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Technical Analysis
Upper Alewife Brook Basin
Impact Study

February 29, 2012

Prepared for:
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Belmont, MA

Sponsored by:
Belmont Land Trust
Cambridge Green
Belmont Citizens Forum

Upper Alewife Brook Watershed
Technical Analysis

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Technical Analysis – Upper Alewife Brook Watershed

1.0 Purpose

This report was prepared to provide the towns of Arlington, Belmont and Cambridge a clear understanding of the hydrologic and ecological considerations associated with continued development of environmentally-sensitive lands associated with the upper Alewife Brook Watershed which includes Little River in Cambridge and several ponds and streams. A specific focus is provided on the proposed development project at the Belmont Uplands site which is characterized by Charles Katuska, PVVS, Chair conservation Commission in Sutton, as a silver maple forest monoculture.

The report provides a technical summary of flooding, habitat, water quality, and climate change as they substantially affect the regional subject area. The document draws upon existing available data sets from Massachusetts Department of Environmental Protection (MADEP), hydrological maps, Federal Emergency Management Agency (FEMA) maps, wildlife studies, proposed development plans, and publications regarding the Alewife Basin and more specifically, the forested Uplands project site.

2.0 The Study Area

The Alewife Brook watershed is a sub-watershed of the Mystic River watershed (shown in red in Figure 1) and includes the Little River. It drains approximately 4,500 highly-urbanized areas of Arlington, Belmont, Cambridge and Somerville. The Brook falls only three feet in elevation over its 2.3 mile run to its confluence with the Mystic River. The urbanized watershed is characterized by high amounts of impervious surfaces (approximately 47%) and exhibits significant flooding problems. Limited areas of naturally-vegetated lands provide critical habitat values as a last refuge for these species.

The Alewife Brook Reservation is an oasis of natural open space within the watershed. It measures approximately 115 acres, largely composed of wetlands, and is owned and managed by the Massachusetts Department of Conservation and Recreation (DCR). The Friends of the Alewife Reservation have been long-term stewards. The Reservation provides significant watershed functions including flooding controls, water quality treatment, habitat and recreational opportunities to surrounding residents. Its southwest tributaries are part of the Mystic River watershed. Its waters include Little, Yates and Blair Ponds; Little River, Wellington Brook and Alewife Brook; linking the Alewife Reservation to the Mystic Lakes and Boston Harbor via the Mystic River. The area is a remnant of the Fresh Pond Marshes, a historically-extensive wetland system that began to be filled during the 1976-84 period. The DCR is responsible for coordinating all planning, management, and maintenance activities within the Reservation.

The Alewife "T" Station is located to the south of the Reservation and provides a significant opportunity for smart growth development associated with transit-oriented development (TOD), where high-density, mixed use land uses and their residents and workers can take advantage of alternative transportation, including the MBTA rail system and extensive bicycle and pedestrian paths.

A Silver Maple Forest is located to the north of the Reservation. This locally-rare woodland provides significant habitat values as a key open space area within the watershed. A residential development project has been proposed in this area by O'Neill Properties on a 12.2-acre parcel of land off Acorn Park Road, commonly referred to as the "Belmont Uplands." The property is surrounded by wetlands and is naturally vegetated, providing habitat for a broad range of species and has a shallow groundwater table. The project applicant plans to develop the site and to infiltrate the stormwater on-site, suggesting this as a flood control measure. Due to the loss of the vegetation and the associated evapotranspiration, the project will generate significantly more water than in its current (natural) state. This will result in an increased water table elevation in the area.

The Alewife area has been extensively degraded by past development practices that have not been sustainably-designed. It is burdened by serious flooding, poor water quality (including combined sewer overflows, or CSOs), and encroachments into the remaining habitat and open space resources. A comprehensive management plan is needed to address existing issues and to prevent further degradation of this area. Attempts have been made by Cambridge, Belmont and Arlington residents and legislators to develop a comprehensive management plan (Sen.Bill 1909) but to no avail.

3.0 Flooding and Stormwater

Flooding has been repeatedly identified as a significant issue in the Alewife Brook Watershed because of the increase in the amount of impervious surfaces from commercial and residential development and roadway expansions.

Flooding problems are caused by increased runoff and/or losses in flood storage capacity. Increased runoff is the direct result of the construction of impervious surfaces, which preclude infiltration into the native soils. Flood storage losses occur as the result of structures that are placed in the floodplain that displace floodwaters to higher elevations and downstream locations. The removal of natural vegetation significantly reduces the evapotranspiration (ET) rates (approximately 50% of the precipitation rates in natural state) and results in significantly higher amounts of net precipitation, or the total water that must be assimilated by the watershed.

To illustrate the hydrologic changes occurring within the Alewife watershed HW prepared hydrologic budgets under natural (pre-development) conditions and post development (see Table 1). The average annual precipitation for the area is estimated at 42 inches/year. This represents an average of 14.2 million gallons/day (MGD) over the 4501 acre watershed.

Table 1. Hydrologic Analysis of Alewife Brook Watershed

	Area Acres	Runoff cfs	Recharge cfs	Total cfs	Total MGD
Natural Conditions	4501	4.2	8.8	13.1	8.5
Developed Conditions	4501				
Impervious	2117	8.5			
Pervious	2384	2.3	4.7	15.4	10.0

*Notes/Assumptions:

Precipitation =	42	inches/year
ET =	16.8	inches/year
Recharge =	17	inches/year
Runoff =	8.2	inches/year

Under natural conditions a little less than half of this precipitation (5.7 MGD) is returned to the atmosphere as evapotranspiration. The remaining net precipitation (8.5 MGD) flows through the watershed as surface runoff or groundwater. Expressed in cubic feet per second (cfs) this equals 13.1 cfs. Based upon the soil types present in the watershed, HW estimates that under natural conditions approximately 8.8 cfs contributed to groundwater recharge and 4.2 cfs to surface runoff.

