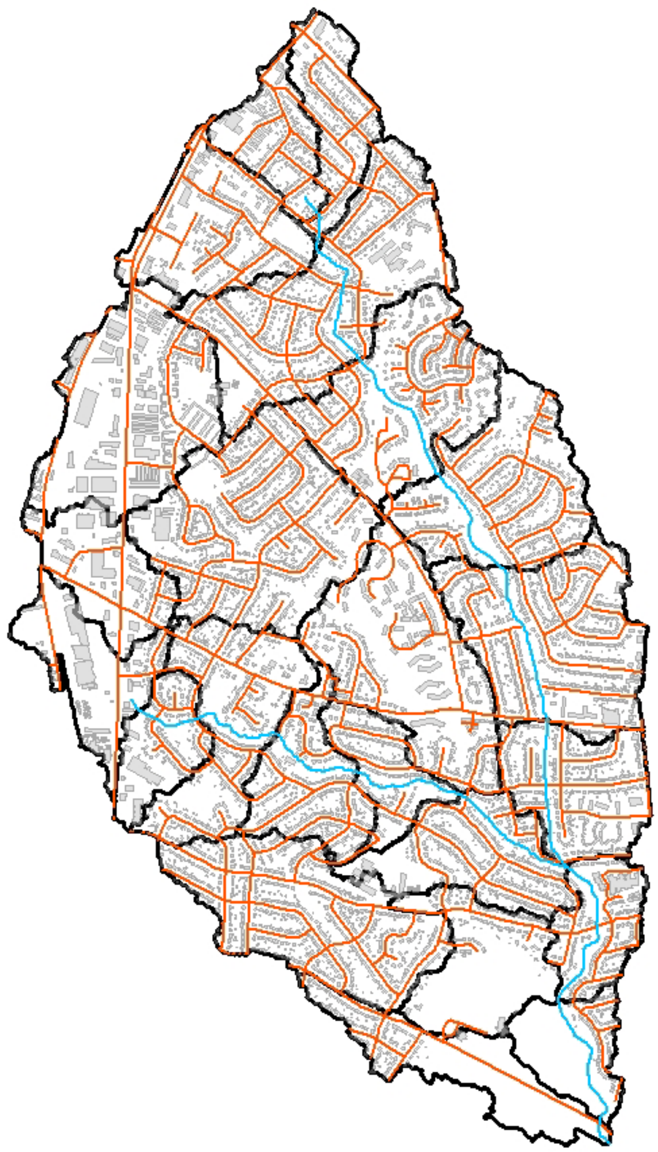
MECKLENBURG COUNTY FLOODPLAIN MAPPING 2008

Little Hope Creek Watershed Letter of Map Revision



AECOM

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1.0 Introduction

AECOM was contracted by the Charlotte Mecklenburg Storm Water Services (CMSWS) to perform a hydrologic, hydraulic, and mapping restudy of the Little Hope Creek watershed. The Little Hope Creek watershed was studied as part of the Little Sugar – Briar Creek (LSBC) watershed study that was conducted during Physical Map Revision Phase I (PMR1) of the Mecklenburg County Floodplain Mapping Initiative of 2008, with an effective date of February 19, 2014. The extents of the Little Hope Creek watershed generally extend from the confluence of Little Hope Creek and Little Sugar Creek to the south, the intersection of South Blvd and New Bern St to the north, Old Pineville Rd on the west, and Park Rd on the east.

The Little Hope Creek watershed restudy followed an investigation that was conducted by AECOM, whose purpose was to verify the assumptions and parameters used in the engineering models created during the PMR1 LSBC study, and to investigate why the newly calculated base flood elevations (BFEs) have decreased in this area despite the presence of a number of flooding events that have been observed in this watershed over the past decade. That investigation determined that the basis of the large decreases in the BFEs appears to be a significant decrease in the reported discharges.

This Letter of Map Revision request is intended to formally revise the effective discharges and water surface elevations based on revised hydrologic and hydraulic analyses.

1.1 Purpose

This Letter of Map Revision request is intended to formally correct the irregularities that were identified in the effective LSBC PMR1 hydrologic and hydraulic analyses pertaining to the Little Hope Creek watershed. As the data contained in this report will illustrate, the effective February 2014 data under-predict 1-percent annual chance event water surface elevations (as well as those for the other modeled events), and the extents of the resulting inundation in a number of areas along Little Hope Creek and Little Hope Creek Tributary. Therefore, this restudy proposes increased water surface elevations and special flood hazard area extents in comparison to the effective data in the Little Hope Creek watershed.

1.2 Letter of Map Revision Package Contents

In furtherance of this LOMR request, AECOM used the final hydrologic and hydraulic data for the Little Hope Creek watershed that was generated during the LSBC PMR1 analysis as a basis for this revised analysis. Additionally, publically available data from the USGS stream gage on Little Hope Creek located at Seneca Place (site **#02146470**) and from various USGS rain gaging sites located in the vicinity of the study area were used to revise the model calibration methodology. This submittal, and all associated attachments, includes all data generated in support of this revision request, as well as a summary of the results of the revised analyses. Attachments include digital versions of the revised hydrologic and hydraulic models, revised floodplain boundary polygon shapefiles for the 1-percent and 1-percent future events, revised floodway boundary polygons for the FEMA and Community Encroachment Area floodways, a topographic workmap showing the effective and revised conditions boundaries, shapefiles indicating the location and elevation of natural cross-section and structure survey points, and a copy of the Little Hope Creek Restudy report.

2.0 Hydrologic Analysis

The parameters and assumptions used in the effective PMR1 LSBC hydrologic analysis were first evaluated to ensure their accuracy and appropriateness. Revisions were made to any parameters that, upon review, were deemed to be sufficiently inaccurate as to have an appreciable negative impact on the end results of the analysis. Once the model input parameters were verified and finalized, the model was reverted to its pre-calibration state before ultimately being recalibrated using observed data collected during various real-world storm events.

2.1 Parameter Evaluation / Verification

As stated above, a detailed review of the hydrologic model parameter calculations and assumptions used in the effective analysis was performed to verify their accuracy and validity. This included an in-depth analysis of sub-basin boundary delineations, curve number calculations, times of concentration flow paths / calculations, and routing methods / calculations. A summary of the findings regarding each parameter listed previously can be found below.

2.1.1 Sub-basin Boundary Delineations

Sub-basin boundaries were found to be generally consistent with the topography and existing stormwater infrastructure, as illustrated by the county's stormwater inventory shapefile. Section 2.1.1 of the PMR1 LSBC hydrology report states that 60 acres was the target sub-basin size for this study (as was stipulated in the *Floodplain Analysis and Mapping Standards Guidance Document,* dated July 2008), with a tolerance of +/-20%. However, examination of the sub-basin dimensions reveals that the majority of the basins in the Little Hope Creek watershed are outside of the stated target basin size and tolerance. Of the 23 sub-basins that comprise the area in question, 12 sub-basins have areas that are greater than 72-acres (the upper threshold of the stated area tolerance), while 5 are below 48-acres (the lower threshold of the stated area tolerance).

In spite of these deviations from the target tolerance, the sub-basin delineations appear to be reasonable, and any revisions to the sub-basin boundaries would have no appreciable impact on the model results. Thus, the sub-basin boundaries were considered **valid** and have been kept constant.

2.1.2 Curve Numbers

Composite curve number (CN) calculations were based on the Curve Number – Landuse – Soil Group look-up table provided by the county, dated December 2008. The CN look-up table is used to relate areas of specific landuse classification and soil type with a CN value, which represents the imperviousness of the ground cover in a specific area in the USDA's TR-55 methodology. According to section 2.1.3 of the LSBC hydrology report:

"*…the land use, soils, and the subbasins were spatially intersected in GIS to obtain polygons representing every unique combination of land use and soils within each subbasin. The CNs were assigned to each polygon using the CN lookup tables described in the paragraph above. Finally, a composite CN was calculated for each subbasin by computing the area-weighted average of the individual CN polygons within the subbasin.*"

While the sub-basin and landuse shapefiles for the Little Hope Creek watershed were available during this investigation, the actual soil shapefile used in the commission of the LSBC watershed study was not readily available, nor was the resulting spatial intersection that was used to derive the composite CN value for each sub-basin. Thus, it was necessary to attempt to recreate the steps used to generate the original composite CN shapefile in order to check the CN values used in the hydrologic modeling. This was accomplished using the sub-basin and landuse shapefiles contained in the LSBC submittal, along with a soil shapefile for the area of interest obtained electronically from the US Department of Agriculture. Once all relevant shapefiles were acquired, a spatial intersection was performed, and composite CN values were calculated in a manner consistent with that described in the hydrology report. The results of this reproduction are tabulated in Table 1 below:

CN Comparison – Recalculated vs LSBC PMR1 Reported				
Basin_ID	**DA_SQMI**	**Recalculated CN**	**LSBC PMR1 CN**	**Difference**
LLS_199	0.072188504	82.90	82.92	0.02
LLS_104	0.081622331	77.43	77.86	0.43
LLS_103	0.13548482	85.30	85.62	0.32
LLS_242	0.242054781	76.27	76.58	0.30
LLS_360	0.186839991	77.01	80.52	3.51
LLS_366	0.212117625	86.93	88.47	1.54
LLS_200	0.177919106	74.04	75.49	1.45
LLS_367	0.254229081	75.40	76.09	0.69
LLS_201	0.091970845	89.63	89.65	0.02
LLS_241	0.208932363	76.84	77.16	0.32
LLS_119	0.206981032	77.41	83.26	5.84
LLS_202	0.096264492	89.68	89.68	0.00
LLS_203	0.065767763	80.40	80.44	0.03
LLS_368	0.145044192	74.83	74.85	0.01
LLS_120	0.064530246	74.48	74.63	0.14
LLS_240	0.09860322	75.30	75.82	0.52
LLS_123	0.117183913	82.80	84.19	1.39
LLS_124	0.122388659	76.65	77.18	0.53
LLS_130	0.073117539	80.38	81.41	1.03
LLS_402	0.203889	74.99	74.99	0.00
LLS_129	0.111911	67.15	67.22	0.07
LLS_371	0.070779	65.18	65.51	0.33
LLS_135	0.105989	69.10	69.08	-0.01

Table 1 – Curve Number Comparison

Comparison of the CNs generated in the commission of the PMR1 LSBC study with those computed during this restudy revealed overall agreement. While the original CN values are generally slightly higher than those generated in this investigation, the differences observed (when differences existed) were minor. Thus, the PMR1 LSBC CN values are considered **valid**, and no changes were made to the raw CN values used in the revised hydrologic analysis for the existing and future conditions.

2.1.3 Time of Concentration / Lag Time

For the LSBC watershed study, the time of concentration (**TC**) for each sub-basin was calculated using the TR-55 methodology. According to the hydrology report, the longest flow path for each sub-basin was determined with respect to sub-basin topography and relevant stormwater infrastructure. This flow path was then divided based on criteria specified in TR-55, and the incremental travel time is calculated for each segment. These incremental times were then summed in order to determine the total TC for a given sub-basin.

The TC flow path shapefile generated in the commission of the PMR1 LSBC watershed study was available during the course of this investigation. Additionally, the incremental travel time calculations for each segment / flow regime in each sub-basin, as well as a summation of each basin's incremental times, was included in a spreadsheet attached to the original hydrology report. Thus, the TC input parameters and calculations could be checked directly without the need to attempt to recreate them. Reviewing the TC calculations for select sub-basins within the Little Hope Creek watershed revealed no significant errors in methodology, and the calculation results appeared to be reasonable and consistent with the input parameters used in the computations. Thus, TC inputs used in the PMR1 LSBC hydrologic analysis were considered as **valid**, and no changes to the raw TC inputs were made for this restudy.

2.1.4 Routing

Reach routing through / between sub-basins in the effective 2014 LSBC study was done using a combination of Modified Puls and Muskinham-Cunge methodologies. For studied streams where the modified puls method was used, storage-discharge relationships were determined from the output of the hydraulic model for that particular stream. Muskingham-Cunge was used for all reaches where no detailed hydraulic analysis was being performed. Input parameters for the Muskingham-Cunge calculations were taken from the stormwater inventory where possible, or from the terrain data and aerial imagery. In the Little Hope Creek watershed, only three (3) of the 15 routing reaches do not have a detailed hydraulic model, and thus use the Muskingham-Cunge routing method. Reservoir routing was also included where applicable in the PMR1 LSBC analysis. However, no ponds / reservoirs are present in the Little Hope Creek watershed.

In order to verify the storage-discharge relationships used in the modified puls routing reaches, output was exported from the finalized hydraulic models for Little Hope Creek and Little Hope Creek Tributary. This output was used to calculate storage volumes in the modeled reaches within the watershed, and these volumes were paired with the corresponding event discharges to create new storage-discharge curves for each sub-basin. Comparison of these storage-discharge curves with those that were present in the PMR1 LSBC hydrologic model revealed that a number of the storage-discharge curves appear to over-predict the amount of storage available in the floodplain, while others appear to under-predict the available storage. An example of this variance can be seen in the storage – discharge graph for routing reach "**R_LLS_130**" below:

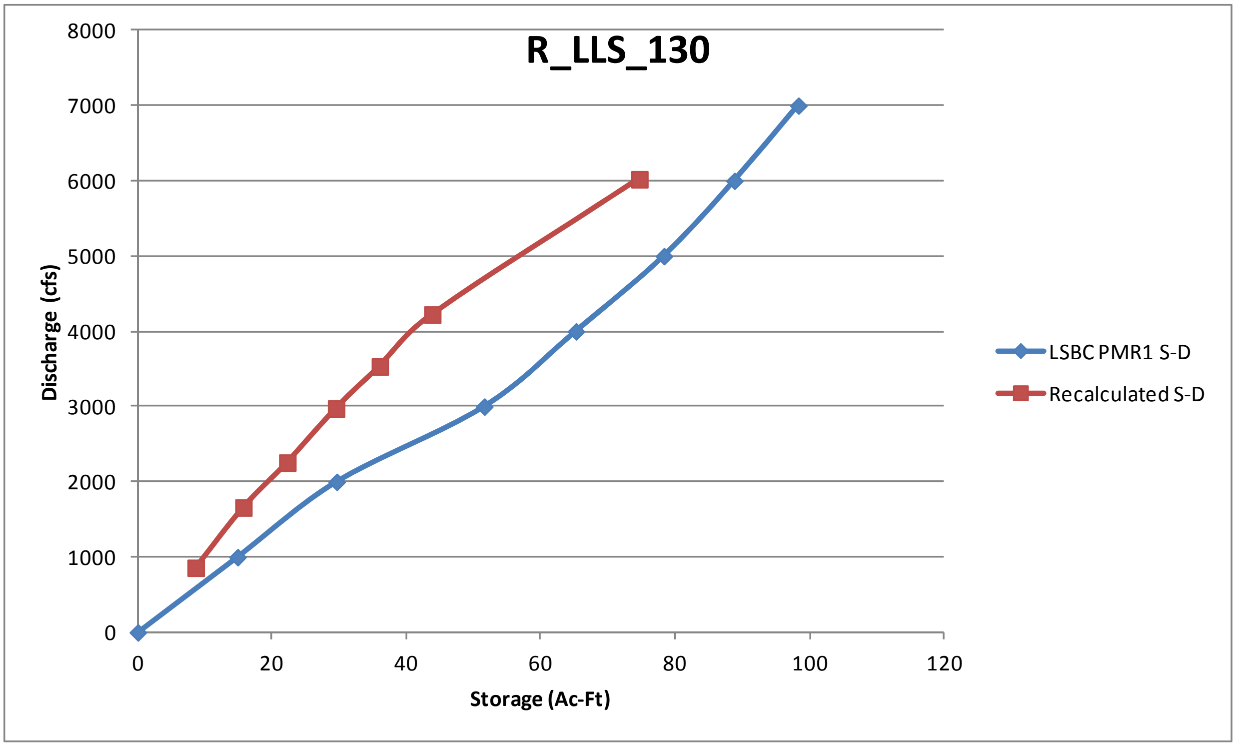


Figure1 – Routing Reach "R_LLS_130" Storage Discharge Curve

Additionally, all modified puls routing reaches in the Little Hope Creek watershed used "1" sub-reach, which is not consistent with the output of the hydraulic models. The number of sub-reaches used in the modified puls routing method affect the amount of flow that is attenuated in each routing reach, with "1" sub-reach yielding the maximum attenuation and an increasing number of sub-reaches approaching zero attenuation. For each routing reach, the number of sub-reaches should be chosen to ensure that the travel time through a sub-reach is approximately equal to the simulation time step (1 minute in this case). This can be approximated for each routing reach using the following equation:

# of sub-reaches = RL / c / TS

where, ***RL*** ***= routing reach length [feet]***
c ***= flood wave celerity [feet / second]***
TS ***= time step [seconds]***

Calculating the number of sub-reaches for each modified puls routing reach using the formula above gives:

Routing Reach ID	Sub-reaches
R_LLS_203	2
R_LLS_368	6
R_LLS_240	5
R_LLS_120	5
R_LLS_124	9

Routing Reach ID	Sub-reaches
R_LLS_104	3
R_LLS_242	8
R_LLS_360	7
R_LLS_200	7
R_LLS_241	11
R_LLS_123	17
R_LLS_130	1
R_LLS_371	8
R_LLS_135	1

Table 2 – Modified Puls Sub-Reach Values

As described previously, increasing the number of sub-reaches for all modified puls routing reaches in the hydrologic model will cause less flow to be attenuated in each routing reach, causing an appreciable increase in the resulting peak discharge values. Thus, the storage – discharge relationships and sub-reach values used in the effective PMR1 LSBC model were considered to be **invalid**, and the recalculated parameter values were used in the **revised** analysis.

2.2 Hydrologic Model Generation

As previously stated, this Letter of Map Revision is intended to correct irregularities in the hydrologic modeling methodology that caused the base flood elevations and discharges calculated for this watershed in the 2014 effective LSBC analysis to decrease in comparison to those that were published previously in the 2009 effective analysis. To do so, this revision request is formally presenting the findings of the aforementioned hydrologic restudy (included with this request as Appendix A). As such, an in-depth discussion of each step in the hydrologic analysis can be found in section 2 of the attached restudy report document.

Once the various input parameters used in the 2014 effective LSBC hydrologic analysis were reviewed and evaluated as described in section 2.1 above, a new hydrologic model was made that removed the calibration measures that were applied in the PMR1 LSBC analysis.

Verification of Effective Results Using HEC-HMS Version 3.5

The 2014 effective LSBC hydrologic analysis was conducted using HEC-HMS version 3.4, as this version was the most up-to-date version of the model that was available when the study was initiated. However, in the time since the effective study was initiated, an updated version of HEC-HMS (version 3.5) has been released. Therefore, the newest version of HEC-HMS was used for this revised analysis.

The final basin file from the effective PMR1 LSBC hydrologic model was imported into version 3.5. The 1-percent event simulation was conducted using the imported basin file, and the version 3.5 results were compared to those yielded in the PMR1 study. Comparison of the results of this simulation showed that the discharges computed using version 3.5 were identical to those reported in the PMR1 LSBC watershed analysis at all locations. This verifies that all differences that are observed between the results of this restudy and the effective PMR1 LSBC analysis results are the direct result of changes to the revised analysis.

The final basin file from the effective PMR1 LSBC HEC-HMS model is included in the revised Little Hope Creek watershed model, and is named "**1_LSugar&Briar_Existing**".

Duplicate Effective Little Hope Creek Watershed Basin Model

Upon verification of the results yielded by HEC-HMS version 3.5, a subset of the complete LSBC watershed model containing the model elements that represent the Little Hope Creek watershed was exported to a new basin model. This basin model, named "**2_LHC_WS_Dup_Eff**", serves as a baseline for evaluating the changes that are yielded by the revisions that arise through this restudy.

Since the elements and assumptions used in this basin model were taken directly from the effective PMR1 LSBC watershed model, and are identical to them in every way, conducting the 1-percent event simulation with this basin file yields results that are identical to those calculated by the PMR1 LSBC model. This is illustrated for select locations / model elements in Appendix A, Table 3.

All subsequent basin models are derived directly from the duplicate effective basin model.

