WEST RIVER TIDE GATES
AND
EDGEWOOD PARK
TIDAL FLUCTUATION AND SALINITY
MIGRATION MONITORING STUDY

NEW HAVEN, CONNECTICUT

April 2005

MMI #1621-05

Prepared for:

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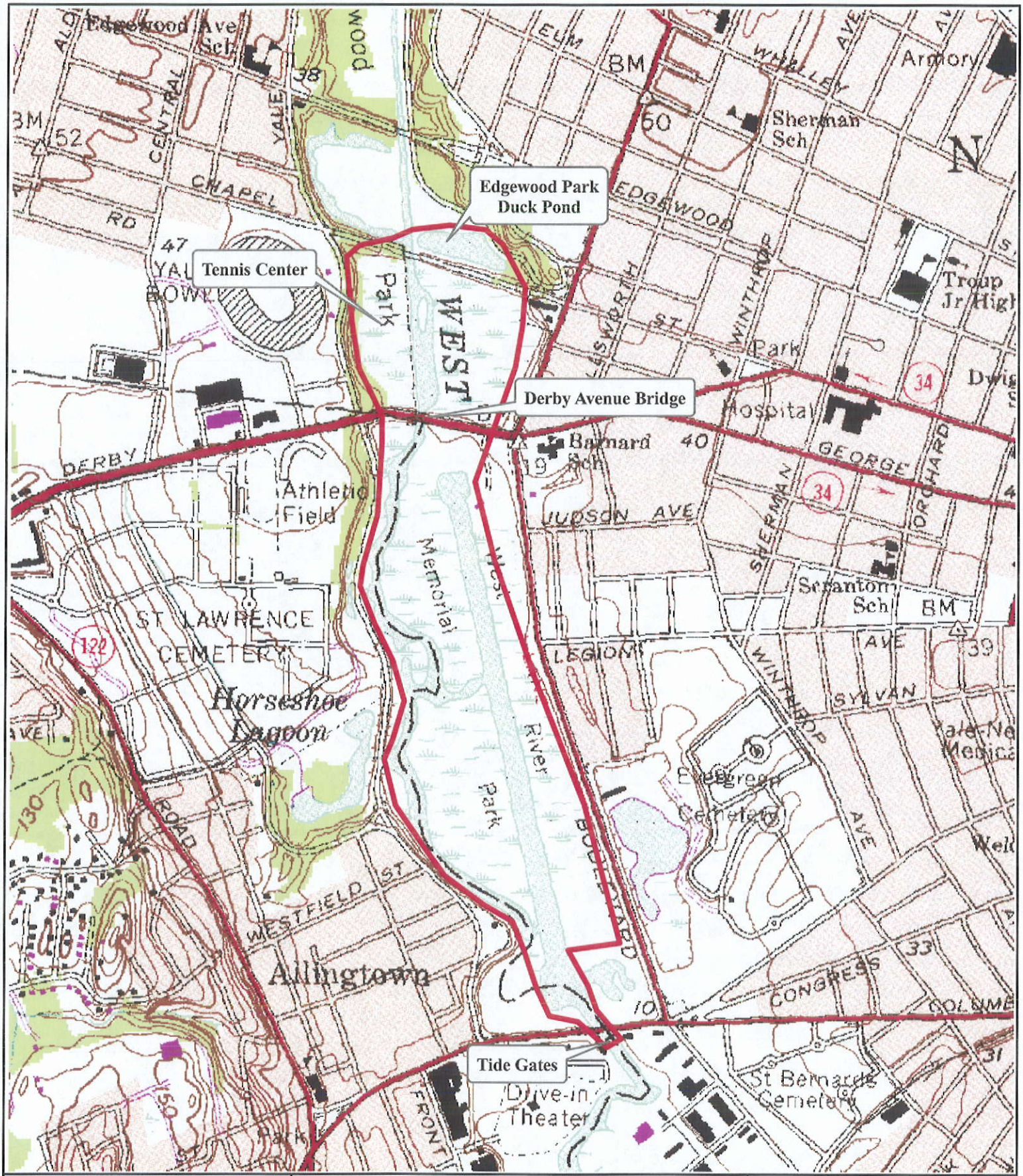
1.0 INTRODUCTION AND BACKGROUND

Milone & MacBroom, Inc. (MMI), was retained by the City of New Haven to complete a tidal fluctuation and salinity migration monitoring study in the West River near Edgewood Park. The study area at West River Memorial Park extends from Congress Avenue (Orange Avenue in West Haven) to the duck pond at Edgewood Park, along the border between New Haven and West Haven, Connecticut. The area is a former salt marsh that once covered approximately 130 acres of land, but has since been disturbed by dredging, filling, and the installation of tide gates. The West River meanders in its floodplain, with backwater sloughs marking its former course.