Significant hydrologic changes have resulted from the urbanization of the watershed. According to MAGIS, 47% of the watershed has been developed with impervious surfaces. There are numerous additional pending development permits. This results in a significant increase in surface runoff (from 4.2 cfs to 10.8 cfs). Because evapotranspiration in impervious areas is significantly reduced, the total discharge (flow) in the watershed increases significantly from 13.1 cfs to 15.4 cfs (an increase of 18%). This means that there is surplus amount of water that must be discharged to the watershed. This surplus occurs during individual (design) rain events and on an average annual basis.

Increased runoff caused by development projects (and the associated impervious surfaces) are typically managed by detaining or retaining the stormwater on-site and then subsequently releasing the water slowly as a surface discharge or as groundwater. Minimizing and/or disconnecting impervious surfaces, and the implementation of low impact development (LID) techniques, can also reduce these impacts. Flood storage losses can occur if a project is not carefully designed. These storage losses can occur at the land's surface and/or subsurface as a result of the direct displacement by structures that occupy the floodplain. For example, if the project proponent plans to infiltrate the excess runoff into the subsurface, water table levels will rise, decreasing the capacity of the soils to store flood waters. This is a loss of flood storage and can result in higher baseflood elevations and increased flooding downstream.

FEMA published a revised floodplain map in 2008. Figure 2 provides a MAGIS compilation of this mapping throughout the Alewife Brook Watershed. The floodplain delineation is a key element of constraints assessment because it provides the basis for the site planning and design. Additionally, the Massachusetts Wetland Protection Regulations; (a) protect portions of the floodplain for wildlife habit, and (b) require a developer to provide compensatory storage for all flood storage lost as a result of a proposed project. The compensatory storage must be located at the same elevations from which flood storage is being removed.

There are also strict restrictions for any development within the floodway (that portion of the floodplain that carries the main flow during storm events). The floodway is defined by FEMA as the central portion of the floodplain, including the stream channel and adjacent lands that must be kept free of encroachment so that the 100-year flood discharge can be conveyed without increasing the elevation of the 100-year flood by more than one foot. The City of Cambridge requires that no encroachment in the floodway shall result in any increase in 100-year flood levels (City of Cambridge Zoning Ordinance, Section 20.71).

Under their minimum compliance with floodplain management criteria, FEMA requires that "any project in a floodway must be reviewed to determine if the project will increase flood heights. An engineering analysis must be conducted before a permit can be issued. A community must have a record of the results of this analysis, which can be in the form of a No-rise Certification. This No-rise Certification must be supported by technical data and signed by a registered professional engineer. The supporting technical data should be based on the standard step-backwater computer model used to develop the 100-year floodway shown on the Flood Insurance Rate Map (FIRM) or Flood Boundary and Floodway Map (FBFM)."

Alternatively, if the project does result in flood level increase, the project applicant can prepare a Conditional Letter of Map Revision (CLOMR) and submit this to the community to determine if these hydrologic modifications are acceptable to the community. While individual projects may have incremented impacts, the cumulative impacts of numerous projects can be significant.

The cumulative impacts of floodplain encroachment are difficult to assess. Even small losses in flood storage from individual projects multiply over time and can have significant, long term, cumulative impacts. Currently there is no available assessment or regulatory approval to account for these cumulative impacts.

The Alewife Reservation and the Silver Maple Forest provide vital floodwater storage in the naturally pervious land and wetland areas. These functions help to ameliorate both flooding and water shortages in the adjacent area through the absorption of rain and snow melt and the slow release of groundwater in the soils. These and other remaining open space areas must be preserved to provide the natural flood storage within the Upper Alewife basin.

Groundwater mounding is another aspect that must be considered with stormwater management that utilizes infiltration systems. Depending on site conditions, mounding may occur when stormwater is collected from impervious surfaces and infiltrated into the ground at a concentrated point or location. Two types of alterations will result: 1) long-term steady-state (or equilibrium conditions) and 2) short-term (during the 10, 25 and 100-year design storms). The combined effects of these two alterations need to be incorporated into a properly designed stormwater infiltration facility. These changes can be readily predicted using an analytical or numerical model.

MADEP Stormwater Management Standard #3 requires that post-development recharge should "approximate" the pre-development recharge rate (see Figure 3). The purpose of this standard is to maintain or restore the natural hydrology to support baseflow to downgradient surface waters and wetlands. If post-development recharge rates are lower, we can expect to see lower baseflows in downgradient streams and de-watering of wetlands. If post-development recharge exceeds the pre-development (or natural) rates, we can expect to see higher groundwater levels and increased baseflow. Where shallow water table conditions exist, higher groundwater levels can be problematic in the functioning of infiltration systems. The MADEP Stormwater Policy requires a minimum vertical separation of two feet between the bottom of the infiltration facility and the high groundwater levels.

An example of a project that has groundwater mounding issues associated with excessive stormwater infiltration is located at Acorn Park Drive in Belmont, Massachusetts, which is located in the Silver Maple Forest area. Based in part on our earlier review and comments on the project and subsequent direction from DEP, the applicant has abandoned the earlier stormwater infiltration designs and has developed an alternative approach that includes a larger infiltration structure (UC-1) and porous pavement. The proposed site plan (revised on June 23, 2008) concentrates the stormwater infiltration into the central portion of the site. The project applicant's Drainage Report indicates that the proposed infiltration facilities will recharge a design volume of 0.776 acre-feet (0.131 acre-feet static storage and 0.645 acre-feet dynamic infiltration). This is more than seven (7) times existing (target) design volume of 0.09 acre-feet. This will result in a significant increase in the water table, known as groundwater mounding. According to hydrologic modeling done by Dr. Bruce Jacobs of Hydro Analysis, Inc. the mounding will cause the proposed infiltration facility to become inundated and will not be able to function during the design storm events. Additionally, year-round water table increases can be expected in the area, thereby reducing subsurface flood storage capacity.