"Pre-Calibration" PMR1 Little Hope Creek Watershed Basin Model

Basin model "**3_LHC_WS_PMR1_PreCal**" represents the effective PMR1 Little Hope Creek model with the calibration measures removed. According to the text of the effective PMR1 LSBC hydrology report:

"*Based on results from six (6) iterations performed during previous steps, it was decided that lag time should be further increased to 1.8*Tc while using reasonable initial abstraction values to achieve a better match with Aug 2008 event. … The model with these revisions (lag time = 1.8*Tc and initial abstraction = 0.7 inch) resulted in peak discharges and volumes which were a closer match to the Aug 2008 event.*"

Thus, in order to return the model to its "pre-calibration" state, the adjustments that were made during the calibration process must be removed. Specifically, since the TCs were universally adjusted using a **1.8 multiplier**, TCs contained in the effective HMS model must be replaced with the original values that were evaluated and verified (described in section 2.1.4 above). Also, due to the fact that the initial abstraction (**I_A**) was set to **0.7 inches** for all sub-basins, new I_A values must be computed. The initial abstraction values were recalculated using a combination of equations 2-2 and 2-4 from TR-55:

$$\mathbf{I_A = 0.2 * ((^{1000}/_{CN})-10)}$$

The "pre-calibration" TCs and the recalculated initial abstraction values, which would eventually be modified in the calibration process of this restudy, are listed in Appendix A, Table 4. Using these "pre-calibration" initial abstraction and lag time parameter values yields discharges that are considerably greater than the final discharges that result from the effective PMR1 LSBC analysis. A comparison of the "pre-calibration" and effective 1-percent event discharges at key locations can be found in Appendix A, Table 5.

The "pre-calibrated" discharges range from 42% to 81% greater than the final discharges computed for this watershed in the effective PMR1 LSBC analysis. The global calibration measures that were implemented in the effective analysis drastically reduced the 1-percent event discharge. The reasons for this will be illustrated in detail in later sections of the report.

Revised "Pre-Calibration" Basin Model

Following the creation of the "pre-calibration" basin model, basin model "**4_LHC_WS_Revised_PreCal**" was added to the revised HMS model. This basin model incorporates changes to the baseflow method, storage-discharge relationships (described in section 2.1.5 above), and to the connectivity of the model elements at confluences. Otherwise, this basin model is the same as the "pre-calibration" effective basin model discussed previously.

The effective LSBC watershed hydrologic model did not include base flow in any of the sub-basins. However, examination of the gage record from USGS gage **#02146470** at Seneca Place revealed the presence of a sustained, "fair weather" runoff of approximately **0.2cfs** in Little Hope Creek. This was accounted for in the model by adding an assumed baseflow of **0.08cfs/mi^2** at all sub-basins in the Little Hope Creek watershed (*this was derived by calculating the ratio of the observed baseflow to the Little Hope Creek watershed drainage area of **2.65mi^2** at the gage location*).

Additionally, examination of the effective LSBC model revealed a somewhat unusual connectivity of elements at confluences. Sub-basin and routing reach elements from tributaries and unmodeled contributing drainage areas are connected directly to the junction elements of the main-stem sub-basins that are located immediately upstream of the confluences.

The implication of this element configuration is that, for example, Little Hope Creek Tributary drains into "**LLS_123**" (the sub-basin immediately upstream of the confluence), rather than into the routing reach of "**LLS_130**" (the sub-basin immediately downstream of the confluence). This causes an artificially inflated peak discharge to be reported at sub-basin **LLS_123**, and an artificially depressed peak discharge to be reported for the downstream end of Little Hope Creek Tributary (**LLS_124**). For Little Hope Creek Tributary, the discharge that is reported at the downstream end in the effective LSBC analysis is from routing reach element "**R_LLS_124**", which neglects the runoff from sub-basin **LLS_124** (whose drainage area accounts for 10% of the Little Hope Creek Tributary drainage area). The effect of these revisions is shown in Table 6 of Appendix A.

Correcting the model element connectivity to properly show the sub-basin relationships at confluences causes the reported drainage areas to decrease at a number of the highlighted locations. This is accompanied by corresponding decreases in the reported discharges of the main streams at these locations due to the changes in the modeled hydrograph combination locations. However, discharges calculated at the elements immediately downstream of the revised confluences are similar to those in the "pre-calibration" effective model.

Most significantly, corrections made to the sub-basin connectivity at confluences cause the "pre-calibration" discharges (and drainage areas) to increase at the outfall locations of both Little Hope Creek and Little Hope Creek Tributary. This occurs due to the inclusion of the areas that were not properly connected when using the original element connectivity.

Results and Conclusions

As shown previously, discharges computed for the Little Hope Creek watershed increase significantly when the effects of the model calibration are reversed. This is to be expected, as the calibration measures used in the PMR1 LSBC study were intended to cause reductions to the peak flow.

Along with the restoration of the model parameters to their "pre-calibrated" state, additional revisions for to the effective model include incorporates changes to the **baseflow method**, **storage-discharge relationships**, and to the **connectivity of the model elements at confluences**.

With the model having been revised to incorporate updates in the modeling methodology and parameters where appropriate, the next phase of the analysis was to calibrate the model by simulating known storm events. The calibration process is discussed below.

2.3 Revised Model Calibration

In an effort to ensure agreement between the revised "pre-calibration" model and real-world data collected at several USGS gage locations throughout the study area, observed precipitation and stream flow data recorded during historical storm events were used to identify adjustments that could / should be made to the input parameters and assumptions of the hydrologic modeling. Of the events used in the calibration process of the effective LSBC study, the August 27, 2008 storm event produced the largest total precipitation in the Little Hope Creek watershed.

The August 2008 event simulation from the effective hydrologic analysis only used 6 of the 16 applicable precipitation gages in and adjacent to the LSBC watershed. Among the excluded gages was ***CRN-60***, which is located within the Little Hope Creek watershed. A detailed discussion of the impacts of not using all available rain gages in the calibration process, specifically in the Little Hope Creek watershed, can be found in Appendix A. **Correcting this calibration methodology is the primary revision to the hydrologic analysis, and is one of the main purposes of this LOMR request.**

Thus, the Little Hope Creek watershed hydrologic analysis will be re-calibrated using the August 2008 event, but also using 2 additional storms that had not occurred at the time of the effective LSBC hydrologic analysis. The revised calibration process will be summarized in the following sections.

2.3.1 Methodology

Analysis of the discharge record for USGS gage# ***02146470*** shows the presence of a number of high flow events that can be used in the calibration process for this restudy. After careful examination of the gage record, the storm events chosen for the calibration effort in this restudy were those that occurred on **August 27, 2008**, **August 16, 2009**, and **August 5, 2011**.

- The August 2008 event was chosen due to the fact that it is the event that was used in the calibration process of the effective hydrologic analysis. This will enable a direct comparison between the calibration efforts of the effective study and those conducted for this restudy.

- The August 2009 event yielded the largest discharge of any event for which sufficient precipitation and stream flow data exists. For the Little Hope Creek watershed, only three discharges have ever been recorded that were larger than that observed during this event, and these occurred during storm events in or before 2006. However, no detailed rainfall data is available for these events. Since the August 2009 event is the largest event recorded in this watershed for which ample data is available, this event was selected for the calibration effort.

- The August 2011 event was chosen due to the moderate size of its peak discharge (less than the August 2008 event). Additionally, this event has a single peak hydrograph that closely resembles the shape of a "typical" hydrograph, making it an ideal event to calibrate to. This differs from that of the August 2008 event, whose hydrograph has multiple peaks.

The "**gage weights**" precipitation method was used to distribute the observed rainfall in each of the event simulations. This precipitation method assigns weights at every sub-basin to each of the precipitation gages used in the event simulation, with weight values varying according to the gages' proximity to the sub-basin in question. Proximity and weight values were determined by first generating Thiessen Polygons for the rain gages in the area surrounding the Little Hope Creek watershed. These polygons were then intersected with the Little Hope Creek watershed sub-basins to determine the areal percentage of each sub-basin that coincided with the polygon for each rain gage. If a particular sub-basin fell entirely within a single Thiessen polygon, then the corresponding rain gage was weighted 100% in that particular sub-basin. In the event that a sub-basin is overlapped by multiple Thiessen polygons, a weight value proportionate to the percentage of the sub-basin's total area in each polygon was assigned to each gage.

Using the methods described above yielded the gage weights shown in Table 3 below:

	August 2008 / 2009 Gages				August 2011 Gages				
	CRN-12	CRN-19	CRN-60	CRN-71	CRN-12	CRN-13	CRN-19	CRN-60	CRN-71
LLS_199	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_104	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_103	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_242	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_360	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_366	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_200	0.0	11.8	88.2	0.0	0.0	0.0	11.8	88.2	0.0
LLS_367	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_201	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_241	0.0	11.1	72.0	16.9	0.0	0.0	11.1	72.0	16.9
LLS_119	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_202	0.0	0.0	100.0	0.0	0.0	47.6	0.0	52.4	0.0
LLS_203	0.0	0.0	100.0	0.0	0.0	90.3	0.0	9.7	0.0
LLS_368	0.0	0.0	100.0	0.0	0.0	47.2	0.0	52.8	0.0
LLS_120	0.0	0.0	100.0	0.0	0.0	50.4	0.0	49.6	0.0
LLS_240	0.0	0.0	100.0	0.0	0.0	83.1	0.0	16.9	0.0
LLS_123	0.0	0.0	22.7	77.3	0.0	0.0	0.0	22.7	77.3
LLS_124	0.0	0.0	61.6	38.4	0.0	75.5	0.0	3.0	21.4
LLS_130	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
LLS_402	0.5	0.0	97.8	1.8	0.0	100.0	0.0	0.0	0.0
LLS_129	8.3	0.0	11.3	80.4	0.0	86.9	0.0	0.0	13.1
LLS_371	24.2	0.0	0.0	75.8	21.9	13.4	0.0	0.0	64.7
LLS_135	87.3	0.0	11.6	1.1	31.2	68.8	0.0	0.0	0.0

Table 3 – Precipitation Gage Weights, August 2008 / 2009 and 2011 Event Simulations

Precipitation data was entered into the model for each precipitation gage in units of 5 minute incremental inches. This information, entered as separate time windows for each storm event, was derived from the detailed precipitation data published by the USGS. Observed discharge data from USGS gage# **02146470** was entered into the model for each event in 15 minute instantaneous increments. This information, entered as separate time windows in a manner similar to that used for the precipitation data, was derived from data published by the USGS. Observed discharge data was used to evaluate the effectiveness of the various adjustments that were made in the calibration process.

In keeping with the hydrologic model calibration standards listed in the guidance document, the following model parameters were considered for adjustment in the calibration process:

- Curve Number (CN)
- Initial Abstraction (I_A)
- Lag Time

These parameters were adjusted within the allowable tolerances to bring the simulated discharges, total volumes, and peak times into agreement with those that were recorded during the observed events.

2.3.2 Event Simulations and Parameter Adjustments

August 2008 Event

Since the August 2008 event was used in the calibration efforts of the PMR1 LSBC study, this event was used as the starting point for the model calibration in this restudy. Using the revised "pre-calibration" model described in **section 2.2.4**, the August 2008 event simulation was executed in order to determine how closely the peak discharge and total runoff volume yielded by the "pre-calibration" model agreed with what was observed.

Examining the results of the August 2008 event baseline simulation shows that the revised raw / pre-calibration model produces a peak discharge of **1202.3 cfs**, which is within **3%** of the observed peak flow at this location. This is well within the target tolerance of 10% recommended in the guidance document. Also, the simulated peak time closely agrees with the time of the observed peak, occurring **4 minutes** ahead of the observed peak. While the total volume in the baseline run is outside of the target tolerance, these values were achieved before any adjustments to the raw parameters / assumptions were made.

The first calibration iteration used a small universal CN increase (+1), along with a 25% increase in initial abstraction. These measures were chosen with the intent of simultaneously raising the peak flow, and reducing the magnitude of the localized swell in the hydrograph that occurs at approximately "8/26/2008 12:00" to reduce the total volume. Calibration adjustments were applied to basin model "**5_LHC_WS_Revised_Cal**". The results of this iteration showed that these very small adjustments only achieved extremely minor changes in the simulated values, yielding a marginal increase in the peak flow with a marginal reduction in total volume.

Subsequent iterations used incrementally larger initial abstraction factors while maintaining the universal CN increase. Incremental increases in the lag time were also included in an attempt to gain even closer agreement with the observed peak time. The final August 2008 event calibration run used a **75% increase in initial abstraction**, a **50% increase in lag time**, and a **1 unit increase in CN**. These calibration measures resulted in close agreement between the simulated values and those that were observed. While the simulated peak discharge obtained in the final calibration run has marginally decreased relative to the baseline simulation discharge, the total residual volume and peak time have improved relative to the observed values. Hydrographs for the observed event, baseline simulation, and final simulation for this event can be found in section 2.3.2 of Appendix A.

Throughout the calibration runs, gaining close agreement between the total volume of the observed and simulated hydrographs proved to be extremely difficult. This was probably caused by the complex nature of the observed event hydrograph, which contains multiple distinct peaks. The hydrograph shape for this event reflects the elongated nature of the precipitation, which fell sporadically and in high intensity bursts over an approximately 36 hour long period. As a result, no extraordinary measures were taken to bring the simulated total volume into agreement with the observed total volume.

The August 2008 baseline and final calibration runs are summarized in Table 4 below:

	IA factor	CN factor	Lag factor	Peak Q (cfs)	Time of Peak	Volume (in)	%Diff Peak Q	Diff Time (min)	%Diff Total Volume
Observed	N/A	N/A	N/A	1240.0	8/27/2008 6:02	2.73	N/A	N/A	N/A
Baseline	1.00	Raw	1.00	1202.3	8/27/2008 5:58	4.39	-3%	-4	61%
Final	1.75	Raw+1	1.50	1195.7	8/27/2008 6:05	4.10	-4%	+3	50%

Table 4 –August 2008 Event Calibration Summary

The August 2008 event was a less than ideal event to use in calibration due to the non-uniform nature of the observed precipitation. Double peak / multiple peak storms with extended precipitation times are difficult to use in calibration primarily because of the model initial abstraction assumptions and calculations, which have a large effect on total hydrograph volume. However, this was the best storm event that was available at the time when the PMR1 LSBC analysis was conducted. In spite of this complexity, the baseline peak flow and peak time were well within the calibration tolerance prior to the application of any adjustments, showing the validity of the initial assumptions / parameters.

August 2011 Event

The baseline simulation of the August 2011 event was executed using the revised "calibrated" basin model, which included the calibration factors developed in the final August 2008 event calibration run.

Using the final calibration measures from the August 2008 event, the baseline simulation for the 2011 event yields peak flow, peak time, and total volume values that agree closely with the observed values. The simulated peak flow value of **812.6cfs** is within **5%** of the observed value, with a simulated peak time that occurs within **5 minutes** of the observed time. Also, the simulated total hydrograph volume is within **7%** of the observed volume. While minor adjustments could potentially be made to gain even closer agreement between simulated and observed values, the degree of agreement between the baseline simulation results and the observed values indicate that **no further calibration measures are warranted** for this event (beyond those that were used in the final August 2008 event calibration run). Observed and baseline simulation hydrographs for this event can be found in section 2.3.3 of Appendix A.

August 2009 Event

The August 2009 event yielded the fourth largest discharge ever recorded in the Little Hope Creek watershed. The baseline simulation of this event was made using the final calibration factors developed in the final August 2008 event calibration run (and maintained in the August 2011 event calibration).
The results of the August 2009 baseline simulation did not show the same close agreement with the observed peak flow and peak time as the 2008 and 2011 event simulations. The baseline simulated peak flow for this event was approximately 16% greater than the observed peak, and occurred 10 minutes before the observed peak time (although, the simulated total volume was within 1% of the observed volume). While peak time and total volume are well within the target tolerances, additional adjustment is needed in order to gain acceptable agreement between simulated and observed peak flows with the possibility of also getting better agreement with the peak time.

Based on the results of the baseline simulation, it was determined that adjustments to the lag time should be made to accomplish the dual goals of decreasing the peak flow and moving the peak time. Calibration iterations were made using 5% incremental increases in the lag factor, while maintaining the CN increase and initial abstraction factor. The final calibration run for this event used a **65% increase in lag times** in comparison with the raw values, in conjunction with the **75% increase in initial abstraction** and **1 unit increase in CN**.

The use of a 15% larger lag time factor in the final August 2009 event simulation achieved a 3% decrease in the peak flow, along with a 3 minute shift in the peak time. Additional increases to the lag time factor could be made to achieve even closer agreement between simulated and observed peak flow and peak time values. However, the calibration effort was halted at this point in order to ensure that the agreement that was achieved for the 2008 and 2011 events was not appreciably disrupted.

The August 2009 baseline and final calibration runs are summarized in Table 5 below:

	IA factor	CN factor	Lag factor	Peak Q (cfs)	Time of Peak	Volume (in)	%Diff Peak Q	Diff Time (min)	%Diff Total Volume
Observed	N/A	N/A	N/A	2050	8/16/2009 15:21	2.02	N/A	N/A	N/A
Baseline	1	1	1	2375.9	8/16/2009 15:11	2.04	16%	-10	1%
Final	**1.75**	**+1**	**1.65**	**2323.8**	**8/16/2009 15:14**	**2.04**	**13%**	**-7**	**1%**

Table 5 –August 2009 Event Calibration Summary

The overall calibration factors that were adopted in the final August 2009 calibration run were considered as the "**final**" calibration measures for this restudy.

2.3.3 Results and Conclusions

The final simulations of 2008 and 2011 calibration events were executed using the final calibration measures from the August 2009 event simulation (listed in Table 5). This yielded the following:

Simulated			Observed			Peak Q %difference	Volume %difference
Peak Q (cfs)	**Time of Peak**	**Volume (in)**	**Peak Q (cfs)**	**Time of Peak**	**Volume (in)**		
1147.1	8/27/2008 6:07	4.09	1240	8/27/2008 6:02	2.73	-7%	50%
786.7	8/5/2011 14:27	0.74	857	8/5/2011 14:20	0.70	-8%	6%
2323.8	8/16/2009 15:14	2.04	2050	8/16/2009 15:21	2.02	13%	1%

Table 6 – Simulations w/ Final Factors vs Observed Outflow Results, All Calibration Events

The final lag factor (a **65% increase in lag times** from the raw values) is greater than what was used in the previous calibration runs for the 2008 and 2011 events, which used a 50% increase in the lag times. It can be seen in the table above that including an increased lag time factor in the final calibration measures results in somewhat lower peak discharges for these events, in addition to greater differences in the peak time. In spite of these decreases, the final calibration measures have yielded results that are well within the target calibration tolerances.

Based on the agreement between the simulated and observed discharges for the chosen historical events, these final calibration measures are considered to be valid, and were used to calculate the "calibrated" discharges for the 50-, 20-, 10-, 4-, 2-, 1-, future 1-, and 0.2-percent-annual-chance events.

A comparison of the PMR1, pre-calibration, and the calibrated 1-percent discharges at key locations can be found in Table 16 of Appendix A.

For the 1-percent event discharge, the table above shows significant increases at most locations in comparison to those that were computed in the PMR1 LSBC analysis. Decreases are also shown immediately upstream of the confluences with Little Hope Creek Tributary, and with an unmodeled tributary to Little Hope Creek Tributary immediately upstream of Bradbury Drive. However, as discussed in section 2.2 of this report, these decreases occur due to corrections that were made to the model element connectivity at confluences.

A hydraulic analysis was conducted using the calibrated discharges from the 50-, 20-, 10-, 4-, 2-, 1-, future 1-, and 0.2-percent-annual-chance event simulations. Water surface elevations computed using the newly calibrated 1-percent discharges show significant increases in comparison to those published in the final PMR1 LSBC analysis. The hydraulic analysis will be discussed below.

3.0 Hydraulic Analysis

In addition to revisions to the effective hydrologic analysis, revisions to the hydraulic analysis are also being proposed in this Letter of Map Revision request. These revisions include the use of the revised discharge values that were computed in the analysis summarized in section 2.0, as well as revisions to the orientation / alignment of select model cross-sections. Additionally, updated survey data was incorporated into the hydrologic model for the Montford Drive crossing, and for 4 natural cross-sections between Montford Drive and Mockingbird Lane.

