NORTH CAMBRIDGE FLOOD RECONNAISSANCE STUDY

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1.1 BACKGROUND

Frequent street and basement flooding has occurred in the North Cambridge residential neighborhood along the Alewife Brook – most notably in recent history during the October 20, 1996 and June 13, 1998 storms. Land surrounding Alewife Brook, which includes this residential neighborhood, was identified in the Metropolitan District Commission (MDC) Mystic River Basins Comprehensive Hydrology Study (1981, Camp Dresser & McKee) as being the area of the watershed most susceptible to flooding with the most intense concentration of anticipated flood damages. The same report forecasts damages during the 100-year storm to commercial business along Route 2, the Acorn Office Park along Little River and 232 homes in Arlington and Cambridge upstream of the Massachusetts Ave. Bridge. The damages forecast by the MDC report were however not considered of significant magnitude to mandate measures to alleviate flooding.

The storm of record at the time of the MDC report was caused by Hurricane Diane in 1955. The Alewife Brook elevation was near that of the forecast 100-yr storm, however CDM (1981) notes that runoff under contemporary conditions would be greater due to the urbanization "boom" of 1950-1975. Urbanization has continued in the watershed since this time at a somewhat slower rate, including commercial development south of Little River and proposed development abutting Russell Field in Cambridge. This more recent development has occurred within the floodplain, as defined by the forecasted extent of the 100-yr storm, with possibly even larger consequences to downstream property owners. Figure 1 shows the report study area including the location of the North Cambridge neighborhood and the boundaries of the Alewife watershed.

1.2 ALEWIFE WATERSHED

The Alewife watershed covers an area of approximately 8 square-miles within the communities of Belmont, Arlington, Cambridge, Watertown and Somerville. Watershed topography may be characterized as bowl shaped with steeper slopes in the upland western fringes and broad flat areas with little or no relief over much of the rest of the watershed. The following description of water bodies within the watershed is summarized from an account in the Environmental Impact Statement for the Route 2/Alewife Brook Parkway Project (FHWA,1987).

The Alewife Brook, which formerly originated from Fresh Pond, now begins as a small northward flowing stream west of the MBTA parking garage. The stream continues to the northeast crossing under the Alewife T access ramp, Route 2, and Massachusetts Ave. It ultimately converges with the Mystic River at a distance of 8,000 feet and a vertical drop of approximately 3 feet.

Little River originates at Little Pond flowing easterly for 4,500 feet with almost no slope. It converges with the Alewife Brook just west of the T access ramp from Route 2. Other significant water bodies in the watershed are Wellington Brook and Winn Brook in Belmont and the Yates Pond, Jerry's Pond and Parkway Pond in North Cambridge.

1.3 OBJECTIVES

This report documents an investigation performed for Alewife Neighbors, Inc. (ANI) of flooding along the Little River and Alewife Brook. Its objectives are to document the frequency of flooding and flood-related damages, describe flood mechanisms, and to introduce recommendations for mitigation of flooding and associated damages. As part of that effort several site visits were performed during storm events and otherwise; interviews were conducted with residents and Cambridge Department of Public Works officials; prior investigations of flooding and Cambridge Conservation Commission files were reviewed, and a survey of North Cambridge residents was implemented with the assistance of ANI. Recommendations are introduced in the final section. Implementation of the recommended measures will require additional engineering studies to finalize design and estimate costs.

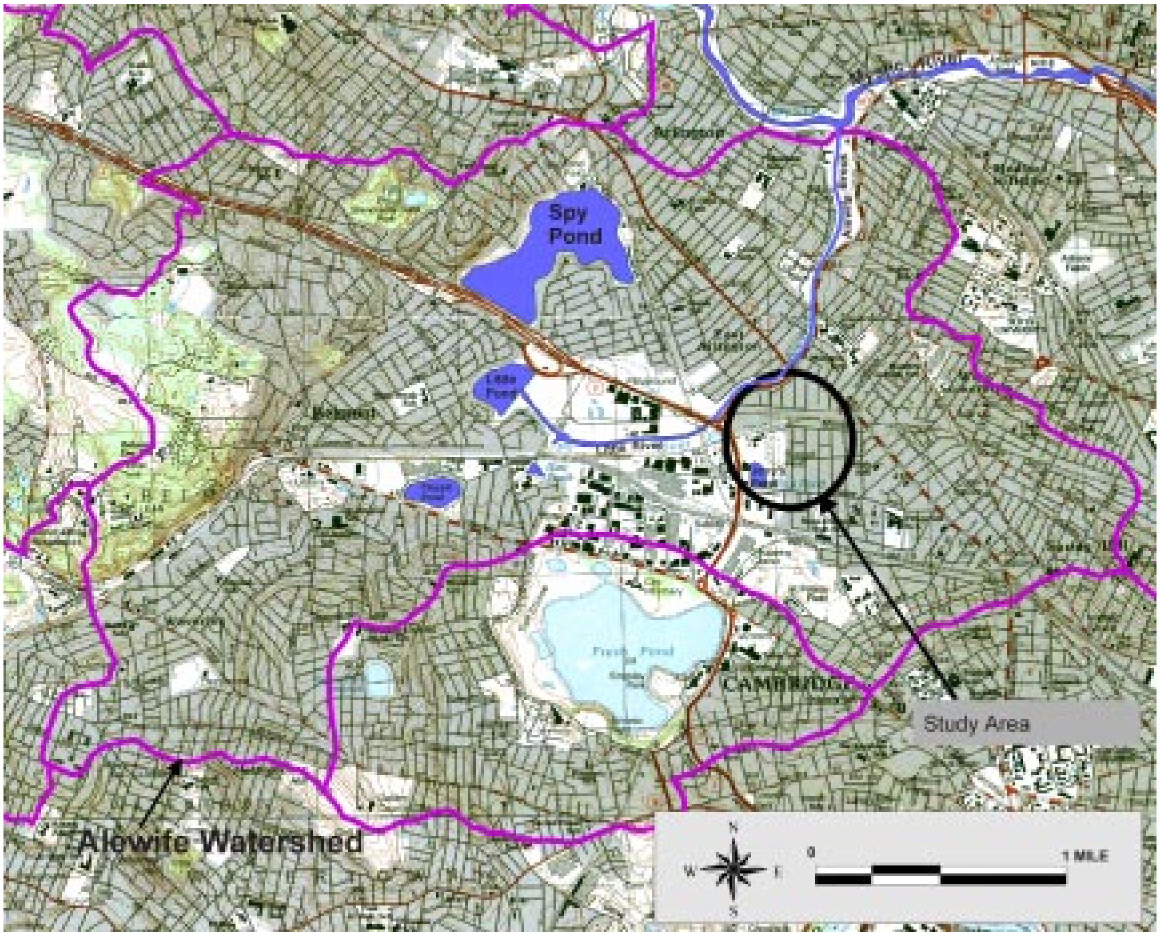

Figure 1. Study area.

2 WATERSHED SCALE AND LOCAL FLOOD CHARACTERISTICS

2.1 INTRODUCTION

This chapter provides an overview of flooding in the Alewife watershed. Regional flooding mechanisms are described. Extreme events are identified from the precipitation record and time histories plotted of particular events of interest. A survey of residents is described and results summarized. Personal accounts of flooding and site visits are described to understand the distribution of flooding and local flooding mechanisms.

