LOMR APPLICATION
STONY BROOK - DARIEN, CONNECTICUT

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1.0 INTRODUCTION

Residences and businesses along Stony Brook in Darien, Connecticut, Fairfield County, have been experiencing increased flooding in recent years. These flood events have been increasing in frequency, with at least three events occurring in the past two years. The Town of Darien selected Milone & MacBroom, Inc. (MMI) in September 2008 to evaluate flooding conditions along several watercourses within the community. Stony Brook was the first watershed for study because resident complaints of flooding have been most numerous. A detailed watershed evaluation was completed in June 2009 by Milone & MacBroom, Inc. (MMI) for the Town of Darien.

Stony Brook has a FEMA-regulated floodplain and floodway that was delineated based on hydrologic and hydraulic modeling in 1978 as reported in the 2010 FEMA Flood Insurance Study (FIS) for the Town of Darien (FEMA 2010). The floodplain and floodway are defined as follows (FEMA 2010):

- The floodplain is the regulated area inundated by the storm event with a recurrence interval of 100 years (1% chance in any year and also called the Base Flood Elevation [BFE]) as predicted by hydrologic and hydraulic modeling.
- The regulatory floodway is defined as the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the entire Base Flood (100-year flood) discharge can be conveyed with no greater than a 1.0-foot increase in the BFE.

The watershed evaluation report presented the results of the updated existing 1% annual chance floodplain based on data that was collected after the FIS. This report contains information to support a submission to FEMA for a Letter of Map Revision (LOMR) application for acceptance of the existing conditions modeling with current data as the new Effective model for the length of current detailed study of Stony Brook in Darien, Connecticut. A new floodway, 1% annual chance floodplains, and 0.2% annual chance floodplain have been delineated. Proposed flood control measures examined as part of that study are not being pursued under this application.

2.0 STUDY AREA

2.1 Project Location

This evaluation investigates the effective floodplain and floodway and updates its configuration based on current existing conditions modeling along the mainstem of Stony Brook in the town of Darien. Hydrologic analyses consider the full Stony Brook watershed area including the portion in New Canaan, while hydraulic modeling of the channel extends from Stony Brook's downstream end at Gorham's Pond upstream into the Wee Burn Country Club. The updated hydraulic model extends approximately 330 feet upstream past the end of the effective FEMA model to include Hanson Road bridge and part of the Wee Burn Country Club. The project area for inclusion in the FEMA LOMR application includes the entire length of the detailed study along Stony Brook 1, plus the 330-foot extension upstream to include the Hanson Road bridge. Stony Brook has a drainage area of 4.1 square miles (2,616 acres). Figure 2-1 depicts the watershed of Stony Brook.

2.2 Project Basemapping

This project used recent basemapping of the Stony Brook watershed obtained from the Town of Darien. The data provided was titled "Topographic Map of Darien, CT" developed by James W. Sewall Company of Old Town, Maine under contract to the town. The data was compiled to meet National Map Accuracy Standards for 1"=40' maps on July 20, 2008 by photogrammetric methods from color aerial photographs dated April 3, 2008 at a scale of 1"=300'. The information provided included one-foot contour topography, roadways, and buildings. High resolution aerial photography was taken at the time of topographic mapping and used in conjunction with field observations to identify land uses and delineate the river channel and other watershed features. Significant supplemental ground survey was completed by MMI in 2009 including wet river cross sections and survey of many bridges, culverts, and dams. The horizontal datum of the basemapping is Connecticut State Plane NAD83 feet. The vertical datum of the basemapping is NAVD 1988.

3.0 <u>HYDROLOGIC ANALYSIS</u>

The 2010 Town of Darien FEMA FIS provides discharge values in cubic feet per second (cfs) at two locations within the Stony Brook watershed based on regression equations published in 1977 (Weiss). Given the trend of increasing precipitation that has been observed in Connecticut in recent years (NERAG 2001; Collins 2009), estimates of flow rates in the FIS are likely lower than current stream flows. The effect of post-1977 residential and commercial development within Connecticut also likely has lead to higher stream flows due to increased runoff from more impervious surfaces. A significant number of large rainstorms have recently occurred in Darien causing flooding and damages to homes along Stony Brook including April 16, 2007, October 11, 2007, and April 22, 2006. These reasons justify a new hydrologic study of the watershed.

No long-term flow monitoring has occurred on Stony Brook to allow a gauge study. MMI used the Hydrologic Modeling System HEC-HMS v. 3.3 (USACE 2001) computer modeling program to estimate existing condition peak flow rates. Created by the U.S. Army Corps of Engineers, the HEC-HMS program forecasts the rate of surface water runoff and river flow rates based upon several factors. The model input data includes information about the contributing watershed area, the runoff curve number (CN), the lag time of the watershed, the available storage volume of the reservoir, the channel routing, and rainfall data for the area. Each of these elements is described in the ensuing text.

We present the following hydrologic analysis for acceptance as part of an updated FEMA Effective model.

3.1 Subwatershed Delineations

The overall Stony Brook watershed, including Cummings Brook, was divided into 31 subwatersheds using basemapping described in Section 2.2. Figure 3-1 presents the delineated subwatershed boundaries. Table 3-1 provides a brief geographic description of local roads or prominent locations within the subwatershed.

3.2 Runoff Curve Numbers

The runoff CN system was developed by the Natural Resources Conservation Service (NRCS) (formerly the Soil Conservation Service [SCS]). Curve numbers range from 30 to 98 based on a combination of underlying soil type and current land use.

Soil types in the watershed were determined from the Connecticut Department of Energy & Environmental Protection GIS database of the NRCS soil survey for Fairfield County, Connecticut, which includes Hydrologic Soil Group (HSG) classifications of all soils. The NRCS divides soils into four HSGs: A, B, C, or D, depending on their infiltration capacity and ability to absorb water. Hydrologic group A soils have a high infiltration capacity and consist of well-drained soils. Group D soils have the lowest infiltration capacity and, hence, generate the highest runoff rates. Sandy soils would generally be considered hydrologic soil group A or B because of their high potential infiltration capacity. Table 3-2 is a summary of watershed areas covered by each soil type. Figure 3-2 depicts the soil group classifications for this watershed.

