Township of Cranford

Interim Project Report - Northeast Quadrant
Stormwater and Flood Management Project
Phases 3&4 - Dike System Improvements

April 2008

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1.0 Introduction

The Township of Cranford authorized Hatch Mott MacDonald (HMM) to perform a study of the Phase 3 and 4 components of the Northeast Quadrant Stormwater Management and Flood Control Program within the Township of Cranford, and prepare preliminary plans and cost estimates for modifications of the dike system and associated improvements. The Phase 3 and 4 components consist of the extension and modifications of the existing dike systems on the east and west sides of the Rahway River in the vicinity of Nomahegan Park between Springfield Avenue and Kenilworth Boulevard (the Project Area).

HMM conducted investigations and performed hydrologic and hydraulic analyses for a range of storms to determine the potential impacts beyond the Project Area associated with modification of the dike system between Springfield Avenue and Kenilworth Boulevard. Services under this study provide preliminary design concepts for improvements to the existing dike system to provide for stability of the dikes, to raise the top of dike elevations, and to extend the dike system to provide a greater level of protection from chronic flooding in the vicinity of the Project Area. HMM has considered alternative conceptual designs and layouts for the dike system improvements, and has analyzed alternative levels of protection and associated upstream and downstream impacts. Measures for mitigation of such impacts immediately adjacent to the Project Area are also considered.

Initially this investigation was intended to evaluate dike improvements required to provide a level of protection for a design storm exceeding the 50-year storm but less than the 100-year storm. It was recognized that raising the elevation of the dikes would reduce the volume of flood storage in the flood plain reach between Kenilworth Boulevard and Springfield Avenue by reducing the extent of the flood area for certain storms. The loss of flood storage associated with the increased dike elevations would result in increased peak flows and associated increased water surface elevations downstream of the Project Area, and increased backwater effects and associated increased water surface elevations along Nomahegan Park and immediately upstream of Kenilworth Boulevard. By limiting the design storm to less than the 100-year storm, there would be no adverse impacts upstream or downstream for the 100-

year or greater floods (which generally serve as the basis for flood regulations). Therefore, mitigation required in association with the project would be limited to that needed to address effects for storms in the range from those that just overtop the existing dikes up to the storm that reaches the selected design elevation for the top of dikes (i.e. the range of storms for which the flood storage volume adjacent to Nomahegan Park would be reduced by virtue of the dike modifications). Such mitigation was anticipated to be within the potential capabilities of the Township of Cranford to implement for a design storm somewhat greater than a 50-year storm but less than a 100-year storm.

During the course of this investigation, the Township of Cranford was successful in engaging the interest of the U.S. Army Corps of Engineers in the flood problems along the Rahway River. Cranford representatives have met with Corps personnel, and the Army Corps of Engineers New York District is now engaged in undertaking a study entitled *Rahway River Basin Flood Damage Reduction & Ecosystem Restoration Study*. With the involvement of the Corps of Engineers in a regional program, it may be possible for Cranford to implement a component of a regional project providing a higher level of flood protection (i.e. higher protection than Cranford could accomplish with a local project). Therefore, additional levels of protection have been analyzed in this investigation, including the effects of elevating the dikes to the levels of the 100, 200 and 500-year water surface elevations in the Rahway River.

The incremental cost to construct the dikes in the Project Area to a higher elevation under a local improvement project would be significantly less than the cost to reconstruct or extend the dikes to a higher elevation at a later date. However, it must be recognized that mitigation of the impacts upstream and downstream of the Project Area may not be possible until a regional plan is implemented. Therefore the benefits of the initial construction will likely have to be limited to less than the 100-year flood level in the Rahway River (as originally planned) by providing designated flood overflow locations until such time as the regional plan is implemented and the adverse impacts can be mitigated.

The purpose of this Interim Report is to provide the Township with the results of analyses for a range of levels of protection, including estimates of associated impacts upstream and downstream and potential

mitigation measures. These concepts then may be reviewed with the Army Corps of Engineers for consideration in implementation of a regional plan. Cranford may then decide to select a plan that would provide benefits to a selected level of protection with initial construction limited to the Northeast Quadrant Project Area, but which would ultimately provide a higher level of protection in combination with implementation of a regional project at some later time. Thus, Phase 3 and 4 improvements implemented by Cranford would form an integral part of a long-range regional plan, and the need for further construction in the Project Area in Cranford may be substantially reduced when the future regional plan is implemented. This concept will be reviewed further following the description of the several alternative levels of protection and associated impacts and mitigation.

1.1 Location

The Township of Cranford is located in Union County, in the Rahway River watershed. The Rahway River winds through the Township over a length of approximately 4.75 miles between Kenilworth Boulevard on the north and the Garden State Parkway at Sperry Dam on the south. The Project Area for Phases 3 & 4 of the Northeast Quadrant Stormwater Management and Flood Control Program is shown on Figure 1.

The Lenape Park Detention Basin is located on the main stem of the Rahway River in the Borough of Kenilworth just north of Kenilworth Boulevard and has a tributary drainage area of 30.8 square miles at its outlet. The detention effect of this facility reduces the peak flow in the downstream reach of the River in Cranford, where residents have experienced severe flooding over a number of years. Downstream of Kenilworth Boulevard, the Rahway River meanders through Nomahegan Park, extending from Kenilworth Boulevard to Springfield Avenue in Cranford (a length of approximately one mile). The existing dikes along Nomahegan Park were overtopped several times prior to the construction of the Lenape Park Detention Basin, and have been overtopped twice since the construction of that facility, namely in 1999 during Hurricane Floyd, and in the storm of April 2007. Residential areas in the vicinity of the park and the Rahway River continue to experience chronic flooding. Several years ago, Cranford embarked on a comprehensive stormwater and flood management project to alleviate the flooding to these residential areas. Some flood relief has been achieved through the completion of Phase 1 improvements in 2006. Further benefits will be realized following the completion of the Phase 2A stormwater pumping station, with initial operation scheduled for May 2008. These phases have been implemented as available funding would allow. The current projects which are the focus of this Interim Report, identified as Phases 3 and 4 as described below, are integral components of this comprehensive program.

FIGURE 1

Note: Figure 1 is included in Appendix B in the electronic copy of this report in order to keep the text file size as small as possible.

1.2 Background

The residential area along the Rahway River in Cranford, between Kenilworth Boulevard and Springfield Avenue, includes three major flood problem areas, identified as follows:

Area #1 Riverside Drive, Brookdale Road, Edgewood Road, Venetia Avenue, Kensington Avenue Area, comprising an internal drainage area of approximately 367 acres on the east bank of the river. Refer to Figure 2.

Area #2 Park Drive, Brookside Place, Beech Street, Willow Street Area, comprising an interior drainage area of 94 acres on the west bank of the river. Refer to Figure 2.

Area #3 Balmiere Parkway, Crescent Place, Hampton Road Area, comprising an interior drainage area of approximately 38 acres on the west bank of the river. Refer to Figure 2.

The flood prone portions of Areas #2 and #3 are served by different storm sewer systems, separated by higher land, and are thus considered individually, although both areas are on the west bank of the river.

The Township, County, State (NJDEP) and federal (Army Corps of Engineers) agencies have undertaken numerous drainage and flood management studies. The findings of these studies were considered in the development of a comprehensive plan for improvements to reduce the frequency of flooding in Cranford. The overall plan includes five (5) Phases as follows:

Phase 1 – Express storm sewer system and interior drainage facilities in the northern portion of Area #1. (Construction completed in 2006.)

Phase 2 – Collector storm sewers along Riverside Drive and permanent stormwater pump station in Area #1 (Construction of the pump station and part of the collector sewer, identified as

FIGURE 2
Note: Figure 2 is included in Appendix B in the electronic copy of this report in order to keep the text file size as small as possible.

Phase 2A, started in April 2007, and is scheduled for operation by May 2008. Remainder of collector sewer construction deferred pending further funding.)

Phase 3 - Extension and modification of the existing dike system on the east side of the river. (serving Area #1)

Phase 4 – Extension and modification of the dike system on the west side of the river (serving Areas #2 and #3).

Phase 5 – Interior drainage improvements in Areas #2 and #3, including a stormwater pump station, express sewer system and collector storm sewer system on the west side of the river.

These five phases are interrelated but yet partially independent. The interior drainage phases (Phases 1, 2 and 5) may be completed without dike improvements. However, the dike improvements under Phases 3 and 4 should not be undertaken without the interior drainage improvements and also Phases 3 and 4 should be undertaken simultaneously, not independently. Each phase provides distinct benefits, which are enhanced by the related phases. For example, Phase 1 improvements will reduce the frequency of flooding in the lower portions of Area #1 due to storm sewer surcharging and excess overland flow from higher elevated areas. However, completion of Phase 1 did not eliminate the need for portable pumps to pump water from behind the existing dikes during severe storms. Phase 2 will eliminate the need for portable pumps by providing a permanent pumping facility with a peak design capacity of 150 cubic feet per second (cfs) (emergency capacity total of 180 cfs with operation of the reserve pump). Phases 3 and 4 will reduce the frequency of the Rahway River overflowing its banks and overtopping the dike system on both sides of the river. Phase 5 will reduce the frequency of storm sewer flooding in Areas #2 and #3 on the west side of the river.

Phase 1 has been completed and has been in operation since 2006. Phase 2 has been designed and Phase 2A is currently under construction with an anticipated completion date of May 2008. The preliminary design for Phase 5 has been completed and the Township is proceeding to select the location for the stormwater pumping station. Phases 3 and 4, as described further below, are being considered and further evaluated by the Township in association with the Township seeking funding for

implementation. Regional involvement in Phases 3 and 4, including coordination with the US Army Corps of Engineers, is essential to implementation of a project with an optimum level of protection. As indicated above, the Corps of Engineers New York District is undertaking a regional study of flood damage reduction and ecosystem restoration in the Rahway River Basin.

2.0 Project Description and Analyses

2.1 General

Phases 3 and 4 of the Northeast Quadrant Stormwater Management and Flood Management Program for the Township of Cranford include modifications and the extension of the existing dike systems in the vicinity of Nomahegan Park. Phases 3 and 4 also consider alternatives for mitigation of potential upstream and downstream impacts on water surface elevations associated with increasing the height of the dikes to reduce the frequency of overtopping. Multiple dike elevations were considered and analyzed and are discussed in this report.

The existing dike system within the vicinity of Nomahegan Park was constructed during the 1950's by the County of Union in cooperation with the Township of Cranford. On the west side of the Rahway River, the dike starts adjacent to Park Drive near the intersection with Springfield Avenue, follows along most of Park Drive, continues towards Balmiere Parkway and ends approximately 300' downstream of the footbridge at Balmiere Parkway. The dike on the east side of the Rahway River follows along Riverside Drive beginning near Kenilworth Boulevard and ending in a stone wall section at Springfield Avenue. The existing dike system through Nomahegan Park generally can contain a peak flow of approximately 3600 cubic feet per second (cfs) in the Rahway River before it is overtopped. The top of the dike is not uniform and some sections that are worn or eroded would be overtopped before other reaches. Since the construction of the existing dike system, it has been overtopped six times in the last 40 years, with the most recent in September 1999 and April 2007. These overtopping events caused significant damage to numerous homes within the low-lying areas of the Northeast Quadrant Project Area and pose a significant health and safety risk.

