Comments on the Proposed Solar Installation in the Scarborough Brook Watershed by BWC Scarborough Brook, LLC, on Land presently owned by Cowls Inc.

Prepared for Belchertown Planning Board and Conservation Commission by Stephen P. Garabedian, Ph.D.

Executive Summary

The proposed solar installation in the Scarborough Brook watershed off Gulf Road in Belchertown by BWC Scarborough Brook, LLC, presents several problems for both abutters and downstream property owners, and particularly the likelihood of increased stormwater runoff and erosion from the site. The existing land use is forest used to harvest timber by Cowls Inc. Slopes on this site are very steep, varying between 15 to 25 percent (see figure 1, below), and along with the poor potential for agricultural use create the likelihood of severe stormwater runoff and erosion from the site after development. A technical review of the "Stormwater Analysis & Calculations Report" by Meridian Associates, which contains the proposed stormwater plan for the Gulf Road site, demonstrates serious errors and unsupported assumptions about the ability of the site to contain and control stormwater runoff. For example, **there is no substantial increase in the predicted runoff after site development because the model parameters used in the Meridian analysis were very carefully selected to insure that was the result**. Evidence in this paper is presented for large amounts of stormwater runoff and erosion from high slope areas underlain by poor agricultural soils at a similar solar array located in West Brookfield and Ware. I would respectfully urge those responsible for stormwater analysis for Belchertown (Planning Board, Conservation Commission, Engineering Department) to find the present stormwater plan for the Gulf Road solar array inadequate to protect the abutting and downstream properties and the site inappropriate for this size of solar development, particularly for an area that is a designated flood zone, a contributing area for a drinking water aquifer, and habitat for protected species.

Introduction and General Comments

My personal interest in the proposed project is the potential overflows of Scarborough Brook and their impact on my property. The stream runs for several hundred feet across the property my wife and I own at 803 Federal Street. Our home is about 1,000-2,000 feet downstream of the area of the proposed solar development, and the stormwater runoff from this proposed site drains to our property. There are four stream crossings between the proposed installation and my property, including culverts under State road route 9, the New England Railroad line, Federal Street, and a culvert that is immediately downstream of the Federal Street culvert that runs under the driveway to our home from Federal Street. The Town-owned culvert that carries Scarborough Brook under Federal Street has reached an over-capacity condition twice recently–three years ago and again this past year. During each of these floods, the culvert has not been able to pass all of the stormwater and the excess flow has run into Federal Street, flooding the street and several driveways along our section of the road. The street and driveways were damaged and required repair by the Town of Belchertown. In addition, my driveway runs directly over an old stone culvert that carries Scarborough Brook through our property. This culvert has been heavily damaged by erosion caused by stormwater runoff in the past, and we've had to make expensive repairs to the culvert to prevent the loss of the structure and loss of the only access to our property from Federal Street. If we were to lose the use of the culvert and our existing driveway, we would need to build another structure, like a bridge, and construct another driveway across a designated wetland area at great additional expense. We repaired the culvert after receiving a permit from the Belchertown Conservation Commission for construction activities near and in a perennial stream (DEP file no. 104-0940). Abutters and near abutters of Scarborough Brook have experienced similar problems, exacerbated by the springs that permeate the Pelham Hills and their steep grades.

Given the above conditions, my concern for the solar installation proposed by BWC is the potential for additional stormwater runoff that could be generated by the clearing of the property and the installation and maintenance of the solar panels on this site upstream from our location. The existing site use is as forested land that I presume has been periodically logged for timber. Logging operations in this area are typically selective tree cuts and not clear cuts. This practice preserves some of the trees on the property and likely reduces the amount of runoff and erosion from the logged areas. The development of the site proposed by BWC would require the complete removal of all trees, stumps, brush, and other existing vegetation under the proposed array, roadways, equipment pads, and array perimeter, at a minimum. The complete removal of all these woody materials, along with the movement of heavy equipment required for that removal, will disrupt, damage, and compact the soils on the site. The likelihood of soil erosion during and after the development of the site is high, further damaging the soils. Finally, the slopes on this site are steep, varying between 15 and 25 percent (see figure 1, below). Maintaining a grassy meadow on these slopes will be difficult, and perhaps impossible, in turn increasing the near certainty of erosion.

Specific Problems with the “Stormwater Analysis & Calculations” Report prepared by Meridian Associates

I've reviewed the "Stormwater Analysis & Calculations Report" by Meridian Associates for the proposed solar development, and find the main result difficult to accept, that is, that the design of the site will create conditions such that "...peak rates and volumes of stormwater runoff in the proposed condition will not result in an increase in the 2, 10, and 100-year storm events at the selected design points" (page 3). Their analysis predicts there would be no additional runoff volume or increase in the peak flow rate from the site after development of the project; this is one of the performance standards required by the MA DEP stormwater regulations. However, I dispute the manner in which the project’s developed areas were characterized and runoff volumes from the developed areas of the site were estimated. I’m concerned that the stormwater management plan and design for this site is woefully inadequate to control the large amount of runoff during high intensity storms. (Please review my resume at the end of this set of comments which documents the training and experience that allow me to evaluate the Meridian Report’s technical adequacy.)

1. The basis for the site design by Meridian Associates is based on runoff projections from the TR-20/ TR55 model, a National Resource Conservation Service (NRCS) model for estimating the effects of

urbanization in small watersheds. The TR55 model is simple and straightforward to use, however, as in this case, the model can be misused as a prediction tool.

