Section 1
Introduction

The Little Calumet River Watershed drains an area of 264.6 square miles in southeastern Cook County, which includes 45 total communities wholly or partly within the watershed. Portions of the watershed extend into northeast Will County and the northwest portion of Lake County, Indiana. The watershed is bounded to the north by Blue Island, on the south by Monee, on the west by Tinley Park, and on the east by Gary, Indiana. The watershed consists of nine subwatersheds: Midlothian Creek, Little Calumet River, Calumet Union Drainage Ditch, Butterfield Creek, Thorn Creek, Deer Creek, North Creek, Plum Creek (known as Hart Ditch in Indiana), and Cady Marsh Ditch. The Little Calumet River originates in Gary, Indiana and flows in a northwest direction along the northern boundary of the watershed. It bends and changes direction to the northeast at Blue Island, Illinois and continues flowing northeast until its confluence with the Calumet-Sag Channel. Flow continues westward in the Calumet-Sag Channel to the Chicago Sanitary and Ship Canal, tributary to the Des Plaines River, from the Des Plaines River to the Illinois River, and from the Illinois River to the Mississippi River basin. Under high flow conditions, the Little Calumet River flows to Lake Michigan through the O'Brien Locks and Dam. Land use within the watershed in Cook County is primarily residential, forested/open land, industrial, commercial and agricultural. Locations with historic flooding exist throughout the watershed.

The Little Calumet River Detailed Watershed Plan (DWP) was developed by the Metropolitan Water Reclamation District of Greater Chicago (District) with the participation of the Little Calumet River Watershed Planning Council (WPC), which provided local input to the District throughout the development process. The DWP was developed to accomplish the following goals:

- Document stormwater problem areas.
- Evaluate existing watershed conditions using hydrologic and hydraulic (H&H) models.
- Produce flow, stage, frequency, and duration information along regional waterways.
- Estimate damages associated with regional stormwater problems.
- Evaluate solutions to regional stormwater problems.

Regional problems are defined as problems associated with waterways whose watersheds encompass multiple jurisdictions and drain an area greater than 0.5 square miles. Problems arising from capacity issues on local systems, such as storm sewer systems and minor open channel ditches, even if they drain more than one municipality, were considered local and beyond the scope of a regional stormwater management program. Streambank stabilization problems addressed in this plan were limited to active erosion along regional waterways within 30 feet of structures or critical infrastructure. Interstate highways, U.S. highways, state routes, county roads with four or more lanes, and smaller roads providing critical access that are impacted by overbank flooding of regional waterways at depths exceeding 0.5 foot were also considered regional problems.

1.1 Scope and Approach

The Little Calumet River DWP scope included data collection and evaluation, H&H modeling, development and evaluation of alternatives, and recommendation of alternatives. The data collection and evaluation task included collection and evaluation of existing H&H models, geospatial data, previous studies, reported problem areas, and other data relevant to the watershed plan. H&H models were developed to produce inundation mapping for existing conditions for the 100-year storm event and to evaluate stormwater improvement project alternatives. Stormwater improvement project alternatives were developed and evaluated to determine their effectiveness in addressing regional stormwater problems in Cook County. Estimates of damage reduction, or benefits, associated with proposed projects were considered along with conceptual cost estimates and non-economic criteria to develop a list of recommended improvement projects for the Little Calumet River Watershed.

1.2 Data Collection and Evaluation

The data collection and evaluation phase (Phase A) of the DWP development focused on obtaining data regarding the watershed and evaluation of the material's acceptability for use. The District contacted all WPC members, as well as federal and state agencies and other stakeholders, to request relevant data. Coordination with WPC members to support the DWP took place throughout development of the DWP. Existing and newly developed data was evaluated according to use criteria defined in the *Cook County Stormwater Management Plan* (CCSMP). Where data was unavailable or insufficient to complete the DWP, additional data was collected. This report includes information on all data collected and evaluated as a part of the Little Calumet River DWP development. **Table 1.2.1** lists key dates of coordination activities, including meetings with WPC members throughout DWP development.

Table 1.2.1: Little Calumet River DWP WPC Coordination Activities

Little Calumet River Detailed Watershed Plan - Phase A - contract (06-712-5C) start date	November 21, 2006
Little Calumet River Detailed Watershed Plan - Phase B - contract (07-713-5C) start date	June 1, 2007
Information Gathering	
Data Request (Forms A and B) sent out as part of Phase A	November 24, 2006
Open meetings with watershed representatives during Phase A to discuss Forms A and B	January 22, 2007, January 23, 2007
Will County GIS Department	October 2007
Office of the Lake County Surveyor, Indiana	August 2007

Table 1.2.1: Little Calumet River DWP WPC Coordination Activities

District phone calls to communities after the September 2008 storm event		September 15, 2008
Little Calumet River Watershed Planning Council Meetings		
June 7, 2007	June 5, 2008	May 7, 2009
September 6, 2007	September 4, 2008	September 10, 2009
November 29, 2007	November 20, 2008	November 5, 2009
March 6, 2008	February 19, 2009	
Modeling Results and Alternatives Review Meetings		
Little Calumet River/Calumet-Sag Channel Coordination		April 2, 2008
Third-Party Model Review Meeting		February 17, 2009
U.S. Army Corps of Engineers Coordination Meetings		April 16, 2009, August 12, 2009
Information Review and Alternatives Development Community Workshops		
Butterfield Creek Communities		August 27, 2008, October 29, 2008, July 23, 2009
Calumet Union Drainage Ditch Communities		August 27, 2008, October 29, 2008, July 30, 2009
Deer Creek Communities		August 27, 2008, October 29, 2008, July 23, 2009
Little Calumet River Communities		October 2, 2008, July 30, 2009
Midlothian Creek Communities		July 23, 2008, October 1, 2008, December 3, 2008
North Creek Communities		July 23, 2008, October 1, 2008, December 4, 2008
Plum Creek Communities		July 23, 2008, October 1, 2008, December 3, 2008
Thorn Creek Communities		October 2, 2008, December 4, 2008, July 23, 2009

1.3 Hydrologic and Hydraulic Modeling

This section provides a description of the H&H modeling completed to support the DWP development. H&H models were developed for all tributaries within the watershed containing open waterways. Most models were developed independent of any past H&H modeling efforts, but some existing models were used to support development of the DWP. Hydraulic model extent was defined based upon the extent of detailed study for effective Flood Insurance Rate Maps (FIRMs). Revised Digital Flood Insurance Rate Map (DFIRM) data produced by the Federal Emergency Management Agency's (FEMA) Map Modernization Program was unavailable at the time of model definition. Models were extended further, where appropriate, to aid evaluation of damages associated with regional stormwater problems. **Appendix A** includes a comparison of FEMA's revised DFIRM panels with inundation areas developed for DWP purposes. Tables comparing DWP inundation area to FEMA floodplain mapping by community and subwatershed are also included in **Appendix A**.