The Phase 3 and 4 Projects will increase the level of flooding protection to the surrounding residential areas in the vicinity of Nomahegan Park by extending the alignment and raising the elevation of the existing dike system. Under this investigation, various elevations of the dike system were considered,

up to and including a 500-year level of protection. Initially, the analysis was to be limited to floods between the 50 and 100-year storm events. However, the potential for participation by the Army Corps of Engineers in a regional project warrants consideration of higher levels of protection which the Township may select to implement as components of a long-range regional plan.

Increasing the elevation of the tops of the dikes and extending the dike system will result in a reduction in the frequency of overtopping of the dikes and an associated reduction in the flood storage volume in the flood plain adjacent to Nomahegan Park at times when the dikes are not overtopped. Under existing conditions, the flood waters stored in the residential areas provide a flood detention effect that reduces the peak flow discharged downstream of Springfield Avenue. Therefore elimination of the flooding of the residential area for certain storms that presently overtop the dikes will result in a reduction in available flood storage volume and a consequential increase in the peak flow discharged downstream. There will also be an increase in the water surface elevation of the flow contained within the higher dikes, which will tend to increase upstream water surface elevations. The analyses reviewed in this report included evaluation of the upstream and downstream impacts associated with the increased dike elevations for a range of storms. Modifications to the existing Lenape Park Detention Basin outlet structure and a bypass culvert generally parallel to Springfield Avenue were considered as potential options to reduce the impacts of the increased water surface elevations upstream and downstream due to the elevated dikes.

2.2 Methodology

The analysis of the effects of increasing the elevations of the tops of the dikes involves both hydrology and hydraulics. Hydrologic analysis is required to estimate the changes in peak flows associated with the reduction in flood storage volume and the increase of water surface elevation in Nomahegan Park, and hydraulic analysis is required to estimate the changes in water surface elevations upstream and downstream due to the flow changes. The analyses involve a series of iterations between hydrologic and hydraulic analyses, first estimating flow changes, then estimating water surface elevation changes,

then recalculating the flow changes based on backwater effects on the Lenape Park Detention Basin outlet, and then recalculating the water surface profiles, until the iterations result in a balance or consistent elevations at the downstream reach of Nomahegan Park and at the downstream side of the Lenape Park outlet.

The first step of this investigation was to determine the existing and proposed flows and flood storage volumes associated with the various levels of protection by using the HEC-1 "Flood Hydrograph Package" computer program, developed by the U.S. Army Corps of Engineers (ACOE). The original HEC-1 model, developed for the New Jersey Department of Environmental Protection, was modified to introduce a node downstream of Nomahegan Park in order to allow evaluation of the effects of the storage provided by Nomahegan Park and its surrounding areas both with and without the dike improvements. Using the new (2007) topographic mapping for the project area, the existing and proposed conditions storage capacities were calculated for Nomahegan Park and adjacent areas. The storage capacities included the interior volume of the dike (the river side of the dikes) for all elevations and the volume outside the dikes (the land side) for elevations greater than the elevation at which flood water will overflow the low reach or control point of the dike and flow into the surrounding areas. For this study, the control point used to model the storage capacities of the dike system was located at the footbridge near the intersection of Riverside Drive and Kensington Avenue. Therefore, the dike overflow elevations referred to in this report correspond to the elevations of the dikes at the footbridge and similarly the elevations at which the HEC-1 models would begin to use storage outside the dikes. Since the water surface profile from Springfield Avenue to Kenilworth Boulevard has some slope, the associated elevations of the tops of the dikes at Springfield Avenue would be slightly lower than the elevation at the footbridge, and the elevations at Kenilworth Boulevard would be slightly higher. All elevations refer to the NAVD 1929 datum.

Following development of the hydrologic and hydraulic models, multiple elevations for the proposed dike system providing various levels of protection were analyzed including an ultimate dike elevation that would provide protection from a 500-year storm event. In addition, as part of the investigation to

provide mitigation upstream and downstream due to the impacts of the elevated dikes, an analysis was performed on providing modifications to the existing Lenape Park Detention Basin outlet structure which included variations to the spillway structure that would modify the flows leaving Lenape Park and flowing through Nomahegan Park. The considered modification of the Lenape Park outlet would increase the height of the opening in the lower part of the outlet structure to allow lower flows to leave the detention basin with less restriction and thus utilize less of the available storage capacity during smaller storms and the early part of larger storms. This arrangement provides for more effective use of the available storage capacity of the Lenape Park detention facility during significant storm events.

The following table, Table 1, shows the estimated capacities (Rahway River flow at the brink of overtopping near the footbridge) of the various dike systems analyzed under this study. This table also provides an general indication of the additional height of dike required at the footbridge for the given level of protection, ranging from approximately 1.5 ft. for 50-year protection to almost 7 feet for 500-year, with about 4 ft required for the 100-year. The additional height required will vary along the lengths of the dikes since the existing dikes are not at uniform elevations and have high and low areas. Also, the required elevations will be lower at Springfield Avenue and higher near Kenilworth Boulevard. The peak flows and corresponding elevations presented in Table 1 are based upon consideration of the loss of flood storage associated with the increased elevation of the dikes. The storm frequencies associated with the indicated flows are for general characterization only and do not reflect any modifications at Lenape Park Detention Basin outlet, which will be addressed below.

Table 1 – Initial Estimate of Dike Elevations Required at Footbridge for Various Levels of Protection Adjacent to Nomahegan Park

	Existing	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
Dike Elev. At Footbridge	Existing Dike Elev. 67.5+/-*	Dike at Elev. 69.0'*	Dike at Elev. 69.6 '*	Dike at Elev. 71.3'*	Dike at Elev. 73.3'*	Dike at Elev. 74.3*
Peak Flow cfs	3600±	4480±	4830±	6,200±	9,440±	11,100±
Approx. Storm Frequency	Less than 50-yr	50-year	50-year plus	100-year	200-year	500-year

* The dike elevation at the footbridge, NAVD 1929. Dike elevations will be lower near Springfield Avenue and higher near Kenilworth Boulevard.

The estimated peak flows during a given storm will vary along the length of the Rahway River. In general, peak flows will increase from upstream to downstream, except where detention facilities or large flood storage areas are encountered. For example, the peak flow into the Lenape Park Detention Basin will be greater than the corresponding peak flow out of the basin. And the peak flow into the Nomahegan Park flood plain will be greater than the peak flow out at the footbridge. Also the peak flow for a given storm return period (e.g. 100-year storm) will vary based upon conditions being analyzed, such as for existing conditions with flooding in the residential area, or with raised dike elevations and associated loss of flood storage, or modification of the Lenape Park Detention Basin outlet structure. Therefore in the various tables presented in this report there will be some variations in the peak flow for a given storm frequency at a given location, depending upon the conditions being analyzed.

The hydrologic models (HEC-1) utilized for these analyses are actually based upon 24-hour rainfall for the indicated return frequencies. The hydrology model computes surface runoff and flows, and routes the flows through the flood storage areas and control structures. By comparing peak flows and flood elevations for a given rainfall frequency we have a means for comparing the effects of the dike scenarios.

With the estimated HEC-1 flows, the next step of the investigation was to determine the approximate elevations required for the dike extensions and modifications within the limits of the proposed project and to evaluate the effects that the proposed project would have both upstream and downstream of the project. This was performed using a portion of the HEC-RAS hydraulic model that was used as part of the recent FEMA study for the Township of Cranford. The cross sections through Nomahegan Park and vicinity were modified to be consistent with the new (2007) topographic mapping for the project area. After calibrating between the HEC-1 and HEC-RAS models, the newly generated design peak flows were inserted into the associated HEC-RAS models, with the proposed models simulating the elevated dikes through Nomahegan Park between Springfield Avenue and Kenilworth Boulevard.

2.3 Results of Analyses

Using various levels of design storms, peak flows through Nomahegan Park were estimated for each dike scenario shown in Table 1 above. The results for raising the dikes will have no effect on the depth of flooding for peak flows that are equal to or less than 3,600 cfs, since such flows do not presently overtop the dikes and raising the dikes would not decrease the flood storage volumes for these flows. However, the results of analyses for peak flows greater than 3,600 cfs show the effects of the loss of storage outside the dikes by yielding greater peak flows and resultant higher water surface elevations for certain design storms. Refer to the Flow tables in Appendix A.

The above dike elevation alternatives were also analyzed in conjunction with a modification of the outlet structure of the Lenape Park Detention Basin. The existing Lenape Park Detention Basin outlet is a two stage broad crested weir with an inline culvert at the base. The first stage of the weir is set at elevation 70.0' and the second stage of the weir is set at elevation 72.0'. The inline culvert is a 30 foot wide by 4 foot high box culvert with an invert elevation of 60.1'. The low level culvert allows the free passage of daily non-storm flows but provides the first restriction to storm induced flows, causing some of the

water to be stored in the basin. The proposed modifications to the spillway structure were analyzed as two separate alternatives. The first alternative, Alternative A, modified the inline culvert vertically to a 30 foot wide by 8 foot high box culvert. The second alternative, Alternative B, modified the inline culvert horizontally to a 60 foot wide by 4 foot high box culvert. Peak flows were estimated through Nomahegan Park for each dike scenario shown above based upon modifications to the Lenape Park detention basin spillway. The results of analyses showed that the peak flows through Nomahegan Park are reduced by releasing more flow through the spillway structure during the early stages of the design storm which provides for a more effective use of the storage capacity within the basin when the upstream peak of the Rahway River arrives. Several modifications to the 30-foot wide by 4-foot high lower outlet were considered and the most effective arrangement was found to be increasing the height of the opening from the present 4 feet to a proposed height of 8 feet.

The results of analyses for the considered modifications at the Lenape Park Detention Basin indicate that such modifications may help reduce the potential adverse effects on upstream and downstream water surface elevations caused by raising the elevations of the dikes in the Project Area. The benefits are on the order of a maximum of approximately 0.3' for the "50-year plus storm" analysis and less for greater storms. This concept should be explored further in detailed design and in planning for a regional project. For further analyses, more detailed data is required for the stage-storage characteristics of the Lenape Park Basin. The current HEC-1 model as developed for flood studies does not have sufficient detail for the storage volume below the crest of the spillway. Therefore refinement of the effects on discharges below the spillway in the early part of a storm is not possible at this time.

Table 2 shows the changes in downstream and upstream water surface elevations associated with the considered dike design elevations, absent any modifications at the Lenape Park Basin outlet. The increases in water surface elevation within the Project Area, that is between Kenilworth Boulevard and Springfield Avenue, are not of concern since they will be contained within the proposed dikes for each Plan. Floods greater than the respective Plan design storm will overflow into the Project Area and restore the flood storage. Thus a given Plan will not adversely affect flood levels for a greater storm

since flood storage will be restored to that of existing conditions. The increases upstream of Kenilworth Boulevard and downstream of Springfield Avenue are of concern and will be addressed in mitigation considerations.

The reductions in water surface elevations achieved by modifying the Lenape Park Detention Basin outlet may not seem to be great benefits. However, these reductions help mitigate the increased water surface elevations caused by raising the elevations of the dikes. Unfortunately, modification of the Lenape Park outlet will not completely offset the increases associated with dike improvements. Additional mitigation will be required, with the extent of mitigation depending upon the level of protection selected for implementation, the impacts of the residual water elevation increases, and the potential for such mitigation to be addressed in a regional plan for the Rahway River Basin.

Following Table 2, on the following page, the results of analyses are reviewed. The adverse impacts of increased flows and water surface elevations must be considered for each alternative. The impacts and potential mitigation for each Plan are discussed in Section 3 of this report.