Attempts to balance the hydrology of a site under post-development conditions are fraught with an integral conundrum. This is related to the loss of vegetation on a development site and the resulting loss of evapotranspiration. This causes an unavoidable increase in net precipitation – excess water that the site designer has to manage. Generally there are two choices: discharging it as surface runoff or as infiltration to groundwater. However, MADEP Stormwater Management Standards 2 and 3 restrict the discharge rate and volume of surface discharges to pre-development rates and restrict the groundwater recharge to approximate the pre-development conditions.

Consequently, the continued development of the watershed adds increasing amounts of net precipitation, either as increased surface runoff or as increased groundwater recharge (and the corresponding increases in water table). Both of these alterations are problematic in this watershed that is characterized by flat terrain, surface flooding and shallow groundwater conditions.

One possible solution is the construction of off-site mitigation wetlands that have the capacity to store flood waters and to evapotranspired at a rate that is roughly double that of upland forested areas. Accordingly one acre of constructed wetlands could offset approximately two acres of lost upland area. The DCR wetland pond project is an excellent example of this type of mitigation project.

Another possibility is the widespread use of vegetated LID technologies such as green roofs, bioretention systems, rain gardens, and grassed swales. These systems provide both water quality treatment and evapotranspiration benefits.

4.0 Habitat

The Upper Alewife Watershed contains important upland, wetland and riverine habitats. The habitat resources of the Silver Maple Forest have been studied by environmental specialists coordinated by Friends of Alewife Reservation, community volunteers, and technical consultants hired by developers. The Forest is an unusual upland forest of silver maples *(Acer Saccarinum)* and a mixed wetland community including trees, shrubs, and other wetland plants providing habitat for a wide variety of wetland and upland species. Silver maple is widely recognized as a tree species most successful in floodplain habitats (Charles Katuska). Katuska has noted that the silver maples and red maples dominate the upland area (defined as that land of elevations higher than 8.2 feet, the 100-year floodplain elevation, of the "Belmont Uplands" property.

The proposed development for this site includes the alteration of 8852 square feet of upper floodplain (defined as the land area between the 10-year floodplain and the 100-year floodplain. According to Katuska this area is significant to the public interest of wildlife habitat. He cites a number of scientific studies that support this (see Table 2). Katuska also asserts that the proposed wildlife habitat mitigation area (proposed by the developer to offset the loss of natural habitat) does not provide the necessary wildlife habitat values stating that, "the Applicant's proposal to provide wildlife habitat mitigation areas immediately adjacent to the expanse of open, non-forested areas to be developed with a 5-building, 299-unit residential complex will result in patterns of shade, airflow, and lighting significantly different from those in the floodplain areas to be lost" (page 5 of his Prefiled Testimony submitted to the MADEP).

Table 2. Scientific Studies on Wildlife Habitat at the Belmont Uplands

Author	Date	Title
Alden, P. et al	2003	Biodiversity Study of Alewife Reservation: Species Habitat and Ecosystems.
Brown, D.	2002	Migrant and Breeding Bird Survey.
Fairburn, P.W	November 15, 2007	Letter to Miriam Weil, Chair, Belmont Conservation Commission regarding wildlife habitat.
Katuska, C.J.	September 22, 2003	Forest Characterization Report: Little River/Little Pond, Belmont/Combridge, MA.
Morimoto, D	May 23, 2003	Site Visit Report/Biological Analysis of Site.
Normandeau Associates, Inc.	2006	The Belmont Uplands Site and Alewife Reservation: An Ecological Overview of Present and Future Status.
Wetlands & Wildlife, Inc.	April 24, 2006	Wetland Resource Evaluation Report.

Many species native to this area require not only the wetlands but also the uplands for successful breeding. Species that need both wetland and upland that have been identified in the Alewife area include three species of mammals, two of reptile, one snake species, 12 species of birds, as well as amphibians. In addition, size and shape of this forest supports interior dwelling species of birds and mammals. The Alewife Biodiversity Study found over 80 species of birds including 45 nesting species and 19 mammals dependent on the area habitat. As Dr. David Morimoto states, "the unique wild nature of this place, with its complex mosaic of habitat types, is not replicated anywhere within the greater Boston area." "The Friends' published assessments of the area in Biodiversity of the Alewife Reservation Area" contain Mammal and bird Surveys of David Brown which include 20 mammal species and over 90 bird species which utilize the area, many for nesting and denning. Rare wilderness species inhabit the densely urban area such as mink, deer and otter.

As demonstrated in the Alewife Master Plan, the Alewife Reservation, with improved access from the Alewife MBTA station and the Minuteman Bike Path as well as the bike path between Blanchard Road and the Alewife MBTA station, could provide a vital link to the existing urban greenway. This greenway connects Little River, Alewife Brook, and Mystic River to Boston Harbor to the east, and to the west, Clay Pit Pond, the McLean "Lone Tree" Meadow, Habitat (operated by the Massachusetts Audubon Society), Belmont's Rock Meadow Conservation Land, and the DCR managed Metropolitan State Open Space. By adding the Silver Maple Forest to the Alewife Reservation, DCR would be permanently extending the current limited corridor to facilitate bird watching, hiking, education and recreation for the large nearby urban/suburban population in Arlington, Cambridge, Medford, Somerville, and Belmont in addition to enhancing the value of the land as wildlife habitat.

The riverine habitat associated with the Alewife Brook has been significantly impacted by urbanization and the associated impervious surfaces. According to MAGIS the overall impervious cover of the watershed is approximately 47% (see Figure 4). Research has shown that total watershed impervious area (IA) is correlated with a number of negative impacts on water resources such as: increased flood peaks and frequency; increased sediment, nutrient, and other pollutant levels; channel erosion; impairments to aquatic biota; and reduced to recharge to groundwater (Center for Watershed Protection, 2003). Typically watersheds with 4-6% IA start to show these impacts, though recent work has found lower % IA threshold values for sensitive species (Wenger et al., 2008). Watersheds exceeding 12% IA often fail to meet aquatic life criteria and narrative standards (Stanfield and Kilgour, 2006).

