Introduction

The paper is designed to analyze nutrient condition of the Whitman's Pond, which is located in Weymouth, MA. The Whitman's Pond is served as a backup water supply for residents of Weymouth. According to some local news reports, the pond has been suffering the problem of eutrophication for some time, and thus adding nitrogen and phosphorus in the watershed could be harmful to the water body. The research hypothesis is that superfluous nutrients could flow from surrounding urban land into watershed, and make water not safe for drinking. The analysis aims to examine water quality of the Whitman's Pond and to provide appropriate suggestions to help address problem.

Introduction of the Watershed

The Whitman's Pond watershed is mainly situated in Weymouth, spreading into Weir River Basin and Coastal Drainage Area, as well the Massachusetts Division of water Pollution Control's Boston Harbor Drainage Area. The watershed encompasses an area of 8850.62 acres, with approximately 75 percent located in Weymouth.

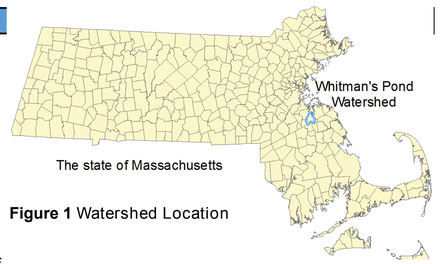


Figure 1 Watershed Location

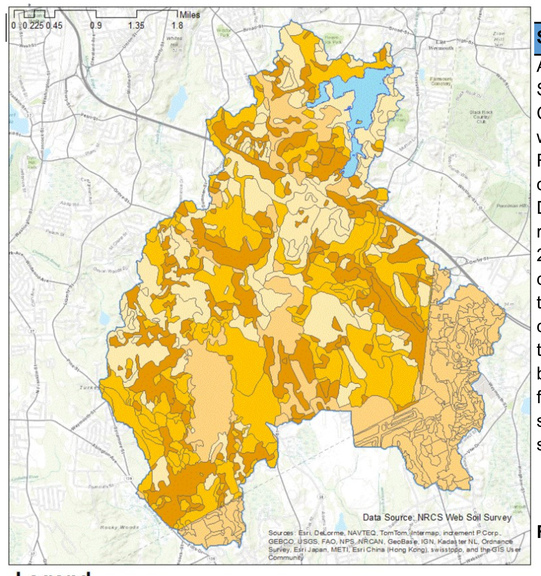
The Whitman's pond has a long history of fighting against aquatic macrophytes, which tend to cover much of the pond surface during summer. Dense aquatic vegetation may clog pumping facility in summer and also hamper public recreational activities including swimming and boating. Sporadic and partial treatment activities have been undertaken since 1976, but these measures had temporarily alleviated the problem rather than achieving long-term success.

Hydrologic Budget

The Whitman's watershed area measures 8850.62acres. Whitman's pond encompasses an area of 192.56 acres, about 2.2 percent of the total watershed. Using the average yearly precipitation for the state of Massachusetts, which is about 46 in/yr, the total amount of precipitation received in the Whitman's pond watershed is calculated to be 1477285376.99ft3/yr and the amount directly goes into the pond is 32025054.12 ft3/yr. The evaporation across the whole watershed is approximately 735982510.74 ft3/yr according to 23 in/yr evaporation rate in the watershed. This hydrological budget assumes that half of this precipitation is lost to evapotranspiration. According to the total precipitation and evaporation amount and direct recharge, the total runoff is 709277812.13 ft3/yr.

Table 1. Hydrologic Budget

Hydrologic Feature	Amount
Total Precipitation	1477285376.99ft3/yr
Precipitation directly into the pond	32025054.12 ft3/yr
Total Evaporation	735982510.74 ft3/yr
Total Runoff	709277812.13 ft3/yr



Soil Analysis

According to the NRCS Web Soil Survey GIS data, A, B, C and D types of soils of the watershed are estimated. Relative recharge potential declines from soil type A to D. After calculation, the total recharge from soil is 243752194.1452ft3/yr. Because total runoff of the watershed equals to soil recharge plus soil discharge, the total discharge (Q) would be about 465525617.9848 ft3/yr (detail calculation is shown in table 2, figure 2 shows the soil distribution).

