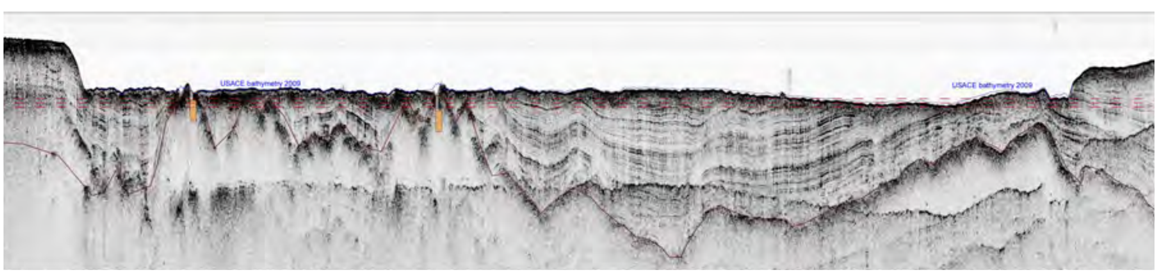
Department Of The Army
US Army Corps of Engineers
New England District
696 Virginia Road
Concord, MA 01742

Contract #W912DS-12-D-0002, DB01
Marine Geophysical and Geological Investigation, Boston Harbor, Boston Massachusetts



Report Section 5 through Section 8

June 15, 2015

e4sciences | Earthworks, LLC
27 Glen Road, North Entrance
Sandy Hook, Connecticut 06482
P.O. Box 178, Newtown, CT 06470
(203) 270-8100, Fax (203) 364-0480
www.e4sciences.com

All interpretations are opinions based on inferences from seismic or other measurements. We cannot, and do not, guarantee the accuracy or correctness of any interpretation. We shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretations made by any of our officers, agents or employees.

5.0 North Channel Area

Plate 14 plots the pair of orthosonographs of the North Channel. Plate 15 plots the seismic image.

Plate 16 plots the results of the geological investigation in the Broad Sound North Channel (North Channel). The four maps show the elevation of the mudline, the top of the Pleistocene, the top of the till and rock, and the top of the rock in the North Channel.

Plate 17 plots the results of the geotechnical investigation in North Channel. The four maps show the isopach maps for silt, Holocene and Pleistocene, till and rock, and rock thickness.

Plate 18 shows a slice map of fast rock at the -53ft overdepth for the entire -51ft project. Plate 19 shows seismic-velocity cross sections of the North Channel area.

5.1 North Channel geography

The North Channel (NC) is the main entrance to Boston Harbor from the Atlantic Ocean. The North Channel is east of Deer Island. Figure 33 plots the boring locations on the bathymetry. The North Channel is 15,300ft long roughly north-northeast to south-southwest. The width of the channel is 1,100ft.

5.2 North Channel grade

The existing grade of the mudline is -40ft MLLW in the South Lane. The newly authorized grade in the North Channel is elevation -51ft. If there is rock or hard bottom, the required overdepth adds 2ft depth to the -51ft to reach -53ft (Figure 34). The optional 2ft overdepth in the case of ordinary material brings the allowable elevation to -53ft. The optional 2ft overdepth in the case of rock would bring the elevation to -55ft.

5.3 North Channel stratigraphy

Figure 32 indicates that the North Channel has relatively simple stratigraphy. Holocene sands and gravels overlie Pleistocene Boston Blue Clay. The Boston Blue Clay overlies Pleistocene drumlins. Table 27 describes the area. Table 28 describes the volume. The Pleistocene Boston Blue Clay constitutes the majority of the volume. The drumlins rise and fall in the subsurface (Figure 34). The tills sit atop highs in the Cambridge Argillite. The rock forming the highs in the dredging prism is decomposed or highly weathered. The core of the rock is fast rock. The fast rock constitutes about half of the rock.

Table 27. Estimates of area for the North Channel per interval. Total area of the North Channel = 16,220,150sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	sqft	sqft
-51ft	11,225,358	3,117,204	256,700	722,691
-53ft	12,019,687	3,537,976	948,307	735,177
-55ft	12,040,583	3,699,164	1,500,928	n/a

Table 28. Estimates of volume for the North Channel per interval.

Elevation	Volume above elevation	Volume of sediment above elevation	Volume of rock/till above elevation	Volume of rock above elevation	Fraction of rock	Side slope volume above elevation
MLLW, ft	cuyd	cuyd	cuyd	cuyd	per interval	cuyd
-51ft	2,686,253	2,308,489	377,763	6,566	0.0024	134,541
-53ft	3,551,380	2,922,939	628,441	49,729	0.0140	161,662
-55ft	4,447,759	3,549,300	898,459	143,805	0.0323	n/a

5.4 North Channel sediments

Table 28 shows that most of the material in the dredging prism is Holocene and Pleistocene sediments. The Holocene sediments are sands and some gravel (Figure 35). The Pleistocene Boston Blue Clay that constitutes more than 80% of the dredge material has cohesion. Nonetheless the clay should be straightforward to dig with a clamshell. The Pleistocene till is compact and may be difficult to dislodge and remove by a clamshell. Figure 36 plots the orthosonograph insonified from the north. Figure 37 plots the targets on the orthosonograph. Figure 38 is isopach map for the Holocene sediments. Figure 39 plots an orthosonograph showing the exposure of grasses and Pleistocene on the channel bottom. Figure 40 plots the top of Pleistocene sediments. Figure 41 plots the isopach map of Pleistocene sediments. Figure 42 plots the isopach of the Holocene and Pleistocene sediments.

5.5 North Channel rock

Figure 43 plots the top of till and rock. Figure 44 shows the top-of-rock map. Much of the rock in the North Channel is decomposed and among the most highly weathered of the Cambridge Argillite that we encountered. Figure 45 plots the top of fast rock. The cores of the rock ledges are fast. Table 29 lists the estimated area of rock in the North Channel. Table 30 lists the estimated rock volume in the North Channel.

Figure 46 plots the isopach map of the till to required overdepth. Figure 47 plots an isopach map of rock to required overdepth. Figure 48 plots isopach map of fast rock to required overdepth. At the required overdepth, only about half of the argillite in the North Channel is fast rock. Figure 49 shows the slice map of the fast rock at -53ft for the entire -51ft project. Figure 50 is a seismic-velocity cross section showing the fast rock in the North Channel.

Table 29. Estimates of rock area in the North Channel.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	sqft
-51ft	3,117,204	256,700	801
-53ft	3,537,976	948,307	51,018
-55ft	3,699,164	1,500,928	503,585

Table 30. Estimates of rock volume in the North Channel.

Elevation	Volume of till/rock above elevation	Volume of rock above elevation	Volume of fast rock above elevation
MLLW, ft	cuyd	cuyd	cuyd
-51ft	377,763	6,566	12
-53ft	628,441	49,729	990
-55ft	898,459	143,805	18,467

5.6 North Channel debris

The North Channel has some lobster pots and other debris on the bottom (Figure 51). These objects may constitute a small but real cost to the dredger to sort from his dredge volume.

5.7 North Channel infrastructure

The Deer Island sewer outfall system lies beneath the North Channel. The sewer tunnel is embedded in the Cambridge Argillite at an elevation of -350ft MLLW. The sewer outfall will not be affected by digging, but any blast plan must consider the vibrations that would be generated within 1,500ft of the tunnel. The plans and specifications should note the location of the Deer Island sewer outfall on the appropriate plan sheets.

5.8 Additional North Channel dredging concerns

A principal issue in dredging is efficiency. This involves lost time due to maintenance, traffic, and weather. Dredging in the North Channel will involve the removal of rock. The Holocene sediment is sand and gravel. Most of the Pleistocene is Boston Blue Clay. Some of the till may be compact. Half of the rock is likely decomposed and highly weathered. The other half is fast rock. The move on demand should be minimal and predictable. Heave is a concern. Dredges are sensitive to heave and are not efficient when the swells exceed 3 to 4ft. Therefore, a major concern for lost time in the North Channel may be (a) maintenance and (b) heave due to swells.

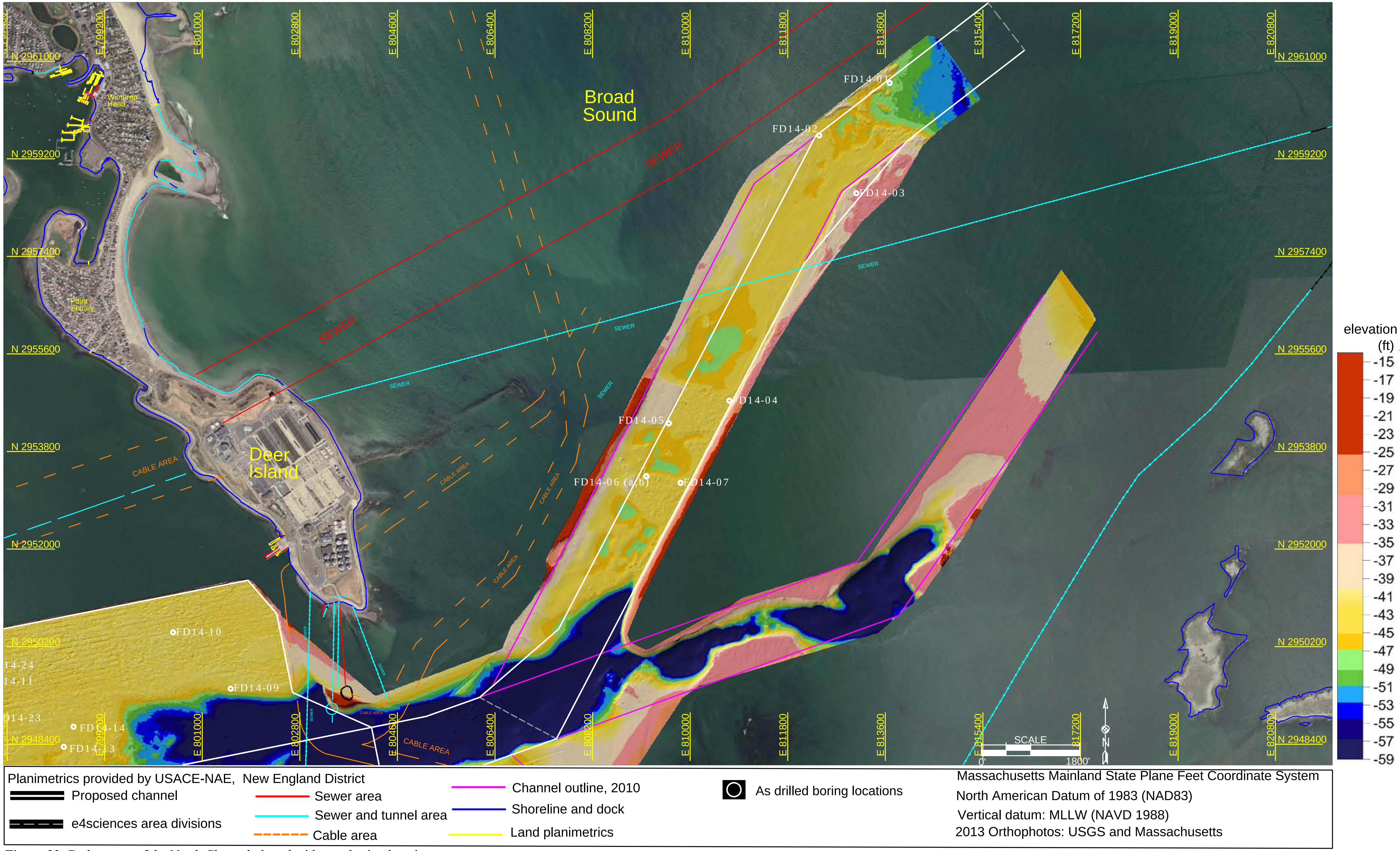


Figure 33. Bathymetry of the North Channel plotted with core boring locations.

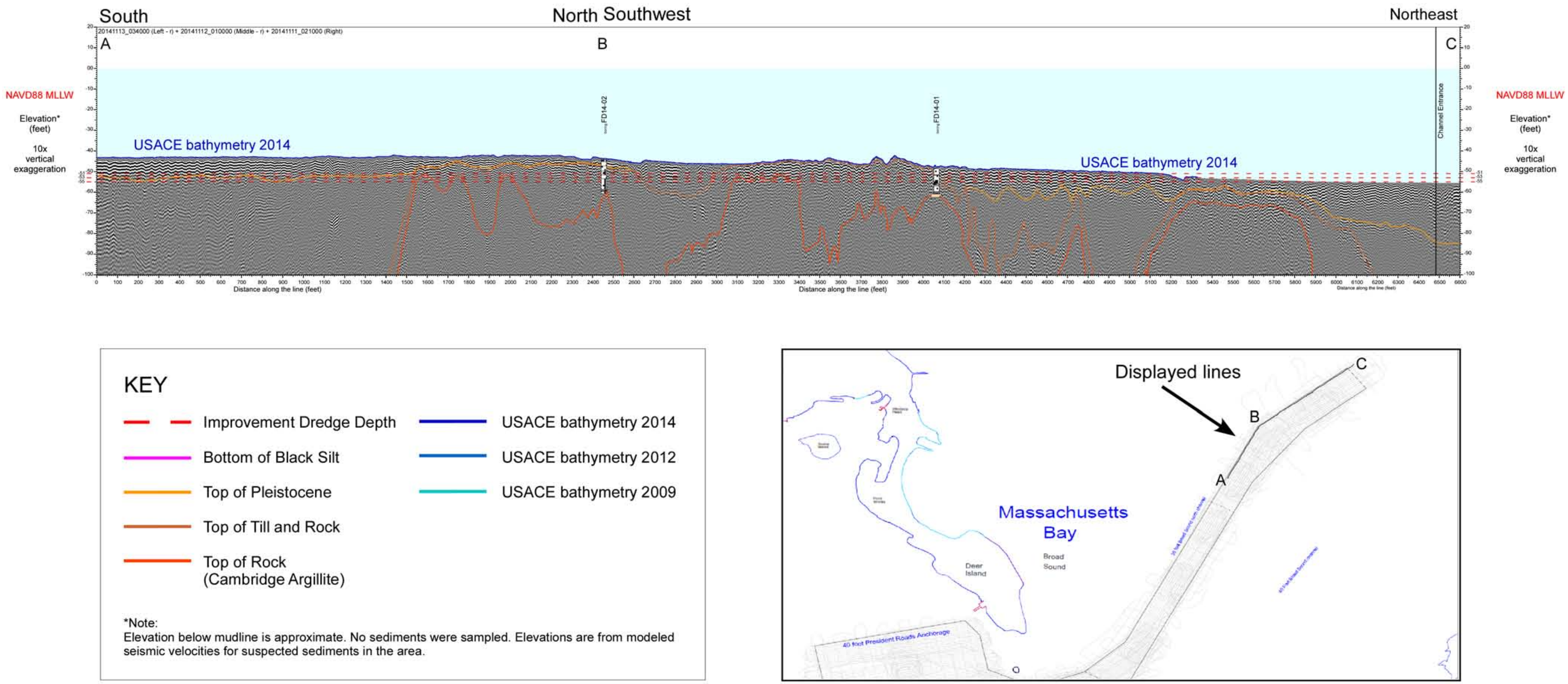


Figure 34. Seismic cross section along the axis of the North Channel.

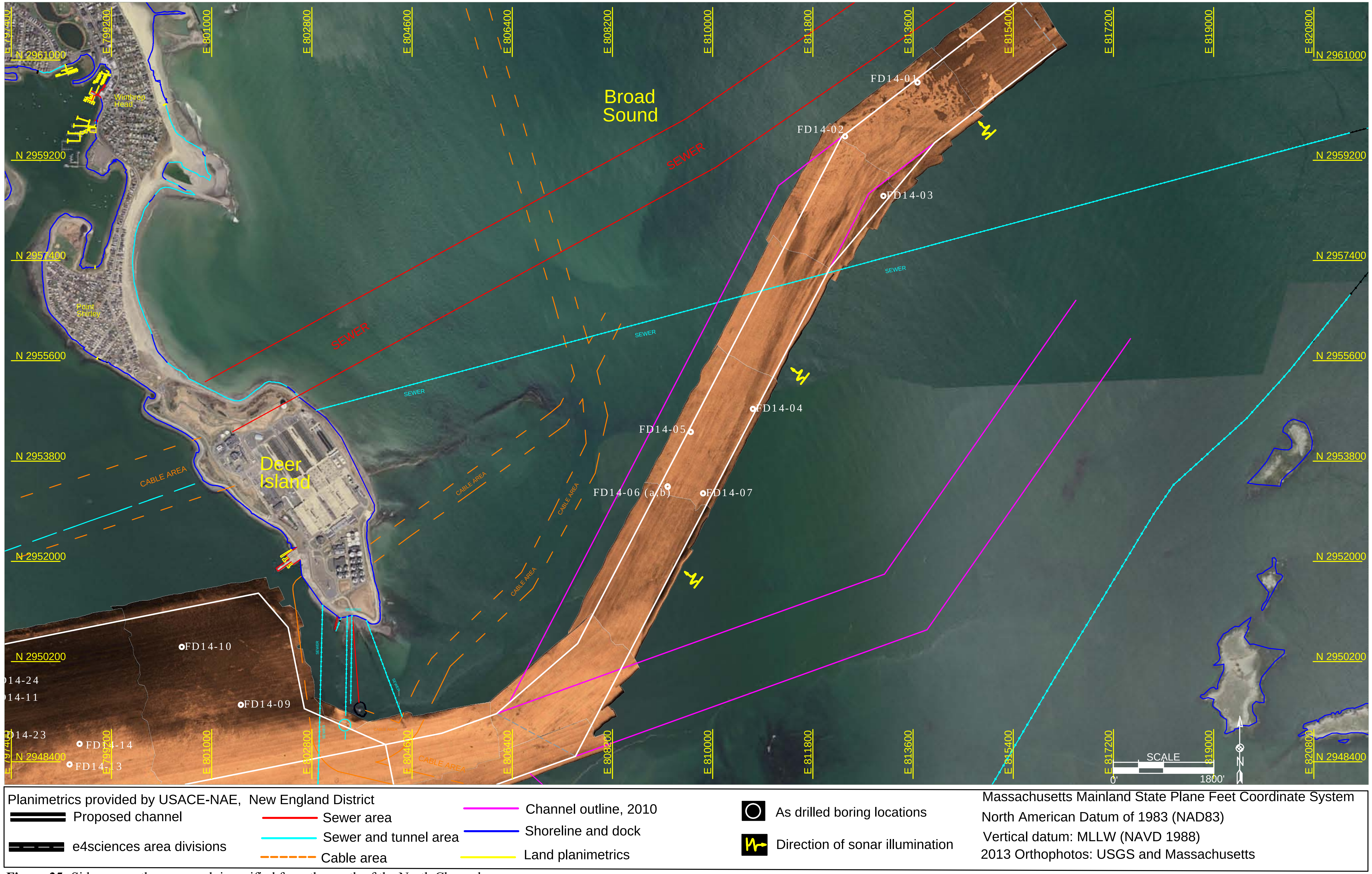


Figure 35. Side-scan orthosonograph insonified from the south of the North Channel.

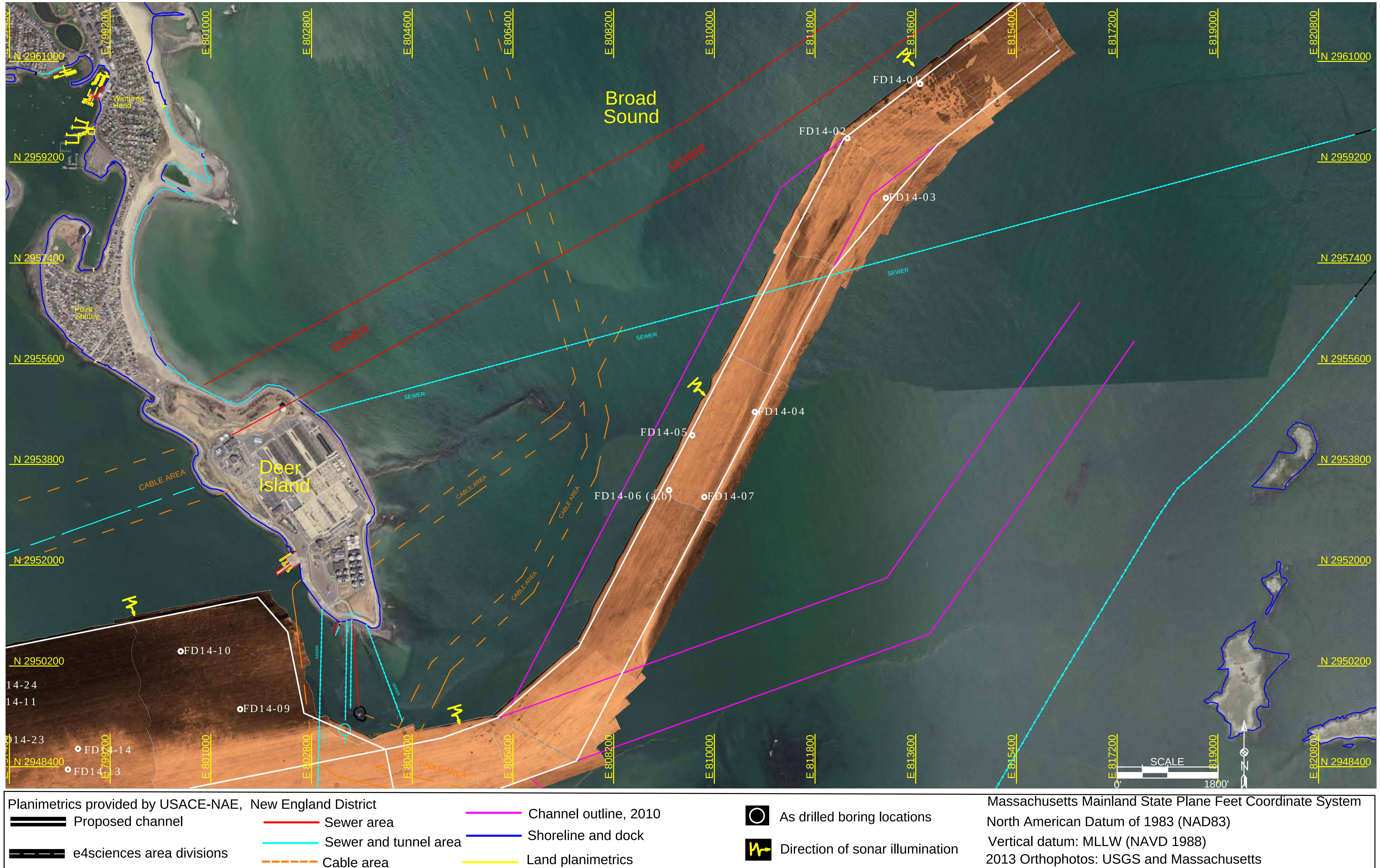


Figure 36. Side-scan orthosonograph insonified from the north of the North Channel.

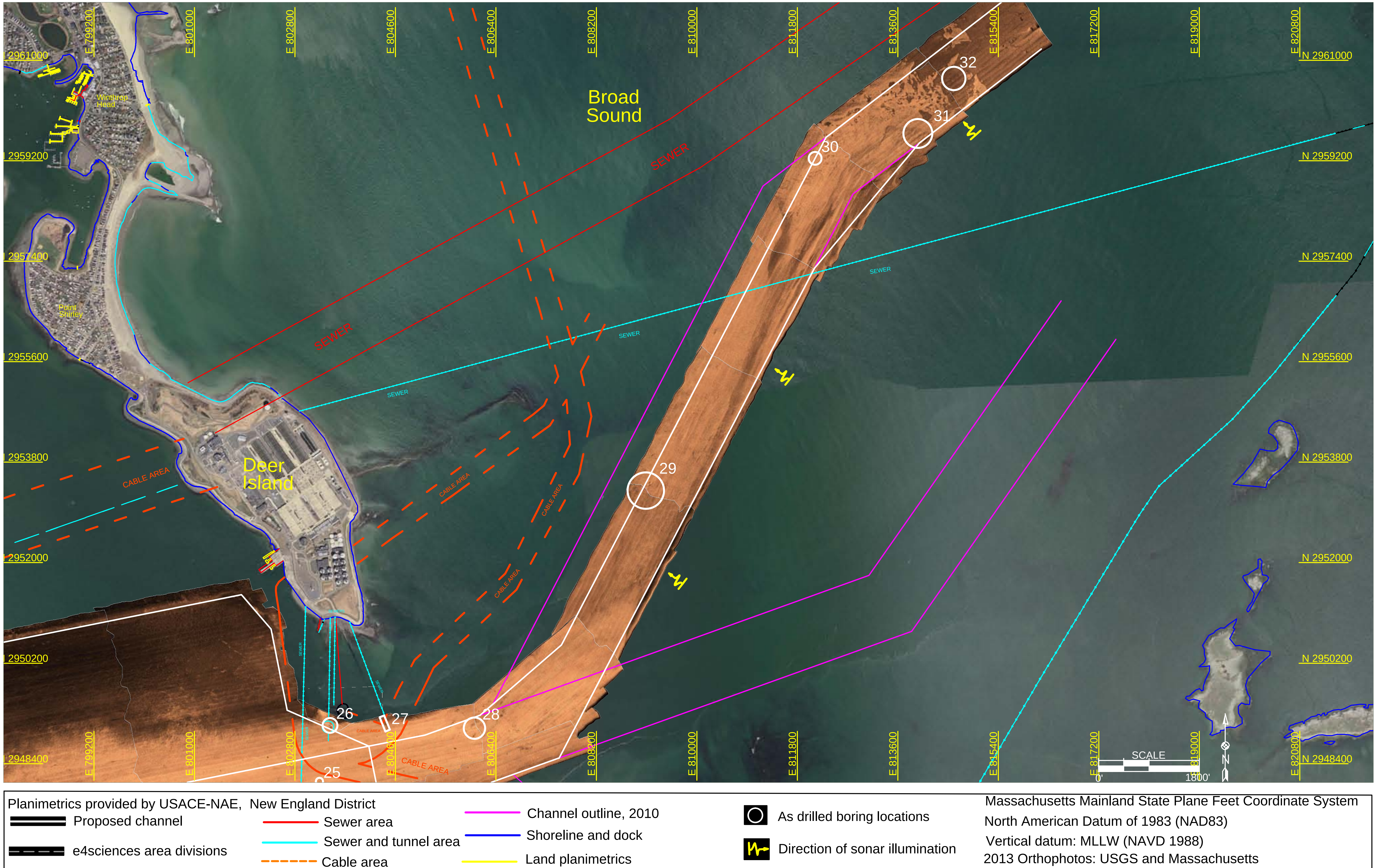


Figure 37. Target map on the side-scan orthosonograph of the North Channel.

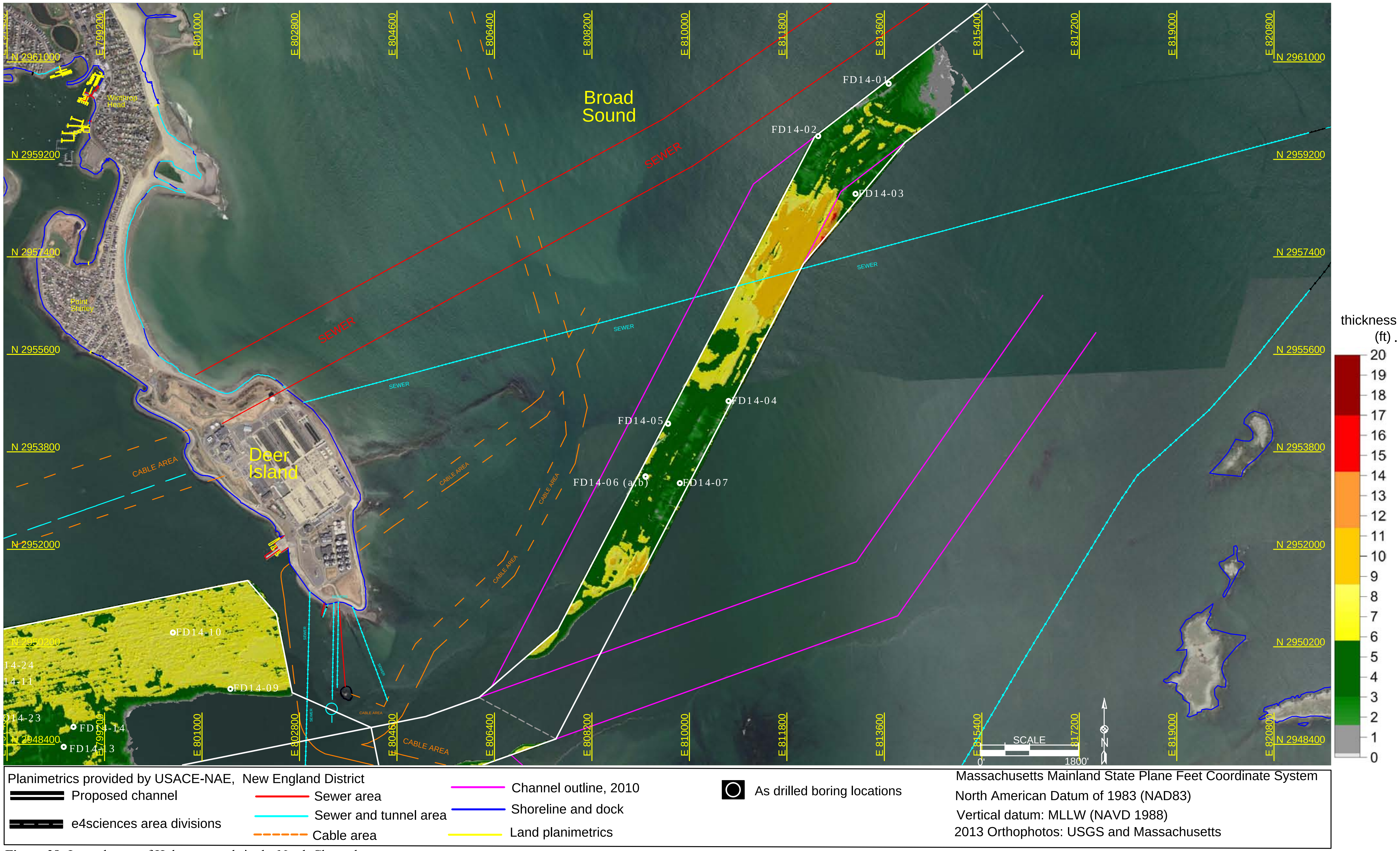


Figure 38. Isopach map of Holocene sands in the North Channel.

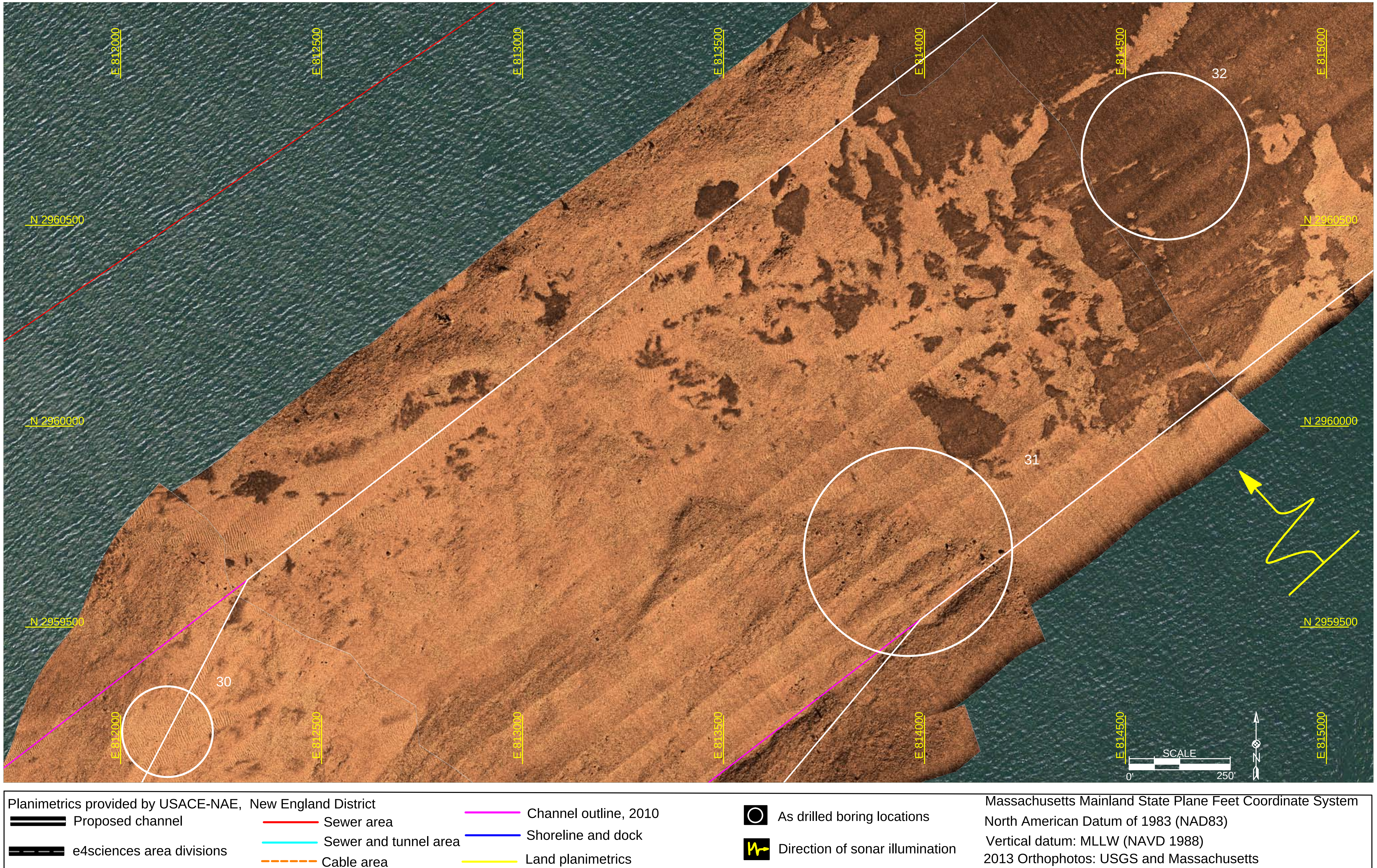


Figure 39. Zoomed in orthosonograph of the northern extent of the North Channel showing grass-covered sediments, boulders on till subcrop and sand waves.

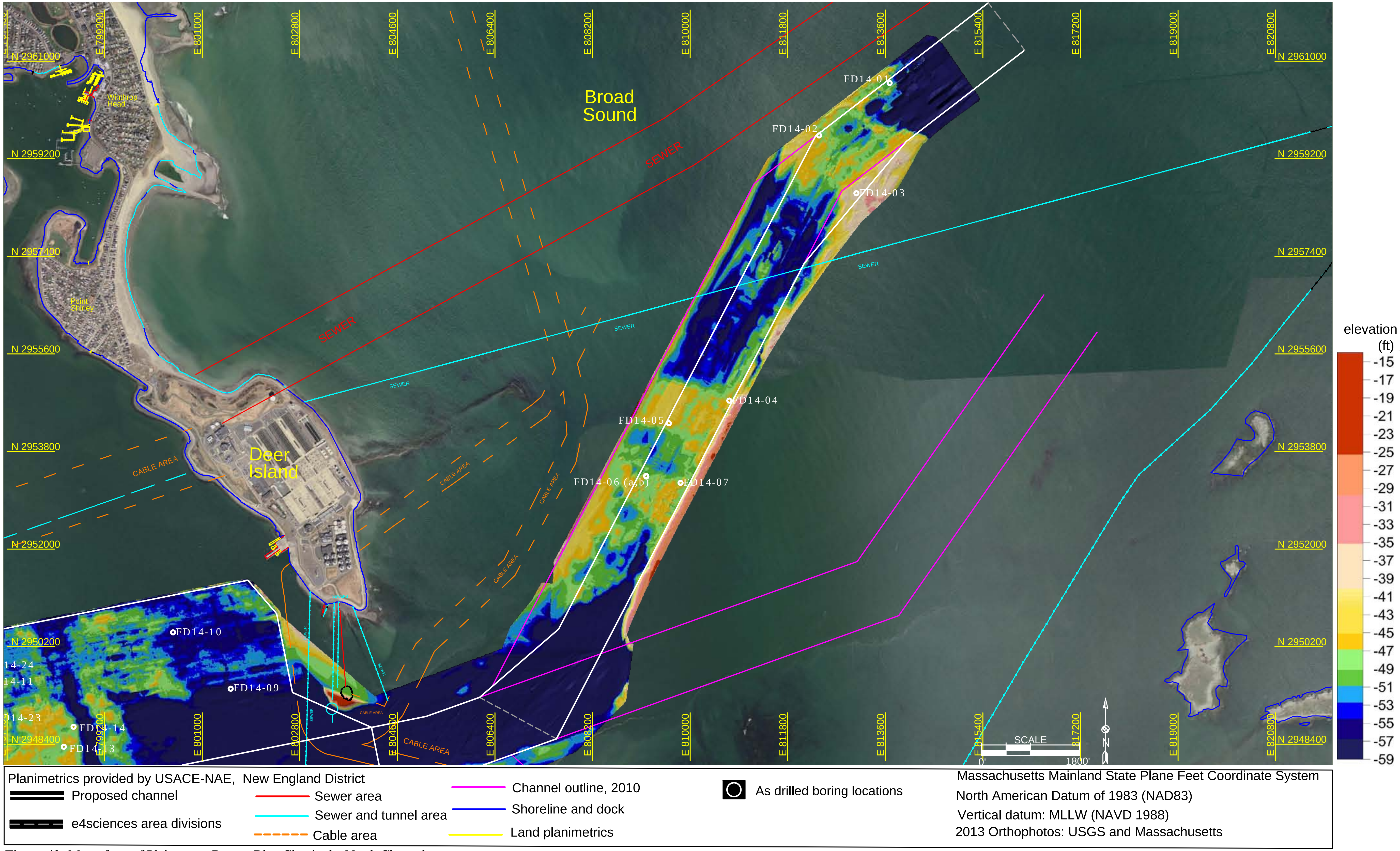


Figure 40. Map of top of Pleistocene Boston Blue Clay in the North Channel.

