BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX B

PROJECT AUTHORIZATION
AND WORK HISTORY

THIS APPENDIX UPDATED JANUARY 2013

BOSTON HARBOR, MASSACHUSETTS
NAVIGATION IMPROVEMENT STUDY

APPENDIX B
PROJECT AUTHORIZATION AND WORK HISTORY

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APPENDIX B
PROJECT AUTHORIZATION AND WORK HISTORY

Summary of Prior Reports and Improvements

The Port of Boston covers a wide geographical area and includes several distinct sections, most of which have been the subject of Corps studies and projects. Records concerning the Works of Preservation of Navigation for the harbor islands and adjacent headlands are also listed separately.

Separate records are provided for the Chelsea River, Mystic River, Island End River, Charles River and the Weir River (Nantasket Channel, Hull) to provide an easier reference for these projects and project features.

The original natural mouth of the Mystic River was located together with the mouth of the Charles River at the confluence bordered by the North End of Boston, Charlestown and East Boston. With the Deepening of the Port, the accepted "mouth" of the Mystic became viewed as being what is now known as the Inner Confluence at the head of the harbor between Chelsea and Charlestown. Accordingly, early authorizations and work for the improvement of harbor areas above the North End are also referenced to the Mystic River.

Early improvements to harbors such as Hingham Harbor, Weir River and Charles River were made under the Authority for Boston Harbor. At later times these projects were the subject of their own named authorizations. Where a duality was noted, applicable authorizations and work were included in both the Boston Harbor and other individual harbor records.

Records are provided in the tables included in this appendix under the following headings:

Boston Harbor – Main Ship Channels
Boston Harbor – Charles River Channel - Boston, Cambridge, Charlestown, Arlington
Boston Harbor – East Boston Channels – Jeffries Point & Governor's Island Channels
Boston Harbor – Fort Point Channel & South Bay – Boston and South Boston
Boston Harbor – Reserved Channel and Drydock Channel – South Boston
Boston Harbor – Seaplane Channels – East Boston
Boston Harbor – Works of Preservation - Seawalls on Harbor Islands & Headlands, Boston, South Boston, Hull & Winthrop
Chelsea River – East Boston, Chelsea & Revere
Island End River – Chelsea and Everett
Mystic River – Charlestown, Chelsea, Everett, Somerville and Medford
Weir River – Nantasket Channel, Hull

Reports have also been prepared for a number of projects and project segments in and around Boston Harbor that were never authorized and constructed, and therefore these projects are not included in this appendix. These reports include the following harbor areas:

Allerton Harbor – Hull (Hog Island Channel constructed for Coast Defense)
Belle Isle Inlet – East Boston and Winthrop – 1919
Boston Harbor Debris Studies – 1973 to 1979

Columbia Point Channel – Dorchester – 1980
Little Mystic Channel – Charlestown – 1911 & 1957
Pleasure Bay and Old Harbor – South Boston – 1942

There are also a number of projects around Boston Harbor that were studied, authorized and constructed under their own individual authorities. Records of these projects are not included in this appendix. These projects include:

Dorchester Bay and Neponset River – Boston, Quincy and Milton
Hingham Harbor – Hingham
Malden River – Malden and Everett
Weymouth Fore River – Weymouth, Quincy and Braintree
Weymouth Back River – Weymouth and Hingham
Winthrop Harbor – Winthrop

TABLE B-1
LIST OF PROJECT AUTHORIZATIONS

BOSTON HARBOR, MASSACHUSETTS, DEEP DRAFT CHANNELS
MAIN SHIPPING CHANNELS & ANCHORAGES
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction
River & Harbor Act of 2 March 1867	23-Foot MLW Channel, 685 Feet Wide through the Narrows and 1,000 Feet Wide in the Main Channel of the Upper Harbor, Removal of Tower and Corwin Rocks from the Narrows, and Seawalls at Point Allerton, Long Island Head and Gallops Island	July 1867 – June 1906
River & Harbor Act of 2 March 1867	Removal of Barrel Rock from the Approach to the Broad Sound South Channel to –22.5 Feet	July 1869 – Aug 1869
River & Harbor Act of 18 June 1878 20 Stat. 152, Ch. 264	Removal of the Man-of-War Shoal, at the Old Confluence of the Charles and Mystic Rivers to -23 Feet MLW over a 10-Acres	Aug 1878 – March 1880
River & Harbor Act of 3 March 1879	Removal of Anchorage Shoal and Bird Island Flats to Widen the 23-Foot Channel to 1,100 Feet, and also Increase the Width of the Channel through the Lower Middle Shoal to 600 Feet	Anchorage Shoal: Sept 1879 – June 1880 Lower Middle: June 1880 - ?
River & Harbor Act of 3 March 1879	Removal of the Shoal at the Mouth of the Mystic River Opposite the Navy Yard to -23 Feet MLW by 400 Feet Wide	Oct 1879 – June 1883 (to 375 Feet Wide)
Annual Report for 1883, Appendix B-4	Nubble Channel between Nixes Mate and the Head of Long Island, -12 Feet MLW by 200 Feet	Sept 1883 – Oct 1883
Annual Report for 1887, Appendix B-7	Increasing the Width of the Nubble Channel to 300 Feet, at -15 Feet MLW	Sept 1891 – Jan 1892
River & Harbor Act of 13 July 1892	A -27-Foot MLW by 1,000-Foot Wide Channel through the Narrows and up into the Upper Harbor to the Wharves at the North End of Boston	Dec 1892 – 1906 (Full Width Achieved Concurrent with 35-Foot Channel)
River & Harbor Act of 3 March 1899	New Entrance Channel through Broad Sound South Channel -30 Feet MLW by 1,200 Feet Wide	July 1900 – Oct 1905

River & Harbor Act of 13 June 1902	A 35-Foot 1500 Foot Wide Entrance Channel by the Broad Sound North Route and then 1,200 Feet Wide into the Inner Harbor up to the Pier Head Lines and First Bridges in the Charles, Mystic and Chelsea Rivers	April 1903 – 1915???
Annual Report for 1907, Appendix B-9, Page 907	The Lower Reaches of the Mystic River below the Chelsea Bridge were Incorporated into the Project for the Main Ship Channel of Boston Harbor as Authorized by the River & Harbor Act of 2 March 1907. Further Work on the 25-Foot Lower Mystic Channel Authorized by the River & Harbor Act of July 1902 Transferred to Boston Harbor Project	Modification – No Further Mystic River Work below Chelsea Bridge
Chief of Engineer's Special Authoriz'n., 11 March 1913	Elimination of the Removal of Finn's Ledge from the 35-Foot Broad Sound North Channel (Annual Report for 1913, Appendix B-9)	Abandonment of Unconstructed Feature
River & Harbor Act of 8 August 1917	Deepen the Southerly 900-Foot Width of the Broad Sound North Entrance Channel to -40 Feet MLW (-45 Feet in Rock) with an Outer Bend Easterly to Clear Finn's Ledge at a Width of 1,100 Feet	June 1926 – Aug 1930
River & Harbor Act of 30 August 1935 and National Industrial Recovery Act of 6 September 1933	Deepen a 600-Foot Width of the Main Ship Channel to -40 Feet MLW Up to Pier #1 in East Boston, along the South Channel Limit from President Roads to the Commonwealth Pier in South Boston, then along the North Limit up to Pier #1, and Providing an Anchorage at the North Side of President Roads, -40 Feet MLW, 2,000 Feet by 5,500 Feet	Anchorage: Oct 1933 – March 1937 Main Ship Channel: March 1936 – Jan 1941
River & Harbor Act of 30 August 1935	Deepen the US Navy Drydock #3 Approach Channel in South Boston to -40 from the Main Ship Channel to the US Harbor Line, with the Navy Funding the Remainder of the Channel Landward of the Harbor Line to the Drydock	January 1937 – August 1939
River & Harbor Act of 17 October 1940	Reserved Channel -30 Feet MLW 300 Feet Wide West from the 40-Foot Main Ship Channel to about 250 Feet Downstream of the L Street Bridge	June 1941 – Sept 1941
River & Harbor Act of 17 October 1940	Seaplane Channel to East Boston	Never Constructed
Act of 7 September 1944	Abandoned the Unconstructed Project for a Seaplane Channel to East Boston	Deauthorization

River & Harbor Act of 2 March 1945	Extension of the 40-Foot Main Ship Channel up-Harbor to Commonwealth Mystic Pier #1 in Charlestown	March 1951 – Oct 1951
River & Harbor Act of 24 July 1946	Expand the 40-Foot President Roads Anchorage by 100 Acres, 700 Feet North and 500 Feet West, Flared 45° to Join the 40-Foot Channel and Cut Off in the Northeast Corner for a Total of about 353 Acres, and a New -35-Foot MLW Anchorage West of President Roads Anchorage 800 Feet Wide by 5,000 Feet Long along the North Limit of the 35-Foot Main Ship Channel with Disposal East of Governor's Island to Enlarge the Airport.	Nov 1956 – May 1960
River & Harbor Act of 3 July 1958	Reserved Channel at -35 Feet MLW by 430 Feet Wide up to the L Street Bridge	May 1960 – Aug 1960
Water Resources Development Act of 31 October 1992, Section 116(2)	Deauthorizes the Portion of the 35-Foot Main Ship Channel Lane West of the 40-Foot Channel along the Charlestown Shore between the Inner Confluence and the 35-Foot Charles River Channel	Deauthorization
1 January 1990, Federal Register, Vol. 55, #194, 5 Oct 1990, Pg. 40906-40908	Deauthorizes the Uncompleted Portion of the 40-foot Main Ship Channel Deepening Project along the East Boston Shore below the Inner Confluence as Authorized by the River & Harbor Act of 2 March 1945	Deauthorization
Water Resources Development Act of 28 November 1990, Section 101(a)(13)	Reserved Channel: Deepen the Lower 3,160 LF of Channel to -40 Feet MLW 400 Feet Wide, a 40-Foot Turning Basin Including a Portion of the 35-Foot Main Ship Channel Lane and an Area between the Reserved Channel and Drydock Channel Inner Confluence: Deepen to -40 Feet, and Widen Approach along the East Boston Shore Mystic River: Deepen the Lower River Channel and Northern Half of the Upper Channel Area to 40 Feet Chelsea River: Deepen the Entire 35-Foot Channel to –38 Feet President Roads: Establish Limits for the 40-Foot 1,200 Foot Wide Channel to Enlarge the Available Anchorage by about 84 Acres	Mystic River: Aug 1998 – Feb 2000 Reserved Channel and Turning Area: Oct 1998 – Feb 2000 Chelsea River: Aug 1999 – Sept 2001 Inner Confluence: Mar 1999 – Feb 2000
Design Memorandum, 5 June 1996	Reserved Channel: Narrows the 40-Foot Lower Channel to 380 Feet to Permit Wider Berth at Conley Terminal	See Above

Water Resources Development Act of 25 September 1996, Section 364(12) & 364(16)	Reserved Channel: Deauthorizes a 54-Foot Wide Strip along the Southern Limit of the 40-Foot Channel for Berthing Chelsea Creek: Deauthorizes a Triangular Area on Chelsea Side Upstream of McArdle Bridge for berth Encroachment	Deauthorizations

BOSTON HARBOR - CHARLES RIVER CHANNEL
BOSTON, CHARLESTOWN, CAMBRIDGE AND ARLINGTON
MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction Dates
River & Harbor Act of 14 June 1880	7-Foot MLW Channel 200 Feet Wide up to Western Avenue, then a 6-Foot 100-Foot Wide Channel up to Market Street, and a 2-Foot MLW 75-Foot Wide Channel up to the Dam at Watertown	Nov 1880 – June 1884
Unknown	Unknown whether or Not this Project was Formally Abandoned with the Construction of the Charles River Dams. There is no record of Deauthorization.	

BOSTON HARBOR - EAST BOSTON CHANNEL
(JEFFRIES POINT & GOVERNORS ISLAND CHANNELS)
EAST BOSTON, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Note: These channels, while never deauthorized, were abandoned and partly filled for the construction of the State Piers at East Boston and the expansion of Logan Airport.

Authorization	Work Authorized & Constructed	Construction
River & Harbor Act of 19 September 1890	Channel –18 Feet MLW by 400 Feet Wide from the Grand Junction Wharves East to the Simpson Drydock, then –15 Feet by 250 Feet Wide to Deep Water East of Jeffries Point	FY 1892 – Nov 1893

BOSTON HARBOR - FORT POINT CHANNEL
BOSTON AND SOUTH BOSTON, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction Dates
River & Harbor Act of 5 August 1886	Channel -23 Feet MLW by 175 Feet Wide Extending 4,200 LF Upstream to the Mount Washington Avenue Bridge	Dec 1886 – Nov 1907
P.L. 84-34, 58 Stat. 728 13 May 1955	Declared Non-Navigable the Fort Point Channel and South Bay above Dorchester Avenue, Abandoning those Project Features	Abandonment
PL 91-624, 31 December 1970	Deauthorized the Channel above Summer Street to Dorchester Avenue	Deauthorization
PL 97-128 § 4(c), 29 December 1981	Deauthorized the Portion of the Channel Above Northern Avenue to Allow Replacement with a Fixed Span	Deauthorization

BOSTON HARBOR - RESERVED CHANNEL AND DRYDOCK CHANNEL
SOUTH BOSTON, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction
River & Harbor Act of 30 August 1935	Deepening the Approach to the US Navy Drydock #3 in South Boston to -40 from the Main Ship Channel to the Drydock	1941
River & Harbor Act of 17 October 1940	Reserved Channel -30 Feet MLW 300 Feet Wide West from the 40-Foot Main Ship Channel to about 250 Feet Downstream of the L Street Bridge	June 1941 - Sept 1941
River & Harbor Act of 3 July 1958	Deepen the Channel to -35 Feet MLW, Widened along Its Northern Limit to 430 Feet, to about 250 Feet Downstream from the L Street Bridge	May 1960 – Aug 1960
Water Resources Development Act of 28 November 1990, Section 101(a)(13)	Reserved Channel: Deepen the Lower 3,160 LF of Channel to -40 Feet MLW 400 Feet Wide, a 40-Foot Turning Basin Including a Portion of the 35-Foot Main Ship Channel Lane and an Area between the Reserved Channel and the Drydock Channel	Reserved Channel and Turning Area: Oct 1998 – Feb 2000

Water Resources Development Act of 1996, §364 (16)	Deauthorized a 54-Foot Wide Strip along the Southern Limit of the 40-Foot Channel to Widen Berths at the Conley Terminal	Deauthorization

BOSTON HARBOR - SEAPLANE CHANNELS
EAST BOSTON, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction
River & Harbor Act of 17 October 1940	Construction of a Seaplane Channel Extending about 17,500 LF Northwesterly from the President Roads Anchorage to a Basin at East Boston at 1,500 Feet Wide by -12 Feet MLW	Never Constructed
Act of 7 September 1944	Abandoned the Unconstructed Project for a Seaplane Channel to East Boston	Deauthorized

BOSTON HARBOR - BOSTON HARBOR WORKS OF PRESERVATION
(SEAWALLS ON HARBOR ISLANDS AND HEADLANDS)
BOSTON, SOUTH BOSTON, HULL AND WINTHROP, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed		Construction
2 March 1825 and 23 May 1828	Construction of Stone Seawalls at Deer Island		1827 - 1869
Act of 2 March 1825		Georges Island Seawalls	1827 – 1835
Act of 23 May 1828 Act of 2 July 1864 Act of 28 Feb 1865 Act of 12 June 1866		Deer Island Seawalls	1828 – 1830 Repaired 1869
Annual Report of the Chief of Engineers, 13 November 1832		Castle Island Seawall	1835
Act of 4 July 1836 Act of 7 July 1838		Rainsford Island Seawall	1836 – 1838 Repaired 1879
Act of 20 July 1848 Act of 2 July 1864 Act of 28 Feb 1865 Act of 12 June 1866		Lovell's Island Seawalls	

Act of 30 Aug 1852 Act of 28 Feb 1865 Act of 12 June 1866		Great Brewster Island Seawalls	1849 - 1869
River & Harbor Act of 2 March 1867	Construction of Stone Seawalls at Point Allerton, Long Island Head and Gallups Island		
		Gallops Island Seawall	1868, Repaired 1873-1874
		Long Island Head Seawall	Unknown
		Point Allerton Seawall	1871 – 1874

CHELSEA RIVER
EAST BOSTON, CHELSEA & REVERE, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction
River & Harbor Act of 3 June 1896	Channel -18 Feet MHW (-8.4 Feet MLW) by 150 Feet Wide (234,000 cy Estimated), above the Grand Junction Railroad Bridge to the Head of Navigation	Nov 1896 - 1907
River & Harbor Act of 25 July 1912	25-Foot MLW Channel in Chelsea Creek between the Meridian Street and Old East Boston Bridges (Lower River only)	July 1915 – April 1916
River & Harbor Act of 26 August 1937	Channel -30 Feet MLW by 200 Feet Wide, Widened in the Bends, from Boston Harbor Upstream to the Upper Oil Wharf at Revere	Oct 1938 - FY 1940 Sewer Lowered in 1946
River & Harbor Act of 23 October 1962	Channel -35 Feet MLW 225 to 250 Feet Wide below Chelsea Street Bridge and 250 to 430 Feet Wide above the Bridge, with a 35-Foot Turning/ Maneuvering Basin Upstream Limit at Revere 800 Feet Wide by 1,000 Feet Long. Remaining Upstream Portions of the 30-Foot Project of 1937 and the 8.4-Foot Project of 1896 were Deauthorized and Abandoned.	July 1965 – May 1966
Water Resources Development Act of 28 November 1990, Section 101(a)(13)	Deepen the Entire 35-Foot Channel and Turning Basin to –38 Feet MLW	April 1999 – Dec 2001

Water Resources Development Act of 25 September 1996, Section 364(12)	Deauthorizes a Triangular Area of the 38-Foot Channel on Chelsea Side Upstream of the McArdle Bridge	Deauthorization

ISLAND END RIVER, CHELSEA & EVERETT, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction
Chief of Engineers, 6 April 1981, under §107 of the River & Harbor Act of 14 July 1960	Channel, -6 Feet MLW by 100 Feet Wide, Extending about 2,500 LF from the Mystic River Channel to a Public Marina Site in Chelsea at the Head of the Island End River	September 1981 – April 1982
Water Resources Development Act of 9 November 2007, Section 3181	Deauthorizes a portion of the upper reach of the Channel alongside the Municipal Marina to Resolve an Encroachment Issue	Deauthorization

MYSTIC RIVER
CHARLESTOWN, CHELSEA, EVERETT, SOMERVILLE, MEDFORD, ARLINGTON & WATERTOWN, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Note: Prior to the 20th Century, the mouth of the Mystic River was at its confluence with the Charles River at the Head of Boston Harbor. As port improvements pushed deep water upstream the accepted mouth of the Mystic River became instead its confluence with the Chelsea River at today's Inner Confluence. Mystic River records through about 1907 include the lower reaches of the Mystic River above the mouth of the Charles River.

Authorization	Work Authorized & Constructed	Construction
River and Harbor Act of 13 July 1892	Channel -6 Feet MLW by 100 Feet Wide from the B&M Bridge Extending 6,300 LF Upriver to the Turn at the Somerville/Medford Line above Dunnings Wharf, then at -4 Feet MLW a Further 2 Miles, Diminishing in Width until 50 Feet at the Head of Navigation at Craddock Bridge at Medford	July 1895 – Nov 1906
River & Harbor Act of 3 March 1899	Channel -25 Feet MLW 300 Feet Wide 2,650 LF Upriver from Boston Harbor to the Chelsea Bridge and then 3,500 LF up to a Point 800 Feet above the Island End River	Jan 1900 -

Annual Report for 1907, Appendix B-9, Page 907	Incorporates the Lower Reaches of the Mystic River below the Chelsea Bridge into the -35-Foot MLW Main Ship Channel Project for Boston Harbor as Authorized by the River & Harbor Act of 2 March 1907	Modification
River & Harbor Act of 25 June 1910	Abandoning the 800 LF of the -25-Foot Channel above the Island End River, Deepen the Remaining Channel to -30 Feet MLW, and Widen the Channel at its Upper End in the Approach to the Mystic Wharf to 600 Feet	Nov 1910 –
River & Harbor Act of 30 August 1935 and the Emergency Relief Appropriations Act of 28 May 1935	A 2,800 LF Extension of the 30-Foot MLW Channel above Island End River Upriver to the Playground at Charlestown at -30 Feet MLW by 500 Feet Wide	Sept 1935 – Feb 1938
River & Harbor Act of 20 June 1938	Assuming Maintenance Responsibility and Improving a State Dredged Channel -20 Feet MLW 270 Feet Wide from the 30-Foot Channel 1,200 LF Upstream to the Malden Bridge, 75 Feet Wide through Span, and Widened above the Bridge for a Turning Basin 340 Feet Wide Ending about 800 Feet above the Malden Bridge	Oct 1939 – Jan 1940
River & Harbor Act of 17 May 1950	A 35-Foot MLW Channel from the 35-Foot Main Ship Channel in Boston Harbor up to the Malden Bridge, for a Width to within 100 Feet of the Bulkhead Lines on Both the North and South Shorelines, Narrowing in the Approach to the Malden Bridge	Jan 1956 - June 1958 (Except for the Upper Section along the Charlestown Shore, that Remained at 30 Feet)
Design Memorandum, 1 July 1955	35-Foot Channel Widths Specified as 940 Feet at Lower End, Widening to 1,060 Feet at about 1,200 LF below the Malden Bridge, then Narrowing to 150 Feet Wide at the Malden Bridge	See above
Water Resources Development Act of 28 November 1990, Section 101(a)(13)	Mystic River: Deepen the Lower River Channel and Northern Half of the Upper Channel Area to 40 Feet	Mystic River: Aug 1998 – Feb 2000
Water Resources Development Act of 12 October 1996,	Deauthorizes a 40-Foot Wide Strip 1000 Feet Long along the Northern Limit of the 35-Foot Channel (Authorized by Section 101 of the	Deauthorization

P.L. 104-303, Section 364(15)	River and Harbor Act of 1950, 64 Stat. 164), in Order to Permit Berthing of Larger Vessels at Facilities in Everett	
Water Resources Development Act of 9 November 2007, Section 3181	Realigns and Narrows a Portion of the Upper 4-Foot Channel to Resolve a Marina Encroachment Issue	Deauthorization and Realignment

WEIR RIVER, HULL, MASSACHUSETTS
LIST OF AUTHORIZATIONS

Authorization	Work Authorized & Constructed	Construction
River & Harbor Act of 14 June 1880	Channel -9½ Feet MLW by 100 Feet Wide to the Pier at Nantasket Beach	Dec 1880 – Sept 1882
Annual Report of 1890, Page 497	Widening the Channel in a Key Turn to 250 Feet	May 1890 – June 1890
River & Harbor Act of 19 September 1890	Widen the -9½ Foot MLW Channel to 150 Feet Wide	March 1891 – April 1891 Ledge - Nov 1894
Chief of Engineers 25 July 1892, Annual Report of 1893, Page 763	Channel -12 Feet MLW by 150 Feet Wide to Nantasket Pier	June 1893 – Nov 1894

TABLE B-2
PROJECT CONSTRUCTION AND MAINTENANCE HISTORY

BOSTON HARBOR, DEEP DRAFT CHANNELS
MAIN SHIPPING CHANNELS & ANCHORAGES
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
July 1867 – Fall 1869	Improvement Dredging of the 23-Foot Narrows Channel at Reduced Width of 625 Feet and Reduced Depth of –21.5 Feet	159,809 cy 47,294
July 1867 – Sept 1867	Removal of Tower Rock from Narrows Channel Approach off Hull to –23 Feet MLW	150 Tons Ledge

Oct 1867 – Dec 1968 and June 1869	Removal of Corwins Rock from Narrows to –23 Feet MLW	1,356 Tons Ledge (609 cy)
FY 1869	Improvement Dredging with Experimental Plant of the 23-Foot Channel at Middle Ground	450 cy Hardpan
July 1869 – Aug 1869	Removal of Barrel Rock from the Approach to the Broad Sound South Channel to –22.5 Feet	225 Tons Rock
Aug 1869 – Dec 1870	Removal of Kelly's Ledge from Narrows Approach	509 Tons Ledge
July 1870 - June 1871	Continue Improvement Dredging of the 23-Foot Harbor Channel at Upper Middle Ground	26,120 cy Yellow Hard Pan
Dec 1871 – June 1872	Continue Improvement Dredging of the 23-Foot Harbor Channel at Upper Middle Ground	20,305 cy
November 1872	Removal of a Large Boulder from Upper Middle Shoal	6 cy Boulder
May 1873 – June 1873	Removal of Wreck of Schooner *Delos* from Nantasket Roads	Wreck Removal
June 1873 – July 1873	Continue Removal of Kelly's Rock from the Narrows Channel	118 Tons Ledge
April 1874 – July 1876	Continue Improvement Dredging of the 23-Foot Harbor Channel at Upper Middle Ground	90,860 cy
Aug 1874 – Sept 1874	Removal of the Ledge Southwest of Bug Light from the Narrows Approach	16 cy Ledge
Sept 1874 – June 1875	Removal of State Rock and Palmyra Rock from the Lower Middle Ground Bar to –23 Feet	62 cy Rock
Oct 1874 – Sept 1875	Continue Improvement Dredging of the 23-Foot Narrows Channel at Lovells Island and Great Brewster Spit	60,284 cy
Oct 1874 – Dec 1875	Continue Improvement Dredging of the 23-Foot Harbor Channel at the Upper Middle Ground	42,844 cy
May 1875 – Sept 1875	Continue Removal of Kelly's Rock from the 23-Foot Narrows Channel	80 cy Ledge
September 1875	Removal of another Ledge from the Narrows East of Georges Island	16 cy Ledge
May 1876 – Nov 1876	Continue Improvement Dredging of the 23-Foot Harbor Channel at the Upper Middle Ground	88,150 cy

FY 1876 – Sept 1876	Removal of Nash's Rock from the Narrows Channel to –21 Feet	200 cy Ledge Estimated
June 1876 – Nov 1876	Removal of Ledge from Dredged Area in Narrows at Great Brewster Spit	96 cy Ledge
July 1876 – August 1876	Removal of Ledge from Dredged Area in 23-Foot Upper Middle Bar Channel	37 cy Ledge
June 1877 – Sept 1877	Continue Improvement Dredging of the 23-Foot Narrows Channel at Lovells Island	29,134 cy
June 1877 – Dec 1877	Partial Removal of Additional Ledges from the Narrows Channel near Kelly's Rock	76 cy Ledge
April 1878 – Aug 1878	Removal of Ledges from the Upper Middle Shoal to –23 Feet	82 cy Ledge
Sept 1877 – Nov 1877	Continue Removal of Nash's Rock from the Narrows Channel to –21 Feet	320 Tons Ledge and Boulders
Aug 1878 – March 1880	Improvement Dredging to Remove the Man-of-War Shoal at the Mystic-Charles Confluence to –23 Feet	85,917 cy
Aug 1878 – June 1879	Partial Removal of Additional Ledges from the Narrows Channel near Kelly's Rock	132 cy Ledge
August 1878	Complete the Removal of Nash's Rock from the Narrows Channel to –21 Feet	45 Tons Ledge and Boulders
July 1879 – Nov 1879	Complete Removal of Kelly's Rock from the Narrows to –23 Feet MLW	146 cy Ledge
Sept 1879 – June 1880	Improvement Dredging of Anchorage Shoal to Widen the 23-Foot Upper Harbor to 1,100 Feet	21,054 cy
June 1880 – Aug 1880	Improvement Dredging to Widen the 23-Foot Lower Middle Channel to 600 Feet	5,007 cy Hardpan
Oct 1879 – March 1880	Begin Improvement Dredging to Remove the Shoal at the Mouth of the Mystic River Opposite the Navy Yard to -23 Feet MLW	47,953 cy
Nov 1880 – June 1881	Continue Improvement Dredging of the Shoal at the Mouth of the Mystic River -23 Feet	48,343 cy
Aug 1880 – April 1883	Continue Improvement Dredging of Anchorage Shoal to Widen the 23-Foot Upper Harbor	155,243 cy
Dec 1881 – June 1883	Continue Improvement Dredging of the Shoal at the Mouth of the Mystic River -23 Feet	82,020 cy

Sept 1883 – Oct 1883	Improvement Dredging of the 12-Foot Nixes Mate Channel	19,900 cy
Sept 1883 – Nov 1883	Improvement Dredging to Remove a Spur Shoal off Castle Island to Widen the 23-Foot Channel	31,950 cy Plus 20 Tons Ledge
Oct 1887 – June 1888	Continue Improvement Dredging of the 23-Foot Channel at the Lower Middle Shoal	65,576 cy
Oct 1887 – June 1888	Continue Improvement Dredging of the 23-Foot Channel at the Narrows	3,430 cy
July 1888 – May 1889	Removal of Ledge from the 23-Foot Channel at the Lower Middle Shoal to Complete the 1,000 Foot Width	375 cy Rock
Dec 1888 – May 1889	Continue Improvement Dredging of the 23-Foot Channel at the Upper and Lower Middle Shoal	146,556 cy
August 1889	Continue Improvement Dredging of the 23-Foot Channel at the Upper Middle Shoal	5,942 cy
April 1890 – June 1890	Continue Improvement Dredging of the 23-Foot Channel at the Upper Middle Shoal	111 cy Ledge
June 1891 – July 1891	Continue Improvement Dredging to Widen the 23-Foot Channel in the Narrows at Great Brewster Spit to 625 Feet	28,510 cy
Sept 1891 – Jan 1892	Improvement Dredging of the 15-Foot Nubble (Nixes Mate) Channel	7,674 cy
FY 1892	Improvement Dredging of the 18-Foot and 15-Foot Jeffries Point Channel	139,962 cy
April 1892 – Nov 1892	Continue Improvement Dredging of the 23-Foot Channel at the Upper Middle Shoal	211,992 cy
Dec 1892 – April 1895	Begin Improvement Dredging of the 27-Foot Narrows Channel along Lovells Island	580,048 cy Plus 31 cy Boulders & 9,000 cy Ledge
April 1895 – Sept 1895	Continue Improvement Dredging of the 27-Foot Narrows Channel along Lovells Island to a Minimum Width of 550 Feet	149,479 cy
May 1895 – Nov 1897	Begin Improvement of the 27-Foot Channel at the Lower Middle Ground and Elsewhere in the Main Channel by Removal of Ledge	6,721 cy Ledge

Oct 1897 – June 1899	Continue Improvement Dredging to Widen the 27-Foot Narrows Channel to 1,000 Feet	1,150,703 cy
July 1899 – Dec 1902	Improvement Dredging of the 27-Foot Channel from President Roads to Boston through the Upper and Lower Middles and Shoals	1,830,653 cy Plus 159 cy Boulders & 3,505 cy Rock
July 1900 – May 1904	Begin Improvement Dredging of the 30-Foot Broad Sound South Entrance Channel	888,957 cy Plus 166 cy Boulders
Oct 1902 – May 1906	Continue Ledge Removal from the 27-Foot Narrows Channel	19,008 cy Ledge (in-place)
December 1902	Removal of a Ledge from President Roads Channel to –30 Feet MLW	21 cy Ledge
April 1903 – Jan 1912	Begin Improvement Dredging of the 35-Foot Main Ship Channel at 600 Feet Wide	7,478,102 cy Plus 19 cy Boulders
Sept 1903 – Nov 1903	Maintenance Dredging of the 27-Foot Narrows Channel	23,147 cy
Sept 1903 – Nov 1910	Improvement Dredging of the 35-Foot Broad Sound North Entrance Channel at 600 Feet	2,101,912 cy Plus 116 cy Boulders
Nov 1903 – Fall 1904	Continue Ledge Removal from the 27-Foot Narrows Channel	223 cy Ledge (in-place)
FY 1904 – March 1906	Continue Ledge Removal from the 27-Foot Lower Main Harbor Channel	2,066 cy Ledge (in-place)
Aug 1904 – Oct 1905	Continue and Complete Improvement Dredging and Ledge Removal from the 30-Foot Broad Sound South Entrance Channel	76,427 cy Plus 156 cy Ledge and 15 cy Boulders
August 1904 – Dec 1904	Maintenance Dredging of the 27-Foot Narrows Channel by Contract	26,600 cy
Jan 1905 – April 1905	Maintenance Dredging of the 27-Foot Narrows Channel by US Hydraulic Dredge Gillespie	46,841 cy
July 1905 – Aug 1908	Removal of Ledge from the 35-Foot Channel off Governors Island (also Completes the 27-Foot Upper Main Ship Channel)	1,338 cy Ledge above –27 Feet & 15,217 cy below 27 Feet (in-place)
Nov 1906 – Jan 1907	Complete Ledge Removal from the 27-Foot Lower Main Ship (Narrows) Channel	25 cy Ledge
Aug 1907 – Aug 1909	Removal of Ledge from the 35-Foot Main Ship Channel in the Lower Harbor	15,200 cy Ledge (in-place)

Annual Report for 1907, Appendix B-9, Page 907	The Lower Reaches of the Mystic River below the Chelsea Bridge were Incorporated into the Project for the Main Ship Channel of Boston Harbor as Authorized by the River & Harbor Act of 2 March 1907	Modification – No Further Mystic River Work below Chelsea Bridge
Nov 1907 – June 1908	Continued Improvement Dredging of the 25-Foot Channel in the Mystic River Mouth below the Chelsea Bridge. Further Work in the Reach Accomplished under the 35-Foot Project	38,732 cy
Oct 1907 – Jan 1912	Improvement Dredging to Widen the 35-Foot Channel to its 1,500 and 1,200 Foot Widths (Divisions 5, 6, 7 & 8 - MSC, and 5a, 6a, 7a & 8a - BSNC)	MSC: 9,169,600 cy Plus 5 cy Boulders BSNEC: 2,625,190 cy Plus 234 cy Boulders
March 1910 – April 1910	Continued Improvement Dredging of the 25-Foot Channel in the Mystic River Mouth below the Chelsea Bridge	24,942 cy
FY 1911	Continued Improvement Dredging of the 25-Foot Channel in the Mystic River Mouth below the Chelsea Bridge	55,853 cy
FY 1911	Removal of 20 Small Ledge Pinnacles from the Upper 35-Foot Main Ship Channel	Unknown
July 1911 - Aug 1911	Shoal in the Old Dump Ground in Broad Sound was Removed to a Depth of -45 Feet MLW	140,000 cy
July 1911 – March 1915	Continue Removal of Ledge from the 35-Foot Main Ship Channel in the Lower Harbor and Inner End of the 35-Foot Broad Sound North Entrance Channel	110,601 cy Ledge
April 1913 – June 1913	Maintenance Dredging of the 35-Foot Broad Sound North Entrance Channel by U.S. Hopper Dredge *Atlantic*	189,744 cy
July 1913 – Dec 1913	Maintenance Dredging of the 30-Foot Broad Sound South Entrance Channel and 35-Foot Broad Sound North Entrance Channel by U.S. Hopper Dredge *Atlantic*	358,839 cy
March 1915	Removal of Ledge from the 35-Foot Inner Confluence	800 cy Ledge
May 1915 – July 1917	Maintenance Dredging of the 35-Foot Main Ship Channel	901,353 cy

May 1915 – July 1917	Maintenance Dredging of the 35-Foot Broad Sound North Entrance Channel	141,162 cy
May 1916 – June 1916	Maintenance Dredging of the 15-Foot Nubble or Nixes Mate Channel	19,494 cy
June 1926 – Oct 1929	Begin Improvement Dredging of the 40-Foot Broad Sound North Entrance Channel Lane	826,773 cy
July 1930 – Aug 1930	Continue and Complete Improvement Dredging of the 40-Foot Broad Sound North Entrance Channel Lane	21,832 cy Plus 39 cy Boulders
March 1933 – Jan 1934	Maintenance Dredging of the 35-Foot Main Ship Channel	714,546 cy
Oct 1933 – April 1935	Improvement Dredging of the 40-Foot President Roads Anchorage	2,853,342 cy Plus 5 cy Boulders
March 1936 – Jan 1937	Begin Improvement Dredging of the 40-Foot Main Ship Channel as Far as South Boston Pier #6 (Commonwealth Pier)	1,714,698 cy
January 1937	Improvement Dredging of the 40-Foot Navy Drydock #3 Channel in South Boston	39,700 cy Estimated
Oct 1936 – March 1937	Improvement Dredging of the Northwest Corner of the 40-Foot President Roads Anchorage	249,529 cy
Feb 1938 – Aug 1939	Improvement - Removal of Ledge from the 40-Foot Navy Drydock #3 Channel in South Boston	6,800 cy Ledge Estimated
Feb 1938 – Aug 1939	Improvement - Removal of Ledge from the Lower 40-Foot Main Ship Channel up to South Boston	61,778 cy Plus 44,171 cy Ledge
Jan 1939 – July 1940	Improvement Dredging of the 40-Foot Main Ship Channel Reach from Commonwealth Pier up to East Boston Pier #1	778,620 cy
Dec 1939 – Jan 1940	Maintenance Dredging of the 40-Foot Main Ship Channel by U.S. Hopper Dredge *Marshall*	52,533 cy
Sept 1939 – Jan 1941	Improvement Dredging and Ledge Removal from the 40-Foot Main Ship Channel above the Drydock to South Boston Commonwealth Pier	35,643 cy Plus 31,757 cy Ledge 43,281 cy Plus 37,165 cy Ledge
June 1941 – Sept 1941	Initiate and Complete Improvement Dredging of the 30-Foot Reserved Channel	152,163 cy

May 1946 – June 1946	Improvement Dredging of the 30-Foot Channel over the Sewer Siphon below Chelsea Street Br.	7,359 cy
Nov 1950 – Dec 1950	Miscellaneous Debris Removal and Minor Associated Maintenance Dredging from the 30-Foot Reserved Channel	Unknown
March 1951 – Oct 1951	Improvement Dredging of the 40-Foot Main Ship Channel Extension up to Mystic Pier #1 in Charlestown	913,073 cy
July 1951 – Oct 1951	Maintenance Dredging of the 35-Foot Sections of the Main Ship Channel	153,020 cy
Nov 1951 – Feb 1952	Maintenance Dredging of the 23-Foot Fort Point Channel to Reduced Depth of –21 Feet	12,450 cy
May 1952 – Aug 1952	Maintenance Dredging of the 30-Foot Reserved Channel	48,182 cy
July 1956	Maintenance Dredging of the 35-Foot Channel in the Inner Confluence to Connect with the New 35-Foot Mystic River Channel by U.S. Hopper Dredge *Comber*	65,871 cy
Nov 1956 – Oct 1958	Improvement Dredging to Extend the 40-Foot President Roads Anchorage North and West and Dredging the 35-Foot Middle Ground Anchorage to the West	4,382,016 cy
Oct 1959 – May 1960	Continue Improvement Dredging to Extend the 40-Foot President Roads Anchorage North and West and Dredging the 35-Foot Middle Ground Anchorage	682,400 cy
May 1960 – Aug 1960	Improvement Dredging of 35-Foot by 430 Foot Wide Reserved Channel	335,000 cy
Feb 1963 – Aug 1963	Maintenance Dredging of the 40-Foot President Roads Anchorage	750,051 cy
August 1963	Maintenance Dredging of a Small Shoal from the 35-Foot Reserved Channel	200 cy
May 1965 – Nov 1965	Maintenance Dredging of the 40-Foot Main Ship Channel Lanes	867,000 cy
April 1966 – June 1966	Maintenance Dredging of the 35-Foot Turning Basin at the Mystic River (Inner Confluence)	92,900 cy
March 1967 – Sept 1967	Maintenance Dredging of the 35-Foot Main Ship Channel Lanes	801,850 cy

June 1968 – FY 1969	Maintenance Dredging of the 40-Foot Broad Sound North Entrance Channel and the 40-Foot Main Ship Channel	300,043 cy Plus 7,250 cy Hard Material
August 1973	Removal of an Isolated Rock Pinnacle from the 40-Foot Main Ship Channel	Unknown (“Several Hundred cy”)
July 1973 – Sept 1973	Removal of Sunken Barge from Harbor	Wreck Removal
June 1982 – March 1983	Maintenance Dredging of the 40-Foot President Roads Anchorage	441,000 cy
June 1982 – Sept 1982	Maintenance Dredging of the 35-Foot Mystic River Channel	308,000 cy
June 1982 – March 1983 June 1984 – July 1984	Maintenance Dredging of the 35-Foot Chelsea River Channel	126,586 cy
FY 1985	Removal of the Sunken Wreck of the *Rose Anna* from the Harbor Area off Jeffries Point	Wreck Removal
Aug 1998 – Aug 1999	CAD Cell Excavation in the Mystic and Chelsea Rivers	1,369,000 cy
Aug 1998 – Dec 1998 and May 1999 Maintenance Sept 1998 – Feb 2000 Improvement	Maintenance and Improvement Dredging for the 40-Foot Lower Mystic River Channel Deepening with Maintenance Dredging to Overlying 35-Foot Depth	Maintenance: 269,743 cy Improvement: 337,861 cy Rock: 24,378 cy
Oct 1998 – Jan 1999 Maintenance May 1999 – Feb 2000 Improvement	Maintenance and Improvement Dredging and Ledge Removal for the 40-Foot Reserved Channel and Turning Basin Deepening with Maintenance Dredging to Overlying 35-Foot Depth and Limited Maintenance Dredging of Adjacent Areas of the Main Ship Channel	Maintenance: 213,680 cy Improvement: 237,978 cy Rock: 15,670 cy
Nov 1998 – Sept 2000	Capping of Mystic River CAD Cells using Sand Dredged from Cape Cod Canal Maintenance	162,200 cy Deposited
Aug 1999 – Jan 2000 Maintenance Feb 2000 – April 2000 Improvement	Maintenance and Improvement Dredging for the 38-Foot Chelsea River Channel Deepening with Maintenance Dredging to Overlying 35-Foot Depth	Maintenance: 218,413 cy Improvement: 176,571 cy Rock: 6,000 cy
1999	Removal of §8 MWRA Water Tunnel from beneath the Chelsea River Channel	N/A

March 1999 and Aug 1999 – Dec 1999 Maintenance Sept 1999 - Feb 2000 Improvement	Maintenance and Improvement Dredging and CAD Cells Excavation for the 40-Foot Inner Confluence Deepening with Maintenance Dredging to Overlying 35-Foot Depth	Maintenance: 148,239 cy Improvement: 193,603 cy Rock: 12,420 cy
June 2001 – Sept 2001	Ledge Removal for 38-Foot Chelsea Creek Deepening at 3 Areas in the Upper Channel and Turning Basin	6,700 cy Plus 6,000 cy Rock
June 2001 – Dec 2001	Improvement Dredging over the MWRA Water Tunnel in Chelsea River, Removal of Portions of the Water Tunnel, Removal of Damaged Electrical Cable & Improvement Dredging Near the McArdle Bridge, and Dredging Small Shoal Areas in the Mystic River	N/A Mystic River Quantity Unknown
September 2001 – December 2001	Maintenance and Improvement Dredging to 38 Feet beneath the A.P. McArdle Bridge	2,735 cy + an Unknown Quantity for FY02
March 2003	Filling of Bridge Utility Trench beside the McArdle Bridge	Backfill Quantity Unknown
August 2004 – June 2005	Maintenance Dredging of the 40-Foot President Roads Anchorage Area to –41 Feet	989,000 cy 1,166,447 cy Pay
September 2004 – June 2005	Maintenance Dredging of the 40-Foot Lanes of the Broad Sound North Entrance Channel to –41 Feet	60,000 cy 74,178 cy Pay
September 2004	Removal of Three Large Boulders from the Broad Sound North Entrance Channel	Quantity Unknown
May 2005	Removal of a Sunken Steel Barge from the Broad Sound North Entrance Channel	Wreck Removal
October 2004 – June 2005	Maintenance Dredging of the 40-Foot and 35-Foot Lanes of the Main Ship Channel Reaches from President Roads up to Spectacle Island Turn	40-Foot Channel: 39,240 cy 35-Foot Channel: 18,480
October 2007 – December 2007	Removal of Ledge Pinnacles from Three Areas: (1) Western Side of the President Roads Anchorage, (2) Main Ship Channel at the 35/40-Foot Lanes Slope Transition between Castle and Spectacle Islands, (3) Broad Sound North Entrance Channel	PRA: 1,029 CY MSC: 235 CY BSNEC: 42 CY BSNEC Not yet Completed

June 2008 – August 2008	Resumed Removal of Ledge Pinnacles from the North Entrance Channel and President Roads Anchorage Area (Total 2035 CY Removed under the Contract from All Areas)	729 CY Rock
April 2008	Dredging of a CAD Cell in the Lower Mystic River beneath the 40-Foot Channel	322,970 cy
April 2008	Dredging of a CAD Cell beneath the 40-Foot Upper Main Ship Channel below the Inner Confluence	393,330 cy
May 2008 – December 2008	Maintenance Dredging of the 35 and 40-Foot Main Ship Channel Lanes between Spectacle Island and the Ted Williams Tunnel, including the Reserved Channel Turning Area	319,800 CY including 156,925 CY to CAD Cell and 162,955 to MBDS CAD Cells Capped with Sand from CCC
May 2008 – December 2008	Maintenance Dredging of the 40-Foot Navy Drydock Approach Channel – CAD Disposal	
May 2008 – December 2008	Maintenance Dredging of the 35-Foot Upper Reach of the Reserved Channel	
May 2008 – December 2008	Maintenance and Improvement Dredging to -38 Feet in the Chelsea River in the Area of the Keyspan Gas Siphon and beneath the Chelsea Street Bridge, and Removal of the Old Gas Siphon, all to Complete the 1990 Project	7,973 CY
May 2008 – December 2008	Removal of the Wreck of a Small Craft from the Chelsea River Channel between the Bridges	Wreck Removal
August 2012 - October 2012	Removal of Rock Pinnacles from 7 Areas of the 40-Foot Main Ship Channel between Spectacle Island and Castle Island	416 CY Rock

BOSTON HARBOR - CHARLES RIVER CHANNEL
BOSTON, CAMBRIDGE, CHARLESTOWN AND ARLINGTON
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
Nov 1880 – Oct 1881	Improvement Dredging of the 7-Foot Channel up to Western Avenue	62,999 cy
June 1883 – June 1884	Improvement Dredging of the 6-Foot Channel above Western Avenue to Arsenal Street at 80 Feet Wide, 100 Feet in Bends	57,623 cy

BOSTON HARBOR - EAST BOSTON CHANNEL
EAST BOSTON (JEFFRIES POINT & GOVERNORS ISLAND CHANNELS)
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Note: These channels, while never deauthorized, were abandoned and partially filled for the construction of the State Piers at East Boston and the expansion of Logan Airport.

Work Dates	Work Accomplished	Quantities
FY 1892	Improvement Dredging of the Jeffries Point Channel -18 Feet MLW by 275 Feet Wide from the Grand Trunk Wharf to Simpson's Dry Docks, then Narrowing to 250 Feet at -15 Feet to East of Jeffries Point	139,962 cy
Oct 1892 – Nov 1892	Improvement Dredging to Widen the 18-Foot Channel Reach	20,697 cy
Sept 1893 – Nov 1893	Continue Improvement Dredging to Widen the 18-Foot Channel Reach to 400 Feet	39,196 cy

BOSTON HARBOR - FORT POINT CHANNEL
BOSTON AND SOUTH BOSTON
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
Dec 1886 – April 1887	Improvement Dredging of the 23-Foot MLW Channel below Congress Street	94,211 cy
FY 1907 – Nov 1907	Continue Improvement Dredging of the 23-Foot Channel up to Federal Street	157,940 cy
FY 1909 – FY 1910	Improvement Dredging to Widen the 23-Foot Channel through the Area of the Recently Removed Mt. Washington Street Bridge	17,457 cy
Nov 1951 – Feb 1952	Maintenance Dredging of the 23-Foot Fort Point Channel to Reduced Depth of –21 Feet	12,450 cy

BOSTON HARBOR - RESERVED CHANNEL, SOUTH BOSTON
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
1918 - 1919	U.S. Army Quartermaster Department Dredged the Access and Berths at the New Army Base to –30 and –35 Feet MLW	Unknown – Not a Civil Works Project
June 1941 – Sept 1941	Initiate and Complete Improvement Dredging of the 30-Foot by 300-Foot Wide Reserved Channel below L Street	152,163 cy
Nov 1950 – Dec 1950	Miscellaneous Debris Removal and Minor Associated Maintenance Dredging from the 30-Foot Reserved Channel	Unknown
May 1952 – Aug 1952	Maintenance Dredging of the 30-Foot Reserved Channel	48,182 cy
May 1960 – Aug 1960	Improvement Dredging of 35-Foot by 430 Foot Wide Reserved Channel	335,000 cy
August 1963	Maintenance Dredging of a Small Shoal from the 35-Foot Reserved Channel	200 cy
Oct 1998 – Jan 1999 Maintenance May 1999 – Feb 2000 Improvement	Maintenance and Improvement Dredging and Ledge Removal for the 40-Foot Reserved Channel and Turning Basin Deepening with Maintenance Dredging to Overlying 35-Foot Depth and Limited Maintenance Dredging of Adjacent Areas of the Main Ship Channel	Maintenance: 213,680 cy Improvement: 237,978 cy Rock: 15,670 cy
May 2008 – December 2008	Maintenance Dredging of the 35-Foot Upper Reach of the Reserved Channel	See Main Channels

BOSTON HARBOR - BOSTON HARBOR WORKS OF PRESERVATION (SEAWALLS ON HARBOR ISLANDS AND HEADLANDS) BOSTON, SOUTH BOSTON, HULL AND WINTHROP
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
1825 – 1827	Begin Construction of Georges Island Seawalls	Unknown
1828 - 1830	Begin Construction of Deer Island Seawalls	Unknown
1829	Continued Work on Georges Island Seawall	Unknown

1831	Repairs to Seawalls at Deer Island	Unknown
1831 - 1832	Completion of Georges Island Seawall	Unknown
1832 - 1834	Continued and Completed Construction of the Deer Island Seawall	Unknown
1833 - 1834	Begin Construction of Castle Island Seawall	2,342 CY Stone
1836 - 1837	Begin Construction of Rainsford Island Seawall at 1,537 LF, 7 to 12 Feet High, 7 Feet Thick	Unknown
1843	Lovell Island Seawall - +22.5 Feet MLW Top Elevation.	Unknown
Summer 1849 – Fall 1850	Great Brewster Island: Stone Seawall +24 Feet MLW Elevation, 18 Feet High, in Two Section – North Head 375 LF, South Head 342 LF	Unknown
May 1851	Great Brewster Island: Repairs to Stone Seawall and 50 LF Stone Jetty built at South Head Wall	Unknown
1853 - 1854	Great Brewster Island: Extend the North Head Wall 640 LF	Unknown
1864 – June 1865	Great Brewster Island: Extend the South Head Wall 145 LF	Unknown
July 1865 – March 1866	Great Brewster Island: Extend the South Head Wall to +24 Feet MLW for 260 LF	Unknown
FY 1865 – Nov 1865	Deer Island: Repairs and Rebuilding the North Seawall	Unknown
Aug 1866 – June 1867	Deer Island: Repairs and Rebuilding 340 LF of the Middle Seawall + 200 LF	Unknown
FY 1868	Deer Island: Repairs and Rebuilding 420 LF of the South Seawall and 206 LF of the North Seawall	Unknown
Aug 1866 – June 1867 -	Great Brewster Island: Extend the North Head Wall 550 LF	Unknown
FY 1868	Gallups Island Seawall: Stone and Materials Delivered in FY 1868	Unknown
	Lovells Island Seawall: Stone Delivered in FY 1868	Unknown
1992	Point Allerton Seawall Repairs	Unknown

CHELSEA RIVER
EAST BOSTON, CHELSEA & REVERE
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
Nov 1896 – March 1897	Improvement Dredging of the –18-Foot MHW (-8.4 Feet MLW) Channel to Head of Navigation in Revere	21,000 cy
June 1902 – FY 1903	Continue Improvement Dredging of the –18-Foot MHW (-8.4 Feet MLW) Channel	17,987 cy
Summer 1906 – FY 1907	Continue Improvement Dredging of the –18-Foot MHW (-8.4 Feet MLW) Channel	195,091 cy Plus 4 cy Boulders
Aug 1915 – Oct 1915	Maintenance Dredging of the 8.4 Foot MLW Channel in the Upper Reaches	95,021 cy
July 1915 – April 1916	Initiate and Complete Improvement Dredging of the 25-Foot MLW Channel	227,840 cy
Oct 1938 – Dec 1939	Improvement Dredging of the 30-Foot MLW Channel	944,343 cy Plus 75 cy Boulders
May 1946 – June 1946	Removal of Sewer Siphon and Improvement Dredging of Siphon Area below Bridge	7,359 cy
Sept 1951 – Nov 1951	Maintenance Dredging of the 30-Foot MLW Channel and Removal of Dolphins and Concrete Pipeline	25,615 cy
April 1953 – July 1953	Maintenance Dredging of the 30-Foot MLW Channel	98,076 cy
Nov 1960 – June 1961	Removal of the Grand Junction Railroad Bridge	Bridge Removal
Feb 1961 – Oct 1961	Replacement of the Timber Fender System for the Chelsea Street Bridge by the City of Boston to Give a Horizontal Clearance of 96 Feet	Fender Replacement
July 1961 – Aug 1961	Maintenance Dredging of the 30-Foot MLW Channel between the Chelsea Street Fenders	5,924 cy
July 1965 – May 1966	Improvement Dredging of the 35-Foot Chelsea Creek Channel	1,425,000 cy
June 1982 – March 1983	Maintenance Dredging of the 35-Foot Chelsea River Channel	126,586 cy
June 1984 – July 1984	Maintenance Dredging of the 35-Foot Chelsea River Channel	25,000 cy Est.

April 1999 - May 2000	Maintenance and Improvement Dredging to Deepen the Channel and Turning Basin to -38 Feet MLW	218,413 cy O&M Plus 176,571 cy Improvement
June 2001 – Sept 2001	Removal of Ledge and Overburden from the Upper 38-Foot Channel along the East Boston Side below the Turning Basin	6,700 cy Plus 6,000 cy Rock
September 2001	Maintenance Dredging to 35 Feet beneath the McArdle Bridge	2,735 cy
September 2001 – December 2001	Improvement Dredging to 38 Feet beneath the McArdle Bridge at MWRA Water Line	Unknown
FY 2002	Replacement of Power Cable at McArdle Bridge Snagged and Cut by Dredge	Cable Replacement
March 2003	Filling of Bridge Utility Trench beneath the McArdle Bridge	Backfill
May 2008 – December 2008	Maintenance and Improvement Dredging to 38 Feet in the Area of the Keyspan Gas Siphon and beneath the Chelsea Street Bridge with Disposal in the Chelsea CAD Cell, and Removal of the Old Gas Siphon as WFO	7,973 CY
May 2008 – December 2008	Removal of the Wreck of a Small Craft from the Chelsea River Channel between the Bridges	Wreck Removal
Counterweight & Debris Removal Jan 2012 – March 2012 Dredging March 2012 – April 2012	Maintenance and Improvement Dredging to Widen the Channel through and in the Approaches to the New Chelsea Street Bridge to a Minimum of 175 Feet. Includes Removal of the Concrete Counterweight, Pilings, and other Debris from the Adjacent Former Grand Trunk Railroad Bridge, and Removal of Abandoned Sheet Pile and Pilings from the Vicinity of the East Boston MWRA Property, and Sections of Abandoned Gas Siphon.	4,651 CY Silt to Chelsea CAD Cell and 27,178 CY Hard Parent Material to MBDS

ISLAND END RIVER, CHELSEA & EVERETT
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
Sept 1981 – April 1982	Improvement Dredging of 6-Foot Channel, 100 Feet Wide, 2,500 LF from the Mystic River Channel to the Public Marina at the Head of the	55,500 cy

	River	
Sept 1981 – April 1982	Improvement Dredging – Work for Others – 6-Foot Marina Basin at the Head of the Channel	80,000 cy

MYSTIC RIVER, CHARLESTOWN, CHELSEA, EVERETT, SOMERVILLE, MEDFORD, ARLINGTON & WATERTOWN PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Note: Prior to the 20th Century, the mouth of the Mystic River was at its confluence with the Charles River at the Head of Boston Harbor. As port improvements pushed deep water upstream the accepted mouth of the Mystic River became instead its confluence with the Chelsea River at today's Inner Confluence. Mystic River records through about 1907 include the lower reaches of the Mystic River above the mouth of the Charles River.

Work Dates	Work Accomplished	Quantities
Nov 1880 – June 1881	Improvement Dredging of the 23-Foot MLW Channel through the Shoal at the River's Mouth off Charlestown	48,343 cy (to 250 Feet Wide)
Dec 1881 -	Continued Improvement Dredging of the 23-Foot MLW Channel through the Shoal at the River's Mouth off Charlestown	48,530 cy 33,490
July 1895 – Nov 1895	Improvement Dredging of the 6-Foot and 4-Foot MLW Channels above the B&M Bridge to Medford	37,614 cy
June 1897 -	Continued Improvement Dredging of the 6-Foot and 4-Foot Channels to Medford	13,222 cy
Jan 1900 – Dec 1900	Begin Improvement Dredging of the 25-Foot Channel from Boston Harbor to above the Island End River	282,017 cy
Feb 1903 – June 1903	Continue Improvement Dredging of the 25-Foot Channel from Boston Harbor to above the Island End River	81,242 cy
July 1905 – April 1906	Continue Improvement Dredging to Widen the 25-Foot Channel from Boston Harbor to above the Island End River	88,641 cy
FY 1906 – Nov 1906	Resume and Complete Improvement Dredging of the 6-Foot and 4-Foot Channels above the B&M Railroad Bridge to Medford	28,765 cy

Annual Report for 1907, Appendix B-9, Page 907	The Lower Reaches of the Mystic River below the Chelsea Bridge were Incorporated into the Project for the Main Ship Channel of Boston Harbor as Authorized by the River & Harbor Act of 2 March 1907	Modification – No Further Mystic River Work below Chelsea Bridge
Nov 1907 – Jan 1908	Maintenance Dredging of the 25-Foot Channel above the Chelsea Bridge	18,215 cy
Nov 1910 – June 1911	Begin Improvement Dredging of the 30-Foot MLW Lower Channel from Chelsea Bridge to the Island End River	226,924 cy
July 1912 – Aug 1912	Improvement Dredging of the 30-Foot MLW Channel to Widen the Cut through the New Chelsea Bridge Drawspan	19,744 cy
March 1913 – March 1914	Improvement Dredging of the 30-Foot MLW Lower Channel from Chelsea Bridge to the Island End River	304,546 cy
Aug 1913 – Dec 1913	Ledge Removal for the 30-Foot MLW Channel	293 cy Rock
May 1916	Maintenance Dredging of the 30-Foot Channel	46,695 cy
Sept 1935 – April 1937	Improvement Dredging to Extend the 30-Foot MLW Channel Upriver to the Charlestown Playground Site 500 Feet Wide	1,406,556 cy
Dec 1937 – Feb 1938	Removal of Ledge to Complete Improvement of the 30-Foot Channel	10,388 cy Plus 2,910 cy Rock
Oct 1939 – Jan 1940	Improvement Dredging of the 20-Foot Channel and Basin at Somerville	74,291 cy
Dec 1943 – Feb 1944	Maintenance Dredging of the 30-Foot Channel	30,481 cy
FY 1948	Maintenance Dredging of the 20-Foot Channel and Basin at Somerville and Widening a Bend	6,033 cy
Feb 1952 – July 1952	Maintenance Dredging of the 30-Foot Channel	132,057 cy
Jan 1956 – March 1957	Improvement Dredging of the 35-Foot MLW Channel 940 to 1,060 Feet Wide	1,729,902 cy Plus 40 cy Boulders
May 1958 – June 1958	Removal of Ledge to Complete Improvement of the 35-Foot Channel Except for the Upper Reach along the South Bank.	23,200 cy (1/3 was Ledge)
June 1966 – FY 1967	Maintenance Dredging of the 35-Foot Channel	291,700 cy
May 1982 – FY 1983	Maintenance Dredging of the 35-Foot Channel	211,000 cy Estimated

Aug 1998 – Feb 2000	Maintenance Dredging of the 35-Foot Channel and Improvement Dredging of the 40-Foot Channel up to the LNG and Scrap Wharves	269,743 cy O&M 337,861 cy Improvement and 24,378 cy Rock

WEIR RIVER, HULL
PROJECT CONSTRUCTION & MAINTENANCE HISTORY

Work Dates	Work Accomplished	Quantities
Dec 1880 – May 1881	Improvement Dredging of the -9½ Foot Channel to Nantasket Pier (at 70 Feet Wide)	21,924 cy
April 1882 – May 1882	Continue Improvement Dredging of the -9½ Foot Channel 100 Feet Wide	19,998 cy Plus 4 cy Rock
September 1882	Removal of Additional Ledge from the 9½-Foot Channel	50 cy Ledge
May 1890 – June 1890	Maintenance and Improvement Dredging to Restore the -9½ Foot Channel and Widen the Channel to 250 Feet in “The Dolphin” Turn	9,025 cy
March 1891 – April 1891	Improvement Dredging to Widen the -9½ Foot Channel to 150 Feet Wide	19,724 cy
June 1893 – July 1893	Improvement Dredging of the 12-Foot MLW 150-Foot Wide Channel (No CY for FY 1894)	21,594 cy
Oct 1894 – Nov 1894	Removal of Additional Ledge from the 12-Foot Channel Completing the Projects of 1890 and 1892	395 cy Ledge

BOSTON HARBOR
MASSACHUSETTS

DEEP DRAFT
NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX C

ECONOMIC ASSESSMENT

UPDATED NOVEMBER 2012

Introduction

The purpose of this appendix is to determine the economic benefits to deepening portions of the Boston Harbor Federal Navigation Project in Boston, Massachusetts. Economic benefits were calculated in accordance with current Corps of Engineers guidance contained in ER 1105-2-100, Appendix E, Section II, Navigation (April 22, 2000), and additional guidance contained in the Institute for Water Resources Report 91-R-13, National Economic Development Procedures Manual, Deep Draft Navigation (November 1991). Benefits are calculated in annual terms, and are converted to average annual equivalents using the FY13 Federal interest rate for water resources projects of 3.75 percent. All benefits are presented at the 2011 price level. The base year of the analysis is 2016, and a 50 year period of analysis is used.

Existing Project

A detailed description of the many elements of the existing Federal Navigation Project in Boston Harbor and detailed maps are contained in the Main Report. A Map showing Boston Harbor and the proposed areas for channel deepening is shown in Figure C-1 at the back of this appendix. The existing Federal project in Boston Harbor includes the following elements: a main ship channel with an authorized depth of 40 feet from deep water into the inner harbor; the President Roads anchorage area with a depth of 40 feet; a channel in the Reserved Channel to the Conley Container Terminal with a depth of 40 feet; a channel in the Mystic River with depths of 35 and 40 feet; and a channel in the Chelsea River with an authorized depth of 38 feet. Boston Harbor has a tidal range of about 9 feet.

The local sponsor for the proposed improvement project is Massport, the Massachusetts Port Authority. Massport is an independent public agency which manages Logan Airport, several smaller airports in Massachusetts, and the Port of Boston. Massport owns and manages the Conley Container Terminal on the Reserved Channel in South Boston.

Proposed Navigation Improvements

The proposed navigation improvement project includes multiple elements. The primary improvement project consists of deepening the main ship channel from deep water into the Conley Container Terminal on the Reserved Channel to depths greater than 40 feet. Depths from 41 to 50 feet are examined to determine the economically optimal channel depth. The primary project also includes deepening the President Roads anchorage area, located adjacent to the main ship channel to the north, to depths of 41 to 50 feet to match the main channel depth. The primary deepening project is shown in Figure C-2 at the back of this appendix.

Three small additional project increments are also examined in this analysis. These increments include the following: deepening a short length of the main ship channel north of the Reserved Channel to provide deep-water access to a new terminal being developed by Massport, the Massport Marine Terminal; deepening a small portion of the channel in the Mystic River to provide 40-foot access to the Medford Street Terminal in Charlestown; and deepening the channel in the Chelsea River from the current authorized depth of 38 feet to a depth of 40 feet. These additional channel segments are detailed in Figures C-3, C-4 and C-5, respectively, at the back of this appendix.

Methodology

The purpose of this economic analysis is to estimate the economic benefits of the proposed deepening project. The primary benefits calculated for this study are National Economic Development (NED) benefits. NED benefits are contributions to national economic development that increase the value of the national output of goods and services. For deep-draft navigation projects, the most common type of NED benefit is transportation cost savings. For this project, both waterborne and landside transportation cost savings are estimated. Benefits from the Regional Economic Development and Other Social Effects accounts are also examined, but in less detail.

Corps of Engineers regulations require that separable elements of a project be separately justified. A project element is considered separable if it could be implemented at a later date as a separate project. In this case, the primary improvement project consists of deepening the main ship channel into the Conley Containership Terminal on the Reserved Channel. The remaining smaller project increments are separable elements.

The primary focus of the economic analysis conducted for this study is to determine the economic benefits of deepening the main ship channel into Conley Terminal in order to provide improved access for containerships. As a result, the most significant portion of economic study time and funds were allocated to the containership analysis, which is contained in Attachment C-1. A detailed analysis of containership traffic and containership benefits from channel deepening was conducted by David Miller and Associates, a private consulting firm based in Vienna, Virginia, under contract to the Corps.

The remaining analyses for the separable project elements are smaller and were conducted by the New England District of the Corps. The economic analyses for the smaller project elements are contained in Attachment C-2. The benefits to deepening the channel to the Massport Marine Terminal and the Medford Street Terminal in the Mystic River are somewhat uncertain because neither terminal is currently in use. The benefits for deepening the channel in the Chelsea River are more certain because they are based on existing oil tanker traffic and existing oil terminals.

Economic Study Area

Greater Boston is a generally affluent area with a full range of industries, employers, and services. The area contains all modes of public, private, and commercial transportation, including extensive highway and road systems, passenger and freight rail service, and multiple airports. Brief summary statistics describing the economy of Boston and the six states of New England are shown below in Table C-1.

Table C-1
Socioeconomic Data
Economic Study Area

Geographic Area	Population	Housing Units	Median Family Income	Employers	Payroll (in $ Millions)	Employees
Boston, city	625,304	260,619	$59,347	19,388	$41,451	585,268
Massachusetts	6,511,176	2,727,374	$80,822	174,290	$161,821	3,074,569
Rhode Island	1,057,381	450,769	$71,037	29,759	$17,469	433,562
New Hampshire	1,315,419	592,898	$75,552	38,906	$24,970	595,384
Maine	1,316,380	696,948	$57,257	41,755	$17,685	509,093
Vermont	620,414	311,617	$63,482	22,121	$9,467	272,488
Connecticut	3,494,487	1,437,133	$83,797	92,597	$82,769	1,551,305

Population, Housing Units, and Median Family Income
Source: 2009 estimates from the American Community Survey, US Census Bureau
Employers, Payroll and Employees
Source: 2008 County Business Patterns, US Census Bureau

Boston Harbor is the largest port in New England, and the Boston area is the largest metropolitan area in New England. For containerized cargo, the hinterland of the port consists of the six New England states, although the largest proportion of containerized cargo shipped through the port originates in or has a destination of Massachusetts. For petroleum products and bulk cargo, the hinterland of the port is better defined as the greater Boston area and, secondarily, Massachusetts. Other New England ports are significant distribution centers for petroleum products, including the ports of Portland and Searsport (Maine), Portsmouth (New Hampshire), Providence (Rhode Island), and several smaller ports in Connecticut. Table C-2 shows recent historical waterborne commerce through the Port of Boston over the last 10 years. Total waterborne commerce in 2009, the most recent year for which summary Waterborne Commerce Statistics data is available, was 20,456,000 tons.

Table C-2
Port of Boston
Waterborne Commerce of the United States

	all data in thousand short tons									
Commodity Classification	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
Petroleum and Petroleum Products	15,365	15,782	17,233	17,018	16,992	19,951	18,762	14,805	14,865	16,397
Chemicals and Related Products	877	843	951	711	225	236	151	230	160	148
Soil, Sand, Gravel, Rock and Stone	11	57	189	188	231	243	626	476	356	383
Iron Ore and Scrap	941	706	608	691	382	367	424	349	569	416
Other non-metal Minerals (Road Salt)	1,260	1,293	797	595	1,531	844	1,085	565	916	634
Cement, Glass and Lime	130	665	796	907	1,051	1,064	907	1,102	1,220	1,214
Food and Farm Products	430	417	470	423	419	422	374	435	299	286
Manufactured Equipment and Machinery	496	531	585	670	521	522	422	673	784	276
Waste and Scrap not elsewhere classified	0	0	0	0	146	1,327	1,352	1,150	1,181	625
All Other Categories	946	741	741	650	880	821	730	569	231	372
Total, All Commodities	20,456	21,035	22,370	21,853	22,378	25,797	24,833	20,354	20,581	20,751

Alternatives Examined

Alternative improvement plans were examined for this Feasibility study, as described below.

Plan ABC consists of deepening the main ship channel from deep water into the Conley Containership Terminal in the Reserved Channel. The lower reach of the Reserved Channel and the turning area outside the channel would also be deepened. In the draft Feasibility Report three depth alternatives were presented in detail: Plan A at 45 feet, Plan B at 48 feet, and Plan C at 50 feet. In the final report the main channels plan is displayed in ten one-foot increments from 41 to 50 feet and referred to as Plan ABC. Channel deepening would allow larger containerships to call the Conley terminal, and allow them to load more deeply. The benefit analysis for Plan ABC is contained in Attachment C-1.

The remaining plans represent smaller, add-on project increments which are only a small portion of total project costs. Plan D consists of extending the main ship channel north of the Reserved Channel to provide deeper access to the Massport Marine Terminal. This would provide deep water access to a bulk terminal to be built at the site. Plan E consists of deepening a small portion of the Mystic River that was not deepened to 40 feet in the previous improvement project and so has a depth of only 35 feet. Plan F consists of deepening the channel in the Chelsea River from 38 feet to 40 feet to provide improved access to the oil terminals along the river. The benefit analyses for Plans D, E and F are contained in Attachment C-2.

Benefits Framework

Annual benefits to channel deepening are estimated by comparing the expected without project transportation costs to the expected with project transportation costs. Net benefits equal the difference between those costs, if any. Transportation costs are estimated based on information about the types of vessels, the origin/destination locations, operating procedures, and typical vessel routes. This information was obtained from interviews with current carriers, shipping agents, terminal operators, harbor pilots, and Massport personnel, and from detailed vessel and trip data obtained from the Corps of Engineers Waterborne Commerce Statistics Center. The benefit analyses focus on those vessels currently using the harbor channels to capacity. The main ship channel is authorized to a depth of 40 feet, but until only recently some areas were limited to 38 feet due to areas of rock and ledge. Maintenance dredging of the main ship channel was completed in 2008, and work to remove remaining rock and ledge was completed in 2012. All without project conditions and projections assume that the existing authorized channel depths are available over the period of analysis.

Benefits to Alternative ABC

Alternative ABC, deepening the main harbor channels into the Reserved Channel to the Conley Container Terminal, would improve the efficiency of container shipping to

the port of Boston. This is the primary purpose of the project, and was the primary focus of the economic analysis. A detailed analysis of container shipping in Boston Harbor and the benefits to channel deepening was performed by a consultant to the Corps of Engineers, David Miller Associates, and is contained in Attachment C-1. The estimated annual benefits for channel deepening to Conley Terminal are summarized below in Table C-3.

Table C-3
Primary Channel Deepening, Boston Harbor
Alternative ABC
Annual Transportation Cost Savings
Base Case

Condition	Channel Depth	Annual Benefits
	(feet)	
Without Project	40	-
With Project (A)	41	$2,578,000
With Project (A)	42	$6,627,000
With Project (A)	43	$8,611,000
With Project (A)	44	$10,049,000
With Project (A)	45	$91,222,000
With Project (B)	46	$96,306,000
With Project (B)	47	$100,176,000
With Project (B)	48	$102,555,000
With Project (C)	49	$103,426,000
With Project (C)	50	$103,720,000

Benefits to Alternatives D, E and F

The potential economic benefits for the smaller channel increments of Alternatives D, E and F were analyzed by New England District of the Corps. The channel extension with Alternative D would allow larger bulk carriers to use the future Massport Marine Terminal. Alternative E would allow larger vessels to use the Medford Street Terminal, and Alternative F would allow larger oil tankers to transit the Chelsea River to reach the multiple terminals located there. The benefit analysis for these smaller channel increments is contained in Attachment C-2. The estimated annual benefits for Alternatives D, E and F, are shown below in Table C-4.

Table C-4 Additional Channel Segments, Boston Harbor Alternatives D, E and F Annual Transportation Cost Savings		
Condition	Channel Depth	Annual Benefits
	(feet)	
With Project (D)	42	$444,047
With Project (D)	43	$800,215
With Project (D)	44	$966,894
With Project (D)	45	$1,162,906
With Project (E)	37	$97,872
With Project (E)	38	$140,082
With Project (E)	39	$167,678
With Project (E)	40	$221,382
With Project (F)	39	$1,242,500
With Project (F)	40	$1,936,200

Project Costs and Economic Justification

Project costs are detailed in the Main Report and Appendix D, Engineering Design and Cost Estimates. Determination of economic justification for each alternative examined is contained in the Main Report.

Regional Economic Development Benefits

New Corps Guidance, EC 1105-2-409, "Planning in a Collaborative Environment," 31 May 2005, allows new studies to include benefits from the Regional Economic Development (RED) and Other Social Effects (OSE) accounts. While project justification and the determination of economic feasibility (positive benefit to cost ratio) are still determined using National Economic Development (NED) benefits as calculated in the sections above, benefits identified in the RED and OSE accounts can be used to guide selection of a recommended plan, to integrate Corps planning goals with the goals of the local sponsor, and to show the complete benefits of a project. RED benefits are derived from the impacts of a project on local income and employment, even if the project would cause no net change in income or employment on a national level. RED benefits are often a primary factor motivating local development projects. OSE benefits are those effects that are not captured in the NED, RED or environmental quality

accounts, and can include effects relating to community cohesiveness, health and safety, energy conservation, emergency preparedness, and security.

Massport recently completed two studies which analyze in detail the regional economic benefits provided by the Port of Boston and, more specifically, by Massport's facilities in the port. The first study, "Economic Impact Study of Massachusetts Port Authority" was completed in March 2006 by Leigh Fisher Associates for Massport and the Greater Boston Chamber of Commerce. The second study, "Economic Impacts of the Port of Boston", was completed by Martin Associates, also in March 2006. Both studies are based on detailed input-output modeling that was conducted for the Martin Associates analysis. The study analyzed the economic impact of the port by examining the size and interconnectedness of the economic sectors dependent on the port, sectors including transportation, cargo handling, maritime services, cruise ship operations, and fish and seafood processing. The total impacts generated by port activity in 2004, for Massport terminals and for private terminals, are summarized in Table C-5, below. Economic impacts generated by activities at Massport terminals include economic activity at the Conley Container Terminal, the Autoport on the Mystic River, the Black Flacon Cruise Terminal, the Boston Fish Pier, and bulk salt and cement activities at Massport terminals. Economic impacts generated by activities at private terminals include impacts from the multiple oil terminals on the Chelsea and Mystic Rivers, at privately owned bulk and scrap terminals, at the private LNG terminal, and at various private recreational marinas.

The Martin study further breaks down the economic impact generated by activities at Massport terminals by type of activity. Four categories are examined, including Cargo (primarily Conley Container Terminal but also including bulk cargo and vehicles), Harbor Tours and Marinas (recreational), Fish and Seafood Processing, and Cruise Ships. These impacts by type of economic activity are shown in Table C-6. Together these make up the total Massport terminal impacts shown in the first column of Table C-5. Direct impacts are the jobs and income directly generated by activities at port facilities. Indirect impacts are additional jobs and income generated in the local economy as the businesses directly dependent on port activities purchase goods and services in the local economy. Induced impacts are the additional economic activity generated from the increased income of households due to port activities, as they spend their increased disposable income in the economy. Together, the indirect and induced impacts make up the multiplier effects of the terminals.

Table C-5 Regional Economic Impacts Generated by Port Activity Port of Boston, 2004			
Impact Category	Massport Terminals	Private Terminals	All Terminals
Jobs			
Direct	2,247	2,680	4,927
Induced	1,751	2,513	4,263
Indirect	860	1,070	1,930
Total	4,857	6,263	11,120
Personal Income ($1,000)			
Direct	$79,690	$118,279	$197,969
Induced	$227,954	$338,338	$566,292
Indirect	$65,284	$49,747	$115,031
Total	$372,929	$506,365	$879,294
Business Revenue ($1,000)	$274,104	$815,654	$1,089,758
Local Purchases ($1,000)	$76,353	$86,831	$163,184
State/Local Taxes ($1,000)	$33,821	$49,447	$83,268

Source: "Economic Impact of the Port of Boston" Martin Associates, Lancaster PA, March 2006

Table C-6 Regional Economic Impacts by Type of Activity Massport Terminals Only					
Impact Category	Cargo	Harbor Tours & Marinas	Fish & Seafood Processing	Cruise Ships	Total, Massport Terminals
Jobs					
Direct	1,474	84	271	418	2,247
Induced	1,267	58	186	239	1,750
Indirect	719	19	74	48	860
Total	3,461	161	531	704	4,857
Personal Income ($1,000)					
Direct	$58,779	$2,559	$8,255	$10,098	$79,690
Induced	$168,138	$7,319	$23,612	$28,885	$227,954
Indirect	$32,746	$698	$2,955	$28,885	$65,284
Total	$259,664	$10,576	$34,822	$67,867	$372,929
Business Revenue ($1,000)	$156,441	$10,174	$90,514	$16,975	$274,104
Local Purchases ($1,000)	$46,878	$2,661	$8,740	$18,074	$76,354
State/Local Taxes ($1,000)	$25,394	$1,034	$3,406	$3,987	$33,821

Source: "Economic Impact of the Port of Boston" Martin Associates, Lancaster PA, March 2006

Activities at the Conley Container Terminal contribute a large portion of the economic benefits due to cargo-related activities, including an estimated 3,461 jobs and nearly $260 Million in personal income, as listed in the first column of Table C-6. With the deepening project, the Conley terminal would handle significant additional volumes of cargo, which would most likely result in a corresponding increase in jobs and incomes in the region. With the project, total cargo volumes handled are projected to increase from 38 to 57 percent, depending on the depth of the channel. For the purpose of this analysis, it is estimated that 75 percent of the economic activity included in the Cargo sector in the Martin Analysis is a result of activity at Conley. As a rough estimate of the potential regional economic benefits from the deepening project, the portion of economic benefits attributed to Conley (75 percent of the Cargo sector) were increased by the degree to which cargo volumes are expected to increase with the project. The resulting figures are shown below in Table C-7.

Using this method, the project could increase employment in the region by up to 555 jobs and increase incomes in the region by up to $22.1 Million. The estimated increase in employment assumes that all of the increased economic activity at the terminal with the project results in increases in employment and not capital expenditures. The exact capital to labor ratio with the project will depend on conditions prevailing at the time. Including induced and indirect effects further increases these benefits. The benefits would result from the shift of cargo handling and related economic activity from the Port of New York and New Jersey, where the cargo would be shipped in the without project condition, to the Port of Boston, where the cargo would be shipped in the with project condition. From a national perspective, the employment and income effects of the project would be simply a shift in economic activity from one region (New York/New Jersey) to another (Boston), and so the benefits are considered regional, not national, benefits. However, these benefits would be significant to Massport and to residents of the region.

Table C-7
Estimated Regional Economic Benefits
Boston Harbor

	Without Project	With 45' Channel	With 48' Channel
Cargo Volume (TEUs), Conley	172,346	224,540	258,829
With Project Increase (TEUs)		52,194	86,483
% With Project Increase		30.3%	50.2%
Direct Impacts Only			
Jobs, Cargo Sector	1,474		
Jobs, Conley (75%)	1,106	1,809	2,029
With Project Increase		335	555
Income, Cargo Sector ($1,000)	$58,779		
Income, Conley (75%) ($1,000)	$44,084	$72,130	$80,900
With Project Increase ($1,000)		$13,351	$22,121
All Impacts (Direct, Induced, Indirect)			
Jobs, Cargo Sector	3,461		
Jobs, Conley (75%)	2,596	3,382	3,898
With Project Increase		786	1,303
Income, Cargo Sector ($1,000)	$259,700		
Income, Conley (75%) ($1,000)	$194,775	$253,761	$292,513
With Project Increase ($1,000)		$58,986	$97,738

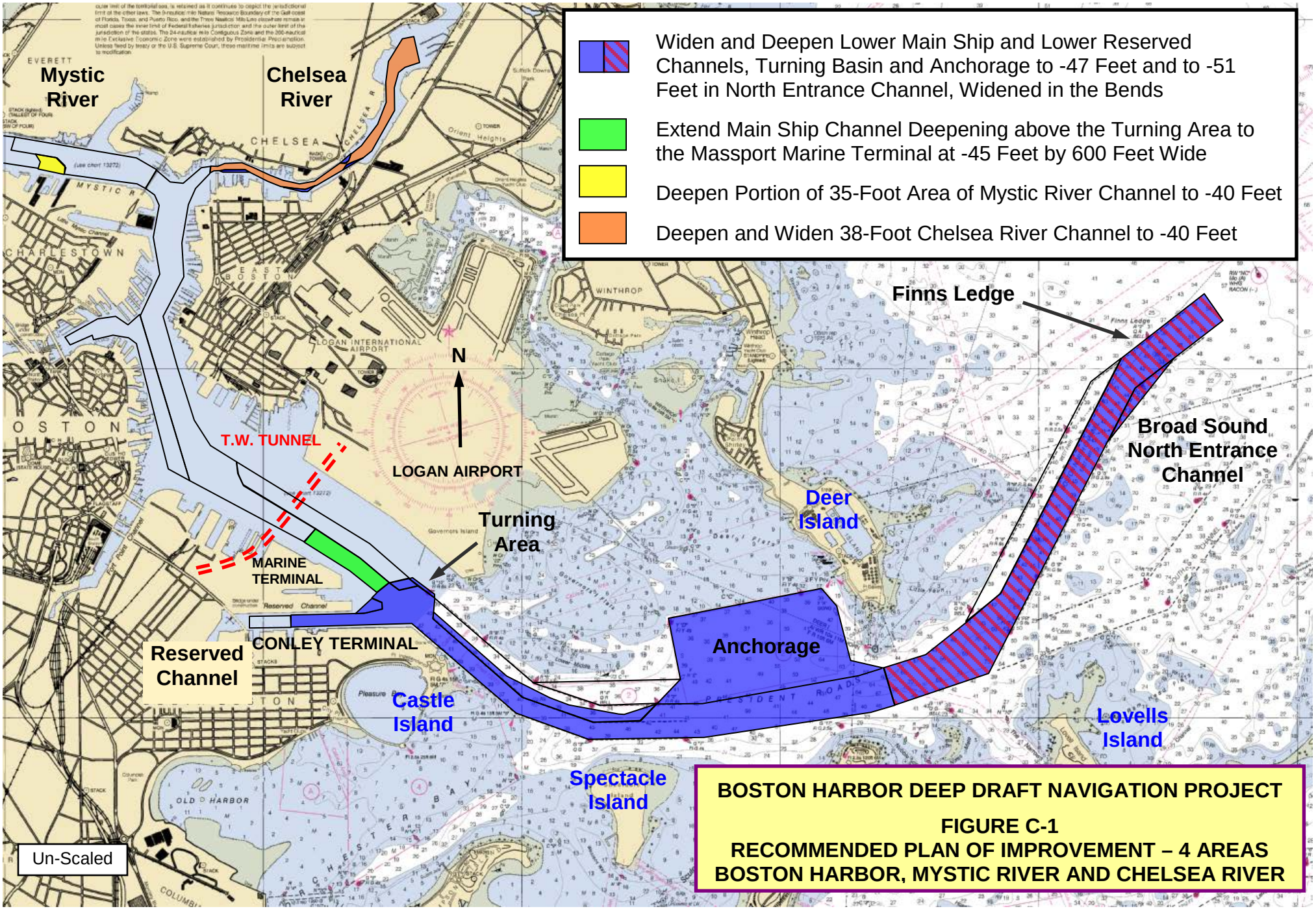
Environmental Quality (EQ) Benefits

Although not quantified, the reduction in air emissions from reduced truck traffic with the project will greatly benefit the northeastern region of the US. Currently, the New York to Massachusetts transportation corridors are in "Non-Attainment" status under the Clean Air Act.

Other Social Effects

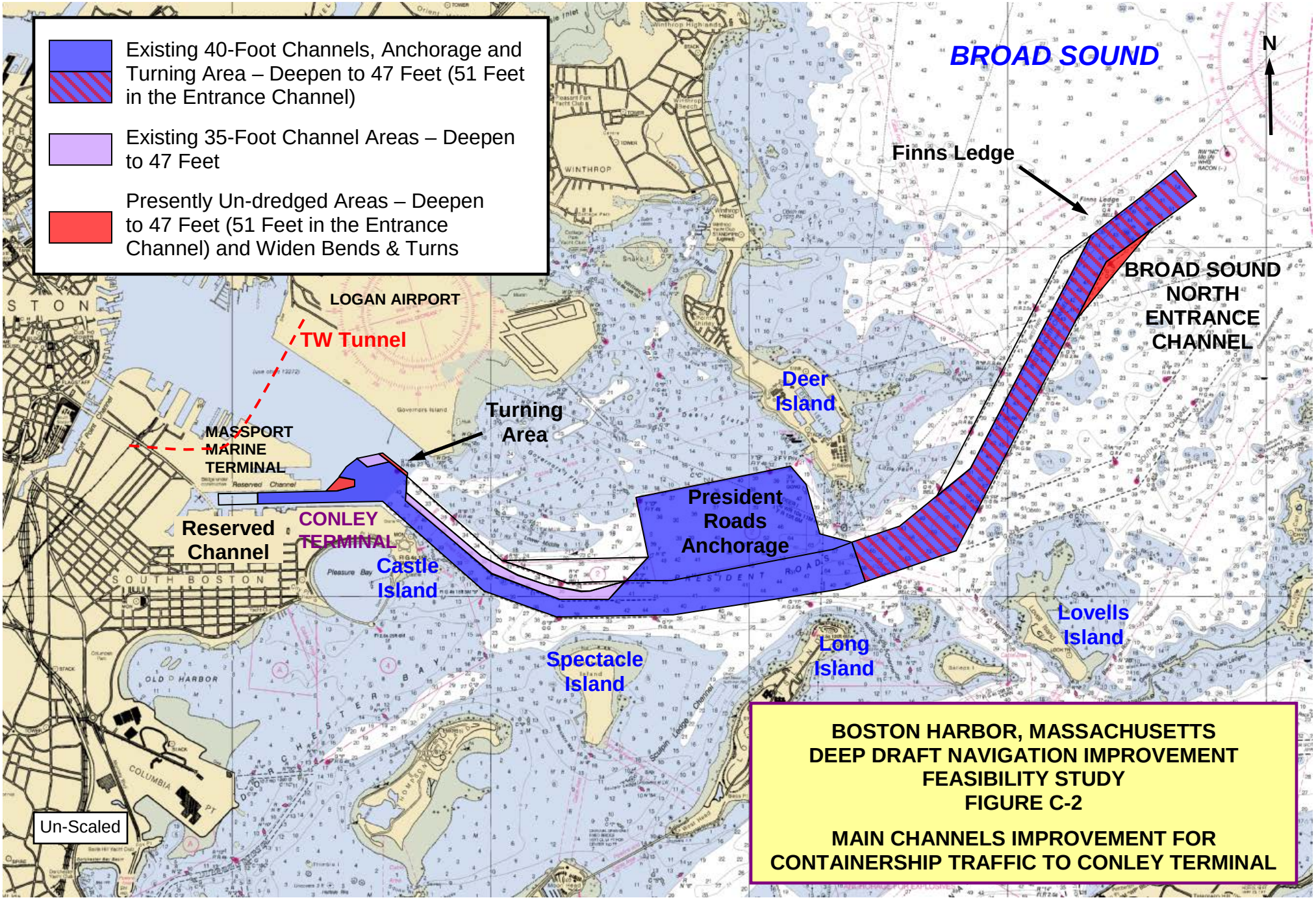
The primary beneficial social effects expected with the channel deepening project are the economic benefits previously described, including both the National Economic Development benefits of reduced transportation costs which will lower the cost of New England imports and exports, and the Regional Economic Development benefits of increased employment and income in the region with the increase in cargo traffic at Conley Terminal.

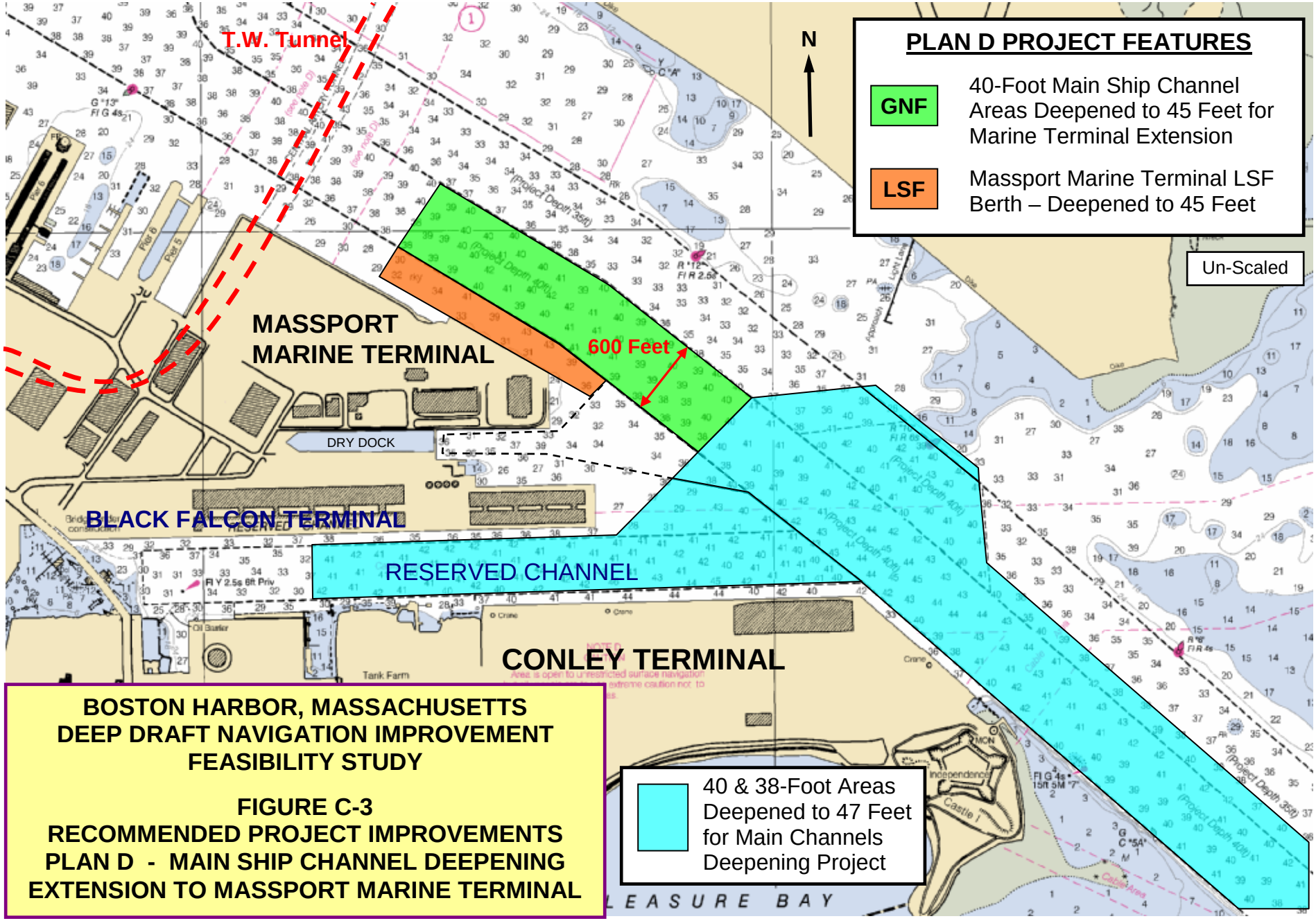
Two other benefit categories in the Other Social Effects account were identified in this analysis. The first is that the project would improve the security of the energy distribution system in Massachusetts. The Chelsea River is a major distribution point for a large portion of oil in the state. Safe navigation to terminals in the Chelsea River is critical to the region, particularly in the winter months when demand for heating oil is high. With the project, a deeper channel in the Chelsea River would improve the efficiency of oil deliveries to the Boston area, and would also increasing the ability of the system to absorb and adjust to changes in demand and supply, reducing the likelihood of supply disruptions. The second benefit category in the Other Social Effects account is that the project would improve emergency preparedness in the containerized cargo sector. For containerized cargo, the ability to bring larger ships into Boston will enable Boston to better function as a back-up port to the Port of New York and New Jersey, allowing Boston to be used as an alternative port in the event of a disruption in service or capacity at New York or other east coast ports. After September 11, 2001, the Port of Boston received cruise ships originally scheduled to call on New York, since the New York dock was being used for clean-up efforts. Increased channel depth into Boston Harbor would increase the degree to which Boston could perform a similar function for New York-bound containerships if needed. Similarly, if the Port of New York and New Jersey reaches capacity in the future as some predict, the Port of Boston will be critically needed to handle overflow cargo volumes. Boston is one day closer in sailing time to Europe, and so Boston is especially well-positioned to handle overflow cargo from European routes.



BOSTON HARBOR DEEP DRAFT NAVIGATION PROJECT

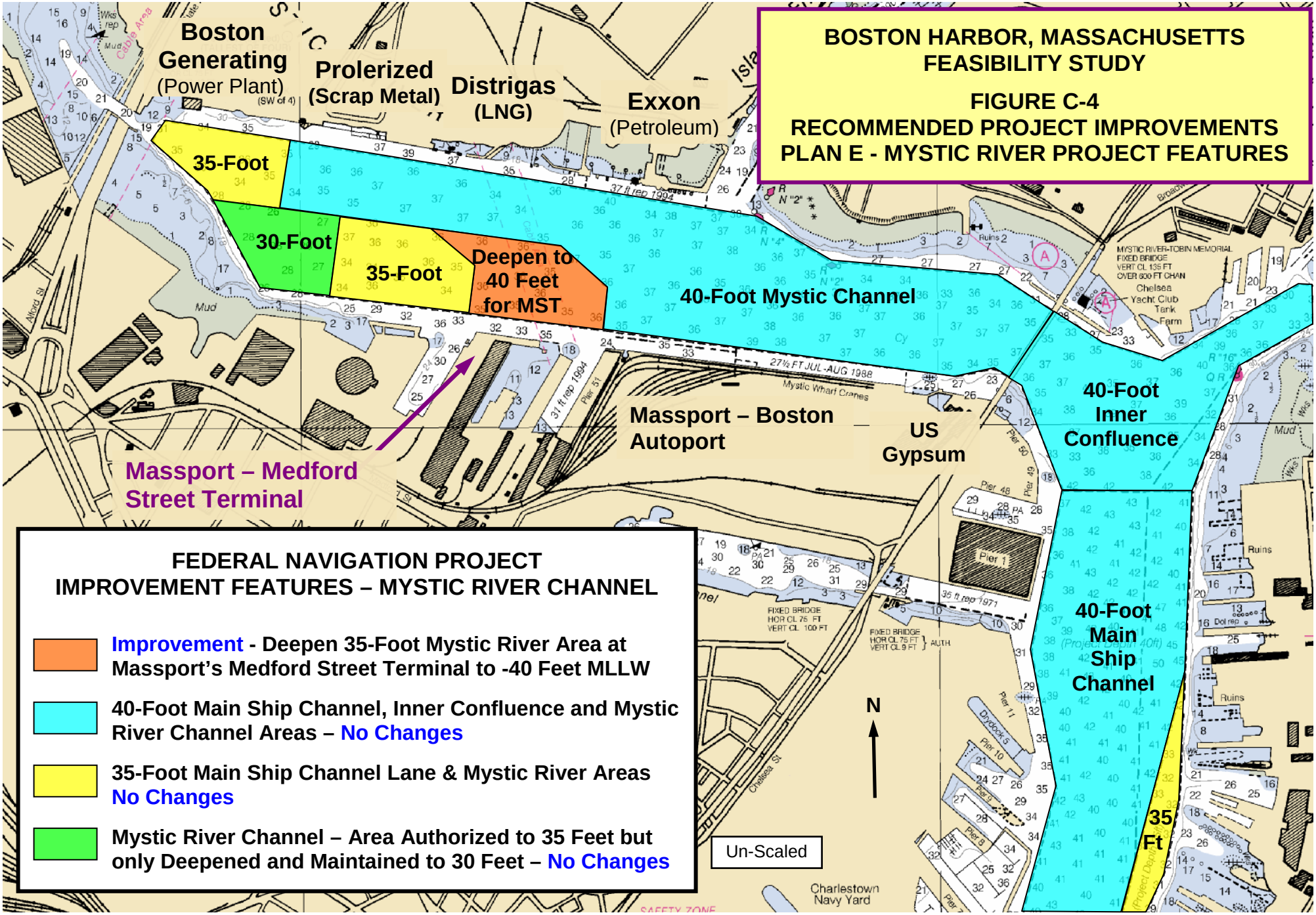
FIGURE C-1
RECOMMENDED PLAN OF IMPROVEMENT – 4 AREAS
BOSTON HARBOR, MYSTIC RIVER AND CHELSEA RIVER

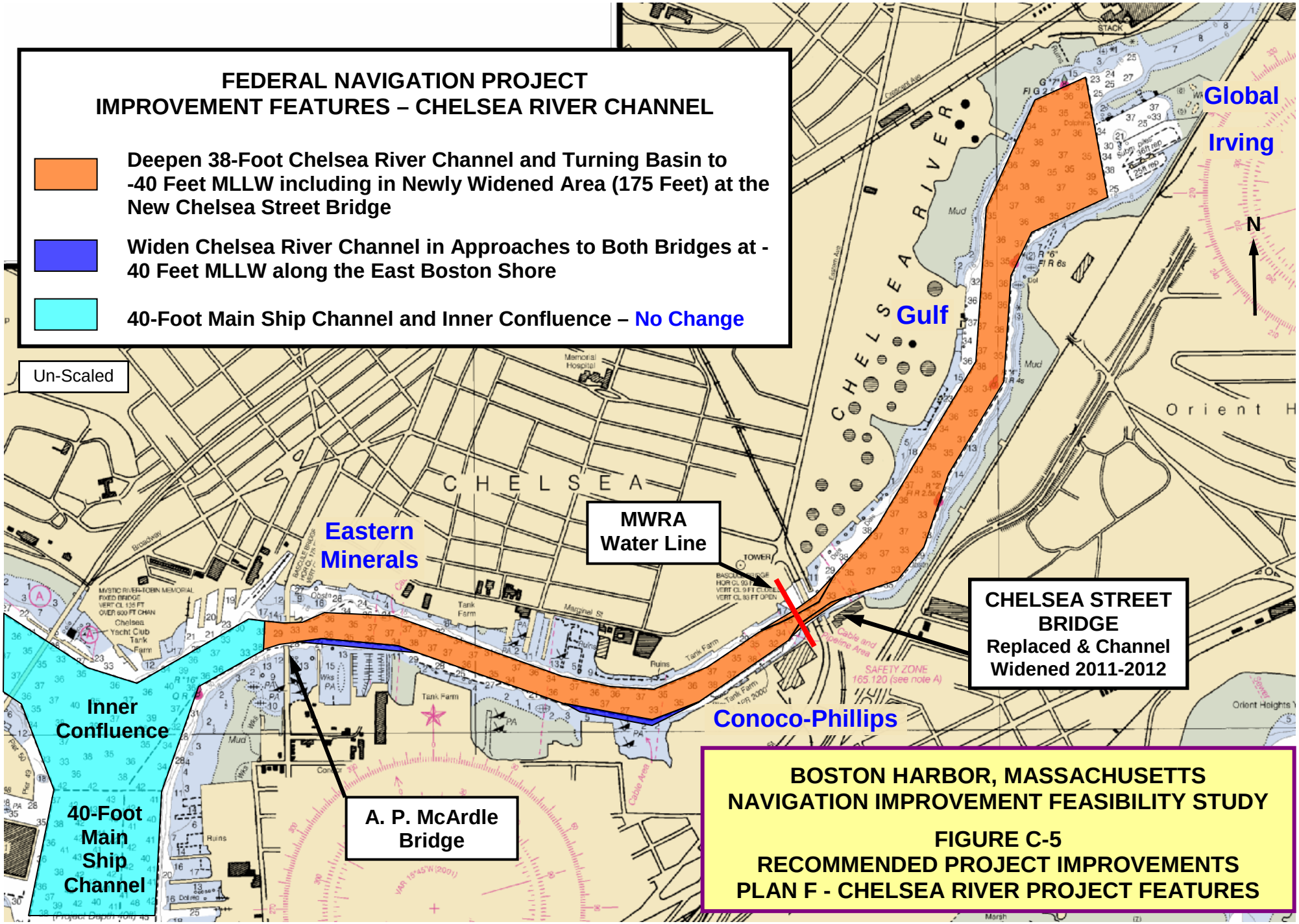

Existing 40-Foot Channels, Anchorage and Turning Area – Deepen to 47 Feet (51 Feet in the Entrance Channel)
Existing 35-Foot Channel Areas – Deepen to 47 Feet
Presently Un-dredged Areas – Deepen to 47 Feet (51 Feet in the Entrance Channel) and Widen Bends & Turns
BROAD SOUND
N
Finns Ledge
BROAD SOUND NORTH ENTRANCE CHANNEL
LOGAN AIRPORT
TW Tunnel
Deer Island
Turning Area
MASSPORT MARINE TERMINAL
President Roads Anchorage
Reserved Channel
CONLEY TERMINAL
Castle Island
Lovells Island
Long Island
Spectacle Island
Un-Scaled
BOSTON HARBOR, MASSACHUSETTS
DEEP DRAFT NAVIGATION IMPROVEMENT
FEASIBILITY STUDY
FIGURE C-2
MAIN CHANNELS IMPROVEMENT FOR
CONTAINERSHIP TRAFFIC TO CONLEY TERMINAL



BOSTON HARBOR, MASSACHUSETTS
DEEP DRAFT NAVIGATION IMPROVEMENT FEASIBILITY STUDY

FIGURE C-3
RECOMMENDED PROJECT IMPROVEMENTS
PLAN D - MAIN SHIP CHANNEL DEEPENING EXTENSION TO MASSPORT MARINE TERMINAL


BOSTON HARBOR, MASSACHUSETTS
FEASIBILITY STUDY
FIGURE C-4
RECOMMENDED PROJECT IMPROVEMENTS
PLAN E - MYSTIC RIVER PROJECT FEATURES
Boston Generating (Power Plant)
Prolerized (Scrap Metal)
Distrigas (LNG)
Exxon (Petroleum)
35-Foot
30-Foot
35-Foot
Deepen to 40 Feet for MST
40-Foot Mystic Channel
Massport – Boston Autoport
US Gypsum
40-Foot Inner Confluence
40-Foot Main Ship Channel
35 Ft
Massport – Medford Street Terminal
FEDERAL NAVIGATION PROJECT
IMPROVEMENT FEATURES – MYSTIC RIVER CHANNEL
Improvement - Deepen 35-Foot Mystic River Area at Massport's Medford Street Terminal to -40 Feet MLLW
40-Foot Main Ship Channel, Inner Confluence and Mystic River Channel Areas – No Changes
35-Foot Main Ship Channel Lane & Mystic River Areas No Changes
Mystic River Channel – Area Authorized to 35 Feet but only Deepened and Maintained to 30 Feet – No Changes
N
Un-Scaled
Charlestown Navy Yard


FEDERAL NAVIGATION PROJECT
IMPROVEMENT FEATURES – CHELSEA RIVER CHANNEL
Deepen 38-Foot Chelsea River Channel and Turning Basin to -40 Feet MLLW including in Newly Widened Area (175 Feet) at the New Chelsea Street Bridge
Widen Chelsea River Channel in Approaches to Both Bridges at -40 Feet MLLW along the East Boston Shore
40-Foot Main Ship Channel and Inner Confluence – No Change
Un-Scaled
Global
Irving
Gulf
N
CHELSEA RIVER
CHELSEA
Eastern Minerals
MWRA Water Line
CHELSEA STREET BRIDGE
Replaced & Channel Widened 2011-2012
Conoco-Phillips
Inner Confluence
40-Foot Main Ship Channel
A. P. McArdle Bridge
BOSTON HARBOR, MASSACHUSETTS
NAVIGATION IMPROVEMENT FEASIBILITY STUDY
FIGURE C-5
RECOMMENDED PROJECT IMPROVEMENTS
PLAN F - CHELSEA RIVER PROJECT FEATURES

Boston Harbor Deep Draft Navigation Improvement Project
Feasibility Study

Appendix C-1

Containerized Cargo Benefits Analysis

Main Report Revised Draft

08 May 2012

Executive Summary

The purpose of this economic analysis is to quantify the potential containerized cargo-related benefits of deepening Boston Harbor's six-mile long main channel to a depth greater than the currently authorized depth of -40 feet. The section of the main channel that would be deepened reaches from the outer harbor to the Conley Marine Terminal, which is owned and operated by the Massachusetts Port Authority (Massport) and is Boston Harbor's only container-port. The economic benefits quantified in this analysis are National Economic Development (NED) benefits consistent with the national objective for Federal project planning. The NED benefits that typically result from general navigation features, such as channels, dredged material disposal facilities, turning basins, etc. are transportation cost savings. Transportation cost savings are calculated as reductions in the cost of transporting goods from their ultimate origin to their ultimate destination.

This Boston Harbor Container Benefits Analysis was conducted in accordance with the "Framework for Additional Economic Analysis" (revised final 06Aug09), which was developed by the New England District, North Atlantic Division, OWPR, and the Institute for Water Resources.

In 2010, Boston Harbor was served by three liner services: one each from Europe, the Mediterranean, and Asia. Boston Harbor handled only 38% of all New England containerized cargo in 2007 (Table 3-1), with 62% handled at the Port of New York and New Jersey (PONYNJ) even though the domestic origins and destinations of most New England cargo is considerably closer to Boston Harbor than to the PONYNJ. Since 2007, each of the three liner services calling at Boston Harbor is using newer and larger vessels (Table 3-6). On average and in terms of dead weight tonnage, vessels on the Europe service are 49% larger, vessels on the Mediterranean service are 47% larger, and vessels on the Asian service are 18% larger (Table 3-6) in 2010 than they were in 2007. The vessels on these liner services are operating at Boston Harbor as deeply as channel conditions allow and have increased vessel arrival and departure drafts (Table 3-11) in response to a single additional foot of depth resulting from the first phase of maintenance dredging. A new Asia Suez service using small Post-Panamax vessels (5,500 – 6,100 TEU) began calling at Boston Harbor in May 2011 and although the service greatly increased TEU throughput at Boston Harbor in 2011, it was suspended after six months and a date for its return has not yet been established.

Nearly all of Boston Harbor's containerized cargo was moved on Panamax-sized vessels in 2010, and often the largest Panamax-sized vessels in the world fleet. The smaller-sized vessel feeder services which have historically called at Boston Harbor, including a coastal barge service, have stopped calling at Boston Harbor because they cannot compete with the more efficient Panamax vessel fleet. In 2011, the Asia via the Suez Canal service brought Post-Panamax vessels (5,500 – 6,100 TEU) vessels to Boston Harbor and in 2012 MSC intermittently schedules a Post-Panamax vessel for Boston Harbor. The deployment of Post-Panamax vessels to Boston Harbor is a result of the industry trend of carriers collaborating in the deployment of larger more efficient vessels where ever possible. The deployment of a new service to Boston Harbor is also indicative of the market for New England cargo. The containership fleet servicing the US east coast is continuously transitioning to even larger, more efficient Post-Panamax vessels.

The primary problems identified in this analysis relate to the inefficient operation of containerships in the Federal channel at Boston Harbor, which affect the Nation's international trade transportation costs. The following problem statements describe these inefficiencies:

1. Existing carriers are experiencing increased/ inflated operations costs due to light loading and tidal delays;
2. Channel depth constraints preclude the use of larger, more efficient ships at Boston Harbor which are replacing smaller, less efficient vessels on services to other US east coast ports; and
3. Existing shippers are experiencing increased origin to destination transportation costs for New England containerized cargo because the Port of New York and New Jersey is used as an alternative to Boston Harbor;

The opportunities identified in this appendix are limited to opportunities related to containership operations at Boston Harbor. The opportunity identified in terms of the Federal interest includes:

- Reduce the transportation cost of import and export trade through Boston Harbor and contribute to increases in national net income (NED).

The potential for substantial landside transportation cost savings, based on shorter distances from domestic origins and destinations to Boston Harbor for New England cargo, indicates there is an economic incentive for shippers to shift some New England containerized cargo from using the PONYNJ to using Boston Harbor. This economic incentive is identified and quantified by the trucking cost analysis (Chapter 7.1). The shipper survey conducted in 2010, as instructed by the "Framework for Additional Economic Analysis", indicates that a substantial number of New England TEUs currently using the PONYNJ appear to have the potential to shift to Boston Harbor (Appendix A: Revised R-1 Report). Some carriers are reluctant to call at Boston Harbor because of the light loading and tide delays that are a regular component of Panamax vessel operations at Boston Harbor (Chapter 3.2). Interviews with the carriers, also conducted in accordance with the "Framework for Additional Economic Analysis", indicate that channel depth constraints are the reason for historically pulling Boston Harbor out of the liner service rotation and for not including Boston Harbor in the rotation today and under without-project conditions (Appendix C: Carrier Interviews).

Several management measures were assessed for their potential as building blocks of alternative plans for potential navigation improvements at Boston Harbor. Equal consideration was given to structural and non-structural measures during the evaluation of management measures.

Non-structural management measures considered include:

- Time arrivals and departures with optimal tide height;
- Reduce underkeel clearance requirement;
- Increase efficiency of landside operations to decrease turn-around time;
- Use feeder vessels in a hub and spoke system;
- Use smaller vessels;
- Coastal barge service;
- Increase capability of landside operations to accommodate larger vessels;

- Load vessel so that it fits within channel constraints;
- Load more New England cargo on existing vessels that call at Boston Harbor;
- Add more vessel calls to services already calling at Boston Harbor; and
- Add Boston Harbor as a port of call.

Structural measures considered include:

- Channel deepening;
- Increased/Improved landside infrastructure capacity; and
- Improve landside infrastructure to accommodate larger vessels.

Under with-project conditions the existing fleet of Panamax vessels calling at Boston Harbor would be able to load more deeply (Chapter 6.3). Large Post-Panamax vessels (8,000 TEU; 48-foot maximum draft) are projected to use Boston Harbor at controlling depths of -45 feet and deeper, because Boston Harbor with a controlling depth of -45 feet would not impact the operating drafts of vessels calling at the PONYNJ as a next or preceding port of call . Base case Boston Harbor TEU amounts and transportation cost savings (presented below) are alternatively calculated assuming no large Post-Panamax vessels call at Boston Harbor under with-project conditions (Table 6-4: Number of TEUs; Table 7-10 Transportation Cost Savings) and assuming that an Asia Suez service calls at Boston Harbor at channel depths of -45 feet and deeper (Table 6-5: Number of TEUs; Table 7-11 Transportation Cost Savings). Vessels are projected to use tidal advantage under both without-project conditions and with-project conditions in the same way that vessels were observed using tidal advantage in 2010, which includes greater reliance on tidal advantage than was observed in 2007. Projected operating draft distributions for large Post-Panamax vessels at Boston Harbor (Tables 7-1 and 7-2) are based on observed Boston Harbor Panamax vessel operating drafts (Tables 3-10 and3-11). In a sensitivity analysis, large Post-Panamax vessel operations at Boston Harbor are modeled after observed 2010 vessel operations at the Port of Oakland for similar vessels under similar operating conditions.

Some of the additional cargo carried on vessels using the Federal channel at Boston Harbor under with-project conditions is projected to be New England containerized cargo, which switched from using the PONYNJ to using Boston Harbor (Chapter 6.4). Under with-project conditions, the total amount of Boston Harbor cargo carried on the vessel is calculated based on the 2010 observed proportion of Boston Harbor cargo. The total amount of cargo projected to shift under the base case with-project condition (at the deepest assessed depth of -51 feet) is 218,892 New England TEUs (Table 6-2). The total amount of New England TEUs projected to shift from the PONYNJ to Boston Harbor includes 87,333 TEUs that are handled at Boston Harbor under existing conditions but are projected to shift to the PONYNJ in 2015 under without-project conditions. Therefore, the projected total number of shifting cargo exclusive of returning cargo is 131,496 TEUs. This projected total number of shifting TEUs is less than the shipper survey-based mid-range estimate number of TEUs available to shift (152,488 TEUs at 2007 trade levels) and approximates the shipper survey-based lower limit estimate of TEUs available to shift (131,049 TEUs at 2007 trade levels). The base case projected number TEUs shifting from the PONYNJ to Boston Harbor (131,496 TEUs) is also less than the number of New England TEUs using the PONYNJ in 2007, which are closer to Boston Harbor than to the PONYNJ (181,371).

Base Case: With-Project Condition TEU Volumes

Depth	Europe	Mediterranean	Asia	Total	Increment
40*	42,526	20,072	-	62,598	
41	46,837	21,127	-	67,965	5,367
42	49,967	26,608	-	76,574	8,610
43	52,825	27,853	-	80,678	4,104
44	54,636	28,962	-	83,598	2,920
45	56,112	29,907	170,927	256,946	173,348
46	57,321	30,647	179,525	267,492	10,546
47	58,097	31,102	186,062	275,261	7,769
48	58,509	31,307	190,034	279,850	4,589
49	58,725	31,485	191,074	281,284	1,435
50	58,784	31,568	191,074	281,427	143
51	58,784	31,568	191,074	281,427	-
*Without Project Condition		**Total Additional With-Project TEUs (51 feet)**			**218,829**

Total transportation cost savings are calculated as the reduction in trucking costs resulting from the switch from using the PONYNJ to using Boston Harbor and the net addition of waterborne transportation costs for containers that do not get offloaded or loaded at the PONYNJ, but instead make the additional ocean voyage to Boston Harbor. Benefits are calculated at the projected base-year (2015) level of containerized traffic and do not include additional potential future growth. A sensitivity analysis is conducted to assess the effects of cargo growth through the deployment of an additional service to Boston Harbor. Base case transportation cost savings are alternatively calculated with the PONYNJ Container Unit Assessment fee excluded as a component of origin to destination costs for New England cargo using the PONYNJ (Chapter 7.4). Sensitivity analyses (Chapter 8) are performed to assess the influence of vessel size (using smaller and larger Post-Panamax vessels and no large Post-Panamax vessels) and to assess the influence of various deployment scenarios. An additional sensitivity analyses assesses the change in with-project condition benefits due to delaying the deployment of large Post-Panamax vessels by five years.

Base Case Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	80,678	4,104	$8,611,171	$1,984,669
44	83,598	2,920	$10,048,815	$1,437,645
45	256,946	173,348	$91,222,428	$81,173,612
46	267,492	10,546	$96,305,684	$5,083,256
47	275,261	7,769	$100,176,470	$3,870,786
48	279,850	4,589	$102,554,678	$2,378,208
49	281,284	1,435	$103,426,171	$871,493
50	281,427	143	$103,719,909	$293,738
51	281,427		$103,858,939	$139,030

Overall, the benefits analysis is based on observed vessel operations, vessel deployment, and industry trends. The dominant trend in the container shipping industry for the past decade and likely into the next decade, based on planned new vessel construction, is the deployment of very efficient, very large vessels. In the time that this analysis has been conducted (2006 – 2012), the largest container ships in the world have increased in size from the 11,000 TEU Emma Maersk to 18,0000 TEU vessels currently being built for Maersk. Carriers are consolidating efforts by sharing space on each other's vessels, by partnering on shared services, and by mixing vessels on shared services. Consolidation is a way to maximize vessel utilization, which increases operating efficiency.

High levels of vessel utilization require ports that are deep enough to accommodate highly utilized (deeply loaded) vessels. Ports that do not provide sufficient channel depth are by-passed by the most efficient vessels. Boston Harbor, under without-project conditions will be 10 feet shallower than the PONYNJ and will not be a viable port of call for large, efficient vessels that will also call at the PONYNJ. The without-project channel depth at Boston Harbor is a strong disincentive for carriers that would otherwise call at Boston Harbor. New England cargo, which is closer to Boston Harbor and which can get to Boston Harbor at a lower cost than it can get to the PONYNJ, will have to incur the higher cost of getting to and from the PONYNJ.

The high landside transportation costs for New England cargo using the PONYNJ under without-project conditions will be substantially reduced under with-project conditions because a deeper channel will allow carriers to operate their vessels more efficiently at Boston Harbor. Increased efficiency at Boston Harbor will allow carriers to include Boston Harbor as a port of call, which provides importers and exporters the opportunity to use Boston Harbor for their New England cargo. All but one of the components needed to realize substantial transportation cost savings exist at Boston Harbor. These existing factors, which are available to support transportation cost savings include:

- Boston Harbor's hinterland (New England), which provides sufficient cargo;
- Large containerships are currently calling at the PONYNJ and larger vessels will be calling there in the future;
- Carriers are looking to diversify to ports other than the PONYNJ to generate competition and to develop alternative markets; and
- New England cargo pays a high landside transportation cost to get to the PONYNJ, which is an incentive to switch to a closer, lower cost port.

The missing component is sufficient channel depth at Boston Harbor. The without-project channel depth at Boston Harbor constrains the transportation system and creates economic inefficiencies.

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1 Introduction

The purpose of this economic analysis is to quantify the potential containerized cargo-related benefits of deepening Boston Harbor's main channel for a length of approximately six miles to a depth greater than the currently authorized depth of -40 feet. The economic benefits quantified in this analysis are National Economic Development (NED) benefits consistent with the national objective for Federal project planning. Regional or local economic benefits are not pursued in this analysis.

The section of the main channel that would be deepened reaches from the outer harbor to the Conley Marine Terminal, which is Boston Harbor's only container-port. Conley Terminal is owned and operated by the Massachusetts Port Authority (Massport). The section of the main channel that would be deepened also approaches the Massport Marine Terminal, which is a bulk cargo terminal. Benefits to bulk cargo operations are addressed in a separate appendix.

The National Environmental Policy Act (NEPA) of 1969 and the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (U.S. Water Resources Council, 10 May 1983) provide the basis for Federal Policy concerning multi-objective planning. The Federal objective of water and related land resources project planning is to contribute to NED consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Water and related land resources project plans are formulated to alleviate problems and take advantage of opportunities in ways that contribute to this objective.

Contributions to NED are increases in the net value of the national output of goods and services expressed in monetary units. Contributions to NED are the direct net economic benefits that accrue in the planning area and in the rest of the Nation[1]. The NED benefits that typically result from general navigation features, such as channels, dredged material disposal facilities, turning basins, etc. are transportation cost savings. Transportation cost savings are calculated as reductions in the cost of transporting goods from their ultimate origin to their ultimate destination. Transportation cost savings are calculated at the projected base-year (2015) level of shipping activity at the PONYNJ and Boston Harbor, and do not account for additional potential future growth. Because any deepening increment at Boston Harbor would potentially induce shifting some, but not all, of the number of New England TEUs that would use the PONYNJ under without-project conditions, a port-specific commodity forecast, which would include future growth, was not conducted. The impacts of potential future growth are addressed in a sensitivity analysis.

This analysis has been formulated to respond to concerns identified by the USACE Office of Water Policy Review (OWPR), which were based on a previous Boston Harbor analysis presented at the 2008 Civil Works Review Board meeting. OWPR identified concerns about without-project conditions for container shipping at Boston Harbor and the resulting optimized depth. Three principal comments were put forth by OWPR:

- The study needs to provide more detailed information that will explain why trucking is used under existing conditions;

[1] USACE, National Economic Development Procedures Manual Overview, 2009

- The benefits analysis for each channel depth, including the future without project condition, should use the appropriate fleet mix and distribution of sailing drafts; and
- The study needs to formulate and evaluate other alternatives that may achieve a reduction in transportation cost.

From September 2008 through August 2009, the New England District, North Atlantic Division, OWPR, and the Institute for Water Resources developed a "Framework for Additional Economic Analysis" (revised final 06Aug09) as the consensus approach to answering these questions.

This Boston Harbor Container Benefits Analysis was conducted in accordance with the framework established in August 2009. This data-intensive re-analysis is based on highly detailed information including:

- 2007 PIERS data for individual container movements and cargo characteristics at Boston Harbor and the PONYNJ;
- 2007 Waterborne Commerce Statistics Center data for vessel operations and characteristics at Boston Harbor and the PONYNJ;
- a 2010 survey of shippers identified in the PIERS data as using Boston Harbor and/or the PONYNJ - the main purpose of the survey (as defined in the Framework) was to determine the physical location where containers are transiting to and from; the shipper survey also asked shippers why they used the PONYNJ and/or Boston Harbor; and
- Interviews conducted in 2010 with the two carriers currently using Boston Harbor, with four carriers who call at the PONYNJ but not at Boston Harbor, and with a barge service which recently discontinued coastal container service ("feeder" service) between the PONYNJ and Boston Harbor.

1.1 Boston Harbor Background Information

The Boston Harbor channel has an authorized depth of -40 feet. Shoaling occurs gradually and maintenance dredging occurs at long multi-year intervals. Currently (2012), the controlling depth at Boston Harbor is -38 feet and maintenance operations are currently being performed. In 2007, which is the year represented by much of the detailed vessel operations data in this report, maintenance dredging of the Main Sip Channel had not been conducted for many years and the controlling depth was -37 feet.

At its authorized depth of -40 feet, Boston Harbor has the least depth of all ports that are on the same liner services with Boston Harbor (Table 1-1). Each of the liner services that call at Boston Harbor also call on the Port of New York and New Jersey (PONYNJ), which currently has a controlling depth of -45 feet. In 2014, the PONYNJ controlling depth will be -50 feet. Boston Harbor's authorized depth, which will be achieved in 2012, is similar to the current controlling depth at the Panama Canal (39.6 feet). In 2014, the Panama Canal controlling depth will be increased to -55 feet.

Table 1-1
Future Controlling Depths for Boston Harbor and Related Ports

Port	Controlling Depth	Year Expected
Boston Harbor (w/out-Project)	40 feet	2012
PONYNJ	45 feet	Current
PONYNJ	50 feet	2014
Philadelphia	45 feet	2012**
Baltimore	50 feet	Current
Norfolk	50 feet	Current
Charleston	45 feet	Current
Savannah*	47 feet	2015
Sines, Portugal	52 feet	Current
Valencia, Spain	52 feet	Current
Le Havre, France	55 feet	Current
Panama Canal	55 feet	2014
Qingdao	57 feet	Current
Shanghai	52 feet	Current
Ningbo	49 feet	Current
Yokohama	52 feet	Current
Lazaro Cardenas	52 feet	Current
Cristobal	48 feet	Current
Suez Canal	78 feet	Current

Notes: *Currently -42 feet, increase contingent upon Tier II EIS and GRR, **Currently under construction
Sources: USACE, Containerization International On-line (www.ci-online.co.uk), Panama Canal Commission, and Suez Canal Authority

Boston Harbor is the 12th largest US east coast container-port (Table 1-2). Although similar in Twenty-foot equivalent unit (TEU) volume to the Port of Philadelphia, Boston Harbor is not a niche port, as compared to Philadelphia which relies heavily on refrigerated cargo. Conley Terminal handles a wide variety of containerized cargo, much of which originates in or is destined for the New England region.

Boston Harbor's average annual 7.5% growth in TEUs handled from 2001 – 2007 (prior to the current recession) was similar to growth experienced in Norfolk (7.25%) and the PONYNJ (6.92%), but less than the growth experienced at Savannah (13.44%). Boston Harbor's number

of TEUs handled grew at a greater rate than Baltimore (3.10%), Charleston (1.99%), Miami (-1.09%), Palm Beach (3.42%), Philadelphia (5.11%), and Wilmington (4.30%).

1.1.1 Conley Terminal

Based on the growth in both import and export containerized cargo experienced at Conley Terminal, Massport conducted a $78 million program of efficiency improvements since 2004, which includes realigning the yard to optimize efficiency, the purchase of 12 new rubber tire gantry cranes, repaving to allow for greater container stacking, and repositioning the chassis pool. Major improvements to Conley Terminal infrastructure include:

- installing four Post-Panamax size cranes;
- purchasing an additional 30 acres of adjacent land for terminal operations;
- upgrading crane drive systems;
- installing an automated gate and yard container tracking system; and
- design and build racks for high density refer storage, and

The berths at Conley terminal are currently dredged to -45 feet. Conley Terminal annual throughput capacity is projected to be more than 500,000 TEUs when all improvements have been completed.

1.1.2 Historical Container Services

Boston Harbor has been serviced by a small number of carriers since 2000 including Mediterranean Shipping Company (MSC), China Ocean Shipping Company (COSCO), Maersk, CMA CGM, SPM Container Line, Eimskip, and Columbia Coastal Transport (barge service). Currently only COSCO and MSC make regular weekly calls (liner service) to Boston Harbor. For comparison, consider that more than 40 containership lines make weekly liner service calls to the PONYNJ.

In 2002, COSCO began calling at Boston Harbor on the Asia – US east coast service via the Panama Canal. This COSCO service continues today. COSCO began a new Asia – US east coast service in May 2011, which called at Boston Harbor from Southeast Asia via the Suez Canal. This service introduced the first Post-Panamax[2] vessels to regular service at Boston Harbor. The service was suspended after six months, however; the additional TEUs brought to Boston Harbor by the Suez service increased Boston Harbor's 2011 TEU total to 192,705, which is a 15% increase over the 2010 total (168,285). It is critically important to also note that growth over the same time period at the PONYNJ was 5%. The growth at Boston Harbor, which is triple the growth observed at the PONYNJ during the same time period is due to the initiation of a new service. This rapid growth with the initiation of a new service to Boston Harbor exemplifies a shift in cargo to Boston Harbor. This same phenomenon was observed in 2003 – 2004, when the COSCO Asia service first started calling at Boston Harbor and Boston's Asia TEU volume grew by 57%, but PONYNJ Asia TEU volume grew by only 16%. It was this

[2] Post-Panamax refers to vessel which are larger, typically too wide, than Panama Canal dimensions. Panamax vessels are vessels which are designed to the maximum transit width of the Panama Canal (106 feet).

observation that initiated the entire investigation into cargo shifting from PONYNJ to Boston. The same phenomenon of shifting cargo observed in 2004 has been observed again in 2011 with the initiation of a new Asia service.

Table 1-2
Major US East Coast Container-Port TEU Volumes 2001 – 2010 (TEUs x 1,000)

Port	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PONYNJ	3,316	3,749	4,068	4,478	4,793	5,093	5,299	5,265	4,562	5,292
Savannah, GA	1,077	1,328	1,521	1,662	1,902	2,160	2,604	2,616	2,357	2,825
Norfolk, VA	1,304	1,438	1,646	1,809	1,982	2,046	2,128	2,083	1,745	1,895
Charleston, SC	1,528	1,593	1,691	1,864	1,985	1,968	1,754	1,636	1,181	1,365
Miami, FL	956	981	1,041	1,010	1,054	977	885	828	807	847
Pt Everglades, FL	621	554	570	654	797	864	948	985	796	793
Jacksonville, FL	699	684	692	728	777	768	710	697	754	857
Baltimore, MD	493	508	536	558	602	628	610	613	525	611
Wilmington, DE	212	245	254	254	251	263	284	268	260	263
Philadelphia, PA	179	215	147	176	205	247	253	256	223	276
Palm Beach, FL	198	221	215	218	248	244	250	245	199	213
Boston, MA	133	142	155	175	189	200	220	209	187	168

PONYNJ: Port of New York and New Jersey.
Source: American Association of Port Authorities (www.aapa-ports.org)

In 2003, MSC split its single Europe/Mediterranean – US east coast service, which called at Boston Harbor, into two services (one from Europe and one from the Mediterranean), which both call at Boston Harbor today. These services use the largest Panamax vessels.

In recent years a number of carriers have attempted to include Boston Harbor in the port-rotation of a weekly liner service. In 2002, Maersk stopped calling at Boston Harbor on its service from Europe to the US east coast because of excessive delays caused by waiting for the tide[3]. In 2004 CMA CGM stopped calling at Boston Harbor on its Europe – US east coast service because it entered into a Europe – US east coast alliance with Maersk, using Maersk vessels, and Maersk had already decided that Boston was not deep enough for their vessels[4]. CMA CGM re-initiated a service with small vessels in 2007, but the service was discontinued during the recent economic downturn.

The Columbia Coastal Transport barge feeder service from the PONYNJ failed at providing a coastal shuttle service because transshipment costs make feeder services uncompetitive with

[3] See Appendix C, 2010 interview with Kenneth Dan Joergensen, Director of Operations, Maersk
[4] See Appendix C, 2010 interview with Kurt Mittenzwei, Director of East Coast Operations, CMA - CGM

direct services to PONYNJ or Boston[5]. In 2006, the SPM Container Line ran a feeder service from Halifax, Nova Scotia to Boston but discontinued the service when the firm ran into financial difficulties.

Eimskip ran a single vessel (700 TEU) bi-weekly service between Iceland and North America, which calls at Everett, MA (up-river from Boston Harbor) and continued down the coast to Richmond, VA. This service was discontinued during the recent economic downturn. Eimskip also attempted a feeder service from Halifax in 2007, but the service was cancelled after only a few months of operation due to the impact of the global recession on Icelandic companies.

1.1.3 Recent Trade and the Economic Downturn

From 2007 to 2009, containerized trade was dramatically reduced due to the economic downturn. Total US containerized trade dropped by 17%, containerized trade at the PONYNJ fell by 14% and by 15% at Boston Harbor. In 2010, containerized trade volumes increased at most US ports but declined by 10% at Boston Harbor. The decline was largely due to a drop in the number of calls by the COSCO Asia service in the summer months. In 2011, although the CMA CGM and Eimskip services have not returned, Boston Harbor TEUs increased by15% over the 2010 level of trade. The large increase in 2011 was due to the COSCO Asia service returning to a regular weekly schedule and to the initiation of a new Asia service via the Suez Canal, which ran for six months of 2011. The Asia service via the Suez Canal, which was operated by Hanjin, has been suspended and does not reflect a change in port rotations which excludes Boston Harbor. Hanjin did not provide an explanation for the suspension of the service.[6]

1.2 Problems and Opportunities

This sub-chapter describes the existing container shipping problems and opportunities at Boston Harbor. The identification of problems and opportunities is the first step in the six-step planning process described in the P&G; however, the analysis in this appendix is limited to containership operations at the Port. Water resource-related problems at Boston Harbor occur under existing conditions and are projected to continue occur in the future under without-project conditions. The problems are related to container ship operations in the Federal navigation channel leading to Conley Terminal. The opportunities described in this chapter include potential improvements to navigation efficiency, which address the federal objective.

1.2.1 Problems

The primary problems identified in this analysis relate to the inefficient operation of containerships in the Federal channel at Boston Harbor, which affect the Nation's international trade transportation costs. The following problem statements describe these inefficiencies:

1. Existing carriers are experiencing increased/ inflated operations costs due to light loading and tidal delays;

[5] See Appendix C, 2010 interview with Bruce Fenimore, President Columbia Coastal Transport

[6] Personal communication with Nick Billows, Massport

2. Channel depth constraints preclude the use of larger, more efficient ships at Boston Harbor which are replacing smaller, less efficient vessels on services to other US east coast ports; and
3. Existing shippers are experiencing increased origin to destination transportation costs for New England containerized cargo because the Port of New York and New Jersey is used as an alternative to Boston Harbor;

1.2.2 Opportunities

The opportunities identified in this appendix are limited to opportunities related to containership operations at Boston Harbor. The opportunity identified in terms of the Federal interest includes:

- Reduce the transportation cost of import and export trade through Boston Harbor and contribute to increases in national net income (NED).

1.3 Report Organization

This study addresses four major questions concerning navigation improvements at Boston Harbor:

- Why doesn't more New England cargo use Boston Harbor under existing conditions?
  - Existing Conditions Analysis (Chapters 2 – 3)
- How will Boston Harbor's cargo and fleet be affected by the Panama Canal Expansion and the 50-foot Deepening Project at the PONYNJ?
  - Without-Project Conditions Analysis (Chapter 4)
- Aren't there a number of non-structural solutions that could meet the planning objectives?
  - Management Measures Evaluation (Chapter 5)
- If the channel at Boston Harbor were deepened would more New England cargo use Boston Harbor and how much cargo might be expected to shift from the PONYNJ?
  - With-Project Conditions Analysis (Chapter 6)
- What would the potential NED benefits be if the channel to Boston Harbor were deepened?
  - Transportation Cost Savings Analysis (Chapter 7).
- How do with-project benefits change if basic assumptions of the analysis are changed?
  - Sensitivity Analyses (Chapter 8)

1.4 Data and Information Resources

Major sources of data used in the analysis include:

- PIERS and Waterborne Commerce Statistics Data (WCSC) for detailed analysis of 2007 cargo and vessel operations.
- Massport and Boston Harbor Pilot Association data for analysis of 2008 - 2010 vessel operations
- Survey of shippers conducted in 2010
- Interviews with carriers conducted in 2004, 2007, 2010, and 2011.