Figure 2 Soil Types

Table 2. Estimated Recharge Rates by Soil Type

Soil Type	Percent of total watershed area	Area (ft2)	Recharge Rate (inches/year)	Estimated Recharge(ft3/yr)
A Soils	12.0	46263761.6412	18	69395642.46
B Soils	28.3	109105371.2038	12	109105371.2038
C Soils	22.3	85973490.3832	6	42986745.1916
D Soils	23.1	89057741.1593	3	22264435.2898
Urban Land		3778207200.698		0
Total Recharge	243752194.1452			

Land Use Analysis

Historically, the majority of land use is forestry land, which covered the 48.4% of the watershed area in 1985. The forests were concentrated in the southern part of the land and also around the Whitman's Pond. During that time, the second largest land use was urban area, which occupied 36.3% of the watershed area.

While, the current land use situation is that the forestry land is about 28.2% of the total land and the second largest type of land with respect to other land uses. The largest portion of the watershed is urban land uses which is about 49.9%. The statistics shows the expansion of urban land. This indicates more direct drainage from urban land surrounding of the pond into the Whitman's Pond. The urban direct drainage is a main cause of eutrophication.

Figure 3 1985 land use

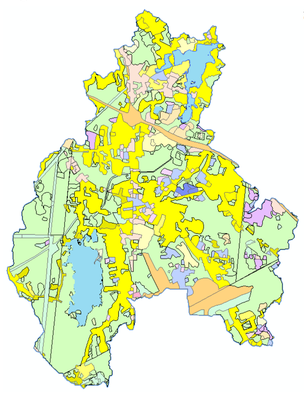
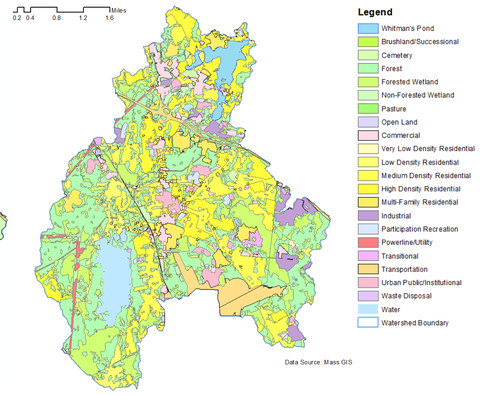


Figure 4 2005 land use



The zoning map is provided by MassGIS. Because zoning is established at the town level, there is no standard district classification. The classification showed in the form is categories assigned to each district in an effort to allow comparison of similar types of allowed uses across town borders. By contrast, zoned urban land is more than twice as large as current urban land. (Table 3 shows the trend of land use changes)

Figure 5 is the result of intersecting current green land data layer and the zoning data layer. It shows in the future about 53.27% current green land will change into residential land and 15.26% green land will transformed into industrial land. (Table 4 shows detail result)

Table 3. Trend of land use changes

Type of land	The year of 1985	Current Land Use	Zoning
Non-urban land	61.0%	44.35%	15.03%
Urban land	36.3%	49.9%	79.97%

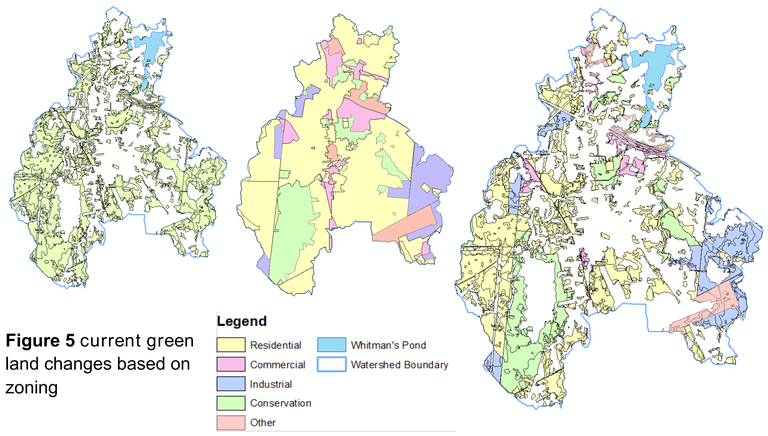


Figure 5 current green land changes based on zoning

Table 4.Current Greenland changes under the influence of Zoning

Zoning Code	Area (acres)	Percent of total land (%)
Residential	11005.689899	53.27
Commercial	2455.342228	11.88
Industrial	3153.524745	15.26
Conservation	3049.583445	14.76
Other	997.705536	4.83
Total	20661.845852	100