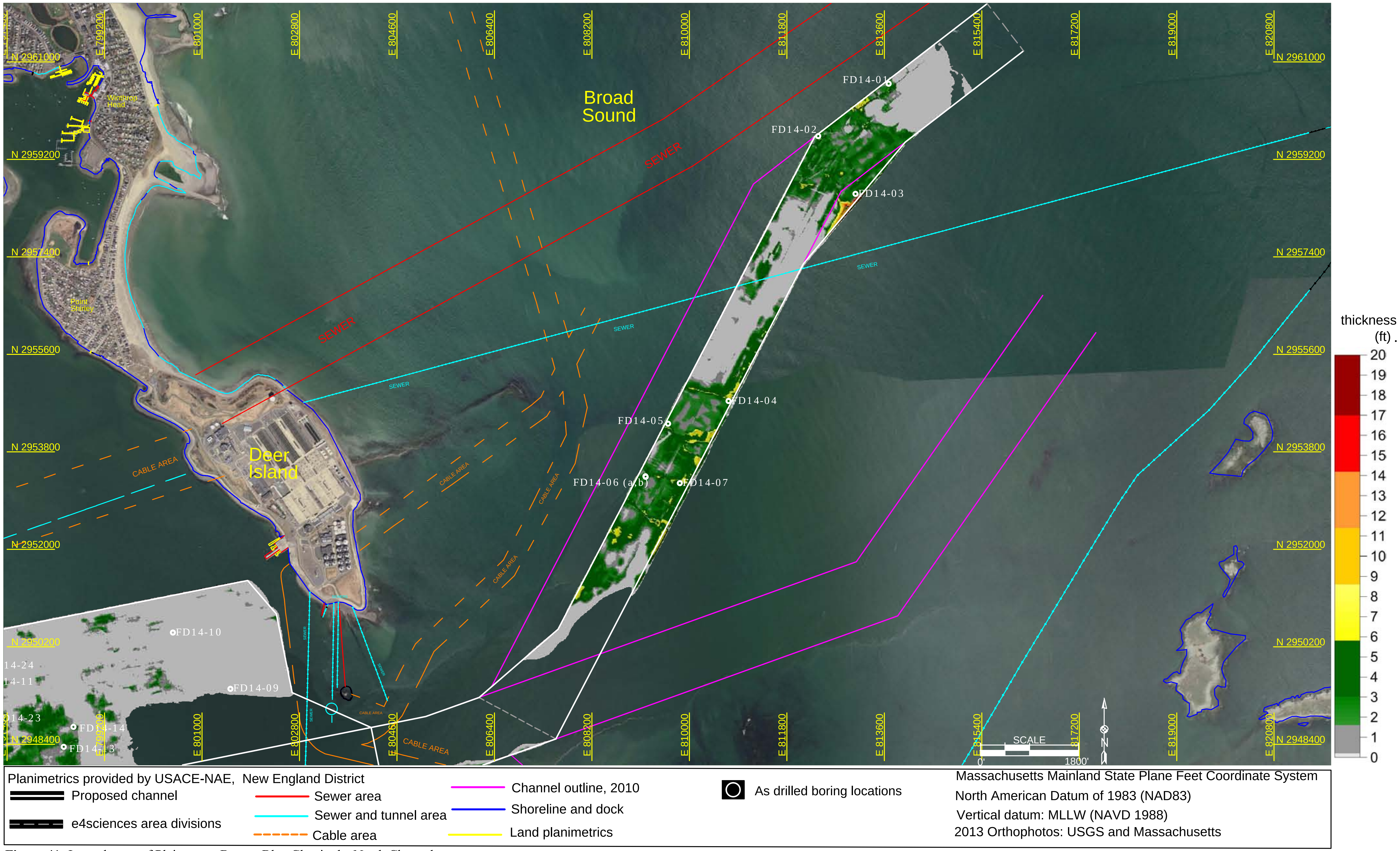


Figure 41. Isopach map of Pleistocene Boston Blue Clay in the North Channel.

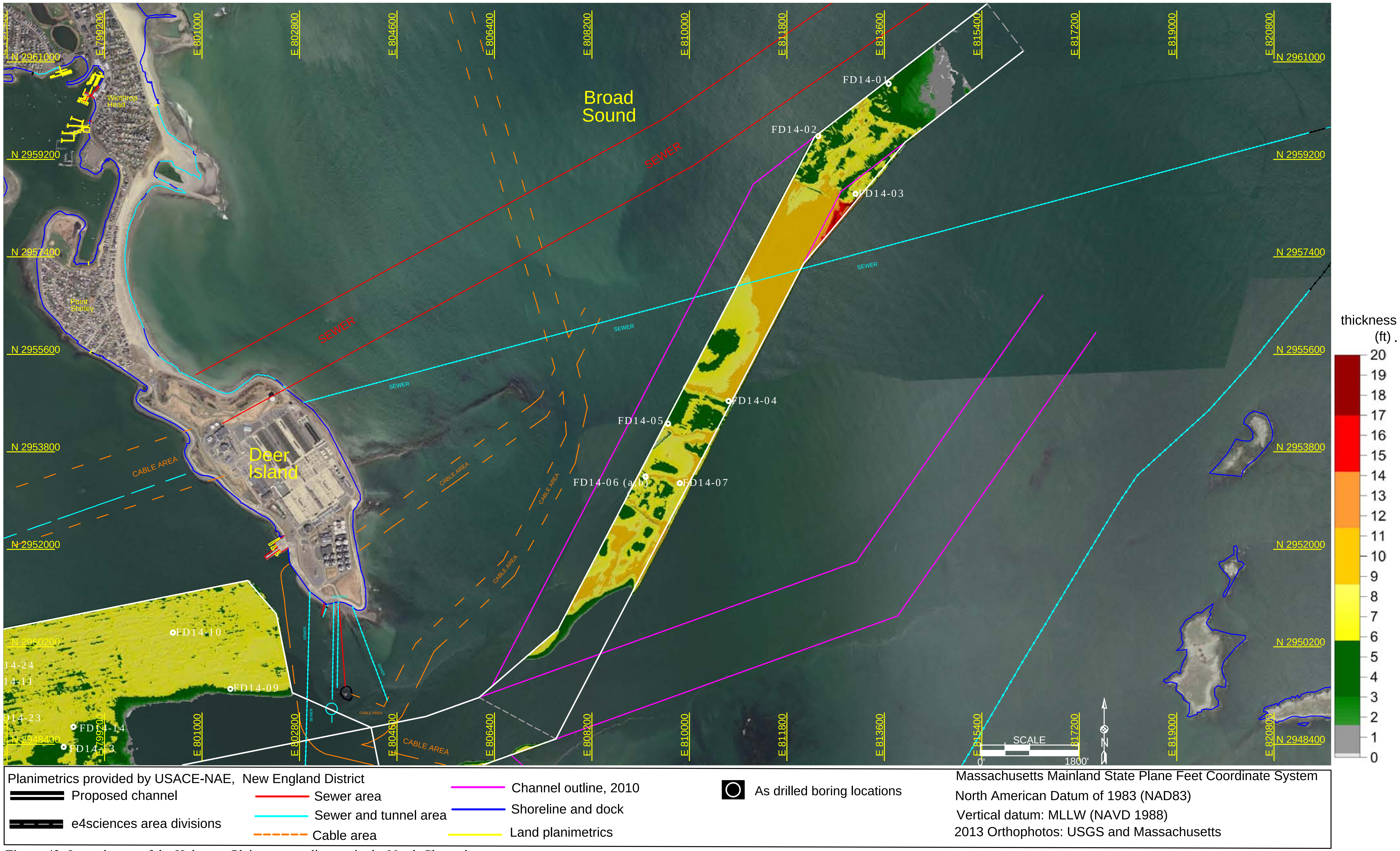


Figure 42. Isopach map of the Holocene-Pleistocene sediments in the North Channel.

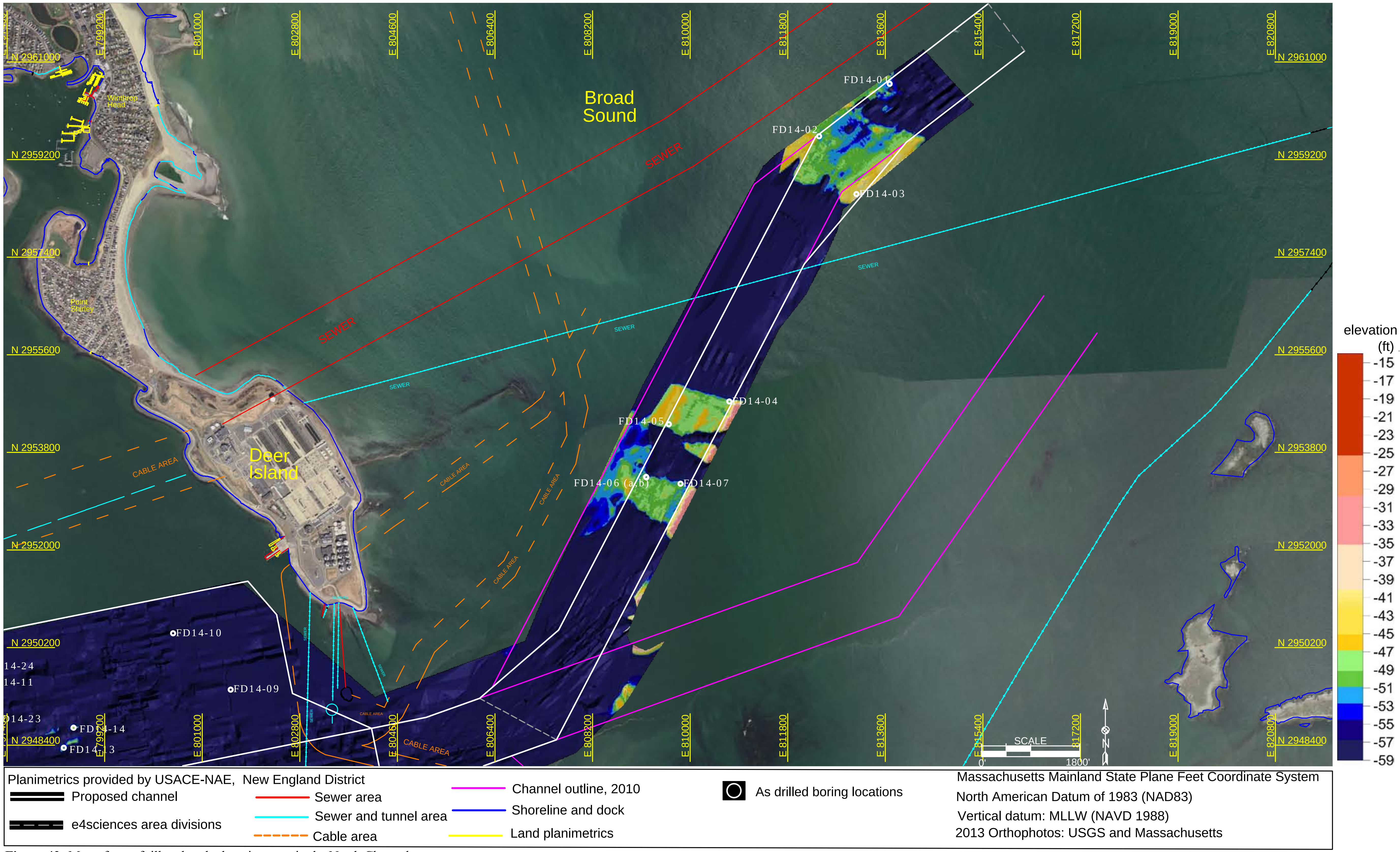


Figure 43. Map of top of till and rock elevation map in the North Channel.

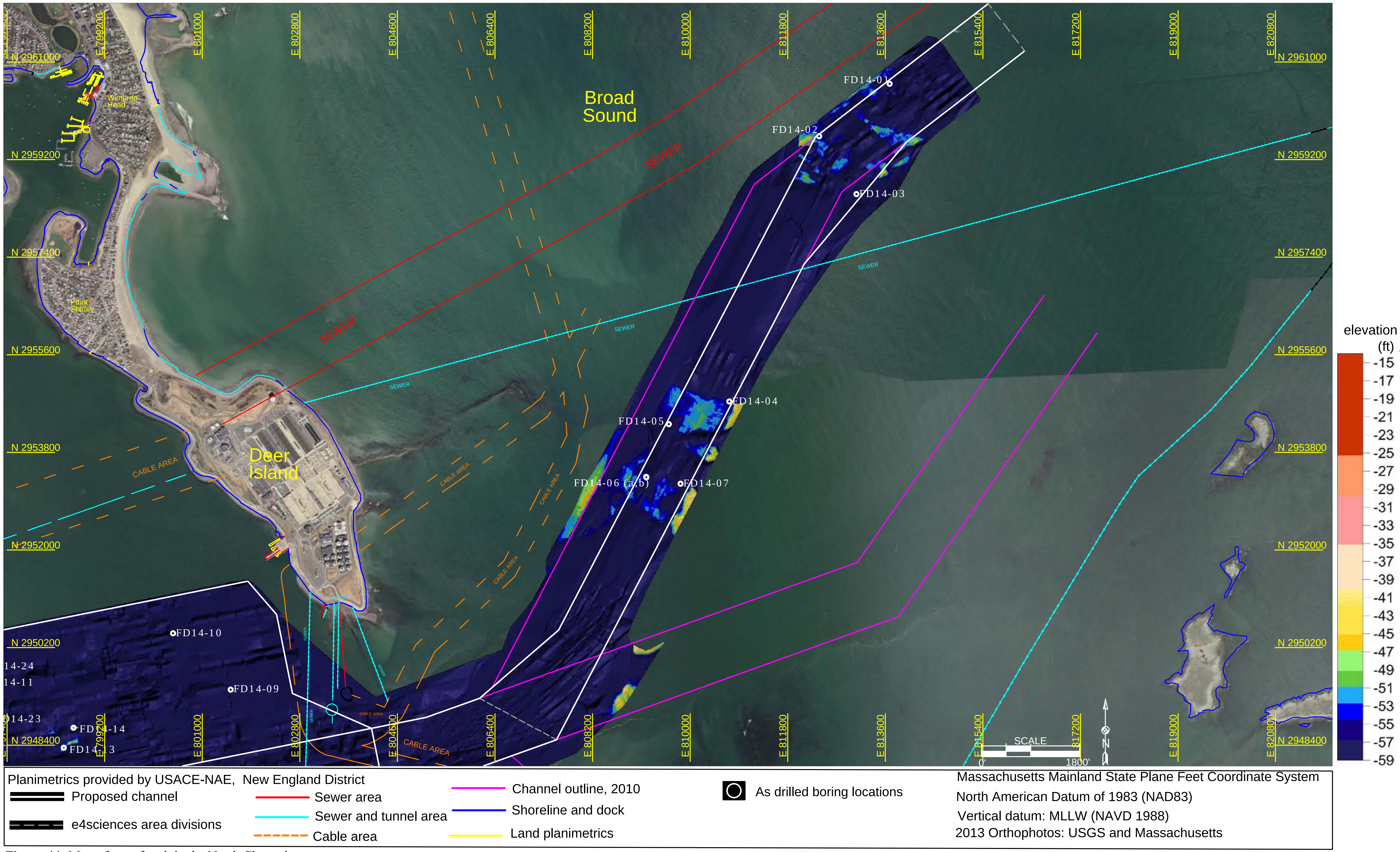


Figure 44. Map of top of rock in the North Channel.

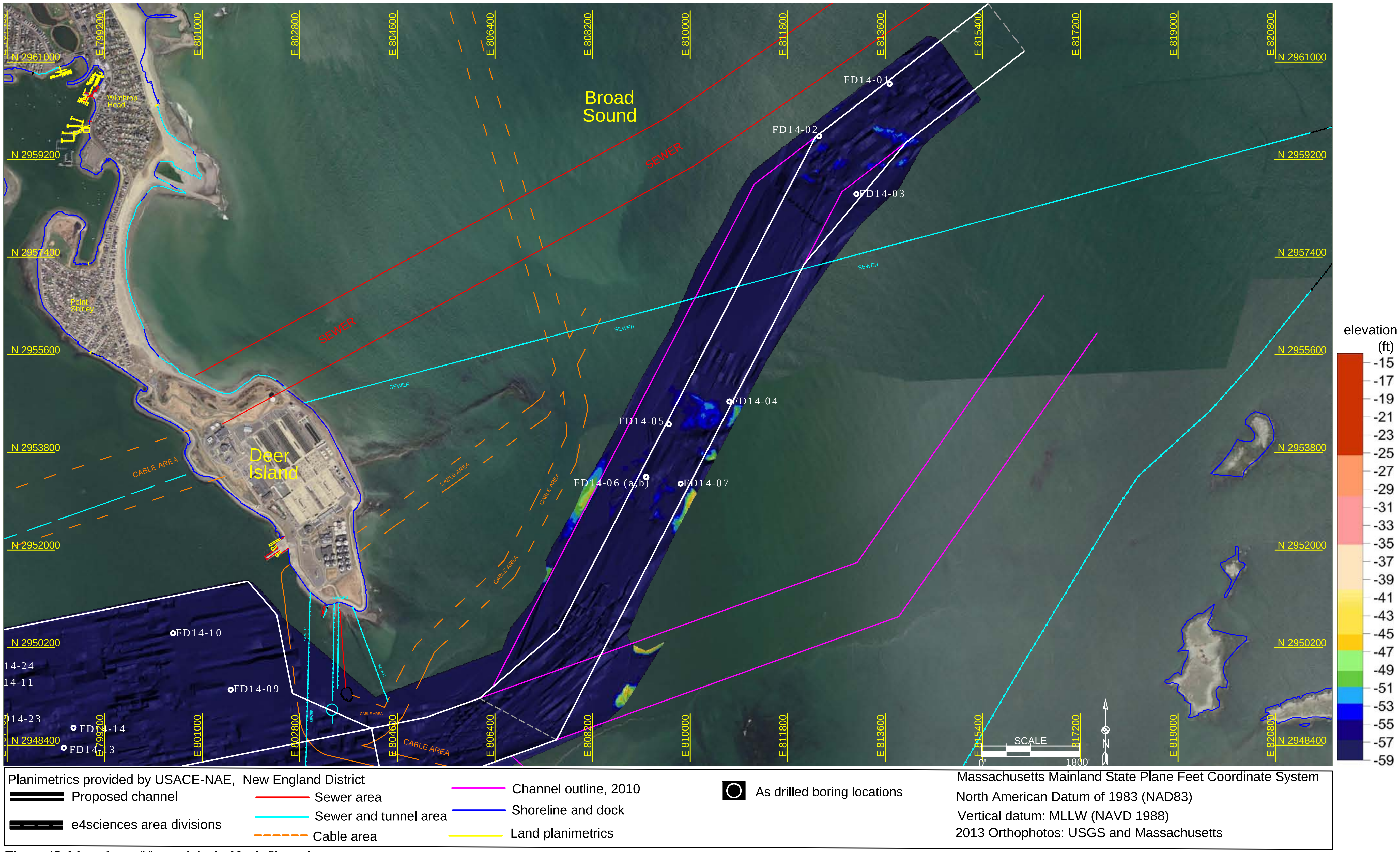


Figure 45. Map of top of fast rock in the North Channel.

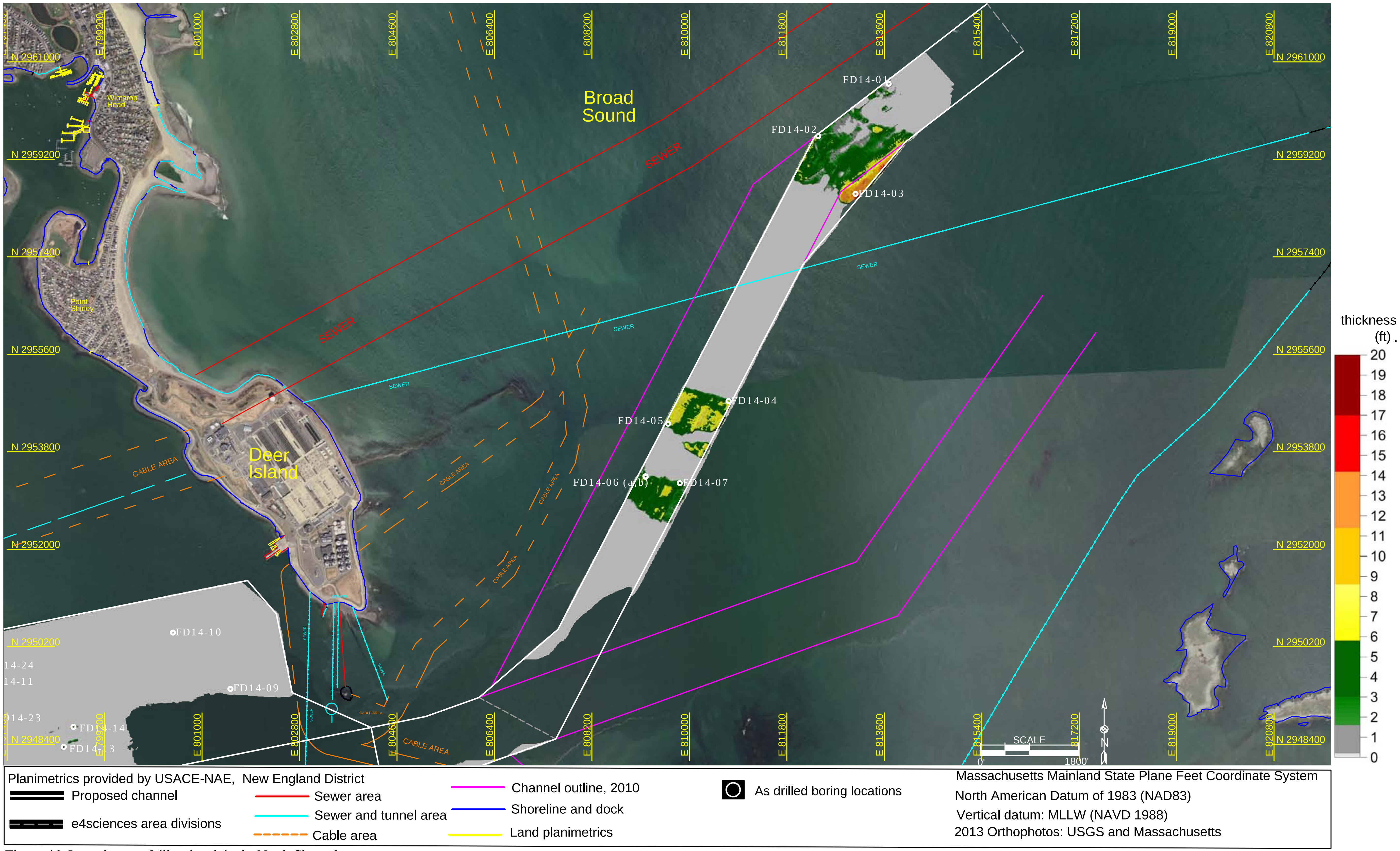


Figure 46. Isopach map of till and rock in the North Channel.

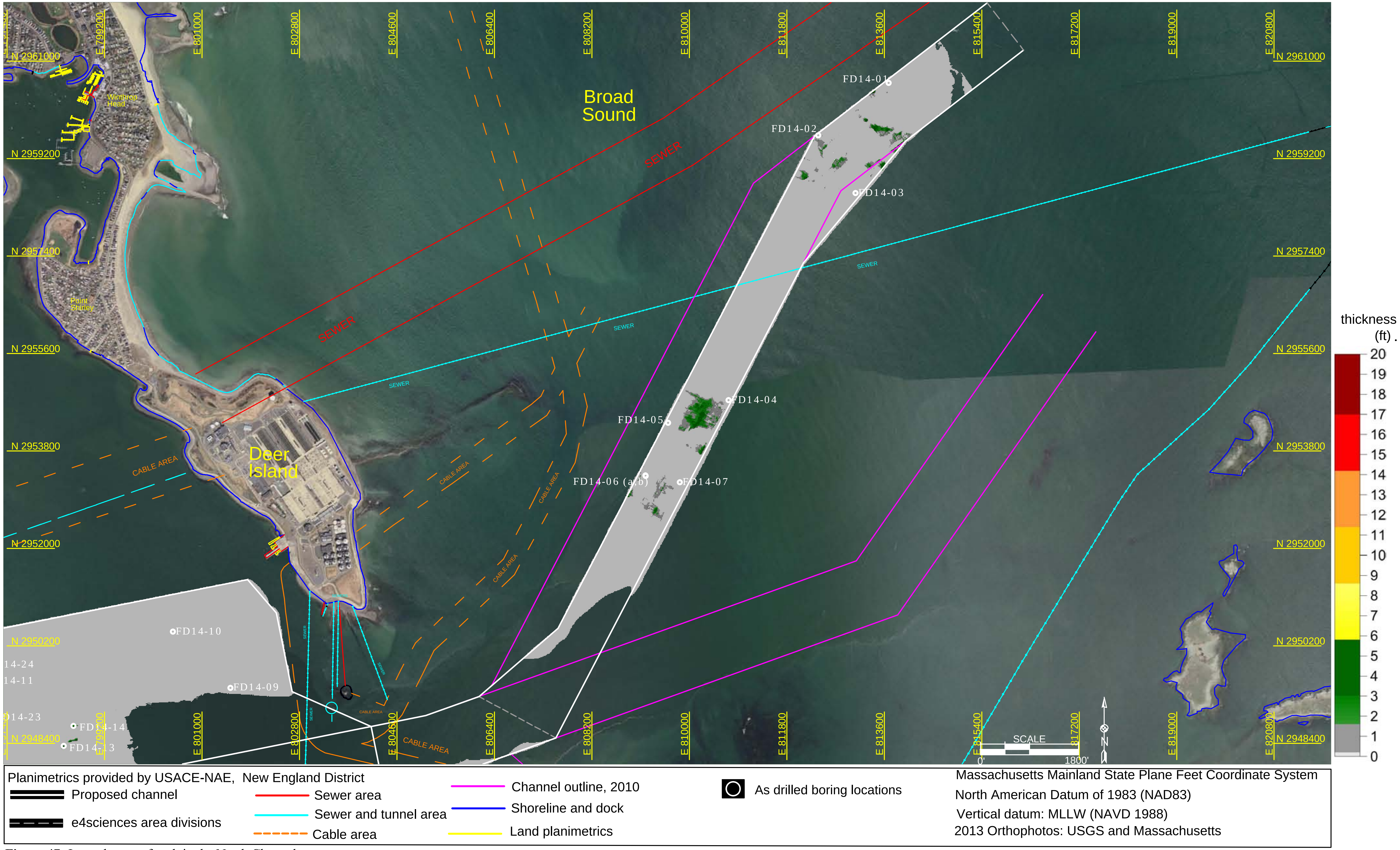
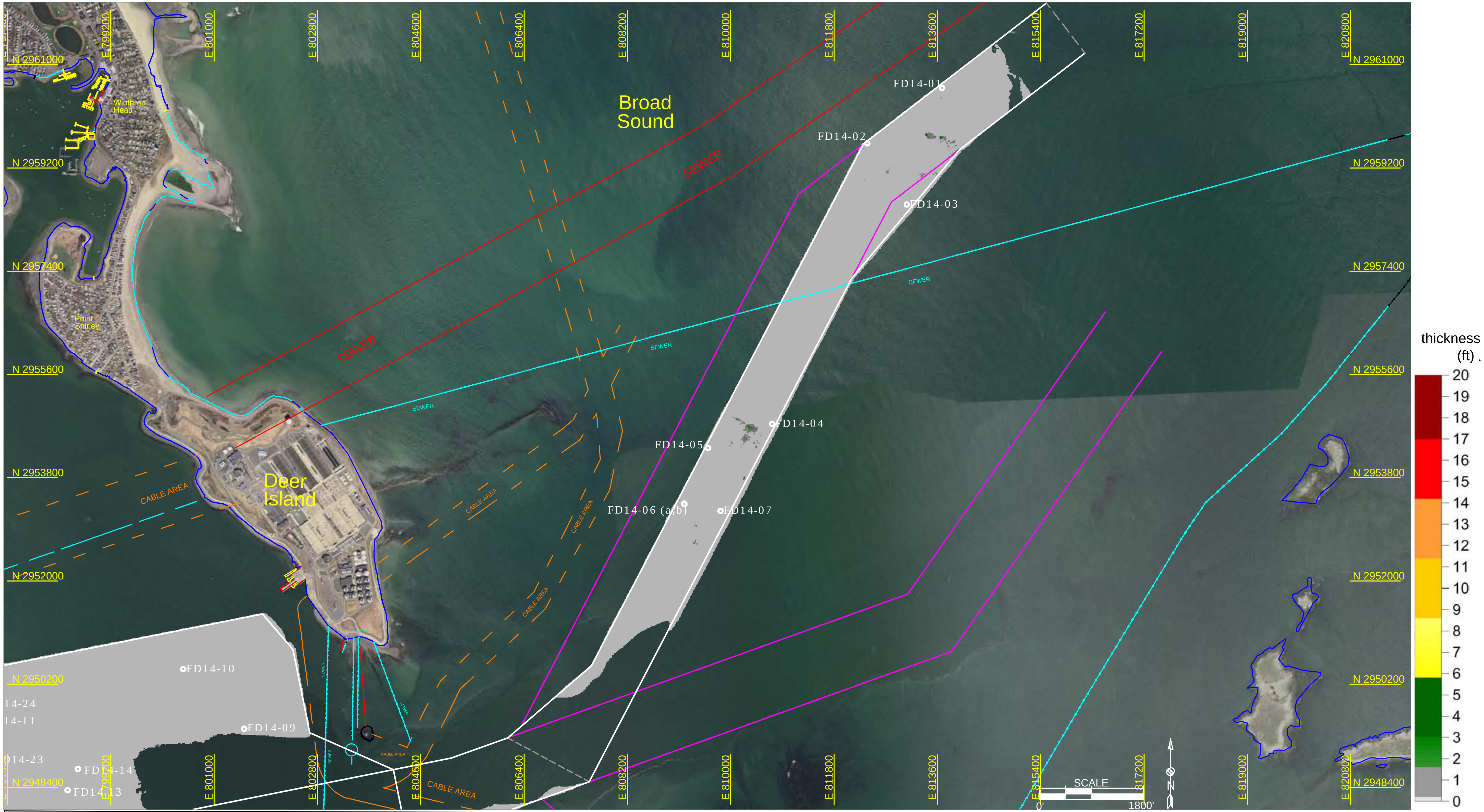


Figure 47. Isopach map of rock in the North Channel.



Planimetrics provided by USACE-NAE, New England District

Proposed channel

e4sciences area divisions

Sewer area

Sewer and tunnel area

Cable area

Channel outline, 2010

Shoreline and dock

Land planimetrics

As drilled boring locations

Massachusetts Mainland State Plane Feet Coordinate System

North American Datum of 1983 (NAD83)

Vertical datum: MLLW (NAVD 1988)

2013 Orthophotos: USGS and Massachusetts

Figure 48. Isopach map of fast rock in the North Channel.

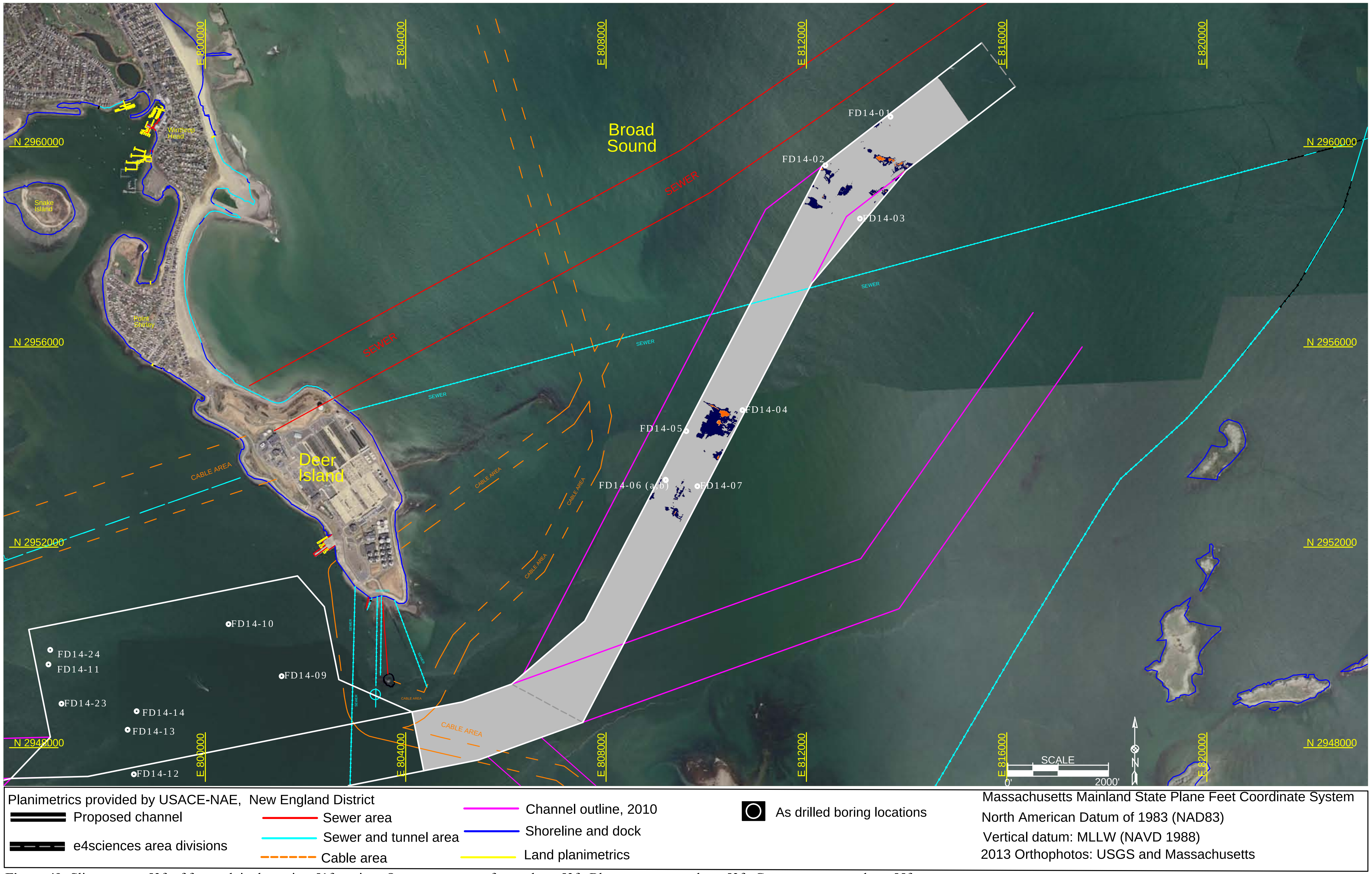


Figure 49. Slice map at -53ft of fast rock in the entire -51ft project. Orange represents fast rock at -53ft. Blue represents rock at -53ft. Gray represents rock at -55ft.

