Economic Appendix B

Rahway River Basin (Fluvial), New Jersey Flood Risk Management Findings Report

September 2025

New Jersey
Department of
Environmental Protection

U.S. Army Corps of Engineers
New York District

Introduction

This appendix was prepared to document procedures and results of the economic flood damage analysis for the report of findings for Rahway River Basin (fluvial), New Jersey. This appendix presents the findings of economic damage assessments for the municipalities of Cranford, Kenilworth, Springfield, Union, and Millburn along the Rahway River, the City of Rahway along the Robinsons Branch, and the Eastern Branch.

Economic analyses include the development of stage versus damage relationships and annual damages over a 50-year analysis period, from year 2030 to year 2080. Damage assessments include inundation damages to structure and contents and vehicles.

Estimates of without-project damages and with-project damages are based on March 2024 price levels and a 50-year period of analysis, damages have been annualized over the 50-year project life using the 2025 fiscal year Federal water resource studies discount rate of 3%.

For the purposes of this report, the study area is divided into three areas: Cranford/Upstream covering municipalities of Cranford, Kenilworth, Springfield, Union, Millburn, Robinson's Branch covering the City of Rahway, and the Eastern Branch covering towns of Millburn, Union, Maplewood, and South Orange.

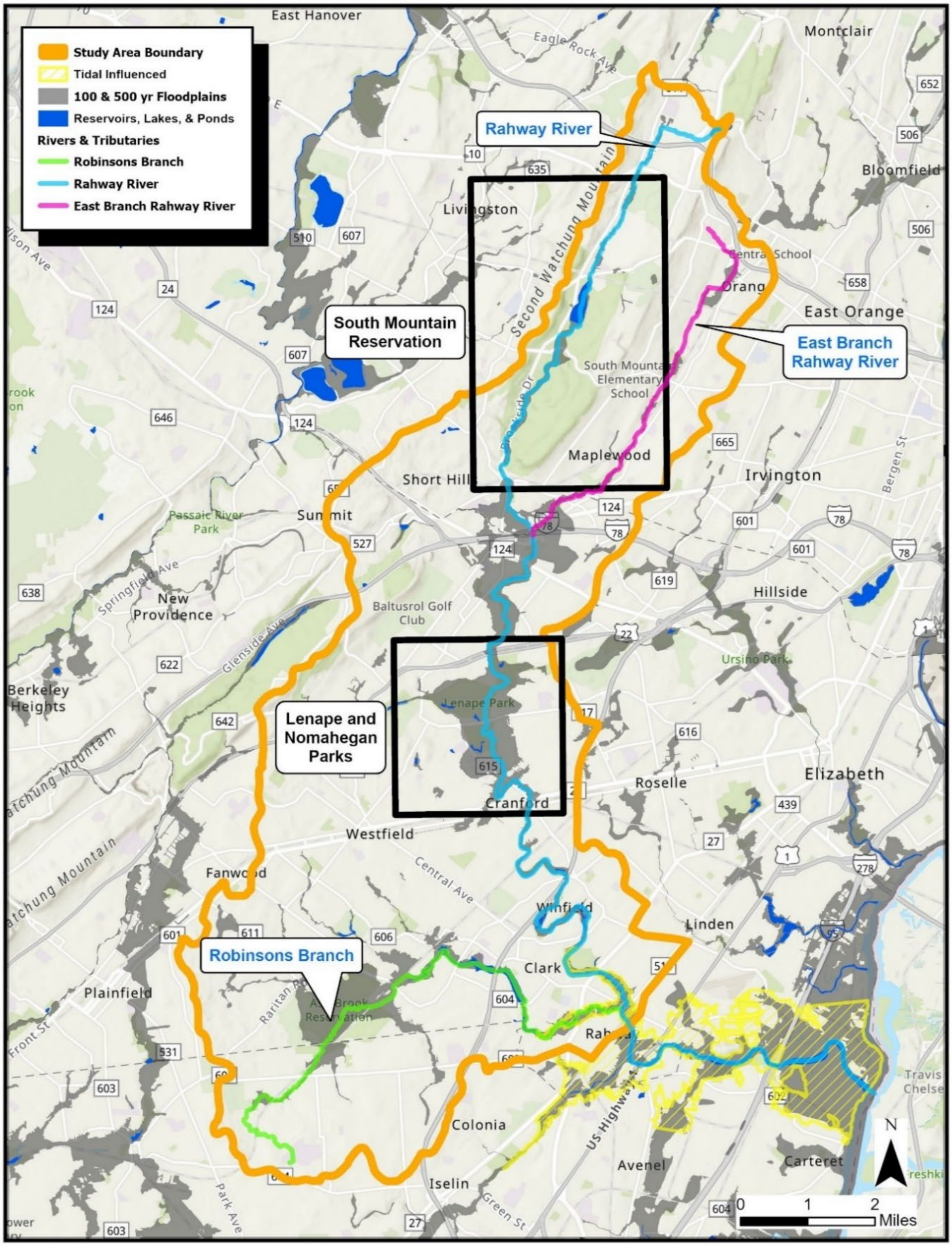
1. Description of Study Area

1.1 Location and Setting

The Rahway River Basin is in northeastern New Jersey. It lies within the metropolitan area of Greater New York City and occupies approximately 15 percent of Essex County, 35 percent of Union County, and 10 percent of Middlesex County. The basin is 83.3 square miles (53,300 acres) in area and is roughly crescent-shaped. Its greatest width is approximately 10 miles in the east-west direction, from the City of Linden to the City of Plainfield. Its greatest length is approximately 18 miles in a north–south direction, from West Orange to Metuchen. The tidal influence on the Rahway River extends roughly 5 miles from the Arthur Kill into the City of Rahway. The dividing line is the rail track in the city of Rahway.

The Rahway River consists of the mainstem Rahway River and four branches. The West Branch flows south from West Orange through South Mountain Reservation and downtown Millburn. The East Branch also originates in West Orange and Montclair and travels through South Orange and Maplewood. These two branches converge near Route 78 in Springfield to form the mainstem of the Rahway River. The Rahway River flows through the municipalities of Springfield, Union, Cranford, and Clark before traveling through the City of Rahway. The Rahway River receives the waters of Robinson's Branch at Elizabeth Avenue between West Grand Avenue and West Main Street and the waters of the South Branch at East Hazelwood Avenue and Leesville Avenue before it leaves the City of Rahway and enters the city limits of Linden and Carteret. The Rahway River then flows into the Arthur Kill. Figure 1 below shows the Rahway River Basin/Study Area.

FIGURE 1: RAHWAY RIVER BASIN STUDY AREA



1.2. Historical Flood Events

Storm events in the Rahway River Basin which caused significant damage are the storms of July 1938, May 1968, August 1971, August 1973, November 1977, July 1979, June 1992, October 1996, July 1997, Tropical Storm Floyd in September 1999, April 2007 Tropical Storm Irene in August 2011, and Tropical Storm Ida in 2021

Tropical Storm Floyd

Rainfall totals from Tropical Storm Floyd in September 1999 were as high as 12 to 16 inches over portions of New Jersey, 4 to 8 inches over southeastern New York, and up to 11 inches over portions of New England. Tropical Storm Floyd resulted in new flood peaks of record at sixty or more stream gages within the portions of New Jersey and New York contained by New York District's Civil Works boundaries. Within the Rahway River basin, the total rainfall at Cranford, NJ was 10.82 inches. This resulted in flows approaching the 100-year level in portions of the Rahway River Basin.

April 2007 Northeaster

The April 2007 northeaster caused about three to ten inches of rain to fall on the watersheds within the New York District's Civil Works boundaries in April 2007, resulting in new flood peaks of record at ten USGS gages in New Jersey. The approximate rainfall of the total rainfall of the April 2007 northeaster over the watersheds of the New York District was an average of 7 to 7 ½ inches. Within the Rahway River basin, the total rainfall at Cranford was 6.47 inches. This resulted in flows from greater than the 25 to greater than the 50-year level in portions of the Rahway River Basin.

Tropical Storm Irene

Tropical Storm Irene began as a tropical wave off the West African coast on 15 August 2011. Tropical Storm Irene had weakened to a tropical storm with winds of 65 mph by the time of its 18 August New York landfall.

Significant damages occurred in north and central New Jersey, where flooding was widespread. Severe flooding took place on the Raritan, Millstone, Rockaway, Rahway, Delaware, and Passaic Rivers due to record rainfall. The flooding affected roads and ten deaths within the state are attributable to the storm.