PIERS and WCSC data for cargo and vessel movements through the PONYNJ and through Boston Harbor for 2007 was used in the assessment of current shipping conditions for New England containerized cargo. PIERS data are collected from vessel manifests. WCSC data are provided to the Federal government for every vessel call.

Throughout the analysis of the PIERS/WCSC data, New England cargo is defined as cargo that has any of the following characteristics:

- The company location fields in the PIERS data indicate a New England state, city, or town;
- The notify field (notify that shipment has arrived or departed) in the PIERS data indicates a New England state, city, or town;
- Any cargo moved through Boston Harbor.

This broad definition of New England cargo is intended to include all New England cargo, whether it is moved through the PONYNJ or Boston Harbor.

The PIERS/WCSC data set includes all PONYNJ and Boston Harbor cargo, regardless of its point of U.S. origin (for exports) or destination (for imports). The full data set was initially filtered to identify only containerships and containerized cargo (excluding bulk or break bulk cargo). The PIERS data are based on actual cargo movements and do not include the movement of empty containers. The total New England containerized cargo identified by the PIERS/WCSC 2007 data set is presented in Table 1-3.

Table 1-3
PIERS/WCSC Total and New England TEUs (2007)

	Imports	Exports
Boston Harbor Total TEUs	89,890	63,526
PONYNJ Total TEUs	2,559,993	1,252,139
PONYNJ New England TEUs	202,211	53,045

Detailed analysis of the PIERS and WCSC data are presented in Task R-1: Assessment of Existing Conditions and in the Task R-1: Assessment of Existing Conditions Reference Appendix.

Massport provided Conley Terminal TEU data for 2007 –2010. These data includes the number and size of containers, number of empty containers, and number of TEUs offloaded and loaded for each vessel call. The Boston Harbor Pilot data identify the arrival and departure drafts for all vessels using Boston Harbor from 2008 through July 2010.

A survey of shippers identified in the PIERS data as using Boston Harbor and/or the PONYNJ was conducted in 2010. The main purpose of the survey was to determine the physical location where containers are transiting to and from. The shipper survey also asked shippers why they used the PONYNJ and/or Boston Harbor. The PIERS data identified 19,528 unique import companies and 3,702 unique export companies that moved New England cargo through either

the PONYNJ or Boston Harbor in 2007. These companies are generically referred to as the shippers.

A two-part mailed questionnaire (OMB Control # 0710-001) was developed to gather information from the shippers. The first part of the questionnaire asked the shippers to identify important factors in their choice of carriers and ports. The second part of the questionnaire presented the shipper with a summary of the company's import and export TEUS by country from the 2007 PIERS data. The shipper was asked to provide actual domestic origin and destination information for those TEUs in order to supplement and verify the data contained in PIERS.

The survey questionnaire, sampling method, and survey results are presented in detail in the Task R-1: Assessment of Existing Conditions. An executive summary of the shipper survey is provided as an attachment. Survey results were used for two purposes in the estimation of project benefits. One use was to identify a 95% confidence interval for origin to destination distances by comparing PIERS data to respondent data. The other use of survey results was to identify the number of New England TEUs using the PONYNJ under without-project conditions, which could potentially shift to using Boston Harbor. Survey results indicate a 95% confidence interval of New England TEUs which could shift to Boston Harbor ranging from a lower limit of 131,049 TEUs to an upper limit of 173,148 TEUs, with a mid-point of 152,488 TEUs at the 2007 level of trade.

The use of survey responses, analyzed in conjunction with transportation cost data, can inform the analyst's decision by providing additional information about near term impediments to making a port shift. Survey responses also provide information useful in understanding why a shipper's port usage decision (which may appear economically irrational from a pure transportation cost differential viewpoint), is actually reasonable when considering a particular shipper's decision making limitations. Survey responses concerning why a shipper uses one port or another are not intended to be relied upon as the final determinant of whether a shift will be made.

Carrier interviews were conducted in 2004, 2007, 2010 and 2011 concerning current and projected future vessel operations at Boston Harbor. The 2004 and 2007 interviews include CMA CGM, COSCO, and MSC. The 2010 interviews include CMA CGM, COSCO, MSC, Columbia Coastal Transport, Evergreen, Maersk, and OOCL. The 2011 interviews include MSC, COSCO, and Hanjin. The carriers have been very consistent in their description of current conditions and projection of future conditions. The carriers have stated that vessels using Boston Harbor are operating under a depth constraint that limits vessel loading and causes costly use of the tide. The carriers have also identified a trend, which has been borne out by experience, of increasing size for vessels calling on US east coast ports. The carriers project that this trend will continue due to the "cascade effect[7]" of ever larger vessels entering the world fleet and the

[7] The "cascade effect" refers to the way that the entry of the newest and largest vessels in the world fleet, say a 14,000 TEU vessel entering the intra-Asia trade displaces the existing 10,000 TEU vessel on that trade. The 10,000 TEU vessel then enters the Asia-Europe trade, which displaces the existing 8,000 TEU vessel. The 8,000 TEU vessel cascades into the Asia – US west coast trade, which pushes the existing 6,000 TEU vessel into the Asia –US east coast trade. This cascade effect is made economically feasible because the carriers collaborate by sharing cargo space on each other's vessel and by having vessels belonging to different carriers on the same service.

continued practice of carriers sharing space on each other's vessels. Post-Panamax vessels are increasingly calling at US east coast ports, and the smallest Post-Panamax vessels will call at Boston Harbor under existing conditions. The carrier interviews are included in the Carrier Interview Appendix to this report.

2 Boston Harbor Hinterland

The Boston Harbor hinterland encompasses all of five New England states (Maine, New Hampshire, Vermont, Rhode Island and Massachusetts) and the eastern half of Connecticut. This area includes a population of 12.3 million people (Table 2-1). Boston Harbor is located at the focal point of the Boston Metropolitan Statistical Area (MSA), which has a population of 4.6 million people.

Table 2-1
Boston Harbor Hinterland Population

Location	Population (millions)
Massachusetts	6.5
Maine	1.3
New Hampshire	1.3
Rhode Island	1.1
Vermont	0.6
Hartford, CT MSA	1.2
Norwich – New London, CT MSA	0.3
Total	**12.3**

Sources:

State Populations: Table 1: Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2000 to July 1, 2008 (http://quickfacts.census.gov/qfd/states/25000lk.html)
MSA Populations: Annual Estimates of the Population of Metropolitan and Micropolitan Statistical Areas: April 1, 2000 to July 1, 2009 (CBSA-EST2009-01) (http://www.census.gov/popest/metro/CBSA-est2009-annual.html).

Boston Harbor is located at the intersection of Interstate Highway 93 (North-South) and Interstate Highway 90 (East-West). Both Interstate Highways 93 and 90 connect to Interstate Highway 95 (North-South), which runs in a ring around Boston. Interstate Highway 90 also connects to Interstate Highway 84 (East-West through Connecticut) and interstate Highway 91 (North-South through Connecticut, Massachusetts, and the New Hampshire/Vermont border). Intermodal (rail – truck) service is available from Worcester, MA. There is no on-dock rail service at Conley Terminal, which greatly limits rail as a transportation alternative to trucking. Figure 1 presents the major highway and rail transportation network surrounding Boston Harbor.

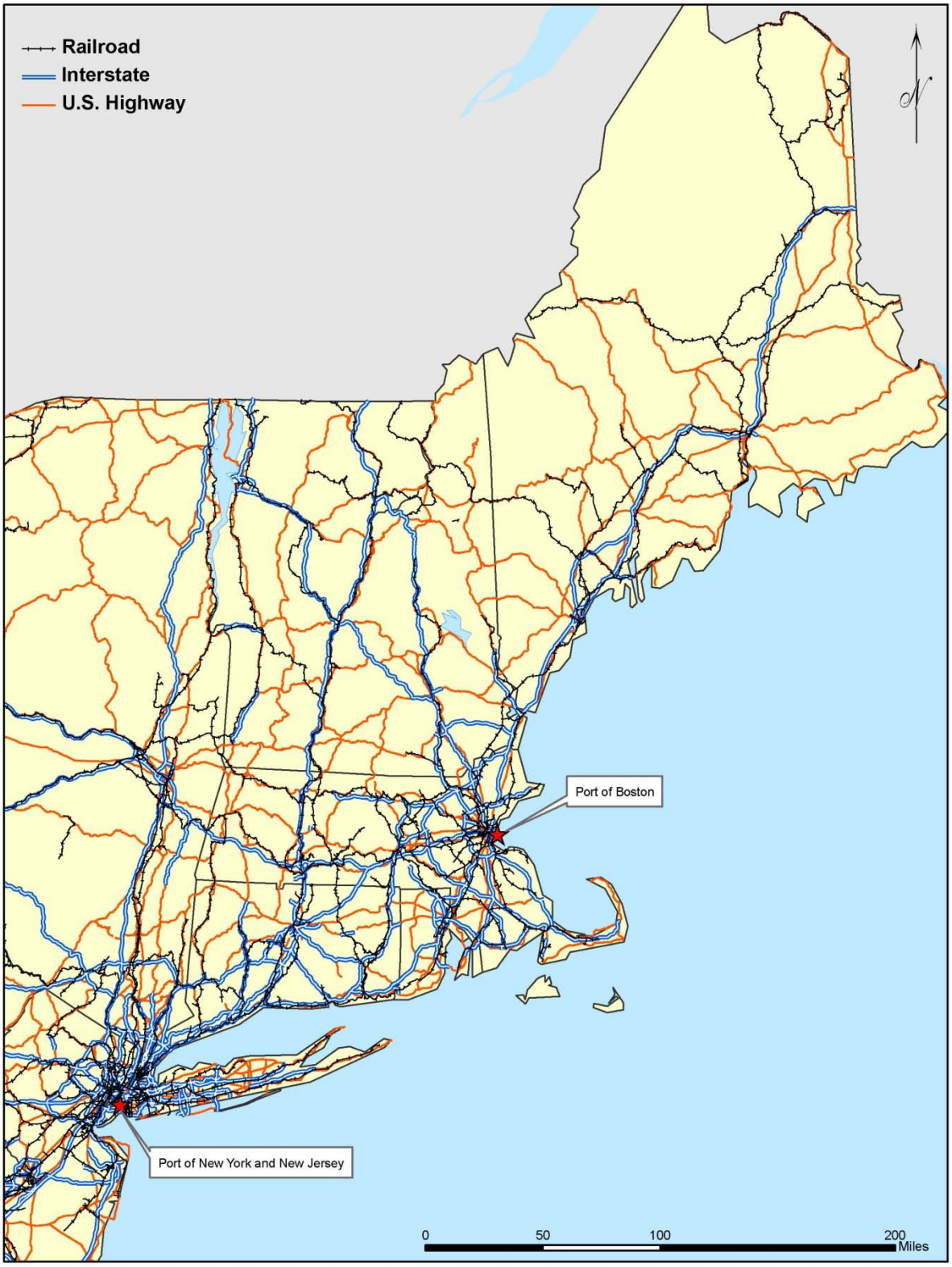

Figure 1: Boston Harbor Major Highways and Railroads

3 Existing Conditions

New England containerized cargo uses both the PONYNJ and Boston Harbor (Table 3-1). Boston Harbor is closer than is the PONYNJ to all points of origin or destination in all New England states, with the exception of Connecticut. Boston Harbor is closer to the point of origin or destination for 29% of Connecticut containerized cargo (71% of Connecticut containerized cargo (73,885 TEUs) is closer to the PONYNJ, based on town of origin and destination data documented in the PIERS 2007 data set.

Table 3-1
PIERS/WCSC Total and New England TEUs (2007)

	Imports	Exports	Total
Boston Harbor Total TEUs	89,890	63,526	153,416
PONYNJ New England TEUs	202,211	53,045	255,256
Total New England TEUs	292,101	116,571	408,672

Boston Harbor handles only 38% of all New England containerized cargo and only 46% of all New England containerized cargo that is closer to Boston Harbor. Overall Boston Harbor is closer to the origin or destination of 334,787 New England TEUs, although only 153,416 use Boston Harbor. Connecticut cargo that is closer to the PONYNJ may however use Boston Harbor as exhibited by the fact that 74% of Connecticut imports and 44% of Connecticut exports using Boston Harbor are closer to the PONYNJ. Figures 2 and 3 display the geographic distribution of New England cargo using Boston Harbor and the PONYNJ, respectively, based on PIERS 2007 data.

3.1 New England Containerized Cargo Characteristics

New England containerized cargo was assessed based on the types of commodities transported, the weight and value of the commodities transported, and the foreign country of origin or destination. A comparison of New England containerized cargo using the PONYNJ and New England containerized cargo using Boston Harbor was conducted to identify any systematic differences in these characteristics between New England containerized cargo using the PONYNJ and New England containerized cargo using Boston Harbor. Task R-1: Assessment of Existing Conditions, Chapter 2.2 Differences Between New England Cargo Moved Through PONYNJ and Boston Harbor contains a more detailed analysis of the information contained in this chapter. This analysis is based on the 2007 PIERS data. The analysis indicates that there are no substantial differences between New England cargo using the PONYNJ and New England cargo using Boston Harbor. Minor differences identified include that Boston Harbor exports are typically slightly heavier than PONYNJ exports and that Boston Harbor has fewer direct service ports and therefore must rely on transshipment more than the PONYNJ for trade with regions not on the direct call services.

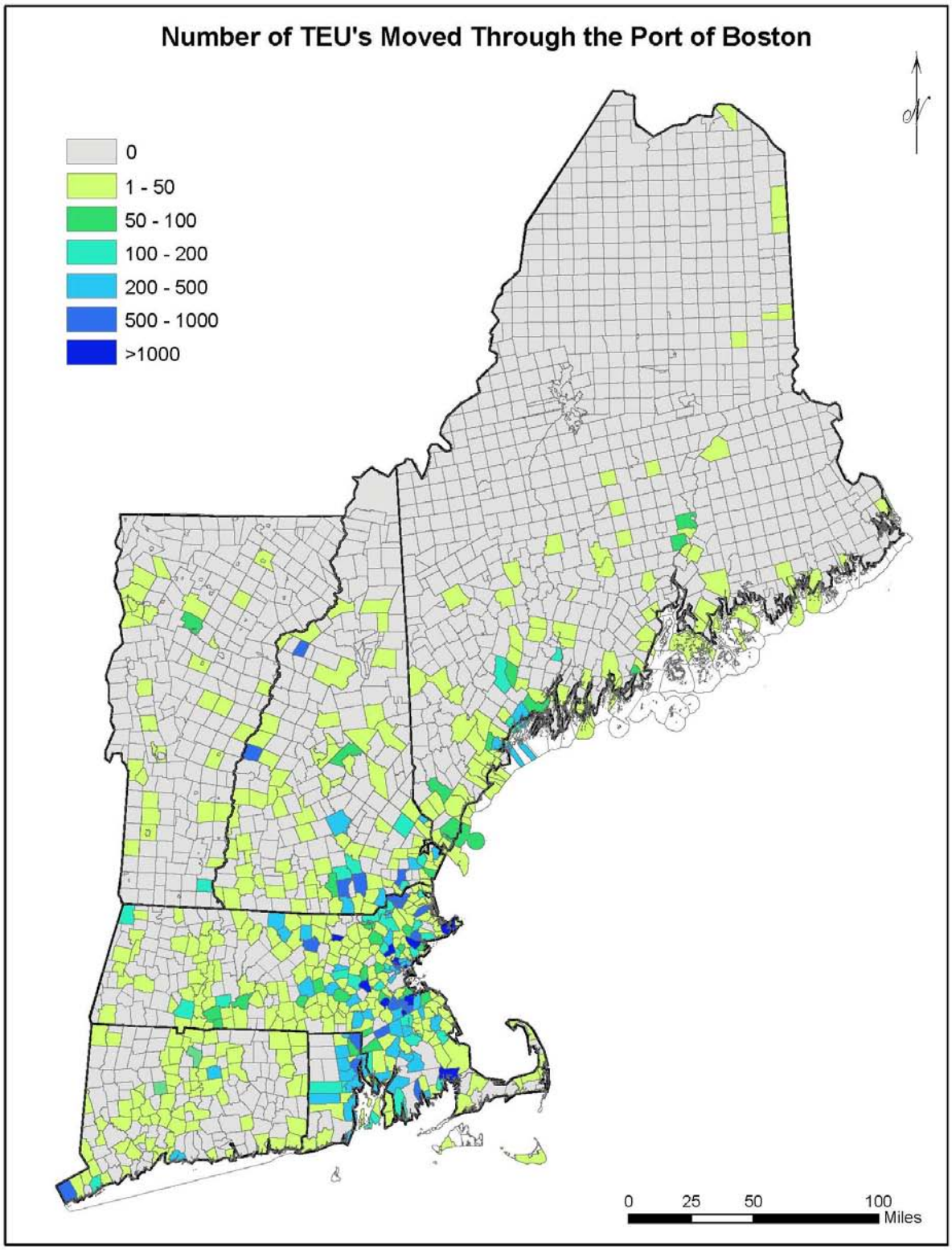

Figure 2: Boston Harbor New England TEU Origins and Destinations

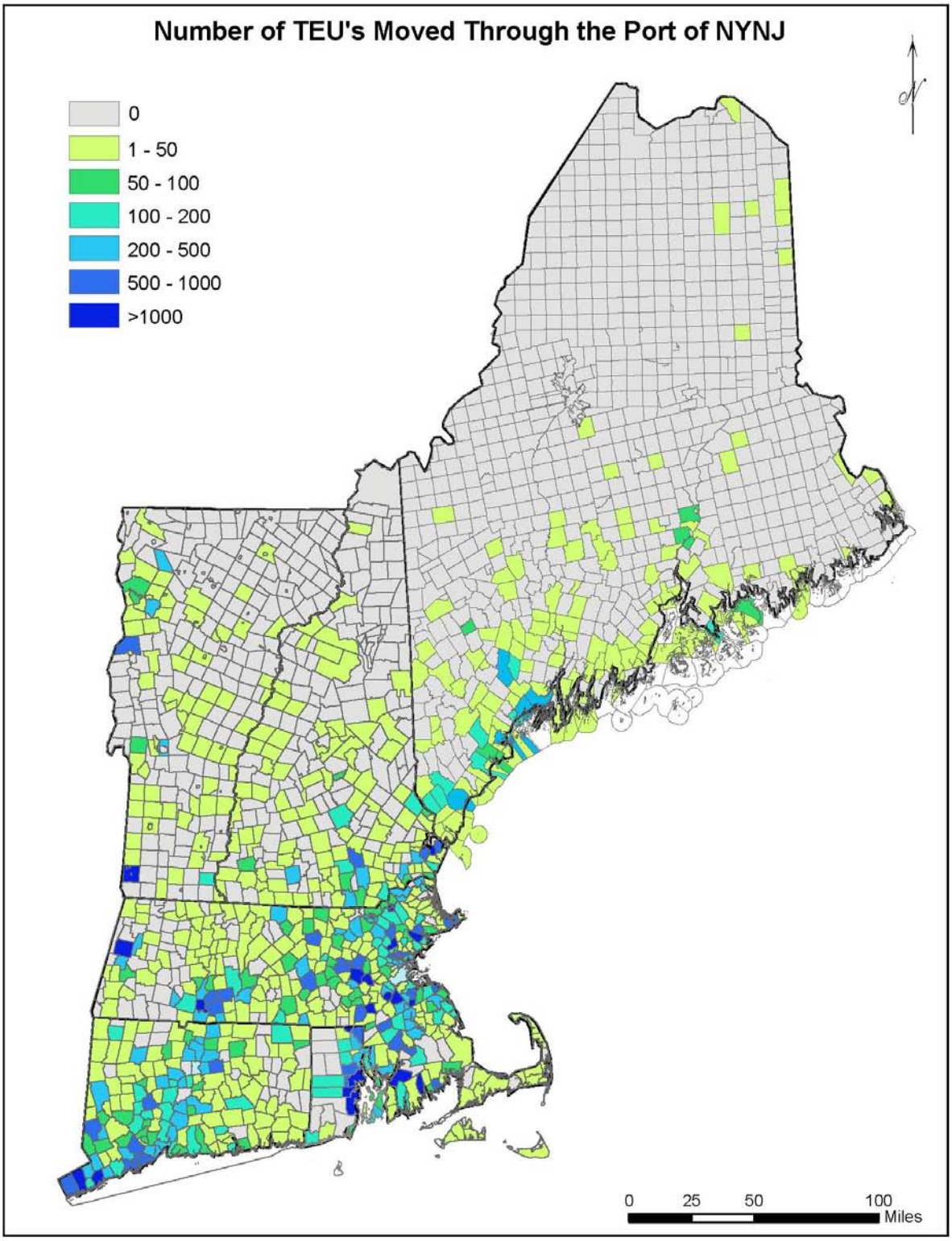

Figure 3: PONYNJ New England TEU Origins and Destinations

3.1.1 Commodity Type

Boston Harbor and the PONYNJ move a broad variety of containerized cargo. The PONYNJ moves many more commodity types than Boston Harbor (Table 3-2). The PIERS data did not identify any commodity type that moves exclusively through Boston Harbor. For both ports, the largest 20 commodity types by volume account for a large portion of total TEUs moved. The two ports share similar commodities in their respective list of top 20 commodity types by volume. Twelve of PONYNJ's top 20 commodities are also in Boston Harbor's top 20 commodity list, and 13 of Boston Harbor's top 20 commodities are on the PONYNJ top 20 list.

Table 3-2
Number of Commodity Types (2007)

	Exports		Imports	
	PONYNJ	POB	PONYNJ	POB
Number of commodity types	744	320	780	502
Total TEUs	1,252,139	63,526	2,559,993	89,890
Top 20 categories number of TEUs	800,214	53,069	1,207,436	51,783
Top 20 categories percent of total	64%	84%	47%	58%

The PIERS data present no indication that commodity type, in and of itself, is a determinant of the port used. Overall, the import commodity types moved through the PONYNJ but not through Boston Harbor account for a minimal 3% of PONYNJ's total 2007 import TEUs. Nearly all of the import commodity types moved through the PONYNJ that were not also moved through Boston Harbor are some type of chemical, compound, or essential oil. There was no consistent difference in types of consumer goods moved through either port. Some South American produce bound for New England was moved exclusively through the PONYNJ, which is attributed to the lack of direct container service between South America and Boston Harbor.

3.1.2 Commodity Weight

An analysis of cargo weights for Boston Harbor cargo and all PONYNJ cargo indicate some minor differences, but not to the extent that cargo weight would be a determining factor for port choice. For example, Northern European imports to PONYNJ are slightly heavier than Northern European imports to Boston Harbor, but Asian imports to Boston Harbor are similarly slightly heavier than Asian imports to PONYNJ (Table 3-3). One consistent aspect of the data are that Boston Harbor exports on all routes are slightly heavier than PONYNJ exports, but to only a small degree.

Table 3-3
PONYNJ and Boston Harbor Tons Per TEU (2007)

	Imports		Exports	
	PONYNJ	POB	PONYNJ	POB
Mediterranean	11.00	10.66	6.56	7.23
North Europe	10.17	8.68	5.48	6.51
Asia	5.03	6.74	8.48	8.92

3.1.3 Commodity Value

Boston Harbor imports have a slightly higher value per ton for Asia and Northern European imports than PONYNJ imports, but the value is lower for Boston Harbor Mediterranean imports (Table 3-4). The differences in import values are consistent with Boston Harbor's import commodity profile, which includes a greater percentage of higher cost/ton primary products such as fish, shellfish, and vegetables than the PONYNJ import profile. PONYNJ exports have consistently higher values than Boston Harbor exports, and there is a major difference in the value of PONYNJ exports and Boston Harbor exports to Asia. Asian exports from the PONYNJ have four times higher value per ton than Boston Harbor exports. This greater value for PONYNJ exports to Asia is explained by Boston Harbor's heavy dependence on paper and metal waste products as primary (61%) export commodities to Asia. This difference in value, while great, is not considered relevant to the question of why vessels call on Boston Harbor today, or whether some may shift from PONYNJ to Boston Harbor in the future.

Table 3-4
PONYNJ and Boston Harbor Dollars per Ton (2007)

	Imports		Exports	
	PONYNJ	POB	PONYNJ	POB
Med	$ 4,038	$ 3,223	$ 6,254	$ 5,597
NEuro	$ 4,202	$ 4,887	$ 8,299	$ 5,521
Asia	$ 4,590	$ 4,710	$ 6,778	$ 1,609

3.1.4 Port of Origin or Destination

In the 2007 data, nearly all of Boston Harbor's containerized cargo was carried on the three major services, which also called at the PONYNJ. These services make direct calls to a limited number of foreign ports (Table 3-5). Each of these ports services its own limited hinterland; however, each service also calls at major transshipment centers which allow cargo from all regions of the world to reach the US east coast and Boston Harbor.

Table 3-5
Boston Harbor Liner Service Direct Call Ports (2007)

Asia	Hong Kong*, China
	Qingdao, China
	Shanghai*, China
	Yantian, China
Mediterranean	La Spezia*, Italy
	Naples, Italy
	Sines, Portugal
	Valencia*, Spain
Northern Europe	Antwerp*, Belgium
	Bremerhaven*, Germany
	Felixstowe, England
	Le Havre, France
	Rotterdam*, Begium

*Indicates major transshipment center; Source: Containerization International 2007 web search

The Boston Harbor liner service direct call ports exclude major trading partners, such as India, and entire world regions, such as Southeast Asia and South America. Therefore, New England containerized cargo destined for or coming from these major trading partners must either transship to a direct call service or use the PONYNJ in order to get direct call container shipping services. Transshipment is a major component of the container shipping industry. The world's largest volume ports such as Shanghai and Singapore transship (move a container from one ship to another) many millions of TEUs each year. Transshipment allows efficient use of large container ships by reducing the number of ports the vessel needs to call on in order to service large regional areas.

3.1.5 Containerized Cargo Characteristics Assessment Conclusion

The purpose of comparing cargo using the PONYNJ with cargo using Boston Harbor is to identify any major differences in cargo using the two ports, which might explain why New England cargo uses the PONYNJ. The comparative assessment of cargo characteristics shows that there are no substantial differences between PONYNJ and Boston Harbor containerized cargo which would be expected to have a substantial systematic impact on port usage.

3.2 Containership Fleet and Operations

Each of the liner services calling at Boston Harbor also call at the PONYNJ. Because of its large population center, port facilities, and intermodal capabilities the PONYNJ is considered an "anchor" port for the US east coast and therefore most major services calling on the US east coast call at the PONYNJ. Currently, on the MSC North Europe service, vessels arrive at the PONYNJ from Le Havre then continue to Boston, Philadelphia, Baltimore and Norfolk before returning to the PONYNJ prior to the trip across the Atlantic. On the MSC Mediterranean service, Boston Harbor is the first US port followed by the PONYNJ. The MSC Mediterranean service continues down the coast to Savannah, but then turns north to Charleston before returning to Valencia, Spain. The Asia Panama service calls on the Pacific side of Mexico

(Lazaro Cardenas) and the Atlantic side of Panama (Cristobal) before working its way up the US east coast. The service calls on Savannah, then PONYNJ, and Boston Harbor before returning to Qingdao via the Panama Canal. Lazaro Cardenas and Cristobal are recent additions to the port rotation. These ports were not included in this service in 2007. The inclusion of these ports opens Boston Harbor to trade with ports on the west and east coasts of South America. South American ports on both coasts run feeder vessels to and from Lazaro Cardenas and Cristobal, which are used as transshipment ports.

The suspended Asia Suez service, which ran from May through December 2011, used vessels ranging from 5,500 TEUs to 6,100 TEUs. The ports-of-call on this service included Boston Harbor (-40 ft.), PONYNJ (-45 feet; -50 feet in 2014), Norfolk (-50 feet), Kaohsiung (-49 feet), Hong Kong (-51 feet), Yantian (-53 feet), Vung Tau (- 48 feet) and Singapore (-53 feet). The port rotation placed Boston between the PONYNJ and Singapore. Singapore, Kaohsiung, and Hong Kong are among the largest transshipment ports in the world.

3.2.1 Vessel Size

An extensive comparative analysis of vessel size was conducted to identify any systematic differences between the fleet calling at the PONYNJ and the fleet calling at Boston Harbor.[8] The analysis was conducted using 2007 data. The comparison was conducted individually for each route with direct service to Boston Harbor. The analysis shows that in 2007 vessels calling at Boston Harbor were consistently smaller in terms of dead weight tonnage (DWT) and maximum sailing draft than vessels calling at the PONYNJ. The use of smaller vessels puts services that call at Boston Harbor at a cost disadvantage. Since 2007, vessel sizes have been upgraded and newer vessels have been added to each service (Table 3-6). COSCO will continue to upgrade the vessels on their service calling at Boston Harbor so that each vessel on the service is the largest possible for Panamax vessels[9]. MSC has also integrated the largest Panamax vessels into services calling at Boston Harbor, which is a substantial change from their 2007 fleet. The Asia Suez service brought Post-Panamax vessels (5,500 TEUs – 6,100 TEUs) to Boston Harbor and the PONYNJ in 2011. This upgrade in vessel size is consistent with a common theme stated by each carrier interviewed, which is that the container shipping business is driven by economies of scale. Smaller, less efficient vessels cannot compete on a service with larger, more efficient vessels. Table 3-7 presents the cost per TEU per 1,000 miles (at service speed) for Panamax and smaller vessels.

[8] Task R-1: Assessment of Existing Conditions and Task R-1: Assessment of Existing Conditions Reference Appendix contain an extensive and detailed analysis of containership operations at the PONYNJ and Boston Harbor in 2007.

[9] COSCO interview 2007; COSCO interview 2010

Table 3-6
Boston Harbor Liner Service Fleets 2007 & 2010

Vessel Name	Total TEU Capacity	DWT	Year Built	Age
Mediterranean Service in 2007				
MSC Bali	2,472	36,314	1980	27
MSC Colombia	4,158	60,348	1996	11
MSC Diego	4,056	56,889	1999	8
MSC Endurance	2,472	36,267	1980	27
MSC Fribourg	*	45,569	1980	27
MSC Greece	2,214	35,551	1995	12
MSC Mediterranean	2,480	41,583	1995	12
MSC Mexico	2,712	40,849	1978	29
MSC Natal	2,638	39,528	1996	11
Average	2,900	43,655	1989	18
Mediterranean Service in 2010				
Cap Victor	4,437	60,639	1989	21
Jennifer Rickmers	5,060	68,189	2004	5
MSC Montreal	4,206	59,283	1989	21
MSC Colombia	4,158	60,348	1996	14
MSC Emma	5,060	68,121	2004	6
MSC Olga	5,060	67,550	2006	4
Average	4,664	64,022	1998	12
Northern Europe Service in 2007				
Hermes	2,490	34,365	2006	1
MSC China	2,808	40,030	1996	11
MSC Christina	3,424	56,902	1998	9
MSC Delhi	3,534	42,183	2004	3
MSC Japan	3,424	43,369	1996	11
MSC Johannesburg	3,467	45,170	1995	12
MSC Prague	3,965	48,930	2003	4
MSC Queensland	3,400	42,183	2004	3
MSC Sardinia	3,074	43,270	1986	21
MSC Sophie	3,500	43,294	1993	14
MSC Ulsan	4,132	52,785	2002	5
MSC Voyager	2,754	36,433	1980	27
MSC Washington	2,824	53,325	1984	23
Average	3,292	44,788	1996	11
Northern Europe Service in 2010				
MSC Eleni	5,060	68,121	2004	6
MSC Ingrid	4,954	66,616	1999	11
MSC Linzie	4,900	67,800	2003	7
MSC Nerissa	5,060	68,121	2004	6
MSC Tanzania	4,545	63,551	1997	13
Average	4,904	66,842	2001	9
Asian Service in 2007				
COSCO Panama	2,702	37,900	2005	2
Da He	4,221	51,946	1994	13
Fei He	4,215	51,280	1994	13
River Wisdom	4,196	49,955	1994	13
Shan He	4,221	51,982	1994	13
Teng He	4,215	51,280	1994	13
Yuan He	4,215	51,280	1994	13
Zhen He	4,221	51,985	1994	13
Zong He	4,221	51,985	1994	13
Average	4,047	49,995	1995	12
Asian Service in 2010				
COSCO Boston	5,089	67,470	2007	3
COSCO New York	5,089	67,470	2007	3
River Elegance	4,196	49,945	1994	16
River Wisdom	4,196	49,995	1994	16
Shan He	4,221	51,982	1994	16
Tian An He	5,100	63,500	2010	0.5
Tian Sheng He	5,106	65,000	2010	0.5
Tian Yun He	5,100	63,500	2009	1
Zhen He	4,221	51,985	1994	16
Average	4,702	58,983	2002	8

*Data not available – vessel decommissioned; Source: Containerization International

Table 3-7: Waterborne Transportation Cost per TEU per 1,000 miles

TEUs	$/TEU
4,800	$33.98
4,000	$36.19
3,500	$38.05
3,000	$40.35
2,800	$41.41
2,500	$43.21

Source: US Army Corps of Engineers Vessel Operating Costs EGM 11-05

3.2.2 Vessel Operations: New England TEUs per Call

New England containerized cargo data for the three liner services calling at both the PONYNJ and Boston Harbor, based on PIERS 2007 data, show that New England cargo on these vessels is predominantly handled at Boston Harbor (Table 3-8). Because these vessels call on Boston Harbor they unload a relatively small amount of New England imports at the PONYNJ. The vessels on these three services account for only 6% of all the New England import TEUs and 4% of New England export TEUs using the PONYNJ. Data for 2010, provided by Massport, indicate small increases in average TEUs per call at Boston Harbor for Asian and European imports from 2007 to 2010 and very small changes for Asian and European exports (Table 3-9). Mediterranean import TEUs per call decreased slightly, but there was a substantial decrease in the number of Mediterranean export TEUs per call.

Table 3-8
Average New England TEUs per Call for Liner Services with Direct Calls at the PONYNJ and Boston Harbor (2007)

	Imports		Exports	
	PONYNJ	POB	PONYNJ	POB
Med	59	261	15	159
NEuro	49	332	32	296
Asia	76	992	16	701

Source: PIERS 2007 data

Table 3-9
Average New England TEUs per Call for Boston Harbor Liner Services (2010)

	Imports	Exports
Mediterranean	252	96
Northern Europe	363	313
Asia	1,090	676

Source: Massport

Although only two carriers handle New England cargo through Boston Harbor, no single carrier dominates the importing of New England TEUs into the PONYNJ. Only two carriers have market share greater than 10% (Maersk and Evergreen), and most carriers have less than 5% market share[10]. Additionally, many carriers call at the PONYNJ with New England cargo more frequently than once a week, indicating that some carriers are active on multiple services.

The average New England TEUs per call for PONYNJ vessel calls are substantially lower than the average New England TEUs per call for vessels on comparable routes calling at Boston Harbor (Appendix A: Table 26). For example, vessels importing New England TEUs through Boston Harbor average 992 New England TEUs on the Asia route versus an average of 97 New England TEUs for vessels importing through the PONYNJ and not calling at Boston Harbor. Similar comparisons can be made for Mediterranean and European cargo.

Overall, the analysis of TEU per call data indicates that New England cargo exhibits a preference for Boston Harbor. When a vessel calls at Boston Harbor, the vast majority of New England cargo on that vessel uses Boston Harbor instead of the PONYNJ. The amount of New England cargo per call at Boston Harbor has remained very stable, with mainly small increases for some services and small decreases for others, despite the impacts of the economic recession. Vessels calling at Boston Harbor carry substantially more New England cargo per call than vessels that call at the PONYNJ and not Boston Harbor.

3.2.3 Vessel Operations: Arrival and Departure Drafts

The controlling depth at Boston Harbor in 2007 was -37 feet. Underkeel clearance is typically three feet or more, which implies that any vessel operating at a draft deeper than -34’0” requires tidal assistance. In 2007, 68% of liner service vessel calls required tidal assistance, which means that these vessels arrived or departed Boston Harbor with operating drafts of 35 feet or more (Appendix A; Table 11). Boston Harbor has a tidal range of approximately 9.4 feet, which carriers often use to gain sufficient underkeel clearance.

In 2007, Asian services calling at the PONYNJ tended to be larger vessels than the Asian service vessels that call at Boston Harbor. Fifty-nine percent of all Asian service calls to PONYNJ were made by vessels larger than the Asian service vessels that call on Boston Harbor (Appendix A:

[10] Task R-1: Assessment of Existing Conditions and Task R-1: Assessment of Existing Conditions Reference Appendix, Chapter 3 Cargo, Vessel, and Vessel operating Characteristics for New England TEUs Using the PONYNJ

Table 19). Similarly 60% of all Asia import cargo was on vessels that are larger than the Asian service vessels calling on Boston Harbor (Appendix A: Table 20). At Boston Harbor with a 37-foot controlling depth, 94% of inbound Asian service vessels arrived with drafts ranging from 34 to a maximum of 37 feet (Appendix A: Table 11). No vessel on the Asia service arrived at Boston Harbor with a draft greater than 37 feet, in 2007. By contrast, Asia service vessels calling at the PONYNJ arrived with drafts greater than 37 feet on 36% of inbound calls (Appendix A: Table 18).

In 2007, MSC rotated 22 vessels on its Europe and Mediterranean services that call at both the PONYNJ and Boston Harbor (Table 3-6). These 22 vessels ranged from 34,000 DWT to 57,000 DWT, although most vessels were in the 36,000 DWT to 45,000 DWT range. Europe and Mediterranean service vessels calling on the PONYNJ included substantially larger vessels than Europe and Mediterranean service vessels that call on Boston Harbor (Appendix A: Table 21). Forty-one percent of the Europe and Mediterranean service vessel calls to the PONYNJ were by vessels larger than the Europe and Mediterranean service vessels that call on Boston Harbor. Europe and Mediterranean services to the PONYNJ include a number of niche services, such as Turkon Line's service with Turkey, which include vessels smaller than 32,000 DWT. These small vessel services increase the proportion of light draft vessel calls at the PONYNJ.

Vessel arrival and departure draft data for the first half of 2010 indicates that vessels are transiting Boston Harbor with deeper drafts than identified in 2007 (Table 3-10). Unfortunately the 2010 operating draft data includes only January through July 2010 and therefore includes only a limited number of trips and does not reflect the larger number of TEUs per call carried on Asia service vessels in August through October, when ships are more heavily laden than at other times of the year due to inventory stocking in anticipation of the December holidays. The average import TEUs per call for the Asian service during those later months was 1,179 TEUs per call, but is not reflected in Table 3-9. In 2010 the controlling depth at Boston Harbor is -38 feet, which is one foot deeper than the controlling depth in 2007 (-37feet). Also, each of the three liner services calling at Boston Harbor is using newer and larger vessels in 2010 (Table 3-6). On average and in terms of DWT, vessels on the Europe service are 49% larger, vessels on the Mediterranean service are 47% larger, and vessels on the Asian service are 18% larger (Table 3-6) than they were in 2007.

Table 3-10 shows that vessels on each of the three services tended to arrive and depart Boston Harbor with deeper drafts in 2010 than in 2007. This increase in operating drafts at Boston Harbor is attributable to the additional foot of controlling depth at Boston Harbor due to maintenance dredging and the use of larger vessels in 2010 as compared to 2007 for each of the three services.

Table 3-10
Comparative Boston Harbor Arrival and Departure Drafts: 2007 and 2010*

	Asia Service				Europe Service				Mediterranean Service			
	Import		Export		Import		Export		Import		Export	
Draft	**2007**	**2010**	**2007**	**2010**	**2007**	**2010**	**2007**	**2010**	**2007**	**2010**	**2007**	**2010**
>40	0%	0%	0%	0%	2%	34%	3%	24%	4%	15%	0%	11%
40	0%	5%	0%	6%	6%	24%	4%	28%	7%	5%	9%	5%
39	0%	5%	0%	6%	10%	7%	8%	17%	11%	15%	2%	16%
38	0%	21%	0%	17%	7%	10%	10%	7%	20%	15%	20%	16%
37	8%	16%	8%	33%	9%	3%	9%	7%	11%	30%	11%	26%
36	22%	47%	22%	22%	11%	10%	13%	7%	20%	5%	24%	11%
35	33%	5%	39%	17%	16%	3%	13%	0%	13%	0%	18%	11%
34	31%	0%	27%	0%	12%	3%	16%	3%	7%	10%	4%	0%
33	4%	0%	4%	0%	5%	0%	9%	0%	4%	0%	7%	0%
32	0%	0%	0%	0%	7%	0%	5%	3%	2%	5%	2%	0%
31	0%	0%	0%	0%	7%	3%	6%	0%	0%	0%	0%	5%
=<30	2%	0%	0%	0%	7%	0%	6%	3%	2%	0%	2%	0%

Source: WCSC (2007) and Boston Harbor Pilot Association (2010);*January through July data

The 2010 vessel operating draft data exhibits an even greater reliance on the tide for vessels on the Europe and Mediterranean services than the 2007 data. Table 3-11 shows the average wait time and the number of vessels that were affected by tidal delays. The average wait time is the expected value of the wait time accounting for the probabilities of tide height and length of height availability. Actual wait times will vary from the average. Vessels on the Asia service show a similar use of tide and much less tolerance for waiting to obtain tidal advantage, which is consistent with statements by COSCO concerning the need to arrive at the Panama Canal according to a very strict and punitive schedule. In the first half of 2010, 91% of liner service vessel calls (inbound and outbound) used tidal advantage. Thirty-nine percent of vessel calls tolerated an average wait of up to nearly three hours. An additional 26% were willing to wait between 2.9 and 3.7 hours and 27% waited from 3.7 hours to 5.1 hours to obtain suitable tidal advantage.

Table 3-11
Boston Harbor Liner Service Vessels Using the Tide 2010

Vessel Draft*	Tide Height Needed (ft)	Average Wait (hrs)	Asia Service		Europe Service		Med Service		Total
			In	Out	In	Out	In	Out	
44	9.0	5.57	-	-	-	-	-	-	0
43	8.0	5.05	-	-	2	-	-	-	2
42	7.0	4.54	-	-	5	4	2	1	12
41	6.0	4.09	-	-	8	11	2	1	22
40	5.0	3.69	1	2	3	6	3	4	19
39	4.0	3.32	4	2	3	2	3	2	16
38	3.0	2.89	4	6	1	2	6	6	25
37	2.0	2.23	7	5	2	2	-	1	17
36	1.0	1.85	3	2	2	-	1	2	10
35	0	0	-	1	1	-	2	1	5
34			-	-	-	1	1	-	2
33			-	-	-	1	1	-	2
32			-	-	1	-	-	1	2
31			-	-	-	1	-	-	1

Source: USACE New England District; * Note drafts rounded up to nearest foot; **Assumes 3 feet underkeel clearance

3.2.4 Containership Fleet and Operations Assessment Conclusion

The trend towards larger vessels as projected by the carriers during the carrier interviews is visible in the data for Boston Harbor and in the data for vessel operations on the US east coast. Boston Harbor is now served by a newer, larger, and more efficient fleet than in 2007, as shown in Table 3-6. Differences in vessel size between the PONYNJ and Boston Harbor fleet have somewhat diminished now that Boston Harbor receives the largest Panamax vessels in the world fleet; however there are no Post-Panamax vessels calling at Boston Harbor.

US east coast container shipping is currently transitioning to Post-Panamax vessels. Even before the opening of the expanded Panama Canal in 2014, carriers are now shifting to Post-Panamax vessels servicing the US east coast by using the Suez Canal. These vessels are as large as 8,500 TEUs. The same carriers are currently using 14,000 TEU vessels on services between Europe and Asia, via the Suez Canal.

Post-Panamax vessels are currently by-passing Boston Harbor. For example, the 5,600 TEU vessels on the Green Alliance (COSCO, Hanjin, Yang Ming, and K-Line) service from Southeast Asia via the Suez Canal to the east coast of North America call at Halifax from Singapore and then stop at the PONYNJ, by-passing Boston Harbor even though none of the ports on that service have a direct call to Boston Harbor. The Green Alliance is also adding another Asia-US east coast service via the Suez Canal, which began in mid-2011. This service uses 8,000 TEU vessels and by-passes Boston Harbor.

Similarly, the Grand Alliance, which includes Hapag-Lloyd, NYK Line and OOCL, runs a service from Southeast Asia, the Indian sub-continent, and Europe to Halifax and the PONYNJ with Post-Panamax vessels ranging from 5,300 to 5,900 TEUs. MSC's Golden gate service uses 8,000 TEU vessels, which go directly to the PONYNJ after transiting the Suez Canal. The Maersk/CMA CGM TP3 service from Asia to the US east coast via the Suez Canal has recently upgraded to 8,500 TEUs, but also does not call at Boston Harbor.

As explained consistently by the carriers during the interviews, Boston Harbor has an excellent geographic advantage as the closest US port to the Suez Canal but Post-Panamax vessels will not call unless greater depth is available. All of the major Asia – US east coast liner services, whether via the Suez Canal or the Panama Canal, will use Post-Panamax vessels after the Panama Canal expansion is complete.

The vessels currently calling at Boston Harbor are loaded as deeply as existing authorized channel conditions allow. The increase in vessel arrival and departure drafts from 2007 to 2010 (Table 3-10), and the increase in TEUs per call from 2007 to 2010 (Tables 3-8 and 3-9), in response to a single additional foot of depth is a strong indication that carrier operations at Boston Harbor are draft constrained. The carriers have consistently stated that the vessels calling at Boston Harbor are loaded as deeply as they can be, and this statement is supported by the data showing that nearly all vessel calls in 2010 required tidal assistance (Table 3-11).

3.3 Existing Conditions Summary

The existing conditions analysis needs to answer the question: Why doesn't more New England cargo use Boston Harbor under existing conditions? The analysis has identified that although Boston Harbor is closer than the PONYNJ to nearly all New England TEU origins and destinations, only 38% of New England TEUs use Boston Harbor and 62% use the PONYNJ (Table 3-1). Furthermore, the shipper survey analysis[11] indicates that there are a minimum of 131,000 New England TEUs (at the 2007 level of trade) that appear to have the potential to shift from the PONYNJ to Boston Harbor (given the opportunity of adequate service), but these TEUs have not made the shift.

The reasons why so much New England cargo uses the PONYNJ are described in the data and in the interviews with carriers. Shippers cannot use Boston Harbor if the carriers do not offer the opportunity. Carriers do not offer the opportunity because:

- Boston Harbor's depth constraint reduces vessel efficiency and causes delays; and

[11] Appendix A: Chapter 6 Shipper Survey and Chapter 7 Estimation of TEUs Available to Shift from the PONYNJ to Boston Harbor

- All liner services carrying New England cargo call at the PONYNJ which is historically the alternative port for New England cargo.

Under existing conditions Boston Harbor (-38 feet) is 7 feet shallower than the PONYNJ. Vessels calling at Boston Harbor, all of which also call at the PONYNJ as either the previous port or next port, make up for this depth differential by using the tide, enduring delays, and restricting vessel loading[12]. Nearly every liner service vessel transit in the first six months of 2010 (128 out of 135) used the tide at Boston Harbor, with average delays ranging from 1 to 5 hours. None of the vessels required the full 9 feet of tide, which would result in an average delay of almost 6 hours. When vessels do call on Boston Harbor, they offload and load far more New England TEUs per call than any vessel offloads or loads New England TEUs at the PONYNJ.

Carriers face the choice of enduring delays, delay-related costs, and loading restrictions that are associated with adding a call at Boston Harbor or offloading and loading New England cargo at the PONYNJ, which is already in the port-rotation. If there are as many New England TEUs that could potentially shift to Boston Harbor as the analysis suggests, the fact that there are more than 40 carriers currently bringing New England import cargo to the PONYNJ, but there are only two carriers calling at Boston Harbor implies that the industry has very limited tolerance for systematic delays, light-loading, and related inefficiencies.

The suspended Asia Suez service did not have the burden of a Panama Canal schedule and associated late fees, however, these vessels were severely restricted by channel depth at Boston Harbor. Discussions with COSCO[13] and Hanjin[14] personnel in 2011 indicate that it is the carriers' intention to draw additional New England cargo from the PONYNJ. According to the carriers, the vessel size for this new service (5,500 – 6,100 TEUs) was determined by projected cargo volume, vessel availability due to the "cascade effect", and the need to put a competitive size vessel in the Asia – US east coast trade. These vessels brought an additional 30,000 TEUs through Boston Harbor in only a few months, which is an indication of the availability of cargo to shift to Boston Harbor. The carriers have not indicated when this service might be renewed.

[12] MSC interview 21Dec04, MSC interview 18Apr07, Maersk interview 09Aug10

[13] COSCO interview 06Apr11

[14] Hanjin interview 05Apr11

4 Without-Project Condition

The major changes between existing conditions and the without-project condition are driven by the Panama Canal Expansion, which will increase the canal's capacity from the current 5,100 TEU vessel to a 12,000 TEU vessel. The expanded Panama Canal will be able to accommodate vessels with sailing drafts of -50 feet. The Suez Canal is already capable of handling vessels with sailing drafts of -66 feet. The PONYNJ is coordinating completion of its 50-foot deepening project with the opening of the expanded Panama Canal, which is scheduled for 2014. At that time, there will be a 10-foot differential between Boston Harbor's without-project condition controlling depth (-40 feet) and the controlling depth at the PONYNJ (-50 feet). All of the major US east coast ports have been upgrading their infrastructure over the past few years to accommodate the larger vessels that will be using the expanded canal. Boston Harbor has upgraded to four Post-Panamax cranes capable of operating a 16-container wide vessel. Massport has also purchased 30 acres of property adjacent to Conley Terminal that would be used for Post-Panamax vessel berthing and cargo handling. This additional acreage allows Conley terminal to avoid air-draft issues associated with the new Post-Panamax cranes[15].

Tables 4-1 and 4-2 present the without-project controlling depths of the ports currently on a direct call service with Boston Harbor. The controlling depths for the PONYNJ and Savannah Harbor assume completion of their currently authorized deepening projects. Each of the US ports in this table is currently called on by 8,500 TEU Post-Panamax vessels. The foreign ports in this table are currently called on by vessels up to 10,000 TEUs. Boston Harbor, under without-project conditions (-40 feet) would be the draft constraint for each service.

[15] COSCO Interview 31Aug10

Table 4-1
Controlling Depths: Boston Harbor MSC Services

Europe Service		Mediterranean Service	
Bremerhaven	-48.2 ft	Gioia Tauro	-49.2 ft
Felixstowe	-49.2 ft	Naples	-49.2 ft
Antwerp	-51.2 ft	La Spezia	-47.5 ft
Le Havre	-50.8 ft	Valencia	-52.5 ft
PONYNJ*	-50 ft	Sines	-52.5 ft
Boston	-40 ft	Boston	-40 ft
Philadelphia	-45 ft	PONYNJ	-50 ft
Baltimore	-50 ft	Baltimore	-50 ft
Norfolk	-50 ft	Norfolk	-50 ft
		Savannah**	-47 ft
		Charleston	-45 ft

Source: Containerization International
Notes: *projected for 2015; ** projected for 2016

Table 4-2
Controlling Depths: Boston Harbor COSCO Panama Service

Qingdao	-57.4 ft
Shanghai	-52.5 ft
Ningbo	-49.2 ft
Yokohama	-52.5 ft
Lazaro Cardenas	-52.5 ft
Cristobal	-47.9 ft
Savannah*	-47 ft
PONYNJ**	-50 ft
Boston	-40 ft

Source: Containerization International
Notes: * projected for 2016; **projected for 2015

Under existing conditions, the depth constraint at Boston Harbor has already caused some carriers to avoid Boston Harbor, and has also caused much New England cargo to use the PONYNJ rather than Boston Harbor. Under future without-project conditions, the deepening of the PONYNJ to -50 feet, the expansion of the Panama Canal, and the continuing trend towards larger and deeper draft vessels in the world container fleet will all coalesce to further intensify the impacts of the depth constraint at Boston Harbor, making it even less attractive as an option for both carriers and shippers to use in transporting New England cargo.

4.1 US East Coast Containership Fleet

The fleet of containerships calling at US east coast ports in the without-project condition will no longer be constrained by the original dimensions of the Panama Canal. Vessel size will be determined by economic efficiency, which requires that large vessels be operated near capacity. All of the major carriers operate collaboratively either through alliances, partnerships, or slot sharing agreements in order to maximize utilization of their fleet. In alliances, carriers make exclusive agreements among alliance members concerning vessel allocation and slot allocation. An example of an alliance agreement is the way that the Green Alliance allocates vessels and slots to the five services it operates between Asia and the US east coast. The AWE1 service is entirely Hanjin vessels, the AWE2 services is entirely COSCO vessels (this service calls at Boston Harbor), the AWE3 service is entirely Yang Ming vessels, the AWE4 service is entirely K-Line vessels and the AWE5 service is half K-Line vessels and half Hanjin vessels. Each carrier also has slots allocated on each of the five services, but there are no slots allocated to carriers outside of the alliance. In partnerships, carriers often share vessels on the same service, such as the Columbus service shared by CMA CGM (6,500 – 8,500 TEU vessels) and Maersk

(6,000 – 7,400 TEU vessels) which links Asia to the US east coast (PONYNJ, Norfolk, and Savannah). This service also allocates slots to Hyundai Merchant Marine[16]. Slot sharing allows carries to offer their clients direct call services to ports that the carrier's vessels do not call on by using space on other carriers' vessels.

The purpose of all of these arrangements is to allow carriers to use larger, more efficient vessels at a high level of utilization. The transition to larger vessels, especially the transition to Post-Panamax vessels calling on the US east coast, is currently ongoing and will continue with the expansion of the Panama Canal.[17] Vessels as large as 8,465 TEUs (CMA CGM Figaro and CMA CGM La Scala, Columbus service from Asia to North America) currently call at the PONYNJ which indicates that the height of the Bayonne Bridge is not a constraint for vessels of this TEU capacity. Under without-project conditions, it is reasonable to project that carriers will continue the trend of deploying Post-Panamax vessels to the US east coast. These vessels would range in size from 5,600 TEUs to 8,500 TEUs, which is consistent with the current Post-Panamax fleet calling on the US east coast.

4.2 Boston Harbor Containership Fleet

Under without-project conditions, which include a -40-foot controlling depth at Boston Harbor, Post-Panamax vessels larger than the existing fleet (5,500 – 6,100 TEUs) will not call at Boston Harbor.[18] Although Boston Harbor is currently served by the largest Panamax vessels in the world fleet (5,060 - 5,100 TEU vessels) and small Post-Panamax vessels (5,500 – 6,100 TEU vessels), draft constraints preclude use of larger Post-Panamax vessels. Recent history at Savannah Harbor is an indication of carrier's concerns about depth constraints and Post-Panamax vessel deployment. Savannah Harbor is the second largest container port on the US east coast (2.4 million TEUs in 2009) but the controlling depth is only -42 feet. MSC deployed Post-Panamax vessels (6,700 TEUs; maximum draft 47 feet) to Savannah in 2007, but pulled Savannah out of the port rotation because of inability to fully laden the vessel because of depth constraints and frustration over tide delays[19]. In 2009, MSC put Savannah back into the rotation because a sufficient amount of Savannah cargo did not follow MSC's Post-Panamax vessels to neighboring Charleston, which has a controlling depth of -45 feet. Carriers struggle with tide delays at Savannah Harbor, but continue to deploy Post-Panamax vessels because of the large volume of cargo at Savannah[20]. Boston Harbor has neither Savannah's cargo volume, even if all New England cargo were to be included, nor its depth. The absence of these two conditions precludes larger Post-Panamax vessels from calling at Boston Harbor under without-project conditions.

Under future without-project conditions, carriers have stated during the interviews (and transportation cost analysis confirms) that large Post-Panamax vessels will not regularly call at Boston Harbor. Therefore, services projected to shift to large Post-Panamax vessels will not

[16] Containerization International website (www.ci-online.uk.com) accessed 08Dec10
[17] COSCO interview 31Aug 10; CMA CGM interview 10Aug10; Evergreen interview 10Aug10; Maersk interview 09Aug10; MSC interview 10Aug10; OOCL interview 02Sep10
[18] Ibid.
[19] Interview conducted with MSC for Savannah Harbor Expansion Project (Report of Interviews with Carriers JD comments 06Jul09.doc)
[20] Personal communication with Hope Moorer, Georgia Ports Authority

include Boston Harbor as a port of call. Boston Harbor will lose its existing Asia service via the Panama Canal under without-project conditions and will no longer have a direct service call from Asia. Boston Harbor will also likely lose cargo to Halifax or the PONYNJ on the Mediterranean and Europe services, which even though they will continue to use Panamax vessels, the increase in Post-Panamax vessels coming to the US east coast through the Suez Canal (and the Mediterranean and Europe) will draw cargo away from these Panamax vessel services.

Continued use of Panamax vessels on an Asia-US east coast service to Boston Harbor would be unlikely after the Panama Canal expansion is complete, because of the relative inefficiency of Panamax vessels on that long haul trade when compared to Post-Panamax vessels (Table 4-3). Carriers make vessel selection, deployment, and port of call decisions based on minimizing their total system transportation costs for the entire service, not just based on the least cost method of servicing one particular region or one port of call (such as Boston Harbor).

Table 4-3 shows the waterborne transportation cost savings per TEU for Post-Panamax vessels compared to a 5,060 TEU Panamax vessel for a one-way trip from Qingdao, China to the PONYNJ[21]. Carriers that shift from a 5,060 TEU Panamax vessel to an 8,750 TEU Post-Panamax vessel would save 19% of the waterborne transportation cost for each TEU. This cost differential explains why carriers have been shifting to larger vessels whenever feasible and explains why Panamax vessels will not be competitive on Asia – US east coast services after the completion of the Panama Canal.

Table 4-3
One-Way Waterborne Transportation Costs per TEU from Qingdao China to the PONYNJ

Vessel Size (TEUs)	$/1,000 miles	Cost to PONYNJ	Savings	% Savings
9,200	$26.37	$302.66	$78.60	20.6%
8,750	$27.00	$309.87	$71.40	18.7%
8,204	$27.84	$319.51	$61.75	16.2%
7,024	$29.72	$341.06	$40.20	10.5%
5,060	$33.22	$381.26	---	---

Source: USACE Vessel Operating Costs EGM 11-05

Furthermore, the carrier would not actually lose New England cargo by not offering Boston Harbor at a port of call, because New England cargo can use the PONYNJ and the carrier can pass the additional cost of the landside transportation on to the shipper, who does not have a lower cost alternative from which to choose, since the same economies of scale apply to all

[21] Waterborne transportation costs calculated at vessel service speed

carriers servicing the same international markets. As a result, the carrier gains the efficiency of using Post-Panamax vessels to service all its other adequately deep ports of call by not calling on Boston Harbor, and the shipper passes along the additional landside transportation costs to the ultimate consumer (and the nation).

The carrier has indicated during the carrier interviews that vessels on Asian services (via the Suez Canal and via the Panama Canal) will be greater than 7,000 TEU vessels based on the Panama Canal expansion, projected vessel availability, and projected cargo volumes. Other carriers have indicated that vessels in the 8,000 TEU range will be the standard for services to the US east coast. The President of the Panama Canal Commission has stated that vessels in the 8,000 TEU range will be the work-horse of the expanded canal.

The size of the fleet calling at US east coast ports will be determined by the projected cargo volumes and port infrastructure of the major ports (PONYNJ, Savannah, Norfolk and Charleston). These are the "anchor ports" which will drive the carrier's vessel size and deployment decisions. The inclusion of smaller volume ports into the port rotation will depend on whether that port has sufficient cargo and infrastructure to support a call by the vessel selected to service the major ports. Under this decision structure, the controlling depth at Boston Harbor will not influence the size of vessels on the major services calling at US east coast ports, but controlling depth at Boston Harbor will influence whether Boston Harbor is included in a service's port rotation.

The projected future without-project fleet at Boston Harbor includes:

- Mediterranean Service: Panamax vessels (4,900 TEUs) similar in size to vessels in the existing fleet;
- Europe Service: Panamax vessels (5,060 TEUs) similar in size to vessels in the existing fleet;
- Asia Panama Service: No calls at Boston Harbor. Vessels on this service are projected to be 8,500 TEU, which will by-pass Boston Harbor; and
- Asia Suez Service: No calls at Boston Harbor. Vessels on this service are projected to be 8,500 TEU, which will by-pass Boston Harbor.

4.2.1 Hub and Spoke System

An alternative scenario, which could result from the Panama Canal expansion, would be a hub and spoke distribution system in which a very large ship from Asia calls on a single hub port near the US east coast, such as Freeport, Bahamas or Cristobal, Panama. The large vessels would unload cargo at the hub port which is then transshipped to smaller, feeder vessels. The feeder vessels would directly call on a series of US east coast ports.

Hub and spoke distribution systems do not have a successful history on the US east coast, largely due to the expense of double handling cargo (loading and unloading at the transshipment terminal) and the availability of an extensive landside distribution network. Transshipment increases marine related transportation costs, although there may be savings on landside transportation costs if the feeder port is closer to the cargo origin or destination. The use of direct calls by large vessels to a limited number of large ports presents lower marine-related costs to the carrier, but may increase total origin to destination costs due to greater landside distances. Carriers have tended not to use hub and spoke distribution systems when alternative

landside transportation infrastructure is available and land side transportation costs can be borne by other parties.

Table 4-4 presents an example of two potential hub and spoke systems from Asia to the US east coast and their associated waterborne transportation costs. One system uses the Panama Canal and transships cargo at the Port of Cristobal on the Atlantic side of the canal. The other system uses Freeport, Bahamas as the transshipment port. In both examples, the large vessel is a 9,200 TEU Post-Panamax vessel (MSC Chicago) and the feeder vessel is a 4,900 TEU Panamax vessel (NYK Meteor). These vessels were selected to display the cost comparison. In these examples the large vessel brings cargo from Asia to the transshipment terminal and the feeder vessel brings the cargo from the transshipment terminal to Boston. The table also shows the waterborne costs for a direct call to PONYNJ (the without-project condition) by an 8,200 TEU Post-Panamax vessel (MSC Paris). These costs do not include the costs of trans-shipment (moving boxes from one vessel to another, storage, etc.) that are not associated with a direct call of a vessel from one port to another.

Table 4-4
Waterborne Transportation Costs Excluding Transshipment Costs

Route	Total Distance	Vessel Cost per TEU/1,000 miles			Total Cost per TEU*
		MSC Paris	MSC Chicago	NYK Meteor	
Hong Kong - PONYNJ	11,028	$27.84			$307.03
Hong Kong – Freeport	10,246		$26.37		$270.22
Freeport - Boston	1,205			$33.68	$40.58
Hong Kong – Freeport - Boston	11,451		$26.37	$33.68	$310.80
Hong Kong – Manzanillo	9,085		$26.37		$239.60
Manzanillo - Boston	2,217			$33.68	$74.67
Hong Kong – Cristobal - Boston	11,302		$26.37	$33.68	$314.27

Source: USACE Vessel Operating Costs EGM 11-05;*Waterborne transportation costs only exclusive of transshipment costs

Table 4-4 indicates that transshipment costs as little as $10 per TEU, added to waterborne transportation costs, would reduce to zero any savings to the carrier resulting from a hub and spoke distribution system to Boston when the alternative is a direct call to the PONYNJ. Transshipment costs range from $100 to $200 per TEU at non-US ports[22] and can range from $500 to $800 at US ports[23]. The Columbia Transport barge service which has transshipped cargo from the PONYNJ to Boston Harbor via barge has recently dropped the PONYNJ to Boston

[22] Asaf Ashar, "Revolution #4", *Containerization International*, December 2006 (page 46).
[23] Columbia Coastal Transport Interview 02Sep10

service, due largely to the cost of double handling cargo and competition from landside transportation alternatives.

An economic analysis of a potential future hub and spoke system conducted by the National Ports and Waterways Institute, University of New Orleans[24] concluded that "there are dwindling economies of scale once any mothership of a direct service reaches 4,000 TEUs or larger and as a consequence the shift from direct service to a hub and spoke network cannot generate the ship cost savings needed to offset higher transshipment expenses" (page 49). A similar result is expressed in Table 4-4 above. The basis for the confirmatory results of both economic analyses (National Ports and Waterways Institute and Table 4-3) is that a hub and spoke system is more expensive than direct service using a Panamax vessel. A hub and spoke network may be a reasonable alternative for carriers if the spoke ports cannot handle a Panamax vessel or if Panamax vessels are not available, but neither of these conditions applies to the US east coast (or Boston Harbor) in the without-project condition.

Overall, the analysis of without-project conditions indicates that Boston Harbor will continue to be called on by a fleet including the largest Panamax vessels in the world fleet, which is consistent with the existing condition. Post-Panamax vessels will not call at Boston Harbor under without-project conditions due to the inefficiencies caused by the without-project channel depth constraint. A hub and spoke system using smaller feeder vessels would be unlikely to include Boston Harbor, and would unlikely be established for the US east coast, because direct call with Panamax vessels is a less costly alternative for the carriers.

4.3 Boston Harbor Cargo

In the without-project condition, New England containerized cargo will continue to use both the PONYNJ and Boston Harbor. To the extent that the Panamax vessels calling at Boston Harbor cannot compete on a cost basis with the Post-Panamax vessels calling at the PONYNJ, Boston Harbor may lose some New England cargo to the PONYNJ because carriers may look to place cargo on the most efficient vessels. In addition, Post-Panamax vessels need to operate at a high level of utilization to maintain efficiency. However, the occurrence of Post-Panamax vessels and Panamax vessels on the same trade route exists today, although on different services, and the vessels calling at Boston Harbor are as full as channel conditions allow. Therefore, it is assumed that vessels calling at Boston Harbor under without-project conditions will continue to carry an equivalent volume of cargo, adjusted for the fully maintained -40 foot channel, as they carry under existing conditions.

An updated long-term commodity forecast for Boston Harbor containerized cargo or for New England containerized cargo was not conducted for this analysis because it would bring limited added value to the analysis. Any deepening increment at Boston Harbor would potentially induce shifting some but not all of the number of New England TEUs which would use the PONYNJ, as will be presented in Chapter 6: With-Project Conditions. The total potential number of TEUs shifting to Boston Harbor under alternative with-project conditions for each alternative is substantially less than the 367,000 New England TEUs projected to use the PONYNJ in the base-year of the analysis (2015).[25] Recent containerized commodity forecasts of

[24] Asaf Ashar, "Revolution #4", *Containerization International*, December 2006 (pages 46 – 49).

[25] Note that 255,300 New England TEUs were identified as using the PONYNJ in 2007 based on PIERS data.

the US east coast, such as the forecasts used in the Savannah Harbor Expansion Project[26] and the Bayonne Bridge Air Draft Analysis[27], indicate overall 20-year average annual growth ranging from approximately 3.5% to 7%. Whether projected growth of New England containerized cargo is somewhat more or somewhat less than this range would have no impact on this analysis.

4.4 Boston Harbor Vessel Operations

Under without-project conditions, the liner service carriers calling at Boston Harbor are projected to take advantage of the additional two feet of depth afforded by the completion of the current maintenance dredging project (-38 feet existing to -40 feet at completion of the maintenance project in 2012) in a manner similar to the way carriers took advantage of the additional foot afforded by initiation of the maintenance project (-37 feet in 2007 to -38 feet existing). Table 3-10 indicates that vessels transited the channel in 2010 with consistently deeper drafts than in 2007. In addition, there was a shift to larger vessels between 2007 and 2010 and a greater reliance on the tide. Carriers are projected to continue making use of the tide in the without-project condition in the same manner as under existing conditions (Table 3-11). Carriers are not projected to make use of larger vessels, other than minor shifts within the Panamax class of vessels, because the carriers are already using the largest Panamax vessels in the world fleet.

4.5 Without-Project Conditions Summary

Under without-project conditions, the potential for cargo to shift from the PONYNJ to Boston Harbor identified in Chapter 3: Existing Conditions is projected to persist and would be only slightly relieved by the increase in controlling depth at Boston Harbor from -38 feet to -40, after all maintenance dredging has been completed (2012). Three of the four liner services calling at Boston Harbor under existing conditions are projected to continue calling at Boston Harbor under without-project conditions using the current fleet of large Panamax vessels and small Post-Panamax vessels. There will be a substantial shift to large Post-Panamax vessels (8,000+ TEUs) for services calling at US east coast ports from Asia after the Panama Canal Expansion and deepening of the PONYNJ are completed (2014). Large Post-Panamax vessels will not call at Boston Harbor under without-project conditions; therefore Boston Harbor will not have a direct call service with Asia via the Panama Canal under without-project conditions.

[26] USACE, Savannah District, Draft General Re-Evaluation Report for Savannah Harbor Expansion Project, Nov 2010
[27] USACE, New York District Bayonne Bridge Air Draft Analysis, Sep 2009.

5 Management Measures

Management measures are the general categories of actions which are the basis for alternative plan development. The management measures used in this economic analysis were developed through discussions and interviews with Massport, Conley Terminal operations and management personnel, and Boston Harbor Pilots Association members. Management measures identified to address the navigation-related problems at Boston Harbor include operational (i.e., non-structural) measures, locally implemented structural measures, and structural modification of the Federally authorized channel.

The management measures presented below were assessed for their potential as building blocks of the alternative plans for potential navigation improvements at Boston Harbor. Equal consideration must be given to structural and non-structural measures during the planning process. Management measures are listed below according to the problem they are designed to address and according to whether the measure is structural or non-structural.

1. Management Measure Objective: Reduce light loading and tidal delays

   Non-Structural Measures

   - Time arrivals and departures with optimal tide height
   - Reduce underkeel clearance requirement
   - Increase efficiency of landside operations to decrease turn-around time
   - Use feeder vessels in a hub and spoke system
   - Use smaller vessels

   Structural Measures

   - Deeper channel
   - Increased/Improved landside infrastructure

2. Management Measure Objective: Allow use of larger, more efficient vessels

   Non-Structural Measures

   - Reduce underkeel clearance requirement
   - Increase capability of landside operations to accommodate larger vessels
   - Load vessel so that it fits within channel constraints

   Structural Measures

   - Deeper channel
   - Improve landside infrastructure to accommodate larger vessels

3. Management Measure Objective: Reduce origin to destination transportation costs for New England containerized cargo

Non-Structural Measures

- Reduce underkeel clearance requirement
- Increase efficiency of landside operations to decrease turn-around time
- Use feeder vessels in a hub and spoke system
- Load more New England cargo on existing vessels that call at Boston Harbor
- Add more vessel calls to services already calling at Boston Harbor
- Add Boston Harbor as a port of call

Structural Measures

- Deeper channel
- Increased/Improved landside infrastructure

Three typical ways to increase the TEU throughput at a port would be to increase the number of vessel calls, increase vessel utilization (more TEUs per call), and/or increase vessel size. Each of these measures is evaluated for conditions at Boston Harbor. The evaluation of increasing the number of vessel calls is presented in section 5.1.9 Add More Vessel Calls to Existing Boston Harbor Services and in section 5.1.10 Add Boston Harbor as a Port of Call. The evaluation of increasing vessel utilization is presented in section 5.1.8 Load More New England Cargo on the Vessels that Currently Call at Boston Harbor. The evaluation of increasing vessel size is presented in section 5.1.7 Light Load Larger vessels So They Can Transit the Federal Channel.

5.1 Evaluation of Alternative Non-structural Measures

Each non-structural management measure must be assessed to determine whether it is feasible to recommend the measure for more detailed analysis and potential implementation. If appropriate, non-structural measures are assessed from the perspective of economic rationality.

5.1.1 Reduce Underkeel Clearance Requirement

Reducing the underkeel clearance requirement at Boston Harbor would allow vessels to load more deeply, incur fewer tide delays, and allow some larger vessels to transit the harbor (management measure objectives 1-3). The minimum three feet of underkeel clearance guideline at Boston Harbor is consistent with other deep-water ports in the United States. Specifically, the ports of New York – New Jersey, Delaware River, Norfolk – Hampton Roads, and Los Angeles – Long Beach, which require a minimum of three feet underkeel in their harbors. The recent economic analysis conducted for the Savannah Harbor Expansion Project[28] used a minimum 4-foot underkeel clearance for Panamax vessels. The Federal channel at Boston Harbor has areas of hard substrate and a reduction of the minimum underkeel clearance guideline is not considered consistent with safe vessel operations.

[28] USACE, Savannah District, Draft General Re-Evaluation Report for Savannah Harbor Expansion Project, Nov 2010

It is the pilot's decision whether conditions are adequate for a vessel to transit the river at a given time. The Boston Harbor underkeel guidelines are minimum standards and are not intended to be limiting for pilots, operators, or owners that choose to require a higher degree of safety for their operations. It is also the owners/operators discretion to require that their vessels transit with underkeel clearance in excess of the minimum requirements established by the guidelines. For example, some carriers consider 10% of the vessels' design draft to be a standard rule of thumb for underkeel clearance, which is more than four feet for the largest container ships calling at Boston Harbor.

Vessels that are depth-constrained by the controlling depth of Boston Harbor can achieve the minimum underkeel clearance by timing arrivals and departures with the tide. Boston Harbor has a mean tide range of 9.4 feet. Containerships regularly make some use of the tide when transiting Boston Harbor (Table 3-11). The berths at Conley terminal are dredged to -45 feet to accommodate vessels that use the tide. The pilots operate with real-time channel depth information. There is no additional navigation information or other operational changes that would be sufficient to allow systematic reduction of the underkeel clearance guideline. Therefore, this alternative will not be considered further.

5.1.2 Improve Scheduling of Vessel Arrivals and Departures

If carriers could more effectively schedule vessel arrivals and departures to coincide with favorable tide heights, then vessels could load more deeply while incurring fewer tidal delays (management measure objective 1). Currently vessels either slow steam or wait for tidal advantage. Scheduling arrivals to catch the favorable tide, without incurring costly delays or the costs associated with increased speed, would require the vessels to leave the previous port at the correct time. In order to leave the previous port at the correct time the vessel may either need to leave the port sooner than was planned or sooner than all offloading and loading is completed. It is simply infeasible to regularly schedule vessel calls at Boston Harbor to catch the favorable tide without incurring a cost somewhere else in the schedule, therefore this management measure is not considered further.

5.1.3 Increase Conley Terminal Operations Capacity

As a non-structural measure, modifications to Conley Terminal operations would include improvements to vessel offloading and loading operations. The rationale for this particular nonstructural alternative is that increasing the efficiency of the terminal could potentially decrease the turn-around time for vessels calling at the terminal. Decreased turn-around time could potentially allow vessels to more effectively time their arrivals and departures with the tide thereby allowing vessels to load more deeply while incurring fewer tidal delays (management measure objectives 1 and 2).

Massport has invested $78 million in port efficiency improvements since 2004. These major improvements include upgrade of its container handling equipment, which includes a transition to Rubber Tired Gantry cranes (RTGs), which allows a greater concentration of containers per acre. Conley Terminal currently has added 12 new RTG's and had paved and reorganized the yard for greater efficiency. Conley Terminal has added high density reefer storage racks and has computerized the terminal management system and gate system. In addition, the drive systems on four cranes have been upgraded to improve offloading and loading speed.

Based on the current levels of facility upgrades and expansion and the projected fulfillment of the Master Plan build-out, there are few if any navigation benefits which would result from additional improvements to Conley Terminal. It is unlikely that additional improvements to Conley Terminal would further increase vessel turn-around time to the extent that depth-constrained vessels would have greater opportunities to take advantage of the tides and transit the system more rapidly. Therefore, this non-structural alternative will not receive further consideration.

5.1.4 Use Feeder Vessels in a Hub and Spoke System

A non-structural measure to reduce tide delays and light loading would be for Boston Harbor to become a component of a hub and spoke network that would use small feeder vessels, which would not be subject to channel depth constraints (management measure objective 1). Columbia Coastal Transport ran a feeder service using barges from the PONYNJ to Boston, but business for the feeder service began to diminish once COSCO began direct service with Asia[29], which is consistent with the economic analyses of hub and spoke networks presented in Chapter 4.2: Without Project Conditions Boston Harbor Containership Fleet. The Columbia Coastal feeder service diminished to an unsustainable level before it was abandoned in 2010. Until that time it was surviving on specialty and overweight cargo.[30] A hub and spoke network using containerships as feeder vessels from a large regional port cannot compete economically with Panamax size direct call vessels, as presented in section 4.2. Servicing Boston Harbor with feeder vessels in a hub and spoke network is economically infeasible as long as Panamax vessels are available as a direct call alternative, therefore this measure will not receive further consideration.

5.1.5 Service Boston Harbor with Smaller Vessels

If the fleet calling at Boston Harbor consisted of smaller vessels that were not constrained by the depth of the Federal channel at Boston Harbor, then vessels would not need to light load or experience tide delays (management measure objective 1). In opposition to this non-structural measure the vessels in the fleet calling at Boston Harbor have increased in size since 2007, as presented in Chapter 3.2.1 Existing Condition Vessel Size. This increase in vessel size is concurrent with the industry trend to leverage economies of scale. Smaller, less efficient vessels cannot compete effectively on a service with larger, more efficient vessels. Table 5-1 (repeated from Table 3-12) presents the waterborne transportation costs per TEU per 1,000 miles for Panamax vessels and smaller (operating at service speed), based on the Corps of Engineers vessel operation costs. The table shows the unit cost advantage of Boston Harbor's existing Panamax fleet over smaller vessels.

[29] Columbia Coastal Transport interview 02Sep10
[30] Ibid

Table 5-1
Waterborne Transportation Cost per TEU per 1,000 miles

TEUs	$/TEU
5,060	$33.22
4,800	$33.98
4,000	$36.19
3,500	$38.05
3,000	$40.35
2,800	$41.41
2,500	$43.21

Source: USACE Vessel Operating Costs EGM 11-05

It is unlikely that carriers would scale the size of vessels in their service to the US east coast to avoid light loading and tide delays at Boston Harbor, not only because of the inefficiencies identified in table 5-1, but also because Boston Harbor is the shallowest port on the service. By sizing the fleet to arrive unconstrained at the shallowest port in the service, the carrier would not be able to take advantage of the other deeper ports in the port rotation, such as the PONYNJ (-50 feet), Philadelphia (-45 feet), etc. The inefficiencies associated with using smaller vessels at Boston Harbor would be carried over to each port in the service. These inefficiencies and the fact that carriers are doing the opposite of the action proposed by this measure by deploying larger vessels to Boston Harbor instead of smaller vessels are the reasons why this measure will not receive further consideration.

5.1.6 Coastal Barge Service from PONYNJ to Boston Harbor

One potential non-structural measure would be a coastal barge service, sometimes referred to as Short-Sea Shipping. In this measure, liner service vessels would call at the PONYNJ and load and unload New England cargo as they do under existing and projected without-project conditions. The liner service vessel would not call at Boston Harbor. New England cargo would be shipped from the PONYNJ to Boston Harbor via a barge towed by a tug. After the cargo is barged to Boston Harbor, it would be loaded onto a truck for delivery to its final destination. Columbia Coastal used to run such a service from the PONYNJ to Boston Harbor, but the service was discontinued for lack of cargo. Columbia Coastal does currently run a barge service connecting Norfolk, Baltimore, and Philadelphia, which carries predominantly military cargo.[31]

Although trucking distances are reduced in this measure, the additional costs of loading and unloading cargo and the cost of barge transport makes this alternative economically infeasible. The origin to destination cost using a coastal barge service is greater than the cost of trucking from the PONYNJ and is greater than the cost of sailing directly to Boston Harbor (Table 5-2). The origin to destination cost analysis presented in table 5-2 is based on a one-way liner service voyage from Qingdao, China on a 5,060 TEU capacity vessel. Coastal barge service costs are based on the Container Barge Feeder Service Study, March 2001 prepared by the Connecticut

[31] Personal communication with Jeff Florin, Virginia Port Authority Director of Engineering

Department of Transportation Office of Intermodal Planning. The 2001 costs were escalated to 2011 annual costs using the Bureau of Labor Statistics Producer Price Index.[32]

Table 5-2
Comparative Origin to Destination Costs per TEU: Coastal Barge Service

PONYNJ to RI/Truck		PONYNJ/Barge to Boston Harbor/Truck		Boston Harbor to RI/Truck	
Total Ocean Cost	$1,940,996	Total Ocean Cost	$1,940,996	Total Ocean Cost	$1,981,758
TEUs on board	4,500	TEUs on board	4,500	TEUs on board	4,500
Ocean Cost/TEU	$431	Ocean Cost/TEU	$431	Ocean Cost/TEU	$440
PONYNJ Fees	$115	PONYNJ Fees	$115	Boston Harbor Fees	$21
Trucking Cost	$744	Tug/Barge Costs	$190	Trucking Cost	$363
Total Transport Cost	**$1,291**	Barge Load/unload	$240	**Total Transport Cost**	**$825**
		Port Space	$82		
		Boston Harbor Fees	$21		
		Trucking Cost	$363		
		Total Transport Cost	**$1,442**		

5.1.7 Light Load Larger Vessels So They Can Transit the Federal Channel

As a non-structural measure, carriers could deploy larger, more efficient vessels to Boston Harbor but load them so that are able to transit the channel in the same manner that the existing fleet is light loaded and uses tidal advantage. In some ways, this measure has already been initiated by the carriers because they have recently upgraded the size of their vessels calling at Boston Harbor to include the largest Panamax vessels in the world fleet. An additional upgrade in vessel size, without allowing the vessel to sail at a deeper draft would increase the waterborne transportation cost per box and reduce overall efficiency.

[32] Producer Price Index industry data: Series ID PCU4831134831133; Industry: Coastal and Great Lakes Transport; Product: Coastal and Inter-coastal Towing Transportation

Table 5-3
Comparative Unit Costs at an Operating Draft of 40 feet

Vessel	TEU Capacity	Operating Draft	TEUs at 40 feet	$/TEU/1000 miles @ 40 feet draft
MSC Nerissa	5,060	40	3,980	$42.36
MSC Shanghai	5,900	40	3,776	$48.74
MSC Alessia	6,732	40	4,544	$44.82
COSCO Seattle	7,455	40	5,077	$42.54

Note: Analysis conducted at TEU weight (cargo and box) of 10.35 tons and at service speeds

Table 5-3 presents an analysis of waterborne transportation costs per TEU for vessels sailing at a draft of 40 feet, which would require three feet of tidal advantage and a 2.9 hour delay on average. The MSC Nerissa is in the existing fleet calling at Boston Harbor and is among the largest Panamax vessels in the world. The table displays the inefficiencies of bringing Post-Panamax vessels to Boston Harbor at the without-project controlling depth of -40 feet. Currently there are no large Post-Panamax vessels calling at any US east coast port that has a controlling depth of less than -42 feet.

The inefficiencies associated with light loading Post-Panamax vessels so that they can use the federal channel at Boston Harbor are exacerbated by the impacts to vessel loading in or out of the PONYNJ (-50 feet), which would be either the next or preceding port. Under existing conditions, some of the five-foot depth differential between the two ports is mitigated by using the tide at Boston Harbor. Vessels use as much as four feet of tidal advantage at Boston Harbor. Under without-project conditions the depth differential will be 10 feet, which is far more than can be effectively mitigated by using the tide at Boston Harbor. The large inefficiencies which would result from this non-structural alternative cause the use of larger vessels under without-project channel conditions to be excluded from further consideration.

5.1.8 Load More New England Cargo on the Vessels that Currently Call at Boston Harbor

A potential non-structural solution that would provide for more New England cargo to use Boston Harbor (management measure objective 3) would be for vessels in the existing fleet to simply load more Boston Harbor cargo. The carriers have stated that the cargo is available[33] and the shipper survey indicates that cargo is available.

The data show that vessels calling at Boston Harbor in 2007 and 2010 are loaded as fully as conditions allow. This is evidenced by the frequent and extensive use of tide by nearly all vessels calling at Boston Harbor (Tables 3-10 and 3-11). This interpretation of the data is corroborated by the carrier's statement that the vessels are already full and at operating at the maximum drafts for channel conditions.[34] The current allocation for Boston Harbor has been negotiated with alliance members, service partners, and slot sharing partners. Slot allocations are certainly flexible, but the carriers are not interested in trading-off a slot with PONYNJ cargo for

[33] MSC interview 2010
[34] MSC interview 2007; Maersk interview 2010; CMA CGM interview 2010

a slot with Boston Harbor cargo.[35] This unwillingness to trade off PONYNJ cargo for Boston Harbor cargo was cited as a reason for not calling at Boston Harbor[36]. If the PONYNJ slot were empty, then it would be reasonable to expect that the carrier would look to fill that empty slot with Boston Harbor cargo, but the PONYNJ slot is full. There would be no net increase in cargo to the carrier by displacing PONYNJ cargo with Boston Harbor cargo.

The carriers are operating in a manner that attempts to keeps the vessels as full as conditions allow, which allows the carriers to take advantage of economies of scale. Displacing PONYNJ cargo with Boston Harbor cargo on a vessel that is already full does not increase vessel efficiency. The proportion of Boston Harbor cargo on the vessel has been stable from 2007 to 2010, although each service has seen a small decrease, which is to be expected in a comparison between the port's highest volume year and current recession conditions. The slot allocation for Boston Harbor and the number of TEUs per call have been stables from 2007 to 2010, considering recessionary conditions in 2010. These allocations and TEUs per call are projected to continue into the future and reallocating more slots to Boston Harbor by displacing slots from the PONYNJ is not considered a viable non-structural solution.

5.1.9 Add More Vessel Calls to Existing Boston Harbor Services

Additional New England TEUs could be handled at Boston Harbor (management measure objective 3) if carriers increased the number of vessel calls on existing Boston Harbor services. The services currently calling at Boston Harbor are liner services providing weekly fixed day service. This is the industry standard. Carriers select the number of vessels for a liner service to provide weekly same-day service. Services with longer distances and transit times will have more vessels than services with shorter distances and less transit time. This can be observed by comparing COSCO's Asia service (63 days round trip; 9 vessels; Boston scheduled for Thursday) to MSC's Europe service (35 days round trip; 5 vessels; Boston scheduled for Tuesday). Liner service schedules are not designed to accommodate additional off-day vessel calls because they are purposefully designed to provide regular, predictable, and reliable service. Furthermore, liner services operate with a string of ports in rotation, so adding additional calls to Boston Harbor would require adding additional calls to the other ports on the rotation also. Accelerating the frequency of port calls on a liner service to more than weekly (six-day or five-day for example) is not the standard operating practice for the industry. Typically, carriers increase their service at a port by increasing vessel size and not by adding additional calls on an existing service; therefore this non-structural solution will not be considered further.

5.1.10 Add Boston Harbor As a Port of Call

One non-structural solution that would bring additional New England TEUs to Boston Harbor (management measure objective 3) would be for services that currently call at the PONYNJ, but not Boston Harbor, to include Boston Harbor in the port rotation. In order to add a port to the rotation another port must be dropped so that the weekly schedule can be maintained at the other ports on the service or the service must be reconfigured. For example, COSCO's Asia service was reconfigured in 2010 to include a vessel call in Mexico (Lazaro Cardenas) and a vessel call in Panama (Cristobal). Adding these ports increased the transit time for the service from 56 days

[35] MSC interview 2010; Evergreen interview 2010
[36] Maersk interview 2010

to 63 days, so the number of vessels was increased from 8 to 9 to maintain weekly same-day service.

The carrier interviews conducted for this analysis include four carriers[37] that do not currently call at Boston Harbor (two of the four have called at Boston Harbor in the past). Each carrier representative stated that there was sufficient cargo to justify calling at Boston Harbor, but each carrier representative also mentioned that a -40 foot channel was a substantial constraint and disincentive. The influence of the PONYNJ was also consistently mentioned. One carrier representative put it clearly:

> *Boston cargo is already established. Boston Harbor has the population density to establish a cargo base. Boston could also potentially develop some distribution centers that would pull cargo from PONYNJ. Boston already has major importers and a strong population base. Boston also has the benefit of proximity to Canada. However, at existing channel depth Boston is mostly a "substitute service port" meaning that even though the Bill of Lading says Boston, the marine carrier will drop the box off in PONYNJ and let it get trucked or barged the rest of the way.*[38]

The great amount of cargo that goes through the PONYNJ (4 to 5 million TEUs each year since 2003) is what brings liner services to the northern US east coast. It would be inconceivable for a carrier to drop the PONYNJ so that Boston Harbor could be added to the port rotation. For an existing service to be reconfigured to include Boston Harbor, that service would also necessarily include the PONYNJ because the PONYNJ has the demand for service and the depth to allow efficient vessel utilization. The carrier that considers New England to be within the PONYNJ hinterland and that is already servicing New England through the PONYNJ, and that has an unfavorable view of Boston Harbor's depth constraint would be an unlikely candidate for adding Boston Harbor as a port of call.

For each of the four carrier representatives interviewed, acknowledgement of sufficient cargo to justify a call at Boston Harbor is not enough incentive to overcome the disincentive of Boston Harbor's depth constraint and the "substitute service" availability of the PONYNJ. These conditions are projected to persist into the future and to become more intractable as the Panama Canal expansion and deepening of the PONYNJ induces larger vessels and existing vessels more deeply loaded to use the PONYNJ. This non-structural solution is unlikely to be effective and is not given further consideration.

5.2 Evaluation of Alternative Structural Measures

Structural measures would include engineered solutions that achieve the management measure objectives. Structural measures include improvements to Conley Terminal infrastructure and improvements to the Federal channel at Boston Harbor.

5.2.1 Conley Terminal Infrastructure Improvements

Improvements to Conley Terminal infrastructure would increase productivity and throughput capacity. Increases in productivity and throughput capacity could conceivably reduce tide delay

[37] Evergreen, OOCL (Grand Alliance), CMA CGM, and Maersk
[38] Evergreen Interview 10Aug10

if vessels could be turned around more quickly, allow larger more efficient vessels to use the terminal, and reduce origin to destination transportation costs by allowing larger vessels to use the terminal (management measure objectives 1-3).

Like many other container ship terminals on the US east coast, Conley Terminal has been engaged in a long-term capital improvement program for the purpose of maintaining competitive productivity levels and to keep pace with the trend of increased vessel size. Since 2004, Massport has spent $78 million on capital improvements at Conley Terminal[39]. The terminal has increased capacity and productivity with the purchase of two additional Post-Panamax cranes to make a total of four Post-Panamax cranes with a reach of 16 containers across. The terminal's two Panamax cranes and existing Post-Panamax cranes have had drive-system upgrades to increase operating speed and productivity.

Terminal operations have switched to rubber tire gantries, which allow for higher density yard use and faster operations. A new rack system has been constructed for higher density reefer storage. Berths have been dredged to -45 feet to accommodate vessels using the tide. Most importantly, 30 acres of adjacent land has been added to the terminal. This acreage is accessible by Post-Panamax vessels. Servicing Post-Panamax vessels in this location avoids the air-draft constraints posed by proximity to Logan Airport, which would restrict crane operation and vessel loading. This constraint on Post-Panamax vessel operations had been identified by the carriers,[40] but is now resolved.

Overall, Conley Terminal's annual throughput capacity will be approximately 500,000 TEUs, which is more than double the terminal's busiest year (220,000 TEUs in 2007; Table 1-2). The recent improvements made to the terminal have increased productivity and capacity. Foreseeable future infrastructure improvements may result in marginal increases in productivity and capacity, but any opportunities for substantial improvements that would affect vessel operations and further support management measure objectives 1 – 3 have already been realized. It is unlikely that additional infrastructure improvements at Conley Terminal would effectively enhance project objectives; therefore, this structural measure will not receive further consideration.

5.2.2 Federal Channel Deepening

The without-project condition controlling depth (-40 feet) will be a constraint to efficient navigation of the without-project fleet projected to call at Boston Harbor as presented in Chapter 4: Without-Project Conditions. The without-project condition controlling depth constraint also precludes Post-Panamax vessels from using Conley Terminal. Increasing the Federal channel controlling depth by deepening the channel would reduce tide delay for vessels constrained by the without-project condition controlling depth, allow vessels to load more deeply, and reduce origin to destination transportation costs by having larger, more efficient vessels use Boston Harbor (management measure objectives 1-3). Channel deepening will be considered for detailed incremental analysis.

[39] Source: personal communication with Nick Billows, Massport Deputy Director Port Sales and Marketing
[40] COSCO Interview 31Aug10

5.3 Description of Alternative Plans

5.3.1 No Action

In this plan, no improvements would be made to the existing Boston Harbor Federal Navigation Project. This is equivalent to the without-project condition. The navigation channel would remain at its presently authorized 40-foot depth. This plan will serve as the basis for comparison of the expected project benefits. It will comprise the economic conditions that are projected to occur over the 50-year period of analysis. The analysis will include an assessment of the origin to destination transportation costs for New England containerized cargo using Boston Harbor if no harbor improvements are implemented. The size and number of vessels that will transport those commodities through the harbor will be identified.

5.3.2 Channel Deepening Alternatives

This plan will include several levels of harbor deepening so that an incremental analysis of economic benefits can be performed. The plan will include several scales, with the benefits of channel deepening evaluated at one-foot depth increments ranging from -42 feet to -50 feet.

6 With-Project Conditions

Under with-project conditions (alternative channel depths) carriers are projected to take advantage of the additional depth afforded by the deepened channel by operating at deeper drafts and by bringing larger vessels to Boston Harbor. By operating at deeper drafts and with larger vessels at Boston Harbor the carriers will be able to present shippers with more opportunities to ship New England cargo through Boston Harbor instead of shipping through the PONYNJ. Shippers are projected to take advantage of the opportunity to ship more New England cargo through Boston Harbor, thereby shifting some New England TEUs from using the PONYNJ in the without-project condition to using Boston Harbor in the with-project condition. The projection that shippers will take advantage of additional opportunities to ship through Boston Harbor is supported by the shipper survey, which was conducted as a component of the "Framework for Additional Economic Analysis" (revised final 06Aug09), which was developed by the New England District, North Atlantic Division, OWPR, and the Institute for Water Resources to support the analysis of containerized cargo benefits..

Only TEUs with sufficient supporting information were considered as potentially able to shift from the PONYNJ to Boston Harbor under with-project conditions. That supporting information includes information from the PIERS data and the survey responses. In 2007, there were 255,256 New England TEUs moved through the PONYNJ, of which 73,885 TEUs were from areas of Connecticut, which are closer to the PONYNJ than to Boston Harbor and 181,371 TEUs which were closer to Boston Harbor (255,256 – 73,885 = 181,371). Therefore the ultimate upper limit of TEUs in 2007, which could potentially shift from the PONYNJ to Boston Harbor, is 181,371. The shipper survey created 95% confidence intervals around the lower limit and upper limit of TEUs which could potentially shift to Boston Harbor, based on responses to eight sets of questions. Survey results indicate that the lower limit of TEUs, which could potentially shift from the PONYNJ to Boston Harbor, is 131,049 and the corresponding upper limit is 173,148. The survey-based upper limit (173,148) is less than the ultimate upper limit of New England TEUs, which are loser to Boston Harbor (181,371).

The mid-range value between the lower and upper limits of the survey results, based on 2007 conditions, is 152,488 New England TEUs which may be available to shift to Boston Harbor. This mid-range value increases to 219,356 TEUs by the base year (2015) assuming the 20-year (1999 – 2009) historical annual growth rate (4.65%) for TEUs at US container ports continues into the future. The mid-range value is the preferred benchmark for the analysis. These survey results only inform the analysis and are not sufficient to suggest a decision to switch from the PONYNJ to Boston Harbor. The decision to switch is based on an economically rational response to reduced origin to destination transportation costs.

6.1 With-Project New England Cargo

The amount of New England containerized cargo is not affected by without-project or with-project conditions. Similarly, the characteristics of New England cargo are not affected by without-project or with-project conditions. This analysis assumes that the amount and characteristics of New England containerized cargo under with-project conditions will be consistent with observations made in 2007. Under this assumption there are no substantial differences between New England containerized cargo domestic origins and destinations observed in the 2007 PIERS data and projected future New England containerized cargo

domestic origins and destinations. Cargo volumes observed in 2007 are projected out to the base-year (2015) using the historical 20-year (1989 – 2009) growth rate (4.65%) of container traffic at US ports.

The analysis conducted on the Shipper Survey responses estimated the mid-point of the range of New England TEUs that could potentially shift from the PONYNJ to Boston Harbor to be 152,488 TEUs at 2007 trade levels (Appendix A: Assessment of Existing Conditions). By the base-year (2015), this estimate increases to 219,356 TEUs, using the historical 20-year (1989 – 2009) growth rate (4.65%) of container traffic at US ports. The base-year "mid-range available to shift" estimate should also include the 87,333 Asia Panama service TEUs that are projected to shift back to the PONYNJ under without-project conditions, which increases the "mid-range available to shift" estimate to 306,689 TEUs by 2015 (Table 6-1).

Table 6-1
Range of New England TEUs Potentially Available to Shift from the PONYNJ to Boston Harbor

	Lower Limit	Mid-Point	Upper Limit
Survey Results (2007)*	131,049	152,488	173,148
Survey Results with growth to 2015 (4.65% annual growth rate)	188,516	219,356	249,076
Return of Asia Service via Panama in 2015	87,333	87,333	87,333
Total Available to Shift in 2015	275,849	306,689	336,409

*See Boston Harbor Container Benefits Appendix A 20April12, section 7: Estimation of TEUs Available to Shift From the PONYNJ to Boston Harbor

It is also important to consider that distribution centers located near the PONYNJ under without-project conditions may shift to locations nearer to Boston Harbor under with-project conditions, or new distribution centers may locate closer to Boston Harbor under with-project conditions. Distribution centers are neither prohibitively expensive, nor difficult to construct. As an example, in 2009 and 2010, at least four new distribution centers have been developed near Savannah Harbor ranging from 192,000 square feet (Dayton Superior) to 800,000 square feet (Gildan Activewear). Distribution center development costs ranged from $12.5 million (Le Creuset) to $20 million (Gildan Activewear). A $20 million investment with repayment over ten years at 6% interest would cost approximately $2.7 million per year, which is the equivalent of the landside transportation cost savings for fewer than 7,000 TEUs or 10 forty-foot trailers per day. This simple example indicates that landside transportation cost savings generate a substantial incentive for the placement of distribution centers at the port nearest to the hinterland.

6.2 With-Project Boston Harbor Fleet

The size of containerships in the fleet calling at Boston Harbor under with-project conditions are projected to be consistent with vessel sizes in the overall fleet calling at other major US east coast ports. These vessels will be Panamax and Post-Panamax vessels. Channel deepening at

Boston Harbor will not affect the size of vessels calling at the US east coast, but channel deepening will affect the size of vessels calling at Boston Harbor.

The base case with–project condition scenario includes Panamax and Post-Panamax vessels calling at Boston Harbor. The design vessels used to determine with-project channel dimensions and to estimate incremental project costs include the COSCO Hamburg (5,600 TEUs, maximum draft 45.9 feet, LOA 918 feet), the MSC Alessia (6,700 TEUs, maximum draft 47.6 feet, LOA 984 feet), and the COSCO Yokohama (7,500 TEUs, maximum draft 46.0 feet, LOA 1,050 feet).

The projected future with-project fleet at Boston Harbor includes:

- Mediterranean Service: Panamax vessels (4,900 - 5,060 TEUs; maximum draft 44 feet) similar in size to vessels in the existing condition fleet, with a transition to 6,700 TEU vessels (maximum draft 48 feet) at depths of -42 feet and deeper;
- Europe Service: Panamax vessels (5,060 TEUs; maximum draft 44 feet) similar in size to vessels in the existing condition fleet; and
- Asia Panama Service: No calls at Boston Harbor at depths less than -45 feet. At controlling depths of -45 feet and deeper, Boston will be added as a port-of-call for 8,500 TEU vessels; and
- Asia Suez Service: No calls at Boston Harbor at depths less than -45 feet. Boston may be added as a port-of-call for 8,500 TEU vessels at controlling depths of -45 feet and deeper, but because this service had been suspended under existing conditions it is included in with-project conditions as an alternative to the base-case, which excludes the Asia Suez service.

Large Post-Panamax vessels, which will not call at Boston Harbor under without-project conditions, are projected to call at Boston Harbor at controlling depths of -45 feet and deeper[41]. A controlling depth of -45 feet at Boston Harbor creates a five-foot depth differential with the PONYNJ that is equivalent to existing conditions. At this depth differential, vessel loading at the PONYNJ would not be severely impacted provided vessels continue to use tidal advantage at Boston Harbor in a manner similar to existing conditions.

The relatively small number of TEUs handled annually at Conley Terminal (187,000 in 2009)[42] is not projected to impact a carrier's decision to deploy Post-Panamax vessels to Boston Harbor. Indeed, the COSCO Asia Suez service called at Boston Harbor from May through December 2011 using vessels ranging from 5,500 TEUs to 6,100 TEUs. Currently two other services deploy Post-Panamax vessels - the Green Alliance's AWE4 (5,600 TEU vessels) and the Grand Alliance's AEX (5,300 – 5,900 TEUs) - through the Suez Canal to the east coast of North America, calling at Halifax, Nova Scotia and the PONYNJ. Halifax (347,000 TEUs in 2009[43]) is a considerably smaller volume port than the PONYNJ. The relatively small volume at Halifax has not stopped Post-Panamax vessels from being successfully deployed there. In the interviews with the carriers, each of the seven liner service carrier representatives indicated that Boston Harbor, with adequate channel depth (depths cited ranged from 45 to 50 feet), would be serviced by Post-Panamax vessels. Not one of the carrier representatives indicated that the total volume of TEUs handled at a port was a consideration in the deployment of Post-Panamax vessels.

[41] Sensitivity analyses were conducted using different size Post-Panamax vessels and without Post-Panamax vessels
[42] Table 1-2
[43] Containerization International website accessed 09Dec10 (www.ci-online.uk.com)

6.3 With-Project Vessel Operations

Under with-project conditions, the Europe and Mediterranean service vessels are projected to operate at Boston Harbor with the same distribution of tidal advantage and willingness to wait for the tide observed in 2010 (Table 3-11). For example, in 2010 two MSC vessels on the Europe route (Table 3-11) were observed arriving at Boston Harbor with an operating draft of 43 feet (rounded upwards). These vessels waited slightly more than 5 hours to use 8 feet of tide to gain 5 feet of additional operating draft while maintaining 3 feet of underkeel clearance. The few vessel calls in 2010 (9%) that did not take advantage of the tide are not projected to take advantage of a deeper channel in the with-project condition – they are removed from any benefits calculations. Incremental increases in Boston Harbor TEUs under with-project conditions are based only on vessel calls that used the tide in 2010.

As the channel is deepened, vessels are projected to load more deeply to take advantage of the additional depth while maintaining or reducing the observed use of tide. Again as an example, the two MSC vessels that were willing to wait 5 hours to arrive with a draft of 43 could, if the channel were deepened one foot, be able to arrive with a draft of 44 feet and incur the same wait time of 5 hours. With-project vessel operations are based on the assumption that carriers will respond to incremental channel deepening by loading vessels more deeply, thereby moving more cargo while incurring an equal or less wait time for tidal advantage. Table 6-2 provides a detailed example.

Table 6-2
Channel Depth and Tidal Advantage Example

Observed 2010 (Table 3-11)			One Foot of Additional Channel Depth		
Sail Draft	Wait Time (hrs)	# of Calls	Sail Draft	Wait Time (hrs)	# of Calls
40	3.69	19	41	3.69	19
41	4.09	22	42	4.09	22
42	4.54	12	43	4.54	12
43	5.05	2	44	5.05	2

In 2010, 55 vessel calls were observed as willing to wait 3.69 hours or more for tidal advantage at Boston Harbor (Table 6-2 and Table 3-11). Those 55 vessel calls were distributed among sailing drafts ranging from 40 feet to 43 feet as presented in the left-hand side of Table 6-2 and in Table 3-11. With an additional one foot of channel depth, those 55 vessels calls could maintain the same tide delay tolerance and load one foot deeper (right hand side of Table 6-2). If, for example, the maximum sailing draft of these vessels was 43 feet, then with an additional foot of channel depth there could be 14 vessels sailing with a draft of 43 feet and two of those vessels would have a tide delay reduction (from 5.05 hours to 4.54 hours). In order for vessels to take advantage of a deeper channel two conditions must be met: there must be cargo available to load the vessel more deeply and the vessel must have available sailing draft – no vessel is projected to load deeper than its design draft.

Large Post-Panamax vessels (8,500 TEU) projected for the COSCO Asia Panama and COSCO Asia Suez services do not have a history of deployment to Boston Harbor and therefore observed

behavior at Boston Harbor by Panamax vessels was used to estimate future vessel operating drafts. In a sensitivity analysis (Sensitivity Analysis 9) projected with-project vessel operations for large Post-Panamax vessels at Boston Harbor are based on observed 2010 operating drafts for similar size vessels arriving at the Port of Oakland on the China Shipping Container line (CSCL) AAC service which calls at Hong Kong, Guangzhou, Yantian, Shanghai, Ningbo, Busan, Los Angeles, and Oakland. The controlling depths at the ports on this service are similar to the Asia Panama and Asia Suez services. Also, Oakland is in a position in the port rotation similar to Boston Harbor's prospective position. The vessels on this service are 8,500 TEU vessels (maximum draft 48 feet), similar to the vessels projected to call at Boston Harbor. In 2010, the Port of Oakland had a controlling depth of 50 feet, so the observed Oakland draft distribution requires vessels to wait for the tide at shallower with-project Boston Harbor depths.

Vessels are projected to carry the same proportion of Boston Harbor TEUs relative to the vessel's capacity as observed in 2010[44]. The analysis assumes that carriers will use the reduced draft constraint at Boston Harbor as an opportunity to also load additional cargo for ports other than Boston Harbor. This cargo transits the Federal channel at Boston Harbor but is not handled at Conley Terminal. There are no benefits calculated for these TEUs.

6.4 With-Project Boston Harbor TEU Projections

Table 6-1 presented the number of New England TEUs, which may potentially shift from the PONYNJ to Boston Harbor under with-project conditions. The number of TEUs projected to shift under with-project conditions is based on the additional Boston Harbor cargo loaded on to vessels at each increment of additional channel depth at Boston Harbor. Additional channel depth increments allow vessels to load more deeply, with some proportion of that cargo (based on the TEUs per call identified in Table 3-9) allocated to Boston Harbor. The additional cargo that would be loaded onto vessels for channel depth increments from the existing condition (-38 feet) to the without-project condition (-40 feet) were calculated in the same manner as with-project condition cargo and has been included in the without-project condition. The base case with-project condition Boston Harbor TEU projections at incremental depths are presented in Table 6-3. Note that the total number of TEUs presented below excludes TEUs on four Europe service vessel calls (two in-bound and two out-bound) and eight Mediterranean service vessel calls (four in-bound and four out-bound), which did not use the full controlling depth available in 2010 and therefore are excluded from the benefits analysis. The average number of export empty TEUs are included in the vessel operating draft calculations (historically there are no import empty containers) at a weight of 2.2 tons per empty container.

[44] Sensitivity analyses were conducted using 2007 observed TEUs per call.

Table 6-3
Base Case: With-Project Condition TEU Volumes

Depth	Europe	Mediterranean	Asia	Total	Increment
40*	42,526	20,072	-	62,598	
41	46,837	21,127	-	67,965	5,367
42	49,967	26,608	-	76,574	8,610
43	52,825	27,853	-	80,678	4,104
44	54,636	28,962	-	83,598	2,920
45	56,112	29,907	170,927	256,946	173,348
46	57,321	30,647	179,525	267,492	10,546
47	58,097	31,102	186,062	275,261	7,769
48	58,509	31,307	190,034	279,850	4,589
49	58,725	31,485	191,074	281,284	1,435
50	58,784	31,568	191,074	281,427	143
51	58,784	31,568	191,074	281,427	-
*Without Project Condition				**Total Additional With-Project TEUs**	**218,829**
				Total Additional With-Project TEUs less 87,333 returning on Panama Canal service	**131,496**

The number of New England TEUs projected to shift from the PONYNJ (Table 6-3: 218,829 TEUs at a channel depth of -50 feet), which includes 87,333 TEUs projected to return to Boston Harbor, is far less than the mid-point range estimate of 306,689 TEUs and less even than the lower limit estimate of 275,849 TEUs available to shift in 2015 (Table 6-1). Base-case projections of shifting TEUs due to channel deepening (Table 6-3) are substantially less than the number of TEUs which are estimated to be available to shift in 2015 (Table 6-1). Table 6-3 and all subsequent presentation of Total and Incremental TEUs are loaded TEUs only. The total number of TEUs, which is in part based on 2010 observations, reflects some diminishment of export TEUs during the 2010 economic recession.

A sensitivity analysis was performed to identify the importance using large Post-Panamax vessels on the Asian services in the with-project condition. Under base case with-project conditions, large Post-Panamax vessels are projected to call at Boston Harbor at controlling

depths of -45 feet and deeper. In the analysis without large Post-Panamax vessels on the Asian service, the vessels on these services are the same as existing 2011 conditions: Panamax vessel on the Asia Panama service. In this sensitivity analysis large Post-Panamax vessels do not enter the Asian services at any channel depth. Table 6-4 presents the "No Large Post-Panamax" sensitivity analysis. The sensitivity analysis indicates that at depths through -45 feet Panamax vessels provide the equivalent of 75% of the TEUs provided by Post-Panamax vessels. At depths deeper than -45 feet Panamax vessels are achieving their draft limitations at a faster rate than Post-Panamax vessels and contribute considerably fewer TEUs.

Table 6-4
No Post-Panamax on Asia Panama Service Sensitivity Analysis TEU Volumes

Depth	Europe	Mediterranean	Asia Panama	Total	Increment
40*	42,526	20,072	87,333	149,931	
41	46,837	21,127	94,371	162,336	12,405
42	49,967	26,608	101,185	177,759	15,423
43	52,825	27,853	106,955	187,633	9,874
44	54,636	28,962	111,244	194,841	7,208
45	56,112	29,907	113,378	199,396	4,555
46	57,321	30,647	113,816	201,783	2,387
47	58,097	31,102	113,816	203,014	1,231
48	58,509	31,307	113,816	203,631	617
49	58,725	31,485	113,816	204,026	395
50	58,784	31,568	113,816	204,169	143
51	58,784	31,568	113,816	204,169	-
*Without Project Condition			**Total Additional With-Project TEUs**		**54,238**

An analysis was also conducted that included an Asia Suez service, which would call at Boston Harbor at channel depth of -45 feet and deeper. This service is projected to bring an additional 152,533 TEUs through Boston Harbor at a channel depth of -49 feet. However, in the base year (2015) the total number of shifted TEUs (Table 6-5; 371,362), would be greater than than the mid-range number of TEUs estimated to be available to shift (306,689) to Boston Harbor in 2015

(Table 6-1). This analysis uses the mid-range number of TEUs as the constraint on the number of TEUs that would shift to Boston Harbor; therefore only a portion of the full potential of Asia Suez service TEUs (152,533 TEUs) would be available to shift in 2015.

Table 6-5
With-Project Condition TEU Volumes including an Asia Suez Service

Depth	Europe	Mediterranean	Asia via Panama Canal	Asia via Suez Canal	Total	Increment
40*	42,526	20,072	-		62,598	
41	46,837	21,127	-		67,965	5,367
42	49,967	26,608	-		76,574	8,610
43	52,825	27,853	-		80,678	4,104
44	54,636	28,962	-		83,598	2,920
45	56,112	29,907	170,927	136,450	393,395	309,798
46	57,321	30,647	179,525	143,313	410,805	17,410
47	58,097	31,102	186,062	148,532	423,793	12,987
48	58,509	31,307	190,034	151,703	431,552	7,760
49	58,725	31,485	191,074	152,533	433,817	2,265
50	58,784	31,568	191,074	152,533	433,960	143
51	58,784	31,568	191,074	152,533	433,960	-
*****Without Project Condition				**Total Additional With-Project TEUs**		**371,362**

Although growth in the number of shifting TEUs after 2015 is not used in the base-case scenario, or in any of the other sensitivity analyses, projected growth in the mid-range number of TEUs available to shift to Boston Harbor would allow the Asia Suez service to increase the number of Boston Harbor TEUs in future years. The mid-range number of TEUs available to shift from the PONYNJ to Boston Harbor is assumed to grow at a rate of 4.65%, which indicates that the full amount of shifted TEUs for the Asia Suez service identified in Table 6-5 (152, 533) would not be achieved until 2026. Table 6-6 shows the projected growth of Asia Suez service cargo from 2015 through 2026.

Table 6-6
Asia Suez Service by Year 2015 - 2026

Year	Mid-Range Available TEUs	Asia Suez Service TEUs
2015	306,356	24,929
2016	316,556	35,129
2017	327,230	45,803
2018	338,401	56,974
2019	350,091	68,664
2020	362,325	80,898
2021	375,128	93,701
2022	388,526	107,099
2023	402,547	121,119
2024	417,219	135,792
2025	432,575	151,148
2026	448,644	152,533*

*Full Asia Suez service Boston Harbor projection

7 Transportation Cost Savings

Transportation costs include all origin to destination costs. Transportation cost savings are defined as the difference in total origin to destination costs between the without-project and with-project conditions. There are three categories of transportation costs that may be affected by alternative channel depths at Boston Harbor: landside transportation costs; waterborne vessel operating costs, and in-port vessel operating costs.

Landside transportation costs, which are affected by the switch of some cargo from the PONYNJ to Boston Harbor, are calculated as trucking costs per TEU in Chapter 7.1 Trucking Costs. Rail transport costs are not included in the calculation of landside transportation costs because the distances New England cargo travels between either the PONYNJ or Boston Harbor are typically far shorter than the distances where rail transport is the lower cost alternative to truck transport.

Waterborne transportation costs are only marginally affected by alternative depths at Boston Harbor. New England cargo that switches from the PONYNJ to Boston Harbor travels an additional 386 nautical miles between the PONYNJ and Boston Harbor[45], which takes approximately an additional 15.5 hours[46]. This additional waterborne transportation cost is included in the transportation cost savings calculations as a minor offset to overall transportation cost savings. Waterborne transportation costs are also marginally affected by differences in the time the Boston Harbor fleet must wait for appropriate tide heights at alternative channel depths. The costs of waiting for the tide are also included as a minor offset to overall transportation cost savings.

In-port vessel operating costs are based on the time the vessel spends in port, which is determined by the number of TEUs offloaded and loaded onto the vessel. The total number of import and export New England TEUs in not affected by alternative channel depths at Boston Harbor. Only the port where the TEUs are handled is changing; therefore there is no difference in the time the vessel spends in port and no change in in-port vessel operating costs. This analysis assumes that each port (PONYNJ and Boston Harbor) offloads and loads TEUs at the same rate.

7.1 Summary of Assumptions

The major underlying assumption supporting with-project transportation costs savings is that carriers would call at Boston Harbor and load vessels more deeply if additional channel depth were available. Under with-project conditions, some of the additional cargo on the more deeply loaded vessels at Boston Harbor would be New England cargo, which would use the PONYNJ under without-project conditions. The availability of cargo to shift from the PONYNJ to Boston Harbor is a critical assumption for with-project transportation cost savings. The assumption that cargo would shift if vessels could load more deeply at Boston Harbor is supported by three major observations:

1. Vessels calling at Boston Harbor are currently loaded to take full advantage of existing channel depth and are using extensive tidal advantage (Table 3-11);

[45] US Department of Commerce, NOAA, Distances Between US Ports 2009 edition
[46] Based on the average service speed of vessels ranging from 4,800 to 8,000 as identified in the USACE Vessel Operating Costs spreadsheet

2. The few vessel calls (12), which did not take advantage of the tide in 2010 (Table 3-11) have been removed from the analysis and are not included in future projections or transportation cost savings calculations;
3. The shipper survey indicates that there is a substantial amount of New England cargo available to shift from the PONYNJ to Boston Harbor (Table 6-1); and
4. There are substantial transportation cost savings available to the shipper, due to reduced landside trucking costs, if New England cargo were to use Boston Harbor instead of the PONYNJ (Table 7-4).

Carriers are assumed to have the same tolerance for tide delays under without-project conditions and with-project conditions as observed in 2010. This assumption means that carriers will load more deeply under with-project conditions as long as they have the same or less need for tidal advantage that was observed in 2010. As channel depth increases under with-project conditions, larger vessels enter the fleet calling at Boston Harbor. At a channel depth of -42 feet, 6,700 TEU vessels enter the European and Mediterranean services. Vessels of this size periodically call at Boston Harbor on these services in 2012 and regularly call at Savannah, which currently has a controlling depth of -42 feet. At a channel depth of -45 feet, the COSCO Asia service via the Panama Canal is projected to return to Boston Harbor with a fleet consisting of 8,500 TEU vessels.

Operating drafts at Boston Harbor are based on observed import and export cargo weight, the number of loaded and empty boxes per call, channel depth, tide delay tolerance, and the vessel design draft. In order to avoid projecting that vessels will operate fully loaded at their design draft, the transportation cost savings model constrains all vessels to sail at no more than 98% of their design draft. For example, the COSCO Japan, which has a design draft of 47.6 feet (rounded to 48 feet), is constrained to a maximum operating draft of 46.7 feet (rounded to 47 feet). Based on these vessel operating assumptions, the transportation cost savings model identifies vessels as fully loaded, including empty containers, ranging from 85% to 95% of their TEU capacity.

Table 7-1 presents a snapshot of projected vessel operations under with-project conditions (-47-foot channel). The design draft for vessels on each of the services is 48 feet. The maximum operating draft for each service, with a -47-foot channel, is 47 feet. Assuming four feet of underkeel clearance for post-Panamax vessels, all vessels operating with drafts greater than 43 feet (80% of calls) are using tidal advantage. Table 7-2 presents the operating draft distributions for the Asia service under with-project conditions channel increments from -45 feet to -48 feet. As the channel becomes incrementally deeper, vessels can load more deeply without requiring additional tidal advantage. It is important to note that there are 14 vessel calls not included in Tables 7-1 or 7-2 because these calls did not use the tide in 2010, therefore they were not included in future projections or transportation cost savings calculations.

Table 7-1
Operating Draft Distributions, Vessel Capacity Utilization, and Number of Shifted TEUs at -47-foot Channel Depth

	Europe Service		**Mediterranean Service**		**Asia Service**	
Design Draft	48 Feet		48 Feet		48 Feet	
Operating draft	# of calls	%	# of calls	%	# of calls	%
47 feet	41	39%	40	39%	25	24%
46 feet	45	43%	0	0%	19	18%
45 feet	7	7%	42	41%	8	8%
44 feet	6	5%	5	5%	0	0%
43 feet	2	2%	7	7%	25	24%
42 feet	0	0%	0	0%	19	18%
41 feet	0	0%	0	0%	8	8%
Non-benefitting calls	4	4%	8	8%	0	0%
Total Calls	104		102		104	
Avg TEU Capacity Utilization*	94%		93%		88%	
Total Shifted TEUs	15,571		11,030		99,062	
Incremental Shifted TEUs from -46-foot	776		455		6,537	

* TEU capacity utilization includes empty containers and only includes benefitting vessel calls

Table 7-2
With-Project Conditions: Asia Operating Draft Distributions (-45-foot to -48-foot Channel)

	Channel Depth			
Operating Draft	**-45 Feet**	**-46 Feet**	**-47 Feet**	**-48 Feet**
48	0	0	0	0
47	3	14	25	44
46	11	11	19	8
45	11	19	8	0
44	19	8	0	0
43	11	14	25	44
42	11	11	19	8
41	11	19	8	0
40	19	8	0	0
<40	8	0	0	0

7.2 Trucking Costs

Seven trucking firms that provide New England container transportation service to and from the PONYNJ and Boston Harbor were interviewed for this analysis in order to develop an estimate of landside trucking costs. Each firm provided quotes for 14 locations to and from Boston Harbor and the PONYNJ, ranging in distance from 24 miles to 405 miles. The locations were selected because they were identified as either origins or destinations in the PIERS data and they provide a broad distribution of distances. The trucking firms noted that round trip is the standard rate charged. One-way rates are not as common and are negotiated individually with the carrier. The trucking firms were each unwilling to provide carrier specific one-way rates. The quotes provided do not include fuel surcharges, which the trucking firms indicated is a percentage of the quote and not calculated by the mileage. There are also additional fees for extended wait times, which are not included in the quotes or in this analysis. The trucking firms indicated that there was no difference in the rates charged for empty or loaded containers. Tables 7-3 and 7-4 present the raw data received from the trucking firms in 2010.

Table 7-3
Round Trip Trucking Cost Raw Data for PONYNJ

City	State	Costs to/from PONYNJ						
		Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6	Firm 7
Waterville	ME	$1,600	$1,495	$1,566	$1,260	$1,500	$1,777	$1,220
Middlebury	VT	$975	$1,456	$867	$1,225	$1,800	$1,240	$928
Bennington	VT	$875	$1,211	$867	$1,045	$1,200	$935	$680
Manchester	NH	$975	$1,040	$1,026	$840	$1,000	$1,318	$928
Pittsfield	MA	$825	$1,071	$852	$750	$1,000	$799	$655
Springfield	MA	$850	$1,060	$852	$1,025	$800	$775	$638
Natick	MA	$875	$944	$934	$850	$800	$1,021	$750
Fall River	MA	$875	$944	$934	$850	$800	$1,003	$730
Woonsocket	RI	$875	$932	$852	$800	$750	$968	$730
North Kingston	RI	$775	$900	$852	$800	$700	$905	$700
Torrington	CT	$725	$1,060	$768	---	$700	$637	$502
Hartford	CT	$750	$800	---	$650	$700	$614	$479
Bridgeport	CT	$700	$1,125	$852	---	$700	$564	$374
Norwich	CT	$750	$998	$852	---	$700	$755	$374
Fuel Surcharge		20%	20%	20%	17%	21%	27%	19%

Table 7-4
Round Trip Trucking Cost Raw Data for Boston Harbor

City	State	Costs to/from Boston Harbor						
		Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6	Firm 7
Waterville	ME	$750	$763	$752	$710	$700	$827	$650
Middlebury	VT	$775	$828	$584	$725	$800	$869	$650
Bennington	VT	$575	$630	$584	$545	$700	$698	$720
Manchester	NH	$375	$345	$385	$335	$325	$360	$308
Pittsfield	MA	$500	$565	$602	$555	$550	$642	$484
Springfield	MA	$475	$520	$469	$425	$425	$399	$422
Natick	MA	$275	$273	$271	$250	$250	$265	$226
Fall River	MA	$350	$323	$373	$350	$300	$360	$293
Woonsocket	RI	$350	$333	$343	$300	$275	$290	$293
North Kingston	RI	$375	$323	$368	$300	$300	$360	$308
Torrington	CT	$550	$540	$605	---	$550	$604	$529
Hartford	CT	$450	$447	---	$475	$425	$600	$500
Bridgeport	CT	$650	$651	$692	---	$550	$717	$545
Norwich	CT	$475	$436	$692	---	$425	$399	$415
Fuel Surcharge		20%	20%	20%	17%	21%	27%	19%

The raw data provided by the trucking firms in 2010 was used to develop a mathematical relationship between distance and trucking costs. A regression analysis was conducted to fit the trucking cost data to the distance data. Multiple types of equations (linear, exponential, etc.) were tried to see which equation provided the best fit. The models provided R^2 values ranging from .653 for the linear model to .733 for the exponential model. Although the exponential model provided the best fit it greatly exaggerated costs when extrapolating beyond the reference data values. The polynomial model and the simple power model also extrapolated poorly or interpolated poorly throughout some range of the reference data. The linear model provided the most reasonable estimates through the reference data range and for extrapolations, and was therefore used to estimate trucking costs. Figure 4 below presents the data plot and regression results.

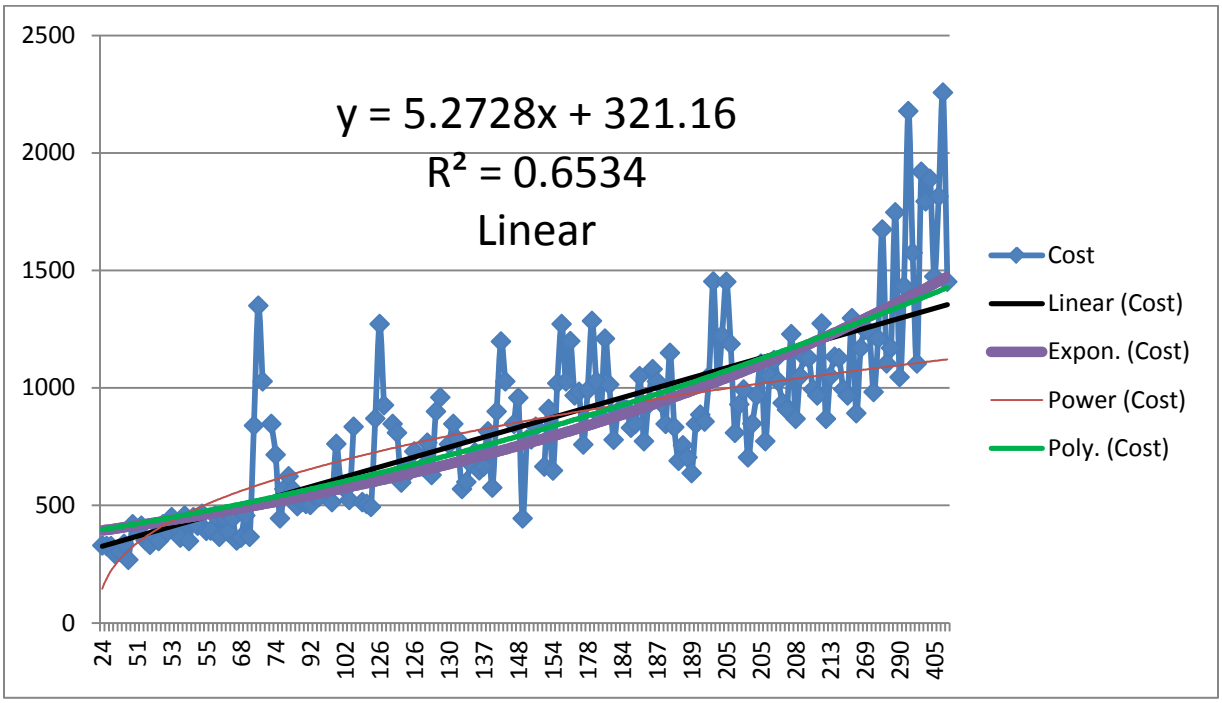

Figure 4: Trucking Distances and Costs

Fixed costs are approximated by the y-intercept ($321.16) in the linear equation. Trucking costs display diminishing costs per mile as portrayed in Figure 5.

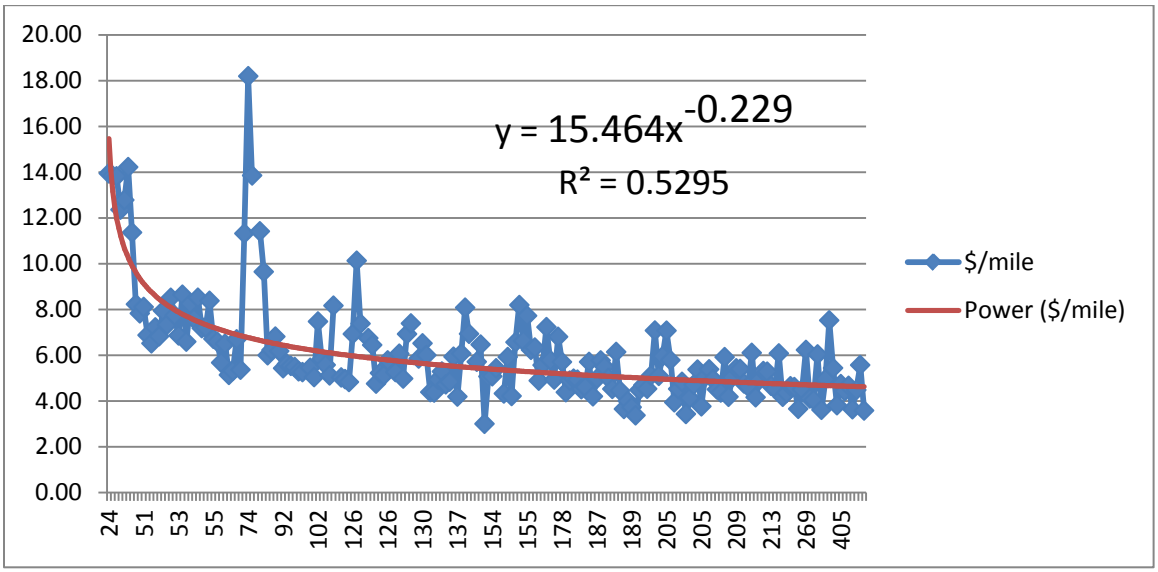

Figure 5: Trucking Costs per Mile

The linear regression model developed from the data provided through the trucking firm interviews was be used to compute the landside transportation costs for each New England TEU identified in the PIERS data. Table 7-5 presents the weighted average trucking cost for all New England TEUs using the PONYNJ in 2007 and the alternative trucking cost through Boston

Harbor. The weighted averages are based on distance and cost calculations conducted for every New England TEU in the PIERS data set that had sufficient origin or destination information (i.e., city, town or zip code).

Table 7-5
Weighted Average Trucking Costs for All New England TEUs Using the PONYNJ in 2007 with Comparative Boston Harbor Cost ($/TEU)

	Imports		Exports	
	Boston	**PONYNJ**	**Boston**	**PONYNJ**
CT	$558.61	$409.82	$568.32	$448.77
MA	$255.32	$713.01	$263.62	$721.01
ME	$621.41	$1,211.64	$548.91	$1,124.65
NH	$373.31	$961.64	$368.45	$916.71
RI	$344.59	$706.16	$355.74	$626.65
VT	$729.29	$932.27	$735.02	$935.81

Note: $/TEU calculations based on 1.85 TEUs per haul as calculated from the PIERS data; costs are presented in FY10 dollars

7.2.1 Landside Transportation Cost Savings

Land side transportation cost savings (Table 7-6) are calculated by multiplying the incremental increases in Boston Harbor TEUs (Table 6-1) by the weighted average distance calculated from the 2007 PIERS data. These landside transportation cost savings include the net difference in ILA Assessment fees for the PONYNJ and Boston Harbor as described in section 7.4 Impact of the International Longshoreman's Association Fees. Trucking costs are updated to February 2012 dollars using the Bureau of Labor Statistics Producer Price Index.[47]

[47] Producer Price Index Industry Data: Series ID PCU484121484121SM; Industry: General freight trucking, long-distance, trailer load, Product: Other receipts.

Table 7-6
Base Case: With-Project Condition Annual Trucking Cost Savings (000's)

Depth	Europe	Mediterranean	Asia	Total	Increment
41	$2,072	$500	$-	$2,572	$2,572
42	$3,575	$3,096	$-	$6,671	$4,100
43	$4,949	$3,686	$-	$8,635	$1,963
44	$5,819	$4,211	$-	$10,030	$1,395
45	$6,528	$4,659	$81,634	$92,821	$82,791
46	$7,109	$5,010	$85,740	$97,858	$5,038
47	$7,482	$5,225	$88,862	$101,569	$3,711
48	$7,679	$5,322	$90,759	$103,761	$2,192
49	$7,783	$5,407	$91,256	$104,446	$685
50	$7,812	$5,446	$91,256	$104,514	$68
51	$7,812	$5,446	$91,256	$104,514	$-

7.3 Additional Waterborne Transportation Costs

New England containerized cargo that shifts from the PONYNJ to Boston Harbor incurs additional waterborne costs consisting of the cost of transporting the additional 386 nautical miles from the PONYNJ to Boston and the cost of waiting for the tide at Boston Harbor. Waterborne transportation costs are calculated using USACE Vessel Operation Costs (EGM 11-05). Table 7-7 presents the additional waterborne transportation costs for each increment of depth.

Table 7-7
Base Case: Additional Waterborne Transportation Costs

Depth	Europe	Mediterranean	Asia Panama	Total	Increment
41	$(5,791)	$12,621		$6,830	$6,830
42	$2,002	$(46,950)		$(44,948)	$(51,778)
43	$15,407	$(39,063)		$(23,656)	$21,292
44	$40,768	$(22,138)		$18,630	$42,286
45	$70,910	$(5,238)	$(1,663,932)	$(1,598,260)	$(1,616,890)
46	$107,165	$24,244	$(1,683,991)	$(1,552,582)	$45,678
47	$162,162	$56,136	$(1,610,773)	(1,392,475)	$160,107
48	$215,575	$173,756	$(1,595,552)	$(1,206,222)	$186,254
49	$341,326	$192,233	$(1,553,496)	$(1,019,938)	$186,283
50	$446,385	$283,903	$(1,524,471)	$(794,183)	$225,755
51	$446,385	$283,903	$(1,385,441)	$(655,153)	$139,030

7.4 Base Case With-Project Total Transportation Cost Savings

The base case with-project total transportation cost savings are calculated as the trucking cost savings less any additional waterborne transportation costs, which would be incurred during the voyage from the PONYNJ to Boston Harbor (Table 7-8). Chapter 1.1.6 Survey and PIERS-Based Landside Distances: Origins and Destinations of the Shipper Survey Attachment identifies the 95% confidence interval for origin to destination distances from the PONYNJ calculated

from the PIERS data (-13.7% to +9.9%)[48]. A 95% confidence interval has been constructed around total and incremental cost savings to illustrate a range of base case benefits for each with-project depth (Table 7-9).