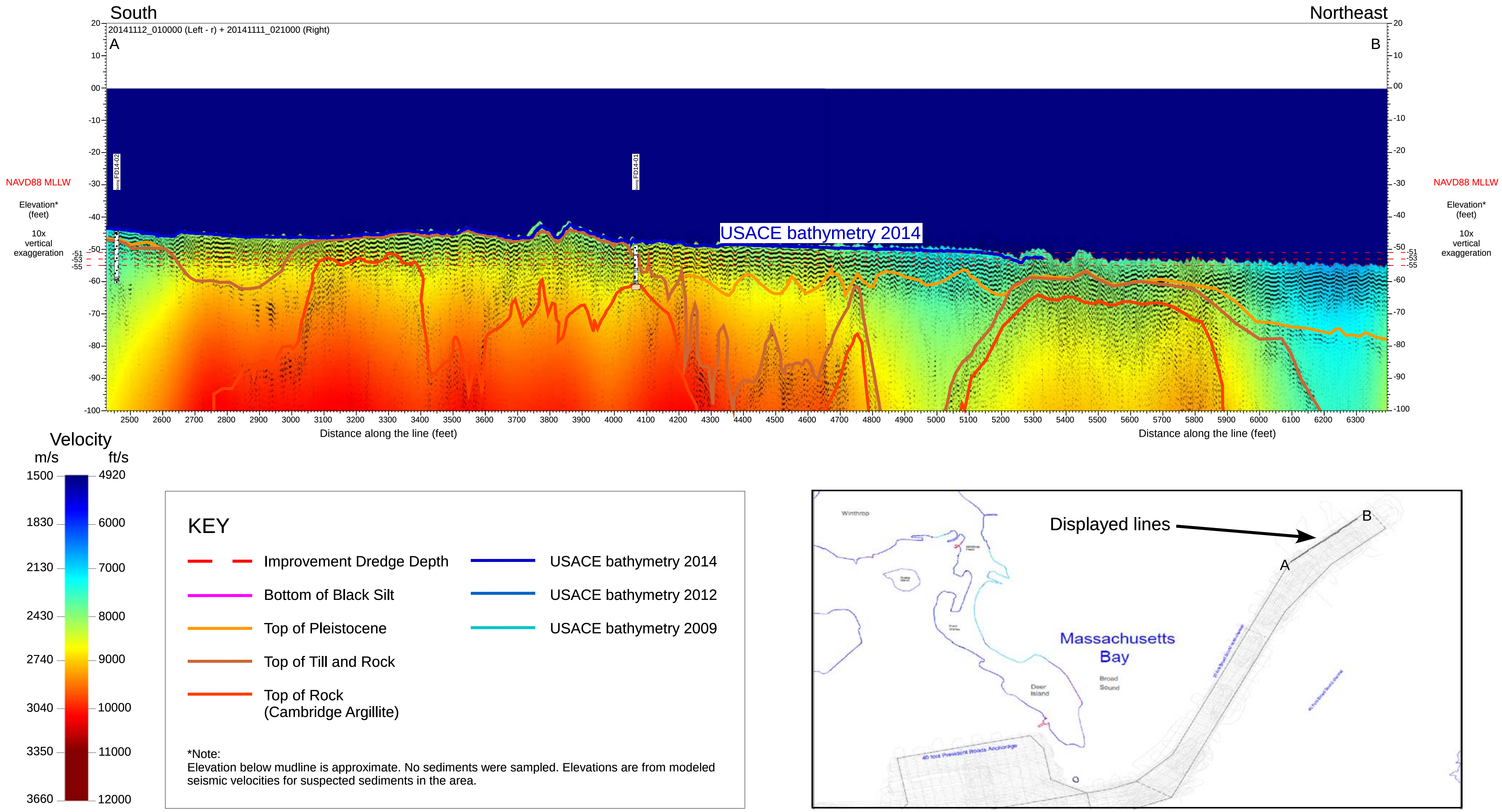
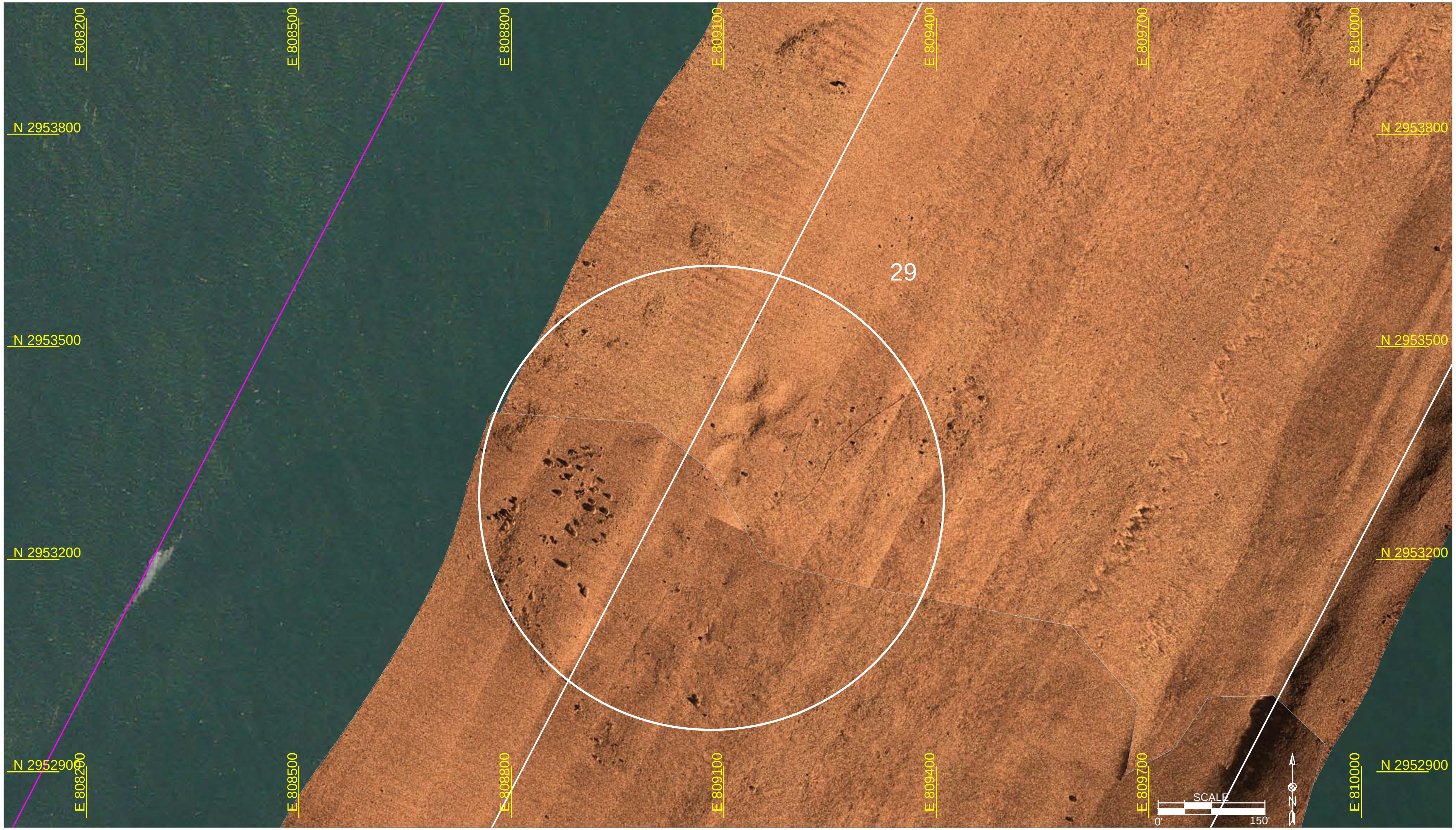


Figure 50. Seismic-velocity cross section in North Channel.



Planimetrics provided by USACE-NAE, New England District

- Proposed channel
- e4sciences area divisions
- Sewer area
- Sewer and tunnel area
- Cable area
- Channel outline, 2010
- Shoreline and dock
- Land planimetrics
- As drilled boring locations
- Direction of sonar illumination

Massachusetts Mainland State Plane Feet Coordinate System
North American Datum of 1983 (NAD83)
Vertical datum: MLLW (NAVD 1988)
2013 Orthophotos: USGS and Massachusetts

Figure 51. Zoomed in orthosonograph of lobster pots in North Channel.

6.0 The Main Ship Channel in President Roads Anchorage area and the Presidents Road Anchorage

Plate 20 plots the pair of orthosonographs for the President Roads Anchorage area. Plate 21 and Plate 22 plot the seismic sections. Plate 23 plots the results of the geological investigation in the President Roads Anchorage area. The four maps show the elevation of the mudline, the top of the Pleistocene, the top of the till and rock, and the top of the rock in the President Roads Anchorage area.

Plate 24 plots the results of the geotechnical investigation in President Roads Anchorage area. The four maps show the isopach maps for silt, Holocene and Pleistocene, till and rock, and rock thickness. Plate 25 plots the slice map for the President Roads Anchorage area at elevation -49ft overdepth. Plate 26 is a seismic-velocity cross section of the President Roads Anchorage area.

6.1 The Main Ship Channel in the President Roads Anchorage area geography

The Main Ship Channel in the Anchorage area (MSCPRA) connects the North Channel to the Main Ship Channel in the Reserved Channel area. The MSCPRA lies between Deer Island to the north and Long Island to the south. MSCPRA is 13,000ft long roughly east to west. The width of the Channel is 1,200ft. Figure 52 plots the multibeam bathymetry in the President Roads Anchorage area with the boring locations superimposed.

6.2 MSCPRA -51ft grade

The eastern part of the MSCPRA is part of the -51ft project. The existing grade of the mudline is at elevation -40ft MLLW. The newly authorized grade in the eastern section MSCPRA is at elevation -51ft MLLW. There is an optional overdepth is 2ft in ordinary material, sediments, bringing the elevation to -53ft MLLW. There is no rock in the -51ft portion of the MSCPRA. Table 31 describes the area in MSCPRA. Table 32 describes the volume in MSCPRA for the -51ft project.

Table 31. Estimates of area for the MSCPRA -51ft reach per interval. Total area of the -51ft reach = 3,180,820sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	sqft	sqft
-51ft	299,003	0	0	30,039
-53ft	374,512	0	0	42,354
-55ft	374,513	n/a	n/a	n/a

Table 32. Estimates of volume for the MSCPRA -51ft reach per interval.

Elevation	Volume above elevation	Volume of sediment above elevation	Volume of rock/till above elevation	Volume of rock above elevation	Fraction of rock	Side slope volume above elevation
MLLW, ft	cuyd	cuyd	cuyd	cuyd	per interval	cuyd
-51ft	47,672	47,672	0	0	0	3,173
-53ft	73,160	73,160	0	0	0	6,423
-55ft	101,804	101,804	n/a	n/a	n/a	n/a

Figures 2, 32 and 52 indicate that dredging of the MSCPRA is straightforward. Much of the reach is below grade. The sediments are Pleistocene Boston Blue Clay. There is no rock and no paid overdepth for rock (Tables 33-34).

Table 33. Estimates of rock area in the MSCPRA -51ft reach per interval.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	Sqft
-51ft	0	0	0
-53ft	0	0	0
-55ft	n/a	n/a	n/a

Table 34. Estimates of rock volume in the MSCPRA -51ft reach per interval.

Elevation	Volume of till/rock above elevation	Volume of rock above elevation	Volume of fast rock above elevation
MLLW, ft	cuyd	cuyd	cuyd
-51ft	0	0	0
-53ft	0	0	0
-55ft	n/a	n/a	n/a

6.3 MSCPRA -47ft grade

The western part of the MSCPRA is part of the -47ft project. The existing authorized grade of the mudline is -40ft MLLW. The newly authorized grade in the western section MSCPRA is elevation -47ft. The optional overdepth in ordinary material is 2ft, bringing the elevation to -49ft. If there is rock or hard till in the dredging prism, the 2ft overdepth is required to achieve the elevation -49ft. In the case of rock or hard bottom, an optional overdepth would add another 2ft depth bringing the elevation to -51ft. A section of the MSCPRA has an existing authorized grade of -35ft and it needs to be cut to deepen the Main Channel to elevation -47ft. Figure 52 plots the multibeam bathymetry with the boring locations.

6.4 MSCPRA stratigraphy

Figures 2, 32 and 52 indicate that dredging of the MSCPRA is straightforward. Much of the reach is below grade. Where the channel is at grade, the Holocene sediments overlie Pleistocene Boston Blue Clay (Figures 53-54), and the Cambridge Argillite is out of the dredging prism. The only concern for rock is in the deep section at the edge of the channel outside of the channel toes. Figure 55 is a seismic cross section of MSCPRA. Most of the material to be dredged is the Pleistocene marine Boston Blue Clay. At the base, compact Pleistocene tills might present a more resistant unit (Figures 56-67). Table 35 describes the areas. Table 36 describes the volumes in MSCPRA for -47ft project.

Table 35. Estimates of area for the MSCPRA -47ft reach per interval. Total area of the MSCPRA = 15,136,620sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	sqft	sqft
-47	4,664,000	45	0	126,136
-49	6,578,865	387	3	194,276
-51	6,872,670	2,196	8	n/a

Table 36. Estimates of volume for the MSCPRA -47ft reach per interval.

Elevation	Volume above elevation	Volume of sediment above elevation	Volume of rock/till above elevation	Volume of rock above elevation	Fraction of rock	Side slope volume above elevation
MLLW, ft	cuyd	cuyd	cuyd	cuyd	per interval	cuyd
-47	473,226	473,224	2	0	0.0000	15,572
-49	892,748	892,738	10	0	0.0000	32,865
-51	1,401,283	1,401,181	102	0	0.0000	n/a

6.5 MSCPRA sediments

The Holocene sediments are sands with some gravel (Figures 56-60). The Pleistocene Boston Blue Clay constitutes the over 95% of the material to be dredged. The Pleistocene till at the base is compact and may be difficult to dislodge and remove by a clamshell. An excavator could remove the till.

6.6 MSCPRA rock

In the Main Ship Channel, the rock (Figure 61) is so deep in the channels that the only rock to be concerned with is on the side slopes outside the channel (Figures 2, 52, and 61-65). The rock may affect the slope (1:3 or 1:1) of the side slopes (Figures 61-67). Figure 67 is a slice map for fast rock at -49ft for the entire -47ft project. Table 37 describes the estimated rock area in MSCPRA. Table 38 describes the estimated rock volume in MSCPRA.

Table 37. Estimates of rock area in the MSCPRA -47ft reach.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	sqft
-47ft	45	0	0
-49ft	387	3	2
-51ft	2,196	8	8

Table 38. Estimates of rock volume in the MSCPRA -47ft reach.

Elevation	Volume of till/rock above elevation	Volume of rock above elevation	Volume of fast rock above elevation
MLLW, ft	cuyd	cuyd	cuyd
-47ft	2	0	0
-49ft	10	0	0
-51ft	102	0	0

6.7 MSCPRA debris

The MSCPRA has many lobster pots and other debris on the bottom. These objects may constitute a small but real cost to the dredger to sort from his dredge volume.

6.8 MSCPRA infrastructure

Cables and pipelines cross from Long Island to Deer Island (Figure 68). The Inter-island conveyance tunnel to the Deer Island Water Treatment Plant is at -250ft MLLW. These facilities cross in the deep part of the channel where dredging is unnecessary (Figure 32). Nonetheless, the plans and specifications should mark the location and type of these facilities. The last thing we would want is to snag a spud on pipeline or cable while in transit.

6.9 Additional MSCPRA dredging concerns

A principal issue in dredging is efficiency. This involves lost time due to maintenance, traffic, and weather. The sediment is clay and till. Most of Pleistocene is Boston Blue Clay. Some of the till may be compact. The move on demand is minimal and predictable. The heave concern is reduced because much of the channel is in the lee of Deer Island. However, the -51ft reach does lie east of the peninsula and is still subject to the swells. Dredges particularly excavators are sensitive to heave and are not efficient when swells exceed 3 to 4ft. The concern over heave remains but is lessened in the Main Ship Channel west of Deer Island.

6.10 President Roads Anchorage geography

The President Roads Anchorage (PRA) is a roughly rectangular area adjacent to the Main Ship Channel. From east to west the PRA is 6,000ft long. From north to south, the width is 3,100ft. The shared boundary with MSCPRA includes two small tapers east and west.

6.11 PRA grade

The existing grade of the mudline is -40ft MLLW. The newly authorized grade in the PRA is an elevation -47ft MLLW. Figure 52 plots the multibeam bathymetry with the core boring locations plotted. The optional 2ft overdepth brings the elevation to -49ft. If there is rock or hard till, the overdepth is required to achieve -49ft. An optional paid overdepth in case of rock would add another 2ft depth bringing the elevation to -51ft.

6.12 PRA stratigraphy

The dredging of the PRA presents several challenges. The USACE-NAE tested the silt, fine-grained organic-rich Holocene sediments, and found it suitable for ocean placement. The orthosonograph in Figures 53 and 54 displays the footprint of the fine-grained material. An orthosonograph is a reflectivity image; as such the lower impedance of the finer-grained sediments indicates the presence of organic material. Ridges of Cambridge Argillite (Figures 61, 62, and 69) reach up into the dredging prism near the northwest boundary of the PRA. The predominant material remains the Pleistocene Boston Blue Clay. Some tills remain between the clays and the argillite. Table 39 describes the estimated area in the PRA. Table 40 describes the estimated volumes in the PRA.

Table 39. Estimates of area for the PRA reach per interval. Total area of the PRA = 19,059,960sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	Sqft	sqft
-47ft	14,604,841	15,479	6,677	350,215
-49ft	15,002,555	61,754	41,264	403,791
-51ft	15,059,374	127,024	93,711	n/a

Table 40. Estimates of volume for the PRA reach per interval.

Elevation	Volume above elevation	Volume of sediment above elevation	Volume of rock/till above elevation	Volume of rock above elevation	Fraction of rock	Side slope volume above elevation
MLLW, ft	cuyd	cuyd	cuyd	cuyd		cuyd
-47ft	2,384,733	2,384,030	703	210	0.0001	39,056
-49ft	3,485,583	3,482,215	3,368	1,799	0.0005	72,741
-51ft	4,601,953	4,591,641	10,312	6,780	0.0015	n/a

6.13 PRA sediments

The Holocene sediments at the mudline of MSCPRA are sandy in the south. Silt begins to cover the sands as one moves north through the PRA (Figures 53-54, 56 and 58). The USACE-NAE has tested the Recent silt in the PRA and the Reserved Channel areas as suitable for ocean disposal. Below the Holocene, Pleistocene Boston Blue Clay constitutes the bulk of the material to be dredged (Figures 57-60). The Pleistocene till at the base is compact and may be difficult to dislodge and remove by a clamshell (Figures 57-61).

6.14 PRA rock

The Cambridge Argillite forms east trending ridges with pinnacles (Figure 69 and 70). The argillite in the PRA is distinguished by the lack of cleavage observed in the borings. The absence of cleavage may render excavator purchase more difficult than if the rock had stronger cleavage. Figure 63 plots the top of fast rock. Figure 66 plots the isopach map of fast rock. Figure 67 plots the slice map of fast rock at -49ft for the entire -47ft project. Figure 70 plots the seismic-velocity cross section in the PRA. Figure 71 plots the side scan orthosonograph of rock subcrops in the PRA. Table 41 describes the estimated rock area in the PRA. Table 42 describes the estimated rock volume in the PRA.

Table 41. Estimates of rock area in the PRA.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	sqft
-47ft	15,479	6,677	0
-49ft	61,754	41,264	1
-51ft	127,024	93,711	400

Table 42. Estimates of rock volume in the PRA.

Elevation	Volume of till/rock above elevation	Volume of rock above elevation	Volume of fast rock above elevation
MLLW, ft	cuyd	cuyd	cuyd
-47ft	703	210	0
-49ft	3,368	1,799	0
-51ft	10,312	6,780	5

6.15 PRA debris

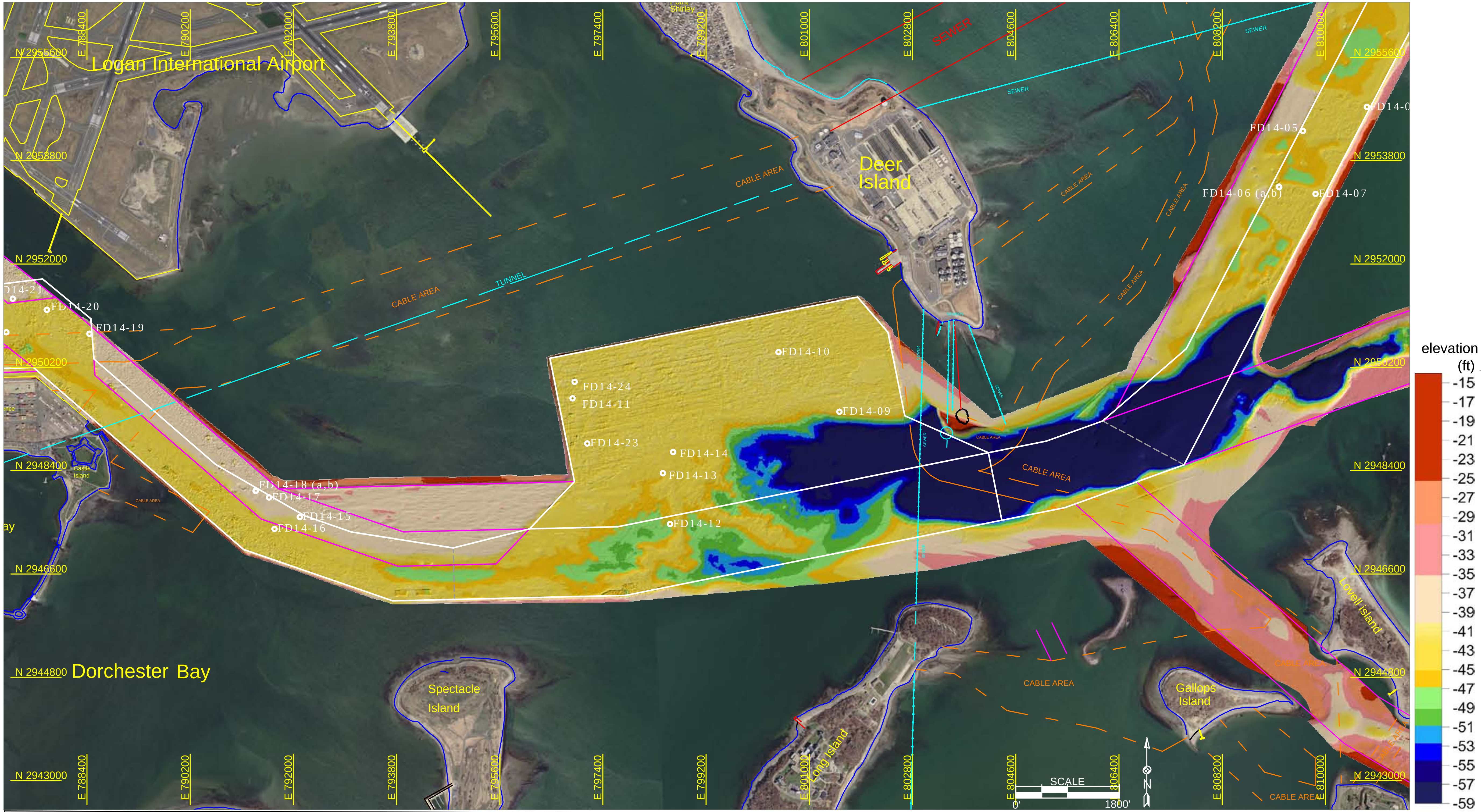
The PRA may have lobster pots and other debris on the bottom. These objects may constitute a small but real cost to the dredger to sort from his dredge volume.

6.16 PRA infrastructure

Cables run north and east of the Anchorage boundary. There are no cables and pipelines within the PRA as far as e4 has been able to discern. Of course, that would make sense for an anchorage. But the USACE-NAE should make sure to map all crossings before the plans and specifications go out to bid.

6.17 Additional PRA dredging concerns

A principal issue in dredging is efficiency. This involves lost time due to maintenance, traffic, and weather. The heave from swells should be minimal because the dredge may be protected by Deer Island. If the dredger were to use an excavator to rip or use a cutterhead dredge to grind the rock, his equipment may of course require maintenance.



Planimetrics provided by USACE-NAE, New England District

Proposed channel

e4sciences area divisions

Sewer area

Sewer and tunnel area

Cable area

Channel outline, 2010

Shoreline and dock

Land planimetrics

As drilled boring locations

Massachusetts Mainland State Plane Feet Coordinate System

North American Datum of 1983 (NAD83)

Vertical datum: MLLW (NAVD 1988)

2013 Orthophotos: USGS and Massachusetts

Figure 52. Multibeam bathymetry in the President Roads Anchorage area, plotted with core boring locations.

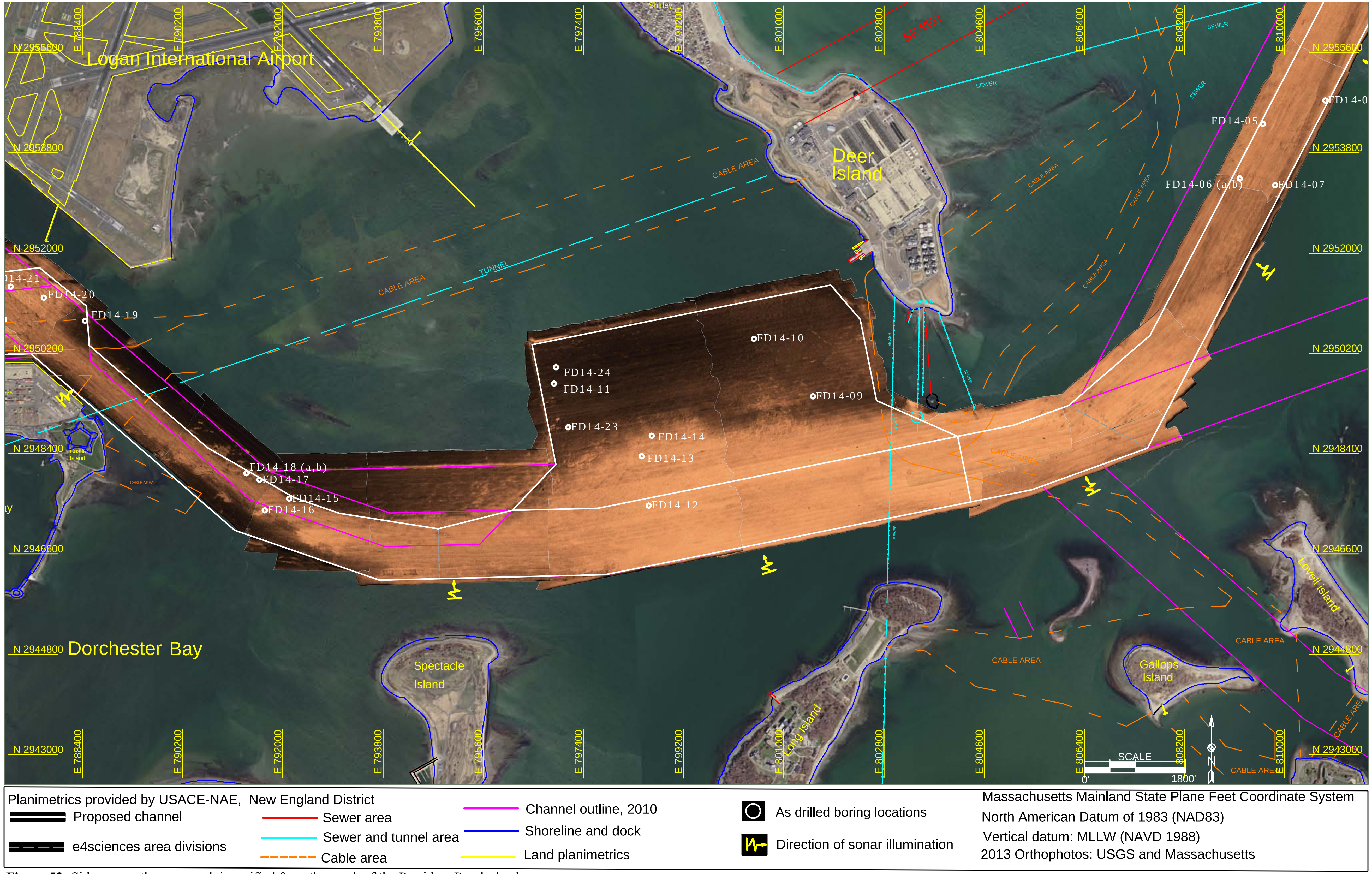
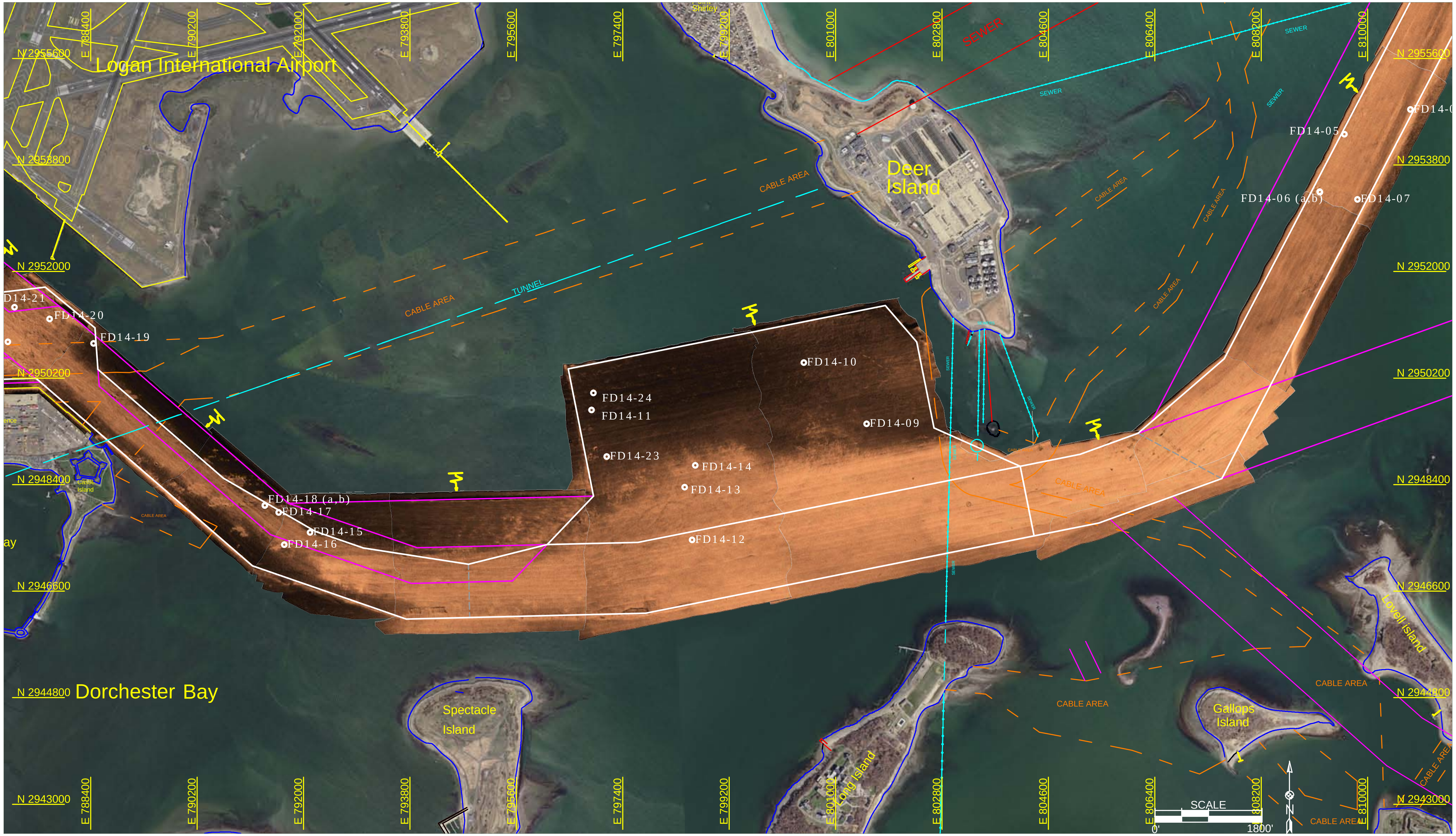


Figure 53. Side-scan orthosonograph insonified from the south of the President Roads Anchorage area.

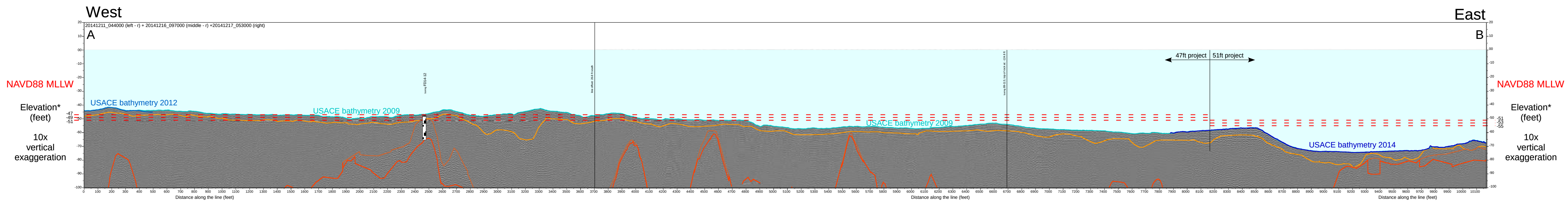


Planimetrics provided by USACE-NAE, New England District

- Proposed channel
- e4sciences area divisions
- Sewer area
- Sewer and tunnel area
- Cable area
- Channel outline, 2010
- Shoreline and dock
- Land planimetrics
- As drilled boring locations
- Direction of sonar illumination

Massachusetts Mainland State Plane Feet Coordinate System
North American Datum of 1983 (NAD83)
Vertical datum: MLLW (NAVD 1988)
2013 Orthophotos: USGS and Massachusetts

Figure 54. Side-scan orthosonograph insonified from the north of the President Roads Anchorage area.



KEY

- Improvement Dredge Depth
- Bottom of Black Silt
- Top of Pleistocene
- Top of Till and Rock
- Top of Rock (Cambridge Argillite)
- USACE bathymetry 2014
- USACE bathymetry 2012
- USACE bathymetry 2009

*Note:
Elevation below mudline is approximate. No sediments were sampled. Elevations are from modeled seismic velocities for suspected sediments in the area.

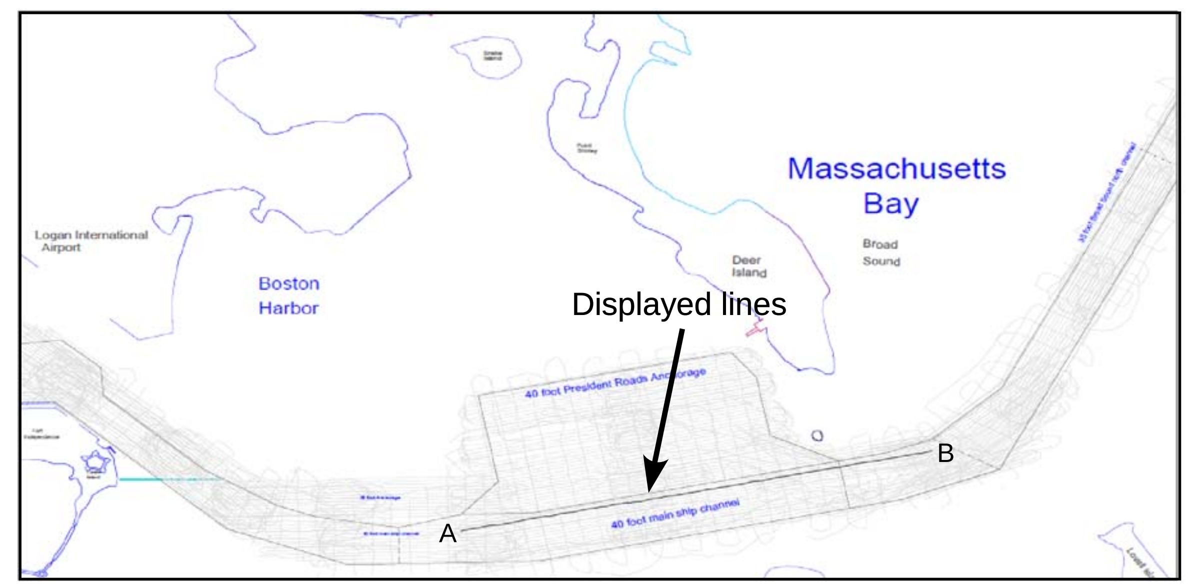


Figure 55. Seismic cross section in MSCPRA.

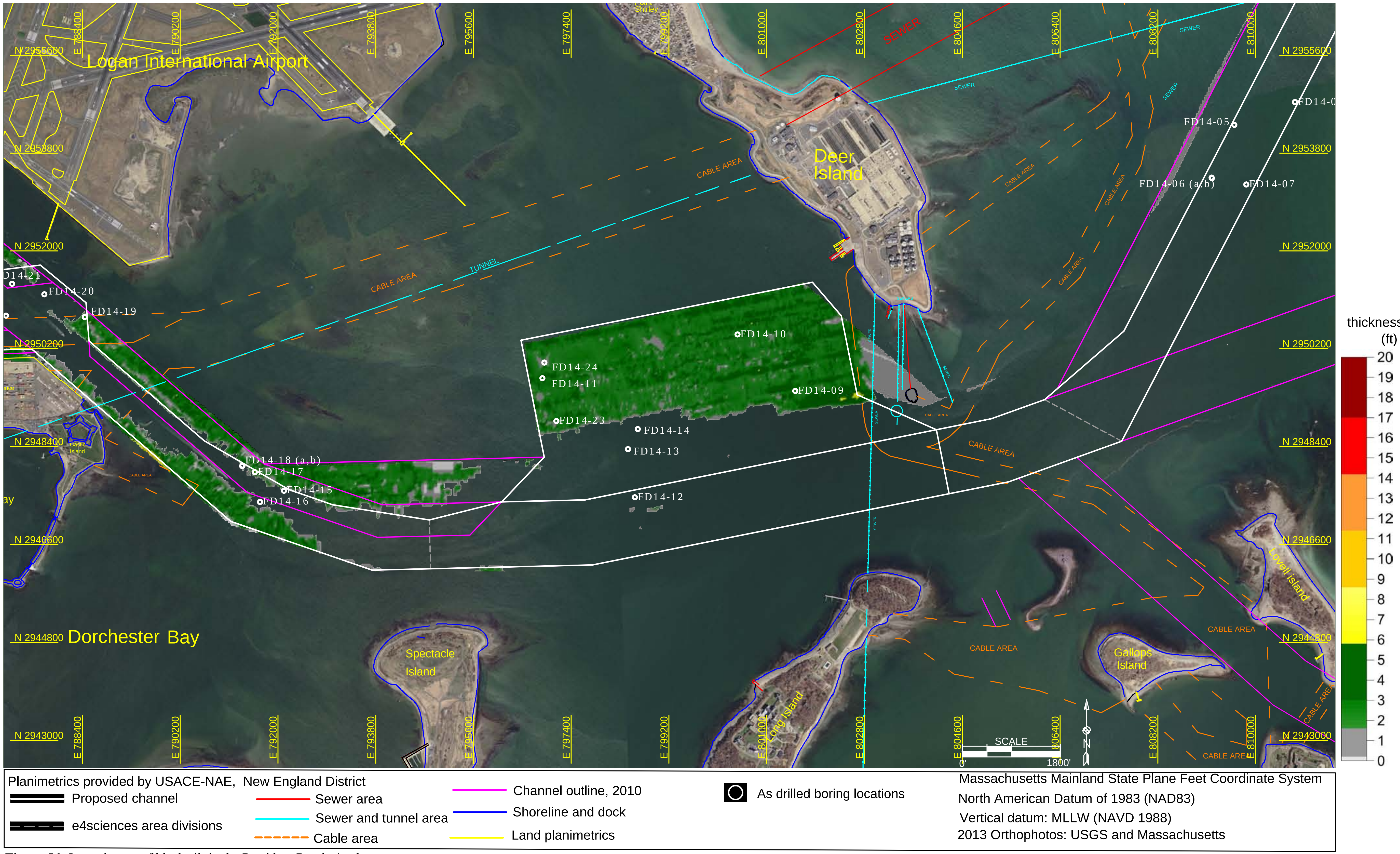


Figure 56. Isopach map of black silt in the President Roads Anchorage area.