In addition to major flooding, the combination of already heavily saturated ground from a wet summer, and heavy wind gusts made New Jersey especially vulnerable to wind damage. One of the hardest hit areas due to high winds was Union County, part of the Rahway River Basin. Fallen trees, many pushed from the soaked ground with their roots attached, blocked vital roads from being accessed by local emergency services. Numerous homes suffered structural damages from the winds, and limbs impacting their roofs. Perhaps the most critical damage however due to wind was fallen wires. Around Union County, fallen wires in combination with flooded electrical substations left parts of

Union County, including Cranford, Garwood, and Westfield without power or phone service for nearly a week. In total, approximately 1.46 million customers of Jersey Central Power & Light (JCP&L) and Public Service Enterprise Group (PSEG) throughout most of the 21 counties lost power.

Tropical Storm Ida

Tropical Storm Ida moved through the state of New Jersey in a flood and tornado event. The historic flooding caused severe damage and devastation to private property, automobiles, structures, public facilities, and transportation networks in parts of Bergen, Essex, Gloucester, Hunterdon, Mercer, Middlesex, Passaic, Somerset, Sussex, and Union. On September 2, 2021. An EF3 tornado destroyed multiple homes in Mullica Hill, New Jersey. The same storm produced an EF1 tornado that tracked from Edgewater Park, New Jersey, to Bristol, Pennsylvania, and prompted a rare tornado emergency for Bristol and Croydon, Pennsylvania, as well as Burlington, New Jersey. Portions of Trenton, New Jersey, were evacuated due to flooding caused by the storm. At least 27 people died in New Jersey, including one person who drowned inside their car in Passaic, New Jersey, and five others who died in their apartment complex in Elizabeth, New Jersey. Over 81,740 power outages were reported on the night of September 1 in New Jersey. In Hunterdon County rain fall topped 11 inches. Six people were killed and 300 plus people were rescued from the flood waters. New Jersey Task Force One and the Burlington County OEM responded to assist local agencies with over 300 water rescues. One victim's truck was swept 1.8 miles downstream in Milford.

One year after the federal disaster declaration more than $873.6 million in federal funds have been provided to New Jersey to aid in their recovery. Funds include grants from FEMA through its Individuals and Households and Public Assistance programs, low-interest disaster loans from the U.S. Small Business Administration and claim payments from the National Flood Insurance Program.

2. Data Preparation for Economic Analysis

Periodic storms have caused severe fluvial flooding along the Rahway River. There are three main areas with high flood risk, the Township of Cranford, Millburn, and the Robinsons Branch in Rahway. Flooding along the Rahway River in Cranford is caused by low channel capacity, constrictions of several bridges and dams along the river and two 90-degree bends forming a “U” turn at the Springfield Ave. just upstream of the center of the Township. The flood waters backup from the main Cranford area into the area of Lenape Park Detention Basin and Kenilworth Township. In the City of Rahway at Robinson’s Branch the high risk of flooding is due to low channel capacity, the constrictions of several bridges, and the backwater from the main stem of the Rahway River, which is independent of the hydraulic conditions in the Robinson’s Branch.

2.1 Delineation of Project Reaches

To conduct economic damage analyses for the without-project condition and alternative plans, the Cranford Upstream model area was divided into two streams containing a total of 74 economic reaches, including left and right banks. The Robinsons Branch model area, fluvial and compound contain 32 and 16 reaches, respectively. Finally the East Branch model area has 32 reaches. Streams, reach locations and the upstream and downstream limits of the reaches in the economic model were selected to be consistent with the hydrologic/hydraulic modeling and were mostly located at the location of bridges, existing levees, and hydraulic structures such as dams, so that the effects of these features could be modeled in detail. A summary of the economic reaches is presented in the addendum Table A.1 – A.4.

2.2 Structure Data

The data sources of the inventory data are NJ MODIV[1] shape file and National Structure Inventory (NSI)[2]. The properties are represented as tax lot (polygon) and points in MODIV and NSI, respectively. Since block and lot numbers are not available in NSI, the two datasets were merged by ArcGIS spatial-join function. The data was cross validated by logical tests. For instance, when the building class is 2 (residential house) in MODIV, but the damage category in NSI is not residential, Google Maps and other online real estate resources were used to verify and correct the occupancy types. Meanwhile, missing structures from NSI were identified by locating non-vacant land tax lots without a point. For instance, when the building class is 2 (residential house) in MODIV but there are no data points from NSI, Google Maps or other online real estate resources were used to verify and correct the property attributes. Outliers were identified by logical tests. The first cleansing procedure is removing structures with unreasonably large size. Single family houses were filtered for building size bigger than 5,000 square feet and verified with the MODIV online database. Parcels with unreasonably small size (smaller than 500 square feet for residential houses) were extracted, identified by a threshold of 500 square feet for residential houses. There were about 300 such parcels. These parcels were sampled via desktop survey and confirmed that the size was too small. Due to resource limitations, the size was corrected to 1,200 square feet and the structures were kept in the inventory.

For an unknown reason, NSI tends to assign a 1,000 square feet structure to vacant public property (property class 15C). They were deleted accordingly. Another limitation of this dataset is missing number of stories as MODIV does not provide this data field. It is likely that NSI sampled number of stories in the study area. This clearly has an implication on the accuracy of occupancy types.

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[1] https://nj.gov/njgin/edata/parcels/

[2] https://www.hec.usace.army.mil/confluence/nsi

First Floor Elevation (FFE) is derived by summing up the ground elevation (in feet) and foundation height. The former is estimated by LiDAR; and the latter are mapped into each foundation type. When foundation type is not available, NSI randomly assigns a foundation type using Federal Emergency Management Agency (FEMA) HAZUS data. These heights were estimated in a 2021 survey completed by USACE economists with each assumed height closely matching the median value from the survey. This process ignores elevated structures in the study area and could over-estimate potential damages as in reality, more structures are elevated than are reflected in the inventory. Elevated buildings were identified from the FEMA Flood Mitigation Assistance (FMA) and Hazard Mitigation Grant Program (HMGP) list provided by the New Jersey Office of Emergency Management (NJOEM). In Cranford Upstream, 16 properties have received HMGP grants, with elevation certificates issued[3]. These federal grants would require the elevation height to be above water elevation of 1% event and the structures were modified in the inventory to reflect these changes.

2.3 Depreciated Replacement Value

The structure value is based on the RSMeans 2024 square foot cost manual. For mass appraisal purpose, only observable data can be used for computation[4]. The depreciated replacement cost is determined by occupancy types (41 categories)[5], construction types (5 categories - wood, masonry, steel, manufactured, and concrete) and size (2 categories) – a total of 410 categories. Size is a dummy variable of large (L) vs small (S) manual, it is classified as L, vice versa for small-sized properties. The table description of the 410 categories is available upon request. Each residential structure is depreciated by 1% per year for the first 20 years (straight line depreciation), after which it is assumed that routine maintenance would keep structure values at 80% of their replacement values. For commercial and public properties, the maximum depreciation is 30%.

The RSMeans square foot cost is an estimate for national average. The RSMeans manual appendix provides location adjustment for residential and commercial properties. There is no adjustment factor for Cranford and subsequently, Long Branch, NJ was used as a reference. The choice is dictated by location proximity. The adjustment factors are 1.13 and 1.1 for residential and commercial, respectively. The structure-contents value ratio of residential structure is one, according to the *Economic Guidance Memorandum (EGM) 01-03, "Generic Depth-Damage Relationships", December 4, 2000.*

Each structure is assigned to the nearest cross section line (not necessarily the nearest river station) and the associated water surface profile is used for damage calculation.

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[3] Fifteen properties are in Cranford and one at Springfield.

[4] For instance, square foot cost should increase with the number of bathrooms in the structure. However, this piece of information is not available from NSI nor tax assessor data.

Figure 2: Rahway Fluvial Structure Inventory shows the spatial distribution of the structure data. In total 7,859 structures in the study area were identified and subjected to the inventory process for the purposes of damage estimation. The Cranford Upstream study area has 4,739 structures; the Robinson's Branch (Compound) study area has 641 structures; the Robinson's Branch (Fluvial) study area has 1,584 structures; and the East Branch has 895 structures

FIGURE 2: RAHWAY FLUVIAL STRUCTURE INVENTORY

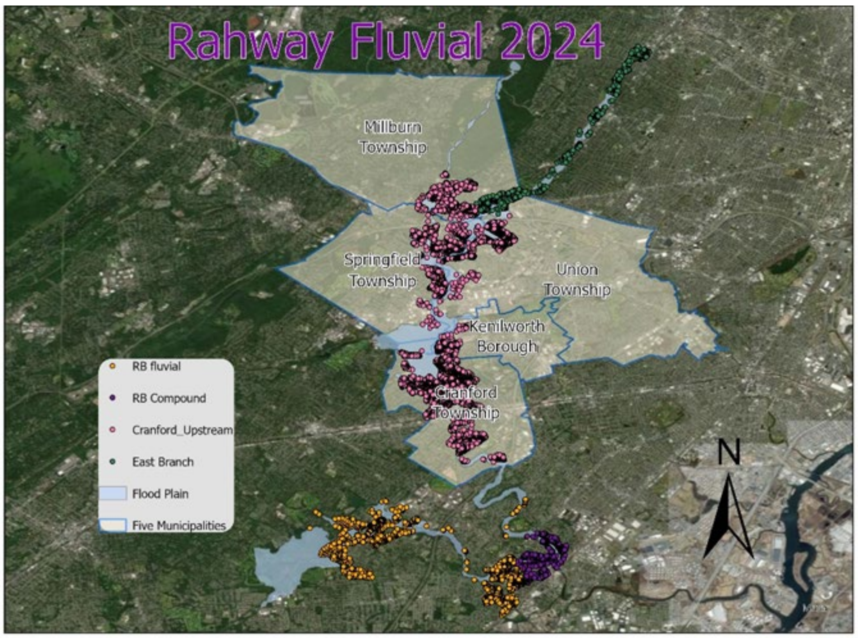


Table1: Summary of Damageable Elements by Model Area presents a summary of the distribution of building types in the study area and total depreciated structure replacement values at the March 2024 price level by damage categories and model areas. All depreciated structure replacement values are expressed in multiples of $1,000.