H&H models were developed to be consistent with the protocols defined in the CCSMP. In numerous instances, models included additional open channel or other drainage facilities not strictly required by the CCSMP to aid the evaluation of community reported problem areas. Available monitoring data, including United States Geological Survey (USGS) stream gage data, District facility data and high water marks observed following storm events were used to perform model verification and calibration consistent with the CCSMP. All H&H modeling data and documentation of the data development are included in the appendixes referenced in the report sections below.

1.3.1 Model Selection

H&H models were developed within the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) Version 3.1.0 modeling application and Hydrologic Engineering Center - River Analysis System (HEC-RAS) Version 4.0. These applications were identified as acceptable in the CCSMP. The Soil Conservation Service (SCS) curve number (CN) loss module was used with the SCS Clark Unit Hydrograph methodology within HEC-HMS to model basin hydrology. The dynamic unsteady flow routing methodology was used within HEC-RAS. Both applications have an extensive toolkit to interface with geographic information systems (GIS) software to produce input data and display model results.

1.3.2 Model Setup and Unit Numbering

1.3.2.1 Hydrologic Model Setup

Hydrologic model data was primarily developed within the ArcHydro, HEC-GeoDozer, and HEC-GeoHMS extensions to Arc GIS Version 9.2. The extensions provide an interface to characterize subbasin parameters within the hydrologic model. HEC-GeoDozer was used to produce a hydrologically corrected Digital Elevation Model (DEM) for watershed delineation. ArcHydro was used to process the hydrologically correct DEM for subbasin delineation and to compute longest flow paths and subbasin slopes. HEC-GeoHMS was used to delineate the subbasins from the hydrologically correct DEM and compute parameters for the Natural Resources Conservation Service (NRCS) TR-55 time of concentration determination. The geoprocessing tools within ArcGIS were used to calculate the CN for each subbasin. HEC-HMS was used to create and sometimes route stormwater runoff hydrographs to the upstream extent of hydraulic models developed within HEC-RAS. Hydrologic model data was transferred between HEC-HMS and HEC-RAS through HEC-Data Storage System (DSS) files.

Subbasin Delineation. The subbasins for the entire Little Calumet River watershed were delineated in one ArcHydro/GeoHMS model. The subbasin delineation points were determined by identifying HEC-RAS stream confluence locations, problem area locations, restrictive bridges/culverts, USGS stream gage locations, and Combined Sewer Overflow (CSO) points. A total of 431 subbasins were delineated in the Little Calumet River watershed, ranging in size from 0.005 to 17.8 square miles. The average subbasin size was 1.40 square miles. In the portion of Cook County there are 331 subbasins. The size of these subbasins ranged from 0.005 to 3.51 square miles with an average of 0.49 square miles. The process used to delineate the subbasins is described in more detail in the following paragraphs.

A 25-foot grid cell Digital Elevation Model (DEM) was prepared to delineate the subbasin boundaries using ArcHydro, HEC-GeoHMS, and HEC-GeoDozer. The base data for the DEM used in the subbasin delineation was the Cook County Digital Terrain Map (DTM) provided by the District for the Cook County portions of the watershed, the State of Indiana 5-foot grid cell DEM available on the Indiana Spatial Data Portal, and the USGS 10-meter grid cell DEM data available from the National Elevation Dataset. A DEM was created from the Cook County DTM. The Indiana DEM was converted from a 5-foot grid cell to a 25-foot grid cell and reprojected to Illinois State Plane East NAD83 to be consistent with the Cook County DEM using ArcGIS Spatial Analyst. The USGS DEM was also converted to a 25-foot grid cell and reprojected using ArcGIS Spatial Analyst. The three DEM’s were then combined using ArcGIS Spatial Analyst with the priority of the data being used in the order of Cook County, Indiana, and USGS.

A stream centerline file was created using the Cook County Hydroline Data, the USGS National Hydrography Dataset, and Illinois and Indiana 2005 aerial photographs. The stream centerline was delineated to assist in the automated delineation of the subbasin boundaries. This stream centerline was burned into the 25-foot grid cell DEM to force drainage patterns to follow the current drainage patterns. This stream centerline does not contain local storm sewer system data. The local storm sewer systems may drain some areas differently than indicated by the topographic data and stream centerline.

The Tunnel and Reservoir Plan (TARP) CSO boundaries were imported into ArcGIS from data provided by the Corps of Engineers. The interior drainage areas behind the Little Calumet River levees in northwest Indiana were delineated from maps prepared by the Corps of Engineers for the Little Calumet River feature design memoranda. These boundaries were extruded from the DEM to force the water in these areas to drain to the man-made outlet (i.e., pump station, drop shaft, etc.).

After incorporation of the stream centerlines and TARP CSO boundaries, the DEM was used to determine flow accumulation, flow direction, slopes, catchments, etc. in ArcHydro and HEC-GeoHMS. The drainage area criteria used in the delineation were that the minimum stream drainage area was to be 1 square mile or the drainage area of the existing FEMA FIS study if the FEMA FIS detailed study extended below 1 square mile. In the tributary areas outside of Cook County, the delineations were performed at confluences, stream gages, significant hydraulic structures, etc. The drainage areas were generally sized between 5 to 15 square miles outside of Cook County.

The watershed boundary between the Calumet-Sag Channel and Little Calumet River watersheds was coordinated with the Calumet-Sag Channel DWP. This overall boundary was implemented in the Little Calumet River models similar to the TARP CSO boundaries.

