study showed approximately 25 percent of the shoreline is composed of sandy sediment, evenly distributed around the lake. These are the most easily eroded shorelines on the lake.

This study included sites facing all compass directions. The south-facing beaches experienced the most change over the study period, but a longer period of data collection at the other beaches could alter this. The potential for a "northeaster" during spring high lake levels is high. Such a storm could cause large and long-lasting changes at north to east-facing beaches.

The Emery method of beach profiling is easily learned and inexpensive in terms of capital costs. It is useful for providing a picture of beach changes over time, and is suitable for use by a diverse group of volunteers. It has some shortcomings, however, as follows.

Any measurement or recording errors are cumulative, affecting all of the profile past the point where the error occurred. If the error is large enough, it is easily recognized and often can be corrected. If the error is of moderate size, it may not be detected and may be erroneously interpreted as an erosion or accretion event. One such error can create a false conclusion.

A common source of error in this method is in the recording of plus or minus values in each reading. Use of a rod and pop-level, or relatively low-cost construction laser level would eliminate these sign errors.

RECOMMENDATIONS

A number of recommendations follow from the results of this study and from our experience in data collection and analysis.

First, we recommend continuing data collection at selected profile sites around the lake. The conclusions drawn in this report are preliminary. At some sites the conclusions are based on only three years of data, sometimes with a single profile in one or more years. At the Songo and Halls beach sites, where data collection has been in progress for six years, only in the fall of the sixth year was a major shoreline-changing event documented. Profiling should be continued to verify some of the conclusions of this study, and to provide a more complete data set for analysis. Beaches representing all compass directions should be included. Future profiling should include many of the existing sites because of the value of the long-term data sets.

Immediately activate a couple of the abandoned beach profiling sites at Long Beach in Standish to collect baseline data. Currently, there is no data from these sites. Long Beach appears to be at risk of large-scale shoreline changes in the event of a "northeaster," a common type of storm in the southern Maine area. Several other sites can be abandoned, especially where there are multiple sites at a beach. We recommend keeping at least two sites per beach, so that longshore currents and intra-beach variation can be evaluated. A third site would be very beneficial in the event of the loss of one of the two others - as has occurred elsewhere by construction or vandalism. Presently the total number of sites is unmanageable for economical data collection, analysis, and reporting. Perhaps some sites "abandoned" can be profiled in August or September (once a year) for long-term trend analysis. For this reason the pins at the beginning point of each profile site should not be removed.

Beaches and sites that we consider important to maintain are:

Songo 3, 4, 5, and 7: long record of data, south-facing, heavy human influence, recreational value, recent storm-caused erosion.

Halls Beach 11 and 12: long data record, southwest-facing, recreational value, recent beach nourishment following storm damage.

Rockwall 7 and 8: 3-year data record, northwest-facing, no human influence, longest fetch on the lake.

Standish 1 and 3: 3-year data record, north-facing, near Portland Water District intakes, public boat launch.

Harmon Beach; Barton, Banks, Straw #2 Residences: 3-year data set, east-facing, developed shoreline, possible wave refraction effects.

Frye Island 1 and 3: 3-year data set, south-facing, recent marina development behind beach, recent storm-caused erosion.

Long Point: north-facing, well exposed with long fetches to northwest, north, and northeast winds.

Long Beach: northeast-facing, well exposed with long fetches to northwest winds, heavy human influence.

Continue periodic surveys of eroding bluffs. A frequency of once per year is adequate, with budget flexibility to increase the frequency following any storm or other event that warrants closer monitoring.

Compare two beach profiling methods to see if Emery method results correlate well with total station survey method results. If the two methods provide the same level of accuracy, then data sets can be combined..

Data from all sites should be collected and analyzed whenever possible by the same individuals. Familiarity with the sites is crucial to profile interpretation and to the development of an understanding of beach dynamics at a site.

All beach profile data should be maintained in a database that is easily accessible to any potential users.

Since high lake levels expose the shoreline to the potential for major storm-generated erosional events, maximum lake levels should be restricted in elevation and duration at any time of the year when storms can be expected.

The elevations of known clay outcroppings around the perimeter of the lake should be surveyed so that the impact of different water levels can be evaluated. Clay exposed to wave erosion can add unwanted nutrients to the lake and have an impact on overall water quality. Elevation data on potential clay erosional sites will assist in overall shoreline protection and planning.

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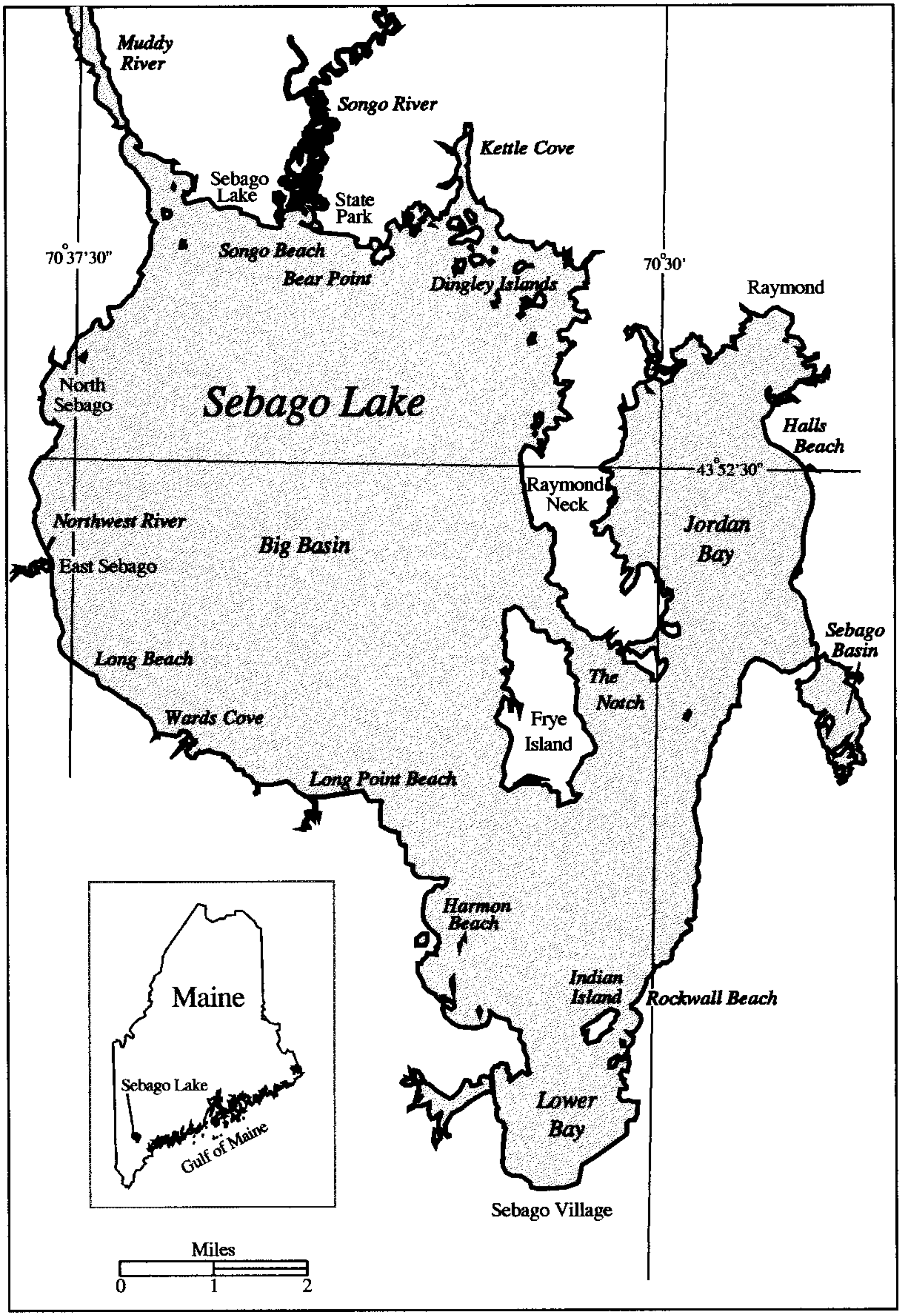


Figure 1. Location of study area.

Figure 2. Tree roots continue to be exposed at Songo Beach, December 1996 (photo by Robert Johnston).

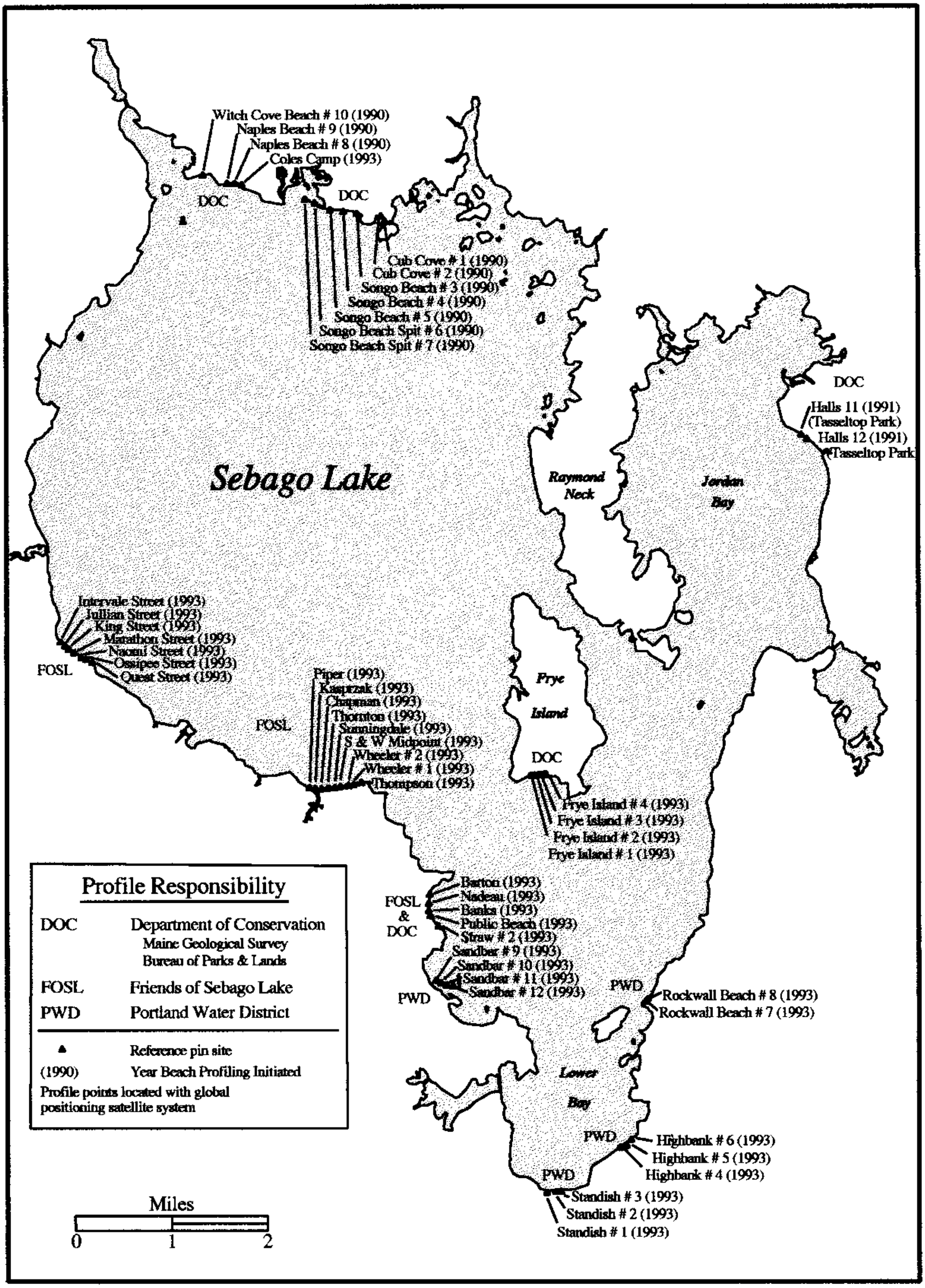


Figure 3. Beach profile sites at Sebago Lake, Maine.

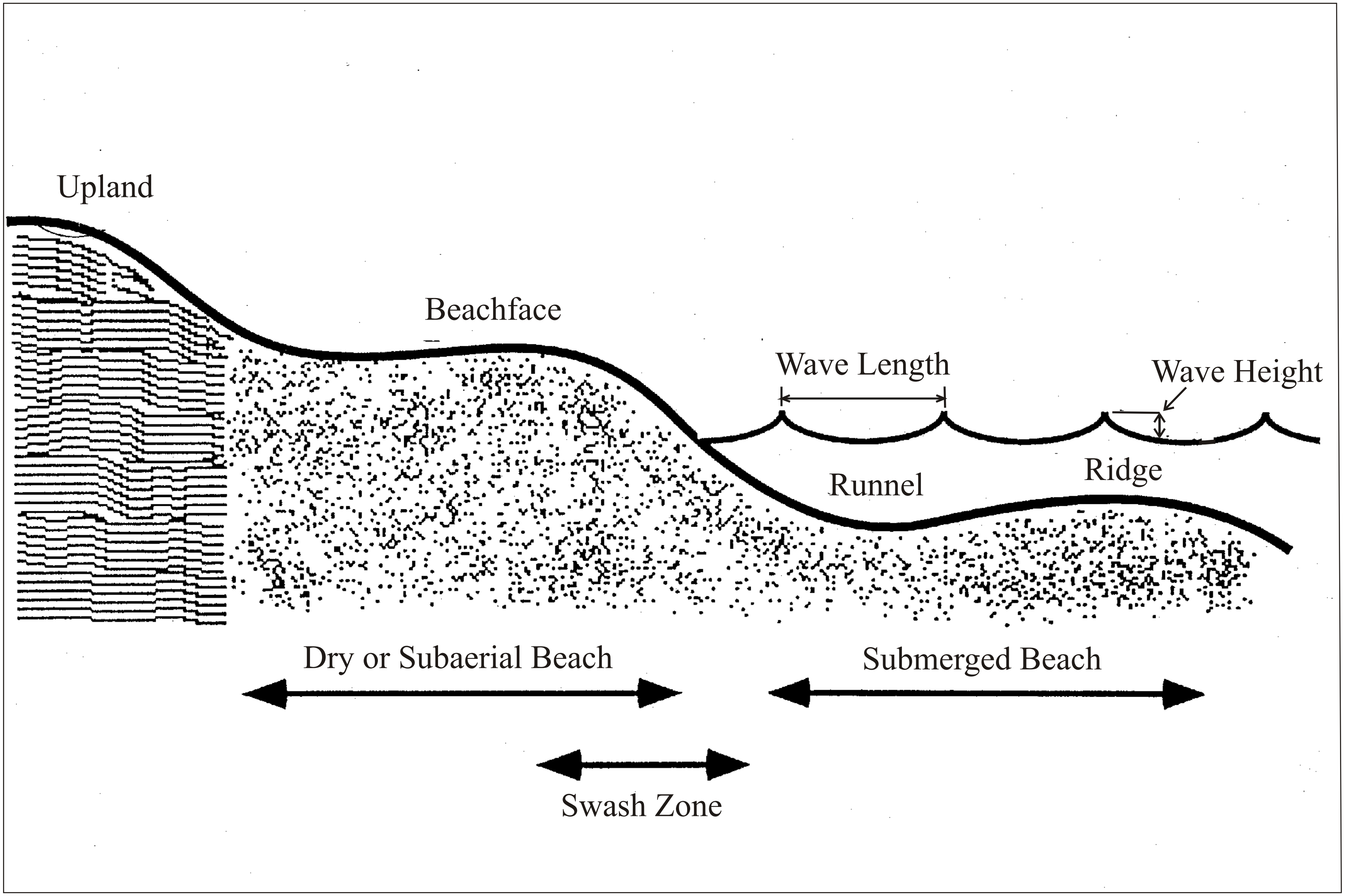


Figure 4. Beach terminology (modified from Dickson and Johnston, 1994).

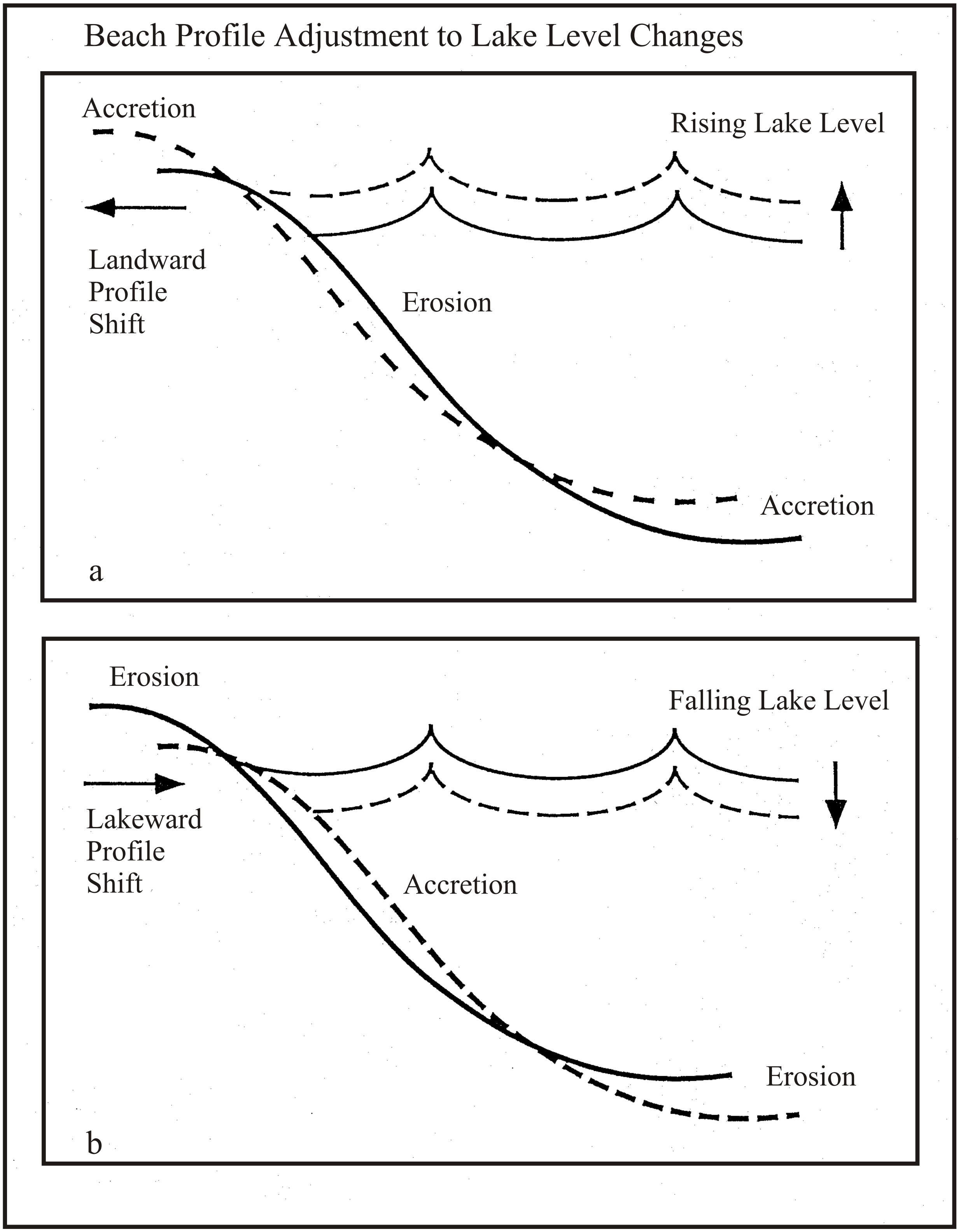


Figure 5. Equilibrium configurations showing a schematic example of profile change from one "equilibrium" configuration (solid line) to another (dashed line). With a lake level rise (a) the profile adjusts upward and landward, while with a lake level fall (b) the profile adjusts downward and lakeward (from Dickson and Johnston, 1994).

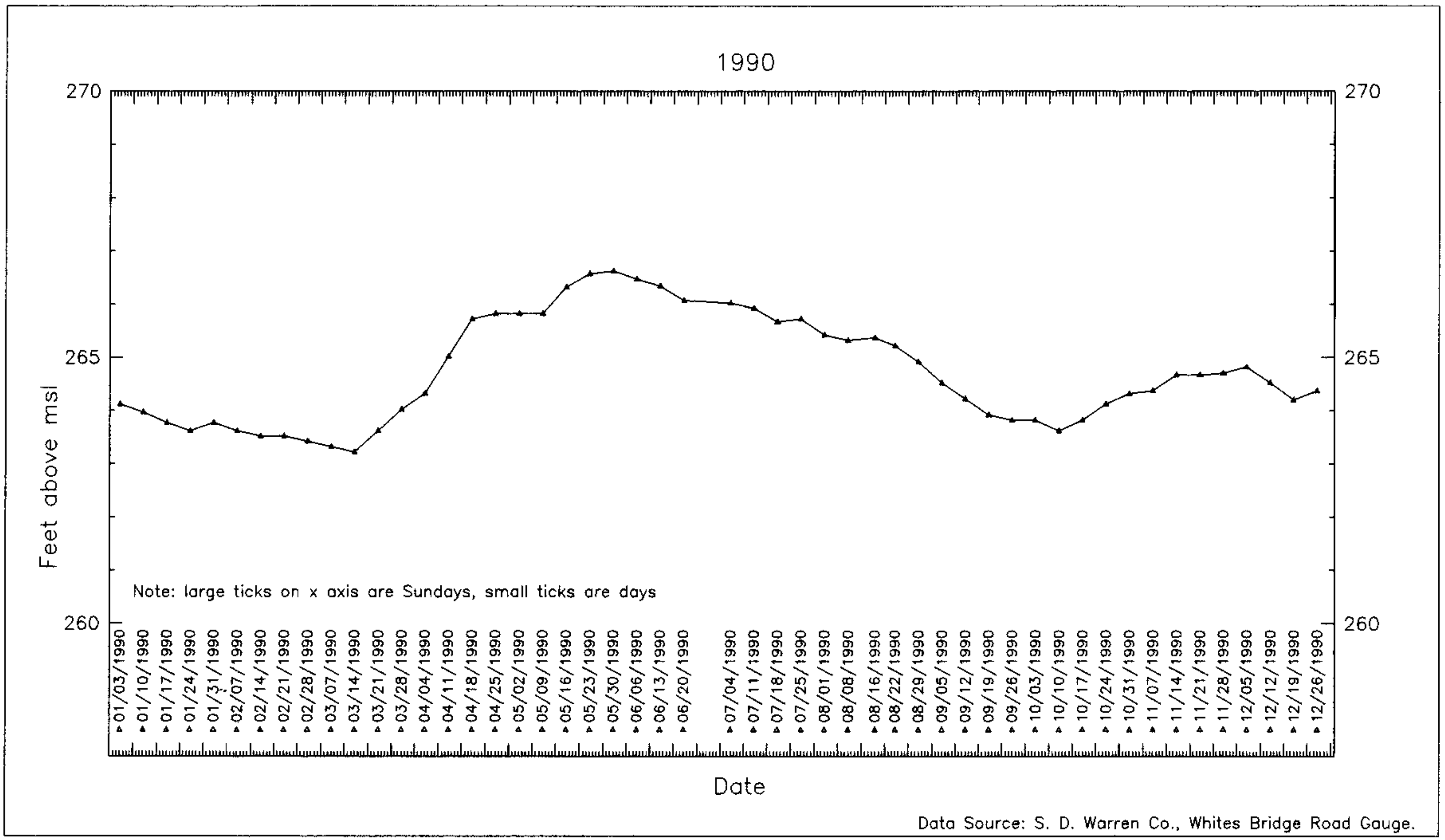


Figure 6: Sebago Lake Weekly Water Levels, 1990.

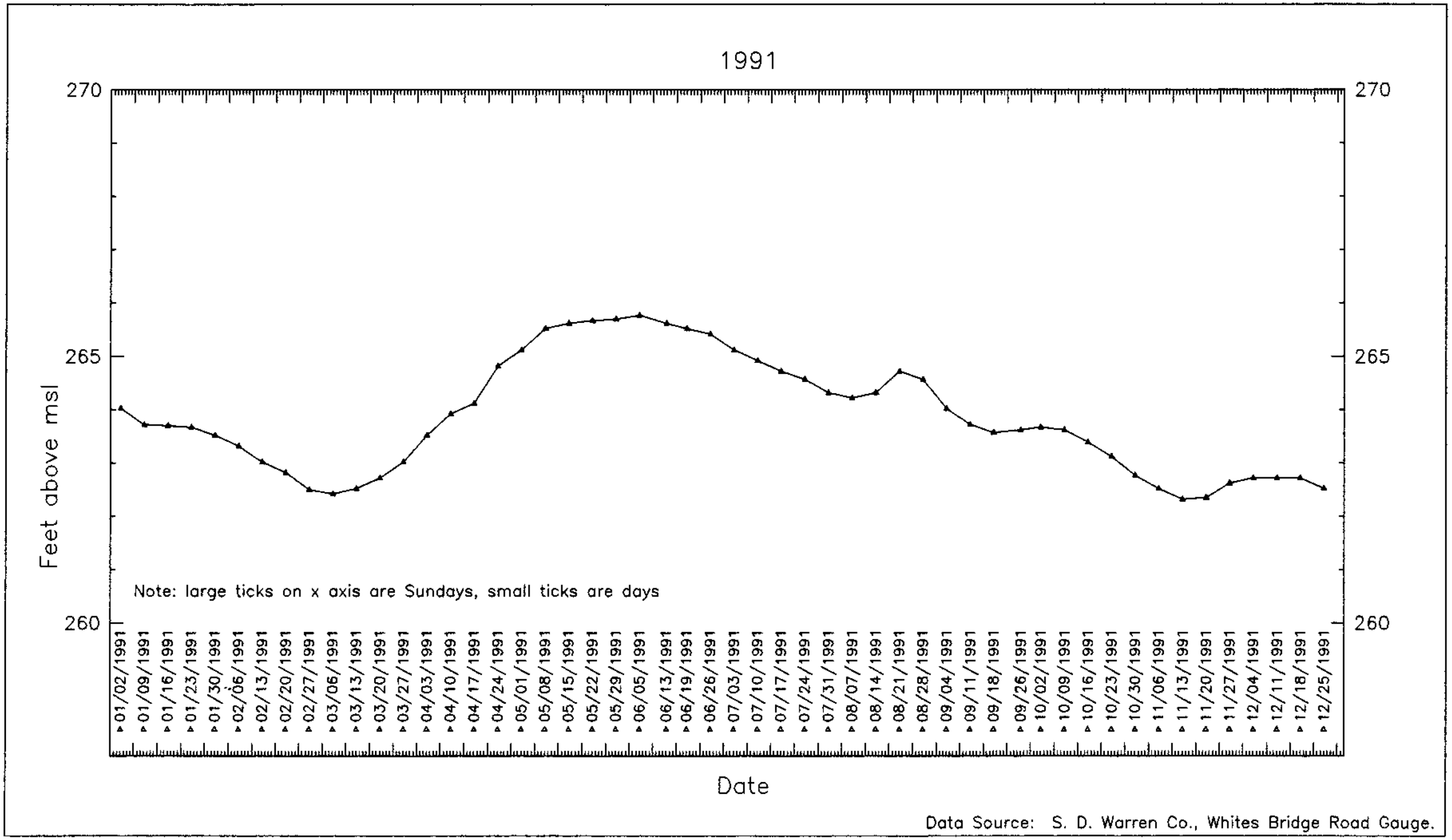


Figure 7: Sebago Lake Weekly Water Levels, 1991.

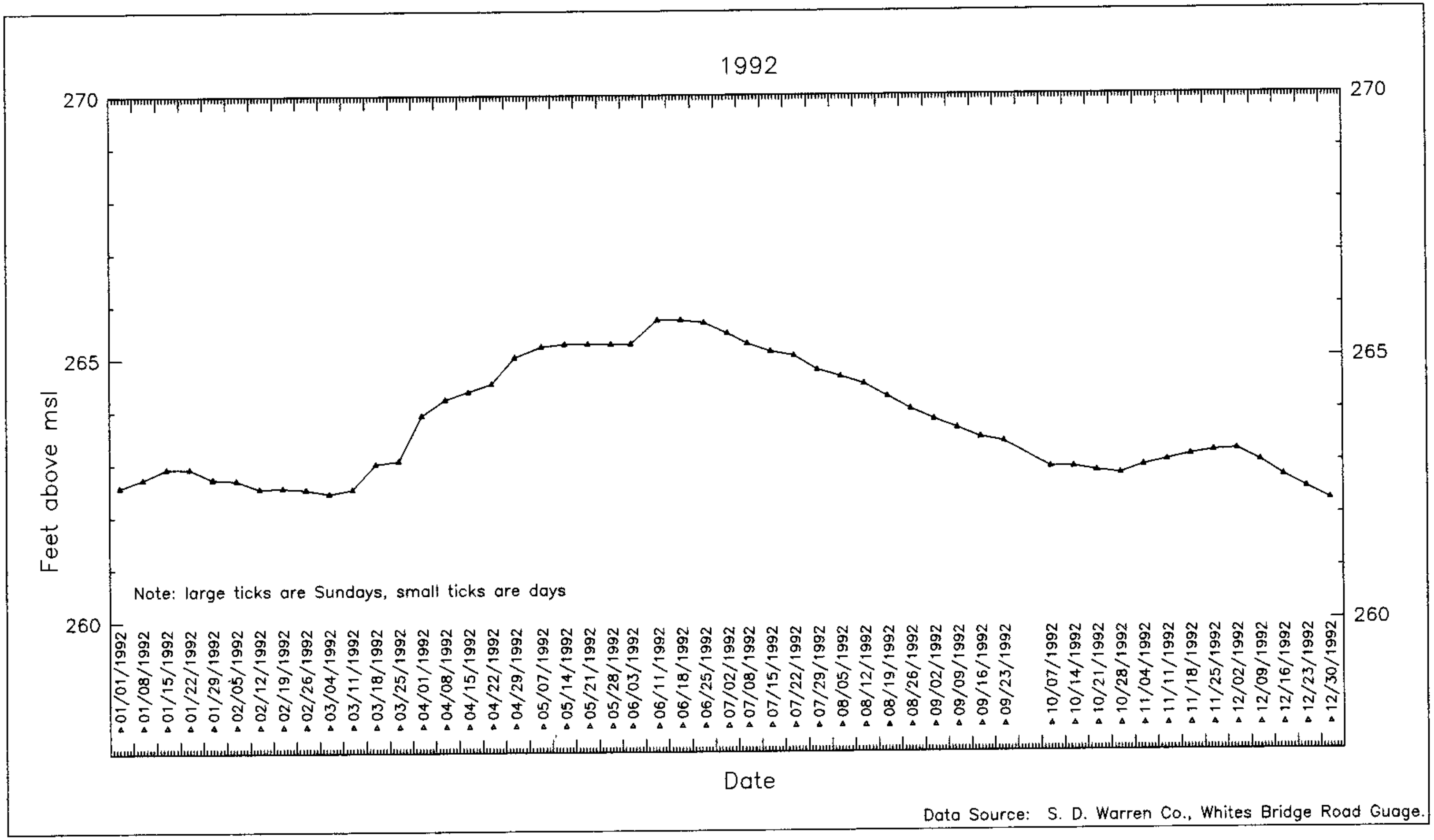


Figure 8: Sebago Lake Weekly Water Levels, 1992.

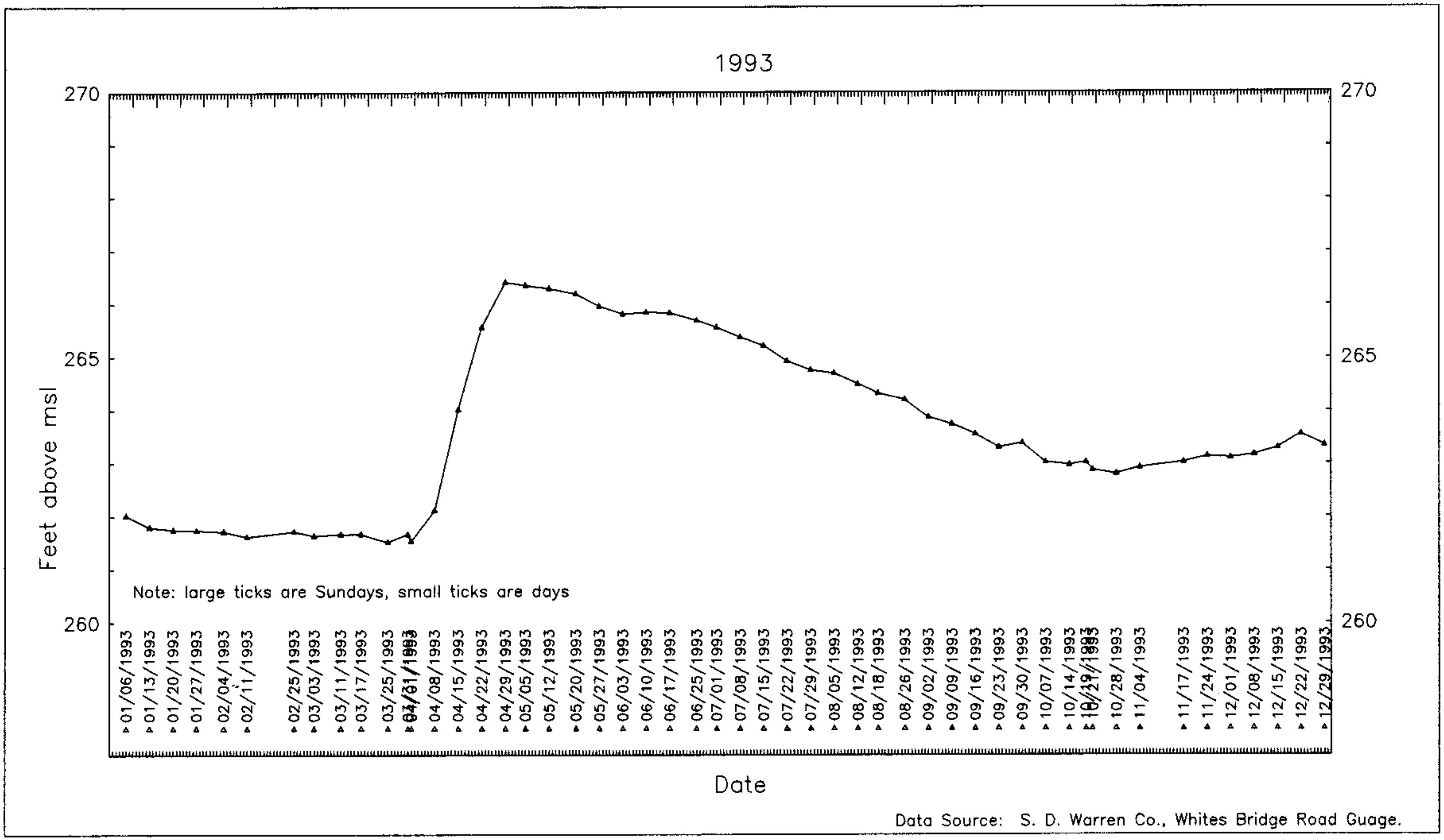


Figure 9: Sebago Lake Weekly Water Levels, 1993.

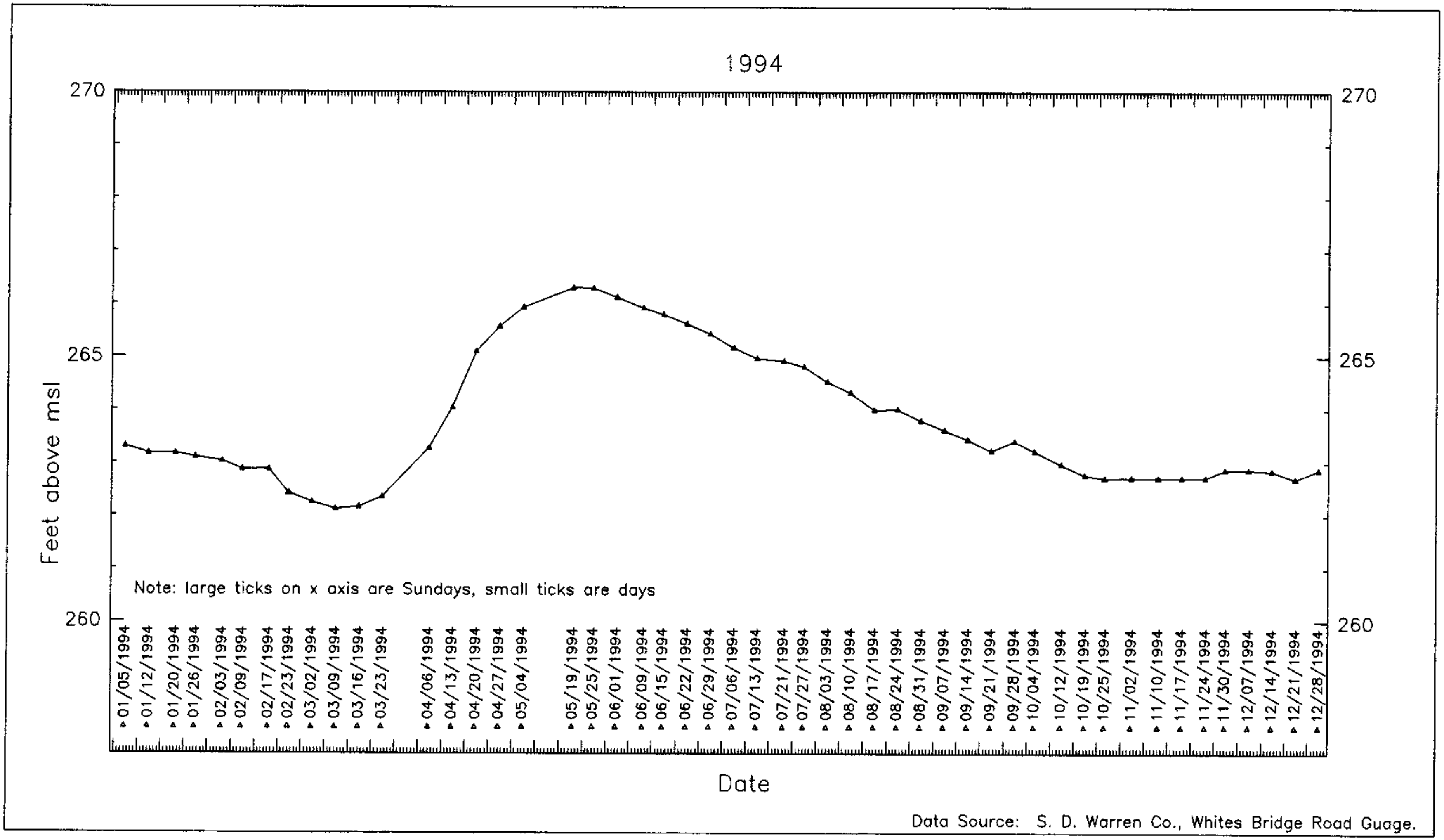


Figure 10: Sebago Lake Weekly Water Levels, 1994.

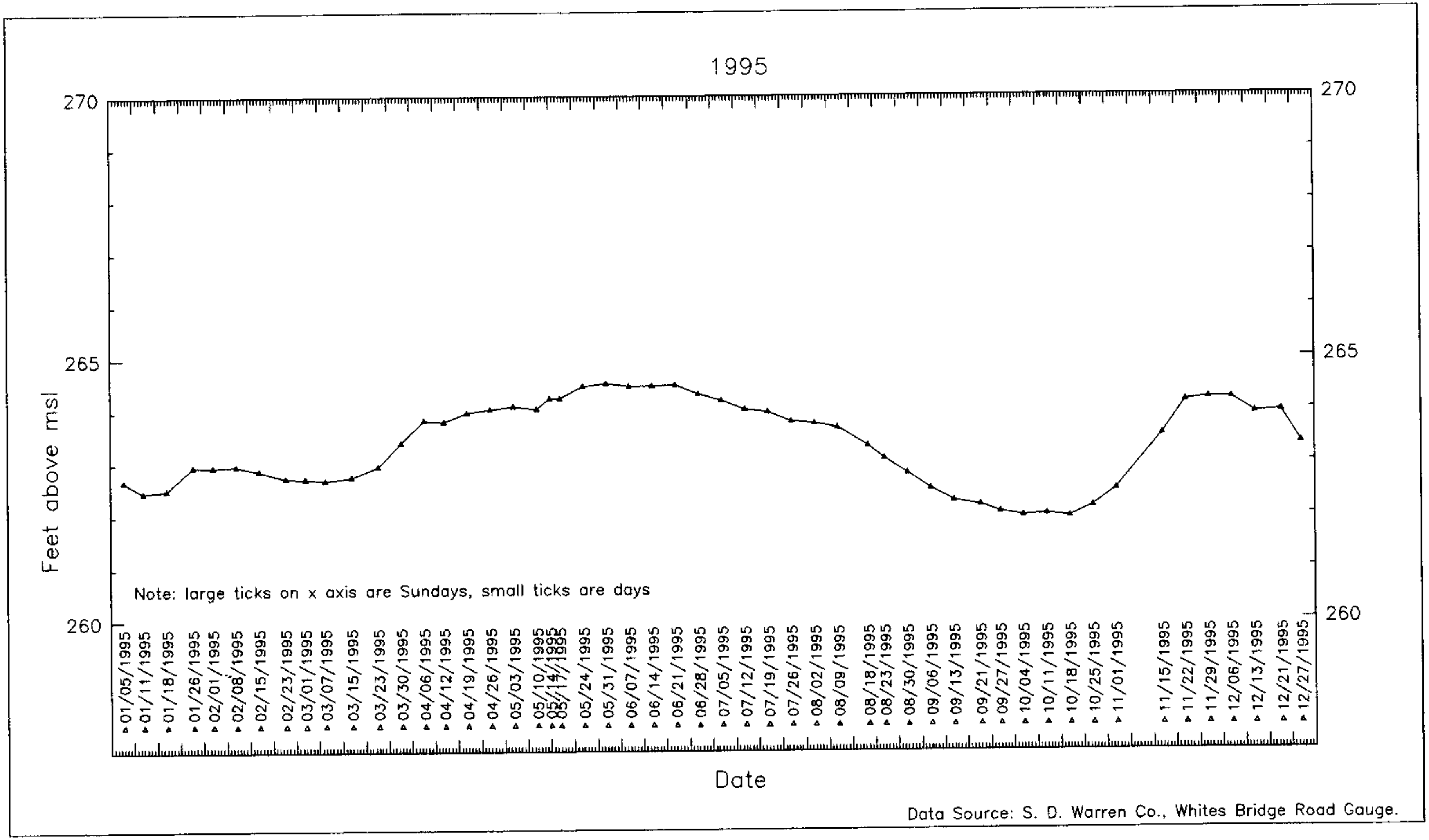


Figure 11: Sebago Lake Weekly Water Levels, 1995.

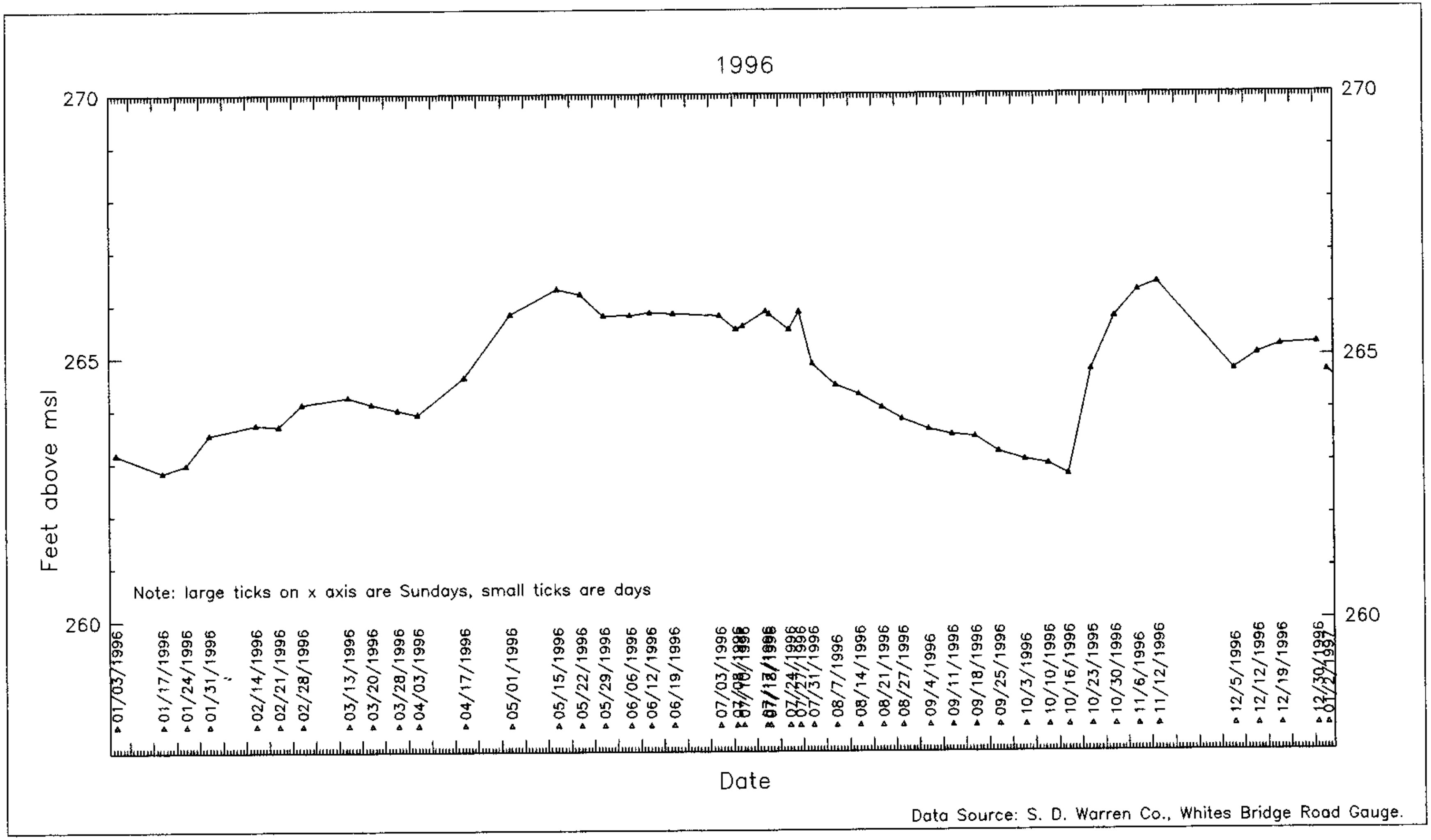


Figure 12: Sebago Lake Weekly Water Levels, 1996.

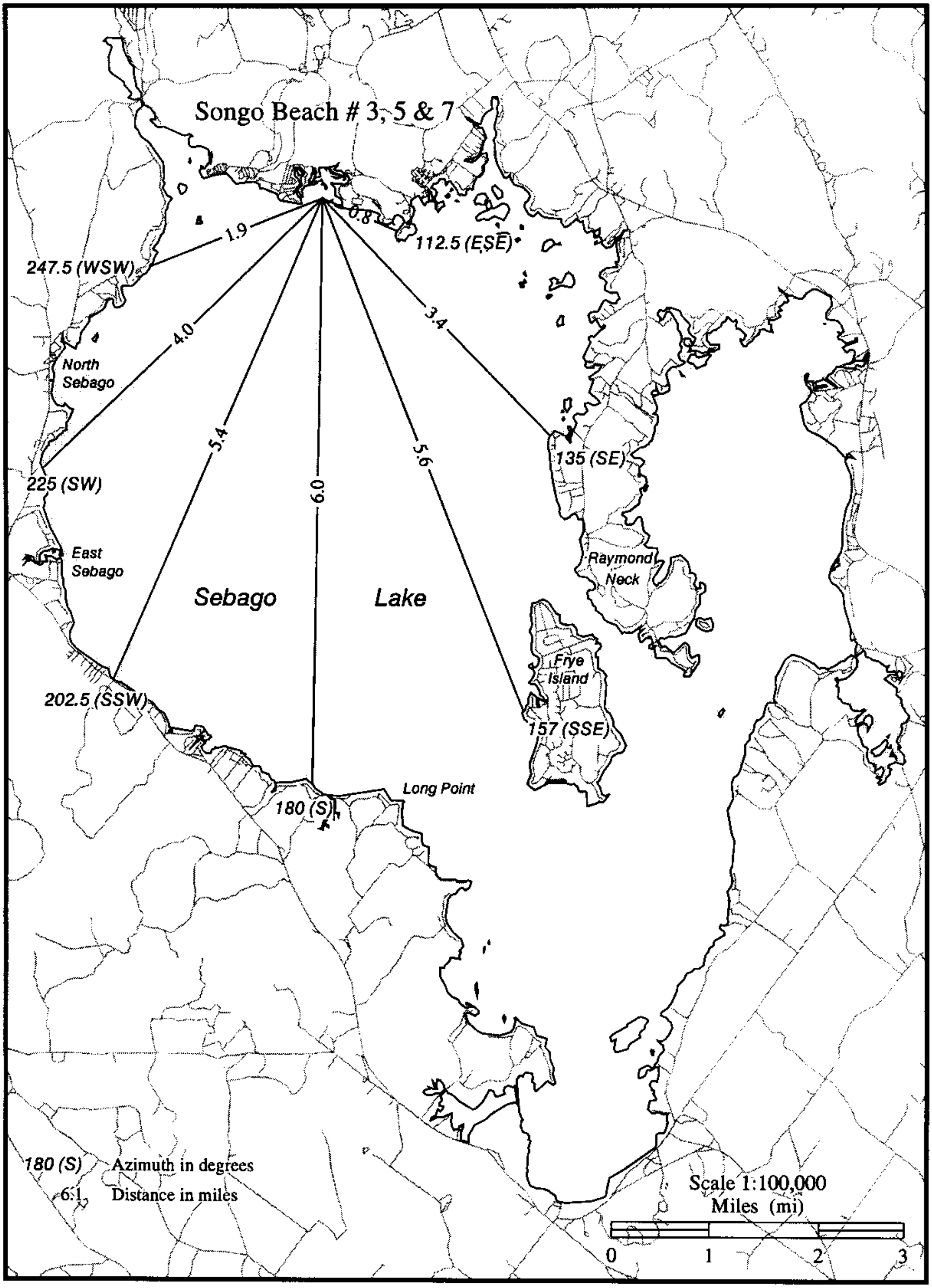


Figure 13. Fetch map of Songo Beach profile sites.

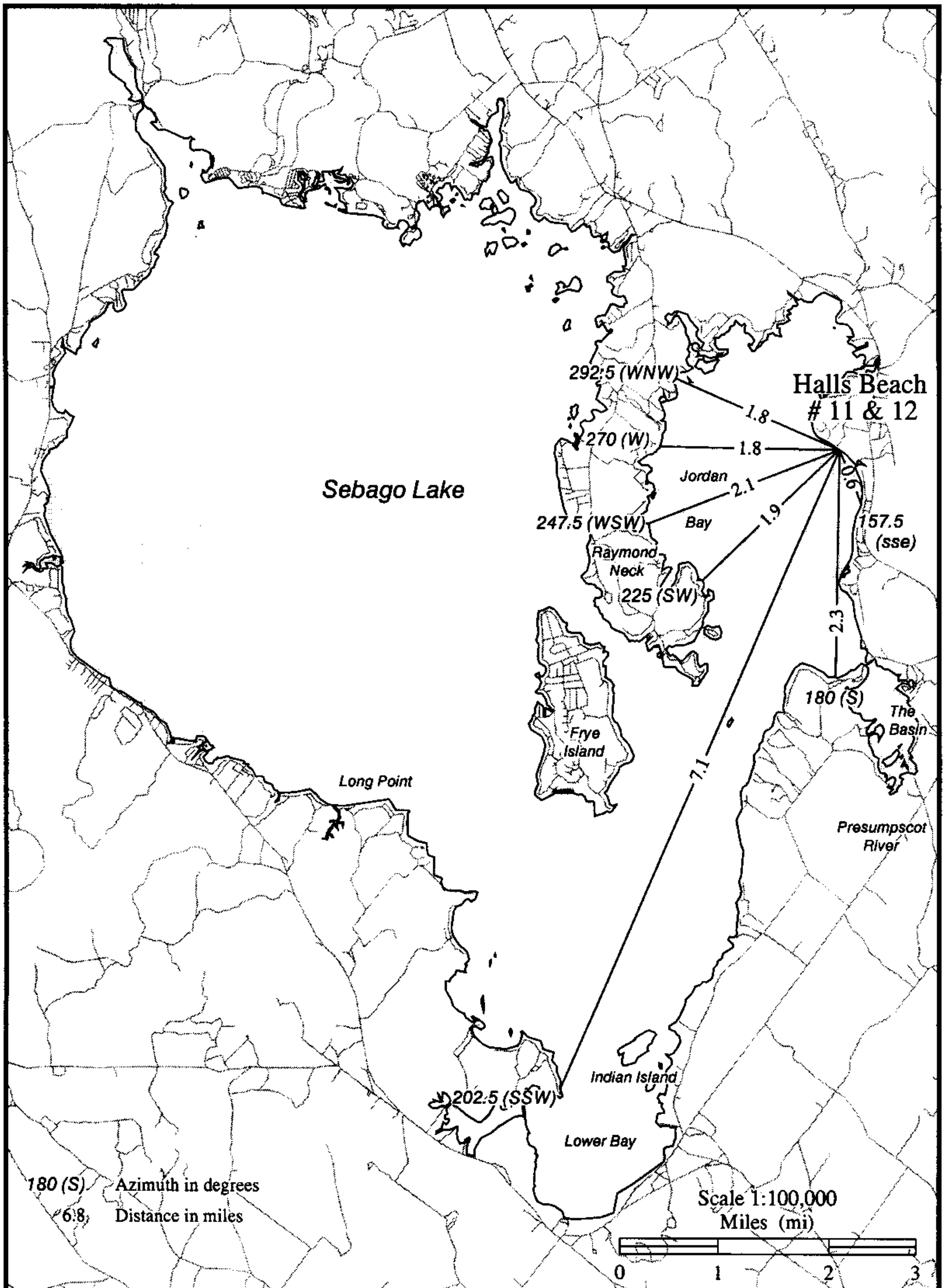


Figure 14. Fetch map of Halls Beach profile sites. (also called Tasseltop Beach)

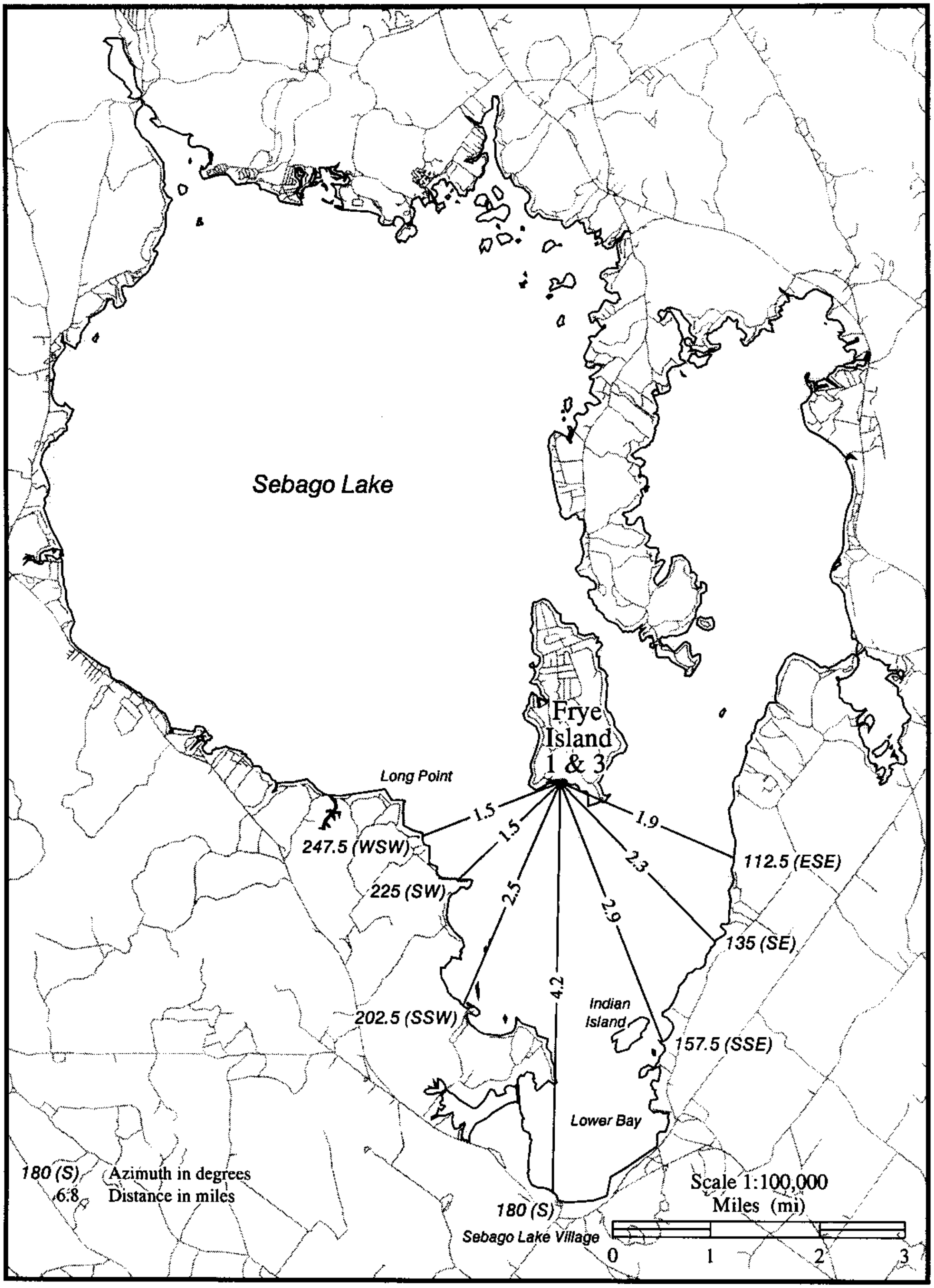


Figure 15. Fetch map of Frye Island Beach profile sites.

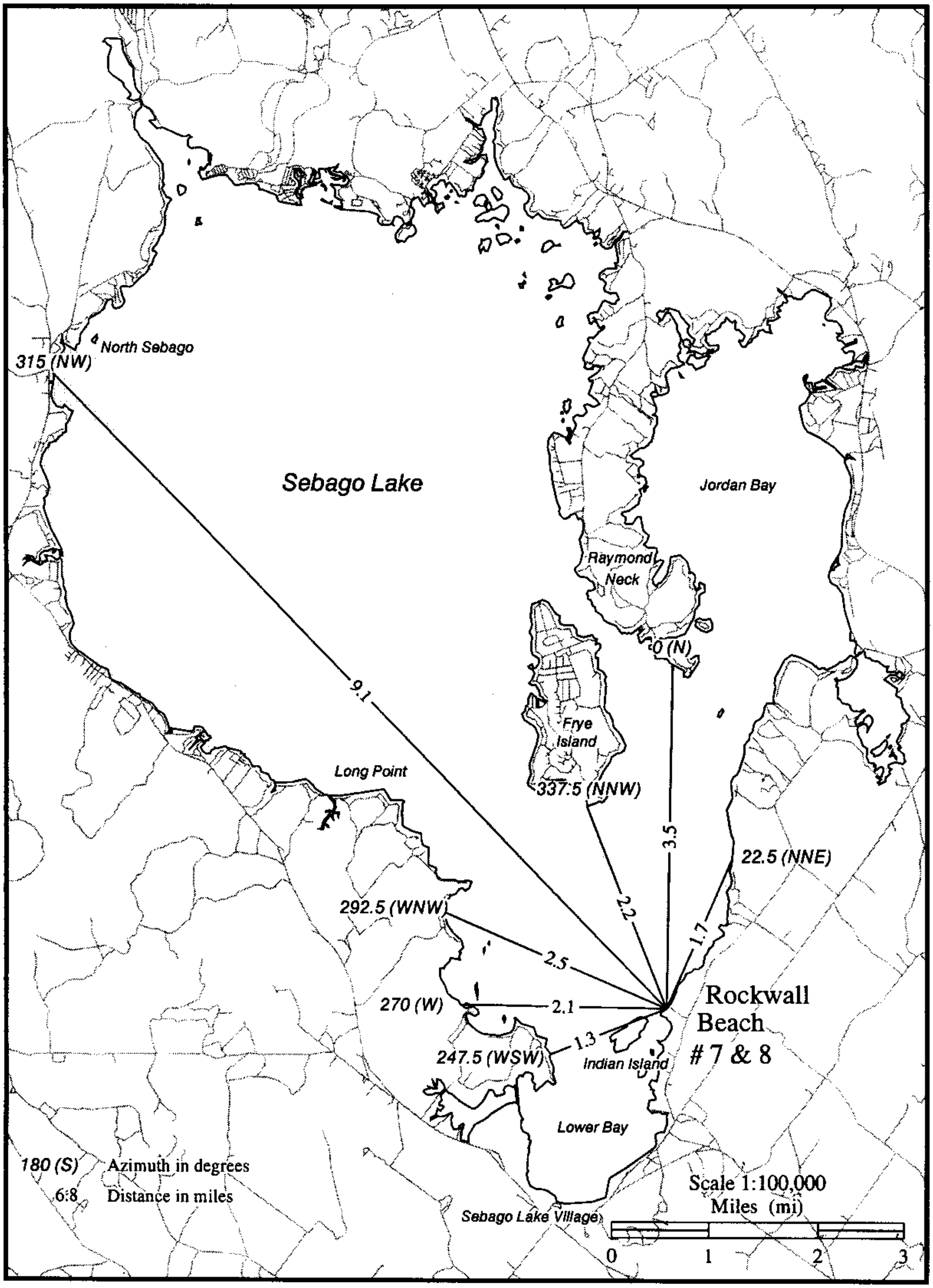


Figure 16. Fetch map of Rockwall Beach profile sites.

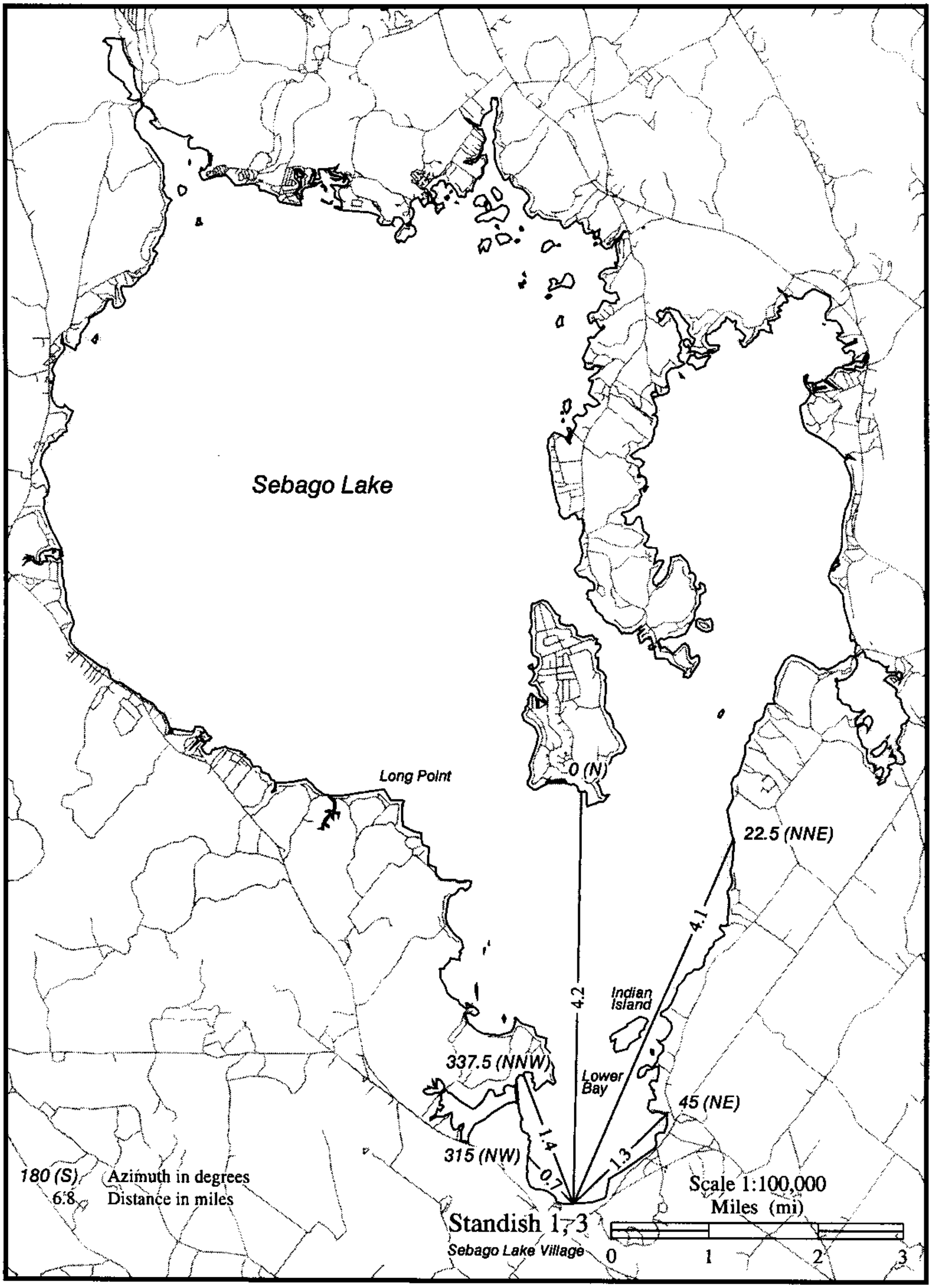


Figure 17. Fetch map of Standish Beach profile sites.

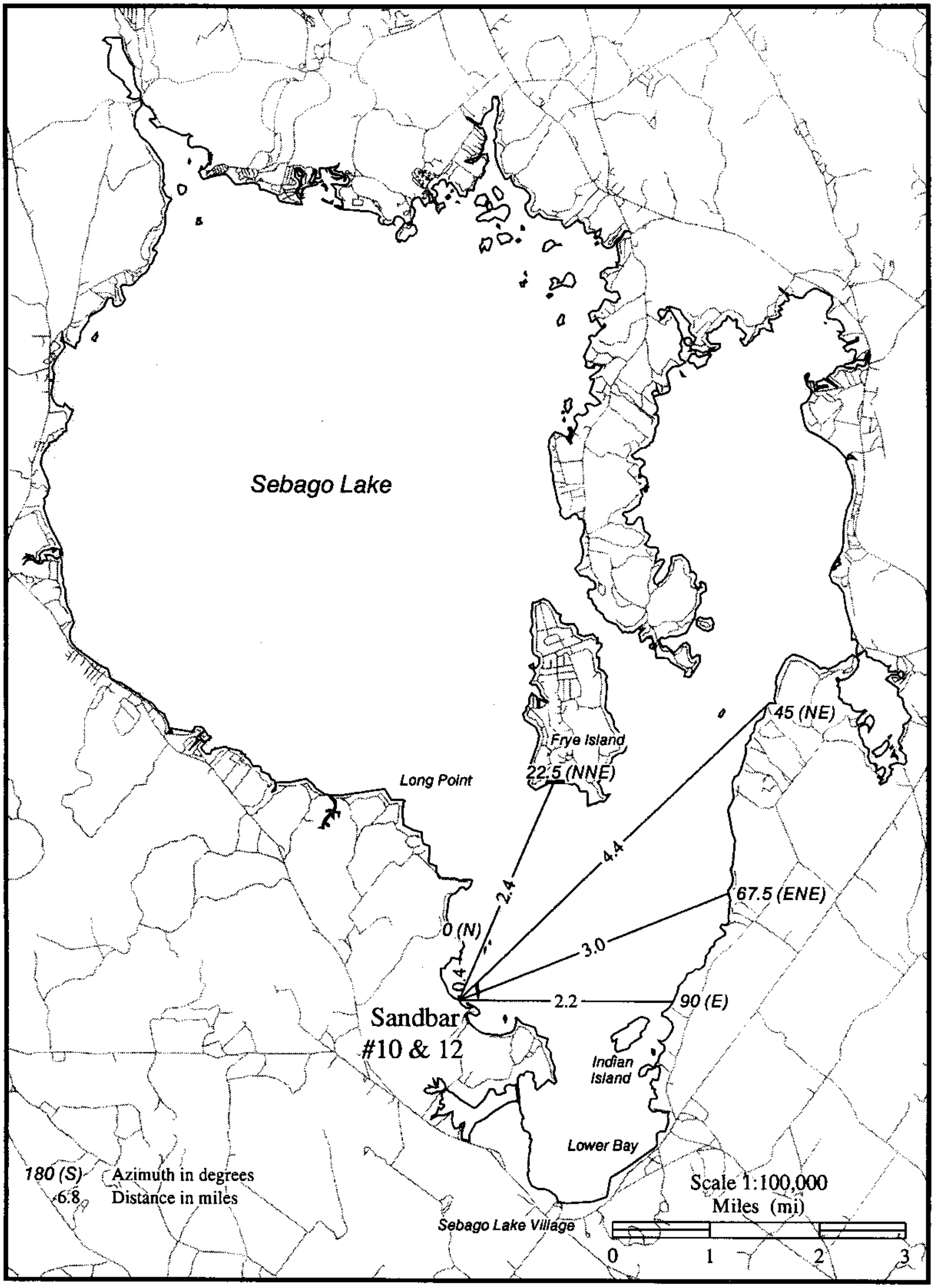


Figure 18. Fetch map of Sandbar Beach profile sites.

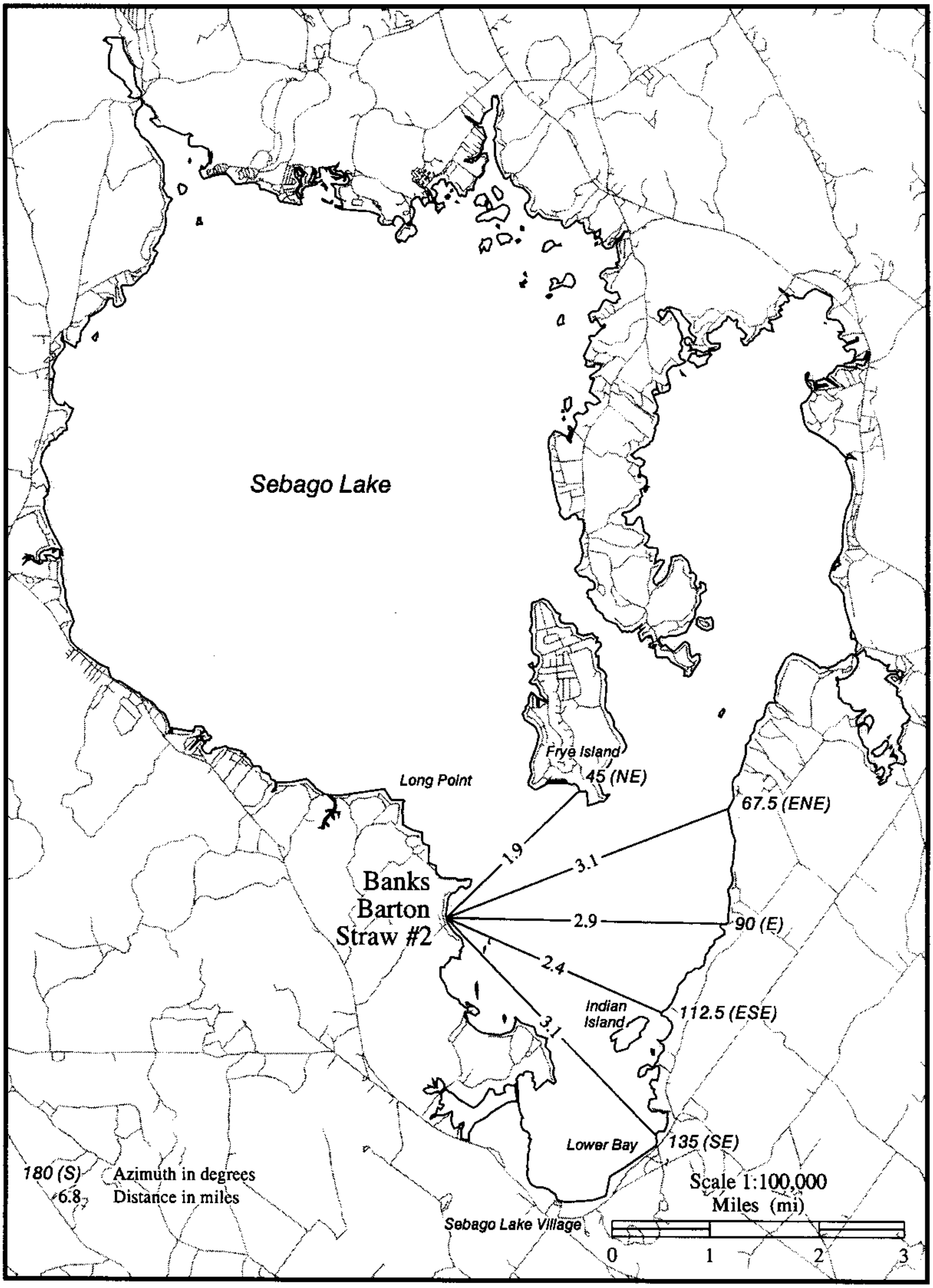


Figure 19. Fetch map of Harmon Beach profile sites (Banks, Barton, Straw #2 residences).

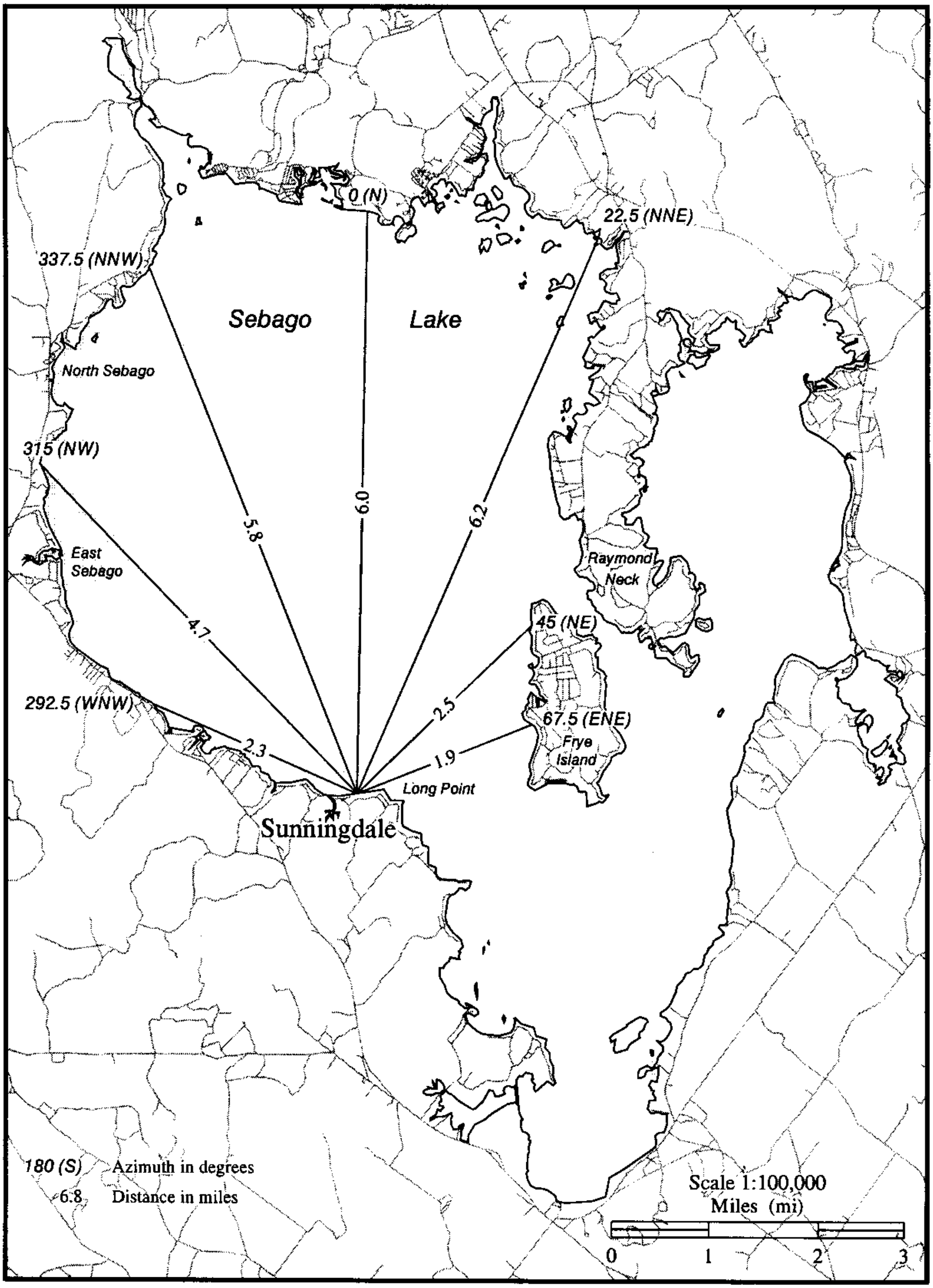


Figure 20. Fetch map of Long Point Beach (Sunningdale) profile sites.

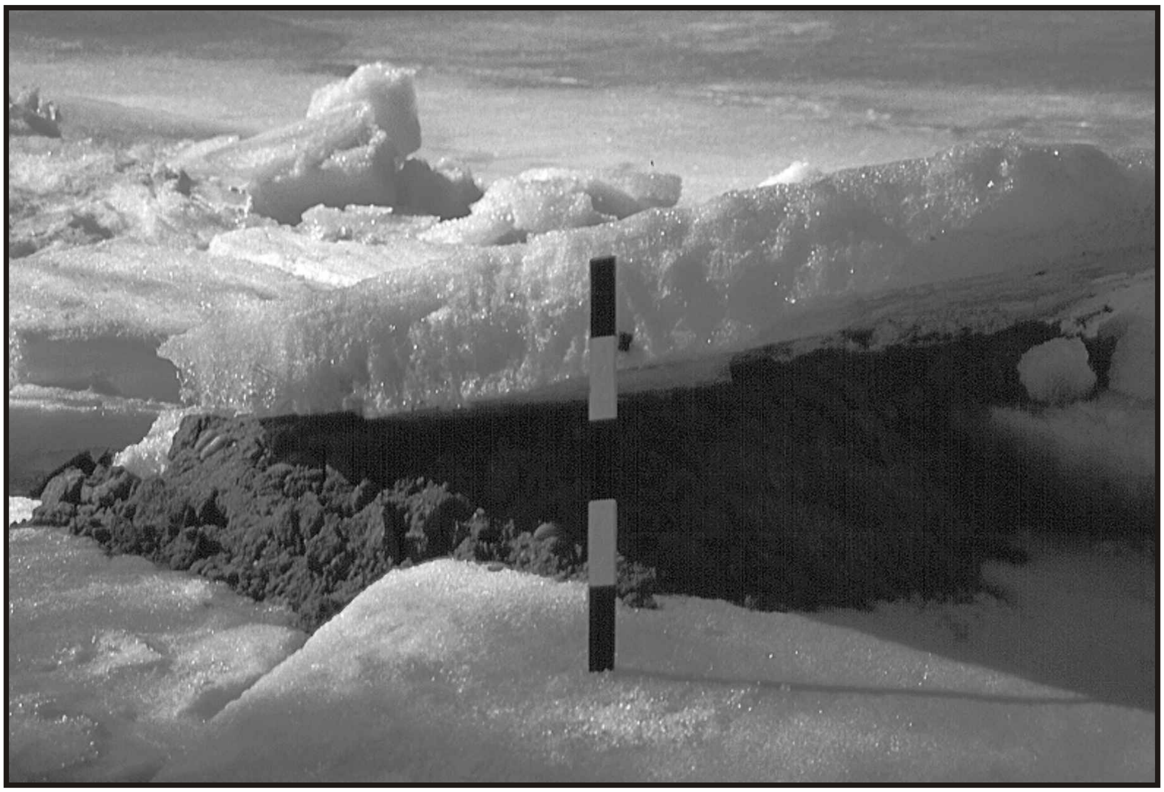


Figure 21. Photograph from spring 1996 of ice carrying sand and ice bulldozing sand on Long Beach (measuring stick is one half meter in length). Photo by Robert Johnston.

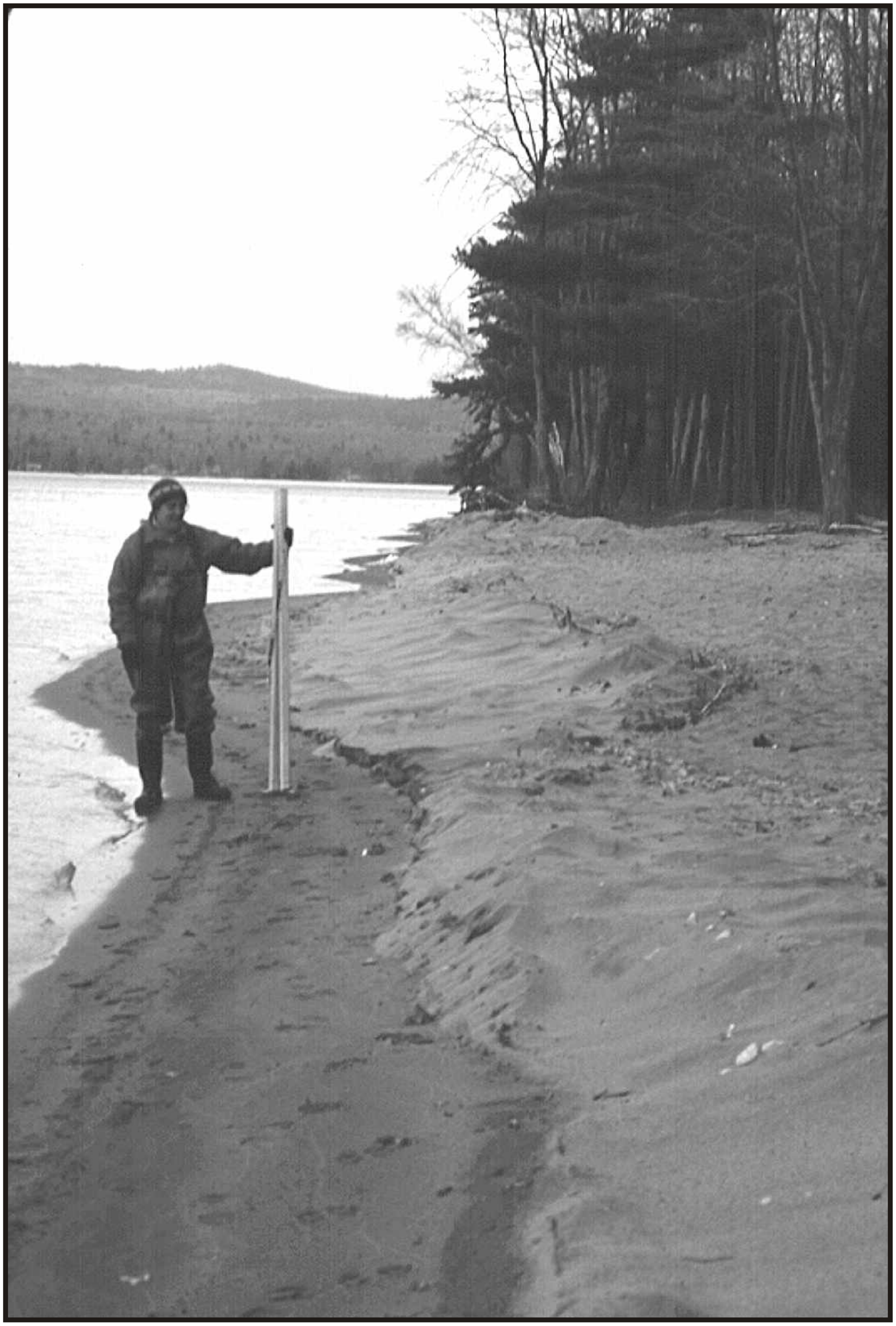


Figure 22. Photograph of spring 1997 ice ridge, Songo Beach (photo by Robert Johnston).

State of Maine Compromise Sebago Lake Plan
April 19, 1996 Revised August 12, 1996

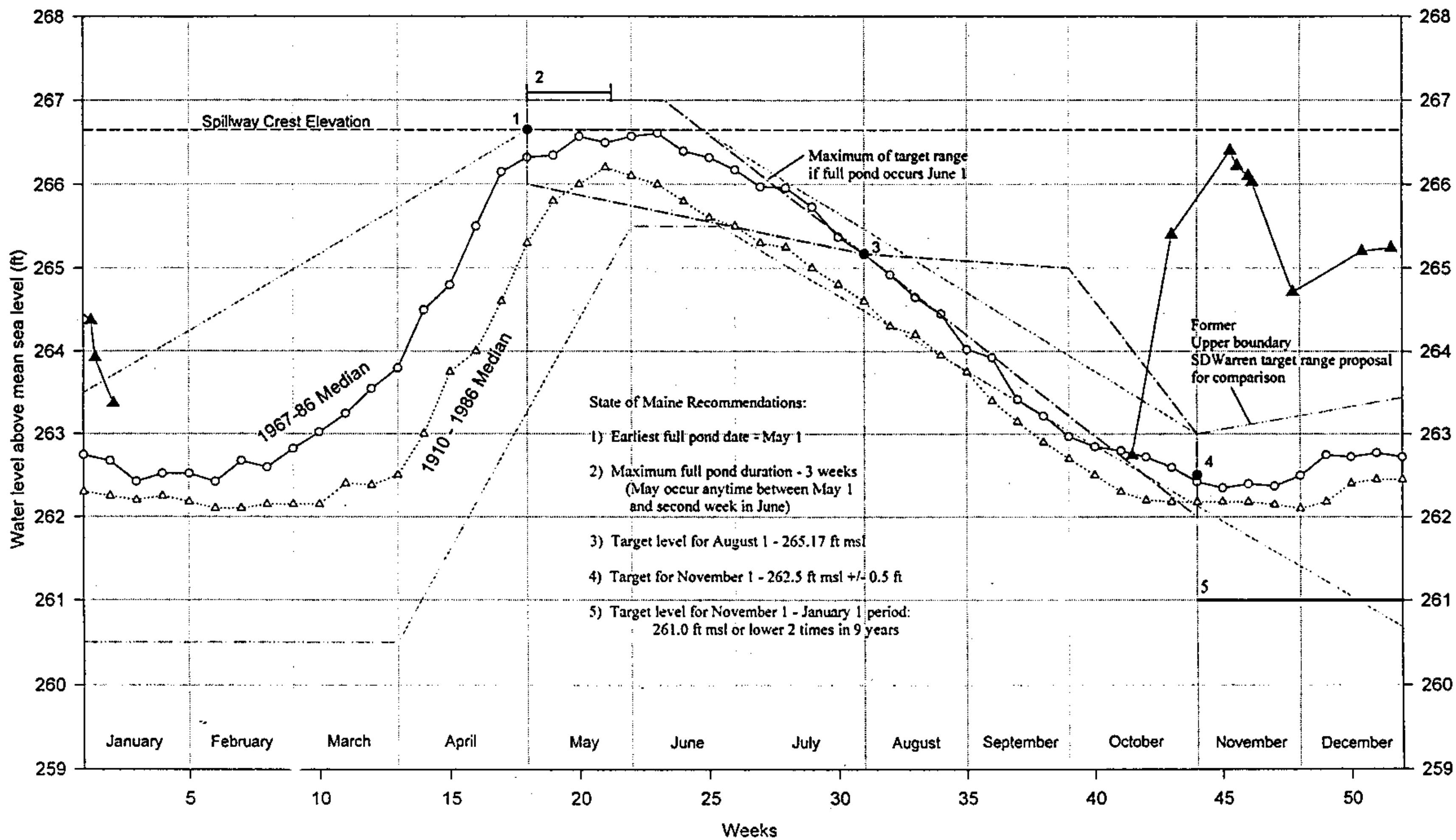


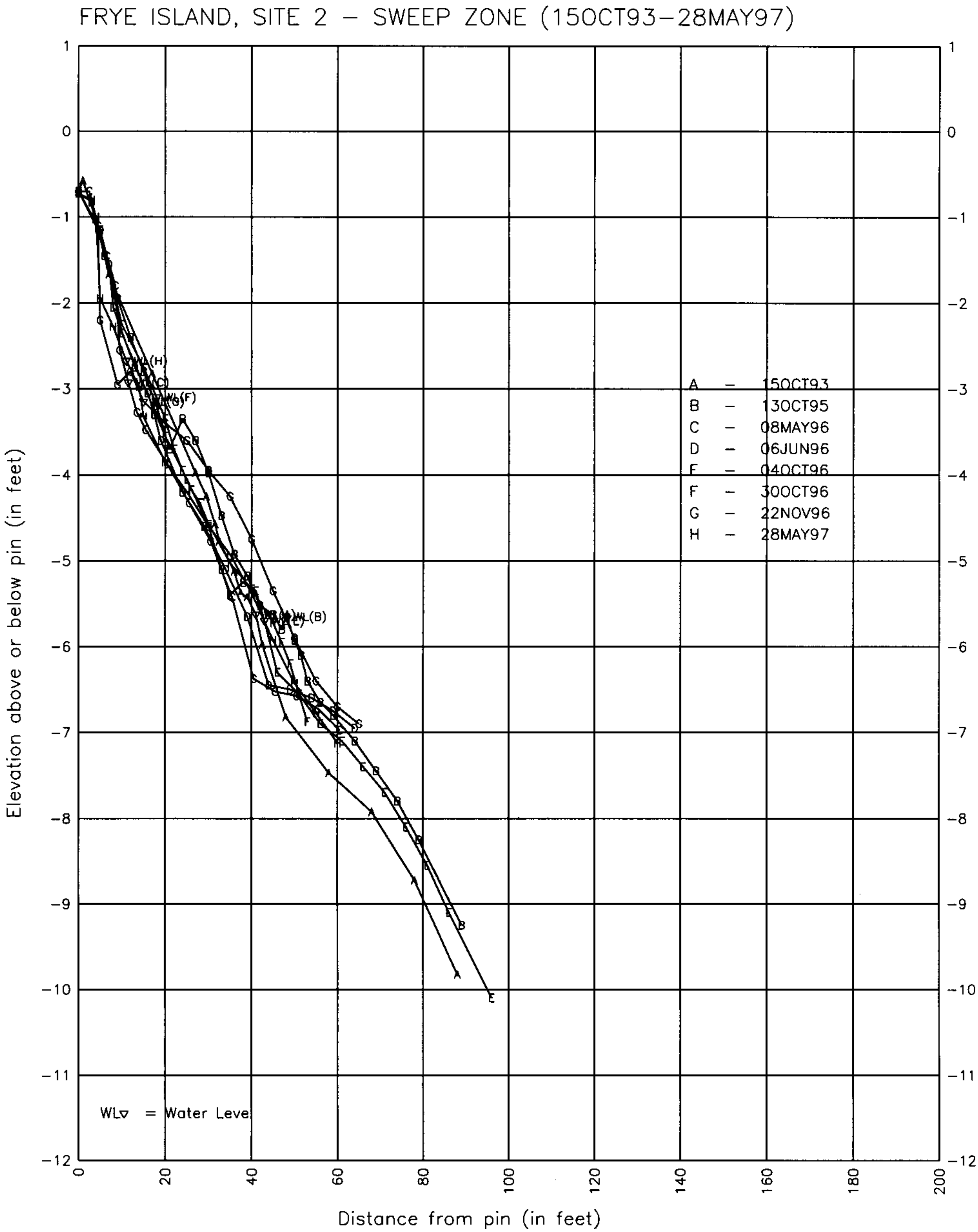
Figure 23. State of Maine Compromise Sebago Lake Plan, 1996.

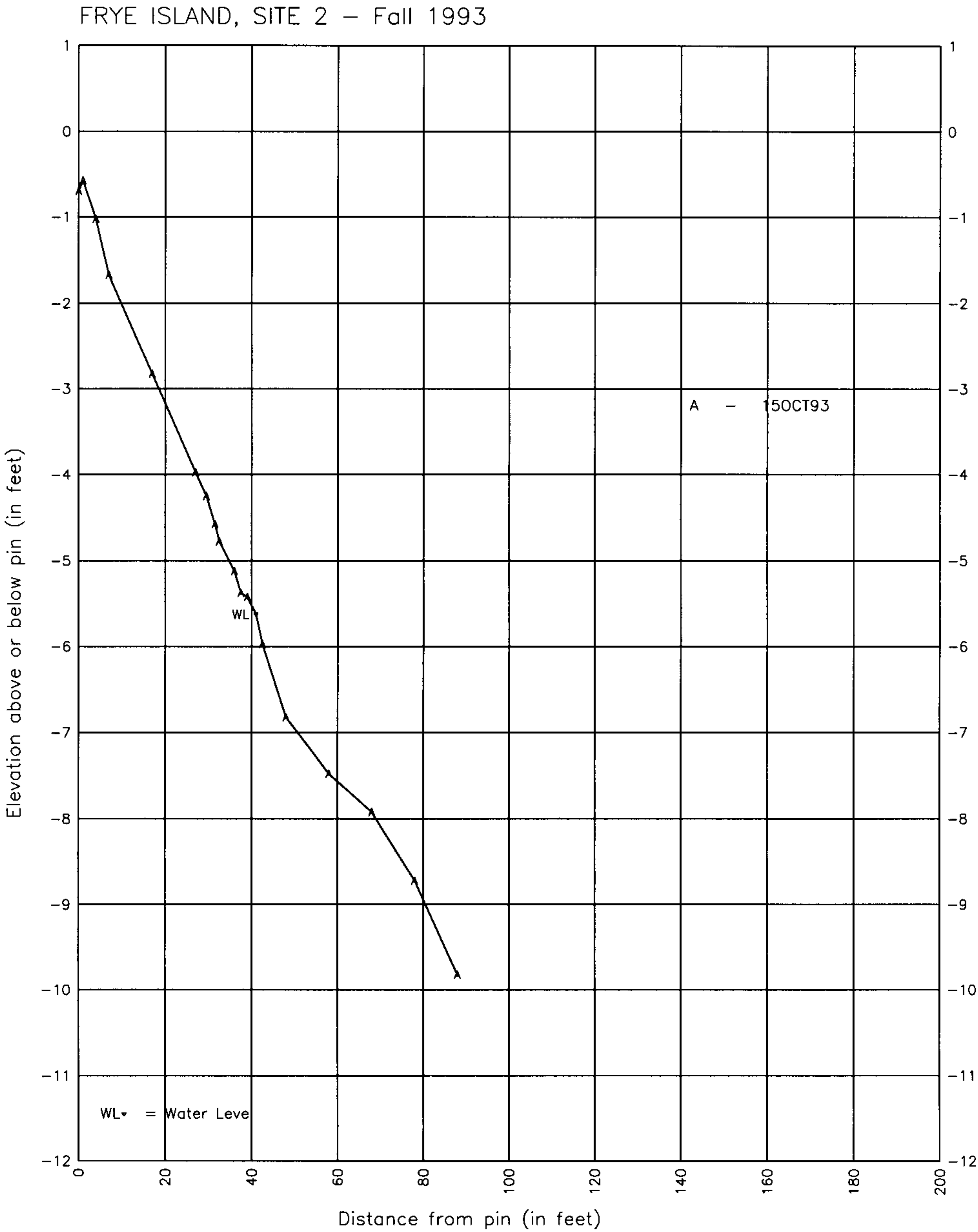
Appendix I

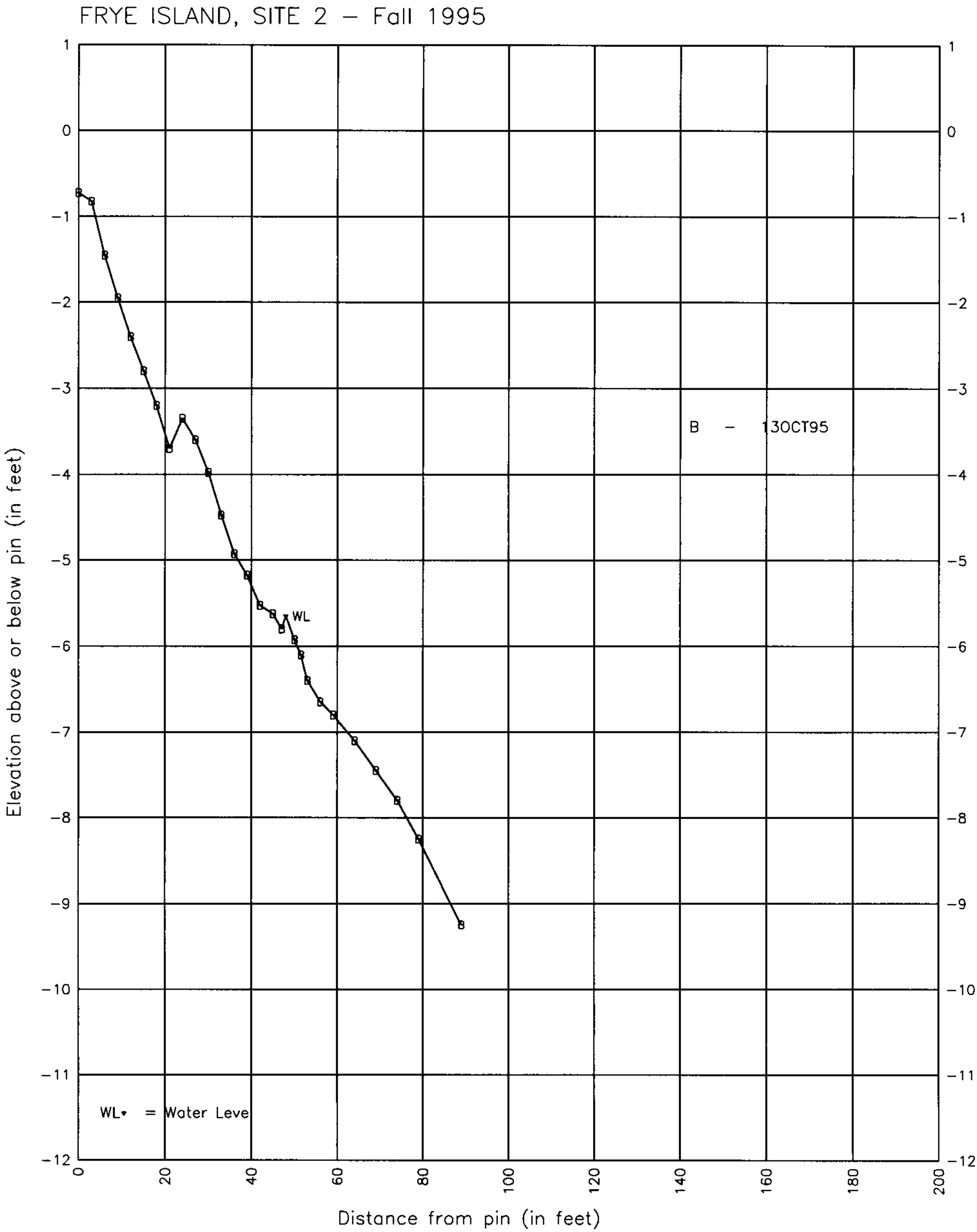
Beach Profiles

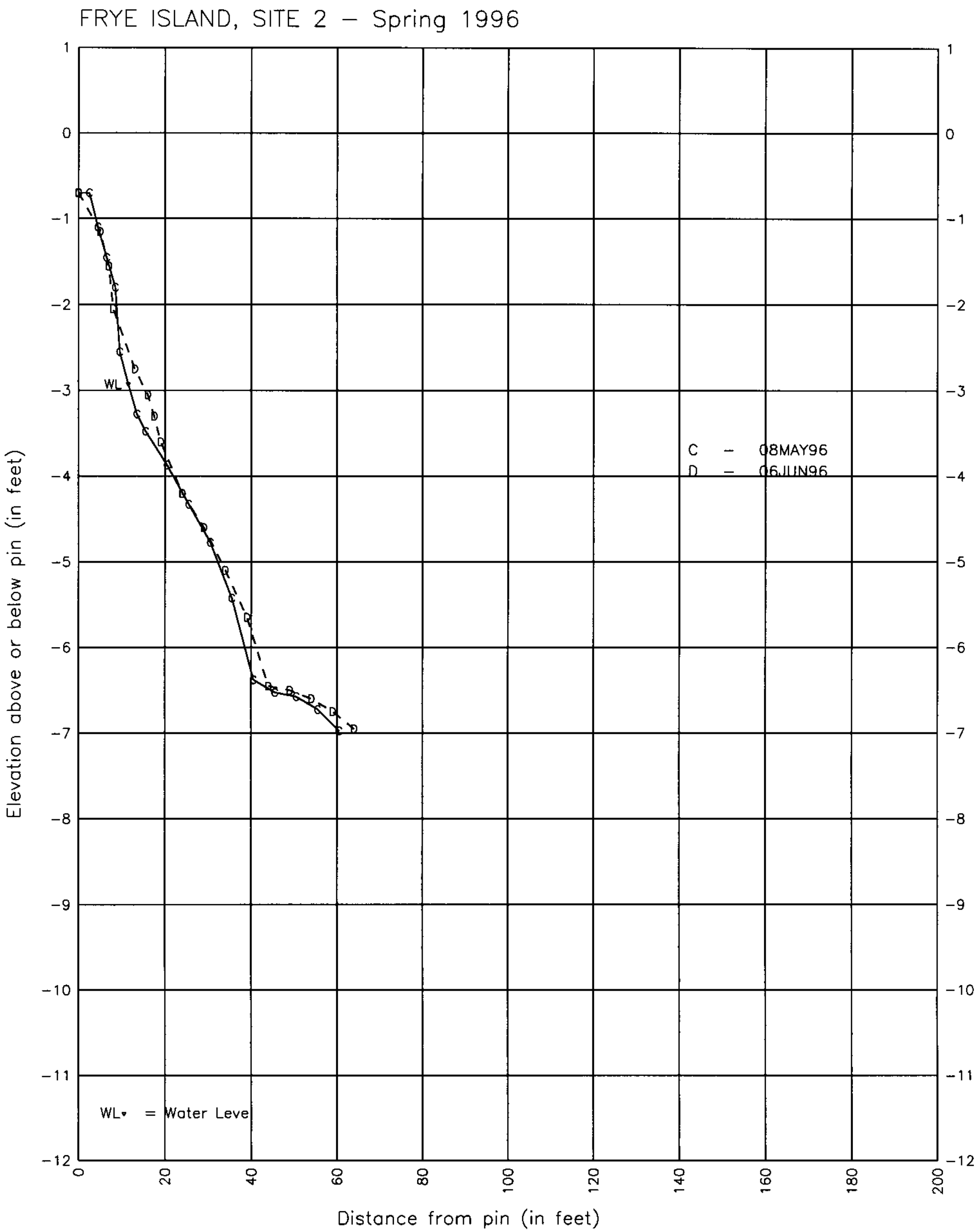
This appendix contains plots of the profiles referred to in the text, where they are arranged by beach and site, in clockwise order around the lake. Within the profile set for each site, profiles are arranged in chronological order by season, with any additional profiles (comparison of all fall profiles, for example) at the end. Figure 3 shows locations of the profile stations.

Profile Lines

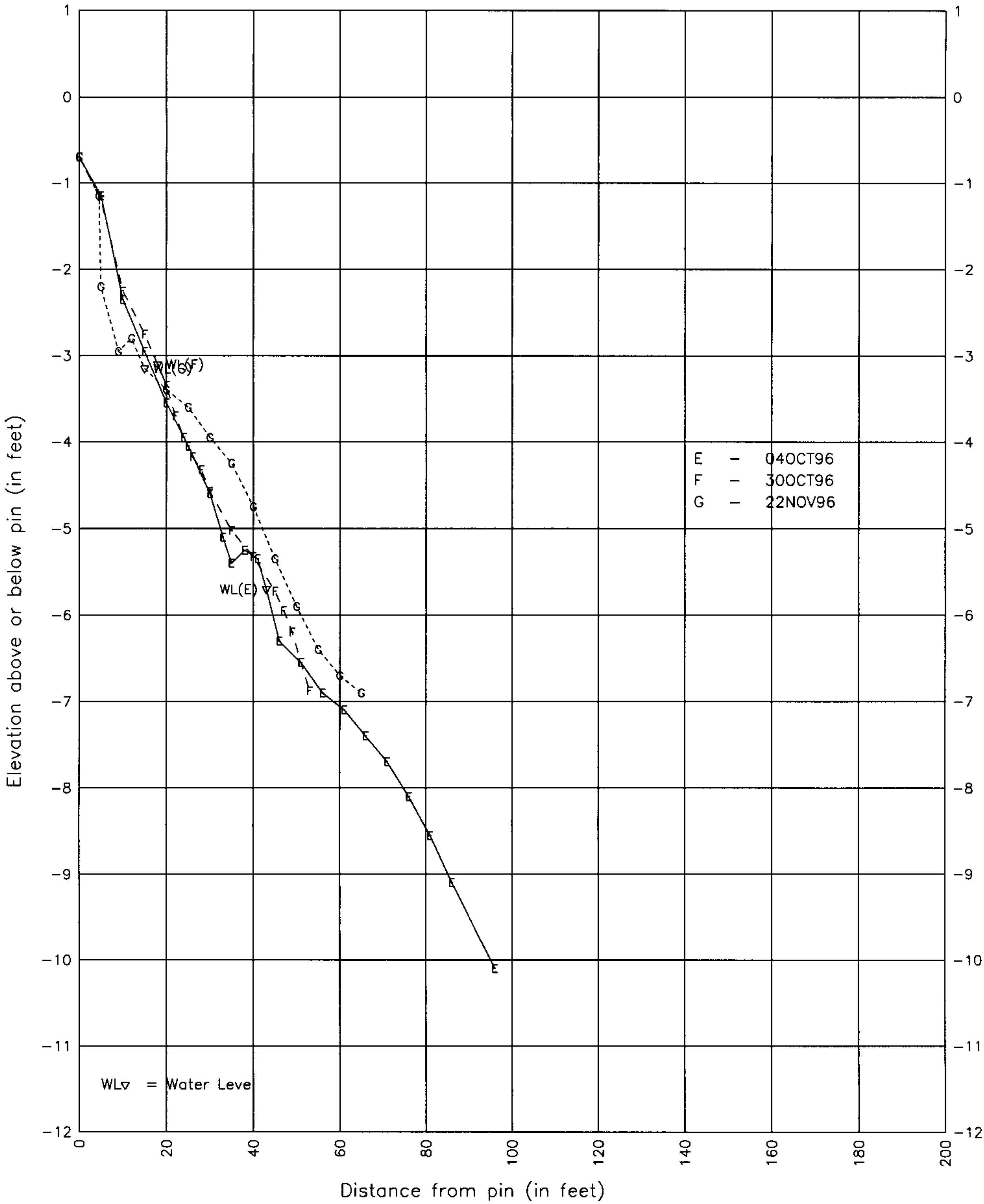

FRYE ISLAND, SITE 2 – SWEEP ZONE (15OCT93–28MAY97)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 15OCT93
B – 13OCT95
C – 08MAY96
D – 06JUN96
E – 04OCT96
F – 30OCT96
G – 22NOV96
H – 28MAY97
WL▽ = Water Level
WL(H)
WL(C)
WL(F)
WL(G)
WL(B)
WL(E)

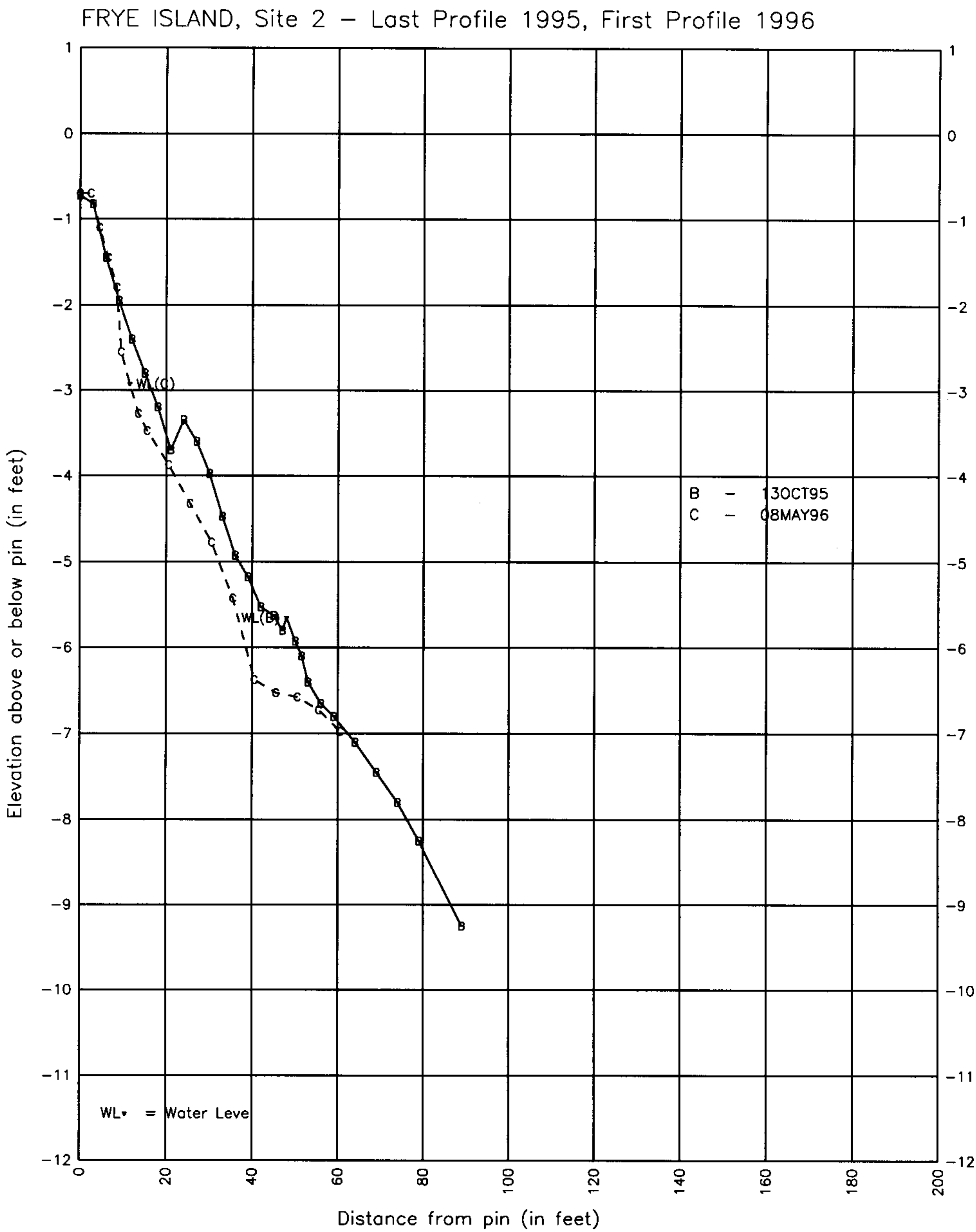

FRYE ISLAND, SITE 2 – Fall 1993
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 15OCT93
WL
WL▾ = Water Leve
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
–12
0
20
40
60
80
100
120
140
160
180
200


FRYE ISLAND, SITE 2 — Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
B — 13OCT95
WL
WL▾ = Water Leve
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0
20
40
60
80
100
120
140
160
180
200

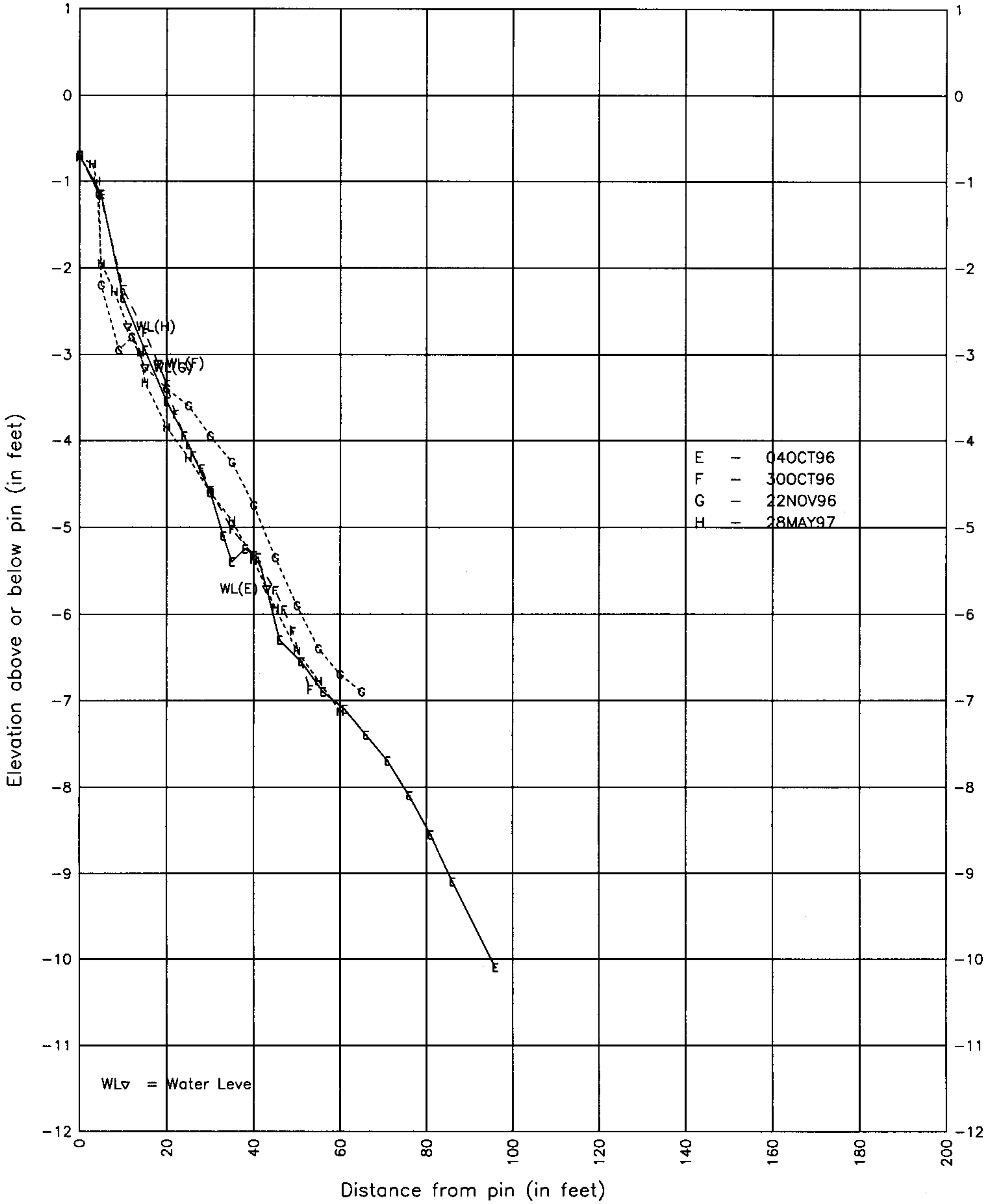

FRYE ISLAND, SITE 2 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 08MAY96
D – 06JUN96
WL
WL▾ = Water Level
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0
20
40
60
80
100
120
140
160
180
200

FRYE ISLAND, Site 2 – Fall 1996

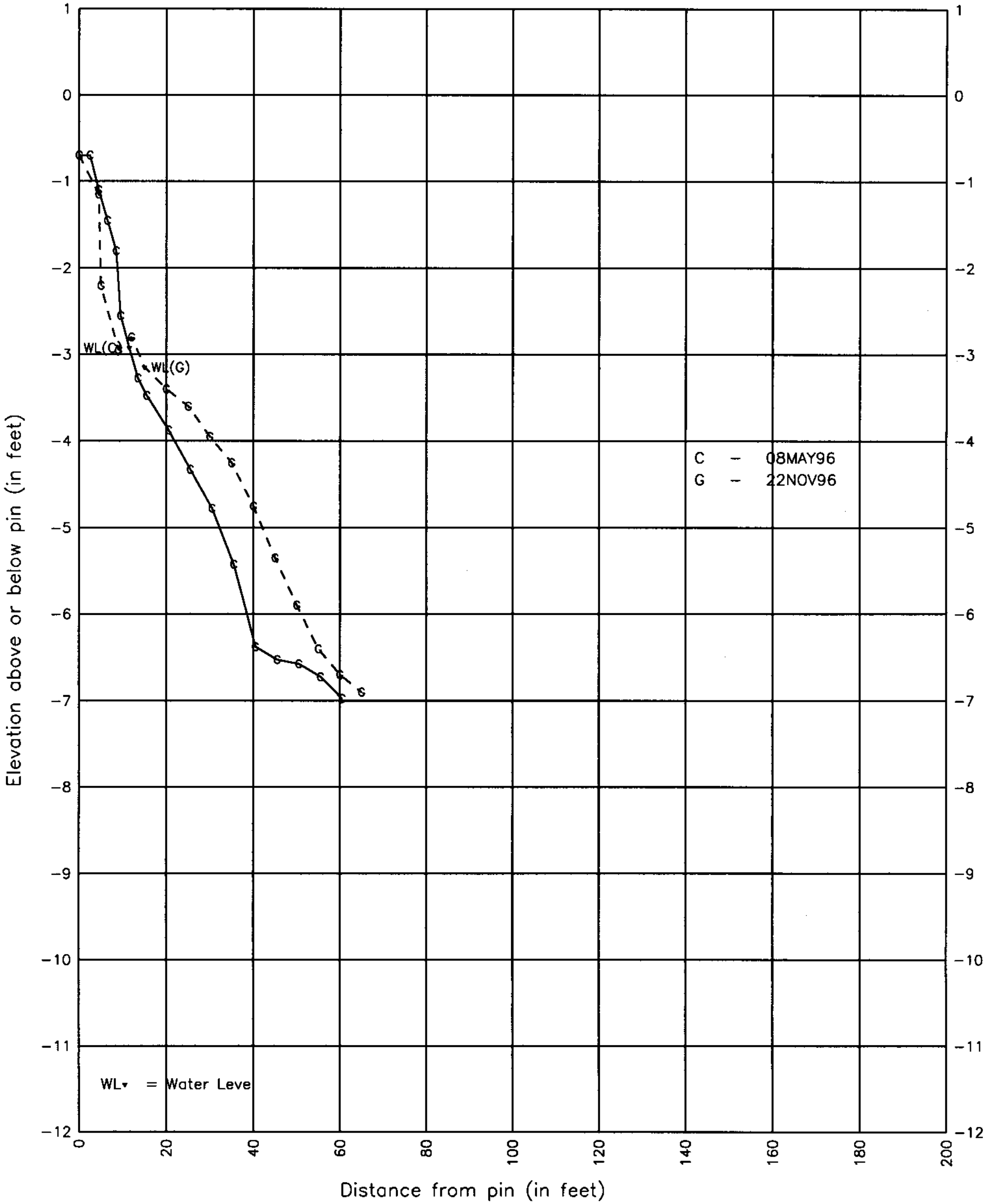


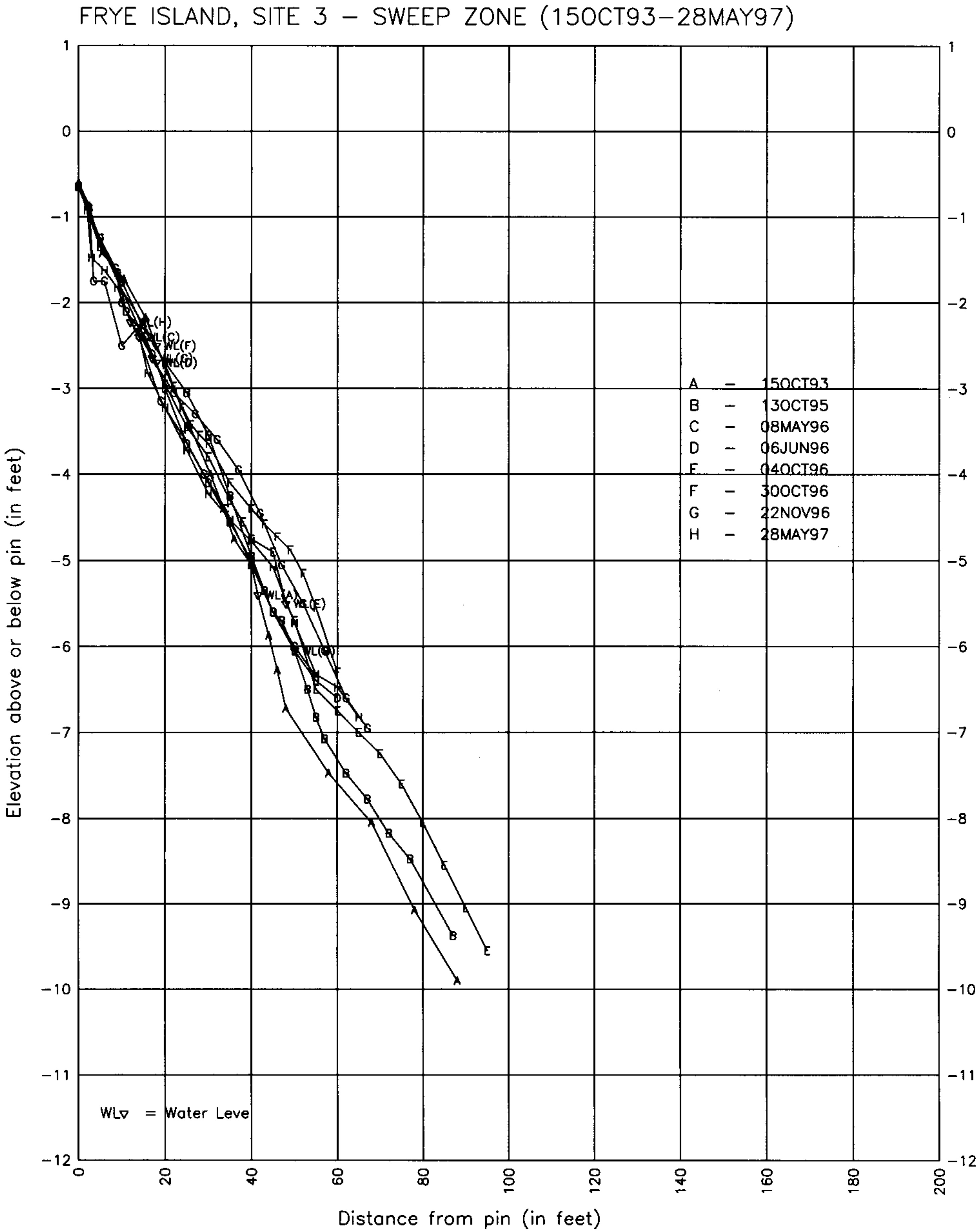

FRYE ISLAND, Site 2 – Last Profile 1995, First Profile 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
B – 13OCT95
C – 08MAY96
WL(C)
WL(B)
WL▾ = Water Leve
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
–12
0
20
40
60
80
100
120
140
160
180
200