Table 7-8
Base Case Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	80,678	4,104	$8,611,171	$1,984,669
44	83,598	2,920	$10,048,815	$1,437,645
45	256,946	173,348	$91,222,428	$81,173,612
46	267,492	10,546	$96,305,684	$5,083,256
47	275,261	7,769	$100,176,470	$3,870,786
48	279,850	4,589	$102,554,678	$2,378,208
49	281,284	1,435	$103,426,171	$871,493
50	281,427	143	$103,719,909	$293,738
51	281,427	-	$103,858,939	$139,030

[48] Domestic origins and destinations identified by respondents for 2007 cargo movements were compared to the PIERS-based domestic origins and destinations for the same cargo to see how well the information in the PIERS data represents actual origin/destination location as provided by the survey responses. In the survey questionnaire, the respondent was presented with the number of import and export TEUs from each trading partner country as identified in the PIERS data. The respondent was asked to identify the domestic origins and destinations for these TEUs. The respondent was asked to provide domestic origin and destination information at the city and town level. A statistical analysis of the city and town information provided by the respondent and of the city, town and zip code information provided by PIERS was conducted to assess whether the information likely comes from the same population (it does) and to develop confidence intervals around the distance estimates.

Table 7-9
Base Case Average Annual Transportation Cost Savings ($000) with 95% Confidence Intervals

Channel Depth	Total Cost Savings			Incremental Cost Savings		
	Low	Expected	High	Low	Expected	High
41	$2,225	$2,578	$2,834	$2,225	$2,578	$2,834
42	$5,719	$6,627	$7,283	$3,494	$4,048	$4,449
43	$7,431	$8,611	$9,464	$1,713	$1,985	$2,181
44	$8,672	$10,049	$11,044	$1,241	$1,438	$1,580
45	$78,725	$91,222	$100,253	$70,053	$81,174	$89,210
46	$83,112	$96,306	$105,840	$4,387	$5,083	$5,586
47	$86,452	$100,176	$110,094	$3,340	$3,871	$4,254
48	$88,505	$102,555	$112,708	$2,052	$2,378	$2,614
49	$89,257	$103,426	$113,665	$752	$871	$958
50	$89,510	$103,720	$113,988	$253	$294	$323
51	$89,630	$103,859	$114,141	$120	$139	$153

A No Post-Panamax sensitivity analysis was performed to identify the impact that the projection of Post-Panamax vessels using Boston Harbor has on annual total transportation cost savings (Table 7-10). The sensitivity analysis indicates that at depths deeper than -45 feet Panamax vessels are achieving their draft limitations at a faster rate than Post-Panamax vessels and contribute considerably fewer transportation cost savings at these depths than provided by Post-Panamax vessels.

Table 7-10
Annual Transportation Cost Savings with No Post-Panamax Vessels on the Asia Panama Service in the With-Project Condition

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	149,931		--	--
41	162,336	12,405	$5,914,014	$5,914,014
42	177,759	15,423	$13,194,319	$7,280,305
43	187,633	9,874	$17,919,614	$4,725,295
44	194,841	7,208	$21,410,553	$3,490,939
45	199,396	4,555	$23,792,704	$2,382,151
46	201,783	2,387	$25,045,825	$1,253,121
47	203,014	1,231	$25,767,239	$721,413
48	203,631	617	$26,406,863	$639,624
49	204,026	395	$26,783,377	$376,514
50	204,169	143	$27,077,115	$293,738
51	204,169	-	$27,216,145	$139,030

The base case scenario was also assessed with the inclusion of an Asia Suez service, which would call at Boston Harbor at channels depths of -45 feet and greater (Table 7-11). The Asia Suez service is assumed to use 8,400 TEU vessels. The addition of the Asia Suez service is projected to bring an additional 152,533 TEUs through Boston Harbor by the year 2026 as indicated in table 6-6, which increases transportation cost savings (at -51 feet) by $62,056,158 ($165,915,097 - $103,858,939 = $62,056,158).

Table 7-11
Average Annual Transportation Cost Savings with Asia Suez Service

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	80,678	4,104	$8,611,171	$1,984,669
44	83,598	2,920	$10,048,815	$1,437,645
45	393,395	309,798	$146,449,815	$136,401,000
46	410,805	17,410	$154,337,325	$7,887,509
47	423,793	12,987	$160,348,989	$6,011,664
48	431,552	7,760	$164,086,799	$3,737,810
49	433,817	2,265	$165,336,138	$1,249,340
50	433,960	143	$165,659,462	$323,324
51	433,960	-	$165,915,097	$255,634

7.5 Impact of International Longshoreman's Association Assessment Fees

The New York Shipping Association (NYSA) represents the interests of the carriers, terminal operators, stevedores, and other marine-related businesses using the PONYNJ. The NYSA negotiates collective bargaining agreements with the International Longshoreman's Association (ILA) on behalf of its membership. One aspect of the negotiated collective bargaining is the NYSA-ILA Assessment Agreement, which is filed with the Federal Maritime Commission Bureau of Trade Analysis, Office of Agreements.[49] The assessment program established under the agreement funds obligations resulting from NYSA-ILA collective bargaining agreements, which include pension, health, and other benefits which are components of the ILA negotiated compensation package.

[49] Federal Maritime Commission Agreement no. 201162

Assessment rates are established for various types of cargo. Container Unit Assessment rates are based on the landside distance from origin or destination to the Center of the Port, which is defined as Columbus Circle in the City, County, and State of New York (57th Street and Broadway). Containers originating from or destined for domestic locations that are more than 260 highway miles from the Center of the Port are assessed at a rate of $21 per container. Containers originating from or destined for domestic locations that are less than 260 highway miles from the Center of the Port are assessed at a rate of $115 per container. Assessment fees are added to the cargo and vessel handling fees charged to the carrier (or agent) by the terminal operator. Boston Harbor also charges a fixed per container assessment fee that does not vary with distance. The Boston Harbor fee is $1.00 per ton of cargo.

Cargo and vessel handling fees are negotiated between carriers and terminal operators an on individual and confidential basis. The Container Unit Assessment rates are negotiated collectively by the representatives of the carriers and terminal operators (NYSA) and organized labor (ILA). This distance based assessment fee takes advantage of the relatively inelastic demand for PONYNJ services for importers and exporters working within the PONYNJ's primary hinterland. This 260 mile threshold includes 89% of New England import and 95% of New England export cargo using the PONYNJ in 2007. The Container Unit Assessment for containerized cargo using Boston Harbor is substantially lower than the PONYNJ fees; therefore New England containerized cargo that switches from the PONYNJ to Boston Harbor would incur a cost savings by avoiding the higher cost of the PONYNJ Container Unit Assessment. The weighted average cost of this assessment per New England TEU is $48.77 per import TEU and $51.46 per export TEU, accounting for the mix of New England containers within and outside of the 260 mile threshold, accounting for 1.85 TEUs per container in 2007, and accounting for the net impact of incurring Boston Harbor assessment fees[50].

The Container Unit Assessment fee is a component of the total cost of handling cargo at the PONYNJ. It is not associated with any government program to redistribute income, fund the provision of public goods, or subsidize government sanctioned behavior. In other words, the Container Unit Assessment fee is not a transfer payment, which is a payment made without the expectation of a good or service being offered in return. The Container Unit Assessment fee is part of the negotiated compensation paid to labor for the provision of container handling services and is therefore included in the base case transportation cost savings estimates.

Table 7-12 presents the base case transportation cost savings with the Container Unit Assessment fee excluded. The exclusion of the Container Unit Assessment fee as a component of transportation costs reduces the transportation cost savings afforded by shifting from the PONYNJ to Boston Harbor.

[50] 1.85 TEUs per container figure is based on calculations conducted with the PIERS data.

Table 7-12
Base Case Average Annual Transportation Cost Savings without Container Unit Assessment Fee Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,353,523	$2,353,523
42	76,574	8,610	$6,042,793	$3,689,269
43	80,678	4,104	$7,855,737	$1,812,945
44	83,598	2,920	$9,171,319	$1,315,582
45	256,946	173,348	$83,101,887	$73,930,568
46	267,492	10,546	$87,744,431	$4,642,544
47	275,261	7,769	$91,290,590	$3,546,158
48	279,850	4,589	$93,477,037	$2,186,447
49	281,284	1,435	$94,288,582	$811,545
50	281,427	143	$94,576,370	$287,788
51	281,427	-	$94,715,400	$139,030

8 Sensitivity Analyses

Analyses identifying the impact of the Container Unit Assessment fee and on restricting Post-Panamax vessels from the Asia Panama service under with-project conditions are presented in Chapter 7: Transportation Cost Savings. Sensitivity analyses are performed to address the uncertainty in projected future conditions and to see how changes in influential factors may impact project benefits. Factors assessed in sensitivity analyses include: timing of carrier response to the deeper channel, vessel size, and potential additional services.

8.1 Uncertainty Discussion

The service with Asia is projected to continue being the largest service, in terms of TEUs, at Boston Harbor, as it has been historically. The Asia service accounted for the majority of loaded TEUs in 2007 as compared to the Europe and Mediterranean services (Appendix A: Table 5). The Asia service moved 86,534 (58%) loaded TEUs through Boston Harbor, while the Mediterranean service moved 19,407 (13%) and the Europe service moved 43,215 (29%).

Projected future benefits are weighted more heavily (79%) towards the Asia service (Table 7-1) because this service has a larger slot allocation and uses larger vessels than the other services, therefore more New England TEUs are handled on this service. The higher risk associated with vessel size on the Asia service is addressed in Sensitivity Analyses 6 and 7, which assess transportation cost savings with smaller vessels on this service.

Under with-project conditions, a channel depth at Boston Harbor of -45 feet is considered a tipping point for the Asia service. At channel depths less than -45 feet, the Asia service is projected to not call at Boston Harbor and all Asian trade New England TEUs would use the PONYNJ. The selection of -45 feet as a tipping point was based on discussions with the carrier (COSCO) and on the relation between a -45-foot channel at Boston Harbor and a -50-foot channel at the PONYNJ. Due to the extensive tidal range at Boston Harbor and the heavy use of tidal advantage exhibited by carriers, it is projected that carriers will continue to rely heavily on tidal advantage at Boston Harbor under without and with-project conditions. The analysis projects that a -45-foot channel depth at Boston Harbor would not constrain vessel operations (vessel departure or arrival drafts) at the PONYNJ for vessels which also call at Boston Harbor as a next or prior port of call. If the tipping point is less than -45 feet, there would be no substantial change to benefits other than a shift of the first increment of Asia service related benefits to a shallower depth. Incremental benefits at depths greater than -45 feet would not be affected.

Project benefits are not dependent on projected future growth of New England cargo using the PONYNJ or Boston Harbor and there is no uncertainty or risk associated with a projected rate of growth. Under the base case scenario and a with-project condition -51-foot channel, the analysis projects that 218,829 TEUs would shift from the PONYNJ to Boston Harbor. Of those 218,829 TEUs are included 87,333 Asia service TEUs which use Boston Harbor under existing conditions, but are projected to shift to the PONYNJ under without-project conditions. These 87,333 TEUs would be considered returning to Boston Harbor under with-project conditions. Therefore, under a with-project condition -51-foot channel, 131,496 TEUs (218,829 – 87,333 = 131,496) would be considered shifting TEUs which historically used the PONYNJ.

This shift of 131,496 New England TEUs, which historically used the PONYNJ, is less than the mid-point of the range of TEUs (152,488) identified as available to shift in the shipper survey at the 2007 level of trade (Table 6-1). The shift of 131,496 TEUs is only slightly more than the lower limit (131,049) also identified in the shipper survey (Table 6-1). The low, middle, and high range estimates of the number of New England TEUs available to shift from the PONYNJ to Boston Harbor are escalated to the base-year (2015) using the 20-year (1989 – 2009) US containerized trade growth rate (4.65%) in Table 6-1. But, growth in New England TEUs is not included in the transportation cost savings calculations. The growth rate is used in Table 6-1 to indicate that there will be more than sufficient cargo available to shift from the PONYNJ to Boston Harbor in 2015 and subsequent years. The middle range estimate of cargo available to shift in 2015 (using the 4.65% growth rate and including the 87,333 returning TEUs) is 306,689 TEUs, which is more than the total 218,829 TEUs (including returning TEUs) projected to shift under with-project conditions and a -51-foot channel at Boston Harbor.

8.2 Sensitivity Analysis Descriptions

The following sensitivity analyses were conducted:

- Sensitivity Analysis 1: Same with and without-project conditions as the base case with the exceptions that the Asia Panama service waits for five years after the base-year before calling at Boston Harbor.
- Sensitivity Analysis 2: Same with and without-project conditions as the base case with the exception that the Post-Panamax vessel entering the Mediterranean service is an 8,400 TEU vessel.
- Sensitivity Analysis 3: Same with and without-project conditions as the base case with the exception that no Post-Panamax vessels enter the Mediterranean service.
- Sensitivity Analysis 4: Same with and without-project conditions as the base case with the exception that a new fifth service (Mediterranean) calls at Boston Harbor using 8,400 TEU vessels beginning at a controlling depth of 42 feet.
- Sensitivity Analysis 5: Same with and without-project conditions as the base case with the exception that a new fifth service (Mediterranean) calls at Boston Harbor using 8,400 TEU vessels beginning at a controlling depth of 45 feet.
- Sensitivity Analysis 6: Same with and without-project conditions as the base case with the exception that the Asia Panama service is constrained to a 5,800 TEU vessel.
- Sensitivity Analysis 7: Same with and without-project conditions as the base case with the exception that there are no Post-Panamax vessels on the Asia Panama service.
- Sensitivity Analysis 8: Same with and without-project conditions as the base case with the exception that the largest vessel to call at Boston Harbor is a 7,500 TEU vessel
- Sensitivity Analysis 9: Same with and without-project conditions as the base case with the exception that the largest Post-Panamax vessels on the two Asia services arrive and depart at drafts similar to operating drafts observed at Oakland Harbor in 2010 for services with similar vessel size, ports of call, and placement in the port rotation.
- Sensitivity Analysis 10: This sensitivity analysis only calculates waterborne transportation cost savings. In the without project condition, existing Panamax containerships in the 4700 TEU range would service Boston Harbor in their current rotation. As Boston channels are deepened under with-project conditions these ships are loaded more fully and ultimately shift to fewer, bigger ships with same cargo volume, achieving economies of scale with larger vessels. Cargo volumes increase due to global growth in trade, and as channel depth increases allow, ship sizes increase and larger ships are used to carry the additional cargo. New England cargo loaded and landed at the PONYNJ under without-project conditions would shift to Boston Harbor, as vessels load to deeper depths and vessel size increases to handle the additional cargo. Use of larger vessels decreases shipping costs for all cargo onboard the vessel irrespective of whether those boxes were loaded or landed at Boston Harbor or at some other port on the service's rotation; therefore, the benefits calculated in this sensitivity analysis are based on all TEUs on the vessel.
- Sensitivity Analysis 11: This sensitivity analysis is exactly the same as Sensitivity Analysis 10 with the exception that benefits are calculated based on the share of Boston Harbor cargo onboard the vessel. The proportion of Boston Harbor cargo on the vessel is the proportion of vessel cost used in the calculation of with-project benefits.
- Sensitivity Analysis 12: This sensitivity analysis calculates the number of additional trips by the existing fleet calling at Boston Harbor required to haul the base case number of shifted TEUs. The waterborne transportation cost of these additional trips is calculated based on the proportion of Boston harbor TEUs historically loaded on these vessels. This

sensitivity analysis excludes the 87,333 Asia service TEUs, which return to Boston Harbor under with-project conditions.

- Sensitivity Analysis 13: This sensitivity analysis assesses the effects of alternative operating draft distributions for the fleet projected to call at Boston Harbor under with-project conditions. Alternative operating draft distributions used in this sensitivity analysis include:
    - Strict adherence to observed operating draft distributions, such that vessels do not load more deeply if any vessel is project to achieve its maximum load at that channel depth.

8.3 Sensitivity Analysis Results

The sensitivity analysis resulting in the largest reduction in benefits is Sensitivity Analysis 7, which constrains the total number of shifted TEUs by 70%. Alternatively, both of the new fifth service sensitivity analyses (Sensitivity Analysis 4 and Sensitivity Analysis 5) increase the number of shifted TEU to 13% more than estimated in the base case.

Sensitivity Analysis 1: Same with and without-project conditions as the base case with the exceptions that the Asia Panama service waits for five years after the base-year before calling at Boston Harbor.

Sensitivity Analysis 1: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,629,454	$2,629,454
42	76,574	8,610	$6,757,732	$4,128,278
43	80,678	4,104	$8,781,705	$2,023,973
44	83,598	2,920	$10,247,821	$1,466,116
45	256,946	173,348	$76,128,401	$65,880,580
46	267,492	10,546	$80,448,769	$4,320,368
47	275,261	7,769	$83,720,894	$3,272,124
48	279,850	4,589	$85,742,075	$2,021,181
49	281,284	1,435	$86,516,962	$774,887
50	281,427	143	$86,810,382	$293,421
51	281,427	-	$86,922,784	$112,401

Sensitivity Analysis 2: Same with and without-project conditions as the base case with the exception that the Post-Panamax vessel entering the Mediterranean service is an 8,400 TEU vessel.

Sensitivity Analysis 2: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	83,461	15,496	$9,855,293	$7,276,901
43	87,814	4,353	$11,964,446	$2,109,153
44	90,956	3,142	$13,502,838	$1,538,392
45	264,493	173,537	$94,768,590	$81,265,751
46	275,188	10,695	$99,927,621	$5,159,032
47	283,048	7,860	$103,848,014	$3,920,393
48	287,677	4,630	$106,271,141	$2,423,127
49	289,148	1,471	$107,163,417	$892,276
50	289,307	159	$107,484,989	$321,572
51	289,307	-	$107,624,019	$139,030

Sensitivity Analysis 3: Same with and without-project conditions as the base case with the exception that no Post-Panamax vessels enter the Mediterranean service.

Sensitivity Analysis 3: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	72,185	4,221	$4,618,300	$2,039,908
43	75,637	3,452	$6,309,423	$1,691,123
44	77,817	2,180	$7,404,265	$1,094,842
45	250,504	172,688	$88,337,700	$80,933,435
46	260,454	9,950	$93,122,837	$4,785,137
47	267,817	7,363	$96,838,561	$3,715,725
48	272,200	4,384	$99,001,997	$2,163,435
49	273,457	1,257	$99,770,528	$768,532
50	273,516	59	$99,933,165	$162,636
51	273,516	-	$100,072,195	$139,030

Sensitivity Analysis 4: Same with and without-project conditions as the base case with the exception that a new fifth service (Mediterranean) calls at Boston Harbor using 8,400 TEU vessels beginning at a controlling depth of 42 feet.

Sensitivity Analysis 4: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	110,068	42,104	$22,300,720	$19,722,328
43	115,667	5,599	$25,002,922	$2,702,202
44	119,917	4,250	$27,079,493	$2,076,571
45	294,400	174,483	$108,806,806	$81,727,313
46	305,835	11,435	$114,343,684	$5,536,878
47	314,149	8,314	$118,510,120	$4,166,436
48	318,984	4,835	$121,147,470	$2,637,349
49	320,633	1,649	$122,142,265	$994,795
50	320,876	243	$122,594,745	$452,480
51	320,876	-	$122,733,775	$139,030

Sensitivity Analysis 5: Same with and without-project conditions as the base case with the exception that a new fifth service (Mediterranean) calls at Boston Harbor using 8,400 TEU vessels beginning at a controlling depth of 45 feet.

Sensitivity Analysis 5: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	80,678	4,104	$8,611,171	$1,984,669
44	83,598	2,920	$10,048,815	$1,437,645
45	294,400	210,802	$108,806,806	$98,757,991
46	305,835	11,435	$114,343,684	$5,536,878
47	314,149	8,314	$118,510,120	$4,166,436
48	318,984	4,835	$121,147,470	$2,637,349
49	320,633	1,649	$122,142,265	$994,795
50	320,876	243	$122,594,745	$452,480
51	320,876	-	$122,733,775	$139,030

Sensitivity Analysis 6: Same with and without-project conditions as the base case with the exception that the Asia Panama service is constrained to a 5,800 TEU vessel.

Sensitivity Analysis 6: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598		--	--
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	80,678	4,104	$8,611,171	$1,984,669
44	83,598	2,920	$10,048,815	$1,437,645
45	210,777	127,179	$69,555,909	$59,507,094
46	216,811	6,034	$72,552,023	$2,996,114
47	219,271	2,460	$73,824,452	$1,272,429
48	219,890	619	$74,318,891	$494,439
49	220,285	395	$74,670,599	$351,708
50	220,427	143	$75,026,302	$355,703
51	220,427	-	$75,026,302	$0

Sensitivity Analysis 7: Same with and without-project conditions as the base case with the exception that there are no Post-Panamax vessels on the Asia Panama service.

Sensitivity Analysis 7: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	149,931		--	--
41	162,336	12,405	$5,864,228	$5,864,228
42	177,759	15,423	$13,103,393	$7,239,165
43	187,633	9,874	$17,799,261	$4,695,868
44	194,841	7,208	$21,263,033	$3,463,772
45	199,396	4,555	$23,521,680	$2,258,647
46	201,783	2,387	$24,751,246	$1,229,566
47	203,014	1,231	$25,444,372	$693,125
48	203,631	617	$25,995,584	$551,212
49	204,026	395	$26,328,295	$332,711
50	204,169	143	$26,593,007	$264,712
51	204,169	-	$26,593,007	$0

Sensitivity Analysis 8: Same with and without-project conditions as the base case with the exception that the largest vessel to call at Boston Harbor is a 7,500 TEU vessel

Sensitivity Analysis 8: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598			
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	80,678	4,104	$8,611,171	$1,984,669
44	83,598	2,920	$10,048,815	$1,437,645
45	235,996	152,399	$81,349,431	$71,300,616
46	245,538	9,541	$85,954,866	$4,605,435
47	252,513	6,976	$89,438,952	$3,484,086
48	256,485	3,971	$91,520,628	$2,081,676
49	257,723	1,239	$92,293,711	$773,083
50	257,866	143	$92,584,239	$290,528
51	257,866	-	$92,707,894	$123,655

Sensitivity Analysis 9: Same with and without-project conditions as the base case with the exception that the largest Post-Panamax vessels on the Asia service arrives and departs at drafts similar to operating drafts observed at Oakland Harbor in 2010 for services with similar vessel size, ports of call, and placement in the port rotation.

Sensitivity Analysis 9: Average Annual Transportation Cost Savings

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598			
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	80,678	4,104	$8,611,171	$1,984,669
44	83,598	2,920	$10,048,815	$1,437,645
45	171,467	87,869	$50,793,847	$40,745,031
46	182,332	10,865	$56,049,373	$5,255,526
47	192,480	10,147	$60,983,126	$4,933,753
48	193,097	617	$61,455,285	$472,158
49	193,491	395	$61,787,996	$332,711
50	193,634	143	$62,052,708	$264,712
51	193,634	-	$62,052,708	$0

Sensitivity Analyses 10 & 11: Average Annual Transportation Cost Savings

	Base Case		Sensitivity Analysis 10		Sensitivity Analysis 11	
Channel Depth	Total Cost Savings	Incremental Cost Savings	Total Cost Savings	Incremental Cost Savings	Total Cost Savings	Incremental Cost Savings
42	$2,578,392	$2,578,392	$65,562,901	$65,562,901	$15,726,712	$15,726,712
43	$6,626,502	$4,048,110	$90,526,903	$24,964,002	$21,266,408	$5,539,696
44	$8,611,171	$1,984,669	$107,469,424	$16,942,521	$25,007,182	$3,740,773
45	$10,048,815	$1,437,645	$141,804,175	$34,334,752	$33,836,365	$8,829,184
46	$91,222,428	$81,173,612	$157,484,609	$15,680,433	$37,632,457	$3,796,092
47	$96,305,684	$5,083,256	$168,151,273	$10,666,664	$40,260,047	$2,627,590
48	$100,176,470	$3,870,786	$174,099,048	$5,947,775	$41,754,019	$1,493,972
49	$102,554,678	$2,378,208	$175,992,504	$1,893,456	$42,166,023	$412,004
50	$103,426,171	$871,493	$176,225,350	$232,846	$42,184,990	$18,967
51	$103,719,909	$293,738	$176,225,350	$0	$42,184,990	$0

Sensitivity Analysis 12: This sensitivity analysis calculates the number of additional trips by the existing fleet calling at Boston Harbor which would be required to haul the base case number of shifted TEUs if the channel were not deepened. The waterborne transportation cost of these additional trips is calculated based on the proportion of Boston harbor TEUs historically loaded on these vessels. This sensitivity analysis excludes the 87,333 Asia service TEUs, which return to Boston Harbor under with-project conditions.

Sensitivity Analyses 12-1: Background Data

	Europe	Mediterranean	Asia
One-way Voyage Cost	$501,307	$440,317	$1,981,758
TEUs per Call	676	348	1,766
% of Vessel TEUs	7.4%	5.4%	23.2%
Boston Cost per Voyage	$37,005	$23,696	$459,371

The transportation cost savings of Sensitivity Analysis #12 are calculated by subtracting the voyage costs of the additional vessel calls from the total landside transportation savings

computed for the Base Case. The resulting analysis is shown in the final table for this sensitivity below.

Sensitivity Analyses 12-2: Base Case Shifted TEUs

Channel Depth	Europe	Mediterranean	Asia*	Total
42	7,441	6,536		13,977
43	10,299	7,781		18,080
44	12,110	8,890		21,000
45	13,586	9,835	83,927	107,348
46	14,795	10,575	92,525	117,894
47	15,571	11,030	99,062	125,663
48	15,983	11,235	103,034	130,252

Note: *Excludes 87,333 Asia service TEUs currently using Boston Harbor

Sensitivity Analyses 12-3: Additional Calls

Channel Depth	Europe	Mediterranean	Asia	Total
42	11	19	0	30
43	15	22	0	38
44	18	26	0	43
45	20	28	48	96
46	22	30	52	105
47	23	32	56	111
48	24	32	58	114

Sensitivity Analyses 12-3: Voyage Costs of Additional Calls

Channel Depth	Europe	Mediterranean	Asia	Total	Incremental
42	$407,325	$445,030		$852,356	
43	$563,798	$529,828		$1,093,626	$241,270
44	$662,936	$605,317		$1,268,252	$174,626
45	$743,719	$669,674	$21,831,107	$23,244,500	$21,976,248
46	$809,885	$720,068	$24,067,541	$25,597,495	$2,352,994
47	$852,380	$751,035	$25,768,057	$27,371,473	$1,773,979
48	$874,915	$764,999	$26,801,257	$28,441,171	$1,069,698

Sensitivity Analyses 12-4: Transportation Cost Savings

Channel Depth	Base Case Landside Savings (Table 7-6)	Additional Call Voyage Costs (Table Sensitivity Analysis 12-3)	Total Transportation Cost Savings	Incremental Transportation Cost Savings
42	6,671,450	$852,356	$5,819,094	$5,819,094
43	8,634,826	$1,093,626	$7,541,200	$1,722,106
44	10,030,185	$1,268,252	$8,761,933	$1,220,733
45	92,820,688	$23,244,500	$69,576,188	$60,814,255
46	97,858,266	$25,597,495	$72,260,771	$2,684,583
47	101,568,945	$27,371,473	$74,197,472	$1,936,701
48	103,760,900	$28,441,171	$75,319,729	$1,122,257

Sensitivity Analysis 13: This sensitivity analysis assesses the effects of alternative operating draft distributions for the fleet projected to call at Boston Harbor under with-project conditions. The first operating draft distribution tested under this sensitivity analysis (13A) is a strict adherence to observed operating draft distributions, such that vessels do not load more deeply if any vessel is project to achieve its maximum load at that channel depth.

Sensitivity Analyses 13A: Strict Observed Distribution with No Advancement

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598			
41	67,965	5,367	$2,578,392	$2,578,392
42	76,574	8,610	$6,626,502	$4,048,110
43	76,574	-	$6,626,502	$0
44	76,574	-	$6,626,502	$0
45	247,502	170,927	$86,596,250	$79,969,748
46	256,099	8,598	$90,682,401	$4,086,151
47	256,099	-	$90,682,401	$0

The second alternative operating draft scenario assessed in this sensitivity analysis (13B) forces each vessel to load as fully as possible at each depth increment. Under this scenario vessels are using tidal advantage much more aggressively than observed at Boston Harbor. Because the maximum vessel operating draft is 47 feet the Europe and Mediterranean services are all fully loaded at a channel depth of -42 feet and the Asia service is fully loaded at a channel depth of -45 feet. Some tide delay benefits continue to accrue at deeper channel depths. This is considered an unrealistic scenario.

Sensitivity Analyses 13B: All Vessels Fully Loaded

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	62,598			
41	74,507	11,909	$5,575,229	$5,575,229
42	90,353	15,846	$12,915,853	$7,340,625
43	90,353	-	$13,023,032	$107,178
44	90,353	-	$13,119,048	$96,016
45	281,427	191,074	$102,604,335	$89,485,287
46	281,427	-	$102,767,594	$163,259
47	281,427	-	$103,043,867	$276,272
48	281,427	-	$103,276,792	$232,926
49	281,427	-	$103,479,744	$202,952
50	281,427	-	$103,719,909	$240,164
51	281,427	-	$103,858,939	$139,030

The third operating draft distribution sensitivity analysis (13C) uses the Post-Panamax Generation 2 Vessel Class distribution, which was used in the Savannah Harbor Expansion Project (Savannah Harbor Economics Appendix; page 144; Table 108). The operating draft distribution presented in the Savannah Economics Appendix was extrapolated to depths shallower than -44 feet. This operating draft distribution is the same at channel depths of -47 and -48 feet, indicating that vessels will not load more deeply at channel depths greater than 47 feet.

Sensitivity Analyses 13C: Savannah Harbor Deepening Distribution

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	65,821			
41	66,195	374	$286,878	$286,878
42	69,908	3,713	$2,074,258	$1,787,380
43	70,084	176	$2,459,874	$385,616
44	70,631	548	$2,776,213	$316,340
45	214,150	143,519	$69,865,162	$67,088,949
46	219,413	5,263	$72,414,269	$2,549,107
47	228,305	8,892	$76,709,624	$4,295,355
48	228,305	-	$76,767,989	$58,365
49	228,305	-	$76,799,292	$31,303
50	228,305	-	$76,820,966	$21,674
51	228,305	-	$76,834,335	$13,368

The fourth operating draft distribution sensitivity analysis (13D) constrains the maximum operating draft of vessels to be 2.5 feet less than their design draft. Under this constraint a vessel with a 47.56 design draft operates at drafts no deeper than 44.99 feet. This constraint is applied to all vessels in this sensitivity analysis.

Sensitivity Analyses 13D: Maximum Operating Draft Constrained by 2.5 Feet

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	64,910			
41	65,240	329	$224,555	$224,555
42	76,524	11,284	$5,542,412	$5,317,857
43	79,084	2,560	$6,820,733	$1,278,322
44	81,172	2,088	$7,894,514	$1,073,781
45	250,715	169,543	$87,391,328	$79,496,814
46	256,668	5,953	$90,396,645	$3,005,317
47	258,903	2,235	$91,519,230	$1,122,584
48	259,219	316	$91,908,830	$389,601
49	259,219	-	$91,937,856	$29,026
50	259,219	-	$92,076,886	$139,030
51	259,219	-	$92,076,886	$0

The fifth operating draft distribution sensitivity analysis (13E) reduces the amount of tidal advantage used at Boston Harbor to one-half of the observed use of tidal advantage. This spreads the operating draft distribution among a broader and shallower range of operating drafts (Sensitivity Analysis 13: Comparison of Operating Drafts With a -47-Foot Channel). The effect of reducing tidal advantage is to reduce overall project benefits and to distribute benefits more evenly among various with-project conditions channel depths (Sensitivity Analysis 13E: Reduced Tidal Advantage).

Sensitivity Analyses 13: Comparison of Operating Drafts with a -47-Foot Channel

Base Case			Reduced Tidal Advantage		
Operating Draft	Number of Calls	% of Total Calls	Operating Draft	Number of Calls	% of Total Calls
47	25	24%	45	3	3%
46	19	18%	44	11	11%
45	8	8%	43	11	11%
44	0	0%	42	19	18%
43	25	24%	41	8	8%
42	19	18%	40	3	3%
41	8	8%	39	11	11%
Total Calls	104		38	11	11%
			37	19	18%
			36	0	0%
			35	8	8%
			Total Calls	104	

Sensitivity Analyses 13E: Reduced Tidal Advantage

Channel Depth	Total TEUs	Incremental TEU Increase	Total Cost Savings	Incremental Cost Savings
40	59,061			
41	60,934	1,873	$925,843	$925,843
42	68,367	7,433	$4,481,475	$3,555,631
43	70,256	1,890	$5,449,796	$968,321
44	72,833	2,576	$6,787,099	$1,337,303
45	213,520	140,687	$72,531,037	$65,743,938
46	218,998	5,477	$75,306,949	$2,775,913
47	225,721	6,724	$78,571,287	$3,264,338
48	232,430	6,708	$81,883,477	$3,312,189
49	238,848	6,418	$85,024,046	$3,140,569
50	245,365	6,517	$88,234,722	$3,210,677
51	251,337	5,972	$91,090,706	$2,855,983

9 Conclusion

Post-Panamax vessels were deployed to Boston Harbor (Asia Suez service) for the first time in May 2011; however, this service was discontinued after six months. The large surge in Boston Harbor throughput which accompanied the new, but short lived, service to Boston Harbor supports the fundamental finding of this analysis, which is that the potential for substantial landside transportation cost savings is an economic incentive for shippers to shift some New England containerized cargo from using the PONYNJ to using Boston Harbor. This economic incentive is identified and quantified by the trucking cost analysis (Chapter 7.1). The shipper survey conducted in 2010 indicates that a substantial number of New England TEUs currently using the PONYNJ appear to have the potential to shift to Boston Harbor (Appendix A: Revised R-1 Report). Carriers are currently providing limited opportunities for shippers to shift to Boston Harbor because of channel constraints at Boston Harbor. Some carriers are reluctant to call at Boston Harbor because of the light loading and tide delays that are a regular component of Panamax vessel operations at Boston Harbor (Chapter 3.2). Interviews with the carriers indicate that channel depth constraints are the reason for historically pulling Boston Harbor out of the liner service rotation and for not including Boston Harbor in the rotation today and under without-project conditions (Appendix C: Carrier Interviews).

Under with-project conditions the existing fleet of Panamax vessels calling at Boston Harbor would be able to load more deeply (Chapter 6.3). Large Post-Panamax vessels are projected to use Boston Harbor at controlling depths of -45 feet and deeper, because at this controlling depth Boston Harbor would not be a constraint on the operating drafts of vessels coming from or going to the PONYNJ. Base case Boston Harbor TEU amounts (Table 6-3) and transportation cost savings (Table 7-8) are alternatively calculated assuming no Post-Panamax vessels call at Boston Harbor on the Asia Panama service under with-project conditions. Vessels are projected to use tidal advantage under both without-project conditions and with-project conditions in the same way that vessels were observed using tidal advantage in 2010.

Some of the additional cargo carried on vessels using the federal channel at Boston Harbor under with-project conditions is projected to be New England containerized cargo, which switched from using the PONYNJ to using Boston Harbor (Chapter 6.4). Under with-project conditions, the total amount of Boston Harbor cargo carried on the vessel is calculated based on the 2010 observed proportion of Boston Harbor cargo. The total amount of cargo projected to shift under the base case with-project condition is 218,829 New England TEUs[51] (Table 6-2). The total amount of New England TEUs projected to shift from the PONYNJ to Boston Harbor includes 87,333 TEUs that are handled at Boston Harbor under existing conditions, so the total number of newly shifting cargo exclusive of returning cargo is 131,496 TEUs.

The PIERS data identifies 255,000 New England TEUs as having used the PONYNJ in 2007 (Table 3-1). By 2015, there will be 367,000 New England TEUs using the PONYNJ under without-project conditions based on the average annual TEU volume growth rate for all US container ports from 1999 – 2009 (4.65%[52]). The 367,000 TEU estimate is based on 2007 data for the PONYNJ and excludes the 87,333 Asian service New England TEUs, which are projected

[51] Calculated at a with-project channel depth of -48 feet

[52] AAPA data accessed at www.aapa-ports.org

to shift from Boston Harbor to the PONYNJ under future without-project conditions. Including the Asian service cargo increases the total number of New England TEUs projected to use the PONYNJ in 2015 to 454,000.

The analysis of shipper survey data[53] estimates that the mid-range number of New England TEUs available to shift from the PONYNJ to Boston Harbor in 2007 was 152,488 TEUs and the low estimate was 131,049 TEUs (Table 6-2). This mid-range estimate of "shiftable" TEUs is projected to increase to 219,356 TEUs by 2015 using the same historical growth rate (4.65%). The "shiftable" TEU estimate is based on 2007 data and excludes the 87,333 Asian service New England TEUs, which currently use Boston Harbor but are projected to shift from Boston Harbor to the PONYNJ under future without-project conditions. Including the Asian service cargo increases the mid-range number of "shiftable" TEUs projected to use the PONYNJ in 2015 to 306,689, which is substantially greater than the 218,829 projected to shift under with-project conditions of a -48-foot channel.

The 218,829 New England TEUs projected to shift from the PONYNJ to Boston Harbor, which includes the 87,333 Asian service TEUs returning to Boston Harbor, are 48% of the of the total New England TEUs projected to use the PONYNJ under without project conditions (218,829/454,000 = 48%). The 218,829 New England TEUs projected to shift to Boston Harbor are only 71% of the mid-range estimate of New England TEUs available to shift to Boston Harbor in 2015 (218,829/306,689 = 71%).

Total transportation cost savings are calculated as the reduction in trucking costs resulting from the switch from using the PONYNJ to using Boston Harbor and the net difference in waterborne transportation costs (including tide delays) for containers that don't get offloaded or loaded at the PONYNJ, but instead make the additional ocean voyage to Boston Harbor. Base case transportation cost saving are alternatively calculated with the PONYNJ Container Unit Assessment fee excluded as a component of origin to destination costs for New England cargo using the PONYNJ (Chapter 7.4). Sensitivity analyses (Chapter 8) are performed to assess the influence of important factors on benefit estimates, including: timing of carrier response to the deeper channel, vessel size, and potential additional services.

[53] Appendix A: Estimation of TEUs Available to Shift from the PONYNJ to Boston Harbor

APPENDIX C-2

Economic Analysis of Additional Channel Segments

Channel Deepening to Bulk Cargo Terminals

Main Ship Channel Extension to Marine Terminal

Mystic River Deepening at Medford Street Terminal

Chelsea River Channel Deepening

Updated November 2012

Attachment C-2
Economic Analysis of Additional Channel Segments

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Appendix C-2
Economic Analysis of Additional Channel Segments

1. Introduction

The purpose of this economic analysis is to estimate the economic benefits of deepening three small additional channel segments in Boston Harbor. The first segment is an extension of the Main Ship channel north of the Reserved Channel to provide deeper access to a new terminal being developed, the Massport Marine Terminal. The second segment is located in the Mystic River, and would extend the existing 40-foot channel to the Medford Street Terminal. The third segment would consist of deepening the Federal channel in the Chelsea River from 38 feet to 40 feet. The Chelsea River is used primarily by oil tankers, and is the main distribution point for gasoline, aviation fuel and heating oil in eastern Massachusetts. Since these additional channel segments are separable elements from the Main Channel deepening to Conley terminal, they are analyzed separately in this analysis.

The base year of the analysis is 2016, and the period of analysis is 2016-2066. Details regarding the channel design and construction are contained in the main report and engineering appendices. All benefits are presented in annual terms, at the 2011 price level. Benefits are converted to average annual equivalents where necessary using the FY13 Federal interest rate for water resources projects of 3.75 percent.

2. Additional Channel Segment to Massport Marine Terminal

The Massport Marine Terminal is located just north of the Reserved Channel on the west side of the harbor in South Boston, on a site known as the North Jetty (Massport Marine Terminal). The 30-acre site was used during the 1990's and early 2000's for storing excavated material from Boston's Big Dig construction project. With the completion of that project, the land is now available for other use and development. The site is owned by the City of Boston but has been leased to Massport through 2070, and includes a berth that is 900 feet long which was dredged to 40 feet with the last channel dredging improvement project. Some repairs would be required to the dock for full usage of the site, as well as construction of some landside support facilities. In 2007, Massport was in final negotiations with a tenant who planned to use the site as a regional import center for cement, but the tenant withdrew due to the economic downturn. The severe recession of 2007 – 2009 has hampered the leasing of the site, but Massport expects it will be used for the import of cement, salt, or construction materials once the local economy recovers.

For the without project condition, it is assumed that the Massport Marine Terminal will be leased and in use for cement or other dry bulk cargo imports by 2016, the base year of the analysis. However, prior to channel dredging, this assumption should be verified, the vessel usage documented, and the economic benefits re-evaluated at that time.

2.1 Benefit Methodology

Benefits for dredging a deeper channel to the Massport Marine Terminal are estimated based on information provided by Massport, and based on information about vessels currently bringing bulk commodities to Boston Harbor obtained from terminal operators and detailed Waterborne Commerce Statistics Center data. Benefits to channel dredging are derived from reduced waterborne transportation costs expected with the project, since a deeper channel would allow larger vessels to be used. Expected waterborne transportation costs were estimated for the without and with project conditions using FY2010 Deep Draft Vessel Operating Costs developed by the Corps of Engineers Institute for Water Resources. The economic benefits to channel dredging equal the difference in expected waterborne transportation costs between the without and with project conditions.

2.2 Economic Study Area and Hinterlands for Bulk Commodities

For the economic analysis of dredging to the Massport Marine Terminal, the economic study area and the hinterlands of the port are defined as the six New England states. It is expected that cement, salt, or other bulk cargo landed at the site would serve the greater Boston area as well as the wider New England-region market.

2.3 Cement and Dry-Bulk Imports to Boston Harbor

There are currently three cement terminals located in Boston Harbor. Coastal Cement operates a terminal in South Boston just above the Reserved Channel. LaFarge Cement has a terminal on the Mystic River near the Autoport facility. St. Lawrence Cement has a terminal off the Mystic River, on Island End River. According to data from the Waterborne Commerce Statistics Center (www.ndc.iwr.usace.army.mil/wcsc), 549,000 tons of cement were brought into Boston Harbor in 2009. Road salt is brought into Boston primarily to the Eastern Minerals terminal at the entrance to the Chelsea River. Total salt volumes vary by year depending on weather conditions, but typically average more than 1 million tons. Recent historical cement, road salt, and other dry bulk volumes for Boston Harbor are shown in Table C2-1, below.

Table C2-1
Recent Historical Imports, Dry Bulk Cargo
Boston Harbor

Commodity Classification	all data in thousand short tons					
	2009	**2008**	**2007**	**2006**	**2005**	**Avg.**
Soil, Sand, Gravel, Rock and Stone	11	57	189	188	231	135
Iron Ore and Scrap	941	706	608	691	382	666
Other Non-Metal Minerals (road salt)	1,260	1,293	797	595	1,531	1,095
Cement, Glass and Lime	549	665	796	907	1,051	794
Primary Iron and Steel	10	126	21	11	64	46
Primary Non-ferrous Metals	90	237	320	242	284	235
Total	2,861	3,084	2,731	2,634	3,543	2,971

Source: Waterborne Commerce of the United States, 2005 - 2009

2.4 World Bulk Carrier Fleet

In 2007, the world bulk carrier fleet consisted of 6,200 vessels greater than 5,000 deadweight tons (*Propulsion Trends in Bulk Carriers*, MAN Diesel A/S, Copenhagen, Denmark, 2007). The size distribution of the bulk carrier fleet of vessels greater than 5,000 DWT is shown in Table C2-2 below. Generally, 35,000 DWT bulk carriers have loaded drafts up to 35 feet, and the larger Handymax bulk carriers of 50,000 to 55,000 DWT have loaded drafts up to 41 feet.

Table C2-2
World Bulk Carrier Fleet, 2007

Vessel Size Class	Deadweight Tonnage (DWT)	Proportion of World Fleet
Small	< 10,000	4.3%
Handysize	10,000-35,000	33.4%
Handymax	35,000-55,000	28.6%
Panamax	60,000-80,000	20.5%
Capesize and larger	80,000-200,000	13.2%

Source: *Propulsion Trends in Bulk Carriers*, MAN Diesel A/S, Copenhagen, Denmark, 2007, www.manbw.com/technical papers

2.5 Without Project Condition

In the Without Project Condition for the Massport Marine Terminal, the channel north of the Reserved Channel remains at the authorized depth of 40 feet, and the berth at the Massport Marine Terminal also remains at a depth of 40 feet. It is assumed that the future tenant develops a bulk terminal at the site with or without a channel deepening project, and that the terminal is fully operational by 2016, the base year of the analysis. Massport expects that the terminal will be used for the receipt of bulk shipments, such as cement, road salt, construction materials, or wind farm components.

2.6 Commerce Forecast and Projected Future Operations

It is expected that shipments to the new Massport Marine Terminal will be brought on large, foreign flag vessels from overseas ports, based on information provided by the previous expected tenant. Based on information provided by Massport and by the tenant expected to use the site before the recession, the commerce forecast for the Massport Marine Terminal is projected to be 300,000 tons of cement, salt, or other bulk cargo by 2016, the base year of the analysis, growing to 600,000 tons by 2020, as the terminal becomes established and assuming moderate economic growth has resumed. These assumptions should be examined prior to construction of the channel deepening project, when actual cargo volumes and the specific characteristics of vessels using the terminal are known.

2.7 Fleet Forecast

A fleet forecast was developed for the Massport Marine Terminal based on information provided to Massport by potential tenants. Without the project, the channel to the Massport Marine Terminal will remain at 40 feet, and vessels calling the new terminal would be limited to 35,000 to 40,000 DWT with drafts of 36 to 37 feet. With underkeel clearance equal to ten percent of loaded draft, these vessels would use the existing 40-foot channel to capacity. In the with project condition, the channel and berth would be deepened to between 42 and 45 feet. With a deeper channel, it is expected that carriers would use larger vessels in order to achieve the economies of scale and lower cost per ton of larger vessels. In interviews with past potential tenants, tenants have indicated that they would prefer to use larger vessels if sufficient depth is available. With channel deepening, shippers could use vessels up to 55,000 DWT with drafts of 40 to 41 feet. These vessels would require 45 feet in the channel with required underkeel clearance. Tenants at the Massport Marine Terminal would be unlikely to use vessels greater than 55,000 DWT due to berth constraints. The fleet forecast for the Massport Marine Terminal is shown below in Table C2-3. Loaded drafts are taken from the Corps Deep Draft Vessel Operating Cost tables (FY2010).

Table C2-3
Fleet Forecast, Massport Marine Terminal
Boston Harbor

Condition	Average Vessel Size	Loaded Draft	Analysis Years
	(DWT)	(feet)	
Without Project (40')	40,000	36.6	2016-2066
With Deepening to 42'	45,000	37.9	2016-2066
With Deepening to 43'	50,000	39.3	2016-2066
With Deepening to 44'	55,000	40.4	2016-2066
With Deepening to 45'	55,000	40.4	2016-2066

2.8 Estimated Benefits

The benefits to channel deepening are estimated by calculating the difference between projected without and with project transportation costs. For the without project condition, transportation costs for transporting bulk cargo on 40,000 DWT vessels requiring 40 feet of channel depths are calculated. For the with project condition, it is projected that shippers will move to larger ships due to the economic efficiencies to be gained. With channel deepening, vessels up to 55,000 DWT could be used, depending on the channel depth available. Transportation costs were estimated using the hourly operating costs developed by the Corps of Engineers Institute for Water Resources, Deep Draft Vessel Operating Costs for Fiscal Year 2010, for the appropriate vessel type, size, and flag. Transportation costs were estimated assuming an average one-way travel time of 20 days for bulk carriers on foreign flag ships from international ports, and 3 days in-port for offloading, based on information provided by the previous expected tenant and by a local shipping agent. Since the vessels would most likely proceed to other US ports to pick up other cargo, only one-way travel time was used. Total transportation costs were calculated as assuming projected volumes of 300,000 tons of cement or other bulk cargo per year in 2016, growing to 600,000 tons per year by 2020, and remaining at 600,000 tons for the following years. The annual benefit figure reflects the average annual equivalent value of the resulting stream of benefits over the 50 year period of analysis. The annual transportation costs and annual benefits using these assumptions are shown below in Table C2-4. No benefits are estimated for channel depths beyond 45 feet since any tenant would be unlikely to use vessels greater than 55,000 DWT due to berth constraints.

Table C2-4
Annual Transportation Cost and Annual Benefits
Channel to Massport Marine Terminal

Condition	Annual Transportation Cost, Initial Volume (300K tons in 2016)	Annual Transportation Cost, Future Volume (600K tons by 2020)	Average Annual Benefits
Without Project (40')	$3,372,000	$6,744,000	-
42' Channel	$3,142,756	$6,285,511	$444,047
43' Channel	$2,958,880	$5,917,760	$800,215
44' Channel	$2,872,830	$5,745,659	$966,894
45' Channel	$2,771,636	$5,543,273	$1,162,906

Two sensitivity analyses were performed to determine how changes in key assumptions affect the estimated benefits. In the first sensitivity analysis, projected commodity volumes were increased to 500,000 tons in year 2016, increasing to 1,000,000 tons by year 2020. These are the volumes that were projected by the past expected tenant, who had intended to import cement to serve markets in the entire northeastern region of the US. The resulting transportation costs and annual benefits are shown in Table C2-5, and represent the potential upper bound of benefits. A second sensitivity analysis was performed in which the assumption that the terminal will be called primarily by foreign flag vessels from international ports was changed. Instead it was assumed that the terminal will be called by US flag vessels from east coast US ports, similar to existing cement traffic into Boston Harbor. These results are shown in Table C2-6, and represent the potential lower bound of benefits. Since the terminal is not in use at this time, it is difficult to project specific usage characteristics of the terminal. Prior to project construction, specific details regarding vessel flags and origin locations can be determined, and the benefits to channel dredging should be re-evaluated.

Table C2-5
Sensitivity Analysis, Massport Marine Terminal
Higher Cargo Volumes

Condition	Annual Transportation Cost, Initial Volume (500K tons in 2016)	Annual Transportation Cost, Future Volume (1M tons by 2020)	Average Annual Benefits
Without Project (40')	$5,620,000	$11,240,000	-
42' Channel	$5,237,926	$10,475,852	$740,078
43' Channel	$4,931,467	$9,862,933	$1,333,691
44' Channel	$4,788,049	$9,576,099	$1,611,491
45' Channel	$4,619,394	$9,238,788	$1,938,177

Table C2-6
Sensitivity Analysis, Massport Marine Terminal
Domestic Traffic Only

Condition	Annual Transportation Cost, Initial Volume (300K tons in 2016)	Annual Transportation Cost, Future Volume (600K tons by 2020)	Average Annual Benefits
Without Project (40')	$1,205,800	$2,411,600	-
42' Channel	$1,135,644	$2,271,289	$135,891
43' Channel	$1,079,200	$2,158,400	$245,225
44' Channel	$1,046,612	$2,093,223	$308,348
45' Channel	$1,009,745	$2,019,941	$379,758

3. Additional Channel Segment – Medford Street Terminal

The Medford Street Terminal is located on the south side of the Mystic River in the Charlestown neighborhood of Boston. The terminal is located next to the Moran Autoport, and was purchased by Massport in the 1980's. Since then, the terminal was leased by the Massachusetts Water Resources Authority to transport construction workers and material to the Deer Island sewage treatment plant, and by others for the waterborne transport of construction materials and equipment. When the existing Federal Navigation Project in the harbor was deepened to 40 feet in the 1990's, the portion of the channel accessing the Medford Street Terminal was not included since the terminal was not in use. As a result, the portion of the channel accessing the terminal has a depth of only 35 feet.

The Medford Street Terminal is still not in use, but was recently leased to the Autoport for long-term development. The Autoport is a private company which imports and exports vehicles, located adjacent to the Medford Street Terminal to the east. The terminal is located in a Designated Port Area, a state zoning designation which requires that the land be used for water-dependent industrial or related uses. Massport expects that the Autoport will find a tenant in the near future when the local economy recovers. The berth at the terminal is 453 feet long and has been dredged by Massport to a depth of 40 feet. The future use of the terminal is unknown at this time, but Massport expects that it will most likely be used to import cement for expanded operations of the LaFarge cement terminal located next to the site.

3.1 Commerce Forecast and Future Operations

The commerce forecast for the Medford Street Terminal is based on information provided by Massport. Massport expects that by 2016, the base year of the analysis, the economy will have recovered and the terminal will be in use. In the without project condition, it is projected that US flag bulk carriers will use the terminal, bringing cement from US east coast ports such as Portland (Maine), Newark, or Baltimore. Based on

information provided by Massport, and based on Massport's discussions with a past potential tenant, it is estimated that 300,000 tons of cement will be landed at the terminal per year. This level of cargo is projected for each year of the 50 year period of analysis, 2016 – 2066.

3.2 Fleet Forecast

A fleet forecast was developed for the future Medford Street Terminal based on information provided by Massport and based on information provided by past potential tenants. Without the project, the channel to the Medford Street Terminal will remain at 35 feet, and the average vessel size will be limited to 25,000 DWT vessels with 32-foot operating drafts assuming 3 feet of underkeel clearance. With the project, the channel would be deepened to a depth between 37 and 40 feet, and larger, more cost-effective vessels could be used. The fleet forecast for the Medford Street Terminal is shown below in Table C2-7.

Table C2-7
Fleet Forecast, Medford Street Terminal
Boston Harbor

Condition	Average Vessel Size	Loaded Draft	Analysis Years
	(DWT)		
Without Project (35')	25,000	31.9	2016-2066
With Deepening to 37'	30,000	33.5	2016-2066
With Deepening to 38'	35,000	35.2	2016-2066
With Deepening to 39'	35,000	35.2	2016-2066
With Deepening to 40'	40,000	36.6	2016-2066

3.3 Estimated Benefits

The benefits to channel deepening are estimated by calculating the difference between the projected without and with project transportation costs. Without channel deepening, it is projected that 300,000 tons of cement will be shipped to the terminal on 25,000 DWT bulk carriers with typical drafts of 32 feet, for which the existing 35-foot channel would be adequate. With channel deepening to 40 feet, the same cargo volume could be carried on 35,000 and 40,000 DWT bulk carriers, depending on the channel depth, vessels with drafts of 35 to 37 feet. Use of larger vessels with channel deepening will allow fewer total trips, thereby reducing total transportation costs. Hourly operating costs as developed by the Corps of Engineers, Deep Draft Vessel Operating Costs for Fiscal Year 2010 were used for the appropriate vessel type, size, and flag to determine total transportation costs under the without and with project conditions. Since the shipments would most likely be between US ports, it is assumed that US flag vessels are used. Total trip costs were estimated assuming 36 hours round-trip travel time for domestic cargo such as cement, and assuming 24 hours in-port. Prior to project

construction, these assumptions should be verified or revised based on the actual usage of the terminal, and the economic benefits reevaluated. The projected transportation costs and estimated annual benefits using these assumptions are shown in Table C2-8.

Table C2-8
Annual Transportation Cost and Annual Benefits
Channel to Medford Street Terminal

Condition	Annual Transportation Cost	Annual Benefits
Without Project (35')	$873,792	-
37' Channel	$775,920	$97,872
38' Channel	$733,710	$140,082
39' Channel	$706,114	$167,678
40' Channel	$652,410	$221,382

As a sensitivity analysis, the commerce forecast for the 40' channel condition was revised to reflect only 150,000 tons of cargo shipped to the terminal each year on vessels large enough to require greater than the existing 35 feet of channel depth. It was assumed that any additional cargo received at the terminal would be on smaller vessels not requiring depth greater than the current 35 feet. This reduces annual benefits with a 40' channel to $110,700, and represents the potential lower bound of benefits.

For a second sensitivity analysis, it was assumed that future cargo at the terminal would be shipped from international ports, with significantly longer travel time on foreign flag ships, similar to existing salt traffic. This increases annual benefits with a 40' channel depth to $563,400, and represents the potential upper bound of benefits.

4. Additional Channel Segment – Chelsea River

The purpose of the analysis contained in this section is to determine the economic justification of deepening the Federal channel in the Chelsea River, Boston Harbor, from 38 feet to 40 feet. The Chelsea River is used primarily by oil tankers, and is one of the main distribution points for gasoline and heating oil in Massachusetts. In addition, most of the airline fuel used at Logan Airport is delivered to a terminal on the river. Until only recently, the use of the river was constrained by the old Chelsea Street Bridge, an old highway drawbridge which connected East Boston and Chelsea. The opening of the old bridge was only 96 feet, which limited the size of vessels using the river. However, that bridge was recently replaced, with the new bridge completed in June 2012. The US Coast Guard, in conjunction with the City of Boston and the Massachusetts Department of Public Works, constructed the new Chelsea Street Bridge to improve navigation safety in the river, reduce the risk and frequency of vessel-bridge collisions, and reduce bridge

repair and vehicle detour costs. The new bridge is a drawbridge with a lift span of 400 feet, allowing for a potential navigation channel of 225 feet between the bridge towers. With construction of the new bridge, the existing navigation channel in the river has been widened to a minimum width of 175 feet.

4.1 Area Description

The Chelsea River, also known as Chelsea Creek, is located in the inner harbor area of Boston Harbor. It is bordered on the west by the city of Chelsea and on the east by East Boston and Revere. Currently, the main channels in the rest of the harbor have authorized depths of 40 feet, while the channel in the Chelsea River has an authorized depth of only 38 feet. Deepening the channel to 40 feet would improve the navigability of the river and increase the safety and efficiency of shipments.

Two bridges cross the Chelsea River, the McArdle Bridge near the inner confluence, and the Chelsea Street Bridge farther upstream. Both are vehicular bridges with heavy urban traffic. The McArdle Bridge has a width clearance of 175 feet, while the original Chelsea Street Bridge had a clearance of only 96 feet. In the past, safety requirements limited the beam of vessels transiting through the old Chelsea Street Bridge to 90.5 feet. However, with the new bridge recently completed, and the channel widened to 175 feet, these restrictions will likely be lifted. From the McArdle Bridge upstream, the authorized depth of the Federal channel in the Chelsea River is 38 feet. The area has a tidal range of 9 feet.

4.2 Chelsea River Terminals

The Chelsea River is one of the primary distribution points for gasoline and oil in Massachusetts and New England. Four oil terminals and one bulk terminal are located along the river. The bulk terminal receives primarily road salt, and is located just upstream of the McArdle Bridge in Chelsea. One of the four oil terminals, Sunoco International, is located on the opposite side of the river in East Boston, between the McArdle and Chelsea Street Bridges. This terminal receives all of the jet fuel for Logan Airport. The remaining three oil terminals are located upstream of the Chelsea Street Bridge, and include Irving Oil and Global Oil on the east side in Revere, and Gulf Oil on the west side in Chelsea. Special oil tankers have been constructed to navigate the narrow Chelsea River, “Chelsea Class” vessels, with beams of only 90.5 feet. These vessels are also used in other restricted ports. The terminals on the Chelsea River with their storage capacities in short tons are: Sunoco - 164,847; Global Oil - 240,691; Irving Oil - 182,981; and Gulf - 236,130.

4.3 Waterborne Commerce on the Chelsea River

In 2009, a total of 5,468,000 tons of petroleum and petroleum products were brought to terminals on the Chelsea River, including gasoline, heating oil, and jet fuel. In addition, 1,004,000 tons of road salt were imported into the Chelsea River in 2009. Recent historical waterborne commerce for the Chelsea River, for petroleum products and road salt, is shown in Table C2-9. The petroleum and petroleum products brought

into Chelsea River terminals consist primarily of gasoline and heating oil. In 2009, 68 percent of the total tonnage was gasoline, 28 percent heating oil, and 3 percent other petroleum products. The significant variation in road salt volumes is due to weather-related demand fluctuation. In years with heavy snowfall and frequent icing conditions there is high demand for road salt, and deliveries to the terminal increase significantly.

Table C2-9
Recent Historical Waterborne Commerce, Chelsea River (only)

Year	Petroleum and Petroleum Products (thousand tons)			Total Petroleum Products	Road Salt (thousand tons)
	Foreign	Canadian	Domestic		
2009	383	3,279	1,806	5,468	1,004
2008	138	2,781	1,979	4,898	1,024
2007	157	3,730	1,947	5,834	526
2006	478	2,593	1,877	4,948	492
2005	403	2,580	2,013	4,996	1,164
2004	533	2,877	1,700	5,110	624
2003	461	3,516	1,801	5,778	959
2002	608	2,672	1,715	4,995	456
2001	1,813	2,184	1,669	5,666	817
2000	1,962	1,373	2,820	6,155	632
1999	1,291	2,216	3,562	7,069	215
1998	1,974	1,714	3,544	7,232	258

Source: Waterborne Commerce of the United States, 1998 – 2009

4.4 Existing Fleet, Chelsea River

The number of inbound vessel trips and vessel drafts for vessels transiting the Chelsea River are shown in Table C2-10. In 2009, the Chelsea River had 599 inbound vessel trips, which included 153 foreign-flag vessels and 446 US-flag vessels. Of the 446 US flag inbound vessel trips, 335 were barges or vessels with shallow drafts less than 19 feet.

Table C2-10
Vessel Draft Distribution, Inbound Trips
Chelsea River, 2009

Draft, in Feet	# of vessels Foreign	# of vessels Domestic	Total # of Vessels
42	0	1	1
41	0	0	0
40	0	0	0
39	11	0	11
38	8	0	8
37	7	0	7
36	17	0	17
35	58	1	59
34	13	0	13
33	5	0	5
32	5	0	5
31	6	1	7
30	6	3	9
29	2	12	14
28	2	11	13
27	3	4	7
26	5	5	10
25	3	9	12
24	1	7	8
23	0	11	11
22	0	7	7
below 22'	1	374	375
Total	153	446	599

Source: Waterborne Commerce of the United States, 2009

Petroleum shipments are brought into the Chelsea River on tankers and barges, with the drafts of the tankers ranging from 22 to 37 feet, and include a mix of US flag and foreign flag vessels. The largest tankers which currently transit to the terminals above the Chelsea Street Bridge are typically 35,000 to 37,000 deadweight tons with 90.5-foot beams. Shipment origins are wide-ranging, with the largest volumes in recent years originating in Canada. Other shipments commonly originate in Europe, Venezuela, and the Caribbean, as well as from domestic ports. The tankers calling on the Chelsea River are sometimes referred to as "Chelsea Class" with beams of 90.5 feet to allow passage through the Chelsea Street Bridge. For domestic shipments, vessels are constructed and placed in dedicated service between U.S. refineries and the Chelsea River terminals. For foreign shipments, vessels are loaded usually in the Caribbean or Europe and their loads

purchased on the spot market by local oil companies. These are small tankers that able to transit the channel without lightering. Road salt is brought into the Chelsea River on foreign flag bulk carriers with drafts ranging from 21 to 42 feet. The salt is imported from a variety of countries, including Mexico, Chile, and Egypt. The US Coast Guard requires that all vessels transiting the river have an underkeel clearance of 2 feet while underway.

Based on detailed Waterborne Commerce Statistics data for the Chelsea River, 71 percent of the vessels calling Chelsea terminals were 20,000 to 25,000 dead-weight tons (DWT), 13 percent were less than 20,000 DWT, 12 percent were 25,000 to 30,000 DWT, and the remaining 4 percent were greater than 30,000 DWT. No vessels transiting the river exceeded 40,000 DWT.

4.5 World Tanker Fleet

In 2007, the world tanker fleet consisted of 5,300 vessels greater than 5,000 DWT (*Propulsion Trends in Tankers,* MAN Diesel A/S, Copenhagen, Denmark, 2007). The current size distribution of the tanker fleet of vessels greater than 5,000 DWT is shown in Table C2-11 below.

Table C2-11
World Tanker Fleet, 2007

Vessel Size Class	Deadweight Tonnage (DWT)	Proportion of World Fleet
Small	< 10,000	21.1%
Handysize	10,000-35,000	19.8%
Handymax	35,000-55,000	24.4%
Panamax	60,000-80,000	5.8%
Aframax	80,000-120,000	13.4%
Suezmax	125,000 - 170,000	6.7%
> Suezmax	200,000 +	8.8%

Source: *Propulsion Trends in Tankers,* MAN Diesel A/S, Copenhagen, Denmark, 2007, www.manbw.com/technical papers

The tankers which call the Chelsea River oil terminals are all in size classes smaller than Panamax. The majority of the world tanker fleet is made up of vessels in the size classes smaller than Panamax, with 65 percent of tankers in the small Handysize and Handymax classes, as shown in Table C2-12. The tankers which call at Boston are primarily Handysize and Handymax vessels, which are also used at other New England petroleum ports.

4.6 Economic Study Area and Chelsea River Hinterlands

For the economic analysis of the Chelsea River deepening, the study area and the hinterlands of the port are defined as the greater Boston area and, secondarily, Massachusetts. Nearly all of the gasoline and heating oil volumes shipped into the Chelsea River are distributed to the greater Boston area of eastern Massachusetts. Other ports in Massachusetts which receive petroleum shipments include Braintree, Weymouth, Quincy, New Bedford, and Fall River, although these ports receive much smaller total volumes than the Chelsea River. Other New England states have their own ports for receipt of petroleum products, including Searsport and Portland harbors in Maine, Portsmouth in New Hampshire, Providence Harbor in Rhode Island, and New Haven, New London, and Bridgeport harbors in Connecticut.

4.7 Chelsea River Without Project Condition

The constraints of the old Chelsea Street Bridge caused many navigation inefficiencies in the Chelsea River. These inefficiencies included requirements of daylight-only transit for large vessels, rules limiting passage upriver while a vessel is at one of the down-river terminals, requirements for extra tugs to navigate safely through the old bridge opening, and limits on the size of vessels which can transit the river which greatly limited vessel capacity. However, with the new, wider Chelsea Street Bridge completed and the channel recently widened to 175 feet, these inefficiencies will likely be eliminated. In terms of channel depth, the existing Federal channel in the river was last dredged in 2008 to the authorized depth of 38 feet.

In the benefit analysis for the deepening the channel in the Chelsea River, it was assumed in the without project condition that construction of the new Chelsea Street Bridge was completed and recent operating restrictions lifted. The new, wider bridge will allow wider vessels to be used. The economic benefits from eliminating the delays and operating inefficiencies caused by the narrowness of the old bridge are allocated to bridge replacement and are not benefits to channel deepening. However, the authorized 38-foot channel depth will continue to constrain navigation in the river to some degree.

4.8 Chelsea River With Project Condition

In the with project condition, the channel in the Chelsea River will be deepened beyond the current authorized depth of 38 feet. Depths of 39 and 40 feet are examined. The deepening will allow oil and bulk shipments to be brought into the river on deeper ships, achieving cost efficiencies and economies of scale. Benefits to channel deepening are calculated by comparing the operating costs of the expected fleet after bridge replacement with the current 38-foot channel, to the operating costs of the expected fleet after bridge replacement with deeper channel depths (39 and 40 feet).

4.9 Chelsea River Commerce Forecast

The primary commodities brought into the Chelsea River are petroleum and petroleum products. As can be seen in Table 9, the total volume of petroleum products brought into the Chelsea River has generally fluctuated between 5 million and 6 million tons per year since 2000. This is a decrease in total volumes from the 1990s, when shipments to terminals in the Chelsea River fluctuated between 6 million and 8 million tons per year. Total volumes have decreased partly because there has been a decrease in terminal capacity over the period, due partly to the institution of just-in-time inventory procedures, and partly to increasing use of natural gas. There have been significant investments in the natural gas pipeline infrastructure in New England, increasing the use of natural gas for heating fuel and electricity generation.

According to the US Census Bureau, the population of Massachusetts is projected to grow by a total of 10 percent between 2000 and 2030, increasing from 6,349,097 to 7,012,009 (US Census, State Interim Population Projections by State to 2030, www.census.gov). This increase reflects projected population growth of approximately 0.35 percent per year, putting Massachusetts in the low to moderate range of expected population growth over the period relative to other states, as southern and western states are expected to grow more quickly. Moderate population growth would generally support moderately increasing demand for both gasoline and heating oil in the study area, the two fuels which are imported into the Chelsea River.

Nationally, the Energy Information Agency (EIA) forecasts steady growth in liquid petroleum consumption in the US through 2030, with total consumption in 2005 of 40.4 quadrillion Btu growing to 52.2 quadrillion Btu's by 2030 (Energy Information Agency, Annual Energy Outlook 2007 with Projections to 2030), an annual increase of 1.2 percent per year. However, the EIA forecasts a slight decrease in heating oil consumption in the northeast over the period 2005 to 2030, from approximately 60 million barrels in 2005 to approximately 55 million barrels by 2030, due largely to the a forecasted increase in natural gas supply into the northeast over the same period, primarily from Canadian sources, and due to the relatively low population growth projected for the northeast over the period (EIA, Future Supply and Demand of Natural Gas, Heating Oil and Propane, Projections for the Northeast from the Annual Energy Outlook 2006). The EIA projects that population in the northeast will increase from 14.3 million in 2005 to 15.3 million by 2020, an increase of 9 percent over the period, or approximately 0.5 percent per year. EIA projects that the ratio of natural gas use over heating oil us will increase from a roughly 1 to 1 ratio in 2005 to 1.3 to 1 by 2030. However, the EIA does projects an increase in gasoline consumption in the northeast, the largest import in the Chelsea River, increasing from approximately 33 million barrels in 2005 to 38 million barrels by 2030, an overall increase of 15 percent, or 0.6 percent per year (EIA, Future Supply and Demand of Natural Gas, Heating Oil and Propane, Projections for the Northeast from the Annual Energy Outlook 2006).

The total commerce forecast for Chelsea River terminals in 2016, the base year of the analysis, is estimated at 6.4 million tons. This includes 5.4 million tons of petroleum products and 1 million tons road salt, equal to the existing 2009 levels. This commerce volume is used for each year of the 50 year period of analysis. While demand for gasoline in the economic study area is project to increase moderately over the planning horizon, corresponding to a moderate increase in population, both factors which would support increased demand for petroleum products brought into the Chelsea River over the planning horizon, these factors were judged to be offset by the increasing use of natural gas for heating fuel in Massachusetts and the lack of recent historic growth in petroleum imports at Chelsea terminals. As a result, a flat forecast of a continuance of existing volumes was judged to be a reasonable commodity forecast over the 50 year period of analysis.

4.10 Benefits to Chelsea River Channel Deepening

The National Economic Development (NED) benefits to deepening the channel in the Chelsea River are determined by estimating the cost of transporting goods into and out of the Chelsea River for the most likely without and with project conditions. The difference in transportation costs between with the without (38-foot channel) and with project (40-foot channel) conditions are the benefits to channel deepening. The deeper channel will permit the use of larger vessels in comparison to the without project condition, beyond that allowed by the bridge replacement alone, as well as reduce tidal delays and lightloading. The difference between the existing condition transportation costs and the without project transportation costs are benefits which accrue to bridge replacement and maintenance dredging. This analysis does not address inefficiencies due to channel width, as there was no indication from channel users that channel width is a problem other than at the Chelsea Street Bridge restriction.

Transportation costs were developed for each terminal for the without project condition, and for the expected likely conditions once the bridge is replaced. Costs were developed on a per-ton basis. Future tonnages were held constant at existing levels as a conservative assumption. For both the without and with project conditions, a future commodity forecast for petroleum and petroleum products delivered to Chelsea River terminals of 6,405,300 tons was used. For each cost calculation, it is assumed that the destination and origin of traffic remains the same over the 50-year period of analysis. The Army Corps of Engineers Institute for Water Resources (IWR) vessel operating costs for FY2010 were used to estimate transportation costs. Each year, IWR publishes vessel operating costs by flag, cargo type, and size of vessel. Cost data for coastal barges was obtained from a report, Coastal Tank Barge Market, authored by the Office of Statistical and Economic Analysis, Maritime Administration, U.S. Department of Transportation, April 23, 2004. This information was updated to reflect the 2011 price level.

Shippers were surveyed about their operating practices, future activity in the Chelsea River, navigational problems currently being experienced, and their views on optimum channel dimensions. Terminals were queried concerning continued operations, desired channel dimensions, tonnages received and shipped, size distribution of fleet

under existing conditions, expected size distribution of fleet after bridge replacement, and the extent of lightering, lightloading and tidal delays. These responses were then combined with detailed vessel movement data from the Corps of Engineers Waterborne Commerce Statistics Center to estimate total transportation costs under the different conditions analyzed.

While transportation cost savings are the benefits analyzed in this analysis, those savings represent only a portion of the advantages of dredging. Improved safety, reduced risk of environmental damage, and a more reliable oil delivery system are important additional benefits of channel dredging.

4.11 Chelsea River Waterborne Transportation Costs

Waterborne transportation costs for goods brought into terminals on the Chelsea River were determined for the expected without project condition and the expected with project condition. Total transportation costs were developed based on detailed movement data for Boston Harbor provided by the Waterborne Commerce Statistics Center (WCSC). The detailed movement data includes information on port destination/origin, trip miles, volume of product carried, type of product carried, vessel identification, operating draft and other data. This file was then matched with a WCSC vessel file to determine ship characteristics, such as design draft, beam, length, deadweight tonnage and other data. Data on both foreign flag and domestic vessel movements were obtained from the WCSC.

The augmented vessel movement data and vessel characteristic data were compiled for each terminal in a spreadsheet. Transportation cost for each vessel movement was calculated for each terminal, and aggregated over all movements for that terminal. Hourly vessel operating costs by vessel size, or deadweight ton (DWT), as developed by the Institute for Water Resources (IWR) were used to calculate transportation costs. The IWR data also includes vessel operating speeds, immersion rates, and vessel dimensions. The types of costs developed in the spreadsheet for this analysis include trip cost and tidal delay cost. Trip hours are determined using the time/distance/velocity relationship. Trip hours are multiplied by the IWR hourly vessel operating cost to determine trip cost. Tidal delay cost is associated with vessels waiting for higher tidal stages in order to safely navigate up the river. Terminal costs include all of the oil terminals in the Chelsea River and the bulk terminal.

Shipper behavioral assumptions were built into the spreadsheet based on information provided by the terminals. Shippers may have different operating preferences with respect to lightloading vessels, lightering vessels, utilizing the tide, underkeel clearance, and channel depth required to shift tonnage to larger vessels. Each vessel movement into (and out of) the harbor is looked at with respect to depth required, depth available and shipper operating procedures. Only those vessels movements that are using the channel to its full capacity are subject to the operating inefficiencies discussed above. The spreadsheet was evaluated at the existing controlling depth for each vessel movement at each terminal. Separate calculations were made for domestic and foreign

flag vessels. If depth required is less than the tidal range, tidal delay is calculated by the spreadsheet. Tidal delay is calculated using a tidal chart relating channel depth to time, depth required, and channel transit time. The average delay is then multiplied by the hourly vessel operating cost to determine tidal delay cost. Lightloading is evaluated using dispersion rates in tons per inch and based on the relationship between maximum vessel draft and available channel depth. No lightering costs were calculated in this analysis, since shippers using the Chelsea River generally do not lighter their vessels.

The spreadsheet was then evaluated for conditions once the bridge is replaced, which includes both the without and with project conditions. For each channel depth evaluated, trip cost and any tidal delay or lightloading costs are calculated for each vessel movement. All vessel movements are then aggregated for each terminal. A cost per ton is developed at each depth for each terminal. This cost per ton is then multiplied by the projected tonnage to determine the shipper's cost at each channel depth.

Tidal delay and any lightloading costs change with each projected increment of channel depth as long as the vessel needs more depth than is available in the channel. As vessel loads increase with additional depth, a given volume can be transported in fewer vessels. Reducing vessel trips lowers total transportation cost. In addition to loading existing vessels more efficiently, shippers will have an incentive to shift tonnage to larger vessels. Larger vessels have greater operating costs, but because they carry proportionately more tonnage, the cost per ton mile declines. Aggregate trip cost will decline for shippers as they substitute larger vessels for smaller vessels or load existing vessels more fully, thereby reducing the number of vessel trips. The depth at which they switch to larger vessels is entered into the spreadsheet based on information provided by the shipper and using judgment based on the economics of using larger vessels. Larger vessels would have to be used efficiently with few delays and only minor lightloading requirements.

Controlling depths for the without and with project conditions were held constant over the 50-year period of analysis. No attempt was made to estimate shoaling rates over the 50-year period, as it is assumed that the project will be maintained at the authorized depth. The difference in total transportation costs between the without and with project conditions equal the benefits to the improvement dredging, deepening the channel in the Chelsea River from 38 feet to 40 feet. Total transportation costs include costs for oil tankers, oil barges, and bulk carriers (salt traffic).

The estimation of transportation costs involves hundreds of arithmetical calculations that cannot be presented in this report. The spreadsheet also contains proprietary information provided to the WCSC by shippers, information that is unlawful to disclose in a public report since disclosure could cause financial harm to the companies which provide the data. For these reasons, only summary data aggregated over all terminals is presented in this report**.**

4.12 Chelsea River Transportation Costs by Channel Depth

Improvement dredging of the Chelsea River would reduce the transportation costs of delivering goods to the Chelsea River. Total transportation costs at different channel depths were calculated for the conditions that will exist when the bridge is replaced. Table 12 displays an estimate of shipping costs by channel depth for the bridge replacement condition. Table 12 includes the without project condition (channel depth of 38 feet), and the with project condition (channel depth of 40 feet). Table 13 shows the expected vessel size distribution at different channel depths once the bridge is replaced and includes the without and with project conditions.

Total transportation costs were developed by channel user and aggregated by channel. Each vessel movement was evaluated as to channel depth needed and channel depth available. If loaded draft plus under keel clearance exceeded depth available for tides other than high tide, tidal delay was calculated. The tidal delay computation involves translating tidal height required into hours through a tidal chart. Transit time to dock was then added to delay and an average delay calculated. The delay was then converted to dollars using the IWR and Maritime Administration vessel operating costs. Tidal delay was summed over all vessel movements and divided by tons carried to arrive at a tidal delay cost per ton. This cost per ton was then multiplied by projected tonnage to determine tidal cost for a user at a given depth. The spreadsheet then changes the channel depth and recalculates tidal delay. This process was repeated for channel depths from the existing controlling depth to the proposed improvement channel depth.

Trip costs were determined by providing additional depth to lightloaded vessels and using dispersion rates to determine the additional tonnage that could be loaded onto vessels. This calculation was only made for vessel trips in which the operating draft was 80 percent of the depth available in the channel for the existing controlling depth. Trip costs were then summed over all vessel movements and divided by tons carried to determine trip cost per ton. Trip cost per ton was then multiplied by projected tonnage to determine trip cost per shipper.

4.13 Chelsea River Transportation Cost With Bridge Replacement

Table C2-12 shows the estimated total transportation costs after the Chelsea Street Bridge is replaced. This condition includes the projected without project condition, in which the channel is dredged to the authorized 38-foot depth and widened at the current restricted area. This condition also includes the with project condition, in which the channel is dredged to an improvement depth of 40 feet. For the without project condition, which includes bridge replacement and the authorized 38-foot channel depth, total transportation cost is estimated to be $48,989,700 annually. For the with project condition, with channel deepening to –40 feet MLLW, the estimated transportation cost is estimated to be $47,053,700 annually. The difference between these two costs is the estimated benefit to channel deepening. The annual benefit to channel deepening thus equals $1,936,000 ($48,989,700 - $47,053,700 = $1,936,000).

Table C2-12
Chelsea River
Annual Transportation Costs by Channel Depth

Depth	Trip Cost	Tidal Delay	Total Cost
33	$49,393,200	$241,700	$49,634,900
34	$49,954,300	$225,600	$50,179,900
35	$50,264,400	$220,600	$50,485,000
36	$49,017,900	$204,700	$49,222,600
37	$49,025,900	$208,800	$49,234,600
38	$48,782,300	$207,400	$48,989,700
39	$47,535,600	$211,700	$47,747,300
40	$46,835,400	$218,400	$47,053,700

Table C2-13 shows the projected number of trips by vessel size at different channel depths once the bridge is replaced, which includes both the without and with project conditions. The projected number of trips for the largest vessel class, vessels greater than 35,000 DWT, increases from 77 trips with the authorized channel depth of 38 feet, to 114 trips with the improvement depth of 40 feet. A review of Paragraph 3.2 shows that the Chelsea terminals have the capacity to accept shipments in larger vessels.

Table C2-13
Number of Vessel trips by DWT and Channel Depth

Channel Depth	Vessel DWT, tons					Total Trips
	<20,000	20,000	25,000	35,000	>=35,000	
33	401	20	74	86	0	581
34	398	5	58	108	2	571
35	383	6	41	115	14	559
36	373	6	17	132	16	544
37	363	0	10	111	47	531
38	356	0	6	81	77	520
39	345	0	6	53	99	503
40	337	0	0	38	114	489

4.14 Chelsea River Fleet Forecast With Bridge Replacement

In the without project condition represented by the channel depth of 38 feet in Table C2-13, a total of 520 vessel trips are projected for the Chelsea River in the without project condition, with 356 (68.5 %) of those trips being barges or vessels less than 20,000 DWT, 6 (1.2 %) trips of vessels in the 25,000 DWT size class, 81 (15.6 %) vessel trips in the 35,000 DWT size class, and 77 (14.8 %) trips in the size class greater than

35,000 DWT. With channel dredging to 40 feet, a total of 489 vessel trips are projected, with 337 (68.9 %) barge trips, 38 (7.8 %) trips of vessels in the 35,000 DWT size class, and 114 (23.3 %) trips of vessels in the size class greater than 35,000 DWT.

From Table C2-11, which shows the breakdown of the world tanker fleet, there are 2,168 (40.9 % of 5,300) vessels in the world fleet that are 35,000 DWT or less. Assuming each of these makes 5 trips annually results in an estimated 10,839 annual trips for the world tanker fleet. For the without project condition in the Chelsea River, it is projected that there will be 443 trips of vessels 35,000 DWT and under, or 4.1 %, of the estimated world fleet trips for vessels of that size. For the with project condition (with channel dredging to 40 feet), it is projected that there will be 375 trips of vessels 35,000 DWT and under, or 3.5 %, of the estimated world fleet trips for vessels of that size.

For vessels in the 35,000 to 55,000 DWT class, it is projected in the without project condition for the Chelsea River that there will be 77 vessel trips, or 1.2 % of the estimated 6,466 world trips for the 35,000 to 55,000 DWT class. This would represent the largest ships likely to transit the channel in the with and without project conditions. For the with project condition (with channel dredging to 40 feet), it is projected that there will be 114 vessel trips in the Chelsea River for vessels in the 35,000 to 55,000 DWT class, or 1.7 % of the estimated world trips for vessels of that size. Thus, the projected fleet distribution for the Chelsea River is reasonable for both the with and without project conditions.

4.15 Chelsea River Channel Deepening Benefit Summary

The annual benefits to deepening the Chelsea River are summarized below in Table C2-14.

Table C2-14
Annual Benefits
Chelsea River Channel Deepening

Project Depth	Without Project Transportation Cost	With Project Transportation Cost	Transportation Cost Reduced	Net Annual Benefits
39' Channel	$48,989,800	$47,747,300	$1,242,500	$1,242,500
40' Channel	$48,989,800	$47,053,600	$1,936,200	$1,936,200

BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND
MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX D-1

PROJECT DESIGN

THIS APPENDIX REVISED APRIL 2013

APPENDIX D1 – PROJECT DESIGN

This appendix consists of three sections. The first section was included in the 2008 Draft and Draft Final Feasibility Report and dealt mainly with channel width design and increased channel bend apex widths, including the results of ship simulation studies.

The second section was prepared in October to December 2012 and dealt with increased depth in the harbor's entrance channel. While increased entrance depth had been analyzed and included in the 2008 report, that analysis relied on PIANC design guidance which yielded an underkeel clearance allowance 50% greater in the entrance channel (6 feet) than in the interior channels (4 feet). Current Corps design guidance used in 2012 required a more detailed and project/vessel specific analysis that forms the basis of the recommendation included in the Final Feasibility Report.

The third section presents an assessment of sea level rise with respect to harbor navigation and facility operations.

APPENDIX D1 – PROJECT DESIGN

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APPENDIX D-1
PROJECT DESIGN
BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY

CHANNEL WIDTH AND BEND DESIGN

In previous improvement studies for the Boston Harbor main ship channel the Corps of Engineers Engineering Manual EM 1110-2-1613 HYDRAULIC DESIGN OF DEEP DRAFT NAVIGATION PROJECTS, dated April 8 1983, provided much of the design criteria for channel depth and width. Additionally, the May 1965 publication of the Committee on Tidal Hydraulics, "Evaluation of Present State of Knowledge of Factors Affecting Tidal Hydraulics and Related Phenomena, Report #3" provided a valuable, if somewhat dated, resource for design criteria. In the intervening years since these publications were issued, vessels have become larger and the ports have expanded to meet the needs of these vessels. New guidance was needed.

A subtle change is taking place with the development of improved knowledge of vessel and human capabilities and reactions to design criteria. The Engineering Manual has been updated with a newer version of the same title and number. Additionally, a joint report of the Permanent International Association of Navigation Congresses (PIANC) and the International Association of Ports and Harbors (IAPH) in cooperation with the International Maritime Pilots Association (IMPA) and the International Association of Lighthouse Authorities (IALA) published the final report of the Working Group II-30 titled "Approach Channels – A Guide for Design" in June 1997.

While both the revised EM and the PIANC guide follow the "traditional" design criteria of examining the location and design vessel specifics, the EM provided more of a scientific/ academic approach whereas the PIANC guide appeared to be written with a more user-friendly, albeit slightly "cook-bookish" approach. The PIANC guide will be relied upon for a majority of this appendix because its clear two-tier approach to design lends itself to this stage of the feasibility study of channel depths in Boston Harbor.

Introduction

Since the 1960s, the engineering effort that has been involved in the design of port channels has been increasingly specialized. Vessels have become larger, longer, and draw more water. They require deeper, wider channels for safety. However, there was a noticeable lack of guidance keeping pace with the industry. Early guidance included the Committee on Tidal Hydraulics report mentioned above, a 1973 report of the PIANC working group 2 on channel dimensions, a 1980 review of the 1973 report, and the EM which was initially published in 1983. For the next fifteen years there was no new guidance issued until the Guide for Design in 1997 (an earlier draft of the guide was available in 1995).

The new guidance reflected developments in ship behavior (hull designs, thrusters, and positioning capability), human factor engineering (using sophisticated computer modeling for

ship handling simulation with live ship pilot operators), and took advantage of nearly thirty years of accumulated data on channel design and ship behavior.

Navigation channel design must be cognizant of the physical location of the channel, i.e. direction of currents and wind, type of vessels calling at the port (liquid bulk, break bulk, containers), capacity for port expansion, bottom geotechnical characteristics, and transportation links. Layout of the channel must provide the correct width, depth, and maneuvering area for the vessels calling at the port.

The PIANC guide calls for two phases of design: 1) a "Concept Design" to rough in the general suggested dimensions; and, 2) a "Detailed Design" to validate the initial design primarily through computer simulation exercises. It will be a stated goal of this design effort to minimize the transit time of vessels calling at Boston Harbor and strive to make the channel available to the design vessel for as much of a tide cycle as possible.

The old adage "time is money" can have a double meaning in the case of navigation channels - it is defined here primarily as meaning the ability to get a vessel into port, off-loaded, and on its way in the minimum time possible. Because of the large hourly operating costs of these vessels, this short turn around can produce more profit to the shipper. However, making a channel capable of providing direct access can be expensive so a trade off will likely be sought.

Channel alignment should consider length of channel, winds, currents, available turning basins, avoiding bends, and avoiding areas where maintenance of channel depths can be troublesome. Straight channels are preferable but when not physically possible smooth bends as opposed to sharp turns should be the rule. Avoid cross currents by aligning the channel with the predominant tidal current. An often-overlooked aspect of channel design is to avoid channels that approach perpendicular to the berth in case of loss of control of the vessel. It is better to have the channel offset and require the vessel to stop and turn to arrive at the berth.

Physical Data

In order to proceed further with the design of the channel more detailed information will need to be documented. While the following listing of suggested data is comprehensive, not all of the inputs are pertinent to this particular analysis.

Design Ship.

- Type, size, and dimensions (length, beam, and draft).
- Maneuverability and normal operational speed.
- Engine type and power rating.
- Bow and/or stern thrusters – power and thrust.
- Number and frequency of transits.
- Type of cargo handled.
- Cargo load condition (trim and draft).
- Number and size of screws and rudders.
- Definitive maneuvering trial or computed data.
- Ballasted operation condition (trim and draft).

Waterway Traffic.

- Ship size variation for present and future channel.
- Smaller vessel use and congestion.
- Navigation cross-traffic condition.
- Ship meeting, passing, and overtaking.
- High number of small craft (sailing ships, fishing vessels).

Weather.

- Visibility, day or night transits.
- Frequency of fog, smog, snow, storms.
- Ice conditions (thickness, duration, extent).
- Rainfall and temperature.

Currents.

- Speed, direction, and duration-flood and ebb.
- Astronomical tide and/or river flow.
- Tide height/current relation.
- Wind tide-induced currents.
- Current variation with depth.

Wind and Waves.

- Wind force, direction, and duration.
- Wind generated waves-heights, period, length, direction, duration, and frequency.
- Wind variability or gustiness.
- Swell waves – heights, period, length, direction, duration and frequency.
- Waves from passing vessels.
- Surges and seiching in berthing areas, particularly where containerships are loaded and unloaded.

Navigation Constraints.

- Obstruction – sunken vessels, abandoned structures.
- Overhead bridges and power line crossing – location, type, and clearances.
- Dredging operations – location and frequency.
- Visible obstructions – high banks, headlands.
- Turns and curves with crosscurrents.
- Strong changes in banks and currents – ends of jetties, side channels, and anchorages.
- Shipyards, terminals, and other moored ships.
- Small-craft harbors and marinas.
- Underground pipelines and cables- location, type, and clearances.

Water Level.

- Tidal variation – range, type of tide (diurnal, semidiurnal, or mixed).
- Tide datum plane – average high and low water.
- Upland river inflow – frequency and duration of effect.
- Abnormal high and low hurricane, storm surge, and wind tide.

Channel Data.

- Channel and overbank hydrography.
- Channel cross section (canal, trench, shallow water).
- Alignment and configuration – turns and curves.
- Channel depth, width, and side slopes.
- Navigation traffic pattern (one-way, two-way).
- Dock and pier configuration – open (piles) or closed (solid, filled construction), finger piers, parallel to channel berthing.
- Length of channel.
- Intersecting lanes, one-way sections in two-way channels, passing areas in one-way channels.
- Approach fairways.

Operational Factors.

- Limits for ship transit operations – wind, daylight/night, tide height, current window.
- Limits for ship sizes.
- Bar closure – waves, fog, and wind.
- Required underkeel ship clearance.
- Ship traffic daily variation.
- Speed reduction to increase safety.
- Tidal advantage – riding high tide for larger draft.
- Ship lightering – offloading to smaller ships, boats, barges.
- Required spacing between ships in tandem.

Geotechnical.

- Stability of side slopes.
- Dredging conditions – hazardous, toxic, and radioactive waste (HTRW), and other polluted material.
- Subsurface bedrock.
- Soil properties – bed and bank material (soft, fluid “mud”, or hard).

Sedimentation.

- Rate of and tendency for siltation.
- Sediment sizes and distribution.
- Movement – scour and shoal areas.
- Source of sediments – upland or littoral.
- Sediment management facilities and techniques.

Water Quality.

- Salinity distribution and variability.
- Dredge disposal areas.
- Biological population – type, density, and distribution.
- Environmentally sensitive areas.

Special Concerns.

- Large change in channel alignment.
- Substantial increase in ship size or load or change in type.
- Major increase in port or terminal ship traffic.
- New port with new pilots.
- Effectiveness of proposed plans to deliver benefits.
- Known safety problems.

Design Opportunities.

- Channel curves – changing to straight segments.
- Channel width – review for possible reduction or need, for local wideners.
- Duplicate channel – ensure absolute requirement.
- Multiple turning basins – possible reduction of number.
- Anchorage areas – determine usage and possibly abandon some.

Support Services.

- Licensed pilotage.
- Tug availability – power, number, and bollard pull.
- Aids to navigation – buoys, channel markers, and range markers.
- Vessel traffic service – advisory or control.
- Information availability (hydrological and hydrometerorological data).
- Dredging and charting services – frequency, accuracy.

Background for Concept Design

A channel design for the design vessel(s) will consider the speed of the vessel with regard to skill of the pilot, ship handling characteristics, and visual clues available to the pilot. Visual clues in the form of buoys generally can be added to the channel once the alignment and channel width has been determined. Although buoys provide the visual clues to pilots and therefore may be used to reduce channel width, current Coast Guard operations are making reliance on buoys being provided and maintained tentative. Buoys should not be used as a crutch for lack of consideration of other factors affecting channel design.

Because crosswinds have an effect on slow moving vessels, allowance for wind must be made. Vessels that sit high in the water present more surface area for the force of cross winds to bear against. Vessel pilots often need maneuvering room within a channel simply due to the continuous course corrections. The depth/draft ratio also plays a role in possible ship maneuverability. As the ratio nears unity bottom drag acts on the vessel which in the case crosswinds is actually beneficial since it is harder for the vessel to be blown off course. Therefore, information on wind speeds and directions are necessary for initial design scenarios.

Similarly, currents affect a vessel's maneuvering in channels to the extent that during certain stages of the tide it may not be safe for transit. A designer will need to weigh the potential time the channel will not be available to a particular vessel against the economics of providing a deeper or wider channel.

Waves and swells will have an effect on both channel depth and width. Swells mostly affect the depth of channels since the amplitude of the swell raises and lowers the vessel keel in relationship to the bottom. Waves have more affect on channel width as they may knock the vessel off course requiring maneuvering area to correct the situation.

Cargo shipped into or out of the port should have an influence on channel design. In the Port of Boston the primary cargo measured by tonnage is petroleum. Running a tanker aground or tearing a gash in its side is not acceptable. Adequate depth and width must be allowed in designing a channel. The liquid natural gas (LNG) ships, although carrying what is considered to be a hazardous cargo, are accorded a nearly complete shutdown of the harbor which is enforced by the Coast Guard when transiting to or from their berths in the Mystic River.

While two-way traffic for large vessels is not critical in Boston at this time due to the existing practice of using the naturally deep area of President Roads for passing, the potential for two-way traffic involving larger vessels in passing situations with smaller ships exists and thought should be given to allowance for a safety lane width between two passing vessels. Typically a one-way channel would be designed for the design vessel(s) and also a two-way channel for the design vessel(s) and a smaller vessel in a passing action. In Boston's case there is such a great number of weekly shallow-draft vessel movements as compared to deep-draft vessel traffic that neither a two deep-draft vessel passing scenario nor concern for passing areas were entertained, but passage between large and small ships was considered.

Bank clearance is part of channel width design. The passage of a vessel within a channel having banks either vertical or sloped is affected by how close the vessel is to the banks. Usually enough width from the bank to negate the effect of the banks is desired. Three factors – speed, bank height, and the depth/draft ratio – control the bank effect phenomenon.

Channel width in bends is also dependent on a vessel's depth/draft ratio. A large ratio (deep water) will allow a tighter bend. Considering most channels have small depth/draft ratios, bend width must be considered even during the concept design. Also, navigational aids, which help pilots keep track of where there are in the bend, may not be available and extra bend width is required for pilot disorientation.

When a vessel is underway in a channel, an effect known as "squat" occurs. This "sinking" of the vessel is related to the speed of the vessel. Designers must account for squat. For initial design it is acceptable practice to use a minimum depth/draft ratio. Typically the ratio used is 1.10 although it sometimes may be as high as 1.15 in calm waters and 1.3 where waves are present. This assumed ratio accounts for the squat as well as inadequate survey information. It must be remembered that as a vessel must travel faster in a channel in order to stay within a portion of the tidal cycle the effect of squat can become pronounced.

Bottom material must be considered when designing a channel. Soft sand is slightly more forgiving than ledge although the designer should keep under keel clearance to a safe level no matter what the bottom consistency. Corps regulations make allowance for hard bottom by permitting extra allowable overdepth in areas of ledge (ER 1130-2-520 Nov 96). This is for channels that have only a small portion of the channel consisting of hard bottom. Otherwise, the channel design depth should have already factored in the under keel clearance and should not be relying on extra overdepth.

Concept Design

The methodology presented in the PIANC guide for the initial design concept has many of the same components as the old EM. They are presented in a simple table format and are additive to a base channel width and depth. The base channel width is a multiple of the vessel beam and the base channel depth is the draft of the vessel. Table D1-1 provides the base channel width while Tables D1-2 thru D1-6 provide the necessary additive widths to complete the concept design. Vessel maneuverability is a subjective view of the design vessel in question.

Table D1-1
Basic Maneuvering Widths

Vessel Maneuverability	Good	Moderate	Poor
Base Channel Width	1.3 B	1.5 B	1.8 B

B = Vessel beam T = Vessel Draft

For demonstration purposes assume Boston's North Broad Sound Channel is being designed for a Post Panamax container ship having a length of 1100 feet, beam of 140 feet, and draft of 47 feet with poor maneuverability. The guidance from Table D1-1 would require a base channel width of 250 feet. Assuming the speed of the vessel in this entrance channel to be 14 knots with winds blowing at 30 knots across the channel requires extra channel width of 56 feet (fast vessel speed in open waters with moderate cross wind requires an adjustment of (0.1 + 0.3) x beam width).

Currents and waves will usually add additional channel width. Based on the hydrodynamic model shown in Appendix G an assumed current of 1.0 ft/sec (ft/sec x 0.5921 = knots) crosses the channel at an angle of 7 degrees the perpendicular component of the current is 0.07 knots and the longitudinal component is 0.6 knots. In this hypothetical case there would be no adjustment of channel width for currents (moderate vessel speed in protected water with cross current of 0.07 knots requires no adjustment and the longitudinal current of 0.6 knots also requires no adjustment to the channel width). Waves are generated by winds blowing over the water surface over some distance. For this channel design example, assume winds of 30 knots blowing for 14 hours over a distance of 150 miles. A significant wave height of 12 feet with a wave period of 9.5 seconds would be generated which equates with a wave length of 462 feet. The guidance indicates a channel width adjustment is needed and would range between 2.0 and 3.0. For this example a factor of 2.0 was used adding another 280 feet to the channel width.

Other factors affecting the width of the channel are the clarity of any navigation aids, the type of bottom material, the depth of the channel, type of cargo typical to the channel, amount of traffic using the channel, type of channel banks, and whether or not the channel will conduct two-way traffic. For this example, assume the navigation aids occasionally are good, the bottom surface is rough and hard, the banks are steep hard edged, the depth of the channel is less than 115 percent of the vessel draft, no hazardous cargo is transported, fewer than one

vessel per hour use the channel, and there will be no two-way traffic. Additional width of channel based on the above is 434 feet (navigation aids adjustment 0.1, bottom surface adjustment 0.2, bank slope adjustment 1.3 for each bank, channel depth adjustment 0.2, hazardous cargo adjustment 0.0, traffic density adjustment 0.0, two-way traffic adjustment 0.0).

Therefore, in this example, the total channel width would sum to 1020 feet or rounded to 1000 feet. However, suppose there were bends in the channel. These too affect the width. The PIANC guidance suggests that the greater the channel depth compared to vessel draft the wider the channel needs to be at a bend due to the vessel "sideslip" since there is little friction between it and the bottom. The variation in width can range from 130% of the vessel's beam to as much as 260% of its beam depending on the depth to draft ratio. In this example of a channel in an inner harbor the depth to draft ratio will be such that the width of the channel will not be governed by the bends.

Table D1-2

Additional Widths for Straight Channel Sections

Width	Vessel speed	Outer channel open water	Inner Channel protected water
Vessel speed (knots)			
- fast > 12		0.1 B	0.1 B
- moderate > 8 - 12		0.0	0.0
- slow 5 - 8		0.0	0.0
Prevailing cross wind (knots)			
- mild < 15 (< Beaufort 4)	all	0.0	0.0
- moderate 15 - 33	fast	0.3 B	-
(Beaufort 4 - 7)	mod	0.4 B	0.4 B
	slow	0.5 B	0.5 B
- severe > 33	fast	0.6 B	-
(Beaufort 7 - 9)	mod	0.8 B	0.8 B
	slow	1.0 B	1.0 B
Prevailing cross current (knots)			
- negligible < 0.2	all	0.0	0.0
- low 0.2 - 0.5	fast	0.1 B	-
	mod	0.2 B	0.1 B
	slow	0.3 B	0.2 B
- moderate 0.5 - 1.5	fast	0.5 B	-
	mod	0.7 B	0.5 B
	slow	1.0 B	0.8 B
- strong > 1.5 - 2.0	fast	0.7 B	-
	mod	1.0 B	-
	slow	1.3 B	-

Prevailing longitudinal current (knots)			
- low < 1.5	all	0.0	0.0
- moderate 1.5 - 3	fast	0.0	-
	mod	0.1 B	0.1 B
	slow	0.2 B	0.2 B
- strong > 3	fast	0.1 B	-
	mod	0.2 B	0.2 B
	slow	0.4 B	0.4 B
Significant wave height H_s and length λ (m)			
- $H_s < 1$ and $\lambda < L$	all	0.0	0.0
- $3 > H_s > 1$ and $\lambda = L$	fast	~2.0 B	-
	mod	~1.0 B	-
	slow	~0.5 B	-
- $H_s > 3$ and $\lambda > L$	fast	~3.0 B	-
	mod	~2.2 B	-
	slow	~1.5 B	-
Aids to Navigation			
- excellent with shore traffic control		0.0	0.0
- good		0.1 B	0.1 B
- moderate with infrequent poor visibility		0.2 B	0.2 B
- moderate with frequent poor visibility		>0.5 B	>0.5 B
Bottom surface			
- if depth > 1.5 T		0.0	0.0
- if depth < 1.5 T then			
- smooth and soft		0.1 B	0.1 B
- smooth or sloping and hard		0.1 B	0.1 B
- rough and hard		0.2 B	0.2 B
Depth of waterway			
> 1.5 T		0.0	> 1.5 T 0.0
- 1.5 T - 1.25 T		0.1 B	< 1.5 T - 1.15 T 0.2 B
- < 1.25 T		0.2 B	< 1.15 T 0.4 B
Cargo hazard level			
- low		0.0	0.0
- medium		~0.5 B	~0.4 B
- high		~1.0 B	~0.8 B

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Table D1-3
Additional Width for Two-Way Traffic

Additional Width	Outer Channel Open Water	Inner Channel Protected Water
Vessel speed (knots)		
- fast > 12	2.0 B	-
- moderate 8 - 12	1.6 B	1.4 B
-slow 5 - 8	1.2 B	1.0 B
Traffic Density		
- light	0.0	0.0
- moderate	0.2 B	0.2 B
- heavy	0.5 B	0.4 B

Table D1-4
Additional Width for Bank Clearance

Bank conditions	Vessel Speed	Outer Channel open water	Inner Channel protected water
Sloping edges			
	fast	0.7 B	-
	moderate	0.5 B	0.5 B
	slow	0.3 B	0.3 B
Steep hard edges			
	fast	1.3 B	-
	moderate	1.0 B	1.0 B
	slow	0.5 B	0.5 B

Table D1-5
Hazardous Cargo Classification

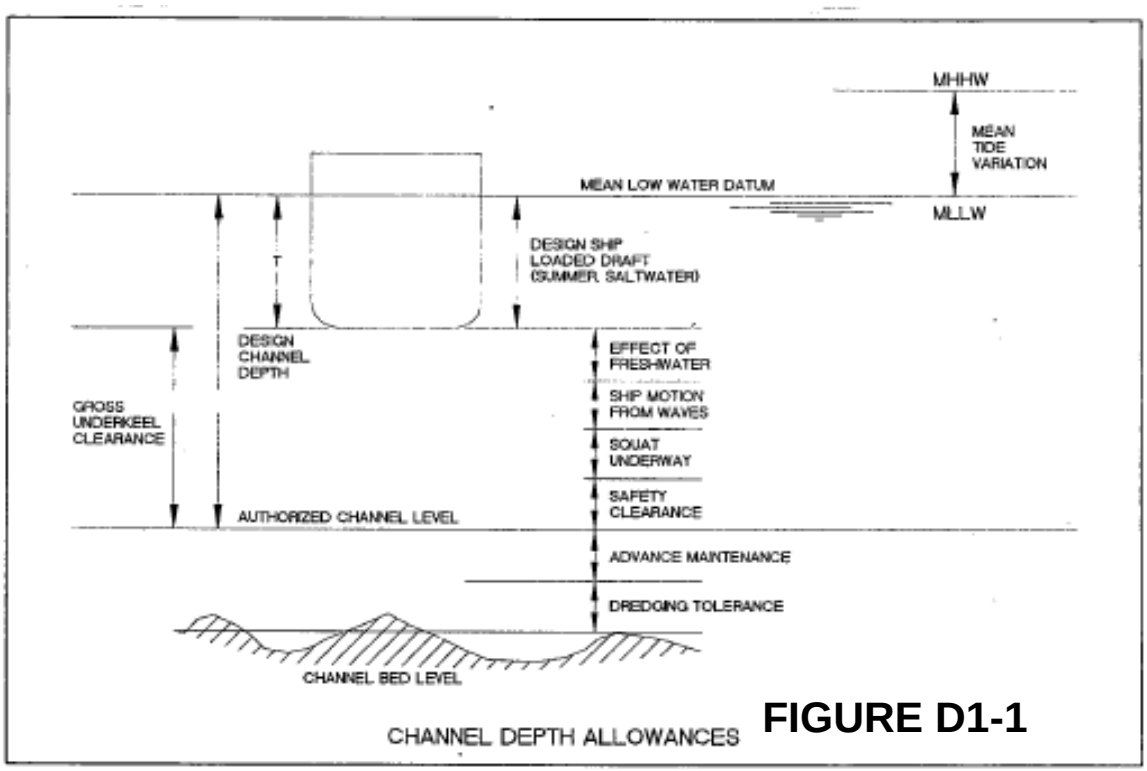
Cargo	Category
Dry bulk, break bulk, containers, passengers, general freight, trailer freight	Low
Oil in bulk	Medium
Aviation fuel, LPG, LNG, Chemicals	High

Table D1-6
Traffic Density Classification

Vessels per Hour	Category
0-1	Light
2 - 3	Moderate
>3	Heavy

Channel depth below a fixed datum is derived from the vessel's draft, squat, wave action, and a safety factor. Typically the tide should not factor into the calculations unless the intent is to "ride the tide" and enter the channel at times other than the minimum tide. Squat is defined as "the tendency of a vessel to sink and trim when underway" in other words as the vessel moves it's underkeel clearance is reduced. These factors are illustrated in Figure D1-1. The PIANC guide provided a formula and a figure to graphically calculate squat. However, the guide also suggested that a minimum depth to draft ratio be used for initial channel depth. The ratio should be 1.1 for calm water all the way up to 1.5 for waters subject to severe wave action

Figure D1-1 is taken from Engineering Manual 1110-2-1613 (2006) – deep draft navigation design. This illustrates in general the various considerations in channel depth design



From: EM 1110-2-1613 (2006)

Design Vessels

The vessels examined in this appendix will be:

Suez-Line	Post Panamax Ship	Typical Ranges
Capacity:	7500 TEUs	7200 - 8500 TEUs
Length:	1050'	1000' - 1200'
Beam:	141'	140' - 150'
Draft:	47'	46' - 48'

Existing Lines	Largest Panamax Ships	Typical Ranges
Capacity:	4500 TEUs	
Length:	900'	up to 900'
Beam:	106'	105' - 106'
Draft:	43'	42' - 43'

Excursion Boat	Boston Cruise Lines
Capacity:	600 passengers
Length:	145'
Beam:	40'
Draft:	12.5'

Tanker	Mystic River
Capacity:	87,000 dwt
Length:	840'
Beam:	138'
Draft:	45' (will be light loaded)

LNG Tank Vessel	Mystic River
Capacity:	125,000 cubic meters
Length:	940'
Beam:	140'
Draft:	42'

Tug	
Length:	100'
Beam:	29'
Draft:	12.5'

Channel Widths

Design conditions to be used for developing channel widths for the various design vessels and one- and two-way traffic are as follows:

Vessel maneuverability without tug support	poor – factor 1.8
Vessel maneuverability with tug support	good – factor 1.3

Vessel speed (pilots indicate 14 knots in entrance channel but slow say to 8-10 knots when meeting tugs in inner channel) without tugs (entrance channel) – fast – factor 0.1
with tugs (inner channel) – moderate – factor 0.0

Cross winds (pilots indicated max wind for operations 30 knots)
without tugs (entrance channel) – moderate – factor 0.3
with tugs (inner channel) – moderate – factor 0.4

Cross current (1993 study of current speeds within Boston Harbor predicted a maximum current in the harbor of less than 2 knots parallel with existing channel)
without tugs (entrance channel) – negligible – factor 0.0
with tugs (inner channel) – negligible – factor 0.0

Longitudinal current (1993 study of current speeds within Boston Harbor predicted a maximum current in the harbor of less than 2 knots parallel with existing channel although the 2005 study indicated stronger currents in the vicinity of Deer Island)
without tugs (entrance channel) – fast – factor 0.0
with tugs (inner channel) – moderate – factor 0.1

Significant waves (pilots indicated max wind for operations 30 knots and considering a fetch length of 300 miles we would have a fully arisen sea state with a significant wave height of 18' and a period of 13 seconds however it was assumed that pilots would not operate when waves were that large so judgment was used in selecting adjustment factor)
without tugs (entrance channel) – fast – factor 2.0
with tugs (inner channel) – slow – factor 0.0

Navigation aids without tugs (entrance channel) – good – factor 0.1
with tugs (inner channel) – good – factor 0.1

Bottom surface (based on existing ledge locations and elevations)
without tugs (entrance channel) – rough and hard – factor 0.2
with tugs (inner channel) – rough and hard – factor 0.2

Channel Depth without tugs (entrance channel) – <1.25 T – factor 0.2
with tugs (inner channel) <1.15 T – factor 0.4

Hazardous cargo (judgment was used on the criteria by assuming the LNG shipments high hazard and the oil shipments medium hazard whether in the entrance or inner harbor channels) without tugs (entrance channel) – high/medium – factor 1.0/0.5
with tugs (inner channel) – high/medium – factor 0.8/0.4

Vessel traffic (traffic is considered light for two-way traffic and in particular the LNG traffic causes the channel to close to other traffic)
without tugs (entrance channel) – light– factor 0.0
with tugs (inner channel) – light– factor 0.0

Bank Clearance (existing ledge creates steep banks factor assigned to inner harbor because of past mishaps with ledge contact)
without tugs (entrance channel) – steep hard edge – factor 1.3
with tugs (inner channel) – steep hard edge – factor 1.0

Using the Concept Design criteria and the Design Vessels Table D1-7 provides suggested channel widths for various combinations for one-way and two-way traffic entering the port of Boston. Although wind roses for various months (see end of appendix) show the greatest winds coming from the west, pilots relate that it is the easterly winds that most affect their operations. Vessel speeds reported by the pilots were 14 knots in the entrance channel, and wind speeds of 30 knots were used for the entrance channel simulation. Channel widths were calculated without tugs. The excursion boat was used for two-way traffic scenarios (larger vessels currently use President Roads for passing). A range of channel depths are shown since further refinement to balance the cost of dredging compared to lost benefits during periods of the tidal cycle when the channel will not have adequate depth for design vessels requires economic analysis.

Tidal delays are something shippers are loath to endure. With a tide range of 9.5 feet most companies plan ahead to load vessels appropriately for expected conditions upon arrival or departure. It is an imprecise exercise but with forethought it becomes a means of providing several extra feet of operating draft. The basic concept is to enter the harbor on a rising tide and be at the berth off loading before the tide falls. Consideration must be given to the rate of tidal fluctuation (9.5 feet in 6 hours or 1.6 feet/hour), tide cycle (predictable), vessel speed (varies by vessel/weather conditions/location in harbor), required underkeel clearance (typically 4 feet), berth depth, and general sea conditions.

Suppose a container vessel with a loaded draft of 42 feet with a required underkeel clearance of 4 feet desired to begin its approach to the harbor three hours before high tide. Water depth at the ocean end of the entrance channel would be approximately 44.7 feet (40 feet + (9.5 feet – 3 x 1.6 feet)). There is not enough depth to begin the transit and a delay is encountered,. In this case a depth of 48 feet is required at the entrance to the harbor (42 feet + 4 feet + 2 feet due to wave conditions at the entrance). The vessel would need to slow its approach to the harbor by two hours allowing a rise in tide level of 3.2 feet thus providing the minimum depth of 47.9 feet (which should be adequate for passage through the entrance).

Traveling at 14 knots it should take roughly 15 minutes to travel the 3.4 miles the North Broad Sound and arrive at the President Roads reach. Slowing to 12 knots it would take another 5 minutes to travel the 0.8 miles to the bends at Spectacle Island and a final 20 minutes to travel the 2.1 miles at 8 knots to the Reserved Channel Turning Area. To get to a berth in the Reserved Channel takes another 25 minutes. Accounting for this transit time the vessel arrives at the berth with a depth in the channel of about 49.5 feet (47.9 feet + 1.6 feet) which allows more than two hours to begin off-loading before depth at the berth becomes an issue. Similar timing is required for out-bound vessels although the drafts tend to be less so there is a larger window of opportunity to leave the berth and still have the required depth at the outer channel entrance. The main report provides more details in a section titled “Tidal Navigation” and Tables 27 and 28.

Table D1-7

CHANNEL DESIGN BY REACH
BROAD SOUND NORTH ENTRANCE CHANNEL

Channel Segment	**North Broad Sound**				
		Type Traffic	1 Way	1 Way	1 Way
Vessel					
		Type	Container	Tanker	LNG
		Length	1100	840	940
		Beam	141	138	140
		Draft	47	45	42
		Speed	14	14	14
Maneuver ability		Poor	1.8	1.8	1.8
Speed	14 knots	fast	0.1	0.1	0.1
Winds	30 knots	Moderate	0.3	0.3	0.3
Cross Currents		negligible	0	0	0
Long Currents	2 knots	fast	0	0	0
Waves	12 ft	fast	2	2	2
Aids to Navigation		good	0.1	0.1	0.1
Bottom		hard	0.2	0.2	0.2
Channel Depth		<1.25	0.2	0.2	0.2
Hazard			low	med 0.5	high 1
Sub-Total			4.7	5.2	5.7
Bank	steep hard	fast	1.3	1.3	1.3
Passing - Speed			0	0	0
- Density			0	0	0
Total			7.3	7.8	8.3
Required Width			1029	1076	1162

Table D1-7 (Continued)

CHANNEL DESIGN BY REACH – PRESIDENT ROADS CHANNEL REACH OF MAIN SHIP CHANNEL

Channel Segment	**President Roads**						
		Type Traffic	1 Way		1 Way		1 Way
Vessel							
		Type	Container		Tanker		LNG
		Length	1100		840		940
		Beam	141		138		140
		Draft	47		45		42
		Speed	10		10		10
Base		good	1.3		1.3		1.3
Speed	10 knots	moderate	0		0		0
Winds	30 knots	moderate	0.4		0.4		0.4
Cross Currents		negligible	0		0		0
Long Currents	2 knots	moderate	0.1		0.1		0.1
Waves			0		0		0
Aids to Navigation		good	0.1		0.1		0.1
Bottom		hard	0.2		0.2		0.2
Depth		<1.15T	0.4		0.4		0.4
Hazard			low	0	med	0.4	high 0.8
Sub-Total			2.5		2.9		3.3
Bank	steep hard	moderate	1		1		1
Passing - Speed		moderate	0		0		0
- Density		light	0		0		0
Total			4.5		4.9		5.3
Required Width			634.5		676.2		742

Table D1-7 (Continued)

CHANNEL DESIGN BY REACH – PRESIDENT ROADS CHANNEL REACH OF MAIN SHIP CHANNEL – TWO-WAY TRAFFIC

Channel Segment	**President Roads**					
		Type Traffic		2 Way		2 Way
Vessel						
		Type		Container		Tanker
		Length		1100		840
		Beam		141		138
		Draft		47		45
		Speed		10		10
Base		poor		1.8		1.8
Speed	10 knots	moderate		0		0
Winds	30 knots	moderate		0.4		0.4
Cross Currents		negligible		0		0
Long Currents	2 knots	moderate		0.1		0.1
Waves	3 ft	moderate		0.5		0.5
Aids to Navigation		good		0.1		0.1
Bottom		hard		0.2		0.2
Depth		<1.15T		0.4		0.4
Hazard			low	0	med	0.4
Sub-Total				3.5		3.9
Bank	steep hard	moderate		1		1
Passing - Speed		moderate		1.4		1.4
- Density		light		0		0
Total				10.4		11.2
Required Width				1466.4		1545.6

Table D1-7 (Continued)

CHANNEL DESIGN BY REACH – LOWER MAIN SHIP CHANNEL REACHES

Channel	**Lower Main Ship**		Lower Main Ship		Lower Main Ship		Lower Main Ship	
		Type Traffic	1	Way	1	Way	1	Way
Vessel								
		Type		Container		Tanker		LNG
		Length		1100		840		940
		Beam		141		138		140
		Draft		47		45		42
		Speed		6		6		6
Base			good	1.3	good	1.3	good	1.3
Speed	6 knots	neg.		0		0		0
Winds	30 knots	moderate		0.4		0.4		0.4
Cross Currents	.2 knots	negligible		0		0		0
Long Currents	2 knots	moderate		0.2		0.2		0.2
Waves				0		0		0
Aids to Nav		good		0.1		0.1		0.1
Bottom		hard		0.2		0.2		0.2
Depth		<1.15		0.4		0.4		0.4
Hazard			low	0	med	0.4	high	0.8
Sub-Total				2.6		3		3.4
Bank	steep hard	slow		0.5		0.5		0.5
Passing - Speed				0		0		0
- Density				0		0		0
Total				3.6		4		4.4
Req'd Width				507.6		552		616

Based on the validated numerical model and the deepening alternatives modeled, current speeds will not change significantly in the Boston Harbor Navigation Channel and that it is likely that changes in channel layout would have more of an impact on ship handling. The maximum increases were found to be less than 5% which likely falls within modeling error and/or the natural variation in real life currents due to spring and neap tide cycles and wind generated current impacts.

Channel width appears to be governed by the LNG ship primarily due to the hazardous nature of its cargo. Since the vessel is only a weekly visitor to the port consideration to other vessels should be given higher priority.

Channel width in the outer entrance channel to Finns Ledge (1100 feet) and the next straight reach to Deer Island turn (900 feet) appear to be adequate. Usually tugs meet the vessels going to the Mystic or Chelsea Rivers in the vicinity of Commonwealth Pier upstream of the Reserved Channel. However, vessels bound for Reserved Channel are met at President Roads. Therefore, channel widths would not necessarily need to account for tugs until after the Deer Island turn. Existing channel width in President Roads reach is 1200-foot wide indicating all of the design vessels would pass easily as verified by the existing practice. It is the 600-foot Spectacle Island, Middle Ground Shoals, and Castle Island channel reaches that appear to need widening.

Since there are no longer oil terminal facilities in the Reserved Channel, both the oil tanker and the LNG design vessels would be docking upstream of the Reserved Channel and the oil tankers would have no need for tugs until past the Reserved Channel. That leaves the two containerships with tugs and a containership and excursion boat upon which to base the channel width for the Main Ship Channel seaward of the Reserved Channel.

A suggested channel width of 500 feet would suffice for either containership for one-way traffic. However, channel widths in the entrance and bends would need to be increased. Table D1-8 shows the effects of the bends between channel segments and the required adjustments are shown in Figures D1-2 thru D1-5. The Ship Simulation exercises conducted for this study (see Appendix H) recommended widening a portion of the inner harbor reach in the vicinity of the bends.

Table D1-9 provides vessels transiting the port. For large carriers the asymmetrical channel configuration at Boston Harbor, with its 35 and 40-foot lanes, does not allow for passing situations, except for smaller vessels using the shallower lane to pass larger ships. Passing of two large vessels only occurs at President Roads and more rarely in the channel lane cross-over off Fort Point. President Roads is a passing reach and retains its 1200-foot width partly for that purpose. However, deepening the entire 1500 to 1200-foot wide entrance and main ship channels would be economically impractical. Any widening of the deeper lane for increased vessel size would be accomplished by incorporating a portion of the shallower lane. This means that the existing passing situation would be incorporated into any plans for channel improvement and would therefore be both a without-project and with-project condition. Given the short main channel transit times to South Boston of 1.25 hours, passing situations for two large vessels would continue to be rare, even in the with-project condition base case, or with the expected increase in container shipping in the higher end economic scenarios that add an additional liner service at Boston. Total transits of the Main Ship Channel under the with-project condition would still be only about 15 to 16 large vessels weekly, an insufficient level to warrant two-way traffic for large vessels passing each other. One-way traffic of large vessels will remain a component of any improvement plans.

Table D1-8

Suggested Bend Widths

	One-Way Traffic								Two-Way Traffic	
Design Vessel	Post-Panamax		Panamax		Tanker		LNG		Post-Panamax	
Beam Width (ft)	141	199	106	164	138	196	140	198	181	239
Length (ft)	1050	1050	900	900	840	840	940	940	1050	1050
Draft (ft)	47	47	43	43	45	45	42	42	47	47
	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)
Criteria (Bends)										
Depth to Draft Ratio (min = 1.10)										
@42	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
@44	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
@46	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
@48	1.1	1.1	1.1	1.1	1.1	1.1	1.15	1.15	1.1	1.1
@50	1.1	1.1	1.15	1.15	1.1	1.1	1.2	1.2	1.1	1.1
@52	1.1	1.1	1.2	1.2	1.1	1.1	1.2	1.2	1.1	1.1
Swept Bend Width (ft)										
@42	543	766	408	631	600	853	679	960	733	968
@44	543	766	408	631	600	853	679	960	733	968
@46	543	766	408	631	600	853	679	960	733	968
@48	543	766	408	631	600	853	686	970	733	968
@50	543	766	413	640	600	853	692	978	733	968
@52	543	766	418	646	600	853	692	978	733	968

D1-20

Table D1-8 (Cont.)

Suggested Bend Widths

	One-Way Traffic								Two-Way Traffic	
Design Vessel	Post-Panamax		Panamax		Tanker		LNG		Post-Panamax	
Beam Width (ft)	141	199	106	164	138	196	140	198	181	239
Length (ft)	1050	1050	900	900	840	840	940	940	1050	1050
Draft (ft)	47	47	43	43	45	45	42	42	47	47
	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)	(w/o tugs)	(w/tugs)
Criteria (Bends)										
Turning Radius (ft)										
@42	15540	15540	13320	13320	12852	12852	14852	14852	15750	15750
@44	15540	15540	13320	13320	12852	12852	14852	14852	15750	15750
@46	15540	15540	13320	13320	12852	12852	14852	14852	15750	15750
@48	15540	15540	13320	13320	12852	12852	11562	11562	15750	15750
@50	15540	15540	10170	10170	12852	12852	10152	10152	15750	15750
@52	15540	15540	8820	8820	12852	12852	10152	10152	15750	15750

D1-21

Upstream of the Reserved Channel and downstream of the depth-limiting Ted Williams Tunnel the suggested one-way traffic channel width is 650 feet for a Post-Panamax vessel and 500 feet for a Panamax dry-bulk vessel (the most likely design vessel to use the Massport Marine Terminal, the one deep-draft facility on this channel reach). However, considering the area between the channel and the berth would need to be dredged to the same depth as the channel to permit vessels to safely traverse to the berth, an allowance was made and the proposed deep channel width will remain at 600 feet. Also, as suggested during the Independent Technical Review of this Appendix, the adjacent 35-foot channel lane would also provide adequate depth for tugs alongside the lager transiting boats, allowing the existing 600-foot width of the channel's deep lane to suffice for these larger bulk carriers.

Bend Widths

However, the Boston Harbor Entrance Channel is not a single straight segment. It consists of several segments connected by channel bends. The bend at Finn's Ledge is a 25-degree bend to port upon entry, the bend at Deer Island consists of three bends – two 21-degree bends and a 9-degree bend all to starboard, the bend at Spectacle Island is also a combination to starboard of 10-degrees and 20-degrees, and the final bend at Middle Ground Shoal is another starboard bend of 22-degrees.

The PIANC guide suggests that at high depth to draft ratios, the width of a bend needs to increase since there is little friction between the vessel and the bottom to prevent "sideslips". The guide provides two figures for use in determining bend widths. Each figure uses the channel depth to draft ratio and the rudder angle during the turn. For the Concept Design phase a rudder angle less than "full rudder" is recommended to allow a margin of safety. A depth to draft ratio of 1.1 is the minimum ratio as anything lower produces very sluggish maneuverability. Examining the figures, which were based on a single screw/single rudder containership, a rudder angle of 15 degrees and depth to draft ratio of 1.1, the turning radius should be 12 times the vessel length and the swept width will be 1.1 times the vessel beam. However, to be conservative, it should be realized that vessels entering the Boston Harbor main ship channel would likely do so near high tide or on a rising tide in order to take advantage of the nine-foot tide. This would change the depth to draft ratio to 1.2 changing the swept width only by 0.1 additional beam width but drastically reduces the turning radius down to 7 times the vessel length.

Laying the turning radius aside for the moment, the bend width necessary would be the base of 1.1-1.2 times the beam plus accounting for the same factors mentioned above which affect the straight segments for a total of 3.9-4 times the beam or 546-560 feet which is just slightly more than the straight segments so the suggested width of the required channel would be constant throughout at say 550 feet.

Channel bends on the other hand present more of a challenge. The turn at Finns Ledge has a radius of 12,000 feet but according to Table D1-8 the Post Panamax design vessel requires a radius of 15,550. This assumes the need for two-way traffic does not exist as the excursion boats follow the Narrows Channel on their way to Provincetown. An 800-foot channel with the 15,550-foot radius on the centerline will not fit within the limits of

the existing Federal channels. A bend easing would be required at the inside of the bend. See Figure D1-2.

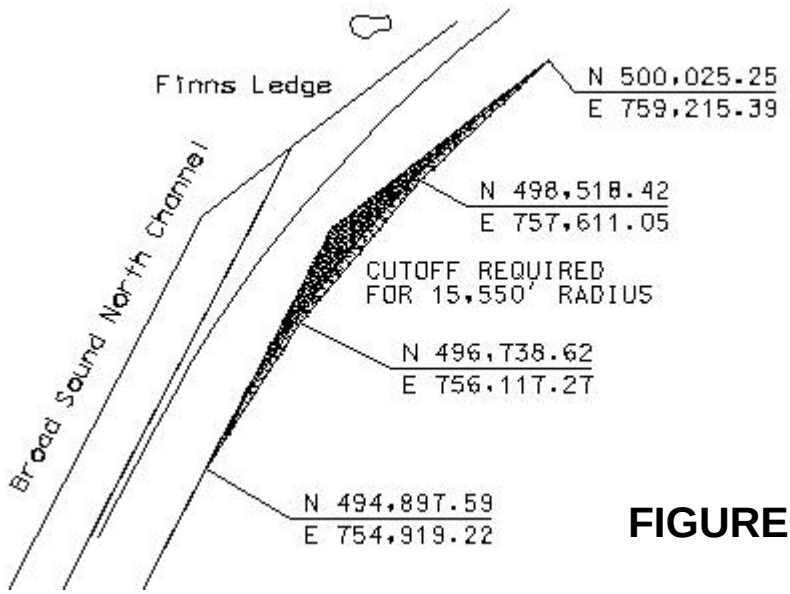


FIGURE D1-2

At the Deer Island bend the combination of three turns within a short distance creates a very difficult situation. A turn radius of 15,550 creates a swath that totally is outside of the existing channel at the apex of the bend. However, vessels are currently negotiating the bend within the existing channel limits. Figure D1-3 shows an 800-foot wide channel bend with a radius of 5000 feet. Pilots may be taking advantage of the wider channel in this bend. Ship simulation with the larger Post Panamax vessels showed the short radius will work with the extra width provided in the bend.

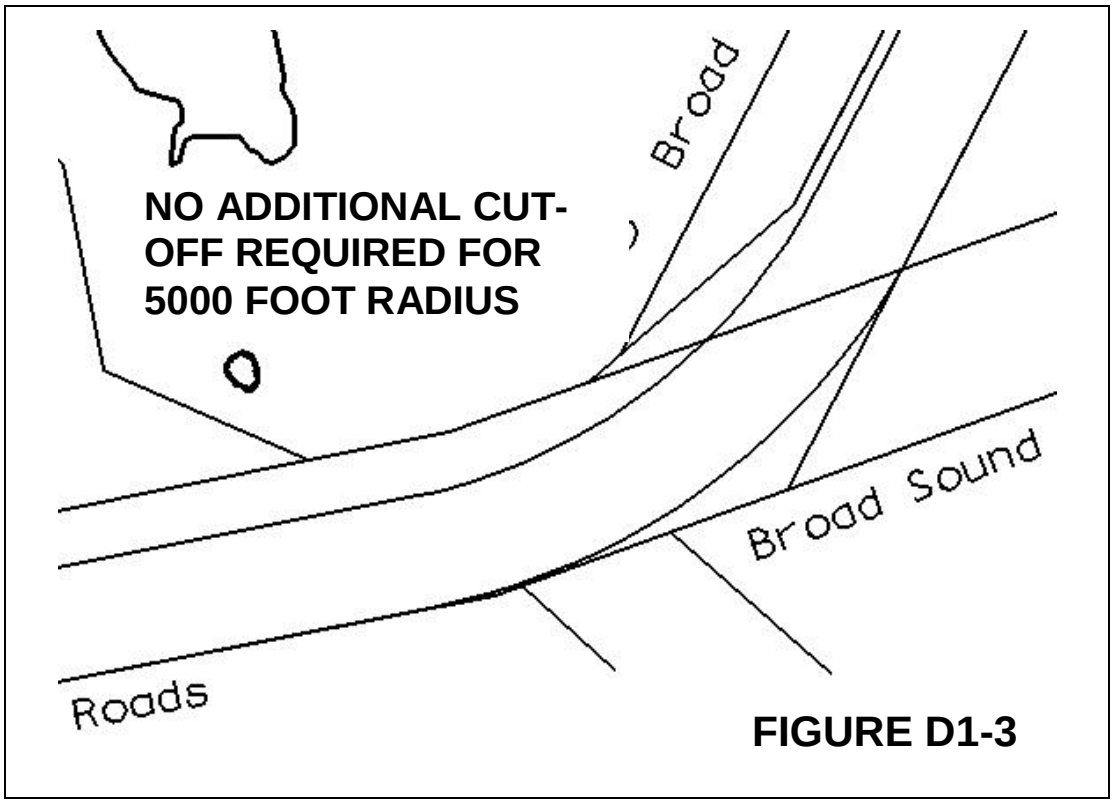


FIGURE D1-3

Similarly, Spectacle Island reach will not allow a 15,550-foot radius bend. Figure D1-4 shows a 10,000-foot radius bend which requires significant bend easing in the 35–foot channel as well as a slight widening adjacent to Spectacle Island.

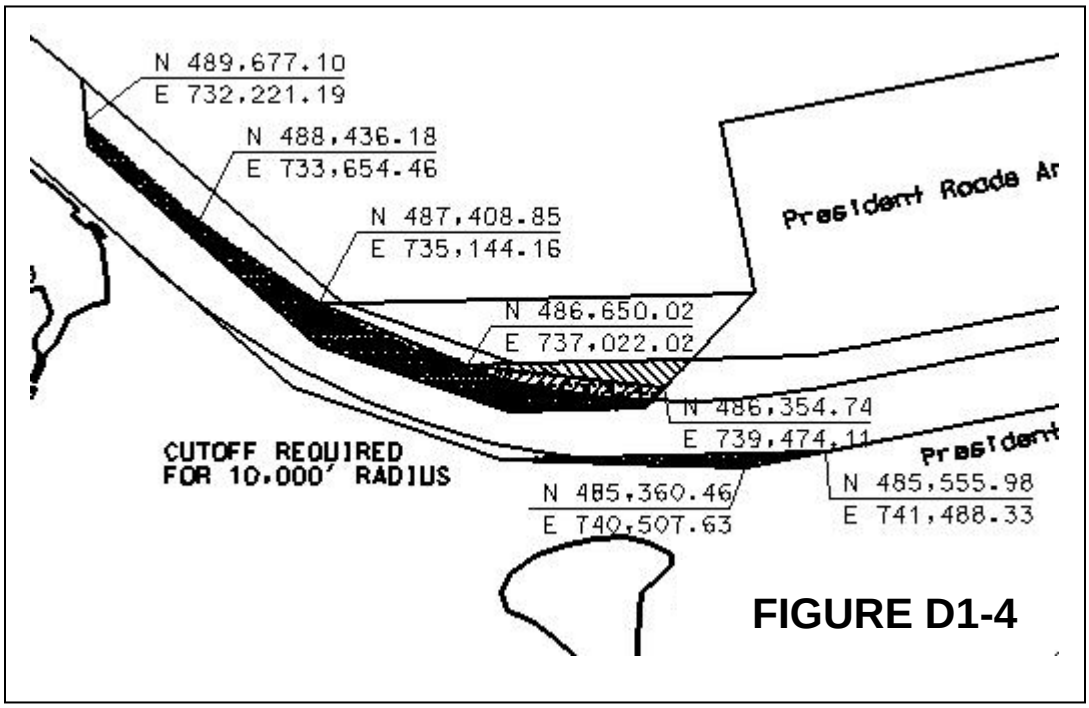


FIGURE D1-4

Figure D1-5 is similar to Figure D1-4 but depicts an 8400-foot radius and does not require any channel widening adjacent to Spectacle Island. This layout assumes vessels would make use of the full 1200 feet of channel width within President Roads. Furthermore, if a triangular portion of the 35-foot channel south of the 35-foot trapezoidal anchorage area is included in the bend easing then the transition from the 1200-foot wide President Roads channel to an 800-foot Main Ship channel is made easier. This has been further refined by the ship simulation exercise and now the recommended channel does not protrude into the existing 35-foot channel as much as initially contemplated.