TABLE 3-1
Stony Brook Subwatershed Descriptions

Subwatershed	Roads and Features Within Subwatershed
Main Stem Stony Brook	
WS SB-010	Waveny Park, New Canaan High School
WS SB-020	Half Mile Road to Talmadge Hill Road
WS SB-031	Northeast of Ox Ridge Lane
WS SB-035	Blueberry Lane
WS SB-038	East side of Wee Burn Country Club
WS SB-040	Hummingbird Lane, Linda Lane
WS SB-050	Darien High School
WS SB-060	Old Parish Road
WS SB-070	Stony Brook Park
WS SB-080	Hecker Avenue, Thorndal Circle
WS SB-090	Spring Grove Cemetery, Mather Fields
WS SB-100	Renshaw Road, Post Road (Rt 1)
WS SB-110	Outlet with Gorham's Pond
Stony Brook Tributaries	
WS SBT1-10	Hancock Lane, Ox Ridge Lane, Hollow Tree Ridge Road
WS SBT2-10	Northeast section of Wee Burn Country Club and Middlesex Road
WS SBT3-10	Rockwell Lane and Hollow Tree Ridge Road
WS SBT3-20	West side of Wee Burn Country Club
WS SBT3-30	Hollow Tree Ridge
WS SBT4-10	Hanson Road, Middlesex Road
WS SBT5-10	Holly Lane, Libby Lane
WS SBT6-10	Edgarton Street, Middlesex Road
WS SBT6-20	The Heights, Heights Road
WS SBT6-30	Laforge Road, Baker Park
WS SBT6-40	Fitch Avenue, Archer Lane
WS SBT7-10	Leroy Avenue, Stony Brook Road, east of Middlesex Road
Cummings Brook	
WS CB-10	Fox Hill Lane, Peach Hill Road
WS CB-20	Knollwood Lane, Royal Road, Mansfield Avenue
WS CB-30	Leroy Avenue, Highfield Lane
WS CB-40	Tanglewood Trail, Rocaton Road
WS CB-50	Baily Avenue
WS CB-60	Hale Lane

TABLE 3-2
Land Area of Each Hydrologic Soil Group

Hydrologic Soil Group	Acres	Percent of Total
A	25	1%
B	1,006	38%
C	1,038	40%
D	548	21%
Total	2,617	100%

Cover type and hydrologic condition in each subwatershed were determined from a zoning map provided by the Town of Darien in GIS format and 2008 aerial photography. Using the cover type and hydrologic conditions listed in Table 2-2a of the TR-55 user's manual, parcel data was classified as open space, impervious (paved or unpaved), urban (commercial or industrial), residential separated by lot size, and wooded (fair or good) (USDA, 1986).

The town of Darien zones residential parcels as either ¼, ½, one, or two acres in size. Approximately 75% of the Stony Brook watershed consists of residential land use. Table 3-3 defines the land use types within the Stony Brook watershed, and Figure 3-3 presents this information graphically. While many residential parcels contain trees, the hydrologic effect of the impervious area from the house and parking lot does have an impact on runoff and so can contribute to flooding. Much of the urbanized land uses, areas with a high degree of impervious area, are clustered around the Interstate 95 corridor. The cumulative effect of increased impervious area typically leads to an increase in peak runoff.

TABLE 3-3
Land Use Cover Types
Stony Brook Watershed

Cover Type and Condition	Area (acres)	Percent of Watershed
Open space: fair	29	1.1%
Open space: good	220	8.4%
Impervious areas: gravel	18	0.7%
Impervious areas: pavement	77	2.9%
Urban district: commercial	58	2.2%
Urban district: industrial	37	1.4%
Residential district: 2 acres	822	31.4%
Residential district: 1 acre	675	25.8%
Residential district: 1/2 acre	128	4.9%
Residential district: 1/3 acre	192	7.3%
Residential district: 1/5 acre	100	3.8%
Wooded: good	247	9.4%
Water	13	0.5%
Total	2,616	100%

Based on the HSG types and land cover type, weighted curve numbers were developed for each subwatershed. Areas of imperviousness such as parking lots and buildings were assigned a Curve Number (CN) of 98. The curve numbers used in the model were based on curve numbers for Connecticut developed by MMI to reflect conditions in Connecticut rather than the Midwestern conditions that were used to develop NRCS's published curve numbers. These numbers have been accepted for use by the NRCS. A memo documenting these numbers and a letter from NRCS authorizing their use are presented in Appendix A along with curve number calculations for each subwatershed in the Stony Brook watershed. A summary of the CNs used in the HEC-HMS model is presented in Table 3-4.

3.3 Time of Concentration

Time of concentration is defined as the time it takes a drop of water to travel from the most hydrologically distant point in the watershed (or subwatershed) to the watershed (or subwatershed) outlet. This value generally defines how quickly after the start of a rainfall event that peak flows will be observed in the stream channel. For each subwatershed, sheet flow, shallow concentrated flow, and channel flow values were determined based on the available topography. Calculations of the time of concentration for each subwatershed are presented in Appendix A. The time of concentration units are in hours.

Model input is lag time rather than time of concentration. Although there are varying definitions of lag time, it is typically taken as the length of time from the start of runoff to the peak of flow through the watershed. NRCS has established a relationship between lag time and the time of concentration as follows:

$$T_l = 0.6t_c$$

Where: T_l = lag time

T_c = time of concentration

TABLE 3-4
CN Values for Existing Conditions HEC-HMS Model

Subwatershed Name	Area (mi^2)	SCS Curve Number
Main Stem Stony Brook		
SB-10	0.41	70
SB-20	0.32	75
SB-31	0.14	74
SB-35	0.09	72
SB-38	0.07	67
SB-40	0.02	68
SB-50	0.15	72
SB-60	0.25	69
SB-70	0.05	76
SB-80	0.17	75
SB-90	0.06	69
SB-100	0.07	74
SB-110	0.08	69
Stony Brook Tributaries		
SBT1-10	0.05	77
SBT2-10	0.08	68
SBT3-10	0.05	76
SBT3-20	0.32	74
SBT3-30	0.15	73
SBT4-10	0.09	74
SBT5-10	0.15	75
SBT6-10	0.18	77
SBT6-20	0.07	91
SBT6-30	0.12	67
SBT6-40	0.12	71
SBT7-10	0.09	74
Cummings Brook		
CB-10	0.28	74
CB-20	0.13	74
CB-30	0.07	74
CB-40	0.13	71
CB-50	0.03	73
CB-60	0.08	81

The coefficient of 0.6 in the equation accounts for the fact that on average the time to peak flow in the watershed is 60% of the time it takes water from the outer limits of the watershed to reach the outlet. Table 3-5 presents the lag time for each subwatershed that was used as input data to the HMS model.

TABLE 3-5
Lag Time Values Used in the Existing Conditions HEC-HMS Model

Subwatershed Name	**SCS Unit Hydrograph - Lag Time (min)**
Main Stem Stony Brook	
SB-10	111
SB-20	58
SB-31	46
SB-35	40
SB-38	36
SB-40	31
SB-50	70
SB-60	62
SB-70	30
SB-80	33
SB-90	17
SB-100	33
SB-110	32
Stony Brook Tributaries	
SBT1-10	39
SBT2-10	29
SBT3-10	40
SBT3-20	53
SBT3-30	31
SBT4-10	49
SBT5-10	54
SBT6-10	28
SBT6-20	19
SBT6-30	36
SBT6-40	33
SBT7-10	58
Cummings Brook	
CB-10	47
CB-20	47
CB-30	60
CB-40	49
CB-50	40
CB-60	50

3.4 Precipitation

Precipitation is a critical element in hydrologic modeling. The total depth of rainfall during a storm event as well as the intensity of that rainfall plays a strong role in dictating the overall runoff from a watershed. The standard of practice for design engineers in Connecticut is to use rainfall data published in Technical Paper 40 (TP-40) by the United States Weather Bureau in 1961. TP-40 provides rainfall depths over a 24-hour period equated to a storm frequency (i.e., 100-year storm or 1% chance recurrence). TP-40 predicts rainfall depths based on storm data from the first half of the 20th century. Table 3-6 presents a summary of rainfall data.