TABLE1: SUMMARY OF DAMAGEABLE ELEMENTS BY MODEL AREA

	Commercial	Industrial	Public	Residential
Cranford Upstream				
Parcels at Risk (#)	287	75	70	4,307
Damageable Value ($1,000s)*	$112,969	$781,462	$416,130	$2,087,836
Average Damageable Value*	$394	$10,419	$5,945	$485
Robinsons Branch				
Parcels at Risk (#)	149	9	43	2024
Damageable Value ($1,000s)*	$399,577	$39,982	$273,126	$1,233,433
Average Damageable Value*	$2,682	$4,442	$6,352	$609

East Branch				
Parcels at Risk (#)	107	8	34	746
Damageable Value ($1,000s)*	$360,230	$25,110	$145,294	$381,148
Average Damageable Value*	$3,367	$3,139	$4,273	$511

*Price Level March 2024

3. ECONOMIC MODEL DEVELOPMENT

3.1 Damage Functions

The Future without Project (FWOP) damage is calculated using the stage-frequency distribution, water surface profile, structure data with parcel features and structure values, and damage functions by HEC-FDA 1.4.3. The Future with Project (FWP) damage is calculated in a similar fashion with a different water surface profile. The benefit is defined as reduction in flood damages to structures and their contents, which will be compared to the cost.

The computation of annual flood damages in this analysis is based on the application of depth-damage functions to the structures in the study area to compute damage incurred by structures, their contents, and other associated features during flood events of different probability of occurrence.

Damage is determined as a percentage of overall structure or content value using a normal distribution of values. For inundation, damage is determined by the storm-surge heights more than the first-floor elevation. While depth-percent damage curves do provide the option for quantifying damages at thresholds below the First Floor Elevation, the begin damage point for all occupancy types is set to 0ft.

After discussion with the vertical team, the depth-percent damage functions utilized in this study are developed by the North Atlantic Coast Comprehensive Study (NACCS) - *Resilient Adaptation to Increasing Risk: Physical Depth Damage Function Summary Report*[6]. Due to the limited availability of damage curves, as well as the similarity in foundation height, foundation type, and risk levels, the same depth-percent damage function is repurposed for commercial, public, and industrial structures.

While the generic residential damage functions do not include a component for other damages, the study attempted to capture damages to motor vehicles using USACE guidance found in *Economic Guidance Memorandum 09-04, "Generic Depth-Damage Relationships for Vehicles", June 22, 2009*. The damageable vehicle values of each occupancy type were extracted from NSI. Vehicle values for each structure are based on the number of housing units for residential structures and the number of employees for

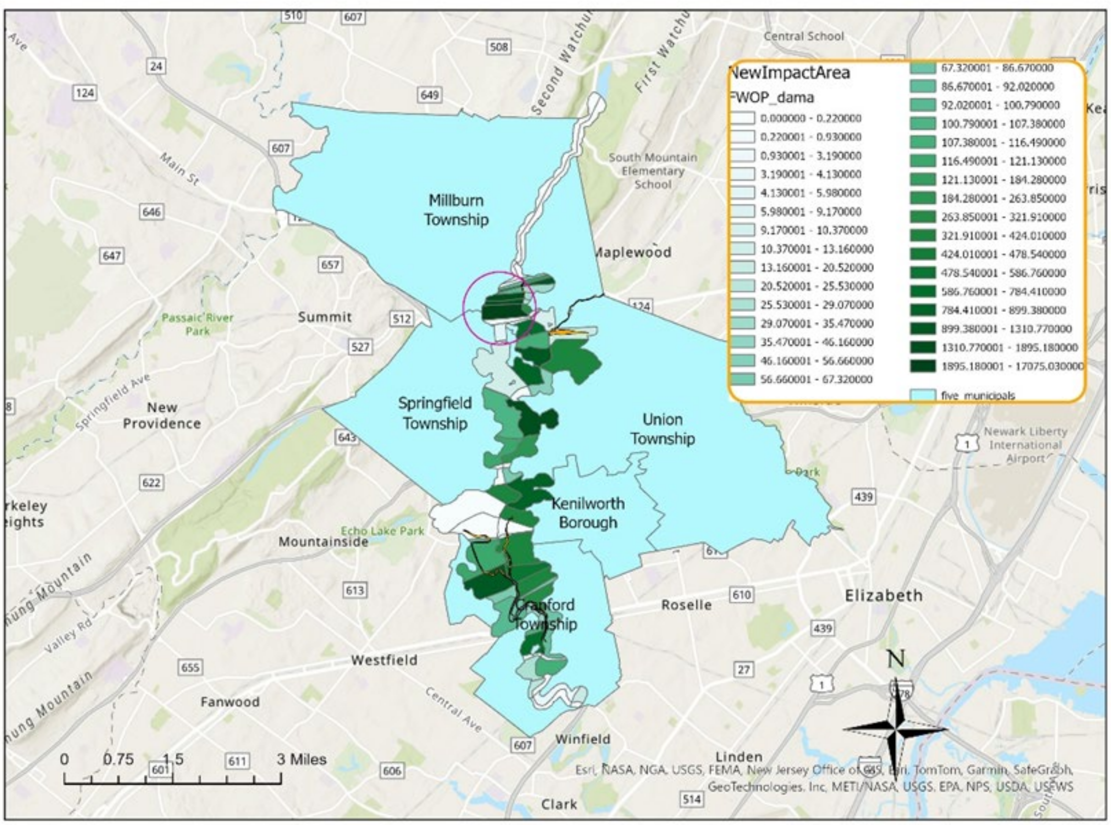
[6] The damage functions are available upon request.

commercial structures. These estimates do not vary with vehicle ownership rates or income levels throughout the nation. An adjustment factor is applied to the FWOP and FWP vehicle damage value because owners are likely to move their cars to higher ground. The probability that vehicle owners would move their vehicles to higher ground before a flood was assumed to be 73%. In the absence of any specific information regarding local warning times in advance of flood events this figure was derived by taking an average of the percentages given in Table 5 of EGM 09-04. Therefore, the adjustment factor is 27%.

3.2 Future Without Project (FWOP Results)

Using a 3% discount rate, the annual FWOP damage values of Cranford Upstream, East Branch, and Robinson's Branch (compound) are $34.11, $7.57 and $9.96 million, respectively. Notice that Robinson's Branch (fluvial) results are not reported because of overlap with the Rahway Tidal study area. The key area of concern is Cranford Upstream. Figure shows the spatial distribution of the FWOP damage by economic reaches. The FWOP damage is highly concentrated in the area circled in pink. More than half of the damage (about 17 million) is recorded in these areas. The location is south of Short Hills – Main Street between Millburn Avenue and I-78 Express.

FIGURE 3: AREAS WITH MOST DAMAGE IN FWOP CONDITION (BY ECONOMIC REACHES)



Figures 4.1A-4.1C shows the finer spatial distribution of damage by structures, divided into 20 percentiles. From figure 4.1A, there is a large cluster of heavy damage, denoted by pink and purple points, in the Millburn area – consistent with the finding from figure 3. Meanwhile, there is a patch of pink points at the southeast corner of Springfield township. This is a block of industrial buildings. The FDA analysis has incorporated an existing levee in the economic reach. However, the total damage is still very high. The damage of East Branch is concentrated at the towns of Vauxhall and Maplewood (Figure 4.1B). Structures with heavy damage are scattered in the rest of the model area; therefore, NS measures are recommended for a more targeted approach. Structures with heavy damage are concentrated in the east side of Robinsons' branch, notably the compound flooding model area (Figure 4.1C), explaining why it is difficult to justify structural measures for the entirety of Robinson's Branch.