2.2 WATERSHED SCALE FLOODING MECHANISMS

The Mystic River Comprehensive Hydrology Study (CDM, 1981) notes that flooding along the Alewife is "principally the result of insufficient storage and/or hydraulic capacity" and generally occurs in response to either hurricanes or spring rains coinciding with a melting snow pack and/or frozen soil conditions (RAI, 1979). High flood levels in the Mystic River have backwater effects, which raise water levels in the Alewife watershed and in some cases reverse flows in the Alewife Brook. This combination of storm flows draining from an urbanized Alewife watershed and high elevation floodwaters in the Mystic River either reducing flow or reversing flows in the Alewife watershed has the potential to cause significant flooding in low-lying areas of the Alewife watershed. Other localized flooding effects are often observed with storms of lesser magnitude. These local flooding mechanisms are discussed in more detail in a later section.

2.3 EXTREME PRECIPITATION

Figure 2 shows the Boston Logan Airport annual maximum daily precipitation depth for the period 1920-1999 (daily rainfall data from Northeast Regional Climate Center) and the annual maximum 24-hour precipitation depth for the period 1948-1999 (hourly rainfall data from National Climatic Data Center). The storm of record was caused by Hurricane Diane on August 18-19, 1955. The total rainfall for the two-day storm exceeded 11 inches, while exceeding 8 inches over the maximum 24-hour period within the storm.

The ten highest maximum annual daily storm depths are listed in Table 1. Extreme events exceeding 5 inches were recorded in 1921, 1933, 1954, 1955, 1996 and 1998.

The absence of significant extreme events during the 1960's and 1970's evident in Figure 2 and Table 1 is consistent with trends in the frequency of hurricanes predicted by atmospheric scientists and reported in the popular press (US New and World Report, 1999). Todd Kimberlain of the National Oceanic Atmospheric Agency's National Hurricane Center was reported to say, "We appear to be entering a whole new era of hurricane activity." Kerry Emanuel of Massachusetts Institute of Technology commented that "the dry spell since the 1960's has lulled people into a false sense of security."

Table 1. Highest ten maximum annual daily storm depths.

Date	**Rainfall Depth (inches)**
August 19, 1955	7.06
July 9, 1921	6.04
September 16, 1933	5.63
September 11, 1954	5.63
June 13, 1998	5.51
October 20, 1996	5.36
August 18, 1955	4.88
May 16, 1954	4.47
December 12, 1992	4.21
August 26, 1924	4.15

Figure 3 shows time histories of cumulative rainfall depth for the Hurricane Diane storm in 1955 and storms occurring in October 1996 and June 1998. Personal observations of flooding during the 1996 event are described below in Section 2.5, however it is of some interest to consider the relative depth of the 1955 and 1996 storms to consider the potential for flooding during events like Hurricane Diane. The October 1996 storm was a prolonged storm of medium intensity. Rainfall of about 0.4 inches per hour occurred over a period of seven hours, followed by 19 hours of fairly constant rain of about 0.2 inches per hour. The cumulative precipitation of the 1955 Hurricane Diane storm follows roughly the same track up to an elapsed time of roughly 27 hours from the start of the storm. At this point, the 1996 storm remains constant for several hours and then begins to dissipate, while the 1955 storm goes through a period of intense rainfall exceeding 1.4 inches per hour. It may be anticipated that a storm similar to the Hurricane Diane storm would generate flooding of significantly greater depth and coverage than the more recent 1996 or 1998 storms.

2.4 SURVEY FINDINGS

A survey was distributed by ANI in the N. Cambridge neighborhood to gather information on neighborhood flooding and flooding mechanisms. Figure 4 shows the location of surveyed homes. Responses were collected during both door-to-door canvassing and by email. As is evident from Figure 4, some blocks had more survey responses than others due to the limited resources of ANI. In other cases homeowners were unavailable or refused to cooperate due to fears that the published survey results would reduce neighborhood or individual property values. Since the survey results were largely tied to the location of the home, efforts to survey every last home on a block were unnecessary. ANI would have liked to expand the coverage to gain more understanding of the spatial distribution of flooding, however this in no way compromises the benefits gained by the survey responses.

The presence of sump pumps in homes is usually indicative of past flooding. Figure 5 shows the location of surveyed homes with sump pumps. Homes on Whittemore Avenue up to the Alewife Brook Parkway all have sump pumps. Most homes in the north part of Clifton St. along Russell Field have sump pumps, with somewhat lower incidence of sump pumps on the opposite side of Clifton St.. The presence of sump pumps is generally consistent with higher reported flooding frequency as shown in Figure 6.

Figure 7 shows whether basement flooding occurred by sinks and floor drains backing up presumably because of surcharging storm drains or by flooding by penetration of groundwater through walls and floors. Consistent reports of flooding through floor drains occurred on Columbus Ave. and points on Clifton St. midway between Dudley St. and Harvey St.

2.5 FLOODING OBSERVATIONS

Significant flooding has occurred in the recent past in October 1996 and June 1998. While survey results report basement and surface flooding during both events, the 1996 event was by all accounts accompanied by more widespread and deeper flooding. Observations of flooding from October 1996 are described below. The information was gathered from survey responses, photographs, and conversations with neighborhood residents. These are supplemented by observations of Jacobs Consulting Services during lesser events in September 1999.

2.5.1 OCTOBER 1996

Widespread basement and street flooding were observed in response to the over seven inches of rain over a 36 hour period.

- Route 2 was closed when its low point near Lake Road was inundated under 6 inches of water

- Arthur D. Little offices in the Acorn office park lie at the top of the north bank of the Little River. Waters in the Little River rose over the banks flooding the office basement and the parking lot as shown in Figure 8. This is in contrast to further upstream where the banks of the Alewife Brook were not overtopped.

- Low spots south of the existing Alewife Center (Figures 9 and 10) and on Russell Field (Figures 11 and 12) were flooded. Figure 12 shows flooding over the catch basin inside the north gate of Russell Field abutting Clifton St.

- Alewife Brook Parkway was under water up to the curbs at its low point near the playground (Figure 13). The Brook had not however risen over its banks.

- Basement flooding occurred throughout the neighborhood at depths from several inches up to seven feet. This type of flooding created the most significant problems at homes on Seagrave Rd. and Columbus Ave.

- Water at low points on Columbus Ave. and Whittemore Ave. were present in the road for several days following the rain (Figure 14).

- Flooding at corner of Clifton St. and Dudley Ave. was accompanied by basement flooding in homes near intersection. The likely mechanism in this case is elevated groundwater elevations forcing water through basement walls.

- The drainage swale west of Russell Field, between Parkway Pond and Jerry's Pond, remained dry (Figure 15). The drainage design plans were not made available for our review, however one might expect that the swales ought to be holding or conveying water to Jerrry's Pond and Parkway Pond when substantial flooding has occurred over much of Russell Field, neighborhood homes and the Alewife Brook Parkway.

- Flood elevations described by high water marks were recorded by the US Army Corps of Engineers in unpublished notes. The Corps recorded high water elevations in Acorn Park, at the Arthur D. Little office of 8.86 and 8.97 feet, NGVD. This is approximately 0.7 feet greater than the 100 year flood elevation of 8.2 feet, NGVD. A high water mark of 5.65 feet was recorded at the Arlington Bicentenial Park near Massachusetts Ave. These reported elevations require additional investigation as flood elevations more than one-half foot greater than predicted for the 100-year event is not anticipated. Further, the difference in water level of more than 3 feet between monitoring points does not seem to be physically consistent.