The revised hydraulic analysis is discussed in detail in the following sections

3.1 Duplicate Effective

The effective PMR1 LSBC hydraulic analysis used **HEC-RAS version 4.0**, as this was the most up-to-date version of the software that was available. However, the analysis conducted in support of this LOMR request used the newer **version 4.1**, which has become available after the completion of the effective analysis.

The geometry and flow files (multi-profile, FEMA floodway, and Community floodway) from the effective HEC-RAS models were imported into the models as **.p01**, **.p02**, and **.p03**, respectively, for this revision. Plans using these imported files were executed as the ***Duplicate Effective*** conditions in order to ensure that the model results from the effective analyses could be obtained using the new models. Base flood elevations calculated using the duplicate effective multi-profile plan are shown at key locations in Table 7 below:

Stream Name	Location Description	Cross-Section Station	Effective WSEL1%	Dup. Effective WSEL1%	Effective vs. Duplicate Difference (ft)
Little Hope Creek Trib	US face of Bradbury Drive	1823	621.91	621.99	0.08
	Approximately 675 feet DS of Bradbury Drive	1104	617.06	617.06	0.00
	Furthest DS Cross-Section on LHCT	538	612.47	612.47	0.00
Little Hope Creek	US face of Woodlawn Road	6971	626.17	626.17	0.00
	US face of Montford Drive	6028	619.05	619.01	-0.04
	US face of Mockingbird Lane	4888	613.80	613.72	-0.08
	US face of Seneca Pl	3759	610.12	608.66	-1.46
	Approximately 1300 ft DS of Seneca Place	2400	601.55	601.55	0.00
	US face of Tyvola Road	444	589.85	589.85	0.00
	Furthest DS Cross-section on LHC	66	579.69	579.69	0.00

Table 7 – Effective and Duplicate Effective 1-Percent Water Surface Elevation Comparison

As Table 7 illustrates, the calculated 1-percent water surface elevations calculated in the duplicate effective model plan exactly match the values yielded by the effective models at the majority of locations. FEMA and Community floodway surcharges computed using the effective encroachment stations also agree with those computed in the effective hydraulic analysis

Of note, a significant deviation exists between the effective and duplicate effective 1-percent elevations calculated at the upstream face of the Seneca Place bridge crossing. The reason for this is explained in the HEC-RAS version 4.1 release notes, which states the following in the "**Problems Repaired**" section:

> 12. **Steady (bridge):** For bridges with class B momentum flow, the momentum answer was occasionally being disregarded. This has now been fixed.

An examination of the effective model results (produced using version 4.0) shows that the bug described above occurred at this location. A warning was given in the effective model at this location, which stated that the "Class B" momentum answer at this location was being disregarded. Instead, the model used the energy equation to calculate the WSEL for this profile. In the duplicate effective model (produced using version 4.1), this does not occur due to the updates made to this version of the program.

Thus, in spite of this anomaly, the duplicate effective model does accurately reproduce the results of the effective analysis within the target tolerance.

3.2 Corrected Effective

The corrected effective models are generally similar to the effective model. The revisions included in the corrected effective model(s) are as follows:

- Revised discharges in both models (calculated in section 2 of this report)
- Cross-section location and alignment revisions (**effective LHC XS1800** relocated to station **1879**, **effective LHC XS7200** relocated to station **7072**, **effective LHCT XS2000** relocated to station **2042**)
- Addition of 5 new cross-sections to the Little Hope Creek corrected effective model (**5852**, **5793**, **5653**, **2219**, and **1683**)
- Updated survey data for the Montford Drive culvert crossing (upstream and downstream face sections, top-of-road profile, culvert inverts, etc.) on Little Hope Creek
- Updated survey data for Little Hope Creek natural cross-sections **5852** to **5653**

While the *magnitude* of the corrected effective discharges have changed, all flow change *locations* used in the effective PMR1 hydraulic analyses have been maintained in the corrected effective analyses.

Using the calibrated discharges yielded higher BFEs at all locations in comparison to those published in the effective PMR1 analysis. A comparison of the effective BFEs and those produced using the calibrated discharges (Duplicate effective multi-profile plan **.p04**) at key locations for Little Hope Creek and Little Hope Creek Tributary can be found in Table 8 below:

Stream Name	Location Description	Cross-Section Station	Effective WSEL1%	Cor. Effective WSEL1%	Effective vs. Corrected Difference (ft)
Little Hope Creek Trib	US face of Bradbury Drive	1823	621.91	622.63	0.72
	Approximately 675 feet DS of Bradbury Drive	1104	617.06	617.78	0.72
	Furthest DS Cross-Section on LHCT	538	612.47	613.87	1.40
Little Hope Creek	US face of Woodlawn Road	6971	626.17	626.85	0.68
	US face of Montford Drive	6028	619.05	619.33	0.28
	US face of Mockingbird Lane	4888	613.80	614.73	0.93
	US face of Seneca Pl	3759	610.12	610.70	0.58
	Approximately 1300 ft DS of Seneca Place	2400	601.55	603.38	1.83
	US face of Tyvola Road	444	589.85	593.65	3.80
	Furthest DS Cross-section on LHC	66	579.69	580.54	0.85

Table 8 – Effective and Corrected Effective 1-Percent Water Surface Elevation Comparison

Throughout the extents of the FEMA floodplain for the Little Hope Creek watershed, the BFEs that were calculated using the calibrated discharges are greater than those calculated in the effective PMR1 analysis by an average of **1.26ft**. The maximum increase in BFE is **3.80ft** and occurs approximately

520ft upstream of Tyvola Road, while the minimum increase is **0.27ft** and occurs **at the upstream face of Montford Road**. A comparison of the base flood elevations at all cross-sections can be found in Appendix B.

Boundaries reflecting the WSELs that result from the calibrated discharges, as well as PMR1 vs. calibrated 1-percent event inundation comparison maps are included as appendices to this report.

3.2.1 FEMA Floodway

The *Mecklenburg County Floodplain Analysis and Mapping Standards Guidance Document* provides guidance to mapping contractors related to creating regulatory and other local floodplain mapping products in Mecklenburg County. In accordance with the guidance, the FEMA floodway "shall be modeled based on a **0.5-foot maximum surcharge** (rather than the typical 1-foot surcharge)". As such, the FEMA floodway was recalculated in plan **.p05** to account for the increased discharges calculated in the revised hydrologic analysis.

The effective encroachment stations were used as a starting point for the FEMA floodway run in the revised analyses for Little Hope Creek and Little Hope Creek Tributary, and were maintained where possible. However, it was necessary to revise the floodway encroachment stations at a number of cross-sections in order to maintain surcharges that are within the allowable tolerance, and to eliminate abrupt changes in floodway width between adjacent cross-sections where possible.

The final FEMA floodway boundary polygon shapefile is included as an appendix to this report, and is depicted on the topographic workmap and annotated FIRM.

3.2.2 Community Encroachment Area Floodway

The community encroachment area (CEA) floodway is an additional floodway that is adopted and regulated at the local level. This floodway is modeled using a **0.1-foot maximum surcharge** in conjunction with a **"modified" 1-percent annual chance discharge**. According to the guidance document, "this 'modified' discharge accounts for loss of floodplain storage associated with potential fill to the FEMA encroachments". Calculating the "modified" 1-percent discharge requires that the storage capacity of the floodway fringe be removed from the storage-discharge relationships used in the hydrologic model. Once this storage has been removed, the 1-percent discharge is to be recalculated, and this newly calculated 1-percent discharge is the "modified" 1-percent discharge.

Using this "modified" 1-percent discharge in plan **.p06**, the initial CEA floodway encroachment stations were calculated. Revisions were made as necessary to ensure that the surcharges were within the allowable tolerance, and adjustments were made where possible to eliminate abrupt changes in CEA width between adjacent cross-sections.

The final CEA floodway boundary polygon shapefile is included as an appendix to this report, and is depicted on the topographic workmap and annotated FIRM.

4.0 Overall Results and Conclusions

By utilizing all relevant and available precipitation data in the hydrologic calibration process, and applying a segmented precipitation approach, significant increases are observed in the calculated discharges and water surface elevations for the Little Hope Creek watershed in comparison to those in the effective PMR1 analysis. These results yield more extensive special flood hazard areas, causing locations and properties that were outside of the delineated extents of the floodplains in the PMR1 analysis to be shown as inundated by flooding from the 1-percent event in this restudy.

A vast network of precipitation and discharge gages exist in the vicinty of the Little Hope Creek watershed, and throughout much of Mecklenburg County. This allows for hydraulic / hydrologic models to be calibrated using site-specific, real-world data collected during observed storm events, resulting in models that better represent conditions as they exist on the ground for that stream / watershed.

Appendix A

Watershed Investigation Hydrologic Analysis

2.0 Hydrologic Analysis

The parameters and assumptions used in the PMR1 LSBC hydrologic analysis were first evaluated to ensure their accuracy and appropriateness. Revisions were made to any parameters that, upon review, were deemed to be sufficiently inaccurate as to have an appreciable negative impact on the end results of the analysis. Once the model input parameters were verified and finalized, the model was reverted to its pre-calibration state before ultimately being recalibrated using observed data collected during real-world storm events.

2.1 Parameter Evaluation / Verification

In accordance with the Little Hope Creek watershed restudy scope, a detailed review of the hydrologic model parameter calculations and assumptions was performed. This included an in-depth analysis of sub-basin boundary delineations, curve number calculations, times of concentration flow paths / calculations, and routing methods / calculations. A summary of the findings regarding each parameter listed previously can be found below.

2.1.2 Sub-basin Boundary Delineations

Sub-basin boundaries were found to be generally consistent with the topography and existing stormwater infrastructure, as illustrated by the county's stormwater inventory shapefile. Section 2.1.1 of the PMR1 LSBC hydrology report states that 60 acres was the target sub-basin size for this study (as was stipulated in the *Floodplain Analysis and Mapping Standards Guidance Document,* dated July 2008), with a tolerance of +/-20%. However, examination of the sub-basin dimensions reveals that the majority of the basins in the Little Hope Creek watershed are outside of the stated target basin size and tolerance. Of the 23 sub-basins that comprise the area in question, 12 sub-basins have areas that are greater than 72-acres (the upper threshold of the stated area tolerance), while 5 are below 48-acres (the lower threshold of the stated area tolerance).

Additionally, sub-basin "**LLS_130**", which is the sub-basin that coincides with the location of **USGS gage# 02146470**, is not broken at the gage location. When a gage is present, the sub-basin break point is typically placed as close as possible to that gage in order to ensure that drainage area and discharge comparisons can be made in the most direct manner possible. The sub-basin break point location plays a role in the calibration procedures and results, which will be discussed in detail in later sections of this report. Since revisions to the sub-basin delineation are beyond the scope of this restudy, the sub-basin boundaries were kept constant.

2.1.3 Curve Numbers

Composite curve number (CN) calculations were based on the Curve Number – Landuse – Soil Group look-up table provided by the county, dated December 2008. The CN look-up table is used to relate areas of specific landuse classification and soil type with a CN value, which represents the imperviousness of the ground cover in a specific area in the USDA's TR-55 methodology. According to section 2.1.3 of the LSBC hydrology report:

"*…the land use, soils, and the subbasins were spatially intersected in GIS to obtain polygons representing every unique combination of land use and soils within each subbasin. The CNs were assigned to each polygon using the CN lookup tables described in the paragraph above. Finally, a composite CN was calculated for each subbasin by computing the area-weighted average of the individual CN polygons within the subbasin.*"

While the sub-basin and landuse shapefiles for the Little Hope Creek watershed were available during this investigation, the actual soil shapefile used in the commission of the LSBC watershed study was not readily available, nor was the resulting spatial intersection that was used to derive the composite CN value for each sub-basin. Thus, it was necessary to attempt to recreate the steps used to generate the original composite CN shapefile in order to check the CN values used in the hydrologic modeling. This was accomplished using the sub-basin and landuse shapefiles contained in the LSBC submittal, along with a soil shapefile for the area of interest obtained electronically from the US Department of Agriculture. Once all relevant shapefiles were acquired, a spatial intersection was performed, and composite CN values were calculated in a manner consistent with that described in the hydrology report. The results of this reproduction, are tabulated in Table 1 below:

CN Comparison – Recalculated vs LSBC PMR1 Reported				
Basin_ID	**DA_SQMI**	**Recalculated CN**	**LSBC PMR1 CN**	**Difference**
LLS_199	0.072188504	82.90	82.92	0.02
LLS_104	0.081622331	77.43	77.86	0.43
LLS_103	0.13548482	85.30	85.62	0.32
LLS_242	0.242054781	76.27	76.58	0.30
LLS_360	0.186839991	77.01	80.52	3.51
LLS_366	0.212117625	86.93	88.47	1.54
LLS_200	0.177919106	74.04	75.49	1.45
LLS_367	0.254229081	75.40	76.09	0.69
LLS_201	0.091970845	89.63	89.65	0.02
LLS_241	0.208932363	76.84	77.16	0.32
LLS_119	0.206981032	77.41	83.26	5.84
LLS_202	0.096264492	89.68	89.68	0.00
LLS_203	0.065767763	80.40	80.44	0.03
LLS_368	0.145044192	74.83	74.85	0.01
LLS_120	0.064530246	74.48	74.63	0.14
LLS_240	0.09860322	75.30	75.82	0.52
LLS_123	0.117183913	82.80	84.19	1.39
LLS_124	0.122388659	76.65	77.18	0.53
LLS_130	0.073117539	80.38	81.41	1.03
LLS_402	0.203889	74.99	74.99	0.00
LLS_129	0.111911	67.15	67.22	0.07
LLS_371	0.070779	65.18	65.51	0.33
LLS_135	0.105989	69.10	69.08	-0.01

Table 1 – Curve Number Comparison

Comparison of the CNs generated in the commission of the PMR1 LSBC study with those computed during this restudy revealed overall agreement. While the original CN values are generally slightly higher than those generated in this investigation, the differences observed (when differences existed) were minor. Thus, the PMR1 LSBC CN values are considered **valid**, and no changes were made to the CN values used in the revised hydrologic analysis for the existing and future conditions.

2.1.4 Time of Concentration / Lag Time

For the LSBC watershed study, the time of concentration (**TC**) for each sub-basin was calculated using the TR-55 methodology. According to the hydrology report, the longest flow path for each sub-basin was determined with respect to sub-basin topography and relevant stormwater infrastructure. This flow path was then divided based on criteria specified in TR-55, and the incremental travel time is calculated for each segment. These incremental times were then summed in order to determine the total TC for a given sub-basin.

The TC flow path shapefile generated in the commission of the PMR1 LSBC watershed study was available during the course of this investigation. Additionally, the incremental travel time calculations for each segment / flow regime in each sub-basin, as well as a summation of each basin's incremental times, was included in a spreadsheet attached to the original hydrology report. Thus, the TC input parameters and calculations could be checked directly without the need to attempt to recreate them. Reviewing the TC calculations for select sub-basins within the Little Hope Creek watershed revealed no significant errors in methodology, and the calculation results appeared to be reasonable and consistent with the input parameters used in the computations. Thus, TC inputs used in the PMR1 LSBC hydrologic analysis were considered as **valid**, and no changes to the TC inputs were made for this restudy.

2.1.5 Routing

Reach routing through / between sub-basins in the PMR1 LSBC study was done using a combination of Modified Puls and Muskinham-Cunge methodologies. For studied streams where the modified puls method was used, storage-discharge relationships were determined from the output of the hydraulic model for that particular stream. Muskingham-Cunge was used for all reaches where no detailed hydraulic analysis was being performed. Input parameters for the Muskingham-Cunge calculations were taken from the stormwater inventory where possible, or from the terrain data and aerial imagery. In the Little Hope Creek watershed, only three (3) of the 15 routing reaches do not have a detailed hydraulic model, and thus use the Muskingham-Cunge routing method. Reservoir routing was also included where applicable in the PMR1 LSBC analysis. However, no ponds / reservoirs are present in the Little Hope Creek watershed.

In order to verify the storage-discharge relationships used in the modified puls routing reaches, output was exported from the finalized hydraulic models for Little Hope Creek and Little Hope Creek Tributary. This output was used to calculate storage volumes in the modeled reaches within the watershed, and these volumes were paired with the corresponding event discharges to create new storage-discharge curves for each sub-basin. Comparison of these storage-discharge curves with those that were present in the PMR1 LSBC hydrologic model revealed that a number of the storage-discharge curves appear to over-predict the amount of storage available in the floodplain, while others appear to under-predict the available storage. An example of this variance can be seen in the storage – discharge graph for routing reach "**R_LLS_130**" below:

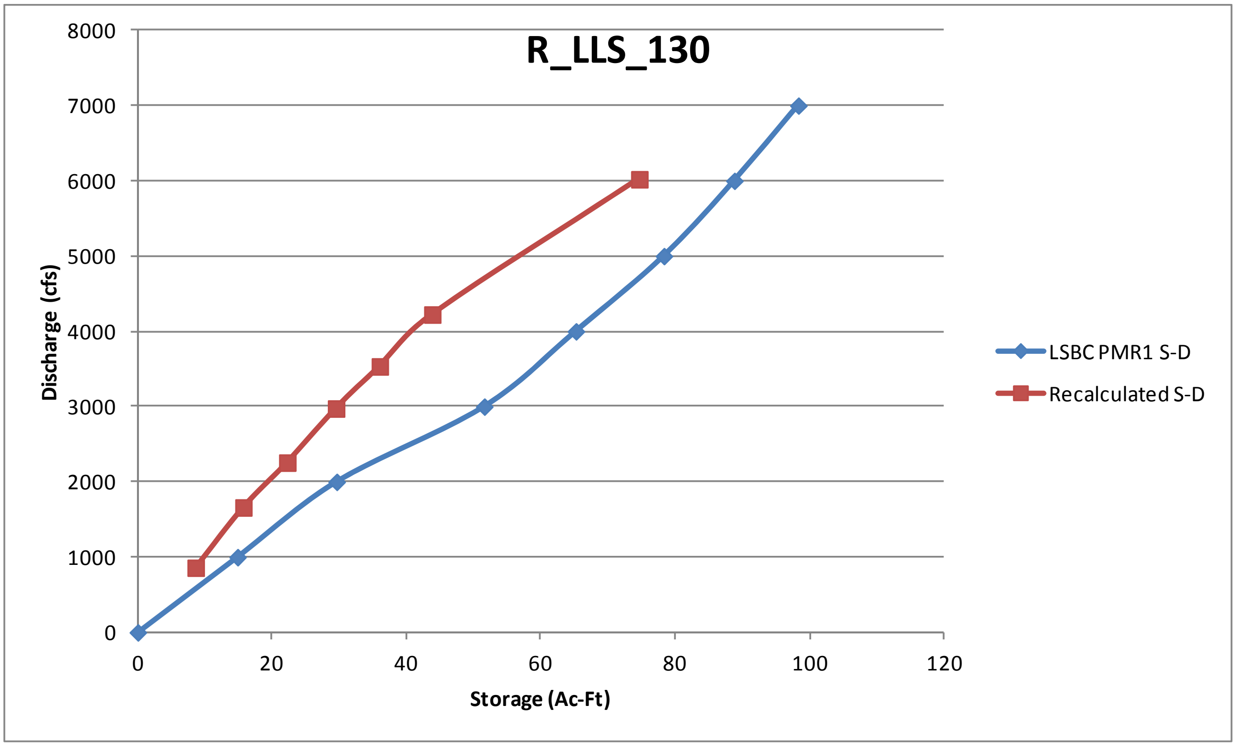


Figure1 – Routing Reach "R_LLS_130" Storage Discharge Curve

Additionally, all modified puls routing reaches in the Little Hope Creek watershed used "1" sub-reach, which is not consistent with the output of the hydraulic models. The number of sub-reaches used in the modified puls routing method affect the amount of flow that is attenuated in each routing reach, with "1" sub-reach yielding the maximum attenuation and an increasing number of sub-reaches approaching zero attenuation. For each routing reach, the number of sub-reaches should be chosen to ensure that the travel time through a sub-reach is approximately equal to the simulation time step (1 minute in this case). This can be approximated for each routing reach using the following equation:

# of sub-reaches = RL / c / TS

where, ***RL*** ***= routing reach length [feet]***
c ***= flood wave celerity [feet / second]***
TS ***= time step [seconds]***

Calculating the number of sub-reaches for each modified puls routing reach using the formula above gives:

Routing Reach ID	Sub-reaches
R_LLS_203	2
R_LLS_368	6
R_LLS_240	5
R_LLS_120	5
R_LLS_124	9
R_LLS_104	3

Routing Reach ID	Sub-reaches
R_LLS_242	8
R_LLS_360	7
R_LLS_200	7
R_LLS_241	11
R_LLS_123	17
R_LLS_130	7
R_LLS_371	8
R_LLS_135	1

Table 2 – Modified Puls Sub-Reach Values

As described previously, increasing the number of sub-reaches for all modified puls routing reaches in the hydrologic model will cause less flow to be attenuated in each routing reach, causing an appreciable increase in the resulting peak discharge values. Thus, the storage – discharge relationships and sub-reach values used in the PMR1 LSBC model were considered to be **invalid**, and the recalculated parameter values were used in the **revised** analysis.