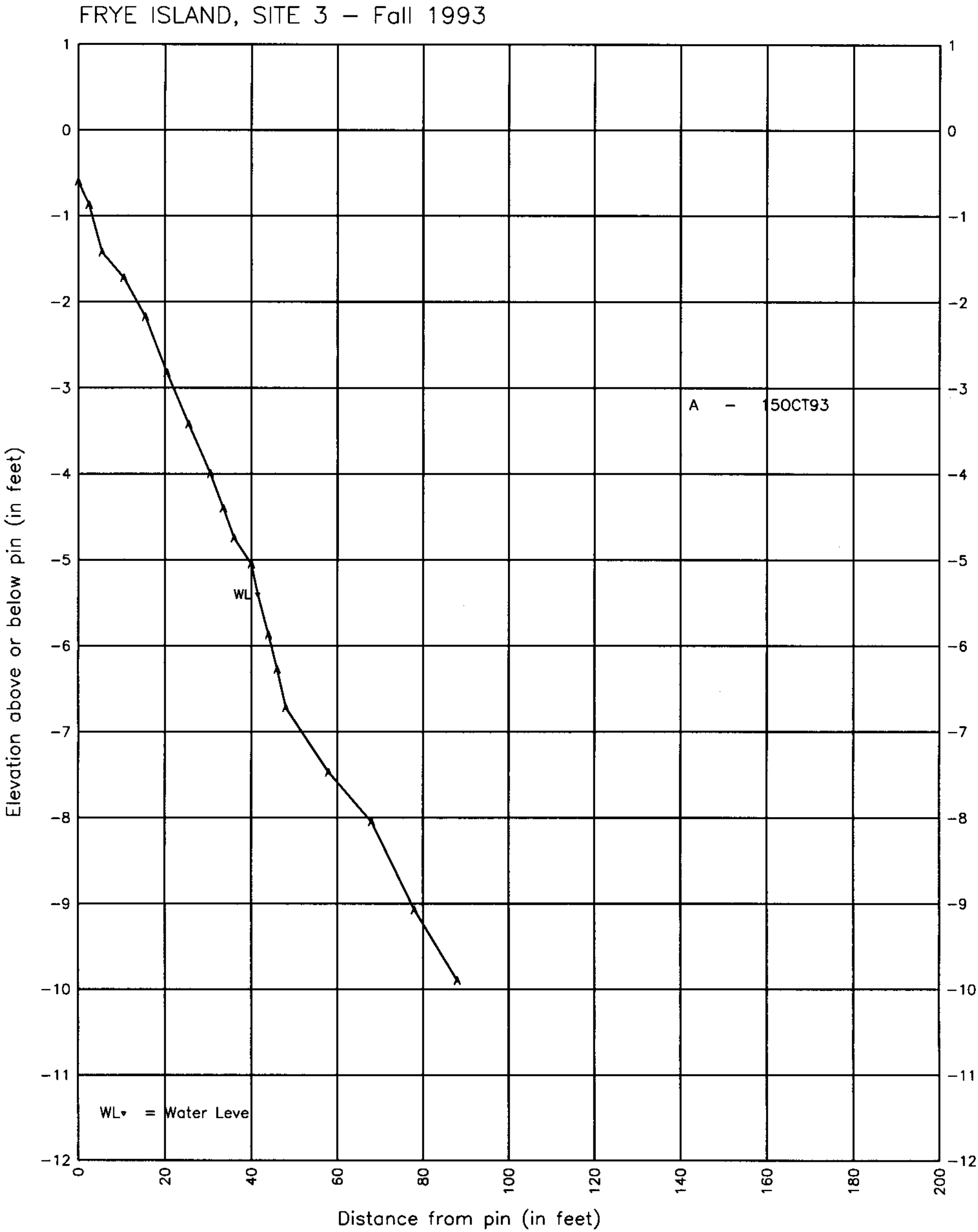
FRYE ISLAND, Site 2 – Fall 1996, Spring 1997

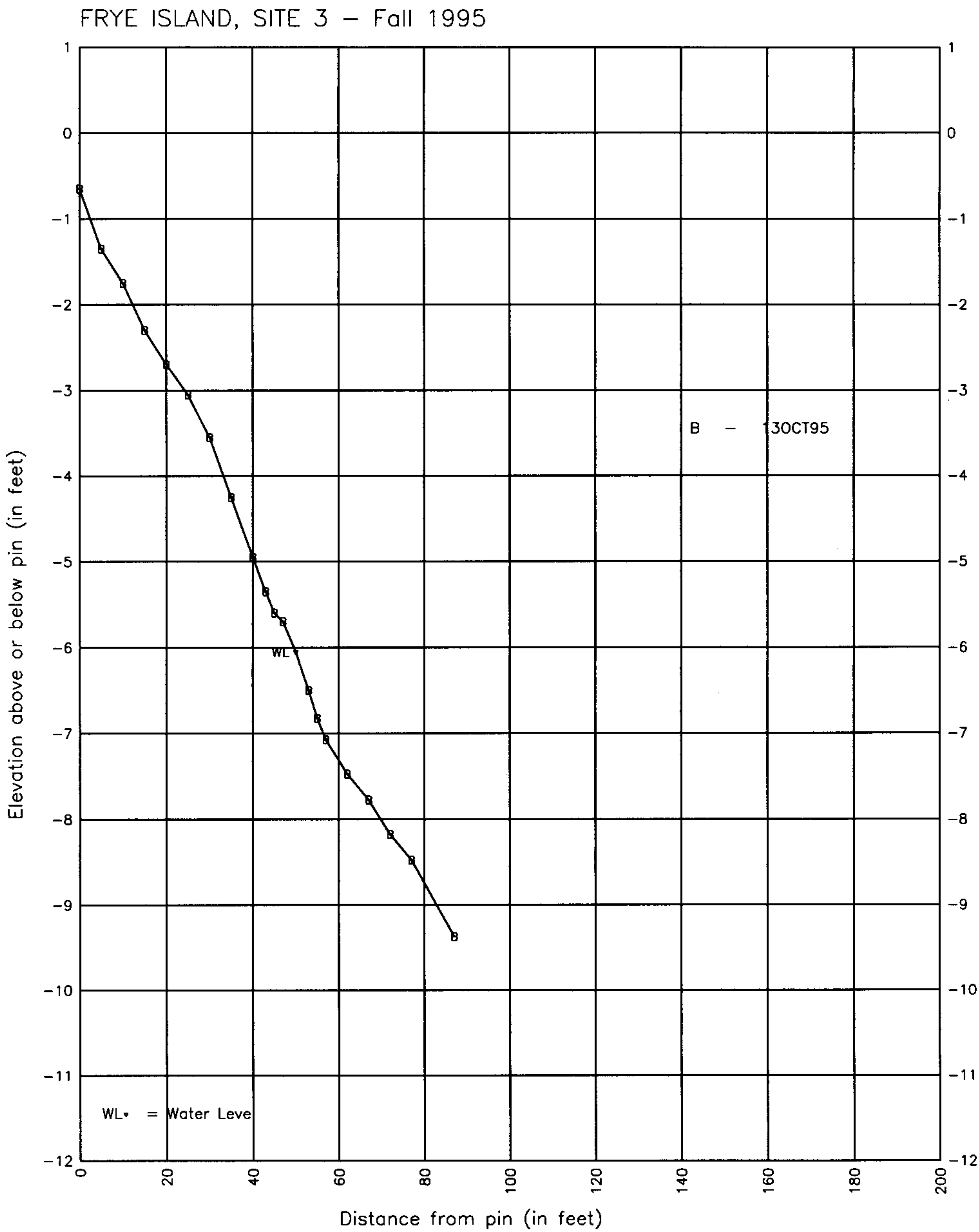


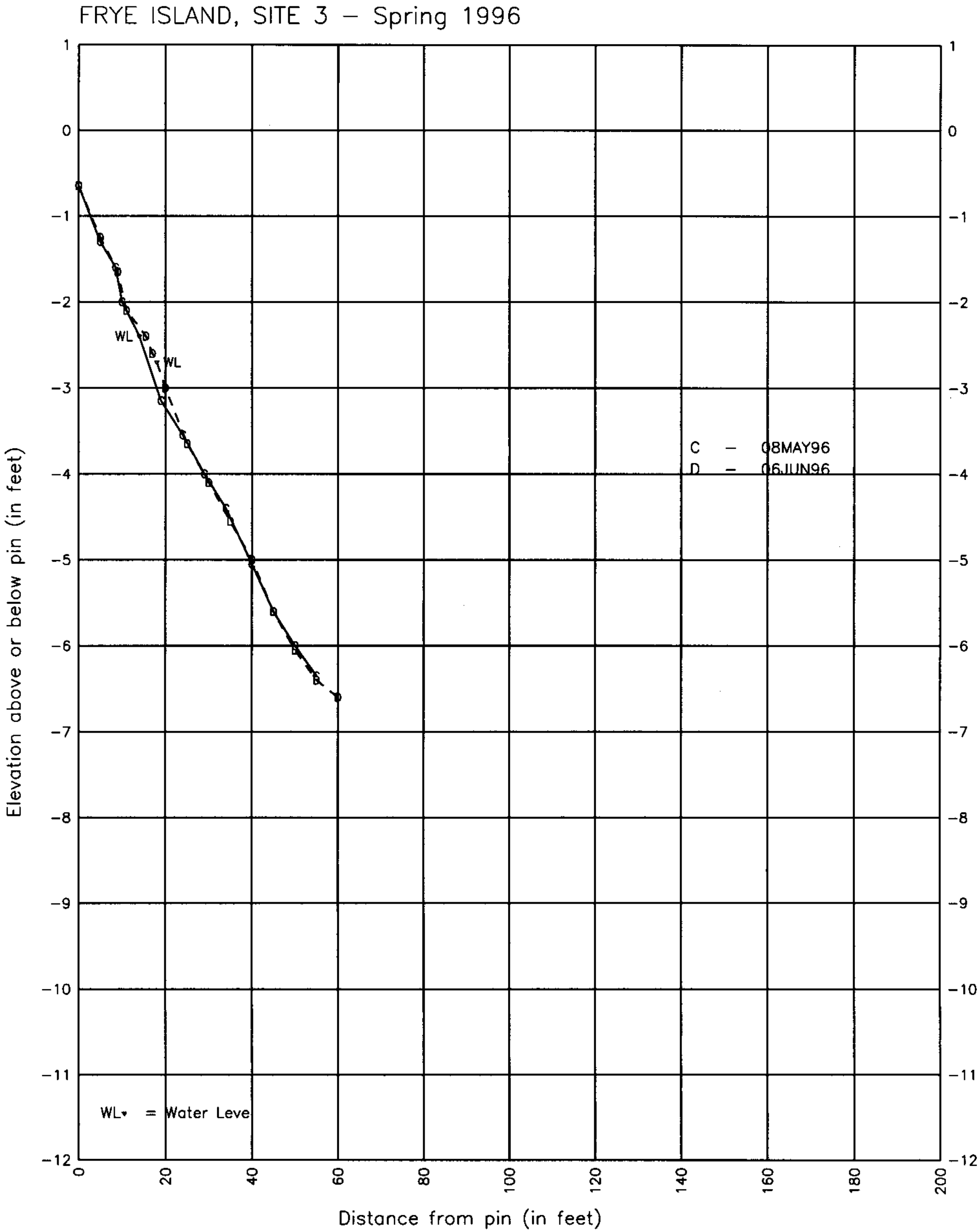
FRYE ISLAND, Site 2 – First & Last Profiles of 1996

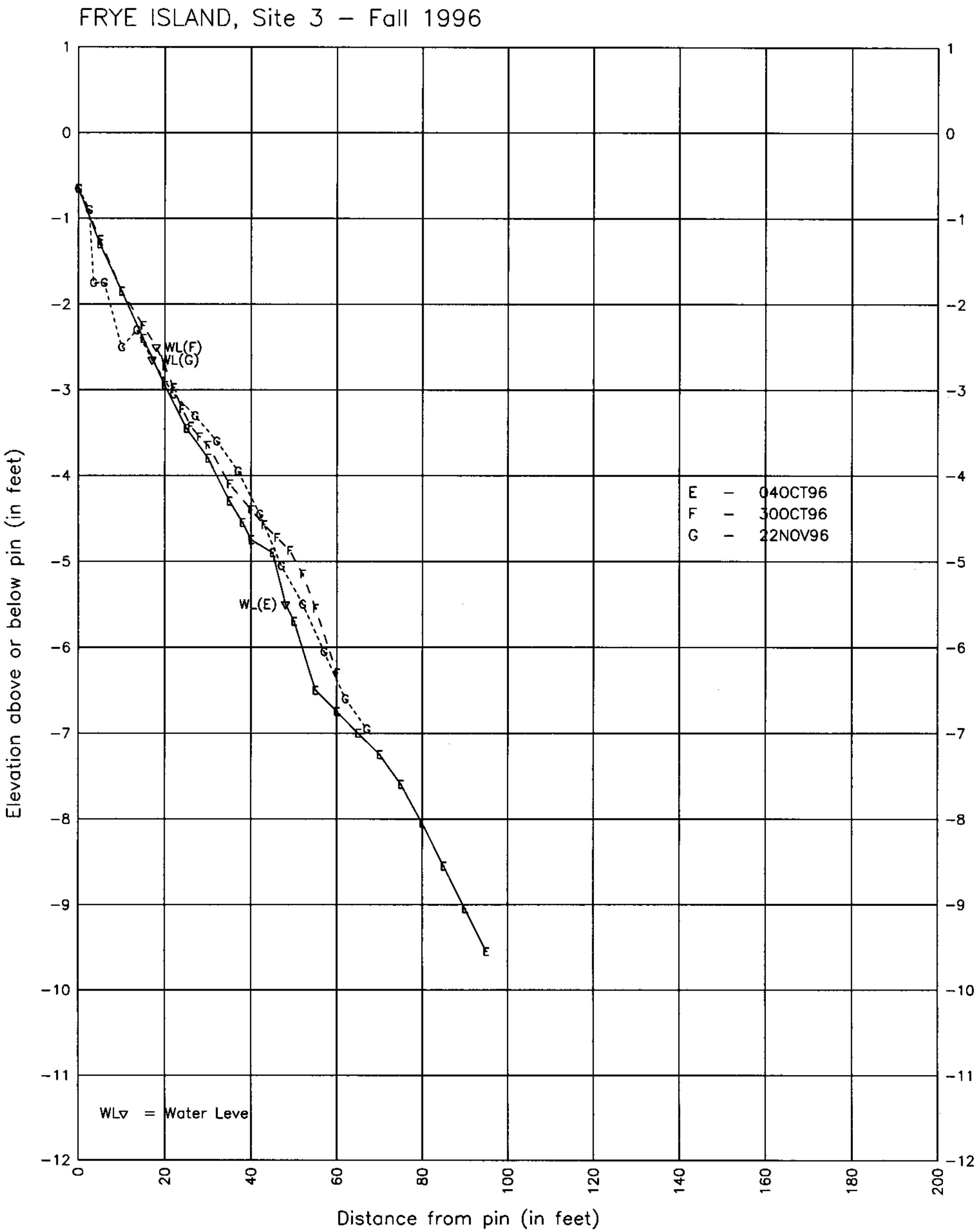



FRYE ISLAND, SITE 3 – SWEEP ZONE (15OCT93–28MAY97)
A – 15OCT93
B – 13OCT95
C – 08MAY96
D – 06JUN96
E – 04OCT96
F – 30OCT96
G – 22NOV96
H – 28MAY97
WL▿ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0
20
40
60
80
100
120
140
160
180
200

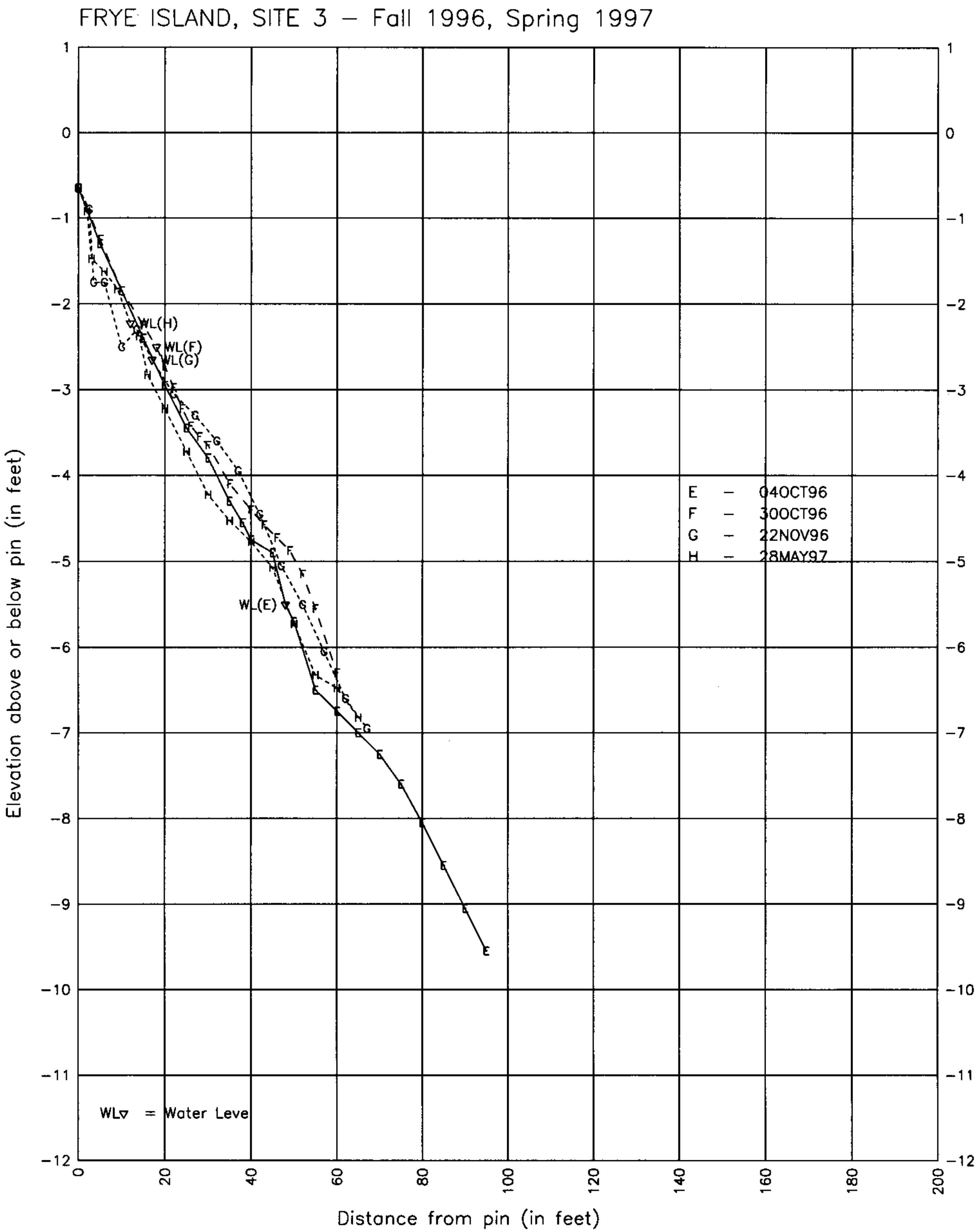

FRYE ISLAND, SITE 3 – Fall 1993
A – 15OCT93
WL
WL▾ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
–12
0
20
40
60
80
100
120
140
160
180
200


FRYE ISLAND, SITE 3 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
B – 13OCT95
WL
WL▾ = Water Leve
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0
20
40
60
80
100
120
140
160
180
200

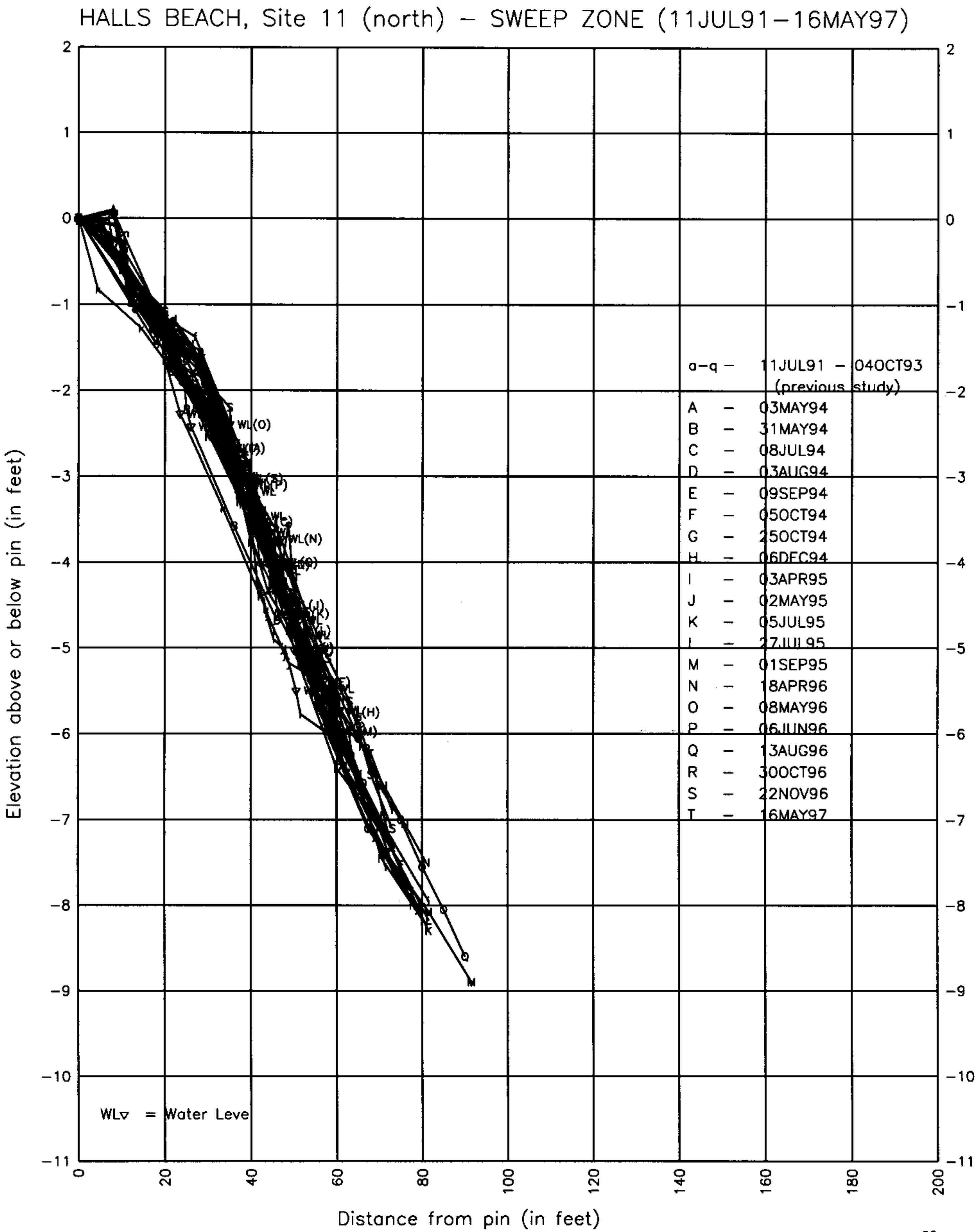

FRYE ISLAND, SITE 3 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 08MAY96
D – 06JUN96
WL
WL
WL▾ = Water Leve
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0
20
40
60
80
100
120
140
160
180
200



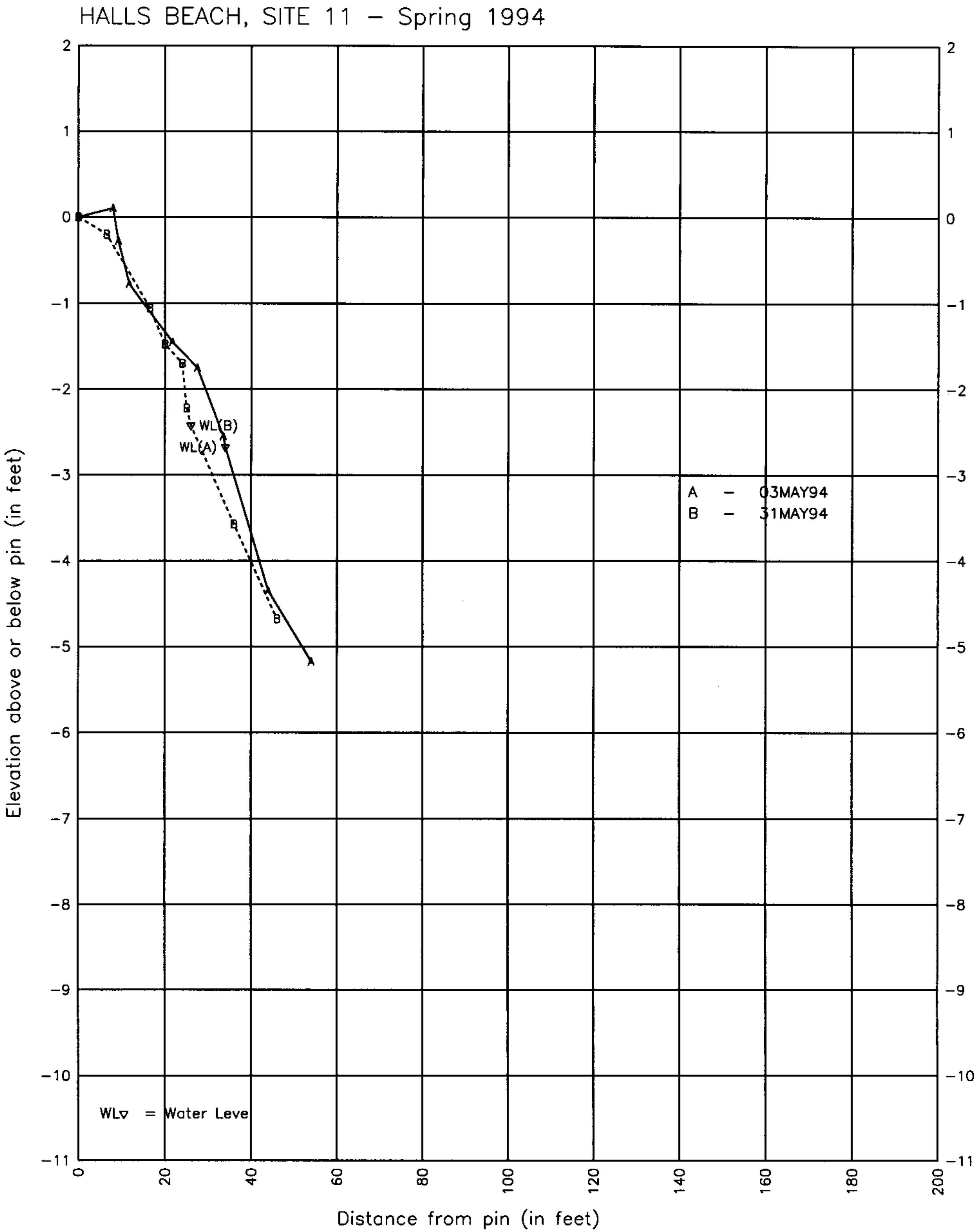
FRYE ISLAND, Site 3 – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
E – 04OCT96
F – 30OCT96
G – 22NOV96
WL(F)
WL(G)
WL(E)
WL▽ = Water Leve

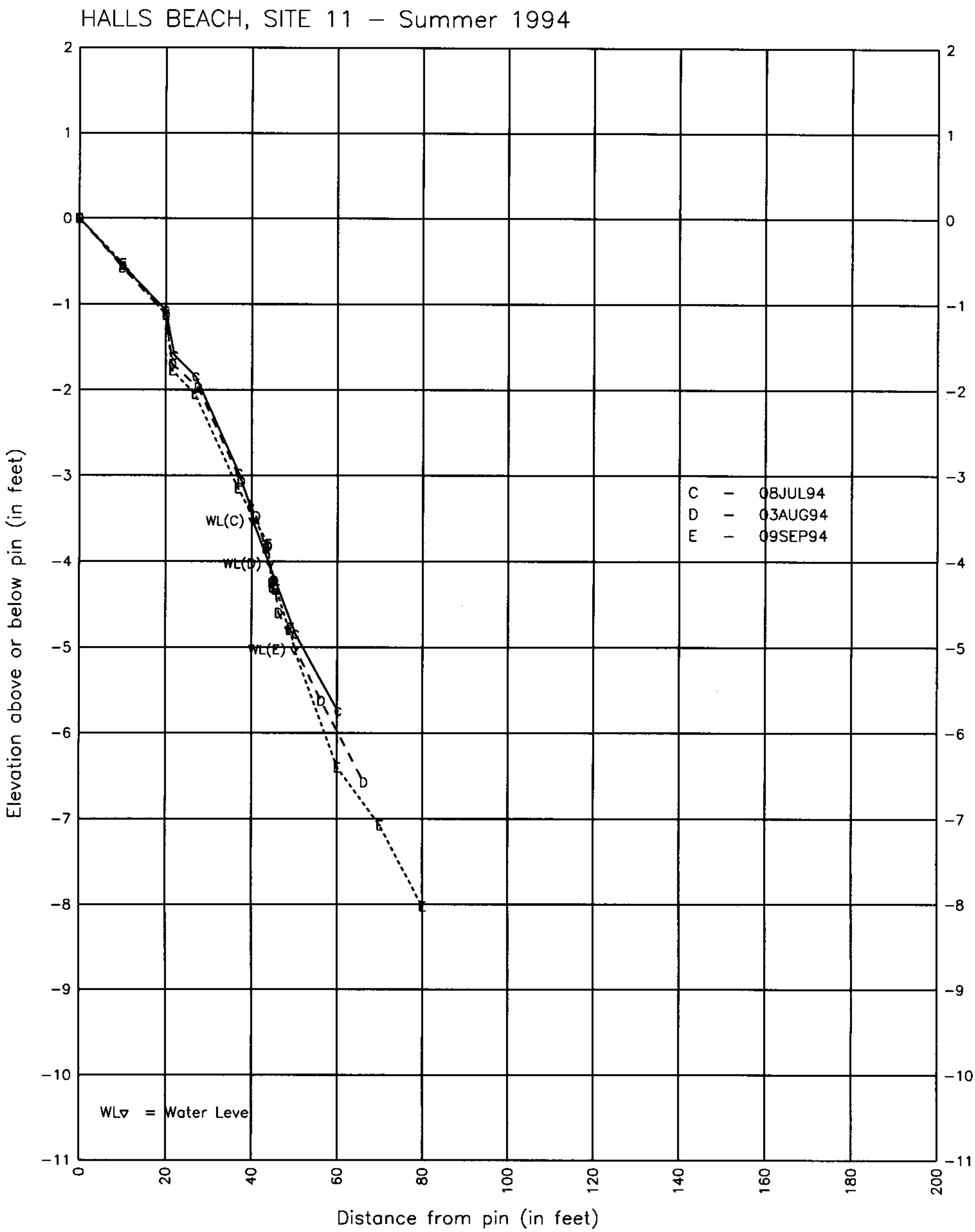


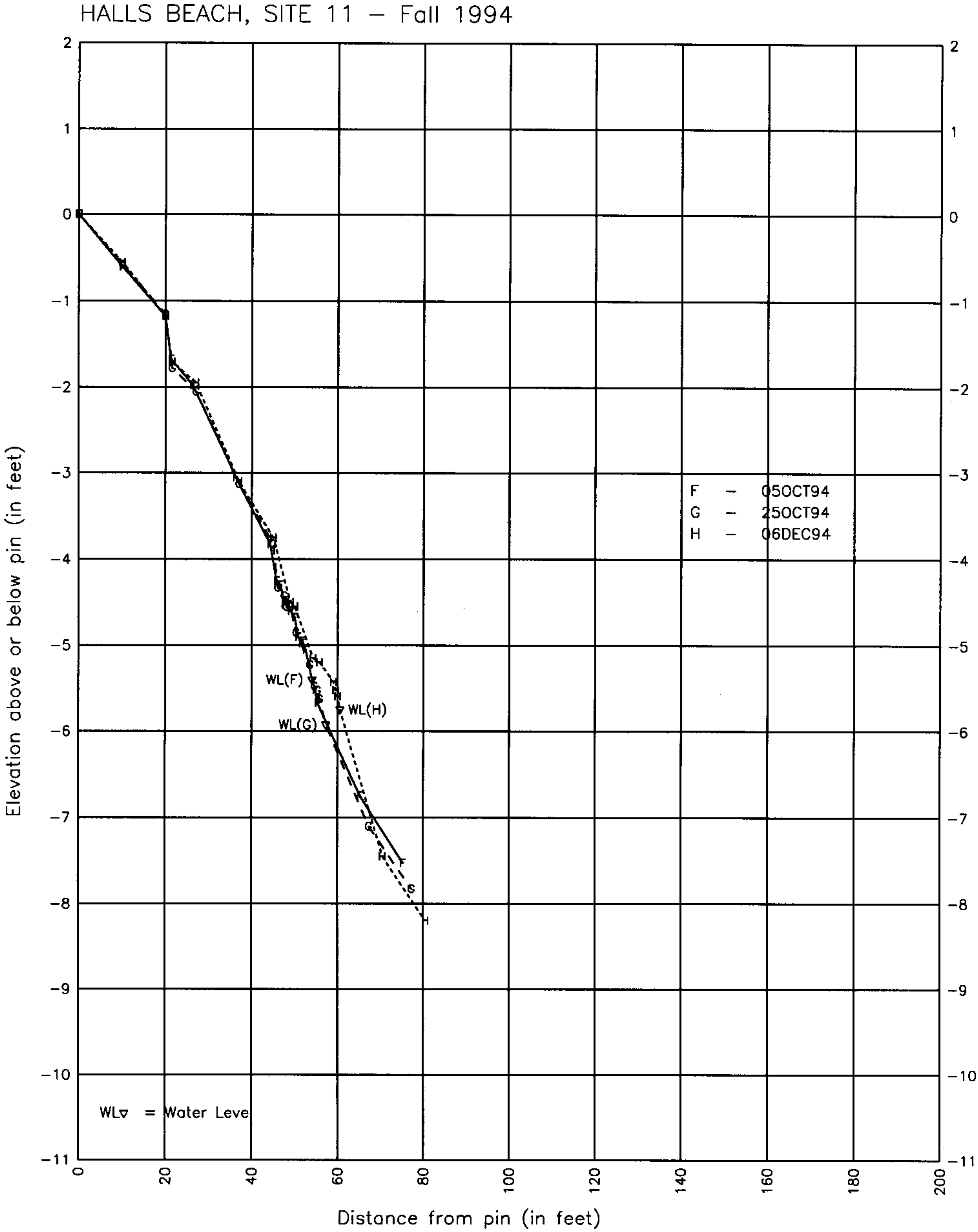
FRYE ISLAND, SITE 3 – Fall 1996, Spring 1997
Elevation above or below pin (in feet)
Distance from pin (in feet)
E – 04OCT96
F – 30OCT96
G – 22NOV96
H – 28MAY97
WL(H)
WL(F)
WL(G)
WL(E)
WL▽ = Water Level



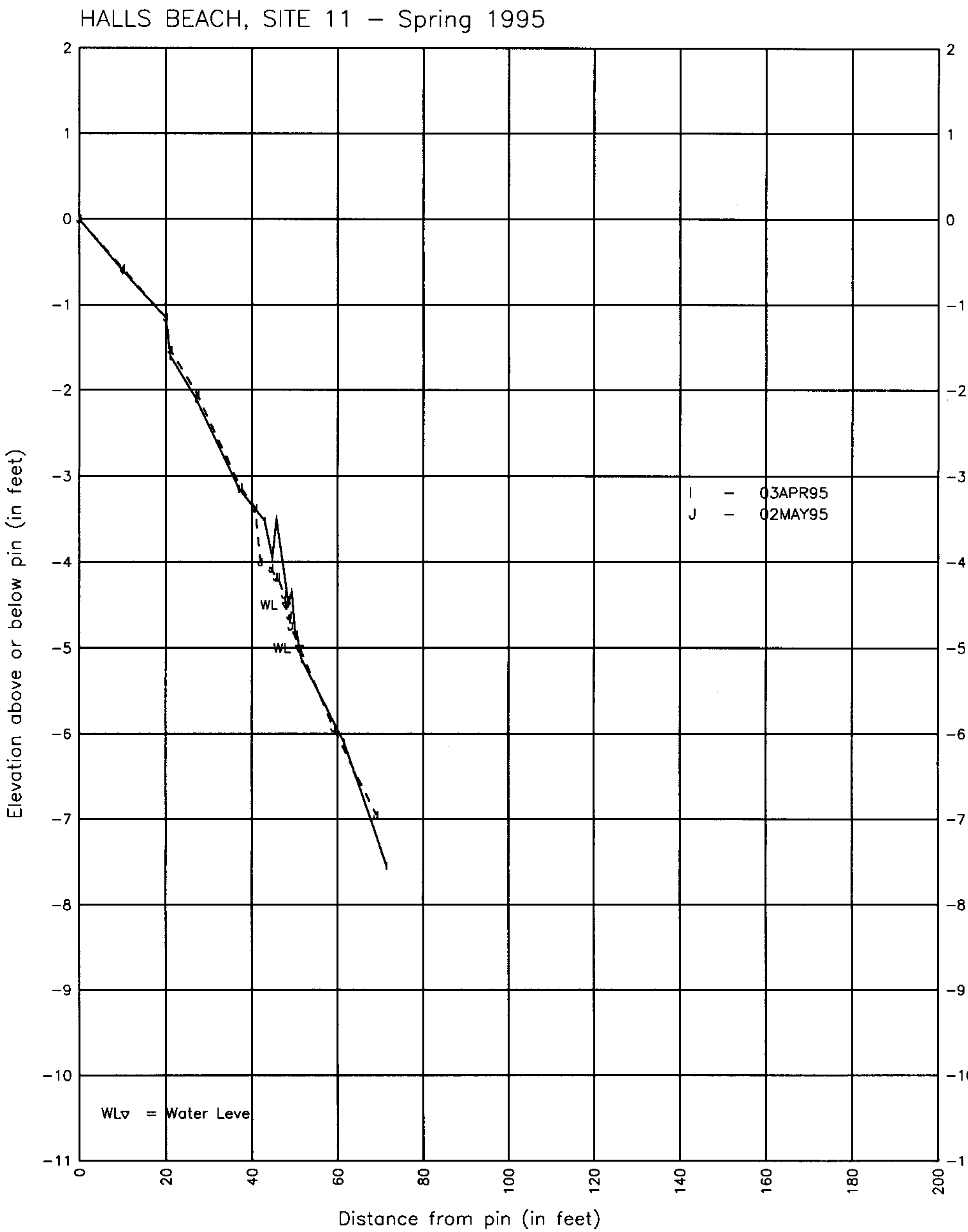
HALLS BEACH, Site 11 (north) – SWEEP ZONE (11JUL91–16MAY97)
Elevation above or below pin (in feet)
Distance from pin (in feet)
a–q – 11JUL91 – 04OCT93 (previous study)
A – 03MAY94
B – 31MAY94
C – 08JUL94
D – 03AUG94
E – 09SEP94
F – 05OCT94
G – 25OCT94
H – 06DEC94
I – 03APR95
J – 02MAY95
K – 05JUL95
L – 27JUL95
M – 01SEP95
N – 18APR96
O – 08MAY96
P – 06JUN96
Q – 13AUG96
R – 30OCT96
S – 22NOV96
T – 16MAY97
WL▽ = Water Level


HALLS BEACH, SITE 11 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 03MAY94
B – 31MAY94
WL(B)
WL(A)
WL▽ = Water Leve
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

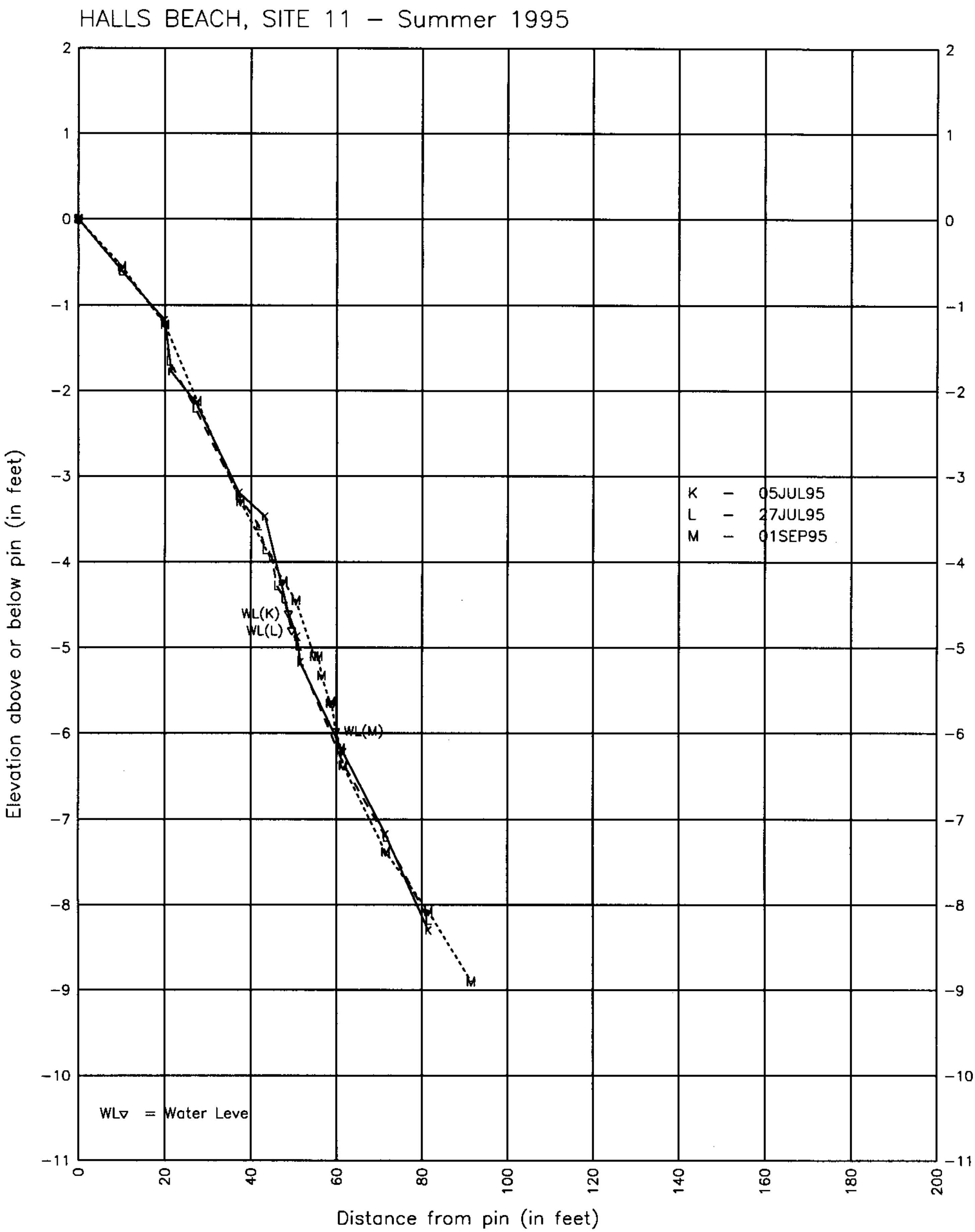

HALLS BEACH, SITE 11 — Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 08JUL94
D – 03AUG94
E – 09SEP94
WL(C)
WL(D)
WL(E)
WL▽ = Water Leve
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

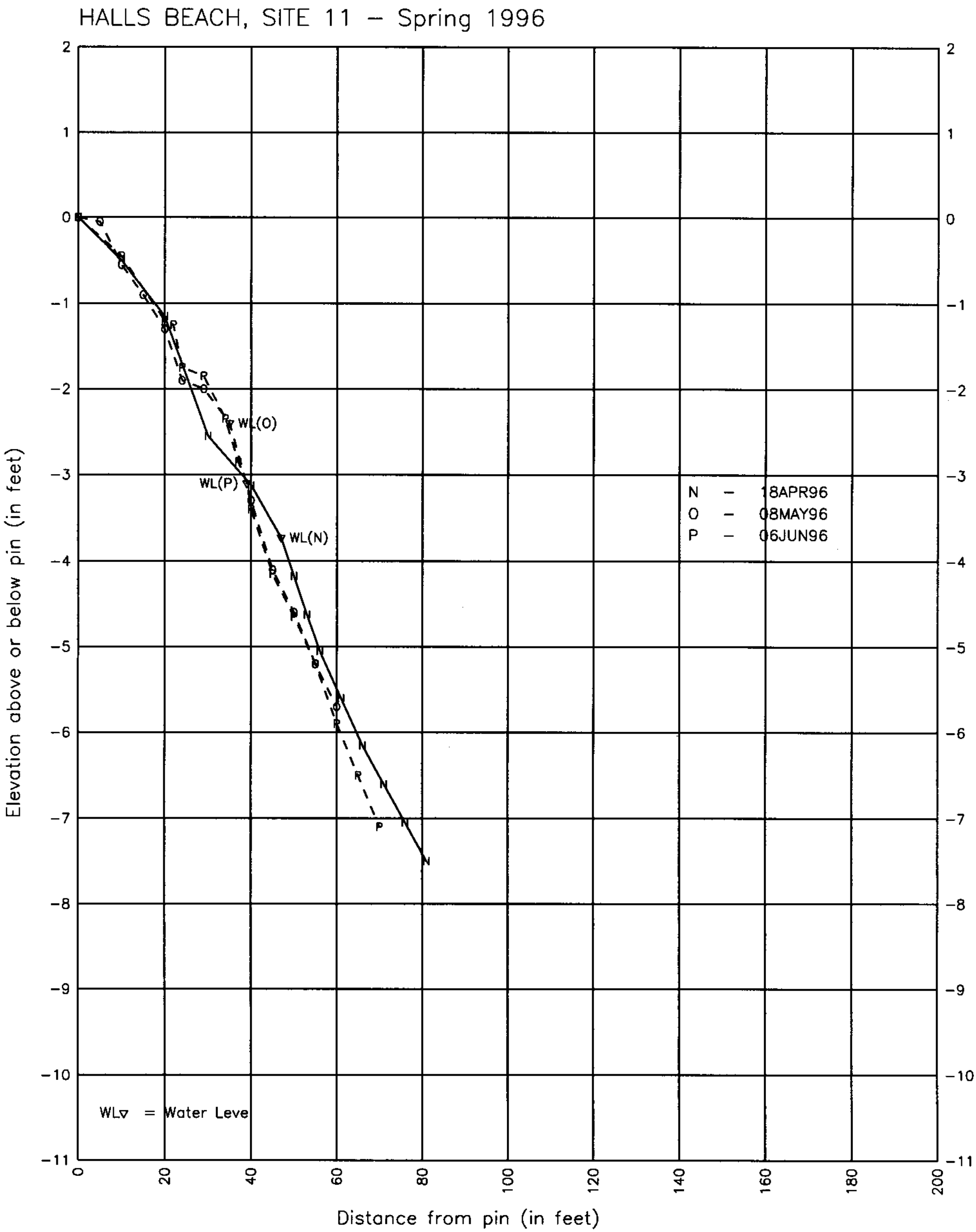


HALLS BEACH, SITE 11 - Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
F - 05OCT94
G - 25OCT94
H - 06DEC94
WL(F)
WL(G)
WL(H)
WL▽ = Water Leve
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

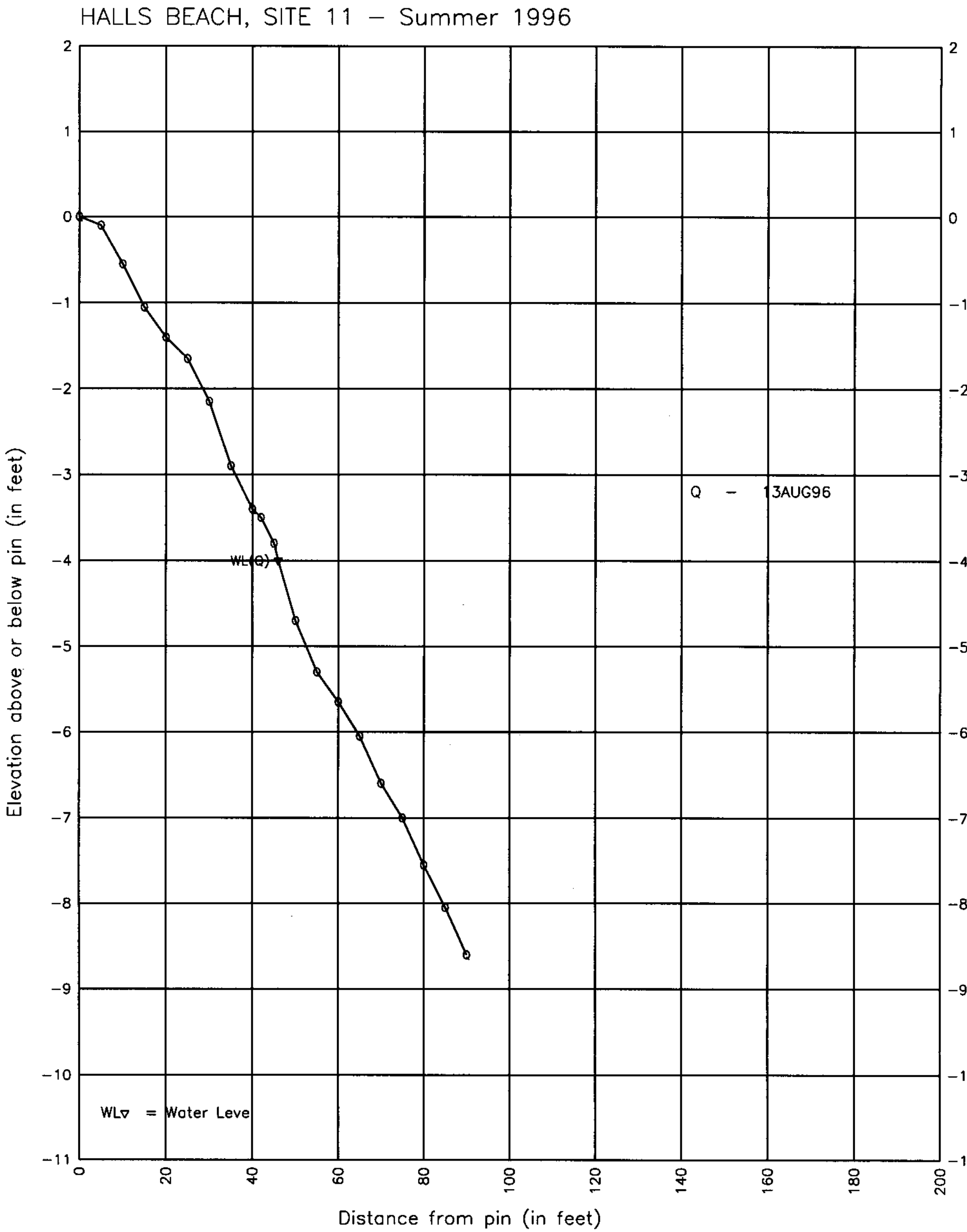


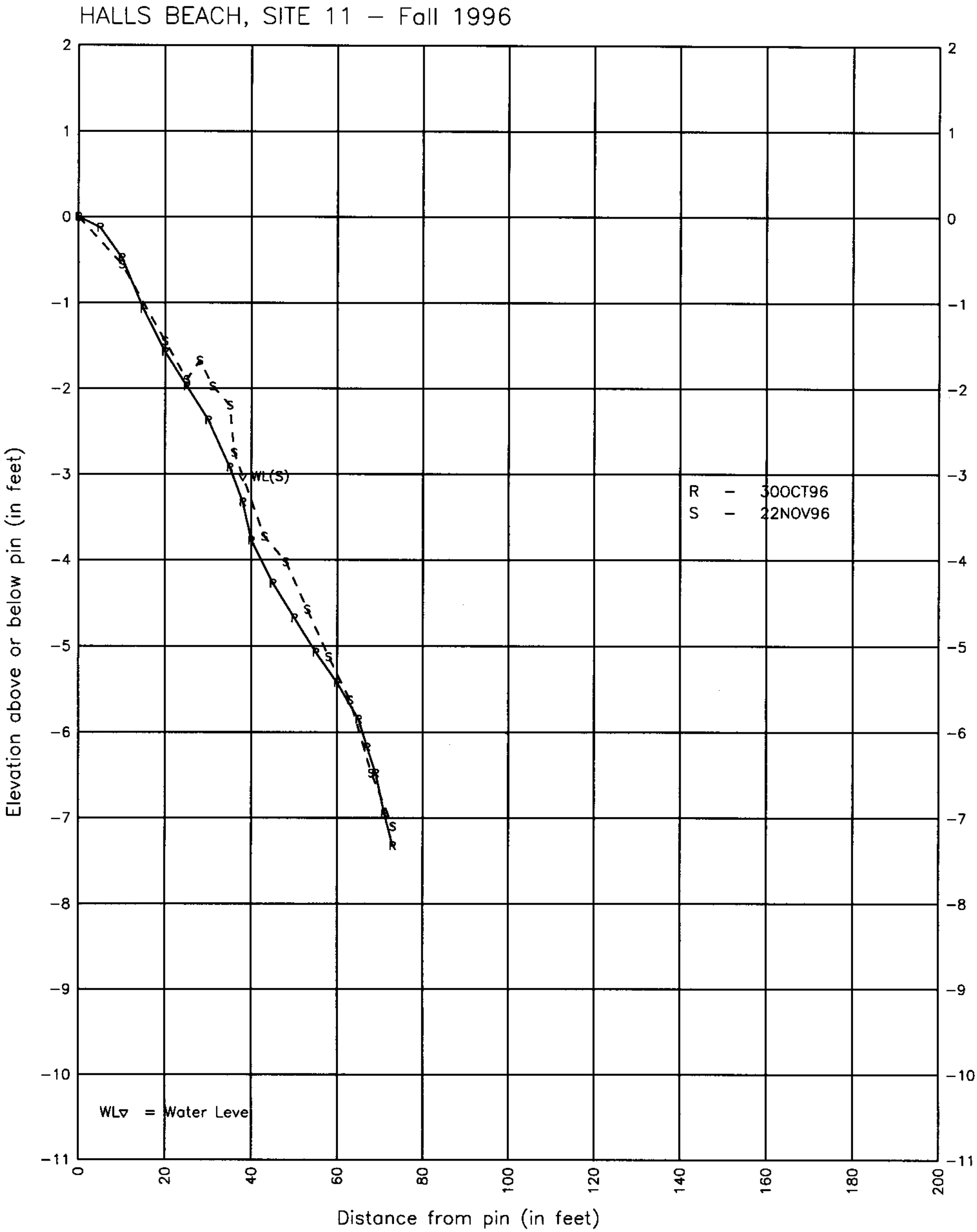
HALLS BEACH, SITE 11 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
I – 03APR95
J – 02MAY95
WL
WL
WL▽ = Water Leve
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

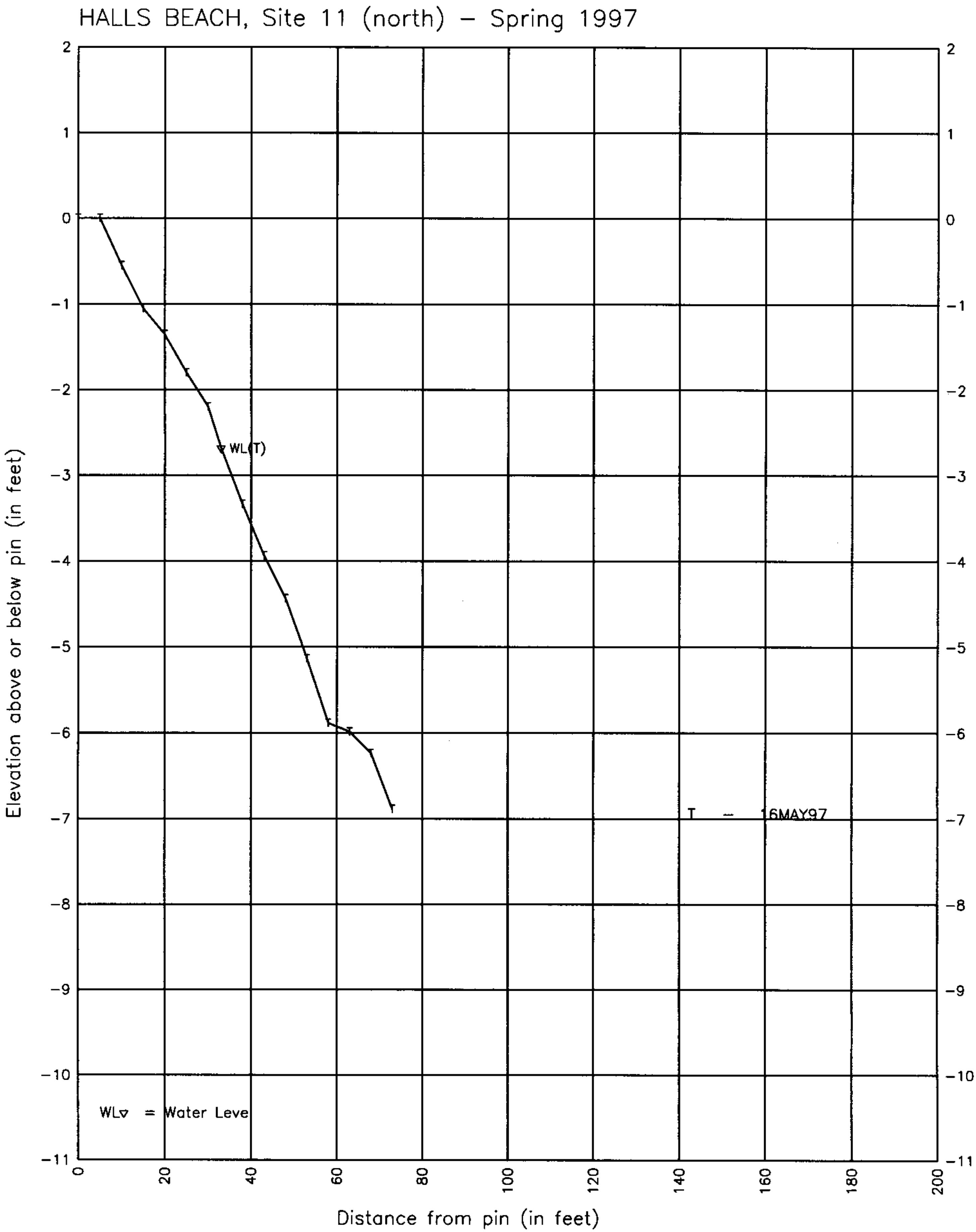

HALLS BEACH, SITE 11 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
K – 05JUL95
L – 27JUL95
M – 01SEP95
WL(K)
WL(L)
WL(M)
WL▽ = Water Leve
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

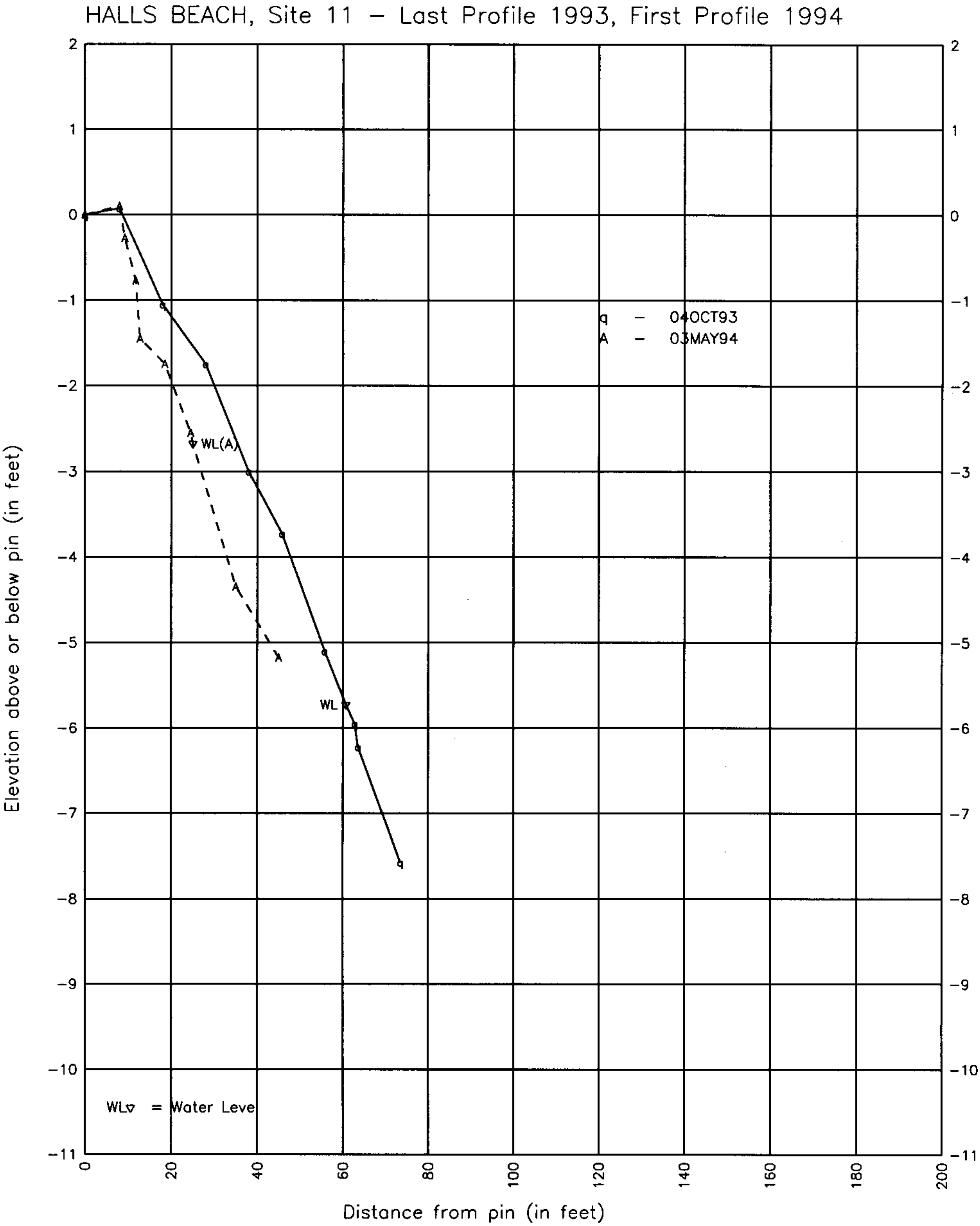


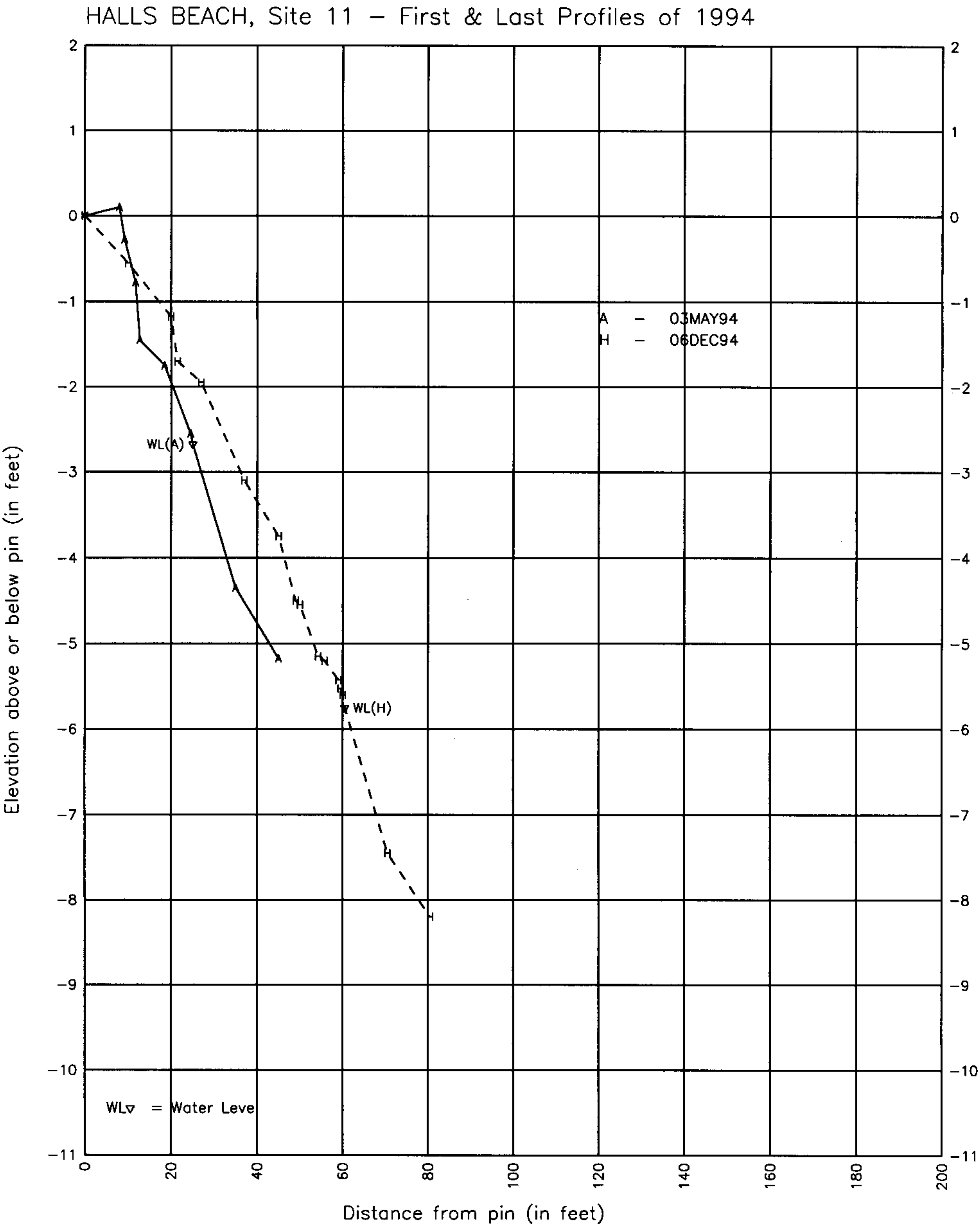
HALLS BEACH, SITE 11 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
N – 18APR96
O – 08MAY96
P – 06JUN96
WL(O)
WL(P)
WL(N)
WL▽ = Water Level

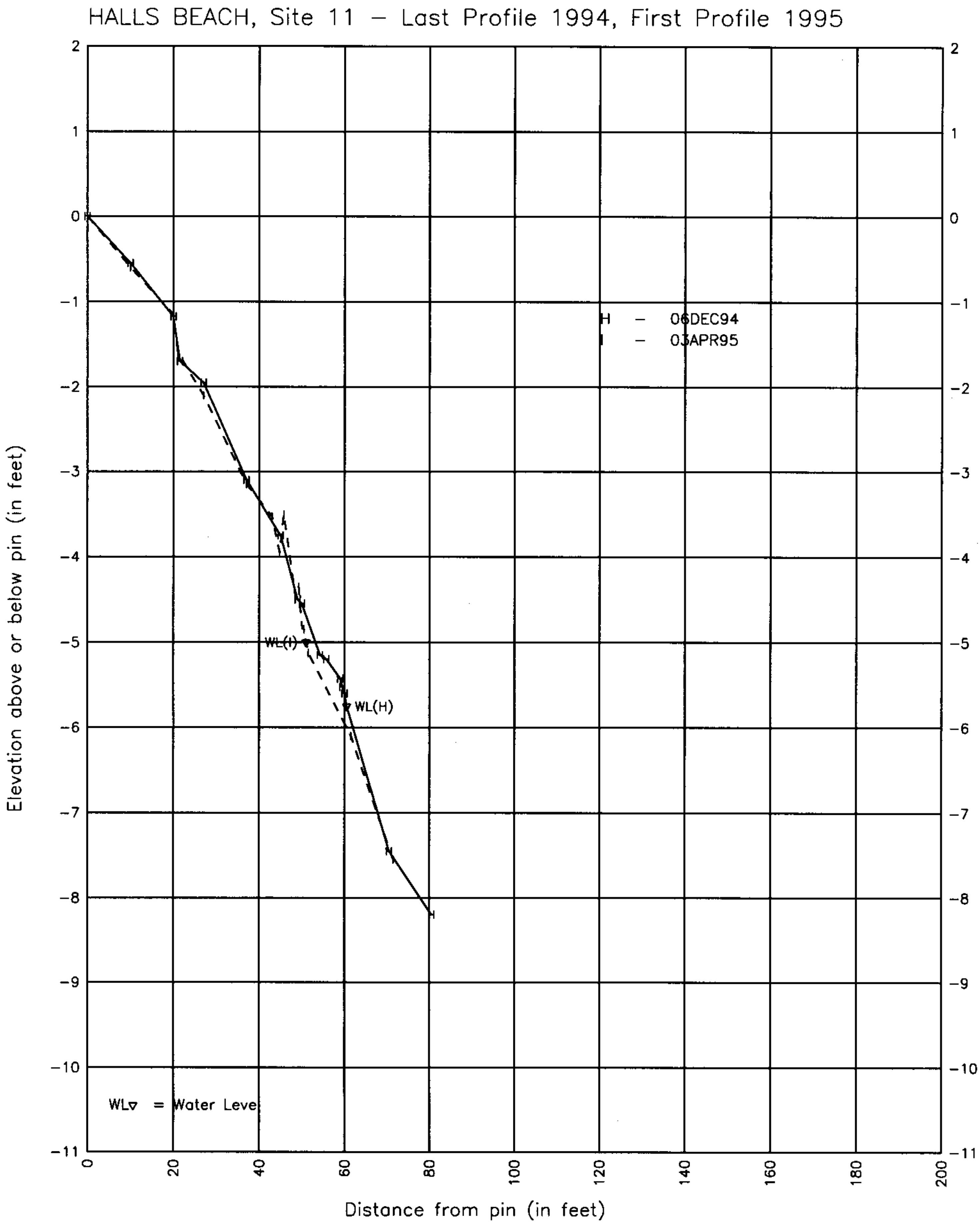

HALLS BEACH, SITE 11 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
Q – 13AUG96
WL(Q)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

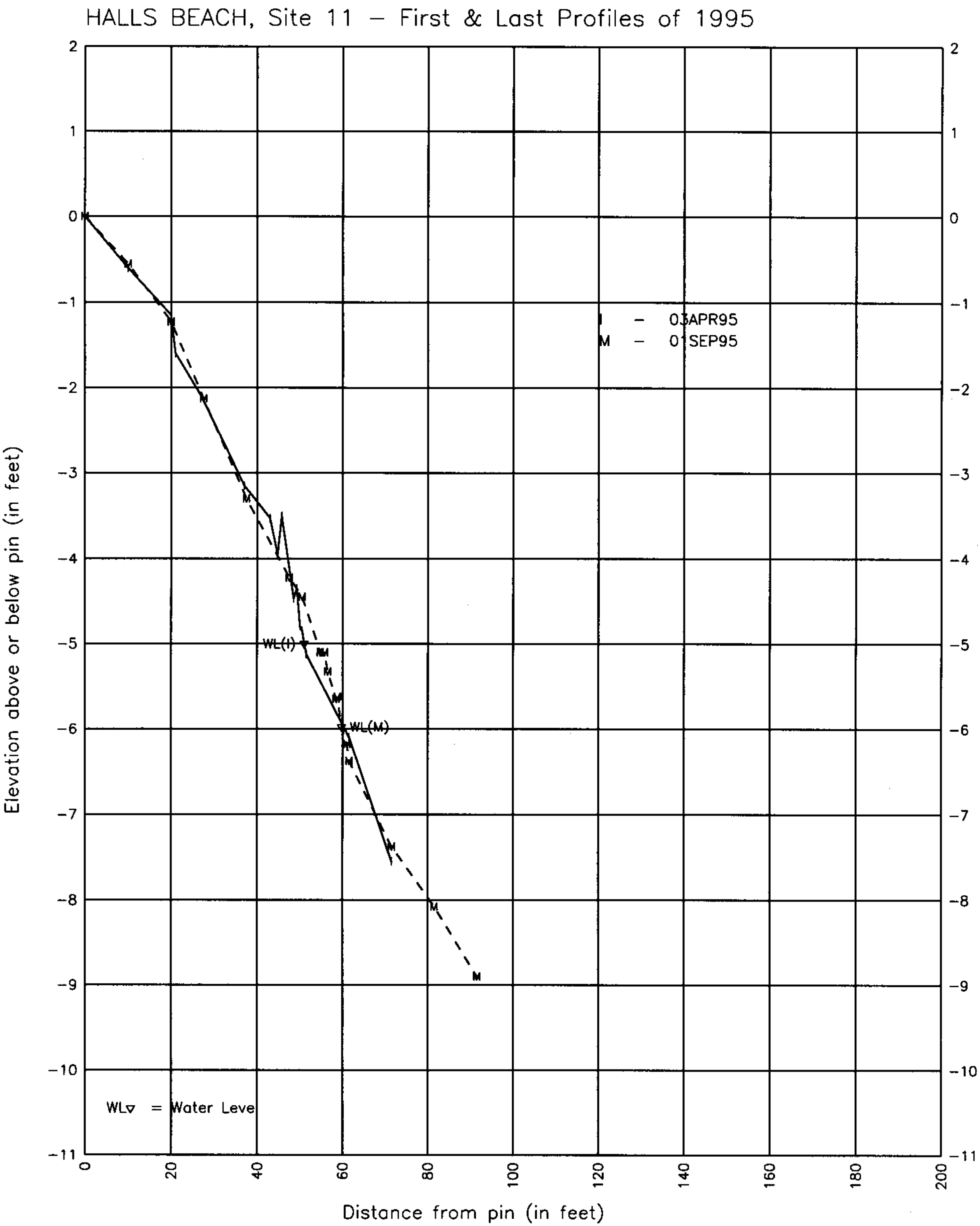

HALLS BEACH, SITE 11 — Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
R – 30OCT96
S – 22NOV96
WL(S)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

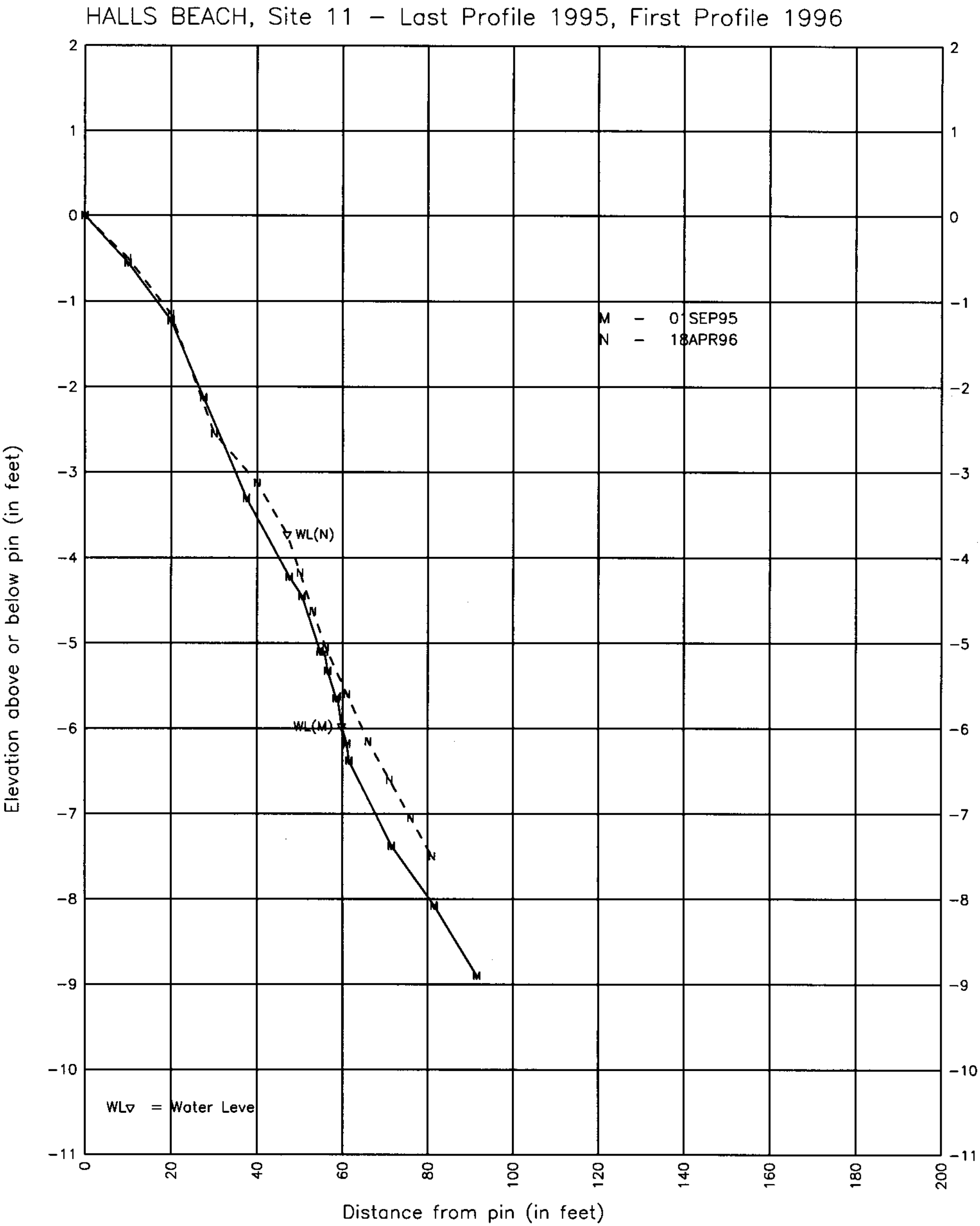

HALLS BEACH, Site 11 (north) - Spring 1997
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(T)
T - 16MAY97
WL▽ = Water Leve
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

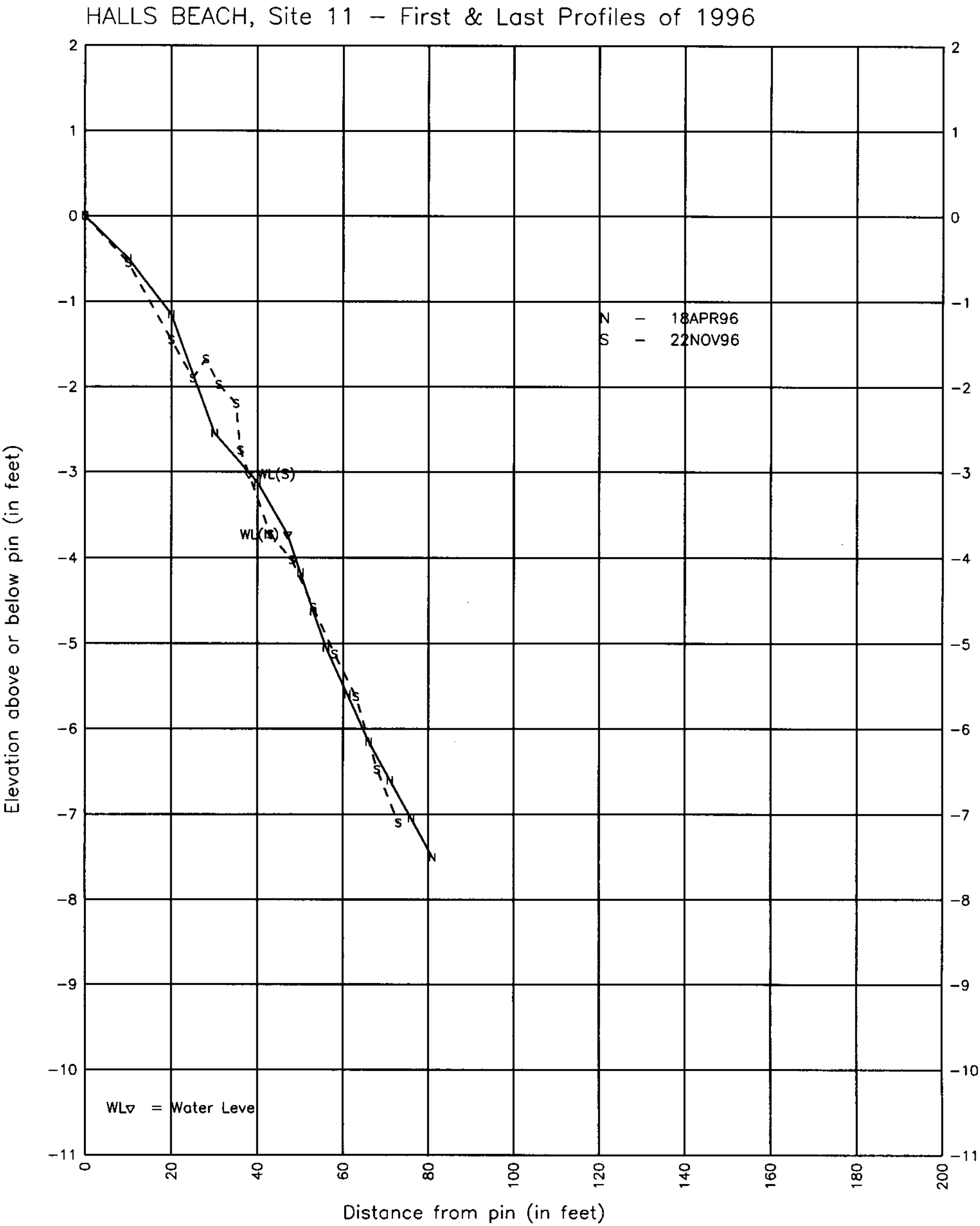

HALLS BEACH, Site 11 – Last Profile 1993, First Profile 1994
q – 04OCT93
A – 03MAY94
WL(A)
WL
WL▽ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

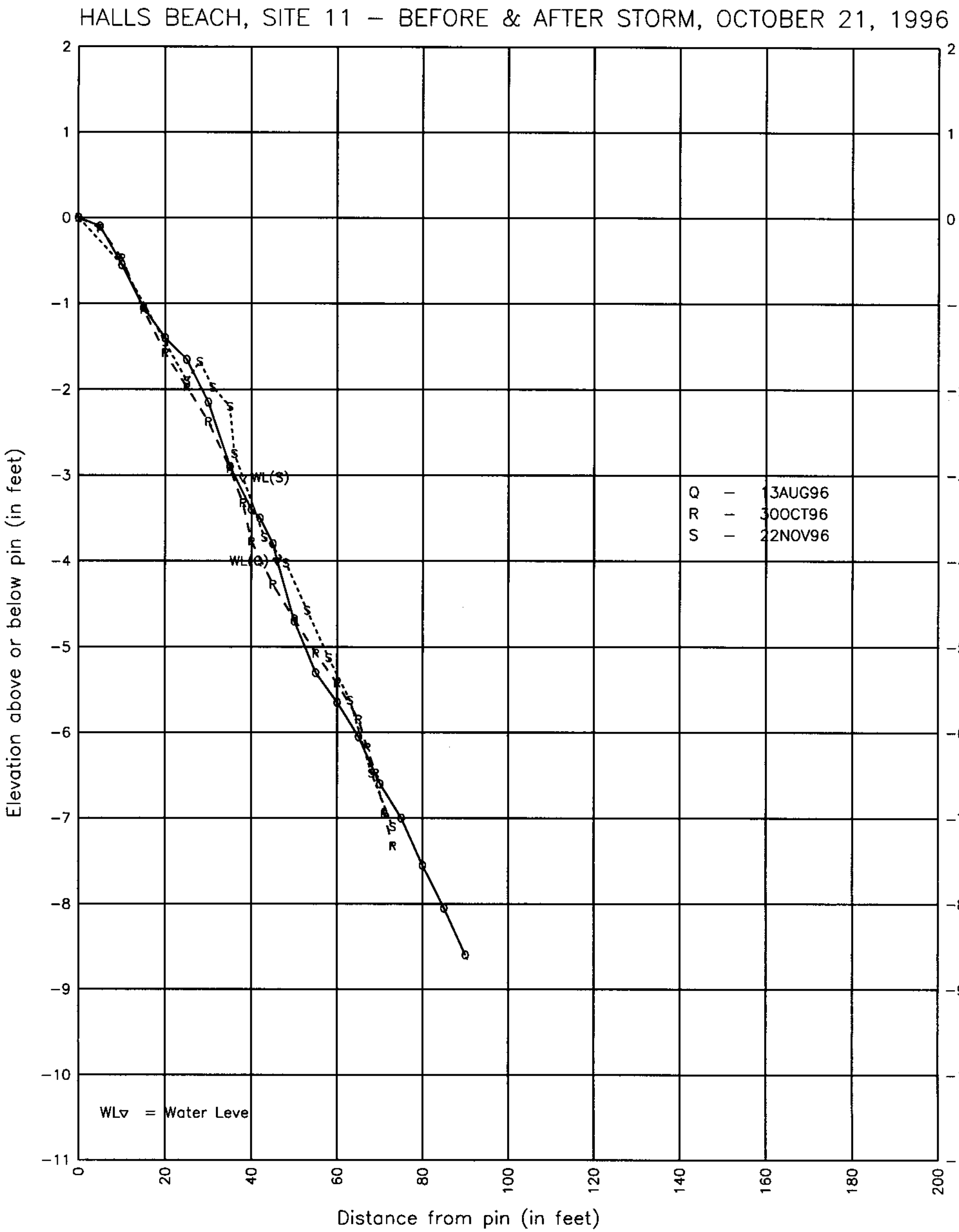

HALLS BEACH, Site 11 – First & Last Profiles of 1994
A – 03MAY94
H – 06DEC94
WL(A)
WL(H)
WL▽ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200


HALLS BEACH, Site 11 – Last Profile 1994, First Profile 1995
H – 06DEC94
I – 03APR95
WL(I)
WL(H)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

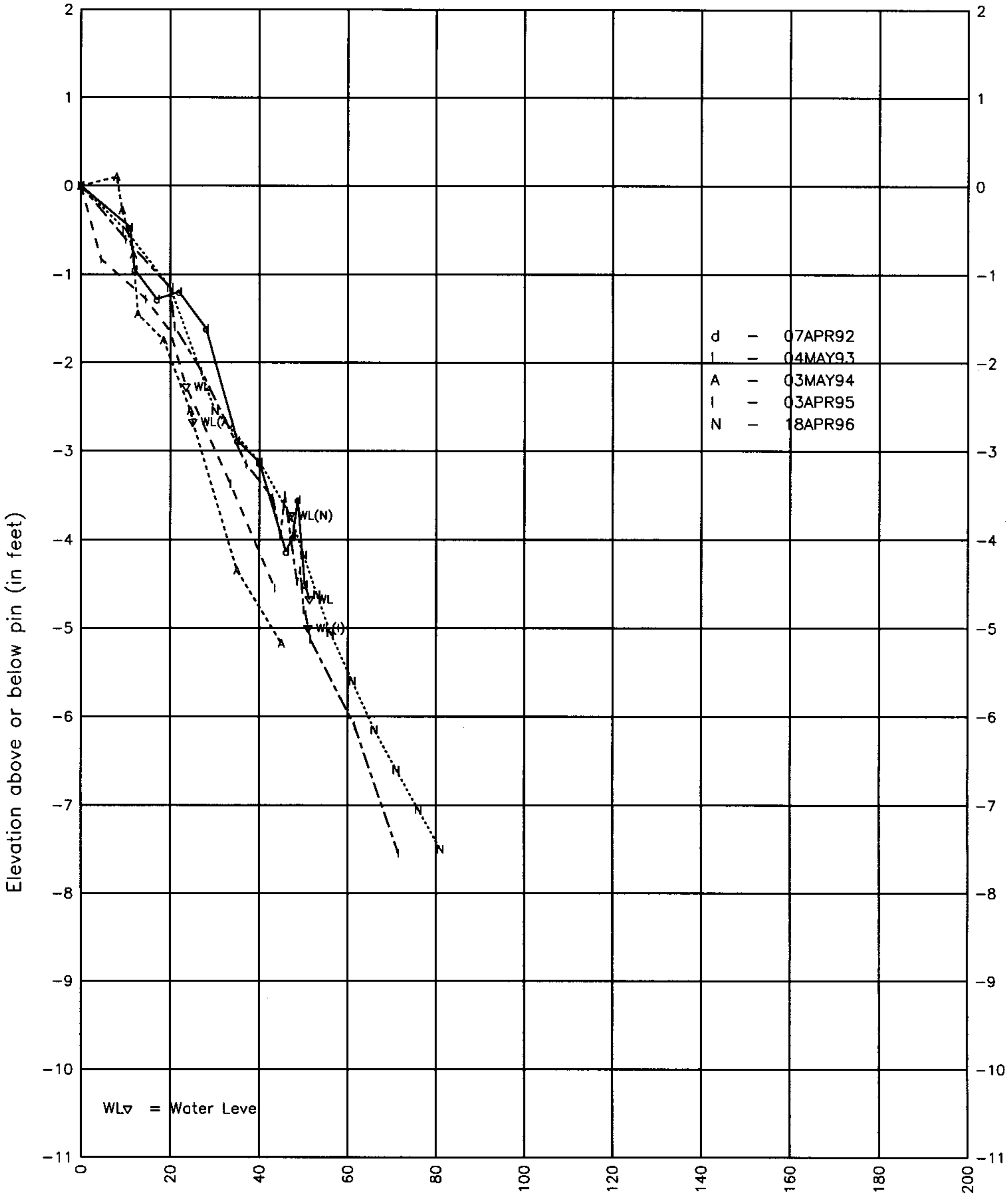

HALLS BEACH, Site 11 – First & Last Profiles of 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
I – 03APR95
M – 01SEP95
WL(I)
WL(M)
WL▽ = Water Leve
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

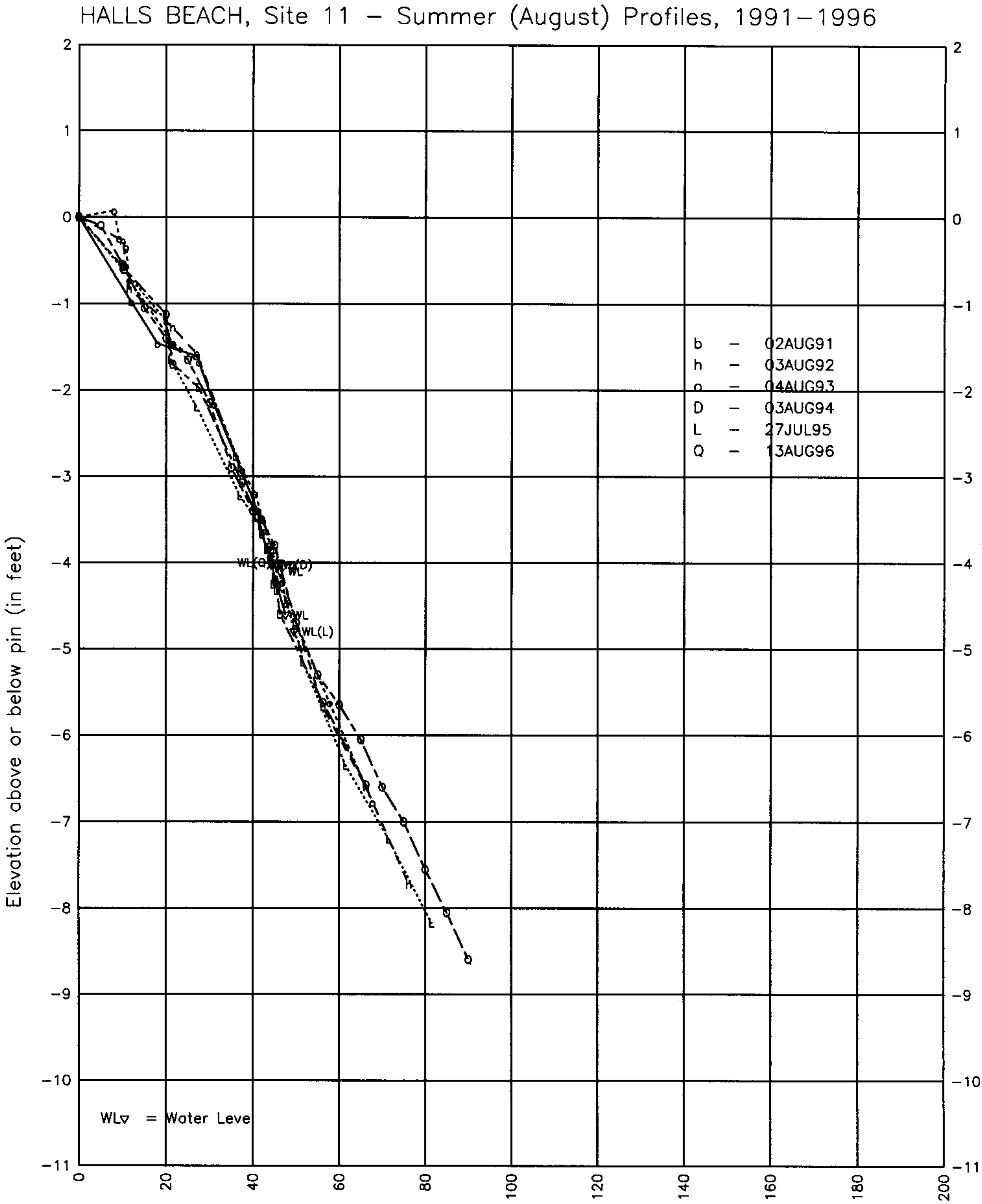

HALLS BEACH, Site 11 – Last Profile 1995, First Profile 1996
M – 01SEP95
N – 18APR96
WL(N)
WL(M)
WLv = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

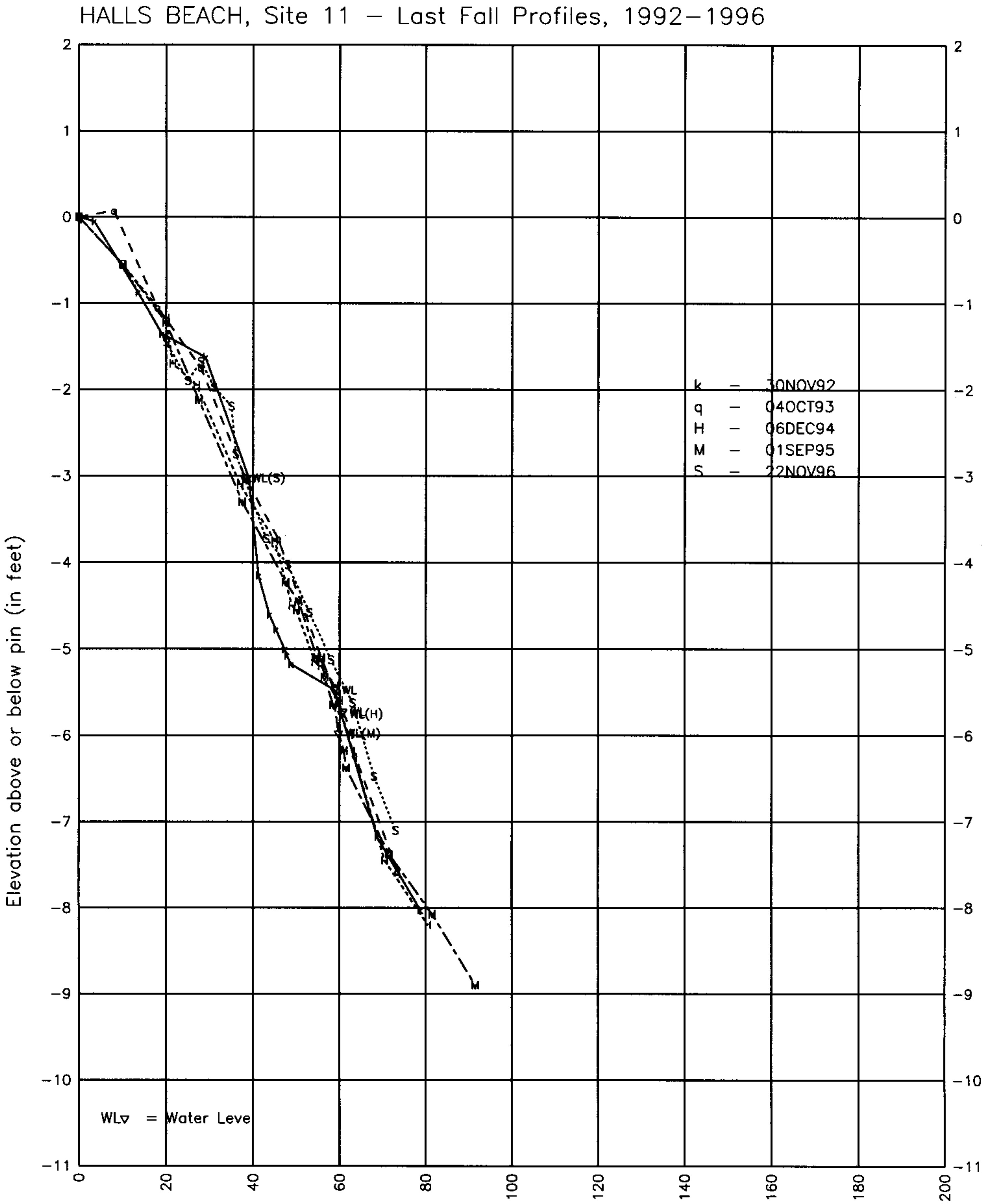

HALLS BEACH, Site 11 – First & Last Profiles of 1996
N – 18APR96
S – 22NOV96
WL(S)
WL(N)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

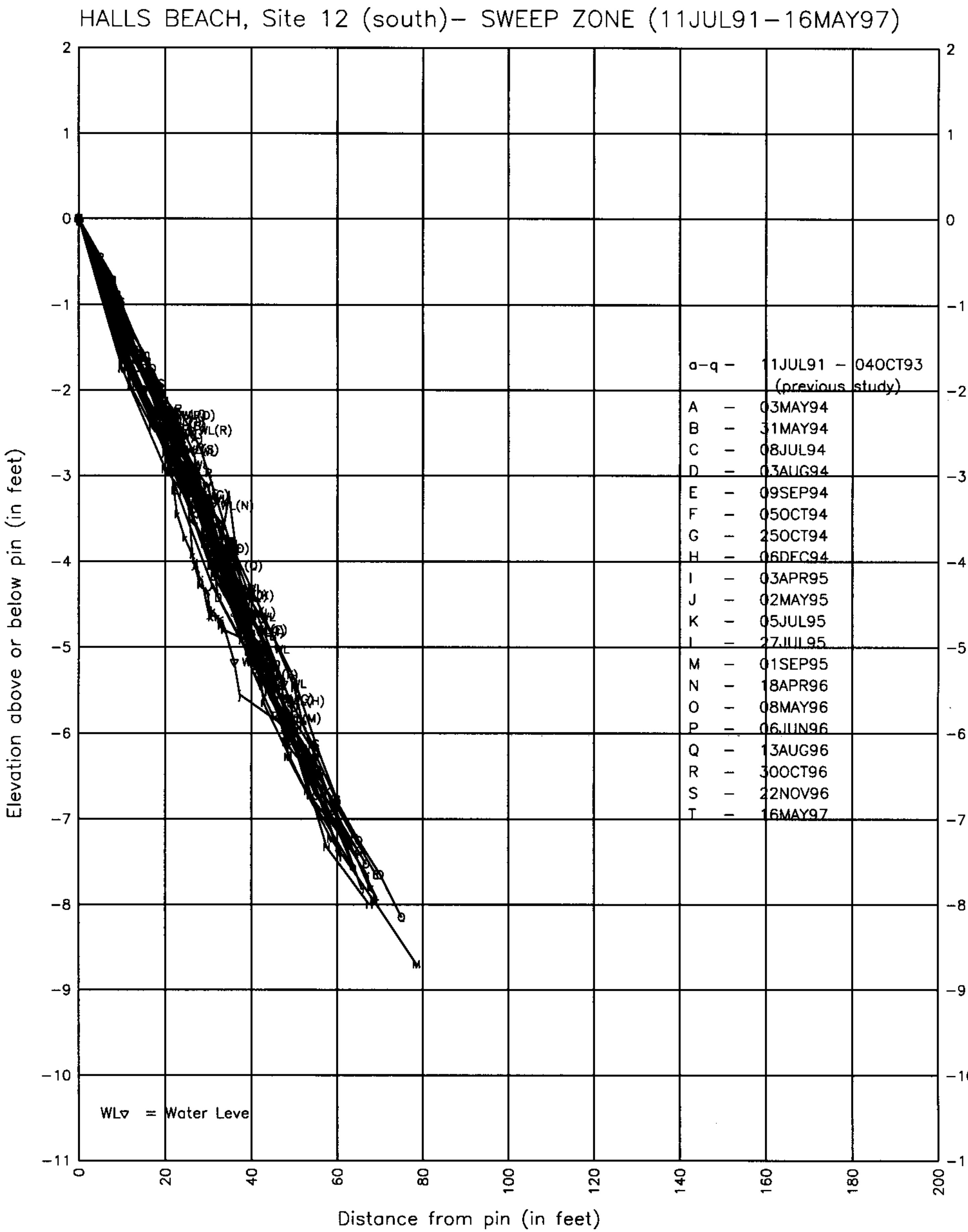

HALLS BEACH, SITE 11 – BEFORE & AFTER STORM, OCTOBER 21, 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
Q – 13AUG96
R – 30OCT96
S – 22NOV96
WL(S)
WL(Q)
WL▽ = Water Leve

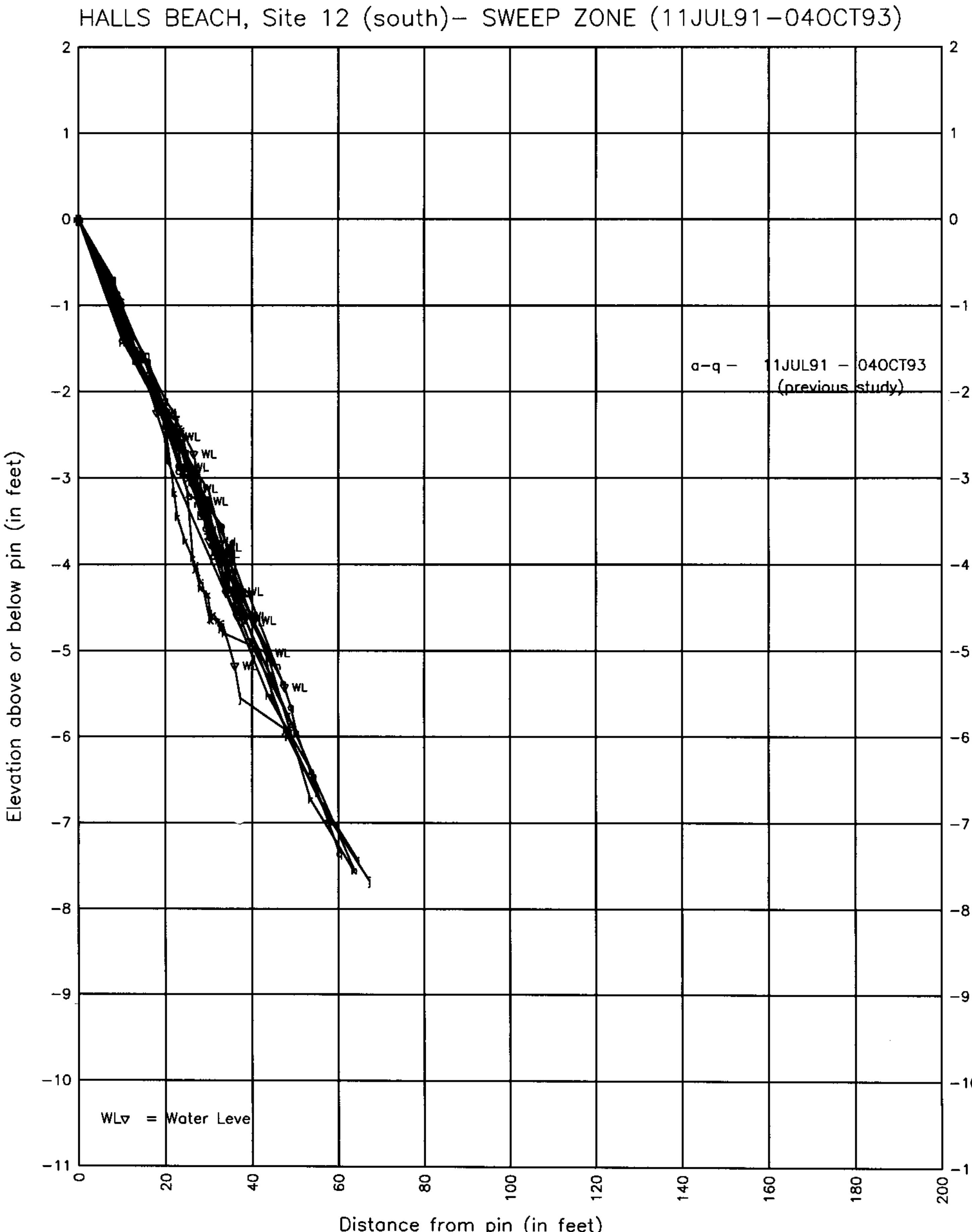
HALLS BEACH, Site 11 – First Spring Profiles, 1992–1996



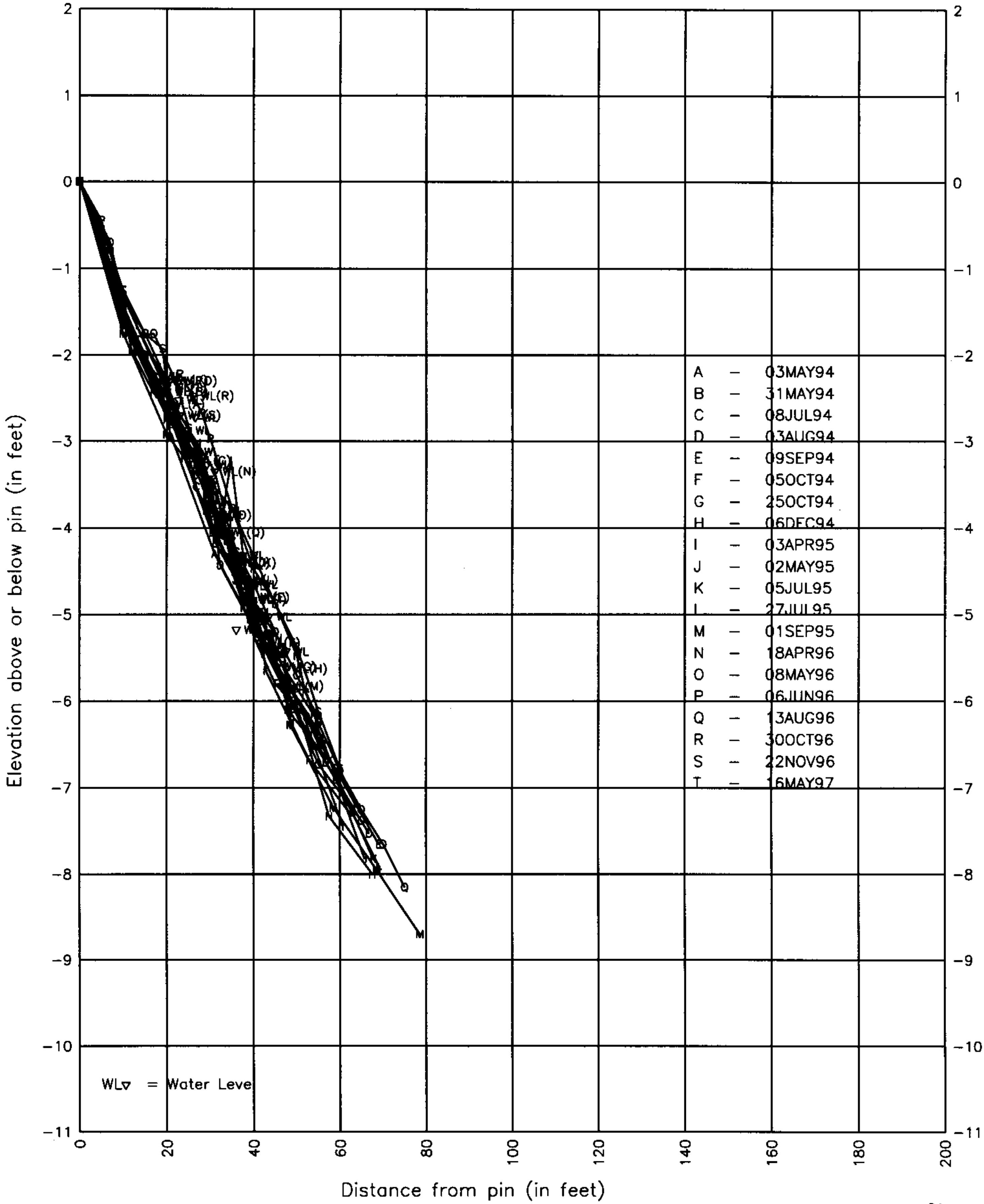

HALLS BEACH, Site 11 – Summer (August) Profiles, 1991–1996
Elevation above or below pin (in feet)
b – 02AUG91
h – 03AUG92
o – 04AUG93
D – 03AUG94
L – 27JUL95
Q – 13AUG96
WL▽ = Water Leve
WL(Q)
WL(D)
WL(L)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

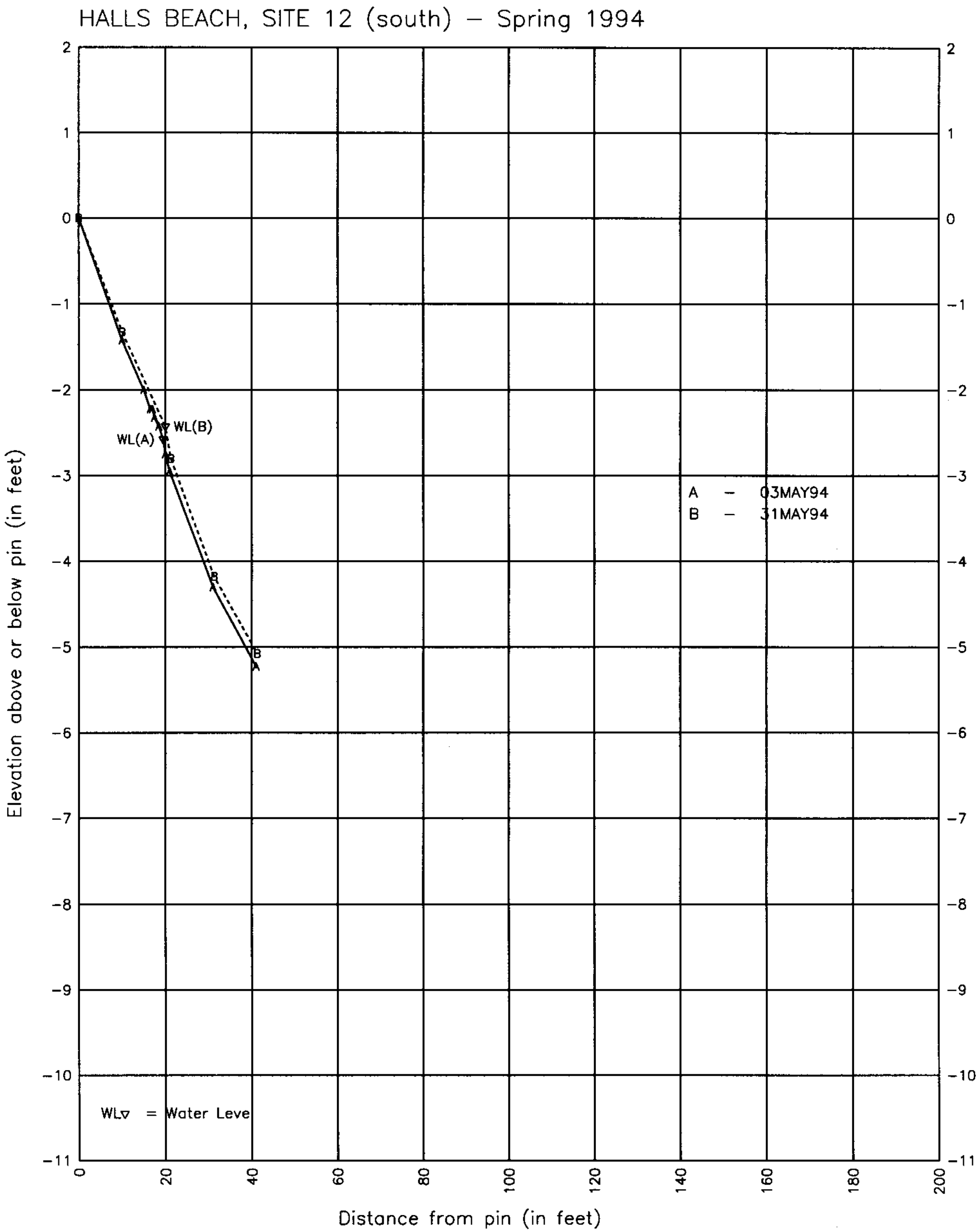

HALLS BEACH, Site 11 – Last Fall Profiles, 1992–1996
Elevation above or below pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200
k – 30NOV92
q – 04OCT93
H – 06DEC94
M – 01SEP95
S – 22NOV96
WL(S)
WL
WL(H)
WL(M)
WL▽ = Water Leve

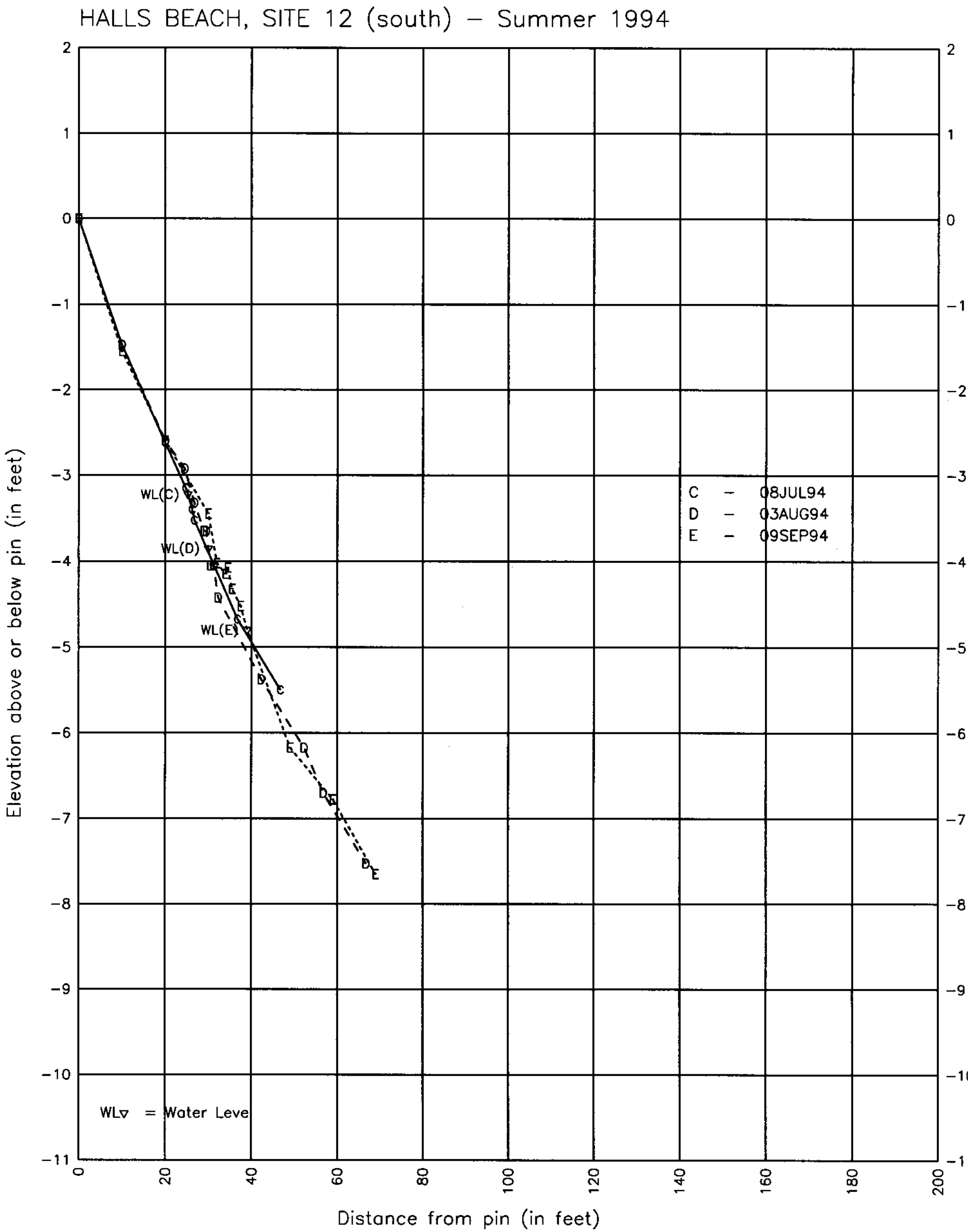

HALLS BEACH, Site 12 (south)– SWEEP ZONE (11JUL91–16MAY97)
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200
a–q – 11JUL91 – 04OCT93 (previous study)
A – 03MAY94
B – 31MAY94
C – 08JUL94
D – 03AUG94
E – 09SEP94
F – 05OCT94
G – 25OCT94
H – 06DEC94
I – 03APR95
J – 02MAY95
K – 05JUL95
L – 27JUL95
M – 01SEP95
N – 18APR96
O – 08MAY96
P – 06JUN96
Q – 13AUG96
R – 30OCT96
S – 22NOV96
T – 16MAY97
WL▽ = Water Leve


HALLS BEACH, Site 12 (south)– SWEEP ZONE (11JUL91–04OCT93)
a–q – 11JUL91 – 04OCT93 (previous study)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL

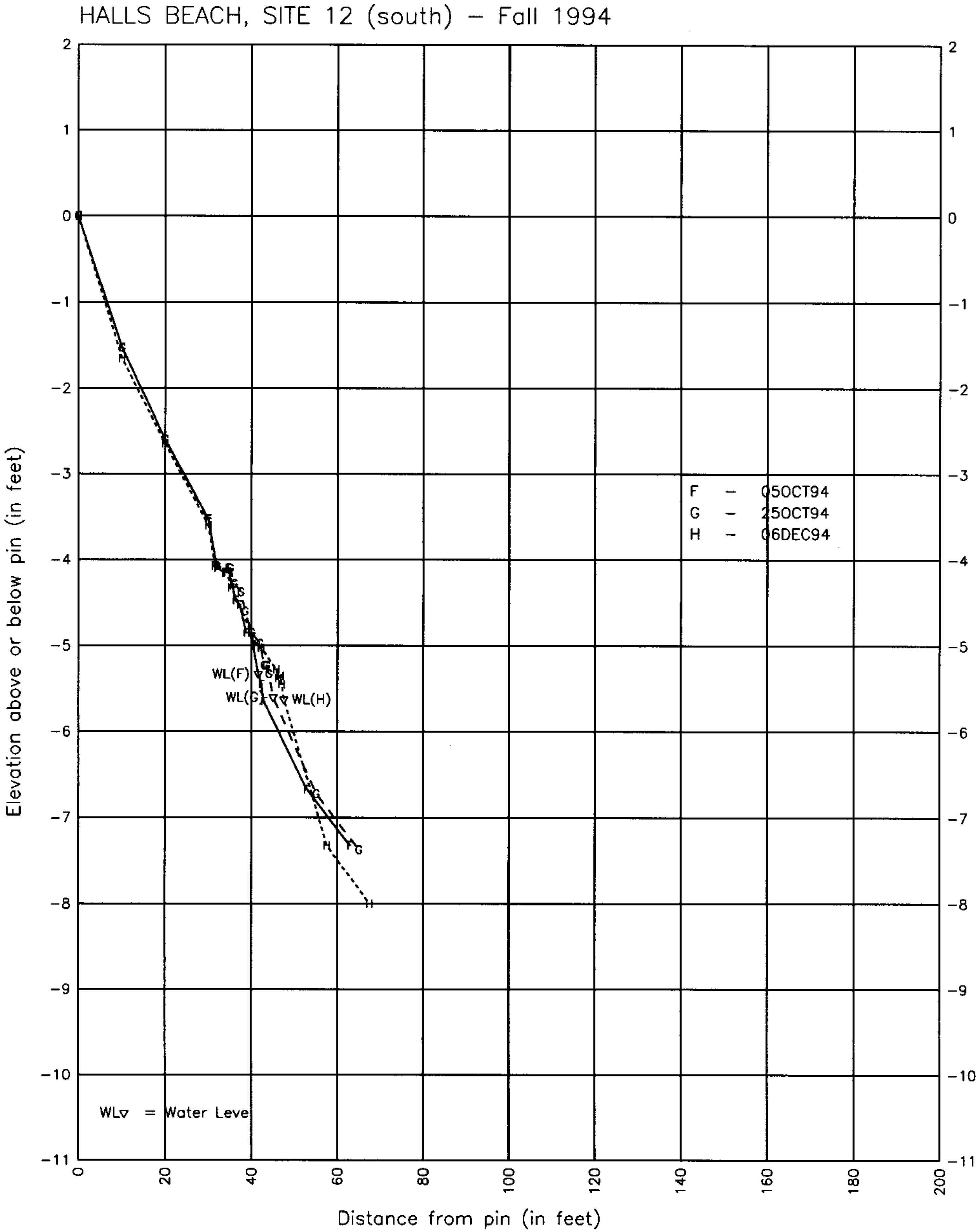
HALLS BEACH, Site 12 (south)- SWEEP ZONE (03MAY94-16MAY97)




HALLS BEACH, SITE 12 (south) – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200
WL(A)
WL(B)
A – 03MAY94
B – 31MAY94
WL▽ = Water Leve

