STATE OF CONNECTICUT
CONNECTICUT SITING COUNCIL

GRE GACRUX LLC petition for a declaratory ruling for the proposed construction, maintenance and operation of a 16.78-megawatt AC solar photovoltaic electric generating facility in Waterford, Connecticut. Reopening of this petition based on changed conditions.	**Petition No. 1347A** **April 27, 2020**

SAVE THE RIVER-SAVE THE HILLS, INC.'S RESPONSES TO INTERROGATORIES ISSUED BY GRE GACRUX LLC

Save the River-Save the Hills, Inc. ("STR-STH") hereby responds to the interrogatories issued by the petitioner, GRE GACRUX LLC ("GRE")

1. Please produce every document read, relied on, or referred to by Intervenor to form those opinions expressed in the STR-STH Correspondence.

RESPONSE: STR-STH objects to this interrogatory as unduly burdensome, as it would be impossible to list every document upon which its witnesses' opinions and experience are based and it is impractical to ask that STR-STH produce copies of every such document. Notwithstanding that objection, STR-STH responds that it has attached many documents upon which its witnesses relied, and further responds that the list of documents upon which it relied including the following, which are not all attached given their length and/or their public availability:

- The entirety of the docket for Petition No. 1347
- The entirety of the docket for Petition No. 1347A, including GRE's motion to reopen proceeding and attached petition with all exhibits
- 2002 Connecticut Guidelines for Soil Erosion and Sediment Control ("2002 Guidelines"), available at: https://portal.ct.gov/DEEP/Water/Soil-Erosion-and-Sediment-Control-Guidelines/Guidelines-for-Soil-Erosion-and-Sediment-Control
- 2004 Connecticut Stormwater Quality Manual ("2004 Manual"), available at: https://portal.ct.gov/DEEP/Water-Regulating-and-Discharges/Stormwater/Stormwater-Manual

- CT General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities ("General Permit") and recently proposed revisions to same, including Appendix I
- Site plans and related reports in Petition No. 1398
- Beauchene, M., M. Becker, C. Bellucci, N. Hagstrom, and Y. Kanno. 2014. Summer thresholds of fish community transitions in Connecticut streams. N. Am. J. Fish. Man. 34:119-131.
- CEQ (Council on Environmental Quality). December 4, 2015. Digging Connecticut…while Protecting Its Waters and History: Recommendations for Reducing Impacts of Earthmoving. 17 pp.
- CEQ (Council on Environmental Quality). February 3, 2017. Energy Sprawl in Connecticut. Why Farmland and Forests are Being Developed for Energy Production: Recommendations for Better Siting. 16 pp.
- CEQ (Council on Environmental Quality). 2020. 2019 CEQ Annual report. Accessed at: https://portal.ct.gov/-/media/CEQ/CEQ-Annual-Report-2019-Final.pdf?la=enCole Ecological, Inc. 2016. 2014-2015 Bioassessment of Streams in the Town of Waterford, CT. 2015 Summary Report. 46 pp.
- CT DEEP (Connecticut Department of Energy and Environmental Protection). 1975. Office of Long Island Sound Programs. Niantic River Watershed Protection Plan. Watershed-wide Strategies to Prevent Nonpoint Source Pollution. Accessed at: https://portal.ct.gov/DEEP/Water/Watershed-Management/Watershed-Management-Plans-and-Documents#nianticriver
- CT DEEP. 2019. 2018 Integrated Water Quality Report. Accessed at: https://portal.ct.gov//media/DEEP/water/water_quality_management/305b/2018CTIntgratedWaterQualityReportpdf.pdf?la=en
- CT DEEP. 2019. 2018 Integrated Water Quality Report. Appendix A-3. Connecticut 305b Assessment Results for Estuaries. Accessed at: https://portal.ct.gov//media/DEEP/water/water_quality_management/305b/2018CTIWQRAppendixA3pdf.pdf?la=en
- CT DEEP. 2019. 2018 Integrated Water Quality Report. Appendix B-1. List of Impaired Waters for Connecticut. Accessed at: https://portal.ct.gov/-/media/DEEP/water/water_quality_management/305b/2018CTIWQRAppendixB1pdf.pdf?la=en
- CT DEEP. 2019. 2018 Integrated Water Quality Report. Appendix C-1. Priority List of Impaired Waters for Action Plan Development (including TMDL development). Accessed at: https://portal.ct.gov/-/media/DEEP/water/water_quality_management/305b/2018CTIWQRAppendixC1pdf.pdf?la=en
- CT DEEP. 2019. 2018 Integrated Water Quality Report. Appendix C-2. List of Waters for Action Plan Development by 2022 Identified in Integrated Water Resource Management Reports. Accessed at: https://portal.ct.gov//media/DEEP/water/water_quality_management/305b/2018CTIWQRAppendixC2pdf.pdf?la=en

- CT DEEP. 2020. Construction Stormwater Permitting: Rain Happens! Presentation by DEEP Stormwater Section, Jan. 8, 2020. Available at: https://www.cbia.com/wp-content/uploads/2020/01/CBIA-CTDEEP-stormwater.pdf
- ECCD (Eastern Connecticut Conservation District). 2009. Niantic River Watershed Protection Plan. Available at: https://www.waterfordct.org/planning-development/pages/land-use-studies-reports
- IER (Institute for Energy Research). 2016. The Levelized Cost of Electricity from Existing Energy Sources. 59 pp.
- IER. 2017. Will Solar Power Be at Fault for the Next Environmental Crisis? 4 pp.
- Klemens, M.W. 1993. Amphibians and Reptile of Connecticut and Adjacent Regions. State Geological and Natural History Survey of Connecticut. Bull. No. 112. 318 pp.
- Milone & MacBroom, Inc. 2009. Stony Brook Watershed Management Plan. Accessed at: https://portal.ct.gov//media/DEEP/water/watershed_management/wm_plans/stonybrookwsplanpdf.pdf?la=en
- Minnesota Stormwater Manual, *Stormwater management for solar projects and determining compliance with the NPDES construction stormwater permit*, available at: https://stormwater.pca.state.mn.us/index.php?title=Stormwater_management_for_solar_projects_and_determining_compliance_with_the_NPDES_construction_stormwater_permit
- Prume, K., J. Viehweg et al. 2018. Guideline. Assessing Fire Safety Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization. (Translated from the German Second Ed. of July 2015). 303 pp.
- Robinson, S.A., and G.A. Meindl. 2019. Potential for leaching of heavy metals and metalloids from crystalline silicon photovoltaic systems. J. Nat. Res. Dev. 2019, 09:19-24.
- Schauffler, M. Siting Solar Projects: The Right Power in the Right Place. Saving Land Fall 2019:14-17.
- *State of Connecticut v. Woods Hill Solar, LLC et al.*, Consent Order #COWRSW18003, dated Nov. 27, 2018.
- Town of Waterford, 2012 Plan of Preservation, Conservation and Development. Available at: https://www.waterfordct.org/sites/waterfordct/files/file/file/policy_guide_effective_010112_rfs.pdf
- USFHA and CT DOT (United States Federal Highway Administration and Connecticut Department of Transportation). 2007. Final Environmental Impact Statement and Environmental Impact Evaluation. Route 82/85/11 Corridor. Salem, Montville, East Lyme and Waterford. Section 5.4. Biological Diversity. Accessed at: https://portal.ct.gov/media/DOT/documents/ddotinfo/rt11final/Section54511Envimpactspdf.pdf?la=en

2. Please identify any individual(s) and/or expert(s) Intervenor retained and/or consulted in connection with the STR-STH Correspondence, including his/her respective qualifications, as applicable.

RESPONSE: STR-STH objects to this interrogatory as vague, in that it fails to define "retained" or "consulted," and such terms could be seeking privileged information. STR-STH further objects to this interrogatory as unduly burdensome, as STR-STH leadership has discussed GRE's proposed project (both Petition Nos. 1347 and 1347A) with many people over the past several years, many of whom provided insight that may be reflected in the STR-STH Correspondence. Notwithstanding those objections, STR-STH responds as follows: The content of the STR-STH Correspondence was based primarily on, though not limited to, review and comment from Steve Trinkaus of Trinkaus Engineering, LLC in Southbury, CT; Don Danila, now retired; and Deborah Moshier-Dunn, vice president of STR-STH for more than 16 years. Mr. Trinkaus is a professional engineer with more than 40 years of experience in civil engineering in the land development field, and has a B.S. in forest management. Mr. Danila is a retired fisheries biologist who is currently a member of the Niantic River Watershed Committee and other organizations related to environmental matters. He was previously employed by Dominion-Millstone Environmental Laboratory, studying the Niantic River and its watershed for Dominion's adherence to its regulatory obligations under a National Pollutant Discharge Elimination System (NPDES) permit. He also worked as a consultant with ASA Analysis and Communication, Inc., dealing with NPDES permit requirements associated with electrical generating stations and a petrochemical facility. Their CVs are attached. Ms. Moshier-Dunn and Fred Grimsey, founder and president of STR-STH, have been advocating for the health of the Niantic River, its watershed and the surrounding hills through environmental programs with

DEEP, the towns of Waterford and East Lyme, other organizations and schools for almost two decades.

3. If any individuals and/or experts were so retained and/or consulted by Intervenor in connection with the STR-STH Correspondence, please state each opinion said individual was retained to provide, the factual basis of that opinion, and its scientific basis, as applicable.

RESPONSE: STR-STH objects to this interrogatory as vague, in that it fails to define "retained" or "consulted," and such terms could be seeking privileged information. STR-STH further objects to this interrogatory as premature, given that the Council has not set a revised schedule for the disclosure of witnesses. STR-STH further objects to this interrogatory as unduly burdensome, given that the STR-STH Correspondence laid out clearly the organization's opinions with respect to the deficiencies in GRE's revised plans. Notwithstanding those objections, and reserving all rights to engage and/or present additional individuals and/or experts as witnesses for the hearing still to be held in this matter, STR-STH responds as follows: Very generally, Mr. Trinkaus provided a technical review of the erosion/sedimentation control plan, stormwater management plan, and overall site plans for compliance with the 2002 Guidelines, the 2004 Manual, the General Permit, including proposed Appendix I for Stormwater Management of Ground Mounted Solar Arrays, and civil engineering standards of care for design work, and has applied his deep knowledge of forestry to his review. Mr. Danila reviewed the petition materials for environmental assessments and impacts on the local ecosystem, which supports wildlife and fish populations. Ms. Moshier-Dunn applied her knowledge and experience working within the Niantic River watershed, including studying and researching such things as the Stony Brook Watershed Management Plan, the Niantic River Watershed Plan, and town and state regulations.

4. Has STR-STH thoroughly reviewed the revised Petition No. 1347A, including all narrative(s), appendices, and engineering plans/drawings contained therein?

RESPONSE: Yes, the entire STR-STH team has reviewed the revised Petition No. 1347A and found it to contain inconsistencies, lack of detail, outright errors, unfounded conclusions, and unsound engineering practices. STR-STH simply cannot understand why GRE would propose to construct a ground-mounted solar installation on environmentally sensitive lands without assuming that the panels in the array are impervious. It seems like such a simple change and there is no evidence that changing that underlying assumption, which would protect the wetlands and watercourses of the state, including the heath of the Niantic River estuary, would be cost-prohibitive. (*See, e.g.*, Petition No. 1398 (proposing a ground-mounted solar array project with stormwater design based on the impervious assumption).)

5. Please answer the following:

   a. What environmental benefits will be lost if the Site is developed as residential property, in keeping with its current zoning designation, as opposed to the construction of a solar facility?

   b. Explain how the environmental benefit of the Site would be maintained if the Site were developed in accordance with its zoning designation, as opposed to a solar facility.

RESPONSE: STR-STH objects to the false dichotomy that GRE is trying to draw with this interrogatory. As GRE is well aware, if the site were to be developed under current residential zoning, all design aspects of the development would have to comply with the Town of Waterford Zoning and subdivision regulations, with approvals obtained from the Planning and Zoning Commission. As Waterford is a coastal town, its regulations have Low Impact Development (LID) standards built into them. This includes required setbacks, limits to impervious cover, set asides as protected open space, and public input. The Waterford Subdivision regulations require the use of Low Impact Development strategies to address stormwater management. Additionally, approval for regulated activities in a delineated inland wetland area and within the defined upland review area would have to be obtained from the Town of Waterford Conservation Commission. Zoning in Waterford is stringent and follows detailed procedures with thorough environmental review and oversight by wetlands staff and the Conservation Commission throughout all phases of the project as well as post-construction. Oversight at this level is currently denied to the town given the restrictions of the petition process for all solar facilities, including large ground mounted facilities like the one proposed by GRE.

If the property owner were to apply to the town to develop this parcel, STR-STH, the Niantic River Watershed Committee, Waterford Land Trust and the citizens of Waterford would certainly participate in any Town of Waterford proceedings (e.g., with Planning and Zoning, Conservation Commission, and the Town's environmental planner) regarding development of this parcel due to its important environmental attributes and relatively large area. That public input process would help ensure that the parcel would be developed using the best LID standards and other environmentally friendly practices. Certainly housing, with lesser impervious surfaces, would not result in 75 acres of clear-cutting, and other damages that will result from the solar arrays and stormwater runoff. A housing developer would be urged (or required through town regulations) to maximize open space on this parcel. Wetlands and stream corridors would be protected to the maximum extent possible. Stormwater would be handled using up-to-date and environmentally sound designs, such as using tree filters and other engineering practices to maximize infiltration and remove pollutants. Modern septic system designs would be promoted, which would reduce nutrient inputs into groundwater.

With respect to the losses of environmental benefits, STR-STH believes much more significant losses will occur if the Site is developed as GRE proposes than if it might at some point in the future be developed per its residential zoning. It is environmentally irresponsible to clear cut 75acres of deciduous forest for the installation of a solar panel farm. The natural wooded, undisturbed environment provides the following environmental benefits which will be completely lost if this project is approved and constructed as proposed. (1) Deciduous and evergreen trees provide interception of rainfall via branches and leaves, thus reducing the amount of rainfall which directly hits the ground surface. Some of the intercepted rainfall is absorbed by the leaves for use in photosynthesis. Other intercepted rainfall runs the branches and trunk to the ground surface, where it will infiltrate into the forest litter layer found on the ground surface. This environmental benefit will be fully lost by this project over the 75 acres. (2) The velocity of the falling raindrops is greatly reduced by the interception of rainfall by the branches and leaves, and thus when the raindrops reach the ground, they do not cause erosion of the forest litter layer. This environmental benefit will also be fully lost by this project over the 75 acres. (3) All growing vegetation (trees, shrubs and herbaceous groundcover species) found in the forest absorb carbon dioxide from the air and release oxygen. Carbon from the carbon dioxide is stored in all woody vegetation and sequestered from being released. This function on 75 acres will be fully lost as a result of this project. (4) As all trees and brush will be removed from 75 acres of the site, so will the stumps and then the soil surface will be disturbed. Additionally, the submitted plans show that large extents of the site will be regraded to varying degrees. This grading disturbs and changes the natural soil properties which exist on the site. The soft forest litter layer will be removed and the underlying soils will be compacted to varying degrees. This disturbance and regrading of the native soils causes two adverse environmental impacts. First, is the loss of the natural soils ability to absorb and sequester carbon. Second is the significant elimination of the soil to absorb and infiltrate rainfall. Disturbance of the soils significantly reduces or eliminates the porosity (void spaces within the soil) of the soil. As the porosity is decreased or eliminated, the ability of the soil to infiltrate runoff is also reduced or eliminated. (5) The clear cutting of 75 acres will eliminate significant forest habitat for terrestrial and aquatic species which reside in these areas as well as those who use the wetland and watercourses on the site. STR-STH agrees with the Town of Waterford's opinion (expressed in its interrogatories issued to GRE) that the "carbon debt analysis should factor into the debt a 60-80 year time period following decommissioning of the site for loss of sequestered carbon by a mature temperate hardwood forest until a mature hardwood forest is re-established on the project site." (Waterford Interrogs., dated Apr. 13, 2020, #30.)

6. Does STR-STH believe that it is appropriate to locate solar energy facilities on forested sites where there is minimal risk of significant environmental effects to occur and feasible mitigation measures available (irrespective of whether mapped core forest is present)?

RESPONSE: As the Siting Council and GRE are aware based on earlier filings in this and the underlying proceeding, STR-STH's mission, in place since its organization in 2001, is specific to the health preservation of the Niantic River estuary, its watershed and the Oswegatchie Hills. STR-STH intervened in this proceeding and the underlying petition due to the location of the Site, which is an environmentally sensitive parcel of land on hilly terrain between two streams that currently support native brown and brook trout and feed into the Niantic River. STR-STH believes that installing a solar array of this size and with these grossly insufficient stormwater plans is irresponsible development.

First, STR-STH believes that the fragmentation of core forest blocks for the placement of many thousands of ground-mounted photovoltaic panels is not good policy for the State of Connecticut. STR-STH shares the opinion of the Connecticut Council on Environmental Quality (CEQ), which stated in 2017:

> Not all solar installations yield equal benefits. Solar panels on commercial rooftops, industrial lands and old landfills can be sustainable home runs. Unfortunately, Connecticut adopted laws and policies that encourage utility-scale solar photovoltaic facilities to be developed on farmland and forest land. Connecticut was, and still is, unprepared to guide the placement of solar facilities to minimize their environmental damage.

(CEQ (2017).) At the time of CEQ's publication, solar photovoltaic facilities had become the largest single type of development consuming agricultural and forest lands in Connecticut and in 2016, the areas of both approved for solar developments nearly equaled the area of such lands preserved by the state in an average year. CEQ (2017) noted:

> There is an irony in the state's spending millions of dollars to preserve agricultural and forest land and to encourage private forest management while, with another hand, encouraging conversion of similar lands into electricity-generating facilities.

STR-STH concurs with the above conclusion.

Besides the complete loss of habitat for obligate forest species, there are other effects to vegetation and forest blocks as a result of land clearing and the accompanying fragmentation of forest lands. (USFHA and CT DOT 2007.) These include induced edge effects, such as changes to topography, light regimes, hydrology, substrates, and the introduction and proliferation of non-native invasive species. Passage corridors for wildlife are also diminished. The adverse effect of forest fragmentation was even noted by GRE's wildlife consultant, who stated:

> The resulting habitat loss will render the site largely uninhabitable for forest-dwelling birds. Beyond the areas converted from forest to solar field, forest within approximately 300-feet of the proposed clearing limits will be diminished with respect to supporting forest-dwelling birds because of the impacts associated with the edge affect. Additionally, the overall 750-acre forest block will be fragmented, and the habitat value diminished. This is exacerbated by the fact that the site lies roughly within the center of the overall 750-acre forest block, which will have a particular affect on the portions of the forest block that lie to the west (west of the site towards I-95, north to Oil Mill Road) as this area will be fragmented into a small forest patch less than 100 acres.

CEQ (2020) recently noted:

> Core forests provide habitat for many species of wildlife that cannot tolerate significant disturbance. Forests that are fragmented, or divided by roads and clearings, provide some forest functions but are not fully-functioning forest ecosystems. Fragmented forests are known to provide substandard or poor habitat for some species of wildlife and, in many cases, less opportunity for hunting and other types of recreation. Invasive species of plants and animals often colonize areas in the wake of activities that result in fragmented forests.

Secondly, GRE certainly has not demonstrated in its submitted materials that, as stated in the above interrogatory, a "minimal risk of significant environmental effects" is associated with its proposal. There was neither a scientific analysis of risk in the materials presented to the Siting Council nor persuasive arguments made for this proposition. Important components of the local environment and their biota (e.g., aquatic species and water quality parameters of the streams that will be impacted) were either not discussed or summarily dismissed by GRE as not an issue. (*See also* STR-STH response to Interrog. 28, below.) Some of the environmental studies submitted by GRE were cursory and lacked complete data. GRE has simply not presented any sound basis for its claim that its project will case no significant environmental effects is true.

Third, although in its question GRE is asking STR-STH's opinion with respect to a project that contains "feasible mitigation measures," the proposed project contains no such thing. STR-STH only found the word "mitigation" three times in GRE's submitted materials (not including its consultant's qualifications sheets). The first was in the testimony of Mr. La Marche, in which he stated that reducing the area to be clear cut from 98 to 75 acres (and presumably also the reduction in the number of solar panels) was a mitigation measure relative to the original petition. Although STR-STH welcomes the reduction in clear cutting, there remains a significant potential for adverse effects related to the plan to clear-cut 75 acres and install 45,976 photovoltaic panels. The 2018 environmental report by Davison Environmental also referenced mitigation:

> The principal mitigation measures to insure no adverse impacts to downstream aquatic resources should be the implementation of a no disturbance buffer around wetlands and watercourses. Recognizing the sensitivity of these headwater wetlands, and the significance of downstream resources for wildlife and recreation, I would recommend a minimum 200-foot buffer around wetlands, with the first 100-feet being a no disturbance zone where existing forest remains intact. The second 100-feet should remain non-impervious [*sic*] (i.e., no solar panels) but can include stormwater management features and associated grading.

(Petition, Exhibit H at 9.) The third mitigation reference was in GRE's April 6, 2020 Responses to the Council's Interrogatories, which attached DEEP's proposed Appendix I to the General Permit:

> Proper stormwater management practices can significantly mitigate the loss of topsoil, erosion and sediment discharges from disturbed areas and stormwater outlets, and erosion along downstream channels and streambanks.

(GRE Interrog. Responses, dated Apr. 6, 2020, Exhibit D at 1.) Certainly, protecting site wetlands and watercourses using a buffer zone needs to be an important component of the design. The specifics of whether or not STR-STH believes GRE's design will properly mitigate environmental effects from stormwater handling and other effects of this project are detailed elsewhere in many of STR-STH's responses to these interrogatories.

7. Please answer the following:

    a. Has STR-STH reviewed the Project's revised construction schedule and phasing plan set forth therein, including the related engineering drawings?

    b. Please identify where, therein, it is suggested that 75 acres would be disturbed at once.

RESPONSE: Yes. On page 3 of Mr. La Marche's testimony, he states the following:

> At that meeting, the Project team suggested that it would be willing to clear the Project Site during the spring/summer of 2020 (assuming regulatory approvals are obtained), and then hydroseed the site before beginning construction. The construction would begin in 2021 after the Site had achieved some level of stabilization.

This statement clearly means the entire 75 acres for the solar array will be disturbed at one time, to varying degrees. Also, the *very* cursory, high-level Construction Schedule GRE submitted is as follows:

Item	**Estimated Date Start**	**Estimated Date Complete**
Discretionary Permit	1/24/2020	7/1/2020
Stormwater General permit	2/15/2020	5/15/2020
Final Electrical interconnection design	6/1/2020	7/1/2020
Initial Site work	6/1/2020	7/1/2020
Seed establishment period	7/1/2020	3/30/2021
Final Construction Notice to Proceed	4/1/2021	4/1/2021
Site prep	4/1/2021	4/15/2021
Civil array installation	4/16/2021	7/15/2021
Mechanical Installation	5/1/2021	8/1/2021
Electrical installation	5/15/2021	8/15/2021
Energization	8/15/2021	9/1/2021
Commissioning and punch list	9/1/2021	10/1/2021

(Note that five spelling errors were corrected in this cut and paste of the Construction Schedule, showing the haste with which it was put together before submittal).

(Petition, Figure 5.) GRE states in its petition that “Initial work will involve site clearing and the installation of erosion control measures, including installation of sediment basins.” (Petition at 14.) Per the above schedule, “initial site work” is to take place in one month. Thus, the petition clearly states that 75 acres would be disturbed within one month.

8. Does STR-STH believe that designing the stormwater management for the site to use a reduction/step down of the Hydrologic Soil Groups that are present on-site (to account for compaction during construction) is a reasonable and protective practice? If not, please explain why not.

RESPONSE: It is appropriate to step down on Soil Class for those areas which are being cleared, stumped but no grading. However, based on the knowledge that Mr. Trinkaus has of soils from his forestry degree and observations in the field, particularly at the East Lyme Antares site, for those areas to be cleared, stumped, *and* graded, stepping down one Soil Class is not adequate and the step down needs to be two Soil Classes. When Mr. Trinkaus visited the

Antares site for a site walk, the ground was as hard as concrete, such that it would be considered a Class D soil. That site started with a Class B soils. There is every reason to expect that the same will be true of this site based on GRE's plans.

9. What is STR-STH's experience and understanding of all applicable CTDEEP stormwater regulations and guidance documents; particularly Appendix I to the Stormwater General Permit for construction? For purposes of these interrogatories, the Appendix I that is being referred to was attached to Petitioner's April 6, 2020 responses to the Siting Council's interrogatories as Exhibit D.

RESPONSE: Mr. Trinkaus is very familiar with all of the stormwater regulations, including Appendix I to the General Permit. Appendix I, which has not yet been adopted by DEEP, on its face provides *minimum* standards for the design of stormwater management systems for ground-mounted solar arrays.

> Therefore, in addition to the terms and conditions of the general permit, registrations for construction of a Solar Array … shall, *at a minimum*, adhere to the conditions listed below. *Depending on site-specific conditions for a particular solar array construction project, additional analyses may be required.*

(Appendix I at 1 (emphases added).) Consistent with that guidance, Mr. Trinkaus designed the stormwater management system for a ground-mounted solar array in Winchester, Connecticut that exceeds the requirements of Appendix I. (The project was recently submitted to the Siting Council as Petition No. 1398.) Design engineers also have the responsibility to design sites to meet the civil engineering standard of care under their professional license. A professional engineer in Connecticut must perform his or her work in accordance with Section 20-300-12 of Title 20 – Professional and Occupational Licensing, Certification, which states the following:

> (1) The engineer or land surveyor shall at all times recognize his or her primary obligation to protect safety, health, and welfare of the public in the performance of his or her professional duties. If his or her professional judgment is overruled under circumstances where the safety, health and welfare of the public are

> endangered, he or she shall inform his or her employer of the possible consequences and notify such other proper authority of the situation, as may be appropriate.

This section obligates the professional engineer to design systems that protect public health, safety and welfare, which means that a minimal compliance with state water quality standards, and with Appendix I in whatever form it is eventually adopted, is not the sole concern of a design engineer.

10. Does Intervenor believe that Petitioner has redesigned the Project to comply with the CTDEEP stormwater regulations and guidance documents referenced in Interrogatory No. 9 above?

RESPONSE: No, the design of the stormwater management system does not meet the standards found in the 2004 Manual, 2002 Guidelines or in Appendix I. For example, there is no phasing plan and there are no intermediate erosion control barriers to break up the slope length (the longer the runoff goes without hitting a sedimentation barrier, the faster it moves, so that it has more force to move soil, thus causing erosion).

11. If the response to Interrogatory No. 10 above is “no,” please explain exactly what elements of Petitioner’s current design are out of compliance with applicable regulations and what elements of Petitioner’s current design are out of compliance with applicable guidance documents.

RESPONSE: STR-STH objects to this interrogatory as premature to the extent that it is seeking a detailed expert witness opinion in advance of the deadlines for submission of prefiled testimony in this proceeding. Notwithstanding that objection, and reserving its right to expand on and/or amend this response in the submission of prefiled testimony, STR-STH responds as follows: Generally, the most troublesome elements of the current design, all of which fail to comply applicable regulations and standards, including water quality standards and standards of care with respect to professional engineering, fall into several categories. (1) The solar panels themselves were not considered impervious, resulting in GRE grossly under-estimating the peak rates and runoff volumes for post-development conditions. (2) The elevated solar panels are no different than a car port, which is a roof supported by four or more posts and open on all four sides. The roof of the car port is impervious and thus the elevated solar panels are impervious. At the solar array in East Lyme was also developed by Greenskies, there is clear evidence that runoff from the solar panels is not infiltrating at all, but occurring as concentrated flow, causing erosion and resultant sedimentation. See Figures 1 and 2 below. (3) The multiple types of stormwater basins proposed by GRE are not in compliance with the design standards found in the 2004 Manual. (4) The Water Quality Volume calculated by GRE is not in compliance with Appendix I, as the solar panels themselves were not considered impervious.

Figure 1 – Eroded path of concentrated Flow from runoff off solar panel (East Lyme)

Figure 2 - Sedimentation of eroded material within area of array (East Lyme)

12. Referring to Point No. 3 of the STR-STH Correspondence, Appendix I speaks to solar panels being considered impervious for the purpose(s) of calculating Water Quality Volume ("WQV"), if certain conditions are not met. Please provide reference to a State of Connecticut regulatory document that holds that solar panels shall be considered impervious in a hydrologic peak-flow drainage analysis.

RESPONSE: On page 10 of the submitted Stormwater Report, GRE states the following:

> To be conservative, water quality computations have been performed using a combination of 2004 CTDEEP Stormwater Quality Manual for the access roads and Minnesota Drainage Manual for the solar panels to determine required water quality volumes. These water quality volumes are addressed in the design of the proposed permanent stormwater basins.

GRE is citing a section taken out of context from the Minnesota Stormwater Manual for Solar Arrays. The Minnesota stormwater standards for ground mounted solar arrays are for flat farm sites, according to an engineer from Minnesota who discussed this issue with Christopher Stone, PE of DEEP, and not for the sloping topographic conditions that are found in

Connecticut. The Minnesota standards also have not been adopted by DEEP and thus are not relevant here. Appendix I, developed but not yet adopted by DEEP, clearly states that the solar panels must be considered impervious for the calculation of the Water Quality Volume subject to conditions (1)(a) through (1)(e), inclusive, in the section titled "Design and construction requirements." GRE does not meet conditions (1)(b), (1)(c) or (1)(d), and therefore cannot consider the panel to be pervious per Appendix I.

13. On page 2 of the STR-STH Correspondence, Intervenor states that, "[t]he Petitioner has a poor track record of creating solar installations that do not 'have a substantial adverse environmental effect in the state' (CGS Sec. 16-50k(a))" and makes certain references to the "Antares Solar Farm."

a. Please identify a project of Petitioner's that was determined, legally, to have a "substantial adverse environmental effect in the state."

b. Notwithstanding the irrelevance of the "Antares Solar Farm," and litigation involving same as it relates to the instant Petition, please identify the corrective action(s) the court imposed upon the defendant in that case, as a result of the testimony of Mr. Steve Trinkaus, PE in that case.

c. Please identify the similarities and differences in engineering design and geotechnical testing between the "Antares Solar Farm," as referenced, and the current iteration of the site plans for the present Petition.

RESPONSE: Whether there has been a project by GRE or its affiliated companies that has been "determined, legally, to have a 'substantial adverse environmental effect in the state'" is irrelevant. As GRE, and likely the Council, is well aware, the Antares Solar Farm stormwater design failed to such a degree that DEEP issued a Notice of Violation and the East Lyme Inland Wetlands Agency (ELIWA) issued a Cease and Desist Order due to the pollution of offsite wetlands and watercourses. Photos of the project were included in a DEEP presentation on the substantial problems with stormwater designs for ground-mounted solar arrays. (CT DEEP 2020.) CEQ also weighed in on the matter, using the Antares project as an example of a deficiency in the permitting process for controlling pollution from stormwater runoff. (CEQ 2015.) CEQ found citizen complaints about the project to be strongly rooted in fact and not matching the expectations of relevant permits, statutes, and related documents, and concluded that the pollution to receiving streams as a result of heavy loads of sediment discharged from the Antares site could have been avoided with adequate stormwater controls.

Given that the agency charged with protecting the environment in this state, as well as the local wetlands agency, issued cease and desist orders, and that DEEP went so far as to use the Antares Solar Farm as a cautionary tale in a public presentation in January 2020 (*see* CT DEEP 2020), STR-STH's position that the Antares Solar Farm had a substantial adverse environmental effect is reasonable, as is its position that the developer is responsible for the wetland and tributary destruction that occurred in 2014 due to that project (all of which is documented in the Town of East Lyme's records). Mr. Trinkaus was identified as an expert witness for the plaintiff property owner, John Bialowans, in his litigation against Greenskies with respect to the Antares Solar Farm, and was deposed by Attorney Hoffman. Mr. Trinkaus submitted two reports in connection with that litigation, detailing the reasons the stormwater design at the Antares Solar Farm failed. Rather than counter the merits of those reports with its own experts, Greenskies took advantage of Mr. Bialowans' status as a pro se plaintiff to attack Mr. Trinkaus' credentials, claiming that he was not qualified to review the stormwater plans – despite his more than 40 years of designing and reviewing stormwater plans. As a pro se party, Mr. Bialowans simply did not understand how to lay a proper foundation to qualify Mr. Trinkaus as an expert witness by demonstrating his qualifications as a professional engineer, or to lay the foundation for documentary evidence. As a result, Mr. Trinkaus was unable to testify in court, his reports were not admitted into evidence, and the case was ultimately dismissed without any review of the merits. The technical issues regarding the adverse impacts on the

Bialowans property from the stormwater runoff from the Antares Solar Farm were never considered on the merits by a court such that it could make a legal determination as to its adverse effect – but that effect is clear to anyone looking at the photos of the destruction caused by that project, and it was clear to the two agencies that issued cease and desist orders. Ultimately, CEQ concluded that the Antares matter illustrated four weaknesses in the state's regulation of stormwater, namely: weak enforcement tools, no turbidity standards, outdated rainfall expectations, and no specific provisions for the unique potential problems caused by large solar energy installations. (CEQ 2015) Many of these issues remain of concern to STR-STH with respect to GRE's now-revised project.

With respect to subsection (c) of the interrogatory, similarities in the design of this project and the Antares Solar Farm in East Lyme include the following significant errors in both projects: (1) the solar panels are not considered to be impervious; (2) large portions of the sites were to be regraded, and the Soil Class for post-development conditions was not properly adjusted from pre-development conditions (in East Lyme, not stepped down at all, in this petition, stepped down only one level rather than two); and (3) runoff did not occur in East Lyme and will not occur in this petition as overland flow perpendicular to the panel rows on the majority of the site, but instead as concentrated flow parallel to the panel rows. In the Antares project, topsoil was removed from the site and not brought back to facilitate the establishment of grass, as the grass cover was very poor at the time Mr. Trinkaus inspected the site in the fall of 2018, and no soil testing of any kind was conducted on the site. In this revised project, GRE has conducted some soil testing, but as discussed below in response to Interrogatory 18, STR-STH does not believe that testing was adequate to capture the soil properties of the Site.

14. Explain quantitatively whether STR-STH is claiming that there is any increased runoff volume from the site from that which the Petitioner has proposed in its stormwater mitigation plans.

RESPONSE: Based upon a quantitative analysis of the Antares Solar Farm in East Lyme, the peak rates of runoff and runoff volumes were under-estimated by approximately 40%. The charts below illustrate these data and are taken from a letter from Trinkaus Engineering to Leslie King, Esq. at Murtha Cullina, dated December 19, 2018 (attached). Because the solar panels are not considered to be impervious in GRE's designs for this Site, the peak rate and runoff volumes on this Site would likewise be at least 40% higher than GRE has claimed.

Table #1

Post-Development Watershed Area	BL Companies	Trinkaus #1	Net Change/ Percent Change	Trinkaus #2	Net Change
Peak Rate	cfs	Cfs		cfs	
A-1	5.36	5.63	+0.27/5.0%	7.66	+2.30/22.9%
A-2	5.52	6.49	+0.97/17.6%	8.25	+2.73/49.4%
A-3	7.12	8.35	+1.23/17.3%	10.60	+3.48/48.9%
A-4	5.11	5.97	+0.86/16.8%	7.53	+2.42/47.3%
A-5	7.43	14.32	+6.89/92.7%	18.13	+10.70/144.0%
B-1	3.40	4.15	+0.75/22.0%	4.97	+1.57/46.2%

Table #2

Post-Development	BL Companies	Trinkaus #1	Net Change/ Percent Change	Trinkaus #2	Net Change
Runoff Volume	cubic feet	cubic feet		cubic feet	
A-1	0.530	0.556	+0.026/4.9%	0.732	+0.202/38.1%
A-2	0.545	0.629	+0.084/15.4%	0.786	+0.241/44.2%
A-3	0.715	0.826	+0.111/15.5%	1.032	+0.317/44.3%
A-4	0.542	0.624	+0.082/15.1%	0.776	+0.234/43.4%
A-5	0.774	0.898	+0.124/16.0%	1.121	+0.347/44.8%
B-1	0.312	0.375	+0.063/20.2%	0.446	+0.134/42.9%

15. Has the Petitioner performed channel protection volume computations in accordance with the 2004 Connecticut Stormwater Quality Manual?

RESPONSE: No. GRE's Channel Protection Volume computations are not in accordance with the 2004 Manual. The post-development runoff rates are under-estimated because they are based on the assumption that the solar panels are not impervious.

16. Referring to Point No. 3 of the STR-STH Correspondence, clearly identify the "stormwater issues in the Waterford Petition" referred to in the last two lines of page 2 of that correspondence and the reasons for those issues.