TABLE 3-6
Rainfall Depth Over 24-Hour Period

	Total Rainfall (Inches)			
Chance Recurrence	**50%**	**10%**	**2%**	**1%**
TP 40 (1961)	3.3	5.0	6.4	7.2

3.5 Results of Existing Conditions Analysis

Table 3-7 presents the predicted channel flow rates at select areas within the watershed; values presented are peak flow (cfs). This study recommends the addition of two flow change locations. Effective FEMA modeling includes two flows, one for each section of the model, with the only change upstream of the Connecticut Turnpike where Cummings Brook joins (FEMA P). Significant flow enters Stony Brook at Tributary 3 (FEMA AK) and Tributary 6 (FEMA J). HEC-HMS input and output files are presented in Appendix B.

TABLE 3-7
Predicted Peak Flows From HMS Modeling and Extrapolation

		TP 40				Estimated
FEMA XS	**HMS Output Location**	**2**	**10**	**50**	**100**	**500**
FEMA AM	JS04-(SBT3-30+RST33)	174	394	630	765	988
FEMA AK	JS04	310	713	1,115	1,350	1745
FEMA P	JS06	570	1,243	1,930	2,380	3041
FEMA J	JS08	679	1,462	2,248	2,741	3507

Rainfall information for a 500-year 24-hour storm is not available. For modeling the 500-year recurrence interval, flows were extrapolated from the flows modeled with HEC-HMS (Table 3-7). Recurrence interval and modeled discharge were plotted for each flow change location (Figure 3-4).

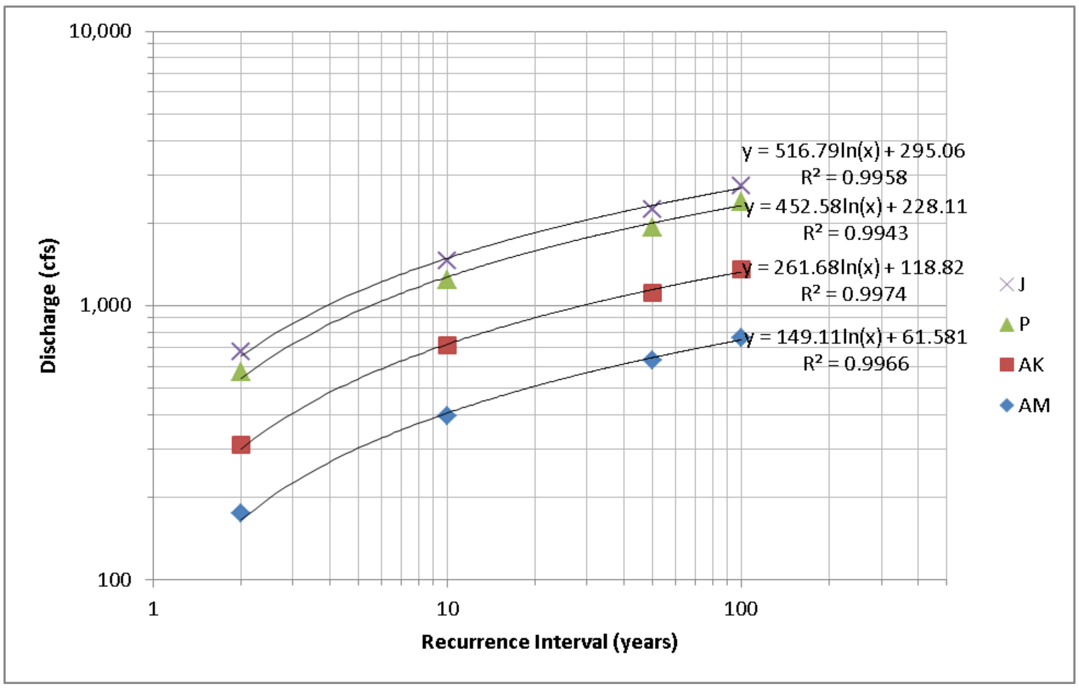

Figure 3-4: Discharge from HEC-HMS existing conditions modeling and recurrence intervals.

Results of the current hydrologic analysis are higher than peak flow estimates in the FEMA FIS for Stony Brook (Table 3-8). The HEC-HMS produces high values for this watershed due to a combination of factors. With a little over 60% of the watershed containing hydrologic soil groups C or D, such an environment will lead to higher runoff values than other watersheds of similar size and development pattern. In part, the possible overestimation is a limitation of the model itself, which is conservative in its flow predictions. The flow rates estimated by MMI's existing conditions analysis were used in the existing conditions hydraulic modeling described in Section 4.

TABLE 3-8
Comparison of FEMA and MMI
Drainage Areas and Predicted Peak Flows

Location	Distance Upstream of Gorham's Pond (feet)	Drainage Area (sq. miles)			100-year Peak Flow (cfs)		
		FEMA-Published	MMI HEC-HMS	Difference (Percent)	FEMA-Published	MMI HEC-HMS	Difference
Hanson Road	14464	Not Listed	1.8		Not Listed	765	N/A
Cummings Brook Confluence	12171	2.5	2.5	0	538	1350	812
Confluence at Tributary 6	4688	Not Listed	3.8	N/A	Not Listed	2380	N/A
Mouth at Gorham's Pond	2576	4.1	4.1	0	800	2741	1941

4.0 HYDRAULIC ANALYSIS

4.1 Introduction

Hydraulic analysis of Stony Brook was completed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) (USACE 2005). The model is used to compute water surface profiles for one-dimensional, gradually varied flow for steady (i.e., flows constant over time) and unsteady (i.e., flows varying over time) scenarios. This system can accommodate a full network of channels, a dendritic system, or a single river reach. HEC-RAS is capable of modeling water surface profiles under subcritical (i.e., tranquil, smooth, and deep), supercritical (i.e., jetting, turbulent, and shallow), and mixed flow conditions.

The basic computational procedure for HEC-RAS is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's Equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varying such as for a mixed-flow regime near dams, bridges, confluences.

A FEMA floodway analysis can be performed in HEC-RAS by limiting the extent of the 100-year floodplain so that a maximum of one-foot rise in water surface elevation occurs between existing conditions. The floodway analysis performed here follows recommended FEMA procedures (FEMA 2003). Encroached conditions refer to the reduced 100-year flood conveyance area used to delineate the regulated floodway. The term unencroached refers to modeling that allows the entire area of floodplain to be subjected to inundation based on existing conditions (i.e., topography, presence of structures, etc.) during a 100-year storm event. FEMA requires that the 100-year water surface elevations in the encroached condition not increase by more than a state-designated surcharge when compared to the unencroached conditions. Most states, including Connecticut, have adopted a one-foot maximum surcharge. The area within the floodplain, but outside the floodway, is called the floodplain fringe.

Typical HEC-RAS cross sections of a floodway analysis show both the encroached and unencroached water surface elevations, along with the portions of the cross section blocked from conveying flow that are outlined in black. Encroachment, or narrowing of the floodplain, generally leads to higher flood water surface elevation. In rare instances, encroached water surfaces may not increase or decrease due to mixed flow regimes that often occur near structures.