2.5.2 SEPTEMBER 6 AND 10, 1999

Jacobs Consulting Services performed site visits following a brief shower on September 6 and on the evening of September 10 following a storm of more than four inches of rain. In both cases water had collected up to the curb on the south side of Alewife Brook Parkway near the playground opposite Kimball St (Figure 16). This flooding had occurred despite the presence of a catch basin at this point along the Parkway curb. There was no debris visible on the catch basin, but it was apparent that the catch basin was not functional. This catch basin and the storm drains are owned and maintained by the MDC (Owen O'Riordan, personal communication). Although there was water pooling on the grassy area along Alewife Brook Parkway, the Brook had not overtopped its banks.

On the evening of September 10, ponding was observed at the corner of Clifton St. and Dudley St. Three catch basins are located at this intersection, as it receives surface drainage from both ends of Clifton St. and from Dudley St. Two of these basins were covered with debris. After the debris was removed, the drainage into the basins was visibly improved. The one functional catch basin had an inlet cut into the curb, apparently allowing debris to flow into the storm drain and not remain trapped at the surface.

I also observed on the evening of September 10, ponding of approximately one-foot depth at the catch basin near the north gate of Russell Field and the fence line of the Clifton St. properties. Water was observed bubbling out of the storm drain inlet. The source of water was surface drainage from the northeast section of Russell Field. No other significant ponding was apparent on this evening at other points on Russell Field. The storm drain in this area appears to be inadequate to handle the large flows from a good portion of Russell Field.

2.5.3 CONCLUSIONS

Flooding in N. Cambridge residential neighborhoods during the October 1996 storm and other storms of similar magnitude is due to local drainage conditions, an overwhelmed storm drain system, and elevated groundwater conditions.

Flooding of homes on Clifton St. is largely caused by the drainage design on Russell Field, which brings water toward catch basins on the east side of the field. The northernmost of these catch basins was likely inundated as I observed on September 10, 1999. The condition is complicated by catch basins at the intersection of Clifton St. and Dudley St. which by residential accounts and my own personal observation are frequently clogged by debris caught on the catch basin grate. Also, the storm drains along Harvey St. were later found to be obstructed and cleaned out in spring 1999 (personal communication, Owen O'Riordan, Cambridge DPW). Some homes on Clifton St. between Dudley St. and Harvey St. also experience water entering their homes through sink drains, evidently caused by overwhelmed storm drains.

Homes north of Whittemore Ave. flood due to a combination of local surface water pooling, surcharging storm drains, and high groundwater. The groundwater flows into the homes is likely both due to regional increases in water table elevation and the effect of local ponding in yards and streets.

Flooding near Alewife Brook Parkway occurs with some frequency. In storms of the magnitude of the October 1996 storm and lesser storms, the flooding is deepest at the low spot on the Parkway between Massachusetts Ave. and Route 2. Further, the banks of the Alewife Brook on the north side of the Parkway contain water. From photos taken on this date one can see that the banks are not inundated as would be the case if the Alewife Brook were overflowing its banks – as is anticipated in simulations of the 100-year storm event (FEMA, 1981). I have observed that the catch basin at this point opposite Kimball St. does not function even during light events and is likely in part responsible for the frequent flooding along the Parkway. The accumulation of surface water on Columbus Ave. may be partly due to this condition and spill over from the Parkway onto Columbus Ave.

2.6 IMPACT OF RED LINE CONSTRUCTION

Residents of several homes have observed a correlation between increased flooding and the construction of the MBTA red line extension to the Alewife T station. The following observations were gathered as part of the survey and of other neighborhood meetings:

- *Ever since the T went in I pump all the time* (96 Jackson St.)

- *In '56 no pumping, last seven years a little flooding, last 3 years – flooding every time it rains* (101 Clifton St.)

- *I have lived here for 40 years and have never experienced flooding. It was only when new construction began.* (53 Madison Ave.)

Figure 17 (reproduced from Figure 11 of Haley and Aldrich, 1985) shows a vertical cross section at Russell Field running from north on the left hand side to south on the right hand side. Note that the groundwater elevation denoted by the height of the triangles generally falls off moving from south to north indicating a northerly flow. Note also that the MBTA tunnel was built across a 30-foot vertical interval from the water table down to clay deposits at depth. Clay deposits are relatively impermeable so without any special design considerations in the tunnel one might rightfully anticipate that the tunnel would in this area act as an impediment to flow and that the water table elevation would be elevated on the south side of the tunnel.

Haley and Aldrich (1985) and notes provided by GeoInsight describe a device designed to allow for flow beneath the tunnel and some indications that the device might not be operating as designed. There are also references in the text of Haley and Aldrich (1985) to seepage into the tunnel. Depression of the water table along the tracks evident in water table elevation maps in that report is consistent with seepage into the tunnel. Ten years later, Haley and Aldrich (1995) conclude that seepage into the tunnel continues to affect flow, although the depth of the water table depression is not as great as in the earlier round of head measurements.

Reviewed documents did not indicate whether similar precautions to not disturb preexisting groundwater flow conditions were taken in the adjoining residential neighborhoods as at Russell Field. Further, design details of the device to allow for under tunnel drainage are not provided from which to make an assessment of the device's performance under flood conditions.

If the T tunnel extension acts as a barrier to groundwater flow, because either no under tunnel device exists in the residential neighborhood or the device is not performing as designed, then the water table elevation would likely increase on the upgradient side of the tunnel. This would place the water table nearer to the foundation elevation of the homes and in the event of rain, houses upgradient of the tunnel would be more susceptible to flooding. A complete determination of the impact would require installation of a minimum of six monitoring wells so as to infer the direction of flow on either side of the tunnel and the drop in head across the tunnel. Continuous monitoring of these wells during a large storm event would be necessary to determine whether the presence of the tunnel were creating elevating groundwater conditions which might precipitate basement flooding.

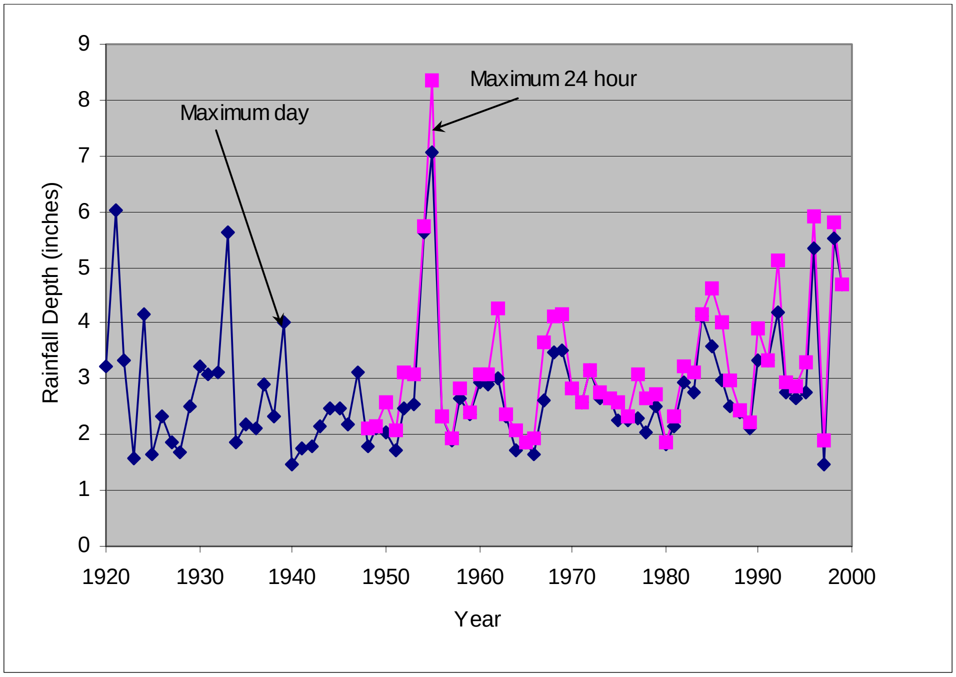

Figure 2. Annual maximum precipitation recorded at Boston Logan Airport.