Runoff Volume Calculation. The NRCS CN methodology was used to determine runoff volumes from the pervious/impervious areas in each of the subbasins. The NRCS CN loss model uses the empirical CN parameter to calculate runoff volumes based on landscape characteristics such as soil type, land cover, imperviousness, and land use development. Areas characterized by saturated or poorly infiltrating soils, or impervious development, have higher CN values, converting a greater portion of rainfall volume into runoff. The NRCS methodology uses **Equation 1.1** to compute stormwater runoff volume for each time step:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (1.1)$$

where:

Q = runoff volume (in.)
P = precipitation (in.)
S = storage coefficient (in.)
I_a = initial abstractions (in.)

Rainfall abstractions due to ponding and evapotranspiration can be simulated using an initial abstractions (I_a) parameter. In the Little Calumet River watershed, the commonly used default value of I_a, estimated as 0.2 × S, where S is the storage coefficient for soil in the subbasin. S is related to CN through **Equation 1.2**:

$$S = \frac{1000}{CN} - 10 \qquad (1.2)$$

where:

CN = curve number (dimensionless)
S = storage coefficient (in,)

Table 1.3.2 describes the input data used to develop the CN values throughout the watershed.

Table 1.3.2: Description of Curve Number Input Data

Variable Used to Determine CN	Approach for Definition of Variable for Little Calumet River Watershed Hydrologic Modeling
Ground cover (Illinois)	Chicago Metropolitan Agency for Planning (CMAP) 2001 land use inventory (v.1.2 2006) was used to define land use. A lookup table was developed to link CMAP categories to CN values and soil types
Ground cover (Indiana)	USGS 2001 land cover was used to define land use. A lookup table was developed to link USGS categories to CN values and soil types
Soil type	The Natural Resources Conservation Service (NRCS) publishes county soil surveys that include a hydrologic classification of A, B, C, or D. If a soil group's infiltration capacity is affected by a high water table, it is classified as, for instance, "A/D," meaning the drained soil has "A" infiltration characteristics, undrained "D." It was assumed that half of these soil groups (by area) are drained
Antecedent moisture condition	Antecedent moisture condition (AMC) reflects the initial soil storage capacity available for rainfall. For areas within Northeastern Illinois, it is typical to assume an AMC of II

The subbasin curve numbers were determined based on existing land use and soil types. The NRCS soil maps were imported into ArcGIS. Northeastern Illinois Planning Commission (NIPC) 2001 land use and USGS 2001 land cover data were imported into ArcGIS. The USGS raster data was converted to a polygon file. The soil type polygons and land use polygons were intersected in ArcGIS to produce consistent land use and soil type in each polygon. A curve number was assigned to each polygon based on the land use and soil type. The land use/soil type/curve number assignment was based on *TR-55: Urban Hydrology for Small Watersheds* (U.S. Department of Agriculture [USDA], 1986). For the USGS land cover classifications, a similar assignment was made based on CH2MHill recommendations within other DWP development. These polygons were then converted to raster grid with 25-foot grid cells identical to the locations of the DEM grid cells. The Spatial Analyst extension was then used to calculate the average curve number for each subbasin.

For each subbasin, the directly connected impervious percentage was estimated. This estimate was based on the total impervious area within the subbasin. Directly connected impervious areas are impervious areas that drain directly to the waterway via sewers or other lined channels where infiltration will not occur before the runoff from the impervious area reaches the stream. The directly connected impervious percentage for each land use type varied from 20 to 50% of the total impervious percentage. **Table 1.3.3** shows the curve number and the percentage directly connected impervious area (%DCIA) by land use type.

Table 1.3.3: Curve Number and Directly Connected Impervious by Land Use Type

NIPC 2001 Land Use Code	Land Use Description	A	B	C	D	A/D	B/D	C/D	%DCIA
11	Open Water	100	100	100	100	100	100	100	0
21	Developed, Open Space	37	58	70	76	57	67	73	0
22	Developed, Low Intensity	51	67	76	81	66	74	78	5
23	Developed, Medium Intensity	58	71	79	83	70	77	81	7
24	Developed, High Intensity	78	84	87	88	83	86	88	37
31	Barren Land	72	81	85	86	79	84	86	0
41	Deciduous Forest	29	52	67	73	51	63	70	0
42	Evergreen Forest	29	52	67	73	51	63	70	0
43	Mixed Forest	29	52	67	73	51	63	70	0
52	Shrub/Scrub	29	46	62	69	49	57	66	0
71	Grassland	37	58	70	76	57	67	73	0
81	Pasture/Hay	29	55	67	74	51	65	71	0
82	Cultivated Crops	64	74	81	85	74	79	83	0
90	Woody Wetlands	46	64	73	79	62	71	76	0
95	Emergent Wetlands	65	75	82	85	75	80	83	0
1110	1110 RES/SF	54	68	77	82	68	75	80	6
1120	1120 RES/FARM	46	63	74	79	63	71	77	3
1130	1130 RES/MF	54	68	77	82	68	75	80	6
1140	1140 RES/MOBILE HM	73	81	86	87	81	85	86	13
1211	1211 MALL	85	87	89	90	87	89	90	40
1212	1212 RETAIL CNTR	85	87	89	90	87	89	90	40
1221	1221 OFFICE CMPS	85	87	89	90	87	89	90	40
1222	1222 SINGL OFFICE	85	87	89	90	87	89	90	40
1223	1223 BUS. PARK	85	87	89	90	87	89	90	40
1231	1231 URB MX W/PRKNG	85	87	89	90	87	89	90	40
1232	1232 URB MX NO PRKNG	77	84	86	88	83	86	87	35
1240	1240 CULT/ENT	85	87	89	90	87	89	90	40
1250	1250 HOTEL/MOTEL	85	87	89	90	87	89	90	40
1310	1310 MEDICAL	77	84	86	88	83	86	87	35
1320	1320 EDUCATION	77	84	86	88	83	86	87	35
1330	1330 GOVT	85	87	89	90	87	89	90	40
1340	1340 PRISON	77	84	86	88	83	86	87	35
1350	1350 RELIGOUS	85	87	89	90	87	89	90	40
1360	1360 CEMETERY	37	58	70	76	57	67	73	0
1370	1370 INST/OTHER	46	63	74	79	63	71	77	3
1410	1410 MINERAL EXT	72	81	85	86	80	84	86	0
1420	1420 MANUF/PROC	77	84	86	88	83	86	87	35
1430	1430 WAREH/DIST/WHOL	77	84	86	88	83	86	87	35
1440	1440 INDUST PK	77	84	86	88	83	86	87	35
1511	1511 INTERSTATE/TOLL	79	85	87	89	84	86	88	0

