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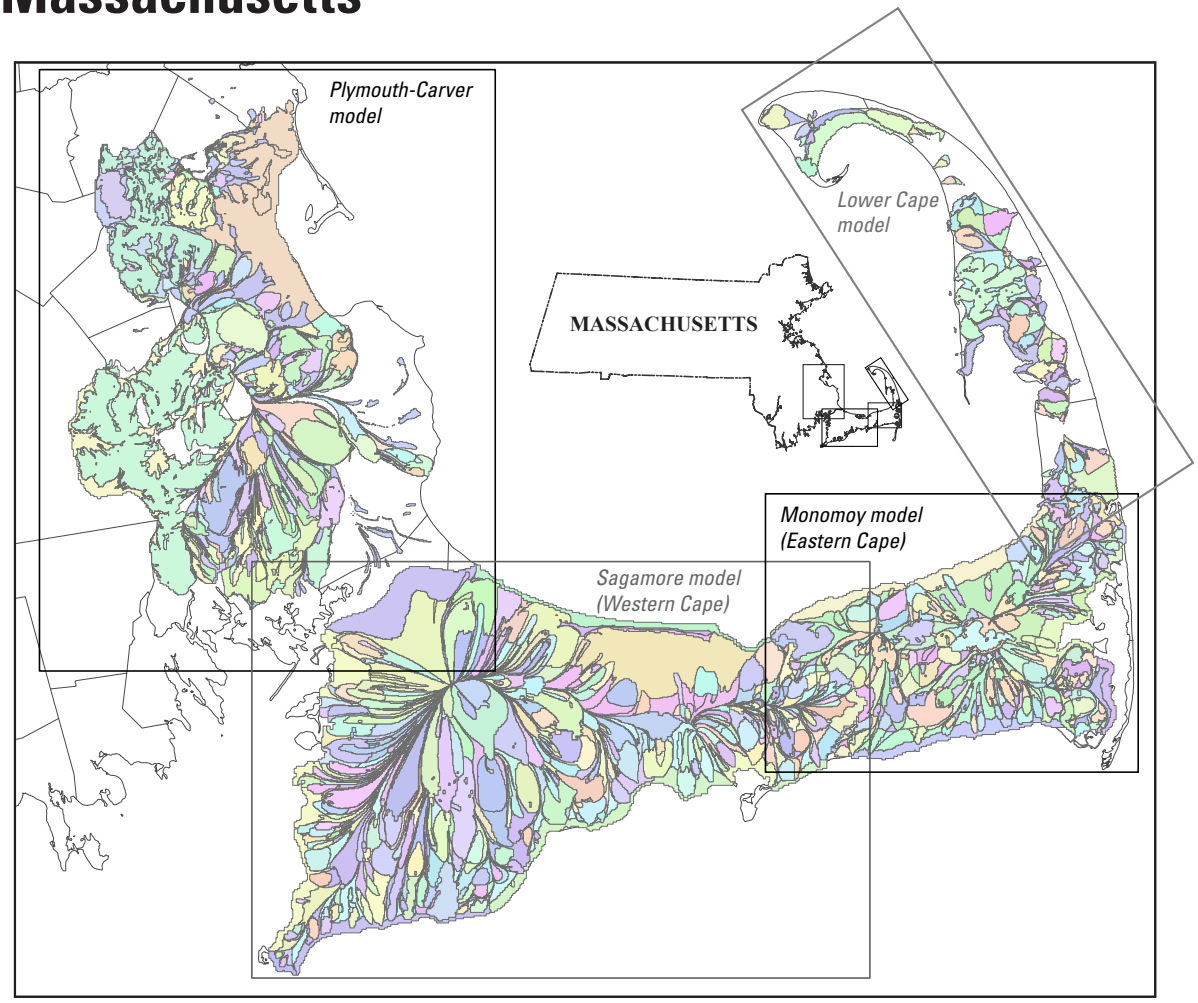
Development of Simulated Groundwater-Contributing Areas to Selected Streams, Ponds, Coastal Water Bodies, and Production Wells in the Plymouth-Carver Region and Cape Cod, Massachusetts



Data Series 1074

U.S. Department of the Interior
U.S. Geological Survey

Cover. Simulated groundwater-contributing areas for the Plymouth-Carver region and Cape Cod in southeastern Massachusetts.

Development of Simulated Groundwater-Contributing Areas to Selected Streams, Ponds, Coastal Water Bodies, and Production Wells in the Plymouth-Carver Region and Cape Cod, Massachusetts

By Carl S. Carlson, John P. Masterson, Donald A. Walter, and Jeffrey R. Barbaro

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Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

GIS	geographic information system
MassDEP	Massachusetts Department of Environmental Protection
MEP	Massachusetts Estuaries Project
SMAST	Massachusetts School for Marine Science and Technology
USGS	U.S. Geological Survey

Development of Simulated Groundwater-Contributing Areas to Selected Streams, Ponds, Coastal Water Bodies, and Production Wells in the Plymouth-Carver Region and Cape Cod, Massachusetts

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Introduction

The U.S. Geological Survey (USGS), in support of the Massachusetts Estuaries Project (MEP), delineated groundwater-contributing areas to various hydrologic receptors including ponds, streams, and coastal water bodies throughout southeastern Massachusetts, including portions of the Plymouth-Carver aquifer system and all of Cape Cod. These contributing areas were delineated over a 6-year period from 2003 through 2008 by using previously published regional USGS groundwater-flow models for the Plymouth-Carver region (Masterson and others, 2009), the Sagamore (western) and Monomoy (eastern) flow lenses of Cape Cod (Walter and Whealan, 2005), and lower Cape Cod (Masterson, 2004). The original USGS groundwater-contributing areas were subsequently revised in some locations by the MEP to remove modeling artifacts or to make the contributing areas more consistent with site-specific hydrologic conditions without further USGS review. This report describes the process used to create the USGS groundwater-contributing areas and provides these model results in their original format in a single, publicly accessible publication.

Background

The coastal waters of southeastern Massachusetts have been degraded by excess nitrogen inputs associated with residential and commercial development in the groundwater-contributing areas that discharge to these waters. The excess nitrogen, originating mainly from anthropogenic sources such as wastewater and fertilizer, causes eutrophication, which results in fish kills, diminished shellfisheries, excessive algal growth, and loss of other marine habitat. Because coastal waters are important economic and recreational resources, protection and restoration of coastal waters are important environmental and economic goals for the region.

In response to concerns over degraded coastal water quality, the Massachusetts Department of Environmental Protection (MassDEP), in collaboration with the School for Marine Science and Technology (SMAST) at the University of Massachusetts-Dartmouth, established the MEP in 2001. The MEP collected data to evaluate water-quality conditions in coastal water bodies and developed models that link nitrogen loading in a watershed to coastal water quality. The MassDEP used the results of these studies to develop total maximum daily loads for a large number of estuaries and embayments and inform wastewater management and nutrient reduction efforts in southeastern Massachusetts.

Between 2003 and 2008, the USGS assisted MassDEP with the MEP investigations by delineating groundwater-contributing areas (also referred to by local stakeholders as groundwater watersheds) to ponds, streams, coastal water bodies, and production wells in the Plymouth-Carver region and on Cape Cod in southeastern Massachusetts (fig. 1).

The USGS provided simulated groundwater-contributing areas to the MEP during a 6-year period (2003–8) that were produced from four groundwater models that were documented in three separate reports. The Cape Cod groundwater-contributing areas were provided to the MEP from 2003 to 2004. The three Cape Cod models are documented in Walter and Whealan (2005) and Masterson (2004). The Plymouth-Carver region groundwater-contributing areas were provided to MEP in 2008; the model used for these delineations is documented in Masterson and others (2009).

The groundwater-contributing areas that were delineated as part of these investigations are integral to the ongoing watershed-based permitting program being implemented by the MassDEP throughout southeastern Massachusetts. Groundwater-contributing areas were delineated for various hydrologic receptors that included coastal water bodies, ponds and streams upgradient of coastal water bodies, and production wells.