According to a recent publication by the USGS and the Commonwealth of Massachusetts that examined the relationship between impervious area and the health of fish communities as an indicator of ecosystem health, watersheds with impervious cover as low as 5% show significant ecological impacts. Figure 5 shows the relationship between impervious cover and native fish species (Armstrong et al, 2011).

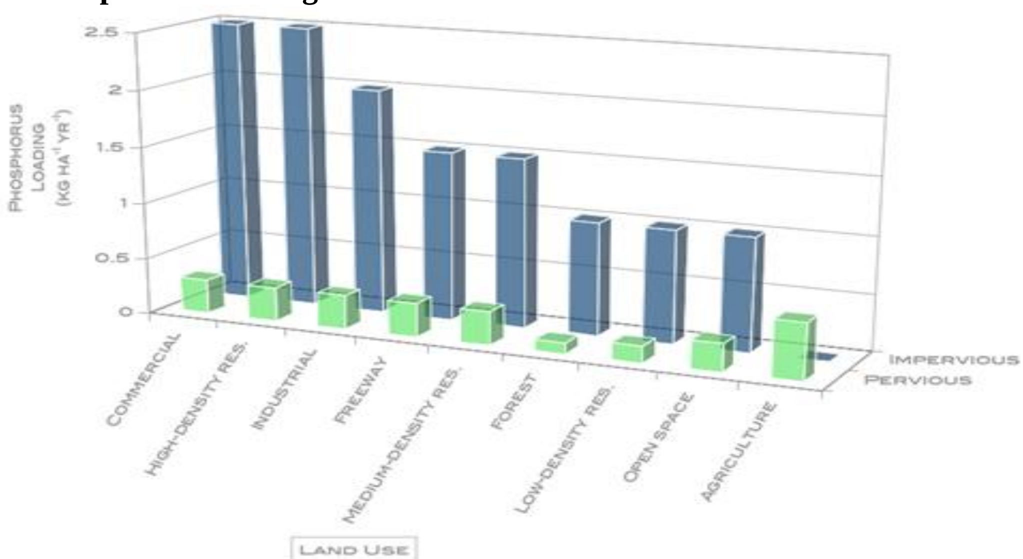
It is important to distinguish between those impervious areas that are directly connected to a drainage pipe (where stormwater runoff flows unimpeded directly to receiving waters) and other impervious areas that are disconnected (therein providing the opportunity for the treatment of the stormwater runoff before it reaches receiving waters). The relative amount of directly connected areas is referred to as the "effective" impervious cover.

5.0 Water Quality

Alewife Brook has been classified as a Class B stream under the Massachusetts Surface Water Regulations. Water sampling results indicate that bacteria commonly exceeds Class B standards. Low dissolved oxygen levels are believed to be a result of excessive phosphorus loading (MWRA, 2004). A broad range of other pollutants (including metals and hydrocarbons) also impact the Brook from untreated stormwater discharges. The Cambridge Open Space Plan describes the Brook as "one of the state's most polluted waterways due to urban runoff and CSOs."

Stormwater runoff carries a broad range of pollutants including nutrients, metals, hydrocarbons and pathogens (including bacteria and viruses) from upland areas into receiving waters. A pollutant loading analysis can identify sources of existing problems and can provide an impact analysis to assess future developments within the watershed. Figure 6 provides an example of how these impacts can be assessed.

Figure 6 – Phosphorus Loading Rates



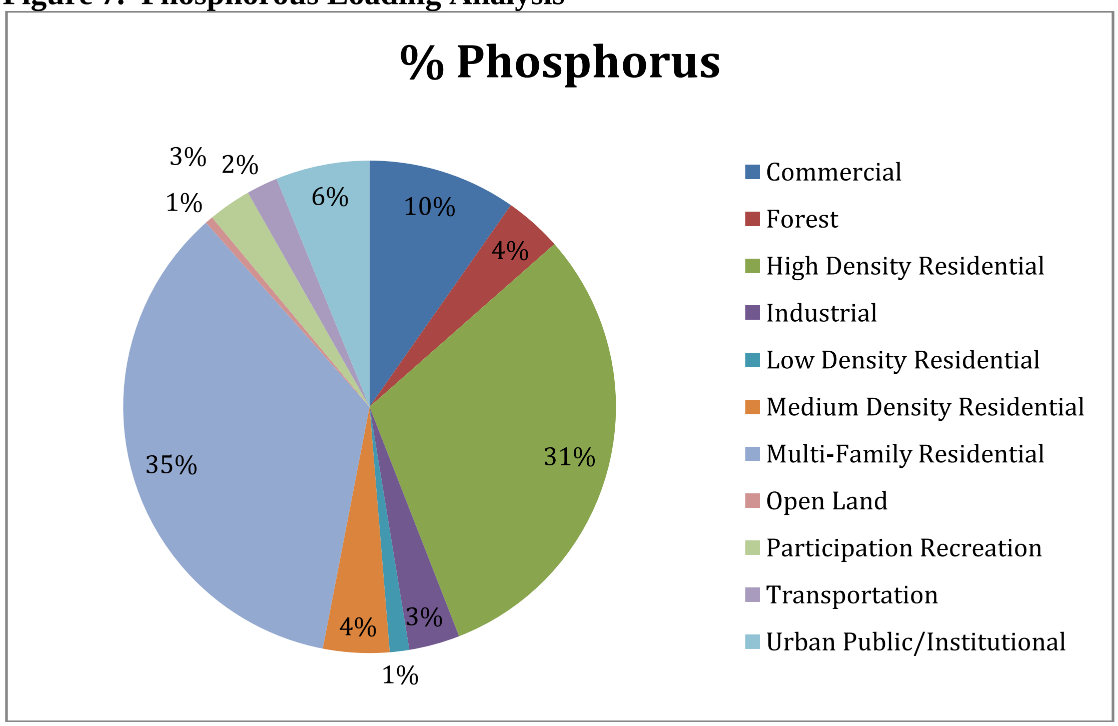
Source: TetraTech 2009

To assess the relative contributions from various land uses HW conducted a phosphorus loading analysis. These loading rates were multiplied times the land use areas within the watershed to develop a phosphorous budget which shows the relative contributions from the various land use categories. The results of this analysis are shown in Table 3 and Figure 7. It suggests that the most significant contributors are phosphorus are multi-family residential and high-density residential land uses. Specific sources from these land uses include lawn fertilizers, pet waste and combined sewer overflows.

