2008

Final Report: Appendix A. Water Balance Analysis Assumptions

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Appendix A - Water Balance Model Assumptions

· Private wastewater flows were estimated for all areas determined not to be within public sewer system service areas.

· Areas serviced by private drinking water withdrawals were estimated for those areas determined not to be within public drinking water service areas.

· Private septic discharge volumes and private drinking water withdrawal volumes were calculated using the MacConnell Land Use data 21-category classification system provided by MassGIS land use data layer (1999) and unit area flow assumptions based on land use.

· Those MacConnell land uses that are assumed to contribute a private septic discharge volume and private water well withdrawal in the Taunton watershed include:

Land Use code	Abbrev.	Category	Definition
7*	RP	Participation Recreation	Golf; tennis; Playgrounds; skiing
10	R0	Residential	Multi-family
11	R1	Residential	Smaller than 1/4 acre lots
12	R2	Residential	1/4 - 1/2 acre lots
13	R3	Residential	Larger than 1/2 acre lots
15	UC	Commercial	General urban; shopping center
16	UI	Industrial	Light & heavy industry

** Because golf is the dominant land use in this category, a wastewater flow was estimated for golf land use and applied across the entire land use category.*

· The following land uses were assumed to have no private septic discharge or private well withdrawal volumes:

Land Use code	Abbrev.	Category	Definition
1	AC	Cropland	Intensive agriculture
2	AP	Pasture	Extensive agriculture
3	F	Forest	Forest
4	FW	Wetland	Nonforested freshwater wetland
5	M	Mining	Sand; gravel & rock
6	O	Open Land	Abandoned agriculture; power lines; areas of no vegetation
8*	RS	Spectator Recreation	Stadiums; racetracks; Fairgrounds; drive-ins
9*	RW	Water Based Recreation	Beaches; marinas; Swimming pools
14	SW	Salt Wetland	Salt marsh
17	UO	Urban Open	Parks; cemeteries; public & institutional greenspace; also vacant undeveloped land
18	UT	Transportation	Airports; docks; divided highway; freight; storage; railroads
19	UW	Waste Disposal	Landfills; sewage lagoons
20	W	Water	Fresh water; coastal embayment
21	WP	Woody Perennial	Orchard; nursery; cranberry bog

** Although these land uses likely have a wastewater flow associated with them, the flow generated by these land uses in the Taunton watershed was assumed to be negligible because these land uses cover a limited area of the watershed.*

Residential flow volumes:

· Residential private septic discharge volumes were calculated using the following equation:
(Residential Land Use Area) / (Average Lot Size) x (Occupancy Rate) x (Per capita wastewater flow)

· Residential private water well withdrawals were calculated using the following equation:
(Residential Land Use Area) / (Average Lot Size) x (Occupancy Rate) x (Per capita water Use)

· The following assumptions were made for the variables in the above equations:

Description	Value	Source
Average "multi-family" lot size (ac)	0.13	1986. Urban Hydrology for Small Watersheds. Technical Release 55.
Average "smaller than 1/4 acre" lot size (ac)	0.17	1986. Urban Hydrology for Small Watersheds. Technical Release 55.
Average "1/4 - 1/2 acre" lot size (ac)	0.38	0.375 ac.; Average between 1/4 ac. and 1/2 ac.
Average "greater than 1/2 acre" lot size (ac)	1.00	1986. Urban Hydrology for Small Watersheds. Technical Release 55.
Occupancy rate (people/household)	2.6	US Census Bureau. Census 2000 Summary File 1 (SF 1), Table P17. Average Household Size (for Bristol County, Plymouth County, and Norfolk County, MA).
Per capita water use (gpcd)	64	MA Executive Office of Energy and Environmental Affairs. November, 2006. Water Assets Study: Regional Summary Report Taunton River Watershed. Boston, MA. 61 pp. 64 gpcd adjusted from 62 gpcd in report because report author informed us of a statistical error in report.
Per capita wastewater flow (gpcd)	54	MA Executive Office of Energy and Environmental Affairs. November, 2006. Water Assets Study: Regional Summary Report Taunton River Watershed. Boston, MA. 61 pp.