The original USGS groundwater-contributing areas were delineated with existing groundwater-flow models and subsequently revised in some locations by the MEP to remove

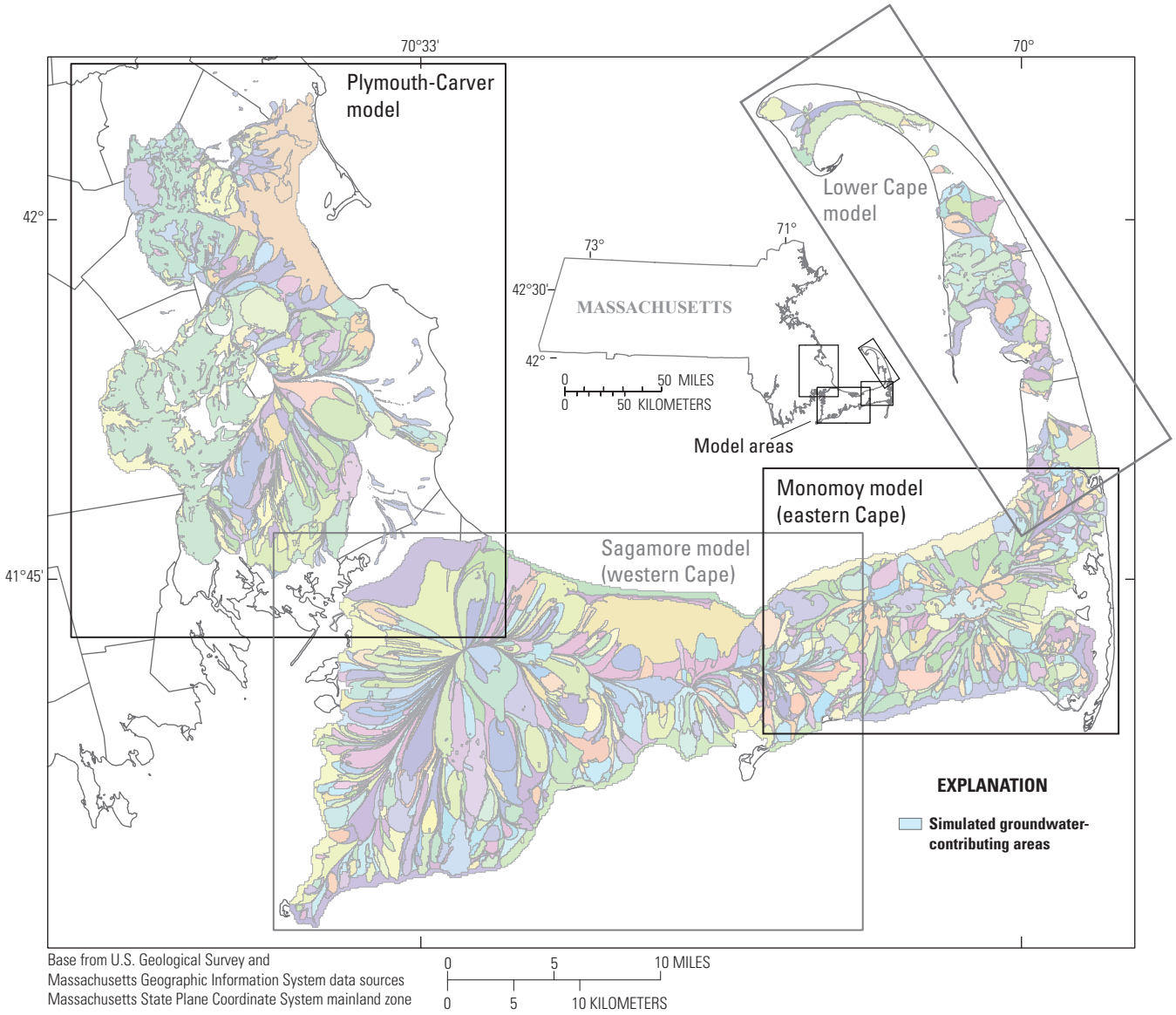

Figure 1. Simulated groundwater-contributing areas for the Plymouth-Carver region and Cape Cod in southeastern Massachusetts.

modeling artifacts—such as portions of the elongated tail of a contributing area upgradient and separate from its main body, which may or may not contribute recharge to that particular receiving water body—or to make the watersheds more consistent with site-specific hydrologic features or streamflow data collected by SMAST. Because the original, unmodified groundwater-contributing areas were not previously published by USGS, individual geographic information system (GIS) shapefiles of the simulated groundwater-contributing areas and an ArcMap project to view the shapefiles are included in the companion data release (Carlson and others, 2017) to this report. Publication of these groundwater-contributing areas, and the methodology used to delineate them, will benefit stakeholders involved in ongoing wastewater management activities in southeastern Massachusetts.

Groundwater-Flow Models

The three-dimensional numerical models used to delineate groundwater-contributing areas to ponds, streams, coastal water bodies, and production wells (fig. 1) for the Plymouth-Carver region, the Sagamore (western) and Monomoy (eastern) flow lenses of Cape Cod, and lower Cape Cod are fully documented in Masterson and others (2009), Walter and Whealan (2005), and Masterson (2004), respectively. These models are based on the USGS finite-difference numerical code MODFLOW (Harbaugh and others, 2000; Harbaugh, 2005). The USGS particle-tracking program MODPATH (Pollock, 1994) was used in conjunction with groundwater heads and flows calculated by MODFLOW to determine the initial locations of water particles that discharge to ponds, streams,