Table 3. Phosphorus Loading Analysis

Phosphorus	P KG/HA	P Load	% Phosphorus
Commercial	2.75	398	9.7%
Forest	1.1	155	3.8%
High Density Residential	2.75	1249	30.6%
Industrial	2.25	136	3.3%
Low Density Residential	1.2	52	1.3%
Medium Density Residential	1.75	178	4.4%
Multi-Family Residential	2.75	1446	35.4%
Open Land	1.3	21	0.5%
Participation Recreation	1.3	115	2.8%
Transportation	1.75	84	2.1%
Urban Public/Institutional	2.75	252	6.2%

Figure 7. Phosphorous Loading Analysis



Sources of pathogens within the Alewife Brook watershed include combined sewer overflows (CSO's) and animal waste. CSO problems occur when excessive stormwater volumes enter the combined sewer system, causing overflows of raw sewage. This problem can be reduced by separating wastewater and stormwater flows into separate infrastructure and developing independent treatment solutions. Animal wastes come from both wildlife and domestic animals. Given the relatively low amounts of natural open space habitats, natural wildlife contributions in the watershed can be expected to be relatively low. Domestic pets, primarily dogs, represent a significant source of pathogens. This source is controllable through pet waste educational and management programs.

6.0 Smart Growth and Low Impact Development

The continued development and re-development of the watershed poses both threats and opportunities to the ecological and hydrologic integrity of the Upper Alewife Brook. Preserving the limited remaining open space is critical to habitat values. This can be accomplished through land acquisition, open space/cluster development, and Transfer of Development Rights (TDR). Flood control can be accomplished by balancing the hydrologic budgets at each site using LID techniques such as green roofs, bioretention, constructed wetlands and limited infiltration (equal to the natural recharge rate).

The land use codes in the member communities contain some of these considerations, but need to be amended to fully integrate these provisions. A hydrologic offset system could also provide opportunities for positive impact development using off-site mitigation to restore the natural floodplain hydrology throughout the watershed. The DCR Stormwater Wetland project with the Alewife Reservation is an excellent example of this.

LID is an alternative approach to site planning, design, and building that minimizes impacts to the landscape and preserves the natural hydrologic cycle. LID is accomplished as a two step process:

- Better site planning; and
- Implementation of best management practices (BMPs).

This approach results in reduced impervious surfaces, smaller lawns and more natural landscaping. Therefore it is commonly less costly to construct, requires less maintenance and is more attractive, which enhances real estate values.

LID site planning begins with an approach first publicized by the planner and landscape architect Ian McHarg which identifies critical site features such as wetlands, flood plains and permeable soils that should be set identified and protected. After the critical site features are identified a thoughtful site plan can then be developed that protects important natural features.

Within the delineated building envelopes, a broad range of design techniques or best management practices (BMPs), such as green roofs, shared driveways, permeable pavers and bioretention systems can be used to reduce the level of impervious cover and improve the quantity and quality of stormwater drainage (see Figure 8). Through these techniques, natural drainage pathways are conserved, critical natural features are preserved, and the overall impact from development is significantly reduced.

LID seeks to balance the hydrologic budget by matching pre-and post development conditions for both surface water runoff rates (to avoid flooding) and groundwater recharge rates (to contain existing water table elevations and baseflow conditions in downgradient wetlands, streams and ponds.

7.0 References

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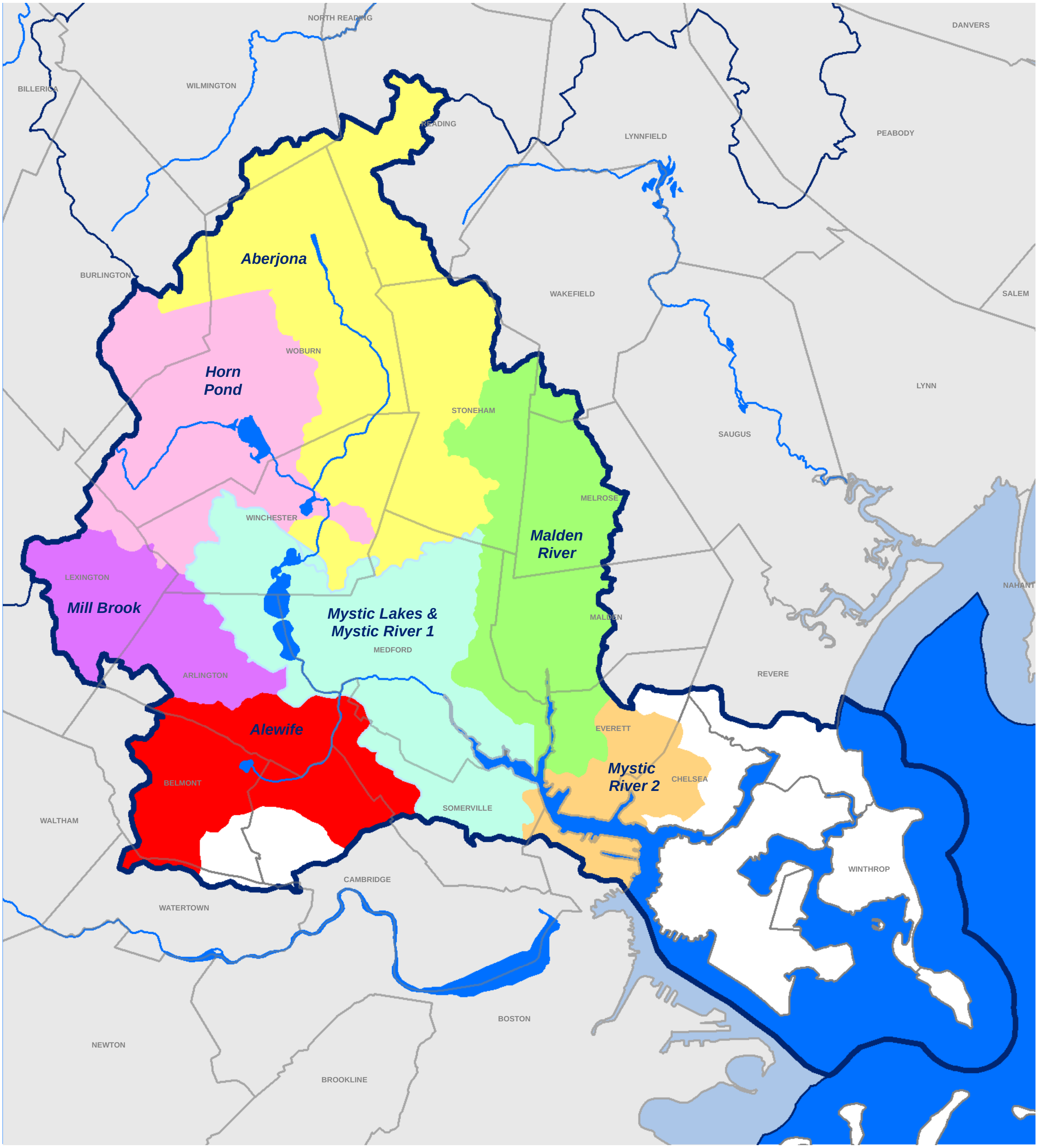
FIGURES