Current Total Maximum Daily Loads Analysis

Based on the accounting presented before, the total runoff of Whitman's watershed is 709277812.13 ft3/yr. Based on current land use, for non-urban land which is in total 3925.25 acres, with the nitrogen concentration 0.9mg/L, nitrogen in Whitman's Pond is 0.44mg/L, with phosphorus concentration 0.015mg/L, phosphorus contained is 0.0073mg/L. On the contrary, for urban land which is in total 4417.34, with the nitrogen concentration 10mg/L, the nitrogen is 5.5mg/L, with phosphorus 0.8mg/L concentration, the phosphorus is 0.4377mg/L. From the comparison, contamination from urban runoff is great larger than from atmosphere land. (The nitrogen concentration and phosphorus concentration are from EPA Protocol for Developing Nutrient TMDLs)

Under the condition of a10mg/L Nitrogen safety drinking standard level or Massachusetts, the nitrogen in total is 5.94mg/L is within the MEPA recommended level. The 0.445mg/L phosphorus contained is also under the 0.72mg/L, which is the MEPA requirement level for phosphorus. From annual analysis, the Whitman's Pond meet the safe drinking water standard for MA. The phenomenon of eutrophication may caused by temporary high level of nitrogen and phosphorus. However, zoned urban land is more than twice times of current urban land. The land transformation will result in breaking safety drinking standard. (The result of the calculation is presented in table 4 and table 5.)

Table 5. Estimated contribution of Nitrogen

Source :Land use type	Area (acre)	Nitrogen Concentration (mg/L)	Nitrogen TMDL (kg/year)	Nitrogen contained (mg/L)
Non-urban	3925.25	0.9	8789.4	0.44
Urban	4417.34	10	109903.4	5.5

Table 6 Estimated contribution of Phosphorous

Land use type	Area (acre)	Phosphorus Concentration (mg/L)	Phosphorus TMDL (kg/year)	Phosphorus contained(mg/L)
Non-urban	3925.25	0.015	146.5	0.0073
Urban	4417.34	0.8	8792.3	0.4377

Watershed Management Options:

1.Zoning and Land Use Planning: Current zoning ignores the potential harm done by sprawling urban land on watershed health. To protect the health of watershed, zoning rules should include more detailed regulation specifications concerning watershed protection. For example, watershed zoning should be in use. Under watershed zoning, water-dependent use will work as a navigator to better protect water body and constrain urban land sprawl. Moreover, mixed land use is a good measure to improve land use value and reduce urban land expansion. Under this scenario, the idea of "transfer of development rights"(TDR) could be introduced. The Weymouth town planning department could set up a development rights transfer parcel plan. Within different land parcels, land owners can separate their rights to develop land and to increase land use density.

2.Site Planning: One reason that urban land could be conterminous is due to impervious land surface in urban area. Urban runoff carries high concentrate of nitrogen and phosphorus flowing into water body without being cleaned up by soils. Reducing some impervious cover will be helpful. The small scale planning enables related soils, potential land uses, locations in watershed, and the impacts of the proposed activities considered in urban planning. More detailed consideration will be helpful to limit to appropriate size and location impervious covers such as driveway surface.

3.Public Education: Public education for watershed protection at Weymouth town level would be useful, because the 75% of the watershed area is located in Weymouth. Moreover, Whitman's Pond serves as a secondary drinking water supply resource for residents at Weymouth. To raise public awareness could involve several different approaches, such as distributing newsletters, facilitating journalist reports, increasing press coverage, conducting workshops, establishing voluntary committees, and preparing brochures on water protection.

Reference: U.S. Environmental Protection Agency. 1999. Protocol for Developing Nutrient TMDLs. *EPA 841-B-99-007. Office of Water (4503F), United States Envi-ronmental Protection Agency, Washington D.C.* 135 pp.

Mass.Gov. Energy and Environmental Affairs. 2012 Standards & Guidelines for Contaminants in Massachusetts Drinking Water. Massachusetts Depart-ment of Conservation and Recreation Lakes and Ponds Program. 2005. The Massachusetts Land and Pond Guide-Protection through Education. *Massa-chusetts Department of Conservation and Recreation Lakes and Ponds Program, Massachusetts, 2005*

U.S. Environmental Protection Agency. Local Government Workshop: Tools for Water Resource Protection.

Thomas C. Mc Mahon, Lenore F. Valutkevich, Richard S. McVOY, and Philip W. Mallard, 1983. Whitman's Pond Diagnostic Study April 1980-March 1981. *Massachusetts Department of Environmental Quality Engineering Division of Water Pollution Control, 1983.*