Participation Recreation (Golf) flow volumes:

Assumptions for golf are presented below:

Description	Value	Source
Golf (gpd per acre)	6	-Title 5: 310 CMR 15.203: Golf is categorized as Country Club: Flow for the dining room, snack bar or lunch room = 10 GPD/seat; Flow for the locker room = 20 GPD/seat. -Assume 40 seats and 40 lockers for an average 100-acre, 9-hole golf course (source: best professional judgment) -Golf play is between May and October (184 days) (40*10)+(40*20) = 1200 GPD during 184 days/year. -Total annual flow = 1200GPD *184 days/yr = 220,800 Gallons per Year (or 605 GPD on an annualized basis)

Commercial flow volumes:

· Commercial flow volumes were calculated using Title V design flows (Title 5: 310 CMR 15.203 (3)) multiplied by either an estimated number of gross square footage of space or number of seats, as specified in Title V for different commercial use categories. Commercial land use is divided into office space, retail space and restaurants. The following equations were used to calculate wastewater flows:
Flow for Office Space = (Gross Office Space) x (Wastewater flow per 1000 square feet)
Flow for Retail Space = (Gross Retail Space) x (Wastewater flow per 1000 square feet)
Flow for Restaurant Space = (Number of Seats) x (Wastewater flow per seat)

· The total impervious area within the total commercial land use area was calculated in GIS using the MassGIS Impervious Surface data layer (2007) and the Land Use data layer (1999).

· The estimated building footprint of commercial land use was then estimated as a percentage of the impervious surface, since much of the impervious area is comprised by streets, sidewalks, and parking areas.

· The percentage of total commercial impervious area that is estimated to be building footprint (rooftop) is as follows:

Description	Value	Source
Percentage of commercial space that is composed of rooftop (%)	20	Kappiella, et. al. 2001. Impervious Cover and Land Use in the Chesapeake Bay Watershed. Center for Watershed Protection, Ellicott City, MD

· The total commercial building footprint was then multiplied by the average number of floors per building to determine a total commercial gross square footage using the following assumption:

Description	Value	Source
Average number of floors per commercial/industrial building (floors)	1.5	Qualitative Observation

· The total commercial gross square footage in each subwatershed was divided into three uses, Office, Retail, and Restaurant, according to the following percentages:

Description	Percentage	Source
Office space (%)	50%	US Census Bureau. 2005 County Business Patterns. NAICS. Bristol, MA. Accessed on 4 Feb 2008 at http://censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl
Retail space (%)	40%	
Restaurant space (%)	10%	

· A wastewater flow volume and water well withdrawal volume were calculated for each commercial category (Office, Retail and Restaurant) using the following design flow volumes:

Description	Design Flow (GPD)	Source
Office building (gpd per 1,000 gross sf)	75	Title 5: 310 CMR 15.203 (3)
Retail store (gpd per 1,000 gross sf)	50	Title 5: 310 CMR 15.203 (3)
Restaurant (gpd per seat)	35	Title 5: 310 CMR 15.203 (3)

· Since Restaurant wastewater design flow is based on number of seats, the average number of seats per 1,000 gross sf was calculated:

Description	Value	Source
1,000 gross sf restaurant space (seats)	29	National Restaurant Brokers Listing, February 2008.

· The design flow (gpd) per gross square foot for each commercial subcategory was then calculated:

Description	Value
Office building design flow (gpd per gross sf)	0.075
Retail store design flow (gpd per gross sf)	0.05
Restaurant design flow (gpd per gross sf)	1.015

· The wastewater design flow for each commercial category was multiplied by a factor of 50% to determine a septic discharge volume and by a factor of 60% to determine an estimated water withdrawal volume, based on the following assumptions and calculations:

Description	Value	Source
Indoor water use is approximately 50% of the Title V design flow	50%	Title 5: 310 CMR 15.203 (6)
Water lost via outdoor use is approximately 15% of total use	15%	US Geological Survey. 1982. Chapter 11: National Handbook of Recommended Methods for Water Data Acquisition.
Total drinking water withdrawal volume is 60% of Title V design flow	60%	US Geological Survey. 1982. Chapter 11: National Handbook of Recommended Methods for Water Data Acquisition. Title 5: 310 CMR 15.203 (6)

· Calculations:

Total water use (total water withdrawal volume) = Total indoor water use + Total outdoor water use
Total indoor water use = 85% * Total water use
Total indoor water use = Title V design flow * 50%
Total outdoor water use = 15% * Total water use

Solving for Total water use as a function of Title V design flow:
Total water use = (85% * Total water use) + (15% * Total water use)
Total water use = (Title V design flow * 50%) + (15% * Total water use)
Total water use - (15% * Total water use) = Title V design flow * 50%
Total water use * 85% = Title V design flow * 50%
Total water use = Title V design flow * (50% / 85%)
Total water use = Title V design flow * 60%

Estimated actual flow (septic discharge volume) = Title V design flow * 50%
Total indoor water use = Title V design flow * 50%
Estimated actual wastewater flow = Total indoor water use

Industrial flow volumes:

· All industrial area was assumed to have the same flow per 1000 gross square feet as office space. The water withdrawal volumes and

Calculation of Natural Recharge

· Existing natural recharge was calculated based on the underlying surficial geology within the subwatershed, as well as the impervious cover and wetland areas on the land surface.

· The surficial geological and wetland areas were determined using the MassGIS Surficial Geology (1:250,000) layer (October 1999) and the MassGIS DEP Wetlands (1:12,000) layer (April 2007) .

· Total Impervious Area (TIA) within each surficial geological formation was calculated in GIS using the MassGIS Impervious Surface layer (February 2007).

· Research has shown that the effect of impervious surfaces in preventing recharge is only realized when impervious cover exceeds a certain threshold. Below this threshold, runoff from the impervious cover generally flows over a pervious area and is recharged to the ground. Above this threshold, runoff such as that which flows in a storm drain or roadside gutter generally concentrates and flows to a surface water, and therefore does not recharge into the ground. This threshold is known as the effective impervious area (EIA). The EIA was calculated from the TIA using the following equations (Zarriello and Ries, 2000; Zarriello and Barlow, 2002):

Effectiveness (%) = -22.6 + 1.774 * TIA (%), min = 0%

EIA (%) = Effectiveness (%) * TIA (%) / 100

· The following recharge rates were used for each type of surficial geology:

Description	Recharge Rate	Source
1: sand and gravel deposits (in/yr)	25	Values assigned through water budget model calibration performed in the pilot "undeveloped" watershed, Rattlesnake Brook in Fall River and Freetown.
2: till or bedrock (in/yr)	14	
distinguished from sand and gravel deposits (in/yr)	25	
6: fine-grained deposits (in/yr)	5	
7: floodplain alluvium (in/yr)	5	

The recharge rates for wetlands and EIA were assumed to be zero (0) ; Cranberry bogs were assumed to have a recharge rate of -17 in/yr.

Description	Recharge Rate	Source
Wetlands (in./yr.)	0	USGS, 1992. Geohydrology and Simulated Ground-Water Flow, Plymouth-Carver Aquifer, Southeastern Massachusetts
Cranberry bogs (in./yr.)	-17	USGS, 1992. Geohydrology and Simulated Ground-Water Flow, Plymouth-Carver Aquifer, Southeastern Massachusetts
EIA (in./yr.)	0	Charles River Watershed Association. February 2007. Water Budget Report, Appendix B: Water Budget Methodology. 12 pp.

Calculation of Water Withdrawals from WMA data

· The Water Management Act permits and registrations allow for a maximum annual volume of water to be withdrawn via a given water system. However, the actual volume that is withdrawn in a year may differ signficantly in some cases from this maximum allowable withdrawal. Therefore, we used two methods to calculate the actual withdrawals for the water systems in the Taunton watershed, depending on the available of data. If 2006 Annual Statistical Reports (ASR) were available from DEP for the water system, then it was used to estimate the annual withdrawal. In the absence of a 2006 ASR, a relationship between the total withdrawals reported in the 2006 ASRs and the permitted plus registered withdrawal volumes for other systems in the Taunton watershed was used to estimate the actual withdrawals. This relationship was calculated to be 48% (i.e., total annual withdrawals were an average of 48% of the registered plus permitted volumes for water withdrawals in the Taunton watershed). Out of a total of 278 permitted and/or registered water withdrawals in the watershed, the withdrawal volumes were estimated for 126, including only 7 public water supply wells.