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Legend

- Mystic River Watershed
- Watershed Boundaries
- Town Boundaries

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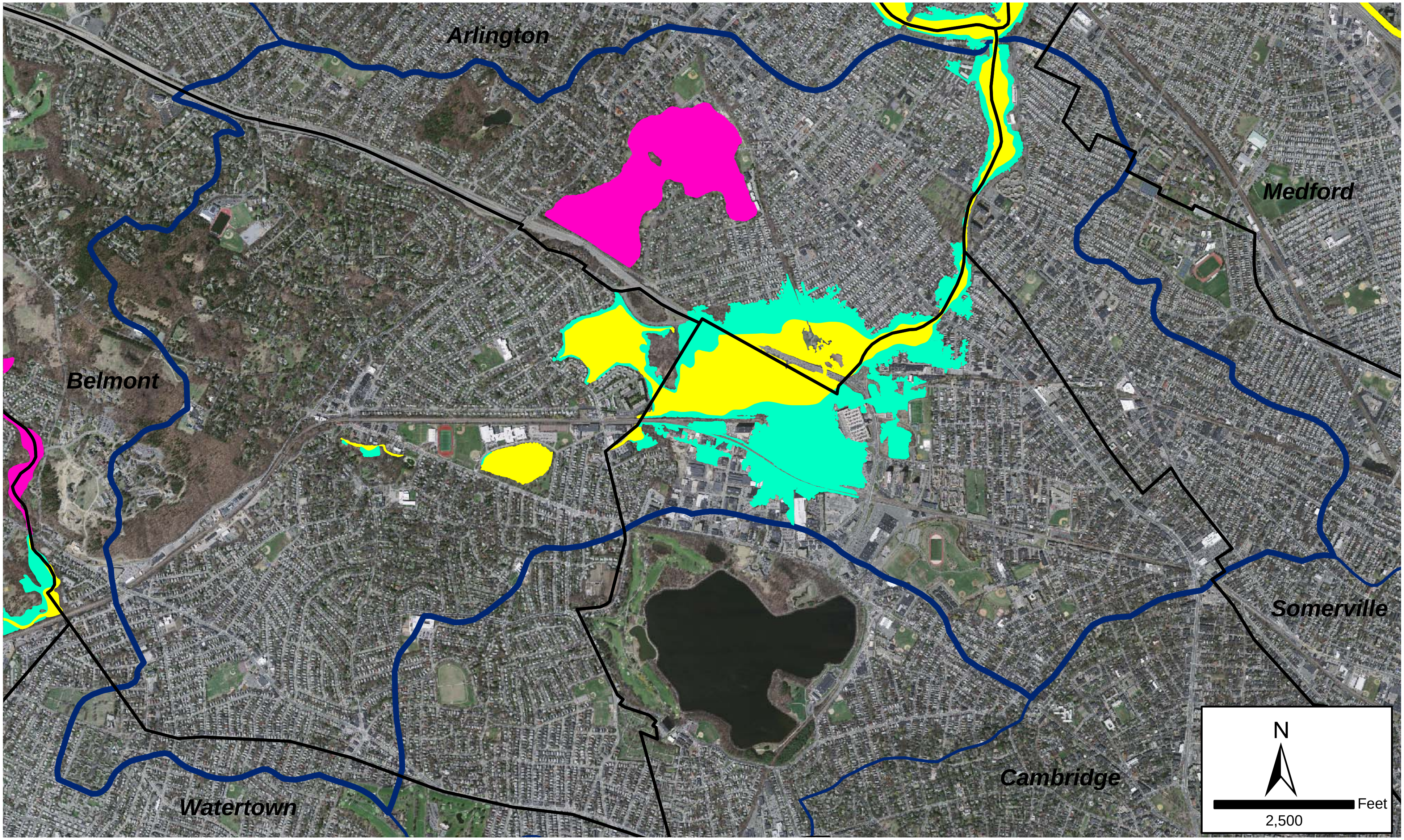
Mystic River Watershed and Subbasins

Date: 1/25/2012

Figure 1



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Legend

- Alewife Subbasin
- Watershed Boundaries
- Town Boundaries

FEMA National Flood Hazard Layer

- A - 100 yr No BFE
- AE - 100 yr BFE
- AE - Floodway

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FEMA National Flood Hazard Layer Alewife Subbasin