The 24-hour rainfall intensity for the 100-year occurrence interval used in the stormwater analysis for the Gulf Road site used by Meridian Associates is 6.4 inches. This is a significant error in the analysis based on the model. A table provided by the Northeast Regional Climate Center (NRCC) provides a rainfall amount of 7.56 inches for the 24-hour, 100-year recurrence interval (see table 1 below). This table is provided on the official NRCS site for use with the TR20/TR55 model. Another table on the National Oceanographic and Atmospheric Administration (NOAA) rainfall site lists 7.8 inches for the same event (24-hour, 100-year recurrence interval). Therefore, the rainfall amount used by Meridian Associates for the rainfall runoff from the Gulf Road site is 1.16 to 1.4 inches too low relative to the information available on the NRCC and NOAA websites. Also, the 6.4 inch figure used by Meridian Associates appears to be identical to the 24-hour, 50-year event figure from the NRCC table, (see table 1 below), so it seems this was a transcription error made by Meridian. This error means they must recalculate all the stormwater runoff volumes for the 100-year event, and redesign all the physical site remediation features that were based on those results in their report.

2. The basic premise of the proposed stormwater design plan by Meridian Associates is that the soils on the Gulf Road site have sufficient capacity to absorb the stormwater runoff, and that because there will be little connected impervious area, the areas around the panels will not create any additional runoff than that generated by the existing wooded conditions. A small detention pond and vegetated swales have been proposed as design elements to retain the runoff generated from the unpaved roads and associated pads required by the solar installation. I strongly disagree with this design for a number of reasons.

    a. The predictions for runoff from the Gulf Road site by Meridian Associates are based on the assumption that replacing the wooded land cover with a meadow land cover will produce equivalent amounts of runoff based on the TR55 runoff number approach. This assumption is flawed, not only due to the steep slopes of the site (15-25%), but also due to the severe disturbance of the existing soils at the site during site development from forest clear-cutting, tree stump removal, and "grubbing" to prepare for solar panel installation. A text I've used in teaching Hydrology (Introduction to Hydrology by Viessman and others, 2nd edition) indicates the fallacy of the Meridian Report's contention that the soils will be able to control stormwater runoff after the removal of the forested land cover: "If a heavily forested area with its thick layer of mulch is converted to cropland or pasture, the soil is disturbed and the overlying adsorptive cover is destroyed. The result is increased runoff volume and a change in the timing of flows" (page 563). So, given the significant changes in the forested land cover at this site, runoff can be expected to increase at the site after conversion from a mature wooded area to an open, steeply sloped, grass field.

    b. The solar installation would require that the cleared area would have to be maintained in its cleared state for decades. This would expose the site to a much longer time period during which a high intensity event, such a hurricane or a late-spring rapid thaw and heavy rain storm, could occur, again with the higher potential for increased runoff from the site than from the existing condition. Even after decommissioning, the forest timber clearing operation would leave the area in a disturbed condition for the decades required for the forest to re-vegetate.

3. The analysis and results presented by Meridian Associates is a "best case" scenario, and is dependent on a lack of change in the soil and stormwater runoff characteristics at the site from pre- to post-site development. This is optimistic in the extreme, and the more likely scenario is one in which there will be significant change in the surface and soil conditions that create additional stormwater runoff from the site, and under the existing plan, without sufficient engineered facilities to mitigate those flows. An analysis of the soil types and conditions illustrates the problems.

    a. The characterization of the soil group 103E, “Charlton-Hollis-Rock outcrop complex, steep” is assigned a Hydrologic Soil Group (HSG) “A” in the Meridian Associates stormwater analysis. This soil group underlies a large portion of the southern part of the project area, and is the soil type underlying much of subcatchment areas 2 and 3. The HSG “A” classification has the most rapid infiltration rate of all soil classifications. The NRCS soil description describes the 103E soil as containing 45% Charlton soil (HSG-A), 10 % Hollis soil (HSG-C/D), rock outcrop (impervious surface), and minor amounts of Brookfield (HSG-B), Brimfield (HSG-C/D, and Paxton (HSG-C) soils. To characterize the whole area of soil type 103E as HSG “A” is misleading. I would expect that a reasonable characterization of the 103E soil would be as an average HSG “B”, decreasing its characterized ability for infiltration, particularly after site development where much of the soil would likely be moved and mixed during forest clear cuts and slope grading. Note that the “steep” in the Charlton soil name refers to a range in slope from 15-45%.

    b. The HSG assignment is an important factor in the runoff calculations using the NRCS TR55 model. For example, the Meridian stormwater report estimates that the total runoff from the project site is dominated by the runoff from subcatchment 2, with 96, 84, and 74 percent of the simulated total runoff for the project area (under existing conditions) produced from subcatchment area 2 for the 2, 10, and 100 year storms, respectively (see page 4 of the report summary). The reason for this dominance by subcatchment area 2 in the simulated runoff using the TR55 runoff model is simple: the predominant HSG for the underlying soil type in subcatchment area 2 is “C”, whereas the predominant HSG for the next largest subcatchment area, 3, is “A”. Given the methodology used in the TR55 model, the runoff number (CN) is the critical factor in determining the volume of runoff generated for a given storm event. Runoff numbers are assigned using values for HSG and land cover type from Table 2-2 in the TR55 model documentation. For example, the CN values of 30 and 70 were assigned to HSG “A” and “C” with wooded land cover in the Meridian report, and then were used in the calculation of runoff across the project area. A CN value of 30 produces a runoff of 0.0 inches for a 3 inch storm (the 2-year event), whereas a CN value of 70 produces 0.7 inches of runoff for the same storm. These differences in runoff amounts between the differing CN values become larger as the precipitation amounts increase.