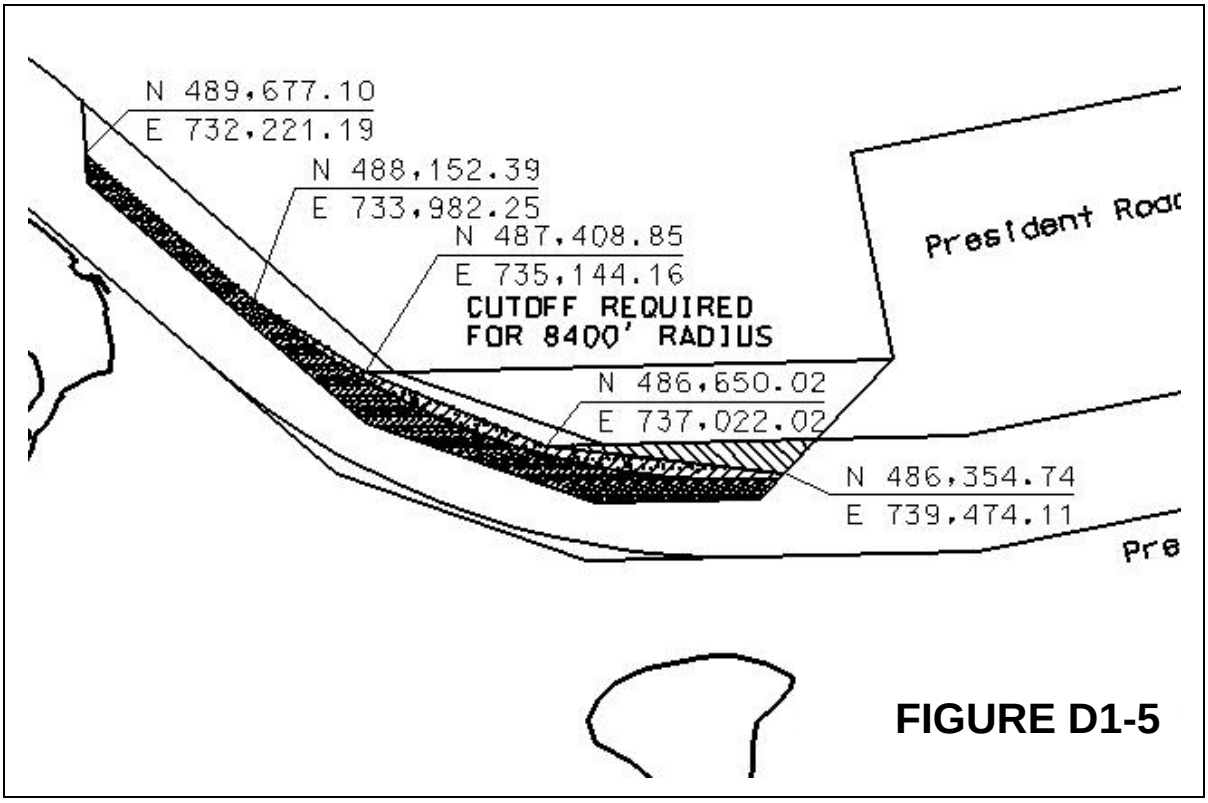


FIGURE D1-5

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Mystic and Chelsea Channels

The only modification under consideration for the Mystic River Channel at this time is an extension of the 40-foot channel cut along the southern, Charlestown, shoreline, upstream above Massport's Boston Autoport (Moran Terminal) to the Medford Street Terminal.

The 1992-93 ship simulation study examined widening of the 40-foot channel downstream of the Inner Confluence as a means of providing tankers a safer access to the Mystic River. These improvements were accomplished during the recent deepening of the Mystic River channel to 40 feet.

The 1995 simulation recommended slight modifications to the Chelsea Channel by minor widening in the two bridge approaches and in the wide bend between the two bridges. An increase in channel width of 50 feet has been incorporated in the design along the East Boston shore immediately upstream of the McArdle Bridge and in the bend between the bridges.

Construction of the new Chelsea Street Bridge is scheduled to begin in 2008 and will require two years to complete the new vertical lift span, after which the old span will be removed. At that time the Corps would widen the channel cut through the bridge to the authorized 38-foot depth under its operations and maintenance authority.

Deepening of the channel to 40 feet would include the widened channel limits through the new bridge passage. The 1992-93 ship simulation study examined the current design vessel for transits of Chelsea Creek under a scenario that considered replacement of the Chelsea Street Bridge, so additional simulation studies for this waterway segment were not repeated for this study.

The impact of the channel widening and deepening on physical parameters such as sedimentation and shoaling rates is expected to be negligible. With a dredging cycle measured in decades it is difficult to predict specific changes to these rates that could be associated with the proposed work. The 1993 Numerical Model Study concluded the proposed improvements will have little effect on tidal circulation in the harbor. Differences in current speeds throughout the harbor were less than 0.1 fps with no significant change in current direction. The 2005 hydrodynamic model reached similar conclusions about current speeds indicating that the predicted different current speeds were within the error margin of the model. Ship wakes would be most noticeable in the entrance channel and comparable to small swells impinging on the outer islands. Within the harbor, under tug assistance, the wake is limited. Concern has been expressed about erosional forces caused by tidal currents and the “drawdown” and “return velocity” effects, particularly in the Chelsea River due to the narrow channel. A 1994 report on the impacts to existing wharves concluded that a review of various formulas for movement of a vessel during post-improvement conditions showed minimal and in some cases no change in drawdown, or bow velocities and thus associated erosional changes were expected to be minimal. Tides and storm surge will not be affected by the proposed improvements.

Conclusions

The vessels examined in this Concept Design phase of the Boston Harbor Entrance Channel Deepening Study appear to be capable of traversing an 800-foot wide channel. As the design effort continues to evolve, the bends will need further refinement. Ship simulation provided the reasonableness of the assumptions made during this early examination. Although the Concept Design suggests bend radii of 15,550 feet this only seems practicable at Finns Ledge and was recommended at that location due to the need of a conservative entrance design. In the case of Spectacle Island/Middle Ground Shoal a recommended bend easing appears to be necessary but the Deer Island bend with a significantly shorter radius than desired proved to be acceptable given the extra channel width in the bend's existing cut-off.

Project plans and survey plots are included at the end of this appendix as follows:

Hydrographic Surveys and Channel Design Layout – Figures D1-6A to 6U
Ledge Removal Areas – Figures D1-7A to 7G
Associated Maintenance Dredging Areas – Figures D1-8A to 8E

ADDITIONAL DEPTH FOR ENTRANCE CHANNEL

Introduction

The Boston Harbor Deep Draft Navigation Improvement Study recommends a design depth of 47 feet below mean lower low water for the interior channels accessing Massport's Conley Terminal from the outer harbor. That recommendation was based on an economic analysis of the future with-project container vessel fleet calling on Boston Harbor. The economic evaluation included foot-by-foot incremental analysis of various proposed project depths from -42 feet to -50 feet MLLW. This included consideration of vessel movement on the tides, vessel loading, departure depths from prior port calls, channel transit times, and industry requirements for minimum safe underkeel clearance of 10 percent of the vessel's loaded draft. This underkeel requirement, adopted by the carriers, vessel insurers and pilots, accounts for all underkeel effects in the inner harbor.

At mean lower low water (MLLW) a vessel drawing 43 feet would require about 47 feet to transit the harbor's inner channels. At Boston the line of harbor islands stretching south across the harbor mouth from approximately Deer Island in the north to Peddocks Island and Pemberton Point in the south marks the boundary between the exposed outer harbor and the more protected lower and inner harbor. The line of peninsulas, islands and headlands results in a reduced wave climate and surface winds in the inner harbor. The different conditions experienced in the exposed outer harbor result in a requirement for additional channel depth in the entrance channel for vessels safety, and to make the improved depths in the inner harbor fully usable.

The recommendation for deepening Boston Harbor includes deepening the existing 40-foot lane of the Broad Sound North Entrance Channel; currently the harbor's deepest entrance. The Broad Sound North Entrance Channel extends northeasterly from the harbor's outer confluence south of Deer Island to deep water in Massachusetts Bay. The 40-foot lane of this channel has a width of 900 feet in its inner main reach out to Finns Ledge, and then 1100 feet wide in its shorter outer approach reach seaward. Ship simulation studies found these channel widths adequate except that bend widening at the junction of the two reaches opposite Finns Ledge was recommended and is included in the plan.

The example analysis of increased channel depth requirements in the Entrance Channel is based on a 100 DWT design vessel with a draft of 43 feet, 1100 feet in length and a beam of 140 feet. This was the equivalent draft of a vessel loaded to 48 feet but riding at least a five-foot tide which is the Boston Pilots current practice and which they intend on doing in the with-project condition. Additional calculations were made for the conditions under which the pilots intend on operating and the minor differences are mentioned in the text.

The following references were used:

EM 1110-2-1613 "Hydraulic Design of Deep Draft Navigation Projects" 31 May 2006

ERDC/CHL CHETN-I-72 “Ship Squat Predictions for Ship/Tow Simulator” Michael J. Briggs August 2006

SANDIA Report SAND2008-1020 “Ship Dynamics for Maritime ISAR Imaging” Armin W. Doerry, Sandia National Laboratories

Wave Information Studies U.S. Army Corps of Engineers Atlantic WIS Station 63053

DISCUSSIONS WITH BOSTON HARBOR PILOTS – October 2012 and December 2012

Underkeel Clearance for Boston Harbor Entrance

In assessing the adequacy of Gross Underkeel Clearance for the Entrance Channel, the following factors must be taken into account:

- Nominal draft of the vessel in salt water
- Freshwater effects
- Wave effects on ship motion
- Squat at the anticipated maximum transit speed
- Trim and/or list effects
- Tide and current effects
- Safety clearance
- Bottom factors: allowance of bed level uncertainties (soundings and sedimentation), allowance for changes between dredging and dredging execution tolerances

Discussions with the Boston Harbor Pilots provided insight to current operational procedures that are followed for vessels transiting the Outer Harbor to Conley Terminal and the pilots anticipated procedures for handling the larger 1100-foot long containerships anticipated with for Boston Harbor the project. The typical speed of the design vessel would be 13 knots in the approach from buoy BG (about 2.7 NM east of the entrance to the North Channel), reducing to 10 knots through the North Channel and President Roads, reducing to 6-8 knots above the Roads and to 6 knots approaching Castle Island to the Reserved Channel.

The Pilots also use 10% underkeel clearance in the entrance channel with added factors for increased squat and roll (heal). Using the pilots stated speed of 10 knots in the entrance adds an additional 1.5 feet underkeel allowance for squat alone above that in the inner channels. The Pilots operational procedures do not include allowances for pitch. The Pilots indicated they do not operate in winds of 35 knots or greater, or in seas of 10 feet or greater. The Pilots also indicate that they do not transit in lesser winds/seas under conditions where other than minimal pitch or roll is expected to be encountered.

NOMINAL DRAFT:

As stated above, the design depth has been calculated for a ship having a nominal draft of 43 feet and operating at low water, and for a vessel with a draft of 48 feet but riding at least a five-foot tide.

FRESH WATER EFFECTS:

Effect of fresh water is negligible given the distance of the nearest fresh water source, therefore will not impact this channel and will not be discussed.

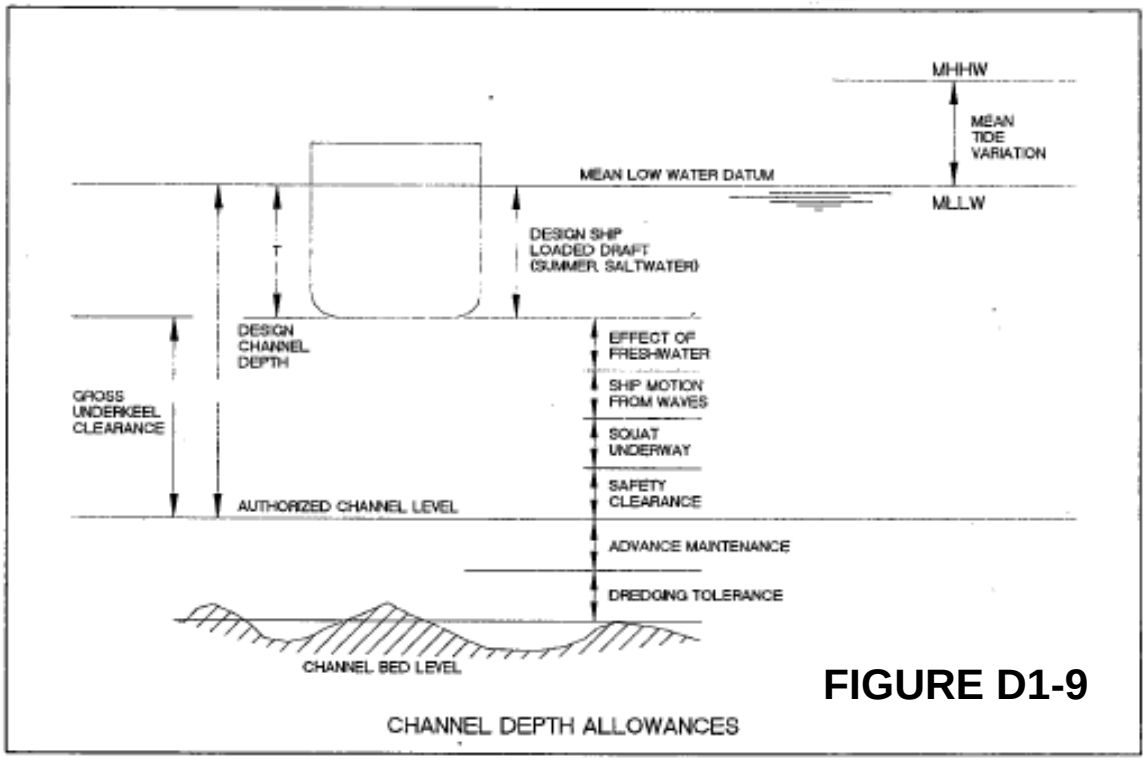


Figure D1-1 from Design Appendix and EM 1110-2-1613

WAVE EFFECTS

Ship motion due to waves is much more pronounced in the entrance channel where open ocean waves have a greater impact on the ship than in the more protected inner harbor channels. Vessel loading typically would prevent significant uneven trim in perfectly flat water but waves acting on the hull cause the vessel to rotate about the plane of even trim. As the bow of the vessel rides either up or down an oncoming wave the stern will follow the movement moments later as the wave passes along the hull.

Unfortunately wave action has a more complex effect than a single direct wave passing along the hull. Motions of pitch, roll, heave, yaw, sway, and surging are all introduced by waves acting on the vessel. While all are important the first three, pitch, roll and heave, have the potential for the greatest impact on channel depth.

Pitch

Pitch is movement of the bow or stern relative to the plane of flat water as measured at the center of the vessel rotating about the lateral axis. So as the vessel sails into an oncoming wave the bow will be forced up relative to the center of the vessel while the stern moves downward. The longer the vessel the more pronounced the effect of pitch. As an example, the assumed container vessel's length of 1100 feet with a rotation of just a half degree would cause the bow or stern to pitch over 4 feet.

X = tan angle x L/2 = tan 0.5° x 550' = 4.8'

Roll

Roll is movement of the sides of the vessel relative to the plane of flat water as measured at the center of the vessel rotating about the longitudinal axis. Calculated roll is the rocking motion from side to side and what is being measured is the motion at the extreme edge of the vessel. Since the vessel beam is perhaps only a tenth of the length the numbers may not seem as critical but this motion can be additive to the pitch motion. Rotation of perhaps five degrees would cause the outer edge of the vessel to move over 6 feet.

X = tan angle x B/2 = tan 5° x 70' = 6.1'

Heave

Heave is the vertical motion of the vessel relative to the plane of flat water. A vessel moves upwards as a wave crest passes and moves down as the trough passes. This movement can be significant for larger waves and swells.

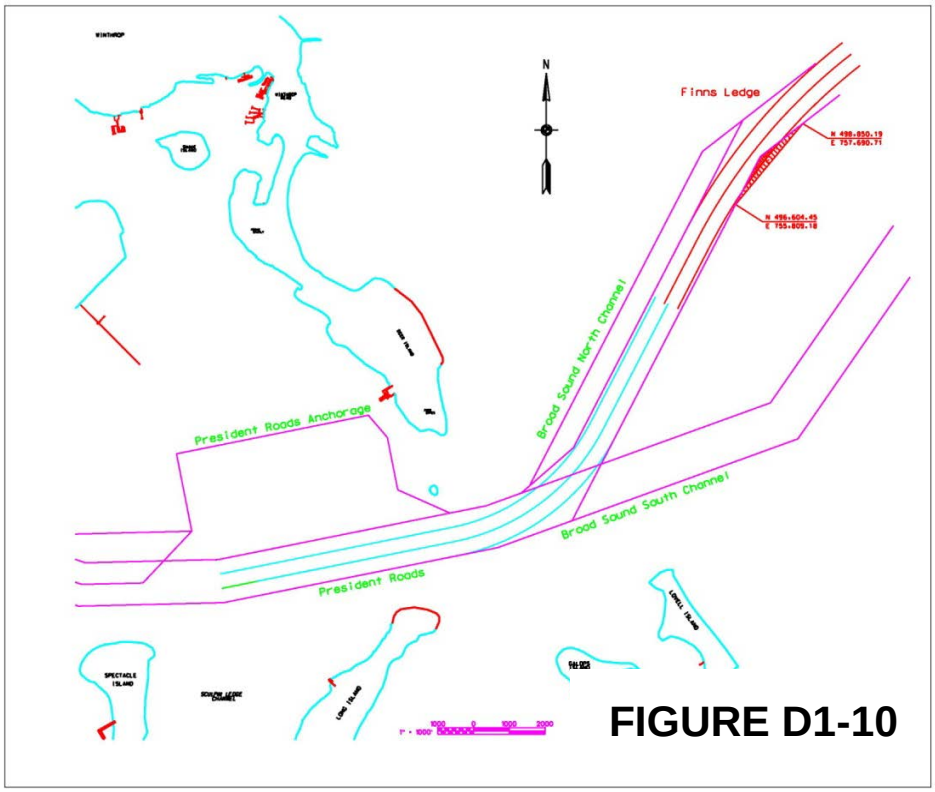


FIGURE D1-10

The orientation of the Boston Harbor entrance channel is shown above. The three motions of pitch, roll, and heave are somewhat controlled by the direction of the waves compared to the channel axis. Waves moving parallel to the channel result in the greatest values of motion. The Wave Information Studies Atlantic WIS Station 63053 was selected to provide general wave characteristics for the Boston Harbor entrance channel. Waves approaching the channel from the direction of NNE to ENE tended to have the largest wave height and period although they are not the most common. A percent occurrence wave rose showing wave direction is provided below. Direction bands are in 22.5 degree increments from 0 to 360 degrees. The data indicates that most waves are approaching from the ocean to the east. The wave hindcast chart is also provided below to show the relationship of the existing channel orientation to the larger waves with the large wave periods.

EM 1110-2-1613 (31 May 06) provides several graphs for determining suggested vertical vessel movement in channels due to waves. While the graphs were made based on a particular vessel speed they might be useful to highlight vessel movement in the entrance channel. It was assumed that both inbound and outbound vessels would be loaded to a 43 foot draft.

Figures from the EM are provided below. For an inbound vessel the calculations for vessel vertical movement resulting from pitch involved the following steps:

Calculate the pitch period (**T_{pitch}**) of the vessel

$T_{pitch} = 2.44 + .032L - .000036L^2$ sec (from Ship Dynamics for Maritime ISAR Imaging –SANDIA Report SAND2008-1020))

Where **L** in meters (Length between Perpendiculars) = length overall x .85 or for this case 1100 feet x .85 = 935 feet or 285 m

T_{pitch} = 8.64 sec

Calculate ratio of wave period (**T_{wave}**) to pitch period

T_{wave} = 5.7 sec from Wave Information Studies (WIS)

T_{pitch} = 8.64 sec

Ratio = 5.7 / 8.64 = .66

Utilize Figure 6-11 in EM 1110-2-1613 for above ratio and assumed speed of 9 knots and following seas to determine the RMS (Root Mean Squared) wave height response of the given vessel in 1 foot seas

RMS response in 1 foot seas= 0.108 ft/ft

Calculate RMS response at a given wave height using Mean Wave Height in feet from WIS data. Mean Wave Height is 4.3 feet.

0.108ft/ft x 4.3 ft = 0.460 feet

Utilize Figure 6-12 in EM to determine Displacement Response Ratio for assumed 100 DWT vessel with following seas ($\Theta = 180°$)

Displacement Response Ratio = 1.3

Apply the Displacement Response Ratio to the Mean Wave Height to determine the final RMS response for the given vessel.

0.460 x 1.3 = 0.599 feet

Utilize Figure 6-15 in EM for Period of Encounter seas (Θ = 180° so F = -1) with assumed speed of 10 knots and wave period of 5.7 sec to determine the period of encounter

Period of Encounter = 15.3 sec

Calculate number of wave encounters

Distance / Speed = [(14,050 ft x .000165) nm / 10 kn] x 3600 / 15.3 = 54.55

Utilize Figure 6-14 in EM to determine Wave Encounter Multiplier

Wave Encounter Multiplier = 4.18

Calculate total vertical movement due to waves (wave allowance for underkeel clearance) which is the Wave Encounter Multiplier times the final RMS response.

4.18 x .599 ft = 2.5 feet

Note: Similar calculations for an Outbound vessel but using a vessel speed of 9 knots and Figure 6-7 for head seas resulted in a total vertical movement due to waves of 1.6 feet. Calculations were also made for wind directions causing beam seas and quartering seas resulting in vertical movements resulting from roll of 2.3 and 1.2 feet. Thus, the vertical movement caused by wind and waves from the NNE direction would be controlling by 0.2 feet.

Page 2 of 17

ATLANTIC WAVE HINDCAST : ST63053_v01
ALL MONTHS FOR YEARS PROCESSED : 1980 - 1999
STATION LOCATION : (-70.58 W / 42.33 N)
DEPTH : 56.0 m

PERCENT OCCURRENCE (X1000) OF HEIGHT AND PERIOD BY DIRECTION
CENTRAL LOCAL ANGLE BAND OF 22.5 (+/- 11.25 DEG)

NO. CASES : 3260
% OF TOTAL: 5.6

HEIGHT IN METERS	PARABOLIC FIT OF PEAK SPECTRAL WAVE PERIOD (IN SECONDS) <5.0	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0- LONGER	TOTAL
0.10-0.49	867	32	8	6	5	17	20	11	.	.	966
0.50-0.99	1009	114	53	20	30	23	34	3	3	.	1289
1.00-1.49	489	349	244	53	30	56	92	3	.	.	1316
1.50-1.99	65	183	491	85	44	41	47	11	.	.	967
2.00-2.49	13	37	237	75	37	23	29	3	.	.	454
2.50-2.99	.	1	78	179	32	6	6	1	.	.	303
3.00-3.49	.	.	1	90	37	10	1	.	.	.	139
3.50-3.99	.	.	.	13	29	11	.	.	.	.	53
4.00-4.49	.	.	.	.	11	11	.	.	.	.	22
4.50-4.99	.	.	.	.	.	22	.	.	.	.	22
5.00-5.49	.	.	.	.	1	10	1	.	.	.	12
5.50-5.99	.	.	.	.	.	.	1	.	.	.	1
6.00-6.49	.	.	.	.	.	.	.	.	.	.	0
6.00+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	2443	716	1112	521	256	230	231	32	3	0	

MEAN Hmo(M) = 1.3 LARGEST Hmo(M) = 6.3 MEAN TPP(SEC) = 5.7 FINITE

FIGURE D1-11

http://wis.usace.army.mil/atl/pent/wave/63053/ST63053_WAVE_allyrs.txt 10/23/2012

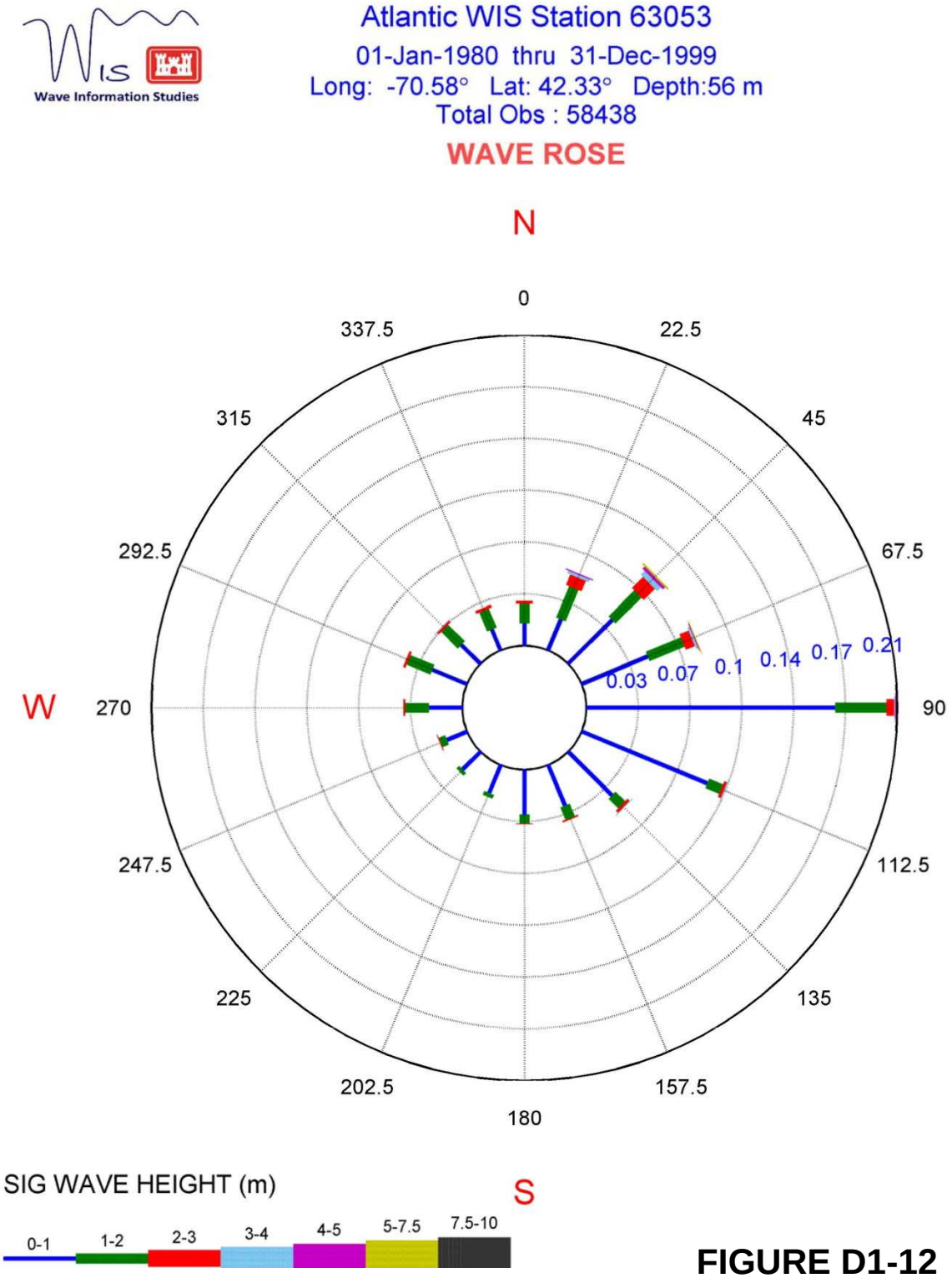

Wave Information Studies
Atlantic WIS Station 63053
01-Jan-1980 thru 31-Dec-1999
Long: -70.58° Lat: 42.33° Depth:56 m
Total Obs : 58438
WAVE ROSE
N
0
22.5
45
67.5
90
112.5
135
157.5
180
202.5
225
247.5
270
292.5
315
337.5
W
S
0.03
0.07
0.1
0.14
0.17
0.21
SIG WAVE HEIGHT (m)
0-1
1-2
2-3
3-4
4-5
5-7.5
7.5-10

FIGURE D1-12

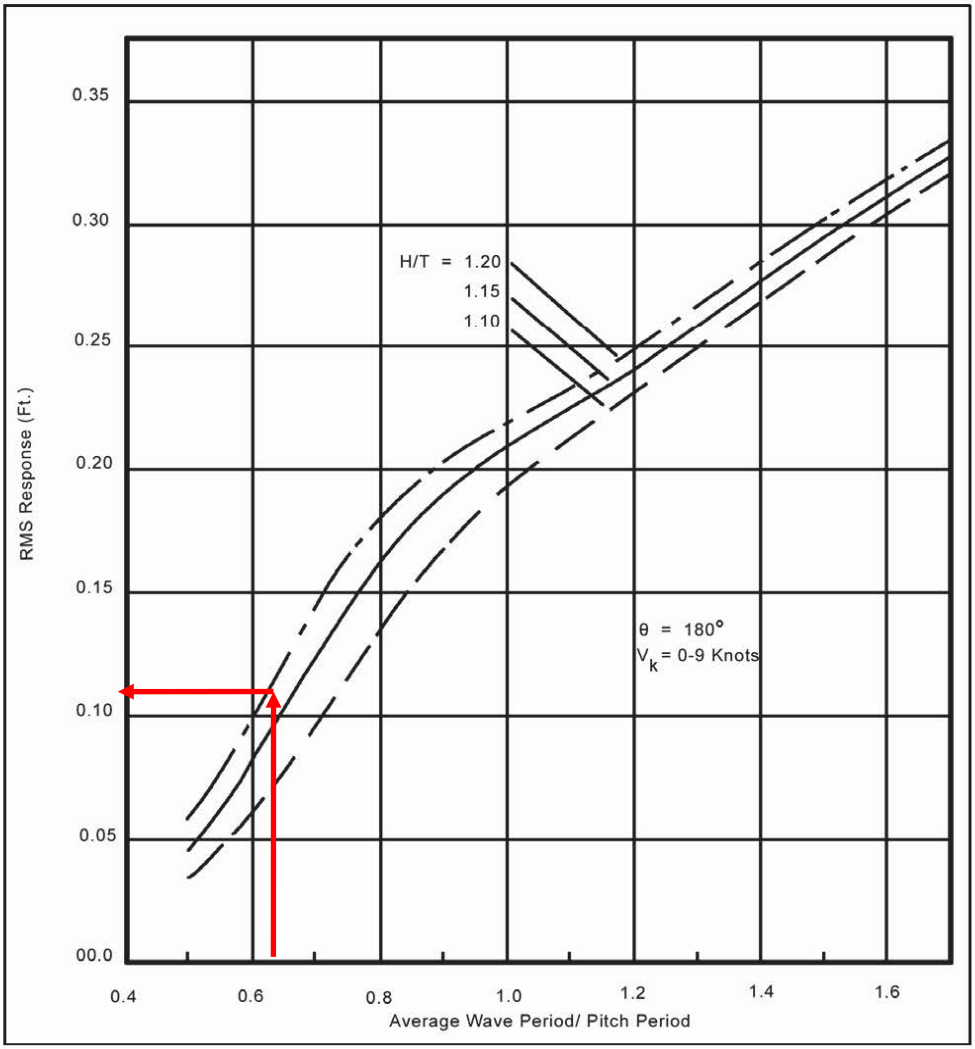


Figure 6-11. Following sea response, V_k = 0-9 knots

FIGURE D1-13

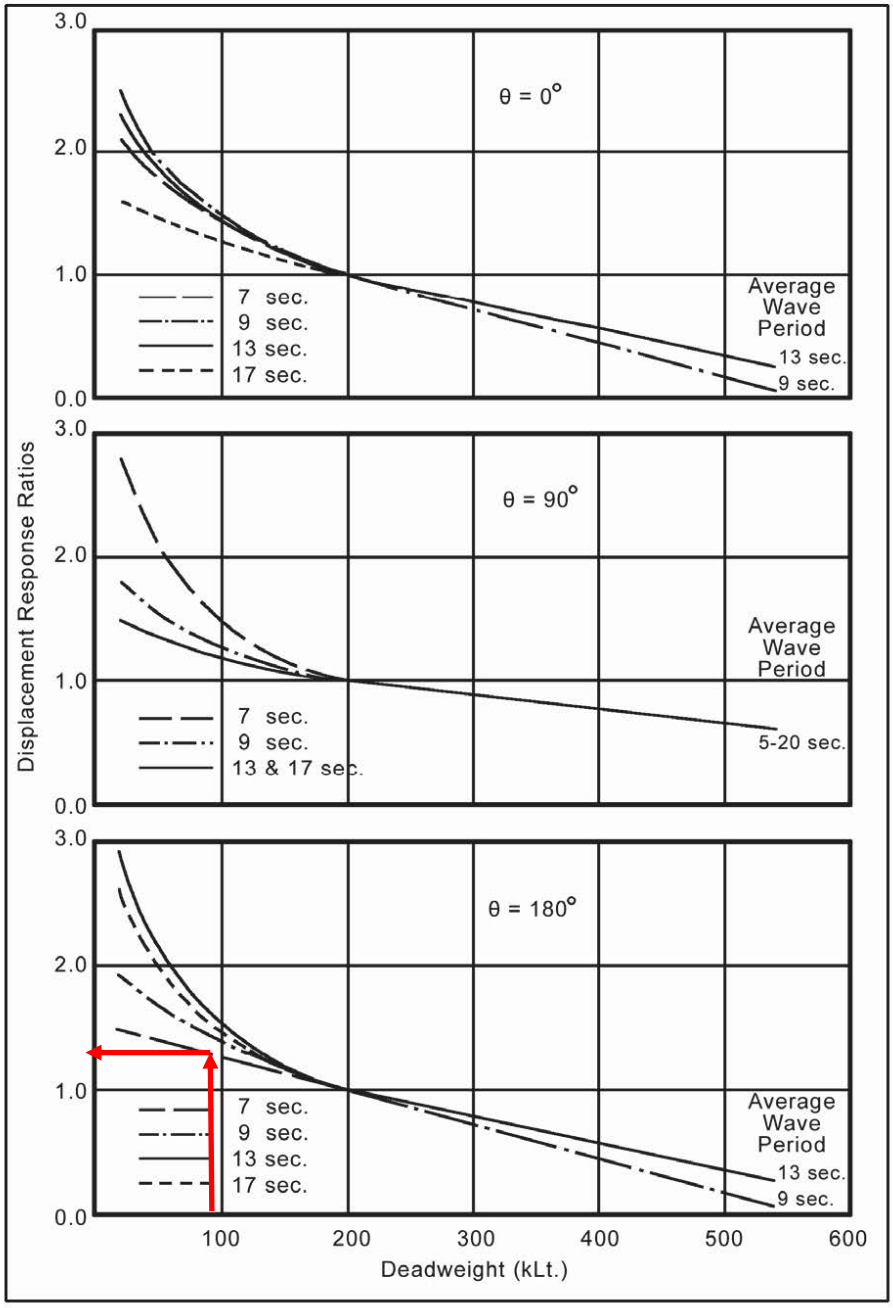


Figure 6-12. Displacement response ratios, θ = 0°, 90°, 180°

FIGURE D1-14

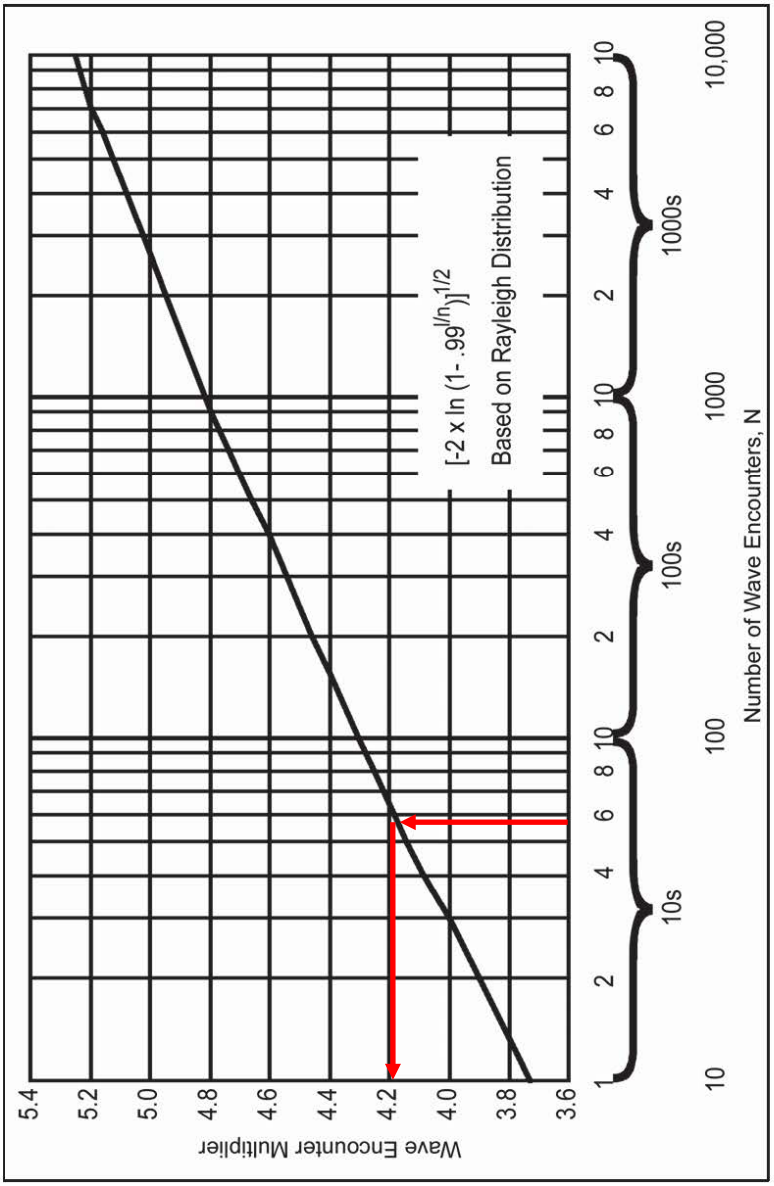


Figure 6-14. Wave encounter multiplier

FIGURE D1-15

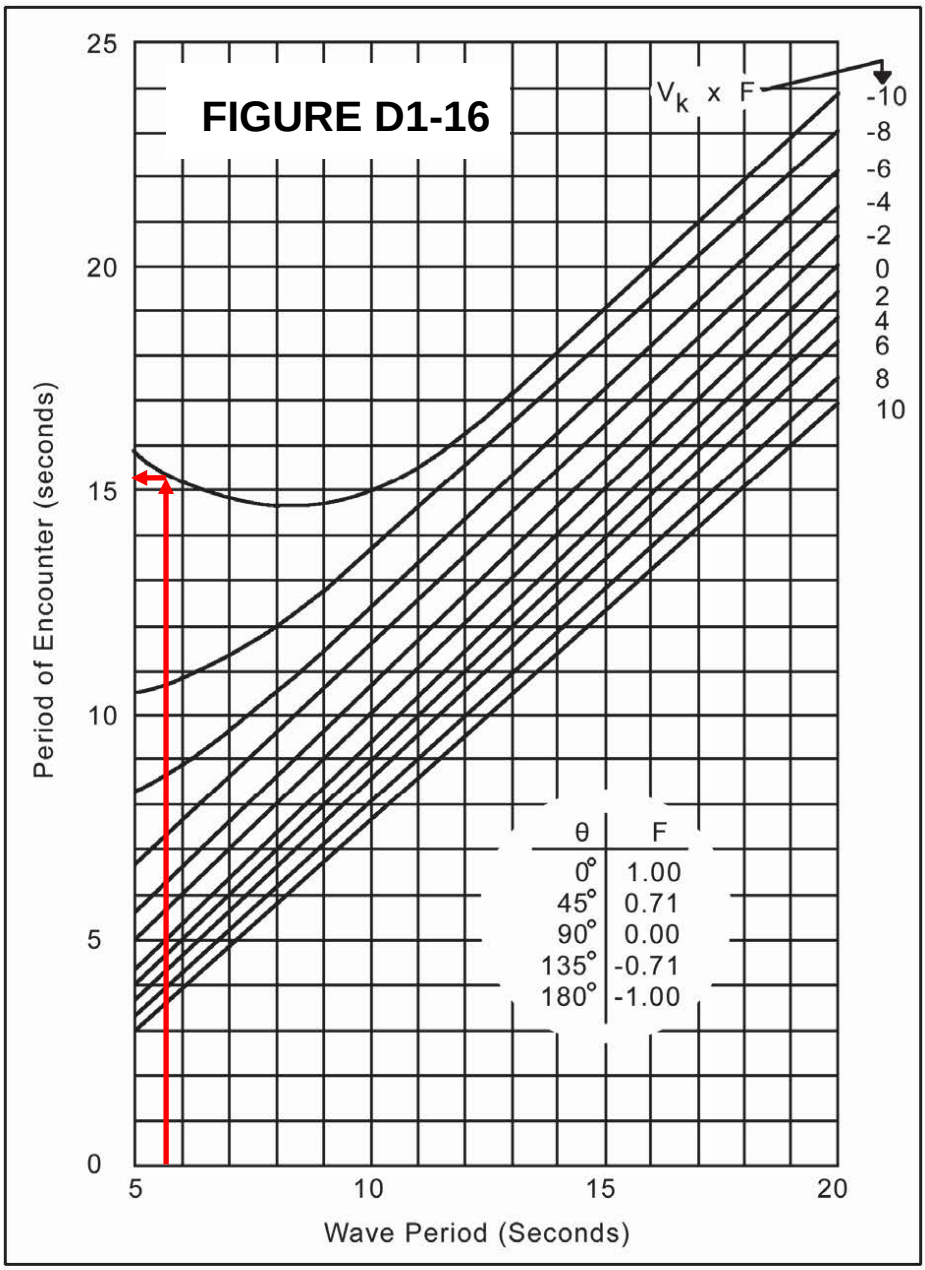


Figure 6-15. Wave encounter period

The above calculations were performed using a mean wave height of 4.3 feet. Since this was a mean height larger waves were also used in calculations to provide a range of vertical movement. A 10 foot wave can be expected to produce a 5.8 foot vertical movement. However as the Boston Harbor Pilots have stated, they use tidal assistance to transit the channels with larger or more heavily laden vessels and will not transit during conditions when pitch and roll are more than minimal. The pilots state that they encounter transit delays from sea states about 20 to 30 times a year, about half of which are with containership transits; among the largest ships calling on the port. The three containership services each make one weekly call, for a total of 312 transits annually. Sea state delays thus account for only about 4 percent of containership transits. Since the larger waves occur less frequently and when other weather related conditions might cause the

pilots not to transit the channel, it was decided to use the movement caused by the mean wave height and rely on the additional safety clearance normally required for entrance channels.

SQUAT

Squat is the phenomenon whereby the ship's draft is increased in shallow water due to the hydrodynamic effects between the ship and the sea floor which causes an increase in draft. It effectively reduces the under-keel clearance in areas where clearance may be critical. Squat is approximately proportional to the speed squared of the ship, hence halving the speed reduces the squat effect by a factor of four. In general, a squat effect starts to be felt in waters where the depth/draft ratio is less than four. Various formulas have been derived over the years for vessels depending on the vessel's block coefficient. The block coefficient is the non-dimensional ratio of the displacement volume (underwater volume) of the molded form of a ship to the volume of a rectangular block with the main ship dimensions of the effective length, beam, and draft. For background on the above and how Huuska/Guliev and Barrass correlate to other methods (see EDRC/CHL CHETN-I-72 August 2006 attached).

The formulas were populated for both Inbound and Outbound vessels. The results shown below are for an Inbound vessel:

<u>Huuska/Guliev Formula</u>:

$\mathbf{S_b = (2.4)(\ BTL/L^2)(F^2/(1\text{-}F^2)^{0.5})(K_s)}$

Where $\mathbf{S_b}$ = vessel squat in meters

B = vessel beam in meters

T = vessel draft in meters

L = vessel length in meters

F = Froude number = $(V/(gh)^{0.5)}$

$\mathbf{K_s}$ = blockage factor correction

$\mathbf{S_1}$ = blockage factor = A_s/A_{ch}

Values used are as follows (converted to meters and m/s): L=1100 feet or 335.28 m; V= 10 knots or 5.144 m/sec; h=50 feet or 15.24 m ; B=140 feet or 42.6 m; T=43 feet or 13.1 m; and an assumed C_B=.87.

Solving:

F = $(V/(gh)^{0.5}) = 5.144/[(9.81)(15.24)]^{0.5} = 0.42$

$\mathbf{L^2} = (335)^2 = 112{,}412\ m^2$

$\mathbf{A_s = .98\ B\ T =} (.98)(42.6)(13.1) = 546\ m^2$

$\mathbf{A_{ch}} = (1200)(.3048)(15.24) = 5574\ m^2$ assumed 1200' channel width at 50'

$\mathbf{S_1} = (A_s/A_{ch})/K_1 = (546/5574)/K_1 = 0.1/K_1 > 0.03$ where $K_1 = 2.5$ (see Fig C6 in PIANC "Approach Channels A Guide for Design" or ERDC/CHL CHETN-1-72 Fig 5) and $K_s = 1$

S = $(2.4)[(42.6)(13.1)(335.28)/112{,}412][(.42)^2/(1\text{-}.42^2)](1.0) = .779$ m or 2.7 feet

Barrass Formula:

$\mathbf{S_b = C_B\ S_2^{2/3}\ V_k^{2.08} / 30}$

Where $\mathbf{S_b}$ = vessel squat in meters

$\mathbf{C_B}$ = block coefficient

$\mathbf{S_2}$ = ratio between ship's cross section and the net cross section of the waterway

$\mathbf{V_k}$ = ship velocity in knots

Values used are as follows (converted to meters and m/s): L=1100 ft or 335.28 m; V= 10 knots or 5.144 m/sec; h=50 ft or 15.24 m ; B=140 ft or 42.6 m; T=43 ft or 13.1 m; and an assumed C_B=.87.

Solving:

$\mathbf{S_2 = A_s / A_w} = .10$

$\mathbf{A_s = .98\ B\ T} = (.98)(42.6)(13.1) = 546\ m^2$

$\mathbf{A_w = Wh} = (1200)(.3048)(15.24) = 5574\ m^2$ assumed 1200' channel width at 50'

$\mathbf{S_b} = (.87)(.10)^{.667}(10)^{2.08}/30 = .741$ meters or 2.4 feet

A variant of the above formula was suggested for effectively open water. A multiple of the ship's beam called "width of influence" which ranges from about 8 for tankers to about 11 for container vessels and is used along with a slightly different blockage factor as follows:

$\mathbf{S_b = C_B\ S_2^{.667}\ V_k^{2.08}/30}$

Where $\mathbf{S} = (\mathbf{b} \times \mathbf{T})/(\mathbf{B} \times \mathbf{b} \times \mathbf{h})$ and $\mathbf{B} = 7.04/\mathbf{C_B}^{.85}$

Solving:

$\mathbf{B} = 7.04 / .87^{.85} = 7.9$

$\mathbf{S} = (42.6 \times 13.1)/(7.9 \times 42.6)(15.24) = .11$

$\mathbf{S_2 = S/(1 - S)} = .11/(1 - .11) = .12$

$\mathbf{S_b} = (.87)(.12)^{.667}(10)^{2.08}/30 = .85$ m or 2.8 feet

A third, simplified variation of the Barrass formula for unrestricted open water use is as follows:

$\mathbf{S_b = C_B\ V^2/100}$

Solving:

$\mathbf{S_b} = (.87)(10)^2/100 = .87$ meters or 2.9 feet

Given the above, inbound vessel squat for the entrance channel which is not quite an open water unrestricted situation is assumed to be 2.9 feet. Because the vessel draft is included in the above equations and it is expected that the pilots will operate with deeper drafts than the 43 feet used above additional calculations for a 48 foot draft assuming at least a five foot tidal assist were performed. Results were predictably higher but only by a few tenths. The value of squat to be used, therefore, will be increase to 3.1 feet.

Note: The Outbound vessel (traveling at 9 knots) squat for the entrance channel calculated to be 2.1 feet, 2.0 feet, and 2.3 feet for the above equations resulting in an assumed squat of 2.3 feet. Likewise, calculations for the deeper draft and tide produced a squat of 2.5 feet. Therefore, the Inbound vessel squat will control.

TRIM OR LIST

Loading of a vessel or adding ballast affects the location of the water line on the hull and more importantly the function of the rudder and propeller. For Boston Harbor it is assumed that vessels arriving have little need to adjust trim and thus the entrance channel depth is not affected.

TIDES

The tidal range for Boston Harbor is 10.3 feet between Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW). The design appendix listed the mean tide range as 9.5 feet which was between Mean High Water (MHW) and Mean Low Water (MLW). The lowest observed tide was 3.7 feet below MLLW recorded in March 1940. It also should be noted that for any month there will be between 5 and 7 days where the tide level is at least a foot lower than MLLW. For this reason 1 foot additional clearance is recommended for the reasonable probability that actual tide would be lower than MLLW.

SAFETY CLEARANCE

A required under keel safety clearance of 2 feet is assumed based on USACE guidance (EM 1110-2-1613, etc). There is intermittent hard bottom (ledge) in areas of the North Entrance Channel, Main Ship Channel, Reserved Channel and Anchorage. In the case of hard bottom USACE guidance recommends a 3-foot safety clearance (EM 1110-2-1613, etc) with EDRC recommending 4 feet (EDRC/CHL CHETN-I-72 August 2006). The improvement project includes an additional 2 feet of required removal in areas of ledge in addition to the normal 2 feet of allowable overdepth. For this reason 2 feet safety clearance is considered sufficient.

BOTTOM FACTORS

Bottom factors include allowance of bed level uncertainties (soundings and sedimentation), allowance for changes between dredging and dredging execution tolerances. As mentioned above, the assumed safety clearance has made allowances for hard bottom. The accuracy of soundings is not a major concern since the existing channel does not shoal at a rate that requires dredging more frequently than every twenty years.

OTHER FACTORS

Atmospheric Pressure: Note that at the time of the in the incident on 11 March 1996 where the M/T LIMAR hit a rock in Boston Harbor, it appears the atmospheric pressure was in the range of 1050mm which could result in a lowering of surface elevation of 55 cms (1.8 feet) (Capt Ajit Vadakayil in his blog: http://ajitvadakayil.blogspot.com/2011/01/ships-squat-bernoulli-and-under-keel.html)

Conclusion and Recommendation for Entrance Channel Depth

Considering the potential vessel movement and other factors identified above in paragraphs 2.a through 2.i, the calculated depth of the Entrance Channel required for the project design vessel is -51.3 feet MLLW. This is a combination of the following considerations: 48 foot Nominal draft+ 2.5 feet Wave effects + 3.1 feet Squat + 1.0 feet Tide effects + 2.0 feet Safety Clearance -5.3 feet of tidal assistance for "riding the tide".

The Recommended Entrance Channel design depth is -51 Feet MLLW with an additional 2 feet Required Overdepth (to -53 Feet MLLW) component in areas of ledge, plus two feet allowable overdepth (to -55 Feet MLLW) in all areas.

Note 1: Eight scenarios were analyzed for combined wave and squat effects as follows:

Outbound Vessel: 43 foot draft - 9 knot squat plus 9 knot wave effect (head seas response) equals 2.3 feet + 1.6 feet = 3.9 feet; 9 knot squat plus 9 knot wave effect (beam seas response) equals 2.3 feet + 2.3 feet = 4.6 feet; 48 foot draft - 9 knot squat plus 9 knot wave effect (head seas response) equals 2.5 feet + 1.6 feet = 4.1 feet; and, 9 knot squat plus 9 knot wave effect (beam seas response) equals 2.5 feet + 2.3 feet = 4.8 feet

Inbound Vessel: 43 foot draft -10 knot squat plus 10 knot wave effect (following seas response) equals 2.9 feet + 2.5 feet = 5.4 feet; 10 knot squat plus 10 knot wave effect (beam seas response) equals 2.9 feet + 2.3 feet = 5.2 feet; 48 foot draft - 10 knot squat plus 10 knot wave effect (following seas response) equals 3.1 feet + 2.5 feet = 5.6 feet; and, 10 knot squat plus 10 knot wave effect (beam seas response) equals 3.1 feet + 2.3 feet = 5.4 feet

The control will be the 48 foot draft Inbound Vessel (5.6 feet) in following seas. The 48 foot draft Inbound vessel was assumed to be riding at least a five foot tide which would equate to a 43 foot draft vessel transiting at MLLW.

Note 2: The District's analysis examined a worse case of an 1100-foot ship at a partially loaded 43-foot draft transiting without regard to the tide and the same ship loaded to 48-foot draft. In a December 21, 2012 letter the Boston Harbor Pilots made their own analysis on the 1100-foot ship near fully loaded to 48+ feet moving on the top third of the tide to ensure themselves that such a vessel transit would work with respect to transit time v available water.

TABLE D1-9
BOSTON HARBOR, MASSACHUSETTS 2005
WATERBORNE COMMERCE STATISTICS - VESSEL TRANSITS FOR THE PORT OF BOSTON

	Inbound Vessel Transits						Outbound Transits						Total All Transits	35-Foot and Up Transits
	Total Inbound	Self-Propelled Vessels			Non-Self Propelled Vessels		Total Outbound	Self-Propelled Vessels			Non-Self Propelled Vessels			
		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		
Total for Waterway	20,389	18,080	530	279	209	563	20,176	18,810	386	263	196	521	40,565	596
Foreign	852	449	380	11	0	12	862	451	381	15	1	14	1,714	591
43	2	2	-	-	-	-	0	-	-	-	-	-	2	
42	16	16	-	-	-	-	7	7	-	-	-	-	23	
41	29	28	1	-	-	-	25	25	-	-	-	-	54	
40	21	21	-	-	-	-	22	22	-	-	-	-	43	
39	26	23	3	-	-	-	20	20	-	-	-	-	46	
38	39	19	20	-	-	-	17	17	-	-	-	-	56	
37	30	9	21	-	-	-	11	11	-	-	-	-	41	
36	163	29	134	-	-	-	26	21	5	-	-	-	189	
35	97	25	72	-	-	-	40	22	18	-	-	-	137	
34	44	10	34	-	-	-	52	13	39	-	-	-	96	
33	30	7	23	-	-	-	19	9	10	-	-	-	49	
32	24	7	17	-	-	-	5	4	1	-	-	-	29	
31	14	0	14	-	-	-	5	-	5	-	-	-	19	
≤30	317	253	41	11	-	12	613	280	303	15	1	14	930	
Total	852	449	380	11	0	12	862	451	381	15	1	14	1,714	
Domestic	19,537	18,359	150	268	209	551	19,314	18,359	5	248	195	507	38,851	5
37	2	-	2	-	-	-	0	-	-	-	-	-	2	
36	1	-	-	-	-	1	1	-	1	-	-	-	2	
35	1	-	1	-	-	-	0	-	-	-	-	-	1	
34	0	-	-	-	-	-	0	-	-	-	-	-	0	
33	0	-	-	-	-	-	0	-	-	-	-	-	0	
32	4	-	-	-	-	4	0	-	-	-	-	-	4	
31	1	-	-	-	-	1	0	-	-	-	-	-	1	
≤30	19,528	18,359	147	268	209	545	19,313	18,359	4	248	195	507	38,841	
Total	19,537	18,359	150	268	209	551	19,314	18,359	5	248	195	507	38,851	

TABLE D1-9 (Continued)
BOSTON HARBOR, MASSACHUSETTS 2005
WATERBORNE COMMERCE STATISTICS - VESSEL TRANSITS FOR THE RESERVED CHANNEL

	Inbound Vessel Transits						Outbound Transits						Total All Transits	35-Foot and Up Transits
	Total Inbound	Self-Propelled Vessels			Non-Self Propelled		Total Outbound	Self-Propelled Vessels			Non-Self Propelled			
		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		
Total for Waterway	628	479	-	56	50	43	621	477	1	53	51	39	1,249	272
Foreign	310	309	-	1	-	-	309	307	1	1	-	-	619	272
43	2	2	-	-	-	-	0	-	-	-	-	-	2	
42	16	16	-	-	-	-	7	7	-	-	-	-	23	
41	28	28	-	-	-	-	25	25	-	-	-	-	53	
40	21	21	-	-	-	-	22	22	-	-	-	-	43	
39	14	14	-	-	-	-	20	20	-	-	-	-	34	
38	10	10	-	-	-	-	16	16	-	-	-	-	26	
37	5	5	-	-	-	-	7	7	-	-	-	-	12	
36	21	21	-	-	-	-	17	17	-	-	-	-	38	
35	20	20	-	-	-	-	21	21	-	-	-	-	41	
34	9	9	-	-	-	-	10	10	-	-	-	-	19	
33	5	5	-	-	-	-	6	6	-	-	-	-	11	
32	4	4	-	-	-	-	4	4	-	-	-	-	8	
31	0	-	-	-	-	-	0	-	-	-	-	-	0	
≤30	155	154	-	1	-	-	154	152	1	1	-	-	309	
Total	310	309	0	1	0	0	309	307	1	1	0	0	619	
Domestic	318	170	-	55	50	43	312	170	-	52	51	39	630	0
27	1	1	-	-	-	-	1	1	-	-	-	-	2	
≤15	317	169	-	55	50	43	311	169	-	52	51	39	628	
Total	318	170	0	55	50	43	312	170	0	52	51	39	630	

TABLE D1-9 (Continued)
BOSTON HARBOR, MASSACHUSETTS 2005
WATERBORNE COMMERCE STATISTICS - VESSEL TRANSITS FOR THE MYSTIC RIVER

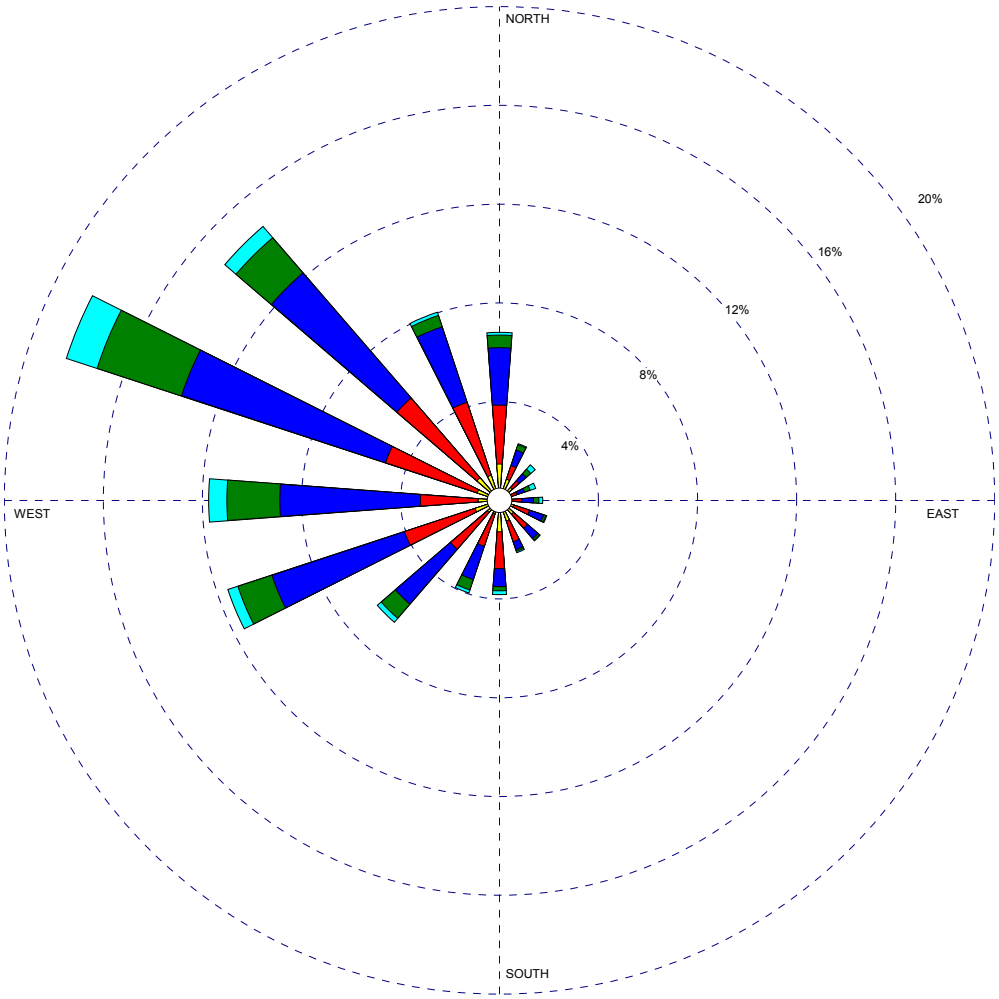
	Inbound Vessel Transits						Outbound Transits						Total All Transits	35-Foot and Up Transits
	Total Inbound	Self-Propelled Vessels			Non-Self Propelled		Total Outbound	Self-Propelled Vessels			Non-Self Propelled			
		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		
Total for Waterway	419	58	159	32	101	69	384	62	133	34	91	64	803	157
Foreign	236	58	157	10	-	11	218	62	132	12	-	12	454	157
39	2	-	2	-	-	-	0	-	-	-	-	-	2	
38	24	5	19	-	-	-	1	1	-	-	-	-	25	
37	20	1	19	-	-	-	4	4	-	-	-	-	24	
36	67	1	66	-	-	-	6	3	3	-	-	-	73	
35	19	1	18	-	-	-	14	1	13	-	-	-	33	
34	12	1	11	-	-	-	41	3	38	-	-	-	53	
33	5	-	5	-	-	-	12	3	9	-	-	-	17	
32	7	1	6	-	-	-	0	-	-	-	-	-	7	
31	1	-	1	-	-	-	3	-	3	-	-	-	4	
≤30	79	48	10	10		11	137	47	66	12	-	12	216	
Total	236	58	157	10	0	11	218	62	132	12	0	12	454	
Domestic	183	-	2	22	101	58	166	-	1	22	91	52	349	0
27	6	-	-	-	6	-	1	-	-	-	-	1	7	
≤26	177	-	2	22	95	58	165	-	1	22	91	51	342	
Total	183	0	2	22	101	58	166	0	1	22	91	52	349	

TABLE D1-9 (Continued)
BOSTON HARBOR, MASSACHUSETTS 2005
WATERBORNE COMMERCE STATISTICS - VESSEL TRANSITS FOR THE CHELSEA RIVER

	Inbound Vessel Transits						Outbound Transits						Total All Transits	35-Foot and Up Transits
	Total Inbound	Self-Propelled Vessels			Non-Self Propelled		Total Outbound	Self-Propelled Vessels			Non-Self Propelled			
		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		Dry Cargo	Tanker	Tow or Tug	Dry Cargo	Tanker		
Total for Waterway	559	28	119	90	0	322	558	31	150	84	1	292	1,117	112
Foreign	143	28	115	-	-	-	178	31	147	-	-	-	321	109
39	10	9	1	-	-	-	0	-	-	-	-	-	10	
38	4	4	-	-	-	-	0	-	-	-	-	-	4	
37	3	3	-	-	-	-	0	-	-	-	-	-	3	
36	54	6	48	-	-	-	1	1	-	-	-	-	55	
35	34	1	33	-	-	-	3	-	3	-	-	-	37	
34	5	-	5	-	-	-	0	-	-	-	-	-	5	
33	10	2	8	-	-	-	0	-	-	-	-	-	10	
32	6	2	4	-	-	-	0	-	-	-	-	-	6	
31	5	-	5	-	-	-	1	-	1	-	-	-	6	
≤30	12	1	11	-	-	-	173	30	143	-	-	-	185	
Total	143	28	115	0	0	0	178	31	147	0	0	0	321	
Domestic	416	-	4	90	-	322	380	-	3	84	1	292	796	3
37	0	-	-	-	-	-	0	-	-	-	-	-	0	
36	2	-	1	-	-	1	0	-	-	-	-	-	2	
35	1	-	1	-	-	-	0	-	-	-	-	-	1	
34	0	-	-	-	-	-	0	-	-	-	-	-	0	
33	0	-	-	-	-	-	0	-	-	-	-	-	0	
32	4	-	-	-	-	4	0	-	-	-	-	-	4	
31	1	-	-	-	-	1	0	-	-	-	-	-	1	
≤30	408	-	2	90	-	316	380	-	3	84	1	292	788	
Total	416	0	4	90	0	322	380	0	3	84	1	292	796	

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

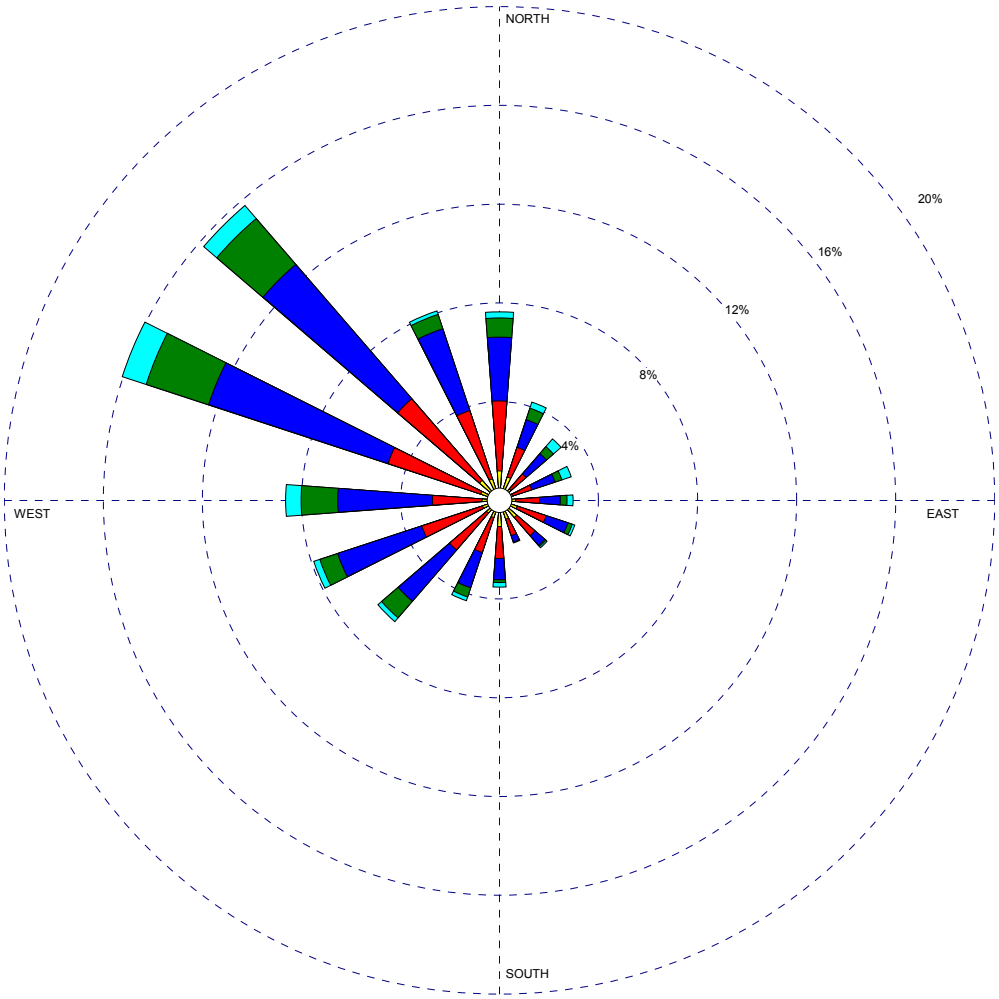


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **6.20 m/s**	CALM WINDS **0.48%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Jan 1 - Jan 31** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

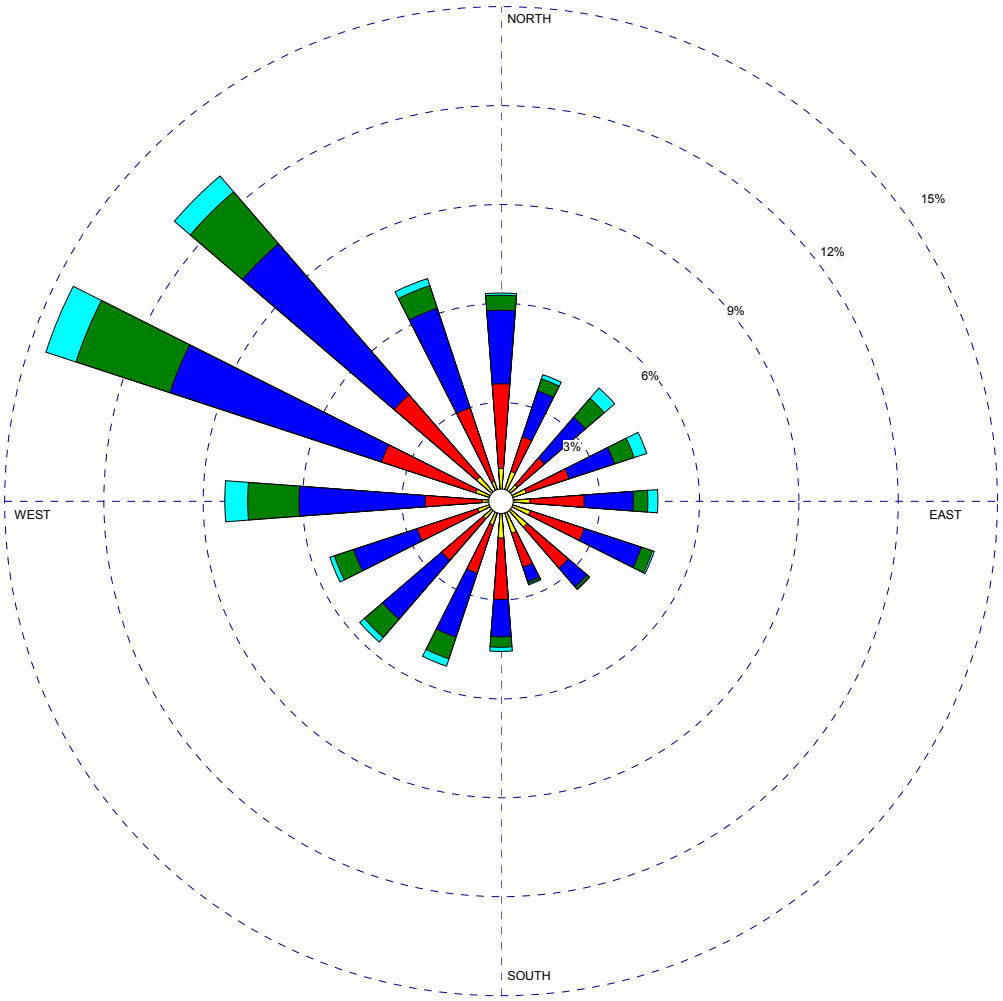


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **6.15 m/s**	CALM WINDS **0.58%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Feb 1 - Feb 29** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

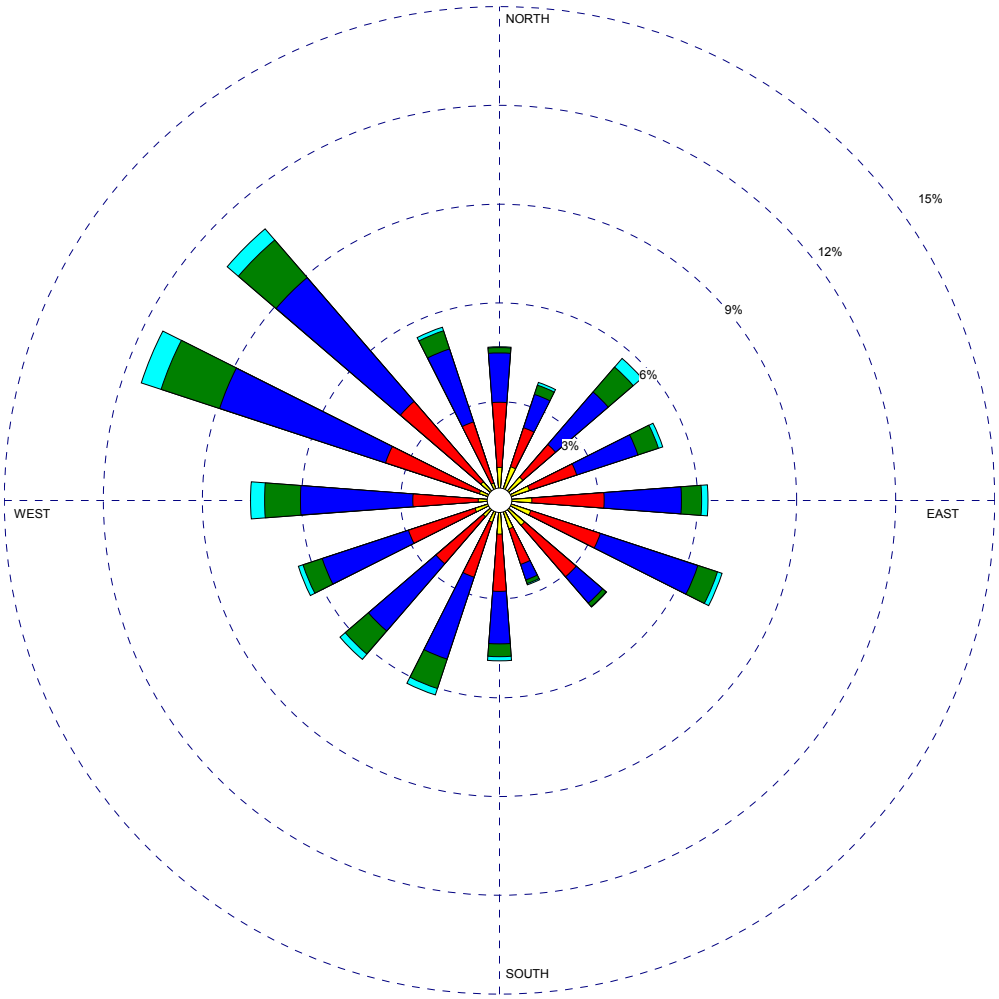


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **6.17 m/s**	CALM WINDS **0.79%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Mar 1 - Mar 31** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

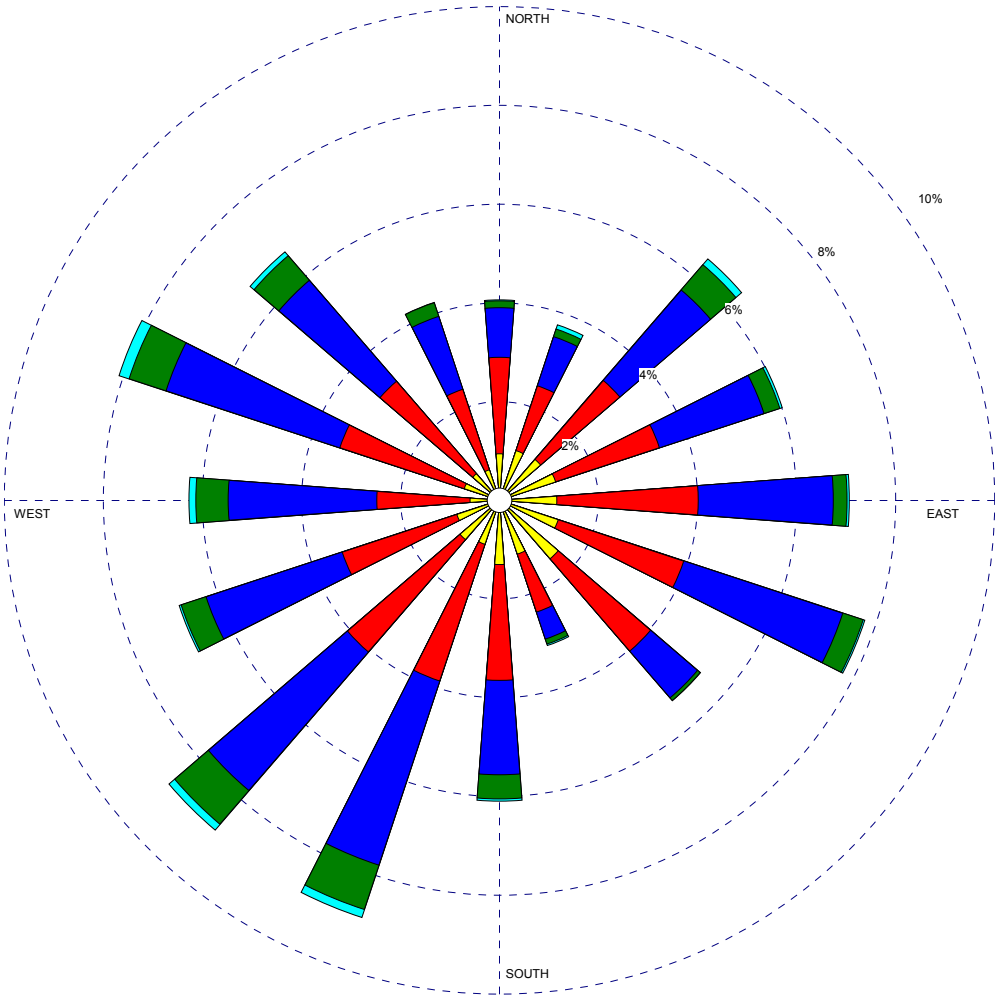


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **5.98 m/s**	CALM WINDS **0.97%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Apr 1 - Apr 30** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

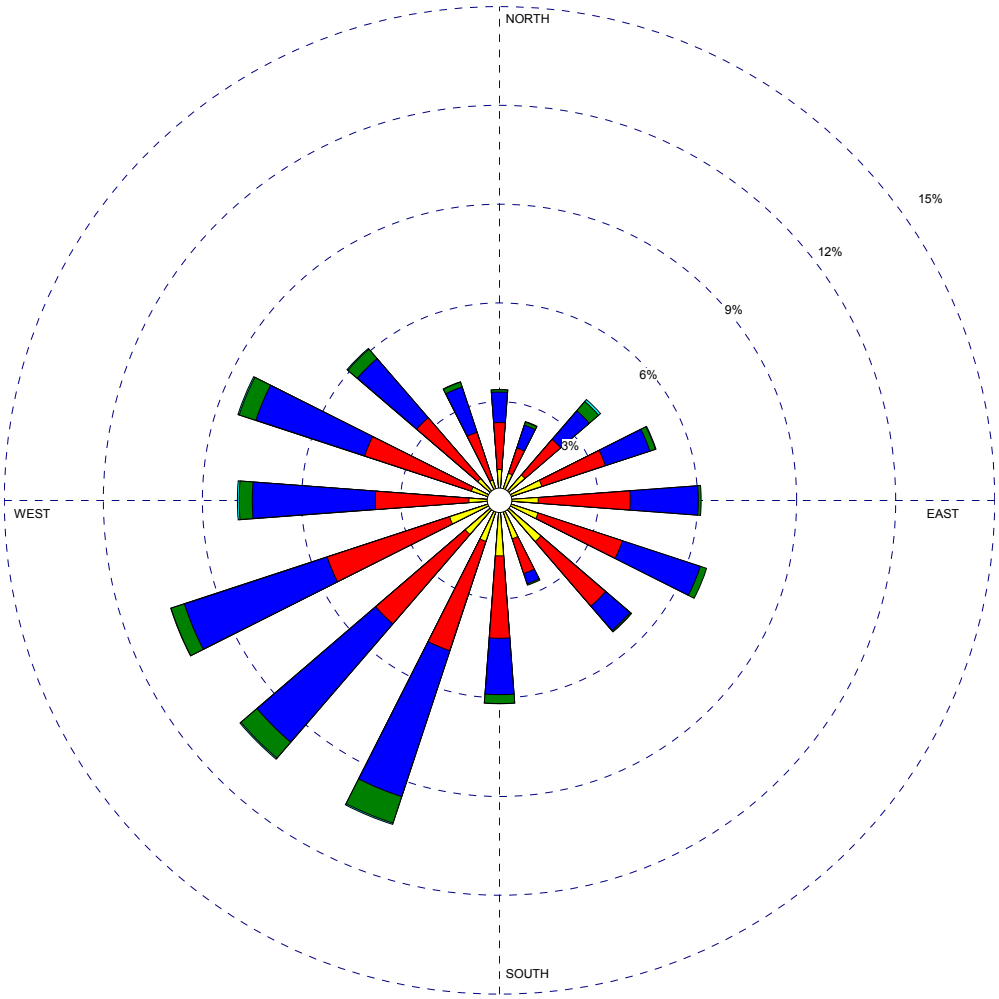


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **5.48 m/s**	CALM WINDS **0.61%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **May 1 - May 31** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

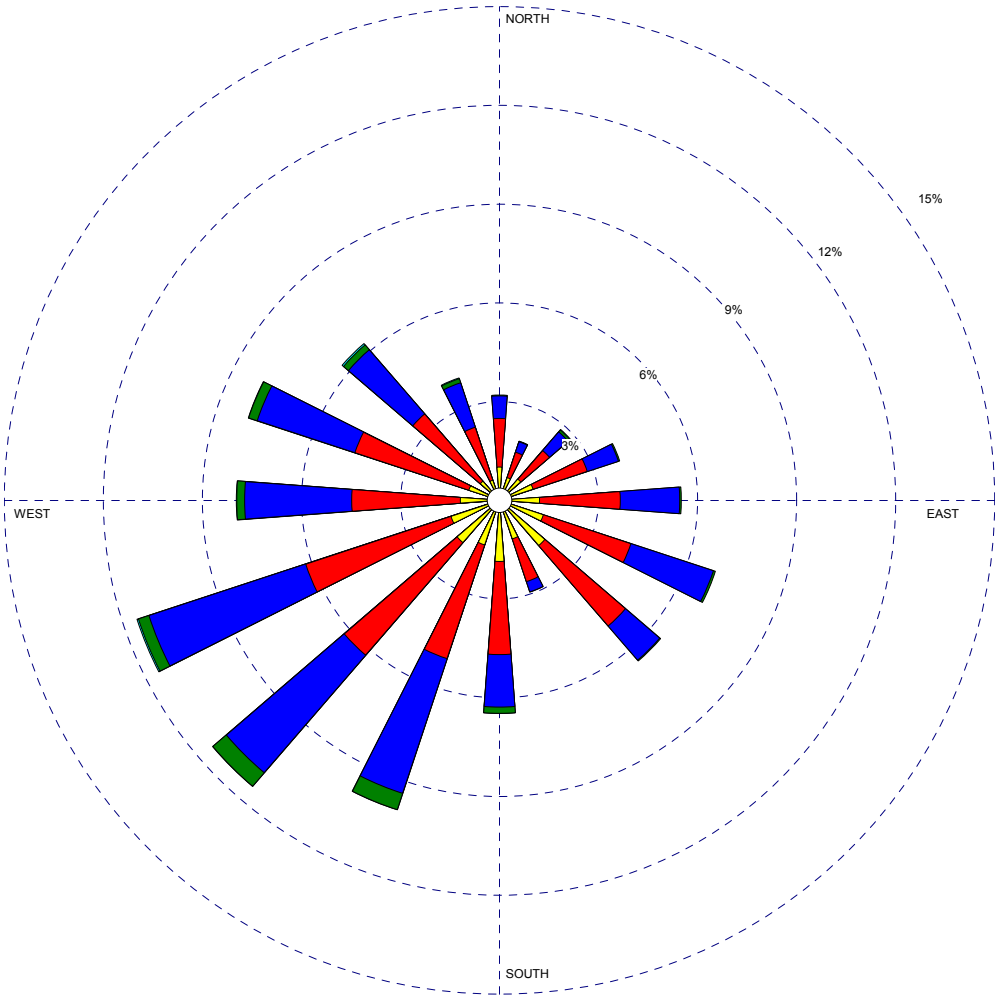


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **5.16 m/s**	CALM WINDS **0.78%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Jun 1 - Jun 30** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA



Wind Speed (m/s)

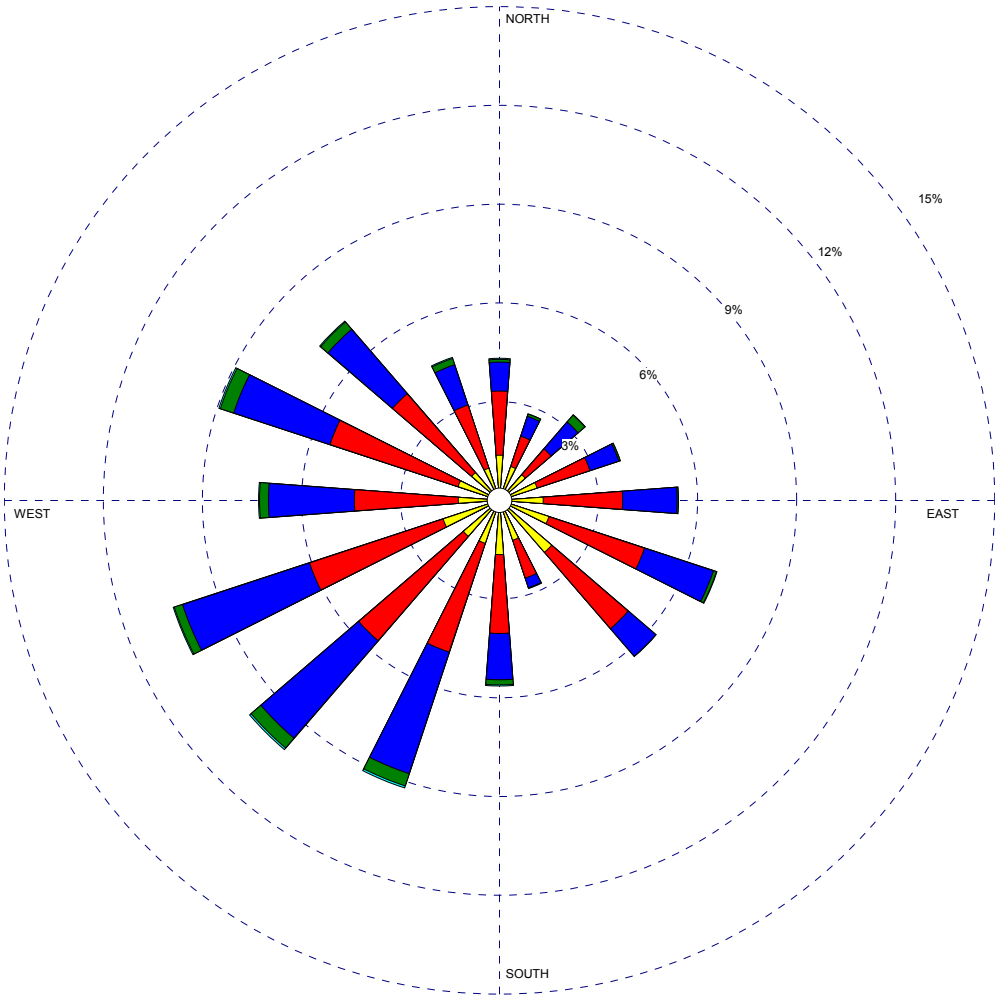
- > 11.06
- 8.49 - 11.06
- 5.40 - 8.49
- 3.34 - 5.40
- 1.80 - 3.34
- 0.51 - 1.80

MODELER	DATE	COMPANY NAME
Sara West	**10/29/2002**	**USDA-ARS**
DISPLAY	UNIT	COMMENTS
Wind Speed	**m/s**	
AVG. WIND SPEED	CALM WINDS	
4.96 m/s	**0.85%**	
ORIENTATION	PLOT YEAR-DATE-TIME	
Direction (blowing from)	**1961 Jul 1 - Jul 31 Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

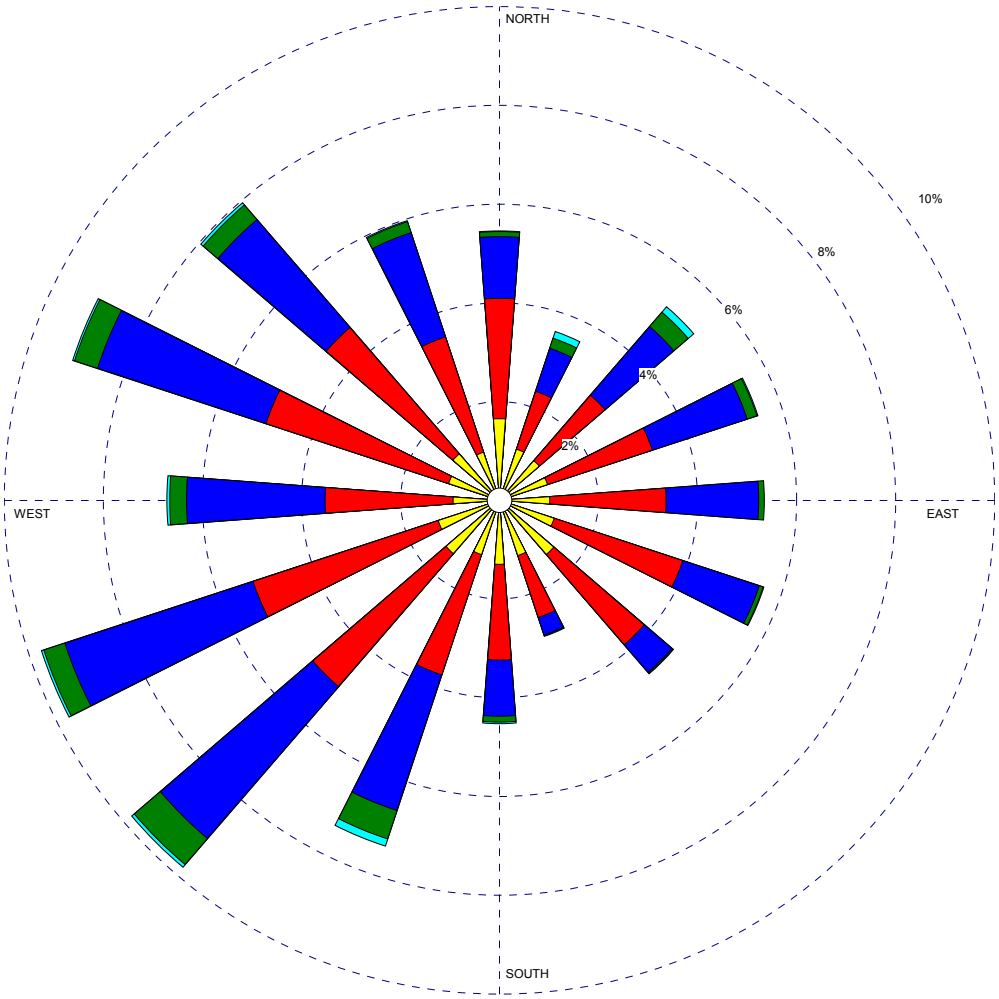


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **4.87 m/s**	CALM WINDS **0.92%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Aug 1 - Aug 31** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

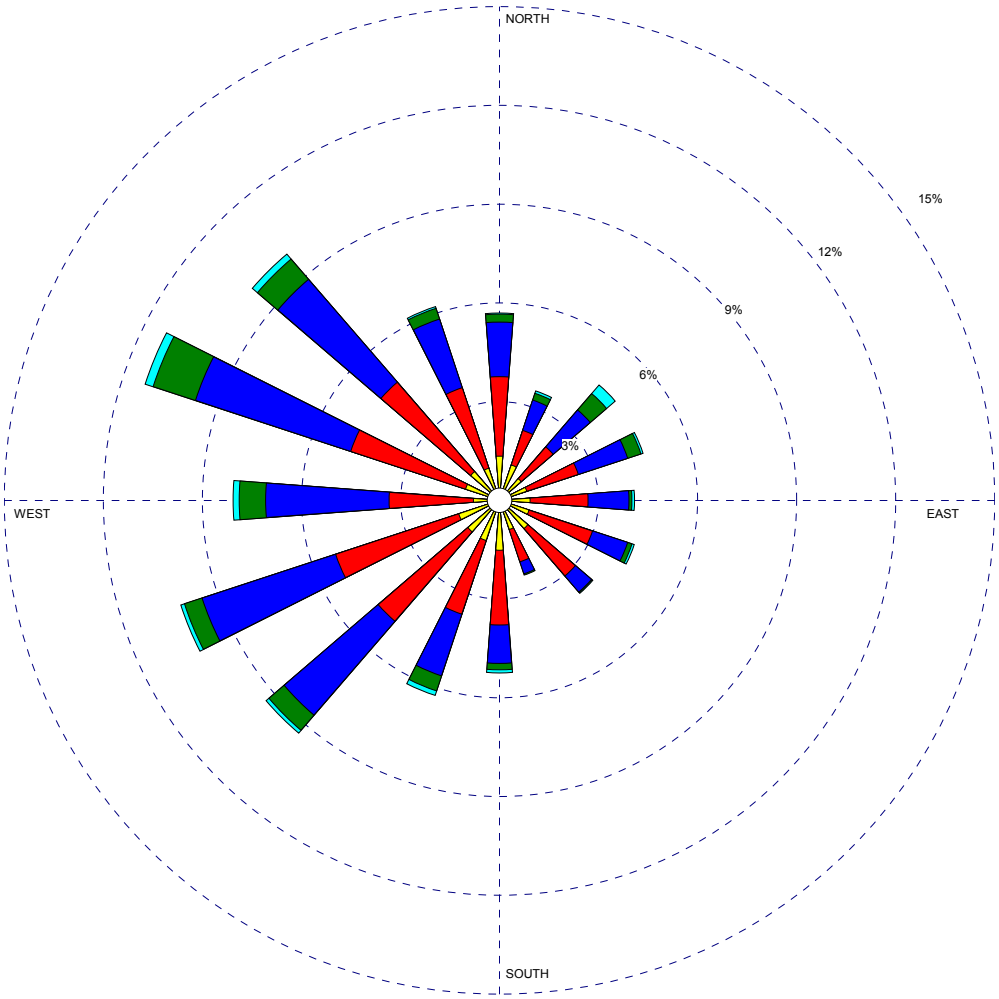


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **5.10 m/s**	CALM WINDS **0.61%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Sep 1 - Sep 30** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

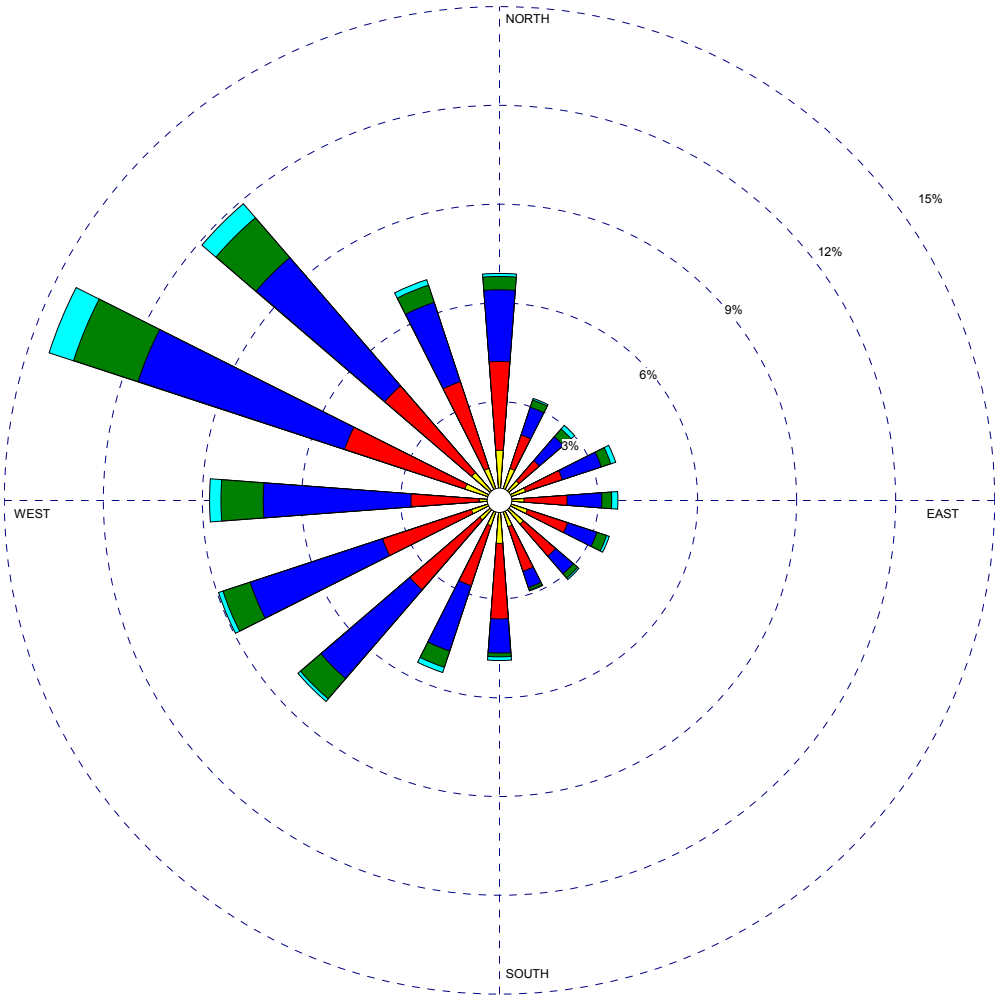


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **5.41 m/s**	CALM WINDS **0.64%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Oct 1 - Oct 31** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA

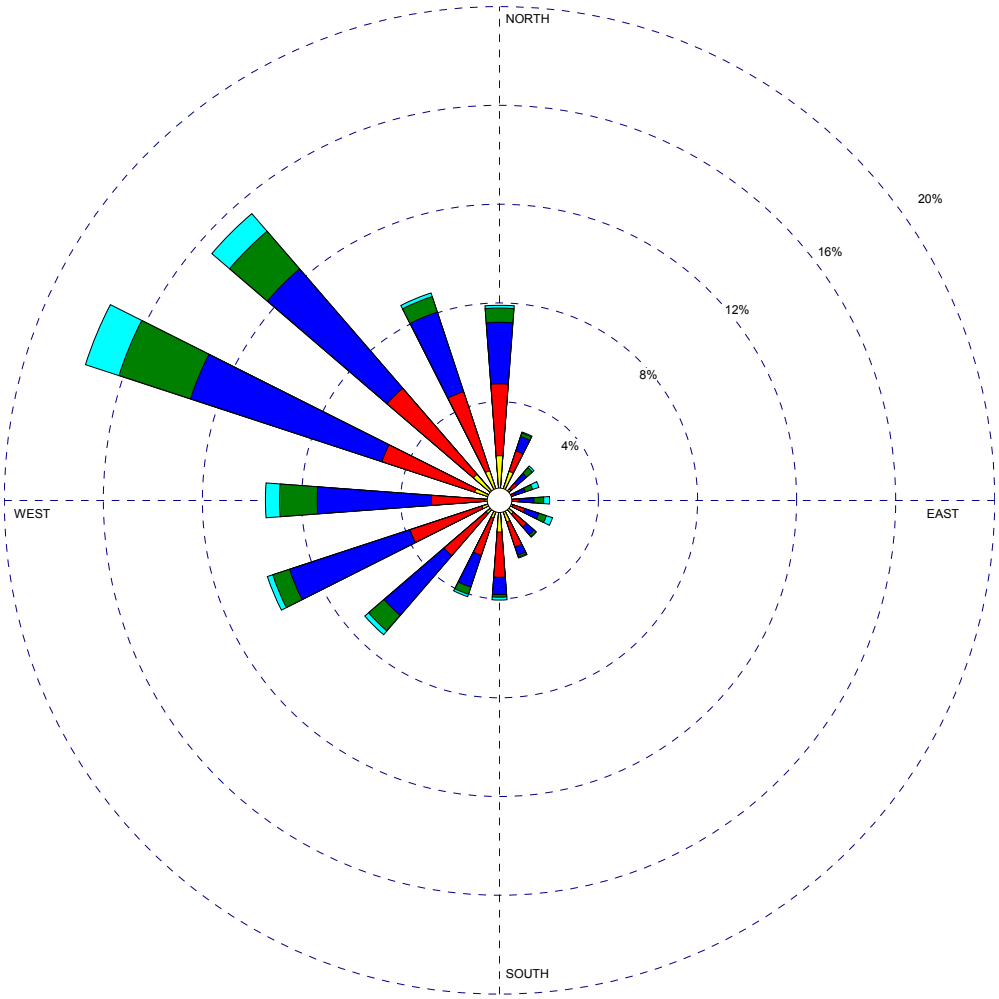


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **5.82 m/s**	CALM WINDS **0.46%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Nov 1 - Nov 30** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #14739 - BOSTON/LOGAN INT'L ARPT, MA



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	**Sara West**	**10/29/2002**	**USDA-ARS**
	DISPLAY **Wind Speed**	UNIT **m/s**	COMMENTS
	AVG. WIND SPEED **6.09 m/s**	CALM WINDS **0.50%**	
	ORIENTATION **Direction (blowing from)**	PLOT YEAR-DATE-TIME **1961** **Dec 1 - Dec 31** **Midnight - 11 PM**	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

Sea Level Rise Assessment

With navigation projects the impacts of projected sea level rise resulting from climate change and post-glacial continental margin subsidence is a consideration principally relative to port facility elevation and operations. Consideration is given to whether port facilities will be able to continue operations under various sea level rise scenarios, or whether modifications to those facilities will be necessary to enable performance over the project life in support of project benefits.

At Boston Harbor Massport's three cargo terminals have deck elevations of between 10.5 and 12 feet above mean sea level (MSL = +5.2 feet MLLW). At mean high water freeboard at these facilities is between 5.9 and 7.4 feet.

Conley Terminal (Reserved Channel)	10.5 to 12.0 feet
Massport Marine Terminal	10.5 to 11.5 feet
Medford Street Terminal (Mystic River)	11.7 to 11.9 feet

The calculation sheet in Table D1-10 uses the latest Corps guidance on eustatic sea level rise (EC 1165-2-212) to calculate sea level rise for the 2016-2066 project life. As shown in the Table D1-11, low, medium and high projections of sea level rise at Boston are 1.03, 1.84 and 2.65 feet over a 60-year period measured from 2010 levels, or 0.87, 1.56 and 2.25 feet as computed over the 50-year project life,. While terminal freeboard will be reduced under these scenarios the terminals will still be operational throughout the anticipated 50-year project life.

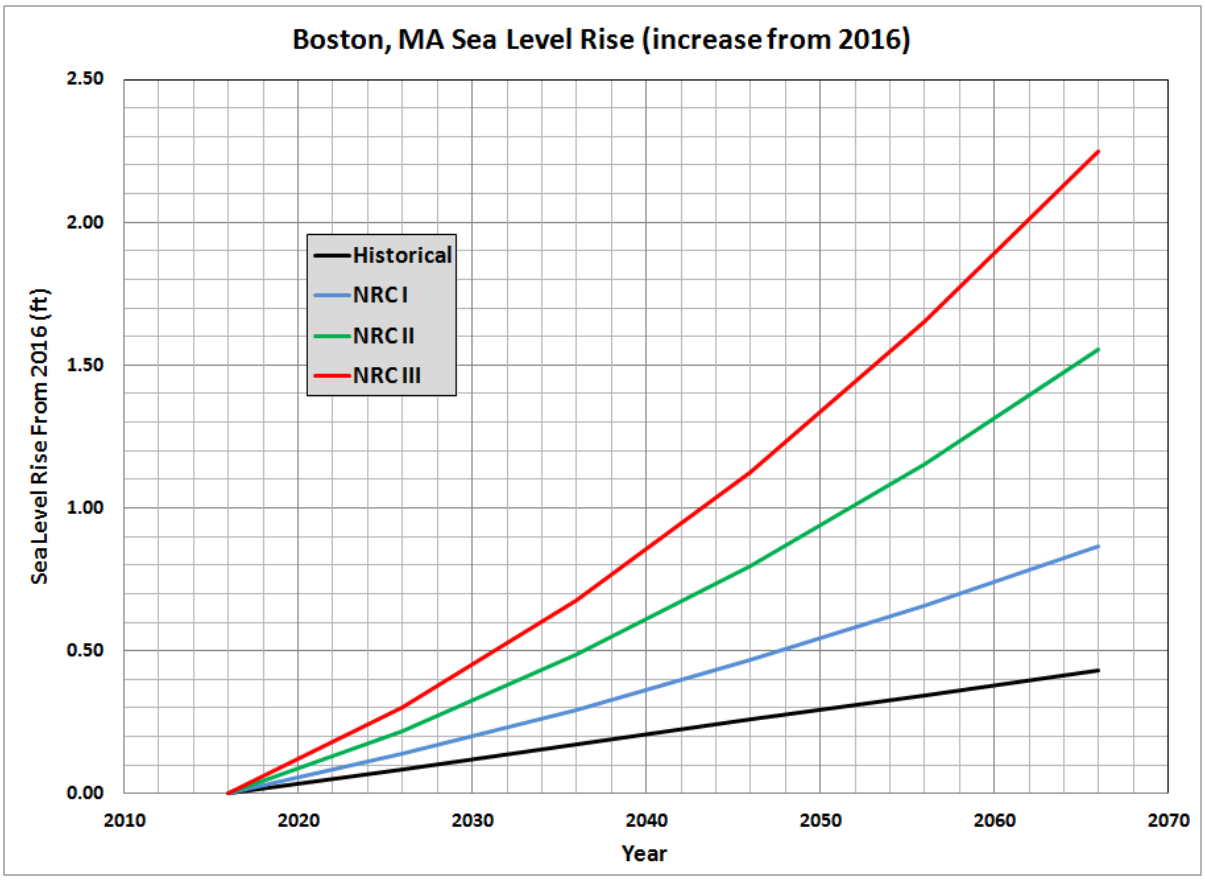


FIGURE D1-17 – Sea Level Rise Projections

Table D1-10 - Sea Level Rise Calculations – Boston Harbor – 2016-2066 Project Life

Start Date for Calculation (t_1): 2016
(Ex: 2010)
Ending Date for Calculation (t_2) 2066
(Ex: 2060)

Variables used in SLR Equations:

	(m/yr^2)
b (Curve I) =	2.71E-05
b (Curve II) =	7.00E-05
b (Curve III)=	1.13E-04

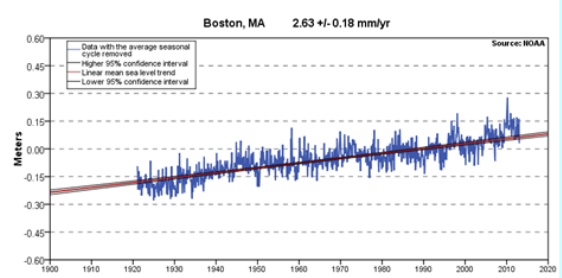
Example: M+0.0017=6.39 mm/yr = 0.00639 m/yr

$$E(t_2) - E(t_1) = 0.0017(t_2 - t_1) + b(t_2^2 - t_1^2)$$

EC 1165-2-212, Eustatic SLR:

Eustatic SLR from year: 2016
To year: 2066

	m	ft
Curve I:	0.22	0.71
Curve II:	0.43	1.40
Curve III:	0.64	2.10



$$RSL(t_2) - RSL(t_1) = (0.0017 + M)(t_2 - t_1) + b(t_2^2 - t_1^2)$$

EC 1165-2-212, RSLR:

M+0.0017 0.00263 (m/yr) (see *, below)

RSLR from year: 2016
To year: 2066

	m	ft
Curve I:	0.26	0.87
Curve II:	0.47	1.56
Curve III:	0.69	2.25

EC 1165-2-211, Eustatic SLR:

Eustatic SLR from year: 2016
To year: 2066

	m	ft
Curve I:	0.23	0.77
Curve II:	0.47	1.54
Curve III:	0.71	2.32

Old Guidance (NRC, 1987):

Eustatic SLR from year: 2016
To year: 2066

	mm	ft
Curve I:	0.21	0.69
Curve II:	0.45	1.46
Curve III:	0.68	2.24

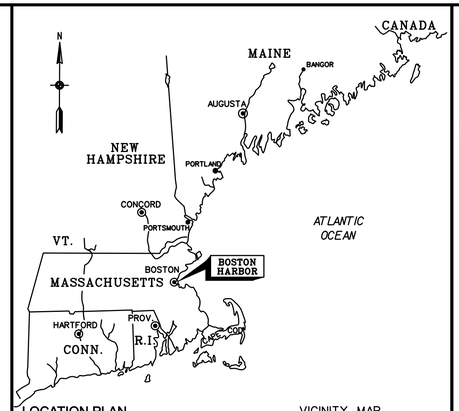
* M is the local adjustment for RSLR in m/yr.
0.0017+M = rate of change observed at gage data at site of interest.
M can be estimated from:
http://tidesandcurrents.noaa.gov/sltrends/index.shtml

NOTE: SLR values are limited to no greater than 0.01m precision. Reporting values to 0.1m precision may be more appropriate due to surveying limitations as described in EM 1110-2-6056.

Other than facility operations, the effect of sea level rise is more of a benefit to navigation. Either the ships can load deeper in response to greater available navigable depth, or after adjusting the sea level and tidal datum project maintenance dredging can be deferred while that additional depth shoals.

TABLE D1-11 Sea Level Rise Scenarios for Boston Harbor				
Sea Level Rise over Project Life				
Year	**Historical**	**NRC I**	**NRC II**	**NRC III**
2016	0.00	0.00	0.00	0.00
2026	0.09	0.14	0.22	0.30
2036	0.17	0.29	0.48	0.68
2046	0.26	0.47	0.80	1.13
2056	0.35	0.66	1.15	1.65
2066	0.43	0.87	1.56	2.25
60-Year Sea Level Rise – 2010-2070				
Year	**Historical**	**NRC I**	**NRC II**	**NRC III**
2010	0.00	0.00	0.00	0.00
2020	0.09	0.13	0.19	0.26
2030	0.17	0.27	0.43	0.59
2040	0.26	0.43	0.71	0.99
2050	0.35	0.62	1.04	1.47
2060	0.43	0.81	1.42	2.03
2070	0.52	1.03	1.84	2.65

DEEP DRAFT FEASIBILITY STUDY
BOSTON HARBOR
BOSTON, MASSACHUSETTS



LOCATION PLAN
NOT TO SCALE

VICINITY MAP
NTS

INDEX TO DRAWINGS

SHEET NO.		DESIGN FILE	SHEET TITLE
1	D1-6A	BOSGCS.DGN	COVER SHEET
2	D1-6B	BOSG002.S02	KEY PLAN
3	D1-6C	BOSC101.S03	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL
4	D1-6D	BOSC102.S04	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL
5	D1-6E	BOSC103.S05	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL
6	D1-6F	BOSC104.S06	MAIN CHANNELS PLAN - OUTER CONFLUENCE
7	D1-6G	BOSC105.S07	MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL
8	D1-6H	BOSC106.S08	MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL
9	D1-6I	BOSC107.S09	MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL
10	D1-6J	BOSC108.S10	MAIN CHANNELS PLAN - MAIN SHIP CHANNEL
11	D1-6K	BOSC109.S11	MAIN CHANNELS PLAN - MAIN SHIP CHANNEL, RESERVED CHANNEL AND RESERVED CHANNEL TURNING AREA
12	D1-6L	BOSC110.S12	MAIN CHANNELS PLAN - UPPER RESERVED CHANNEL
13	D1-6M	BOSC111.S13	MAIN SHIP CHANNEL DEEPENING EXTENSION TO MARINE TERMINAL
14	D1-6N	BOSC112.S14	MYSTIC RIVER CHANNEL
15	D1-6O	BOSC113.S15	MYSTIC RIVER CHANNEL AT MEDFORD STREET TERMINAL
16	D1-6P	BOSC114.S16	MYSTIC RIVER CHANNEL
17	D1-6Q	BOSC115.S17	CHELSEA RIVER CHANNEL
18	D1-6R	BOSC116.S18	CHELSEA RIVER CHANNEL
19	D1-6S	BOSC117.S19	CHELSEA RIVER CHANNEL
20	D1-6T	BOSC118.S20	CHELSEA RIVER CHANNEL
21	D1-6U	BOSC119.S21	CHELSEA RIVER CHANNEL AND TURNING BASIN

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maeder
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE:
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
COVER SHEET

SHEET IDENTIFICATION NUMBER
D1-6A
SHEET 1 OF 21

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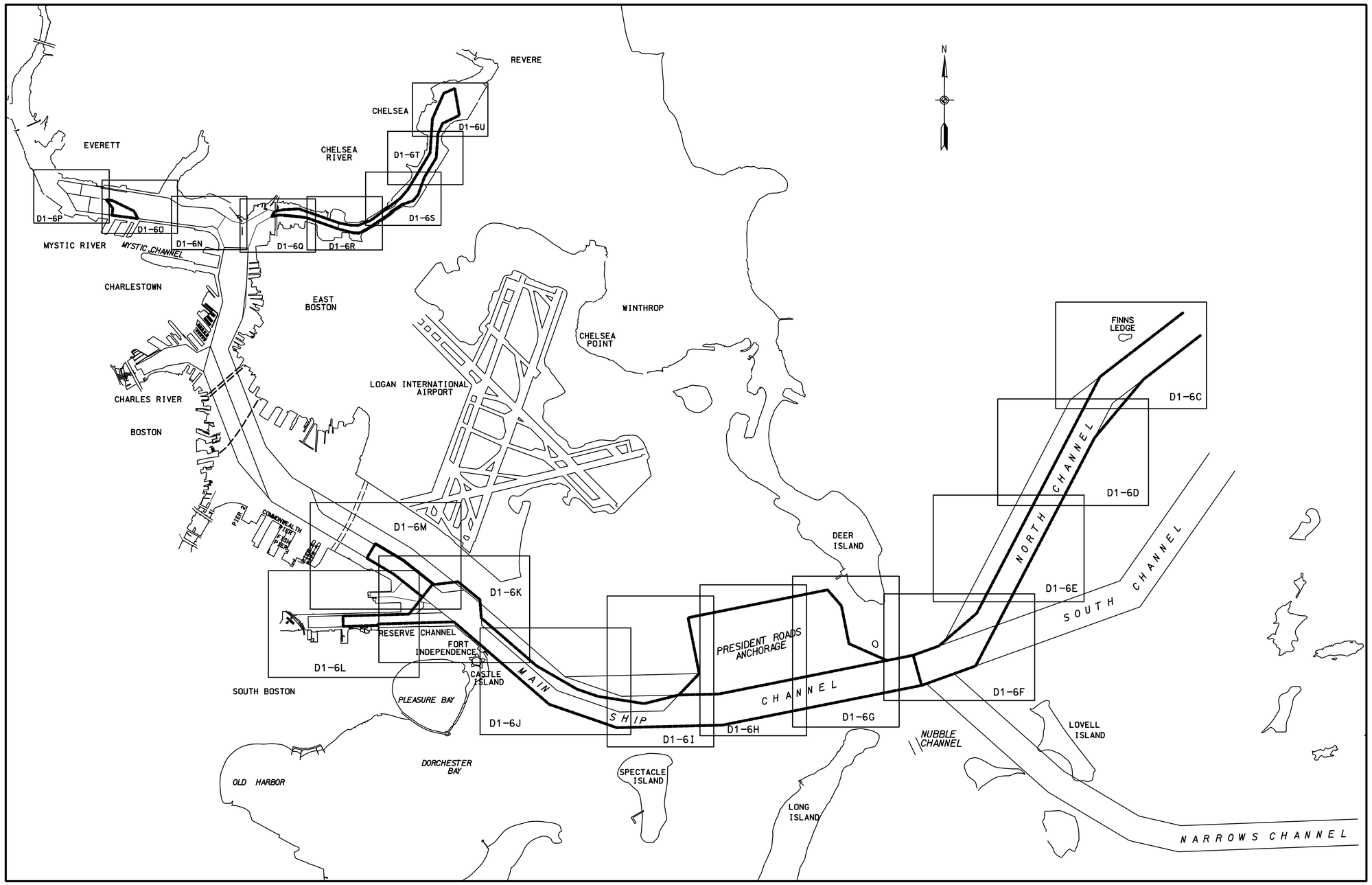

KEY PLAN

NOT TO SCALE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Annie Chin | DATE: Dec. 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSGBS.DGN | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=2000' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

KEY PLAN

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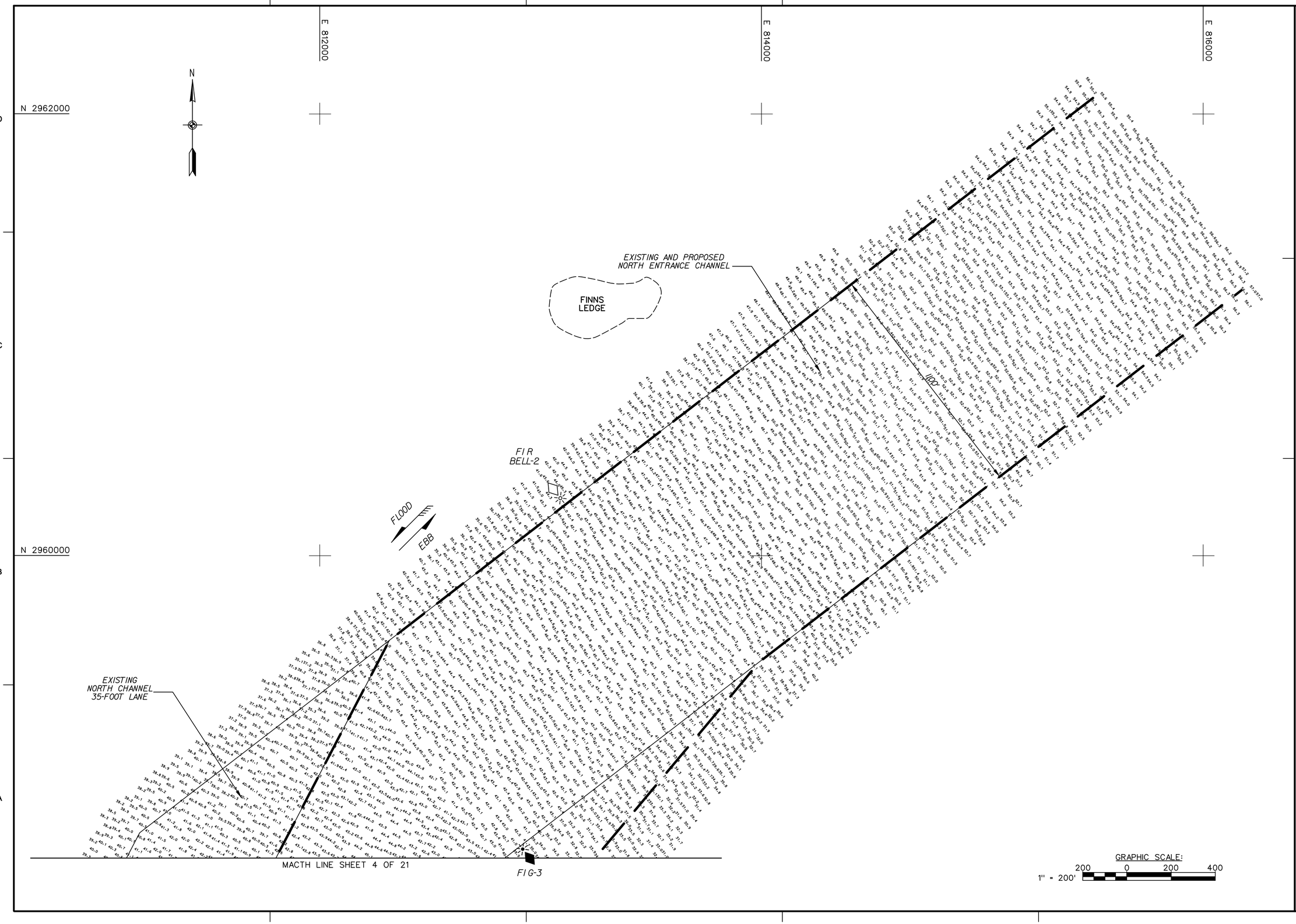

R/W
NC

US ARMY CORPS
OF ENGINEERS
NEW ENGLAND
DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maeder
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
BOSC101.S03
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=200'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
MAIN CHANNELS PLAN - BROAD SOUND
NORTH ENTRANCE CHANNEL

SHEET
IDENTIFICATION
NUMBER
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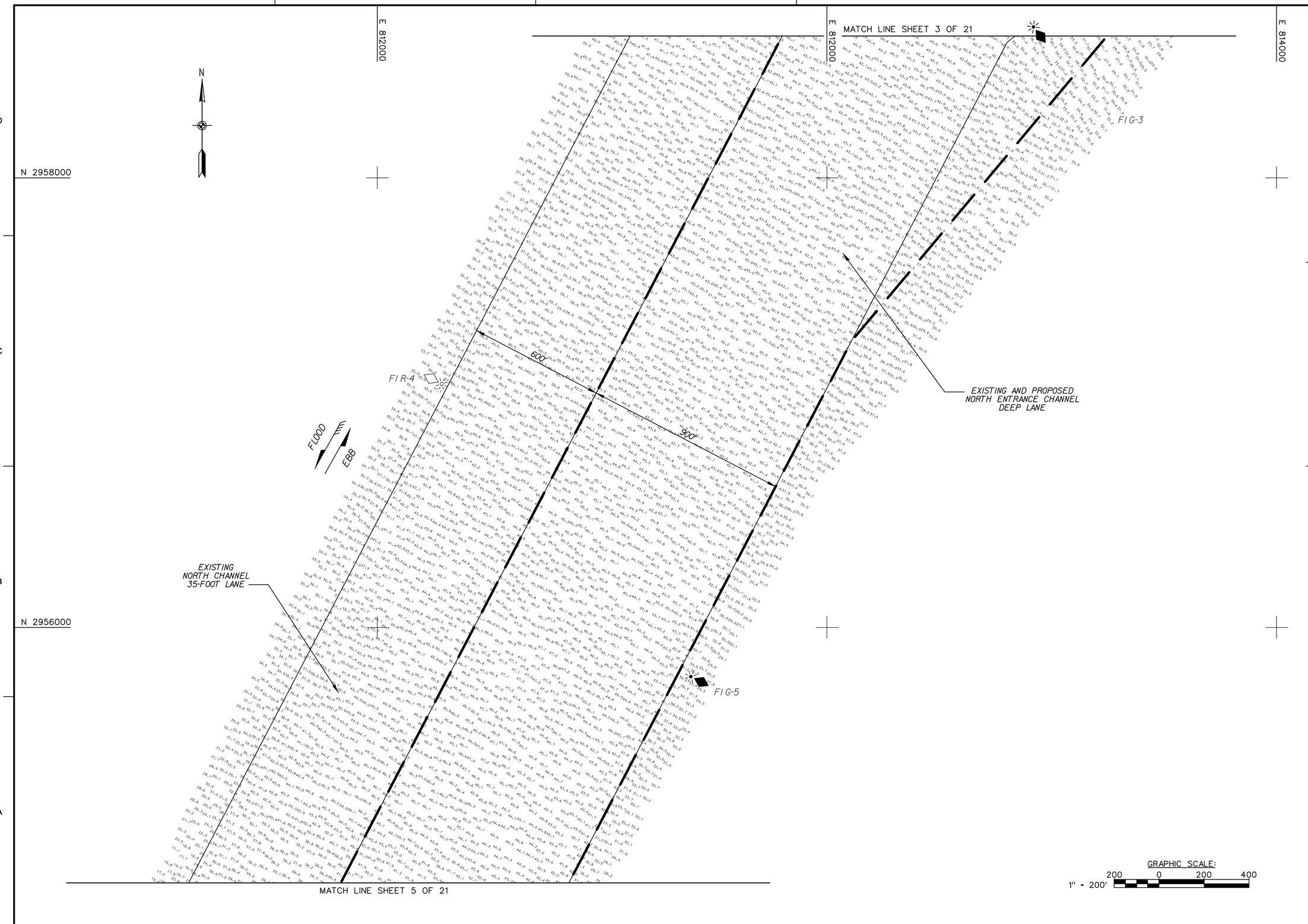

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DWN BY: Annie Chin
CKD BY: Mark Habel
SUBMITTED BY:
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
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PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN CHANNELS PLAN - BROAD SOUND
NORTH ENTRANCE CHANNEL

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D1-6D
SHEET 4 OF 21

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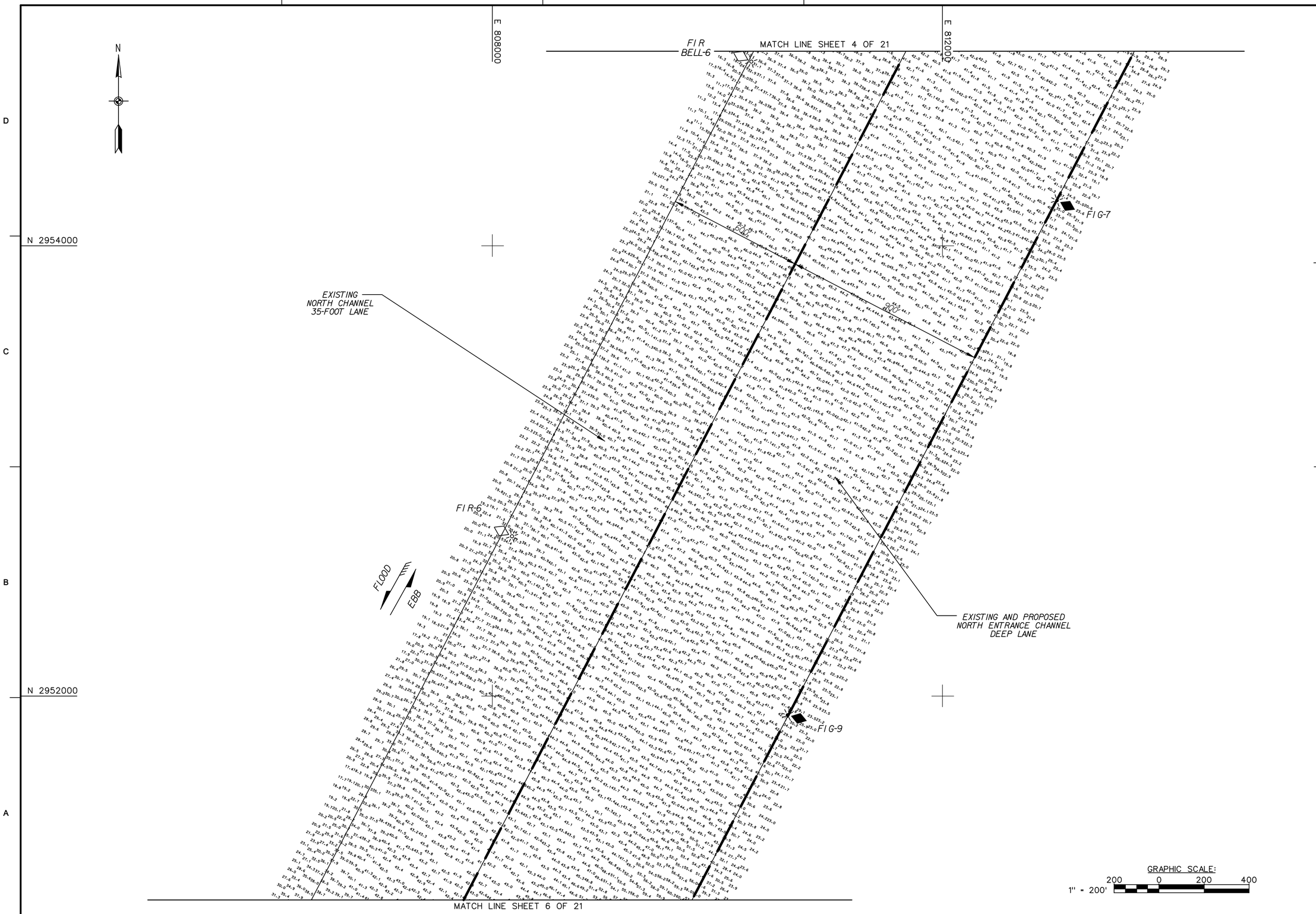

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSGBS.DGN BOSC103.S05 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=200' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
MAIN CHANNELS PLAN - BROAD SOUND
NORTH ENTRANCE CHANNEL

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SHEET 5 OF 21

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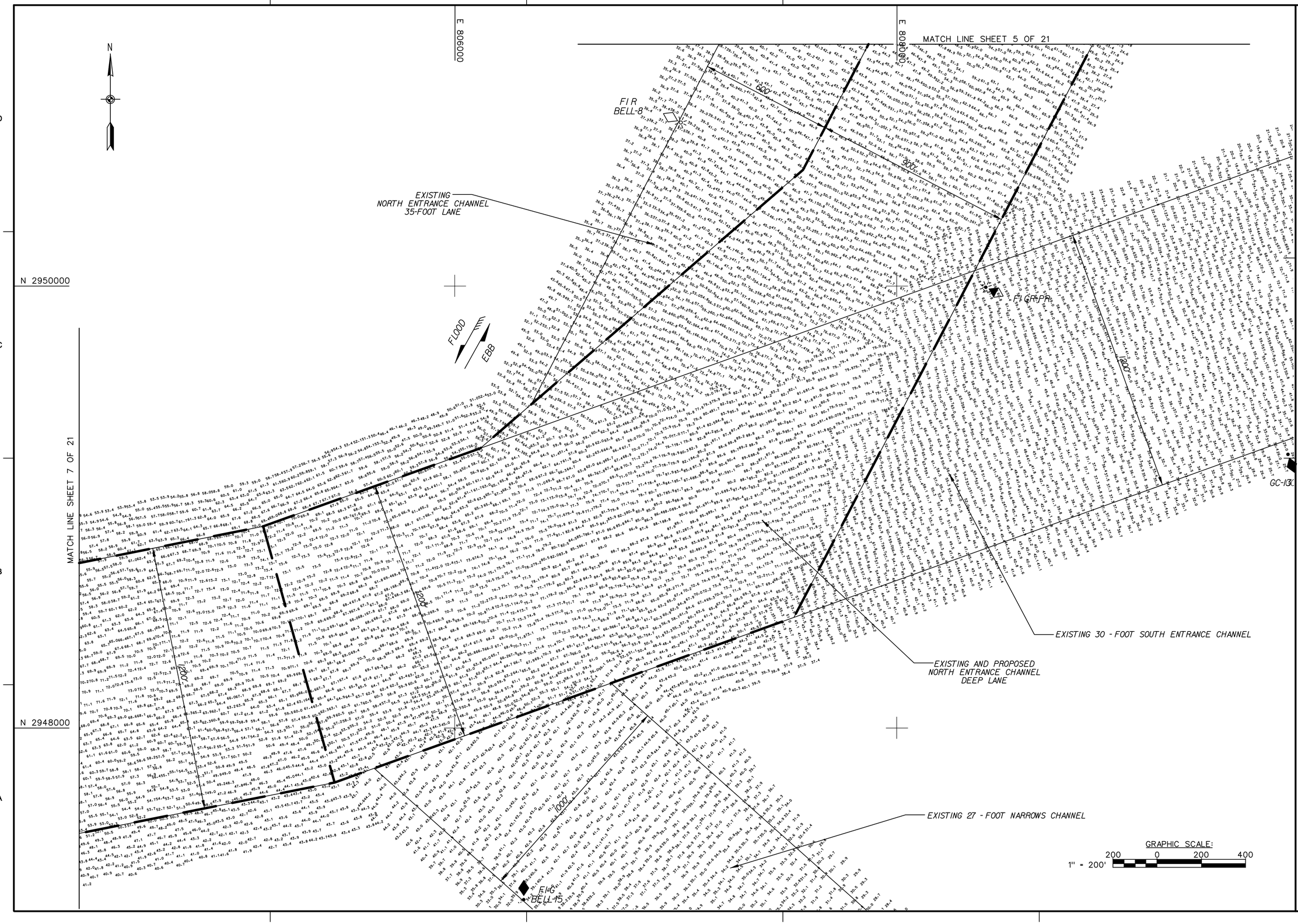

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maeder	DATE: July 2007
DWN BY: Annie Chin	CKD BY: Mark Haberl
SUBMITTED BY:	SOLICITATION NO.:
	CONTRACT NO.:
FILE NAME: BOSG6BS.DGN BOSC104.S06	DRAWING CODE:
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	PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN CHANNELS PLAN
OUTER CONFLUENCE

SHEET IDENTIFICATION NUMBER
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SHEET 6 OF 21