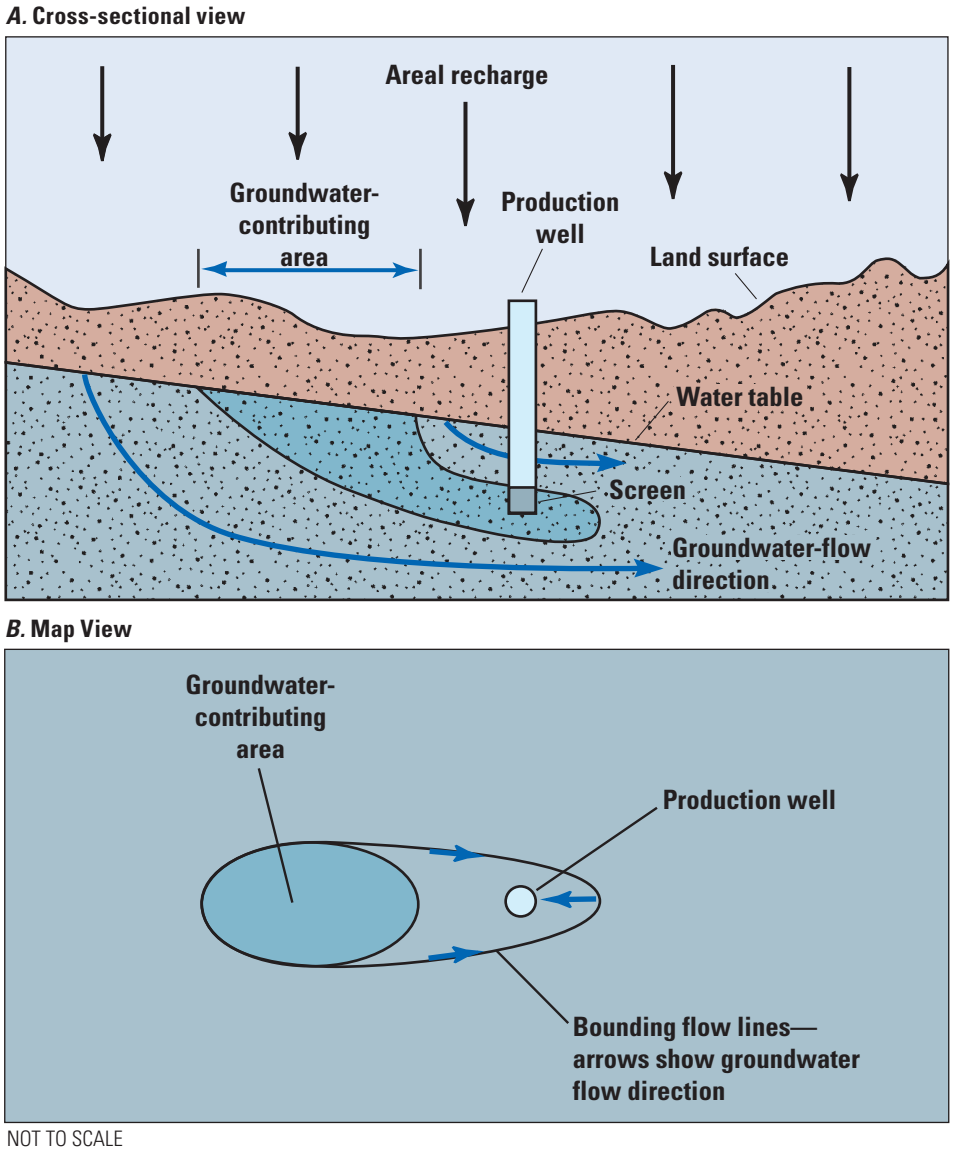

Figure 2. Groundwater-contributing area to a production well in a simplified hypothetical groundwater system showing *A*, cross-sectional view and *B*, map view (modified from Reilly and Pollock, 1993). These areas can appear to be disconnected from the well site in map view; their location and appearance depend on the production (pumping) rate, slope of the water table, and depth of the screen below the water table.

coastal water bodies, and production wells for simulated steady-state conditions.

The original documentation of each of the models provides detailed descriptions of the spatial discretization and layering of the models; hydrologic boundaries; hydraulic properties of the aquifers; hydrologic stresses; simulation of streams, ponds, and water use (withdrawals and wastewater return flows); calibration procedures; and model results and limitations.

Development of Groundwater-Contributing Areas

The concept of a contributing area, within which water enters the groundwater system at the water table as recharge, flows to a production well, and is removed from the aquifer as discharge (fig. 2), is well documented (Reilly and Pollock, 1993). The same concept can be applied to any surface-water body, such as a pond, stream, or coastal water body that is connected hydraulically to the groundwater-flow system and receives groundwater discharge (fig. 3).

In a steady-state system, the amount of water that enters an aquifer through contributing areas at the water table equals the amount of groundwater that discharges from the aquifer to hydrologic receptors, such as production wells, gaining reaches of streams, coastal areas, or ponds. The contributing areas to these receptors typically are elongated in the direction of flow, and the area is proportional to the rate of groundwater discharge to the receptor. The size and shape of the contributing areas to a given receptor can vary on the basis of the position of the receptor relative to the groundwater divide (that is, the boundary between two groundwater-contributing areas represented by a high point in the water table). For receptors on Cape Cod, many of the divides are at the tops

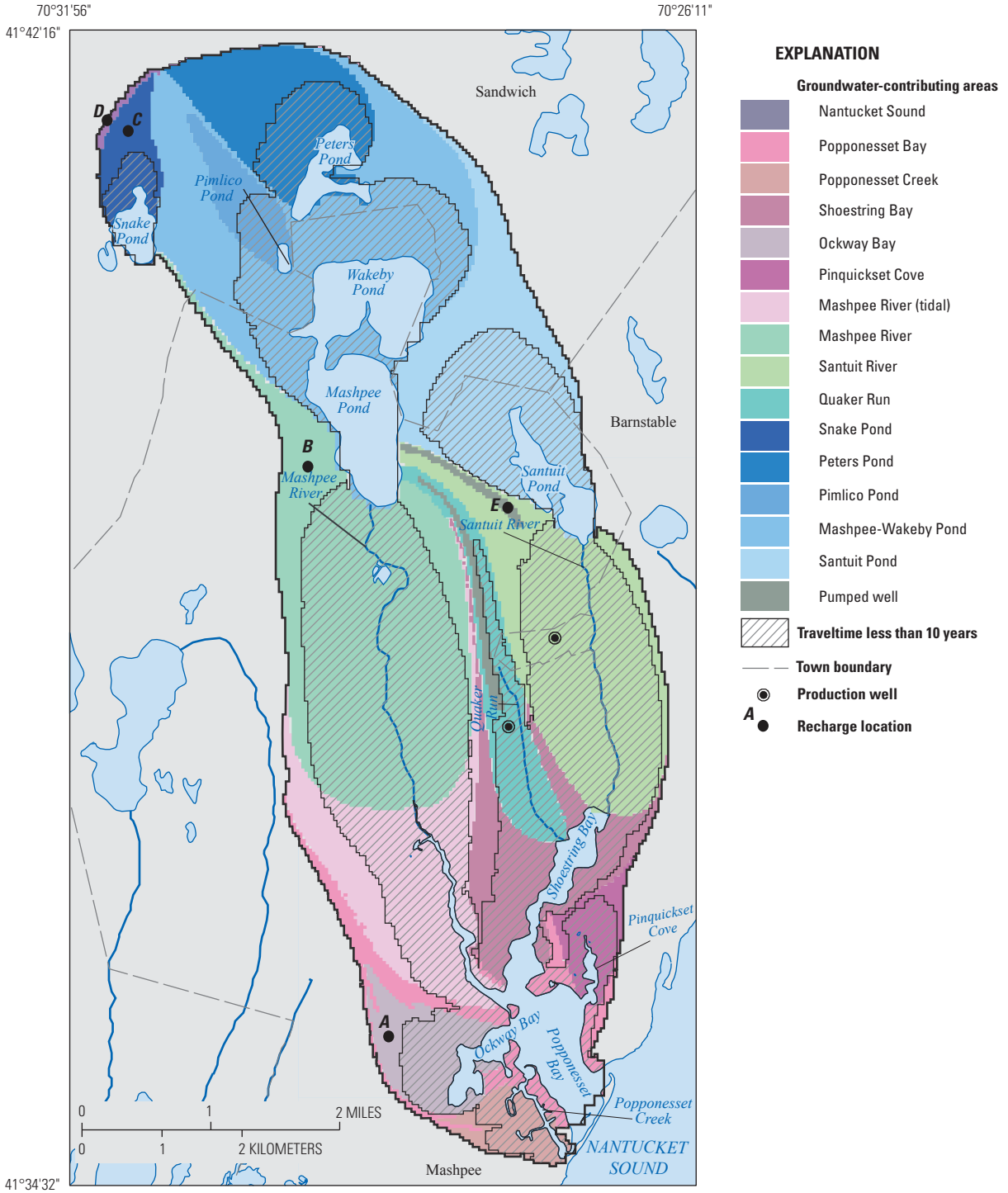

Figure 3. Groundwater-contributing areas to production wells, ponds, and coastal water bodies within the Popponesset Bay watershed (modified from Walter and others, 2004). The coastal water bodies receive most of their freshwater from surface-water inflows. Groundwater recharged near the coast (point A, for example) flows through shallow parts of the aquifer and discharges directly to coastal water bodies. Water recharged in the central part of the watershed (point B) discharges into streams that flow to coastal water bodies. In the upper part of the watershed, recharged water flows through one or more ponds before discharging to streams (point C). Some water recharging the aquifer near the northern edge of the watershed (point D) underflows the ponds and streams and discharges directly to the coast. Production wells remove some water from the watershed (point E).

of groundwater mounds where groundwater flows radially outward toward the coast (for example, fig. 7 in Walter and Whealan, 2005). Because there is a strong downward component of flow near divides, water that recharges near the center of a groundwater mound travels deeper through the aquifer system than water that recharges near the coast. Therefore, for a given receptor, the closer the contributing area at the water table is to the top of a groundwater divide, the greater the vertical flow captured by the receptor because of the three-dimensional nature of the flow system.