    c. In addition to the HSG soil group, land cover determines the runoff number used in the NRCS TR55 model (see Table 2-2 in the TR55 documentation). At the beginning of the Meridian report sections entitled “Existing Conditions Stormwater Calculations” and “Proposed Conditions Stormwater Calculations”, there are tables of “Area Listing (all nodes)”. These tables have a CN number assigned based on the land cover and HSG for the project area as a whole. The largest land use/HSG subareas in the “Existing Conditions” table are for wooded areas with HSG “A” (1,775,500 sq ft) and HSG “C” (1,843,485 sq ft); the combined areas are 94% of the total for the project area. A comparison with the similar table in the “Proposed Conditions” section shows the largest land cover/HSG areas are for meadow (HSG “A”; 1,228,266 sq ft), woods (“A”; 626,934 sq ft), woods (“C”; 995,619 sq ft), and meadow (“C”; 786,353 sq ft); the combined areas are also 94%. In short, much of the wooded land cover area is to be converted to meadow land cover, and these are the areas where the solar arrays will be placed.

If we look at table 2-2 in the TR55 model documentation, we can see that the CN is determined by the various land cover and HSG groups assigned by the user. In the Meridian report, the CN value for wooded land cover with HSG “A” is 30, and for the meadow land cover with HSG “A”, the CN value is the same, 30. Also, the CN value for the wooded land cover with HSG “C” is 70, and the CN for meadow land cover with HSG “C” is 71, nearly identical. Therefore, the runoff from the project area after development is nearly the same as the runoff before development because the runoff numbers (CN values) for the pre-existing and post-development areas are nearly identical. This result is irrational.

I conclude that there wasn’t any substantial increase in simulated runoff after site development because the TR55 model parameters were carefully selected to produce that result.

If, however, we use a more likely land cover characterization for developed areas from table 2-2 in the TR55 model documentation, we can see that the CN values are distinctly different. For example, if we select the more likely, post-development land cover of “Open Space (lawns, parks, golf courses, cemeteries, etc.; fair condition)” in table 2-2 of TR55, along with the HSG “A” soil classification, we obtain a CN value of 49, rather than the Meridian report value of 30 for “Meadow-HSG A”. If we use this equally likely value of CN, along with the increase in open area as noted in the Meridian report (meadow, HSG “A”; 1,228,266 sq ft), we obtain an increase in the estimated runoff depth for the 6.4 inch storm from 0.12’’for CN = 30, to 1.27” for CN = 49. The increased volume of runoff is ((1.27-0.12)/12)*1,228,266 sq ft = 177,700 cf (cubic feet) for this storm from one land cover/soil type subarea–a 35% increase in runoff volume from existing conditions. If we use a CN of 79 for the open space area with the HSG “C” soil, rather than the meadow value of CN=71, we obtain 53,380 cf more runoff volume. Combining the two additional runoff volumes creates an increase of 231,100 cf of runoff volume, an increase of 46% from the simulated existing conditions. This additional runoff volume is due solely to a selection of a land cover type that’s more likely to result after development from the same table as was used in analysis presented in the Meridian report.

We can also consider the potential for changes in the soil characteristics in the runoff calculations. It would be reasonable after site development, for example, to change the hydrologic soil group (HSG) classification from “A” to “B” to account for the mixing of soil types, along with degradation of the soil during the forest clear cut and site development work (grading slopes and “grubbing”), as discussed above. Using the HSG “B” soil class, and the “Open Space (lawns, parks, …fair condition)” in table 2-2 of TR55, a CN value of 69 can be assigned to the “meadow (HSG “A”; 1,228,266 sq ft)” area used in the Meridian report. This change creates an additional 297,700 cf of runoff volume; combined with the additional volume from the HSG “C” class noted previously, the increase in runoff volume is 351,100 cf, an increase of 70% from the simulated existing conditions.

Please note that I’ve used the 6.4 inch value of rainfall for the 24-hour, 100 year event, for comparative purposes in the analysis above, even though the true value should be 7.6 to 7.8

inches. If the 7.56 inch rainfall amount is used then 440,000 cf of additional runoff is generated, another 90,000 cf of runoff due to the difference in rainfall.

4. The potential for the 46-70% increase in runoff volume, as noted in comments above, is without any criticism of the methodology used in the TR55 model. I simply make a reasonable selection of different soil and land cover characterization of the post-development site conditions. **The data selected for use in the Meridian report represent a "best case" scenario, with the result that the simulated runoff conditions were found to not increase from the existing to post-development conditions for the site.** I believe that good engineering practice, with a reasonable safety factor applied, would require that a scenario with significantly additional runoff after site development be used as the design criteria for site development. In short, I'd expect the site design to include the expectation of, and protection from, significantly increased runoff volume that is much greater than that from existing conditions. For example, the single detention pond used in the current design has a maximum capacity of about 30,000 cf, used primarily to store the additional runoff estimated from the gravel roads. If the increased runoff volume of 350,000 cf as estimated above were applied, then approximately 10-12 additional detention ponds of the same size would need to be constructed across the developed site to accommodate the potential additional runoff volume expected after the construction of the solar installation.
5. The above point is particularly important because of the difficulties of mitigating runoff over frozen ground. The TR-20/TR-55 model used in the Meridian report can't be used to predict runoff during rain on a frozen ground event. These events represent a significant subset of flood events that occur in Massachusetts. Of the major events listed in the USGS report on historical floods (U.S. Geological Survey Water-Supply Paper 2375: National Water Summary 1988-89--Floods and Droughts), about half occurred during the period from December through early April, that is, they were rain on frozen ground events. This limitation means that other methods must be used to predict the amount of runoff from the site after development. Importantly, rain on frozen ground events could be expected to produce more runoff from a cleared field than from a mature forest.