Date: 2/13/2012 Figure 2

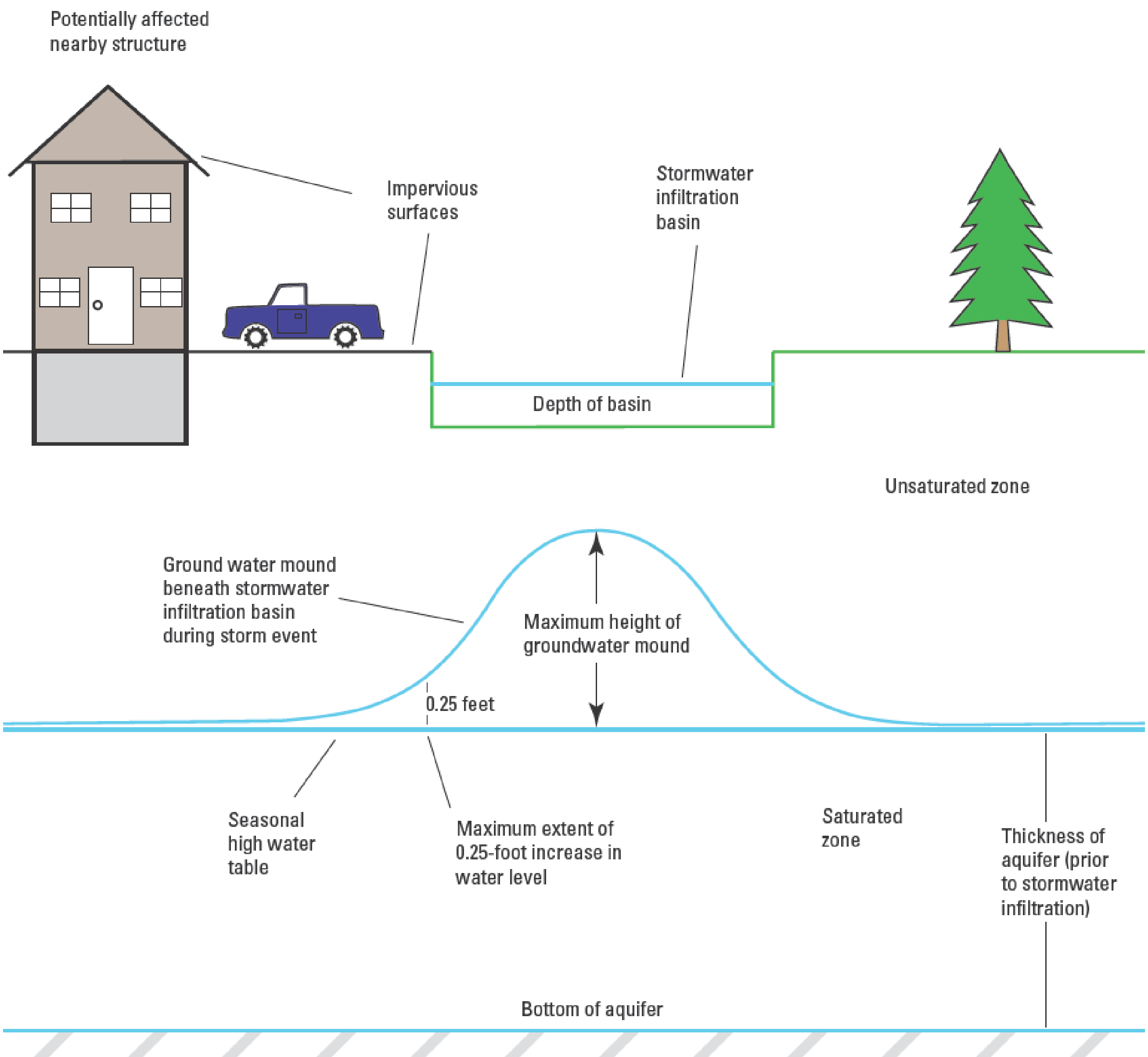

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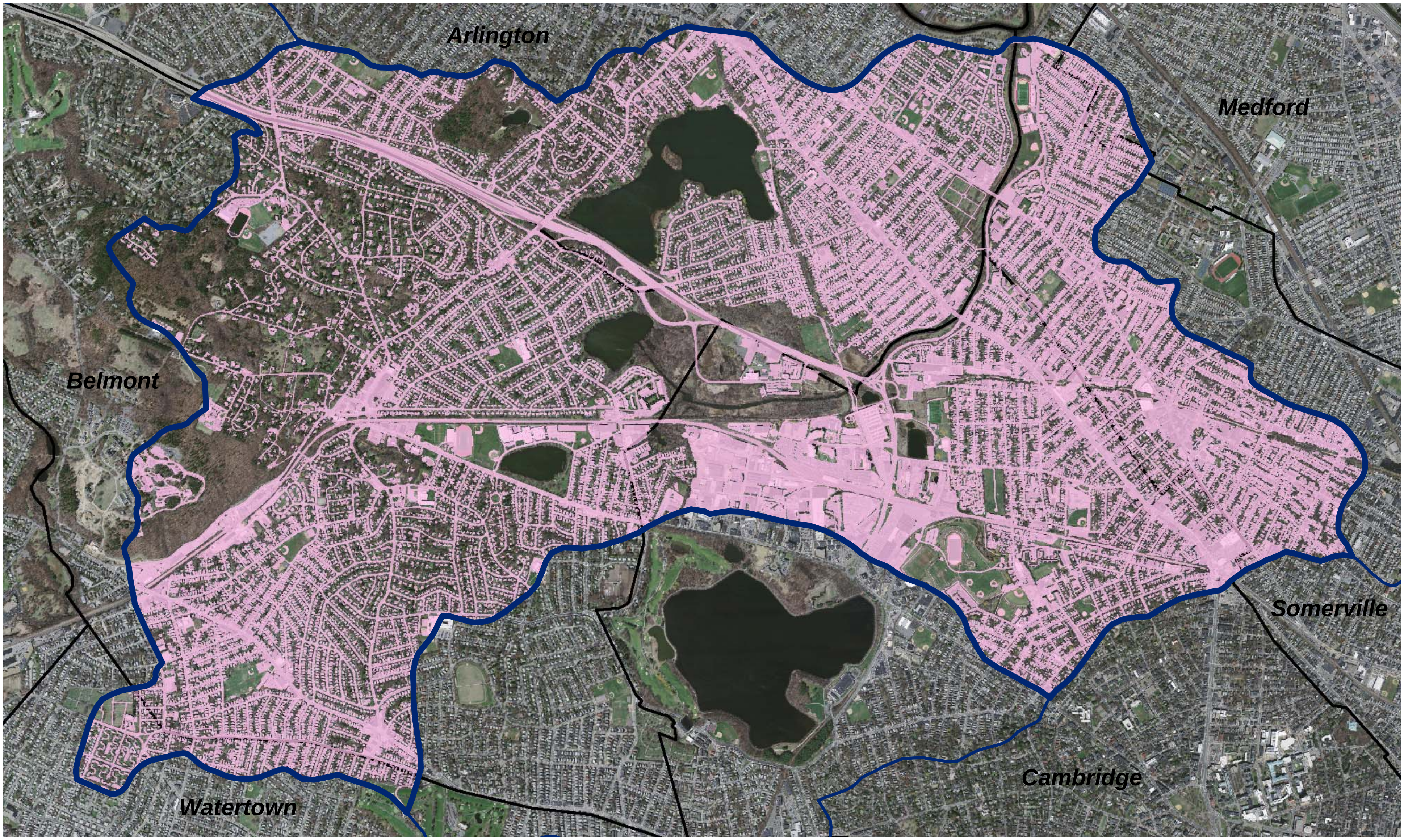
Figure 3