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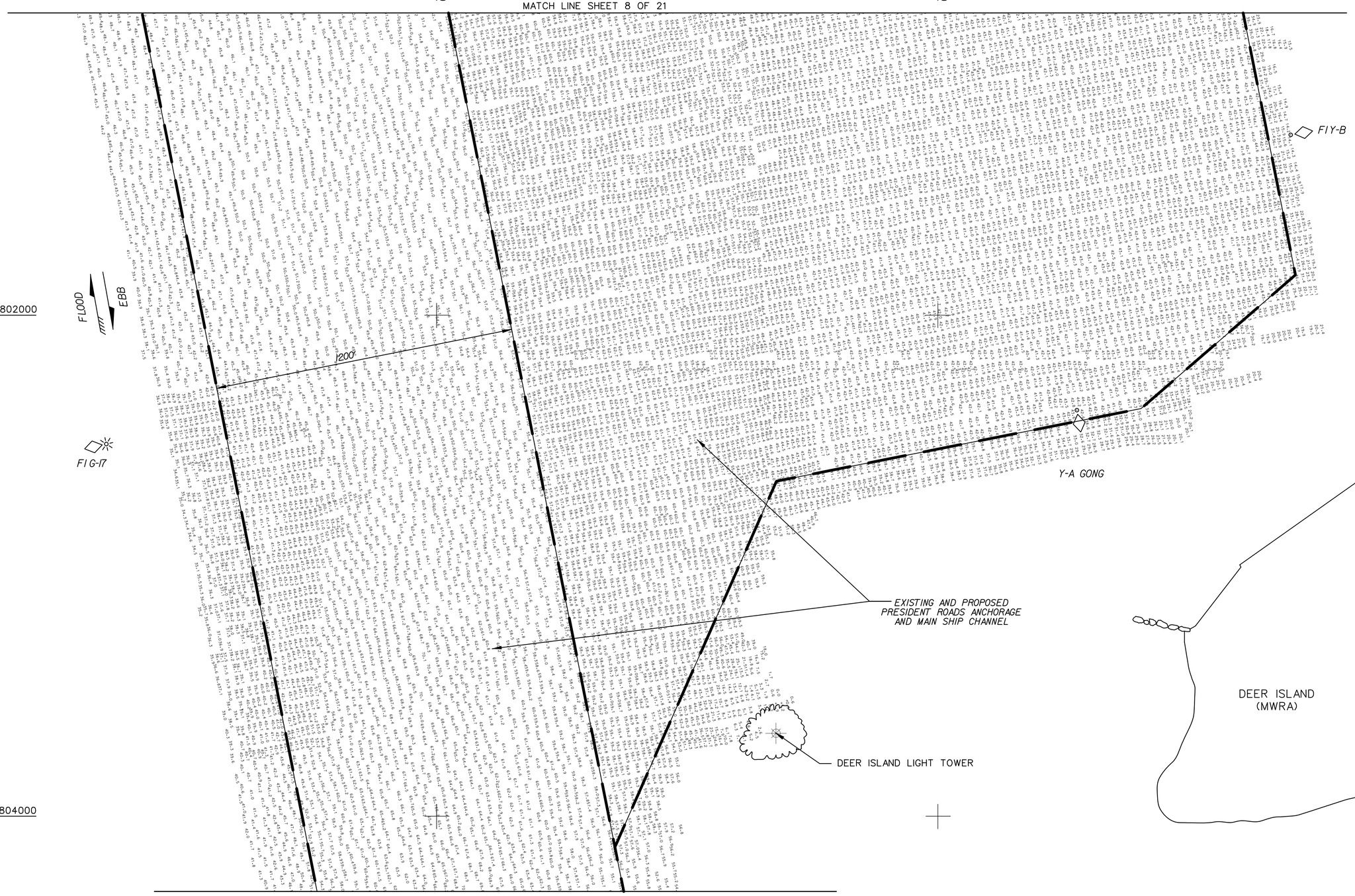

US ARMY CORPS
OF ENGINEERS
NEW ENGLAND
DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maeder
DWN BY: Anne Chin
CKD BY: Mark Habel
SUBMITTED BY:
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
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FILE NAME: BOSGBS.DGN
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DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN CHANNELS PLAN -
PRESIDENT ROADS ANCHORAGE
AND MAIN SHIP CHANNEL

SHEET
IDENTIFICATION
NUMBER
D1-6G
SHEET 7 OF 21

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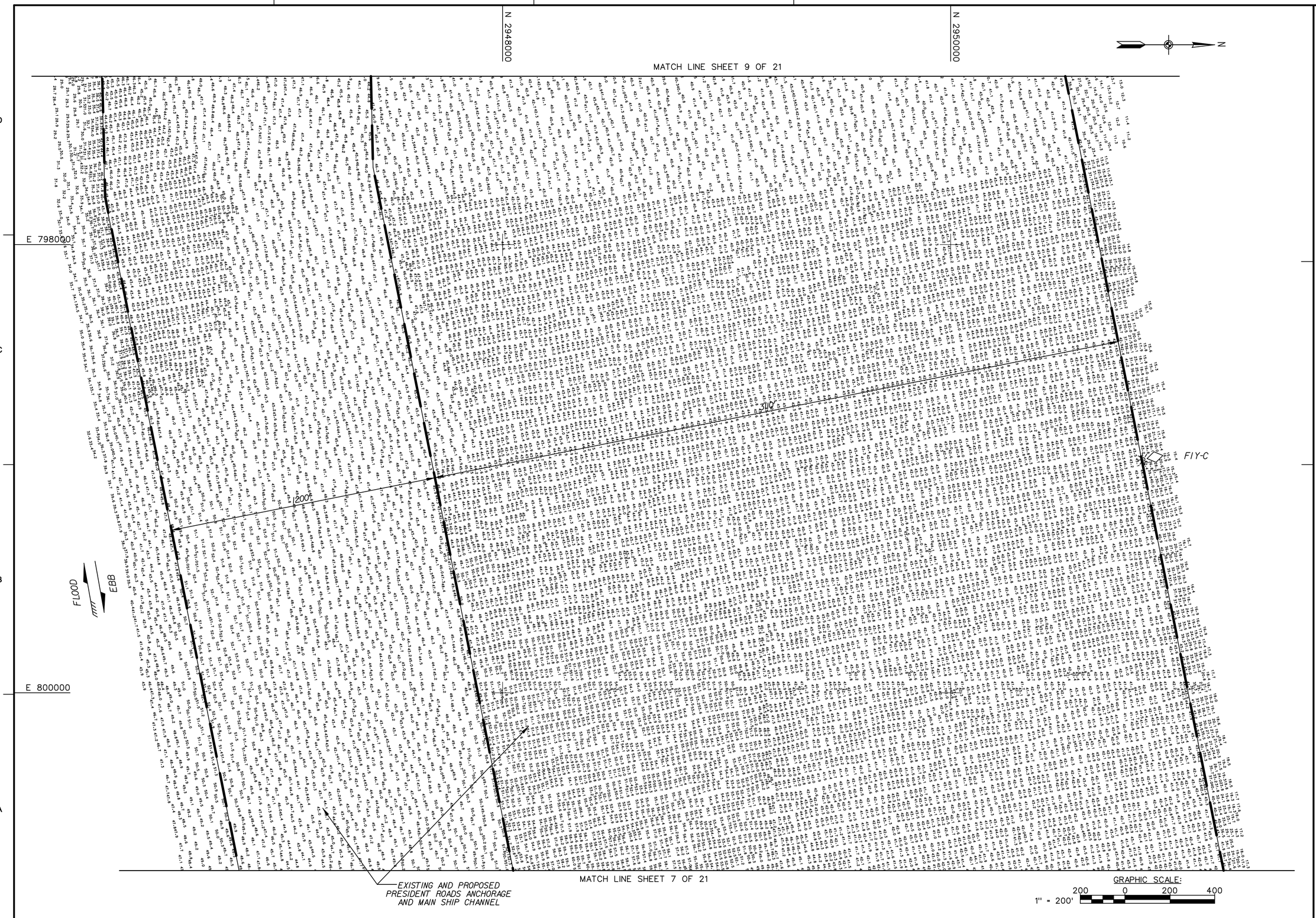

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meeder
DWN BY: Annie Chin
CKD BY: Mark Habel
SUBMITTED BY:
FILE NAME: BOSGBS.DGN
BOSC106.S08
SIZE: ANSI D
PLOT SCALE: 1"=200'
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN CHANNELS PLAN -
PRESIDENT ROADS ANCHORAGE
AND MAIN SHIP CHANNEL

SHEET IDENTIFICATION NUMBER
D1-6H
SHEET 8 OF 21

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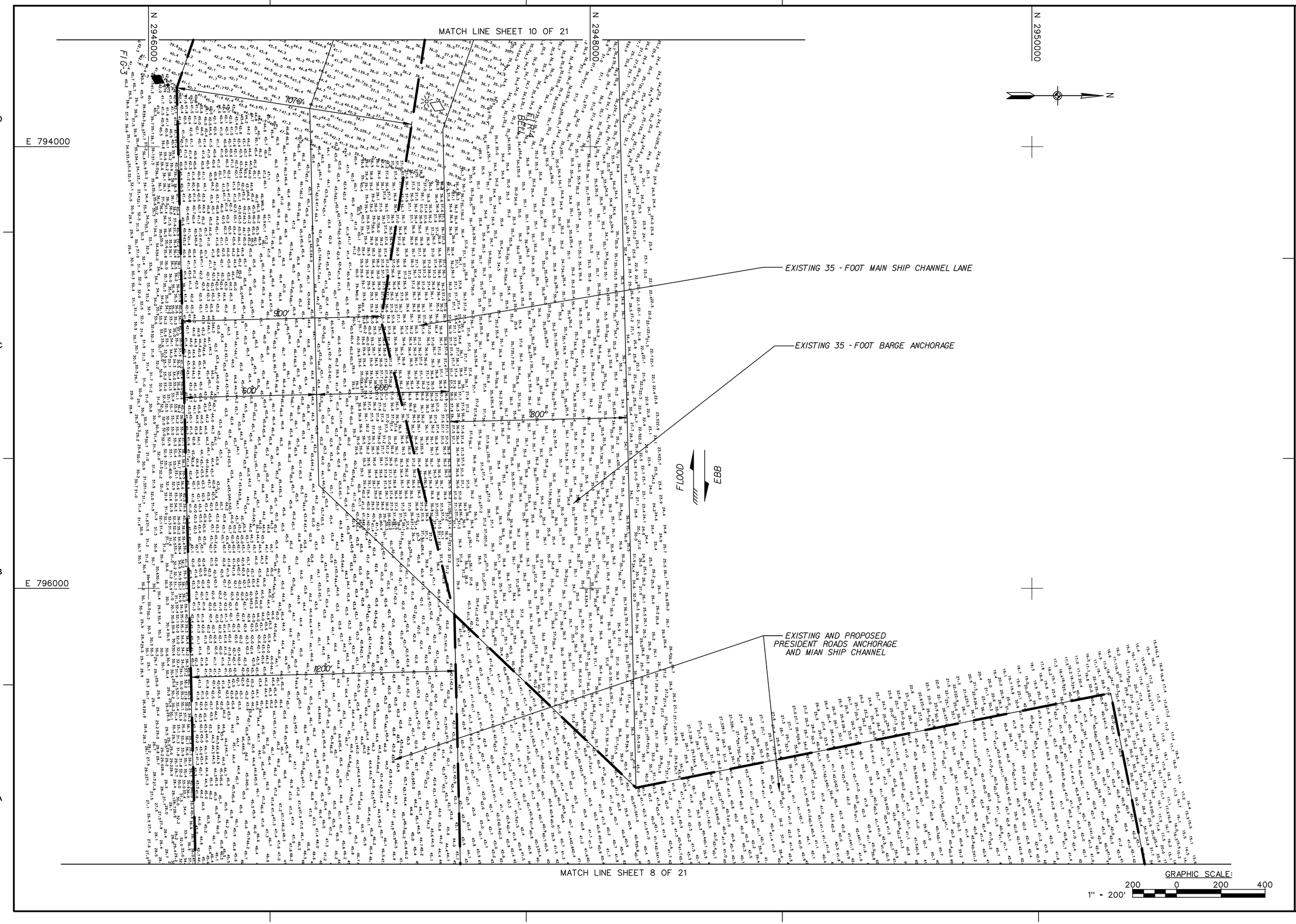

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maeder | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSGBS.DGN BOSC107.S09 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=200' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN CHANNELS PLAN -
PRESIDENT ROADS ANCHORAGE
AND MAIN SHIP CHANNEL

SHEET IDENTIFICATION NUMBER
D1-6I
SHEET 9 OF 21

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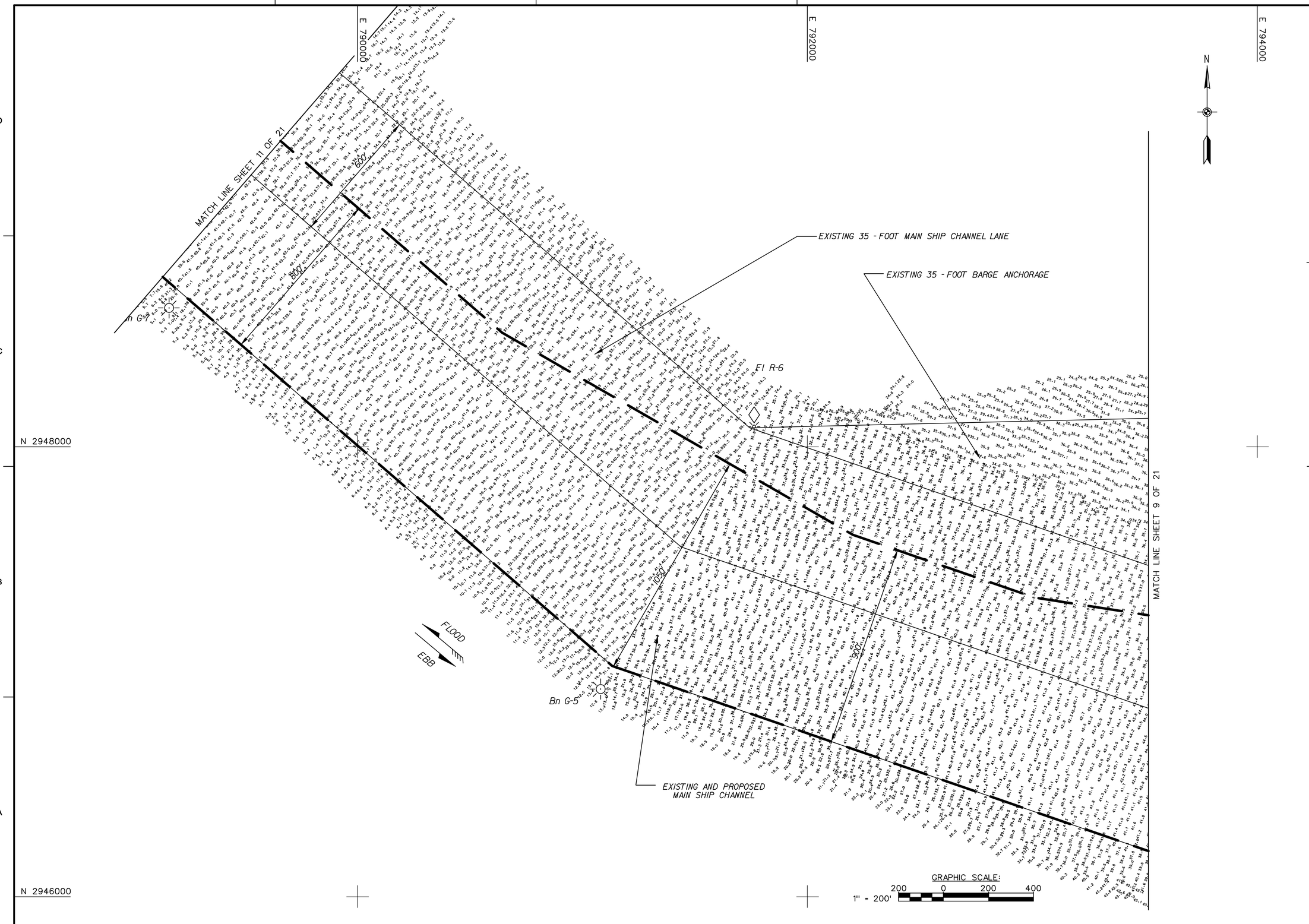

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maeder
DWN BY: Annie Chin
CKD BY: Mark Habel
SUBMITTED BY:
FILE NAME: BOSGBS.DGN BOSC108.S10
SIZE: ANSI D
PLOT SCALE: 1" = 200'
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN CHANNELS PLAN -
MAIN SHIP CHANNEL

SHEET IDENTIFICATION NUMBER
D1-6J
SHEET 10 OF 21

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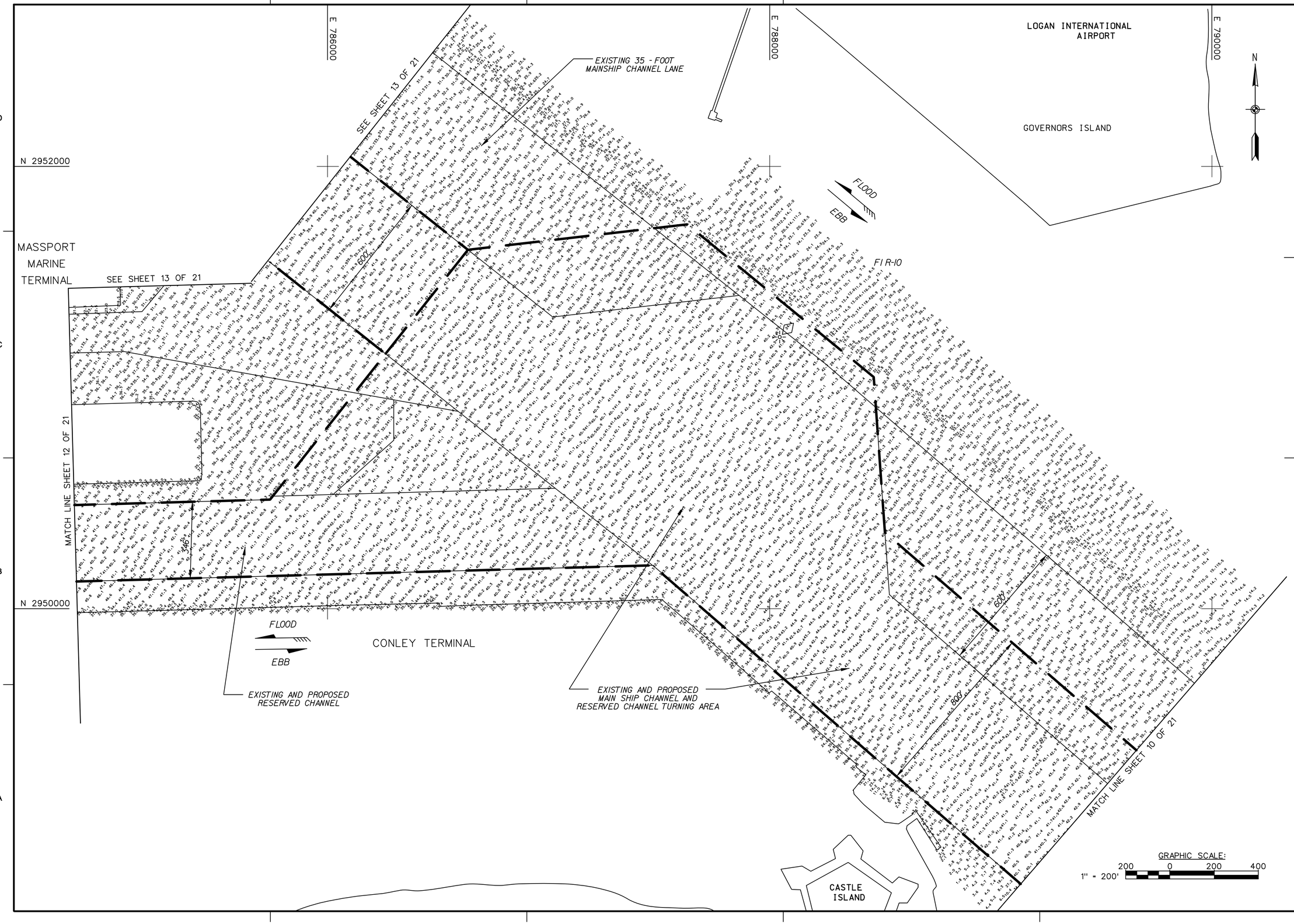

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader		DATE: July 2007	
DWN BY: Annie Chin	CKD BY: Mark Habel	SOLICITATION NO.:	
SUBMITTED BY:		CONTRACT NO.:	
FILE NAME: BOSGBS.DGN BOSC109.S11		DRAWING CODE:	
SIZE: ANSI D	PLOT SCALE: 1" = 200'	PLOT DATE: February 2008	

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
MAIN CHANNELS PLAN-
MAIN SHIP CHANNEL, RESERVED CHANNEL
AND RESERVED CHANNEL TURNING AREA

SHEET IDENTIFICATION NUMBER
D1-6K
SHEET 11 OF 21

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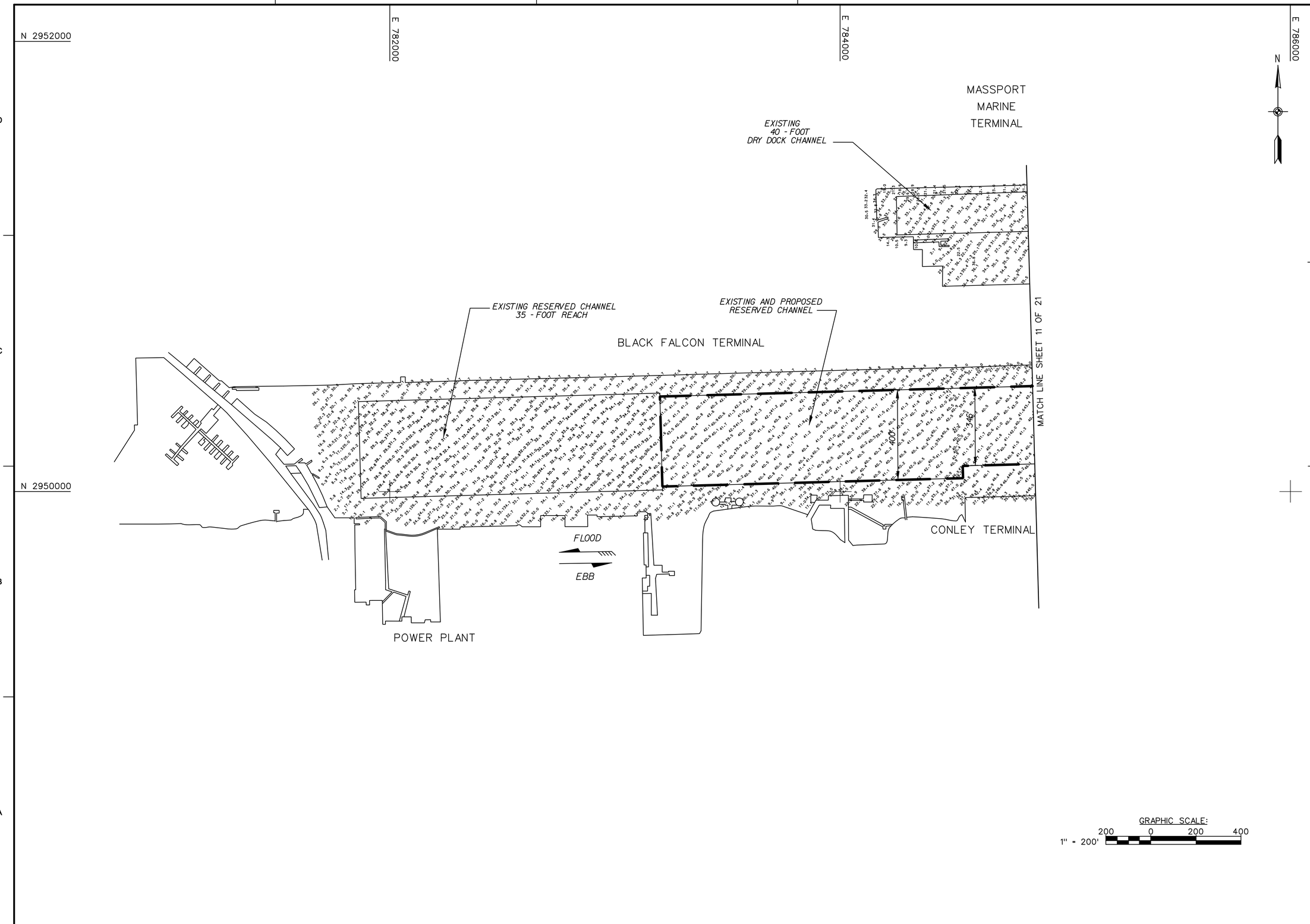

US ARMY CORPS
OF ENGINEERS
NEW ENGLAND
DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meeder
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
BOSC110.S12
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=200'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN CHANNELS PLAN -
UPPER RESERVED CHANNEL

SHEET
IDENTIFICATION
NUMBER
D1-6L
SHEET 12 OF 21

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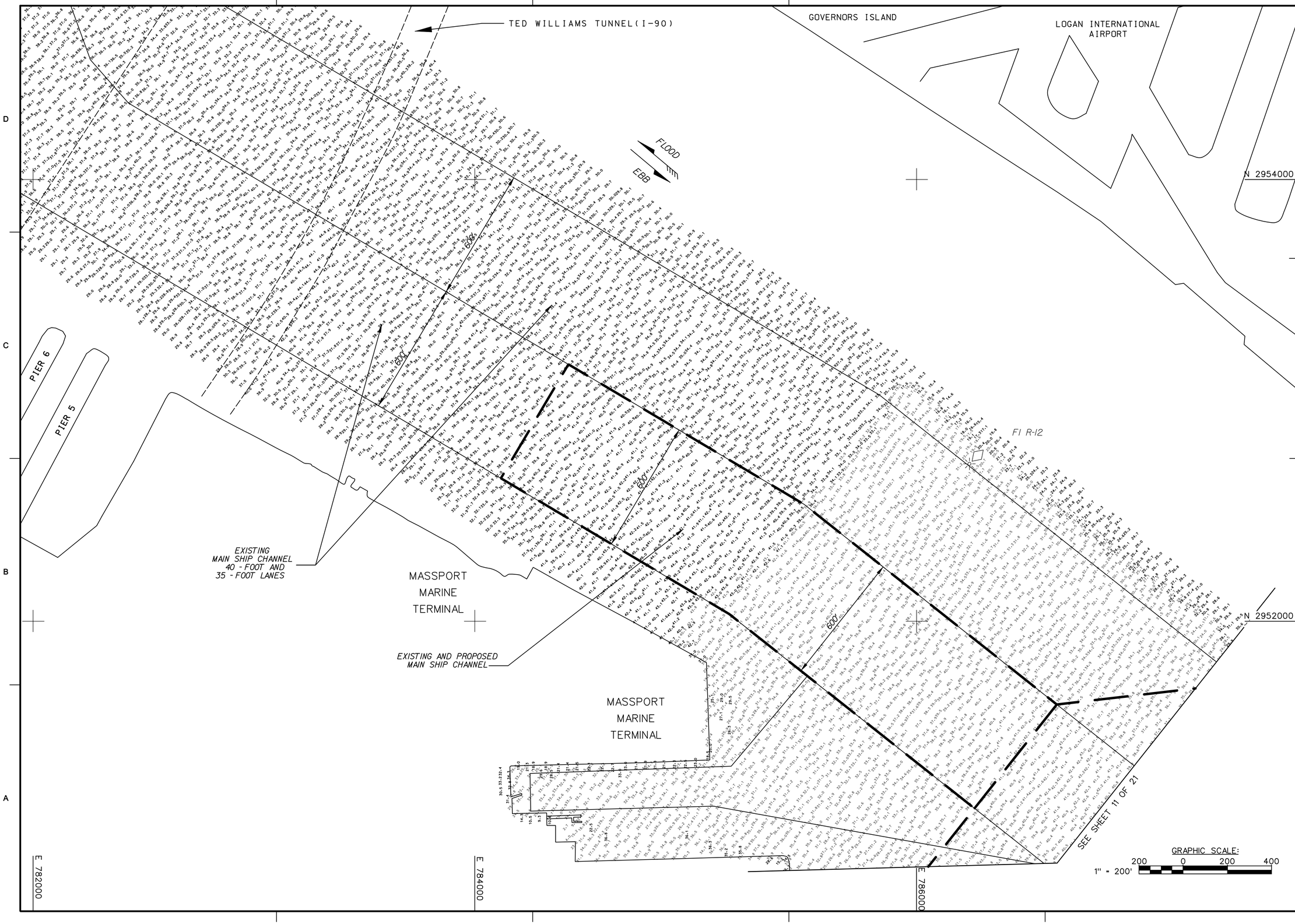

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

1"=200'

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
BOSC111.S13
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE:
PLOT DATE: February 2008

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MAIN SHIP CHANNEL
DEEPENING EXTENSION
TO MARINE TERMINAL

SHEET IDENTIFICATION NUMBER
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SHEET 13 OF 21

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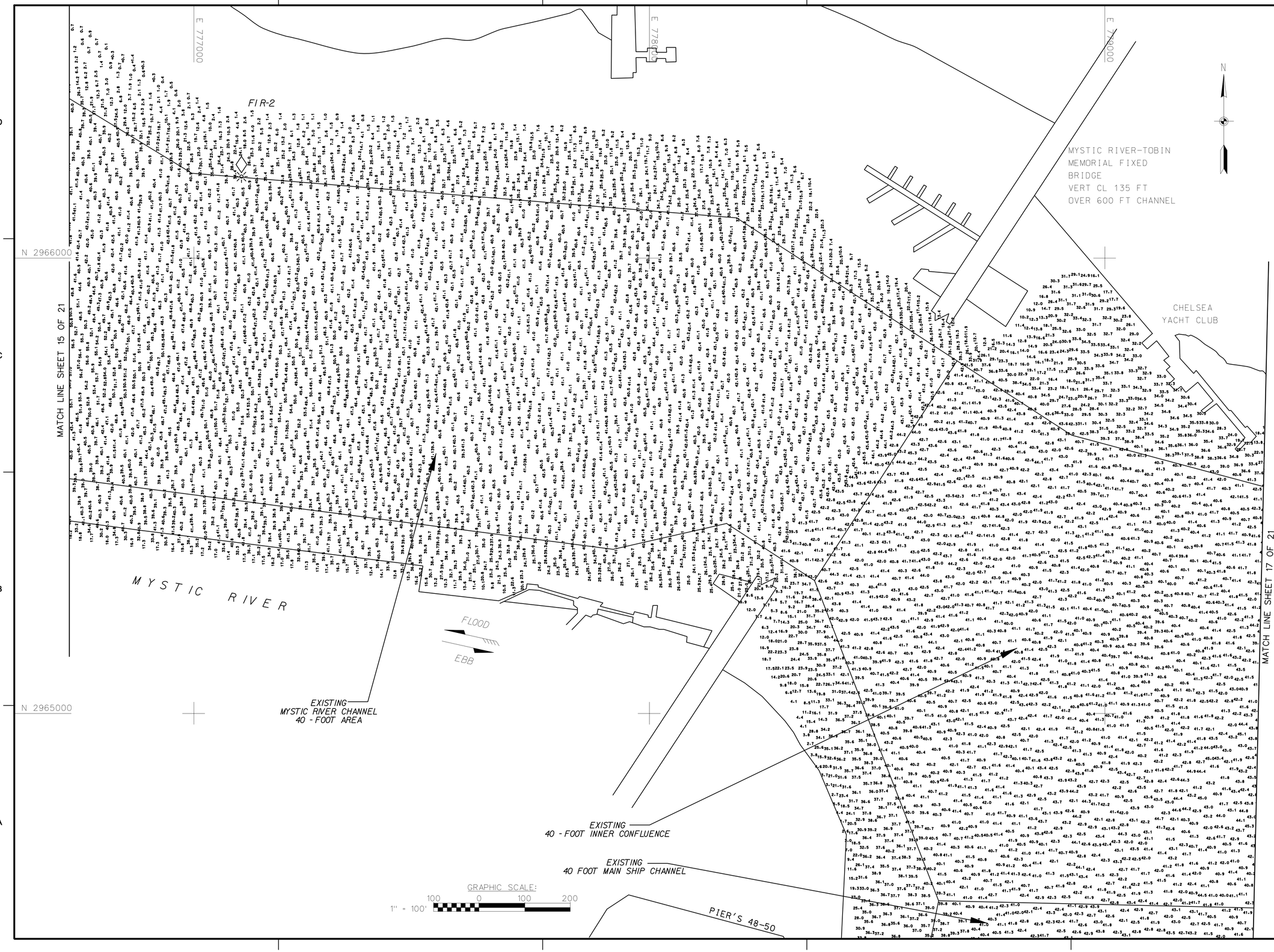

US ARMY CORPS
OF ENGINEERS
NEW ENGLAND
DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Haber
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
DRAWING CODE:
BOSC112.S14
SIZE: ANSI D
PLOT SCALE: 1" = 100'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MYSTIC RIVER CHANNEL

SHEET
IDENTIFICATION
NUMBER
D1-6N

SHEET 14 OF 21

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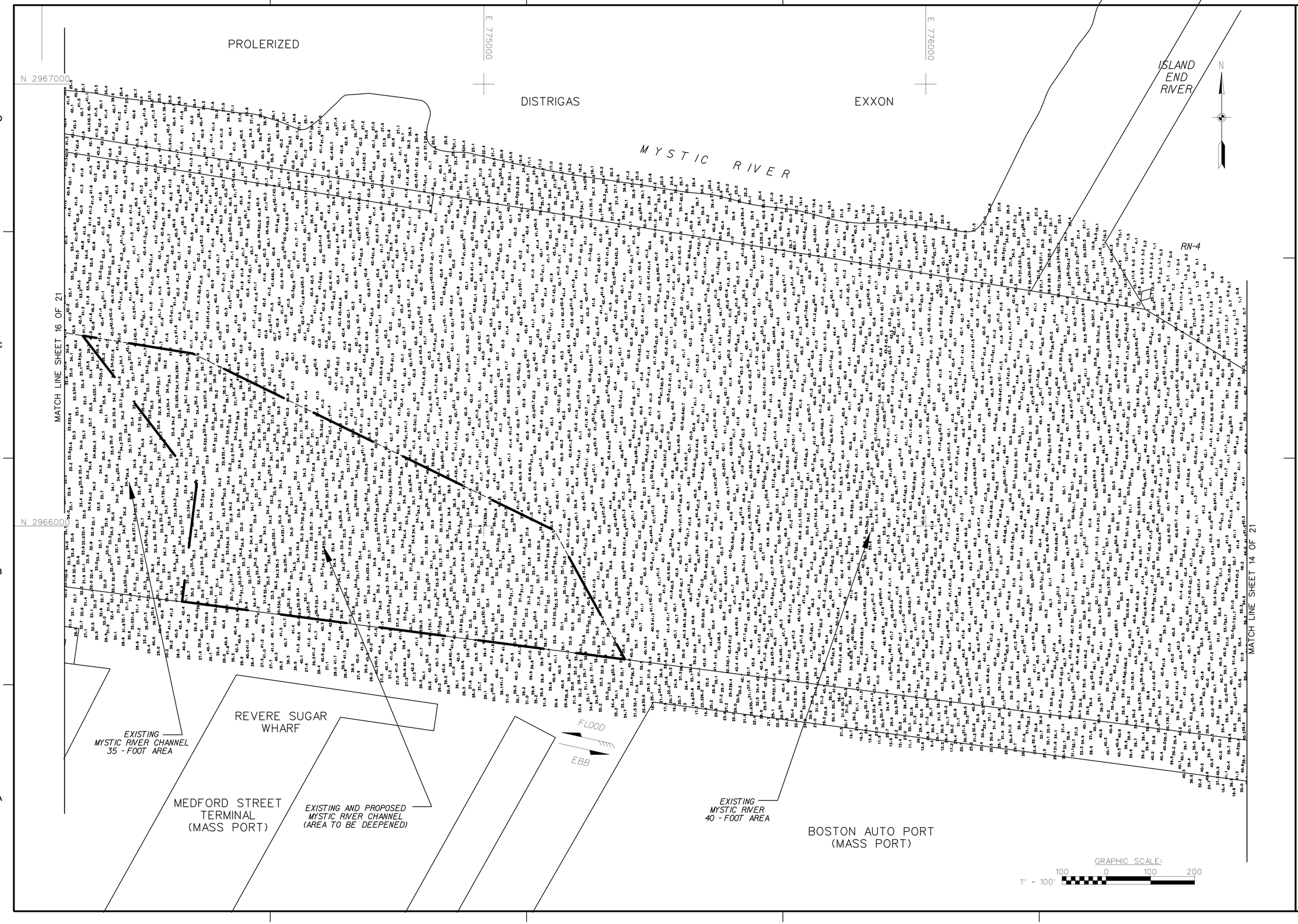

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: AnnieGlinn
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
BOSC113.S15
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SIZE: ANSI D
PLOT SCALE: 1" = 100'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MYSTIC RIVER CHANNEL
AT MEDFORD STREET TERMINAL

SHEET IDENTIFICATION NUMBER
D1-6O
SHEET 15 OF 21

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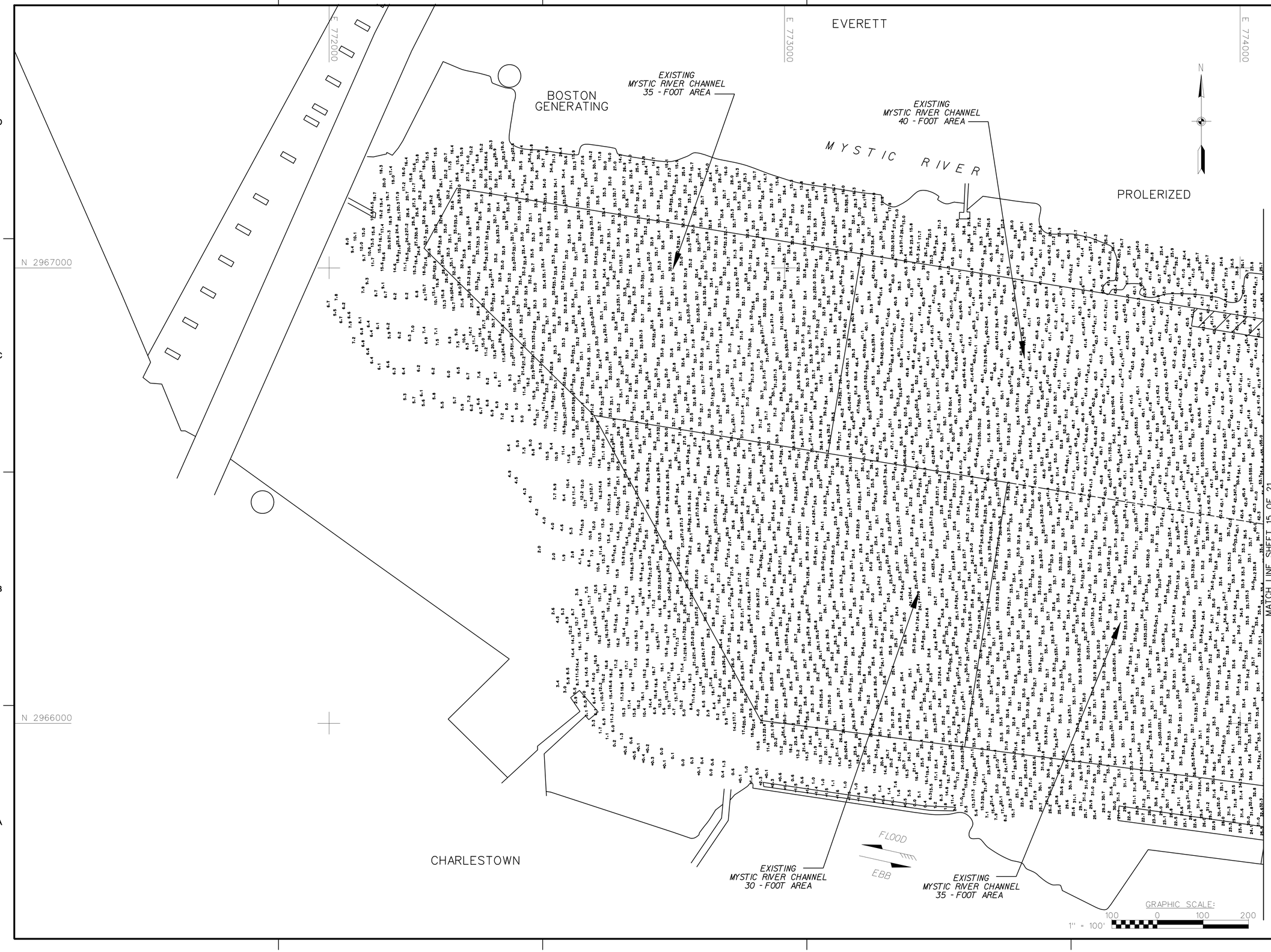

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maisder	DATE: July 2007	
DWN BY: Annie Chin	CKD BY: Mark Habel	SOLICITATION NO.:
SUBMITTED BY:		CONTRACT NO.:
FILE NAME: BOSGBS.DGN BOSC114.S16		DRAWING CODE:
SIZE: ANSI D	PLOT SCALE: 1" = 100'	PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

MYSTIC RIVER CHANNEL

SHEET IDENTIFICATION NUMBER
D1-6P
SHEET 16 OF 21

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US ARMY CORPS
OF ENGINEERS
NEW ENGLAND
DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
BOSC115.S17
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=100'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

CHELSEA RIVER CHANNEL

SHEET
IDENTIFICATION
NUMBER
D1-6Q
SHEET 17 OF 21

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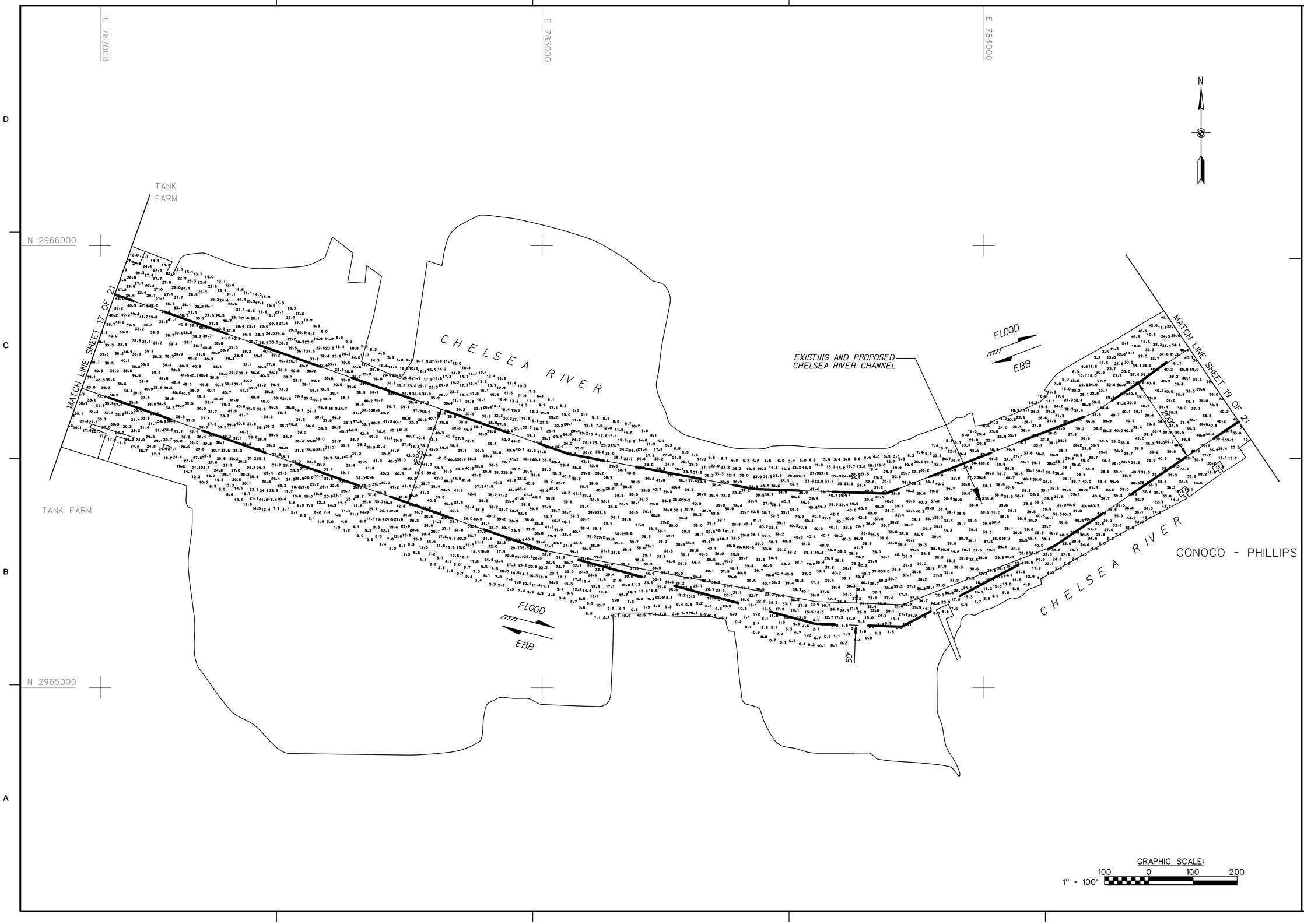

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.: | CONTRACT NO.:
SUBMITTED BY: | DRAWING CODE:
FILE NAME: BOSGBS.DGN | PLOT DATE: February 2008
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DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

CHELSEA RIVER CHANNEL

SHEET IDENTIFICATION NUMBER
D1-6R
SHEET 18 OF 21

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US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE:
DWN BY: Anita Chin
CKD BY: Mark Habel
SOLICITATION NO.:
CONTRACT NO.:
SUBMITTED BY:
DRAWING CODE:
FILE NAME: BOSGBS.DGN
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SIZE: ANSI D
PLOT SCALE: 1"=100'
PLOT DATE: Dec 28, 2012

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

CHELSEA RIVER CHANNEL

SHEET IDENTIFICATION NUMBER
D1-6S
SHEET 19 OF 21

US ARMY CORPS
OF ENGINEERS
NEW ENGLAND
DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSGBS.DGN
BOSC118.S20
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1" = 100'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

CHELSEA RIVER CHANNEL

SHEET
IDENTIFICATION
NUMBER
D1-6T
SHEET 20 OF 21

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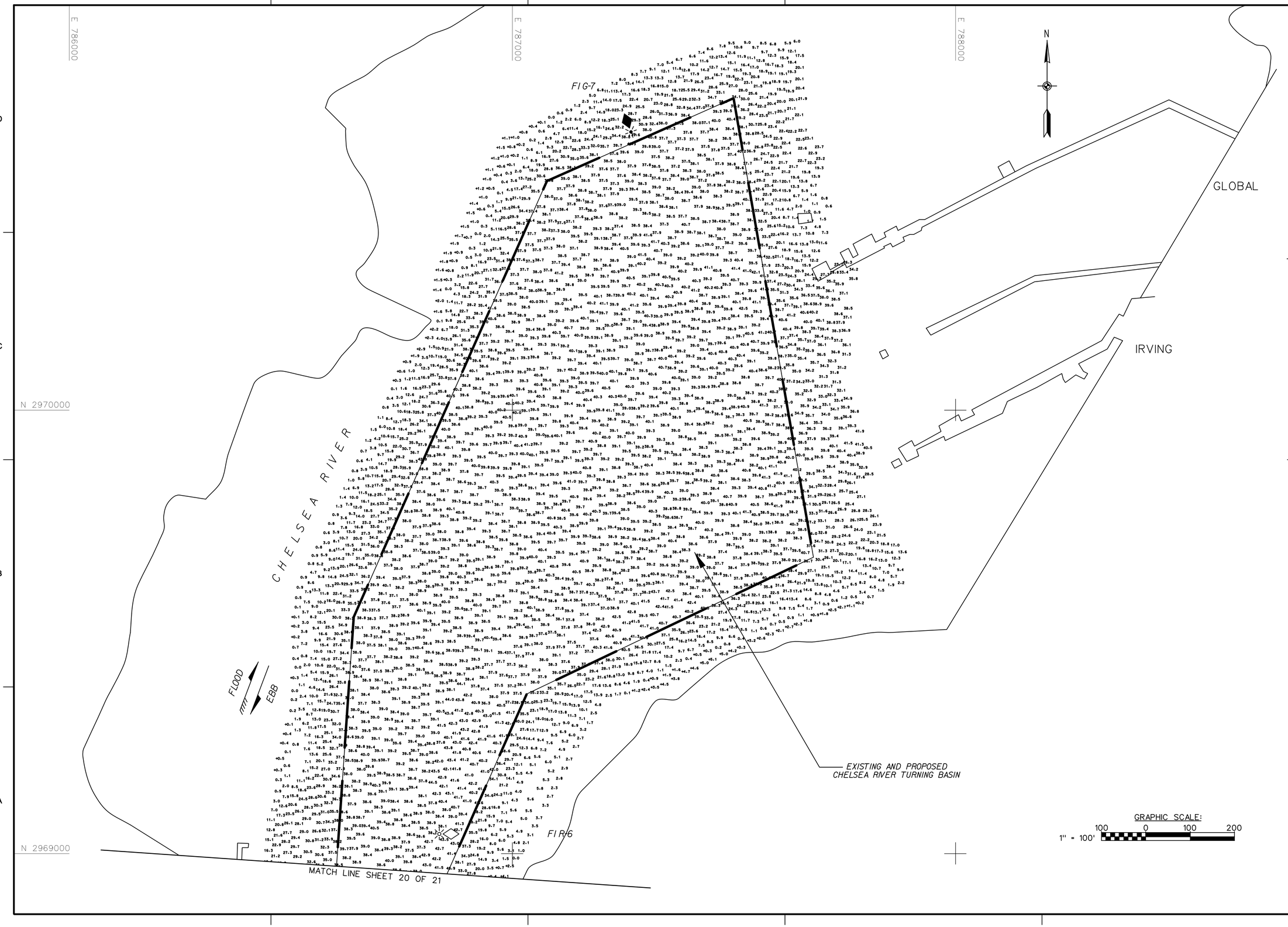

US ARMY CORPS
OF ENGINEERS
NEW ENGLAND
DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: Bob Meader		DATE: July 2007	
DWN BY: Arnie Chin	CKD BY: Mark Habel	SOLICITATION NO.:	
SUBMITTED BY:		CONTRACT NO.:	
FILE NAME: BOSG8S.DGN BOSC119.S21		DRAWING CODE:	
SIZE: ANSI D	PLOT SCALE: 1"=100'	PLOT DATE: February 2008	

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS

CHELSEA RIVER CHANNEL
AND TURNING BASIN

SHEET
IDENTIFICATION
NUMBER
D1-6U
SHEET 21 OF 21

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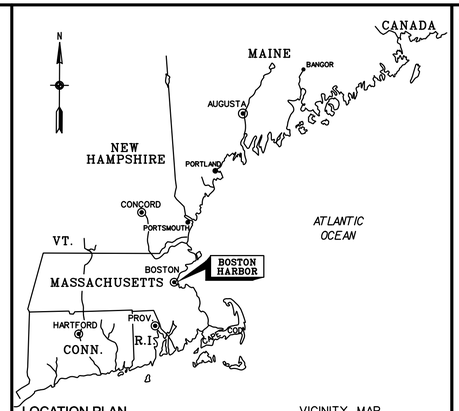
DEEP DRAFT FEASIBILITY STUDY
BOSTON HARBOR
BOSTON, MASSACHUSETTS



LOCATION PLAN
NOT TO SCALE

VICINITY MAP
NTS

INDEX TO LEDGE AREA DRAWINGS			
SHEET NO.		DESIGN FILE	SHEET TITLE
1	D1-7A	BOSG001.S01	COVER SHEET
2	D1-7B	BOSG002.S02	KEY PLAN
3	D1-7C 1 OF 5	BOSC101.S03	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL ROCK ELEVATIONS AT 45, 47 AND 49 FEET
4	D1-7C 2 OF 5	BOSC101.S04	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL ROCK ELEVATIONS AT 47, 49 AND 51 FEET (PLAN A)
5	D1-7C 3 OF 5	BOSC101.S05	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL ROCK ELEVATIONS AT 48, 50 AND 52 FEET
6	D1-7C 4 OF 5	BOSC101.S06	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL ROCK ELEVATIONS AT 50, 52 AND 54 FEET (PLAN B)
7	D1-7C 5 OF 5	BOSC101.S07	MAIN CHANNELS PLAN - BROAD SOUND NORTH ENTRANCE CHANNEL ROCK ELEVATIONS AT 52, 54 AND 56 FEET (PLAN C)
8	D1-7D 1 OF 3	BOSC102.S08	MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL ROCK ELEVATIONS AT 45, 47 AND 49 FEET (PLAN A)
9	D1-7D 2 OF 3	BOSC102.S09	MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL ROCK ELEVATIONS AT 48, 50 AND 52 FEET (PLAN B)
10	D1-7D 3 OF 3	BOSC102.S10	MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL ROCK ELEVATIONS AT 50, 52 AND 54 FEET (PLAN C)
11	D1-7E 1 OF 3	BOSC103.S11	MAIN CHANNELS PLAN - MAIN SHIP CHANNEL, RESERVED CHANNEL AND RESERVED CHANNEL TURNING AREA - ROCK ELEVATIONS AT 45, 47 AND 49 FEET (PLAN A)
12	D1-7E 2 OF 3	BOSC103.S12	MAIN CHANNELS PLAN - MAIN SHIP CHANNEL, RESERVED CHANNEL AND RESERVED CHANNEL TURNING AREA - ROCK ELEVATIONS AT 48, 50 AND 52 FEET (PLAN B)
13	D1-7E 3 OF 3	BOSC103.S13	MAIN CHANNELS PLAN - MAIN SHIP CHANNEL, RESERVED CHANNEL AND RESERVED CHANNEL TURNING AREA - ROCK ELEVATIONS AT 50, 52 AND 54 FEET (PLAN C)
14	D1-7F	BOSC104.S14	MAIN SHIP CHANNEL DEEPENING EXTENSION TO MARINE TERMINAL ROCK ELEVATIONS AT 45, 47 AND 49 FEET (PLAN D)
15	D1-7G	BOSC105.S15	CHELSEA RIVER CHANNEL AND TURNING BASIN ROCK ELEVATIONS AT 40, 42 AND 44 FEET (PLAN F)

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Maeder | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSG001.S01 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
COVER SHEET

SHEET IDENTIFICATION NUMBER
D1-7A
SHEET 1 OF 15

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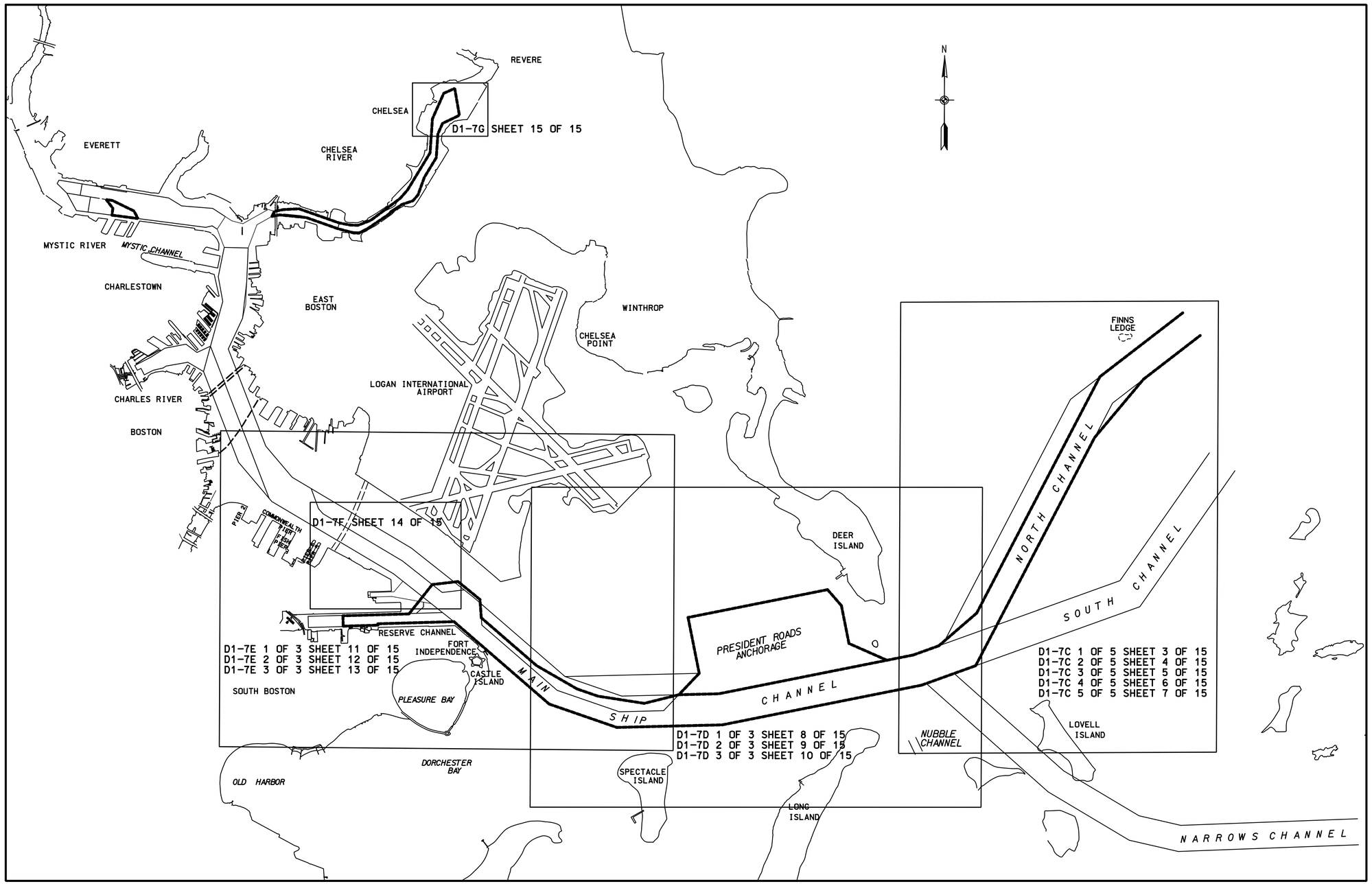

KEY PLAN
NOT TO SCALE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Annie Chin | DATE: Dec. 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSG001.S01 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=2000' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
KEY PLAN

SHEET IDENTIFICATION NUMBER
D1-7B
SHEET 2 OF 15

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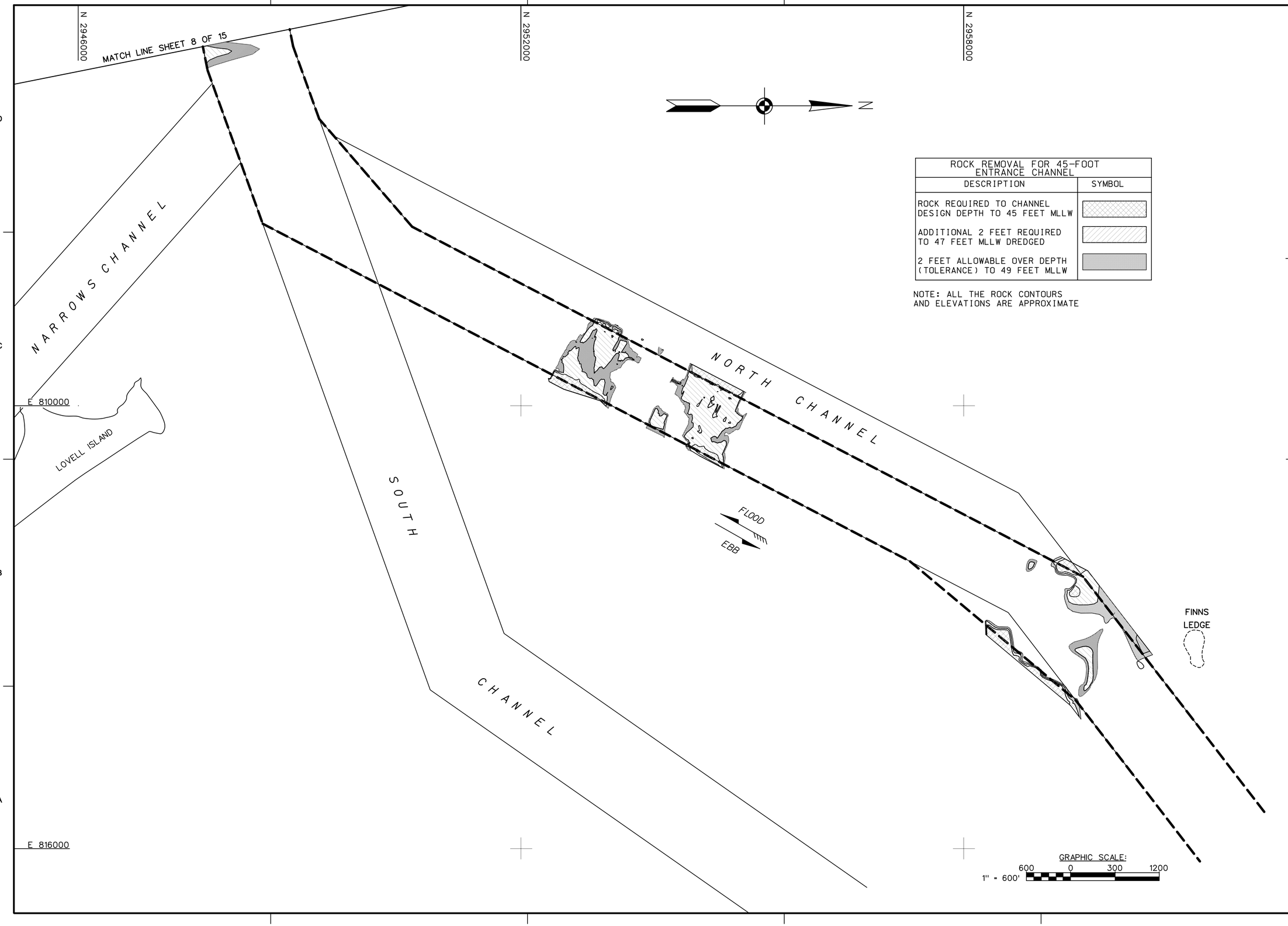

ROCK REMOVAL FOR 45-FOOT ENTRANCE CHANNEL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 45 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 47 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 49 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSC101.S03 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=600' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN -
BROAD SOUND NORTH CHANNEL
ROCK ELEVATIONS AT 45, 47 AND 49 FEET

SHEET IDENTIFICATION NUMBER
D1-7C 1 OF 5
SHEET 3 OF 15

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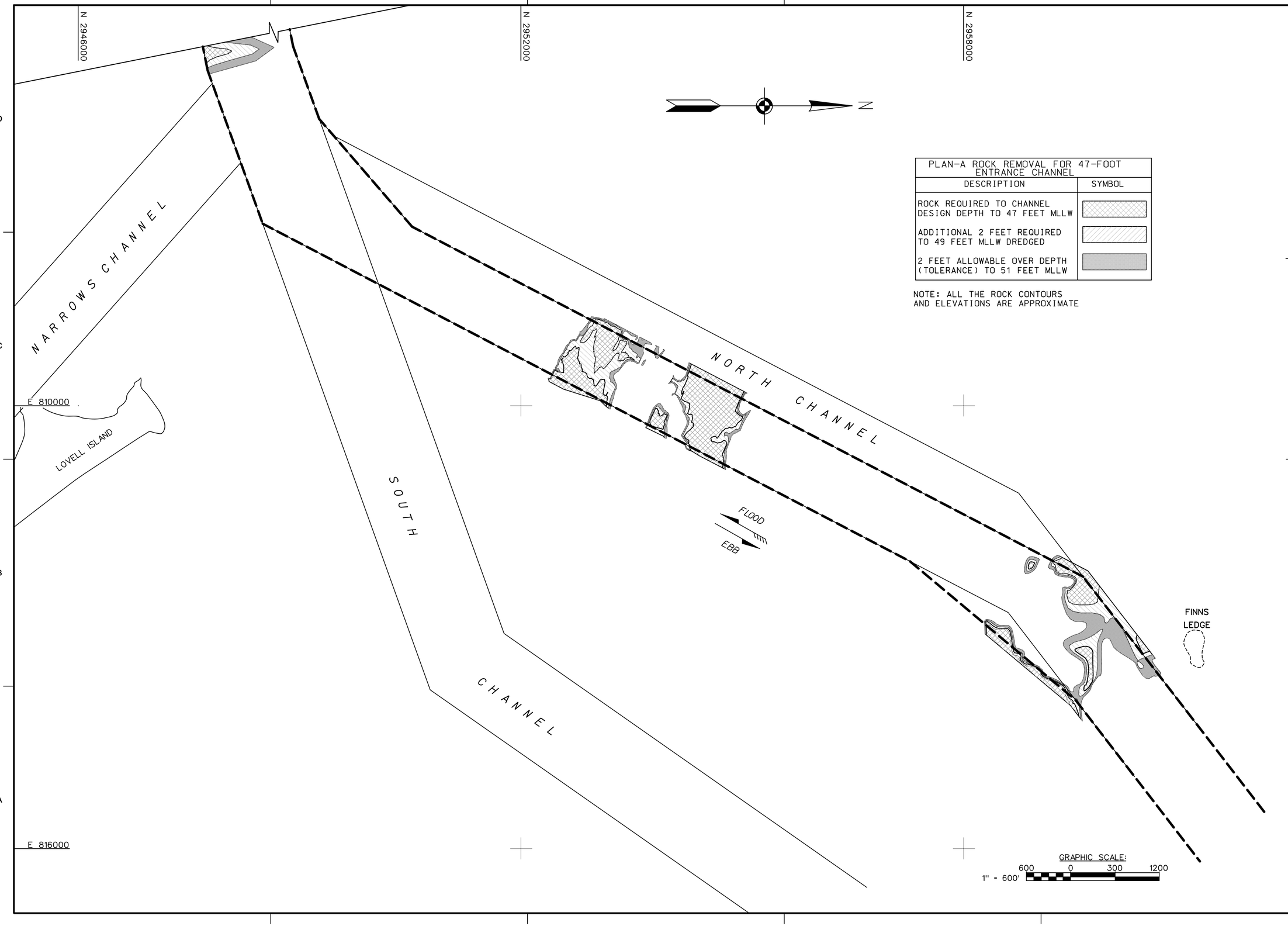


PLAN-A ROCK REMOVAL FOR 47-FOOT ENTRANCE CHANNEL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 47 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 49 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 51 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

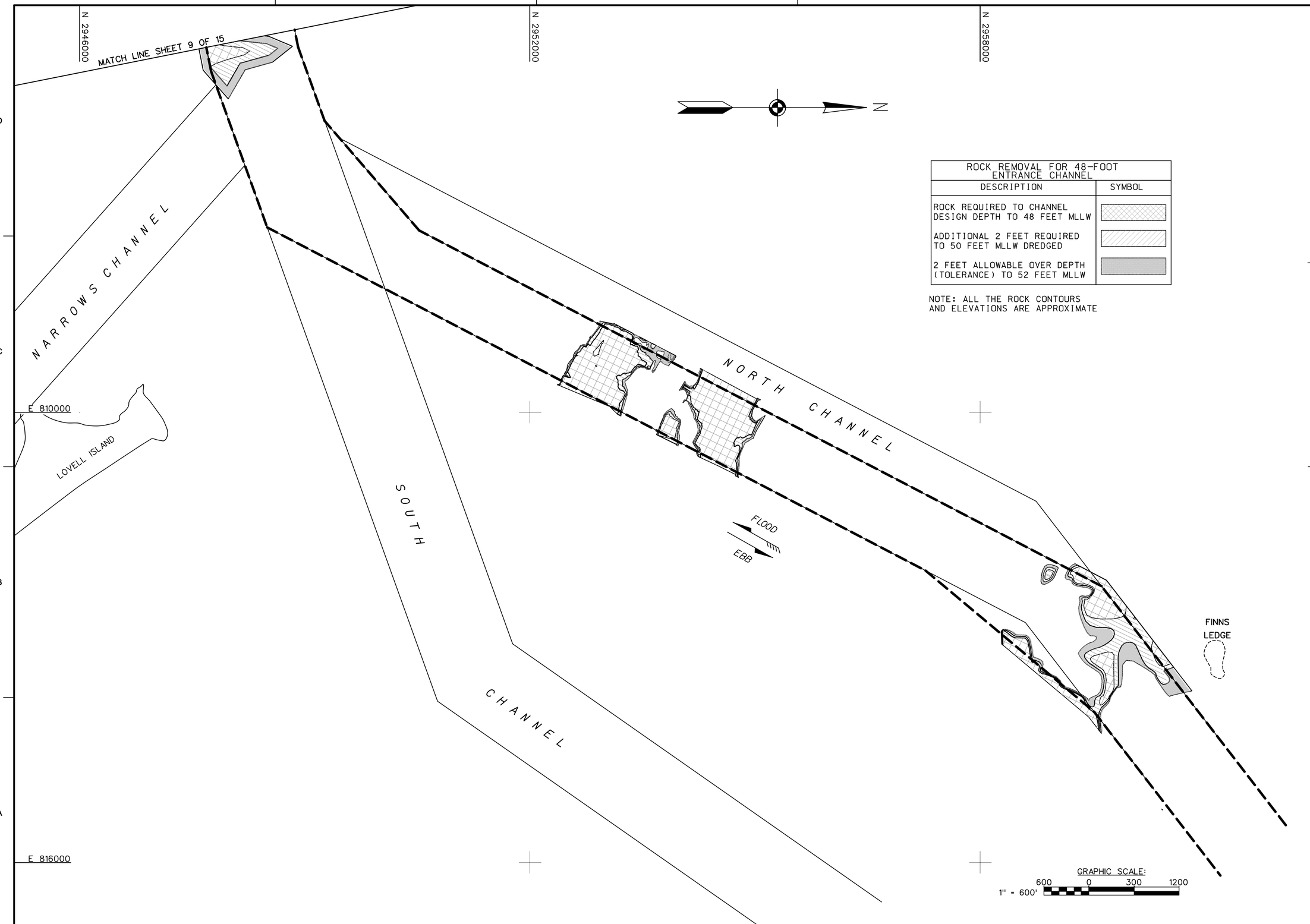
U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSC101.S04 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=600' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN -
BROAD SOUND NORTH CHANNEL
ROCK ELEVATIONS AT 47, 49 AND 51 FEET
(PLAN A)

SHEET IDENTIFICATION NUMBER
D1-7C 2 OF 5
SHEET 4 OF 15

...\Ledge Area_Plan\BOSC101.S04 3/19/2008 8:24:32 AM



ROCK REMOVAL FOR 48-FOOT ENTRANCE CHANNEL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 48 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 50 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 52 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSC101.S05 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=600' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN -
BROAD SOUND NORTH CHANNEL
ROCK ELEVATIONS AT 48, 50 AND 52 FEET

SHEET IDENTIFICATION NUMBER
D1-7C 3 OF 5
SHEET 5 OF 15

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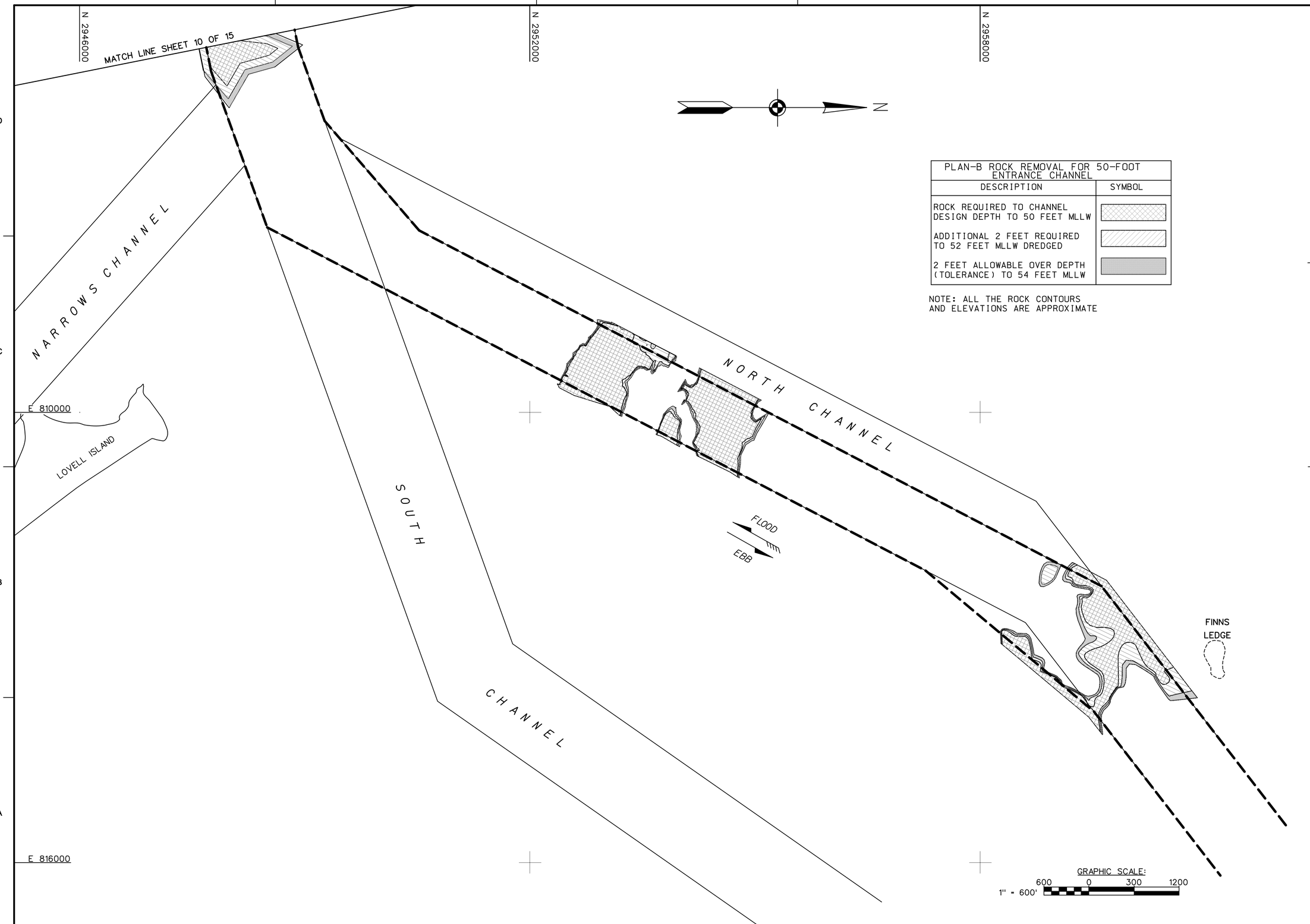

PLAN-B ROCK REMOVAL FOR 50-FOOT ENTRANCE CHANNEL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 50 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 52 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 54 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DWN BY: Annie Chin
CKD BY: Mark Habel
SUBMITTED BY:
FILE NAME: BOSC101.S06
SIZE: ANSI D
PLOT SCALE: 1"=600'
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN -
BROAD SOUND NORTH CHANNEL
ROCK ELEVATIONS (-50, -52 AND -54 FEET (PLAN B)

SHEET IDENTIFICATION NUMBER
D1-7C 4 OF 5
SHEET 6 OF 15

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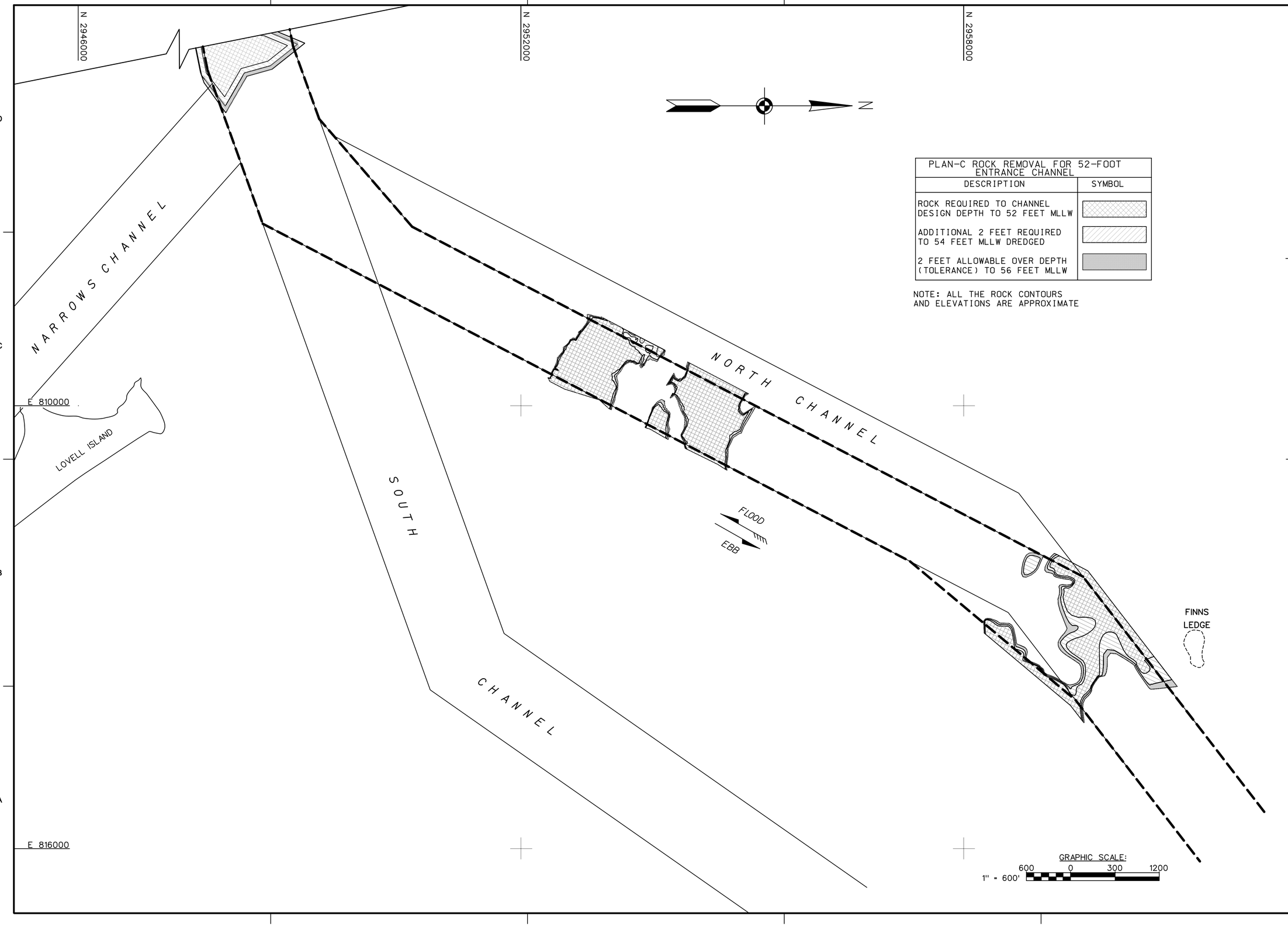


PLAN-C ROCK REMOVAL FOR 52-FOOT ENTRANCE CHANNEL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 52 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 54 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 56 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

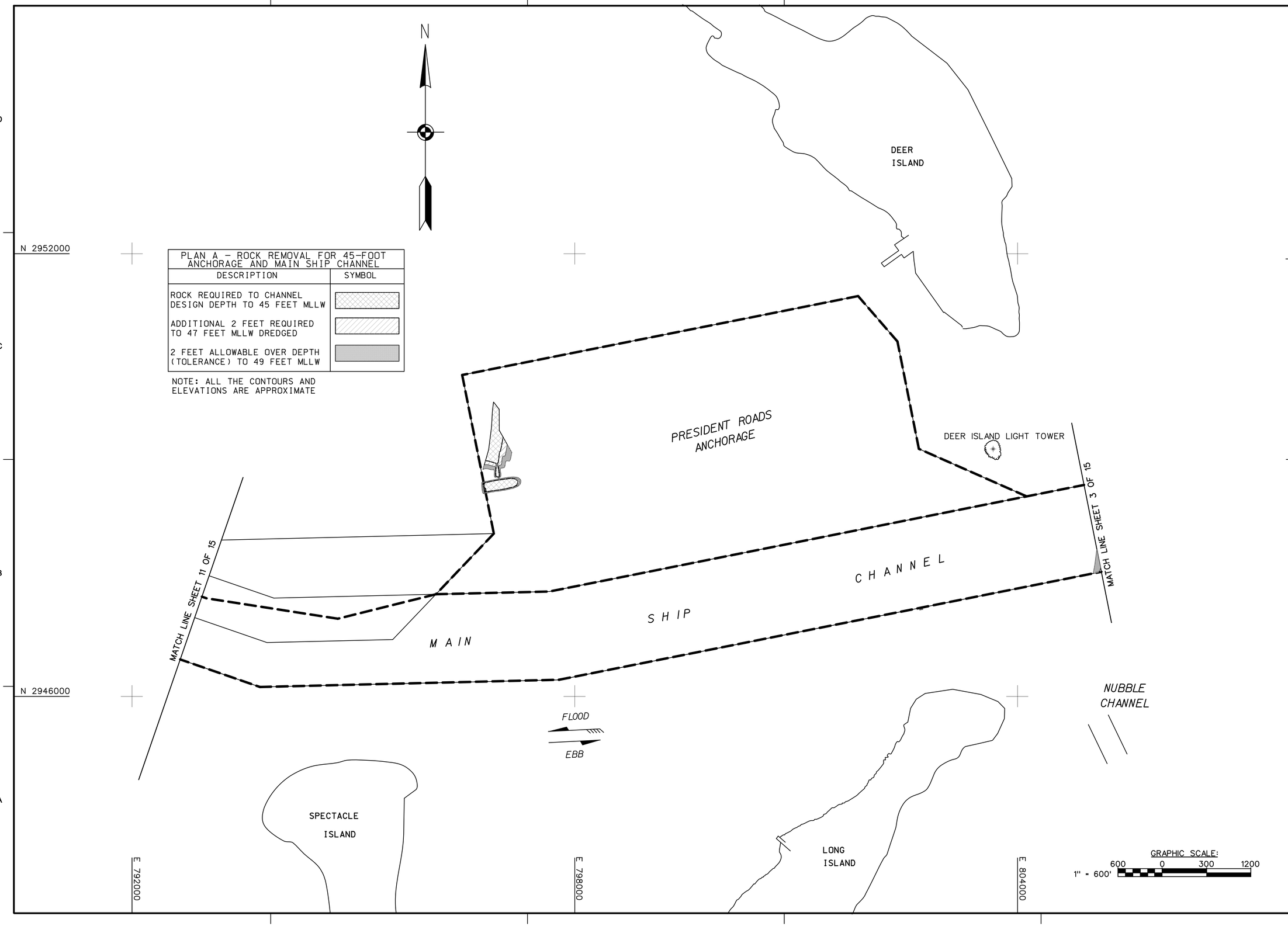
U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DWN BY: Annie Chin
CKD BY: Mark Habel
SUBMITTED BY:
FILE NAME: BOSC101.S07
SIZE: ANSI D
PLOT SCALE: 1"=600'
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN -
BROAD SOUND NORTH CHANNEL
ROCK ELEVATIONS AT 52, 54 AND 56 FEET
(PLAN C)

SHEET IDENTIFICATION NUMBER
D1-7C 5 OF 5
SHEET 7 OF 15

...\Ledge Area_Plan\BOSC101.S07 3/19/2008 8:28:07 AM



PLAN A – ROCK REMOVAL FOR 45-FOOT ANCHORAGE AND MAIN SHIP CHANNEL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 45 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 47 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 49 FEET MLLW	

NOTE: ALL THE CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Arnie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSC102.S08 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=600' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA

MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL ROCK ELEVATIONS AT 45, 47 AND 49 FEET (PLAN A)

SHEET IDENTIFICATION NUMBER
D1-7D 1 to 3
SHEET 8 OF 15

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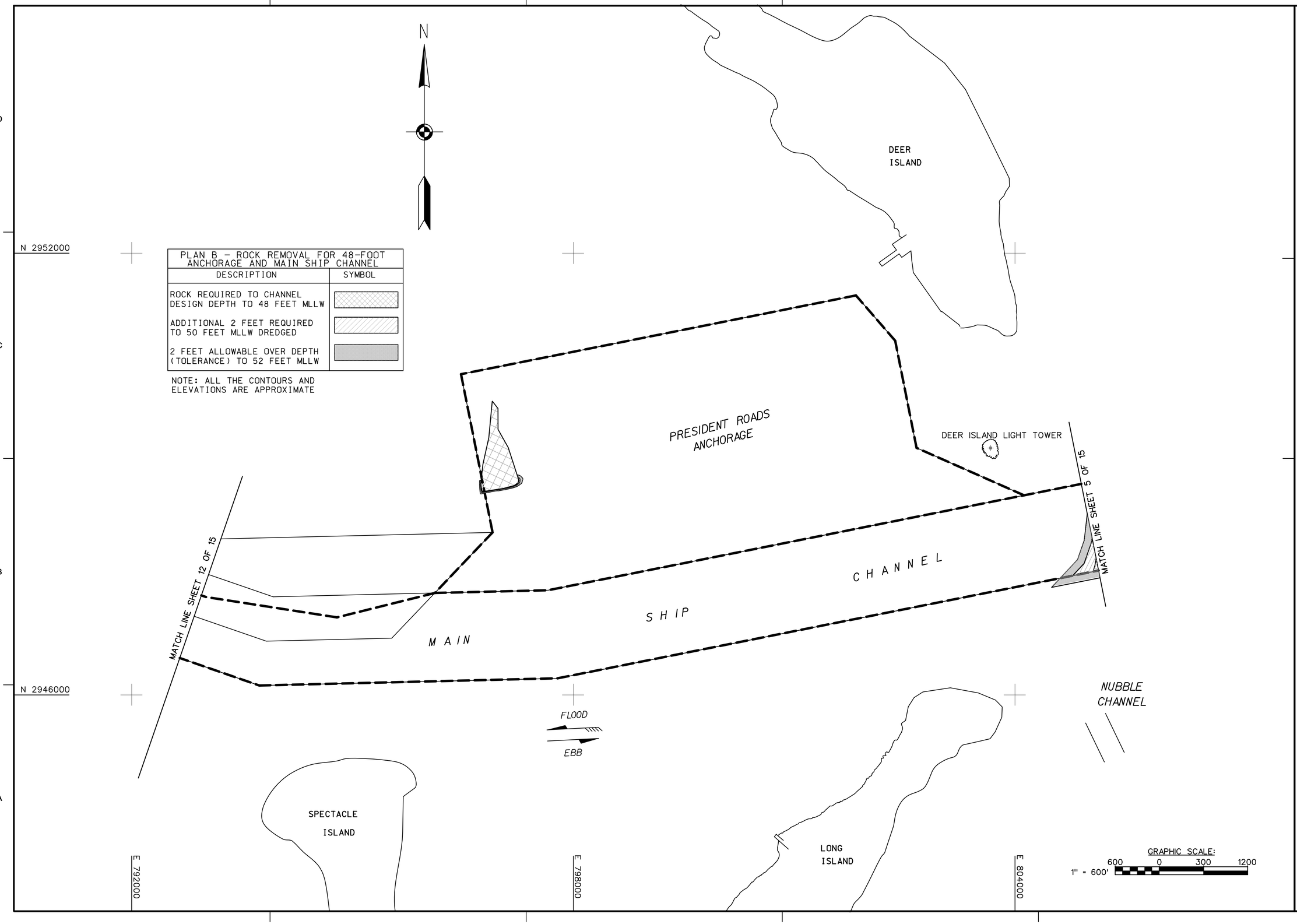

PLAN B – ROCK REMOVAL FOR 48-FOOT ANCHORAGE AND MAIN SHIP CHANNEL

DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 48 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 50 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 52 FEET MLLW	

NOTE: ALL THE CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Arnie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSC102.S07 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=600' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA

MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL ROCK ELEVATIONS AT 48, 50 AND 52 FEET (PLAN B)

SHEET IDENTIFICATION NUMBER
D1-7D 2 to 3
SHEET 9 OF 15

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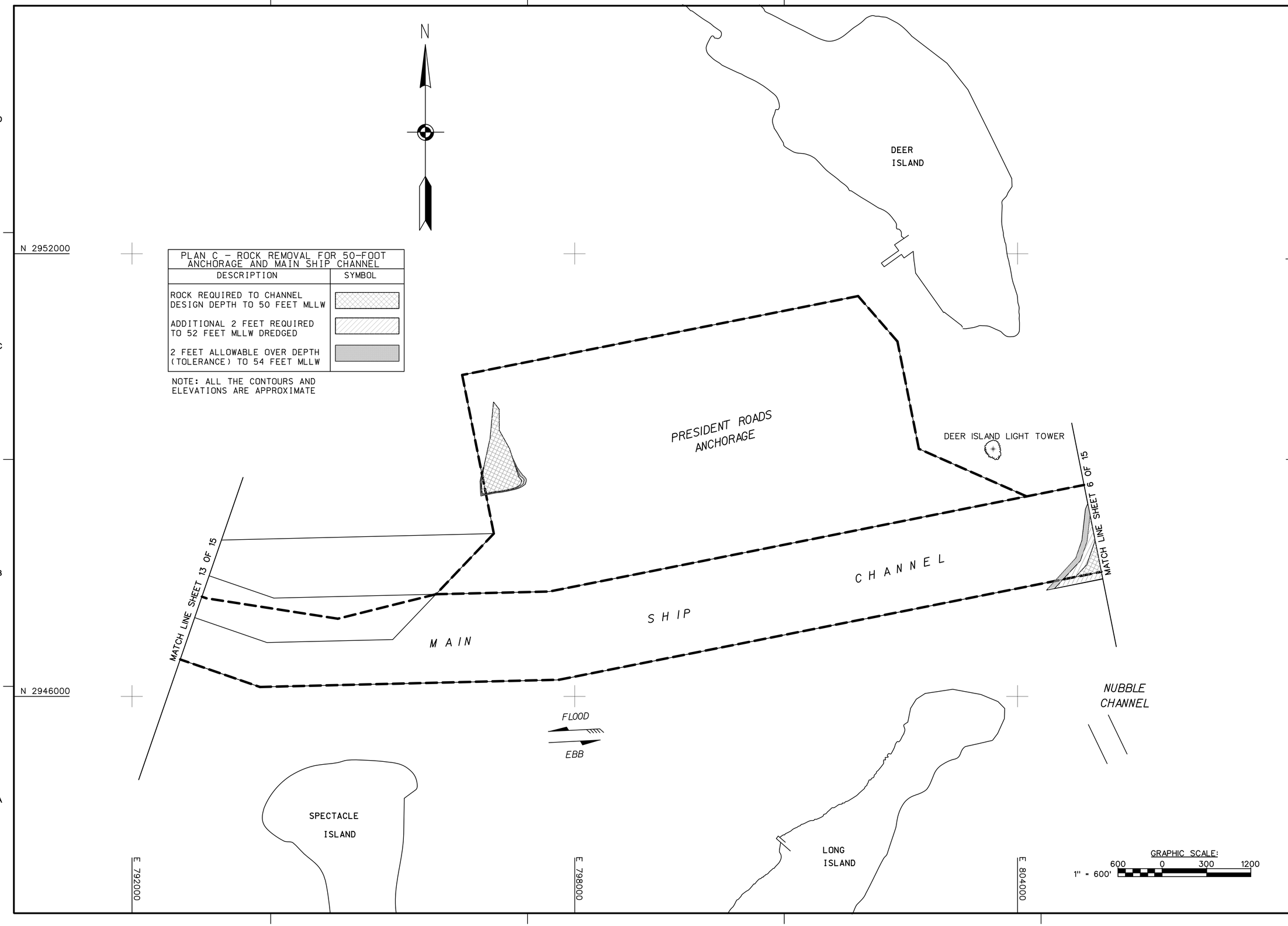

PLAN C – ROCK REMOVAL FOR 50-FOOT ANCHORAGE AND MAIN SHIP CHANNEL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 50 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 52 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 54 FEET MLLW	

NOTE: ALL THE CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader | DATE: July 2007
DWN BY: Arnie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSC102.S08 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=600' | PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN - PRESIDENT ROADS ANCHORAGE & MAIN SHIP CHANNEL ROCK ELEVATIONS AT 50, 52 AND 54 FEET (PLAN C)

SHEET IDENTIFICATION NUMBER
D1-7D 3 to 3
SHEET 10 OF 15

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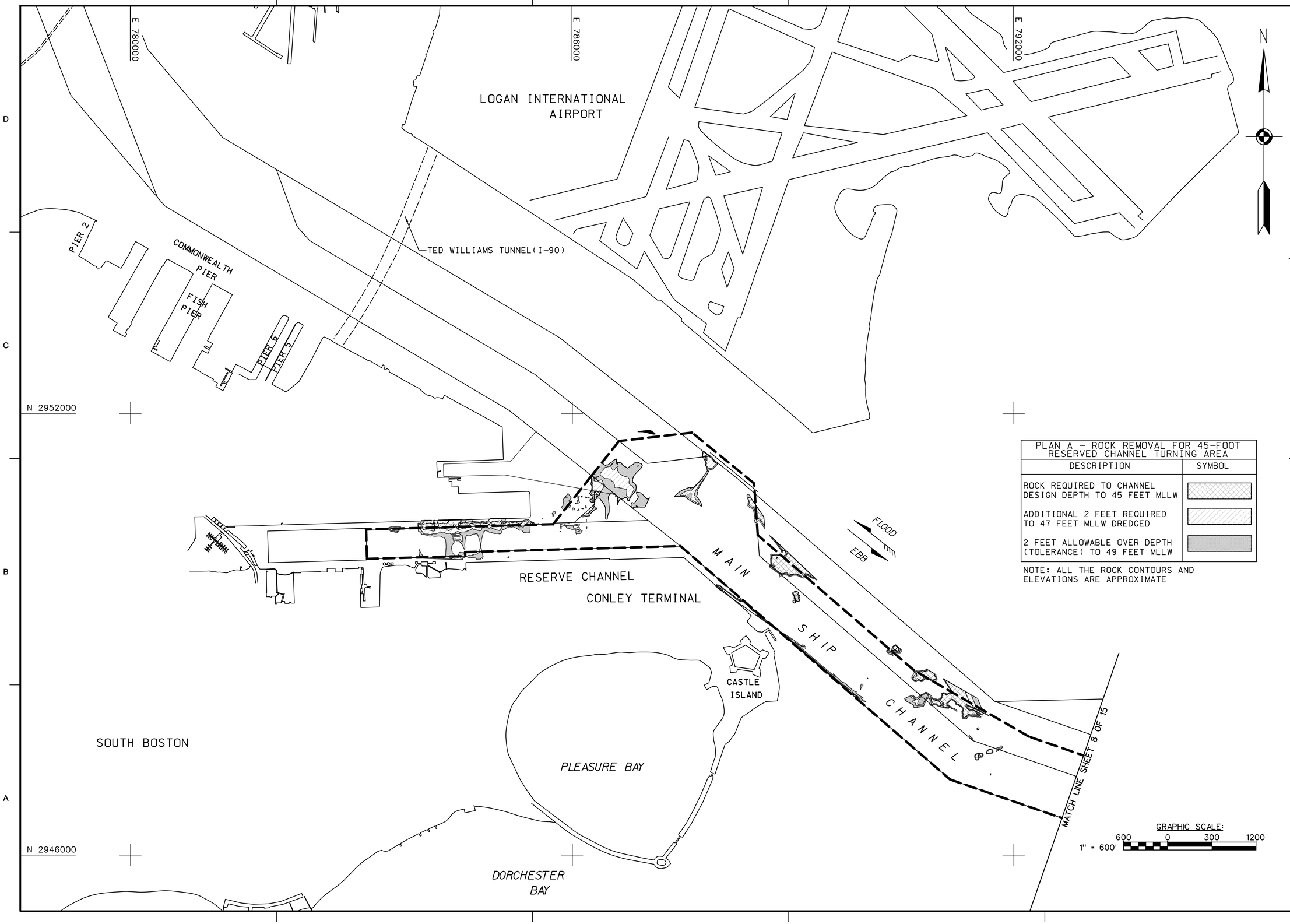

PLAN A – ROCK REMOVAL FOR 45-FOOT RESERVED CHANNEL TURNING AREA

DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 45 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 47 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 49 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSC103.S09
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=600'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN - MAIN SHIP CHANNEL
RESERVED CHANNEL AND CONLEY
RESERVED CHANNEL TURNING AREA
ROCK ELEVATIONS AT 45, 47 AND 49 FEET
(PLAN A)

SHEET IDENTIFICATION NUMBER
D1-7E 1 to 3
SHEET 11 OF 15

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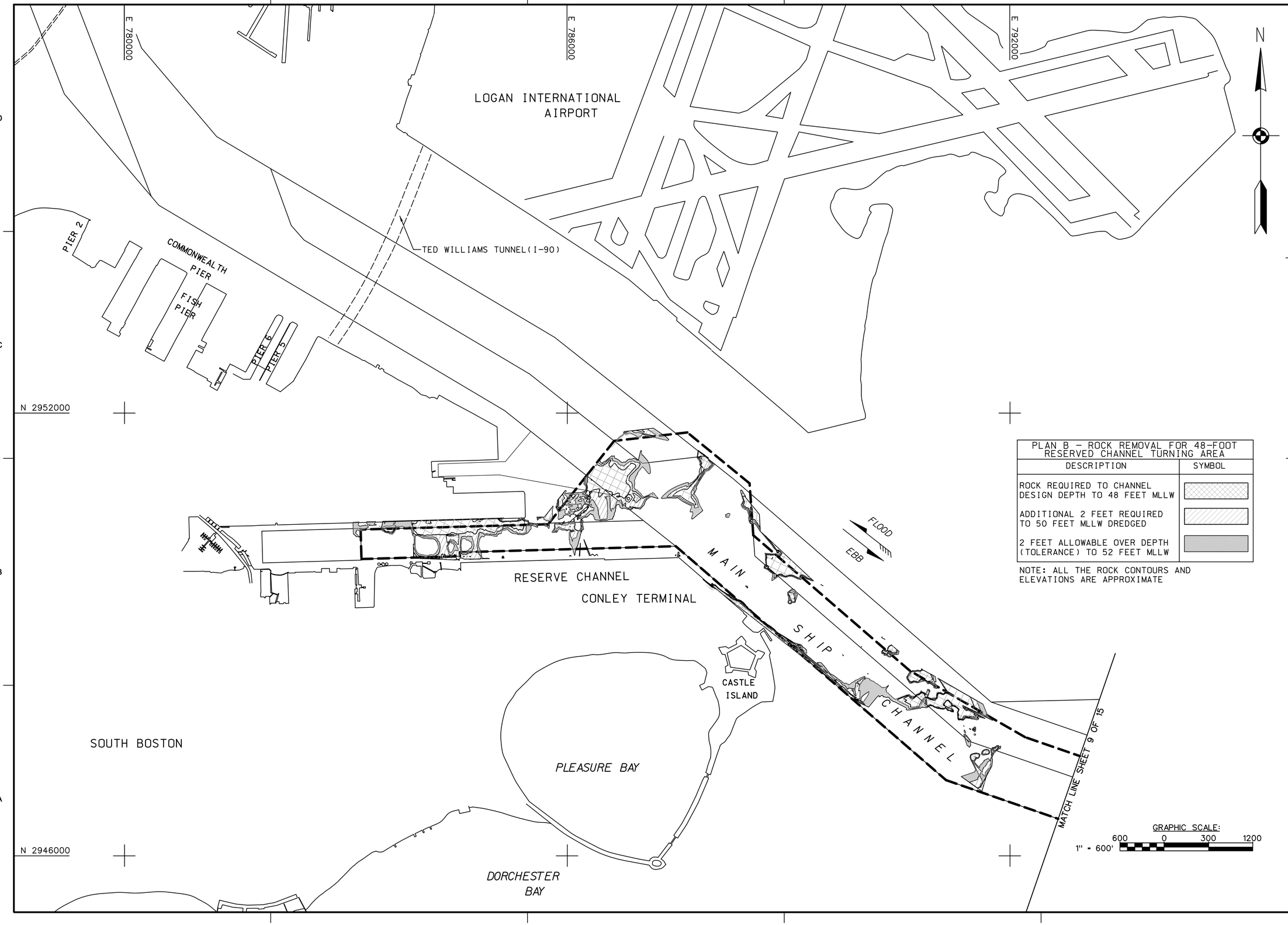

PLAN B – ROCK REMOVAL FOR 48-FOOT RESERVED CHANNEL TURNING AREA	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 48 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 50 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 52 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSC103.S10
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=600'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN - MAIN SHIP CHANNEL
RESERVE CHANNEL AND CONLEY TERMINAL
RESERVED CHANNEL TURNING AREA
ROCK ELEVATIONS AT 48, 50 AND 52 FEET
(PLAN B)

SHEET IDENTIFICATION NUMBER
D1-7E 2 to 3
SHEET 12 OF 15

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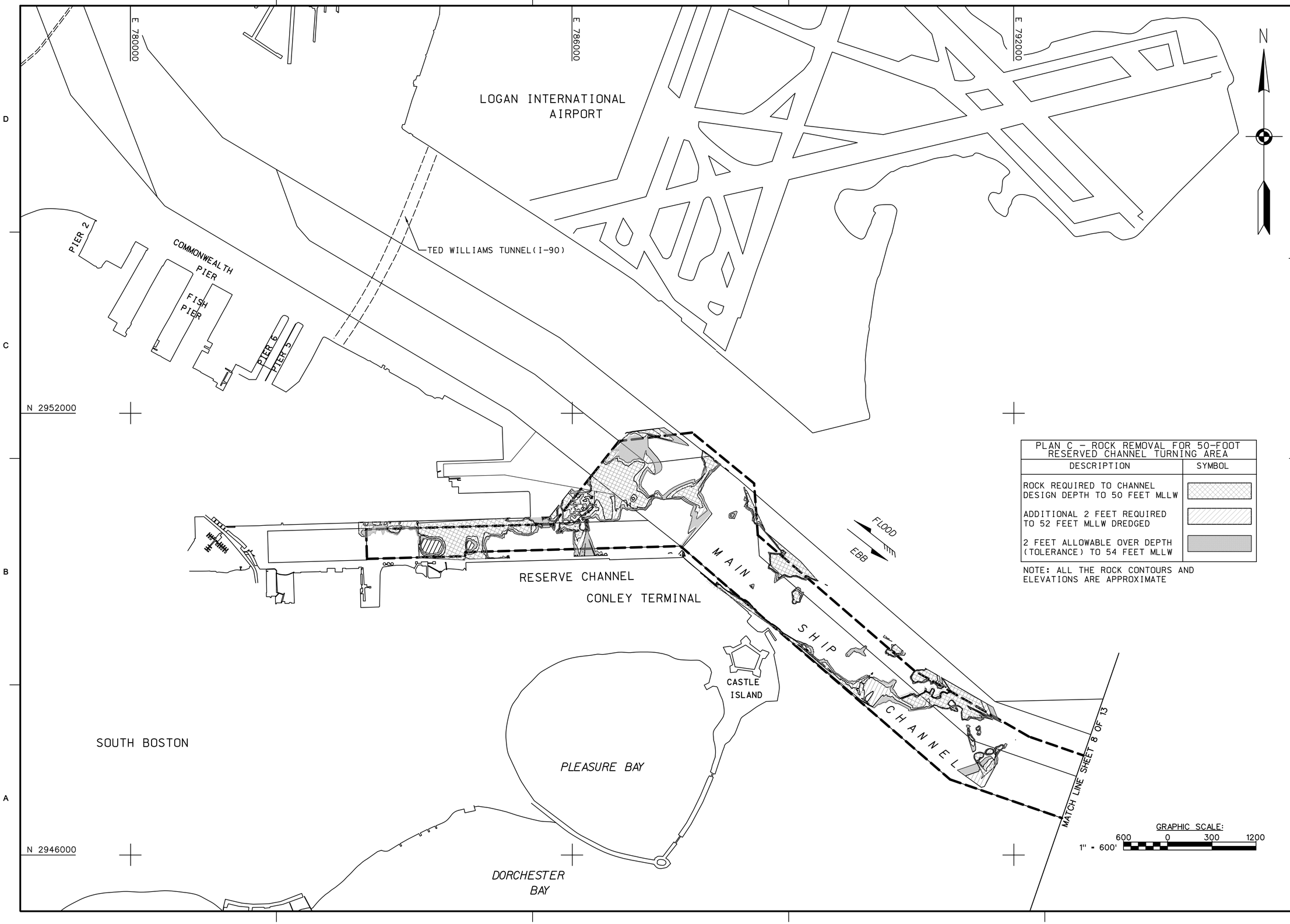

PLAN C – ROCK REMOVAL FOR 50-FOOT RESERVED CHANNEL TURNING AREA

DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 50 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 52 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 54 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meeder
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSC103.S11
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=600'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN CHANNELS PLAN - MAIN SHIP CHANNEL
RESERVED CHANNEL AND TURNING AREA
RESERVED CHANNEL TURNING AREA
ROCK ELEVATIONS AT 50, 52 AND 54 FEET
(PLAN C)

SHEET IDENTIFICATION NUMBER
D1-7E 3 to 3
SHEET 13 OF 15

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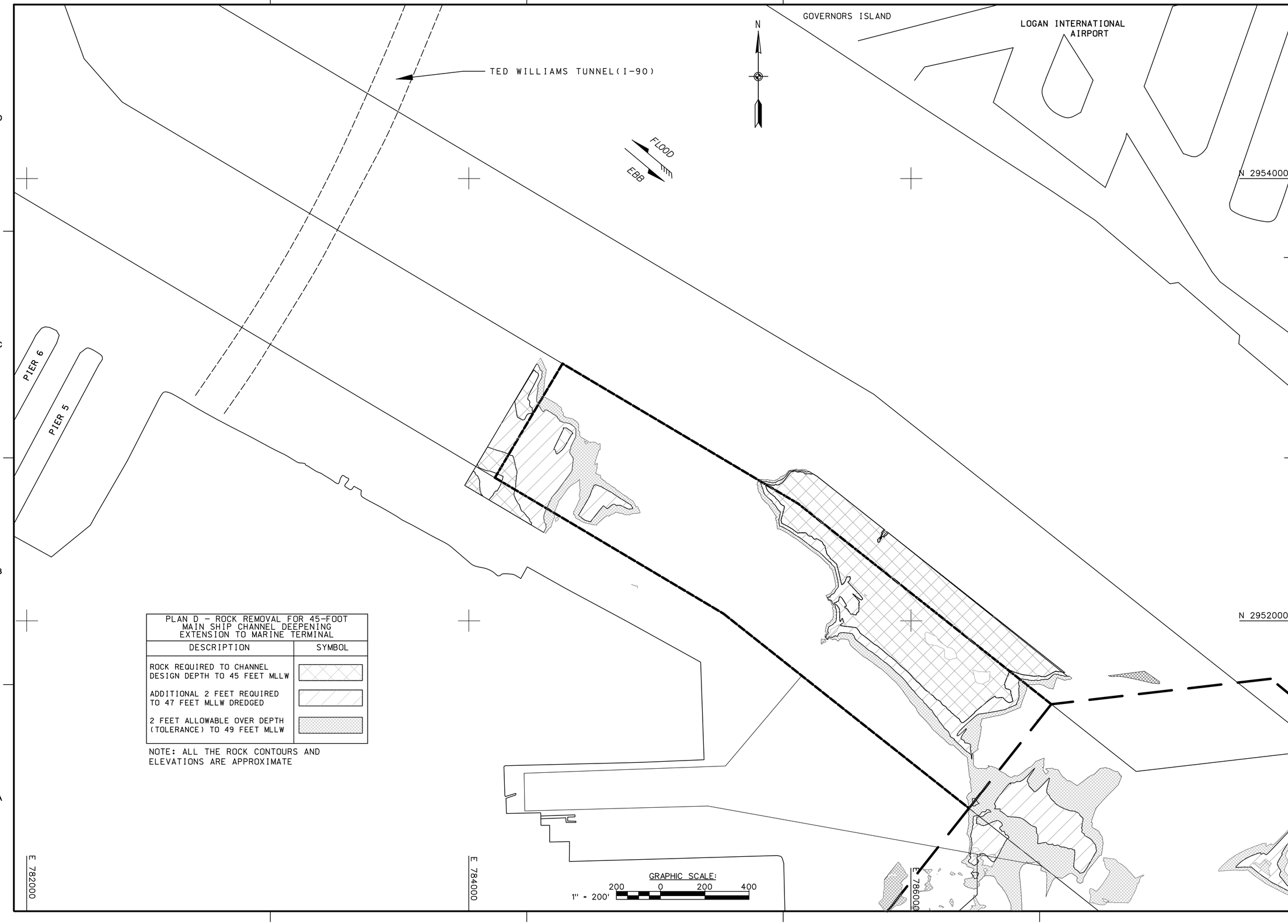

PLAN D – ROCK REMOVAL FOR 45-FOOT MAIN SHIP CHANNEL DEEPENING EXTENSION TO MARINE TERMINAL	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 45 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 47 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 49 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

1"=200'

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSC104.S12
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=200'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
MAIN SHIP CHANNEL DEEPENING
EXTENSION TO MARINE TERMINAL
ROCK ELEVATIONS AT 45, 47 AND 49 FEET
(PLAN D)

SHEET IDENTIFICATION NUMBER
D1-7F
SHEET 14 OF 15

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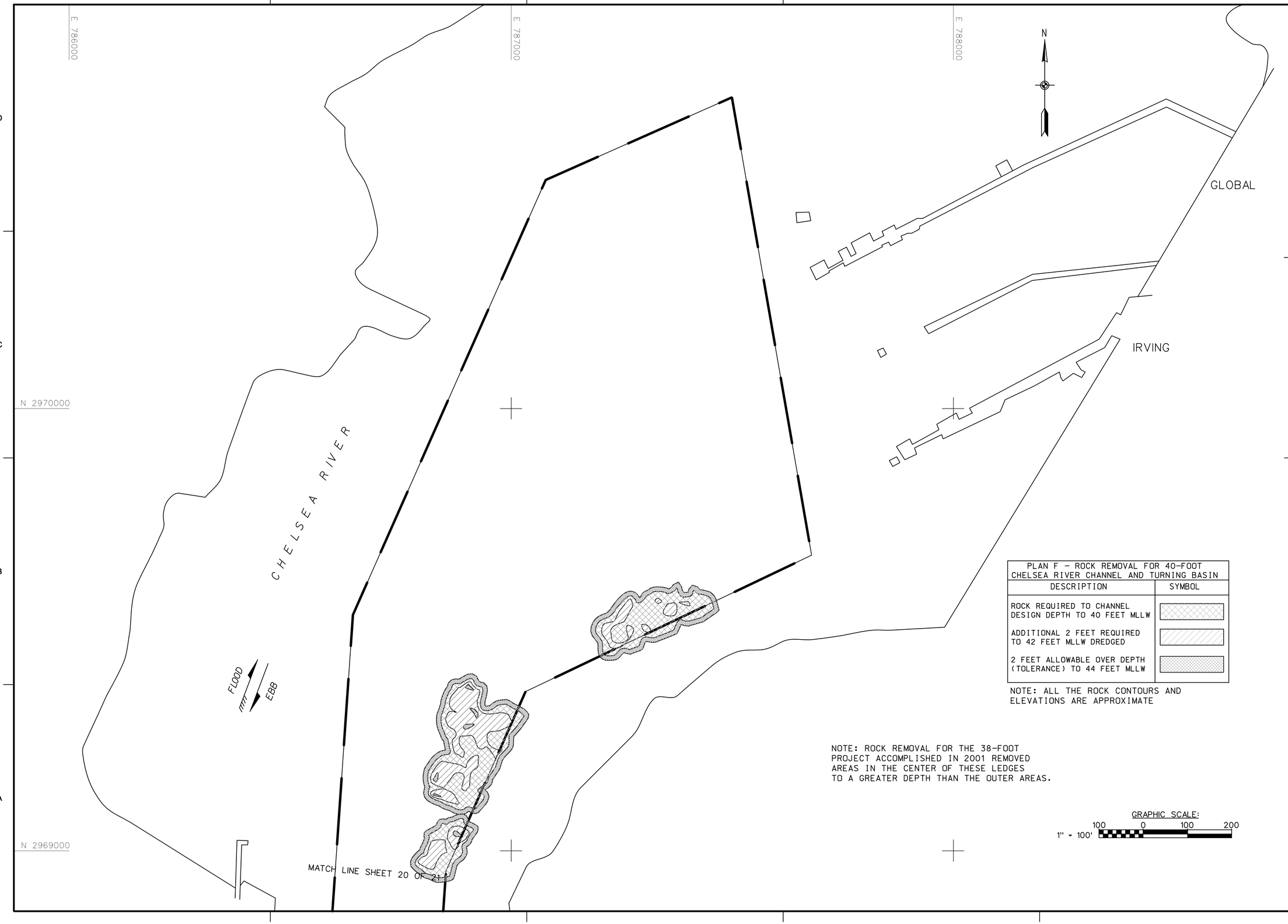


PLAN F – ROCK REMOVAL FOR 40-FOOT CHELSEA RIVER CHANNEL AND TURNING BASIN	
DESCRIPTION	SYMBOL
ROCK REQUIRED TO CHANNEL DESIGN DEPTH TO 40 FEET MLLW	
ADDITIONAL 2 FEET REQUIRED TO 42 FEET MLLW DREDGED	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 44 FEET MLLW	

NOTE: ALL THE ROCK CONTOURS AND ELEVATIONS ARE APPROXIMATE

NOTE: ROCK REMOVAL FOR THE 38-FOOT PROJECT ACCOMPLISHED IN 2001 REMOVED AREAS IN THE CENTER OF THESE LEDGES TO A GREATER DEPTH THAN THE OUTER AREAS.

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

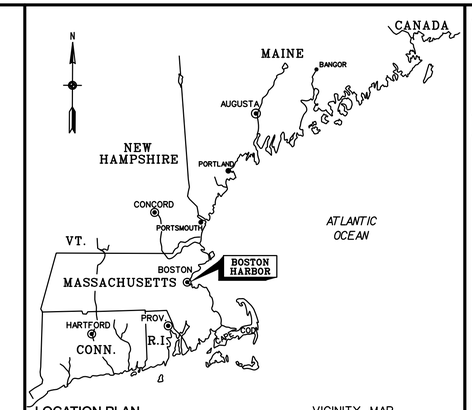
DESIGNED BY: Bob Meader
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSC105.S13
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=100'
PLOT DATE: February 2008

DEEP DRAFT FEASIBILITY STUDY
REPORT SURVEY
BOSTON HARBOR
BOSTON, MASSACHUSETTS
LEDGE AREA
CHELSEA RIVER CHANNEL
AND TURNING BASIN
ROCK ELEVATIONS AT 40, 42 AND 44 FEET
(PLAN F)

SHEET IDENTIFICATION NUMBER
D1-7G
SHEET 15 OF 15

...\Ledge Area_Plan\BOSC105.S15 3/19/2008 8:37:12 AM

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS



LOCATION PLAN
NOT TO SCALE

VICINITY MAP
NTS

INDEX TO DRAWINGS			
SHEET NO.		DESIGN FILE	SHEET TITLE
1	D1-8A	BOSG001.S01	COVER SHEET
2	D1-8B	BOSG002.S02	KEY PLAN
3	D1-8C1	BOSC101.S03	SOUTH CHANNEL MAINTENANCE PLAN - 1
4	D1-8C2	BOSC102.S04	SOUTH CHANNEL MAINTENANCE PLAN - 2
5	D1-8C3	BOSC103.S05	SOUTH CHANNEL MAINTENANCE PLAN - 3
6	D1-8D	BOSC104.S06	NUBBLE CHANNEL MAINTENANCE
7	D1-8E	BOSC105.S07	35 - FOOT ANCHORAGE MAINTENANCE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

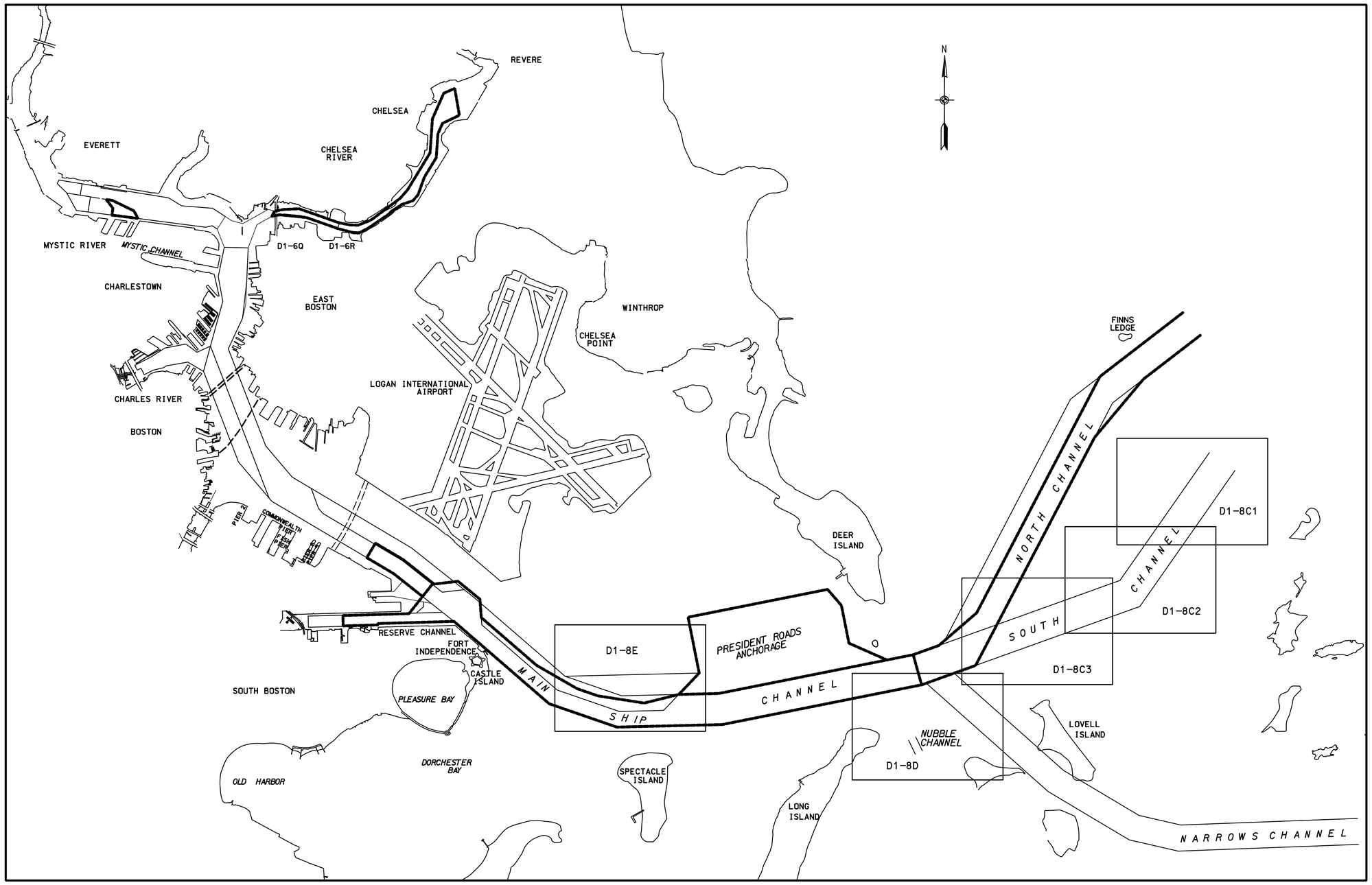
MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Mark Habel | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSG001.S01 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: | PLOT DATE: March 2008

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS
COVER SHEET

SHEET IDENTIFICATION NUMBER
D1-8A
SHEET 1 OF 7



KEY PLAN
NOT TO SCALE

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

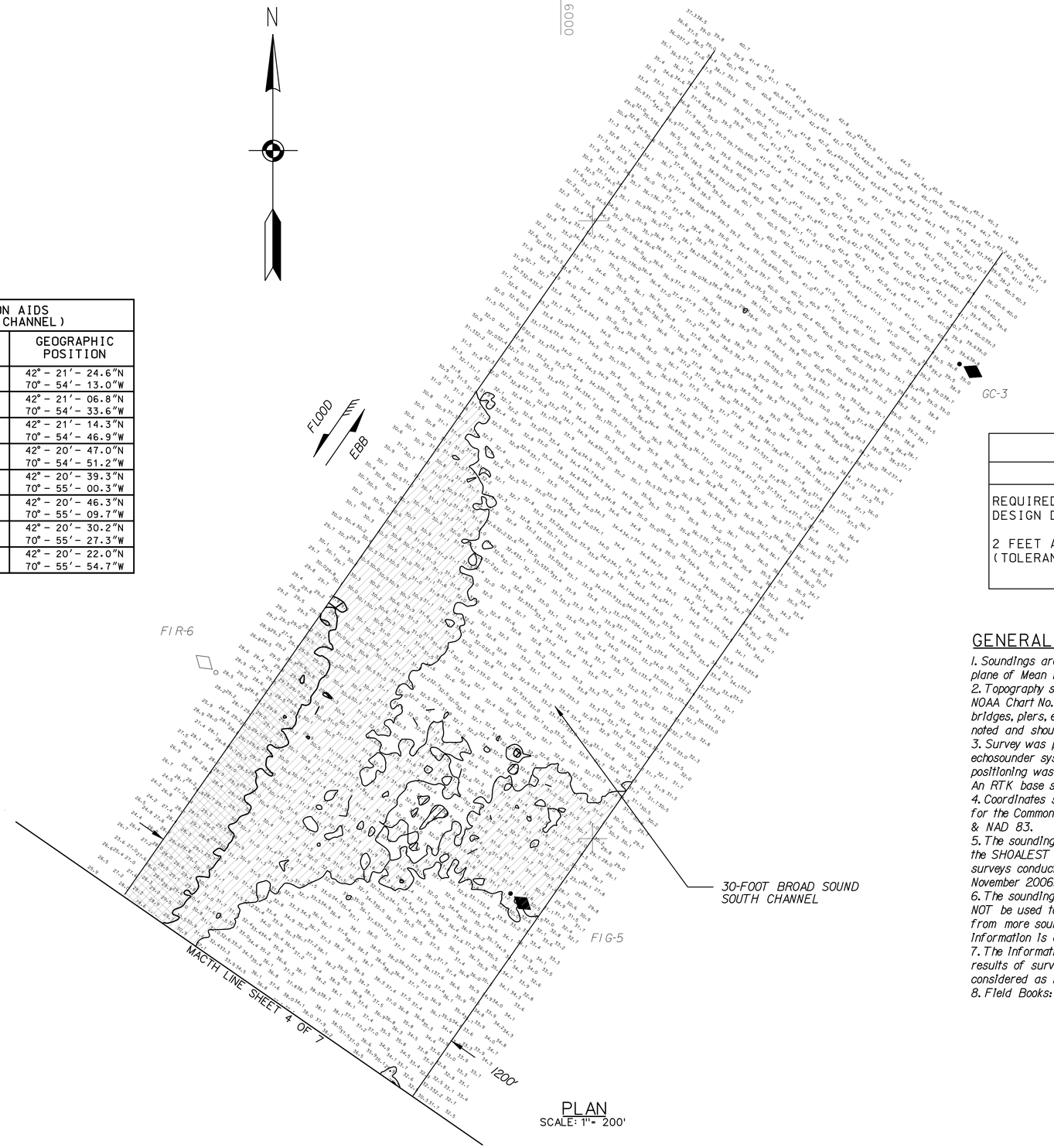
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Annie Chin | DATE: Dec. 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME: BOSG001.S01 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=2000' | PLOT DATE: March 2008

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS
KEY PLAN

SHEET IDENTIFICATION NUMBER
D1-6B
SHEET 2 OF 7

INDEX OF NAVIGATION AIDS (FOR SOUTH ENTRANCE CHANNEL)			
NO.	DATE	STATE PLANE COORDINATES	GEOGRAPHIC POSITION
GC-3	8/18/2006	N 2955619.48 E 817361.02	42° - 21′- 24.6″N 70° - 54′- 13.0″W
Fl G-5	8/18/2006	N 2953812.71 E 815828.32	42° - 21′- 06.8″N 70° - 54′- 33.6″W
Fl R-6	8/18/2006	N 2954567.05 E 814822.53	42° - 21′- 14.3″N 70° - 54′- 46.9″W
GC-7	8/18/2006	N 2951798.53 E 814521.98	42° - 20′- 47.0″N 70° - 54′- 51.2″W
Fl G-9	8/18/2006	N 2951014.43 E 813844.31	42° - 20′- 39.3″N 70° - 55′- 00.3″W
Fl R-10	8/18/2006	N 2951719.74 E 813132.83	42° - 20′- 46.3″N 70° - 55′- 09.7″W
GC-11	8/18/2006	N 2950074.47 E 811823.24	42° - 20′- 30.2″N 70° - 55′- 27.3″W
GC-13	8/18/2006	N 2949238.62 E 809770.52	42° - 20′- 22.0″N 70° - 55′- 54.7″W



PLAN
SCALE: 1"= 200'

LEGEND	
DESCRIPTION	SYMBOL
REQUIRED TO CHANNEL DESIGN DEPTH TO 30 FEET MLLW	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 32 FEET MLLW	

GENERAL NOTES:

1. Soundings are in feet and tenths and refer to the plane of Mean Lower Low Water (MLLW).
2. Topography shown is from previous surveys and/or NOAA Chart No.13270. All topography, including shoreline, bridges, piers, etc., is located approximate unless otherwise noted and should be used as a general reference only.
3. Survey was performed using a Reson 8124 multibeam echosounder system with a 200 kHz transducer. Horizontal positioning was obtained utilizing a Leica 1200 GPS System. An RTK base station was set up on Sta.School (06).
4. Coordinates shown are based on the Lambert Grid System for the Commonwealth of Massachusetts (Mainland Zone) & NAD 83.
5. The sounding information shown on these maps represents the SHOALEST soundings of those obtained from hydrographic surveys conducted during June thru August and October thru November 2006.
6. The sounding information depicted on these maps should NOT be used to determine volumes. Volumes are determined from more sounding information than shown. Additional sounding information is available upon request.
7. The information depicted on these maps represents the results of surveys made on the dates indicated, and can only be considered as indicating the general conditions existing at that time.
8. Field Books: R&H 4446, 5100, & 5106

GRAPHIC SCALE:
200 0 200 400
1" = 200'

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

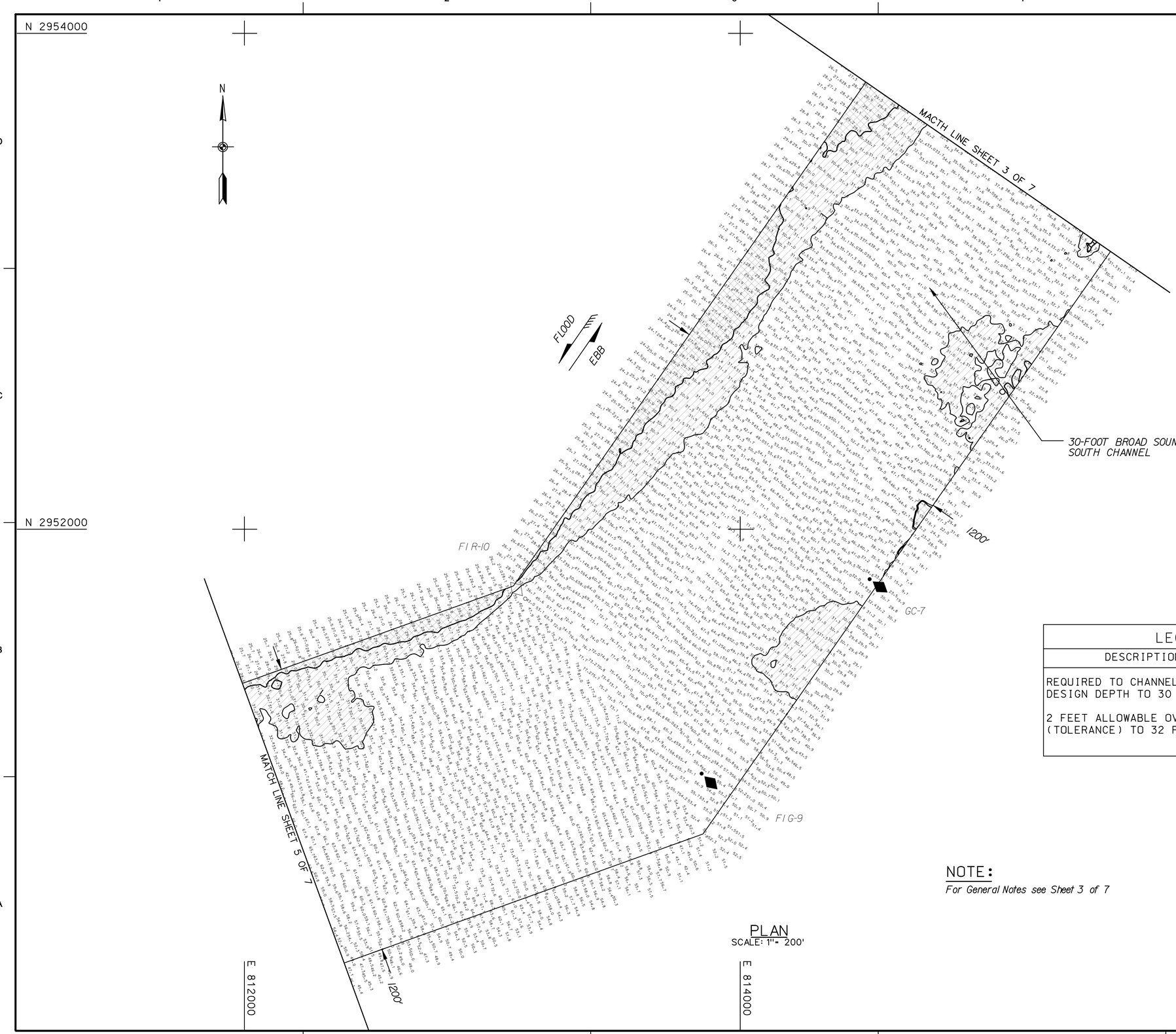
MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Mark Habel
DWN BY: Annie Chin
CKD BY: Mark Habel
SUBMITTED BY:
FILE NAME: BOSG001.S01 BOSC101.S03
SIZE: ANSI D
PLOT SCALE: 1"=200'
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
PLOT DATE: March 2008

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS
SOUTH CHANNEL MAINTENANCE
PLAN - 1

SHEET IDENTIFICATION NUMBER
D1-8C1
SHEET 3 OF 7



PLAN
SCALE: 1" = 200'

LEGEND	
DESCRIPTION	SYMBOL
REQUIRED TO CHANNEL DESIGN DEPTH TO 30 FEET MLLW	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 32 FEET MLLW	

NOTE:
For General Notes see Sheet 3 of 7

GRAPHIC SCALE:
1" = 200'
200 0 200 400

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

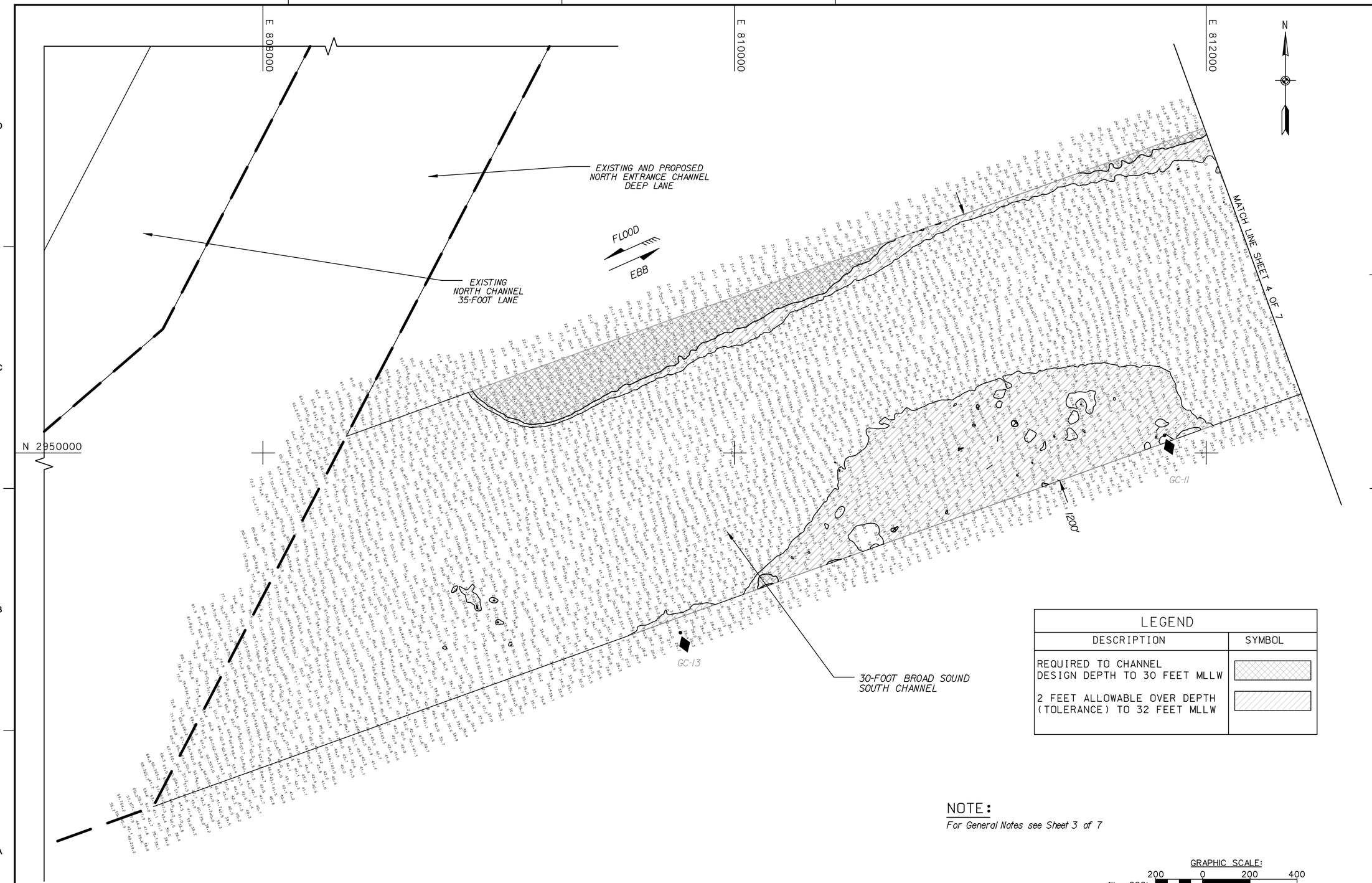
MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Mark Habel
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSC102.S04
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=200'
PLOT DATE: March 2008

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS
SOUTH CHANNEL MAINTENANCE
PLAN - 2

SHEET IDENTIFICATION NUMBER
D1-8C2
SHEET 4 OF 7



LEGEND	
DESCRIPTION	SYMBOL
REQUIRED TO CHANNEL DESIGN DEPTH TO 30 FEET MLLW	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 32 FEET MLLW	

NOTE:

For General Notes see Sheet 3 of 7

GRAPHIC SCALE:

200 0 200 400

1" = 200'

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

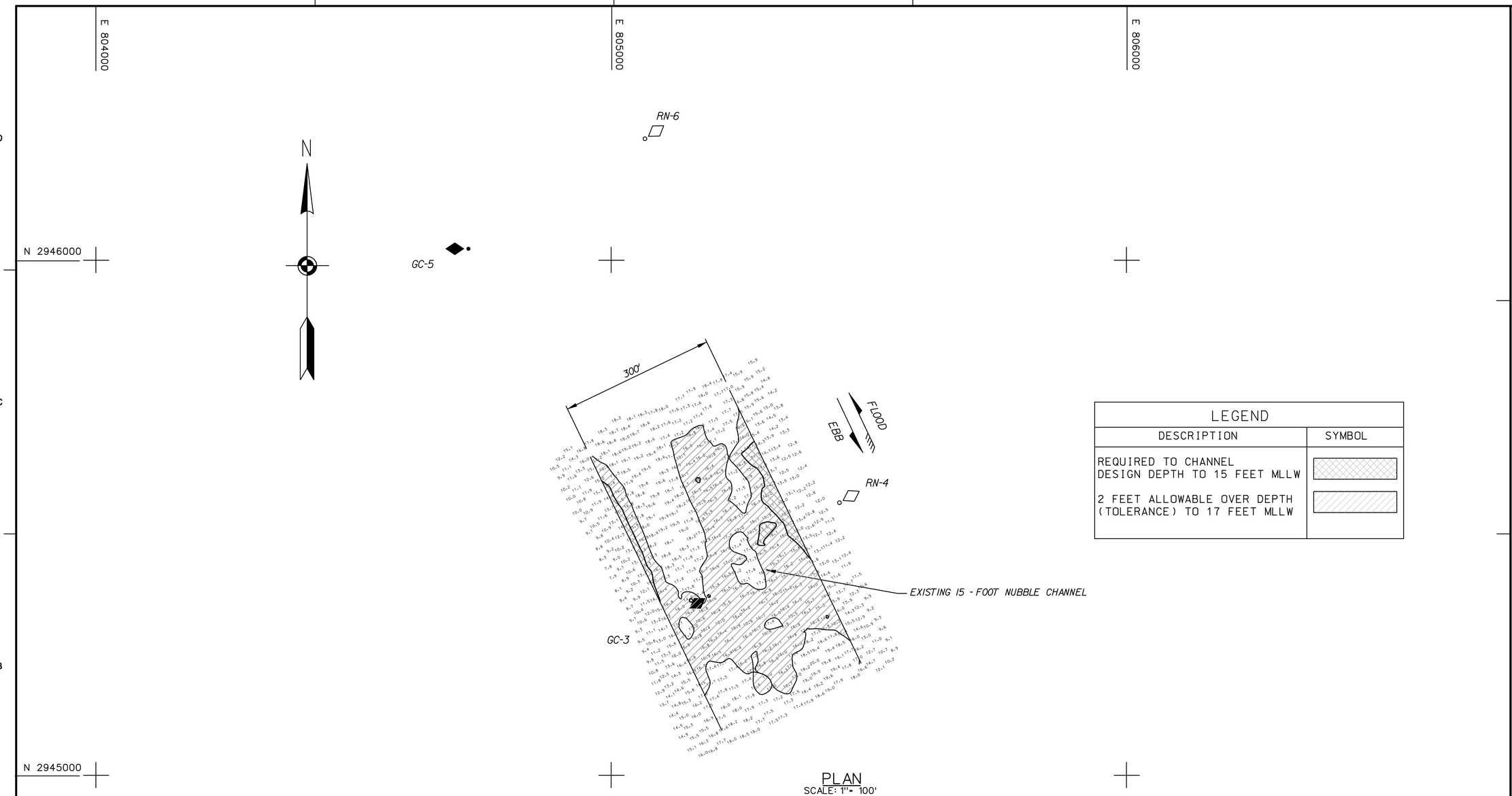
MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Mark Habel | DATE: July 2007
DWN BY: Annie Chin | CKD BY: Mark Habel | SOLICITATION NO.:
SUBMITTED BY: | CONTRACT NO.:
FILE NAME:BOSC103.S05 | DRAWING CODE:
SIZE: ANSI D | PLOT SCALE: 1"=200' | PLOT DATE: March 2008

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS
SOUTH CHANNEL MAINTENANCE
PLAN - 3

SHEET IDENTIFICATION NUMBER
D1-8C3
SHEET 5 OF 7



PLAN
SCALE: 1" = 100'

LEGEND	
DESCRIPTION	SYMBOL
REQUIRED TO CHANNEL DESIGN DEPTH TO 15 FEET MLLW	
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 17 FEET MLLW	

GRAPHIC SCALE:
1" = 100'
100 0 100 200

US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Mark Habel
DATE: July 2007
DWN BY: Annie Chin
CKD BY: Mark Habel
SOLICITATION NO.:
SUBMITTED BY:
CONTRACT NO.:
FILE NAME: BOSC104.S06
DRAWING CODE:
SIZE: ANSI D
PLOT SCALE: 1"=100'
PLOT DATE: March 2008

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS
NUBBLE CHANNEL MAINTENANCE

SHEET IDENTIFICATION NUMBER
D1-8D
SHEET 6 OF 7

LEGEND	
DESCRIPTION	SYMBOL
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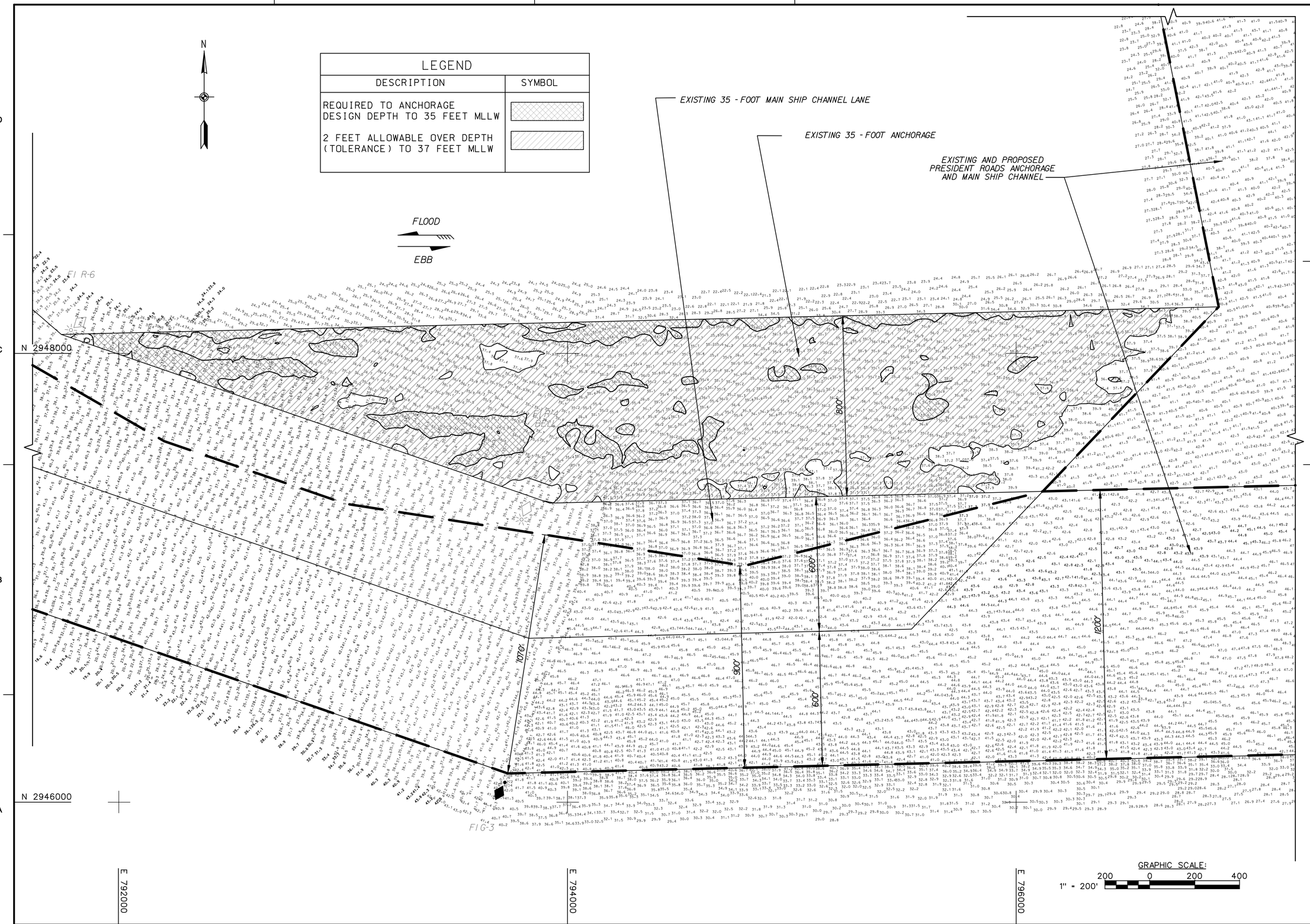
2 FEET ALLOWABLE OVER DEPTH (TOLERANCE) TO 37 FEET MLLW	



US ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

DESIGNED BY: Mark Habel
DWN BY: Annie Chin
CKD BY: Mark Habel
SUBMITTED BY:
FILE NAME: BOSC105.S07
SIZE: ANSI D
PLOT SCALE: 1" = 200'
DATE: July 2007
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
PLOT DATE: March 2008

DEEP DRAFT FEASIBILITY STUDY
ASSOCIATED MAINTENANCE DREDGING
BOSTON HARBOR
BOSTON, MASSACHUSETTS

35 - FOOT ANCHORAGE MAINTENANCE

SHEET IDENTIFICATION NUMBER
D1-8E
SHEET 7 OF 7

BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS FINAL
ENVIRONMENTAL IMPACT REPORT

APPENDIX D-2

PROJECT COST ESTIMATES

(REVISED FEBRUARY 2013)

APPENDIX D2 – PROJECT COST ESTIMATES

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APPENDIX D-2
PROJECT COST ESTIMATES
BOSTON HARBOR NAVIGATION IMPROVEMENT STUDY

PROJECT SCOPE

The Boston Harbor Deep Draft Navigation Improvement Project involves improvements to four separate segment of the existing waterway. These are:

PLAN ABC (nine depth increments): These alternatives, referred to as the Main Channels Improvement Plan, or Plan ABC, consist of deepening access from the sea to the Conley Container Terminal in South Boston for the benefit of the larger Panamax and Post-Panamax containerships. These plans include deepening the Broad Sound North Entrance Channel, the Main Ship Channel from President Roads to the Reserved Channel, the Reserved Channel Turning Area, the lower Reserved Channel up to the Conley Terminal, and the President Roads Anchorage Area. In all plans, the entrance channel would be deepened an additional two feet to compensate for increased sea states in the bay and outer harbor.