Comparisons to West Brookfield and Ware Solar Installation

It is useful to compare a nearby commercial large-scale solar array developed on a site located in the towns of West Brookfield and Ware (the Ware project or site) with the proposed Gulf Road solar project. The site is located at 33 Gilbertville Road in Ware, MA, close to the intersection of routes 32 and 9 (figure 3 below, accessed August, 2018). This array of approximately 30 acres was developed by Seaboard Solar and is now owned by Nautilus Solar. The array was installed last year (2017) and is operational. An examination of the satellite photos available on Google Maps (figure 3) shows three different areas of photovoltaic panels on this site: the eastern two areas are on the highest slopes and the western array is installed at a lower elevation on a relatively low-sloped area (topography shown on figure 4). The Ware site has strong similarities to the proposed Gulf Road site. Although the Ware site is smaller (30 acres vs 48 acres), the slopes are similar, both exceeding 15 percent, increasing to 25 percent for the Gulf Road site and 35 percent for the Ware site. Despite substantial engineering of the latter, however, there is considerable evidence of erosion. Some observations follow.

6. Both sites have sandy loam soils with components that are in both the “A” and “D” soil groups. Both soil groups would be considered poor agricultural soils, primarily due to the stoniness and potential for serious erosion. As the NRCS states, “The exposed bedrock, slope, and the stones make these soils poorly suited to farming” (NRCS soil survey). Soils at the Ware site are primarily the Brimfield-Brookfield-Rock outcrop complex underlying the high-slope areas, and the Canton fine sandy loam underlying a low-slope area (NRCS soil survey, see figure 5 below). The high-slope areas are described as ranging from 15-35% slope. The Brimfield unit is very thin (18-22 inches to un-weathered bedrock) and is in the “D” hydrologic soil group. The Brookfield soil unit also is high slope,15-35%, with a deeper profile (up to 65 inches), and is in the “A” hydrologic soil group. Both are described as containing gravelly fine sandy loam and are derived from glacial till overlying metamorphic/igneous bedrock.

7. An effort to produce a pasture or grassland ground cover on the Ware site, which was the land cover type selected for its TR20/TR55 modeling, has not been successful. A visit to this site in late August, 2018 showed that the solar array site is sparsely vegetated, primarily with weeds and limited growth of grass (see figure 6 below).

8. Also evident from an examination of the Ware site, both on the ground and from the Google Maps satellite photography, is significant erosion (see figures 7 to10), likely caused by the heavy summer rain during 2018, which has caused sediment to be carried into the detention/sedimentation ponds. It was fortunate for the abutters that there was a significant amount of on-site storage to control the large amount of runoff that has evidently occurred. The stormwater authorities in West Brookfield and Ware were evidently sufficiently concerned about runoff from the site to require five detention and/or sedimentation ponds (see figure 11), four of which are located on the southern edge of the site and appear to be designed for the higher slope areas (figure 12). The total area for the ponds estimated from the satellite photos is about 35,000 square feet. If we assume an active storage depth of about 4 feet in these ponds, their total storage capacity would be about 140,000 cubic feet of stormwater runoff. If the high slope areas are about 20 acres (871,200 square feet), I estimate the runoff volume designed for the site as about 2 inches depth across the high-slope areas of the array.

Given the similarity of the Ware and Gulf Road sites, I conclude that the proposed stormwater runoff design at the Gulf Road site is substantially inadequate. The present capacity of designed runoff detention is about 30,000-40,000 cubic feet for this 48 acre site (which is about 0.2 inches of runoff potential from the overall site area) in contrast with the 140,000 cubic feet runoff capacity (with a projected depth of 2 inches) for the Ware site. From these estimates, it would appear that the Gulf Road site would need about 10 times as much runoff detention as presently designed in order to match the design capacity at the Ware site.

Concluding Remarks about the Impact of the Gulf Road Solar Project

9. The proposed solar project off Gulf Road site is a particularly sensitive site as the runoff flows to a designated flood zone along Scarborough Brook, which is also a contributing area for a drinking water aquifer and is a habitat area for protected fish species.

10. The Operation and Maintenance section in the Meridian Report specifies the potential use of pesticides on the site. This is notable, particularly as herbicides may be used to control brushy growth across the project area. The widespread use of pesticides on the project area, combined with the likelihood of runoff that leaves the site, could create a contamination problem for sensitive downstream receptors, including the contributing area for the water supply and habitat for protected fish species. This contamination could affect not only the water running off the site but also could be adsorbed by the sediment eroding from the site and carried downstream in Scarborough Brook.

