

Appendix A

Navigation Channel and Bathymetry

1 Lower Passaic River and Newark Bay Navigational Channels

The Lower Passaic River (LPR) federal navigation channel extends from the mouth of the river (U.S. Army Corps of Engineers [USACE] river mile [RM] 0) to the Eighth Street Bridge in Wallington, New Jersey (USACE RM 15.4; USACE 2014a).¹ This channel has the following four distinct segments due to four different authorized depths (USACE 2014a):

1. 30-foot segment (USACE RM 0 to USACE RM 2.6): the channel has an authorized constructed depth of 30 feet mean low water (MLW) and is 300 feet wide. The mean tidal range in this segment of the river is 5.5 feet.
2. 20-foot segment (USACE RM 2.6 to USACE RM 7.1): the channel has an authorized constructed depth of 20 feet MLW and is 300 feet wide. From USACE RM 4.1 to USACE RM 7.1, the project was only constructed to 16 feet MLW.
3. 16-foot segment (USACE RM 7.1 to USACE RM 8.1): the channel has an authorized constructed depth of 16 feet MLW and is 200 feet wide.
4. 10-foot segment (USACE RM 8.1 to USACE RM 15.4): the channel has an authorized constructed depth of 10 feet MLW and is 150 feet wide.

The federal navigation channel for Newark Bay was authorized by The Rivers and Harbors Act of 1922. The Newark Bay channels include the following (USACE 2014b):

1. A main channel, including widening and maneuvering areas, 40 feet deep, 700 feet wide to the branch channel at Port Newark, thence 500 feet wide, to a turning basin at the junction of the Hackensack and Passaic river channels, length about 4.7 miles
2. A branch channel at Port Newark (Port Newark Branch Channel) 35 feet deep, 800 feet wide, leading to an inshore channel, 400 feet wide, total length 1.6 miles
3. A pierhead channel (Port Newark Pierhead Channel) 200 feet wide, between the Port Newark and Elizabeth branch channels, length 4,100 feet
4. A branch channel (Elizabeth Channel) 40 feet deep, 500 feet wide, leading to an inshore channel, 400 feet wide, total length 1.4 miles
5. A pierhead channel (Port Elizabeth Pierhead Channel) 40 feet deep, 290 feet wide, between Elizabeth and South Elizabeth branch channels, length 1.1 miles
6. A branch channel (South Elizabeth Channel) 40 feet deep, 290 feet wide, and 0.6 miles long

¹ USACE and the U.S. Environmental Protection Agency (USEPA) Remedial Investigation (RI) RM on the site differ by about 0.3 miles due to the specification of the zero RM location. The USACE RMs can be seen in Figures 1a and 1b of USACE 2014a. In this document, USACE RMs are designated by the prefix USACE, while the RI RMs have no such prefix.

1.1 Dredging History of the Lower Passaic River Navigation Channel

The LPR navigation channel was initiated in the late-1800s following completion of the Dundee Dam and lock system in 1858. The first dredging for commercial navigation occurred in 1874. From then to the late 1920s, numerous deepening and maintenance dredging activities took place (USACE 2014a). Since 1932, no new channel construction has been authorized, although parts of the existing channel were maintained for 50 more years. A list of historical maintenance projects can be found in USACE (2014a).

In addition to the maintenance projects listed in USACE (2014a), a review of USACE dredging drawings identified regions that were dredged in the 1970s, including stretches between RM 7.8 and RM 8.3 (dredged in 1974), between RM 10.6 and RM 11 (dredged in 1976), and between RM 12.1 and RM 12.4 (dredged in 1976).² These dredging events have been included in the RI analysis (Sections 1.2 and 4 of the main Remedial Investigation [RI] document).

2 Bathymetry Surveys of the Lower Passaic River

Bathymetry surveys used in the RI are listed in Table 1, and discussed in the following paragraphs.

Surveys conducted in 1989 or earlier are documented in map form. The data presented on these maps were digitized for use in the RI. The digitized data are subject to several sources of uncertainty. While the uncertainty is not quantifiable, some possible sources are the accuracy of positioning and water depth measurements, errors introduced during the scanning of the paper drawings, errors in the rectifying process, and errors in interpretation of handwritten depth values. Further, the 1949 data was not collected using specific transects but soundings covering the entire river area (see Section 3 of Attachment B of the Sediment Transport Appendix [Appendix M] for details).

The earliest surveys for which electronic data are available are single-beam surveys conducted between RM 1 and RM 7 in 1995, 1996, 1997, 1999, and 2001. Of these, only the 1995 survey was used in the RI. The spatial extent of the remaining bathymetry transects included points on land and were thus excluded due to data quality concerns.