Table 2 – Approx. Water Surface Elevation Changes Associated with Increased Dike Elevations Without Modification of Lenape Park Basin Outlet

At Footbridge:	Existing Exist. Dike Elev.67.5'*	Plan 1 Dike at Elev.69.0'*	Plan 2 Dike at Elev.69.6'*	Plan 3 Dike at Elev.71.3'*	Plan 4 Dike at Elev.73.3'*	Plan 5 Dike at Elev.74.3'*
24 hr rainfall	6.1"+/-	6.4"	6.7"	7.5"	10"	12"
Overtopping Flow at Footbridge	3,600± cfs	4,500± cfs	4,830± cfs	6,200± cfs	9,440± cfs	11,100± cfs
Approx. frequency	Less than 50-year	50-year	50-year plus	100-year	200-year	500-year
Kenilworth Blvd US side						
WSEL		70.60'	70.94'	71.91'	74.18'	75.31'
Change in WSEL	No change	+0.63'	+0.33'	+0.75'	+1.55'	+1.29'
US of Footbridge						
WSEL		68.98'	69.57'	71.27'	73.28'	74.29'
Change in WSEL	No change	+0.72'	+0.85'	+1.30'	+1.17'	+0.79'
US of Springfield Ave						
WSEL		67.98'	68.46'	70.36'	72.03'	72.91'
Change in WSEL	No change	+0.50'	+0.61'	+1.39'	+0.77'	+0.44'
DS of Eastman St Bridge						
WSEL		67.38'	67.80'	68.95'	70.87'	71.75'
Change in WSEL	No change	+0.63'	+0.54'	+0.72'	+0.89'	+0.37'
DS of Central RR						
WSEL		62.95'	63.22'	64.11'	65.51'	66.01'
Change in WSEL	No change	+0.29'	+0.33'	+0.54'	+0.55'	+0.22'
Rahway Gage						
WSEL		19.47'	19.95'	23.01'	24.96'	25.79'
Change in WSEL	No change	+0.33'	+0.44'	+0.38'	+0.59'	+0.31'

* The dike elevation at the footbridge, NAVD 1929. Dike elevations will be lower near Springfield Avenue and higher near Kenilworth Boulevard.

2.4 Discussion of Results of Analyses

The results of analyses presented in Table 2 indicate that there will be increased water surface elevations upstream and downstream of the Project Area due to modification and extension of the dikes. For some of the considered Plans, mitigation of these impacts will be beyond the capability of the Township of Cranford and must be part of a regional plan, such as may be developed by the US Army Corps of Engineers. Under the analyses of this report, the changes in water surface elevation have been estimated to serve as a basis for discussion of such regional approach and exploration of potential mitigation.

The design elevations for the top of dikes will depend upon the level of protection selected for the Project Area. As indicated above the required elevations would be slightly less for the 50 to 100-year storm range with the modification of the Lenape Park Detention Basin outlet. However, the difference in design elevation with the Lenape Park outlet modifications is small, and the selected design elevations will normally be increased slightly to provide a modest freeboard above the design flood elevation. Therefore, the flood elevations estimated without the Lenape Park outlet modifications (Table 2) should be selected, even if the Lenape Park outlet is modified. It must be recognized that even after the dikes are raised, they will be subject to overtopping for storms greater than the selected design storm. The improved dikes will be designed to be stable during overtopping, and will overtop less frequently than the existing dikes, but overtopping must be considered.

Table 3 below presents preliminary design minimum elevations for the tops of dikes or floodwalls at key locations in the Project Area for a range of storm frequencies. As indicated above, the top of dike elevations may be increased slightly in final design.

Table 3 – Minimum Top of Dike Design Elevations for Various Levels of Protection (Based on Water Surface Elevations Presented on Table 2 – Without Modification of Lenape Park Basin Outlet

	Existing Exist. Dike	Plan 1 Dike at:	Plan 2 Dike at:	Plan 3 Dike at:	Plan 4 Dike at:	Plan 5 Dike at:
24 hr rainfall	6.0"+/-	6.4"	6.7"	7.5"	10"	12"
Overtopping Flow at Footbridge	3,600± cfs	4,500± cfs	4,830± cfs	6,200± cfs	9,440± cfs	11,100± cfs
Approx. frequency	Less than 50-year	50-year	50-year plus	100-year	200-year	500-year
Kenilworth Blvd US side		**70.6'**	**71.0'**	**72.0'**	**74.2'**	**75.4'**
US of Footbridge	**67.5'**	**69.0'**	**69.6'**	**71.3'**	**73.3'**	**74.3'**
US of Springfield Ave		**68.0'**	**68.5'**	**70.4'**	**72.1'**	**73.0'**

Dike elevations NAVD 1929. Dike elevations will be lower near Springfield Avenue and higher near Kenilworth Boulevard. Note: Top of dike or floodwall elevations shown on drawings are slightly higher to provide some freeboard.

The dike improvements considered will extend from Springfield Avenue to Kenilworth Boulevard. The ends of the dikes must tie into higher ground to prevent flow from going around the ends of the dikes into the area to be protected. Aerial topographic maps of the Project Area were prepared based upon 2007 aerial photography and with contour intervals of one foot. These maps show that the existing low point in Kenilworth Boulevard is about Elevation 70.0' near the Lenape Park access road. However the road elevation is at Elevation 70.7' +/- to the east of the Rahway River, near the upstream location of the proposed dike system, with a low point at Elevation 70.4' about 300' further to the east along the road. The low point in Springfield Avenue at the downstream limit of the dikes is 67.5' at a location between the River and Central Avenue. At each road the low point is to the east of the Rahway River crossing, with the elevation to the west slightly higher.

Table 4 below includes the results of analysis for water surface elevations upstream of Kenilworth Boulevard and downstream of Springfield Avenue for a range of storms, along with the low point elevations at these two roads near where the dikes would have to tie in to higher ground.

Table 4 – Flood Elevations (from Table 2) at Dike Ends for Various Levels of Protection (Without Modification of Lenape Park Basin Outlet)

	Top of Road Low Point Near Tie-in	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
24 hr rainfall		6.4"	6.7"	7.5"	10"	12"
Overtopping Flow at Footbridge		4,500± cfs	4,830± cfs	6,200± cfs	9,440± cfs	11,100± cfs
Approx. frequency		50-year	50-year plus	100-year	200-year	500-year
Kenilworth Blvd US side (east)	70.7'	**70.60'**	**70.94'**	**71.91'**	**74.18'**	**75.31'**
US of Footbridge	N/A	**68.98'**	**69.57'**	**71.27'**	**73.28'**	**74.29'**
Down Stream of Springfield Ave	67.5'	**67.71**	**68.11'**	**69.22'**	**71.24'**	**72.16'**

Elevations NAVD 1929.

As indicated in Table 4, under Plan 1 dike improvements, the peak flow of the 50-year storm would not overtop Kenilworth Boulevard, but would backup over the low point in Springfield Avenue by about 2-½ inches. The low point could easily be raised to prevent such backup by adding about 3 inches of pavement to the low section of road, or only one inch of pavement would be required with the slightly lower water surface elevation achieved by modifying the Lenape Park Basin outlet. For the more severe storms, more extensive work would be required at Springfield Avenue. Under Plan 2 dike improvements, for a storm somewhat greater than the 50-year but less than the 100-year, addition of about 3 inches of pavement at the low section of Kenilworth Boulevard would serve to prevent overflow of that road. Under Plan 2, there would be about a 7-inch depth of backflow over Springfield Avenue to the east of the bridge, requiring re-grading of the road and tying in to grade above Elevation 68' in the adjacent park. The reach of Springfield Avenue to the west of the bridge (near Hampton Road) is at or above Elevation 68.5' and thus would not require modification to prevent backflow from downstream under Plan 2. More extensive work would be required at both Springfield Avenue and Kenilworth Boulevard under Plans 3, 4 and 5 (100-year and greater levels of protection). Considerations at these points of closure will be reviewed under the discussion of alternatives below.

3.0 Alternatives for Dike Improvements

Five alternative levels of protection have been analyzed to estimate changes in flows and water surface elevations associated with extending the dike system and raising the elevation of the tops of the existing dikes on both sides of the Rahway River between Springfield Avenue and Kenilworth Boulevard. These alternatives, identified as Plans 1 through 5, have several common elements, but also have some differences in required construction and impacts beyond the Project Area. The common elements will be presented first, followed by discussion of unique aspects of each plan.

It must be recognized that implementation of Plans 3, 4 and 5 (100-year and greater protection) will require extensive work outside of the Project Area, will require regional solutions to mitigate impacts, and are not anticipated to be implementable on a local level. These Plans are included to present a concept of what is required for higher levels of protection and for consideration as a component of a future regional plan.

3.1 Common Elements

For each plan, the top of the existing dike elevations would be increased and the dikes would be extended on each side of the Rahway River, generally from Springfield Avenue to Kenilworth Boulevard. The type of construction would vary along the lengths of the dikes, depending upon the location of the dike reach, elevation of adjacent ground, and proximity to structures. Construction would include earthen dikes protected from erosion during overtopping, cantilevered steel sheeting with earth or concrete covering, and reinforced concrete floodwalls. Exposed concrete surfaces would be constructed with the use of form liners so that the finished appearance would simulate a stone wall. Paths for walking or bicycling would be incorporated adjacent to the dikes in appropriate locations in public right-of-way or park areas.

On the west side of the Rahway River, the proposed dike or floodwall would begin at Springfield Avenue and continue through the backyards of the homes along the River towards the footbridge. From

the footbridge, the dike would continue along Park Drive and end near the intersection of Springfield Avenue and Park Drive. Some additional dike construction would be required along Springfield Avenue north of Park Drive under Plans 3, 4 and 5. On the east side of the River, the dike or floodwall would begin at Springfield Avenue, generally follow the alignment of the existing dike, continue along Riverside Drive and end at Kenilworth Boulevard. Under Plans 2, 3, 4 and 5, the dike would have to be continued to the east along Kenilworth Boulevard to intercept water that would flow over the road.

For most of the length of the dikes on each side of the River, the alignment will not vary due to the selected level of protection. An exception to this concept is considered on the west side of the River between Springfield Avenue and the footbridge, where the dike will be extended on private properties. For a lesser level of protection (i.e. Plan 2), it may be desirable to construct low floodwalls close to the houses. However, for a greater level of protection (i.e. Plans 3, 4 and 5), the floodwalls would be located somewhat further from the houses to encompass patios, decks and similar features. These alternative alignments are shown on the drawings that accompany this report.

Interior drainage facilities are required in association with each plan to provide for drainage of stormwater from the area protected by the dikes or floodwalls. For the most part, the interior drainage is common to all alternatives and is provided under Phases 1 and 2 on the east side of the River and under Phase 5 on the west side of the River. Some modifications or additions to the interior drainage facilities may be required in association with a particular alternative, depending upon the final dike alignment selected.

3.2 Closure at the Ends of the Dikes

Under each of the alternatives, the ends of the dikes will need to tie into higher ground to prevent water from flowing around the ends into the protected area. On the east side of the River the dikes will tie into Springfield Avenue on the downstream end and Kenilworth Boulevard on the upstream end. On the west side, the dike system will start at the bridge at Springfield Avenue and end near the intersection of

Park Drive with Springfield Avenue. Additional extensions of the dikes will be required at the upstream ends on one or both sides of the River under Plans 2, 3, 4 and 5.

The existing low point along Springfield Avenue is approximately Elevation 67.5' to the east of the bridge (near Riverside Drive) and 68.5' to the west of the bridge (near Hampton Road). The connection point in Kenilworth Boulevard to the east of the proposed dikes is Elevation 70.7' (with a near by low point at Elevation 70.4'). The pavement elevation of Springfield Avenue near Park Drive is Elevation 70.0'. There is also a low point in Springfield Avenue at Elevation 69.9' about halfway between the Union County Community College and Kenilworth Boulevard, near a storm sewer discharge (about 1,000' south of Kenilworth Boulevard). Dike closure is required at each of these locations to prevent flood waters from flowing around the ends of the dikes or floodwalls below the design level of protection.