11. The permitting requirements and any special orders of conditions for the Gulf Road site will set a precedent for solar arrays developed on high-slope hillsides in other locations in Belchertown. Designs that assure proper protection of down-slope properties are needed and prudent, particularly in a location that is already as sensitive an area as the section of Scarborough Brook from lower Gulf Road through and across Federal Street.

12. **In conclusion, the engineering design as presented in the Meridian report for the proposed solar array off Gulf Road does not provide adequate protection from large storm events for the abutting and downstream properties**. I respectfully urge the stormwater authorities for Belchertown (Planning Board, Conservation Commission, Engineering Department) to find the present stormwater plan for the Gulf Road solar array inadequate to protect the abutting and downstream properties, and the site inappropriate for this size of solar development, particularly for an area that is a designated flood zone, a contributing area for a drinking water aquifer, and habitat for protected species.

Photos:

Figure 1. Topography of the Gulf Road, Belchertown, location.

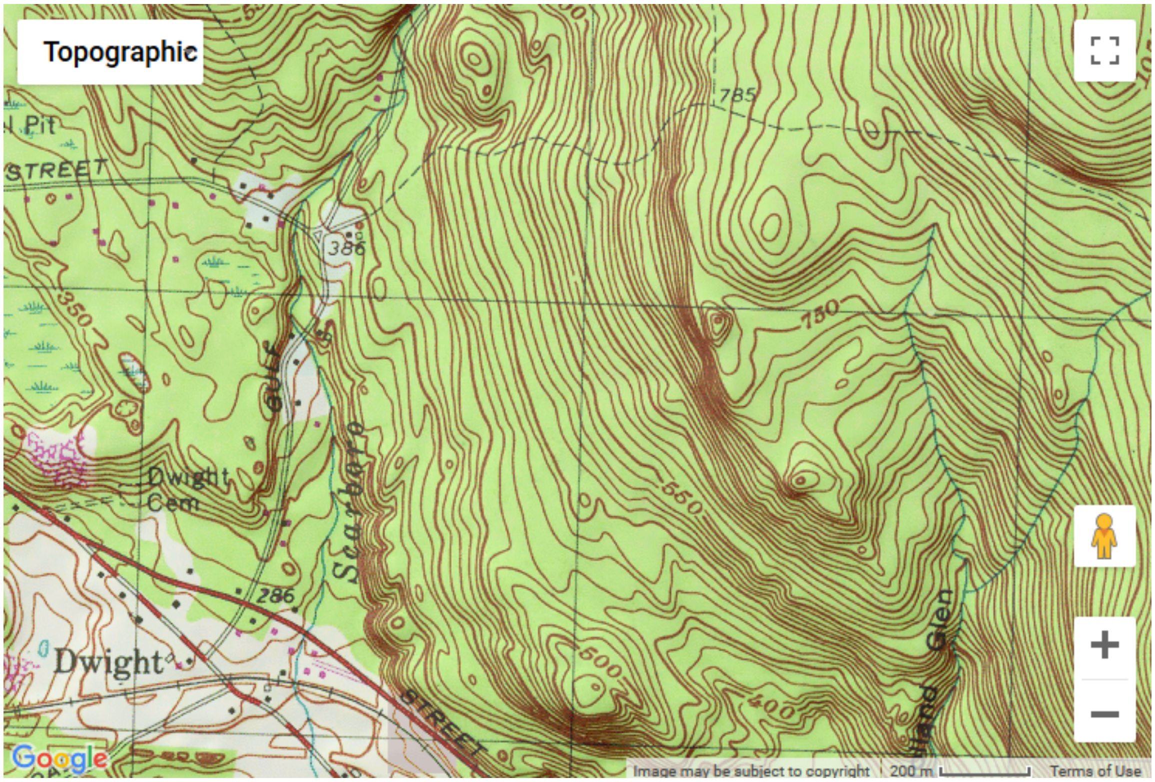

Figure 2. Gulf Road, Belchertown, NRCS soils map.