The FEMA floodway and floodplains documented in FIS represent the regulated flood areas to reduce risks to human infrastructure associated with inundation. In many instances, the established flood limits do not accurately reflect field conditions determined using modern, more detailed data. However, the effective floodway and floodplain must still be considered until it is formally changed either by FEMA during map modernization or by the town via submission of more current flood data to FEMA. This analysis follows FEMA protocols to facilitate implementation of a revised floodway and to facilitate future permitting of recommended mitigation measures. The analysis performed here first reviews this existing Stony Brook information and then delineates an updated floodplain and floodway based on existing conditions using the following steps:

Effective Model: The model used to delineate the current floodway and floodplains. The effective model is typically presented in the FIS, unless an update has been performed without a full revision of the FIS. The effective model is provided by FEMA as a starting point for analysis.

Duplicate Effective Model: The model is a replication of the model provided by FEMA. The purpose of this modeling effort is to ensure that the results presented by FEMA can be reasonably reproduced using current computers and software.

Revised Duplicate Effective Model: The model includes the correction of any modeling errors in the effective FEMA model. Examples of corrections made in the revised duplicate model are removal of typographic errors and incorrect hydraulic coefficients. The revised duplicate model does not include input of data representing existing conditions.

Existing Conditions Model: The model that represents the current existing conditions. The existing conditions model utilizes more modern and detailed data than available for the previous FIS. In the existing conditions analysis, additional cross sections are typically added to the model using GIS and HEC-GeoRAS that allows for rapid importation of cross section data.

Proposed Conditions Model: The model makes changes to the existing conditions model to represent any proposed project plans. This model is typically used for permitting to evaluate hydraulic effects of a proposed design before implementation. This is not included in the current analysis.

The hydraulic results of each modeling step are compared to those of the previous model.

4.2 Review of the FEMA Effective Model

FEMA has produced floodplain and floodway mapping for Stony Brook on FIRM Panel Numbers 09001C0536F, 09001C0528F, and 09001C0526F. An initial FIS of Darien with Flood Insurance Rate Maps (FIRMs) was published in 1978. The FIS included a detailed study of Stony Brook between Hanson Road and the confluence with the Goodwives River at Gorham's Pond. The 2010 FIS indicates that Stony Brook was only updated to include tidal backwatering effects, and the original modeling was maintained. MMI received the FEMA Effective model from FEMA contractors Michael Baker Corp. on October 30, 2008. A hardcopy of HEC-2, the precursor to HEC-RAS, input and output files used to delineate the floodway and floodplain in the current FIS were supplied (Appendix C).

Upon review of the model, we noted that the model data did not reflect the information published in the FEMA study. FEMA was contacted, and it was confirmed that we received the most current model. That HEC-2 model served as the starting point for the hydraulics analysis. The HEC-2 model was run in two sections. The upstream extent of the Lower Stony Brook model was upstream of Ledge Road. The downstream extent of the Upper Stony Brook model began at the top of the steep slope upstream of Ledge Road. The steep slope was not modeled in HEC-2.

Upon comparison of the published data in the FIS and the FEMA Effective Model, small differences in river stationing and 1% annual chance water elevation were found. The predicted 100-year water surface elevation at FEMA cross section Z was 0.19 feet lower in the model (hardcopy of output file) than what was reported in the study. The predicted elevation at cross section AB was 0.35 feet lower.

It should be noted that the flood profile in the FIS shows three dams between West Avenue and Middlesex Road that are not included in the model received from FEMA. FEMA was contacted to confirm that we received the most current model, so it appears that the dams were graphically shown in the profile but not modeled, most likely due to their low head and lack of impact on flooding.

Lettered FEMA cross section locations are used for reference in previous modeling and the FIS, and MMI maintained this naming convention where possible for consistency.

4.3 FEMA Duplicate Effective Model

The Effective Duplicate Model was created by inputting the Effective Model into the USACE HEC-RAS 4.0 program (USACE, 2005). System geometry, boundary conditions, and encroachment data were manually input into HEC-RAS from the HEC-2 input file. This model retains differences from the FIS as mentioned above in addition to typos and errors present in the HEC-2 code. Flow rates from the FIS were used for this model run as well. Boundary conditions were maintained from HEC-2, including a downstream starting water surface elevation, and run in subcritical flow regime. An upstream boundary condition of critical depth was used. Unlike HEC-2, HEC-RAS requires an upstream boundary condition. The upper and lower sections of the HEC-2 model were combined here into one continuous HEC-RAS model. The model was preserved in the original datum of NGVD29 and output was converted to NAVD88 with a conversion factor of 1.0.

The Effective Duplicate Model approximately represents the Effective FEMA Model although in multiple locations the predicted water surface elevations varied. Model input and output is located in Appendix D. Table 4-1 is a comparison of published water surface elevations and the results of MMI's Effective Duplicate Model. Ineffective flow areas did not transfer accurately between the programs and caused blocked flow at the downstream end of multiple bridges and needed to be adjusted. Specific observed differences between the two models are described below.

- At cross section Q, the HEC-RAS model predicts a water surface elevation -0.5 feet different than the published FIS. The Effective HEC-2 model is run in two sections. This cross section is the downstream section of the upper section. We believe the two models should be combined. Good model agreement occurs upstream of this cross section.

- At cross section U, the HEC-RAS model predicts a water surface elevation 0.5 feet different than the published FIS. This is directly upstream of the Conrail Railroad bridge. In HEC-2 this arch structure was modeled using the SB (Special Bridge) card. HEC-RAS models bridges using a different method. This small difference does not affect hydraulics upstream.

- Cross section AB is located upstream of a series of three low-head dams. These dams are represented on the FEMA Effective Flood Profile 384P but are not included in the HEC-2 model. Because these dams were not included in the HEC-2 modeling, our Duplicate Model also does not include them. This small difference does not affect hydraulics upstream.

- At the upstream end of the model, cross sections AL and AM show differences of -1.8 and 0.7, indicating a possible difference in boundary conditions. Critical depth was used as an upstream boundary condition. Normal depth (S=0.005) was also tested and produced the same results. Cross Section AL is at critical depth (Froude Number = 1.00). Differences observed here may be due to differences in how HEC-2 and HEC-RAS calculated critical depth. AM is the upstream limit of the model.