The recharge areas for ponds can be delineated in a manner similar to that for streams and coastal areas because the upgradient side of a pond acts as a groundwater discharge zone. Unlike the discharge into streams and coastal areas, however, water that discharges to a pond is not removed from the flow system but, instead, mixes within the pond and either passes through the downgradient side of the pond and reenters the aquifer or moves directly into outflowing streams. The water that reenters the aquifer is then available to move toward and discharge at production wells, streams, or coastal areas downgradient from the ponds.

Because water flows through ponds and reenters the aquifer, any production wells located downgradient from these ponds would receive some part of their total discharge from water that previously moved through ponds. For the purposes of this analysis, the contributing areas for wells are only the areas at the water table that directly contribute water to the wells; however, the influence of ponds on the source of water to production wells also should be considered (see Masterson and others [1998] for a detailed discussion of this concept).

The procedure used in this analysis to delineate groundwater-contributing areas was based on the methodology first documented in Barlow (1997) for delineating contributing areas for production wells on Cape Cod, which was subsequently used by Masterson and others (1998), Masterson and Walter (2000), and Walter and others (2004) for similar analyses. The analyses of Masterson and Walter (2000) and Walter and others (2004) also included the delineation of groundwater-contributing areas to other discharge locations, such as ponds, streams, and coastal water bodies.

The MODPATH particle-tracking model developed by Pollock (1994), which uses the heads and intercell flow rates (the flow rate at the face of each cell in the model) calculated by the MODFLOW model, was used to determine water particle pathlines and groundwater velocities. Starting locations of particles must be specified to initiate a particle-tracking analysis. Particles may be tracked either forward (from the water table to a discharge location) or backward (from a discharge location to the water table), but forward tracking has proven to be more reliable for delineating groundwater-contributing areas (Barlow, 1997). Detailed information on the use of particle tracking for the delineation of groundwater-contributing areas to discharge locations is provided in Masterson and others (1998), Masterson and Walter (2000), and Walter and others (2004).

The steady-state groundwater models for the Plymouth-Carver region, the Sagamore (western) and Monomoy (eastern) flow lenses of Cape Cod, and lower Cape Cod were used to track particles forward in the direction of groundwater flow from the water table to discharge locations. In the MODPATH simulations, a single instantaneous release was specified of a two-dimensional four-by-four array of particles that were placed at the top face in each grid cell (each model grid cell was 400 feet on each side) in the model, and endpoints were recorded for the particles that terminated in a specific zone. "Zone" is a term used by MODPATH that refers to a hydrologic receptor for which a groundwater-contributing area will be delineated. In this analysis, the receptors of interest include streams, ponds, coastal water bodies, and production wells.

Groundwater-Contributing Area Output

The process of delineating groundwater-contributing areas produced a total of 1,155 individual shapefiles for the Plymouth-Carver region and Cape Cod model areas (table 1), which are included in Carlson and others (2017). The three main hydrologic receptors for which groundwater-contributing areas were delineated were ponds, streams, and coastal water bodies (estuaries). Additionally, groundwater-contributing areas for production wells were delineated for 88 wells in the Sagamore (western) flow lens model. In this model, each well was assigned a unique zone identification number, which resulted in 88 separate groundwater-contributing area shapefiles, one for each well. However, in the Plymouth-Carver region and Monomoy (eastern) Cape Cod models, all of the wells in the respective model area were assigned the same zone identification number. This resulted in one shapefile containing the groundwater-contributing areas for all of the wells in the model area. For most of the receptors, the groundwater-contributing areas were subdivided into two separate traveltime zones that represented areas where the traveltime from the water table to a given receptor was less than or equal to 10 years (lt10) and where traveltime was greater than 10 years (gt10). This division produced two separate contributing area zones for each receptor that, when combined, represent the entire groundwater-contributing area to that receptor.

Groundwater-contributing areas for the Plymouth-Carver region were grouped into three separate subfolders, one each for the Agawam-Wareham River, Duxbury-Kingston Bay, and Ellisville Harbor watersheds, containing 125, 137, and 9 separate groundwater-contributing areas, respectively (table 1). These groundwater-contributing areas were classified into two receptor types, "estuaries" and "ponds," both with "lt10" and "gt10" divisions, where "lt10" refers to areas where traveltime from the water table to the receptor was less than or equal to 10 years and "gt10" refers to areas where traveltime from the water table to the receptor exceeded 10 years. The "estuaries" type included stream, river, and estuary receptors.

Table 1. Directory structure for simulated groundwater-contributing areas in Carlson and others (2017), Plymouth-Carver Region and Cape Cod, Massachusetts.

[—, indicates no subfolder]

Source groundwater model	Model directory folder[1]	Model directory subfolder[1]	Subfolder of shapefiles by receptor type[1]	Original format[2]	Number of shapefiles
Plymouth-Carver model	PlyCar	PlyCar_Agawam_Wareham_River_watershed	estuaries_gt10	e00	18
			estuaries_lt10	e00	18
			ponds_gt10	e00	44
			ponds_lt10	e00	45
		PlyCar_Duxbury_Kingston_Bay_watershed	estuaries_gt10	e00	13
			estuaries_lt10	e00	13
			ponds_gt10	e00	55
			ponds_lt10	e00	56
		PlyCar_Ellisville_Harbor_watershed	estuaries_gt10	e00	2
			estuaries_lt10	e00	3
			ponds_gt10	e00	2
			ponds_lt10	e00	2
		wells[3]	—	coverage	1
Sagamore model	Sagamore	—	estuaries_gt10	coverage	124
			estuaries_lt10	coverage	124
			ponds	coverage	83
			streams_gt10	coverage	24
			streams_lt10	coverage	24
			wells	coverage	88
Monomoy model	Monomoy	—	estuaries_gt10	coverage	76
			estuaries_lt10	coverage	76
			ponds_gt10	coverage	67
			ponds_lt10	coverage	67
			streams_gt10	coverage	15
			streams_lt10	coverage	15
			wells[3]	coverage	1
Lower Cape model	LowerCape	—	estuaries_gt10	coverage	35
			estuaries_lt10	coverage	36
			ponds	coverage	28
Total					1,155

[1]Refers to associated directory structure for resulting shapefiles published in Carlson and others (2017). Subfolder of shapefiles by receptor type contains: estuaries, ponds, and streams; if present, "gt10" refers to areas where traveltime from the water table to the receptor exceeded 10 years; if present, "lt10" refers to areas where traveltime from the water table to the receptor was less than or equal to 10 years; gt10 and lt10 areas when combined represent the entire groundwater-contributing area to the receptor.

[2]e00, ArcInfo interchange file; coverage, ArcInfo coverage.

[3]All combined.

Groundwater-contributing areas for the Cape Cod model areas were not grouped into subfolders by watershed (table 1). There are a total of 379 contributing areas in the Sagamore model area, 316 in the Monomoy model area, and 99 in the lower Cape Cod model area. The Sagamore model had both lt10 and gt10 divisions for groundwater-contributing areas for estuaries and streams, whereas ponds within the Sagamore model were not subdivided into two separate traveltime portions. The Monomoy model had both lt10 and gt10 divisions for estuaries, streams, and ponds. Also, groundwater-contributing areas in the lower Cape Cod model were only delineated for estuaries and ponds, with lt10 and gt10 divisions applied only to the estuaries.

In the Plymouth-Carver region and Cape Cod model areas, 25 receptors have no associated groundwater-contributing areas and appear as shapefiles with empty attribute tables. These receptors as represented in the models receive little or no simulated groundwater discharge and, therefore, receive no discharging particles. Particles entering the water table adjacent to these receptors instead discharge into nearby larger receptors and are part of those simulated groundwater-contributing areas.

Appendix 1 provides an overview of the conversion process from the original electronic format files to the shapefiles in Carlson and others (2017).