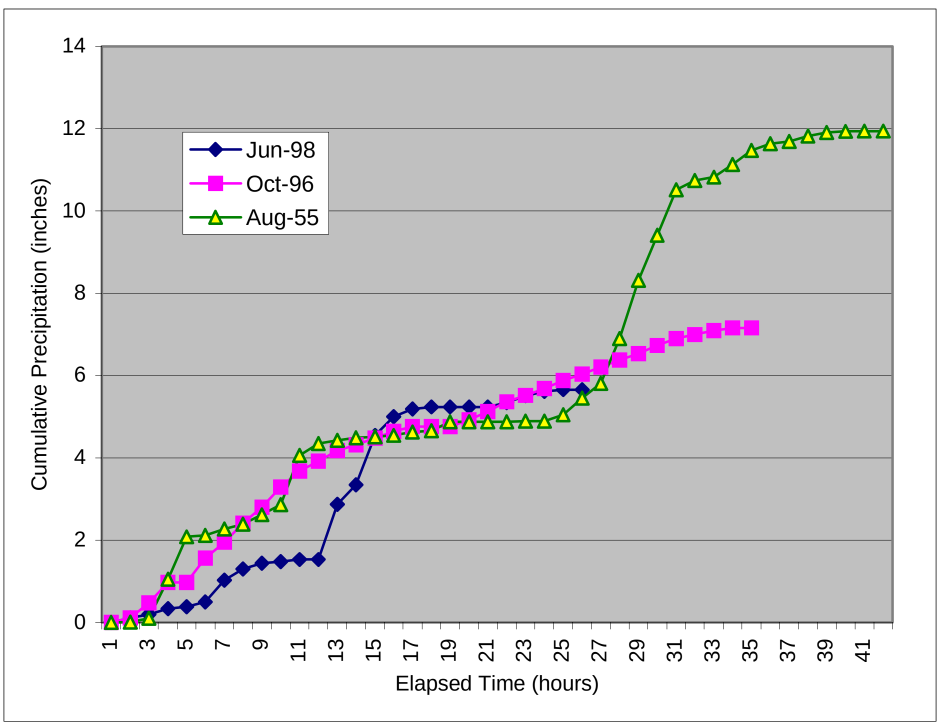

Figure 3. Cumulative rainfall depth for August 1955, October 1996 and June 1998 storms.

Figure 4. Location of surveyed homes

Figure 5. Surveyed homes with sump pumps.

Figure 6. Reported flooding frequency.

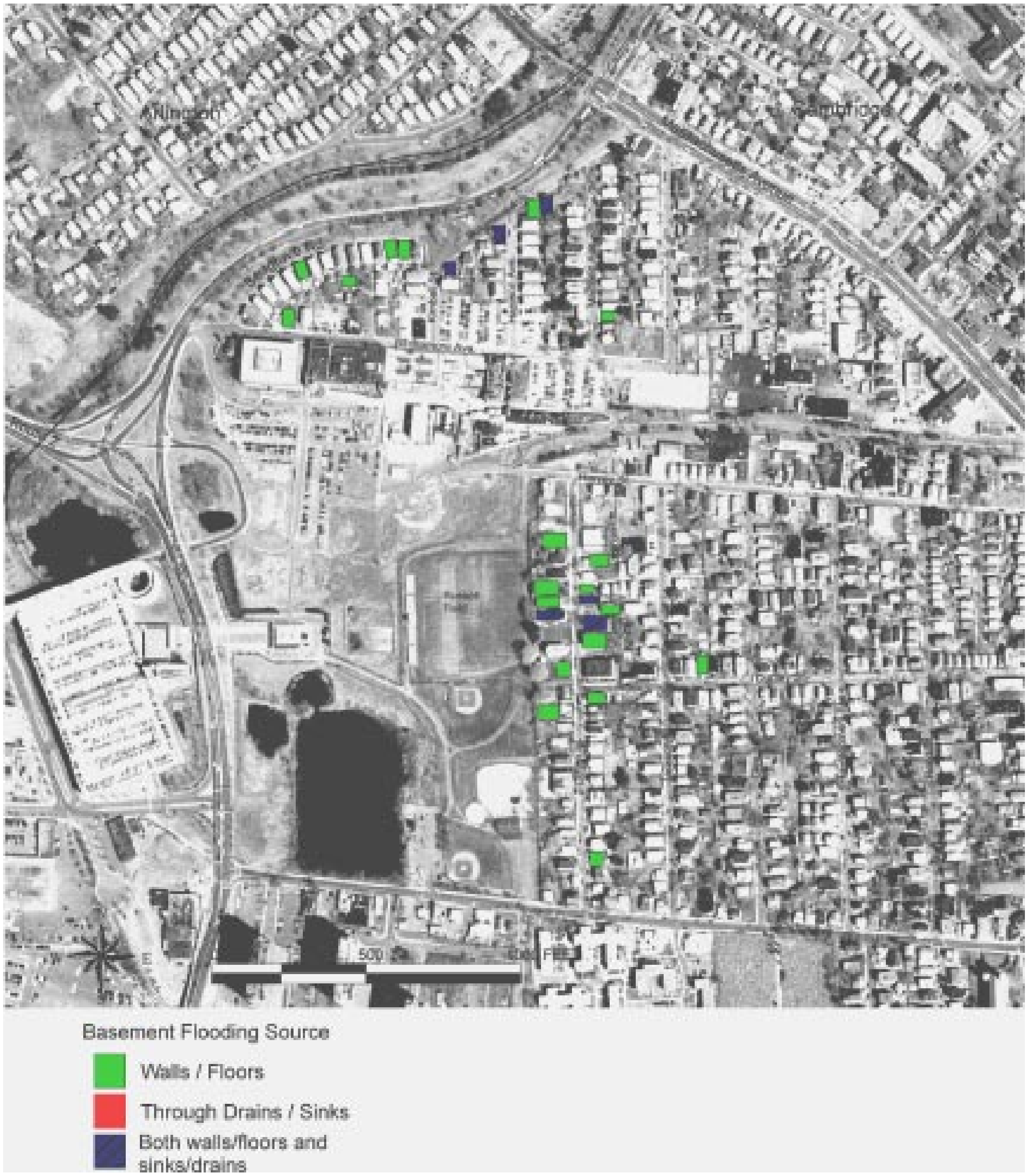

Figure 7. Basement flooding water source.

Figure 8. Flood conditions during October 1996 storm in Arthur D. Little eastern parking lot on north bank of Little River (by permission of J. Howard).

