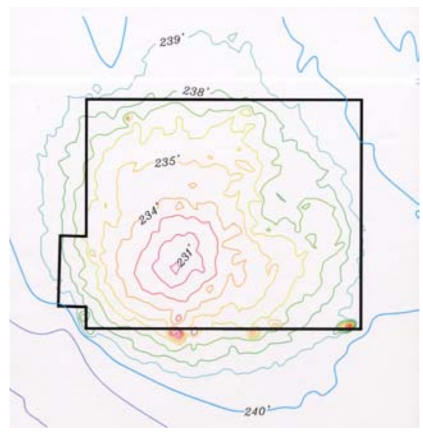
FINAL REPORT

An Assessment and Physical Characterization of Shell Mounds Associated with Outer Continental Shelf Platforms Located in the Santa Barbara Channel and Santa Maria Basin, California

February 2003



Prepared For: MINERALS MANAGEMENT SERVICE
PACIFIC OCS
770 Paseo Camarillo
Camarillo, CA 93010

Prepared By: MEC ANALYTICAL SYSTEMS, INC.
2433 Impala Drive
Carlsbad, CA 92008

And

SEA SURVEYOR, INC.
960 Grant Street, Suite C
Benicia, CA 9451

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Table of Contents

Figures/Charts

Tables

1. INTRODUCTION

Since 1958, offshore oil platforms have been part of the Southern California ecosystem. At the present time there are 23 offshore platforms in Federal waters. These platforms have finite economic lifespans and, as they become uneconomical, numerous questions and options arise as to the fate of these structures relative to environmental and economic impacts. Minerals Management Service (MMS) regulations require the complete removal of platform structures and associated debris and site clearance following decommissioning of offshore oil and gas facilities. Over the life of the platform, drilling muds and cuttings discharges mixed with dislodged shells and marine organisms from the platform jacket have accumulated into detectable mounds beneath these platforms. These topographic features have been referred to as shell mounds and the specific physical, chemical, and biological composition of these mounds is generally unknown. This study characterizes the size of shell mounds beneath 16 OCS platforms with an assessment of factors that contribute to shell mound formation.

Between April and June 2001, the MEC team, with Sea Surveyor, Inc. as the major subcontractor, conducted multibeam sonar surveys around eight OCS platforms in the Santa Barbara Channel and Santa Maria Basin, California. The results of this field study were reported to MMS in a Draft Report August 2001. In September of 2002 another eight OCS platforms were surveyed and the results of the study were reported to MMS in a Draft Report November 2002 (Figure 1). This final report incorporates the results of the two field surveys along with an analysis of factors contributing to shell mound formation. This study was part of the MMS's Environmental Mitigation Monitoring Study. The objectives of the multibeam hydrographic surveys were to identify and spatially delineate any shellmounds or debris piles under existing platforms and to integrate survey results with a literature review to describe possible factors (depth, slope, platform age, etc.) that may contribute to the presence of shell mounds. The eight OCS platforms surveyed in 2001 were Gina, Gail, Grace, Hidalgo, Houchin, Hondo, Henry, and Hermosa. The eight OCS platforms surveyed in 2002 were Gilda, Habitat, Hogan, Hillhouse, A, B, C and Irene (Table 1). Thus, all the platforms in the Santa Barbara Channel and the Santa Maria Basin were surveyed except for Platforms Harmony and Heritage in the channel and Platform Harvest in the basin. Platforms Harmony and Heritage are the most recently placed platforms with the least probability of having significant shell mounds and Platform Harvest is comparable to the nearby Platform Hermosa, which was surveyed.

The results of these multibeam surveys indicate that the largest and most detectable shell mounds are found under platforms that are located in shallow, flat bottom areas (<350' depth and <1% slope). Shell mounds will be found under any platform with fouling organisms, but in deeper waters, currents tend to be stronger and the "fall time" of shells and muds is longer so that these materials are dispersed over a broader area. This greater dispersion means that mounding directly under the platform jacket is less and any shell mound slope is more gradual blending with background topography making it difficult to separate any shell mounds from the irregularities of the sea floor. However, the absence of altered bathymetry consistent with mounding near these deeper platforms indicates that while shell debris can be seen on the bottom near these platforms there has not been enough accumulation to significantly alter the bottom bathymetry. The multibeam survey data was used to generate a detailed map of the seafloor beneath each platform and to delineate the physical proximity of the mounds to the platform, mound size and dimensions and any correlations between water depth, platform orientation, and platform age.

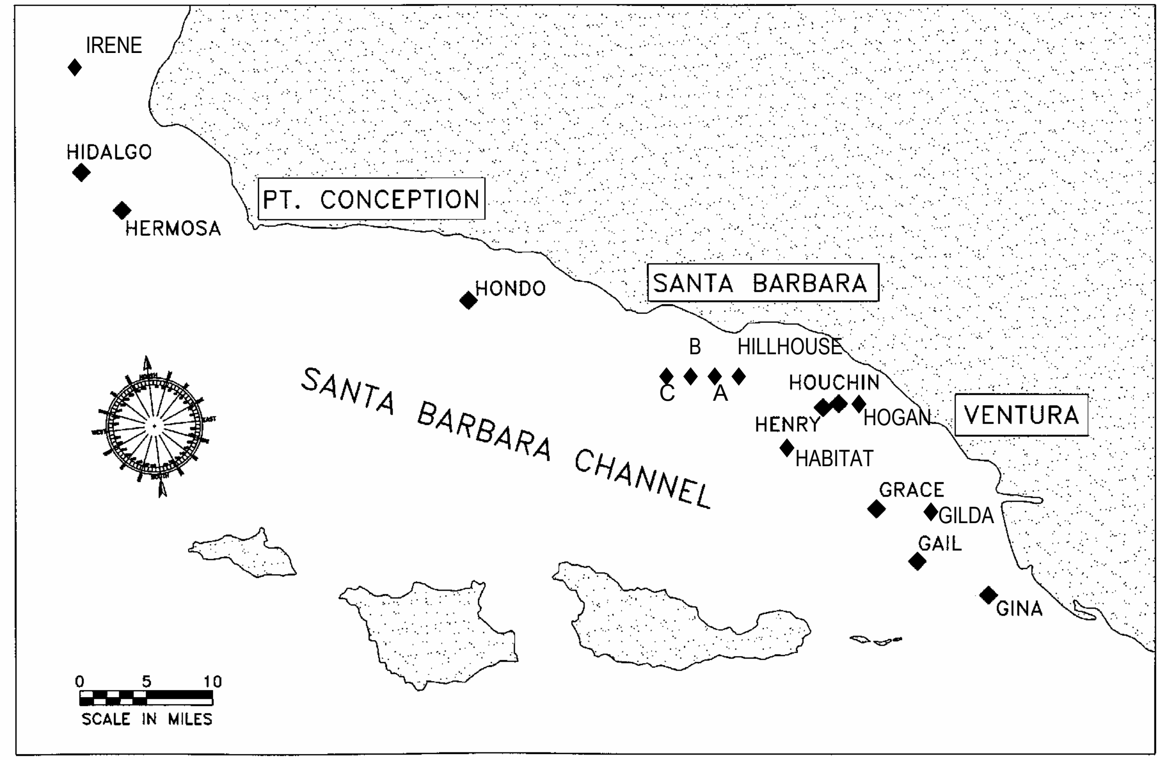


Figure 1. Site Map Showing Location of Platforms Surveyed**.**

The following sections describe the methodology, results, and conclusions from the multibeam hydrographic surveys. Bathymetric contour charts for each offshore platform are presented at the end of this report, along with profile views of the seafloor.

2. MULITBEAM SURVEYS AND SURVEY EQUIPMENT

A multibeam sonar system consists of numerous separate components, including the survey vessel, a navigation system, software, motion sensor, gyrocompass, and transducer. The multibeam surveys were conducted using standard hydrographic survey methodology and data processing techniques. The 2001 multibeam survey investigated OCS platforms located in a wide range of water depths (-96' to –840'), while the 2002 survey focused on platforms located in a narrow range of water depths (-152' to -293'). The multibeam transducer used for the 2001 survey was selected for its ability to acquire soundings in deep water (>-600'), while the multibeam transducer used for the 2002 surveys was selected because it provides higher resolution soundings in shallow water (<-300').

Table 1. Summary of Oil and Gas Platforms in Federal Waters with a Description of Associated Shell Mounds.

* = Platforms surveyed in 2001 otherwise surveys were conducted in 2002

Area/Production Unit	Platform Name	Operator	Date Installed	First Production	Water Depth (m/ft)	Distance from Shore (miles)	Years Platform Installed at Time of Survey	Years in Production	Shell Mound Volume (yds^3)	Shell Mound Height (ft)	Estimate Shell Mound size (ft)	Center of Shell Mound Location	Bottom Slope (%)
San Pedro Unit	Edith	Nuevo	1/12/83	1/21/84	49/161	8.5	20	19					
	Elly	Aera	3/12/80		78/256	8.6	23	Na					
	Ellen	“	1/15/80	1/13/81	81/266	8.6	23	22					
	Eureka	“	7/8/84	3/17/85	213/699	9.0	19	18					
Pt Hueneme Unit	Gina*	Nuevo	12/11/80	2/11/82	29/96	3.7	21	21	4200	13	150x210	North side	1.01
Santa Clara Unit	Gail*	Venoco	4/5/87	8/8/88	225/740	9.9	14	15	<500	3	4 Scattered small mounds		3.6
	Grace*	“	7/30/79	7/25/80	97/318	10.5	22	23	5500	13	200x390	Northwest side	0.38
	Gilda	Nuevo	1/6/81	12/19/81	63/208	8.8	21	21	7370	18	220x285	North side	1.10
Pitas Point Unit	Habitat	“	10/8/81	12/15/83	89/293	7.8	21	20	6840	19	Dia 250	Centered	0.40
Carpinteria Area	Hogan	Pacific	9/1/67	6/10/68	47/152	3.7	35	35	12500	26	Dia 260	Western side	0.33
	Houchin*	“	7/1/68	4/28/69	50/163	4.1	33	34	10900	21	Dia 280	Centered	0.38
	Henry*	Nuevo	8/31/79	5/15/80	53/172	4.3	22	23	7200	19	Dia 250	Centered	0.67
	Hillhouse	“	11/26/69	7/21/70	58/190	5.5	33	33	6800	22	180x270	Western side	0.88
	A	“	9/14/68	3/3/69	58/190	5.8	34	34	7260	20	140x260	Centered	1.02
	B	“	11/8/68	7/19/69	58/190	5.7	34	34	8590	18	160x210	Centered	1.03
	C	“	2/28/77	8/1/77	59/193	5.7	25	26	4590	13	160x235	Southwest corner	1.14
Santa Ynez Unit	Hondo*	Exxon Mobile	6/23/76	4/2/81	256/840	5.1	25	22	1500	9	3 mounds 40x170, 60x130, & 50x100		5.6
	Harmony	“	6/21/89	12/30/93	365/1197	6.4	14	10					
	Heritage	“	10/7/89	12/18/93	328/1076	8.2	14	10					
Pt. Arguello Unit	Hermosa*	Arguello Inc.	10/5/85	6/9/91	184/604	6.8	16	12	<500	2	2 mounds 30x60 & Dia 20		5.0
	Harvest	“	6/12/85	6/3/91	206/676	6.7	17	12					
	Hildago*	“	7/2/86	5/27/91	131/430	5.9	15	12	<500	<2	Small and scattered		4.3
Pt Pedernales Unit	Irene	Torch	8/7/85	4/13/87	73/240	4.7	17	16	3720	9	Dia 215	Western side	0.71

Multibeam sonar surveys are becoming the preferred technology for conducting hydrographic surveys because this method conveys more information about complex bottom topography. The analysis of multibeam sonar data using sophisticated software programs can provide images of the bottom topography. However, it must be noted that these bottom images are an interpretation of the data and while believed to be representative of the bottom topography, the multibeam technology was not designed specifically to be an imaging tool but to provide data for an interpretation of the bottom. Thus, the figures depicting shell mounds beneath the platforms should be viewed as evidence for the presence and physical characteristics of the shell mound but not as an actual image of the bottom.

The multibeam surveys used Class 1 methods and accuracies as outlined in the Army Corps of Engineers' *HYDROGRAPHIC SURVEYING MANUAL* (EM 1110-2-1003, October 1994). All platforms except those in the Santa Maria Basin were surveyed using a 25' multibeam survey vessel. The survey around Platforms Hildago and Hermosa were conducted from the 100' vessel "COLLEEN", leased from *Antone Sylvester Tug Service* in Long Beach, California.

The multibeam hydrographic surveys were conducted along 12 survey lines at various spacings and orientations around each offshore platform. The spacing and orientation of the survey lines provided 100% coverage of the seafloor underneath and around each platform surveyed. Navigation utilized *OMNISTAR* LR-8 differential GPS navigation system. Soundings for the 2001 surveys were corrected for tides monitored by the National Oceanic and Atmospheric Administration (NOAA) at Platform Harmony and reported via the Internet. Soundings for the 2002 survey were corrected for tides at Platform Irene using NOAA predicted tides from Point Arguello and for the other platforms using NOAA predicted tides from Santa Barbara Harbor. The soundings were referenced to the Mean Lower Low Water (MLLW) vertical datum and the California State horizontal coordinate system, Zone 6 (NAD-27). For quality control purposes, a self-recording tide gauge installed in Santa Barbara Harbor during the survey and referenced to Tidal Benchmark #2, 1930 (Elevation: 13.1' MLLW) verified that actual tides matched predicted tides within 0.2".

Soundings around and under the offshore platforms were collected in 2001 using a SEABEAM Model 1180 and in 2002 using a RESON Model 8101 multibeam sonar, which consisted of a transducer head, an onboard processor, and a video monitor. These transducers operate at 180-kHz or 240-kHz, respectively and were fixed mounted to the port side of the survey vessels. Motion sensors, located at different points on the vessels, measure and compensate for the motion of the sonar. An interactive mouse utilizes the video monitor to adjust system settings such as gain, power, and range. During data collection, the video monitor also shows the acoustic signal being collected along with each digitized beam. The SEABEAM system can measure water depths to 2000' while the RESON system is best for water depths less than 400'.

These multibeam sonar systems were dynamically compensated for roll/pitch/heave. For the 2001 survey a TSS 335B motion sensor monitored and measured sonar roll (rotation port and starboard), pitch (rotation fore and aft), and heave (vertical displacement) during data collection. A SCAN 2000 gyrocompass recorded vessel and sonar yaw (rotation about the Z-axis) during sonar data collection. For the 2002 survey a TSS/DMS Type 2-05 motion sensor monitored and measured sonar roll, pitch, and heave during data collection. A SG BROWN Model MERIDIAN gyrocompass recorded vessel and sonar yaw during sonar data collection. A Pentium 533 MHz laptop navigation computer using HYPACK Max data acquisition software for recording soundings, navigation data, gyrocompass data, and vessel roll, pitch, and heave. The software was also used for calibrating the multibeam sonar and processing soundings.

Sound velocity profiles were recorded at each platform before and after the hydrographic surveys using a *Valeport* Model 650 (2001) or a APPLIED MICROSYTEMS Model SV-PLUS (2002) sound velocity profiler in order to correct the soundings for varying speed-of-sound through the water column.

3. MULTIBEAM DATA PROCESSING

After completing the hydrographic surveys around the offshore platforms, the multibeam soundings were processed using *HYSWEEP/HYPACK Max* Multibeam Processing and Editing Software. The soundings were processed using the following steps:

1. Sensor Alignment and Calibration Adjustments: The entire multibeam sonar system was calibrated using industry standards prior to, and immediately following, each survey.
2. Sounding were Inspected and corrected for vessel motion and position data:
3. Vertical profiles of sound velocity were collected before and after each survey and used to establish sound velocity for the oceanographic conditions for each site:
4. Soundings were merged and corrected for motion, position, and tide data and adjusted for a common time base.
5. Editing sounding data manually and automatically:
    - Fully resolved soundings were edited both manually and automatically to eliminate spikes and bad returns.
    - Soundings at swath angles of greater than 60 degrees were not utilized.
    - Automatic spike filters eliminated 2m or greater jumps in point-to-point soundings.
6. Thinning edited data to desired density
    - The soundings around and under the platforms are displayed in the smallest possible grid to provide the best resolution. Since grid size increases with water depth, the shallow soundings collected during the 2002 surveys had a greater resolution than the deep soundings collected in 2001.
    - Data was averaged to one sounding per 10' x 10' grid for all 8 OCS platforms surveyed in 2002 while 15' x 15' grid was used for the deep platforms surveyed in 2001. The center sounding in the grid square were retained along with that point's Northing and Easting. If no soundings occurred in a particular grid square, no data were reported.
7. DXF files were used for contour creation.
8. The soundings and DXF contour files were imported into AutoCAD for adding text, graphics and final plotting. The AutoCAD files can be converted to an ARCVIEW format for inclusion into a GIS format.

4. MULTIBEAM SURVEY RESULTS

The results of the multibeam surveys are graphically depicted for each platform showing the bathymetry in planar view and in cross section. The figures are compiled at the end of the report in the order they are discussed below (Charts 1-16). Table 1 summarizes some of the attributes of the OCS platforms and the shell mounds associated with each platform. Of the 16 platforms surveyed, single large shell mounds were detectable beneath the 12 platforms located in water depths of less than 394 ft (<100 m). These single shell mounds ranged in height from 9 to 26 ft above the adjacent bottom depths with an estimated volume of from 3,720 to 12,500 cubic yards (Table 1). The four platforms located in water depths greater than 430 ft (>131 m) were found to have either no significant shell mounding (i.e., Platform Hidalgo) or poorly defined multiple shell mounds ranging in height from less than 2 ft to about 9 ft above the adjacent bottom depths with a volume of less than 500 to 1,500 cubic yards (i.e., Platforms Hermosa, Gail and Hondo).

The results from the multibeam hydrographic surveys around and under the offshore platforms are presented in this section.

4.1 Platform Gina

Platform Gina was installed in the Santa Barbara Channel 21-years ago and is located approximately 3.7 miles from shore. The water depth around the platform is -96’ MLLW. The seafloor around the platform is slightly sloping (1.0%) towards the southwest (Table 1). A mound under Platform Gina rises to –83’ MLLW (Chart 1). The 13’-high mound located under Platform Gina is centered under the northern edge of the platform. The base of the mound is oval-shaped, 150’ x 210’ as measured along the -95’ MLLW depth contour. The long-axis of the mound is oriented northwest-southeast. This mound under Platform Gina has an estimated volume of 4,200 cubic yards.

4.2 Platform Gail

Platform Gail was installed in the Santa Barbara Channel 14-years ago and is located approximately 9.9 miles from shore. The water depth at the platform is approximately -740’ MLLW (Chart 2). The seafloor around the platform has a 3.6% downward slope towards the south-southwest (Table 1) and the platform appears to influence the bathymetry because several upslope contours (-738’ to –741’ MLLW) dip under the platform. Several small mounds are present under Platform Gail, but these mounds are difficult to identify because they have low relief. Two 3’-high mounds rise to –736’ MLLW under the northern edge of the platform. One of the 3’-high mounds measures 40’ x 60’ at its base, while the other 3’-high mound has a base of 40’ x 50’. In addition to the two 3’-high mounds, there are two 2’-high mounds under the platform. Both 2’-high mounds are located under the western edge of the platform. One of the 2’-high mounds has a base dimension of 20 'x 70', and the other 2’-high mound has a base of 25' x 50'. The total volume of the 4 mounds under Platform Gail cannot be calculated accurately because the mounds are too small and difficult to identify on a sloping seafloor but it is estimated to be less than 500 yds^3.

4.3 Platform Grace

Platform Grace was installed in the Santa Barbara Channel 22-years ago and is located approximately 10.5 miles from shore. The water depth at the platform is approximately –318' MLLW. The seafloor around the platform gradually slopes (0.38%) down towards the south (Table 1). A mound under Platform Grace rises to –305' MLLW and this 13'-high mound is centered in the northwest quadrant under the platform (Chart 3). The base of the mound is oval-shaped, 200' x 390' as measured along the -317' MLLW depth contour. The long-axis of the mound is oriented northwest-southeast. This mound has an estimated volume of 5,500 cubic yards.

4.4 Platform Gilda

Platform Gilda was installed in the Santa Barbara Channel 20-years ago and is located approximately 8.8 miles from shore. The water depth around the platform is -208' MLLW and the seafloor gradually slopes (1.1%) downwards towards the southwest (Table 1). The mound under Platform Gilda rises to –190' MLLW and this 18'-high mound is centered under the northern edge of the platform (Chart 4). The base of the mound is oval-shaped, 220' x 285' as measured along the -206' MLLW depth contour. The long-axis of the mound is oriented north-south. This mound has an estimated volume of 7,370 cubic yards.

4.5 Platform Habitat

Platform Habitat was installed in the Santa Barbara Channel 21-years ago and is located approximately 7.8 miles from shore. The water depth at the platform is approximately -293' MLLW and the seafloor has a gentle slope to the southwest (0.40%) (Table 1). The mound under Platform Habitat rises to –274' MLLW and the 19'-high mound is centered under the platform (Chart 5). The base of the mound is circular-shaped with a diameter of approximately 250' as measured along the -292' MLLW depth contour. This mound under Platform Habitat has an estimated volume of 6,840 cubic yards.

4.6 Platform Hogan

Platform Hogan was installed in the Santa Barbara Channel 35-years ago and is located approximately 3.7 miles from shore. The water depth at the platform is approximately –152' MLLW and the seafloor is nearly flat (0.33%) (Table 1). A mound under Platform Hogan rises to –126' MLLW and the 26'-high mound is centered under the western half of the platform (Chart 6). The base of the mound is circular with a diameter of approximately 260' as measured along the -150' MLLW depth contour. The mound crests at a north-south oriented ridge, possibly corresponding to the location of the drill pipes. The crest of the mound is oval-shaped, measuring 25' x 90' as measured along the -130' MLLW depth contour. This mound has an estimated volume of 12,500 cubic yards.

4.7 Platform Houchin

Platform Houchin was installed in the Santa Barbara Channel 33-years ago and is located approximately 4.1 miles from shore. The water depth at the platform is approximately –163' MLLW and the seafloor has a gentle down slope (0.38%) towards the south (Table 1). A mound under Platform Houchin rises to –142' MLLW and this 21'-high mound is centered under the platform (Chart 7). The base of the mound is circular, with a diameter of 280' as measured along the -162' MLLW contour. The mound crests at a north-south oriented ridge that is located under the western half of the platform, possibly corresponding to the location of the drill pipes. The crest of the mound is oval-shaped, measuring 35' x 75' as measured along the -146' MLLW depth contour. This mound has an estimated volume of 10,900 cubic yards

4.8 Platform Henry

Platform Henry was installed in the Santa Barbara Channel 22-years ago and is located approximately 4.3 miles from shore. The water depth at the platform is approximately –172' MLLW and the seafloor has a gentle down slope to the south (0.67%) (Table 1). A mound under Platform Henry rises to –153' MLLW and the 19'-high mound is centered in the northwest quadrant under the platform (Chart 8). The base of the mound is circular, with a diameter of about 250' as measured along the –171' MLLW contour. This mound has an estimated volume of 7,200 cubic yards.