As indicated by the water surface elevations in Table 4, closure for the 50-year storm or for the "50-year plus" storm (Plans 1 or 2) can be accomplished by raising the elevation of the pavement at the points of closure of the dikes to the roads. The "50-year plus" storm evaluated under Plan 2 is almost a perfect balance for tying in the dikes at Springfield Avenue, Park Drive and Kenilworth Boulevard. However for greater levels of protection, construction required for closure of the dikes will be more significant, with closure heights ranging from about 1.5' to 4.7' at Kenilworth Boulevard and from 1.7' to 4.7' at Springfield Avenue for the 100-year to 500-year levels of protection, respectively.

3.3 Plan 1 - 50-Year Storm Protection

Plan 1 would provide protection from a storm with a 24-hour rainfall of about 6.4", approximately a 50-year storm. Key features of Plan 1 are as follows:

- Common elements described above, including:
  - Dikes and floodwalls on the east side of the River from Springfield Avenue to Kenilworth Boulevard

  - Dikes and floodwalls on the west side from Springfield Ave. to the west end of Park Drive
- Proposed dike/floodwall at Springfield Avenue (both sides) El. 68.0'
- Minor repaving required at Springfield Ave to close dike east of bridge (low point El 67.5').
- Proposed low floodwalls near houses upstream of Springfield Ave.
- Proposed dike at Footbridge (both sides) El. 69.0'
- Proposed dike (low earthen dike, not floodwall) at west end Park Drive El. 70.0'
- No additional dike required at the end of Park Drive (at Springfield Avenue)
- No repaving required at Springfield Ave low point (El. 69.9') located 1,000' south of Kenilworth Boulevard.
- Proposed top of dike at Kenilworth Boulevard (east)El. 70.6' (road El. 70.7')
- No repaving required at Kenilworth Boulevard to close end of dike
- Water surface (WS) elevation increases (without modification of Lenape Basin outlet):
  - U.S. Kenilworth Blvd. +0.63' (above existing 50-yr WS El. 69.97')
  - D.S. Eastman Street +0.63' (above existing 50-yr WS El. 66.75')
  - D.S. Central RR. +0.29' (above existing 50-yr WS El. 62.66')
- Include modification of Lenape Park Detention Basin outlet
- Include bypass box culvert parallel to Springfield Avenue (approx. 1,000 long)

Plan 1 would provide for low reinforced concrete floodwalls on private properties on the west side of the River immediately upstream of Springfield Avenue, with top of wall elevations ranging from El. 68.0' near Springfield Avenue to El. 69.0' near the footbridge. These floodwalls would run close to the houses, with the final locations to be determined based upon the grade elevations and features at each property. The existing grades near these houses generally range between El. 67' and El. 68', so the floodwalls would be less than 2 feet high. An additional foot of wall height should be considered to provide some freeboard (additional height for waves and additional safety). Walls on adjoining properties must be coordinated to provide a contiguous flood barrier.

3.4 Plan 2 - "50-Year Plus" Storm Protection

Plan 2 would provide protection from a storm with a 24-hour rainfall of about 6.7", approximately a "50-year plus" storm (more than the 50-year, less than the 100-year). Key features of Plan 2 are as follows:

- Common elements described above, including:
  - Dikes and floodwalls on the east side of the River from Springfield Avenue to Kenilworth Boulevard
  - Dikes and floodwalls on the west side from Springfield Ave. to the west end of Park Drive
- Proposed dike/floodwall at Springfield Avenue (both sides) minimum El. 68.5', use El 69.0'
- Repaving required along Springfield Avenue and Riverside Drive to close dike east of bridge (low point El. 67.5'), and possibly some re-grading in the adjacent park.
- No changes to Springfield Avenue west of bridge (road low point El. 68.5' near Hampton Road)
- Low floodwalls proposed near houses upstream of Springfield Ave.
- Dike at Footbridge (both sides) Minimum El. 69.6', use El 70.0'
- Dike (low earthen dike, not floodwall)at west end of Park Drive El. 70.5'
- Minor repaving (add 0.3') required at Springfield Ave low point (El. 69.9') located 1,000' south of Kenilworth Boulevard.
- Proposed top of dike at Kenilworth Boulevard (east)El. 71.0' (road El. 70.7'+/-)
- Low floodwall required parallel to Kenilworth Boulevard to close end of dike and provide controlled overflow for storms exceeding "50-year plus" design flow. Length approx. 550', top of overflow wall El. 70.9' (only slightly above existing top of road elevation)
- Water surface (WS) elevation increases (without modification of Lenape Basin outlet):
  - U.S. Kenilworth Blvd. +0.33' (above existing "50-yr plus" WS El. 70.61')
  - D.S. Eastman Street +0.54' (above existing "50-yr plus" WS El. 67.26')
  - D.S. Central RR. +0.33' (above existing "50-yr plus" WS El. 62.89')
- Include modification of Lenape Park Detention Basin outlet

- Include bypass box culvert parallel to Springfield Avenue (approx. 1,000 long)

Similar to Plan 1, Plan 2 would provide for low reinforced concrete floodwalls on private properties on the west side of the River immediately upstream of Springfield Avenue, with top of wall elevations ranging from El. 69.0' near Springfield Avenue to El. 70.0' near the footbridge. These floodwalls would run close to the houses, with the final locations to be determined based upon the grade elevations and features at each property. The existing grades near these houses generally range between El. 67' and El. 68', so the floodwalls would be less than 3 feet high. An additional foot of height may be considered to provide some freeboard. If the height of the floodwall on a given property exceeds an acceptable height for the property use, the wall location may have to be shifted further from the house, which will be to a lower ground area, resulting in the need for a greater exposed wall face. Walls on adjoining properties must be coordinated to provide a contiguous flood barrier.

3.5 Plan 3 - 100-Year Storm Protection

Plan 3 would provide protection from a storm with a 24-hour rainfall of about 7.5", approximately a 100-year storm. Key features of Plan 3 are as follows:

- Common elements described above, including:
  - Dikes and floodwalls on the east side of the River from Springfield Avenue to Kenilworth Boulevard
  - Dikes and floodwalls on the west side from Springfield Ave. to the west end of Park Drive
- Proposed dike/floodwall at Springfield Avenue (both sides) Minimum El. 70.4', use El. 71.0'
- Major repaving required at Springfield Ave, east and west of bridge and re-grading required (average 1 foot of fill) in the adjacent park to close dike.
- Proposed higher floodwalls proposed near houses upstream of Springfield Ave.
- Proposed dike at Footbridge (both sides) Minimum El. 71.3', use El. 72.0'
- Proposed dike/floodwall at west end of Park Drive Minimum El. 71.7', use El. 72.5'

- Additional 550'+/- dike required along Springfield Ave near low point (El. 69.9) located 1,000' south of Kenilworth Boulevard, to close dike
- Proposed top of dike at Kenilworth Boulevard (east)El. 72.5' (road El. 70.7')
- Major construction required at Kenilworth Boulevard to close end of dike (extend dike 1000'+ to east, parallel to Kenilworth Blvd., modify at driveway to park office on south side of road.)
- Water surface (WS) elevation increases (without modification of Lenape Basin outlet):
    - U.S. Kenilworth Blvd. +0.75' (above existing 100-yr WS El. 71.16')
    - D.S. Eastman Street +0.72' (above existing 100-yr WS El. 68.23')
    - D.S. Central RR. +0.54' (above existing 100-yr WS El. 63.57')
- Include modification of Lenape Park Detention Basin outlet
- Additional mitigation required under a regional plan. Bypass culvert parallel to Springfield Avenue not sufficient due to existing overflow along Springfield Avenue for 100-year and greater floods.

Unlike provisions under Plans 1 and 2 for low floodwalls on private properties on the west side of the River immediately upstream of Springfield Avenue, Plan 3 would require higher walls, with top of wall elevations ranging from El. 71.0' near Springfield Avenue to El. 72.0' near the footbridge. These floodwalls would enclose facilities requiring ready access from the houses, such as patios and decks. Final locations must be determined based upon the grade elevations and features at each property. The existing grades near these houses range from about El. 67' to El. 68' close to the houses, but drop significantly between the houses and the River. Thus the use of low walls (as in Plans 1 and 2) near the homes may work on some properties, but higher walls will be required on other properties, necessitating moving the walls sufficiently away from the houses to encompass the adjacent patios, decks and similar facilities. The appropriate design must be developed for each property, taking several factors into account. Walls on adjoining properties must be coordinated to provide a contiguous flood barrier.

3.6 Plan 4 - 200-Year Storm Protection

Plan 4 would provide protection from a storm with a 24-hour rainfall of about 10", approximately a 200-year storm. Key features of Plan 4 are as follows:

- Common elements described above, including:
  - Dikes and floodwalls on the east side of the River from Springfield Avenue to Kenilworth Boulevard
  - Dikes and floodwalls on the west side from Springfield Ave. to the west end of Park Drive
- Proposed dike/floodwall at Springfield Avenue (both sides) El. 72.1' (road low point El.67.5' east and El. 68.5' west)
- Major extensive construction required at Springfield Ave, Hampton Road, Riverside Drive and Central Avenue to close dike. The backwater from downstream of Springfield Avenue at El. 71.3' is about at the limit of possible dike closure without need of buying out homes to achieve closure to higher ground.
- Higher floodwalls proposed near houses upstream of Springfield Ave.
- Dike at Footbridge (both sides) Minimum El. 73.3'
- Dike/floodwall at west end of Park Drive Minimum El. 74.0'
- Additional 600'+/- dike required along Springfield Ave (immediately north of Park Drive) to close dike.
- Additional 900'+/- dike required along Springfield Ave near low point (El. 69.9) located 1,000' south of Kenilworth Boulevard, to close dike.
- Proposed top of dike at Kenilworth Boulevard (east)El. 74.2' (road El 70.7')
- Extensive major construction required at Kenilworth Boulevard to close end of dike (extend dike 1,500'+ to east, parallel to Kenilworth Blvd.)
- Water surface elevation increases (without modification of Lenape Basin outlet):
  - U.S. Kenilworth Blvd. +1.55' (above existing 200-yr WS El. 72.63')

  - D.S. Eastman Street +0.89' (above existing 200-yr WS El. 69.98')
  - D.S. Central RR. +0.55' (above existing 200-yr WS El. 64.96')
- Include modification of Lenape Park Detention Basin outlet (will mitigate increases under more frequent storms)
- Additional mitigation required under a regional plan.

Similar to Plan 3, Plan 4 would require high floodwalls on private properties on the west side of the River immediately upstream of Springfield Avenue, with top of wall elevations ranging from El. 72.1' near Springfield Avenue to El. 73.3' near the footbridge (with some additional freeboard, about 2' higher than elevations under Plan 3). These floodwalls would enclose facilities requiring ready access from the houses, such as patios and decks. Final locations must be determined based upon the grade elevations and features at each property. The existing grades near these houses range from between El. 67' and El. 68'. Thus, under Plan 4, some of the walls would be approximately 6' high. Walls on adjoining properties must be coordinated to provide a contiguous flood barrier.