Limitations

Numerical models are useful tools for delineating groundwater-contributing areas in complex, three-dimensional flow systems such as in southeastern Massachusetts and Cape Cod. The groundwater-contributing areas described in this report, which were delineated by using the groundwater models for the Plymouth-Carver region (Masterson and others, 2009), the Sagamore (western) and Monomoy (eastern) flow lenses of Cape Cod (Walter and Whealan, 2005), and lower Cape Cod (Masterson, 2004), are valid only for the specific water use and recharge conditions used in those analyses. If water use and recharge conditions change in the future, the groundwater-contributing areas to ponds, streams, coastal water bodies, and production wells in the Plymouth-Carver region and Cape Cod would need to be reevaluated. Groundwater-contributing areas also are subject to the limitations of simulating groundwater flow at the regional scales as detailed in the original model-documentation reports.

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Appendix 1. Conversion Process from Original Electronic Format Files to Shapefiles

The original, simulated groundwater-contributing areas were in the form of ArcInfo interchange files (.e00) for the Plymouth-Carver region model and ArcInfo coverages for the Cape Cod models. The original electronic format files were converted to current-format shapefiles and organized by model area as outlined in table 1.

Files in their original format were converted to shapefiles by using ArcPy (Price, 2017) in a Jupyter Notebook (Pérez and Granger, 2007) with the programming language Python (https://www.python.org/). Conversion of the groundwater-contributing areas for the Plymouth-Carver region model needed an extra step to first import from the .e00 format to a coverage format through use of the ”ImportFromE00_conversion” feature. Once in coverage format, files from all model areas were converted to shapefiles by using the “FeatureClassToFeatureClass_conversion” feature. Additional unnecessary fields were automatically added during the conversion from .e00, and these were removed. In addition to the existing “AREA” and “PERIMETER” fields in the data table, one new field called “Name” that contained the name of each groundwater-contributing area was added to the data table for each shapefile.

To make the filename for each shapefile as useful as possible, additional information was included, such as the original .e00 or coverage name (for comparison to the files previously supplied), the name of model area, the receptor type and whether or not it was a divided zone for lt10 or gt10, and the name of the groundwater-contributing area (same as that added to the new field “Name”). The original .e00 and coverage name included a code, and the code and receptor name appeared in a lookup table. These original codes and corresponding groundwater-contributing area names are listed in table 1–1. An ArcMap project (USGS_original_contributing_areas_PlyCar_CapeCod_shapefiles.mxd) that contains all of the groundwater-contributing area shapefiles for the Plymouth-Carver region and Cape Cod model areas is included in Carlson and others (2017).

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Table 1–1. Original codes and corresponding names of the groundwater-contributing areas for the groundwater models of the Plymouth-Carver region and Cape Cod, Massachusetts.

[Codes are distinguished by model area and receptor type, followed by a decoded example of an original filename for that model and receptor type]

Code	Description
Plymouth-Carver region, Agawam-Wareham River watershed	
Estuaries[1]	
33	Rose_Brook_above_confluence_with_Wareham
34	Wankinco_upstream_Tihonet_Pond
35	Agawam_River_confluence_with_Wareham
36	Agawam_River_confluence_with_Wareham
37	Agawam_River_confluence_with_Wareham
38	Agawam_River_confluence_with_Wareham
39	Agawam_upstream_Glen_Charlie
40	model_area_west
41	Gibbs_Brook_lower
77	Harlow_Brook
78	Maple_Spring_Brook_upstream_Mill_Pond
79	Frog_Foot_Brook
80	Wankinco_upstream_Harlow_Brook
81	Wankinco_downstream_Park_Mill_Pond
82	Agawam_River_outflow_Mill_Pond
83	Agawam_River_confluence_with_Wareham
84	Wankinco_upstream_Park_Mills
85	Agawam_Halfway_Pond_outlet
Ponds[2]	
142	College_Pond_Plymouth
148	Torrey_Pond_Plymouth
150	Three_Cornered_Pond_Plymouth
153	Halfway_Pond_Plymouth
161	New_Long_Pond_Plymouth
164	Bumps_Pond_Plymouth
167	East_Head_Pond_Carver_Plymouth
169	Barrett_Pond_Carver
173	Reservoir_Pond_Plymouth
176	Fearing_Pond_Plymouth
181	Fawn_Pond_Plymouth
182	New_Grassy_Pond_Plymouth
189	Deer_Pond_Plymouth
190	Golden_Field_Pond_Carver
191	White_Island_Pond_Plymouth_Wareham
192	Abner_Pond_Plymouth
193	Raccoon_Pond_Carver
198	Charge_Pond_Plymouth
201	Unnamed_near_Agawam_River_Plymouth
202	Unnamed_near_Wareham_Street_Carver
204	Unnamed_near_Frogfoot_Brook_Plymouth
205	Fivemile_Pond_Plymouth
206	Unnamed_near_Wareham_Street_Carver
214	Unnamed_near_Wareham_Street_Carver
215	Little_Long_Pond_Plymouth_Wareham
218	Unnamed_near_Hammond_Street_Carver

Code	Description
Plymouth-Carver region, Agawam-Wareham River watershed —*Continued*	
Ponds[2]—*Continued*	
220	Glen_Charlie_Pond_Wareham
223	Unnamed_southeast_of_Little_Long_Pond_Wareham
224	Unnamed_near_Hammond_Street_Carver_Wareham
225	Tihonet_Pond_Wareham
229	Unnamed_near_Charge_Pond_Road_Wareham
232	Bartlett_Pond_Wareham
233	Unnamed_near_Charge_Pond_Road_Wareham
234	Unnamed_near_Charge_Pond_Road_Wareham
235	Unnamed_near_Charge_Pond_Road_Wareham
236	Mosquito_Pond_Wareham
237	Unnamed_near_Charge_Pond_Road_Wareham
239	Unnamed_west_of_Glen_Charlie_Pond_Wareham
241	Unnamed_near_Rose_Brook_Wareham
242	Unnamed_near_Maple_Swamp_Wareham
243	Unnamed_near_Maple_Swamp_Wareham
245	Mill_and_Spectacle_Ponds_Wareham
246	Unnamed_near_Harlow_Brook_Wareham
249	Unnamed_near_Harlow_Brook_Wareham
251	Parker_Mills_Pond_Wareham
Plymouth-Carver region, Duxbury-Kingston Bay watershed	
Estuaries[3]	
13	Duxbury_Kingston_Bay_Proper
48	Eel_River_Lower
49	unnamed_stream
51	unnamed_stream
52	unnamed_stream
53	Jones_River_North
54	Jones_River_Main
56	Island_Pond_Brook
57	unnamed_stream
58	West_Brook
73	Eel_River_West
74	Eel_River_East
75	Town_Brook
Ponds[4]	
005	Unnamed_north_of_Bourne_Wharf_River_Marshfield
010	Unnamed_west_Duxbury_Duxbury
012	North_Hill_Marsh_Duxbury
013	Unnamed_west_Duxbury_Duxbury
016	Upper_Chandler_Pond_Duxbury_Pembroke
017	Unnamed_near_Town_Forest_Pembroke
019	Lower_Chandler_Pond_Duxbury_Pembroke
021	Island_Creek_Duxbury
022	Silver_Lake_Pembroke_Plympton_Kingston

Table 1–1. Original codes and corresponding names of the groundwater-contributing areas for the groundwater models of the Plymouth-Carver region and Cape Cod, Massachusetts.—Continued

[Codes are distinguished by model area and receptor type, followed by a decoded example of an original filename for that model and receptor type]