RESPONSE: Generally, the stormwater issues referenced include the following:

- under-estimated peak rates and runoff volumes for post-development conditions (because solar panels not considered impervious, and soil class for proposed graded area was not lowered sufficiently to account for the soil properties adversely changed as a result of the grading);
- both stormwater ponds and infiltration basins (including sand filters) are not designed in accordance with the requirements found in the 2004 Manual (because the basins do not include the minimum requirements of pre-treatment of a percentage of the required water quality volume, dimension standards for length to width ratio, vertical separations to groundwater and/or bedrock); and
- water quality of the non-point source runoff is not being addressed (because none of the stormwater basins contain the required components per the 2004 Manual, which are necessary to reduce non-point source pollutant loads).

17. Page 3 of the STR-STH Correspondence states: *Another reason STR-STH does not trust the Petitioner is that STR-STH was notified by a group that owns land adjacent to the proposed Waterford solar site. This adjacent property contains Stony Brook and several of its tributaries as well as wetlands. The group reported that the Petitioner was asking them if they would sell acres of their land or grant an easement on their land for "stormwater mitigation purposes."*

a. Please identify the "group" referred to herein.

b. Please provide copies of all correspondence between STR-STH and the referenced group.

c. Is Intervenor aware that the CTDEEP specifically asked Petitioner to investigate the possibility of acquiring land control on adjacent parcels of the Site to expand the project's boundaries?

RESPONSE: STR-STH objects to the demand that it produce all correspondence between it and "the referenced group," as such communications would be irrelevant to this proceeding and duplicative of the admissions of one of GRE's own principal's statements to one of STR-STH leaders, as described below. Notwithstanding that objection, STR-STH responds as follows: The referenced "group" is a group of landowners who own the property directly to the south and east of the Site. The spokesman for the group, Gil Strickland, spoke with Ms. Moshier-Dunn, VP of STR-STH, over the phone and informed her that GRE had offered first to purchase and then to lease 14 acres of the group's property for "stormwater mitigation," but that GRE was not clear with respect to what part of the property it was interested in. Mr. Strickland asked Ms. Moshier-Dunn to contact GRE to ask why it was offering to buy or lease some of the group's land. Ms. Moshier-Dunn called Ryan Linares of GRE, and he confirmed that GRE was originally interested in purchasing part of the group's land but they had instead decided to try to lease it. Mr. Linares said he was not sure why GRE was pursuing the land, as it was not decided within his department.

With respect to subsection (c) of this interrogatory, STR-STH is not aware of any such request by DEEP, and is frankly surprised by the apparent admission that such a request was made. Assuming DEEP actually requested that GRE obtain land on an adjacent parcel to expand the project's boundaries, STR-STH asks that all written communications about that request be made part of the record of this proceeding, as they would be highly relevant to the Siting Council's decision here. If that request was indeed made of GRE, it would only serve to prove STR-STH's point, namely, that the design proposed by GRE contains inadequate stormwater and erosion controls that will be overwhelmed. Any request by DEEP that GRE secure more property, outside of the Site's boundaries, upon which to employ more stormwater mitigation measures would be proof that DEEP does not believe GRE's design is adequate and will need to go onto adjoining land to correct this problem. If the Site does not have sufficient land to handle stormwater mitigation, or more land is needed for any other purposes, the Siting Council and other interested parties should be aware of what they are before any decisions are made regarding this petition.

18. Regarding Intervenor's assessment that on page 3 of the STR-STH Correspondence, "the design of the stormwater management has not materially changed from the original application," please explain how the following "changed conditions" and redesign of the Project does not constitute a "material change": (1) the investigation of approximately 100 soil test pits across the Site; (2) the incorporation of engineered water quality treatment features into the Project design; (3) the utilization of a stepped-down Hydrologic Soil Group for hydrologic peak-flow rate analysis; (4) meeting State guidance relating to stream/channel protection; and, (5) completing all requested wildlife studies by CTDEEP resulting in NDDB concurrence on no impact to wildlife.

RESPONSE: STR-STH objects to this inquiry as an improper contention interrogatory that does not comply with the Siting Council's rules of practice. Notwithstanding that objection, STR-STH responds as follows to each point raised by GRE: (1) The soil test holes are an improvement over the original petition. However, many areas of the Site have no test holes, primarily in the area of the proposed solar panels, and it is the professional opinion of Mr. Trinkaus that the soil investigation conducted is therefore inadequate for understanding the geological conditions within the large areas of the solar panels. The locations of the soil testing by Terracon and VHB are only shown on a reduced scale map of the site and are not shown on the actual site plans reflecting the locations of the stormwater basins and solar panels, making it difficult to relate the soil test locations to those of the stormwater basins and the solar array. (2) None of the proposed stormwater basins contain the required components required by the 2004 Manual to address water quality. The missing components include forebays, long flow paths from inlet to outlet, micro-pools and appropriate vegetation. (3) GRE did drop down the Soil Class value by one class for post-development, but this is not adequate for those areas being regraded, where the step down basis should be two classes. Areas where the grade is being changed by cutting or filling of 2 feet or more will have little to no infiltrative capacity as the soil porosity (void spaces within the soil profile) is eliminated by that grading so that there is no ability for runoff to infiltrate the soil profile. (This condition was clearly present at the Antares Solar Farm, as the ground surface was almost as compacted as concrete when walked on.) (4) The design of the stormwater management system does not comply with the Channel Protection requirements found in the 2004 Manual because the solar panels were not considered impervious.

With respect to subsection (5) of this interrogatory, *see* STR-STH's response to Interrogatory 28, below, with respect to STR-STH's conclusions about the inadequacy of GRE's wildlife studies. In sum, STR-STH believes that GRE's conclusion is neither accurate nor justified, as nowhere in the NDDB Determination of February 28, 2020 is there a statement of "concurrence on no impact to wildlife."

19. Does STR-STH agree that the Project's revised stormwater management design includes 14.1 +/- acre-feet of basin storage, as compared to the original design of 6.4 +/- acre-feet, thereby representing a 120 (%) percent increase in basin storage? If not, please explain why not.

RESPONSE: Whether the storage volume has increased 20% or 120% is irrelevant if the increase is still inadequate to control the runoff of the proposed project. Here, although the storage volume has been increased, it is still inadequate to control the runoff volumes from the proposed solar array because the solar panels were not considered impervious in the post-development analysis. That means that the amount of runoff both in terms of rate and volume are under-estimated. Additionally, according to the site plans, only a singular spillway will be used to control the flow of runoff out of all basins and the invert (bottom) of the spillway is located an average of three (3) feet above the bottom of the basin. This will result in the nominal water surface in the basin being located at the invert elevation, so that the storage volume below the invert is not available to runoff. Only the volume above the invert of the spillway to the top of the berm will be available for the storage of runoff, thus the actual available storage volume for runoff is actually substantially less than the 120% GRE is claiming above. This is true for all stormwater practices which are not proposed as infiltration basins. There are also issues with the infiltration basins which reduce their functional storage volume, such as using percolation test data and not Double Ring Infiltration tests. Double Ring Infiltration tests only measure the vertical infiltration rate into the soil which is used for the design of stormwater infiltration practices. Percolation tests measure both the horizontal and vertical movement of water into the soil, thus over-estimating the vertical infiltration of water into the soil. In many cases, the infiltration basins also do not provide the required 36" vertical separation to seasonal groundwater as required by the 2004 Manual.

20. Refer to Page 3 of the STR-STH Correspondence, wherein Intervenor provides:

Our review of the current design proposed by the petitioner discovered that it does not address the significant increases in runoff volume that would be generated by the proposal.

a. Please provide documentation and evidence that shows how the current design of the Project fails to adequately address associated stormwater runoff.

b. Has Intervenor investigated the respective discharge locations of the proposed stormwater basins at the Site?

c. Please provide all stormwater calculations that were completed to demonstrate that the Petitioner did not address the "significant increases in runoff volume" that would be generated by the proposal.

RESPONSE: STR-STH objects to subsection (a) of this interrogatory as premature to the extent that it is seeking a detailed expert witness opinion in advance of the deadlines for submission of prefiled testimony in this proceeding. STR-STH further objects to this interrogatory as unduly burdensome and duplicative, as STR-STH's evidence for its opinion is cited throughout these interrogatory responses and indeed was cited in the STR-STH Correspondence. Notwithstanding that objection, and reserving its right to expand on and/or amend this response in the submission of prefiled testimony, STR-STH responds as follows: Generally, and as stated repeatedly throughout these interrogatories, the most fundamental problem with the design of the Project, and the reason it fails to adequately address associated stormwater runoff, is the assumption that the solar panels are not impervious. They are in fact impervious structures. Water will hit them and run off of them in predictable ways; yet, GRE has not accounted for that increased runoff volume, velocity, or flow path. That underlying erroneous assumption is a fatal flaw, and not one that can be corrected in the "details" of a development and management plan. That assumption means that all of the stormwater control features designed by GRE to handle runoff will be overwhelmed and will fail, resulting in erosion and sedimentation of the brooks and tributaries that lead directly to the Niantic River.

STR-STH has not investigated the discharge locations physically on the Site itself; like the Council and its staff, it is relying on GRE's site plans, and it has reviewed those plans and observed the outlet points for each basin on those plans. STR-STH has not conducted stormwater calculations to support its position that GRE has not addressed the significant increases in runoff volume because those calculations are not necessary to reach that conclusion. However, because the assumptions made by GRE in this petition are identical to those used by its affiliate, Greenskies, in the Antares Solar Farm, the computational analysis set forth above in response to Interrogatory 14 and provided in the attached letter from Mr. Trinkaus to Ms. King in connection with the Bialowans/Antares litigation would be virtually identical for this Site, except all the values would be higher because GRE's proposed project is more than twice the size of the Antares Solar Farm.

21. Page 3 of the STR-STH Correspondence states, in pertinent part: *instead of the overland flow that occurs in the forest today, the petitioner will create multiple points of discharge where concentrated flow will occur*. Please provide calculations that demonstrate how the Project will affect "the overland flow that occurs in the forest today."

RESPONSE: No calculations are necessary to support that statement. A simple review of the existing and proposed topographic conditions and the location of the outlet points from the 15 proposed stormwater basins is all that is needed. In a natural undisturbed environment, runoff from rainfall will flow in perpendicular to the contour of the land until it reaches a wetland or stream. On flatter slopes, some of the rainfall may infiltrate depending upon the ground cover, thus reducing the amount of surface runoff. On steeper slopes, little if any infiltration will occur, thus most of the rainfall becomes runoff. GRE's stormwater management design uses swales to collect overland flow and redirect it to one of the stormwater basins. Each basin has a spillway as an outlet, which is point discharge; thus, concentrated flow will occur. While GRE's site plans show a 40′ wide energy dissipator at the end of the spillway, the dissipator is basically a hole lined with riprap, which will not spread the flow out across the 40′ length. Runoff will find the lowest point on the downhill side of the dissipator and this is where the majority of runoff will go, because the low point becomes the point of least resistance for the movement of water. With the exception of Basin #8, all of the other discharge points are not located where there is currently a topographic condition, which would see slightly concentrated flow. When concentrated flow is discharged onto a slope that has not previously (under natural conditions) experienced concentrated flow, erosion and downgradient sedimentation will always occur.

22. Explain, quantitively, how the design of the Project's stormwater management plan is not in compliance with "sound engineering practices." Please provide copies of the "sound engineering practices" that have been referred to and/or consulted by Intervenor.

RESPONSE: "Sound Engineering Practices" are comprised of educational knowledge and real-world experience, which allow design professionals to perform work in their field of practice. Mr. Trinkaus relied upon the following education and experience in formulating his professional opinions: (1) knowledge of soils, land cover and the hydrologic response of forested sites as part of his Bachelor of Science in Forest Management from the University of New Hampshire in 1980; (2) 40 years of experience designing stormwater management systems for all types of land development projects, including ground-mounted solar arrays; and (3) local, regional, national and international expertise in Low Impact Development strategies to address runoff volumes and non-point source pollutants.

23. On page 3 of the STR-STH Correspondence, Intervenor states: *It is frustrating for STR-STH to watch as solar companies claim to be following regulations when they could be doing more to prevent stormwater runoff by changing their underlying assumptions. Assumptions that are obviously wrong to the untrained eye when you see the actual amount of runoff in the pictures shown in the DEEP presentation.*

a. Please clarify the following statement: "…solar companies claim to be following regulations when they could be doing more to prevent stormwater runoff by changing their underlying assumptions."

b. Please identify the "underlying assumptions" referred to herein.

RESPONSE: Stormwater designs for solar arrays in East Lyme, Old Lyme, Pomfret, and Waterford did not consider the solar panels to be impervious, which is a faulty assumption and thus the stormwater management systems (when proposed) are insufficient to handle the runoff that is actually generated by the solar array. All of the stormwater management designs for these solar arrays, which STR-STH and Mr. Trinkaus have reviewed, only provide the bare minimum protections to address the runoff – which results in failures like that at the East Lyme Antares site, with cease and desist orders issued, and at the Woods Hill Solar, LLC site in Pomfret, with orders that eventually resulted in a 2018 consent decree with DEEP for violation of the General Permit that included a civil penalty of $575,000 and a requirement to fund a supplemental environmental project for another $287,500. (Copy of consent order attached to these responses.) Many of the stormwater designs are based upon incorrect assumptions that the runoff will flow occur in a certain manner as overland flow or will simply infiltrate into the ground. In reality, infiltration is minimal if at all and runoff is flowing as concentrated flow. The "underlying assumptions" made by solar developers include the following: (1) solar panels are not impervious because there is grass growing under the panels; (2) runoff will always occur as overland flow and not become concentrated; (3) grading has no effect on the porosity of the soil and thereby, the infiltrative capacity of the soil; (4) the post-development vegetative cover under and between the rows of solar panels is in Good Hydrologic Condition.

24. Does any portion of the Project's proposed solar panel array drain directly to Oil Mill Brook prior to entering a tributary thereof?

RESPONSE: STR-STH objects to this interrogatory because as the petitioner, GRE should be able to answer that question itself based on its design work, rather than asking a non-profit group to do the work for it. STR-STH further objects to this interrogatory to the extent GRE is implying that the only way the proposed project could have an adverse environmental effect on Oil Mill Brook would be by draining directly in to the brook. Notwithstanding these objections, STR-STH responds as follows:

No. However, the access road has a direct connection to the brook over the main (paved) road (less than 80 feet from base of access road to the brook). There are no provisions for handling runoff on the road, which is very narrow in its current condition. The road likely will require improvements to provide access for construction equipment, but no improvements are proposed for the road; those improvements, which the Town agrees must happen, will impact Oil Mill Brook. Moreover, while the solar panels array does not drain toward Oil Mill Brook, the outlet from Basin #1 drains to a wetland with an imbedded vernal pool, and then to an intermittent watercourse that runs roughly parallel to Oil Mill Brook and ultimately directly to the Niantic River. GRE has failed to address how the discharge from Basin #1 will affect the hydro-period of the vernal pool and the impacts to species which use the vernal pool for breeding, or the capacity of the intermittent stream to handle the increased runoff from the Site as it drains through the vernal pool.

25. What is the closest distance (in feet) that any portion of the Project's proposed solar panel array is to Oil Mill Brook?

RESPONSE: STR-STH objects to this interrogatory because as the petitioner, GRE should be able to measure that distance itself based on its design work, rather than asking a non-profit group to do the work for it. STR-STH further objects to this interrogatory to the extent that GRE is implying that distance from the array to Oil Mill Brook is the only way to measure the adverse environmental effect the proposed project would have on the brook. Notwithstanding these objections, STR-STH responds as follows: From the nearest solar panels to Oil Mill Brook, the direct line distance is 850 feet. From the nearest proposed panel clearing limit to Oil Mill Brook is 560 feet, and from the access road to Oil Mill Brook is 80 feet.

26. What is the closest distance (in feet) that any portion of the Project's proposed solar panel array is to Stony Brook?

RESPONSE: STR-STH objects to this interrogatory because as the petitioner, GRE should be able to measure that distance itself based on its design work, rather than asking a non-profit group to do the work for it. STR-STH further objects to this interrogatory to the extent that GRE is implying that distance from the array to Stony Brook is the only way to measure the adverse environmental effect the proposed project would have on the brook. Notwithstanding these objections, STR-STH responds as follows: From the solar array to the main brook, the direct line distance 925 feet. From the array to the nearest intermittent tributary is 0 feet (at Basin #8).

27. A final determination by NDDB was issued for the Project on February 28, 2020; it was submitted to the Siting Council as part of the Intervenor's April 6, 2020 Interrogatory Responses to the Council as Exhibit G. A copy of the NDDB determination is attached hereto for convenience. Please provide any comments regarding same.

RESPONSE: STR-STH believes the first sentence of the above interrogatory concerning the April 6 correspondence is factually incorrect, as the April 6 submission was actually prepared by GRE GACRUX LLC (the Petitioner), not STR-STH (the Intervenor) Nevertheless, STR-STH acknowledges that the February 28, 2020 NDDB determination is indeed Exhibit G of the April 6, 2020 GRE interrogatory responses. STR-STH's concerns about this NDDB determination are addressed in response to the following interrogatory.

28. Is STR-STH aware that Petitioner has received both a Preliminary Assessment and Final Determination from the CTDEEP's Wildlife Division, neither of which reference suggested studies of any aquatic species?

RESPONSE: STR-STH is aware of the DEEP NDDB Determination memorandum of February 28, 2020. STR-STH is also well aware of the DEEP letter of August 24, 2018 (date of cover letter; report itself was dated August 20; herein referred to as "August 24 letter"), which formed one of the bases for the denial of the first Petition No. 1347 by the Council.

With respect to GRE's question about aquatic species, STR-STH notes that the environmental analyst who prepared the NDDB memorandum was identified as being a Wildlife Biologist. DEEP has both a Wildlife Division and a Fisheries Division as part of its Natural Resources Bureau. The scope and responsibilities of these two divisions may be inferred by their names and by a perusal of the information available about the responsibilities of each Division, which may be found on the DEEP website (https://portal.ct.gov/DEEP/About/Main/Natural-Resources). STR-STH believes the omission of references to aquatic species is explained by the fact that the review was not conducted by a member of the Fisheries Division, and further believes that had that review been conducted, other conclusions may have been made with respect to aquatic resources. STR-STH also believes that the absence of a very specific directive by DEEP to undertake studies of aquatic studies should not give GRE a free pass to ignore the potential impact on aquatic resources, given the location and nature of the

Site and the content of DEEP's August 24 letter. In that letter, DEEP went into detail regarding watershed issues associated with the underlying petition and stated that:

> [T[he petition lacks recognition of the current hydrologic connections of this proposed development site to the shared watersheds of Stony Brook and Oil Mill Brook, or to their individual water quality assessments. This watershed contains a high water quality stream system as supported by over ten years of water quality data from DEEP, the U.S. Geological Survey, the local Niantic River Watershed Committee, as well as stream macroinvertebrate data and recent cold and cool water fisheries population and habitat evaluations. The Petition documents do not appear to sufficiently evaluate the proposed stormwater management systems for potential thermal and sediment impacts to downstream aquatic resources or describe any measures to mitigate any such potential adverse water quality impacts.

The letter went on to note information about assessments of the Niantic River (a DEEP priority coastal embayment) and Oil Mill and Stony Brooks, both of which are classified as Class A waters providing fish and wildlife habitat. Further, letter details describe the current impairment status of the Niantic River and concerns that the proposed project will worsen the river's water quality condition. Given the statements made by that DEEP analyst with respect to a lack of information and analysis of water quality and aquatic life (both macroinvertebrates and fishes), how could GRE *not* have undertaken studies of the two on-site streams and their biota as well as an evaluation of potential water quality impacts to both streams and the Niantic River? The need for a complete biological study that was strongly pointed out by DEEP was then directed to GRE by the Council in its denial without prejudice on October 26, 2018. STR-STH believes that the continued omission of aquatic studies to be a serious defect in the revised Petition No. 1347A, and notes that the lack of information on aquatic species may not be the only omission. The August 24 letter also states:

> The wildlife assessment was generally based on habitat with a focus on vernal pools and not on detailed surveys which may have identified state listed plants, presence/absence of bats or other animals, and state listed insects in the area. Breeding bird surveys were not conducted, although avian species were observed when biologists were at the site. Given the lack of available

> information, it is recommended that a comprehensive wildlife survey be conducted at the site.

With respect to the NDDB Determination noted in interrogatory #27, it is notable that the DEEP letter of August 24 stated "the site does not fall in an existing Natural Diversity Database area, but it is likely that this location has never been surveyed." Yet, a NDDB Determination was subsequently made because a ribbon snake was fortuitously sighted near a site wetland, presumably by GRE's consultant, Davison Environmental. STR-STH wonders if the person observing this specimen had been present an hour earlier or later or was onsite on another day if a ribbon snake would have ever been seen on this site. Subsequently, would the NDDB database for this quadrant have had any more information than it did before this sighting? (The ribbon snake is discussed in more detail in response to the following interrogatory.) This example illustrates that a lack of inclusion of aquatic species in a NDDB Determination is not evidence for the absence of any species of concern on the site. In fact, the NDDB Determination also clearly noted "consultations with the NDDB *should not be substituted for on-site surveys required for environmental assessments*." Presence or absence can only be determined by performing more complete systematic sampling of the communities of interest.

An illustrative local example of the adequacy of an NDDB Determination is the environmental work done in conjunction with the proposed Routes 82/85/11 transportation corridor improvements in the Towns of Salem, Montville, and East Lyme, all located just to the west of the Waterford site. Although no threatened or endangered fishes or other aquatic species were reported for this project study in the DEP (predecessor agency to DEEP) NDDB Determination, by the DEP Fisheries Division (apparently this Division was consulted for this work), or the U.S. Fish and Wildlife Service, biological surveys were nevertheless conducted to verify available information on aquatic species. (USFHA and CT DOT 2007.) These surveys revealed the presence of two state-listed stream invertebrates, the Eastern pearlshell mussel (*Margaritifera argaritifera*) and the tiger spiketail dragonfly (*Cordulegaster erronea*). (USFHA and CT DOT 2007.) Thus, sampling proved to be a better indicator of the actual presence of species of concern rather than in paperwork determinations, even ones completed by experts.

With respect to GRE's emphasis on the NDDB Determination, STR-STH also notes that VHB, GRE's consultant, stated:

> According to the U.S. Fish and Wildlife Service (USFWS) Information for Planning and Consultation (IPaC) tool, federally-listed species that may occur of the Project Site, and/or may be affected by the project include Small Whorled Pogonia (*Isotria medeoloides*) and Northern Long-eared Bat (*Myotis septentrionalis*; see Attachment 1 USFWS Consultation Response Letter dated September 17, 2019).

(Petition Ex. I, VHB memo, dated Oct. 2, 2019, at 1.) Yet, one page later, VHB notes "Northern Long-eared Bat surveys were not conducted because NDDB did not identify this species as potentially occurring on the site." (*Id.* at 2.) GRE's own wildlife consulted noted "This assessment does not address all biota that inhabit the site (e.g., bats, insects)." (Petition, Ex. H at 4.) STR-STH wonders why the information provided by the USFWS on a federally-listed bat species, as well as mentions of a lack of information about bats possibly residing on the site in the DEEP August 24 letter, were ignored during the wildlife studies.

Finally, it is laudable that GRE is so concerned over listed species, which are the subject of NDDB Determinations. However, given STR-STH's mission, it has a broader interest on all of the fish and wildlife populations that will be impacted by this development. The presence of brook trout in both adjacent streams and additionally brown trout (possibly of sea-run origin) found in Oil Mill Brook (Cole Ecological, Inc. 2016) are of great concern to STR-STH. These fishes are indicative of very good water quality, as are the suite of aquatic insects also found in these streams. This issue was even highlighted by GRE's own wildlife consultant (Petition

Exhibit H at 9), who stated that "Brook trout are an indicator of high water quality, requiring cold well-oxygenated waters, with temperatures not exceeding the upper 60s Fahrenheit." Wild trout populations are not common in Connecticut due to their specific habitat requirements for cool, clean waters, and they should be protected. Knowledge of other listed aquatic species of concern, such as mussels, is lacking. This is one of the reasons why an assessment of aquatic biota should have been undertaken by GRE, as was most certainly mentioned by the DEEP August 24 letter.

29. Please refer to the CTDEEP Wildlife Division's Final Determination for the Project. Therein, did the Wildlife Division indicate that, because the contractor will be following prescribed avoidance measures for Eastern Ribbon Snakes, tree-clearing can occur between April 1st and October 15th?

RESPONSE: The February 28, 2020 NDDB Determination **did not** specifically state "tree-clearing can occur between April 1st and October 15th." It did, however, state "if work, traffic or staging will occur within the 300ft wetland buffer of 'wetlands' during the snakes [*sic*] active season (between April 1 – Oct 15) apply the following avoidance measures…" The latter measures included developing and implementing a contractor awareness program about the eastern ribbon snake, safely relocating any snakes outside of the work area, removing silt fences as clearing is completed and soils are stabilized, and reporting all confirmed sightings of this species to the NDDB. No mention is made of any other areas on the project site outside of wetland areas and the utility ROW, let alone granting wholesale permission for any tree clearing. Also included in the NDDB Determination was some brief information regarding the life history of the eastern ribbon snake, which noted its preference for sunny areas bordering streams and swamps and having a dormancy period from October 15 through March 31.

However, Klemens (1993) provided observational evidence that ribbon snakes can be found several hundred meters in horizontal distance and up to 100 meters higher in elevation from its typical waterside habitats during early April and after mid-September. Thus, this is evidence for additional critical habitat areas used by this species and also establishes a more restrictive temporal window for any potential site work. Klemens (1993) also brings up the issue of ribbon snake winter hibernacula, which he concluded could be found in rocky upland areas, but also near water where various types of cover might exist (e.g., the noted ribbon snakes using piles of railroad ties). The winter hibernacula issue was not discussed in any of the petition materials, so there is still a less than complete plan for protecting this species of Special Concern that can only be resolved by further environmental assessments.

In fact, GRE's wildlife consultant stated that "All clearing should occur between October 15th and March 1st, to prevent impacts to wildlife." (Petition, Ex. H at 10). This time period for no tree clearing would also be partially protective for any bat species roosting on the Waterford site. STR-STH notes that the wildlife studies associated with Petition Nos. 1310 and 1310A (Quinebaug Solar, LLC in Brooklyn/Canterbury) included bat surveys as a result of the NDDB listing of the Northern Long-eared bat for that site area. Although that species was not found during the Quinebaug bat surveys, two other species were inhabitants: the little brown bat and the tri-colored bat, both of which are state-listed as Endangered. This once again illustrates the necessity for undertaking complete wildlife surveys rather than relying solely on presumptions. To avoid potential impacts to these two bat species, which roost in trees on the Quinebaug site, the Siting Council, in its decision just last week, limited tree clearing to the period between October 1 and March 31. (Petition No. 1310A, Findings of Fact at 42 and Opinion at 8.) Given that the USFWS planning tool indicates a listed bat species may be on the Site, and that GRE has not presented any evidence that bats do not roost on the Site – because it knowingly chose *not* to conduct bat surveys – protective measures regarding tree clearing must be undertaken to protect listed bat species, just as GRE is proposing for the eastern ribbon snake.

STR-STH also notes the complete absence of any details presented regarding the vascular plant species Virginia copperleaf (*Acalypha virginica*; called Virginia three-seeded-Mercury by VHB biologists in Attachment 4 of Petition Exhibit I), which is also mentioned in the NDDB Determination of February 28, 2020. The latter notes:

> This plant is found in dry, open soils and bloom [sic] in August-September … Delineate and avoid impacts to this plant from construction activities. Where possible, encourage habitat characteristics that will promote the plant onsite. Additionally, please forward location information to our program for our records.

STR-STH believes GRE's information and plans to protect this plant should be part of the record of this proceeding as much as the aforementioned less than fully adequate plans for construction activities deemed necessary to protect the eastern ribbon snake.

30. On p. 7 of the STR-STH Correspondence, Intervenor notes that the carbon debt analysis for the Project assumes a 30-year project life. That is correct. Site control for the additional ten (10) years is achieved through two (2), five (5)-year extensions of the subject lease after twenty (20) years. With that being said, what is STR-STH's specific concern regarding same?

RESPONSE: STR-STH's concern is that GRE is presenting what it claims will be an environmental benefit of this project that is measured over 30 years, when the initial lease for the project is only 20 years, so it is possible that the project would only have any such benefits for 20 years. GRE should present the Siting Council, and the parties, with the full picture on its carbon debt claims. STR-STH is also concerned with the inconsistencies in the petition and its attachments, which at various times refer to the project life as 20, 30, or even 35 years. (*See* Petition at 10 ("Greenskies has full control of the parcel via a 20-year lease with the property owner. Greenskies can also extend the lease by an additional 15 years if needed.”); Petition Exhibit D, Cost Estimate, at 1 (“items from the array will be recycled, and many of these will have a salvage value in 20 years that exceed the cost of labor to remove them); Petition Exhibit D, Carbon Debt Analysis Memo, at 2 (“Estimated emissions generated, avoided, or sequestered were extended over a 30-year period – the assumed lifetime of the Project.”); Petition at 17 (“The project is proposed with at least a 35 year design life”); Petition, Exhibit I, Attachment C to Request for NDDB State Listed Species Review (“The anticipated project lifespan is 35 years and after that point the Project Area will be restored in accordance with a Decommissioning Plan.”).) The project life is significant for other reasons, including the decommissioning plan, which could impose a significant burden on the Town of Waterford. The Siting Council is charged with balancing the need for reliable energy sources against the public health and welfare and the environmental impact. Here, GRE is seeking to substantially modify the environment on this environmentally sensitive parcel of land, and is claiming that the benefits outweigh the risks because of the “green” electrical power that it will be providing, demonstrated in part by that carbon debt analysis. In STR-STH’s opinion, the environmental damage that will be caused by this project outweighs its benefits, given the relatively low capacity factor for photovoltaic power production in our state. STR-STH wants GRE to commit to the citizens and governments of the Town of Waterford and the State of Connecticut that if this project is approved, it will be operated for the entire period for which it was justified to the Council. A shorter period of operation will make any environmental impacts all the more onerous, given that the recovery period for this parcel of land following decommissioning will likely be lengthy regardless of when its operation ceases.

SAVE THE RIVER-SAVE THE HILLS, INC.

By: */s/ Emily A. Gianquinto*
Emily A. Gianquinto
EAG Law LLC
21 Oak Street, Suite 601
Hartford, CT 06106
Tel: (860) 785-0545
Fax: (860) 838-9027
emily@eaglawllc.com

CERTIFICATION

I hereby certify that a copy of the foregoing document was delivered by e-mail to the following service list:

Lee Hoffman
Pullman & Comley LLC
90 State House Square
Hartford, CT 06103-3702
lhoffman@pullcom.com

The Honorable Robert J. Brule
First Selectman
Waterford Town Hall
15 Rope Ferry Road
Waterford, CT 06385
rbrule@waterfordct.org
apiersall@waterfordct.org

Jean-Paul La Marche
Development Manager
Clean Focus Renewables, Inc.
jean-paul.lamarche@cleanfocus.us

Deborah Moshier-Dunn
VP, Save the River-Save the Hills, Inc.
P.O. Box 505
Waterford, CT 06385
debm0727@sbcglobal.net

/s/ Emily A. Gianquinto
Emily Gianquinto

EXHIBIT A
(responsive to Interrogatory #1)

North American Journal of Fisheries Management 34:119–131, 2014

ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2013.855280

ARTICLE

Summer Thermal Thresholds of Fish Community Transitions in Connecticut Streams

Mike Beauchene*
Connecticut Department of Energy and Environmental Protection, Inland Fisheries Division, 79 Elm Street, Hartford, Connecticut 06106, USA

Mary Becker and Christopher J. Bellucci
Connecticut Department of Energy and Environmental Protection, Bureau of Water Protection and Land Reuse, Planning and Standards Division, 79 Elm Street, Hartford, Connecticut 06106, USA

Neal Hagstrom
Connecticut Department of Energy and Environmental Protection, Inland Fisheries Division, 79 Elm Street, Hartford, Connecticut 06106, USA

Yoichiro Kanno[1]
U.S. Geological Survey, Silvio O. Conte Anadromous Fish Research Center, One Migratory Way, Turners Falls, Massachusetts 01376, USA

Abstract

Thermal tolerances have been studied for individual fish species but few have investigated how stream fish assemblages respond along a temperature gradient and which thermal ranges act as a threshold, triggering discernible community change. The purpose of this study was to define summer temperature thresholds of fish community transitions in Connecticut streams. The program Threshold Indicator Taxa Analysis suggested that the coldwater class had a June–August mean water temperature < 18.29°C, the coolwater class 18.29–21.70°C, and a warmwater class > 21.70°C. Significant indicator species of coldwater streams were Slimy Sculpin *Cottus cognatus* and Brook Trout *Salvelinus fontinalis.* Significant indicator species of warmwater streams were Cutlip Minnow *Exoglossum maxillingua*, Smallmouth Bass *Micropterus dolomieu*, Rock Bass *Ambloplites rupestris*, Brown Bullhead *Ameiurus nebulosus*, Redbreast Sunfish *Lepomis auritus* and Yellow Bullhead *A. natalis*. The narrow 3.41°C temperature range between the coldwater and warmwater thresholds was designated as a coolwater transition zone, with potential for the presence of both coldwater and warmwater species and lack of species uniquely associated with this thermal range. Our approach based on a robust set of water temperature and fish community data should be applicable to other temperate regions and will be useful for informing development of thermal criteria, application of multimetric indices, and planning for anticipated effects of climate change.

Stream temperature is an important environmental variable for aquatic ectotherms. Stream temperature affects survival (Xu et al. 2010), growth (Sloat et al. 2005), spawning timing (Warren et al. 2012), abundance (Merten et al. 2010), and geographic distributions (Buisson et al. 2008) of fish. Thermal requirements and preferences have been studied for many freshwater fishes (Coutant 1977; Carveth et al. 2006; Hartman and Cox 2008; Underwood et al. 2012), and fisheries managers have

*Corresponding author: mike.beauchene@ct.gov
[1]Present address: School of Agricultural, Forest, and Environmental Sciences, Clemson University, Clemson, South Carolina 29634, USA.
Received July 2, 2013; accepted October 8, 2013

traditionally classified their inland fishes as coldwater, coolwater, or warmwater species (Eaton et al. 1995; Stoneman and Jones 1996). Biological monitoring using stream fish communities has applied different sets of indicators for coldwater (Lyons et al. 1996; Kanno et al. 2010), coolwater (Leonard and Orth 1986; Lyons 2012), and warmwater (Karr 1981; Smogor and Angermeier 2001) streams.

Understanding thermal thresholds at the community level is critical for sound fisheries resources management. Stream temperature is influenced by a number of anthropogenic factors including construction of dams (Sinokrot et al. 1995), riparian zone modification (Gaffield et al. 2005; Isaak et al. 2010), groundwater extraction (Markle and Schincariol 2007), and urbanization (Nelson and Palmer 2007). Climate change is potentially a major threat to stream biota (Ficke et al. 2007). In particular, the impact of climate change on coldwater streams is of great interest to natural resources managers, but the magnitude of such an impact is uncertain and will vary spatially (Chu et al. 2008; Isaak et al. 2010; Velasco-Cruz et al. 2012). Protective measures of fisheries resources will depend upon identifying thermal thresholds at which discernible changes in biological communities occur, as well as improving our abilities to predict changes in stream temperatures in response to anthropogenic activities.

Although simple in concept and potentially useful in fisheries resources management, it is challenging to quantify thresholds associated with noticeable fish community changes along a thermal gradient. Lyons et al. (2009) defined coolwater streams in Michigan and Wisconsin as those having June–August mean temperatures of 17.0–20.5°C, but two subgroups were identifiable within their coolwater streams: “cold transition” (17.0–18.7°C) and “warm transition” (18.7–20.5°C). Thus, our abilities to classify streams thermally rely upon precise measurements of stream temperatures and analytical techniques that can identify subtle changes in taxonomic composition. However, a robust stream temperature data set has not been used in thermal classifications of fish communities. Thermal classifications have been attempted based on single measurements of daily maximum air and water temperatures (Stoneman and Jones 1996; Chu et al. 2009) or model-predicted stream temperatures (Lyons et al. 2009; McKenna et al. 2010). Continuous monitoring of stream temperatures temporally over a spatially dispersed area is now feasible due to technical developments in temperature-measurement devices. In addition, analyses of fish community patterns have nearly always used certain multivariate approaches, particularly ordination and cluster analyses (Maret et al. 1997; Kanno and Vokoun 2008; Lyons et al. 2009). These approaches may not identify community thresholds with precision and mask taxonomic contributions to the community shift patterns (Baker and King 2010).