Figure 9. Flooding south of Alewife Center during October 1996 storm.

Figure 10. Flooding south of Alewife Center during October 1996 storm.

Figure 11 Flooding in Russell Field during October 1996 storm.

Figure 12 Flooding at storm drain inlet near northeast gate to Russell Field during October 1996 storm.

Figure 13. Surface flooding during October 1996 storm of Alewife Brook Parkway at low point near playground between Massachusetts Ave. and Route 2.

Figure 14. Surface flooding of Columbus Ave. near playground between Massachusetts Ave. and Route 2.

Figure 15. Swale between Jerry's Pond and Parkway Pond during October 1996 storm.

Figure 16. Surface flooding of Alewife Brook Parkway between Massachusetts Ave. and Route 2 following brief shower on September 6, 1999.

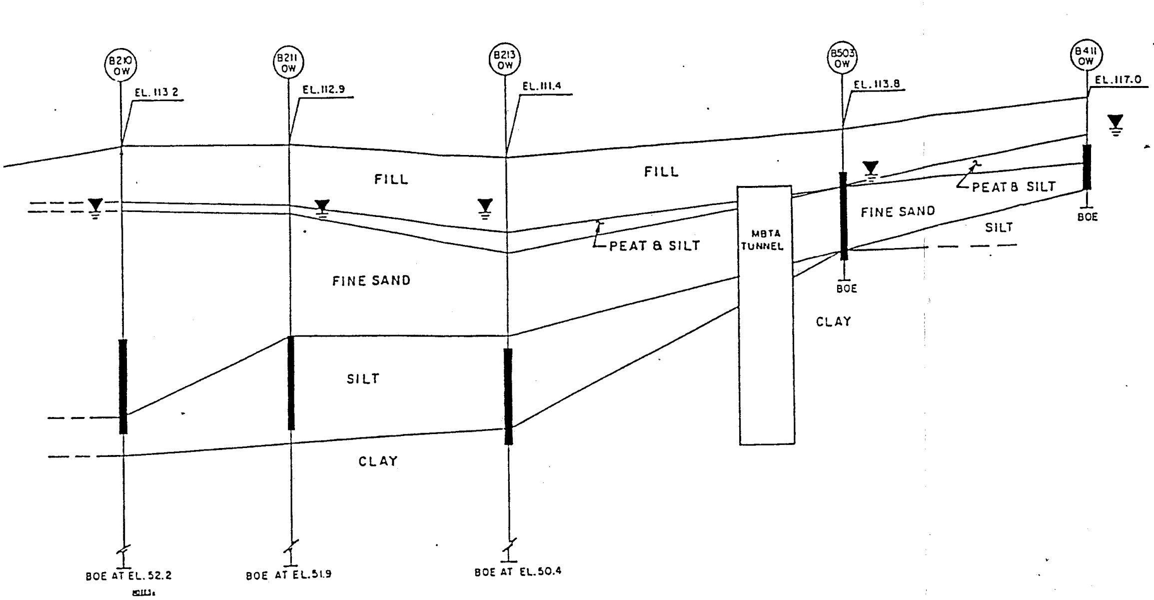

Figure 17. MBTA tunnel location on vertical section at Russell Field.

3 FLOOD PLAIN DEVELOPMENT ISSUES

3.1 IMPACT OF URBANIZATION

A floodplain is a low-lying area near a stream that becomes inundated during substantial floods when the rate of flow exceeds stream capacity. In natural systems, these floodplains are generally of far greater surface area than the streams themselves enabling the floodplains to serve as safety valves by receiving floodwaters and distributing those waters over a broad area. Further, local depressions in the flood plain and flood plain soils store water and release it at a slow pace so that the peak flow rate is diminished. The presence of an undeveloped floodplain therefore serves to reduce the intensity of flooding which would otherwise occur.

There is a clear consensus among practicing hydrologists and engineers (Chow et al, 1988; Debo and Reese, 1995) that watershed urbanization increases the frequency of substantial floods – that is floods capable of causing substantial property damage and presenting a danger to health and safety. The construction of roads, parking lots, bridges, and rooftops reduces the pervious surface area and therefore reduces the rate of recharge during storm events. Natural variability in surface elevation of undeveloped properties allows for local storage of surface runoff. See for example, Figures 18 and 19 showing the activation of local storage at 200 Cambridge Park Drive and at the location of the proposed Alewife Center. From the standpoint of an individual residential or commercial development, an important design objective is rapid and complete drainage of paved surfaces. Unfortunately, depression storage is often lost or severely diminished in the effort to attain these objectives. Both the reduction in recharge and the loss of depression storage increase the flood volume that must pass downstream to the watershed outlet.

Urbanization is also commonly accompanied by the channelization of storm flows on roads, gutters, curbs and underground storm drains. This drainage infrastructure reduces the time required for water to reach streams, increasing peak flood flows and in turn the elevation of stream waters. In some cases, the construction of bridges and development on stream embankments locally reduces stream capacity. During large storm events, these areas of reduced capacity may serve as choke points, causing further increases in river elevation and flooding at upstream points.

The consensus among technical experts on the impact of urbanization has translated into federal and state policies that encourage conservation as a means of reducing the occurrence of substantial floods. These types of measures are commonly referred to as non-structural measures, in contrast to structural measures involving pumps, storm drains, levees and dams. The Interagency Task Force on Floodplain Management developed *A Unified National Program for Floodplain Management,* which expresses support for a combination of structural and nonstructural measures. Regarding floodplain development, they assert that

> Development in or adversely affecting floodplains should be avoided unless it is considered necessary from a public interest standpoint and unless no suitable alternative exists. … Proposed development and new uses should be carefully regulated to insure the harmonious development of floodplains by minimizing the hazards present and preserving the natural values. … There is a moral responsibility upon all levels of government and nongovernmental interests to attempt to minimize the potential environmental and human losses associated with decisions affecting floodplains.

The task force which prepared the report consisted of representatives from nine federal departments and agencies, reflecting unanimity of intent among these agencies on this issue.

3.2 FLOODPLAIN DEVELOPMENT IN ALEWIFE-LITTLE RIVER WATERSHED

Cambridge Park Drive lies south of the Little River, upstream of the portion of the Alewife Brook abutting the study area of this report. An investigation of the hydrologic impact of the conversion of this area to commercial uses was undertaken to evaluate its impact on flooding in North Cambridge. Over the past 20 years Cambridge Park Drive has experienced a dramatic shift from industrial to commercial land use due to construction of the MBTA Alewife Station, and office buildings at 100, 115, 150 and 160 Cambridge Park Drive. An office building at 200 Cambridge Park Drive is under construction and a Notice of Intent has been filed with the Cambridge Conservation Commission for residential development at 30 Cambridge Park Drive. Figure 20 is a circa 1974 aerial photograph of what is now Cambridge Park Drive from its westward tip facing east. Photos in Figure 21 show the contemporary office buildings and the surrounding parking lots. The hydrologic consequences of construction on Cambridge Park Drive is of particular concern as it and anticipated future development in the area are largely within the estimated boundaries of the 100-year flood event (FEMA, 1982). Figure 22 shows the estimated bounds of the 100-year flood from the FEMA flood insurance maps of Cambridge and Arlington. It is important to point out that there has been frequent flooding noted in residential neighborhoods in the lower reaches of the catchment (i.e., North Cambridge and Arlington) (CDM, 1981) and that the severity of the 100-year flood is likely to have serious consequences for residents of this neighborhood. In light of the low-lying flat topography of the Alewife neighborhood and the consequent sensitivity to flooding, it should be anticipated that upstream property owners, in portions of Belmont and Cambridge within the Alewife watershed, be particularly attentive to mitigating the impact of land uses on flooding of off-site property.