Code	Description
Plymouth-Carver region, Duxbury-Kingston Bay watershed —*Continued*	
Ponds[4]—*Continued*	
023	Near_Halls_Brook_Duxbury
024	Mill_Pond_Duxbury
026	Reeds_Mill_Pond_Kingston
028	Bracketts_Pond_Kingston
029	Unnamed_near_Winthrop_Street_Kingston
032	Blackwater_Pond_Kingston
033	Unnamed_near_Jones_River_Brook_Plympton
035	Crossman_Pond_Kingston
036	Foundry_Pond_Kingston
037	Soules_Pond_Kingston
039	Russell_Pond_Kingston
040	Unnamed_near_Jones_River_Brook_Kingston
042	Dennetts_Pond_Plympton
043	Smelt_Pond_Kingston
044	Goose_Pond_Kingston
045	Pratt_Pond_Kingston
046	Indian_Pond_Kingston_Plympton
048	Little_Smelt_Pond_Kingston
049	Unnamed_near_Upland_Road_Plympton
050	Muddy_Pond_Kingston
052	Triangle_Pond_Plymouth
054	Little_Muddy_Pond_Plymouth
055	Little_Pond_Plymouth
059	Billington_Sea_Plymouth
061	Lout_Pond_Plymouth
069	Briggs_Reservoir_Plymouth
074	Howland_Pond_Plymouth
076	Unnamed_on_Eel_River_Plymouth
077	Cooks_Pond_Plymouth
080	Little_Big_and_Grassy_West_Ponds_Plymouth
082	Micajah_Pond_Plymouth
084	Forge_Pond_Plymouth
085	Russell_Mill_Pond_Plymouth
087	Great_South_Pond_Plymouth
088	Little_Micajah_Pond_Plymouth
090	Unnamed_southwest_of_Forge_Pond_Plymouth
092	South_Triangle_Pond_Plymouth
093	Spring_Pond_Plymouth
096	Ellis_Pond_Plymouth
098	Unnamed_near_Sandwich_Road_Plymouth
103	Unnamed_near_Valley_Road_Plymouth
106	Island_Pond_Plymouth
107	Powderhorn_Pond_Plymouth
112	Hoyts_Pond_Plymouth
115	Little_Widgeon_Pond_Plymouth
117	Negro_Pond_Plymouth
119	Widgeon_Pond_Plymouth
Plymouth-Carver region, Ellisville Harbor watershed	
Estuaries[5]	
98	Ellisville_Harbor_Bay_Proper
44	Savery_Pd_Stream
45	Cran_Bog_Stream
Ponds[6]	
156	Bloody_Pond_Plymouth
166	Savery_Pond_Plymouth
Sagamore and Monomoy	
Estuaries[7]	
002	Upper_Rock_Harbor_Creek_Orleans
003	Namskaket_Creek_Marsh_Orleans
004	The_Narrows_The_Horseshoe_Chatham
005	Crows_Pond_Chatham
006	Chatham_Port_Ryder_Cove_Frost_Fish_Creek
007	Bassing_Harbor_Chatham
008	Stage_Harbor_Chatham
009	Unnamed_Toms_Neck_Chatham
010	Mill_Pond_Mitchell_River_Chatham
011	Oyster_Pond_River_Chatham
012	Stony_Brook_Marsh_Brewster
013	Upper_Herring_River_Marsh_Harwich
014	Doanes_Creek_Allens_Harbor_Harwich
015	Wychmere_Harbor_Harwich
016	Saquatucket_Harbor_Harwich
017	Mill_Creek_Chatham
018	Cockle_Cove_Creek_Chatham
019	Muddy_Creek_Chatham_Harwich
020	NE_of_Barley_Neck_Orleans
021	Round_Cove_Chatham
022	Black_Flats_Chase_Garden_Creek_Dennis
023	Sesuit_Creek_Sesuit_Harbor_Dennis
024	Quivett_Creek_Dennis
025	North_of_Davis_Beach_Dennis
026	Unnamed_Cove_Dennis
027	Grand_Cove_Dennis
028	Swan_Pond_Yarmouth
029	Woods_Cove_Orleans
030	Rachel_Cove_Orleans
031	Whites_Brook_Dennis_Yarmouth
033	Weir_Creek_Dennis_Yarmouth
034	Mill_Pond_Dennis_Yarmouth
035	Muddy_Creek_Yarmouth
036	Swamp_Cove_Follins_Pond_Dennis_Yarmouth
037	Dinahs_Pond_Dennis

Table 1–1. Original codes and corresponding names of the groundwater-contributing areas for the groundwater models of the Plymouth-Carver region and Cape Cod, Massachusetts.—Continued

[Codes are distinguished by model area and receptor type, followed by a decoded example of an original filename for that model and receptor type]

Code	Description
Sagamore and Monomoy—*Continued*	
Estuaries[7]—*Continued*	
038	Lone_Tree_Bass_Clays_Creeks_Yarmouth
039	Parkers_River_Lewis_Pond_Dennis
040	Seine_Pond_Dennis
041	Ockway_Bay_Anns_Cove_Mashpee
042	Eel_Pond_Bourne_Pocasset
043	Rands_Harbor_Barnstable
044	Fiddlers_Creek_Barnstable
045	Wild_Harbor_River_Barnstable
046	Wild_Harbor_Barnstable
047	Herring_Brook_Falmouth
048	West_Falmouth_Snug_Harbors_Woods_Hole
050	Little_Sippewisset_Marsh_Falmouth
051	Outer_Quisset_Harbor_Falmouth
052	Eel_Pond_Falmouth
053	Little_Harbor_Falmouth
054	Oyster_Pond_Falmouth_Quissett
055	Salt_Pond_Falmouth
056	Falmouth_Inner_Harbor_Falmouth
057	Little_Pond_Falmouth
058	Great_Pond_Falmouth
059	Perch_Pond_Falmouth
060	Green_Pond_Falmouth
061	Bournes_Pond_Falmouth
062	Isreals_Cove_Falmouth
063	Eel_Pond_South_East_Falmouth
064	Quashnet_River_Falmouth
065	Childs_River_Falmouth
066	Sage_Lot_Pond_Mashpee
067	Hamblin_Pond_Mashpee
068	Great_River_Mashpee
069	East_Bay_Barnstable
070	Centerville_River_Long_Beach_Barnstable
071	Scudder_Bay_Bumps_Barnstable
072	Sqaw_Island_Halls_Creek_Barnstable
073	Hyannis_Inner_Harbor_Barnstable
074	Mill_Creek_Barnstable
075	Snows_Creek_Barnstable
076	Jehus_Pond_Mashpee
078	Flat_Pond_Mashpee
079	Mashpee_River_Mashpee
080	Shoestring_Bay_Bryants_Cove_Mashpee
081	Pinquickset_Fullers_Marsh_Barnstable
082	Rushy_Marsh_Pond_Barnstable
083	Popponesset_Bay_Barnstable
084	Marstons_Mills_River_Barnstable
085	North_Cotuit_Bay_Barnstable
086	Eel_River_Barnstable
087	Quanset_Pond_Orleans
088	Paw_Wah_Pond_Orleans
089	The_River_Orleans
090	Namequoit_River_Orleans
091	Areys_Pond_Orleans
092	Mill_Pond_Orleans
093	Kescayo_Gansett_Pond_Orleans
094	Upper_Pocasset_River_Mill_Pond_Onset
095	Hen_Cove_Bourne
096	Red_Brook_Harbor_Bourne
097	Squeteague_Harbor_Bourne_Onset
098	Upper_Back_River_Bourne_Onset_Pocasset
099	Seapit_River_Falmouth
100	Mill_Creek_Dock_Creek_Sandwich
101	Unnamed_Embayment_North_Sandwich
102	Old_Harbor_Springhill_Creeks_Sandwich
103	Scorton_Creek_Sandwich
104	Great_Marshes_Barnstable_Harbor
105	Maraspin_Creek_Barnstable
106	Mill_Short_Wharf_Barnstable
107	Miss_Thachers_Pond_Yarmouth_Dennis
108	Fill_in_default
109	Bass_River_Dennis_Yarmouth
110	Kelleys_Bay_Dennis
111	Taylors_Pond_Chatham
112	Bucks_Creek_Chatham
113	Siders_Pond_Falmouth
115	Flume_Pond_Falmouth
116	Oyster_Pond_Onset_Pocasset
117	Quissett_Beach_Falmouth
119	Dam_Pond_Barnstable
120	Stewarts_Creek_Barnstable
121	Crowell_Pond_Yarmouth
122	Red_River_Chatham
123	Weir_Creek_West_Dennis
124	Dennis_model_boundary_drains
125	Boat_Meadow_Creek_Orleans
126	Nauset_Beach_Orleans
127	West_Bay_Cotuit
128	Cotuit_Bay_Cotuit_Barnstable
129	Poppanosset_Creek_Barnstable
130	Waquoit_Bay_Falmouth
131	Middle_Bass_River_model_boundary
132	Little_Namskaket_Creek_Orleans
133	Oyster_Pond_Chatham
134	Lower_Mitchell_River_Stage_Harbor
135	Little_Mill_Pond_Chatham