Identifying thermal thresholds and characterizing fish community types has met challenges in Connecticut. The state harbors coldwater streams dominated by the families Salmonidae and Cottidae, and warmwater streams occupied by a greater diversity of species (e.g., families Cyprinidae and Centrarchidae). Yet, a good portion of wadeable streams in Connecticut appear to be inhabited by both coldwater and warmwater species (i.e., coolwater streams). Kanno et al. (2010) developed two indices of biotic integrity in the region, the first for coldwater streams and the second for all other wadeable streams (“mixed-water” streams). However, the lack of an objective assessment of thermal classifications is an obstacle in their practical applications. Co-occurrence of coldwater, coolwater, and warmwater streams is a common feature in many temperate regions of North America (Vannote et al. 1980; Chu et al. 2008; Lyons et al. 2009). Still, characterization of how fish communities respond along the thermal gradient, especially the transition between cold water and warm water is poorly understood.

This study was initiated to describe summer thermal thresholds and fish community transitions for Connecticut streams. Our objectives were to (1) identify thermal thresholds that trigger fish community changes using three summer temperature metrics (Lyons et al. 2009), and (2) describe taxonomic composition and indicator species of each fish community.

METHODS

Fieldwork.—This study was based on stream fish survey and water temperature data collected at 160 sites located on primarily wadeable, perennial, first- to fourth-order streams that contained a mix of riffle, run, and pool habitat types across Connecticut (Figure 1). We omitted sites with substantial habitat alterations (e.g., immediately downstream from a dam, adjacent to significant stream diversion, or contained within flood control channels), or ones that were low gradient (dominated by pool–glide habitat and having fine silt–sand substrate).

Our analysis included 212 paired fish community and water temperature samples collected between 2002 and 2011. The majority of the 160 sites had one fish community sample and one temperature data set during the same year, although 36 sites had more than one pair collected during multiple years. Fish were collected primarily during base flow conditions, the months of June and July, to maximize capture efficiency. In addition, these months correspond to the time of the year when temperature differences between coldwater, coolwater, and warmwater streams are greatest in Connecticut (see Results). Fish were collected by a crew of 4–8 people using pulsed-DC electrofishing (Smith-Root model L-24 backpack electrofisher, Smith-Root, Vancouver, Washington; or Coffelt model BP-4 backpack electrofisher, Coffelt Manufacturing, Flagstaff, Arizona, or a tote-barge with a Coffelt model VVP-2 electrofisher, powered by a generator). In general, the sampled reach lengths were between 100 and 150 m and total electrofishing time per reach ranged from 15 to 35 min. Reach lengths were determined by trying to target a length of 15–30 times the stream width to characterize fish community composition (Dauwalter and Pert 2003; Reynolds et al. 2003). After a single pass in a stream reach, all fish were identified

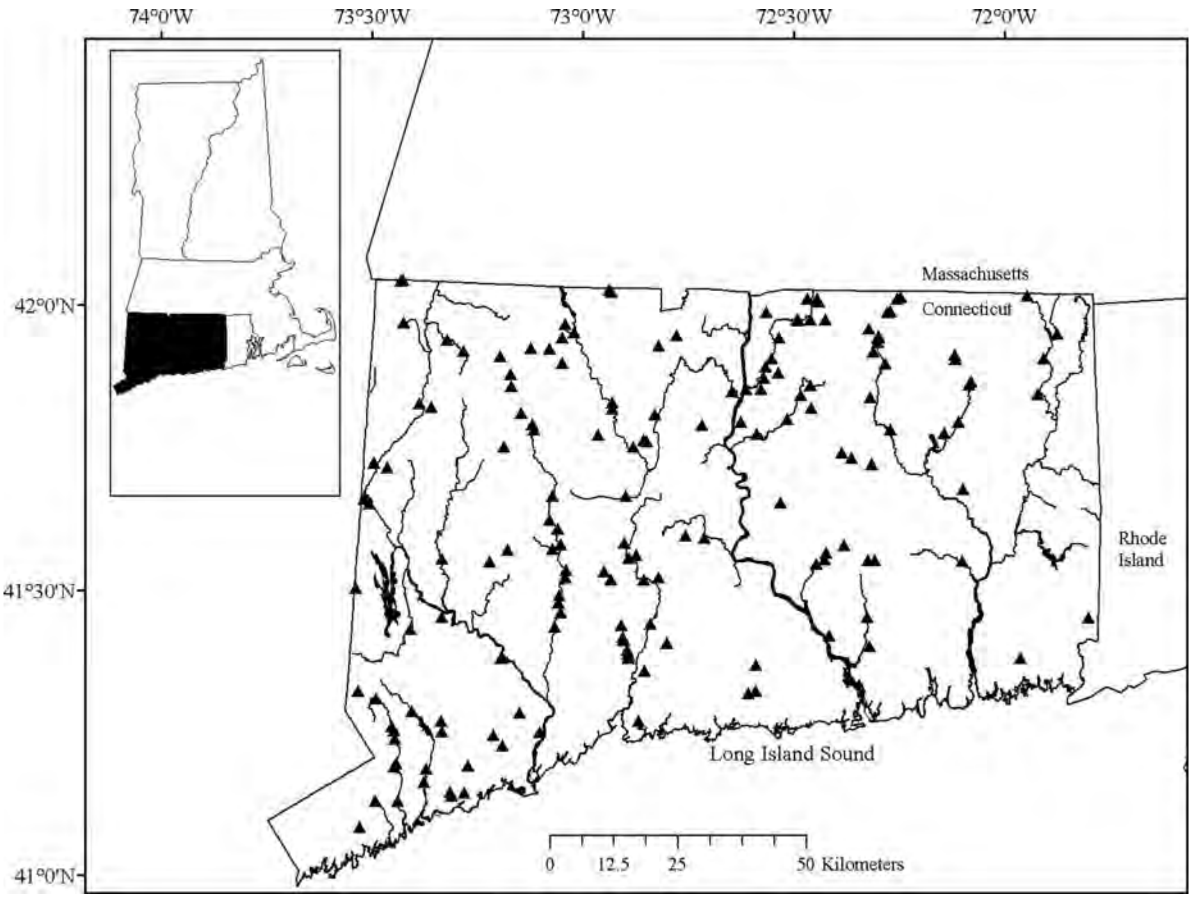


FIGURE 1. Site locations (solid triangles) in Connecticut where fish community and water temperature data were collected.

to species, measured to nearest centimeter, and returned to the stream.

Stream water temperatures were collected hourly using data loggers (TidBit v2 Data Logger and Pro v2 Data Logger, ONSET Computer Corporation, Bourne, Massachusetts) deployed in the thalweg of the same stream reach where we sampled the fish community. Prior to deployment, all data loggers went through a quality control procedure using an ice bath to ensure that accuracy was within the manufacturer's specifications (CT DEEP 2012). Once the data loggers passed the quality control procedures, they were placed in PVC pipe, secured to weighted angle iron, placed in the stream location with adequate depth to keep the probe submerged throughout the duration of the deployment period, and covered with large rocks to secure from high stream flows and prevent discovery and reduce vandalism. The data loggers were deployed year round, but were visually inspected approximately every 6 months, and data were downloaded during site visits. After each deployment, water temperature values were reviewed for anomalies and quality-controlled values were stored in a relational database.

Statistical analysis.—Our analyses were based on commonly distributed fish species in Connecticut. Stocked salmonids (Brook Trout *Salvelinus fontinalis*, Brown Trout *Salmo trutta*, Rainbow Trout *Oncorhynchus mykiss*, and Atlantic Salmon *S. salar*), defined as adults or fry and fingerlings of hatchery origin, were removed from the data set and not included in analysis. Adult stocked salmonids are easily distinguished by the presence of multiple regenerated fins, damaged opercula, and bland coloration. Liberation records were used to identify sites where Brown Trout or Atlantic Salmon fry and fingerling stocking had occurred. At these sites all individuals were considered to be of hatchery origin as holdover individuals of these species are virtually impossible to distinguish from fish of similar size that were hatched within the stream. Species that occurred in less than 5% of the samples were removed because ecological thresholds cannot be reliably inferred for these rare species (Baker and King 2010). We calculated fish abundance per 100 m of stream to standardize count data among samples.

We calculated three water temperature metrics: June–August mean, July mean, and maximum daily mean (Lyons et al. 2009). We then used the program Threshold Indicator Taxa Analysis (TITAN) (Baker and King 2010) to identify change points in fish species response to thermal gradients and community-level temperature thresholds by considering aggregate changes across species. We ran TITAN to identify thermal thresholds for each of the three water temperature metrics. The TITAN method integrates information on the occurrence, abundance, and directionality of taxa responses (Baker and King 2010) using indicator value (IndVal) scores (Dufrêne and Legendre 1997). The IndVal scores are calculated and used to associate individual taxa with either a positive or negative response across the observed continuous gradient, in our case a thermal gradient. The TITAN method identifies the point at which the maximum IndVal of the taxon occurs across the observed gradient as the observed change point and assigns the taxa to either a positive or negative partition. Evidence for community thresholds is identified by synchronous taxa response. The TITAN method standardizes the observed IndVal as z-scores and sums the z-scores of each individual taxon within each partition for every candidate change point across the observed thermal gradient. This standardization ensures that both common and uncommon species contribute equally to the community change analysis (Baker and King 2010). The largest sums for each positive and negative partition are identified as observed community-level change points. The TITAN program was written in Program R and the code is included in Baker and King (2010).

Bootstrap resampling was used to estimate uncertainty and identify significant indicator taxa by providing measures of indicator purity and reliability. Indicator purity provides information on the proportion of agreement between the observed change-point response direction (negative or positive) and the bootstrap replicates. Indicator reliability provides an estimate of how significantly different the data set is from a random distribution. Individual taxa were considered significant if at least 95% of the bootstrap runs indicated the same response direction as the observed response (i.e., high purity) and at least 95% of the bootstrap runs were significantly different from a random distribution at $P \leq 0.05$ (i.e., high reliability). Bootstrap replicates were also used to develop empirical confidence limits around the community level change points. Bootstrap replicates were run 500 times and used to define thermal classes for Connecticut streams. We used the 5% sum $z-$ from 500 bootstrap replicates to define the change point for cold water to cool water, and we used the 95% sum $z+$ from the 500 bootstrap replicates to define the temperature change point for cool water to warm water. This approach would result in a more liberal range of coolwater streams, compared with using the median values of sum $z+$ and sum $z-$. We chose our approach because coolwater streams are, by definition, a transitional zone where both coldwater and warmwater species co-occur (Lyons et al. 2009), and thus there is an inherent difficulty when characterizing the thermal range of the coolwater community precisely.

To further assess the temperature preferences of fish species and identify indicator species of cold, cool, and warm waters, we used an extension of the original indicator species analysis proposed by Dufrêne and Legendre (1997) that considers an association between indicator species of both individual site groups and combinations of site groups (De Cáceres et al. 2010). For example, one particular species may be associated with only cold waters, while another may be associated with both cold and cool waters. We assigned sites to one of the temperature groups based upon the TITAN cutoffs described above. The method looks at each possible combination of site groups and retains the strongest group association with the target species. We choose the square-root indicator value index (Sqrt IndVal) as the measure of association (De Cáceres et al. 2010). The indicator value index is composed of two metrics: the probability of a site belonging to a site-group combination when the species has been found at that site and how frequently the species is found at sites belonging to the site-group. The indicator value measure ranges from 0 to 1 with higher values representing a greater association with a particular site-group. Statistical significance of the association was evaluated with a permutation test that uses the maximum Sqrt IndVal for the test value. We ran 999 random permutations. Species with P-values < 0.05 were considered significant indicators of a particular site-group. Indicator species analysis was implemented using the "indicspecies" package version 1.6.7. in R (De Cáceres and Legendre 2009).

We also used the sum $z+$ and sum $z-$ scores from the TITAN runs as an additional measure of thermal preferences for stream fish. Each species was categorized as either an increaser ($z+$) or a decreaser (z–) through TITAN analysis of each of the three temperature metrics and the final response to temperature category was determined by simple majority of two out of the three metrics.

RESULTS

A total of 26 fish species were used in our analysis (Table 1). Blacknose Dace and White Sucker were the most common species and were present in 84.4% and 79.6% of the stream samples, respectively. Slimy Sculpin, Brook Trout, Brown Trout, and Redfin Pickerel were categorized as "decreasers" in response to increasing stream temperature (Table 1; Tables A.1–A.3 in the Appendix), although Redfin Pickerel was not a statistically significant species (purity $\leq$0.95, reliability $\leq$0.95, $P >$ 0.05 in response to any of the temperature metrics). All of the other species (22) were categorized as "increasers."

The 5th–95th percentiles of fish community change points overlapped between decreasers (sum $z-$) and increasers (sum $z+$) in all three temperature metrics (Table 2). Fish community change points for decreasers (sum $z-$) were 19.40°C for the June–August mean temperature, 21.00°C for the July mean, and 23.35°C for the maximum daily mean. The fish community change points for increasers (sum $z+$) were 20.50°C for the June–August mean temperature, 21.90°C for the July mean, and 23.30°C for the maximum daily mean.

As all of the species were consistently increasers or decreasers across three temperature metrics tested, except for Creek Chub (Tables 1, A.1–A.3); hence, we focused on the results for the June–August mean in the subsequent sections. Thermal classes for Connecticut streams using the June–August mean were defined as cold water, <18.29°C; cool water,

TABLE 1. The 26 fish species in order of decreasing percent occurrence among the 212 stream samples. Species response as an increaser or decreaser to increasing water temperature is based on the TITAN analysis.

Family	Species	Percent occurrence	Response to temperature
Cyprinidae	Blacknose Dace *Rhinichthys atratulus*	84.4	Increaser
Catostomidae	White Sucker *Catostomus commersonii*	79.6	Increaser
Anguillidae	American Eel *Anguilla rostrata*	64.0	Increaser
Percidae	Tessellated Darter *Etheostoma olmstedi*	63.0	Increaser
Cyprinidae	Longnose Dace *Rhinichthys cataractae*	58.3	Increaser
Centrarchidae	Bluegill *Lepomis macrochirus*	40.8	Increaser
Salmonidae	Brook Trout *Salvelinus fontinalis*	38.9	Decreaser
Cyprinidae	Common Shiner *Luxilus cornutus*	38.4	Increaser
Salmonidae	Brown Trout *Salmo trutta*	36.0	Decreaser
Cyprinidae	Fallfish *Semotilus corporalis*	35.5	Increaser
Centrarchidae	Pumpkinseed *Lepomis gibbosus*	35.1	Increaser
Centrarchidae	Largemouth Bass *Micropterus salmoides*	33.6	Increaser
Centrarchidae	Redbreast Sunfish *Lepomis auritus*	31.8	Increaser
Cyprinidae	Creek Chub *Semotilus atromaculatus*	21.8	Increaser
Centrarchidae	Smallmouth Bass *Micropterus dolomieu*	19.0	Increaser
Cyprinidae	Cutlip Minnow *Exoglossum maxillingua*	17.1	Increaser
Centrarchidae	Rock Bass *Ambloplites rupestris*	14.2	Increaser
Ictaluridae	Brown Bullhead *Ameiurus nebulosus*	11.4	Increaser
Cottidae	Slimy Sculpin *Cottus cognatus*	10.9	Decreaser
Esocidae	Redfin Pickerel *Esox americanus*	10.4	Decreaser
Ictaluridae	Yellow Bullhead *Ameiurus natalis*	10.4	Increaser
Cyprinidae	Golden Shiner *Notemigonus crysoleucas*	10.0	Increaser
Centrarchidae	Green Sunfish *Lepomis cyanellus*	9.0	Increaser
Percidae	Yellow Perch *Perca flavescens*	9.0	Increaser
Esocidae	Chain Pickerel *Esox niger*	7.6	Increaser
Petromyzontidae	Sea Lamprey *Petromyzon marinus*	5.2	Increaser

18.29–21.70°C; and warm water, >21.70°C (Table 3). Frequency and abundance of decreaser species sharply declined above the coolwater thermal range, while increaser species became more prevalent, suggesting a community shift across the thermal gradient for the July–August mean (Figure 2A, B). Similar patterns were observed for the other two metrics. The coolwater thermal range was 3.41°C for the June–August mean and less than 4°C for all three metrics.

Fourteen species were considered significant indicators (*P*-value > 0.05) of one or more temperature groups using indicator species analysis (Table 4; Figure 3). Two species were significant indicators of coldwater only (Slimy Sculpin and Brook Trout); six species were significant indicators of warm water only (Redbreast Sunfish, Cutlip Minnow, Smallmouth Bass, Rock Bass, Brown Bullhead, and Yellow Bullhead). No species were considered to be significant indicators for the coolwater range, 18.29–21.70°C. One species (Brown Trout) was a significant indicator for the combination of cold and cool waters and five species (American Eel, Tessellated Darter, Common Shiner, Bluegill, and Fallfish) were

TABLE 2. Threshold Indicator Taxa ANalysis (TITAN) community-level thresholds estimated from fish species responses to water temperature metrics (°C). The observed change point (CP) corresponds to the value of the *x* resulting in the largest sum of indicator value (IndVal) *z*-scores among all negative ($z-$) and positive ($z+$) taxa, respectively. Percentages (5%, 50%, 95%) correspond to change points from 500 bootstrap replicates and represent uncertainty around the CP.

	June–August mean				July mean				Maximum daily mean			
Method	CP	5%	50%	95%	CP	5%	50%	95%	CP	5%	50%	95%
TITAN sum ($z-$)	19.40	18.29	19.70	20.20	21.00	18.45	20.65	21.70	23.35	22.40	23.20	24.00
TITAN sum ($z+$)	20.50	20.00	20.35	21.70	21.90	21.50	21.90	22.30	23.20	23.00	24.23	26.30

TABLE 3. The three stream temperature metrics (°C) for classifying streams in Connecticut into thermal classes.

	Water temperature (°C)		
Thermal Class	June–August mean	July mean	Maximum daily mean
Cold	<18.29	<18.45	<22.40
Cool	18.29–21.70	18.45–22.30	22.40–26.30
Warm	>21.70	>22.30	>26.30

significant indicators of the combination of cool and warm waters.

We used water temperature change points from the TITAN analysis for the June–August mean metric to evaluate annual stream temperature distribution among the thermal classes for the 160 study sites. Mean daily stream water temperatures were warmest in July (Figure 4). The maximum June–August mean temperature values for cold water was (22.9°C, $N = 25$), cool water (27.6°C, $N = 109$), and warm water (29.0°C, $N = 26$) with thermal differences between temperature groups greatest during June–September. Mean daily stream temperatures were similar between coldwater, coolwater, and warmwater streams in November–March.

TABLE 4. Species identified as significant indicators (P-value < 0.05) of a particular temperature group or combination of groups using indicator species analysis. We indicate the temperature site-group or group combination that obtained the highest indicator index value (Sqrt IndVal) and the statistical significance of the association (P-value). Larger Sqrt IndVals indicate a greater association with a particular temperature group.

Species	Group	Sqrt IndVal	P-value
Brook Trout	Cold	0.890	0.001
Slimy Sculpin	Cold	0.608	0.001
Brown Trout	Cold + cool	0.606	0.019
American Eel	Cool + warm	0.812	0.002
Tessellated Darter	Cool + warm	0.807	0.002
Common Shiner	Cool + warm	0.662	0.003
Bluegill	Cool + warm	0.653	0.009
Fallfish	Cool + warm	0.629	0.003
Redbreast Sunfish	Warm	0.759	0.001
Smallmouth Bass	Warm	0.652	0.001
Rock Bass	Warm	0.535	0.001
Cutlip Minnow	Warm	0.495	0.007
Brown Bullhead	Warm	0.489	0.002
Yellow Bullhead	Warm	0.403	0.016

DISCUSSION

Applying the TITAN method to a robust fish community and temperature data set, we defined stream temperature ranges

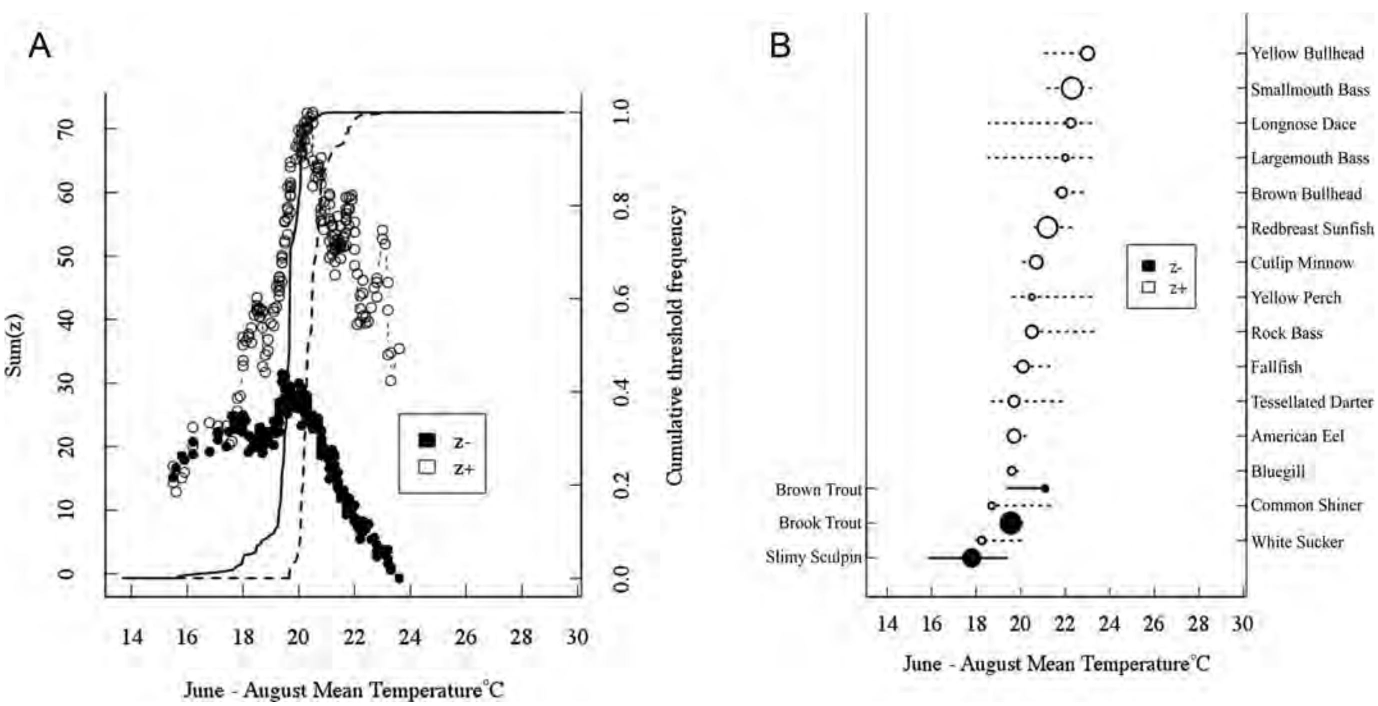


FIGURE 2. Threshold Indicator Taxa ANalysis (TITAN) outputs. (**A**) sum (z) scores for decreasers (filled circles) and increasers (open circles) across the summer temperature gradient. Vertical lines are cumulative frequency distributions of change points for negative (solid) and positive (dashed) indicator species across 500 replicate runs. (**B**) Significant species (purity ≥ 0.95, reliability ≥ 0.95, $P < 0.05$) in response to increasing ($z+$) or decreasing ($z-$) June–August mean water temperature. The circle size represents z-scores and horizontal lines overlapping each circle cover the 5th and 95th percentiles among 500 replicate runs.

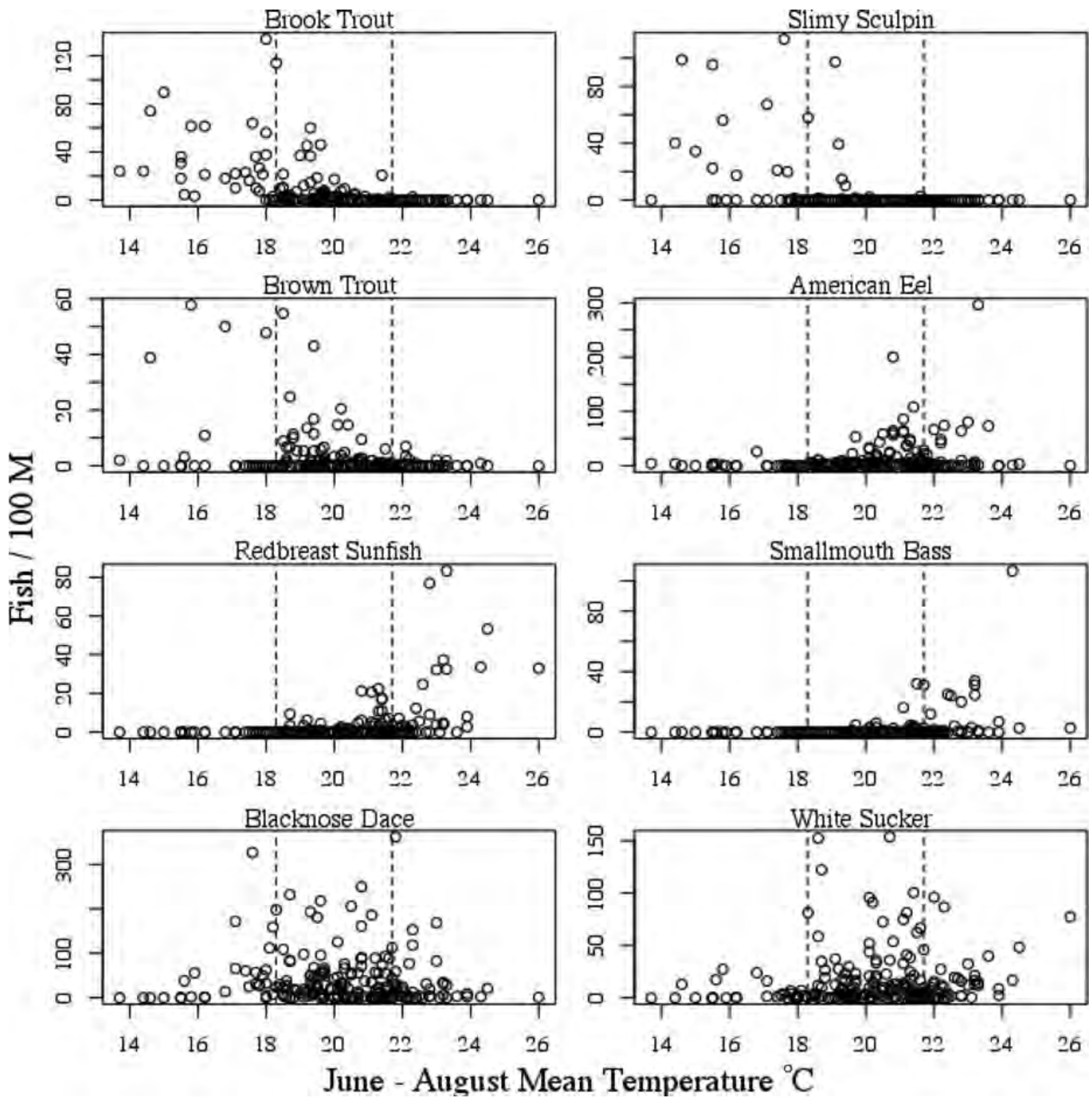


FIGURE 3. Scatter plots of select species displaying standardized abundance (fish count per 100 m) in response to June–August mean water temperature. Shown are representative coldwater species (Brook Trout, Slimy Sculpin), coldwater + coolwater species (Brown Trout), coolwater + warmwater species (American Eel), and warmwater species (Redbreast Sunfish, Smallmouth Bass), as well as cosmopolitan species (Blacknose Dace, White Sucker). Vertical lines show temperature cutoffs (cold, <18.29°C; cool, 18.29–21.70°C; warm, >21.70°C) from TITAN analysis.

for coldwater, coolwater, and warmwater streams in Connecticut. Thermal ranges have been defined in previous studies using various approaches, and the ranges have differed slightly among studies (Lyons et al. 1996, 2009; Stoneman and Jones 1996; Wehrly et al. 2003; McKenna et al. 2010). The ranges of June–August mean temperatures were <18.29°C for coldwater, 18.29–21.70°C for coolwater, and >21.70°C for warmwater streams in Connecticut. Thermal ranges of June–August mean temperatures were lower for coldwater (<17.0°C), coolwater (17.0–20.5°C), and warmwater (>20.5°C) streams in Michigan and Wisconsin (Lyons et al. 2009). As another example, McKenna et al. (2010) used daytime summer stream temperature records to define cold water (<18°C), cool water (18–24°C), and warm water (>24°C) in New York. The inconsistency may reflect true biological patterns among regions, differences among analytical approaches among studies, or a combination of both. Given that many temperate regions of North America harbor cold-, cool-, and warmwater habitats, a continental-scale analysis using a standard approach could advance our understanding of this important topic in fisheries management.

Some previous studies divided the coolwater community into two subclasses: "cold transition" and "warm transition" (Lyons

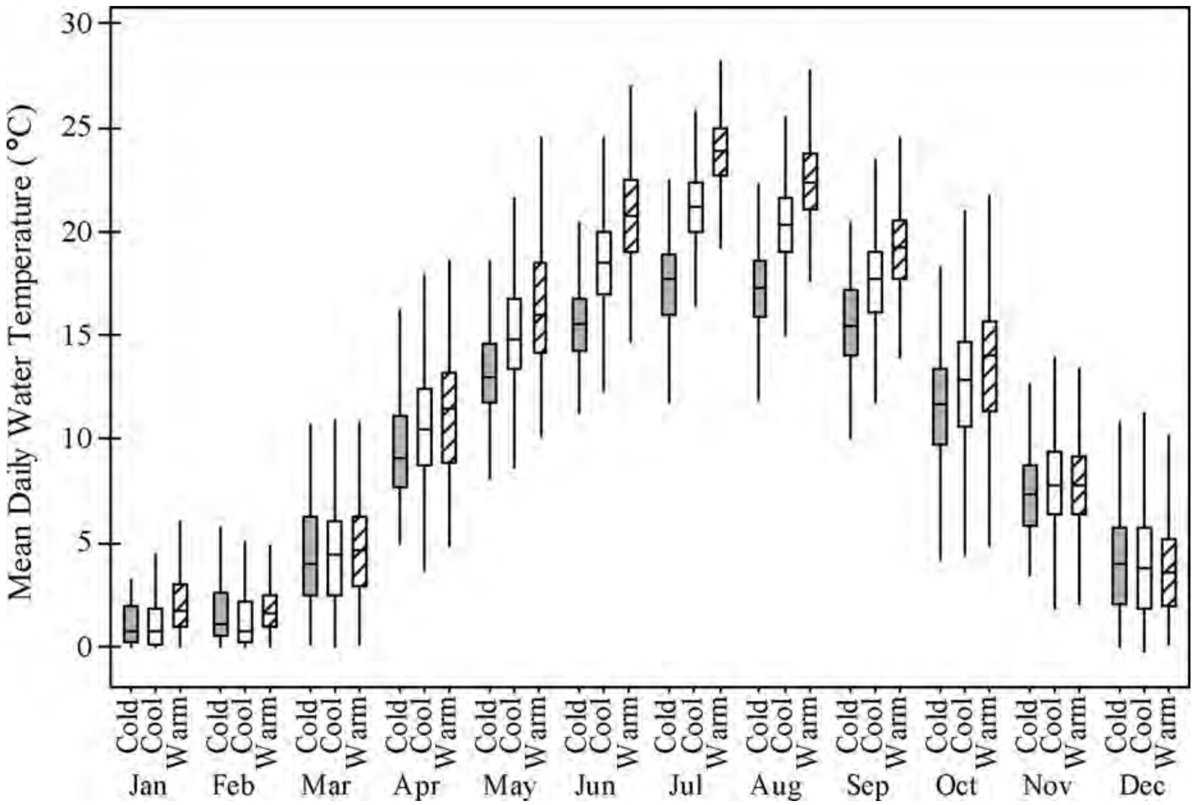


FIGURE 4. Box and whisker plots of mean daily water temperature (°C) by month and thermal class: cold (solid grey), cool (solid white), and warm (striped). The box represents the 25th percentile, median (horizontal line), and 75th percentile, and whiskers indicate the range of temperatures excluding outlier values.

et al. 2009; McKenna et al. 2010), but we did not attempt the finer classification within the coolwater community. Our inability to make a finer classification is attributable to low species richness (e.g., 26 species in this study versus 99 species in Lyons et al. 2009) and the absence of characteristic species (i.e., indicator species) for the coolwater community in Connecticut streams. Blacknose Dace and White Sucker, which are typically considered coolwater species, had cosmopolitan distributions across the thermal range observed (Figure 3). Also, the coolwater range was liberally defined by including 5th and 95th percentiles of change points for decreasers and increasers. As a result, the coolwater community could be best viewed as the transition zone where coldwater (“decreasers”) and warmwater (“increasers”) species co-occur, rather than as a distinct community composed of obligate coolwater species (Lyons et al. 2009). We believe the differences between the two studies can be attributed to the natural variation in ecological preferences of fish species throughout their ranges and methodological differences in how thresholds were defined including in situ measurement versus modeled values, use of TITAN, and paired fish community and water temperature data.

The coolwater class had a 3.41°C range for the June–August metric and <4°C for all three metrics. Despite this narrow range, 68.1% of the 160 streams were classified as coolwater streams. As such, the coolwater class represents the majority habitat class as represented by total stream miles and this is similar to findings in Lyons et al. (2009). The similarity illustrates that coolwater streams are more common than previously recognized, and identifying the distribution and function of coolwater habitat is an important area of research for many regions experiencing increasing trends in air and water temperature regimes.

The coldwater–coolwater transition was characterized by discernible changes in the presence and abundance of Slimy Sculpin, Brook Trout, and Brown Trout. Identifying this threshold is of particular interest in understanding the potential impact of climate change and other anthropogenic factors on coldwater resources. Slimy Sculpin was associated with the coldest streams among the three species (July–August mean temperature threshold, 17.80°C [90% CI: 15.7–19.5°C]). The distribution of this species in Connecticut is geographically limited (Kanno and Vokoun 2008), yet its high thermal sensitivity would make it a suitable candidate species for monitoring thermal changes caused by anthropogenic factors in a region where the species is distributed more commonly (e.g., northern New England). Brook Trout was the other indicator species of coldwater communities, while Brown Trout was an indicator of coldwater–coolwater communities. Preference of Brook Trout for colder temperatures has been known from laboratory behavioral observations (Taniguchi et al. 1998) and broad-scale spatial distributions of the two trout species in the field (Eaton et al. 1995; Wehrly et al. 2003). We had considered removing naturalized nonnative species (including Brown Trout) from our analyses as it would have lowered the coldwater–coolwater transition threshold. However, we retained naturalized nonnative species in our analyses because they are actively managed for recreational fishing and comprise a nontrivial part of fish communities in our landscape.

The coolwater–warmwater transition represented a thermal range in which a number of species became more common and abundant (i.e., members of the families Anguillidae, Cyprinidae, Centrarchidae, Ictaluridae, and Percidae). This pattern was to be expected because stream temperature is positively associated with species richness in Connecticut (Kanno and Vokoun 2008) and other temperate regions (Rathert et al. 1999; Buisson et al. 2008). Thermal associations of a couple of species found in this study differed slightly from those reported in the literature. Smallmouth Bass was an indicator species of warmwater streams in Connecticut but it is often regarded as a coolwater species (Halliwell et al. 1999); similarly, Bluegill was indicative of coolwater–warmwater streams in this study although it is considered a warmwater species (Halliwell et al. 1999). We do not necessarily suggest changes in thermal preference classification for these species, because this study was limited primarily to wadeable streams. Inclusion of nonwadeable streams and rivers would be required for an improved understanding of thermal preferences for warmwater species in the region. Restricting the scope of the current study to wadeable streams allowed us to understand the summer temperature effect on fish community changes without introducing the confounding effect of stream size.

Continuous temperature monitoring throughout the year revealed an interesting seasonal pattern; thermal differences among coldwater, coolwater, and warmwater streams were noticeable only during summer but not during the rest of the year (Figure 4). Air temperature alone cannot explain stream temperature variation within a watershed or among neighboring watersheds (Velasco-Cruz et al. 2012; Kanno et al. 2013). An important factor contributing to heightened thermal differences during the summer base flow period is probably groundwater discharge (Wehrly et al. 2003). Understanding how groundwater mediates stream temperature is a much-needed area of research that would improve our ability to classify stream fish communities, as well as our assessment of climate change effects on fisheries resources.