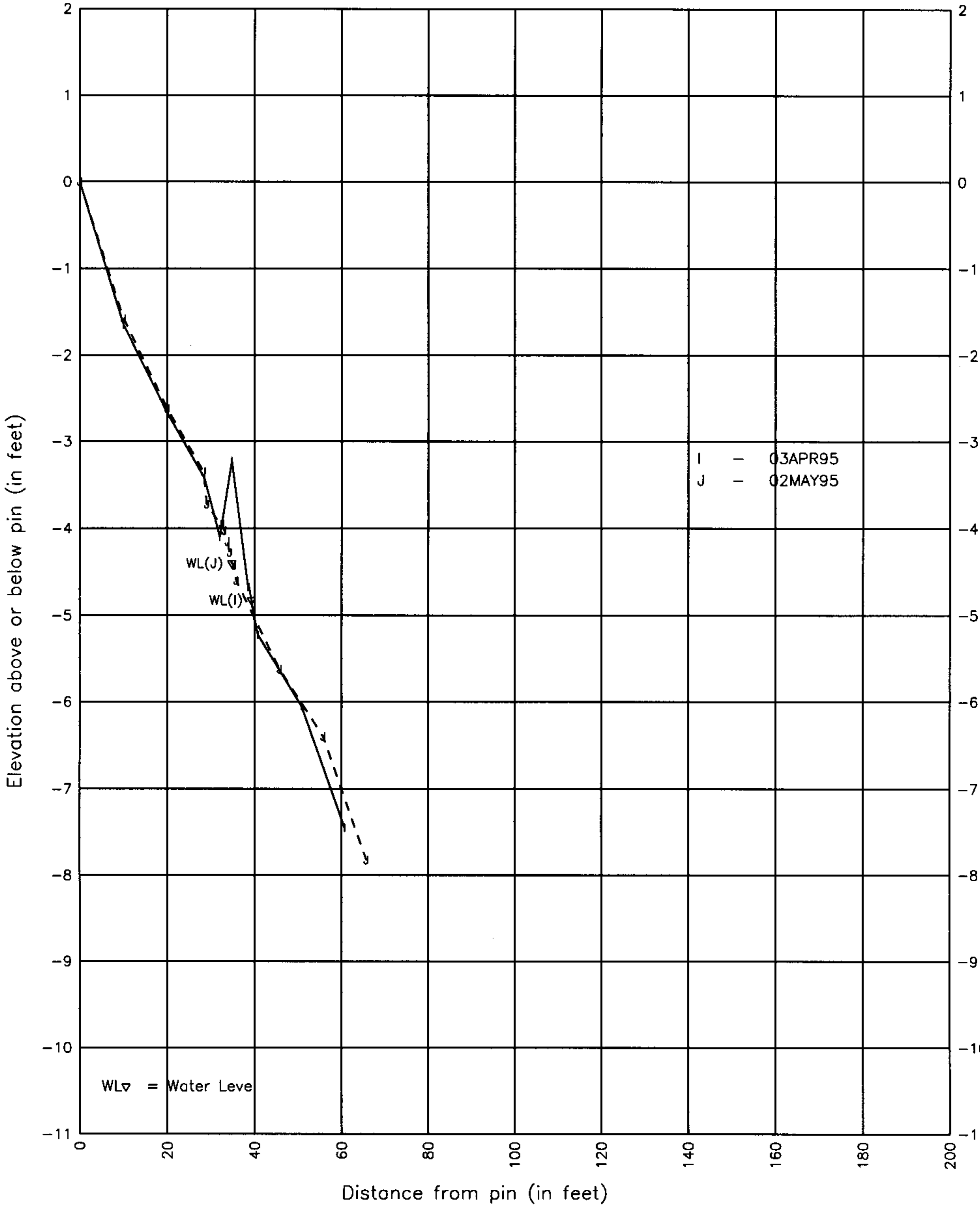


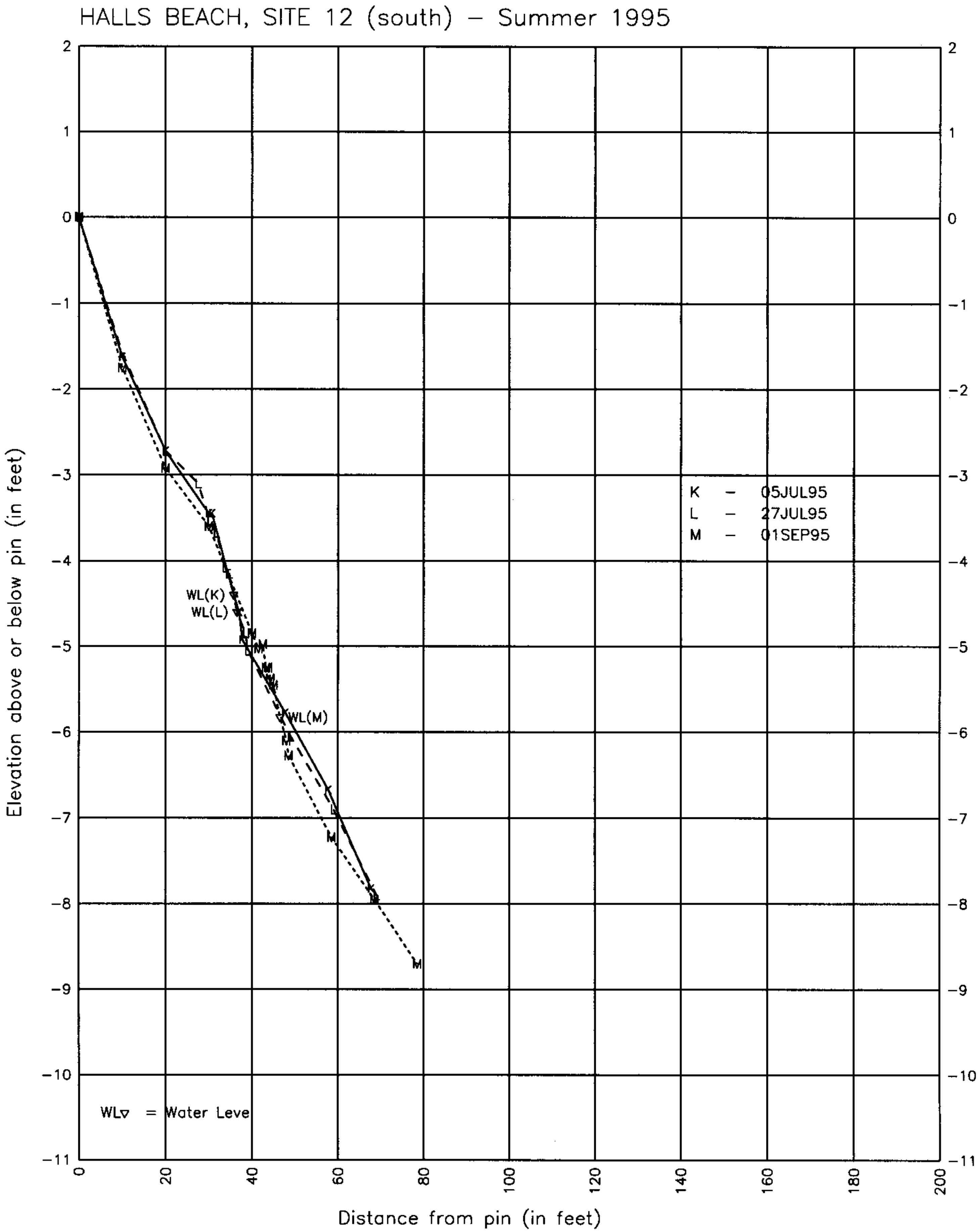
HALLS BEACH, SITE 12 (south) – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 08JUL94
D – 03AUG94
E – 09SEP94
WL(C)
WL(D)
WL(E)
WL▽ = Water Leve



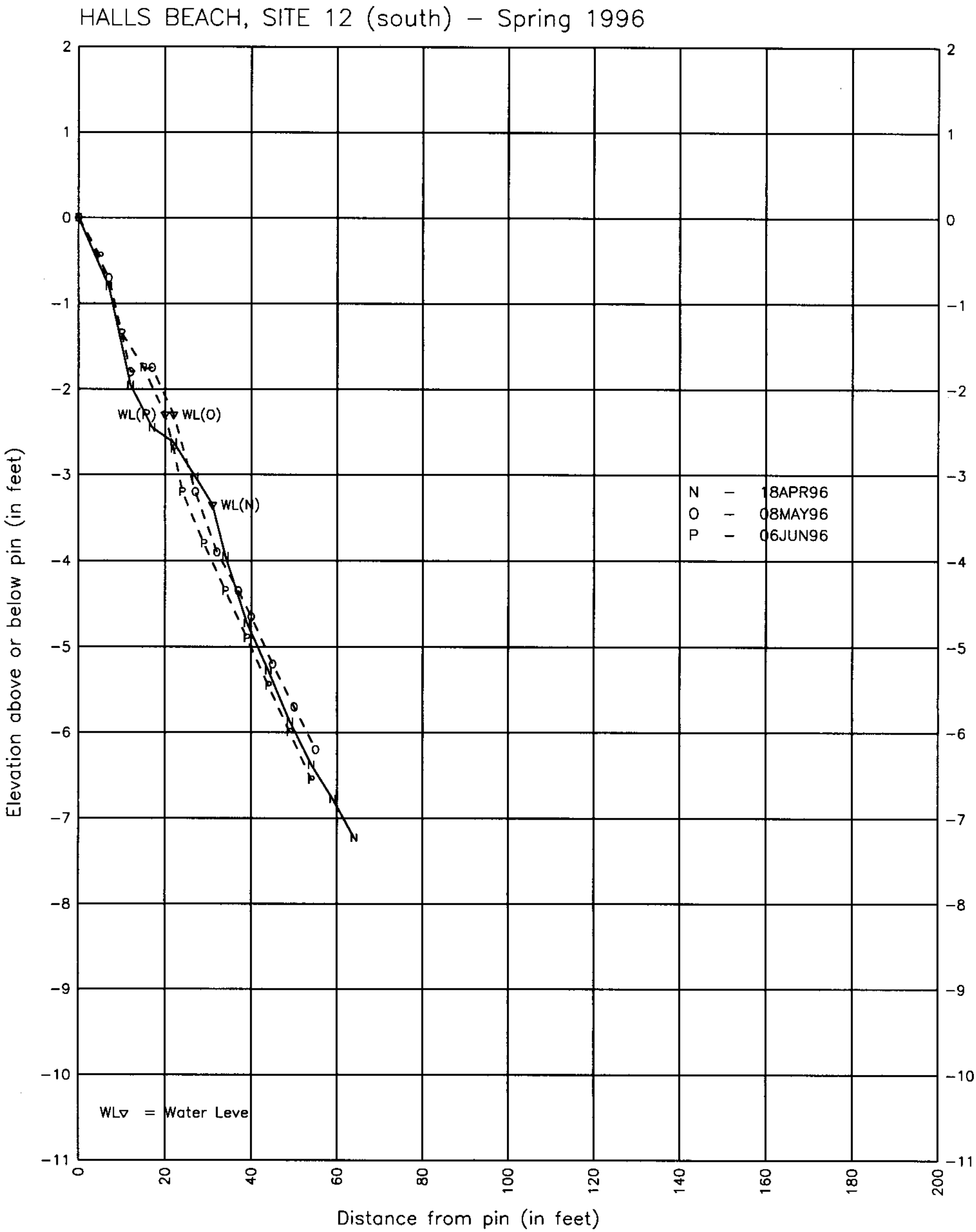
HALLS BEACH, SITE 12 (south) - Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
F - 05OCT94
G - 25OCT94
H - 06DEC94
WL(F)
WL(G)
WL(H)
WL▽ = Water Level

HALLS BEACH, SITE 12 (south) - Spring 1995

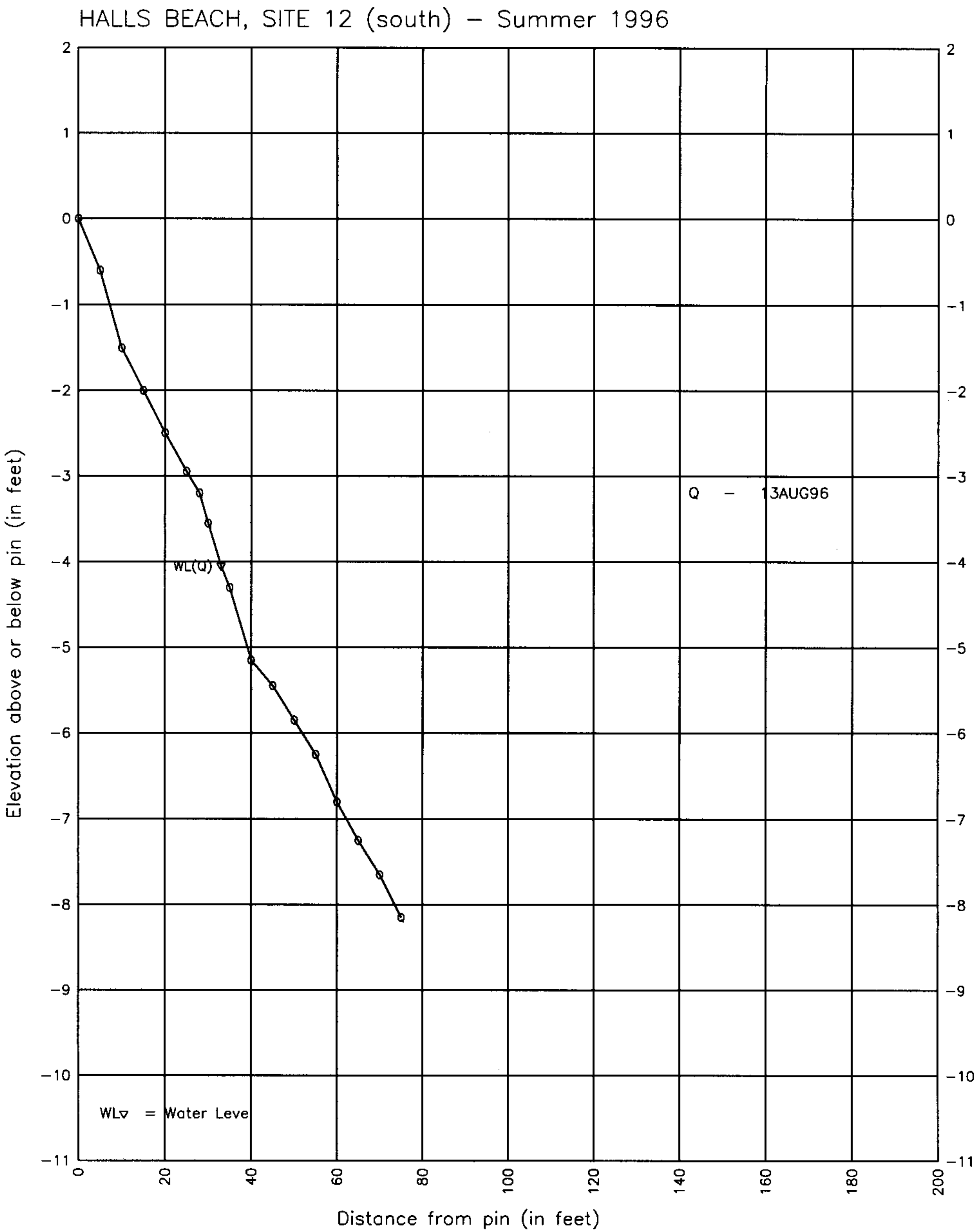


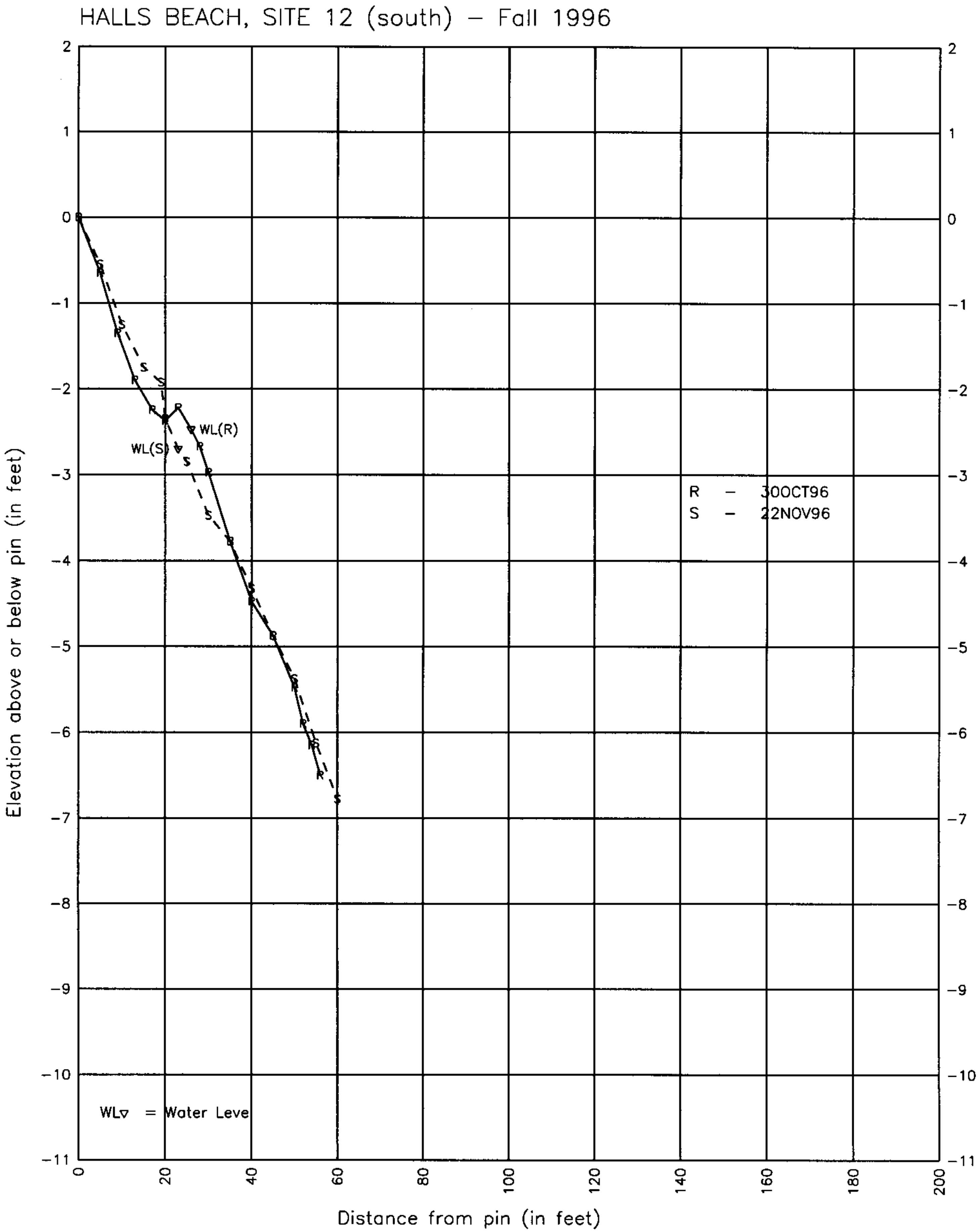


HALLS BEACH, SITE 12 (south) – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
K – 05JUL95
L – 27JUL95
M – 01SEP95
WL(K)
WL(L)
WL(M)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

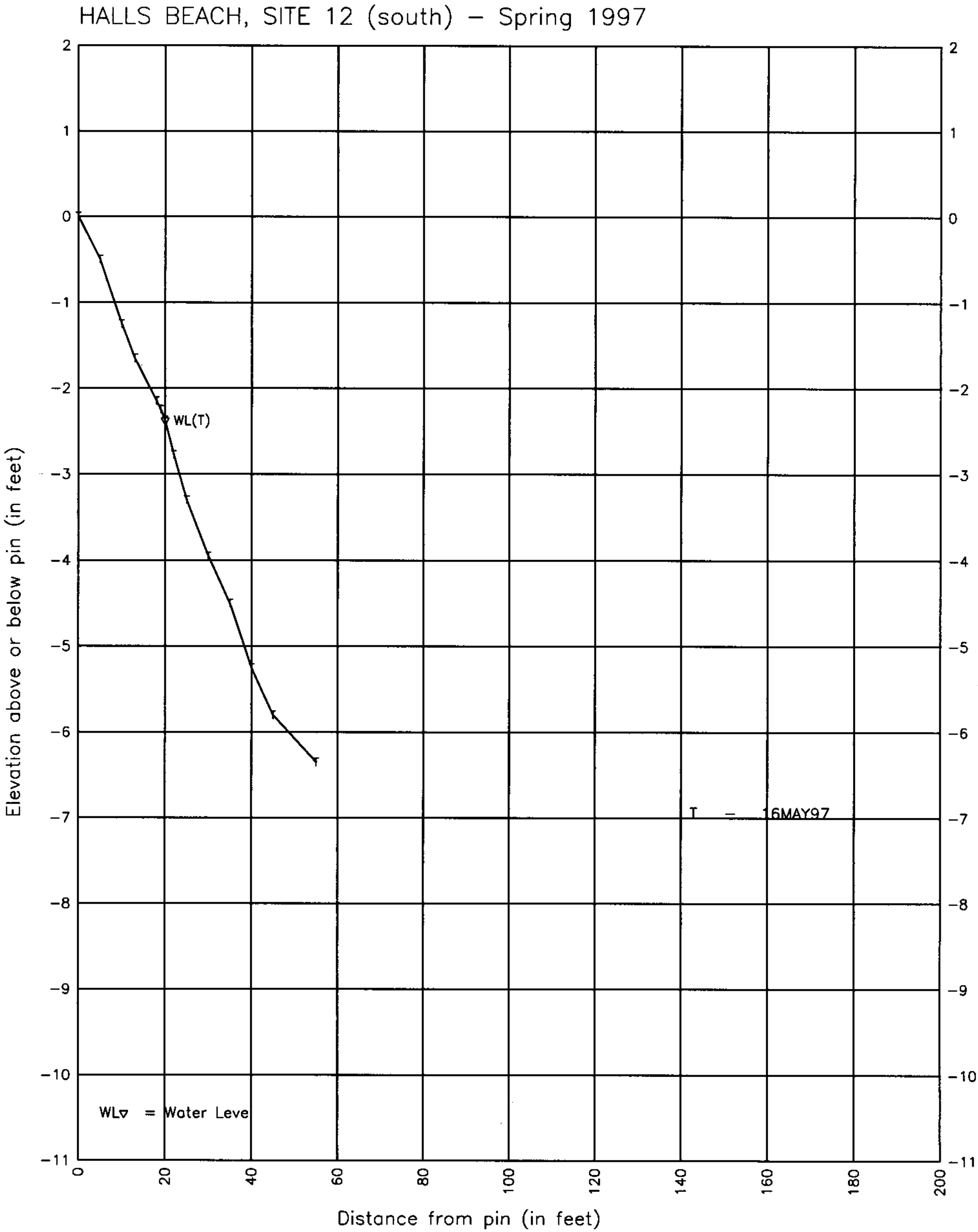


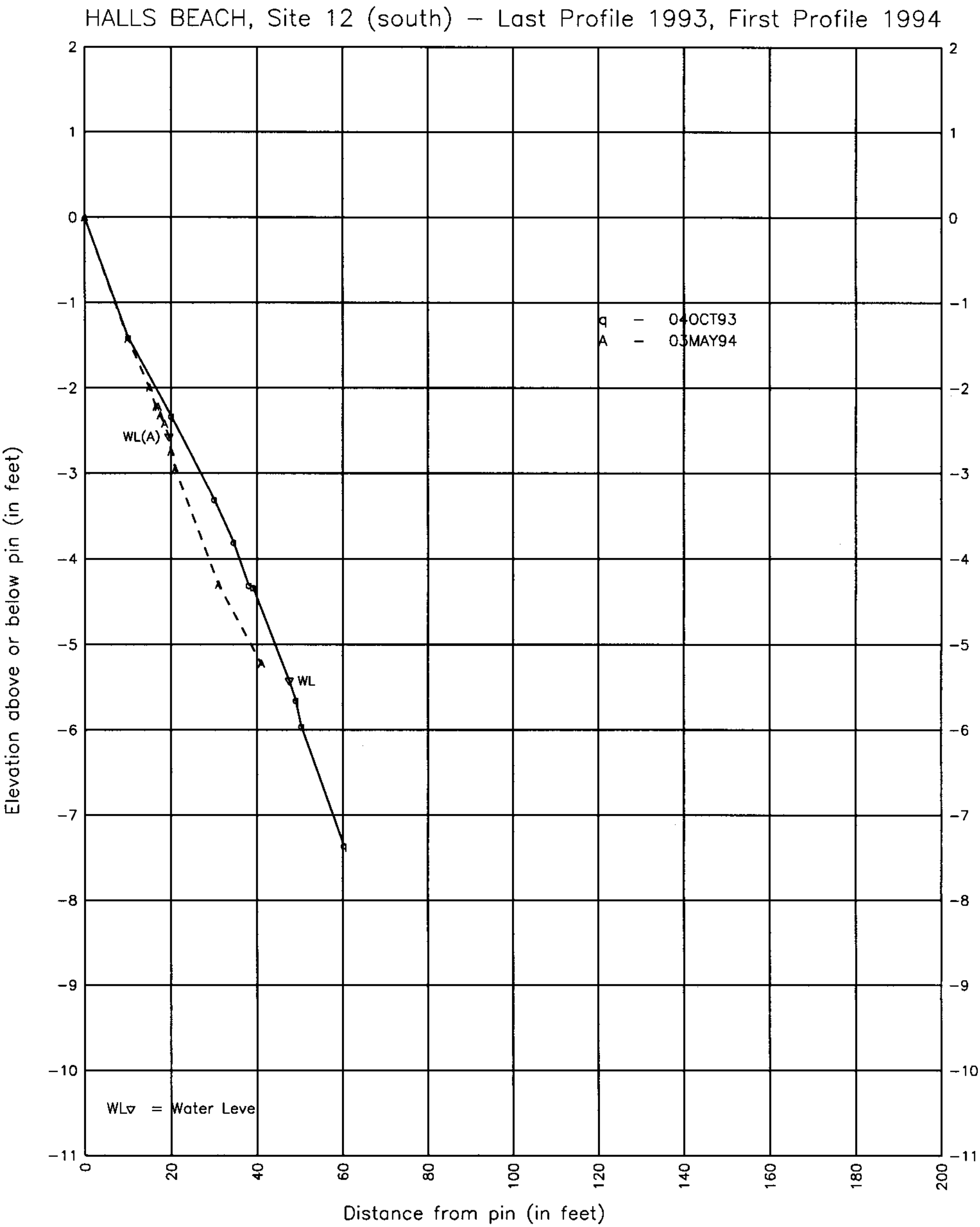
HALLS BEACH, SITE 12 (south) – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(P)
WL(O)
WL(N)
N – 18APR96
O – 08MAY96
P – 06JUN96
WL▽ = Water Leve


HALLS BEACH, SITE 12 (south) – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
Q – 13AUG96
WL(Q)
WL▽ = Water Leve
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

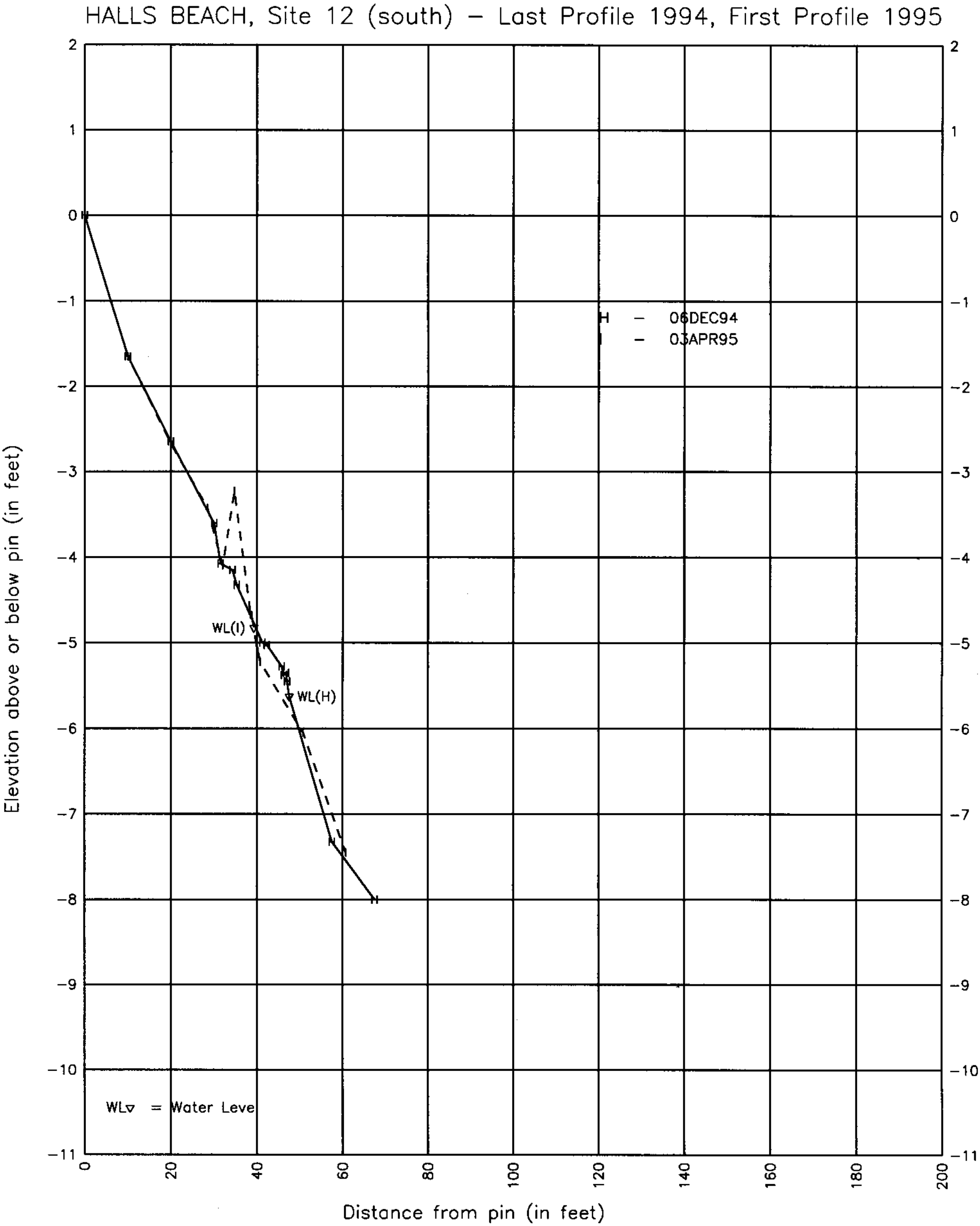


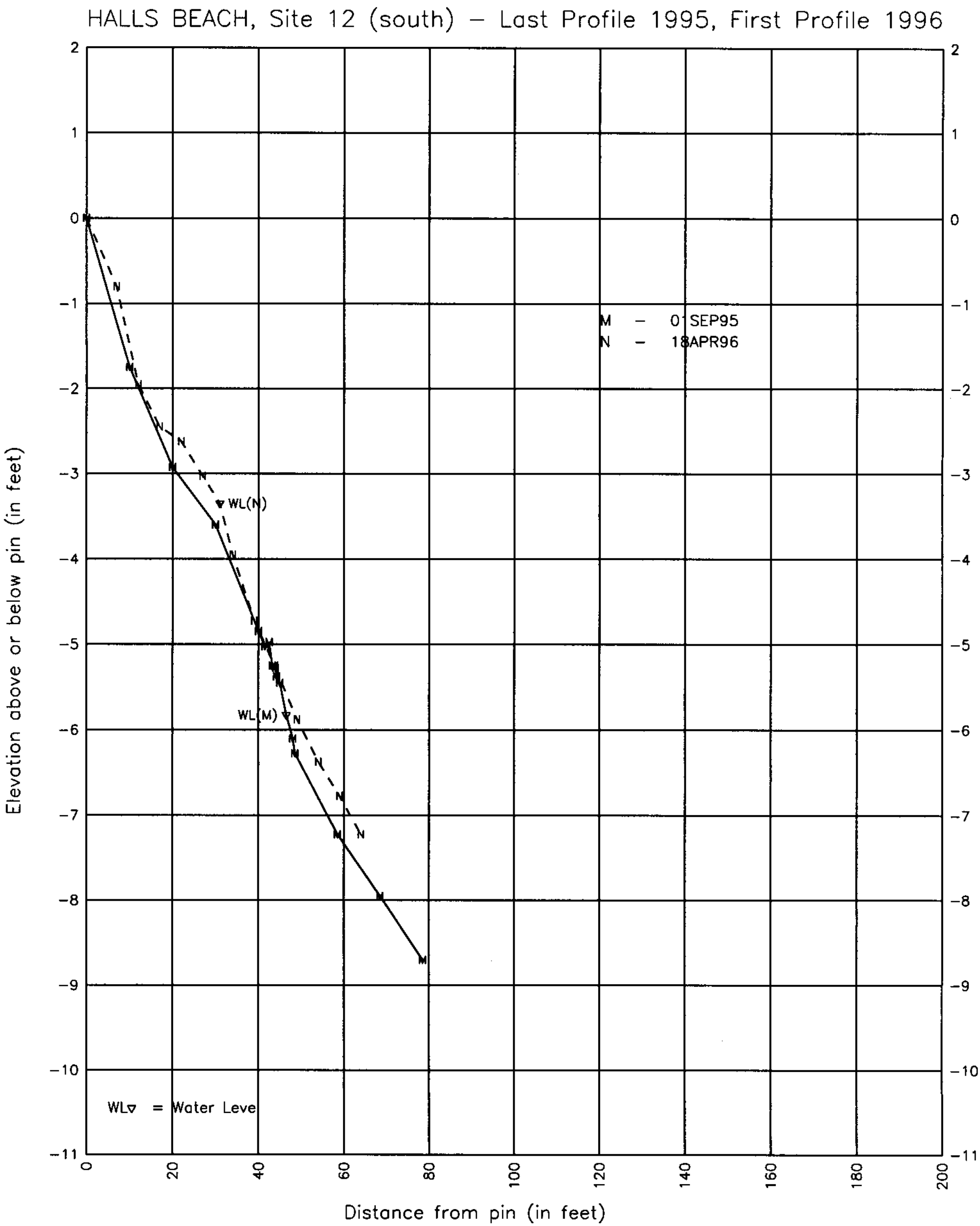
HALLS BEACH, SITE 12 (south) – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(S)
R – 30OCT96
S – 22NOV96
WL▽ = Water Leve


HALLS BEACH, SITE 12 (south) – Spring 1997
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(T)
T — 16MAY97
WL▽ = Water Leve
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

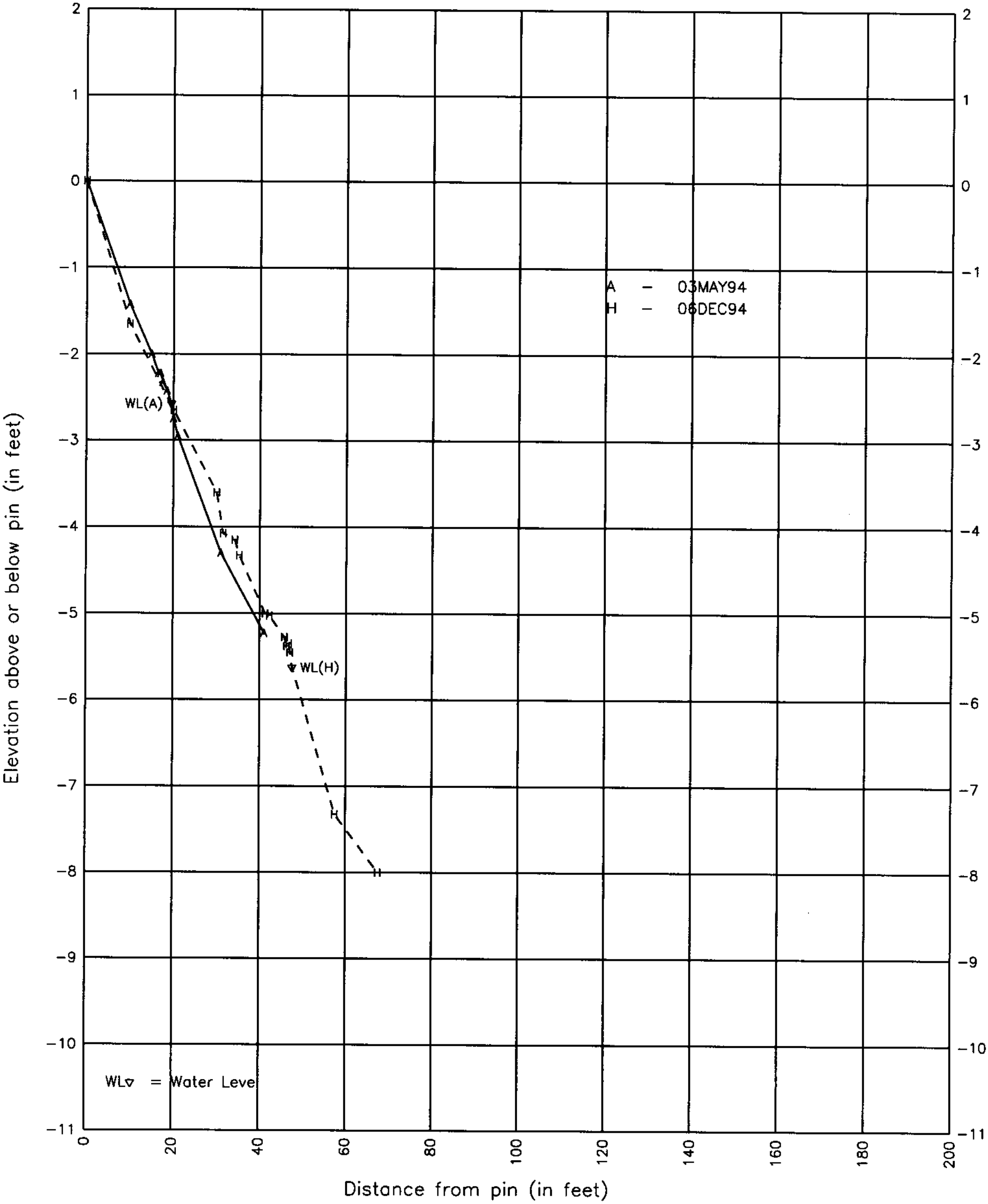


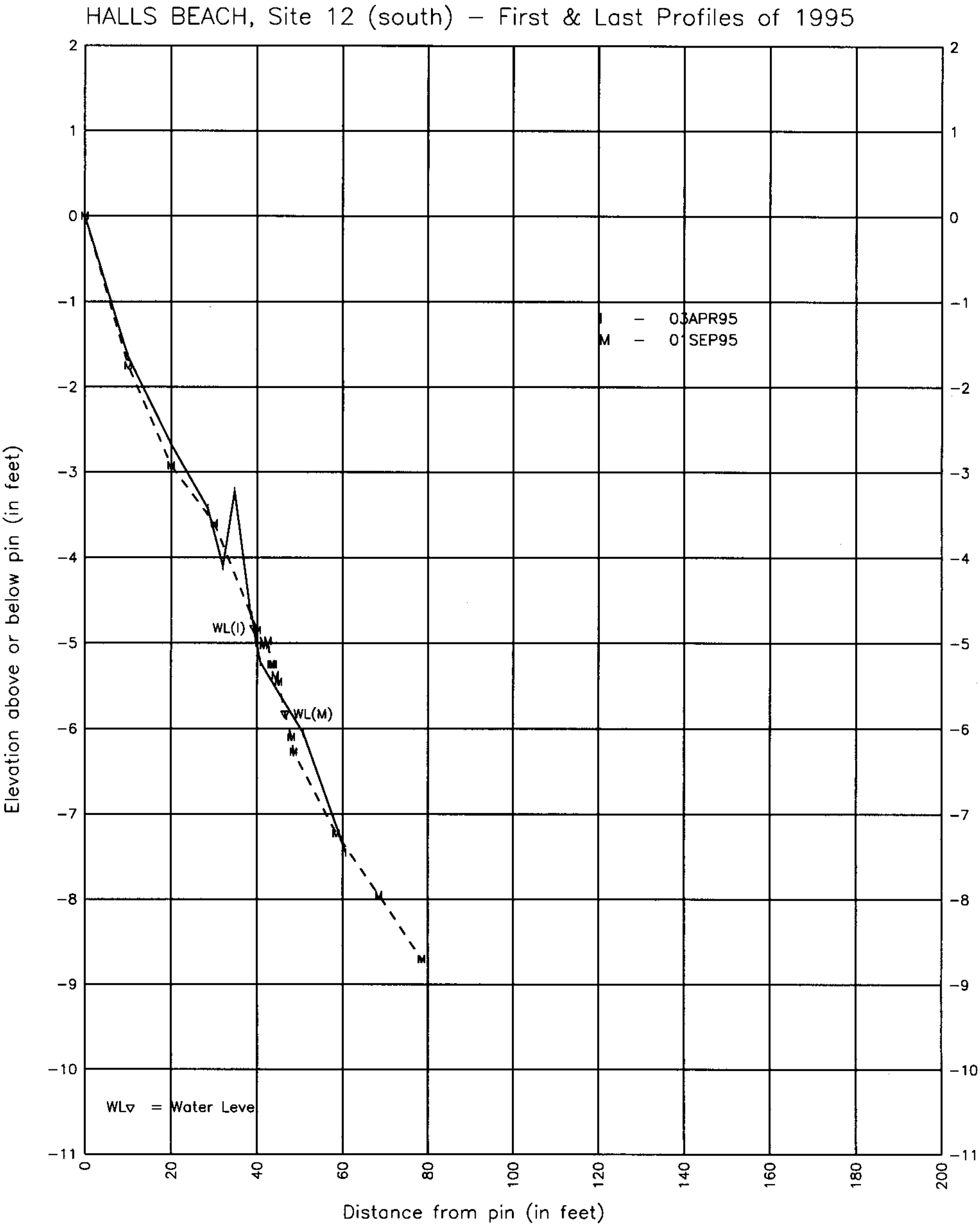
HALLS BEACH, Site 12 (south) – Last Profile 1993, First Profile 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
q – 04OCT93
A – 03MAY94
WL(A)
WL
WL▽ = Water Leve
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

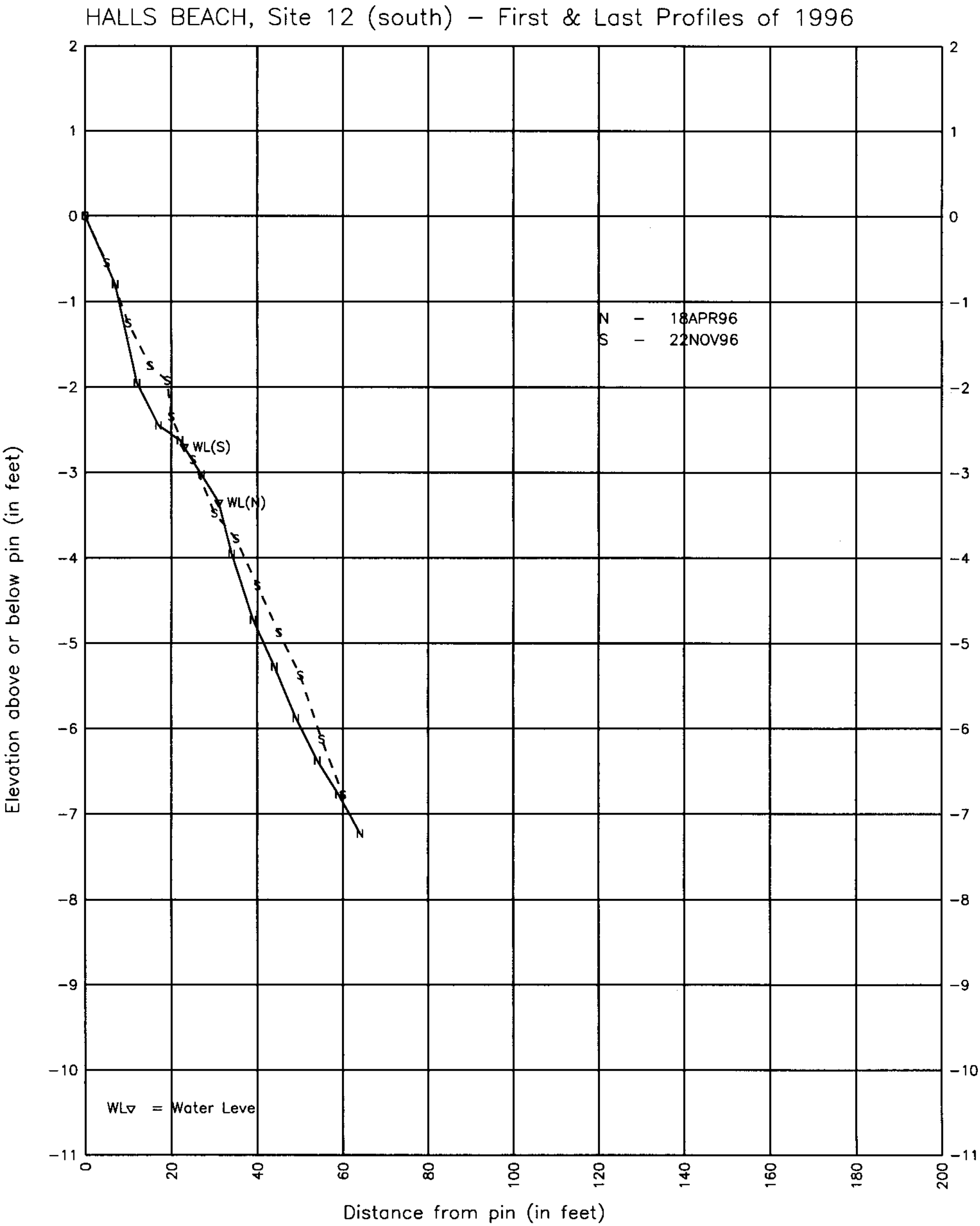

HALLS BEACH, Site 12 (south) - Last Profile 1994, First Profile 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
H - 06DEC94
I - 03APR95
WL(I)
WL(H)
WL▽ = Water Leve
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

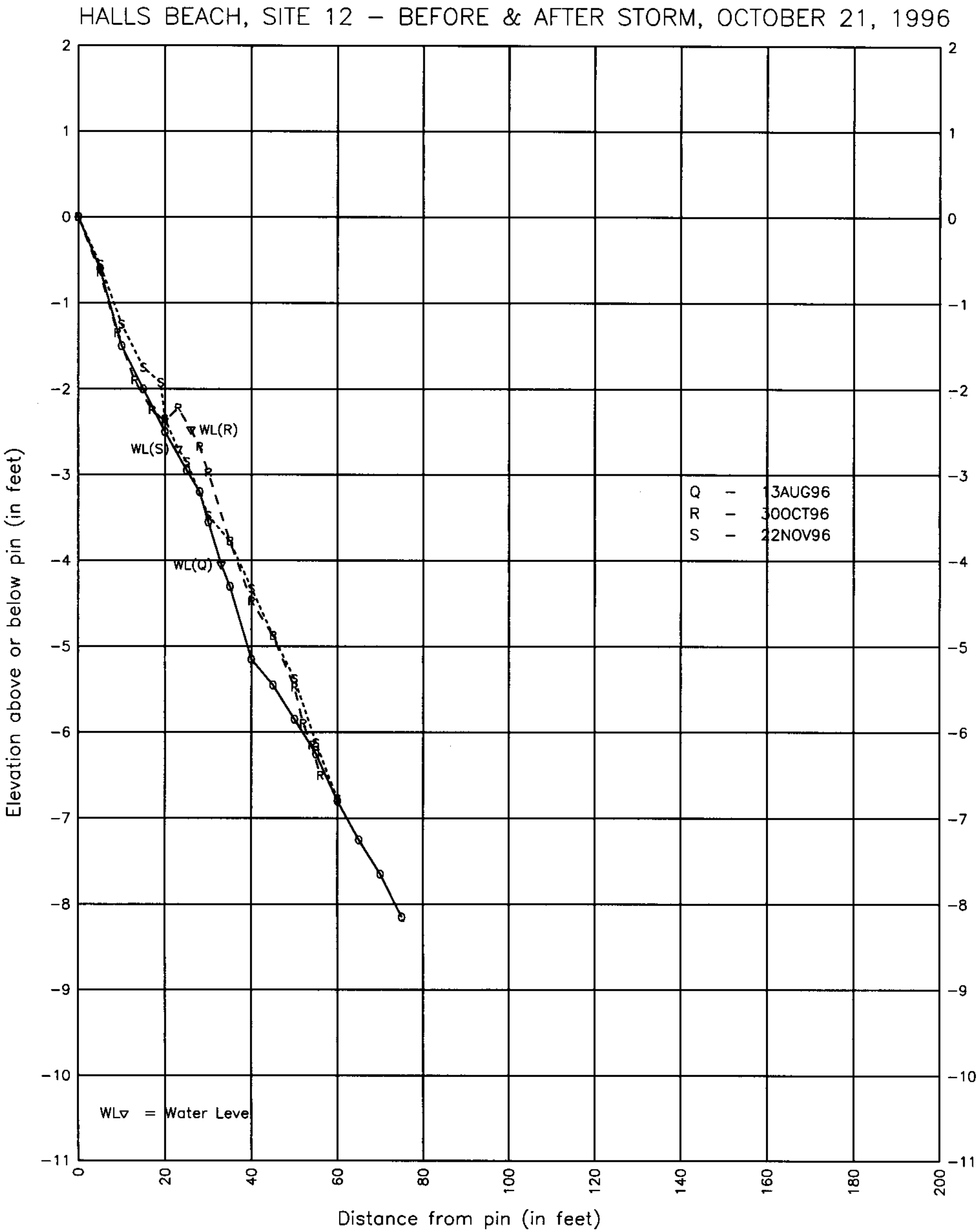

HALLS BEACH, Site 12 (south) – Last Profile 1995, First Profile 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
M – 01SEP95
N – 18APR96
WL(N)
WL(M)
WL▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

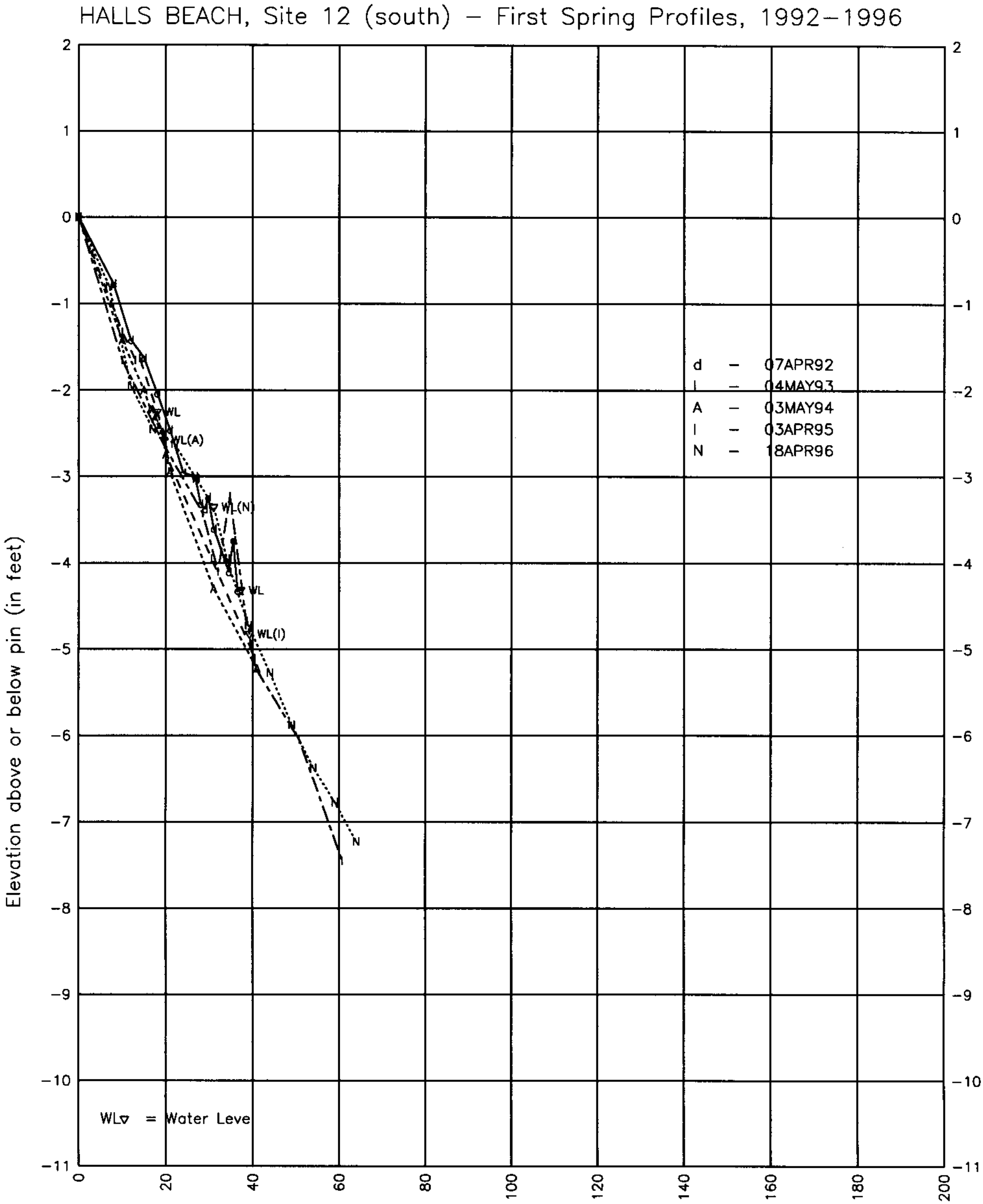
HALLS BEACH, Site 12 (south) - First & Last Profiles of 1994

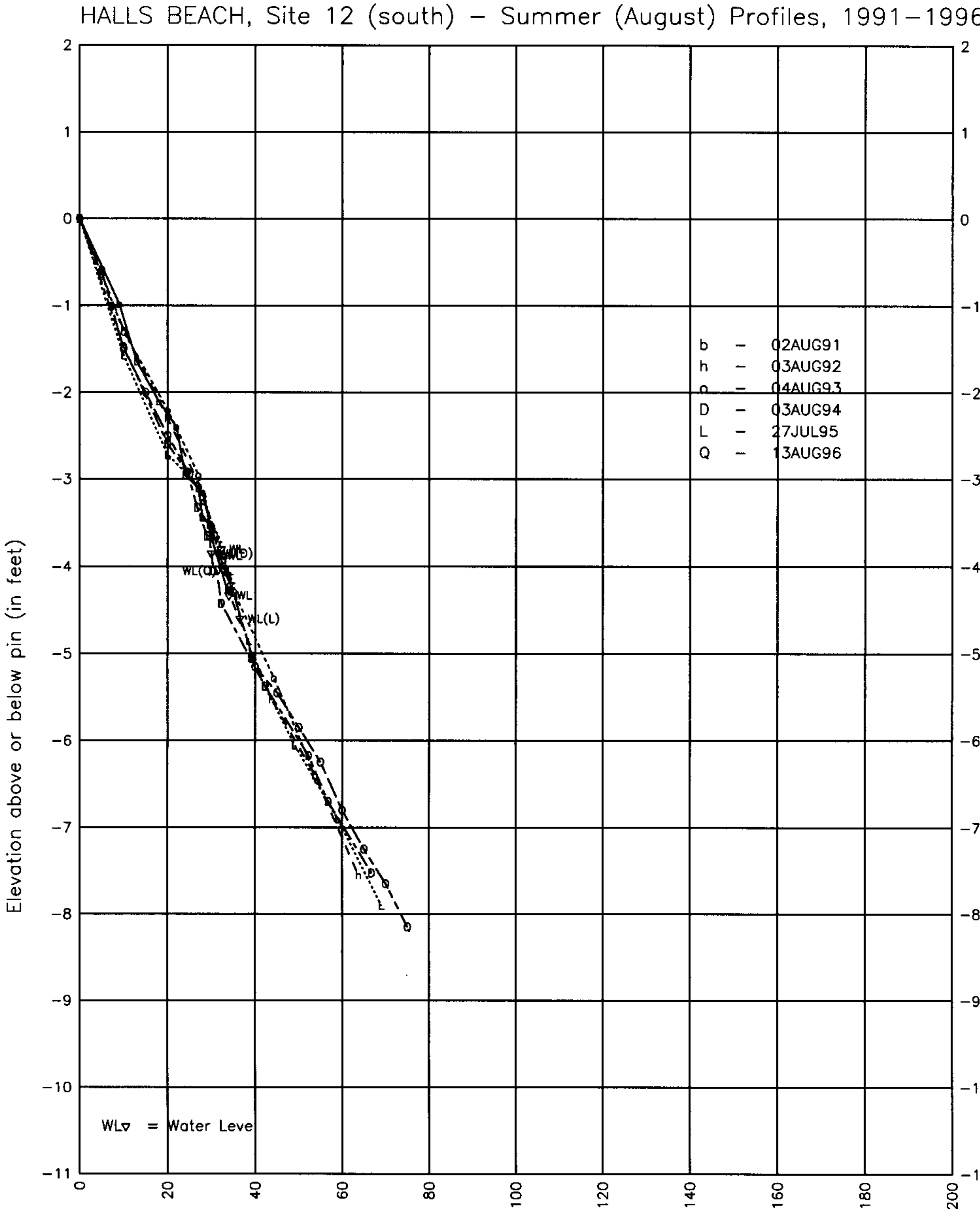



HALLS BEACH, Site 12 (south) – First & Last Profiles of 1995
I – 03APR95
M – 01SEP95
WL(I)
WL(M)
WL▽ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

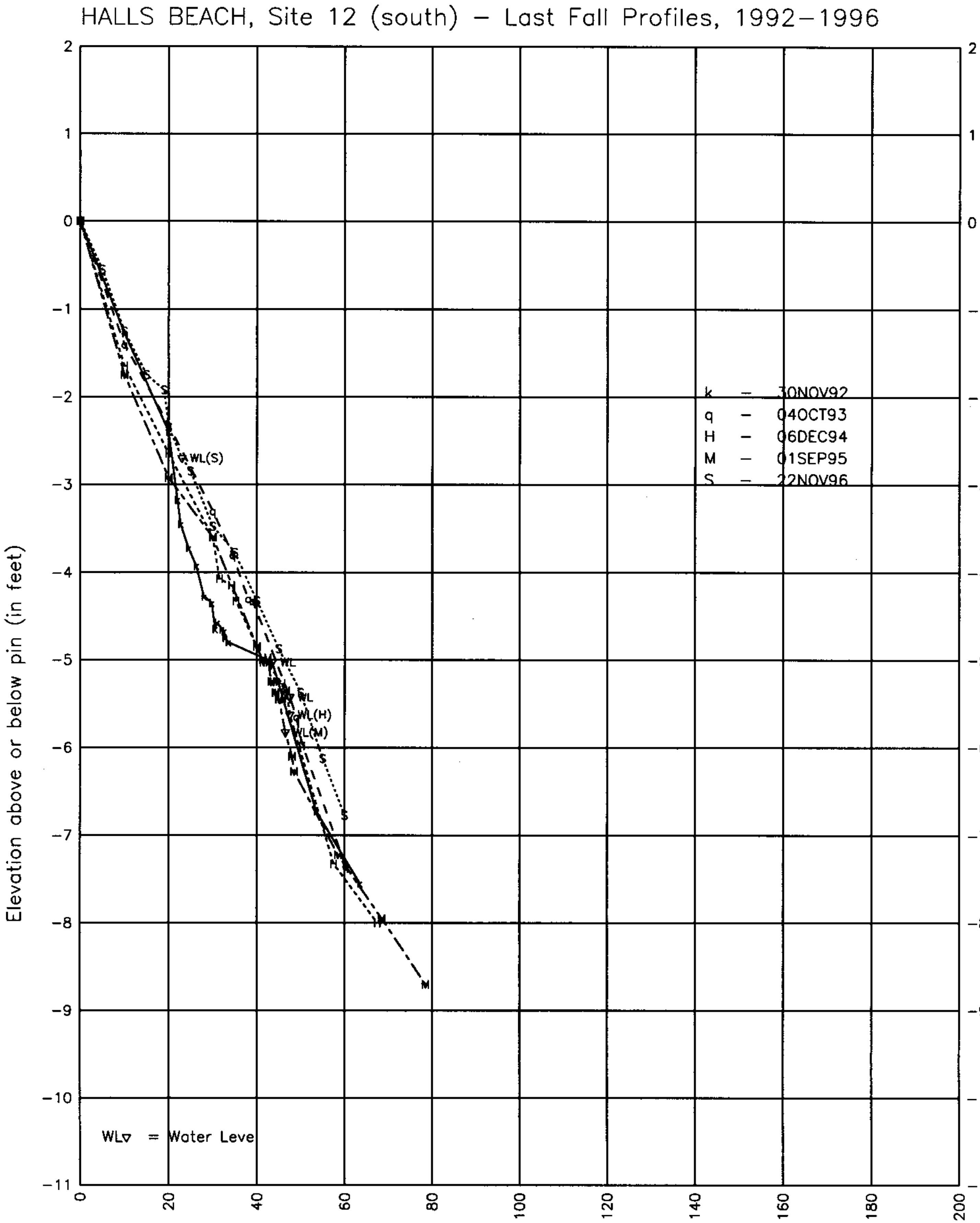

HALLS BEACH, Site 12 (south) - First & Last Profiles of 1996
N - 18APR96
S - 22NOV96
WL(S)
WL(N)
WL▽ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200


HALLS BEACH, SITE 12 – BEFORE & AFTER STORM, OCTOBER 21, 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(S)
WL(Q)
Q – 13AUG96
R – 30OCT96
S – 22NOV96
WL▽ = Water Level


HALLS BEACH, Site 12 (south) – First Spring Profiles, 1992–1996
Elevation above or below pin (in feet)
d – 07APR92
l – 04MAY93
A – 03MAY94
I – 03APR95
N – 18APR96
WL▽ = Water Level

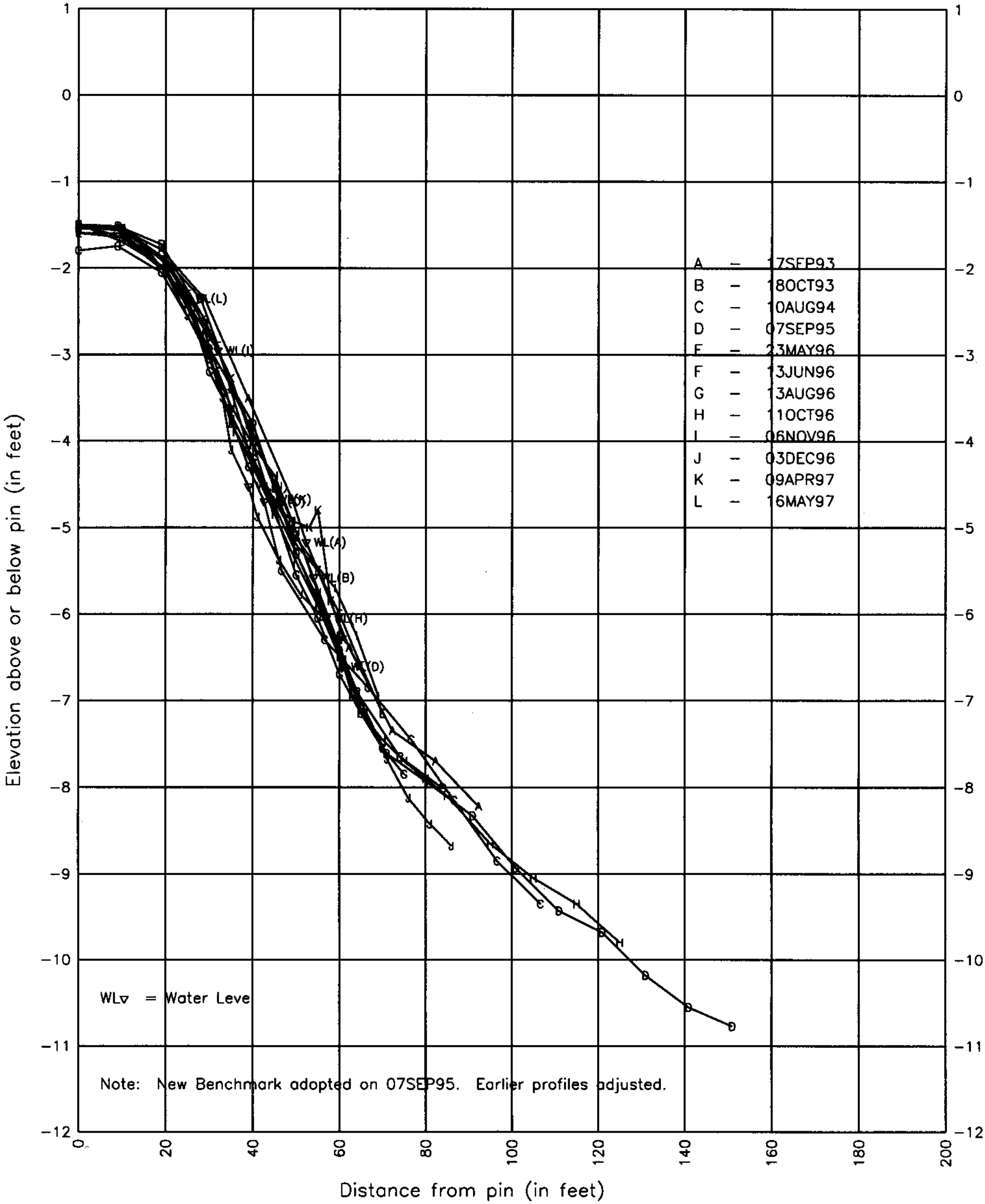


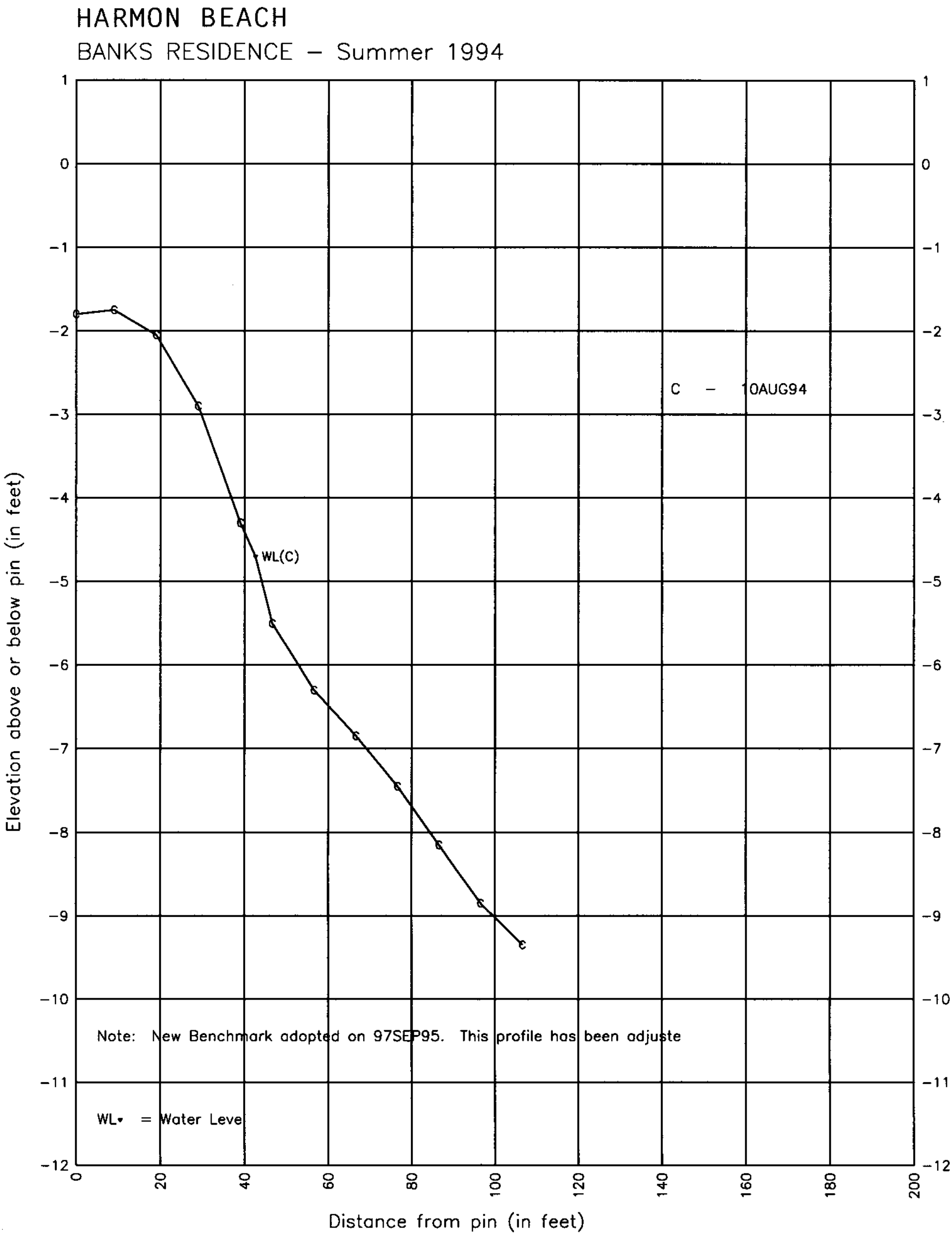
HALLS BEACH, Site 12 (south) – Summer (August) Profiles, 1991–1996
Elevation above or below pin (in feet)
b – 02AUG91
h – 03AUG92
o – 04AUG93
D – 03AUG94
L – 27JUL95
Q – 13AUG96
WL▽ = Water Level
WL(Q)
WL(D)
WL(L)
WL
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200


HALLS BEACH, Site 12 (south) – Last Fall Profiles, 1992–1996
Elevation above or below pin (in feet)
k – 30NOV92
q – 04OCT93
H – 06DEC94
M – 01SEP95
S – 22NOV96
WL(S)
WL(H)
WL(M)
WL▽ = Water Leve

HARMON BEACH

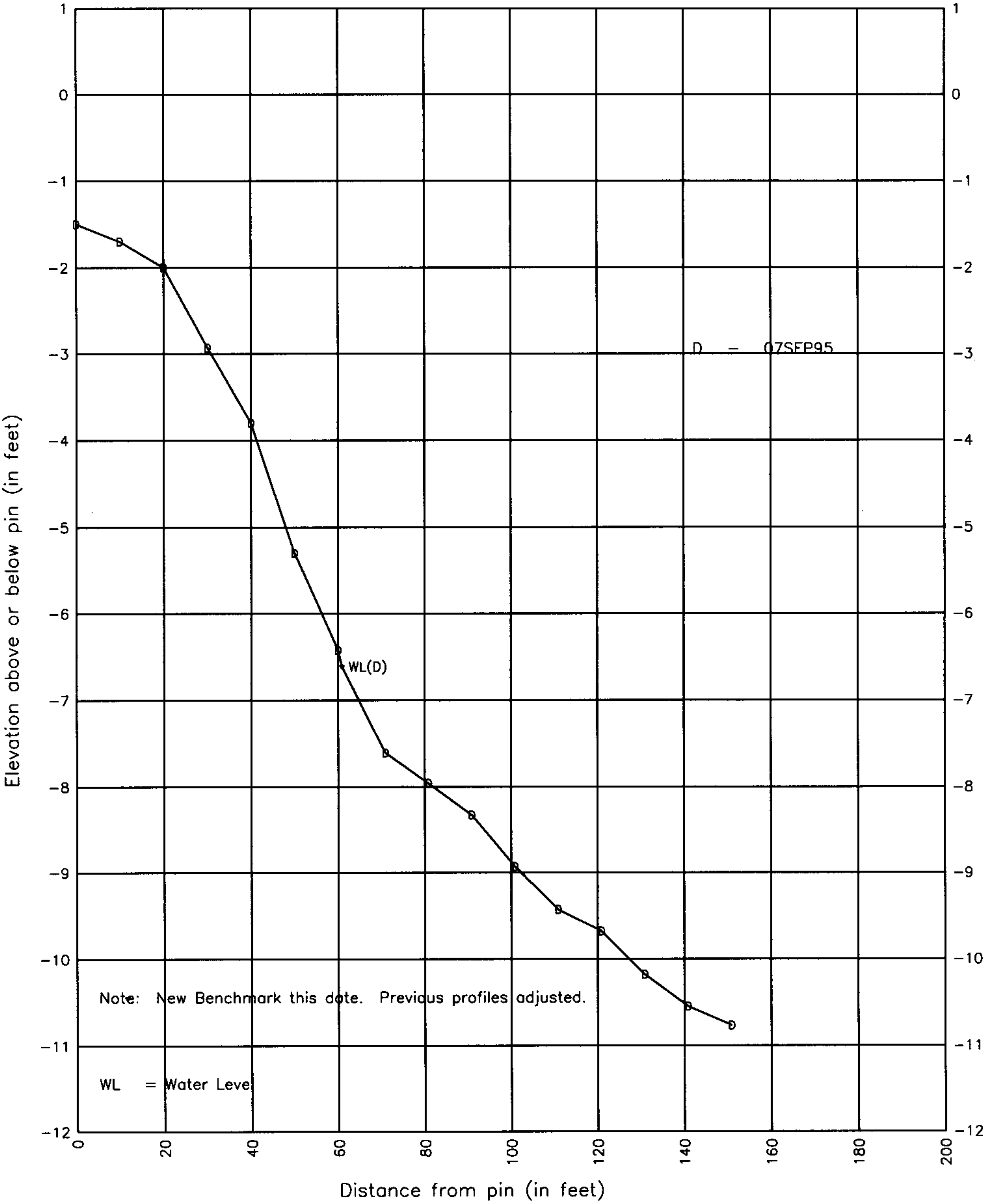
BANKS RESIDENCE – SWEEP ZONE (17SEP93–16MAY97)

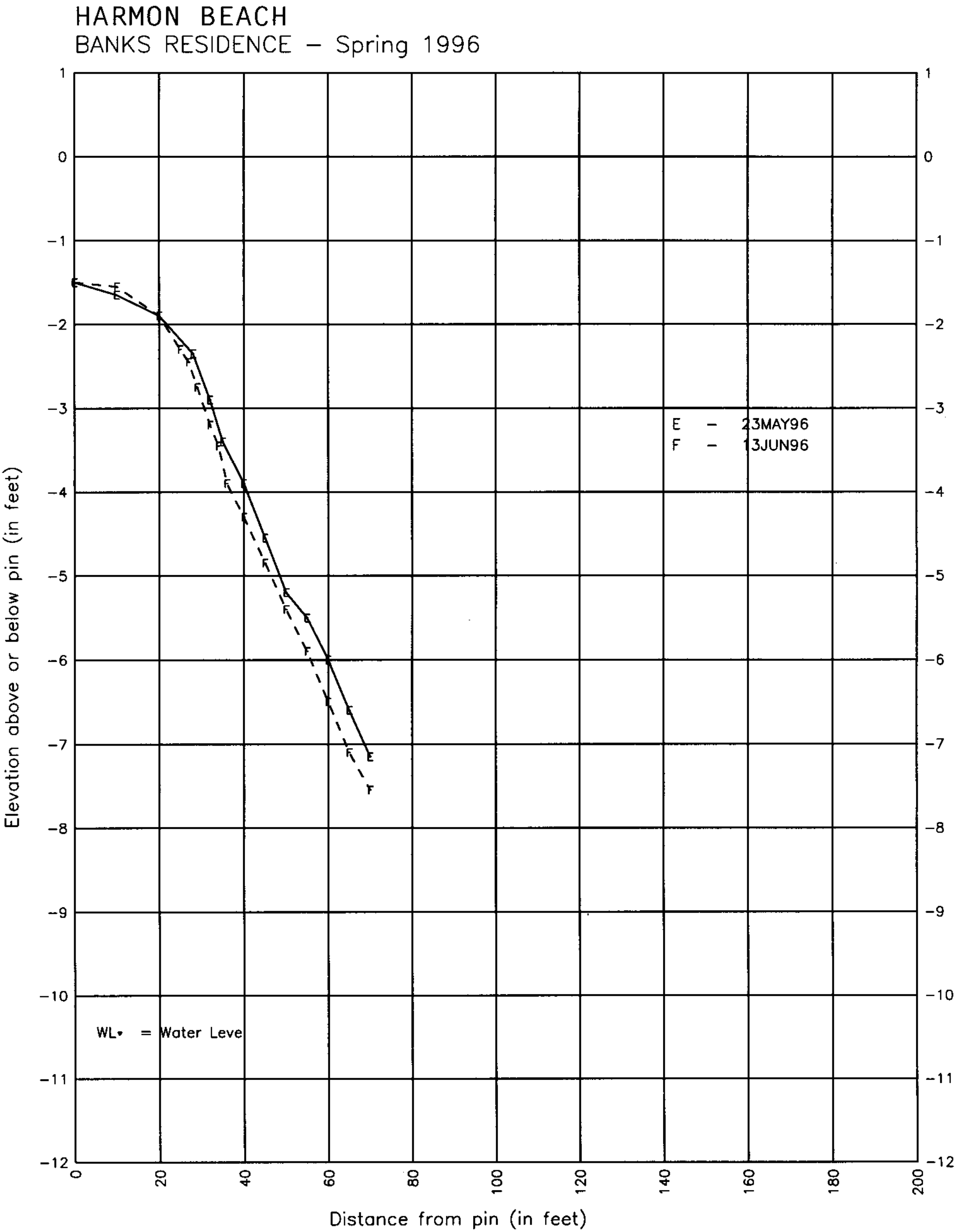


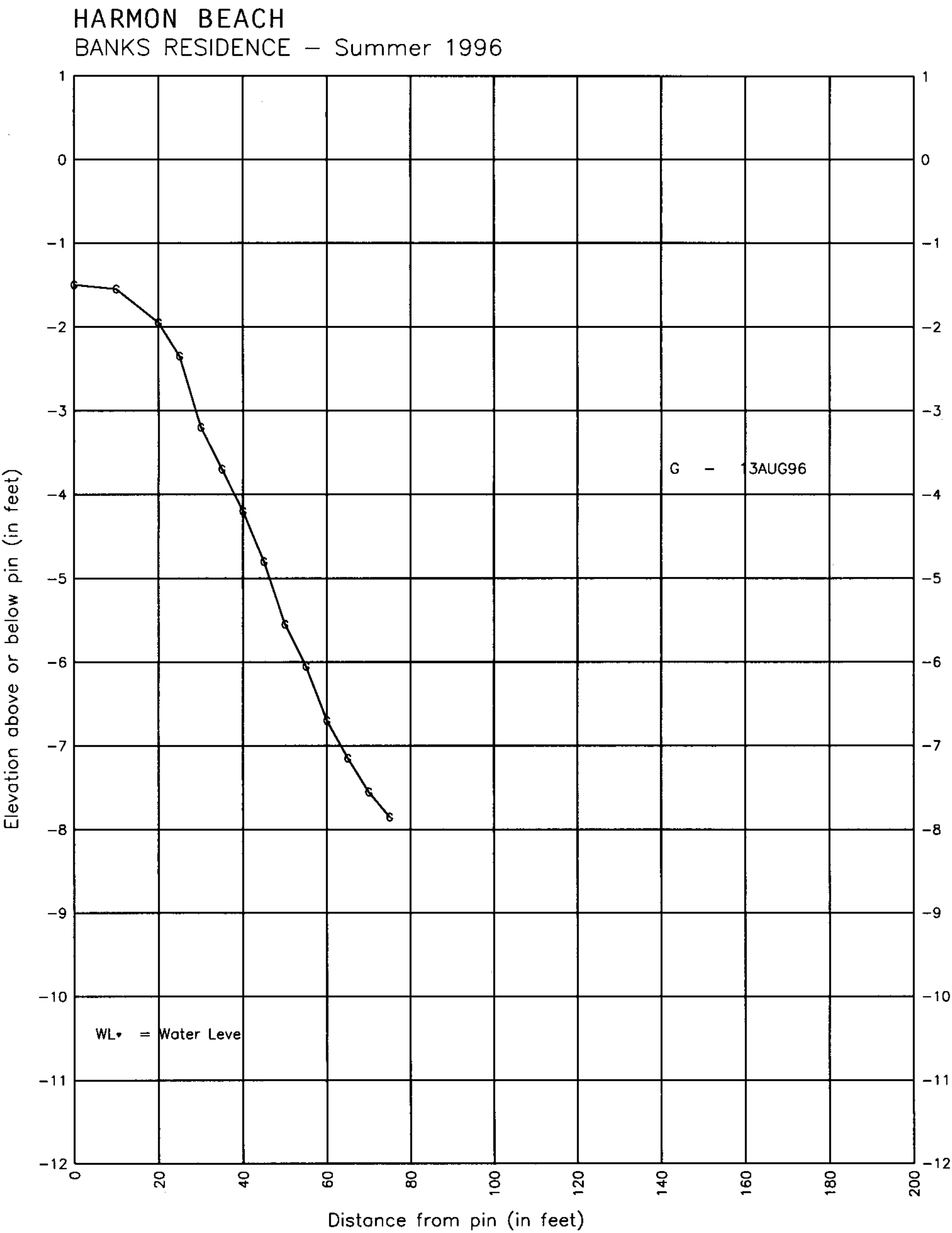

HARMON BEACH
BANKS RESIDENCE – Summer 1994
C – 10AUG94
WL(C)
Note: New Benchmark adopted on 97SEP95. This profile has been adjuste
WL▾ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0
20
40
60
80
100
120
140
160
180
200

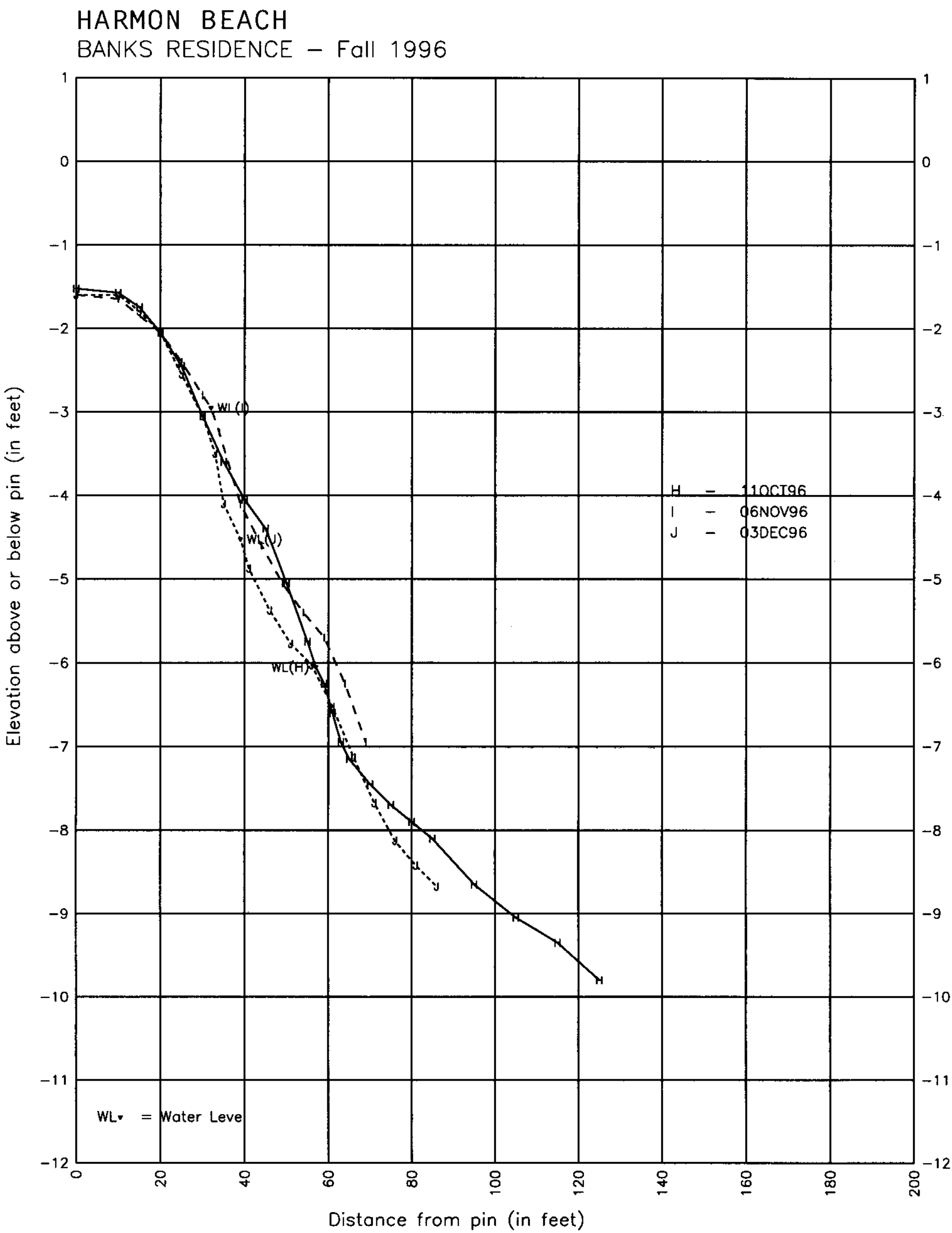
HARMON BEACH

BANKS RESIDENCE – Summer 1995




HARMON BEACH
BANKS RESIDENCE – Spring 1996
E – 23MAY96
F – 13JUN96
WL• = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
0
20
40
60
80
100
120
140
160
180
200

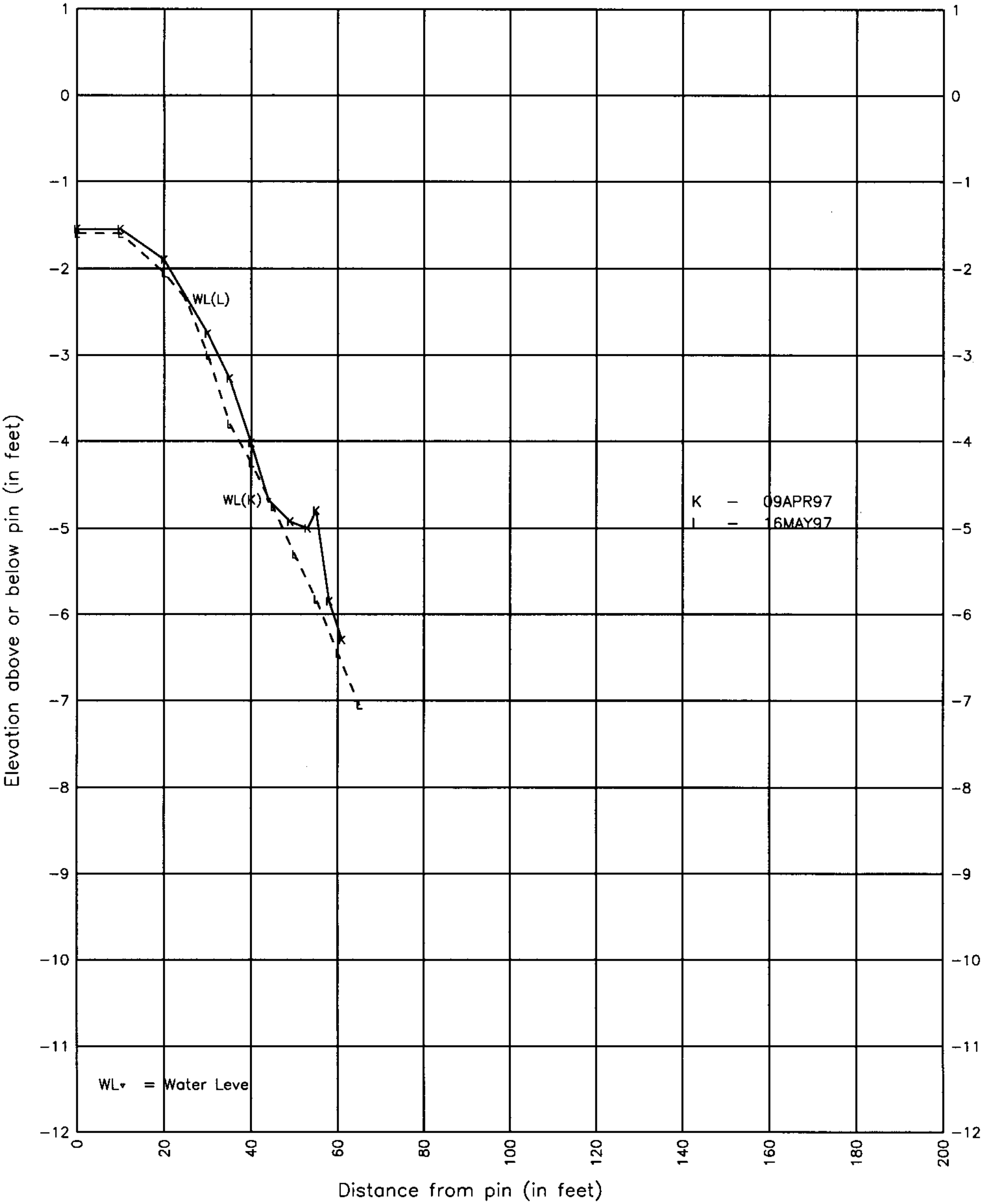

HARMON BEACH
BANKS RESIDENCE – Summer 1996
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
–12
Elevation above or below pin (in feet)
G – 13AUG96
WL• = Water Leve
0
20
40
60
80
100
120
140
160
180
200
Distance from pin (in feet)



HARMON BEACH
BANKS RESIDENCE – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
H – 11OCT96
I – 06NOV96
J – 03DEC96
WL(I)
WL(J)
WL(H)
WL▾ = Water Leve

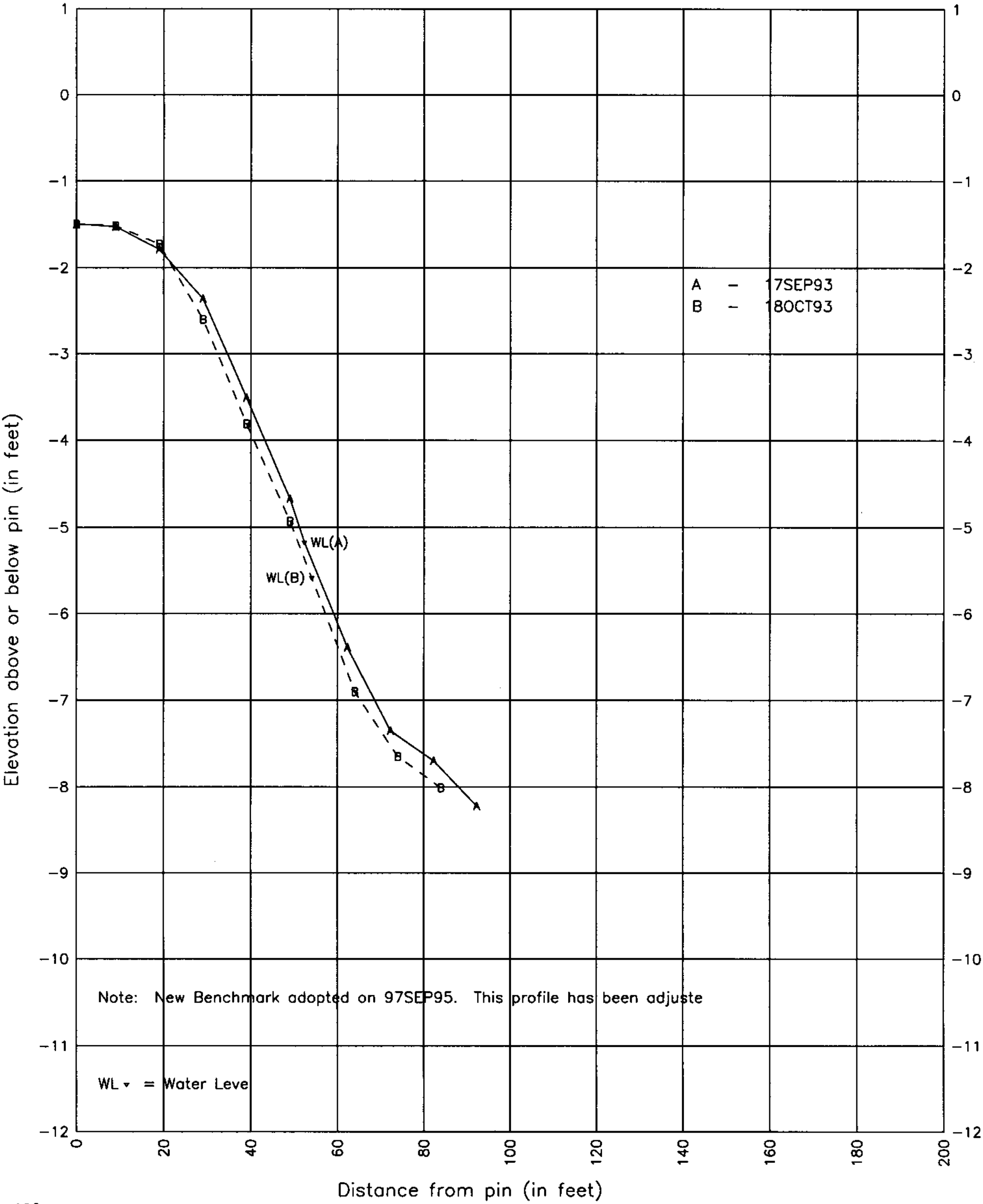
HARMON BEACH

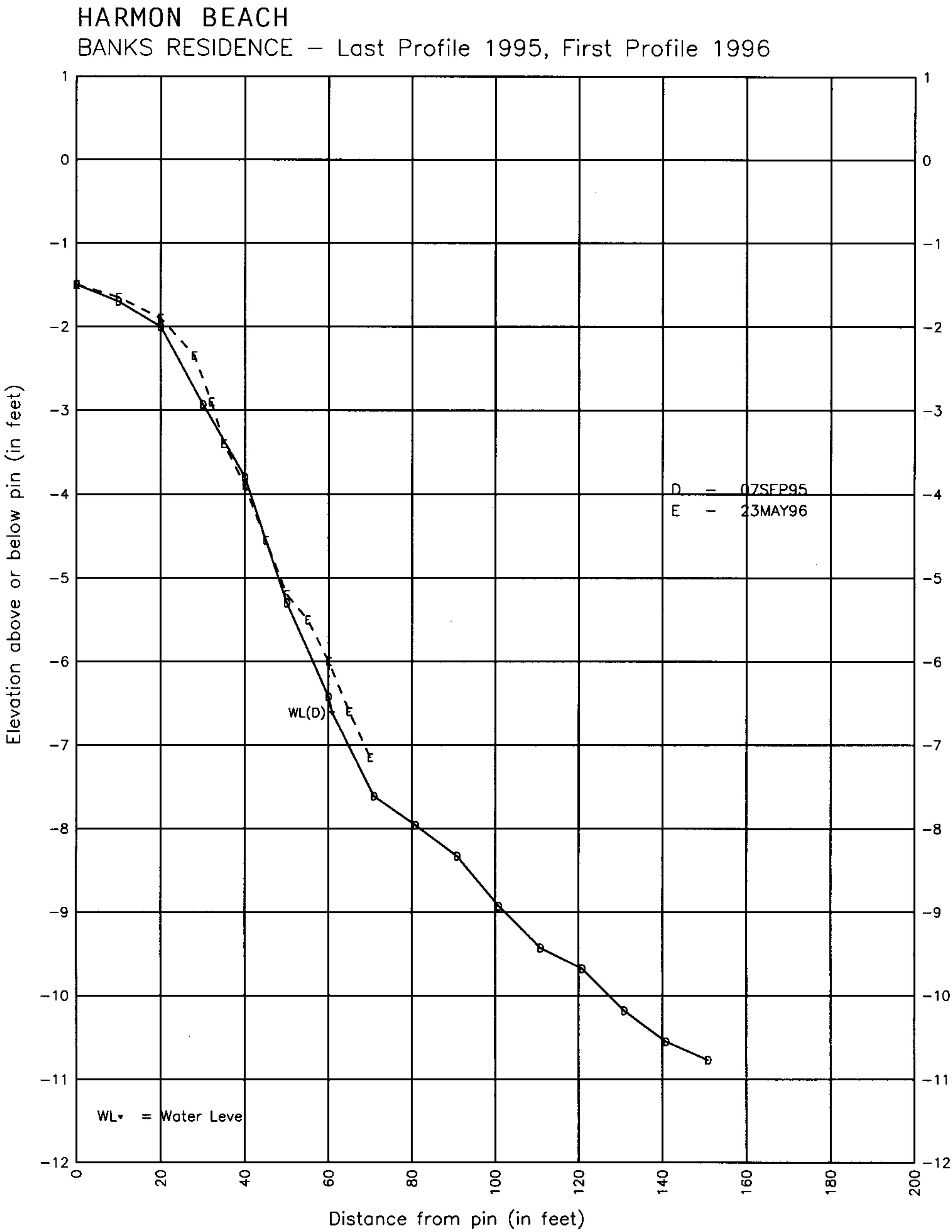
BANKS RESIDENCE – Spring 1997



HARMON BEACH

BANKS RESIDENCE – Summer and Fall 1993

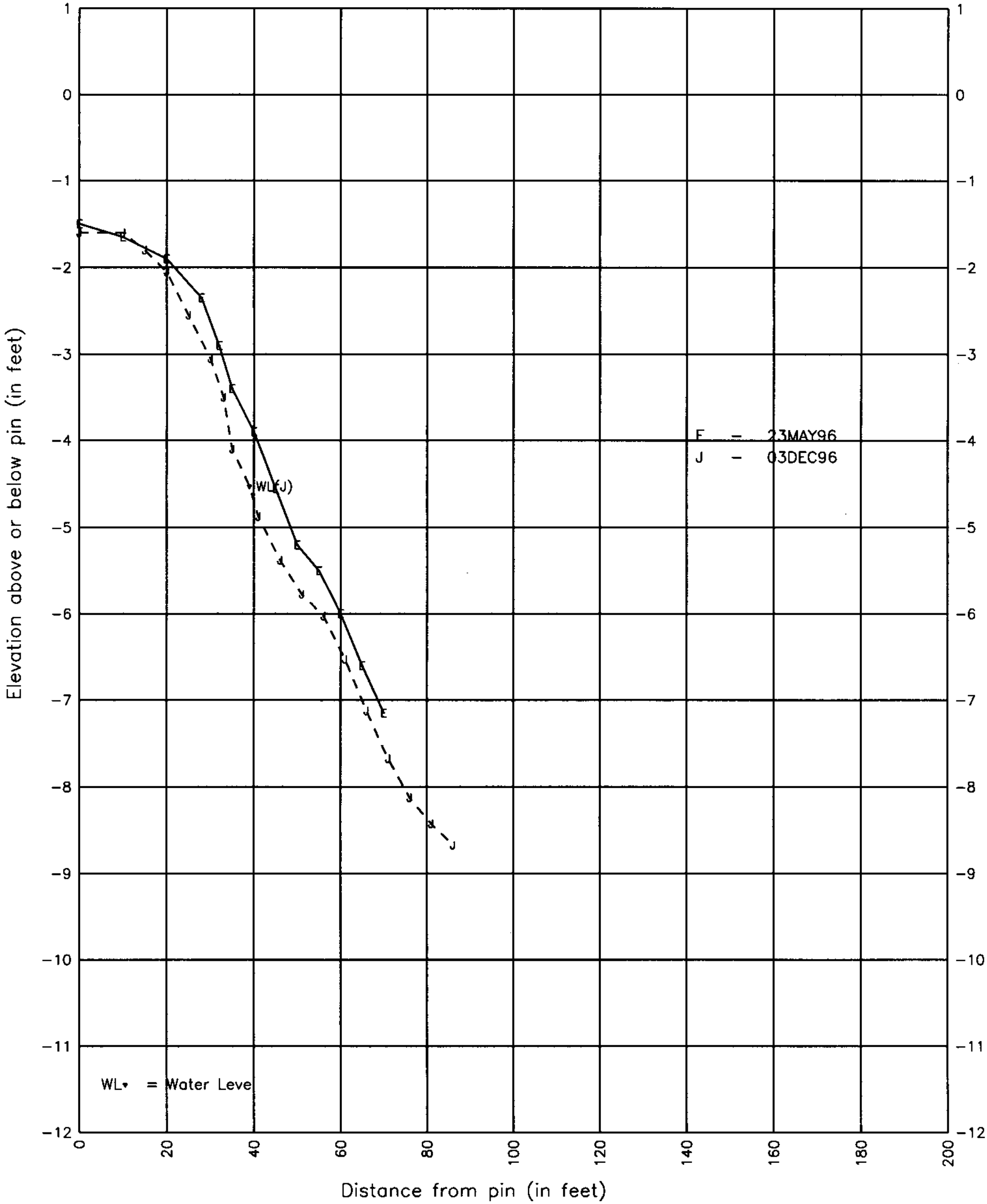




HARMON BEACH
BANKS RESIDENCE — Last Profile 1995, First Profile 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
D — 07SEP95
E — 23MAY96
WL(D)
WL▾ = Water Leve
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
0
20
40
60
80
100
120
140
160
180
200

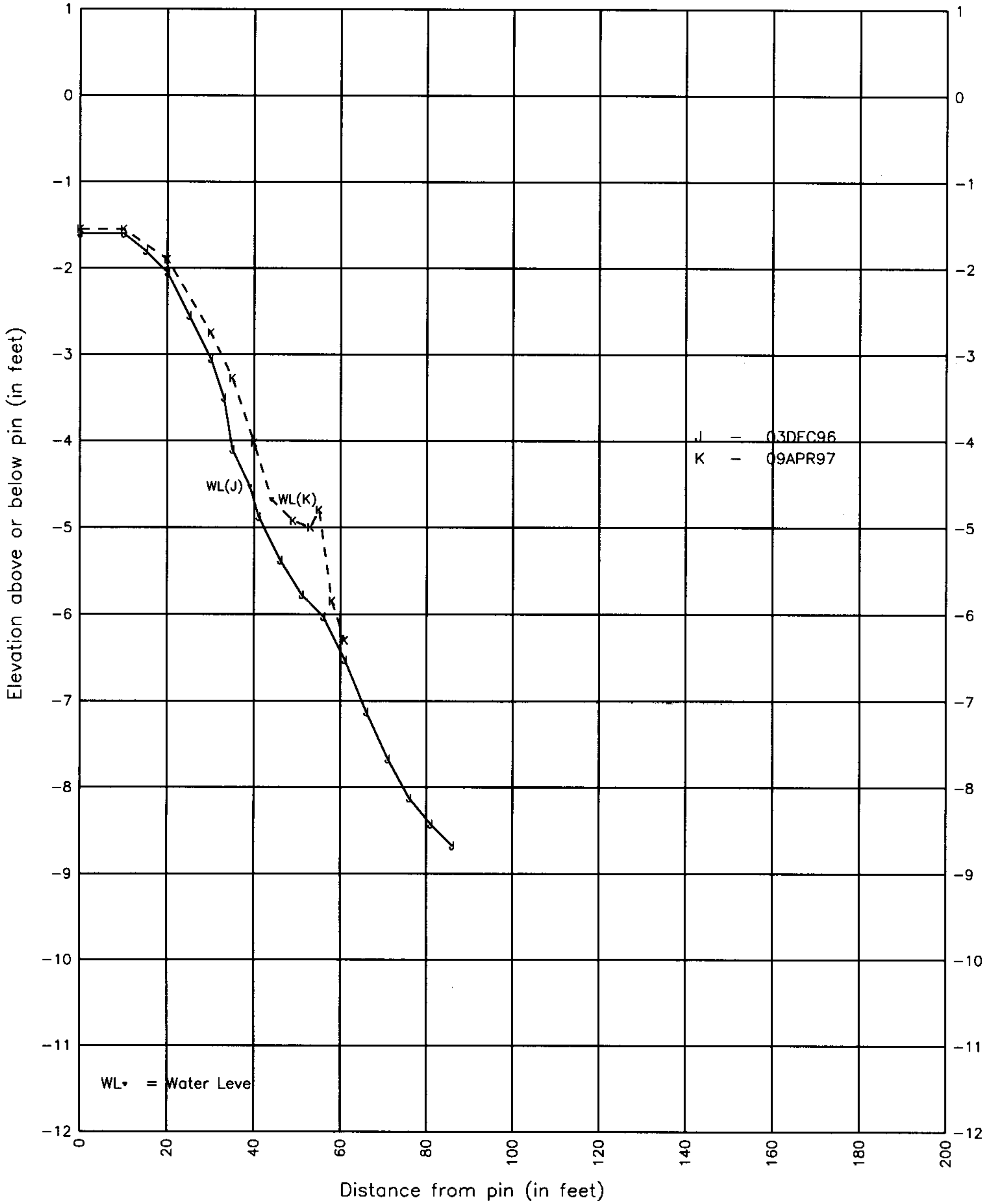
HARMON BEACH

BANKS RESIDENCE – First & Last Profiles of 1996



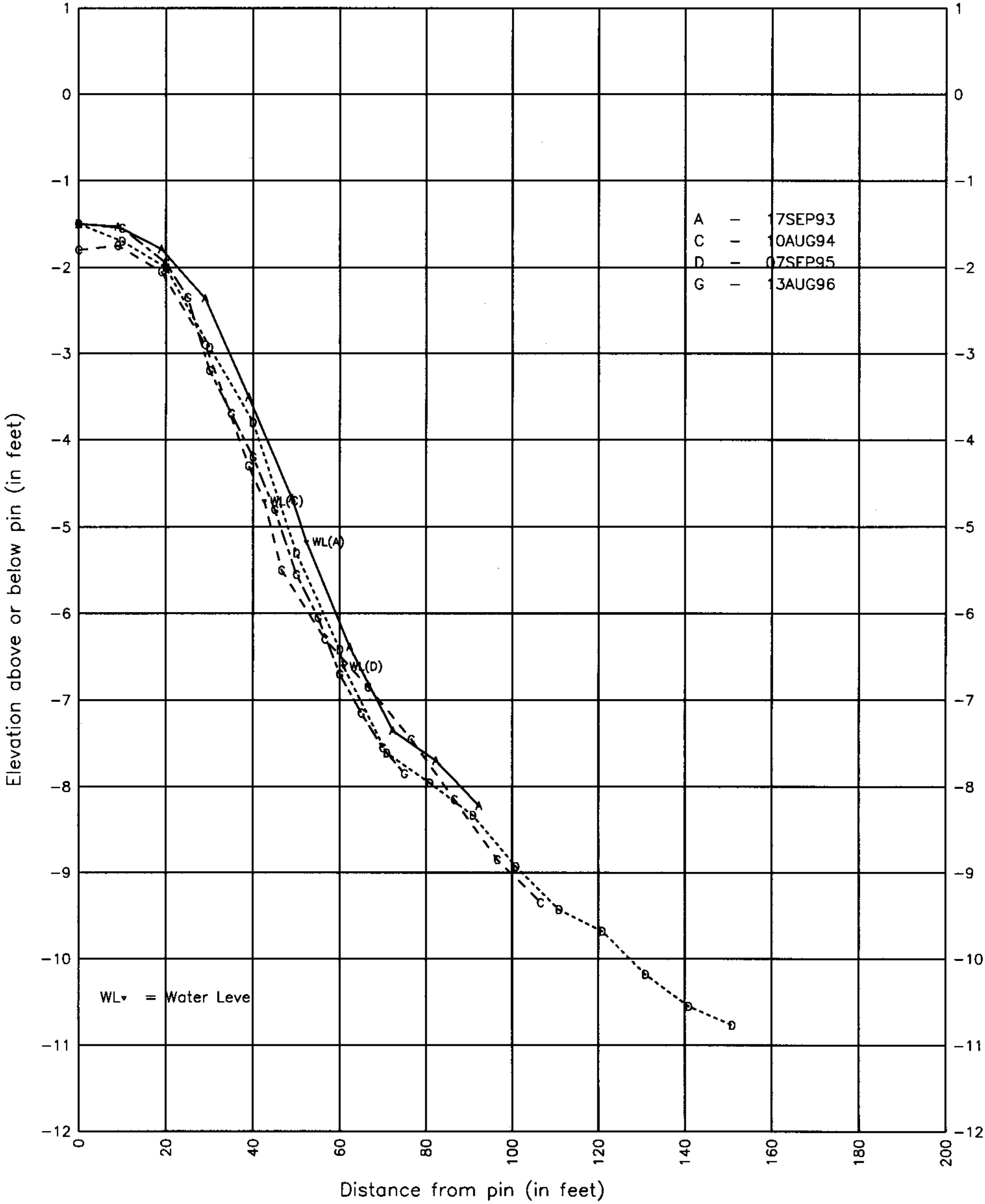
HARMON BEACH

BANKS RESIDENCE – Last Profile 1996, First Profile 1997



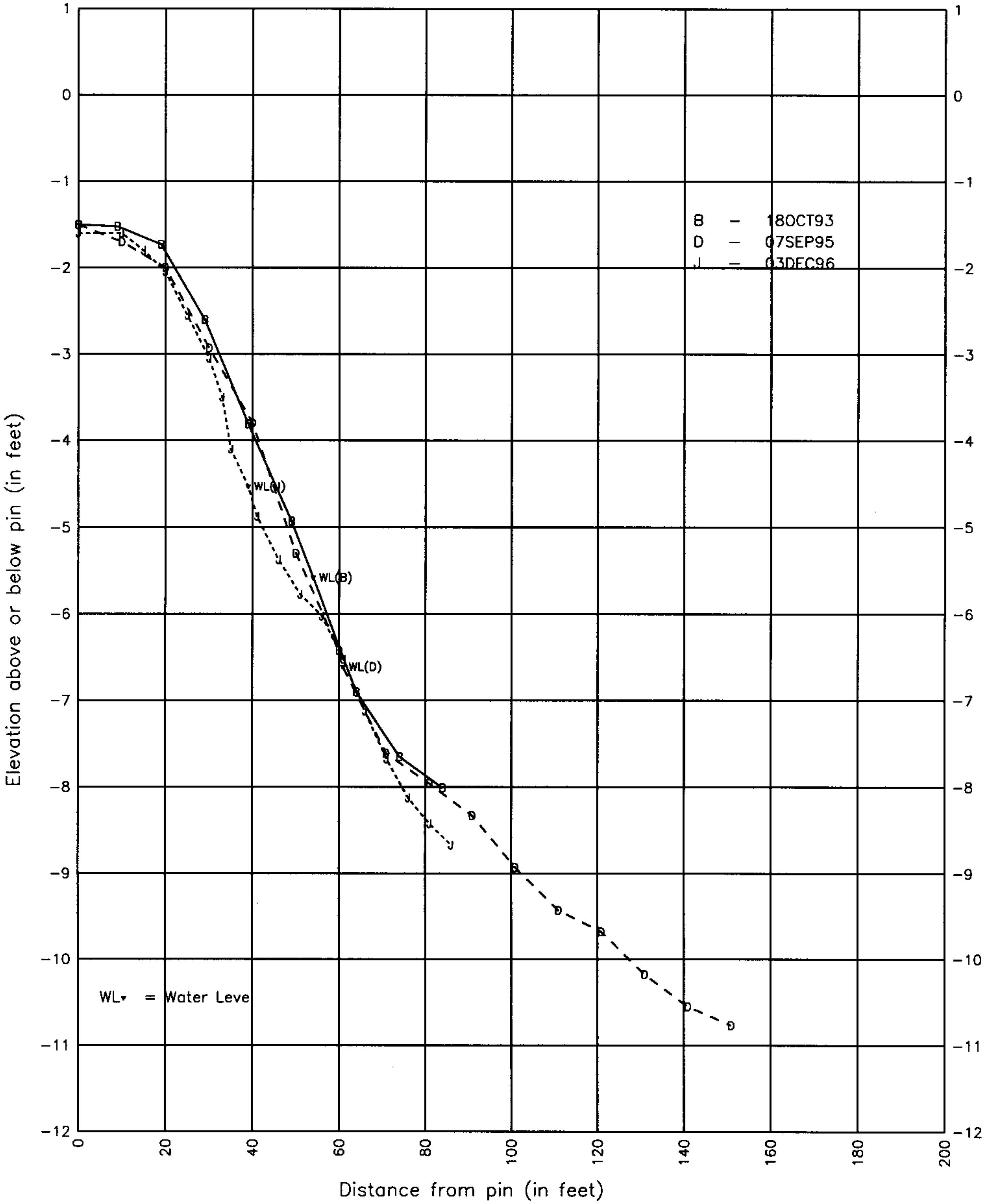
HARMON BEACH

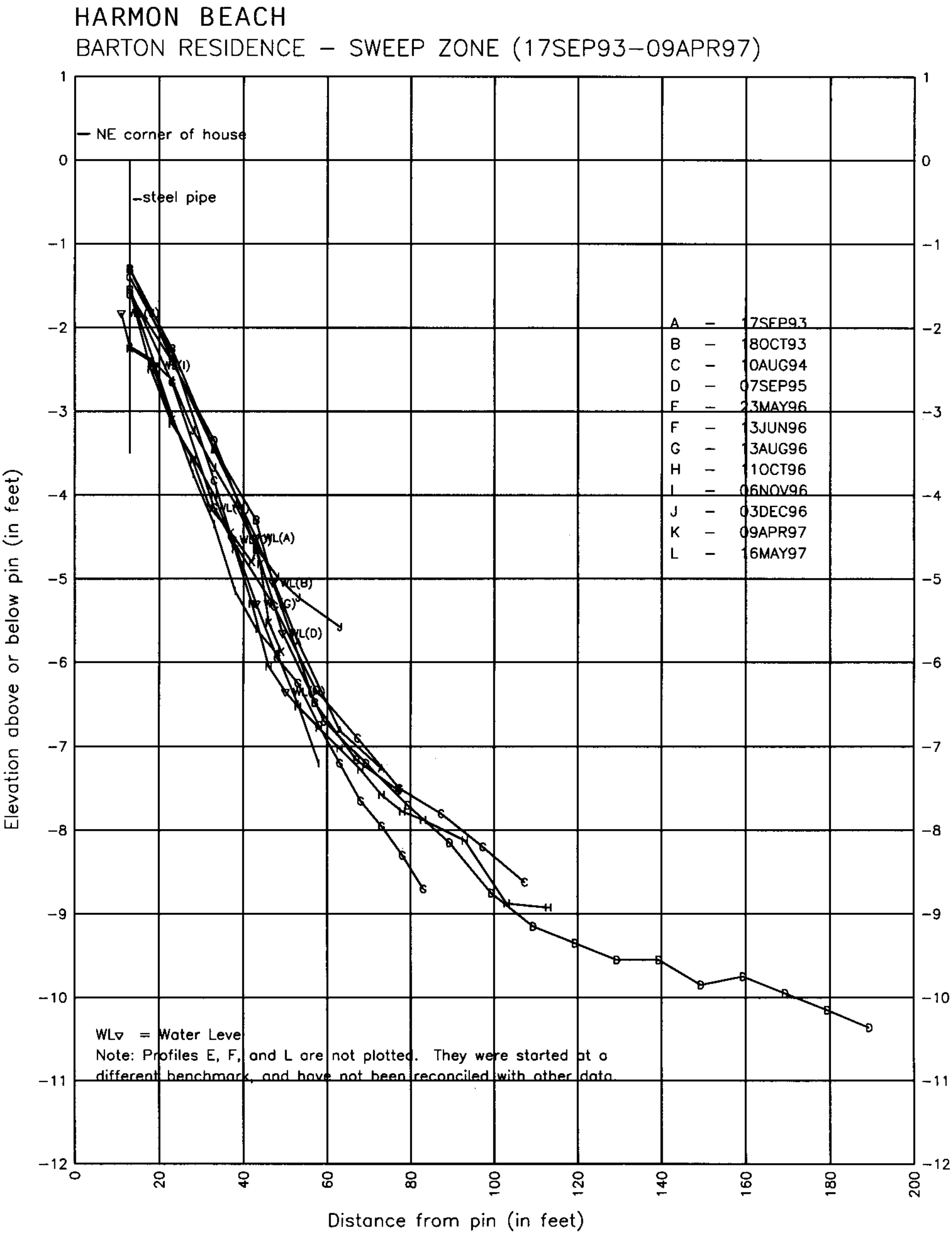
BANKS RESIDENCE – SUMMER PROFILES, 1993–1996



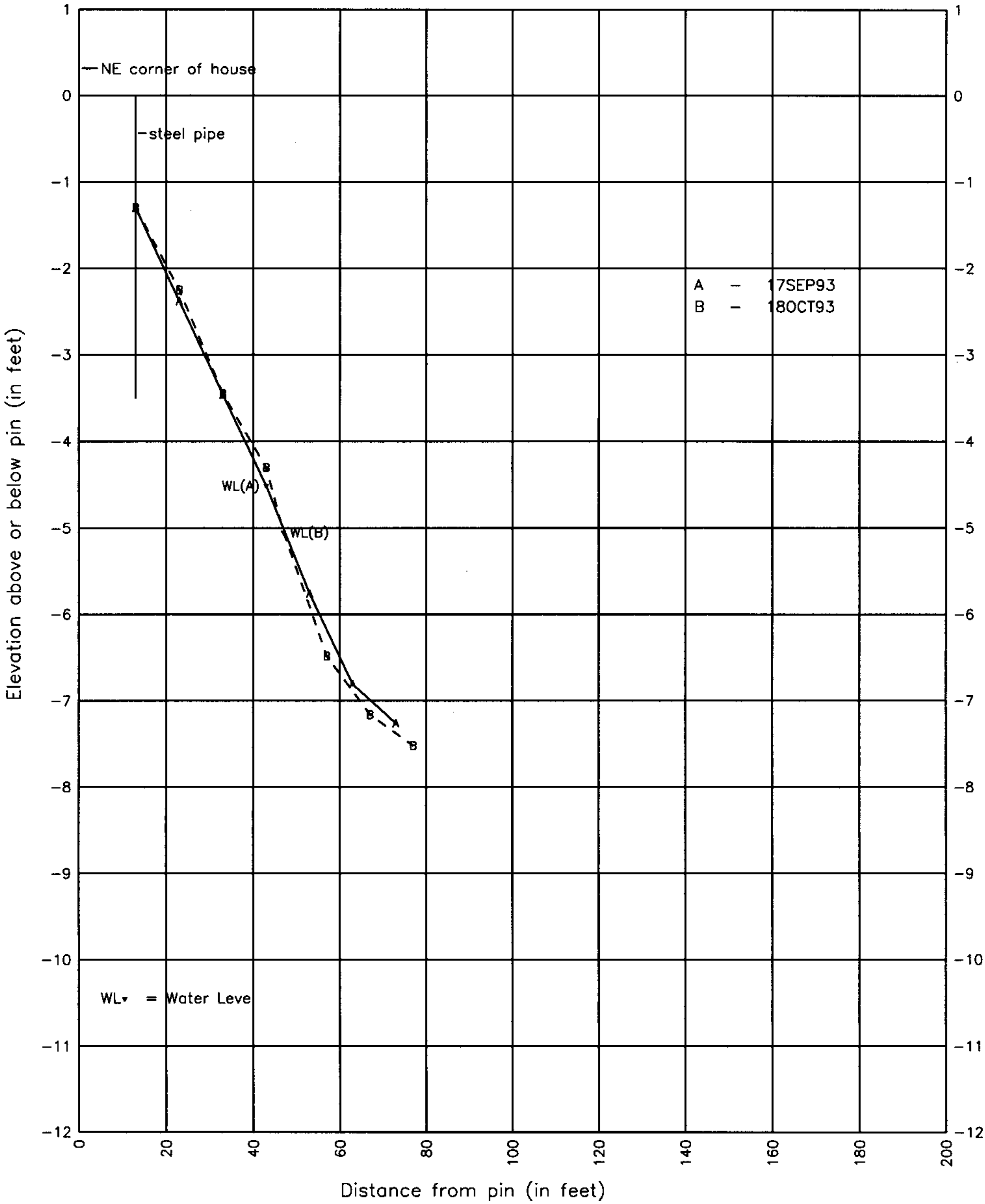
HARMON BEACH

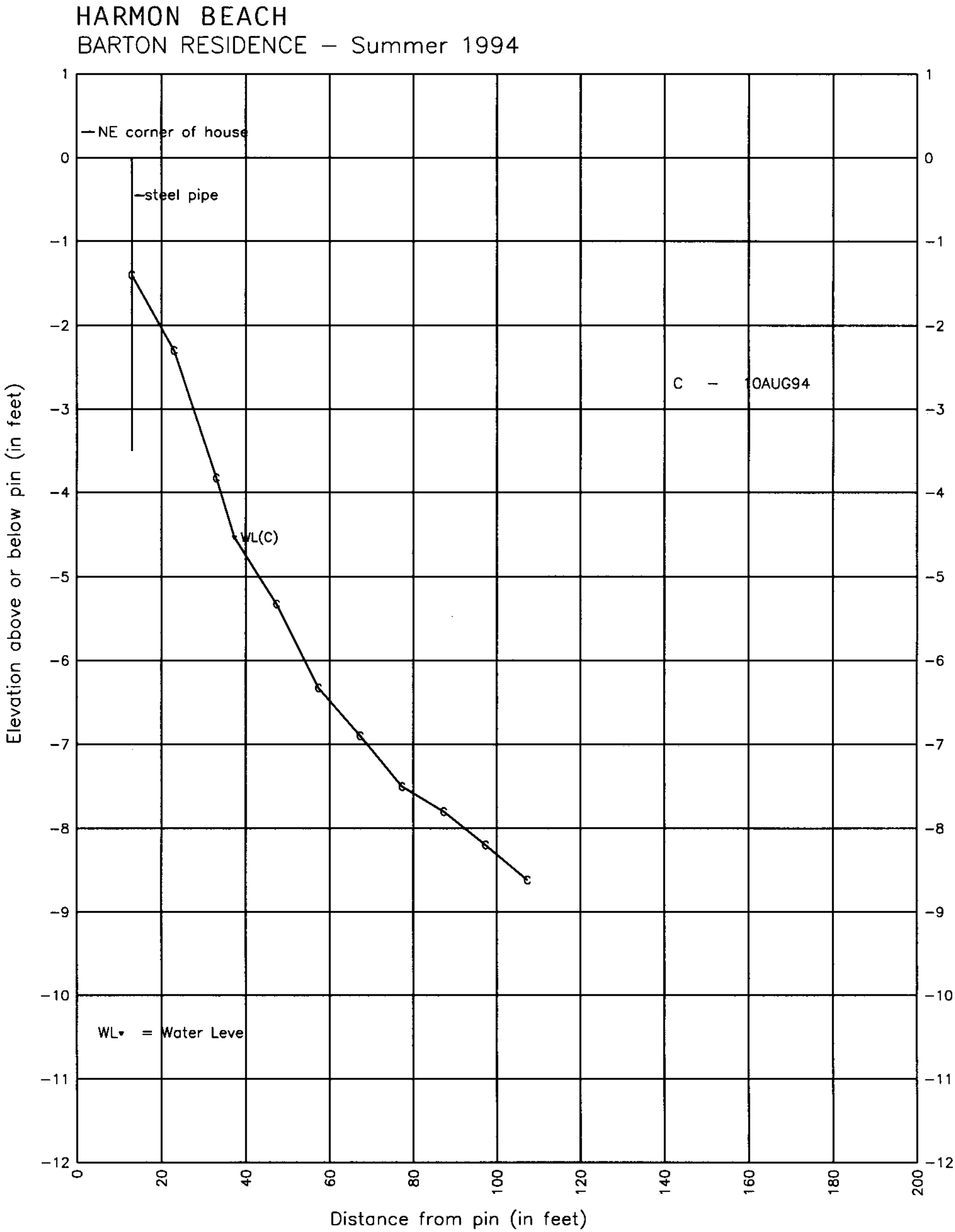
BANKS RESIDENCE – LAST FALL PROFILES, 1993–1996