2.2 Reversion of Model to Pre-Calibration State

As previously stated, this restudy follows an investigation that was conducted by AECOM, whose purpose was to determine why the base flood elevations and discharges calculated for this watershed in the PMR1 LSBC analysis have significantly decreased in comparison to those that were published in the 2009 effective analysis. In response to the findings of the aforementioned investigation, which identified inaccuracies in the calibration process as the source of the decreases, this restudy reverted the PMR1 LSBC hydrologic model to its pre-calibration state in order to have a fresh starting point from which to determine new calibration measures. Once the various input parameters used in the PMR1 LSBC hydrologic analysis were reviewed and evaluated, a new hydrologic model was made that removed the calibration measures that were applied in the PMR1 LSBC analysis.

This section describes the process used to restore the model to its “pre-calibration” state.

2.2.1 Verification of Results Using HEC-HMS Version 3.5

The PMR1 LSBC watershed hydrologic analysis was conducted using HEC-HMS version 3.4, as this version was the most up-to-date version of the model that was available when the study was initiated. However, in the time since PMR1 was initiated, an updated version of HEC-HMS (version 3.5) has been released. Therefore, the newest version of HEC-HMS will be used for this restudy.

In order to ensure that valid comparisons can be made between the discharge values yielded by the PMR1 LSBC analysis and those yielded in this restudy, the final basin file from the PMR1 LSBC hydrologic model was imported into version 3.5. The 1-percent event simulation was conducted using the imported basin file, and the version 3.5 results were compared to those yielded in the PMR1 study. Comparison of these results showed that the discharges computed using version 3.5 were identical to those reported in the PMR1 LSBC watershed analysis at all locations. This verifies that all differences that are observed between the results of this restudy and the PMR1 LSBC analysis results can be directly attributed to changes in the input parameters or other elements of the restudied analysis.

The final basin file from the PMR1 LSBC HEC-HMS model is included in the Little Hope Creek watershed restudy model, and is named “**1_LSugar&Briar_Existing**”.

2.2.2 Duplicate PMR1 Little Hope Creek Watershed Basin Model

Upon verification of the results yielded by HEC-HMS version 3.5, a subset of the complete LSBC watershed model containing the model elements that represent the Little Hope Creek watershed was exported to a new basin model. This basin model, named "**2_LHC_WS_Dup_PMR1**", serves as a baseline for evaluating the changes that are yielded by the revisions that arise through this restudy.

Since the elements and assumptions used in this basin model were taken directly from the PMR1 LSBC watershed model, and are identical to them in every way, conducting the 1-percent event simulation with this basin file yields results that are identical to those calculated by the PMR1 LSBC model. This is illustrated for select locations / model elements in the table below:

Stream Name	Element Name	Drainage Area (Sq Mi)	Location Description	LSBC PMR1 HEC-HMS Version 3.4* Q1%	"1_Lsugar&Briar_Ex" Q1%	"Duplicate PMR1" Q1%
Little Hope Creek Trib	J_LLS_120	1.24	Immediately US of Bradbury Dr	1753.1	1753.1	1753.1
	R_LLS_124	1.24	Furthest DS model element on LHCT	1683.2	1683.2	1683.2
Little Hope Creek	J_LLS_241	1.11	At Woodlawn Road	1193.3	1193.3	1193.3
	J_LLS_123	2.58	Immediately US of confluence with LHCT	3001	3001	3001
	J_LLS_130	2.97	Approximately 1300 feet DS of Seneca Pl	3170.5	3170.5	3170.5
	R_LLS_135	3.04	Furthest DS model element on LHC	3136.7	3136.7	3136.7

**Final values calculated using the final version of the PMR1 LSBC hydrologic model and published in the PMR1 LSBC hydrologic report*

Table 3 – Published vs. Baseline Basin Model Discharge Comparison

All subsequent basin models are derived directly from this one, and revised as necessary for this restudy.

2.2.3 "Pre-Calibration" PMR1 Little Hope Creek Watershed Basin Model

Basin model "**3_LHC_WS_PMR1_UnCal**" represents the PMR1 LSBC model with the calibration measures removed. According to the text of the PMR1 LSBC hydrology report:

"*Based on results from six (6) iterations performed during previous steps, it was decided that lag time should be further increased to 1.8*Tc while using reasonable initial abstraction values to achieve a better match with Aug 2008 event. … The model with these revisions (lag time = 1.8*Tc and initial abstraction = 0.7 inch) resulted in peak discharges and volumes which were a closer match to the Aug 2008 event.*"

Thus, in order to return the model to its "pre-calibration" state, the adjustments that were made during the calibration process must be removed. Specifically, since the TCs were universally adjusted using a **1.8 multiplier**, TCs contained in the final model must be replaced with the original values that were evaluated and verified (described in section 2.1.4 above). Also, due to the fact that the initial abstraction (**I_A**) was set to **0.7 inches** for all sub-basins, new I_A values must be computed. The initial abstraction values were recalculated using a combination of equations 2-2 and 2-4 from TR-55:

$$I_A = 0.2 * ((^{1000}/_{CN})-10)$$

The "pre-calibration" TCs and the recalculated initial abstraction values, which would eventually be modified in the calibration process of this restudy, are listed in the table below:

Sub-basin ID	Curve Number	Initial Abstration (in)	Tc (Hours)	Tc (Minutes)	Lag Time (Minutes)
W_LLS_366	88.47	0.26	0.39	23.43	14.06
W_LLS_367	76.09	0.63	0.42	25.42	15.25
W_LLS_119	83.26	0.40	0.40	23.73	14.24
W_LLS_201	89.65	0.23	0.43	26.00	15.60
W_LLS_202	89.68	0.23	0.51	30.51	18.30
W_LLS_203	80.44	0.49	0.34	20.12	12.07
W_LLS_368	74.85	0.67	0.33	19.97	11.98
W_LLS_240	75.82	0.64	0.16	9.61	5.77
W_LLS_120	74.63	0.68	0.72	43.23	25.94
W_LLS_124	77.18	0.59	0.61	36.88	22.13
W_LLS_199	82.92	0.41	0.56	33.84	20.30
W_LLS_104	77.86	0.57	0.84	50.24	30.14
W_LLS_103	85.62	0.34	0.60	36.28	21.77
W_LLS_242	76.58	0.61	0.43	26.00	15.60
W_LLS_360	80.52	0.48	0.30	17.88	10.73
W_LLS_200	75.49	0.65	0.33	20.01	12.01
W_LLS_241	77.16	0.59	0.46	27.68	16.61
W_LLS_123	84.19	0.38	0.21	12.69	7.61
W_LLS_130	81.41	0.46	0.27	16.37	9.82
W_LLS_402	74.99	0.67	0.54	32.42	19.45
W_LLS_129	67.22	0.98	0.53	31.68	19.01
W_LLS_371	65.51	1.05	0.18	10.56	6.34
W_LLS_135	69.08	0.90	0.84	50.24	30.14

Table 4 – "Pre-Calibration" CN / IA values and Lag Times

Using the "pre-calibration" initial abstraction and lag time parameter values in the PMR1 LSBC model yields discharges that are considerably greater than the final discharges that result from the calibrated PMR1 LSBC analysis. A comparison of the "pre-calibration" and 1-percent event discharges at key locations can be found in the table below:

Stream Name	Element Name	Drainage Area (Sq Mi)	Location Description	"Duplicate PMR1" Q1%	"PMR1 Pre-Calibration" Q1%	% Difference
Little Hope Creek Trib	J_LLS_120	1.24	Immediately US of Bradbury Dr	1753.1	3175.8	81.2%
	R_LLS_124	1.24	Furthest DS model element on LHCT	1683.2	2748.6	63.3%
Little Hope Creek	J_LLS_241	1.11	At Woodlawn Road	1193.3	1816.7	52.2%
	J_LLS_123	2.58	Immediately US of confluence with LHCT	3001	4647.4	54.9%
	J_LLS_130	2.97	Approximately 1300 feet DS of Seneca Pl	3170.5	4670.9	47.3%
	R_LLS_135	3.04	Furthest DS model element on LHC	3136.7	4450.8	41.9%

Table 5 – Baseline vs. "Pre-Calibration" Basin Model Discharge Comparison

As the table above illustrates, the "pre-calibrated" discharges range from 42% to 81% greater than the final discharges computed for this watershed in the PMR1 LSBC analysis. The global calibration measures that were implemented in the PMR1 analysis drastically reduced the 1-percent event discharge. The reasons for this will be illustrated in detail in later sections of the report

2.2.4 Revised "Pre-Calibration" Basin Model

Following the creation of the "pre-calibration" basin model, basin model "**4_LHC_WS_Revised_UnCal**" was added to the restudy HMS model. This basin model incorporates changes to the baseflow method, storage-discharge relationships (described in section 2.1.5 above), and to the connectivity of the model elements at confluences. Otherwise, this basin model is the same as the "pre-calibration" effective basin model discussed in section 2.2.3 above.

The PMR1 LSBC watershed hydrologic model did not include base flow in any of the sub-basins. However, examination of the gage record from USGS gage **#02146470** at Seneca Place revealed the presence of a sustained, "fair weather" runoff of approximately **0.2cfs**. This was accounted for in the model by adding an assumed baseflow of **0.08cfs/mi^2** at all sub-basins in the Little Hope Creek watershed (*this was derived by calculating the ratio of the observed baseflow to the Little Hope Creek watershed drainage area of **2.65mi^2** at the gage location*).

Additionally, examination of the PMR1 LSBC model revealed a somewhat unusual connectivity of elements at confluences. Sub-basin and routing reach elements from tributaries and unmodeled contributing drainage areas are connected directly to the junction elements of the main-stem sub-basins that are located immediately upstream of the confluences. This is illustrated in Figure 1 below:

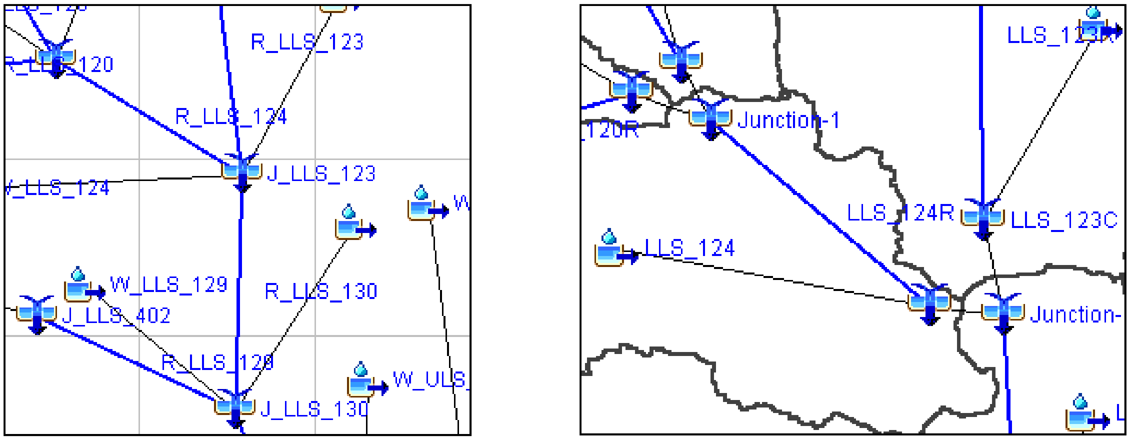


Figure 2 – HEC-HMS element configuration comparison

The figure on the left is an image of the schematic view from the PMR1 LSBC HEC-HMS model, focused specifically on the confluence of Little Hope Creek and Little Hope Creek Tributary. The figure on the right shows the revised junction connectivity used in the revised "pre-calibration" basin model. The PMR1 LSBC model connects the routing reach and sub-basin elements for "**LLS_124**" (the sub-basin at the downstream end of Little Hope Creek Tributary) directly to the junction of "**LLS_123**" (the sub-basin on Little Hope Creek that is immediately upstream of the confluence).

The implication of this element configuration is that Little Hope Creek Tributary drains into "**LLS_123**", rather than into the routing reach of "**LLS_130**". This causes an artificially inflated peak discharge to be reported at sub-basin "**LLS_123**", and an artificially depressed peak discharge to be reported at the outlet of Little Hope Creek Tributary ("**LLS_124**"). For Little Hope Creek Tributary, the discharge that is reported at the downstream end in the PMR1 LSBC analysis is from routing reach element "**R_LLS_124**", which neglects the runoff from tributary sub-basin "**LLS_124**" (whose drainage area accounts for 10% of the Little Hope Creek Tributary drainage area). The effect of these revisions is shown in the table below:

Stream Name	Element Name	Drainage Area (Sq Mi)	Location Description	"PMR1 Pre-Calibration" Q1%	"Revised Pre-Calibration" Q1%	% Difference
Little Hope Creek Trib	J_LLS_120	0.56*	Immediately US of Bradbury Dr	3175.8	1235.8	-61.1%
	J_LLS_124*	1.36*	Furthest DS model element on LHCT	2748.6	3058.0	11.3%
Little Hope Creek	J_LLS_241	1.11	At Woodlawn Road	1816.7	1813.7	-0.2%
	J_LLS_123	1.22*	Immediately US of confluence w/ Trib	4647.4	1691.4	-63.6%
	J_LLS_130	2.65*	Approximately 1300 feet DS of Seneca Pl	4670.9	4239.0	-9.2%
	J_LLS_135*	3.15*	Furthest DS model element on LHC	4450.8	4606.7	3.5%

**Revised Element names and drainage areas reflect corrections to the model element connectivity*

Table 6 – "Pre-Calibration" vs. Revised "Pre-Calibration" Basin Model Discharge Comparison

As the above table illustrates, revising the model element connectivity to properly show the sub-basin relationships at confluences causes the reported drainage areas to decrease at a number of the highlighted locations. This is accompanied by corresponding decreases in the reported discharges at these locations, due to the changes in the modeled hydrograph combination locations. However, discharges calculated at the elements immediately downstream of the revised confluences are similar to those in the “pre-calibration” effective model.

Most significantly, corrections made to the sub-basin connectivity at confluences cause the “pre-calibration” discharges (and drainage areas) to increase at the outfall locations of both Little Hope Creek and Little Hope Creek Tributary. This occurs due to the inclusion of the areas that were not properly connected when using the original element connectivity.

2.2.5 Results and Conclusions

As shown previously, discharges computed for the Little Hope Creek watershed increase significantly when the effects of the model calibration are reversed. This is to be expected, as the calibration measures used in the PMR1 LSBC study were intended to cause reductions to the peak flow.

Along with the restoration of the model parameters to their “pre-calibrated” state, additional revisions for this restudy include incorporates changes to the **baseflow method**, **storage-discharge relationships**, and to the **connectivity of the model elements at confluences**.

In accordance with the scope of this restudy, a hydraulic analysis was conducted using the revised “pre-calibration” conditions discharges from the 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent-annual-chance event simulations. Water surface elevations computed using the “pre-calibration” 1-percent discharges show significant increases in comparison to those published in the final PMR1 LSBC analysis. This will be discussed in greater detail in section 3.1. Calibration measures and results are discussed below.

2.3 Revised Model Calibration

In an effort to ensure agreement between the revised “pre-calibration” model and real-world data collected at several USGS gage locations throughout the study area, observed precipitation and stream flow data recorded during historical storm events were used to identify adjustments that could / should be made to the input parameters and assumptions of the hydrologic modeling. Of the events used in the calibration process of the PMR1 LSBC study, the August 27, 2008 storm event produced the largest total precipitation in the Little Hope Creek watershed.

The August 2008 event simulation from the PMR1 LSBC hydrologic analysis did not use 10 of the 16 applicable precipitation gages in and adjacent to the LSBC watershed. Among the excluded gages was ***CRN-60***, which is located within the Little Hope Creek watershed. Examination of the precipitation record shows that this ultimately resulted in greater precipitation totals being used in the PMR1 LSBC event simulation than were actually observed, particularly in the Little Hope Creek watershed. As a result, the final calibrated model used lag times that were three times greater than the “pre-calibration” values and initial abstraction values that were set at a constant value of 0.7 inches, all in an effort to bring the simulated discharge values into agreement with those that were observed.

For this restudy, the Little Hope Creek watershed hydrologic analysis will be re-calibrated using the August 2008 event, but also using 2 additional storms that had not occurred at the time of the PMR1 LSBC analysis. The calibration process for this restudy will be discussed in the following sections.

2.3.1 Methodology

Analysis of the discharge record for USGS gage# ***02146470*** shows the presence of a number of high flow events that can be used in the calibration process for this restudy. This can be seen in the figure below:

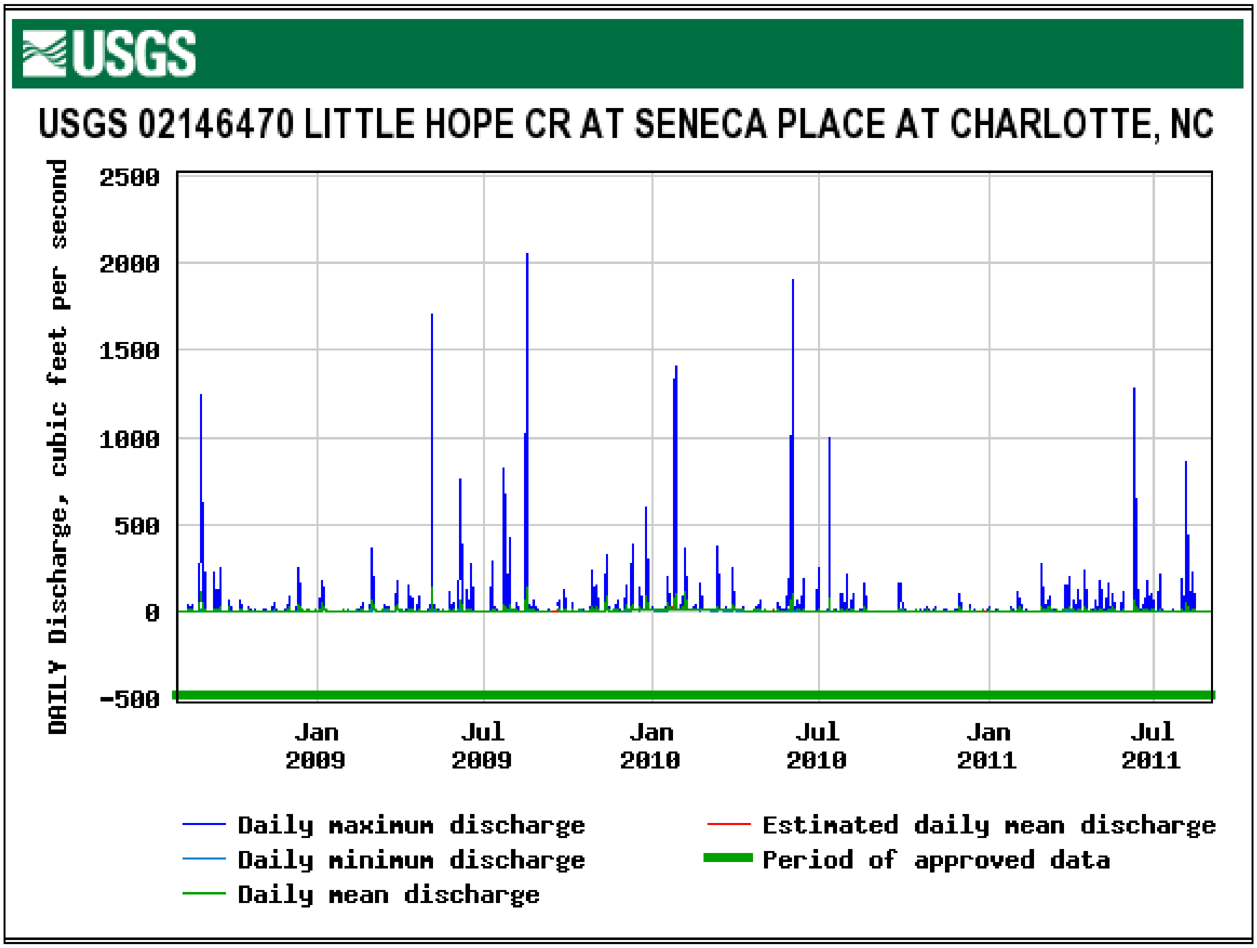


Figure 3 – USGS Gage# 02146470 Stream Flow Record, August 2008 – September 2011 (*http://waterdata.usgs.gov/nwis/rt*)

After careful examination of the gage record, the storm events chosen for the calibration effort in this restudy were those that occurred on **August 27, 2008**, **August 16, 2009**, and **August 5, 2011**.