In addition to benefiting fisheries management, our findings will help state environmental regulatory agencies in their efforts to develop biology-based water temperature criteria (Todd et al. 2008), and to augment biological assessments (Barbour et al. 1999) as required under the U.S. Clean Water Act (CWA). Our ability to develop biology-based water temperature criteria to protect fish and other aquatic species has been hindered by our incomplete understanding of species' thermal thresholds. Historically, temperature criteria have been developed primarily based on lethal and sublethal thresholds for fish derived from laboratory studies (e.g., Brungs and Jones 1977). More recently, there is recognition that maintaining a distribution of natural temperature regimes, spatially and temporally, is perhaps a better approach to protect aquatic species (Poole et al. 2004).

In summary, we have identified a coldwater and warmwater summer temperature threshold with statistically significant indicator fish species. In addition we have defined coolwater habitat between the thresholds, but this temperature range did not have any statistically significant indicator species. When the coolwater range was viewed as a transition, combining the coldwater–coolwater sites or coolwater–warmwater sites, at least one significant indicator was present. The 3.41°C coolwater transition zone, encompassing the majority of river miles in Connecticut, is an important habitat harboring many of our native species. The definition of these summer temperature thresholds and resulting fish community structure will help to inform future fish community and water resource management in the context of changing climatic conditions and other direct and indirect human-related impacts to stream water temperatures.

ACKNOWLEDGMENTS

We thank the many biologists, technicians, and seasonal researchers who helped to collect the fish and water temperature data, especially Edward Machowski, Gerald Leonard, Brian Jennes, and Tracy Lizotte. We are especially grateful to the collaborative relationship between the Inland Fisheries Division and the Monitoring and Assessment Program within the Bureau of Water Protection and Land Reuse at the Connecticut Department of Energy and Environmental Protection, without which the volume of data these analyses are based would be greatly truncated. We thank James McKenna and two anonymous reviewers for their review of an earlier version of this manuscript.

REFERENCES

Baker, M. E., and R. S. King. 2010. A new method for detecting and interpreting biodiversity and ecological community thresholds. Methods in Ecology and Evolution 1:25–37.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, 2nd edition. U.S. Environmental Protection Agency, Office of Water, EPA841-B-99-002, Washington, D.C.

Brungs, W. S., and B. R. Jones. 1977. Temperature criteria for freshwater fish: protocols and procedures. U.S. Environmental Protection Agency, Ecological Resources Service, Environmental Research Lab, EPA 600/3-77-061, Duluth, Minnesota.

Buisson, L., L. Blanc, and G. Grenouillet. 2008. Modeling stream fish species distribution in a river network: the relative effects of temperature versus physical factors. Ecology of Freshwater Fish 17:244–257.

Carveth, C. J., A. M. Widmer, and S. A. Bonar. 2006. Comparison of upper thermal tolerances of native and nonnative fish species in Arizona. Transactions of the American Fisheries Society 135:1433–1440.

Chu, C., N. E. Jones, N. E. Mandrak, A. R. Piggott, and C. K. Minns. 2008. The influence of air temperature, groundwater discharge, and climate change on the thermal diversity of stream fishes in southern Ontario watersheds. Canadian Journal of Fisheries and Aquatic Sciences 65:297–308.

Chu, C., N. E. Jones, A. R. Piggott, and J. M. Buttle. 2009. Evaluation of a simple method to classify the thermal characteristics of streams using a nomogram of daily maximum air and water temperatures. North American Journal of Fisheries Management 29:1605–1619.

Coutant, C. C. 1977. Compilation of temperature preference data. Journal of the Fisheries Research Board of Canada 34:739–745.

CT DEEP (Connecticut Department of Energy and Environmental Protection). 2012. Standard operating procedures for measuring continuous water temperature. CT DEEP, Hartford.

Dauwalter, D. C., and E. J. Pert. 2003. Electrofishing effort and fish species richness and relative abundance in Ozark Highland streams of Arkansas. North American Journal of Fisheries Management 23:1152–1166.

De Cáceres, M., and P. Legendre. 2009. Associations between species and groups of sites; indices and statistical inference. Ecology 90:3566–3574.

De Cáceres, M., P. Legendre, and M. Moretti. 2010. Improving indicator species analysis by combining groups of sites. Oikos 119:1674–1684.

Dufrêne, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345–366.

Eaton, J. G., J. H. McCormick, B. E. Goodno, D. G. O'Brien, H. G. Stefany, M. Hondzo, and R. M. Scheller. 1995. A field information-based system for estimating fish temperature tolerances. Fisheries 20(4):10–18.

Ficke, A. D., C. A. Myrick, and L. J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries 17:581–613.

Gaffield, S. J., K. W. Potter, and L. Wang. 2005. Predicting the summer temperature of small streams in southwestern Wisconsin. Journal of the American Water Resources Association 41:25–36.

Halliwell, D. B., R. W. Langdon, R. A. Daniels, J. P. Kurtenbach, and R. A. Jacobson. 1999. Classification of freshwater fish species of the northeastern United States for use in the development of indices of biological integrity, with regional applications. Pages 301–335 *in* T. P. Simon, editor. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Florida.

Hartman, K. J., and M. K. Cox. 2008. Refinement and testing of a Brook Trout bioenergetics model. Transactions of the American Fisheries Society 137:357–363.

Isaak, D. J., C. H. Luce, B. E. Rieman, D. E. Nagel, E. E. Peterson, D. L. Horan, S. Parkes, and G. L. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20:1350–1371.

Kanno, Y., B. H. Letcher, and J. C. Vokoun. In press. Paired stream-air temperature measurements reveal fine-scale thermal heterogeneity within headwater Brook Trout stream networks. River Research and Applications. DOI: 10.1002/rra.2677.

Kanno, Y., and J. C. Vokoun. 2008. Biogeography of stream fishes in Connecticut: defining faunal regions and assemblage types. Northeastern Naturalist 15:557–576.

Kanno, Y., J. C. Vokoun, and M. Beauchene. 2010. Development of dual fish multi-metric indices of biological condition for streams with characteristic thermal gradients and low species richness. Ecological Indicators 10:565–571.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6):21–27.

Leonard, P. M., and D. J. Orth. 1986. Application and testing of an index of biotic integrity in small, coolwater streams. Transactions of the American Fisheries Society 115:401–414.

Lyons, J. 2012. Development and validation of two fish-based indices of biotic integrity for assessing perennial coolwater streams in Wisconsin, USA. Ecological Indicators 23:402–412.

Lyons, J., L. Wang, and T. D. Simonson. 1996. Development and validation of an index of biotic integrity for coldwater streams in Wisconsin. North American Journal of Fisheries Management 16:241–256.

Lyons, J., T. Zorn, J. Stewart, P. Seelbach, K. Wehrly, and L. Wang. 2009. Defining and characterizing coolwater streams and their fish assemblages in Michigan and Wisconsin, USA. North American Journal of Fisheries Management 29:1130–1151.

Maret, T. R., C. T. Robinson, and G. W. Minshall. 1997. Fish assemblages and environmental correlates in least-disturbed streams of the upper Snake River basin. Transactions of the American Fisheries Society 126:200–216.

Markle, J. M., and R. A. Schincariol. 2007. Thermal plume transport from sand and gravel pits – potential thermal impacts on cool water streams. Journal of Hydrology 338:174–195.

McKenna, J. E., Jr., R. S. Butryn, and R. P. McDonald. 2010. Summer stream water temperature models for Great Lakes streams: New York. Transactions of the American Fisheries Society 139:1399–1414.

Merten, E. C., N. A. Hemstad, S. L. Eggert, L. B. Johnson, R. K. Kolka, R. M. Newman, and B. Vondracek. 2010. Relations between fish abundances, summer temperatures, and forest harvest in a northern Minnesota stream system from 1997 to 2007. Ecology of Freshwater Fish 19:63–73.

Nelson, K. C., and M. A. Palmer. 2007. Stream temperature surges under urbanization and climate change: data, models, and responses. Journal of the American Water Resources Association 43:440–452.

Poole, G. C., J. B. Dunham, D. M. Keenan, S. T. Sauter, D. A. McCullough, C. Mebane, J. C. Lockwood, D. A. Essig, M. P. Hicks, D. J. Sturdevant, E. J. Materna, S. A. Spalding, J. Risley, and M. Deppman. 2004. The case for regime-based water quality standards. Bioscience 54:154–161.

Rathert, D., D. White, J. C. Sifneos, and R. M. Hughes. 1999. Environmental correlates of species richness for native freshwater fish in Oregon, USA. Journal of Biogeography 26:257–273.

Reynolds, L., A. T. Herlihy, P. R. Kaufmann, S. V. Gregory, and R. M. Hughes. 2003. Electrofishing effort requirements for assessing species richness and biotic integrity in western Oregon streams. North American Journal of Fisheries Management 23:450–461.

Sinokrot, B. A., H. G. Stefan, J. H. McCormick, and J. G. Eaton. 1995. Modeling of climate change effects on stream temperatures and fish habitats below dams and near groundwater inputs. Climatic Change 30:181–200.

Sloat, M. R., B. B. Shepard, R. G. White, and S. Carson. 2005. Influence of stream temperature on the spatial distribution of Westslope Cutthroat Trout growth potential within the Madison River basin, Montana. North American Journal of Fisheries Management 25:225–237.

Smogor, R. A., and P. L. Angermeier. 2001. Determining a regional framework for assessing biotic integrity of Virginia streams. Transactions of the American Fisheries Society 130:18–35.

Stoneman, C. L., and M. L. Jones. 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperature. North American Journal of Fisheries Management 16:728–737.

Taniguchi, Y., F. J. Rahel, D. C. Novinger, and K. G. Gerow. 1998. Temperature mediation of competitive interactions among three fish species that replace each other along longitudinal stream gradients. Canadian Journal of Fisheries and Aquatic Sciences 55:1894–1901.

Todd, A. S., M. A. Coleman, A. M. Konowal, M. K. May, S. Johnson, N. K. Vieira, and J. F. Saunders. 2008. Development of new water temperature criteria to protect Colorado's fisheries. Fisheries 33:433–443.

Underwood, Z. E., C. A. Myrick, and K. B. Rogers. 2012. Effect of acclimation temperature on the upper thermal tolerance of Colorado River Cutthroat Trout *Oncorhynchus clarkia pleuriticus*: thermal limits of a North American salmonid. Journal of Fish Biology 80:2420–2433.

Vannote, R. L., G. W. Minshall, K. W. Cummings, J. R. Sedell, and C. E. Gushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130–137.

Velasco-Cruz, C., S. C. Leman, M. Hudy, and E. P. Smith. 2012. Assessing the risk of rising temperature on Brook Trout: a spatial dynamic linear risk model. Journal of Agricultural, Biological, and Environmental Statistics 17:246–264.

Warren, D. R., J. M. Robinson, D. C. Josephson, D. R. Sheldon, and C. E. Kraft. 2012. Elevated summer temperatures delay spawning and reduce redd construction for resident Brook Trout (*Salvelinus fontinalis*). Global Change Biology 18:1804–1811.

Wehrly, K. E., M. J. Wiley, and P. W. Seelbach. 2003. Classifying regional variation in thermal regime based on stream fish community patterns. Transactions of the American Fisheries Society 132:18–38.

Xu, C., B. H. Letcher, and K. H. Nislow. 2010. Size-dependent survival of Brook Trout *Salvelinus fontinalis* in summer: effects of water temperature and stream flow. Journal of Fish Biology 76:2342–2369.

Appendix: Temperature–Fish Species Relationships Based on TITAN

TABLE A.1. Threshold Indicator Taxa ANalysis (TITAN) change points of fish species in response to June–August mean water temperature (°C). The observed change points (CP) corresponds to the value resulting in the largest indicator value (IndVal) *z*-scores for each taxon either as an increase (+) or decrease (−) to the temperature gradient. Percentiles (5%, 50%, 95%) correspond to change points from 500 bootstrap replicates. Purity is the mean proportion of correct response direction (*z*− or *z*+) assignments; reliability (Rel) is the mean proportion of *P*-values < 0.05 among 500 bootstrap iterations.

		June–August mean temperature (°C)								
Species	±	CP	5%	50%	95%	IndVal	*P*-value	*z*-score	Purity	Rel
Blacknose Dace	*z*+	15.50	15.50	16.50	22.80					
White Sucker	*z*+	18.25	17.95	18.50	20.50	66.42	<0.01	4.54	1.00	1.00
American Eel	*z*+	19.70	19.40	19.70	20.45	65.93	<0.01	7.89	1.00	1.00
Longnose Dace	*z*+	22.25	18.25	22.10	23.20	62.88	<0.01	5.55	1.00	1.00
Smallmouth Bass	*z*+	22.30	20.90	22.30	23.25	62.74	<0.01	12.52	1.00	1.00
Tessellated Darter	*z*+	19.70	18.50	20.10	22.15	57.03	<0.01	6.61	1.00	1.00
Redbreast Sunfish	*z*+	21.20	20.45	21.30	22.80	53.68	<0.01	12.15	1.00	1.00
Fallfish	*z*+	20.10	19.65	20.10	22.45	44.59	<0.01	7.06	1.00	1.00
Common Shiner	*z*+	18.70	18.50	20.20	21.75	44.46	<0.01	4.09	1.00	1.00
Bluegill	*z*+	19.60	19.30	19.70	20.20	42.47	<0.01	4.87	1.00	1.00
Largemouth Bass	*z*+	22.00	18.00	22.00	23.45	37.23	<0.01	3.84	0.98	0.93
Yellow Bullhead	*z*+	23.00	20.85	21.50	23.45	32.53	<0.01	8.10	1.00	1.00
Pumpkinseed	*z*+	19.40	17.55	20.30	23.25	27.94	0.06	1.93	0.88	0.82
Rock Bass	*z*+	20.50	20.45	21.75	23.47	27.33	<0.01	7.38	1.00	1.00
Cutlip Minnow	*z*+	20.70	19.80	20.45	21.30	27.00	<0.01	7.84	1.00	1.00
Brown Bullhead	*z*+	21.85	20.65	21.80	23.20	24.20	0.01	5.99	1.00	1.00
Yellow Perch	*z*+	20.50	19.40	21.70	23.45	12.34	0.01	3.48	1.00	0.99
Green Sunfish	*z*+	18.50	18.50	20.30	21.70	10.80	0.06	1.48	0.56	0.32
Golden Shiner	*z*+	20.20	19.30	20.30	23.15	10.95	0.03	2.37	0.83	0.72
Chain Pickerel	*z*+	22.00	18.70	21.20	23.20	9.37	0.06	1.55	0.90	0.69
Sea Lamprey	*z*+	19.30	19.10	20.15	22.20	7.24	0.06	2.11	0.96	0.79
Brook Trout	*z*−	19.55	18.75	19.70	20.30	69.09	<0.01	16.49	1.00	1.00
Slimy Sculpin	*z*−	17.80	15.55	17.80	19.50	50.21	<0.01	13.68	1.00	1.00
Brown Trout	*z*−	21.10	17.55	20.80	21.30	36.99	<0.01	5.02	0.99	0.99
Creek Chub	*z*−	20.50	18.35	20.30	22.00	17.79	0.07	1.71	0.70	0.53
Redfin Pickerel	*z*−	21.30	17.25	20.55	21.70	11.22	0.06	1.93	0.88	0.68

TABLE A.2. Threshold Indicator Taxa ANalysis (TITAN) change points of fish species in response to July mean stream temperature (°C). The observed change points (CP) corresponds to the value resulting in the largest indicator value (IndVal) *z*-scores for each taxon either as an increase (+) or decrease (−) to the temperature gradient. Percentiles (5%, 50%, 95%) correspond to change points from 500 bootstrap replicates. Purity is the mean proportion of correct response direction ($z-$ or $z+$) assignments; reliability (Rel) is the mean proportion of *P*-values < 0.05 among 500 bootstrap iterations.

		July mean temperature								
Species	±	CP	5%	50%	95%	IndVal	*P*-value	*z*-score	Purity	Rel
Blacknose Dace	$z+$	16.75	15.80	18.35	24.45	72.42	<0.01	3.56	0.69	0.69
Yellow Bullhead	$z+$	24.55	21.95	24.50	24.95	67.87	<0.01	10.88	1.00	1.00
Smallmouth Bass	$z+$	24.30	22.05	23.43	24.40	67.08	<0.01	11.48	1.00	1.00
White Sucker	$z+$	18.60	16.73	19.05	23.30	62.81	0.01	3.38	0.99	0.97
American Eel	$z+$	21.20	20.60	21.10	22.10	61.66	<0.01	7.00	1.00	1.00
Tessellated Darter	$z+$	22.10	20.90	21.80	23.30	58.31	<0.01	6.49	1.00	1.00
Longnose Dace	$z+$	22.85	19.30	22.90	23.85	54.57	<0.01	6.04	1.00	1.00
Redbreast Sunfish	$z+$	22.50	21.50	22.35	24.00	52.06	<0.01	10.83	1.00	1.00
Common Shiner	$z+$	19.20	19.05	20.85	24.65	43.92	<0.01	4.05	1.00	1.00
Bluegill	$z+$	20.35	19.10	20.45	21.65	42.65	<0.01	4.35	1.00	1.00
Fallfish	$z+$	21.20	20.15	21.60	24.80	39.33	<0.01	5.91	0.99	0.99
Largemouth Bass	$z+$	21.90	18.95	22.20	24.00	29.26	0.01	2.92	0.94	0.86
Rock Bass	$z+$	22.20	21.70	22.15	22.65	28.98	<0.01	8.37	1.00	1.00
Pumpkinseed	$z+$	21.15	18.18	21.10	23.35	27.68	0.02	2.31	0.87	0.83
Creek Chub	$z+$	18.60	18.60	21.18	23.70	22.47	0.11	1.69	0.47	0.31
Cutlip Minnow	$z+$	20.80	20.75	21.95	22.80	25.34	<0.01	8.01	1.00	1.00
Brown Bullhead	$z+$	22.30	20.60	22.70	24.80	19.04	<0.01	4.00	1.00	0.99
Yellow Perch	$z+$	20.50	19.80	21.50	24.80	10.98	0.03	2.58	0.96	0.88
Green Sunfish	$z+$	19.05	19.30	21.03	22.80	10.80	0.05	1.36	0.59	0.43
Golden shiner	$z+$	22.10	19.10	21.90	24.30	9.10	0.19	1.28	0.82	0.57
Chain Pickerel	$z+$	22.80	19.60	22.80	24.50	8.57	0.06	1.71	0.89	0.70
Sea Lamprey	$z+$	20.75	20.60	20.90	23.35	8.40	0.02	3.15	0.99	0.94
Brook Trout	$z-$	21.20	19.60	20.60	21.50	62.39	<0.01	14.94	1.00	1.00
Slimy Sculpin	$z-$	18.55	16.40	18.50	20.90	45.17	<0.01	11.61	1.00	1.00
Brown Trout	$z-$	22.40	20.80	22.25	22.75	40.49	<0.01	5.35	1.00	1.00
Redfin Pickerel	$z-$	15.40	15.40	19.80	22.90	28.82	0.09	2.54	0.88	0.80

TABLE A.3. Threshold Indicator Taxa ANalysis (TITAN) change points of fish species in response to maximum daily mean stream temperature (°C). The observed change points (CP) corresponds to the value resulting in the largest indicator value (IndVal) *z*-scores for each taxon either as an increase (+) or decrease (−) to the temperature gradient. Percentiles (5%, 50%, 95%) correspond to change points from 500 bootstrap replicates. Purity is the mean proportion of correct response direction ($z-$ or $z+$) assignments; reliability (Rel) is the mean proportion of P-values < 0.05 among 500 bootstrap iterations.

		Maximum daily mean temperature								
Species	±	CP	5%	50%	95%	IndVal	*P*-value	*z*-score	Purity	Rel
Blacknose Dace	$z+$	19.95	19.25	23.00	28.40	70.86	0.01	3.14	0.49	0.49
White Sucker	$z+$	22.30	21.75	22.30	24.75	69.64	<0.01	5.89	1.00	1.00
Longnose Dace	$z+$	27.10	22.30	27.10	27.95	66.13	<0.01	6.43	1.00	1.00
American Eel	$z+$	24.00	22.90	23.90	24.60	61.26	<0.01	6.67	1.00	1.00
Tessellated Darter	$z+$	24.30	22.30	24.30	26.66	60.36	<0.01	7.05	1.00	1.00
Cutlip Minnow	$z+$	28.15	23.70	27.10	28.40	59.38	<0.01	9.53	1.00	1.00
Redbreast Sunfish	$z+$	25.50	25.10	25.80	27.15	54.85	<0.01	11.78	1.00	1.00
Rock Bass	$z+$	28.25	24.65	27.10	28.55	51.61	0.01	7.22	1.00	1.00
Common Shiner	$z+$	27.15	22.30	25.10	27.60	50.63	<0.01	4.57	1.00	1.00
Bluegill	$z+$	23.20	22.40	23.25	24.16	47.22	<0.01	5.36	1.00	1.00
Fallfish	$z+$	24.50	23.65	24.50	25.90	46.27	<0.01	8.28	1.00	1.00
Smallmouth Bass	$z+$	26.05	25.30	26.00	28.25	45.01	<0.01	11.84	1.00	1.00
Largemouth Bass	$z+$	24.65	22.75	24.85	27.80	34.38	<0.01	4.74	0.99	0.98
Pumpkinseed	$z+$	23.25	21.50	23.25	26.30	32.96	0.01	3.60	0.94	0.93
Yellow Bullhead	$z+$	25.80	25.40	25.80	27.55	26.66	<0.01	9.13	1.00	1.00
Brown Bullhead	$z+$	26.95	23.55	26.65	27.65	25.35	0.00	5.87	1.00	0.99
Creek Chub	$z+$	20.55	20.95	24.10	28.25	22.10	0.15	0.88	0.71	0.45
Golden Shiner	$z+$	25.00	22.35	25.00	26.10	12.31	0.01	3.06	0.94	0.81
Yellow Perch	$z+$	23.20	23.00	23.55	27.95	12.30	0.01	3.52	0.97	0.95
Green Sunfish	$z+$	23.55	23.10	23.70	25.00	12.22	0.02	3.01	0.85	0.77
Chain Pickerel	$z+$	23.50	22.50	24.10	26.00	9.66	0.03	2.95	0.99	0.93
Sea Lamprey	$z+$	22.80	22.50	24.00	25.61	6.96	0.09	1.63	0.86	0.55
Brook Trout	$z-$	23.00	22.50	23.10	24.00	81.06	<0.01	17.58	1.00	1.00
Slimy Sculpin	$z-$	21.80	19.35	21.50	23.36	44.63	<0.01	12.50	1.00	1.00
Brown Trout	$z-$	25.50	19.25	25.30	26.00	38.38	<0.01	5.08	1.00	1.00
Redfin Pickerel	$z-$	25.30	19.25	24.00	26.10	11.40	0.04	2.08	0.92	0.80

Connecticut Department of Energy Environmental Protection

Connecticut Department of
ENERGY &
ENVIRONMENTAL
PROTECTION

Construction Stormwater Permitting

Rain Happens!

January 8, 2020

Christopher Stone, P.E.
DEEP Stormwater Section

Connecticut Department of Energy and Environmental Protection

CT STORMWATER PROGRAM

Construction Stormwater Permitting

> National Urban Runoff Program (NURP)
- 1979-1983 – studied runoff pollutants
- Construction runoff - high levels of sed/pollutants
- Post-construction increased runoff is damaging

> 1987 CWA Reauthorization
- EPA directed to regulate stormwater
- Created concept of general permits

> 1992 – CT Authorized by EPA to run SW

program > 2013 – Most recent permit reissuance

CT STORMWATER PROGRAM

Program goals

- Improve construction oversight utilizing QPE & QLP

- Ensure proper plan implementation
- Implement full electronic submittal and review process (no paper)
- Address issues with Locally Exempt (solar arrays, DOT, etc)

CT STORMWATER PROGRAM
Construction GP

Current Permit Structure

- Registration
- Stormwater Pollution Control Plan
- Inspections
- Monitoring
- Termination

CT STORMWATER PROGRAM
Proposed Mods

Registration

- **Only electronic filing**
  - All projects submit Plan - No paper option
- **Electronic public review**
  - 30 days (formerly 15 days)
- **Existing permittees reregister**
  - 120 days from reissuance date

CT STORMWATER PROGRAM
Proposed Mods

Registration (cont)

- Locally Exempt authorization
  - 60/90 day threshold 15 acres (formerly 20 acres)

Requirements for Authorization

- LA financial assurance to town
- Design QPE does pre-const. mtg, site walk & Plan Imp.

CT STORMWATER PROGRAM
Proposed Mods

- Eliminate turbidity monitoring
- State agencies (DOT/DAS)
- Create list of approved QPEs
  - QPE does Plan review (not DEEP)
  - QPE does Plan Imp. Inspection
  - QPE does Post-Const. Inspection

CT STORMWATER PROGRAM
Proposed Mods

Inspections

- Design QPE does Plan Imp. Insp.
  - Also at start of each phase
- State agencies can use QPE list
- Inspection checklists part of Plan
  - Plan Imp. & Routine Inspections
- Qualified Inspector
  - Qualifications identified in Plan

CT STORMWATER PROGRAM
Proposed Mods

- Keeping Plans Current
  - Disturbance increase – Notify DEEP
  - Revisions reviewed by Design QPE
- Conservation District MOA
  - Loc. Approvable MOA changed to straight hourly fee
  - New Loc. Exempt MOA for Plan review/pre-const mtg/inspection

CT STORMWATER PROGRAM
Proposed Mods

Reporting & Record Keeping

- All reporting through Net DMR

  - Inspections, Plan mods, other
- Mods documented as part of Plan

Duty to Correct & Report Violations

- Construction ceases until fixed
- Violations reported to DEEP

CT STORMWATER PROGRAM
Proposed Mods

- Notice of Termination
  - DOT/DAS use QPE list for Post-Construction Inspection
  - Final stabilization – One full growing season after stabilized
- Endangered/Threatened Species
  - Eliminate $^1/_4$ mile buffer
  - 1 year determination is now 2 years

CT STORMWATER PROGRAM

Solar Array Construction

2013 CGP did not consider Solar Arrays

- Extremely large (>100 ac) disturbed area
- Typical design makes phasing impractical
- Frequently on hillsides (slope issues)
- Construction timelines very short (< 1 year)
- Designs insufficient to protect such large areas
- Contractors not following plans
- Lack of independence = unreliable inspections
- Soil compaction increases runoff
- Ineffective/untimely corrective actions
- Inadequate post-construction controls

CT STORMWATER PROGRAM

200 acre clear cut

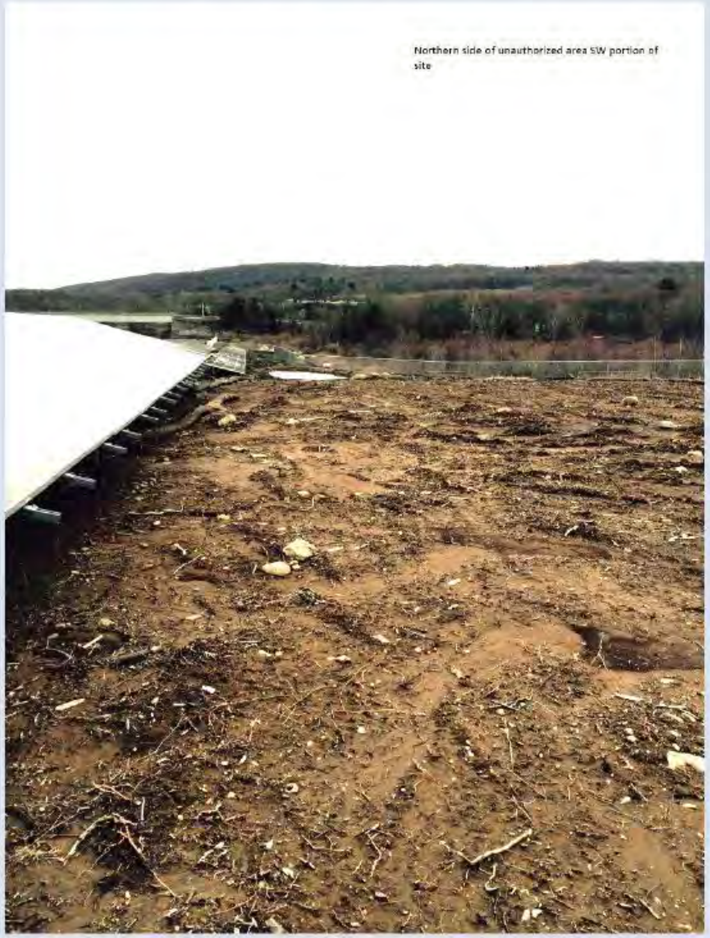
CT STORMWATER PROGRAM

Slope failure

CT STORMWATER PROGRAM

"Finished" basin

CT STORMWATER PROGRAM



No stabilization

CT STORMWATER PROGRAM

Erosion/stabilization failures

CT STORMWATER PROGRAM

Basin failure

CT STORMWATER PROGRAM

Severe runoff/erosion

CT STORMWATER PROGRAM

Severe runoff/erosion

CT STORMWATER PROGRAM

Severe runoff/erosion

CT STORMWATER PROGRAM

Stream bank high flow undercutting

CT STORMWATER PROGRAM

Post-construction erosion

CT STORMWATER PROGRAM

Post-construction erosion

CT STORMWATER PROGRAM
Solar Construction

How to Address Problems?

- **Review other large projects**
- **Review other states' procedures**
  - **- MN, MD, PA, NH**
  - **- Minnesota solar calculator**
- **NEIWPCC Stormwater Workgroup**
- **Discussions with consultants**

CT STORMWATER PROGRAM
CGP Solar Appendix I

Design & Construction Measures

- Array impervious if slopes > 15%
- Slopes <15% array is impervious unless:

- Increase stabilization as slopes increase - Provide adequate spacing between rows
- Maintain sheet flow
- 100 foot watercourse/wetland buffer

- Height of panels ≤ 10 feet
- Routine inspections by Qualified PE

CT STORMWATER PROGRAM
CGP Solar Appendix I

Design & Construction Measures (cont)

- Inspection reports submitted to DEEP
- District & Design QPE at pre-construction mtg
- District conducts periodic inspections
- District conducts Post-Const/Final Inspections
- Registrant provides letter of credit

  - $15,000/acre disturbance (Appendix J)

CT STORMWATER PROGRAM

CGP Solar Appendix I

Post-Construction Design Measures

- Consider panel orientation for drainage pattern
- Conduct pre- & post- runoff calculations
- Maintain non-erosive velocity & volume at property line
- Site specific soil mapping
- Conduct complete hydrologic analysis
- Downgrade Hydrologic Soil Group one level
  - Ex. HSG A B, HSG B C, etc.

CT STORMWATER PROGRAM
Construction Permitting

Questions?

DEEP Stormwater Staff

Karen Allen (860)424-3842
karen.allen@ct.gov

Chris Stone (860)424-3850
chris.stone@ct.gov

Donna Seresin (860)424-3267
donna.seresin@ct.gov

Neal Williams (860)424-3356
neal.williams@ct.gov

Karen Abbott (860)424-4038
karen.abbott@ct.gov

Emily Anness (860)424-4009
emily.anness@ct.gov

Digging Connecticut…

…while Protecting Its Waters and History: Recommendations for Reducing Impacts of Earthmoving

Rain ♦ Runoff ♦ Construction ♦ Mining ♦ Archaeology ♦ Solar Farms ♦ Rare Species

A Special Report of the Council on Environmental Quality **December 4, 2015 *Discussion Draft***

In Short

Connecticut's effort to reduce the pollution in stormwater that flows from construction and industrial sites almost certainly has improved the quality of streams and rivers (though such improvements mostly are conjectured, not measured). Several complaints to the Council have pointed out, however, that the state's efforts are incomplete, illogical or flawed.

Of all earthmoving activities in the state, the one with potentially the greatest environmental impact – the clearing and mining of land for the extraction of sand, gravel or rock – may avoid state regulation altogether.

Any would-be violator of state stormwater control laws can be fairly confident that he or she will not be caught or, if caught, will not face financial penalties.

The flawed regulatory structure that evolved over many years is not the one that would be designed today. The Council on Environmental Quality offers 14 recommendations (see page 13) aimed at building a more logical, efficient and effective approach to protecting Connecticut's environment – including historic and archaeological resources – from the effects of large earthmoving activities. These actions will clarify the permitting process to make it more effective and enforceable, enhance public access to information, improve requirements for mines and solar farms, and close the gaps by which parties avoid regulation or enforcement.

Three Cases

Residents of East Lyme, Madison and Suffield spoke to the Council in 2015 about three separate cases that illustrate deficiencies in the state's regulation of mining and in the permitting process for controlling pollution from stormwater runoff. One of the complaints concerned the protection of historic and archaeological sites, a protection that is tied to the regulation of stormwater.

The Council investigated all three complaints and found them to be rooted strongly in fact. The realities of regulation simply do not match the expectations of citizens who might read the relevant statutes, permits and related documents. There are gaps and deficiencies that could be fixed with adequate resources, simpler procedures and, in some cases, amendments to laws.

Citizens presented detailed reports of the following incidents or cases:

1. During a spring rain, a surge of stormwater and sediment flowed from a solar-energy facility under construction, polluting and altering nearby streams.

2. Developers submitted inaccurate or incomplete information on archaeological and historic resources to obtain stormwater permits, with no consequences.

3. A company received approval to open a sand and gravel mine with no state input or oversight, despite its location over an important aquifer.

Because all the complaints concern the regulation of earthmoving activities, the Council decided to address all three in one report. Together, these cases reveal a pattern of common problems.

1. Washout: Lessons from Water Pollution at a Solar Farm

A lot of rain fell on East Lyme in late March, 2014, but it was an amount (about four inches) that should be expected every few years.[1] To the dismay of neighbors, much dirt was washed into their streams from the site of a nearby solar energy facility that was under development. The streambed itself was changed. The pollution could have – should have – been avoided.

The solar energy project, exempt from local permitting requirements, received approval from the Connecticut Siting Council. It also was required to register for DEEP's General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities (known more simply as the "Construction General Permit"). The general permit appears to limit construction to five acres at any one time:

> "Wherever possible, the site shall be phased to avoid the disturbance of over five acres at one time."

A close reading of that requirement, however, suggests that the phrase "wherever possible" counters the mandatory ("shall") nature of the requirement, even though, in a strict sense, most things are possible.

In any event, approximately 30 acres were cleared and graded, and the solar panels were

Stormwater is…

…the water that flows over the ground during a rain event, including water from melting snow and ice. What begins as rainwater picks up pollutants of all sorts as it flows over pavement, lawns and construction and mining sites on its way to the nearest stream.

Stormwater is the most common source of water pollution impairing Connecticut's streams.

What Is a Registrant?

How General Permits Work

This report refers to permit *registrants*, not applicants. This is because the developer, mining company or landowner who is subject to stormwater regulations usually is not required to apply for a permit. The permit is a general permit, which means that DEEP has already issued the permit for everyone who qualifies. The developer registers to be covered by the general permit, and in doing so agrees to abide by the terms and conditions of the general permit. (Some projects are too large to qualify for a general permit and so their developers must apply for their own individual permits.)

DEEP issues general permits for 55 categories of pollution, activities and structures. This use of general permits, as opposed to the bygone practice of requiring each regulated entity to apply for its own permit, generally is regarded as a big benefit for the regulated world. They also reduce the bureaucratic burden on DEEP; without general permits, the Department would be a grim mire of delayed permits numbering in the thousands.

DEEP updates and re-issues each general permit every five years or so.

Most of the general permits are essentially self-implementing for the regulated party: complete the paperwork and go. Some, such as the general permit for stormwater at construction sites, allow for limited public review and comment.

For general permits to yield their intended environmental benefits, there must be honesty among the registrants and enforcement capability within DEEP to bring the dishonest or confused into compliance. It is fortunate that honesty appears to be commonplace, as enforcement is in short supply.

erected on bare ground. The Siting Council inspected the site and concluded that the runoff from the panels and bare earth overwhelmed the stormwater controls.[2]

Five months later, DEEP issued a Notice of Violation. As noted elsewhere in this report, NOVs are informal enforcement tools that carry no penalty.

The Town of East Lyme, while lacking permitting authority, issued a cease and desist order because of the pollution of offsite wetlands and watercourses. The case extended for months, a considerable burden for a town and its residents who had no permitting jurisdiction over the project.

This example illustrates at least four weaknesses in Connecticut's regulation of stormwater: weak enforcement tools, no actual standards for turbidity, outdated rainfall expectations, and no provisions for the unique potential problems caused by large solar energy installations.

Weak Enforcement Tools

The Construction General Permit was written and adopted to include mandatory requirements, but compliance borders on the voluntary. Penalties are assessed for violations only on the rarest of occasions, if ever. No registrations are revoked. Occasionally an alleged violator receives a Notice of Violation (NOV) which, though considered an informal enforcement tool, is more like an educational tool or a reprimand because it does not include a penalty. Usually, upon receipt of an NOV, the violator does what he or she should have been doing all along.