HARMON BEACH
BARTON RESIDENCE – SWEEP ZONE (17SEP93–09APR97)
NE corner of house
steel pipe
A – 17SEP93
B – 18OCT93
C – 10AUG94
D – 07SEP95
E – 23MAY96
F – 13JUN96
G – 13AUG96
H – 11OCT96
I – 06NOV96
J – 03DEC96
K – 09APR97
L – 16MAY97
WL▽ = Water Level
Note: Profiles E, F, and L are not plotted. They were started at a different benchmark, and have not been reconciled with other data.
Elevation above or below pin (in feet)
Distance from pin (in feet)

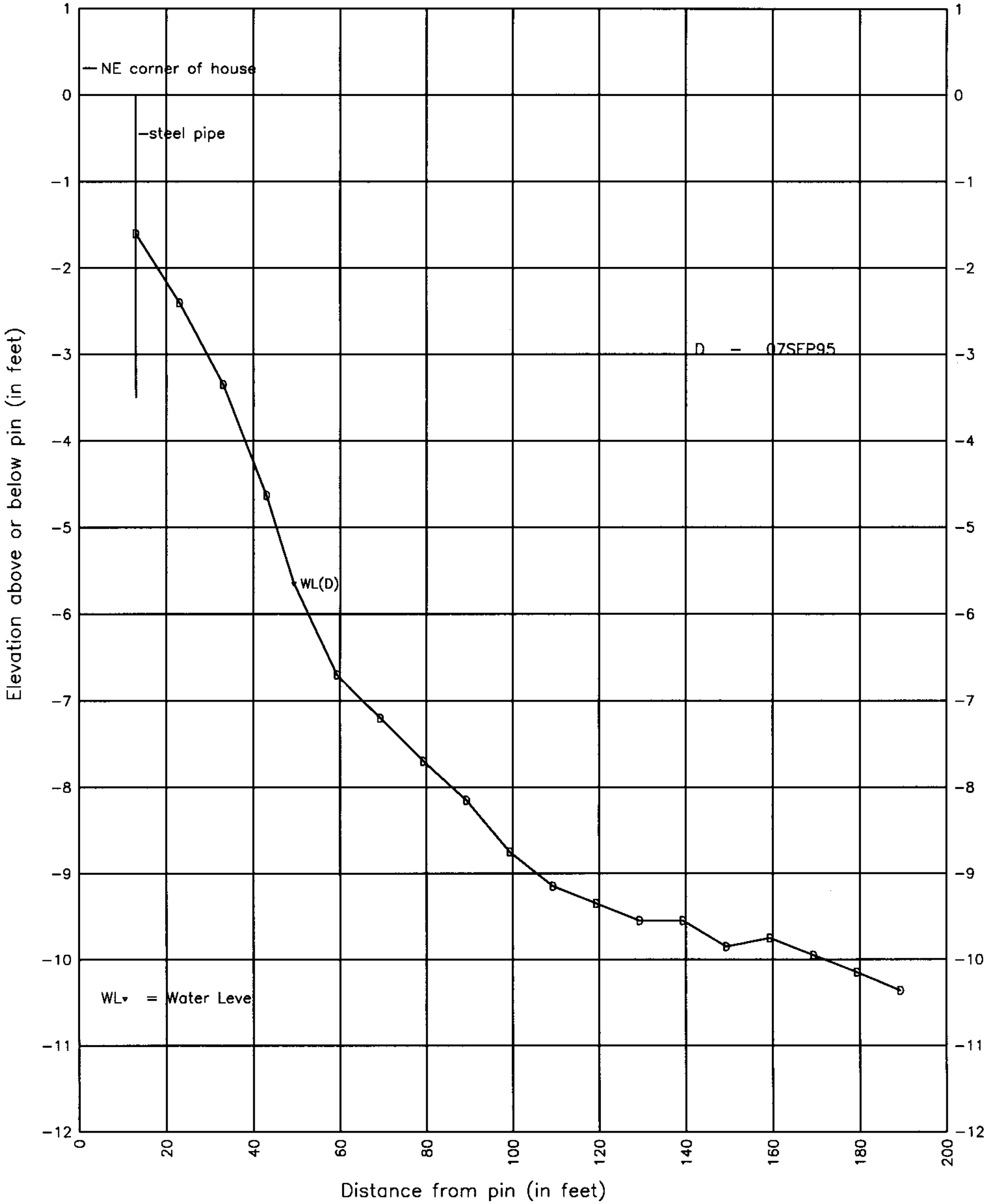
HARMON BEACH
BARTON RESIDENCE – Fall 1993





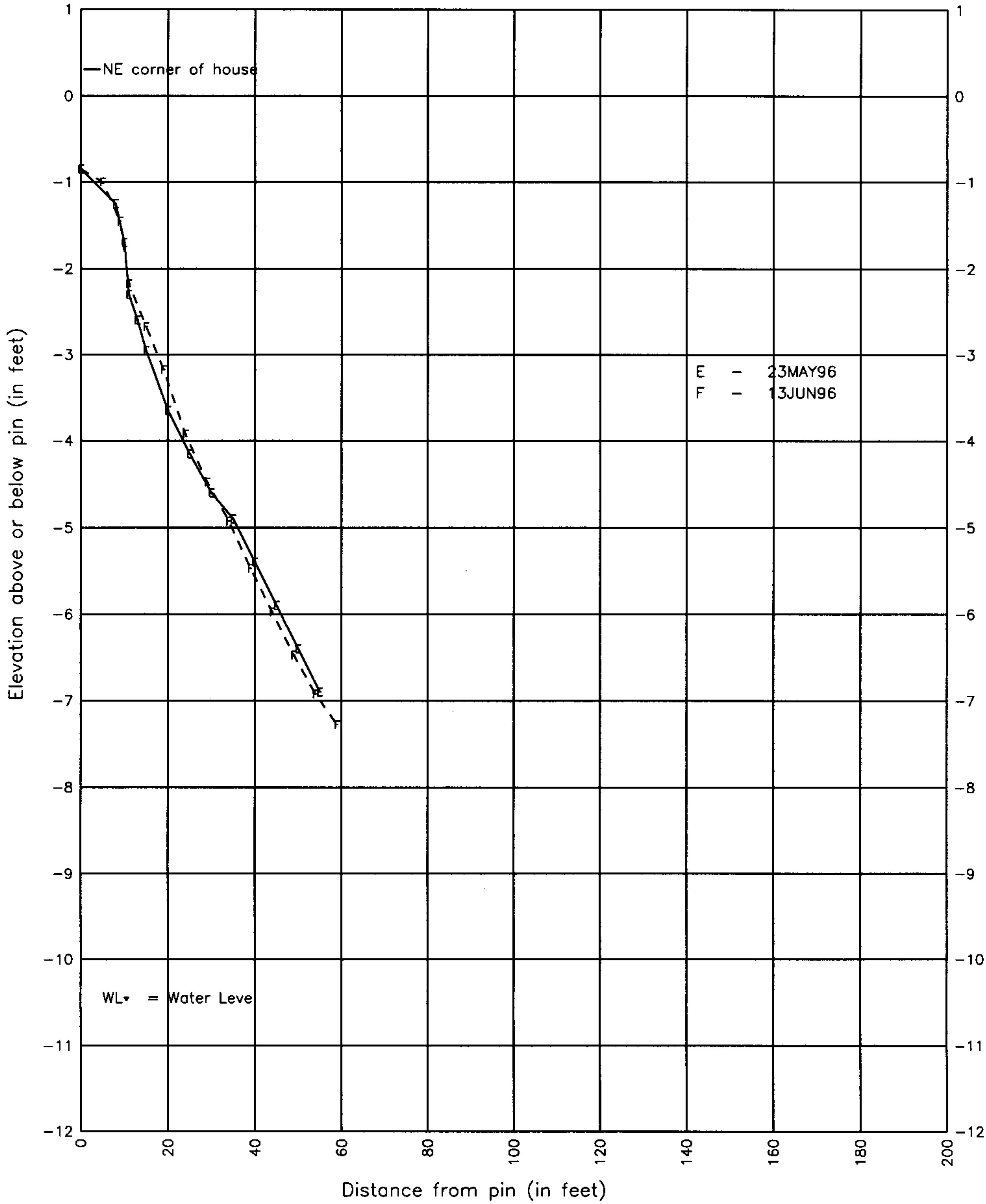
HARMON BEACH
BARTON RESIDENCE – Summer 1994
NE corner of house
steel pipe
C – 10AUG94
WL(C)
WL▾ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
–12
0
20
40
60
80
100
120
140
160
180
200

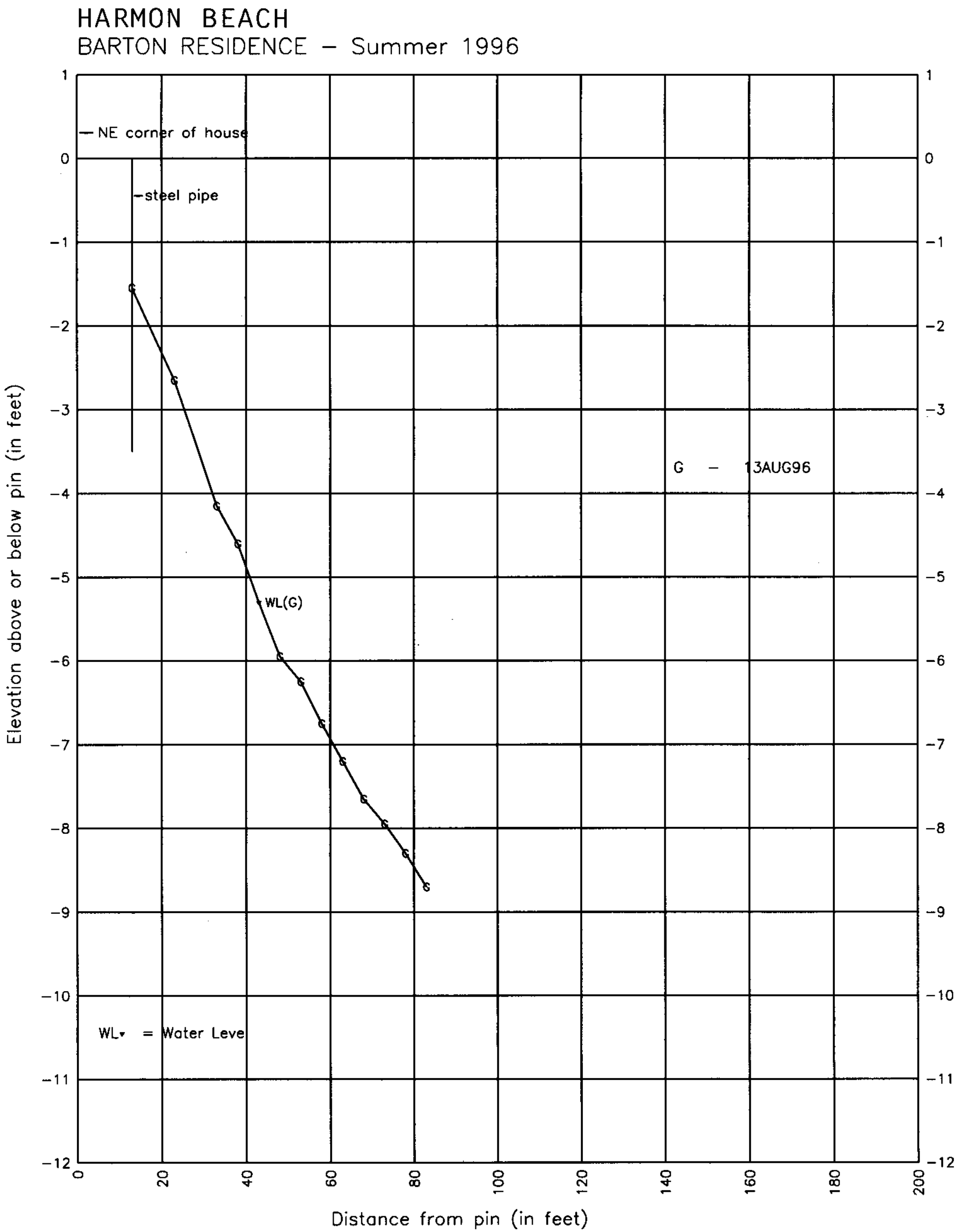
HARMON BEACH
BARTON RESIDENCE – Summer 1995



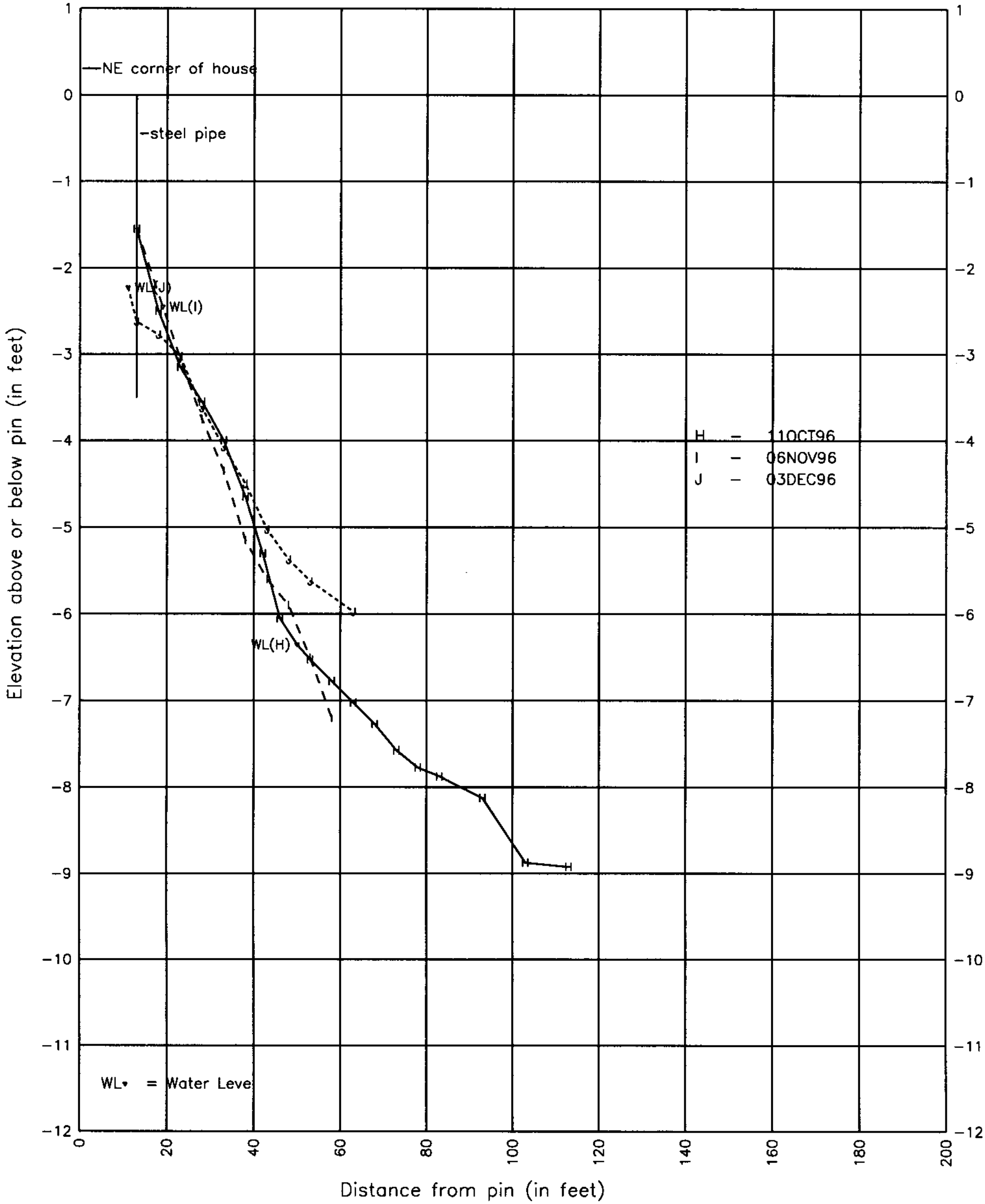
HARMON BEACH

BARTON RESIDENCE – Spring 1996

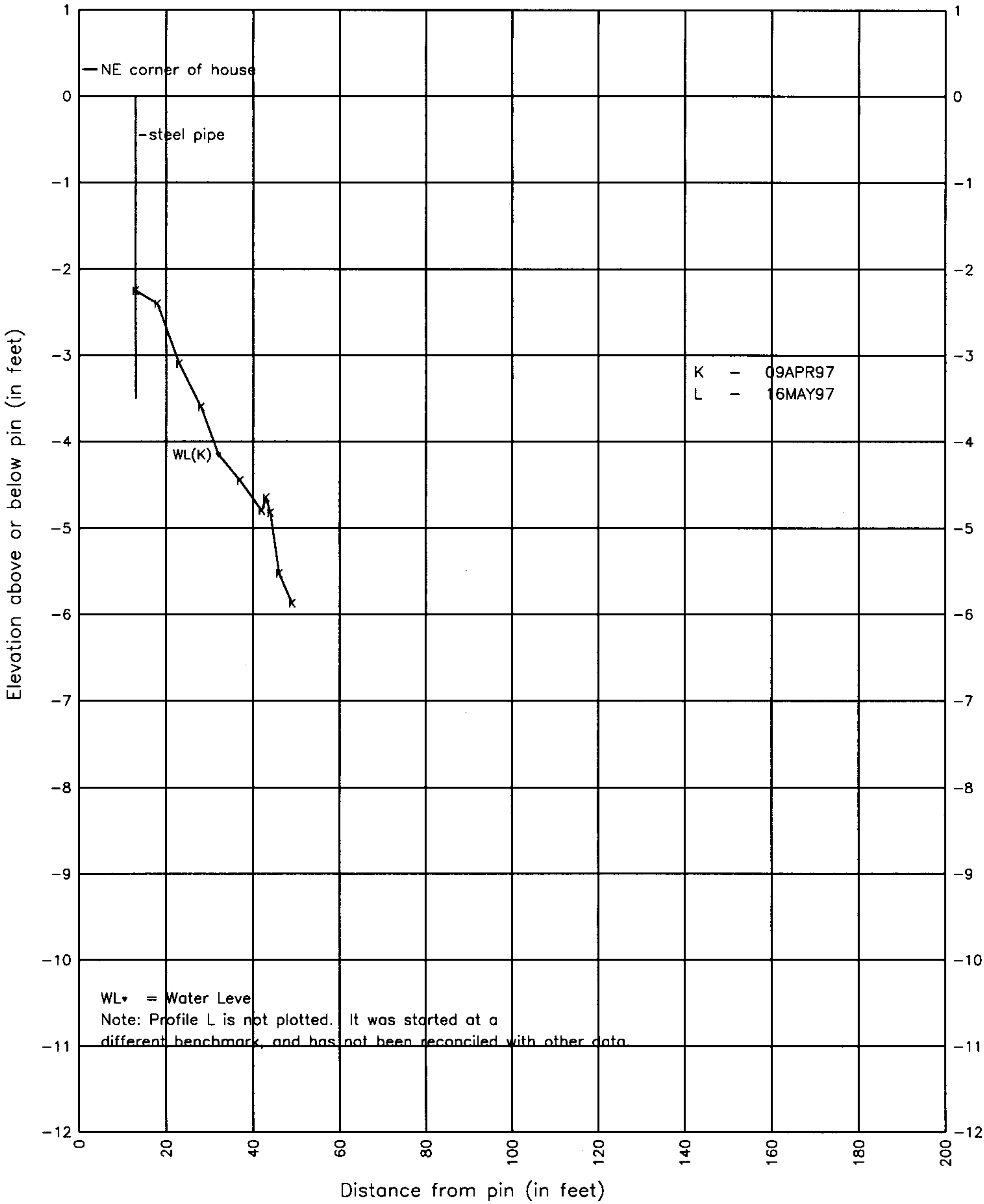



HARMON BEACH
BARTON RESIDENCE – Summer 1996
NE corner of house
steel pipe
WL(G)
G – 13AUG96
WL▾ = Water Leve
Elevation above or below pin (in feet)
Distance from pin (in feet)
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
–12
0
20
40
60
80
100
120
140
160
180
200

HARMON BEACH
BARTON RESIDENCE – Fall 1996

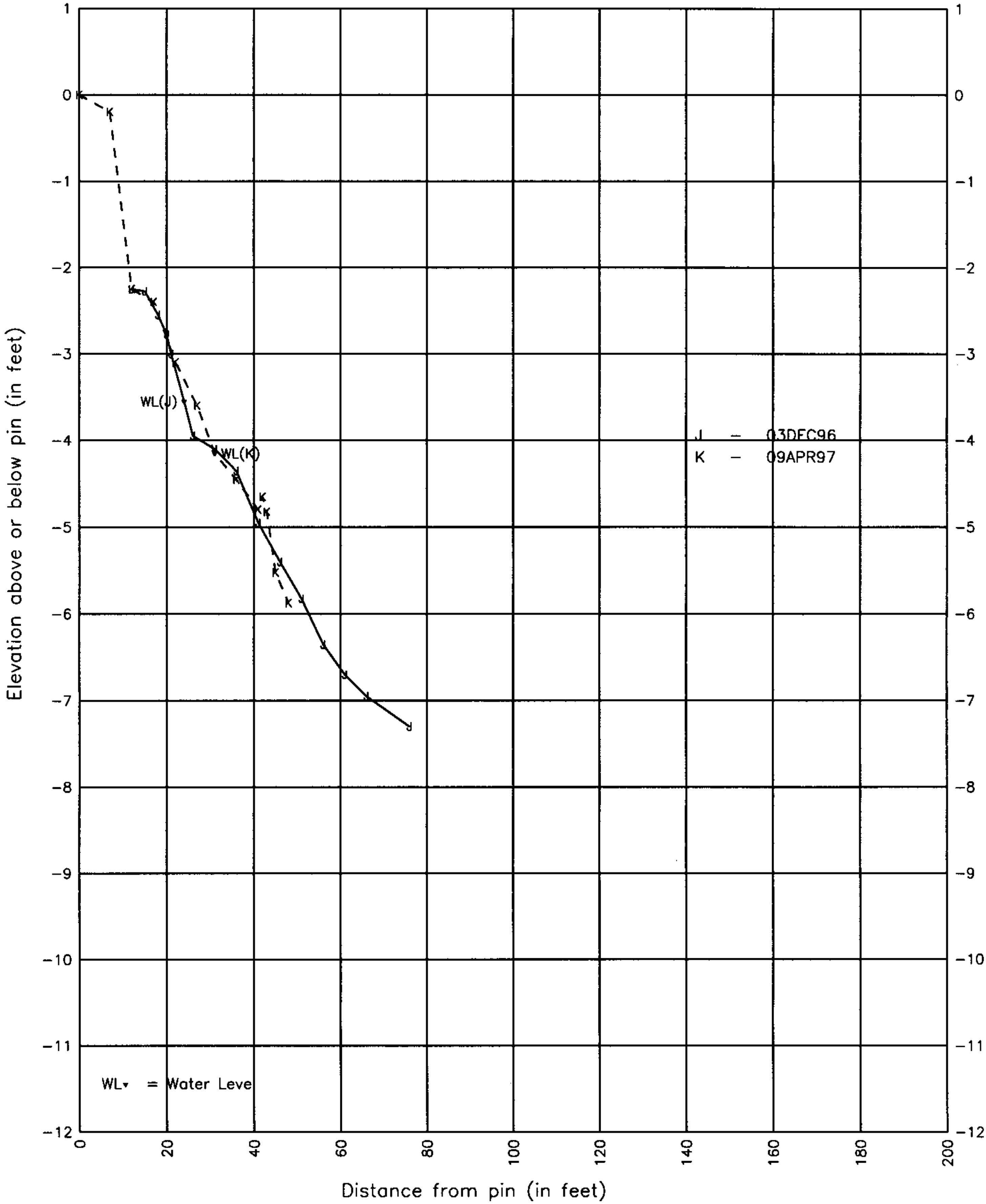


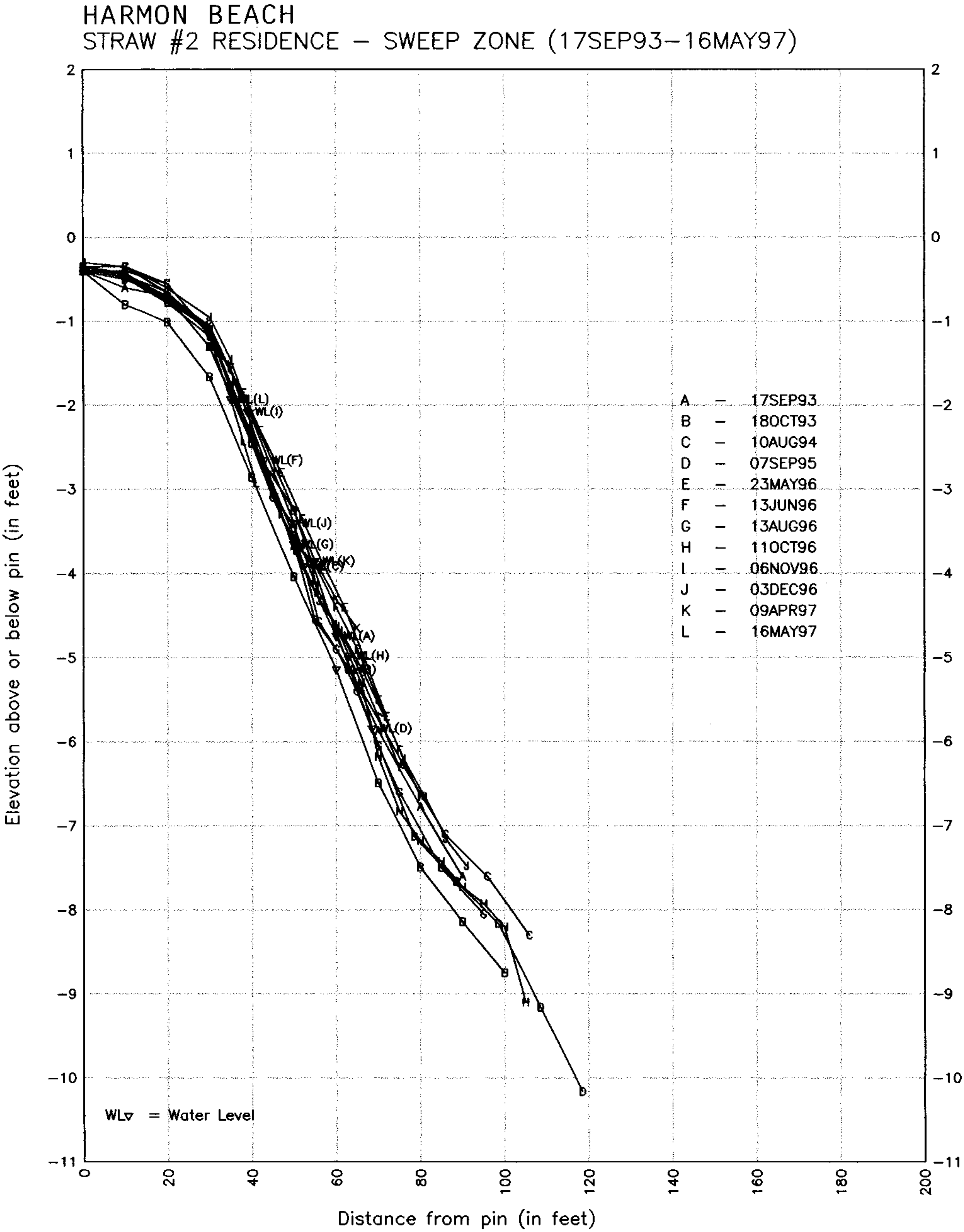
HARMON BEACH
BARTON RESIDENCE – Spring 1997

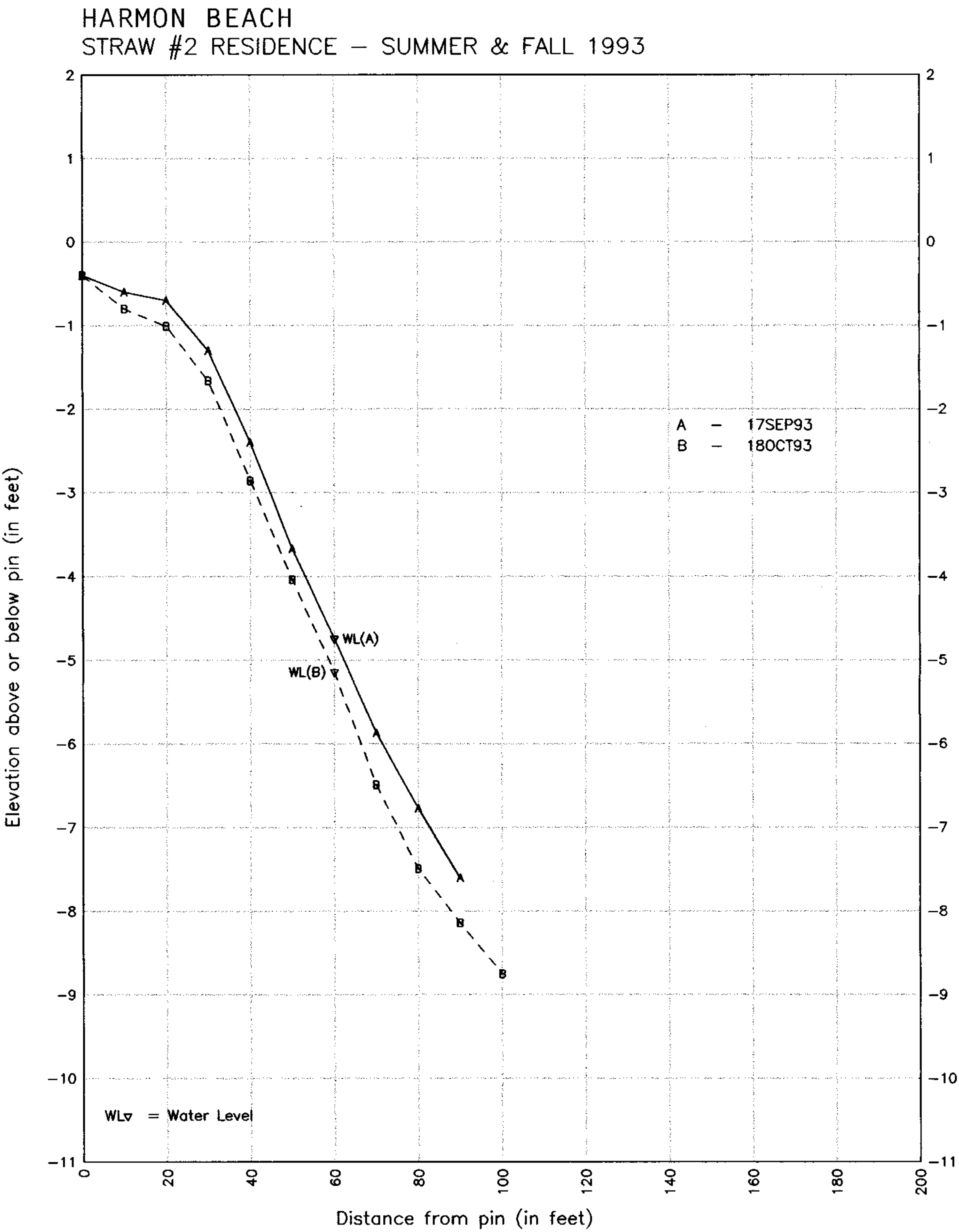


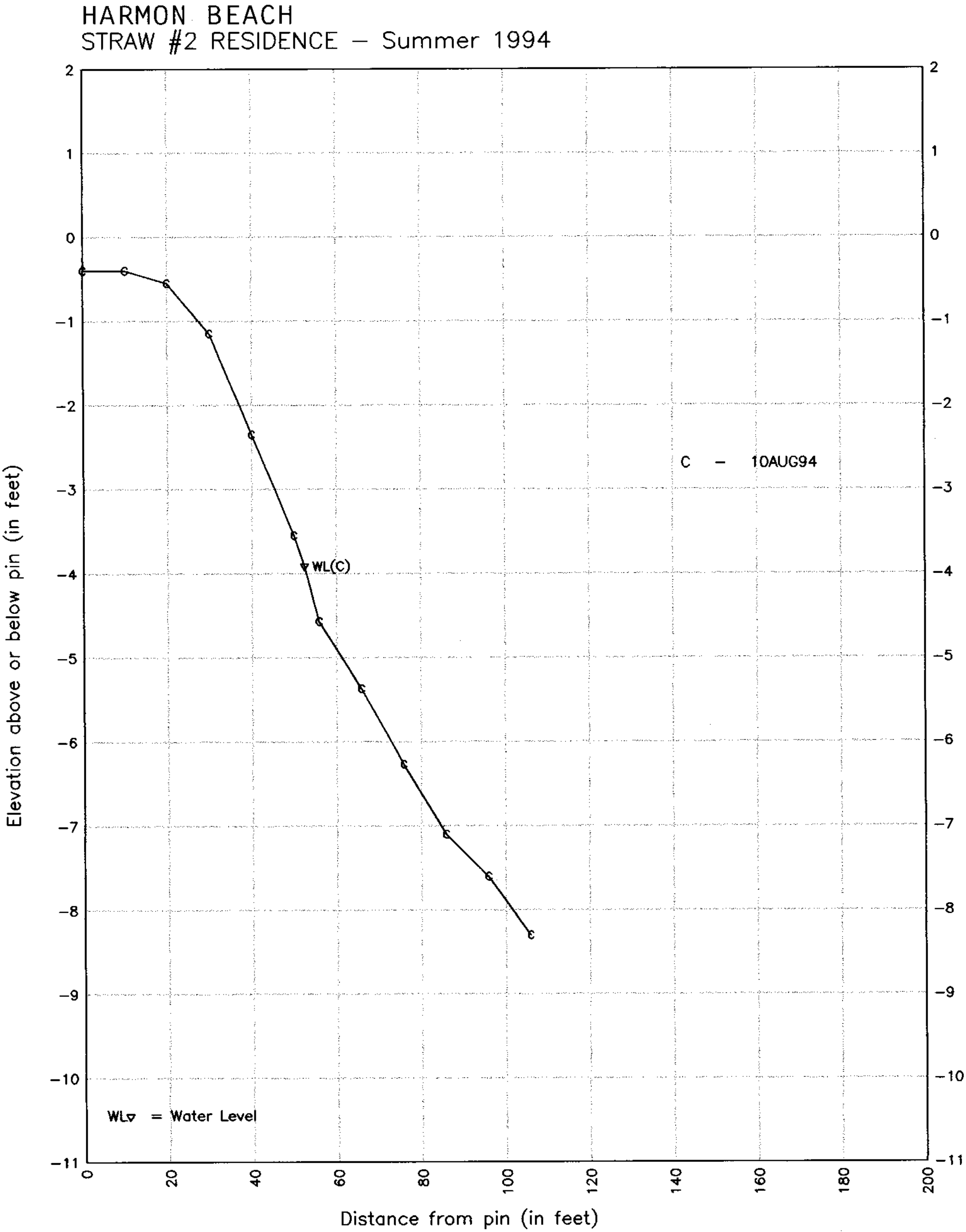
HARMON BEACH

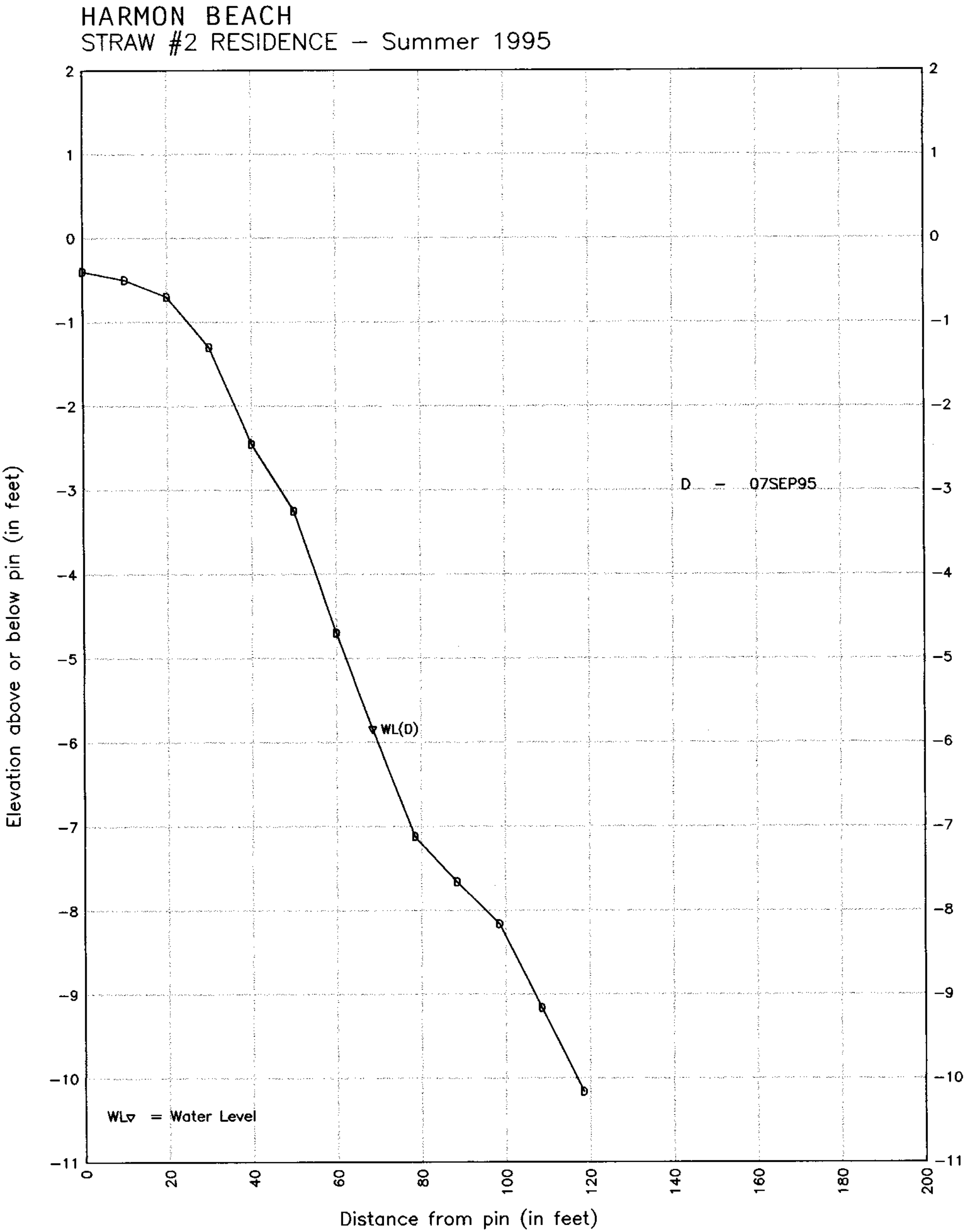
BARTON RESIDENCE – Last Profile 1996, First Profile 1997




HARMON BEACH
STRAW #2 RESIDENCE – SWEEP ZONE (17SEP93–16MAY97)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 17SEP93
B – 18OCT93
C – 10AUG94
D – 07SEP95
E – 23MAY96
F – 13JUN96
G – 13AUG96
H – 11OCT96
I – 06NOV96
J – 03DEC96
K – 09APR97
L – 16MAY97
WL▽ = Water Level

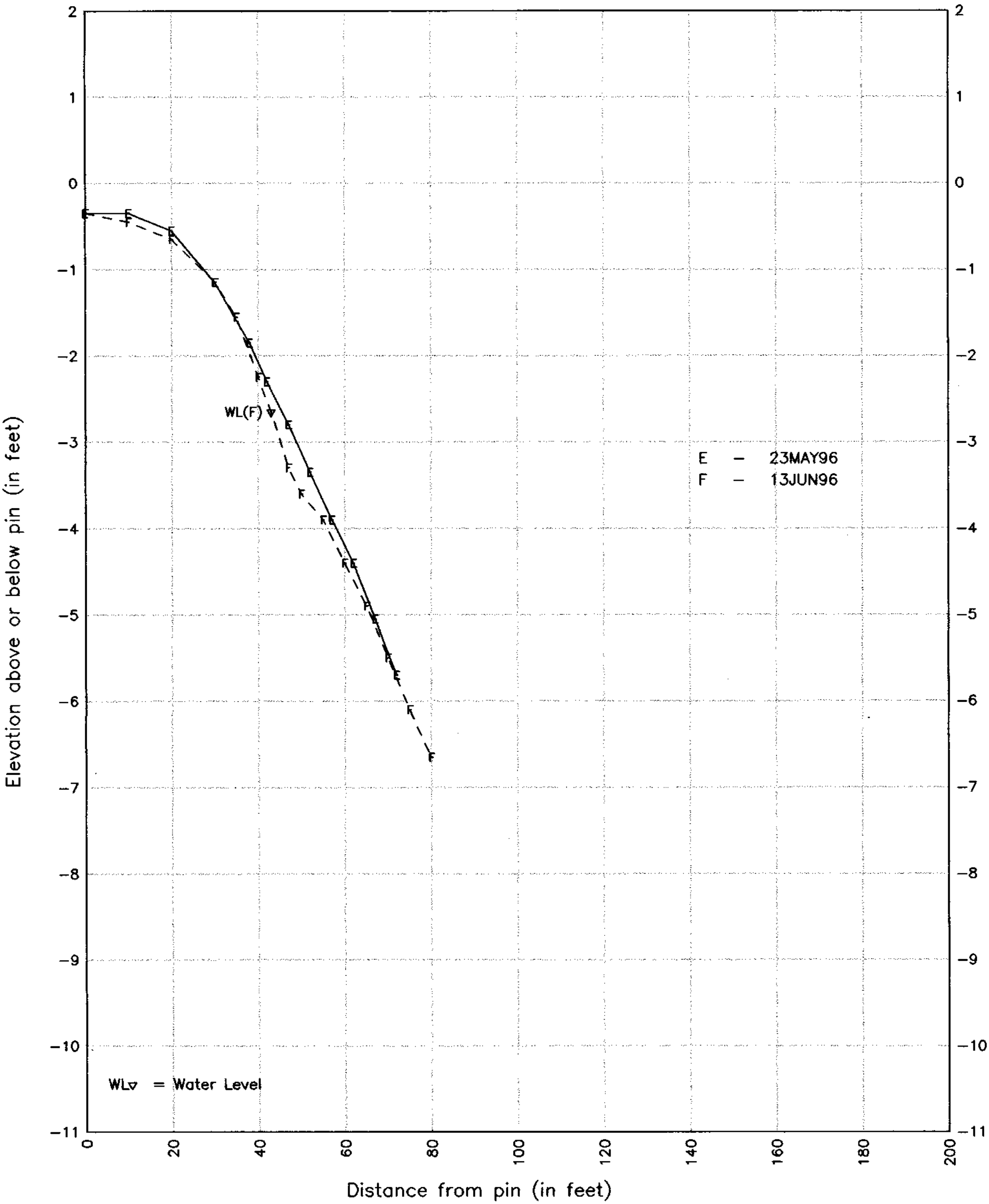

HARMON BEACH
STRAW #2 RESIDENCE – SUMMER & FALL 1993
A – 17SEP93
B – 18OCT93
WL(A)
WL(B)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200


HARMON BEACH
STRAW #2 RESIDENCE – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 10AUG94
WL(C)
WL▽ = Water Level
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

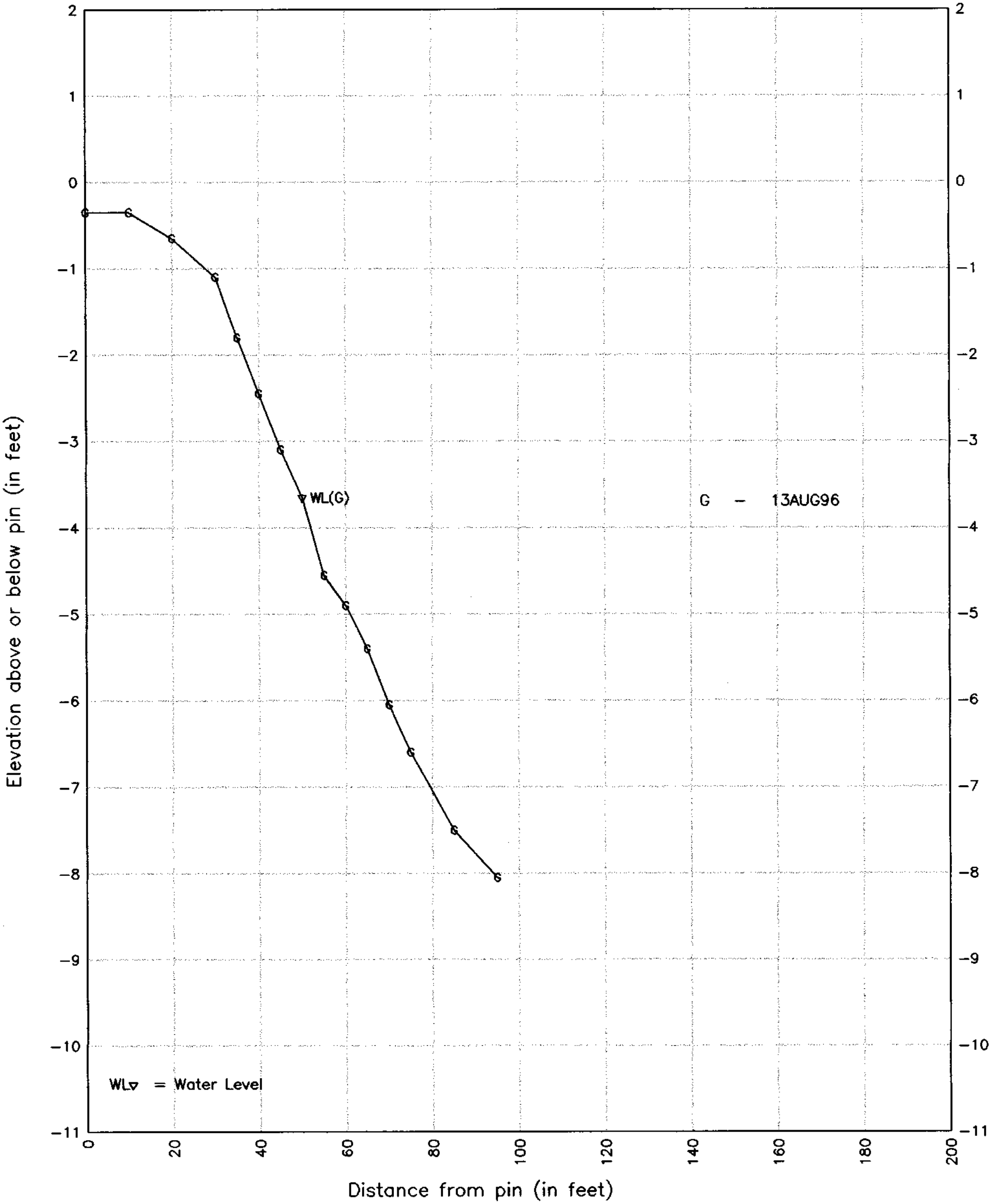


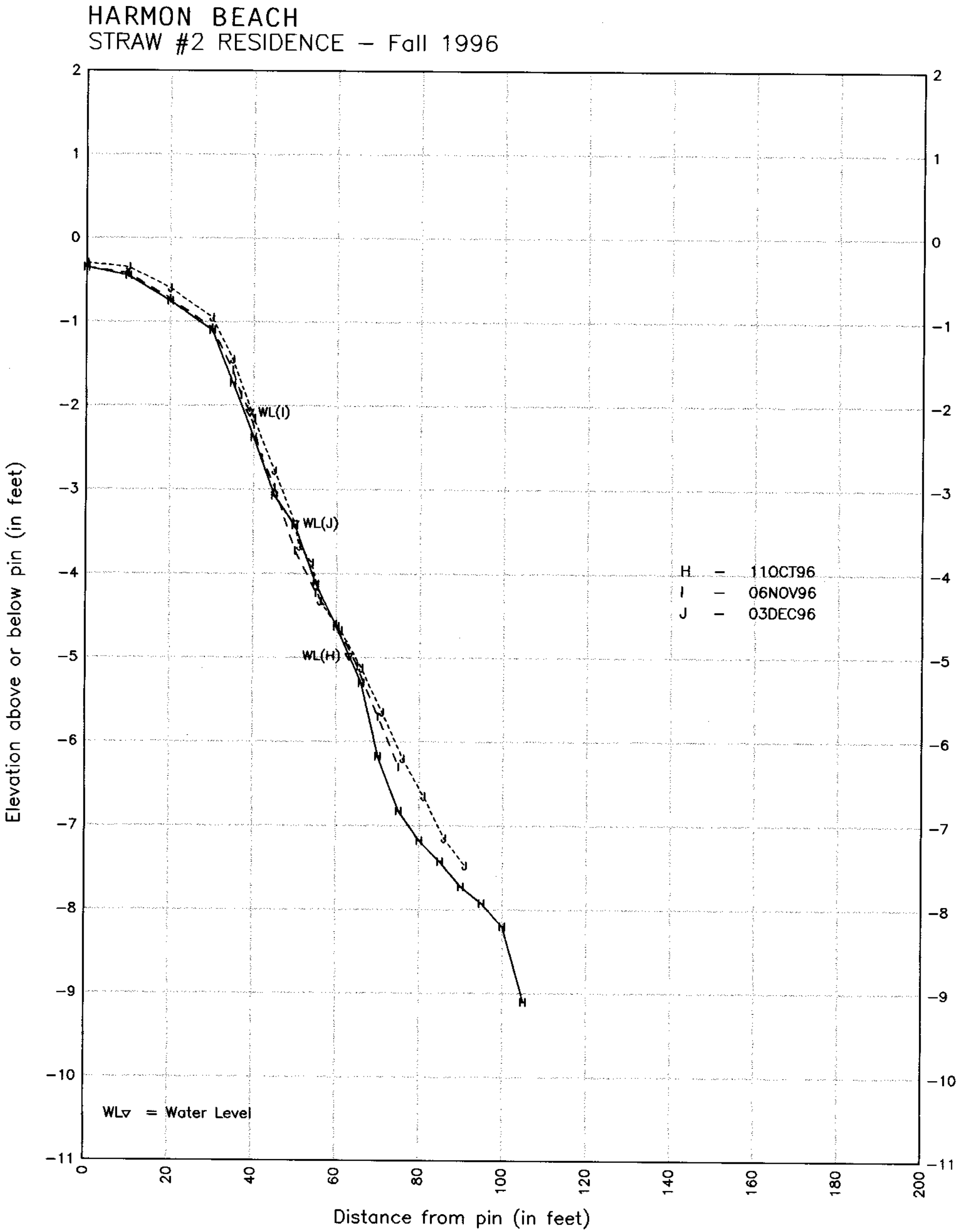
HARMON BEACH
STRAW #2 RESIDENCE - Summer 1995
D - 07SEP95
WL(D)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

HARMON BEACH
STRAW #2 RESIDENCE – Spring 1996



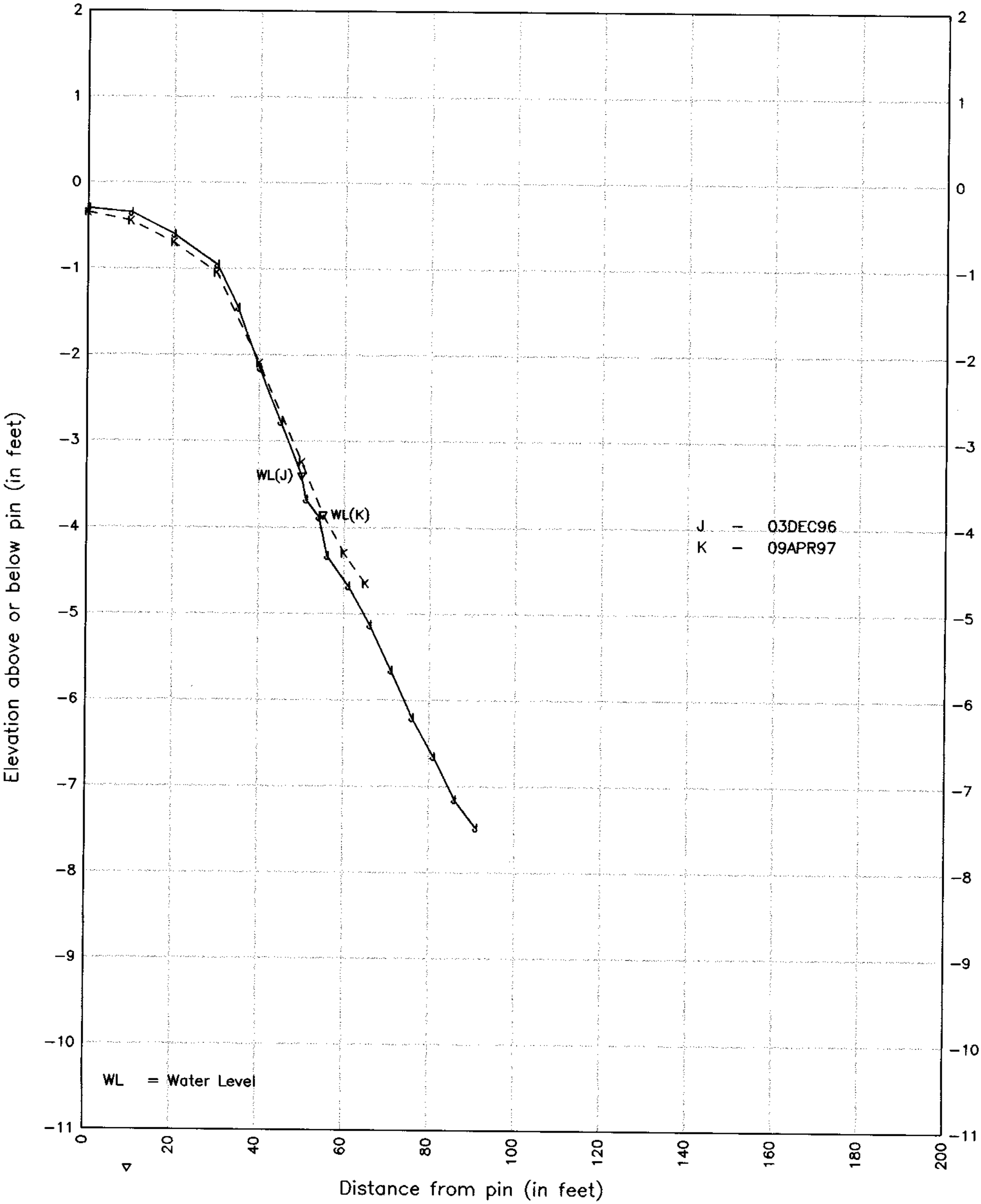
HARMON BEACH
STRAW #2 RESIDENCE – Summer 1996

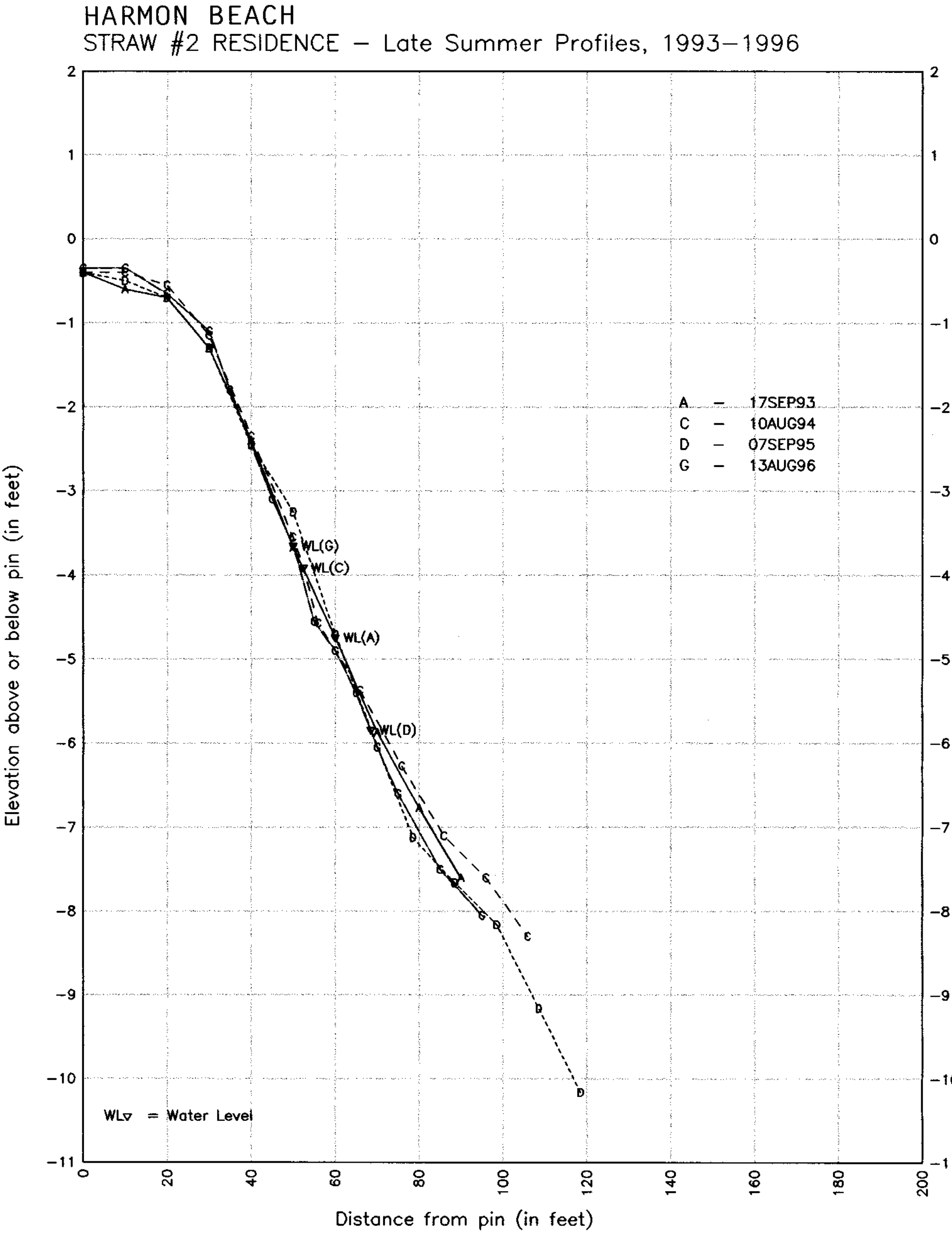



HARMON BEACH
STRAW #2 RESIDENCE – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200
WL(I)
WL(J)
WL(H)
H – 11OCT96
I – 06NOV96
J – 03DEC96
WL▽ = Water Level

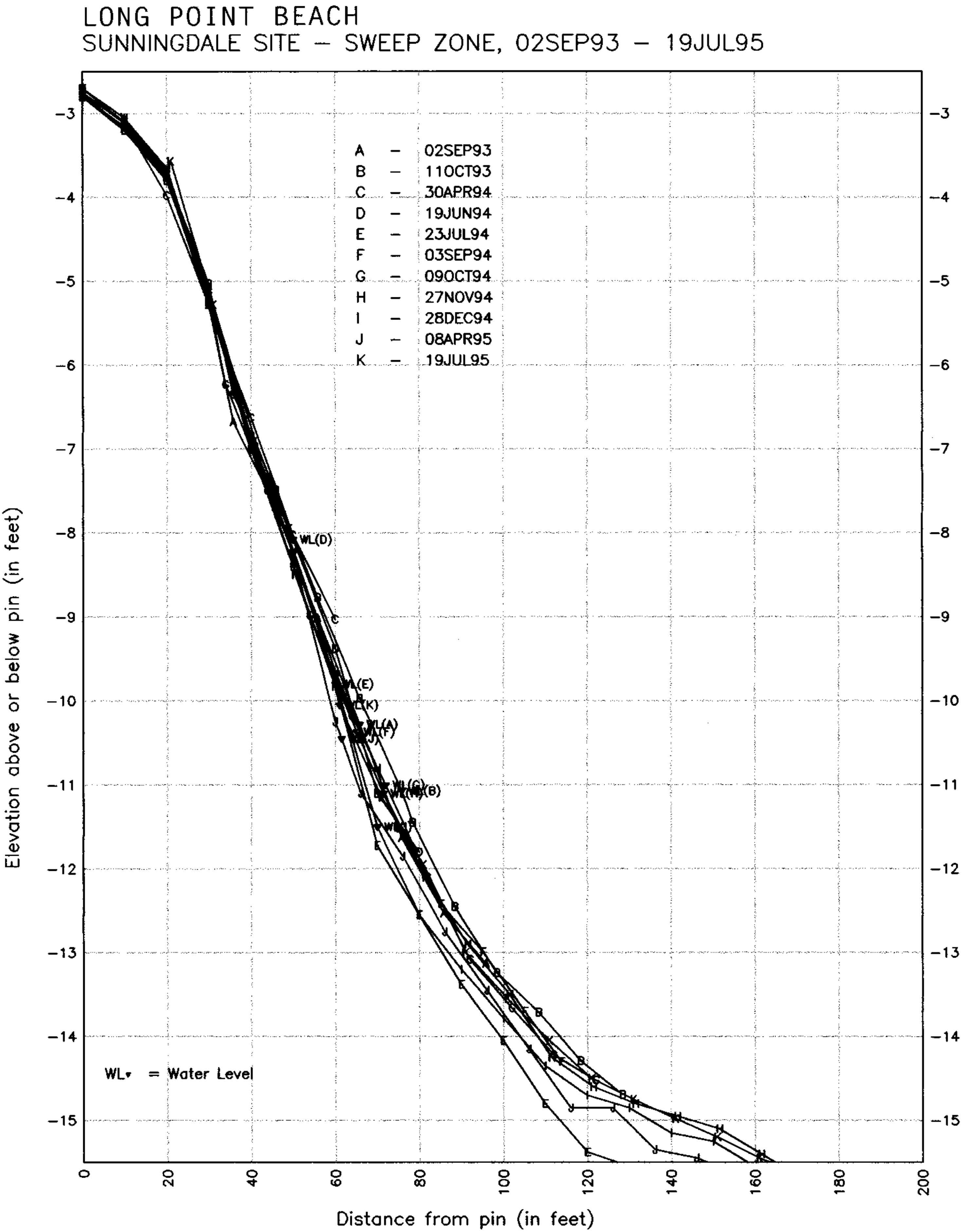
HARMON BEACH

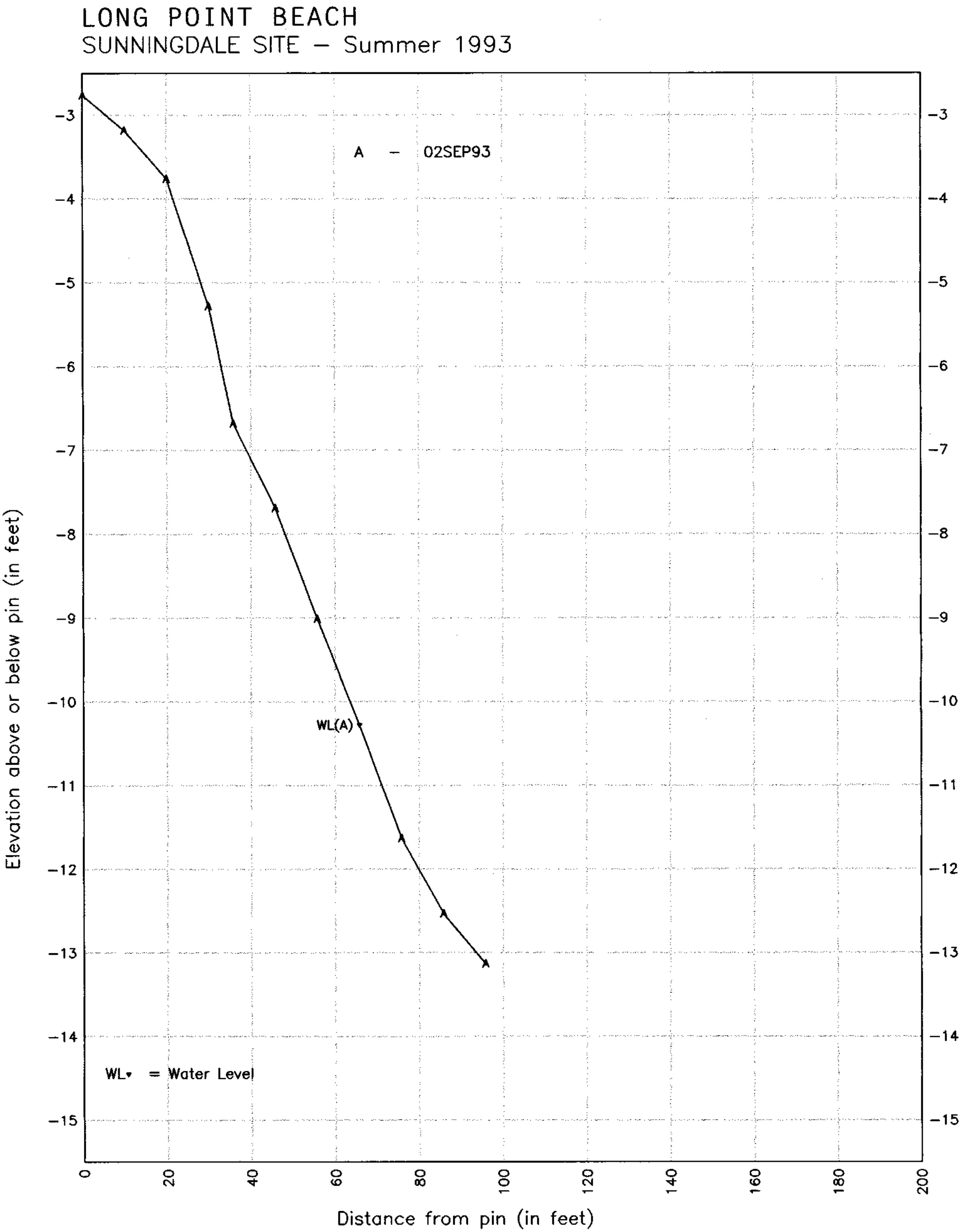
STRAW #2 RESIDENCE – Last Profile 1996, First Profile 1997



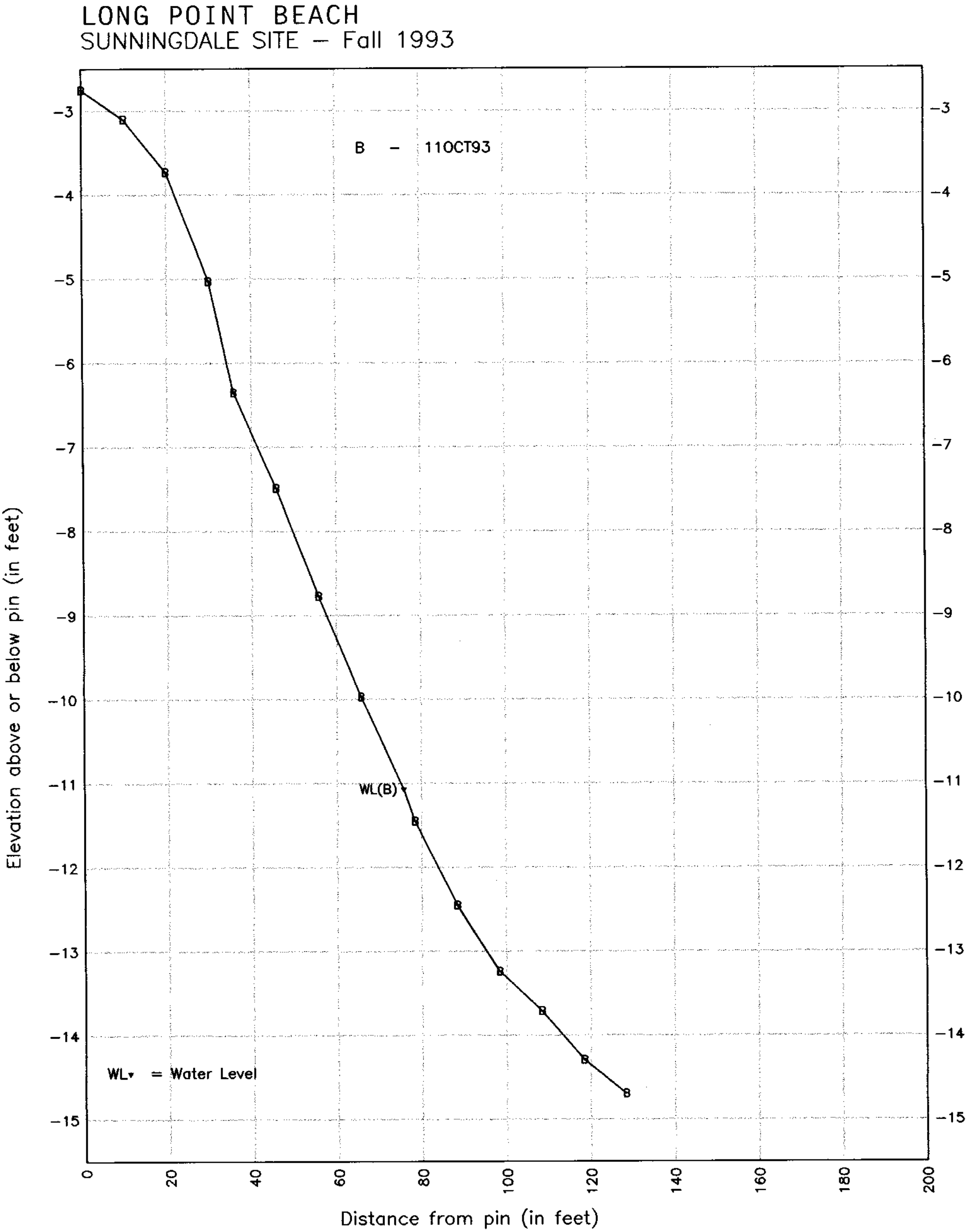


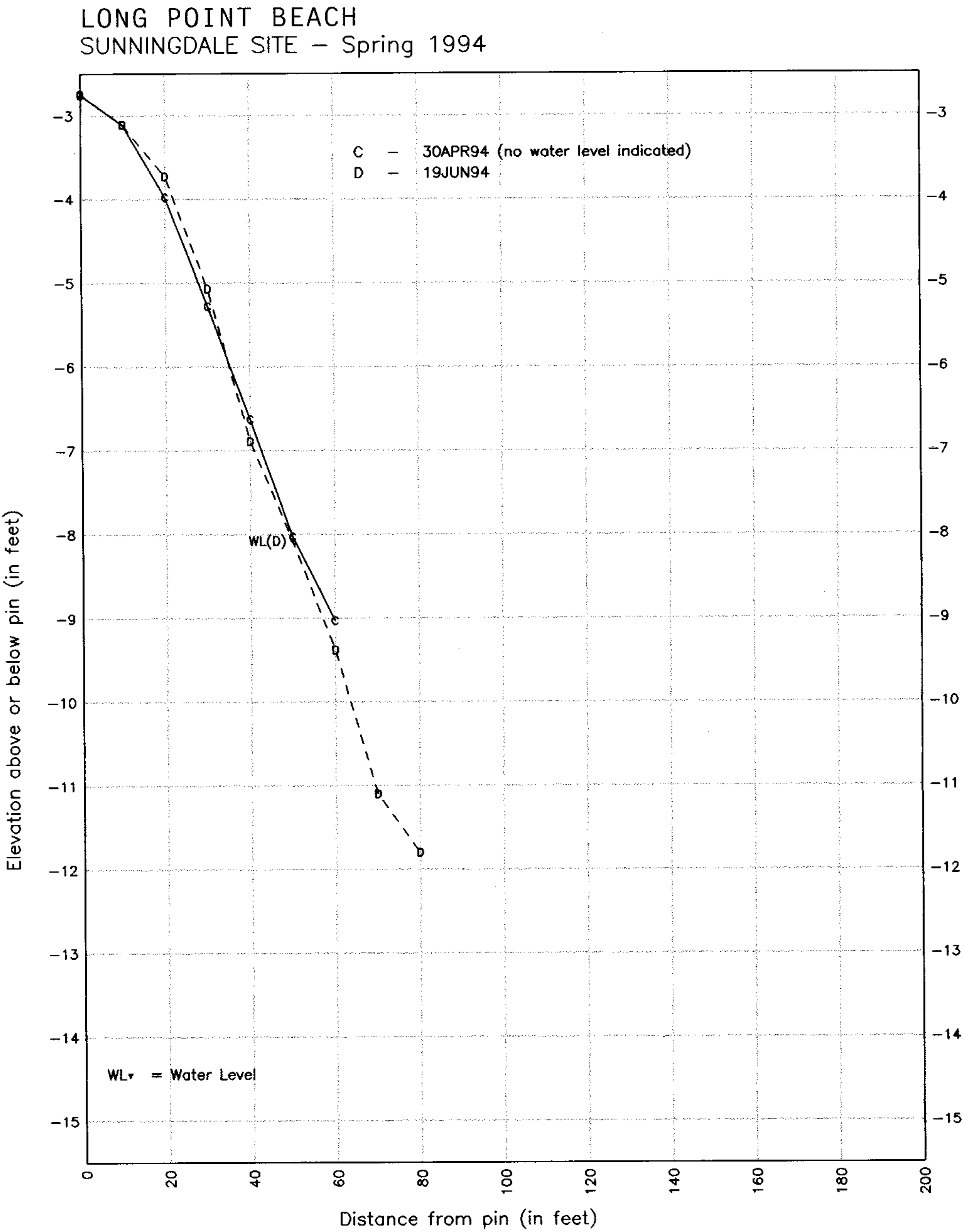
HARMON BEACH
STRAW #2 RESIDENCE – Late Summer Profiles, 1993–1996
A – 17SEP93
C – 10AUG94
D – 07SEP95
G – 13AUG96
WL(G)
WL(C)
WL(A)
WL(D)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200


LONG POINT BEACH
SUNNINGDALE SITE – SWEEP ZONE, 02SEP93 – 19JUL95
A – 02SEP93
B – 11OCT93
C – 30APR94
D – 19JUN94
E – 23JUL94
F – 03SEP94
G – 09OCT94
H – 27NOV94
I – 28DEC94
J – 08APR95
K – 19JUL95
WL▾ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
0
20
40
60
80
100
120
140
160
180
200

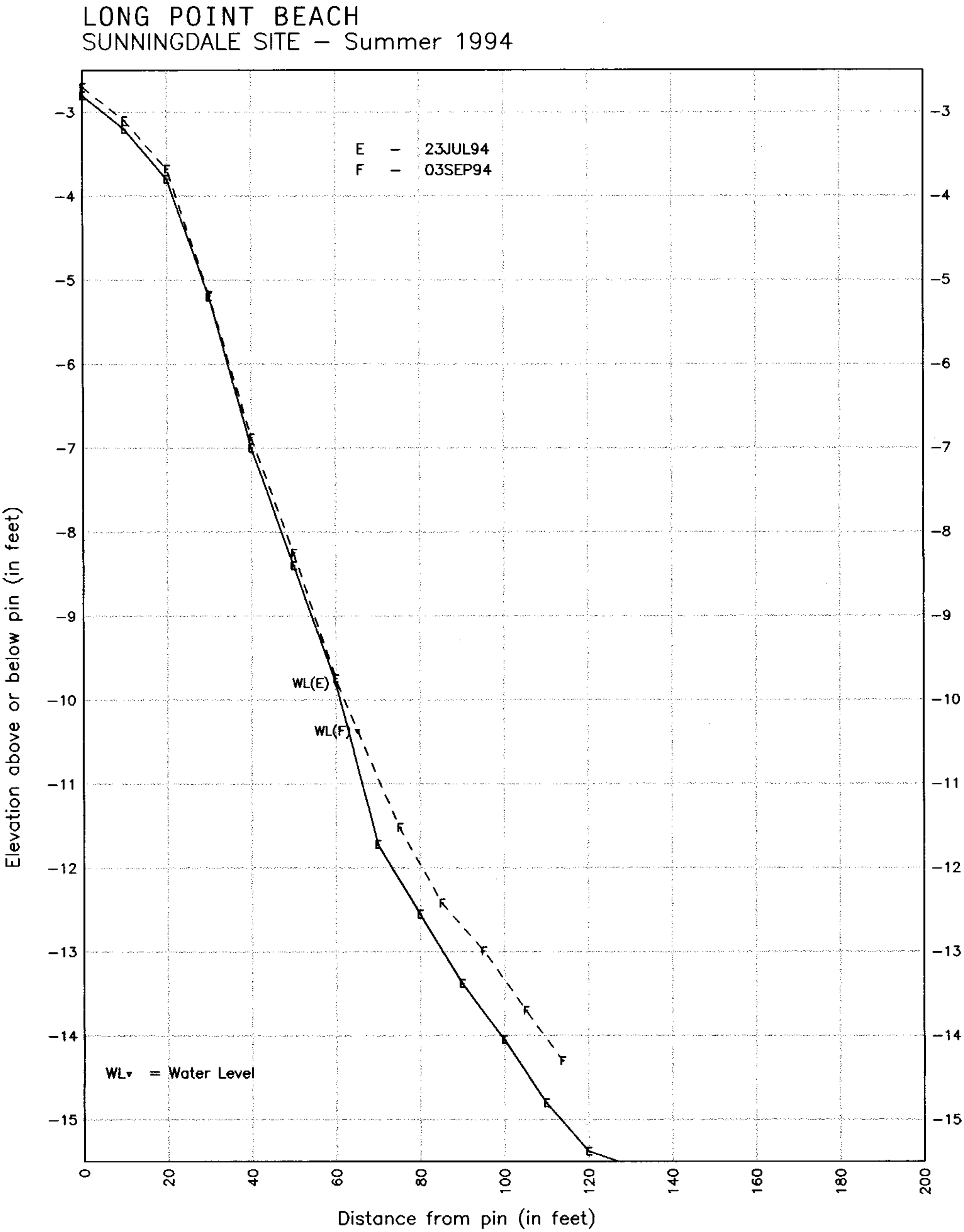


LONG POINT BEACH
SUNNINGDALE SITE – Summer 1993
A – 02SEP93
WL(A)
WL▾ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
0
20
40
60
80
100
120
140
160
180
200


LONG POINT BEACH
SUNNINGDALE SITE – Fall 1993
B – 11OCT93
WL(B)
WL▾ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
0
20
40
60
80
100
120
140
160
180
200

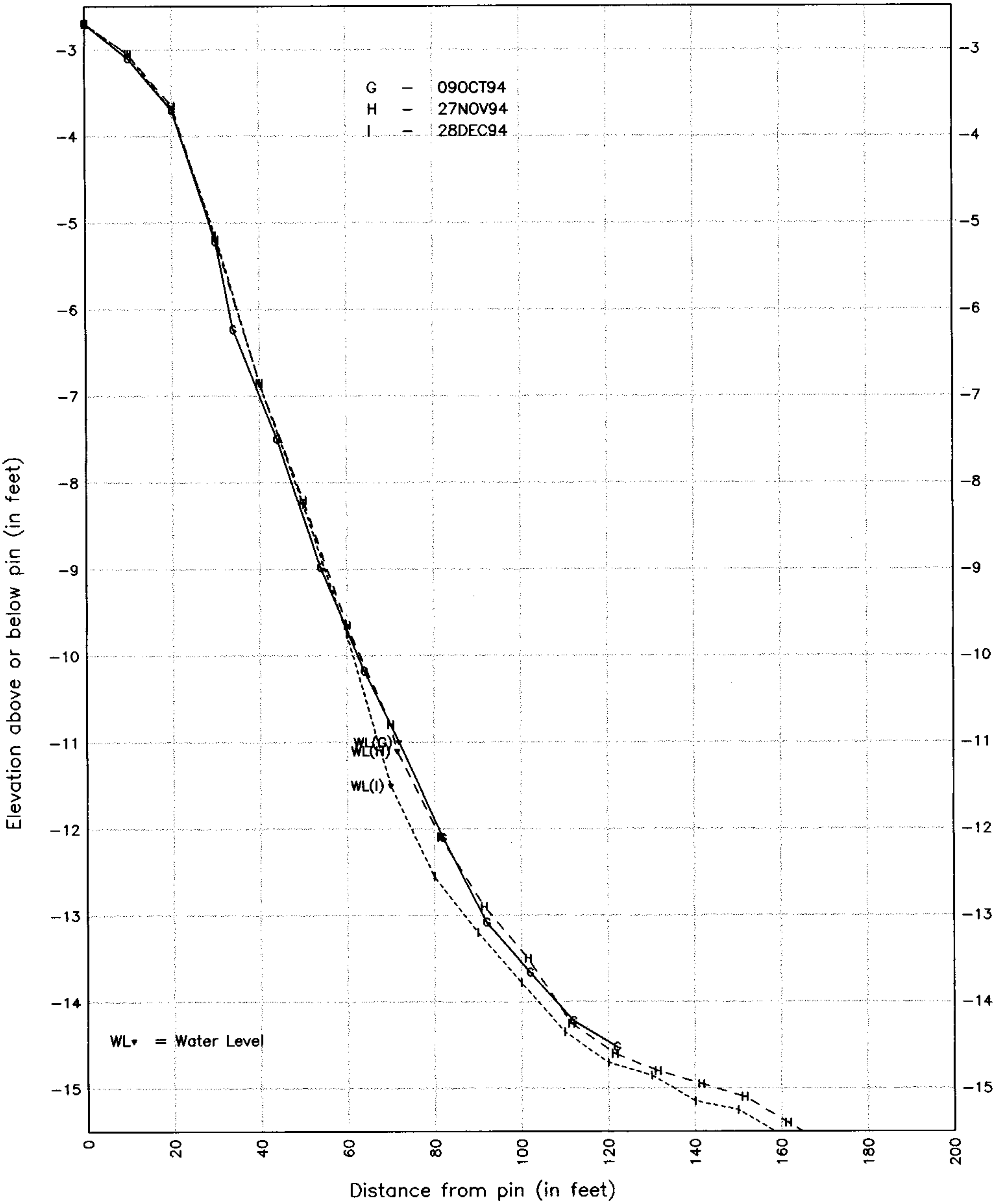


LONG POINT BEACH
SUNNINGDALE SITE – Spring 1994
C – 30APR94 (no water level indicated)
D – 19JUN94
WL(D)
WL▾ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
0
20
40
60
80
100
120
140
160
180
200

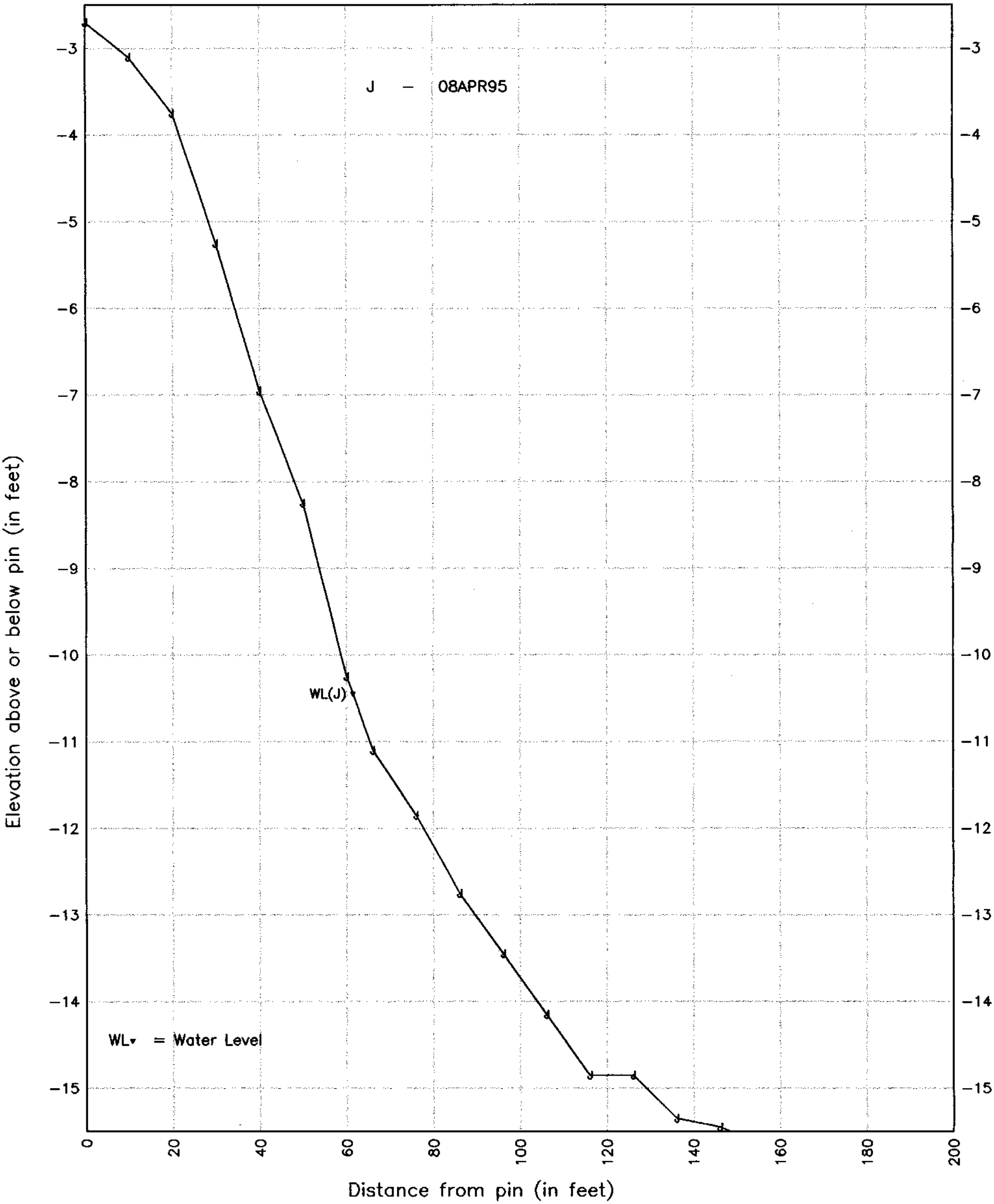


LONG POINT BEACH
SUNNINGDALE SITE – Summer 1994
E – 23JUL94
F – 03SEP94
WL(E)
WL(F)
WL▾ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
0
20
40
60
80
100
120
140
160
180
200

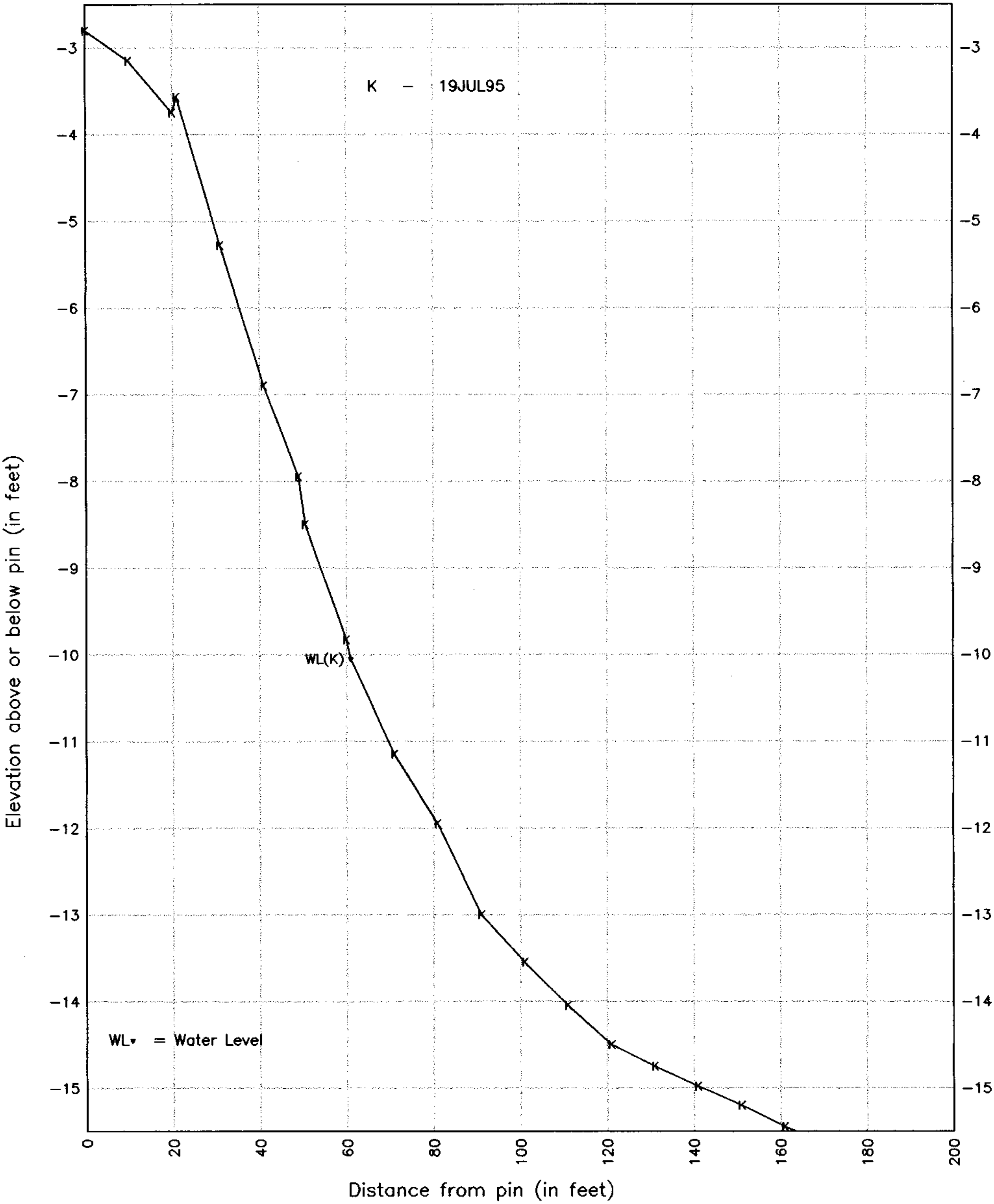
LONG POINT BEACH
SUNNINGDALE SITE – Fall 1994



LONG POINT BEACH
SUNNINGDALE SITE – Spring 1995

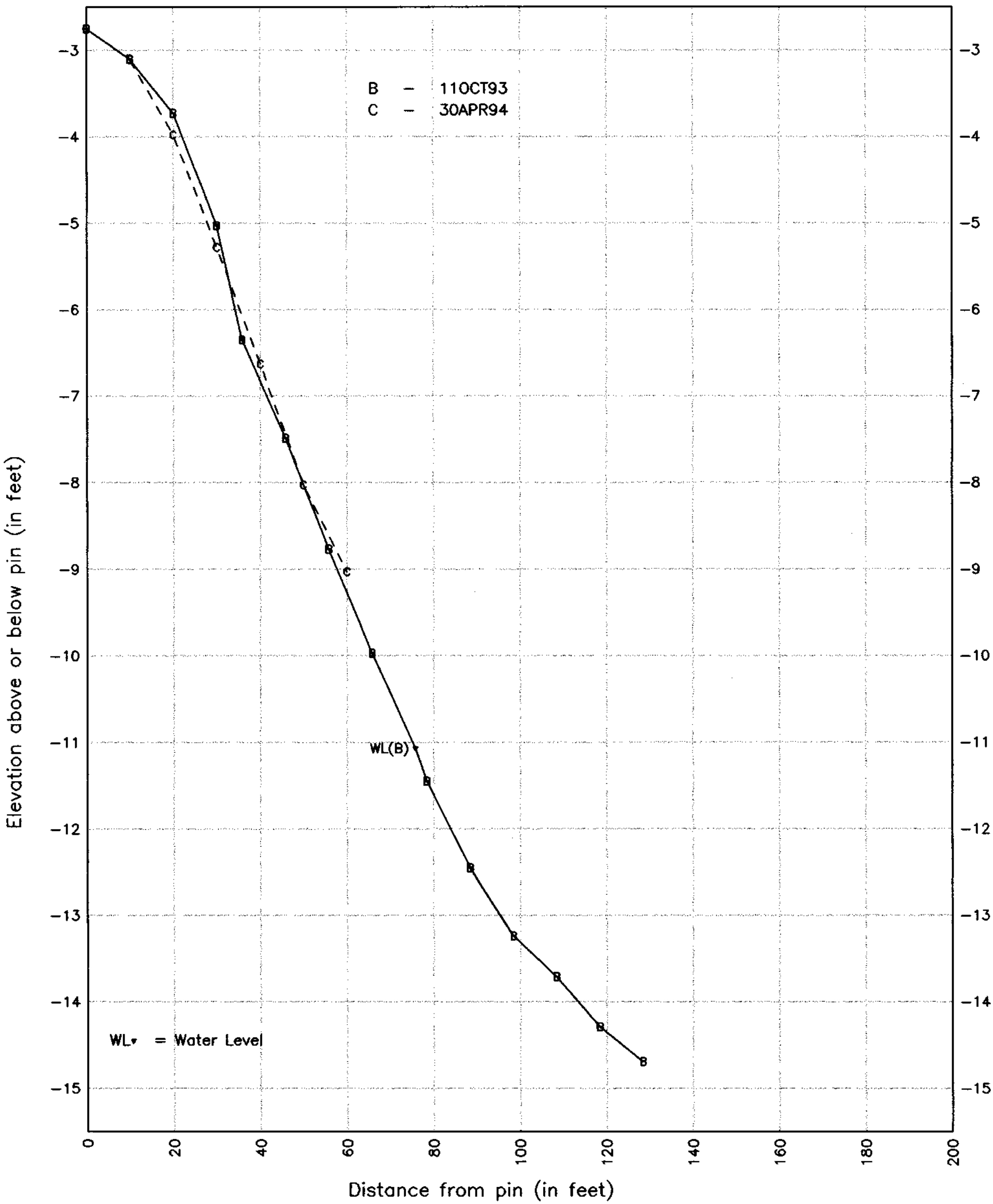


LONG POINT BEACH
SUNNINGDALE SITE – Summer 1995



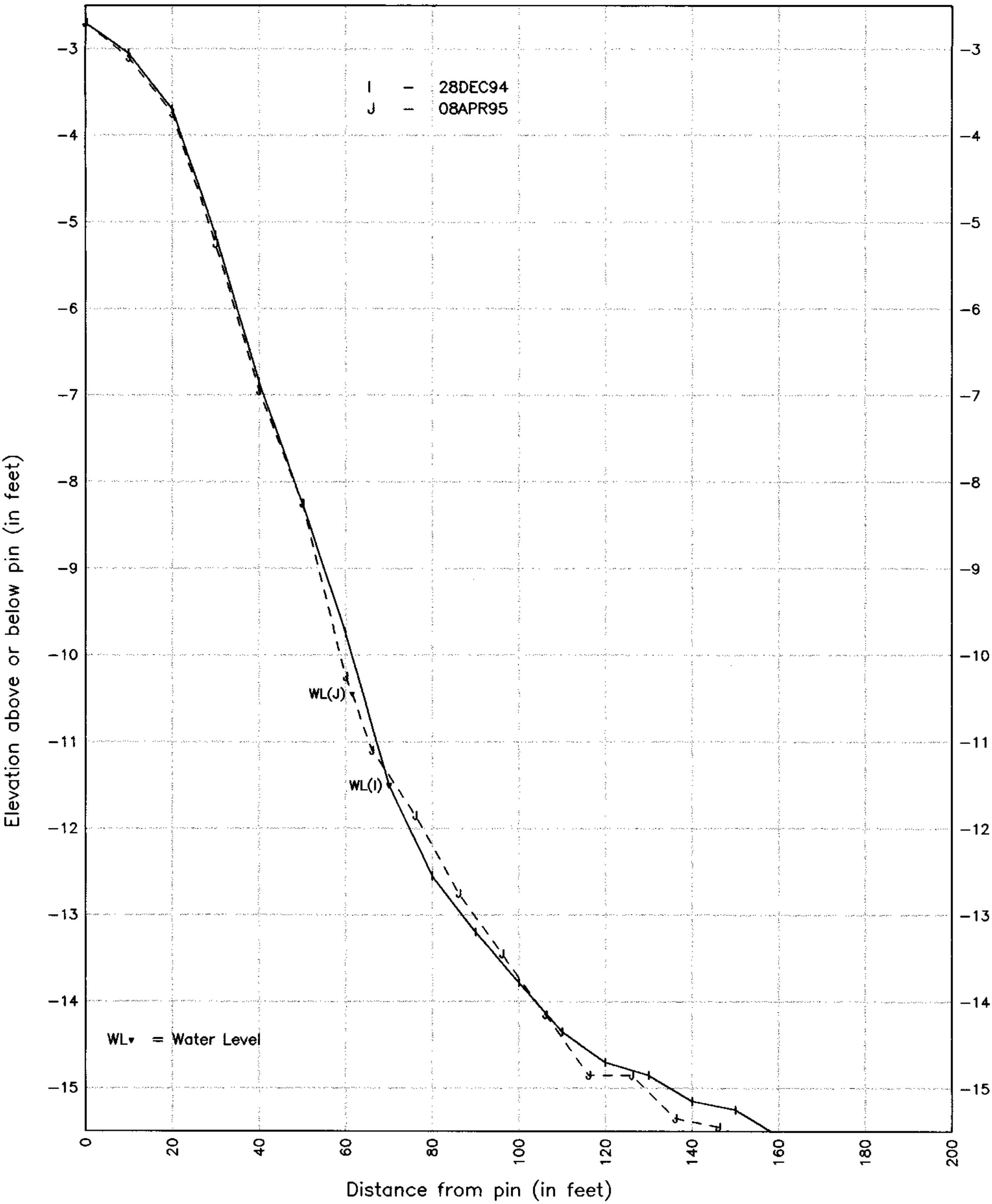
LONG POINT BEACH

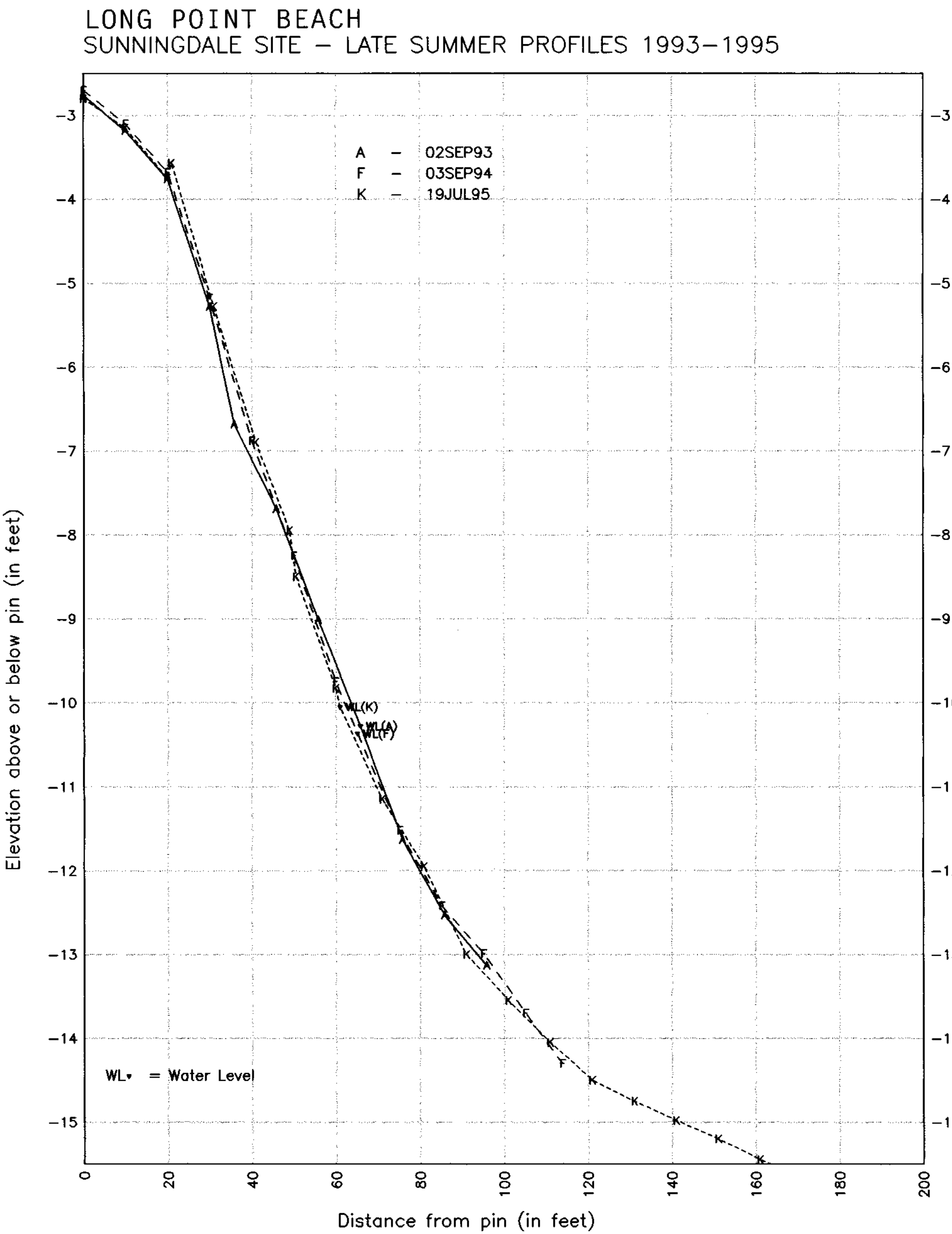
SUNNINGDALE SITE – Last Profile 1993, First Profile 1994

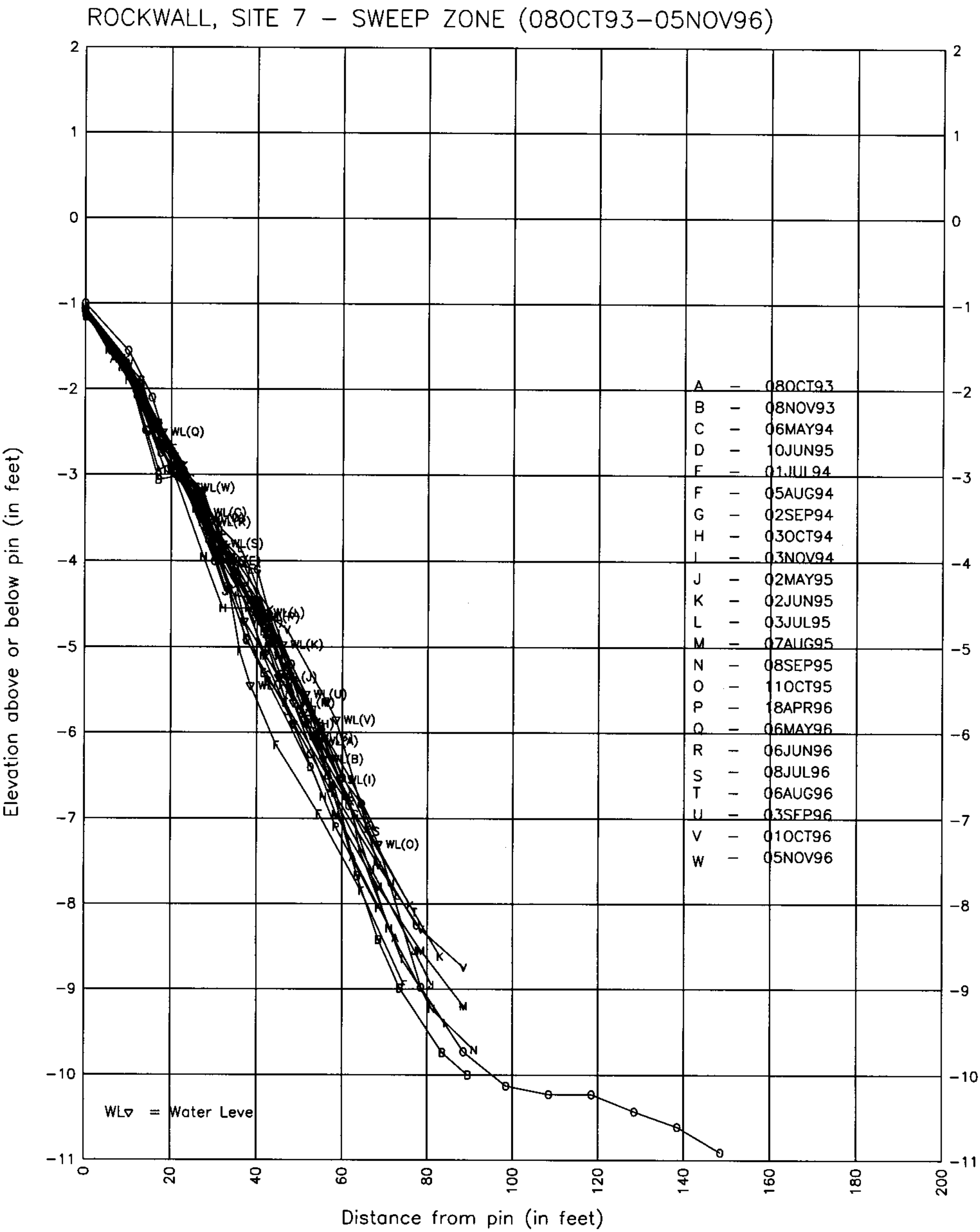


LONG POINT BEACH

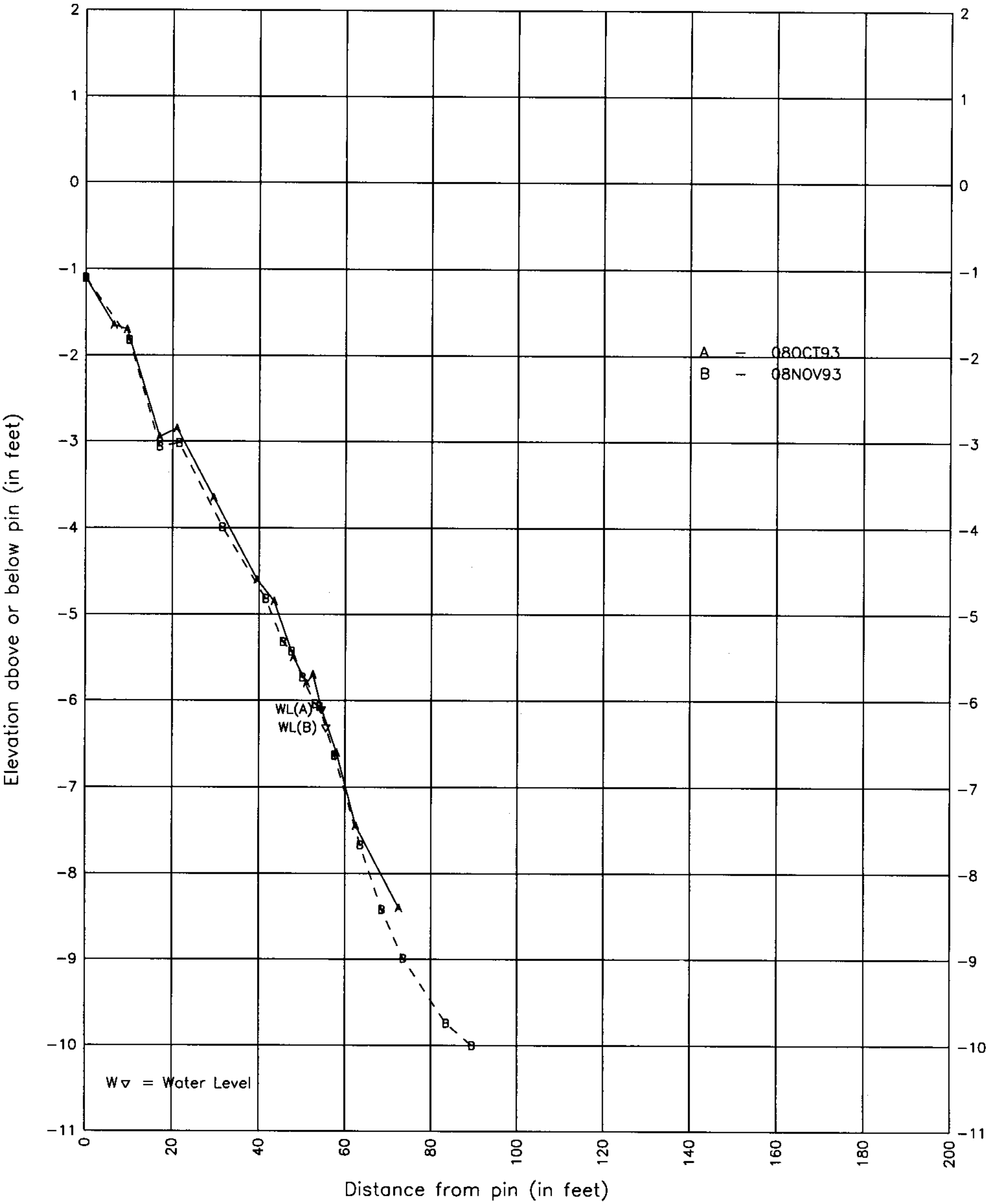
SUNNINGDALE SITE – Last Profile 1994, First Profile 1995

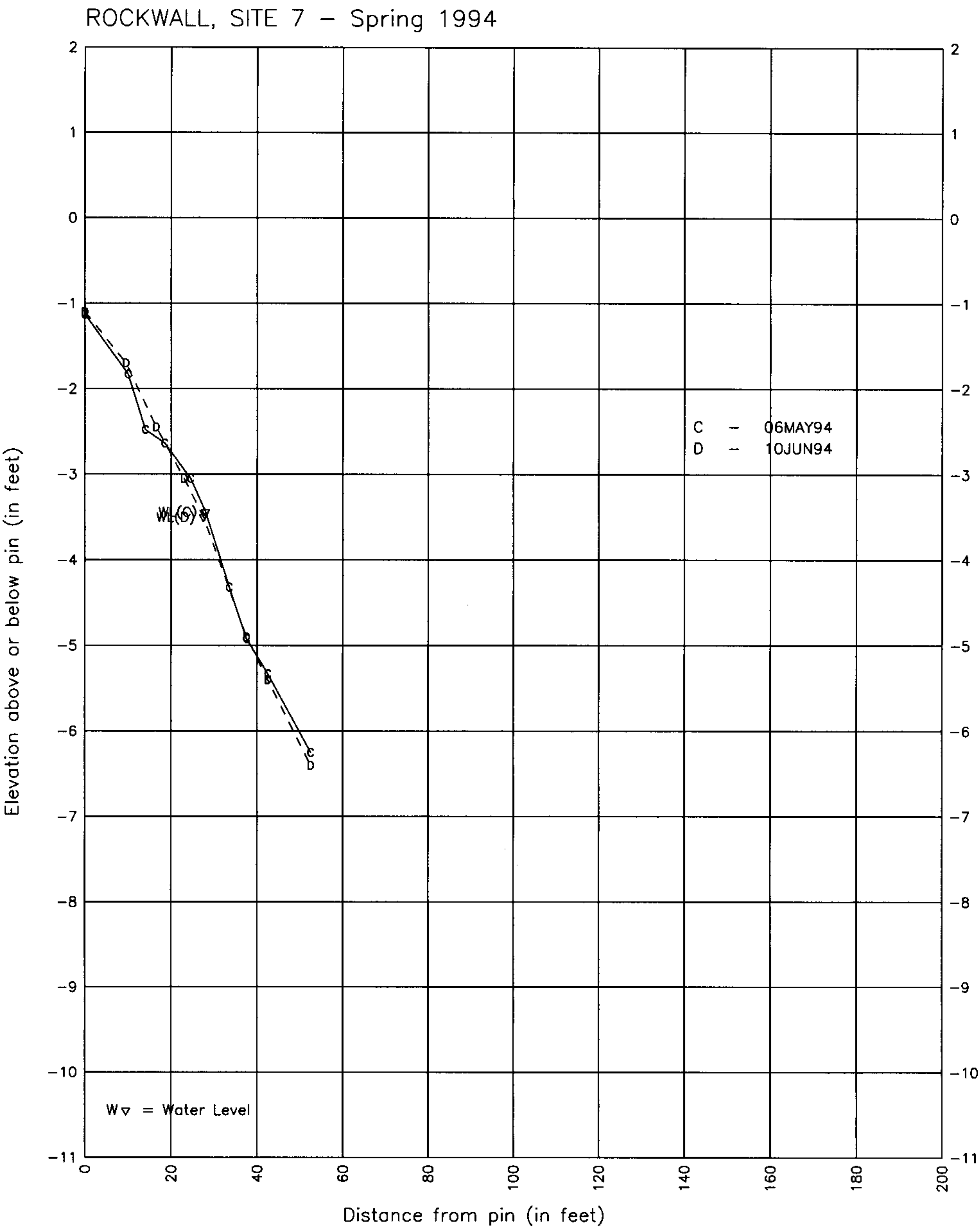



LONG POINT BEACH
SUNNINGDALE SITE – LATE SUMMER PROFILES 1993–1995
A – 02SEP93
F – 03SEP94
K – 19JUL95
WL(K)
WL(A)
WL(F)
WL▾ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
0
20
40
60
80
100
120
140
160
180
200


ROCKWALL, SITE 7 - SWEEP ZONE (08OCT93-05NOV96)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A - 08OCT93
B - 08NOV93
C - 06MAY94
D - 10JUN95
E - 01JUL94
F - 05AUG94
G - 02SEP94
H - 03OCT94
I - 03NOV94
J - 02MAY95
K - 02JUN95
L - 03JUL95
M - 07AUG95
N - 08SEP95
O - 11OCT95
P - 18APR96
Q - 06MAY96
R - 06JUN96
S - 08JUL96
T - 06AUG96
U - 03SEP96
V - 01OCT96
W - 05NOV96
WL▽ = Water Leve

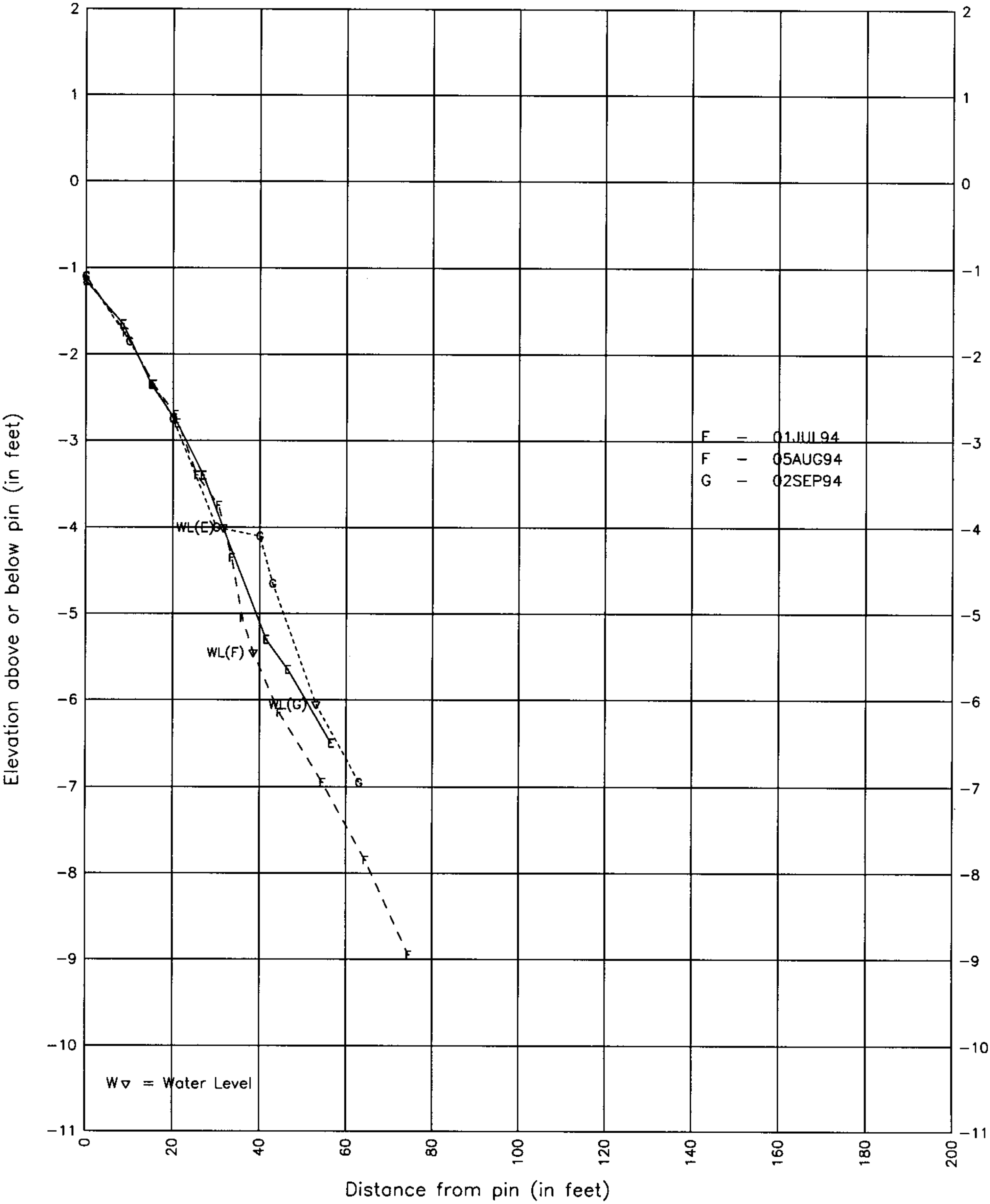
ROCKWALL, SITE 7 – Fall 1993

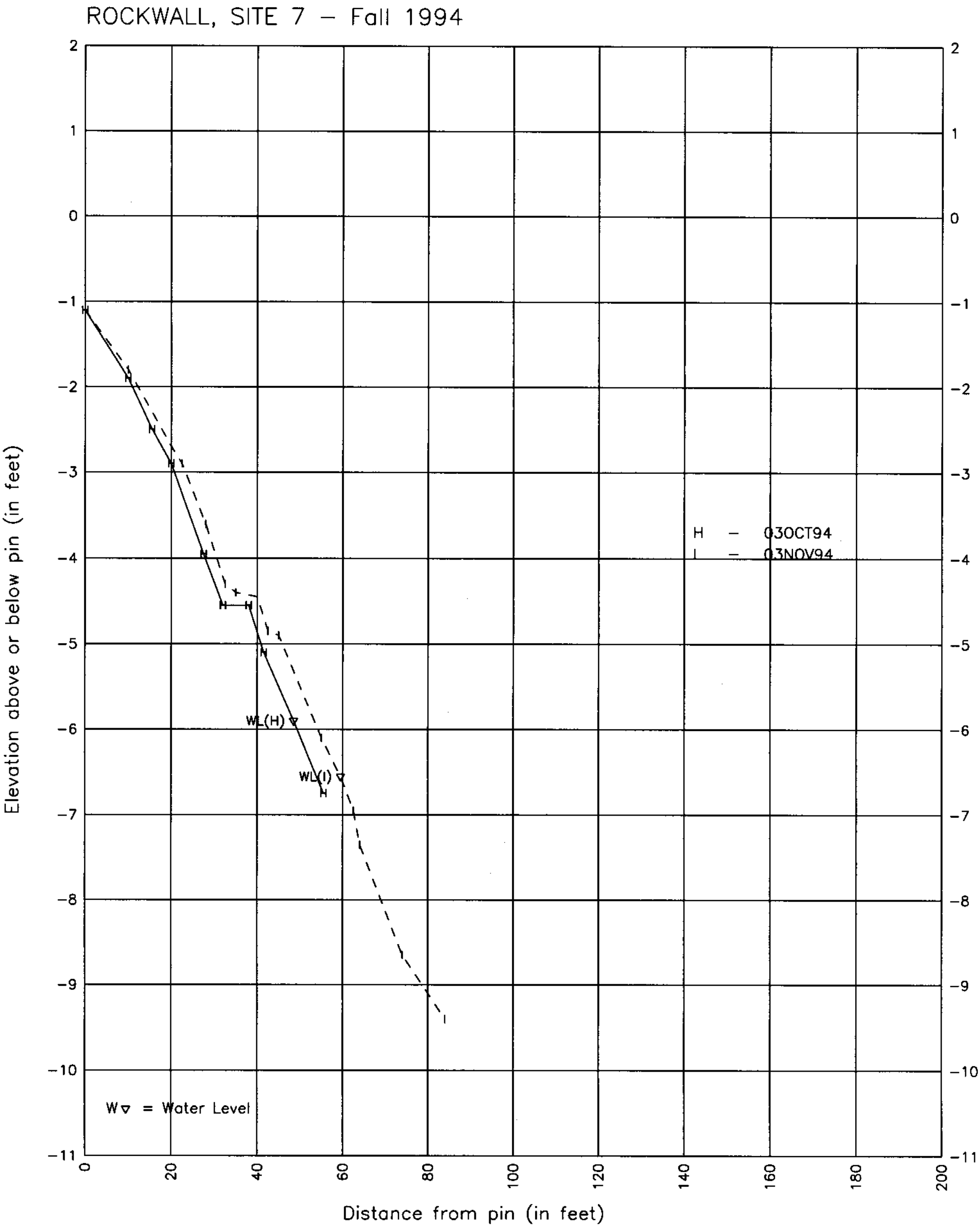




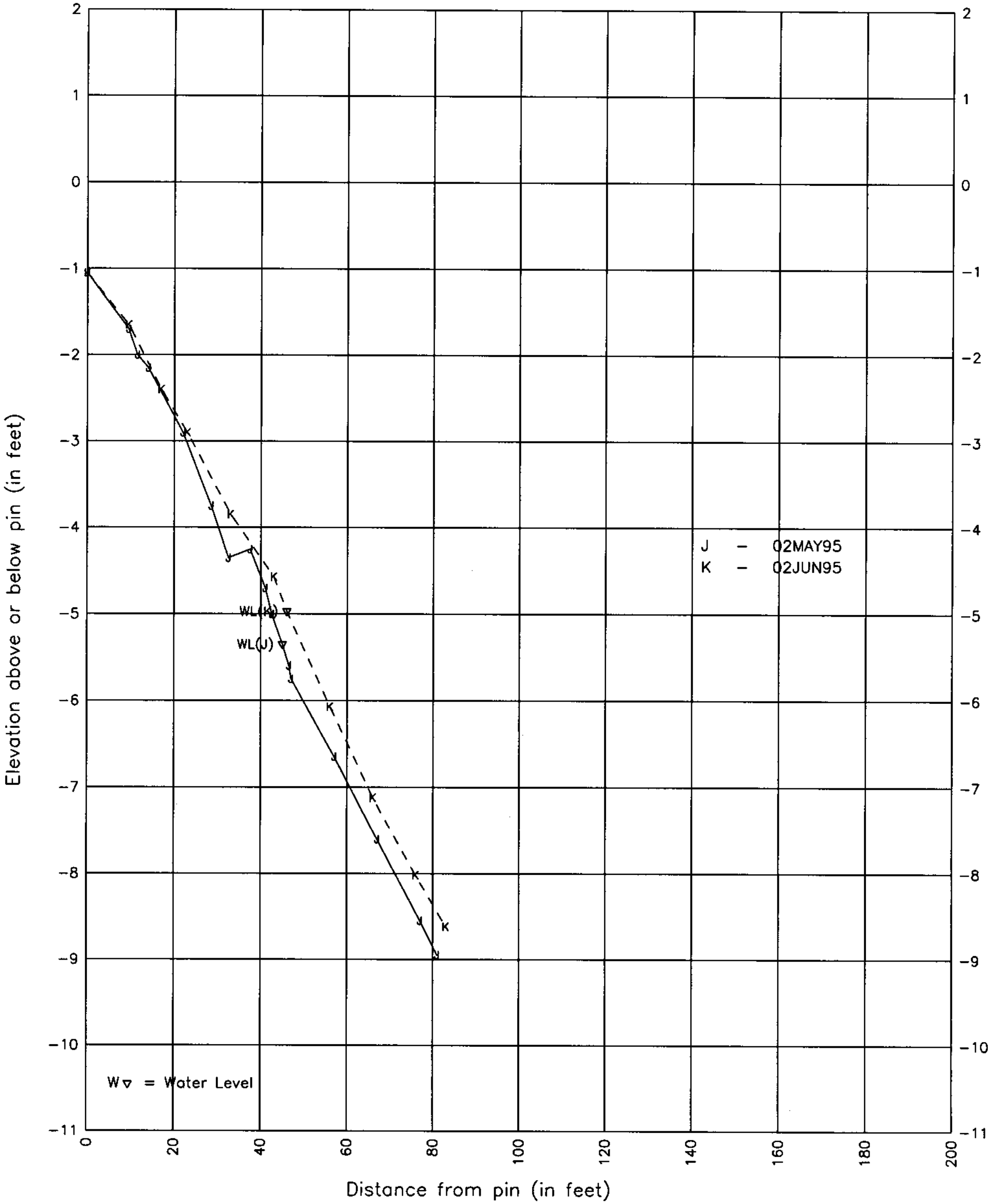
ROCKWALL, SITE 7 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 06MAY94
D – 10JUN94
WL(C)
WL(D)
W▽ = Water Level