4.9 Platform Hillhouse

Platform Hillhouse was installed in the Santa Barbara Channel 33-years ago and is locatedf approximately 5.5 miles from shore. The water depth at the platform is approximately –190' MLLW and the seafloor has a gentle downward slope (0.88%) towards the south (Table 1). A mound under Platform Hillhouse rises to –168' MLLW and the 22'-high mound is centered under the western half of the platform (Chart 9). The base of the mound is oval-shaped, 180' x 270' as measured along the -188' MLLW depth contour. The long-axis of the mound is oriented northwest-southeast. This mound has an estimated volume of 6,800 cubic yards.

4.10 Platform A

Platform A was installed in the Santa Barbara Channel 34-years ago and is located approximately 5.8 miles from shore. The water depth at the platform is approximately –190' MLLW and the seafloor around the platform slopes (1.02%) down towards the south (Table 1). A mound under Platform A rises to –170' MLLW and the 20'-high mound is centered under the platform (Chart 10). The base of the mound is oval-shaped, 240' x 160' as measured along the -188' MLLW contour. The mound crests under the western half of the platform. This mound has an estimated volume of 7,260 cubic yards.

4.11 Platform B

Platform B was installed in the western Santa Barbara Channel 34-years ago and is located approximately 5.7 miles from shore. Water depth at the platform is approximately –190' MLLW and the seafloor slopes (1.03%) down towards the south (Table 1). A mound under Platform B rises to –172' MLLW and the 18'-high mound is centered under the platform (Chart 11). The base of the mound is oval-shaped, 160' x 210' as measured along the –188' contour. The long-axis of the mound is oriented east-west. The mound crests under the western half of the platform. This mound has an estimated volume of 8,590 cubic yards.

4.12 Platform C

Platform C was installed in the Santa Barbara Channel 25-years ago and is located approximately 5.7 miles from shore. The water depth around the platform is approximately –193' MLLW and the seafloor slopes (1.14%) downward towards the south (Table 1). A mound under Platform C rises to –180’ MLLW and the 13’-high mound is centered under the southwest quadrant of the platform (Chart 12). The base of the mound is oval-shaped, 160’ x 235’ as measured along the -192’ MLLW depth contour. The long-axis of the mound is oriented northwest-southeast. This mound has an estimated volume of 4,590 cubic yards.

4.13 Platform Hondo

Platform Hondo was installed in the western Santa Barbara Channel 25-years ago and is located approximately 8.2 miles from shore. Water depth at the platform ranges between –826’ to –840’ MLLW and the seafloor around the platform has a complex bathymetry with a steep (5.6% downward slope towards the south (Table 1). The platform appears to influence the bathymetry because the bathymetric contours between –823’ to –839’ MLLW dip south under the platform (Chart 13). Two larger mounds and one to several smaller mounds are located under Platform Hondo. One of the larger mounds is located under the northern half of the platform and a smaller mound located under the southern half of the platform. The mounds are adjacent to, and upslope of, the platform legs. The west side of the southern and northern mounds may connect. The mound under the northern half of Platform Hondo is approximately 8’ high, rising to elevation –815’ MLLW. The northern mound has a base of 40’ x 170’ along the –820' MLLW contour, with the long-axis oriented east-west. The smaller mound located under the southern half of Platform Hondo is 9’ high and has dimensions of 60' x 130' as measured along the –834’ MLLW contour. The mound rises to –825’ MLLW and its long axis is oriented east-west. Numerous isolated mounds and depressions are scattered around Platform Hondo, the most prominent being an isolated 6’-high mound with base dimensions of 50' x 100' located 200’ east of the platform. The 3 mounds around and under Platform Hondo have a combined volume of approximately 1,500 cubic yards.

4.14 Platform Hermosa

Platform Hermosa was installed in the Santa Maria Basin 16-years ago and is located approximately 6.8 miles from shore. Water depth under the platform ranges between –597 to –607' MLLW with the water depth directly under the center of the platform being approximately –602' MLLW. The seafloor around the platform has a steep 5.0% downward slope towards the southwest (Chart 14). Platform Hermosa does not appear to significantly influence the seafloor bathymetry; however, the –600' contour under the platform extends further southwest than surrounding contours, and two small 2'-high mounds exist under the northeast and northwest edges of the platform. The total volume of the mounds around and under Platform Hermosa cannot be calculated accurately because the mounds are too small and difficult to identify on a sloping seafloor but the volume is estimated to be less than 500 cubic yards.

4.15 Platform Hidalgo

Platform Hidalgo was installed in the Santa Maria Basin 15-years ago and is located approximately 5.9 miles from shore. Water depth under the platform ranges between –430' and –

440' MLLW (Table 1). The water depth directly under the center of the platform is approximately –434' MLLW. The seafloor around the platform has a 4.3% downward slope towards the southwest (Chart 15). The seafloor slope is steeper to the southwest (down slope) of the platform. Platform Hidalgo does not appear to affect the seafloor bathymetry and there is no indication of significantly sized mounds beneath the platform. However, the bathymetry is complex and it is possible that there may be scattered small mounds (<less than 2 ft) beneath the platform. In the vicinity of the platform there appears to be several small mounds and depression that are randomly distributed possibly representing some hard bottom habitat.

4.16 Platform Irene

Platform Irene was installed in the Santa Maria Basin 17-years ago and is located approximately 4.7 miles from shore. The seafloor around the platform has a downward slope (0.71%) towards the west (Table 1). The water depth around the platform is approximately –240' MLLW. A mound beneath Platform Irene rises to –231' MLLW and this 9'-high mound is centered under the western quadrant of the platform. The base of the mound is circular, with a diameter of approximately 210-220' as measured along the –239' MLLW depth contour. This mound has an estimated volume of 3,720 cubic yards.

5. FACTORS CONTRIBUTING TO SHELL MOUND FORMATION

While shell mounds and debris piles may be found under any platform where muds and cuttings may have been discharged or where fouling organisms can be dislodged, the size of the shell mounds appears to be related to several factors. Platforms located in deeper waters and on the outer continental shelf or slope, which are further from the shore, tend to be in areas where currents are stronger. Stronger currents coupled with increased water depth means that the "fall time" and horizontal displacement of shells and muds dislodged or discharged from the platform would take longer to reach the bottom and consequently these materials would be dispersed over a broader spatial area. This greater dispersion means that mounding directly under the platform jacket is less and the slope of the mounds would be more gradual blending with background topography over a larger spatial extent. Thus, for the deeper platforms there are valid reasons why shell mounds might be smaller and less detectable. However, if accumulation of shells and muds is significant there still should be detectable changes in bathymetry centered on or near the platform reflecting an accumulation of material above the surrounding bottom surface. The lack of detectable mounding at Platform Hildago and poorly defined mounds at Platforms Gail and Hermosa suggests that either the accumulation of muds and shell material is less than the depth intervals used for contouring bottom depths or other factors related to the limitations of the multibeam technology such as bottom slope, water depth and interference from the platform structure limit the sensitivity of the method to discern shell mounds. However, mounding was discernable beneath Platform Honda in 840 ft of water (256 m) on the steepest bottom slope observed (5.6%), which suggests that the multibeam equipment used was capable of discerning mounding beneath the other platforms. Another factor contributing to smaller shell mounds is that the deeper platforms generally have been in place fewer years than the shallower platforms providing less time for mounds to accumulate material.

Table 1 lists some of the factors considered likely to be important for shell mound formation. The most important factors considered for analyses were number of years the platform had been installed, water depth, bottom slope, and distance from shore. Interestingly, there was a significant and strong correlation (r^2=0.73) between water depth and bottom slope (% slope transformed to arcsin) (Figure 2) and less surprising was that shell mounds having the largest volume were also the ones having the greatest height above the bottom. For this study it was found that bottom slope increases with greater water depths and this was negatively correlated with shell mound volume. While the number of wells drilled may also be an important contributor of mounding due to discharges of drilling muds and cuttings it was not possible to quantify this variable as operators and their methods have varied over the past three decades.

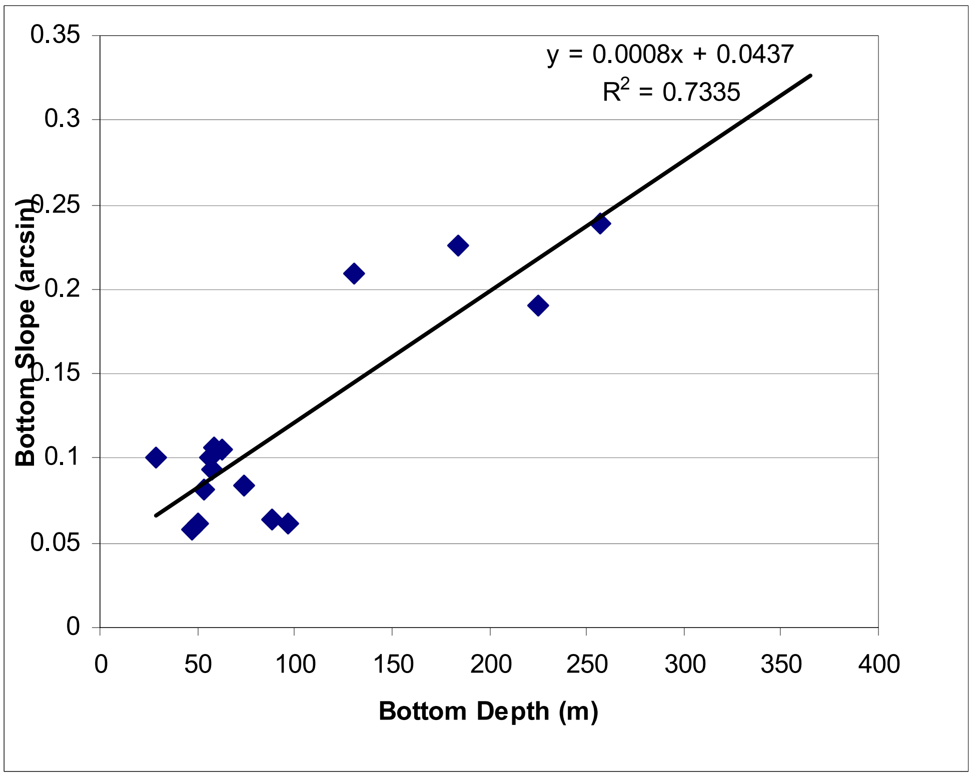


Figure 2. Correlation of water depth (m) with bottom slope (% transformed to arcsin)

In order to discern those factors most important (i.e., correlated) with shell mound formation several different analytical approaches were utilized. A Principal Component Analysis (PCA) was conducted to determine which variables covary. This analysis showed that water depth and bottom slope were covariants. This was also demonstrated with regression analysis, which showed that water depth accounted for 64% of the variance in shell mound formation but bottom slope accounted for 80% of the variance (Figure 3). Thus, water depth cannot be isolated from bottom slope, but since bottom slope was the best fit of the data incorporating all the variability related to water depth the discussion will focus on bottom slope. However, it should not be forgotten that water depth is a covariant of bottom slope. The best multiple regression fit for shell volume (ln transformed) was with bottom slope (% arcsin transformed) and years since jacket installation which when combined accounted for 91.7% of the variability in the data set. The addition of distance from shore and water depth did not improve this correlation suggesting that these factors contribute no additional new information for the correlation. This is a remarkable strong and significant correlation and suggests that the volume of a shell mound formation beneath a platform in the study area can be predicted with a relatively high degree of confidence knowing just these two factors. The equation for predicting shell mound volume is: volume of shell mound in cubic yards (log) = 8.39 + (0.060 x age) + [-12.9 x slope (arcsin)]. Consequently, It is not surprising that the largest shell mounds were found beneath platforms older than 30 years on relatively flat bottoms. The smallest shell mounds were found beneath the newest platforms located on the steepest sloping bottoms (Table 1).

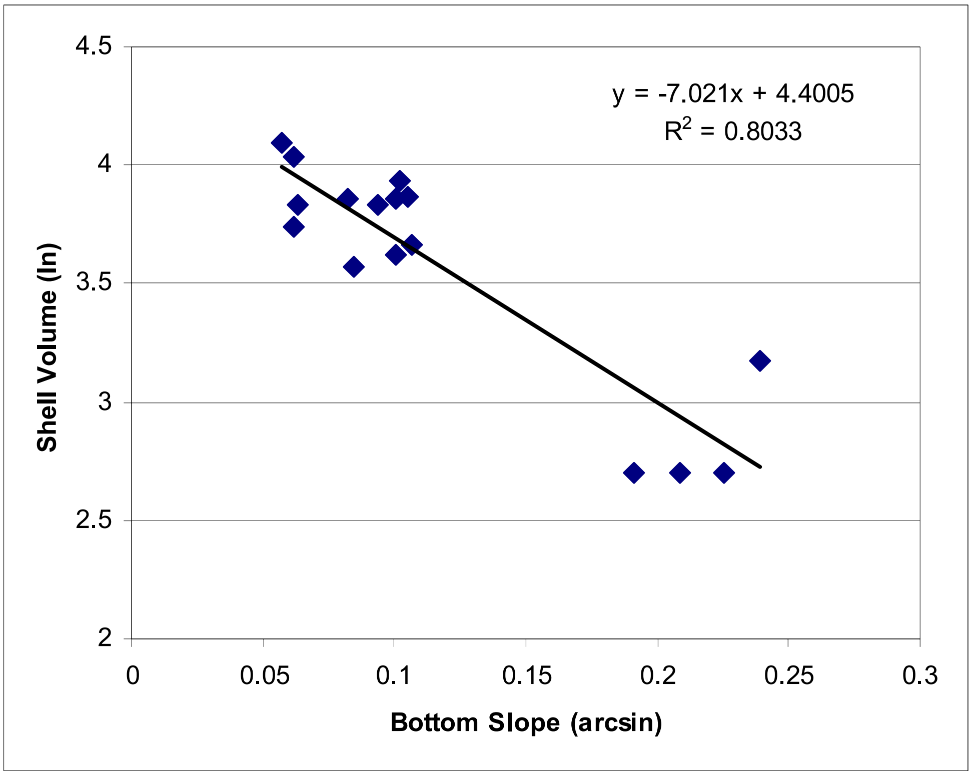


Figure 3. Correlation of shell mound volume (ln) with bottom slope (% transformed to arcsin)

6. CONCLUSIONS

Multibeam sonar surveys are an effective tool for mapping shell mounds and debris piles around and under platforms in waters less than 350 ft. Mulitbeam survey results for platforms in deeper water also appear to be valid but verification by other methods would increase confidence in the results. The following conclusions are derived after review of the bathymetric charts and analysis of the information presented in Table 1.

- The results from the bathymetric surveys show a high degree of comparability against historical soundings. The soundings around 10 platforms match historical soundings within ±1'and the soundings around the other six platforms match historical soundings within 1 ±m. Thus, we have high confidence in the multibeam methods used for these surveys.

- The size of the survey vessel does not influence the quality of the soundings, but increasing sea state (wave height and period) can decrease sounding resolution. Thus, larger vessels are recommended in areas where large and heavy seas may be encountered.

- The multibeam sonar provides excellent resolution in a 10' x 10' grid for mapping large mounds under shallow (<350') platforms. Mapping small mounds requires better resolution, which cannot be achieved in deep water from a surface-mounted sonar. For better resolution of small mounds under the deep (>350') offshore platforms, it might be necessary to use a submersible as a survey platform, which would shorten the sonar beam and increase resolution.

- Single, well-defined mounds were delineated beneath 12 of the 16 platforms surveyed in water depths less than 350' and with bottom slopes less than 1.1%. Platforms located in deeper water and on steeper sloping bottoms generally had smaller, multiple, and less well-defined mounds i.e., Platforms Gail (740' with 3.6% slope), Platform Hondo (840' with 5.6% slope) and Platform Hermosa (604' with 5.0% slope). No significant mounding was delineated beneath Platform Hildago (430' with 4.3% slope) but there may be several small depressions and mounds beneath and in the vicinity of this platform having relief heights of less than 2'.

- For the OCS platforms shell mound volume was significantly correlated with bottom slope (% arcsin transformed) and years since jacket installation, which when combined accounted for 91.7% of the variability in the data set. The addition of distance from shore and water depth did not improve this correlation suggesting that these factors contribute no additional new information.

- Formation of shell mounds beneath an OCS platform and the mound volume can be predicted with a relatively high degree of confidence by the following formula: mound volume in cubic yards (ln) = 8.39 + (0.060 x age) + [-12.9 x slope (arcsin)].

- A multibeam sonar collects considerable information regarding the location of the platform's legs and drill pipes; however, it is a poor tool for imaging these structures. Multibeam soundings are individual points that do not allow the platform legs or drill pipes to be differentiated from struts, cross-braces, or schools of fish under the platform. Figure 4 shows raw soundings from a single sweep of the multibeam sonar under Platform Hondo. Used alone, the soundings show an infinite number of possible structures under the platforms. The most practical method for outlining the legs and drill pipes under the platforms is to analyze the soundings in conjunction with a side-scan sonar survey around the platform, and then compare the results to detailed engineering drawings of the submerged superstructure.

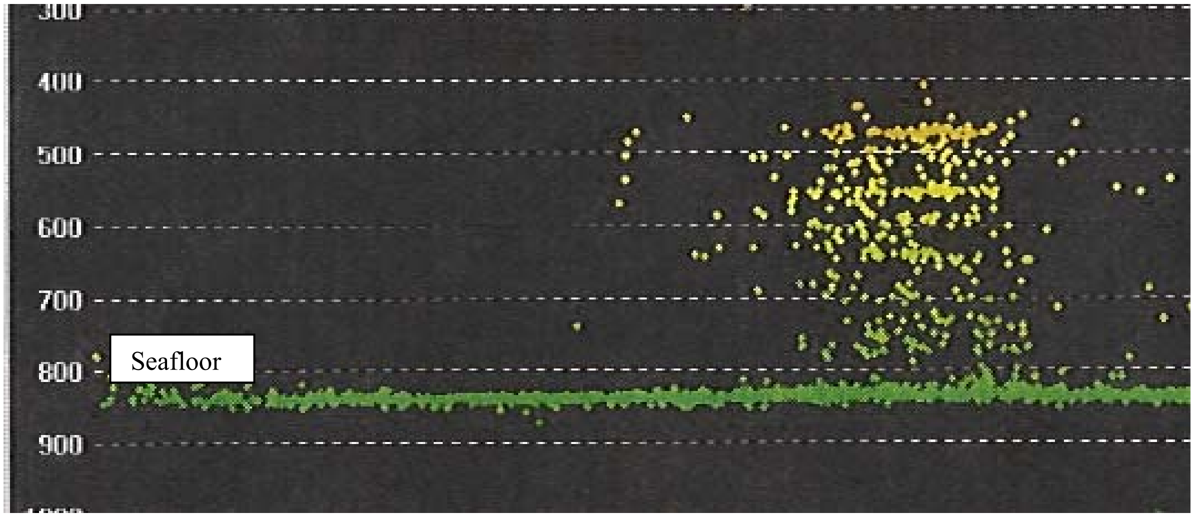


Figure 4. Raw individual soundings around and under Platform Hondo. Soundings in the water column are from the platform's legs, struts, and other structures, as well as schools of fish. Please note that discrete "levels" of the platform can be seen at 475' and 550' water depths.