The main channel plans differ only with respect to depth optimization. Economic optimization evaluated the range of channel depths from 42 to 50 feet in one-foot increments. Originally these were further broken down in the 2008 draft report based on specific language included with the appropriation that called for the reconnaissance study asked for an examination of a depth to the Conley Terminal of 45 feet and anticipated container vessel class increases. These were: Plan A – 45 feet, Plan B – 48 feet, and Plan C – 50 feet. Since 2008 extensive additional economic analysis has been conducted with the aim of refining depth optimization for the main channels plans that would improve containership navigation. The nine depth alternatives from 42 feet to 50 feet are now collectively referred to as Plan ABC. In three additional plans formulated after the economic analysis yielded a recommendation for a 47-foot inner channels design depth, the entrance channel would be deepened an additional three, four or five feet. Therefore the 47-foot channel plan has four entrance channel alternative depths: 49, 50, 51 and 52 feet.

The alternatives of Plan ABC include expansion of the Reserved Channel Turning Area to a 1500-Foot diameter, widened at its junctions with the Main Ship and Reserved Channels and further widened to the northeast by 100 feet, all as recommended by the ship simulation study. These three plans also include widening the deep lane of the Main Ship Channel to a width of 800 to 900 feet in the reaches above the Roads to the Reserved Channel, and widened further at the three critical bends at Finns Ledge, Spectacle Island and the Lower Middle Shoal below Castle Island.

PLAN D: This plan, referred to as the Main Ship Channel Deepening Extension, involves extending the deepening of the harbor's Main Ship Channel above the Reserved Channel Turning Area to the Massport Marine Terminal in South Boston to a depth of up to –45 feet MLLW. This plan's costs would be incremental to the main channels plans, and would benefit Massport's redevelopment of the MMT as a bulk cargo facility with 45-foot berth.

PLAN E: Deepening a small portion of the 35-foot segment of the Mystic River Channel to up to 40 feet to access Massport's Medford Street Terminal in Charlestown, and connect the existing 40-foot channel to the 40-foot berth at the terminal. This are was not deepened as part of the 1990 authorized improvement as the benefits of improving access to an undefined planned bulk cargo facility were not yet developed. Massport has now redeveloped this terminal and deepened its berth to 40 feet to accommodate smaller bulk cargo operations for which space is not available at the Marine Terminal in South Boston.

PLAN F: This plan involves deepening and minor widening of the Chelsea River Channel, including its upstream turning basin from its current depth of –38 feet to –40 feet MLLW, to improve access to most of the port's petroleum terminals and other users of that channel. This plan assumes that construction of the new Chelsea Street Bridge, now underway, will be completed by the Massachusetts Highway Department, the City of Boston and the US Coast Guard prior to any channel deepening and that the Corps will increase the channel width through the new wider bridge opening to at least 175 feet under its O&M authority. The channel widening is scheduled for either the 2011-2012 or 2012-2013 dredging seasons. The Keyspan gas siphon located under the channel immediately downstream of the Chelsea Street Bridge has been replaced since the publication of the 2008 Draft Final Feasibility Report by a deep directional bore and the old siphon was removed during the 2008-2010 major maintenance dredging operation for the inner harbor. The presence of a second MWRA water tunnel downstream of the Chelsea Street Bridge, not identified at the time of the 2008 report, required additional investigations by the Corps and State. The MWRA estimates the 2015 cost of replacement and removal of that water tunnel at about $15 million including design efforts.

Details of each of these plans will be provided in separate sections of this appendix together with the quantity and cost estimates for each.

PROJECT IMPLEMENTATION COSTS

Project cost estimates involve several assumptions. Those involving quantities and material types, dredged material disposal options, utilities, bridges and associated non-Federal facilities and berth improvements are discussed above. Cost estimates are broken down into line items for the various stages in the construction process, the types of work being accomplished (e.g. the types of material being removed), or whether efforts are accomplished under contract or through direct agency resources (e.g. labor). Contingencies were developed using risk analysis for the contract cost and are included in the construction estimates. Contingencies are also worked into non-contract costs separately. Items estimated in prior fiscal years are escalated to the current period for cost-benefit comparison purposes, and are further escalated to the anticipated construction period for budgeting purposes.

Mobilization and Demobilization Costs (Mob-Demob): Mob-Demob costs include the contractor's costs for preparing his plant and transporting it to and from the project site. Mob-demob costs for this project assume a large contractor mobilizing from an east coast port to and from Boston Harbor. Major mobilization and demobilization are included with only one feature or segment of the project and lesser costs were associated with moving

within the project from one segment to the next. A summation of Mob-Demob costs is provided in Table D2-1. Due to Air Quality concerns discussed elsewhere there are shut-down periods built into the schedules for the larger volume and longer duration plans that will require demobilizations and remobilizations every other winter to reduce air emissions. Costs for these additional activities are reflected in the estimates. If during the project's design phase, changes to EPA air attainment standards and thresholds, or lesser cost means of meeting the air quality regulations, such as purchase of credits, or implementation of offset methods are identified that would results in a cost savings to the project, then use of construction period shut-downs with their increase mob-demob costs would be reconsidered.

Unit Costs for Dredging and Disposal: Costs for removal of material to construct the deepened and widened channels are provided per cubic yard of material in-place based on hydrographic surveys performed by New England District survey crews. Separate costs are given for (1) dredging and disposal of ordinary material, (2) drilling and blasting of rock and other hard materials (consolidated tills), and (3) removal and disposal of rock and hard materials. Ordinary material dredging unit costs include dredging, transport and disposal. Rock removal costs include drilling and blasting, dredging, transport and disposal. The details of each type of work are discussed below.

Construction Sequencing for Marine Resource Impacts: It is assumed that due to the wide range of resource issues in the harbor and the larger areas covered by the several proposed improvements, that dredging could occur year-round with proper sequencing of work to avoid environmentally sensitive areas at different times of year. This has been the experience with the recent large-scale dredging operations in the harbor; the 1998-2001 maintenance and improvement dredging of the main tributary channels, and the 2004-2005 major maintenance dredging of the outer harbor features, and the 2008-2010 inner harbor major maintenance operation which was timed to minimize lobster impacts in the lower harbor. Winter flounder are found in various areas of the lower harbor at different times of year, while anadromous fish transit the harbor to and from the Mystic and Charles Rivers in the spring and late fall. Maintenance construction in 2008-2010 occurred year-round, but will shift between different areas of the harbor seasonally to minimize impacts. A similar sequencing will be developed for this deep draft improvement project, which provides more flexibility for these adaptations given its larger scope. Sequencing will be developed in consultation with the State and Federal resource agencies during the design phase, and will incorporate the air quality shutdown periods as discussed below should that aspect of the sequencing be retained.

Dredging Plant and Process: It was originally anticipated that two to three large mechanical dredges (bucket or clamshell) would be employed on the job round the clock and year-round for the period of construction. At the conclusion of the air quality analysis it was determined that use of a third dredge would increase annual emissions beyond the level that could be reasonably addressed through biannual construction shutdowns. The final plan for removal of ordinary material is based on two dredges working 24/7 except during the air quality shutdown periods which will occur every other winter as described in the air quality mitigation section below. Both dredges are anticipated to be large barge-mounted cable arm dredges using toothed buckets of 22 cubic yards or greater in size, except in the Mystic and

Chelsea River where use of smaller equipment was estimated. During the 1998-2001 construction, and subsequent maintenance operations, the contractor used the same larger-sized equipment for all project areas, including the Mystic and Chelsea Rivers.

The dredges would remove the material from the channel bottom and place the material in large split-hull scows for transport to the disposal site. Each dredge would require at least three scows of 5000 cubic yards capacity and two or more ocean-going tugs, so that one scow may be filled while the others are in transit to and from the disposal site, to minimize dredge idle time. Scows of 3000 cubic yards capacity would be used in the Mystic and Chelsea Rivers with the smaller dredge. The contractor is also expected to employ smaller harbor tugs to help position the equipment, work boats for crew and supply transfer, a fuel barge, and a survey boat.

Blasting Plant and Process: Rock removal during the 1998-2001 improvement dredging of the Reserved Channel, Turning Basin, Inner Confluence and Mystic River was accomplished by ripping the bedrock with a large toothed bucket mounted on a heavy excavator. Only the granite ledge in the upper Chelsea River required blasting for removal under that project. However, until the conclusion of the subsurface exploration program included in the design phase of this project, it cannot be determined whether the large volumes of rock required to be removed will lend itself to ripping or removal by other means such as a rock hammer. It may be that the rock cuts from the last improvement project were from zones that were more heavily weathered and fractured thus lent themselves to removal by ripping, and that the rock encountered in this improvement will be different in character. Rock cuts of more than five feet were made in all areas of the 1998-2001 work by bucket ripping without difficulty. For the feasibility level estimates it was assumed that drilling and blasting would be required for removal of all rock under this project.

Blasting and removal of rock ledge is a two-stage operation: drilling and blasting followed by dredging and disposal. It is assumed that one or two large drill barges (depending on the project segment) would be employed for fracturing the ledge areas or any very large boulders identified for removal from the several project segments. Whether one or two drilling rigs will be required is based largely on the depth increment and total volume of rock requiring removal. The drill barges would each mount three drill frame set for an average 9-foot spacing (7-foot spacing at Chelsea River). An explosives barge would be used to transfer charges from shore to the blasting sites and to store charges.

The area to be drilled and blasted for rock removal includes side slope areas outside the channel limits, additional holes around the perimeter of the target area to ensure sufficient fracturing, and an additional required removal horizon of two feet and the two-foot allowable overdepth horizon. Over-drilling of the charge holes by four to five feet below the allowable overdepth is included to ensure that the cones of rock fractured by each charge will overlap below the overdepth elevation, ensuring the ability to remove of all rock to at least the allowable grade. This requires drilling and blasting over a slightly larger area than that within the contour of the target removal elevation.

Rock removal estimates also include costs for test blasts, seismic monitoring, safety inspection, fish monitors, fish startle systems, and daylight-only operations for blasting. In developing the estimates for Boston Harbor the New England District relied on the New York District's generic drilling and blasting program developed from their extensive experience with the New York – New Jersey Harbor Kill Van Kull blasting and rock removal operation. The District also consulted with the Corps Walla Walla District (the Corps Center of Expertise for Cost Estimating) in development of the drilling and blasting estimates. Drilling costs are dependent on the square-footage of the area to be drilled, hole spacing, the depth of cut required, and the drilling efficiency (linear feet of hole drilled per day). Side slope areas were included in these estimates. To be conservative at this phase of project cost estimating, the area used to calculate the drilling and blasting plan and for rock removal area included all areas of required material, plus an area outside the required footprint equal to 20 percent of the additional footprint to the allowable overdepth elevation. This will ensure that the estimate includes sufficient area to permit fracturing of all required and allowable material within the required dredging footprint, and attainment of the required elevation by dredging all rock within the required elevation.

The estimates assume that a large barge-mounted excavator or heavy clam shell bucket of 16 cubic yards or greater would be used for removal of rock and other hard materials. As with the unconsolidated materials, the rock and hard material would be placed in split-hull scows for transport to the disposal or beneficial use site(s). The additional equipment supporting the excavator operations, including tugs, scows, work boats, survey boats, and fuel barge were also included in the rock estimates.

Disposal of Dredged Material: All disposal costs are included in the unit costs for each of the two classes of material to be removed. All improvement dredging material has been found suitable for unconfined open-water disposal at the MPRSA designated Massachusetts Bay Disposal Site, based on a Suitability Determination with US EPA concurrence dated 8 December 2006. Under the Federal Base Plan for this improvement project all dredged material would be loaded into scows and towed to the MBDS for discharge. The MBDS is located about 18 miles easterly of the harbor entrance. The actual haul distance from each dredge area to the Massachusetts Bay Disposal Site was used to compute cycle times and transit costs. Multiple scow and tug units would be assigned to each dredge or excavator to allow for uninterrupted dredging operations. Depending on which project area was being worked, any overlying maintenance material would either be dredged and disposed along with the improvement material at the MBDS, or would be removed separately and placed in scows for deposit in one or more of the existing CAD cells dredged beneath the channel in the upper harbor above the tunnels.

Haul Costs: Hauling costs are included in the unit costs for each of the two classes of material to be removed. Haul times to the disposal site are based on the actual haul distance to the Massachusetts Bay Disposal Site from each plan under consideration. For the several channel improvement plans the actual distance varied from 21 to 31 miles. The haul times were used to determine the cycle times for the scows and the number of scows and tugs needed to maintain a continuous dredging operation.

Air Quality Impacts on Project Cost: Air quality concerns with potential threshold exceedance for non-attainment pollutants during construction required stretching out the construction period. This was accomplished by adding no-work periods to limit construction to nine months per year, thus lowering the annual emissions totals for the construction plant. During design the potential to avoid shut-downs through air quality mitigation or the purchase of air quality credits will be examined. Proposed EPA changes to attainment designations as of December 2012 were not finalized or implemented through changes in regulations and therefore could not be considered in the timeline and estimates. Also at this time opportunities for mitigation and availability of credits for sale within the non-attainment area were considered speculative. Mitigation, including the purchase of emissions credits must reduce emissions of those target pollutants to zero, not merely back to the threshold level. Contingent on further investigation, construction shut-down periods, even with the additional mobilization/demobilization and escalation costs, are considered the least-cost means of compliance with the Clean Air Act. These shutdowns increased the mobilization/ demobilization costs and cost escalation factors for the affected plans. The shut-down periods were sequenced to bridge calendar years, thereby minimizing additional mobilization/ demobilization costs. The impact of air quality emission threshold shutdowns on the construction period is shown in the estimate tables for the individual main channels improvement plans. A graphic representation of the construction sequencing timeline for the recommended plan is included with the Construction Schedule at the end of this Appendix.

Contract Costs: Mob-demob costs and unit costs for material removal and disposal include contractor's plant, labor, insurance and materials costs, as well as overhead, bond and profit. The sum of these costs represents the anticipated contract cost, subject to contingencies and escalation.

Contingencies: Contingencies are applied to the construction contract estimates to account for actual variations in the nature and quantities of dredged materials, potential weather impacts, types and sizes of equipment available to potential bidders, bid competition, changes in market rates for equipment rental and operation, costs of bonds, and other factors affecting dredging production and costs. Contingency levels may be adjusted during final design based on changes in the level of certainty and risk associated with these variables.

As of August 2007, the Corps requires that all project cost estimates for large construction projects undergo a risk analysis to determine the appropriate contingency to use for each aspect of project construction. In consultation with the Walla Walla District Cost Estimating Center of Expertise, models were developed for each segment of the project including drilling and blasting, dredging, and rock removal efforts. Contingency estimates were adjusted based on the results of this analysis. Samples of the risk evaluation, the resulting contingency determinations, and detailed cost estimates for the several improvement plans are provided for the optimized depth alternative in the following sections on each project segment. As contingency risk analysis was calculated separately for the four major project segments for the main channels improvement plans, a weighted average contingency was developed for those plans and depth increments, as shown in Table D2-2. The resulting contingency values were used for these individual plans. The contingency

values for the 46-foot increment were used for all lesser increments. The contingency values for the 49-foot increment were used for the 50-foot depth increment.

Environmental Monitoring: Environmental monitoring (EM) costs are included as a separate line item in the Construction Management costs. These costs would be incurred during the period of construction and for a period of five years post-construction. These costs include field monitoring investigations and analysis, and preparation of monitoring reports for the dredging areas and the MBDS. Monitoring of CAD Cells used for maintenance material is an operations and maintenance cost and is not included in these estimates. Monitoring for any beneficial use alternatives and sites would be developed further during the design phase if it is decided to include such opportunities in the implemented project. The feasibility level estimate has drawn on the District's experience with the recent projects in Boston Harbor and requests by City, State and Federal agencies for monitoring at the dredge site, and the Corps ongoing efforts for monitoring activity at the MBDS in concert with US EPA's site management and monitoring plan. It was assumed for the purpose of developing EM costs that monitoring of turbidity at the dredge site and surveys of mound formation at the MBDS would be the focus of monitoring efforts. A plume tracking study is being conducted for the Inner Harbor maintenance dredging effort to verify SSFATE modeling of the harbor. Depending on the results of this study, further turbidity plume monitoring may be found unnecessary.

Environmental monitoring costs are largely a function of the construction duration of any particular plan (the length of time of dredging and disposal activities) and therefore relative to the construction contract cost. For this level of analysis a series of monitoring events were forecast during the construction period for each of the improvement plans. Pre and immediate post-construction monitoring events were also included in the total of events and a cost per event was assumed. These calculations are shown in Table D2-3 and are included in the cost estimate tables for the individual plans.

Planning, Engineering and Design Costs (PED): PED costs consist of costs for the design phase including development of any required design phase document and preparation of Plans and Specifications, Design phase costs for this project include final development of beneficial use plans, preparation of a final Design Document, final regulatory permitting for the project, specifications surveys, preparation of Plans and Specifications, and related costs for management and pre-construction contracting and other pre-construction phase activities. Table D2-4 contains a detailed table of itemized PED estimates for the several plans and increments under consideration. PED estimates for this project include the below listed tasks.

- Project management and advanced planning activities during design
- Hydrographic surveys of the dredging and disposal areas for refinement of quantity estimates and design of disposal activities
- Subsurface explorations (borings and probings) to define the nature and quantities of various material classes at depth, particularly rock and other hard materials
- Seismic surveys of areas of the project not surveyed during feasibility also to be used to help refine the nature and extent of various materials at depth
- Additional ship simulator runs using larger container ships if necessary

- Geotechnical investigations to establish set-backs for dredging alongside various facilities and to assist in developing the blasting plans
- Structural engineering investigations of waterfront structures to assist in set back development and to assist in developing the blasting plans
- Cultural resource investigations in areas not already covered during feasibility, including the channel widening areas along Chelsea River and the beneficial use sites
- Preparation of a supplemental NEPA document to cover design changes and the beneficial use alternatives
- Continued public involvement and participation of the Corps in the Technical Working Group during the design phase
- Preparation of a design document and reviews
- Updates to the economic evaluation
- Updates to the project design and cost estimates if necessary from the other investigations and to decision-making parameters current
- Environmental investigations of the beneficial use sites, should the State, EPA and the Sponsor support including these sites and plans in the project
- Preparation of Plans and Specifications for soliciting bids for construction

Construction Management Costs (CM): Construction Management costs include costs for contract administration; supervision and inspection of the construction contract activities, including silent inspector services; pre-dredge, progress and after-dredge surveys; and management during the construction phase. These costs are also largely relative to the construction duration and some are estimated in part as a percentage of the contract cost. Costs for Engineering During Construction (EDC) dealing with construction phase engineering investigations and design modifications are traditionally included with PED costs, but have been included in the Construction Management discussion, as they would be budgeted in this phase, not in PED. Table D2-5 contains a detailed table of itemized S&A estimates for the several plans and increments under consideration. S&A estimates for this project include the following tasks:

- Project management and advanced planning activities during construction
- Hydrographic surveys of the dredging area prior to, during and after construction of each major project segment to determine pre-dredge, progress and post-dredge quantities for purposes of assuring project acceptance and completion, and for measurement and payment
- Contracting division, safety office and other support during contract award, construction and contract close-out
- Construction contract administration costs
- Construction supervision and inspection costs, including inspectors, construction management, travel and other inspection costs
- Diving inspection and supervision costs during blasting operations
- Continued public involvement and participation of the Corps in the Technical Working Group during the construction phase
- Preparation of a construction summary document
- Engineering during construction (EDC)

Aids to Navigation: The United States Coast Guard is responsible for managing and maintaining the systems of aids to navigation in the nation's ports and harbors. As the proposed improvement plans involve deepening of existing marked Federal channels, no new aids to navigation would be required for any of the improvement plans. Relocation and resetting of some buoys may be required during construction to facilitate dredging operations, and at the conclusion of construction of each channel area to mark the new deep lane width and turns. The relocation of navigation aids is a Federal expense to be paid by the United States Coast Guard, and is included in the project cost. The number of aids that require resetting is shown below. Costs for these relocations are included in the estimates for each plan as required. Table D2-6 displays the costs for Aids to Navigation.

AIDS TO NAVIGATION REQURING RESETTING BY CHANNEL REACH			
Broad Sound North Entrance Channel	6	Reserved Channel	0
President Roads Anchorage	2	Main Ship Channel Extension to MMT	2
President Roads Reach of MSC	2	Mystic River	0
Lower Main Ship Channel	6	Chelsea River	4

Real Estate Costs: All lands required for construction and future maintenance of the project, including areas needed for disposal of dredged material and beneficial use of dredged material, are subtidal, and subject to the navigation servitude. Temporary use of a waterfront parcel to locate construction trailers, construction crew parking, shore access and berths for vessels and some equipment, during construction and future maintenance dredging operations are the only interests needed for the project. On the recent improvement and maintenance projects Massport made land at its waterfront facilities available for these uses. Massport has agreed to provide space at one of its many facilities for temporary office space, construction team parking and berth access for survey and work boats and tugs. The Sponsor's costs for temporarily providing this access, have been included in the project costs, and described in a Real Estate Plan dated 17 September 2007, included with this Feasibility Report as Appendix E. For purposes of the Feasibility analysis, these costs were considered creditable against the Sponsor's reimbursable share of project costs. Whether these real estate costs are in fact reimbursable will depend on whether the areas made available are upland or are subject to the navigation servitude. This determination will be made during negotiation of the Project Partnership Agreement with the Sponsor when actual temporary space to be used is identified.

As the berths and piers are also subject to navigation servitude no credit would be due the Sponsor for this use. However, during the 1998-2001 improvement project, the temporary office space and a parking area were located on an upland site adjacent to a Massport pier in East Boston. Massport as project sponsor for that work was given a credit against the

reimbursement amount for the project. For purposes of the feasibility level estimate, real estate costs were estimated based on the square footage of land and reimbursement rates used for the 1998-2001 work, escalated to July 2011. This cost is also largely a function of the construction duration, which was used to compute the term the temporary facilities would be needed. These calculations are shown in Table D2-7 and in the tables presenting the costs of each project segment.

Cost Escalation: Costs were estimated at July 2011 price levels. The July 2011 cost is the first cost for purposes of the benefit-cost analysis which also uses benefits discounted to spring 2011 levels. For budget purposes, costs must also be escalated to the period of construction, so that project authorization amounts will more closely reflect the actual costs that will be incurred at the time of construction. This escalated cost is referred to as the fully funded cost. Typically the mid-point of the construction period for each plan and increment is used to compute the escalation factor to be applied. A cost escalation table developed for use with each project segment and increment from factors from the current Civil Works Construction Cost Index System (CWCCIS) document is provided as Table D2-8, and shows the derivation of the factors used for each plan and increment. Separate escalation factors were developed for the design and construction phases. The fully funded cost is used solely for budget purposes and is not used for benefit-cost analysis.

Cost Estimate Summary: Project cost estimates are presented in detail in the following sections. Estimates were developed using the Corps of Engineers Dredge Estimating Program (CEDEP), and are based in part on recent bids for similar work in the New England District (in particular at Boston Harbor) and elsewhere. Rock removal estimates also relied on the experience of the New York District in the New York – New Jersey Harbor deepening project, and on assistance from the Walla Walla District, as discussed above. The tables below summarize the cost estimates for the principal plans of improvement. In order to support an economic depth optimization analysis, project costs were estimated for one-foot depth increments for the principal channels under consideration. The estimates include costs for mobilization and demobilization (including shut-downs every other winter to avoid exceeding air emissions thresholds that would otherwise trigger more costly mitigation measures), dredging, rock blasting and removal, and disposal of materials, contingencies, environmental monitoring during and after construction, supervision and administration, planning, engineering and design, and real estate costs. Facility costs are also included where required.

The estimates of quantities, dredging areas, and construction and annualized costs for the several improvement plans and incremental depths are shown in the tables accompanying the detailed sections for each of the four project segments (Main Channels Improvements, Main Ship Channel Extension, Mystic River Channel, and Chelsea River Channel). For the recommended plan (depth) for each segment, the CDEP cost estimate spreadsheet including the contingency risk assessment summary sheet, is provided. Separate estimates are made for: (1) dredging and disposal of ordinary material, (2) drilling and blasting of rock, and (3) removal and disposal of the rock. A Total Project Cost Summary (TPCS) form for the recommended plan of improvement with separate tables for each project segment is provided at the end of this appendix.

Costs for non-Federal berth deepening for each plan are included in the tables for each detailed section, except for the Mystic River Channel (Plan D) where there are no non-Federal improvements required as Massport has already deepened that berth to the maximum elevation under consideration for the channel.

ANNUAL COSTS

The costs of dredging and disposal for the Federal project improvements must be annualized to place them on an equal footing to enable comparison to evaluated project benefits. First the total improvement cost of the Federal project is increased for interest during construction, to account for the cost of construction funds over the period of construction, yielding the total investment cost. The project construction period is expected to be about four to seven years for the large 42 to 50 foot containership channel deepening plan increments. Lesser periods of three to four months would be required for the Main Ship Channel Deepening Extension to the MMT, one month for the Mystic River Channel, and two months for the Chelsea River Channel improvement. Project implementation costs are annualized using factors developed from interest rates adjusted in accordance with Federal statutes and regulations covering evaluation of civil works water resources projects. The period of economic analysis for navigation improvements is 50 years, and the capital recovery factor for the current fiscal year (2013) is 3-3/4 percent amortized over that period. This factor (0.04457) is applied to the investment costs for each plan to determine the annual cost for interest and amortization of the investment cost. Regulations also require that annual costs for recommended improvements be displayed using a 7 percent interest rate for the 50-year period of analysis for the purpose of budget prioritization. Annual costs using this factor (0.07245) are also provided in the tables.

Annual costs also include an annualized estimate of the cost of maintaining the project over the period of analysis. Since the General Navigation Features of the proposed project are limited to dredging to deepen existing Federal channels, the only annual maintenance cost applicable to this improvement project is the increase in periodic maintenance dredging of the improved areas to their new recommended depth. This requires an analysis of current maintenance dredging frequency and volume for each channel segment and an estimate of any increase in shoaling rate and volume that would result from a deeper channel.

Maintenance dredging of the main channels and anchorage at Boston is typically required every 16 to 40 years, depending on the project segment. The last two maintenance cycles and volumes for each channel segment were examined to determine a representative annual shoaling rate. Channel deepening would not change the sediment discharge loads of the harbor tributaries (all of which are controlled by dams), longshore sediment transport (not a large factor at Boston), or the resulting channel shoaling rates. It is therefore not expected that channel deepening would increase the frequency or volume of maintenance required for the project. However, for purposes of this analysis it was decided to allocate an increase to the current maintenance requirements for the various plans relative to the increase in depth.

Table D2-9 displays the calculation used to compute increased maintenance volume. The total volume removed from each channel segment during its last maintenance dredging was divided by the years between the last two maintenance operations to yield an annual shoaling volume for each channel or segment. For the main channels improvements (ABC) the resulting annual volumes were aggregated into a single number. For Plan D, the MSC extension, the annual volume for the lower main ship channel was divided by 4, representing that segments length relative to the total length of the lower Main Ship Channel, as a separate volume for that segment could not be calculated from the historical record. For the Mystic River the area under consideration in Plan E for deepening was compared to the total area of that channel last dredged and a factor was used (13 percent) to calculate the annual volume solely for that area's footprint. For the Chelsea River a single number for the entire channel and basin area was used.

To arrive at a volume representing the increase in maintenance requirements attributable to the channel deepening, a percentage was selected based on the magnitude of the depth increase. For all areas a base increase of 10 percent was used for the first depth increment. That percentage was increased two percent for each additional depth increment. For the main channels improvement (the nine ABC increments) 10 percent was used for the 42-foot improvement, 12 percent for 43 feet, up to 26 percent for 50 feet. Plan D, the MSC extension, used 10 percent at 42 feet, up to 16 percent at 45 feet. The Mystic River calculation used 10 percent at 37 feet, up to 16 percent at 40 feet. The Chelsea River calculation used 10 percent at 39 feet and 12 percent at 40 feet. The resulting annual increase in shoaling volume was multiplied by the unit cost for each plan and increment's first cost for dredging ordinary material, as adjusted to the total first cost of that plan (i.e. increased to account for mobilization-demobilization, contingencies, and non-contract costs) to arrive at an annual increased maintenance cost. Table 40 shows a sample computation for the 49-foot main channels (Conley) improvement plan, and the greatest depth increments of the other three plans. Annual increases in maintenance costs were also calculated for the non-Federal berth deepening for the Conley Terminal (the nine depth increments Plan ABC, and other main channels increments), the Massport Marine Terminal (MMT), and the four petroleum terminals on the Chelsea River.

The annual costs for the alternative plans and incremental depths, including Federal GNF and non-Federal improvements, are shown the following Tables. Table 41 shows the annual costs for the nine depth increments of Plan ABC for the main channels plan for access to the Conley Terminal. Tables 42, 43 and 44, show the annual costs for the Main Ship Channel Deepening Extension to the MMT, the Mystic River Channel at the MST, and the Chelsea River Channel, respectively.

ASSOCIATED MAINTENANCE DREDGING

Maintenance dredging of existing Federal navigation features would be carried out concurrent with the deep draft improvement project in two ways. First, while major maintenance dredging of the outer and inner harbor areas was and will be accomplished in the 2004-2005 and 2008-2012 timeframes, respectively, minor amounts of maintenance material may remain at the time of the improvement dredging. Second, additional channel areas not maintained in the past two operations may be maintained at the time of the improvement dredging.

Maintenance of Project Features Deepened by the Improvement Project

Removal of any remaining maintenance material from the project areas being deepened under the deep draft improvement project would be accomplished concurrent with removal of the improvement materials. Given the recentness of the two major maintenance operations and the low shoaling rate in Boston Harbor these amounts are expected to be minimal.

In project areas where the maintenance material was tested and determined suitable for ocean disposal under the 2004 and 2008-2013 projects, any remaining maintenance materials would be removed, transported, and disposed along with the improvement materials, in accordance with existing suitability determinations, at the Massachusetts Bay Disposal Site. These areas include the Broad Sound North Entrance Channel (deep lane), the President Roads Anchorage, the lower Reserved Channel and its Turning Area, and the Main Ship Channel from President Roads to Spectacle Island, and from Castle Island to the Massport Marine Terminal.

In channel areas where the maintenance material was determined unsuitable for ocean disposal, the Corps will either place that material in CAD Cells constructed at previously identified locations in the upper harbor, or the Corps will re-test those materials and dispose of them in accordance with any revised suitability determination. Any re-testing and any new suitability determinations will be fully coordinated with Federal, State and local agencies. These areas include the reach of the Main Ship Channel between Spectacle and Castle Islands, the Mystic River, and the Chelsea River, including the area of the Chelsea River where the existing 38-foot channel will be widened to conform to the new Chelsea Street Bridge opening. Quantities and footprint areas for the Chelsea Street Bridge widening and maintenance of the existing channel limits are shown with the estimate tables for Plan F.

Maintenance of Other Federal Project Features

Maintenance of the Boston Harbor Federal Navigation Project in existing channel areas outside of those proposed for deepening may also be carried out concurrent with the deep draft improvement project. This would occur because some areas not dredged in the 2004 to 2012 maintenance operations would require maintenance by the 2014-2017 improvement project timeframe, or because maintenance to improve the controlling depths of those project features was needed to assist in harbor traffic management during the

construction of the improvement project. Areas under consideration include the 30-foot Broad Sound South Entrance Channel, the 35-foot northern lane of the Broad Sound North Entrance Channel, the 15-foot Nubble Channel, and the 35-foot West Anchorage at President Roads (the barge anchorage). Minimizing navigation traffic disruptions of the drilling, blasting and dredging operations for the deep draft improvement project can be accomplished by providing alternative routes for shallow-draft traffic not needing the 40-foot channels that would be deepened. Routing of shallower-draft vessels, consistent with tidal navigation, through the South Entrance Channel with its 30-foot authorized depth, and later also through the 35-foot north lane of the North Entrance Channel, would allow deepening of the deep lane of the North Entrance Channel to progress with minimal shut-downs for large vessel passage, thereby shortening the construction duration for deepening that project feature. Similarly, encouraging a greater volume of smaller ferry and small craft traffic to use the Nubble Channel rather than transiting the Outer Confluence would aid in deepening that area of the project with minimal navigation disruption. Maintenance of the 35-foot anchorage would enable more barge and smaller cargo vessels to use that area instead of the 40-foot President Roads Anchorage while the latter area is being deepened.

Maintenance materials from these project areas would need to be tested during the design phase of the improvement project, and suitability determinations made for their disposal. At this time, given the suitable determinations issued for maintenance of adjacent areas, and the location of these project features in the Outer Harbor, it is assumed that the materials would be found suitable for ocean disposal and would be disposed at the Massachusetts Bay Disposal Site. An estimate of the dredging volumes and dredging footprints for these areas is provided in the Feasibility Report.

TABLE D2-1
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
MOBILIZATION & DEMOBILIZATION COSTS

MAIN CHANNELS DEEPENING PLANS TO CONLEY TERMINAL - INNER CHANNEL DEPTH / ENTRANCE CHANNEL DEPTH

PLAN ABC July/Aug 2011 Price Levels	42 Feet 44 Feet	43 Feet 45 Feet	44 Feet 46 Feet	45 Feet 47 Feet	45 Feet 49 Feet	46 Feet 48 Feet	46 Feet 50 Feet	47 Feet 49 Feet	47 Feet 50 Feet	47 Feet 51 Feet	47 Feet 52 Feet	48 Feet 50 Feet	48 Feet 52 Feet	49 Feet 51 Feet	50 Feet 52 Feet
Dredging and Disposal Plant															
BSN Entrance Channel	$487,000	$487,000	$593,000	$593,000	$687,000	$699,000	$690,000	$687,000	$690,000	$703,000	$794,000	$690,000	$794,000	$703,000	$794,000
Main Ship Chan Incl PRR	$93,000	$93,000	$93,000	$100,000	$100,000	$100,000	$100,000	$106,000	$106,000	$106,000	$106,000	$106,000	$106,000	$106,000	$106,000
Res Chan & Res Turn Area	$466,000	$466,000	$466,000	$573,000	$573,000	$573,000	$573,000	$681,000	$681,000	$681,000	$681,000	$681,000	$681,000	$681,000	$788,000
Pres Roads Anchorage	$87,000	$93,000	$93,000	$100,000	$100,000	$100,000	$100,000	$106,000	$106,000	$106,000	$106,000	$113,000	$113,000	$113,000	$113,000
Total Dredging	$1,133,000	$1,139,000	$1,245,000	$1,366,000	$1,460,000	$1,472,000	$1,463,000	$1,580,000	$1,583,000	$1,596,000	$1,687,000	$1,590,000	$1,694,000	$1,603,000	$1,801,000
Drilling and Blasting Plant															
BSN Entrance Channel	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000	$1,226,000
Main Ship Chan Incl PRR	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000	$189,000
Res Chan & Res Turn Area	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000	$1,038,000
Pres Roads Anchorage	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000	$163,000
Total Drill & Blast	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000	$2,616,000
Rock Removal and Disposal Plant															
BSN Entrance Channel	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000	$659,000
Main Ship Chan Incl PRR	$80,000	$80,000	$80,000	$80,000	$80,000	$87,000	$87,000	$87,000	$87,000	$87,000	$87,000	$87,000	$87,000	$87,000	$87,000
Res Chan & Res Turn Area	$271,000	$378,000	$378,000	$378,000	$378,000	$378,000	$378,000	$378,000	$378,000	$378,000	$378,000	$378,000	$378,000	$484,000	$484,000
Pres Roads Anchorage	$78,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000
Total Rock Removal	$1,088,000	$1,197,000	$1,197,000	$1,197,000	$1,197,000	$1,204,000	$1,204,000	$1,204,000	$1,204,000	$1,204,000	$1,204,000	$1,204,000	$1,204,000	$1,310,000	$1,310,000
Total All Mob & Demob	$4,837,000	$4,952,000	$5,058,000	$5,179,000	$5,273,000	$5,292,000	$5,283,000	$5,400,000	$5,403,000	$5,416,000	$5,507,000	$5,410,000	$5,514,000	$5,529,000	$5,727,000
AQ Remobilization-Demobilization	$4,147,000	$4,254,000	$4,360,000	$4,467,000	$4,561,000	$4,573,000	$4,564,000	$4,669,000	$4,672,000	$4,685,000	$4,776,000	$4,672,000	$4,776,000	$4,791,000	$4,989,000
Number of Air Quality Shutdowns	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2
AQ Remobilization-Demob Cost	$0	$0	$4,360,000	$4,467,000	$4,561,000	$4,573,000	$4,564,000	$4,669,000	$4,672,000	$4,685,000	$4,776,000	$4,672,000	$4,776,000	$4,791,000	$9,978,000
Miscellaneous Costs															
BSN Entrance Channel	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000
Main Ship Chan Incl PRR	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000
Res Chan & Res Turn Area	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000
Pres Roads Anchorage	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000	$71,000
Rounding Adjustment for TPCS															
Total Miscellaneous	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000

TABLE D2-2
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
CONSTRUCTION CONTINGENCY COSTS - WEIGHTED AVERAGE - FROM CONTINGENCY RISK ANALYSIS

ORIGINAL PLANS FROM 2008 DRAFT REPORT AND MAY 2012 INTERNAL REVIEW DRAFT WITH 2-FOOT INCREASED ENTRANCE CHANNEL DEPTH

MAIN CHANNELS IMPROVEMENT PLANS December 2012 Contingency Risk Analysis	Contingency Percentage 46/48	Contingency Percentage 47/49	Contingency Percentage 48/50	Contingency Percentage 49/51	Item Cost 46/48-Foot	Item Cost 47/49-Foot	Item Cost 48/50-Foot	Item Cost 49/51-Foot	Contingency Cost 46/48-Foot	Contingency Cost 47/49-Foot	Contingency Cost 48/50-Foot	Contingency Cost 49/51-Foot
Broad Sound North Entrance Channel	14.3%	14.3%	14.3%	14.3%	$70,029,000	$80,835,000	$92,311,000	$105,106,000	$10,014,000	$11,559,000	$13,200,000	$15,030,000
Main Ship Chan Including President Roads Reach	20.8%	20.8%	20.8%	20.8%	$32,262,000	$38,032,000	$42,785,000	$49,609,000	$6,710,000	$7,911,000	$8,899,000	$10,319,000
Reserved Channel & Turning Area	20.6%	20.6%	20.6%	20.6%	$22,381,000	$27,576,000	$33,971,000	$40,138,000	$4,610,000	$5,681,000	$6,998,000	$8,268,000
President Roads Anchorage	16.3%	16.3%	16.3%	16.3%	$34,719,000	$38,162,000	$42,468,000	$45,752,000	$5,659,000	$6,220,000	$6,922,000	$7,458,000
Weighted Average Contingency	16.9%	17.0%	17.0%	17.1%	$159,391,000	$184,605,000	$211,535,000	$240,605,000	$26,993,000	$31,371,000	$36,019,000	$41,075,000
Air Quality Shutdowns	16.9%	17.0%	17.0%	17.1%	$4,573,000	$4,669,000	$4,672,000	$4,791,000	$774,000	$793,000	$796,000	$818,000
Total Dredging	17.0%				$163,964,000	$189,274,000	$216,207,000	$245,396,000	$27,767,000	$32,164,000	$36,815,000	$41,893,000

REVISED PLANS FROM NOVEMBER 2012 WITH 4-FOOT INCREASED ENTRANCE CHANNEL DEPTH

MAIN CHANNELS IMPROVEMENT PLANS December 2012 Contingency Risk Analysis	Contingency Percentage 45/49	Contingency Percentage 46/50	Contingency Percentage 47/51	Contingency Percentage 48/52	Item Cost 45/49-Foot	Item Cost 46/50-Foot	Item Cost 47/51-Foot	Item Cost 48/52-Foot	Contingency Cost 45/49-Foot	Contingency Cost 46/50-Foot	Contingency Cost 47/51-Foot	Contingency Cost 48/52-Foot
Broad Sound North Entrance Channel	14.3%	14.3%	14.3%	14.3%	$80,835,000	$105,286,000	$105,299,000	$118,032,000	$11,559,000	$15,056,000	$15,058,000	$16,879,000
Main Ship Chan Including President Roads Reach	20.8%	20.8%	20.8%	20.8%	$28,076,000	$32,262,000	$38,032,000	$42,785,000	$5,840,000	$6,710,000	$7,911,000	$8,899,000
Reserved Channel & Turning Area	20.6%	20.6%	20.6%	20.6%	$17,500,000	$22,381,000	$27,576,000	$33,971,000	$3,605,000	$4,610,000	$5,681,000	$6,998,000
President Roads Anchorage	16.3%	16.3%	16.3%	16.3%	$30,866,000	$34,719,000	$38,162,000	$42,468,000	$5,031,000	$5,659,000	$6,220,000	$6,922,000
Weighted Average Contingency	16.6%	16.5%	16.7%	16.7%	$157,277,000	$194,648,000	$209,069,000	$237,256,000	$26,035,000	$32,035,000	$34,870,000	$39,698,000
Air Quality Shutdowns	16.6%	16.5%	16.7%	16.7%	$4,561,000	$4,564,000	$4,685,000	$4,776,000	$755,000	$751,000	$781,000	$799,000
Total Dredging	16.7%				$161,838,000	$199,212,000	$213,754,000	$242,032,000	$26,790,000	$32,786,000	$35,651,000	$40,497,000

TABLE D2-3
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ENVIRONMENTAL MONITORING COSTS

ENVIRONMENTAL MONITORING COSTS FOR MONITORING DURING THE CONSTRUCTION PERIOD AND POST-CONSTRUCTION PERIOD MONITORING FOR A FIVE-YEAR PERIOD

MAIN CHANNELS DEEPENING PLANS TO CONLEY TERMINAL

PLAN ABC **Twelve Depth Increments**	**42 Feet** **44 Feet**	**43 Feet** **45 Feet**	**44 Feet** **46 Feet**	**45 Feet** **47 Feet**	**45 Feet** **49 Feet**	**46 Feet** **48 Feet**	**46 Feet** **50 Feet**	**47 Feet** **49 Feet**	**47 Feet** **50 Feet**	**51 Feet** **50 Feet**	**52 Feet** **50 Feet**	**48 Feet** **50 Feet**	**48 Feet** **52 Feet**	**49 Feet** **51 Feet**	**50 Feet** **52 Feet**
Monitoring During Construction															
Construction Duration - Months	16	18	26	27	0	28	31	29	30	34	35	31	34	40	51
Monitoring Events	8	9	13	14	0	14	16	15	15	17	18	16	17	20	26
Pre & Post Dredge Events	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total Monitoring Events During Construction Period	10	11	15	16	2	16	18	17	17	19	20	18	19	22	28
Cost per Event	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000
Monitoring Cost During Construction	$70,000	$77,000	$105,000	$109,000	$14,000	$112,000	$123,000	$116,000	$119,000	$133,000	$137,000	$123,000	$133,000	$154,000	$193,000
Monitoring After Construction															
Quarterly Monitoring for 5 Years															
Harbor Monitoring Events	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Rock Site Monitoring Events	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Cost per Event	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000	$14,000
Monitoring Cost After Construction	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000	$420,000
Total Monitoring Costs	$490,000	$497,000	$525,000	$529,000	$434,000	$532,000	$543,000	$536,000	$539,000	$553,000	$557,000	$543,000	$553,000	$574,000	$613,000

TABLE D2-3 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ENVIRONMENTAL MONITORING COSTS

ENVIRONMENTAL MONITORING COSTS FOR MONITORING DURING THE CONSTRUCTION PERIOD AND POST-CONSTRUCTION PERIOD MONITORING FOR A FIVE-YEAR PERIOD

	PLAN D - MAIN SHIP CHANNEL DEEPENING EXTENDED TO MASSPORT MARINE TERMINAL				PLAN E - MYSTIC RIVER CHANNEL DEEPENING TO MASSPORT MEDFORD STREET TERMINAL				PLAN F - CHELSEA RIVER CHANNEL	
	42 Feet	**43 Feet**	**44 Feet**	**45 Feet**	**37 Feet**	**38 Feet**	**39 Feet**	**40 Feet**	**39 Feet**	**40 Feet**
Monitoring During Construction										
Construction Duration - Months	3	3	4	4	1	1	1	1	4	5
Monitoring Events	2	2	2	2	1	1	1	1	2	3
Pre & Post Dredge Events	2	2	2	2	2	2	2	2	2	2
Total Monitoring Events During Construction Period	4	4	4	4	3	3	3	3	4	5
Cost per Event	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000
Monitoring Cost During Construction	$25,000	$25,000	$28,000	$28,000	$18,000	$18,000	$18,000	$18,000	$28,000	$32,000
Monitoring After Construction										
Annual Monitoring for 5 Years										
Monitoring Events	5	5	5	5	5	5	5	5	5	5
Cost per Event	$4,000	$4,000	$4,000	$4,000	$2,000	$2,000	$2,000	$2,000	$4,000	$4,000
Monitoring Cost After Construction	$20,000	$20,000	$20,000	$20,000	$10,000	$10,000	$10,000	$10,000	$20,000	$20,000
Total Monitoring Costs	$45,000	$45,000	$48,000	$48,000	$28,000	$28,000	$28,000	$28,000	$48,000	$52,000

TABLE D2-4
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ENGINEERING AND DESIGN COSTS - PLAN ABC - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

ENGINEERING AND DESIGN COSTS - IMPROVEMENT			42/44 Feet	43/45 Feet	44/46 Feet	45/47 Feet	45/49 Feet	46/48 Feet	46/50 Feet	47/49 Feet	47/50 Feet	47/51 Feet	47/52 Feet	48/50 Feet	48/52 Feet	49/51 Feet	50/52 Feet
ORIGINAL PERCENTAGE ESTIMATES FOR IMPROVEMENT PROJECT																	
Construction Subtotal			$80,871,000	$111,832,000	$140,371,000	$164,384,000	$188,628,000	$191,731,000	$231,998,000	$221,438,000	$234,868,000	$249,405,000	$265,284,000	$253,022,000	$282,529,000	$287,289,000	$332,395,000
First Cost - July-August 2011			$89,598,000	$121,407,000	$151,653,000	$176,057,000	$200,710,000	$204,045,000	$245,015,000	$234,427,000	$248,281,000	$263,648,000	$279,920,000	$266,870,000	$297,717,000	$303,142,000	$350,563,000
Construction Duration	10000		16	18	26	27	28	28	29	29	30	34	35	31	37	40	51
Planning, Engineering & Design	0.0200		$4,044,000	$4,273,000	$4,522,000	$4,710,000	$4,830,000	$4,916,000	$5,039,000	$5,130,000	$5,267,000	$5,361,000	$5,442,000	$5,362,000	$5,533,000	$5,802,000	$6,146,000
DETAILED ESTIMATES FOR IMPROVEMENT PROJECT																	
Design Phase Costs																	
Project Management		0.0015	$301,000	$358,000	$441,000	$482,000	$523,000	$528,000	$593,000	$577,000	$602,000	$644,000	$673,000	$635,000	$709,000	$731,000	$854,000
Public Involvement			$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000
Advanced Planning		0.0010	$141,000	$172,000	$200,000	$224,000	$249,000	$252,000	$292,000	$281,000	$295,000	$309,000	$325,000	$313,000	$343,000	$347,000	$392,000
Cultural Resource Investigations			$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000
SEIS Document		0.0005	$85,000	$101,000	$115,000	$127,000	$139,000	$141,000	$161,000	$156,000	$162,000	$170,000	$178,000	$172,000	$186,000	$189,000	$211,000
Economic Updates		0.0005	$115,000	$131,000	$145,000	$157,000	$169,000	$171,000	$191,000	$186,000	$192,000	$200,000	$208,000	$202,000	$216,000	$219,000	$241,000
Environmental Investigations	Fish		$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
Environmental Investigations	Lobster		$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
Hydrographic Surveys	Harbor		$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
Hydrographic Surveys	MBDS		$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000	$96,000
Subsurface Explorations			$1,020,000	$1,080,000	$1,140,000	$1,200,000	$1,200,000	$1,260,000	$1,200,000	$1,320,000	$1,380,000	$1,380,000	$1,380,000	$1,380,000	$1,380,000	$1,440,000	$1,500,000
Seismic Surveys - New Areas	PRA		$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000
Geotechnical Investigations			$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000
Structural Investigations			$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000	$59,000
Additional Ship Simulation Efforts			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$135,000	$135,000
Design Updates			$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000
Cost Estimate Updates			$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000
Rock Site - Beneficial Use																	
Beneficial Use Investigations	Rock		$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000	$140,000
Cultural Resource Investigations	Rock Site		$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000
Hydrographic Surveys	Rock Site		$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000
Industrial Waste Site - Beneficial Use																	
Beneficial Use Investigations	IWS		$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000
Cultural Resource Investigations	IWS		$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000
Hydrographic Surveys	IWS		$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000
Design Document Preparation & Review			$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000
Contracting and Contract Documents Prep, ITR & Production			$100,000	$116,000	$130,000	$142,000	$154,000	$156,000	$176,000	$171,000	$177,000	$185,000	$193,000	$187,000	$201,000	$204,000	$226,000
Subtotal Design Phase Costs			$3,456,000	$3,652,000	$3,865,000	$4,026,000	$4,128,000	$4,202,000	$4,307,000	$4,385,000	$4,502,000	$4,582,000	$4,651,000	$4,583,000	$4,729,000	$4,959,000	$5,253,000
Contingencies		17.0%	$588,000	$621,000	$657,000	$684,000	$702,000	$714,000	$732,000	$745,000	$765,000	$779,000	$791,000	$779,000	$804,000	$843,000	$893,000
Total PED (Design Phase) Costs			$4,044,000	$4,273,000	$4,522,000	$4,710,000	$4,830,000	$4,916,000	$5,039,000	$5,130,000	$5,267,000	$5,361,000	$5,442,000	$5,362,000	$5,533,000	$5,802,000	$6,146,000

TABLE D2-4 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ENGINEERING AND DESIGN COSTS - PLANS D, E & F - MAIN SHIP CHANNEL EXTENSION, MYSTIC RIVER, AND CHELSEA RIVER IMPROVEMENTS

ENGINEERING AND DESIGN COSTS - IMPROVEMENT			MAIN SHIP CHANNEL EXTENSION TO MMT				MYSTIC RIVER				CHELSEA RIVER	
			42 Feet	43 Feet	44 Feet	45 Feet	37 Feet	38 Feet	39 Feet	40 Feet	39 Feet	40 Feet
ORIGINAL PERCENTAGE ESTIMATES FOR IMPROVEMENT PROJECT												
Construction Subtotal			$6,884,000	$10,191,000	$13,138,000	$15,481,000	$1,207,000	$1,435,000	$1,623,000	$1,894,000	$7,353,000	$9,960,000
First Cost - January 2008			$7,858,000	$11,217,000	$14,349,000	$16,730,000	$1,641,000	$1,871,000	$2,060,000	$2,337,000	$8,601,000	$11,380,000
Construction Duration			3	3	4	4	1	1	1	1	4	5
Planning, Engineering & Design	0.0200		$313,000	$332,000	$353,000	$367,000	$168,000	$168,000	$168,000	$170,000	$384,000	$394,000
DETAILED ESTIMATES FOR IMPROVEMENT PROJECT												
Design Phase Costs												
Project Management		0.0015	$32,000	$37,000	$42,000	$45,000	$22,000	$22,000	$22,000	$23,000	$31,000	$35,000
Public Involvement			$0	$0	$0	$0	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Advanced Planning		0.0015	$30,000	$35,000	$40,000	$43,000	$12,000	$12,000	$12,000	$13,000	$21,000	$25,000
Cultural Resource Investigations	Chelsea		$0	$0	$0	$0	$0	$0	$0	$0	$80,000	$80,000
SEIS Document			$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Economic Updates			$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Environmental Investigations	Fish		$10,000	$10,000	$10,000	$10,000	$3,000	$3,000	$3,000	$3,000	$2,000	$2,000
Environmental Investigations	Lobster		$12,000	$12,000	$12,000	$12,000	$0	$0	$0	$0	$0	$0
Hydrographic Surveys	Harbor		$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$36,000	$36,000
Hydrographic Surveys	MBDS		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subsurface Explorations			$94,000	$99,000	$105,000	$110,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000
Seismic Surveys - New Areas			$0	$0	$0	$0	$0	$0	$0	$0	$20,000	$20,000
Geotechnical Investigations			$5,000	$5,000	$5,000	$5,000	$0	$0	$0	$0	$32,000	$32,000
Structural Investigations			$5,000	$5,000	$5,000	$5,000	$0	$0	$0	$0	$8,000	$8,000
Additional Ship Simulation Efforts			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Design Updates			$12,000	$12,000	$12,000	$12,000	$4,000	$4,000	$4,000	$4,000	$8,000	$8,000
Cost Estimate Updates			$8,000	$8,000	$8,000	$8,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000
Rock Site - Beneficial Use												
Beneficial Use Investigations	Rock		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cultural Resource Investigations	Rock Site		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Hydrographic Surveys	Rock Site		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Industrial Waste Site - Beneficial Use												
Beneficial Use Investigations	IWS		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cultural Resource Investigations	IWS		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Hydrographic Surveys	IWS		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Design Document Preparation & Review			$14,000	$14,000	$14,000	$14,000	$8,000	$8,000	$8,000	$8,000	$8,000	$8,000
Contracting and Contract Documents Prep, ITR & Production			$23,000	$25,000	$27,000	$28,000	$21,000	$21,000	$21,000	$21,000	$24,000	$25,000
Subtotal Design Phase Costs			$272,000	$289,000	$307,000	$319,000	$146,000	$146,000	$146,000	$148,000	$334,000	$343,000
Contingencies		15.0%	$41,000	$43,000	$46,000	$48,000	$22,000	$22,000	$22,000	$22,000	$50,000	$51,000
Total Design Phase Costs			$313,000	$332,000	$353,000	$367,000	$168,000	$168,000	$168,000	$170,000	$384,000	$394,000

TABLE D2-5
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
CONSTRUCTION MANAGEMENT COSTS - PLAN ABC - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

CONSTRUCTION MANAGEMENT COSTS - IMPROVEMENT			42/44 Feet	43/45 Feet	44/46 Feet	45/47 Feet	45/49 Feet	46/48 Feet	46/50 Feet	47/49 Feet	47/50 Feet	47/51 Feet	47/52 Feet	48/50 Feet	48/52 Feet	49/51 Feet	50/52 Feet
ORIGINAL PERCENTAGE ESTIMATES FOR IMPROVEMENT PROJECT																	
Construction Subtotal			$80,871,000	$111,832,000	$140,371,000	$164,384,000	$188,628,000	$191,731,000	$231,998,000	$221,438,000	$234,868,000	$249,405,000	$265,284,000	$253,022,000	$282,529,000	$287,289,000	$332,395,000
First Cost - January 2008			$89,598,000	$121,407,000	$151,653,000	$176,057,000	$200,710,000	$204,045,000	$245,015,000	$234,427,000	$248,281,000	$263,648,000	$279,920,000	$266,870,000	$297,717,000	$303,142,000	$350,563,000
Supervision & Administration	0.0800		$4,432,000	$5,044,000	$6,473,000	$6,672,000	$6,957,000	$7,103,000	$7,680,000	$7,561,000	$7,844,000	$8,565,000	$8,874,000	$8,180,000	$9,327,000	$9,712,000	$11,643,000
Construction Duration - Total	Months		16	18	26	27	28	28	29	29	30	34	35	31	37	40	51
Construction Duration - Work Only	Months		16	18	26	21	22	22	23	23	24	28	29	25	31	31	39
DETAILED SUPERVISION & ADMINISTRATION COSTS ESTIMATES FOR IMPROVEMENT PROJECT																	
Supervision & Administration	Base	0.0005	$128,000	$155,000	$213,000	$231,000	$248,000	$250,000	$275,000	$270,000	$282,000	$312,000	$325,000	$297,000	$345,000	$364,000	$447,000
Project Management During Construction		0.0025	$302,000	$380,000	$451,000	$511,000	$572,000	$579,000	$680,000	$654,000	$687,000	$724,000	$763,000	$733,000	$806,000	$818,000	$931,000
Public Involvement			$13,000	$15,000	$22,000	$23,000	$23,000	$23,000	$24,000	$24,000	$25,000	$28,000	$29,000	$26,000	$31,000	$33,000	$43,000
Construction Summary Document Prep			$27,000	$30,000	$43,000	$45,000	$47,000	$47,000	$48,000	$48,000	$50,000	$57,000	$58,000	$52,000	$62,000	$67,000	$85,000
Planning During Construction		0.0015	$193,000	$245,000	$308,000	$347,000	$386,000	$390,000	$453,000	$438,000	$460,000	$493,000	$519,000	$490,000	$550,000	$565,000	$661,000
Pre-Dredge Hydrographic Surveys	Harbor		$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
Progress Hydrographic Surveys	Harbor		$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
After Dredge Hydrographic Surveys	Harbor	& MBDS	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
Contracting Support			$32,000	$36,000	$52,000	$54,000	$56,000	$56,000	$58,000	$58,000	$60,000	$68,000	$70,000	$62,000	$74,000	$80,000	$102,000
Contract Administration			$48,000	$54,000	$78,000	$63,000	$66,000	$66,000	$69,000	$69,000	$72,000	$84,000	$87,000	$75,000	$93,000	$93,000	$117,000
Supervision and Inspection			$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000
2 Inspectors			$992,000	$1,116,000	$1,612,000	$1,674,000	$1,736,000	$1,736,000	$1,798,000	$1,798,000	$1,860,000	$2,108,000	$2,170,000	$1,922,000	$2,294,000	$2,480,000	$3,162,000
Construction Management			$243,000	$273,000	$394,000	$410,000	$425,000	$425,000	$440,000	$440,000	$455,000	$516,000	$531,000	$470,000	$561,000	$607,000	$774,000
Travel and Miscellaneous			$16,000	$18,000	$26,000	$21,000	$22,000	$22,000	$23,000	$23,000	$24,000	$28,000	$29,000	$25,000	$31,000	$31,000	$39,000
Silent Inspector System (Corps)			$160,000	$180,000	$260,000	$210,000	$220,000	$220,000	$230,000	$230,000	$240,000	$280,000	$290,000	$250,000	$310,000	$310,000	$390,000
Diving Inspection - Blasting			$243,000	$273,000	$394,000	$319,000	$334,000	$334,000	$349,000	$349,000	$364,000	$425,000	$440,000	$379,000	$470,000	$470,000	$592,000
Rock Site - Beneficial Use																	
After-Dredge Hydrographic Surveys	Rock Site		$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000
Industrial Waste Site - Beneficial Use																	
After-Dredge Hydrographic Surveys	IWS		$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000	$72,000
Sub-Total Construction Management Costs			$2,957,000	$3,335,000	$4,413,000	$4,468,000	$4,695,000	$4,708,000	$5,007,000	$4,961,000	$5,139,000	$5,683,000	$5,871,000	$5,341,000	$6,187,000	$6,478,000	$7,903,000
Contingency	15%		$444,000	$500,000	$662,000	$670,000	$704,000	$706,000	$751,000	$744,000	$771,000	$852,000	$881,000	$801,000	$928,000	$972,000	$1,185,000
Total Construction Management Costs			$3,401,000	$3,835,000	$5,075,000	$5,138,000	$5,399,000	$5,414,000	$5,758,000	$5,705,000	$5,910,000	$6,535,000	$6,752,000	$6,142,000	$7,115,000	$7,450,000	$9,088,000
Environmental Monitoring Costs	15.0%	0.0050	$564,000	$572,000	$604,000	$608,000	$499,000	$612,000	$624,000	$616,000	$620,000	$636,000	$641,000	$624,000	$636,000	$660,000	$705,000
Engineering During Construction	10.0%	0.0050	$467,000	$637,000	$794,000	$926,000	$1,059,000	$1,077,000	$1,298,000	$1,240,000	$1,314,000	$1,394,000	$1,481,000	$1,414,000	$1,576,000	$1,602,000	$1,850,000
Total Construction Phase			$4,432,000	$5,044,000	$6,473,000	$6,672,000	$6,957,000	$7,103,000	$7,680,000	$7,561,000	$7,844,000	$8,565,000	$8,874,000	$8,180,000	$9,327,000	$9,712,000	$11,643,000

TABLE D2-5 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
CONSTRUCTION MANAGEMENT COSTS - PLANS D, E & F - MAIN SHIP CHANNEL EXTENSION, MYSTIC RIVER, AND CHELSEA RIVER IMPROVEMENTS

CONSTRUCTION MANAGEMENT COSTS - IMPROVEMENT			MAIN SHIP CHANNEL EXTENSION TO MMT				MYSTIC RIVER				CHELSEA RIVER	
			42 Feet	43 Feet	44 Feet	45 Feet	37 Feet	38 Feet	39 Feet	40 Feet	39 Feet	40 Feet
ORIGINAL PERCENTAGE ESTIMATES FOR IMPROVEMENT PROJECT												
Construction Subtotal			$6,884,000	$10,191,000	$13,138,000	$15,481,000	$1,207,000	$1,435,000	$1,623,000	$1,894,000	$7,353,000	$9,960,000
First Cost - January 2008			$7,858,000	$11,217,000	$14,349,000	$16,730,000	$1,641,000	$1,871,000	$2,060,000	$2,337,000	$8,601,000	$11,380,000
Planning, Engineering & Design	0.0200		$313,000	$332,000	$353,000	$367,000	$168,000	$168,000	$168,000	$170,000	$384,000	$394,000
Construction Duration - Total	Months		3	3	4	4	1	1	1	1	4	5
Construction Duration - Work Only	Months		3	3	4	4	1	1	1	1	4	5
DETAILED SUPERVISION & ADMINISTRATION COSTS ESTIMATES FOR IMPROVEMENT PROJECT												
Supervision & Administration												
Project Management		0.0025	$39,000	$47,000	$55,000	$61,000	$23,000	$24,000	$24,000	$25,000	$38,000	$45,000
Public Involvement			$3,000	$3,000	$3,000	$3,000	$1,000	$1,000	$1,000	$1,000	$3,000	$4,000
Design Document Prep & Review			$5,000	$5,000	$7,000	$7,000	$2,000	$2,000	$2,000	$2,000	$7,000	$8,000
Advanced Planning		0.0015	$30,000	$35,000	$40,000	$43,000	$12,000	$12,000	$12,000	$13,000	$21,000	$25,000
Pre-Dredge Hydrographic Surveys	Harbor		$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$36,000	$36,000
Progress Hydrographic Surveys			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
After Dredge Hydrographic Surveys	MBDS		$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$36,000	$36,000
Contracting Support			$6,000	$6,000	$8,000	$8,000	$2,000	$2,000	$2,000	$2,000	$8,000	$10,000
Contract Administration			$9,000	$9,000	$12,000	$12,000	$3,000	$3,000	$3,000	$3,000	$12,000	$15,000
Supervision and Inspection			$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
2 Inspectors			$186,000	$186,000	$248,000	$248,000	$62,000	$62,000	$62,000	$62,000	$248,000	$310,000
Construction Management			$46,000	$46,000	$61,000	$61,000	$15,000	$15,000	$15,000	$15,000	$61,000	$76,000
Travel and Miscellaneous			$3,000	$3,000	$4,000	$4,000	$1,000	$1,000	$1,000	$1,000	$4,000	$5,000
Silent Inspector System (Corps)			$30,000	$30,000	$40,000	$40,000	$10,000	$10,000	$10,000	$10,000	$40,000	$50,000
Diving Inspection - Blasting			$46,000	$46,000	$61,000	$61,000	$0	$0	$0	$0	$61,000	$76,000
Rock Site - Beneficial Use												
Hydrographic Surveys	Rock Site		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Industrial Waste Site - Beneficial Use												
Hydrographic Surveys	IWS		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sub-Total S&A Costs			$447,000	$460,000	$583,000	$592,000	$175,000	$176,000	$176,000	$178,000	$595,000	$716,000
Contingency	15%		$67,000	$69,000	$87,000	$89,000	$26,000	$26,000	$26,000	$27,000	$89,000	$107,000
Total Construction Management Costs			$514,000	$529,000	$670,000	$681,000	$201,000	$202,000	$202,000	$205,000	$684,000	$823,000
Environmental Monitoring Costs	15.0%	0.0050	$52,000	$52,000	$55,000	$55,000	$32,000	$32,000	$32,000	$32,000	$55,000	$60,000
Engineering During Construction	10.0%	0.0050	$60,000	$78,000	$94,000	$107,000	$29,000	$30,000	$31,000	$32,000	$62,000	$77,000
Total Construction Management			$626,000	$659,000	$819,000	$843,000	$262,000	$264,000	$265,000	$269,000	$801,000	$960,000

TABLE D2-6
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
AIDS TO NAVIGATION COSTS (USCG ATON)

COSTS FOR RELOCATING ATONS IN ADVANCE OF DREDGING AND BLASTING OPERATIONS AND RESETTING AIDS AFTER COMPLETION OF IMPROVEMENT WORK (JULY 2011)

PLANS	Number of Aids Requiring Movement	Cost Per Movement	Initial Relocation	Final Setting	Total ATON Cost
PLAN ABC - MAIN CHANNELS DEEPENING PLANS TO CONLEY TERMINAL					
42/44-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
43/45-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
44/46-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
45/47-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
45/49-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
46/48-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
46/50-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
47/49-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
47/50-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
47/51-Foot Channel Depth - PLAN ABC	16	$6,000	$96,000	$96,000	$192,000
47/52-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
48/50-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
48/52-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
49/51-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
50/52-Foot Channel Depth	16	$6,000	$96,000	$96,000	$192,000
PLAN D - MAIN SHIP CHANNEL DEEPENING EXTENSION TO MASSPORT MARINE TERMINAL TERMINAL					
42-Foot Channel Depth	2	$6,000	$12,000	$12,000	$24,000
43-Foot Channel Depth	2	$6,000	$12,000	$12,000	$24,000
44-Foot Channel Depth	2	$6,000	$12,000	$12,000	$24,000
45-Foot Channel Depth - PLAN D	2	$6,000	$12,000	$12,000	$24,000
PLAN E - MYSTIC RIVER CHANNEL DEEPENING TO MASSPORT MEDFORD STREET TERMINAL					
37-Foot Channel Depth	None	$6,000	$0	$0	$0
38-Foot Channel Depth	None	$6,000	$0	$0	$0
39-Foot Channel Depth	None	$6,000	$0	$0	$0
40-Foot Channel Depth - PLAN E	None	$6,000	$0	$0	$0
PLAN F - CHELSEA RIVER CHANNEL DEEPENING					
39-Foot Channel Depth	4	$6,000	$24,000	$24,000	$48,000
40-Foot Channel Depth - PLAN F	4	$6,000	$24,000	$24,000	$48,000

TABLE D2-7
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
REAL ESTATE COSTS

SOLE REAL ESTATE REQUIREMENT IS FOR TEMPORARY CONSTRUCTION OFFICE SPACE AND SMALL BOAT WHARF ACCESS AT MASSPORT-OWNED WATERFRONT LOCATION

SAME PLAN AS FOR 1998-2001 CONSTRUCTION - 22,500 SQUARE FEET FOR TRAILERS AND PARKING MONTHLY RATE OF $1.78 PER SQUARE FOOT (JULY 2011)

MAIN CHANNELS DEEPENING PLANS TO CONLEY TERMINAL - INNER CHANNEL DEPTH / ENTRANCE CHANNEL DEPTH

PLANS A-B-C	42/44 Feet	43/45 Feet	44/46 Feet	45/47 Feet	45/49 Feet	46/48 Feet	46/50 Feet	47/49 Feet	47/50 Feet	47/51 Feet	47/52 Feet	48/50 Feet	48/52 Feet	49/51 Feet	50/52 Feet
Area of Office Site - SF	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500
Annual Rate per Square Foot	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78	$1.78
Annual Rental Rate	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050	$40,050
Monthly Rental Rate	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338	$3,338
Construction Duration - Months	16	18	26	27	28	28	29	29	30	34	35	31	37	40	51
Real Estate Cost	$53,400	$60,075	$86,775	$90,113	$93,450	$93,450	$96,788	$96,788	$100,125	$113,475	$116,813	$103,463	$123,488	$133,500	$170,213
Plus Contingency - 10%	$58,740	$66,083	$95,453	$99,124	$102,795	$102,795	$106,466	$106,466	$110,138	$124,823	$128,494	$113,809	$135,836	$146,850	$187,234
Rounded	$59,000	$66,000	$95,000	$99,000	$103,000	$103,000	$106,000	$106,000	$110,000	$125,000	$128,000	$114,000	$136,000	$147,000	$187,000

PLAN D - MAIN SHIP CHANNEL DEEPENING EXTENSION TO MASSPORT MARINE TERMINAL TERMINAL

PLAN D	42 Feet	43 Feet	44 Feet	45 Feet
Construction Duration - Months	3	3	4	4
Real Estate Cost	$10,013	$10,013	$13,350	$13,350
Plus Contingency - 10%	$11,014	$11,014	$14,685	$14,685
Rounded	$11,000	$11,000	$15,000	$15,000

PLAN E - MYSTIC RIVER CHANNEL DEEPENING TO MASSPORT MEDFORD STREET TERMINAL

PLAN E	37 Feet	38 Feet	39 Feet	40 Feet
Construction Duration - Months	1	1	1	1
Real Estate Cost	$3,338	$3,338	$3,338	$3,338
Plus Contingency - 10%	$3,671	$3,671	$3,671	$3,671
Rounded	$4,000	$4,000	$4,000	$4,000

PLAN F - CHELSEA RIVER CHANNEL DEEPENING

PLAN F	39 Feet	40 Feet
Construction Duration - Months	4	5
Real Estate Cost	$13,350	$16,688
Plus Contingency - 10%	$14,685	$18,356
Rounded	$15,000	$18,000

TABLE D2-8
COST ESCALATION FOR JANUARY 2008 FEASIBILITY REPORT PRICE LEVELS
TO PERIOD OF DESIGN AND CONSTRUCTION
CWBS-12 NAVIGATION PORTS AND HARBORS

Date of Index Factors: 31 March 2012

Design Phase Cost Escalation

Design Phase Escalation	July 2011 #	Begin June 2013 - End April 2014 Mid-Point = Dec 2013 #	Escalation Factor
	813.49	846.66	1.04077

Project First Cost Escalation - July/August 2011 Price Levels to the Program Year

Program Year 2013 Escalation	July 2011	813.49	FY2013	Sept 2013	843.52	Factor	1.03692	
PED Escalation Factors	Initial Estimate	1.0055	Program Year	1.0435	PED Fully Funded Mid-Point	1.0523		

Construction Phase Cost Escalation - Program Year Price Levels to the Period of Construction

Plan & Increment	Construct Duration (Months)	Initiate Construct	End Construct	Mid Point Date	Mid Point #	July 2013 #	Escalation Factor	CM Escalation Factor
Main Channels 42 Feet (44 Entrance)	16	Apr 2014	July 2015	Dec 2014	861.25	843.52	1.02102	1.093
Main Channels 43 Feet (45 Entrance)	18	Apr 2014	Sept 2015	Jan 2015	865.15	843.52	1.02564	1.103
Main Channels 44 Feet (46 Entrance)	26	Apr 2014	May 2016	May 2015	869.05	843.52	1.03027	1.114
Main Channels 45 Feet (47 Entrance)	27	Apr 2014	June 2016	May 2015	869.05	843.52	1.03027	1.114
Main Channels 45 Feet (49 Entrance)	28	Apr 2014	July 2016	June 2015	869.05	843.52	1.03027	1.114
Main Channels 46 Feet (48 Entrance)	28	Apr 2014	July 2016	June 2015	869.05	843.52	1.03027	1.114
Main Channels 46 Feet (50 Entrance)	29	Apr 2014	Aug 2016	June 2015	869.05	843.52	1.03027	1.114
Main Channels 47 Feet (49 Entrance)	29	Apr 2014	Aug 2016	June 2015	869.05	843.52	1.03027	1.114
Main Channels 47 Feet (50 Entrance)	30	Apr 2014	Sept 2016	June 2015	869.05	843.52	1.03027	1.114
Main Channels 47 Feet (51 Entrance)	34	Apr 2014	Jan 2017	Aug 2015	872.95	843.52	1.03489	1.125
Main Channels 47 Feet (52 Entrance)	35	Apr 2014	Feb 2017	Oct 2015	876.75	843.52	1.03939	1.135
Main Channels 48 Feet (50 Entrance)	31	Apr 2014	Oct 2016	July 2015	872.95	843.52	1.03489	1.125
Main Channels 48 Feet (52 Entrance)	37	Apr 2014	Apr 2017	Oct 2015	876.75	843.52	1.03939	1.135
Main Channels 49 Feet (51 Entrance)	40	Apr 2014	July 2017	Dec 2015	876.75	843.52	1.03939	1.135
Main Channels 50 Feet (52 Entrance)	51	Apr 2014	June 2018	May 2016	884.69	843.52	1.04881	1.157
Main Channels 47 Feet (50 Entrance)	30	Apr 2014	Sept 2016	July 2015	872.95	843.52	1.03489	1.125
MSC Extension to MMT - 42 Feet	3	Sept 2016	Nov 2016	Oct 2016	892.53	843.52	1.05810	1.178
MSC Extension to MMT - 43 Feet	3	Sept 2016	Nov 2016	Oct 2016	892.53	843.52	1.05810	1.178
MSC Extension to MMT - 44 Feet	4	Sept 2016	Dec 2016	Nov 2016	892.53	843.52	1.05810	1.178
MSC Extension to MMT - 45 Feet	4	Sept 2016	Dec 2016	Nov 2016	892.53	843.52	1.05810	1.178
Mystic River - MST - 37, 38, 39, 40 Ft	1	Sept 2014	Sept 2014	Sept 2014	856.88	843.52	1.01584	1.082
Chelsea River Channel - 39 Feet	4	Apr 2014	Aug 2014	June 2014	853.47	843.52	1.01180	1.072
Chelsea River Channel - 40 Feet	5	Apr 2014	Sept 2014	July 2014	856.88	843.52	1.01584	1.082

TABLE D2-9
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ANNUAL MAINTENANCE DREDGING INCREASE CALCULATIONS FOR ALTERANTIVE PLANS AND DEPTHS

EXISTING MAINTENANCE FREQUENCY AND VOLUMES BY PROJECT SEGMENT

Channel Segment	Ocean Disposal Suitability	Last Prior Maintenance Actions	Years of Last Maintenance Actions	O&M Interval (Years)	CY Dredged in Last Operation	Annual Cubic Yards
BSN Entrance Channel	Suitable	1969	2005	36	72,192	2,005
President Roads Anchorage	Suitable	1982	2004	22	1,166,447	53,020
Lower Main Ship Channel	Suitable	1967	2005	38	177,132	4,661
Lower Main Ship Channel	Unsuitable	1967	2008	41	672,804	16,410
Reserved Channel	Both	1960	1999	39	214,000	5,487
Mystic River (13% of Area)	Both	1982	1998	16	270,000	2,194
Chelsea River	Both	1983	1999	16	218,000	13,625
TOTAL ALL AREAS				MSC Total	849,936	21,071

MAIN CHANNELS IMPROVEMENT TO CONLEY TERMINAL - INNER CHANNEL DEPTH / ENTRANCE CHANNEL DEPTH

Improvement Dredge Depth - MSC	Annual CY	42 Feet 44 Feet	43 Feet 45 Feet	44 Feet 46 Feet	45 Feet 47 Feet	45 Feet 49 Feet	46 Feet 48 Feet	46 Feet 50 Feet	47 Feet 49 Feet	47 Feet 50 Feet	47 Feet 51 Feet	47 Feet 52 Feet	48 Feet 50 Feet	48 Feet 52 Feet	49 Feet 51 Feet	50 Feet 52 Feet
Percent Increase over Current O&M		10	12	14	16	17	18	19	20	21	22	23	22	23	24	26
Annnual Cubic Yards	81,584	8,158	9,790	11,422	13,053	13,869	14,685	15,501	16,317	17,133	17,948	18,764	17,948	18,764	19,580	21,212
Unit Cost (Incl Cont., E&D, S&A, etc)		$27.31	$22.12	$17.97	$15.65	$14.85	$14.11	$12.97	$13.03	$12.62	$12.36	$12.57	$12.01	$12.00	$11.31	$11.42
Annual O&M Increase over Existing		$223,000	$217,000	$205,000	$204,000	$206,000	$207,000	$201,000	$213,000	$216,000	$222,000	$236,000	$216,000	$225,000	$222,000	$242,000

MAIN SHIP CHANNEL DEEPENING EXTENSION ABOVE RESEREVD CHANNEL TO MASSPORT MARINE TERMINAL

Improvement Dredge Depth - MSC	Annual CY	42 Feet	43 Feet	44 Feet	45 Feet
Percent Increase over Current O&M		10	12	14	16
Annnual Cubic Yards	5,268	527	632	737	843
Unit Cost (Incl Cont., E&D, S&A, etc)		$31.13	$24.50	$20.88	$18.15
Annual O&M Increase over Existing		$16,000	$15,000	$15,000	$15,000

MYSTIC RIVER CHANNEL DEEPENING TO MASSPORT MEDFORD STREET TERMINAL

Improvement Dredge Depth	Annual CY	37 Feet	38 Feet	39 Feet	40 Feet
Percent Increase over Current O&M		10	12	14	16
Annnual Cubic Yards	2,194	219	263	307	351
Unit Cost (Incl Cont., E&D, S&A, etc)		$53.86	$40.87	$33.29	$30.00
Annual O&M Increase over Existing		$12,000	$11,000	$10,000	$11,000

CHELSEA RIVER CHANNEL DEEPENING WITH WIDENED BEND AND BRIDGE APPROACHES

Improvement Dredge Depth	Annual CY	39 Feet	40 Feet
Percent Increase over Current O&M		10	12
Annnual Cubic Yards	13,625	1,363	1,635
Unit Cost (Incl Cont., E&D, S&A, etc)		$41.90	$31.32
Annual O&M Increase over Existing		$57,000	$51,000

DETAILED ESTMATES

MAIN CHANNELS IMPROVEMENT PLANS – PLAN ABC

Project Description

The Main Channels Improvement Plans consist of improvements to deepen access from the sea to the Conley Container Terminal in South Boston. This requires deepening the Broad Sound North Entrance Channel from Massachusetts Bay into the harbor, the Main Ship Channel from the Outer Confluence of the entrance channels through President Roads and up-harbor to the Reserved Channel, the Reserved Channel Turning Area at the confluence of that channel with the Main Ship Channel, the lower Reserved Channel up to the Conley Terminal, and the President Roads Anchorage Area. These project segments are shown in Figure D2-1.

These main channels improvements for container shipping were evaluated by one-foot increments from 42 feet to 50 feet (MLLW) to enable economic optimization of the proposed improvements. The main channels improvement plans underwent hydrodynamic and ship simulation analyses that further modified the proposed channel layout and widths.

All plans include the following features. The Broad Sound North Entrance Channel would be deepened only within its existing 40-foot deep lane, with a width of 1100 feet in its entrance reach from the Bay seaward of Finns Ledge and 900 feet thereafter up-harbor to the upstream end of the Inner Confluence opposite Deer Island Light. The channel bend opposite Finns Ledge would be widened to ease the turn for larger vessels.

In the 2008 draft feasibility report, design guidance for additional depth in entrance channels to account for increased vessel motion from winds, waves and other factors followed PIANC guidance as discussed in Appendix D-1. In 2012 more site and vessel specific Corps guidance was used to re-analyze the entrance channel depth requirements. Based on the new analysis, the entrance channel would be deepened to a depth of four feet greater that the remaining project features inside the harbor to allow for greater sea states and vessel motion in the less protected entrance.

The Main Ship Channel from the Outer Confluence through President Roads would retain its existing 1200-foot width to enable, as at present, the turning of vessels into and out of the President Roads Anchorage and to allow for transition between the confluence of the entrance channels and the bends of the Main Ship Channel up-harbor from the Roads. Above the Roads, the existing channel layout of two parallel 600-foot wide lanes at 40 feet (south) and 35 feet (north) would be modified by incorporating various widths of the shallower 35-foot lane into the deepened and widened southerly lane. The new deepened channel lane would have a width of 900 feet between the roads and Castle Island, widened further in the two bends to 1050 feet, and a width of 800 feet above Castle Island to the Reserved Channel Turning Area.

The Reserved Channel Turning Area was expanded from its current 1200-foot diameter to 1500 feet, with eased transitions between the basin and the adjacent channels. As recommended by the Ship Simulation Study, the transition in the northwest angle between the channels east of the former Army Base Pier was expanded further and the basin limit widened a further 100 feet to the northeast, to compensate for the effects of currents on vessels turning in the basin.

The Reserved Channel's existing width to 400 feet along the Conley Terminal was retained. Only the existing 40-foot reach of the channel, comprising about two-thirds of its total length, is proposed for deepening, as this is the extent of the Conley Terminal's with-project length. The upper reach of the channel will remain at 35 feet. Details of the improvements to the Reserved Channel and its Turning Area are shown in Figure D2-2.

All material would be removed by bucket dredge and transported by scows. Disposal of all dredged material would be at the Massachusetts Bay Disposal Site (MBDS), located seaward of the territorial sea about 20 miles seaward of the harbor.

The following tables provide detail estimates for the main channels improvements.

Table D2-10 shows the quantity estimates by project segment by one-foot increments.

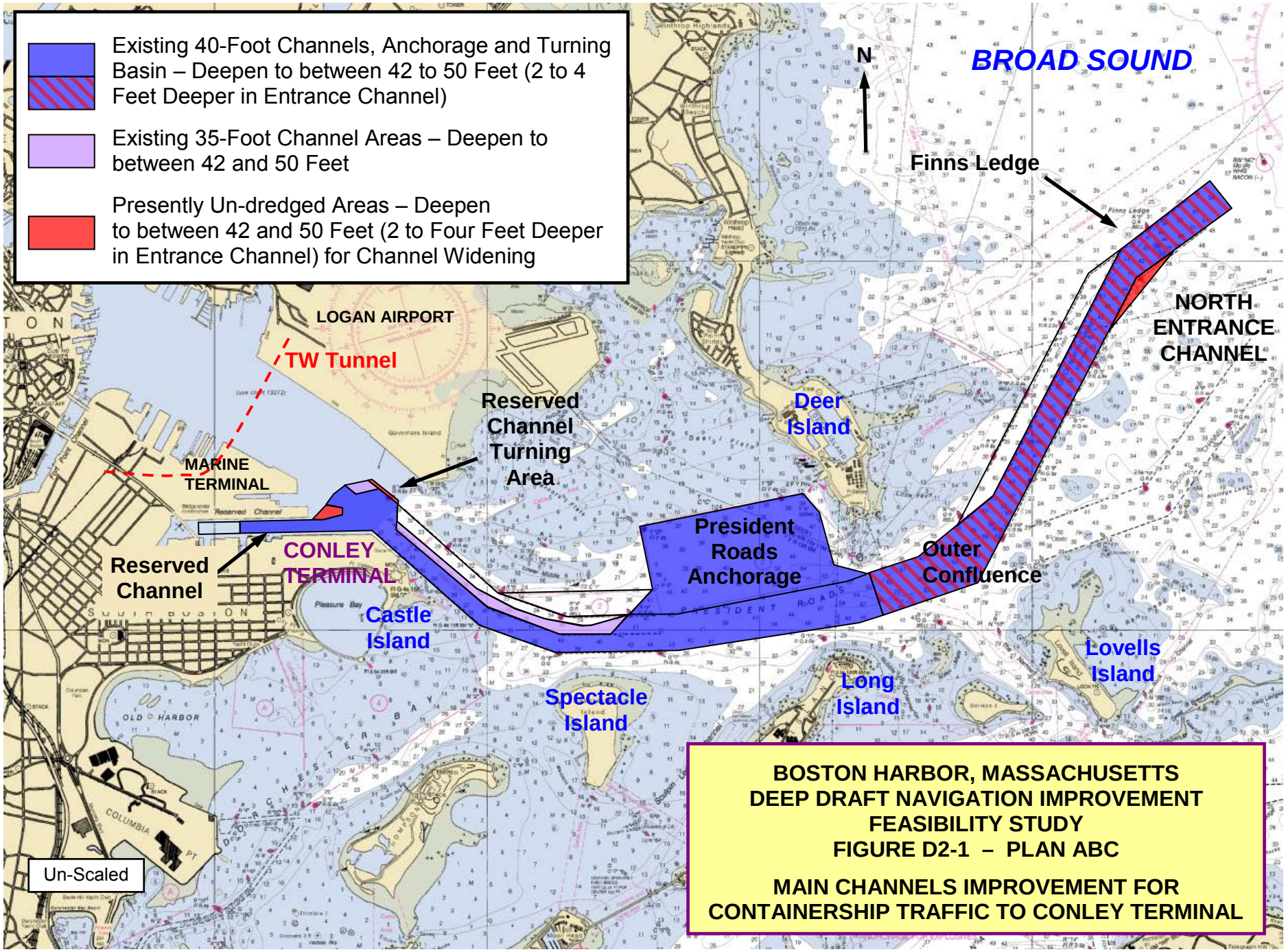
Table D2-11 shows the project footprint area estimates by segment in one-foot increments for ordinary material dredging and rock removal.

Table D2-12 shows the cost estimates for the 9 incremental depths for the main channels improvement plan (Plans ABC).

Table D2-13 shows the costs for the deepening of Massport's berths at the Conley Terminal; the Non-Federal Local Service Facilities (LSF).

Table D2-14 shows the annual costs of the 9 incremental depths.

Following these tables are the summary sheets from the contingency risk analyses for the recommended plan for the main channels improvements; the 47-foot project plan with a 51-foot entrance channel, as divided in its four major segments.



BOSTON HARBOR, MASSACHUSETTS
DEEP DRAFT NAVIGATION IMPROVEMENT
FEASIBILITY STUDY
FIGURE D2-1 – PLAN ABC

MAIN CHANNELS IMPROVEMENT FOR
CONTAINERSHIP TRAFFIC TO CONLEY TERMINAL

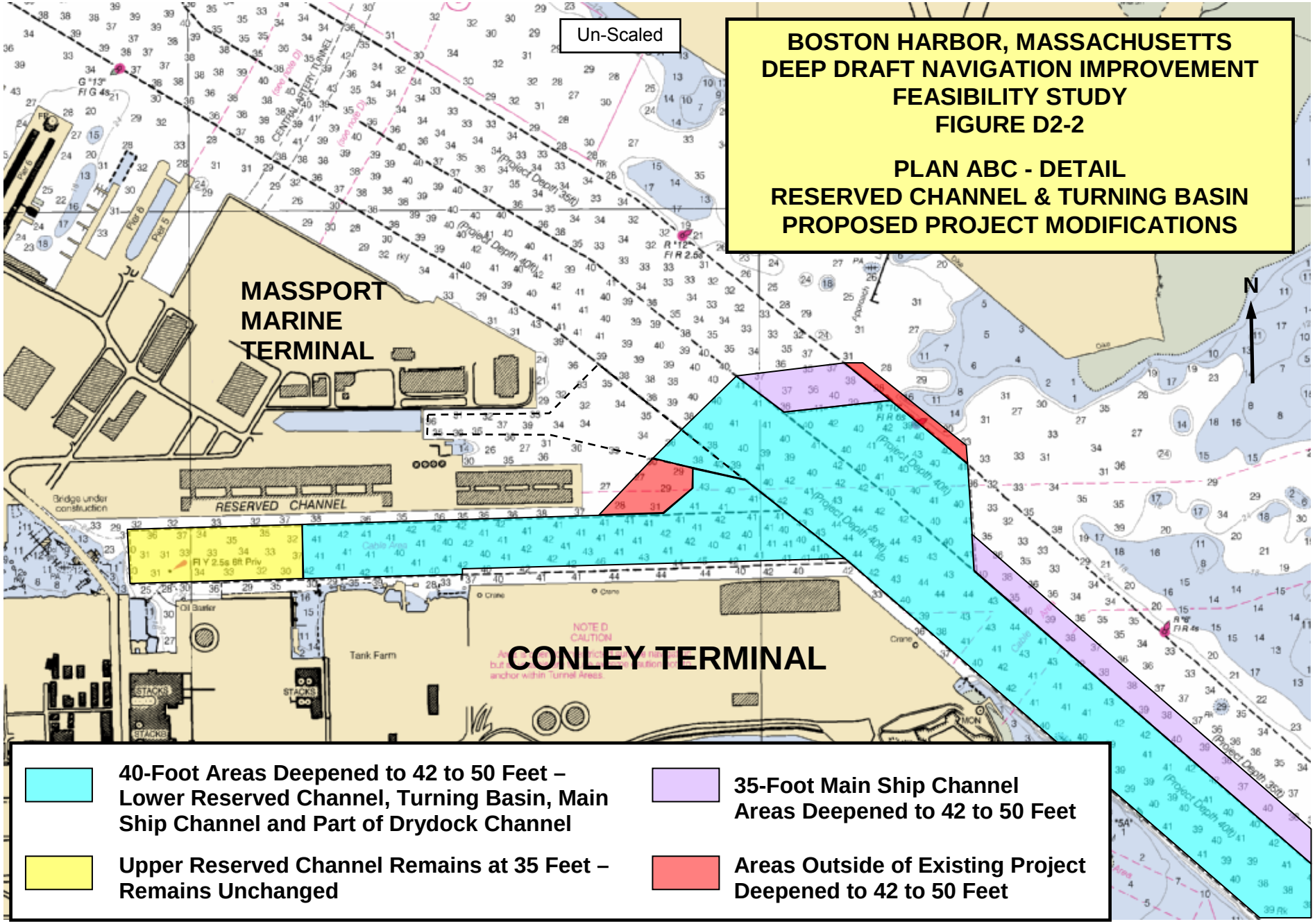

Un-Scaled
BOSTON HARBOR, MASSACHUSETTS
DEEP DRAFT NAVIGATION IMPROVEMENT
FEASIBILITY STUDY
FIGURE D2-2
PLAN ABC - DETAIL
RESERVED CHANNEL & TURNING BASIN
PROPOSED PROJECT MODIFICATIONS
N
MASSPORT
MARINE
TERMINAL
RESERVED CHANNEL
CONLEY TERMINAL
Tank Farm
Bridge under construction
Pier 6
Pier 5
(Project Depth 35ft)
(Project Depth 40ft)
40-Foot Areas Deepened to 42 to 50 Feet – Lower Reserved Channel, Turning Basin, Main Ship Channel and Part of Drydock Channel
35-Foot Main Ship Channel Areas Deepened to 42 to 50 Feet
Upper Reserved Channel Remains at 35 Feet – Remains Unchanged
Areas Outside of Existing Project Deepened to 42 to 50 Feet

TABLE D2-10
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 42-FOOT PROJECT DEPTH (44 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -42 Feet	2-Foot Overdepth to -44 Feet	Total CY Ordinary Material	Cut to Depth -42/-44 Feet	2-Foot Additional Required	2-Foot Overdepth to -46/-48 Feet	Total Rock CY	All Required Material	All Overdepth	Total All Material
BSNEC (44 Ft)	269,500	523,600	793,100	7,000	14,700	48,700	70,400	291,200	572,300	863,500
MSC-PR Reach	0	50,800	50,800	0	0	0	0	0	50,800	50,800
MSC-PR to RC	210,500	401,100	611,600	6,300	7,200	9,100	22,600	224,000	410,200	634,200
Expanded RCTA	107,200	134,800	242,000	200	400	600	1,200	107,800	135,400	243,200
Reserved Channel	8,700	90,400	99,100	0	10	250	260	8,700	90,700	99,360
Pres. Roads Anch	0	479,100	479,100	0	5,000	9,300	14,300	5,000	488,400	493,400
TOTAL	595,900	1,679,800	2,275,700	13,500	27,310	67,950	108,760	636,710	1,747,750	2,384,460

MAIN CHANNELS DEEPENING PLAN - 43-FOOT PROJECT DEPTH (45 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -43 Feet	2-Foot Overdepth to -45 Feet	Total CY Ordinary Material	Cut to Depth -43/-45 Feet	2-Foot Additional Required	2-Foot Overdepth to -47/-49 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (45 Ft)	503,000	606,300	1,109,300	11,400	41,400	102,000	154,800	555,800	708,300	1,264,100
MSC-PR Reach	13,500	105,200	118,700	0	0	0	0	13,500	105,200	118,700
MSC-PR to RC	388,300	472,800	861,100	9,300	9,300	11,800	30,400	406,900	484,600	891,500
Expanded RCTA	164,000	166,800	330,800	300	700	1,800	2,800	165,000	168,600	333,600
Reserved Channel	44,300	119,900	164,200	0	200	1,800	2,000	44,500	121,700	166,200
Pres. Roads Anch	136,800	817,600	954,400	1,800	8,900	12,700	23,400	147,500	830,300	977,800
TOTAL	1,249,900	2,288,600	3,538,500	22,800	60,500	130,100	213,400	1,333,200	2,418,700	3,751,900

TABLE D2-10 (CONTINUED)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 44-FOOT PROJECT DEPTH (46 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -44 Feet	2-Foot Overdepth to -46 Feet	Total CY Ordinary Material	Cut to Depth -44/-46 Feet	2-Foot Additional Required	2-Foot Overdepth to -48/-50 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (46 Ft)	793,100	645,900	1,439,000	21,700	86,800	134,000	242,500	901,600	779,900	1,681,500
MSC-PR Reach	50,800	168,200	219,000	0	0	0	0	50,800	168,200	219,000
MSC-PR to RC	611,700	514,800	1,126,500	13,500	11,300	13,900	38,700	636,500	528,700	1,165,200
Expanded RCTA	242,000	185,400	427,400	600	1,500	4,700	6,800	244,100	190,100	434,200
Reserved Channel	99,200	132,900	232,100	0	1,700	5,100	6,800	100,900	138,000	238,900
Pres. Roads Anch	479,100	1,001,400	1,480,500	5,000	12,200	15,400	32,600	496,300	1,016,800	1,513,100
TOTAL	2,275,900	2,648,600	4,924,500	40,800	113,500	173,100	327,400	2,430,200	2,821,700	5,251,900

MAIN CHANNELS DEEPENING PLAN - 45-FOOT PROJECT DEPTH (47 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -45 Feet or -47 Feet	2-Foot Overdepth to -47 Feet or -49 Feet	Total CY Ordinary Material	Cut to Depth -45/-47 Feet	2-Foot Additional Required	2-Foot Overdepth to -49/-51 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (47 ft)	1,109,400	673,200	1,782,600	52,800	122,800	152,100	327,700	1,285,000	825,300	2,110,300
MSC-PR Reach	118,700	232,700	351,400	0	0	0	0	118,700	232,700	351,400
MSC-PR to RC	861,000	541,500	1,402,500	18,700	13,400	17,000	49,100	893,100	558,500	1,451,600
Expanded RCTA	330,800	198,000	528,800	1,000	4,100	12,400	17,500	335,900	210,400	546,300
Reserved Channel	164,200	136,200	300,400	200	4,500	8,900	13,600	168,900	145,100	314,000
Pres. Roads Anch	954,400	1,073,400	2,027,800	10,700	13,800	14,300	38,800	978,900	1,087,700	2,066,600
TOTAL	3,538,500	2,855,000	6,393,500	83,400	158,600	204,700	446,700	3,780,500	3,059,700	6,840,200

TABLE D2-10 (CONTINUED)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 46-FOOT PROJECT DEPTH (48 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -46 Feet	2-Foot Overdepth to -48 Feet	Total CY Ordinary Material	Cut to Depth -46/-48 Feet	2-Foot Additional Required	2-Foot Overdepth to -50/-52 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (48 Ft)	1,439,000	690,800	2,129,800	108,500	145,600	174,500	428,600	1,693,100	865,300	2,558,400
MSC-PR Reach	219,000	296,400	515,400	0	0	10	10	219,000	296,400	515,400
MSC-PR to RC	1,126,500	562,200	1,688,700	24,800	16,300	20,800	61,900	1,167,600	583,000	1,750,600
Expanded RCTA	427,400	199,800	627,200	2,100	10,800	21,200	34,100	440,300	221,000	661,300
Reserved Channel	232,000	136,400	368,400	1,700	7,800	14,400	23,900	241,500	150,800	392,300
Pres. Roads Anch	1,480,600	1,107,300	2,587,900	17,200	15,400	15,900	48,500	1,513,200	1,123,200	2,636,400
TOTAL	4,924,500	2,992,900	7,917,400	154,300	195,900	246,800	597,000	5,274,700	3,239,700	8,514,400

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (49 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -47 Feet	2-Foot Overdepth to -49 Feet	Total CY Ordinary Material	Cut to Depth -47/-49 Feet	2-Foot Additional Required	2-Foot Overdepth to -51/-53 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (49 Ft)	1,782,600	700,200	2,482,800	175,600	167,400	192,400	535,400	2,125,600	892,600	3,018,200
MSC-PR Reach	351,500	361,300	712,800	0	10	40	50	351,500	361,300	712,900
MSC-PR to RC	1,402,400	574,900	1,977,300	32,100	20,100	25,500	77,700	1,454,600	600,400	2,055,000
Expanded RCTA	528,800	193,800	722,600	5,100	19,200	26,300	50,600	553,100	220,100	773,200
Reserved Channel	300,500	133,100	433,600	4,600	13,500	24,000	42,100	318,600	157,100	475,700
Pres. Roads Anch	2,027,800	1,128,000	3,155,800	24,500	16,900	17,400	58,800	2,069,200	1,145,400	3,214,600
TOTAL	6,393,600	3,091,300	9,484,900	241,900	237,100	285,600	764,700	6,872,600	3,376,900	10,249,600

TABLE D2-10 (CONTINUED)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 48-FOOT PROJECT DEPTH (50 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -48 Feet	2-Foot Overdepth to -50 Feet	Total CY Ordinary Material	Cut to Depth -48/-50 Feet	2-Foot Additional Required	2-Foot Overdepth to -52/-54 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (50 Ft)	2,129,800	715,000	2,844,800	254,100	186,300	207,400	647,800	2,570,200	922,400	3,492,600
MSC-PR Reach	515,400	429,200	944,600	0	20	110	130	515,400	429,300	944,700
MSC-PR to RC	1,688,600	576,900	2,265,500	41,100	24,900	32,200	98,200	1,754,600	609,100	2,363,700
Expanded RCTA	627,200	189,100	816,300	12,900	25,200	30,800	68,900	665,300	219,900	885,200
Reserved Channel	368,400	125,800	494,200	9,500	22,700	36,300	68,500	400,600	162,100	562,700
Pres. Roads Anch	2,588,000	1,143,000	3,731,000	32,500	18,400	18,900	69,800	2,638,900	1,161,900	3,800,800
TOTAL	7,917,400	3,179,000	11,096,400	350,100	277,500	325,700	953,300	8,545,000	3,504,700	12,049,700

MAIN CHANNELS DEEPENING PLAN - 49-FOOT PROJECT DEPTH (51 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -49 Feet	2-Foot Overdepth to -51 Feet	Total CY Ordinary Material	Cut to Depth -49/-51 Feet	2-Foot Additional Required	2-Foot Overdepth to -53/-55 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (51 Ft)	2,482,800	736,000	3,218,800	343,000	201,900	218,800	763,700	3,027,700	954,800	3,982,500
MSC-PR Reach	712,800	488,100	1,200,900	10	60	200	270	712,900	488,300	1,201,200
MSC-PR to RC	1,977,300	575,100	2,552,400	52,200	31,000	41,300	124,500	2,060,500	616,400	2,676,900
Expanded RCTA	722,600	185,500	908,100	24,300	30,100	35,800	90,200	777,000	221,300	998,300
Reserved Channel	433,600	116,500	550,100	18,100	33,700	45,900	97,700	485,400	162,400	647,800
Pres. Roads Anch	3,155,800	1,157,200	4,313,000	41,400	19,900	20,400	81,700	3,217,100	1,177,600	4,394,700
TOTAL	9,484,900	3,258,400	12,743,300	479,000	316,700	362,400	1,158,100	10,280,600	3,620,800	13,901,400

TABLE D2-10 (CONTINUED)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 OR 3 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 50-FOOT PROJECT DEPTH (52 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -50 Feet or -52 Feet	2-Foot Overdepth to -52 Feet or -54 Feet	Total CY Ordinary Material	Cut to Depth -50/-52 Feet	2-Foot Additional Required	2-Foot Overdepth to -54/-56 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (52 Feet)	2,844,700	763,100	3,607,800	440,500	214,400	228,200	883,100	3,499,600	991,300	4,490,900
MSC-PR Reach	944,600	532,900	1,477,500	20	150	320	490	944,800	533,200	1,478,000
MSC-PR to RC	2,265,600	571,300	2,836,900	66,000	39,000	51,400	156,400	2,370,600	622,700	2,993,300
Expanded RCTA	816,200	181,400	997,600	38,200	35,400	42,600	116,200	889,800	224,000	1,113,800
Reserved Channel	494,200	108,300	602,500	32,200	43,500	53,100	128,800	569,900	161,400	731,300
Pres. Roads Anch	3,730,900	1,173,000	4,903,900	51,000	21,400	23,500	95,900	3,803,300	1,196,500	4,999,800
TOTAL	11,096,200	3,330,000	14,426,200	627,900	353,900	399,100	1,380,900	12,078,000	3,729,100	15,807,100

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (50 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -47 Feet or -50 Feet	2-Foot Overdepth to -49 Feet or -52 Feet	Total CY Ordinary Material	Cut to Depth -47/-50 Feet	2-Foot Additional Required	2-Foot Overdepth to -51/-54 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (50 Feet)	2,129,800	715,000	2,844,800	254,100	186,300	207,400	647,800	2,570,200	922,400	3,492,600
MSC-PR Reach	351,500	361,300	712,800	0	10	40	50	351,500	361,300	712,900
MSC-PR to RC	1,402,400	574,900	1,977,300	32,100	20,100	25,500	77,700	1,454,600	600,400	2,055,000
Expanded RCTA	528,800	193,800	722,600	5,100	19,200	26,300	50,600	553,100	220,100	773,200
Reserved Channel	300,500	133,100	433,600	4,600	13,500	24,000	42,100	318,600	157,100	475,700
Pres. Roads Anch	2,027,800	1,128,000	3,155,800	24,500	16,900	17,400	58,800	2,069,200	1,145,400	3,214,600
TOTAL	6,740,800	3,106,100	9,846,900	320,400	256,000	300,600	877,100	7,317,200	3,406,700	10,724,000

TABLE D2-10 (CONTINUED)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 4 OR 5 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (51 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -47 Feet or -51 Feet	2-Foot Overdepth to -49 Feet or -53 Feet	Total CY Ordinary Material	Cut to Depth -47/-51 Feet	2-Foot Additional Required	2-Foot Overdepth to -51/-55 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (51 Feet)	2,482,800	736,000	3,218,800	343,000	201,900	218,800	763,700	3,027,700	954,800	3,982,500
MSC-PR Reach	351,500	361,300	712,800	0	10	40	50	351,500	361,300	712,900
MSC-PR to RC	1,402,400	574,900	1,977,300	32,100	20,100	25,500	77,700	1,454,600	600,400	2,055,000
Expanded RCTA	528,800	193,800	722,600	5,100	19,200	26,300	50,600	553,100	220,100	773,200
Reserved Channel	300,500	133,100	433,600	4,600	13,500	24,000	42,100	318,600	157,100	475,700
Pres. Roads Anch	2,027,800	1,128,000	3,155,800	24,500	16,900	17,400	58,800	2,069,200	1,145,400	3,214,600
TOTAL	7,093,800	3,127,100	10,220,900	409,300	271,600	312,000	993,000	7,774,700	3,439,100	11,213,900

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (52 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -47 Feet or -52 Feet	2-Foot Overdepth to -49 Feet or -54 Feet	Total CY Ordinary Material	Cut to Depth -47/-52 Feet	2-Foot Additional Required	2-Foot Overdepth to -51/-56 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (52 Feet)	2,844,700	763,100	3,607,800	440,500	214,400	228,200	883,100	3,499,600	991,300	4,490,900
MSC-PR Reach	351,500	361,300	712,800	10	60	200	270	351,600	361,500	713,100
MSC-PR to RC	1,402,400	574,900	1,977,300	52,200	31,000	41,300	124,500	1,485,600	616,200	2,101,800
Expanded RCTA	528,800	193,800	722,600	24,300	30,100	35,800	90,200	583,200	229,600	812,800
Reserved Channel	300,500	133,100	433,600	18,100	33,700	45,900	97,700	352,300	179,000	531,300
Pres. Roads Anch	2,027,800	1,128,000	3,155,800	41,400	19,900	20,400	81,700	2,089,100	1,148,400	3,237,500
TOTAL	7,455,700	3,154,200	10,609,900	576,510	329,200	371,800	1,277,500	8,361,410	3,526,000	11,887,400

TABLE D2-10 (CONTINUED)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 4 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 45-FOOT PROJECT DEPTH (49 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -45 Feet or -49 Feet	2-Foot Overdepth to -47 Feet or -51 Feet	Total CY Ordinary Material	Cut to Depth -45/-49 Feet	2-Foot Additional Required	2-Foot Overdepth to -49/-53 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (49 Feet)	1,782,600	700,200	2,482,800	175,600	167,400	192,400	535,400	2,125,600	892,600	3,018,200
MSC-PR Reach	118,700	232,700	351,400	0	0	0	0	118,700	232,700	351,400
MSC-PR to RC	861,000	541,500	1,402,500	18,700	13,400	17,000	49,100	893,100	558,500	1,451,600
Expanded RCTA	330,800	198,000	528,800	1,000	4,100	12,400	17,500	335,900	210,400	546,300
Reserved Channel	164,200	136,200	300,400	200	4,500	8,900	13,600	168,900	145,100	314,000
Pres. Roads Anch	954,400	1,073,400	2,027,800	10,700	13,800	14,300	38,800	978,900	1,087,700	2,066,600
TOTAL	4,211,700	2,882,000	7,093,700	206,200	203,200	245,000	654,400	4,621,100	3,127,000	7,748,100

MAIN CHANNELS DEEPENING PLAN - 46-FOOT PROJECT DEPTH (50 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -46 Feet or -50 Feet	2-Foot Overdepth to -48 Feet or -52 Feet	Total CY Ordinary Material	Cut to Depth -46/-50 Feet	2-Foot Additional Required	2-Foot Overdepth to -50/-54 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (50 Feet)	2,129,800	715,000	2,844,800	254,100	186,300	207,400	647,800	2,570,200	922,400	3,492,600
MSC-PR Reach	219,000	296,400	515,400	0	0	10	10	219,000	296,400	515,400
MSC-PR to RC	1,126,500	562,200	1,688,700	24,800	16,300	20,800	61,900	1,167,600	583,000	1,750,600
Expanded RCTA	427,400	199,800	627,200	2,100	10,800	21,200	34,100	440,300	221,000	661,300
Reserved Channel	232,000	136,400	368,400	1,700	7,800	14,400	23,900	241,500	150,800	392,300
Pres. Roads Anch	1,480,600	1,107,300	2,587,900	17,200	15,400	15,900	48,500	1,513,200	1,123,200	2,636,400
TOTAL	5,615,300	3,017,100	8,632,400	299,900	236,600	279,700	816,200	6,151,800	3,296,800	9,448,600

TABLE D2-10 (CONTINUED)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 4 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

MAIN CHANNELS DEEPENING PLAN - 48-FOOT PROJECT DEPTH (52 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Depth -48 Feet or -52 Feet	2-Foot Overdepth to -50 Feet or -54 Feet	Total CY Ordinary Material	Cut to Depth -48/-52 Feet	2-Foot Additional Required	2-Foot Overdepth to -52/-56 Feet	Total Rock CY	Cut to Depth	All Overdepth	Total All Material
BSNEC (52 Ft)	2,844,700	763,100	3,607,800	440,500	214,400	228,200	883,100	3,499,600	991,300	4,490,900
MSC-PR Reach	515,400	429,200	944,600	0	20	110	130	515,400	429,300	944,700
MSC-PR to RC	1,688,600	576,900	2,265,500	41,100	24,900	32,200	98,200	1,754,600	609,100	2,363,700
Expanded RCTA	627,200	189,100	816,300	12,900	25,200	30,800	68,900	665,300	219,900	885,200
Reserved Channel	368,400	125,800	494,200	9,500	22,700	36,300	68,500	400,600	162,100	562,700
Pres. Roads Anch	2,588,000	1,143,000	3,731,000	32,500	18,400	18,900	69,800	2,638,900	1,161,900	3,800,800
TOTAL	8,632,300	3,227,100	11,859,400	536,500	305,600	346,500	1,188,600	9,474,400	3,573,600	13,048,000

TABLE D2-11
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 42-FOOT PROJECT DEPTH (44 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -42 Feet or -44 Feet	2-Foot Overdepth to -44 Feet or -46 Feet	Total SF Ordinary Material	Cut to Depth -42/-44 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -46/48 Ft	Total Rock SF			
BSNEC (44 Ft)	7,169,238	2,173,226	9,342,464	115,584	385,350	155,847	656,781			
MSC-PR Reach	483,235	1,596,341	2,079,576	0	0	0	0			
MSC-PR to RC	5,275,558	1,395,318	6,670,876	75,913	39,545	7,720	123,178			
Expanded RCTA	917,401	1,290,123	2,207,524	1,478	3,466	2,771	7,715			
Reserved Channel	1,252,829	586,983	1,839,812	0	145	3,261	3,406			
Pres. Roads Anch	3,742,900	9,172,122	12,915,022	37,261	78,592	10,346	126,199			
TOTAL	18,841,161	16,214,113	35,055,274	230,236	507,098	179,945	917,279			

MAIN CHANNELS DEEPENING PLAN - 43-FOOT PROJECT DEPTH (45 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -43 Feet	2-Foot Overdepth to -45 Feet	Total SF Ordinary Material	Cut to Depth -43/-45 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -47/49 Ft	Total Rock SF			
BSNEC (45 Ft)	8,294,797	1,964,557	10,259,354	192,737	1,087,431	96,812	1,376,980			
MSC-PR Reach	1,162,576	1,808,197	2,970,773	0	0	0	0			
MSC-PR to RC	6,190,208	818,856	7,009,064	96,195	57,865	5,158	159,218			
Expanded RCTA	1,791,866	621,102	2,412,968	2,993	15,806	4,994	23,793			
Reserved Channel	1,702,939	176,491	1,879,430	0	16,451	8,378	24,829			
Pres. Roads Anch	9,644,691	4,221,178	13,865,869	59,212	108,370	4,370	171,952			
TOTAL	28,787,077	9,610,381	38,397,458	351,137	1,285,923	119,712	1,756,772			

TABLE D2-11 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 44-FOOT PROJECT DEPTH (46 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -44 Feet or -46 Feet	2-Foot Overdepth to -46 Feet or -48 Feet	Total SF Ordinary Material	Cut to Depth -44/-46 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -48/50 Ft	Total Rock SF			
BSNEC (46 Ft)	9,342,464	1,422,017	10,764,481	500,934	1,263,295	45,260	1,809,489			
MSC-PR Reach	2,079,576	1,706,395	3,785,971	0	0	0	0			
MSC-PR to RC	6,670,876	574,697	7,245,573	115,458	64,392	7,805	187,655			
Expanded RCTA	2,207,524	1,325,026	3,532,550	4,944	38,824	19,604	63,372			
Reserved Channel	1,839,812	51,488	1,891,300	145	58,196	9,934	68,275			
Pres. Roads Anch	12,915,022	1,451,808	14,366,830	115,853	73,580	4,197	193,630			
TOTAL	35,055,274	6,531,431	41,586,705	737,334	1,498,287	86,799	2,322,420			

MAIN CHANNELS DEEPENING PLAN - 45-FOOT PROJECT DEPTH (47 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -45 Feet or -47 Feet	2-Foot Overdepth to -47 Feet or -49 Feet	Total SF Ordinary Material	Cut to Depth -45/-47 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -49/51 Ft	Total Rock SF			
BSNEC (47 ft)	10,259,354	833,926	11,093,280	1,280,168	710,359	63,213	2,053,740			
MSC-PR Reach	2,970,773	1,695,512	4,666,285	0	0	0	0			
MSC-PR to RC	7,009,064	485,573	7,494,637	154,060	64,813	10,021	228,894			
Expanded RCTA	2,412,968	1,196,722	3,609,690	18,799	122,988	26,061	167,848			
Reserved Channel	1,879,430	16,462	1,895,892	16,451	91,560	12,684	120,695			
Pres. Roads Anch	13,865,869	831,667	14,697,536	167,582	42,838	4,103	214,523			
TOTAL	38,397,458	5,059,862	43,457,320	1,637,060	1,032,558	116,082	2,785,700			

TABLE D2-11 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 46-FOOT PROJECT DEPTH (48 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -46 Feet or - 48 Feet	2-Foot Overdepth to -48 Feet or - 50 Feet	Total SF Ordinary Material	Cut to Depth -46/-48 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -50/52 Ft	Total Rock SF			
BSNEC (48 Ft)	10,764,481	650,386	11,414,867	1,764,229	542,361	49,781	2,356,371			
MSC-PR Reach	3,785,971	1,820,959	5,606,930	0	0	60	60			
MSC-PR to RC	7,245,573	259,364	7,504,937	179,850	89,128	11,629	280,607			
Expanded RCTA	3,532,550	81,040	3,613,590	43,768	228,325	14,034	286,127			
Reserved Channel	1,891,300	5,328	1,896,628	58,341	113,090	23,425	194,856			
Pres. Roads Anch	14,366,830	514,858	14,881,688	189,433	41,501	4,105	235,039			
TOTAL	41,586,705	3,331,935	44,918,640	2,235,621	1,014,405	103,034	3,353,060			

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (49 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -47 Feet or - 49 Feet	2-Foot Overdepth to -49 Feet or - 51 Feet	Total SF Ordinary Material	Cut to Depth -47/-49 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -51/53 Ft	Total Rock SF			
BSNEC (49 Ft)	11,093,280	686,805	11,780,085	1,990,527	564,967	42,421	2,597,915			
MSC-PR Reach	4,666,285	1,762,286	6,428,571	0	300	180	480			
MSC-PR to RC	7,494,637	10,300	7,504,937	218,873	108,250	16,818	343,941			
Expanded RCTA	3,609,690	3,900	3,613,590	141,787	200,478	12,306	354,571			
Reserved Channel	1,895,892	736	1,896,628	108,011	180,545	34,828	323,384			
Pres. Roads Anch	14,697,536	359,244	15,056,780	210,420	41,039	4,014	255,473			
TOTAL	43,457,320	2,823,271	46,280,591	2,669,618	1,095,579	110,566	3,875,763			

TABLE D2-11 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 48-FOOT PROJECT DEPTH (50 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -48 Feet or -50 Feet	2-Foot Overdepth to -50 Feet or -52 Feet	Total SF Ordinary Material	Cut to Depth -48/-50 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -52/54 Ft	Total Rock SF			
BSNEC (50 Ft)	11,414,867	829,332	12,244,199	2,306,590	461,010	32,267	2,799,867			
MSC-PR Reach	5,606,930	1,411,386	7,018,316	0	1,200	240	1,440			
MSC-PR to RC	7,504,937	0	7,504,937	268,978	142,234	23,563	434,775			
Expanded RCTA	3,613,590	0	3,613,590	272,093	131,702	12,332	416,127			
Reserved Channel	1,896,628	0	1,896,628	171,431	291,263	27,523	490,217			
Pres. Roads Anch	14,881,688	362,372	15,244,060	230,934	40,593	4,233	275,760			
TOTAL	44,918,640	2,603,090	47,521,730	3,250,026	1,068,002	100,159	4,418,187			

MAIN CHANNELS DEEPENING PLAN - 49-FOOT PROJECT DEPTH (51 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -49 Feet or -51 Feet	2-Foot Overdepth to -51 Feet or -53 Feet	Total SF Ordinary Material	Cut to Depth -49/-51 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -53/55 Ft	Total Rock SF			
BSNEC (51 Ft)	11,780,085	894,502	12,674,587	2,555,494	373,442	25,403	2,954,339			
MSC-PR Reach	6,428,571	1,051,970	7,480,541	300	2,000	300	2,600			
MSC-PR to RC	7,504,937	0	7,504,937	327,123	201,906	28,998	558,027			
Expanded RCTA	3,613,590	0	3,613,590	342,265	123,192	17,894	483,351			
Reserved Channel	1,896,628	0	1,896,628	288,556	311,753	19,446	619,755			
Pres. Roads Anch	15,056,780	405,847	15,462,627	251,459	41,231	4,064	296,754			
TOTAL	46,280,591	2,352,319	48,632,910	3,765,197	1,053,524	96,105	4,914,826			

TABLE D2-11 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 2 OR 3 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 50-FOOT PROJECT DEPTH (52 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -50 Feet or -52 Feet	2-Foot Overdepth to -52 Feet or -54 Feet	Total SF Ordinary Material	Cut to Depth -50/-52 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -54/56 Ft	Total Rock SF			
BSNEC (52 Feet)	12,244,199	891,352	13,135,551	2,767,600	288,352	25,242	3,081,194			
MSC-PR Reach	7,018,316	863,571	7,881,887	1,200	2,700	380	4,280			
MSC-PR to RC	7,504,937	0	7,504,937	411,212	262,809	20,281	694,302			
Expanded RCTA	3,613,590	0	3,613,590	403,795	151,131	20,696	575,622			
Reserved Channel	1,896,628	0	1,896,628	462,694	234,844	19,517	717,055			
Pres. Roads Anch	15,244,060	509,009	15,753,069	271,527	41,484	3,902	316,913			
TOTAL	47,521,730	2,263,932	49,785,662	4,318,028	981,320	90,019	5,389,367			

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (50 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -47 Feet or -50 Feet	2-Foot Overdepth to -49 Feet or -52 Feet	Total SF Ordinary Material	Cut to Depth -47/-50 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -51/54 Ft	Total Rock SF			
BSNEC (50 Feet)	11,414,867	829,332	12,244,199	2,306,590	461,010	32,267	2,799,867			
MSC-PR Reach	4,666,285	1,762,286	6,428,571	0	300	180	480			
MSC-PR to RC	7,494,637	10,300	7,504,937	218,873	108,250	16,818	343,941			
Expanded RCTA	3,609,690	3,900	3,613,590	141,787	200,478	12,306	354,571			
Reserved Channel	1,895,892	736	1,896,628	108,011	180,545	34,828	323,384			
Pres. Roads Anch	14,697,536	359,244	15,056,780	210,420	41,039	4,014	255,473			
TOTAL	43,778,907	2,965,798	46,744,705	2,985,681	991,622	100,412	4,077,715			

TABLE D2-11 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 4 OR 5 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (51 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -47 Feet or -51 Feet	2-Foot Overdepth to -49 Feet or -53 Feet	Total SF Ordinary Material	Cut to Depth -47/-51 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -51/55 Ft	Total Rock SF			
BSNEC (51 Feet)	11,780,085	894,502	12,674,587	2,555,494	373,442	25,403	2,954,339			
MSC-PR Reach	4,666,285	1,762,286	6,428,571	0	300	180	480			
MSC-PR to RC	7,494,637	10,300	7,504,937	218,873	108,250	16,818	343,941			
Expanded RCTA	3,609,690	3,900	3,613,590	141,787	200,478	12,306	354,571			
Reserved Channel	1,895,892	736	1,896,628	108,011	180,545	34,828	323,384			
Pres. Roads Anch	14,697,536	359,244	15,056,780	210,420	41,039	4,014	255,473			
TOTAL	44,144,125	3,030,968	47,175,093	3,234,585	904,054	93,548	4,232,187			

MAIN CHANNELS DEEPENING PLAN - 47-FOOT PROJECT DEPTH (52 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -47 Feet or -52 Feet	2-Foot Overdepth to -49 Feet or -54 Feet	Total SF Ordinary Material	Cut to Depth -47/-52 Feet	2-Foot Additional Required	20% of 1-Ft Overdepth Increment -51/56 Ft	Total Rock SF			
BSNEC (52 Feet)	12,244,199	891,352	13,135,551	2,767,600	288,352	25,242	3,081,194			
MSC-PR Reach	4,666,285	1,762,286	6,428,571	0	300	180	480			
MSC-PR to RC	7,494,637	10,300	7,504,937	218,873	108,250	16,818	343,941			
Expanded RCTA	3,609,690	3,900	3,613,590	141,787	200,478	12,306	354,571			
Reserved Channel	1,895,892	736	1,896,628	108,011	180,545	34,828	323,384			
Pres. Roads Anch	14,697,536	359,244	15,056,780	210,420	41,039	4,014	255,473			
TOTAL	44,608,239	3,027,818	47,636,057	3,446,691	818,964	93,387	4,359,042			