Table 1–1. Original codes and corresponding names of the groundwater-contributing areas for the groundwater models of the Plymouth-Carver region and Cape Cod, Massachusetts.—Continued

[Codes are distinguished by model area and receptor type, followed by a decoded example of an original filename for that model and receptor type]

Code	Description
Sagamore and Monomoy—*Continued*	
Estuaries[7]—*Continued*	
136	Upper_Frost_Fish_Creek_Chatham
137	Upper_Muddy_Creek_Chatham_Harwich
138	Sulfur_Springs_Chatham
139	Inner_Coast_Town_Cove_Orleans
140	Coast_Nauset_Bay_Orleans
141	Nauset_Beach_Pleasant_Bay_Harbor
142	Little_River_Falmouth
143	Upper_Seapit_River_Falmouth
144	Red_Brook_Falmouth
145	Coast_Woods_Hole_Passage
146	Coast_Cape_Cod_Canal
147	Prince_Cove_Barnstable_Marstons_Mills
149	Great_Sippewisset_Creek_and_Marsh
150	Upper_Bumps_River
151	Lewis_Bay_Proper
152	Pine_Island_Creek_Yarmouth
153	Lower_Rock_Creek_Orleans
154	COAST_Outer_Town_Cove_Orleans
155	COAST_Little_Pleasant_Bay
156	Inlet_to_Kescayo_Gansett_Pond_Orleans
157	Meetinghouse_Pond_Orleans
158	Frostfish_Cove_The_River_Orleans
159	COAST_Pleasant_Bay_Orleans
160	N_Tar_Kill_Rd_Orleans
161	Upper_Namskaket_Ck_Orleans
162	Upper_Doanes_Creek_Harwich
163	Upper_Sesuit_Creek_Dennis
164	Lower_Swan_Pond_River_Dennis
165	Upper_Swan_Pond_River_Dennis
166	Lower_Herring_River_Harwich
167	Inner_Quisset_Harbor_Falmouth
168	Harbor_Head_Falmouth
169	Inner_Snug_Harbor_Falmouth
170	SW_Falmouth_Harbor_Falmouth
171	Outer_Snug_Harbor_Falmouth
172	Upper_Back_River_Bourne_Onset_Pocasset
173	Lower_Pocasset_River_Bourne_Onset
174	COAST_Pocasset_Harbor_Bourne_Onset
175	COAST_N_Outer_Red_Brook_Harbor_Bourne
176	COAST_S_Outer_Red_Brook_Harbor_Bourne
177	COAST_Megansett_Onset_Falmouth
178	Lower_Quashnet_River_Falmouth
179	Lower_Great_River_Falmouth
180	Lower_Eel_Pond_Falmouth
181	Lower_Marstons_Mills_River_Cotuit
182	Osterville_Grand_Island_Inlet_Cotuit
183	Osterville_GI_NW_West_Bay_Cotuit
184	East_Section_Scorton_Creek_Ext
185	West_Section_Scorton_Creek_Ext
186	South_Bass_River_Model_Boundary
187	West_Kelleys_Bay_Den_Yar_model_boundary
188	Upper_Parkers_River_Yarmouth
189	Lower_Parkers_River_Yarmouth
190	Bound_Marsh_S_of_Matthews_Pond_Yarmouth
191	Allens_Harbor_Arm_Harwich
192	Upper_Snows_Creek_Hyannis
333	Coast_Buzzards_Bay
444	Atlantic_Ocean
555	Coast_Cape_Cod_Bay
666	Coast_Nantucket_Sound
777	Coast_Vineyard_Sound
888	Coast_Pleasant_Bay
900	Bass_River
435	Unnamed_near_Sandwich
436	Unnamed_near_Sandwich
437	Unnamed_near_Great_Marsh_Barnstable
438	Unnamed_near_Great_Marsh_Barnstable
439	Unnamed_near_Great_Marsh_Barnstable
999	Grouped_435_439_Sandwich_Barnstable
Sagamore	
Ponds[8]	
03	Shawme_Lake
04	Upper_Shawme_Lake
05	Hoxie_Pond
06	Nye_Pond
07	Mill_Pond
08	Clay_Pond
10	unnamed_pond
11	Hinckley_Pond
12	Spectacle_Pond
13	Lawrence_Pond
14	Dennis_Pond
16	Greenough_Pond
17	Elishas_Pond
18	Triangle_Pond
19	Garretts_Pond
20	Peters_Pond
21	Flax_Pond
23	Hathaway_Ponds
24	Snake_Pond
26	Israel_Pond
27	Mystic_Middle_Hamblin_Ponds
28	Lamson_Pond
29	Hathaway_Ponds

Table 1–1. Original codes and corresponding names of the groundwater-contributing areas for the groundwater models of the Plymouth-Carver region and Cape Cod, Massachusetts.—Continued

[Codes are distinguished by model area and receptor type, followed by a decoded example of an original filename for that model and receptor type]

Code	Description
Sagamore—*Continued*	
Ponds[8]—*Continued*	
30	Wequaquet_Lake
31	Pimlico_Pond
32	Weeks_Pond
33	Shallow_Pond
34	Mashpee_Wakeby_Pond
35	Mary_Dunn_Pond
36	Red_Brook_Pond
37	Long_Pond
38	Plashes_Pond
39	Long_Pond
40	Shubael_Pond
41	Bassetts_Pond
42	Long_Pond
43	Horse_Pond
44	Muddy_Pond
45	Little_Sandy_Pond
46	Big_Sandy_Pond
47	Jabinettes_Pond
49	Santuit_Pond
50	Long_Pond
51	Osborne_Pond
52	Fawcetts_Pond
53	North_Pond
54	Lovell_Pond
55	West_Pond
56	Cedar_Lake
57	Washburn_Pond
58	Simmons_Pond
59	Moody_Pond
60	Micah_Pond
61	Bog_Pond
62	Joshua_Pond
63	Ashumet_Pond
64	Eagle_Pond
65	Johns_Pond
67	Wings_Pond
68	Deep_Pond
69	Coonamessett_Pond
70	Grassy_Pond
72	Martha_Pond
73	Round_Pond
74	Crooked_Pond
76	Crocker_Pond
77	Shallow_Pond
78	Round_Pond
79	Jenkins_Pond
80	Fresh_Pond
81	unnamed_pond
82	Deer_Pond
84	Flax_Pond
85	Mares_Pond
86	Spectacle_Pond
87	Bourne_Pond
88	Long_Pond
89	Dean_Pond
90	Grews_Pond
91	James_Pond
92	Morse_Pond
93	Shivericks_Pond
Streams[9]	
02	Phlashes_Brook
03	unnamed_stream
04	Coonamessett_River
05	unnamed_stream
06	Childs_River
07	Quashnet_River
08	Red_Brook
09	Mashpee_River
10	Quaker_Run
11	Santuit_River
12	Little_River
13	Marstons_Mills_River
14	outflow_Wequaquet_Lake
15	Hawes_Run
16	unnamed_stream
17	outflow_Upper_Shawme_Lake
18	outflow_Shawme_Lake
19	unnamed_stream
20	unnamed_stream
21	outflow_Hoxie_Pond
22	outflow_Nye_Pond
23	Herring_Brook
24	unnamed_stream
25	Shawme_Lake_outflow
26	Upper_Shawme_Lake_outflow
Monomoy	
Ponds[10]	
02	Cedar_Pond
03	Uncle_Harvey_Pond
04	Crystal_Lake
05	Baker_Pond
06	Flax_Pond
07	Pilgrim_Lake
08	Blueberry_Pond