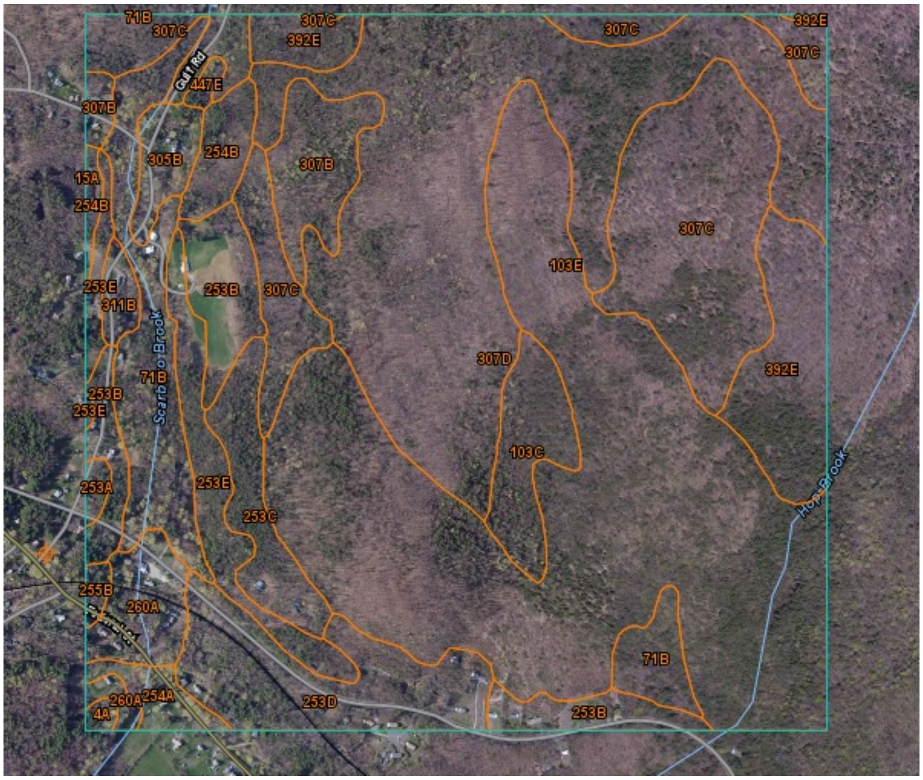

Table 1. Northeast Regional Climate Center Rainfall estimates for the Gulf Road Solar Site.

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	Yes
State	Massachusetts
Location	
Longitude	72.441 degrees West
Latitude	42.332 degrees North
Elevation	0 feet
Date/Time	Sat, 15 Sep 2018 12:06:53 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.29	0.45	0.56	0.73	0.91	1.14	**1yr**	0.79	1.05	1.31	1.63	2.03	2.52	2.79	**1yr**	2.23	2.69	3.12	3.79	4.41	**1yr**
2yr	0.35	0.54	0.67	0.88	1.11	1.39	**2yr**	0.96	1.27	1.60	1.98	2.44	3.01	3.38	**2yr**	2.66	3.25	3.77	4.49	5.14	**2yr**
5yr	0.42	0.65	0.82	1.09	1.40	1.76	**5yr**	1.21	1.59	2.03	2.51	3.06	3.73	4.27	**5yr**	3.30	4.11	4.73	5.55	6.33	**5yr**
10yr	0.48	0.75	0.95	1.29	1.67	2.12	**10yr**	1.44	1.88	2.44	3.00	3.64	4.39	5.10	**10yr**	3.88	4.90	5.63	6.53	7.40	**10yr**
25yr	0.57	0.91	1.16	1.60	2.11	2.69	**25yr**	1.82	2.35	3.10	3.79	4.57	5.45	6.44	**25yr**	4.82	6.20	7.08	8.09	9.11	**25yr**
50yr	0.65	1.04	1.33	1.87	2.52	3.23	**50yr**	2.17	2.78	3.73	4.55	5.44	6.41	7.70	**50yr**	5.68	7.41	8.43	9.52	10.67	**50yr**
100yr	0.75	1.21	1.56	2.21	3.02	3.88	**100yr**	2.60	3.30	4.48	5.44	6.46	7.56	9.21	**100yr**	6.69	8.85	10.05	11.20	12.50	**100yr**
200yr	0.86	1.40	1.82	2.61	3.61	4.66	**200yr**	3.12	3.92	5.38	6.50	7.68	8.91	11.02	**200yr**	7.89	10.59	11.98	13.19	14.65	**200yr**
500yr	1.05	1.73	2.25	3.27	4.59	5.93	**500yr**	3.96	4.92	6.84	8.22	9.64	11.09	13.97	**500yr**	9.81	13.44	15.13	16.39	18.09	**500yr**

Figure 3. Nautilus Solar Array; West Brookfield/Ware (Google Maps, accessed August, 2018).

Figure 4. Topography at the Nautilus Solar Site in West Brookfield and Ware.