Figure 4.1A: Spatial Distribution of FWOP Damage by assets (Cranford Upstream)

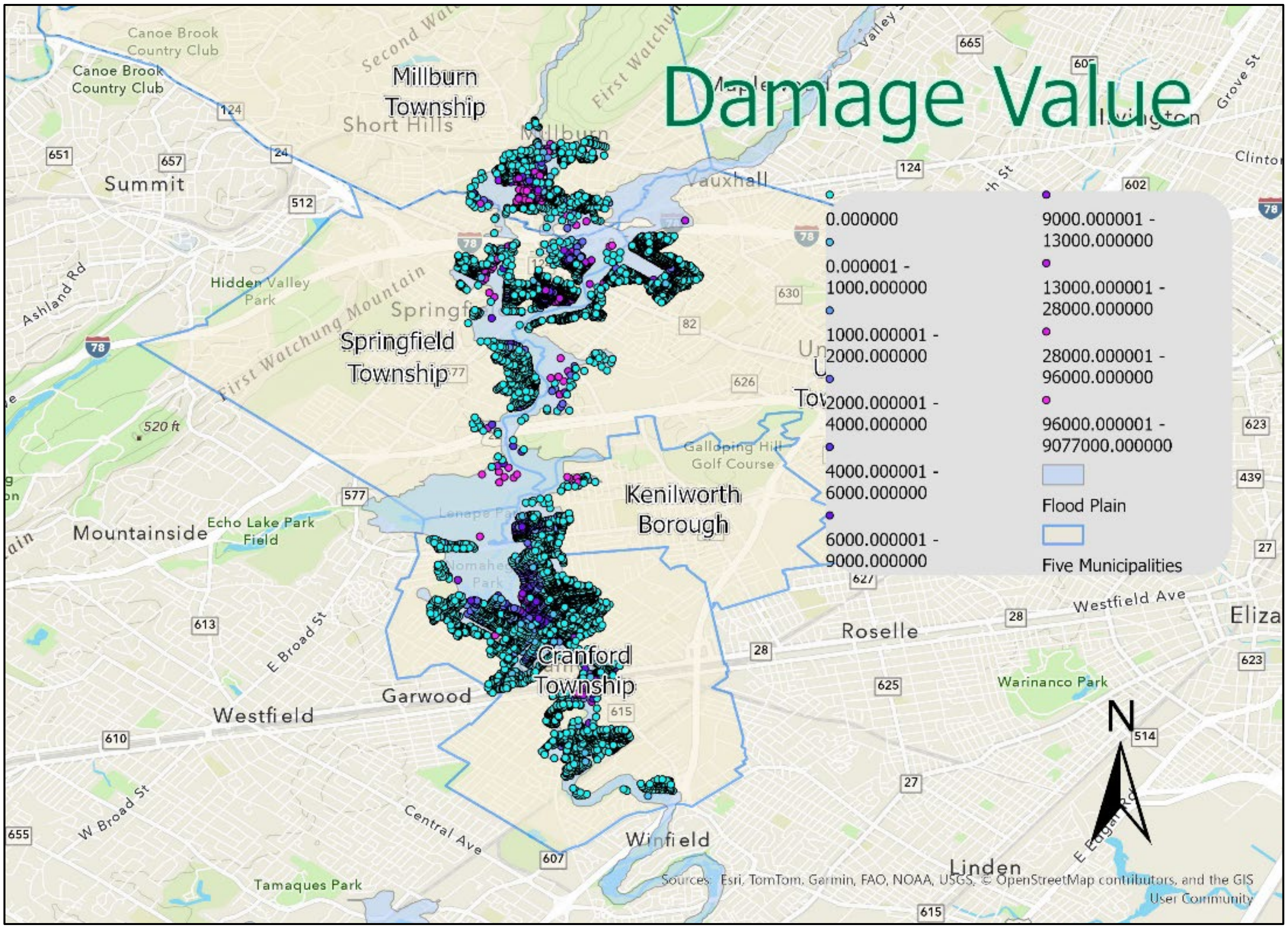


Figure 4.1B Spatial Distribution of FWOP Damage by assets (East Branch)

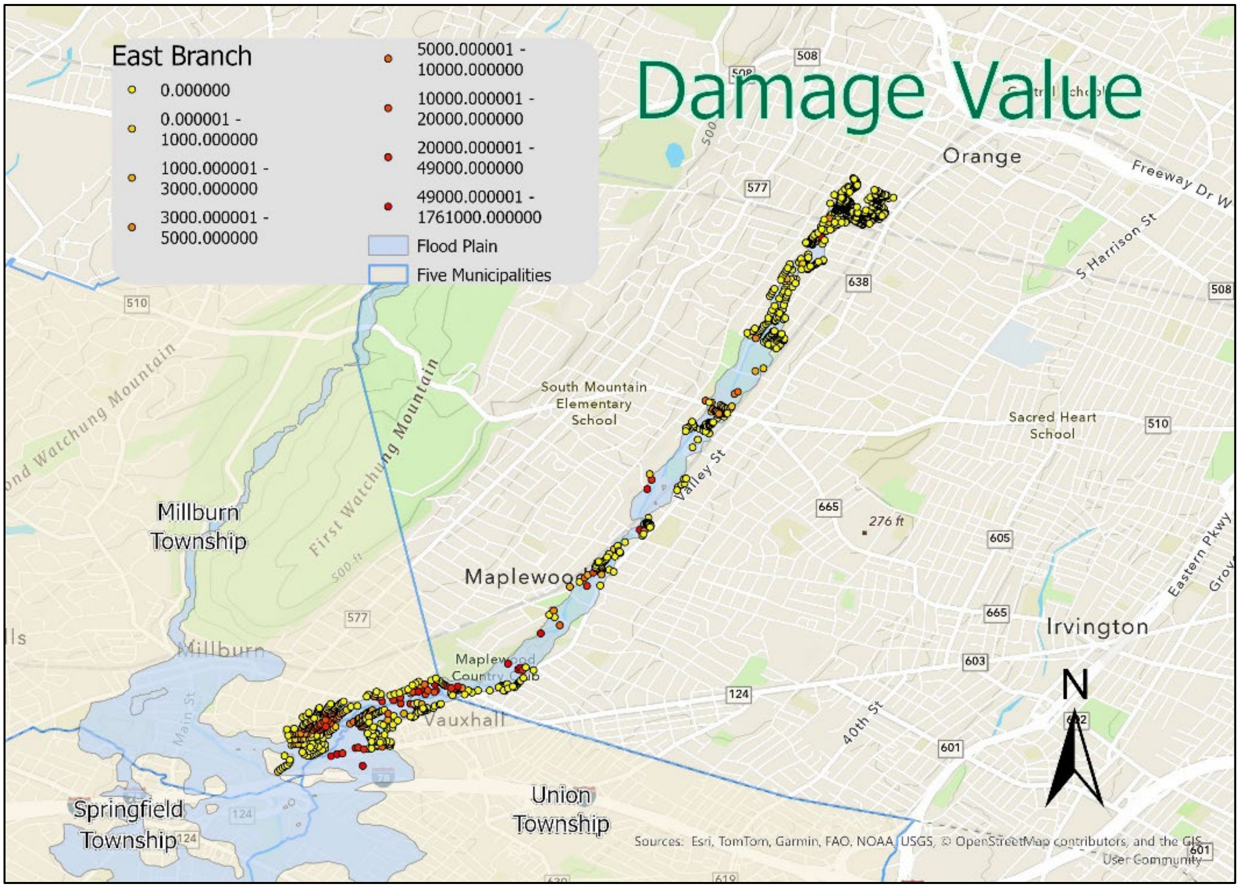
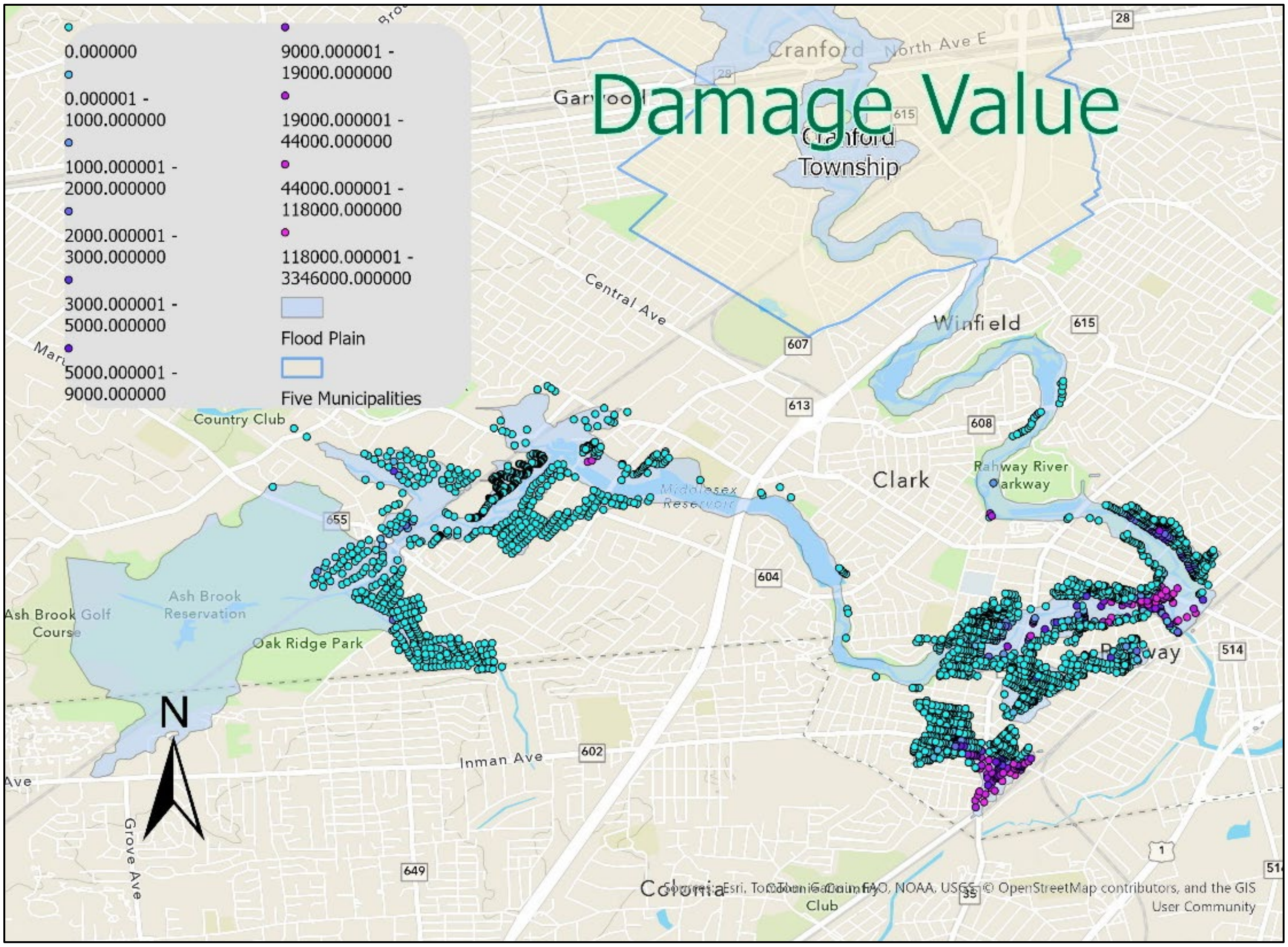