A long, linear pool was dredged parallel to the main river channel as part of an earlier park development plan. This area is referred to as the *reflecting pool*, as its purpose was to highlight the spectacular view of West Rock Ridge to the north. For many years, it served as a rowing course for Yale University.

The remainder of the study area has been partially developed as a City park with active and passive recreation opportunities, including the World War I Memorial Statue, Marginal Drive for walking and biking, soccer fields, basketball courts, parking areas, canoe launches, trails, and areas for fishing access. New Haven's Edgewood Park, located along the West River upstream of Derby Avenue Bridge, has its own complex of roads, trails, a baseball field, basketball courts, a duck pond, and other structures and facilities. Edgewood Park also includes areas of former tidal marsh.

In addition, the City has built a championship level tennis center adjacent to the West River between the Derby Avenue and Chapel Street bridges. The tide gates downstream of Orange Avenue Bridge were installed in 1920 to help control mosquitoes and reclaim the marsh for park usage, as per common practice at that time. The study area is illustrated on Figure 1.



Engineering, Landscape Architecture and Environmental Science

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West River Tide Gate Study

LOCATION: New Haven, CT

MMI#: 1621-05
MXD: H:gauge_locations.mxd
SOURCE: DEP Bulletin 37

Study Area Location Map

DATE: April 2005
SCALE: 1:12,000

SHEET: Figure 1

A manually operated sluice gate and port was installed on one of the tide gates in February 2004 by the City to increase tidal flushing upstream of the Orange Avenue Bridge. The sluice gate is approximately 18-inches wide by 30-inches long and remains open throughout the daily tidal cycle. In April 2004, the City observed abnormally high water levels following heavy rains in the duck pond at Edgewood Park. This condition may have been caused by the unusually wet 2004 spring conditions (i.e. fresh water flooding) or possibly as a result of the modified gate structure. This study was completed to determine impacts (or lack thereof) from the tide gate modification at critical ground elevations associated with the newly renovated soccer fields, tennis center, and duck pond at Edgewood Park.

In coordination with the tide gate modification, the City installed a *Flowline Echonet* wireless water level transmitter on the downstream side of the middle pier under the Orange Avenue Bridge. The sensor is located at elevation 4.60 feet National Geodetic Vertical Datum (NGVD) 1929. The sensor transmits a laser beam to the river's water surface, allowing monitoring of the elevation of the river throughout each day's tidal cycle. If the water level reaches a critical elevation (specified by the City), then the sensor transfers a text message to the City's Planning Department, warning staff to take precautionary measures, such as closing the sluice gate and/or tide gates. Note that under normal conditions the tide gates remain closed during incoming high tides with the exception of the sluice gate.

As part of this study, MMI completed the following data collection tasks:

- Installed four pressure sensitive water level gauges within the West River and monitored water levels from November 2004 to January 2005.

- Surveyed the location and elevation of the water level gauges and the City's water level sensor located on the downstream side of Orange Avenue Bridge.

- Obtained West River salinity measurements at high tide at the gauge stations on a weekly basis for approximately six weeks.

- Performed hourly salinity measurements for one complete 12-hour spring tide cycle. These measurements were collected with three tide gates open during low and high tide.

2.0 TIDAL FLUCTUATION

2.1 Flood Tides

Coastal salt marshes are subject to abnormally high flood tides in addition to the daily ebb and flow of the sea. In Connecticut, most flood tides are caused by near shore maritime storms, including hurricanes, tropical storms, and nor'easters. These events create a storm surge that temporarily raises the sea level due to a combination of low barometric pressure and on-shore winds.

Long Island Sound is particularly sensitive to storms that move northwards up the eastern seaboard and across Long Island. With counterclockwise circular winds, the leading edge of northward moving coastal storms produce easterly winds that force water into Long Island Sound, creating storm surge. The storm surge of a 100-year frequency event is estimated to be six to eight feet above the ambient still water level, depending upon location. The magnitude of the storm tide is influenced by its timing relative to the normal astronomical tide. The worst combination is when the storm surge occurs simultaneously with a normal high tide or spring tide.