PLATFORM GINA

MULTIBEAM HYDROGRAPHIC SURVEY

APRIL 2001

MINERALS MANAGEMENT SERVICE

PACIFIC OCS REGION

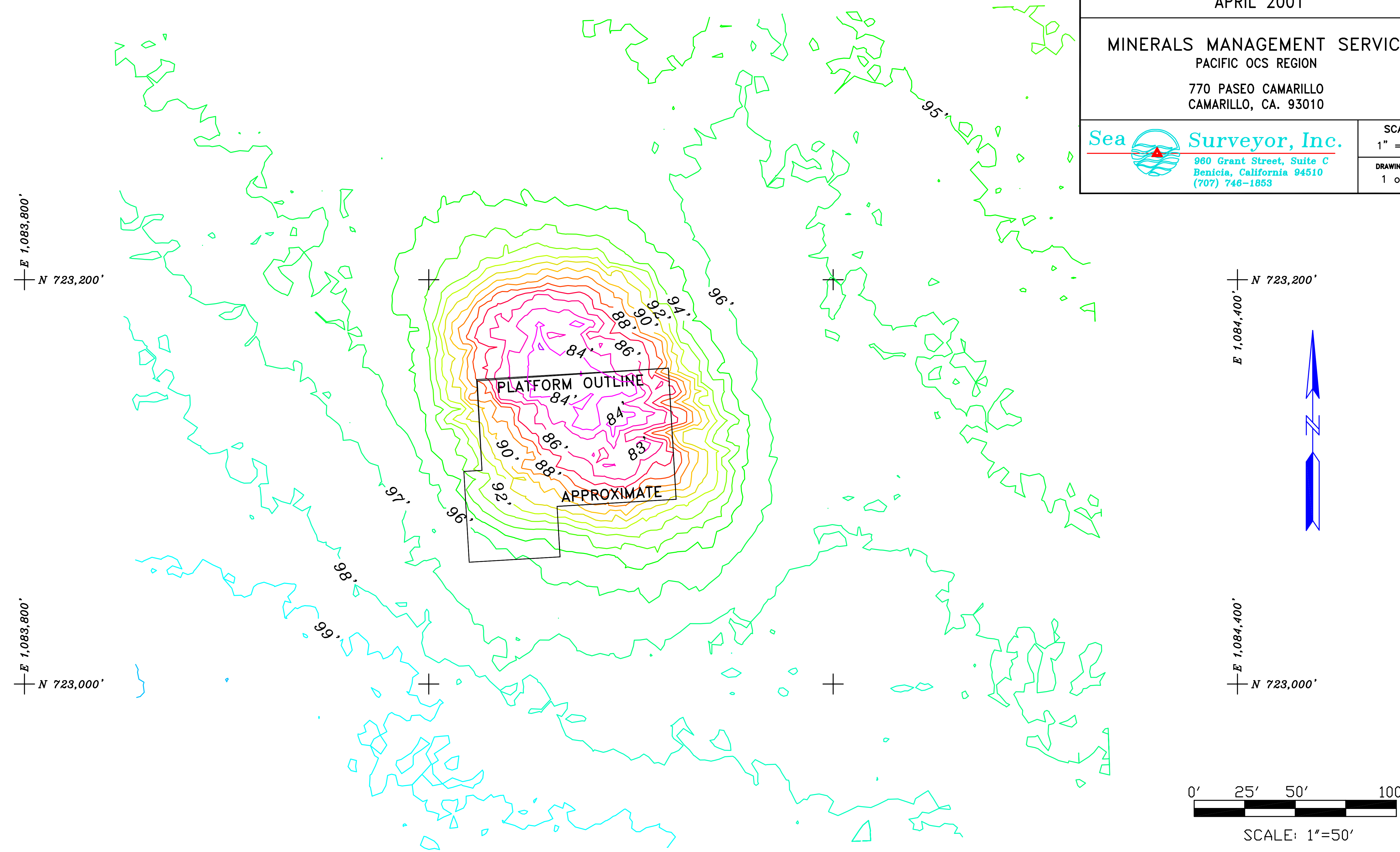
770 PASEO CAMARILLO

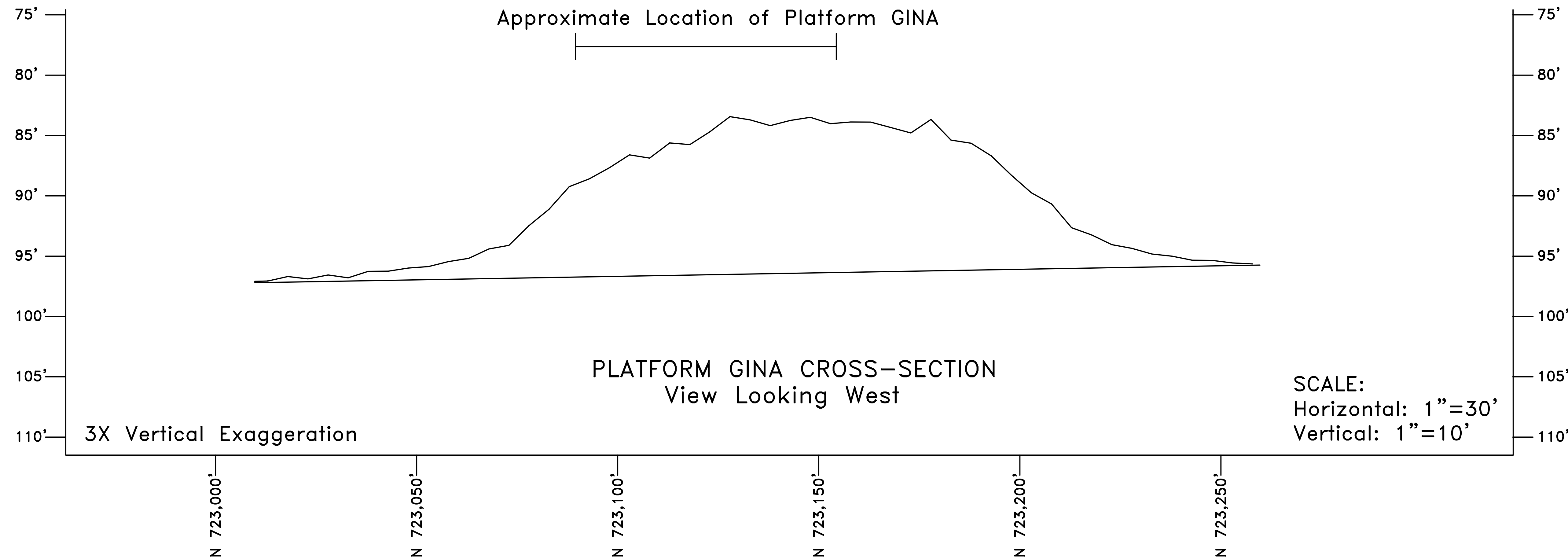
CAMARILLO, CA. 93010

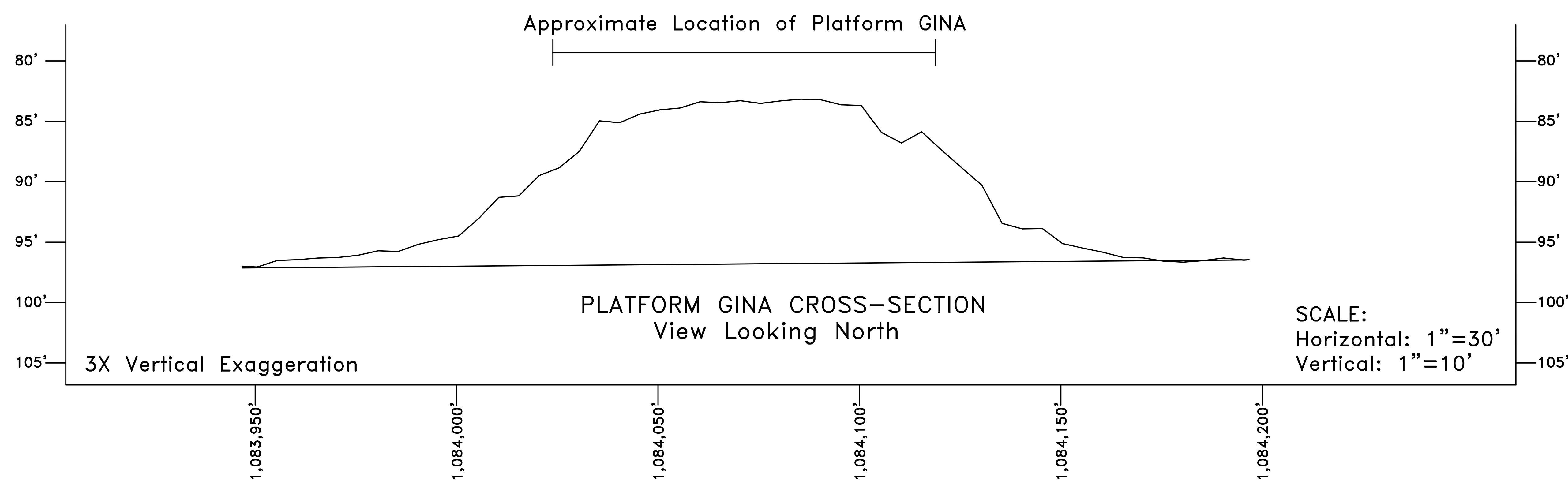
Sea Surveyor, Inc.
960 Grant Street, Suite C
Benicia, California 94510
(707) 746-1853

SCALE: 1" = 50'

DRAWING NO. 1 of 8







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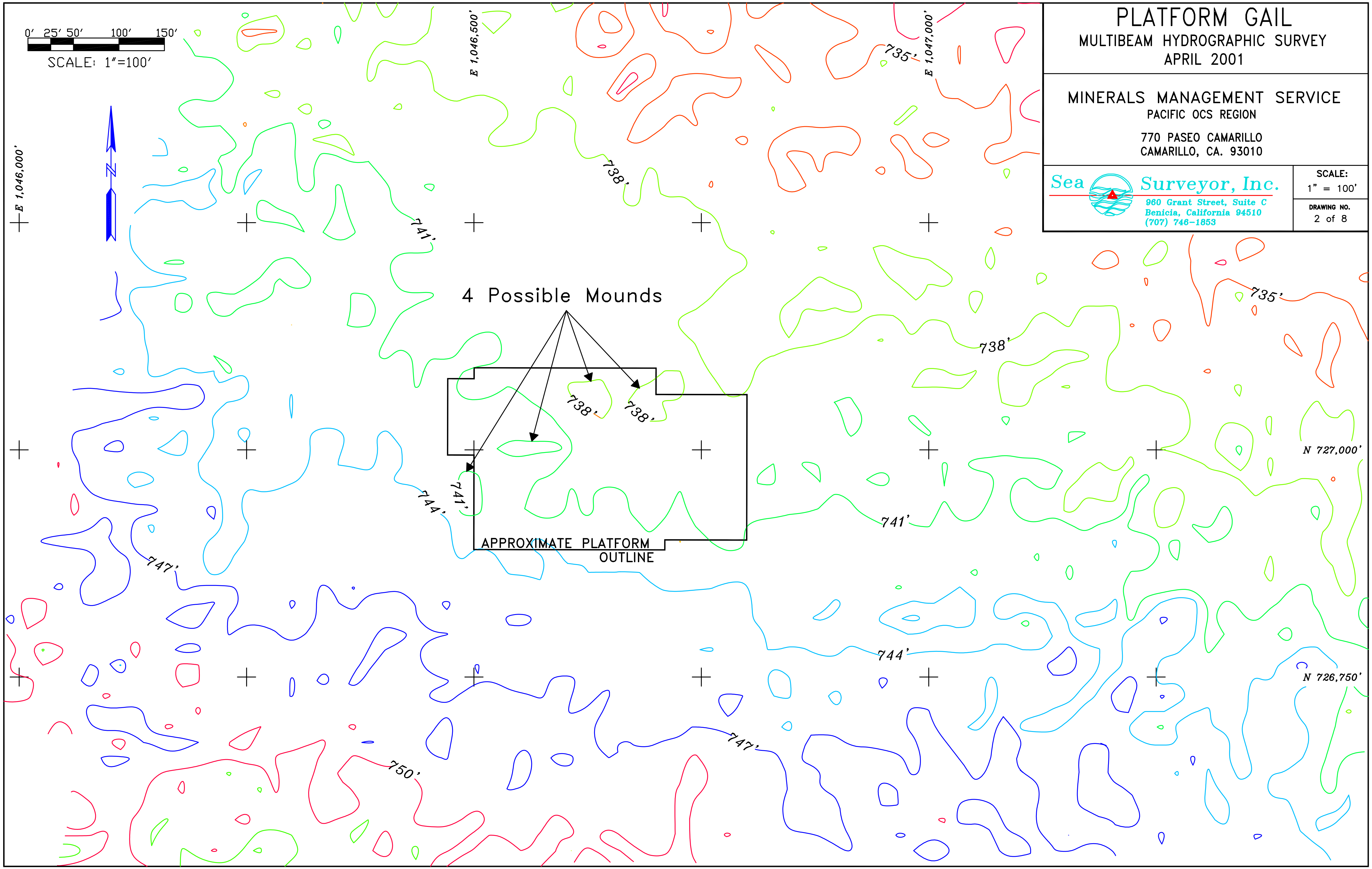
PLATFORM GINA



PLATFORM GAIL
MULTIBEAM HYDROGRAPHIC SURVEY
APRIL 2001
MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION
770 PASEO CAMARILLO
CAMARILLO, CA. 93010
Sea Surveyor, Inc.
960 Grant Street, Suite C
Benicia, California 94510
(707) 746-1853
SCALE:
1" = 100'
DRAWING NO.
2 of 8
0' 25' 50' 100' 150'
SCALE: 1"=100'
N
E 1,046,000'
E 1,046,500'
E 1,047,000'
N 727,000'
N 726,750'
4 Possible Mounds
APPROXIMATE PLATFORM OUTLINE
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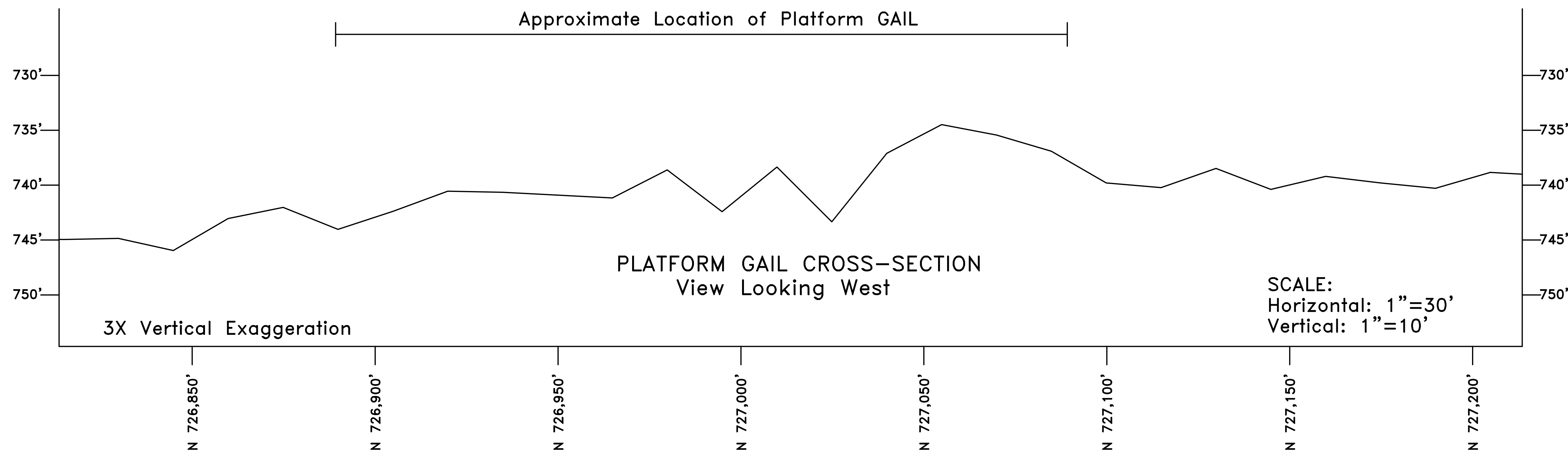
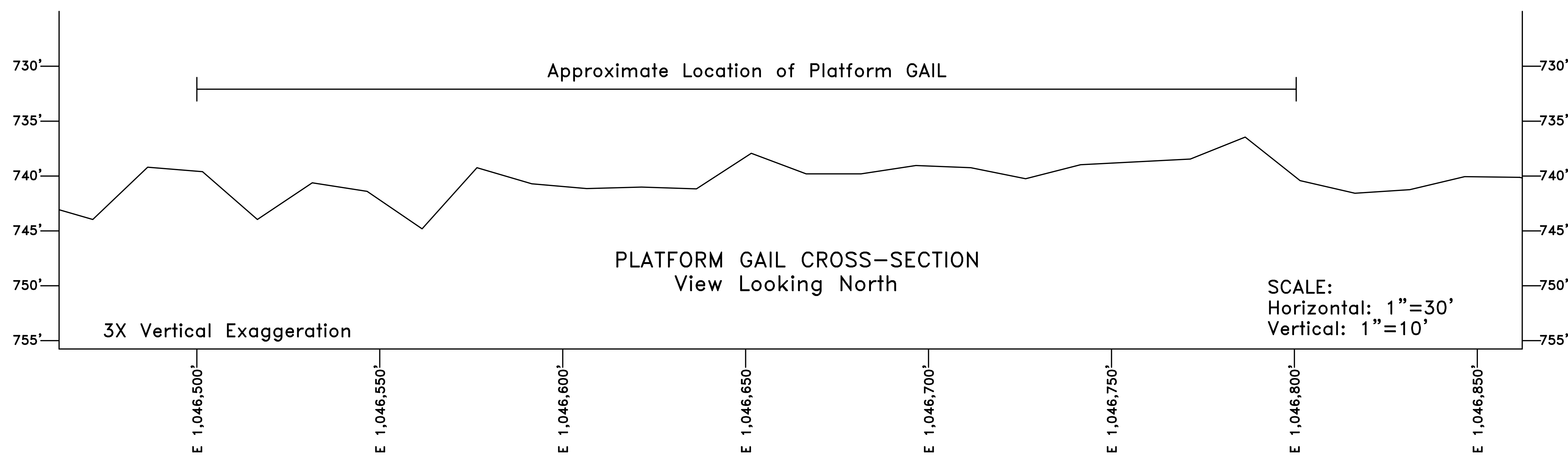
738'
741'
744'
747'
750'





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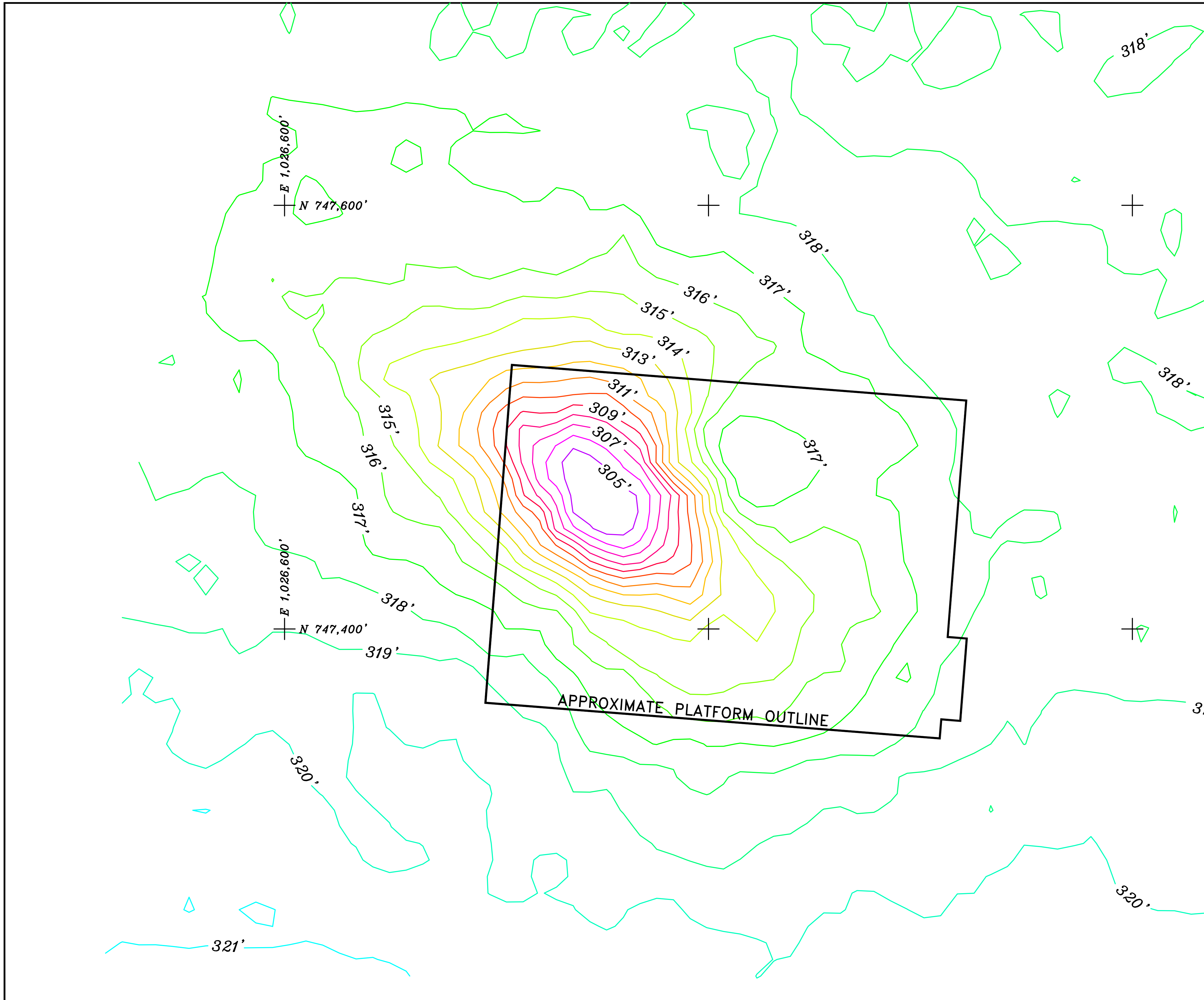
PLATFORM GAIL



PLATFORM GRACE

MULTIBEAM HYDROGRAPHIC SURVEY
APRIL 2001

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CAMARILLO, CA. 93010

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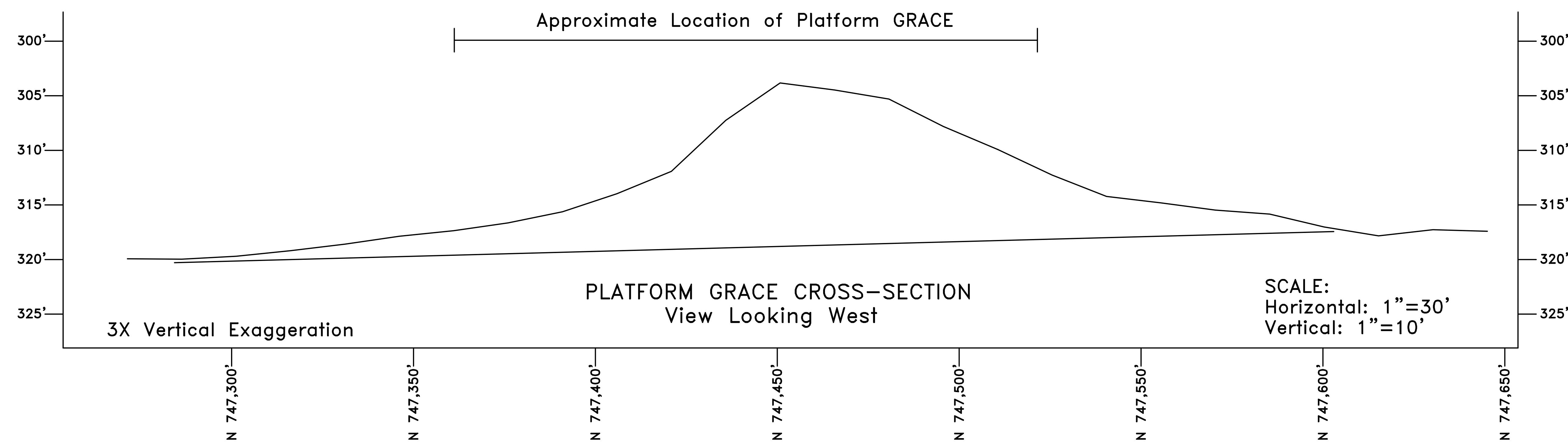
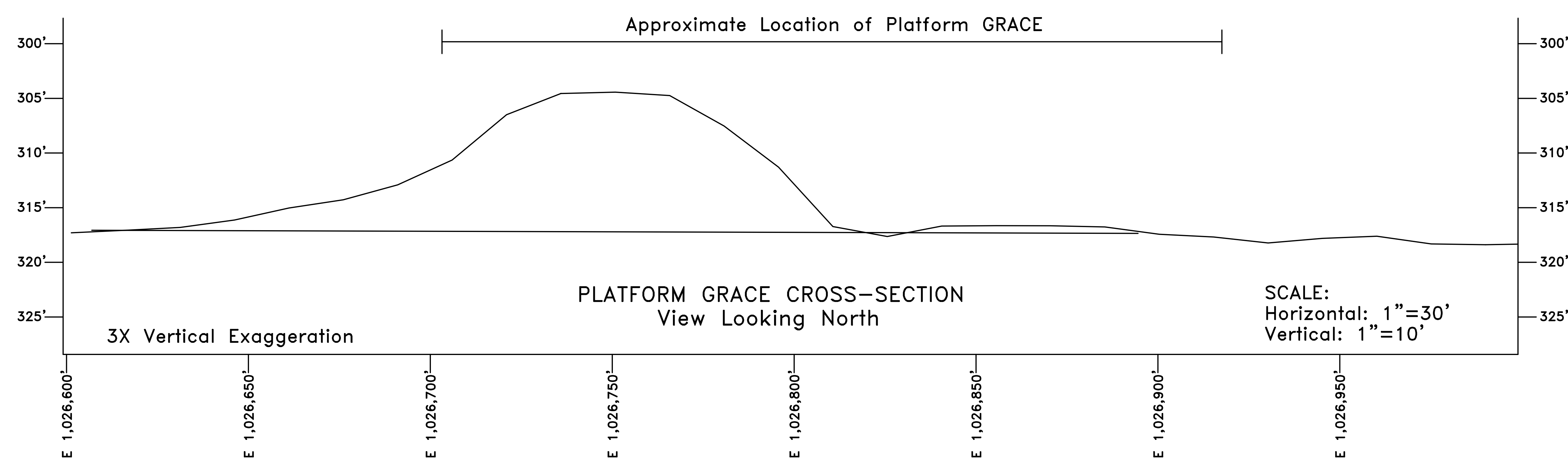
SCALE: 1" = 50'
DRAWING NO. 3 of 8