Table 1–1. Original codes and corresponding names of the groundwater-contributing areas for the groundwater models of the Plymouth-Carver region and Cape Cod, Massachusetts.—Continued

[Codes are distinguished by model area and receptor type, followed by a decoded example of an original filename for that model and receptor type]

Code	Description
	Monomoy—*Continued*
	Ponds[10]—*Continued*
09	Cobbs_Pond
10	Cliff_Pond
11	Higgins_Pond
12	Coles_Pond
13	Schoolhouse_Pond
14	Ruth_Pond
15	Smith_Pond
16	Rafe_Pond
17	Sheep_Pond
18	Sarahs_Pond
19	Twinnings_Pond
20	Griffiths_Pond
21	Lower_Millpond
22	Scargo_Lake
23	Shoal_Pond
24	Uncle_Seths_Pond
25	Canoe_Pond
26	Upper_Millpond
27	Long_Pond
28	Cedar_Pond
29	Seymour_Pond
30	Aunt_Pattys_Pond
31	Walkers_Pond
32	Slough_Pond
33	Simmons_Pond
34	Pine_Pond
35	Bakers_Pond
36	Hinckleys_Pond
37	Hawksnest_Pond
38	Grassy_Pond
39	Flax_Pond
40	Walkers_Pond
41	Elbow_Pond
42	Matthews_Pond
43	Aunt_Edies_Pond
44	unnamed_pond
45	Cornelius_Pond
46	Robbins_Pond
47	Stillwater_Pond
48	Josephs_Pond
49	White_Pond
50	Lovers_Lake
51	Bucks_Pond
52	unnamed_pond
53	unnamed_pond
54	unnamed_pond
55	Mill_Pond
56	Eagle_Pond
57	Goose_Pond
58	Schoolhouse_Pond
59	Emery_Pond
60	Flax_Pond
61	White_Pond
62	Perch_Pond
63	Sand_Pond
64	Reservoir
65	Paddocks_Pond
66	Grass_Pond
67	Fresh_Pond
68	Skinequit_Pond
	Streams[11]
02	Stony_Brook
03	inflow_Swan_Pond
04	unnamed_stream
05	Red_River
06	Herring_River
07	outflow_Robbins_Pond
08	lower_Herring_River
09	outflow_Upper_Millpond
10	outflow_Long_Pond
11	outflow_Seymour_Pond
12	Long_Pond_outflow
13	Hinckleys_Pond_outflow
14	Seymour_Pond_outflow
15	Upper_Millpond_outflow
16	Lower_Millpond_outflow
	Lower Cape Cod
	Estuaries[12]
101	Stream_into_Nauset_Bay_Eastham
201	Nauset_Bay_Eastham
202	Salt_Pond_Eastham
203	Salt_Pond_Bay_Nauset_Marsh_Eastham
204	Town_Cove_Eastham
104	Marsh_adjacent_to_Town_Cove_Eastham
205	Boast_Meadow_Eastham
206	Herring_River_Eastham
207	Herring_Brook_Eastham
208	Sunken_Meadow_Eastham
209	Hatches_Creek_Eastham
210	Silver_Spring_Wellfleet
211	Fresh_Brook_Wellfleet
212	Lieutenant_Island_Marsh_South_Wellfleet
213	Loagy_Bay_Wellfleet
214	Blackfish_Creek_Wellfleet

Table 1–1. Original codes and corresponding names of the groundwater-contributing areas for the groundwater models of the Plymouth-Carver region and Cape Cod, Massachusetts.—Continued

[Codes are distinguished by model area and receptor type, followed by a decoded example of an original filename for that model and receptor type]

Code	Description
Lower Cape Cod—*Continued*	
Estuaries[12]—*Continued*	
215	Drummer_Cove_Wellfleet
216	Wellfleet_Harbor_Wellfleet
217	The_Cove_Wellfleet
218	Pilgrim_Spring_1_Wellfleet
219	Pilgrim_Spring_2_Wellfleet
220	Duck_Creek_Wellfleet
221	Wellfleet_Creek_Wellfleet
222	Herring_River_Wellfleet
223	Mouth_of_Herring_River_Wellfleet
224	Pamet_Harbor_Truro
225	Mill_Creek_Truro
226	Lower_Pamet_River_Truro
227	Upper_Pamet_River_Truro
228	Little_Pamet_River_Truro
229	Great_Swamp_Truro
230	Village_Pond_Truro
231	Pilgrim_Lake_Truro
232	Provincetown_Harbor_Provincetown
233	Great_Marsh_Provincetown
234	Hatches_Harbor_Provincetown
Ponds[13]	
235	Herring_Pond_Eastham
237	Mill_Pond_Eastham
238	Jemina_Pond_Eastham
239	Depot_Pond_Eastham
241	Great_Pond_Eastham
243	Widow_Harding_Eastham
244	Minister_Pond_Eastham
245	Duck_Pond_Wellfleet
247	Great_Pond_Wellfleet
249	Dyer_Pond_Wellfleet
251	Long_Pond_Wellfleet
253	Gull_Pond_Wellfleet
256	Higgins_Pond_Wellfleet
258	Herring_Pond_Wellfleet
259	Willam_Pond_Wellfleet
260	Slough_Pond_Wellfleet
262	Horseleech_Pond_Wellfleet
264	Round_Pond_Wellfleet
265	Great_Pond_Truro
267	Snow_Pond_Truro
268	Ryder_Pond_Truro
269	Great_Pond_Provincetown
270	Bennett_Pond_Provincetown
271	Duck_Pond_Provincetown
272	Clapps_Pond_Provincetown
273	Shank_Painter_Pond_1_Provincetown
274	Shank_Painter_Pond_2_Provincetown
275	Unnamed_Pond_near_Picnic_Area_Provincetown

[1]Example original filename: es83gt10_33; where "es," estuary; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10_," area where traveltime from the water table to the receptor exceeded 10 years; "33," code for receptor name.

[2]Example original filename: 83gt10_142; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10_," area where traveltime from the water table to the receptor exceeded 10 years; "142," code for receptor name.

[3]Example original filename: es83gt10_13; where "es," estuary; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10_," area where traveltime from the water table to the receptor exceeded 10 years; "13," code for receptor name.

[4]Example original filename: 83gt10_5; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10_," area where traveltime from the water table to the receptor exceeded 10 years; "5," code for receptor name, with zero(s) added as placeholder to left of code digit.

[5]Example original filename: es83gt10_44; where "es," estuary; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10_," area where traveltime from the water table to the receptor exceeded 10 years; "44," code for receptor name.

[6]Example original filename: 83gt10_156; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10_," area where traveltime from the water table to the receptor exceeded 10 years; "156," code for receptor name.

[7]Example original filename: em02283gt10e; where "em," estuary; "022," code for receptor name, with zero(s) added as place holder to left of code digit; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10e," area where traveltime from the water table to the receptor exceeded 10 years.

[8]Example original filename: pd0883e; where "pd," pond; "08," code for receptor name, with zero added as place holder to left of code digit; "83e," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001.

[9]Example original filename: st0283gt10e; where "st," stream; "02," code for receptor name, with zero added as place holder to left of code digit; "83," projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; "gt10e," area where traveltime from the water table to the receptor exceeded 10 years.

[10]Example original filename: pd0283gt10e; where “pd,” pond; “02,” code for receptor name, with zero added as place holder to left of code digit; “83,” projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; “gt10e,” area where traveltime from the water table to the receptor exceeded 10 years.

[11]Example original filename: st0283gt10e; where “st,” stream; “02,” code for receptor name, with zero added as place holder to left of code digit; “83,” projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; “gt10e,” area where traveltime from the water table to the receptor exceeded 10 years.

[12]Example original filename: em10483gt10e; where “em,” estuary; “104,” code for receptor name; “83,” projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; “gt10e,” area where traveltime from the water table to the receptor exceeded 10 years.

[13]Example original filename: em24183p2; where “em,” estuary contributing area; “241,” code for receptor name; “83,” projection NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001; “p2,” pond.

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