TABLE 4-1
Comparison of Water Surface Elevations of FEMA-Published Data to the Effective Duplicate Model (Unencroached)

	Water Surface Elevation			
FEMA Cross Section Letter	Effective Duplicate (NGVD)	Effective Duplicate (NAVD)	FEMA FIS (NAVD)	Difference (Effective Duplicate - FEMA FIS)
	Unencroached	Unencroached	Unencroached	Unencroached
A	6.4	5.4	5.4	0.0
B	10.2	9.2	9.1	0.1
C	11.2	10.2	10.3	-0.1
D	11.0	10.0	10.0	0.0
E	11.8	10.8	10.8	0.0
F	12.8	11.8	11.8	0.0
G	13.5	12.5	12.5	-0.1
H	13.5	12.5	12.5	0.0
I	13.8	12.8	12.8	0.0
J	16.0	15.0	14.7	0.3
K	16.0	15.0	14.9	0.0
L	16.0	15.0	15.3	-0.3
M	17.8	16.8	16.7	0.1
N	18.8	17.8	17.8	0.0
O	19.0	18.0	18.1	-0.1
P	27.8	26.8	26.5	0.3
Q	59.3	58.3	58.8	-0.5
R	61.2	60.2	60.0	0.2
S	62.5	61.5	61.6	-0.1
T	65.3	64.3	64.2	0.1
U	72.1	71.1	70.6	0.5
V	72.1	71.1	71.5	-0.4
W	75.4	74.4	74.4	-0.1
X	75.9	74.9	74.9	0.0
Y	77.7	76.7	77.0	-0.3
Z	84.0	83.0	83.1	-0.1
AA	86.6	85.6	85.6	0.0
AB	89.7	88.7	89.2	-0.5
AC	90.7	89.7	89.7	0.0
AD	92.8	91.8	91.5	0.3
AE	93.5	92.5	92.8	-0.3
AF	94.5	93.5	93.5	0.0
AG	96.8	95.8	95.8	0.0
AH	98.0	97.0	96.9	0.1
AI	99.3	98.3	98.6	-0.3

TABLE 4-1 continued
Comparison of Water Surface Elevations of
FEMA-Published Data to the Effective Duplicate Model (Unencroached)

	Water Surface Elevation			
FEMA Cross Section Letter	**Effective Duplicate (NGVD)**	**Effective Duplicate (NAVD)**	**FEMA FIS (NAVD)**	**Difference (Effective Duplicate - FEMA FIS)**
	Unencroached	**Unencroached**	**Unencroached**	**Unencroached**
AJ	101.7	100.7	100.8	-0.1
AK	102.2	101.2	101.2	0.0
AL	103.8	102.8	104.6	-1.8
AM	110.8	109.8	109.1	0.7

The encroached Duplicate Effective model was also created. Effective left and right encroachment stations are specified in the HEC-2 model for each cross section (floodway delineation method #1). These encroachment stations were input to HEC-RAS using Encroachment Method #1 and were not altered to obtain a better match to the Effective Model. The downstream boundary condition of known water surface elevation (EL= 6.3 feet NGVD29) for both the floodplain and floodway runs was preserved in the HEC-RAS model, as originally used in the HEC-2 model. The downstream boundary condition for the floodway run was not the usual one foot increase in water surface elevation.

The encroached model produced varied results when compared to the Effective FIS (Table 4-2). The encroachment stations were held constant to ensure the floodway was modeled equivalently. Using the same encroachment stations, some surcharge values were negative or greater than 1. It was determined that changing the encroachment stations to better match the surcharge and water surface elevations reported in the FIS would misrepresent the floodway. The Existing Conditions modeling effort presented in this report creates a new floodway the length of Stony Brook based on updated modeling and geometry. Based on our analysis, the Effective floodway should be replaced in entirety (see below sections).

TABLE 4-2
Comparison of Water Surface Elevations of
FEMA-Published Data to the Effective Duplicate Model (Encroached)

	Water Surface Elevation			
FEMA Cross Section Letter	**Effective Duplicate (NGVD)**	**Effective Duplicate (NAVD)**	**FEMA FIS (NAVD)**	**Difference (Effective Duplicate - FEMA FIS)**
	Encroached	**Encroached**	**Encroached**	**Encroached**
A	6.4	5.4	5.4	0.0
B	10.2	9.2	9.1	0.1
C	11.3	10.3	10.3	0.0
D	11.1	10.1	10	0.1
E	12.4	11.4	11.4	0.0
F	13.4	12.4	12.4	0.0
G	13.6	12.6	12.6	0.0
H	13.8	12.8	12.8	0.0
I	14.9	13.9	13.8	0.1
J	16.3	15.3	15.7	-0.4
K	16.5	15.5	15.9	-0.4
L	16.6	15.6	16.3	-0.7
M	17.7	16.7	16.9	-0.2
N	18.9	17.9	18.1	-0.2
O	19.8	18.8	18.9	-0.1
P	27.8	26.8	26.5	0.3
Q	59.2	58.2	58.8	-0.6
R	61.7	60.7	60.5	0.2
S	63.0	62.0	62	0.0
T	65.9	64.9	65	-0.1
U	71.5	70.5	70.6	-0.1
V	74.0	73.0	72.5	0.5
W	75.1	74.1	74.4	-0.3
X	76.2	75.2	75.6	-0.4
Y	79.3	78.3	78	0.3
Z	84.3	83.3	83.6	-0.3
AA	87.5	86.5	86.4	0.1
AB	90.4	89.4	89.8	-0.4
AC	91.4	90.4	90.2	0.2
AD	93.1	92.1	91.9	0.2
AE	95.0	94.0	93.8	0.2
AF	96.0	95.0	94.2	0.8
AG	97.1	96.1	96.2	-0.1
AH	99.1	98.1	97.9	0.2
AI	100.4	99.4	98.6	0.8

TABLE 4-2 continued
Comparison of Water Surface Elevations of
FEMA-Published Data to the Effective Duplicate Model (Encroached)

	Water Surface Elevation			
FEMA Cross Section Letter	**Effective Duplicate (NGVD)**	**Effective Duplicate (NAVD)**	**FEMA FIS (NAVD)**	**Difference (Effective Duplicate - FEMA FIS)**
	Encroached	**Encroached**	**Encroached**	**Encroached**
AJ	102.6	101.6	101.8	-0.2
AK	103.0	102.0	102.2	-0.2
AL	103.8	102.8	105.4	-2.6
AM	111.0	110.0	109.4	0.5

4.4 Revised Duplicate Effective Model

Modeling and obvious typographic errors were corrected in the Duplicate Effective Model to create the Revised Duplicate Effective Model. The following changes and corrections were made:

- Corrected ineffective flow areas (i.e., locations where water ponds but does not move) upstream and downstream of structures to reflect 1:1 flow expansion and contraction ratios (1:1.5 downstream of culverts). Also corrected elevations to be minimum road elevation on upstream side and an average of minimum road elevation and maximum low chord on the downstream side of structure.

- Corrected location of bank stations. In HEC-2 bank stations were used to set the ineffective flow areas so they were placed away from the true bank and in the channel at model cross sections 6.1, 6.4, 18, 26.1, 26.2, 26.3, 26.4, 28.4, 36.4, 37, 38, 39.1, 39.4, 43.1, and 43.4.

- Corrected obvious typographical errors in elevation data at model cross sections 13, 15.4, and 16 based on Town of Darien 2008 topographic mapping and MMI field observations.

Model revisions caused some differences between the floodways delineated in the Duplicate Effective and Revised Duplicate Effective model results (Table 4-3). These differences are attributed to correction of the ineffective flow areas. In the Duplicate Effective model, multiple bridge openings were blocked by incorrectly placed ineffective flow areas. The increased conveyance through these structures most notably lowered water surface elevations upstream of the railroad bridge. The correction of the typographic errors at cross sections 13 (FEMA H), and 15.4 and 16 (FEMA J) also caused small changes in water surface elevation. Model input and output is located in Appendix E.