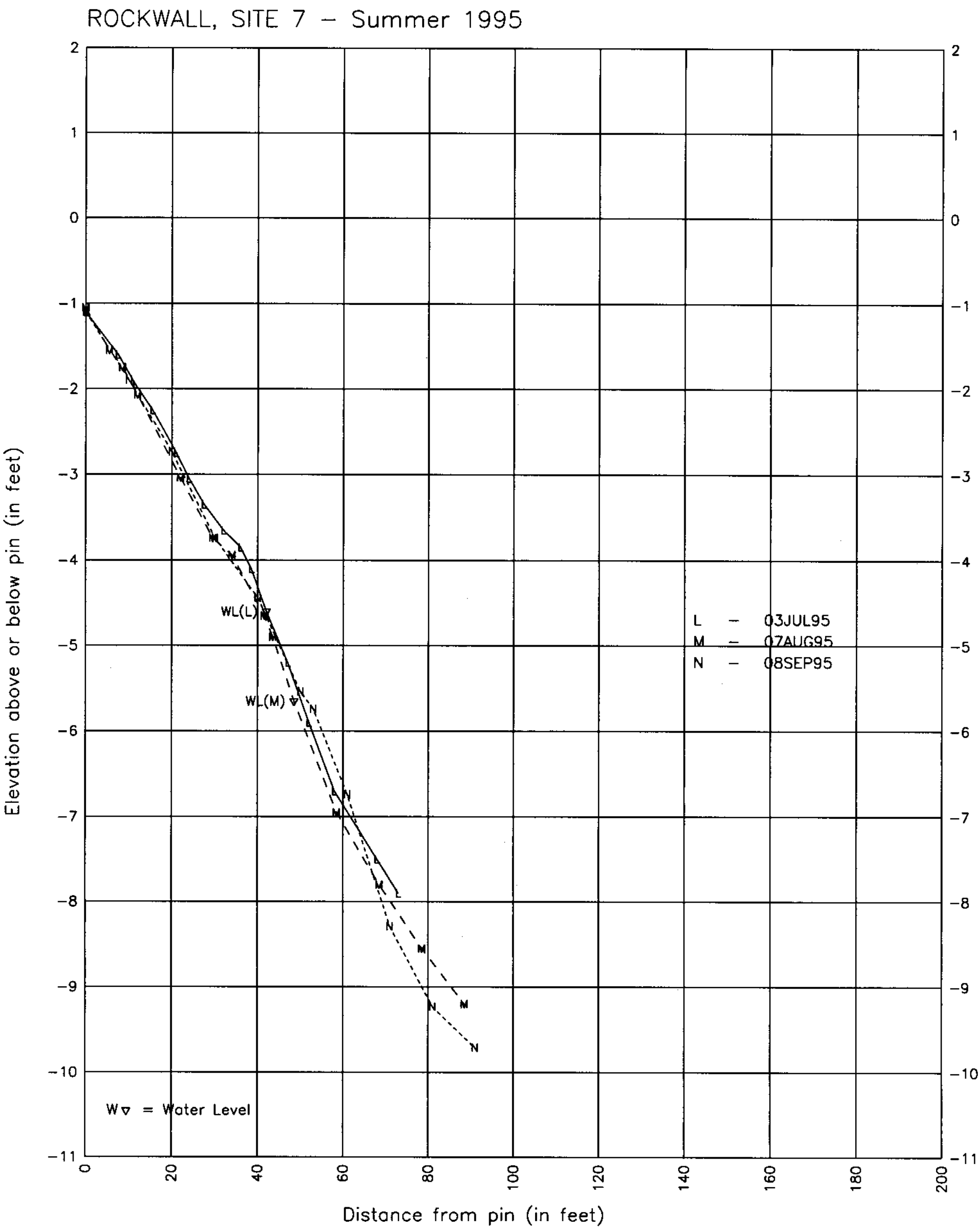
ROCKWALL, SITE 7 – Summer 1994

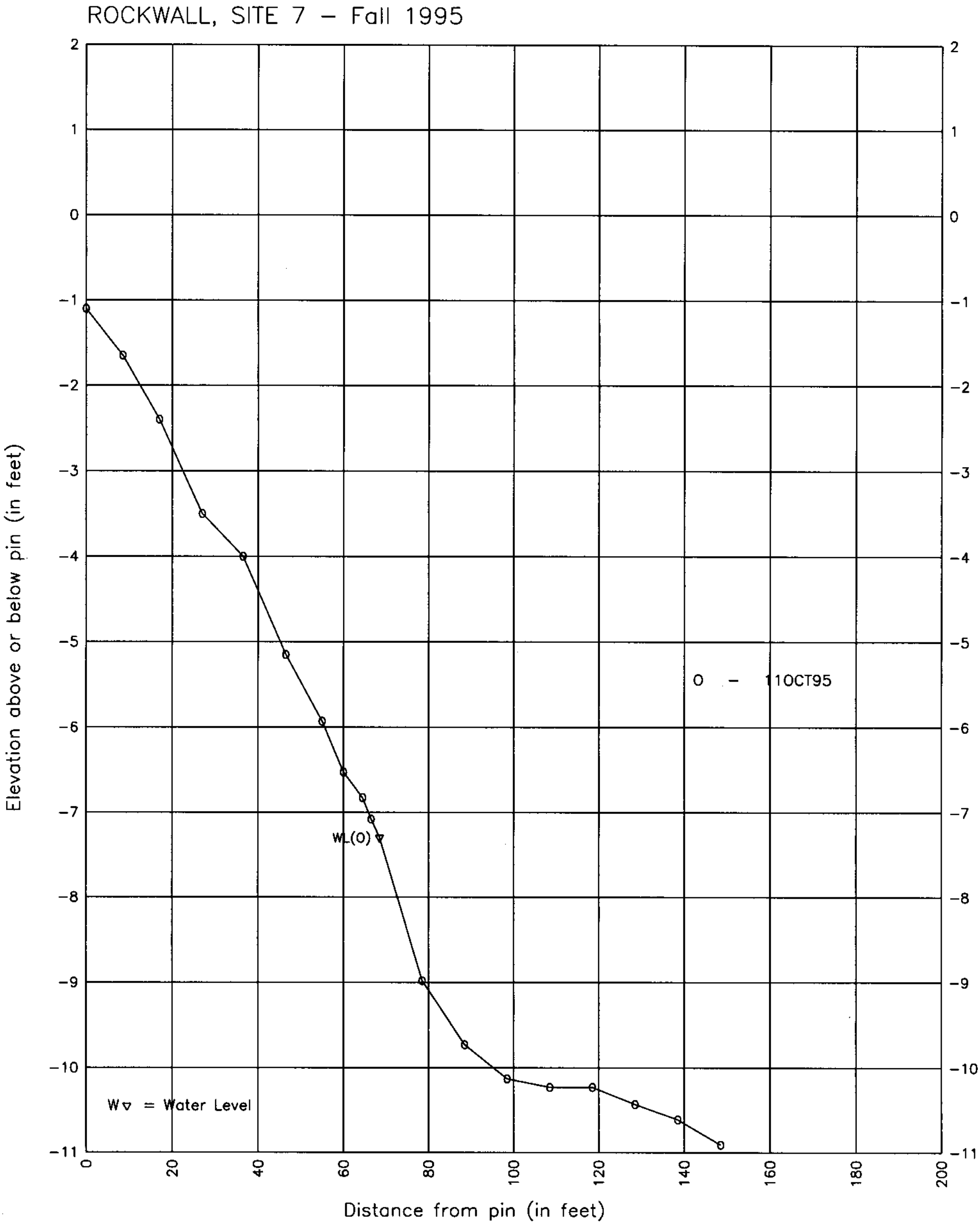


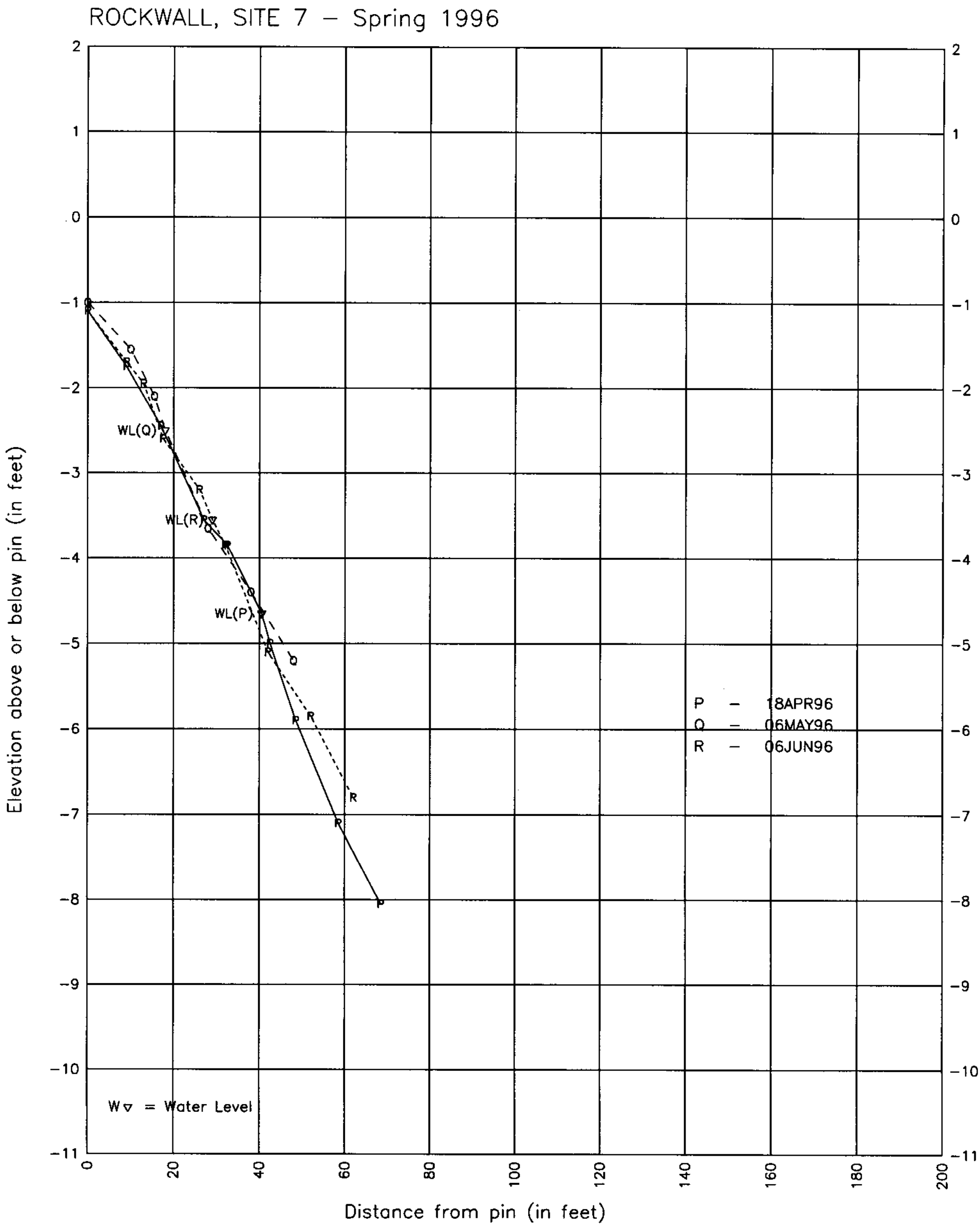

ROCKWALL, SITE 7 – Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
H – 03OCT94
I – 03NOV94
WL(H)
WL(I)
W▽ = Water Level

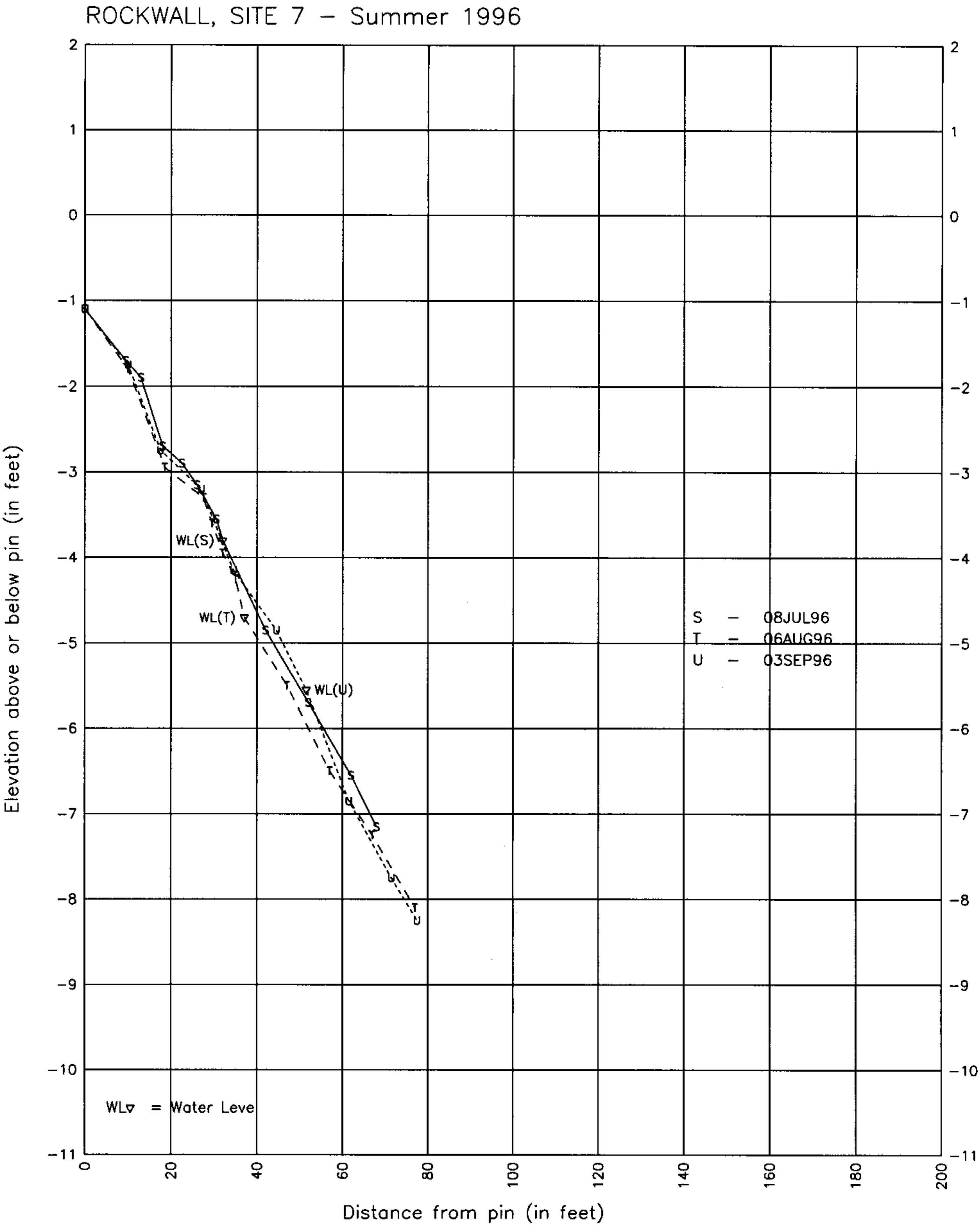
ROCKWALL, SITE 7 – Spring 1995




ROCKWALL, SITE 7 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200
WL(L)
WL(M)
L – 03JUL95
M – 07AUG95
N – 08SEP95
W▽ = Water Level

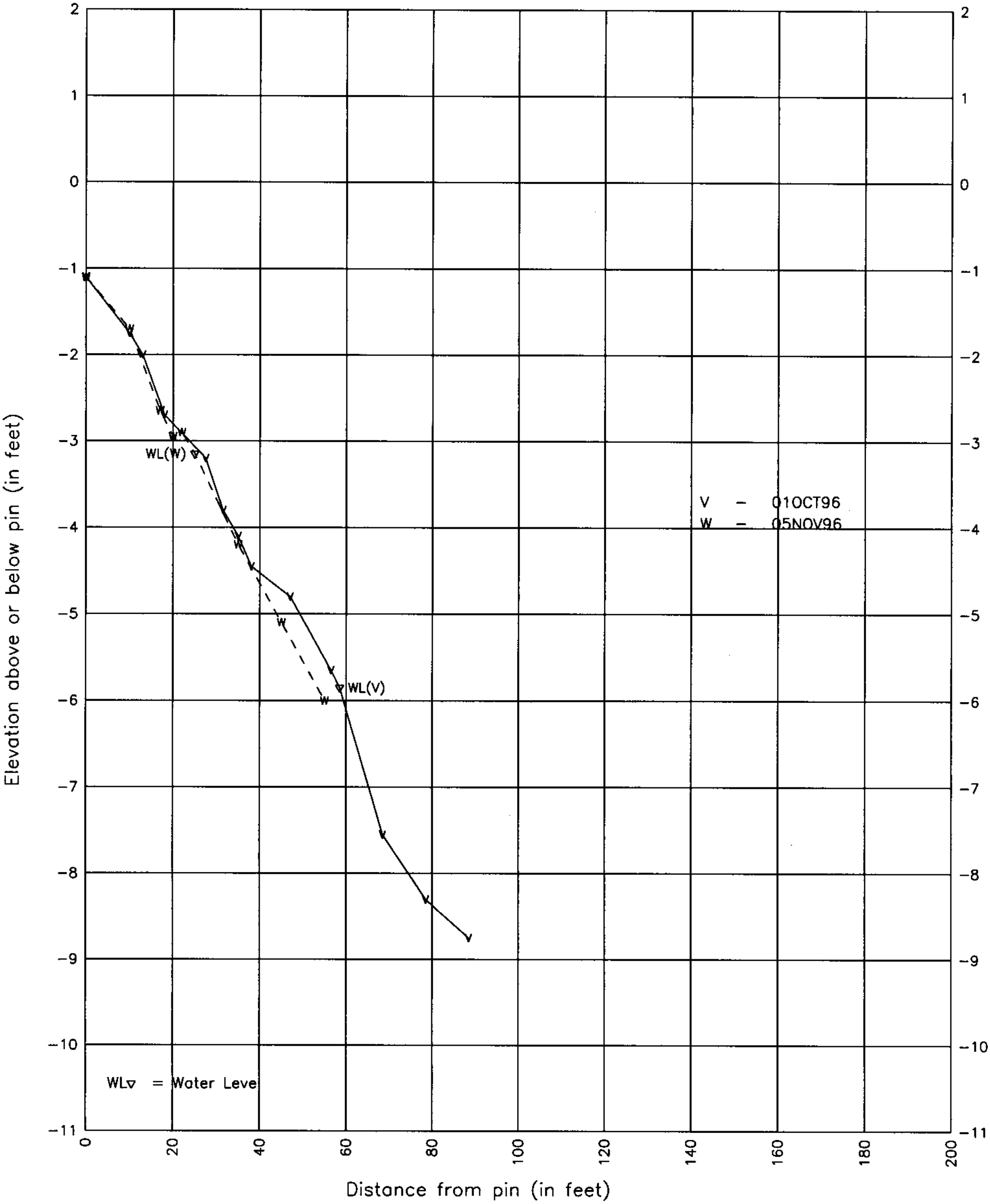

ROCKWALL, SITE 7 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
O – 11OCT95
WL(O)
W▽ = Water Level
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

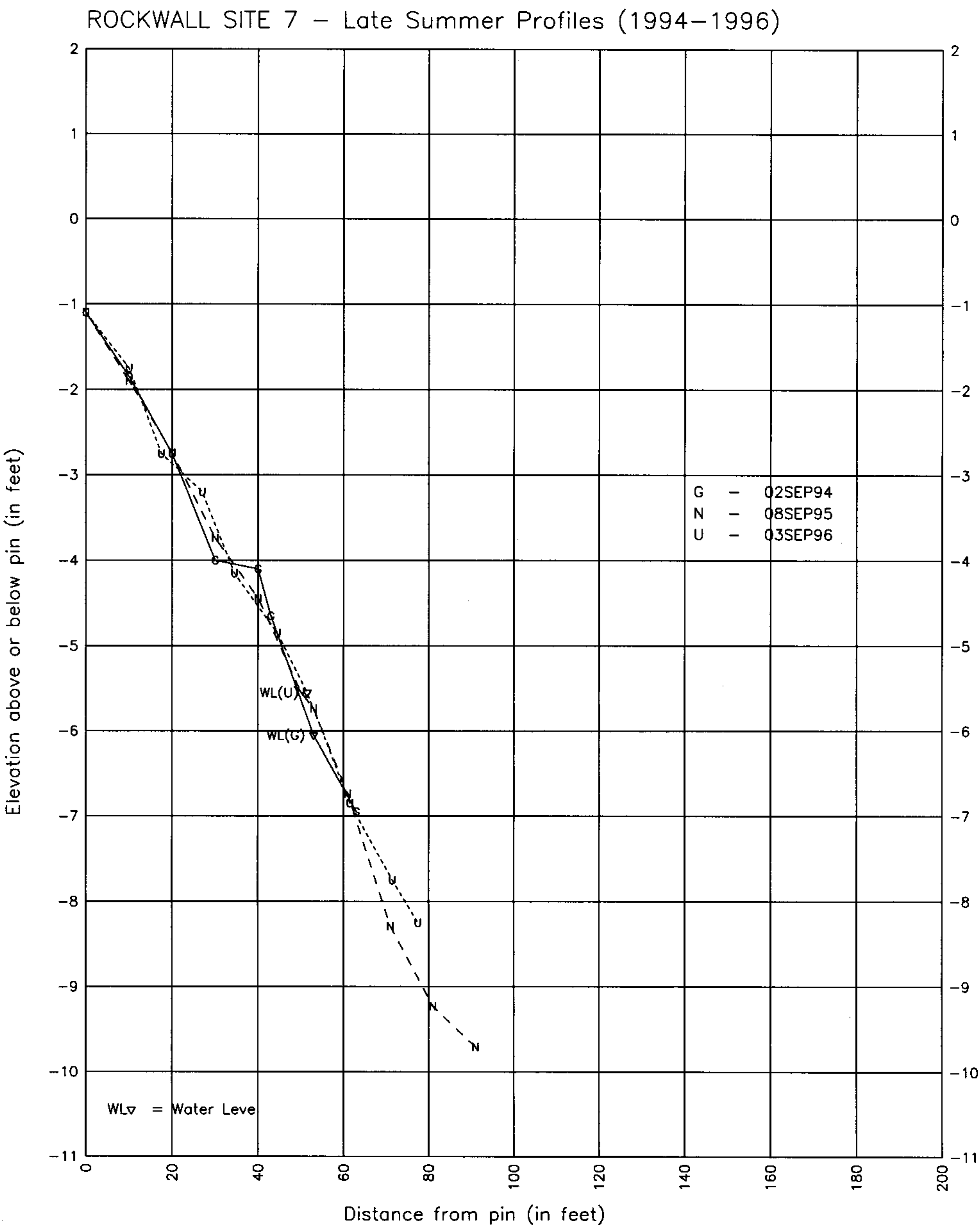

ROCKWALL, SITE 7 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200
WL(Q)
WL(R)
WL(P)
P – 18APR96
Q – 06MAY96
R – 06JUN96
W▽ = Water Level

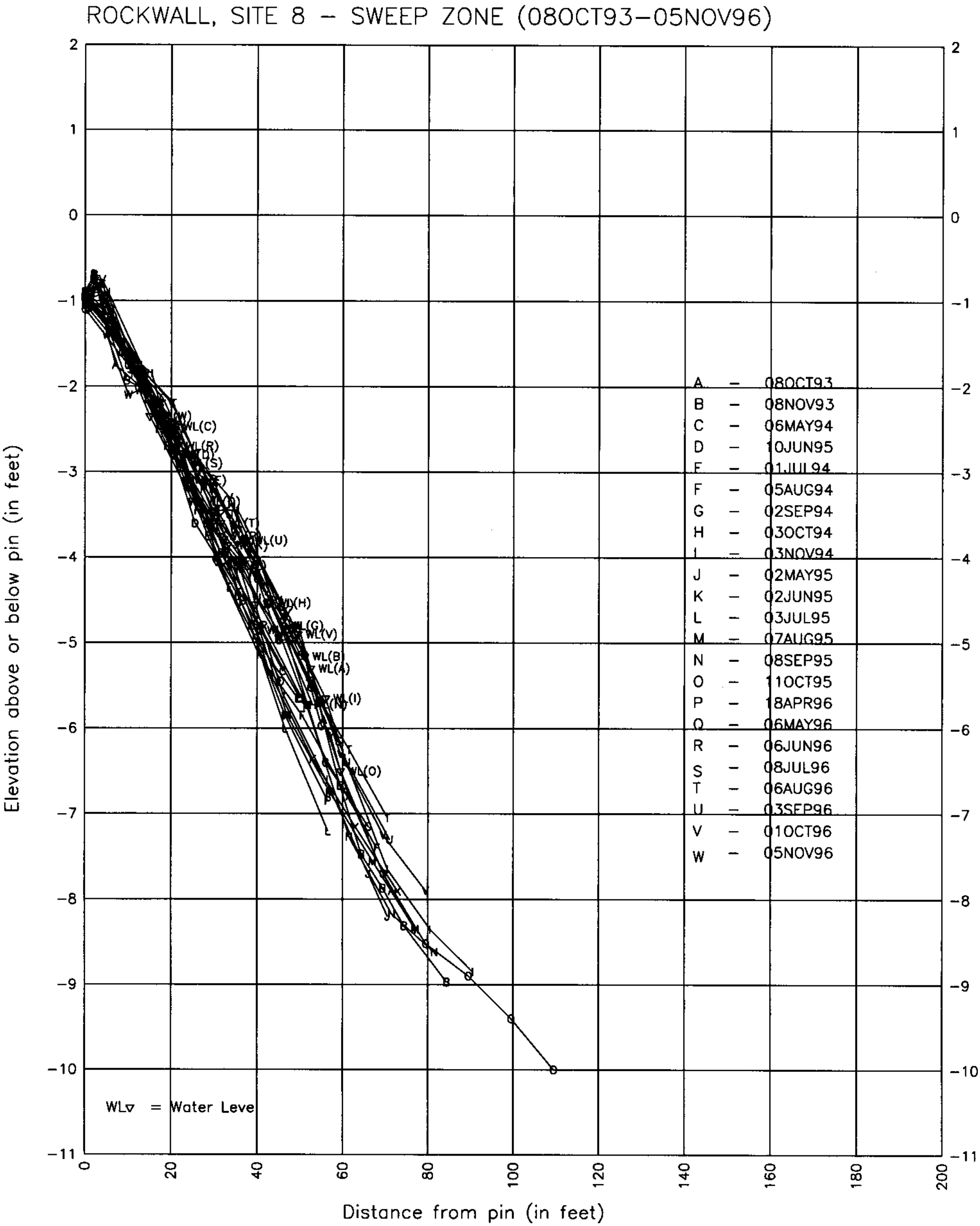


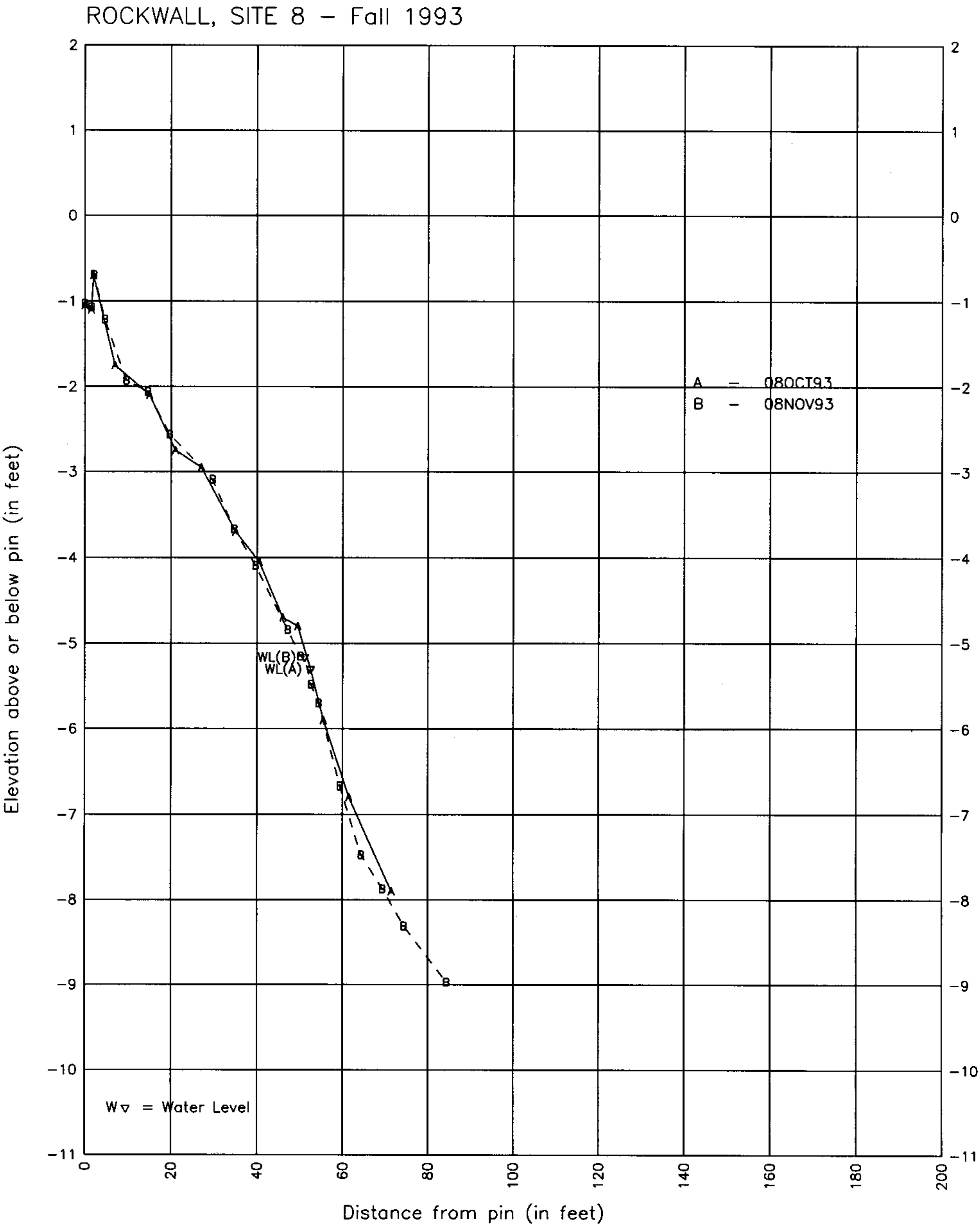
ROCKWALL, SITE 7 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(S)
WL(T)
WL(U)
S – 08JUL96
T – 06AUG96
U – 03SEP96
WL▽ = Water Leve

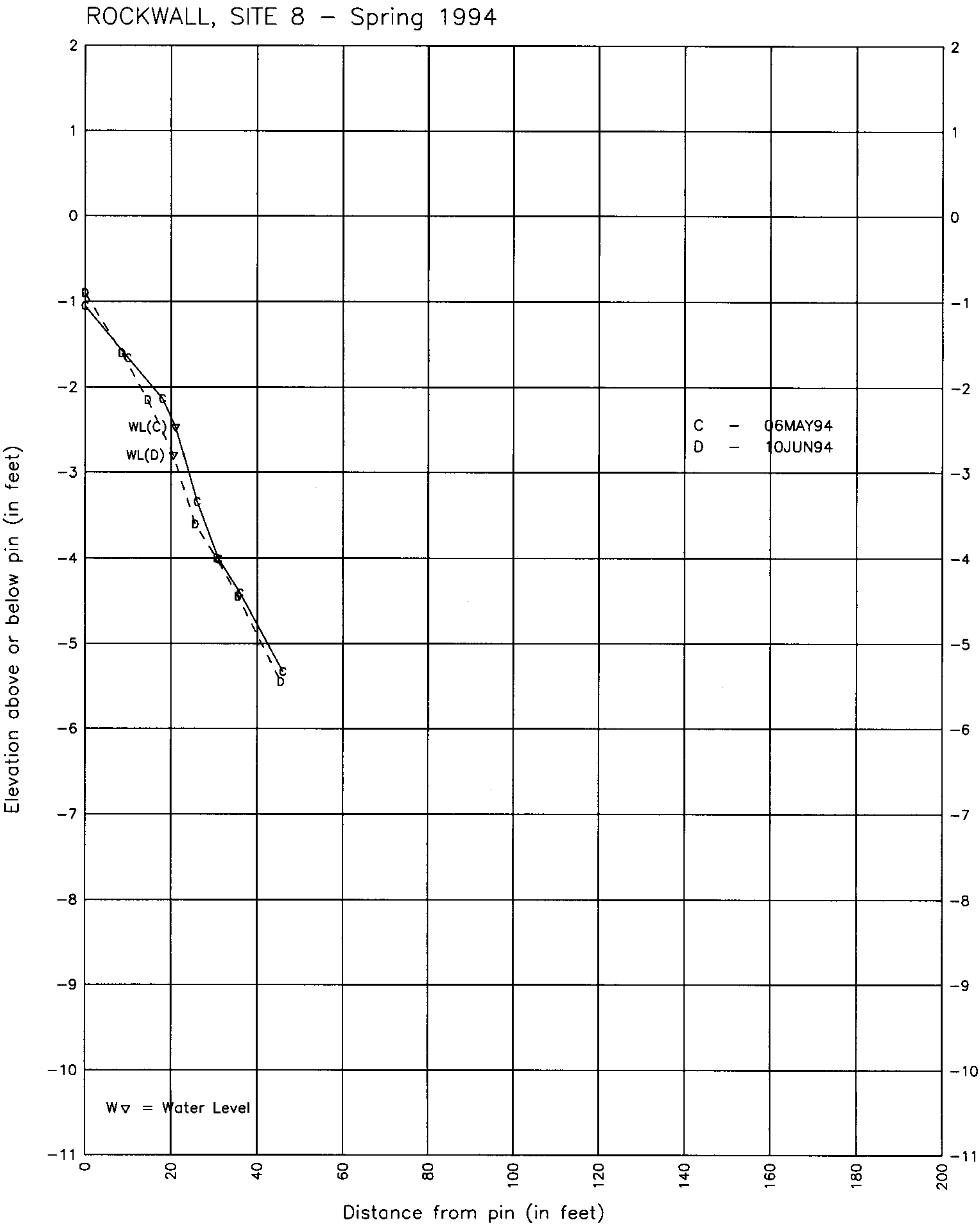
ROCKWALL, SITE 7 - Fall 1996



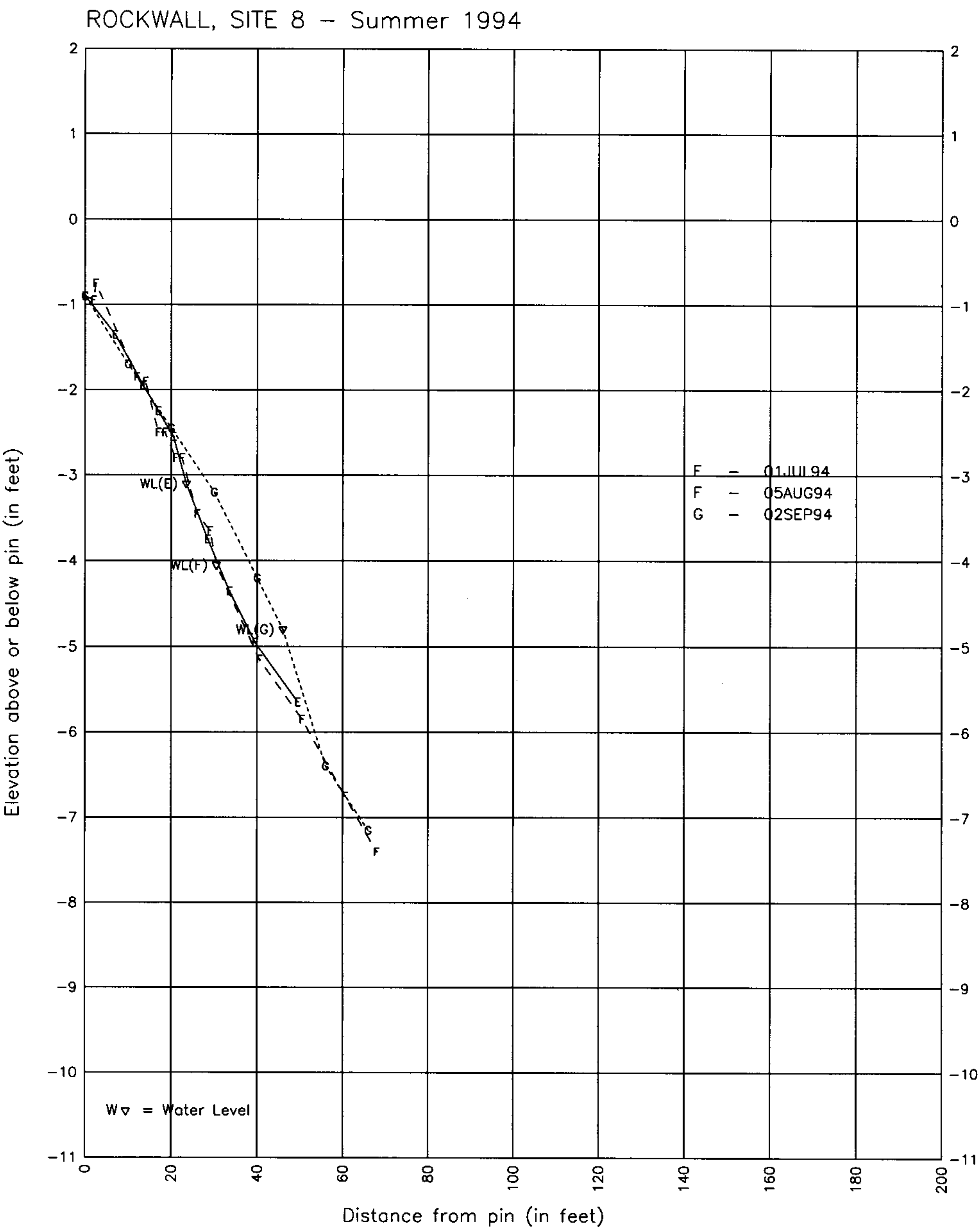

ROCKWALL SITE 7 – Late Summer Profiles (1994–1996)
Elevation above or below pin (in feet)
Distance from pin (in feet)
G – 02SEP94
N – 08SEP95
U – 03SEP96
WL(U)
WL(G)
WL▽ = Water Leve


ROCKWALL, SITE 8 – SWEEP ZONE (08OCT93–05NOV96)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 08OCT93
B – 08NOV93
C – 06MAY94
D – 10JUN95
E – 01JUL94
F – 05AUG94
G – 02SEP94
H – 03OCT94
I – 03NOV94
J – 02MAY95
K – 02JUN95
L – 03JUL95
M – 07AUG95
N – 08SEP95
O – 11OCT95
P – 18APR96
Q – 06MAY96
R – 06JUN96
S – 08JUL96
T – 06AUG96
U – 03SEP96
V – 01OCT96
W – 05NOV96
WL▽ = Water Leve

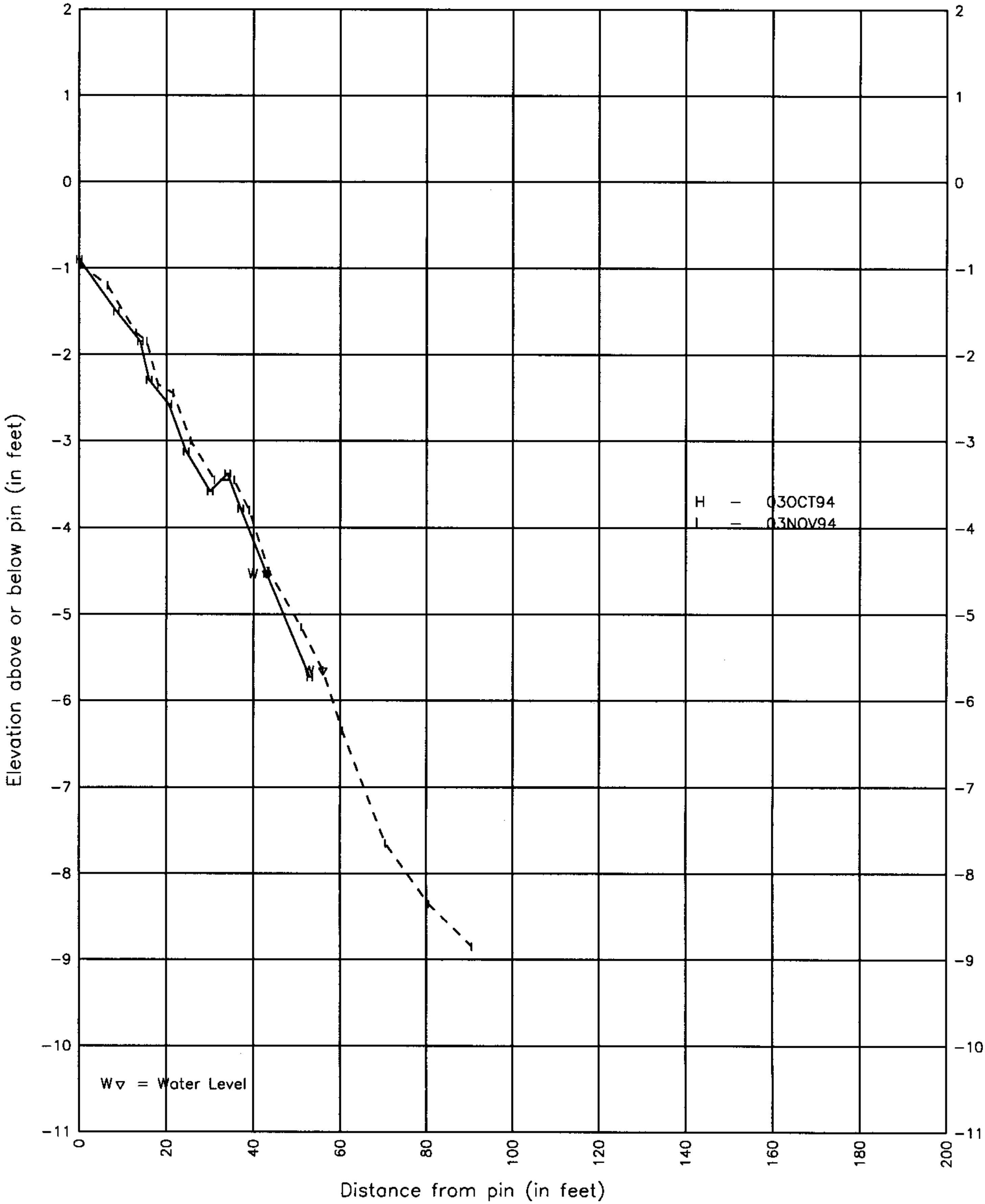

ROCKWALL, SITE 8 – Fall 1993
A – 08OCT93
B – 08NOV93
WL(B)
WL(A)
W▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

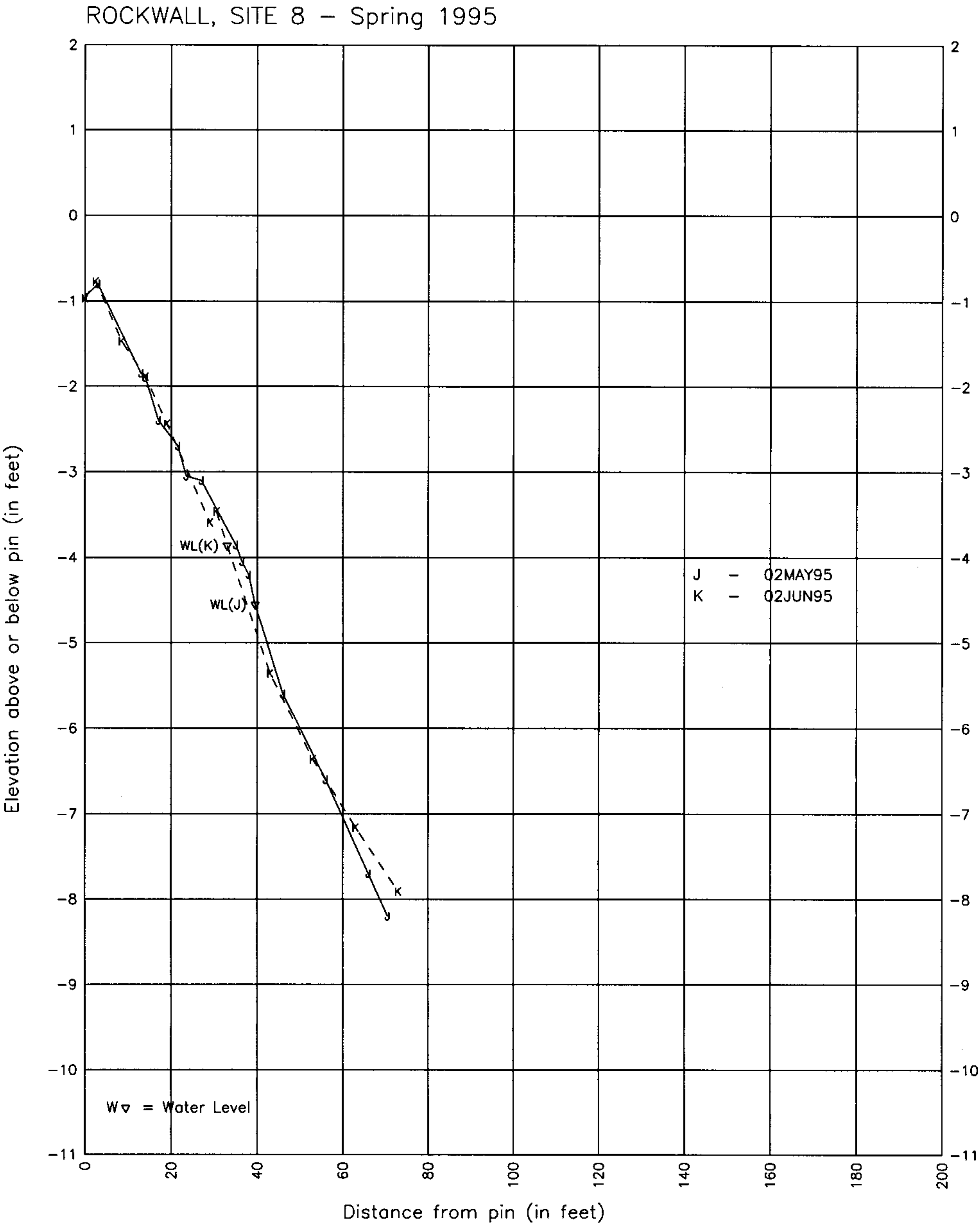


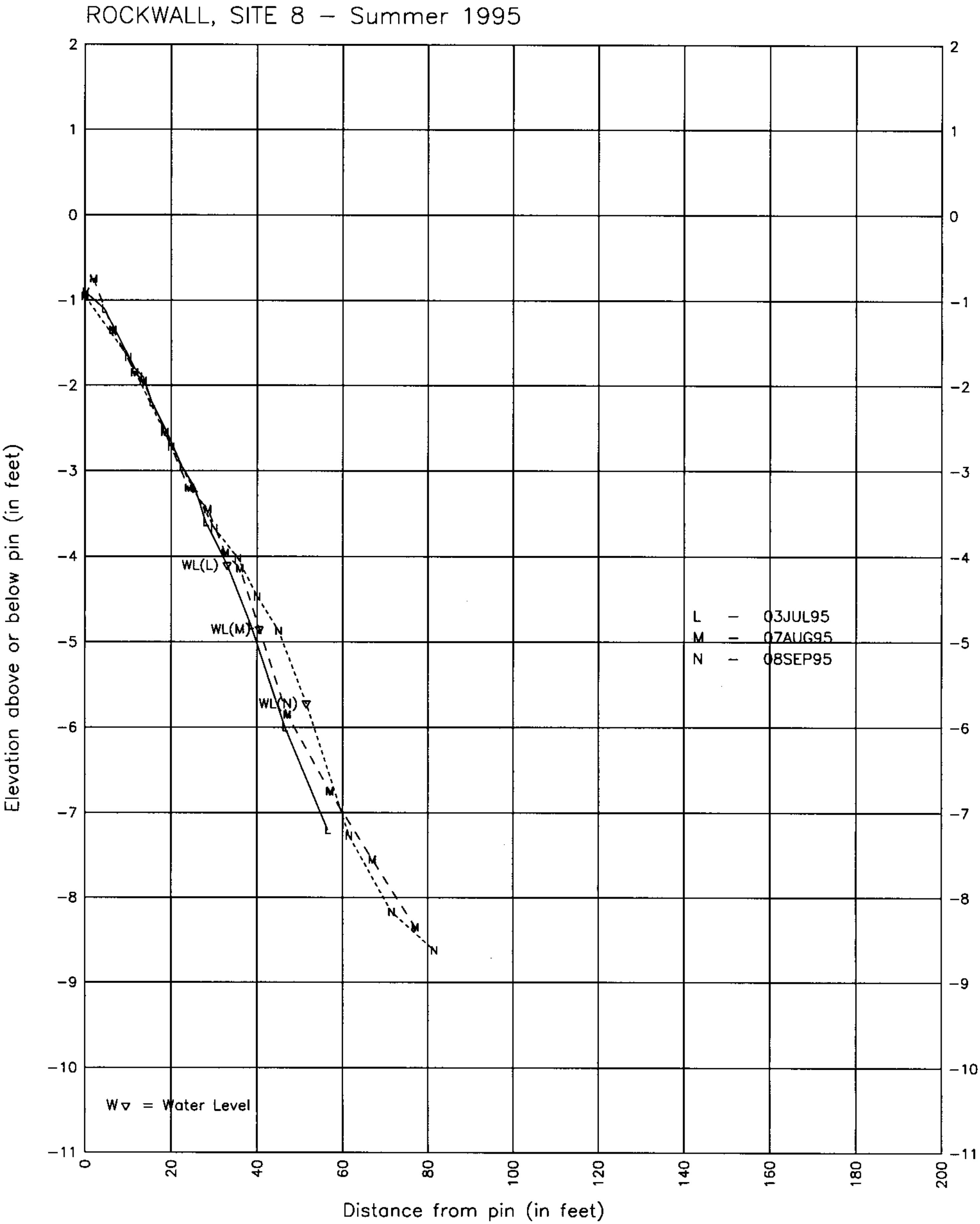
ROCKWALL, SITE 8 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(C)
WL(D)
C – 06MAY94
D – 10JUN94
W▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200


ROCKWALL, SITE 8 – Summer 1994
E – 01JUL94
F – 05AUG94
G – 02SEP94
WL(E)
WL(F)
WL(G)
W▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

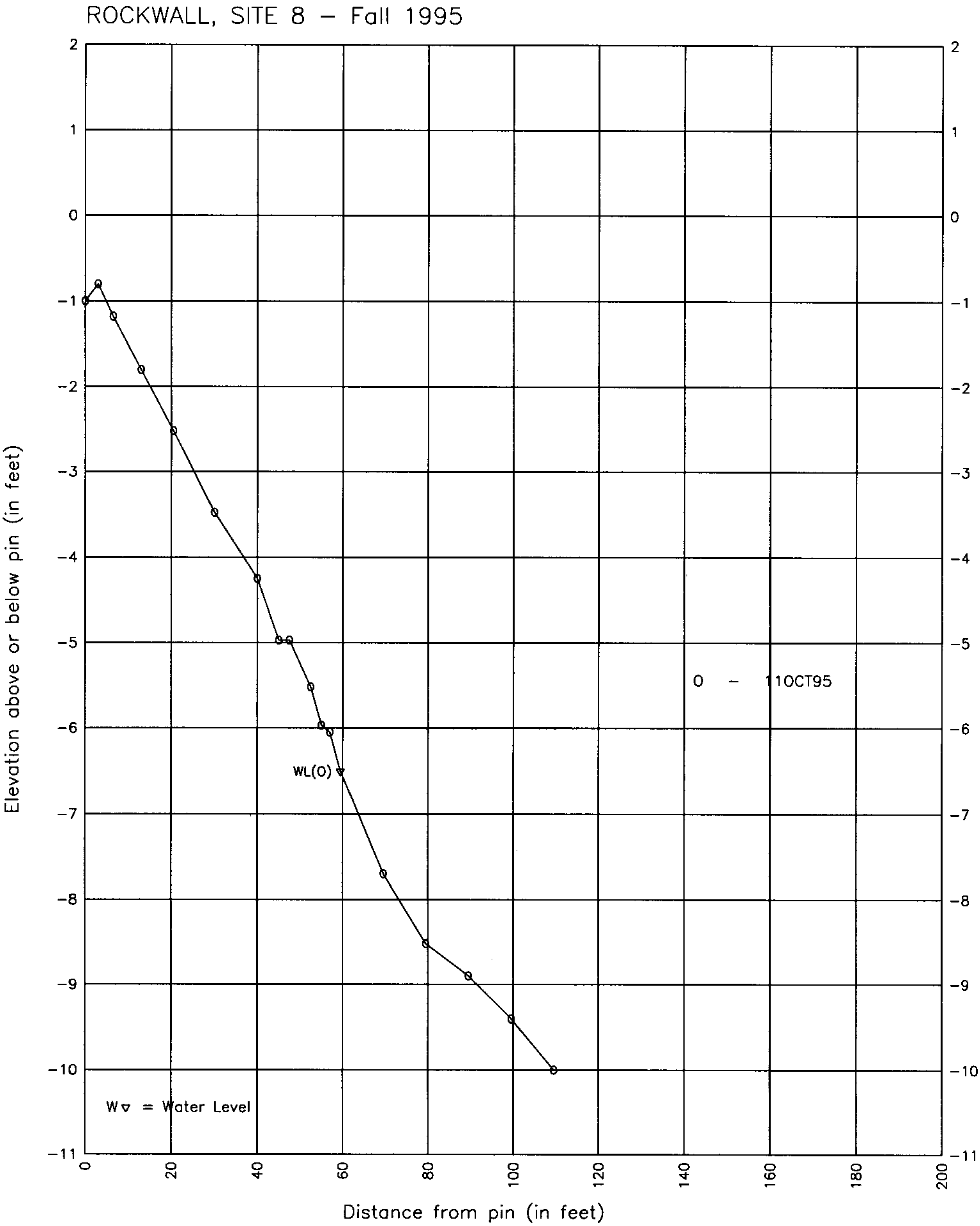
ROCKWALL, SITE 8 – Fall 1994

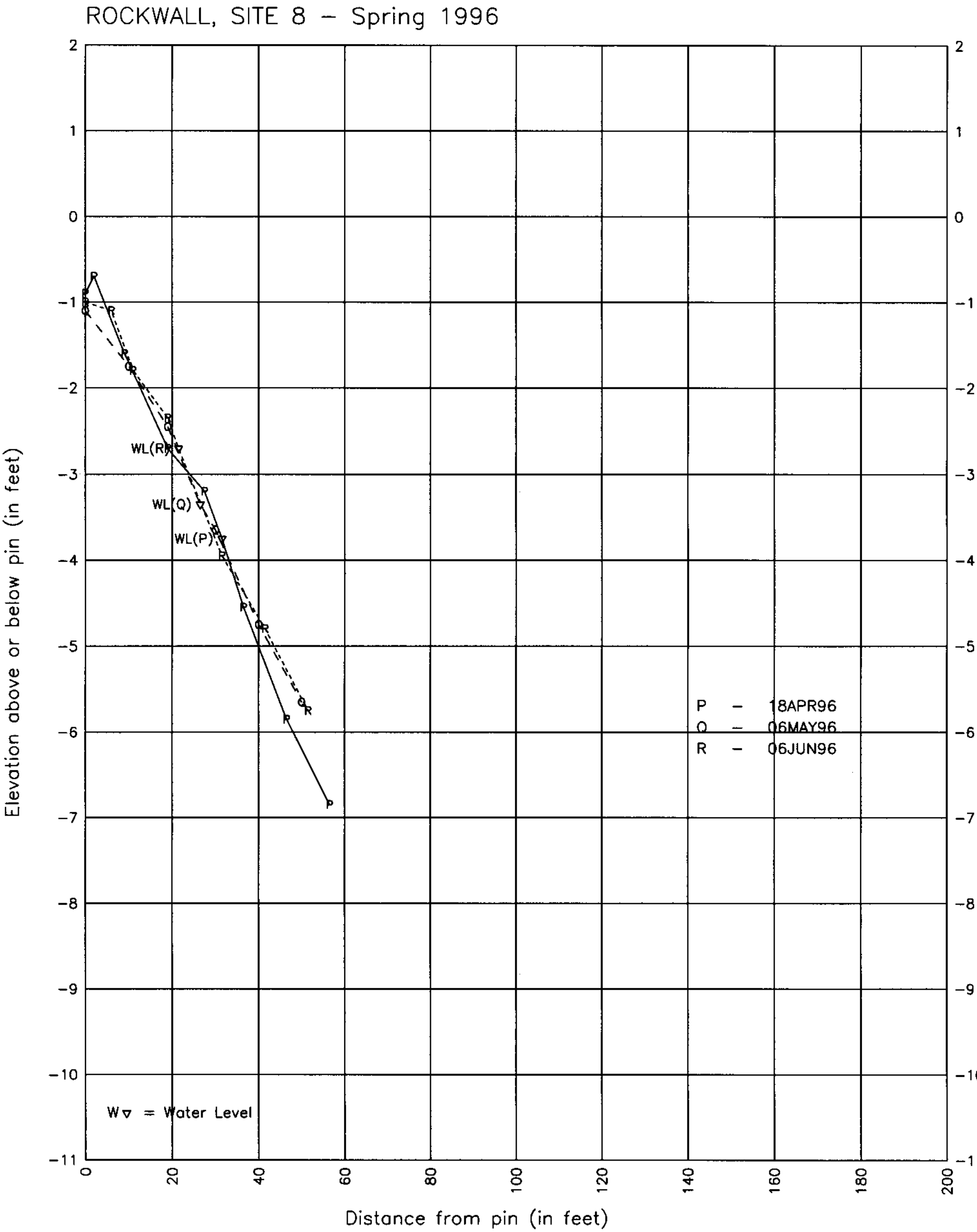


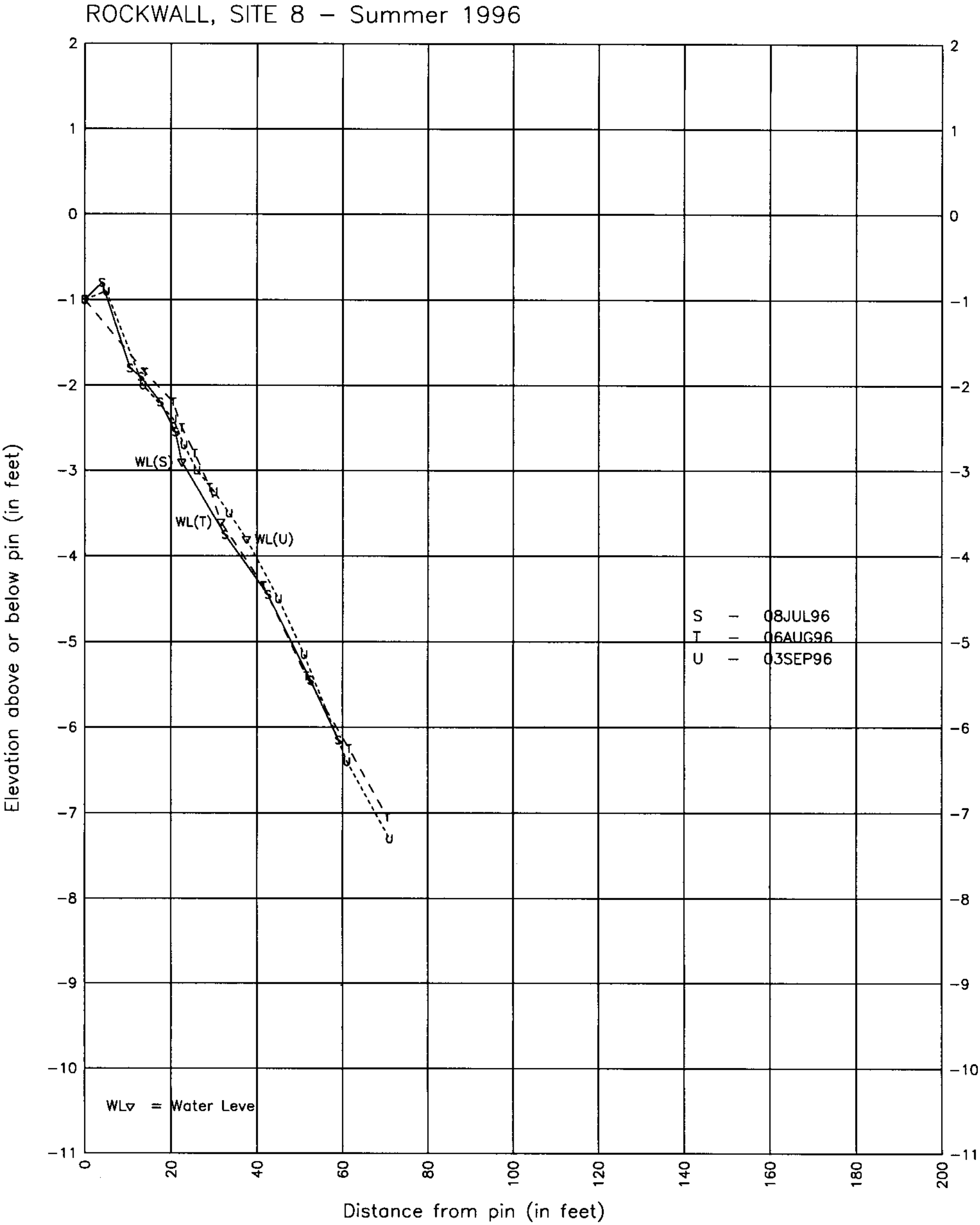

ROCKWALL, SITE 8 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
J – 02MAY95
K – 02JUN95
WL(K)
WL(J)
W▽ = Water Level



ROCKWALL, SITE 8 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200
WL(L)
WL(M)
WL(N)
L – 03JUL95
M – 07AUG95
N – 08SEP95
W▽ = Water Level

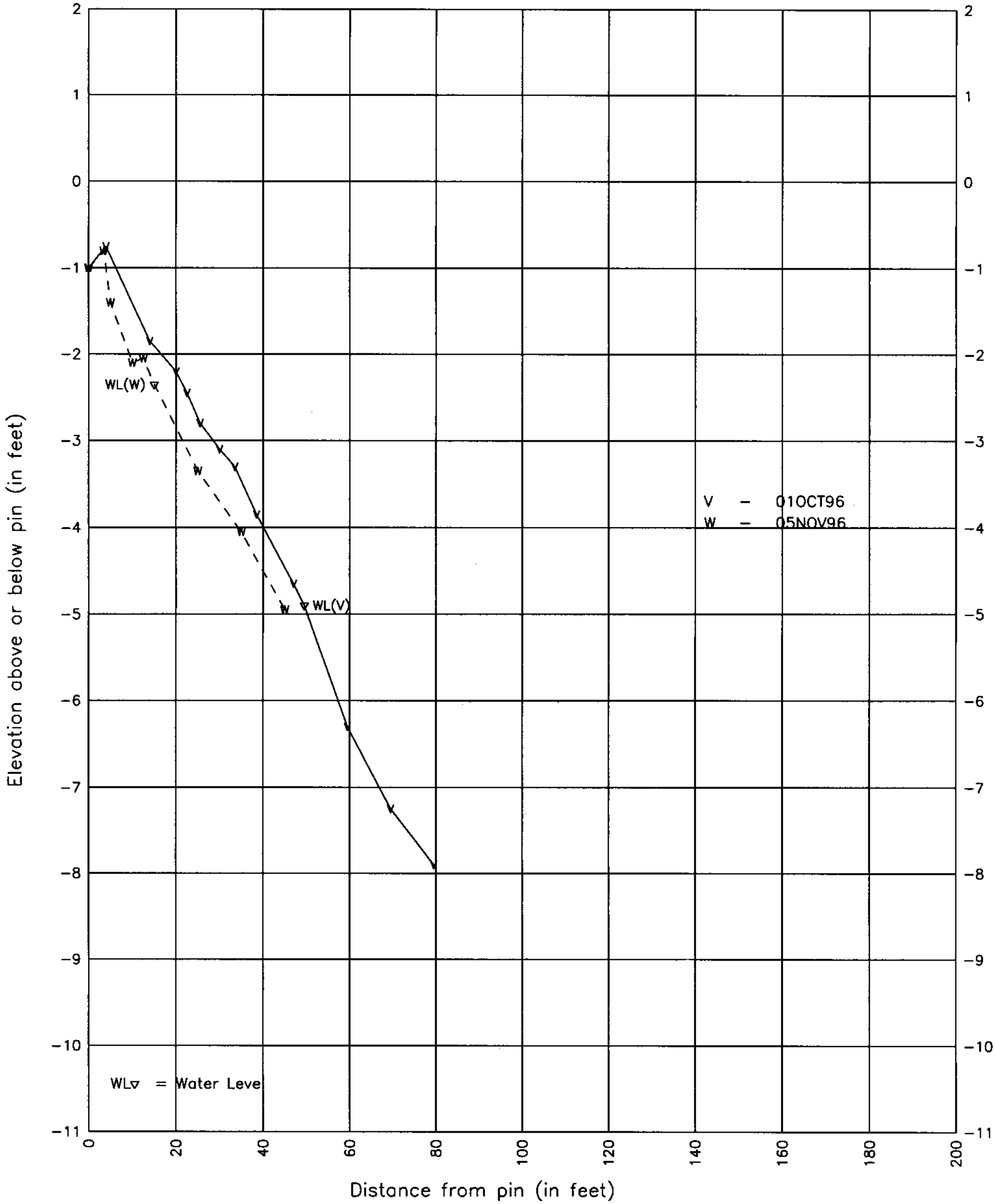

ROCKWALL, SITE 8 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
O – 11OCT95
WL(O)
W▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

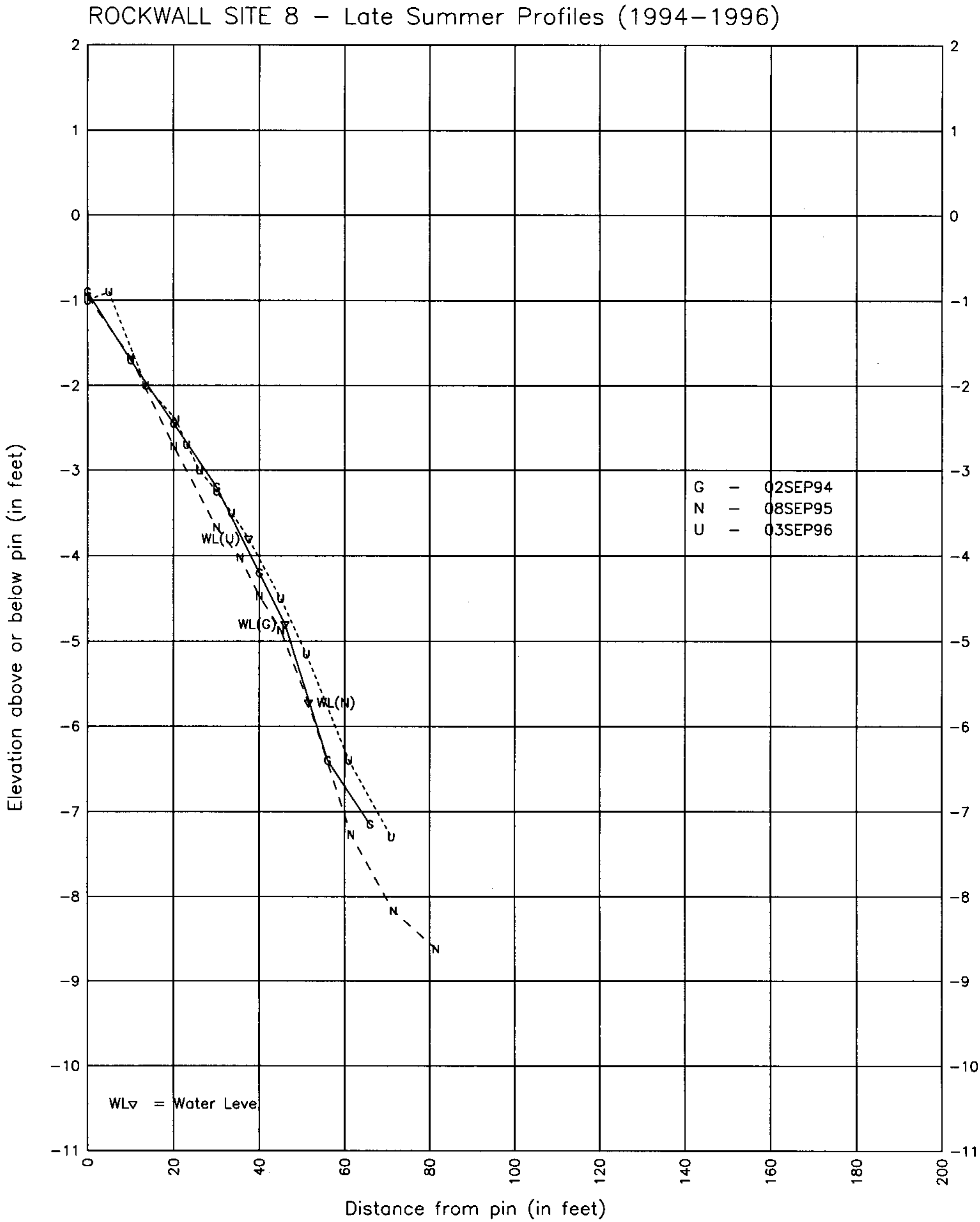

ROCKWALL, SITE 8 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(Q)
WL(P)
P – 18APR96
Q – 06MAY96
R – 06JUN96
W▽ = Water Level

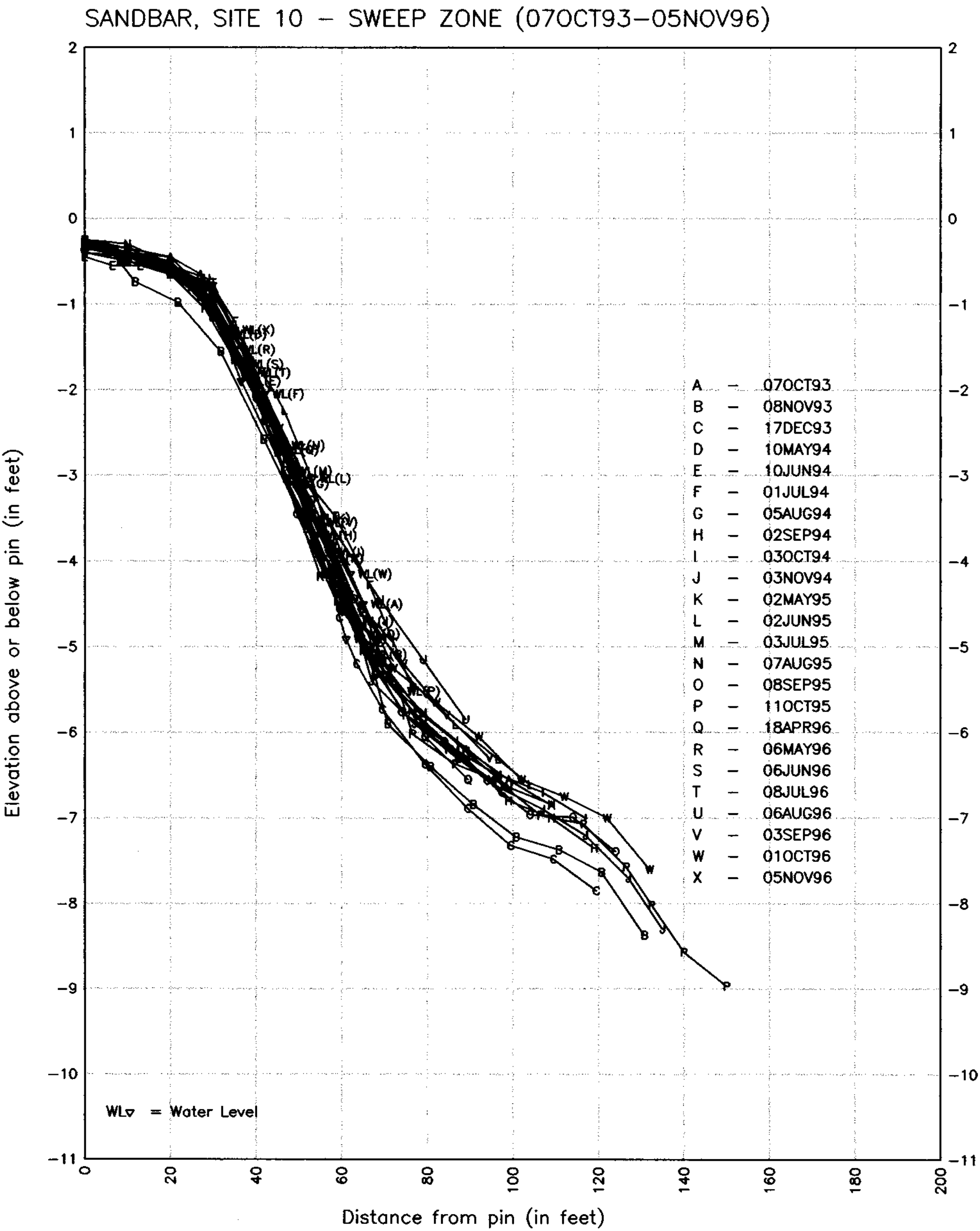


ROCKWALL, SITE 8 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
S – 08JUL96
T – 06AUG96
U – 03SEP96
WL(S)
WL(T)
WL(U)
WL▽ = Water Leve

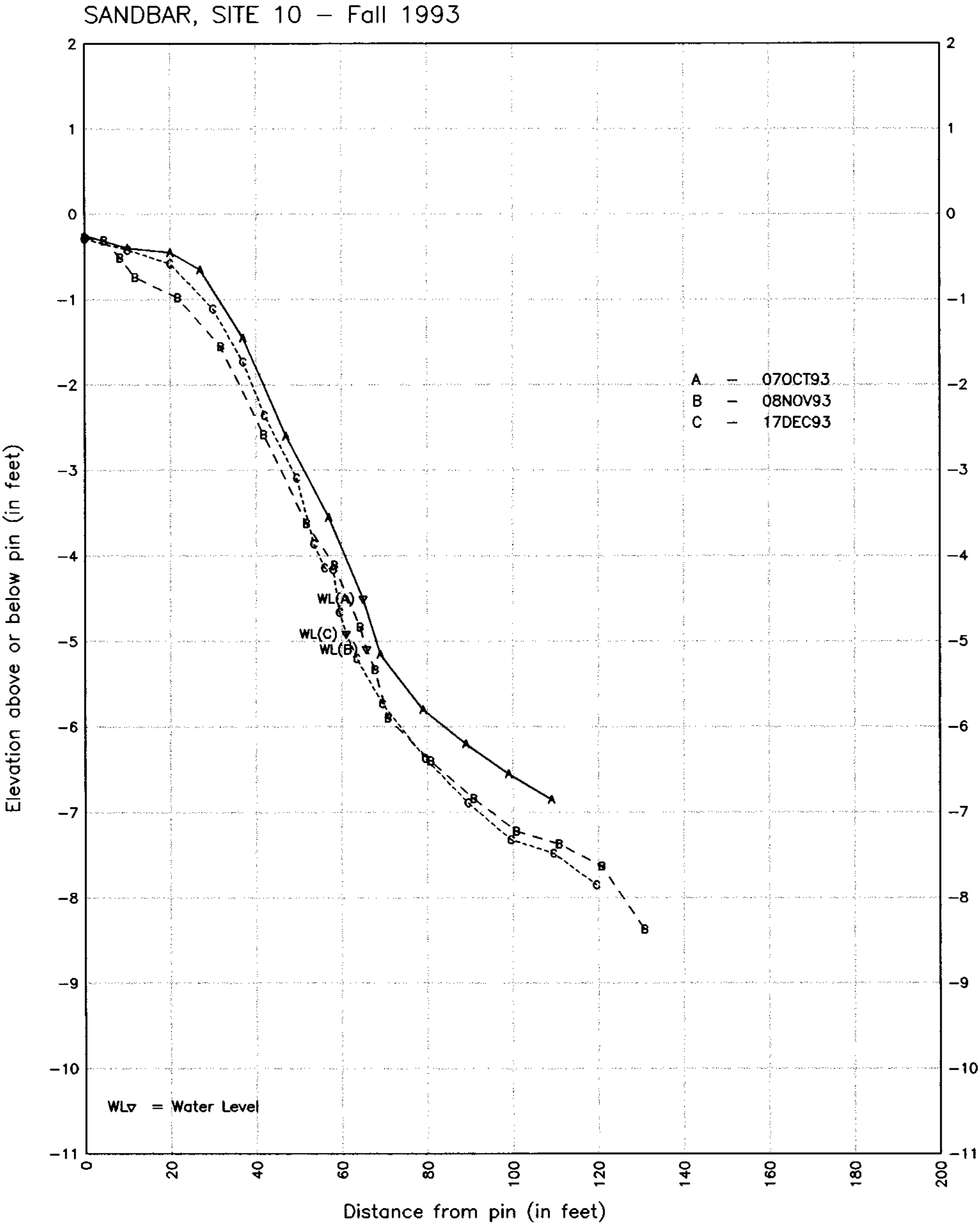
ROCKWALL, SITE 8 – Fall 1996

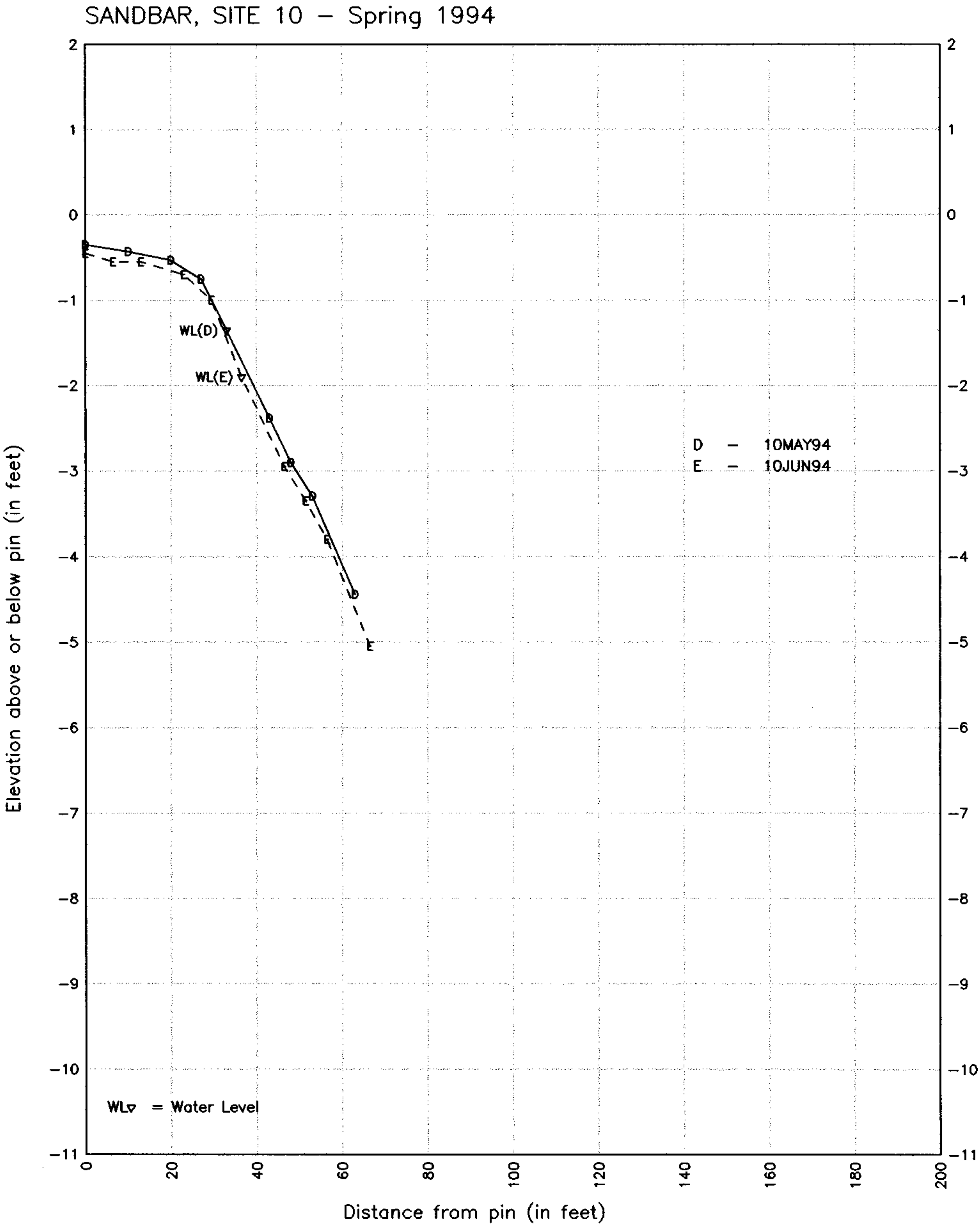



ROCKWALL SITE 8 - Late Summer Profiles (1994-1996)
Elevation above or below pin (in feet)
Distance from pin (in feet)
G - 02SEP94
N - 08SEP95
U - 03SEP96
WL(U)
WL(G)
WL(N)
WL▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

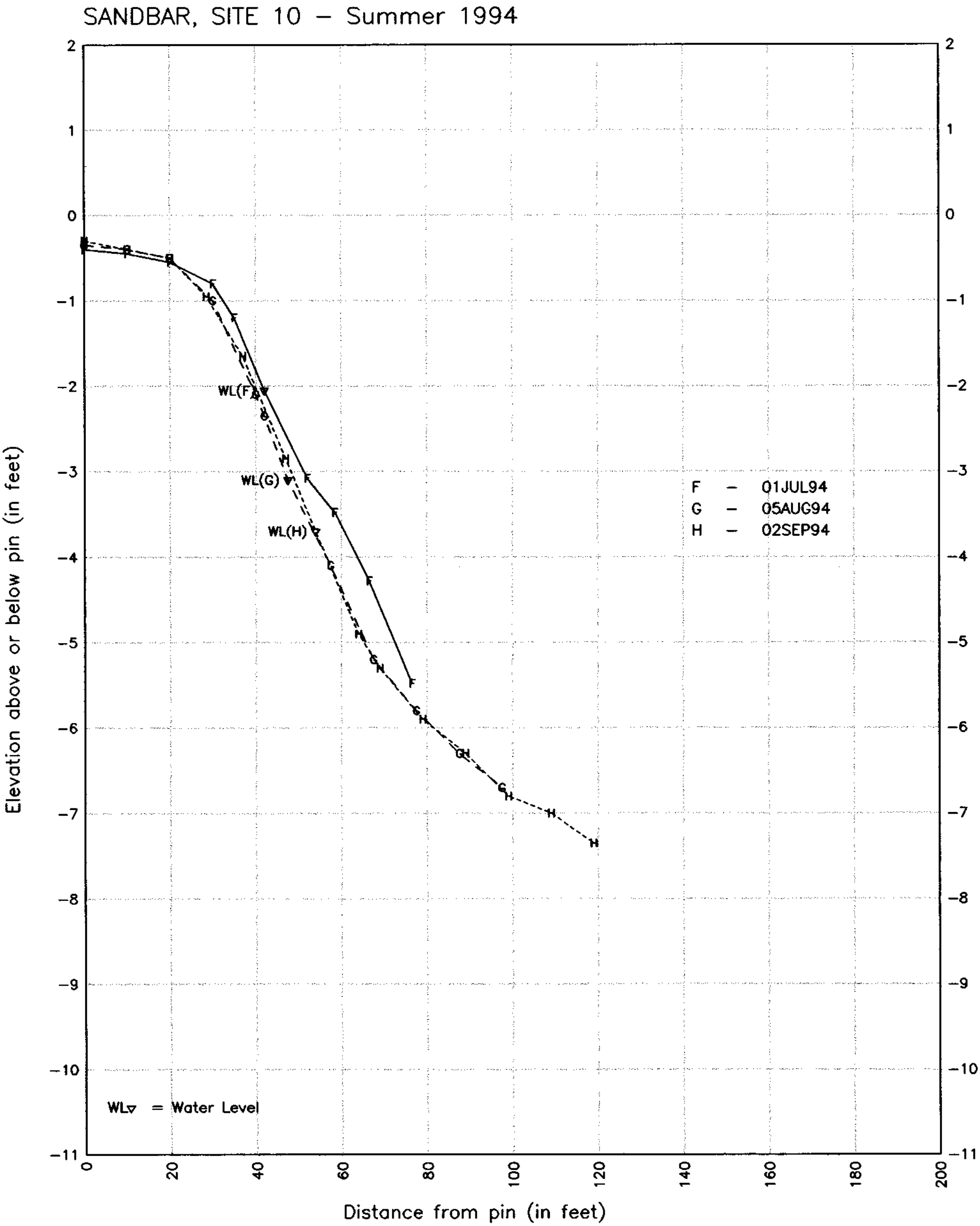


SANDBAR, SITE 10 – SWEEP ZONE (07OCT93–05NOV96)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 07OCT93
B – 08NOV93
C – 17DEC93
D – 10MAY94
E – 10JUN94
F – 01JUL94
G – 05AUG94
H – 02SEP94
I – 03OCT94
J – 03NOV94
K – 02MAY95
L – 02JUN95
M – 03JUL95
N – 07AUG95
O – 08SEP95
P – 11OCT95
Q – 18APR96
R – 06MAY96
S – 06JUN96
T – 08JUL96
U – 06AUG96
V – 03SEP96
W – 01OCT96
X – 05NOV96
WL▽ = Water Level

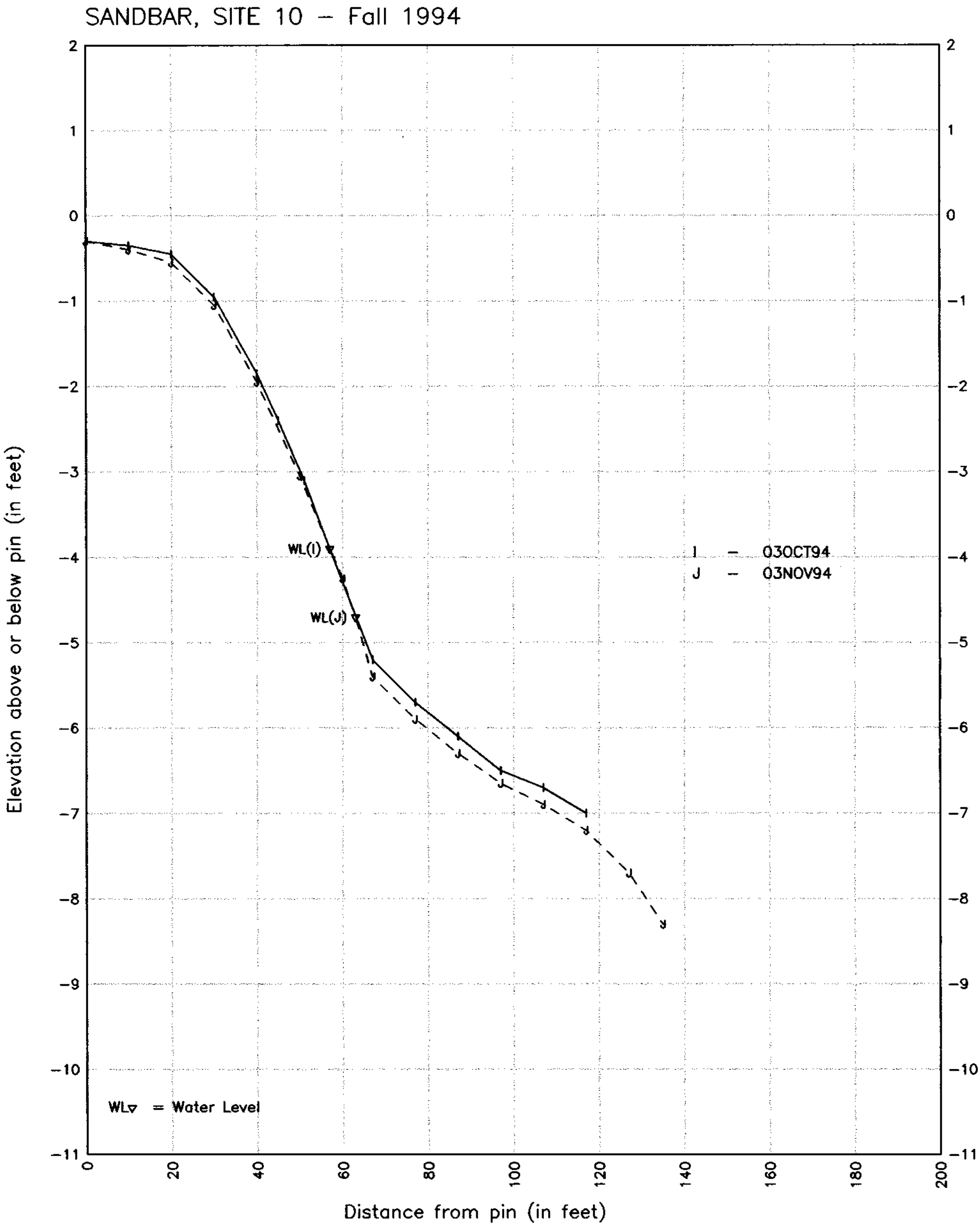

SANDBAR, SITE 10 – Fall 1993
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 07OCT93
B – 08NOV93
C – 17DEC93
WL(A)
WL(B)
WL(C)
WL▽ = Water Level
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

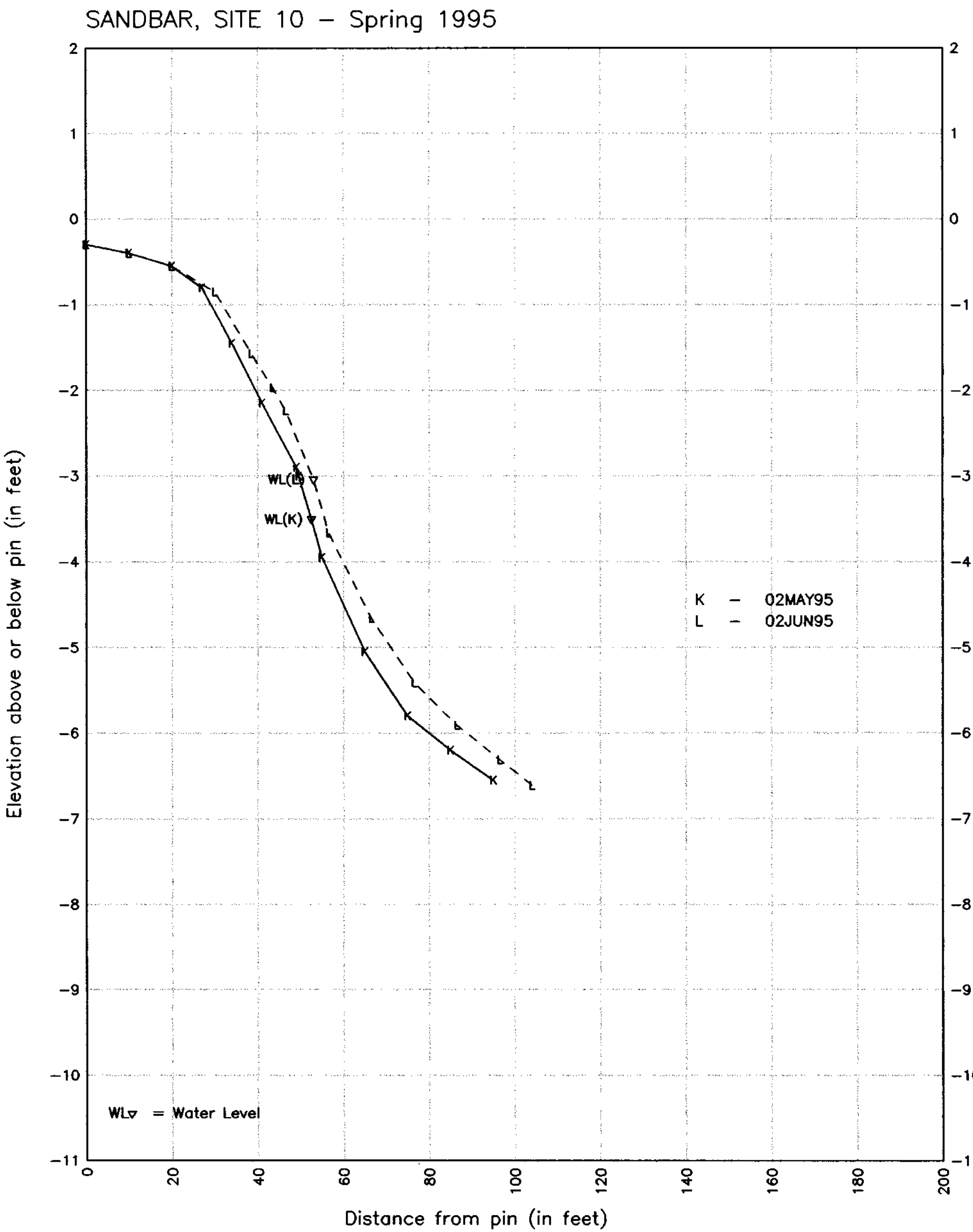


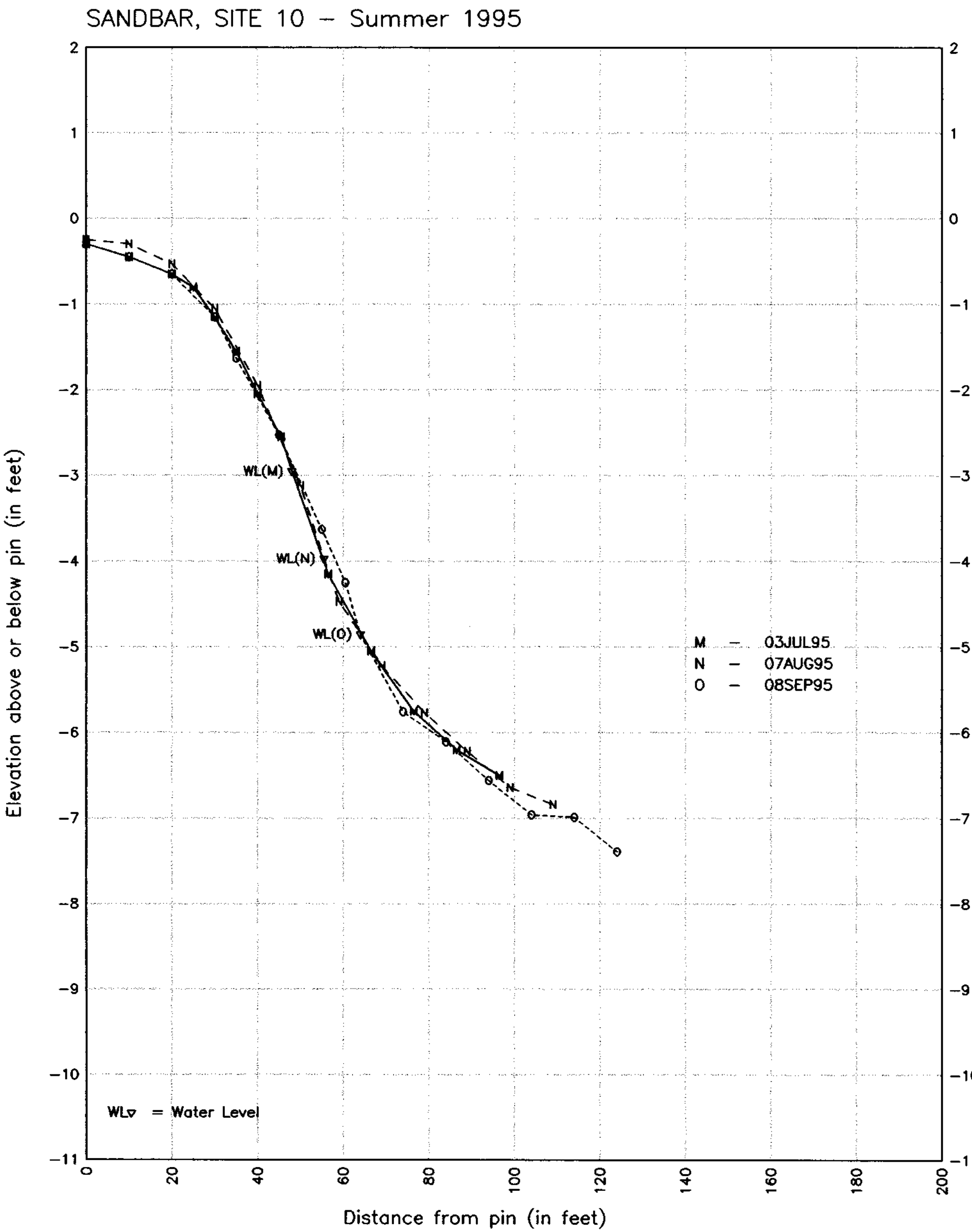
SANDBAR, SITE 10 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
D – 10MAY94
E – 10JUN94
WL(D)
WL(E)
WL▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

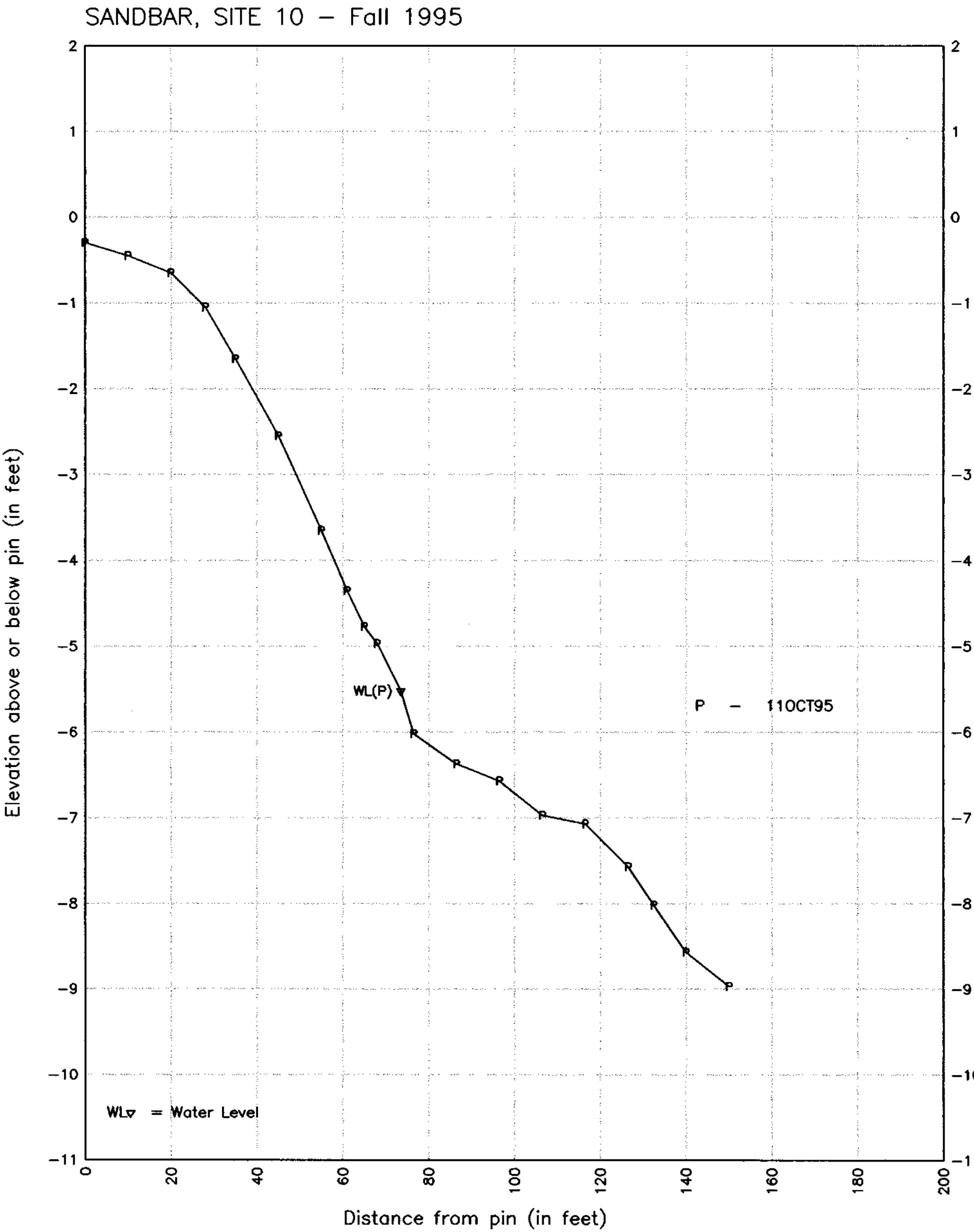


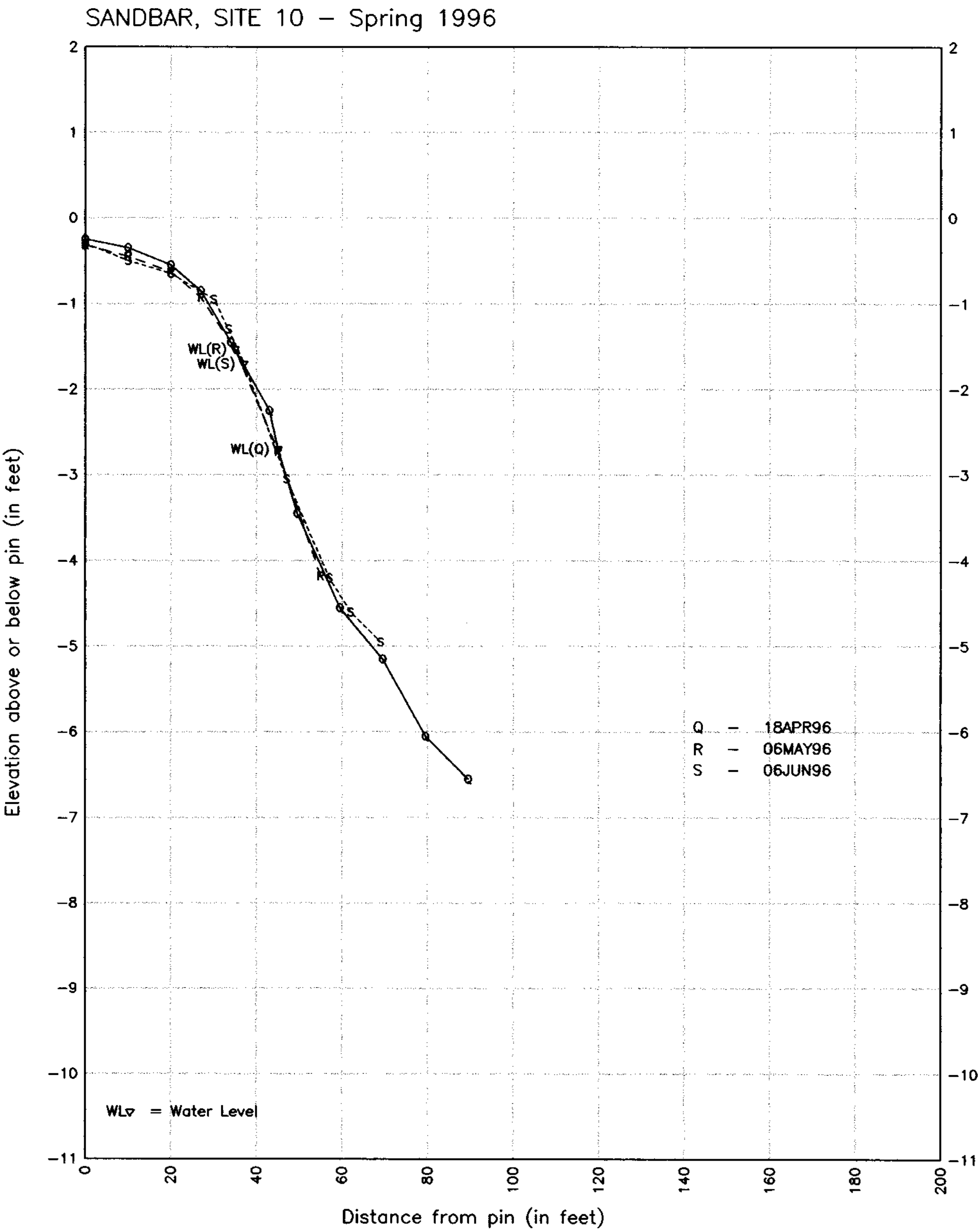
SANDBAR, SITE 10 – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
F – 01JUL94
G – 05AUG94
H – 02SEP94
WL(F)
WL(G)
WL(H)
WL▽ = Water Level


SANDBAR, SITE 10 – Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(I)
WL(J)
I – 03OCT94
J – 03NOV94
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

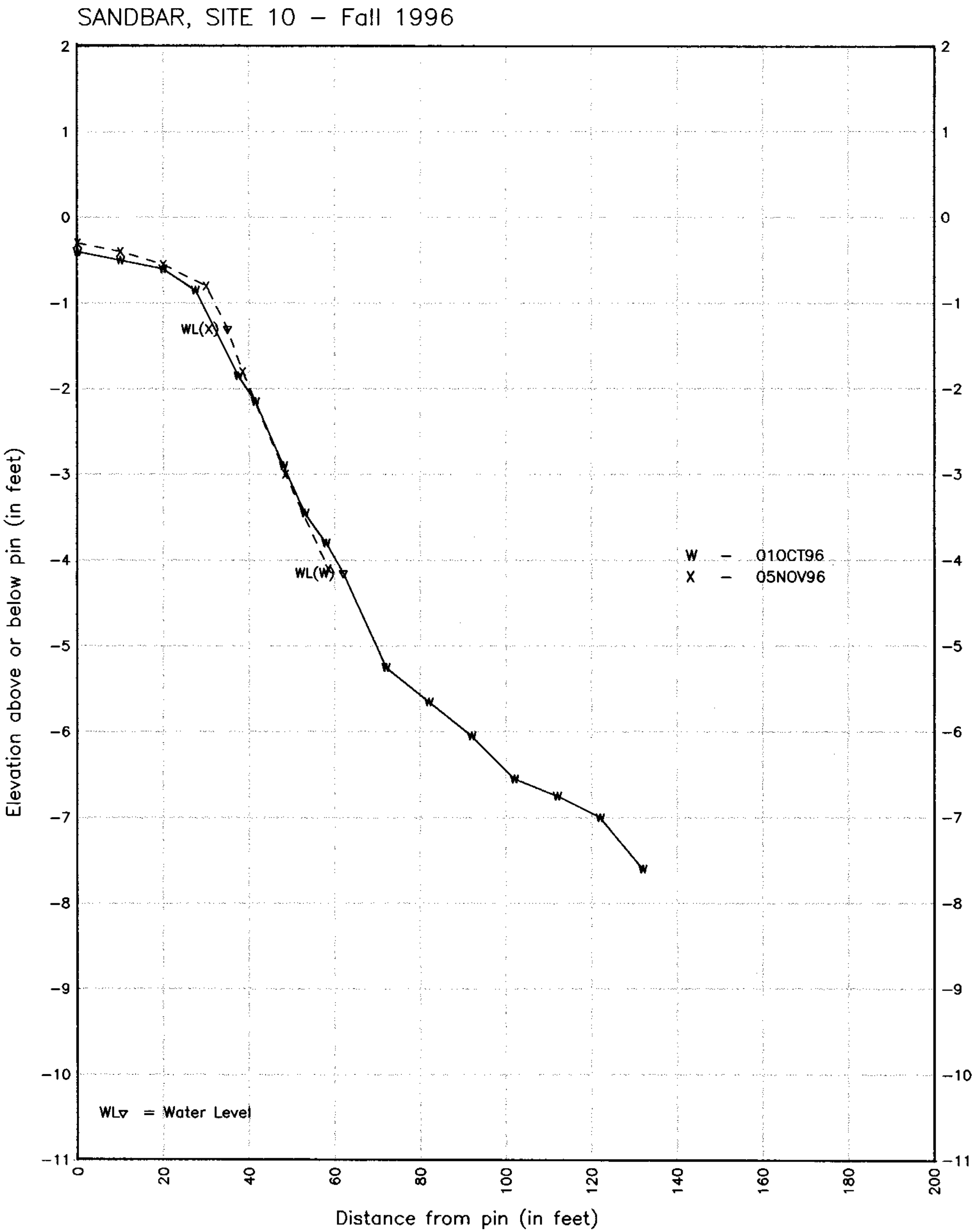

SANDBAR, SITE 10 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200
WL(L)
WL(K)
K – 02MAY95
L – 02JUN95
WL▽ = Water Level


SANDBAR, SITE 10 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(M)
WL(N)
WL(O)
M – 03JUL95
N – 07AUG95
O – 08SEP95
WL▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

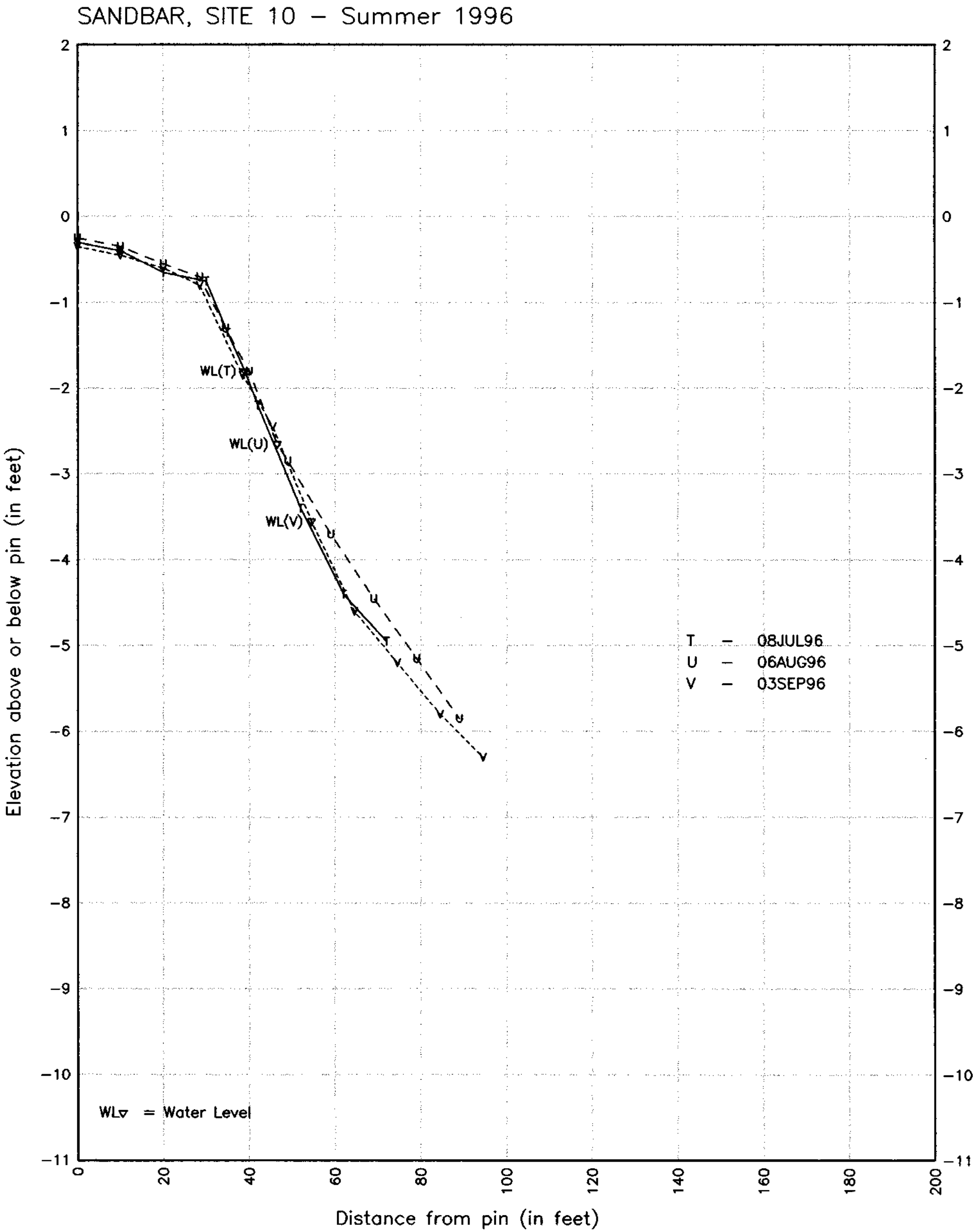

SANDBAR, SITE 10 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(P)
P – 11OCT95
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

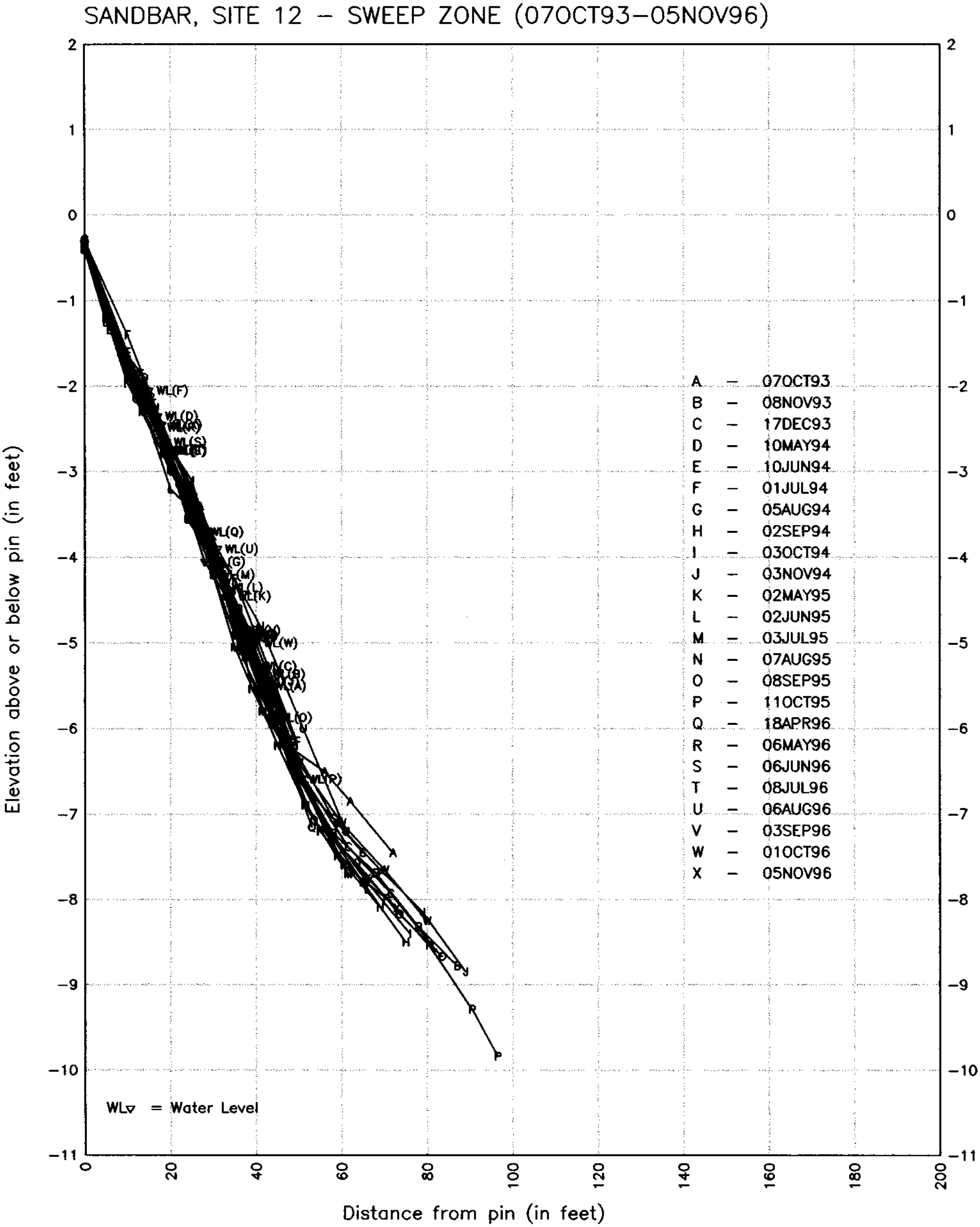


SANDBAR, SITE 10 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(S)
WL(Q)
Q – 18APR96
R – 06MAY96
S – 06JUN96
WL▽ = Water Level