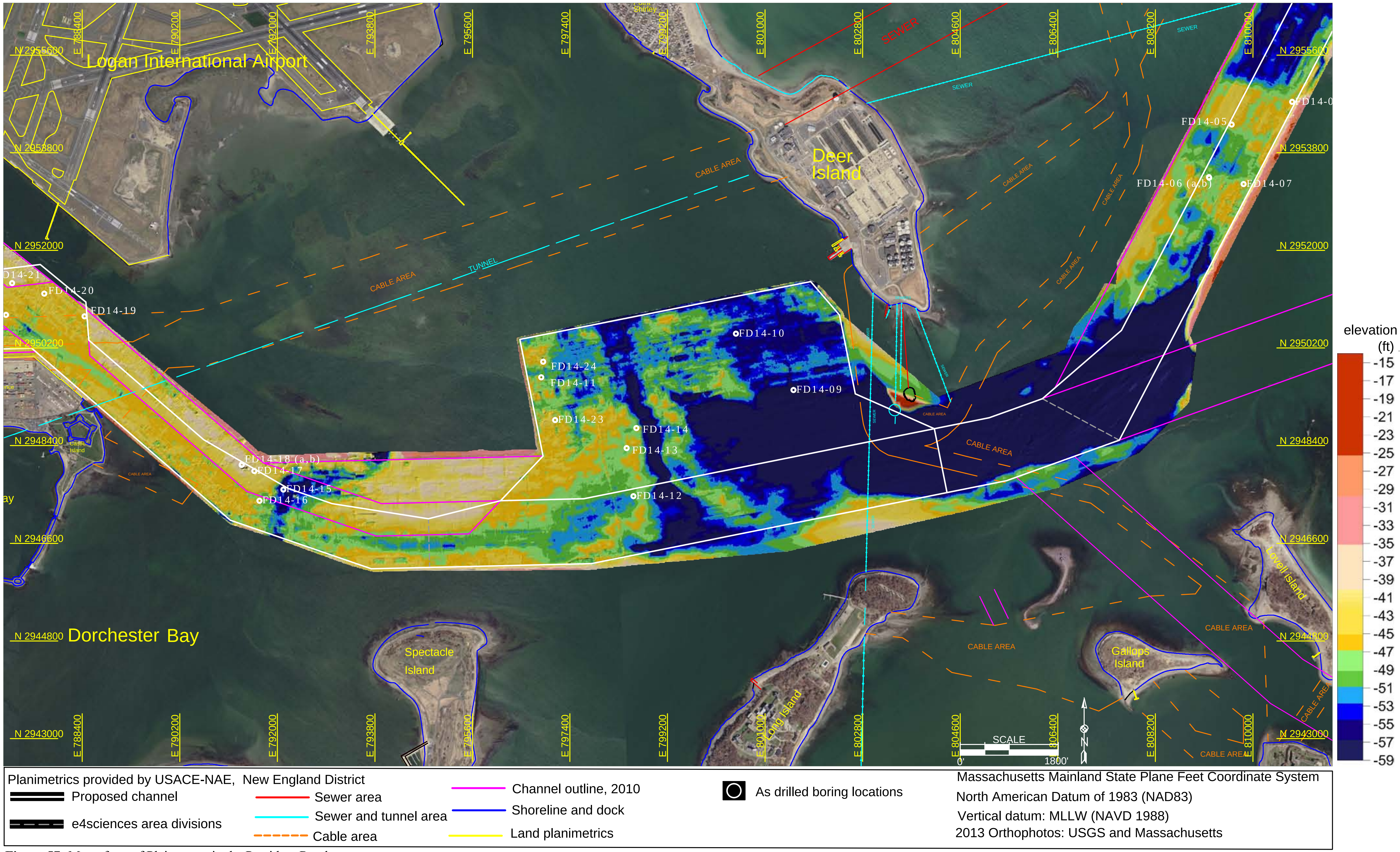


Figure 57. Map of top of Pleistocene in the President Roads area.

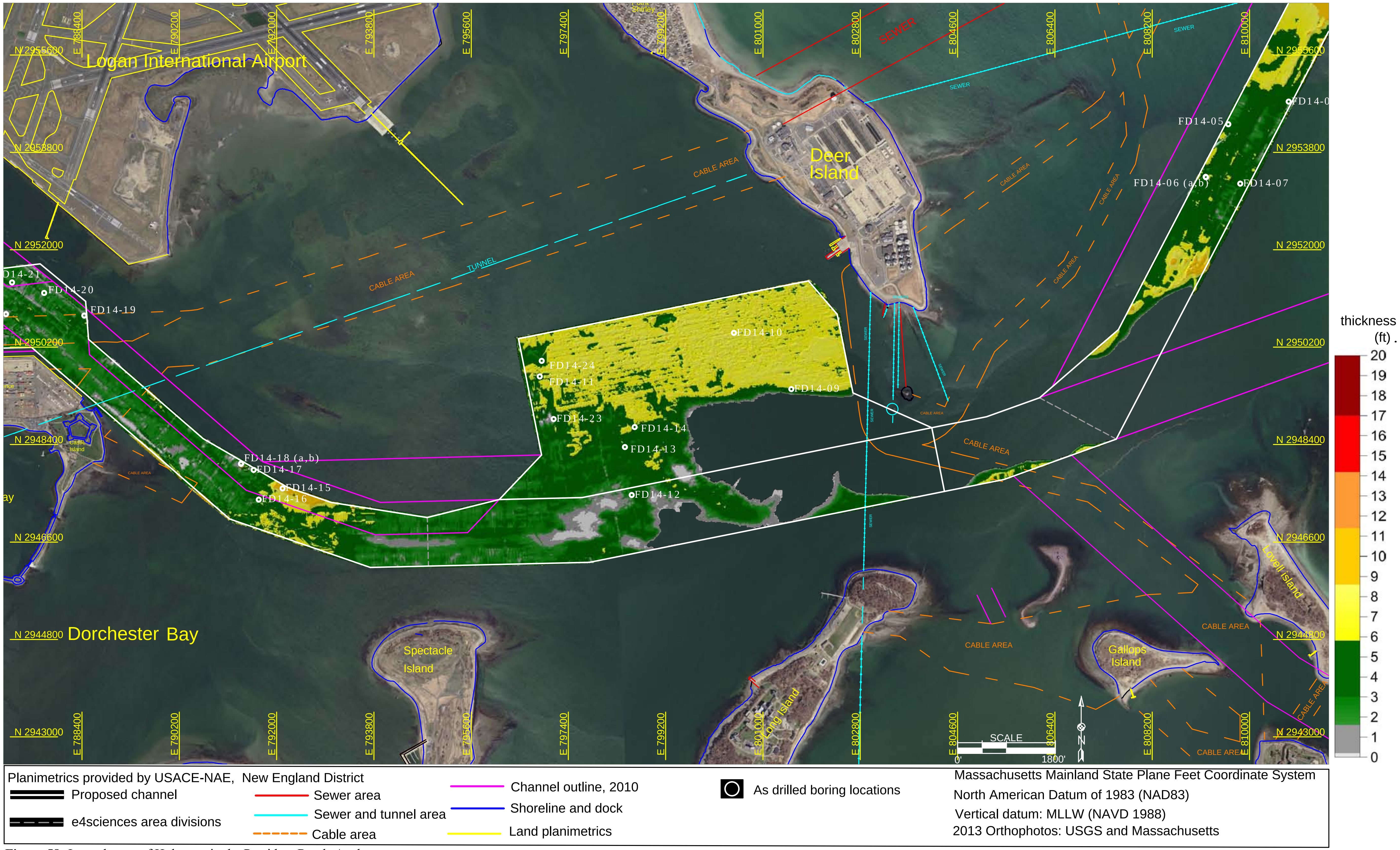


Figure 58. Isopach map of Holocene in the President Roads Anchorage area.

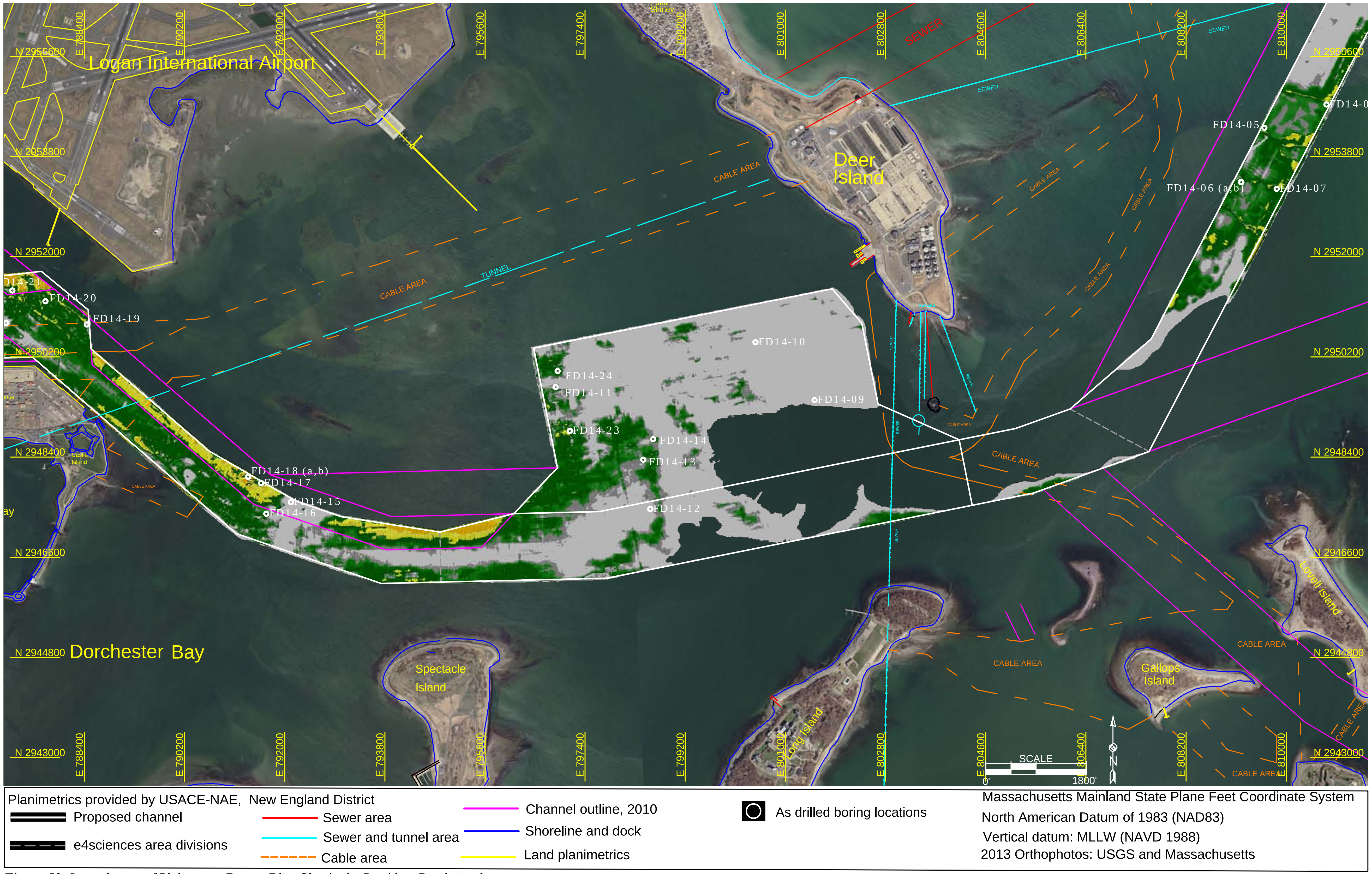


Figure 59. Isopach map of Pleistocene Boston Blue Clay in the President Roads Anchorage area.

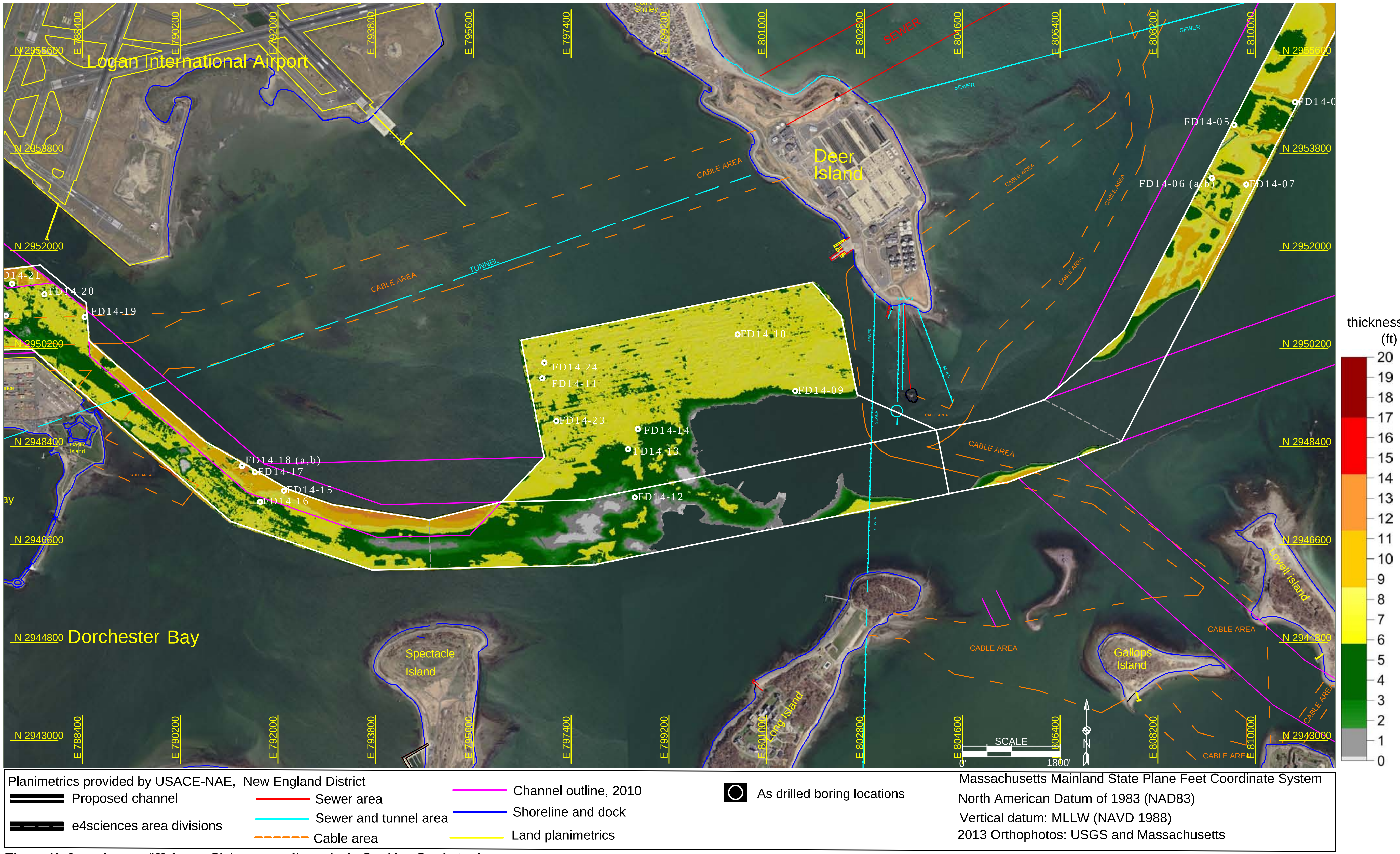


Figure 60. Isopach map of Holocene-Pleistocene sediment in the President Roads Anchorage area.

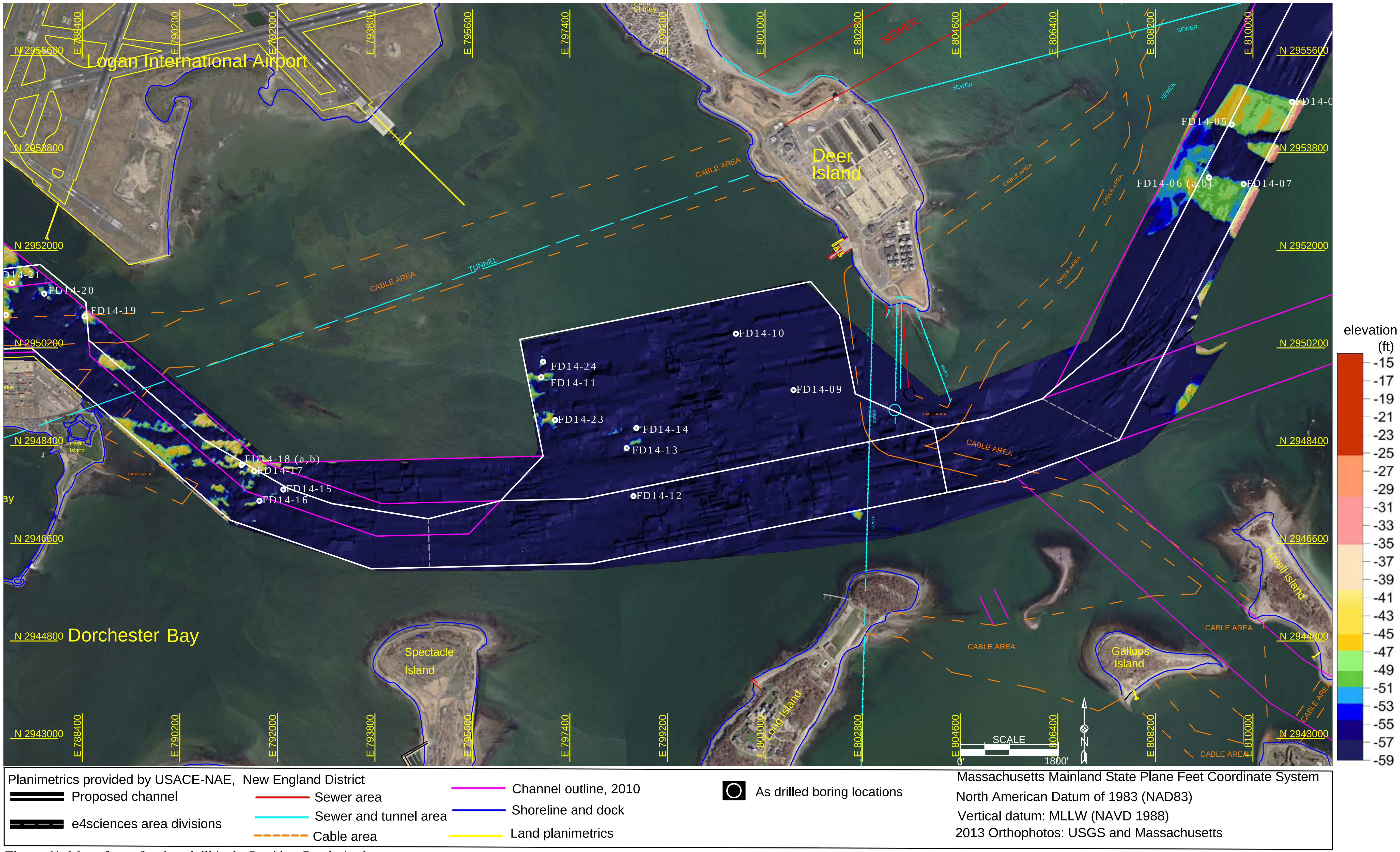


Figure 61. Map of top of rock and till in the President Roads Anchorage area.

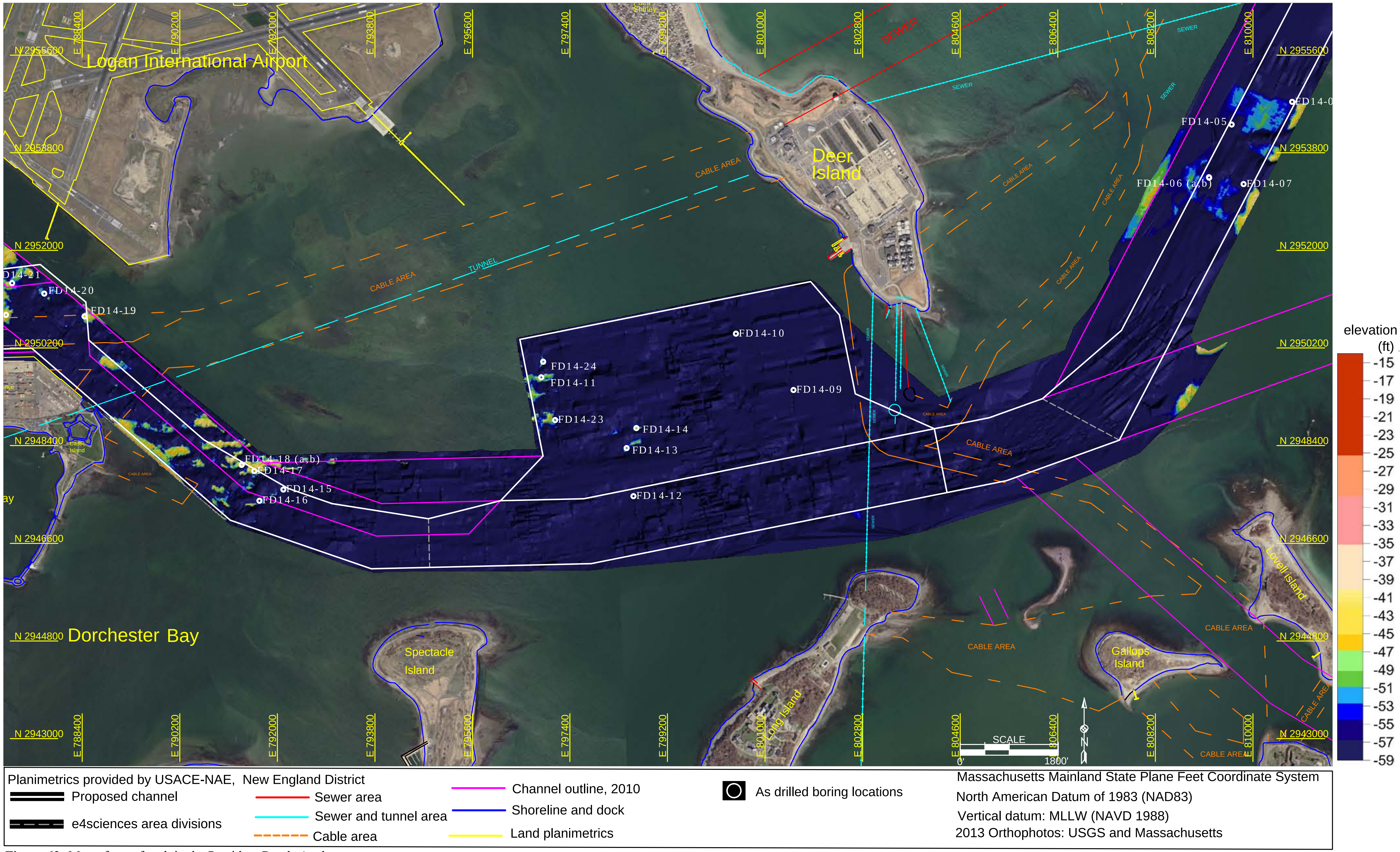


Figure 62. Map of top of rock in the President Roads Anchorage area.

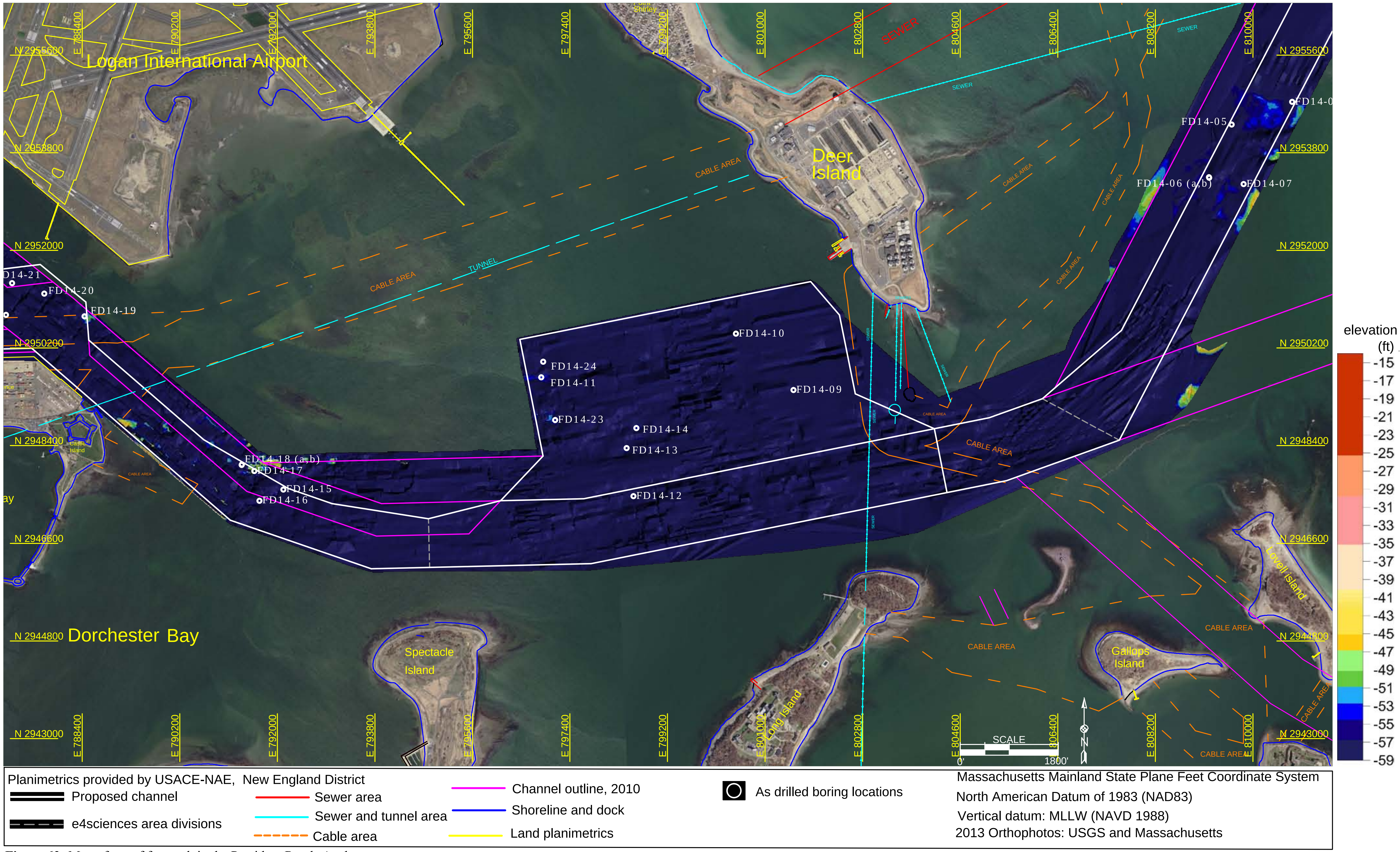


Figure 63. Map of top of fast rock in the President Roads Anchorage area.

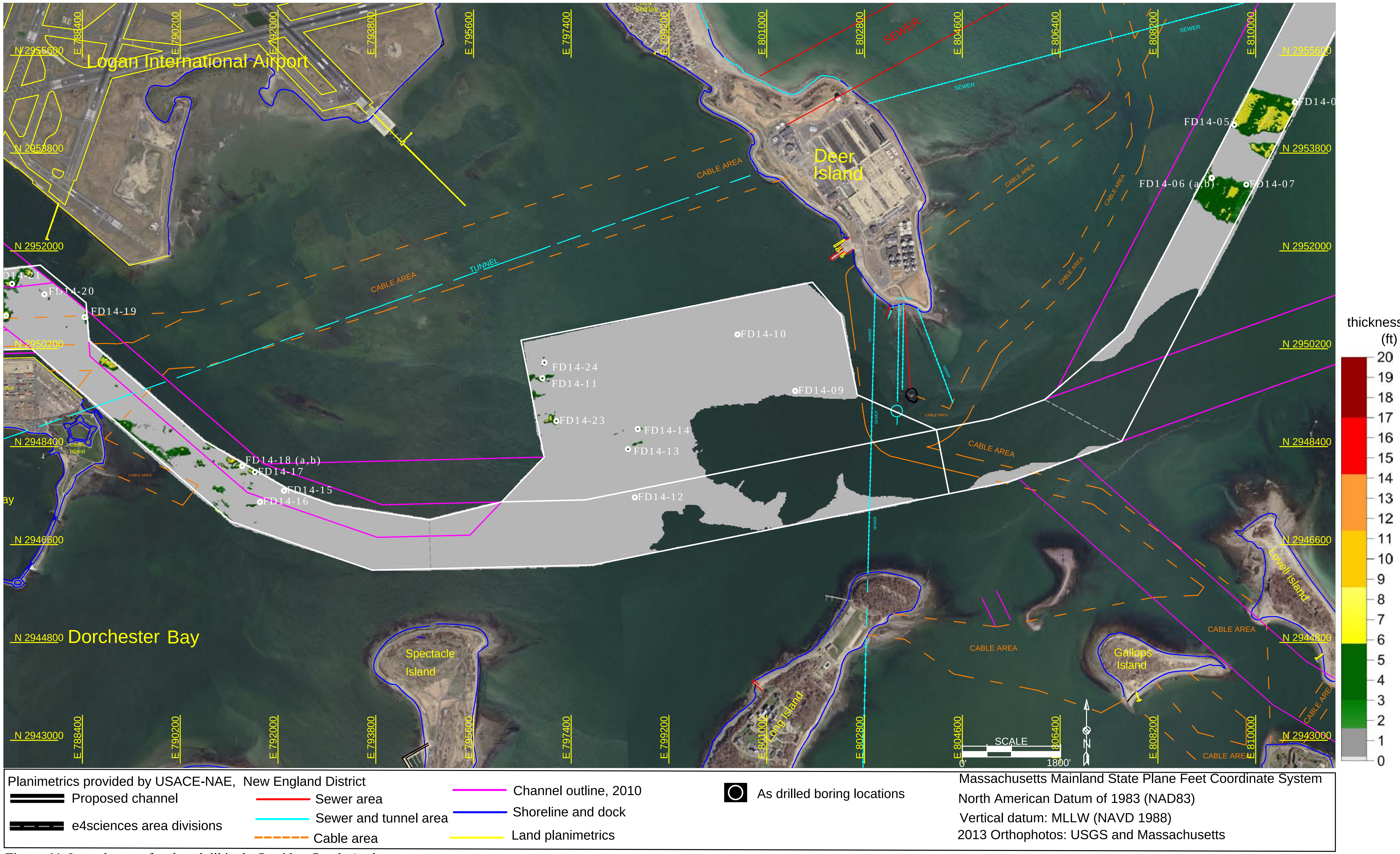


Figure 64. Isopach map of rock and till in the President Roads Anchorage area.

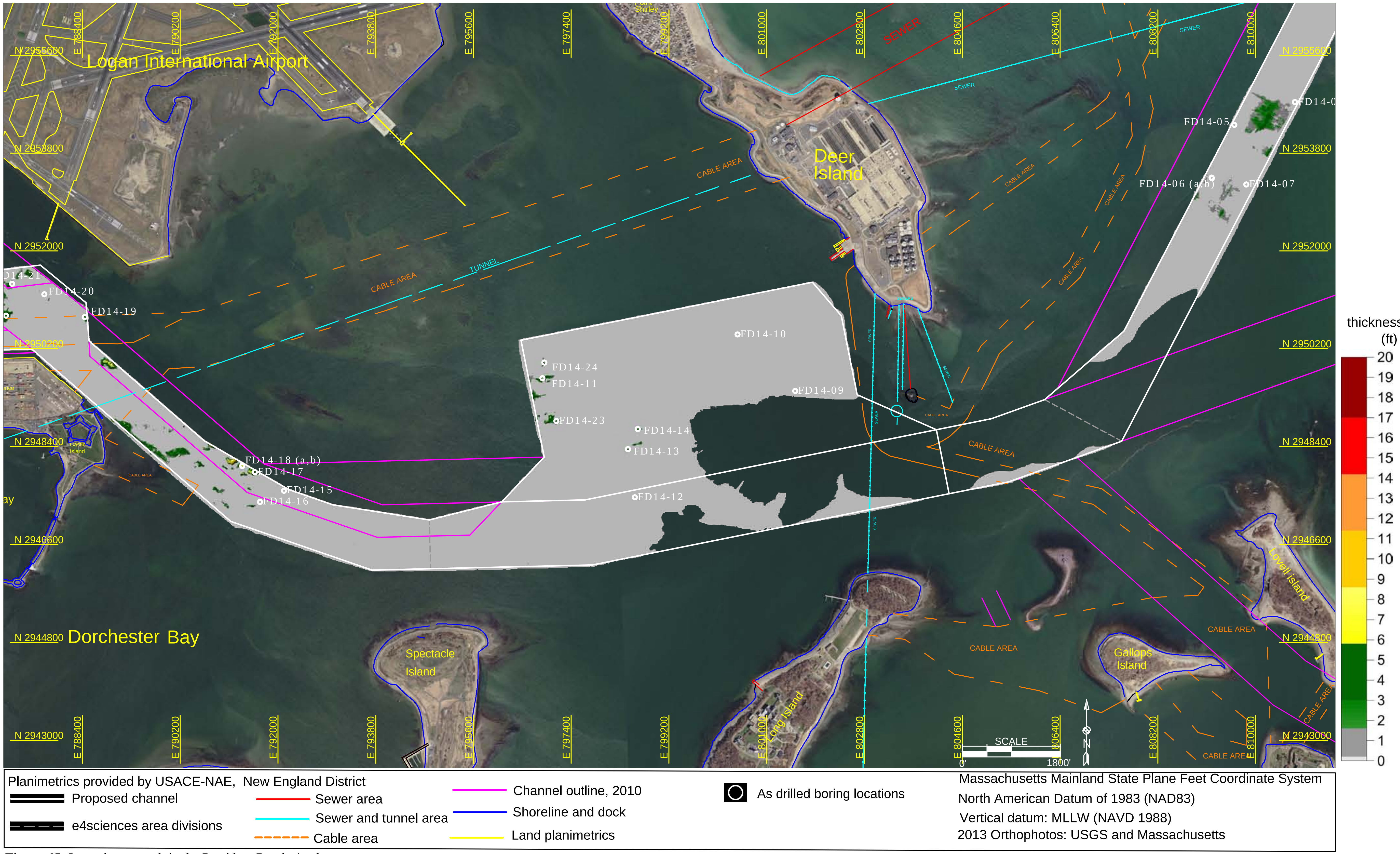


Figure 65. Isopach map rock in the President Roads Anchorage area.

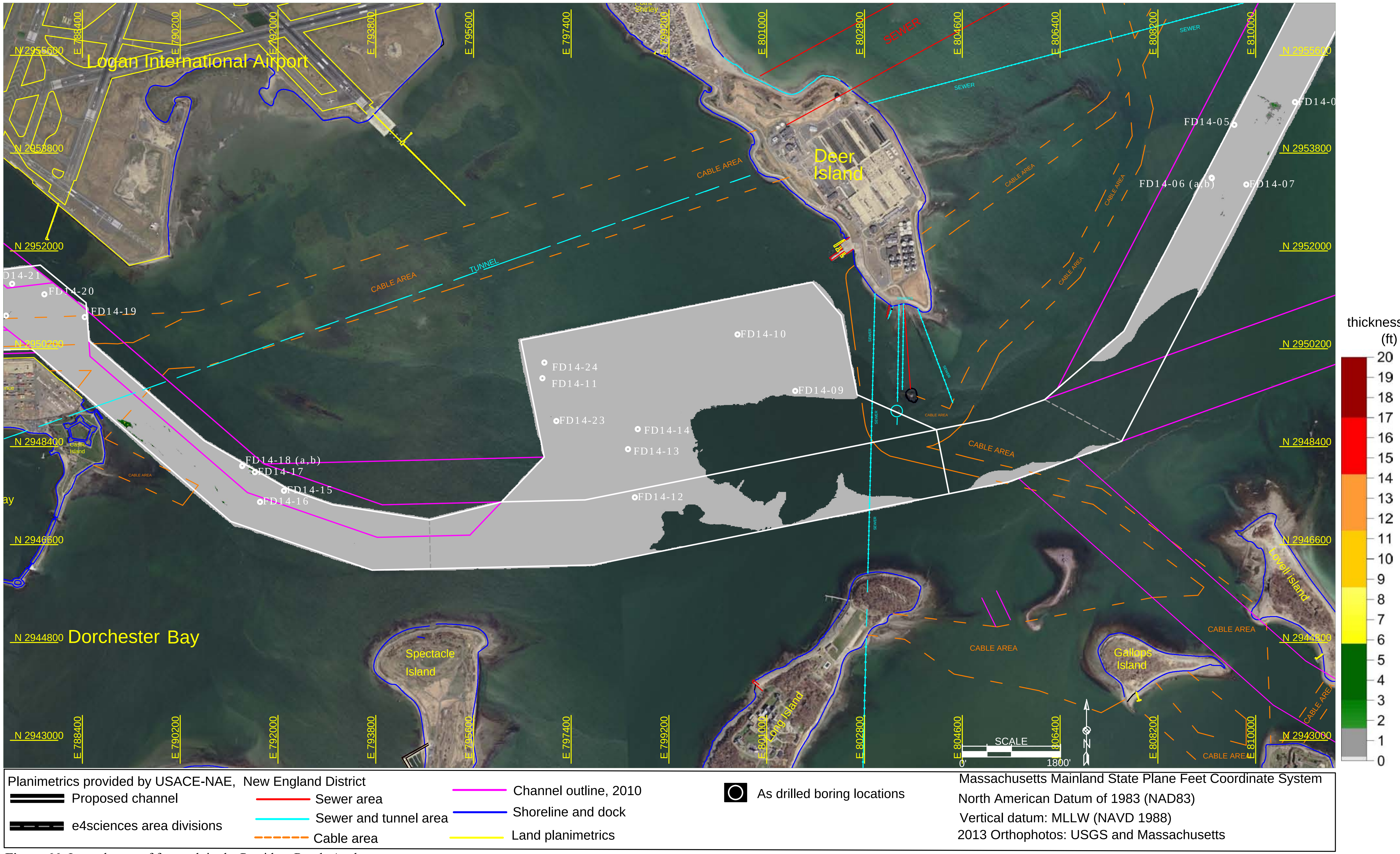
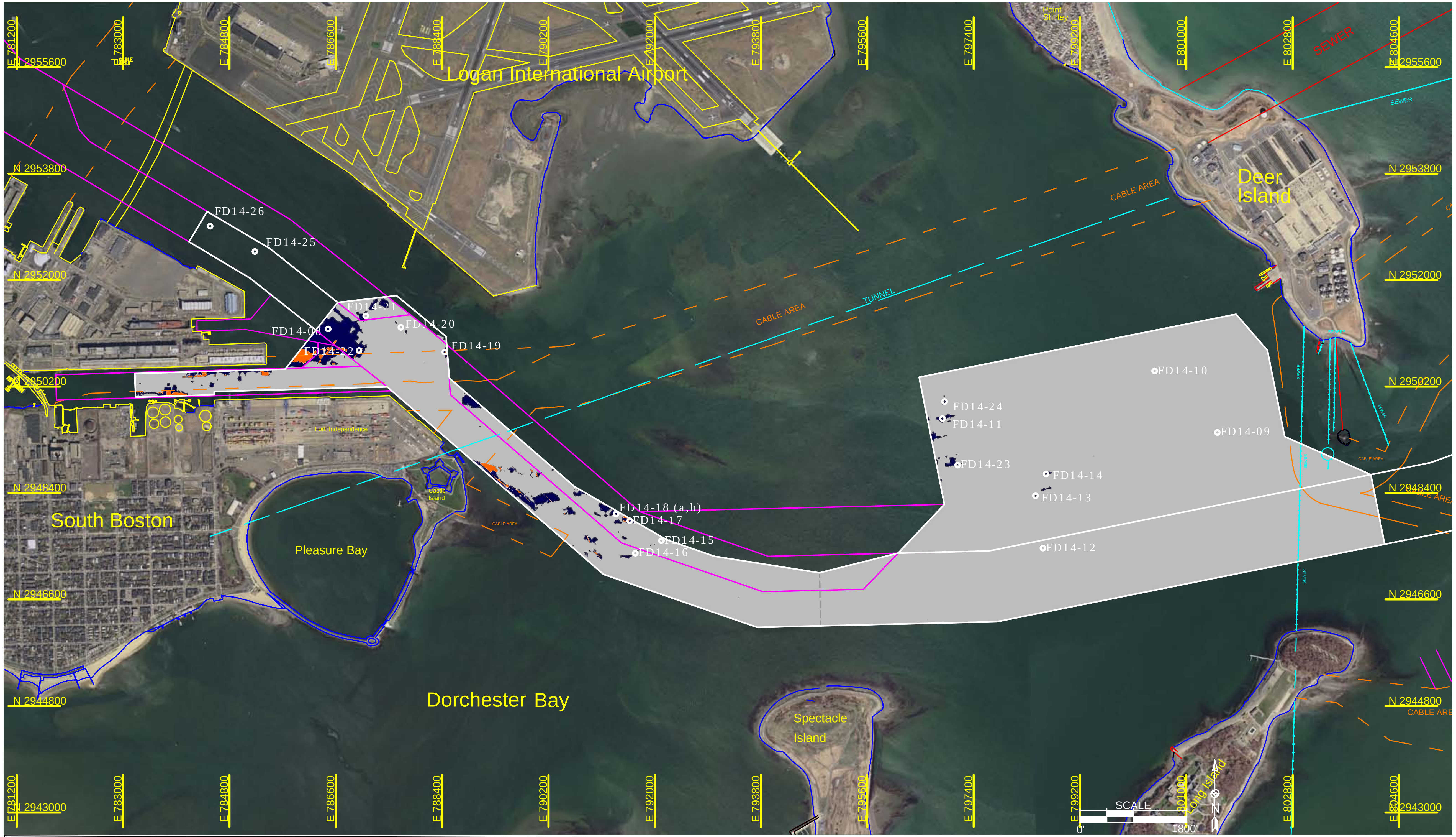


Figure 66. Isopach map of fast rock in the President Roads Anchorage area.