Table 1.3.3: Curve Number and Directly Connected Impervious by Land Use Type

NIPC 2001 Land Use Code	Land Use Description	A	B	C	D	A/D	B/D	C/D	%DCIA
1512	1512 OTHER ROADWY	79	85	87	89	84	86	88	35
1520	1520 OTH LINEAR TRAN	72	81	85	86	80	84	86	0
1530	1530 AIR TRANSPORT	66	76	82	85	75	80	84	0
1540	1540 INDEP AUTO PRK	85	87	89	90	87	89	90	40
1550	1550 COMMUNICATION	64	73	79	83	73	78	81	0
1560	1560 UTILITIES/WASTE	72	81	85	86	80	84	86	0
2100	2100 CROP/GRAIN/GRAZ	64	73	79	83	73	78	81	0
2200	2200 NRSRY/GRNHS/ORC	64	73	79	83	73	78	81	0
2300	2300 AG/OTHER	64	73	79	83	73	78	81	0
3100	3100 OPENSP REC	37	58	70	76	57	67	73	0
3200	3200 GOLF COURSE	37	58	70	76	57	67	73	0
3300	3300 OPENSP CONS	37	58	70	76	57	67	73	0
3400	3400 OPENSP PRIVATE	37	58	70	76	57	67	73	0
3500	3500 OPENSP LINEAR	37	58	70	76	57	67	73	0
3600	3600 OPENSP OTHER	37	58	70	76	57	67	73	0
4110	4110 VAC FOR/GRASS	37	58	70	76	57	67	73	0
4120	4120 WETLAND	29	55	67	74	51	65	71	0
4210	4210 CONST RES	72	81	85	86	80	84	86	0
4220	4220 CONST NONRES	72	81	85	86	80	84	86	0
4300	4300 OTHER VACANT	37	58	70	76	57	67	73	0
5100	5100 RIVERS/CANALS	100	100	100	100	100	100	100	0
5200	5200 LAKE/RES/LAGOON	100	100	100	100	100	100	100	0
5300	5300 LAKE MICHIGAN	100	100	100	100	100	100	100	0
9999	9999 OUT OF REGION	100	100	100	100	100	100	100	0

1.3.2.1.1 Unit Hydrograph Determination

The Clark's unit hydrograph method was used in the HEC-HMS model. The methodology used to compute the Clark's unit hydrograph parameters is described in the USGS publication Water Resources Investigation 82-22 titled "A Technique for Estimating Time of Concentration and Storage Coefficient Values for Illinois Streams." The length of the longest flow path and slope between the 10 and 85% points along the flow path were estimated using the ArcHydro extension. The regional factor for the relationship between R/(Tc + R) was set at 0.7. The equation used to determine Tc + R is shown below:

$$(Tc + R) = 35.2 \times L^{0.39} \times S^{-0.78}$$

1.3.2.1.2 Rainfall Data

Historic rainfall data for the calibration storms was obtained from the Illinois State Water Survey (ISWS) Cook County Network, National Weather Service (NWS), USGS, and the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS).

The storm periods modeled were the July 17-23, 1996; July 20-25, 2003; May 29-June 5, 2004; April 15-21, 2006; April 24-30, 2007; August 22-27, 2007; and September 11-20, 2008. The storms used for calibration varied by tributary watershed.

ISWS Bulletin 71 "Rainfall Frequency Atlas of the Midwest" was used to obtain the rainfall data for storm durations of 1 hour to 48 hours for the 2- through 100-yr frequencies. The Bulletin 71 data was used for the design storms used in evaluating the current flooding conditions and the benefits of the proposed alternatives. **Table 1.3.4** lists the rainfall depths for the 2- through 500-year frequency for a 48-hour duration.

Table 1.3.4: Rainfall Depths

Recurrence Interval (year)	48-hr Duration Rainfall Depth (inches)*
2	3.30
5	4.09
10	4.81
25	5.88
50	6.84
100	8.16
500	12.0[a]

*Aerial reduction factor not applied

[a] 500-year rainfall depth was determined based on a logarithmic relationship between rainfall depth and recurrence interval.

1.3.3 Storm Duration

A critical duration analysis was performed to determine the storm duration that generally results in higher water surface estimates for a range of tributary sizes within the Little Calumet River Watershed. The critical storm duration varied by tributary watershed. For several watersheds, more than one critical duration was used in the analysis. These watersheds had existing flood control reservoirs located within the watershed that controlled flooding to some extent downstream and resulted in longer duration storms being more critical downstream of the reservoirs. The 48-hr storm was the critical duration for Little Calumet River, Plum Creek, and the downstream portion of all the other tributary watersheds. The critical duration varied for the upstream portions of the tributary watersheds. **Table 1.3.5** lists the critical durations by subwatershed.

Table 1.3.5: Critical Duration by Tributary Watershed

Subwatershed	100 Year Critical Durations (hr)
Butterfield Creek	12 and 48
Deer Creek	48
Calumet-Union Drainage Ditch	6 and 48
Little Calumet River	48
Midlothian Creek	12 and 48
North Creek	12 and 48
Plum Creek/Hart Ditch	48
Thorn Creek	6 and 48

1.3.4 Areal Reduction Factor

The Bulletin 71 rainfall amounts for the various duration and frequency storm events were adjusted based on an average tributary watershed size of 25 square miles. The areal reduction factors for the various storm durations are shown in **Table 1.3.6**

Table 1.3.6: Areal Reduction Factors for Various Storm Durations

Storm Duration	Areal Reduction Factor (25 sq mi)	Areal Reduction Factor (400 sq mi)
1 hour	0.87	-
3 hour	0.93	-
6 hour	0.94	-
12 hour	0.96	-
24 hour	0.97	-
48 hour	0.98	0.94
72 hour	0.98	-

For the Little Calumet River, the 25 square mile watershed areal reduction factor was not correct in modeling the critical duration storms. This resulted in over predicted stages and flows along the Little Calumet River. The drainage area at the USGS South Holland gage is 208 square miles and the entire Little Calumet River drainage area is approximately 605. The tributary and local runoff hydrographs to the Little Calumet River were multiplied by 0.96 to adjust the flow rates to match the areal reduction factors for 400 square miles.