The U.S. Army Corps of Engineers has used historic tide elevation data and computer models to predict the elevation of rare flood tides on Long Island Sound, corrected for sea

level rise. Table 1 presents data from the publication *Tidal Flood Profiles New England Coastline*, published in 1988.

TABLE 1
ACOE New Haven Harbor Flood Tide Elevations

Tide Frequency	*Stillwater Elevation, NGVD (feet)*
100 Year	10.6
50 Year	9.9
10 Year	8.6
1 Year	5.4

2.2 Non-Flood Tides

The NOAA mean tide level at the entrance to New Haven Harbor, after conversion to National Geodetic Vertical Datum, is at elevation 0.58 feet NGVD. Based upon the NOAA mean tide range of 6.2 feet, the mean high water (MHW) would fall at elevation 3.68 feet NGVD and the mean low water (MLW) would fall at elevation -2.52 feet NGVD.

The U.S. Army Corps of Engineers has also published mean tide data for Long Island Sound based upon the 1978 Tidal Epoch. This reference date is used because mean sea level varies throughout the world. The mean tide level at the entrance to New Haven Harbor, based upon the Army Corps of Engineers 1978 Tidal Flood Survey, is at elevation 0.7 feet NGVD. MHW is at elevation 3.8 feet NGVD and MLW is at elevation -2.3 feet NGVD.

Table 2 compares NOAA and ACOE tidal data.

TABLE 2
Published New Haven Harbor Tide Data USACOE & NOAA (NGVD 1929)

Tidal Condition	*Army Corps of Engineers*	*NOAA*
Mean Spring High Water	4.2	4.2
Mean High Water	3.8	3.68
Mean Tide	0.6	0.58
Mean Low Water	-2.5	-2.52
Tidal Range (Feet)	6.3	6.20

Spring tides represent the highest tides that occur on a frequent basis and generally represent the upper potential elevation limit of salt marsh vegetation. The predicted mean spring tide for Long Island Sound has a range of 7.1 feet, with corresponding high water at elevation 4.2 feet NGVD. This compares well with field-measured data during spring tides.

2.3 Previous West River Tide Gauging

William Kenny and Paul Barten, then of the Yale School of Forestry & Environmental Studies, collected water levels during a 1992 study of the West River Memorial Park. Table 3 summarizes the tidal data collected as part of that study.

TABLE 3
Water Elevation Data Upstream of the West River Tide Gates
June to October 1992

	Water Elevations		
Condition	*MHW*	*MLW*	*Range, Ft.*
Gates Closed	0.45	-0.75	1.20
One Gate Open	2.00	-0.8	2.80
Two Gates Open	2.20	-0.9	3.1

The Kenny and Barten tide data for the period June 27 to October 7, 1992 is the best available information for this area. They collected water elevations upstream and downstream of the tide gates. Upstream of the tide gates, with the gates closed, marsh high tide levels ranged from -0.5 feet to about +2.0 feet, depending on rainfall and runoff, with a mean of +0.45 NGVD. The experiment with one tide gate open resulted in high

tides of 1.5 to 2.5 NGVD, except in dry weather. Water levels with two gates open were only slightly higher but were open primarily in dry weather.

The average tidal lag downstream of the gate was 19 minutes after spring high tides in the harbor, indicating limited restriction over the 1.1 miles. Kenny found the tide range on the downstream side of the gate to be only 0.6 feet less than the harbor predictions, with an average spring high tide at elevation 5.1 NGVD.

MMI conducted additional gauging at the West River tide gates in 2002 to develop a relationship between tides at the gate versus tide levels in the harbor. Using data obtained by MMI at the tide gate, and corresponding high tides at the United Illuminating harbor gauge, MMI computed a regression relation between the two. This allowed the use of long-term data from the harbor to be used in forecasting tide levels at the downstream side of the West River tide gate. The data was highly correlated.

The following table presents the conversion between the tidal data determined for the New Haven Harbor to tide levels.