Figure 4.1C: Spatial Distribution of FWOP Damage by assets (Robinson's Branch)



3.3 Comparison with Historical Damage

This section compares the FWOP damage to historical damage using FEMA National Flood Insurance Program (NFIP) claim data. FEMA publishes the NFIP insurance claim data with a moving window of 46 years[7]. It records redacted individual claim data. Some notable fields are claim paid on building, claim paid on contents and an indicator of post-FIRM. The historical claim payment is only a proxy to past damage. It underestimates actual damage loss for two reasons. 1). Due to adverse selection (hidden types) and moral hazard (hidden action), insurance companies do not compensate damage loss fully, and 2). Residential properties not under mortgage are not required to buy flood insurance. Nonetheless, the spatial and temporal distribution of NFIP can provide useful insights for policy.

[7] https://www.fema.gov/about/openfema/data-sets

Claim payments are summed up over time (temporally) or across census tracts (spatially) to generate a graphs and maps to understand the temporal and spatial distribution of damage. Inflation adjustment is not made because it will only change the scale. To be more specific, inflation adjustment will not alter the ordinal ranking of census tracts by total claim payments.

FIGURE 5: CRANFORD UPSTREAM DAMAGE LOSS OVER TIME

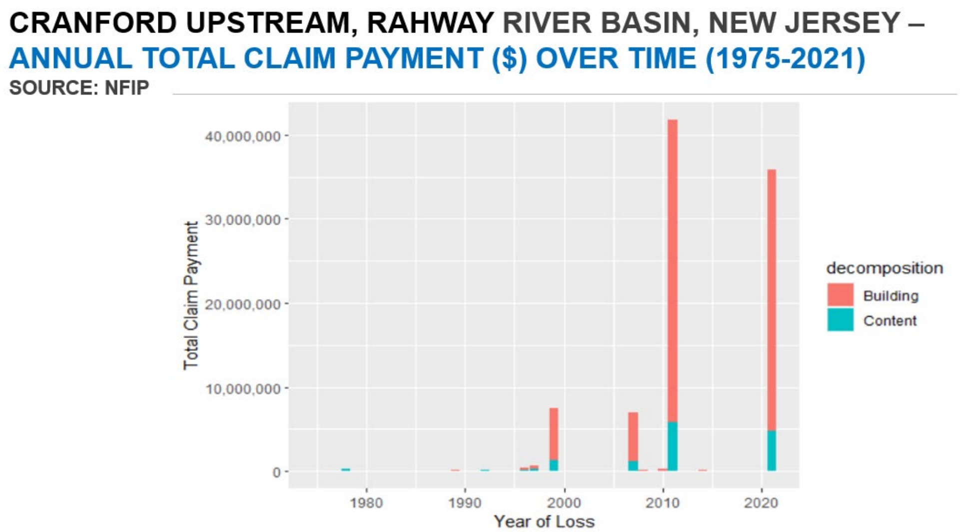


Figure5 shows the total damage loss from 1975-2021. While the loss distribution is sporadic, the trend is obviously increasing. Building loss is significantly higher than contents loss. Hurricane is the key driving force of damage. The highest loss is about $42 million in 2011 due to Hurricane Irene. Figure 6 highlights the four years with severe damage by locations. Cranford suffered most loss in all scenarios; Kenilworth experienced the least damage. A prolonged period of rain (1 month) in 2007contributed to the fourth largest loss in past 46 years.

FIGURE 6: CRANFORD UPSTREAM DAMAGE LOSS OVER TIME BY MUNICIPALITIES

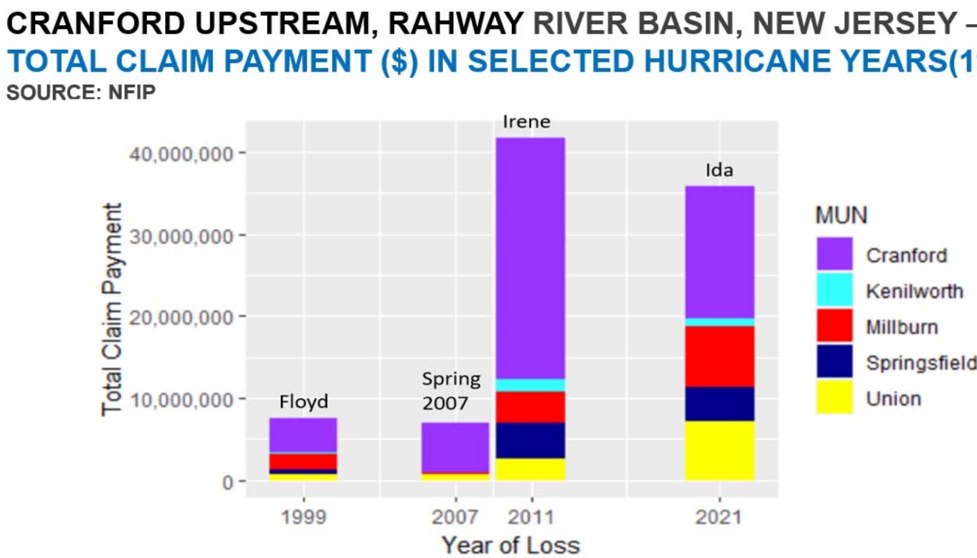


Figure 7 illustrates the spatial distribution of loss by census tracts. Darker color means heavier loss. The confluence of east and west branch (Millburn), and Cranford had the highest loss in history, consistent with the FWOP damage distribution.

4. FUTURE WITH PROJECT (FWP) RESULTS

Table 2 summarizes the initial array of alternatives. Readers can refer to the main report for detailed description of the plans.

TABLE 2: INITIAL ARRAY OF ALTERNATIVES

Alternative	Alternative Description	Name
Alternative 1	No Action	No Action
Alternative 2	Upstream Detention	Upstream Detention Plan
Alternative 3	Combination Plan – targeted channel modification, localized storage, and targeted levees and floodwalls, road raisings, and dam and bridge modifications	Combination Plan
Alternative 4	Nonstructural Plan consisting of acquisition, relocation, elevation, and floodproofing	Nonstructural Plan
Alternative 5	Lenape Park Detention Basin & Channel Modifications	Lenape Park Plan

Following the resumption of the study, and the request to reanalyze the Lenape Park alternative that was considered in the 2016 effort, USACE decided to perform a planning level analysis, through a sensitivity analysis on escalated benefits and costs, to assess the viability of Alternative 5. The benefits and costs from the 2016 report, shown in the table 3, were used as the basis for the updated analysis.