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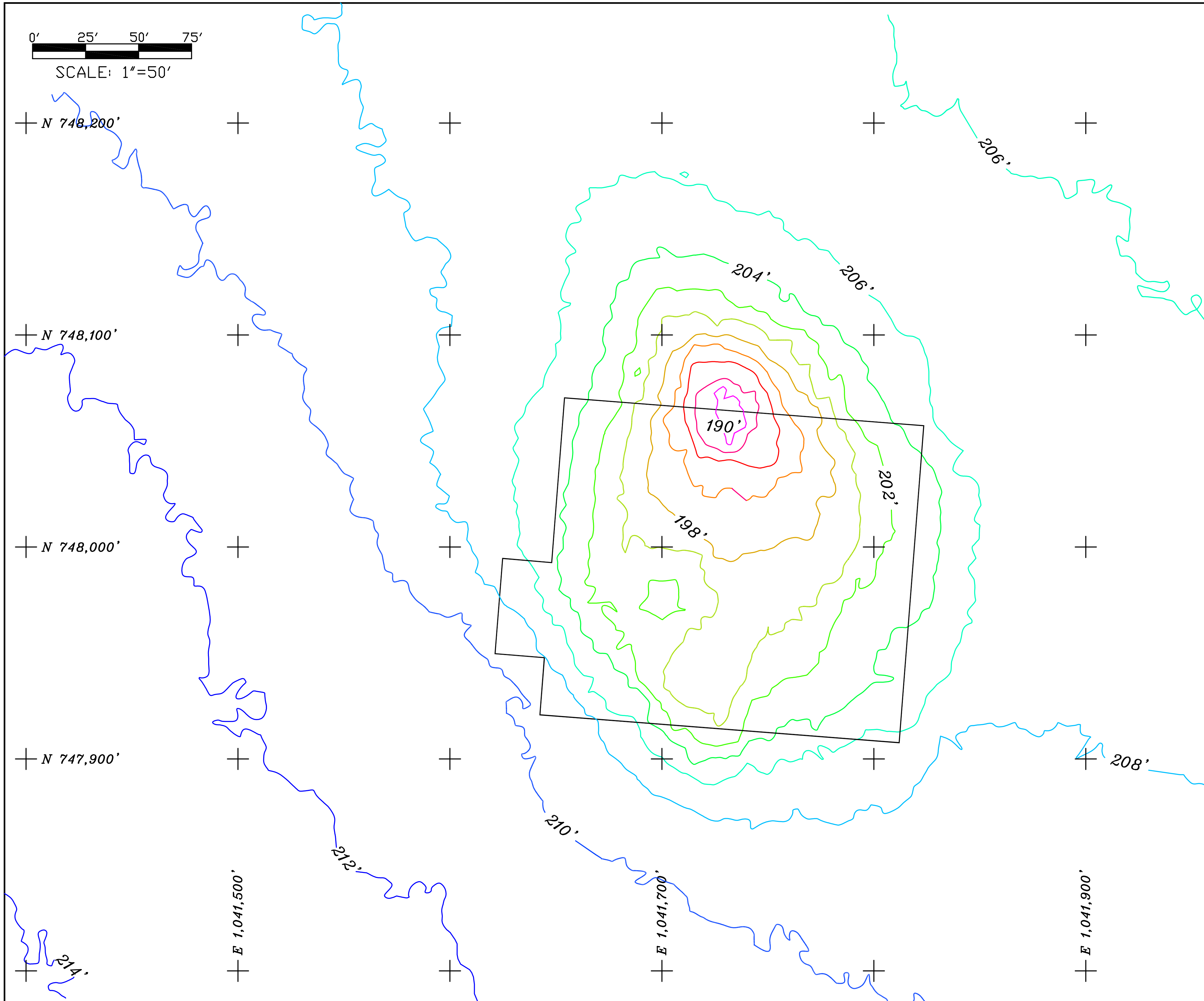
PLATFORM GRACE



PLATFORM GILDA

MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002

MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION

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CAMARILLO, CA. 93010

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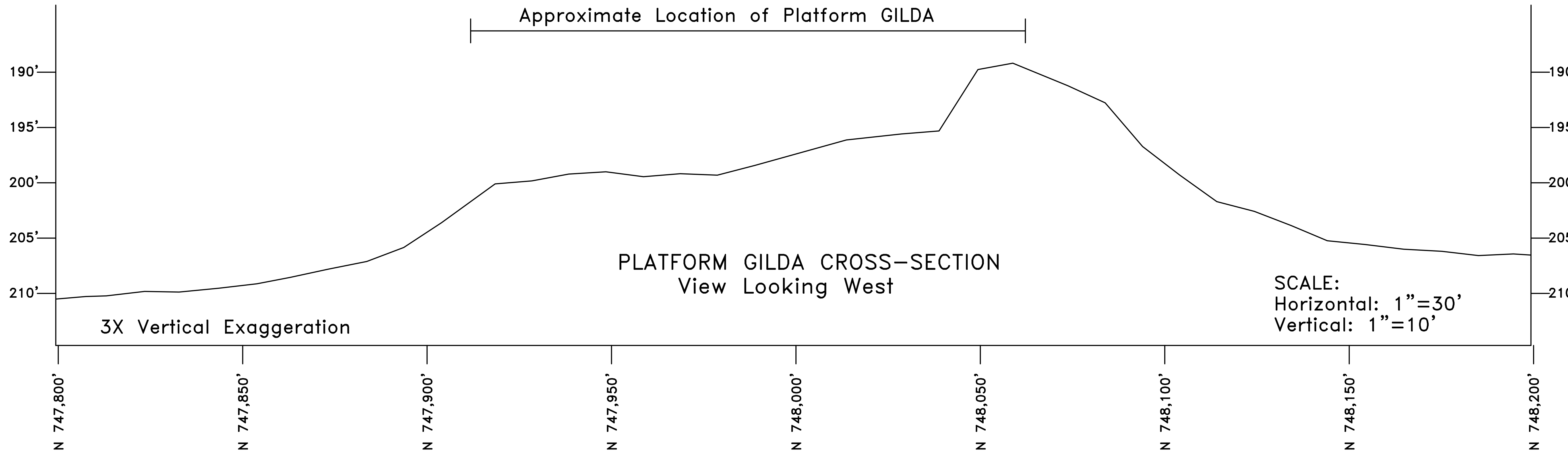
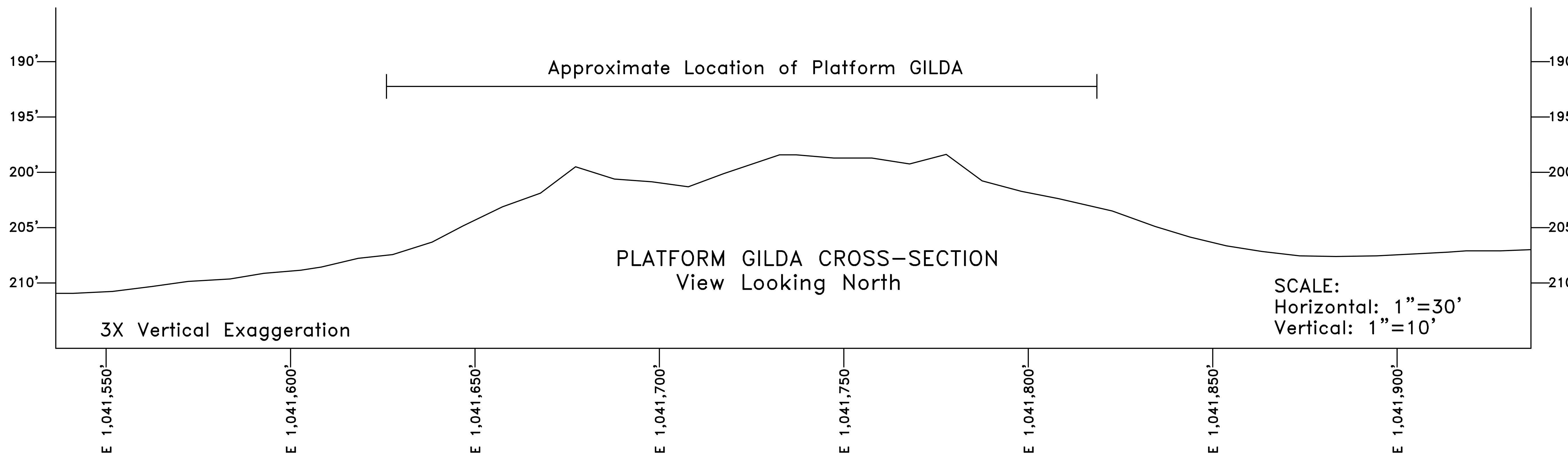
SCALE: 1" = 50'

FIGURE NO. 2





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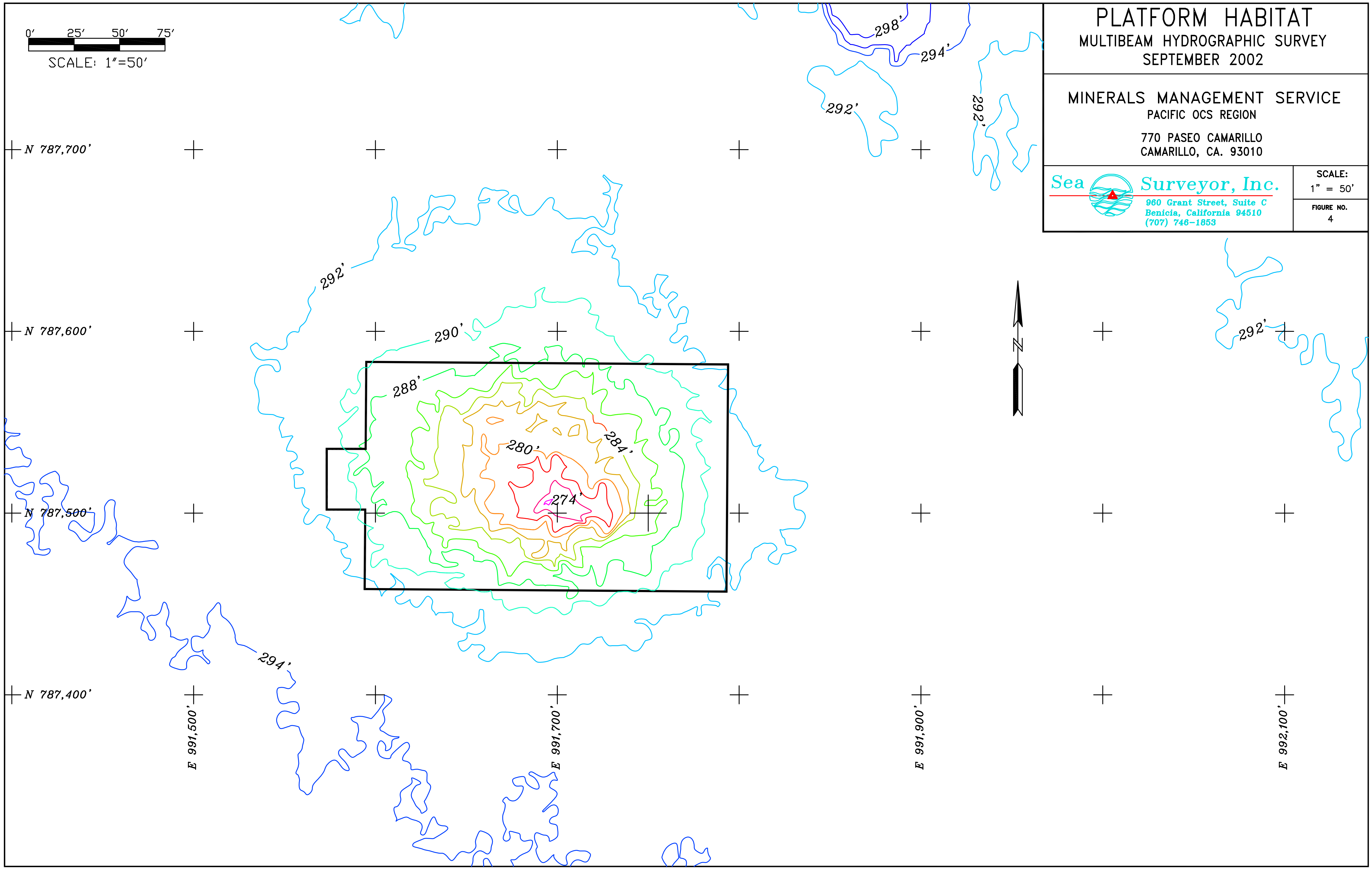
PLATFORM GILDA


PLATFORM HABITAT
MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002
MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION
770 PASEO CAMARILLO
CAMARILLO, CA. 93010
Sea Surveyor, Inc.
960 Grant Street, Suite C
Benicia, California 94510
(707) 746-1853
SCALE:
1" = 50'
FIGURE NO.
4
0' 25' 50' 75'
SCALE: 1"=50'
N 787,700'
N 787,600'
N 787,500'
N 787,400'
E 991,500'
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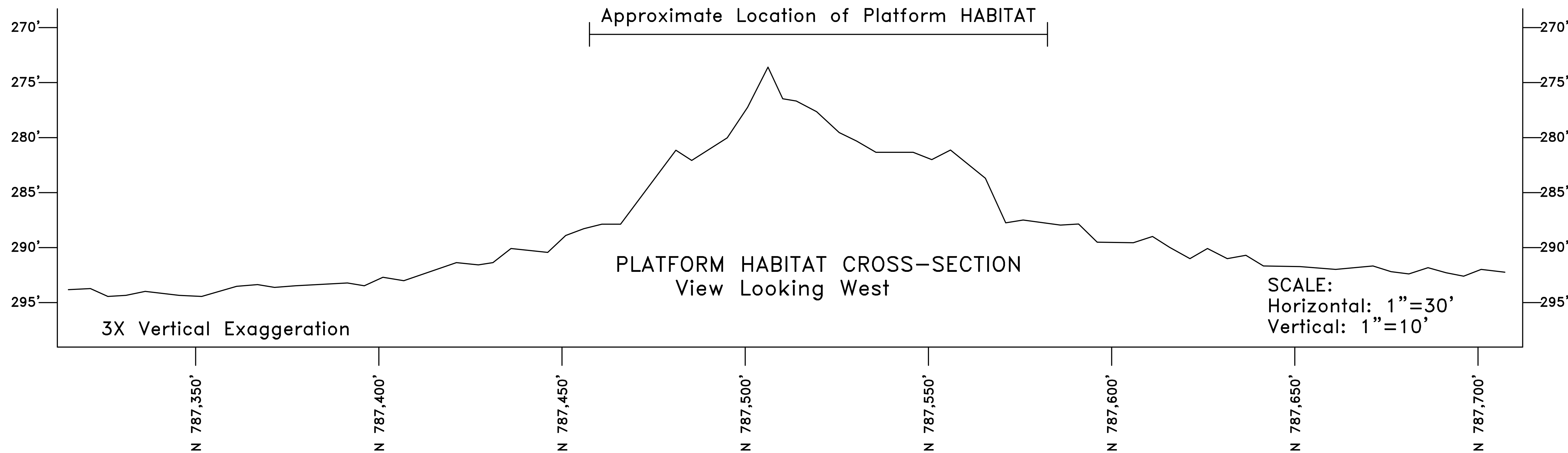

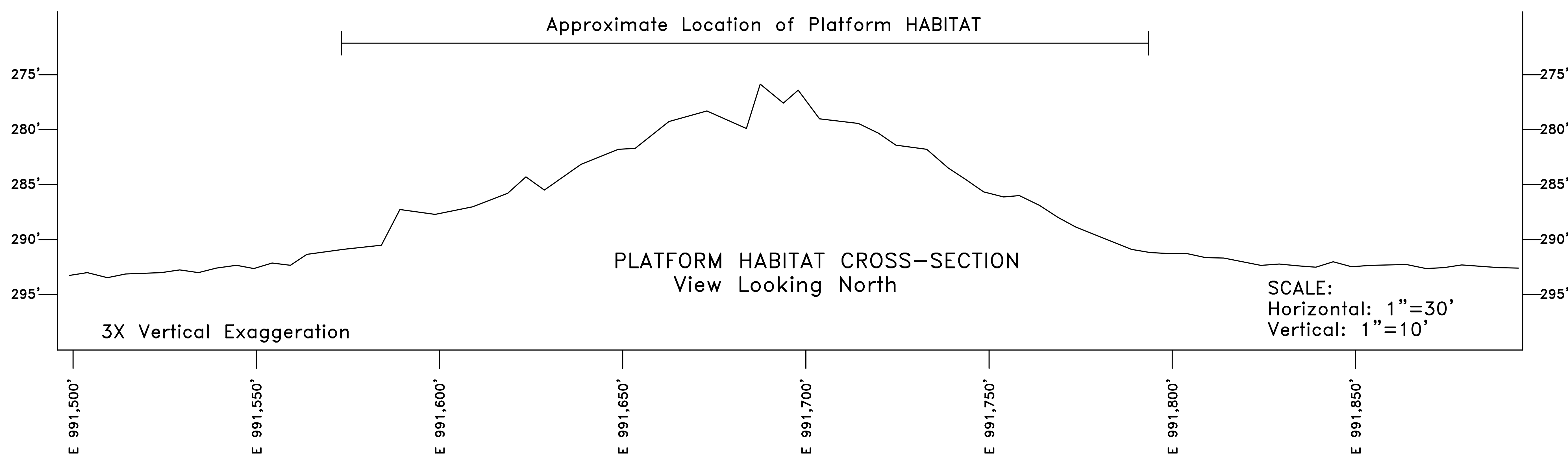

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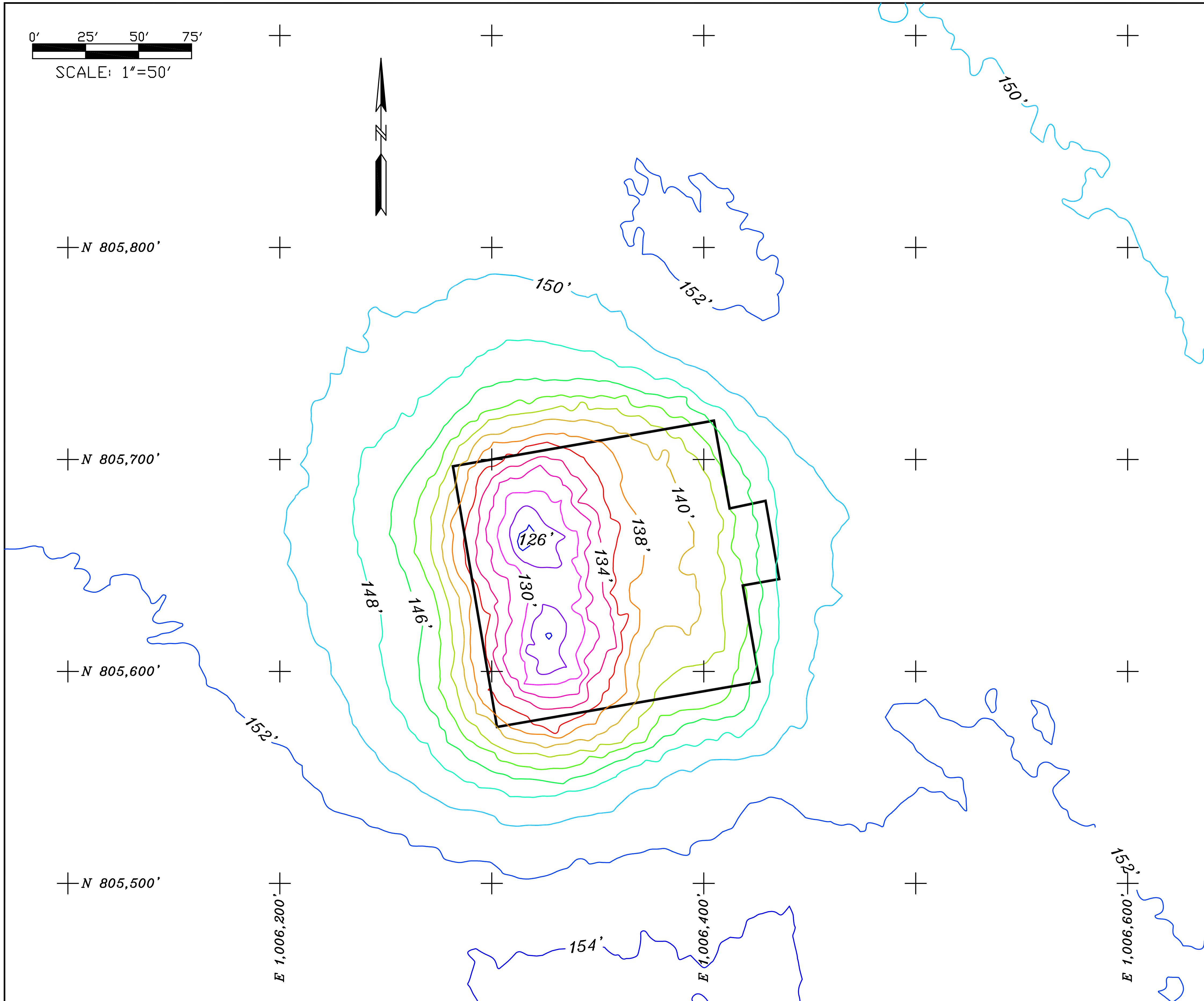
PLATFORM HABITAT