The 2004 single-beam survey was the first (and only) survey to extend nearly bank to bank for the entire 17.4 miles of the LPR. Multi-beam surveys were conducted in 2007, 2008, 2010, 2011, and 2012, generally over the region between RM 0 and RM 14. Due to the inability to collect multi-beam data in shallow water, these surveys typically only covered the channels and the deeper portions of the adjacent shoals. As part of the multi-beam surveys, 13 single-beam transects were collected downstream of RM 7 for a direct comparison with pre-2007 data. The 2007 and 2012 multi-beam surveys were supplemented by single-beam data in certain shoals. A single-beam survey was also

² The RMs here denote the RI/FS RMs.

collected in 2013 to characterize the RM 10.9 removal area. The main 2011 multi-beam survey was conducted between October and November, after Hurricane Irene. A pre-Irene multi-beam survey from July 2011 is also available between RM 10 and RM 12.

The 2008 bathymetry was found to vary from the other multi-beam data at locations where no change is expected (such as locations with car wrecks and sonar targets) and was consequently adjusted by systematically adding 0.3 feet to all measurements (see Section 4 of Attachment B of the Sediment Transport Appendix [Appendix M] for details). The bathymetry data used in each of the ten reaches discussed in Section 4 of the main report are listed in Table 2.

The multi-beam bathymetry was collected on a 1-foot by 1-foot grid, and has a depth accuracy of approximately +/- 0.15 meters (m) (AECOM 2010). The uncertainty of estimating a difference between two surveys on a 1-foot by 1-foot basis is the square root of the sum of the squares of the measurement uncertainty, thus +/- 0.21 m (0.7 feet or 8.4 inches).

The uncertainty declines when multiple measurements are combined to calculate an average depth over a larger area (Wolfs 2013).

The uncertainty in the average difference between two 1-foot by 1-foot bathymetry datasets on a 5-foot by 5-foot basis is calculated as follows in Equation 1:

Equation 1

$$\Delta B_{5 \times 5} = \frac{\sqrt{25 * \Delta B_{1 \times 1}^2}}{25} = \frac{\sqrt{25 * (\pm 0.21)^2}}{25} = 0.04m \cong 0.14ft$$

In other words, absent other sources of error, the multi-beam bathymetry data evaluated at a 5-foot by 5-foot resolution can distinguish differences greater than about 0.14 foot (roughly 2 inches). However, other sources of error do exist, including datum differences that are evaluated in Appendix B of Attachment B of Appendix M and summarized in Table 4-3 of Attachment B of Appendix M (included here as Table 3). The aforementioned adjustment to the 2008 bathymetry survey, which made each location 3.6 inches shallower than measured, is an approximate correction given the range of possible corrections evident in Table 3. The differences between the 2008 and 2010 bathymetry suggest a smaller correction of 2.4 inches with a range of 1.7 to 3.4 inches shallower. The difference between the 2008 and 2011 bathymetry suggest an even smaller correction of 1.2 inches with a range of 0.4 inches deeper to 2.5 inches shallower. This uncertainty in the appropriate correction factor means that bathymetric differences involving the 2008 survey have

several inches of additional uncertainty beyond the roughly 2 inches derived from instrument measurement error. For this reason, comparisons using the 2008 survey use a threshold of 6 inches for meaningful difference to ensure that conclusions regarding erosion or deposition between surveys are not corrupted by instrument noise and datum uncertainty. Even with this threshold, the estimates of erosion or deposition are affected by the datum uncertainty. If the lower estimates of 2008 bias are correct (1.2 or 2.4 inches rather than the 3.6 inches used), comparisons to more recent surveys would yield smaller areas with 6 inches or more of erosion and larger areas with 6 inches or more of deposition (the opposite would be true when comparing the 2008 survey to the 2007 survey).

The analysis in Table 4-3 of Attachment B of Appendix M also indicates approximately 0.1 feet (1.2 inches) of datum uncertainty for the 2010 to 2011 survey comparison. For this reason, multibeam comparisons that do not involve the 2008 survey are in some portions of the RI (where noted) evaluated using a 3-inch uncertainty threshold, assuming approximately 1 inch of datum uncertainty and 2 inches of measurement error (based on Equation 1).

Differences in elevations involving a single-beam bathymetry survey are subject to interpolation error between survey transect lines in addition to instrument error and datum differences. Datum differences are difficult to assess with these data because transect lines of compared surveys do not precisely overlap. Absent any assessment of datum differences, but recognizing interpolation error and instrument measurement error, the minimum differences considered in these comparisons was set at 6 inches.

3 References

AECOM, 2010. Quality Assurance Project Plan. Lower Passaic River Restoration Project. Revision 2, May 2010.

USACE, 2014a. Lower Passaic River Commercial Navigation Analysis. Revised April 2014.

USACE, 2014b. FACT SHEET – Newark Bay, Hackensack and Passaic Rivers, New Jersey. Newark Bay Channels Federal Navigation Channel Maintenance and Stewardship. U.S. Army Corps of Engineers, New York District. February 2014. Available at:
<http://www.nan.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/11241/Article/9371/fact-sheet-newark-bay-hackensack-and-passaic-rivers-new-jersey.aspx>.

Wolfs, F.L., 2013. Error Analysis. Available at:
http://teacher.pas.rochester.edu/PHY_LABS/AppendixB/AppendixB.html.