TABLE 3: BENEFITS AND COSTS FOR ALTERNATIVE 5: 2016 REPORT

Alternative	Without Project	With-Project	Annual Benefits	Annual Cost	Net Benefits	BCR
Lenape Park Plan	$9,773,600	$7,499,200	$2,274,400	$4,096,300	-$1,821,900	0.6

The Bureau of Labor Statistics Consumer Price Index (CPI) calculator was used to escalate the benefits from Fiscal Year (FY) 2016 to 2024. The CPI calculator is used to determine the present value of a figure based on changes in inflation between two time periods. Similarly, costs were escalated to the current FY using the Civil Works Construction Cost Index System (CWCCIS) after receiving updated contingency inputs from the cost team. Finally, to test the sensitivity of the benefit cost ratio, the average annual benefits were increased by both 10% and 20%, while holding the costs constant. Table 4 shows the results of these escalations.

TABLE 4: UPDATED BENEFITS AND COSTS FOR ALTERNATIVE 5

FY16 Benefits	FY24 Escalated Benefits (CPI)	10% Benefit Increase	20% Benefit Increase	FY24 Escalated Costs	10% BCR	20% BCR
$2,274,400	$3,019,600	$3,321,500	$3,623,500	$4,885,700	0.7	0.7

As a result of this analysis, Alternative 5 was removed from further consideration. While its possible benefits could have increased beyond the 10 and 20 percent estimations used in this analysis, its likely costs would have increased by an equal, or more likely greater, amount than the benefits.

Table. 5 summarizes the results of benefit and cost analysis (benefit to cost ratio) of alternatives 2 through 4. The second column reports the number of structures protected by that measure while the third and fourth present the without and with project expected annual damages (EAD). All cost and benefits have been annualized using the FY25 interest rate of 3% and a period of 50 years. All figures presented are in millions.

Table 5: Annual Costs/Benefits, Net Benefits, and BCRs for Each Alternative (FY2025 Price level, 3% discount rate)

Alternative	Structure #	FWOP EAD (Million)	FWP EAD (Million)	Benefits (Million)	Cost (Million)	Net Benefit (Million)	BCR
Alternative 2 Upstream Detention Plan	5634	$41.68	$31.57	$10.11	$11.30	$ (1.18)	0.90
Alternative 3 Combination Plan	5634	$41.68	$34.92	$6.76	$19.077	$ (12.32)	0.35
Alternative 4a: 10-year NS Cranford Upstream	119	$34.11	$15.18	$18.92	$6.13	$12.8	3.09
Alternative 4b: 100-year NS Cranford Upstream	175	$34.11	$13.29	$20.81	$9.75	$11.06	2.13
Alternative 4c: 10-year NS East Branch	19	$7.57	$7.34	$0.24	$0.97	$ (0.73)	0.24
Alternative 4d: 100-year NS East Branch	51	$7.57	$4.54	$3.03	$2.78	$2.78	1.09
Alternative 4e: 10-year NS Robinson's Brand (compound)	23	$9.96	$4.99	$4.97	$1.41	$3.57	3.54
Alternative 4f: 100-year NS Robinson's Brand (compound)	32	$9.96	$3.15	$6.81	$1.99	$4.82	3.43

Alternative 2, the Upstream Detention plan has an annual cost is $11.3 M and annual benefits of $10.11 M. The net benefit is -$1.18 M and the BCR is 0.9. The Upstream Detention Plan reduces roughly a quarter of the total FWOP damages, primarily benefitting Milburn and Springfield.

Alternative 3, the Combination Plan provides annual benefits of $6.76 million and when compared to annual costs of $19 million yields a BCR of 0.35. The costs are primarily driven by the proposed 4.5 miles of levees and floodwalls through the Township of

Cranford (Measure 6 in Figure 10) which account for roughly 50% of the total cost for Alternative 3.

Alternative 4, the Nonstructural Plan, is split up into six separate and independent plans to facilitate timely implementation. Five of them (Alt. 4a, 4b, 4d, 4e and 4f) yielded positive net benefits and BCRs of 3.09, 2.13, 1.09, 3.54, and 3.43 respectively. Annual costs vary by number of structures included in the plan and the treatment assigned to those structures. More information on number of structures in each plan and their treatment is found in Tables 7 and 8 above. These nonstructural plans could be implemented through "Section 205" of USACE's Continuing Authorities Program, for small flood risk management projects. It is assumed that potential nonstructural projects, organized by municipalities in the Cranford area and along Robinson's Branch, would be the best candidates for these future efforts. Currently, USACE has paused investigations of nonstructural treatments while it reevaluates its methods for implementation. This pause is in effect until further notice. Until then, USACE may identify potential nonstructural treatments, but will have to defer further investigations for nonstructural treatments until the pause is lifted by the agency.

5. Other Social Effects (OSE)

Socio-economically vulnerable neighborhoods were identified by eleven environmental, social, and economic factors. The spatial unit is census tract (2023). The sole environmental factor is Parcels at Risk which is the number of structures under the 100-year (1% AEP) floodplain in the census tract[8]. A census tract is deemed more vulnerable when the Parcels at Risk factor is larger[9]. The data source of the remaining ten social and economic factors is 2022 Census American Community Survey (ACS). The values in Table 6 are 5-year average; they are extracted from an R package known as Tidycensus. U.S Census department authorized an Application Programming Interface (API) developed by Walker and Herman (2021)[10].

Other than population having a degree and median income, a census tract is considered to be more socio-economic vulnerable when the indicator value is higher. Table 6. reports the values of the 11 factors from ACS. The whole study area does not seem to be economically inferior. Only one census tract has median income (census tract # 336) lower than the 2022 national level ($ 37,585). Two census tracts (#201 and 202) have median income over $100,000. The percentage of households receiving public assistance is zero in four census tracts.

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[8] The data source of PAR is NSI. This analysis was initially conducted for the charrette.

[9] Relative area of floodplain to the size of census tract was considered initially. However, it is possible that there is no structure in floodplain, especially along floodway. PAR seems to be a more reliable index of environmental vulnerability.

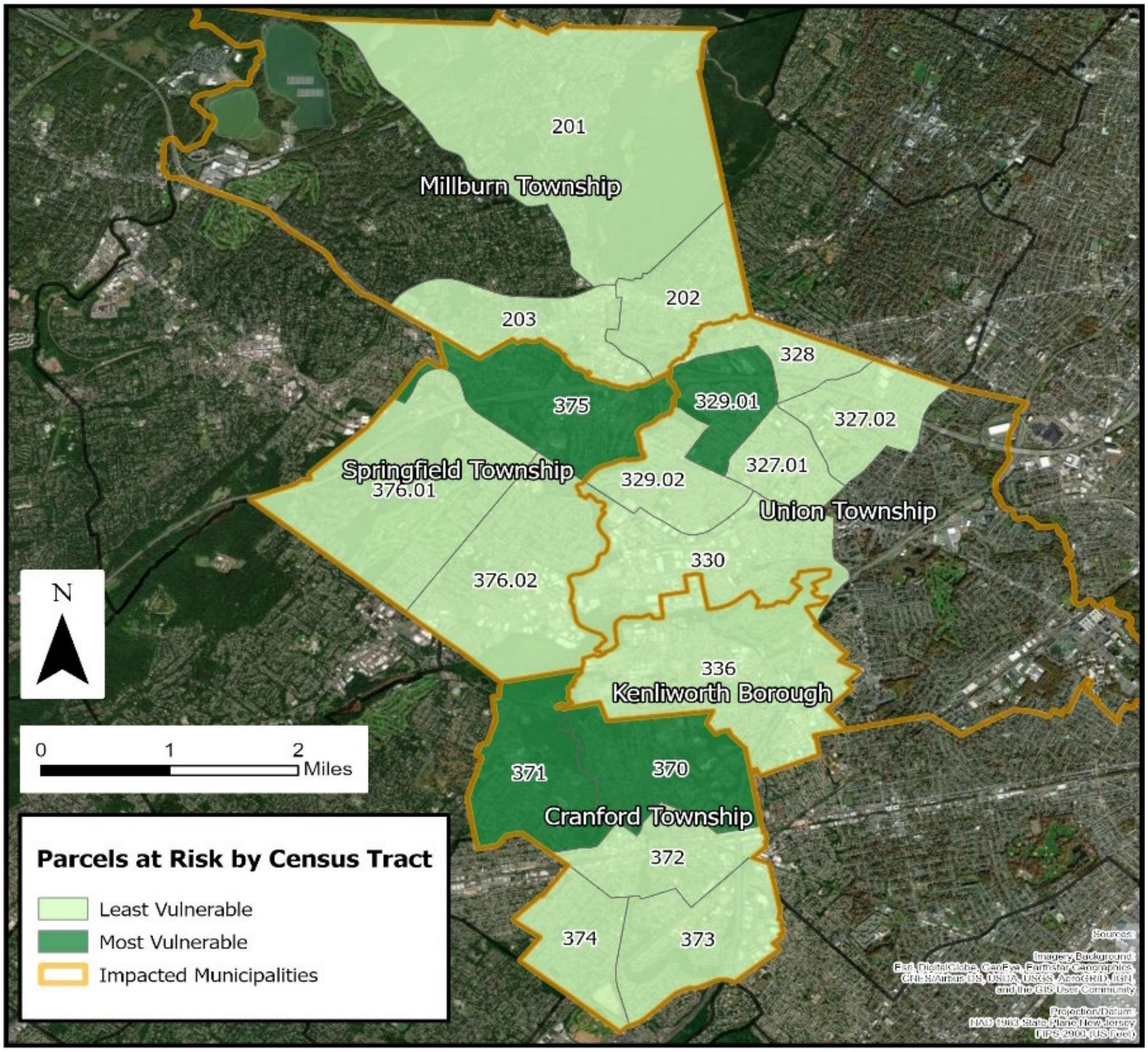
[10] https://walker-data.com/census-r/an-introduction-to-tidycensus.html#searching-for-variables-in-tidycensus