PLATFORM HOGAN
MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002

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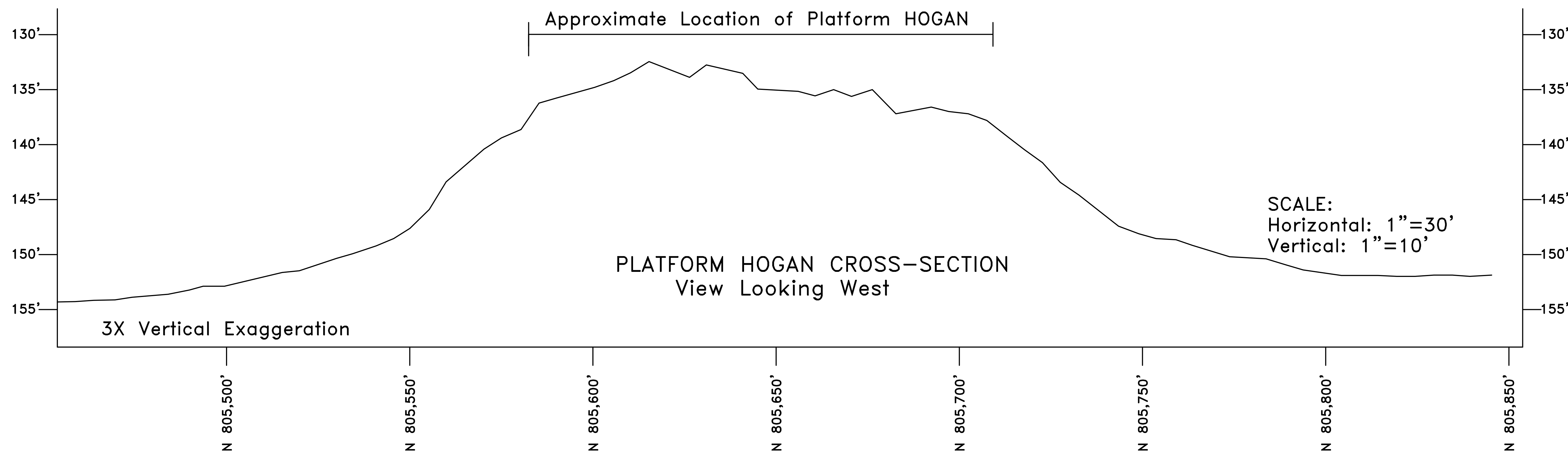
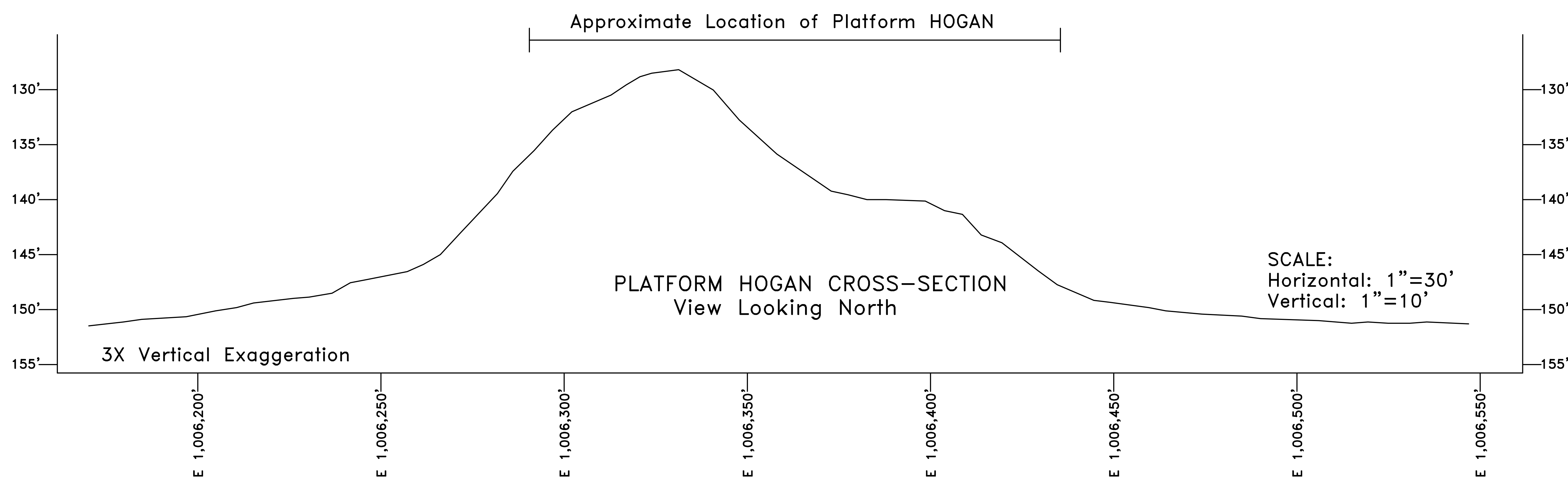
SCALE: 1" = 50'

FIGURE NO. 6





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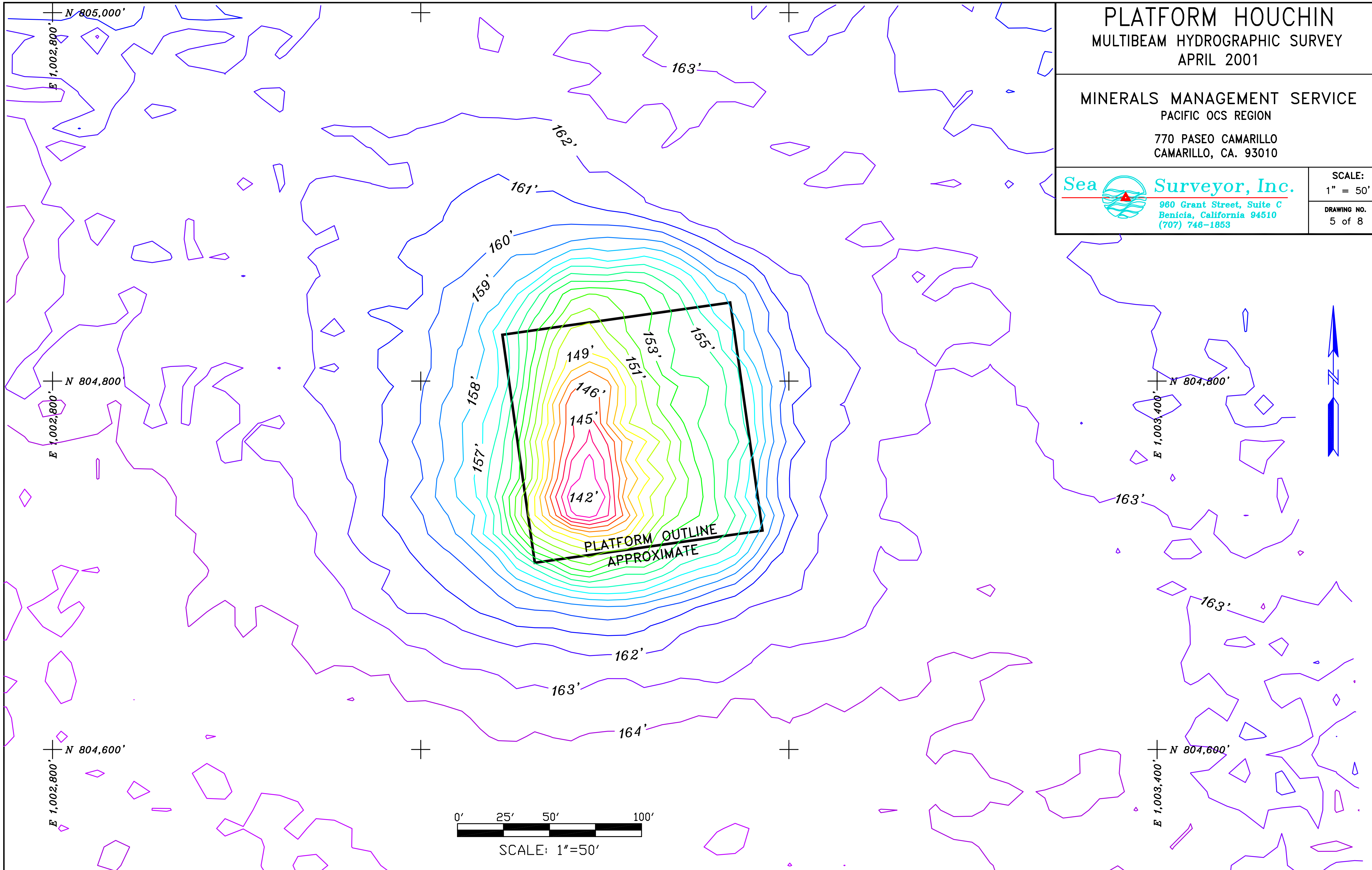
Camarillo, CA 93010

PLATFORM HOGAN


PLATFORM HOUCHIN
MULTIBEAM HYDROGRAPHIC SURVEY
APRIL 2001
MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION
770 PASEO CAMARILLO
CAMARILLO, CA. 93010
Sea Surveyor, Inc.
960 Grant Street, Suite C
Benicia, California 94510
(707) 746-1853
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N 804,800
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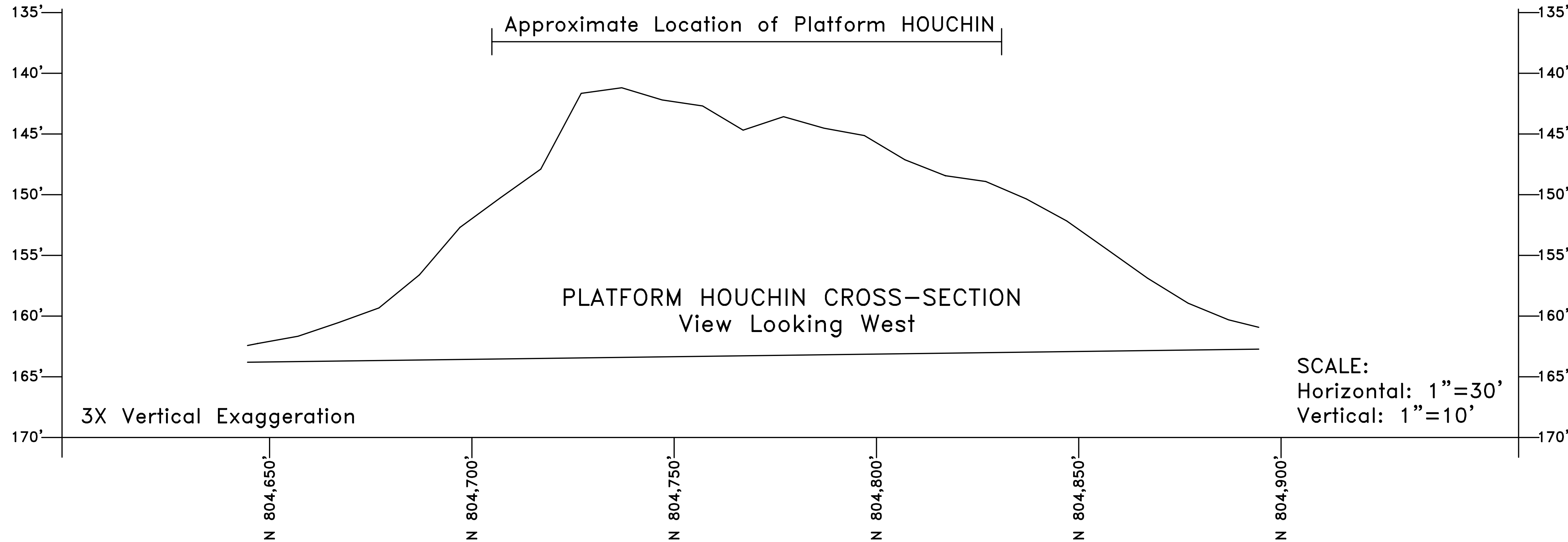

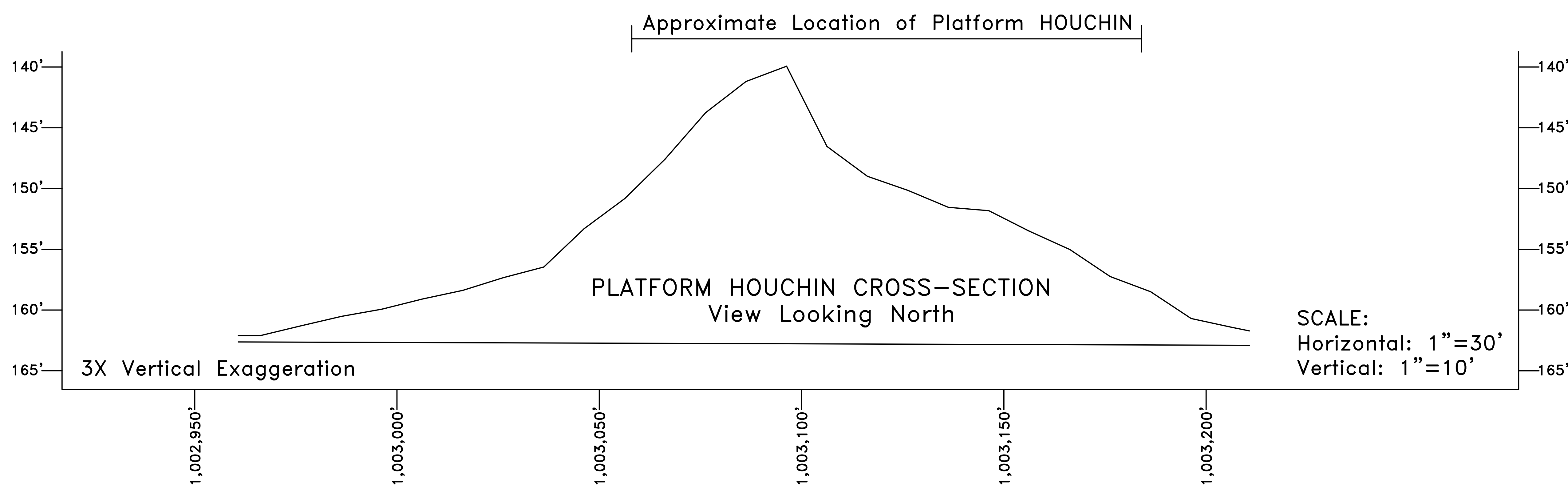

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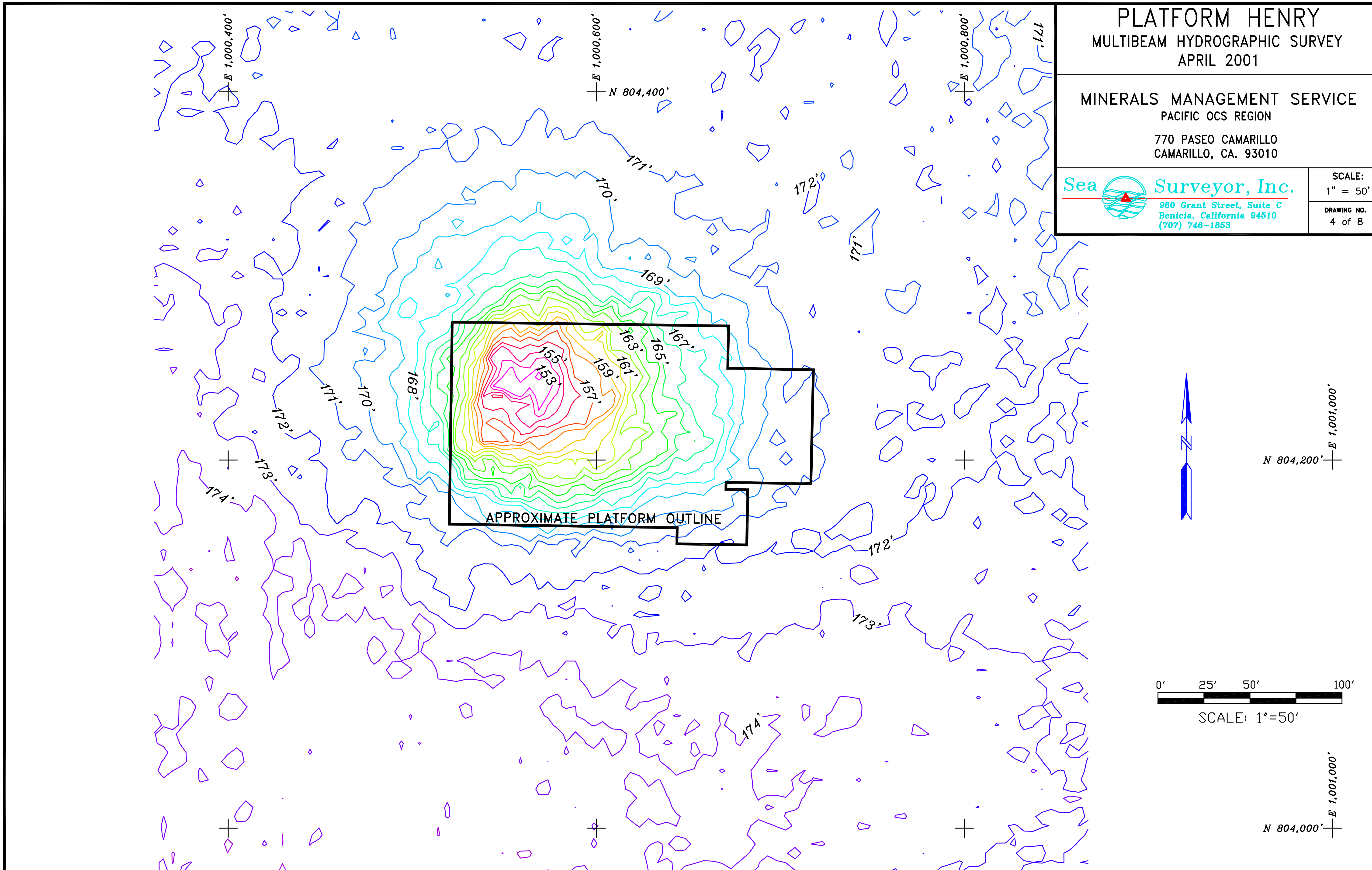
Camarillo, CA 93010

PLATFORM HOUCHIN



PLATFORM HENRY

MULTIBEAM HYDROGRAPHIC SURVEY

APRIL 2001

MINERALS MANAGEMENT SERVICE

PACIFIC OCS REGION

770 PASEO CAMARILLO

CAMARILLO, CA. 93010

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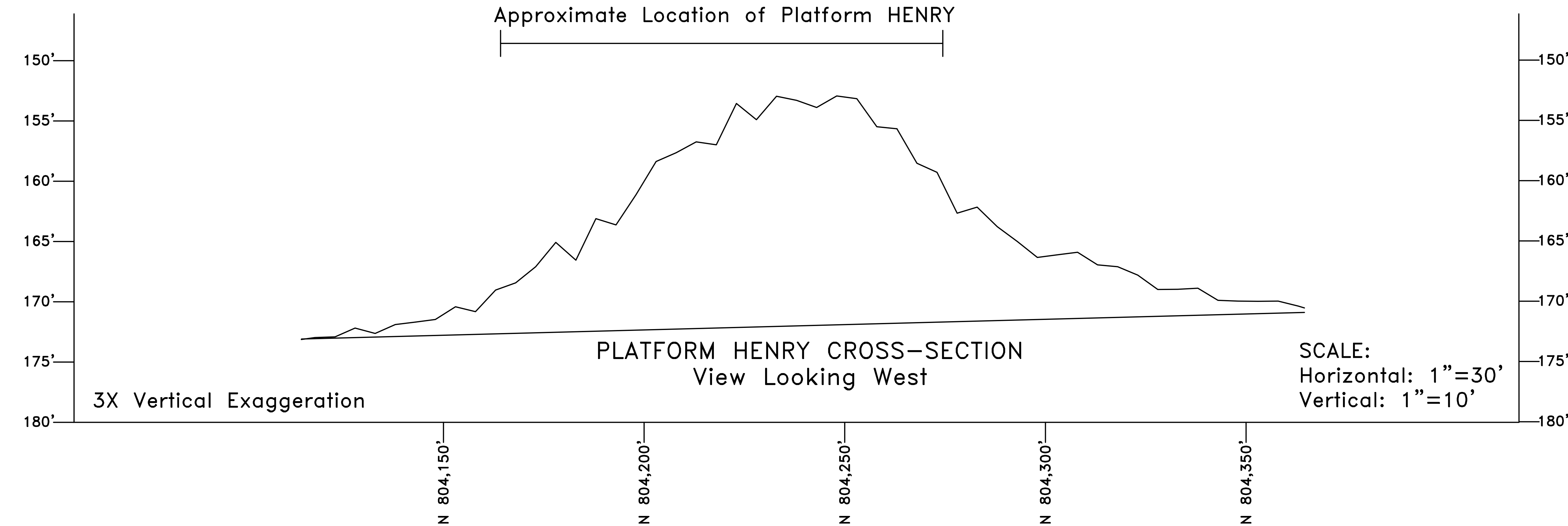
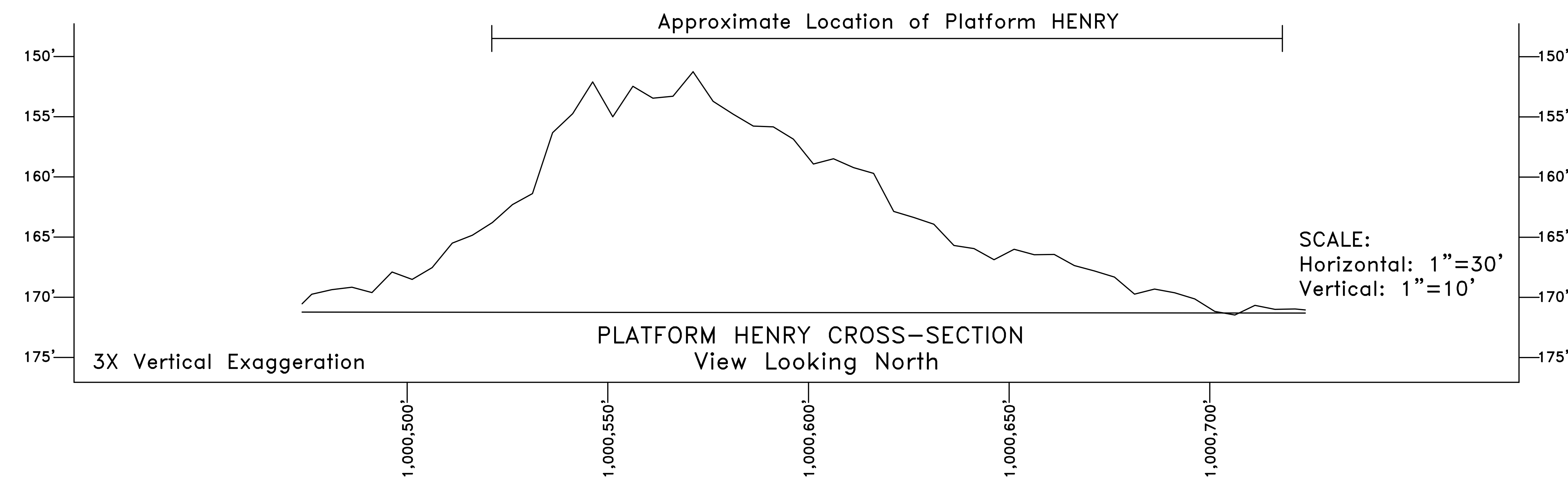
SCALE: 1" = 50'