TABLE D2-11 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 4 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 45-FOOT PROJECT DEPTH (49 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -45 Feet or -49 Feet	2-Foot Overdepth to -47 Feet or -51 Feet	Total CY Ordinary Material	Cut to Depth -45/-49 Feet	2-Foot Additional Required	2-Foot Overdepth to -49/-53 Feet	Total Rock SF			
BSNEC (49 Feet)	11,093,280	686,805	11,780,085	1,990,527	564,967	42,421	2,597,915			
MSC-PR Reach	2,970,773	1,695,512	4,666,285	0	0	0	0			
MSC-PR to RC	7,009,064	485,573	7,494,637	154,060	64,813	10,021	228,894			
Expanded RCTA	2,412,968	1,196,722	3,609,690	18,799	122,988	26,061	167,848			
Reserved Channel	1,879,430	16,462	1,895,892	16,451	91,560	12,684	120,695			
Pres. Roads Anch	13,865,869	831,667	14,697,536	167,582	42,838	4,103	214,523			
TOTAL	39,231,384	4,912,741	44,144,125	2,347,419	887,166	95,290	3,329,875			

MAIN CHANNELS DEEPENING PLAN - 46-FOOT PROJECT DEPTH (50 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -46 Feet or -50 Feet	2-Foot Overdepth to -48 Feet or -52 Feet	Total CY Ordinary Material	Cut to Depth -46/-50 Feet	2-Foot Additional Required	2-Foot Overdepth to -50/-54 Feet	Total Rock SF			
BSNEC (50 Feet)	11,414,867	829,332	12,244,199	2,306,590	461,010	32,267	2,799,867			
MSC-PR Reach	3,785,971	1,820,959	5,606,930	0	0	60	60			
MSC-PR to RC	7,245,573	259,364	7,504,937	179,850	89,128	11,629	280,607			
Expanded RCTA	3,532,550	81,040	3,613,590	43,768	228,325	14,034	286,127			
Reserved Channel	1,891,300	5,328	1,896,628	58,341	113,090	23,425	194,856			
Pres. Roads Anch	14,366,830	514,858	14,881,688	189,433	41,501	4,105	235,039			
TOTAL	42,237,091	3,510,881	45,747,972	2,777,982	933,054	85,521	3,796,557			

TABLE D2-11 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING AND ROCK AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLANS A, B & C - MAIN CHANNEL ALTERNATIVES

PLANS A, B & C - DEEPEN THE LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE AND RESERVED CHANNEL & TURNING AREA TO UNIFORM DEPTH WITH AN ADDITIONAL 4 FEET IN THE BROAD SOUND NORTH ENTRANCE CHANNEL

ROCK OVERDEPTH AREA CALCULATED AT 20% OF THE 1-FOOT OVERDEPTH ELEVATION

MAIN CHANNELS DEEPENING PLAN - 48-FOOT PROJECT DEPTH (52 FEET IN ENTRANCE CHANNEL)
NORTH ENTANCE CHANNEL, LOWER MAIN SHIP CHANNEL, P.R. ANCHORAGE, RESERVED CHANNEL & TURNING AREA

Channel Improvement Design Depth	Ordinary Material (Total All Areas - Sq Ft)			Area of Ledge Removal (Sq Ft - Requires Added 2 Feet)						
	Cut to Depth -48 Feet or -52 Feet	2-Foot Overdepth to -50 Feet or -54 Feet	Total CY Ordinary Material	Cut to Depth -48/-52 Feet	2-Foot Additional Required	2-Foot Overdepth to -52/-56 Feet	Total Rock SF			
BSNEC (52 Ft)	12,244,199	891,352	13,135,551	2,767,600	288,352	25,242	3,081,194			
MSC-PR Reach	5,606,930	1,411,386	7,018,316	0	1,200	240	1,440			
MSC-PR to RC	7,504,937	0	7,504,937	268,978	142,234	23,563	434,775			
Expanded RCTA	3,613,590	0	3,613,590	272,093	131,702	12,332	416,127			
Reserved Channel	1,896,628	0	1,896,628	171,431	291,263	27,523	490,217			
Pres. Roads Anch	14,881,688	362,372	15,244,060	230,934	40,593	4,233	275,760			
TOTAL	45,747,972	2,665,110	48,413,082	3,711,036	895,344	93,133	4,699,513			

TABLE D2-12
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	42/44-FOOT CHANNEL PLAN			43/45-FOOT CHANNEL PLAN		
	NORTH ENTRANCE & MAIN SHIP CHANNEL ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA 42/44-FOOT PROJECT DEPTH			NORTH ENTRANCE & MAIN SHIP CHANNEL ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA 43/45-FOOT PROJECT DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$1,133,000	LS	LS	$1,139,000
Drilling & Blasting Plant	LS	LS	$2,616,000	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,088,000	LS	LS	$1,197,000
Remobilization for AQ Shutdowns	0	$4,147,000	$0	0	$4,254,000	$0
			$4,837,000			$4,952,000
Dredging and Ocean Disposal						
BSN Entrance Channel	793,100	$17.67	$14,014,000	1,109,300	$14.98	$16,617,000
Main Ship Chan Incl PRR	662,400	$19.43	$12,870,000	979,800	$17.97	$17,607,000
Res Chan & Res Turn Area	341,100	$17.84	$6,085,000	495,000	$14.39	$7,123,000
Pres Roads Anchorage	479,100	$32.80	$15,714,000	954,400	$20.91	$19,957,000
	2,275,700	$21.39	$48,683,000	3,538,500	$17.32	$61,304,000
Ledge Drilling and Blasting						
BSN Entrance Channel	70,400	$124.20	$8,744,000	154,800	$119.37	$18,478,000
Main Ship Chan Incl PRR	22,600	$105.80	$2,391,000	30,400	$102.80	$3,125,000
Res Chan & Res Turn Area	1,460	$150.68	$220,000	4,800	$169.79	$815,000
Pres Roads Anchorage	14,300	$136.85	$1,957,000	23,400	$119.23	$2,790,000
	108,760	$122.40	$13,312,000	213,400	$118.13	$25,208,000
Ledge Removal & Disposal						
BSN Entrance Channel	70,400	$17.25	$1,214,000	154,800	$17.26	$2,672,000
Main Ship Chan Incl PRR	22,600	$20.29	$459,000	30,400	$20.51	$624,000
Res Chan & Res Turn Area	1,460	$41.58	$61,000	4,800	$26.14	$125,000
Pres Roads Anchorage	14,300	$21.59	$309,000	23,400	$19.97	$467,000
	108,760	$18.78	$2,043,000	213,400	$18.22	$3,888,000
Miscellaneous Costs			$284,000			$284,000
Subtotal without Contingency			$69,159,000			$95,636,000
Construction Contingency		16.9%	$11,712,000		16.9%	$16,196,000
Subtotal - Construction			$80,871,000			$111,832,000
Planning, Engineering & Design		5.0%	$4,044,000		3.8%	$4,273,000
Supervision & Administration		5.5%	$4,432,000		4.5%	$5,044,000
Resetting of Aids to Navigation			$192,000			$192,000
Real Estate			$59,000			$66,000
Total First Cost GNF - July 2011 Prices		111%	$89,598,000		109%	$121,407,000
Program Year 2013 First Cost			$92,713,000			$125,697,000
PED Escalation	1.03779		$4,197,000	1.03779		$4,434,000
CM Escalation	1.03779		$4,599,000	1.03779		$5,235,000
Real Estate Escalation	1.03692		$61,000	1.03692		$68,000
Construction Escalation	1.03692		$83,856,000	1.03692		$115,960,000
ATON Escalation (USCG)	1.03692		$199,000	1.03692		$199,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$4,232,000	1.00843		$4,471,000
CM Escalation	1.04744		$4,817,000	1.05702		$5,533,000
Real Estate Escalation	1.02102		$62,000	1.02564		$70,000
Construction Escalation	1.02102		$85,619,000	1.02564		$118,934,000
Total Cost Escalated to Construction			$94,730,000			$129,008,000
ATON Escalation (USCG)	1.02102		$203,000	1.02564		$204,000
Construction Period (Months)		16			18	
July 2011 First Cost Plus IDC	0.0031250	1.02378	$91,729,000	0.0031250	1.02701	$124,686,000
Annual Costs at 3-3/4%						
Interest & Amortization	3-3/4%	0.04457	$4,088,000	3-3/4%	0.04457	$5,557,000
Increased Annual Maintenance			$223,000			$217,000
TOTAL			$4,311,000			$5,774,000
Annual Costs at 7%						
Interest & Amortization	7%	0.07245	$6,646,000	7%	0.07245	$9,034,000
Increased Annual Maintenance			$223,000			$217,000
TOTAL			$6,869,000			$9,251,000

TABLE D2-12 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	44/46-FOOT CHANNEL PLAN			45/47-FOOT CHANNEL PLAN		
	NORTH ENTRANCE & MAIN SHIP CHANNEL ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA 44/46-FOOT PROJECT DEPTH			NORTH ENTRANCE & MAIN SHIP CHANNEL ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA 45/47-FOOT PROJECT DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$1,245,000	LS	LS	$1,366,000
Drilling & Blasting Plant	LS	LS	$2,616,000	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,197,000	LS	LS	$1,197,000
Remobilization for AQ Shutdowns	1	$4,360,000	$4,360,000	1	$4,467,000	$4,467,000
			$9,418,000			$9,646,000
Dredging and Ocean Disposal						
BSN Entrance Channel	1,439,000	$12.97	$18,664,000	1,782,600	$11.67	$20,803,000
Main Ship Chan Incl PRR	1,345,500	$14.18	$19,079,000	1,753,900	$12.55	$22,011,000
Res Chan & Res Turn Area	659,500	$14.07	$9,279,000	829,200	$12.05	$9,992,000
Pres Roads Anchorage	1,480,500	$15.06	$22,296,000	2,027,800	$12.61	$25,571,000
	4,924,500	$14.08	$69,318,000	6,393,500	$12.26	$78,377,000
Ledge Drilling and Blasting						
BSN Entrance Channel	242,500	$105.91	$25,683,000	327,700	$94.64	$31,014,000
Main Ship Chan Incl PRR	38,700	$97.70	$3,781,000	49,100	$95.17	$4,673,000
Res Chan & Res Turn Area	13,600	$160.29	$2,180,000	31,100	$154.02	$4,790,000
Pres Roads Anchorage	32,600	$111.29	$3,628,000	38,800	$106.44	$4,130,000
	327,400	$107.73	$35,272,000	446,700	$99.86	$44,607,000
Ledge Removal & Disposal						
BSN Entrance Channel	242,500	$16.62	$4,030,000	327,700	$16.18	$5,302,000
Main Ship Chan Incl PRR	38,700	$19.74	$764,000	49,100	$19.39	$952,000
Res Chan & Res Turn Area	13,600	$23.71	$322,000	31,100	$21.15	$658,000
Pres Roads Anchorage	32,600	$19.44	$634,000	38,800	$19.35	$751,000
	327,400	$17.56	$5,750,000	446,700	$17.15	$7,663,000
Miscellaneous Costs			$284,000			$284,000
Subtotal without Contingency			$120,042,000			$140,577,000
Construction Contingency		16.9%	$20,329,000		16.9%	$23,807,000
Subtotal - Construction			$140,371,000			$164,384,000
Planning, Engineering & Design		3.2%	$4,522,000		2.9%	$4,710,000
Supervision & Administration		4.6%	$6,473,000		4.1%	$6,672,000
Resetting of Aids to Navigation			$192,000			$192,000
Real Estate			$95,000			$99,000
Total First Cost GNF - July 2011 Prices		108%	$151,653,000		107%	$176,057,000
Program Year 2013 First Cost			$157,063,000			$182,367,000
PED Escalation	1.03779		$4,693,000	1.03779		$4,888,000
CM Escalation	1.03779		$6,718,000	1.03779		$6,924,000
Real Estate Escalation	1.03692		$99,000	1.03692		$103,000
Construction Escalation	1.03692		$145,553,000	1.03692		$170,452,000
ATON Escalation (USCG)	1.03692		$199,000	1.03692		$199,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$4,733,000	1.00843		$4,929,000
CM Escalation	1.06756		$7,172,000	1.06756		$7,392,000
Real Estate Escalation	1.03027		$102,000	1.03027		$106,000
Construction Escalation	1.03027		$149,958,000	1.03027		$175,611,000
Total Cost Escalated to Construction			$161,965,000			$188,038,000
ATON Escalation (USCG)	1.03027		$205,000	1.03027		$205,000
Construction Period (Months)		26			27	
July 2011 First Cost Plus IDC	0.0031250	1.04006	$157,728,000	0.0031250	1.04170	$183,399,000
Annual Costs at 3-3/4%						
Interest & Amortization	3-3/4%	0.04457	$7,030,000	3-3/4%	0.04457	$8,174,000
Increased Annual Maintenance			$205,000			$204,000
TOTAL			$7,235,000			$8,378,000
Annual Costs at 7%						
Interest & Amortization	7%	0.07245	$11,427,000	7%	0.07245	$13,287,000
Increased Annual Maintenance			$205,000			$204,000
TOTAL			$11,632,000			$13,491,000

TABLE D2-12 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	46/48-FOOT CHANNEL PLAN			47/49-FOOT CHANNEL PLAN		
	NORTH ENTRANCE CHANNEL AT 48 FEET WITH 46-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA			NORTH ENTRANCE CHANNEL AT 49 FEET WITH 50-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$1,472,000	LS	LS	$1,580,000
Drilling & Blasting Plant	LS	LS	$2,616,000	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,204,000	LS	LS	$1,204,000
Remobilization for AQ Shutdowns	1	$4,573,000	$4,573,000	1	$4,669,000	$4,669,000
			$9,865,000			$10,069,000
Dredging and Ocean Disposal						
BSN Entrance Channel	2,129,800	$10.85	$23,108,000	2,482,800	$10.05	$24,952,000
Main Ship Chan Incl PRR	2,204,100	$11.27	$24,840,000	2,690,100	$10.76	$28,945,000
Res Chan & Res Turn Area	995,600	$10.98	$10,932,000	1,156,200	$10.06	$11,631,000
Pres Roads Anchorage	2,587,900	$11.07	$28,648,000	3,155,800	$9.92	$31,306,000
	7,917,400	$11.06	$87,528,000	9,484,900	$10.21	$96,834,000
Ledge Drilling and Blasting						
BSN Entrance Channel	428,600	$87.30	$37,417,000	535,400	$83.70	$44,813,000
Main Ship Chan Incl PRR	61,910	$93.43	$5,784,000	77,750	$92.03	$7,155,000
Res Chan & Res Turn Area	58,000	$141.10	$8,184,000	92,700	$128.47	$11,909,000
Pres Roads Anchorage	48,500	$97.71	$4,739,000	58,800	$91.00	$5,351,000
	597,010	$94.01	$56,124,000	764,650	$90.54	$69,228,000
Ledge Removal & Disposal						
BSN Entrance Channel	428,600	$15.98	$6,849,000	535,400	$15.74	$8,427,000
Main Ship Chan Incl PRR	61,910	$19.23	$1,191,000	77,750	$19.02	$1,479,000
Res Chan & Res Turn Area	58,000	$20.78	$1,205,000	92,700	$20.15	$1,868,000
Pres Roads Anchorage	48,500	$18.93	$918,000	58,800	$18.46	$1,085,000
	597,010	$17.02	$10,163,000	764,650	$16.82	$12,859,000
Miscellaneous Costs			$284,000			$284,000
Subtotal without Contingency			$163,964,000			$189,274,000
Construction Contingency		16.9%	$27,767,000		17.0%	$32,164,000
Subtotal - Construction			$191,731,000			$221,438,000
Planning, Engineering & Design		2.6%	$4,916,000		2.3%	$5,130,000
Supervision & Administration		3.7%	$7,103,000		3.4%	$7,561,000
Resetting of Aids to Navigation			$192,000			$192,000
Real Estate			$103,000			$106,000
Total First Cost GNF - July 2011 Prices		106%	$204,045,000		106%	$234,427,000
Program Year 2013 First Cost			$211,389,000			$242,893,000
PED Escalation	1.03779		$5,102,000	1.03779		$5,324,000
CM Escalation	1.03779		$7,371,000	1.03779		$7,847,000
Real Estate Escalation	1.03692		$107,000	1.03692		$110,000
Construction Escalation	1.03692		$198,809,000	1.03692		$229,612,000
ATON Escalation (USCG)	1.03692		$199,000	1.03692		$199,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$5,145,000	1.00843		$5,369,000
CM Escalation	1.06756		$7,869,000	1.06756		$8,377,000
Real Estate Escalation	1.03027		$110,000	1.03027		$113,000
Construction Escalation	1.03027		$204,826,000	1.03027		$236,561,000
Total Cost Escalated to Construction			$217,950,000			$250,420,000
ATON Escalation (USCG)	1.03027		$205,000	1.03027		$205,000
Construction Period (Months)		28			29	
July 2011 First Cost Plus IDC	0.0031250	1.04335	$212,891,000	0.0031250	1.04501	$244,978,000
Annual Costs at 3-3/4%						
Interest & Amortization	3-3/4%	0.04457	$9,489,000	3-3/4%	0.04457	$10,919,000
Increased Annual Maintenance			$207,000			$213,000
TOTAL			$9,696,000			$11,132,000
Annual Costs at 7%						
Interest & Amortization	7%	0.07245	$15,424,000	7%	0.07245	$17,749,000
Increased Annual Maintenance			$207,000			$213,000
TOTAL			$15,631,000			$17,962,000

TABLE D2-12 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	48/50-FOOT CHANNEL PLAN			49/51-FOOT CHANNEL PLAN		
	NORTH ENTRANCE CHANNEL AT 50 FEET WITH 48-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA			NORTH ENTRANCE CHANNEL AT 51 FEET WITH 49-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$1,590,000	LS	LS	$1,603,000
Drilling & Blasting Plant	LS	LS	$2,616,000	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,204,000	LS	LS	$1,310,000
Remobilization for AQ Shutdowns	1	$4,672,000	$4,672,000	1	$4,791,000	$4,791,000
			$10,082,000			$10,320,000
Dredging and Ocean Disposal						
BSN Entrance Channel	2,844,800	$8.95	$25,461,000	3,218,800	$8.36	$26,909,000
Main Ship Chan Incl PRR	3,210,100	$9.79	$31,427,000	3,753,300	$9.39	$35,243,000
Res Chan & Res Turn Area	1,310,500	$9.70	$12,712,000	1,458,200	$9.33	$13,605,000
Pres Roads Anchorage	3,731,000	$9.32	$34,773,000	4,313,000	$8.62	$37,178,000
	11,096,400	$9.41	$104,373,000	12,743,300	$8.86	$112,935,000
Ledge Drilling and Blasting						
BSN Entrance Channel	647,800	$83.48	$54,079,000	763,700	$83.25	$63,578,000
Main Ship Chan Incl PRR	98,330	$92.04	$9,050,000	124,770	$92.70	$11,566,000
Res Chan & Res Turn Area	137,400	$119.34	$16,398,000	187,900	$110.10	$20,687,000
Pres Roads Anchorage	69,800	$85.83	$5,991,000	81,700	$81.76	$6,680,000
	953,300	$89.71	$85,518,000	1,158,070	$88.52	$102,511,000
Ledge Removal & Disposal						
BSN Entrance Channel	647,800	$15.63	$10,125,000	763,700	$15.66	$11,960,000
Main Ship Chan Incl PRR	98,330	$18.86	$1,855,000	124,770	$18.81	$2,347,000
Res Chan & Res Turn Area	137,400	$19.60	$2,693,000	187,900	$19.01	$3,572,000
Pres Roads Anchorage	69,800	$18.30	$1,277,000	81,700	$17.96	$1,467,000
	953,330	$16.73	$15,950,000	1,158,070	$16.71	$19,346,000
Miscellaneous Costs			$284,000			$284,000
Subtotal without Contingency	12,049,730		$216,207,000	13,901,370		$245,396,000
Construction Contingency		17.0%	$36,815,000		17.1%	$41,893,000
Subtotal - Construction			$253,022,000			$287,289,000
Planning, Engineering & Design		2.1%	$5,362,000		2.0%	$5,802,000
Supervision & Administration		3.2%	$8,180,000		3.4%	$9,712,000
Resetting of Aids to Navigation			$192,000			$192,000
Real Estate			$114,000			$147,000
Total First Cost GNF - July 2011 Prices		105%	$266,870,000		106%	$303,142,000
Program Year 2013 GNF First Cost			$276,532,000			$314,146,000
PED Escalation	1.03779		$5,564,000	1.03779		$6,021,000
CM Escalation	1.03779		$8,489,000	1.03779		$10,079,000
Real Estate Escalation	1.03692		$118,000	1.03692		$152,000
Construction Escalation	1.03692		$262,362,000	1.03692		$297,894,000
ATON Escalation (USCG)	1.03692		$199,000	1.03692		$199,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$5,612,000	1.00843		$6,072,000
CM Escalation	1.07810		$9,151,000	1.08769		$10,963,000
Real Estate Escalation	1.03489		$121,000	1.03939		$158,000
Construction Escalation	1.03489		$271,517,000	1.03939		$309,629,000
Total Cost Escalated to Construction			$286,401,000			$326,822,000
ATON Escalation (USCG)	1.03489		$206,000	1.03939		$207,000
Construction Period (Months)		31			40	
July 2011 First Cost Plus IDC	0.0031250	1.04832	$279,766,000	0.0031250	1.06342	$322,368,000
Annual Costs at 3-3/4%						
Interest & Amortization	3-3/4%	0.04457	$12,469,000	3-3/4%	0.04457	$14,368,000
Increased Annual Maintenance			$216,000			$222,000
TOTAL			$12,685,000			$14,590,000
Annual Costs at 7%						
Interest & Amortization	7%	0.07245	$20,269,000	7%	0.07245	$23,356,000
Increased Annual Maintenance			$216,000			$222,000
TOTAL			$20,485,000			$23,578,000

TABLE D2-12 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	50/52-FOOT CHANNEL PLAN			HYBRID 47/50-FOOT CHANNEL PLAN		
	NORTH ENTRANCE CHANNEL AT 52 FEET WITH 50-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA			NORTH ENTRANCE CHANNEL AT 50 FEET WITH 47-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$1,801,000	LS	LS	$1,583,000
Drilling & Blasting Plant	LS	LS	$2,616,000	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,310,000	LS	LS	$1,204,000
Remobilization for AQ Shutdowns	2	$4,989,000	$9,978,000	1	$4,672,000	$4,672,000
			$15,705,000			$10,075,000
Dredging and Ocean Disposal						
BSN Entrance Channel	3,607,800	$9.04	$32,615,000	2,844,800	$8.95	$25,461,000
Main Ship Chan Incl PRR	4,314,400	$9.25	$39,908,000	2,690,100	$10.76	$28,945,000
Res Chan & Res Turn Area	1,600,100	$9.07	$14,513,000	1,156,200	$10.06	$11,631,000
Pres Roads Anchorage	4,903,900	$8.56	$41,977,000	3,155,800	$9.92	$31,306,000
	14,426,200	$8.94	$129,013,000	9,846,900	$9.89	$97,343,000
Ledge Drilling and Blasting						
BSN Entrance Channel	883,100	$78.26	$69,111,000	647,800	$83.48	$54,079,000
Main Ship Chan Incl PRR	156,890	$92.14	$14,456,000	77,750	$92.03	$7,155,000
Res Chan & Res Turn Area	245,000	$102.51	$25,115,000	92,700	$128.47	$11,909,000
Pres Roads Anchorage	95,900	$77.41	$7,424,000	58,800	$91.00	$5,351,000
	1,380,890	$84.08	$116,106,000	877,050	$89.50	$78,494,000
Ledge Removal & Disposal						
BSN Entrance Channel	883,100	$15.35	$13,556,000	647,800	$15.63	$10,125,000
Main Ship Chan Incl PRR	156,890	$18.64	$2,924,000	77,750	$19.02	$1,479,000
Res Chan & Res Turn Area	245,000	$18.80	$4,606,000	92,700	$20.15	$1,868,000
Pres Roads Anchorage	95,900	$18.05	$1,731,000	58,800	$18.46	$1,085,000
	1,380,890	$16.52	$22,817,000	877,050	$16.60	$14,557,000
Miscellaneous Costs			$284,000			$284,000
Subtotal without Contingency			$283,925,000			$200,753,000
Construction Contingency		17.1%	$48,470,000		17.0%	$34,115,000
Subtotal - Construction			$332,395,000			$234,868,000
Planning, Engineering & Design		1.8%	$6,146,000		2.2%	$5,267,000
Supervision & Administration		3.5%	$11,643,000		3.3%	$7,844,000
Resetting of Aids to Navigation			$192,000			$192,000
Real Estate			$187,000			$110,000
Total First Cost GNF - July 2011 Prices		105%	$350,563,000		106%	$248,281,000
Program Year 2013 First Cost			$363,320,000			$257,258,000
PED Escalation	1.03779		$6,378,000	1.03779		$5,466,000
CM Escalation	1.03779		$12,083,000	1.03779		$8,140,000
Real Estate Escalation	1.03692		$194,000	1.03692		$114,000
Construction Escalation	1.03692		$344,665,000	1.03692		$243,538,000
ATON Escalation (USCG)	1.03692		$199,000	1.03692		$199,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$6,432,000	1.00843		$5,512,000
CM Escalation	1.10877		$13,397,000	1.06756		$8,690,000
Real Estate Escalation	1.04881		$203,000	1.03027		$117,000
Construction Escalation	1.04881		$361,487,000	1.03027		$250,909,000
Total Cost Escalated to Construction			$381,519,000			$265,228,000
ATON Escalation (USCG)	1.04881		$209,000	1.03027		$205,000
Construction Period (Months)		51			30	
July 2011 First Cost Plus IDC	0.0031250	1.08227	$379,403,000	0.0031250	1.04666	$259,866,000
Annual Costs at 3-3/4%						
Interest & Amortization	3-3/4%	0.04457	$16,910,000	3-3/4%	0.04457	$11,582,000
Increased Annual Maintenance			$242,000			$216,000
TOTAL			$17,152,000			$11,798,000
Annual Costs at 7%						
Interest & Amortization	7%	0.07245	$27,488,000	7%	0.07245	$18,827,000
Increased Annual Maintenance			$242,000			$216,000
TOTAL			$27,730,000			$19,043,000

TABLE D2-12 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	HYBRID 47/51-FOOT CHANNEL PLAN NORTH ENTRANCE CHANNEL AT 51 FEET WITH 47-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA			HYBRID 47/52-FOOT CHANNEL PLAN NORTH ENTRANCE CHANNEL AT 52 FEET WITH 47-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$1,596,000	LS	LS	$1,603,000
Drilling & Blasting Plant	LS	LS	$2,616,000	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,204,000	LS	LS	$1,310,000
Remobilization for AQ Shutdowns	1	$4,685,000	$4,685,000	1	$4,776,000	$4,776,000
			$10,101,000			$10,305,000
Dredging and Ocean Disposal						
BSN Entrance Channel	3,218,800	$8.42	$27,102,000	3,607,800	$9.04	$32,615,000
Main Ship Chan Incl PRR	2,690,100	$10.76	$28,945,000	2,690,100	$10.76	$28,945,000
Res Chan & Res Turn Area	1,156,200	$10.06	$11,631,000	1,156,200	$10.06	$11,631,000
Pres Roads Anchorage	3,155,800	$9.92	$31,306,000	3,155,800	$9.92	$31,306,000
	10,220,900	$9.68	$98,984,000	10,609,900	$9.85	$104,497,000
Ledge Drilling and Blasting						
BSN Entrance Channel	763,700	$83.25	$63,578,000	883,100	$78.26	$69,111,000
Main Ship Chan Incl PRR	77,750	$92.03	$7,155,000	77,750	$92.03	$7,155,000
Res Chan & Res Turn Area	92,700	$128.47	$11,909,000	92,700	$128.47	$11,909,000
Pres Roads Anchorage	58,800	$91.00	$5,351,000	58,800	$91.00	$5,351,000
	992,950	$88.62	$87,993,000	1,112,350	$84.08	$93,526,000
Ledge Removal & Disposal						
BSN Entrance Channel	763,700	$15.66	$11,960,000	883,100	$15.35	$13,556,000
Main Ship Chan Incl PRR	77,750	$19.02	$1,479,000	77,750	$19.02	$1,479,000
Res Chan & Res Turn Area	92,700	$20.15	$1,868,000	92,700	$20.15	$1,868,000
Pres Roads Anchorage	58,800	$18.46	$1,085,000	58,800	$18.46	$1,085,000
	992,950	$16.51	$16,392,000	1,112,350	$16.17	$17,988,000
Miscellaneous Costs			$284,000			$284,000
Subtotal without Contingency			$213,754,000			$226,600,000
Construction Contingency		16.7%	$35,651,000		17.1%	$38,684,000
Subtotal - Construction			$249,405,000			$265,284,000
Planning, Engineering & Design		2.1%	$5,361,000			$5,442,000
Supervision & Administration		3.4%	$8,565,000			$8,874,000
Resetting of Aids to Navigation			$192,000			$192,000
Real Estate			$125,000			$128,000
Total First Cost GNF - July 2011 Prices		106%	$263,648,000		106%	$279,920,000
Program Year 2013 First Cost			$273,195,000			$290,067,000
PED Escalation	1.03779		$5,564,000	1.03779		$5,648,000
CM Escalation	1.03779		$8,889,000	1.03779		$9,209,000
Real Estate Escalation	1.03692		$130,000	1.03692		$133,000
Construction Escalation	1.03692		$258,612,000	1.03692		$275,077,000
ATON Escalation (USCG)	1.03692		$199,000	1.03692		$199,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$5,611,000	1.00843		$5,696,000
CM Escalation	1.07810		$9,583,000	1.08769		$10,016,000
Real Estate Escalation	1.03489		$135,000	1.03939		$138,000
Construction Escalation	1.03489		$267,635,000	1.03939		$285,914,000
Total Cost Escalated to Construction			$282,964,000			$301,764,000
ATON Escalation (USCG)	1.03489		$206,000	1.03939		$207,000
Construction Period (Months)		34			35	
July 2011 First Cost Plus IDC	0.0031250	1.05332	$277,707,000	0.0031250	1.05500	$295,315,000
Annual Costs at 3-3/4%						
Interest & Amortization	3-3/4%	0.04457	$12,377,000	3-3/4%	0.04457	$13,162,000
Increased Annual Maintenance			$222,000			$236,000
TOTAL			$12,599,000			$13,398,000
Annual Costs at 7%						
Interest & Amortization	7%	0.07245	$20,120,000	7%	0.07245	$21,396,000
Increased Annual Maintenance			$222,000			$236,000
TOTAL			$20,342,000			$21,632,000

TABLE D2-12 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	HYBRID 45/49-FOOT CHANNEL PLAN			HYBRID 46/50-FOOT CHANNEL PLAN		
	NORTH ENTRANCE CHANNEL AT 49 FEET WITH 45-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA			NORTH ENTRANCE CHANNEL AT 50 FEET WITH 46-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$1,460,000	LS	LS	$1,463,000
Drilling & Blasting Plant	LS	LS	$2,616,000	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,197,000	LS	LS	$1,204,000
Remobilization for AQ Shutdowns	1	$4,561,000	$4,561,000	1	$4,564,000	$4,564,000
			$9,834,000			$9,847,000
Dredging and Ocean Disposal						
BSN Entrance Channel	2,482,800	$10.05	$24,952,000	3,218,800	$8.42	$27,102,000
Main Ship Chan Incl PRR	1,753,900	$12.55	$22,011,000	2,204,100	$11.27	$24,840,000
Res Chan & Res Turn Area	829,200	$12.05	$9,992,000	995,600	$10.98	$10,932,000
Pres Roads Anchorage	2,027,800	$12.61	$25,571,000	2,587,900	$11.07	$28,648,000
	7,093,700	$11.63	$82,526,000	9,006,400	$10.16	$91,522,000
Ledge Drilling and Blasting						
BSN Entrance Channel	535,400	$83.70	$44,813,000	763,700	$83.25	$63,578,000
Main Ship Chan Incl PRR	49,100	$95.17	$4,673,000	61,910	$93.43	$5,784,000
Res Chan & Res Turn Area	31,100	$154.02	$4,790,000	58,000	$141.10	$8,184,000
Pres Roads Anchorage	38,800	$106.44	$4,130,000	48,500	$97.71	$4,739,000
	654,400	$89.25	$58,406,000	932,110	$88.28	$82,285,000
Ledge Removal & Disposal						
BSN Entrance Channel	535,400	$15.74	$8,427,000	763,700	$15.66	$11,960,000
Main Ship Chan Incl PRR	49,100	$19.39	$952,000	61,910	$19.23	$1,191,000
Res Chan & Res Turn Area	31,100	$21.15	$658,000	58,000	$20.78	$1,205,000
Pres Roads Anchorage	38,800	$19.35	$751,000	48,500	$18.93	$918,000
	654,400	$16.49	$10,788,000	932,110	$16.39	$15,274,000
Miscellaneous Costs			$284,000			$284,000
Subtotal without Contingency			$161,838,000			$199,212,000
Construction Contingency		16.6%	$26,790,000		16.5%	$32,786,000
Subtotal - Construction			$188,628,000			$231,998,000
Planning, Engineering & Design		2.6%	$4,830,000			$5,039,000
Supervision & Administration		3.7%	$6,957,000			$7,680,000
Resetting of Aids to Navigation			$192,000			$192,000
Real Estate			$103,000			$106,000
Total First Cost GNF - July 2011 Prices		106%	$200,710,000		106%	$245,015,000
Program Year 2013 First Cost			$207,931,000			$253,871,000
PED Escalation	1.03779		$5,013,000	1.03779		$5,229,000
CM Escalation	1.03779		$7,220,000	1.03779		$7,970,000
Real Estate Escalation	1.03692		$107,000	1.03692		$110,000
Construction Escalation	1.03692		$195,591,000	1.03692		$240,562,000
ATON Escalation (USCG)	1.03692		$199,000	1.03692		$199,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$5,055,000	1.00843		$5,273,000
CM Escalation	1.06756		$7,708,000	1.06756		$8,508,000
Real Estate Escalation	1.03027		$110,000	1.03027		$113,000
Construction Escalation	1.03027		$201,511,000	1.03027		$247,843,000
Total Cost Escalated to Construction			$214,384,000			$261,737,000
ATON Escalation (USCG)	1.03027		$205,000	1.03027		$205,000
Construction Period (Months)		28			29	
July 2011 First Cost Plus IDC	0.0031250	1.04335	$209,411,000	0.0031250	1.04501	$256,042,000
Annual Costs at 3-3/4%						
Interest & Amortization	3-3/4%	0.04457	$9,333,000	3-3/4%	0.04457	$11,412,000
Increased Annual Maintenance			$206,000			$201,000
TOTAL			$9,539,000			$11,613,000
Annual Costs at 7%						
Interest & Amortization	7%	0.07245	$15,172,000	7%	0.07245	$18,550,000
Increased Annual Maintenance			$206,000			$201,000
TOTAL			$15,378,000			$18,751,000

TABLE D2-12 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH TWO FEET GREATER DEPTH IN THE ENTRANCE CHANNEL

July-August 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escallation Index Factors	HYBRID 48/52-FOOT CHANNEL PLAN NORTH ENTRANCE CHANNEL AT 52 FEET WITH 48-FOOT MAIN SHIP CHANNEL, ANCHORAGE, RESERVED CHANNEL & RESERVED TURNING AREA		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization			
Ordinary Dredging & Disposal Plant	LS	LS	$1,694,000
Drilling & Blasting Plant	LS	LS	$2,616,000
Rock Removal & Disposal Plant	LS	LS	$1,204,000
Remobilization for AQ Shutdowns	1	$4,776,000	$4,776,000
			$10,290,000
Dredging and Ocean Disposal			
BSN Entrance Channel	3,607,800	$9.04	$32,615,000
Main Ship Chan Incl PRR	3,210,100	$9.79	$31,427,000
Res Chan & Res Turn Area	1,310,500	$9.70	$12,712,000
Pres Roads Anchorage	3,731,000	$9.32	$34,773,000
	11,859,400	$9.40	$111,527,000
Ledge Drilling and Blasting			
BSN Entrance Channel	883,100	$78.26	$69,111,000
Main Ship Chan Incl PRR	98,330	$92.04	$9,050,000
Res Chan & Res Turn Area	137,400	$119.34	$16,398,000
Pres Roads Anchorage	69,800	$85.83	$5,991,000
	1,188,630	$84.59	$100,550,000
Ledge Removal & Disposal			
BSN Entrance Channel	883,100	$15.35	$13,556,000
Main Ship Chan Incl PRR	98,330	$18.86	$1,855,000
Res Chan & Res Turn Area	137,400	$19.60	$2,693,000
Pres Roads Anchorage	69,800	$18.30	$1,277,000
	1,188,630	$16.31	$19,381,000
Miscellaneous Costs			$284,000
Subtotal without Contingency			$242,032,000
Construction Contingency		16.7%	$40,497,000
Subtotal - Construction			$282,529,000
Planning, Engineering & Design		2.0%	$5,533,000
Supervision & Administration		3.3%	$9,327,000
Resetting of Aids to Navigation			$192,000
Real Estate			$136,000
Total First Cost GNF - July 2011 Prices		105%	$297,717,000
Program Year 2013 First Cost			$306,641,000
PED Escalation	1.03779		$5,742,000
CM Escalation	1.03779		$9,679,000
Real Estate Escalation	1.03027		$140,000
Construction Escalation	1.03027		$291,080,000
ATON Escalation (USCG)	1.03027		$198,000
Fully Funded Cost Escalation			
PED Escalation	1.00843		$5,790,000
CM Escalation	1.08769		$10,528,000
Real Estate Escalation	1.03939		$146,000
Construction Escalation	1.03939		$302,547,000
Total Cost Escalated to Construction			$319,011,000
ATON Escalation (USCG)	1.03939		$206,000
Construction Period (Months)		37	
July 2011 First Cost Plus IDC	0.0031250	1.05836	$315,091,000
Annual Costs at 3-3/4%			
Interest & Amortization	3-3/4%	0.04457	$14,044,000
Increased Annual Maintenance			$225,000
TOTAL			$14,269,000
Annual Costs at 7%			
Interest & Amortization	7%	0.07245	$22,828,000
Increased Annual Maintenance			$225,000
TOTAL			$23,053,000

TABLE D2-13
BOSTON HARBOR IMPROVEMENT STUDY
COST ESTIMATES FOR NON-FEDERAL BERTH DEEPENING FOR ALTERANTIVE PLANS AND DEPTHS

PLAN A-B-C - DEEPEN BERTHS #11 AND #12 AT THE CONLEY TERMINAL TO A DEPTH 3 FEET GREATER THAN THE PROPOSED INNER FEDERAL CHANNELS DEPTH

INNER FEDERAL CHANNELS DEPTH	42 FEET	43 FEET	44 FEET	45 FEET	46 FEET	47 FEET	48 FEET	49 FEET	50 FEET
BERTH DEPTH	45 FEET	46 FEET	47 FEET	48 FEET	49 FEET	50 FEET	51 FEET	52 FEET	53 FEET
CUBIC YARDS - 2 BERTHS (2 Ft OD)	0	6,200	12,400	18,700	24,900	31,100	37,300	43,600	49,800
First Cost of Construction - July/August 2011 Price Levels									
Mobilization/Demobilization	NA	$53,000	$53,000	$53,000	$53,000	$53,000	$53,000	$53,000	$53,000
Dredging and Ocean Disposal	NA	$14.39	$14.07	$12.05	$10.98	$10.06	$9.70	$9.33	$9.07
Ordinary Material	NA	$89,218	$174,468	$225,335	$273,402	$312,866	$361,810	$406,788	$451,686
Construction Contingency - Percentage	NA	17%	17%	17%	17%	17%	17%	17%	17%
Construction Contingency - Cost	NA	$15,100	$29,500	$38,200	$46,300	$53,200	$61,600	$69,400	$77,100
Subtotal - Construction	NA	$157,300	$257,000	$316,500	$372,700	$419,100	$476,400	$529,200	$581,800
Planning, Engineering and Design	NA	$6,000	$8,300	$9,100	$9,600	$9,700	$10,100	$10,700	$10,800
Construction Management	NA	$7,100	$11,900	$12,800	$13,800	$14,300	$15,400	$17,900	$20,400
Total First Cost - July 2011	NA	$170,000	$277,000	$338,000	$396,000	$443,000	$502,000	$558,000	$613,000
Escalated Costs									
Costs Escalated to Program Level FY2013	NA	$176,000	$287,000	$350,000	$411,000	$459,000	$521,000	$579,000	$636,000
Cost Escalated to Construction	NA	$181,000	$296,000	$361,000	$423,000	$473,000	$539,000	$602,000	$667,000
LSF PED Costs Only Escalated	NA	$6,000	$9,000	$10,000	$10,000	$10,000	$11,000	$12,000	$12,000
Annual Costs at 3-3/4%									
Construction Period (Months)	1	1	1	1	1	1	1	1	1
First Cost Plus IDC	0.0031250	$170,000	$277,000	$338,000	$396,000	$443,000	$502,000	$558,000	$613,000
Interest & Amortization (3-3/4%)	0.04457	$8,000	$12,000	$15,000	$18,000	$20,000	$22,000	$25,000	$27,000
Increased Annual Maintenance	5%	$9,000	$14,000	$17,000	$20,000	$22,000	$25,000	$28,000	$31,000
TOTAL		$17,000	$26,000	$32,000	$38,000	$42,000	$47,000	$53,000	$58,000
Annual Costs at 7%									
Construction Period (Months)	1	1	1	1	1	1	1	1	1
First Cost Plus IDC	0.0031250	$170,000	$277,000	$338,000	$396,000	$443,000	$502,000	$558,000	$613,000
Interest & Amortization (7%)	0.07245	$12,000	$20,000	$24,000	$29,000	$32,000	$36,000	$40,000	$44,000
Increased Annual Maintenance	5%	$9,000	$14,000	$17,000	$20,000	$22,000	$25,000	$28,000	$31,000
TOTAL		$21,000	$34,000	$41,000	$49,000	$54,000	$61,000	$68,000	$75,000

TABLE D2-14
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ANNUAL COSTS FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN THE NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH 2 TO 4 FEET GREATER DEPTH IN THE ENTRANCE

PLAN					
Inner Federal Channels Depth		42 Feet	43 Feet	44 Feet	45 Feet
North Entrance Channel Depth		44 Feet	45 Feet	46 Feet	47 Feet
Conley Terminal Berths Depth		45 Feet	46 Feet	47 Feet	48 Feet
Federal Project GNF Annual Cost - 3-3/4%					
First Cost - July/Aug 2011		$89,598,000	$121,407,000	$151,653,000	$176,057,000
Construction Duration (Months)		16	18	26	27
IDC Rate		1.02378	1.02701	1.04006	1.04170
Implementation Cost (+ IDC)		$91,729,000	$124,686,000	$157,728,000	$183,399,000
Interest & Amortization - 3-3/4%	0.04457	$4,088,000	$5,557,000	$7,030,000	$8,174,000
Increased Annual Maintenance		$223,000	$217,000	$205,000	$204,000
Total Federal GNF Annual Cost		$4,311,000	$5,774,000	$7,235,000	$8,378,000
Non-Federal Annual Cost - 3-3/4%					
First Cost - July/Aug 2011		NA	$170,000	$277,000	$338,000
Implementation Cost (+ IDC)		NA	$170,000	$277,000	$338,000
Interest & Amortization - 3-3/4%	0.04457	NA	$8,000	$12,000	$15,000
Increased Annual Maintenance		NA	$9,000	$14,000	$17,000
Total Federal GNF Annual Cost		NA	$17,000	$26,000	$32,000
Federal Project GNF Annual Cost - 7%					
Interest & Amortization - 7%	0.07245	$6,646,000	$9,034,000	$11,427,000	$13,287,000
Increased Annual Maintenance		$223,000	$217,000	$205,000	$204,000
Total Federal GNF Annual Cost		$6,869,000	$9,251,000	$11,632,000	$13,491,000
Non-Federal Annual Cost - 7%					
Interest & Amortization - 7%	0.07245	$1	$12,000	$20,000	$24,000
Increased Annual Maintenance		NA	$9,000	$14,000	$17,000
Total Federal GNF Annual Cost		NA	$21,000	$34,000	$41,000
Total Federal and Non-Federal Annual Costs					
Total Project Annual Costs	3-3/4%	$4,311,000	$5,791,000	$7,261,000	$8,410,000
Total Project Annual Costs	7%	$6,869,000	$9,272,000	$11,666,000	$13,532,000

TABLE D2-14 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ANNUAL COSTS FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN THE NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH 2 TO 4 FEET GREATER DEPTH IN THE ENTRANCE

PLAN					
Inner Federal Channels Depth		46 Feet	47 Feet	48 Feet	49 Feet
North Entrance Channel Depth		48 Feet	49 Feet	50 Feet	51 Feet
Conley Terminal Berths Depth		49 Feet	50 Feet	51 Feet	52 Feet
Federal Project GNF Annual Cost - 3-3/4%					
First Cost - July/Aug 2011		$204,045,000	$234,427,000	$266,870,000	$303,142,000
Construction Duration (Months)		28	29	31	40
IDC Rate		1.04335	1.04501	1.04832	1.06342
Implementation Cost (+ IDC)		$212,891,000	$244,978,000	$279,766,000	$322,368,000
Interest & Amortization - 3-3/4%	0.04457	$9,489,000	$10,919,000	$12,469,000	$14,368,000
Increased Annual Maintenance		$207,000	$213,000	$216,000	$222,000
Total Federal GNF Annual Cost		$9,696,000	$11,132,000	$12,685,000	$14,590,000
Non-Federal Annual Cost - 3-3/4%					
First Cost - July/Aug 2011		$396,000	$443,000	$502,000	$558,000
Implementation Cost (+ IDC)		$396,000	$443,000	$502,000	$558,000
Interest & Amortization - 3-3/4%	0.04457	$18,000	$20,000	$22,000	$25,000
Increased Annual Maintenance		$20,000	$22,000	$25,000	$28,000
Total Federal GNF Annual Cost		$38,000	$42,000	$47,000	$53,000
Federal Project GNF Annual Cost - 7%					
Interest & Amortization - 7%	0.07245	$15,424,000	$17,749,000	$20,269,000	$23,356,000
Increased Annual Maintenance		$207,000	$213,000	$216,000	$222,000
Total Federal GNF Annual Cost		$15,631,000	$17,962,000	$20,485,000	$23,578,000
Non-Federal Annual Cost - 7%					
Interest & Amortization - 7%	0.07245	$29,000	$32,000	$36,000	$40,000
Increased Annual Maintenance		$20,000	$22,000	$25,000	$28,000
Total Federal GNF Annual Cost		$49,000	$54,000	$61,000	$68,000
Total Federal and Non-Federal Annual Costs					
Total Project Annual Costs	3-3/4%	$9,734,000	$11,174,000	$12,732,000	$14,643,000
Total Project Annual Costs	7%	$15,680,000	$18,016,000	$20,546,000	$23,646,000

TABLE D2-14 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ANNUAL COSTS FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN THE NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH 2 TO 4 FEET GREATER DEPTH IN THE ENTRANCE

PLAN					
Inner Federal Channels Depth		50 Feet	47 Feet	47 Feet	47 Feet
North Entrance Channel Depth		52 Feet	50 Feet	51 Feet	52 Feet
Conley Terminal Berths Depth		53 Feet	50 Feet	50 Feet	50 Feet
Federal Project GNF Annual Cost - 3-3/4%					
First Cost - July/Aug 2011		$350,563,000	$248,281,000	$263,648,000	$279,920,000
Construction Duration (Months)		51	30	34	35
IDC Rate		1.08227	1.04666	1.05332	1.05500
Implementation Cost (+ IDC)		$379,403,000	$259,866,000	$277,707,000	$295,315,000
Interest & Amortization - 3-3/4%	0.04457	$16,910,000	$11,582,000	$12,377,000	$13,162,000
Increased Annual Maintenance		$242,000	$216,000	$222,000	$236,000
Total Federal GNF Annual Cost		$17,152,000	$11,798,000	$12,599,000	$13,398,000
Non-Federal Annual Cost - 3-3/4%					
First Cost - July/Aug 2011		$613,000	$443,000	$443,000	$443,000
Implementation Cost (+ IDC)		$613,000	$443,000	$443,000	$443,000
Interest & Amortization - 3-3/4%	0.04457	$27,000	$20,000	$20,000	$20,000
Increased Annual Maintenance		$31,000	$22,000	$22,000	$22,000
Total Federal GNF Annual Cost		$58,000	$42,000	$42,000	$42,000
Federal Project GNF Annual Cost - 7%					
Interest & Amortization - 7%	0.07245	$27,488,000	$18,827,000	$20,120,000	$21,396,000
Increased Annual Maintenance		$242,000	$216,000	$222,000	$236,000
Total Federal GNF Annual Cost		$27,730,000	$19,043,000	$20,342,000	$21,632,000
Non-Federal Annual Cost - 7%					
Interest & Amortization - 7%	0.07245	$44,000	$32,000	$32,000	$32,000
Increased Annual Maintenance		$31,000	$22,000	$22,000	$22,000
Total Federal GNF Annual Cost		$75,000	$54,000	$54,000	$54,000
Total Federal and Non-Federal Annual Costs					
Total Project Annual Costs	3-3/4%	$17,210,000	$11,840,000	$12,641,000	$13,440,000
Total Project Annual Costs	7%	$27,805,000	$19,097,000	$20,396,000	$21,686,000

TABLE D2-14 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
ANNUAL COSTS FOR ALTERANTIVE PLANS AND DEPTHS
PLANS A, B & C - MAIN CHANNELS DEEPENING TO CONLEY TERMINAL

DEEPEN THE NORTH ENTRANCE, LOWER MAIN SHIP CHANNEL, PRESIDENT ROADS ANCHORAGE, LOWER RESERVED CHANNEL & RESERVED CHANNEL TURNING AREA TO A DEPTH OF UP TO -50 FEET MLLW WITH 2 TO 4 FEET GREATER DEPTH IN THE ENTRANCE

PLAN				
Inner Federal Channels Depth		45 Feet	46 Feet	48 Feet
North Entrance Channel Depth		49 Feet	50 Feet	52 Feet
Conley Terminal Berths Depth		48 Feet	49 Feet	51 Feet
Federal Project GNF Annual Cost - 3-3/4%				
First Cost - July/Aug 2011		$200,710,000	$245,015,000	$297,717,000
Construction Duration (Months)		28	29	37
IDC Rate		1.04335	1.04501	1.05836
Implementation Cost (+ IDC)		$209,411,000	$256,042,000	$315,091,000
Interest & Amortization - 3-3/4%	0.04457	$9,333,000	$11,412,000	$14,044,000
Increased Annual Maintenance		$206,000	$201,000	$225,000
Total Federal GNF Annual Cost		$9,539,000	$11,613,000	$14,269,000
Non-Federal Annual Cost - 3-3/4%				
First Cost - July/Aug 2011		$338,000	$396,000	$502,000
Implementation Cost (+ IDC)		$338,000	$396,000	$502,000
Interest & Amortization - 3-3/4%	0.04457	$15,000	$18,000	$22,000
Increased Annual Maintenance		$17,000	$20,000	$25,000
Total Federal GNF Annual Cost		$32,000	$38,000	$47,000
Federal Project GNF Annual Cost - 7%				
Interest & Amortization - 7%	0.07245	$15,172,000	$18,550,000	$22,828,000
Increased Annual Maintenance		$206,000	$201,000	$225,000
Total Federal GNF Annual Cost		$15,378,000	$18,751,000	$23,053,000
Non-Federal Annual Cost - 7%				
Interest & Amortization - 7%	0.07245	$24,000	$29,000	$36,000
Increased Annual Maintenance		$17,000	$29,000	$25,000
Total Federal GNF Annual Cost		$41,000	$49,000	$61,000
Total Federal and Non-Federal Annual Costs				
Total Project Annual Costs	3-3/4%	$9,571,000	$11,651,000	$14,316,000
Total Project Annual Costs	7%	$15,419,000	$18,800,000	$23,114,000

DETAILED ESTMATES

MAIN SHIP CHANNEL DEEPENING EXTENSION TO THE MASSPORT MARINE TERMINAL – PLAN D

Project Description

The Main Ship Channel Deepening Extension Plan consists of improvements to deepen the existing 40-foot deep lane of the Main Ship Channel above the Reserved Channel Turning Area to access the Massport Marine Terminal located between the Drydock Channel and the Ted Williams Tunnel (I-90). The proposed deepening would extend about 2,600 feet above the turning area. This plan is shown in Figure D2-3.

This improvement also requires that the berth at the Marine Terminal be deepened to at least the depth provided by any improved channel. No other Local Service Facility costs are necessary to accrue project benefits as Massport and its partners are moving forward with the development of this terminal with or without any channel deepening. The deeper channel would enable larger bulk carriers to access the terminal.

The following tables provide detail estimates for the main channels improvements.

Table D2-15 shows the quantity estimates for this project feature by one-foot increments.

Table D2-16 shows the quantity estimates for maintenance material for this channel reach.

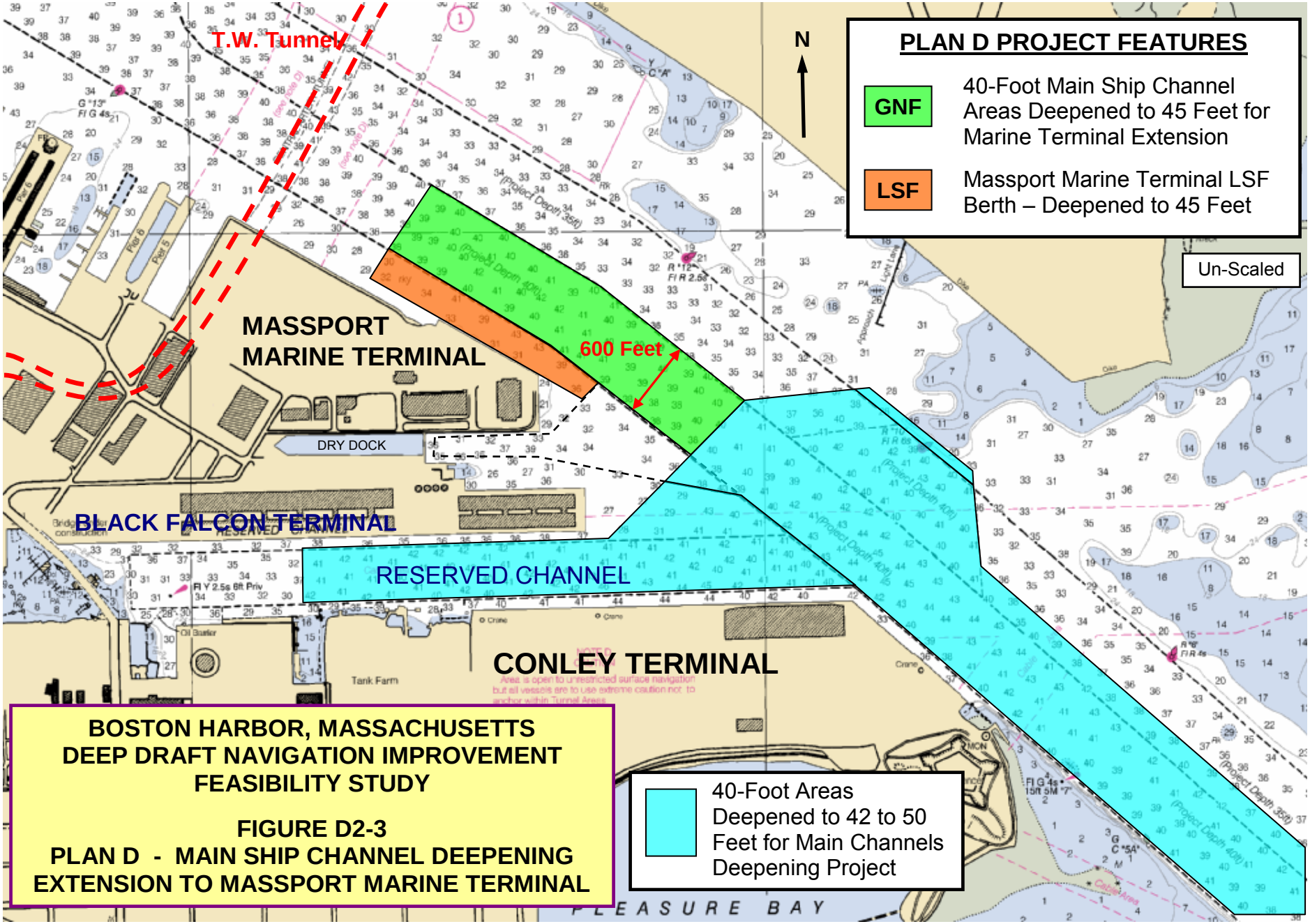
Table D2-17 shows the detailed quantity and dredging footprint area estimates in one-foot increments for ordinary material dredging and rock removal.

Table D2-18 shows the cost estimates for the 4 incremental depths for the main ship channel deepening extension improvement plan (Plan D).

Table D2-19 shows the costs for the deepening of Massport's berth at the Marine Terminal; the Non-Federal Local Service Facilities (LSF).

Table D2-20 shows the annual costs of the 4 incremental depths.

Following these tables are the summary sheets from the contingency risk analyses for the recommended plan for the main ship channel deepening extension improvement; the 45-foot project plan.



BOSTON HARBOR, MASSACHUSETTS
DEEP DRAFT NAVIGATION IMPROVEMENT
FEASIBILITY STUDY

FIGURE D2-3
PLAN D - MAIN SHIP CHANNEL DEEPENING
EXTENSION TO MASSPORT MARINE TERMINAL

TABLE D2-15
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLAN D - MAIN SHIP CHANNEL EXTENSION

DEEPEN THE AREA OF THE MAIN SHIP CHANNEL ABOVE THE RESERVED CHANNEL TURNING AREA ALONG THE SOUTHERN CHANNEL LANE ADJACENT TO MASSPORT'S MARINE TERMINAL IN SOUTH BOSTON TO DEPTHS GREATER THAN THE 40-FOOT EXISTING PROJECT DEPTH AT 600 FEET WIDE

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Design Depth	2-Foot Overdepth	Total CY Ordinary	Cut to Design Depth	2-Foot Additional Required	2-Foot Overdepth Allowance	Total Rock CY	All Required Material	All Overdepth	Total All Material
42-Foot Depth	0	100,000	100,000	300	4,100	13,700	18,100	4,400	113,700	118,100
43-Foot Depth	46,200	105,600	151,800	900	11,700	23,700	36,300	58,800	129,300	188,100
44-Foot Depth	99,800	100,400	200,200	4,300	21,400	31,200	56,900	125,500	131,600	257,100
45-Foot Depth	151,800	94,500	246,300	12,600	29,500	36,300	78,400	193,900	130,800	324,700
46-Foot Depth	200,200	90,100	290,300	25,800	35,300	41,100	102,200	261,300	131,200	392,500
47-Foot Depth	246,200	85,600	331,800	42,200	40,300	46,000	128,500	328,700	131,600	460,300
48-Foot Depth	290,200	80,800	371,000	61,100	45,100	50,300	156,500	396,400	131,100	527,500
49-Foot Depth	331,900	76,300	408,200	82,400	49,600	54,800	186,800	463,900	131,100	595,000
50-Foot Depth	371,100	71,800	442,900	106,100	54,100	59,000	219,200	531,300	130,800	662,100

DREDGE AND ROCK AREAS BY CHANNEL DESIGN DEPTH FOR 600-FOOT WIDE CHANNEL

	Ordinary Material - SF			Ledge Removal (Requires Added 2 Feet) - SF						
	Required	2-Foot Overdepth	Total Area Ordinary	Required to Design Depth	2-Foot Additional Required	20% of 1/2 of 2-Foot Overdepth Allowance	Total Rock			Total Project Footprint (Acres)
42-Foot Depth	1,024,182	518,600	1,542,782	8,874	147,965	28,234	185,073			36.2
43-Foot Depth	1,403,872	174,397	1,578,269	40,149	257,860	21,747	319,756			36.5
44-Foot Depth	1,542,782	49,124	1,591,906	156,839	249,905	13,999	420,743			36.6
45-Foot Depth	1,578,269	17,461	1,595,730	298,009	178,730	12,924	489,663			36.6
46-Foot Depth	1,591,906	3,824	1,595,730	406,744	134,615	13,558	554,917			36.6
47-Foot Depth	1,595,730	0	1,595,730	476,739	132,408	11,454	620,601			36.6
48-Foot Depth	1,595,730	0	1,595,730	541,359	125,057	12,267	678,683			36.6

Notes: Rock Overdepth Allowance Area is area for 20 Percent of One-Half of overdepth elevation. Rock overdepth quantity is for 2-foot removal increment below that area plus requried area. Side slopes are 1:3 in ordinary material and 1:1 in rock.

TABLE D2-16
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR 40-FOOT MAINTENANCE INCREMENT - PLAN D - MAIN SHIP CHANNEL EXTENSION

MAINTENANCE DREDGING QUANTITY
FOR MAINTENANCE DREDGING OF 40-FOOT CHANNEL LANE 600 FEET WIDE OVER SAME DIMENSIONS

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Design Depth	2-Foot Overdepth	Total CY Ordinary	Cut to Design Depth	2-Foot Additional Required	2-Foot Overdepth Allowance	Total Rock CY	All Required Material	All Overdepth	Total All Material
35-Foot Channel Lane for 50-Foot Width	0	200	200	0	0	0	0	0	200	200
40-Foot Channel Lane for 600-Foot Width	10,300	47,600	57,900	0	0	0	0	10,300	47,600	57,900
Total O&M	10,300	47,800	58,100	0	0	0	0	10,300	47,800	58,100

TABLE D2-17
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY AND AREA ESTIMATES FOR ORDINARY MATERIAL - ALTERANTIVE PLANS AND DEPTHS
PLAN D - MAIN SHIP CHANNEL DEEPENING EXTENSION TO MASSPORT MARINE TERMINAL

QUANTITIES AND AREAS BY ELEVATION BY FOOT AT MEAN LOWER LOW WATER

Elevation (Maintenance)	Total for All Material (A.C. 12-07)				Rock (A.C. 03-08)				Quantity for Rock Overdepth Calculation	
	Quantity (CY)		Area (SF)		Quantity (CY)		Area (SF)			
	Existing 600-Foot Channel Limits	50-Foot Width of Existing 35-Foot Lane	Existing 600-Foot Channel Limits	50-Foot Width of Existing 35-Foot Lane	Existing 600-Foot Channel Limits	50-Foot Width of Existing 35-Foot Lane	Existing 600-Foot Channel Limits	50-Foot Width of Existing 35-Foot Lane	Overdepth Elevation Increment	Rock Overdepth Quantity (CY)
-35	0	0	0	0	0	0	0	0	For 600-foot wide channel. Area at bottom of required depth, plus 20% of additional area for one-foot greater depth (for side slopes and overwidth drilling, times 2 feet of removal.	
-36	0	7	0	865	0	0	0	0		
-37	4	249	689	14,767	0	0	0	0		
-38	690	1,622	35,491	50,967	0	0	0	0		
-39	3,064	4,615	94,524	94,534	0	0	0	0		
-40	10,260	9,420	295,434	126,102	0	12	0	2,891		
-41	27,735	15,153	620,001	136,526	1	234	318	29,794		
-42	57,812	21,026	1,024,182	136,526	281	1,595	8,874	69,962	42 to 44	1,121
-43	104,911	26,890	1,403,872	136,526	925	3,842	40,149	82,998	43 to 45	4,703
-44	161,951	32,741	1,542,782	136,526	4,345	6,473	156,839	86,694	44 to 46	13,709
-45	222,225	38,577	1,578,269	136,526	12,648	9,193	298,009	88,968	45 to 47	23,686
-46	283,799	44,390	1,591,906	136,526	25,765	12,078	406,744	91,686	46 to 48	31,166
-47	346,206	50,178	1,595,730	136,526	42,164	15,079	476,739	93,293	47 to 49	36,271
-48	409,154	55,952	1,595,730	136,526	61,071	18,186	541,359	94,710	48 to 50	41,105
-49	472,102	61,726	1,595,730	136,526	82,434	21,398	609,147	94,060	49 to 51	45,970
-50	535,050	67,500	1,595,730	136,526	106,129	24,728	666,416	96,392	50 to 52	50,273
-51	597,998	73,274	1,595,730	136,526	132,034	28,199	727,753	98,834	51 to 53	54,761
-52	660,946	79,048	1,595,730	136,526	160,227	31,850	785,373	101,221	52 to 54	58,953
-53					190,459	35,637	837,854	104,974		
-54					222,695	39,570	888,908	107,707		

TABLE D2-18
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MASSPORT MARINE TERMINAL

DEEPEN THE REACH OF THE MAIN SHIP CHANNEL ABOVE THE RESERVED CHANNEL TURNING AREA AND BELOW THE TED WILLIAMS TUNNEL TO ACCESS THE MASSPORT MARINE TERMINAL IN SOUTH BOSTON TO DEPTHS UP TO -45 FEET MLLW

DEEPENING INCLUDES THE 600-FOOT WIDTH OF THE 40-FOOT CHANNEL LANE

July 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escalation Index Factors	PLAN D-42			PLAN D-43		
	MAIN SHIP CHANNEL DEEPENING EXTENSION TO MARINE TERMINAL 42-FOOT PROJECT DEPTH			MAIN SHIP CHANNEL DEEPENING EXTENSION TO MARINE TERMINAL 43-FOOT PROJECT DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$74,000	LS	LS	$74,000
Drilling & Blasting Plant	LS	LS	$189,000	LS	LS	$189,000
Rock Removal & Disposal Plant	LS	LS	$100,000	LS	LS	$100,000
Dredging and Ocean Disposal						
Ordinary Material	100,000	$24.39	$2,439,000	151,800	$19.19	$2,913,000
Ledge Drilling & Blasting	18,100	$129.17	$2,338,000	36,300	$116.31	$4,222,000
Ledge Removal & Disposal	18,100	$22.82	$413,000	36,300	$20.86	$757,000
Miscellaneous Costs			$71,000			$71,000
Subtotal - Before Contingency			$5,624,000			$8,326,000
Construction Contingency		22.4%	$1,260,000		22.4%	$1,865,000
Subtotal - Construction	118,100		$6,884,000	188,100		$10,191,000
Planning, Engineering & Design		4.5%	$313,000		3.3%	$332,000
Supervision & Administration		9.1%	$626,000		6.5%	$659,000
Resetting of Aids to Navigation			$24,000			$24,000
Real Estate			$11,000			$11,000
Total First Cost - July 2011 Prices		114%	$7,858,000		110%	$11,217,000
Program Year 2013 First Cost			$8,124,000			$11,607,000
PED Escalation	1.03779		$325,000	1.03779		$345,000
CM Escalation	1.03779		$650,000	1.03779		$684,000
Real Estate Escalation	1.03692		$11,000	1.03692		$11,000
Construction Escalation	1.03692		$7,138,000	1.03692		$10,567,000
ATON Escalation (USCG)	1.03692		$25,000	1.03692		$25,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$328,000	1.00843		$348,000
CM Escalation	1.12889		$734,000	1.12889		$772,000
Real Estate Escalation	1.05810		$12,000	1.05810		$12,000
Construction Escalation	1.05810		$7,553,000	1.05810		$11,181,000
Total Cost Escalated to Construction			$8,627,000			$12,313,000
ATON Escalation (USCG)	1.05810		$26,000	1.05810		$26,000

NOTES:

Ordinary Material - Plant for 44-Foot Plan = One 21 CY Bucket Dredge with 16 CY bucket, 2 Tugs, 3 Scows, 1.39 Months Dredging Time, 1.04 Months Haul Time. Plant for 45-Ft Plan = One 21 CY Bucket Dredge with 16 CY bucket, 2 Tugs, 3 Scows, 1.38 Months Dredging Time, 1.23 Months Haul Time.

Drilling and Blasting: Plant for 42 Feet = 2 Drill Boats, 0.62 Months. For 43 Feet = 2 Drill Boats, 1.13 Months.

Rock Removal: Plant for 42 Feet = One 21 CY Bucket Dredge with 14 CY Bucket, 3 Tugs, 4 Scows, 0.12 Months Excavation Time, 0.12 Months Haul Time. Plant for 43 Feet = One 21 CY Bucket Dredge with 14 CY Bucket, 3 Tugs, 4 Scows, 0.23 Months Excavation Time, 0.23 Months Haul Time.

Quantities for Ordinary Material Include a 2-Foot Allowable Overdepth (Dredging Tolerance) and 1/3 Side Slopes

Quantities in Rock Include an Additional 2-Foot Required Removal and a 2-Foot Allowable Overdepth and 1/1 Side Slopes

TABLE D2-18
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MASSPORT MARINE TERMINAL

DEEPEN THE REACH OF THE MAIN SHIP CHANNEL ABOVE THE RESERVED CHANNEL TURNING AREA AND BELOW THE TED WILLIAMS TUNNEL TO ACCESS THE MASSPORT MARINE TERMINAL IN SOUTH BOSTON TO DEPTHS UP TO -45 FEET MLLW

DEEPENING INCLUDES THE 600-FOOT WIDTH OF THE 40-FOOT CHANNEL LANE

July 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escalation Index Factors	PLAN D-44			PLAN D-45		
	MAIN SHIP CHANNEL DEEPENING EXTENSION TO MARINE TERMINAL 44-FOOT PROJECT DEPTH			MAIN SHIP CHANNEL DEEPENING EXTENSION TO MARINE TERMINAL 45-FOOT PROJECT DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$81,000	LS	LS	$81,000
Drilling & Blasting Plant	LS	LS	$189,000	LS	LS	$189,000
Rock Removal & Disposal Plant	LS	LS	$100,000	LS	LS	$100,000
Dredging and Ocean Disposal						
Ordinary Material	200,200	$16.36	$3,275,000	246,300	$14.22	$3,502,000
Ledge Drilling & Blasting	56,900	$103.11	$5,867,000	78,400	$91.80	$7,197,000
Ledge Removal & Disposal	56,900	$20.22	$1,151,000	78,400	$19.23	$1,508,000
Miscellaneous Costs			$71,000			$71,000
Subtotal - Before Contingency			$10,734,000			$12,648,000
Construction Contingency		22.4%	$2,404,000		22.4%	$2,833,000
Subtotal - Construction	257,100		$13,138,000	324,700		$15,481,000
Planning, Engineering & Design		2.7%	$353,000		2.4%	$367,000
Supervision & Administration		6.2%	$819,000		5.4%	$843,000
Resetting of Aids to Navigation			$24,000			$24,000
Real Estate			$15,000			$15,000
Total First Cost - July 2011 Prices		109%	$14,349,000		108%	$16,730,000
Program Year 2013 First Cost			$14,855,000			$17,324,000
PED Escalation	1.03779		$366,000	1.03779		$381,000
CM Escalation	1.03779		$850,000	1.03779		$875,000
Real Estate Escalation	1.03692		$16,000	1.03692		$16,000
Construction Escalation	1.03692		$13,623,000	1.03692		$16,052,000
ATON Escalation (USCG)	1.03692		$25,000	1.03692		$25,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$369,000	1.00843		$384,000
CM Escalation	1.12889		$960,000	1.12889		$988,000
Real Estate Escalation	1.05810		$17,000	1.05810		$17,000
Construction Escalation	1.05810		$14,415,000	1.05810		$16,985,000
Total Cost Escalated to Construction			$15,761,000			$18,374,000
ATON Escalation (USCG)	1.05810		$26,000	1.05810		$26,000

NOTES:

Ordinary Material - Plant for 44-Foot Plan = One 21 CY Bucket Dredge, 2 Tugs, 3 Scows, 1.39 Months Dredging Time, 1.04 Months Haul Time. Plant for 45-Ft Plan = One 21 CY Bucket Dredge, 2 Tugs, 3 Scows, 1.38 Months Dredging Time, 1.23 Months Haul Time.

Drilling and Blasting: Plant for 44 Feet = 2 Drill Boats, 1.54 Months. For 45 Feet = 2 Drill Boats, 1.90 Months.

Rock Removal: Plant for 44 Feet = One 21 CY Bucket Dredge with 14 CY Bucket, 3 Tugs, 4 Scows, 0.35 Months Excavation Time, 0.35 Months Haul Time. Plant for 45 Feet = One 21 CY Bucket Dredge with 14 CY Bucket, 3 Tugs, 4 Scows, 0.46 Months Excavation Time, 0.46 Months Haul Time.

Quantities for Ordinary Material Include a 2-Foot Allowable Overdepth (Dredging Tolerance) and 1/3 Side Slopes

Quantities in Rock Include an Additional 2-Foot Required Removal and a 2-Foot Allowable Overdepth and 1/1 Side Slopes

TABLE D2-19
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR NON-FEDERAL BERTH DEEPENING - PLAN D - MAIN SHIP CHANNEL EXTENSION

DEEPEN THE BERTH AT THE MASSPORT MARINE TERMINAL IN SOUTH BOSTON TO THE SAME DEPTH AS THE MAIN SHIP CHANNEL EXTENSION ABOVE THE RESERVED CHANNEL

July 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escalation Index Factors	PLAN D-42			PLAN D-43		
	MASSPORT MARINE TERMINAL 42-FOOT BERTH DEPTH			MASSPORT MARINE TERMINAL 43-FOOT BERTH DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization	LS	LS	$37,000	LS	LS	$37,000
Dredging and Ocean Disposal	29,400	$24.39	$717,000	44,100	$19.19	$846,000
Construction Contingency		22.4%	$169,000		22.4%	$198,000
Planning, Engineering & Design Costs			$8,000			$6,000
Construction Management Costs			$15,000			$13,000
Subtotal - Construction	29,400		$946,000	44,100		$1,100,000
Cost Escalated to Program Year 2013			$981,000			$1,141,000
Cost Escalated to Construction			$1,038,000			$1,207,000
PED Only Escalated			$9,000			$7,000

July 2011 Price Levels with Dec 2012 Contingency Adjustments & Oct 2012 Escalation Index Factors	PLAN D-44			PLAN D-45		
	MASSPORT MARINE TERMINAL 44-FOOT BERTH DEPTH			MASSPORT MARINE TERMINAL 45-FOOT BERTH DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization	LS	LS	$41,000	LS	LS	$41,000
Dredging and Ocean Disposal	58,800	$16.36	$962,000	73,500	$14.22	$1,045,000
Construction Contingency		22.4%	$225,000		22.4%	$243,000
Planning, Engineering & Design Costs			$6,000			$6,000
Construction Management Costs			$14,000			$13,000
Subtotal - Construction	58,800		$1,248,000	73,500		$1,348,000
Cost Escalated to Program Year 2013			$1,294,000			$1,398,000
Cost Escalated to Construction			$1,369,000			$1,479,000
PED Only Escalated			$7,000			$7,000

TABLE D2-20
PLAN D - MAIN SHIP CHANNEL DEEPENING EXTENSION
ANNUAL COSTS

EXTEND THE DEEPENING OF THE LOWER MAIN SHIP CHANNEL AT 600 FEET WIDE FROM ABOVE THE RESERVED CHANNEL TO BELOW THE TED WILLIAMS TUNNEL TO ACCESS THE MASSPORT MARINE TERMINAL IN SOUTH BOSTON

PLAN D - FEDERAL GNF			42 Feet	43 Feet	44 Feet	45 Feet
First Cost - July 2011			$7,858,000	$11,217,000	$14,349,000	$16,730,000
Construction Duration (Months)			3	3	4	4
IDC Rate			1.00318	1.00312	1.00467	1.00472
Implementation Cost (+ IDC)		0.003125	$7,883,000	$11,252,000	$14,416,000	$16,809,000
Interest & Amortization	3-3/4%	0.04457	$351,000	$502,000	$643,000	$749,000
Increased Annual Maintenance			$16,000	$15,000	$15,000	$15,000
Total Federal GNF Annual Cost			$367,000	$517,000	$658,000	$764,000
Interest & Amortization	7%	0.07245	$571,000	$815,000	$1,044,000	$1,218,000
Increased Annual Maintenance			$16,000	$15,000	$15,000	$15,000
Total Federal GNF Annual Cost			$587,000	$830,000	$1,059,000	$1,233,000
PLAN D - NON-FEDERAL BERTH (LSF)			**42 Feet**	**43 Feet**	**44 Feet**	**45 Feet**
First Cost - July 2011			$946,000	$1,100,000	$1,248,000	$1,348,000
Interest & Amortization	3-3/4%	0.04457	$42,000	$49,000	$56,000	$60,000
Increased Annual Maintenance			$5,000	$6,000	$6,000	$7,000
Total Non-Federal LSF Annual Cost			$47,000	$55,000	$62,000	$67,000
Interest & Amortization	7%	0.07245	$69,000	$80,000	$90,000	$98,000
Increased Annual Maintenance			$5,000	$6,000	$6,000	$7,000
Total Non-Federal LSF Annual Cost			$74,000	$86,000	$96,000	$105,000
PLAN D - TOTAL ANNUAL COST			**42 Feet**	**43 Feet**	**44 Feet**	**45 Feet**
Total Annual Cost - July 2011	3-3/4%		$414,000	$572,000	$720,000	$831,000
Total Annual Cost - July 2011	7%		$661,000	$916,000	$1,155,000	$1,338,000

DETAILED ESTMATES

MYSTIC RIVER CHANNEL DEEPENING TO ACCESS MASSPORT'S MEDFORD STREET TERMINAL – PLAN E

Project Description

The Mystic River Channel deepening is limited to a small 9-acre area of the 35-foot Federal channel lying between the 40-foot channel and Massport's 40-foot berth at the Medford Street Terminal in Charlestown. This area was not included in the last 40-foot deepening project (WRDA 1990) as that terminal's future use had not been determined. This plan is shown in Figure D2-4.

As Massport has already deepened their berth at the Medford Street Terminal to 40 feet, no local service facility costs are included with this plan. The deeper channel would enable larger bulk carriers to access the terminal.

The following tables provide detail estimates for the main channels improvements.

Table D2-21 shows the quantity estimates for this project feature by one-foot increments.

Table D2-22 shows the quantity estimates for maintenance material for this channel reach and the dredging area calculations for this project feature.

Table D2-23 shows the cost estimates for the 4 incremental depths for the Mystic River Channel improvement plan (Plan E).

Table D2-24 shows the annual costs of the 4 incremental depths.

Following these tables are the summary sheets from the contingency risk analyses for the recommended plan for the Mystic River Channel deepening to the Medford Street Terminal; the 40-foot project plan.

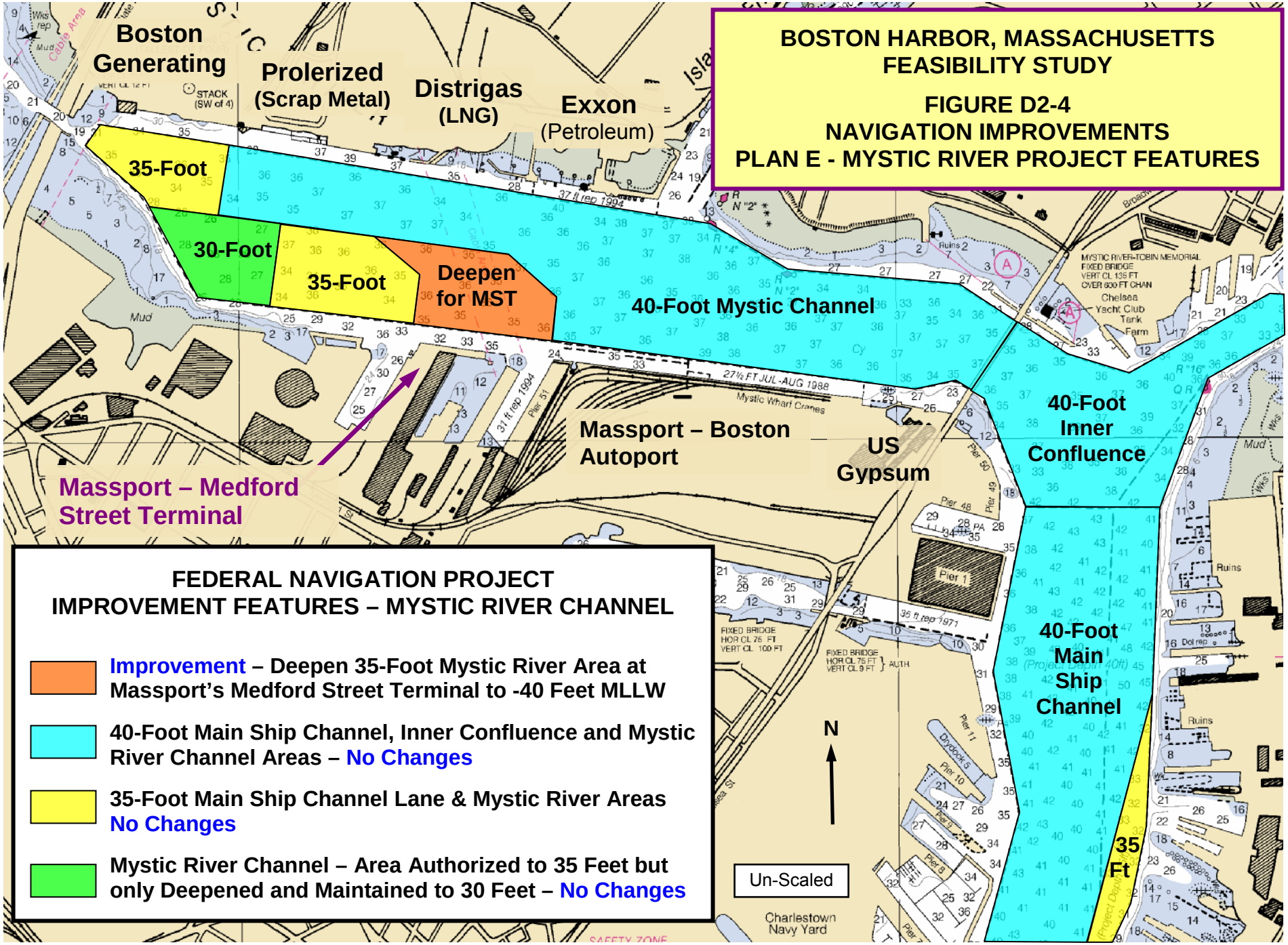

BOSTON HARBOR, MASSACHUSETTS
FEASIBILITY STUDY
FIGURE D2-4
NAVIGATION IMPROVEMENTS
PLAN E - MYSTIC RIVER PROJECT FEATURES
Boston Generating
Prolerized (Scrap Metal)
Distrigas (LNG)
Exxon (Petroleum)
35-Foot
30-Foot
35-Foot
Deepen for MST
40-Foot Mystic Channel
Massport – Boston Autoport
US Gypsum
40-Foot Inner Confluence
Massport – Medford Street Terminal
40-Foot Main Ship Channel
35 Ft
N
Un-Scaled
Charlestown Navy Yard
FEDERAL NAVIGATION PROJECT
IMPROVEMENT FEATURES – MYSTIC RIVER CHANNEL
Improvement – Deepen 35-Foot Mystic River Area at Massport's Medford Street Terminal to -40 Feet MLLW
40-Foot Main Ship Channel, Inner Confluence and Mystic River Channel Areas – No Changes
35-Foot Main Ship Channel Lane & Mystic River Areas No Changes
Mystic River Channel – Area Authorized to 35 Feet but only Deepened and Maintained to 30 Feet – No Changes

TABLE D2-21
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLAN E - MYSTIC RIVER CHANNEL AT MST

IMPROVEMENT DREDGING QUANTITIES FOR 37, 38, 39 AND 40 FOOT DEPTHS
DEEPEN THE AREA OF THE MYSTIC RIVER ALONG THE SOUTHERN CHANNEL LANE ADJACENT TO MASSPORT'S MEDFORD STREET TERMINAL TO DEPTHS GREATER THAN THE 35-FOOT EXISTING PROJECT DEPTH UP TO -40 FEET

Channel Improvement Design Depth	Ordinary Material			Ledge Removal - None Required in Mystic River				Total All Materials		
	Cut to Design Depth	2-Foot Overdepth	Total CY Ordinary	Cut to Design Depth	2-Foot Additional Required	2-Foot Overdepth	Total Rock CY	All Required Material	All Overdepth	Total All Material
37-Foot Depth	0	25,100	25,100	0	0	0	0	0	25,100	25,100
38-Foot Depth	12,200	26,300	38,500	0	0	0	0	12,200	26,300	38,500
39-Foot Depth	25,100	27,400	52,500	0	0	0	0	25,100	27,400	52,500
40-Foot Depth	38,500	28,600	67,100	0	0	0	0	38,500	28,600	67,100

TABLE D2-22
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
MAINTENANCE QUANTITY ESTIMATE AND DREDGING AREA ESTIMATES FOR ALTERANTIVE PLANS
PLAN E - MYSTIC RIVER CHANNEL AT MST

MAINTENANCE DREDGING QUANTITY
FOR MAINTENANCE DREDGING OF 35-FOOT CHANNEL AREA AT MEDFORD STREET TERMINAL

Channel Improvement Design Depth	Ordinary Material - 2007 Survey			Ledge Removal - None Required in Mystic River				Total All Materials		
	Cut to 35-Ft Design Depth	2-Foot Overdepth	Total CY Ordinary	Cut to Design Depth	2-Foot Additional Required	2-Foot Overdepth	Total Rock CY	All Required Material	All Overdepth	Total All Material
35-Foot Depth - Maintenance Over Improvement Area Only	5,500	19,200	24,700	0	0	0	0	5,500	19,200	24,700
35-Foot Depth - Maintenance of Larger Area from 2008 Specs Survey	10,000	30,600	40,600	0	0	0	0	10,000	30,600	40,600

Note: This material is scheduled to be removed in 2008-2009 as part of the Inner Harbor Maintenance project.

DREDGING AREAS FOR MYSTIC RIVER AT MEDFORD STREET TERMINAL

Dredge Areas by One-Foot Elevation (Including Side Slopes)			Dredging Areas for Alterantive Plans				
Square Feet	Acres	Elevation Feet MLLW	Channel Design Depth	Cut to Depth	2-Foot Overdepth	Total Square Feet	Total Acres
244,936	5.6	35 Feet	35-Foot Maintenance	244,936	86,630	331,566	7.6
307,483	7.1	36 Feet					
331,566	7.6	37 Feet	37-Foot Improvement	331,566	31,311	362,877	8.3
349,186	8.0	38 Feet	38-Foot Improvement	349,186	27,566	376,752	8.6
362,877	8.3	39 Feet	39-Foot Improvement	362,877	27,147	390,024	9.0
376,752	8.6	40 Feet	40-Foot Improvement	376,752	20,451	397,203	9.1
390,024	9.0	41 Feet					
397,203	9.1	42 Feet					

TABLE D2-23
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLAN E - MYSTIC RIVER CHANNEL

IMPROVEMENT DREDGING COSTS FOR 37, 38, 39 AND 40 FOOT DEPTHS
DEEPEN THE AREA OF THE MYSTIC RIVER ALONG THE SOUTHERN CHANNEL LANE
ADJACENT TO MASSPORT'S MEDFORD STREET TERMINAL
TO DEPTHS GREATER THAN THE 35-FOOT EXISTING PROJECT DEPTH UP TO -40 FEET

July 2011 Price Level with Dec 2012 Contingency Adjustments and Oct 2012 Cost Escalation	PLAN E-37			PLAN E-38		
	MYSTIC RIVER CHANNEL MEDFORD STREET TERMINAL AREA 37-FOOT PROJECT DEPTH			MYSTIC RIVER CHANNEL MEDFORD STREET TERMINAL AREA 38-FOOT PROJECT DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization	LS	LS	$86,000	LS	LS	$86,000
Dredging and Ocean Disposal						
Ordinary Material	25,100	$34.45	$865,000	38,500	$27.26	$1,050,000
Miscellaneous Costs			$26,000			$26,000
Subtotal - Before Contingency			$977,000			$1,162,000
Construction Contingency		23.5%	$230,000		23.5%	$273,000
Subtotal - Construction			$1,207,000			$1,435,000
Planning, Engineering & Design	13.92%		$168,000	11.71%		$168,000
Construction Management	21.71%		$262,000	18.40%		$264,000
Resetting of Aids to Navigation	None		$0	None		$0
Real Estate			$4,000			$4,000
Total First Cost - July 2011 Prices		136%	$1,641,000		130%	$1,871,000
Program Year 2013 First Cost			$1,702,000			$1,940,000
PED Escalation	1.03779		$174,000	1.03779		$174,000
CM Escalation	1.03779		$272,000	1.03779		$274,000
Real Estate Escalation	1.03692		$4,000	1.03692		$4,000
Construction Escalation	1.03692		$1,252,000	1.03692		$1,488,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$175,000	1.00843		$175,000
CM Escalation	1.03690		$282,000	1.03690		$284,000
Real Estate Escalation	1.01584		$4,000	1.01584		$4,000
Construction Escalation	1.01584		$1,272,000	1.01584		$1,512,000
Total Cost Escalated to Construction			$1,733,000			$1,975,000
NOTES:						
Ordinary Material Plant - Dredge	One 16 CY Bucket on 21 CY Dredge			One 16 CY Bucket on 21 CY Dredge		
Tugs	2			2		
Scows	3			3		
Dredging Time	0.36 Months			0.44 Months		
Hauling Time	0.30 Months			0.44 Months		
Quantities Include a 2-Foot Overdepth Allowance for Dredging Tolerance						

TABLE D2-23 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLAN E - MYSTIC RIVER CHANNEL

IMPROVEMENT DREDGING QUANTITIES FOR 37, 38, 39 AND 40 FOOT DEPTHS
DEEPEN THE AREA OF THE MYSTIC RIVER ALONG THE SOUTHERN CHANNEL LANE
ADJACENT TO MASSPORT'S MEDFORD STREET TERMINAL
TO DEPTHS GREATER THAN THE 35-FOOT EXISTING PROJECT DEPTH UP TO -40 FEET

July 2011 Price Level with Dec 2012 Contingency Adjustments and Oct 2012 Cost Escalation	PLAN E-39			PLAN E-40		
	MYSTIC RIVER CHANNEL MEDFORD STREET TERMINAL AREA 39-FOOT PROJECT DEPTH			MYSTIC RIVER CHANNEL MEDFORD STREET TERMINAL AREA 40-FOOT PROJECT DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization	LS	LS	$90,000	LS	LS	$90,000
Dredging and Ocean Disposal						
Ordinary Material	52,500	$22.81	$1,198,000	67,100	$21.14	$1,418,000
Miscellaneous Costs			$26,000			$26,000
Subtotal - Before Contingency			$1,314,000			$1,534,000
Construction Contingency		23.5%	$309,000		23.5%	$360,000
Subtotal - Construction			$1,623,000			$1,894,000
Planning, Engineering & Design	10.35%		$168,000	8.98%		$170,000
Construction Management	16.33%		$265,000	14.20%		$269,000
Resetting of Aids to Navigation	None		$0	None		$0
Real Estate			$4,000			$4,000
Total First Cost - July 2011 Prices		127%	$2,060,000		123%	$2,337,000
Program Year 2013 First Cost			$2,136,000			$2,423,000
PED Escalation	1.03779		$174,000	1.03779		$176,000
CM Escalation	1.03779		$275,000	1.03779		$279,000
Real Estate Escalation	1.03692		$4,000	1.03692		$4,000
Construction Escalation	1.03692		$1,683,000	1.03692		$1,964,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$175,000	1.00843		$177,000
CM Escalation	1.03690		$285,000	1.03690		$289,000
Real Estate Escalation	1.01584		$4,000	1.01584		$4,000
Construction Escalation	1.01584		$1,710,000	1.01584		$1,995,000
Total Cost Escalated to Construction		134%	$2,174,000		130%	$2,465,000

NOTES:		
Ordinary Material Plant - Dredge	One 16 CY Bucket on 21 CY Dredge	One 16 CY Bucket on 21 CY Dredge
Tugs	3	3
Scows	4	4
Dredging Time	0.40 Months	0.41 Months
Hauling Time	0.39 Months	0.47 Months
Quantities Include a 2-Foot Overdepth Allowance for Dredging Tolerance		

TABLE D2-24
PLAN E - MYSTIC RIVER CHANNEL
ANNUAL COSTS AND BENEFIT-COST ANALYSIS

DEEPEN THE AREA OF THE MYSTIC RIVER ALONG THE SOUTHERN CHANNEL LANE ADJACENT TO MASSPORT'S MEDFORD STREET TERMINAL TO DEPTHS GREATER THAN THE 35-FOOT EXISTING PROJECT DEPTH UP TO -40 FEET

PLAN E - FEDERAL GNF - MYSTIC RIVER			37 Feet	38 Feet	39 Feet	40 Feet
First Cost (July 2011 - without Escalation)			$1,641,000	$1,871,000	$2,060,000	$2,337,000
Construction Duration (Months)			1	1	1	1
IDC Rate			1.00000	1.00000	1.00000	1.00000
Implementation Cost (+ IDC)		0.003125	$1,641,000	$1,871,000	$2,060,000	$2,337,000
Interest & Amortization	3-3/4%	0.04457	$73,000	$83,000	$92,000	$104,000
Increased Annual Maintenance	10% or 16%		$12,000	$11,000	$10,000	$11,000
Total Federal GNF Annual Cost			$85,000	$94,000	$102,000	$115,000
Interest & Amortization	7%	0.07245	$119,000	$136,000	$149,000	$169,000
Increased Annual Maintenance	10% or 16%		$12,000	$11,000	$10,000	$11,000
Total Federal GNF Annual Cost			$131,000	$147,000	$159,000	$180,000

DETAILED ESTMATES

CHELSEA RIVER CHANNEL DEEPENING – PLAN F

Project Description

The Chelsea River Channel improvement would deepen the existing 38-foot channel to a depth of either 39 or 40 feet at mean lower low water (MLLW). This improvement is contingent on the completion of construction of the new Chelsea Street Bridge by the State, City and USCG, as currently underway, and the removal of the old highway span and appurtenant in-water works, and removal of the remaining debris, piles and counterweight from the former Grand Trunk Railroad Bridge immediately upstream of Chelsea Street. Replacement of the KeySpan gas line beneath the channel with a deep directional bore as cited in the 2008 Draft Final Feasibility Report was accomplished in 2008. Widening of the 38-foot existing channel to 175 feet (the current width between fenders at the McArdle Bridge) to take advantage of the new wider bridge opening at Chelsea Street is currently underway under O&M authority and scheduled to be completed in the 2011-2012 dredging season. As part if that ongoing work, temporary bulkheads were placed through the old Chelsea Street Bridge area to prevent vessel passage impacts on the remaining MWRA water line.

With the deepening improvement beyond the current 38 feet, whether or not further widening is accomplished in this area, the temporary bulkheads would need to be relocated. The presence of a second MWRA water tunnel downstream of the Chelsea Street Bridge, not identified at the time of the 2008 report, required additional investigations by the Corps and State. The cost of replacing this second water line, removing the old line, and relocating the temporary bulkheads, was estimated by State agencies at about $15 million including design efforts. Downstream of Chelsea Street the channel would be widened by 50 feet towards the East Boston shore in two locations to ease transit of larger tank ships: immediately upstream of the McArdle Bridge at the River's mouth, and in the bend between the two bridges.

The five beneficiary terminals, Eastern Minerals and the four upstream petroleum terminals would all need to deepen their berths to at least the same depth as the improve channel in order to benefit from the proposed improvements. This plan is shown in Figure D2-5.

The following tables provide detail estimates for the main channels improvements.

Table D2-25 shows the improvement quantity estimates for the two depths investigated for this project feature, and quantity estimates for maintenance of the channel.

Table D2-26 shows the dredging area calculations for maintenance and improvement material for this project feature.

Table D2-27 shows the detailed foot-by-foot incremental quantities and areas for the Chelsea River Channel (Plan F).

Table D2-28 shows the cost estimates for the two improvement depths examined and for non-Federal berth deepening.

Table D2-29 shows the annual costs of the two incremental depths and the non-Federal berth deepening.

Following these tables are the summary sheets from the contingency risk analyses for the recommended plan for the Chelsea River Channel deepening; the 40-foot project plan.

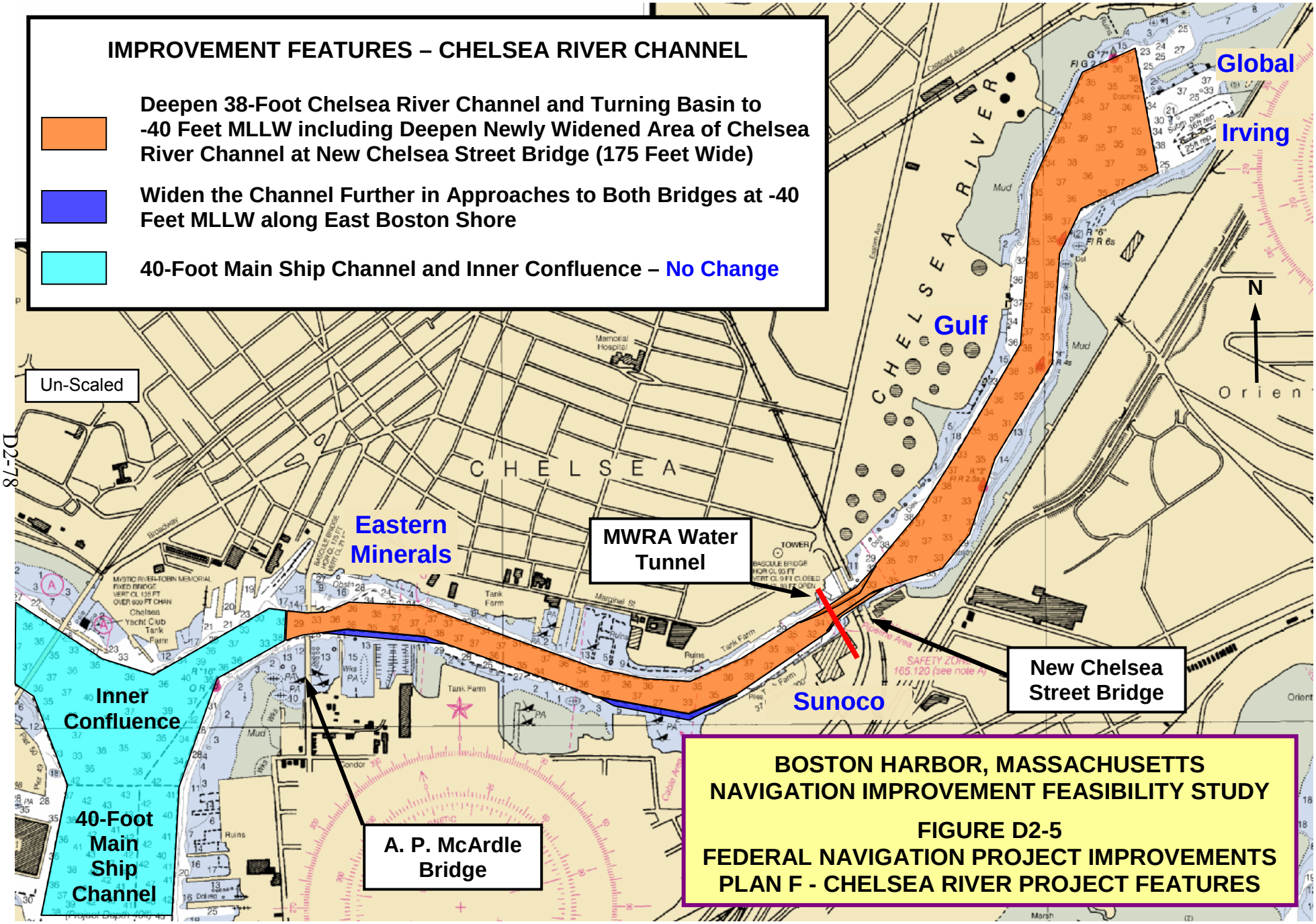

IMPROVEMENT FEATURES – CHELSEA RIVER CHANNEL
Deepen 38-Foot Chelsea River Channel and Turning Basin to -40 Feet MLLW including Deepen Newly Widened Area of Chelsea River Channel at New Chelsea Street Bridge (175 Feet Wide)
Widen the Channel Further in Approaches to Both Bridges at -40 Feet MLLW along East Boston Shore
40-Foot Main Ship Channel and Inner Confluence – No Change
Un-Scaled
Global
Irving
Gulf
Eastern Minerals
MWRA Water Tunnel
Sunoco
New Chelsea Street Bridge
Inner Confluence
40-Foot Main Ship Channel
A. P. McArdle Bridge
CHELSEA
CHELSEA RIVER
N
BOSTON HARBOR, MASSACHUSETTS
NAVIGATION IMPROVEMENT FEASIBILITY STUDY
FIGURE D2-5
FEDERAL NAVIGATION PROJECT IMPROVEMENTS
PLAN F - CHELSEA RIVER PROJECT FEATURES

TABLE D2-25
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLAN F - CHELSEA RIVER CHANNEL & BASIN

IMPROVEMENT DREDGING QUANTITIES FOR 39 AND 40 FOOT DEPTHS
ASSUMES WITHOUT-PROJECT REPLACEMENT OF THE CHELSEA STREET BRIDGE AND KEYSPAN GAS LINE BY OTHERS
WIDENING OF CHANNEL THROUGH NEW CHELSEA STREET BRIDGE OPENING ACCOMPLISHED UNDER O&M AUTHORITY
IMPROVEMENT INCLUDES CHANNEL WIDENING AT KEY TURNS AND BRIDGE APPROACHES

Channel Improvement Design Depth	Ordinary Material			Ledge Removal (Requires Added 2 Feet)				Total All Materials		
	Cut to Design Depth	2-Foot Overdepth Allowance	Total CY Ordinary	Cut to Design Depth	2-Foot Additional Required	2-Foot Overdepth Allowance	Total Rock CY	All Required Material	All Overdepth	Total All Material
39-Foot Depth	74,100	119,300	193,400	0	10	60	70	74,100	119,400	193,500
40-Foot Depth	80,200	262,400	342,600	0	50	490	540	80,200	262,900	343,100

MAINTENANCE DREDGING QUANTITY
FOR MAINTENANCE TO 38 FEET INCLUDING WIDENED CHANNEL AREA AT NEW CHELSEA STREET BRIDGE OPENING

Channel Maintenance to -38 Feet MLLW	Ordinary Material - From 2007 Survey as Adjusted from 2012 Afterdredge Survey of Chelsea Street Bridge Area			Ledge Removal - None Required for Chelsea O&M				Total All Materials		
	Cut to Design Depth	2-Foot Overdepth Allowance	Total CY Ordinary	Cut to Design Depth	2-Foot Additional Required	2-Foot Overdepth Allowance	Total Rock CY	All Required Material	All Overdepth	Total All Material
Pre-2012 Channel Limits	100,900	82,100	183,000	0	0	0	0	100,900	82,100	183,000
Widened Area at New Bridge	5,100	3,400	8,500	0	0	0	0	5,100	3,400	8,500
Total O&M	106,000	85,500	191,500	0	0	0	0	106,000	85,500	191,500

TABLE D2-26
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
DREDGING FOOTPRINT AREA ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS
PLAN F - CHELSEA RIVER CHANNEL & BASIN

Elevation MLLW	Rock Area		Total Dredge Area Incl. Ordinary Material		Improvement Plans		SF Area for Drill & Blast and Rock Removal (20% of 1st Foot of OD)	CY Rock Quantity Estimates by Elevation (Ft MLLW)	Quantity for Rock Overdepth Calculation	
	Square Feet	Acres Including Side Slopes	Square Feet	Acres Including Side Slopes	Plan and Channel Design Depth (MLLW)	Acres Including Side Slopes			Overdepth Elevation Increment	CY Rock Overdepth Quantity
-38	0	0.0	360,991	8.3				0		
-39	0	0.0	1,138,228	26.1	Plan F-39	66.9	785	0		
-40	0	0.0	2,358,789	54.2	Plan F-40	68.7	6,648	0		
-41	95	0.0	2,915,338	66.9				10	41 to 43	60
-42	3,546	0.1	2,992,237	68.7				50	42 to 44	490
-43	19,056	0.4						430		
-44	36,165	0.8						1,520		

Note: Drill & Blast Area and Rock Removal Area are limited to requried area plus 20% of the first foot of overdepth elevation foorprint.
Rock Calculations by R. Meader - March 2008, Checked by J. Garabedian

TABLE D2-27
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
QUANTITY AND AREA ESTIMATES FOR ORDINARY MATERIAL
ALTERANTIVE PLANS AND DEPTHS - PLAN F - CHELSEA RIVER CHANNEL & BASIN

AREAS BY ELEVATION BY FOOT AT MEAN LOWER LOW WATER

Elevation (Maintenance)	Dredging Quantities (CY)				Dredging Areas (SF)				Total Dredging Area	Acres
	Pre-2012 Channel Limits	Widening Area #1	Widening Area #2	Areas Widened to 175 Feet at New Cheslea Street Bridge	Pre-2012 Channel Limits	Widening Area #1	Widening Area #2	Areas Widened to 175 Feet at New Cheslea Street Bridge		
-38	126,326	26,241	41,931	5,062	232,510	36,363	32,493	59,625	360,991	8.3
-39	158,928	29,211	44,853	6,328	1,000,921	40,680	33,908	62,719	1,138,228	26.1
-40	214,644	32,405	47,821	8,524	2,218,129	41,719	33,908	65,033	2,358,789	54.2
-41	316,929	35,741	50,835	13,005	2,773,776	41,995	33,908	65,659	2,915,338	66.9
-42	453,253	39,059	53,876	19,666	2,850,675	41,995	33,908	65,659	2,992,237	68.7

Notes: Ordinary Material Calculations by A. Chin - December 2007, Except Bridge Area from 2012 Afterdredge Survey (R. Meader 2012)

TABLE D2-28
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLAN F - CHELSEA RIVER CHANNEL

IMPROVEMENT DREDGING COSTS FOR 39 AND 40 FOOT DEPTHS
IMPROVEMENT INCLUDES CHANNEL WIDENING AT KEY TURNS AND BRIDGE APPROACHES
ASSUMES WITHOUT-PROJECT REPLACEMENT OF THE CHELSEA STREET BRIDGE
AND KEYSPAN GAS LINE BY OTHERS AND WIDENING OF CHANNEL THROUGH
NEW CHELSEA STREET BRIDGE OPENING ACCOMPLISHED UNDER O&M AUTHORITY

July 2011 Price Levels with Dec 2012 Contingency Adjustments and Oct 2012 Cost Esclation	PLAN F-39			PLAN F-40		
	CHELSEA RIVER CHANNEL DEEPEN ENTIRE CHANNEL & BASIN 39-FOOT PROJECT DEPTH			CHELSEA RIVER CHANNEL DEEPEN ENTIRE CHANNEL & BASIN 40-FOOT PROJECT DEPTH		
First Cost of Construction	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization						
Ordinary Dredging & Disposal Plant	LS	LS	$82,000	LS	LS	$100,000
Drilling & Blasting Plant	LS	LS	$140,000	LS	LS	$142,000
Rock Removal & Disposal Plant	LS	LS	$89,000	LS	LS	$89,000
Dredging and Ocean Disposal						
Ordinary Material	193,400	$29.85	$5,773,000	342,600	$22.84	$7,825,000
Ledge Drilling & Blasting	70	$1,528.57	$107,000	540	$457.41	$247,000
Ledge Removal & Disposal	70	$166.00	$12,000	540	$44.26	$24,000
Miscellaneous Costs			$71,000			$71,000
Subtotal - Before Contingency			$6,274,000			$8,498,000
Construction Contingency		17.2%	$1,079,000		17.2%	$1,462,000
Subtotal - Construction	193,470		$7,353,000	343,140		$9,960,000
Planning, Engineering & Design		0.05222	$384,000		0.03956	$394,000
Construction Management		0.10894	$801,000		0.09639	$960,000
Resetting of Aids to Navigation			$48,000			$48,000
Real Estate			$15,000			$18,000
Total First Cost - July 2011 Prices		117%	$8,601,000		114%	$11,380,000
Program Year 2013 First Cost			$8,870,000			$11,753,000
PED Escalation	1.03779		$399,000	1.03779		$409,000
CM Escalation	1.03779		$831,000	1.03779		$997,000
Real Estate Escalation	1.03692		$16,000	1.03692		$19,000
Construction Escalation	1.03692		$7,624,000	1.03692		$10,328,000
ATON Escalation (USCG)	1.03692		$50,000	1.03692		$50,000
Fully Funded Cost Escalation						
PED Escalation	1.00843		$402,000	1.00843		$412,000
CM Escalation	1.02731		$854,000	1.03690		$1,034,000
Real Estate Escalation	1.01180		$16,000	1.01584		$19,000
Construction Escalation	1.01180		$7,714,000	1.01584		$10,492,000
Total Cost Escalated to Construction			$8,986,000			$11,957,000
ATON Escalation (USCG)	1.01180		$51,000	1.01584		$51,000

NOTES:

Ordinary Material: Plant = One 10 CY Bucket Dredge with 8 CY bucket. For 40-Foot Depth: 2 Tugs, 3 Scows, 4.38 Months Dredging Time, 3.4 Months Haul Time. For 39-Foot Depth: 1 Tug, 2 Scows, 4.1 Months Dredging Time, 4.25 Months Hauling Time.

Drilling and Blasting - Plant = 1 Drill Boat. For 39 Feet = 1 Day Drilling Time. For 40 Feet = 3 Days Drilling Time

Rock Removal - Plant = One 21 CY Bucket Dredge with a 14 CY bucket, One Tug, 2 Scows. For 39 Feet = 0.01 Months Excavation Time, 0.01 Months Haul Time. For 40 Feet = 0.02 Months Excavation Time, 0.02 Months Haul Time.

Quantities for Ordinary Material Include a 2-Foot Allowable Overdepth (Dredging Tolerance)

Quantities in Rock Include an Additional 2-Foot Required Removal and a 2-Foot Allowable Overdepth (Beneath the Required Footprint plus the 20% of the Area of One-Half the Overdepth Footprint to Account for Side Slopes and Overdrill)

TABLE D2-28 (Continued)
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY
COST ESTIMATES FOR ALTERANTIVE PLANS AND DEPTHS - PLAN F - CHELSEA RIVER CHANNEL

CHELSEA RIVER - ASSOCIATED NON-FEDERAL BERTH DEEPENING						
July 2011 Price Levels with Dec 2012 Contingency Adjustments and Oct 2012 Cost Esclation	PLAN F-39			PLAN F-40		
	CHELSEA RIVER CHANNEL 39-FOOT PROJECT DEPTH			CHELSEA RIVER CHANNEL 40-FOOT PROJECT DEPTH		
First Cost of Non-Federal Berths	Quantity (CY)	Unit Cost	Cost	Quantity (CY)	Unit Cost	Cost
Mobilization/Demobilization			$41,000			$50,000
Dredging and Ocean Disposal - 5 Berths	20,500	$35.79	$734,000	41,000	$26.66	$1,093,000
Construction Contingency		17%	$116,000		17%	$171,000
LSF Planning, Engineering & Design			$47,000			$52,000
LSF Construction Management			$97,000			$127,000
Total First Cost LSF - July 2011 Prices			$1,035,000			$1,493,000
LSF Cost Escalated to Program Year 2013			$1,073,000			$1,548,000
LSF PED Escalated to PY2013			$49,000			$54,000
LSF Construction Escalated to PY2013			$1,024,000			$1,494,000
Fully Funded LSF Cost Escalation	1.01180		$1,086,000	1.01584		$1,573,000
LSF PED Escalated to Design Mid-Point			$50,000			$55,000
LSF Construction Escalated to Mid-Point			$1,036,000			$1,518,000

TABLE D2-29
PLAN F - CHELSEA RIVER CHANNEL
ANNUAL COST AND BENEFIT COST ANALYSIS

DEEPEN THE EXISTING 38-FOOT CHELSEA RIVER CHANNEL AND TURNING BASIN TO 39 OR 40 FEET WITH MINOR WIDENING IN CRITICAL BENDS AND BRIDGE APPROACHES

ASSUMES NEW CHELSEA STREET BRIDGE COMPLETED UNDER THE WITHOUT PROJECT CONDITION AND BULKHEAD AND UTILITY RELOCATION BY OTHERS UNDER THE WITH-PROJECT CONDITION AND CHANNEL WIDENING THORUGH THE BRIDGE AT 38 FEET UNDER O&M AUTHORITY

PLAN F - FEDERAL GNF			39 Feet	40 Feet
First Cost (July 2011 - without Escalation)			$8,601,000	$11,380,000
Construction Duration (Months)			4	5
IDC Rate			1.00465	1.00624
Implementation Cost (+ IDC)		0.0031250	$8,641,000	$11,451,000
Interest & Amortization	3-3/4%	0.04457	$385,000	$510,000
Increased Annual Maintenance			$57,000	$51,000
Total Federal GNF Annual Cost			$442,000	$561,000
Interest & Amortization	7%	0.07245	$626,000	$830,000
Increased Annual Maintenance			$57,000	$51,000
Total Federal GNF Annual Cost			$683,000	$881,000

PLAN F - TERMINAL BERTHS (Local Service Facilities)			39 Feet	40 Feet
First Cost (July 2011 - without Escalation)			$1,035,000	$1,493,000
Interest & Amortization	3-3/4%	0.04457	$46,000	$67,000
Increased Annual Maintenance	5% or 6%		$52,000	$90,000
Total Non-Federal LSF Annual Cost			$98,000	$157,000
Interest & Amortization	7%	0.07245	$75,000	$108,000
Increased Annual Maintenance			$52,000	$75,000
Total NF LSF Annual Cost			$127,000	$183,000

PLAN F - TOTAL ANNUAL COSTS		39 Feet	40 Feet
Total Annual Cost - July 2011	3-3/4%	$540,000	$718,000
Total Annual Cost - July 2011	7%	$1,897,000	$1,064,000

PROJECT CONSTRUCTION SCHEDULE
AND CONSTRUCTION TIMELINES FOR ALTERANTIVE PLANS

Table D2-30 – Detailed Project Construction Schedule for Alternative Plans
- 30A –Including 45-Foot Main Channels Improvement with 49-Foot Entrance Channel
- 30B –Including 46-Foot Main Channels Improvement with 48 or 50-Foot Entrance
- 30C –Including 47-Foot Main Channels Improvement with 49, 50, 51 or 52-Ft Entrance
- 30D –Including 48-Foot Main Channels Improvement with 50 or 52-Foot Entrance
- 30E –Including 49-Foot Main Channels Improvement with 51-Foot Entrance Channel

Table D2-31 – Construction Timelines for the Nine Original Alternative Depth Increments – In 2 Pages

TABLE D2-30A (Page 1 of 1) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 45/49-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN A2 - MAIN CHANNELS IMPROVEMENT - 45/49 FEET	28					1					June 2015	July 2016
Broad Sound North Entrance Channel - 49 Feet	15											
Dredging and Disposal - Ordinary Material		2	4	6			10	10	4.94 MO	5.03 MO	Nov 2014	June 2015
Drill and Blast Ledge					2			25		12.30 MO		
Rock Removal and Disposal		2	4	6			3	4	1.72 MO	1.81 MO		
President Roads Anchorage - 46 Feet	10										March 2015	July 2015
Dredging and Disposal - Ordinary Material		2	5	7			12	11	6.17 MO	5.43 MO		
Drill and Blast Ledge					2			2		1.10 MO		
Rock Removal and Disposal		1	3	4			1	1	0.25 MO	0.30 MO		
Main Ship Channel - Roads to Reserved Channel - 46 Feet	5										Feb 2016	July 2016
Dredging and Disposal - Ordinary Material		2	3	5			10	9	5.14 MO	4.54 MO		
Drill and Blast Ledge					2			3		1.30 MO		
Rock Removal and Disposal		1	2	3			1	1	0.31 MO	0.39 MO		
Lower Reserved Channel and Turning Area - 46 Feet	5										Oct 2015	April 2016
Dredging and Disposal - Ordinary Material		2	3	5			5	4	2.32 MO	2.14 MO		
Drill and Blast Ledge					2			5		1.30 MO		
Rock Removal and Disposal		1	2	3			1	1	0.21 MO	0.26 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4										Sept 2016	Oct 2016
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO		
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			0	0	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1										Sept 2014	Sept 2014
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO		
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5										July 2014	Aug 2014
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO		
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS A2-D-E-F	34											

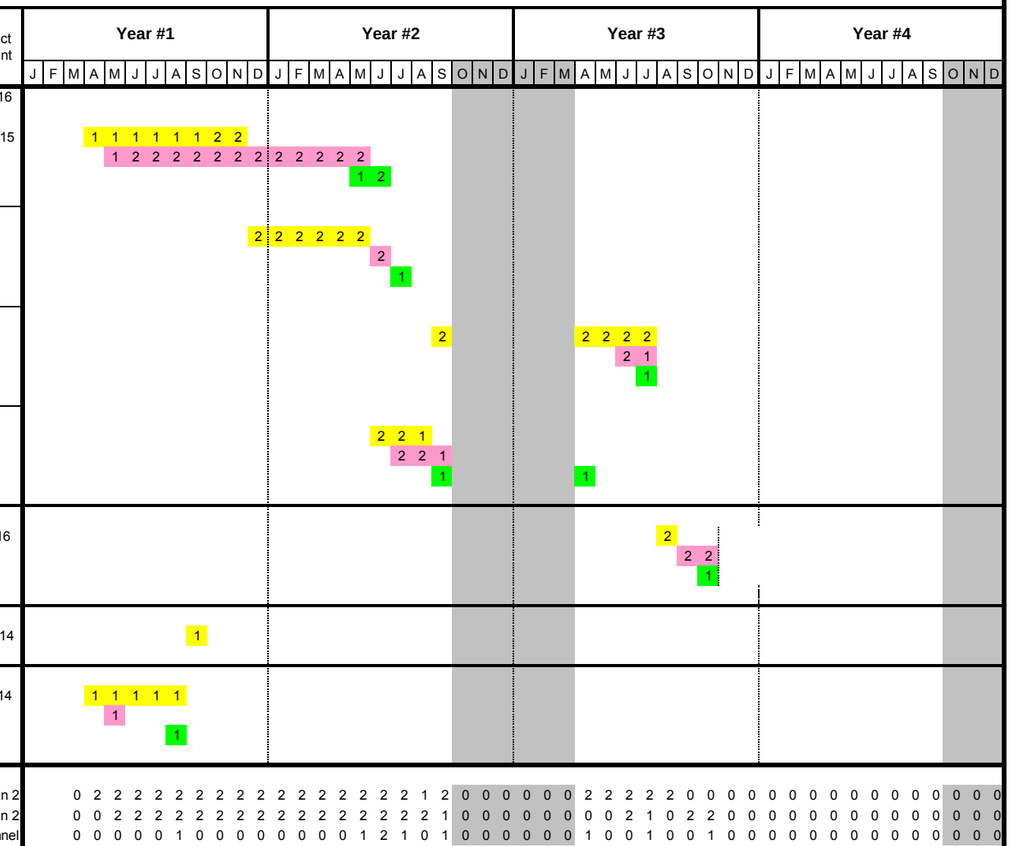


TABLE D2-30B (Page 1 of 2) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 46/48-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN A2 - MAIN CHANNELS IMPROVEMENT - 46/48 FEET	31					1					June 2015	July 2016
Broad Sound North Entrance Channel - 48 Feet	17											
Dredging and Disposal - Ordinary Material		2	4	6			10	9	4.82 MO	4.36 MO	Oct 2014	April 2015
Drill and Blast Ledge					2			20		10.10 MO		
Rock Removal and Disposal		2	4	6			3	3	1.38 MO	1.46 MO		
President Roads Anchorage - 46 Feet	10										March 2015	June 2015
Dredging and Disposal - Ordinary Material		2	5	7			13	14	6.34 MO	6.77 MO		
Drill and Blast Ledge					2			3		1.30 MO		
Rock Removal and Disposal		1	3	4			1	1	0.31 MO	0.37 MO		
Main Ship Channel - Roads to Reserved Channel - 46 Feet	8										Feb 2016	July 2016
Dredging and Disposal - Ordinary Material		2	3	5			11	11	5.48 MO	5.62 MO		
Drill and Blast Ledge					2			5		2.53 MO		
Rock Removal and Disposal		1	2	3			1	1	0.40 MO	0.33 MO		
Lower Reserved Channel and Turning Area - 46 Feet	9										Dec 2015	May 2016
Dredging and Disposal - Ordinary Material		2	3	5			5	5	2.33 MO	2.53 MO		
Drill and Blast Ledge					2			5		2.23 MO		
Rock Removal and Disposal		1	2	3			1	1	0.39 MO	0.49 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4										Sept 2016	Oct 2016
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO		
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			0	0	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1										Sept 2014	Sept 2014
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO		
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5										July 2014	Aug 2014
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO		
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS A2-D-E-F	34											

Dredging and Disposal - Ordinary Material (1 Plant Only)
Drill and Blast Ledge (1 Plant Only)
Rock Removal and Disposal (1 Plant Only)

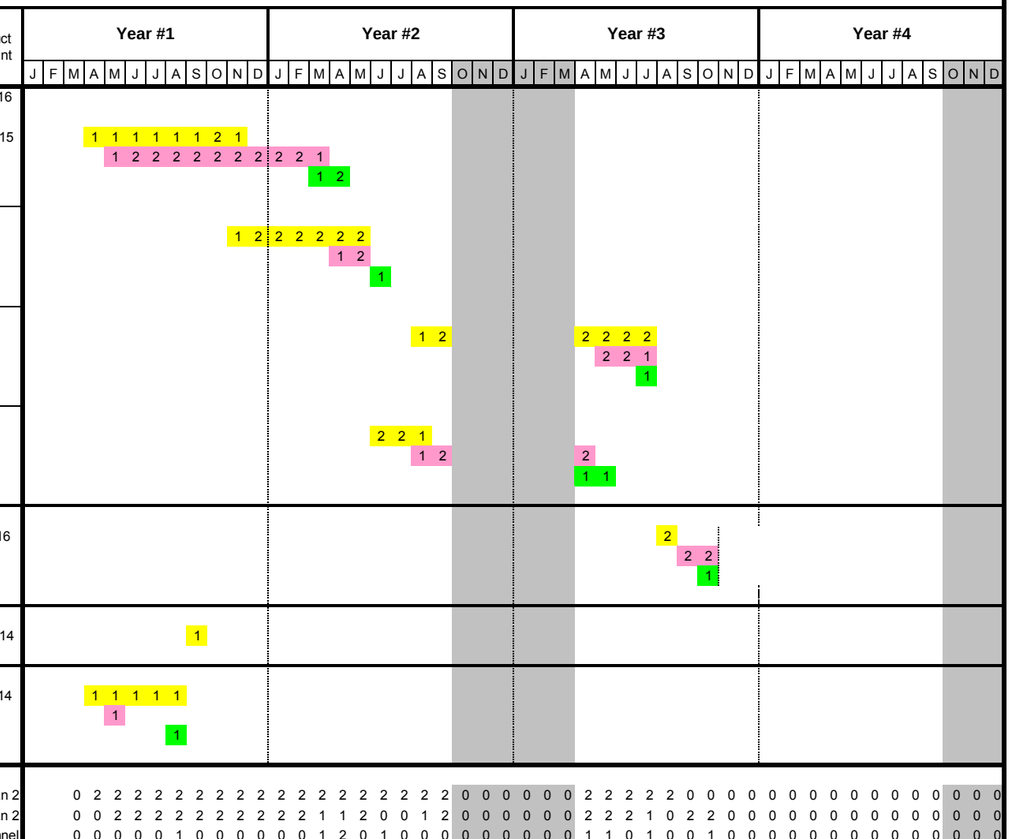
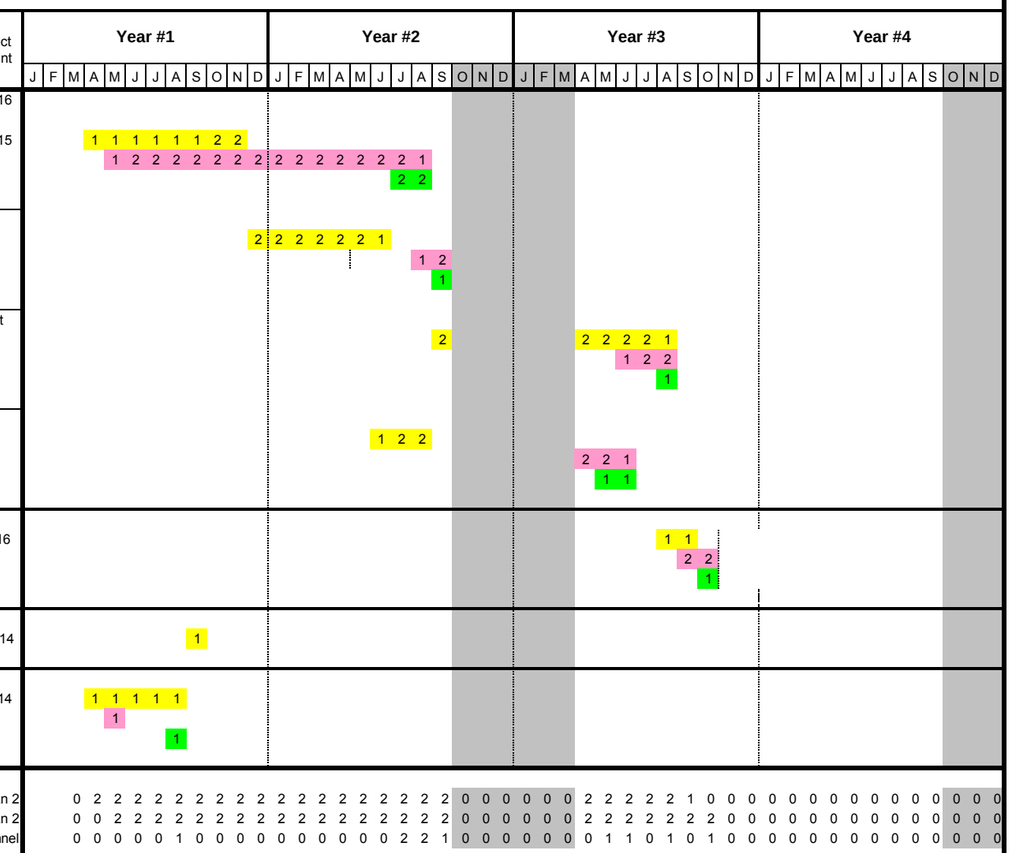


TABLE D2-30B (Page 2 of 2) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 46/50-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN A2 - MAIN CHANNELS IMPROVEMENT - 46/50 FEET	29					1					June 2015	Aug 2016
Broad Sound North Entrance Channel - 50 Feet	17											
Dredging and Disposal - Ordinary Material		2	4	6			10	9	5.20 MO	4.61 MO	Dec 2014	Aug 2015
Drill and Blast Ledge					2			30		15.20 MO		
Rock Removal and Disposal		2	4	6			4	4	2.06 MO	2.18 MO		
President Roads Anchorage - 46 Feet	10										March 2015	Sept 2015
Dredging and Disposal - Ordinary Material		2	5	7			13	14	6.34 MO	6.77 MO		
Drill and Blast Ledge					2			3		1.30 MO		
Rock Removal and Disposal		1	3	4			1	1	0.31 MO	0.37 MO		
Main Ship Channel - Roads to Reserved Channel - 46 Feet	8										Feb 2016	August 2016
Dredging and Disposal - Ordinary Material		2	3	5			11	11	5.48 MO	5.62 MO		
Drill and Blast Ledge					2			5		2.53 MO		
Rock Removal and Disposal		1	2	3			1	1	0.40 MO	0.33 MO		
Lower Reserved Channel and Turning Area - 46 Feet	9										Dec 2015	June 2016
Dredging and Disposal - Ordinary Material		2	3	5			5	5	2.33 MO	2.53 MO		
Drill and Blast Ledge					2			5		2.23 MO		
Rock Removal and Disposal		1	2	3			1	1	0.39 MO	0.49 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4										Sept 2016	Oct 2016
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO		
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			0	0	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1										Sept 2014	Sept 2014
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO		
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5										July 2014	Aug 2014
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO		
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS A2-D-E-F	34											

Dredging and Disposal - Ordinary Material (1 Plant Only)
Drill and Blast Ledge (1 Plant Only)
Rock Removal and Disposal (1 Plant Only)



Dredge Plants (Two 21 CY Dredges, 5 Tugs & 7 Scows)

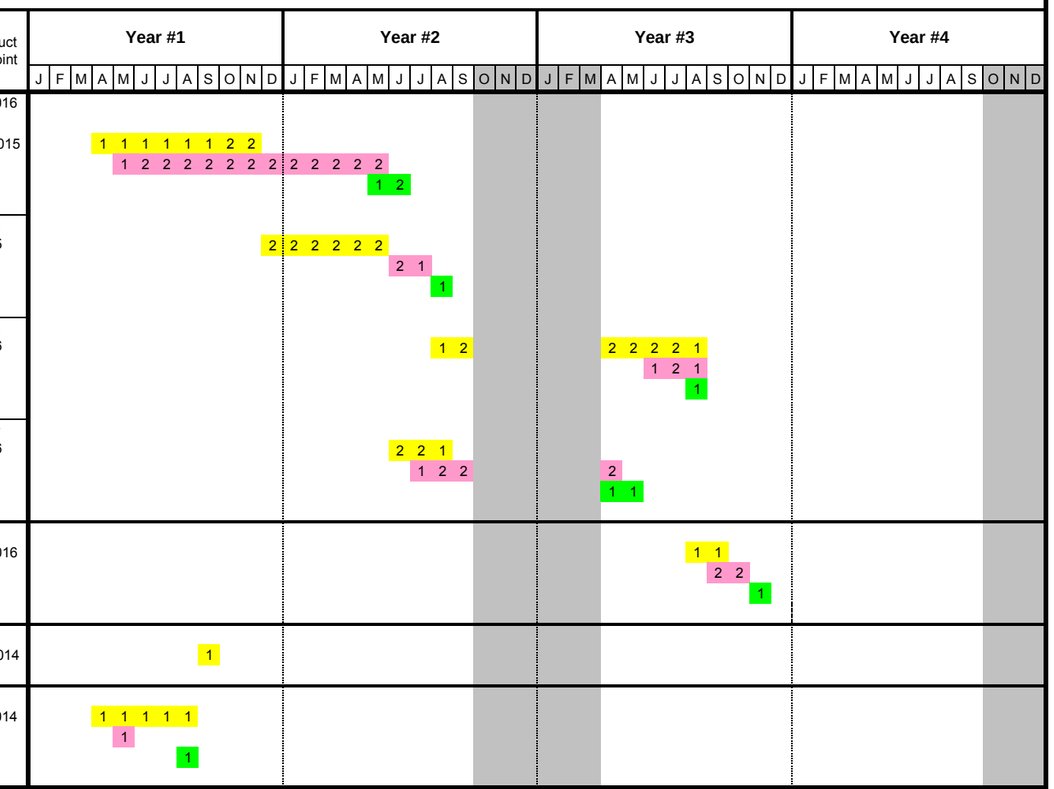
Drill & Blast Plant (2 Drill Barges, Blast Barge, Small Tug)

Rock Removal Plants (21 CY Buckets)

TABLE D2-30C (Page 1 of 4) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 47/49-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN A3 - MAIN CHANNELS IMPROVEMENT - 47/49 FEET	31					1					June 2015	Aug 2016
Broad Sound North Entrance Channel - 49 Feet	17											
Dredging and Disposal - Ordinary Material		2	4	6			10	10	4.94 MO	5.03 MO	Nov 2014	June 2015
Drill and Blast Ledge					2			25		12.30 MO		
Rock Removal and Disposal		2	4	6			3	4	1.72 MO	1.81 MO		
President Roads Anchorage - 47 Feet	10										April 2015	Aug 2015
Dredging and Disposal - Ordinary Material		2	4	6			12	13	6.10 MO	6.37 MO		
Drill and Blast Ledge					2			3		1.50 MO		
Rock Removal and Disposal		1	2	3			1	1	0.37 MO	0.44 MO		
Main Ship Channel - Roads to Reserved Channel - 47 Feet	8										Feb 2016	Aug 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	10	5.92 MO	5.10 MO		
Drill and Blast Ledge					2			4		2.00 MO		
Rock Removal and Disposal		1	3	4			1	1	0.50 MO	0.41 MO		
Lower Reserved Channel and Turning Area - 47 Feet	9										Dec 2015	May 2016
Dredging and Disposal - Ordinary Material		2	4	6			5	4	2.32 MO	2.18 MO		
Drill and Blast Ledge					2			7		3.27 MO		
Rock Removal and Disposal		1	2	3			2	2	0.61 MO	0.77 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4											
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO	Sept 2016	Nov 2016
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			1	1	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1											
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO	Sept 2014	Sept 2014
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5											
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO	July 2014	Aug 2014
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS A2-D-E-F	34											
Dredging and Disposal - Ordinary Material (1 Plant Only)											Total Never More than 2	
Drill and Blast Ledge (1 Plant Only)											Total Never More than 2	
Rock Removal and Disposal (1 Plant Only)											Total Never More than 1 Except for Entrance Channel	



Dredge Plants (Two 21 CY Dredges, 5 Tugs & 7 Scows)

Drill & Blast Plant (2 Drill Barges, Blast Barge, Small Tug)

Rock Removal Plants (21 CY Buckets)