TABLE6: IDENTIFY SOCIO-ECONOMIC VULNERABLE CENSUS TRACTS

Identify Socio-Economic Vulnerable Census Tracts											
	Environmental	Social				Economic					
Census Tract #	Parcels at Risk (PAR)	Population	over65	Population having a degree	Households with at least one member with disability	Median Income	Poverty Rate	Unemployment rate	GINI Index	Households receiving public assistance	Gross rent as percentage of income
201	28	5213	14.4%	32.4%	7.1%	$ 156,250	1.1%	3.5%	44.9%	0.0%	20.1%
202	367	5139	15.6%	36.1%	12.6%	$ 116,250	3.7%	3.9%	41.7%	4.4%	31.2%
203	399	5098	8.7%	35.0%	4.2%	$ 86,573	12.4%	7.6%	48.4%	3.6%	27.4%
327.01	73	3768	19.1%	36.8%	14.1%	$ 47,906	2.1%	6.5%	48.6%	30.6%	23.5%
327.02	73	5330	18.5%	22.3%	22.3%	$ 50,518	2.7%	4.8%	39.8%	6.2%	21.5%
328	161	4928	17.9%	21.2%	30.2%	$ 34,665	13.4%	6.2%	40.4%	36.4%	41.9%
329.01	615	4940	15.4%	23.6%	17.5%	$ 41,440	2.3%	3.2%	32.6%	4.1%	29.6%
329.02	260	4499	23.3%	24.0%	19.9%	$ 45,146	8.5%	4.0%	41.9%	15.9%	37.1%
330	254	4032	15.3%	35.2%	12.2%	$ 68,063	4.1%	9.7%	31.1%	5.3%	22.4%
336	614	8345	14.5%	19.0%	24.1%	$ 37,089	7.6%	8.4%	50.8%	6.3%	26.5%
370	849	6052	26.7%	34.2%	31.0%	$ 67,339	2.6%	2.5%	40.6%	0.0%	32.1%
371	854	4458	15.1%	43.3%	13.5%	$ 94,167	3.1%	4.3%	44.4%	3.7%	22.0%
372	239	4237	22.3%	39.9%	16.4%	$ 46,373	7.4%	3.1%	50.0%	1.1%	29.7%
373	327	4498	13.7%	35.3%	21.8%	$ 69,861	2.4%	5.2%	36.4%	4.2%	34.9%
374	138	4593	16.5%	39.6%	15.2%	$ 73,186	2.3%	3.2%	36.8%	4.0%	22.4%
375	1107	5484	10.4%	46.8%	16.3%	$ 70,024	3.5%	4.8%	40.1%	0.0%	26.9%
376.01	17	4913	18.2%	39.8%	22.4%	$ 65,625	5.1%	3.5%	44.3%	20.3%	32.4%
376.02	430	6614	20.1%	37.0%	19.0%	$ 68,010	8.8%	5.7%	37.7%	0.0%	21.2%

Census tract #375 has highest Parcels at Risk, followed by #370, #371 and #329.01. There is larger variation among the social factors. Census tract #370 has the highest percentage of population over 65 years old and second highest at least one household member having disability. Considering all these, the study team determined that Census tract #370 is the most socio-economic vulnerable area in the study area. Three areas are classified as moderately socio-economic vulnerable. Census tract #371 and #375 have more Parcels at Risk than #370 although its members may be less vulnerable according to other traits such as education or median income. Although census tract #329.01 has less Parcels at Risk than #371, the median income is one of the lowest in the study area. The location of the four socio-economic vulnerable census tracts is shown in8. Two are in Cranford, one at Springfield and one at Union.

FIGURE 8: LOCATION OF SOCIO-ECONOMIC CENSUS TRACTS



To sum up, areas with high FWOP damage coincides with areas with high historical damage; and socio-economically vulnerable census tracts.

Economics Addendum A

Table A.1					
Summary of Economic Reaches (**Cranford Upstream**)					
Reach Name	Stream Name	Beginning Station	End Station	Bank	Index Station
LCR1A	Millburn-Clark 2	51426.3	52244.71	Right	51779.7
LCR1B	Millburn-Clark 2	52244.71	56643.72	Right	54695.58
LCR1C	Millburn-Clark 2	56643.72	58619.69	Right	58354.31
LCR1	Millburn-Clark 2	58619.69	60594.7	Right	59833.37
LCR2	Millburn-Clark 2	60594.7	60818.6	Right	60753.75
UCR1	Millburn-Clark 2	60818.6	62753.50	Right	62249.61
UCR2	Millburn-Clark 2	62753.50	63335.51	Right	62971.07
UCR3	Millburn-Clark 2	63335.51	64233.62	Right	63926.28
UCR4	Millburn-Clark 2	64233.62	65841.78	Right	64757.84
UCR5	Millburn-Clark 2	65841.78	69263.94	Right	67944.94
UCR6	Millburn-Clark 2	69263.94	70500.94	Right	69818.94
UCR7	Millburn-Clark 2	70500.94	72265.94	Right	71604.94
UCR7.1	Millburn-Clark 2	72265.94	75679.58	Right	73712.94
UCR8	Millburn-Clark 2	75679.58	75840.77	Right	75751.24
UCR10	Millburn-Clark 2	75840.77	77436.81	Right	77092.76
UCR10A	Millburn-Clark 2	77436.81	78556.27	Right	78028.43
UCR11	Millburn-Clark 2	78556.27	81528.77	Right	79175.24
UCR12	Millburn-Clark 2	81528.77	82722.32	Right	81914.01
UCR13	Millburn-Clark 2	82722.32	83037.32	Right	82822.32
UCR14	Millburn-Clark 2	83037.32	85902.32	Right	84602.32
UCR15	Millburn-Clark 2	85902.32	90052.32	Right	87622.32
UCR16	Millburn-Clark 2	90052.32	91727.32	Right	91222.32
UCR17	Millburn-Clark 2	91727.32	94328.60	Right	93317.32
UCR18	Millburn-Clark 2	94328.60	96345.60	Right	95370.60
UCR19	Millburn-Clark 2	96345.60	97513.55	Right	96752.60
ML20R	Millburn-Clark	97513.55	99054.85	Right	98517.31
ML21R	Millburn-Clark	99054.85	99150.78	Right	99150.78
ML22R	Millburn-Clark	99150.78	99391.75	Right	99236.39
ML23R	Millburn-Clark	99391.75	100418.1	Right	100074.6
ML24R	Millburn-Clark	100418.1	100820.1	Right	100554.6
ML25R	Millburn-Clark	100820.1	101336.8	Right	101050.7
ML26R	Millburn-Clark	101336.8	101748.8	Right	101657.3
ML27R	Millburn-Clark	101748.8	101936.4	Right	101870.2
ML28R	Millburn-Clark	101936.4	102262.9	Right	102022.1
ML29R	Millburn-Clark	102262.9	102801.2	Right	102290.4