DRAWING NO. 4 of 8





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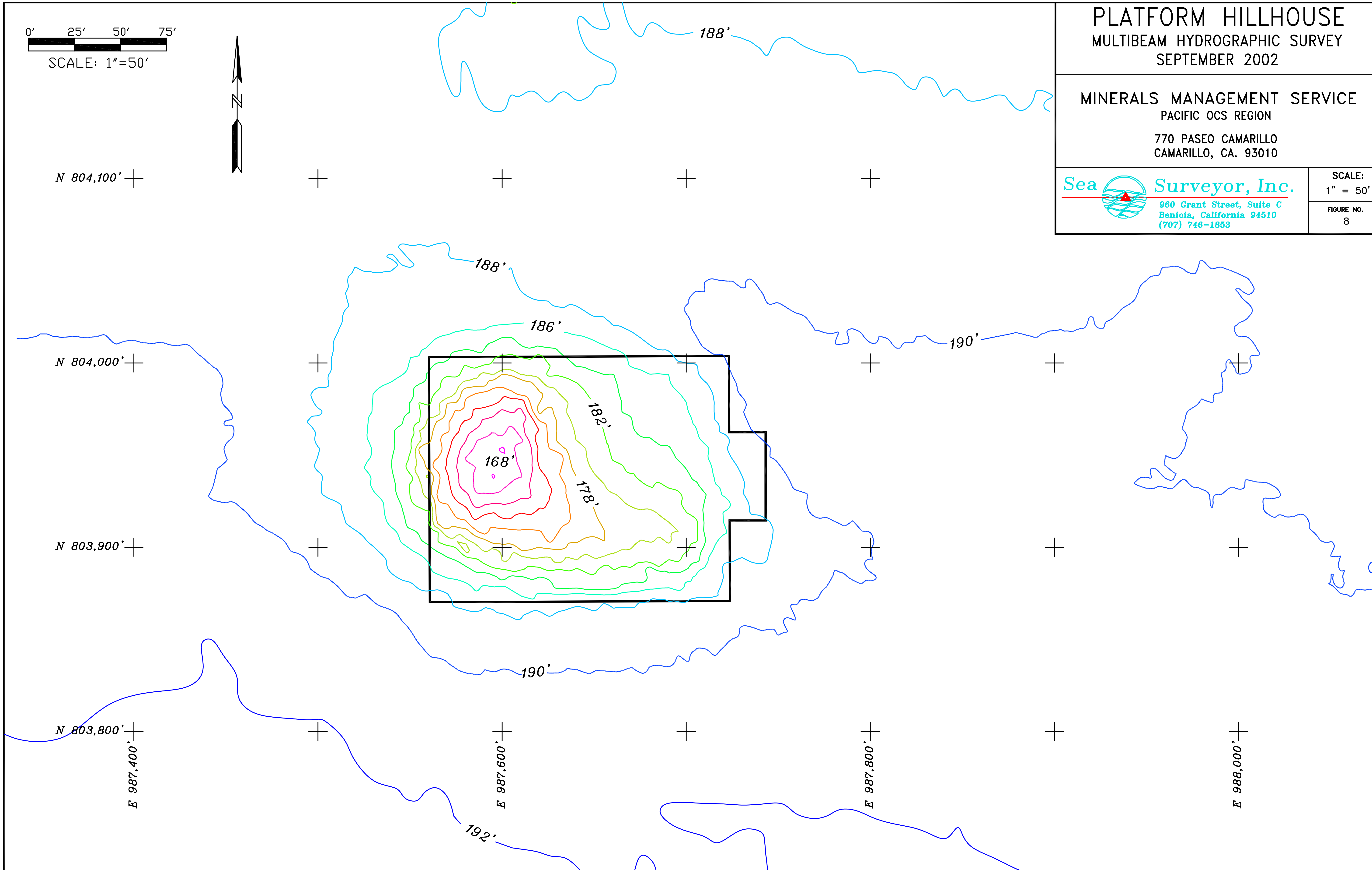
PLATFORM HENRY



PLATFORM HILLHOUSE

MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002

MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION
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CAMARILLO, CA. 93010

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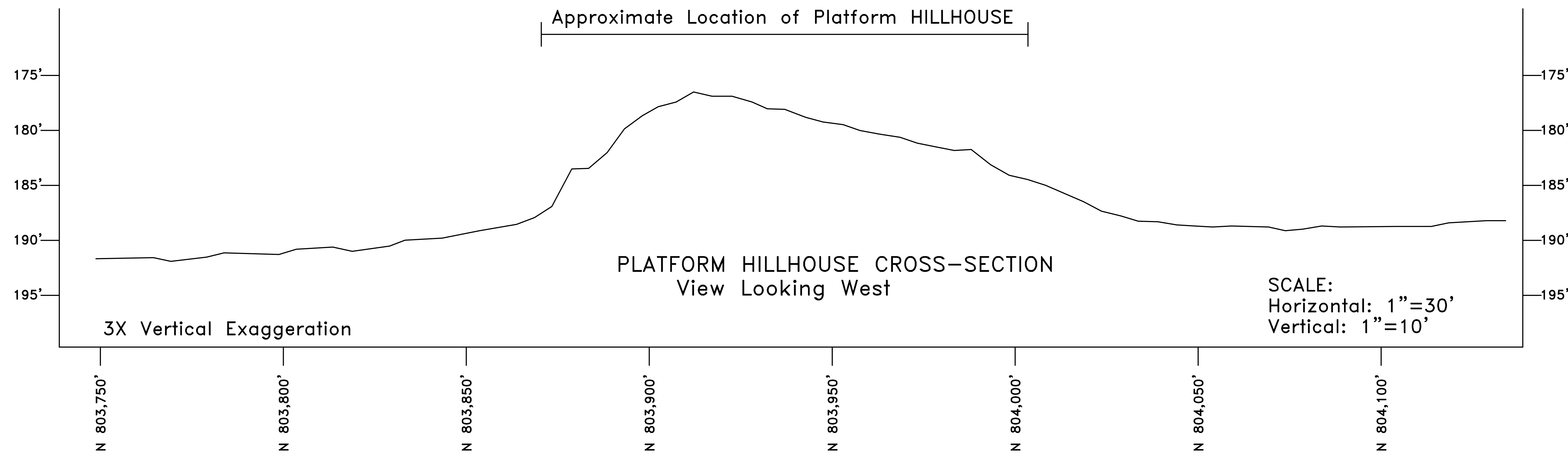
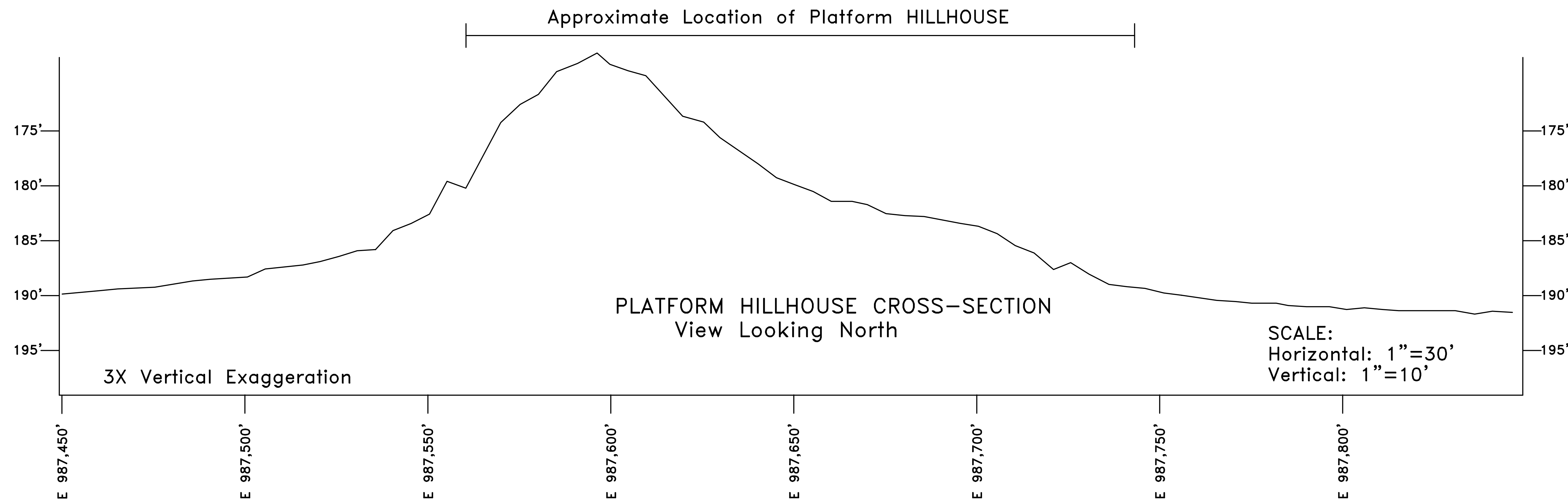
SCALE: 1" = 50'

FIGURE NO. 8





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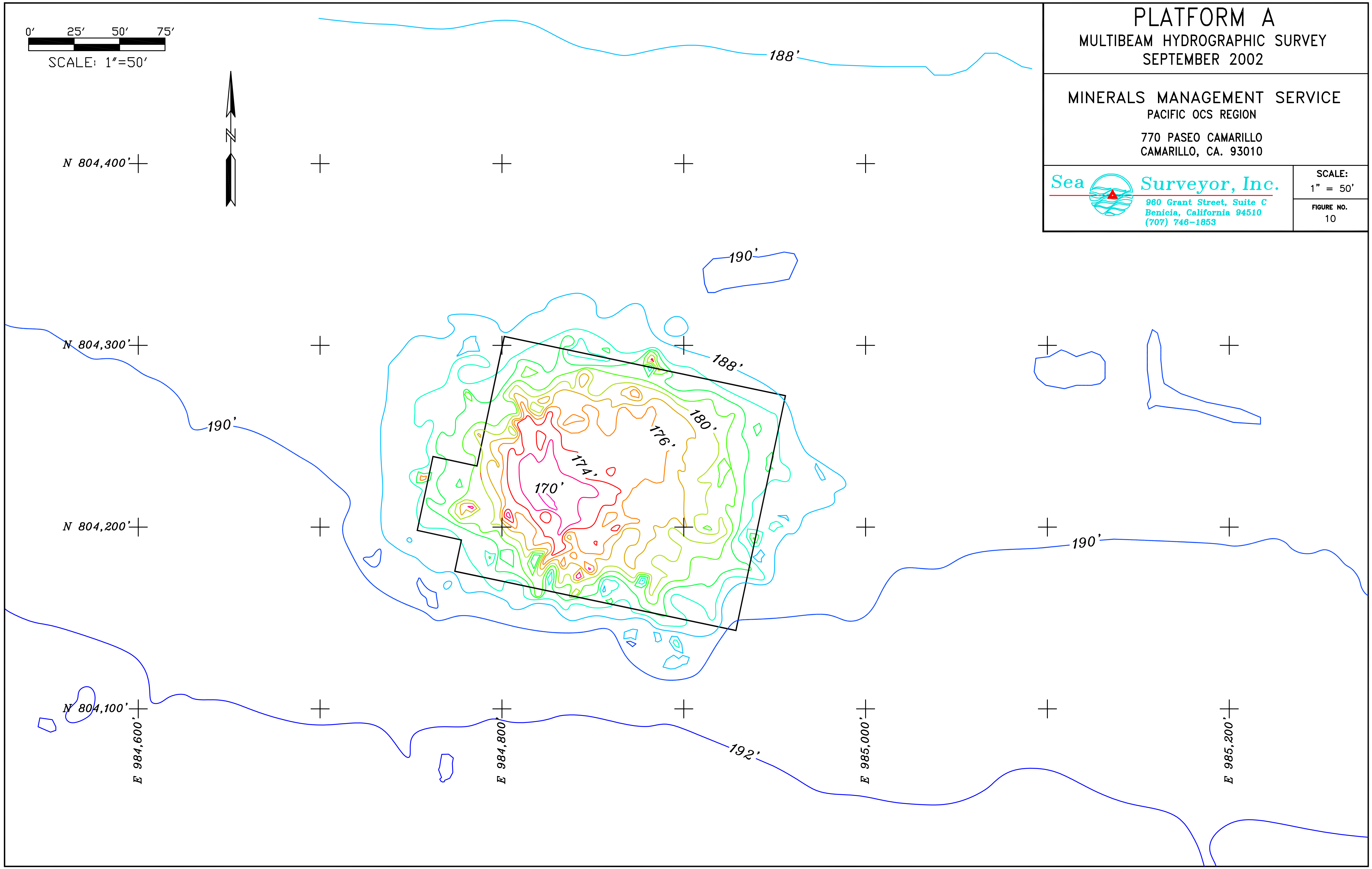
PLATFORM HILLHOUSE
Figure 9


PLATFORM A
MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002
MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION
770 PASEO CAMARILLO
CAMARILLO, CA. 93010
Sea Surveyor, Inc.
960 Grant Street, Suite C
Benicia, California 94510
(707) 746-1853
SCALE:
1" = 50'
FIGURE NO.
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SCALE: 1"=50'
N
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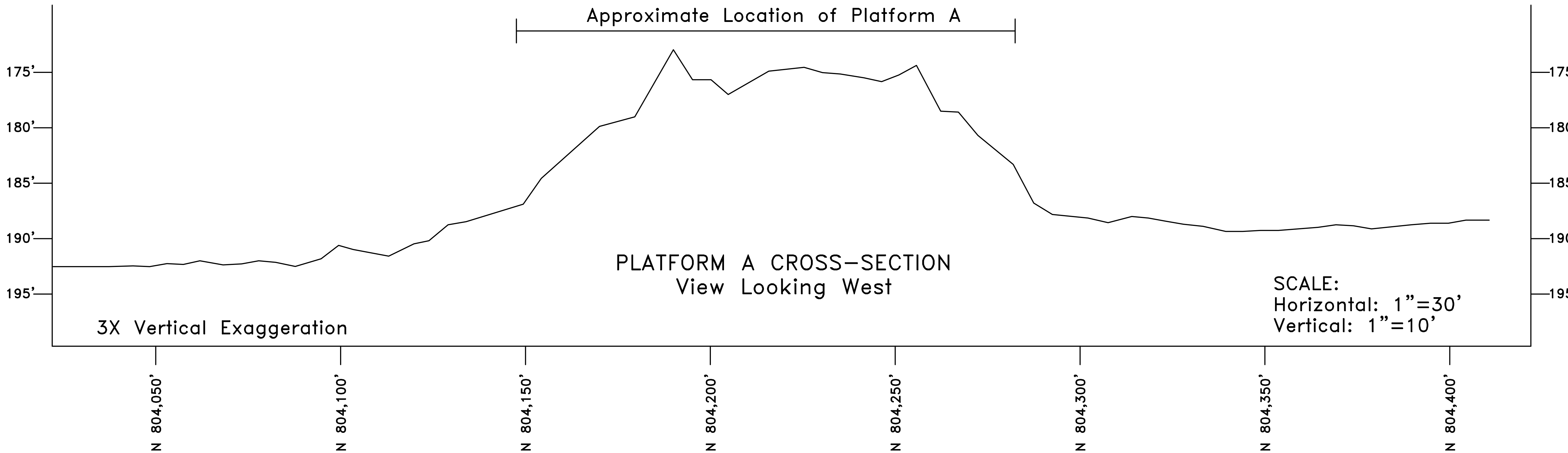

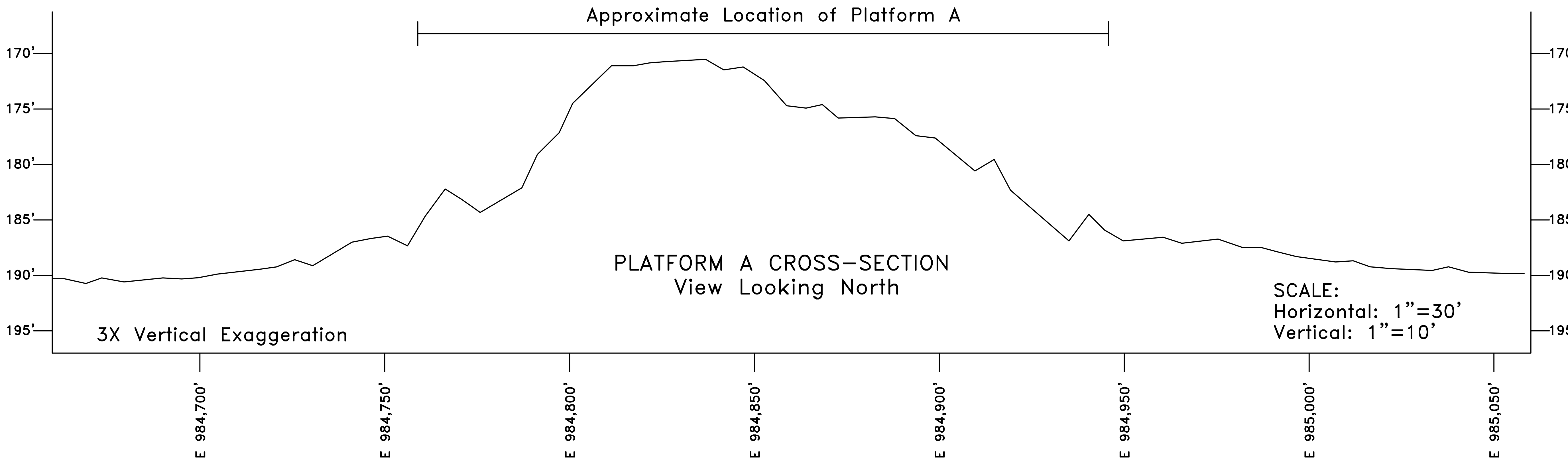

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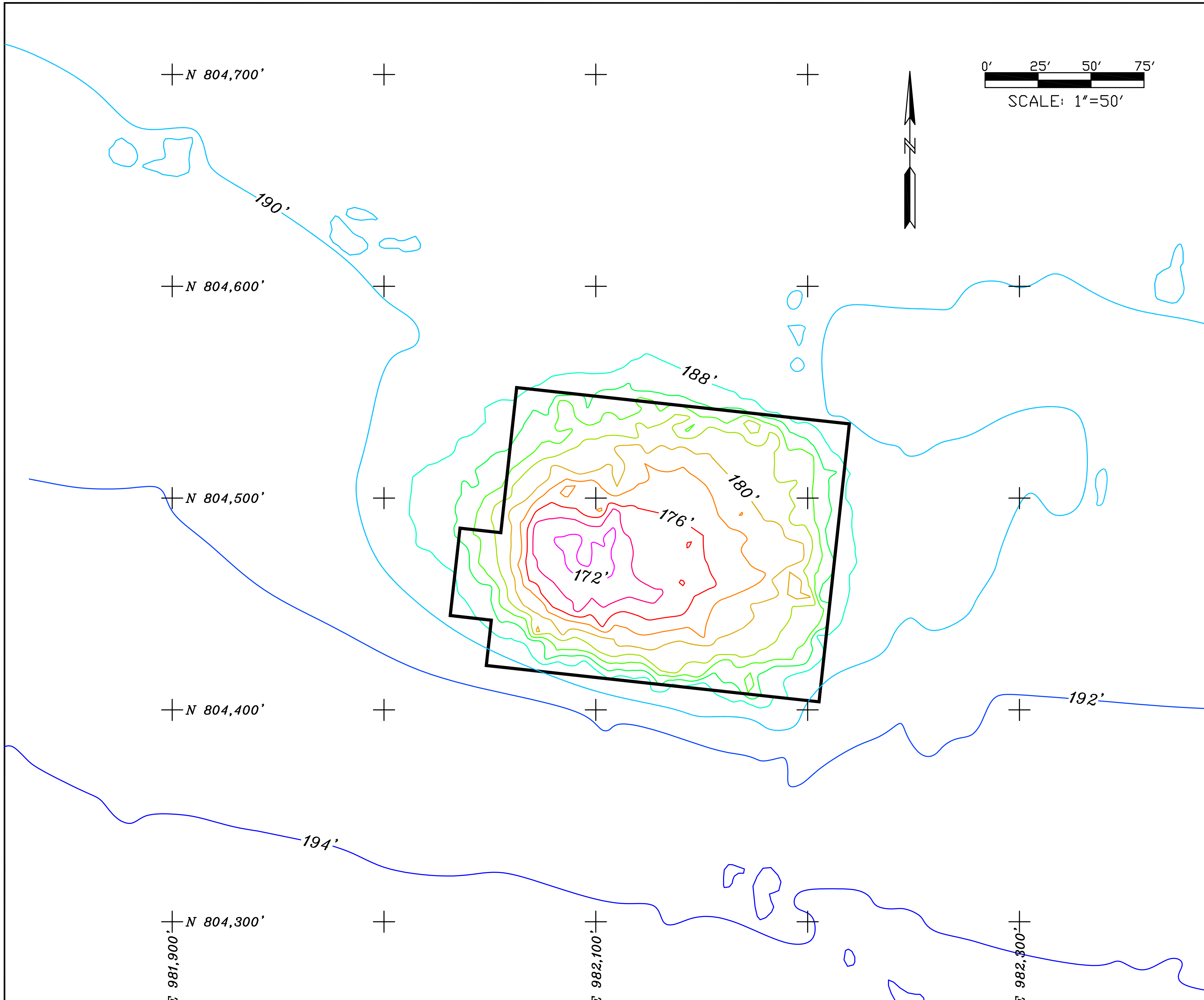
Camarillo, CA 93010