Registrants for the Construction General Permit are required to self-report problems to DEEP within five days of their occurrence, but such reporting occurs very rarely, if ever. The lack of such reports does not mean that compliance hovers anywhere near 100 percent. DEEP is required by the USEPA to inspect ten percent of registrants each year. Staff shortages in Federal Fiscal Year (FFY) 2015 required DEEP to lower that inspection rate to five percent.

Of the 21 sites inspected by DEEP in FFY 2015, violations were found at four. The sites with violations were inspected because of complaints or incomplete registrations. It is hard to extrapolate from such a small sample size. Nonetheless, if one assumes that some violations would not or could not be observed by third parties and therefore would not be reported, the data suggest that dozens of violations go undetected each year.

When DEEP discovers a violation, its enforcement options are severely restricted. The common enforcement tool is the NOV which, as stated above, carries no penalty. Going to court to seek a penalty is an extraordinary use of DEEP staff time that is seldom pursued for stormwater violations. Any would-be violator can be fairly confident that he or she will not be caught and, if caught, will not face financial penalties.

The Construction General Permit states that a registration can be revoked, but revocation does not occur. The statute that authorizes general permits (CGS Section 22a-430b(c)) can be interpreted to prohibit DEEP from revoking a registration for a general permit until it has issued an individual permit for the discharge, but there are other possible interpretations. (For example, it is possible that this restriction on DEEP's authority applies only when DEEP seeks to require an individual permit for a site, and not when DEEP seeks to revoke a registration for submitting false information.) Whether or not that law actually does limit revocation is a question that has not been tested.

Unless the law is changed to equip DEEP with an effective enforcement tool, compliance with the Construction General Permit will remain a voluntary endeavor.

Turbidity: No Limit

Turbidity is a measure of the relative clarity or cloudiness of water. High turbidity (cloudiness) occurs when much soil or other material is suspended in the water.

A major purpose of stormwater management at construction sites is to reduce the amount of soil that is discharged to nearby streams. Permit registrants are required to monitor turbidity levels. How much turbidity is too much? There actually is no standard. The only violation would be for failure to monitor the turbidity levels, not for creating any excessive level of turbidity.

The United States Environmental Protection Agency issued numerical limits on turbidity in 2009 and repealed them in 2014, opting for an approach that, like Connecticut's, depends on best management practices for controlling turbidity. Nonetheless, but the potential for appropriate numerical limits still exists.

Breaking News

It's Going to Rain

The company developing a solar-energy facility in East Lyme wrote to DEEP to report that on March 30, 2014 the area experienced "unprecedented rainfall which subsequently caused an unforeseen erosion and sediment control event at the project area." Was it unprecedented and unforeseen? A review of rainfall records for New London County shows that it was far from unprecedented. The four or so inches that fell that day was surpassed by an inch or more during a storm four years before (to the day), which itself was not close to the record (seven-plus inches on September 21, 1961).

Unforeseen? Using the federal precipitation-frequency guidance in effect at the time, one should have been expecting four inches to fall in a day at least once every five years, and probably more often.

Further review of the record one-day rainstorms for New London County for each month of the year from 1941 to 2010 reveals that most (eight of twelve) of the record storms occurred since 1991.[3] Does this mean that rainfalls are heavier now than they used to be? In October 2015, this question was answered with an unequivocal "Yes!" Prior to October, engineers relied on a National Weather Service document that was published in 1961. Updated in October 2015, the data confirm what has been predicted by many: rainfalls are getting heavier, and heavy rains are becoming more frequent. In 1961, most of the state would have expected a four-inch one-day rainfall every five years or so; in some northwestern towns, that five-year storm would have brought less than four inches. Now, all portions of the state can expect the five-year storm to bring well over four inches and, in some northwestern Connecticut towns, close to five inches.

This significant increase in rainfall intensity has large implications for water quality, and especially for the control of pollution from stormwater runoff. And if predictions regarding climate change continue to hold true, rain in this region will intensify even more.[4]

Certifications Not Audited

The credibility of general permits relies greatly on the certifications provided by registrants and licensed engineers (or other professionals). This is especially true for the Construction General Permit. The General Assembly charged DEEP in 2012 with auditing a percentage (10 percent was the goal) of such certifications and reporting the results to the General Assembly by 2014 (CGS 22a-430b(f)). That mandate has not been fulfilled; no report was completed.

It's Not Always Sunny: the Runoff Problems of Solar Farms

Large photovoltaic developments – commonly known as solar farms – are unique facilities that do not fit well into existing permit requirements. The few requirements imposed at present are not adequate.

The petition to the Connecticut Siting Council for approval of the East Lyme facility listed only two regulatory requirements: Siting Council approval and registration for the Construction General Permit. That was sufficient until it rained.

When the Siting Council was considering the petition for the East Lyme facility, it solicited the advice of DEEP, as it always does. Part of DEEP's recommendation reads, "DEEP recommends that adherence to the O&M Plan [Operation and Management Plan] be incorporated as a condition of any Council approval of this project and that the reports of the specified inspections be provided to the Council to verify that the on-going inspection and maintenance activities contemplated in Appendix F [Stormwater Management] are being carried out." The Siting Council declined to implement the recommendation. When asked, Siting Council staff stated that they did not wish to receive such reports, as they viewed DEEP as the agency with the expertise in stormwater. Siting Council staff nonetheless continued to inspect the project site for compliance with the approved plans, and in November 2015 noted several "concerns" that were required to be addressed by the site developer. Multiple visits from Siting Council staff and DEEP inspectors (as discussed on page 3) to a single project site constitute a significant deployment of resources that should be avoidable.

The 30-acre installation in East Lyme is just one among several solar farms being built as a product of state energy policy. Some solar farms, such as one approved in 2015 to be built in Sprague, would convert 134 acres of low-runoff woodland habitat into many acres of impervious surface (the solar panels) alternating with channels of low vegetation.[5]

Maryland and Pennsylvania agencies have published special guidelines for managing stormwater at solar farms. “The goal is to try to replicate the predevelopment condition after the construction is finished,” states the latter.[6]

Maryland Department of the Environment
Stormwater Design Guidance – Solar Panel Installations

“Revisions to Maryland’s stormwater management regulations in 2010 require that environmental site design (ESD) be used to the maximum extent practicable (MEP) to mimic natural hydrology, reduce runoff to reflect forested wooded conditions, and minimize the impact of land development on water resources. This applies to any residential, commercial, industrial, or institutional development where more than 5,000 square feet of land area is disturbed. Consequently, stormwater management must be addressed even when permeable features like solar panel installations exceed 5,000 square feet of land disturbance.”

2. Archaeology and Water Pollution: A Difficult Relationship

The Construction General Permit requires registrants to certify that their projects will not imperil prehistoric or historic sites of interest or the habitat of rare species of plants and wildlife. The implementation of those requirements – especially the one for historic sites – is a loose and confusing patchwork of steps and checklists that does not actually mirror the language of the requirements. The opportunities for errors and misrepresentations are many and significant.

While enforcement is limited for water pollution violations, it is virtually nonexistent for failure to properly assess impacts to historic and archaeological sites. DEEP does not claim expertise in historic preservation or archaeology, and the State Historic Preservation Office (SHPO), within the Department of Economic and Community Development, is not charged with enforcement.

The Council was presented with examples of Construction General Permit registrations that would appear to inaccurately represent the potential impacts to historic and archaeological resources. Such misrepresentations could largely be avoided through a combination of greater transparency, tighter documentation, simpler requirements and, on rare occasions, some possibility of enforcement.

The review of archaeological resources in connection with stormwater regulation is complicated in its details. An example of an unexpected feature is the fact that the presence of certain soil types alone will trigger the need for an archaeological review. These soil types occur near waterways where the probability of prehistoric human activity is relatively high. In some regards, this is not a complicated requirement, as soil types are ascertained more easily than some potential historic resources. Even so, the Council is aware of registrants presenting wrong information about soil types and avoiding the necessary detailed review.

Some of the misinformation in registrations can be tied to the complicated and unclear nature of the registration form, as well as of the entire permit. When approving the Construction General Permit in 2013, the DEEP Hearing Officer wrote,

> "I note that the revised permit is 45 pages long plus 30 pages of incorporated attachments… The permit would benefit from a subsequent review from the perspective of readability and organization."

The Council reviewed registrations that answered "Yes" to "Verify that the site of the proposed activity [has] been reviewed for historic and/or achaeological resources," and then checked "No" for both "(a) The review indicates the proposed site does not have the potential for historic/ archaeological resources, OR (b) The review indicated historic and/ or archaeological resource potential exists and the proposed activity is being or has been reviewed by the Offices of Culture and Tourism." Note that a "No" response to (a) means that there IS potential for historic or archaeological resources, and thus the sequence of Yes and No's submitted by the registrant makes no sense. Is if confusion or evasion?

Transparency is important because of the large number of residents with knowledge of historic resources who could view the information online if the information was posted online as originally intended. The Construction General Permit states that registrations will be posted on the website along with the stormwater management plans if the latter are available electronically. However, registrations are not posted on the DEEP website. DEEP publishes a monthly *list* of registrations received (usually numbering between five and twenty). If a member of the public requests a listed registration to review, and that registration is for a project that was approved by a municipality, then DEEP in turn requests a copy from the registrant and makes it available to the requestor. Only then does the clock *start* for the public review and comment period. This convoluted process, perhaps one of the most "un-LEAN" in all of state government, consumes DEEP staff time and delays development projects.

There is some good news: After a long delay in deploying the necessary technology, DEEP now is receiving stormwater registrations electronically, which would in theory make posting on the website more efficient and likely to happen.

As noted above, the Construction General Permit states that a registration can be revoked for submittal of inaccurate information, but revocation does not occur.

If a registrant attempts to adhere completely to the spirit and letter of the permit, the exact outcome still can remain a mystery to state agencies and the public. If the registrant's initial "prescreening" concludes that there is some potential for impacts to historic or archaeological resources, the registrant is directed to contact SHPO and to indicate to DEEP that a review has been or is being conducted. There is no requirement to submit SHPO's ultimate recommendations to DEEP, nor does DEEP follow up to ascertain adherence to any such recommendations.

The requirement to consider potential impacts to historic and archaeological resources does not mesh well with DEEP's fields of expertise. Nonetheless, federal law (under which DEEP must regulate stormwater) requires such consideration, and all Connecticut state agencies have a statutory responsibility to

> "review, in consultation with the Department of Economic and Community Development, their policies and practices for consistency with the preservation and study of the state's archaeological sites and sacred lands and sites. Such review shall include preparation of an **evaluation document** which specifies projects and programs requiring detailed consultation to identify and protect archaeological sites and sacred lands and sites." (CGS Section 10-387)

DEEP has not fulfilled the requirement to prepare such an evaluation document (as highlighted in the above statute). DEEP is not unique among state agencies in this deficiency. This point is revisited in the section below on mining.

Stormwater, Rare Species and Archaeology: Does the Connection Make Sense?

When a business plans to create or expand a facility, it must take steps to limit pollution to nearby waterways. Does it make sense that the business might also be required to hire an archaeologist and an ornithologist to assess potential impacts not directly associated with water quality? Yes, it makes sense, because DEEP is required to ensure, under various laws, that its programs are consistent with the preservation of historic resources and rare species. Presiding over the extermination of those resources would be a peculiar role for DEEP. Yet tying the study and protection of historic and biological resources to specific water pollution permits might be far from the most efficient path available.

3. State Regulation of Mining Sites: Nothing Ado About Much

A mining company can remove the vegetation and wildlife from dozens of acres of land lying over a significant aquifer, haul away the earth and obliterate archaeological artifacts with little or no state oversight and with no requirement to restore the land.

> *"…the water diversion act does not authorize the department's attempts to regulate the plaintiff's excavation activities."*
>
> *Connecticut Supreme Court, 2015*[8]

It was not intended to be so. Since 1972, The Department of Energy and Environmental Protection (DEEP) has had a statutory mandate to "provide for minimum state-wide standards for the mining, extraction, excavation or removal of earth materials of all types" (CGS Section 22a-5), but this has not been done.

Consequently, DEEP does not regulate mining directly and holds only a few modest tools that could minimize harm from mining. A tool that DEEP thought was available, the water diversion act, was removed from DEEP's toolbox in July, 2015. The Connecticut Supreme Court ruled that "the water diversion act does not authorize the department's attempts to regulate the plaintiff's excavation activities."[8] At issue was DEEP's attempt to regulate the environmental effects of a mining excavation when the company applied for a water diversion permit. The Court said that DEEP's jurisdiction was limited to the diversion itself, not the effects of the mining operation, and DEEP could not require the applicant to provide such things as a plan to mitigate impacts to wetlands.

DEEP's other indirect regulatory tools are similarly limited. *Some* sand and gravel mines are required to register for the General Permit for the Discharge of Stormwater Associated with Industrial Activity (or more simply, the "Industrial General Permit"), which would require the mine to control and monitor the quality of the water that is discharged to waterways. The effect of this sole requirement is limited by three factors:

- Mines that do not comply. It appears that some active sand and gravel mines have not registered for the Industrial General Permit, but the Council cannot determine how many might be in violation of that requirement. There is no state census of sand and gravel mines. Such operations are required to register with the federal Mine Safety and Health Administration (MSHA). MSHA records indicate 46 active mines in the state. Of those, 13 have not registered for the Industrial General Permit. An operation that contains all of its stormwater on site would not be required to register, so absence of a permit does not necessarily mean the operation is in violation. Also, some mines apply for an individual permit, not the general permit (see *What is a Registrant?* on page 3). If a company is found to be operating without a permit, the consequences are likely to be minimal.

- Weak enforcement tools. Except in extraordinary cases, an alleged violator receives a Notice of Violation (NOV), which carries no financial penalty. The recipient of an NOV gets thirty days to respond. Fines are rare to nonexistent. DEEP does not have the authority to order a violator of general-permit requirements to cease and desist. In fact, if DEEP seeks to cancel an alleged violator's registration for a General Permit, its authority to do so might be limited by statute (see page 4).

- Mines with no need to register. If stormwater is not expected to leave the property, the mining company does not need to register for the Industrial General Permit. Many mines are depressions in the landscape; regardless of the acreage cleared, many of these mines require no state permit.

Where one finds high-yield aquifers that supply public drinking water, one often finds sand and gravel. However, mining of sand and gravel is not listed as one of the land uses that are regulated under state and municipal aquifer protection regulations. In the Suffield case, an interesting twist is the reliance on the underlying aquifer for public drinking water in Massachusetts but not in Connecticut. This year, DEEP added the cross-border aquifer to its statewide aquifer map "for informational purposes only." Again, even if an aquifer protection area were to be designated, any state regulatory obligations would not apply to removal of sand and gravel.

Other regulations that could apply to sand and gravel mines include limits on dust, but enforcement is undertaken only when a problem is observed; no dust permit is required in advance. Another is, in theory, a state-approved municipal river protection ordinance that would include "restrictions on earth-moving for mining or other purposes," but river protection is another program that exists only in statute. DEEP never completed the model ordinance which is mandated by statute:

> "Model river protection ordinance. The Commissioner of Energy and Environmental Protection…shall prepare a model river protection ordinance…Such model ordinance may include, but need not be limited to, recommendations for…restrictions on earth-moving for mining or other purposes." (CGS Section 25-102xx)

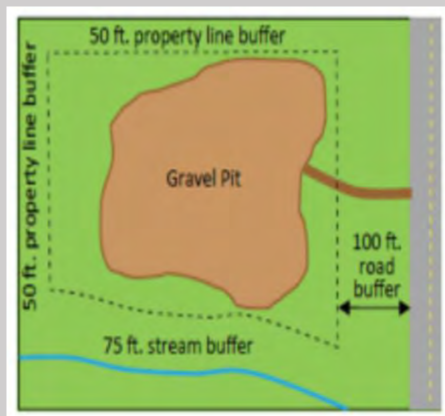
The Role of Towns in Regulating Mining

In the 1990s, the Southwest [Connecticut] Conservation District prepared model municipal regulations for earth excavation activities. No one knows how many towns have adopted such regulations. Using federal grant funds administered by DEEP, the Rivers Alliance of Connecticut surveyed approximately 50 towns in 2007 and found that more than one in five said they did not have a regulation for excavation. For many proposed sand and gravel operations, municipal permit requirements, if any exist, would be the only such requirements. Information provided to the Council reveals that some towns which purport to regulate mining use an approach that is, at best, incomplete.

Other States Regulate Mining

New York, Maine, and Massachusetts are among the northeastern states that regulate mining with requirements to protect aquifers, restore wildlife habitat and/or minimize other impacts. New York requires restoration plans for all mines, and Maine has the following requirements:

- Registration with the Department of Environmental Protection
- Buffer and set-back requirements
- Maximum size restrictions (10 acres working)
- Drainage must be on site not to off site location
- Depth to water table cannot be less than five feet of cover
- Fuel storage must be inside a covered structure
- Reclamation must coincide with mining activity



Recommendations…

The regulatory structure that has developed over many years is not one that would be designed today. The following recommendations are aimed at building a more logical, efficient and effective approach to protecting Connecticut's environment, including streams, historic and archaeological resources and rare species, from negative effects of large earthmoving activities.

…for Stormwater Permitting and Enforcement

1. **Simplify and clarify the Construction General Permit**. Specifically, when this and other stormwater general permits are revised and renewed, DEEP should

- eliminate such phrases as "where possible" in conjunction with "shall," reduce in number the 75+ pages of the permit, and eliminate wording that requires a "no" to assert the affirmative in the checklist of the historic resources section,
- incorporate by reference the 2015 National Weather Service data on precipitation frequency to replace the 1961 data cited in the Construction General Permit, and
- include limits on turbidity (cloudiness) in stormwater discharges.

2. **DEEP should adopt a new general permit for solar farms** or adopt special guidelines for them under existing permits.

   If DEEP concludes that it does not have sufficient authority to adopt this recommendation, the **General Assembly** should authorize DEEP to adopt such a permit.

3. **DEEP should adopt regulations for a new enforcement tool** (administrative penalties) that would create the possibility that violators of stormwater regulations might face and pay financial penalties without a protracted court case.

   If DEEP concludes that it does not have sufficient authority to adopt this recommendation, the **General Assembly** should authorize DEEP to adopt such a tool.

4. **The General Assembly should authorize DEEP to order a violator of a general permit requirement to cease and desist**.

5. **DEEP should clarify its authority to revoke** the stormwater general permit registration if a registrant provides inaccurate information.

   If DEEP concludes that it does not have sufficient authority to adopt this recommendation, the **General Assembly** should authorize DEEP to adopt such clarification.

…for Public Information

6. **DEEP should post all stormwater general permit registrations on its website.**

7. **DEEP should post inspection results online**.

8. **DEEP should audit the veracity of ten percent of the certifications** submitted with Construction General Permit registrations, as required by CGS Section 22a-430b.

…for Preventing Destruction of Historic and Archaeological Sites

See also #14 Below

9. **The Construction General Permit should be revised by DEEP to require that all registrations be reviewed by the State Historic Preservation Officer (SHPO),** and that the registration shall include the SHPO's conclusions.

> If DEEP concludes that it does not have sufficient authority to adopt this recommendation, the **General Assembly** should authorize DEEP to adopt such a requirement.

10. **The Industrial General Permit should be revised by DEEP to include the same protections for archaeological and historic resources** that are included in the Construction General Permit (excepting sites where no earthmoving is involved).

> If DEEP concludes that it does not have sufficient authority to adopt this recommendation, the **General Assembly** should authorize DEEP to adopt such a requirement.

11. **DEEP should fulfill its statutory obligation** (CGS Section 10-387) to determine which of its programs require "detailed consultation **to identify and protect archaeological sites**."

…for Regulation of Mining

12. **DEEP should fulfill its statutory obligation (CGS Section 22a-5) to develop minimum standards for mining.**

13. **DEEP should adopt a new permit program for mining sites**, including sand and gravel mining, to implement the standards, and should remove mining from the Industrial General Permit.

> The new permit should include provisions for review of archaeological, groundwater, surface water and ecological resources, unless another new process is used to regulate those impacts (see Recommendation #13, below).
>
> If DEEP concludes that it does not have sufficient authority to adopt this recommendation, the **General Assembly** should authorize DEEP to adopt such a permit.

The Bigger Picture: Should Connecticut Separate Endangered Species and Historic Resources from Stormwater Permits?

14. **The General Assembly should adopt meaningful protections for endangered species and historic resources as stand-alone statutes** as an alternative to the current process of imposing them only on registrants for stormwater permits and applicants for a few other permits.

Notes

1. According to an April 30, 2014 assessment prepared for the site developer by a consultant, 3.6 inches of rain fell on March 30, 2014. Slightly more than one inch had fallen on the previous day, for a two-day total of about 4.7 inches. The assessment is an attachment to the minutes of the May 5, 2014 hearing of the East Lyme Inland Wetlands Agency at http://eltownhall.com/wp-content/uploads/2014/03/May-5-2014-Show-Cause-Hearing-Minutes.pdf A November 21, 2014 evaluation prepared for an affected landowner by the Eastern Connecticut Conservation District puts the two-day total at "approximately 3.83 inches."

2. Letter from Connecticut Siting Council, April 7, 2014 at http://www.ct.gov/csc/lib/csc/pendingproceeds/petition_1056/pe1056-20140407-siteconditionsltr.pdf

3. The following are the heaviest one-day rainfalls recorded in New London County between 1941 and 2010 for each month of the year, as recorded at official weather stations.

U.S. Department of Commerce
National Oceanic & Atmospheric Administration

Precipitation
Daily Extreme Maximum By Month

Connecticut / New London County		POR For Element **EMXP: 1941 to 2010**
Month	**Precipitation (inches)**	**Location(s) / Date(s)**
1	3.35	Jewett City (063857/99999): 01/24/1998
2	3.05	Colchester 2 W (061499/99999): 02/02/1973
3	5.54	Norwich Pub Utility Plant (065910/99999): 03/30/2010
4	4.28	Norwich Pub Utility Plant (065910/99999): 04/13/2004
5	4.31	Norwich Pub Utility Plant (065910/99999): 05/13/2006
6	6.30	Groton (063207/99999): 06/05/1982
7	4.81	Norwich Pub Utility Plant (065910/99999): 07/02/2009
8	5.21	Norwich Pub Utility Plant (065910/99999): 08/19/1991
9	7.43	Groton (063207/99999): 09/21/1961
10	6.18	Norwich Pub Utility Plant (065910/99999): 10/15/2005
11	3.55	Pachaug Forest (066131/99999): 11/12/1947
12	4.24	Jewett City (063857/99999): 12/12/2008

Source: National Climatic Data Center at http://www7.ncdc.noaa.gov/CDO/cdoextremesdata.cmd

4. 2014 National Climate Assessment, U.S. Global Change Research Program at http://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing

5. "Site development would require the clearing of 134 acres of trees or the removal of approximately 21,130 trees with a diameter of six inches or greater…" Connecticut Siting Council Staff Report re: Petition No. 1178, September 17, 2015 at http://www.ct.gov/csc/lib/csc/pending_petitions/1_petitions_1144through1200/pe1178-dcltr-energy-sprague.pdf

6. *Information to use in the Determination of Stormwater Management (SWM) Impacts for Solar Projects,* PA DEP SERO WSHD SW DR rev. 10/4/2011 at http://www.chesco.org/documentcenter/view/7375

7. Kenneth M. Collette, Hearing Officer, Department of Energy and Environmental Protection, Proposed Final Decision in the Matter of the General Permit for Discharge of Stormwater and Dewatering Wastewater from Construction Activities, August 15, 2013, page 8, at http://www.ct.gov/deep/lib/deep/adjudications/decisions_pdf/081513gpconstructionstormwaterproposedfinaldecision.pdf

8. Tilcon Connecticut, Inc. v. Commissioner of Environmental Protection, 317 Conn. 628 (2015) at http://www.jud.ct.gov/external/supapp/Cases/AROCR/CR317/317CR65.pdf

About the Council on Environmental Quality

The duties of the Council on Environmental Quality (CEQ) are described in Sections 22a-11 through 22a-13 of the Connecticut General Statutes.

The Council is a nine-member board that works independently of the Department of Energy and Environmental Protection (except for administrative functions). The Chairman and four other members are appointed by the Governor, two members by the President Pro Tempore of the Senate and two by the Speaker of the House. The Council's primary responsibilities include:

1. Submittal to the Governor of an annual report on the status of Connecticut's environment, including progress toward goals of the statewide environmental plan, with recommendations for remedying deficiencies of state programs.

2. Review of state agencies' construction projects.

3. Investigation of citizens' complaints and allegations of violations of environmental laws.

In addition, under the Connecticut Environmental Policy Act (CEPA) and its attendant regulations, the Council on Environmental Quality reviews Environmental Impact Evaluations that state agencies develop for major projects. The Council publishes the *Environmental Monitor*, the official publication for scoping notices and environmental impact evaluations for state projects under CEPA. The *Environmental Monitor* also is the official publication for notice of intent by state agencies to sell or transfer state lands.

Council Members

Susan D. Merrow, Chair — Janet P. Brooks — Alicea Charamut

Lee E. Dunbar — Karyl Lee Hall — Alison Hilding

Kip Kolesinskas

Contact the CEQ

Website: www.ct.gov/ceq (for this and all Council publications)

Mail: 79 Elm Street Hartford, CT 06106

Phone: 860-424-4000 (messages can be left 24 hours a day)

E-mail the Council's Executive Director: karl.wagener@ct.gov

Energy Sprawl in Connecticut

Why Farmland and Forests are Being Developed for Electricity Production; Recommendations for Better Siting

A Special Report of the Council on Environmental Quality **February 3, 2017**

One industry that continues to grow in Connecticut is the installation of photovoltaic equipment that converts sunlight to electricity.

Not all solar installations yield equal benefits. Solar panels on commercial rooftops, industrial lands and old landfills can be sustainable home runs. Unfortunately, Connecticut adopted laws and policies that encourage utility-scale solar photovoltaic facilities* to be developed on farmland and forest land. Connecticut was, and still is, unprepared to guide the placement of solar facilities to minimize their environmental damage.

Laws that encourage utility-scale solar facilities should remain in place but be corrected. Drawing on hindsight and five years of other agencies' experiences, the Council on Environmental Quality (CEQ) has identified two critical deficiencies and offers three recommendations to correct them.

Two Deficiencies, Three Recommendations

Deficiency: Selection criteria for renewable energy projects value short-term price above all else. DEEP selects renewable energy projects which promise to deliver electricity at the lowest cost while effectively excluding environmental siting considerations and long-term indirect or external costs. As a result, solar facilities are directed by the market to farmland and forest land and away from previously-developed land.

> **Recommendation 1: The General Assembly should amend renewable-energy procurement statutes (CGS Section 16a-3j) to require DEEP to give meaningful weight to non-price factors, including impacts to agricultural land, forest, grasslands and other natural resources.** (Note: The CEQ is not recommending that agricultural or forest landowners be prohibited from leasing their land to energy producers; the CEQ's recommendations are aimed at changing the manner in which state agencies steer projects to particular sites.)
>
> **Recommendation 2: Solar developers should realize substantial incentives if they use previously-developed land.** DEEP should be authorized to give substantial weight to projects that will fulfill state policy objectives such as redevelopment of previously-developed land. For brownfield sites, DEEP should coordinate with the Department of Economic and Community Development to determine what other incentives could be provided.

---

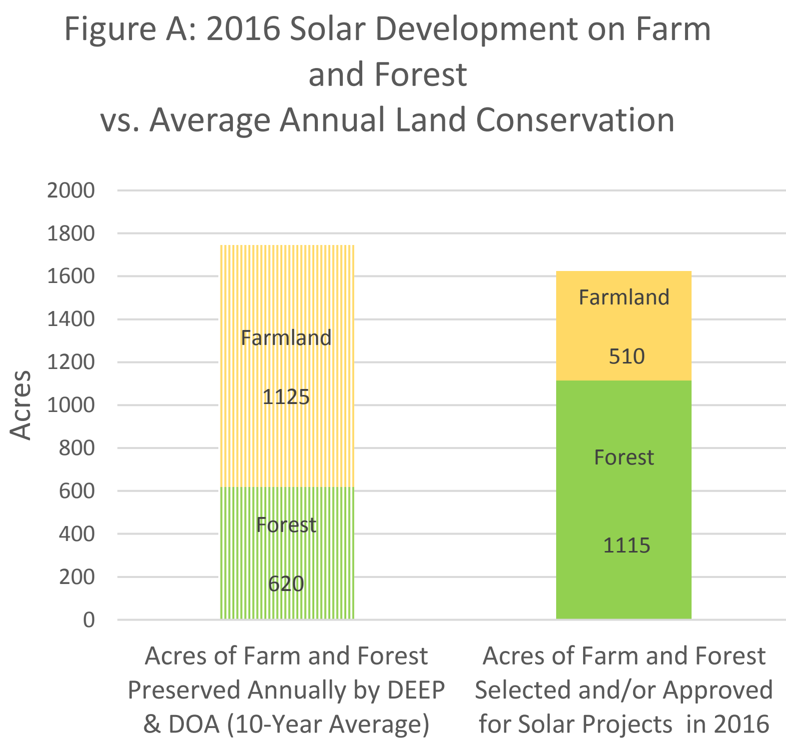
*Solar photovoltaic panels convert sunlight to electricity. This report considers "utility-scale" photovoltaic facilities to be those capable of generating more than two megawatts (MW) of electricity (after conversion to alternating current, or AC). A two MW facility usually will have about 8,000 panels across ten acres.

Deficiency: Utility-scale photovoltaic facilities must be approved by the Connecticut Siting Council (CSC) with very limited discretion. The CSC, required to approve solar facilities by declaratory ruling, cannot deny approval if a solar project meets DEEP's air and water standards. Except where wetlands are affected, forests and other natural resources are not factors in siting approvals. (Municipal regulation is pre-empted.[1])

> **Recommendation 3: Utility-scale solar developments should be required to obtain a Certificate of Environmental Compatibility and Public Need from the Connecticut Siting Council.** Current statutes (CGS Section 16-50k) require the CSC to approve such projects by declaratory ruling. The Certificate is the approval tool for most facilities regulated by the CSC, from power plants to cell towers. In addition, the General Assembly should amend the statute to require the CSC to consider impacts to agricultural land in all decisions.

Hindsight

Important laws to encourage renewable energy development were adopted in 2005, 2011, 2013 and 2015. Probably few residents in 2005 realized that, by 2016, solar photovoltaic facilities would become the largest single type of development consuming agricultural land and forest land in Connecticut. In 2016, the area of farmland and forest selected and/or approved for development of solar facilities nearly equaled the area of such lands preserved by the state in an average year.



"Selected" means selected by DEEP for renewable-energy procurement. "Approved" means approved by the Connecticut Siting Council (CSC). Any project that was selected AND approved was counted only once. The 2016 figures do not include the 25 small-scale (less than 20 MW each) projects selected in November.

The category of land – farmland or forest – was determined from information provided by the project developers to DEEP and/or the CSC. Zoning was not considered.

The trend toward placement of solar photovoltaic facilities on farmland and forest is accelerating, with 1600 acres selected and/or approved in 2016 (Figure A), up from 200 acres in 2015. There is an irony in the state's spending millions of dollars to preserve agricultural and forest land and to encourage private forest management and conservation while, with another hand, encouraging conversion of similar lands into electricity-generating facilities.

In 2011, DEEP made its first foray into selecting large solar projects to provide renewable power to the major electric distribution companies (EDCs). After soliciting bids from 21 projects, DEEP selected two. One has been built on (formerly) active farmland in Somers and one on inactive agricultural soils in East Lyme. DEEP awarded points for non-price criteria, but the weighting was done in a way that caused pricing criteria to completely overwhelm non-price considerations. Several projects were proposed for brownfields or other developed sites but were not selected. Predictably, the proposed electricity price from some of those projects was higher than from farmland-based projects, but that was not true in every case. Either way, the differences in price were small, and the actual impact, if any, of the price differential to retail electricity customers was not determined prior to selection.

Even if the selection criteria had been designed so that siting criteria *could* have made a difference, DEEP did not intend to disadvantage farmland. The projects proposed for farmland received three out of a possible five points awarded for siting criteria (a very small percentage of the overall selection criteria) because farmland was scored as "otherwise reclaimed

Corn & Birds vs. Kilowatts?
Or Corn, Birds *and* Kilowatts?

Connecticut operates a Department of Agriculture to "foster a healthy economic, environmental and social climate for agriculture by developing, promoting and regulating agricultural businesses; protecting agricultural resources…" To accomplish this mission, Connecticut spends more than ten million state dollars every year, much of which is matched or boosted by federal, municipal and private funds. In 2011, the General Assembly directed the Governor's Council for Agricultural Development to recommend ways to increase consumer spending on food grown in-state to five percent of all food spending (double its current share). Does it make sense for another agency to promote industrial development of productive farmland?

Until the past decade, housing and commercial development were the biggest sectors converting land out of agriculture. Then, according to land-cover data presented in *Environmental Quality in Connecticut*, the acreage of land used for agriculture remained fairly steady during and after the recession that began in 2007. It now appears that development of energy facilities is the largest single factor driving land out of agriculture. While agricultural landowners benefit from leasing land for energy production, other farmers lose leased acreage essential to their business. Farmers looking for replacement lands could find rents increasing as available land diminishes. Connecticut long ago concluded that support of the agricultural sector and conservation of productive land was worth state investment. When the state selects energy facilities solely on the basis of their electricity price, it neglects the costs incurred elsewhere in the economy. Farmland and forest land provide important ecosystem services, including dampening the effects of a changing climate, that benefit Connecticut residents.

space;" there was very little opportunity for the brownfield projects (getting all five points) to gain any advantage. As noted above, the pricing criteria dominated the point system completely; the siting points were effectively meaningless.

In 2016, DEEP worked with Massachusetts and Rhode Island to issue a three-state Clean Energy Request for Proposals for large (at least 20 MW capacity) renewable energy projects. From 27 proposals, which included solar, wind, fuel cells, hydroelectric and interstate transmission lines, the winners were overwhelmingly solar farms proposed for farmland and forest (see Figures B and C, next page).

Even though the selection of projects is ostensibly neutral with regard to generation sources (solar, wind, fuel cells, etc.), the outcome of the 2016 selection process could have been predicted to result in a preponderance of solar photovoltaic power facilities on farmland and forest. Reports from as long ago as 2012 explain very clearly why developers of such facilities prefer farmland.[2] Also, it has been reported to the CEQ that the site-selection criteria of some solar development companies clearly favor flat, cleared land away from ledge and shallow bedrock that can be developed rapidly. One of the criteria – proximity to transmission facilities – means that some farmland that was adjacent to transmission lines was selected for solar development and probably was not in jeopardy of being developed for other purposes and therefore would have remained productive farmland.

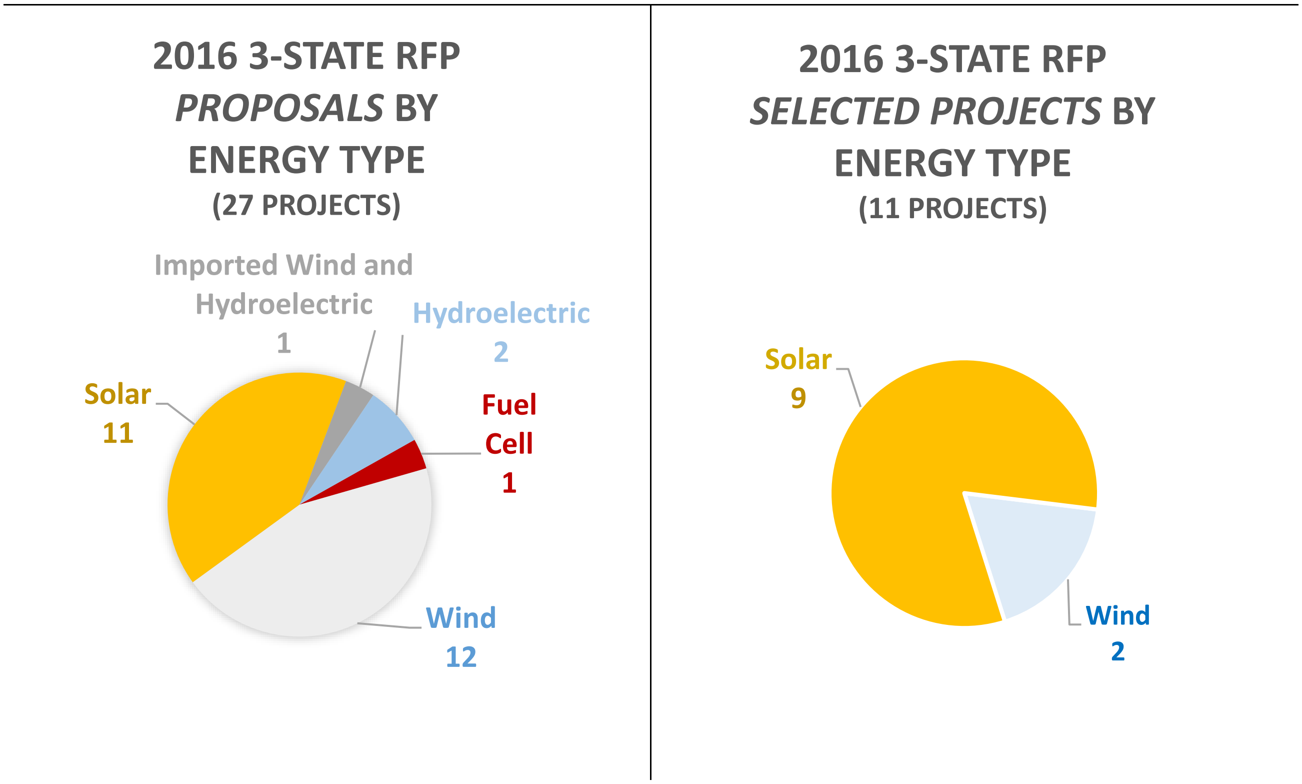
Energy facilities are no exception to the general rule guiding development: it is nearly always cheaper to build on agricultural land and clean forest land than it is to remediate a parcel that might be contaminated or in some way complicated by previous land uses. Without policies that guide solar photovoltaic power facilities toward brownfields, industrial lands and other disturbed areas, the market will place them on farmland and forest.