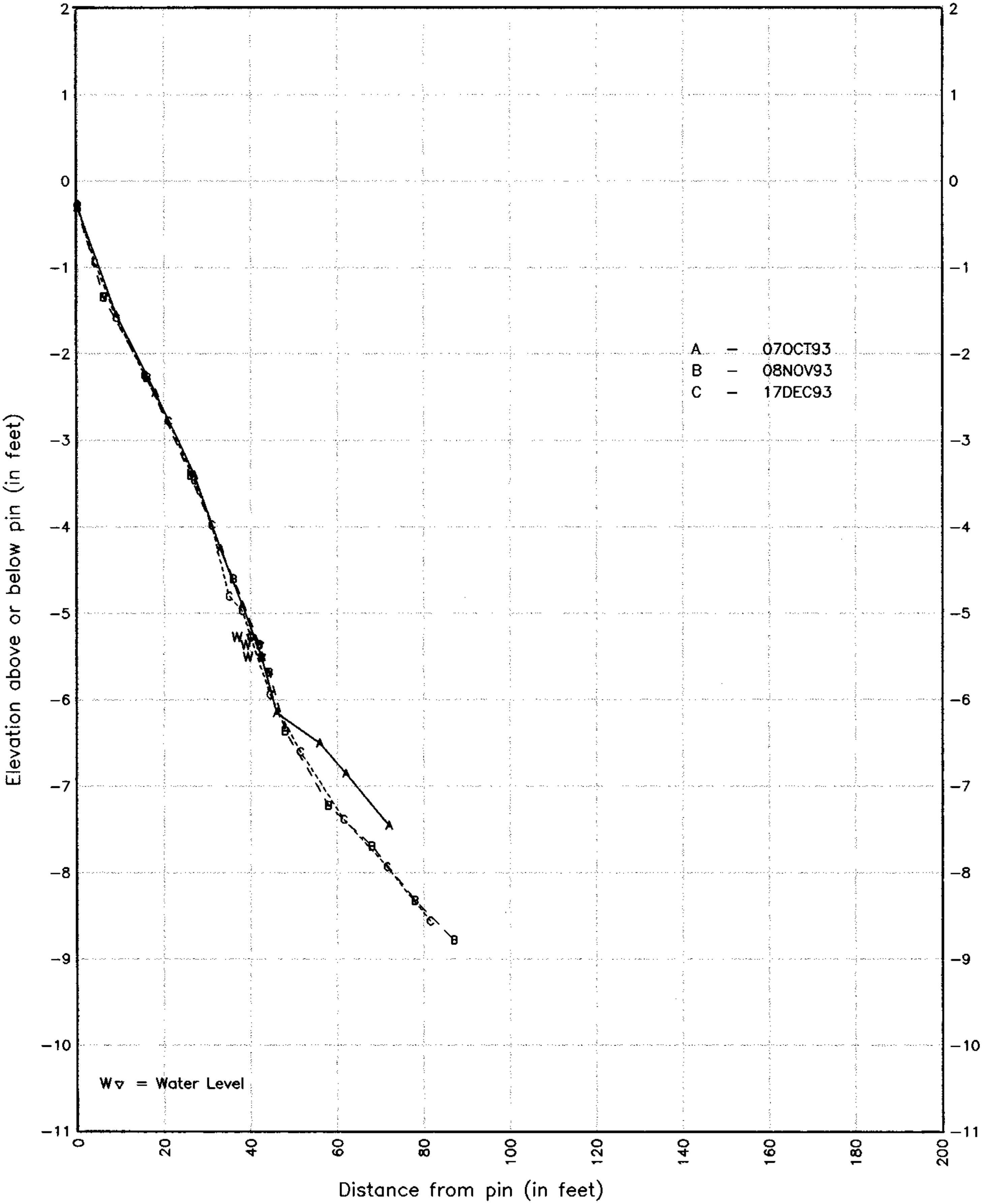


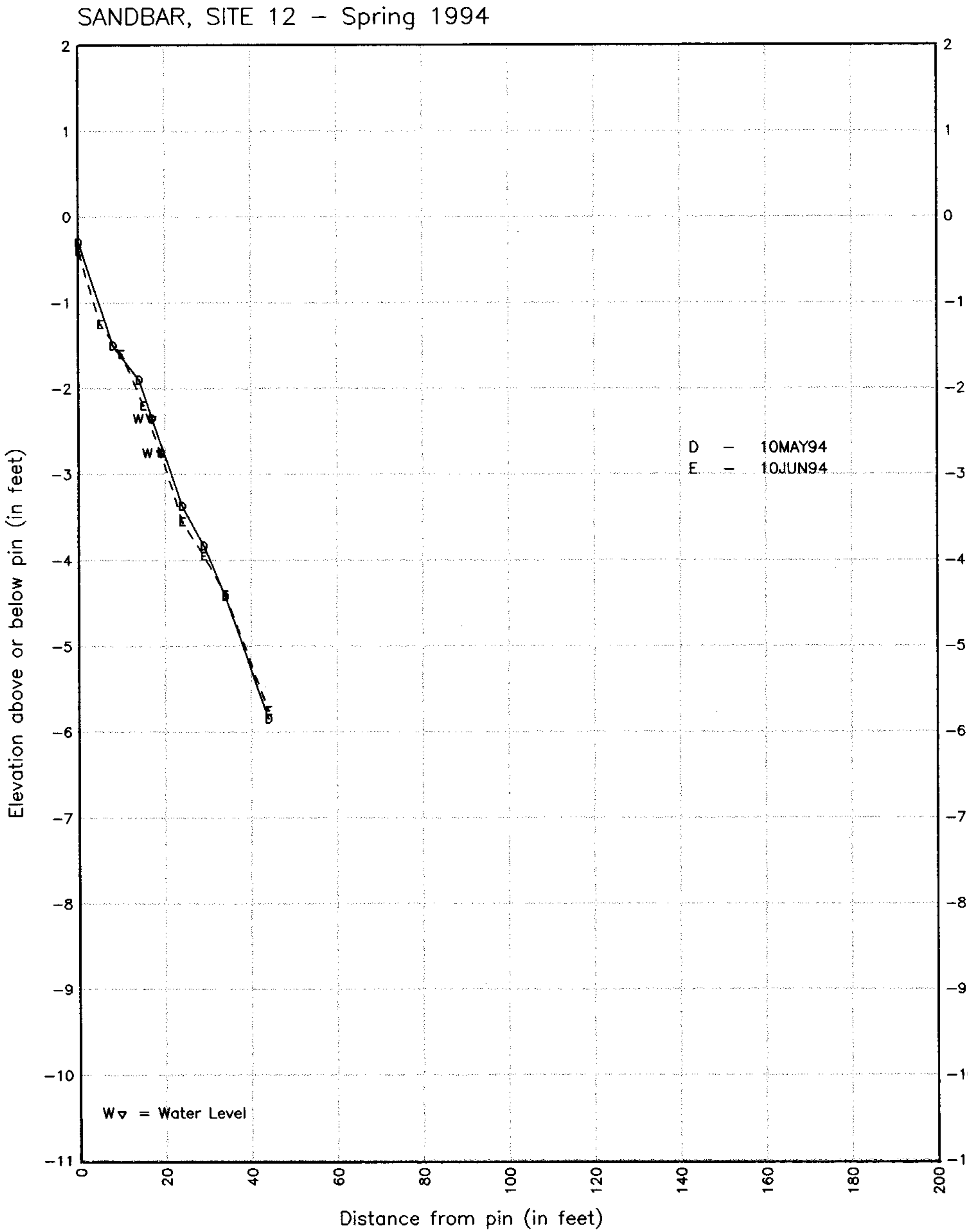
SANDBAR, SITE 10 - Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(X)
WL(W)
W - 01OCT96
X - 05NOV96
WL▽ = Water Level

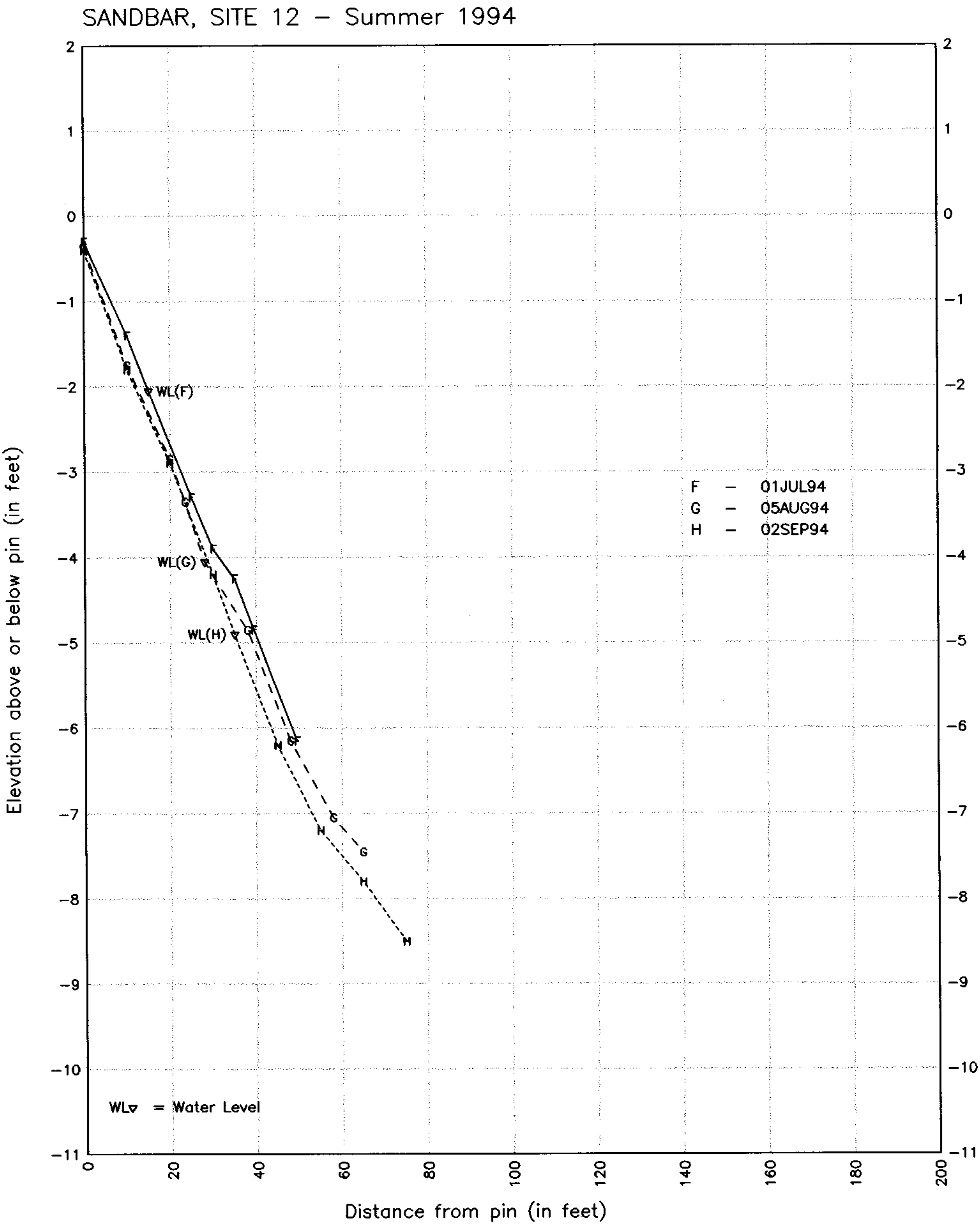

SANDBAR, SITE 10 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(T)
WL(U)
WL(V)
T – 08JUL96
U – 06AUG96
V – 03SEP96
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

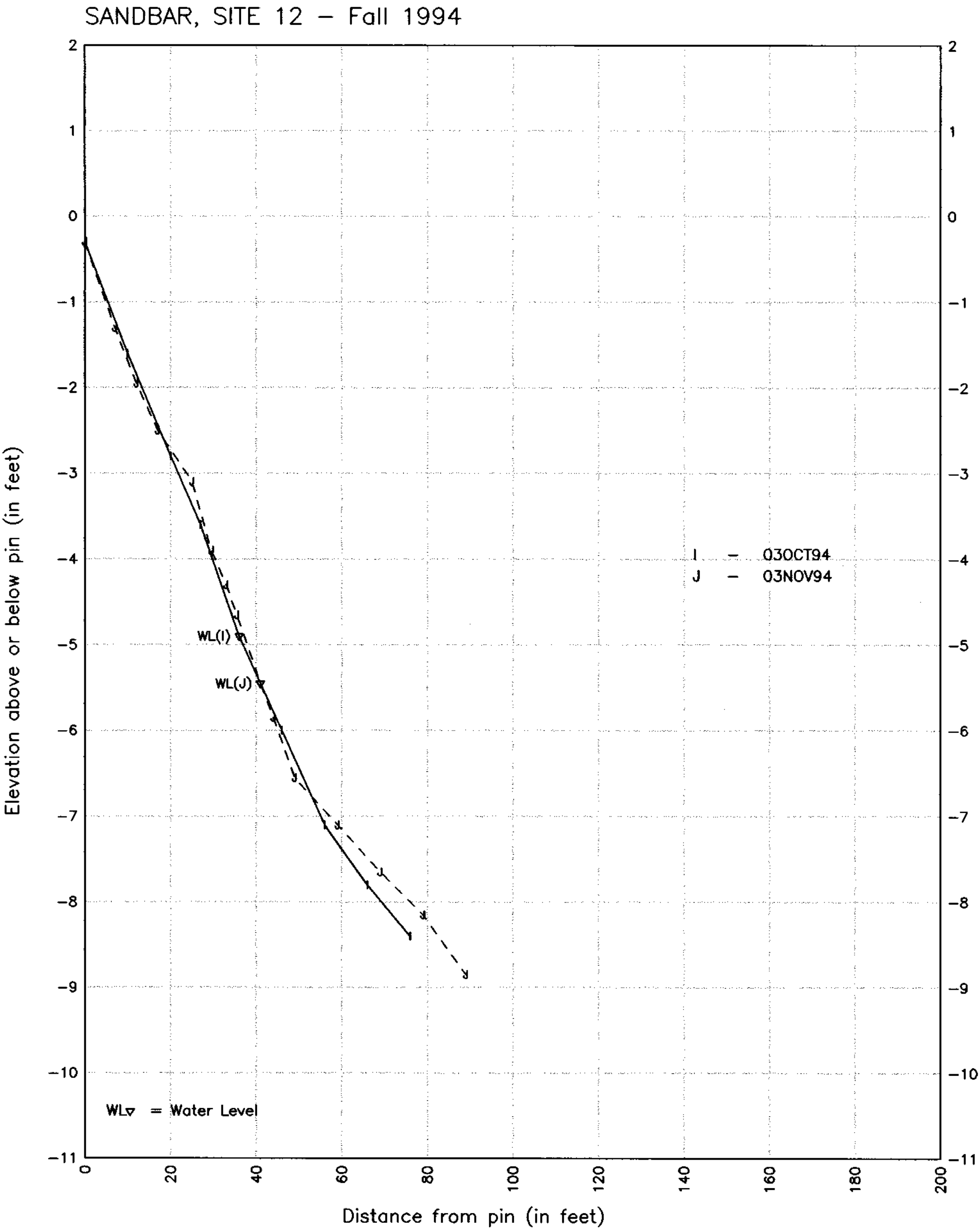

SANDBAR, SITE 12 – SWEEP ZONE (07OCT93–05NOV96)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 07OCT93
B – 08NOV93
C – 17DEC93
D – 10MAY94
E – 10JUN94
F – 01JUL94
G – 05AUG94
H – 02SEP94
I – 03OCT94
J – 03NOV94
K – 02MAY95
L – 02JUN95
M – 03JUL95
N – 07AUG95
O – 08SEP95
P – 11OCT95
Q – 18APR96
R – 06MAY96
S – 06JUN96
T – 08JUL96
U – 06AUG96
V – 03SEP96
W – 01OCT96
X – 05NOV96
WL▽ = Water Level

SANDBAR, SITE 12 – Fall 1993

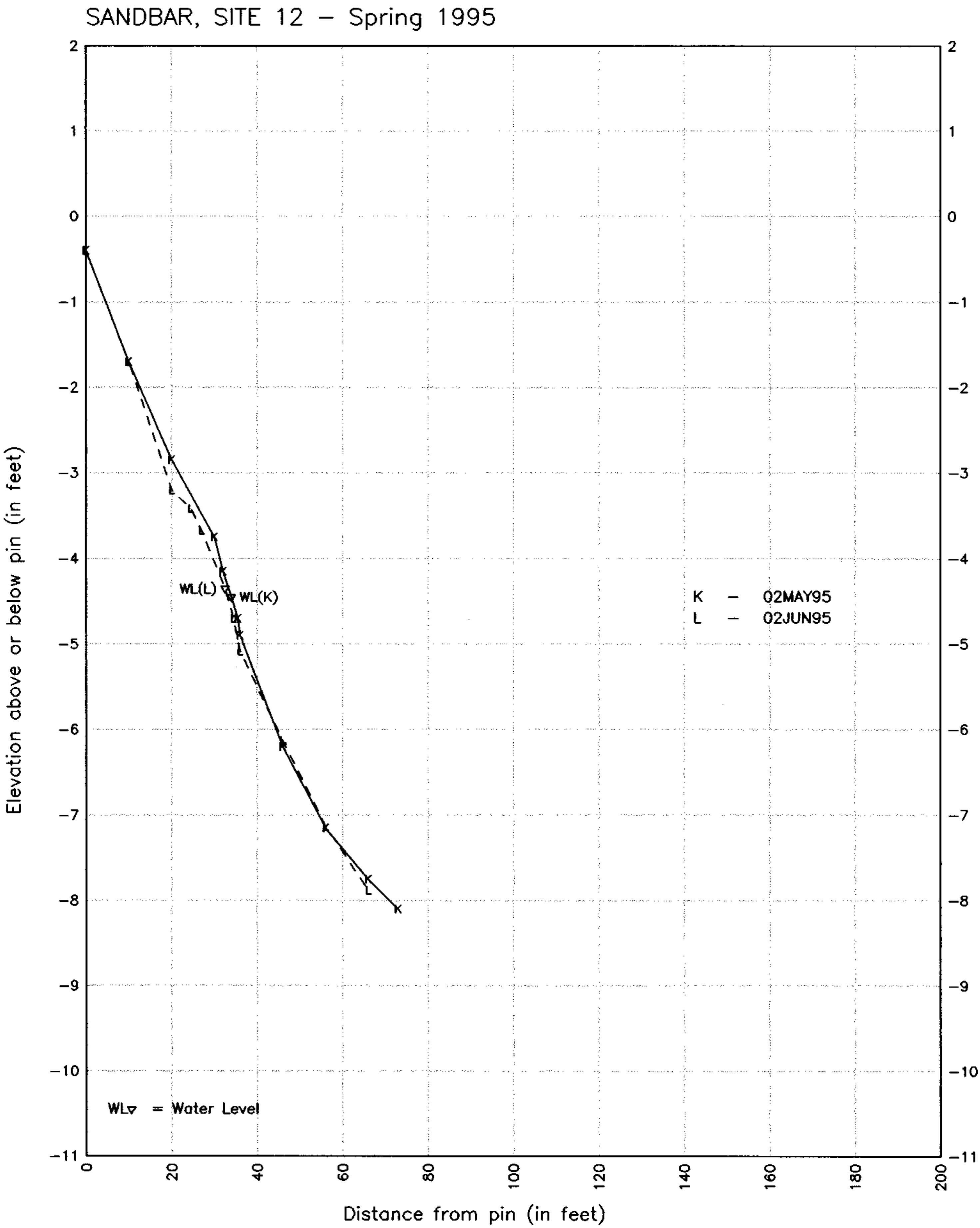



SANDBAR, SITE 12 - Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
D - 10MAY94
E - 10JUN94
W▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

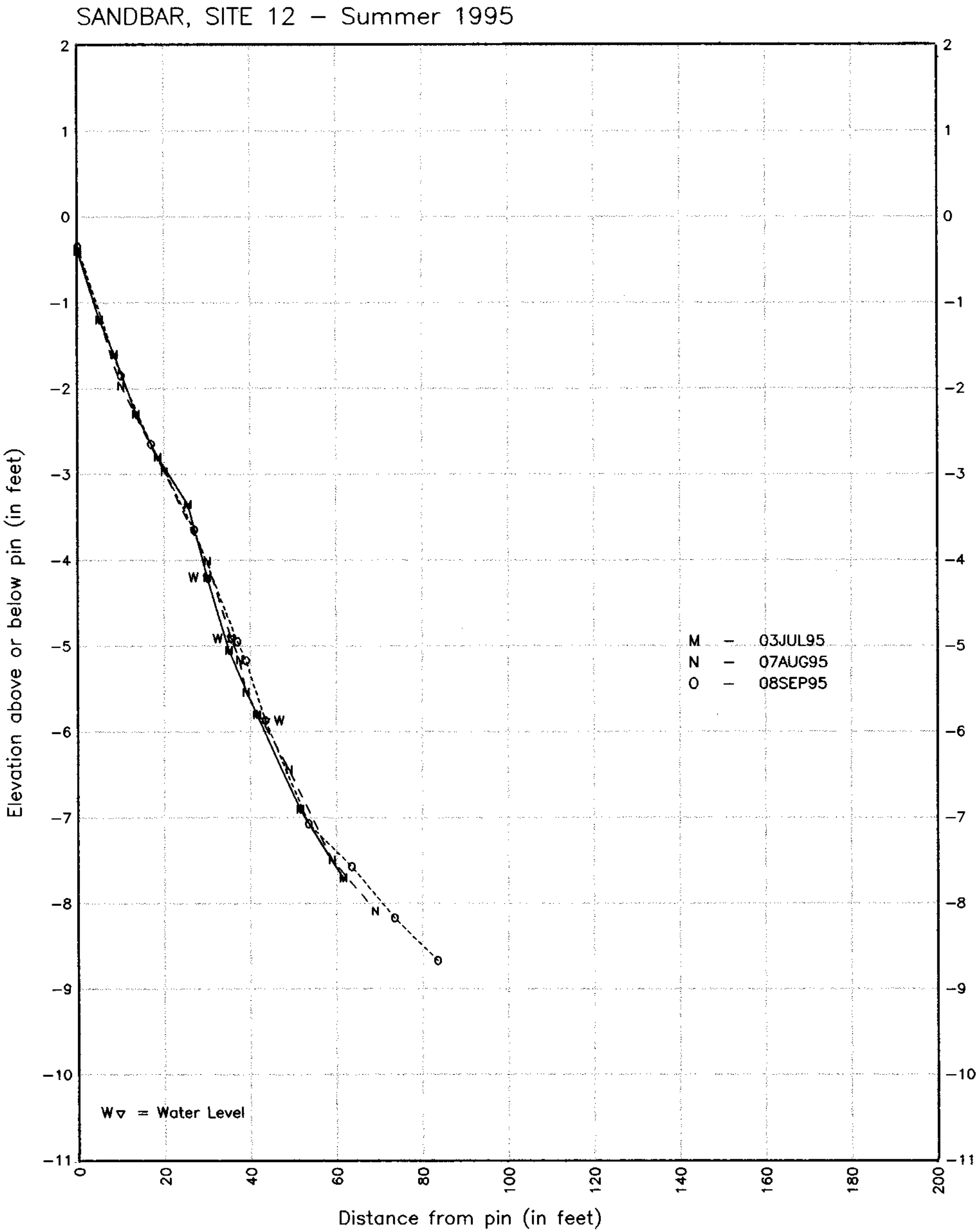

SANDBAR, SITE 12 – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(F)
WL(G)
WL(H)
F – 01JUL94
G – 05AUG94
H – 02SEP94
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

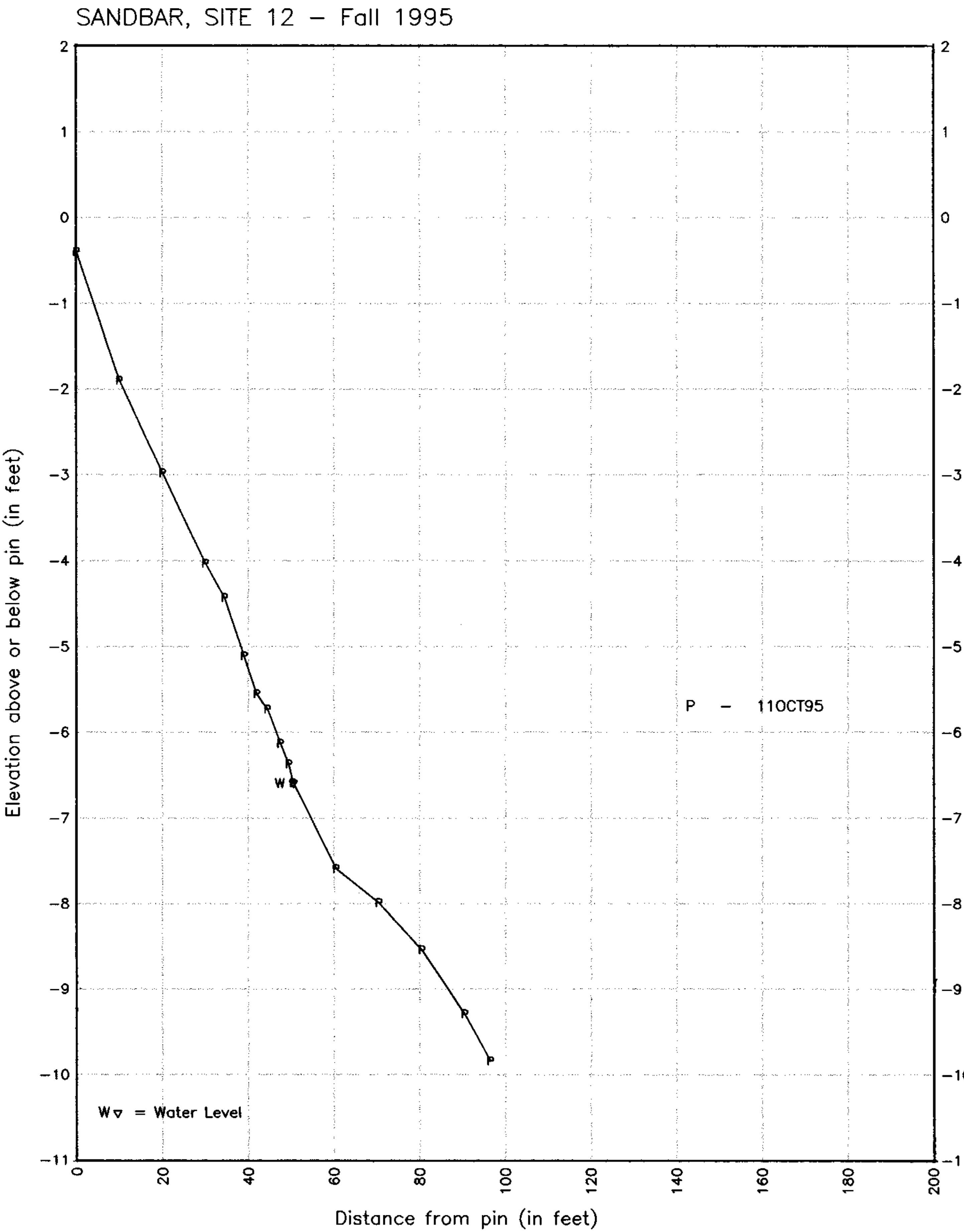


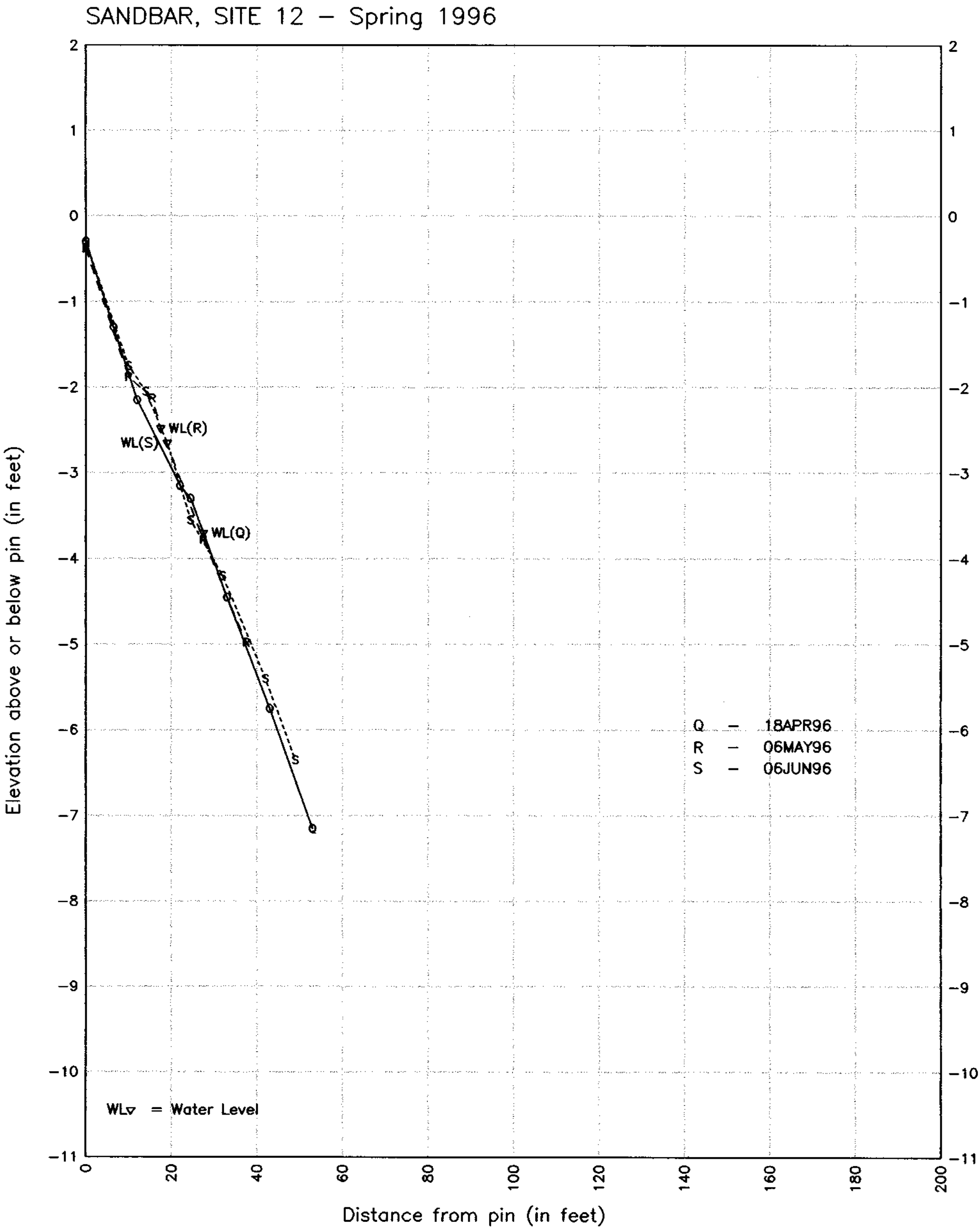
SANDBAR, SITE 12 – Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200
I – 03OCT94
J – 03NOV94
WL(I)
WL(J)
WL▽ = Water Level



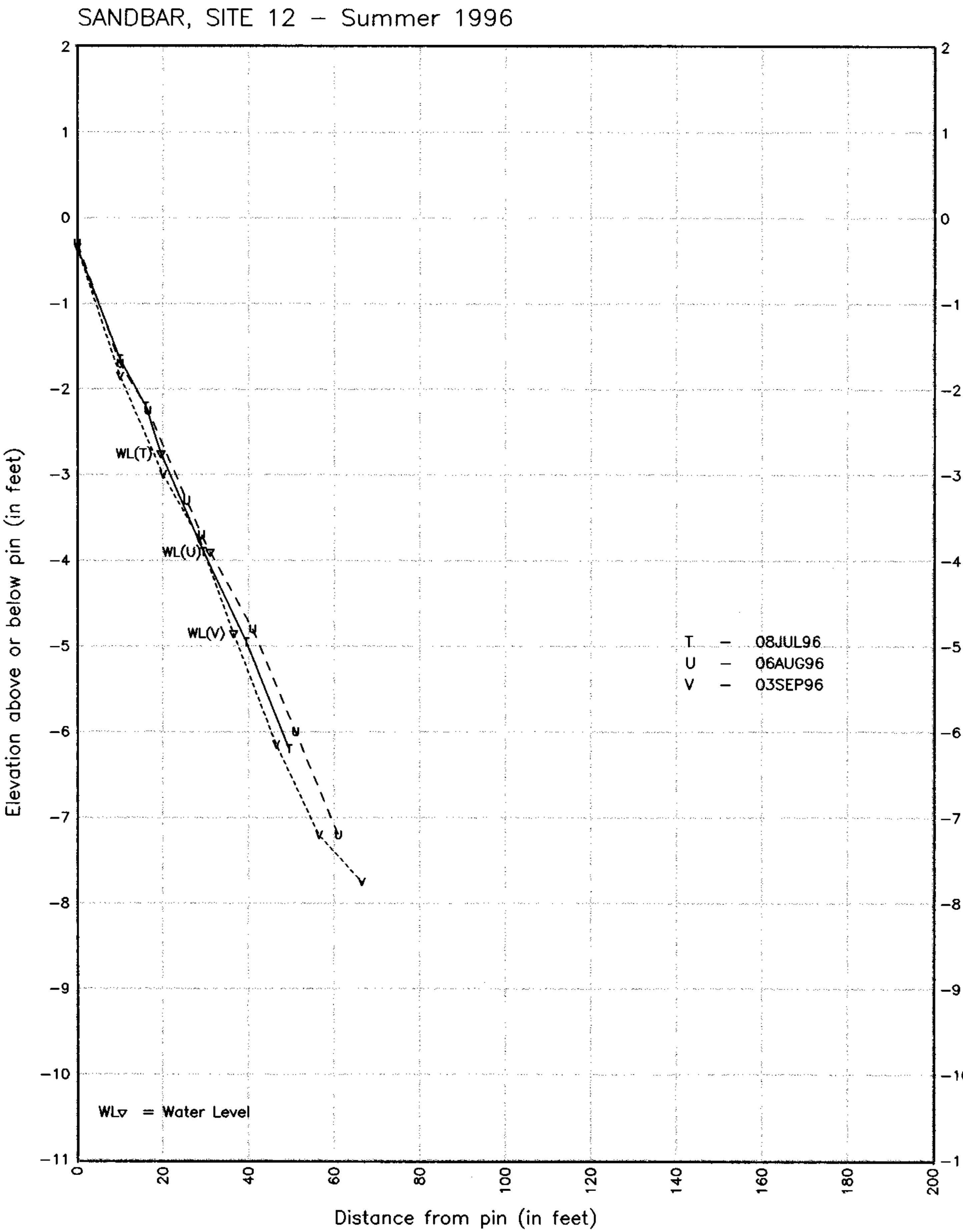
SANDBAR, SITE 12 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(L)
WL(K)
K – 02MAY95
L – 02JUN95
WL▽ = Water Level


SANDBAR, SITE 12 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
M – 03JUL95
N – 07AUG95
O – 08SEP95
W▽ = Water Level

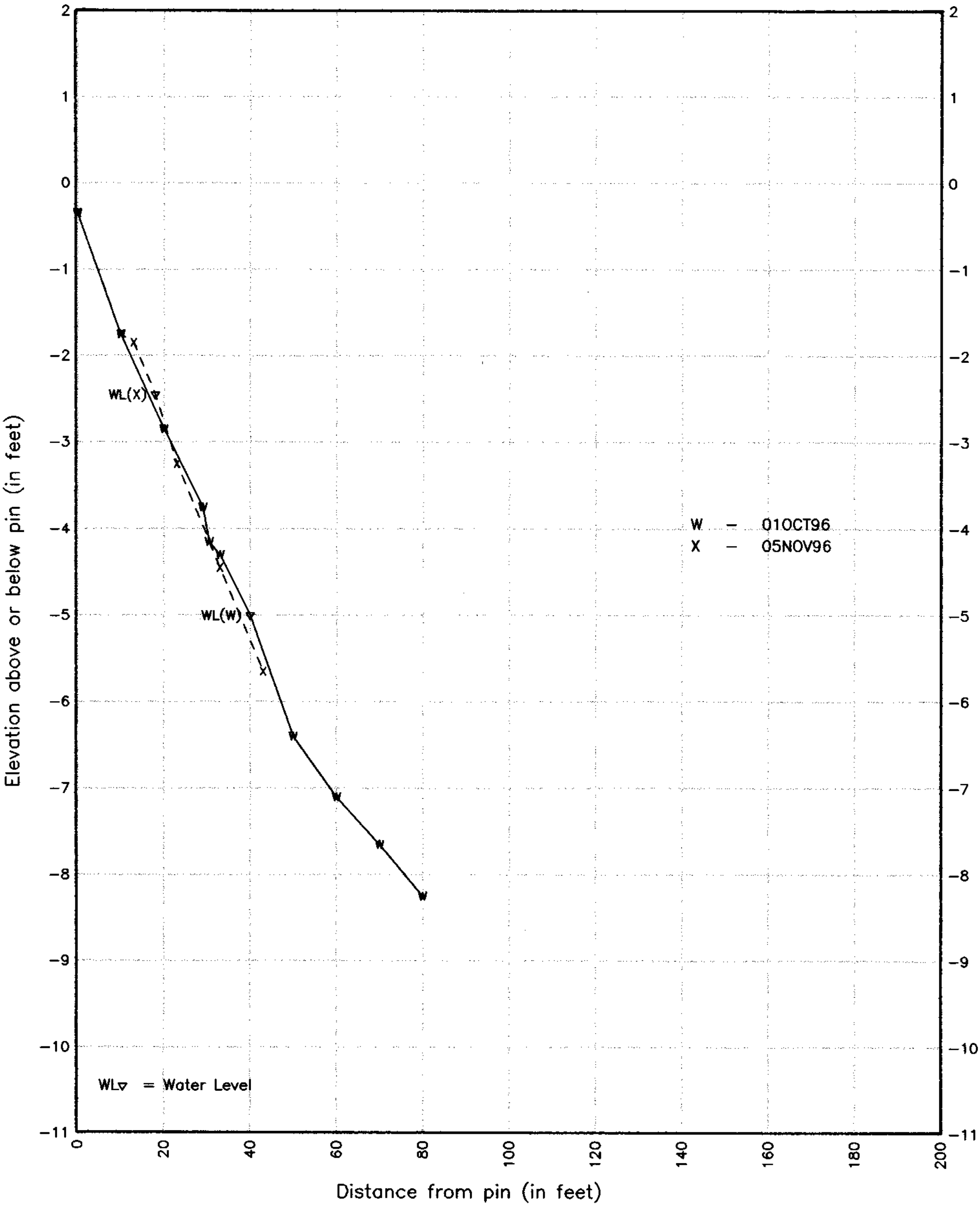

SANDBAR, SITE 12 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
P – 11OCT95
W▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

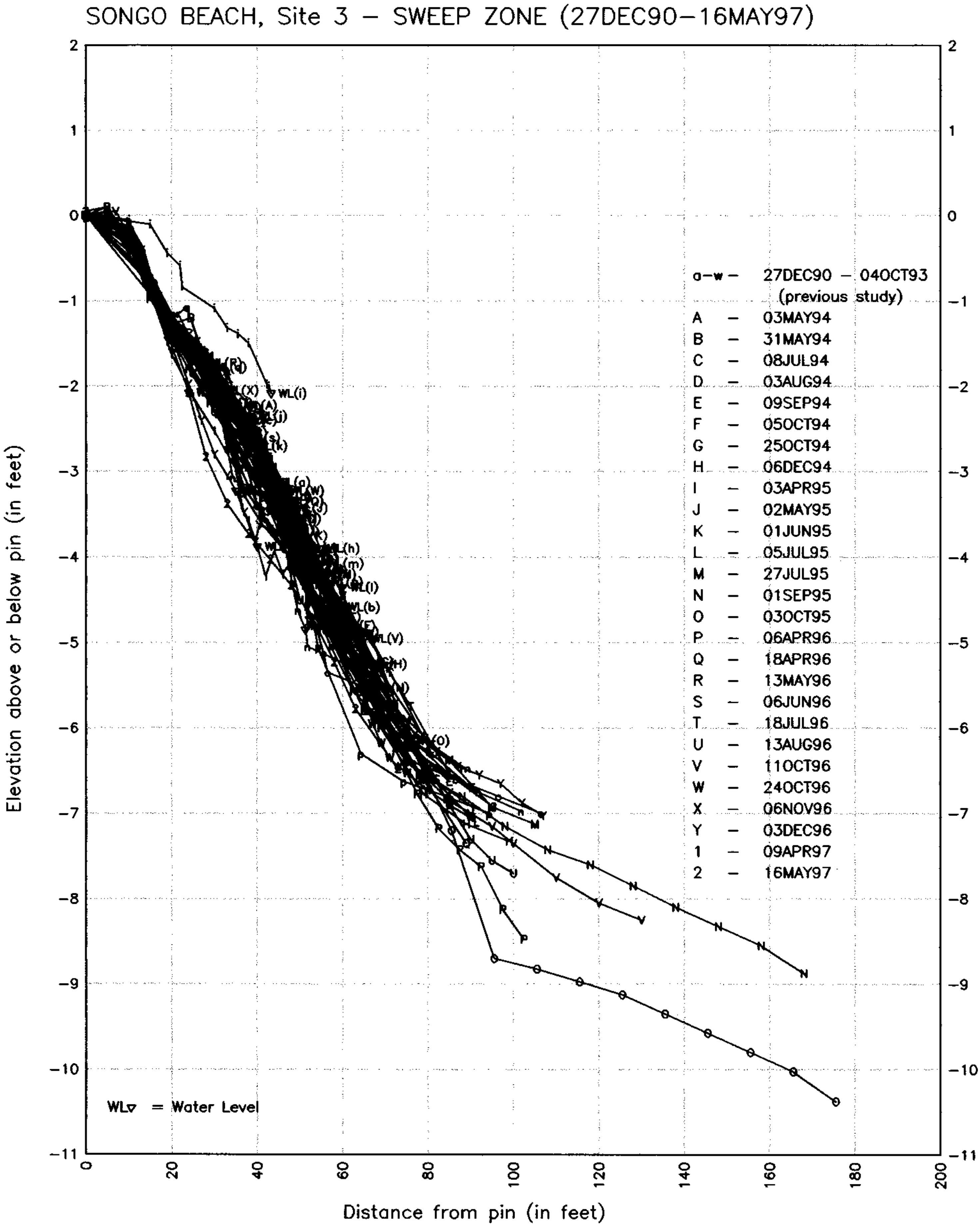


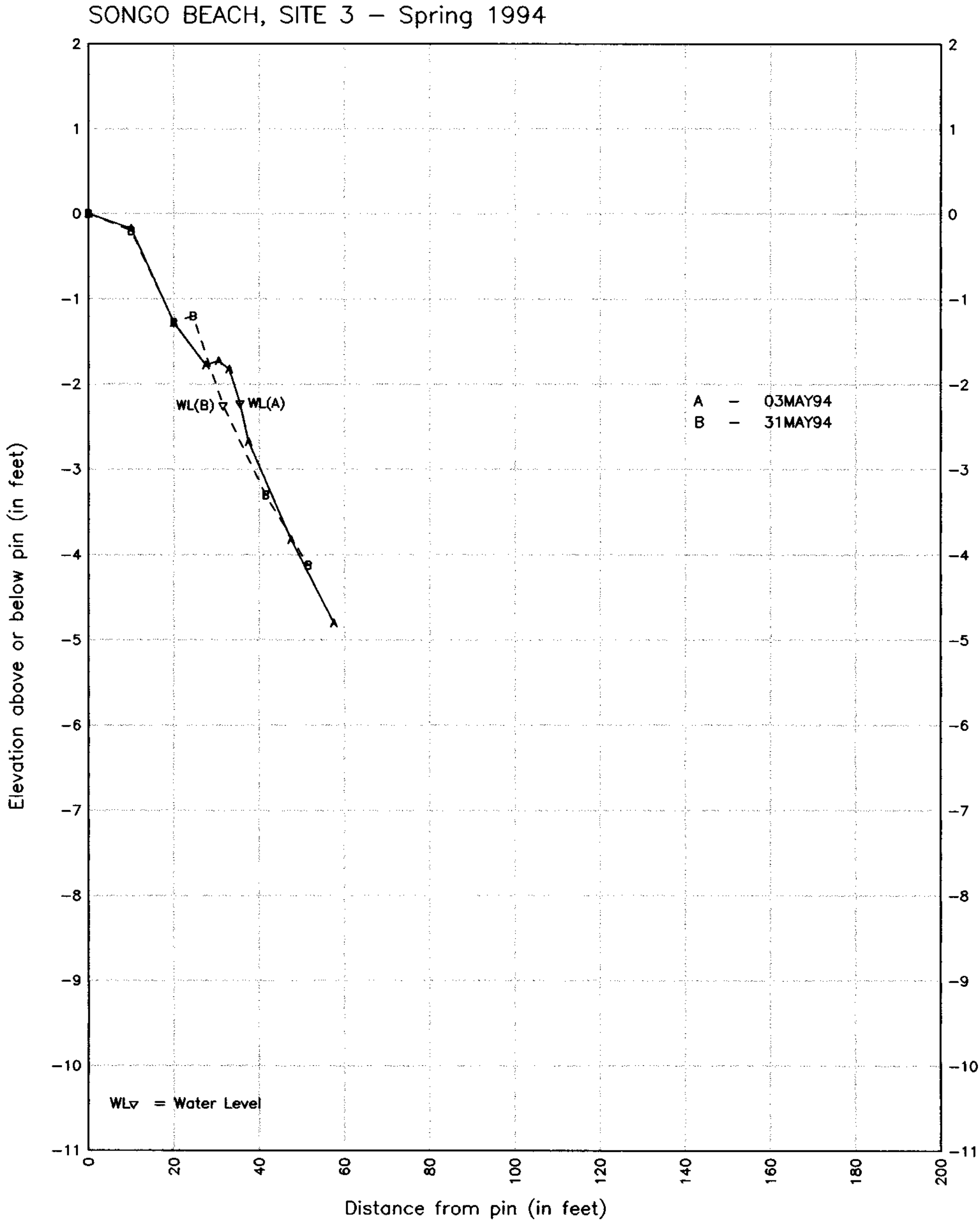
SANDBAR, SITE 12 - Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(S)
WL(Q)
Q - 18APR96
R - 06MAY96
S - 06JUN96
WL▽ = Water Level


SANDBAR, SITE 12 - Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(T)
WL(U)
WL(V)
T - 08JUL96
U - 06AUG96
V - 03SEP96
WL▽ = Water Level

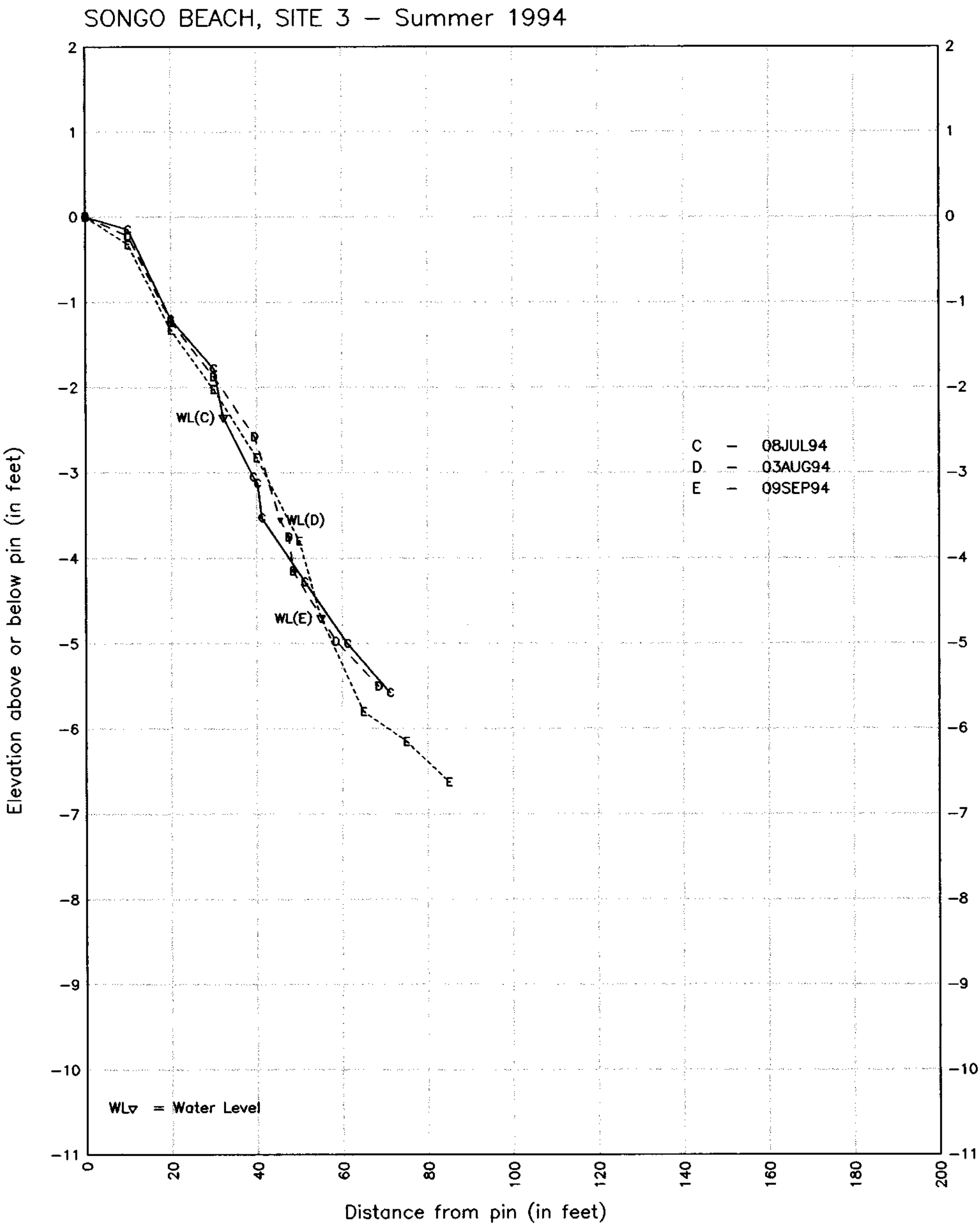
SANDBAR, SITE 12 – Fall 1996

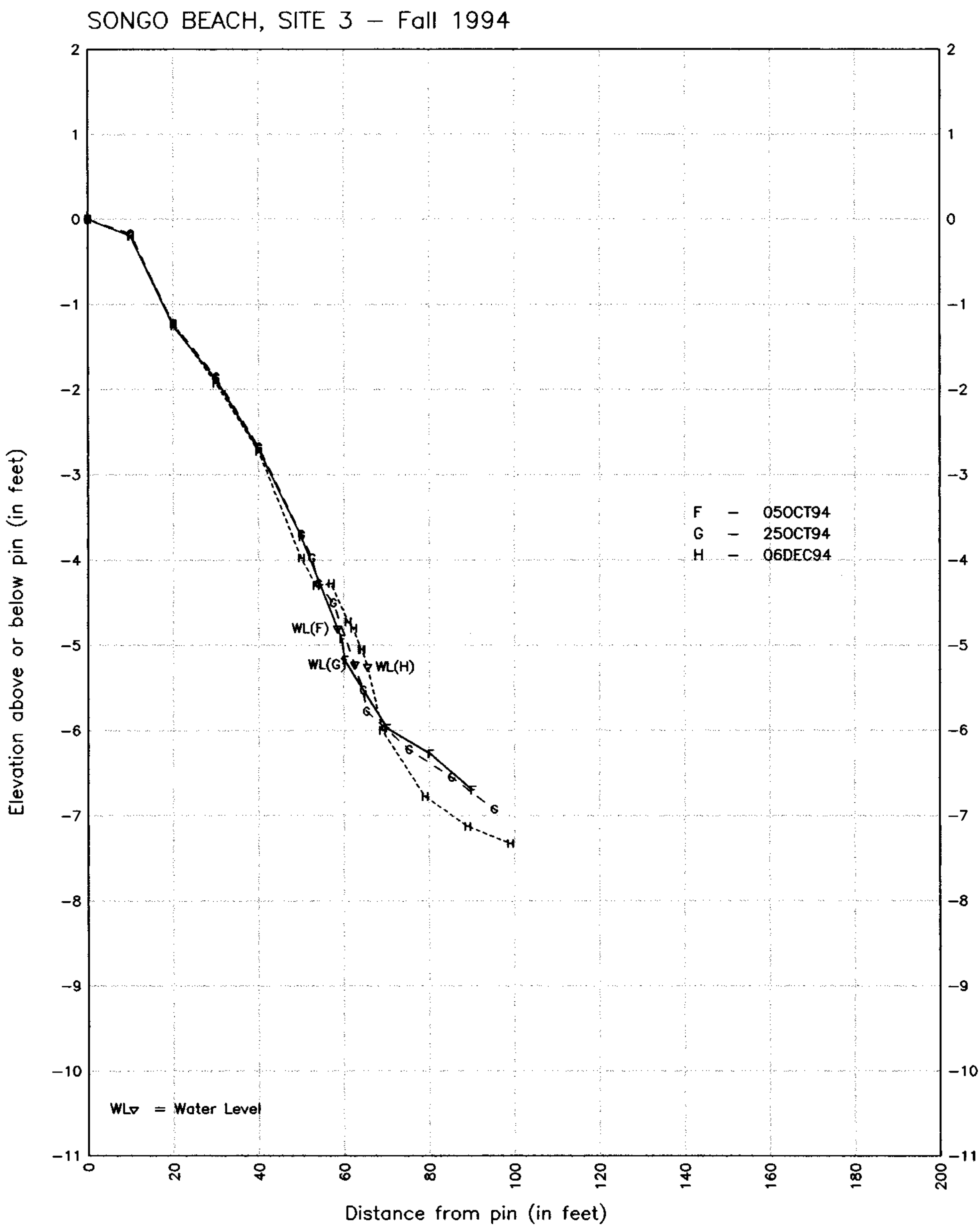


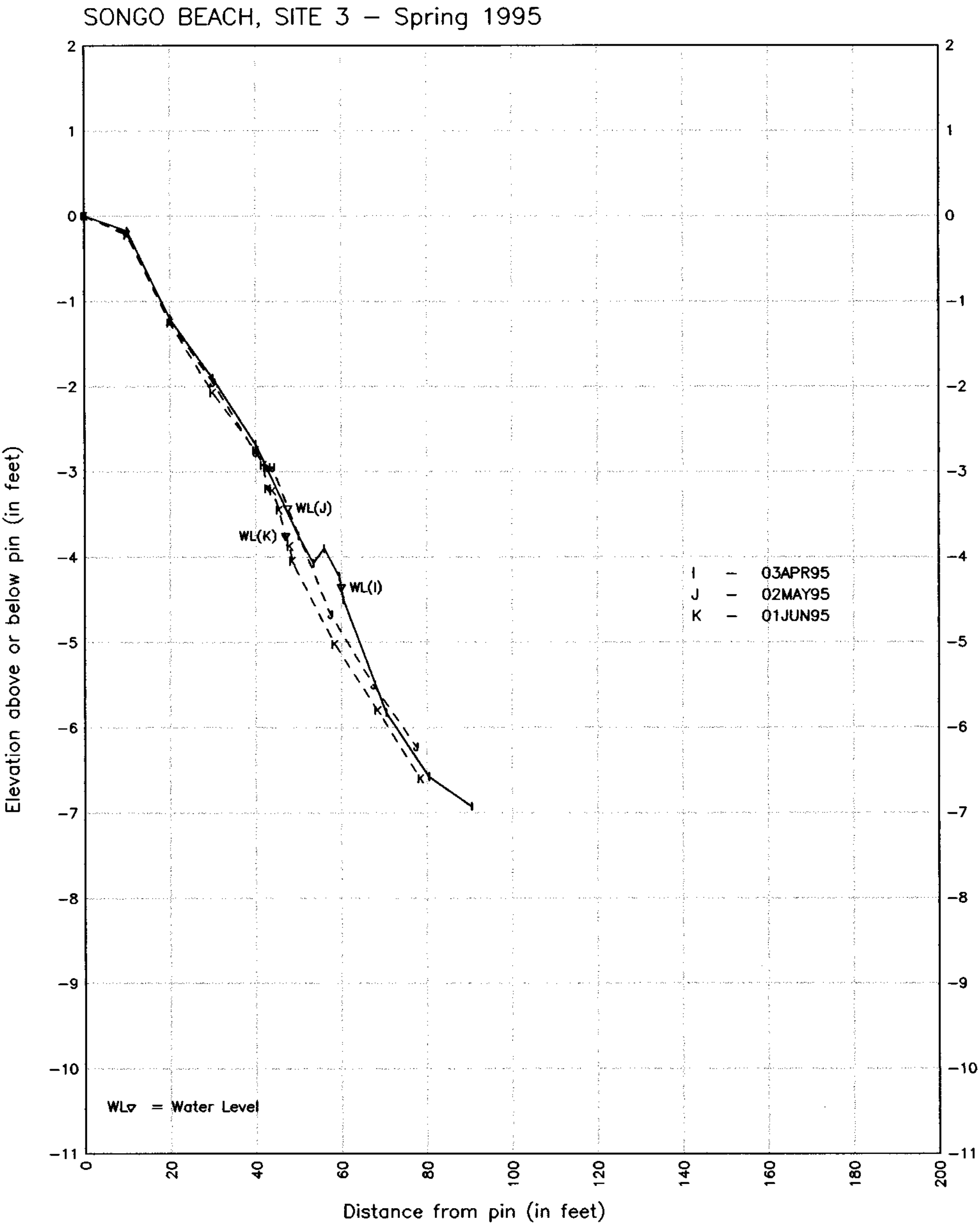

SONGO BEACH, Site 3 – SWEEP ZONE (27DEC90–16MAY97)
Elevation above or below pin (in feet)
Distance from pin (in feet)
a–w – 27DEC90 – 04OCT93 (previous study)
A – 03MAY94
B – 31MAY94
C – 08JUL94
D – 03AUG94
E – 09SEP94
F – 05OCT94
G – 25OCT94
H – 06DEC94
I – 03APR95
J – 02MAY95
K – 01JUN95
L – 05JUL95
M – 27JUL95
N – 01SEP95
O – 03OCT95
P – 06APR96
Q – 18APR96
R – 13MAY96
S – 06JUN96
T – 18JUL96
U – 13AUG96
V – 11OCT96
W – 24OCT96
X – 06NOV96
Y – 03DEC96
1 – 09APR97
2 – 16MAY97
WL▽ = Water Level



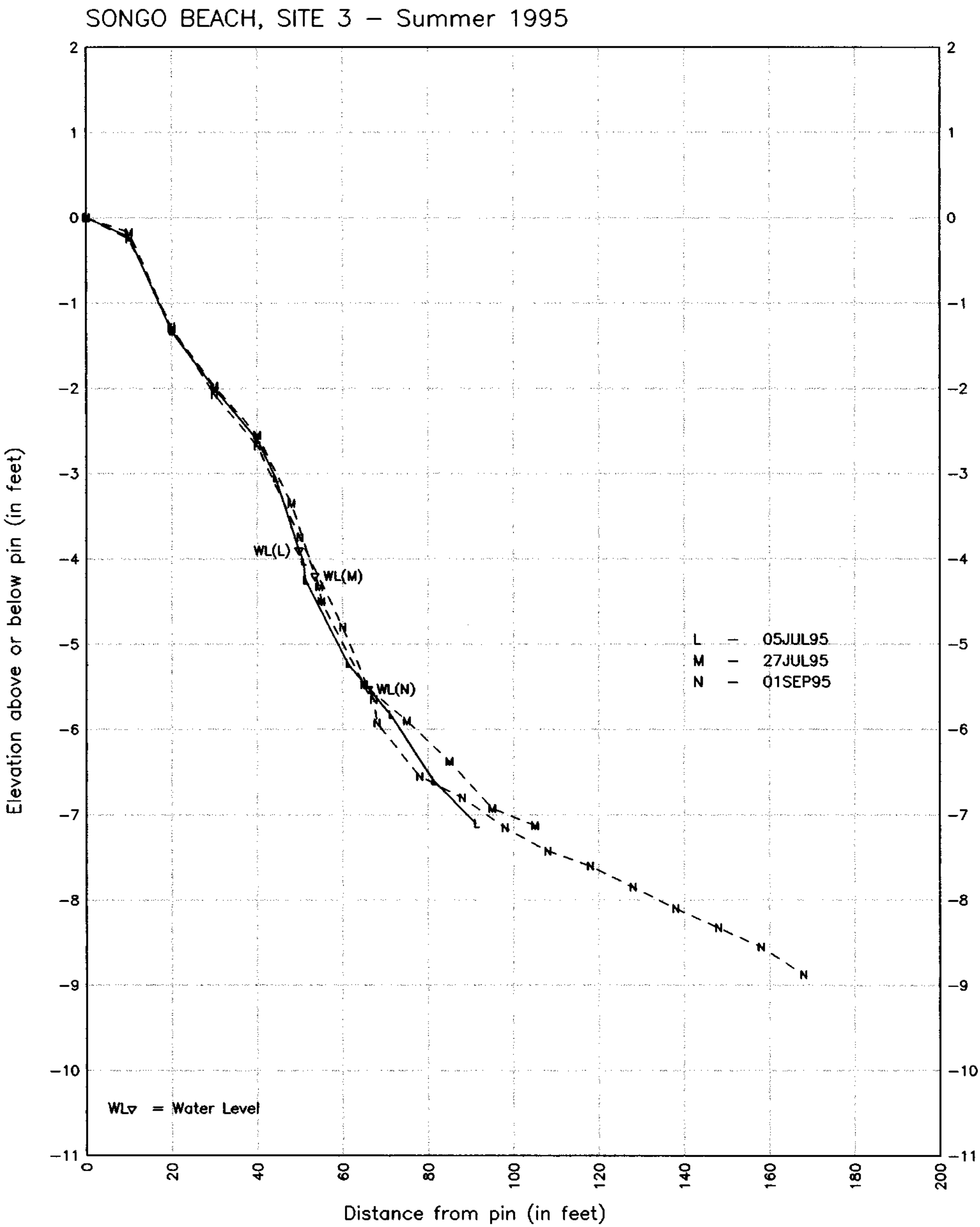
SONGO BEACH, SITE 3 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200
WL(B)
WL(A)
A – 03MAY94
B – 31MAY94
WL▽ = Water Level

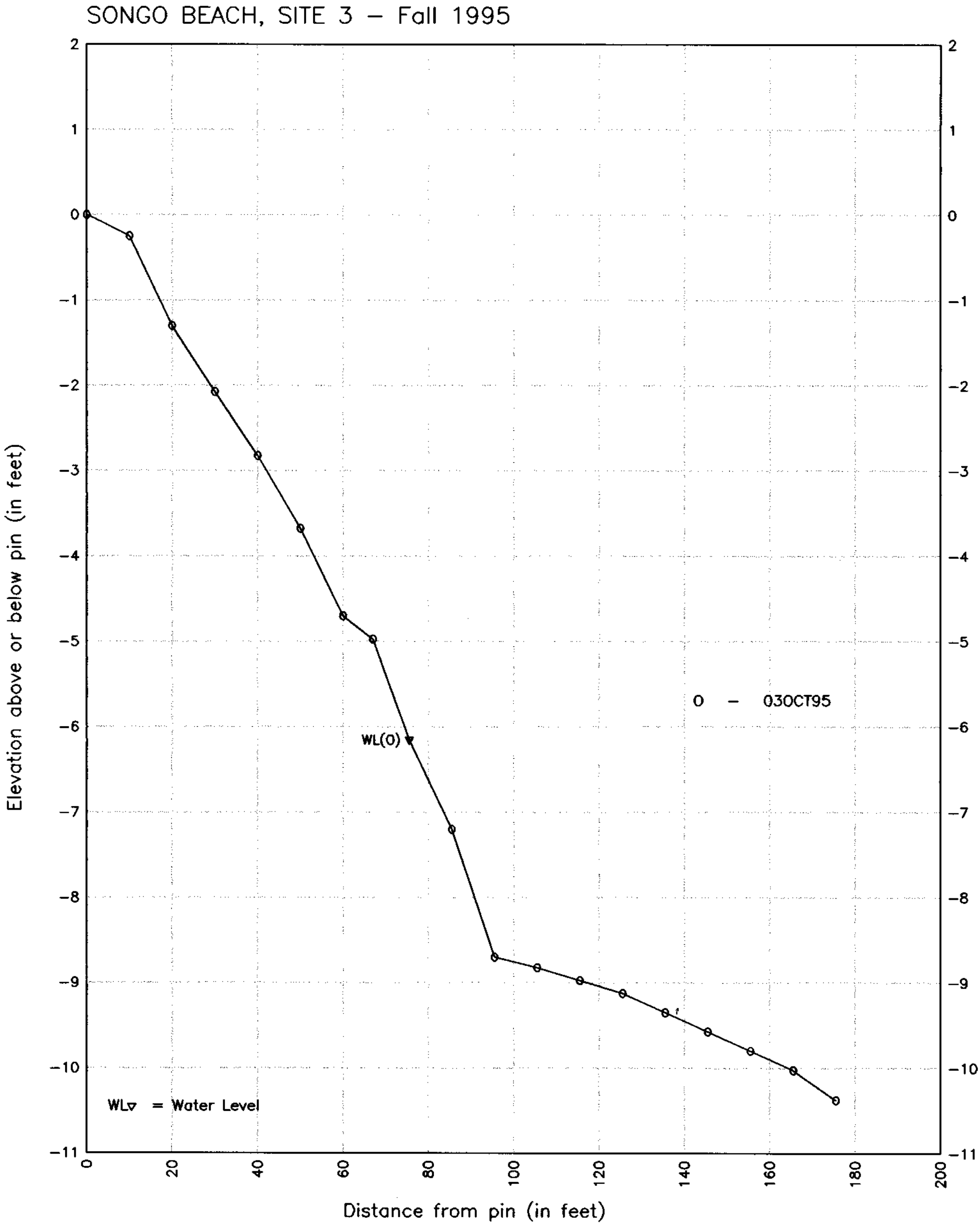

SONGO BEACH, SITE 3 – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 08JUL94
D – 03AUG94
E – 09SEP94
WL(C)
WL(D)
WL(E)
WL▽ = Water Level
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

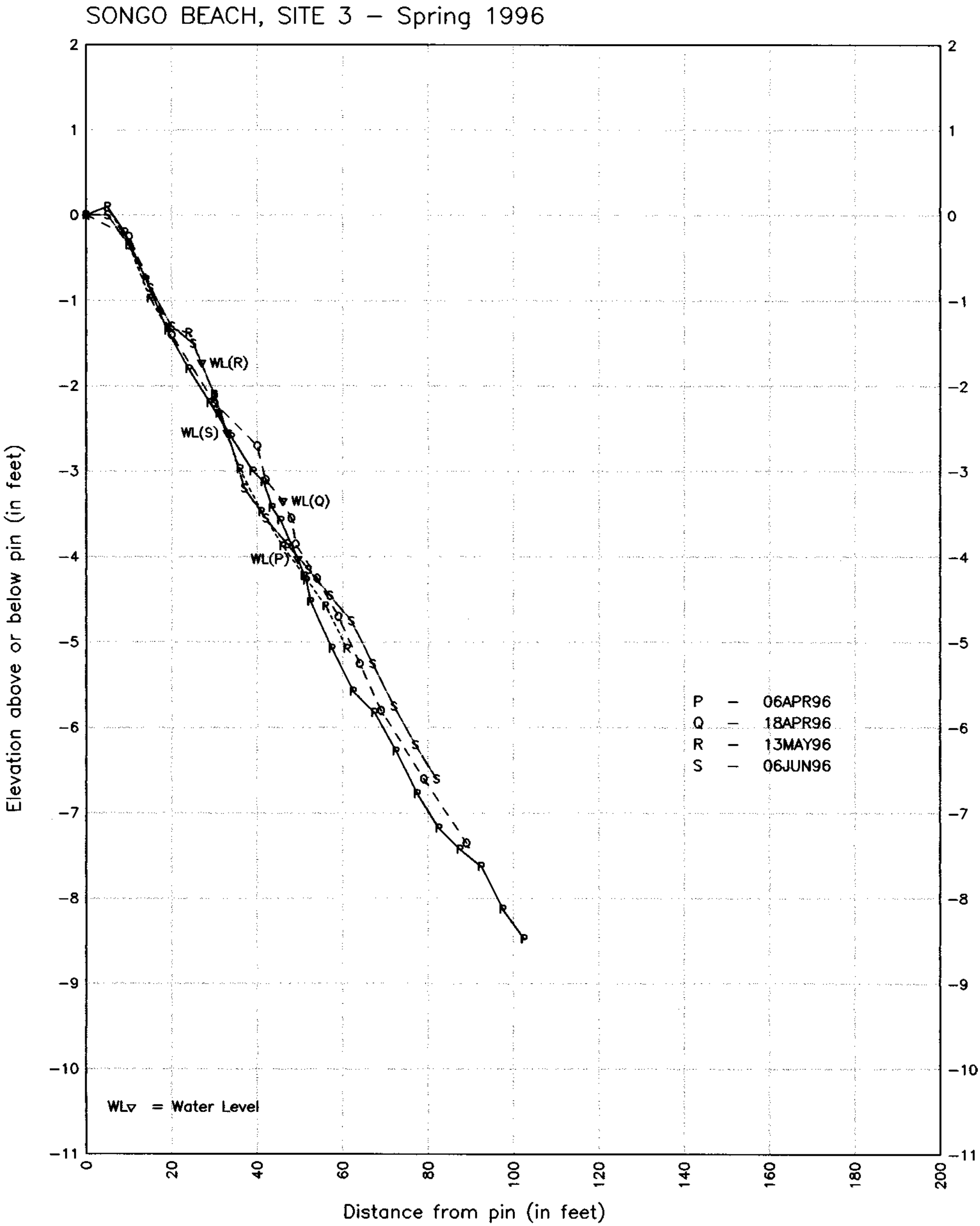

SONGO BEACH, SITE 3 – Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
F – 05OCT94
G – 25OCT94
H – 06DEC94
WL(F)
WL(G)
WL(H)
WL▽ = Water Level



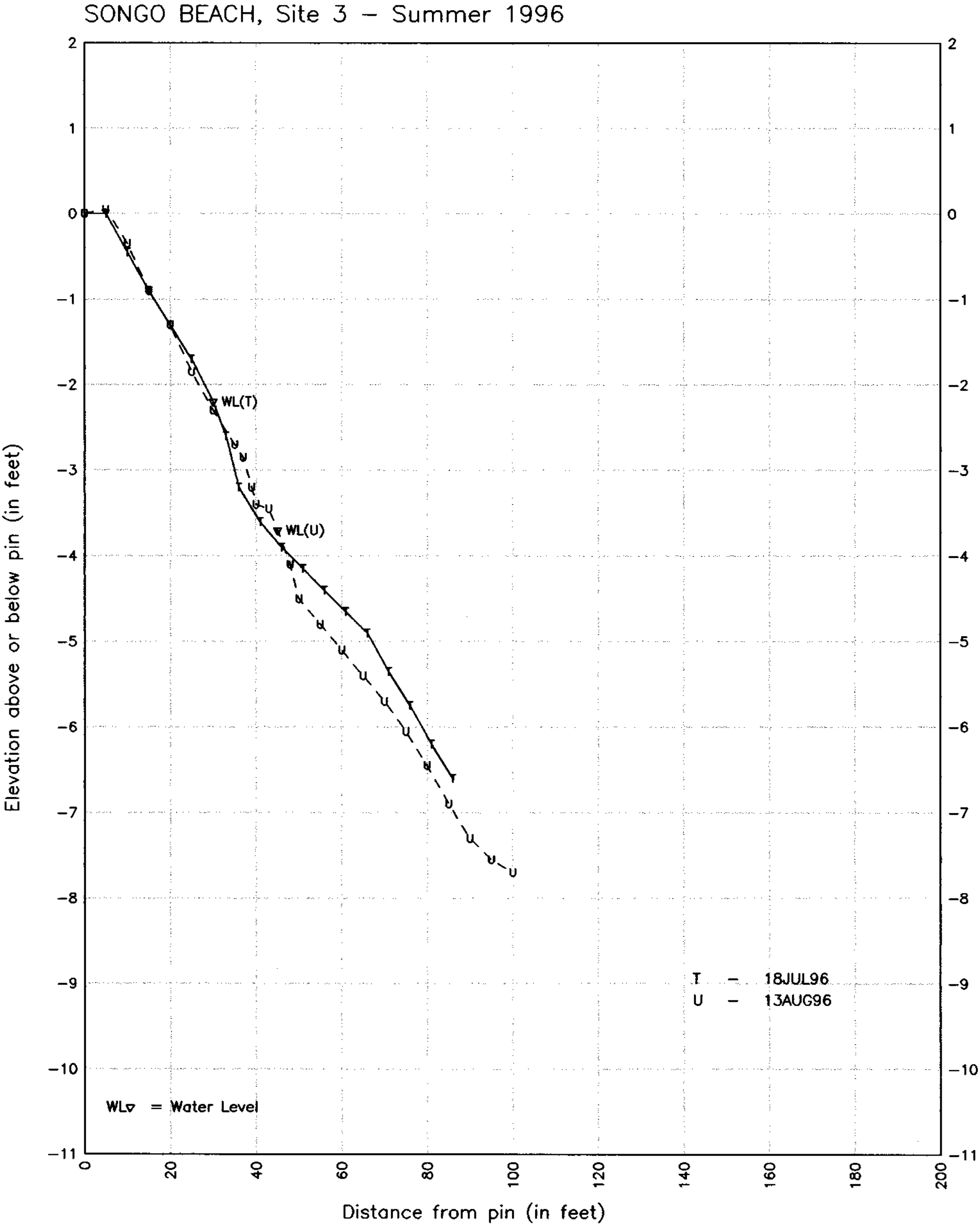
SONGO BEACH, SITE 3 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200
WL(J)
WL(K)
WL(I)
I – 03APR95
J – 02MAY95
K – 01JUN95
WL▽ = Water Level

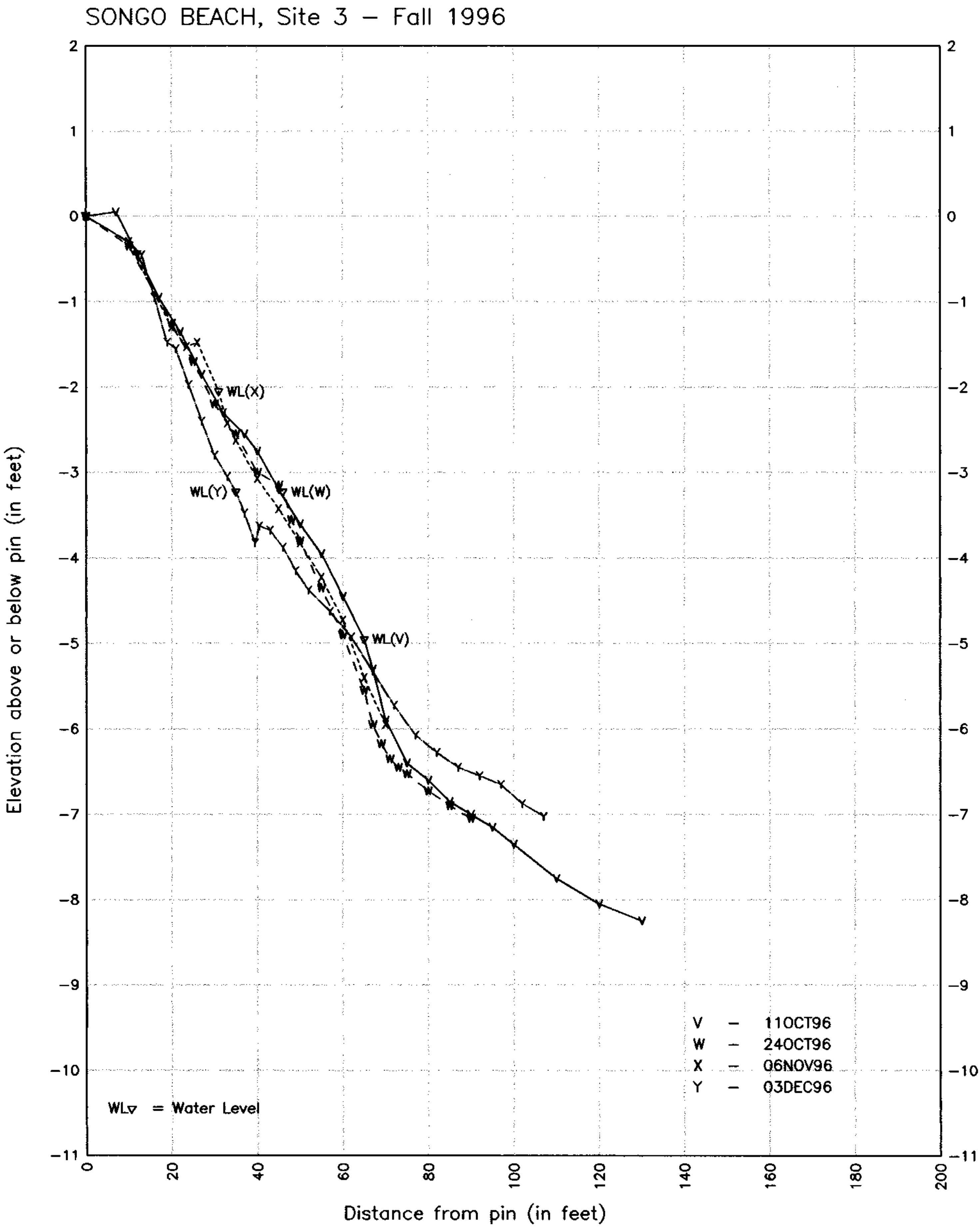

SONGO BEACH, SITE 3 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(L)
WL(M)
WL(N)
L – 05JUL95
M – 27JUL95
N – 01SEP95
WL▽ = Water Level

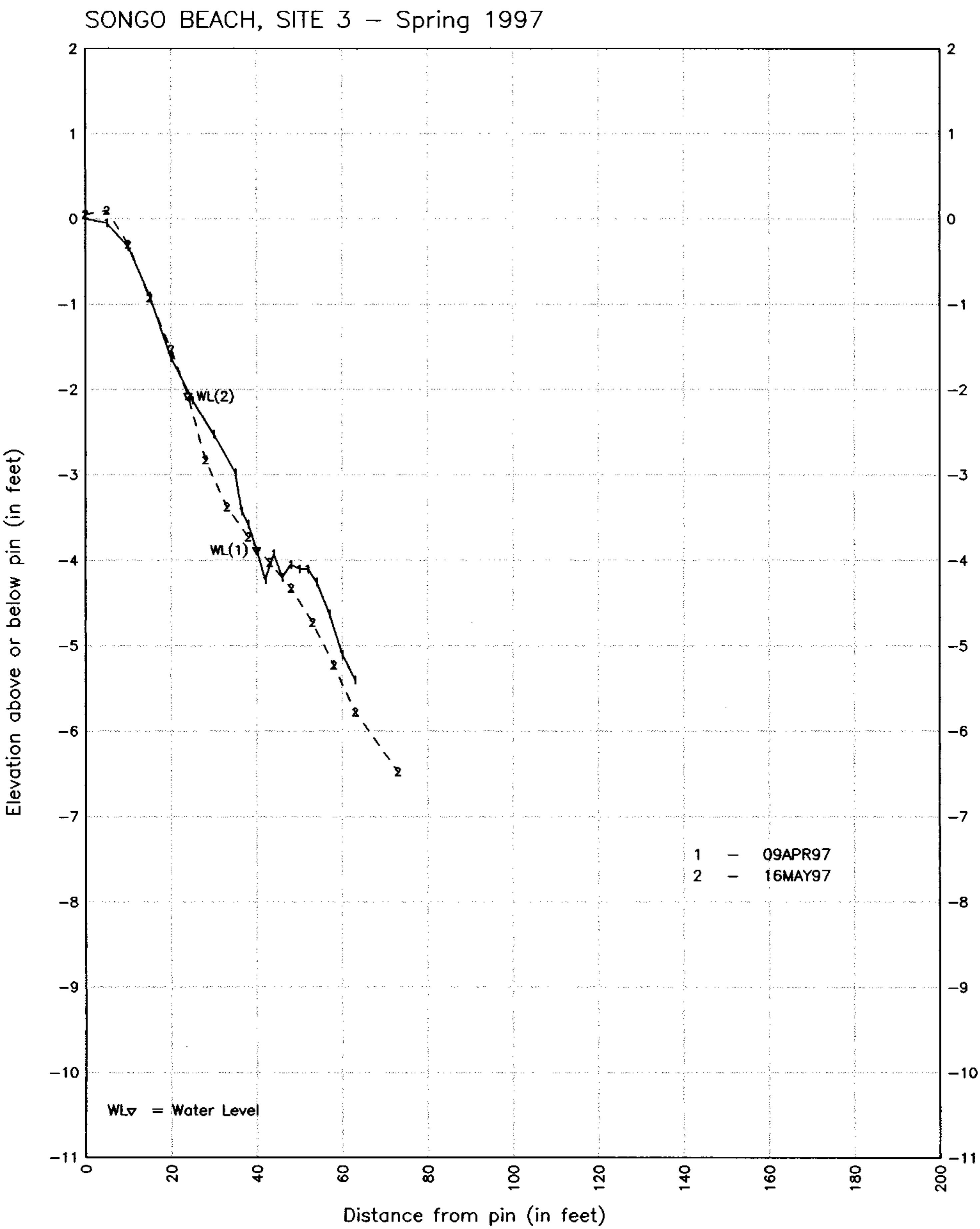

SONGO BEACH, SITE 3 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200
WL(0)
O – 03OCT95
WLᐁ = Water Level



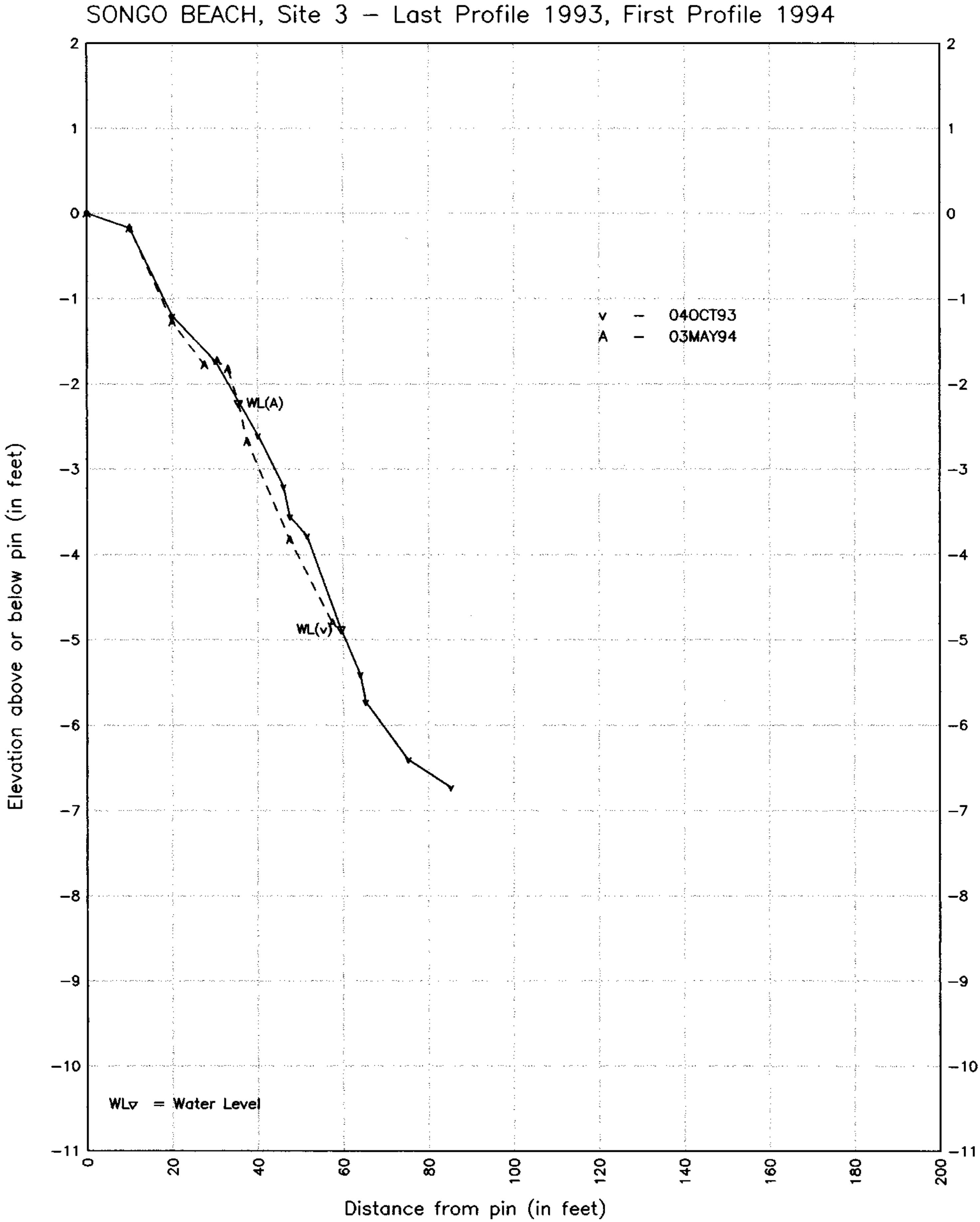
SONGO BEACH, SITE 3 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(S)
WL(Q)
WL(P)
P – 06APR96
Q – 18APR96
R – 13MAY96
S – 06JUN96
WL▽ = Water Level


SONGO BEACH, Site 3 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(T)
WL(U)
T – 18JUL96
U – 13AUG96
WL▽ = Water Level

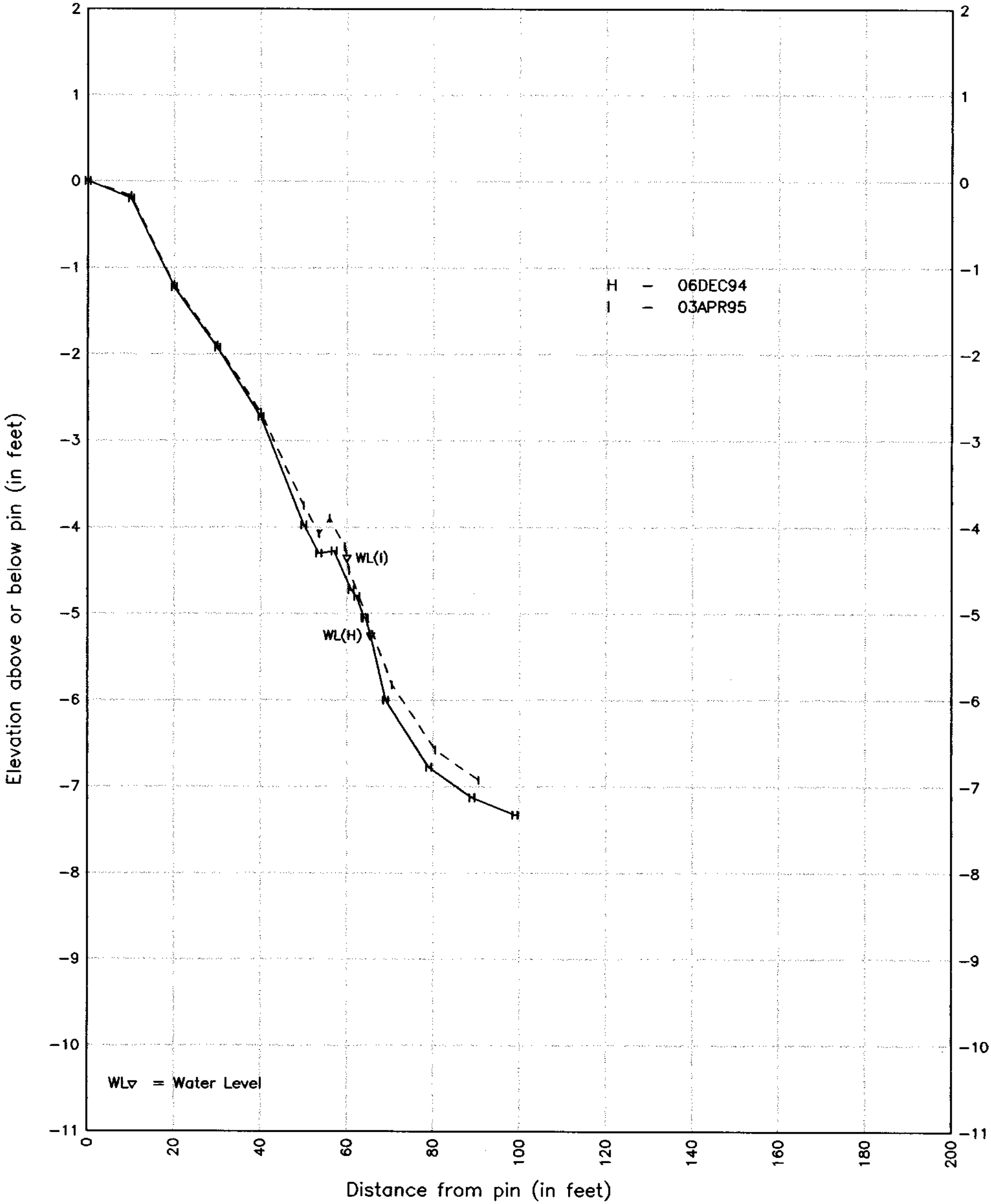

SONGO BEACH, Site 3 – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200
WL(X)
WL(Y)
WL(W)
WL(V)
V – 11OCT96
W – 24OCT96
X – 06NOV96
Y – 03DEC96
WL▽ = Water Level



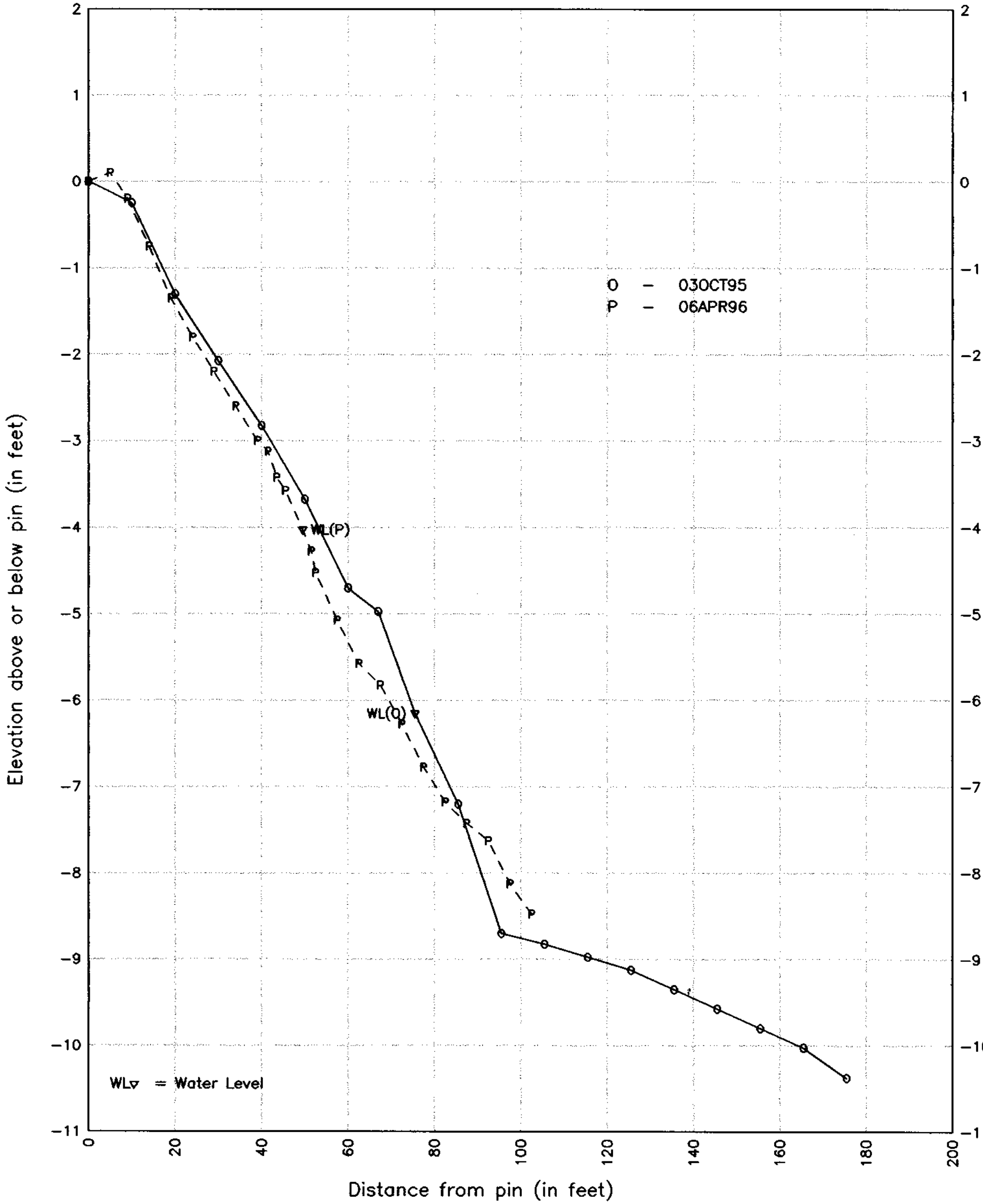
SONGO BEACH, SITE 3 – Spring 1997
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(2)
WL(1)
1 – 09APR97
2 – 16MAY97
WL▽ = Water Level

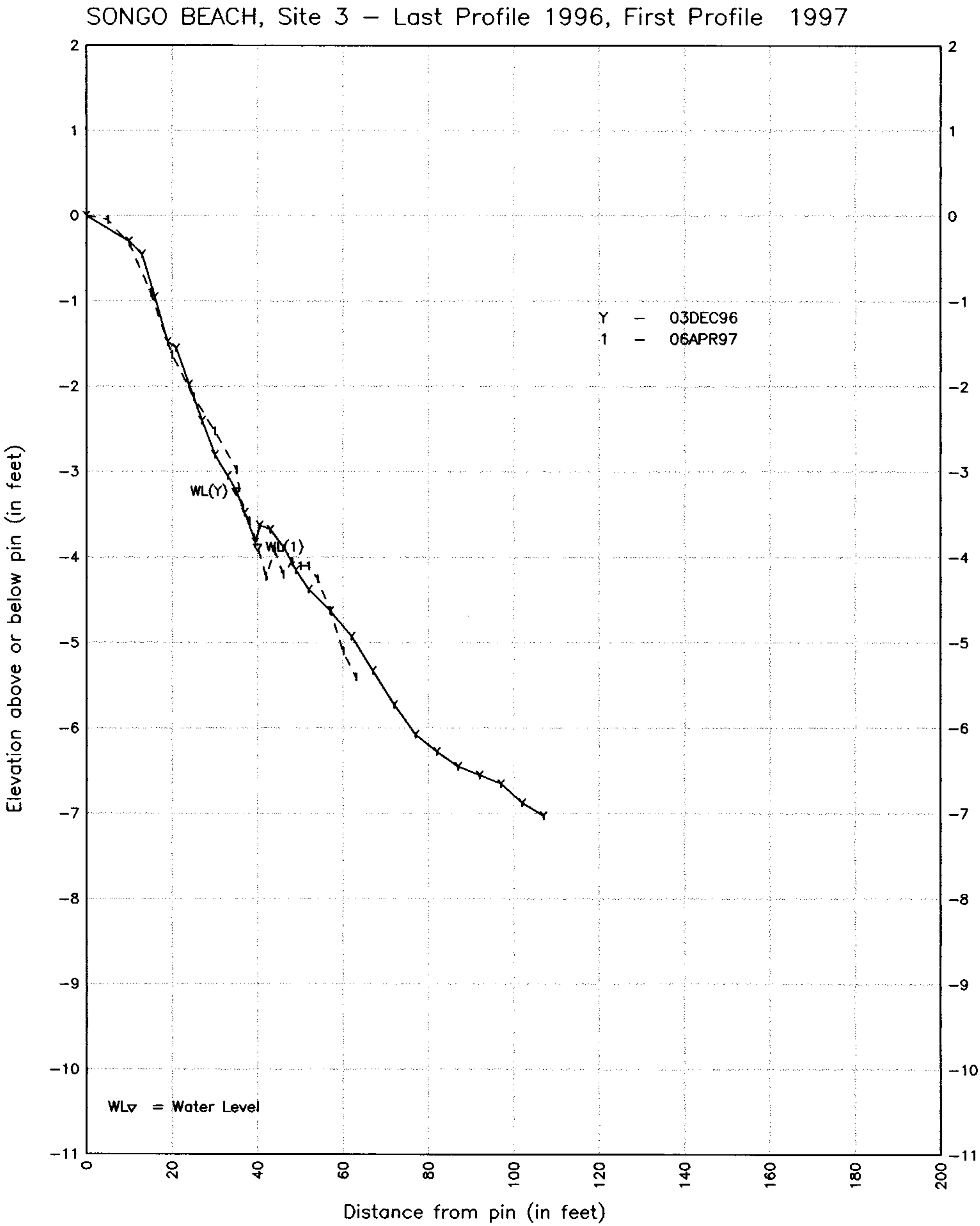

SONGO BEACH, Site 3 – Last Profile 1993, First Profile 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
v – 04OCT93
A – 03MAY94
WL(A)
WL(v)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

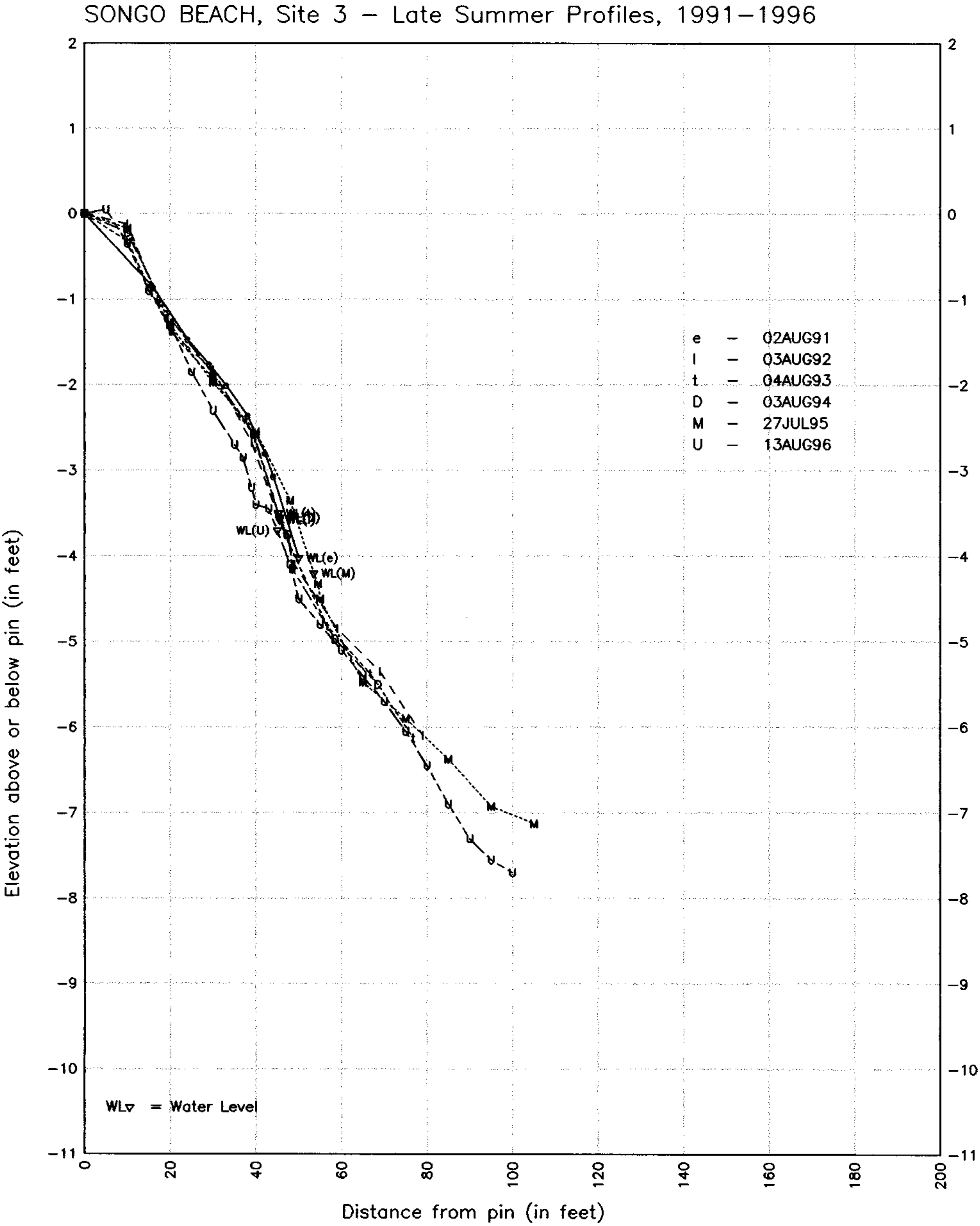
SONGO BEACH, Site 3 – Last Profile 1994, First Profile 1995

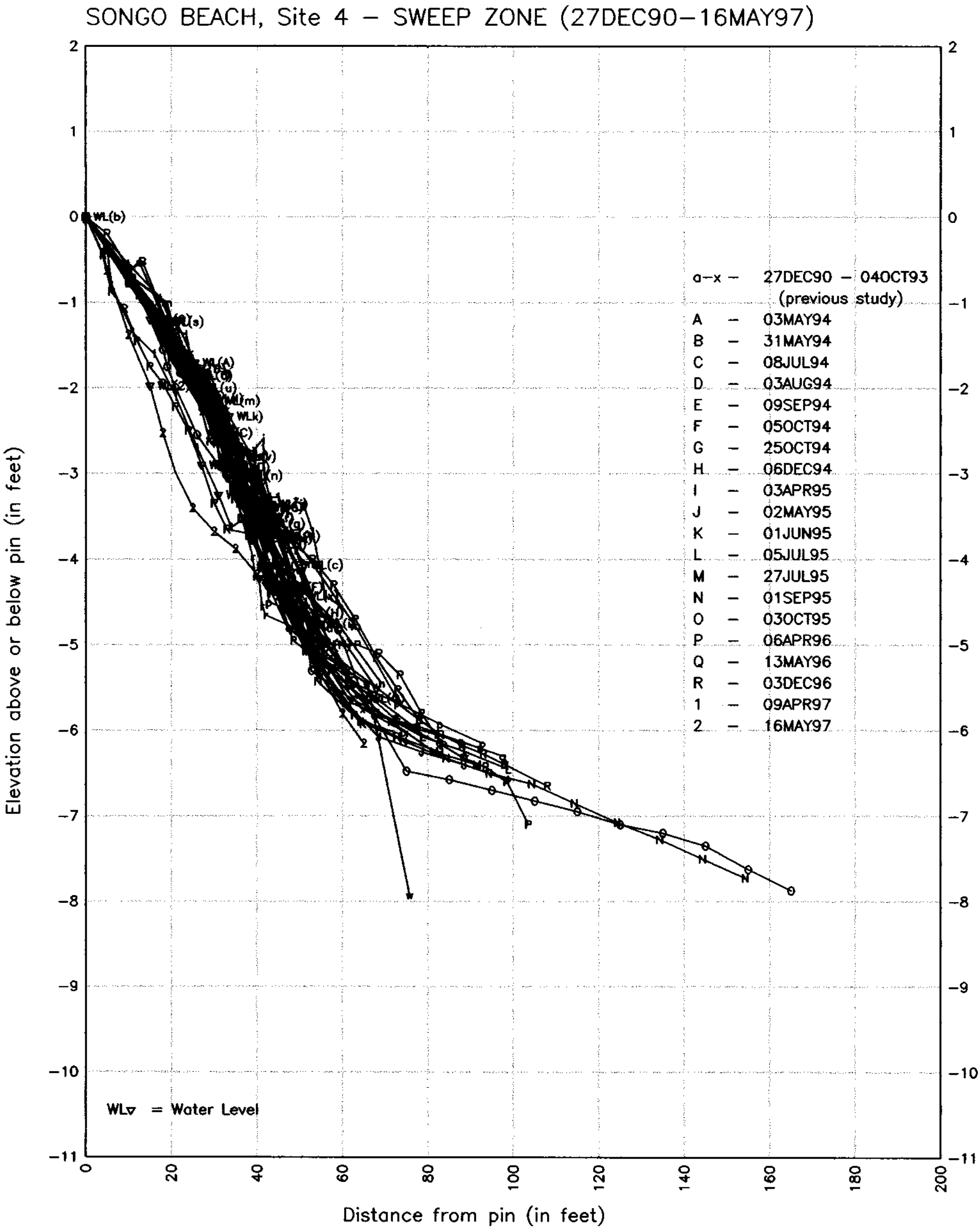


SONGO BEACH, Site 3 – Last Profile 1995, First Profile 1996



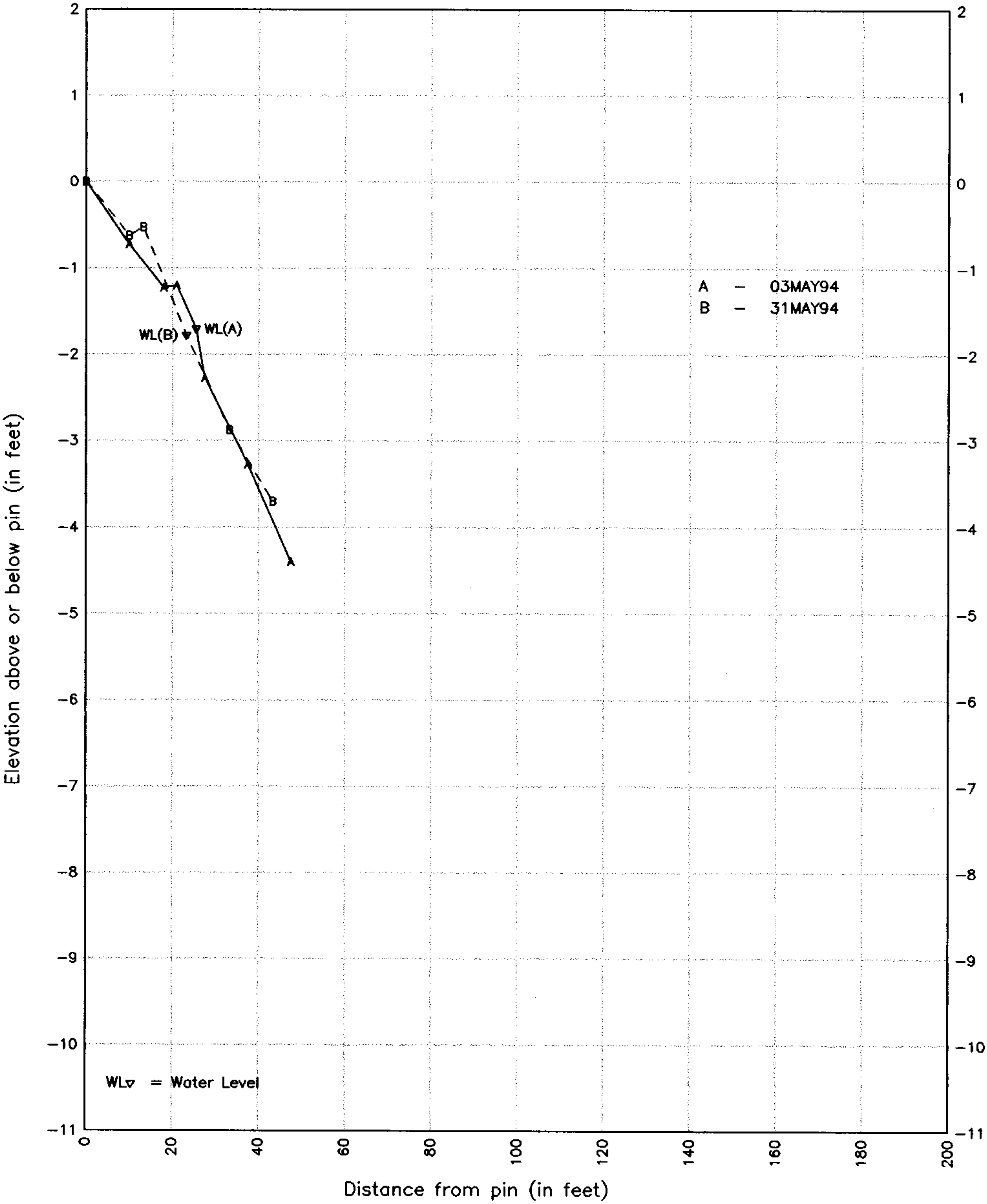

SONGO BEACH, Site 3 – Last Profile 1996, First Profile 1997
Y – 03DEC96
1 – 06APR97
WL(Y)
WL(1)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

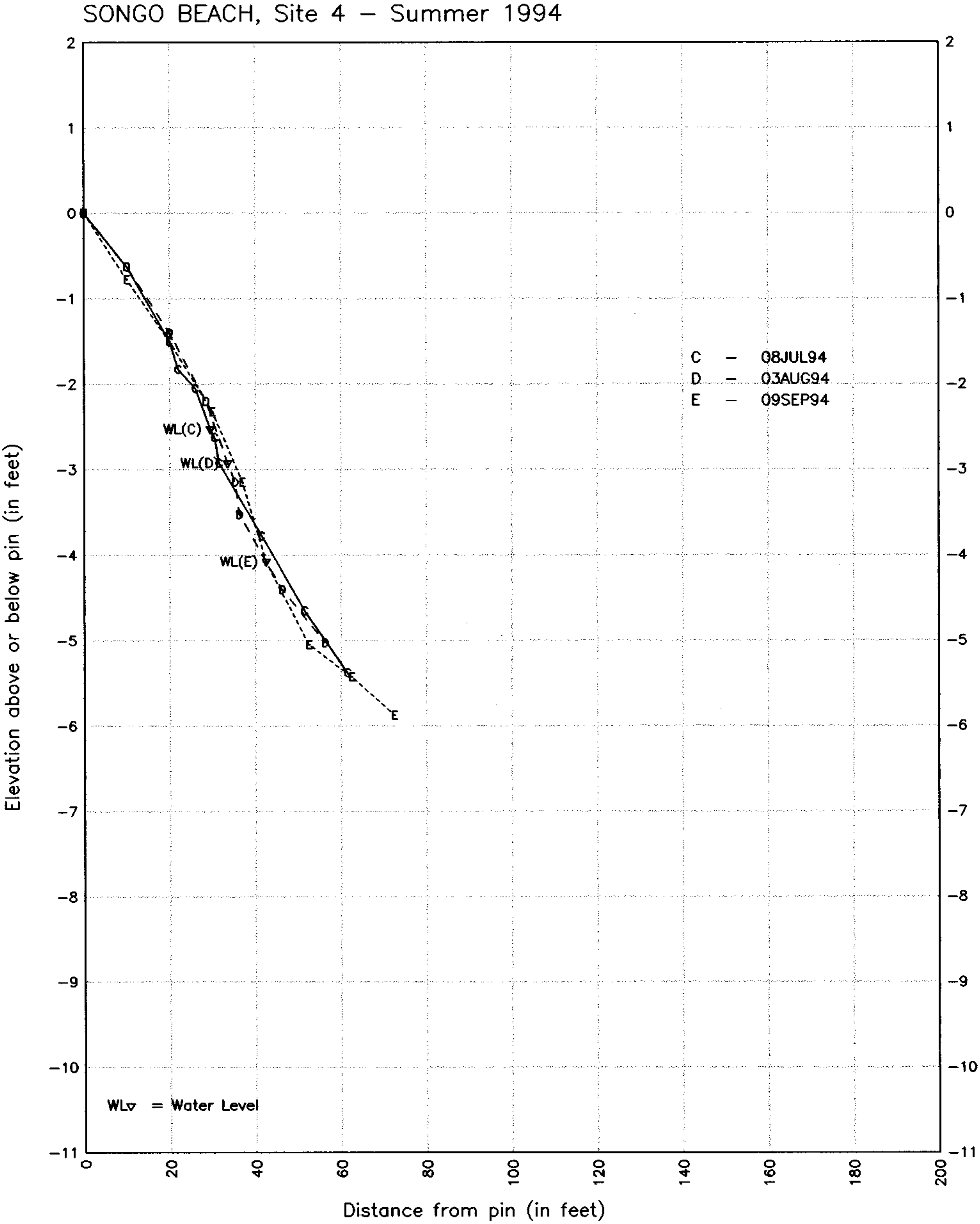

SONGO BEACH, Site 3 – Late Summer Profiles, 1991–1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
e – 02AUG91
l – 03AUG92
t – 04AUG93
D – 03AUG94
M – 27JUL95
U – 13AUG96
WL(U)
WL(e)
WL(M)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

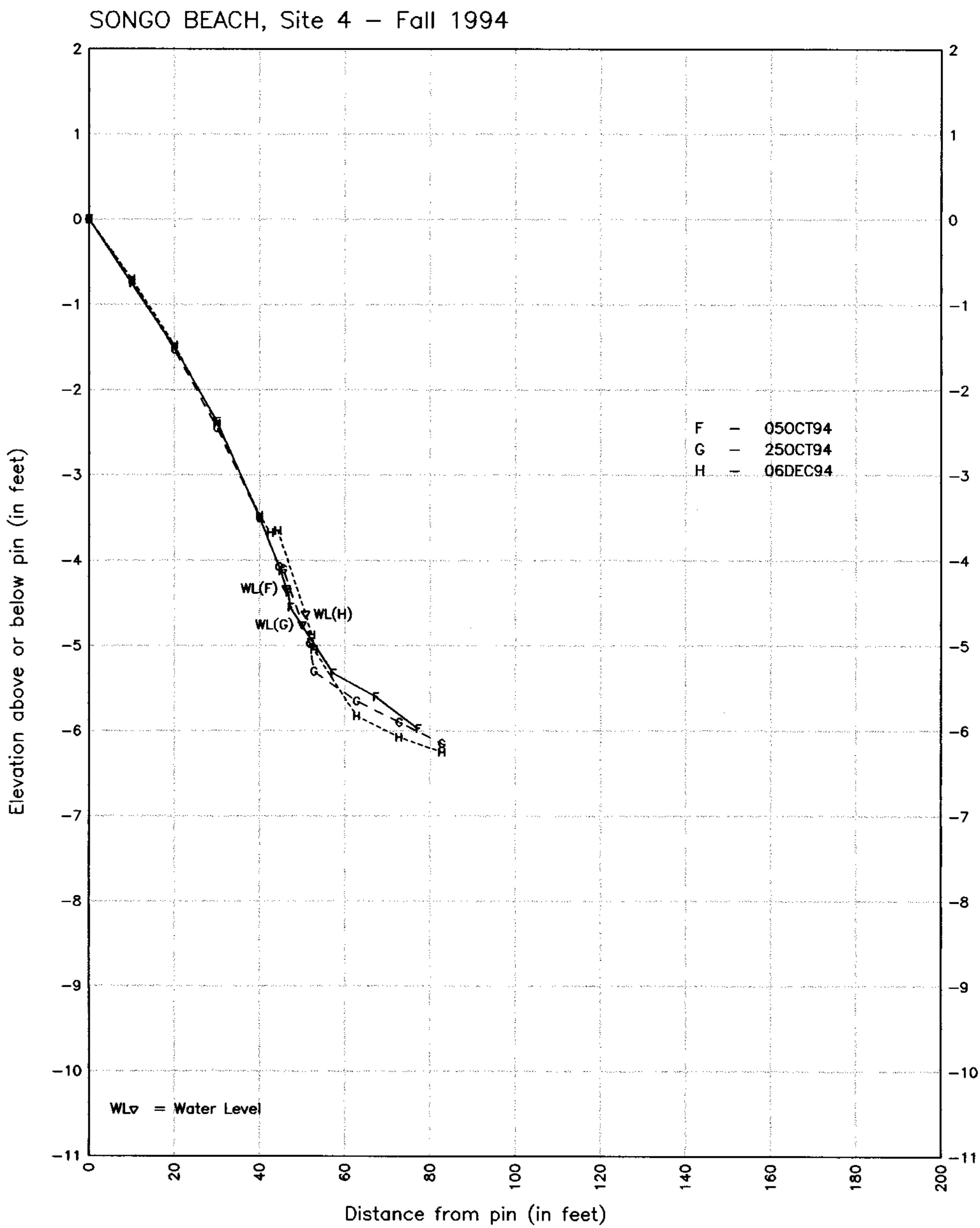


SONGO BEACH, Site 4 – SWEEP ZONE (27DEC90–16MAY97)
Elevation above or below pin (in feet)
Distance from pin (in feet)
a–x – 27DEC90 – 04OCT93 (previous study)
A – 03MAY94
B – 31MAY94
C – 08JUL94
D – 03AUG94
E – 09SEP94
F – 05OCT94
G – 25OCT94
H – 06DEC94
I – 03APR95
J – 02MAY95
K – 01JUN95
L – 05JUL95
M – 27JUL95
N – 01SEP95
O – 03OCT95
P – 06APR96
Q – 13MAY96
R – 03DEC96
1 – 09APR97
2 – 16MAY97
WL▽ = Water Level

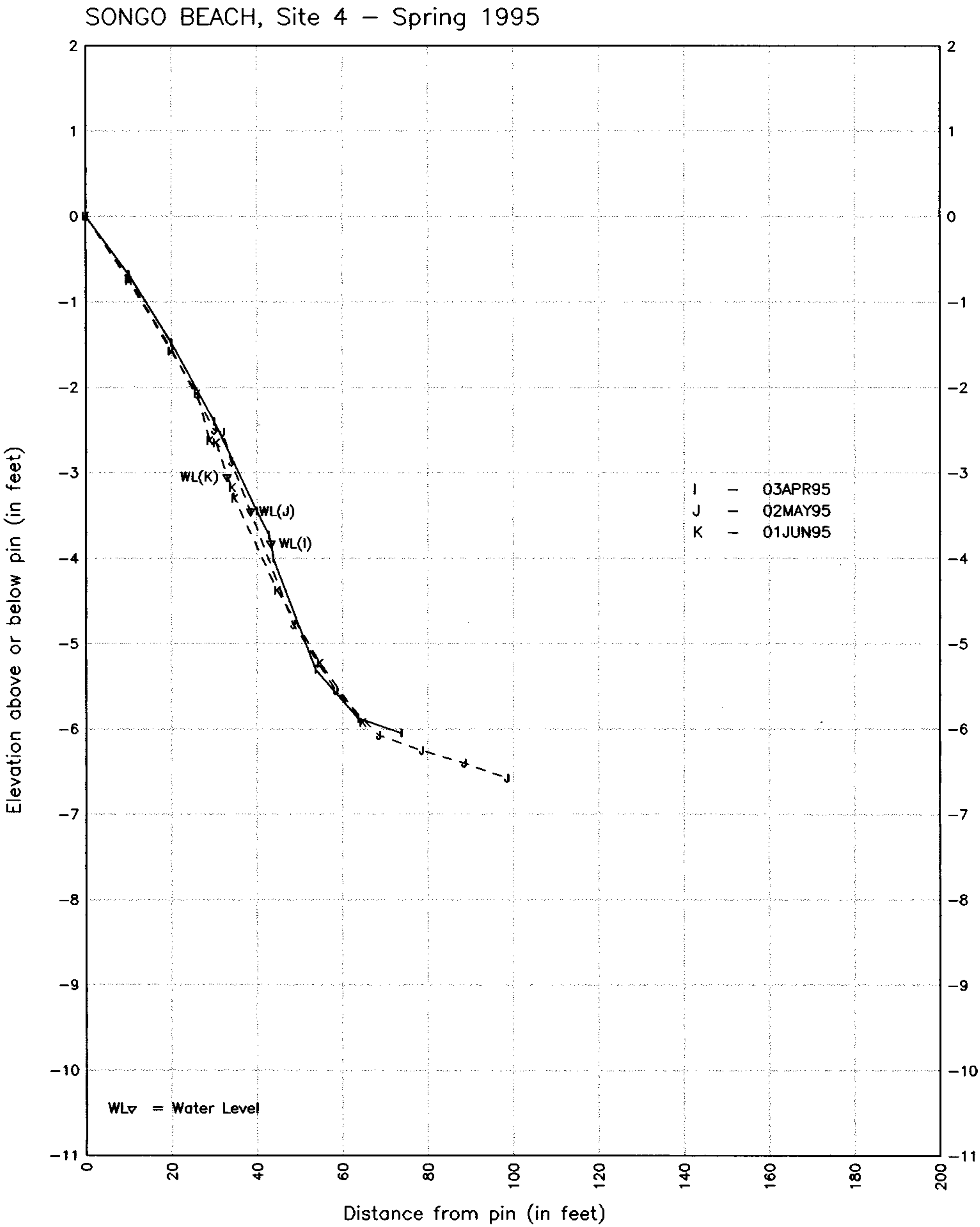
SONGO BEACH, Site 4 – Spring 1994

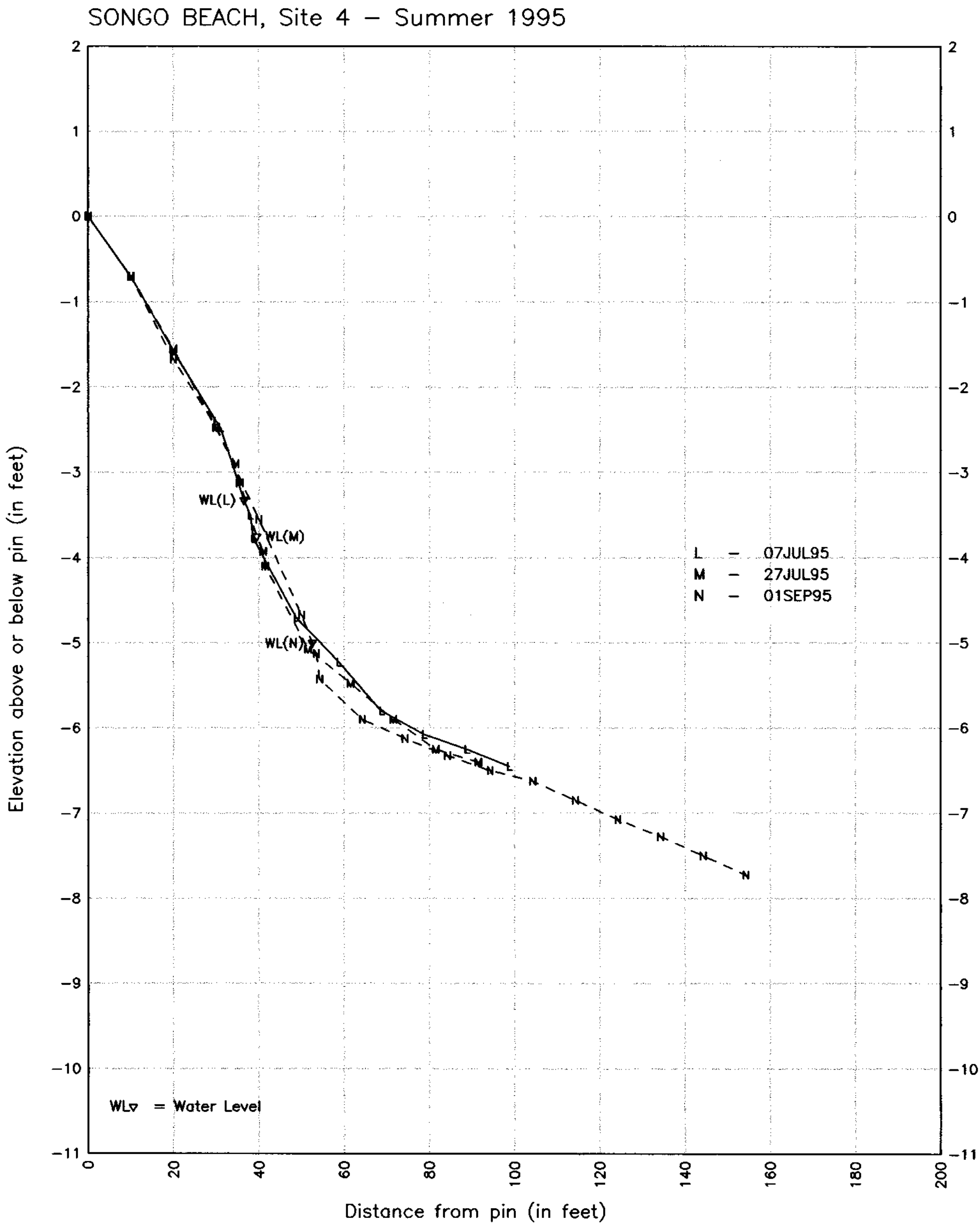


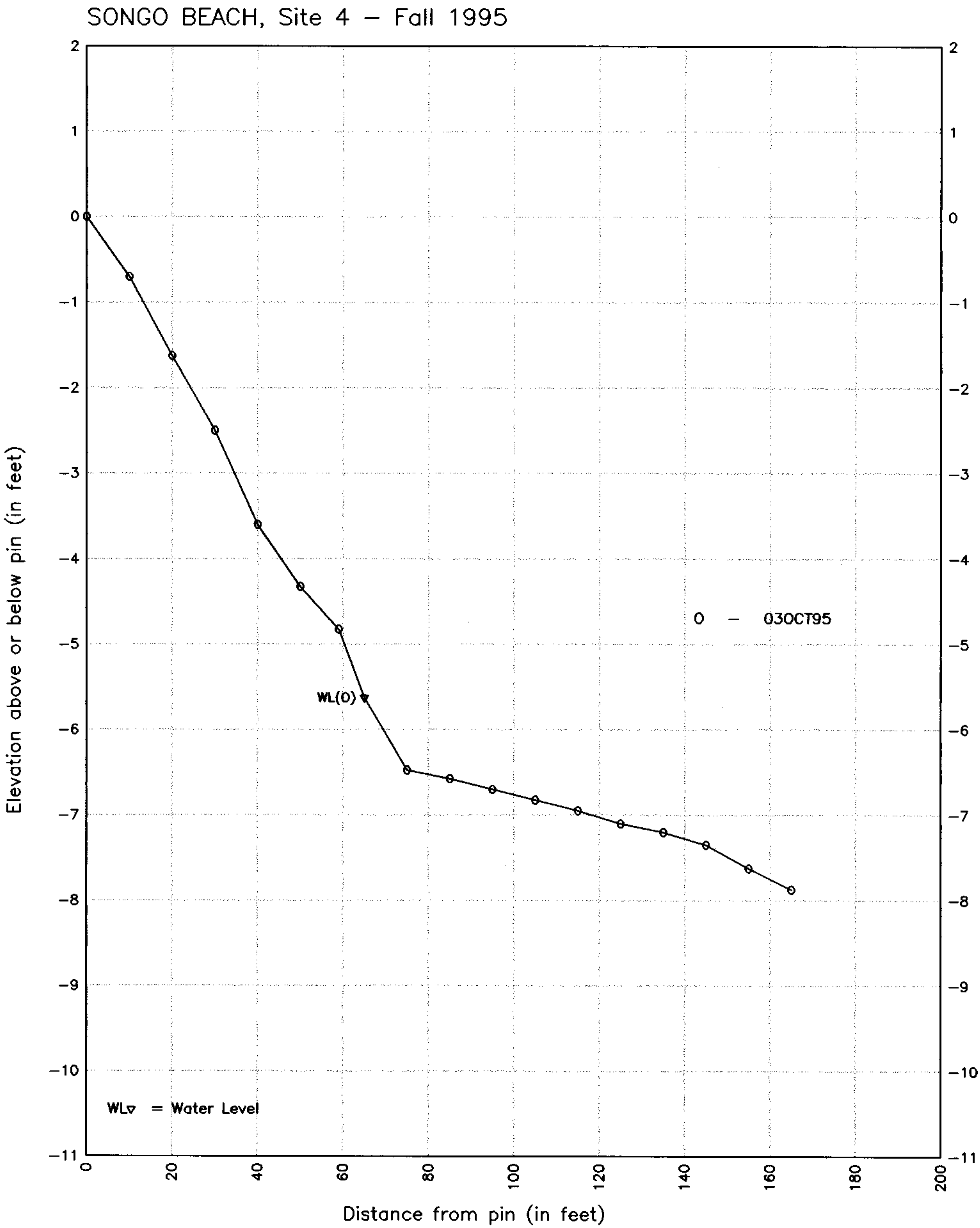

SONGO BEACH, Site 4 – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 08JUL94
D – 03AUG94
E – 09SEP94
WL(C)
WL(D)
WL(E)
WL▽ = Water Level
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200