- The August 2008 event was chosen due to the fact that it is the event that was used in the calibration process of the PMR1 LSBC study. This will enable a direct comparison between the calibration efforts of the PMR1 LSBC study and those conducted for this restudy.

- The August 2009 event yielded the largest discharge of any event for which sufficient precipitation and stream flow data exists. For the Little Hope Creek watershed, only three discharges have ever been recorded that were larger than that observed during this event, and these occurred during storm events in or before 2006. However, no detailed rainfall data is available for these events. Since the August 2009 event is the largest event recorded in this watershed for which ample data is available, this event was selected for the calibration effort.

- The August 2011 event was chosen due to the moderate size of its peak discharge (less than the August 2008 event). Additionally, this event has a single peak hydrograph that closely resembles the shape of a "typical" hydrograph, making it an ideal event to calibrate to. This differs from that of the August 2008 event, whose hydrograph has multiple peaks.

The "**gage weights**" precipitation method was used to distribute the observed rainfall in each of the event simulations. This precipitation method assigns weights at every sub-basin to each of the precipitation gages used in the event simulation, with weight values varying according to the gages' proximity to the sub-basin in question. Proximity and weight values were determined by first generating Thiessen Polygons for the rain gages in the area surrounding the Little Hope Creek watershed. These polygons were then intersected with the Little Hope Creek watershed sub-basins to determine the areal percentage of each sub-basin that coincided with the polygon for each rain gage. If a particular sub-basin fell entirely within a single Thiessen polygon, then the corresponding rain gage was weighted 100% in that particular sub-basin. In the event that a sub-basin is overlapped by multiple Thiessen polygons, a weight value proportionate to the percentage of the sub-basin's total area in each polygon was assigned to each gage.

For the August 2008 and 2009 events, basins "**LLS_200**", "**LLS_241**", "**LLS_123**", "**LLS_124**", "**LLS_402**", "**LLS_129**", "**LLS_135**", and "**LLS_371**" were overlapped with the Thiessen polygons for multiple rain gages. Basin "**LLS_130**" fell entirely within the polygon for rain gage "**CRN-71**" (which was not used in the PMR1 LSBC watershed model). All other sub-basins fell entirely within the polygon for rain gage "**CRN-60**" (which was also not used in the PMR1 LSBC study). The locations of the rain gages relative to the Little Hope Creek watershed sub-basins are illustrated in Figure 4 below:

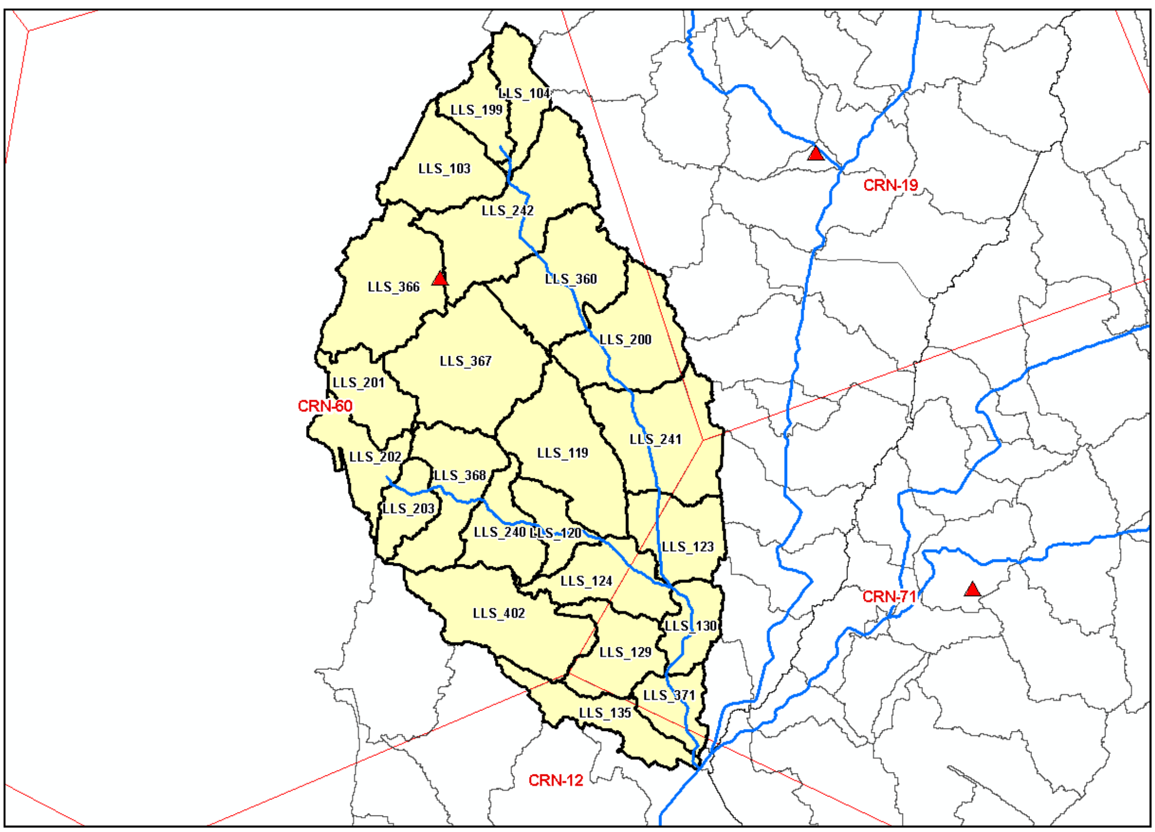


Figure 4 – Rain gage and Thiessen Polygon Locations – August 2008 and 2009 Event Simulations

Beginning in October 2009, detailed rainfall records from precipitation gage **CRN-13** became available for use. Data from this gage was therefore used in the August 2011 event simulation, even though it was not available for the 2008 and 2009 event simulations. With the addition of this new gage, a new set of Thiessen polygons needed to be generated in order to weight the precipitation for this event, as this added gage represented a change to the precipitation gage network. For the August 2011 event, basins "**LLS_199**", "**LLS_104**", "**LLS_103**", "**LLS_242**", "**LLS_360**", "**LLS_119**", "**LLS_367**", and "**LLS_366**" were entirely within the polygon for rain gage "**CRN-60**"**.** Basin "**LLS_402**" fell entirely within the polygon for gage "**CRN-13**", while "**LLS_130**" fell entirely within the polygon for rain gage "**CRN-71**". All other sub-basins were overlapped with the Thiessen polygons for multiple rain gages. The locations of the rain gages used in the August 2011 event simulation relative to the Little Hope Creek watershed sub-basins are illustrated in Figure 5 below:

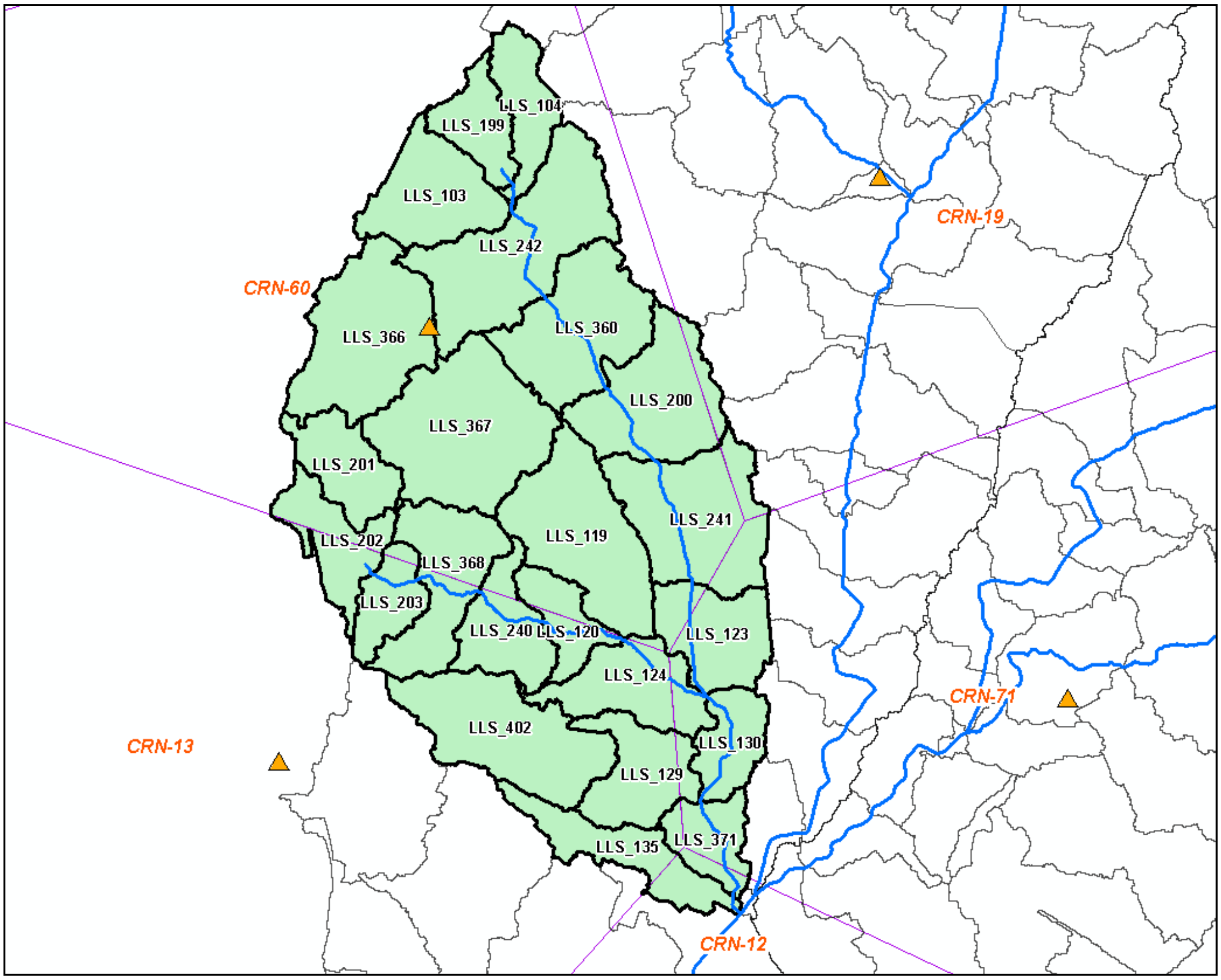


Figure 5 – Rain gage and Thiessen Polygon Locations – August 2011 Event Simulation

Using the methods described above yielded the gage weights shown in Table 7 below:

	August 2008 / 2009 Gages				August 2011 Gages				
	CRN-12	CRN-19	CRN-60	CRN-71	CRN-12	CRN-13	CRN-19	CRN-60	CRN-71
LLS_199	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_104	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_103	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_242	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_360	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_366	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_200	0.0	11.8	88.2	0.0	0.0	0.0	11.8	88.2	0.0
LLS_367	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_201	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_241	0.0	11.1	72.0	16.9	0.0	0.0	11.1	72.0	16.9
LLS_119	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0
LLS_202	0.0	0.0	100.0	0.0	0.0	47.6	0.0	52.4	0.0
LLS_203	0.0	0.0	100.0	0.0	0.0	90.3	0.0	9.7	0.0
LLS_368	0.0	0.0	100.0	0.0	0.0	47.2	0.0	52.8	0.0
LLS_120	0.0	0.0	100.0	0.0	0.0	50.4	0.0	49.6	0.0
LLS_240	0.0	0.0	100.0	0.0	0.0	83.1	0.0	16.9	0.0
LLS_123	0.0	0.0	22.7	77.3	0.0	0.0	0.0	22.7	77.3
LLS_124	0.0	0.0	61.6	38.4	0.0	75.5	0.0	3.0	21.4
LLS_130	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
LLS_402	0.5	0.0	97.8	1.8	0.0	100.0	0.0	0.0	0.0
LLS_129	8.3	0.0	11.3	80.4	0.0	86.9	0.0	0.0	13.1
LLS_371	24.2	0.0	0.0	75.8	21.9	13.4	0.0	0.0	64.7
LLS_135	87.3	0.0	11.6	1.1	31.2	68.8	0.0	0.0	0.0

Table 7 – Precipitation Gage Weights, August 2008 / 2009 and 2011 Event Simulations

Precipitation data was entered into the model for each precipitation gage in units of 5 minute incremental inches. This information, entered as separate time windows for each storm event, was derived from the detailed precipitation data published by the USGS. Observed discharge data from USGS gage# **02146470** was entered into the model for each event in 15 minute instantaneous increments. This information, entered as separate time windows in a manner similar to that used for the precipitation data, was derived from data published by the USGS. Observed discharge data was used to evaluate the effectiveness of the various adjustments that were made in the calibration process.

In keeping with the hydrologic model calibration standards listed in the guidance document, the following model parameters were considered for adjustment in the calibration process:

- Curve Number (CN)
- Initial Abstraction (I_A)
- Lag Time

These parameters were adjusted within the allowable tolerances to bring the simulated discharges, total volumes, and peak times into agreement with those that were recorded during the observed events.

2.3.2 August 2008 Event Simulation and Model Calibration

Since the August 2008 event was used in the calibration efforts of the PMR1 LSBC study, this event was used as the starting point for the model calibration in this restudy. Using the revised "pre-calibration" model described in **section 2.2.4**, the August 2008 event simulation was executed in order to determine how closely the peak discharge and total runoff volume yielded by the "pre-calibration" model agreed with what was observed. The results of this simulation can be seen in Figure 6 and Table 8 below:

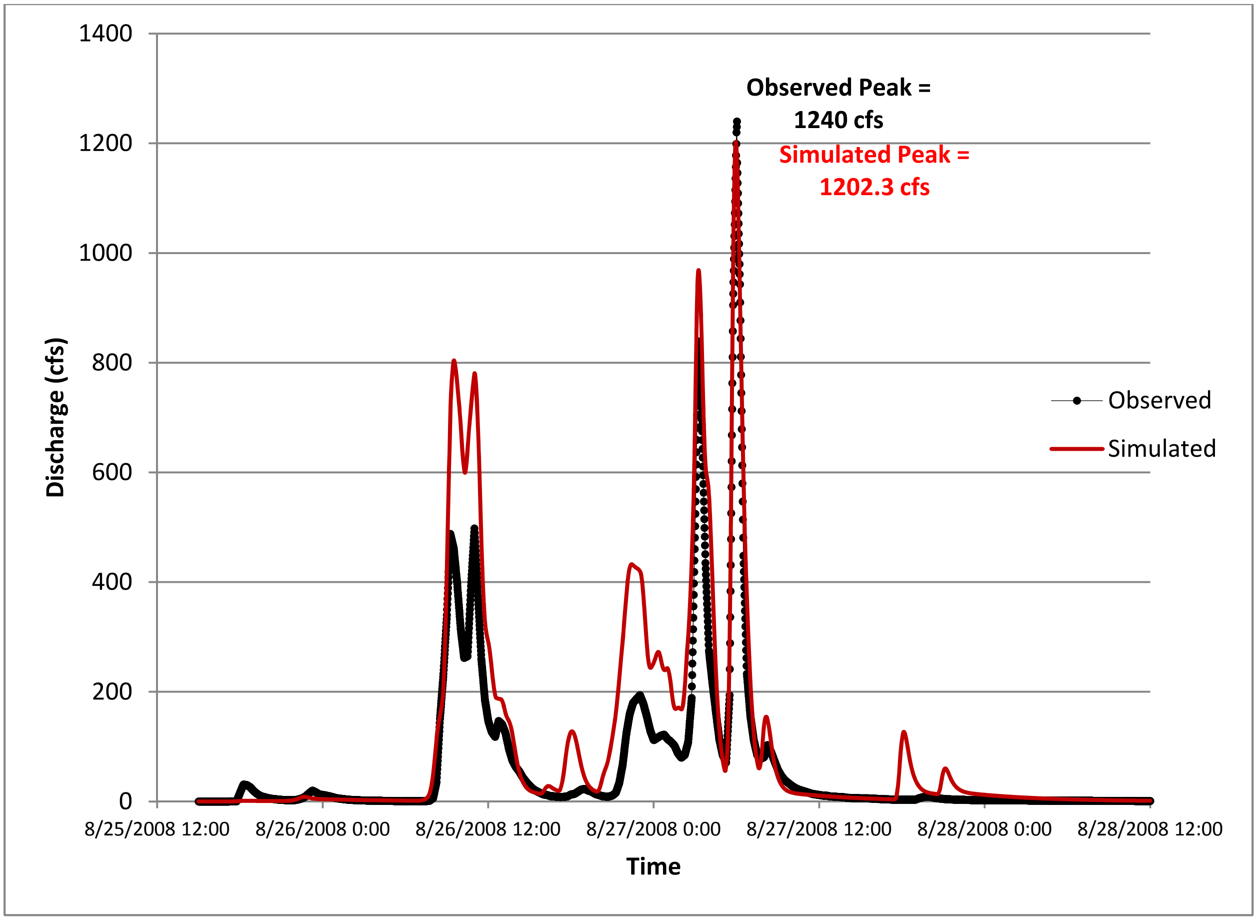


Figure 6 – Baseline Simulation vs Observed Outflow Hydrograph, August 2008 Event Simulation

Simulated			Observed			Peak Q %difference	Volume %difference
Peak Q (cfs)	Time of Peak	Volume (in)	Peak Q (cfs)	Time of Peak	Volume (in)		
1202.3	8/27/2008 5:58	4.39	1240	8/27/2008 6:02	2.73	-3%	61%

Table 8 – Baseline Simulation vs Observed Outflow Results, August 2008 Event Simulation

Examining the results of the August 2008 event baseline simulation shows that the revised raw / pre-calibration model produces a peak discharge of **1202.3 cfs**, which is within **3%** of the observed peak flow at this location. This is well within the target tolerance of 10% recommended in the guidance document. Also, the simulated peak time closely agrees with the time of the observed peak, occurring **4 minutes** ahead of the observed peak. While the volume is outside of the target tolerance, these values were achieved before any adjustments to the raw parameters / assumptions were made.

The first calibration iteration used a small universal CN increase (+1), along with a 25% increase in initial abstraction. These measures were chosen with the intent of simultaneously raising the peak flow, and reducing the magnitude of the localized swell in the hydrograph that occurs at approximately "8/26/2008 12:00" to reduce the total volume. Calibration adjustments were applied to basin model "**5_LHC_WS_Revised_Cal**". The results of this iteration showed that these very small adjustments only achieved extremely minor changes in the simulated values, yielding a marginal increase in the peak flow with a marginal reduction in total volume.