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Legend

- Alewife Subbasin
- Watershed Boundaries
- Town Boundaries
- Impervious Cover

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Feet
2,500

Horsley Witten Group
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Impervious Cover
Alewife Subbasin

Date: 1/25/2012 Figure 4

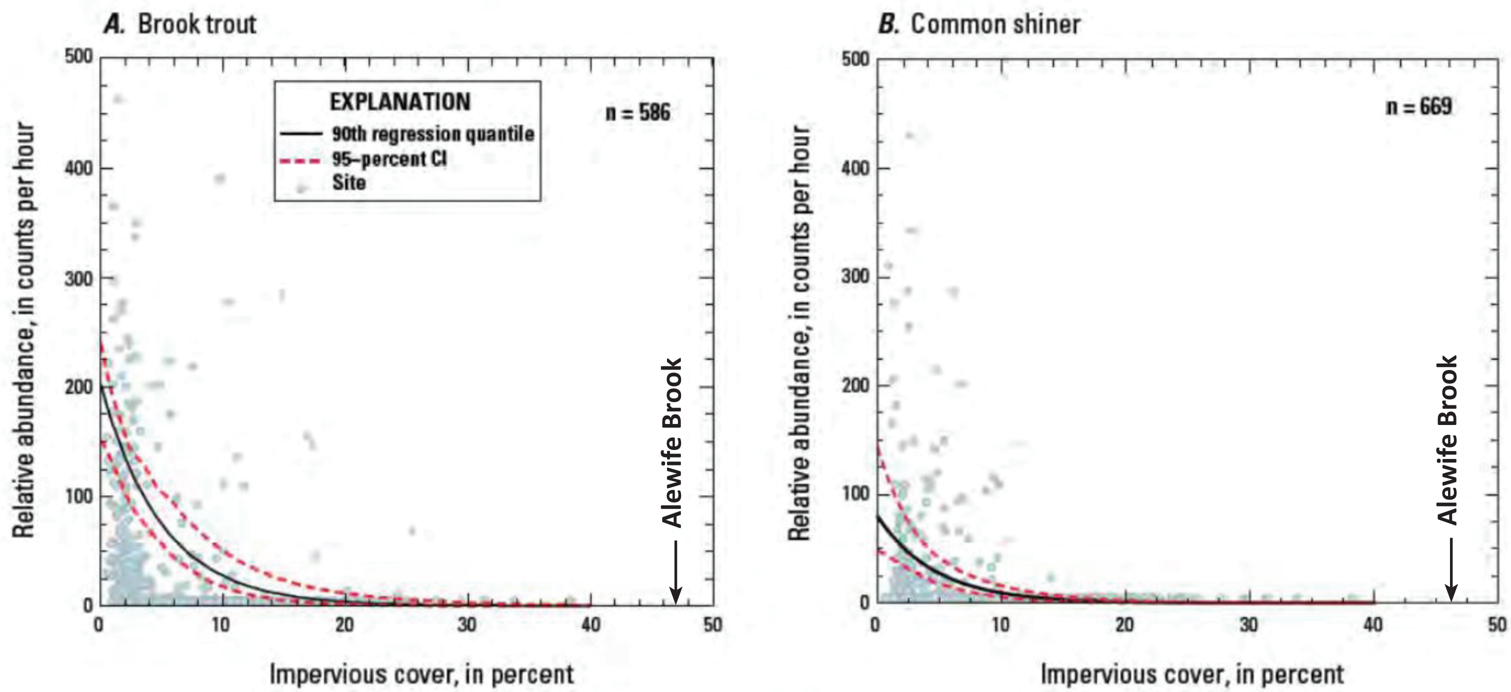

Figure 5 – Quantile regression relations between relative abundance of A, brook trout and B, common shiner and percent impervious cover for the contributing areas to selected fish-sampling sites on Massachusetts streams. CI, confidence interval; n, number of sites. Fish samples were collected from 1998 to 2008.

Source: Armstrong, D.S., Richards, T.A., and Levin, S.B., 2011, Factors influencing riverine fish assemblages in Massachusetts: U.S. Geological Survey Scientific-Investigations Report 2011–5193, 58p. (Also available at http://pubs.usgs.gov/sir/2011/5193.)

Figure 8: Low-Impact Development Stormwater BMPs

Stormwater Bioretention

Low-Impact Roadways

Pervious Pavement

Green Roofs

Stormwater Planters