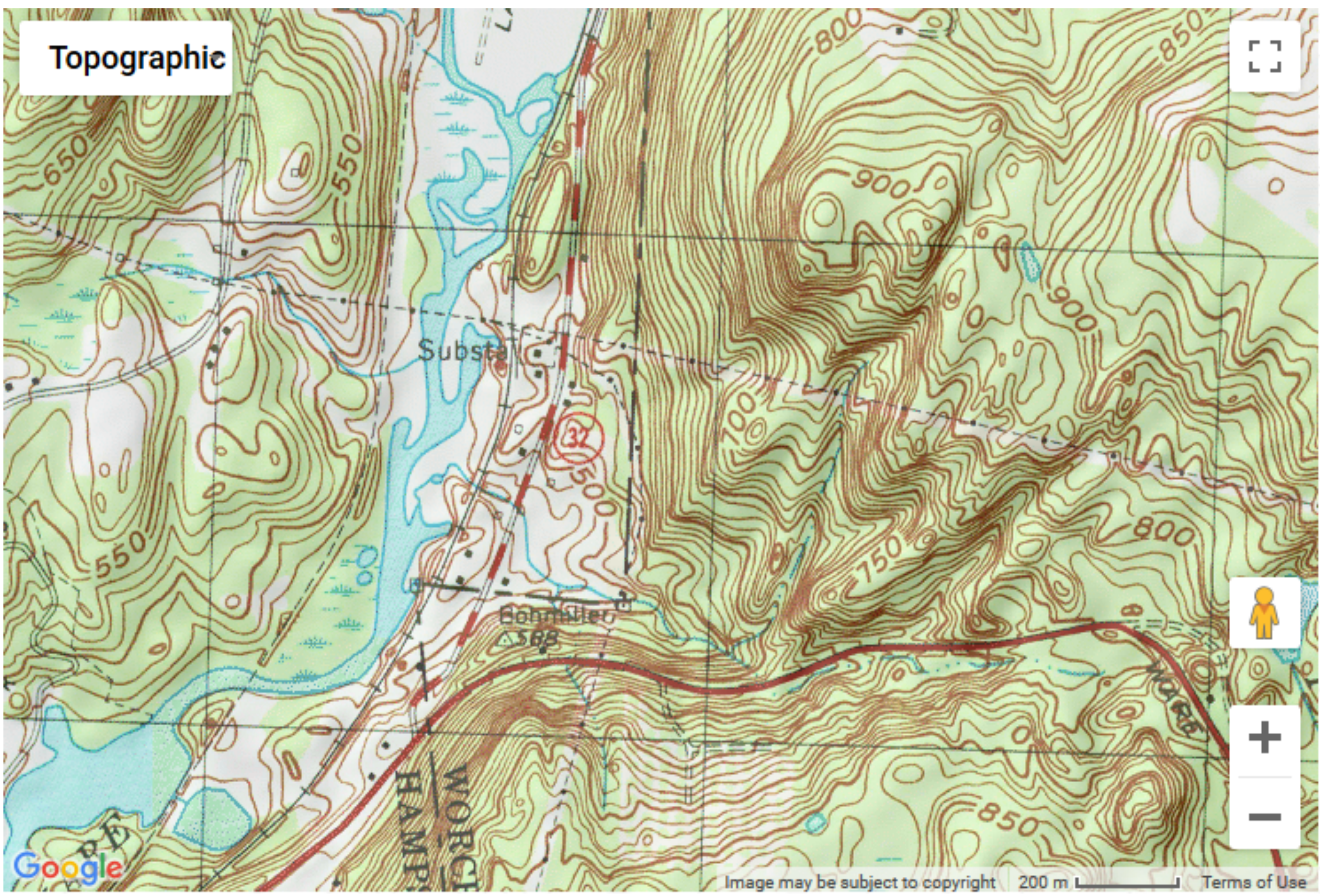

Figure 5. Soils at the Nautilus Solar Site, West Brookfield and Ware, from NRCS soils maps.

Figure 6. Photo of southern part of the WB/Ware solar array; note detention ponds and thin vegetation

Figure 7. South side of WB/Ware solar array; note erosion on the access road into the detention basins.

Figure 8. Erosion on the southern access road near gate, left of the above photo.

Figure 9. Erosion on access road to WB/Ware solar array, note exposed rock.

Figure 10. Down-slope photo of erosion on access road.

Figure 11. Plan for the WB/Ware Solar Array; note the detention/sedimentation basins (inside boxes).