1.3.5 Hydrologic Routing

Hydrologic routings were performed for the portions of the tributary watersheds located in Will County, Illinois and Lake, Porter, and LaPorte Counties, Indiana. The Muskingum-Cunge method was used for channel routings. An 8-point cross section was determined using the DEM developed for the watershed delineation and USGS 7.5-minute quadrangle maps. Manning's n-values were estimated from aerial photos. A modified Puls reservoir routing was used to simulate Lake George on Deep River.

Hydrologic routings were also used in the CSO areas tributary to the Little Calumet River and Calumet-Union Drainage Ditch. A 3-point curve was established for each of the CSO areas that limited the peak flow from the CSO area to the maximum capacity of the outfall at the TARP drop shaft. The capacities of the outfalls at the TARP drop shafts were obtained from the Corps of Engineers TARP models used for the design of the Thornton Composite Reservoir. The Thornton Composite Reservoir volume reserved for CSO volumes was prorated to each of the CSO areas based on drainage area. This volume was diverted from the CSO runoff hydrographs when generating the runoff hydrographs from the CSO areas.

1.3.6 Hydraulic Model Setup

Hydraulic model data typically was developed through field surveys with some additional definition of channel overbank areas and roadway crests defined using Cook County topographic data. Cross section locations were developed in HEC GeoRAS, and surveyed channel geometry were inserted into topographically generated cross-sectional data. Cross sections were generally surveyed at intervals of 500 to 1,000 feet. Interpolated cross sections were added at many locations to the models to increase stability and reduce errors. Bridges, culverts, and other major hydraulic structures were surveyed within the hydraulic model extent. The locations of all surveyed and modeled cross sections, bridges, culverts, and other structures are shown in a figure within **Appendix D**.

1.3.6.1 Bridges, Culverts, and Hydraulic Structures

Bridges, culverts, and hydraulic structures were surveyed consistent with FEMA mapping protocol as identified in *Guidelines and Specifications for Flood Hazard Mapping Partners*, "Guidance for Aerial Mapping and Surveying" (FEMA 2003). A State of Illinois licensed professional land surveyor certified each location as FEMA compliant. Documentation of certifications is provided in **Appendix D**. Bridges, culverts, and hydraulic structures were surveyed consistent with the NAVD 1988 datum using 5-centimeter or better Global Positioning System (GPS) procedures (as specified in NGS-58 for local network accuracy) or third-order (or better) differential leveling, or trigonometric leveling for short distances. In a few cases, information from construction plans was used for recently constructed bridges in lieu of surveying. Ineffective flow areas were placed at cross sections upstream and downstream of crossings, generally assuming a contraction ratio of 1:1 and an expansion ratio of 2:1. Contraction and expansion coefficients generally were increased to 0.3 and 0.5, respectively, at cross sections adjacent to crossings.

1.3.6.2 Cross-Sectional Data

Cross-sectional data was surveyed consistent with FEMA mapping protocol as identified in *Guidelines and Specifications for Flood Hazard Mapping Partners*, "Guidance for Aerial Mapping and Surveying" (FEMA 2003).

All survey work, including survey of cross sections, was certified as compliant to FEMA mapping protocol by a licensed professional land surveyor. Documentation of certifications is provided in **Appendix D**. Cross sections were surveyed consistent with the North American Vertical Datum, 1988 (NAVD 1988) using 5-centimeter or better GPS procedures (as specified in NGS-58 for local network accuracy) or third-order (or better) differential leveling, or trigonometric leveling for short distances. Cross sections were interpolated at many locations within the hydraulic models, to aid model stability and reduce errors.

1.3.6.3 Boundary Conditions

A downstream boundary condition was used at the most downstream cross section for each subwatershed model. In most cases, normal depth was used. In situations where a backflow condition existed at the downstream end of the reach, a stage hydrograph generated by the subbasin model for the receiving reach was entered as the boundary condition. Boundary conditions for each subwatershed are further defined in the individual tributary sections in **Section 3**.

1.3.6.4 Model Run Settings

All hydraulic model simulations were carried out using the fully dynamic, unsteady flow simulation settings within HEC-RAS. The Saint-Venant equations, or the continuity and momentum balance equations for open channel flow, were solved using implicit finite difference schemes. HEC-RAS has the ability to model storage areas and hydraulic connections between storage areas and between stream reaches. The computational time step for model runs varied between 1 and 60 seconds, as necessary for model stability.

1.3.7 Model Calibration and Verification

A detailed calibration was performed for each subwatershed using historic gage records under the guidelines of the CCSMP. A minimum of three historical storms were used for calibration and verification. Runoff hydrographs from each historical storm were routed through the HEC-RAS hydraulic models for each subwatershed. The peak flow rate, hydrograph shape and timing, and total volume matched were compared between the observed hydrographs and the model output. During calibration, the curve number, directly connected impervious area percentage, and storage coefficients were adjusted so the modeled hydrographs were within the CCSMP's criteria of peak flow (within 30%) and peak stage (within 0.5 foot) of observed data.

To aid in calibration, high water mark data was collected from the Illinois Department of Natural Resources (IDNR), USGS, and from survey information collected after the September 2008 storm event. The peak stages reported by the various sources were compared to those predicted by the hydraulic model. This provided a verification of stages at locations other than those with reporting gages.

Subwatershed-specific explanations of model calibration and verification are included in **Section 3** for each tributary.

1.3.8 Flood Inundation Mapping

Flood inundation maps were produced to display the inundation areas associated with the 100-year event. The flood inundation maps were produced by overlaying the results of the hydraulic modeling on the ground elevation model of the watershed, which was derived from Cook County LiDAR data.

1.3.9 Discrepancies Between Inundation Mapping and Regulatory Flood Maps

Discrepancies may exist between inundation mapping produced under this DWP and regulatory flood maps. Discrepancies may be the result of updated rainfall data, more detailed topographic information, updated land use data, and differences in modeling methodology. A discussion of discrepancies is included in **Appendix A**.