Subsequent iterations used incrementally larger initial abstraction factors while maintaining the universal CN increase. Incremental increases in the lag time were also included in an attempt to gain even closer agreement with the observed peak time. The final August 2008 event calibration run used a **75% increase in initial abstraction**, a **50% increase in lag time**, and a **1 unit increase in CN**. The results of applying these calibration factors can be seen in Figure 7 and Table 9 below:

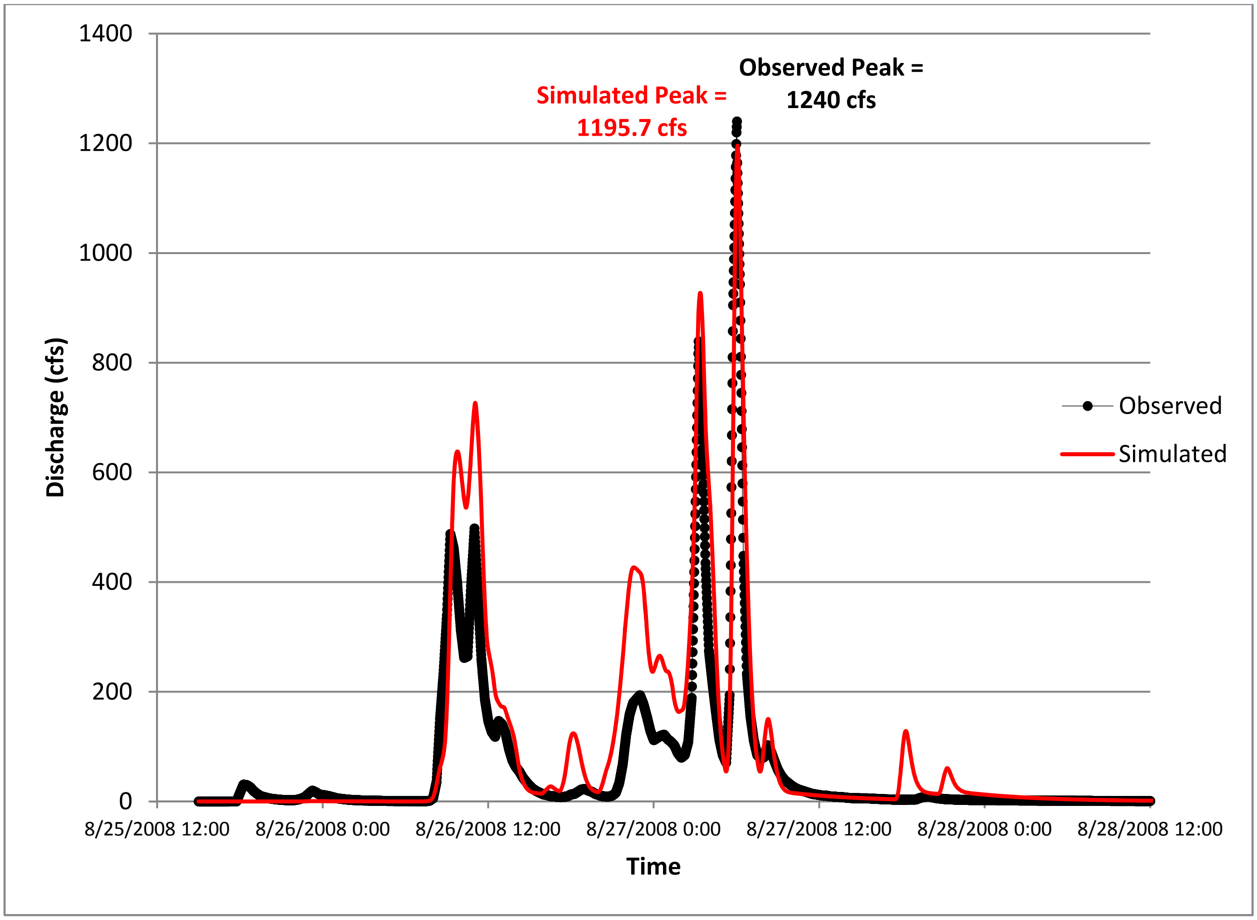


Figure 7 – Final Simulation vs Observed Outflow Hydrograph, August 2008 Event Simulation

Simulated			Observed			Peak Q %difference	Volume %difference
Peak Q (cfs)	Time of Peak	Volume (in)	Peak Q (cfs)	Time of Peak	Volume (in)		
1195.7	8/27/2008 6:05	4.10	1240	8/27/2008 6:02	2.73	-4%	50%

Table 9 – Final Simulation vs Observed Outflow Results, August 2008 Event Simulation

The calibration measures used in the final August 2008 event simulation resulted in close agreement between the simulated values and those that were observed. While the simulated peak discharge obtained in the final calibration run has marginally decreased relative to the baseline simulation discharge, the total residual volume and peak time have improved relative to the observed values.

Throughout the calibration runs, gaining close agreement between the total volume of the observed and simulated hydrographs proved to be extremely difficult. This was probably caused by the complex nature of the observed event hydrograph, which contains multiple distinct peaks. The hydrograph shape for this event reflects the elongated nature of the precipitation, which fell sporadically and in high intensity bursts over an approximately 36 hour long period. As a result, no extraordinary measures were taken to bring the simulated total volume into agreement with the observed total volume.

The August 2008 baseline and final calibration runs are summarized in Table 10 below:

	IA factor	CN factor	Lag factor	Peak Q (cfs)	Time of Peak	Volume (in)	%Diff Peak Q	Diff Time (min)	%Diff Total Volume
Observed	N/A	N/A	N/A	1240.0	8/27/2008 6:02	2.73	N/A	N/A	N/A
Baseline	1.00	Raw	1.00	1202.3	8/27/2008 5:58	4.39	-3%	-4	61%
Final	**1.75**	**Raw+1**	**1.50**	**1195.7**	**8/27/2008 6:05**	**4.10**	**-4%**	**+3**	**50%**

Table 10 –August 2008 Event Calibration Summary

Due to the non-uniform nature of the observed precipitation, this was a less than ideal event to use in calibration. Double peak / multiple peak storms with extended precipitation times are difficult to use in calibration primarily because of the model initial abstraction assumptions and calculations, which have a large effect on total hydrograph volume. However, this was the best storm event that was available at the time when the PMR1 LSBC analysis was conducted. In spite of this complexity, the baseline peak flow and peak time were well within the calibration tolerance prior to the application of any adjustments, showing the validity of the initial assumptions / parameters.

2.3.3 August 2011 Event Simulation and Model Calibration

The initial simulation of the August 2011 event was executed using the revised "calibrated" basin model, which included the calibration factors developed in the final August 2008 event calibration run. This yielded the following results, which can be seen in Figure 8 and Table 11 below:

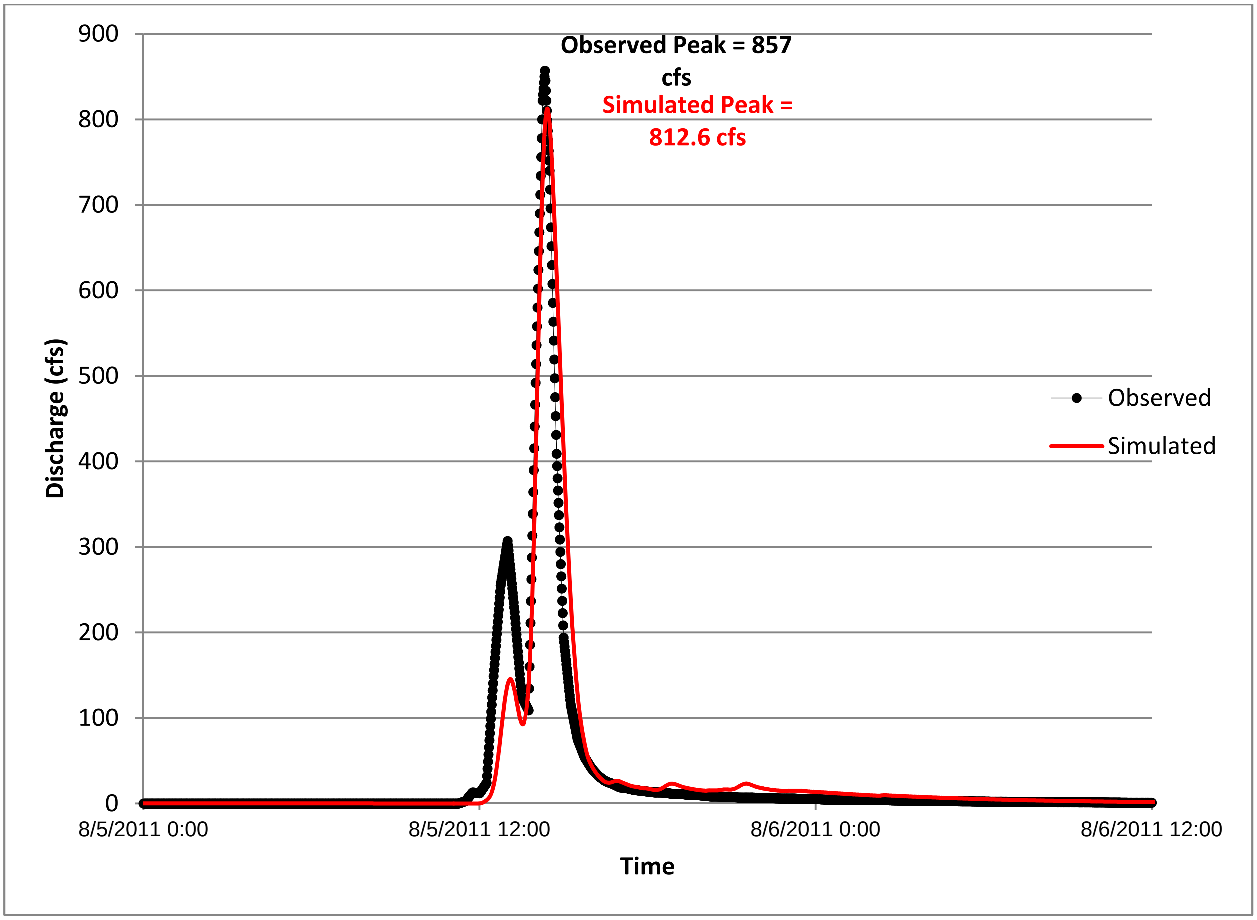


Figure 8 – Baseline Simulation vs Observed Outflow Hydrograph, August 2011 Event Simulation

Simulated			Observed			Peak Q %difference	Volume %difference
Peak Q (cfs)	Time of Peak	Volume (in)	Peak Q (cfs)	Time of Peak	Volume (in)		
812.6	8/5/2011 14:25	0.75	857	8/5/2011 14:20	0.70	-5%	7%

Table 11 – Baseline Simulation vs Observed Outflow Results, August 2011 Event Simulation

Using the final calibration measures from the August 2008 event, the baseline simulation for this event yields peak flow, peak time, and total volume values that agree closely with the observed values. The simulated peak flow value of **812.6cfs** is within **5%** of the observed value, with a simulated peak time that occurs within **5 minutes** of the observed time. Also, the simulated total hydrograph volume is within **7%** of the observed volume. While minor adjustments could potentially be made to gain even closer agreement between simulated and observed values, the degree of agreement between the baseline simulation results and the observed values indicate that **no further calibration measures are warranted** for this event (beyond those that were used in the final August 2008 event calibration run).

2.3.4 August 2009 Event Simulation and Model Calibration

The August 2009 event yielded the fourth largest discharge ever recorded in the Little Hope Creek watershed. The initial simulation of this event was made using the final calibration factors developed in the final August 2008 event calibration run (and maintained in the August 2011 event calibration). This yielded the results shown in Figure 9 and Table 12 below:

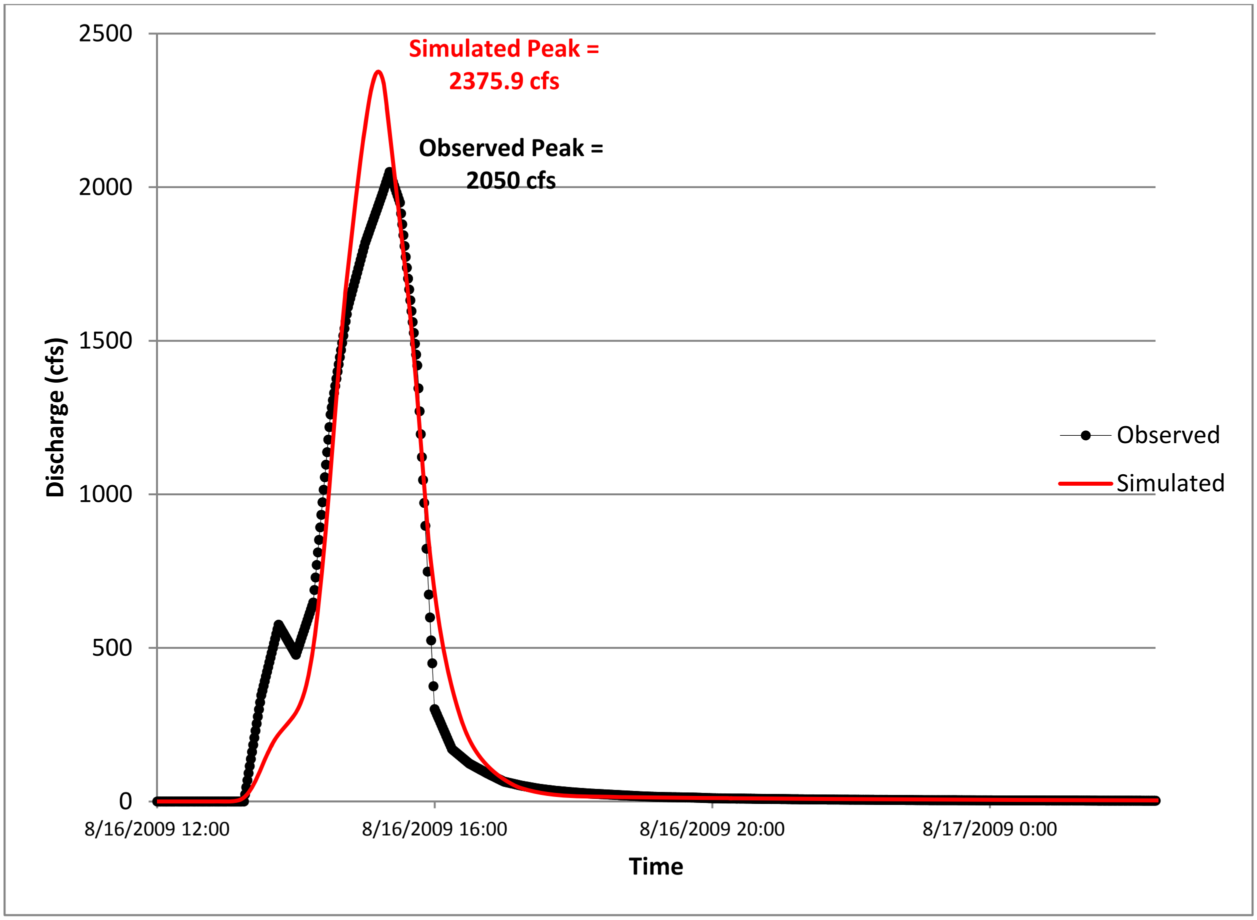


Figure 9 – Baseline Simulation vs Observed Outflow Hydrograph, August 2009 Event Simulation

Simulated			Observed			Peak Q %difference	Volume %difference
Peak Q (cfs)	Time of Peak	Volume (in)	Peak Q (cfs)	Time of Peak	Volume (in)		
2375.9	8/16/2009 15:11	2.04	2050	8/16/2009 15:21	2.02	16%	1%

Table 12 – Baseline Simulation vs Observed Outflow Results, August 2009 Event Simulation

The results of the August 2009 baseline simulation did not show the same close agreement with the observed peak flow and peak time as the 2008 and 2011 event simulations. The baseline simulated peak flow for this event was approximately 16% greater than the observed peak, and occurred 10 minutes before the observed peak time. While peak time and total volume are well within the target tolerances, additional adjustment is needed to gain acceptable agreement between simulated and observed peak flows (while also possibly getting better agreement with the peak time).

Based on the results of the baseline simulation, it was determined that adjustments to the lag time should be made to accomplish the dual goals of decreasing the peak flow and moving the peak time. Calibration iterations were made using 5% incremental increases in the lag factor, while maintaining the CN increase and initial abstraction factor. The final calibration run for this event used a **65% increase in lag times** in comparison with the raw values, in conjunction with the **75% increase in initial abstraction** and **1 unit increase in CN**. This yielded the results shown in Figure 10 and Table 13 below:

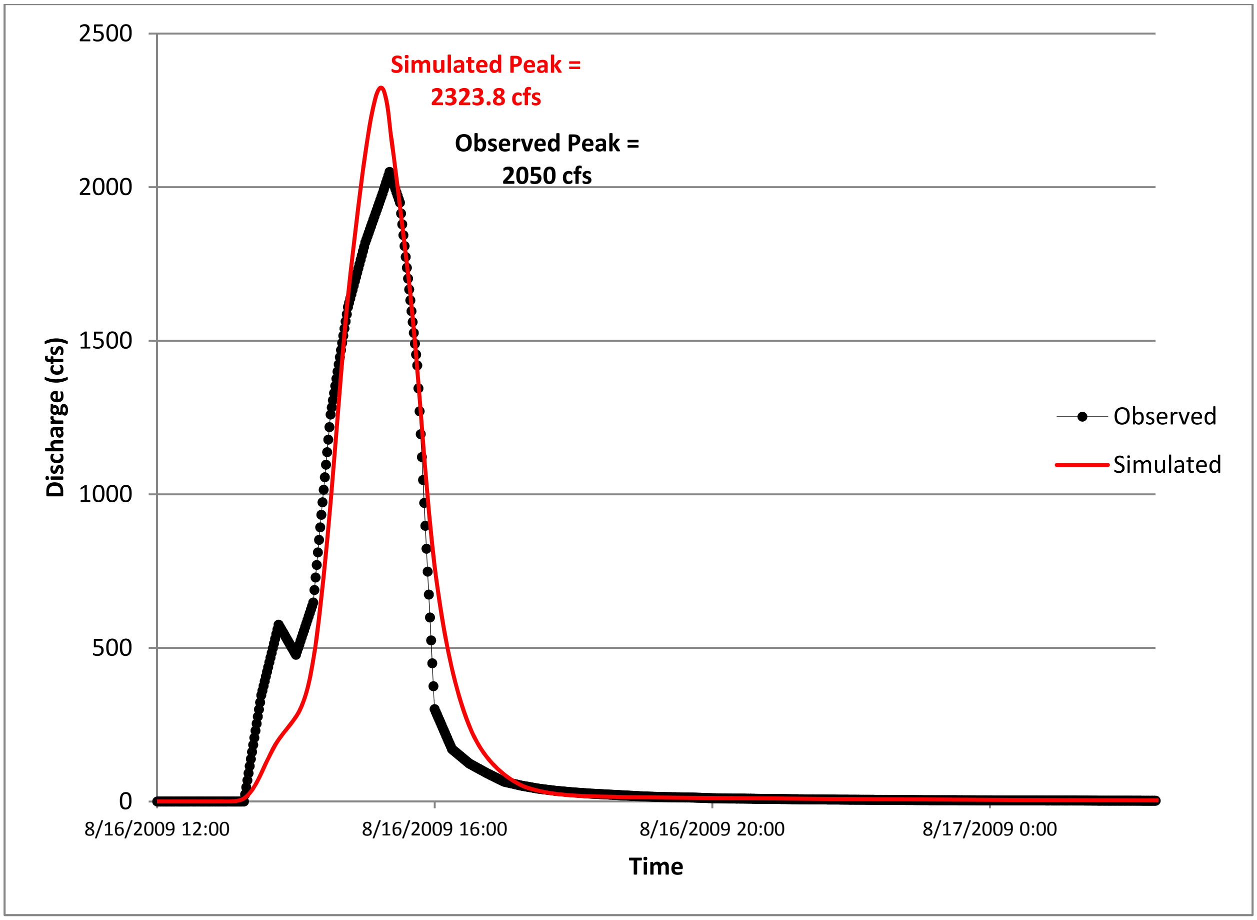


Figure 10 – Final Simulation vs Observed Outflow Hydrograph, August 2009 Event Simulation

Simulated			Observed			Peak Q %difference	Volume %difference
Peak Q (cfs)	Time of Peak	Volume (in)	Peak Q (cfs)	Time of Peak	Volume (in)		
2323.8	8/16/2009 15:14	2.04	2050	8/16/2009 15:21	2.02	13%	1%

Table 13 – Final Simulation vs Observed Outflow Results, August 2009 Event Simulation

The use of a 15% larger lag time factor in the final August 2009 event simulation achieved a 3% decrease in the peak flow, along with a 3 minute shift in the peak time. Additional increases to the lag time factor could be made to achieve even closer agreement between simulated and observed peak flow and peak time values. However, the calibration effort was halted at this point in order to ensure that the agreement that was achieved for the 2008 and 2011 events was not appreciably disrupted.