A surprising result (to the CEQ) of the 2016 three-state RFP process is that two of the six solar photovoltaic power facilities selected for Connecticut were selected by Massachusetts and Rhode Island but not Connecticut itself. Nevertheless, the projects probably will be constructed here.

There are More

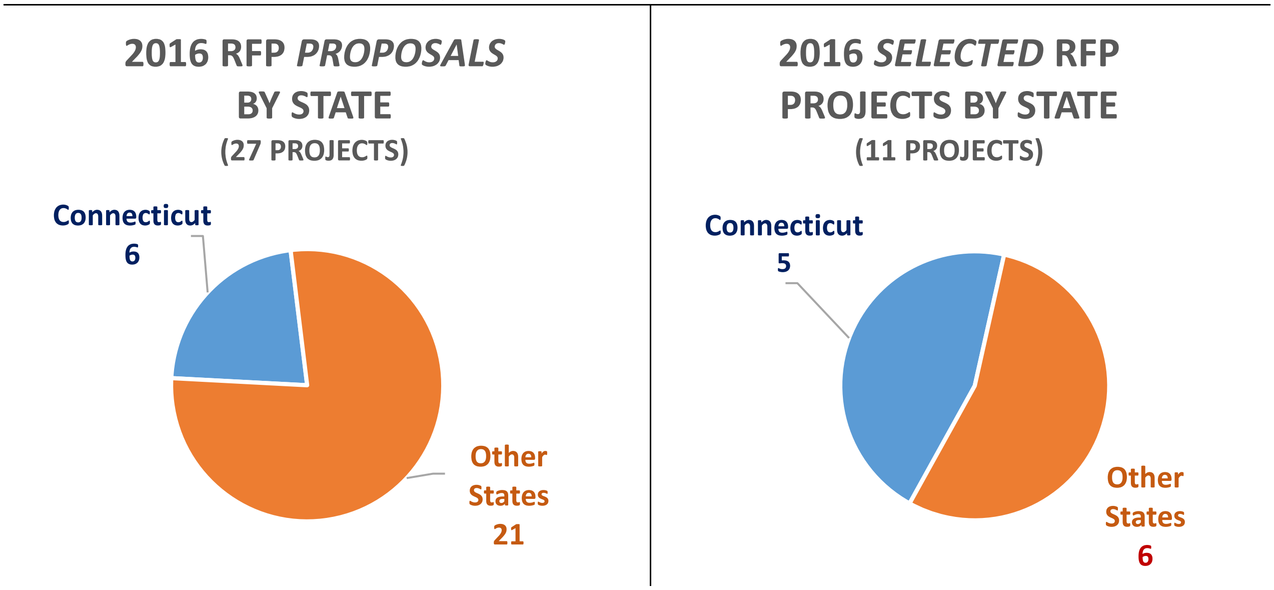
In late November, 2016, DEEP selected 25 smaller-scale (between two and 20 MW) renewable energy projects out of 105 proposed. Some of the selected projects are proposed for landfills or other previously-developed sites, but the locations of others are not yet available to the public, as bidders (and DEEP) are allowed to keep the proposed locations confidential. No further analysis of the November selections is possible at this time.

Figure B: Types of Utility-Scale Renewable Energy Facilities, Proposed vs. Selected in 2016



Conclusion: The use of price criteria alone strongly favored solar over other project types.

Figure C: Location of Utility-Scale Renewable Energy Facilities, Proposed vs. Selected in 2016



Conclusion: The 2016 project-selection process resulted in a disproportionate number of projects in Connecticut. All of the projects selected for Connecticut (unlike other states) were proposed for farmland or undeveloped land.

What is Driving the Push for Solar on Farms and Forests?

The Need for Renewables

For nearly 20 years, Connecticut's electric distribution companies, or EDCs – Eversource, United Illuminating, etc., or what we used to call utilities – have been required by statute to certify that a certain percentage of the electricity sold to customers is from renewable sources (solar, wind, and 13 other types). Each year, that percentage escalates; it is 22.5 percent in 2017, rising to 27 percent in 2020. Since 2011, and especially more recently, the state, through DEEP, has assisted the EDCs by selecting renewable-energy projects to supply the EDCs. Generally, as this report documents, the selected projects in Connecticut are solar photovoltaic facilities on farmland and forest land.

Connecticut's EDCs are not expected to meet the minimum required renewable-source electricity this year; they must pay fees (compliance payments) for missing the target.

Large-scale Waste

Much of the electricity generated in Connecticut, including that generated by solar panels, is wasted. This is true because many of the devices using the electricity – air conditioners, heating units, appliances, computers and televisions – are old and/or inefficient, meaning they use measurably more electricity than necessary to get the job done. If Connecticut's residential consumers and companies used more efficient equipment, then the amount of electricity needed from all sources, including renewable sources, would decline.

Energize Connecticut aptly advises residential solar purchasers that "it's important to make your home as energy efficient as possible" first. Meanwhile, utility-scale generation is fed into a system that wastes electricity throughout.

Successful Projects Away from Farm and Forest

The unimpeded rays of the sun that fall on several Connecticut landfills have been exploited successfully, and more landfill-based systems are under development or consideration. DEEP has encouraged municipalities to develop closed landfills for energy production. It maintains a list of 17 municipalities and other entities that are seeking developers interested in solar projects, and offers some incentives. At least two of the 17 are among the sites of smaller-scale projects selected by DEEP in November 2016 (see "There are More" on previous page).

The Hartford Landfill 1 MW solar array started production in 2014

Several large companies have installed significant solar arrays on their roofs. (See below)

What Are the Options?

State Lands – The CEQ has received numerous comments from Connecticut residents who have noticed the prominent solar arrays along the Massachusetts Turnpike (I-90). They are indeed prominent, but not truly significant in terms of power production: their total generation capacity is about six MW. (If on farmland, that capacity would consume approximately 30 acres.)

Could Connecticut identify non-conservation state properties that might be suitable for solar photovoltaic facilities and lease them to bidders? To do so might conserve private forest and farmland and generate revenue for the state. Potential lands might include highway corridors and institutional land. It is an opportunity to explore, but the CEQ is not aware of many large state properties that would be available. (There is more discussion of state property on page 14.)

Landfills – The typical landfill solar installation in Connecticut is between one and two MW (but generally toward the lower end of that range). Most of the 17 closed landfills mentioned on page six are small, but three exceed 50 acres. Based on gross acreage, development of all 17 landfills mentioned above could perhaps yield up to 80 MW of clean electricity – worth pursuing, but not the major portion of Connecticut's goal for Class I renewable energy generation, estimated to be 2,000 MW by 2030. (For perspective, Connecticut's peak electricity demand on a hot summer day reaches about 7,000 MW.) Because nearly every municipality has one or more closed landfills, there likely are additional ones suitable for solar photovoltaic development.

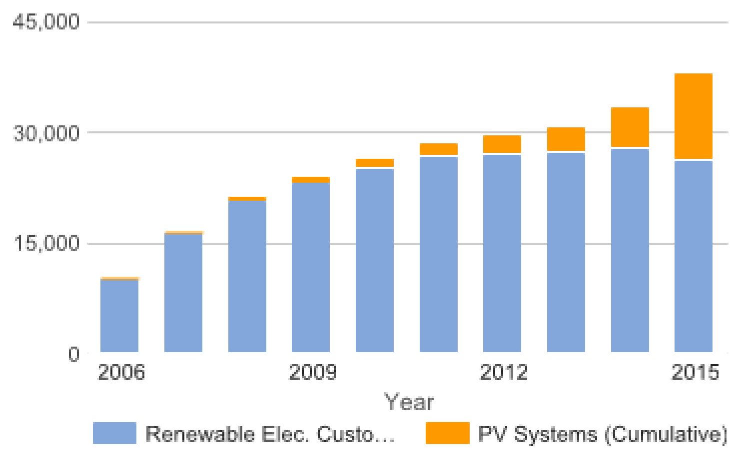
Brownfields and Industrial Lands – If effective incentives were offered to develop solar generating facilities on brownfields (which include derelict or underused contaminated properties but not landfills), could the electricity generation be significant? The National Energy Research Laboratory answered that question for the nation as a whole: only a small fraction of disturbed and contaminated lands are suitable for utility-scale solar photovoltaic facilities, but even those sites would yield enough electricity to meet federal solar-energy goals without disturbing any agricultural or forested lands at all![3]

The national data reveal that the largest contaminated and disturbed sites are well west of Connecticut. For a more local projection, the Unites States Environmental Protection Agency (USEPA), through its Re-Powering America's Land project, estimates that the solar photovoltaic capacity on brownfields and certain other potentially-contaminated industrial lands in Connecticut is about 2,000 MW, an astounding amount that would nearly equal the potential output of Millstone nuclear generating station (which in 2015 produced 46 percent of the electricity generated in Connecticut). However, review of the site-by-site data shows that many of those industrial sites, whether currently contaminated or not, are in use for regular commercial or industrial purposes; the actual area of abandoned or underutilized brownfield properties would yield far less electricity. Nobody knows how many brownfield sites in Connecticut would be suitable. Despite these weaknesses in the USEPA data, the composite potential of these currently unproductive brownfields, of which there are hundreds, could be significant and worth pursuing.

Rooftops – The potential is enormous. Dozens of companies have installed solar photovoltaic panels on their extensive rooftops. These companies stand to benefit financially, in part because of incentives offered through tax credits and successful financing mechanisms adopted to spur the adoption of solar energy. Dozens more manufacturing firms expressed interest in a 2016 incentive program administered by the Connecticut Green bank.

More than 12,000 single-family Connecticut homes sport photovoltaic panels. The growth in residential systems has been rapid (Figure D, below), and the growth potential is even greater: more than 70 percent of Connecticut homes could benefit from solar photovoltaic systems, according to a 2013 study commissioned by the Connecticut Green Bank.[4] In total, those properties could generate nearly 4,000 MW of electricity during the day. Complementary battery storage systems will satisfy part of the nighttime demand. If homeowners who do not have favorable conditions for their own photovoltaic systems were allowed to partner with others through community systems, the potential would be greater still.

Figure D: Households Buying Renewable Electricity and Households with Solar Photovoltaic Systems



The yellow (upper) portion of the bars represent Connecticut homes with solar photovoltaic systems. (The chart is reproduced from Environmental Quality in Connecticut. The blue (lower) portion of the bars tracks customers who buy renewable electricity through a program that was discontinued in 2016.}

In sum, the potential for solar development on rooftops is so great that development of farm and forest land for electricity production could be redundant. The National Renewable Energy Laboratory estimated in 2012 that the generating capacity of solar panels on all suitable rooftops (including residential, industrial and commercial) in Connecticut would be 6,000 MW, equivalent to photovoltaic facilities on nearly 30,000 acres of rural land.[5] Assuming this estimate of technical potential to be wildly optimistic (and bringing it in line with the 2013 study of residential solar potential, discussed above), an estimate of 60-percent development of the rooftop potential would yield electricity generation equivalent to 18,000 acres of installations on rural fields and forests.

Despite the potential for rooftop solar generation to dwarf what is being developed on farms and forests, the latter cannot simply be cast aside in favor of more rooftop generation until state policies and statutes are adjusted. Rooftop generation generally is developed "behind the meter" to

The corporate and manufacturing headquarters for Polamer Precision, Inc., in New Britain

reduce the occupant's own electricity purchases, not to supply the grid and EDCs with a stream of renewable electricity for their portfolios. Nonetheless, rooftop generation helps the state achieve its renewable-energy goals by reducing the amount of electricity that EDCs need to purchase from generation sources of all types. For the future, the CEQ recommends that DEEP's 2016 revisions to the Comprehensive Energy Strategy include an expansive strategy for rooftop solar.

Connecticut's Sustainable Economy

Achieving Connecticut's goals for stability, efficiency, land conservation, economic opportunity, health and happiness requires more than a fixation on the lowest price for a commodity. To choose a supplier solely because its product is the cheapest ignores the costs that its production imposes elsewhere in the economy. In the case of solar photovoltaic generation, widespread use of farmland and forest is likely to result in several costs that should be considered in decision making: the reduction in available farmland and consequent rent increases; the loss of jobs in agriculture and forestry; the continued costs of carrying brownfields and under-utilized lands that could be hosting energy facilities if those facilities were not built on green fields; the additional costs of finding alternate uses for the brownfield sites; the loss of jobs in one renewable-energy industry that is based in Connecticut if another technology built with imported materials is selected instead; the additional costs of making up lost progress toward the state's goals for Connecticut Grown food and wood; and ecological costs such as habitat fragmentation and destruction .

The Balance Trap

The simultaneous pursuit of two state goals which appear to be in conflict is often portrayed as a balancing act. Unfortunately, the "balancing" approach usually results in the diminishment of both pursuits. In the case of renewable energy and the conservation of land – two goals in which the state has invested much – the solution is to integrate or harmonize the two: find a way to stimulate the development of renewable energy on appropriate sites while continuing policies that conserve productive lands. An integrated approach will require accurate evaluation of all costs and benefits.

In future rounds of renewable project selection, **the Council recommends that DEEP be required by statute to give meaningful weight to siting considerations; this likely would require DEEP to create a point system that awards substantial points for siting a project on land that is not farmland, forest, grasslands or other land of ecological value**. **DEEP should consult the Department of Agriculture and the Council on Soil and Water Conservation. (In comments to the CEQ, the latter expressed a willingness to assist in such an effort.)**

Incentives?

The Connecticut Green Bank manages powerful incentives for solar development. However, its successful efforts to spur solar development by homeowners and corporate consumers have not eliminated the push for utility-scale solar photovoltaic facilities that consume farm and forest. If Connecticut continues to seek utility-scale solar photovoltaic generation, incentives will be needed to overcome the market's bias toward farmland and forest.

The Department of Economic and Community Development periodically awards competitive grants to municipalities to assess and/or clean up brownfield properties. Points are awarded for projects that include renewable energy production, but the total (five out of 130) probably is too small to be a powerful incentive. Developers will need something more substantial to abandon farm and forest for brownfields, especially brownfields that might be small and scattered.

Major impediments to siting generating facilities on brownfields are the same ones that impede other types of development: the cost, time and uncertainty inherent in cleaning up contaminated property. As long as it is faster, cheaper, and more certain to develop on uncontaminated properties, the results are predictable: Connecticut residents will watch productive green lands be converted to industrial uses while the abandoned properties sit idle, untaxed and possibly blighted. **The CEQ is recommending adoption, perhaps through a pilot program, of incentives that would lead to use of brownfields for solar development.**

The Massachusetts Department of Energy Resources is proposing a new solar incentive program that would reward projects proposed to be developed on brownfields and landfills.

Regulation of Location

Under current law, there are only two major governmental decision points that influence the siting of utility-scale solar photovoltaic facilities: 1) DEEP's selection of renewable-energy projects for electricity procurement, discussed above, and 2) approval by the Connecticut Siting Council.

Most large fossil-fueled electric generating facilities proposed in Connecticut must obtain a Certificate of Environmental Compatibility and Public Need from the CSC. Most other types of facilities regulated by the CSC, including telecommunications facilities (i.e., cell phone towers), also must obtain such a certificate. The application process for obtaining a certificate affords each project a high level of scrutiny and grants the CSC considerable decision-making discretion. However, neither is true for utility-scale solar facilities. Because of a law adopted in 2005,[6] years before the current solar boom, renewable energy projects less of less than 65 MW generating capacity need not obtain a certificate:

> **"Section 16-50k** – Notwithstanding the provisions of this chapter or title 16a, the [siting] council **shall approve by declaratory ruling** [that no certificate is required for]… the construction or location of any customer-side distributed resources project or facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts**, as long as such project meets air and water quality standards** of the Department of Energy and Environmental Protection." [emphasis added]

In Connecticut, utility-scale solar photovoltaic facilities are always less than 65 MW. As long as a project avoids significant impact to wetlands and watercourses, it will be approved. There are several deficiencies evident in this limited oversight required by statute; examples include:

- A 65 MW solar facility approved by declaratory ruling will affect more than 300 acres.
- If an entire project is proposed to be developed on prime agricultural soils, the CSC has no option but to approve it by declaratory ruling.
- If a project eliminates the upland habitat of a very rare species, the CSC has no option but to approve it by declaratory ruling.
- Impacts to historic or cultural sites cannot be considered.

The CEQ concludes that the 65-MW exemption is ill-suited to utility-scale solar photovoltaic installations (while being potentially useful to less land-intensive technologies). **The General Assembly should amend the CGA Section 16-50k to require utility-scale solar photovoltaic facilities to obtain a Certificate of Environmental Compatibility and public Need and should require the CSC to consider the full range of environmental impacts it normally considers when evaluating energy projects as well as the impacts to agriculture and agricultural land.**

Determining What is at Stake: the Need for Careful Siting

Potential impacts to agriculture are discussed on page three. It is important to note that more acres of forest land than farmland are being transformed into energy facilities.

According to Environmental Quality in Connecticut, the birds that inhabit mature forests and young forest have been declining over the long term, even as the total area of forest in the state stabilized during the recent recession and recovery period. The birds inhabiting mature forests are affected greatly when the forests are fragmented into smaller parcels, and the young-forest birds face numerous challenges.

Some areas with no trees, potentially ideal for solar energy production, can harbor even more threatened species than forests do. Several rare grassland bird species have benefitted over the last decade from a targeted initiative by DEEP and its partners, but others declined. Conservation of grasslands remains a formidable and high-priority challenge for Connecticut.

The habitat potential of many non-wetland areas is often underestimated. Even lands that appear at first glance to be no more than sandy wastelands can harbor very rare species that depend exclusively on such lands. Does this mean that there are no suitable sites for large-scale energy facilities, or that all sites should be treated equally? No. It means that each site should be subject to a thorough review of its natural resources, and that the CSC should have the authority to act on that information. The desired outcome is development of energy facilities where the impacts are least.

The CSC collects information from petitioners about trees and wildlife but cannot do much with it except where wetlands and watercourses are involved. (There could be consequences if a petitioner documented federally-listed species on the land, but that is a rare occurrence.)

Conclusion

Connecticut's 2013 Comprehensive Energy Strategy (CES) envisioned careful siting: "It is important that each renewable power project be considered in light of other state policy objectives, such as optimizing the way land is used in the state." (p. 90, CES) That same strategy, in discussing the large potential for utility-scale solar, adds the phrase "ideally on underutilized lands." (p. 91)

Under current laws, such land-use objectives cannot be realized or even considered.

Can Utility-Scale Solar Photovoltaic Electricity Generation be *Good* for Agriculture?

In the long-term, probably not. Solar developers have asserted that photovoltaic generation could be regarded as a temporary use of land that, once restored 30 years hence, could be returned to growing crops. Information submitted to the Connecticut Siting Council by the Commissioner of Agriculture disputes that assertion, noting the trenching, mixing of soil layers and other disruptions of the land.[7] For one solar development, much of the topsoil reportedly was removed from the site, while a storm washed much of the remaining soil into nearby streams. Clearly the placement of solar arrays and associated equipment has the potential to damage soils; that potential is not evaluated by DEEP or the CSC.

Other arguments have been made to the effect that farming is an uncertain business for which leasing some land for electricity production could be a stabilizing force, and in some cases essential to the long-term prospects for a farm's success. CEQ does not recommend that such farms be prohibited from leasing their land for electricity production. However, the CEQ notes that the potential benefit to individual farms is not evaluated by DEEP when it selects renewable-energy projects, nor does DEEP consider the impacts to individual farms that might *lose* critical leased farmland. Furthermore, it appears that many solar facilities could be expanded easily to consume more of the farm. One cannot conclude, without further research, that utility-scale energy facilities are good for the overall agricultural sector in Connecticut. In any event, there should be no need to sacrifice agricultural production to increase electricity production.

Looking Ahead

The National Renewable Energy Laboratory is studying ways to integrate agriculture with solar facilities as an alternative to "balancing" the two.

Minnesota has adopted laws and policies to encourage solar photovoltaic facilities to be planted with pollinator-friendly plants. For Connecticut, this would appear to be a beneficial approach to solar facilities, but not a reason to place the facilities on farmland.

Connecticut offers "virtual net metering" policies that offer incentives for the placement of renewable energy facilities on farms *when they benefit the agricultural business*; these policies are beneficial and could be expanded beneficially if they do not take prime agricultural soils out of production. Even without virtual net metering, agricultural businesses can benefit from installation of solar arrays for their own consumption; such development is very different from utility-scale development and should not be impeded by the CEQ's recommendations.

How Have Other States Responded?

Many states, counties and municipalities have recognized the contradiction inherent in sacrificing valuable natural and economic resources for renewable electricity production. The following is a very small sample of legislative responses, included here to illustrate the challenge nationwide; they should not be confused with the CEQ's recommendations for Connecticut action.

- The Massachusetts Department of Energy Resources announced, in January 2017, a proposal to overhaul its solar incentive programs. The proposals would reward proposals to use landfills, brownfields, rooftops and parking lots and impose a fee on proposals to use undeveloped lands.

- Wright County, Minnesota, enacted a six-month moratorium on applications in 2016, while Stearns County convened a work group to recommend ordinance revisions, adopted in December, that require solar facilities to include habitat for pollinators.

- Santa Clara County, California, specifically prohibits facilities on certain agricultural lands and allows them on others that are deemed to be of marginal quality for farming purposes (Ord. NS–1200.331, adopted in 2010).

- The New Jersey Energy Master Plan 2015 Update states: "The State should continue its policy of discouraging the development of solar farms on farmland and undeveloped open spaces, such as forests, and encouraging their placement on or above impervious surfaces or on landfills, brownfields or areas of historic fill."

- Monson, Massachusetts approved a bylaw amendment restricting large solar facilities to industrial and commercially-zoned districts.

- Talbot County, Maryland enacted a six-month moratorium on solar arrays larger than two acres to "consider the impact of solar array energy systems on environmentally sensitive areas and agriculturally productive lands."

Good Questions & Interesting Ideas for Future Research and Action

The CEQ posted a draft version of this report on its website in January 2017 and received dozens of excellent comments. Many of the suggestions were applied to the text of the report above. Some of the suggestions struck the Council as very worthwhile, but time did not allow for their full evaluation. Here is a sampling of suggestions for future research and action:

- State lands: Conducting an inventory of state-owned non-conservation lands for their solar potential would take too long. Could DEEP simply issue a Request for Proposals (RFP) that invited solar developers to propose specific state lands for case-by-case consideration? The state potentially could reap lease revenue while the private sector shoulders the cost of identifying the best lands.

- Reportedly there are municipalities that might wish to participate in procurement rounds but are precluded from large-scale project procurement because the available land is not in one parcel. Could future RFPs allow for an assemblage of projects that in combination exceed the minimum 20 MW threshold?

- Which utility rights-of-way, which already consume considerable acreage, could accommodate solar photovoltaic generation? Could the benefit of the generation's proximity to the grid (in the case of electricity-transmission rights-of-way) help to overcome problems inherent in using the transmission corridors for generation?

- What types of land not discussed in this report also should be considered for solar development?

- There is considerable research underway in other states on co-location of solar energy and agricultural production, as well as pollinator-friendly vegetation, that could be applied to Connecticut.

- The concept of steering energy facilities toward previously-developed land and away from farm and forest is a good one; it should be included explicitly in the State Conservation and Development Policies Plan and should apply to other state-supported projects.

- Invasive species, including fast-spreading *Phragmites* (Common Reed), follow land disturbances in Connecticut. The CSC should include mandatory requirements for post-construction maintenance of properties, including effective control of invasive species.

- Connecticut should pursue renewable-energy sources that consume less land.

- Some of the recommendations in this report could be included in DEEP's ongoing update to the Comprehensive Energy Strategy.

Notes

1. Connecticut Siting Council procedures provide for input from affected municipalities, but the local zoning, inland wetlands and other regulatory agencies do not have decision-making authority. Municipal agencies do have enforcement authority when there is a violation of inland wetlands and watercourses regulations and the impacts go beyond the solar development's boundaries.

2. *Solar Siting and Sustainable Land Use*, Association of New Jersey Environmental Commissions, 2012, available at http://www.anjec.org/pdfs/SolarWhitePaper2012.pdf

3. *Solar Development on Contaminated and Disturbed Lands*, National Renewable Energy Laboratory, December 2013, available at http://www.nrel.gov/docs/fy14osti/58485.pdf The estimates in this document are based on a conservative formula where one MW of photovoltaic generation needs 10 acres; most estimates use a ratio of one MW to five acres.

4. *The Addressable Solar Market in Connecticut*, prepared for Connecticut Clean Energy Finance and Investment Authority (now the Connecticut Green Bank) by GeoStellar, Inc., 6 December 2013, available at http://www.ctgreenbank.com/wp-content/uploads/2016/03/Total_Addressable_Market_CT_Final.pdf

5. *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*, National Renewable Energy Laboratory, July 2012, available at http://www.nrel.gov/docs/fy12osti/51946.pdf

6. The legislation that exempted facilities up to 65 MW from the certificate requirement was not the subject of a public hearing at the Connecticut General Assembly; the exemption was inserted via a floor amendment.

7. Commissioner of Agriculture Steven K. Reviczky, letter to Connecticut Siting Council Re: Petition No. 1224, May 11, 2016, available at http://www.ct.gov/csc/lib/csc/pending_petitions/2_petitions_1201through1300/pe1224-deptagriculturecomments.pdf

About the Council on Environmental Quality

The duties of the Council on Environmental Quality (CEQ) are described in Sections 22a-11 through 22a-13 of the Connecticut General Statutes.

The Council is a nine-member board that works independently of the Department of Energy and Environmental Protection (except for administrative functions). The Chairman and four other members are appointed by the Governor, two members by the President Pro Tempore of the Senate and two by the Speaker of the House. The Council's primary responsibilities include:

1. Submittal to the Governor of an annual report on the status of Connecticut's environment, including progress toward goals of the statewide environmental plan, with recommendations for remedying deficiencies of state programs.
2. Review of state agencies' construction projects.
3. Investigation of citizens' complaints and allegations of violations of environmental laws.

In addition, under the Connecticut Environmental Policy Act (CEPA) and its attendant regulations, the Council on Environmental Quality reviews Environmental Impact Evaluations that state agencies develop for major projects. The Council publishes the *Environmental Monitor*, the official publication for scoping notices and environmental impact evaluations for state projects under CEPA. The *Environmental Monitor* also is the official publication for notice of intent by state agencies to sell or transfer state lands.

Council Members

Susan D. Merrow, *Chair*
Janet P. Brooks
Alicea Charamut
Lee E. Dunbar
Karyl Lee Hall
Alison Hilding
Kip Kolesinskas
Matthew Reiser
Charles Vidich

Contact the CEQ

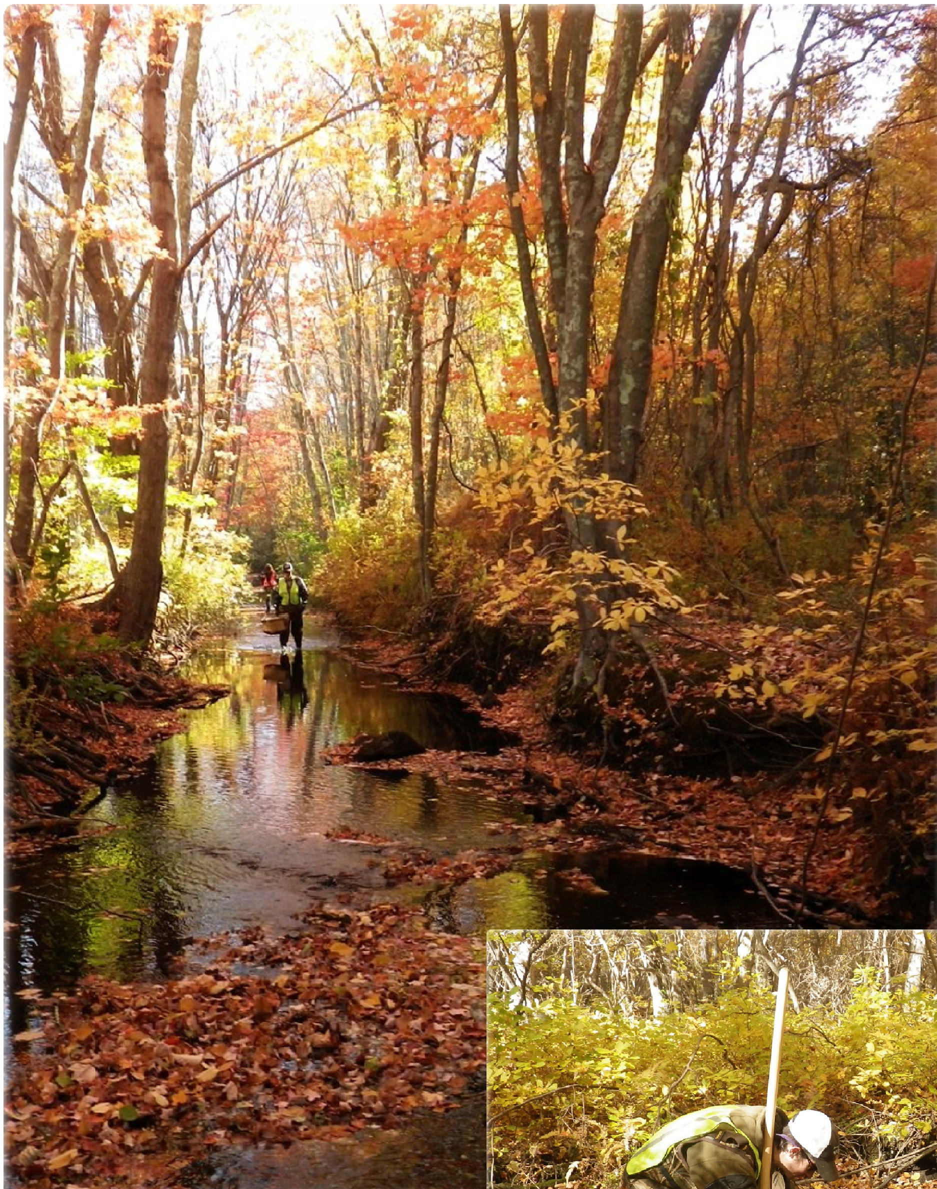
Website: www.ct.gov/ceq (for this and all Council publications)

Mail: 79 Elm Street Hartford, CT 06106

Phone: 860-424-4000 (messages can be left 24 hours a day)

E-mail the Council's Executive Director: karl.wagener@ct.gov

2014-2015 BIOASSESSMENT OF STREAMS IN THE TOWN OF WATERFORD, CT



2015 Summary Report

Prepared for

Town of Waterford
Connecticut

By

Michael Cole, Ph.D.
Cole Ecological, Inc.
Greenfield, MA

June 2016

EXECUTIVE SUMMARY

- The Town of Waterford has conducted stream water quality monitoring on the Town's surface waters for the past seventeen years. To further assist with evaluating and tracking changes in water quality over time, the Town of Waterford initiated a macroinvertebrate bioassessment survey in selected local streams in 2014. The purpose of the macroinvertebrate survey was to assess stream biological conditions and evaluate potential impacts from existing land development. This bioassessment program will also allow for long-term tracking and trending of the ecological condition of the Town's freshwater streams, should monitoring continue or periodic assessments are performed.

- This survey was performed in three local streams – Jordan Brook, Oil Mill Brook, and Stony Brook – to begin to characterize the current condition of macroinvertebrate communities and temporal variability in those conditions. Field sampling was performed in October of 2014 and 2015 in accordance with Connecticut Department of Energy and Environmental Protection's (DEEP) Standard Operating Procedures (SOPs) for Ambient Biological Monitoring: Benthic Macroinvertebrate Community Sampling Field and Laboratory Procedures (DEEP 2013). Macroinvertebrate samples were processed and data were analyzed also using these DEEP SOPs.

- Upper Jordan Brook sites JB02 and JB04 each received Biological Condition Gradient (BCG) level 1/2 classification in both 2014 and 2015, which indicates a natural and native macroinvertebrate community, with minimal or no changes to community structure and composition from an undisturbed condition. BCG Level 1 and 2 communities are comprised largely of species that are sensitive to water pollution and habitat degradation. Multimetric Index (MMI) scores at JB02 and JB04 were 77.5 and 81.8 in 2014 and 79.7 and 77.1 in 2015 (on a scale of 0 to 100). Jordan Brook sites JB05A and JB05B each received a BCG level 3 classification in 2014, while JB05A received a BCG level 3 classification and JB05B a level 4 classification in 2015. A BCG level 3 community shows some evident changes in structure of the biotic community and minimal changes in ecosystem function, whereas a BCG level 4 community shows moderate changes in structure with still minimal changes in function. In a BCG 3 level community, several of the most sensitive species are missing, but the community remains diverse and sensitive species remain abundant, while at BCG level 4, intermediate and tolerant species are increasingly abundant.

- BCG classifications ranged among Oil Mill Brook's three sampling sites in both 2014 and 2015. The uppermost site, OM01A, received a BCG level 4 classification in both 2014 and 2015, as well as the lowest MMI score in either of the two study years of 47.7. Oil Mill Brook site OM02A received MMI scores corresponding to a BCG level 1/2 classification in both 2014 and 2015. This site supports a healthy richness of mayfly, caddisfly, and stonefly (EPT) taxa. In 2015 the lowest Oil Mill Brook site, OM03A, received a total MMI score of 86.0 and a corresponding BCG level 1/2 classification, an apparent improvement over a score of 69.5 and BCG level 3 classification in 2014. This difference at OM03A from 2014 to 2015 of 16.5 points was the largest measured in the two-year study, and exemplifies the need to collect several years of baseline data. In doing so, an average condition can be derived, and variability around this condition can be quantified.

- In 2015 Stony Brook sites SB02 and SB02B both received BCG level 3 classifications, while SB03 received a BCG level 4 classification. Upper Stony Brook at SB02 received a BCG level 3 classification in both 2014 and 2015. Middle Stony Brook, SB02B, was sampled for the first time in 2015, and received a modestly higher MMI score than did SB02, resulting in a BCG level 3 classification. Lower Stony Brook, SB03, received an MMI score of 57.4 and a corresponding BCG Level 4 classification, as compared to scoring 69.8 and receiving a level 3 classification in 2014.

- The results of these two years of sampling these waterbodies collectively suggest that these three small drainages in the Town of Waterford presently support largely diverse native macroinvertebrate communities that have largely not yet been significantly affected by development of the watersheds. Differences in community conditions among sites were not clearly related to differences in water quality, as indicated either by instantaneous measurements collected during macroinvertebrate sampling or by the Town's water quality monitoring data. Among the three watersheds, Stony Brook's macroinvertebrate community presently appears to be the most consistently affected throughout the stream's length. While sections of Jordan and Oil Mill brooks received BCG level 1/2 classifications in both 2014 and 2015, Stony Brook received only level 3 or 4 classifications throughout.