Pre-existing development along Cambridge Park Drive was principally industrial with pavement consisting of both concrete and packed gravel surfaces. The concrete pad construction utilized at what is now 200 Cambridge Park Drive is likely typical of past construction practices elsewhere in the area. New offices have been built with basements down to the water table reducing subsurface storage capacity by a volume equal to the area of the building footprint times the distance from the ground surface to the water table times the displaced soil porosity. It is likely that the unimpeded drainage paths in the expansive parking lots have reduced the drainage time relative to its preexisting state. The impact of these two factors – reduced subsurface storage and increased water velocity would be to increase the magnitude of peak discharges to the Little River and therefore increase flood flow in the Little River and points downstream.

Compensatory storage requirements of the Wetland Protection Act are intended to ensure that storage capacity within the 100-year flood plain is not reduced by filling low-lying areas. The elevation of the provided compensatory storage must be at the same elevation as lost storage in order to reproduce pre-existing conditions. The regulations do not however specify the relation between the location of the compensatory storage and site drainage patterns. That is, from a regulatory perspective flood storage over a pervious surface and compensatory storage on a paved surface with an immediate hydraulic connection to the storm drain system are identical. This regulatory language should not be interpreted to suggest that there is no difference in the hydrologic characteristics of storage over paved and unpaved surfaces. Storage over unpaved surfaces with intermittent hydraulic connections to streams or storm drains will recharge more water to groundwater, leaving less to runoff than would be the case with an identical paved storage volume surrounding a storm drain inlet.

Compensatory storage for 115, 150 and 160 Cambridge Park Drive was provided in depressions surrounding parking lot catch basins raising questions about the effectiveness of this additional storage in reducing flood flows. Given the obviously good drainage characteristics of the parking lots, this compensatory storage volume will likely remain unutilized for most flood events less than the 100-year flood. In the case of floods greater or equal to the 100-year flood, the compensatory storage will not hold water or reduce flow to the Little River until the River is high enough to have already inundated office buildings immediately to the north of Little River.

There are also questions as to whether the regulatory agencies were appropriately vigilant in enforcing the regulations related to the volume of compensatory storage provided for much of the development at Cambridge Park Drive. The text of CMR 10.57 (2)a3 describes Bordering Land Subject to Flooding to be, "determined by reference to the most recently available flood profile data prepared for the community within which the work is proposed under the National Flood Insurance Program." The Flood Insurance Rate Map for the City of Cambridge (FEMA, 1982) show the 100-year flood elevation to exceed 8 feet mean sea level. The 100-year flood elevation in the area of Cambridge Park Drive is shown as 8.2 feet on the profiles from the flood insurance study on which the flood map was computed.

Despite this evidence of anticipated flood elevations, the compensatory storage requirements for 115 Cambridge Park Drive, 150 Cambridge Park Drive, and 62 Whittemore Avenue were all computed using a 100-year flood elevation of 7.2 feet. Table 3 of the Flood Insurance Study reports a 7.2-foot elevation predicted ignoring backwater effects of the Mystic River and no floodway development. On the same table, 8.2 feet is reported to be the regulatory base flood elevation and is consistent with both the stream profiles in the same study and the flood insurance map. It is impossible to know the motivation or thought process of the engineers in charge of estimating the compensatory storage requirement. The evidence would suggest that they were either intentionally disingenuous in overlooking evidence of higher flood elevations to reduce expenses for their client or that they at the very least committed significant errors in judgement.

The Order of Conditions issued by the Cambridge Conservation Commission for 160 Cambridge Park Drive cites a DEQE interpretation in determining that compensatory storage for that lot should be computed based on the 8.2-foot elevation. In addition, the Order of Conditions directed the applicant to reestimate the storage requirements using the 8.2-foot elevation and to provide the Commission with written verification on completion of this task. The Conservation Commission files do not contain any record of modifications to the compensatory storage calculations. Also, the file did not contain a certificate of compliance for the site so it is not possible to verify the elevation for which the compensatory storage requirements were estimated at this location.

At 100 Cambridge Park Drive, compensatory storage requirements were first estimated using 7.2 feet NGVD and at the direction of the Cambridge Conservation Commission later reestimated using 8.2 feet NGVD. The compensatory storage requirement estimated using the higher elevation was roughly four times greater than when estimated using the lower elevation.

In conclusion, there is some impact due to changes in the drainage patterns on the site from preexisting conditions. Compensatory storage has been provided but in a way which minimizes its benefits and inadequate compensatory storage, from both a regulatory and hydrologic standpoint, has been provided for over much of the newly developed area. The cumulative effect of these factors is difficult to quantify. Even if one were to make the argument that there is none or only minimal hydrologic impact, it would seem undeniable that the redevelopment of the area as built represents a lost opportunity to improve storage and drainage characteristics in an area in which flooding has been problematic for commercial and residential property owners as well as the general public.

Figure 18. Depression flood storage during June 1998 storm at 200 Cambridge Park Drive prior to breaking ground for new office building.

Figure 19. Depression flood storage during October 1996 storm at site of proposed commercial development abutting Russell Field.

Figure 20. Aerial photograph of land use along Cambridge Park Drive in 1974.

Figure 21. Contemporary commercial land uses along Cambridge Park Drive.

Figure 22. Estimated bounds of 100-year flood event from FEMA flood insurance map (1982)

4 FLOODING IMPACT

4.1 INTRODUCTION

The MDC Mystic River Comprehensive Study (CDM, 1981) presents costs and benefits for eleven proposed measures to reduce flooding and flood impacts in the Mystic River watershed. As most of the estimated damages in the water shed are located in the Alewife Brook portion of the watershed, many of these measures were directed at alleviating flooding along Alewife Brook. The estimated damage in the Alewife Brook watershed associated with the 100-yr event alone is $1,208,250. Of this $922,650 is due to physical damages and $250,000 attributed to nonphysical damages. Much of the latter nonphysical damages are attributed to lost wages of Arthur D. Little's (ADL) 1200 employees. Physical damages of $451,000 are attributed to the 232 homes along the Alewife Brook in Cambridge and Arlington between Route 2 and Massachusetts whose homes are anticipated to be flooded during the 100-year event.

Total annualized damages were computed based on the frequency and expected damages of all storms up to the 200-yr event. In their analysis of damages, flooding of greater magnitude than the 200-yr event were assumed to cause the same damages as estimated for the 200-yr event. Annual damages for the Alewife Brook watershed were estimated at $33,000 per year. Of the eleven alternative under consideration, three were recommended for implementation: modification of the operating policy at the Amelia Earhart dam, lowering of the Mystic Lake and floodproofing or flood insurance of homes on a case-by-case basis.

The objectives of this chapter are to encourage a reevaluation of the economic and other impacts associated with flooding in the Alewife Watershed. Economic damages not accounted for in the MDC report are described, as well as modified land uses since the time of the MDC study and their effect on estimates of economic damages. Quantitative estimates of damages are beyond the scope of this project and are not presented. Instead, the chapter presents a qualitative review and where possible, order of magnitude estimates of damages. Health and safety issues, which were not addressed in the MDC study, are also introduced.