TABLE 4
Tide Data Conversion from New Haven Harbor to Tide Gates

Condition	*Harbor Tide Data (NGVD feet)*
Mean annual high tide	5.4
Mean spring high water	4.2
Mean high water	3.8
Mean tide level	0.6
Mean low water	-2.5

2.4 2004/05 West River Tide Gauging

In addition to using the published tide data, MMI installed four pressure sensitive water level gauges within the West River. MMI recorded water levels at the four gauge stations during November 2004, December 2004, and January 2005. Water surface elevation

measurements were recorded at 15 minute intervals. An illustration of the gauge station locations is presented in Figure 2. The gauge stations were installed at the following locations:

- Gauge Station #1 (GS-1) was attached to the bulkhead immediately downstream of the tide gates.

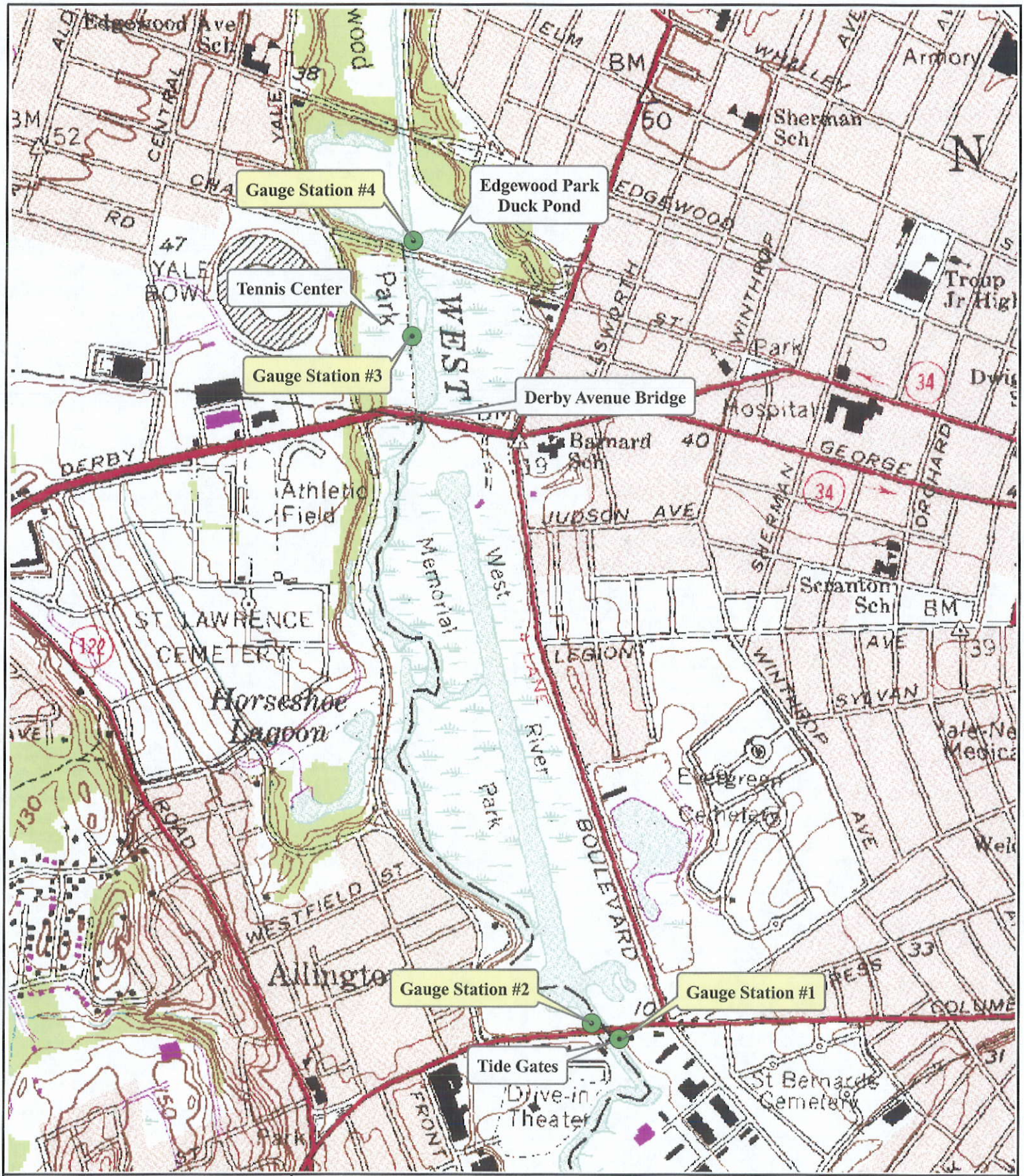
- Gauge Station #2 (GS-2) was located approximately 40 feet upstream of the Orange Avenue Bridge.