1.3.10 Model Review

The hydrologic and hydraulic models developed under this DWP were independently reviewed by Christopher B. Burke Engineering, Ltd (CBBEL). CBBEL's review of the hydrologic models included a general verification of drainage areas, subbasin divides, and hydrologic model parameters such as Curve Number and time of concentration. CBBEL's review of the hydraulic models included a general verification of roughness values, bank stations, ineffective flow areas, hydraulic structures, boundary conditions and connectivity with the hydrologic model output files. A recommendation from the independent review was to calibrate the models to a large storm event which occurred in the watershed in mid September, 2008. This and other recommendations from the independent review have been addressed in the hydrologic and hydraulic models developed to support the Little Calumet River DWP.

1.3.11 Problem Area Identification

Problem area data for the Little Calumet River Watershed was generated from two sources. The first was community, agency and stakeholder response data that identified flooding, erosion, water quality, and maintenance problems recognized by the communities to be problems. In addition, problem areas were identified by overlaying the results of H&H modeling on the ground elevation model of the watershed to identify structures at risk of flooding along regional waterways. Modeled problems generally corroborated the communities' reported problems; however, in many instances the model results also showed additional areas at risk of flooding for larger magnitude events. A secondary source of problem area identification was the existing FEMA FIRM panel maps. Areas shown within FEMA floodplain were carefully considered in H&H modeling and communication with communities in order to identify problem areas.

1.3.12 Economic Analysis

1.3.12.1 Flood Damages

Property damages due to flooding were assessed based upon the intersection of inundation areas for modeled recurrence intervals (2-, 5-, 10-, 25-, 50-, and 100-year) with the Cook County parcel data, considering ground elevation data, to calculate estimated flood depths. Damages were estimated using a methodology consistent with one developed by the USACE that estimates structure and contents damage as a fraction of structure value and based upon the estimated depth of flooding (USACE 2003). The general procedure for estimating property damage due to flooding is outlined in the CCSMP. This method of damage calculation requires estimating a number of parameters for properties at risk of flooding which are detailed below.

The foundation for property damage values due to flooding is derived from the 2006 Cook County Tax Assessor (CCTA) data multiplied by a standard factor derived from a statistical analysis comparing recent sales data to the CCTA property values. The CCTA data includes tax assessed value of land, improvements, total tax assessed value, structure class (residential single family, multi-family, industrial etc.), number of stories, basement information, land area (square footage), and other data fields not relevant to this study.

1.3.12.2 Identification of Parcels at Risk of Flooding

Parcel boundaries were converted to points within the GIS application, and then the points were moved to the low side of structures at risk of flooding. Intersection of floodplain boundaries with parcel data was then performed for each modeled recurrence interval storm and used to identify parcels within the subwatershed that may, based upon their zero-damage elevations, be subject to property damage due to flooding for a particular recurrence interval.

1.3.12.3 Parcel Zero-Damage Elevation

Structures do not incur damage due to flooding until the water surface exceeds the zero-damage elevation, at which water is assumed to begin flowing into the structure and causing damages. For most structures, the zero-damage elevation is the ground surface. Floodwaters exceeding the ground surface may enter the structure through doorways, window wells, and other openings within the structure. The zero-damage elevation was assumed to be the ground elevation for all parcels within the Little Calumet River Watershed. The ground elevation estimate was obtained at the point representing the parcel, generally on the lower, stream-side of the actual structure.

1.3.12.4 Parcel First Floor Elevation

USACE depth-damage curves relate flooding depths to the first floor elevation of the structure, a value not provided within the CCTA data. First floor elevations (FFE) generally were not surveyed for the Little Calumet River DWP, as that would require several thousand measurements. During field reconnaissance, the typical structure in the residential area and a typical height above ground was determined near each stream crossing. This information was used to estimate the first floor elevations for the inundated parcels.

1.3.12.5 Estimated Structure Value

The estimated value of flooded structures is an input to damage calculations. The CCTA data identified land value as well as the improvement value (i.e., building, garage, etc.). The values in the CCTA data are assessed valuations of the estimated property value, which require a factor to bring the value, depending on the structure's use, to the CCTA estimation of property value. For example, residential structures receive an assessed valuation of 16 percent, thus the value identified by CCTA is the CCTA estimated value divided by a standardized value of 0.16. The adjusted CCTA data (reported values divided by the assessed valuation factor) was then compared with recent sales data throughout the county to statistically derive a multiplier that brings the 2006 CCTA estimated value of the properties to 2008 market value. This multiplier was calculated to be 1.66. Since this plan analyzes damage to structures, the land component of the property value was removed from the analysis by applying the assessed valuation multiplier and the District calculated market value multiplier to the improvement value identified in the CCTA data to produce a value of the structure. This method was used on all property types to generate information to be used in the damage calculations.

1.3.12.6 Depth-Damage Curves

Six residential depth-damage curves were obtained from the USACE technical guidance memorandum EGM 04-01 (USACE, 2003) to relate estimated structure and contents damage to structure replacement value as a function of flooding depth. These damage curves are one story, two-story, and split-level resident structures, either with or without basements. For non-residential structures, a depth-damage curve representing the average of structure and contents depth-damage curves for a variety of structure types, generated by the Galveston District of the USACE was selected for use. **Appendix F** contains the depth-damage curves used to calculate property damage due to flooding. CCTA data was analyzed to identify the number of stories on residential structures and the presence or absence of a basement.

1.3.12.7 Property Damage Calculation

The estimated structure value, flooding depth, and depth-damage curve information were used to estimate the property damage from flooding for a specific structure due to a storm of given recurrence interval. Higher magnitude events, such as the 100-year event, cause higher damages for flooded properties but also have a lower likelihood of occurring in a given year. **Figure 1.3.1** shows the hypothetical relationship between expected damage and modeled recurrence interval. Estimated annual damages were calculated according to the CCSMP, essentially weighting the expected annual damages by their annual probability of occurrence. Damages were then capitalized over a 50-year period of analysis, consistent with the period of analysis over which maintenance and replacement costs were calculated, using the federal discount rate for 2008 of 4.875 percent.