3.7 Plan 5 - 500-Year Storm Protection

Plan 5 would provide protection from a storm with a 24-hour rainfall of about 12", approximately a 500-year storm. Key features under Plan 5 are as follows:

- Common elements described above, including:
  - Dikes and floodwalls on the east side of the River from Springfield Avenue to Kenilworth Boulevard
  - Dikes and floodwalls on the west side from Springfield Ave. to the west end of Park Drive
- Dike/floodwall at Springfield Avenue (both sides) El. 73.0' (road low point El.67.5' east and El. 68.5' west)
- Major extensive construction required at Springfield Ave, Hampton Road, Riverside Drive and Central Avenue to close dike. The backwater from downstream of Springfield Avenue at El.

72.2' is above the limit of possible dike closure without need of buying out homes to achieve closure to higher ground.

- Higher floodwalls proposed near houses upstream of Springfield Ave.
- Proposed dike at Footbridge (both sides) Minimum El. 74.3'
- Proposed dike/floodwall at west end of Park Drive Minimum El. 75.1'
- Additional 600'+/- dike required along Springfield Ave (immediately north of Park Drive) to close dike.
- Additional 1,100'+/- dike required along Springfield Ave near low point (El. 69.9) located 1,000' south of Kenilworth Boulevard, to close dike (to within about 250' of Kenilworth Boulevard).
- Top of dike at Kenilworth Boulevard (east) El. 75.4' (road low point El. 70.7')
- Extensive major construction required at Kenilworth Boulevard to close end of dike (extend dike 2,000'+ to east, parallel to Kenilworth Blvd.)
- Water surface elevation increases (without modification of Lenape Basin outlet):
    - U.S. Kenilworth Blvd. +1.29' (above existing 500-yr WS El. 74.02')
    - D.S. Eastman Street +0.37' (above existing 500-yr WS El. 71.38')
    - D.S. Central RR. +0.22' (above existing 500-yr WS El. 65.79')
- Include modification of Lenape Park Detention Basin outlet (causes minor change for 500-year storm, but will mitigate increases under more frequent storms)
- Additional mitigation required under a regional plan.

Similar to Plans 3 and 4, Plan 5 would require high floodwalls on private properties on the west side of the River immediately upstream of Springfield Avenue, with minimum top of wall elevations ranging from El. 73.0' near Springfield Avenue to El. 74.3' near the footbridge. These floodwalls would enclose facilities requiring ready access from the houses, such as patios and decks. Final locations must be determined based upon the grade elevations and features at each property. The existing grades near these houses range between El. 67' and El. 68', with lower elevations closer to the River. Thus some

wall heights may exceed 7 feet. Walls on adjoining properties must be coordinated to provide a contiguous flood barrier.

3.8 Combination Plan

Each plan described above, Plans 1 through 5, provides an increased level of protection for the Project Area, but requires higher elevations for the tops of the dikes and floodwalls, presents increasing complexity for closure of the ends of the dikes to higher ground, and has increased associated hydrologic impacts upstream and downstream of the Project Area.

The original concept for dike improvements was to provide a level of protection for a storm exceeding the 50-year but less than the 100-year event. This "50-year plus" level of protection is represented by Plan 2. The principal reason for this initial limitation to less than the 100-year storm was the belief that the Township of Cranford would not be able to implement a local project for a 100-year storm or greater due to the need to mitigate any adverse hydrologic impacts upstream and downstream of the Project Area. However, during the course of the investigations and analyses for this report, the US Army Corps of Engineers has initiated an active involvement in a regional study of the Rahway River Basin. Therefore, it is possible that dike improvements implemented by the Township of Cranford could eventually become part of a regional flood management system. With that possibility, it is to Cranford's benefit to consider a combination plan wherein any dike improvements that are constructed are consistent with a regional plan.

The initial benefits of the dike improvements under a combination plan would be limited to the level of protection provided at the closure points at the ends of the dikes. This would also limit the adverse upstream and downstream impacts that would need to be mitigated for the initial project. It may also be necessary to provide some selected overflow locations on each side of the River to allow floodwaters to enter the area protected by the dikes for flows above the level of protection so that the required flood storage can be provided to avoid increased adverse impacts upstream and downstream.

This concept of a combination plan warrants further consideration and discussions with the US Army Corps of Engineers and the County of Union. It may be practical for Cranford to implement the "50-year plus" level of protection under Plan 2, but increase the height of any dike or floodwalls constructed to the elevations indicated under Plans 3, 4 or 5 (100-year, 200-year, or 500-year level of protection). The closure facilities at Springfield Avenue, Park Drive and Kenilworth Boulevard would be as needed for the lower level of protection, to limit the adverse impacts beyond the Project Area until such time as a regional plan can be implemented.

Obviously, the cost differential for increased dike heights will be a consideration in selection of the design elevations for implementation. Other factors will include the design level selected or found to be cost-effective by the US Army Corps of Engineers for a regional plan, the impacts on local properties due to the dike (or floodwall) elevations, construction limitations and constraints at the dike ends for tie-in to higher ground.

A review of the Plans described above reveals that Plan 2 ("50-year plus") could be implemented without excessive major construction at the ends of the dikes for closure, and with reasonable wall heights on private properties. Plan 3 (100-year) could also be implemented with significant, but not impractical, construction at the dike closure points, and floodwall heights ranging from about 3 to 5 feet on private properties. Under Plan 4 the closure at the dike ends requires extensive major construction and may be impractical, and under Plan 5 dike closure becomes impractical and would require purchase of private properties. Under each of these two plans, the wall heights on some private properties would exceed 6 feet.

Until advised otherwise by the US Army Corps of Engineers or other competent authority, it is recommended that the Township of Cranford consider a combination plan that would initially provide the benefits of Plan 2 ("50-year plus" level of protection), and would require mitigation of Plan 2 impacts, but would incorporate the top of dike elevations provided in Plan 3 (100-year) to the maximum extent possible. Construction at closure points would be in accordance with Plan 2. Thus floodwaters

from storms exceeding the "50-year plus" design storm would overflow Kenilworth Boulevard to Riverside Drive and would also backup over Springfield Avenue to the south end of Riverside Drive. As flood levels increased for greater storms, there would be overflow to Hampton Road and to Springfield Avenue near Park Drive. Additional overflow control points may be required on each side of the River to allow controlled entry of floodwaters into the areas protected by the dikes. In the future, when a regional plan is implemented addressing the adverse impacts beyond the Project Area, the overflow points could be closed, thus implementing the higher (100-year) level of protection.

Combination Plan 2-3

The key components of a combination plan for Plan 2 (50-year plus) initial level of protection with Plan 3 (100-year) dike heights (Combination Plan 2-3) are presented below.

- Common elements described above, including:
  - Dikes and floodwalls on the east side of the River from Springfield Avenue to Kenilworth Boulevard
  - Dikes and floodwalls on the west side from Springfield Ave. to the west end of Park Drive
- Proposed dike/floodwall at Springfield Avenue (both sides), use El 71.0' (per Plan 3)
- Repaving required along Springfield Avenue and Riverside Drive to close dike east of bridge (low point El. 67.5'), and possibly some re-grading in the adjacent park (per Plan 2).
- No changes to Springfield Avenue west of bridge (road low point El. 68.5' near Hampton Road) (Per Plan 2)
- Higher floodwalls proposed near houses upstream of Springfield Ave.(per Plan 3)
- Dike at Footbridge (both sides), use El 72.0' (per Plan 3)
- Dike/floodwall at west end of Park Drive, use El. 72.5' (per Plan 3)
- Minor repaving (add 0.3') required at Springfield Ave low point (El. 69.9') located 1,000' south of Kenilworth Boulevard. (per Plan 2). Defer 550'+/- dike required until Plan 3 is implemented.
- Proposed top of dike at Kenilworth Boulevard (east)El. 72.5' (per Plan 3) (road El. 70.7'+/-)

- Low floodwall required parallel to Kenilworth Boulevard to close end of dike and provide controlled overflow for storms exceeding "50-year plus" design flow. Length approx. 550', top of overflow wall El. 70.9' (only slightly above existing top of road elevation) (Per Plan 2 as required to allow overflow. Modify when Plan 3 is fully implemented.)
- Water surface (WS) elevation increases (without modification of Lenape Basin outlet) (Per Plan 2 since overflow will be allowed for flows exceeding "50-year plus" design flow):
    - U.S. Kenilworth Blvd. +0.33' (above existing "50-yr plus" WS El. 70.61')
    - D.S. Eastman Street +0.54' (above existing "50-yr plus" WS El. 67.26') (this impact is mitigated by the bypass box culvert parallel to Springfield Avenue)
    - D.S. Central RR. +0.33' (above existing "50-yr plus" WS El. 62.89')
- Include modification of Lenape Park Detention Basin outlet
- Include bypass box culvert parallel to Springfield Avenue (approx. 1,000 long) (Per Plan 2) as mitigation for "50-year plus" adverse impacts to area in Rahway River loop downstream of Springfield Avenue.

On private properties on the west side of the River immediately upstream of Springfield Avenue, Combination Plan 2-3 would require higher walls, with top of wall elevations ranging from El. 71.0' near Springfield Avenue to El. 72.0' near the footbridge. These floodwalls would enclose facilities requiring ready access from the houses, such as patios and decks. Final locations must be determined based upon the grade elevations and features at each property. The existing grades near these houses range from about El. 67' to El. 68' close to the houses, but drop significantly between the houses and the River. Thus the use of low walls (as in Plan 2) near the homes may work on some properties, but higher walls will be required on other properties, necessitating moving the walls sufficiently away from the houses to encompass the adjacent patios, decks and similar facilities. The appropriate design must be developed for each property, taking several factors into account. Walls on adjoining properties must be coordinated to provide a contiguous flood barrier.

Initial proposed alignments for floodwalls and dikes under Plans 2 and 3 are shown on the drawings that accompany this report. The low floodwalls considered for Plan 2 are shown as an alternative for alignment on the west bank of the Rahway River. These low floodwalls are close to the houses and have several turns in alignment. Representatives of the U.S. Army Corps of Engineers New York District have indicated that the District would not be favorable to walls that have frequent turns and would prefer a more streamline alignment. Therefore, for incorporation into a regional plan acceptable to the Corps, the Combination Plan 2-3 walls would follow the alignment indicated for 100-year protection.

Preliminary estimated costs for Plan 2 (50-year plus) and for Combination Plan 2-3 as described above are presented in Section 5 of this report.

4.0 Hydrologic Impacts and Mitigation

4.1 Springfield Avenue and Downstream - Bypass Culvert

The hydrologic and hydraulic analyses described in Section 2 of this report indicate that there will be some increase in the peak flood elevations downstream of the Project Area due to the loss of flood storage resulting from the increase in elevation and extension of the dikes and floodwalls along Nomahegan Park. As indicated in Table 2 (in Section 2.3), the increase in water surface elevation immediately downstream of Eastman Street (the 2007 bridge) will range from about 0.5' to 0.9' for the 50-year plus and the 200-year storms, respectively. Downstream of the Central Railroad crossing and further downstream along the Rahway River the water surface elevation increases would be somewhat less.

A significant portion of the residential area along the loop in the Rahway River between the two crossings of Springfield Avenue is in the floodplain of the river. Based upon a review of the grade elevations shown on topographic maps of the area, some of the properties would be adversely affected by increased flood elevations. Therefore, the concept of providing a bypass box culvert parallel to Springfield Avenue was considered. The bypass culvert would convey the additional flow directly from upstream of Springfield Avenue to a discharge point downstream of the Canoe Club, thus avoiding any increase in peak flow and water surface elevation in the loop between the two Springfield Avenue crossings.