- Gauge Station #3 (GS-3) was placed approximately 600 feet upstream of the Derby Avenue Bridge.

- Gauge Station #4 (GS-4) was installed at the outlet of the Edgewood Park duck pond.

Each data logger was placed in a perforated PVC pipe. The PVC pipes were placed vertically within the river's water column and were anchored by driving fence posts into the river's substrate. MMI removed the gauges on January 10, 2005. The data was downloaded from each recorder and is included as Appendix A. This data is summarized below. The water level recorder at GS-1 malfunctioned and therefore its data could not be included in this study.

MMI collected water level data under two conditions: (1) normal; and (2) experimental. Normal conditions were during high tide while the tide gates were closed. Experimental data was collected during a spring tide cycle while three tide gates were open. Under the experimental conditions, the City opened three tide gates by chaining the gates to existing eyehooks that were attached to the top of the tide gate bulkhead. However, due to the gates' size and weight, the City was not able to fully open them. In fact, the gates were suspended only approximately two feet higher than their normal resting position at low tide.



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West River Tide Gate Study

LOCATION: New Haven, CT

MMI#: 1621-05
MXD: H:gauge_locations.mxd
SOURCE: DEP Bulletin 37

Gauge Stations Location Map

DATE: April 2005
SCALE: 1:12,000

SHEET: Figure 2

MMI monitored precipitation during the study period by accessing the weather underground website (www.wunderground.com). Table 5 presents a list of days that received equal to or greater than 0.1 inches of precipitation in New Haven, during the study period.

TABLE 5
Precipitation Data for New Haven from November 8, 2004 through January 10, 2005

Date	*Precipitation (inches) recorded in New Haven*
11-12-04	0.68
11-13-04	0.20
11-20-04	0.17
11-24-04	0.18
11-25-04	0.16
11-28-04	1.00
12-1-04	0.83
12-7-04	0.27
12-8-04	0.11
12-9-04	0.22
12-10-04	0.78
12-19-04	0.10
12-23-04	0.63
1-3-05	0.55
1-4-05	0.23
1-5-05	0.15
1-6-05	0.55
1-8-05	0.65

Source: weather underground website

MMI analyzed the water levels in the West River under normal conditions (i.e. tide gates closed, but sluice gate open), as well as our experimental condition (i.e. three tide gates and sluice gate open). After reviewing the data, MMI did not observe any significant rise in water levels at any of the gauge stations under the experimental conditions; however, it is apparent that precipitation has a significant influence on water levels within the study area.

The predicted New Haven Harbor tide elevations versus the water levels recorded at GS-2 are illustrated on Figure 3; at GS-3 on Figure 4; and at GS-4 on Figure 5. In the study area, days and/or a series of days receiving equal to or greater than 0.1 inches of

precipitation experienced a significant rise during high tide in surface water elevations. In fact, under normal conditions, GS-3 and GS-4 experienced a rise in elevation of almost two feet over their predicted high tide elevation.

During high tide, the water levels at GS-2 never exceeded 4.0 feet NGVD. GS-2 did experience water levels greater than 3.5 feet NGVD, however, these levels correspond to days and/or a series of days receiving greater than 0.1 inches of precipitation.

Water levels observed at GS-3 exceeded 3.0 feet NGVD on only one occasion. Again this water level was attributed to precipitation that fell on December 1, 2004. Overall, the water levels recorded at GS-3 under both normal and experimental conditions were almost two feet below the lowest sensitive upland elevation of 5.0 feet NGVD.

Similar to GS-3, water levels at GS-4 exceeded a high tide elevation of 3.5 feet NGVD on December 1, 2004. In fact, the water level reached an elevation of 3.9 feet NGVD, which would have overtopped the Edgewood Park Berm (maximum elevation at 3.0 feet NGVD). The data shows that water levels rose above elevation 3.0 feet NGVD on approximately six days during the study period. After analyzing the precipitation and water level data, MMI found that all six days experienced appreciable amounts of precipitation.

As previously indicated, MMI observed no substantial increase in water levels during the experimental conditions. In general, water levels recorded at GS-2, GS-3, and GS-4 did not exceed a spring high tide elevation greater than 3.0 feet NGVD. Moreover, the water levels never exceeded critical upland elevations.