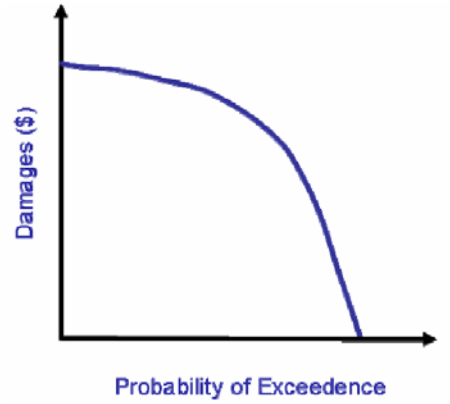

Figure 1.3.1: Hypothetical Damage-Frequency Relationship

1.3.12.8 Erosion Damages

Locations of potential erosion risk were identified through community response data. The CCSMP contains direction that erosion damages be estimated as the full value of structures at "imminent risk" of damage due to stream bank erosion, and that erosion damages not be assessed for loss of land. Field visits to areas identified as erosion problems were performed. Properties and infrastructure were judged to be at risk if they were located within 30 feet of a site of active erosion, characterized by exposed earth, lack of vegetation, or collapsing banks. The estimated market value of the structure derived from CCTA data was used to estimate erosion damages for structures deemed at imminent risk. For infrastructure other than property at risk, such as roads and utilities, an estimate of the replacement value of these structures was used to assess erosion damages.

1.3.12.9 Transportation Damages

Transportation damage generally was estimated as 15 percent of property damage due to flooding. In some specific instances, significant transportation damages may occur in absence of attendant property damage due to flooding. For the Little Calumet River Watershed, specific transportation damages were calculated when flooding fully blocked all access to a specific area in the watershed and these damages were not adequately captured as a fraction of property damages. In such instances, transportation damages were calculated according to FEMA guidance in the document "What Is a Benefit?" (FEMA, 2001). The duration of road closure was estimated for the modeled storms, and transportation damage was calculated according to a value of $32.23 per hour of delay per vehicle based on average traffic counts.

1.3.13 Alternative Development and Evaluation

Potential stormwater improvements, referred to within the DWP as alternatives, were developed using a systematic procedure to screen, develop, and evaluate technologies consistently throughout the Little Calumet River Watershed. Tributary-specific technologies were screened and evaluated in consideration of the stormwater problems identified through community response data and modeling. An alternative is a combination of the technologies developed to address the identified stormwater problems. In many instances, communities had ideas or suggestions regarding potential resolution of their stormwater problems, and these ideas were solicited during workshops and subsequent comment periods and were considered during alternative development.

Alternatives were evaluated with respect to their ability to reduce flooding, erosion, and other damages under existing conditions. The reduction in expected damages for an alternative was called a benefit. Conceptual level costs were developed for each alternative using countywide unit cost data that considered expected expenses such as land acquisition, excavation, pipe costs, channel lining, etc. Standard countywide markups were used to account for the cost of utility relocation, design engineering and construction management costs, profit, and contingency. Expected maintenance and replacement costs were considered over a 50-year design period. Detailed design studies are required to confirm details associated with the feasibility of construction and precise configuration of proposed facilities.

Additional non-economic factors, such as the number of structures protected, the expected water-quality benefit, and the impact on wetland or riparian areas were considered in alternative development and evaluation.

1.3.13.1 Flood Control

Flood control technologies were considered during the development of alternatives for addressing flooding problems, as summarized in **Table 1.4.1**. After selection of an appropriate technology or technologies for a problem area, and review of information provided by communities and obtained from other sources (such as aerial photography and parcel data) regarding potentially available land, conceptual alternatives were developed.

Hydrologic or hydraulic models for alternative conditions were created to analyze the effect of the conceptual alternatives. Initial model runs were performed to determine whether an alternative significantly affected water surface elevation (WSEL) near the target problem area, or had negative impacts in other parts of the tributary area. For models that resulted in significant reduction in WSEL, a set of alternative condition model runs was performed, and expected damages due to flooding were evaluated for the alternative conditions. Benefits were calculated based on damages reduced from existing to proposed conditions.

1.3.13.2 Floodproofing and Acquisition

Alternatives consisting of structural flood control measures may not feasibly provide a 100-year level of protection for all structures. The DWP identifies areas that will experience flooding at the 100-year event, even if recommended alternatives are implemented. Floodproofing and/or acquisition of such structures are non-structural flood control measures that may reduce or eliminate damages during flood events, which is why these measures are listed in **Table 1.4.1**. However, due to the localized nature of implementing such solutions, the District may look to address structures that are candidates for non-structural flood control measures under separate initiatives, outside of the Capital Improvement Program (CIP).

1.3.13.3 Streambank Stabilization

Streambank stabilization alternatives were developed to address problem areas where erosion problems on regional waterways were determined to threaten structures. Damages were calculated based on the value of the threatened structures. Streambank stabilization alternatives considered a range of alternative technologies as summarized in **Table 1.4.2**.

1.3.13.4 Water Quality

The potential effect of alternatives on water quality was considered qualitatively. Most detention basins built for flood control purposes have an ancillary water quality benefit because pollutants in sediment will settle out while water is detained. Sediments can be removed as a part of maintenance of the detention basin, preventing the pollutants from entering the waterway. Detention basins typically have a sediment forebay specifically designed for this purpose. Some detention basins could be designed as constructed wetland basins with wetland plants included which could naturally remove pollutants and excess nutrients from the basin. Streambank stabilization alternatives can help address water quality problems through reduction of sedimentation.

Table 1.4.1: Flood Control Technologies

Flood Control Option	Description	Technology Requirements
Detention/Retention		
Detention facilities (Dry basins)	Impoundments to temporarily store stormwater in normally dry basins	Open space, available land. Only an upstream option
Retention facilities (Wet basins)	Impoundments that include a permanent pool which stores stormwater and removes it through infiltration and evaporation. Retention facilities generally have an outfall to the receiving waterway that is located at an elevation above the permanent pool	Open space, available land. Only an upstream option
Pumped detention	Similar to detention or retention facilities, but includes a portion of the impoundment which cannot be drained by gravity and must be pumped out	Open space, available land. Only an upstream option. Best applied when significant area is available to allow for filling only during large storms
Underground detention	A specialized form of storage where stormwater is detained in underground facilities such as vaults or tunnels. Underground detention may also be pumped	Space without structures, available land. Only an upstream option. Significantly more expensive than above ground facilities. Surface disruption must be acceptable during construction