TABLE D2-30C (Page 2 of 4) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 47/50-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN A3 - MAIN CHANNELS IMPROVEMENT - 47/50 FEET	30					1					June 2015	Sept 2016
Broad Sound North Entrance Channel - 50 Feet	17											
Dredging and Disposal - Ordinary Material		2	4	6			10	9	5.20 MO	4.61 MO	Dec 2014	Aug 2015
Drill and Blast Ledge					2			30		15.20 MO		
Rock Removal and Disposal		2	4	6			4	4	2.06 MO	2.18 MO		
President Roads Anchorage - 47 Feet	10										April 2015	Sept 2015
Dredging and Disposal - Ordinary Material		2	4	6			12	13	6.10 MO	6.37 MO		
Drill and Blast Ledge					2			3		1.50 MO		
Rock Removal and Disposal		1	2	3			1	1	0.37 MO	0.44 MO		
Main Ship Channel - Roads to Reserved Channel - 47 Feet	12										Nov 2015	May 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	10	5.92 MO	5.10 MO		
Drill and Blast Ledge					2			4		2.00 MO		
Rock Removal and Disposal		1	3	4			1	1	0.50 MO	0.41 MO		
Lower Reserved Channel and Turning Area - 47 Feet	6										July 2016	Sept 2016
Dredging and Disposal - Ordinary Material		2	4	6			5	4	2.32 MO	2.18 MO		
Drill and Blast Ledge					2			7		3.27 MO		
Rock Removal and Disposal		1	2	3			2	2	0.61 MO	0.77 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4											
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO	Sept 2016	Nov 2016
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			1	1	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1											
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO	Sept 2014	Sept 2014
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5											
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO	July 2014	Aug 2014
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS A2-D-E-F	34											

Dredging and Disposal - Ordinary Material (1 Plant Only) — Total Never More than 2
Drill and Blast Ledge (1 Plant Only) — Total Never More than 2
Rock Removal and Disposal (1 Plant Only) — Total Never More than 1 Except for Entrance Channel

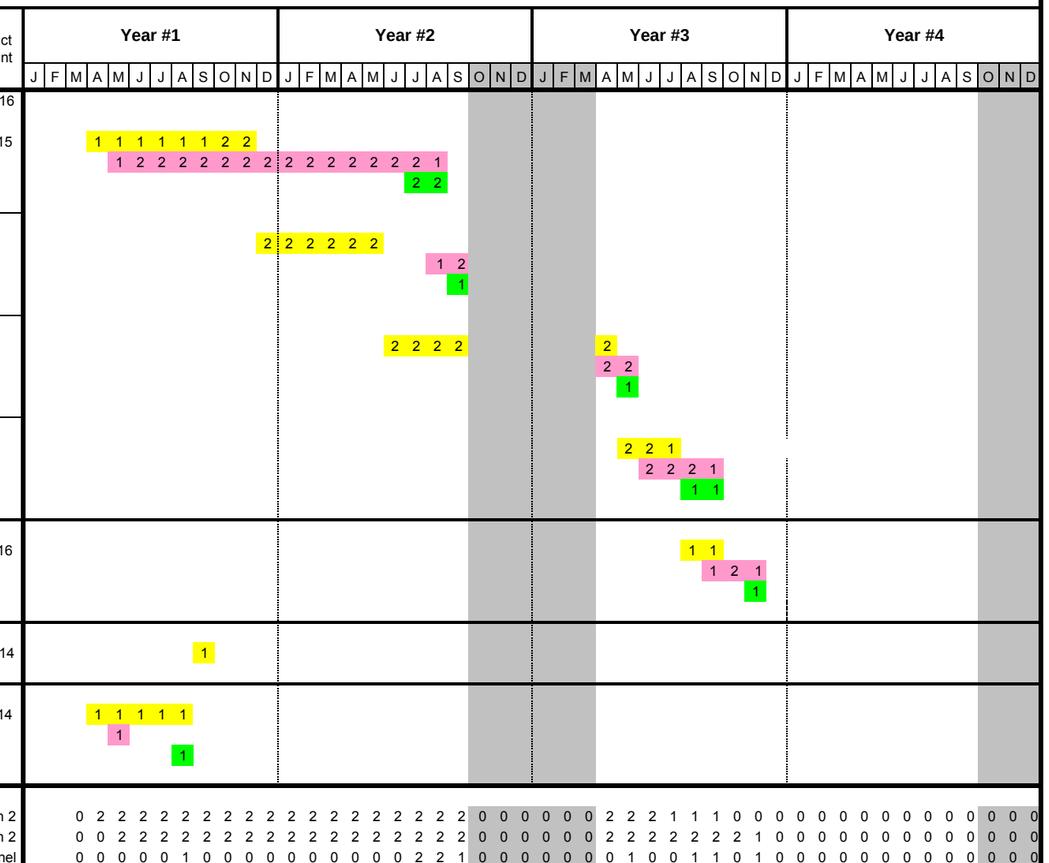
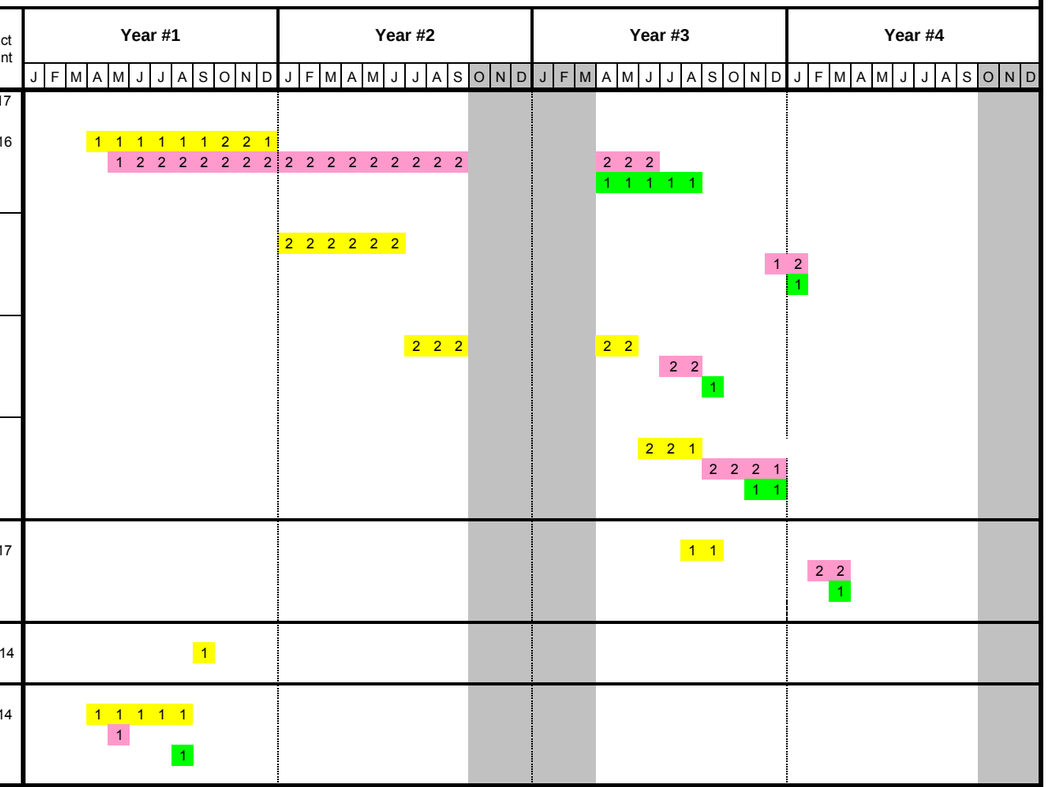


TABLE D2-30C (Page 3 of 4) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 47/51-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN A3 - MAIN CHANNELS IMPROVEMENT - 47/51 FEET	34					1					Aug2015	Jan 2017
Broad Sound North Entrance Channel - 51 Feet	17											
Dredging and Disposal - Ordinary Material		2	4	6			11	10	5.36 MO	5.19 MO	May 2015	July 2016
Drill and Blast Ledge					2			36		18.20 MO		
Rock Removal and Disposal		2	4	6			5	5	2.41 MO	2.59 MO		
President Roads Anchorage - 47 Feet	10										Oct 2015	Aug 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	13	6.10 MO	6.37 MO		
Drill and Blast Ledge					2			3		1.50 MO		
Rock Removal and Disposal		1	2	3			1	1	0.37 MO	0.44 MO		
Main Ship Channel - Roads to Reserved Channel - 47 Feet	12										Feb 2016	Oct 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	10	5.92 MO	5.10 MO		
Drill and Blast Ledge					2			4		2.00 MO		
Rock Removal and Disposal		1	3	4			1	1	0.50 MO	0.41 MO		
Lower Reserved Channel and Turning Area - 47 Feet	6										Sept 2016	Jan 2017
Dredging and Disposal - Ordinary Material		2	4	6			5	4	2.32 MO	2.18 MO		
Drill and Blast Ledge					2			7		3.27 MO		
Rock Removal and Disposal		1	2	3			2	2	0.61 MO	0.77 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4											
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO	Nov 2016	Mar 2017
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			1	1	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1											
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO	Sept 2014	Sept 2014
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5											
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO	July 2014	Aug 2014
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS A2-D-E-F	34											
Dredging and Disposal - Ordinary Material (1 Plant Only)											Total Never More than 2	
Drill and Blast Ledge (1 Plant Only)											Total Never More than 2	
Rock Removal and Disposal (1 Plant Only)											Total Never More than 1 Except for Entrance Channel	



	Year #1	Year #2	Year #3	Year #4
Dredging and Disposal - Ordinary Material (1 Plant Only)	0 2 2 2 2 2 2 2 2 1	2 2 2 2 2 2 2 2 2 2	0 0 0 0 0 0	2 2 2 2 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Drill and Blast Ledge (1 Plant Only)	0 0 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2	0 0 0 0 0 0	2 2 2 2 2 2 2 2 2 2 2 2 0 0 0 0 0 0 0 0 0 0 0 0
Rock Removal and Disposal (1 Plant Only)	0 0 0 0 0 1 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0	1 1 1 1 1 1 0 1 1 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0

Dredge Plants (Two 21 CY Dredges, 5 Tugs & 7 Scows)

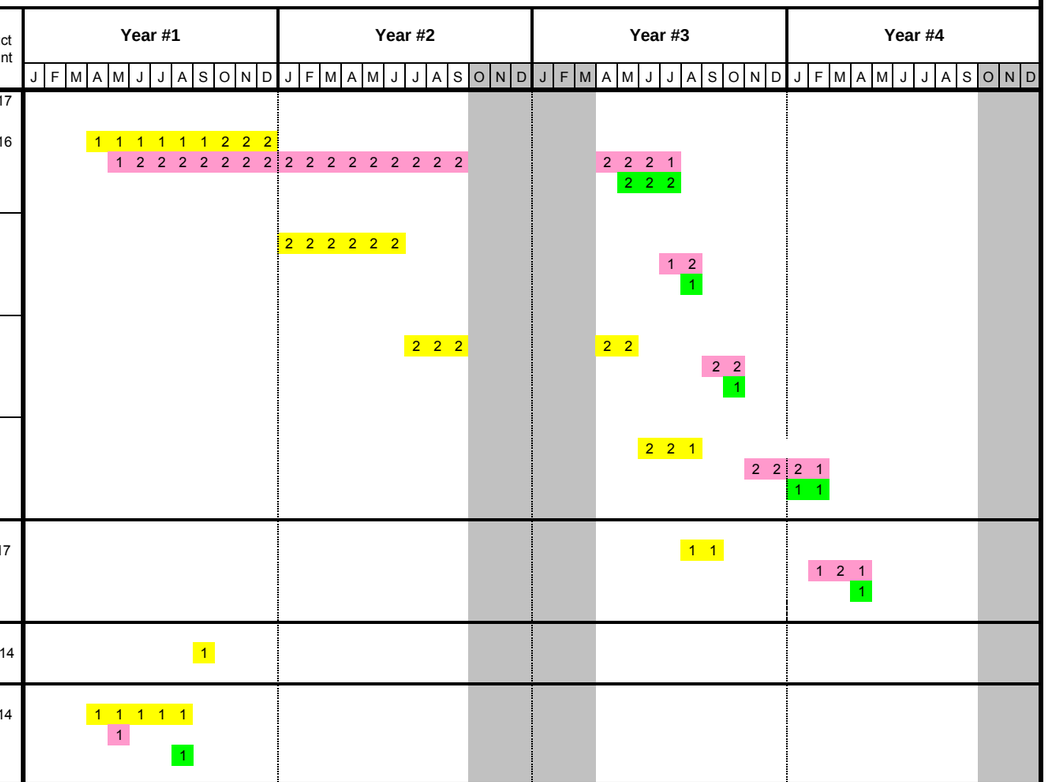
Drill & Blast Plant (2 Drill Barges, Blast Barge, Small Tug)

Rock Removal Plants (21 CY Buckets)

TABLE D2-30C (Page 4 of 4) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 47/52-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN A3 - MAIN CHANNELS IMPROVEMENT - 47/52 FEET	35					1					Sept 2015	Feb 2017
Broad Sound North Entrance Channel - 52 Feet	28											
Dredging and Disposal - Ordinary Material		2	4	6			11	12	5.53 MO	5.79 MO	May 2015	July 2016
Drill and Blast Ledge					2			40		19.90 MO		
Rock Removal and Disposal		2	4	6			5	6	2.78 MO	2.93 MO		
President Roads Anchorage - 47 Feet	20										Oct 2015	Aug 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	13	6.10 MO	6.37 MO		
Drill and Blast Ledge					2			3		1.50 MO		
Rock Removal and Disposal		1	2	3			1	1	0.37 MO	0.44 MO		
Main Ship Channel - Roads to Reserved Channel - 47 Feet	16										Feb 2016	Oct 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	10	5.92 MO	5.10 MO		
Drill and Blast Ledge					2			4		2.00 MO		
Rock Removal and Disposal		1	3	4			1	1	0.50 MO	0.41 MO		
Lower Reserved Channel and Turning Area - 47 Feet	9										Oct 2016	Feb 2017
Dredging and Disposal - Ordinary Material		2	4	6			5	4	2.32 MO	2.18 MO		
Drill and Blast Ledge					2			7		3.27 MO		
Rock Removal and Disposal		1	2	3			2	2	0.61 MO	0.77 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	9											
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO	Dec 2016	Apr 2017
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			1	1	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1											
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO	Sept 2014	Sept 2014
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5											
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO	July 2014	Aug 2014
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS A2-D-E-F	34											
Dredging and Disposal - Ordinary Material (1 Plant Only)											Total Never More than 2	
Drill and Blast Ledge (1 Plant Only)											Total Never More than 2	
Rock Removal and Disposal (1 Plant Only)											Total Never More than 1 Except for Entrance Channel	



	Year #1	Year #2	Year #3	Year #4
Dredging and Disposal - Ordinary Material (1 Plant Only)	0 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 1 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
Drill and Blast Ledge (1 Plant Only)	0 0 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 1 0	0 0 0 0 0 0 0 0 0 0 0 0
Rock Removal and Disposal (1 Plant Only)	0 0 0 0 0 1 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 2 2 2 1 0 1 0 0 1 1 0	1 0 0 0 0 0 0 0 0 0 0 0

Dredge Plants (Two 21 CY Dredges, 5 Tugs & 7 Scows)

Drill & Blast Plant (2 Drill Barges, Blast Barge, Small Tug)

Rock Removal Plants (21 CY Buckets)

TABLE D2-30D (Page 1 of 2) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 48/50-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN B1 - MAIN CHANNELS IMPROVEMENT - 48/50 FEET	31					1					July 2015	Oct 2016
Broad Sound North Entrance Channel - 50 Feet	17											
Dredging and Disposal - Ordinary Material		2	4	6			10	9	5.20 MO	4.61 MO	Dec 2014	Aug 2015
Drill and Blast Ledge					2			30		15.20 MO		
Rock Removal and Disposal		2	4	6			4	4	2.06 MO	2.18 MO		
President Roads Anchorage - 48 Feet	10										April 2015	Sept 2015
Dredging and Disposal - Ordinary Material		2	5	7			13	11	6.40 MO	5.70 MO		
Drill and Blast Ledge					2			3		1.70 MO		
Rock Removal and Disposal		1	2	3			1	1	0.44 MO	0.52 MO		
Main Ship Channel - Roads to Reserved Channel - 48 Feet	8										March 2016	Oct 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	12	6.11 MO	6.01 MO		
Drill and Blast Ledge					2			5		2.53 MO		
Rock Removal and Disposal		1	3	4			1	1	0.63 MO	0.52 MO		
Lower Reserved Channel and Turning Area - 48 Feet	9										Feb 2016	Sept 2016
Dredging and Disposal - Ordinary Material		2	4	6			5	5	2.50 MO	2.45 MO		
Drill and Blast Ledge					2			9		4.51 MO		
Rock Removal and Disposal		1	2	3			1	1	0.90 MO	1.12 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4											
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO	Nov 2016	Dec 2016
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			1	1	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1											
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO	Sept 2014	Sept 2014
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5											
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO	July 2014	Aug 2014
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS B1-D-E-F	34											

Dredging and Disposal - Ordinary Material (1 Plant Only) — Total Never More than 2
Drill and Blast Ledge (1 Plant Only) — Total Never More than 2
Rock Removal and Disposal (1 Plant Only) — Total Never More than 1 Except for Entrance Channel

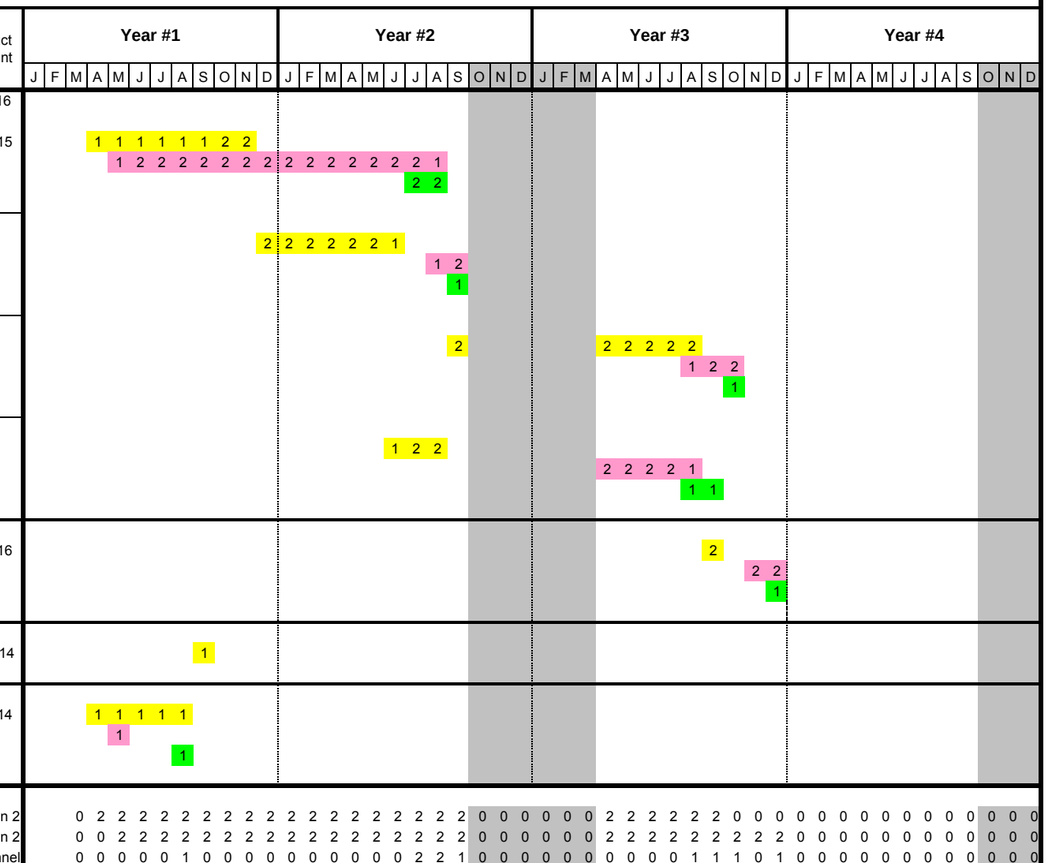
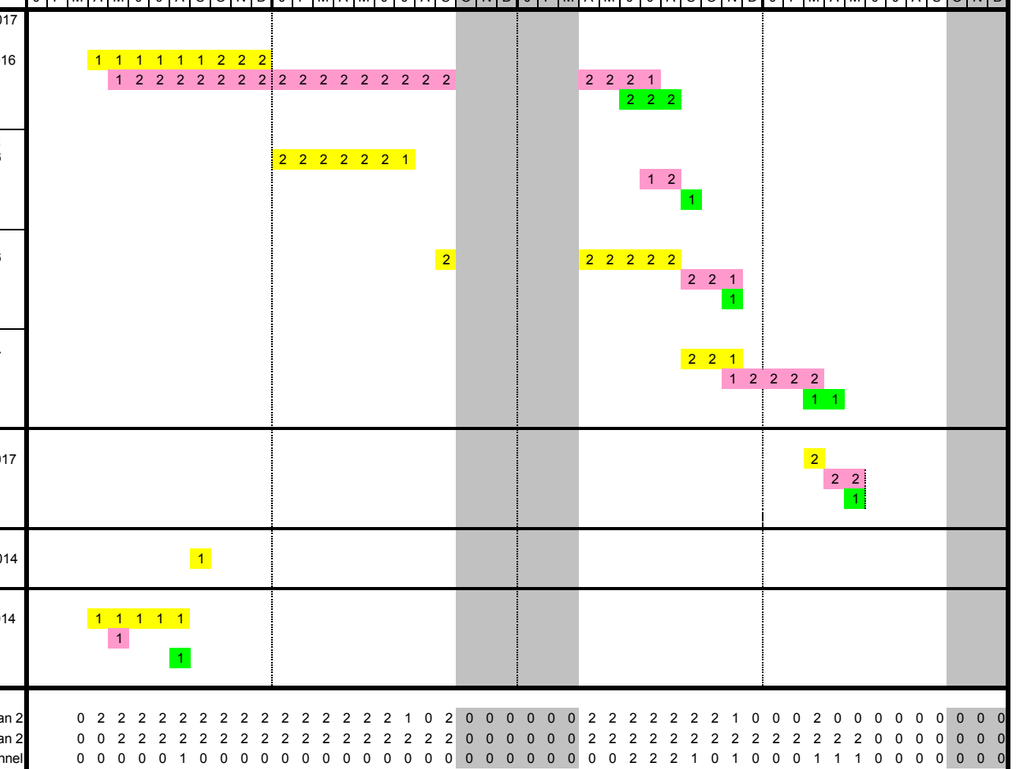


TABLE D2-30D (Page 2 of 2) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 48/50-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN B1 - MAIN CHANNELS IMPROVEMENT - 48/52 FEET	37					1					Oct 2015	April 2017
Broad Sound North Entrance Channel - 52 Feet	20											
Dredging and Disposal - Ordinary Material		2	4	6			11	12	5.53 MO	5.79 MO	June 2015	Aug 2016
Drill and Blast Ledge					2			40		19.90 MO		
Rock Removal and Disposal		2	4	6			6	6	2.78 MO	2.93 MO		
President Roads Anchorage - 48 Feet	10										Nov 2015	Sept 2016
Dredging and Disposal - Ordinary Material		2	5	7			13	11	6.40 MO	5.70 MO		
Drill and Blast Ledge					2			3		1.70 MO		
Rock Removal and Disposal		1	2	3			1	1	0.44 MO	0.52 MO		
Main Ship Channel - Roads to Reserved Channel - 48 Feet	8										April 2016	Nov 2016
Dredging and Disposal - Ordinary Material		2	4	6			12	12	6.11 MO	6.01 MO		
Drill and Blast Ledge					2			5		2.53 MO		
Rock Removal and Disposal		1	3	4			1	1	0.63 MO	0.52 MO		
Lower Reserved Channel and Turning Area - 48 Feet	9										Dec 2016	April 2017
Dredging and Disposal - Ordinary Material		2	4	6			5	5	2.50 MO	2.45 MO		
Drill and Blast Ledge					2			9		4.51 MO		
Rock Removal and Disposal		1	2	3			1	1	0.90 MO	1.12 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4											
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO	April 2017	May 2017
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			1	1	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1											
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO	Sept 2014	Sept 2014
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5											
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO	July 2014	Aug 2014
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS B1-D-E-F	34											

Dredging and Disposal - Ordinary Material (1 Plant Only) — Total Never More than 2
Drill and Blast Ledge (1 Plant Only) — Total Never More than 2
Rock Removal and Disposal (1 Plant Only) — Total Never More than 1 Except for Entrance Channel



Dredge Plants (Two 21 CY Dredges, 5 Tugs & 7 Scows)

Drill & Blast Plant (2 Drill Barges, Blast Barge, Small Tug)

Rock Removal Plants (21 CY Buckets)

TABLE D2-30E (Page 1 of 1) - CONSTRUCTION SCHEDULE
BOSTON HARBOR, MASSACHUSETTS - DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT - RECOMMENDED PLANS OF IMPROVEMENT WITH 49/51-FOOT MAIN CHANNELS PLAN

Schedule assuming air quality shutdown from months 19 to 24, and assuming separate rock removal plant(s)
Schedule also assumes Chelsea and Mystic Rivers will be done in Year #1

CURRENT FEASIBILITY ESTIMATE	Total Duration Months	# of Dredges	# of Tugs	# of Scows	# of D&B Plants	Numer of 6-Month Air Quality Shutdowns	Plant-Months Excavation	Plant-Months D&B or Hauling	Excavation Time (Months)	Hauling Time (Months)	Construct Mid-Point	Construct End-Point
PLAN B2 - MAIN CHANNELS IMPROVEMENT - 49/51 FEET	31					1					Dec 2015	July 2017
Broad Sound North Entrance Channel - 51 Feet	17											
Dredging and Disposal - Ordinary Material		2	4	6			11	10	5.36 MO	5.19 MO	Mar 2015	July 2016
Drill and Blast Ledge					2			36		18.20 MO		
Rock Removal and Disposal		2	4	6			5	5	2.41 MO	2.59 MO		
President Roads Anchorage - 49 Feet	10										March 2016	July 2017
Dredging and Disposal - Ordinary Material		2	5	7			13	13	6.52 MO	6.55 MO		
Drill and Blast Ledge					2			4		1.90 MO		
Rock Removal and Disposal		1	2	3			1	1	0.51 MO	0.60 MO		
Main Ship Channel - Roads to Reserved Channel - 49 Feet	8										July 2016	May-17
Dredging and Disposal - Ordinary Material		2	4	6			13	14	6.30 MO	6.97 MO		
Drill and Blast Ledge					2			6		3.23 MO		
Rock Removal and Disposal		1	3	4			2	1	0.80 MO	0.66 MO		
Lower Reserved Channel and Turning Area - 49 Feet	9										May 2016	March 2017
Dredging and Disposal - Ordinary Material		2	4	6			5	5	2.48 MO	2.71 MO		
Drill and Blast Ledge					2			11		5.72 MO		
Rock Removal and Disposal		1	3	4			1	1	1.22 MO	1.01 MO		
PLAN D - MAIN SHIP CHANNEL EXTENSION TO MMT - 45 Feet	4											
Dredging and Disposal - Ordinary Material		1	2	3			2	1	1.38 MO	1.23 MO	Nov 2016	Dec 2016
Drill and Blast Ledge					2			4		1.97 MO		
Rock Removal and Disposal		1	3	4			1	1	0.46 MO	0.46 MO		
PLAN E - MYSTIC RIVER CHANNEL AT MST - 40 Feet	1											
Dredging and Disposal - Ordinary Material		1	3	4			1	1	0.41 MO	0.47 MO	Sept 2014	Sept 2014
PLAN F - CHELSEA RIVER CHANNEL - 40 Feet	5											
Dredging and Disposal - Ordinary Material (1 Plant Only)		1	2	3			4	3	4.38 MO	3.40 MO	July 2014	Aug 2014
Drill and Blast Ledge (1 Plant Only)					1			1		0.11 MO		
Rock Removal and Disposal (1 Plant Only)		1	1	2			1	1	0.02 MO	0.02 MO		
TOTAL - COMBINED PLANS B2-D-E-F	34											

Dredging and Disposal - Ordinary Material (1 Plant Only)
Drill and Blast Ledge (1 Plant Only)
Rock Removal and Disposal (1 Plant Only)

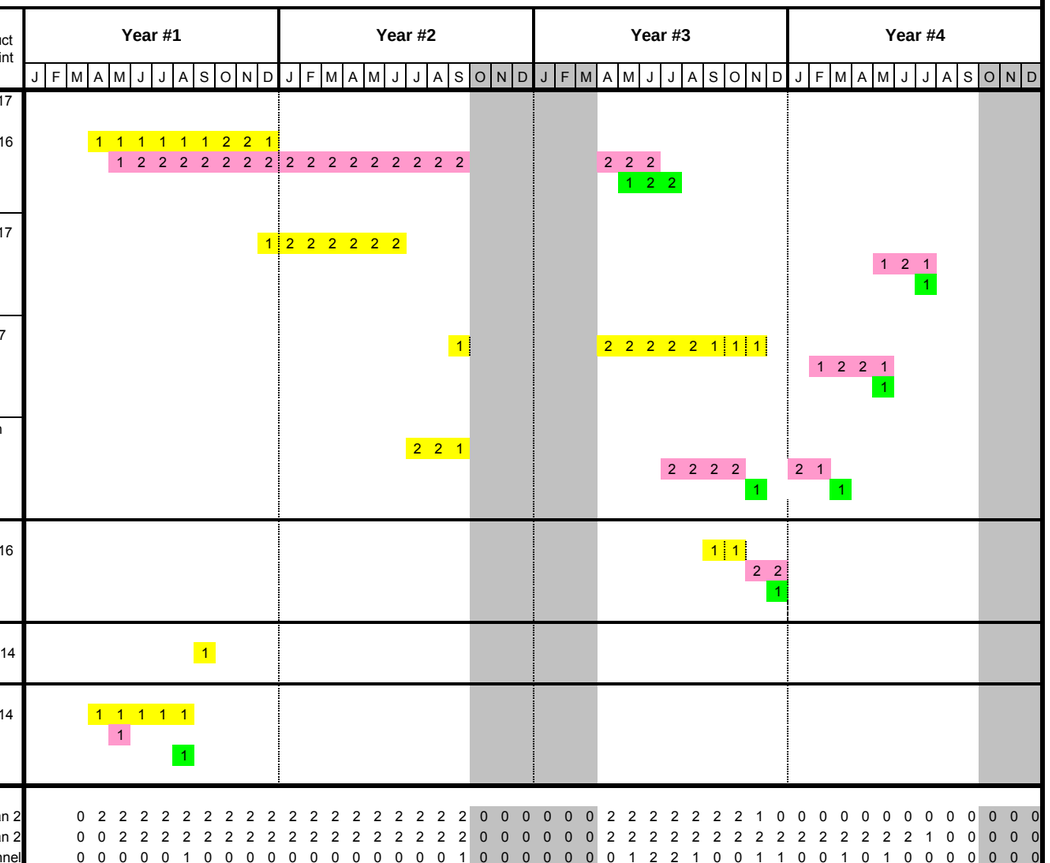


TABLE D2-31
CONSTRUCTION TIMELINE FOR AIR QUALITY IMPACT AVOIDANCE
COMPARISON OF ALL PLANS WITH 2-FOOT ENTRANCE CHANNEL INCREASE

PLAN	Total Project Constr Months	Total Project Months Duration	Total Project # of Shutdowns	Total Project Shutdown Months	Main Channels Duration (Mid Pt)	Year #1												Year #2											
						J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
42/44-Foot	16	16	0	0	Dec-14				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
D	3	3			Feb-16																								
E&F	6	6	0	0	Sep-14				1	1	1	1	1	1															
43/45-Foot	18	18	0	0	Jan-15				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	3	3	1	3	Feb-16																								
E&F	6	6							1	1	1	1	1	1															
44/46-Foot	20	26	1	6	May-15				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	4	4			Aug-16																								
E&F	6	6							1	1	1	1	1	1															
45/47-Foot	21	27	1	6	May-15				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	4	4			Sep-16																								
E&F	6	6							1	1	1	1	1	1															
46/48-Foot	22	28	1	6	May-15				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	4	4			Oct-16																								
E&F									1	1	1	1	1	1															
47/49-Foot	23	29	1	6	June 2015				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	4	4			Nov-16																								
E&F									1	1	1	1	1	1															
48/50-Foot	25	31	1	6	July 2015				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	4	35			Jan-17																								
E&F									1	1	1	1	1	1															
49/51-Foot	34	40	1	6	Dec 2015				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	4	4	1	5	Mar-18																								
E&F									1	1	1	1	1	1															
50/52-Foot	39	51	2	12	May-16				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
D	4	4			Sep-18																								
E&F									1	1	1	1	1	1															

M & C = Mystic and Chelsea River Tributaries - Smaller Dredge Plant

1 Main Channels (Conley) Plans

1 Main Ship Channel Extension to MMT

1 Mystic River (MST) Deepening

1 Chelsea River Deepening

TABLE D2-31 (Continued)
CONSTRUCTION TIMELINE FOR AIR QUALITY IMPACT AVOIDANCE
COMPARISON OF ALL PLANS WITH 2-FOOT ENTRANCE CHANNEL INCREASE

	Year #3												Year #4												Year #5											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
42/44-Foot																																				
	1	1	1																																	
M&C																																				
43/45-Foot																																				
M&C	1	1	1																																	
44/46-Foot				1	1																															
M&C						1	1	1	1																											
45/47-Foot				1	1	1																														
M&C							1	1	1	1																										
46/48-Foot				1	1	1	1																													
M&C							1	1	1	1																										
47/49-Foot				1	1	1	1	1																												
M&C								1	1	1	1																									
48/50-Foot				1	1	1	1	1	1	1																										
M&C									1	1	1	1																								
49/51-Foot				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																	
M&C									1	1	1	1																								
50/52-Foot				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1						
M&C																															1	1	1	1		

1	Main Channels (Conley) Plans	1	Mystic River (MST) Deepening
1	Main Ship Channel Extension to MMT	1	Chelsea River Deepening

TOTAL PROJECT COST SUMMARY SPREADHSEETS

TPCS Summary Sheets are provided for the combined Recommended Plan of Improvement including all four project segments, including:

- 47-Foot Main Channels Improvement to the Conley Terminal with 51-Foot Entrance Channel
- 45-Foot Main Ship Channel Extension Improvement to the Marine Terminal
- 40-Foot Mystic River Channel Deepening at the Medford Street Terminal
- 40-Foot Chelsea River Channel Deepening

PROJECT: **Boston Harbor Deep Draft Navigation Improvement** DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION: Boston, Massachusetts **Total of 4 Project Segments - with 47/51 Main Channels Plan** POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
						Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Spent Thru: 1-Jul-11 ($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*O*
12	NAVIGATION PORTS & HARBORS													
	Plan ABC - Main Channels	$213,754	$35,651	17%	$249,405	3.7%	$221,646	$36,967	$258,613			$229,378	$38,257	$267,634
	Plan D - Main Ship Channel Extension	$12,648	$2,833	22%	$15,481	3.7%	$13,115	$2,938	$16,053			$13,877	$3,108	$16,985
	Plan E - Mystic River Channel	$1,534	$360	24%	$1,894	3.7%	$1,591	$374	$1,964			$1,616	$380	$1,996
	Plan F - Chelsea River Channel	$8,498	$1,462	17%	$9,960	3.7%	$8,812	$1,516	$10,327			$8,951	$1,540	$10,491
	CONSTRUCTION ESTIMATE TOTALS:	$236,434	$40,306		$276,740	3.7%	$245,163	$41,794	$286,958			$253,821	$43,285	$297,106
01	LANDS AND DAMAGES	$144	$17	12%	$161	3.7%	$149	$18	$167			$154	$19	$173
30	PLANNING, ENGINEERING & DESIGN	$5,392	$901	17%	$6,293	3.8%	$5,596	$935	$6,531			$5,643	$943	$6,586
31	CONSTRUCTION MANAGEMENT	$9,314	$1,324	14%	$10,638	3.8%	$9,666	$1,374	$11,040			$10,413	$1,480	$11,894
	PROJECT COST TOTALS:	$251,284	$42,549	17%	$293,833		$260,575	$44,122	$304,696			$270,032	$45,726	$315,758

CHIEF, COST ENGINEERING, PATRICIA BOLTON

PROJECT MANAGER, MIKE KEEGAN

CHIEF, REAL ESTATE, JOSEPH REDLINGER

CHIEF, PLANNING, JOHN KENNELLY

CHIEF, ENGINEERING, ANTHONY MACKOS

CHIEF, OPERATIONS, FRANK FEDELE

CHIEF, CONSTRUCTION, SEAN DOLAN

CHIEF, CONTRACTING, SHEILA WINSTON

CHIEF, PM-PB, **

CHIEF, DPM, WILLIAM SCULLY

ESTIMATED FEDERAL COST:	70%	**$219,550**
ESTIMATED NON-FEDERAL COST:	30%	**$96,208**
ESTIMATED TOTAL PROJECT COST:		**$315,758**

Project includes 4 separable navigation project segments, one of which (Plan ABC) involes deepening both above and below -45 feet MLLW. A 25% up-front cost ahare applies to dredging for project feature depths up to 45 feet, and 50% for project feature depths beyond 45 feet. LERRDs are a 100% non-Federal project cost up-front. Estimated cost-sharing shown above is based on up-front cost distribution and apportionment.

Matches Dec 2012 Feasibility Cost Appendix D-2

****** CONTRACT COST SUMMARY ******

PROJECT: Boston Harbor Deep Draft Navigation Improvement DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION: Boston, Massachusetts **PLAN ABC - Main Channels Improvement Plan** POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN ABC - Main Channels Improvement 47/51-Foot Deepening/Widening	Estimate Prepared: 1-Aug-11 Effective Price Level: 1-Jul-11				Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12								
				RISK BASED										
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Base													
12	NAVIGATION PORTS & HARBORS													
12	Broad Sound North Entrance Channel	$105,299	$15,058	14%	$120,357	3.7%	$109,187	$15,614	$124,800	2015Q4	3.5%	$112,996	$16,158	$129,154
	Main Ship Channel	$38,032	$7,911	21%	$45,943	3.7%	$39,436	$8,203	$47,639	2015Q4	3.5%	$40,812	$8,489	$49,301
	Reserved Channel & Turning Area	$27,576	$5,681	21%	$33,257	3.7%	$28,594	$5,890	$34,485	2015Q4	3.5%	$29,592	$6,096	$35,688
	President Roads Anchorage	$38,162	$6,220	16%	$44,382	3.7%	$39,571	$6,450	$46,021	2015Q4	3.5%	$40,951	$6,675	$47,627
	Air Quality Shutdown Remob-Demob	$4,685	$781	17%	$5,466	3.7%	$4,858	$810	$5,668	2015Q4	3.5%	$5,027	$839	$5,866
	CONSTRUCTION ESTIMATE TOTALS:	$213,754	$35,651	17%	$249,405		$221,646	$36,967	$258,613			$229,379	$38,257	$267,635
01	LANDS AND DAMAGES	$114	$11	10%	$125	3.7%	$118	$12	$130	2015Q4	3.5%	$122	$12	$135
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$704	$120	17%	$824	3.8%	$731	$124	$855	2014Q1	0.8%	$737	$125	$862
2.0%	Planning & Environmental Compliance	$1,006	$171	17%	$1,177	3.8%	$1,044	$177	$1,222	2014Q1	0.8%	$1,053	$179	$1,232
8.5%	Engineering & Design	$2,517	$428	17%	$2,945	3.8%	$2,612	$444	$3,056	2014Q1	0.8%	$2,634	$448	$3,082
2.0%	Engineering Tech Review ITR & VE	$170	$29	17%	$199	3.8%	$176	$30	$206	2014Q1	0.8%	$178	$30	$208
2.0%	Contracting & Reprographics	$185	$32	17%	$217	3.8%	$192	$33	$225	2014Q1	0.8%	$194	$33	$227
2.0%	Project Operations													
					$5,361				$5,564					$5,610
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$4,934	$740	15%	$5,674	3.8%	$5,120	$768	$5,889	2015Q4	7.8%	$5,519	$828	$6,347
3.0%	Engineering During Construction	$1,267	$127	10%	$1,394	3.8%	$1,315	$131	$1,446	2015Q4	7.8%	$1,418	$142	$1,560
2.0%	Planning During Construction	$493	$74	15%	$567	3.8%	$512	$77	$589	2015Q4	7.8%	$551	$83	$635
2.0%	Project Operation:													
2.5%	Project Management	$809	$121	15%	$930	3.8%	$840	$126	$966	2015Q4	7.8%	$906	$136	$1,041
					$8,566				$8,889					$9,582
	CONTRACT COST TOTALS:	$225,953	$37,504		$263,457		$234,306	$38,890	$273,196			$242,690	$40,273	**$282,963**

****** CONTRACT COST SUMMARY ******

PROJECT: Boston Harbor Deep Draft Navigation Improvement

LOCATION: Boston, Massachusetts

PLAN D - Main Ship Channel Extension Plan

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

DISTRICT: NAE New England PREPARED: 12/19/2012

POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN D - Main Ship Channel Extension **45-Foot Deepening/Widening** **246,300 CY Ordinary Dredging** **78,400 CY Rock**	Estimate Prepared: Effective Price Level:			1-Aug-11 1-Jul-11	Program Year (Budget EC): Effective Price Level Date:			2013 1 OCT 12					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Option 1													
12	NAVIGATION PORTS & HARBORS	$12,648	$2,833	22%	$15,481	3.7%	$13,115	$2,938	$16,053	2017Q1	5.8%	$13,877	$3,108	$16,985
	CONSTRUCTION ESTIMATE TOTALS:	$12,648	$2,833	22%	**$15,481**		$13,115	$2,938	$16,053			$13,877	$3,108	$16,985
01	LANDS AND DAMAGES	$12	$3	22%	$15	3.7%	$12	$3	$15	2017Q1	5.8%	$13	$3	$16
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$45	$7	15%	$52	3.8%	$47	$7	$54	2014Q1	0.8%	$47	$7	$54
2.0%	Planning & Environmental Compliance	$80	$12	15%	$92	3.8%	$83	$12	$95	2014Q1	0.8%	$84	$13	$96
8.5%	Engineering & Design	$152	$23	15%	$175	3.8%	$158	$24	$182	2014Q1	0.8%	$159	$24	$183
2.0%	Engineering Tech Review ITR & VE	$14	$2	15%	$16	3.8%	$15	$2	$17	2014Q1	0.8%	$15	$2	$17
2.0%	Contracting & Reprographics	$28	$4	15%	$32	3.8%	$29	$4	$33	2014Q1	0.8%	$29	$4	$34
2.0%	Project Operations													
					$367				$381					$384
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$526	$79	15%	$605	3.8%	$546	$82	$628	2017Q1	12.9%	$616	$93	$709
3.0%	Engineering During Construction	$97	$10	10%	$107	3.8%	$101	$10	$111	2017Q1	12.9%	$114	$11	$125
2.0%	Planning During Construction	$43	$6	15%	$49	3.8%	$45	$7	$51	2017Q1	12.9%	$50	$8	$58
2.0%	Project Operation:													
2.5%	Project Management	$71	$11	15%	$82	3.8%	$74	$11	$85	2017Q1	12.9%	$83	$12	$96
					$843				$875					$988
	CONTRACT COST TOTALS:	$13,716	$2,990		**$16,706**		$14,223	$3,101	$17,324			$15,088	$3,286	**$18,374**
									1.0370					

****** CONTRACT COST SUMMARY ******

PROJECT: **Boston Harbor Deep Draft Navigation Improvement**

DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION: Boston, Massachusetts **PLAN E - Mystic River Channel - Medford St. Terminal Area Deepening** POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN E - Mystic River Channel 40-Foot Deepening 67,100 CY Ordinary Dredging	Estimate Prepared: Effective Price Level:			1-Aug-11 1-Jul-11	Program Year (Budget EC): Effective Price Level Date:			2013 1 OCT 12					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Option 2													
12	NAVIGATION PORTS & HARBORS	$1,534	$360	24%	$1,894	3.7%	$1,591	$374	$1,964	2014Q4	1.6%	$1,616	$380	$1,996
	CONSTRUCTION ESTIMATE TOTALS:	$1,534	$360	24%	**$1,894**		$1,591	$374	$1,964			$1,616	$380	$1,996
01	LANDS AND DAMAGES	$3	$1	24%	$4	3.7%	$3	$1	$4	2014Q4	1.6%	$3	$1	$4
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$28	$4	15%	$32	3.8%	$29	$4	$33	2014Q1	0.8%	$29	$4	$34
2.0%	Planning & Environmental Compliance	$31	$5	15%	$36	3.8%	$32	$5	$37	2014Q1	0.8%	$32	$5	$37
8.5%	Engineering & Design	$60	$9	15%	$69	3.8%	$62	$9	$72	2014Q1	0.8%	$63	$9	$72
2.0%	Engineering Tech Review ITR & VE	$8	$1	15%	$9	3.8%	$8	$1	$10	2014Q1	0.8%	$8	$1	$10
2.0%	Contracting & Reprographics	$21	$3	15%	$24	3.8%	$22	$3	$25	2014Q1	0.8%	$22	$3	$25
2.0%	Project Operations													
					$170				$177					$178
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$165	$24	15%	$189	3.8%	$171	$25	$196	2014Q4	3.7%	$178	$26	$204
3.0%	Engineering During Construction	$29	$3	10%	$32	3.8%	$30	$3	$33	2014Q4	3.7%	$31	$3	$34
2.0%	Planning During Construction	$13	$2	15%	$15	3.8%	$13	$2	$16	2014Q4	3.7%	$14	$2	$16
2.0%	Project Operation:													
2.5%	Project Management	$29	$4	15%	$33	3.8%	$30	$5	$35	2014Q4	3.7%	$31	$5	$36
					$269				$280					$290
	CONTRACT COST TOTALS:	$1,921	$417		**$2,338**		$1,992	$432	$2,425			$2,028	$440	**$2,468**
									1.0371					1.0177

****** CONTRACT COST SUMMARY ******

PROJECT: Boston Harbor Deep Draft Navigation Improvement

LOCATION: Boston, Massachusetts

PLAN F - Chelsea River Channel Deepening Plan

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

DISTRICT: NAE New England

PREPARED: 12/19/2012

POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN F - Chelsea River Channel **40-Foot Deepening/Widening** **342,600 CY Ordinary Dredging** **540 CY Rock**	Estimate Prepared: 1-Aug-11 Effective Price Level: 1-Jul-11				Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12				FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Option 3													
12	NAVIGATION PORTS & HARBORS	$8,498	$1,462	17%	$9,960	3.7%	$8,812	$1,516	$10,327	2014Q4	1.6%	$8,951	$1,540	$10,491
	CONSTRUCTION ESTIMATE TOTALS:	$8,498	$1,462	17%	**$9,960**		$8,812	$1,516	$10,327			$8,951	$1,540	$10,491
01	LANDS AND DAMAGES	$15	$3	17%	$18	3.7%	$16	$3	$18	2014Q4	1.6%	$16	$3	$19
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$40	$6	15%	$46	3.8%	$42	$6	$48	2014Q1	0.8%	$42	$6	$48
2.0%	Planning & Environmental Compliance	$122	$18	15%	$140	3.8%	$127	$19	$146	2014Q1	0.8%	$128	$19	$147
8.5%	Engineering & Design	$148	$22	15%	$170	3.8%	$154	$23	$177	2014Q1	0.8%	$155	$23	$178
2.0%	Engineering Tech Review ITR & VE	$8	$1	15%	$9	3.8%	$8	$1	$10	2014Q1	0.8%	$8	$1	$10
2.0%	Contracting & Reprographics	$25	$4	15%	$29	3.8%	$26	$4	$30	2014Q1	0.8%	$26	$4	$30
2.0%	Project Operations													
					$394				$409					$413
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$686	$102	15%	$788	3.8%	$712	$106	$818	2014Q4	3.7%	$738	$110	$848
3.0%	Engineering During Construction	$57	$6	10%	$63	3.8%	$59	$6	$65	2014Q4	3.7%	$61	$6	$67
2.0%	Planning During Construction	$25	$4	15%	$29	3.8%	$26	$4	$30	2014Q4	3.7%	$27	$4	$31
2.0%	Project Operation:													
2.5%	Project Management	$70	$11	15%	$81	3.8%	$73	$11	$84	2014Q4	3.7%	$75	$11	$87
					$960				$996					$1,033
	CONTRACT COST TOTALS:	$9,694	$1,638		**$11,332**		$10,053	$1,698	$11,751			$10,228	$1,728	**$11,955**
									1.0370					

WALLA WALLA COST ENGINEERING TECHNICAL CENTER OF EXPERTISE

COST AGENCY TECHNICAL REVIEW

CERTIFICATION STATEMENT

For

NAE – Boston Harbor Deep Draft Navigation Improvement (109034)

The Boston Harbor Deep Draft Navigation Improvements as presented by New England District has undergone a successful Cost Agency Technical Review (Cost ATR), performed by the Walla Walla District Cost Engineering Mandatory Center of Expertise (Cost MCX) team. The Cost ATR included study of the project scope, report, cost estimates, schedules, escalation, and risk-based contingencies. This certification signifies the products meet the quality standards as prescribed in ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering.

Qualifiers: Several items were questioned by ATR reviewer as being non-typ. 1) The Total Project Cost carries below average Planning Engineering and Design (2.3%) and Construction Management (3.9%). The contingencies for these are 17% and 14%. The PM has stated all offices concur with these values and will execute within these parameters. 2) The Project cites a Program Year of 2013, the PM has stated the project is slated for FY13 authorization.

As of December 21, 2012, the Cost MCX certifies the estimated total project cost of:

FY 2013 Price Level: $304,696,000
Fully Funded Amount: $315,758,000

It remains the responsibility of the District to correctly reflect these cost values within the Final Report and to implement effective project management controls and implementation procedures including risk management throughout the life of the project.

Michael Jacobs, PE, CCE
Chief, Cost Engineering
Walla Walla District

Date 14 Feb 2013

US Army Corps of Engineers®

US Army Corps
of Engineers®

Boston Harbor Deep Draft Navigation Improvement Project

Project Cost and Schedule Risk Analysis Report

Prepared by:

New England District
U.S. Army Corps of Engineers
Cost Engineering Section

February 13, 2013

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EXECUTIVE SUMMARY

Under the auspices of the US Army Corps of Engineers (USACE), New England District, this report presents a recommendation for the project cost and schedule contingencies for the Boston Harbor Deep Draft Navigation Improvement Project Feasibility Report. In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a formal risk analysis study was conducted for the development of contingency on the project cost. The purpose of this risk analysis study was to establish project contingencies by identifying and measuring the cost and schedule impact of project uncertainties with respect to the estimated project cost.

New England District, in concert with the Walla Walla Cost TCX performed risk analysis using the *Monte Carlo* technique, producing the aforementioned contingencies and identifying key risk drivers.

The Boston Harbor Deep Draft Navigation Improvement Project is divided into 4 Plans. Plan ABC Main Channel Improvement 47/51 Foot Deepening/Widening is the base plan. Specific to this plan, the project cost (base case at price level) is estimated at $213.7 Million. Based on the results of the analysis, the NAE Cost Engineer is submitting a recommended total contingency value of $35.7 Million, or 16.7%. This contingency is a weighted average of contingencies calculated separately for each reach on the recommended plan. The following table ES-1 portrays the development of contingencies (16.7%). The contingency is based the development of on an 80% confidence level on all reaches compromising the recommended plan, as per USACE Civil Works guidance.

Table ES-1. Contingency Analysis Table, Estimated Cost

TABLE D2-2 BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT STUDY CONSTRUCTION CONTINGENCY COSTS - WEIGHTED AVERAGE - FROM CONTINGENCY RISK ANALYSIS			
REVISED PLANS FROM NOVEMBER 2012 WITH 4-FOOT INCREASED ENTRANCE CHANNEL DEPTH			
MAIN CHANNELS IMPROVEMENT PLANS December 2012 Contingency Risk Analysis	Contingency Percentage 47/51	Item Cost 47/51-Foot	Contingency Cost 47/51-Foot
Broad Sound North Entrance Channel	14.3%	$105,299,000	$15,058,000
Main Ship Chan Including President Roads Reach	20.8%	$38,032,000	$7,911,000
Reserved Channel & Turning Area	20.6%	$27,576,000	$5,681,000
President Roads Anchorage	16.3%	$38,162,000	$6,220,000
Weighted Average Contingency	16.7%	$209,069,000	$34,870,000
Air Quality Shutdowns	16.7%	$4,685,000	$781,000
		Total	$35,651,000
Total Dredging	16.7%		

Page 1

The following table ES-2 portrays the full costs of the recommended alternative based on the anticipated contracts. The costs are intended to address the congressional request of estimates to implement the project. The contingency is based on an 80% confidence level, as per accepted USACE Civil Works guidance.

Table ES-2. Total Project Cost (Fully Funded) Cost Summary

INSERT TABLE FROM PAGE D2-245 OF APPENDIX

Boston Harbor Deep Draft Navigation Improvement Project		COST ($1,000)	CNTG ($1,000)	TOTAL ($1,000)
01	LANDS AND DAMAGES	154	19	173
12	NAVIGATION PORTS & HARBORS			
	Plan ABC – Main Channels	229,378	38,257	267,634
	Plan D – Main Ship Channel Extension	13,877	3,108	16,985
	Plan E – Mystic River Channel	1,616	380	1,996
	Plan F – Chelsea River Channel	8,951	1,540	10,491
30	PLANNING, ENGINEERING AND DESIGN	5,643	943	6,586
31	CONSTRUCTION MANAGEMENT	10,413	1,480	11,894
	TOTAL PROJECT COSTS	**270,032**	**45,726**	**315,758**
	Schedule Completion with Contingency	**5 SEPT 2016**	**6 months**	**5 MAR 2017**

Notes:
1) Costs include the recommended contingency of 18%.
2) Costs exclude O&M and Life Cycle Cost estimates.

KEY FINDINGS/OBSERVATIONS RECOMMENDATIONS

Risk Mitigation was conducted through a formal analysis of the project as it is currently presented in addition to the acknowledgement of risk in the estimated quantity of rock. The District has taken an approach to mitigate this risk through a conservative approach to the amount of ledge, the required excavation means, and the planning of extensive subsurface explorations during the Design phase. The mitigation of this risk will be further discussed in the main report. Additional factors assessed that may have additional impact to the project were considered and addressed in the base cost. These factors were weather and jobsite conditions and commodities/raw materials. The district chose to mitigate through direct cost addition to each reach due to a large amount of historical information and contractor familiarity to the area. The amounts included in the project cost provide an amount that the PDT is confident will provide substantive costs to mitigate issues. The district will continue to monitor

and include all risks in continuing assessment of contingency and amend as necessary as an essential element to the continued development of the project.

The key cost risk drivers identified through formal risk and sensitivity analysis were; Current Fuel Price, Contractor Overhead, and Daily Hours Worked, which together contribute an absolute value of 18.06 percent of the statistical cost variance.

Current Fuel Price. This risk identified is significant and present on all reaches. The eventual impact of fuel price is largely dependent on the time of the construction contract and national economic factors. This item presents potential risk for cost and impacted by schedule, as well as opportunity for savings for the same. This risk is mitigated through contingency risk % on the project costs and added cost escalation to the midpoint of construction.

Contractor Overhead. This moderate risk impacts the reaches of Broad Sound North, President Roads Anchorage, Main Ship Channel, Reserve Channel and Turning Area, Main Ship Channel Extension, and Chelsea. The only reach not impacted is the Mystic. The risk identified in contractor overhead includes the differences in both contractor and subcontractor overhead markups for the work effort. This is largely dependent on the contractor performing the work and company operations which may vary from one contractor to another. This risk is mitigated through the application of contingency to the project cost.

Daily Hours Worked. The risk due to daily hours worked is not present in all reaches and found only in the Broad Sound North, Reserved Channel and Turning Area, and the Main Ship Channel Extension. The risk is related not correlated with other risks, however may be related to environmental factors and potentially contractor dependant. There is a strong likelihood that the level of effort will be less than presumed for the Drill & Blast work in these reaches, hence greater man-hours may be required. There exists and opportunity for savings by completing additional analysis to determine the exact quantities of material to be blasted. The current estimate was derived from the assumption that all material with minimal rebound was determined as rock whereas the quantities likely represent some loose rock in addition to the hard consolidated rock material. This risk is weighted to the right indicating that this is addressed as a more significant factor and increasing the risk percentage for these areas. This risk has been mitigated through increased contingency percentage.

The key schedule risk drivers identified through sensitivity analysis were Risk PPM-8 (Construction Schedule – 4 years) EST – 2 (Fuel), and EST – 4 (Two Dredge Productivity), which together have already been computed in the percent of the statistical schedule variance as a part of the CEDEP risk analysis computations.

Risk PPM-8 (Construction Schedule 3 – 4 years), represents moderate risk on the project and is identified in the CEDEP Risk Analysis. Historically, 2 dredges have been utilized based on market availability as well as quantities. The construction estimate assumes two medium sized dredges. The mechanical dredge size and number of dredges is commonly established by the quantity in the contract. A market study and contract development could result in opportunity for reduction of costs and schedule. Secondly, this risk has also been associated with CON-2(Schedule Constraints). The risk presented highlights potential requirement for shut down for air quality. The PDT has confirmed with the sponsor that it is strongly anticipated that purchased or earned credits will be used to avoid shutdown due to air quality requirements. Though this is strongly anticipated, the PDT has decided to include the full costs of shutdowns directly in the project cost and is detailed in the

TPCS. This is a full 100% contingency applied, thereby mitigated and any changes would be represented by a credit or reduction in cost of the the project.

Risk EST-2 (Fuel), represents the largest risk contingency on the project. Immediate market history with in the last 6 months indicates increasing costs of fuel, however they have leveled in the past month and historically recede and rebound. There exists an opportunity for savings on fuel should prices continue on the current historical path given the additional contingency reflected in the cost estimate and contingency.

Risk EST-4 (Two Dredge Productivity), the estimate assumes certain productivity based on two medium sized dredges with a 20-28 mile haul (depending on the project reach being worked) where productivity may vary. These estimate assumptions establish the schedule. There exists great opportunity for risk reduction through determining the number of dredges and dredge size.

Recommendations, as detailed within the main report, include the implementation of cost and schedule contingencies, further iterative study of risks throughout the project life-cycle, potential mitigation throughout the PED phase, and proactive monitoring and control of risk identified in this study.

MAIN REPORT

1.0 PURPOSE

Under the auspices of the US Army Corps of Engineers (USACE), New England District, this report presents a recommendation for the project cost and schedule contingencies for the Boston Harbor Deep Draft Navigation Improvement Project.

2.0 BACKGROUND

The Main Channels Improvement Plans consist of improvements to deepen access from the sea to the Conley Container Terminal in South Boston. This requires deepening the Broad Sound North Entrance Channel from Massachusetts Bay into the harbor, the Main Ship Channel from the Outer Confluence of the entrance channels through President Roads and up-harbor to the Reserved Channel, the Reserved Channel Turning Area at the confluence of that channel with the Main Ship Channel, the lower Reserved Channel up to the Conley Terminal, and the President Roads Anchorage Area.

3.0 REPORT SCOPE

The scope of the risk analysis report is to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for cost risks for all project features. The study and presentation does not include consideration for life cycle costs.

3.1 Project Scope

The Boston Harbor Deep Draft Navigation Improvement Project involves improvements to four separate segments of the existing waterway. These are:

PLAN ABC: This plan, referred to as the Main Channels Improvement Plan, consist of deepening access from the sea to the Conley Container Terminal in South Boston for the benefit of the larger Panamax and Post-Panamax containerships. This plan includes deepening the Broad Sound North Entrance Channel, the Main Ship Channel

from President Roads to the Reserved Channel, the Reserved Channel Turning Area, the lower Reserved Channel up to the Conley Terminal, and the President Roads Anchorage Area. In all segments, the entrance channel would be deepened an additional two feet to compensate for increased sea states in the bay and outer harbor. The contingency risk analysis was developed for plans A-C was to the 47 foot project depth with a 51 ft depth at the for the Broad Sound North Entrance Channel.

The Main Channels Improvement Plans (ABC) include expansion of the Reserved Channel Turning Area to a 1500-Foot diameter, widened at its junctions with the Main Ship and Reserved Channels and further widened to the northeast by 100 feet, all as recommended by the ship simulation study. This plan also includes widening the deep lane of the Main Ship Channel to a width of 800 to 900 feet in the reaches above the Roads to the Reserved Channel, and widened further at the three critical bends at Finns Ledge, Spectacle Island and the Lower Middle Shoal below Castle Island.

Plans D, E, and F were also included in the contingency analysis as part of the complete project package.

PLAN D: This plan, referred to as the Main Ship Channel Deepening Extension, involves extending the deepening of the harbor's Main Ship Channel above the Reserved Channel Turning Area to the Massport Marine Terminal in South Boston to a depth of up to –45 feet MLLW. This plan's costs would be incremental to the main channels plans, and would benefit Massport's redevelopment of the MMT as a bulk cargo facility with 45-foot berth.

PLAN E: Deepening a small portion of the 35-foot segment of the Mystic River Channel to up to 40 feet to access Massport's Medford Street Terminal in Charlestown, and connect the existing 40-foot channel to the 40-foot berth at the terminal. This area was not deepened as part of the 1990 authorized improvement as the benefits of improving access to an undefined planned bulk cargo facility were not yet developed. Massport has now redeveloped this terminal and deepened its berth to 40 feet to accommodate smaller bulk cargo operations for which space is not available at the Marine Terminal in South Boston.1

PLAN F: This plan involves deepening and minor widening of the Chelsea River Channel, including its upstream turning basin from its current depth of –38 feet to –40 feet MLLW, to improve access to most of the port's petroleum terminals and other users of that channel. The Keyspan gas siphon located under the channel immediately downstream of the Chelsea Street Bridge has been replaced since the publication of the 2008 Draft Final Feasibility Report by a deep directional bore and the old siphon was

removed during the 2008-2010 major maintenance dredging operation for the inner harbor. The presence of a second MWRA water tunnel downstream of the Chelsea Street Bridge, not identified at the time of the 2008 report, required additional investigations by the Corps and State. The MWRA estimates the 2015 cost of replacement and removal of that water tunnel at about $15 million including design efforts and temporary bulkhead relocation.

3.2 USACE Risk Analysis Process

The risk analysis process for this study follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering PCX. The risk analysis process reflected within this report uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analysis is considered as an ongoing process and will be conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, this risk analysis was performed to meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering PCX.

- Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008.

- Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

The formal process included extensive involvement of the PDT for risk identification and the development of the risk register. The analysis process evaluated the base case Cost Engineering Dredge Estimating Program(CEDEP) cost estimate, schedule, and

funding profiles using Crystal Ball software to conduct a *Monte Carlo* simulation and statistical sensitivity analysis, per the guidance in Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

The project technical scope, estimates, and schedules were developed and presented by the New England District. Consequently, these documents serve as the basis for the risk analysis.

The scope of this study addresses the identification of problems, needs, opportunities and potential solutions that are viable from an economic, environmental, and engineering viewpoint.

4.0 METHODOLOGY / PROCESS

The Cost and Schedule Risk Analysis, was developed relying on local District staff to provide expertise and information gathering. The Chief of Cost Engineering facilitated risk identification meetings on site with the PDT. The initial risk identification meeting also included qualitative analysis to produce a risk register that served as the framework for the risk analysis. Revisions to the cost estimate and schedule occurred and were provided on April 20, 2012. The revised report was transmitted May 5, 2012. The final estimate for this report was revised on 17 December to accommodate changes in depth, however this does not affect the risk methodology since the same methodology was applied to all estimates.

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve any desired level of cost confidence.

In simple terms, contingency is an amount added to an estimate to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost PCX guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk averse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as

compared to a P50 confidence level. The selection of contingency at a particular confidence level is ultimately the decision and responsibility of the project's District and/or Division management.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. Cost estimates are completed in an Excel format and used directly for cost risk analysis purposes. The level of detail recreated in the Excel-format schedule is sufficient for risk analysis purposes that reflect the established risk register, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in Section 6.

4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT is considered a qualitative process that results in establishing a risk register that serves as the document for the quantitative study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

Formal PDT meetings were held for the purposes of identifying and assessing risk factors. The formal meeting conducted on November 8-9, 2011 included the following:

Figure 1. Project Delivery Team

Name	Organization	Title
Michael Keegan	USACE - NAE	Project Manager
Mark Habel	USACE – NAE	Study Team Lead
Rosemary Schmidt	USACE – NAE	Chief, Geology & Chemistry Engineering
Patricia Bolton	USACE – NAE	Chief, Cost Engineering
Christopher Lindsay	USACE - NAE	Former Chief, Cost Engineering
Catherine Rogers	USACE – NAE	Environmental Team Member
Robert Meader	USACE – NAE	Civil Engineer

The initial formal meetings focused primarily on risk factor identification using brainstorming techniques, but also included some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Subsequent meetings focused primarily on risk factor assessment and quantification.

Additionally, numerous conference calls and informal meetings were conducted throughout the risk analysis process on an as-needed basis to further facilitate risk factor identification, market analysis, and risk assessment.

4.2 Quantify Risk Factor Impacts

The quantitative impacts of risk factors on project plans were analyzed using a combination of professional judgment, empirical data, and analytical techniques. Risk factor impacts were quantified using probability distributions (density functions) because risk factors are entered into the Crystal Ball software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involved multiple project team disciplines and functions. However, the quantification process relied more extensively on collaboration between cost engineering and risk analysis team members with lesser inputs from other functions and disciplines. This process used an iterative approach to estimate the following elements of each risk factor:

- Maximum possible value for the risk factor
- Minimum possible value for the risk factor
- Most likely value (the statistical mode), if applicable
- Nature of the probability density function used to approximate risk factor uncertainty
- Mathematical correlations between risk factors
- Affected cost estimate and schedule elements

The resulting product from the PDT discussions is captured within a risk register as presented in section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

4.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate. *Monte Carlo* simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the baseline cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

5.0 PROJECT ASSUMPTIONS

The following data sources and assumptions were used in quantifying the costs associated with the Boston Harbor Deep Draft Navigation Improvement Project.

a. The NAE District used an Excel based CEDEP (Cost Engineering Dredge Estimating Program) program for the bases of cost and schedule risk analyses.

b. The cost comparisons and risk analyses performed and reflected within this report are based on design scope and estimates that are at the feasibility level.

c. Schedules are analyzed for impact to the project cost in terms of both uncaptured escalation (variance from OMB factors and the local market) and unavoidable fixed contract costs and/or languishing federal administration costs incurred throughout delay. Specific to the Boston Harbor Deep Draft Navigation Improvement Project, the schedule was analyzed only for impacts due to residual fixed costs in the CEDEP.

d. Per the CWCCIS Historical State Adjustment Factors in EM 1110-2-1304, State Adjustment Factor for the Commonwealth of Massachusetts 1.12, meaning that the average inflation for the project area is assumed to be 12% higher than the national average for inflation. Therefore, the area cost adjustment factor was accounted in the base cost estimate within the CEDEP cost estimate and the project has been escalated 2.5% to 2013 program year.

e. Per the data in the estimate, the Job Office Overhead (JOOH) percentage for the Dredge Contractor is 17% and the JOOH for the Drilling Contractor is 15%. However, since construction is not anticipated to begin until 2015, a weighted average based on overall duration versus construction duration was calculated.

f. The Cost TCX guidance focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

g. Only high and moderate risk level impacts, as identified in the risk register, were considered for the purposes of calculating cost contingency. Low level risk impacts should be maintained in project management documentation, and reviewed at each project milestone to determine if they should be placed on the risk "watch list".

6.0 RESULTS

The cost and schedule risk analysis results are provided in the following sections. In addition to contingency calculation results, sensitivity analyses are presented to provide decision makers with an understanding of variability and the key contributors to the cause of this variability.

6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The actual risk register is provided in Appendix A. The complete risk register includes low level risks, as well as additional information regarding the nature and impacts of each risk.

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined, especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

6.2 Cost Contingency and Sensitivity Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. These results, as applied to the analysis herein, depict the overall project cost at intervals of confidence (probability).

Table 1 provides the construction cost contingencies calculated for the P80 confidence level and rounded to the nearest thousand. The construction cost contingencies for the P50 and P100 confidence levels are also provided for illustrative purposes only.

Contingency was quantified as approximately $26 Million at the P80 confidence level (25% of the baseline cost estimate). For comparison, the cost contingency at the P50 and P100 confidence levels was quantified as 13% and 72% of the baseline cost estimate, respectively.

Table 1. Project Construction Cost Contingency Summary (x100)

Risk Analysis Forecast	Baseline Estimate	Total Contingency[1,2] ($)	Total Contingency (%)
50% Confidence Level			
Project Cost	$236,434	$13,457	5.4%
80% Confidence Level			
Project Cost	$236,433	$40,246	16.7%
100% Confidence Level			
Project Cost	$236,433	$143,984	60.6%

Notes:
1) These figures combine uncertainty in the baseline cost estimates and schedule.
2) A P100 confidence level is an abstract concept for illustration only, as the nature of risk and uncertainty (specifically the presence of "unknown unknowns") makes 100% confidence a theoretical impossibility.

6.2.1 Sensitivity Analysis

Sensitivity analysis generally ranks the relative impact of each risk/opportunity as a percentage of total cost uncertainty. The Crystal Ball software uses a statistical measure (contribution to variance) that approximates the impact of each risk/opportunity contributing to variability of cost outcomes during *Monte Carlo* simulation.

Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register, sensitivity analysis results can also be used to support development of strategies to eliminate, mitigate, accept or transfer key risks.

6.2.2 Sensitivity Analysis Results

The risks/opportunities considered as key or primary cost drivers are ranked in order of importance in contribution to variance bar charts. Opportunities that have a potential to reduce project cost and are shown with a negative sign; risks are shown with a positive

sign to reflect the potential to increase project cost. A longer bar in the sensitivity analysis chart represents a greater potential impact to project cost.

Figure 1 presents a cost confidence sensitivity analysis for cost growth risk from the high level cost risks identified in the risk register. Figure 2 presents the sensitivity analysis depicting factors and relative impact to the confidence levels. Appendix B is the complete list of all Cost Contingency developed for each reach and plan.

Figure 2. Sample Cost Sensitivity Confidence Levels Analysis

Cost Basis (ie Feasibility)

Contingency Analysis

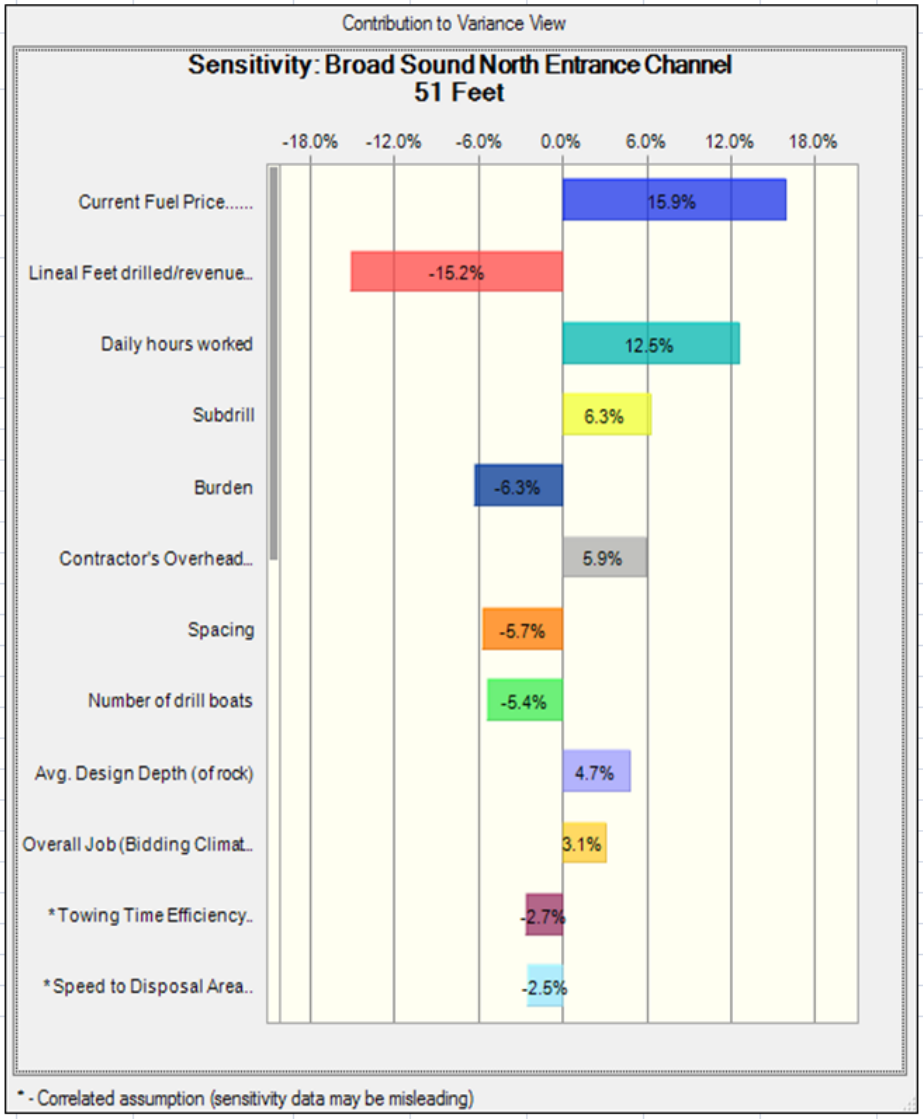
Broad Sound North Entrance Channel

51 Feet

Most Likely		$ 105,298,000
Confidence Level	**Project Cost**	**Contingency**
0%	$70,099,000	-33.4%
5%	$90,871,000	-13.7%
10%	$94,769,000	-10.0%
15%	$97,386,000	-7.5%
20%	$99,458,000	-5.5%
25%	$101,290,000	-3.8%
30%	$103,184,000	-2.0%
35%	$104,773,000	-0.5%
40%	$106,306,000	1.0%
45%	$107,857,000	2.4%
50%	$109,464,000	4.0%
55%	$111,031,000	5.4%
60%	$112,611,000	6.9%
65%	$114,233,000	8.5%
70%	$116,103,000	10.3%
75%	$118,049,000	12.1%
80%	$120,321,000	14.3%
85%	$122,917,000	16.7%
90%	$126,321,000	20.0%
95%	$131,382,000	24.8%
100%	$164,533,000	56.3%

Confidence Level of 80% means, for a base project cost of $105,298,000 with a 14% contingency would have a 80% probability that project cost would not be exceeded.

Figure 2. Sample Cost Sensitivity Analysis



6.3 Schedule and Contingency Risk Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. Though the probability of reducing or eliminating these risks is high, the results are applied directly to the baseline schedule herein through inclusion of extension of time in the baseline project schedule and cost. Since the base schedule and cost are extended and

conservatively estimated, the PDT decided to maintain this conservative estimate in lieu of estimating the anticipated and applying contingency. In summary, the schedule includes the risk and mitigation and will be revisited during the Design phase.

The primary risks identified in the schedule of the project were rock quantities and air quality shutdown.

Air quality shutdowns are included in the baseline schedule every other year from October through March, hence have been mitigated through current project duration in the project schedule. Cost mitigation is applied through the direct addition of the full cost for Remob and Demob for air quality shutdown. This cost is applied directly to the project cost in the TPCS, thereby applying the full value of the contingency to Plan ABC, hence mitigating the total cost of this risk. Though it was decided by the PDT to apply the full contingency of this item, it is anticipated that the sponsor will purchase or use credits to continue work and avoid shutdown for air quality and may result only in the reduction of the project cost.

Rock quantities and means of removal were conservatively developed. All sonar data with rebound which historically have proven to be clay in addition to rock was assessed as 100% rock. Additionally, historical dredging and boring data confirm the composition of the rock is ardulite. The dredging experience by the District has shown that much of the ardulite is fractured and does not require extensive measures for removal and mechanical means have been sufficient, however rock quantities have been quantified and estimated as rock, hence has mitigated the risk.

6.4 External and Other Risk Factors

Weather and Other Jobsite Conditions and Commodities/Raw Materials are identified as External Risk factors by the PDT. A review of these factors and impacts to cost and schedule was developed through a historical review of projects. Review of these risks did not provide the anticipated impact to the overall project schedule, however were included in the risk analysis. Figure 2 presents a sensitivity analysis for both of these items used in the development of contingency to mitigate the impact of these risks.

7.0 MAJOR FINDINGS/OBSERVATIONS/RECOMMENDATIONS

This section provides a summary of significant risk analysis results that are identified in the preceding sections of the report. Risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as projects progress through planning and implementation. Because of the potential for use of risk analysis results for such diverse purposes, this section also reiterates and highlights important steps, logic, key assumptions, limitations, and decisions to help ensure that the risk analysis results are appropriately interpreted.

7.1 Major Findings/Observations

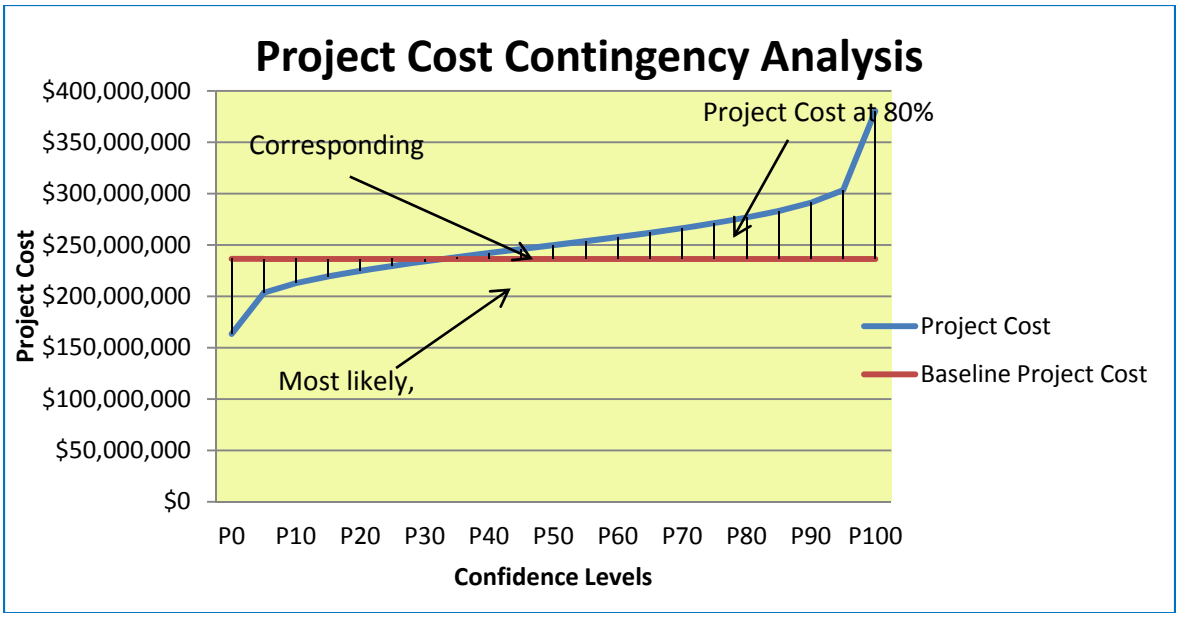
Project cost comparison summaries are provided in Table 3 and Figure 3. Additional major findings and observations of the risk analysis are listed below.

The key schedule risk drivers identified through sensitivity analysis were Risk PPM-8 (Construction Schedule – 4 years) EST – 2 (Fuel), and EST – 4 (Two Dredge Productivity), which together have already been computed in the percent of the statistical schedule variance as a part of the CEDEP risk analysis computations.

Table 2. Project Cost Comparison Summary (Uncertainty Analysis)

Confidence Level	Contingency(%)	Contingency ($)	Project Cost ($)
P0	-33.8%	-$72,967,358	$163,466,642
P5	-14.2%	-$32,900,545	$203,533,455
P10	-10.2%	-$23,506,686	$212,927,314
P15	-7.5%	-$16,938,274	$219,495,726
P20	-5.2%	-$11,569,366	$224,864,634
P25	-3.2%	-$6,851,205	$229,582,795
P30	-1.3%	-$2,337,764	$234,096,236
P35	0.5%	$1,816,151	$238,250,151
P40	2.1%	$5,744,247	$242,178,247
P45	3.7%	$9,557,692	$245,991,692
P50	5.4%	$13,456,784	$249,890,784
P55	7.0%	$17,334,613	$253,768,613
P60	8.6%	$21,246,945	$257,680,945
P65	10.4%	$25,402,069	$261,836,069
P70	12.3%	$30,031,823	$266,465,823
P75	14.3%	$34,763,409	$271,197,409
P80	16.7%	$40,245,820	$276,679,820
P85	19.4%	$46,655,219	$283,089,219
P90	22.8%	$54,743,377	$291,177,377
P95	27.9%	$66,979,681	$303,413,681
P100	60.0%	$143,983,784	$380,417,784

Figure 3. Project Cost Summary



7.2 Recommendations

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *4th edition*, states that "project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation) and risk monitoring and control. In short, the effectiveness of the project risk management effort requires that the proactive management of risks not conclude with the study completed in this report.

The Cost and Schedule Risk Analysis (CSRA) produced by the PDT identifies issues that require the development of subsequent risk response and mitigation plans. This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Note that this list is not all inclusive and should not substitute a formal risk management and response plan.

1. Key Cost Risk Drivers: The key schedule risk drivers identified through sensitivity analysis were Risk PPM-8 (Construction Schedule – 4 years) EST – 2 (Fuel), and EST – 4 (Two Dredge Productivity), which together have already been computed in the percent of the statistical schedule variance as a part of the CEDEP risk analysis computations.

a) Current Fuel Price. This risk identified is significant and present on all reaches. The eventual impact of fuel price is largely dependent on the time of the construction contract and national economic factors. This item presents potential risk for cost and impacted by schedule, as well as opportunity for savings for the same. This risk is mitigated through contingency risk % on the project costs and added cost escalation to the midpoint of construction.

b) Contractor Overhead. This moderate risk impacts the reaches of Broad Sound North, President Roads Anchorage, Main Ship Channel, Reserve Channel and Turning Area, Main Ship Channel Extension, and Chelsea. The only reach not impacted is the Mystic. The risk identified in contractor overhead includes the differences in both contractor and subcontractor overhead markups for the work effort. This is largely dependent on the contractor performing the work and company operations which may vary from one contractor to another. This risk is mitigated through the application of contingency to the project cost.

c) Daily Hours Worked. The risk due to daily hours worked is not present in all reaches and found only in the Broad Sound North, Reserved Channel and Turning Area, and the Main Ship Channel Extension. The risk is related not correlated with other risks, however may be related to environmental factors and potentially contractor dependant. There is a strong likelihood that the level of effort will be less than presumed for the Drill & Blast work in these reaches, hence greater man-hours may be required. There exists and opportunity for savings by completing additional analysis to determine the exact quantities of material to be blasted. The current estimate was derived from the assumption that all material with minimal rebound was determined as rock whereas the quantities likely represent some loose rock in addition to the hard consolidated rock material. This risk is weighted to the right indicating that this is addressed as a more significant factor and increasing the risk percentage for these areas. This risk has been mitigated through increased contingency percentage.

The key schedule risk drivers identified through PDT Review were Risk PPM-8 (Construction Schedule – 4 years) EST – 2 (Fuel), and EST – 4 (Two Dredge Productivity), which together have already been computed in the percent of the statistical schedule variance as a part of the CEDEP risk analysis computations.

Risk PPM-8 (Construction Schedule 3 – 4 years), represents moderate risk on the project and is identified in the CEDEP Risk Analysis. Historically, 2 dredges have been utilized based on market availability as well as quantities. The construction estimate assumes two medium sized dredges. The mechanical dredge size and number of dredges is commonly established by the quantity in the contract. A market study and contract development could result in opportunity for reduction of costs and schedule. Secondly, this risk has also been associated with CON-2(Schedule Constraints). The risk presented highlights potential requirement for shut down for air quality. The PDT has confirmed with the sponsor that it is strongly anticipated that purchased or earned credits will be used to avoid shutdown due to air quality requirements. Though this is strongly anticipated, the PDT has decided to include the full costs of shutdowns directly in the project cost and is detailed in the TPCS. This is a full 100% contingency applied, thereby mitigated and any changes would be represented by a credit or reduction in cost of the the project.

Risk EST-2 (Fuel), represents the largest risk contingency on the project. Immediate market history with in the last 6 months indicates increasing costs of fuel, however they have leveled in the past month and historically recede and rebound. There exists an opportunity for savings on fuel should prices continue on the current historical path given the additional contingency reflected in the cost estimate and contingency.

Risk EST-4 (Two Dredge Productivity), the estimate assumes certain productivity based on two medium sized dredges with a 20-28 mile haul (depending on the project reach being worked) where productivity may vary. These estimate assumptions establish the schedule. There exists great opportunity for risk reduction through determining the number of dredges and dredge size.

Recommendations, as detailed within the main report, include the implementation of cost and schedule contingencies, further iterative study of risks throughout the project

life-cycle, potential mitigation throughout the PED phase, and proactive monitoring and control of risk identified in this study.

3. Risk Management: Project leadership should use of the outputs created during the risk analysis effort as tools in future risk management processes. The risk register should be updated at each major project milestone. The results of the sensitivity analysis may also be used for response planning strategy and development. These tools should be used in conjunction with regular risk review meetings.

4. Risk Analysis Updates: Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life-cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk management watch lists if any risk's likelihood or impact significantly increases. Project leadership should also be mindful of the potential for secondary (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: **Boston Harbor Deep Draft Navigation Improvement** DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION Boston, Massachusetts **Total of 4 Project Segments - with 47/51 Main Channels Plan** POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
						Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Spent Thru: 1-Jul-11 ($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
12	NAVIGATION PORTS & HARBORS													
	Plan ABC - Main Channels	$213,754	$35,651	17%	$249,405	3.7%	$221,646	$36,967	$258,613			$229,378	$38,257	$267,634
	Plan D - Main Ship Channel Extension	$12,648	$2,833	22%	$15,481	3.7%	$13,115	$2,938	$16,053			$13,877	$3,108	$16,985
	Plan E - Mystic River Channel	$1,534	$360	24%	$1,894	3.7%	$1,591	$374	$1,964			$1,616	$380	$1,996
	Plan F - Chelsea River Channel	$8,498	$1,462	17%	$9,960	3.7%	$8,812	$1,516	$10,327			$8,951	$1,540	$10,491
	CONSTRUCTION ESTIMATE TOTALS:	$236,434	$40,306		$276,740	3.7%	$245,163	$41,794	$286,958			$253,821	$43,285	$297,106
01	LANDS AND DAMAGES	$144	$15	10%	$159	3.3%	$149	$15	$164			$154	$15	$170
30	PLANNING, ENGINEERING & DESIGN	$5,392	$901	17%	$6,293	3.8%	$5,586	$935	$6,531			$5,643	$943	$6,586
31	CONSTRUCTION MANAGEMENT	$9,314	$1,324	14%	$10,638	3.8%	$9,666	$1,374	$11,040			$10,413	$1,480	$11,894
	PROJECT COST TOTALS:	$251,284	$42,547	17%	$293,831		$260,575	$44,119	$304,693			$270,032	$45,723	$315,755

BOLTON.PATRICIA.HAAS.1008970544 — CHIEF, COST ENGINEERING, PATRICIA BOLTON

KEEGAN.MICHAEL.F.1228576316 — PROJECT MANAGER, MIKE KEEGAN

REDLINGER.JOSEPH.MARK.1246005156 — CHIEF, REAL ESTATE, JOSEPH REDLINGER

KENNELLY.JOHN.R.1228532939 — CHIEF, PLANNING, JOHN KENNELLY

MACKOS.ANTHONY.T.1228547480 — CHIEF, ENGINEERING, ANTHONY MACKOS

FEDELE.FRANCIS.J.1228588993 — CHIEF, OPERATIONS, FRANK FEDELE

CHIEF, CONSTRUCTION, SEAN DOLAN

WINSTON.SHEILA.M.1228580461 — CHIEF, CONTRACTING, SHEILA WINSTON

SCULLY.WILLIAM.C.1228587415 — CHIEF, PM-PB, **

SCULLY.WILLIAM.C.1228587415 — CHIEF, DPM, WILLIAM SCULLY

ESTIMATED FEDERAL COST:	67%	**$211,558**
ESTIMATED NON-FEDERAL COST:	33%	**$104,197**
ESTIMATED TOTAL PROJECT COST:		**$315,755**

Project includes 4 separable navigation project segments, one of which (Plan ABC) involes deepening both above and below -45 feet MLLW. A 25% up-front cost share applies to dredging for project feature depths up to 45 feet, and 50% for project feature depths beyond 45 feet. LERRDs are a 100% non-Federal project cost up-front. Estimated cost-sharing shown above is based on up-front cost distribution and apportionment.

FEDERAL O&M COST OUTSIDE OF TOTAL PROJECT COST ($k): **$10,633**

Matches May 2012 Feasibility Cost Appendix D-2

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Boston Harbor Deep Draft Navigation Improvement

DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION: Boston, Massachusetts

PLAN ABC - Main Channels Improvement Plan

POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN ABC - Main Channels Improvem													
	47/51-Foot Deepening/Widening													
		Estimate Prepared:			1-Aug-11	Program Year (Budget EC):			2013					
		Effective Price Level:			1-Jul-11	Effective Price Level Date:			1 OCT 12					
				RISK BASED										
WBS	Civil Works	COST	CNTG	CNTG	TOTAL	ESC	COST	CNTG	TOTAL	Mid-Point	INFLATED	COST	CNTG	FULL
NUMBER	Feature & Sub-Feature Description	($K)	($K)	(%)	($K)	(%)	($K)	($K)	($K)	Date	(%)	($K)	($K)	($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Base													
12	NAVIGATION PORTS & HARBORS													
12	Broad Sound North Entrance Channel	$105,299	$15,058	14%	$120,357	3.7%	$109,187	$15,614	$124,800	2015Q4	3.5%	$112,996	$16,158	$129,154
	Main Ship Channel	$38,032	$7,911	21%	$45,943	3.7%	$39,436	$8,203	$47,639	2015Q4	3.5%	$40,812	$8,489	$49,301
	Reserved Channel & Turning Area	$27,576	$5,681	21%	$33,257	3.7%	$28,594	$5,890	$34,485	2015Q4	3.5%	$29,592	$6,096	$35,688
	President Roads Anchorage	$38,162	$6,220	16%	$44,382	3.7%	$39,571	$6,450	$46,021	2015Q4	3.5%	$40,951	$6,675	$47,627
	Air Quality Shutdown Remob-Demob	$4,685	$781	17%	$5,466	3.7%	$4,858	$810	$5,668	2015Q4	3.5%	$5,027	$839	$5,866
	CONSTRUCTION ESTIMATE TOTALS:	$213,754	$35,651	17%	$249,405		$221,646	$36,967	$258,613			$229,379	$38,257	$267,635
01	LANDS AND DAMAGES	$114	$11	10%	$125	3.7%	$118	$12	$130	2015Q4	3.5%	$122	$12	$135
30	PLANNING, ENGINEERING & DESIGN													
0.3%	Project Management	$704	$120	17%	$824	3.8%	$731	$124	$855	2014Q1	0.8%	$737	$125	$862
0.5%	Planning & Environmental Compliance	$1,006	$171	17%	$1,177	3.8%	$1,044	$177	$1,222	2014Q1	0.8%	$1,053	$179	$1,232
1.2%	Engineering & Design	$2,517	$428	17%	$2,945	3.8%	$2,612	$444	$3,056	2014Q1	0.8%	$2,634	$448	$3,082
0.1%	Engineering Tech Review ITR & VE	$170	$29	17%	$199	3.8%	$176	$30	$206	2014Q1	0.8%	$178	$30	$208
0.1%	Contracting & Reprographics	$185	$32	17%	$217	3.8%	$192	$33	$225	2014Q1	0.8%	$194	$33	$227
	Project Operations													
					$5,361				$5,564					$5,610
31	CONSTRUCTION MANAGEMENT													
2.3%	Construction Management	$4,934	$740	15%	$5,674	3.8%	$5,120	$768	$5,889	2015Q4	7.8%	$5,519	$828	$6,347
0.6%	Engineering During Construction	$1,267	$127	10%	$1,394	3.8%	$1,315	$131	$1,446	2015Q4	7.8%	$1,418	$142	$1,560
0.2%	Planning During Construction	$493	$74	15%	$567	3.8%	$512	$77	$589	2015Q4	7.8%	$551	$83	$635
	Project Operation:													
0.4%	Project Management	$809	$121	15%	$930	3.8%	$840	$126	$966	2015Q4	7.8%	$906	$136	$1,041
					$8,566				$8,889					$9,582
	CONTRACT COST TOTALS:	$225,953	$37,504		$263,457		$234,306	$38,890	$273,196			$242,690	$40,273	**$282,963**

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: **Boston Harbor Deep Draft Navigation Improvement**

DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION: Boston, Massachusetts **PLAN D - Main Ship Channel Extension Plan**

POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN D - Main Ship Channel Extension **45-Foot Deepening/Widening** **246,300 CY Ordinary Dredging** **78,400 CY Rock**	Estimate Prepared: 1-Aug-11 Effective Price Level: 1-Jul-11				Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Option 1													
12	NAVIGATION PORTS & HARBORS	$12,648	$2,833	22%	$15,481	3.7%	$13,115	$2,938	$16,053	2017Q1	5.8%	$13,877	$3,108	$16,985
	CONSTRUCTION ESTIMATE TOTALS:	$12,648	$2,833	22%	**$15,481**		$13,115	$2,938	$16,053			$13,877	$3,108	$16,985
01	LANDS AND DAMAGES	$12	$1	10%	$13	3.7%	$12	$1	$14	2017Q1	5.8%	$13	$1	$14
30	PLANNING, ENGINEERING & DESIGN													
0.4%	Project Management	$45	$7	15%	$52	3.8%	$47	$7	$54	2014Q1	0.8%	$47	$7	$54
0.6%	Planning & Environmental Compliance	$80	$12	15%	$92	3.8%	$83	$12	$95	2014Q1	0.8%	$84	$13	$96
1.2%	Engineering & Design	$152	$23	15%	$175	3.8%	$158	$24	$182	2014Q1	0.8%	$159	$24	$183
0.1%	Engineering Tech Review ITR & VE	$14	$2	15%	$16	3.8%	$15	$2	$17	2014Q1	0.8%	$15	$2	$17
0.2%	Contracting & Reprographics	$28	$4	15%	$32	3.8%	$29	$4	$33	2014Q1	0.8%	$29	$4	$34
	Project Operations													
					$367				$381					$384
31	CONSTRUCTION MANAGEMENT													
4.2%	Construction Management	$526	$79	15%	$605	3.8%	$546	$82	$628	2017Q1	12.9%	$616	$93	$709
0.8%	Engineering During Construction	$97	$10	10%	$107	3.8%	$101	$10	$111	2017Q1	12.9%	$114	$11	$125
0.3%	Planning During Construction	$43	$6	15%	$49	3.8%	$45	$7	$51	2017Q1	12.9%	$50	$8	$58
	Project Operation:													
0.6%	Project Management	$71	$11	15%	$82	3.8%	$74	$11	$85	2017Q1	12.9%	$83	$12	$96
					$843				$875					$988
	CONTRACT COST TOTALS:	$13,716	$2,989		**$16,705**		$14,223	$3,099	$17,323			$15,088	$3,285	**$18,372**
									1.0370					

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****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: **Boston Harbor Deep Draft Navigation Improvement**

DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION: Boston, Massachusetts **PLAN E - Mystic River Channel - Medford St. Terminal Area De** POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN E - Mystic River Channel **40-Foot Deepening** **67,100 CY Ordinary Dredging**	Estimate Prepared: 1-Aug-11 Effective Price Level: 1-Jul-11				Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Option 2													
12	NAVIGATION PORTS & HARBORS	$1,534	$360	24%	$1,894	3.7%	$1,591	$374	$1,964	2014Q4	1.6%	$1,616	$380	$1,996
	CONSTRUCTION ESTIMATE TOTALS:	$1,534	$360	24%	**$1,894**		$1,591	$374	$1,964			$1,616	$380	$1,996
01	LANDS AND DAMAGES	$3	$0	10%	$3	3.7%	$3	$0	$3	2014Q4	1.6%	$3	$0	$3
30	PLANNING, ENGINEERING & DESIGN													
1.8%	Project Management	$28	$4	15%	$32	3.8%	$29	$4	$33	2014Q1	0.8%	$29	$4	$34
2.0%	Planning & Environmental Compliance	$31	$5	15%	$36	3.8%	$32	$5	$37	2014Q1	0.8%	$32	$5	$37
3.9%	Engineering & Design	$60	$9	15%	$69	3.8%	$62	$9	$72	2014Q1	0.8%	$63	$9	$72
0.5%	Engineering Tech Review ITR & VE	$8	$1	15%	$9	3.8%	$8	$1	$10	2014Q1	0.8%	$8	$1	$10
1.4%	Contracting & Reprographics	$21	$3	15%	$24	3.8%	$22	$3	$25	2014Q1	0.8%	$22	$3	$25
	Project Operations													
					$170				$177					$178
31	CONSTRUCTION MANAGEMENT													
10.8%	Construction Management	$165	$24	15%	$189	3.8%	$171	$25	$196	2014Q4	3.7%	$178	$26	$204
1.9%	Engineering During Construction	$29	$3	10%	$32	3.8%	$30	$3	$33	2014Q4	3.7%	$31	$3	$34
0.8%	Planning During Construction	$13	$2	15%	$15	3.8%	$13	$2	$16	2014Q4	3.7%	$14	$2	$16
	Project Operation:													
1.9%	Project Management	$29	$4	15%	$33	3.8%	$30	$5	$35	2014Q4	3.7%	$31	$5	$36
					$269				$280					$290
	CONTRACT COST TOTALS:	$1,921	$416		$2,337		$1,992	$432	$2,424			$2,028	$439	**$2,467**
									1.0371					1.0177

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****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Boston Harbor Deep Draft Navigation Improvement

DISTRICT: NAE New England PREPARED: 12/19/2012

LOCATION: Boston, Massachusetts **PLAN F - Chelsea River Channel Deepening Plan** POC: CHIEF, COST ENGINEERING, PATRICIA BOLTON

This Estimate reflects the scope and schedule in report; Updated Cost Engineering Appendix D2 for Feasibility Report, Dec 2012

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
	PLAN F - Chelsea River Channel **40-Foot Deepening/Widening** **342,600 CY Ordinary Dredging** **540 CY Rock**	Estimate Prepared: 1-Aug-11 Effective Price Level: 1-Jul-11				Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12				FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Contract 1 Option 3													
12	NAVIGATION PORTS & HARBORS	$8,498	$1,462	17%	$9,960	3.7%	$8,812	$1,516	$10,327	2014Q4	1.6%	$8,951	$1,540	$10,491
	CONSTRUCTION ESTIMATE TOTALS:	$8,498	$1,462	17%	**$9,960**		$8,812	$1,516	$10,327			$8,951	$1,540	$10,491
01	LANDS AND DAMAGES	$15	$2	10%	$17	3.7%	$16	$2	$17	2014Q4	1.6%	$16	$2	$17
30	PLANNING, ENGINEERING & DESIGN													
0.5%	Project Management	$40	$6	15%	$46	3.8%	$42	$6	$48	2014Q1	0.8%	$42	$6	$48
1.4%	Planning & Environmental Compliance	$122	$18	15%	$140	3.8%	$127	$19	$146	2014Q1	0.8%	$128	$19	$147
1.7%	Engineering & Design	$148	$22	15%	$170	3.8%	$154	$23	$177	2014Q1	0.8%	$155	$23	$178
0.1%	Engineering Tech Review ITR & VE	$8	$1	15%	$9	3.8%	$8	$1	$10	2014Q1	0.8%	$8	$1	$10
0.3%	Contracting & Reprographics	$25	$4	15%	$29	3.8%	$26	$4	$30	2014Q1	0.8%	$26	$4	$30
	Project Operations													
					$394				$409					$413
31	CONSTRUCTION MANAGEMENT													
8.1%	Construction Management	$686	$102	15%	$788	3.8%	$712	$106	$818	2014Q4	3.7%	$738	$110	$848
0.7%	Engineering During Construction	$57	$6	10%	$63	3.8%	$59	$6	$65	2014Q4	3.7%	$61	$6	$67
0.3%	Planning During Construction	$25	$4	15%	$29	3.8%	$26	$4	$30	2014Q4	3.7%	$27	$4	$31
	Project Operation:													
0.8%	Project Management	$70	$11	15%	$81	3.8%	$73	$11	$84	2014Q4	3.7%	$75	$11	$87
					$960				$996					$1,033
	CONTRACT COST TOTALS:	$9,694	$1,637		**$11,331**		$10,053	$1,697	$11,750			$10,228	$1,726	**$11,954**
									1.0370					

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BOSTON HARBOR
MASSACHUSETTS

NAVIGATION IMPROVEMENT STUDY

FINAL FEASIBILITY REPORT
AND FINAL SUPPLEMENTAL
ENVIRONMENTAL IMPACT STATEMENT
AND MASSACHUSETTS
FINAL ENVIRONMENTAL IMPACT REPORT

APPENDIX E

REAL ESTATE PLAN

THIS APPENDIX SUPPLEMENTED AUGUST 2008
TO INCLUDE NAD INTERNAL TECHNICAL REVIEW
CERTIFICATION

CENAE-RE-E 17 September 2007

MEMORANDUM FOR Chief, Planning Branch, ATTN: Mark Habel

SUBJECT: Boston Harbor Deep Draft Navigation Improvement Project, Boston, Massachusetts

1. Attached is the Real Estate Plan for the subject project in Boston, Massachusetts. All the work will be done in the water, including the disposal of the dredged material. The local sponsor, the Massachusetts Port Authority (Massport), owns extensive waterfront land, facilities and berthing space in the Port of Boston and they intend to make land and berthing space available for the construction staging area. The Board of Directors of Massport authorized leases and tenant-at-will agreements for 22,500 square feet of space at a set rate of $3,337.50 per month.

2. Should you have any questions regarding this report, feel free to contact Mary Dunn at extension 465.

JOSEPH M. REDLINGER
Chief, Real Estate Division

Enclosure

NEW ENGLAND DISTRICT
U.S. ARMY CORPS OF ENGINEERS
696 VIRGINIA ROAD
CONCORD, MASSACHUSETTS 01742-2751

REAL ESTATE PLAN
BOSTON HARBOR DEEP DRAFT NAVIGATION IMPROVEMENT PROJECT
BOSTON, MASSACHUSETTS

PREPARED BY:

A. MARY DUNN
STAFF APPRAISER

SEPTEMBER 2007

Boston Harbor Deep Draft Navigation Improvement Project, Boston, Massachusetts.

1.PURPOSE: This report is a result of a cost-shared feasibility study conducted by the New England District, Corps of Engineers, and the Massachusetts Port Authority (Massport). The purpose of this project is to deepen the major channels in Boston Harbor between 48 and 50 feet. Economic optimization indicates a depth of 48 feet yields the greatest net benefits.

2.a. PROJECT AREA DESCRIPTION: The construction effort for deepening the major channels in Boston Harbor is anticipated to take six years. All the construction work will be done in the water, below Mean Lower Low Water (MLLW). All the dredged material has been determined suitable for ocean disposal by US EPA.

2.b. RECOMMENDED PLAN:

The work for all of the alternatives will be in the water with access from Massport facilities for the work boats, tugs, and other floating plant. The disposal site for the dredging material is in the water.

The proposed project consists of four separate improvements:

1. Deepening areas of the Federal navigation channels providing access from Broad Sound to the Conley container terminal in South Boston, including the Broad Sound North Entrance Channel, President Roads Anchorage, lower Main Ship Channel through the roads to the Reserved Channel, the lower Reserved Channel and the Reserved Channel Turning Area. Depths of 45 to 50 feet are being examined, with an additional two feet required in the North Entrance Channel, which would also be widened at the Finns Ledge bend. The Reserved Channel Turning Area would also be widened.

2. Extending the deepening of the Main Ship Channel above the Reserved Channel to access Massport's Marine Terminal in South Boston at a depth of up to 45 feet.

3. Deepening a small 35-foot portion of the Mystic River Channel to 40 feet to access Massport's Medford Street Terminal in Charlestown.

4. Deepening the 38-foot Chelsea River Channel and its turning basin to 40 feet, with minor widening in the bridge approaches and the channel bend between bridges.

All the project areas to be deepened under the main channel's plan are presently part of the existing 40-foot and 35-foot deep Federal navigation project features except of small ledge areas that would be removed to widen the outer approach turn in the entrance channel opposite Finns Ledge and enlargement of the Reserved Channel Turning Area.

The main ship channel deepening extension to the Marine Terminal, the deepening of the Mystic River at Medford Street, and the deepening of the Chelsea River all involve dredging to deepen the existing project limits, except for three small areas along the Chelsea River Channel. The area immediately upstream of the A.P. McArdle Bridge and the area of the bend between the bridges just downstream of the Conoco-Philips Terminal, both along the East Boston side of the channel, would be widened by no more than 50 feet. At the Chelsea Street Bridge, the Federal channel would be widened to conform to the new fender opening as part of the next maintenance dredging operation (the Chelsea Street Bridge is scheduled for replacement in 2008-2009 by the City and the U.S. Coast Guard). The widened channel cut through the bridge opening would also be deepened.

The Corps and Environmental Protection Agency (EPA) have determined that all of the material to be removed by the deep draft improvement project consists of parent glacial material and rock determined suitable for disposal at the Massachusetts Bay Disposal Site. The main channel improvement plan at 48 feet and the three additional plans (main ship channel extension, Mystic River and Chelsea River) would generate about 12 million cubic yards of ordinary unconsolidated material and 1.1 million cubic yards of blasted rock. The rock would either be used for beneficial purposes, made available for use upland as structural fill by other parties, or placed at the Mass Bay Disposal Site.

As with the 1998-2001 improvement dredging, Massport will provide some space at one of its terminals for the construction office trailers, construction team parking, and temporary berthing as needed for the construction plant (in 1998, they used a site in East Boston).

It appears that a channel depth of 48 feet (MLLW) with 50 feet in the entrance channel for the main channel improvement to the Conley Terminal results in the highest net benefit.

2.c. OWNERSHIPS: All of the work will be done in the water and the open sea will be used as a disposal site for the dredged material. The Massachusetts Port Authority owns extensive waterfront land, facilities and berthing space in the Port of Boston, and they intend to make land and berthing space available to the contractor or the Corps for construction staging and access to the water. A specific site will be identified by Massport prior to the issuance of the project solicitation.

3. DESCRIPTION OF NON-FEDERAL SPONSOR'S EXISTING OWNERSHIP:

Massport owns extensive waterfront land, facilities and berthing space in the Port of Boston including the Fish Pier, Boston Autoport, and the Conley Terminal.

4. RECOMMENDED ESTATES: The work will all be done in the water and the open sea will be used as a disposal site for the dredged material. The only land needed for this project is approximately 22,500 square feet of land that will be utilized by the contractor for a staging area. The Massachusetts Port Authority owns extensive waterfront land, facilities and berthing space in the Port of Boston, and they intend to make land and berthing space available to the contractor or the Corps for construction staging area. They (Massport) will be given credit for the temporary use of the land area needed during construction.

5. EXISTING FEDERAL PROJECTS: There are no current projects in the project area.

6. EXISTING FEDERAL OWNERSHIPS: There are no federally owned lands in the project area.

7. NAVIGATION SERVITUDE: Navigation servitude applies since the purpose of this project is to deepen and widen the anchorage areas and channels at Boston Harbor. All construction, operation, and maintenance are within the navigation servitude and the navigation servitude will be exercised.

8. REAL ESTATE MAPPING: No real estate maps are available and none are anticipated to be needed for this project. The Massachusetts Port authority owns extensive waterfront land, facilities and berthing space in the Port of Boston and they intend to make land and berthing space available to the contractor for the construction staging area. A specific site will be identified by Massport prior to the issuance of the project solicitation. Some of the options are the Fish Pier, Boston Autoport, and the former Coastal Oil property.

9. INDUCED FLOODING: No induced flooding is anticipated due to the proposed project.

10. BASELINE COST ESTIMATE FOR REAL ESTATE:

Fee Value: No fee acquisition is required.

Permanent Easement Value: No permanent easement areas will be required.

Temporary Easement Value: In 1995, the Board of Directors of the Massachusetts Port Authority voted to authorize leases and tenants-at-will agreements for space at their various facilities at a rate of $1.25 per square foot per year, for storage areas greater than 1000 square feet. This rate was effective March 1, 1995 through February 28, 1999. The board also voted that the rate would escalate at a rate of between 2% and 10% annually, effective on the first day of March each year. The annual escalation set was 2.7% which brings the current annual rate to $1.78 per square foot.

Thus, using the rate authorized by the Board of Directors of the Massachusetts Port Authority, the annual rent for the temporary use of the 22,500 square feet of land is $40,050 or $3,337.50 per month.

Administrative Costs: There are no administrative costs associated with this project.

11. PUBLIC LAW 91-646 RELOCATIONS: No potential Public Law 91-646 relocations are required in connection with this project.

12. MINERAL/TIMBER ACTIVITY: There is no present or anticipated mineral or timber harvesting activity in the vicinity of the project that may affect the operation thereof.

13. ASSESSMENT OF NON-FEDERAL SPONSOR'S REAL ESTATE ACQUISITION CAPABILITIES: The non-federal sponsor is the Massachusetts Port Authority (Massport). There will not be any real estate acquired for this project, therefore, the *Assessment of Non-Federal Sponsor's Real Estate Acquisition Capability* is not required.

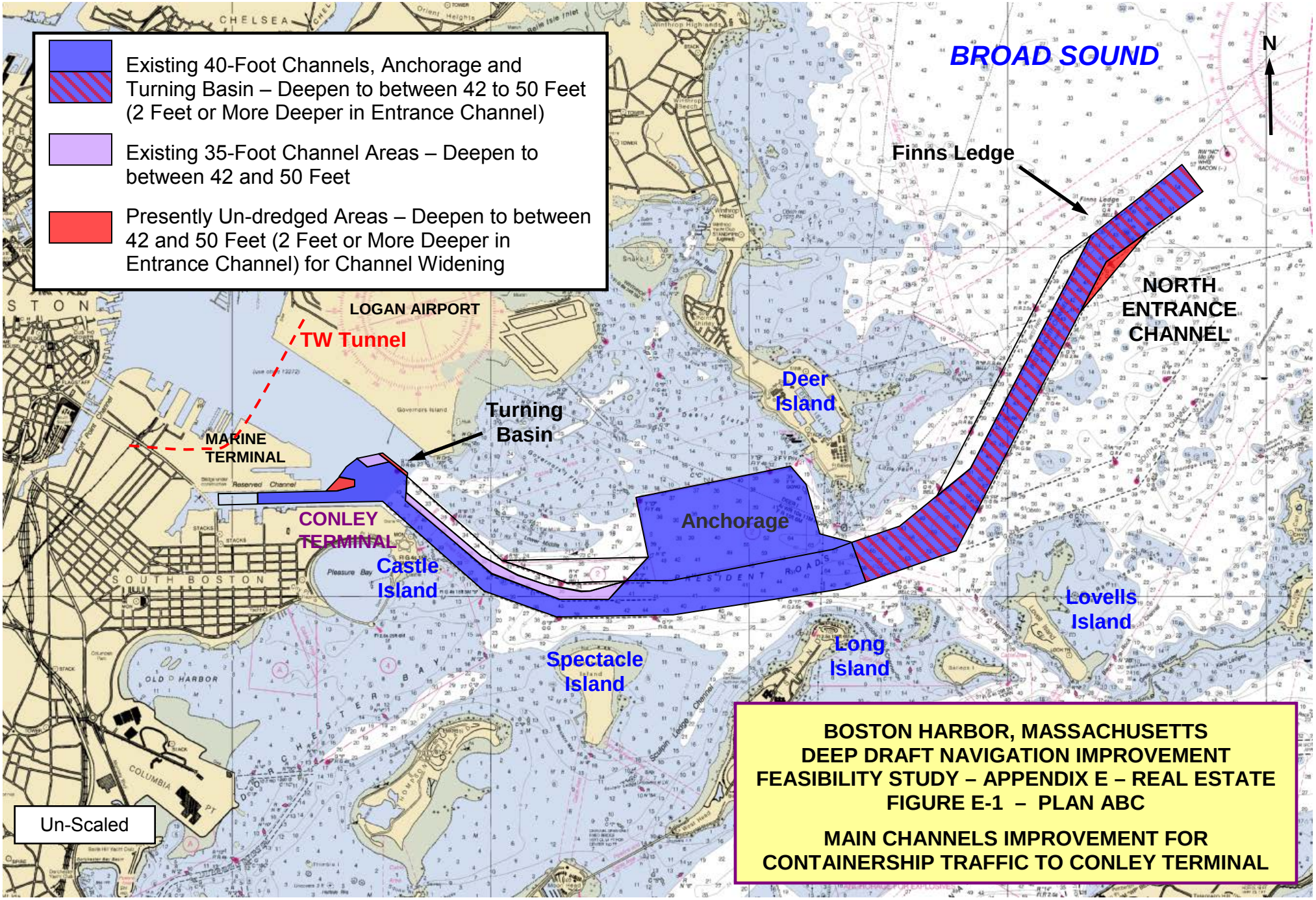
14. ZONING CHANGES: No zoning changes are proposed in lieu of, or to facilitate, real estate acquisitions.

15. ACQUISITION SCHEDULE: There is no real estate being acquired for this project, since all the work will be in the water and the disposal site is also in the water. Massport owns extensive waterfront land, facilities and berthing space in the Port of Boston and will make land and berthing space available to the Corps and the contractor for a staging area.

16. FACILITIES AND UTILITIES RELOATIONS: The proposed project will not require any utility and/or facility relocations.

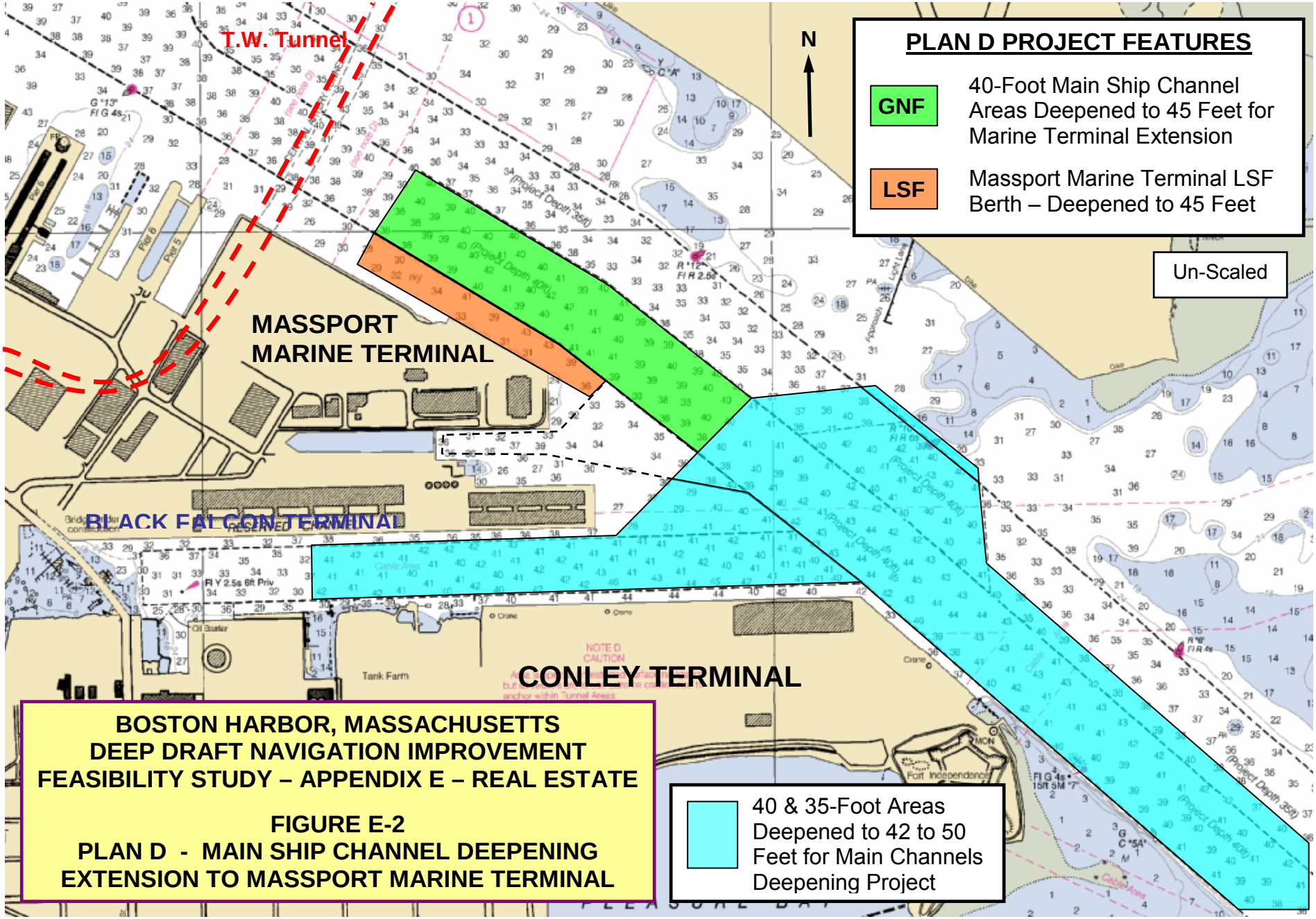
17. HAZARDOUS, TOXIC, AND READIOACTIVE WASTE: There is no known on-site contamination.

18. LANDOWNER SENTIMENT: The Massachusetts Port Authority is very much in favor of this project, and any deep draft navigation dependent terminal that receives large vessels would benefit from the project.



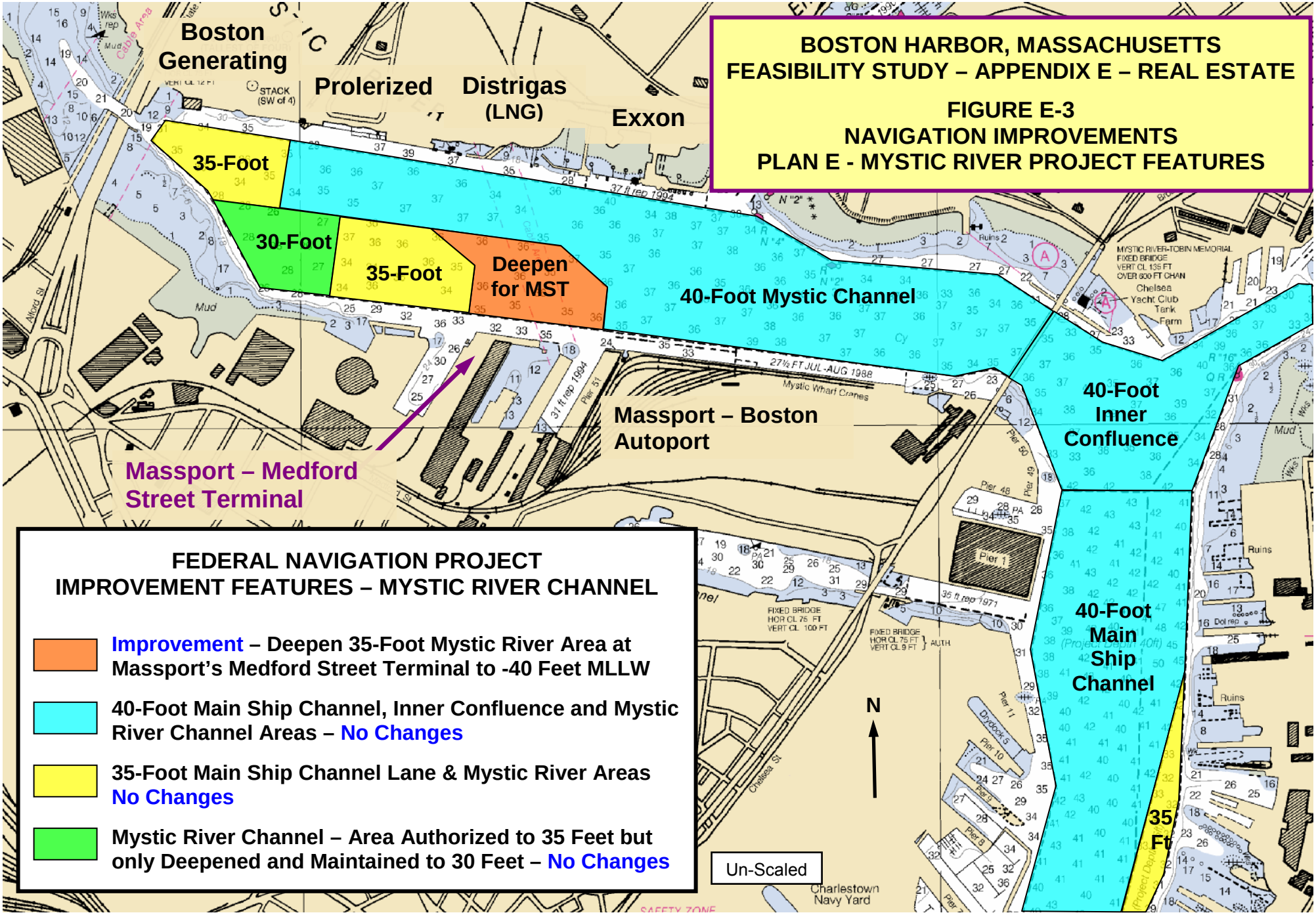
BOSTON HARBOR, MASSACHUSETTS
DEEP DRAFT NAVIGATION IMPROVEMENT
FEASIBILITY STUDY – APPENDIX E – REAL ESTATE
FIGURE E-1 – PLAN ABC

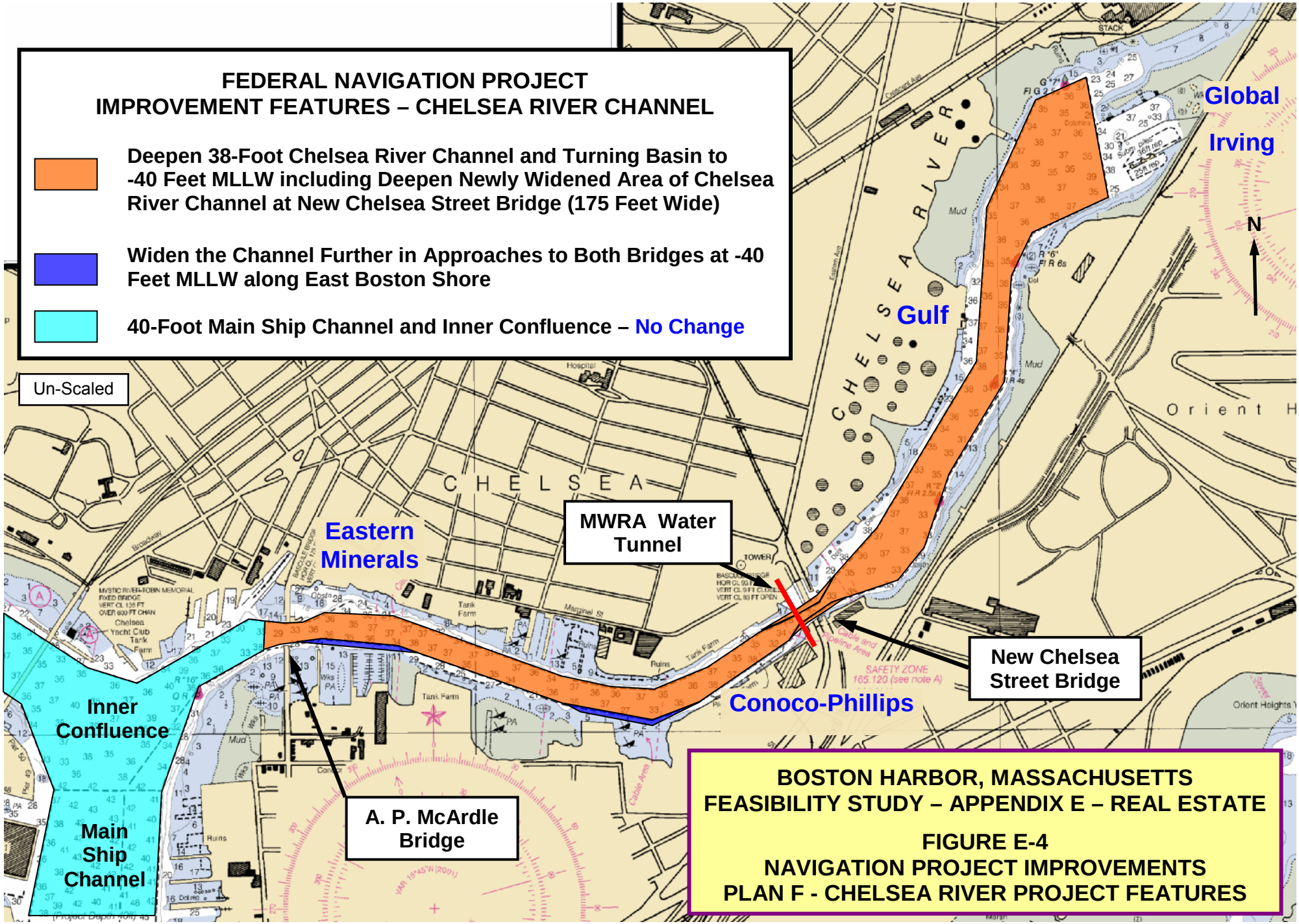
MAIN CHANNELS IMPROVEMENT FOR CONTAINERSHIP TRAFFIC TO CONLEY TERMINAL



BOSTON HARBOR, MASSACHUSETTS
DEEP DRAFT NAVIGATION IMPROVEMENT
FEASIBILITY STUDY – APPENDIX E – REAL ESTATE

FIGURE E-2
PLAN D - MAIN SHIP CHANNEL DEEPENING EXTENSION TO MASSPORT MARINE TERMINAL


BOSTON HARBOR, MASSACHUSETTS
FEASIBILITY STUDY – APPENDIX E – REAL ESTATE
FIGURE E-3
NAVIGATION IMPROVEMENTS
PLAN E - MYSTIC RIVER PROJECT FEATURES
Boston Generating
Prolerized
Distrigas (LNG)
Exxon
35-Foot
30-Foot
35-Foot
Deepen for MST
40-Foot Mystic Channel
Massport – Boston Autoport
Massport – Medford Street Terminal
40-Foot Inner Confluence
40-Foot Main Ship Channel
35 Ft
FEDERAL NAVIGATION PROJECT
IMPROVEMENT FEATURES – MYSTIC RIVER CHANNEL
Improvement – Deepen 35-Foot Mystic River Area at Massport's Medford Street Terminal to -40 Feet MLLW
40-Foot Main Ship Channel, Inner Confluence and Mystic River Channel Areas – No Changes
35-Foot Main Ship Channel Lane & Mystic River Areas No Changes
Mystic River Channel – Area Authorized to 35 Feet but only Deepened and Maintained to 30 Feet – No Changes
Un-Scaled
N
Charlestown Navy Yard


FEDERAL NAVIGATION PROJECT
IMPROVEMENT FEATURES – CHELSEA RIVER CHANNEL
Deepen 38-Foot Chelsea River Channel and Turning Basin to -40 Feet MLLW including Deepen Newly Widened Area of Chelsea River Channel at New Chelsea Street Bridge (175 Feet Wide)
Widen the Channel Further in Approaches to Both Bridges at -40 Feet MLLW along East Boston Shore
40-Foot Main Ship Channel and Inner Confluence – No Change
Un-Scaled
Global
Irving
Gulf
N
CHELSEA RIVER
CHELSEA
Eastern Minerals
MWRA Water Tunnel
New Chelsea Street Bridge
Conoco-Phillips
Inner Confluence
Main Ship Channel
A. P. McArdle Bridge
BOSTON HARBOR, MASSACHUSETTS
FEASIBILITY STUDY – APPENDIX E – REAL ESTATE
FIGURE E-4
NAVIGATION PROJECT IMPROVEMENTS
PLAN F - CHELSEA RIVER PROJECT FEATURES

Integrated General Reevaluation Report
&
Environmental Impact Statement
Review Report

Boston Harbor Deep Draft Navigation Improvement Project

Boston
Massachusetts

Internal Technical Review of
Real Estate Plan

Location: Federal Navigation Channels, Boston Harbor, Boston, Massachusetts

User: USACE

Appraiser: A, Mary Dunn
Staff Appraiser, New England District
North Atlantic Division
USACE
Boston, Massachusetts

Effective Date of Valuation: September 2007

Appraisal Report Date: September 2007

Date of Review: 19 June 2008

Navigational Servitude: Navigational servitude applies since the purpose of this project is to deepen and widen the anchorage areas and channels at Boston Harbor. All construction, operation, and maintenance are within the navigational servitude and the navigational servitude will be exercised.

Estate Appraised: There is no real estate or rights to real estate being acquired for this project since all the work will be in the water and the disposal site is also in the water. Massachusetts Port Authority (Massport) owns extensive waterfront land, facilities and berthing space in the Port of Boston and will make land and berthing space available to the USACE and the contractor for a staging area.

Recommended Estates:	All work will be done in the water and the open sea will be used as a disposal site for the dredged material. Massport owns extensive waterfront land, facilities and berthing space in the Port of Boston, and they intend to make land and berthing space available to the contractor of the Corps for construction staging area. Massport will be given credit for the temporary use of the land area needed during construction. The land area required by the contractor is approximately 22,500 square feet.
Purpose:	The report is a result of a cost-shared feasibility study conducted by New England District Corps of Engineers, and the Massachusetts Port Authority. The purpose of this project is to deepen and widen the major channels in Boston Harbor between 48 and 50 feet. Economic optimization indicates a depth of 48 feet yields the greatest net benefits.
Project Area Description:	The construction effort for deepening the major channels in Boston Harbor is anticipated to take six years. All the construction work will be done in the water, below Mean Lower Low Water (MLLW). All dredged material has been determined suitable for ocean disposal by the US EPA.
Baseline cost Estimated for Real estate:	No fee acquisition is required and no permanent easement areas will be required. In 1995 , the Board of Directors of Massport voted to authorize leases and tenants-at-will agreements for space in their various facilities at a rate of $1.25 per square foot per year, for storage areas greater than 1,000 square feet. When the annual escalations are applied a current rental of $1.78 per foot is derived or $40,050 annually or $3,357.50 per month.
Intended Use:	The Intended Use of this review report is to recommend approval/disapproval of the report under review.
Scope of Review:	This survey is reviewed by the undersigned. The review is a desk review only. The report was reviewed for adequacy of community data, property/channel description, comparative data, and support for the reasonableness of the final value conclusion. In addition, I have reviewed the report for compliance with USPAP and UASFLA. The rental rate determined by the Board of Director of Massport is for internal use of the USACE and considered to be subject to the Jurisdictional Exception provision of USPAP.

General Comments: The work for all of the project alternatives will be in the water with access from Massport facilities for the work boats, tugs, and other floating plant. The disposal for the dredging material is also in the water. The proposed projects are well defined, explained and readily understandable. The USACE and EPA have determined that all of the material to be removed by the deep draft improvement project consists of parent glacial material and rock determined suitable for disposal at the Massachusetts Bay Disposal Site. The description is based on information made by the owner, appraiser or his representative.

The rental rate for the land appears to be justified and is supported by Massport. The appeal for the subject project is due to the fact that it will increase commerce by allowing larger and wider ships to pass, and hence potentially bring in more business.

I am in agreement with the USACE appraiser's report. I agree with the methodology employed used to obtain said value and conclusions. The methods used to estimate said conclusions are very descriptive and encompass adequate analysis.

Conclusions

I am in agreement with the report prepared by the government appraiser and is in accordance with USPAP, UASFLA or USACE guidelines.

It does provide a comprehensive market analysis of the subject.

It explains the valuation portion of the report.

It explains the revaluation report and the environmental impact statement.

It reaches supported conclusions.

I recommend acceptance of the Navigation Improvement Study, Draft Feasibility Report and Supplemental Impact Statement (and Massachusetts EIR) Appendix E Real Estate Plan performed on the subject property by A. Mary Dunn, government appraiser, New England District, USACE with an effective date of September 2007

Certification:

CERTIFICATION:

I certify that to the best of my knowledge and belief:

- The facts and data reported by the review appraiser and used in the review process are true and correct.

- The analyses, opinions, and conclusions in this review report are limited only by the assumptions and limiting conditions stated in this review report, and are my personal, impartial and unbiased professional analyses, opinions and conclusions.

- I have no present or prospective interest in the property that is the subject of this report and I have no personal interest with respect to the parties involved.

- I have no bias with respect to the property that is the subject of this report or to the parties involved with this assignment.

- My engagement in this assignment was not contingent upon developing or reporting predetermined results.

- My compensation is not contingent on an action or event resulting from the analyses, opinions, or conclusions in this review or from its use.

- My analyses, opinions, and conclusions were developed, and this review report was prepared in conformity with the Uniform Appraisal Standards for Federal Land Acquisitions and in conformity to the Uniform Standards of Professional Appraisal Practice.

- I did not personally inspect the subject property(s) of the report under review. I did not make a personal inspection of the market comparables cited in the appraisal report under review. I did not verify the factual data presented in the appraisal report.

- No one provided significant real or personal property appraisal or appraisal review assistance to the person signing this certification.

- The Appraisal Foundation through each state's division of registration of Real Estate Appraisers requires a mandatory program of continuing education for recertification. I am in compliance with the requirements of the program."

Charles P. Cavanna

Charles P. Cavanna, MAI, SRA
Chief Appraiser
New York District.