Banks station locations were updated at multiple cross sections to move them out of the channel and to the correctly locate the top of bank. As expected, the correction of bank stations did not alter the floodway configuration but just correctly separated the channel and overbanks.

The encroachment stations were set using Method 1, which specifies the horizontal stationing and does not constrain the stations to outside the channel. Inspection of cross sections shows that the floodway does not always encompass the entire channel. FEMA guidelines specify that the entire active channel must be contained in the floodway and encroachment stations should be constrained to the top of the banks (FEMA 2003). In these locations, the water surface elevation is not raised more than the acceptable one-foot surcharge, yet the floodway is narrower than FEMA guidelines would allow.

TABLE 4-3
Comparison of Water Surface Elevations of Duplicate Effective and Revised Duplicate Effective Models

	Water Surface Elevation					
FEMA Cross Section Letter	**Duplicate Effective (NAVD)**	**Revised Duplicate Effective (NAVD)**	**Difference (Revised - Duplicate)**	**Duplicate Effective (NAVD)**	**Revised Duplicate Effective (NAVD)**	**Difference (Revised - Duplicate)**
	Unencroached	**Unencroached**	**Unencroached**	**Encroached**	**Encroached**	**Encroached**
A	5.4	5.4	0.0	5.4	5.4	0.0
B	9.2	9.2	0.0	9.2	9.2	0.0
C	10.2	10.3	0.0	10.3	10.3	0.0
D	10.0	10.0	0.0	10.1	10.1	0.0
E	10.8	10.8	0.0	11.4	11.5	0.0
F	11.8	11.8	0.0	12.4	12.4	0.0
G	12.5	12.5	0.0	12.6	12.6	0.0
H	12.5	12.5	0.0	12.8	13.0	0.2
I	12.8	12.7	-0.1	13.9	13.5	-0.4
J	15.0	14.9	-0.1	15.3	15.5	0.1
K	15.0	14.8	-0.1	15.5	15.6	0.1
L	15.0	15.1	0.1	15.6	15.8	0.2
M	16.8	16.8	0.0	16.7	16.7	0.0
N	17.8	17.8	0.0	17.9	17.9	0.0
O	18.0	18.0	0.0	18.8	18.8	0.0
P	26.8	26.8	0.0	26.8	26.8	0.0
Q	58.3	58.3	0.0	58.2	58.2	0.0
R	60.2	60.2	0.0	60.7	60.7	0.0
S	61.5	61.5	0.0	62.0	62.0	0.0
T	64.3	63.9	-0.4	64.9	64.5	-0.4
U	71.1	71.1	0.0	70.5	70.5	0.0
V	71.1	70.9	-0.2	73.0	73.0	0.0
W	74.4	74.4	0.0	74.1	74.1	0.0
X	74.9	74.9	0.0	75.2	75.2	0.0
Y	76.7	76.7	0.0	78.3	78.3	0.0
Z	83.0	83.0	0.0	83.3	83.3	0.0
AA	85.6	85.6	0.0	86.5	86.5	0.0
AB	88.7	88.7	0.0	89.4	89.4	0.0
AC	89.7	89.7	0.0	90.4	90.4	0.0
AD	91.8	91.6	-0.2	92.1	92.0	0.0
AE	92.5	92.4	-0.1	94.0	94.0	0.0
AF	93.5	93.5	0.0	95.0	95.0	0.0
AG	95.8	95.8	0.0	96.1	96.1	0.0
AH	97.0	97.0	0.0	98.1	98.1	0.0
AI	98.3	98.7	0.3	99.4	99.5	0.0

TABLE 4-3 continued
Comparison of Water Surface Elevations of
Duplicate Effective and Revised Duplicate Effective Models

	Water Surface Elevation					
FEMA Cross Section Letter	**Duplicate Effective (NAVD)**	**Revised Duplicate Effective (NAVD)**	**Difference (Revised - Duplicate)**	**Duplicate Effective (NAVD)**	**Revised Duplicate Effective (NAVD)**	**Difference (Revised - Duplicate)**
	Unencroached	**Unencroached**	**Unencroached**	**Encroached**	**Encroached**	**Encroached**
AJ	100.7	100.5	-0.3	101.6	101.6	0.0
AK	101.2	101.2	0.0	102.0	102.0	0.1
AL	102.8	102.8	0.0	102.8	103.4	0.5
AM	109.8	109.8	0.0	110.0	109.8	-0.2

4.5 Existing Conditions Model Creation

Changes to the system have occurred since the FEMA Effective Model was created. The Town of Darien has high resolution aerial photography and topographic mapping with one-foot contour data created in 2008, which, along with supplemental survey of river cross sections, served as a basis for the model updates. HEC-GeoRAS 4.1.1, an extension for ArcGIS (ESRI 2006), was used to extract stream system geometry from terrain data for automated input to HEC-RAS. HEC-GeoRAS is an interactive platform for setting up all geometry components necessary for HEC-RAS modeling and viewing results. Topography from the town was processed using ArcGIS to create a triangulated irregular network (TIN) representing ground elevation for use in modeling. The vertical datum of the HEC-RAS model is NAVD 1988.

The stream centerline and overbank distances were delineated based on 2008 mapping, updating the distance between cross sections and length of river channel from the FEMA model. FEMA Effective Model cross section locations were maintained, and additional new cross sections were added where necessary. Floodplain topography was extracted from the 2008 topographic mapping with HEC-GeoRAS for all model cross sections.

Field survey of the wet channel cross section completed by MMI included all bridges, most dams, and wet sections at all but two FEMA Effective Model sections. Field survey was then substituted into the model for all new cross sections and to update selected FEMA Effective Model cross sections. Figure 4-1 depicts the location of cross sections surveyed by MMI for this study.

Ineffective flow areas (i.e., locations where water ponds but does not move) and flow obstructions such as buildings were defined using HEC-RAS user manual recommended flow expansion and contraction ratios of 1:1 (1:1.5 downstream of culverts). Bridge and culvert geometry was updated with survey, field measurements, and existing bridge plans. Bridge plans reviewed for this study are listed in the References section of this report.

Manning's N values used in the FEMA Effective Model were verified and updated based on field observations, digital photographs, and high resolution aerial photography. N values were varied horizontally in HEC-RAS to allow for accurate representation of changes in roughness in each cross section. N values in the channel are between 0.03 and 0.045, and N values in the overbank ranged from 0.04 to 0.12.

Expansion and contraction coefficients were verified and largely maintained from the FEMA Effective Duplicate Model. Coefficients were increased from 0.3 and 0.5 to 0.5 and 0.7 upstream and downstream of the severe constrictions at the I-95 twin culvert and the railroad arch bridge. Coefficients were also increased from 0.1 and 0.3 to 0.3 and 0.5 at constriction points such as an inline sediment basin or dam.

Flow data were updated based on hydrologic modeling described in Section 3 (Table 4-4).