Planimetrics provided by USACE-NAE, New England District				Massachusetts Mainland State Plane Feet Coordinate System
Proposed channel	Sewer area	Channel outline, 2010	As drilled boring locations	North American Datum of 1983 (NAD83)
e4sciences area divisions	Sewer and tunnel area	Shoreline and dock		Vertical datum: MLLW (NAVD 1988)
	Cable area	Land planimetrics		2013 Orthophotos: USGS and Massachusetts

Figure 67. Slice map at -49ft of fast rock in the entire -47ft project. Orange represents fast rock at -49ft. Blue represents rock at -49ft. Gray represents rock at -51ft.

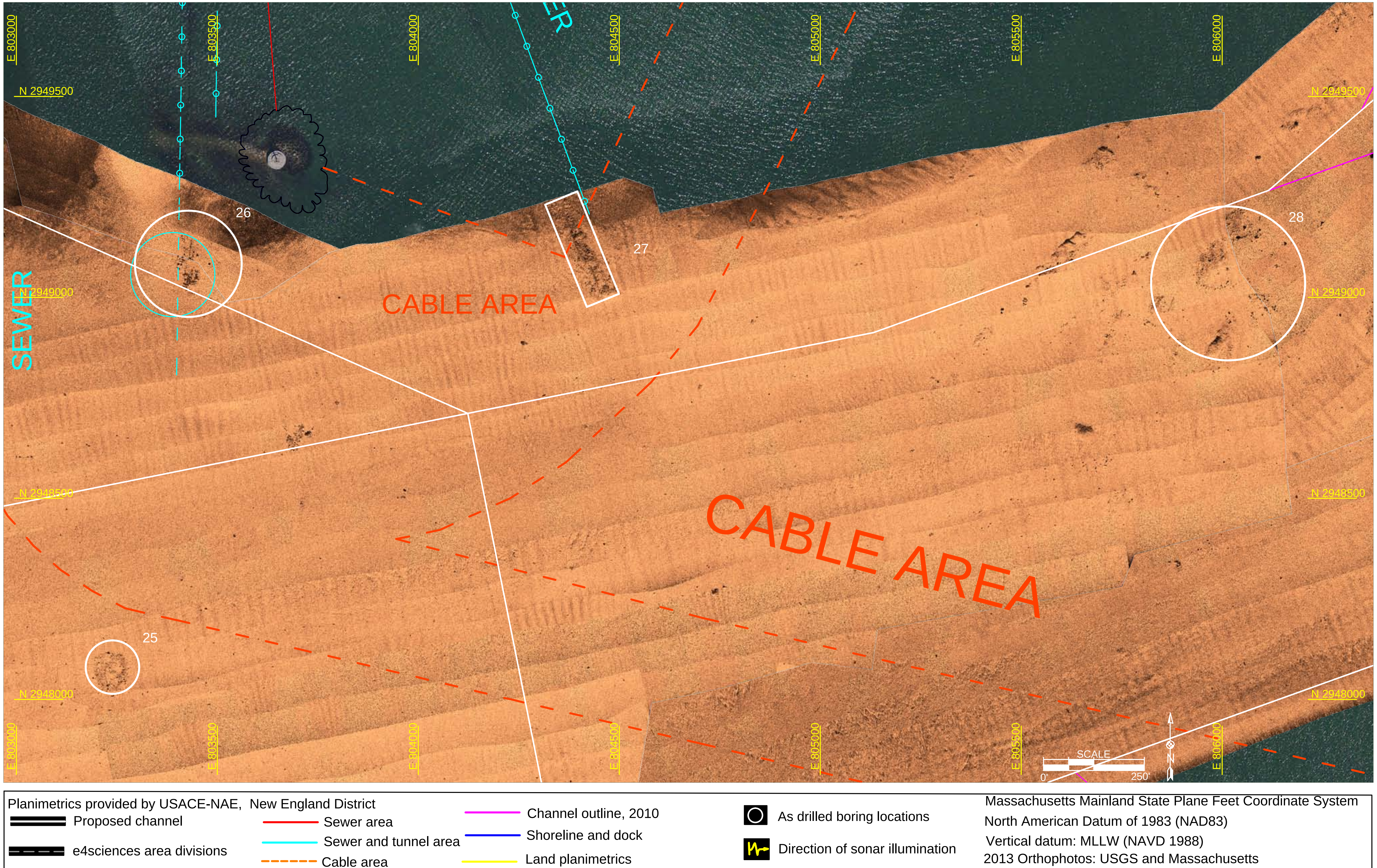


Figure 68. Side-scan orthosonograph with targets in the cable area of the President Roads Anchorage Area.

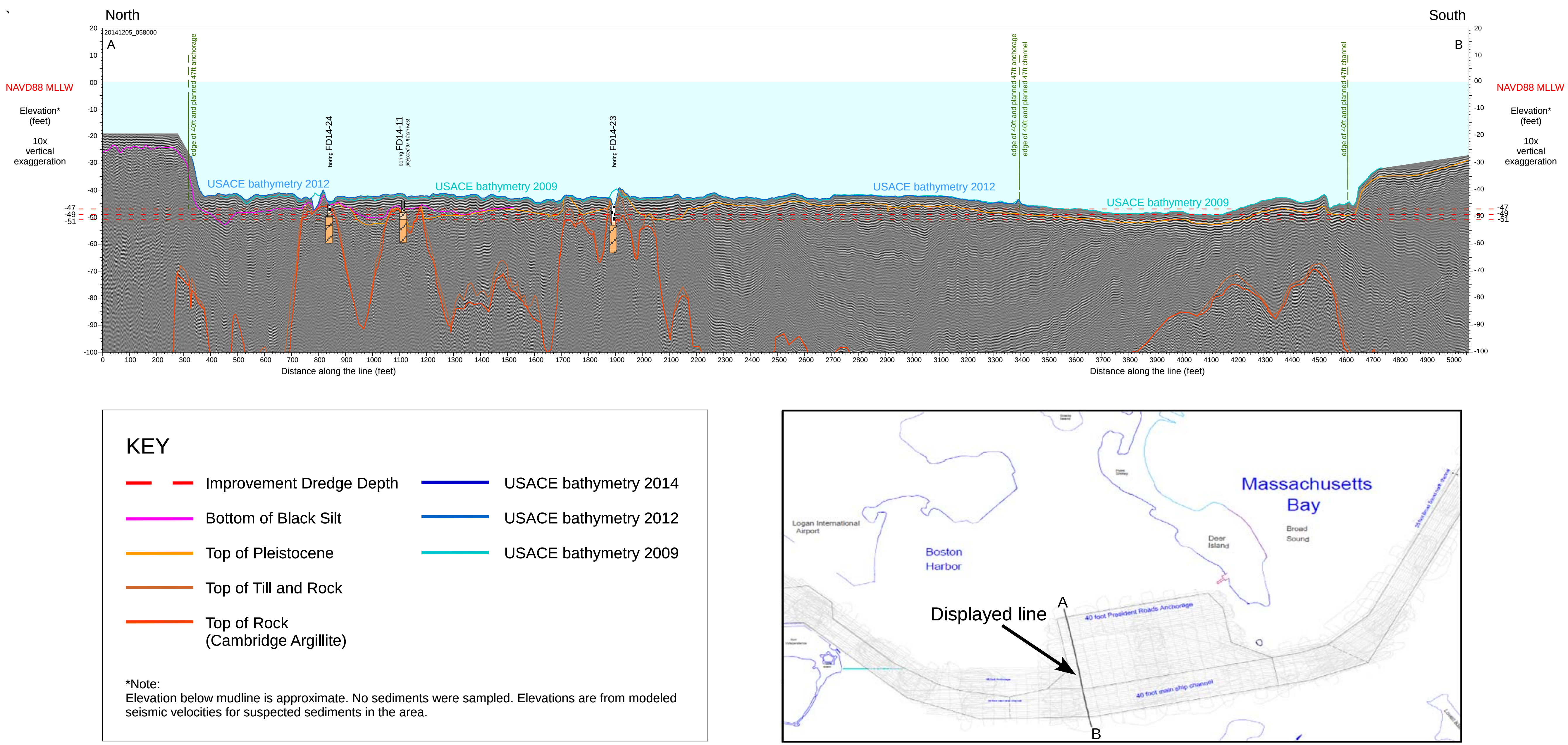


Figure 69. Seismic cross section through the PRA.

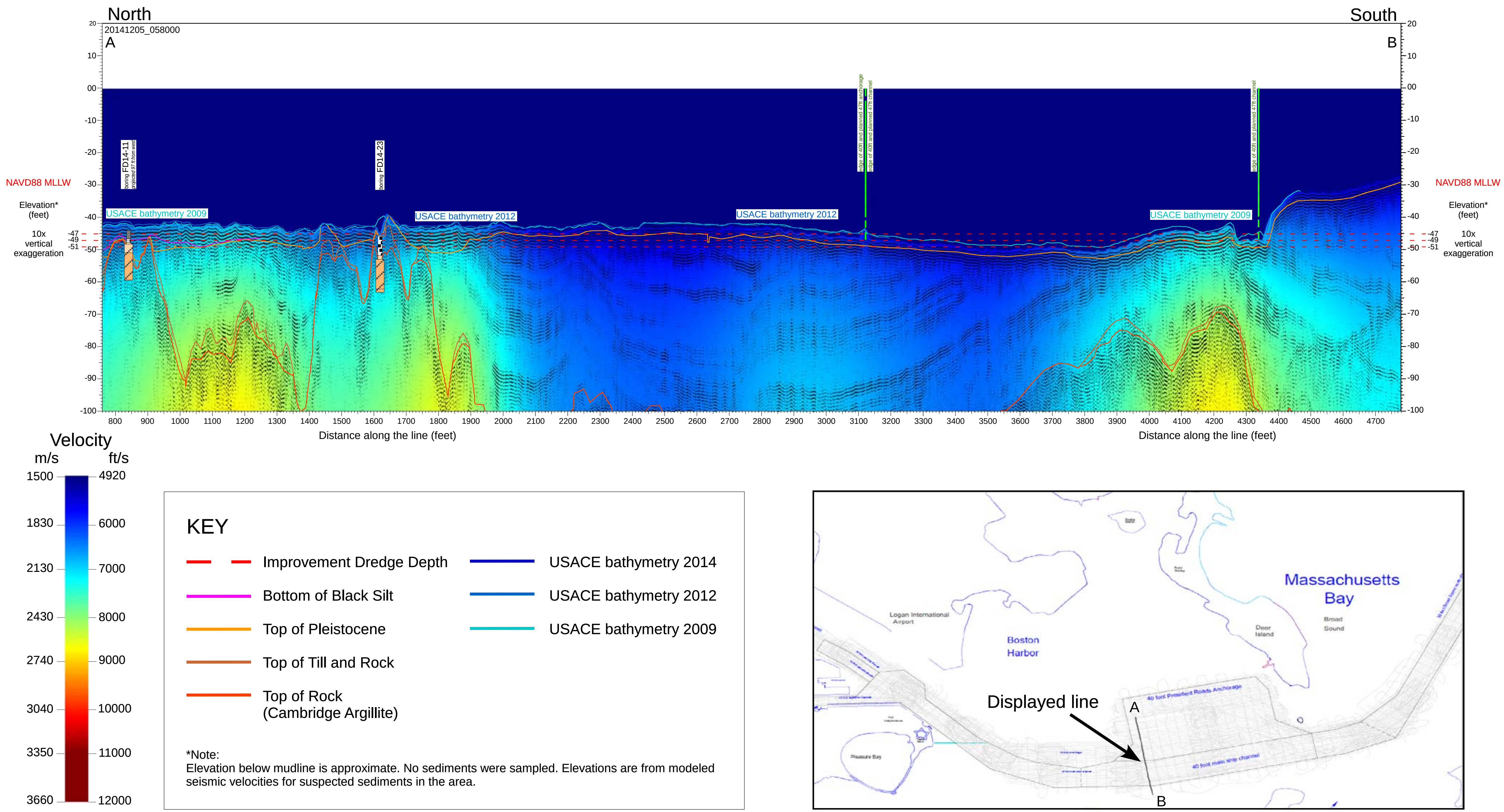


Figure 70. Seismic-velocity cross section in President Roads Anchorage Area.

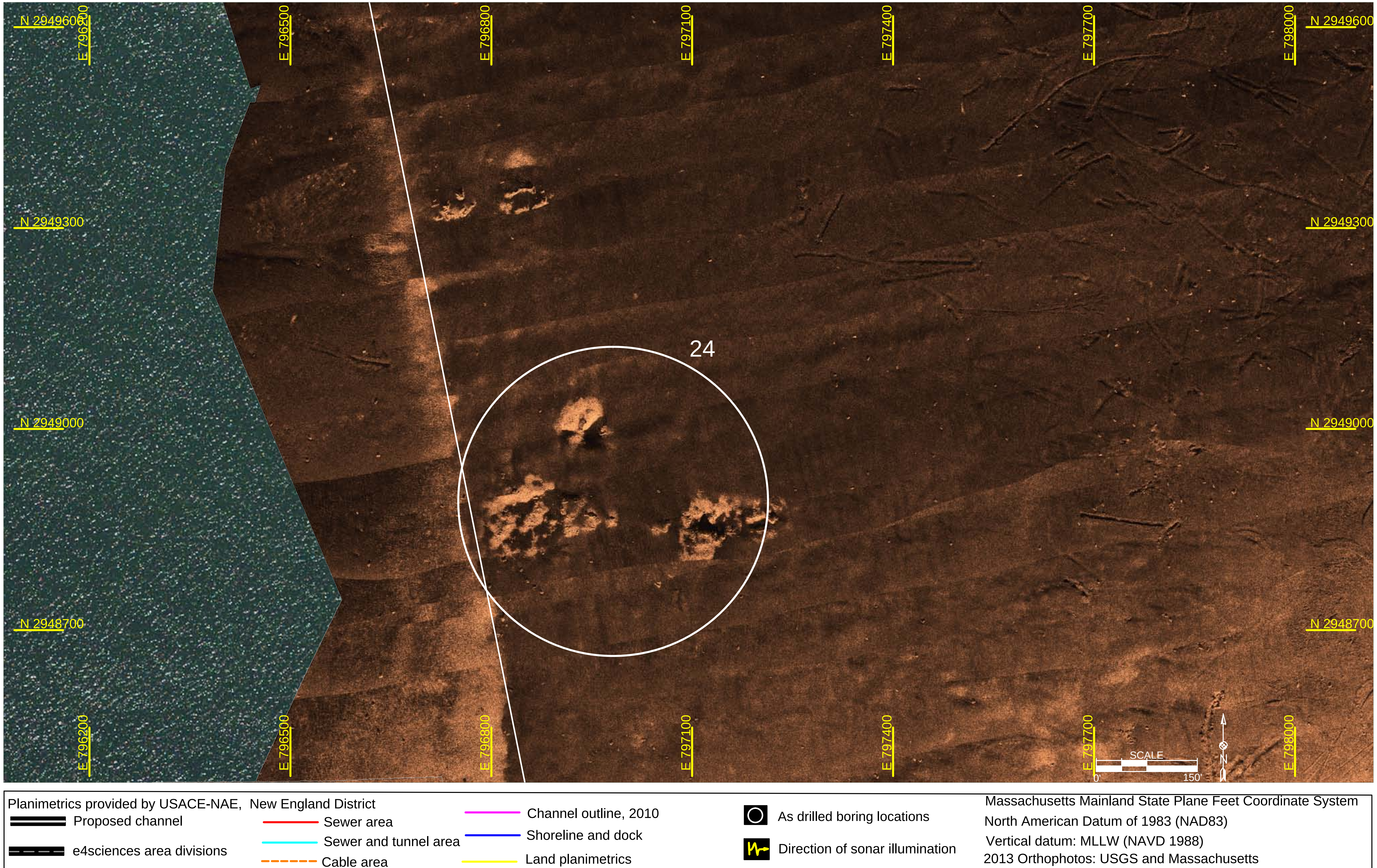


Figure 71. Side-scan orthosonograph of the rock subcrops in PRA.

7.0 The Reserved Channel Area: The Main Ship Channel, Turning Basin, Reserved Channel, and the Main Ship Channel at the Massport Maritime Terminal

Other than heave in the North Channel, the challenge for dredging is greatest in the Reserved Channel area. The relative amounts of fast rock and the compressional velocity of rock are highest in the Reserved Channel area.

Plate 27 plots the pair of orthosonographs for the Reserved Channel area. Plates 28-30 plot the seismic sections. Plate 31 plots the results of the geological investigation in the Reserved Channel area. The four maps show the elevation of the mudline, the top of the Pleistocene, the top of the till and rock, and the top of the rock in the Reserved Channel area.

Plate 32 plots the results of the geotechnical investigation in the Reserved Channel area. The four maps show the isopach maps for silt, Holocene and Pleistocene, till and rock, and rock thickness. Plate 33 shows a slice map of fast rock at the -47ft overdepth. Plate 34 is a seismic-velocity cross section showing fast rock in the Reserved Channel area.

7.1 Main Ship Channel in Reserved Channel area geography

The Main Ship Channel in the Reserved Channel area (MSCRCA) connects the MSCPRA to the Reserved Channel and the Main Ship Channel at the Massport Maritime Terminal. The MSCRCA is 10,500ft long, roughly east-southeast to west-northwest. The width is 850ft.

7.2 MSCRCA grade

The existing grade of the mudline is -40ft MLLW. Figure 72 plots the bathymetry with the core borings located. The newly authorized grade in the MSCRCA is elevation -47ft MLLW. An optional 2ft paid overdepth in sediments brings the elevation to -49ft MLLW. If there is rock or hard bottom, the required overdepth is -49ft. An optional paid overdepth in the case of rock adds another 2ft depth bringing the elevation to -51ft.

7.3 MSCRCA stratigraphy

The dredging of the MSCRCA presents several challenges. Fine-grained organic-rich Holocene sediments, silts, were observed. The orthosonograph in Figure 73 displays the footprint of the silt material. The USACE has tested the Recent silt in the Reserved Channel areas as suitable for ocean disposal. Figure 74 shows the paired orthosonograph insonified from the north. Figure 75 plots the targets on the orthosonograph for the Main Ship Channel. High east to west ridges of Cambridge Argillite (Figure 76) reach up into the dredging prism to -38ft in the north lane (Figure 77). Figure 78 plots the top of rock. Less compact tills remain between the clays and the argillite (Figure 79). The Pleistocene Boston Blue Clay was deposited between the ridges (Figure 80). Table 43 describes the estimated area for the MSCRCA per interval. Table 44 describes the estimated volume for the MSCRCA per interval.

Table 43. Estimates of area for the MSCRCA reach per interval. Total area of the MSCRCA = 8,093,959sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	sqft	sqft
-47ft	7,795,707	647,304	511,550	542,795
-49ft	8,045,075	882,118	705,810	607,394
-51ft	8,046,909	1,071,518	878,440	n/a

Table 44. Estimates of volume for the MSCRCA reach per interval.

Elevation	Volume above elevation	Volume of sediment above elevation	Volume of rock/till above elevation	Volume of rock above elevation	Fraction of rock	Side slope volume above elevation
MLLW, ft	cuyd	cuyd	cuyd	cuyd		cuyd
-47ft	1,321,583	1,262,133	59,450	40,258	0.0305	123,763
-49ft	1,914,218	1,797,268	116,950	85,922	0.0449	185,051
-51ft	2,513,754	2,323,816	189,938	145,057	0.0577	n/a

7.4 MSCRCA sediments

At the edges, the MSCRCA has a thin veneer (less than a few feet) of silt (Figure 81). The silt has been eroded in places by propeller wash (Figures 82-85). Figure 82 focuses on the bathymetry where the Reserved Channel meets the MSCRCA. The Pleistocene Boston Blue Clay constitutes (Table 44) the majority of the material to be dredged (Figure 85). An excavator could remove the till.

7.5 MSCRCA rock

The argillite varies from decomposed, highly weathered, fractured and broken rock to massive rock. The rock ridges cross the channel obliquely (Figure 86-90). The crests are high. The rock comes to the surface (Figure 89). Table 45 describes the estimated rock area in the MSCRCA. The cores of the ridges, the knobs of massive rock in the MSCRCA, constitute the fast rock (Figures 88 and 90-93). The rock here may be the most resistant to digging. The main area of concern is the area of high rock across the channel. Figure 89 shows a subcrop of rock. Table 46 describes the estimated rock volume in the MSCRCA. Figure 67 is a slice map of fast rock at elevation of -49ft for the entire -47ft project.

Table 45. Estimates of rock area in the MSCRCA.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	sqft
-47ft	647,304	511,550	23,744
-49ft	882,118	705,810	45,501
-51ft	1,071,518	878,440	84,816

Table 46. Estimates of rock volume in the MSCRCA.

Elevation	Volume of till/rock above elevation	Volume of rock above elevation	Volume of fast rock above elevation
MLLW, ft	cuyd	cuyd	cuyd
-47ft	59,450	40,258	1,615
-49ft	116,950	85,922	4,094
-51ft	189,938	145,057	8,773

7.6 MSCRCA debris

Figure 91 and 92 shows rock subcrops and a lost stick and bucket from an excavator lying on the MSCRCA floor. This object weighs several tons. The MSCRCA has many lobster pots and other debris on the bottom (Figure 93). Removing these objects may constitute a real cost to the dredger to sort them from his dredge volume.

7.7 MSCRCA infrastructure

Cables and pipelines cross from the south of the Reserved Channel across the MSCRCA (Figure 89). The cables are apparent in the orthosonographs. The plans and specification should mark the location and type of these facilities. The cables may need to be removed from the MSCRCA before dredging commences.

7.8 Additional MSCRCA dredging concerns

A principal issue in dredging is efficiency. This involves lost time due to maintenance, traffic, and weather. The treatment and ripping of the rock may wreak havoc on the equipment. Traffic in the MSCRCA will be minimal. The exposure to heave may be limited. Coordination with the airport may be required as the height of spuds and the crane may concern traffic control.

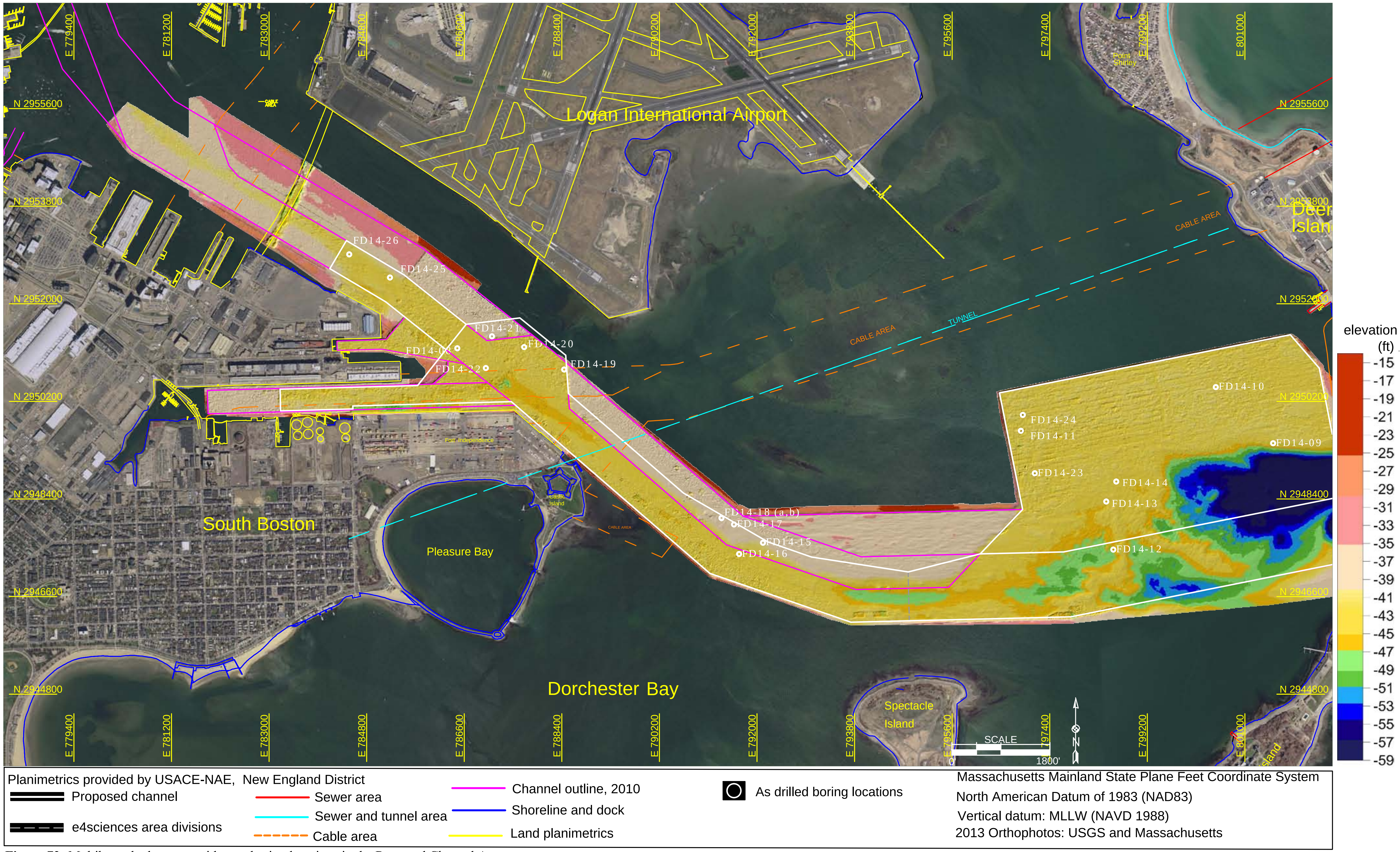


Figure 72. Multibeam bathymetry with core boring locations in the Reserved Channel Area.

Figure 73. Orthosonograph insonified from the south in the Reserved Channel Area.

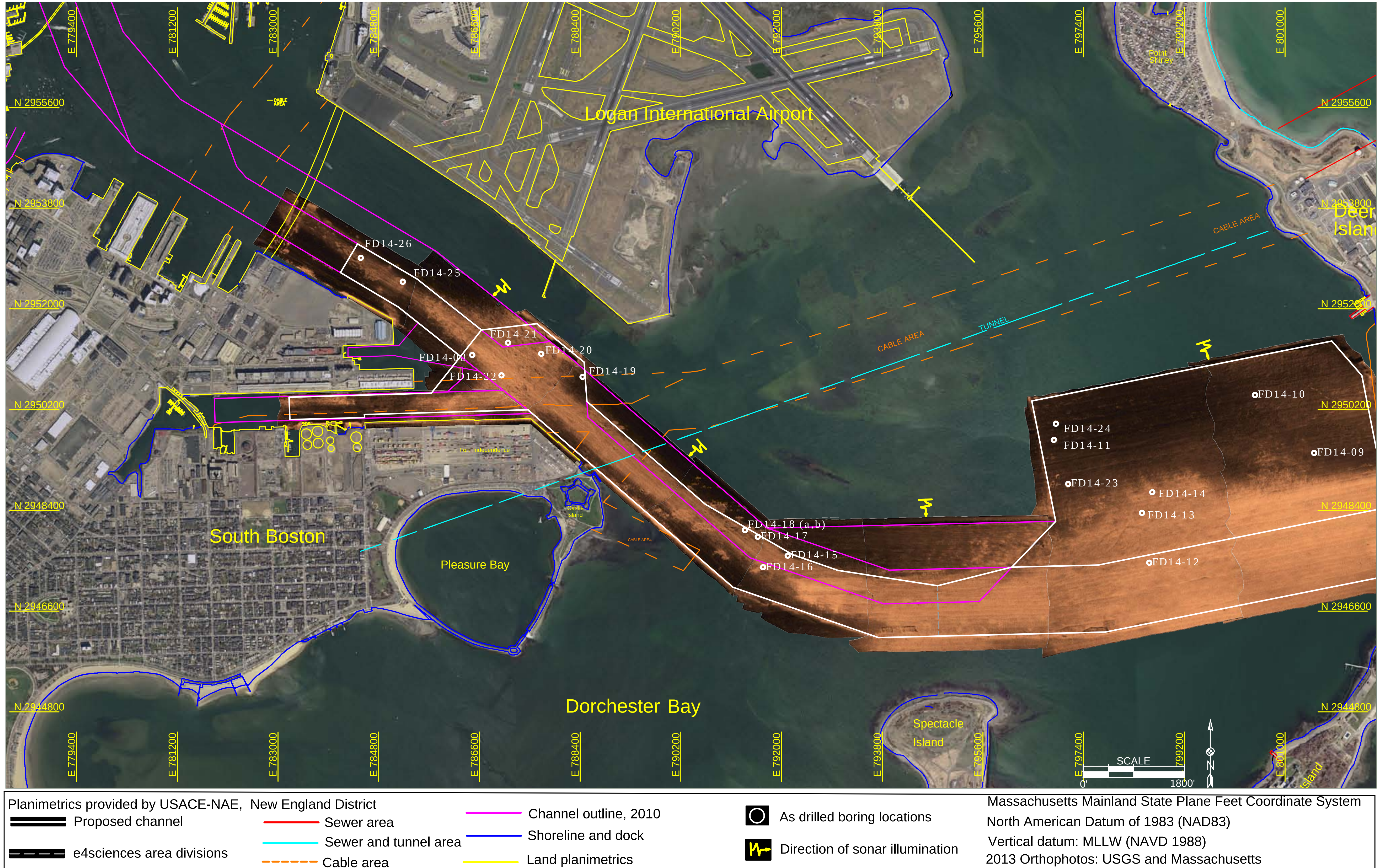
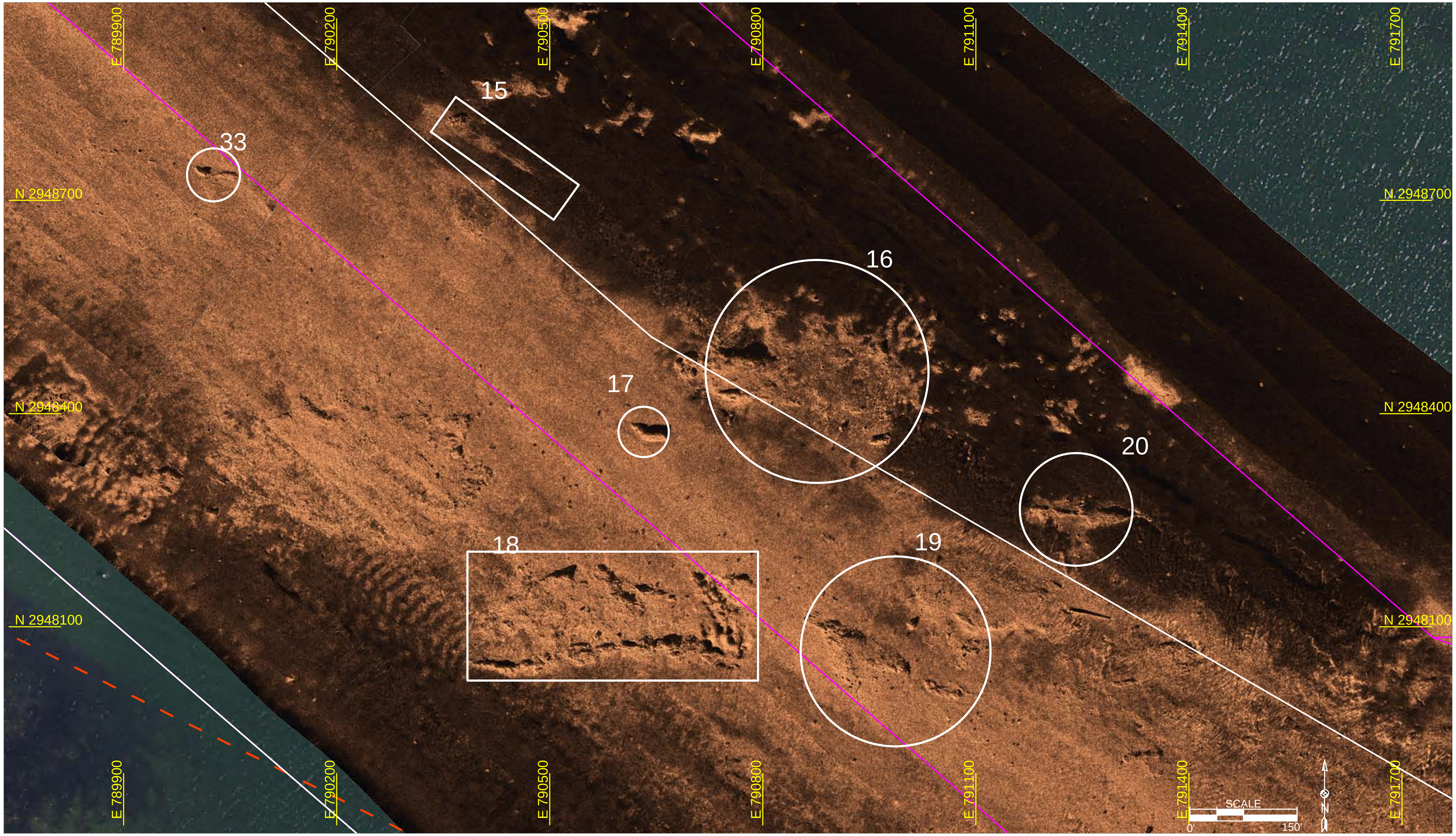


Figure 74. Orthosonograph insonified from the north in the Reserved Channel Area.



Planimetrics provided by USACE-NAE, New England District
Proposed channel
e4sciences area divisions
Sewer area
Sewer and tunnel area
Cable area
Channel outline, 2010
Shoreline and dock
Land planimetrics
As drilled boring locations
Direction of sonar illumination
Massachusetts Mainland State Plane Feet Coordinate System
North American Datum of 1983 (NAD83)
Vertical datum: MLLW (NAVD 1988)
2013 Orthophotos: USGS and Massachusetts

Figure 75. Orthosonograph with targets in the MSCRCA.