Table 1.4.1: Flood Control Technologies

Flood Control Option	Description	Technology Requirements
Bioretention	Decentralized microbasins distributed throughout a site or watershed to control runoff close to where it is generated. Runoff is detained in the bioretention facilities and infiltrated into the soil and removed through evapotranspiration	Open space, multiple available opportunities for various sizes of open space
Conveyance Improvement		
Culvert/bridge replacement	Enhancement of the hydraulic capacity of culverts or bridges through size increase, roughness reduction, and removal of obstacles (for example, piers)	Applicable only if restricted flow and no negative impact upstream or downstream. May require compensatory storage to prevent negative downstream impact. Permitting requirements and available adjacent land
Channel improvement	Enhancement of the hydraulic capacity of channels by enlarging cross sections (for example, floodplain enhancement), reducing roughness (for example, lining), or channel realignment	No negative upstream or downstream impact of increased conveyance capacity. Permitting requirements and available adjacent land. Permanent and/or construction easements
Flood Barriers		
Levees	Earth embankments built along rivers and streams to keep flood waters within a channel	Permitting requirements and available adjacent land. Wide floodplains will be analyzed. Requires 3 feet of freeboard to remove structures behind levees from regulatory floodplain. Often requires compensatory storage
Floodwalls	Vertical walls typically made of concrete or other hard materials built along rivers and streams to keep flood waters within a channel	Permitting requirements and available adjacent land. Permanent and/or construction easements
Acquisition	Acquisition and demolition of properties in the floodplain to permanently eliminate flood damages. In some cases, acquired property can be used for installation of flood control facilities	Severe flooding, repetitive losses, other alternatives are not feasible
Floodproofing		
Elevation	Modification of a structure's foundation to elevate the building above a given flood level. Typically applied to houses	Severe flooding, repetitive losses, other alternatives are not feasible
Dry floodproofing	Installation of impermeable barriers and flood gates along the perimeter of a building to keep flood waters out. Typically deployed around commercial and industrial buildings that cannot be elevated or relocated	Better suited for basement or shallow flooding. Need the ability to provide closure of openings in walls or levees. Plan for emergency access to permit evacuation

Table 1.4.1: Flood Control Technologies

Flood Control Option	Description	Technology Requirements
Wet floodproofing	Implementation of measures that do not prevent water from entering a building but minimize damages; for example, utility relocation and installation of resistant materials	Most applicable for larger buildings where content damage due to flooding can be minimized. Waterproofing sealant applied to walls and floors, a floor drain and sump pump

Table 1.4.2: Streambank Stabilization Technologies

Streambank Stabilization Option	Description	Technology Requirements
Natural (vegetated or bioengineered) stabilization	The stabilization and protection of eroding overland flow areas or stream banks with selected vegetation using bioengineering techniques. The practice applies to natural or excavated channels where the stream banks are susceptible to erosion from the action of water, ice, or debris and the problem can be solved using vegetation. Vegetative stabilization is generally applicable where bankfull flow velocity does not exceed 5 ft/sec and soils are more erosion resistant, such as clayey soils. Combinations of the stabilization methods listed below and others may be used	Requires stream bank slopes flat enough to prevent slope failure based upon underlying soils. Channels with steep banks with no room for expansion or high bank full velocities (> 5 ft/sec) should avoid these technologies
Vegetating by sodding, seeding, or planting	Establishing permanent vegetative cover to stabilize disturbed or exposed areas. Required in open areas to prevent erosion and provide runoff control. This stabilization method often includes the use of geotextile materials to provide stability until the vegetation is established and able to resist scour and shear forces	
Vegetated armoring (joint planting)	The insertion of live stakes, trees, shrubs, and other vegetation in the openings or joints between rocks in riprap or articulated block mat (ABM). The object is to reinforce riprap or ABM by establishing roots into the soil. Drainage may also be improved through extracting soil moisture	

Table 1.4.2: Streambank Stabilization Technologies

Streambank Stabilization Option	Description	Technology Requirements
Vegetated cellular grid (erosion blanket)	Lattice-like network of structural material installed with planted vegetation to facilitate the establishment of the vegetation, but not strong enough to armor the slope. Typically involves the use of coconut or plastic mesh fiber (erosion blanket) that may disintegrate over time after the vegetation is established	
Reinforced grass systems	Similar to the vegetated cellular grid, but the structural coverage is designed to be permanent. The technology can include the use of mats, meshes, interlocking concrete blocks, or the use of geocells containing fill material	
Live cribwall	Installation of a regular framework of logs, timbers, rock, and woody cuttings to protect an eroding channel bank with structural components consisting of live wood	
Structural stabilization	Stabilization of eroding stream banks or other areas by use of designed structural measures, such as those described below. Structural stabilization is generally applicable where flow velocities exceed 5 ft/sec or where vegetative stream bank protection is inappropriate	Applicable to areas with steep stream bank slopes (> 3:1) and no room for channel expansion, or areas with high velocities (> 5 ft/sec) can benefit from this technology
Interlocking concrete	Interlocking concrete may include A-Jacks®, ABM, or similar structural controls that form a grid or matrix to protect the channel from erosion. A-Jacks armor units may be assembled into a continuous, flexible matrix that provides channel toe protection against high velocity flow. The matrix of A-Jacks can be backfilled with topsoil and vegetated to increase system stability and to provide in-stream habitat. ABM can be used with or without joint planting with vegetation. ABM is available in several sizes and configurations from several manufacturers. The size and configuration of the ABM is determined by the shear forces and site conditions of the channel	

Table 1.4.2: Streambank Stabilization Technologies

Streambank Stabilization Option	Description	Technology Requirements
Riprap	A section of rock placed in the channel or on the channel banks to prevent erosion. Riprap typically is underlain by a sand and geotextile base to provide a foundation for the rock, and to prevent scour behind the rock	
Gabions	Gabions are wire mesh baskets filled with river stone of specific size to meet the shear forces in a channel. Gabions are used more often in urban areas where space is not available for other stabilization techniques. Gabions can provide stability when designed and installed correctly, but failure more often is sudden rather than gradual	
Grade control	A constructed concrete channel designed to convey flow at a high velocity (greater than 5 ft/sec) where other stabilization methods cannot be used. May be suitable in situations where downstream areas can handle the increase in peak flows and there is limited space available for conveyance	
Concrete channels	Prevent stream bank erosion from excessive discharge velocities where stormwater flows out of a pipe. Outlet stabilization may include any method discussed above	