For the existing 100-year flood, this bypass condition already exists since flood waters will flow overland along Springfield Avenue, cross the highpoint near the intersection of Springfield Avenue and Central Avenue and return to the river near the Canoe Club building, thus bypassing the loop. For the existing conditions 50-year plus peak flow, the flood elevation would be just below that required for overland flow along Springfield Avenue. Thus, under existing conditions, all of the flow for the 50-year plus storm will follow around the loop. Installation of a bypass culvert would convey the additional

flow resulting from the storage loss due to the dike system improvements, thus eliminating any increased flooding along the loop. However, the bypass culvert would also convey a portion of the flow from lesser storms, mitigating any adverse effects for those storms and possibly providing a benefit by reducing flood levels for some of the more frequent storms.

The drawings that accompany this report show a bypass box culvert that is sized to convey the additional flow estimated at the upstream side of Springfield Avenue for a 50-year plus storm. This culvert would be appropriate for either Plan 2 or Combination Plan 2-3, since both plans provide protection for the 50-year plus design storm. In final planning and design, consideration may be given to constructing a slightly larger box culvert, within practical limits, to provide some additional benefit to the properties in the Rahway River loop between the Springfield Avenue crossings.

Downstream of the discharge point of the bypass box culvert, the Rahway River will be subject to some increase in peak flow and water surface elevations due to the Phase 3 & 4 project. A review of the Flood Insurance Study (FIS) maps adopted in 2006 for Union County communities reveals that there are some developed properties in the Rahway River 100-year floodplain in Cranford downstream of the bypass culvert outlet and in downstream communities, particularly in the City of Rahway. Between Cranford and Rahway there are long stretches of the river without structures in the 100-year floodplain. The FIS includes a water surface profile for a 50-year flood, but the limits are not shown on the maps. Since the floodplain of the 50-year plus storm would be smaller than that of the 100-year flood, the number of structures affected would be less than are shown in the 100-year floodplain on the FIS maps.

Although the downstream effects on water surface elevations would be expected to be less downstream than in Cranford, some increase is estimated based upon the hydrologic and hydraulic modeling for this report. Although the increases may be small, the impacts will have to be determined, and where structures would be affected, some form of mitigation will be required. Following selection of a plan for implementation, appropriate evaluation can be made of such potential impacts and possible mitigation. For appropriate evaluation it may be necessary to obtain topographic maps of affected areas or conduct

field surveys of affected structures. Since the Corps of Engineers has already completed some investigations of the Rahway River, the Corps should be consulted regarding available data and the potential for incorporating appropriate mitigation in a regional program.

4.2 Kenilworth Boulevard and Upstream

The hydrologic and hydraulic analyses undertaken for this report indicate that there will be some increase in peak water surface elevations upstream of Kenilworth Boulevard due to the dike and floodwall improvements proposed under Phases 3 & 4. The estimated increases for the range of storms evaluated are presented in Table 2 in Section 2.3 of this report. These estimated increases are limited to the area between Kenilworth Boulevard and the Lenape Park Detention Basin. There will be no adverse impacts upstream of the Lenape Basin.

The increased water surface elevations that would be associated with Plans 3, 4 and 5 providing 100, 200 and 500-year storm protection for the Project Area would affect numerous houses upstream of Kenilworth Boulevard at elevations expected to significantly adversely affect many structures. The impacts in the area to the east of the Lenape Park Basin would be expected to be more severe than in the area west of Lenape Park since the area to the east is generally somewhat lower in elevation. Many of these same structures are already affected by significant flood events.

Based upon the hydrologic and hydraulic analyses undertaken for this report and elevations indicated on the topographic maps prepared for Cranford in 2007, Kenilworth Boulevard would not be overtopped during a 50-year storm under existing conditions. Some portions of Kenilworth Boulevard would be overtopped at shallow depths during a "50-year plus" storm under existing conditions. The reach of road that would be overtopped is primarily the stretch of road nearest to the Rahway River crossings just downstream of the basin outlet facilities. There would also be some overtopping at a local low area in Kenilworth Boulevard near the intersection with Dorset Drive. The overflow of the road near the Lenape Basin outlet would be allowed to continue under all of the Phase 3 & 4 Plans. However, the

overflow near the Dorset Drive intersection would be controlled to not overflow until the water elevation exceeded the elevation for the level of protection selected. Under Plan 2 and Combination Plan 2-3, this controlled overflow would be at Elevation 70.9' for the 50-year plus storm design elevation. Flows exceeding the selected design elevation would continue to overflow from Kenilworth Boulevard into the adjacent park area immediately to the south. The distance from the proposed overflow control structure to the rear of the properties fronting on Brookdale Road to the south is about 400 to 500 feet. This park area includes some small ponding areas and low areas that will provide some storage to contain small initial overflows before they continue toward Riverside Drive. Thus flows that barely overtop Kenilworth Boulevard and the control structure for short periods may be fully or partially contained in the park area.

This controlled overflow along Kenilworth Boulevard will allow the flows exceeding the 50-year plus design elevation to enter the area behind the dikes along Riverside Drive and restore the flood storage for greater storms, thus avoiding adverse impacts associated with loss of flood storage. This overflow structure can be modified when a regional plan is implemented providing for a higher level of protection.

The overflow structure also helps limit adverse impacts upstream of Kenilworth Boulevard by allowing flows above the design elevation to overflow downstream. However, for the 50-year plus design storm and some lesser storms, there will be an increase in water elevation upstream of Kenilworth Boulevard. Based upon the water surface elevation and increase under Plan 2 as indicated on Table 2, a review was made of the additional flooding upstream of Kenilworth Boulevard for the 50-year plus design conditions. The estimated existing and proposed conditions water surface elevations were plotted on the topographic mapping developed for Cranford in 2007. This mapping extends about 400 feet to the north of Kenilworth Boulevard.

The above review indicates that to the west of the Lenape Basin, the 50-year plus storm inundation limit is close to or touches 3 houses fronting on Nomahegan Road, with the rear of the properties abutting

County Park Drive. The small increase associated with the Phase 3 & 4 Project under Plan 2 or Combination Plan 2-3 would be less than 0.5 foot. However, this increase appears to result in the flood elevation reaching the foundations of these 3 houses and possibly crossing one driveway near the garage. Whether or not this increase would result in water entering each house will depend upon the elevation of the lowest opening and also refinement of the grade elevation adjacent to each house. Mitigation at each of these 3 houses may be as simple as regrading adjacent to each house or may involve construction of a low earth berm between the house and County Park Drive. Field survey data for each of these 3 houses would be required to fully evaluate the impacts of this increase.

Adverse impacts due to increased water surface elevations upstream of Kenilworth Boulevard will be more extensive to the east of the Lenape Park Detention Basin. Review of the limits of flooding for the 50-year plus design storm for existing and proposed conditions reveals that there are several houses where the flood limits would be at or very close to the structure at the existing 50-year plus flood elevation, just slightly above the elevation of the low sections of Kenilworth Boulevard. The 2007 topographic mapping prepared for Cranford extends approximately 400 feet to the north of Kenilworth Boulevard and includes portions of Dorset Drive, Epping Drive, Pembrook Drive, and Brasser Lane. Within the limits of this mapping, there are 15 homes in this area that would have the 50-year plus waters reach the structures under proposed conditions, while under existing conditions the flood limit would be close to but not touching all but 3 or 4 of these same houses. A review of older mapping of the area indicates that there are approximately 18 additional houses at or below Elevation 71 feet. Therefore some of these houses may also have adverse impacts. Not all of the residential area of concern appears on either of the topographic maps. Therefore there may be additional houses of concern on Sherwood Road and Wilshire Drive.

Due to the significant number of houses upstream of Kenilworth Boulevard that would be affected by implementation of Phases 3 & 4 in Cranford, and since these same houses and possibly some others experience flooding under existing conditions under severe storm conditions (i.e. they are in the delineated 100-year floodplain as shown on the FIS) this are should be considered for flood mitigation

under a regional Rahway River flood mitigation project. Mitigation of the potential adverse impacts due to implementation of Plan 2 or Combination Plan 2-3 in Cranford may be a simple as regrading at some properties, but may be more significant at other properties. Since this residential area is in Kenilworth, the Township of Cranford must coordinate with the Borough of Kenilworth regarding potential impacts and additional investigations, including field surveys where needed to assess the impacts of the increased water surface elevations.

4.3 Other Regional Mitigation

In addition to the potential for obtaining financial assistance, advantages of coordinating the development of Phases 3 & 4 in Cranford with the Corp of Engineers' development of a regional plan for the Rahway River Basin are that mitigation required to address the adverse impacts beyond the Project Area may be included in the regional plan and the Corps may provide assistance to Cranford in evaluating the significance of impacts outside of Cranford. Future regional facilities may serve to enhance the level of protection afforded by the facilities constructed in Cranford.

In such regional planning, consideration should be given to new facilities, improvements to existing facilities, and changes in operation of existing facilities. Consideration should be given to major improvements to the Lenape Park Detention Basin, such as raising the elevation of the tops of the dikes, modifying the outlet structure, and improvements benefiting adjacent flood prone areas (such as improvements to local pumping facilities for areas behind the dikes). Potential for improving capacities at existing stormwater detention basins should be evaluated and sites for new stormwater detention facilities should be explored. Consideration should be given to modifying the operation of upstream reservoirs to provide flood attenuation. As indicated above, the area immediately upstream of Kenilworth Boulevard should be included in a regional plan for the Rahway River Basin.

4.4 Other Modifications to the Lenape Park Detention Basin

Preliminary investigations into conceptual modifications at the Lenape Park Detention Basin indicate that minor changes to increase the storage volume would not appreciably alter the peak flows to provide a noticeable benefit downstream of the detention basin through Nomahegan Park. Modifications to the basin may result in adverse impacts upstream of the detention basin location. In addition, significant modifications may not be feasible from both a construction and cost standpoint without additional improvements upstream of the basin. Further investigation of increasing the storage capacity of the Lenape Park Detention Basin may be warranted under a regional investigation of the Rahway River Basin.

5.0 Preliminary Estimated Construction Costs

The preliminary estimated construction costs for the alternatives of Combination Plan 2-3 and for Plan 2 as presented above are listed in Table 5 on the following page, followed by preliminary estimated project costs in Table 6. Plan 2 provides for protection for a 50-year plus design storm, while Combination Plan 2-3 provides for initial protection for the 50-year plus design storm but also includes additional height for most of the constructed dikes and floodwalls to facilitate integration into a future regional plan providing protection for the 100-year design storm. Under both the Combination Plan 2-3 and Plan 2, the closure facilities at Springfield Avenue and at Kenilworth Boulevard would be identical. These end closure conditions and additional selected overflow locations incorporated in Combination Plan 2-3 will allow floodwaters exceeding the 50-year plus design elevations to overflow into the Project Area and avoid the flood storage loss that would adversely affect areas upstream and downstream of the Project Area, until such time as the adverse impacts can be mitigated under a regional plan.

These costs are preliminary estimates and serve to provide a basis for the relative evaluation of the alternatives for project selection and for preliminary budget purposes only. The actual capital improvement costs will be dependant on other factors, such as additional administrative costs, land easement costs, results of negotiations with the County of Union and the NJDEP Green Acres Program regarding activities in park land, negotiations with the NJDEP regarding freshwater wetlands disturbance mitigation, site specific subsurface conditions and major utility conflicts which are beyond the scope of this investigation. The plans that accompany this report can serve as a basis for discussions with affected property owners, the several agencies involved in review and approval of the project, and with the US Army Corps of Engineers New York District for coordination with a regional plan. Such discussions will facilitate the refinement of required measures and quantification of associated project costs.