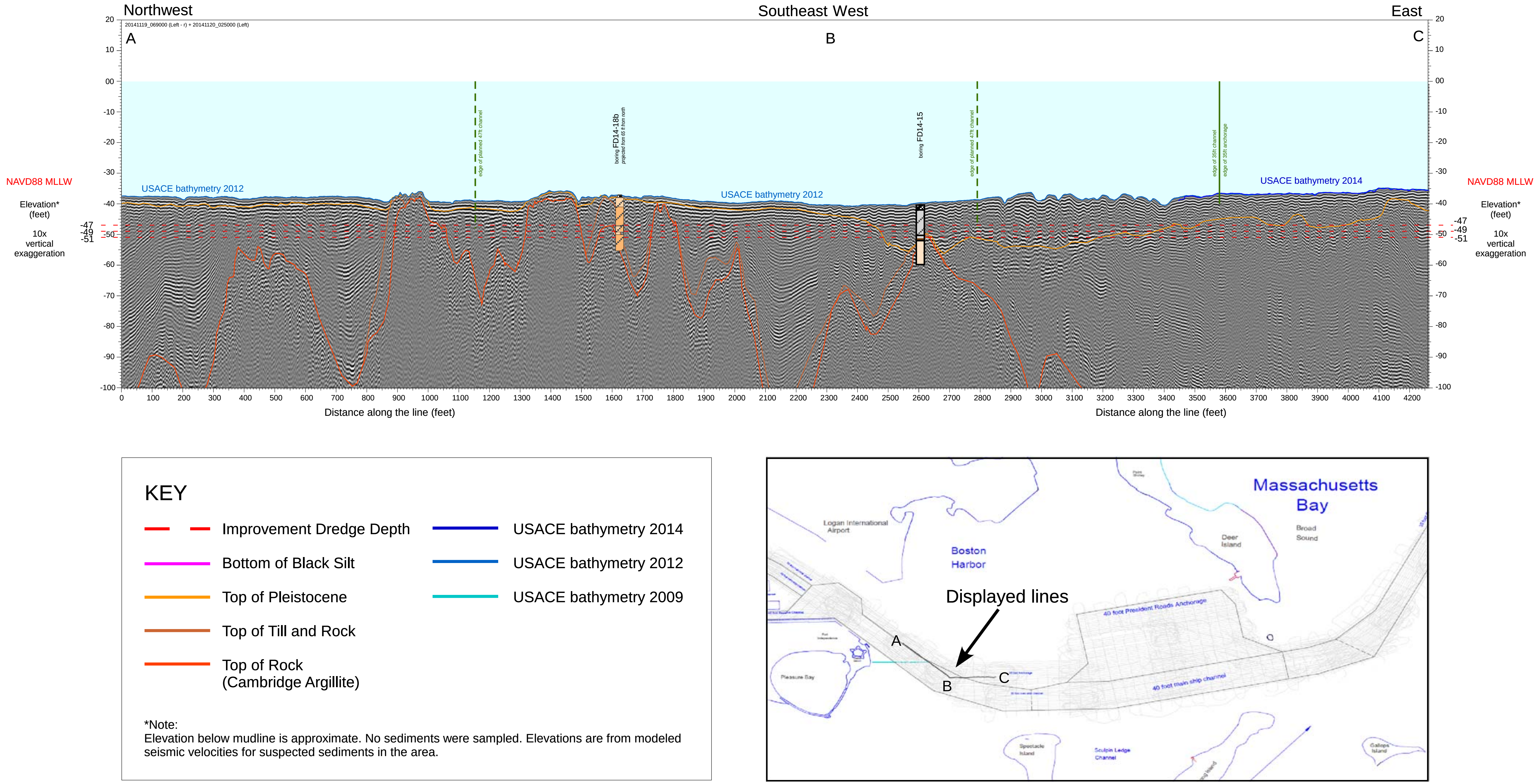


Figure 76. Seismic cross section of MSCRCA.

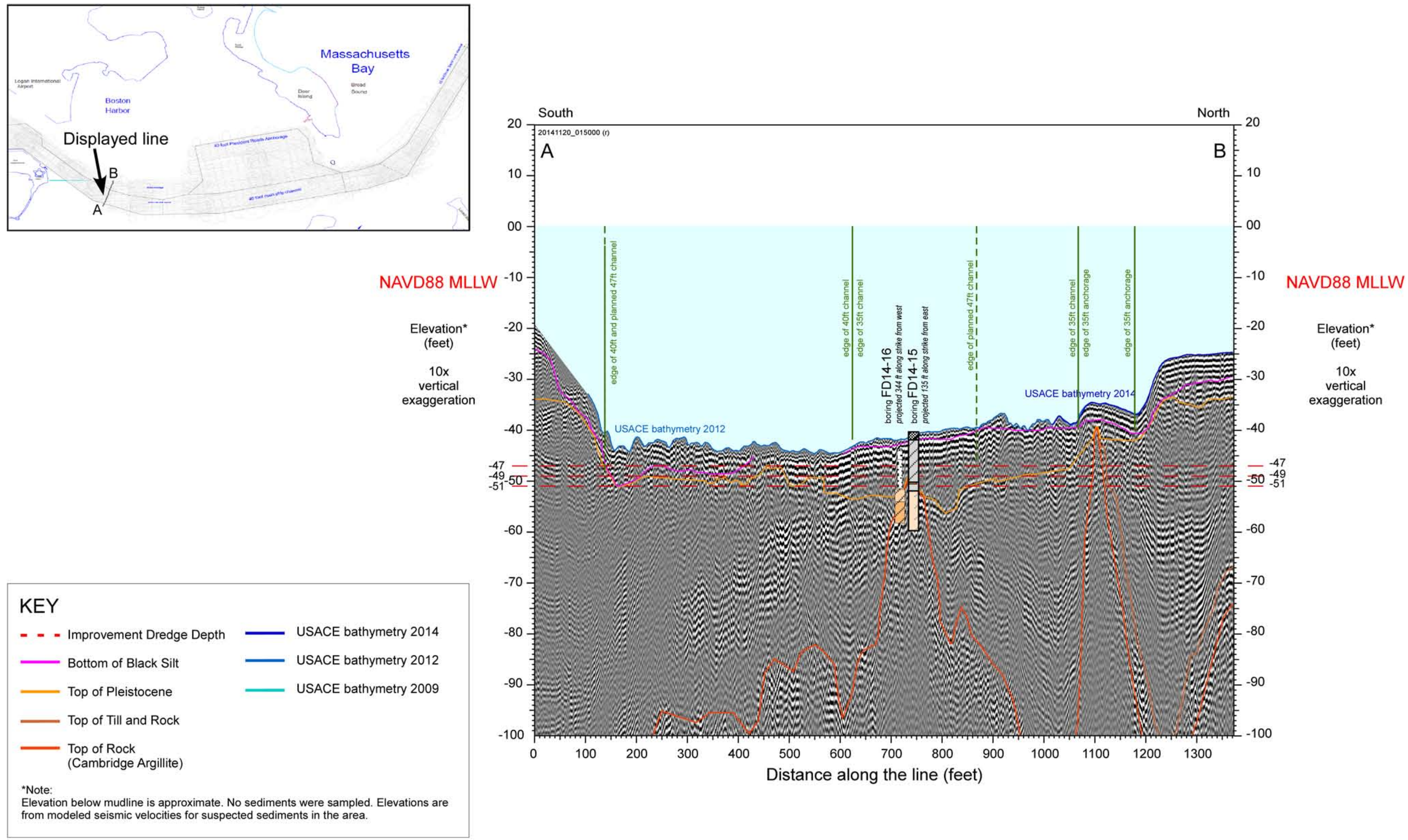


Figure 77. Seismic cross section across the MSCRCA.

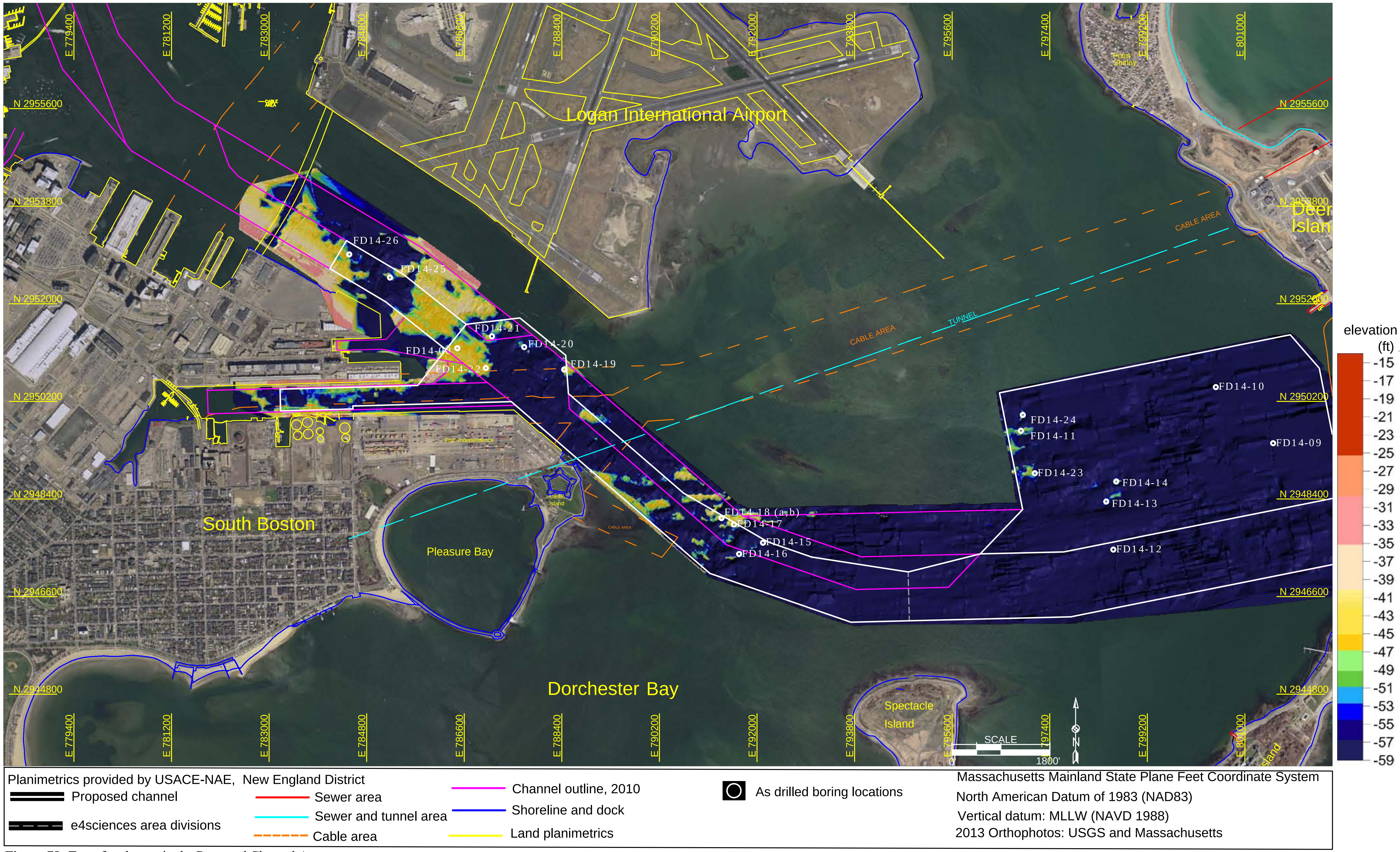


Figure 78. Top of rock map in the Reserved Channel Area.

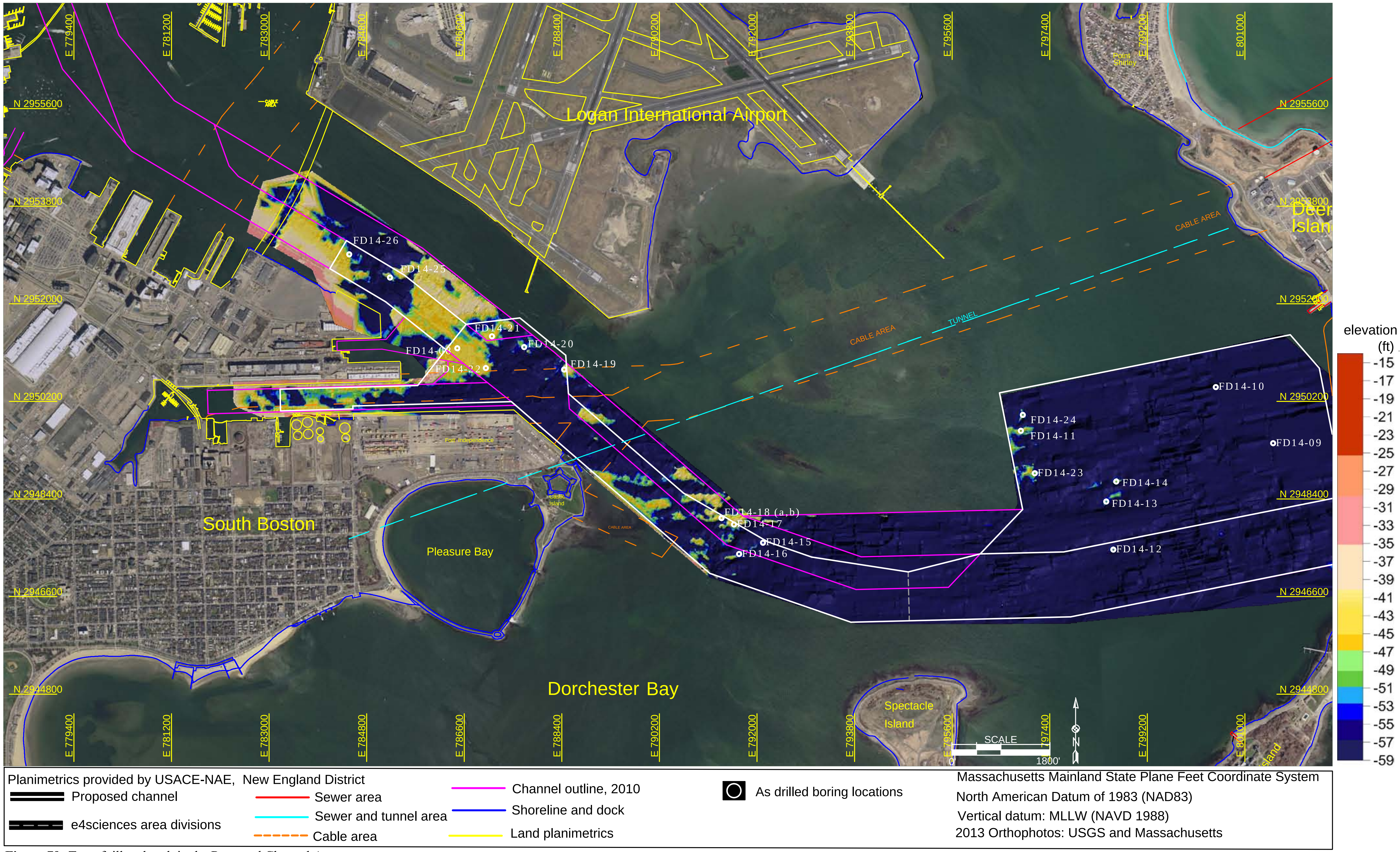


Figure 79. Top of till and rock in the Reserved Channel Area.

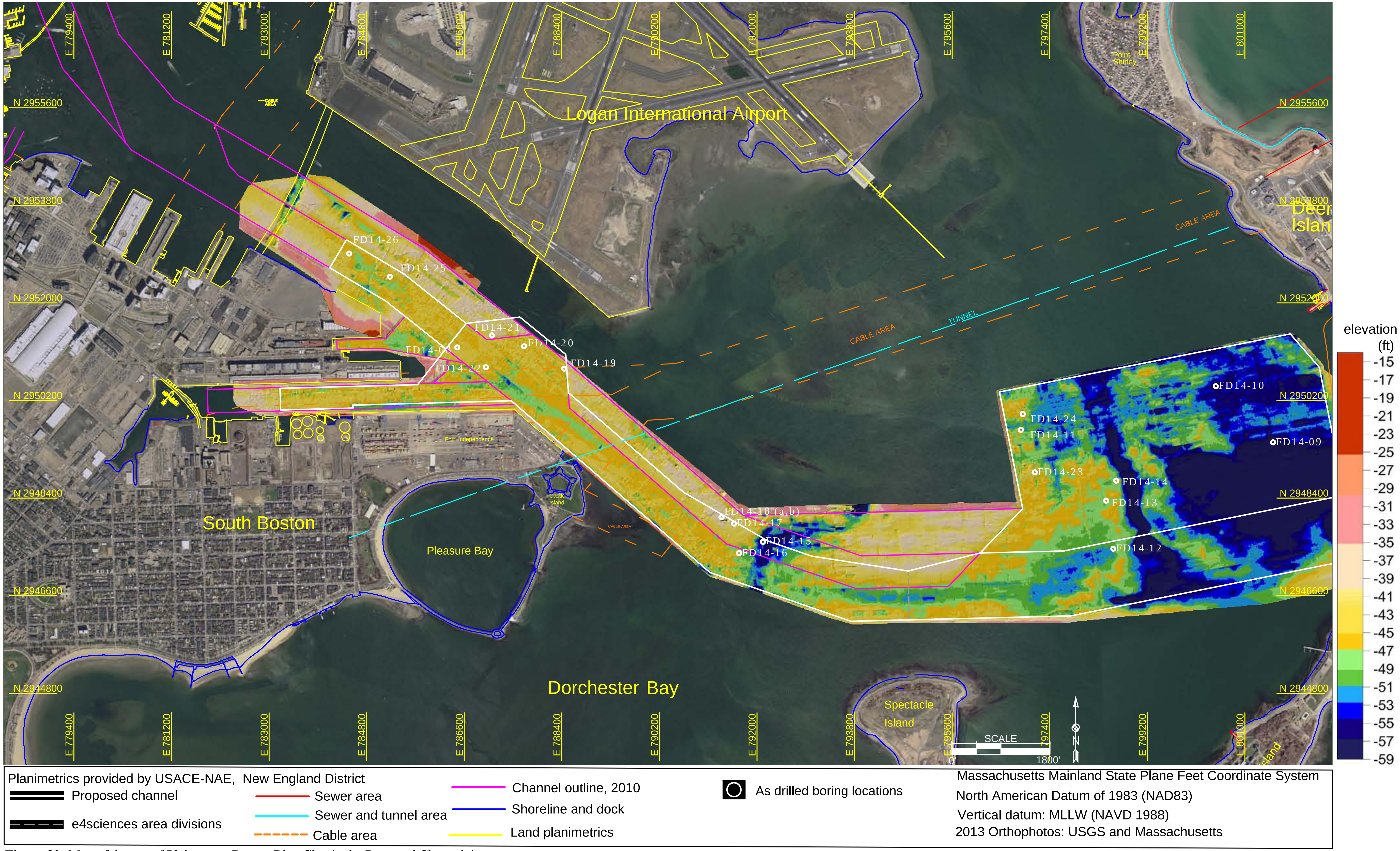


Figure 80. Map of the top of Pleistocene Boston Blue Clay in the Reserved Channel Area.

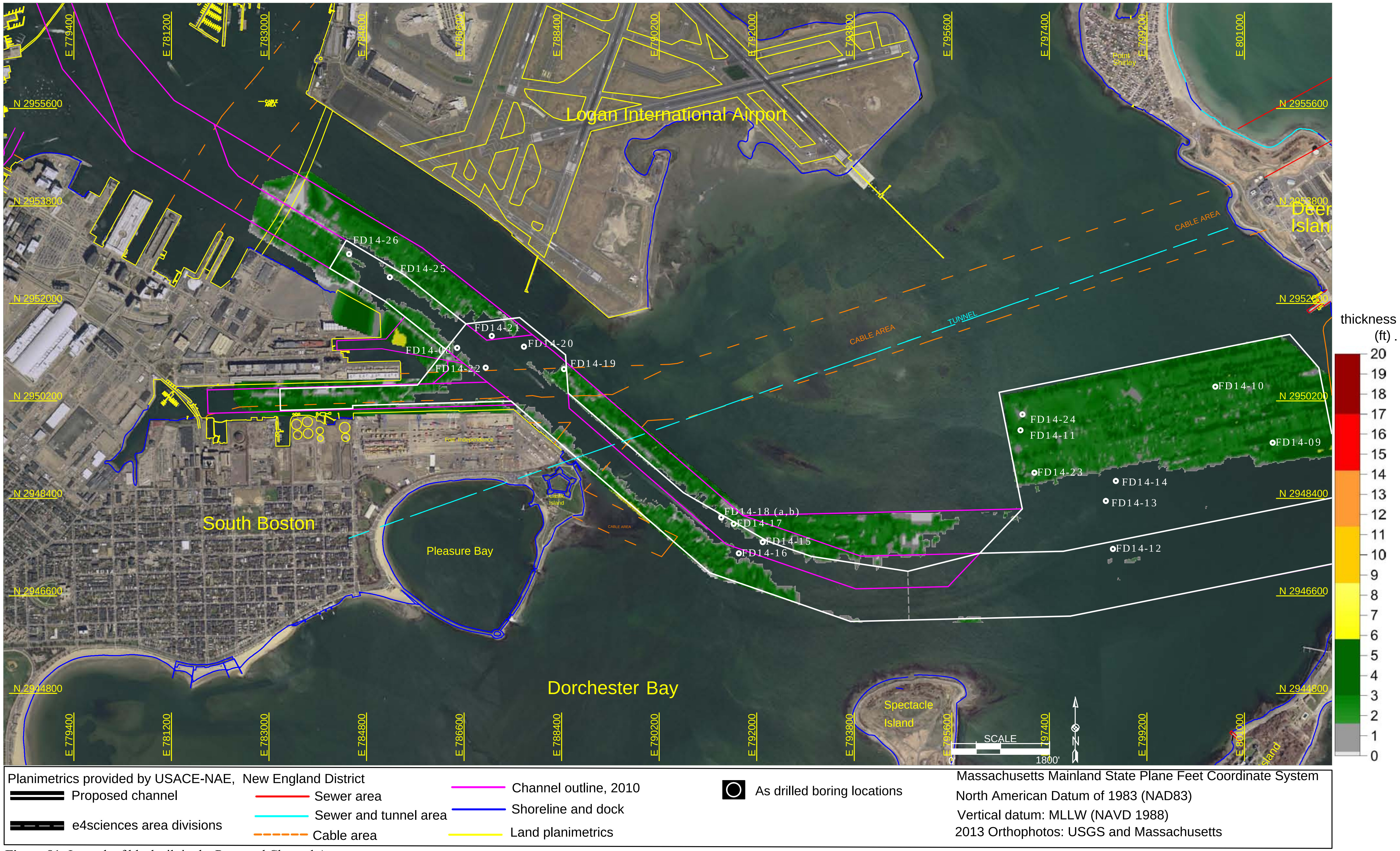


Figure 81. Isopach of black silt in the Reserved Channel Area.

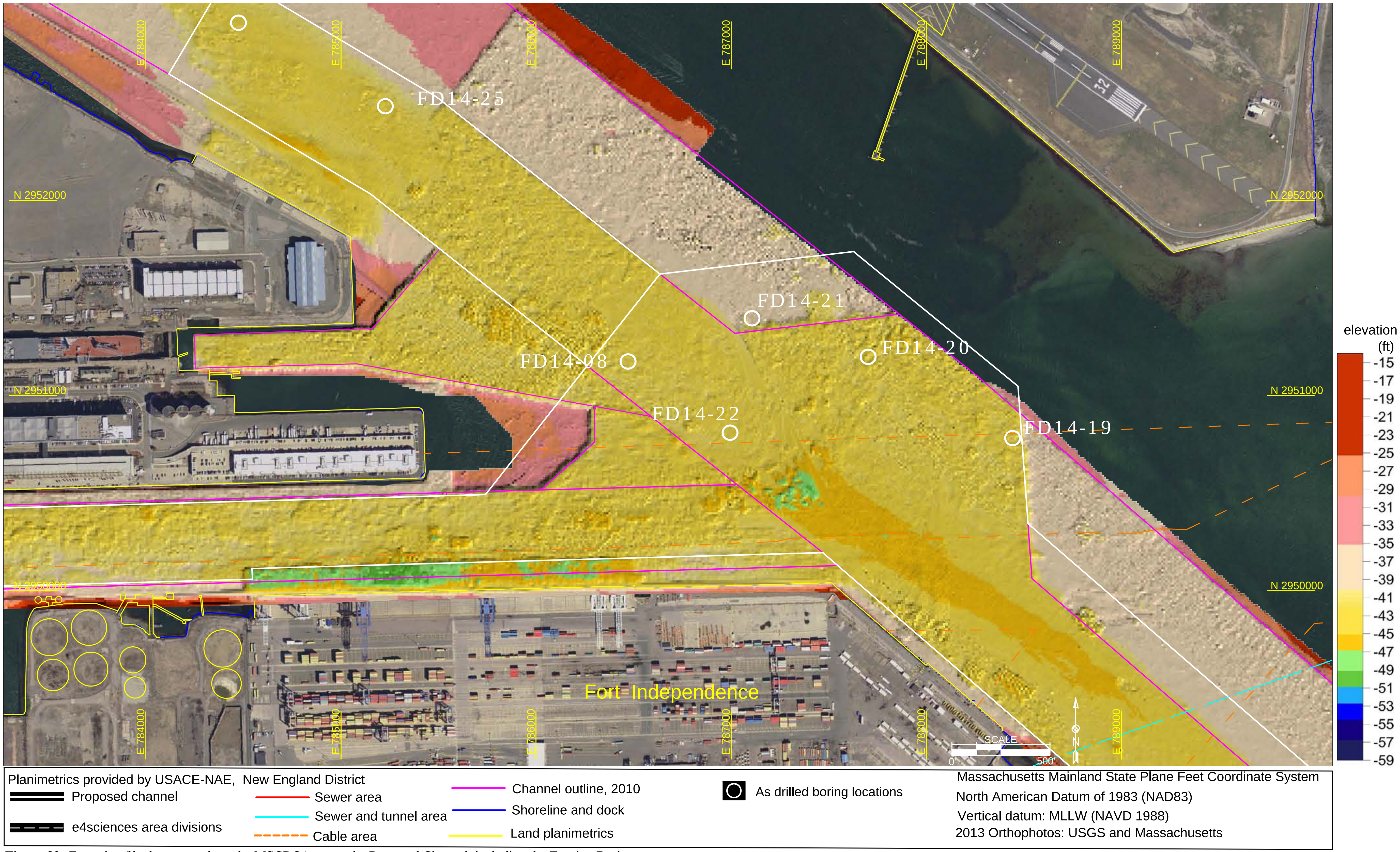


Figure 82. Zoom in of bathymetry where the MSCRCA meets the Reserved Channel, including the Turning Basin.

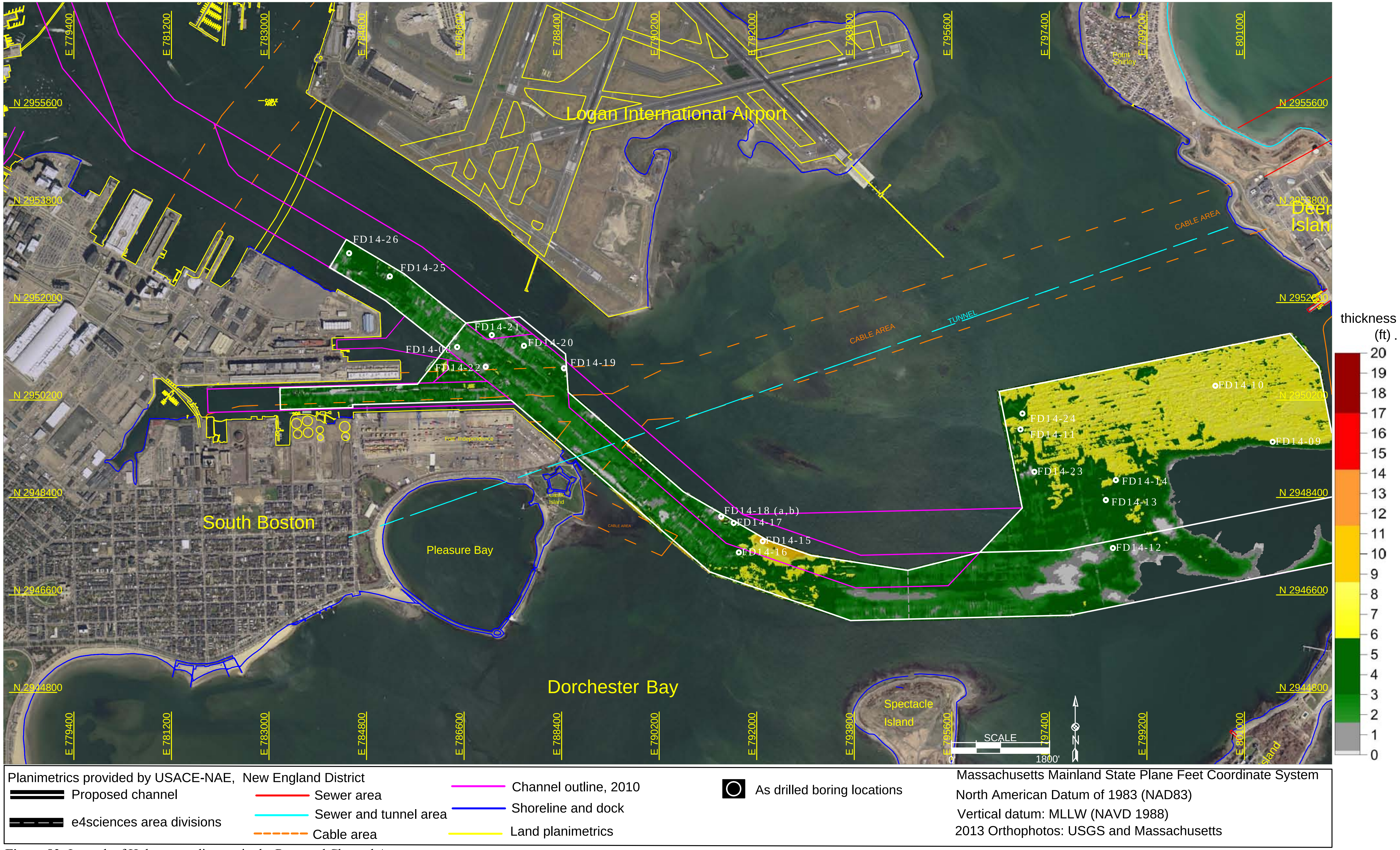


Figure 83. Isopach of Holocene sediments in the Reserved Channel Area.

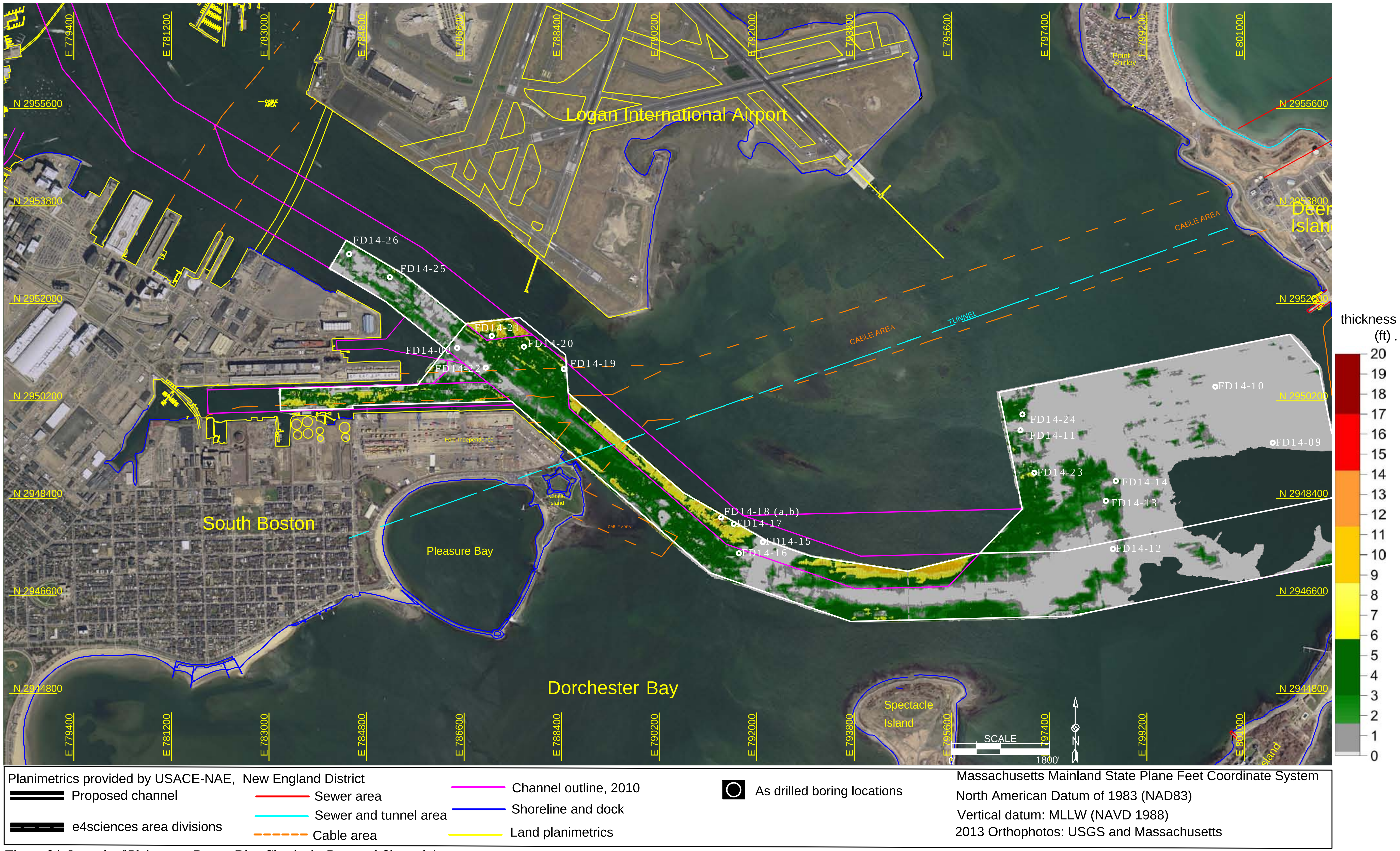


Figure 84. Isopach of Pleistocene Boston Blue Clay in the Reserved Channel Area.

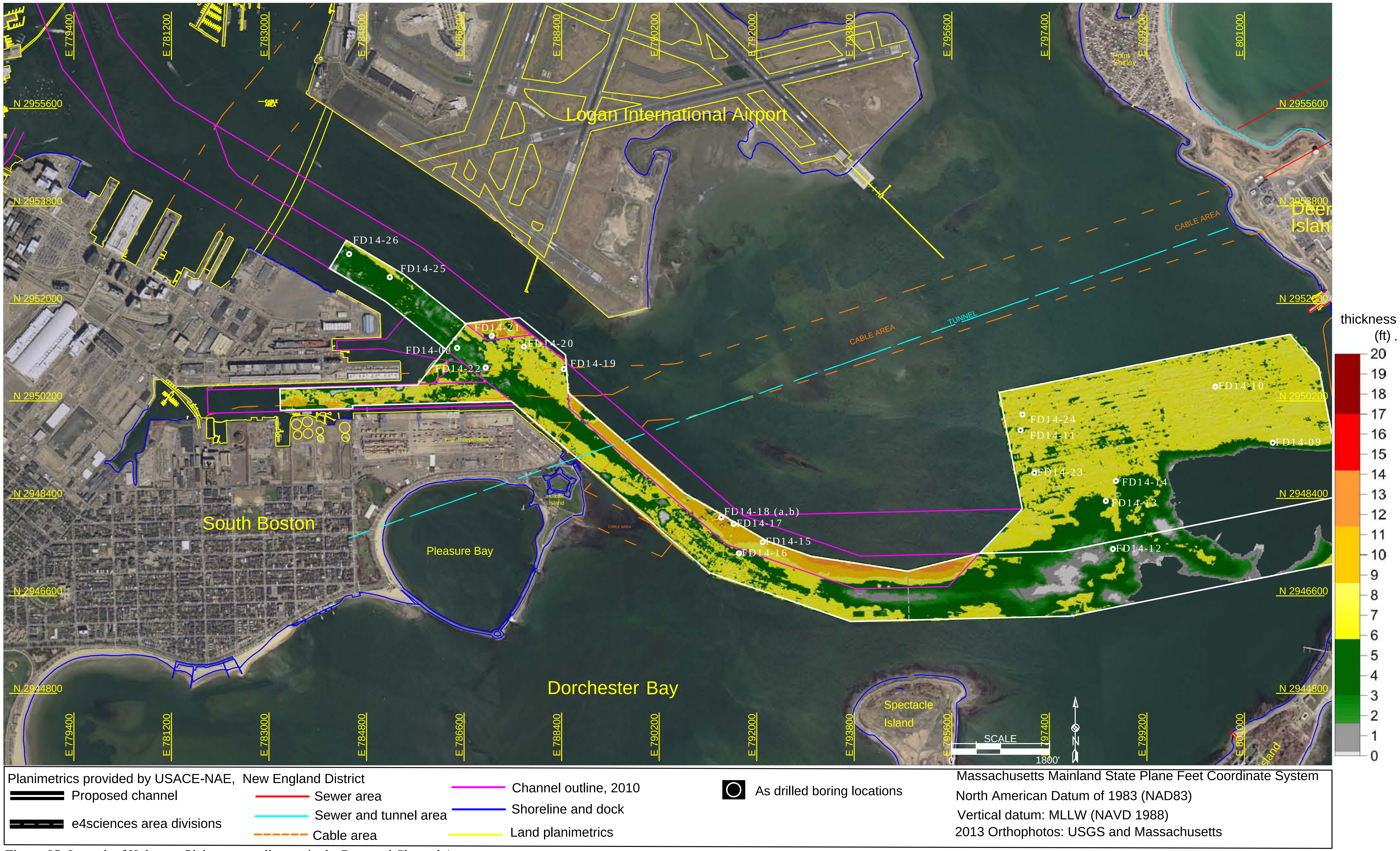


Figure 85. Isopach of Holocene-Pleistocene sediments in the Reserved Channel Area.