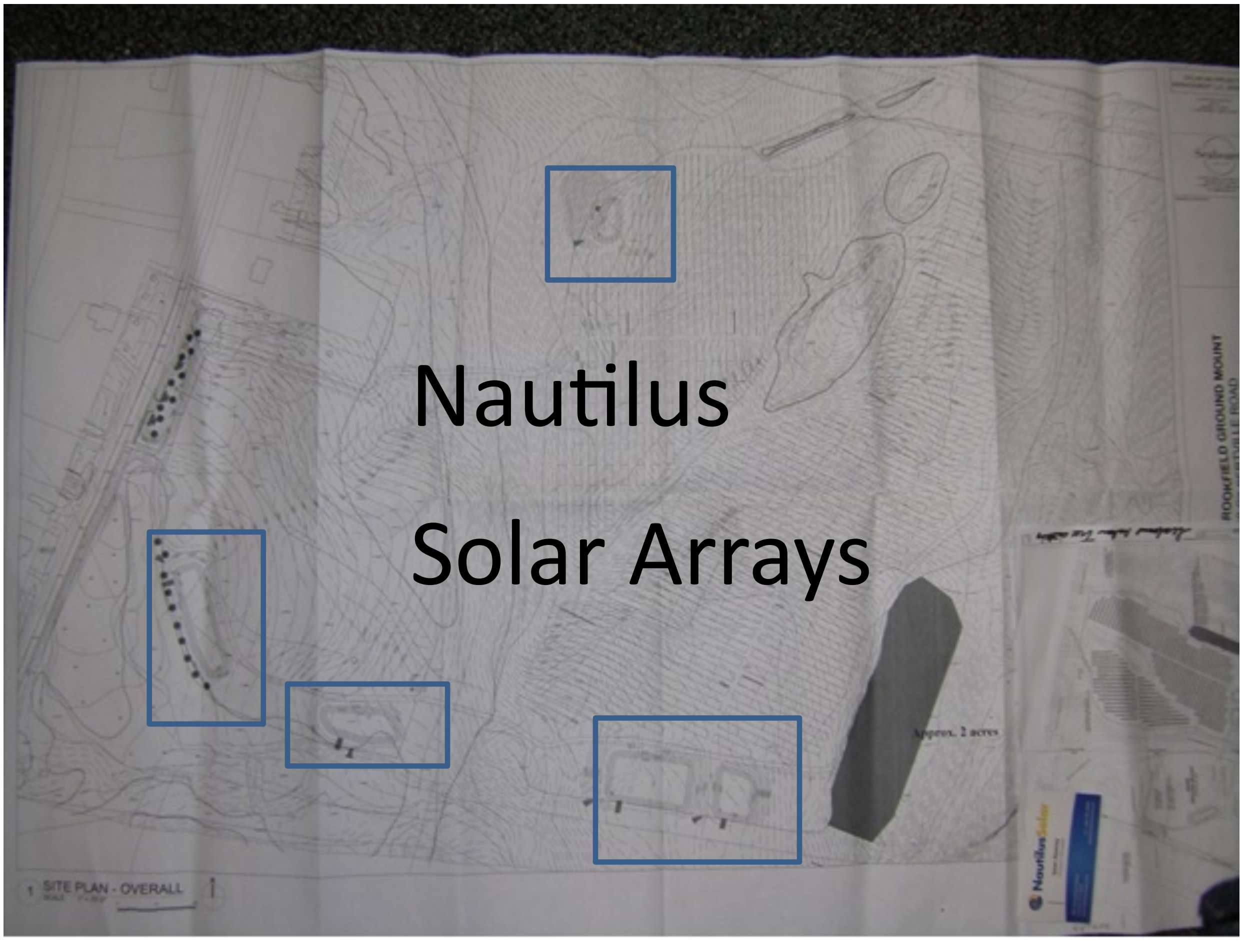

Figure 12. WB/Ware solar array looking upslope (northeast) toward rocky outcrop.

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Education

B.S., University of Connecticut, Geology, 1977
M.S., Pennsylvania State University, Geology, 1980
Ph.D., Massachusetts Institute of Technology, Civil Engineering, 1987

Professional Interests

Water Resources, Groundwater Hydrology and Water Quality, Aqueous Geochemistry

Experience

July 2009 – Present : Independent hydrologist (specializing in hydrogeology), and lecturer working in the New England region.

May 2006 – June 2009: Branch Chief and Lab Director, USGS, Leetown Science Center - S.O. Conte Anadromous Fish Research Laboratory, Turners, Falls, MA.

October 1998 - April 2006: Associate Director, U.S. Geological Survey, Massachusetts- Rhode Island Water Science Center.

January 1991 - March 1999: U.S. Geological Survey, Water Resources Division, Massachusetts-Rhode Island District, Supervisory Hydrologist, Chief of the Connecticut River National Water Quality Assessment Project.

Winter 1988 - 2009: Tufts University, Northeastern University, Boston College, Massachusetts Licensed Professionals Association; Instructor/ Lecturer in Hydrogeology, Hydrology, and Geochemistry.

September 1983 - December 1990: U.S. Geological Survey, Water Resources Division, Massachusetts Office, Research Hydrologist, Cape Cod Toxic Waste Research Project.

November 1979 to August 1983: U.S. Geological Survey, Water Resources Division, Idaho District, Hydrologist with the Snake River Plain Regional Aquifer study.

June 1979 to October 1979: U.S. Geological Survey, Water Resources Division, Reston, VA, Student intern with the Ground-Water Branch.

Selected Publications

Garabedian, S.P., 2013, Estimation of Salt Water Upconing Using a Steady-State Solution for Partial Completion of a Pumped Well: Groundwater, v. 51, no. 6, pp. 927-934.

Selected Publications

Archfield, S.A., Vogel, R.M., Steeves, P.A., Brandt, S.L., Weiskel, P.W., and Garabedian, S.P., 2009, The Massachusetts Sustainable-Yield Estimator: A decision-support tool to assess water availability at ungaged stream locations in Mas-sachusetts: U.S. Geoloical Survey Scientific Investigations Report 2009–5227, 41 p.

Garabedian, S.P., and Stone, J.R., 2004, Delineation of contributing areas and hydrologic responses to pumping in a confined aquifer, South Hadley, Massachusetts: U.S. Geological Survey Water-Resources Investigations Report 03-4320.

Garabedian, S.P., 1998, Water-quality in the Connecticut, Housatonic, and Thames River Basins--Connecticut, Massachusetts, New Hampshire, New York, and Vermont, 1992-95: U.S. Geological Survey Circular 1155.

Garabedian, S.P., 1992, Hydrology and digital simulation of the regional aquifer system, eastern Snake River Plain, Idaho: U.S. Geological Survey Professional Paper 1408-F, 102 p.

LeBlanc, D.R., Garabedian, S.P., Hess, K.H., Gelhar, L.W., Quadri, R.D., Stollenwerk, K.G., and Wood, W.W., 1991, Large-scale natural-gradient tracer test in sand and gravel, Cape Cod, Massachusetts: 1. Experimental design and observed tracer movement, Water Resources Research, Vol. 27, pp. 895-910.

Garabedian, S.P., LeBlanc, D.R., Gelhar L.W., and Celia M.A., 1991, Large-scale natural-gradient tracer test in sand and gravel, Cape Cod, Massachusetts: 2. Analysis of spatial moments for a nonreactive tracer, Water Res. Res., v 27, pp. 911-924.

Courses Taught

Environmental Professional Organization of Connecticut

- 2017 Ground-Water Quality and Geochemistry

Massachusetts Licensed Site Professional Association

- 2003 - 2017 Hydrogeology of Massachusetts
- 2009 - 2012 Ground-Water Geochemistry
- 2012 Applied Fluorescence Tracing

Tufts University - Medford, MA

- 1989 - 2004 Groundwater Hydrology (CE 113)
- 1988 - 2000 Hydrogeology (Geology 131)

Boston College - Boston, MA

- 1989 Hydrology (Geology 495)

Northeastern University - Boston, MA

- 1989 Hydrology II (CE 3356)
- 1988 Hydrology I (CE 3355)

Professional Associations

American Geophysical Union (Hydrology section)
Geological Society of America
National Ground Water Association, AGWSE