TABLE 5

COMPARISON OF PRELIMINARY ESTIMATED 2008 CONSTRUCTION COSTS
FOR MODIFICATIONS AND IMPROVEMENTS TO THE DIKE SYSTEM

		COMBINATION PLAN 2-3		PLAN 2	
EAST SIDE IMPROVEMENTS:		Quantity	Preliminary Estimated Consruction Costs	Quantity	Preliminary Estimated Consruction Costs
A)	MOBILIZATION		$200,000		$200,000
B)	SOIL EROSION AND SEDIMENT CONTROL		$120,000		$120,000
C)	CLEARING SITE/COORDINATION WITH UTILITY COMPANIES		$90,000		$90,000
D)	CONTROL OF WORK/CONSTRUCTION LAYOUT		$30,000		$30,000
E)	SHEET PILE WALL W/CONCRETE CAP	4980 L.F.	$4,262,000	4980 L.F.	$4,085,000
F)	CONCRETE WALL	550 L.F.	$270,000	550 L.F.	$270,000
G)	3'X17' CONCRETE BOX CULVERT DIVERSION STRUCTURE	1,000 L.F.	$2,100,000	1,000 L.F.	$2,100,000
H)	REGRADING AT SPRINGFIELD AVE AND VICINITY		$150,000		$150,000
I)	CONSTRUCTION OF FLOOD GATE		$75,000		$75,000
J)	FOR RESTORATION WORK AND MISC.		$85,000		$85,000
	SUBTOTAL		$7,382,000		$7,205,000
	15% CONTINGENCIES		$1,107,300		$1,080,750
	TOTAL ESTIMATED CONSTRUCTION COSTS - EAST SIDE		$8,489,300		$8,285,750

WEST SIDE IMPROVEMENTS:		Quantity	Preliminary Estimated Consruction Costs	Quantity	Preliminary Estimated Consruction Costs
A)	MOBILIZATION		$125,000		$90,000
B)	SOIL EROSION AND SEDIMENT CONTROL		$120,000		$120,000
C)	CLEARING SITE/COORDINATION WITH UTILITY COMPANIES		$40,000		$40,000
D)	CONTROL OF WORK/CONSTRUCTION LAYOUT		$30,000		$30,000
E)	SHEET PILE WALL W/CONCRETE CAP	4260 L.F.	$3,385,000	1274 L.F.	$830,000
F)	CONCRETE WALL	0	$0	1778 L.F.	$1,010,000
G)	EARTHEN DIKE	0	$0	1225 L.F.	$260,000
H)	INTERNAL DRAINAGE SYSTEM		$125,000		$125,000
I)	CONSTRUCTION OF FLOOD GATE		$75,000		$75,000
J)	FOR RESTORATION WORK AND MISC.		$200,000		$200,000
	SUBTOTAL		$4,100,000		$2,780,000
	15% CONTINGENCIES		$615,000		$417,000
	TOTAL ESTIMATED CONSTRUCTION COSTS - WEST SIDE		$4,715,000		$3,197,000
TOTAL ESTIMATED CONSTRUCTION COSTS -BOTH SIDES			$13,204,300		$11,482,750
ESTIMATED ADDITIONAL CONSTRUCTION COST FOR COMBINATION PLAN 2-3			$1,721,550		
	PERCENTAGE ADDITIONAL COMPARED TO PLAN 2		15.0%		

COMBINATION PLAN 2-3:
INCREASE HEIGHTS OF DIKES AND FLOODWALLS ON BOTH SIDES TO THE 100-YEAR DESIGN ELEVATIONS (PER PLAN 3)
CONSTRUCT CLOSURES AT ENDS FOR 50-YEAR PLUS PROTECTION (PER PLAN 2)
WILL LIMIT LOCATIONS OF OVERFLOW FOR FLOODS EXCEEDING 50-YEAR PLUS DESIGN, AND WILL FACILITATE INTEGRATION INTO A FUTURE REGIONAL PLAN PROVIDING 100-YEAR PROTECTION

PLAN 2:
INCREASE HEIGHTS OF DIKES AND FLOODWALLS ON BOTH SIDES TO THE 50-YEAR PLUS DESIGN ELEVATIONS (PER PLAN 2)
CONSTRUCT CLOSURES AT ENDS FOR 50-YEAR PLUS PROTECTION (PER PLAN 2)
WILL ALLOW OVERFLOW FOR FLOODS EXCEEDING 50-YEAR PLUS DESIGN ALONG MOST OF THE DIKES AND FLOODWALLS
WILL NOT BE ADEQUATE FOR INTEGRATION INTO A FUTURE REGIONAL PLAN PROVIDING 100-YEAR PROTECTION

With respect to freshwater wetlands mitigation, the preliminary project cost estimates presented on Table 6 include an allowance for enhancement of 2 acres of wetlands as mitigation for disturbance of 1 acre of wetlands due to extension of dikes and floodwalls. The 2:1 ratio is based upon the NJDEP minimum requirement for mitigation of permanent wetland disturbance. This value may be increased to a ratio of as much as 9:1 depending upon the determination of the NJDEP at the time of the permit review process. The estimate of 1 acre of permanent wetland disturbance is based upon the lengths of dikes and floodwalls along new alignments, with an estimated average permanent disturbance width of 20 feet. For the most part, modification of the existing dikes will be within the footprint of the existing dike and should not involve significant permanent disturbance of wetlands. In association with final design, detailed freshwater wetlands delineation will be required along the length of the dikes and floodwalls to permit a determination of the area of temporary and permanent disturbance associated with the project in wetlands and transition areas. Final design alignments will be modified as much as practical to avoid or minimize disturbance of wetlands.

Table 6 identifies the potential for additional costs associated with Green Acres mitigation for new dikes in the Union County parklands and for easements on private property. The project includes incorporation of footpaths along the dikes in park areas, and most of the dikes and floodwalls in the park would be along existing dike alignments. Therefore, it is anticipated that the Green Acres mitigation would be limited to disturbance of park areas where there are no dikes at present, such as parallel to Kenilworth Boulevard. It will be important to secure the cooperation of the County of Union with respect to this aspect of the project, to obtain agreement as to what areas of disturbance will require mitigation and what forms of mitigation are acceptable, with discussion of possible alternatives to additional property dedication.

The costs for easements on private property will depend upon the Township policy with respect to acquisition of such easements and the cooperation of the affected property owners. Easements will be required both for the permanent facilities and for access for construction and future maintenance.

TABLE 6

COMPARISON OF PRELIMINARY ESTIMATED 2008 PROJECT COSTS
FOR MODIFICATIONS AND IMPROVEMENTS TO THE DIKE SYSTEM

	COMBINATION PLAN 2-3 Preliminary Estimated Costs	PLAN 2 Preliminary Estimated Costs
EAST SIDE IMPROVEMENTS:		
PRELIMINARY ESTIMATED CONSTRUCTION COSTS (FROM TABLE 5)	$8,489,300	$8,285,750
WEST SIDE IMPROVEMENTS:		
PRELIMINARY ESTIMATED CONSTRUCTION COSTS (FROM TABLE 5)	$4,715,000	$3,197,000
TOTAL ESTIMATED CONSTRUCTION COSTS (CC) -BOTH SIDES	$13,204,300	$11,482,750
ALLOWANCES FOR:		
LEGAL AND ENGINEERING 20% OF CC	$2,640,860	$2,296,550
FRESHWATER WETLANDS MITIGATION		
EST 2 AC ENHANCEMENT @ $50,000/AC.*	$100,000	$100,000
GREEN ACRES MITIGATION (NEW DIKES IN PARK)		
SUBJECT TO NEGOTIATION	NC	NC
EASEMENTS ON PRIVATE PROPERTY		
SUBJECT TO NEGOTIATION	NC	NC
TOTAL ESTIMATED PROJECT COSTS - BOTH SIDES	**$15,945,160**	**$13,879,300**
ESTIMATED ADDITIONAL PROJECT COST FOR COMBINATION PLAN 2-3	**$2,065,860**	
PERCENTAGE ADDITIONAL COMPARED TO PLAN 2	**14.9%**	

COMBINATION PLAN 2-3:
INCREASE HEIGHTS OF DIKES AND FLOODWALLS ON BOTH SIDES TO THE 100-YEAR DESIGN ELEVATIONS (PER PLAN 3)
CONSTRUCT CLOSURES AT ENDS FOR 50-YEAR PLUS PROTECTION (PER PLAN 2)
WILL LIMIT LOCATIONS OF OVERFLOW FOR FLOODS EXCEEDING 50-YEAR PLUS DESIGN, AND WILL FACILITATE INTEGRATION INTO A FUTURE REGIONAL PLAN PROVIDING 100-YEAR PROTECTION

PLAN 2:
INCREASE HEIGHTS OF DIKES AND FLOODWALLS ON BOTH SIDES TO THE 50-YEAR PLUS DESIGN ELEVATIONS (PER PLAN 2)
CONSTRUCT CLOSURES AT ENDS FOR 50-YEAR PLUS PROTECTION (PER PLAN 2)
WILL ALLOW OVERFLOW FOR FLOODS EXCEEDING 50-YEAR PLUS DESIGN ALONG MOST OF THE DIKES AND FLOODWALLS
WILL NOT BE ADEQUATE FOR INTEGRATION INTO A FUTURE REGIONAL PLAN PROVIDING 100-YEAR PROTECTION

* The estimated 2 acres of wetlands enhancement is based on the NJDEP minimum required wetland mitigation ration of 2:1. This value may be increased to a ratio as high as 9:1 depending on the determination of the NJDEP at the time of the permit review process.

A review of Tables 5 and 6 reveals that the additional costs for Combination Plan 2-3, compared to the costs for Plan 2, are greater for the west side of the river than for the east side, both in terms of the dollar value and the percentage increase. The reason for this is that the types of facilities required on the east side are essentially the same for both alternatives. The dikes and floodwalls on the east side would be constructed to a higher elevation under the Combination Plan, but would be the same basic design as under Plan 2. However on the west side, the types of facilities would differ between the two alternatives. The most significant differences are that the dike along Park Drive under Plan 2 would be a low earthen dike, not exceeding 18-inches in height above the adjacent terrain, and the floodwalls near the houses upstream of Springfield Avenue would be low reinforced concrete walls. Under the Combination Plan 2-3 with higher top of dike design elevations, the dike along Park Drive and the floodwalls near the houses would be of similar design to the dikes and floodwalls on the east side, that is they would have a core of cantilevered steel sheeting with a concrete cap on the exposed faces and top. All exposed concrete wall surfaces would be constructed with form liners to provide the appearance of a stone wall.

Estimated costs presented in Tables 5 and 6 are in terms of estimated 2008 costs. For future planning and funding purposes an additional allowance should be included based upon the anticipated timing of construction.

6.0 Conclusions and Recommendations

Hatch Mott MacDonald has completed an investigation of modification and extension of the dike system along the Rahway River in the Township of Cranford between Kenilworth Boulevard and Springfield Avenue. Alternative levels of protection have been analyzed, including the 50-year storm, 50-year plus storm, 100, 200 and 500-year storms, with the associated top of dike (or floodwall) elevations determined for each level of protection. End closure conditions and requirements were investigated at Kenilworth Boulevard and at Springfield Avenue, the upstream and downstream limits of the Project Area. Closure conditions were also investigated near the intersection of Park Drive with Springfield Avenue and at a low area along Springfield Avenue at a location about 1,000 feet from Kenilworth Boulevard.