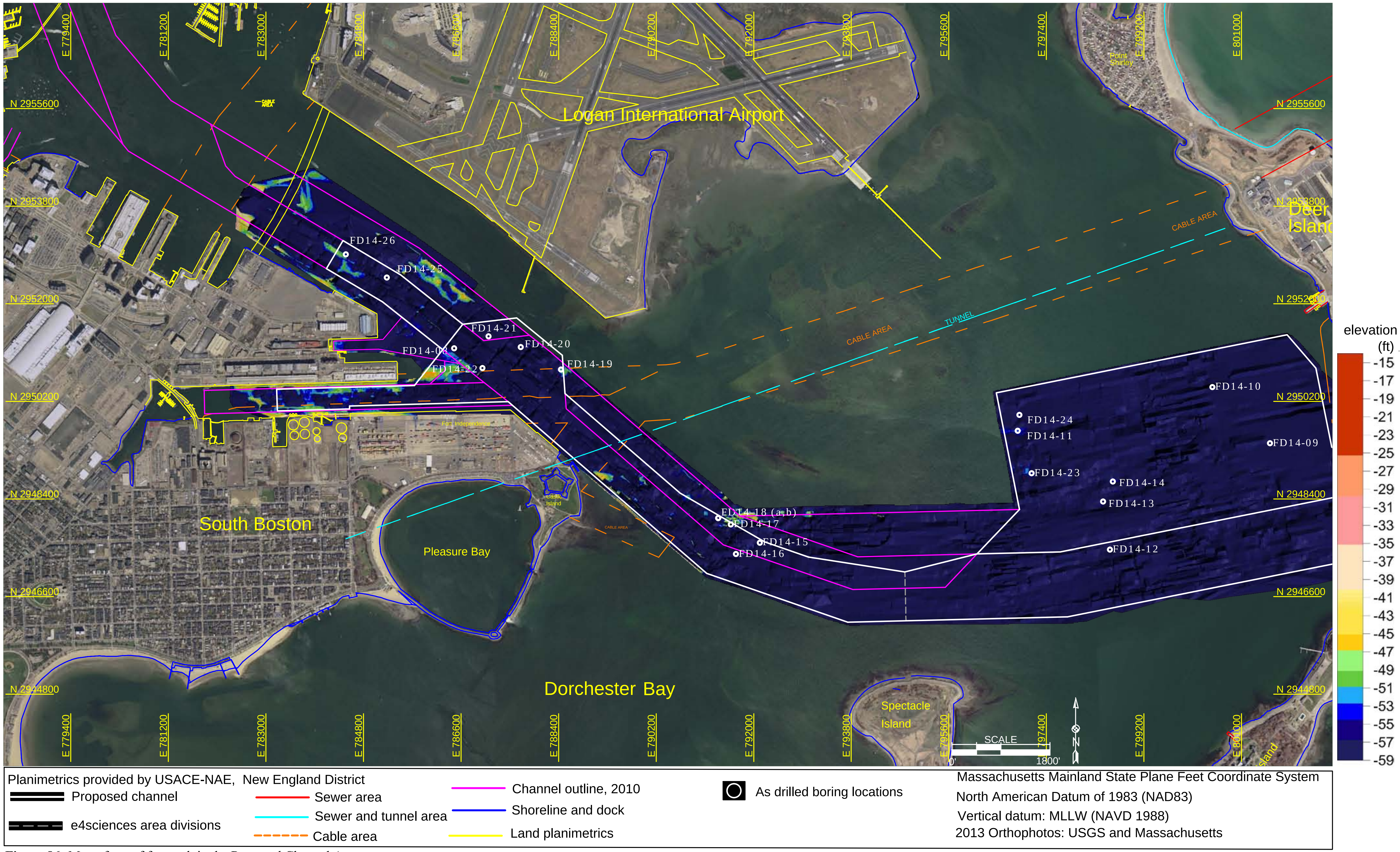


Figure 86. Map of top of fast rock in the Reserved Channel Area.

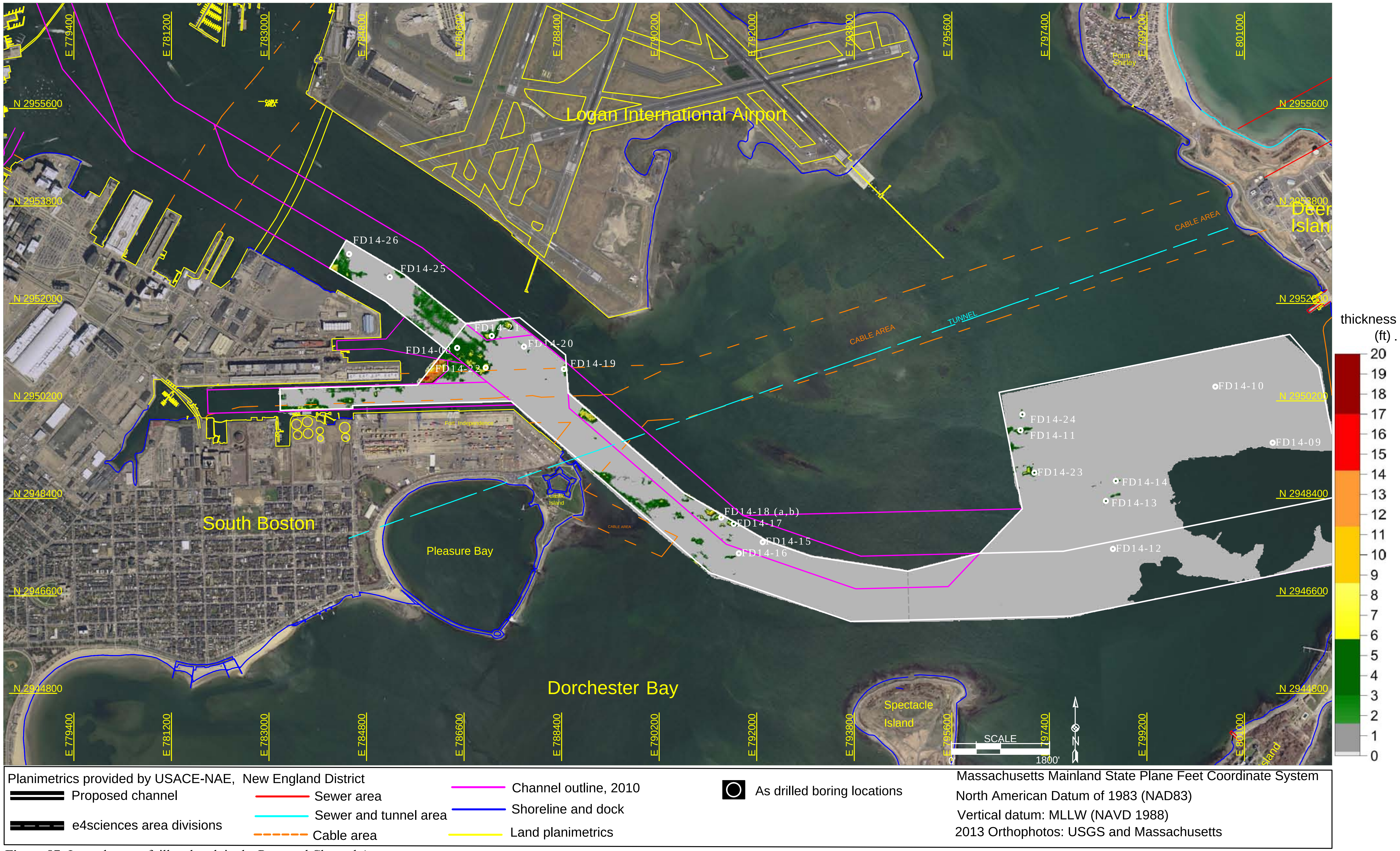


Figure 87. Isopach map of till and rock in the Reserved Channel Area.

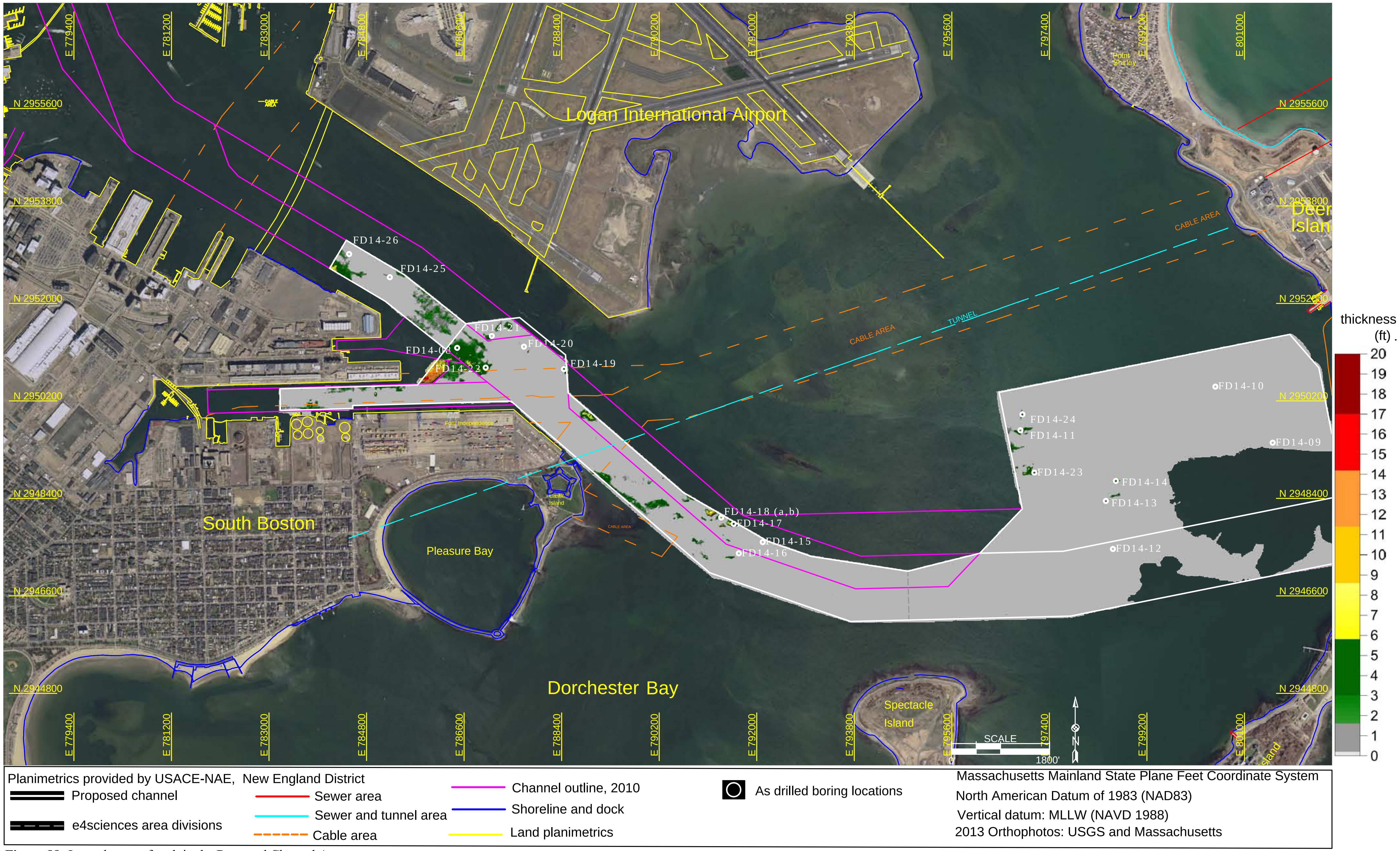
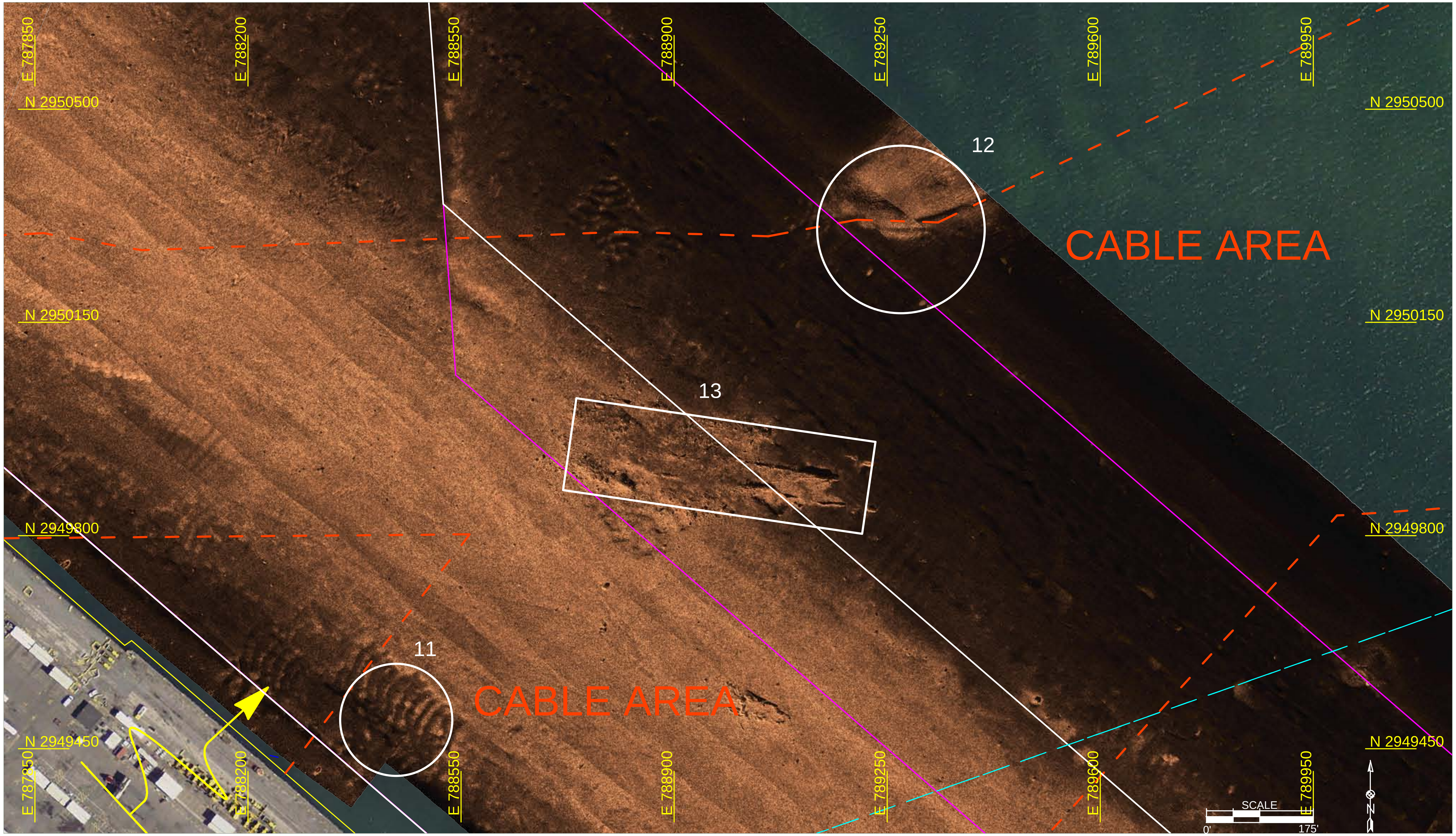


Figure 88. Isopach map of rock in the Reserved Channel Area.



Planimetrics provided by USACE-NAE, New England District
Proposed channel
e4sciences area divisions
Sewer area
Sewer and tunnel area
Cable area
Channel outline, 2010
Shoreline and dock
Land planimetrics
As drilled boring locations
Direction of sonar illumination
Massachusetts Mainland State Plane Feet Coordinate System
North American Datum of 1983 (NAD83)
Vertical datum: MLLW (NAVD 1988)
2013 Orthophotos: USGS and Massachusetts

Figure 89. Orthosonograph of the MSCRCA showing dredge marks, rock subcrop, and cables on the surface.

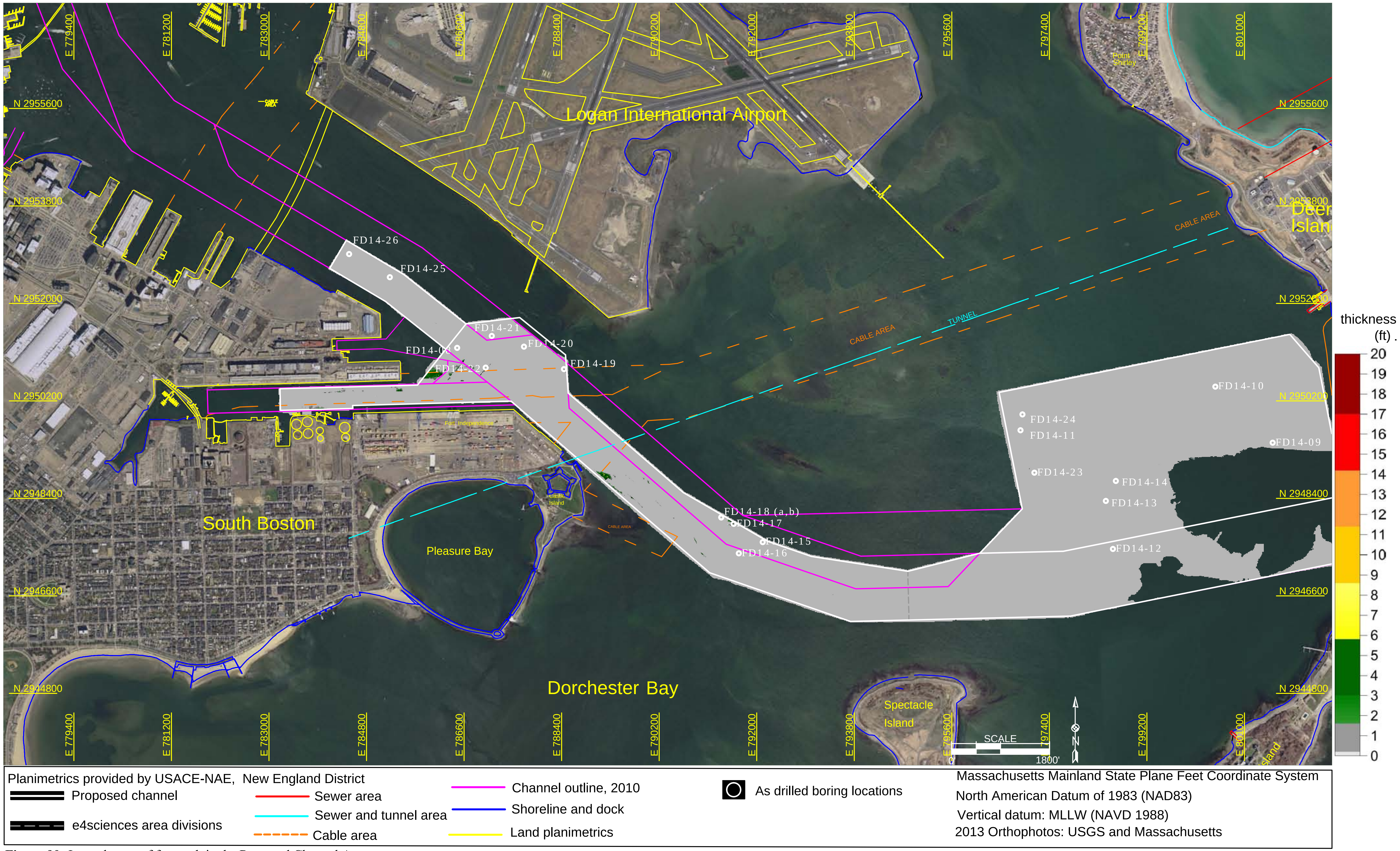


Figure 90. Isopach map of fast rock in the Reserved Channel Area.

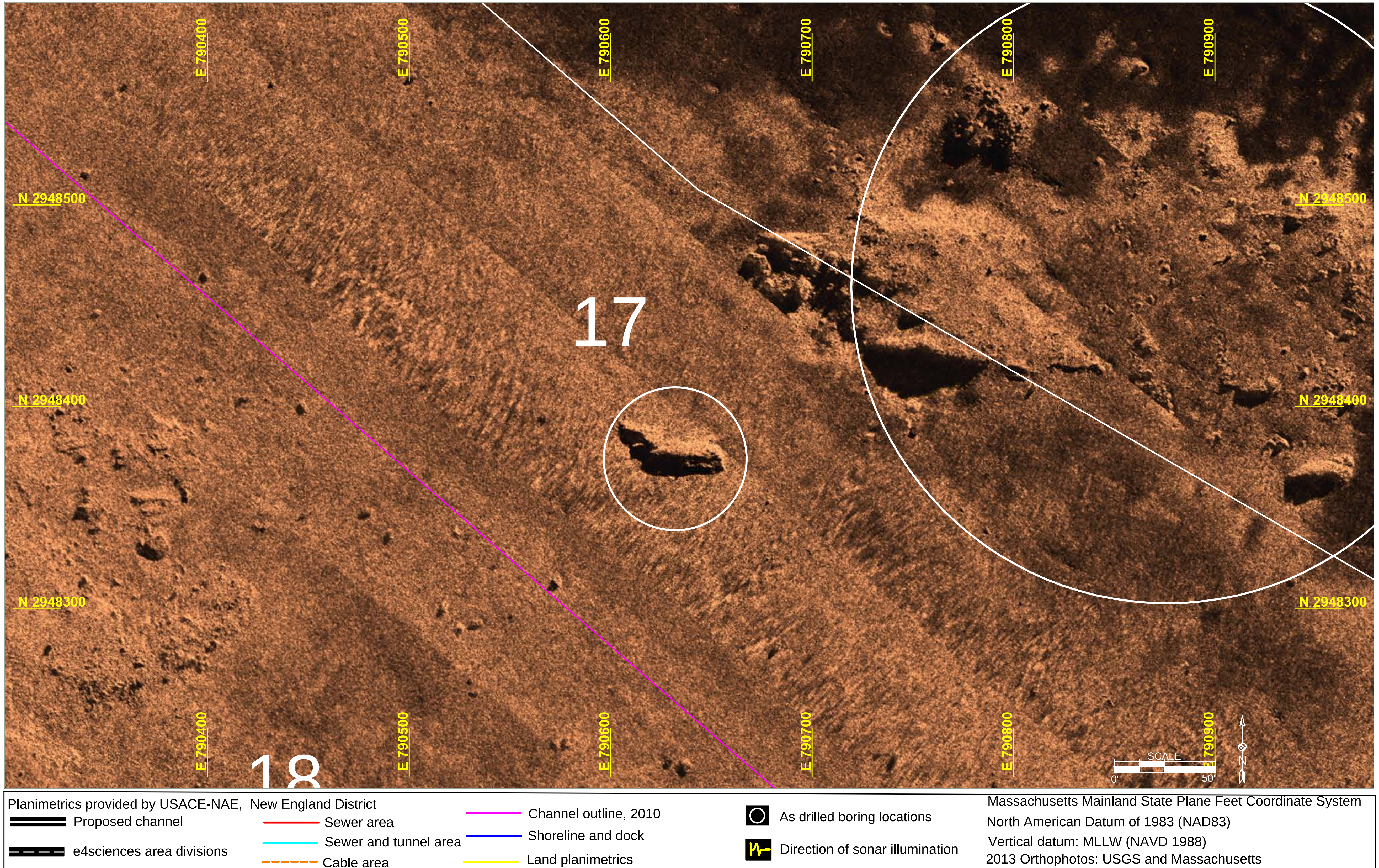


Figure 91. Zoomed in orthosonograph in MSCRCA of dredge marks on rock ledge and lost stick and bucket from dredge.

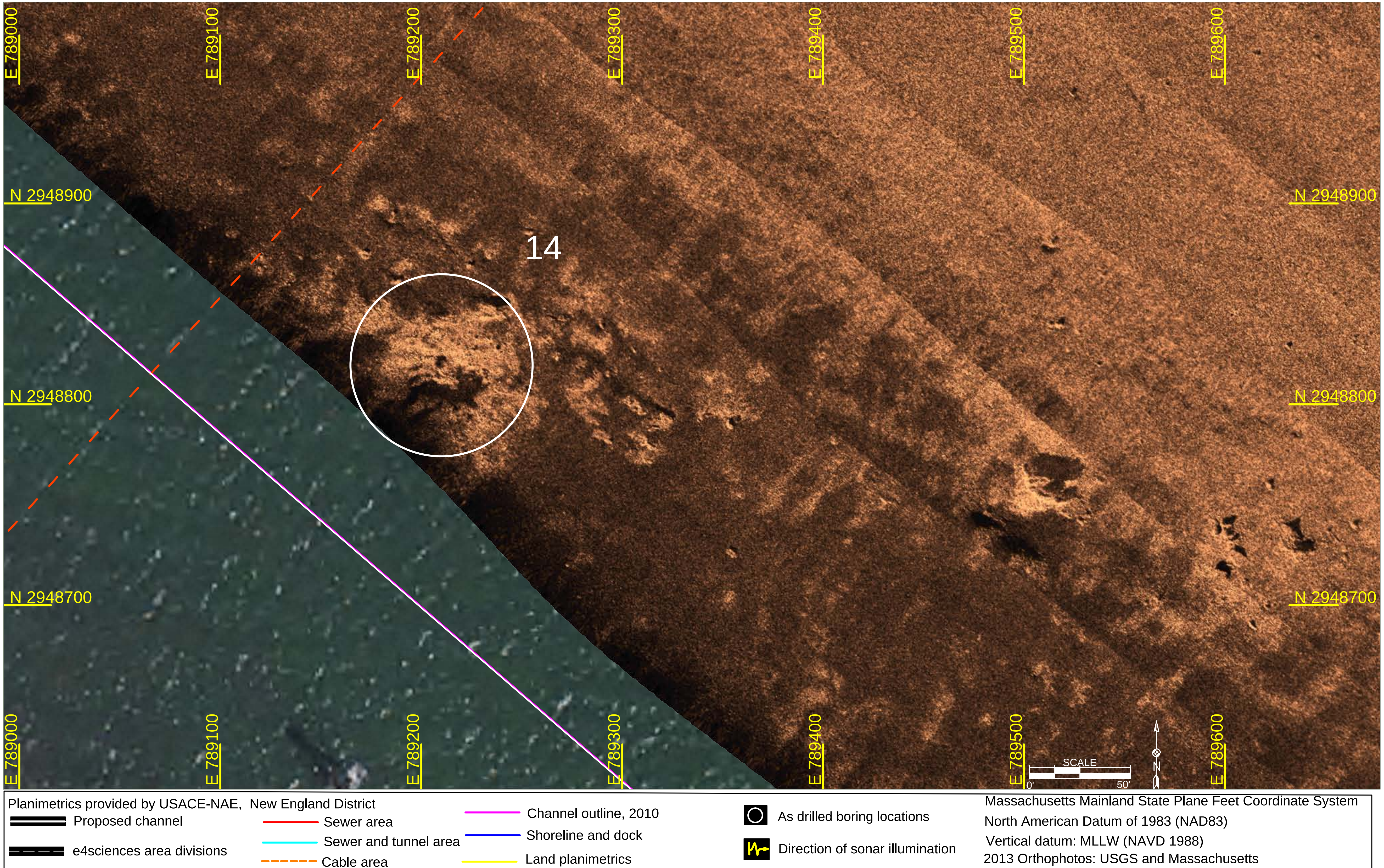


Figure 92. Zoomed in orthosonograph of high rock subcrop (cored in 2010) in MSCRCA.

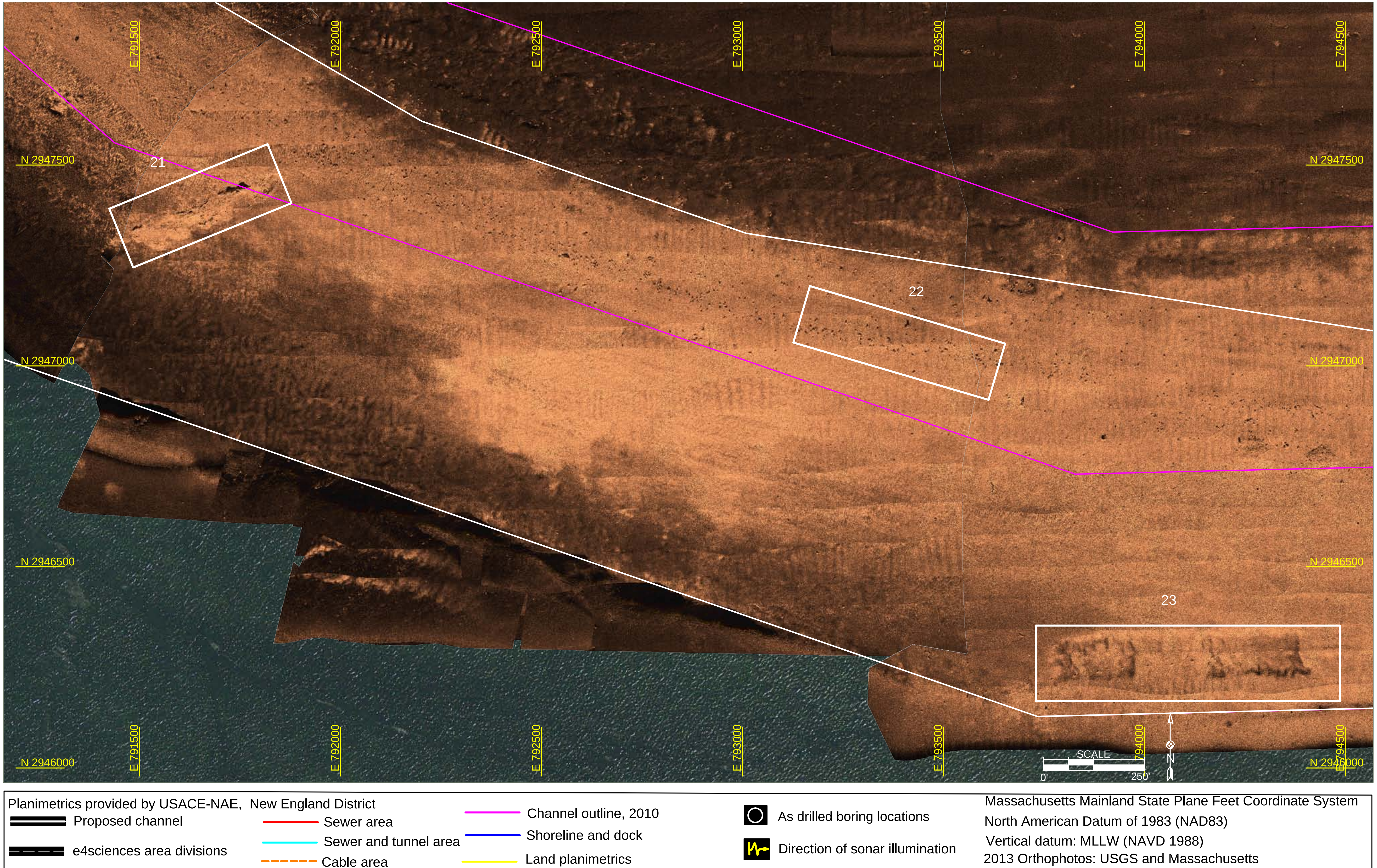


Figure 93. Zoomed in orthosonograph of lobster-pot rows, rock subcrop, and dredge marks in MSCRCA.

7.9 The Reserved Channel geography

The Reserved Channel is the entrance to berths. The Reserved Channel is 4,100ft long, roughly east to west. The width is 400ft. The associated Turning Basin north of the MSCRCA is 2,000ft long and 650ft in width.

7.10 The Reserved Channel grade

The existing grade of the mudline is -40ft MLLW. The newly authorized grade in the Reserved Channel is elevation -47ft. In the case of rock or hard bottom, the required 2ft overdepth brings the elevation to -49ft. The optional 2ft overdepth in the case of rock or hard bottom brings the elevation to -51ft MLLW. Figure 72 plots the multibeam bathymetry in the Reserved Channel.

7.11 Reserved Channel stratigraphy

The dredging of the Reserved Channel involves mostly Pleistocene Boston Blue Clay (Figures 84 and 96). Silt covers much of the channel floor except where swept away by propeller wash (Figure 81). An east to west ridge of Cambridge Argillite runs across the north boundary of the Reserved Channel (Figures 78 and 96). Table 47 describes the estimated area. Less compact tills remain between the clays and the argillite. Figures 96 and 97 are orthosonographs of the Reserved Channel. Table 48 describes the estimated volume for the Reserved Channel.

Table 47. Estimates of area for the Reserved Channel reach per interval. Total area of the Reserved Channel = 1,896,650sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	sqft	sqft
-47ft	1,865,172	417,784	293,308	154,271
-49ft	1,877,841	608,349	444,622	176,552
-51ft	1,877,841	767,554	551,311	n/a

Table 48. Estimates of volume for the Reserved Channel reach per interval.

Elevation	Volume above elevation	Volume of sediment above elevation	Volume of rock/till above elevation	Volume of rock above elevation	Fraction of rock	Side slope volume above elevation
MLLW, ft	cuyd	cuyd	cuyd	cuyd		cuyd
-47ft	356,346	298,610	57,736	43,971	0.1234	22,928
-49ft	496,235	399,354	96,882	72,212	0.1455	33,811
-51ft	636,431	487,765	148,666	109,561	0.1721	n/a

7.12 Reserved Channel sediments

A thin veneer (less than a few feet) of fine-grained silt covers half of the channel floor. In places, it has been eroded by propeller wash exposing thin Holocene sediments that are sands and silts (Figures 83-85). The Pleistocene Boston Blue Clay constitutes the majority of the material to be dredged. An excavator could remove the till at the base of the sediments.

7.13 Reserved Channel rock

The argillite varies from decomposed and highly weathered to fractured and broken rock. The rock comes to the surface on the northern edge of the channel (Figure 78, 88, and 94). Table 49 describes the rock area in the Reserved Channel. Table 50 describes the rock volume in the Reserved Channel. Figure 67 is a slice map of fast rock at -49ft for the entire -47ft project. Figure 95 plots seismic-velocity cross section for the Reserved Channel.

Table 49. Estimates of rock area in the Reserved Channel.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	sqft
-47ft	417,784	293,308	35,399
-49ft	608,349	444,622	103,029
-51ft	767,554	551,311	228,780

Table 50. Estimates of rock volume in the Reserved Channel.

Elevation	Volume of till/rock above elevation	Volume of rock above elevation	Volume of fast rock above elevation
MLLW, ft	cuyd	cuyd	cuyd
-47ft	57,736	43,971	1,317
-49ft	96,882	72,212	6,050
-51ft	148,666	109,561	18,487

7.14 Reserved Channel debris

The Reserved Channel has several piles and cables on the bottom (Figure 97).

7.15 Reserved Channel infrastructure

Cables and pipelines run from the south of the Reserved Channel across the MSCRCA (Figure 89 and 97). The cables are apparent in the orthosonographs (Figure 97). The plans and specification should mark the location and type of these facilities.

7.16 Additional Reserved Channel dredging concerns

A principal issue in dredging is efficiency. This involves lost time due to maintenance, traffic, and weather. The treatment and ripping of the rock may wreak havoc on the equipment. Traffic in the Reserved Channel may be minimal. The Reserved Channel is protected from wave activity.

7.17 Turning Basin geography

The Turning Basin north of the MSCRCA is 2,000ft long and 650ft in width. Table 51 describes the estimated area of material in the Turning Basin. Table 52 describes the volume of material in the Turning Basin.

Table 51. Estimates of area for the Turning Basin reach per interval. Total area of the Reserved Channel = 1,273,470sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	sqft	sqft
-47ft	1,166,040	80,721	24,187	41,563
-49ft	1,166,040	131,088	49,791	47,466
-51ft	1,166,040	190,057	79,773	n/a

Table 52. Estimates of volume for the Turning Basin reach per interval.

Elevation	Volume above elevation	Volume of sediment above elevation	Volume of rock/till above elevation	Volume of rock above elevation	Fraction of rock	Side slope volume above elevation
MLLW, ft	sqft	cuyd	cuyd	sqft		cuyd
-47ft	235,649	229,971	5,677	1,410	0.0060	7,183
-49ft	322,553	309,036	13,518	4,126	0.0128	13,736
-51ft	409,458	383,959	25,499	8,914	0.0218	n/a

7.18 Turning Basin sediments

A thin veneer (less than a few feet) of fine-grained black stilt covers much of the channel floor. Mostly it has been eroded by propeller wash exposing thin Holocene sediments that are sands and silts. The Pleistocene Boston Blue Clay constitutes most of the material to be dredged. An excavator could remove the till at the base of the sediments.

7.19 Turning Basin rock

The argillite varies from decomposed and highly weathered to fractured and broken rock. Table 53 describes the estimated rock area for the Turning Basin. Table 54 describes the estimated rock volume for the Turning Basin. Figure 67 is a slice map of fast rock at -49ft for the entire -47ft project.

Table 53. Estimates of rock area in the Turning Basin.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	sqft
-47ft	80,721	24,187	5
-49ft	131,088	49,791	1,071
-51ft	190,057	79,773	3,456

Table 54. Estimates of rock volume in the Turning Basin.