SONGO BEACH, Site 4 – Fall 1994
F – 05OCT94
G – 25OCT94
H – 06DEC94
WL(F)
WL(G)
WL(H)
WL▿ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

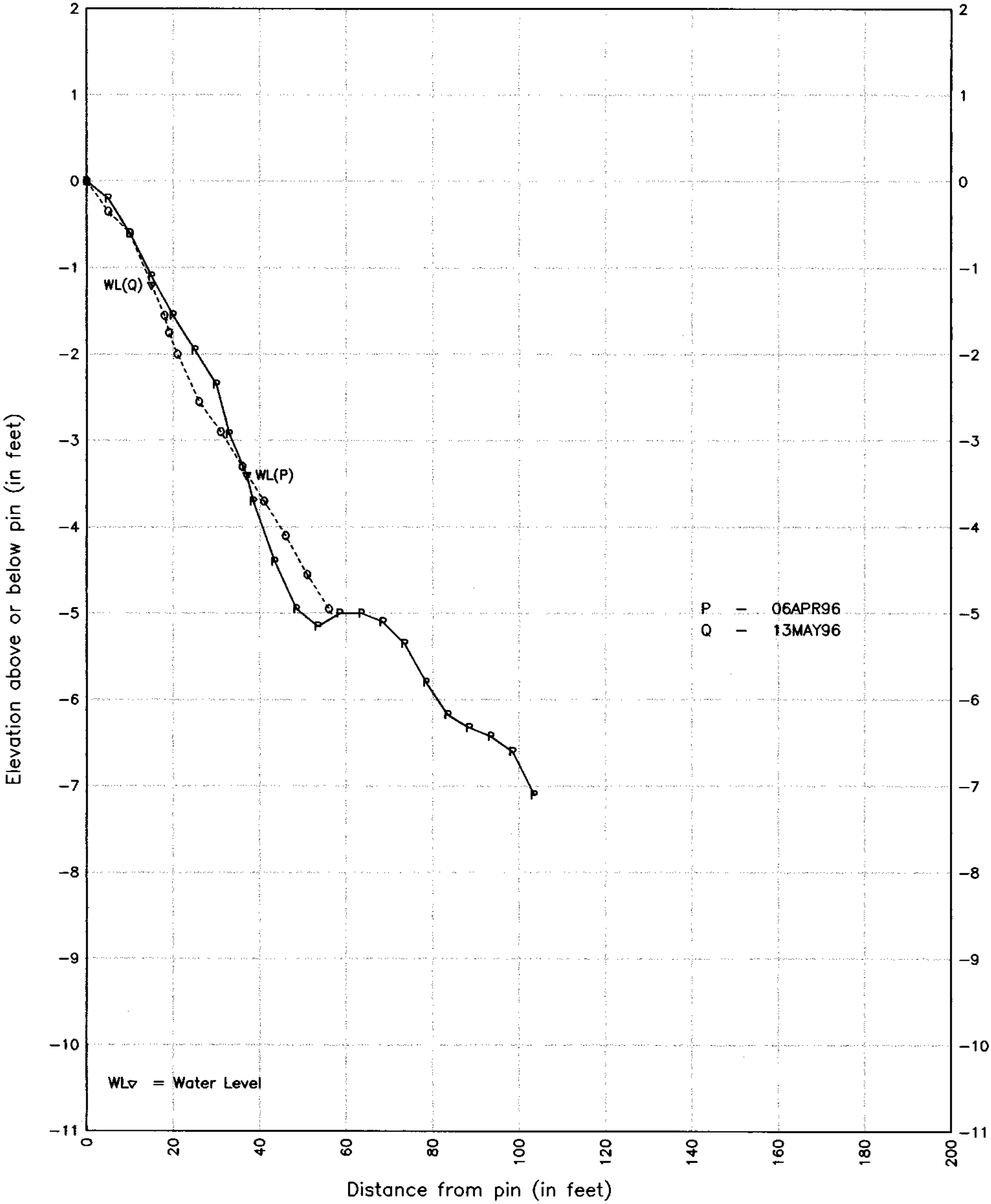

SONGO BEACH, Site 4 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
I – 03APR95
J – 02MAY95
K – 01JUN95
WL(K)
WL(J)
WL(I)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

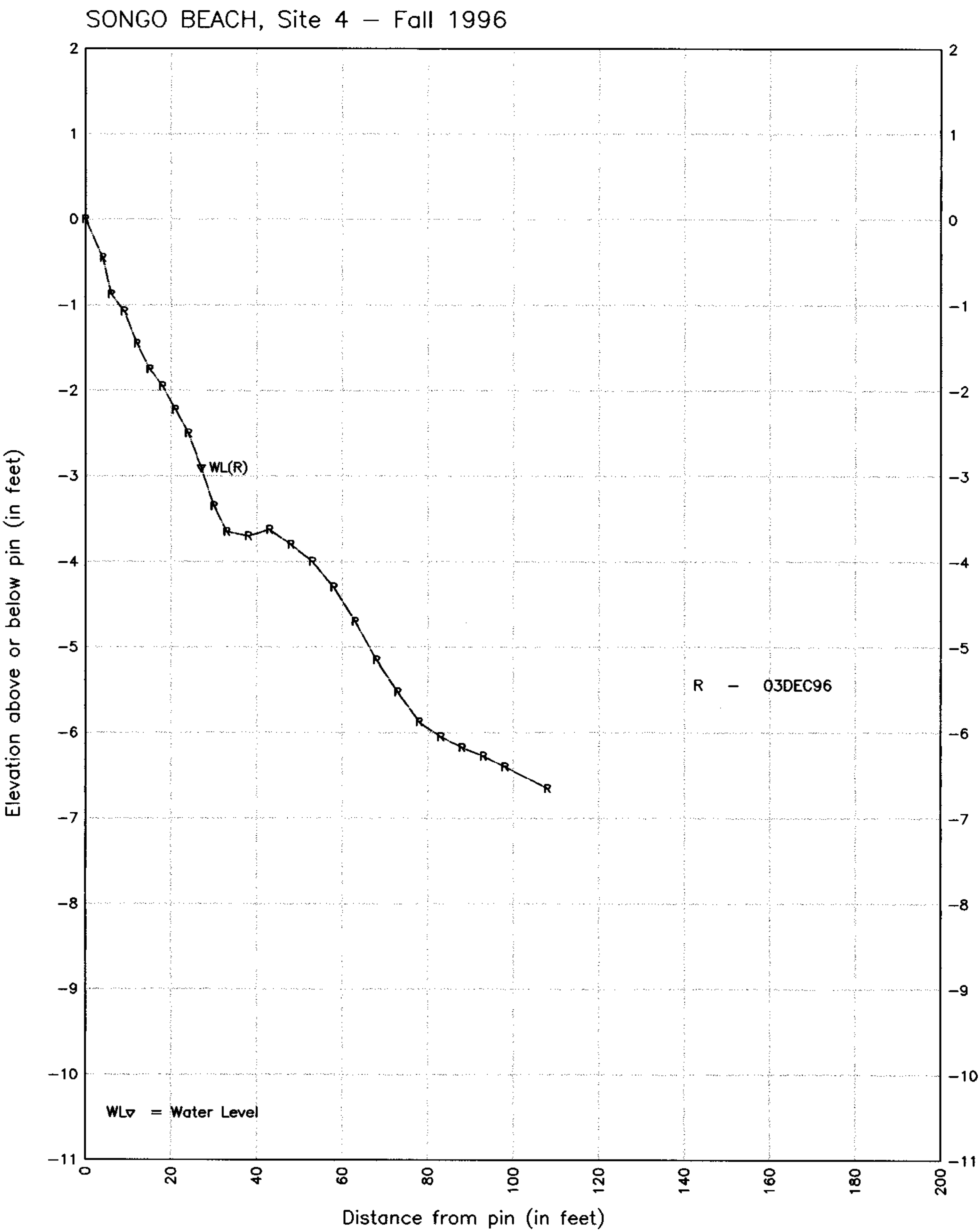

SONGO BEACH, Site 4 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(L)
WL(M)
WL(N)
L – 07JUL95
M – 27JUL95
N – 01SEP95
WL▽ = Water Level

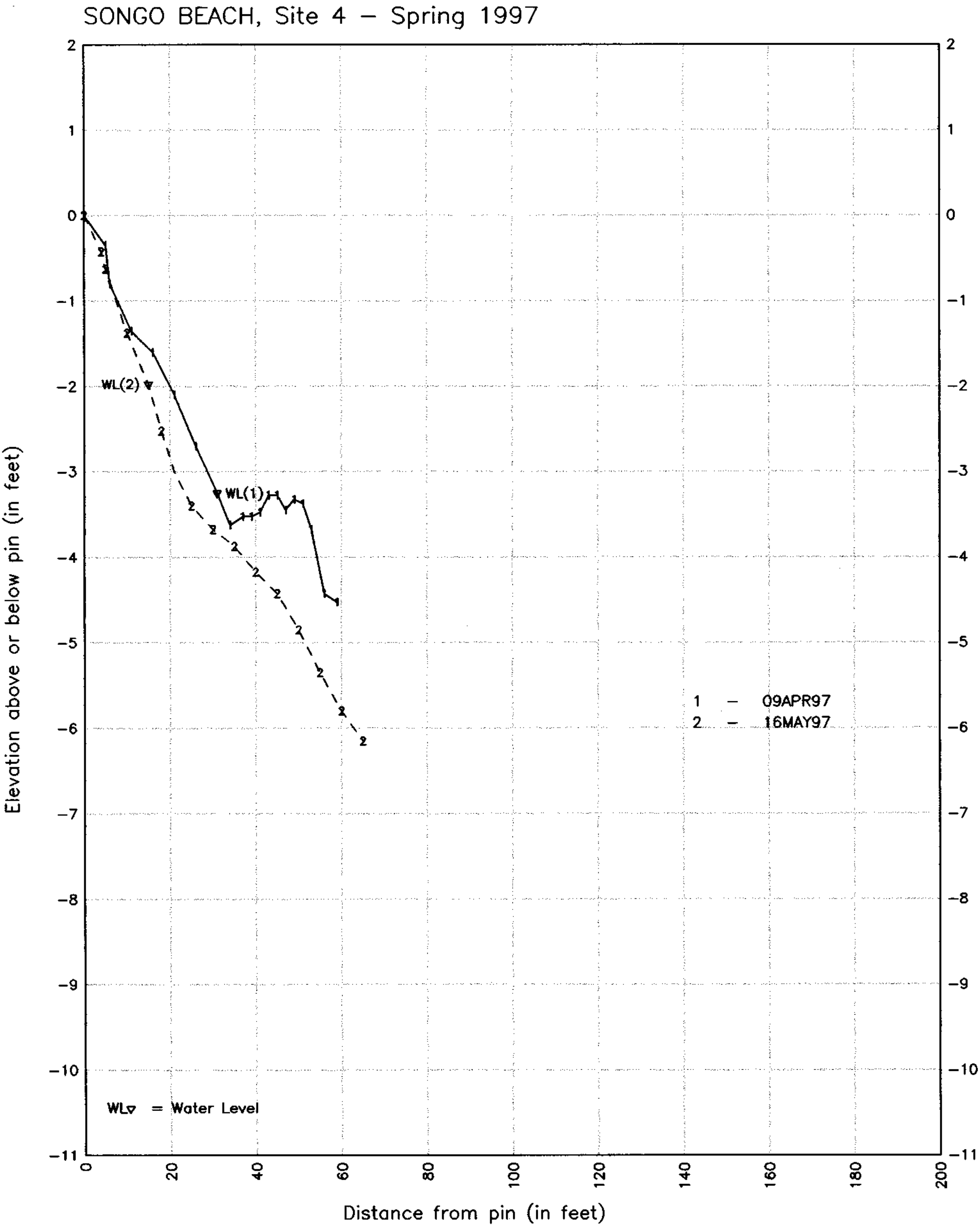


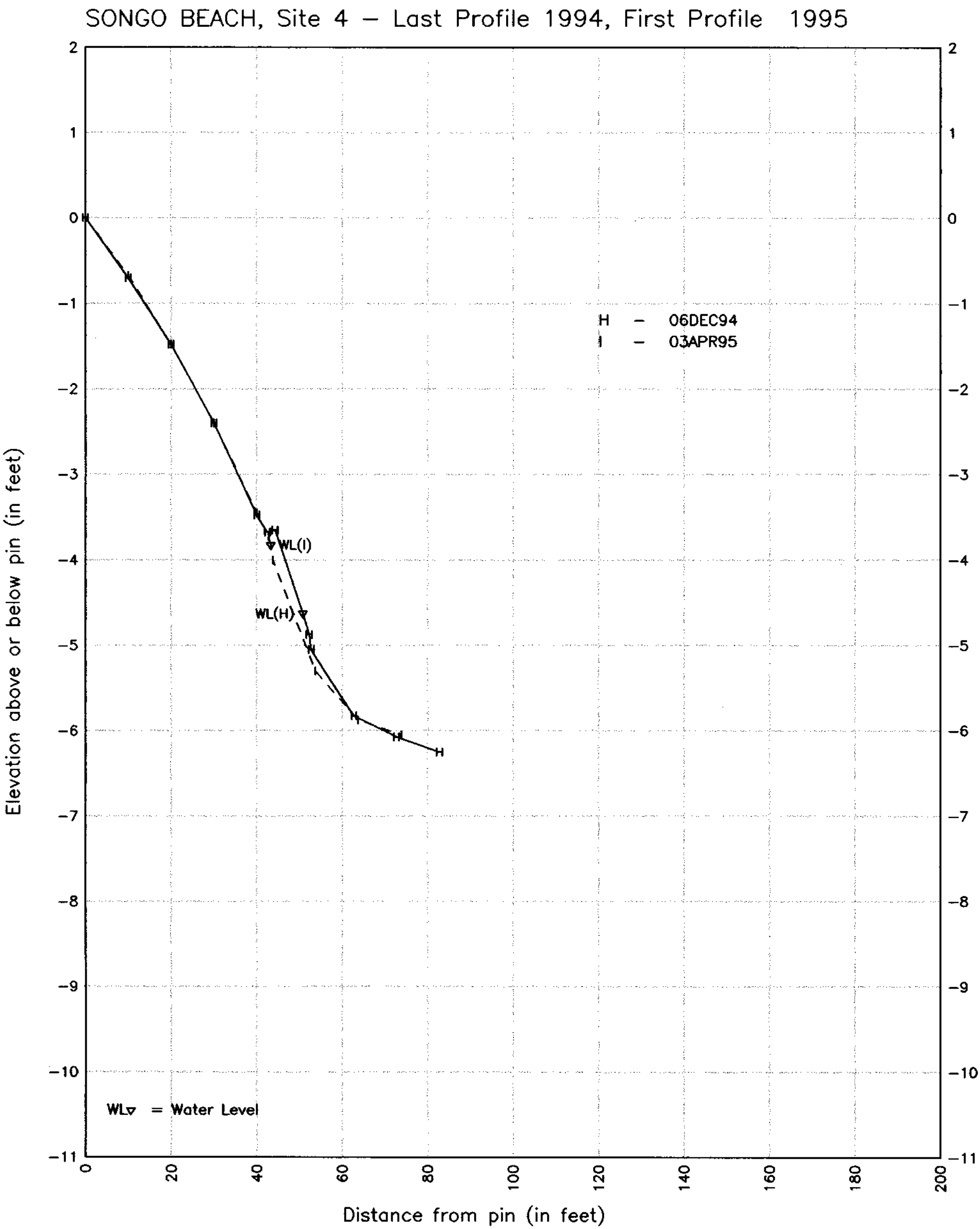
SONGO BEACH, Site 4 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
O – 03OCT95
WL(O)
WL▽ = Water Level

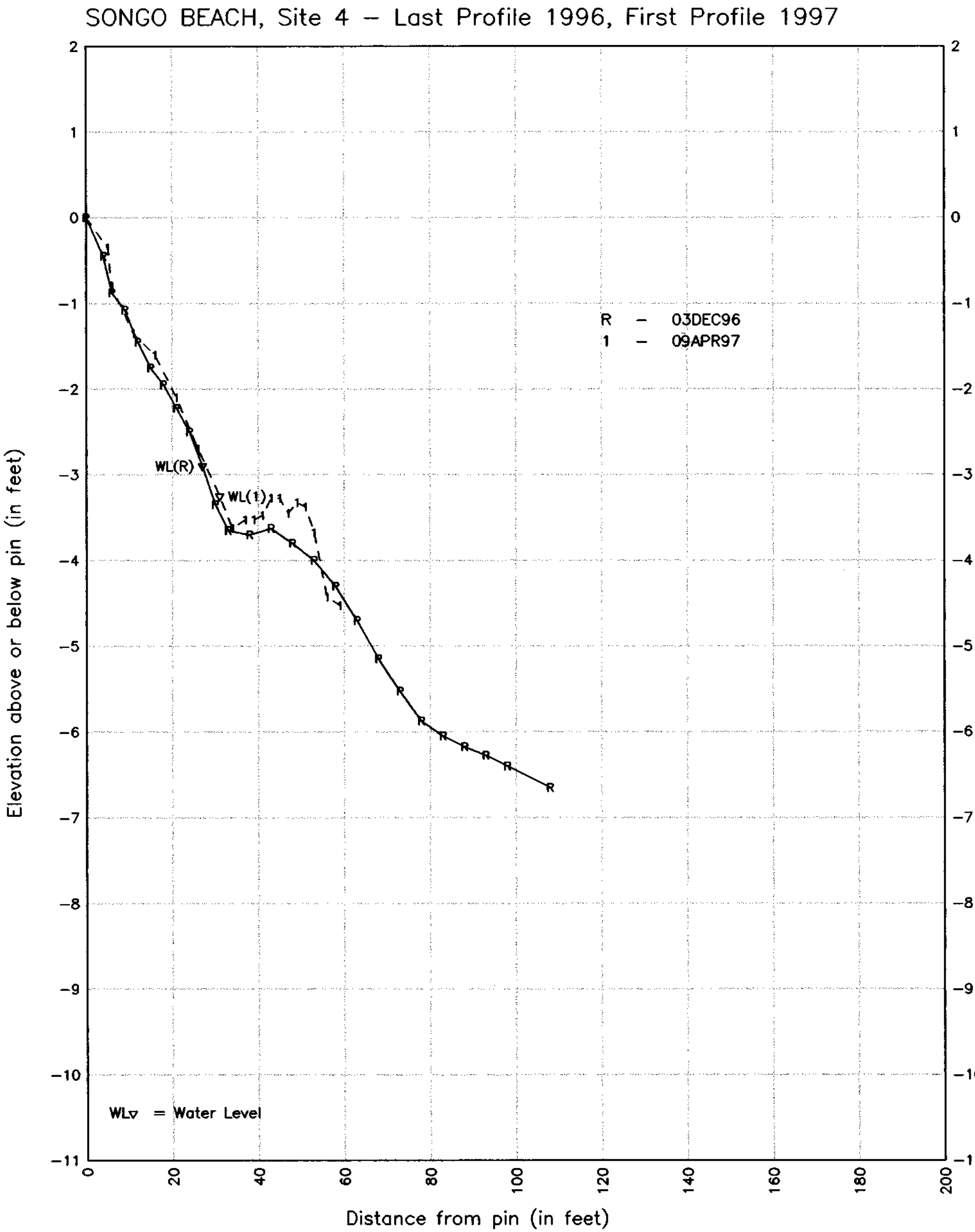
SONGO BEACH, Site 4 – Spring 1996

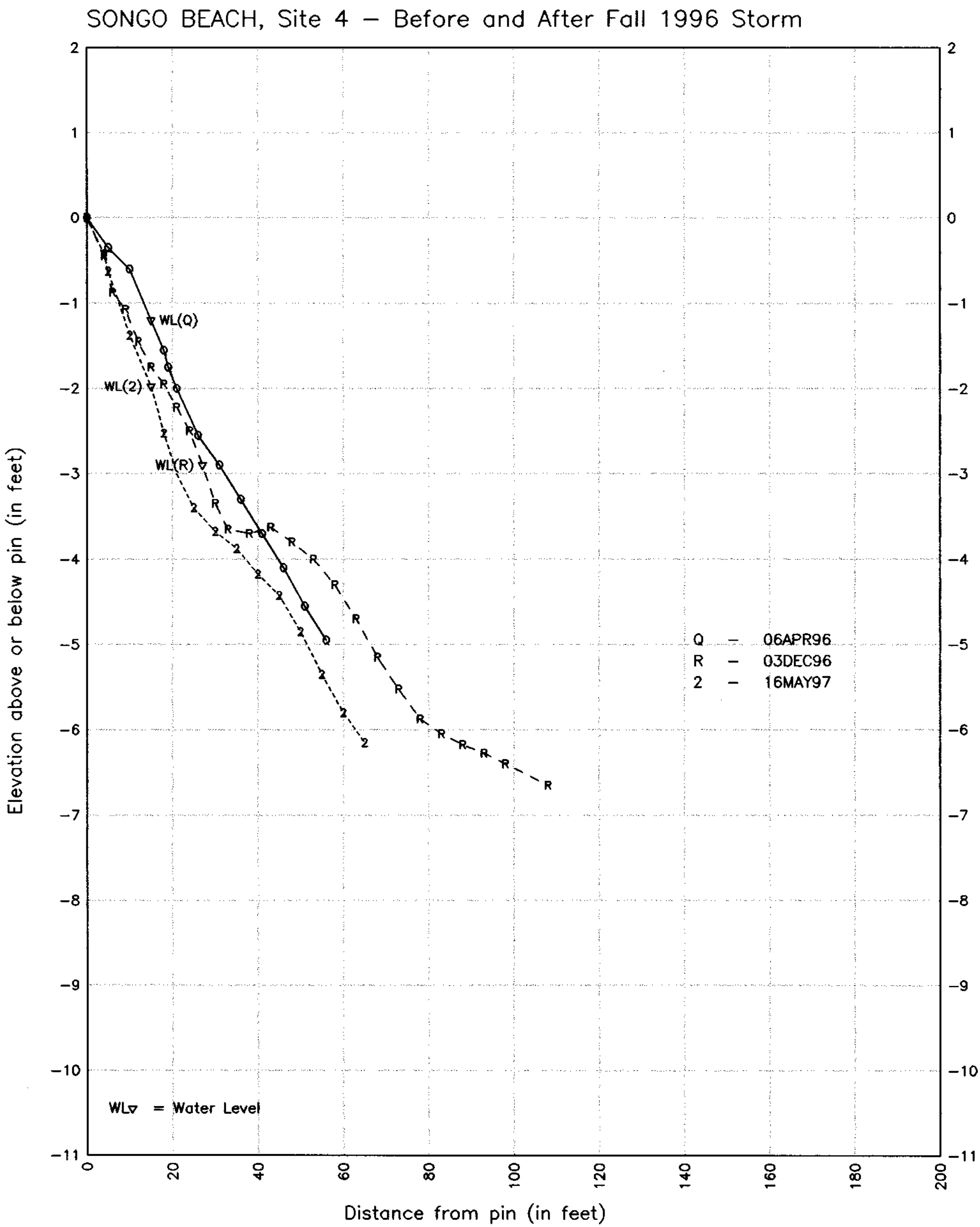



SONGO BEACH, Site 4 – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
R – 03DEC96
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

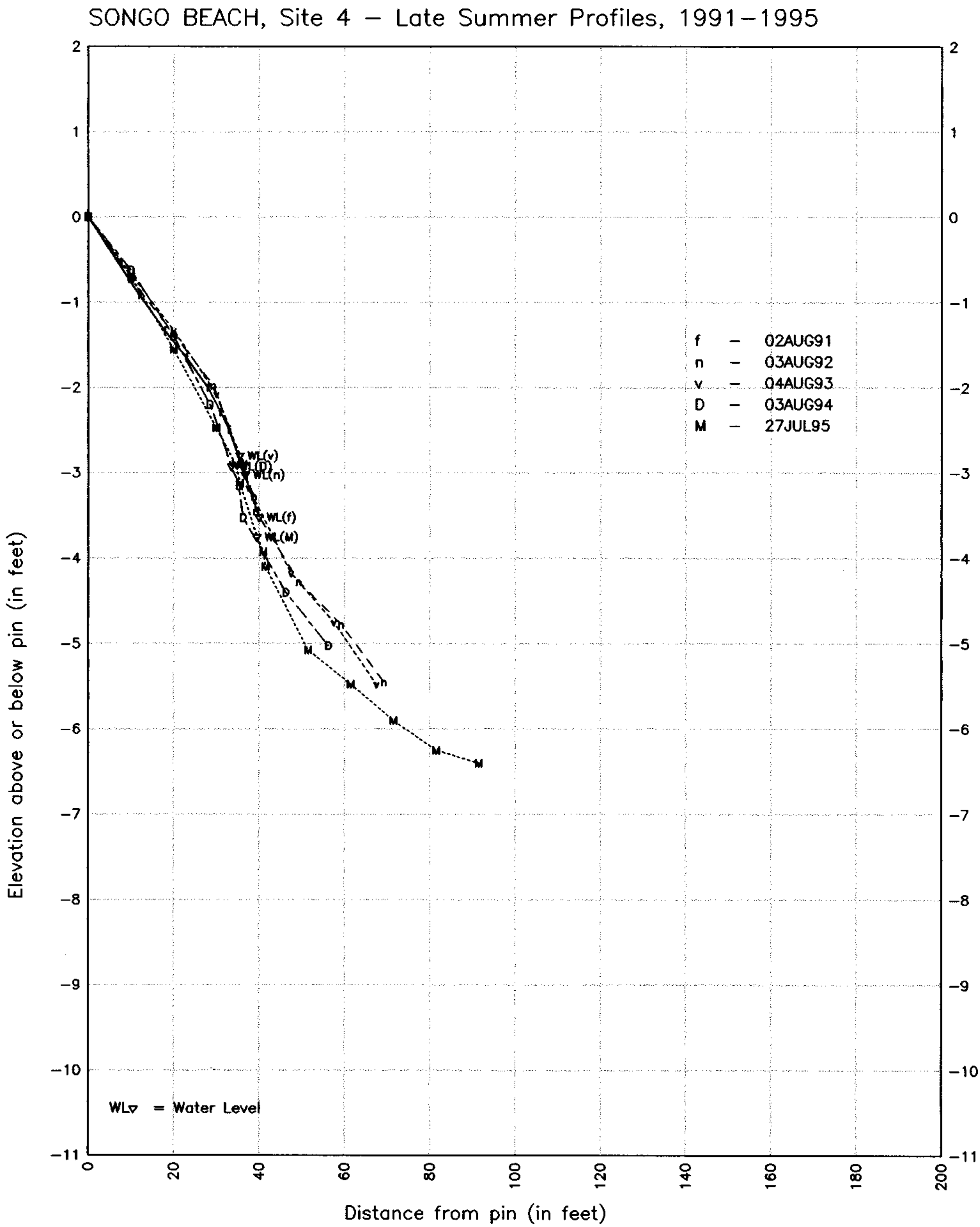

SONGO BEACH, Site 4 – Spring 1997
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(2)
WL(1)
1 – 09APR97
2 – 16MAY97
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200


SONGO BEACH, Site 4 – Last Profile 1994, First Profile 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
H – 06DEC94
I – 03APR95
WL(I)
WL(H)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

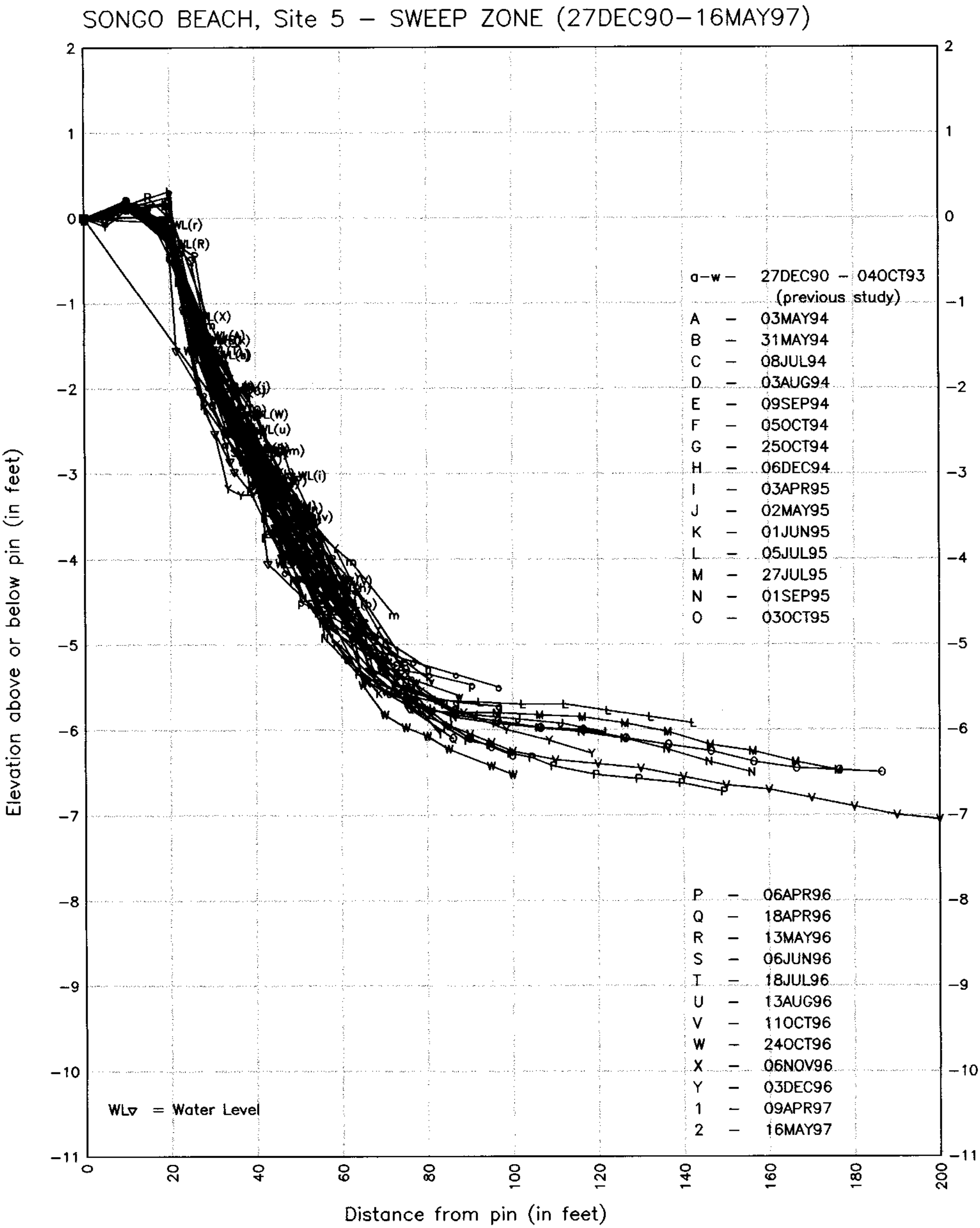

SONGO BEACH, Site 4 – Last Profile 1996, First Profile 1997
Elevation above or below pin (in feet)
Distance from pin (in feet)
R – 03DEC96
1 – 09APR97
WL(R)
WL(1)
WL▽ = Water Level

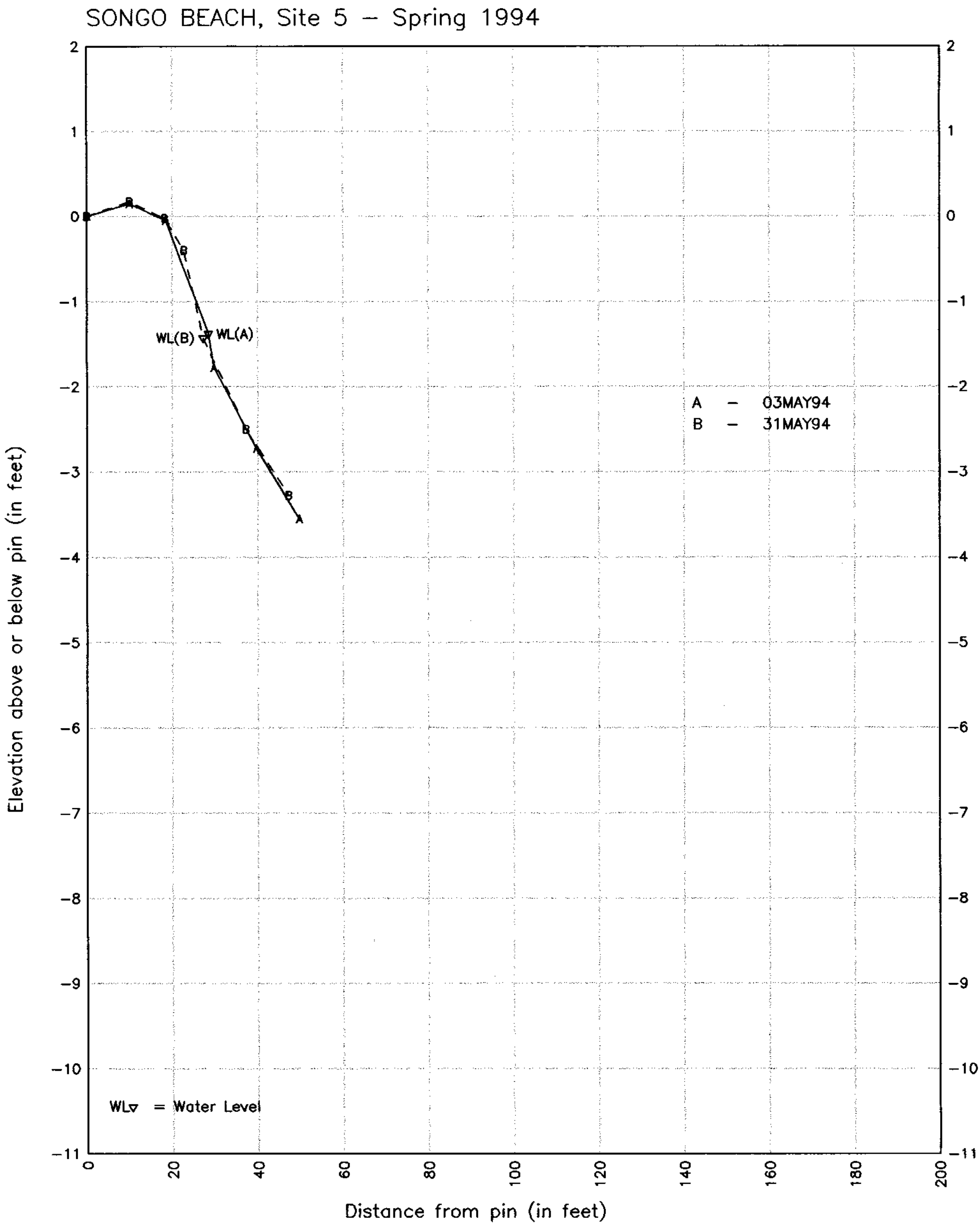


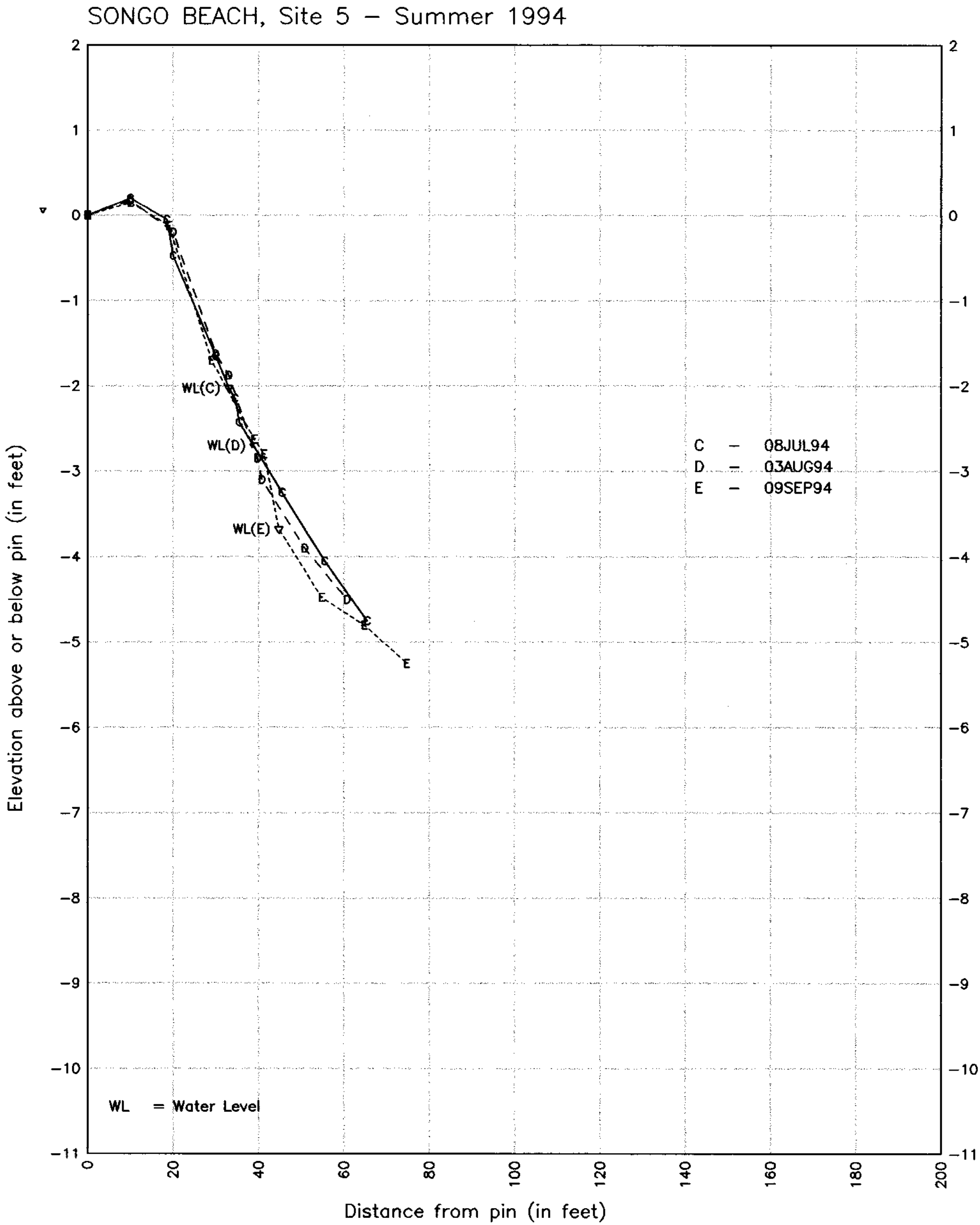
SONGO BEACH, Site 4 – Before and After Fall 1996 Storm
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(Q)
WL(2)
WL(R)
Q – 06APR96
R – 03DEC96
2 – 16MAY97
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

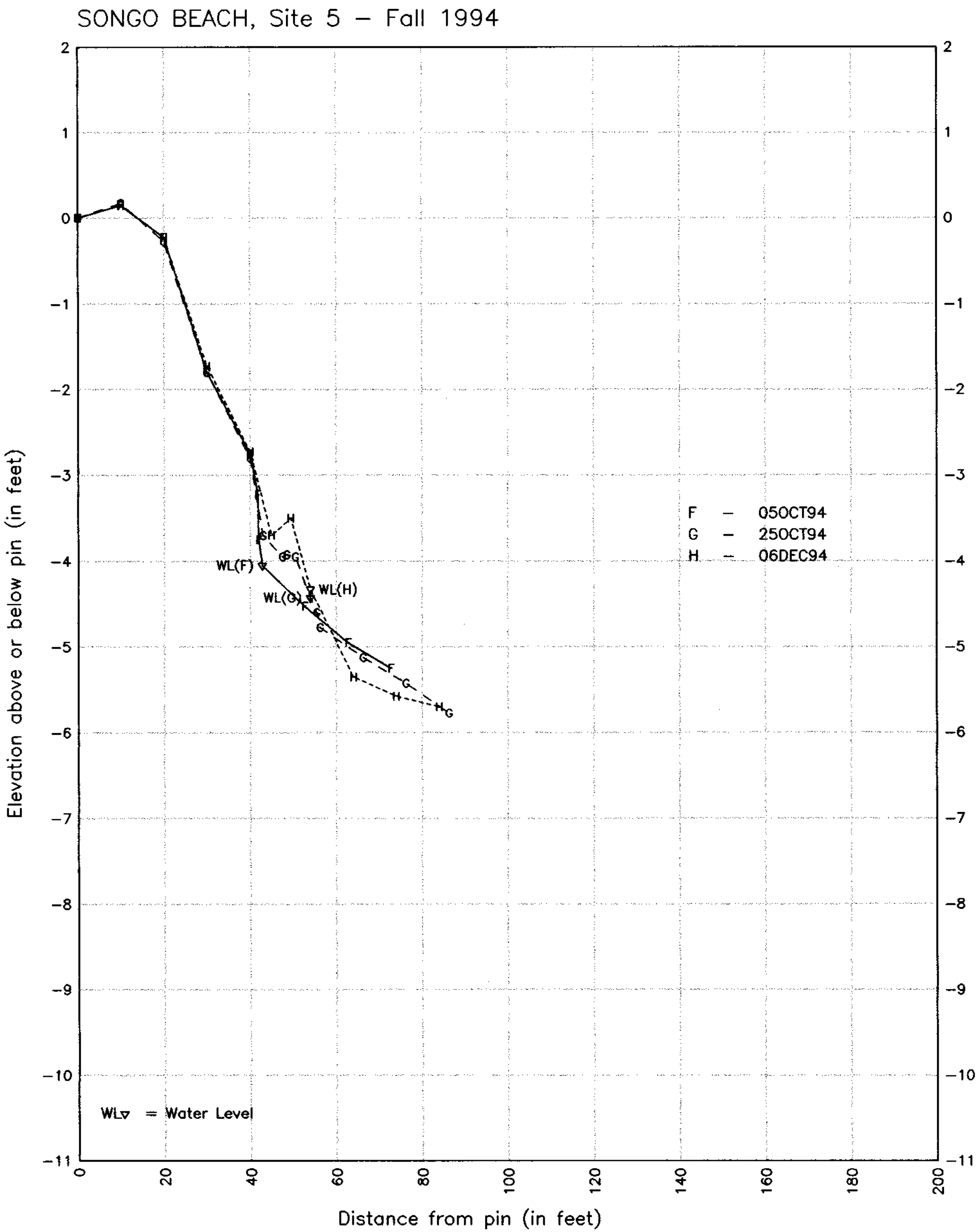


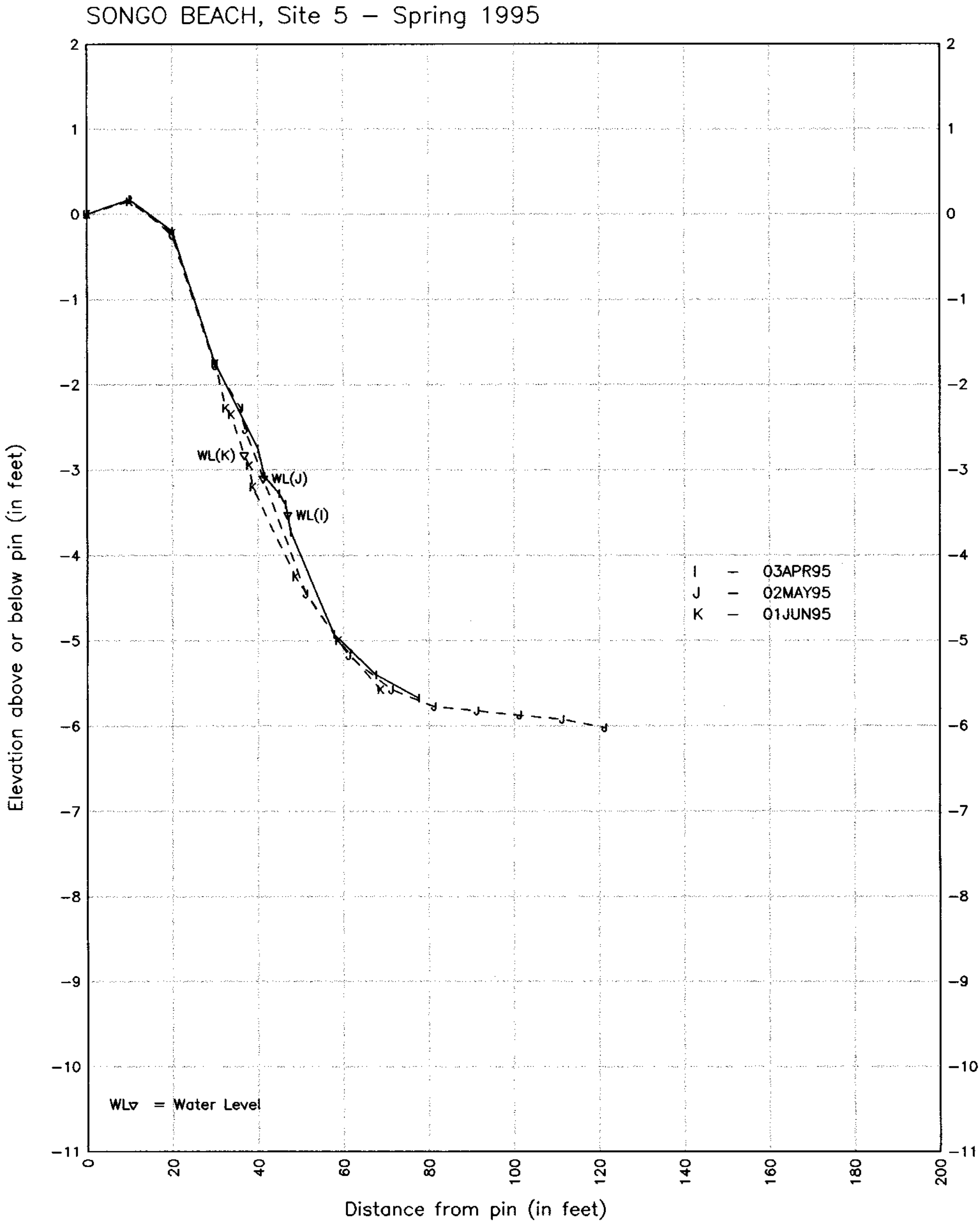
SONGO BEACH, Site 4 – Late Summer Profiles, 1991–1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
f – 02AUG91
n – 03AUG92
v – 04AUG93
D – 03AUG94
M – 27JUL95
WL(v)
WL(D)
WL(n)
WL(f)
WL(M)
WL▽ = Water Level

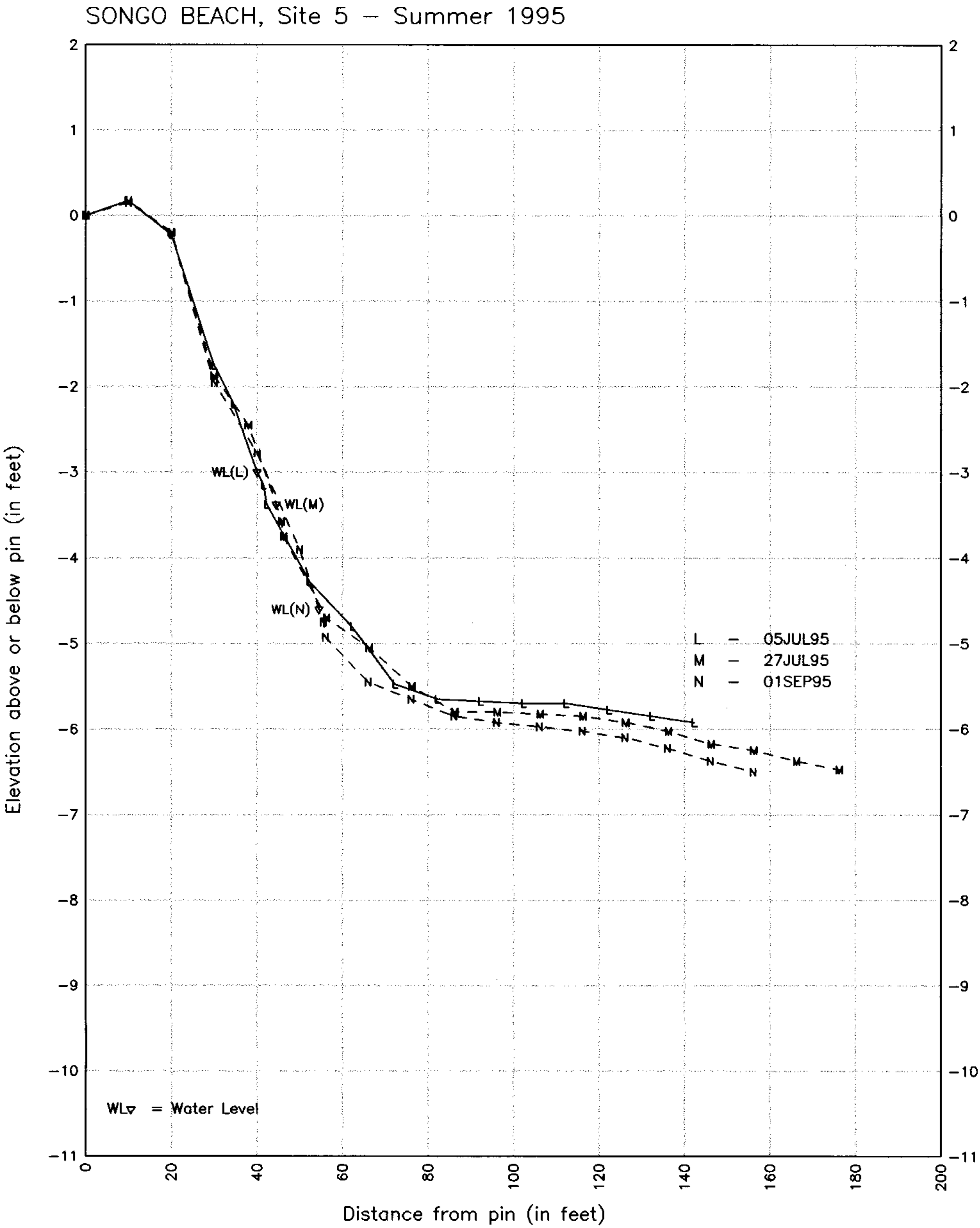

SONGO BEACH, Site 5 – SWEEP ZONE (27DEC90–16MAY97)
Elevation above or below pin (in feet)
Distance from pin (in feet)
a–w – 27DEC90 – 04OCT93 (previous study)
A – 03MAY94
B – 31MAY94
C – 08JUL94
D – 03AUG94
E – 09SEP94
F – 05OCT94
G – 25OCT94
H – 06DEC94
I – 03APR95
J – 02MAY95
K – 01JUN95
L – 05JUL95
M – 27JUL95
N – 01SEP95
O – 03OCT95
P – 06APR96
Q – 18APR96
R – 13MAY96
S – 06JUN96
T – 18JUL96
U – 13AUG96
V – 11OCT96
W – 24OCT96
X – 06NOV96
Y – 03DEC96
1 – 09APR97
2 – 16MAY97
WL▽ = Water Level

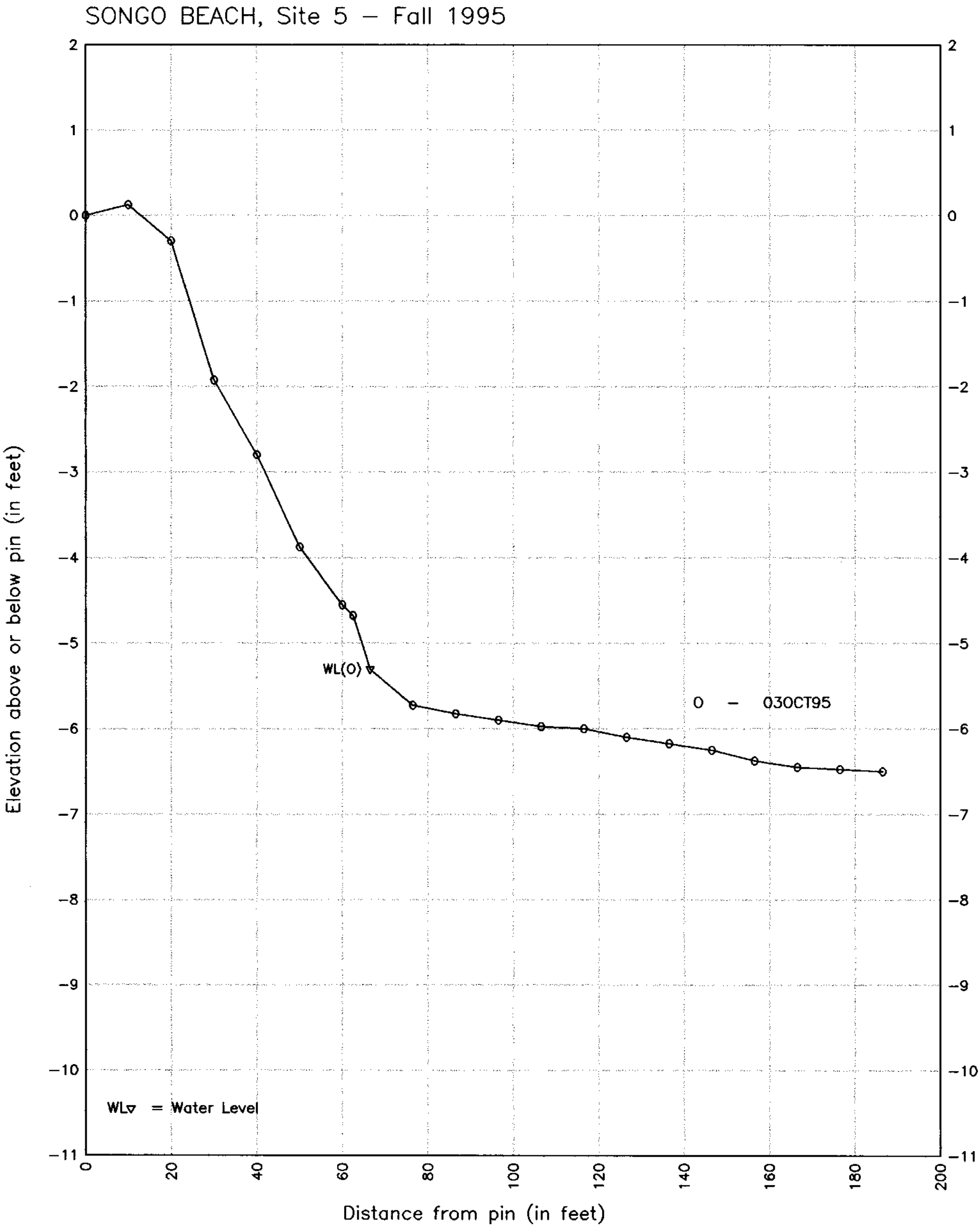

SONGO BEACH, Site 5 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(B)
WL(A)
A – 03MAY94
B – 31MAY94
WL▽ = Water Level
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

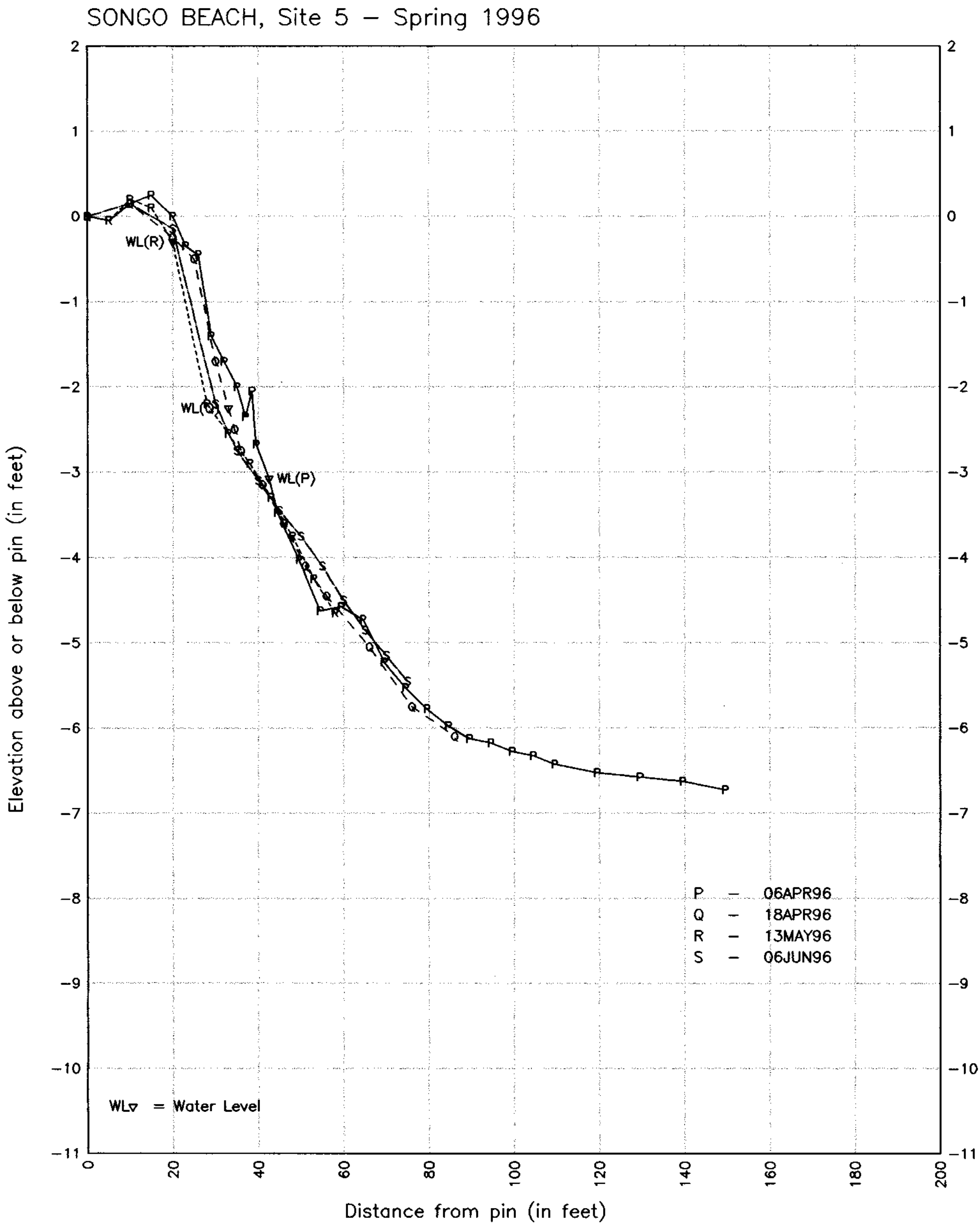

SONGO BEACH, Site 5 – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(C)
WL(D)
WL(E)
C – 08JUL94
D – 03AUG94
E – 09SEP94
WL = Water Level

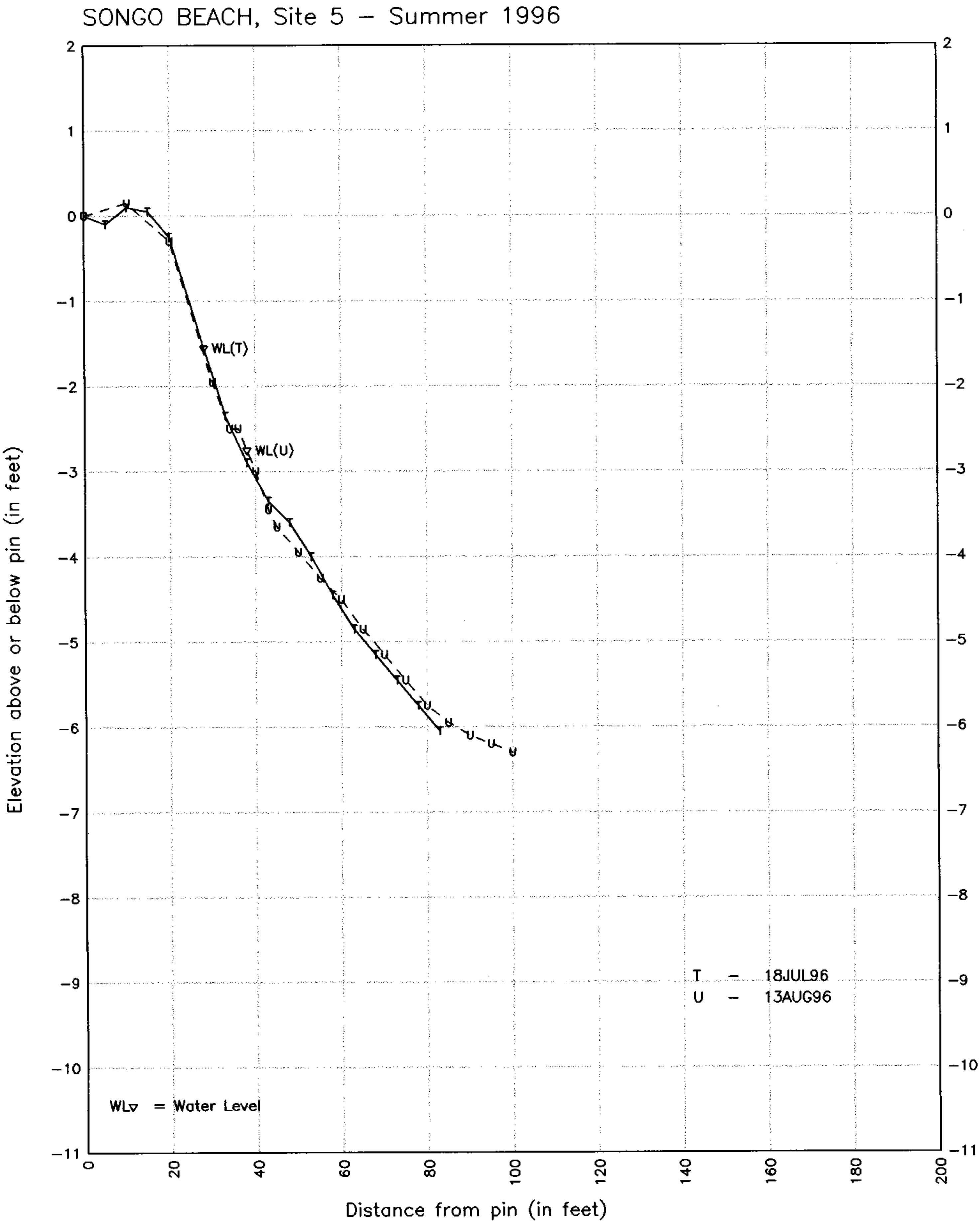

SONGO BEACH, Site 5 – Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
F – 05OCT94
G – 25OCT94
H – 06DEC94
WL(F)
WL(G)
WL(H)
WL▽ = Water Level


SONGO BEACH, Site 5 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(K)
WL(J)
WL(I)
I – 03APR95
J – 02MAY95
K – 01JUN95
WL▽ = Water Level

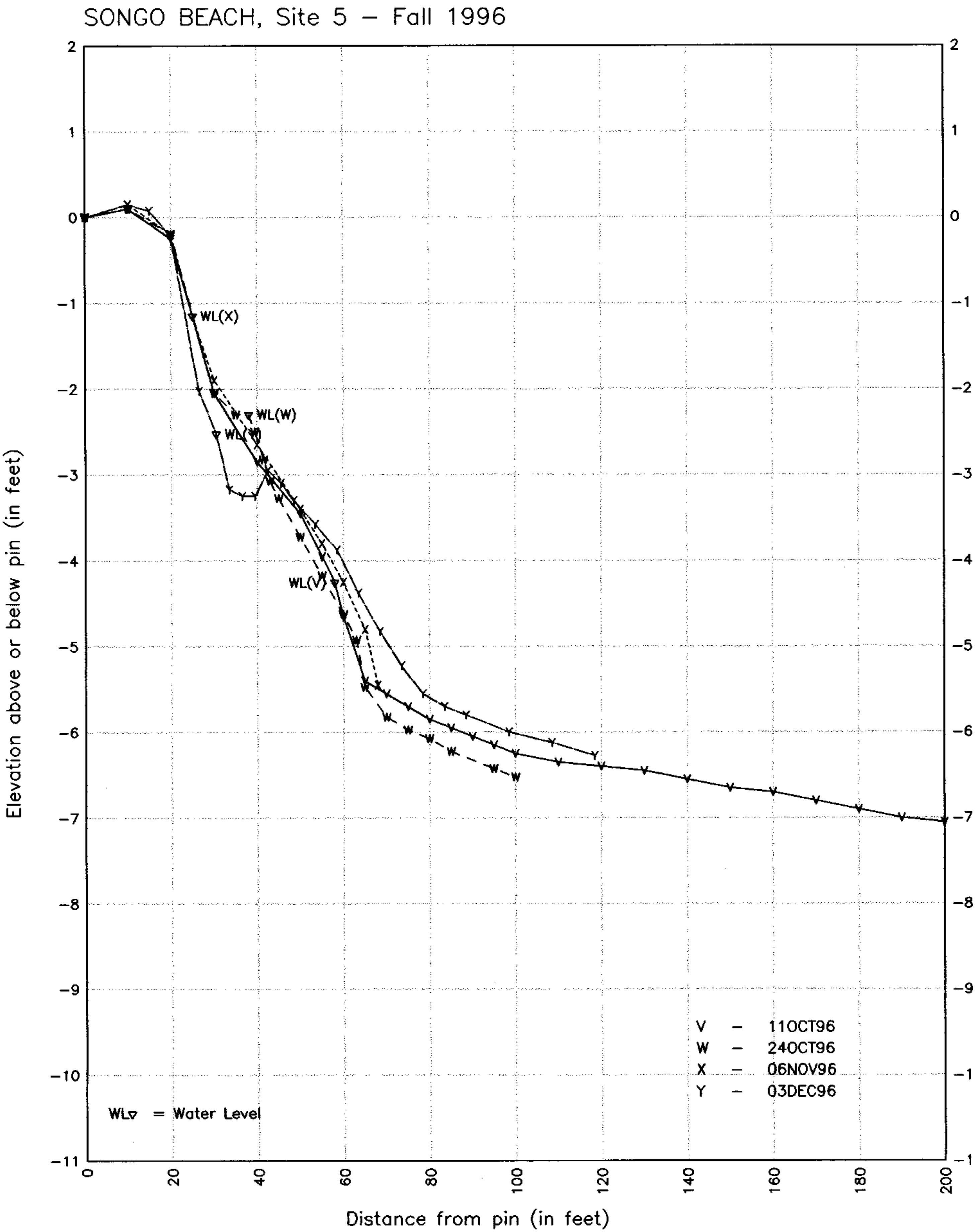

SONGO BEACH, Site 5 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(L)
WL(M)
WL(N)
L – 05JUL95
M – 27JUL95
N – 01SEP95
WL▽ = Water Level

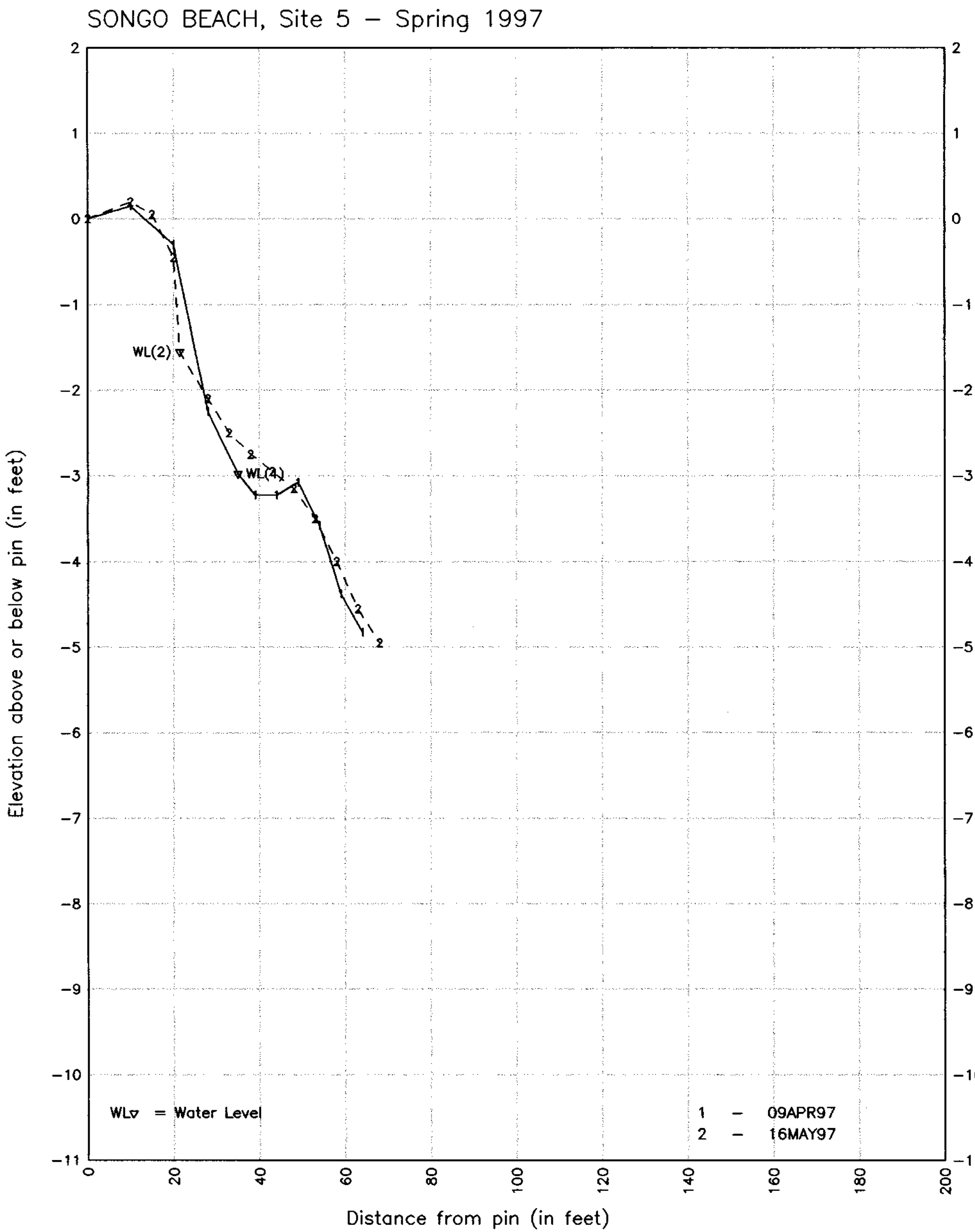

SONGO BEACH, Site 5 – Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(O)
O – 03OCT95
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

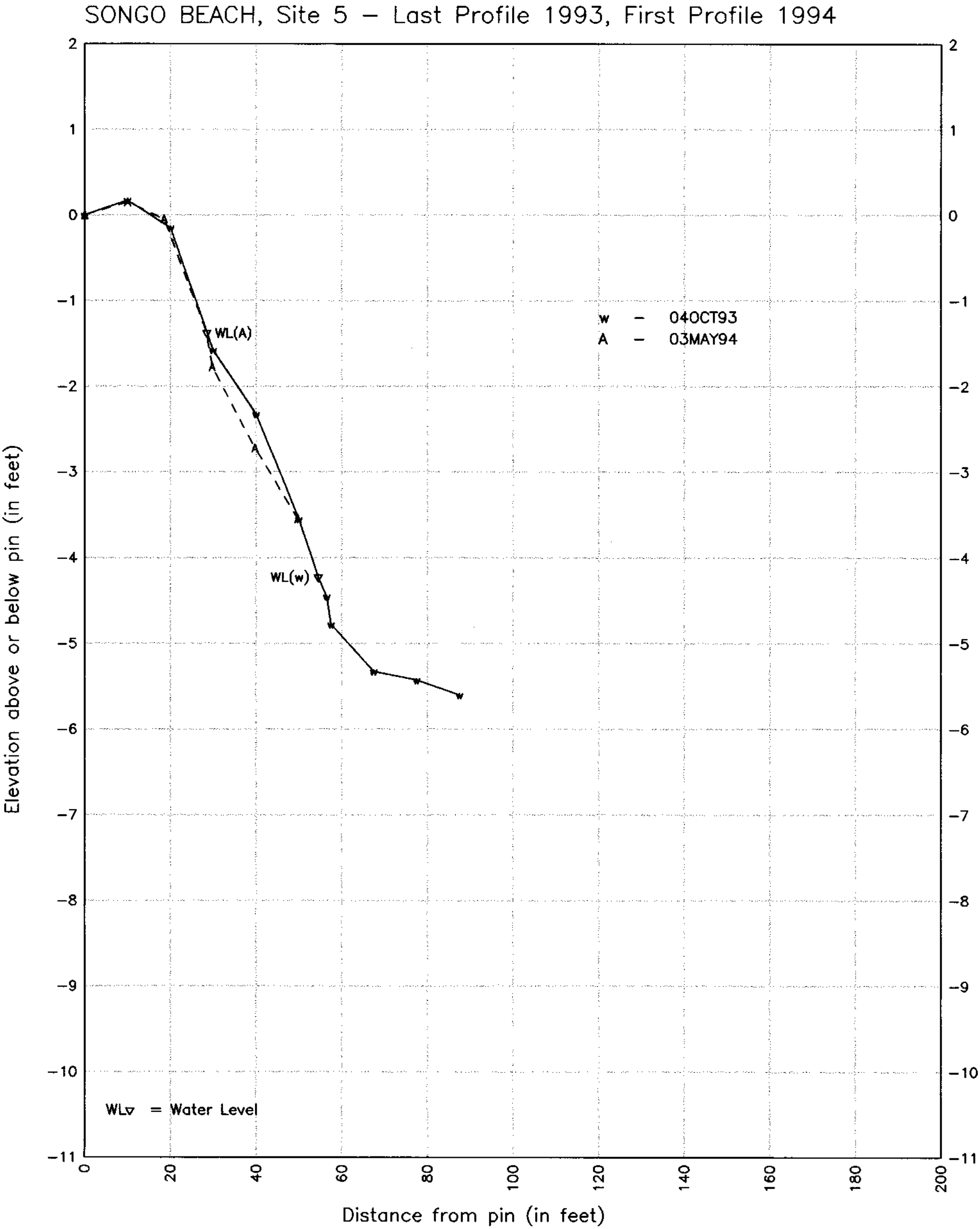

SONGO BEACH, Site 5 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(Q)
WL(P)
P – 06APR96
Q – 18APR96
R – 13MAY96
S – 06JUN96
WL▽ = Water Level

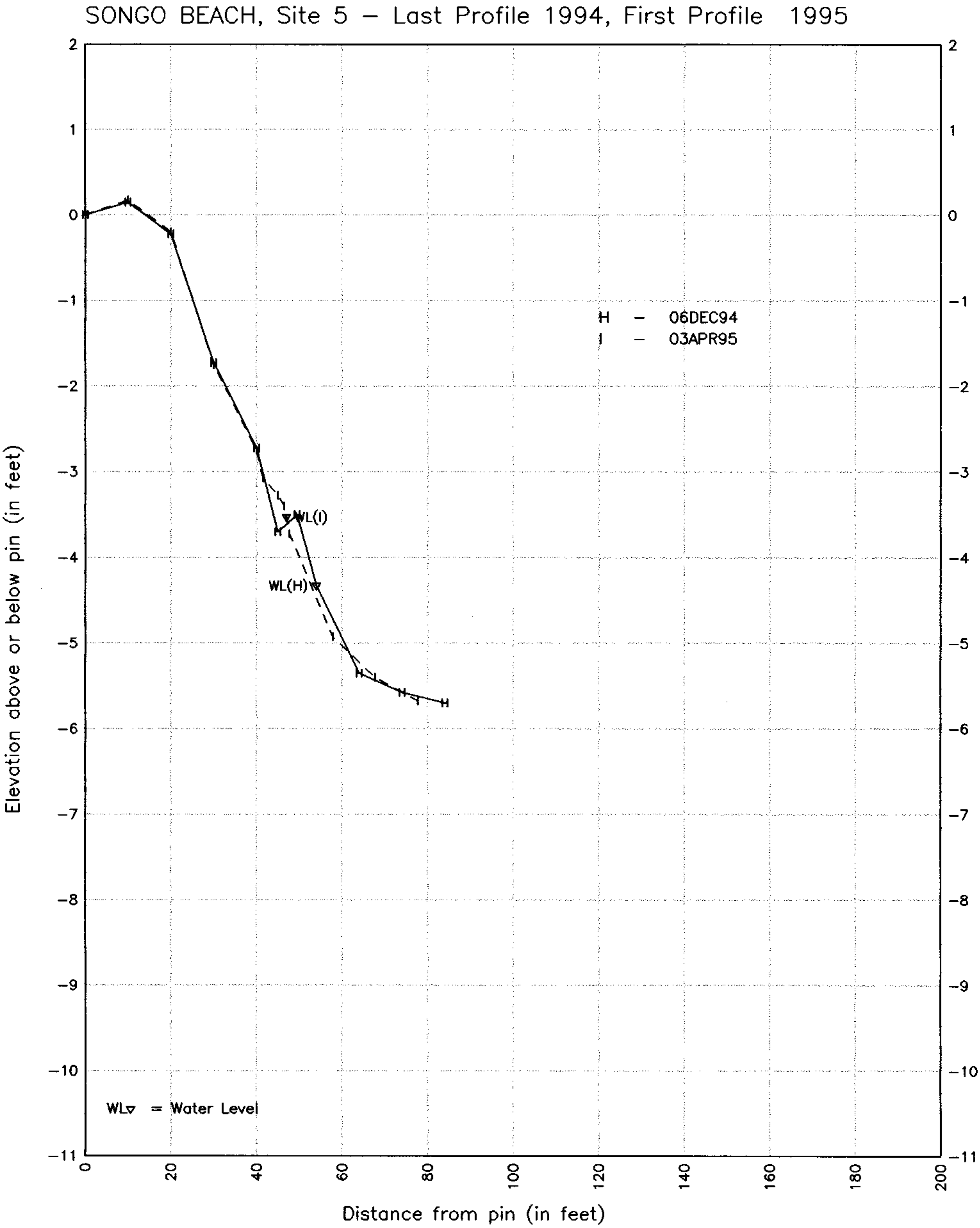


SONGO BEACH, Site 5 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(T)
WL(U)
T – 18JUL96
U – 13AUG96
WL▽ = Water Level

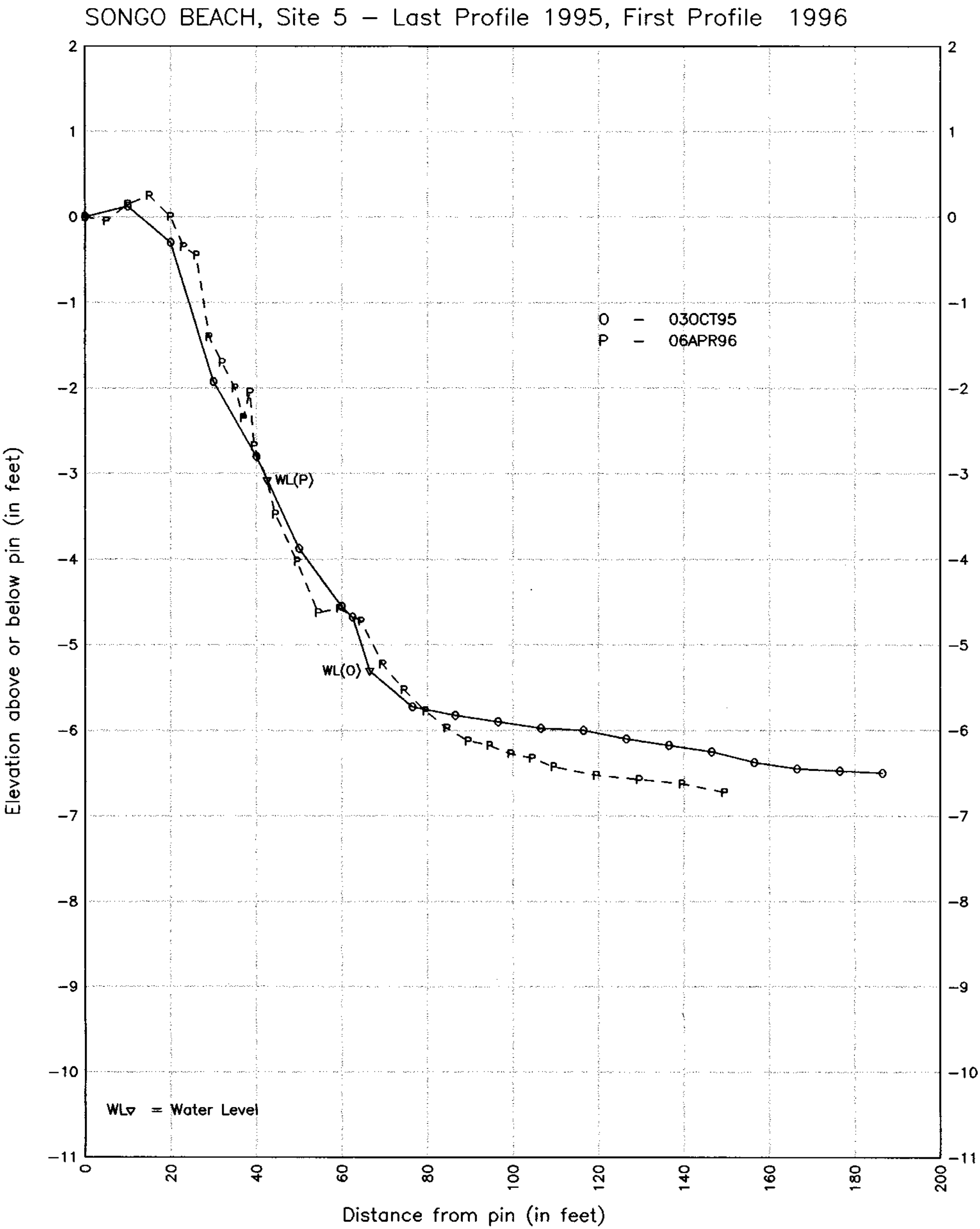

SONGO BEACH, Site 5 – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200
WL(X)
WL(W)
WL(Y)
WL(V)
V – 11OCT96
W – 24OCT96
X – 06NOV96
Y – 03DEC96
WL▽ = Water Level


SONGO BEACH, Site 5 – Spring 1997
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(2)
WL(1)
WL▿ = Water Level
1 – 09APR97
2 – 16MAY97
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200


SONGO BEACH, Site 5 – Last Profile 1993, First Profile 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
w – 04OCT93
A – 03MAY94
WL(A)
WL(w)
WL▽ = Water Level
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200

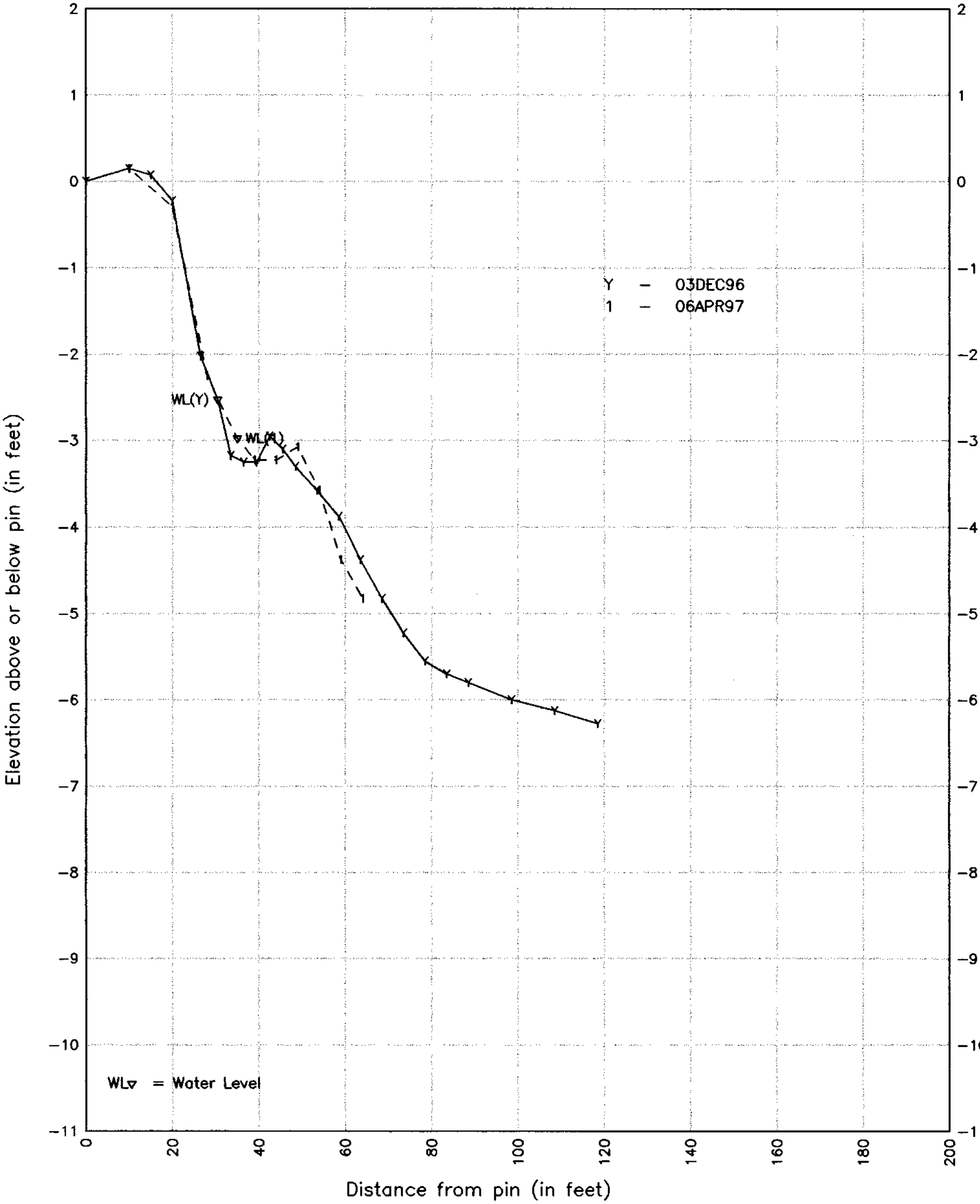


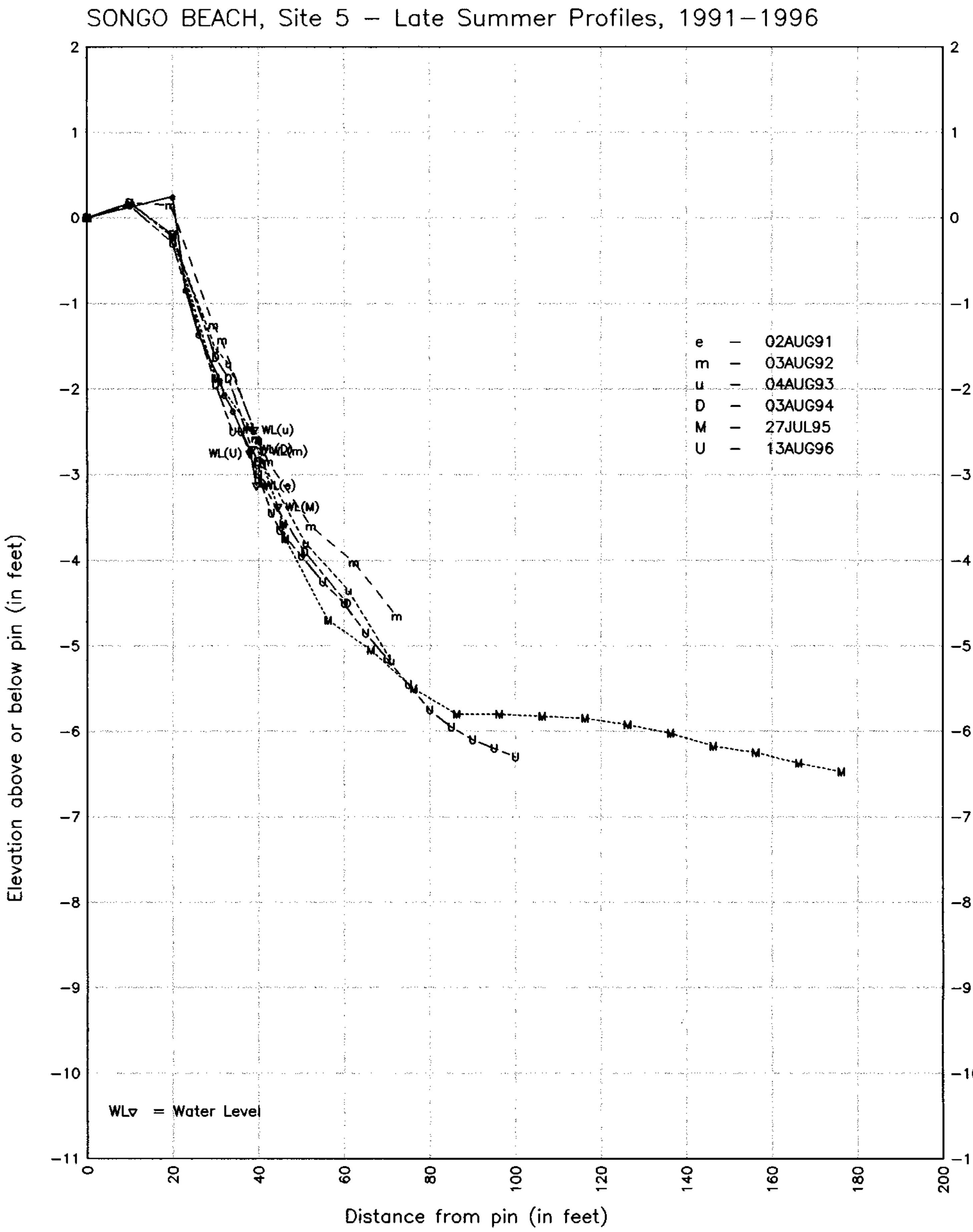
SONGO BEACH, Site 5 – Last Profile 1994, First Profile 1995
H – 06DEC94
I – 03APR95
WL(I)
WL(H)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200



SONGO BEACH, Site 5 – Last Profile 1995, First Profile 1996
O – 03OCT95
P – 06APR96
WL(P)
WL(O)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)

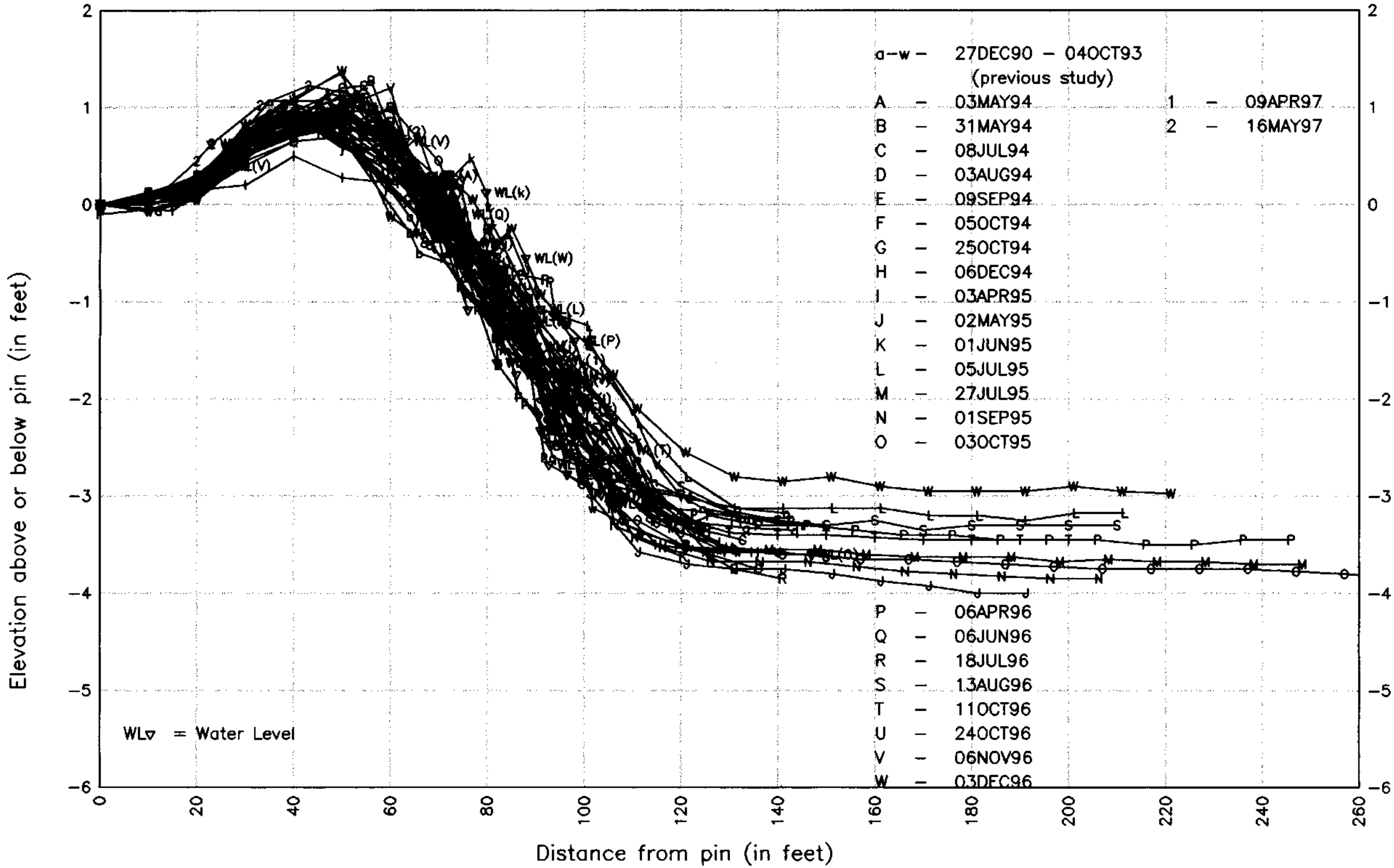
SONGO BEACH, Site 5 - Last Profile 1996, First Profile 1997



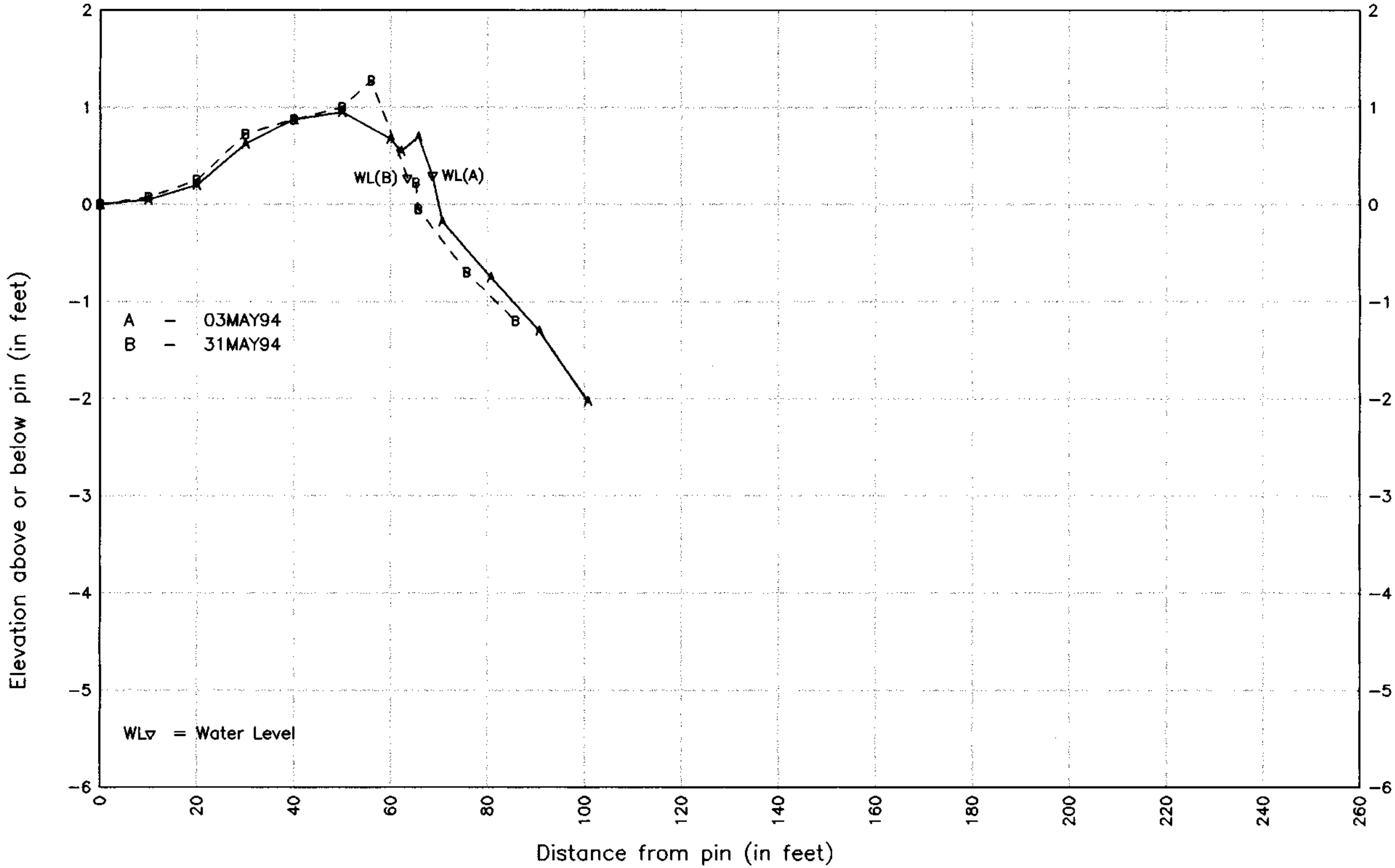


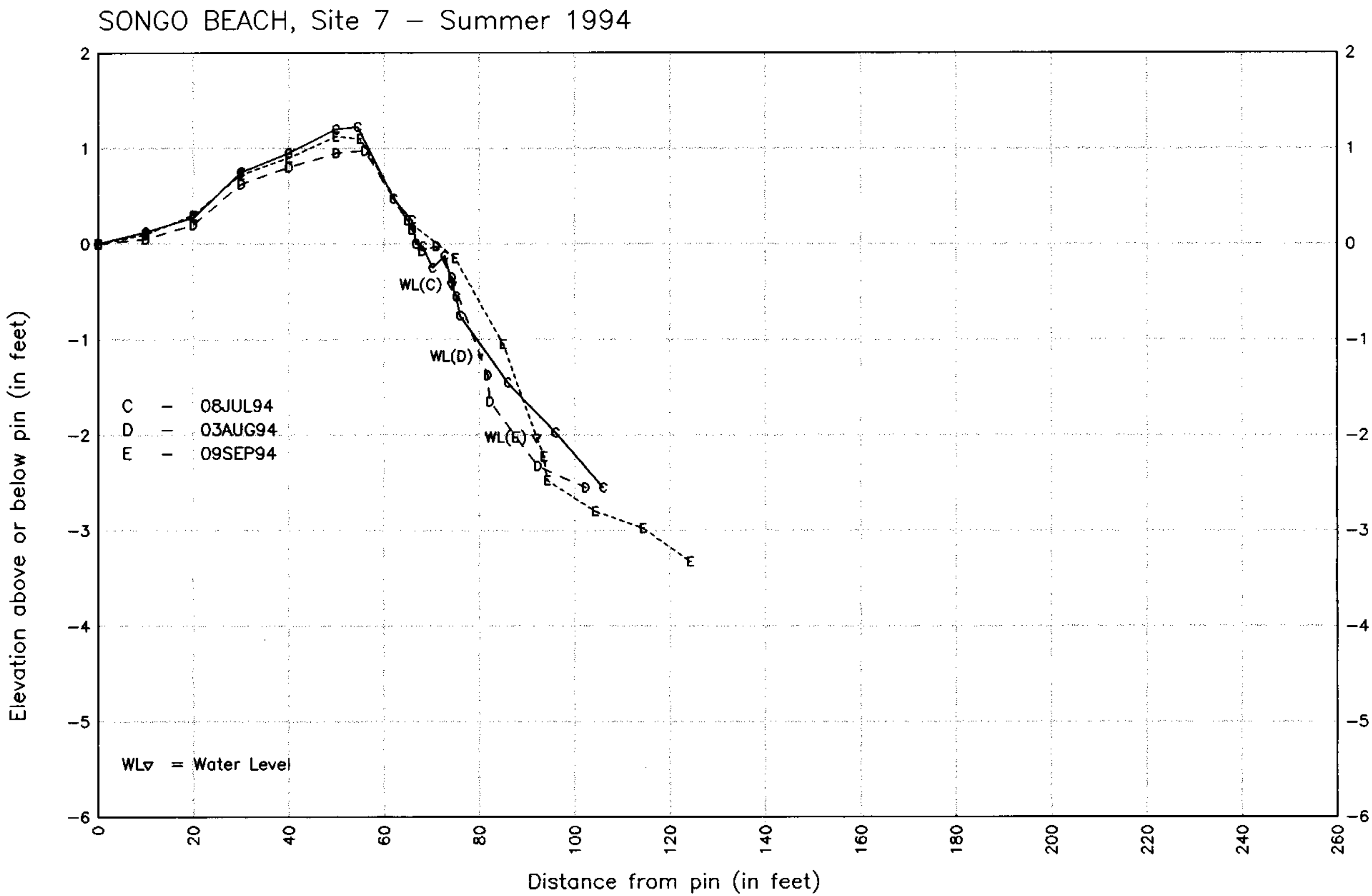
SONGO BEACH, Site 5 – Late Summer Profiles, 1991–1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
e – 02AUG91
m – 03AUG92
u – 04AUG93
D – 03AUG94
M – 27JUL95
U – 13AUG96
WL▽ = Water Level

SONGO BEACH, Site 7 – SWEEP ZONE (27DEC90–16MAY97)



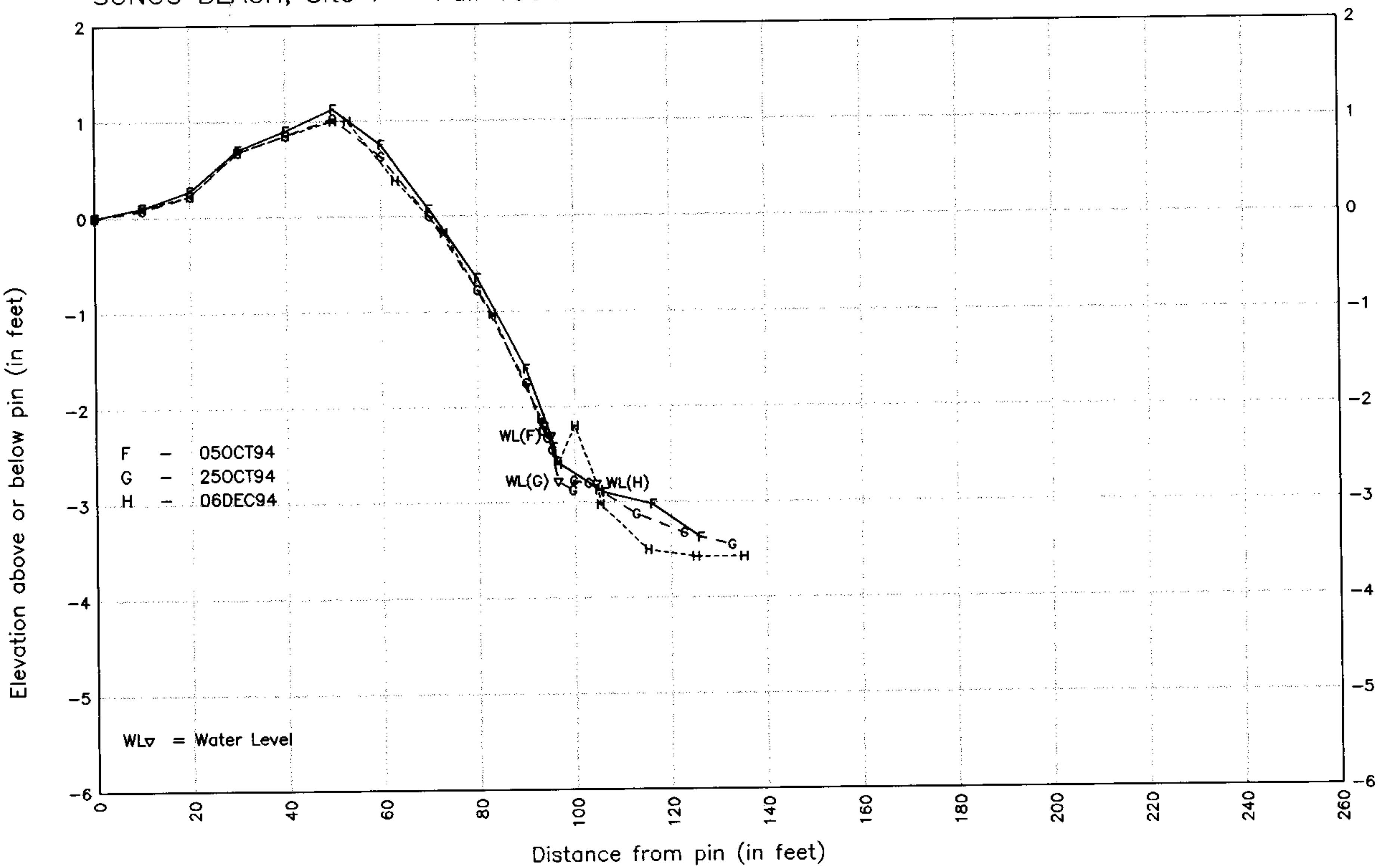
SONGO BEACH, Site 7 – Spring 1994



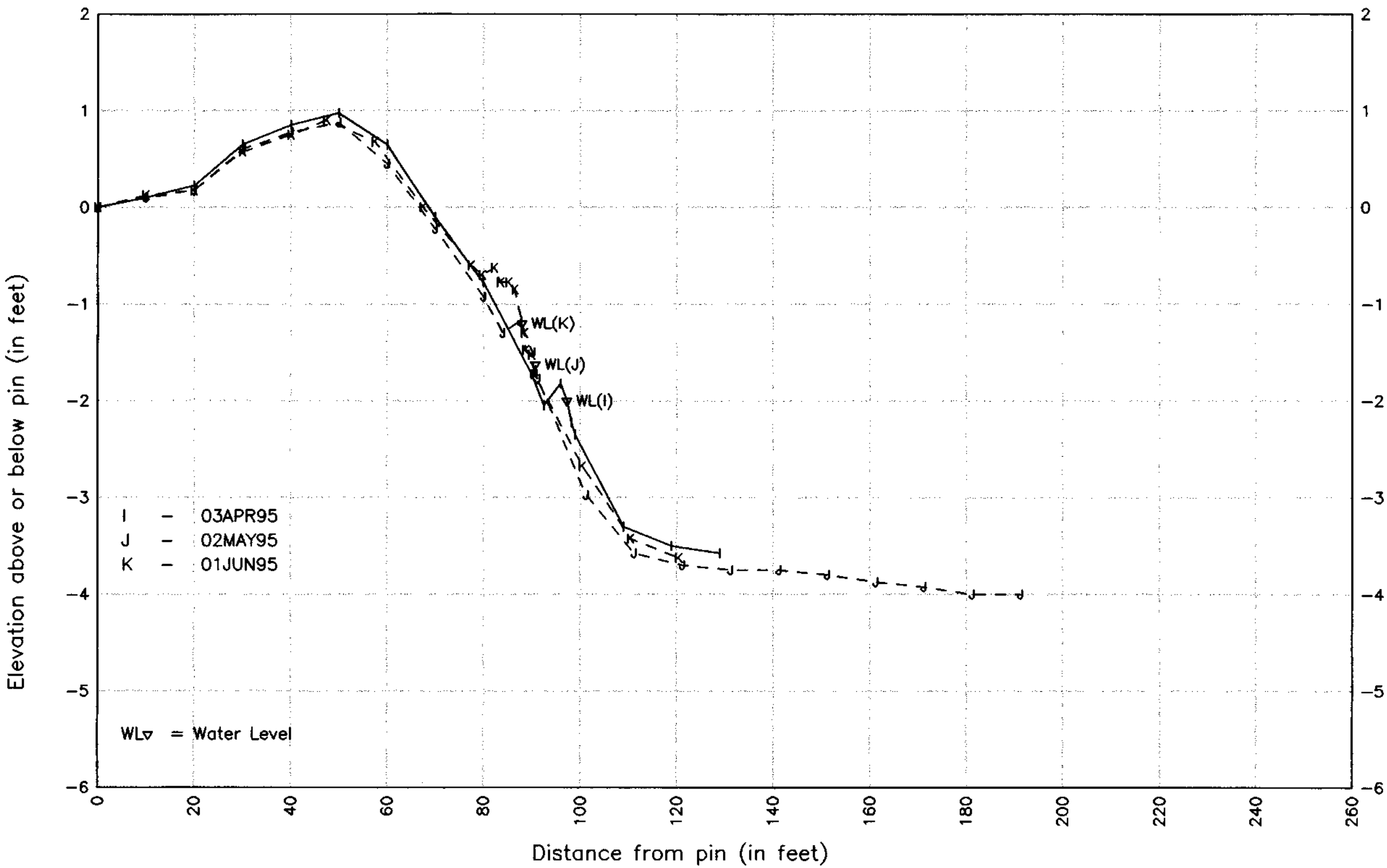


SONGO BEACH, Site 7 – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
C – 08JUL94
D – 03AUG94
E – 09SEP94
WL▽ = Water Level
WL(C)
WL(D)
WL(E)