- Streams in urban areas often suffer adverse effects from numerous concurrent stressors. This phenomenon, known as "urban stream syndrome" or "multiple stressors syndrome", is well documented among urban streams. Mechanisms driving the syndrome are complex and interacting, but increased stormwater delivery into physically altered streams is largely the root cause of measured biological impacts. These highly modified hydrologic patterns alter seasonal high and low flows, pollutant concentrations, temperature and dissolved oxygen extremes, sediment inputs, and channel morphology. Presently, these stressors are modest throughout most of each of these three streams, allowing for the persistence of moderate to high ecological integrity in these systems. The long-term conservation of these waterbodies depends largely on the ability to manage stormwater and maintain riparian zone conditions and functions in the face of development pressure. These two years of data serve as a baseline against which to measure those future conditions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGMENTS

Maureen Fitzgerald, Environmental Planner, served as the technical contact and project manager for the Town of Waterford. We thank Ms. Fitzgerald for her support for and management of the project. Michael Cole and Rob Creamer of Cole Ecological, Inc. performed all field and laboratory work for this project. Ms. Fitzgerald accompanied Dr. Cole and Mr. Creamer to all field sites during fall 2014 and 2015 field sampling. We also thank Guy Hoffman with CT DEEP for providing technical information and guidance as necessary to ensure proper application of CT DEEP's field, laboratory, and analysis protocols to this project.

INTRODUCTION

The Town of Waterford has conducted a stream water quality monitoring program on the Town's surface waters for the past seventeen years. Under this program, water chemistry data are collected at designated sampling locations twice a year. To further assist with evaluating and tracking changes in water quality over time, the Town of Waterford initiated a macroinvertebrate bioassessment survey in selected local streams in 2014.

The purpose of this macroinvertebrate survey was to assess stream biological condition and water quality and evaluate potential impacts from existing land development. The biological information can be used in conjunction with existing water quality and land-use data from these systems to more fully inform the overall ecological condition of each of these waterbodies. Furthermore, establishment of this bioassessment program will allow for long-term tracking and trending of the ecological condition of the Town's freshwater streams, should monitoring continue or if periodic assessments are performed.

This survey was performed in local streams in 2014 and 2015 to begin to characterize the current condition of macroinvertebrate communities and temporal variability in those conditions. Collection of this information over several years will better allow detection of changes to biological conditions in the future, should they occur. The first two years of data collection occurred in the fall of 2014 and 2015 following sample site selection in the spring and summer of 2014. This summary report describes the methods and results of these first two years of sampling.

STUDY AREA

Three small coastal watersheds occur wholly or partially within the Town of Waterford. From east to west, these drainages are Jordan Brook (6.35 mi^2), Stony Brook (2.86 mi^2), and Oil Mill Brook (5.73 mi^2). From north to south, Jordan Brook is bisected by Interstate-395, Route 85, Interstate-95, and Route 1. Each of these three watersheds comprises mixed land uses, with more developed land uses generally occurring in the middle and lower portions of each. The Jordan Brook headwaters north (upstream) of I-395 are largely undeveloped; development pressure increases to the south, beginning at the I-395/Route 85 intersection. Additional development is proposed for this area, as well as in the central portion of the watershed immediately south of I-95. The most intensive development within the watershed generally occurs in the southern portion of the drainage along Route 1. Stony Brook is bisected by I-95 and bound by I-395 to the north, and Route 1 to the south. Development pressure increases from north to south in the watershed, with the heaviest development presently in the south and southeast portions of the drainage. A large track of presently undeveloped land to the south and west of I-95 is zoned for development. Oil Mill Brook is bisected by I-395 and Route 85. Development pressure in the Oil Mill drainage is presently lightest among the three survey watersheds; as is the case with the other two watersheds, development pressure is generally heavier in the southern (downstream) portion of the drainage.

METHODS

SITE SELECTION

Macroinvertebrate survey sites were selected within the Jordan Brook, Stony Brook, and Oil Mill Brook watersheds. Two to four sampling sites were selected within each watershed to represent conditions across the length of the mainstem streams and to monitor the effects of current and potential future development on the ecological conditions of each system. When habitat conditions allowed (higher-gradient reaches with suitable riffle habitat and coarse substrates), macroinvertebrate monitoring sites were co-located with the Town's current water quality monitoring stations. To the extent possible, an upstream, least-disturbed (with respect to upstream drainage land-use condition) site was selected within each watershed. Potential sample sites were visited in the field in spring 2014, and a sample site list was developed in fall 2014. Fall 2015 sampling included the addition of a third sample site on Stony Brook, located downstream of I-95 (Table 1). This site was added to capture a larger drainage area within the upper/middle section of the Stony Brook watershed.

FIELD DATA COLLECTION

Field sampling was performed in October of 2014 and 2015 in accordance with Connecticut Department of Energy and Environmental Protection's (DEEP) Standard Operating Procedures for Ambient Biological Monitoring: Benthic Macroinvertebrate Community Sampling Field and Laboratory Procedures (DEEP 2013). Strict adherence to these protocols ensured data integrity and is necessary to produce meaningful, relevant results from the analyses employed. Field sampling followed CT DEEP's standard high gradient semi-quantitative sampling method. Using this protocol, macroinvertebrates were sampled from riffles within each sample reach with a rectangular frame kick net. Samples were properly labeled and preserved in ethanol as described in the SOPs. A physical habitat characterization was performed at each sample site using the CT DEEP's rapid habitat assessment adapted from USEPA (DEEP 2013).

SAMPLE SORTING AND MACROINVERTEBRATE IDENTIFICATION

Laboratory methods employed in the execution of this study followed those as described in CT DEEP's Standard Operating Procedures for Ambient Biological Monitoring: Benthic Macroinvertebrate Community Sampling Field and Laboratory Procedures (DEEP 2013) and Standard Operating Procedures: Subsampling Procedures for Benthic Macroinvertebrate Stream Samples (DEEP 2012). Samples were processed at Cole Ecological, Inc.'s macroinvertebrate sample processing lab in Greenfield, Massachusetts. Sample processing was performed using one or more 56-cell gridded pans to remove a 200-organism (+/- 10%) subsample from the original sample. As specimen condition and maturity allowed, all subsampled organisms were identified to DEEP target levels, including all insects and most other taxonomic groups to genus or species.

Table 1. Stream reaches included in the macroinvertebrate bioassessment survey performed for the Town of Waterford in fall, 2014 and fall, 2015.

Waterbody Name	Site ID	Location	Lat	Long	2014 Site	2015 Site	Area (mi^2)	Ref Site?
Jordan Brook	JB02	Vauxhall St. Extension Conservation Easement Area - DS of old mill dam	41.4026	72.1624	Y	Y	0.48	Y
	JB04	East of Crossroads Storage Facility	41.3804	72.1565	Y	Y	1.65	N
	JB05A	Below Coca Cola plant	41.3612	72.1474	Y	Y	3.34	N
	JB05B	Yorkshire Drive @ Fog Plain Road	41.3528	72.1441	Y	Y	3.57	N
Oil Mill Brook	OM01A	West of Speedbowl property	41.3979	72.1785	Y	Y	2.99	Y
	OM02A	DS of I-395 overpass/Oil Mill Road	41.3885	72.1777	Y	Y	3.69	N
	OM03A	US of I-95	41.376	72.1908	Y	Y	5.37	N
Stony Brook	SB02	US of I-95	41.3728	72.1732	Y	Y	0.42	Y
	SB02B	~400 m DS I-95	41.3668	72.1743		Y	1.3	N
	SB03	Below Rte 1 immed US of tidal section	41.3574	72.1761	Y	Y	1.96	N

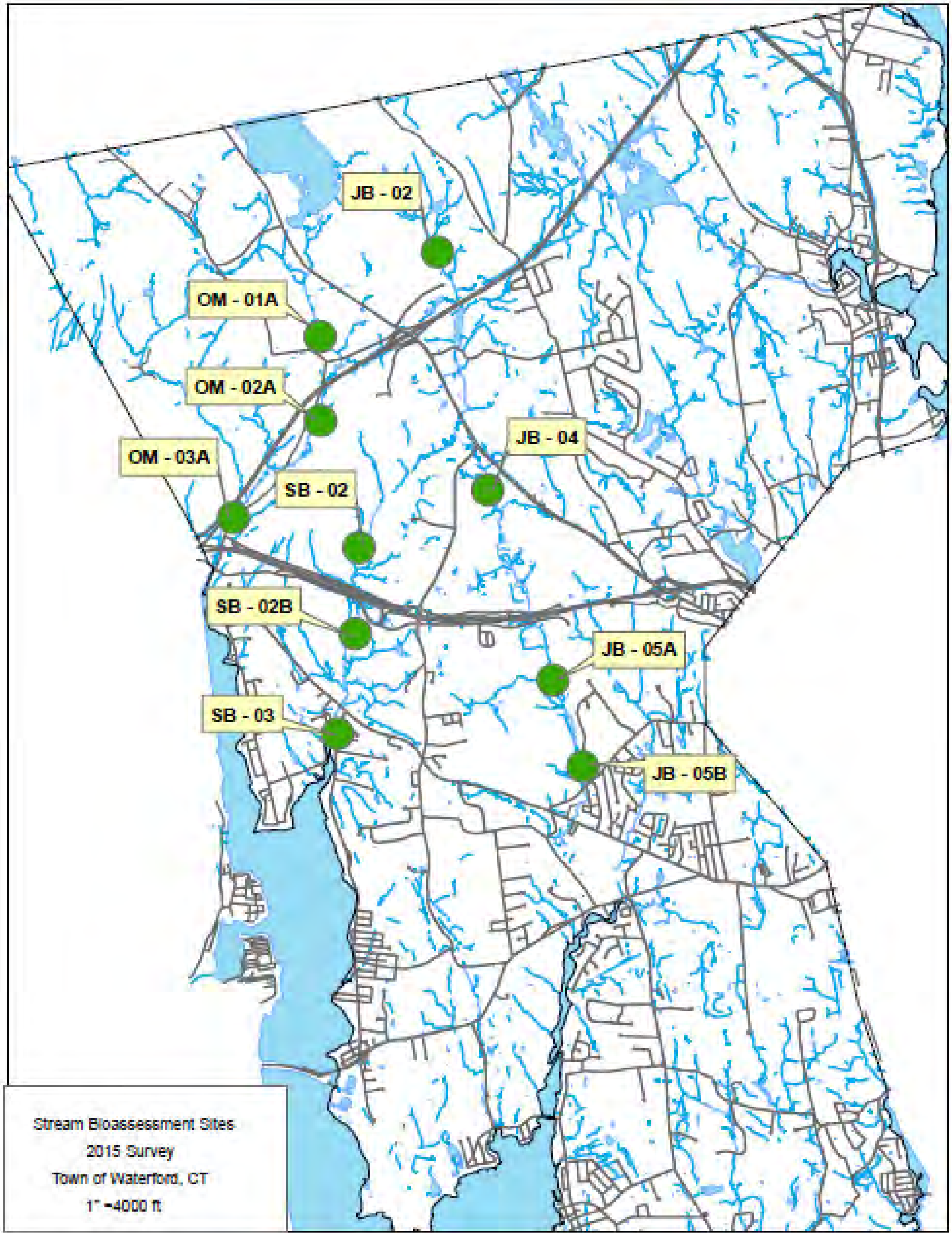


Figure 1. 2014-2015 Macroinvertebrate bioassessment sites, Town of Waterford, CT.

DATA ANALYSIS

Data reduction, analysis, and biological condition determinations also followed DEEP's SOP (DEEP 2013) and utilized the multimetric index and biological condition gradient developed for Connecticut's streams (Tetra Tech 2007a). The multimetric index method is a commonly used tool for evaluating the overall effects of human disturbance on aquatic communities, in this case macroinvertebrates. As the name implies, the index includes a number of ecological attributes or "metrics", each of which is known to be responsive to disturbance. These metrics are each calculated from the raw data and converted to standardized scores that can be summed or averaged to produce a single index or value that reflects overall biological condition. The biological condition gradient is a universal system (a measurement scale, of sorts) for measuring biological condition based on known relationships between disturbance and biological responses to disturbance. Both a multimetric index and biological condition gradient have been developed for Connecticut's higher-gradient streams.

Data analysis employed the seven-metric Multi-metric Index (MMI) developed by Tetra Tech and now in use by DEEP for high-gradient streams (Table 2; Tetra Tech 2007a). Following calculation of the MMI, each sample site was assigned a Biological Condition Class according to the criteria on page 6-1 in Tetra Tech's technical document (2007a).

Table 2. Metrics used to assess the condition of macroinvertebrate communities collected from stream in the Town of Waterford, CT in the fall of 2014 and 2015 (source: Jessup and Gerritson 2007).

Metric	**Scoring Formula**
Ephemeroptera taxa (mayflies)	100* (X + 1.4) / 8.5
Plecoptera taxa (stoneflies)	100* X / 6
Trichoptera taxa (caddisflies)	100* X / 13
% sensitive EPT (mayflies, stoneflies, & caddisflies)	100* (X + 9.2) / 75.2
Scraper taxa	100* X / 11
BCG Taxa Biotic Index	100*(4.6-X) / 1.5
% dominant genus	100*(85-X) / 73

RESULTS & DISCUSSION

Stream reaches sampled in this study were small, as wetted channel widths ranged only between approximately 5 and 18 feet (Table 3) and upstream drainage areas ranged from 0.42 to 5.37 square miles. Habitat conditions observed in the field were very similar between 2014 and 2015. Pool-to-riffle ratio varied among the sample sites, ranging from 80/20 to 30/70 (Table 3). Banks generally showed little or no sign of significant erosion, with the exception of the lower Stony Brook site (SB03) and the middle Jordan Brook JB05A and JB05B sites (Table 3). Reaches were generally well shaded by mature riparian trees and shrubs, as canopy cover ranged from 65 to 90% across the 10 sample sites in 2015 (Table 3). Summary tables of physical habitat data collected in 2014 are presented in Appendix 5.

Streambed substrate was generally dominated by coarse materials in sampled riffle habitats (Table 4). Cobble sized-substrate dominated riffle bed material in the upper Jordan Brook site (JB02), all three Oil Mill Brook sites, and co-dominated substrate along with gravels at the lower Stony Brook site (SB03; Table 4). Gravel was the dominant bed material at the three middle/lower Jordan Brook sites. Only the upper Stony Brook site was dominated by boulder and sand substrates (Table 4).

Table 3. Select physical habitat attributes recorded from stream reaches sampled during the Town of Waterford macroinvertebrate assessment survey in fall 2015.

	Jordan Brook				Oil Mill Brook			Stony Brook		
Attribute	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB02B	SB03
Width (ft)	5	12	15	17	12	15	15	6	9	10
Pool/Riffle Ratio	70/30	50/50	60/40	80/20	60/40	50/50	30/70	80/20	40/60	50/50
Erosion/Bank Fail]	No	No	Yes	Yes	No	No	No	No	No	Yes
Canopy/Shading %	80	90	80	80	80	65	80	80	80	75

Table 4. Summary of stream substrate conditions at sites included in the Town of Waterford macroinvertebrate assessment survey in fall 2015.

	Jordan Brook				Oil Mill Brook			Stony Brook		
Description	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB02B	SB03
Bedrock	0	0	0	0	0	0	0	0	0	0
Boulder	15	5	5	0	10	20	10	40	5	15
Cobble	45	30	25	20	60	45	60	15	65	35
Gravel	25	50	45	60	15	20	20	15	20	35
Sand	15	15	20	15	15	15	10	30	10	15
Silt	0	0	5	5	0	0	0	0	0	0
Clay	0	0	0	0	0	0	0	0	0	0

Rapid habitat assessment scores suggested relatively similar habitat quality among 9 of the 10 study sites, as scores ranged between 140 and 154 (on a scale of 0 to 200) among these 9 sites. One site, Jordan Brook JB05B, received a lower Rapid Habitat score of 112 in 2015 and 116 in 2014 (Table 5), largely the result of increased sediment deposition and significant bank scour throughout this reach (Table 5). Jordan Brook site JB05 was historically straightened, resulting in altered geomorphic and physical habitat conditions into the present. Upper Jordan Brook at JB02 received a habitat score 13 points lower in 2015 than in 2014. Channel flow status and frequency of riffles were both lower by at least three points in 2015, indicating that lower flows in summer 2015 were visibly affecting habitat conditions in this reach. Furthermore, the pool/riffle ratio in this reach was higher in 2015 than in 2014, likely also a reflection of the effects of lower flows in 2015.

Field measurement of water chemistry at the time of macroinvertebrate sampling indicated generally supportive conditions among the 10 sites with respect to water temperature, and dissolved oxygen (7.19 to 10.58 mg/L). This range of concentrations was very similar to that observed in 2014 (6.92 to 11.37 mg/L). Dissolved oxygen concentrations were lowest at upper Oil Mill Brook OM1A at 7.19 mg/L at 1100 hours.

Table 5. Summary of rapid habitat assessment scores of sites included in the Town of Waterford macroinvertebrate assessment survey in fall 2015. 2014 total scores are also included for comparison.

	Jordan Brook				Oil Mill Brook			Stony Brook		
Description	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB02B	SB03
Epifaunal Substrate	17	16	17	14	17	18	18	13	17	17
Embeddedness	14	12	11	10	11	12	12	10	11	10
Velocity/Depth Regimes	14	15	16	14	17	15	13	14	17	17
Sediment Deposition	13	12	12	11	11	12	12	8	12	10
Channel Flow Status	14	18	18	18	17	17	15	13	16	18
Channel Alteration	16	16	16	9	17	18	17	19	15	14
Frequency of Riffles	13	17	16	10	16	12	17	10	17	16
Bank Stability	16	15	14	6	18	18	16	18	13	18
Vegetative Prot.	14	12	12	6	16	16	14	18	13	14
Riparian Zone Width	20	20	18	14	14	13	17	20	20	6
2015 TOTAL SCORE	**151**	**153**	**150**	**112**	**154**	**151**	**151**	**143**	**151**	**140**
2014 TOTAL SCORE	164	153	149	116	159	152	151	148		140

Specific conductance ranged between 107 and 418 µS/cm (versus 90 and 331 µS/cm in 2014) among the 10 sites (Table 6). As in 2014, the most significant change in specific conductance between sites occurred between JB02 and JB04, as specific conductance increased from 117 to 418 µS/cm (from 90 to 320 µS/cm in 2014). These two sites are bisected by Rte 85; as such, JB04 receives runoff from this road, while JB02 does not. The JB04 sample site is also downstream of a tributary drainage that receives stormwater discharge from a treatment basin associated with the commercial retail center known as Waterford Commons (M. Fitzgerald, personal communication).

Macroinvertebrate communities in the Jordan Brook watershed received multimetric index (MMI) scores ranging from 56.8 to 79.7 in 2015, resulting in Biological Condition Gradient (BCG) Levels of 1/2, 3, and 4. BCG levels are described for Connecticut as follows (Tetra Tech 2007b):

Level 1.

Natural or native condition. For Connecticut streams, this means the community is dominated by species that are sensitive and indicative of clean waters and undisturbed habitat.

Level 2

Minimal changes in structure of the biotic community and minimal changes in ecosystem function. Some rare native species may be locally or regionally absent; some migratory fish absent due to downstream blockages. This level is generally not distinguishable from Level 1 from Connecticut's macroinvertebrate monitoring data only.

Level 3

Evident changes in structure of the biotic community and minimal changes in ecosystem function. Several of the most sensitive species have disappeared, but the community remains diverse, and still has abundant sensitive species that fill many ecological roles.

Level 4

Moderate changes in structure of the biotic community with minimal changes in ecosystem function. Sensitive species are reduced but remain present and moderately diverse, and fill a few ecological roles. Intermediate and tolerant species are abundant and dominant, but not completely dominant.

Level 5

Major changes in structure of the biotic community and moderate changes in ecosystem function. Tolerant and intermediate species have completely replaced sensitive species, and these now fill the ecological roles. They may be moderately diverse, and abundance can be high.

Level 6

Severe changes in structure of the biotic community and major loss of ecosystem function. Only a few of the most tolerant species remain (the "last survivors"), although they may be abundant. Several ecological roles have been lost (loss of function).

Table 6. Summary of stream water quality measured at sites included in the Town of Waterford macroinvertebrate assessment survey in fall 2015.

	Jordan Brook				Oil Mill Brook			Stony Brook		
Description	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB02B	SB03
Date	10/27	10/26	10/26	10/26	10/26	10/26	10/26	10/26	10/27	10/26
Time	1020	1530	1645	1435	1110	1030	945	1350	915	1200
Temperature (^{o}C)	7.24	10.86	10.42	10.51	9.3	9.29	8.91	9.75	7.59	9.21
Specific Cond (µS/cm)	117	418	322	296	107	132	144	238	318	291
DO (% sat)	78.8	83.8	91.3	76.9	67.3	86.2	91.4	79.9	83.8	76.3
DO (mg/L)	9.52	9.21	10.17	8.63	7.19	9.82	10.58	8.78	9.97	8.18

Jordan Brook sites JB02 and JB04 each received BCG level 1/2 classification in both 2014 and 2015 (Table 7), which indicates a natural and native community, with minimal or no changes to community structure and composition (please see Appendix 2 for a complete list of macroinvertebrates sampled from each site). BCG Level 1 and 2 communities are comprised largely of species that are sensitive to water pollution and habitat degradation. MMI scores at JB02 and JB04 were 77.5 and 81.8 in 2014 and 79.7 and 77.1 in 2015 (on a scale of 0 to 100). Both sites received the highest possible standardized metric score of 100 for both Ephemeroptera taxa richness in both 2014 and 2015 (Table 7). Trichoptera taxa richness at JB02 and JB04 decreased from 10 and 11 in 2014 to 8 and 7 in 2015 (Table 8). This range of variability in individual community metrics can be expected among sampling years, and while potentially related to year-to-year variability in flows and ambient environmental conditions, does not warrant cause for concern.

Percent dominance by a single genus was low at both sites in both 2014 and 2015, indicative of a well-balanced biological community structure. As further indication of the ecological health of this reach, a number of brook trout were observed spawning on the day of the macroinvertebrate survey in 2014 (Figure 2). Brook trout spawning activity was not observed in JB02 in 2015, likely a consequence of the low flows that occurred throughout the region in fall 2015.

The cold-water obligate caddisfly *Palaeagapetus celsus* was sampled from JB02 in 2014; CT DEEP has only one other record of occurrence of this species in the state (Guy Hoffman, CT DEEP, personal communication).

The caddisfly *Palaeagapeus celsus*

Wiggins (1996) describes the known distribution of *P. celsus* as the Appalachian Mountains of North Carolina and Tennessee and the Laurentians of Quebec, and further states that the species is local in occurrence. The author of this report has sampled *P. celsus* from western Massachusetts and has seen the species from several locations in Pennsylvania. *P. celsus* was not sampled from JB02 again in 2015, indicating that the taxon likely occurs only in low abundance at this sample site.

Jordan Brook sites JB05A and JB05B each received a BCG level 3 classification in 2014, while JB05A received a BCG level 3 classification and JB05B a level 4 classification in 2015 (Table 7). A BCG level 3 community shows some evident changes in structure of the biotic community and minimal changes in ecosystem function, whereas a BCG level 4 community shows moderate changes in structure with still minimal changes in function. In a BCG 3 level community, several of the most sensitive species are missing, but the community remains diverse and sensitive species remain abundant, while at BCG level 4, intermediate and tolerant species are increasingly abundant.

While JB05A and JB05B each received a lower BCG classification than the upper two Jordan Brook sites, MMI scores were not remarkably different between these two pairs of sites (Table 7), indicating generally similar community conditions. Furthermore, while 2014-2015 JB05B MMI scores fell into different BCG classes, the two scores were similar (56.8 versus 67.0), suggesting that the community condition in this reach presently scores around the BCG 3/4 threshold.

Richness of Ephemeroptera (mayflies) and Plecoptera (stoneflies) orders was generally similar between JB05A and JB05B in both 2014 and 2015, as was percent dominance by one genus (Table 8). In both 2014 and 2015, lower MMI scores and corresponding BCG levels at JB05A and JB05B resulted primarily from poorer "% sensitive EPT" metric values when compared to the upstream Jordan Brook sites. The lower BCG classification in 2015 appears to result primarily from fewer caddisfly taxa having been sampled in 2015 as compared to 2014, as well as a lower % sensitive EPT in 2015 (Table 8).

Figure 2. Adult brook trout observed sitting on a redd in upper Jordan Brook (site JB02).

The communities at JB05A and JB05B exhibited a number of characteristics that were similar to those in the other Jordan Brook reaches. Modest reductions in the diversity and abundance of sensitive caddisfly and stonefly taxa in the lower reaches are primarily responsible for the lower BCG classifications at JB05A and JB05B. These changes to the community in lower Jordan Brook are potentially the result of reduced habitat quality at JB05B, as indicated by lower Rapid Habitat Assessment scores). While lower dissolved oxygen at JB05A and JB05B relative to JB02 and JB04 was a suspected stressor on macroinvertebrate communities in Jordan Brook's mid reaches, dissolved oxygen data collected periodically by the Town of Waterford suggest that dissolved oxygen concentrations are not consistently higher in the upper Jordan Brook reaches than in the middle reaches (data provided by M. Fitzgerald, Town of Waterford). Examination of these water quality data collected by the Town of Waterford suggest that while dissolved oxygen concentrations may be modestly lower just downstream from JB05A and JB05B than upstream of these sites, most of the reductions in dissolved oxygen along Jordan Brook occur downstream of JB05B. At present, these data suggest that dissolved oxygen is not likely contributing to the lower MMI scores at JB05B. Rather, lower rapid habitat scores at JB05B relative to all of the other Jordan Brook macroinvertebrate sample sites suggest that habitat conditions such as lower abundance of riffle habitat and slightly higher substrate embeddedness may be contributing to these lower biological condition scores.

BCG classifications ranged among Oil Mill Brook's three sampling sites in both 2014 and 2015 (Table 7). The uppermost site, OM01A, received a BCG level 4 classification in both 2014 and 2015, resulting primarily from fewer Plecoptera taxa, Trichoptera taxa, scraper taxa, far fewer sensitive EPT individuals, and a higher biotic index (indicating a community more tolerant to organic enrichment pollution) than the other two sites (Table 8). Fewer than half as many caddisfly taxa were sampled from OM01A than from OM02A and OM03A in 2015 (Table 8). In 2015, fewer stonefly taxa were sampled from OM01A than from any other site (Table 8), which contributed largely to OM01A receiving the lowest MMI score in either of the two study years of 47.7. Based on data collected by the Town of Waterford, this change in BCG Level from 4 to 1/2 from OM01A to OM02A does not appear to be related to differences in water quality between the two sites. A review of the Town's water quality data suggests similar dissolved oxygen and pH conditions throughout Oil Mill Brook. Furthermore, the OM01A macroinvertebrate sampling station occurs upstream of any influence of Speedbowl property on the brook. While habitat assessment scores suggest similar conditions among the three Oil Mill Brook site, the lower biological condition measured in OM01A could potentially be related to legacy effects of an upstream dam on the hydrologic and thermal regimes in this upper section of the brook. Continuous temperature monitoring in this location and further downstream could further address this consideration.

Oil Mill Brook site OM02A received MMI scores corresponding to a BCG level 1/2 classification in both 2014 and 2015 (Table 7). This site supports a healthy richness of mayfly, caddisfly, and stonefly (EPT) taxa (Table 8). Furthermore, a 7-inch brown trout was incidentally captured while sampling for macroinvertebrates in OM02A in 2015. This fish was most likely of wild origin, further suggesting that the biological communities of middle Oil Mill Brook are not significantly degraded (Figure 4).

Figure 3. Brown trout (*Salmo trutta*) captured from OM02A during fall 2015 macroinvertebrate sampling.

In 2015 the lowest Oil Mill Brook site, OM03A, received a total MMI score of 86.0 and a corresponding BCG level 1/2 classification, an apparent improvement over a score of 69.5 and BCG level 3 classification in 2014. This difference at OM03A from 2014 to 2015 of 16.5 points was the largest measured in the two-year study, and exemplifies the need to collect several years of baseline data. In doing so, an average condition can be derived, and variability around this condition can be quantified. As a result, future assessment results are given more context, and inferences about change can be made with higher confidence. In 2015, 24 EPT taxa were collected from this site, as compared to only 17 EPT taxa collected in 2014. Percent sensitive EPT was highest among all sites in both 2014 and 2015, suggesting that this site presently supports a diverse macroinvertebrate community that includes an abundance of sensitive species.

Among the three study watersheds, Stony Brook exhibited the smallest range of MMI scores in 2015, ranging from 57.4 at SB03 to 64.7 SB02B. In 2015 Stony Brook sites SB02 and SB02B both received BCG level 3 classifications, while SB03 received a BCG level 4 classification (Table 7). As in 2014, the uppermost Stony Brook site SB02 once again supported fewer Trichoptera and scraper taxa than did most other sites, resulting in low standardized scores for each of these metrics. In 2015, SB02 was once again the only site from which no Ephemeroptera taxa were sampled. However, the Ephemeroptera taxa metric is adjusted by drainage area (Tetra Tech 2007a) and results in fewer mayfly taxa predicted to occur in smaller drainages. Consequently, the small drainage area size of SB02 (0.48 square miles) resulted in the absence of mayflies having minimal effect on the standardized score (because very few mayfly taxa would be expected to occur in a stream as small as upper Stony Brook, even in the absence of disturbance). Both SB02 and JB02 drainage areas were less than 1.0 square mile, resulting in potentially biased standardized Ephemeroptera richness scores. The JB02 Ephemeroptera richness scores for 2014 and 2015 do not appear to be biased, as JB02 had the same Ephemeroptera richness and received the same standardized score as did JB04. As such, only the SB02 Ephemeroptera richness metric and corresponding overall average score are flagged in Table 7 as potentially biased.

Middle Stony Brook, SB02B, was sampled for the first time in 2015, and received a modestly higher MMI score than did SB02 (Table 7), resulting in a BCG level 3 classification. Similar to the other Stony Brook sites, relatively few EPT taxa were sampled from SB02B. Across all three Stony Brook sites, one mayfly taxon was sampled from two of the sites, while none were sampled from SB02. Both mayfly diversity and abundance are considerably lower across Stony Brook than in the other two study watersheds. Stonefly taxa richness was 2 at each Stony Brook site, but averaged more than 3 taxa across the Oil Mill and Jordan Brook sites.

Lower Stony Brook, SB03, received an MMI score of 57.4 and a corresponding BCG Level 4 classification, as compared to scoring 69.8 and receiving a level 3 classification in 2014 (Table 7). Both stonefly richness and caddisfly richness were lower in 2015 than 2014, largely contributing to the lower BCG classification. The Plecoptera taxa, Trichoptera taxa, and percent sensitive EPT metrics performed the poorest at this site in 2015.

Biological conditions were generally similar among the three Stony Brook sample sites. Several community metrics, particularly mayfly richness and percent sensitive EPT, underperformed in Stony Brook relative to the other study watersheds. Examination of Stony Brook water quality data collected by the Town of Waterford and the Niantic Watershed River Committee (NWRC) suggest that water quality is similar among the three sites with respect to DO, pH, and specific conductance. NWRC pH data collected in 2014 and 2015 suggest that pH in Stony Brook seasonally fall between 5.5 and 6.0, which is sufficiently low to be affecting the stream's biology, particularly sensitive mayfly taxa. Furthermore, as the smallest of the three study drainages, Stony Brook may be more severely affected by drought conditions. Such potential issues could be further assessed with continuous temperature monitoring and dissolved oxygen monitoring during peak-stress conditions (AM hours during heat spells).

The results of these two years of sampling these waterbodies collectively suggest that these three small drainages in the Town of Waterford presently support largely diverse native macroinvertebrate communities that have not yet been significantly affected by development of the watersheds. Measured differences in community conditions among sites were not clearly related to differences in water quality, as indicated either by instantaneous measurements collected during macroinvertebrate sampling or by the Town of Waterford's or the NRWC's water quality monitoring data. Furthermore, long-term water quality and macroinvertebrate sampling sites often could not be co-located owing to requirements that macroinvertebrates be sampled from riffle habitats, reducing the value of water quality data for purposes of evaluating potential site-specific stressors to macroinvertebrates.

Among the three watersheds, Stony Brook presently appears to be the most consistently affected throughout its length. While sections of Jordan and Oil Mill brooks received BCG level 1/2 classifications in both 2014 and 2015, Stony Brook received only level 3 or 4 classifications throughout. As discussed earlier, additional temperature and dissolved oxygen monitoring during peak-stress periods may further inform the likely causes of the observed variation in biological conditions among sampling locations. Nevertheless, conditions throughout the study area are generally intact: all sites received BCG classifications between levels 1/2 and 4, suggesting that no communities have undergone "major" or "severe" changes in conditions, despite these three systems occurring at least partially within urbanized areas. These present conditions provide an opportunity to protect and conserve relatively intact biological conditions and functions. The continued maintenance of these conditions and functions will depend largely on the ability to minimize the impact of future development on the hydrology of these systems. Such hydrologic protection will help buffer against changes in sediment loads, temperature regimes, and water quality, all known to deleteriously impact aquatic life.

As further indication of the relatively intact ecological condition of each of these brooks, brook trout were observed in each brook during the study period. These three brooks continue to support native fish and macroinvertebrate communities because development is presently limited in each watershed, and a significant amount of intact forest in each continues to provide the necessary functions to maintain relatively unmodified hydrologic (streamflow) regimes.

The upper Jordan Brook site, JB02, and the upper Stony Brook site, SB02, each occurred in drainages of less than 1 square mile. CT DEEP's multimetric index development and calibration data set included no sites with drainage areas smaller than 1 square mile. Accordingly, the BCG condition levels assigned to these two sites should be interpreted loosely. As an additional measure of the current condition of upper/middle Stony Brook, a third sample site (SB02B) was added in 2015. This site's drainage area exceeded one square mile, better assuring proper application of the CT DEEP multimetric index. Importantly, the total MMI scores currently assigned to both SB02 and JB02 provide a valuable baseline for measuring trends in ecological conditions at these two sites over time. Potential bias occurs in only one metric (mayfly richness) among seven metrics used in the multimetric index; all of which can prove useful at assessing biological conditions and detecting changes when they occur. Furthermore, this bias likely occurs presently only at SB02. Accordingly, continuing to sample macroinvertebrates from these upstream locations is recommended.

Streams in urban areas often suffer adverse effects from numerous concurrent stressors. This phenomenon, known as "urban stream syndrome" or "multiple stressors syndrome", is well documented among urban streams (Walsh et al. 2005). Mechanisms driving the syndrome are complex and interacting, but efficient stormwater delivery into physically altered streams is largely the root cause of measured biological impacts. These highly modified hydrologic patterns alter seasonal high and low flows, pollutant concentrations, temperature and dissolved oxygen extremes, sediment inputs, and channel morphology. Presently, these stressors are modest throughout most of each of these three streams, allowing for the persistence of moderate to high ecological integrity in these systems. The long-term conservation of these waterbodies depends largely on the ability to manage stormwater and maintain riparian zone conditions and functions in the face of development pressure. These two years of data serve as a baseline against which to measure those future conditions.

QUALITY CONTROL RESULTS

Two of the 22 samples processed in 2014 and 2015 were re-examined by a second macroinvertebrate taxonomist for quality control re-identification of the sample material. The samples passed re-inspections with Bray-Curtis similarity scores of 96.6% and 97.9%. Field duplicate samples were collected at OM02A in 2014 and at JB05A in 2015. Duplicate samples produced similar MMI scores of 84.1 and 79.0 at OM02A and 64.6 and 61.7 at JB05A in 2015, resulting in the same BCG level classifications. Sample SB03 was processed as a lab duplicate (split sample) for this project in both 2014 and 2015. Lab duplicate MMI scores were similar: 69.8 and 65.7 in 2014 and 57.4 and 61.5 in 2015.

Table 7. Multimetric scores and corresponding biological condition gradient (BCG) levels calculated from macroinvertebrate samples collected during the Town of Waterford's fall 2014 and 2015 bioassessment surveys.

	STANDARDIZED SCORES								
Sample Site	Ephemeroptera taxa	Plecoptera taxa	Trichoptera taxa	% sensitive EPT	Scraper taxa	BCG Taxa Biotic Index	% dominant genus	AVG SCORE	BCG LEVEL
2014									
JB02	100.0	50.0	76.9	100.0	36.4	81.1	98.3	77.5	1,2
JB04	100.0	33.3	84.6	100.0	81.8	81.7	90.8	81.8	1,2
JB05A	74.8	33.3	69.2	39.6	54.5	65.6	98.1	62.2	3
JB05B	100.0	33.3	61.5	49.7	63.6	67.9	92.8	67.0	3
OM01A	100.0	66.7	38.5	35.5	27.3	56.2	89.6	59.1	4
OM02A	84.0	83.3	92.3	78.0	72.7	84.9	93.2	84.1	1,2
OM03A	65.1	50.0	76.9	60.6	54.5	79.3	100.0	69.5	3
SB02	96.0*	66.7	38.5	86.2	36.4	63.9	95.9	69.1	3
SB03	66.9	50.0	76.9	54.6	81.8	74.7	83.5	69.8	3
2015									
JB02	100.0	83.3	61.5	96.5	36.4	80.5	100.0	79.7	1,2
JB04	100.0	50.0	53.8	93.1	81.8	60.9	100.0	77.1	1,2
JB05A	74.8	33.3	61.5	69.2	54.5	82.4	76.4	64.6	3
JB05B	73.0	33.3	38.5	35.0	54.5	67.4	95.8	56.8	4
OM01A	100.0	16.7	38.5	26.9	54.5	49.4	47.9	47.7	4
OM02A	95.7	83.3	84.6	55.6	54.5	75.1	84.4	76.2	1,2
OM03A	100.0	66.7	100.0	69.9	72.7	94.8	98.2	86.0	1,2
SB02	96.1*	33.3	38.5	83.8	36.4	65.3	80.6	62.0	3
SB02B	100.0*	33.3	30.8	97.2	36.4	76.4	78.8	64.7	3
SB03	66.9	33.3	46.2	49.6	63.6	75.0	67.3	57.4	4

**indicates potentially biased score as a result of small drainage area*

Table 8. Individual, unadjusted metric scores calculated from macroinvertebrate samples collected during the Town of Waterford's fall2014 and 2015 bioassessment surveys.