TABLE 4-4
Estimated Existing Peak Flows Used for the Hydraulic Model

HEC-RAS River Station	Discharge (cfs)				
	50%	10%	2%	1%	0.2%
14464	174	394	630	765	988
12171	310	713	1,115	1,350	1745
4688	570	1,243	1,930	2,380	3041
2576	679	1,462	2,248	2,741	3507

4.6 Existing Conditions Model Floodplain Results

Table 4-5 presents water surface elevations for the Existing Conditions Model and effective FEMA values reported in the 2010 FIS. Appendix F contains the HEC-RAS summary report generated for the Existing Conditions Model and also a summary of river stationing differences between the two models.

The river stationing of the Existing Conditions Model indicates a net increase in total stream length of 755 feet due to higher resolution data defining a more sinuous channel and extension of the model approximately 330 feet upstream to include the Hanson Road bridge instead of ending at the downstream face of the structure. This bridge was included to evaluate potential mitigation for overtopping of Hanson Road during floods.

TABLE 4-5
Comparison of Water Surface Elevations
Revised Effective Duplicate and Existing Conditions Model Results
100-year (1%) Recurrence Discharge

	Water Surface Elevation (feet NAVD)		
FEMA Cross Section Letter	**Existing Conditions**	**FEMA-Published 2010 FIS**	**Difference (Existing Conditions - 2010 FIS)**
	Unencroached	**Unencroached**	**Unencroached**
A	6.4	5.4	1.0
B	9.5	9.1	0.4
C	12.0	10.3	1.7
D	11.7	10.0	1.7
E	14.9	10.8	4.1
F	14.7	11.8	2.9
G	17.1	12.5	4.6
H	17.1	12.5	4.6
I	17.2	12.8	4.4
J	17.7	14.7	3.0
K	18.2	14.9	3.3
L	18.2	15.3	2.9
M	19.8	16.7	3.1
N	21.1	17.8	3.3
O	21.3	18.1	3.2
P	39.1	26.5	12.6
Q	62.5	58.8	3.7

TABLE 4-5 continued
Comparison of Water Surface Elevations
Revised Effective Duplicate and Existing Conditions Model Results
100-year (1%) Recurrence Discharge

	Water Surface Elevation (feet NAVD)		
FEMA Cross Section Letter	**Existing Conditions**	**FEMA-Published 2010 FIS**	**Difference (Existing Conditions - 2010 FIS)**
	Unencroached	**Unencroached**	**Unencroached**
R	63.5	60.0	3.5
S	63.6	61.6	2.0
T	65.0	64.2	0.8
U	77.3	70.6	6.7
V	77.2	71.5	5.7
W	77.5	74.4	3.1
X	77.6	74.9	2.7
Y	77.6	77.0	0.6
Z	83.7	83.1	0.6
AA	86.4	85.6	0.8
AB	90.4	89.2	1.2
AC	90.4	89.7	0.7
AD	92.5	91.5	1.0
AE	94.2	92.8	1.4
AF	95.9	93.5	2.3
AG	97.9	95.8	2.1
AH	98.5	96.9	1.6
AI	101.3	98.6	2.7
AJ	101.4	100.8	0.6
AK	101.9	101.2	0.7
AL	105.1	104.6	0.5
AM	108.4	109.1	-0.7

Peak 1% annual chance existing conditions water surface elevations are generally higher than the FEMA effective base flood elevations. Higher values are in part a result of higher flow values used in the model. Changes in channel configurations identified by MMI also increase predicted water surface elevations. For example, upstream of Old Kings Highway at FEMA section D a bedrock vane was surveyed and incorporated into the Existing Conditions Model. This natural feature constricts flow and causes backwatering upstream.

In the FEMA Effective and Duplicate Models, I-95 was modeled as a bridge with a pier instead of two culverts. In the FEMA Effective Model, this structure was modeled as the upstream end of a HEC-2 model of the lower section of Stony Brook. Another HEC-2 model started at the top of a steep cascade located immediately upstream of Ledge Road. The Existing Conditions model includes a continuous reach by adding several cross sections to the model along the cascade upstream of I-95, more accurately describing the channel geometry, slope, and location of the cascade. FEMA section P was surveyed by MMI and found to have a bed elevation that is 5.7 feet higher than in the Effective FEMA Model. FEMA Section P is located only 27 feet upstream of the culvert entrance, at a sharp bend in the river. The Existing Conditions Model shows a peak flood water surface elevation increase of 12.6 feet upstream of this structure and the road overtopping. We believe this result is an artificial product of limitations in HEC-RAS representing storage and not fully modeling Cummings Brook as it joins Stony Brook just upstream of the I-95 twin culvert. In reality, water would back up Cummings Brook before overtopping I-95. The mapping shows the floodplain and floodway contained within the I-95 culverts.

Floodplain mapping was developed by exporting HEC-RAS results back to ArcGIS using HEC-GeoRAS for each flood profile. Water depth is calculated and mapped for the inundated area. The FEMA effective floodplain and Existing Conditions Model results for the 1% annual chance flood were compared, and this mapping is presented in Appendix G. The inundation area of the Existing Conditions Model extends beyond the FEMA floodplain in multiple areas and is expected to be larger due to larger discharges modeled. The shape of the Existing Conditions floodplain is also much more detailed as it is based on more accurate topography.

4.7 Existing Conditions Model Floodway Results

A new floodway for Stony Brook was defined using the Existing Conditions Model. The floodway delineated with the Existing Conditions Model produces a surcharge between less than or equal to 1.0 foot (Table 4-6). Model output is presented in Appendix F.

The predicted water surface elevations in the floodway delineated in the MMI Existing Conditions Model are higher in almost all locations than those in the effective floodway determined from the FEMA Effective Model (Table 4-6). These differences can be attributed to new survey data, changes to bridge geometry, and significantly larger discharge values. Some differences are due to modeling approaches in the two programs, as described in detail in the Duplicate Effective and Revised Duplicate Effective Models as previously described. Specifically, updated bridge geometry increased water surface elevations upstream of I-95 (FEMA P), railroad bridge (FEMA U), Middlesex Road (FEMA AF), and High School Lane (FEMA AI). Inclusion of a rock vane (FEMA D) and a footbridge (downstream of FEMA G) combined to increased water surface elevations in the lower section of the river, up to I-95.

The new existing conditions floodway delineated here differs from the effective floodway defined in the 2010 FIS. The new floodway is on average approximately 100 feet wider than previously defined with a larger cross sectional flow. The larger conveyance area is necessary to accommodate the larger peak discharges used in the Existing Conditions Model. Cross sectional conveyance area decreases and flow velocity increases as more area of the floodplain is blocked by encroachments. Floodway velocities are a function of the conveyance area and discharge. These variables have changed between the Existing Conditions Model and FEMA Effective Model causing differences in mean floodway velocity with no overall trend.