4.2 ECONOMIC IMPACTS

4.2.1 NEW COMMERCIAL DEVELOPMENT

MDC's economic analysis largely preceded the commercial development along Cambridge Park Drive and did not therefore consider damages to commercial properties built since that time in this area. It is safe to say that lost wages attributable to loss of access to Cambridge Park Drive is on the order of five to ten times that of the Arthur D. Little wage losses, due to the much larger total number of employees in the Cambridge Park Drive area. Further, it is notable that Cambridge Park Drive was shut down during the June 1998 storm (Steve Kaiser, personal communication), which was something on the order of a 25-year event and that the Arthur D. Little offices were closed during both the October 1996 and June 1998 flood events.

4.2.2 NON-PHYSICAL DAMAGES OF RESIDENTIAL FLOODING

Non-physical damages are defined in the MDC watershed study as "costs associated with the loss of productive economic activity because of flooding and costs incurred providing alternative shelter and food for evacuated residents. Wages lost because flooding forced a business to close down for a day or because of a worker's inability to reach his place of employment are other examples of non-physical damages."

The MDC report does not attribute non-physical damages to residential flooding, yet many of the ANI survey respondents reported spending several days cleaning up in the aftermath of recent flood events of significantly less magnitude than the 100-yr storm. Even if these hours were occupied outside of normal working hours, it is inequitable not to attribute non-physical damages to the time spent in these nonproductive activities. A rough estimate of the additional expenses per home might be obtained by anticipating that one week is occupied in the removal of water, disposal of damaged property, cleaning flooded rooms, and arranging for and overseeing repairs to furnaces, appliances and hot water heaters. At an hourly cost of $25 per hour this would translate to roughly $1000 per home of nonphysical damages for each substantial storm event of the same or greater magnitude as the October 1996 or June 1998 storms.

4.2.3 UNANTICIPATED RESIDENTIAL FLOODING

The flooding mechanism described in the MDC report (CDM, 1981) and implied by the boundaries of the 100-year flood in the FEMA flood insurance map is one of stream flow in the Alewife Brook overtopping its banks and inundating neighborhoods directly abutting the Brook. The numerical rainfall-runoff models employed in these studies embody only this conceptual model of flooding and can not be used to estimate flooding due to elevated groundwater, or surcharging or obstructed storm drains. Flooding in North Cambridge, within and beyond the estimated boundaries of the 100-year flood have been documented in photographs and the ANI survey, without overtopping of flows in the Alewife Brook. Compare for example the reported frequency of flooding shown in Figure 6 and the estimated 100-year flood boundaries shown in Figure 22. The dominant flooding mechanisms in this area are elevated groundwater levels, surcharging storm drains, and local surface flooding. The result is that basement flooding occurs with greater frequency and over a larger area than could have been predicted using the techniques of prior flood studies.

4.2.4 REDUCTION IN HOME PROPERTY VALUE

Property values in neighborhoods with a known propensity for flooding are reduced relative to the value of equivalent homes in areas without flooding. Several survey respondents were in fact hesitant to respond due to fears that reporting the frequency of neighborhood flooding would have a negative impact on the value of their homes. The reduction in home value is difficult to quantify, however if say 200 homes, each worth roughly $250,000, were reduced in value by 2 percent, this would result in a reduced aggregate property value of 1 million dollars.

4.2.5 IMPAIRED USE OF MAJOR HIGHWAYS

Portions of Route 2 and the Alewife Brook Parkway are within the bounds of the 100-year flood as defined in both the MDC report and the FEMA flood maps, yet the MDC report does not cite loss of access routes in estimating damages in the Alewife Basin. Both of these highways carry significant traffic loads for commuters traveling to points both inbound and outbound. If commuters were not completely prevented from traveling to their destinations by loss of these roads, it is certain that travel around these points would impose significant delays, which ought to be accounted for in estimation of non-physical damages. It has been reported (Steve Kaiser, personal communication) that Route 2 was closed during the October 1996 storm – a storm on the order of the 25-year event. Use of Alewife Brook Parkway was also impaired during this event and during events of lesser magnitude.

4.3 HEALTH AND SAFETY

It was reported by Alewife residents that traffic diverted from a flooded Alewife Brook Parkway often ends up on residential streets. This includes the use of Seagrave Ave. opposite to its posted direction, with obvious safety consequences. Figure 23 shows flood conditions on Alewife Brook Parkway and the simultaneous hazardous use of Seagrave Ave.

A significant number of residents described water entering basements through backed up sinks and floor drains. Figure 7 shows the location of surveyed homes for which flooding has occurred in this fashion. This presents opportunities for exposure to untreated sewage and the spread of communicable illnesses. Diseases transmitted by water include dysentery, gastroenteritis, typhoid and hepatitis, which may be spread through exposure to fecal and urinary discharges of infected individuals (Steel and McGhee, 1979). Further the presence of contaminated soils on the property previously owned by Grace Chemical raises concerns of exposure to toxic compounds and carcinogens.

Figure 23. Flooded Alewife Brook Parkway and cars driving wrong way on Seagrave Ave.

5 RECOMMENDATIONS

5.1 INTRODUCTION

Recommendations are presented with both regional and local scope. Regional measures are largely focused on restoration of storage within the watershed. The goal of these measures is to reduce flooding impacts associated with storms of a magnitude equal to and greater than the 100-year event. Recommendations for local scale measures are aimed at improving local drainage and exploration of measures for improving the design and operation of the local storm drain system. These recommendations are largely focused on mitigation of flood impacts for more frequent storms on the order of the 25-year storm event.

5.2 REGIONAL RECOMMENDATIONS

An investigation of the feasibility of increasing watershed storage through wetland preservation and other artificial means is recommended to explore measures to reduce the magnitude of peak flows in extreme events. Increasing storage throughout the watershed reduces peak flows by trapping water and releasing it slowly enough so as not to overwhelm the hydraulic capacity of downstream points in the watershed. Storage may be derived from both natural storage sources – such as wetlands or other undeveloped property – and the provision of artificial subsurface storage.

A local precedent exists for the implementation of a watershed scale plan of this type (Faber, 1996). The Natural Valley Storage Project, proposed, developed and managed by the US Army Corps of Engineers, utilized wetland preservation as a means of reducing flood damage in the Charles River watershed in eastern Massachusetts. Easements were obtained for 4680 acres of wetlands in private hands, which commit landowners to not disturb the storage potential of their properties. At the same time, 3350 acres of wetlands were purchased outright. The total expense for this project was $10 million in 1984 dollars.

In order to understand the magnitude of storage that might be required to capture enough water to reduce peak flows, consider the case of 8 ft of underground artificial storage tanks built beneath one or more golf courses. If for example storage were built beneath 8 holes, each of which is 450 yards in length by 75 yards wide this would provide 19.5 million cubic feet of storage. This is approximately 9 percent of the total rainfall for a 12-inch depth storm over the entire 8.1 square mile watershed.

The proposed investigation would explore the availability of undeveloped properties and potential sights for artificial underground storage throughout the watershed, estimate the market price of available land, quantify the increased storage and estimate the anticipated reduction of flood flow rates. An important objective of the investigation would to build a coalition of interested individuals, advocacy groups, and state and municipal officials to develop the political support that will be needed to successfully press for implementation of the plan.