ML30R	Millburn-Clark	102801.2	104168.0	Right	103501.5
ML31R	Millburn-Clark	104168.0	105224.7	Right	104819.3
LCL1A	Millburn-Clark 2	51426.3	52244.71	Left	51779.7
LCL1B	Millburn-Clark 2	52244.71	56643.72	Left	54695.58
LCL1C	Millburn-Clark 2	56643.72	58619.69	Left	58354.31
LCL1	Millburn-Clark 2	58619.69	60594.7	Left	59833.37
LCL2	Millburn-Clark 2	60594.7	60818.6	Left	60753.75
UCL1	Millburn-Clark 2	60818.6	62753.50	Left	62249.61
UCL2	Millburn-Clark 2	62753.50	63335.51	Left	62971.07
UCL3	Millburn-Clark 2	63335.51	64233.62	Left	63926.28
UCL4	Millburn-Clark 2	64233.62	65841.78	Left	64757.84
UCL5	Millburn-Clark 2	65841.78	69263.94	Left	67944.94
UCL6	Millburn-Clark 2	69263.94	70500.94	Left	69818.94
UCL7	Millburn-Clark 2	70500.94	72265.94	Left	71604.94
UCL7.1	Millburn-Clark 2	72265.94	75679.58	Left	73712.94
UCL8	Millburn-Clark 2	75679.58	75840.77	Left	75751.24
UCL10	Millburn-Clark 2	75840.77	77436.81	Left	77092.76
UCL10A	Millburn-Clark 2	77436.81	78556.27	Left	78028.43
UCL11	Millburn-Clark 2	78556.27	81528.77	Left	79175.24
UCL12	Millburn-Clark 2	80391.94	82722.32	Left	81914.01
UCL13	Millburn-Clark 2	82722.32	83037.32	Left	82822.32
UCL14	Millburn-Clark 2	83037.32	85902.32	Left	84602.32
UCL15	Millburn-Clark 2	85902.32	90052.32	Left	87622.32
UCL16	Millburn-Clark 2	90052.32	91727.32	Left	91222.32
UCL17	Millburn-Clark 2	91727.32	94328.60	Left	93317.32
UCL18	Millburn-Clark 2	94328.60	96345.60	Left	95370.60
UCL19	Millburn-Clark 2	96345.60	97513.55	Left	96752.60
ML20L	Millburn-Clark	97513.55	99054.85	Left	98517.31
ML21L	Millburn-Clark	99054.85	99150.78	Left	99150.78
ML22L	Millburn-Clark	99150.78	99391.75	Left	99236.39
ML23L	Millburn-Clark	99391.75	100418.1	Left	100074.6
ML24L	Millburn-Clark	100418.1	100820.1	Left	100554.6
ML25L	Millburn-Clark	100820.1	101336.8	Left	101050.7
ML26L	Millburn-Clark	101336.8	101748.8	Left	101657.3
ML27L	Millburn-Clark	101748.8	101936.4	Left	101870.2
ML28L	Millburn-Clark	101936.4	102262.9	Left	102022.1
ML29L	Millburn-Clark	102262.9	102801.2	Left	102290.4
ML30L	Millburn-Clark	102801.2	104168.0	Left	103501.5
ML31L	Millburn-Clark	104168.0	105224.7	Left	104819.3

Table A.2					
Summary of Economic Reaches (**Robinsons Branch, Fluvial**)					
Reach Name	Stream Name	Beginning Station	End Station	Bank	Index Station
M1-R	Millburn-Clark 2	37658.63	38888.4	Right	38152.62
M2-R	Millburn-Clark 2	39069.36	40015	Right	39678.3
RB1-R	Robinsons Branch	4252.515	5282.545	Right	4610.255
RB2-R	Robinsons Branch	5282.545	6724.135	Right	6358.735
RB3-R	Robinsons Branch	6724.135	7752.935	Right	7463.545
RB4-R	Robinsons Branch	7752.935	8920.195	Right	8345.365
RB5-R	Robinsons Branch	8920.195	10353.94	Right	9748.67
RB6-R	Robinsons Branch	10533.52	10921.33	Right	10754.22
RB7-R	Robinsons Branch	10921.33	11739.95	Right	11422.09
RB8-R	Robinsons Branch	11739.95	12246.56	Right	12024.56
RB9-R	Robinsons Branch	12310.76	12870.29	Right	12467.23
RB10-R	Robinsons Branch	17696.49	20226.37	Right	19078.03
RB11-R	Robinsons Branch	20226.37	23206.35	Right	21931.45
RB12-R	Robinsons Branch	23206.35	25160.63	Right	24170.09
RB13-R	Robinsons Branch	25160.63	27333.26	Right	26431.45
RB14-R	Robinsons Branch	27333.26	30132.20	Right	28937.53
M1-L	Millburn-Clark 2	37658.63	38888.4	Left	38152.62
M2-L	Millburn-Clark 2	39069.36	40015	Left	39678.3
RB1-L	Robinsons Branch	4252.515	5282.545	Left	4610.255
RB2-L	Robinsons Branch	5282.545	6724.135	Left	6358.735
RB3-L	Robinsons Branch	6724.135	7752.935	Left	7463.545
RB4-L	Robinsons Branch	7752.935	8920.195	Left	8345.365
RB5-L	Robinsons Branch	8920.195	10353.94	Left	9748.67
RB6-L	Robinsons Branch	10533.52	10921.33	Left	10754.22
RB7-L	Robinsons Branch	10921.33	11739.95	Left	11422.09
RB8-L	Robinsons Branch	11739.95	12246.56	Left	12024.56
RB9-L	Robinsons Branch	12310.76	12870.29	Left	12467.23
RB10-L	Robinsons Branch	17696.49	20226.37	Left	19078.03
RB11-L	Robinsons Branch	20226.37	23206.35	Left	21931.45
RB12-L	Robinsons Branch	23206.35	25160.63	Left	24170.09
RB13-L	Robinsons Branch	25160.63	27333.26	Left	26431.45
RB14-L	Robinsons Branch	27333.26	30132.20	Left	28937.53

Table A.3					
Summary of Economic Reaches (**Robinsons Branch, Compound**)					
Reach Name	Stream Name	Beginning Station	End Station	Bank	Index Station
R1-R	Rahway	27107.37	27995.02	Right	27559.02
M1-R	Millburn-Clark 2	28472.74	30053.46	Right	29222.75
M2-R	Millburn-Clark 2	30053.46	32915.62	Right	31664.23
M3-R	Millburn-Clark 2	32915.62	33162.1	Right	33034.82
RB1-R	Robinsons Branch	175.4458	721.8958	Right	564.14558
RB2-R	Robinsons Branch	721.8958	880.7058	Right	777.8658
RB2.2-R	Robinsons Branch	880.7058	2535.375	Right	1725.635
RB3-R	Robinsons Branch	2535.375	4008.985	Right	3334.935
R1-L	Rahway	27107.37	27995.02	Left	27559.02
M1-L	Millburn-Clark 2	28472.74	30053.46	Left	29222.75
M2-L	Millburn-Clark 2	30053.46	32915.62	Left	31664.23
M3-L	Millburn-Clark 2	32915.62	33162.1	Left	33034.82
RB1-L	Robinsons Branch	175.4458	721.8958	Left	564.14558
RB2-L	Robinsons Branch	721.8958	880.7058	Left	777.8658
RB2.2-L	Robinsons Branch	880.7058	2535.375	Left	1725.635
RB3-L	Robinsons Branch	2535.375	4008.985	Left	3334.935

Table A.4					
Summary of Economic Reaches (**East Branch**)					
Reach Name	Stream Name	Beginning Station	End Station	Bank	Index Station
Reach 1-R	East Branch	0	4050	Right	2446
Reach 2-R	East Branch	4050	5843	Right	5300
Reach 3-R	East Branch	5843	7916	Right	7214
Reach 4-R	East Branch	7916	10000	Right	9427
Reach 5-R	East Branch	10000	10817	Right	10535
Reach 6 -R	East Branch	10817	11696	Right	11347
Reach 7 -R	East Branch	11696	12803	Right	12316
Reach 8 -R	East Branch	12803	13462	Right	13241
Reach 9 -R	East Branch	13462	14053	Right	13693
Reach 10 -R	East Branch	14053	17173	Right	15592
Reach 11 -R	East Branch	17173	17960	Right	17674
Reach 12 -R	East Branch	17960	20417	Right	19069
Reach 13 -R	East Branch	20417	22340	Right	21239
Reach 14 -R	East Branch	22340	24523	Right	23277
Reach 15 -R	East Branch	24523	25576	Right	25046
Reach 16 -R	East Branch	25576	26258	Right	26001
Reach 1-L	East Branch	0	4050	Left	2446
Reach 2-L	East Branch	4050	5843	Left	5300
Reach 3-L	East Branch	5843	7916	Left	7214
Reach 4-L	East Branch	7916	10000	Left	9427
Reach 5-L	East Branch	10000	10817	Left	10535
Reach 6 -L	East Branch	10817	11696	Left	11347
Reach 7 -L	East Branch	11696	12803	Left	12316
Reach 8 -L	East Branch	12803	13462	Left	13241
Reach 9 -L	East Branch	13462	14053	Left	13693
Reach 10 -L	East Branch	14053	17173	Left	15592
Reach 11 -L	East Branch	17173	17960	Left	17674
Reach 12 -L	East Branch	17960	20417	Left	19069
Reach 13 -L	East Branch	20417	22340	Left	21239
Reach 14 -L	East Branch	22340	24523	Left	23277
Reach 15 -L	East Branch	24523	25576	Left	25046
Reach 16 -L	East Branch	25576	26258	Left	26001