Hydrologic and hydraulic analyses completed included consideration of the downstream and upstream effects of the loss of flood storage associated with reduction of flooding in the area protected by the improved and extended dikes and floodwalls. The results of analysis indicate that there will be an increase in water surface elevations upstream of Kenilworth Boulevard and downstream of Springfield Avenue in association with the project. The computed increases for the range of storms analyzed are shown on Table 2 in Section 2.3 of this report.

Mitigation for the estimated increases in peak flows discharged downstream of Springfield Avenue through the loop in the Rahway River from the upper to the lower crossings of Springfield Avenue is proposed by including a bypass culvert from upstream of Springfield Avenue to downstream of the Canoe Club. The bypass culvert would be sized to convey the additional flow associated with Project Area storage loss for the selected design storm, thus eliminating adverse impacts in the loop between the Springfield Avenue crossings.

In addition, a preliminary analysis was made of potential benefits that may be derived from modification of the Lenape Park Detention Basin outlet to open up the lower outlet and more effectively utilize the detention storage. This analysis was not included in the original scope of this investigation for Phases 3 & 4, but was added as the investigations evolved to estimate whether there could be a potential benefit for further consideration. The preliminary analysis indicated that the benefits of modifying the outlet may be small in terms of effects on water surface elevations, but may be beneficial in terms of helping mitigate the adverse impacts of raising the dikes and the associated flood storage loss in the protected area. The analysis of the Lenape Park Detention Basin outlet was undertaken by modifying the HEC-1 hydrology model previously developed by others for the NJDEP and FEMA flood delineation investigations for the Rahway River. This model is intended for analysis of major storms that will overtop the principal spillway at the Lenape Basin. The model does not contain refinement of the storage volume at levels below the elevation of the principal spillway. It is storage volumes at these lower levels that are key to detailed analysis of the effects of modifying the outlet facility to more effectively utilize the basin flood storage. Therefore, it is recommended that future consideration of modification of the Lenape Park outlet be based upon further analysis with storage volumes computed based upon detailed topographic mapping of the Lenape Park Detention Basin. At the same time, consideration could be given to other modifications of the Lenape Basin, including raising the elevations of the dikes around the basin and other modifications to the outlet facilities.

The cooperation of the County of Union will be required to undertake any modification of the Lenape Basin. It is suggested that the concept of modifying the basin be discussed further with the County in coordination with the Corps of Engineers' current Rahway River study.

Hydrologic and hydraulics analyses were undertaken for a range of storms, as indicated above. The associated tops of dike and floodwall elevations at key locations in the Project Area were identified for five Plans with levels of protection ranging from a 50-year storm to a 500-year storm. Based upon the results of analysis and with consideration of the top of dike elevations and closure conditions at the ends of the dikes and floodwalls, Plan 2 providing protection for the 50-year plus design storm (more than 50-

year, but less than 100-year) was found to be plan which would allow local implementation without excessive or impractical construction at the closure areas at Kenilworth Boulevard and at Springfield Avenue. Since this "50-year plus" level of protection would be less than would be required for incorporation into a future regional program, consideration was given to developing a combination plan that would provide "50-year plus" protection following initial construction, but would include dike and floodwall elevations at a higher design elevation (e.g. the 100-year level) so that the constructed dikes and floodwalls could be incorporated into a future regional program. The end closure facilities would be based upon the "50-year plus" design elevations so that greater storms would overflow at the closure facilities and at selected overflow locations to eliminate the flood storage volume loss during greater storms and thus avoid upstream and downstream adverse impacts that will require regional project solutions.

Preliminary estimated construction costs and project costs have been developed for Plan 2 (50-year plus) and for Combination Plan 2-3 (50-year plus overflow facilities, but with 100-year dike elevations). These costs are presented on Tables 5 and 6 in Section 5 of this report. As indicated in these tables, the additional cost for Combination Plan 2-3 as compared to Plan 2 is greater on the west side of the river than on the east side. On the east side of the river, the same types of facilities are required under both Plan 2 and Combination Plan 2-3, with some additional cost associated with the top of dike elevations being somewhat higher under Combination Plan 2-3. On the west side the differential between Plan 2 and Combination Plan 2-3 is greater due to the fact that the 100-year dike and floodwall elevations would require a different type of structure than would be required for the "50-year plus" design elevations on the west side. Under Plan 2, a low earthen dike (less than 18-inches high and protected for overtopping) would be provided along Park Drive, and low reinforced concrete walls would be constructed on the private properties upstream of Springfield Avenue. Under the Combination Plan 2-3, dikes and floodwalls with a steel-sheeting core and concrete cap would be required due to the greater height for 100-year design elevations.

The final selection between Plan 2 and Combination Plan 2-3 may ultimately depend upon the acceptability of dike and floodwall alignments and elevations, particularly on private properties, the potential for project funding and the potential for implementation of a regional project. Selection of Plan 2 would preclude inclusion in a regional program since the level of protection would be less than the 100-year storm. Ultimately, if the Corps of Engineers proceeds with a regional program, the selected level of protection may be greater than the 100-year storm. If this decision is made prior to final design of Combination Plan 2-3, the design elevations for the dikes and floodwalls could be increased somewhat to meet the regional program standards since, unlike Plan 2, Combination Plan 2-3 would include the types of facilities that could be increased in height. Under Plan 2, increases in the design heights of dikes and floodwalls on the west side of the river would require a change in the types of facilities required, as was reviewed above.

Many of the actions required to further the development of Phases 3 & 4 will be the same, whether for Plan 2 or Combination Plan 2-3. However, due to the potential for inclusion in a regional plan providing a higher level of protection than Cranford can provide with a local program, continued actions based upon implementation of Combination Plan 2-3 is recommended. Following review of this report by the Township of Cranford, the following actions are recommended to proceed concurrently with exploration of potential project funding. The order of undertaking these actions may vary from the order listed below, as the Township may deem appropriate.

Recommended actions, in general order of implementation:

1. Submit a copy of this report and the accompanying plans to the U.S. Army Corps of Engineers, New York District, for review, comment and coordination with the Corps study of the Rahway River Basin. Follow up with a meeting with Corps staff. Discussions should include further investigation of modification of the Lenape Park Detention Basin by the Corps and other possible measures of mitigation for impacts beyond the Phase 3 & 4 Project Area. These discussions should also address the potential

level of protection (i.e. 100-year, or higher) that may be the design basis for a Corps sponsored regional project.

2. Submit a copy of this report and the accompanying plans to the County of Union for review, comment and coordination with respect to proposed construction on park property. Discuss the Green Acres Program aspects of the project with County Parks Department staff and reach a conceptual understanding of the need for mitigation for proposed construction (prior to meeting with the NJDEP Green Acres Program staff). It is suggested that these discussions also include facilities proposed under Phase 5.

3. Submit copies of this report and accompanying plans to the NJDEP Green Acres Program, the NJDEP Division of Land Use Regulation, and the NJDEP Bureau of Dam Safety and Flood Control. Request a pre-application meeting with these agencies to discuss project concepts and associated regulatory requirements. Initial discussions of freshwater wetlands impacts and the need for mitigation for permanent disturbance can be based upon available general wetland mapping in the Project Area. The need for detailed wetland delineation can also be discussed with the NJDEP. Initial discussions of the need for mitigation for parkland areas "diverted" for new facilities can be discussed with Green Acres staff, but only after a conceptual understanding is reached with Union County Department of Parks and Community Renewal staff. It is suggested that these discussions also include facilities proposed under Phase 5.

4. Meet individually or in neighborhood groups with the private property owners directly affected by proposed dike or floodwall construction. Review the alignment and top of floodwall elevations pertaining to each specific property. Obtain comments regarding the alternatives as they pertain to specific properties. Possibly show the alignment and top elevation with temporary markers in the yards. Follow up with a public meeting, as appropriate.

5. Arrange a meeting with representatives of the Borough of Kenilworth to review the program and potential impacts in Kenilworth. Follow up with a public meeting in Kenilworth, if appropriate.

6. Following completion of the above coordination and consideration of comments received, make a final selection of alignment and proposed top elevations for proposed facilities. Develop a program and schedule for investigations (including freshwater wetlands delineation and soils investigations), easement acquisitions, property owner consent, Green Acres Program applications, final design (including final hydrology, hydraulics, and selection of controlled overflow locations, detailed plans and specifications), permit applications, mitigation (freshwater wetlands, riparian zone, Green Acres and off-site impacts), and other actions needed to continue project development.

Planning for implementation of Phases 3 & 4 must provide for construction of equivalent facilities on the opposite sides of the Rahway River in a coordinated fashion. Since a dike or floodwall is not effective until it is tied into high ground or closed at the ends, construction may proceed at varying pace on opposing sides of the river. However, final closure at the ends should be nearly simultaneous on the two sides of the river. Also, on the west side of the river, the dikes should not be completed until the associated portion of Phase 5 is completed as needed to provide interior drainage behind the dikes and floodwalls. Interior drainage on the east side of the river is provided by completion of Phase 1 and Phase 2A. Completion of Phase 2B would enhance the interior drainage capacity on the east side, but is not required prior to the improvement of the dikes on the east side.

This Interim Report and the accompanying drawings are intended for planning and discussion purposes. No construction should be undertaken based upon these documents. Detailed design, including refined analyses of the plan selected for implementation, and acquisition of appropriate permits and approvals will be required prior to construction of any components of the project.

Flow Tables

TOWNSHIP OF CRANFORD
UNION COUNTY, NEW JERSEY

NORTHEAST QUADRANT - PHASE 3 AND 4

HEC-1 RESULTS - FLOWS THROUGH LENAPE PARK DAM, NOMAHEGAN PARK AND DOWNSTREAM (cfs)
EXISTING CONDITIONS - INCLUDES IMPROVEMENTS UNDER PHASE 1, 2, AND 5

LOC.	EXISTING CONDITIONS					PROP. CONDITION 1 - MODIFICATIONS TO LENAPE DAM				
	25-YEAR STORM	6.2"/24HR	50-YEAR STORM	6.7"/24HR	100-YEAR STORM	25-YEAR STORM	6.2"/24HR	50-YEAR STORM	6.7"/24HR	100-YEAR STORM
DETENT	3556	4822	5310	5826	6842	3346	4393	4857	5788	6786
NOMAH	3387	3906	4105	4387	5263	3232	3790	3965	4229	5158
DSL	3702	4299	4517	4828	5773	3547	4212	4349	4650	5672
RAHDSM	3753	4480	4702	5010	5961	3723	4416	4583	4876	5874

LOC.	PROP. CONDITION 2 - MODIFICATIONS TO EXISTING DIKES					PROP. CONDITION 3 - MODIFICATIONS TO EXISTING DIKES AND LENAPE DAM				
	25-YEAR STORM	6.2"/24HR	50-YEAR STORM	6.7"/24HR	100-YEAR STORM	25-YEAR STORM	6.2"/24HR	50-YEAR STORM	6.7"/24HR	100-YEAR STORM
DETENT	3556	4822	5310	5826	6842	3346	4393	4857	5788	6751
NOMAH	3385	4176	4475	4825	6180	3230	3980	4240	4596	6055
DSL	3699	4564	4890	5282	6707	3544	4355	4632	5047	6568
RAHDSM	3751	4656	4975	5374	6648	3721	4504	4774	5185	6509

Location Discription

DETENT - Lenape Detantion Basin
NOMAH - Nomahegan Park
DSL - Combined Flow at NJ Central Railroad
RAHDSM - Combined Flow at USGS Gage at Rahway

Figures

Note: The Figures included in Appendix B of the electronic copy of this report are in separate files in order to keep the text file size as small as possible.