TABLE 4-6
Comparison of Water Surface Elevations
Effective FEMA and Existing Conditions Encroached Model Results
100-year (1%) Recurrence Discharge

	Water Surface Elevation (feet NAVD)				
FEMA Cross Section Letter	**Existing Conditions**	**Existing Conditions**	**Existing Conditions Surcharge**	**FEMA-Published 2010 FIS**	**Difference (Existing Conditions - 2010 FIS)**
	Unencroached	**Encroached**	**Difference**	**Encroached**	**Encroached**
A	6.4	6.4	0.0	5.4	1.0
B	9.5	9.5	0.0	9.1	0.4
C	12.0	12.0	0.0	10.3	1.7
D	11.7	11.7	0.0	10.0	1.7
E	14.9	15.0	0.1	11.4	3.6
F	14.7	15.5	0.8	12.4	3.1
G	17.1	17.7	0.6	12.6	5.1
H	17.1	17.8	0.7	12.8	5.0
I	17.2	17.9	0.7	13.8	4.1
J	17.7	18.6	0.9	15.7	2.9
K	18.2	19.0	0.8	15.9	3.1
L	18.2	19.0	0.8	16.3	2.7
M	19.8	20.8	1.0	16.9	3.9
N	21.1	21.7	0.6	18.1	3.6
O	21.3	21.8	0.5	18.9	2.9
P	39.1	39.1	0.0	26.5	12.6
Q	62.5	62.5	0.0	58.8	3.7
R	63.5	63.5	0.0	60.5	3.0
S	63.6	63.7	0.1	62.0	1.7
T	65.0	65.8	0.9	65.0	0.8
U	77.3	77.5	0.2	70.6	6.9
V	77.2	77.5	0.2	72.5	5.0
W	77.5	78.5	1.0	74.4	4.1
X	77.6	78.6	1.0	75.6	3.0
Y	77.6	78.3	0.7	78.0	0.3
Z	83.7	84.2	0.5	83.6	0.6
AA	86.4	86.4	0.0	86.4	0.0
AB	90.4	91.1	0.7	89.8	1.3
AC	90.4	91.1	0.7	90.2	0.9
AD	92.5	93.5	1.0	91.9	1.6
AE	94.2	95.0	0.9	93.8	1.2
AF	95.9	96.7	0.9	94.2	2.5
AG	97.9	98.8	0.9	96.2	2.6

TABLE 4-6 continued
Comparison of Water Surface Elevations
Effective FEMA and Existing Conditions Encroached Model Results
100-year (1%) Recurrence Discharge

	Water Surface Elevation (feet NAVD)				
FEMA Cross Section Letter	**Existing Conditions**	**Existing Conditions**	**Existing Conditions Surcharge**	**FEMA-Published 2010 FIS**	**Difference (Existing Conditions - 2010 FIS)**
	Unencroached	**Encroached**	**Difference**	**Encroached**	**Encroached**
AH	98.5	98.6	0.1	97.9	0.7
AI	101.3	101.4	0.0	98.6	2.8
AJ	101.4	101.5	0.1	101.8	-0.3
AK	101.9	102.0	0.1	102.2	-0.2
AL	105.1	105.8	0.8	105.4	0.4
AM	108.4	109.4	0.9	109.4	0.0

The existing conditions floodway has been mapped using FEMA mapping guidelines using the encroachment widths calculated in the Existing Conditions Model (Appendix G). The proposed mapping places 20 homes and 14 additional structures in the floodway that were previously outside the boundary. Many of these homes are in areas with known flood problems. They include areas at Old King's Highway crossing, upstream of Boston Post Road, along Crimmins Road, Cherry Street, upstream of Hecker Avenue, upstream and downstream of West Avenue, including along Stony Brook Drive, and upstream of Middlesex Road.

Many changes in floodway extent are due to a widening of the floodway due to increased discharges, but in some locations the more accurate topography places the existing conditions floodway in a different location than the effective floodway. Floodway boundaries coincide with the 1% annual chance floodplain boundary in areas where no encroachment is allowable. The 1% annual chance floodplain was updated using more accurate topography than was available at the time the FEMA effective 1% annual chance floodplain was modeled causing significant changes in some locations. This is particularly notable in narrow channel locations, such as in Stony Brook Park and between West Avenue and Middlesex Road.

Similarly, FEMA requires that the entire channel is contained within the floodway. In some locations, the channel appears to have moved or be more precisely located according to the recent topography. Apparent changes in channel, and therefore floodway, locations are near Gorham's Pond, both upstream and downstream of West Avenue, downstream of West Avenue, and upstream of the High School. Detailed mapping and field observations show a wide low floodplain just downstream of Hanson Road that contains multiple channels and, therefore, a much wider floodway.

5.0 CONCLUSIONS

This analysis has defined a new existing conditions floodway based on the 2009 Existing Conditions Model of Stony Brook in Darien, Connecticut. Floodway modeling has been completed in accordance with FEMA-prescribed guidelines (FEMA 2003). Updated hydrology and hydraulics represent existing conditions using the best available data and is recommended for adoption by FEMA as the Effective Model.

All electronic modeling HEC-HMS and HEC-RAS files used in this floodplain and floodway modeling effort are included in electronic format on a CD-ROM in Appendix H.

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Bridge plans were evaluated for updating the hydraulic modeling. Plans reviewed include the following:

- *Old Kings Highway* – updated based on Bridge Safety Inspection State Project No. 170-2357, Routine Inspection Report for Bridge No. 04991, Carrying Old Kings Highway Over Stony Brook, Darien, Connecticut, Inspected September 28, 2005 by AI Engineers, Inc.

- *Boston Post Road Bridge (Route 1)* – Plan "Route US 1 Over Stony Brook (Structure Number 35-127-1)" by Connecticut Department of Transportation Bridge Design Unit, Dated August 19, 1983.

- *Renshaw Road* – Plan "Renshaw Road Over Stony Brook (Town of Darien Bridge Number 035-014)" by Goodkind & O'Dea, Inc. Consulting Engineers and Planners, Hamden, Connecticut, Dated July 22, 1991.

- *Hecker Road* – Plan "Hecker Avenue Over Stony Brook (Town of Darien Bridge Number 035-006)" by Goodkind & O'Dea, Inc. Consulting Engineers and Planners, Hamden, Connecticut, Dated July 15, 1991.

- *I-95 Culverts* – Plan "Rehabilitation of Interstate 95 Over The Stony Brook (Structure Number 35-164-4)" by Andrews & Clark, Inc./United International Corp., State of Connecticut Department of Transportation, Dated December 14, 1950 and Revised February 5, 1991.

- *Railway Bridge* – no plans

- *West Road* – no plans

- *Private Driveway* – no plans

- *Middlesex Road* – Bridge Safety Inspection State Project No. 170-2357, Routine Inspection Report for Bridge No. 04143, Carrying Middlesex Road Over Stony Brook, Darien, Connecticut, Inspected September 21, 2005 by AI Engineers, Inc.

- *High School Lane* – Bridge Safety Inspection State Project No. 170-2357, Routine Inspection Report for Bridge No. 04993, Carrying High School Lane Over Stony Brook, Darien, Connecticut, Inspected September 21, 2005 by AI Engineers, Inc.

- *Hanson Road* – Plan "Hanson Road Over Stony Brook (Town of Darien Bridge Number 035-005)" by Goodkind & O'Dea, Inc. Consulting Engineers and Planners, Hamden, Connecticut, Dated July 10, 1991.

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