PLATFORM A



PLATFORM B

MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002

MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION

770 PASEO CAMARILLO
CAMARILLO, CA. 93010

Sea Surveyor, Inc.
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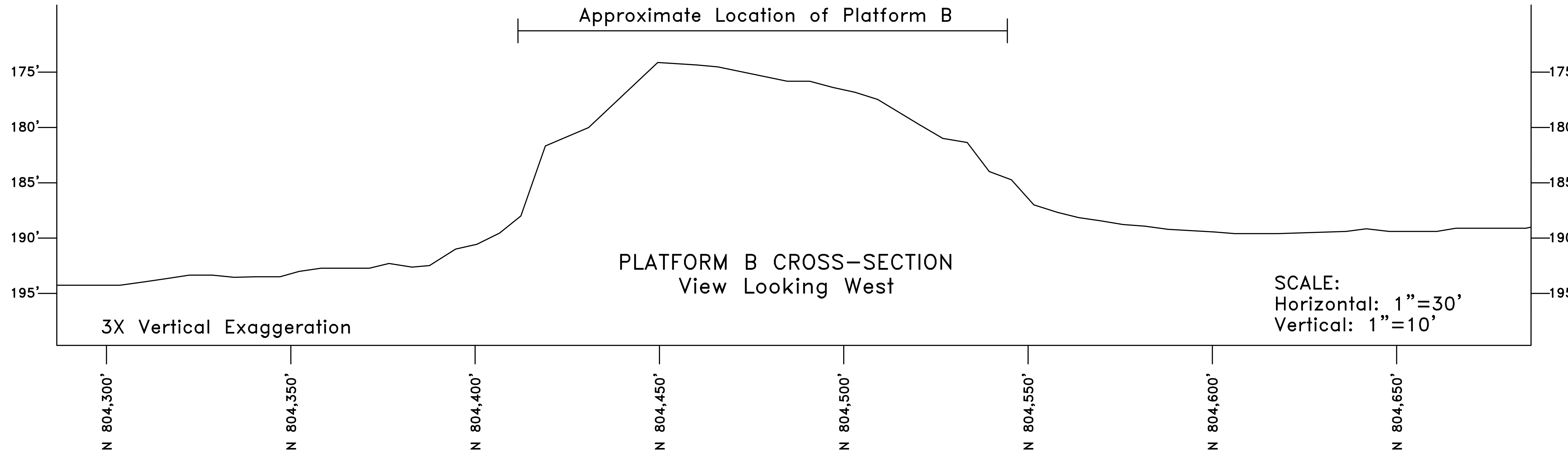
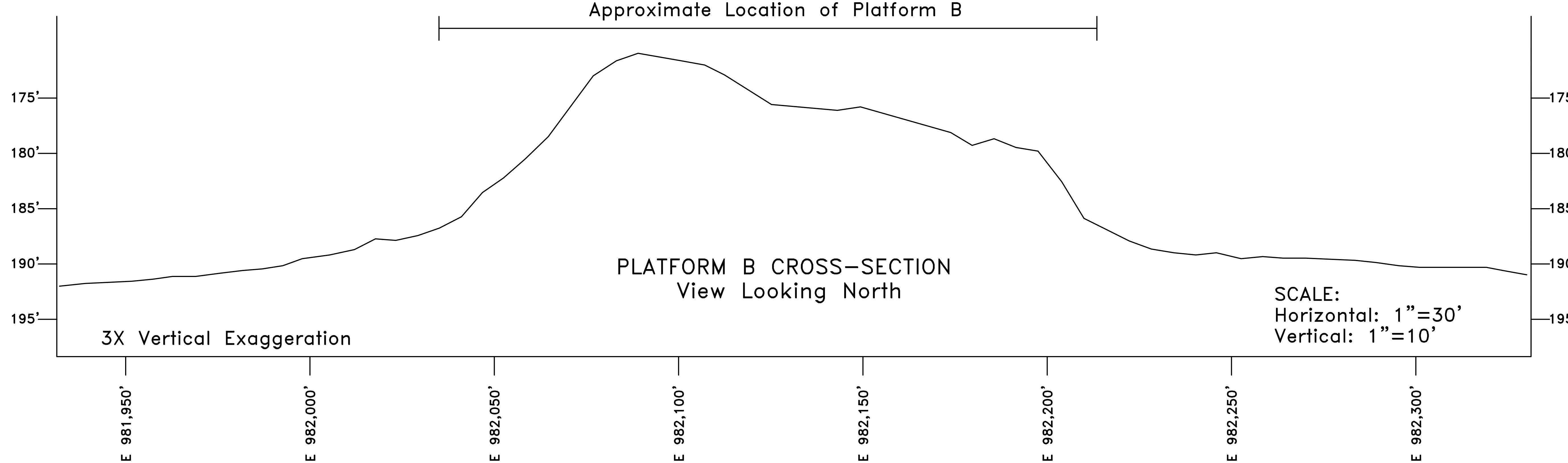
SCALE: 1" = 50'

FIGURE NO. 12





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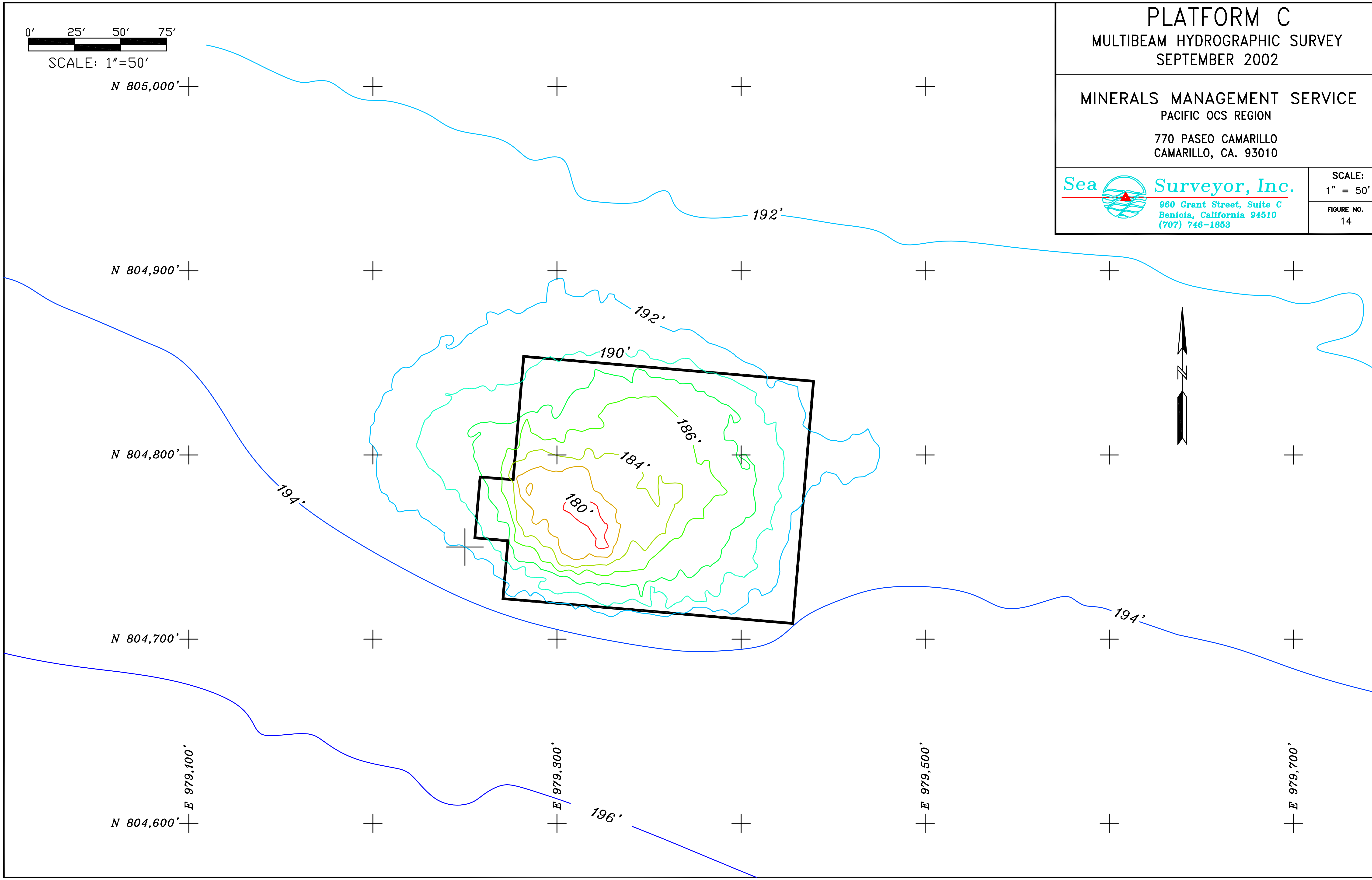
PLATFORM B



PLATFORM C
MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002
MINERALS MANAGEMENT SERVICE
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770 PASEO CAMARILLO
CAMARILLO, CA. 93010
Sea Surveyor, Inc.
960 Grant Street, Suite C
Benicia, California 94510
(707) 746-1853
SCALE:
1" = 50'
FIGURE NO.
14
0' 25' 50' 75'
SCALE: 1"=50'
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N 804,900'
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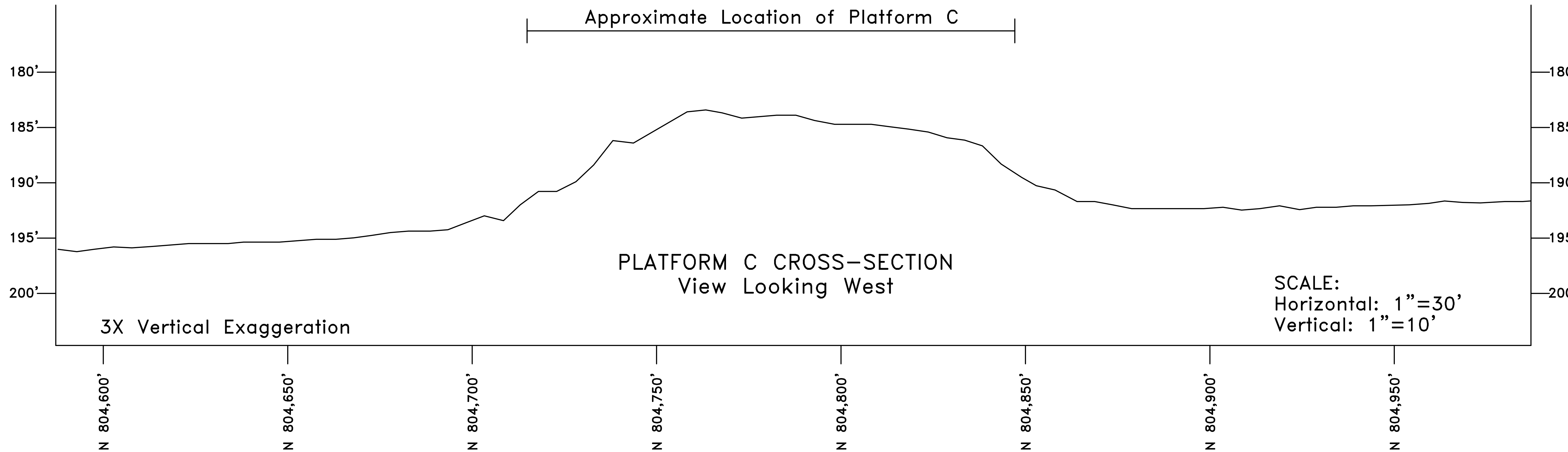

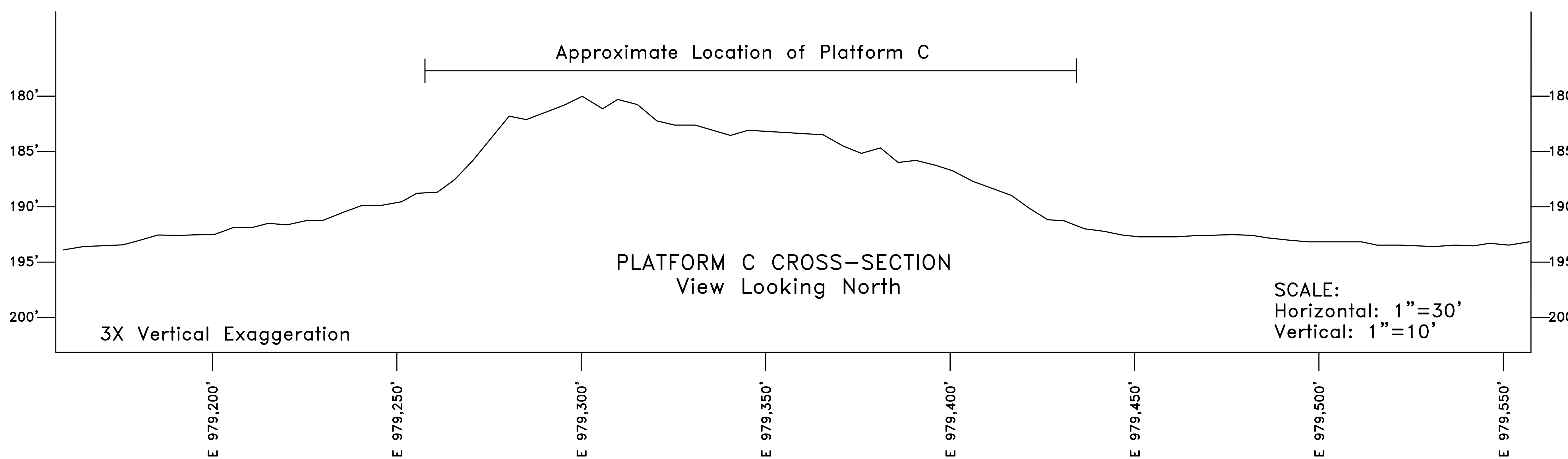

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(707) 746-1853

Prepared For:
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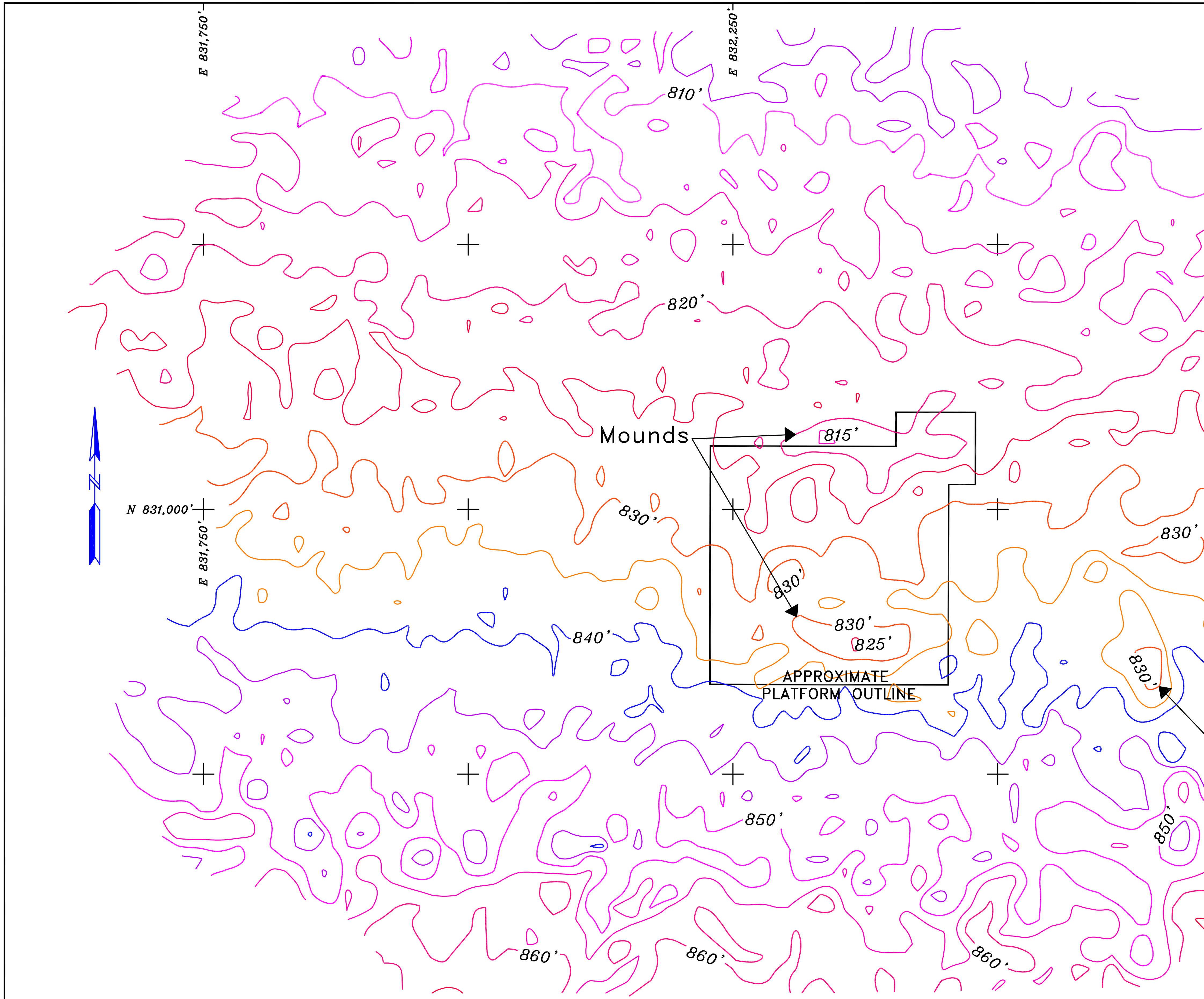
770 Paseo Camarillo
Camarillo, CA 93010

PLATFORM C



PLATFORM HONDO

MULTIBEAM HYDROGRAPHIC SURVEY
APRIL 2001

MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION
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CAMARILLO, CA. 93010

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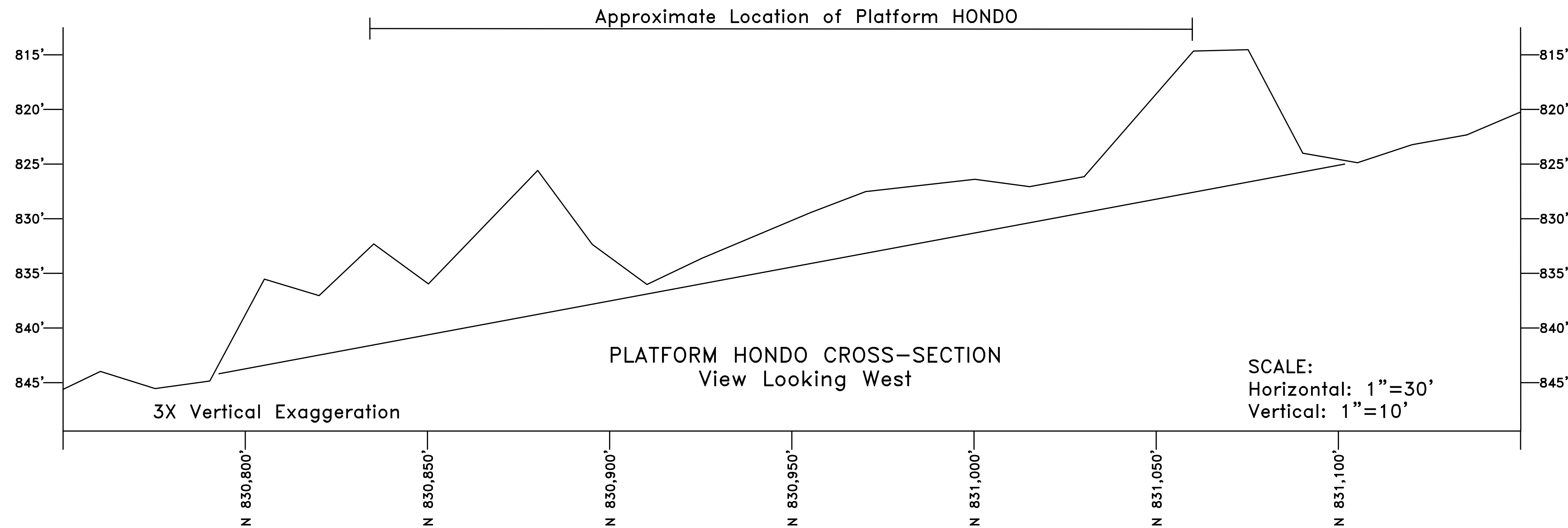
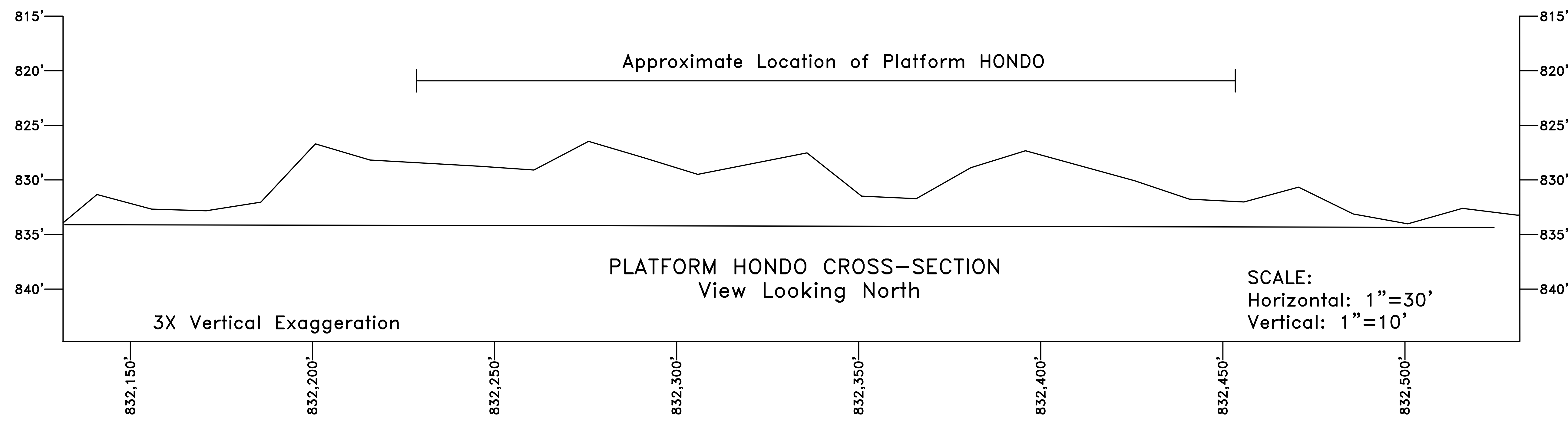
SCALE: 1" = 100'

DRAWING NO. 6 of 8





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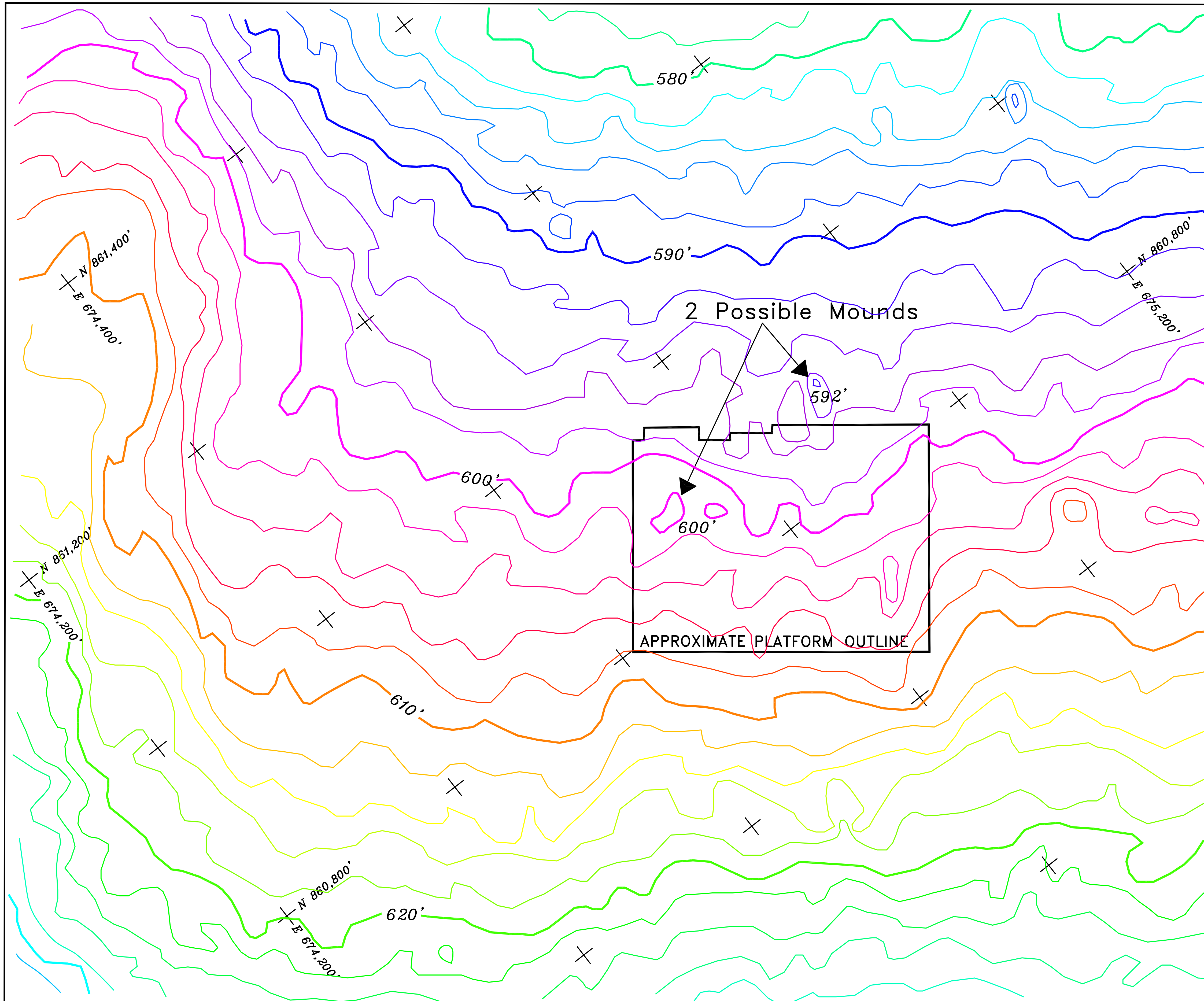