Funding sources should be investigated as well, with exploration of both federal and state funding sources. A handbook on federal programs compiled by the Office of Management and Budget (1998) describes many potential funding sources for wetland restoration under the auspices of FEMA, the US Army Corps of Engineers, the Fish and Wildlife Service, the Environmental Protection Agency and the Commodity Credit Corporation.

5.3 LOCAL RECOMMENDATIONS

5.3.1 UPGRADE STORM DRAIN INLETS AT INTERSECTION OF CLIFTON AND DUDLEY

Surface flows from Dudley Street and both ends of Clifton Street converge at the corner of Clifton Street and Dudley Street. Three inlets collect water and convey it to the storm drains, however debris has been observed to frequently collect on the surface of the two inlets on this corner without a curb inlet. As a result, water frequently pools at this corner during storms of any significance. Curb inlets are reportedly more effective than grate type inlets where debris flows are expected (ASCE, 1994), which is consistent with observations of debris clogging at this intersection. It is recommended that the grate-only inlets at this intersection be upgraded by construction of curb inlets.

5.3.2 REGRADE RUSSELL FIELD

The eastern half of the soccer field, bordering homes on Clifton Street, drains toward inlets along the eastern side of Russell Field. Survey responses document the presence of flooding in Russell Field behind their homes. Most problematic is the storm drain near the northeast gate of Russell Field. Photographs from the October 1996 storm document knee high flooding and surcharging of this inlet was observed by Jacobs Consulting Services on the evening of September 10, 1999. At the same time, a system of swales connecting ponds on the western edge of the field was observed to be not carrying any significant flows. Alternatives to drainage of any portion of Russell Field toward the Clifton Street homes are available and ought to be explored. This might include regrading Russell Field to drain toward inlets in the center and western side of the field and the construction of swales to convey water to the Parkway Pond / Jerry's Pond swales. Attention should be paid to drainage of sidewalks, which were reported by residences to be frequently ice-covered during the winter months.

5.3.3 IMPROVE DRAINAGE ON ALEWIFE BROOK PARKWAY

The low point of Alewife Brook Parkway between Route 2 and Massachusetts Ave. occurs near the playground opposite the intersection of Kimball Street and Columbus Ave. At this low point, the Parkway floods across the east-bound lanes even after modest showers and from curb-to-curb in more substantial storms. Further, it appears that street flooding of the Alewife Brook Parkway may contribute to street flooding on the adjacent Columbus Ave. There is a storm drain inlet at the southern curb, however it is completely nonfunctional and most likely has been in this state for a number of years. According to Owen O'Riordan of the Cambridge DPW, inlets along the Alewife Brook Parkway and the storm drains to which they contribute flows are owned and maintained by the MDC. It is recommended that the MDC investigate why the inlet at the low point of Alewife Brook Parkway between Massachusetts Ave. and Route 2 is not receiving water and immediately make any necessary repairs.

5.3.4 RETROFIT HOMES

Given the minimal relief in the area and high groundwater elevations encountered at homes near the Alewife Brook, it is most likely infeasible to alleviate all flooding by improving surface drainage. Homes subject to frequent and intense flooding should be floodproofed to reduce the magnitude and impact of basement flooding. The FEMA publication *Engineering Principles and Practices for*

Retrofitting Flood Prone Residential Buildings (FEMA, 1995) describes dry floodproofing, wet floodproofing and floodwall construction methods for retrofitting homes. The dry floodproofing techniques include strengthening of existing foundations, floors and walls to withstand flood forces while making the structure watertight. Dry floodproofing techniques include:

- Epoxy or cement based sealants to prevent leakage through basement walls
- French drain system to relieve water pressure outside home
- Backwater valves to prevent backup of storm or sanitary system through floor drains and basement fixtures

Wet floodproofing involves making utilities, structure components, and contents flood- and water-resistant. Typical wet floodproofing measures include relocating or floodproofing utilities and furnaces and the installation of backflow valves to reduce backup of sewer or storm waters into sinks and drains.

One possible scheme to encourage home owners to floodproof their homes is to have the city contract an engineer or contractor with expertise in design and implementation of floodproofing measures as described in FEMA (1995). This individual would be available for consultation with individual homeowners, providing case-by-case recommendations of floodproofing strategies. The City might also negotiate with and reach agreements with contractors to provide services at a reduced rate. Ideally, subsidies should be made available to residents of low to moderate income to assist in implementation of floodproofing measures. Federal funding sources for flood retrofitting may also be available and should be explored. The US Army Corps of Engineers conducts feasibility studies and constructs flood control measures which have in the past included in some cases floodproofing of existing structures. The Commonwealth's Department of Environmental Management (DEM) Flood Hazard Management Program provides grants to municipalities for mitigation of flood risks and damages. Pre-disaster grants are made available annually through the Flood Hazard Mitigation and post-flood grants are offered through the Hazard Mitigation Grant Program. Keith Turi is the Flood Mitigation Project Manager at DEM and should be considered as a resource to provide information on the nature and availability of such grants. reference *Flood Hazard Mitigation Planning: A Community Guide*, available from the Massachusetts Flood Hazard Management Program, is a good reference to assist in planning for grant applications.

5.3.5 STORM DRAIN MAINTENANCE AND INVESTIGATION OF SYSTEM IMPROVEMENTS

In large storms, the presence of locally surcharging storm drains in low-lying areas is anticipated, however the presence of water several days after a storm would suggest that some portion of the drains is partially or completely obstructed. Survey responses were spotty in the area north of Whittemore Ave., however there were a number of responses indicative of problems in this area:

- rain pools at corner of Whittemore and Madison for at least a day after rain has stopped
- storm drain on corner of Whittemore Ave. and Madison Ave. has always created gutter flooding
- water in basement for several days till water on parkway reduced

- flooding at end of Harrison Ave. at Grace Chemical parking lot, storm drains on Columbus Ave at Harrison Ave and Kimball street do not function well

An inspection program is recommended to determine whether storm drains on Whittemore Ave., Harrison Ave., Kimball Street and Columbus Ave. are obstructed. Should problems be detected, appropriate actions should be carried out to restore the hydraulic capacity of the storm drains.

In as much as the Alewife Brook was not at capacity during either the October 1996 or June 1998 storms, the brook itself ought to be viewed as a reservoir capable of receiving surface runoff during events of this magnitude. Consultants should be employed by the City of Cambridge to explore schemes to drain local streets to the brook. System improvements might include the construction of new storm drains to ensure that the system is capable of handling storm flows, check valves to prevent high stream flows from backing up onto local depressions and/or pumps to lift storm waters up to the brook elevation if necessary.

5.3.6 INVESTIGATION OF IMPACT OF RED LINE EXTENSION TUNNEL

The observation of several long-time residents that flooding has increased since construction of the Red Line extension and a plausible physical explanation for increases in water table elevation associated with the tunnel design would appear to be sufficient arguments to merit investigation of the impact of the tunnel construction. The MBTA has a responsibility to investigate reasonable and plausible claims that their property is producing ill effects on neighboring land uses. This investigation should include review and analysis by an independent engineer of the tunnel design and its effects on preexisting groundwater flow, as well as the installation of a network of monitoring wells upgradient and downgradient of the tunnel. The wells should be equipped with continuous recording devices and be of sufficient density to measure the groundwater elevation and flow direction during large storms.

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