Elevation	Volume of till/rock	Rock volume above elevation	Volume of fast rock
MLLW, ft	cuyd	cuyd	cuyd
-47ft	5,677	1,410	0
-49ft	13,518	4,126	28
-51ft	25,499	8,914	191

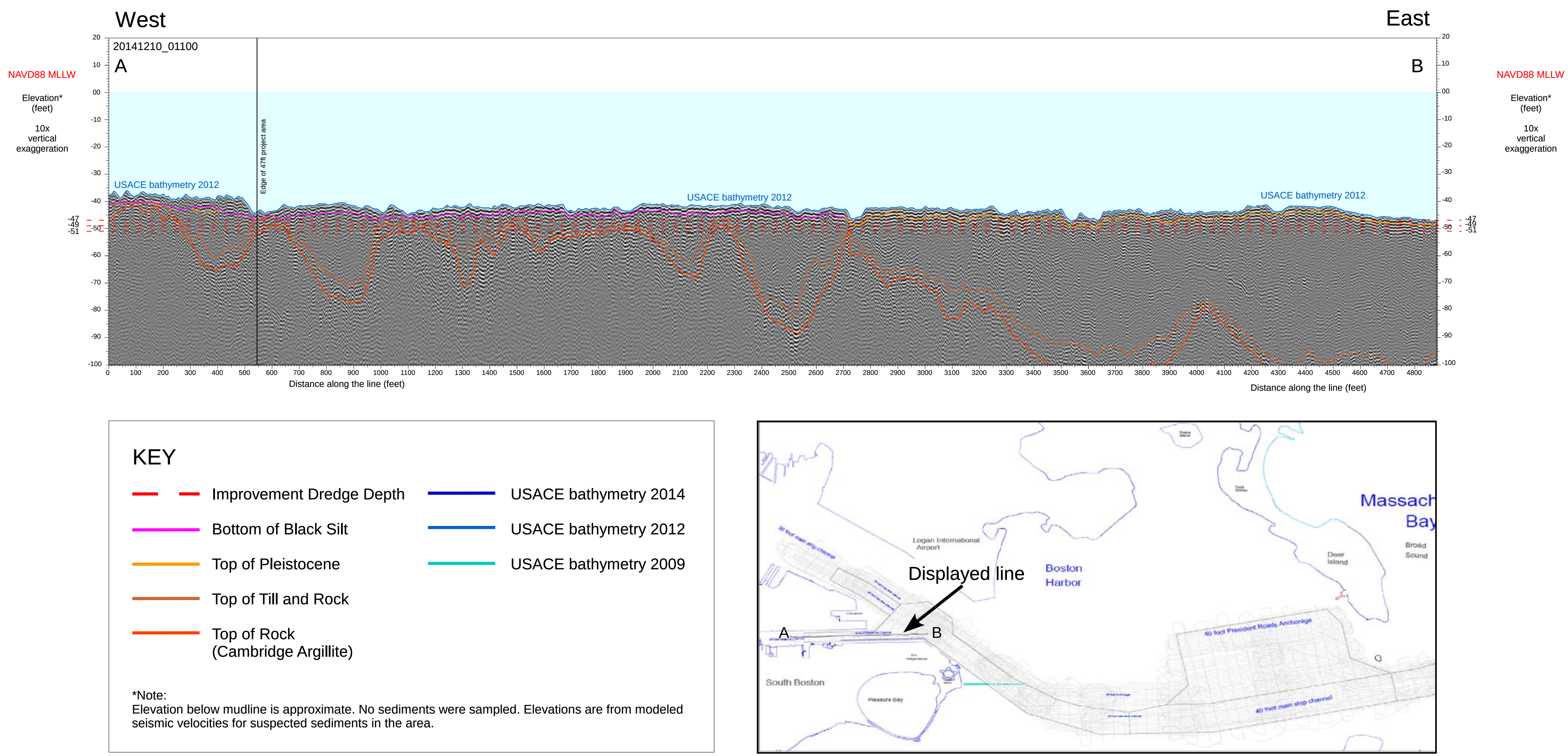


Figure 94. Seismic cross section in the Reserved Channel.

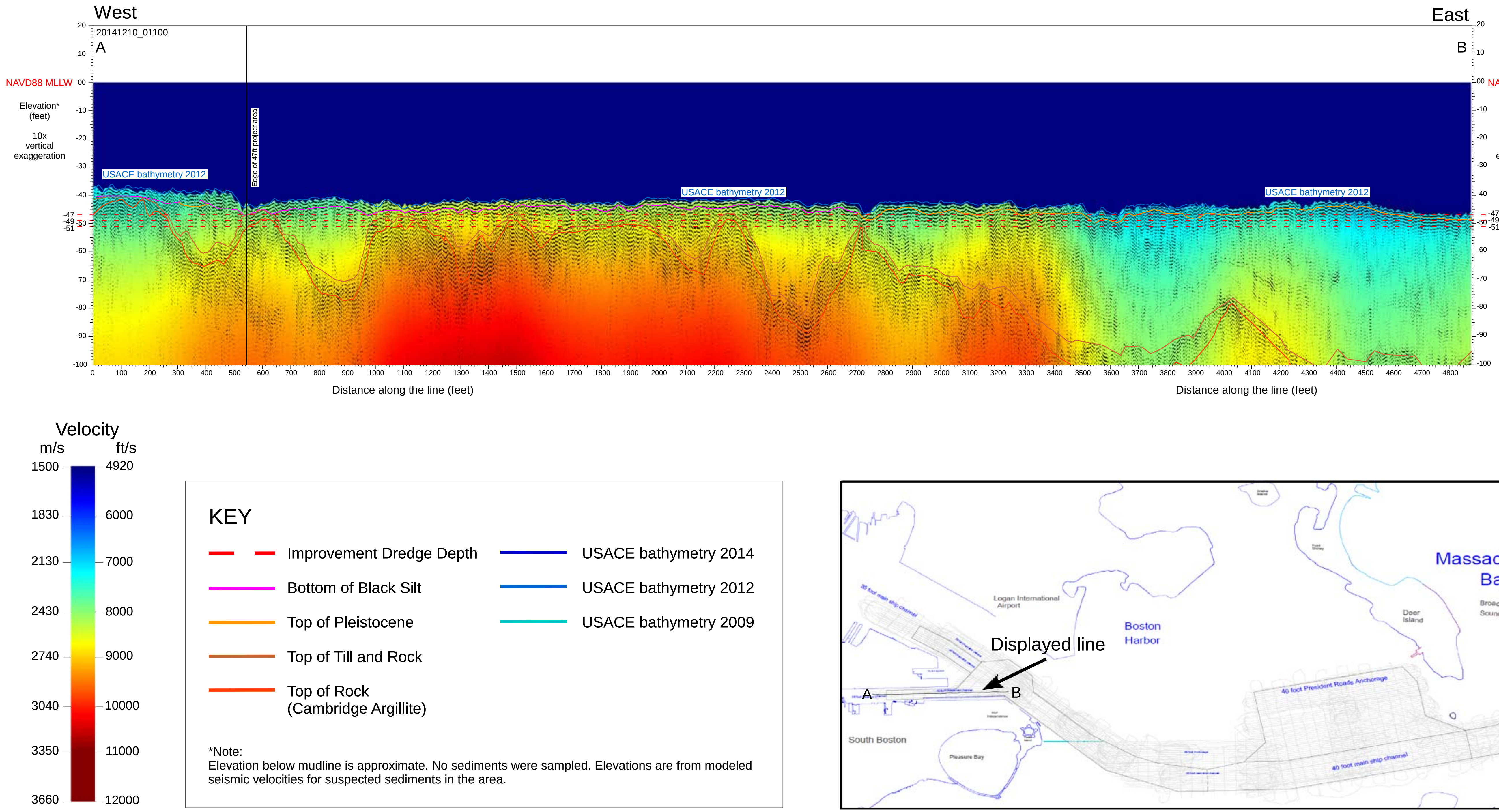


Figure 95. Seismic-velocity cross section in Reserved Channel.

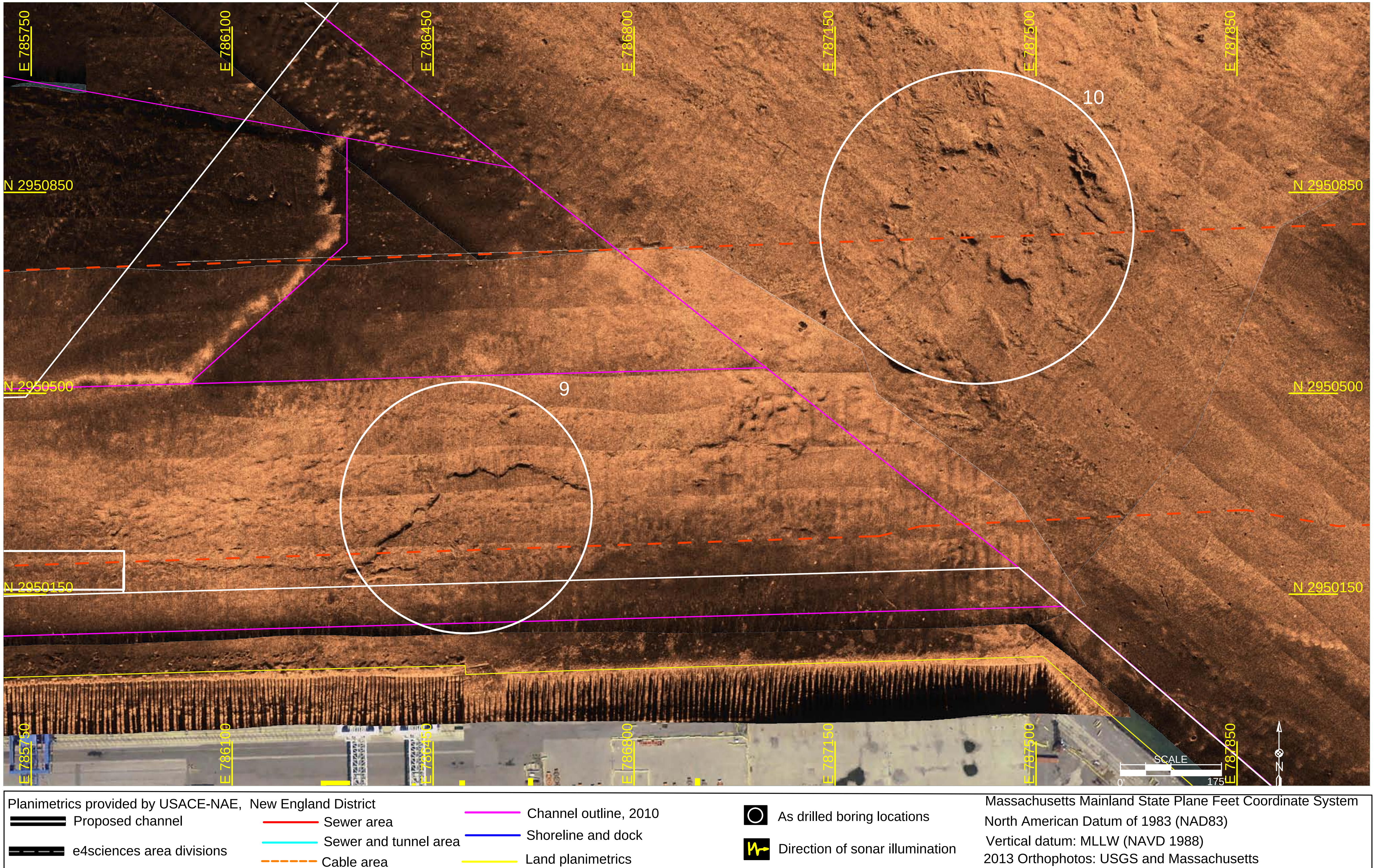


Figure 96. Orthosonograph showing rock subcrop and Pleistocene Boston Blue Clay subcrop in the MSCRCA.

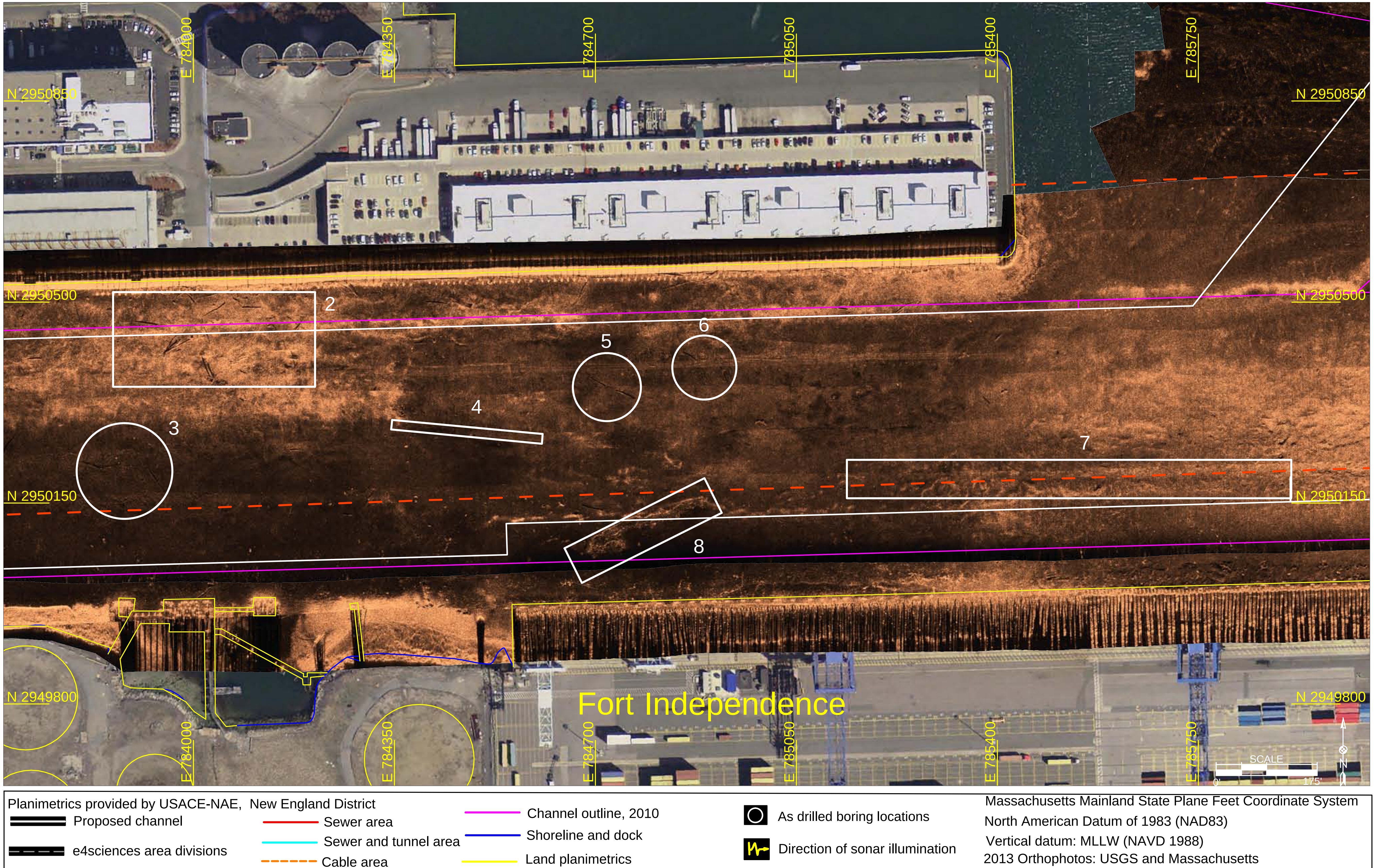


Figure 97. Orthosonograph with targets in the Reserved Channel.

7.20 The Main Ship Channel at the Massport Maritime Terminal

The Main Ship Channel at the Massport Maritime Terminal (MSCMMT) connects the MSCRCA to the Massport Maritime Terminal and the inner harbor. The MSCMMT is 4,200ft long, roughly southeast to northwest. The width is 900ft.

7.21 MSCMMT grade

The existing grade of the mudline is -40ft MLLW. The newly authorized grade in the MSCMMT is an elevation -45ft. The optional 2ft overdepth in the ordinary material brings the elevations to -47ft. In the case of rock or hard bottom, the required 2ft overdepth brings the elevation to -47ft. In the case of rock or hard bottom, an optional overdepth adds another 2ft depth, bringing the elevation to -49ft MLLW.

7.22 MSCMMT stratigraphy

The dredging of the MSCMMT involves mostly rock gravel. Two massive highs of Cambridge Argillite run east to west across the MSCMMT (Figure 78 and 98-99). Less compact tills remain between the Boston Blue Clay and the argillite. Table 55 describes the estimated area for MSCMMT. Table 56 describes the estimated volume for the MSCMMT.

Table 55. Estimates of area for MSCMMT reach per interval. Total area of the MSCMMT = 1,595,750sqft.

Elevation	Area above elevation	Area of till/rock above elevation	Area of rock above elevation	Area of side slope
MLLW, ft	sqft	sqft	sqft	sqft
-45ft	1,562,239	366,214	181,738	85,448
-47ft	1,586,210	648,420	548,683	109,838
-49ft	1,586,210	758,756	687,924	n/a

Table 56. Estimates of volume for MSCMMT reach per interval.

Elevation	Volume above elevation	Sediment volume above elevation	Volume of till/rock	Rock volume above elevation	Volume of side slope
MLLW, ft	cuyd	cuyd	cuyd	cuyd	cuyd
-45ft	150,740	133,918	16,821	7,197	9,523
-47ft	268,458	212,409	56,049	34,663	22,592
-49ft	386,623	277,402	109,221	81,541	n/a

7.23 MSCMMT sediments

A thin veneer (less than a few feet) of silt covers the channel floor. A thin layer of Holocene sands and silts lie below the silt (Figures 81-85). The Pleistocene Boston Blue Clay constitutes most of the material to be dredged. An excavator could remove the till.

7.24 MSCMMT rock

The argillite varies from highly weathered, fractured and broken rock to massive rock. The rock comes to the surface (Figures 78, 88 and 98-99). Much of the rock appears to be broken from previous dredging. Table 57 describes the estimated rock area for the MSCMMT. Table 58 describes the estimated rock volume for the MSCMMT. Figure 100 shows a slice map of fast rock at -47ft for the entire -45ft project.

Table 57. Estimates of rock area in the MSCMMT.

Elevation	Area of till and rock	Area of rock above elevation	Area of fast rock
MLLW, ft	sqft	sqft	sqft
-47ft	366,214	181,738	0
-49ft	648,420	548,683	78
-51ft	758,756	687,924	5,905

Table 58. Estimates of rock volume in the MSCMMT.

Elevation	Volume of till/rock	Rock volume above elevation	Volume of fast rock
MLLW, ft	cuyd	cuyd	cuyd
-47ft	16,821	7,197	0
-49ft	56,049	34,663	1
-51ft	109,221	81,541	169

7.25 MSCMMT debris

The MSCRCA has many lobster pots and other debris on the bottom. These objects may constitute a real cost to the dredger to sort from his dredge volume.

7.26 MSCMMT infrastructure

Cables and pipelines run from the south of the Reserved Channel across the MSCRCA (Figure 101). Monitoring in the Ted Williams tunnel may be required if blasting is a possibility in the MSCMMT (Figure 101).

7.27 Additional MSCMMT dredging concerns

A principal issue in dredging is efficiency. This involves lost time due to maintenance, traffic, and weather. The treatment and ripping of the rock may wreak havoc on the equipment. Traffic in the MSCMMT will be minimal. The exposure to heave may be limited.

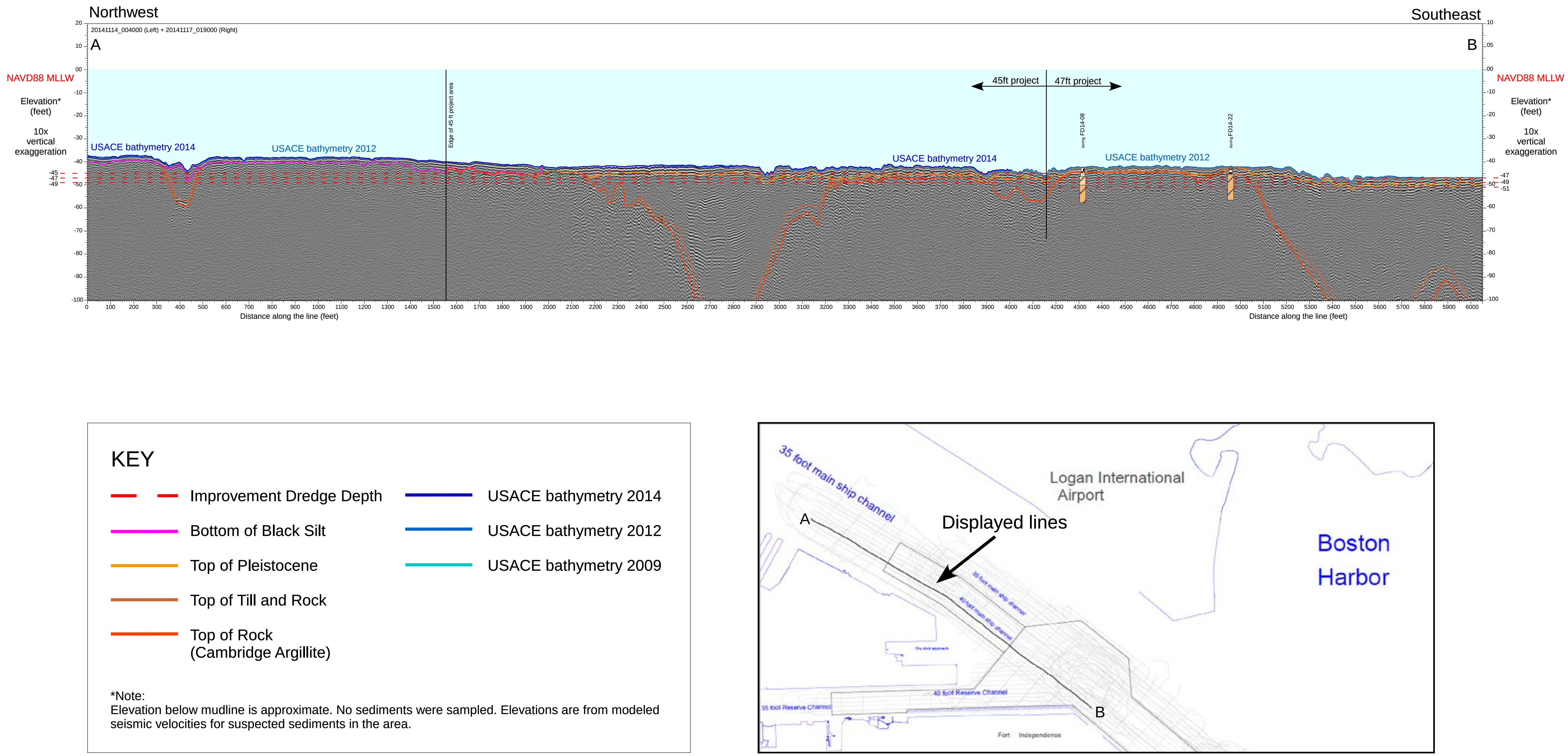


Figure 98. Seismic cross section of the MSCMMT.

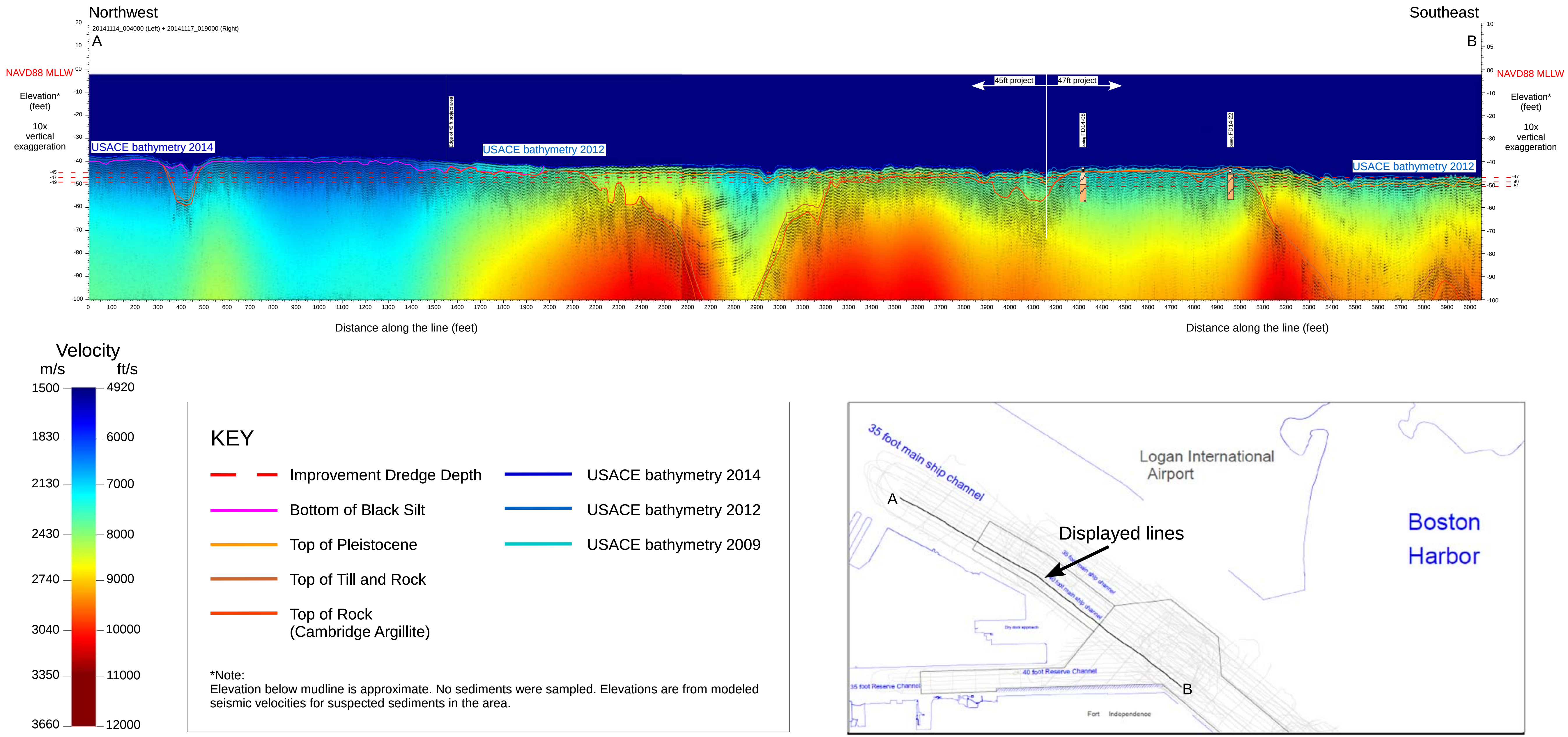
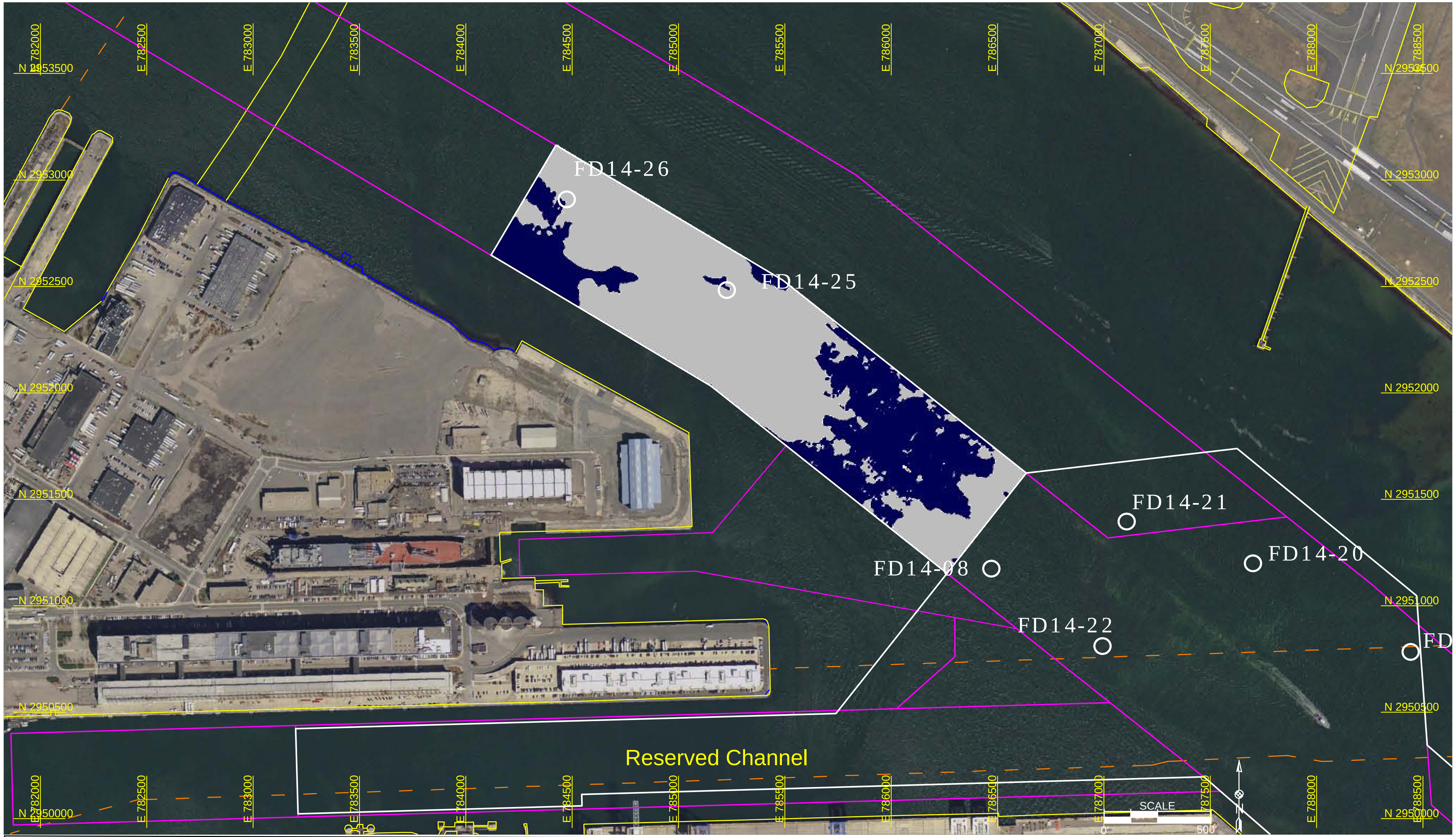
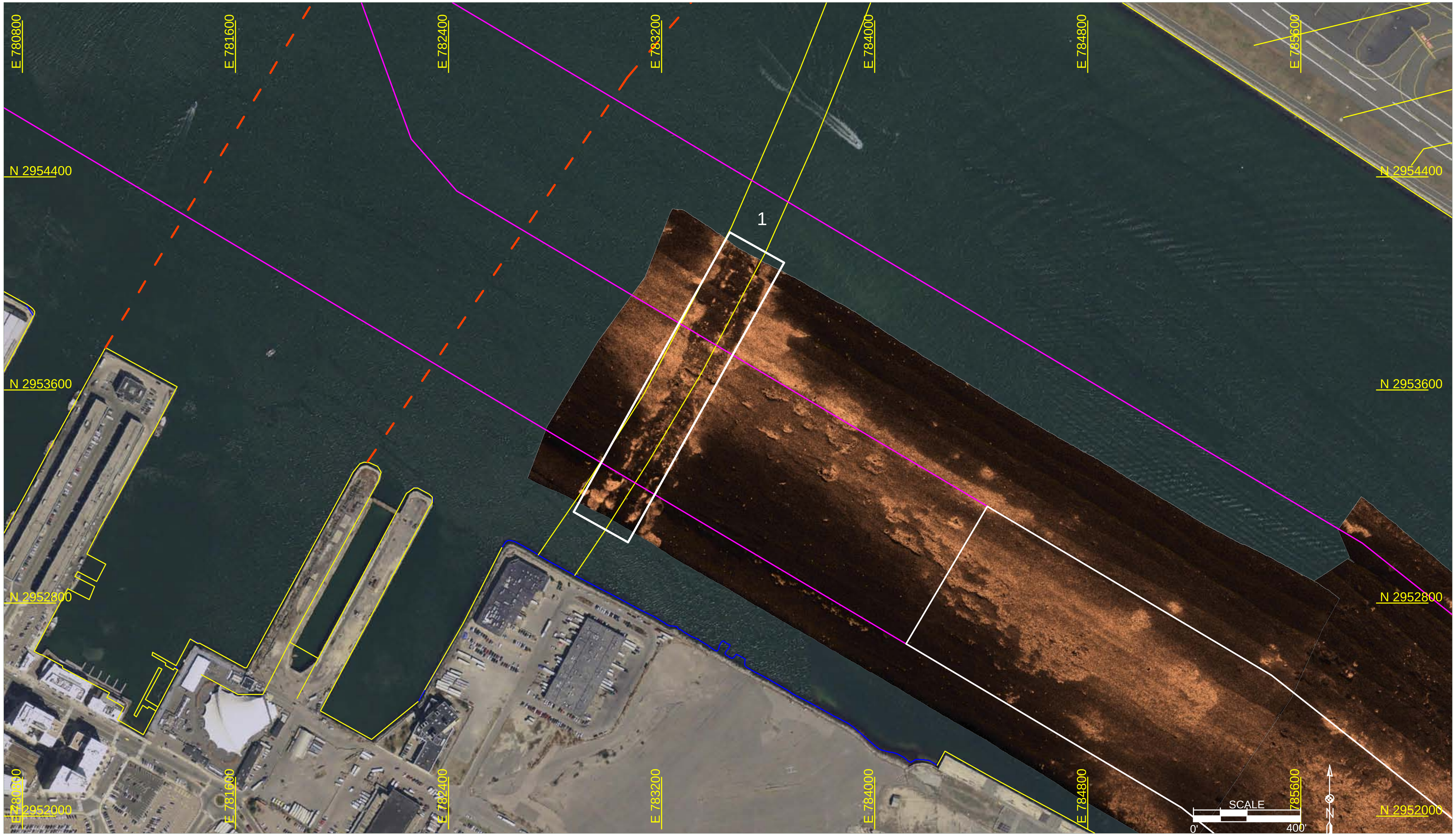


Figure 99. Seismic-velocity cross section in the MSCMMT.



Planimetrics provided by USACE-NAE, New England District
Proposed channel
e4sciences area divisions
Sewer area
Sewer and tunnel area
Cable area
Channel outline, 2010
Shoreline and dock
Land planimetrics
As drilled boring locations
Massachusetts Mainland State Plane Feet Coordinate System
North American Datum of 1983 (NAD83)
Vertical datum: MLLW (NAVD 1988)
2013 Orthophotos: USGS and Massachusetts

Figure 100. Slice map at -47ft of fast rock in the entire -45ft project. Orange represents fast rock at -47ft. Blue represents rock at -47ft. Gray represents rock at -49ft.



Planimetrics provided by USACE-NAE, New England District
Proposed channel
e4sciences area divisions
Sewer area
Sewer and tunnel area
Cable area
Channel outline, 2010
Shoreline and dock
Land planimetrics
As drilled boring locations
Direction of sonar illumination
Massachusetts Mainland State Plane Feet Coordinate System
North American Datum of 1983 (NAD83)
Vertical datum: MLLW (NAVD 1988)
2013 Orthophotos: USGS and Massachusetts

Figure 101. Orthosonograph of Ted Williams Tunnel west of the MSCMMT.

8.0 Conclusions

The strata of interest are the Holocene sediments, Pleistocene Boston Blue Clay, Pleistocene till, weathered Neoproterozoic Cambridge Argillite, and fast Neoproterozoic Cambridge Argillite. A Jurassic diabase was observed in boring FD14-26 outside of the required dredging prism.

The harbor deepening consists of three distinct projects: the -51ft project, the -47ft project, and the -45ft project. Each project is divided into three distinct elevations: (1) the newly authorized required grade; (2) the first paid overdepth, or in the case of rock or hard bottom, the required overdepth; (3) and in the case of rock in the first overdepth, the second paid overdepth.

The principle issues of concern are (a) rock properties, (b) sediment properties, (c) bathymetry, (d) infrastructure, and (e) debris.

The harbor deepening consists of three distinct project segment depths: the -51ft project segments, the -47ft project segments, and the -45ft project segment. Each project is divided into three distinct elevations: (1) the newly authorized required grade; (2) 2ft of optional paid overdepth in ordinary material, or required overdepth in the case of rock or hard bottom; (3) and an additional optional 2ft-paid overdepth in the case of rock or till at grade and the first overdepth.

1. The total volume to the newly authorized grade is 8.09 million cuyd including side slopes.

2. The volume of the rock is less than 1% of the total volume to be removed to the newly authorized grade.

3. A small portion of the rock, mostly in the North Channel and Main Ship Channel in the Reserved Channel area, is fast rock.

4. Fast rock is defined as rock whose compressional wave velocity is faster than 2,700m/s.

5. The total amount of fast rock above grade is 2,944cuyd.

6. That constitutes less than 0.04% of the total volume or less than 3% of the volume of rock.

7. e4 calculated an error of ±3% on each of these volume estimates. No contingency was applied to any of these estimates.

8. The USACE has tested the silt in President Roads Anchorage and the Reserved Channel areas as suitable for ocean disposal.

9. Adding an additional 2ft for paid overdepth and the required overdepth in the case of hard bottom or rock throughout the project adds 3.52 million cuyd and raises the total volume to 11.53 million cuyd.

10. The volume of rock rises to 0.28 million cuyd or 22% of the total cumulative volume.

11. In the first overdepth, the volume of fast rock 8,219cuyd or 5% of the total rock.

12. In the case of rock or hard bottom, an optional 2ft overdepth beyond the required 2ft overdepth is allowed. This second overdepth adds 0.49 million cuyd and raises the total

volume of material to be dredged to 12.02 million cuyd.

13. The second overdepth raises the total volume of rock to 495,659cuyd. This estimate puts the total volume of rock at roughly 4.1% of the total cumulative volume to the second overdepth.

14. The cumulative total amount of fast rock is 46,092cuyd and constitutes less than 9.3% of total rock volume.

15. In the North Channel, the volume of rock and till is 377,763cuyd above grade and that constitutes 3.6% of total volume.

16. In the North Channel, volume of fast rock is 19,000cuyd, or less than 13% of the total rock volume.

17. In the Main Ship Channel in Reserved Channel area, the rock and till constitutes 145,057cuyd, and that is less than 7% of the total volume.

18. In the Reserved Channel, the rock represents as much as 20% of the total volume. In the Reserved Channel, 17% of the rock is fast rock.

19. In the Main Ship Channel at the Massport Maritime Terminal, fast rock is a small concern. In the Main Ship Channel in the President Roads area, the rock is an even smaller concern.

20. The total volume required to be dredged is the sum of the material above newly authorized grade and the material above the required overdepth in case of rock or hard bottom.

21. The total required volume to be dredged is 8.09 million cuyd.

22. Live infrastructure such as cables and pipelines may need to be moved before it delays the project. The crossings in the Main Ship Channel in Reserved Channel area may need to be removed or abandoned. We have not been assigned a one-to-one identification of the pipes and cables in the channels.

23. The utilities should be mapped and resolved as soon as possible.

24. If pipelines crossing the channel are abandoned, or cleaned and capped, then the materials become debris. If abandoned, beware of possible leaks or spills during removal.

25. The cables and pipelines in the Main Ship Channel in President Roads Anchorage area are deep enough not to be of concern except on the slope. However, all infrastructure regardless of depth should be marked on the plans to warn about no spudding.

26. The various areas that e4 investigated have enough differences among them that they may warrant discrete consideration for separate dredging contracts. Separate smaller contracts may also provide the opportunity to apply lessons learned.

27. Heave and ocean swells may likely be a factor in lost time during the deepening project.