HERMOSA

CONDITION HYDROGRAPHIC SURVEY
JUNE 2001

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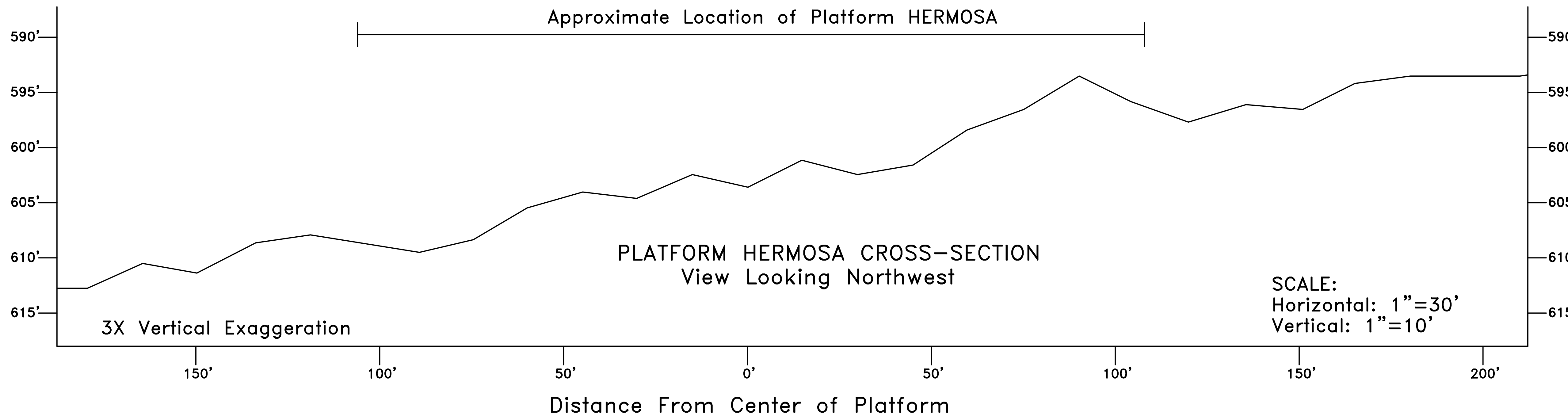
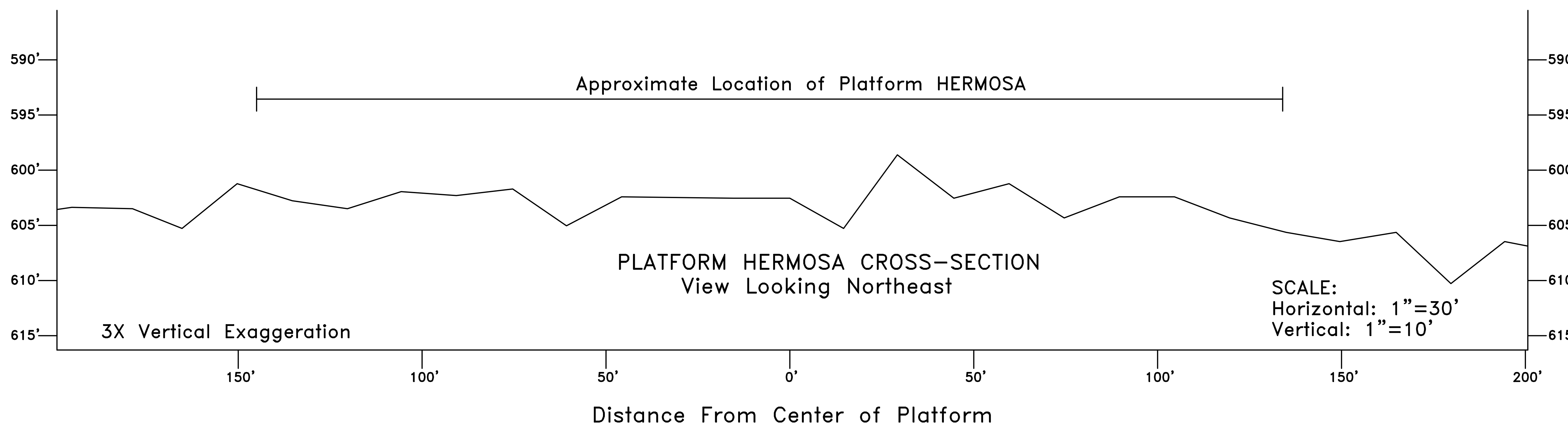
SCALE: 1" = 100'
DRAWING NO. 7 of 8





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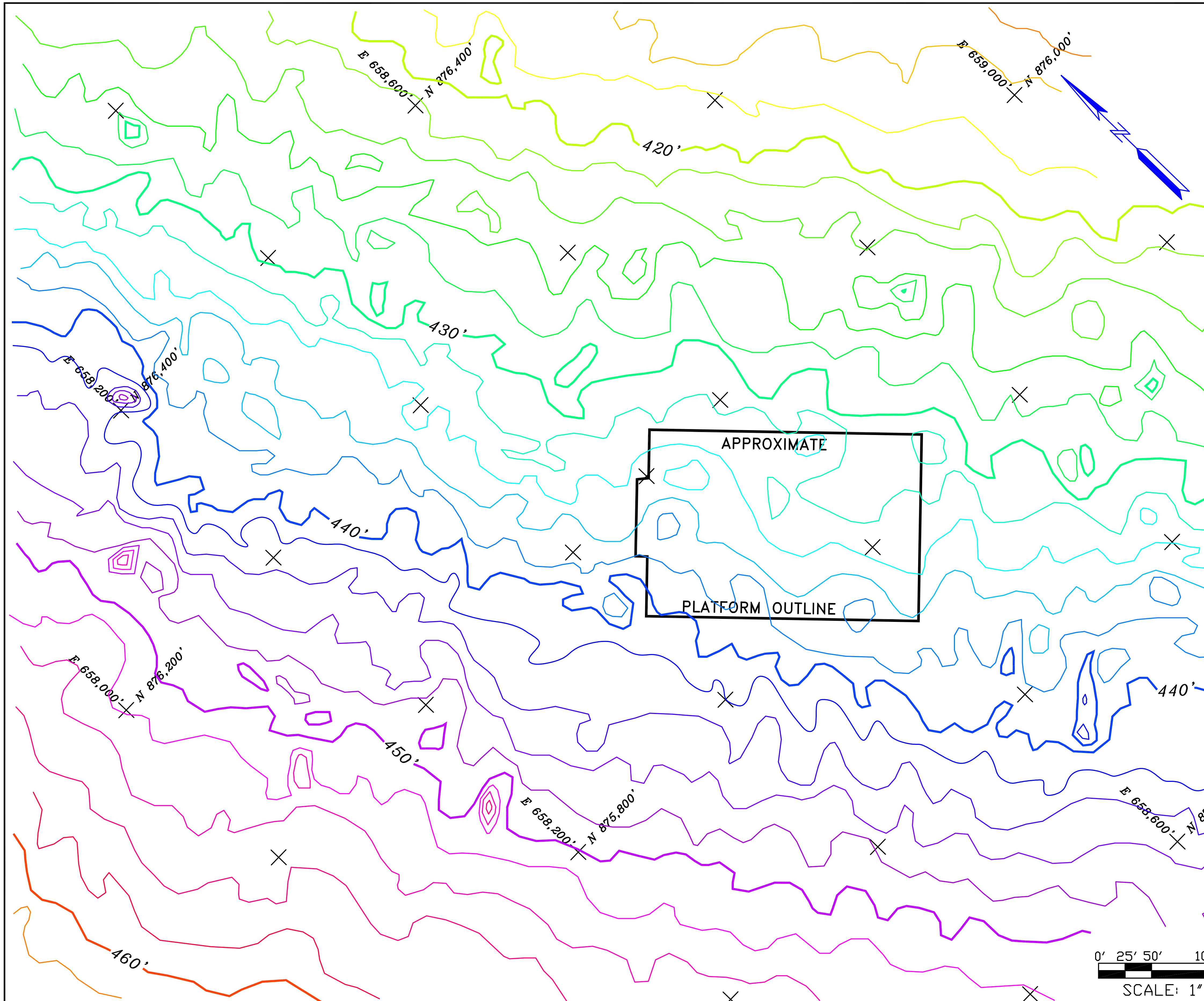
PLATFORM HERMOSA



HIDALGO

CONDITION HYDROGRAPHIC SURVEY
JUNE 2001

MINERALS MANAGEMENT SERVICE
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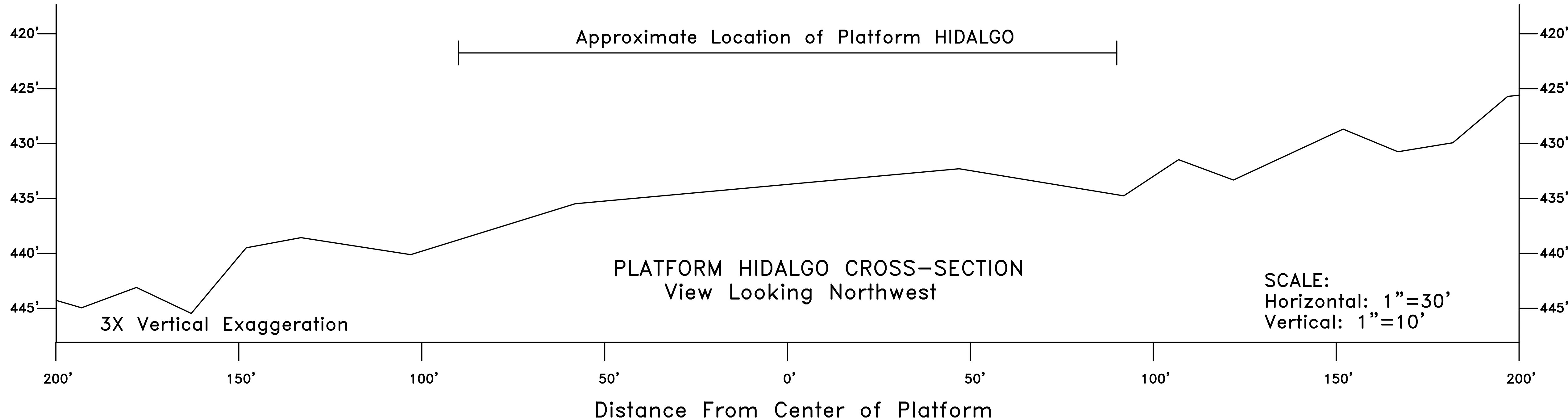
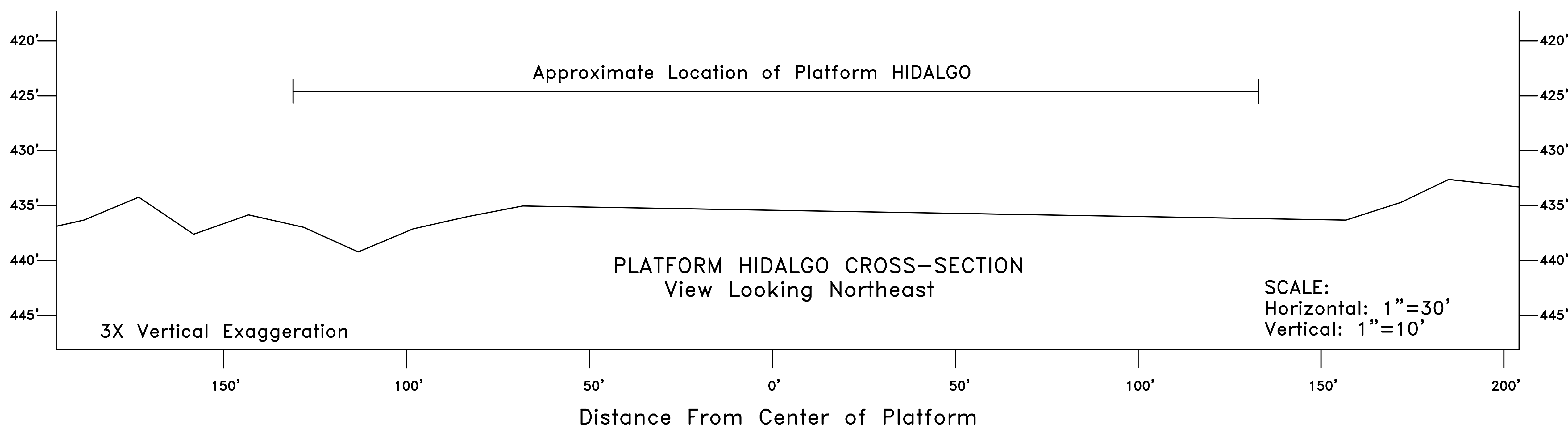
SCALE: 1" = 100'

DRAWING NO. 8 of 8





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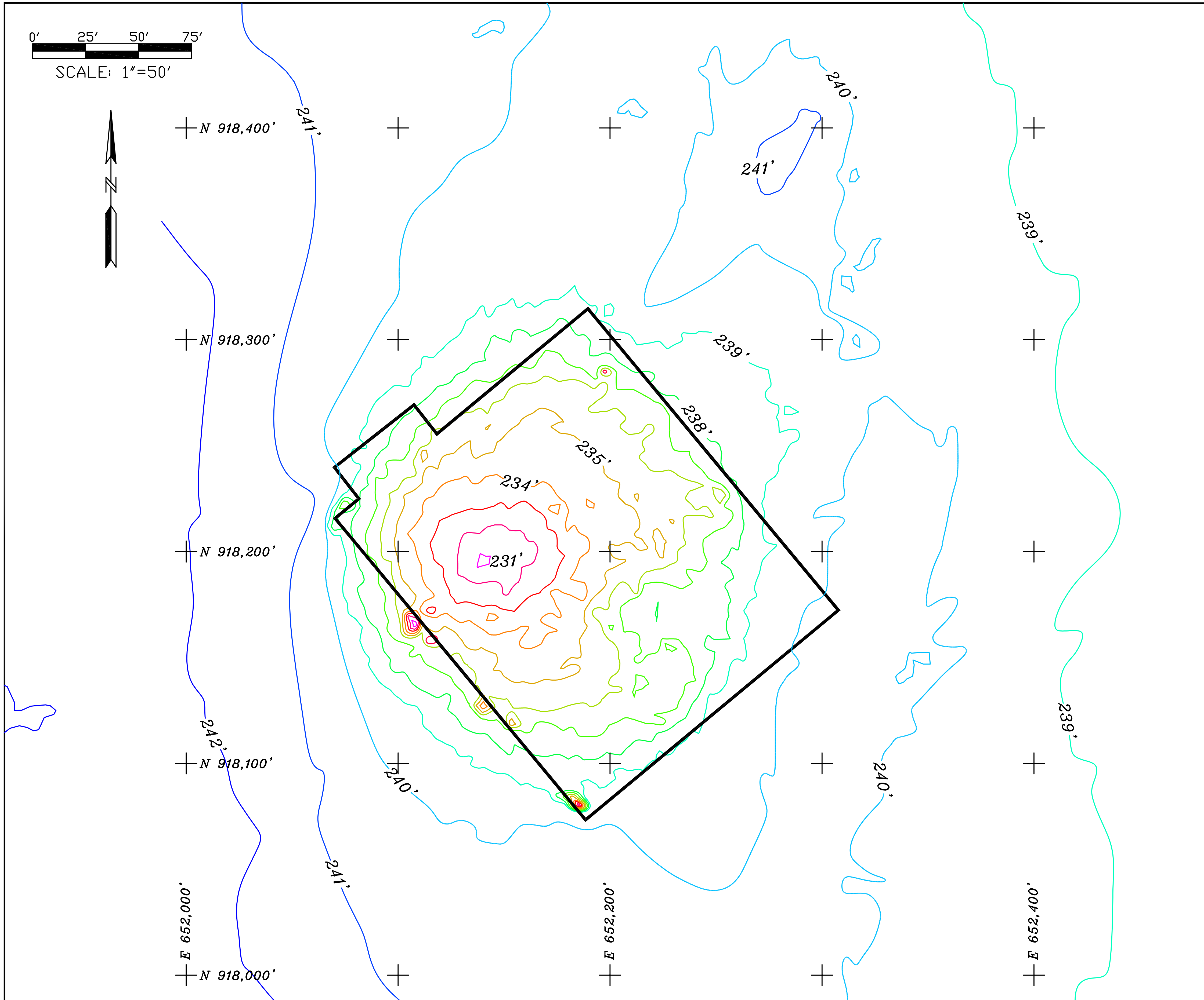
PLATFORM HIDALGO



PLATFORM IRENE

MULTIBEAM HYDROGRAPHIC SURVEY
SEPTEMBER 2002

MINERALS MANAGEMENT SERVICE
PACIFIC OCS REGION

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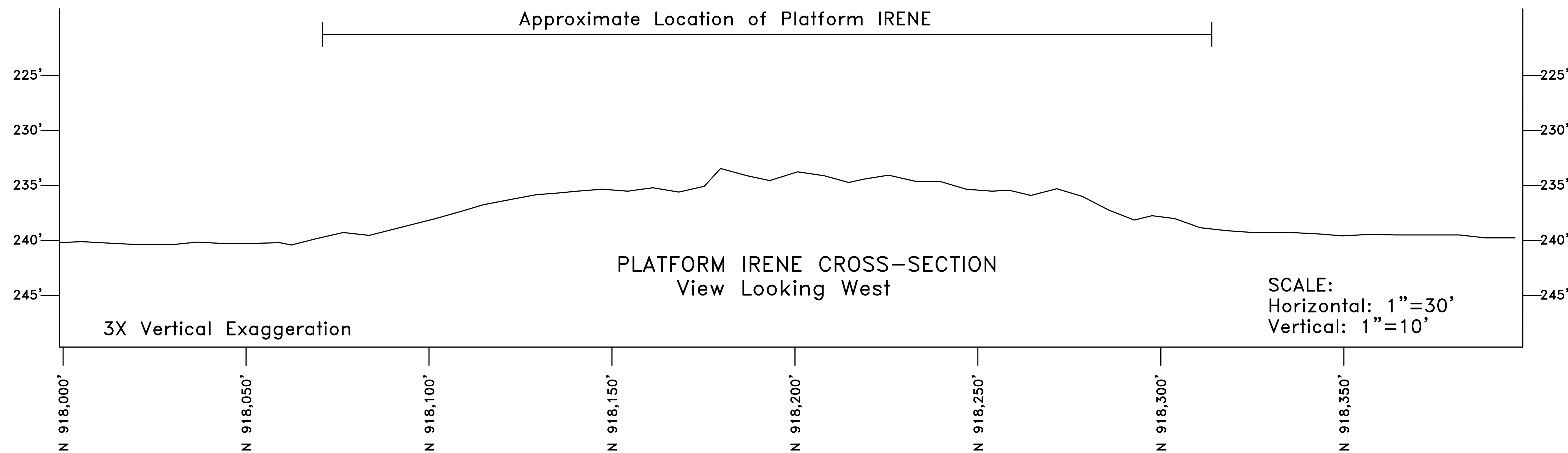
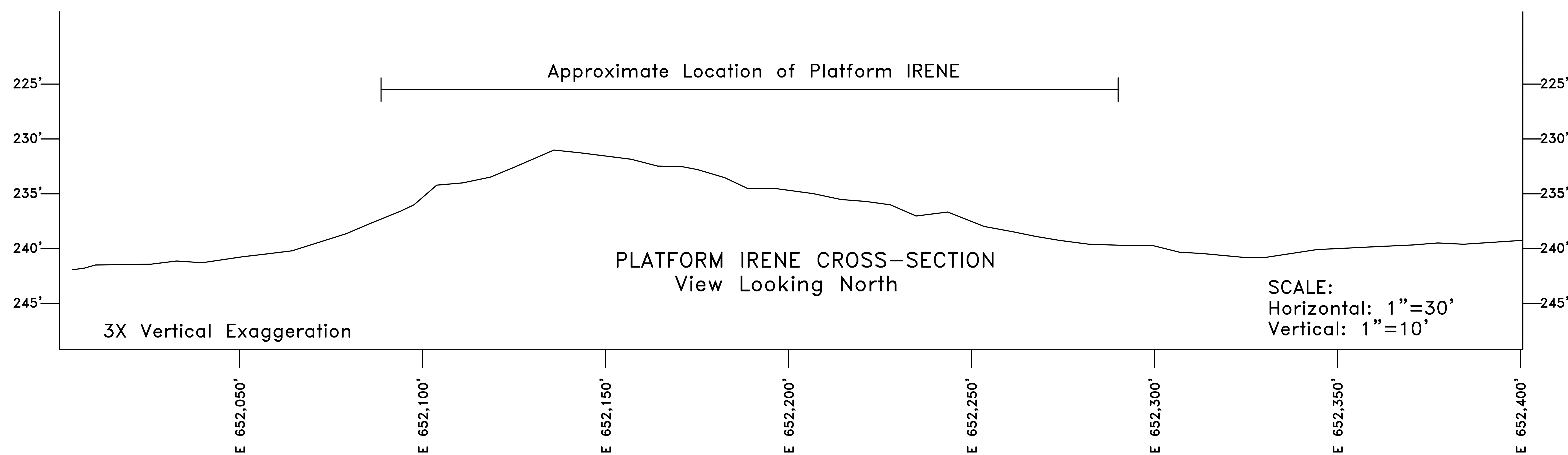
SCALE: 1" = 50'

FIGURE NO. 16





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PLATFORM IRENE