The August 2009 baseline and final calibration runs are summarized in Table 14 below:

	IA factor	CN factor	Lag factor	Peak Q (cfs)	Time of Peak	Volume (in)	%Diff Peak Q	Diff Time (min)	%Diff Total Volume
Observed	N/A	N/A	N/A	2050	8/16/2009 15:21	2.02	N/A	N/A	N/A
Baseline	1	1	1	2375.9	8/16/2009 15:11	2.04	16%	-10	1%
Final	**1.75**	**+1**	**1.65**	**2323.8**	**8/16/2009 15:14**	**2.04**	**13%**	**-7**	**1%**

Table 14 –August 2009 Event Calibration Summary

The overall calibration factors that were adopted in the final August 2009 calibration run were considered as the "**final**" calibration measures for this restudy.

2.3.5 Results and Conclusions

The final simulations of 2008 and 2011 calibration events were executed using the final calibration measures from the August 2009 event simulation (listed in Table 14). This yielded the following:

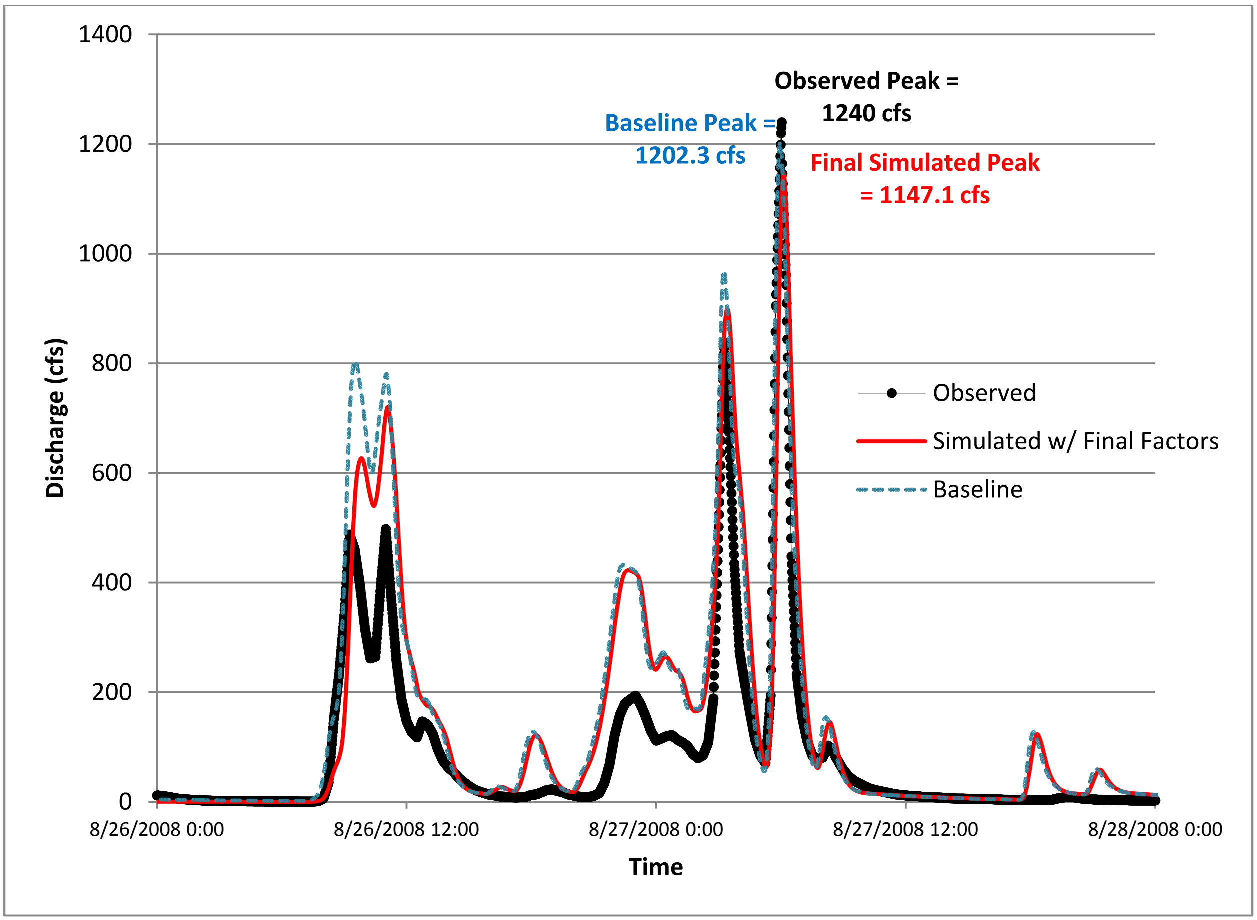


Figure 11 – Simulation w/ Final Factors vs Observed Outflow Hydrograph, August 2008 Event

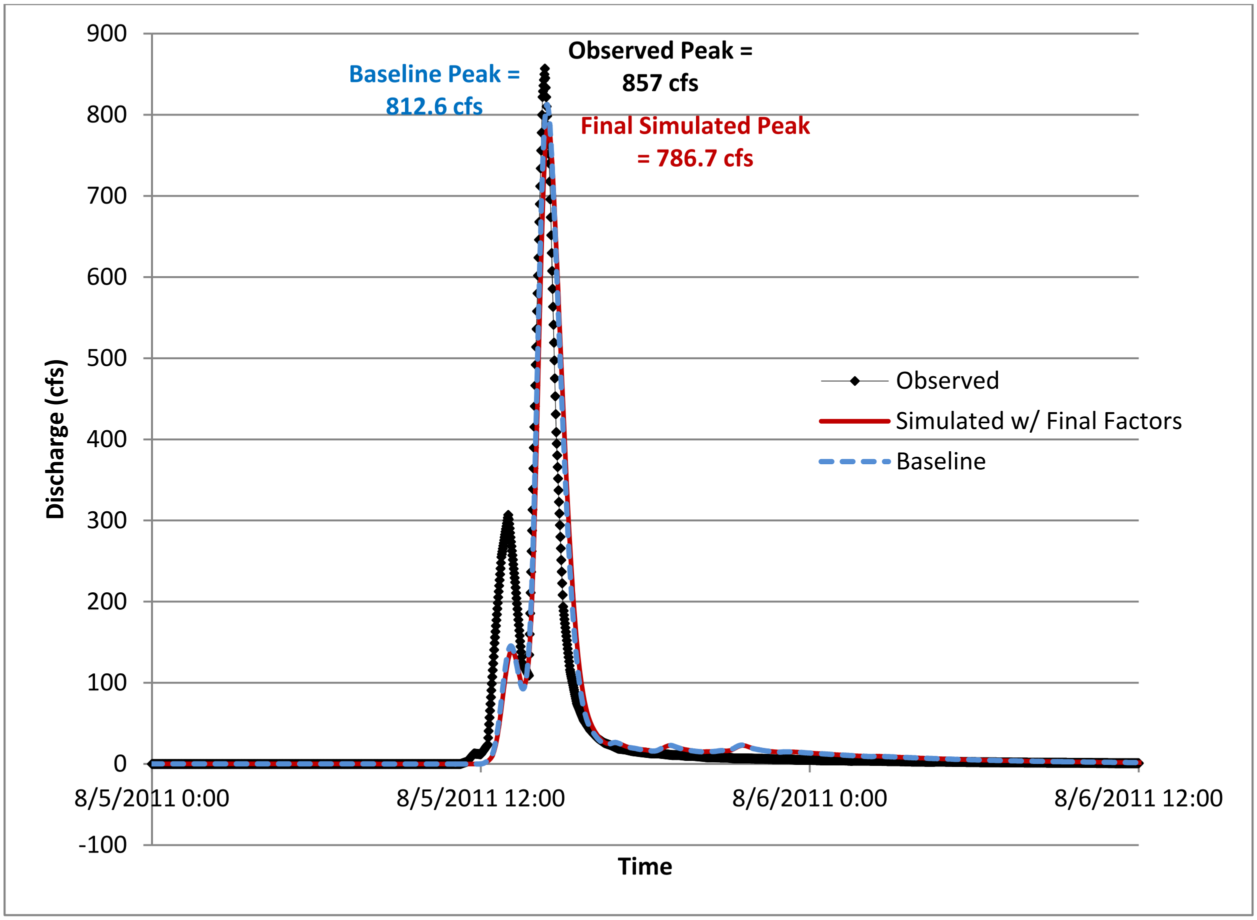


Figure 12 – Simulation w/ Final Factors vs Observed Outflow Hydrograph, August 2011 Event

Simulated			Observed			Peak Q %difference	Volume %difference
Peak Q (cfs)	Time of Peak	Volume (in)	Peak Q (cfs)	Time of Peak	Volume (in)		
1147.1	8/27/2008 6:07	4.09	1240	8/27/2008 6:02	2.73	-7%	50%
786.7	8/5/2011 14:27	0.74	857	8/5/2011 14:20	0.70	-8%	6%
2323.8	8/16/2009 15:14	2.04	2050	8/16/2009 15:21	2.02	13%	1%

Table 15 – Simulations w/ Final Factors vs Observed Outflow Results, All Calibration Events

The final lag factor (a **65% increase in lag times** from the raw values) is greater than what was used in the previous calibration runs for the 2008 and 2011 events, which used a 50% increase in the lag times. It can be seen in the table above that including an increased lag time factor in the final calibration measures results in somewhat lower peak discharges for these events, in addition to greater differences in the peak time. In spite of these decreases, the final calibration measures have yielded results that are well within the target calibration tolerances.

Based on the agreement between the simulated and observed discharges for the chosen historical events, these final measures are considered to be valid, and were used to calculate the "calibrated" conditions discharges for the 50-, 20-, 10-, 4-, 2-, 1-, future 1-, and 0.2-percent-annual-chance events.

A comparison of the PMR1, pre-calibration, and the calibrated 1-percent discharges at key locations can be found in Table 16 below:

Stream Name	Element Name	Drainage Area (Sq Mi)	Location Description	PMR1 LSBC Q1%	Pre-Calibration Q1%	Calibrated Q1%	%Difference PMR1 vs. Calibrated
Little Hope Creek Trib	J_LLS_120	0.56	Immediately US of Bradbury Dr	1753.1	1235.8	1034.5	-41.0%
	J_LLS_124	1.36	Furthest DS model element on LHCT	1683.2	3058.0	2670.8	58.7%
Little Hope Creek	J_LLS_241	1.11	At Woodlawn Road	1193.3	1813.7	1643.3	37.7%
	J_LLS_123	1.22	Immediately US of confluence with LHCT	3001	1691.4	1632.1	-45.6%
	J_LLS_130	2.65	Approximately 1300 feet DS of Seneca Pl	3170.5	4239.0	3775.8	19.1%
	J_LLS_135	3.15	Furthest DS model element on LHC	3136.7	4606.7	4225.5	34.7%

Table 16 – PMR1, Pre-Calibration, and Calibrated 1-Percent Discharge Comparison

For the 1-percent event discharge, the table above shows significant increases at most locations in comparison to those that were computed in the PMR1 LSBC analysis. Decreases are also shown immediately upstream of the confluences with Little Hope Creek Tributary, and with an unmodeled tributary to Little Hope Creek Tributary immediately upstream of Bradbury Drive. However, as discussed in section 2.2.4 of this report, these decreases occur due to corrections that were made to the model element connectivity at confluences.

In accordance with the scope of this restudy, a hydraulic analysis was conducted using the calibrated discharges from the 50-, 20-, 10-, 4-, 2-, 1-, future 1-, and 0.2-percent-annual-chance event simulations. As with the pre-calibration conditions, water surface elevations computed using calibrated 1-percent discharges show significant increases in comparison to those published in the final PMR1 LSBC analysis.

Appendix B

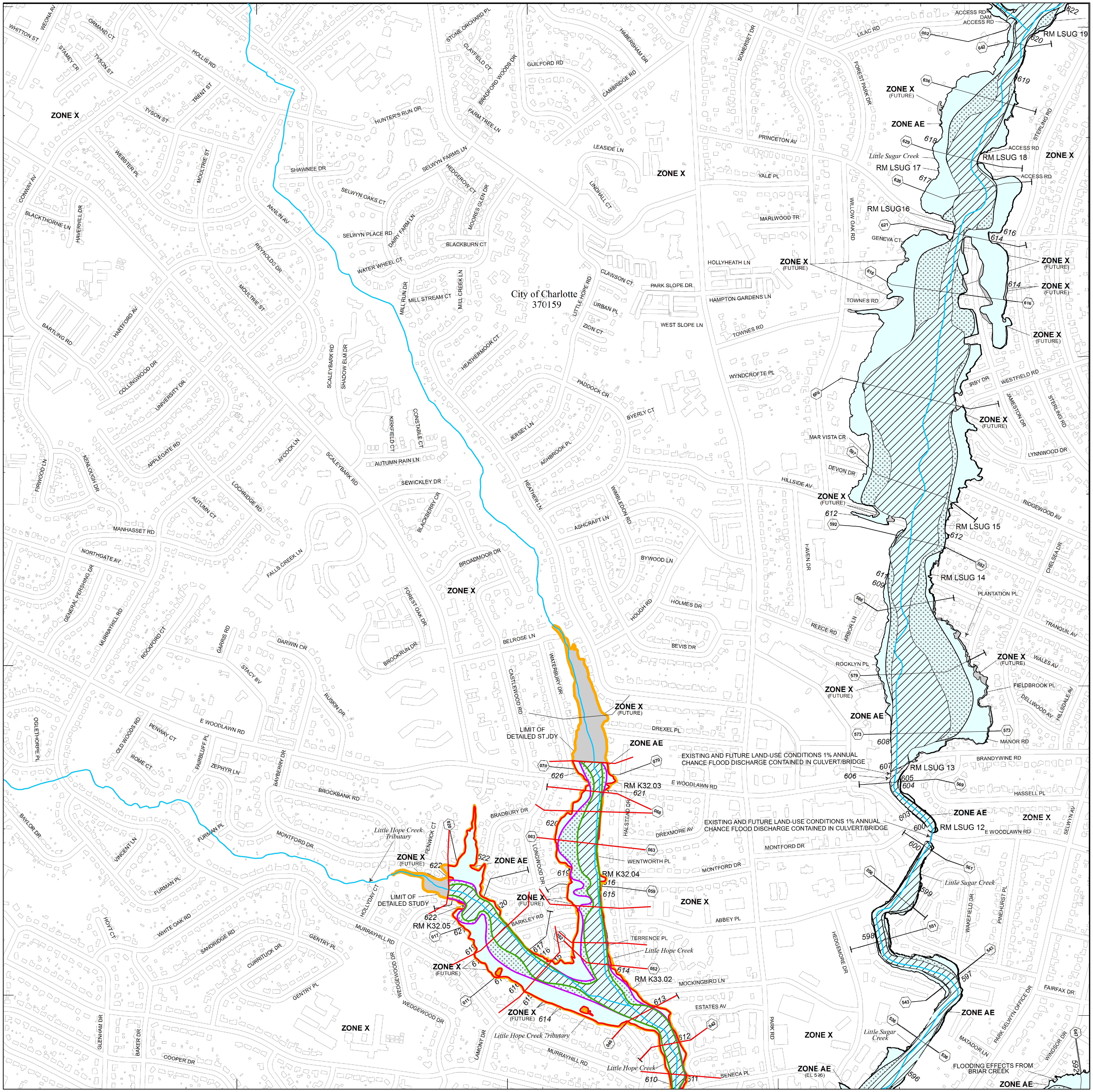
Topographic WorkMaps / Annotated FIRMs

Topographic Workmap - Little Hope Creek Watershed
(Panel #1)

Topographic Workmap - Little Hope Creek Watershed
(Panel #2)

Topographic Workmap - Little Hope Creek Watershed
(Panel #3)

Topographic Workmap - Little Hope Creek Watershed
(Panel #4)