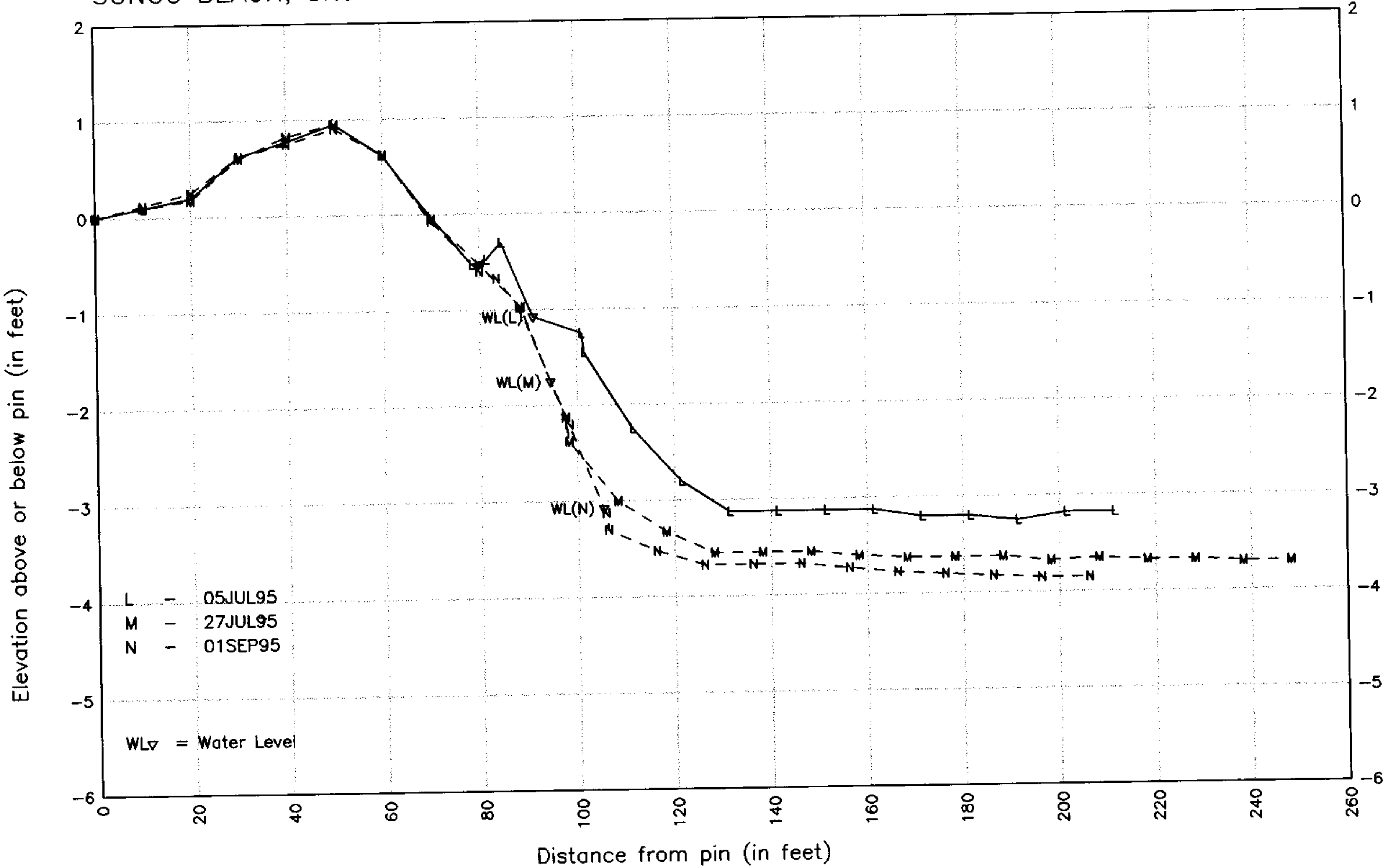
SONGO BEACH, Site 7 — Fall 1994

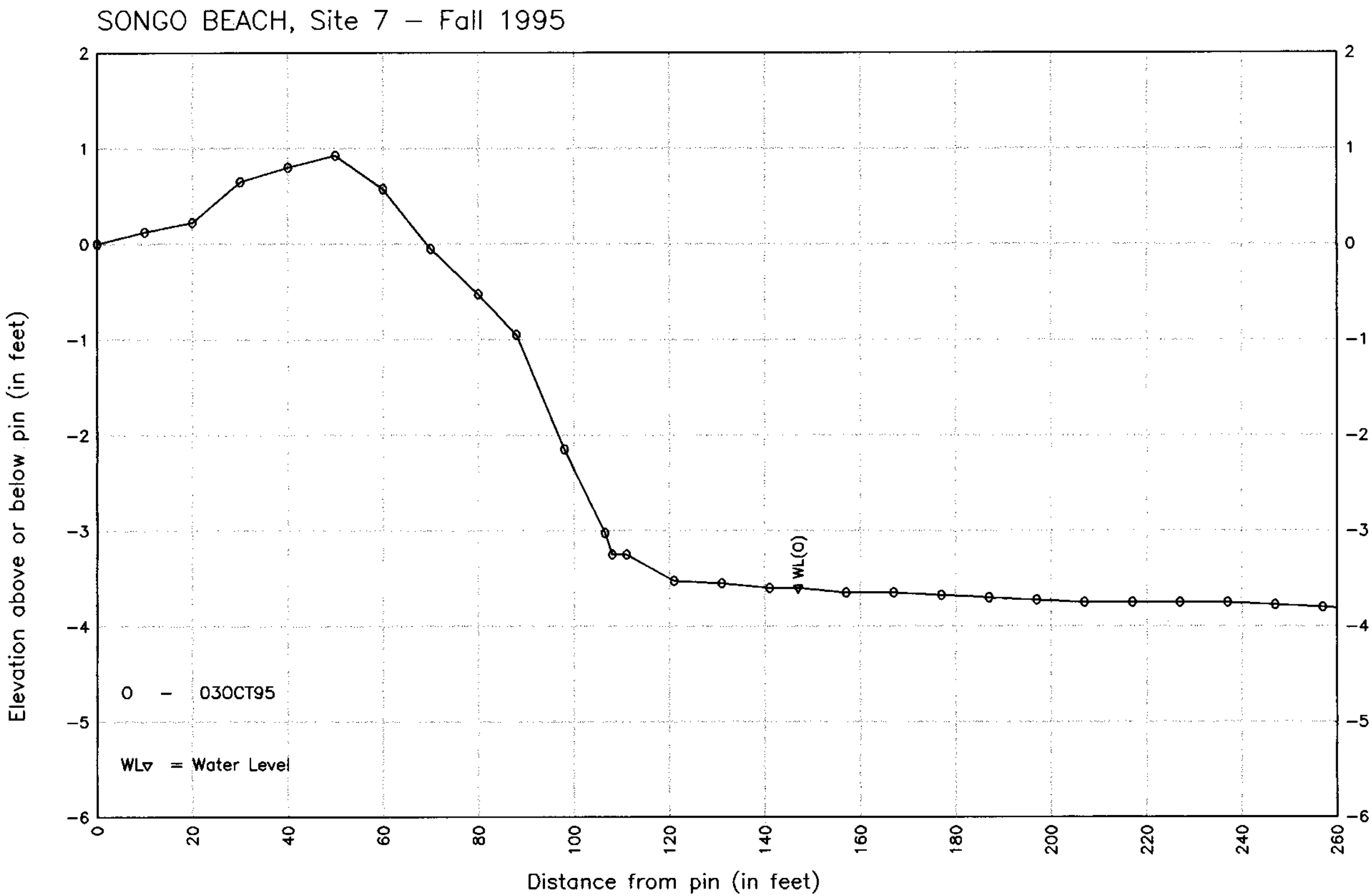


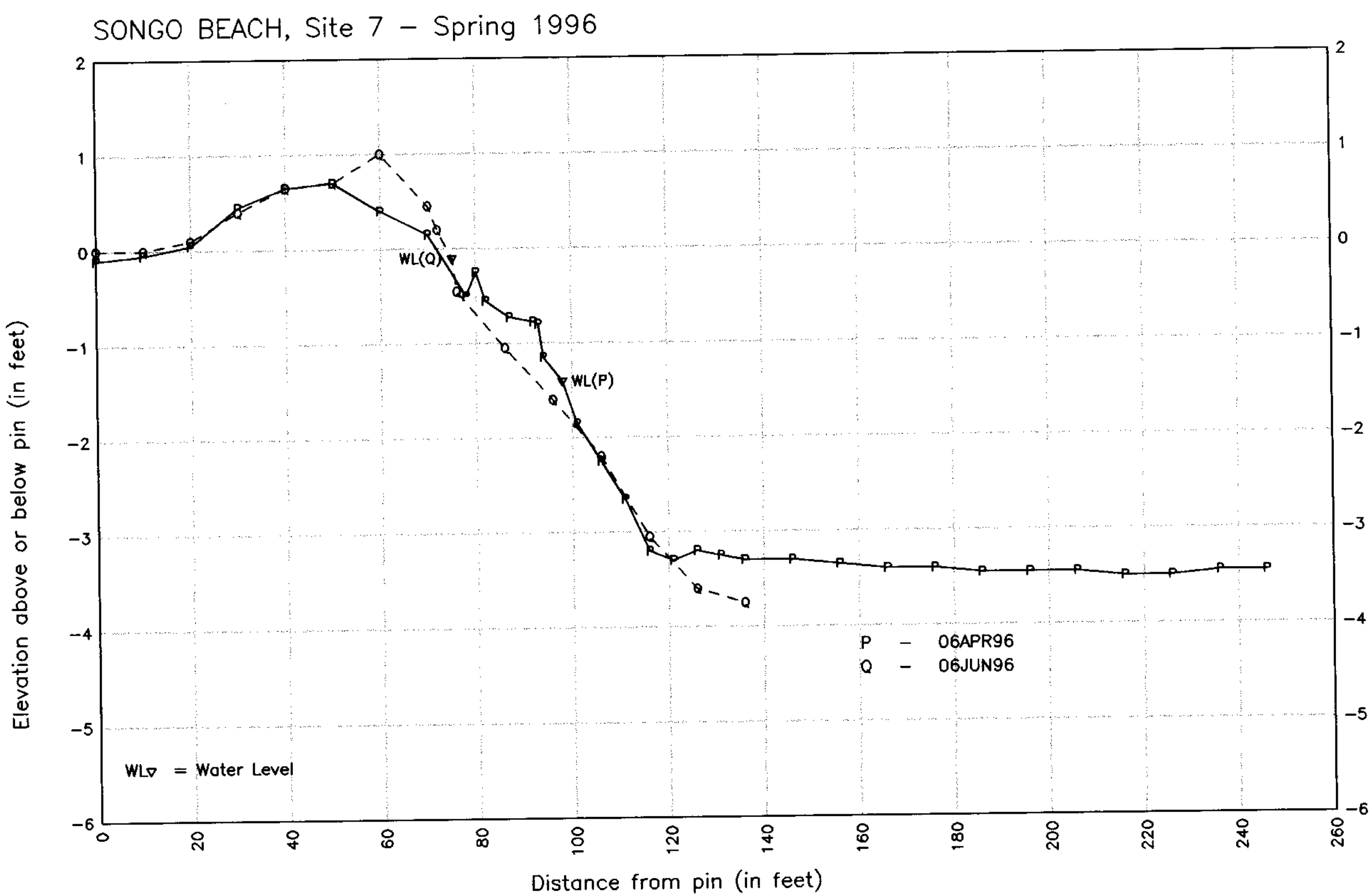
SONGO BEACH, Site 7 — Spring 1995

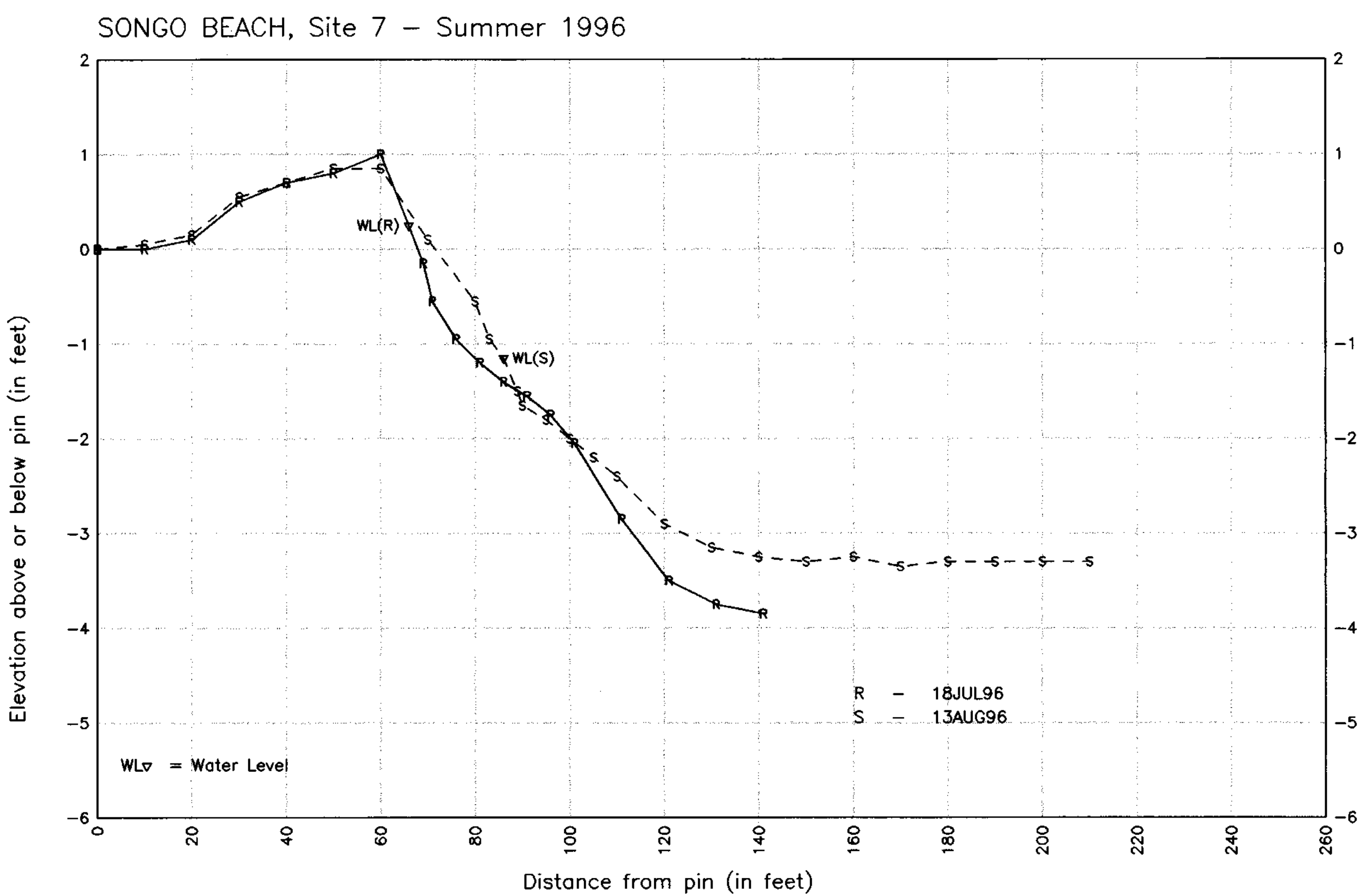


SONGO BEACH, Site 7 – Summer 1995

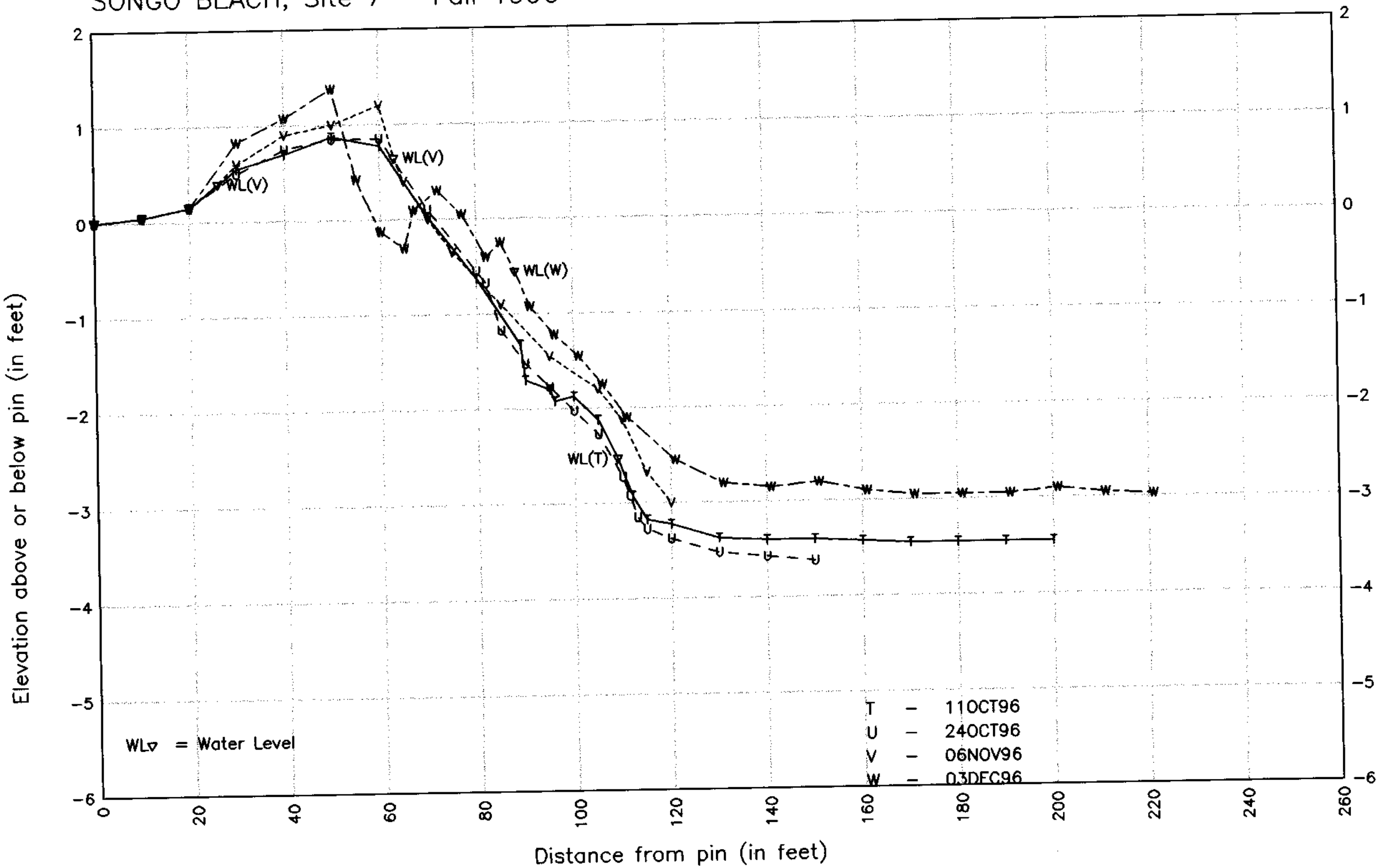


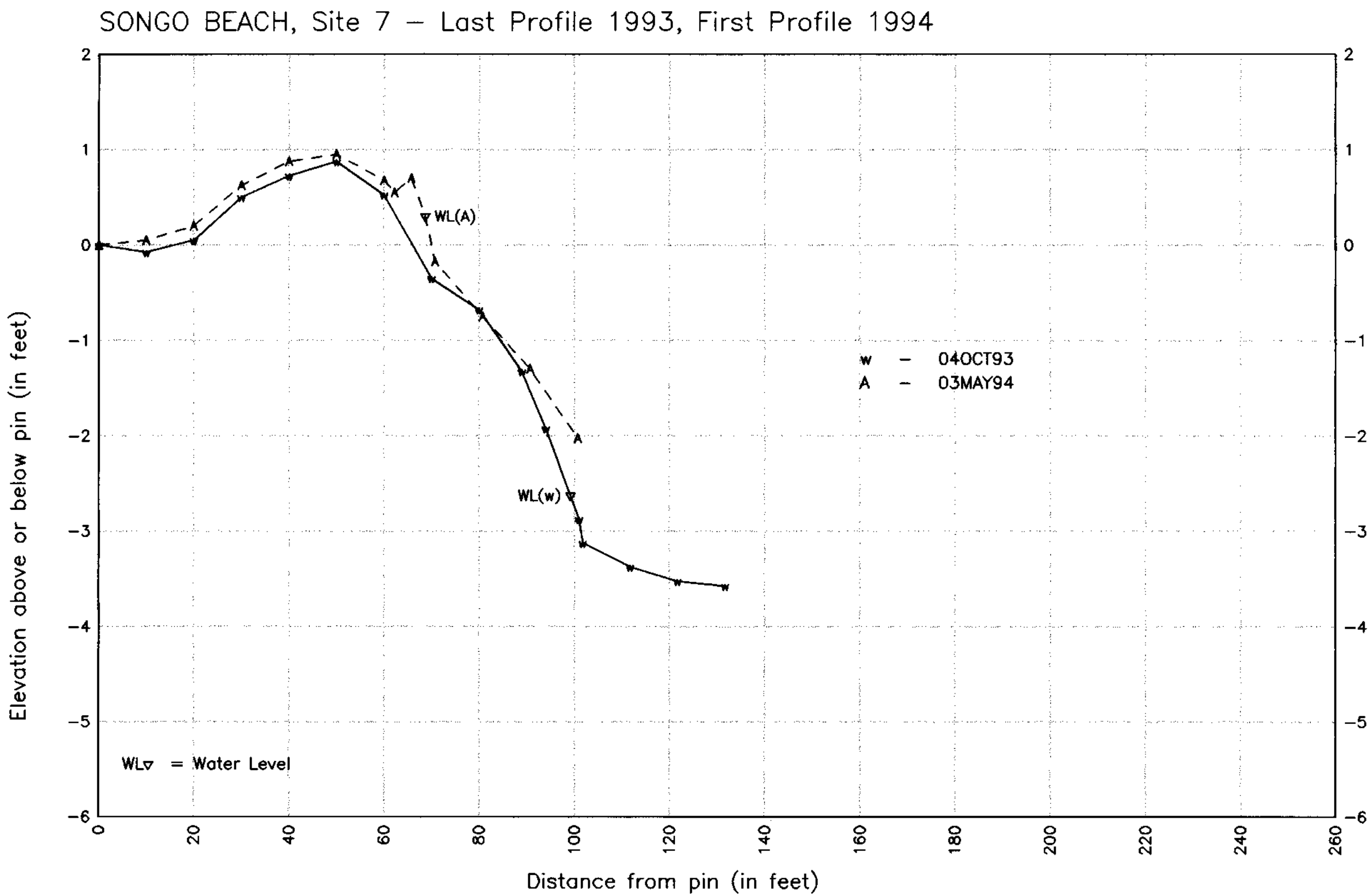

SONGO BEACH, Site 7 — Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
O - 03OCT95
WL▽ = Water Level
WL(O)
2
1
0
-1
-2
-3
-4
-5
-6
0
20
40
60
80
100
120
140
160
180
200
220
240
260


SONGO BEACH, Site 7 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(Q)
WL(P)
P – 06APR96
Q – 06JUN96
WL▽ = Water Level

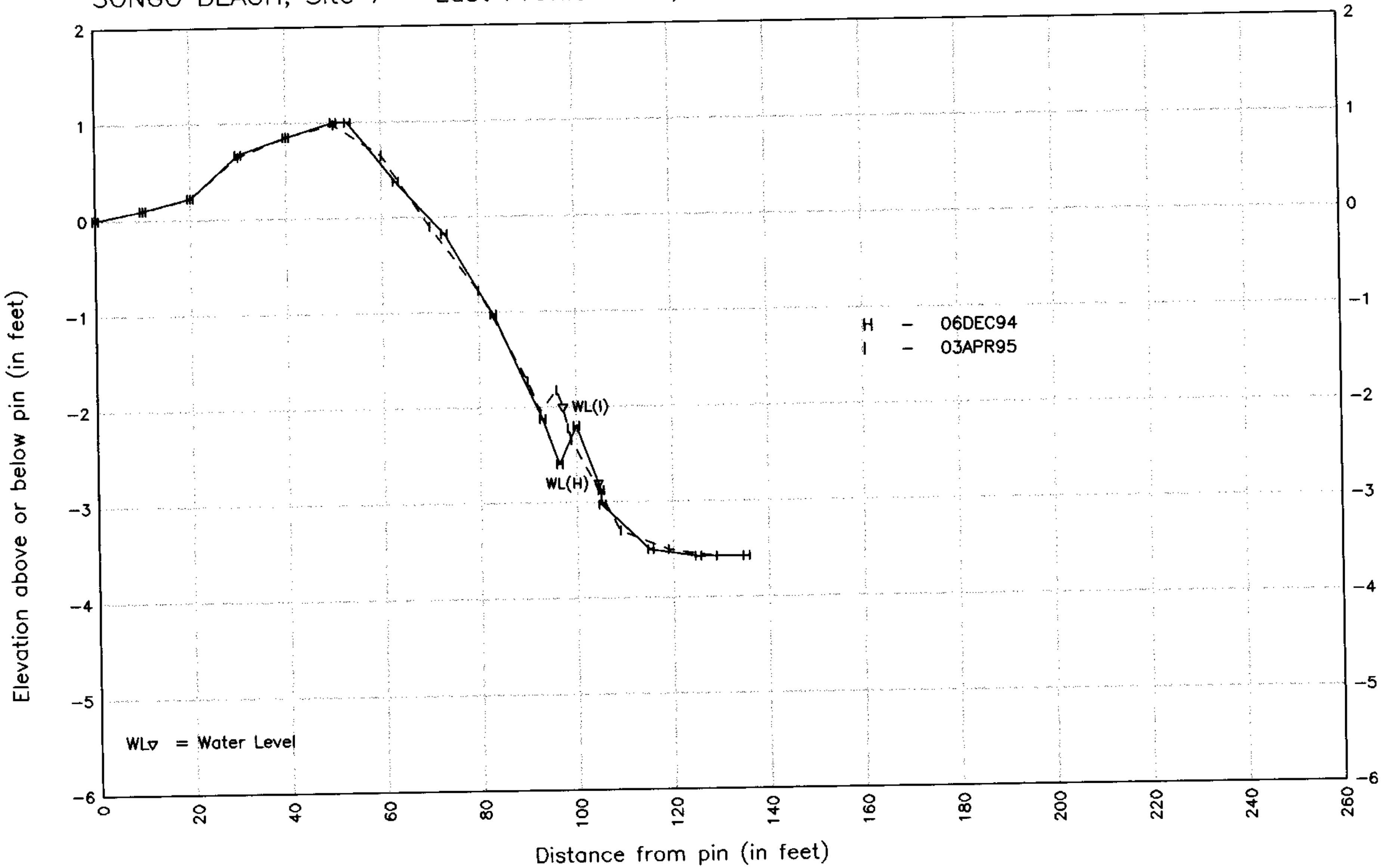

SONGO BEACH, Site 7 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
0
20
40
60
80
100
120
140
160
180
200
220
240
260
WL(R)
WL(S)
R – 18JUL96
S – 13AUG96
WL▽ = Water Level

SONGO BEACH, Site 7 – Fall 1996

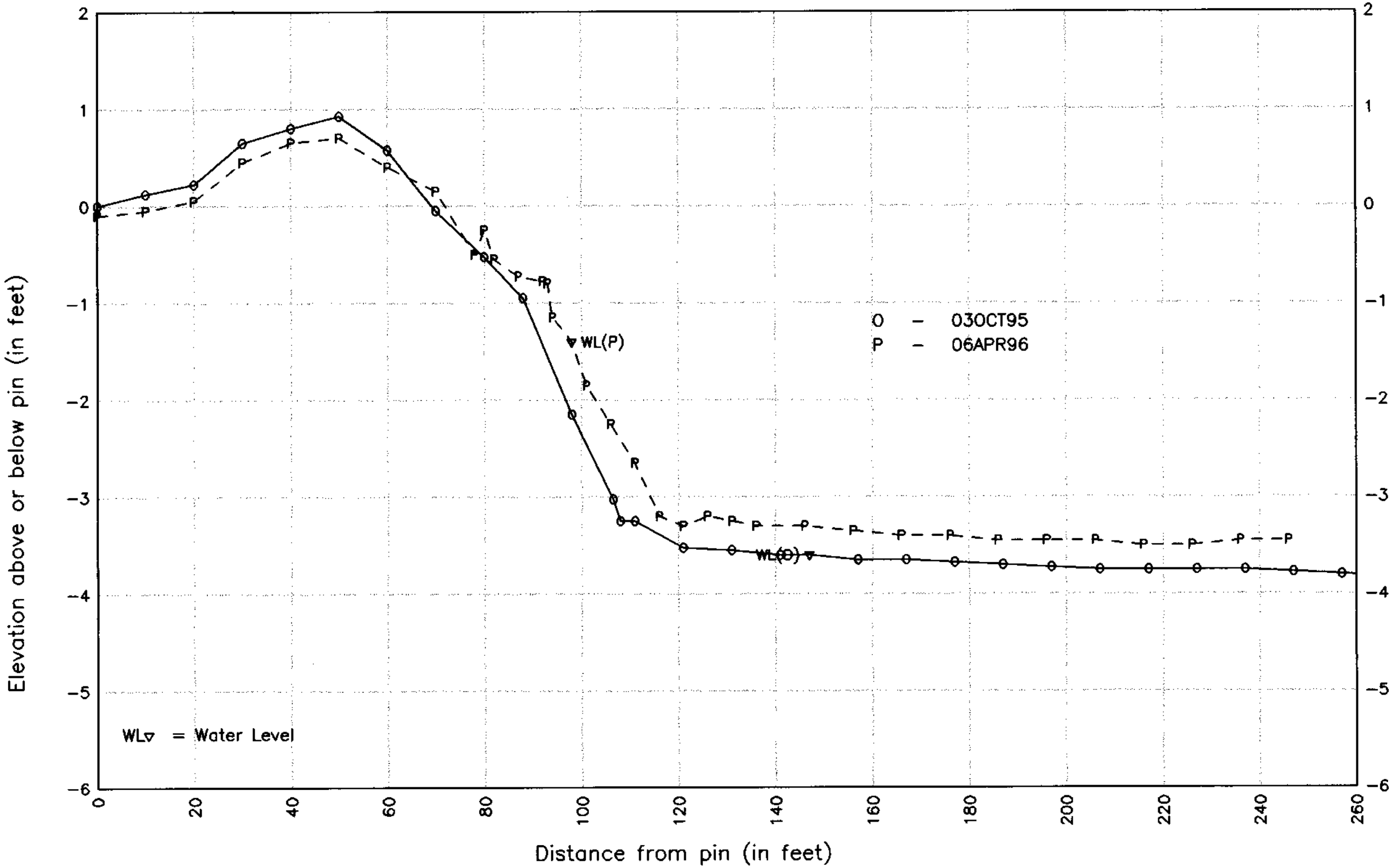



SONGO BEACH, Site 7 – Last Profile 1993, First Profile 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(A)
WL(w)
w – 04OCT93
A – 03MAY94
WL▽ = Water Level

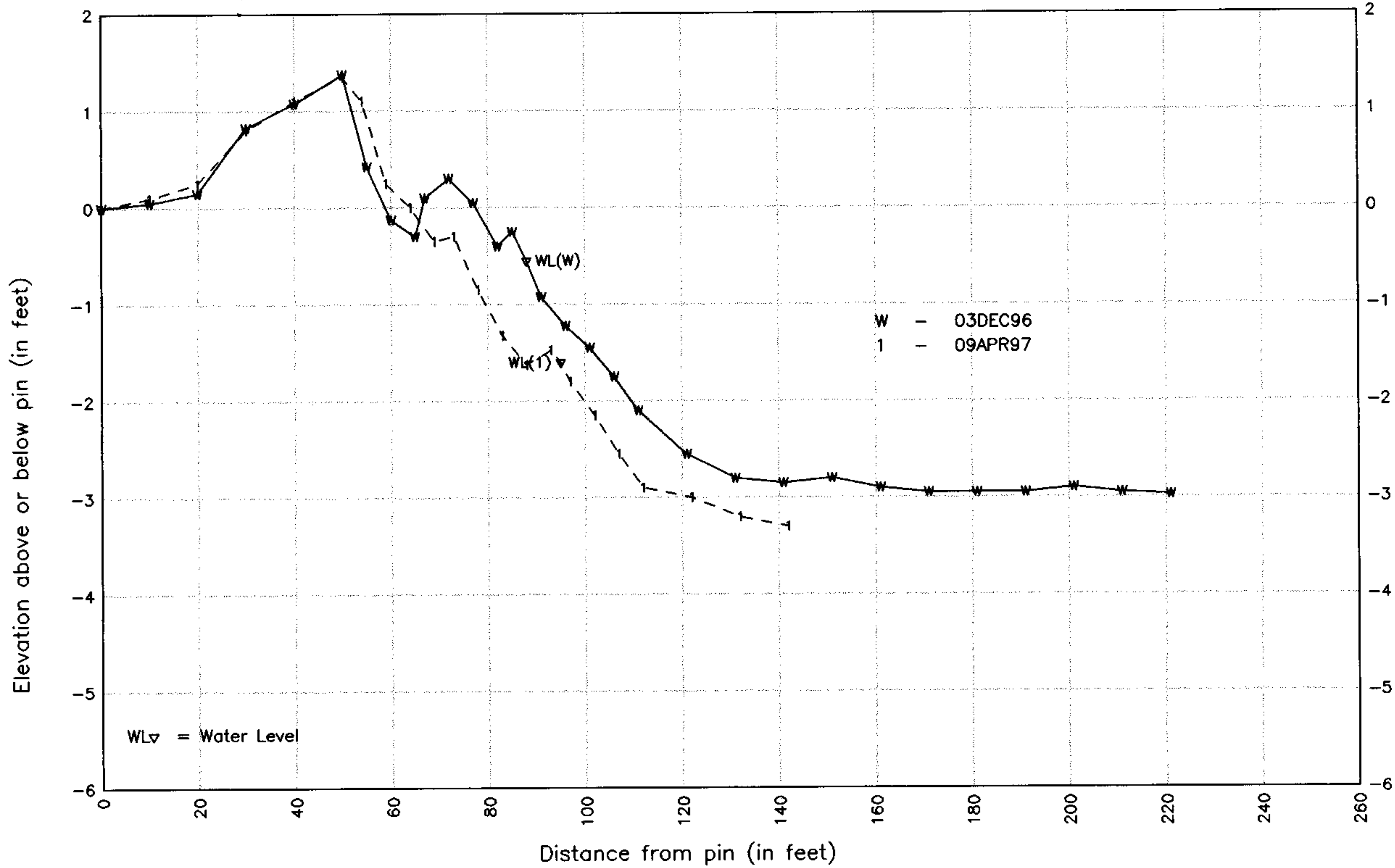
SONGO BEACH, Site 7 – Last Profile 1994, First Profile 1995



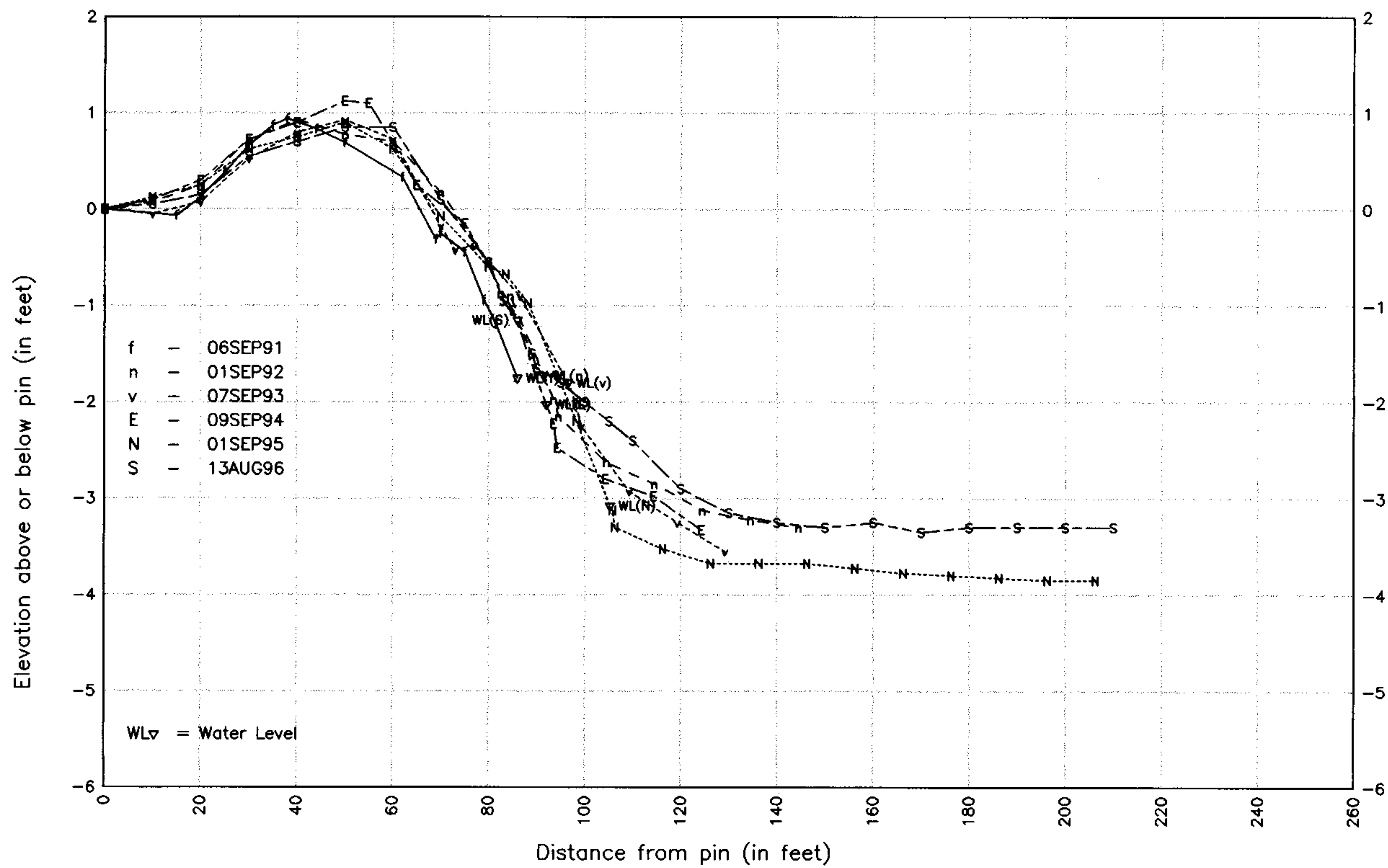
SONGO BEACH, Site 7 – Last Profile 1995, First Profile 1996

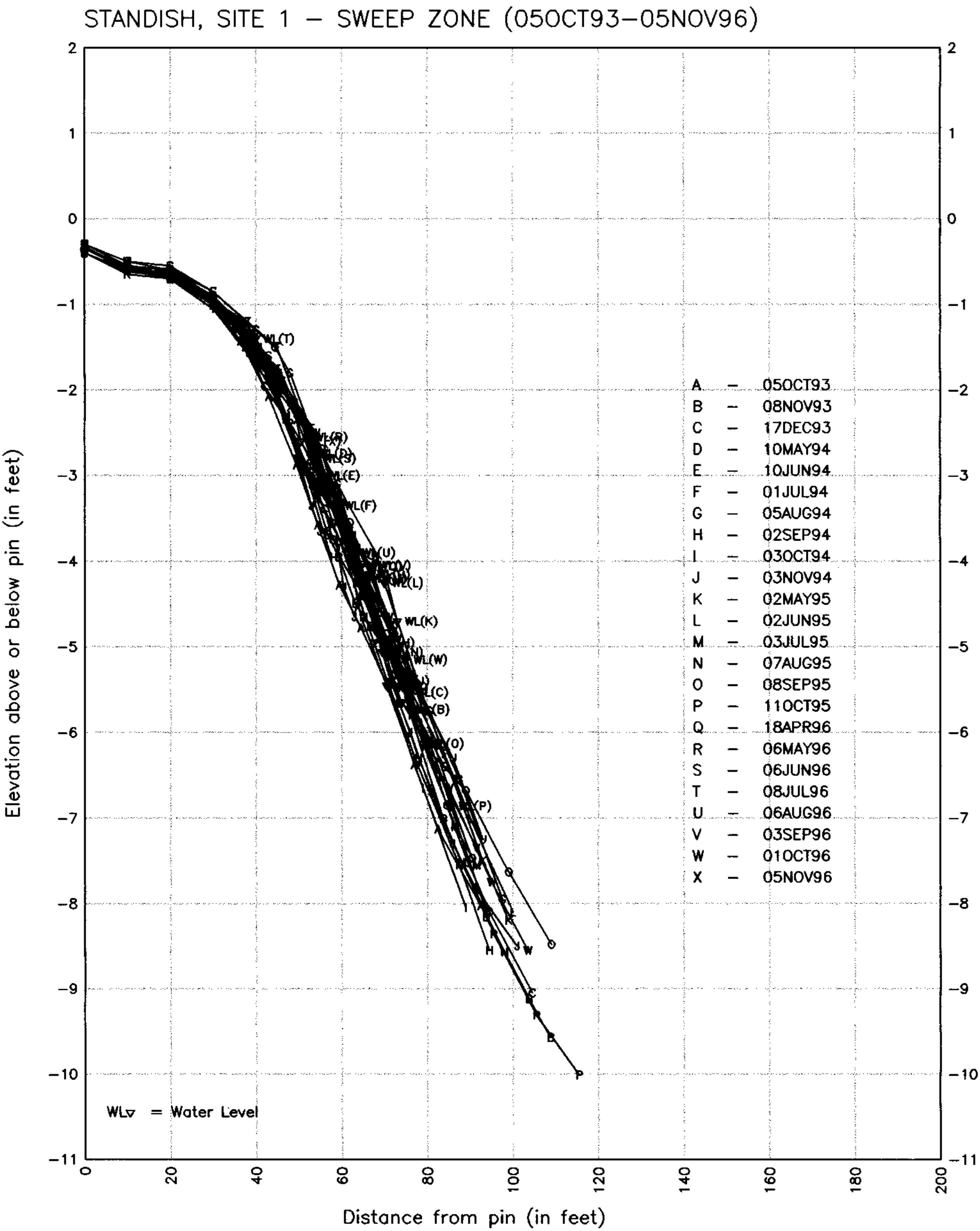


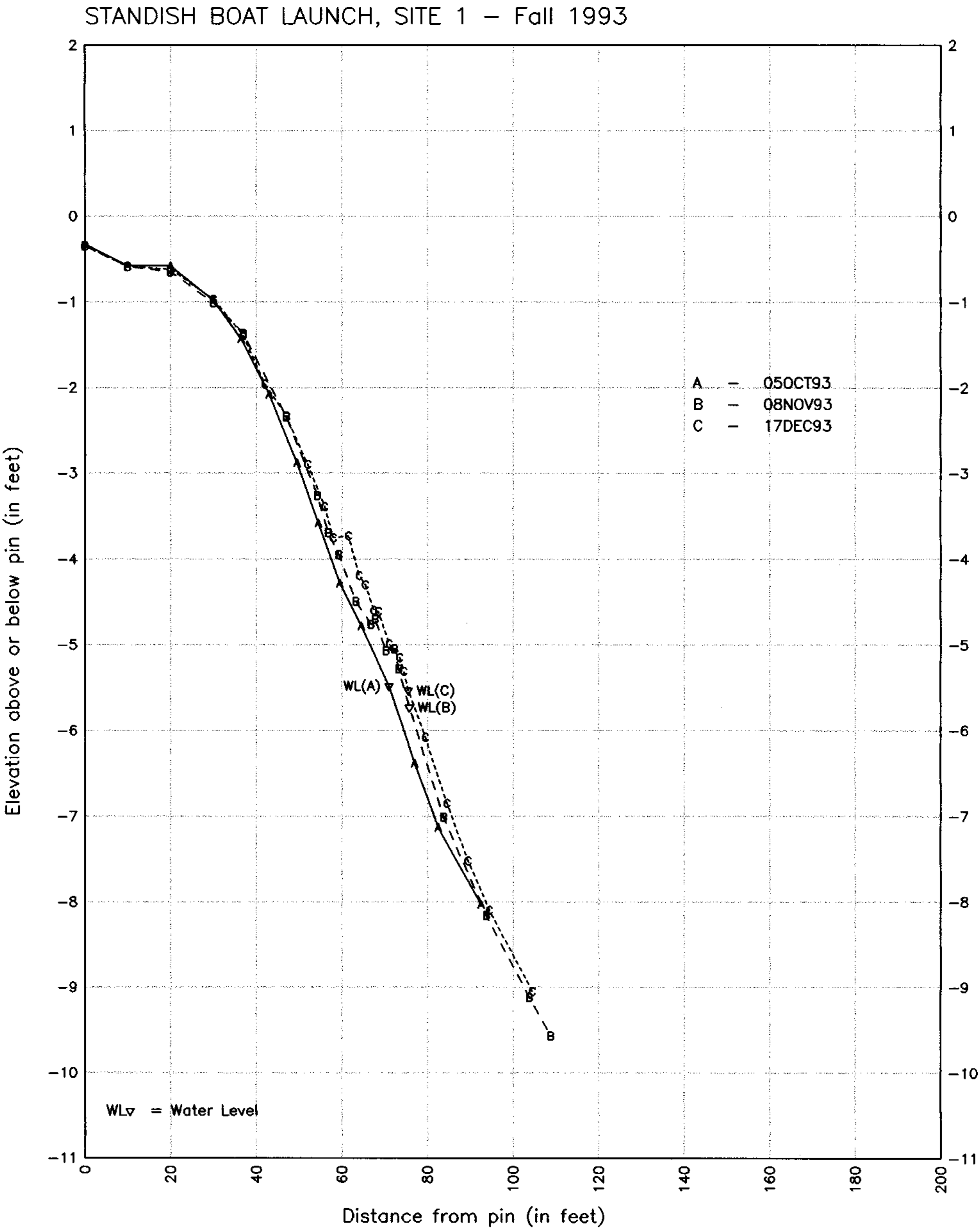
SONGO BEACH, Site 7 – Last Profile 1996, First Profile 1997

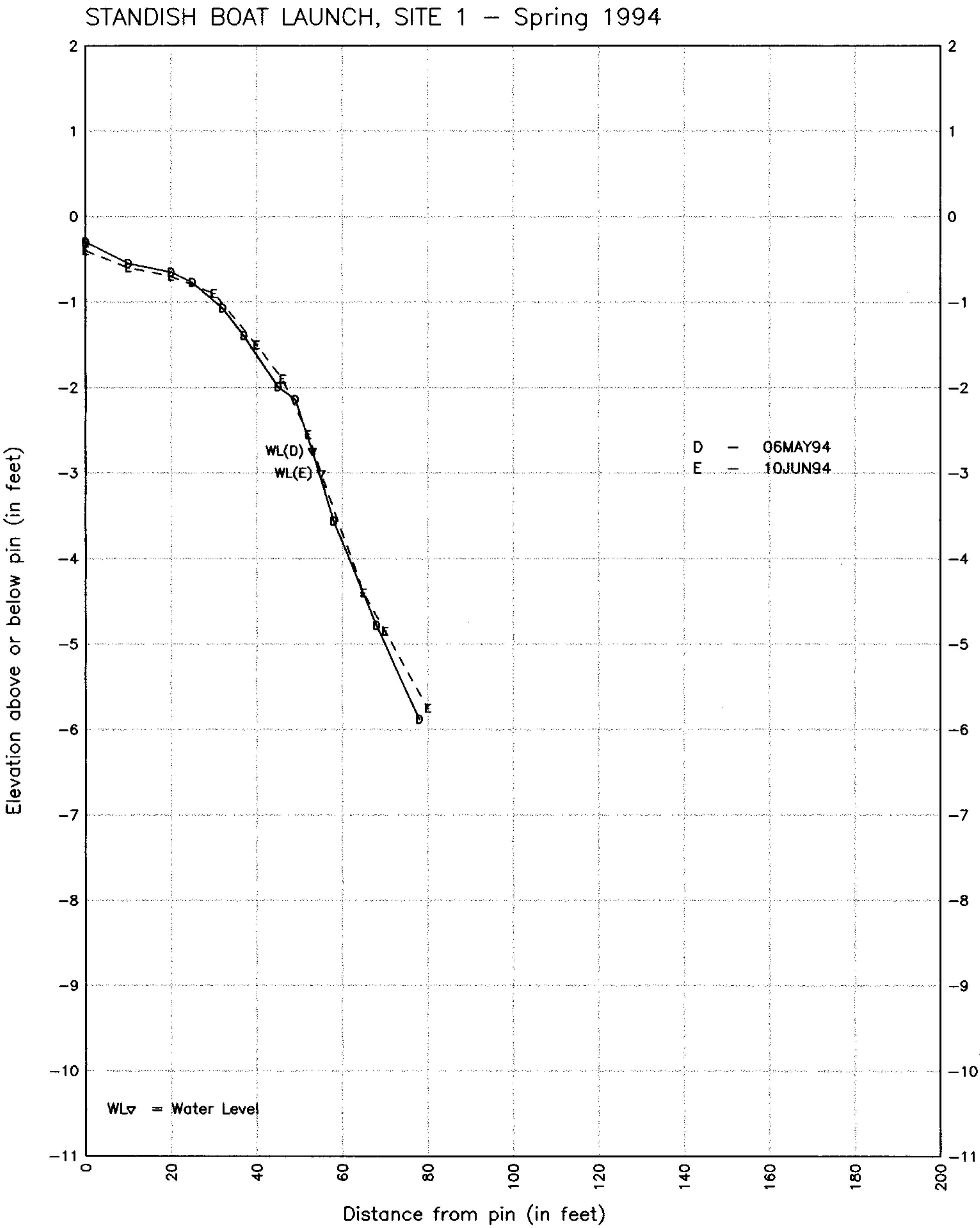


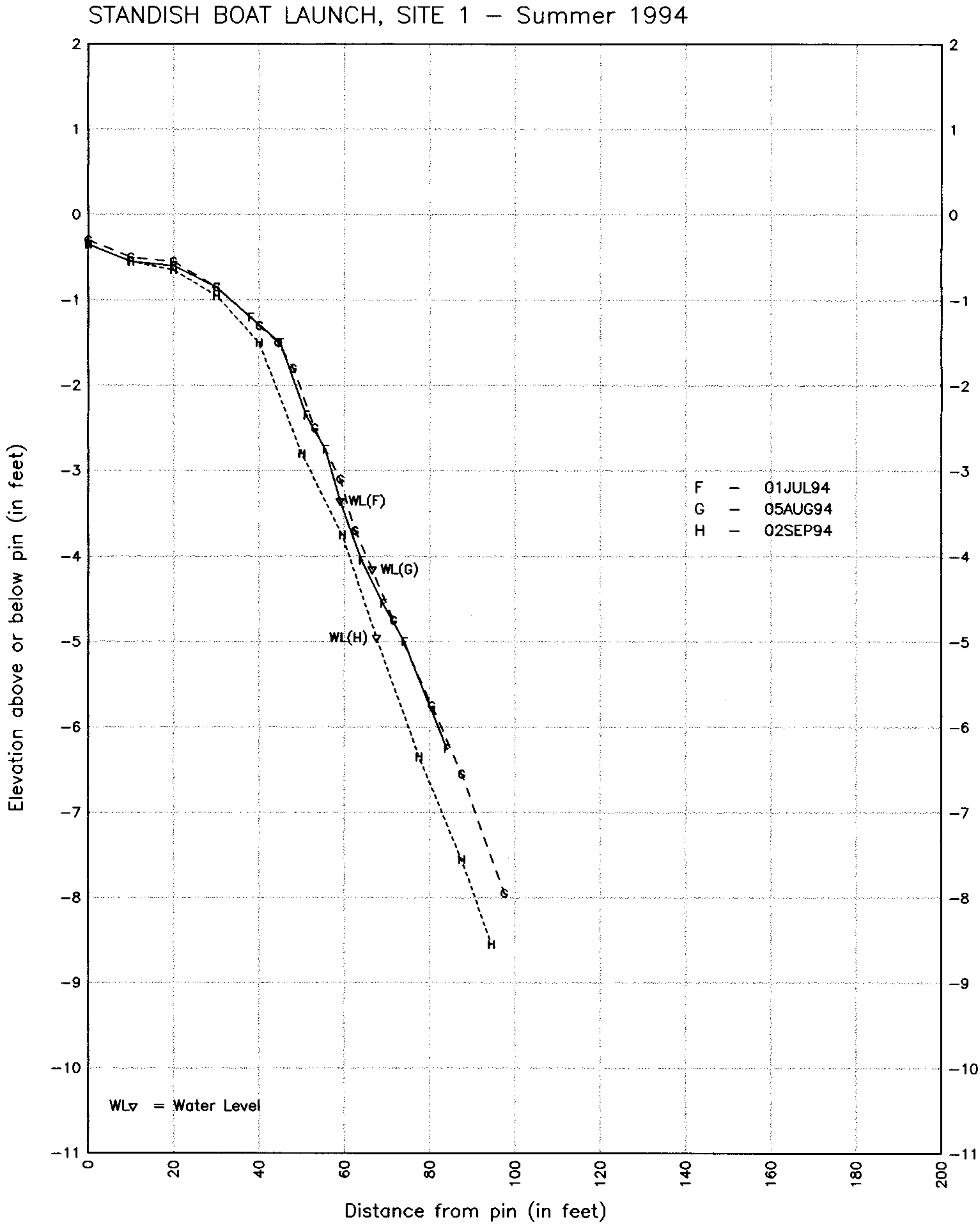
SONGO BEACH, Site 7 – Late Summer Profiles, 1991–1996



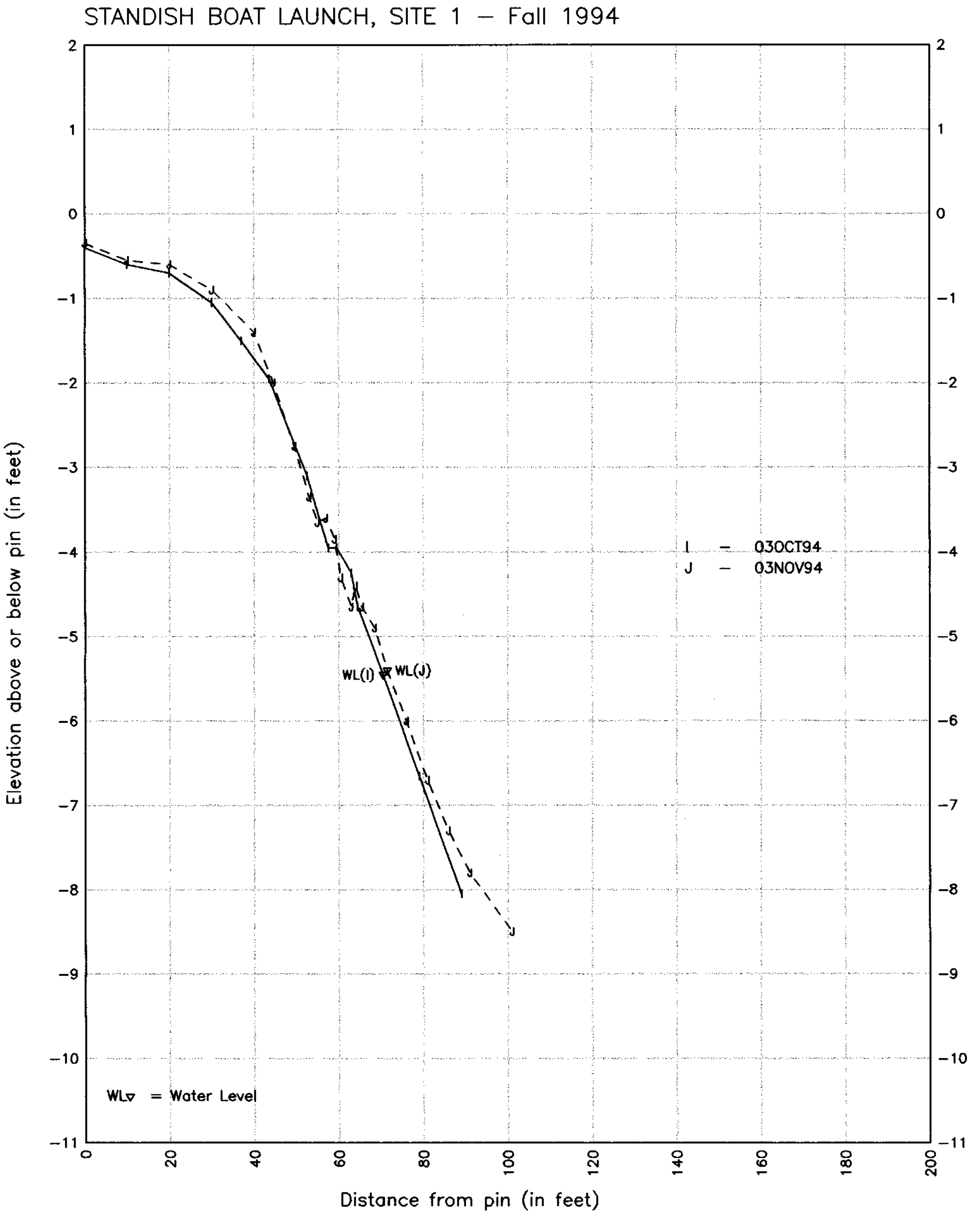

STANDISH, SITE 1 – SWEEP ZONE (05OCT93–05NOV96)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 05OCT93
B – 08NOV93
C – 17DEC93
D – 10MAY94
E – 10JUN94
F – 01JUL94
G – 05AUG94
H – 02SEP94
I – 03OCT94
J – 03NOV94
K – 02MAY95
L – 02JUN95
M – 03JUL95
N – 07AUG95
O – 08SEP95
P – 11OCT95
Q – 18APR96
R – 06MAY96
S – 06JUN96
T – 08JUL96
U – 06AUG96
V – 03SEP96
W – 01OCT96
X – 05NOV96
WL▽ = Water Level

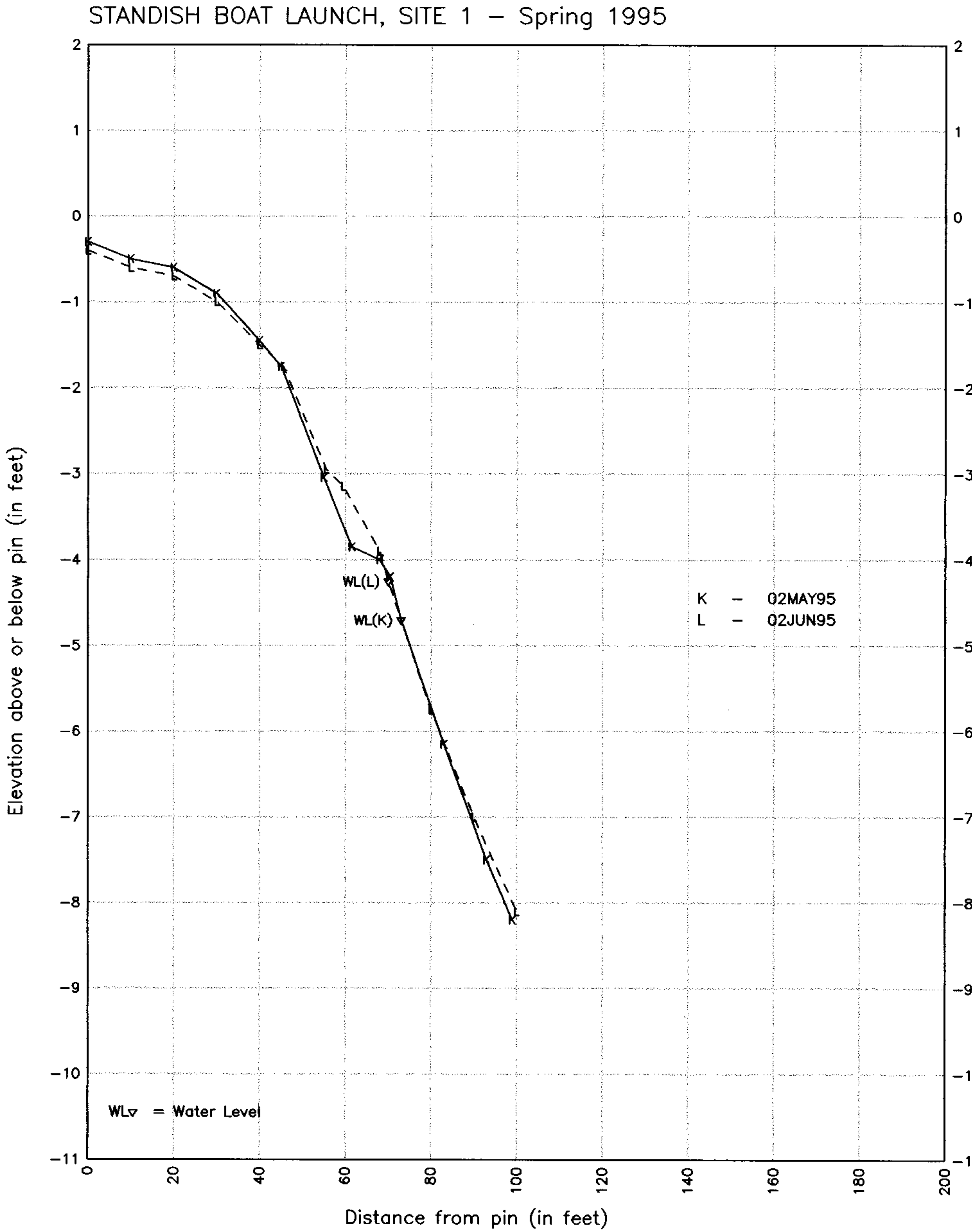

STANDISH BOAT LAUNCH, SITE 1 – Fall 1993
A – 05OCT93
B – 08NOV93
C – 17DEC93
WL(A)
WL(C)
WL(B)
WLᐁ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200


STANDISH BOAT LAUNCH, SITE 1 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
D – 06MAY94
E – 10JUN94
WL(D)
WL(E)
WL▽ = Water Level

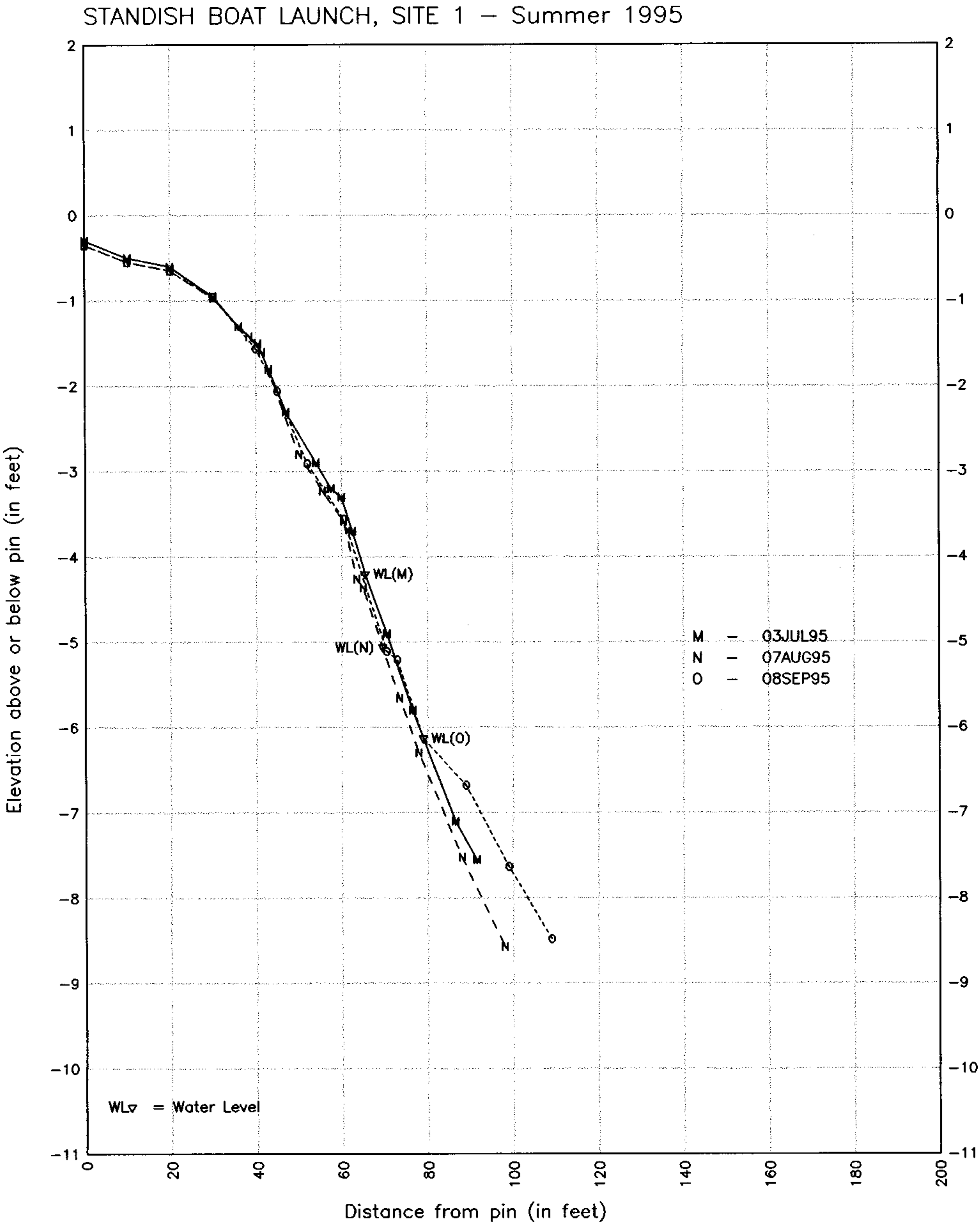


STANDISH BOAT LAUNCH, SITE 1 – Summer 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(F)
WL(G)
WL(H)
F – 01JUL94
G – 05AUG94
H – 02SEP94
WL▽ = Water Level

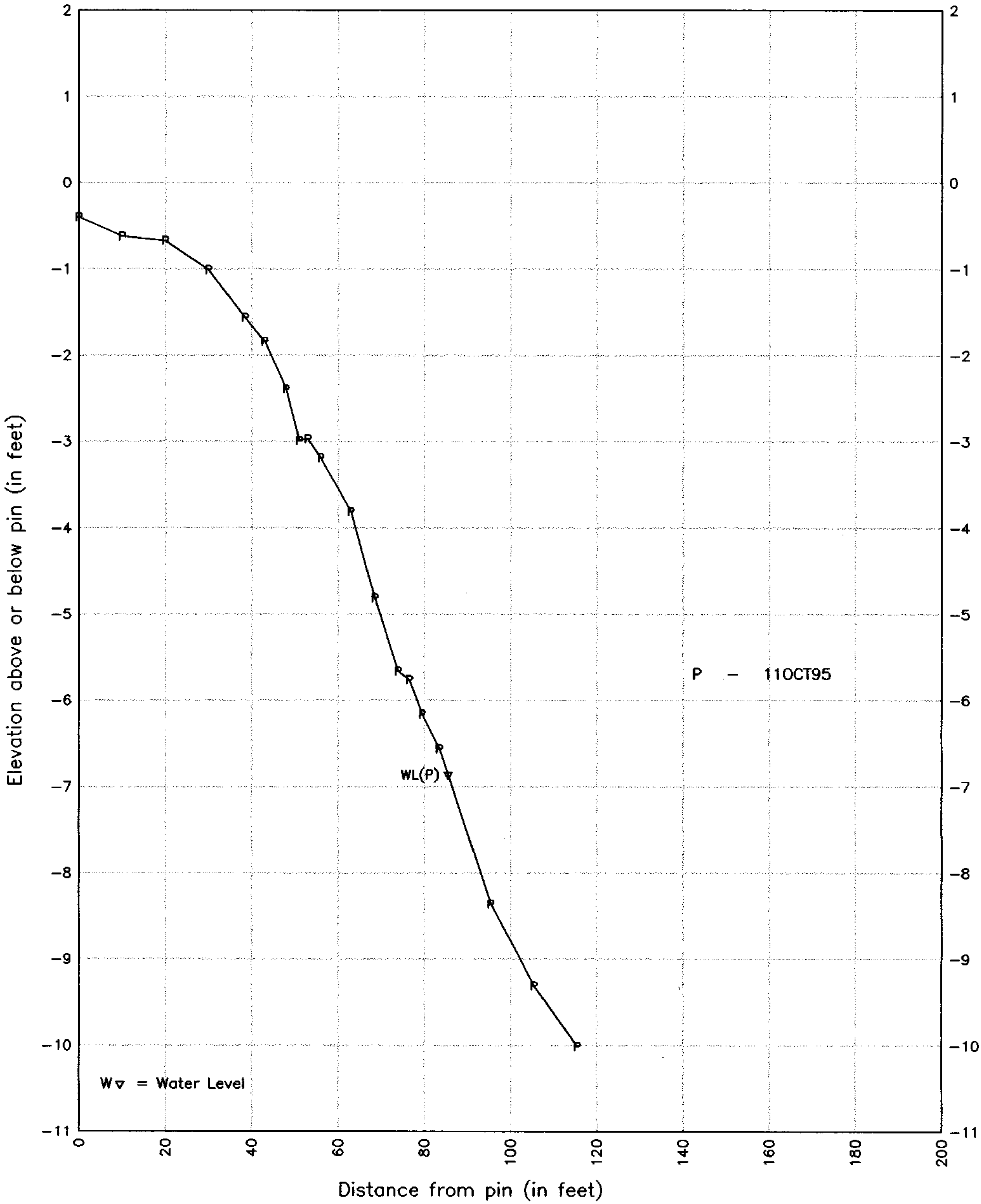

STANDISH BOAT LAUNCH, SITE 1 — Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
I — 03OCT94
J — 03NOV94
WL(I)
WL(J)
WL▽ = Water Level

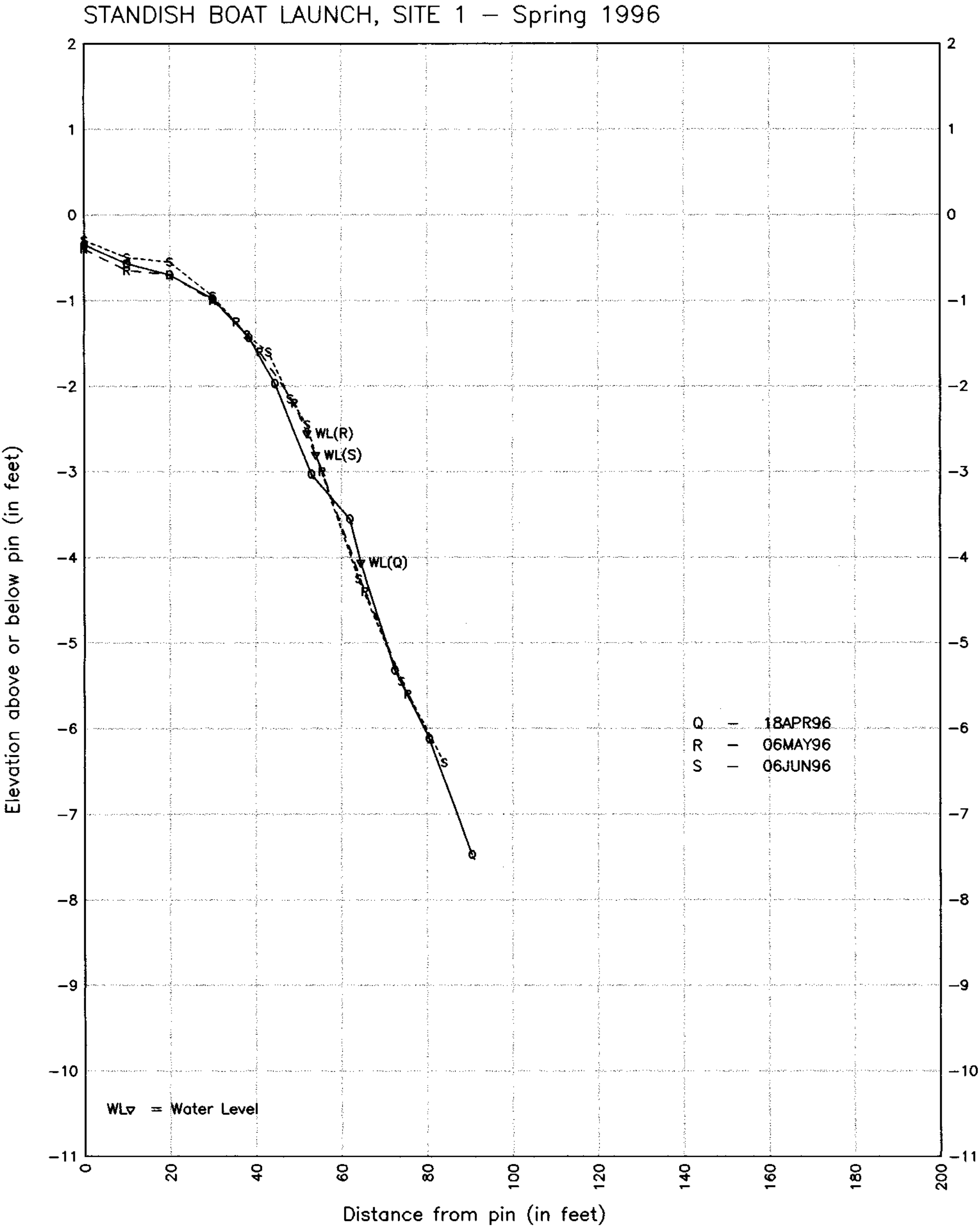


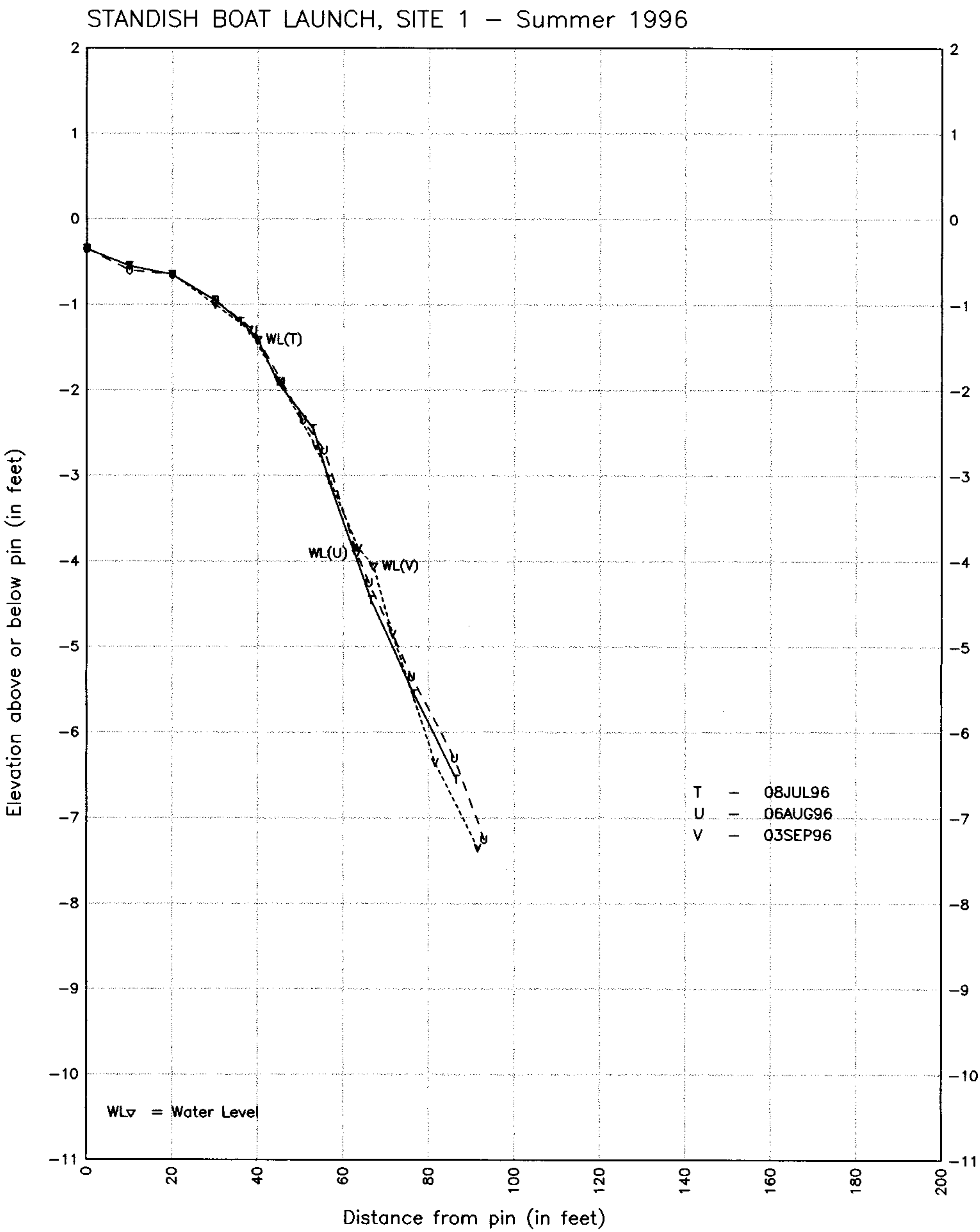
STANDISH BOAT LAUNCH, SITE 1 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200
WL(L)
WL(K)
K – 02MAY95
L – 02JUN95
WL▽ = Water Level

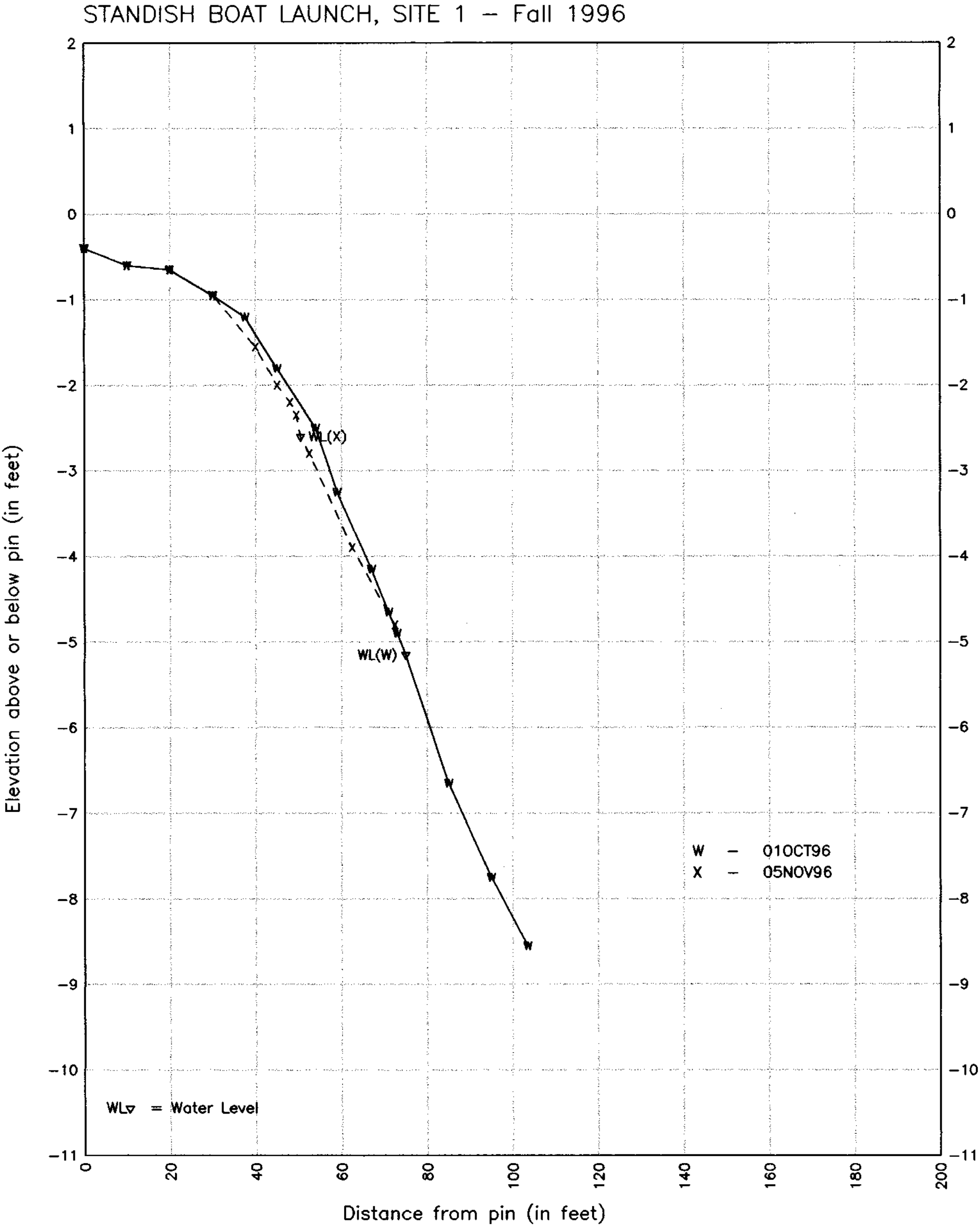

STANDISH BOAT LAUNCH, SITE 1 — Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(M)
WL(N)
WL(O)
M — 03JUL95
N — 07AUG95
O — 08SEP95
WL▽ = Water Level

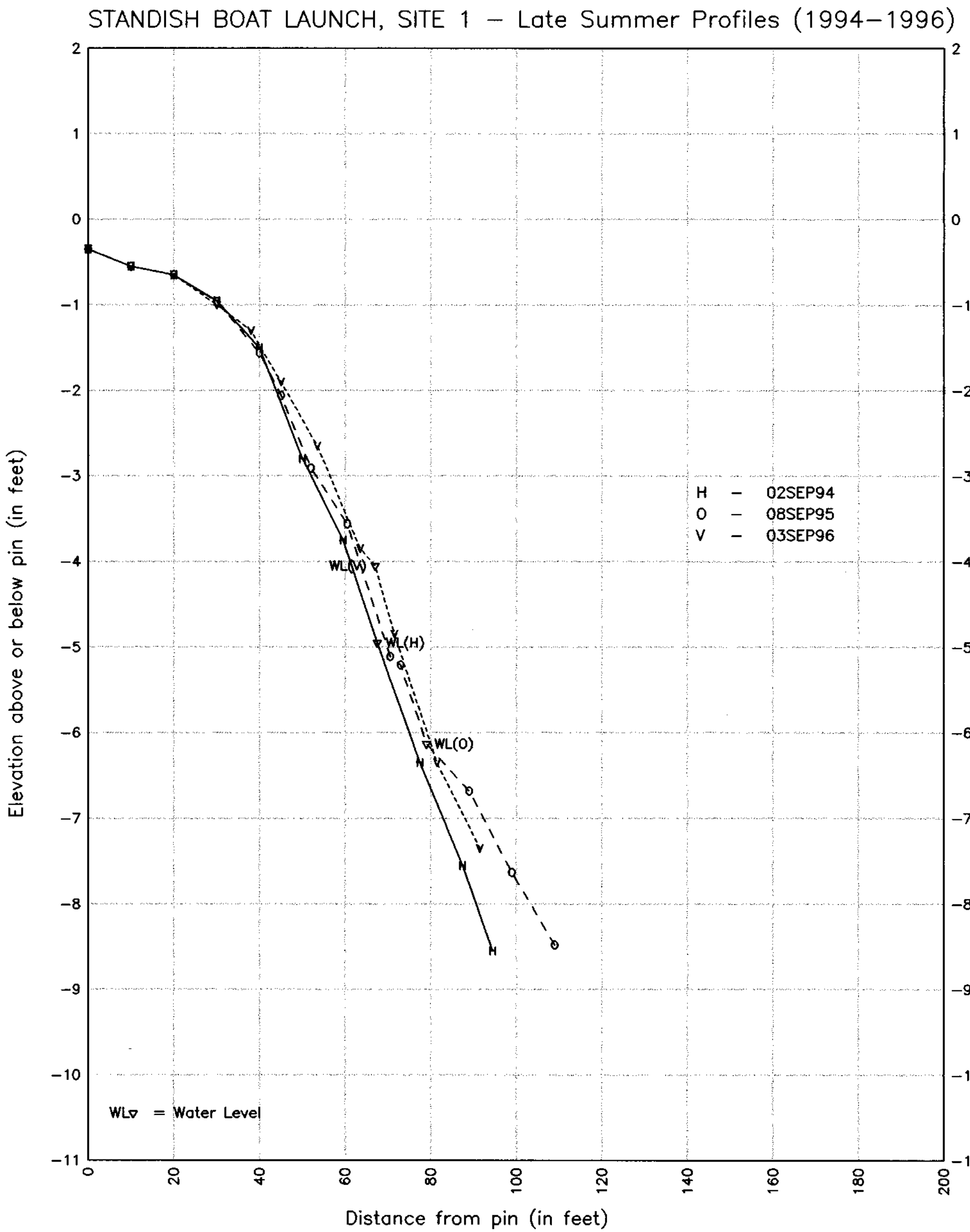
STANDISH BOAT LAUNCH, SITE 1 – Fall 1995



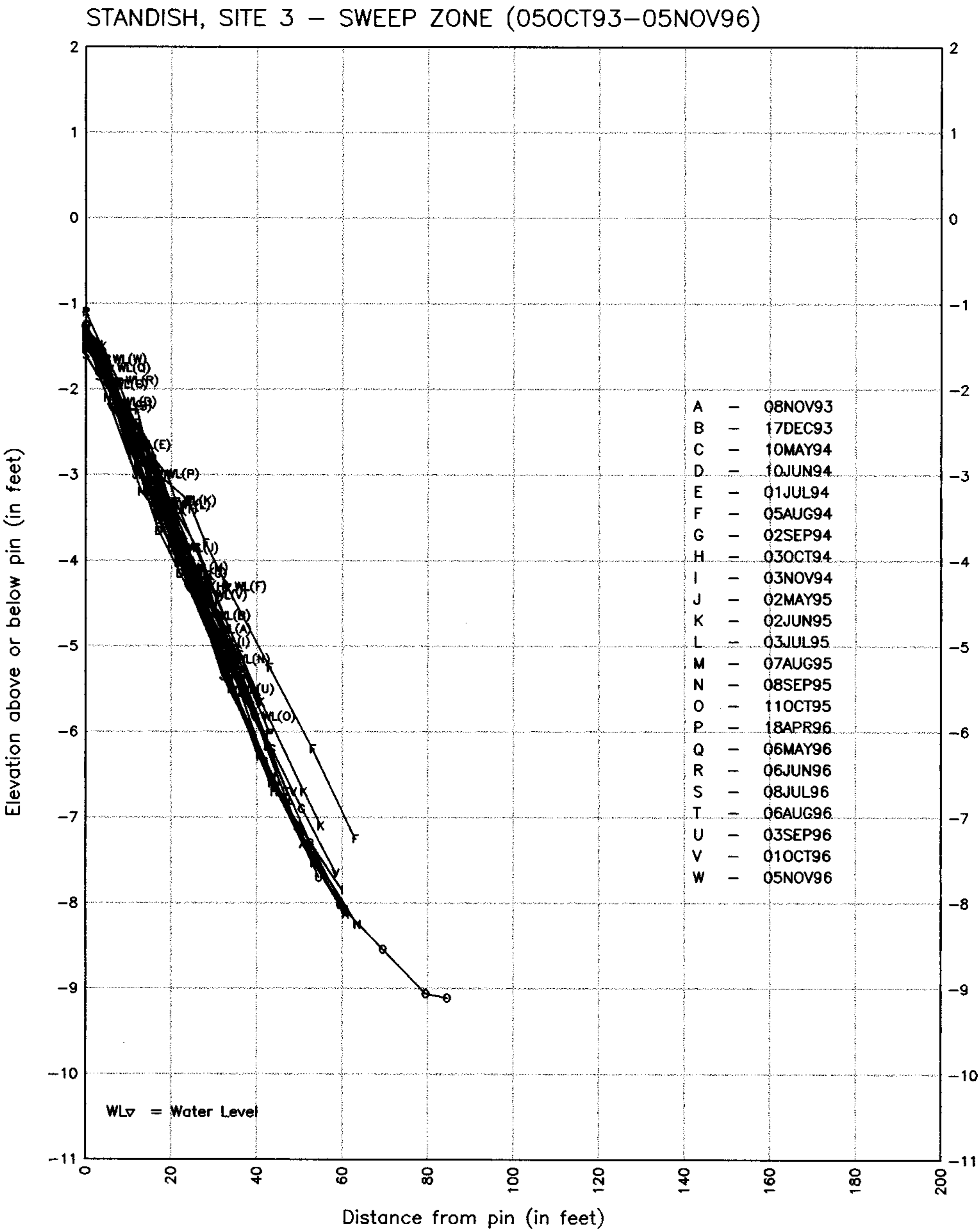

STANDISH BOAT LAUNCH, SITE 1 — Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(R)
WL(S)
WL(Q)
Q — 18APR96
R — 06MAY96
S — 06JUN96
WL▽ = Water Level

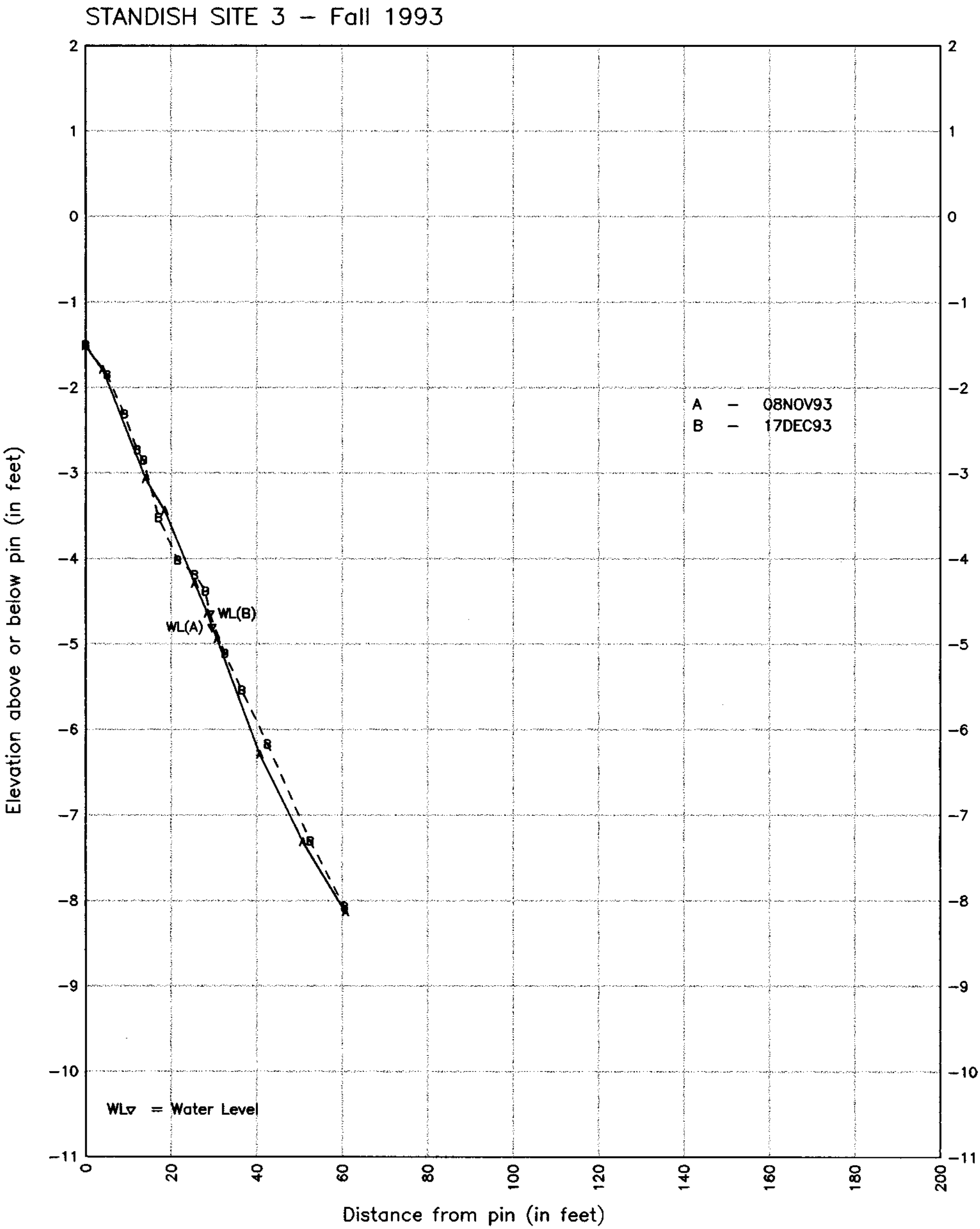

STANDISH BOAT LAUNCH, SITE 1 – Summer 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200
WL(T)
WL(U)
WL(V)
T – 08JUL96
U – 06AUG96
V – 03SEP96
WL▽ = Water Level

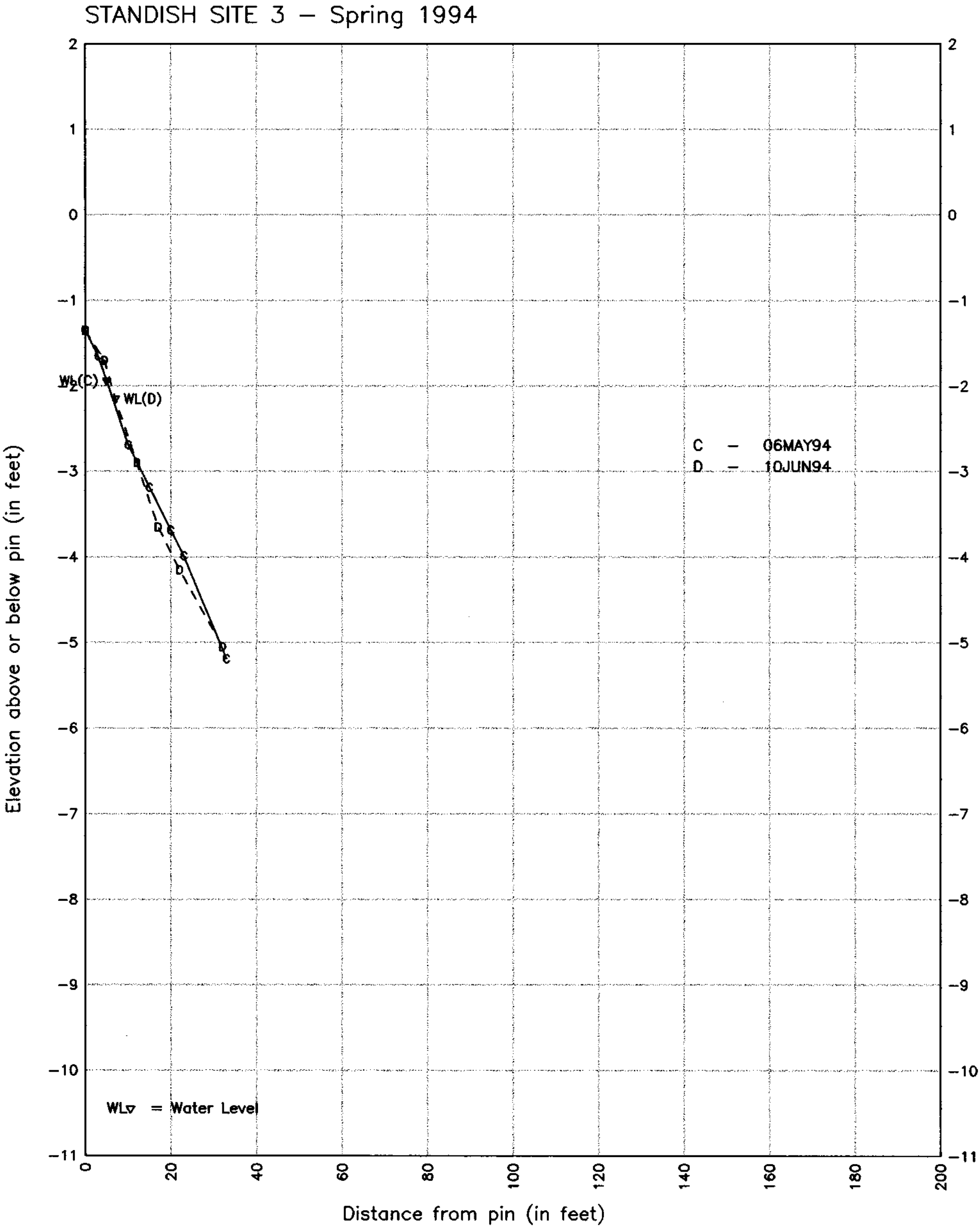

STANDISH BOAT LAUNCH, SITE 1 – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200
WL(X)
WL(W)
W – 01OCT96
X – 05NOV96
WL▽ = Water Level

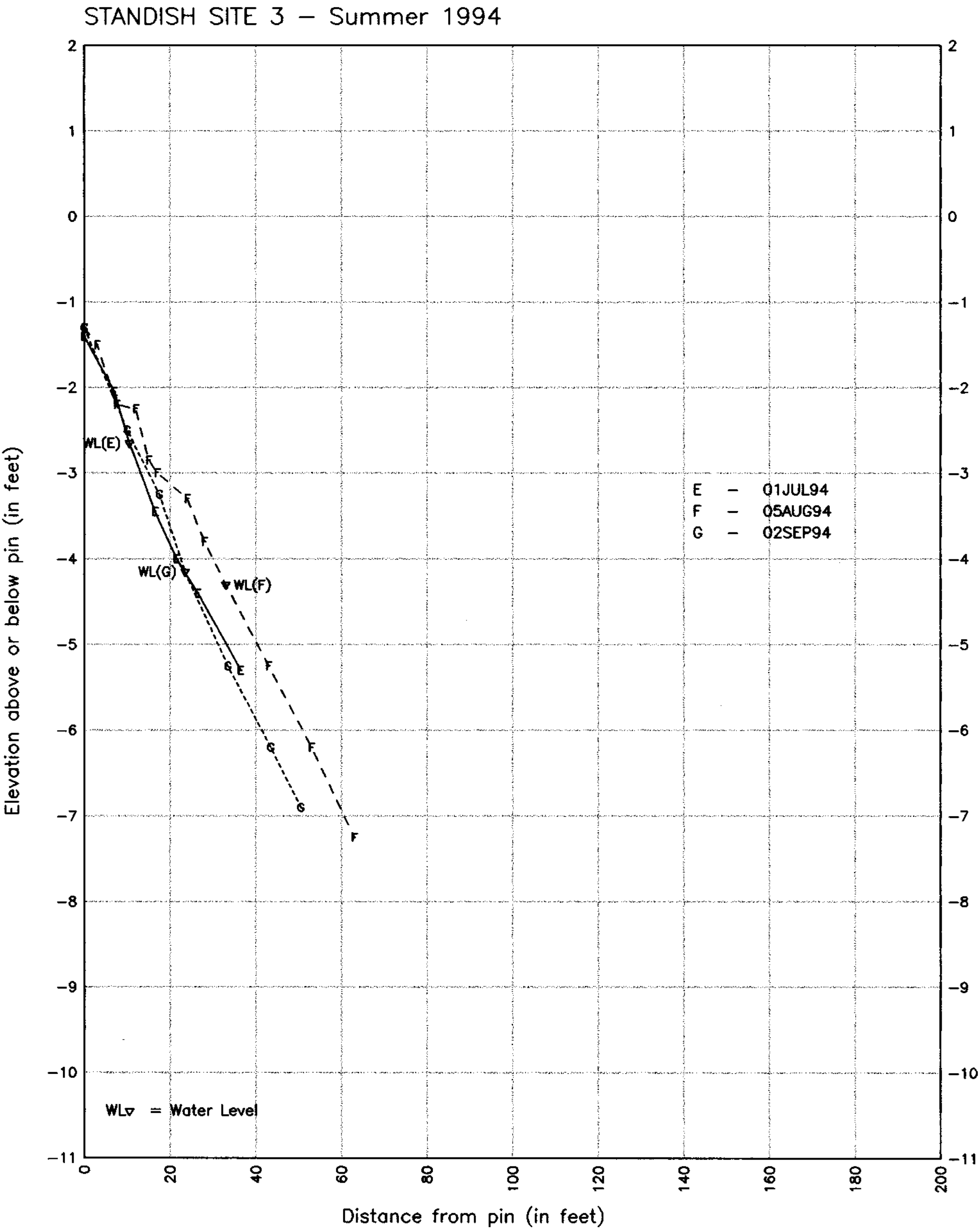


STANDISH BOAT LAUNCH, SITE 1 – Late Summer Profiles (1994–1996)
Elevation above or below pin (in feet)
Distance from pin (in feet)
H – 02SEP94
O – 08SEP95
V – 03SEP96
WL(V)
WL(H)
WL(O)
WL▽ = Water Level
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

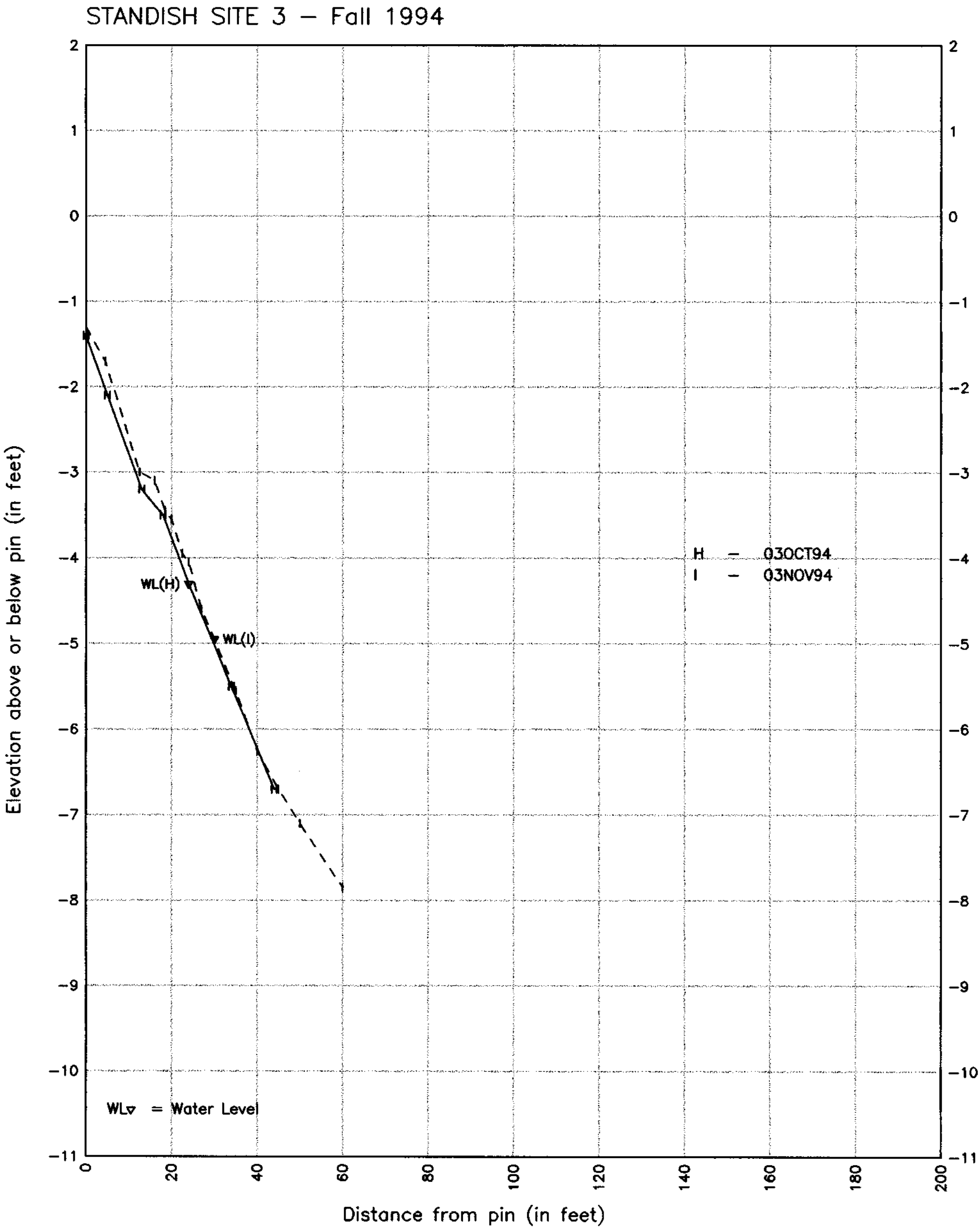

STANDISH, SITE 3 – SWEEP ZONE (05OCT93–05NOV96)
Elevation above or below pin (in feet)
Distance from pin (in feet)
A – 08NOV93
B – 17DEC93
C – 10MAY94
D – 10JUN94
E – 01JUL94
F – 05AUG94
G – 02SEP94
H – 03OCT94
I – 03NOV94
J – 02MAY95
K – 02JUN95
L – 03JUL95
M – 07AUG95
N – 08SEP95
O – 11OCT95
P – 18APR96
Q – 06MAY96
R – 06JUN96
S – 08JUL96
T – 06AUG96
U – 03SEP96
V – 01OCT96
W – 05NOV96
WL▽ = Water Level


STANDISH SITE 3 – Fall 1993
A – 08NOV93
B – 17DEC93
WL(A)
WL(B)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
–1
–2
–3
–4
–5
–6
–7
–8
–9
–10
–11
0
20
40
60
80
100
120
140
160
180
200

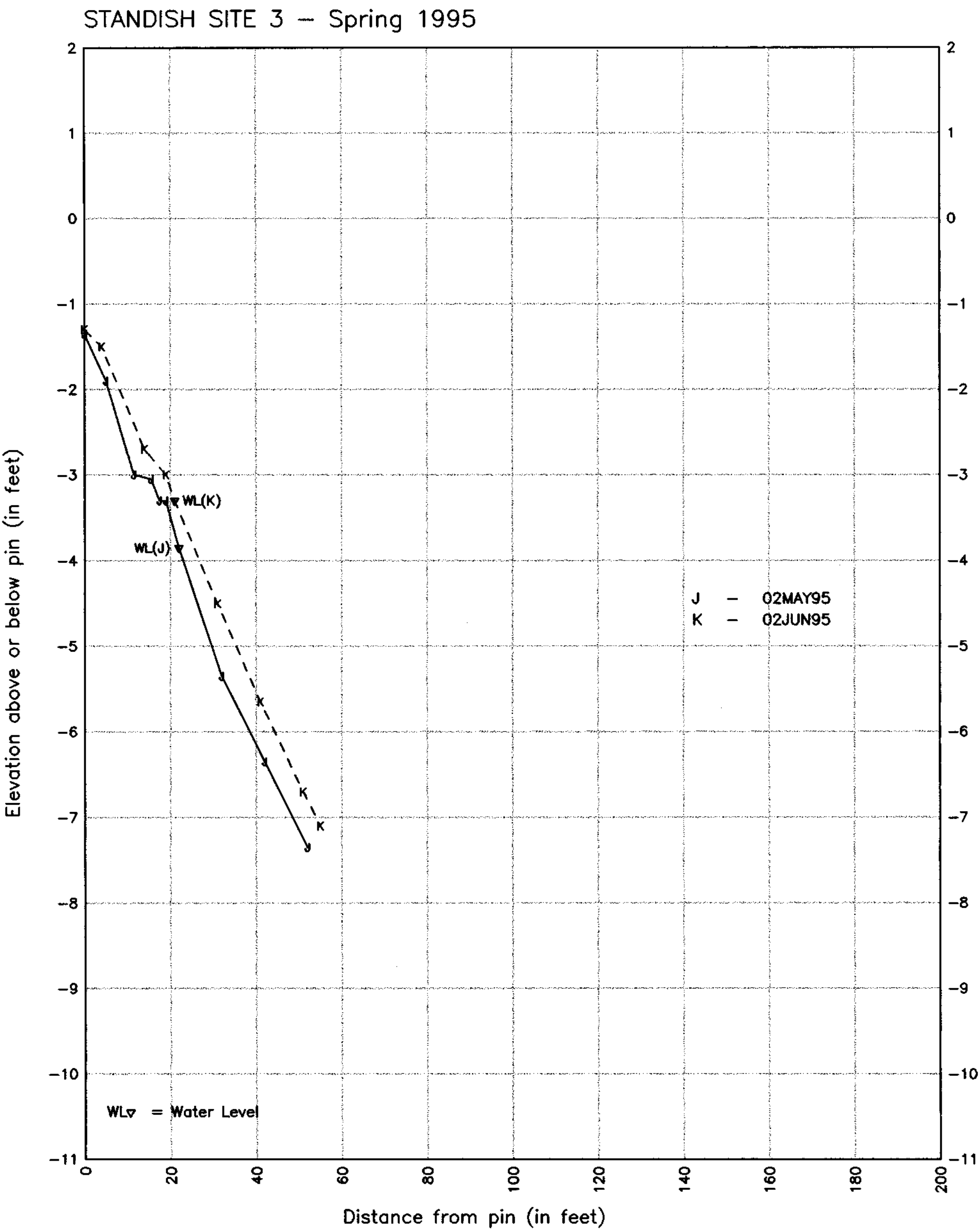

STANDISH SITE 3 – Spring 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(C)
WL(D)
C – 06MAY94
D – 10JUN94
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

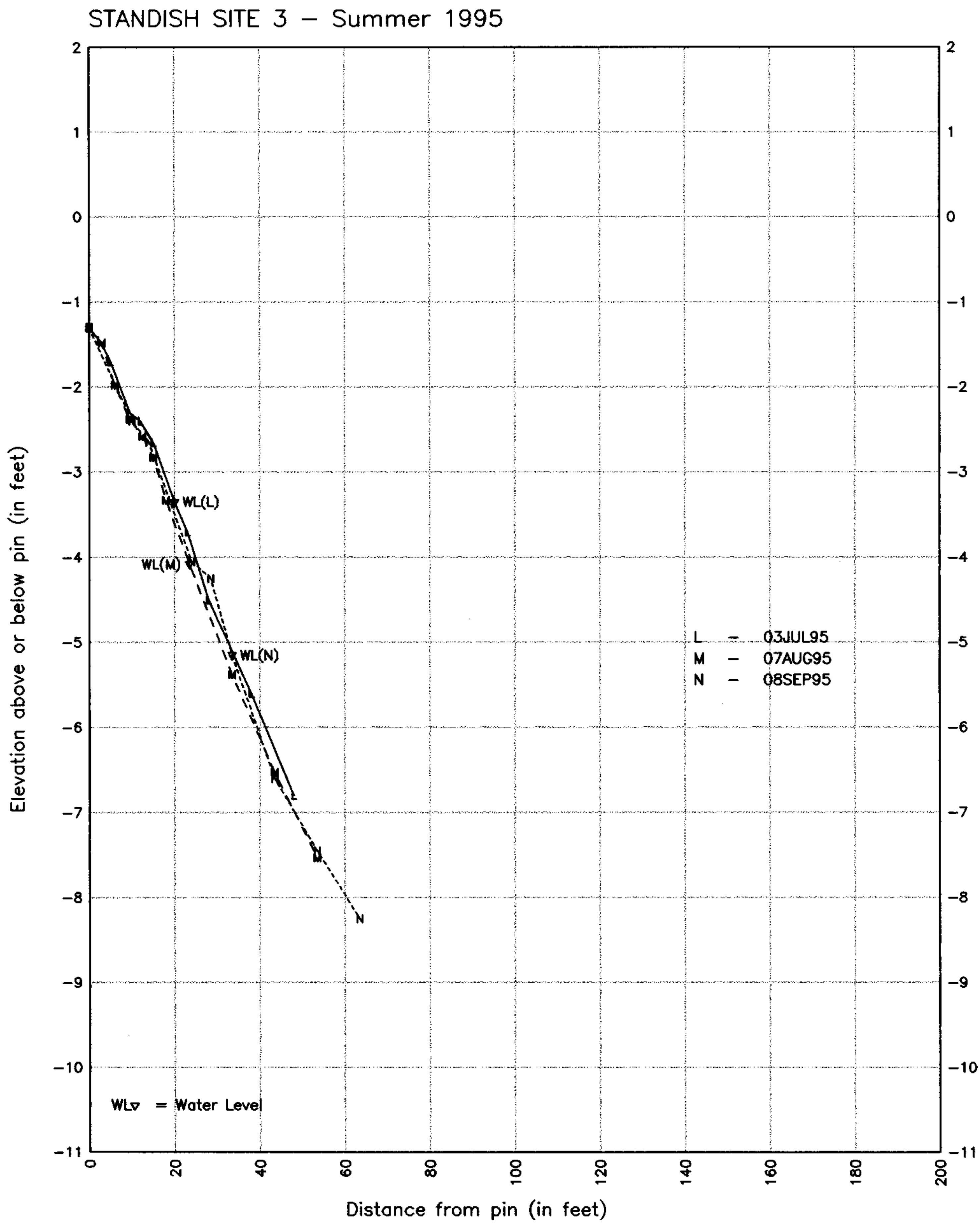


STANDISH SITE 3 – Summer 1994
E – 01JUL94
F – 05AUG94
G – 02SEP94
WL(E)
WL(G)
WL(F)
WL▽ = Water Level
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

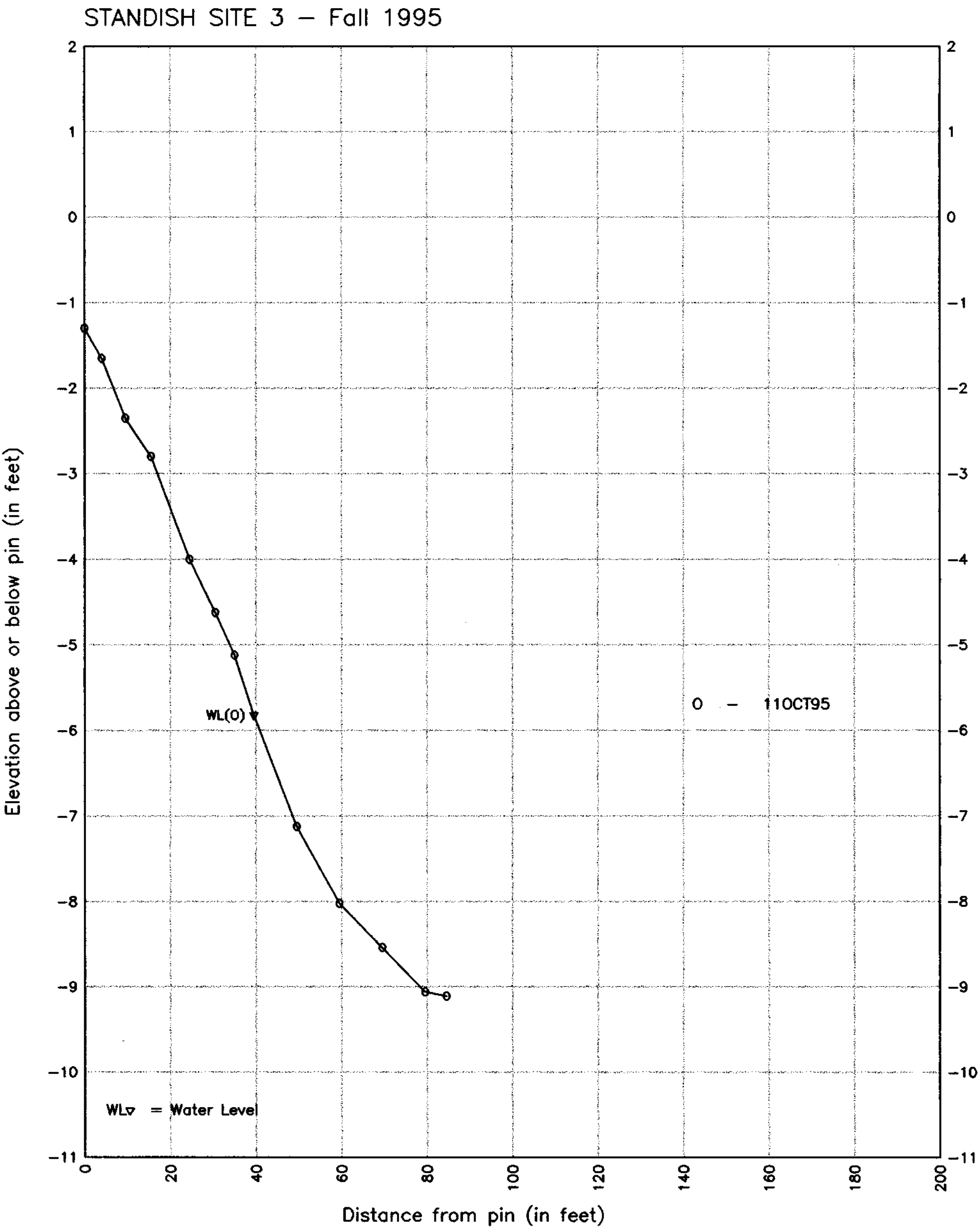


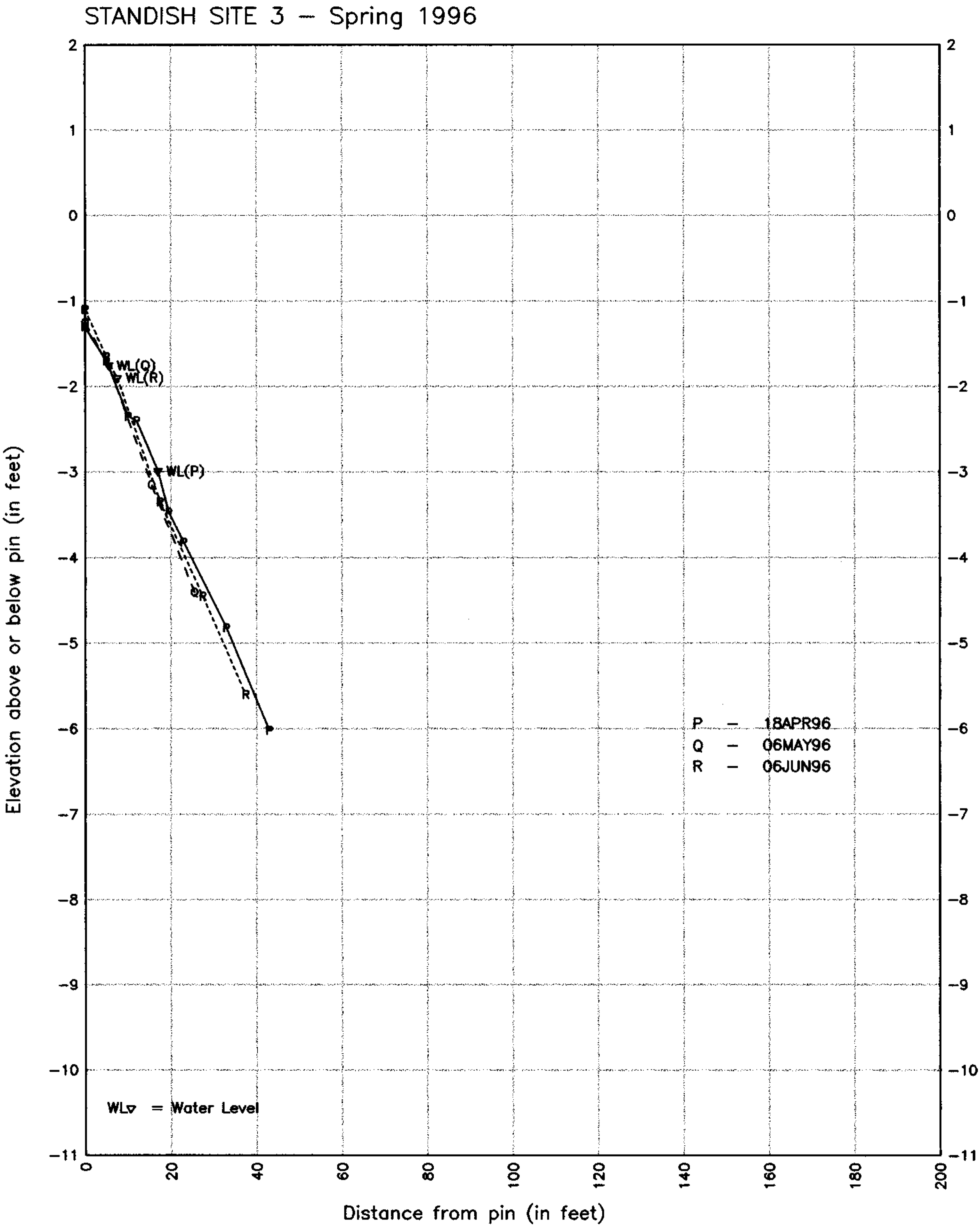
STANDISH SITE 3 – Fall 1994
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(H)
WL(I)
H – 03OCT94
I – 03NOV94
WL▽ = Water Level


STANDISH SITE 3 – Spring 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(K)
WL(J)
J – 02MAY95
K – 02JUN95
WL▽ = Water Level



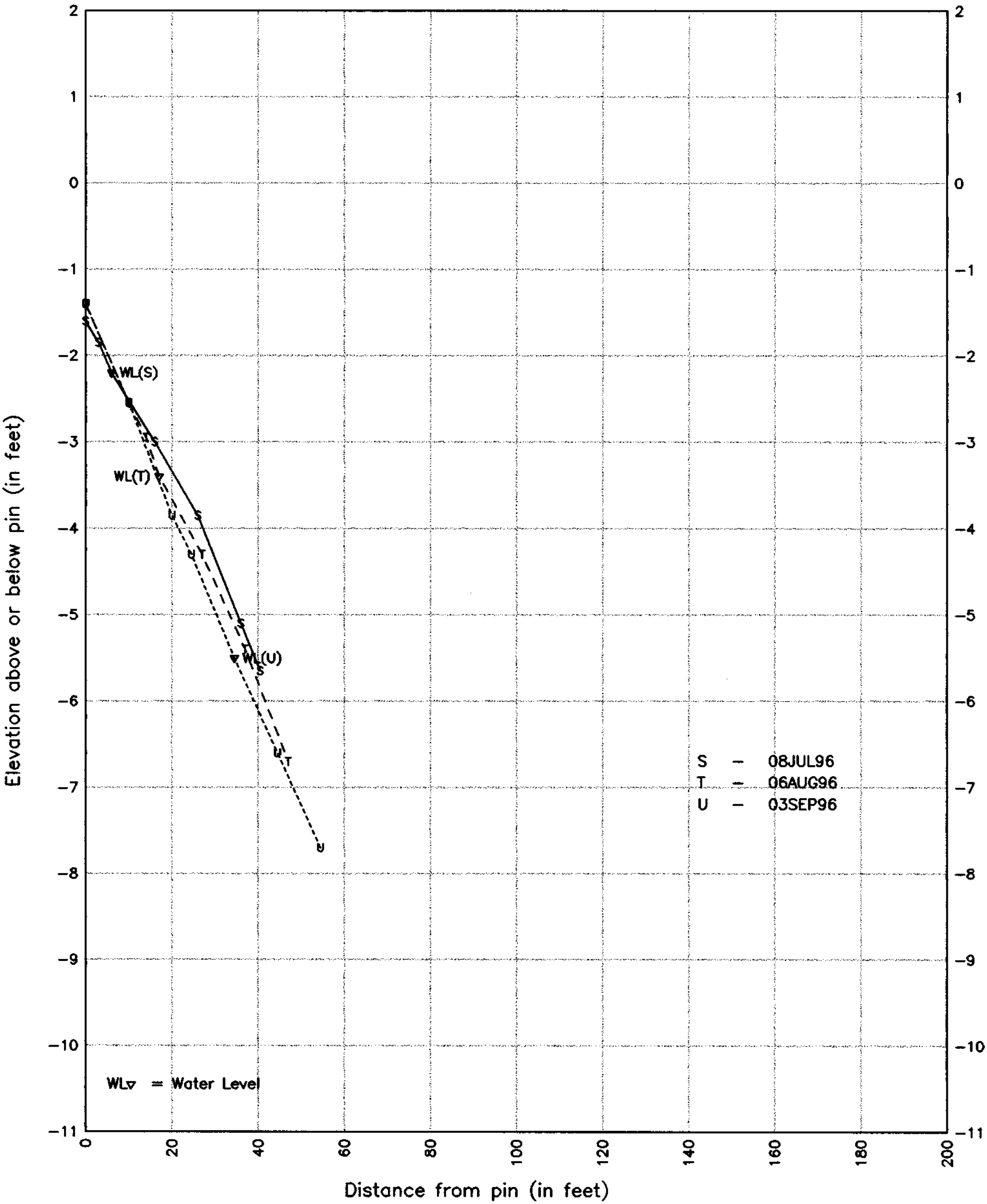
STANDISH SITE 3 – Summer 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100
120
140
160
180
200
WL(L)
WL(M)
WL(N)
L – 03JUL95
M – 07AUG95
N – 08SEP95
WL▿ = Water Level

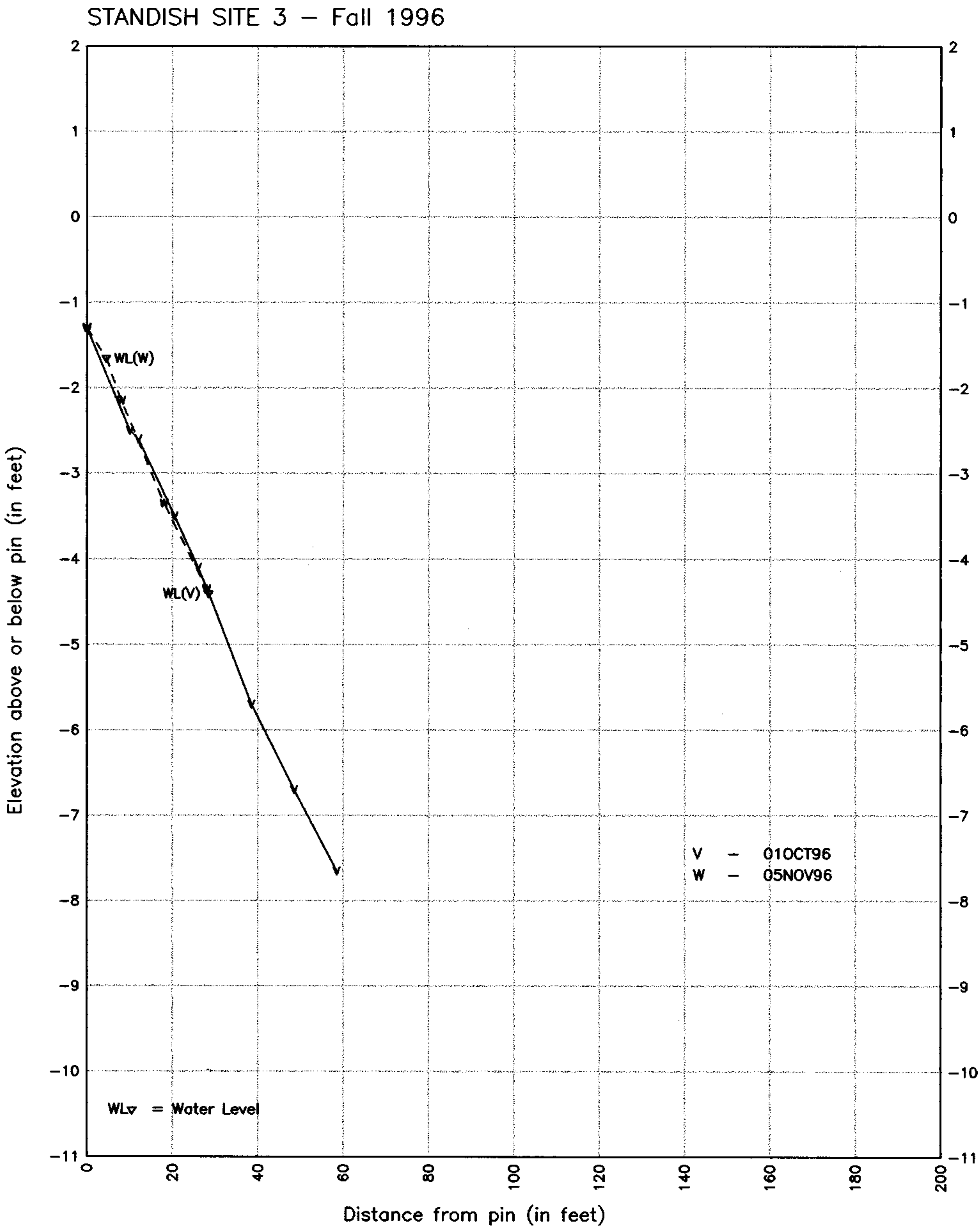

STANDISH SITE 3 — Fall 1995
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(0)
O — 11OCT95
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200

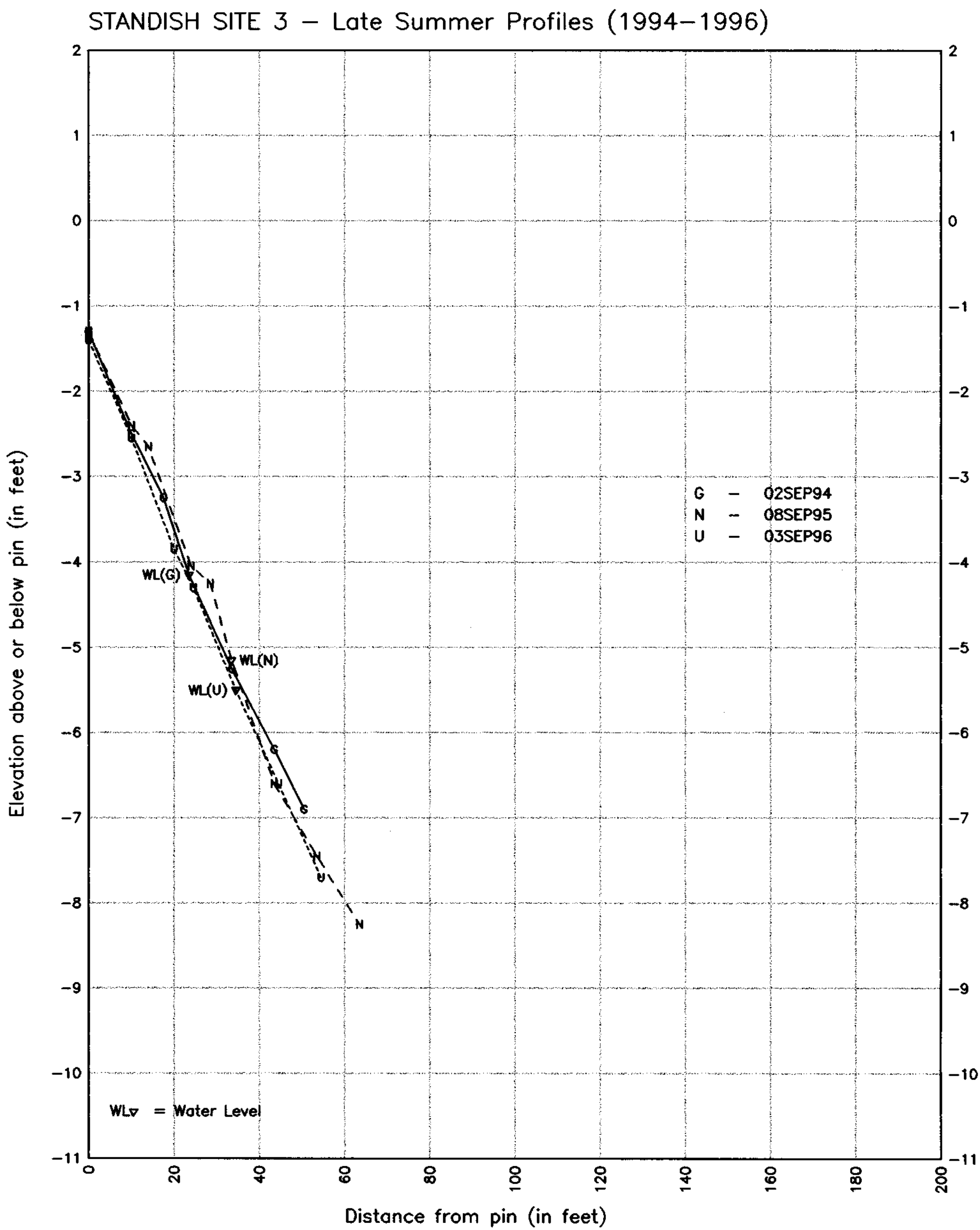


STANDISH SITE 3 – Spring 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
WL(Q)
WL(R)
WL(P)
P – 18APR96
Q – 06MAY96
R – 06JUN96
WL▽ = Water Level

STANDISH SITE 3 – Summer 1996




STANDISH SITE 3 – Fall 1996
Elevation above or below pin (in feet)
Distance from pin (in feet)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200
WL(W)
WL(V)
V – 01OCT96
W – 05NOV96
WL▽ = Water Level


STANDISH SITE 3 – Late Summer Profiles (1994–1996)
Elevation above or below pin (in feet)
Distance from pin (in feet)
G – 02SEP94
N – 08SEP95
U – 03SEP96
WL(G)
WL(N)
WL(U)
WL▽ = Water Level
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
0
20
40
60
80
100
120
140
160
180
200