Legend

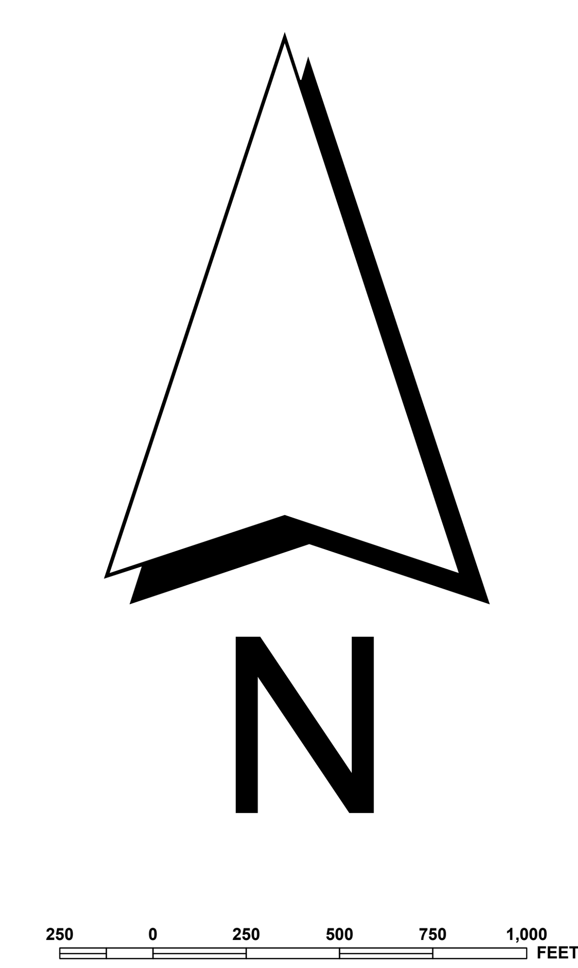
- LETTERED XS (LOMR)
- Stream

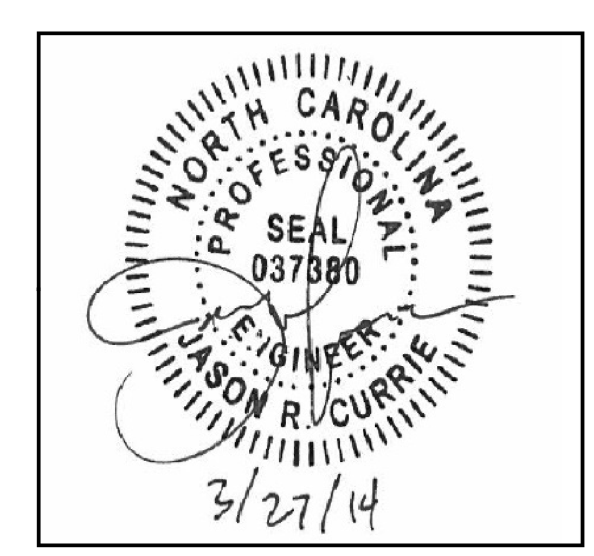
Area of Revision

- FEMA FW
- Community FW
- 1-Percent
- 1-Percent Future

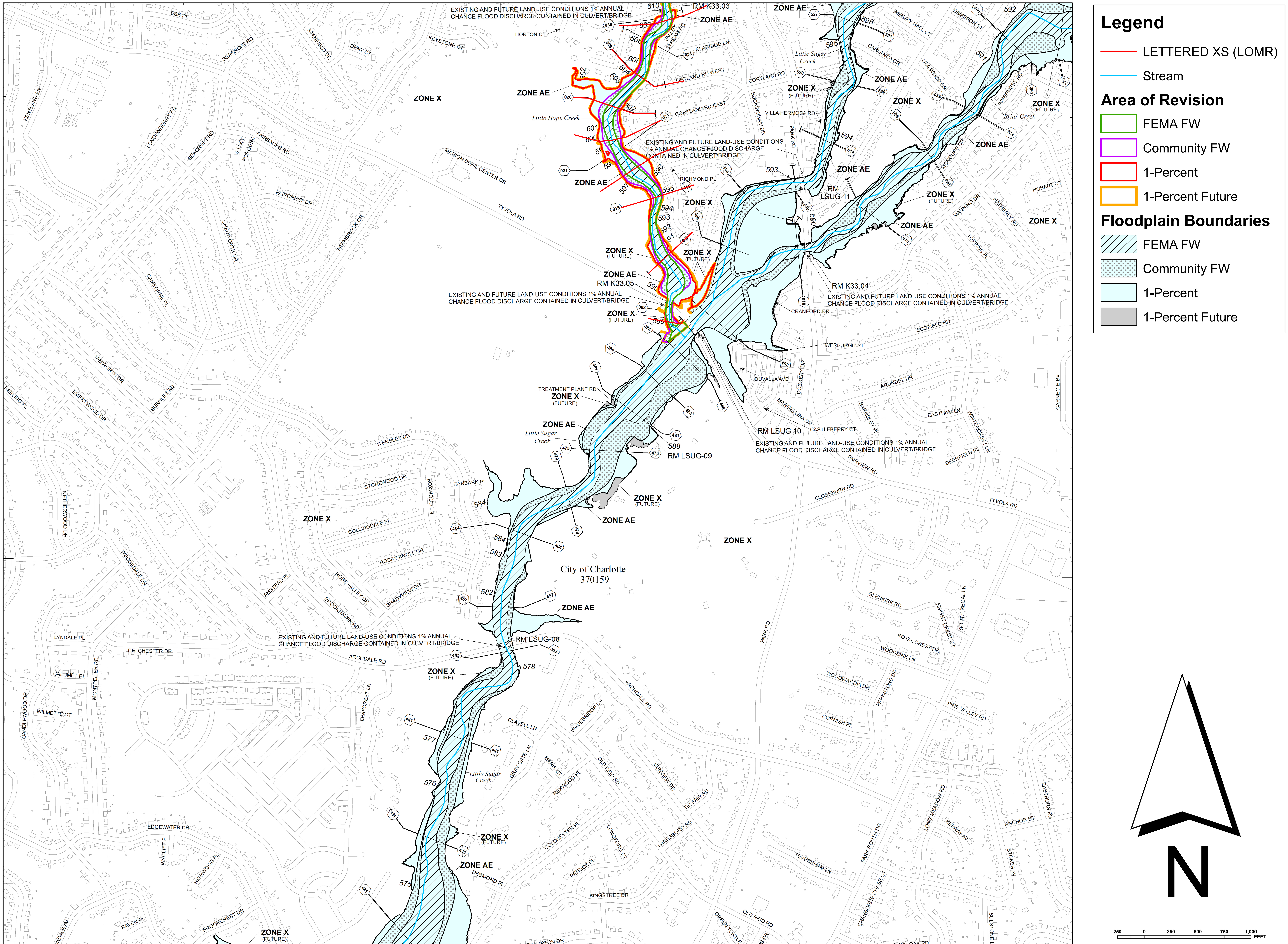
Floodplain Boundaries

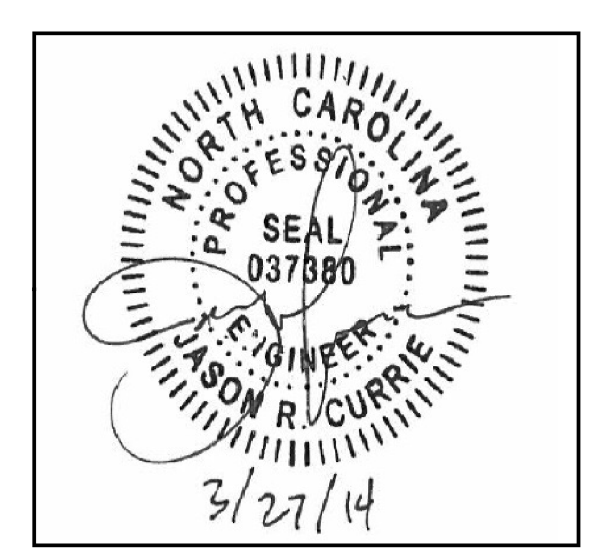
- FEMA FW
- Community FW
- 1-Percent
- 1-Percent Future





Annotated FIRM - Panel 4542





Annotated FIRM - Panel 4541

Appendix C

Effective vs. Corrected Effective 1-Percent WSEL Comparison

XS Stream Station	Stream Name	WSEL2	WSEL5	WSEL10	WSEL25	WSEL50	WSEL100	WSEL 100-F	WSEL500
15699	LittleHopeCreek	-0.66	-0.65	-0.33	-0.47	-0.35	-0.25	-0.33	-0.45
15547	LittleHopeCreek	-0.47	-0.50	-1.24	-1.14	-0.74	-0.42	-0.20	-0.26
15466	LittleHopeCreek	-0.34	-0.39	-0.44	-0.53	-0.54	-0.49	-0.38	-0.83
15398	LittleHopeCreek	-0.47	-0.54	-0.61	-0.67	-0.67	-0.53	-0.39	-0.33
15342	LittleHopeCreek	-0.52	-0.66	-0.73	-0.76	-0.75	-0.57	-0.41	-0.28
15285	LittleHopeCreek	-0.45	-0.21	-0.07	0.00	0.09	-0.17	0.01	0.14
15131	LittleHopeCreek	-0.40	-0.06	0.00	0.06	0.13	0.34	0.52	0.85
15033	LittleHopeCreek	0.32	0.50	0.51	0.54	0.63	0.89	1.09	1.28
14969	LittleHopeCreek	0.38	0.53	0.54	0.56	0.62	0.87	1.07	1.26
14699	LittleHopeCreek	0.51	0.66	0.58	0.50	0.56	1.24	1.61	1.94
14463	LittleHopeCreek	0.49	0.66	0.77	0.80	1.15	2.35	2.73	2.43
14382	LittleHopeCreek	0.50	0.68	0.76	1.01	1.89	3.09	3.20	2.59
14269	LittleHopeCreek	0.46	0.71	1.07	2.77	2.68	3.53	3.47	2.73
14168	LittleHopeCreek	0.46	0.63	0.69	0.83	0.90	1.06	1.19	1.35
13980	LittleHopeCreek	0.44	0.57	0.73	0.88	1.00	1.16	1.21	1.66
13800	LittleHopeCreek	0.50	0.66	0.80	0.95	1.09	1.26	1.39	1.50
13499	LittleHopeCreek	0.45	0.66	0.68	0.73	0.65	0.57	0.57	0.54
13234	LittleHopeCreek	0.49	0.75	0.93	0.94	1.24	1.42	1.50	1.15
13080	LittleHopeCreek	0.38	0.85	1.10	0.96	1.56	1.86	1.91	1.23
12927	LittleHopeCreek	0.32	0.66	0.75	0.17	0.60	0.71	0.92	0.93
12690	LittleHopeCreek	0.22	0.61	0.77	1.04	0.59	0.80	0.95	0.97
12300	LittleHopeCreek	0.30	0.63	0.79	0.70	0.70	0.66	0.90	1.01
11900	LittleHopeCreek	0.24	0.61	0.47	0.39	0.85	1.32	1.16	0.85
11674	LittleHopeCreek	0.29	0.64	0.70	0.63	0.72	0.91	1.11	1.11
11400	LittleHopeCreek	0.25	0.61	0.67	0.57	0.67	0.92	1.17	1.27
11084	LittleHopeCreek	0.25	0.64	0.67	0.53	0.59	0.78	0.97	0.97
10741	LittleHopeCreek	0.30	0.73	0.72	0.62	0.69	0.83	1.05	1.05
10465	LittleHopeCreek	0.28	0.73	0.83	0.73	0.77	0.81	1.08	1.08
10236	LittleHopeCreek	0.21	0.55	0.57	0.34	0.74	1.24	1.16	1.18
9900	LittleHopeCreek	0.30	0.82	0.73	0.51	0.46	0.68	0.87	0.94
9647	LittleHopeCreek	0.32	0.86	0.92	0.68	0.26	0.65	0.87	0.90
9321	LittleHopeCreek	0.30	0.52	0.37	0.41	1.09	0.63	0.71	0.71
9000	LittleHopeCreek	0.31	0.65	0.75	0.27	0.52	0.71	0.92	0.92
8670	LittleHopeCreek	0.23	0.66	0.75	1.30	0.50	0.61	0.70	0.85
8468	LittleHopeCreek	0.23	0.57	0.70	0.58	0.66	0.84	1.07	2.51
8300	LittleHopeCreek	0.25	0.63	0.74	0.66	0.77	1.01	1.26	3.12
8250	LittleHopeCreek	0.20	0.59	0.70	0.94	0.88	0.71	1.09	1.37
8086	LittleHopeCreek	0.21	0.84	1.19	1.17	1.00	0.78	0.88	0.81
7784	LittleHopeCreek	0.04	0.84	1.30	1.40	1.09	0.72	0.80	0.68
7500	LittleHopeCreek	-0.36	0.94	1.49	1.55	1.13	0.73	0.81	0.67
7072	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6971	LittleHopeCreek	0.42	1.35	1.77	1.67	1.19	0.68	0.73	0.56
6784	LittleHopeCreek	0.28	0.62	0.51	0.32	0.33	0.32	0.64	1.00
6599	LittleHopeCreek	0.27	0.62	0.56	0.39	0.42	0.46	0.51	0.49
6301	LittleHopeCreek	0.18	0.51	0.41	0.31	0.32	0.46	0.56	0.40
6028	LittleHopeCreek	0.29	0.41	0.28	0.17	0.16	0.28	0.39	0.30
5915	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5852	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5793	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5716	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5653	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5383	LittleHopeCreek	1.11	0.97	0.79	0.77	0.87	0.98	1.12	0.96
5184	LittleHopeCreek	0.62	0.86	0.73	0.76	0.86	0.96	1.10	0.95
4888	LittleHopeCreek	0.58	0.79	0.62	0.71	0.85	0.93	1.05	0.91
4776	LittleHopeCreek	0.58	0.75	0.79	0.86	0.92	0.99	1.12	0.93
4601	LittleHopeCreek	0.48	0.63	0.78	0.96	1.04	1.10	1.25	0.95
4200	LittleHopeCreek	0.46	0.53	0.95	1.11	1.16	1.12	1.27	0.89
3900	LittleHopeCreek	1.06	1.40	1.77	1.35	1.27	1.15	1.29	0.87
3759	LittleHopeCreek	0.82	1.22	1.32	0.62	0.64	0.58	0.73	0.79
3638	LittleHopeCreek	0.44	0.87	1.20	0.90	0.83	0.92	0.97	1.11
3591	LittleHopeCreek	0.52	0.82	0.97	1.15	1.12	1.11	1.21	1.05
3287	LittleHopeCreek	0.57	0.88	0.90	0.98	0.96	0.96	1.06	0.88
2931	LittleHopeCreek	0.57	0.77	0.87	1.02	1.04	1.06	1.16	0.96
2710	LittleHopeCreek	0.90	1.17	1.29	1.42	1.41	1.41	1.52	1.34
2550	LittleHopeCreek	1.09	1.29	1.56	1.85	1.88	1.82	1.91	1.70
2400	LittleHopeCreek	1.22	1.41	1.66	1.92	1.91	1.83	1.91	1.70
2219	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2106	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1879	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1683	LittleHopeCreek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1521	LittleHopeCreek	0.43	0.76	0.93	1.05	1.09	1.36	1.78	2.73
1284	LittleHopeCreek	0.42	0.81	1.04	0.94	1.06	1.97	2.65	3.24
900	LittleHopeCreek	0.49	0.90	0.86	2.00	3.04	3.86	4.42	3.66
612	LittleHopeCreek	0.65	1.31	1.64	2.52	3.18	3.80	4.34	3.62
444	LittleHopeCreek	0.69	1.32	1.60	2.46	3.17	3.80	4.34	3.60
259	LittleHopeCreek	0.63	1.10	1.27	1.46	1.55	1.71	1.79	0.69
206	LittleHopeCreek	0.48	1.06	1.04	1.10	1.13	1.02	2.00	2.41
126	LittleHopeCreek	1.37	2.29	0.17	1.61	1.45	1.33	1.41	1.05
87	LittleHopeCreek	0.36	0.75	0.83	0.93	0.99	1.00	1.11	0.99
66	LittleHopeCreek	0.40	0.77	0.89	0.88	0.85	0.85	0.93	0.74

FEMA FLOODPLAIN (applies to stations 7072 through 66)

XS Stream Station	Stream Name	WSEL2	WSEL5	WSEL10	WSEL25	WSEL50	WSEL100	WSEL 100-F	WSEL500
7366	LHopeCrkT1	1.08	1.39	1.28	1.08	1.14	1.29	1.25	2.07
7186	LHopeCrkT1	4.56	1.19	0.73	0.72	0.68	0.71	0.61	0.57
6773	LHopeCrkT1	1.15	1.01	0.90	0.86	0.83	0.77	0.74	0.57
6660	LHopeCrkT1	1.19	0.95	0.74	0.65	0.59	0.60	0.62	0.82
6500	LHopeCrkT1	0.76	0.88	1.02	1.23	1.35	1.42	1.42	1.34
6369	LHopeCrkT1	1.08	1.27	1.43	1.71	1.84	1.86	1.84	1.54
6272	LHopeCrkT1	0.68	0.95	0.96	1.05	1.20	1.23	1.24	1.17
6066	LHopeCrkT1	0.59	0.80	0.92	0.85	0.76	0.60	0.67	0.78
5877	LHopeCrkT1	0.90	0.92	0.75	0.94	0.97	1.13	1.02	0.75
5636	LHopeCrkT1	0.82	1.08	1.28	1.12	1.10	1.06	1.16	1.44
5272	LHopeCrkT1	1.10	1.05	1.09	0.99	0.90	0.84	0.88	0.92
5052	LHopeCrkT1	1.08	1.04	1.09	1.03	0.96	0.90	0.92	0.92
4923	LHopeCrkT1	1.24	1.07	1.08	0.97	0.87	0.85	0.86	0.88
4833	LHopeCrkT1	0.98	0.92	1.03	1.04	0.98	1.02	1.07	1.18
4630	LHopeCrkT1	1.24	0.95	1.04	1.02	0.94	0.97	1.01	1.08
4399	LHopeCrkT1	1.51	0.27	0.96	1.22	1.22	1.01	1.02	0.81
4066	LHopeCrkT1	0.77	1.96	0.75	0.88	0.83	0.85	0.93	1.51
3800	LHopeCrkT1	1.06	1.01	0.81	0.91	0.94	1.07	1.11	1.20
3498	LHopeCrkT1	1.24	2.10	2.13	1.45	1.32	1.05	1.08	1.00
3197	LHopeCrkT1	1.04	1.17	1.01	0.99	1.05	1.15	1.24	1.38
2880	LHopeCrkT1	1.30	1.99	1.97	1.82	1.29	1.17	1.23	1.70
2600	LHopeCrkT1	1.18	1.08	0.99	1.49	3.06	3.40	3.44	2.15
2300	LHopeCrkT1	1.81	1.91	1.83	1.96	1.88	1.87	1.92	1.93
2042	LHopeCrkT1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1823	LHopeCrkT1	1.40	2.26	1.70	0.96	0.79	0.72	0.74	0.81
1714	LHopeCrkT1	1.20	1.57	1.39	1.07	0.95	0.92	0.99	1.13
1661	LHopeCrkT1	1.11	1.52	1.42	0.93	0.65	0.55	0.61	0.80
1400	LHopeCrkT1	1.19	1.47	1.28	1.15	1.08	1.15	1.16	1.05
1104	LHopeCrkT1	1.20	1.54	1.56	0.73	0.43	0.72	0.78	0.99
870	LHopeCrkT1	1.00	1.30	1.44	1.58	1.57	1.35	1.43	0.98
538	LHopeCrkT1	0.99	1.30	1.50	1.62	1.52	1.40	1.41	1.35

FEMA FLOODPLAIN (applies to stations 2042 through 538)

** **N/A** values present for XSs that were relocated in the LOMR analysis*

Appendix D

Electronic Data Deliverables

Appendix E

Sample Property Owner BFE Increase and Floodway Notification Letters

March 17, 2014

Affected property owner name and address (See second page for list of properties impacted by LOMR)

Re: Notification of 1% (100-year) annual chance water-surface elevation increases and widening of the 1% annual chance floodplain

Dear Affected property owner:

The Flood Insurance Rate Map (FIRM) for a community depicts land which has been determined to be subject to a 1% (100-year) or greater annual chance of flooding in any given year. The FIRM is used to determine flood insurance rates and to help the community with floodplain management.

Mecklenburg County is applying for a Letter of Map Revision (LOMR) from the Federal Emergency Management Agency (DHS-FEMA) to revise FIRMs 4541K and 4542K for the City of Charlotte, NC along Little Hope Creek and Little Hope Creek Tributary.

The Letter of Map Revision will result in:

1. Increases in the Little Hope Creek 1% annual chance water-surface elevations with a maximum increase of 3.86 feet at a point approximately 540 feet upstream of Tyvola Road.
2. Increases in the Little Hope Creek Tributary 1% annual chance water-surface elevations with a maximum increase of 1.40 feet at a point approximately 538 feet upstream of the confluence with Little Hope Creek.
3. Widening of the Little Hope Creek 1% annual chance floodplain with the maximum widening of approximately 190 feet at a point approximately 260 feet downstream of Montford Drive.
4. Widening of the Little Hope Creek Tributary 1% annual chance floodplain with the maximum widening of approximately 110 feet at a point approximately 360 feet downstream of Bradbury Drive.

This letter is to inform you of revision of the 1% annual chance water-surface elevation and 1% annual chance floodplain on your property at {insert physical address}.

If you have any questions or concerns about the proposed changes to the FIRM or its effect on your property, you may contact me at {Revision requester contact phone number}.

Sincerely,

{Revision requester name}

Addresses impacted by the LOMR (I.E. these addresses were not in 1-percent floodplain based on the FIRMs that went effective February 19, 2014, but are in the proposed LOMR floodplain):

4550 Bradbury Dr
4556 Bradbury Dr
1225 Estates Ave
1108 Montford Dr
1200 Montford Dr
1208 Montford
1200 Terrence Pl
1210 Terrence Pl
5042 Valley Stream Rd
5553 Wedgewood Dr
5646 Wedgewood Dr
5652 Wedgewood Dr
5701 Wedgewood Dr
5827 Wedgewood Dr
1224 E Woodlawn Rd

March 17, 2014
Affected property owner name and address (See second page for list of properties impacted by LOMR)
Re: Notification of Floodway Revision for Little Hope Creek and Little Hope Creek Tributary

Dear Affected property owner:

The Flood Insurance Rate Map (FIRM) for a community depicts the floodplain, the area which has been determined to be subject to a 1% (100-year) or greater chance of flooding in any given year. The floodway is the portion of the floodplain that includes the channel of a river or other watercourse and the adjacent land area that must be reserved in order to discharge the base flood without cumulatively increasing the water-surface elevation by more than a designated height.

The Mecklenburg County Flood Mitigation Program, in accordance with National Flood Insurance Program regulation 65.7(b)(1), hereby gives notice of the County's intent to revise the 1% annual chance (100-year) floodways for Little Hope Creek and Little Hope Creek Tributary. As a result of the floodway revision, the floodway for Little Hope Creek shall widen and/or narrow with a maximum widening of 117 feet at a point approximately 330 feet upstream of Montford Drive, and a maximum narrowing of 60 feet at a point approximately 220 feet downstream of Mockingbird Lane. For Little Hope Creek Tributary, the floodway shall widen with a maximum widening of 140 feet at a point approximately 360 feet downstream of Bradbury Drive.

Maps and detailed analysis of the floodway revision can be reviewed at the offices of the Charlotte-Mecklenburg Stormwater Services at 700 North Tryon Street, Charlotte, NC 28202. If you have any questions or concerns about the revised analysis or its effect(s) on your property, you may contact Tim Trautman, PE, of Mecklenburg County at 704-336-7357.

Sincerely,
{Community official name}
{Community official position}
{Community official contact information}

Addresses Impacted by the LOMR (I.E. these addresses were not in 1-percent floodplain based on the FIRMs that went effective in February 19, 2014, but are in the proposed LOMR floodplain)

4550 Bradbury Dr
4556 Bradbury Dr
1225 Estates Ave
1108 Montford Dr
1200 Montford Dr
1208 Montford
1200 Terrence Pl
1210 Terrence Pl
5042 Valley Stream Rd
5553 Wedgewood Dr
5646 Wedgewood Dr
5652 Wedgewood Dr
5701 Wedgewood Dr
5827 Wedgewood Dr
1224 E Woodlawn Rd