RAW METRIC VALUES							
Sample Site	Ephemeroptera taxa	Plecoptera taxa	Trichoptera taxa	% sensitive EPT	Scraper taxa	BCG Taxa Biotic Index	% dominant genus
2014							
JB02	4	3	10	21	4	3.38	13
JB04	4	2	11	41	9	3.37	19
JB05A	4	2	9	14	6	3.62	13
JB05B	8	2	8	23	7	3.58	17
OM01A	7	4	5	9	3	3.76	20
OM02A	5	5	12	45	8	3.33	17
OM03A	4	3	10	60	6	3.41	11
SB02	0	4	5	10	4	3.64	15
SB03	1	3	10	10	9	3.48	24
2015							
JB02	5	5	8	18	4	3.06	11
JB04	4	3	7	27	9	3.54	11
JB05A	4	2	8	37	6	3.29	29
JB05B	4	2	5	12	6	3.39	15
OM01A	6	1	5	3	6	3.68	50
OM02A	6	5	11	28	6	3.13	23
OM03A	7	4	13	43	8	3.11	13
SB02	0	2	5	8	4	3.38	26
SB02B	1	2	4	18	4	3.23	27
SB03	1	2	6	6	7	3.03	36

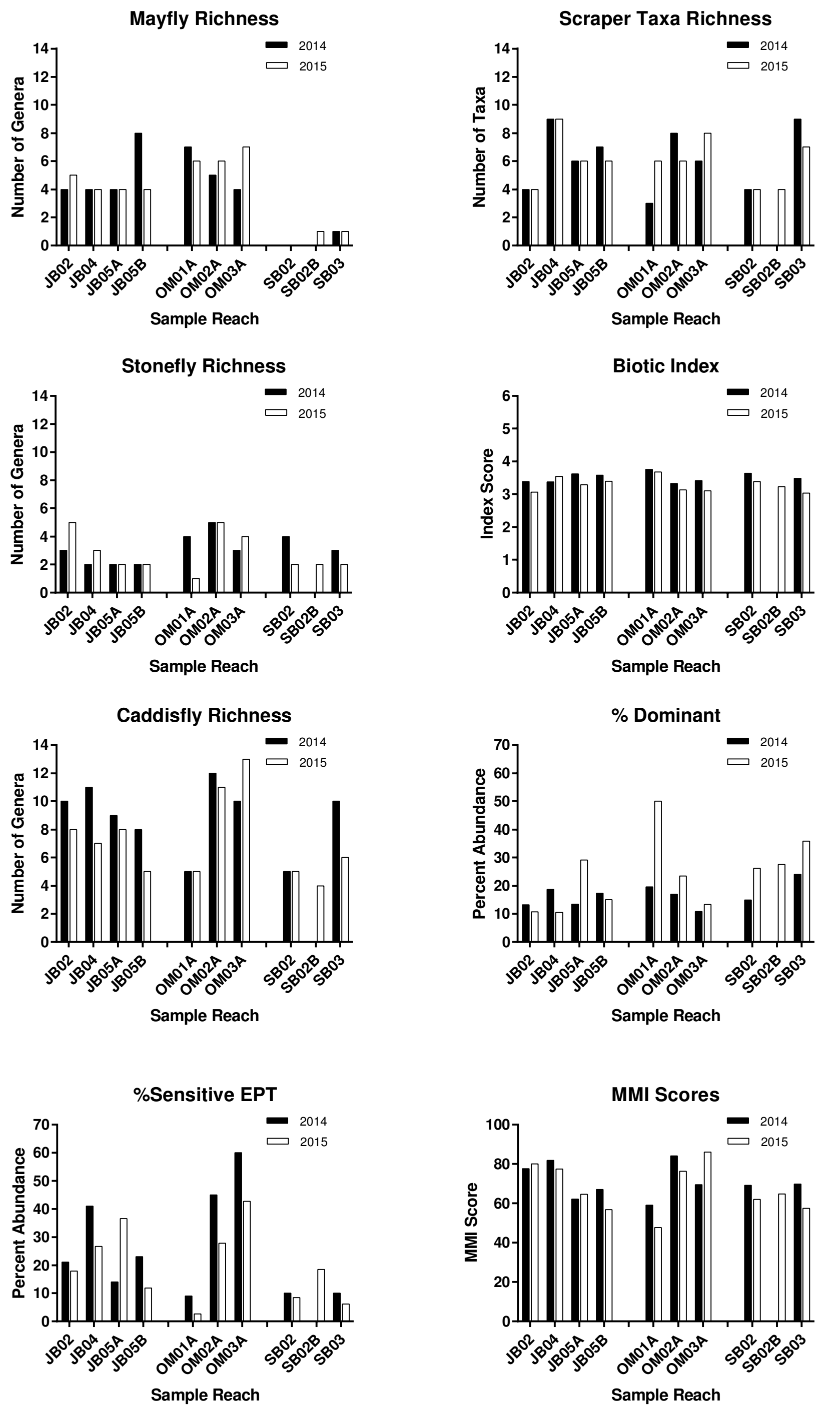


Figure 4. Individual community metrics and multimetric index scores from macroinvertebrate samples collected during the Town of Waterford's fall 2014 and 2015 bioassessment surveys.

LITERATURE CITED

CT DEEP. 2013. Standard Operating Procedures: Ambient Biological Monitoring: Benthic Macroinvertebrate Community Sampling Field and Laboratory Procedures. Connecticut Department of Energy and Environmental Protection. Hartford, CT. 47 pp.

CT DEEP. 2012. Standard Operating Procedures: Subsampling Procedures for Benthic Macroinvertebrate Stream Samples. Connecticut Department of Energy and Environmental Protection. Hartford, CT. 20 pp.

Tetra Tech. 2007a. Calibration of the Biological Condition Gradient for High Gradient Streams of Connecticut. Unpublished report prepared by Tetra Tech, Inc. Owings Mills, MD. 86 pp.

Tetra Tech. 2007b. Framework for Implementation of Tiered Aquatic Life Uses in Connecticut: Supplement to Calibration of the Biological Condition Gradient for High Gradient Streams of Connecticut. Unpublished report prepared by Tetra Tech, Inc. Owings Mills, MD. 7 pp.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, and R.P Morgan II. 2005. The urban stream syndrome: current knowledge and the search for a cure. J. N. Am. Benthol. Soc. 24(3): 706-723.

Wiggins, G. B. 1996. Larvae of the North American caddisfly genera (Trichoptera), 2nd Edition. University of Toronto Press, Toronto.

Appendix 1: 2014 Reach Summary Sheets

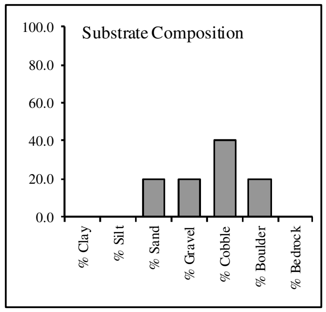
Site ID:	**JB02**		
Stream Name:	**Jordan Brook**		
Location:	Vauxhall St. Extension Conservation Easement Area		
County, State:	New London County, CT	Latitude:	41.40255
Date sampled:	10/28/2014	Longitude:	72.16237
Field Personne	MBC, RTC		

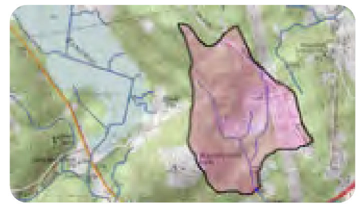
Reach Assessment Summary

COLE ECOLOGICAL, Inc.

Physical and Chemical Conditions Summary

Drainge Area: 0.48 mi^2





Instream Physical Characteristics

Wetted Width (m)	5.0
Riffle Depth (ft)	0.2
Run Depth (ft)	0.5
Pool Depth (ft)	1 to 2
Pool/Riffle Ratio	40/60
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Exc
Evidence Scouring	No
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	20.0
% Gravel	20.0
% Cobble	40.0
% Boulder	20.0
% Bedrock	0.0

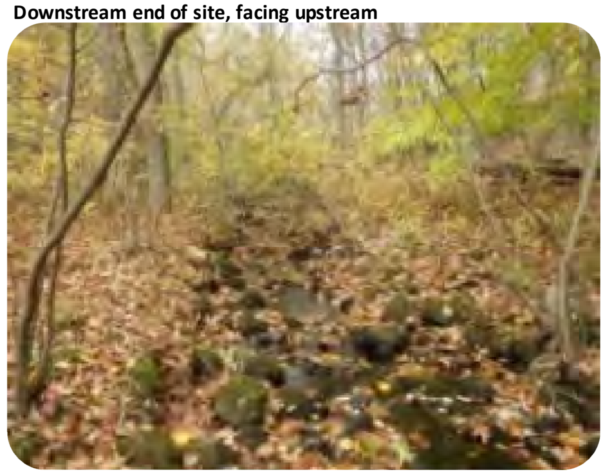
Rapid Habitat Assessment Scores

1. Epifaunal Substrate	18
2. Embeddedness	15
3. Vel/Depth Regimes	15
4. Sediment Deposition	14
5. Channel Flow Status	17
6. Channel Alteration	16
7. Frequency of Riffle	17
8. Bank Stability	18
9. Vegetative Prot.	14
10. Rip Zone Width	20
TOTAL SCORE	**164**

Water Chemistry

Time	12:00
Temp	10.93
Sp Cond	90
Cond	66
DO%	86.3
DO mg/L	9.53
Depth (ft)	0.3
pH	6.72

Downstream end of site, facing upstream



Upstream end of site, facing downstream

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	Score
Ephemeroptera ta	4	100.0
Plecoptera taxa	3	50.0
Trichoptera	10	76.9
% sens EPT	21	100.0
Scraper taxa	4	36.4
Biotic Index	3.4	81.1
% dom genus	13.2	98.3
TOTAL SCORE		**77.5**

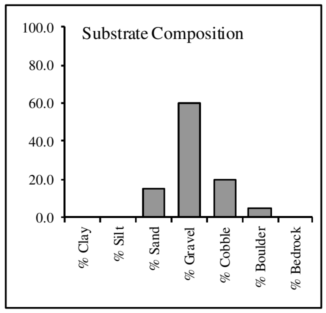
CE Sample ID: 14-102-01
Sample Method: CT DEEP $2m^2$ Kick Net
Habitat(s) Sampled: Riffles

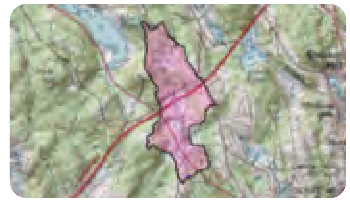
Site ID:	**JB04**		
Stream Name:	**Jordan Brook**		
Location:	Behind Crossroads Storage Facility		
County, State:	New London County, CT	Latitude:	41.38041
Date sampled:	10/28/2014	Longitude:	72.15649
Field Personne	MBC, RTC		

Reach Assessment Summary

Physical and Chemical Conditions Summary

Drainge Area: 1.65 mi^2





Instream Physical Characteristics

Wetted Width (m)	15.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1.0
Pool/Riffle Ratio	60/40
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Exc
Evidence Scouring	No
Canopy/Shading %	90.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	60.0
% Cobble	20.0
% Boulder	5.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	16
2. Embeddedness	12
3. Vel/Depth Regimes	15
4. Sediment Deposition	12
5. Channel Flow Status	19
6. Channel Alteration	16
7. Frequency of Riffle	16
8. Bank Stability	15
9. Vegetative Prot.	12
10. Rip Zone Width	20
TOTAL SCORE	**153**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	10.64
Sp Cond	320
Cond	232
DO%	90
DO mg/L	10
Depth (ft)	0.3
pH	6.63

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	4	100
Plecoptera taxa	2	33.33
Trichoptera	11	84.62
% sens EPT	41	100
Scraper taxa	9.0	81.82
Biotic Index	3.4	81.7
% dom genus	18.7	90.84
TOTAL SCORE		**81.8**

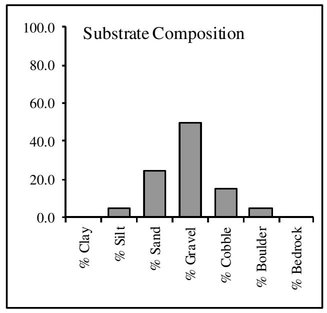
CE Sample ID: 14-102-02
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID:	**JB05A**		
Stream Name:	**Jordan Brook**		
Location:	Below Coca Cola plant		
County, State:	New London County, CT	Latitude:	41.36124
Date sampled:	10/28/2014	Longitude:	72.14744
Field Personne	MBC, RTC		

Reach Assessment Summary

Physical and Chemical Conditions Summary

Drainge Area: 3.34 mi^2



Instream Physical Characteristics

Wetted Width (m)	15.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1.0
Pool/Riffle Ratio	60/40
Erosion/Bank Fail?	Yes
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	Yes
Canopy/Shading %	75.0

Substrate

% Clay	0.0
% Silt	5.0
% Sand	25.0
% Gravel	50.0
% Cobble	15.0
% Boulder	5.0
% Bedrock	0.0

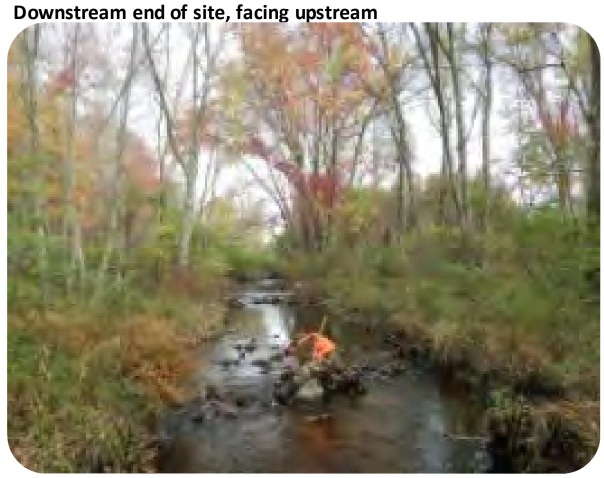
Rapid Habitat Assessment Scores

1. Epifaunal Substrate	16
2. Embeddedness	11
3. Vel/Depth Regimes	16
4. Sediment Deposition	12
5. Channel Flow Status	19
6. Channel Alteration	16
7. Frequency of Riffle	15
8. Bank Stability	14
9. Vegetative Prot.	12
10. Rip Zone Width	18
TOTAL SCORE	**149**

Water Chemistry

Time	0:00
Temp	9.66
Sp Cond	208
Cond	147
DO%	97.7
DO mg/L	11.12
Depth (ft)	0.5
pH	6.78

Downstream end of site, facing upstream



Upstream end of site, facing downstream

Biological Conditions Summary

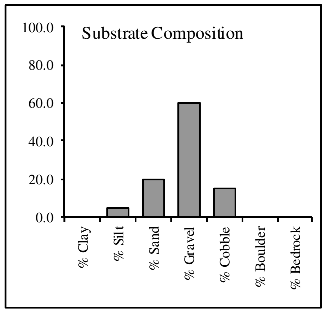
CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	4	74.83
Plecoptera taxa	2	33.33
Trichoptera	9	69.23
% sens EPT	14	39.61
Scraper taxa	6.0	54.55
Biotic Index	3.6	65.6
% dom genus	13.4	98.05
TOTAL SCORE		**62.2**

CE Sample ID: 14-102-03
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID:	**JB05B**	**Reach Assessment Summary**		
Stream Name:	**Jordan Brook**			
Location:	Yorkshire Drive @ Fog Plain Road			
County, State:	New London County, CT		Latitude:	41.35278
Date sampled:	10/28/2014		Longitude:	72.14408
Field Personne	MBC, RTC			

Physical and Chemical Conditions Summary



Drainge Area: 3.57 mi^2

Instream Physical Characteristics

Wetted Width (m)	18.0
Riffle Depth (ft)	0.3
Run Depth (ft)	1.0
Pool Depth (ft)	1 to 1.5
Pool/Riffle Ratio	80/20
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	Yes
Canopy/Shading %	70.0

Substrate

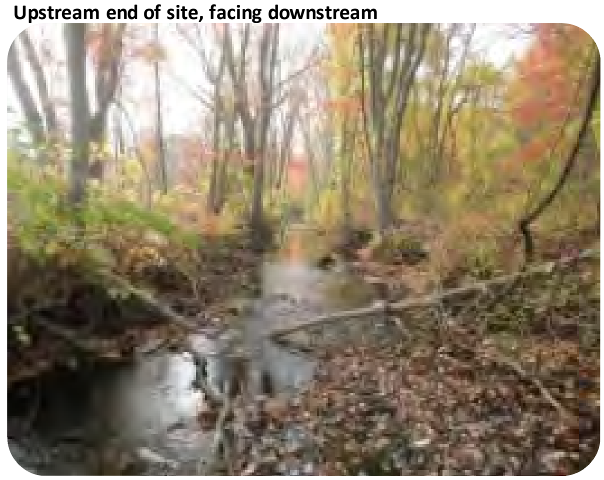
% Clay	0.0
% Silt	5.0
% Sand	20.0
% Gravel	60.0
% Cobble	15.0
% Boulder	0.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	14
2. Embeddedness	11
3. Vel/Depth Regimes	15
4. Sediment Deposition	12
5. Channel Flow Status	19
6. Channel Alteration	9
7. Frequency of Riffle	10
8. Bank Stability	6
9. Vegetative Prot.	6
10. Rip Zone Width	14
TOTAL SCORE	**116**

Upstream end of site, facing downstream



Water Chemistry

Time	0:00
Temp	10.76
Sp Cond	227
Cond	164
DO%	62.4
DO mg/L	6.92
Depth (ft)	0.5
pH	6.5

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	8	100
Plecoptera taxa	2	33.33
Trichoptera	8	61.54
% sens EPT	23	49.67
Scraper taxa	7.0	63.64
Biotic Index	3.6	67.9
% dom genus	17.3	92.78
TOTAL SCORE		**67**

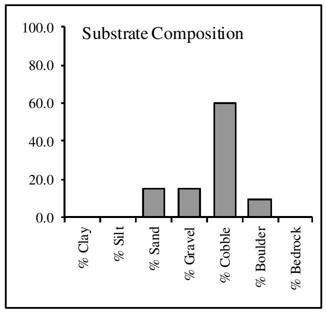
CE Sample ID: 14-102-04
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

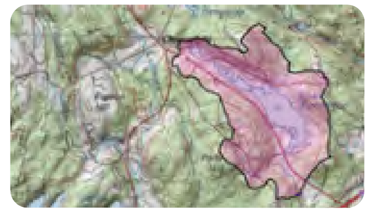
Site ID:	**OM01A**		
Stream Name:	**Oil Mill Brook**		
Location:	behind Speedbowl Race Track		
County, State:	New London County, CT	Latitude:	41.39787
Date sampled:		Longitude:	72.17852
Field Personne	MBC, RTC		

Reach Assessment Summary

Physical and Chemical Conditions Summary

Drainge Area: 2.99 mi^2





Instream Physical Characteristics

Wetted Width (m)	12.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1.0
Pool/Riffle Ratio	60/40
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	No
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	15.0
% Cobble	60.0
% Boulder	10.0
% Bedrock	0.0

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	17
2. Embeddedness	13
3. Vel/Depth Regimes	17
4. Sediment Deposition	12
5. Channel Flow Status	18
6. Channel Alteration	17
7. Frequency of Riffle	16
8. Bank Stability	18
9. Vegetative Prot.	16
10. Rip Zone Width	15
TOTAL SCORE	**159**

Water Chemistry

Time	0:00
Temp	12.49
Sp Cond	97
Cond	74
DO%	72.4
DO mg/L	7.72
Depth (ft)	0.5
pH	6.54

Downstream end of site, facing upstream

Upstream end of site, facing downstream

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	7	100
Plecoptera taxa	4	66.67
Trichoptera	5	38.46
% sens EPT	9	35.5
Scraper taxa	3.0	27.27
Biotic Index	3.76	56.2
% dom genus	19.6	89.61
TOTAL SCORE		**59.1**

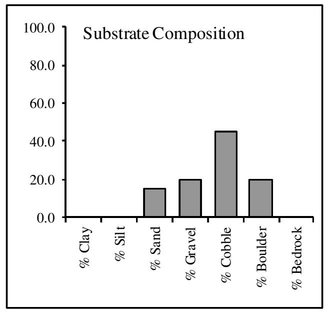
CE Sample ID: 14-102-05

Sample Method: CT DEEP 2m2 Kick Net

Habitat(s) Sampled: Riffles

Site ID:	**OM02A**	**Reach Assessment Summary**		
Stream Name:	**Oil Mill Brook**			
Location:	Immediately DS of Rt 395			
County, State:	New London County, CT		Latitude:	41.38852
Date sampled:	10/29/2014		Longitude:	72.17767
Field Personne	MBC, RTC			

Physical and Chemical Conditions Summary



Drainge Area: 3.69 mi^2

Instream Physical Characteristics

Wetted Width (m)	15.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1 to 2
Pool/Riffle Ratio	50/50
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	No
Canopy/Shading %	70.0

Substrate

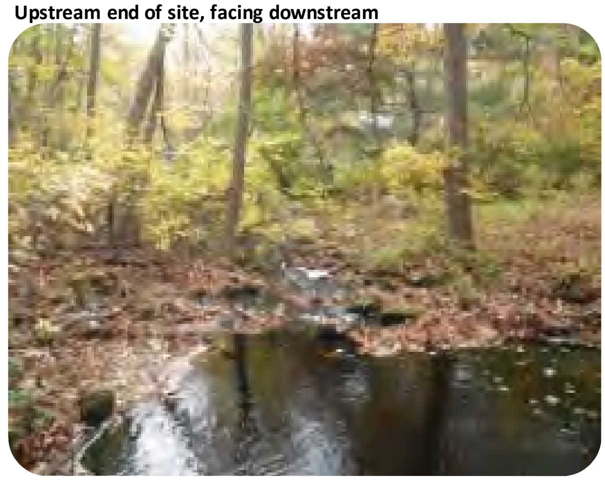
% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	20.0
% Cobble	45.0
% Boulder	20.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	18
2. Embeddedness	12
3. Vel/Depth Regimes	15
4. Sediment Deposition	12
5. Channel Flow Status	18
6. Channel Alteration	18
7. Frequency of Riffle	12
8. Bank Stability	18
9. Vegetative Prot.	16
10. Rip Zone Width	13
TOTAL SCORE	**152**

Upstream end of site, facing downstream



Water Chemistry

Time	0:00
Temp	12
Sp Cond	123
Cond	92
DO%	95.2
DO mg/L	10.25
Depth (ft)	0.3
pH	6.79

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	5	83.95
Plecoptera taxa	5	83.33
Trichoptera	12	92.31
% sens EPT	45	78
Scraper taxa	8.0	72.73
Biotic Index	3.3	84.9
% dom genus	17.0	93.16
TOTAL SCORE		**84.1**

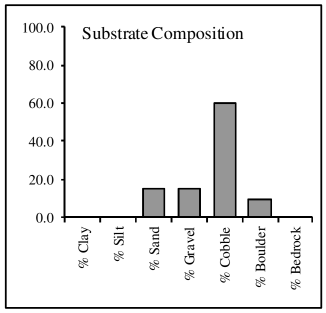
CE Sample ID: 14-102-06
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

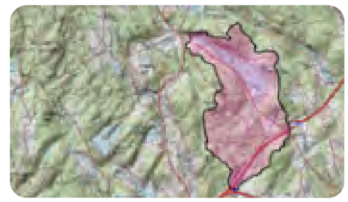
Site ID:	**OM03A**		
Stream Name:	**Oil Mill Brook**		
Location:	US of Rt 95		
County, State:	New London County, CT	Latitude:	41.37604
Date sampled:	10/28/2014	Longitude:	72.19077
Field Personne	MBC, RTC		

Reach Assessment Summary

Physical and Chemical Conditions Summary

Drainge Area: 5.37 mi^2





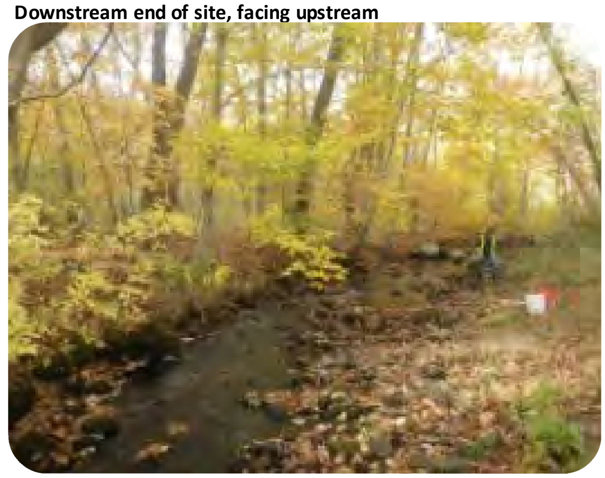
Instream Physical Characteristics

Wetted Width (m)	15.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1.0
Pool/Riffle Ratio	30/70
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	No
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	15.0
% Cobble	60.0
% Boulder	10.0
% Bedrock	0.0

Downstream end of site, facing upstream



Rapid Habitat Assessment Scores

1. Epifaunal Substrate	18
2. Embeddedness	11
3. Vel/Depth Regimes	13
4. Sediment Deposition	11
5. Channel Flow Status	17
6. Channel Alteration	17
7. Frequency of Riffle	16
8. Bank Stability	17
9. Vegetative Prot.	14
10. Rip Zone Width	17
TOTAL SCORE	**151**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	12.02
Sp Cond	116
Cond	87
DO%	105.5
DO mg/L	11.37
Depth (ft)	0.3
pH	6.89

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	4	65.05
Plecoptera taxa	3	50
Trichoptera	10	76.92
% sens EPT	60	60.6
Scraper taxa	6.0	54.55
Biotic Index	3.4	79.3
% dom genus	10.9	100
TOTAL SCORE		**69.5**

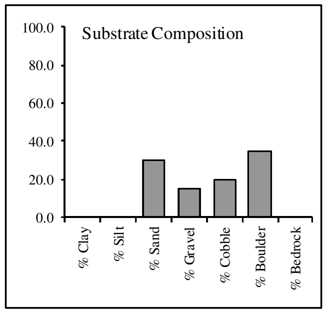
CE Sample ID: 14-102-08
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID: **SB02**
Stream Name: **Stony Brook**
Location: US of Rte 395
County, State: New London County, CT
Date sampled: 10/29/2014
Field Personne MBC, RTC

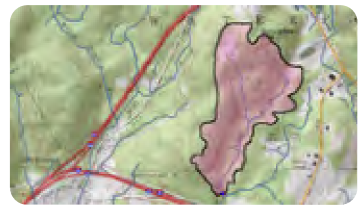
Reach Assessment Summary

Latitude: 41.37275
Longitude: 72.17317

Physical and Chemical Conditions Summary



Drainge Area: 0.42 mi^2



Instream Physical Characteristics

Wetted Width (m)	6.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1 to 1.5
Pool/Riffle Ratio	80/20
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Exc
Evidence Scouring	No
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	30.0
% Gravel	15.0
% Cobble	20.0
% Boulder	35.0
% Bedrock	0.0

Downstream end of site, facing upstream

NO PHOTO

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	14
2. Embeddedness	10
3. Vel/Depth Regimes	15
4. Sediment Deposition	8
5. Channel Flow Status	16
6. Channel Alteration	19
7. Frequency of Riffle	10
8. Bank Stability	18
9. Vegetative Prot.	18
10. Rip Zone Width	20
TOTAL SCORE	**148**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	12.26
Sp Cond	331
Cond	250
DO%	89.5
DO mg/L	9.58
Depth (ft)	0.3
pH	6.67

Biological Conditions Summary

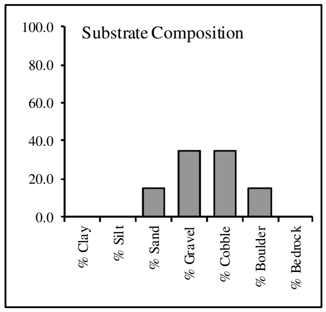
CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	0	96
Plecoptera taxa	4	66.67
Trichoptera	5	38.46
% sens EPT	10	86.2
Scraper taxa	4.0	36.36
Biotic Index	3.6	63.9
% dom genus	15.0	95.95
TOTAL SCORE		**69.1**

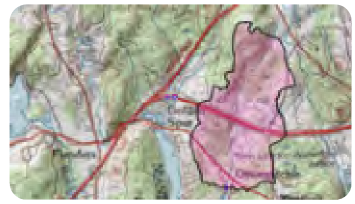
CE Sample ID: 14-102-09
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID: **SB03** **Reach Assessment Summary**
Stream Name: **Stony Brook**
Location: Below Rte 1 immed US of tidal section
County, State: New London County, CT Latitude: 41.35739
Date sampled: 10/29/2014 Longitude: 72.17608
Field Personne MBC, RTC

Physical and Chemical Conditions Summary



Drainge Area: 1.96 mi^2



Instream Physical Characteristics

Wetted Width (m)	10.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1 to 2
Pool/Riffle Ratio	50/50
Erosion/Bank Fail?	Yes
Water Clarity	Clear
Aesthetic Rating	Fair
Evidence Scouring	Yes
Canopy/Shading %	70.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	35.0
% Cobble	35.0
% Boulder	15.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	17
2. Embeddedness	10
3. Vel/Depth Regimes	17
4. Sediment Deposition	10
5. Channel Flow Status	18
6. Channel Alteration	14
7. Frequency of Riffle	16
8. Bank Stability	18
9. Vegetative Prot.	14
10. Rip Zone Width	6
TOTAL SCORE	**140**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	11.56
Sp Cond	273
Cond	203
DO%	69.5
DO mg/L	7.56
Depth (ft)	0.3
pH	6.49

Biological Conditions Summary
CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	1	66.93
Plecoptera taxa	3	50
Trichoptera	10	76.92
% sens EPT	10	54.6
Scraper taxa	9.0	81.82
Biotic Index	3.5	74.4
% dom genus	24.1	83.48
TOTAL SCORE		**69.8**

CE Sample ID: 14-102-10
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Appendix 2: 2015 Reach Summary Sheets

Site ID: **JB02**

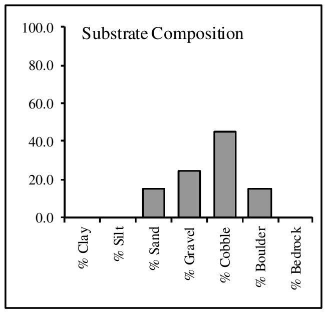
Reach Assessment Summary

Stream Name: **Jordan Brook**
Location: Vauxhall St. Extension Conservation Easement Area
County, State: New London County, CT
Latitude: 41.40255
Date sampled: 10/27/2015
Longitude: 72.16237
Field Personne MBC, RTC

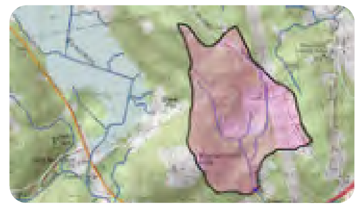
Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)	5.0
Riffle Depth (ft)	0.1
Run Depth (ft)	0.2
Pool Depth (ft)	1.0
Pool/Riffle Ratio	70/30
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Exc
Evidence Scouring	No
Canopy/Shading %	80.0



Drainge Area: 0.48 mi[2]



Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	25.0
% Cobble	45.0
% Boulder	15.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	17
2. Embeddedness	14
3. Vel/Depth Regimes	14
4. Sediment Deposition	13
5. Channel Flow Status	14
6. Channel Alteration	16
7. Frequency of Riffle	13
8. Bank Stability	16
9. Vegetative Prot.	14
10. Rip Zone Width	20
TOTAL SCORE	**151**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	7.24
Sp Cond	117
Cond	78
DO%	78.8
DO mg/L	9.52
Depth (ft)	0.1
pH	

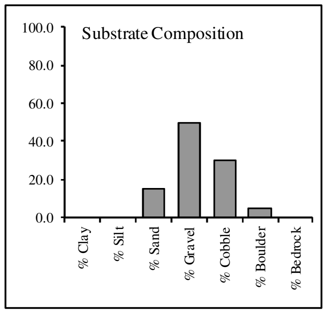
Biological Conditions Summary
CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	Score
Ephemeroptera ta	5	100.0
Plecoptera taxa	5	83.3
Trichoptera	8	61.5
% sens EPT	17.9	96.5
Scraper taxa	4	36.4
Biotic Index	3.1	80.5
% dom genus	10.7	101.8
TOTAL SCORE		**80**

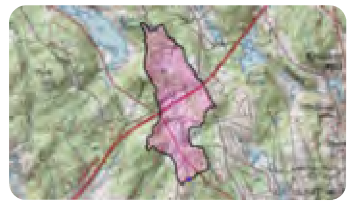
CE Sample ID: 14-102-12
Sample Method: CT DEEP 2m[2] Kick Net
Habitat(s) Sampled: Riffles

Site ID:	**JB04**	**Reach Assessment Summary**		
Stream Name:	**Jordan Brook**			
Location:	Behind Crossroads Storage Facility			
County, State:	New London County, CT		Latitude:	41.38041
Date sampled:	10/26/2015		Longitude:	72.15649
Field Personne	MBC, RTC			

Physical and Chemical Conditions Summary



Drainge Area: 1.65 mi^2



Instream Physical Characteristics	
Wetted Width (m)	12.0
Riffle Depth (ft)	0.2
Run Depth (ft)	0.4
Pool Depth (ft)	1.0
Pool/Riffle Ratio	50/50
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Exc
Evidence Scouring	No
Canopy/Shading %	90.0

Substrate	
% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	50.0
% Cobble	30.0
% Boulder	5.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores	
1. Epifaunal Substrate	16
2. Embeddedness	12
3. Vel/Depth Regimes	15
4. Sediment Deposition	12
5. Channel Flow Status	18
6. Channel Alteration	16
7. Frequency of Riffle	17
8. Bank Stability	15
9. Vegetative Prot.	12
10. Rip Zone Width	20
TOTAL SCORE	**153**

Upstream end of site, facing downstream

Water Chemistry	
Time	0:00
Temp	10.86
Sp Cond	418
Cond	309
DO%	83.8
DO mg/L	9.21
Depth (ft)	0.2
pH	

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	Score
Ephemeroptera ta	4	100
Plecoptera taxa	3	50
Trichoptera	7	53.85
% sens EPT	26.6	93.1
Scraper taxa	9.0	81.82
Biotic Index	3.5	60.9
% dom genus	10.6	102
TOTAL SCORE		**77.38**

CE Sample ID: 14-102-13
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID: **JB05A**

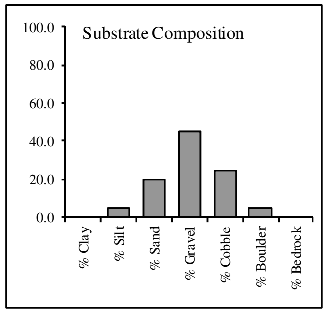
Reach Assessment Summary

Stream Name: **Jordan Brook**
Location: Below Coca Cola plant
County, State: New London County, CT
Date sampled: 10/26/2015
Field Personne MBC, RTC

Latitude: 41.36124
Longitude: 72.14744

Physical and Chemical Conditions Summary

Drainge Area: 3.34 mi^2



Instream Physical Characteristics

Wetted Width (m)	15.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1.0
Pool/Riffle Ratio	60/40
Erosion/Bank Fail?	Yes
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	Yes
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	5.0
% Sand	20.0
% Gravel	45.0
% Cobble	25.0
% Boulder	5.0
% Bedrock	0.0

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	17
2. Embeddedness	11
3. Vel/Depth Regimes	16
4. Sediment Deposition	12
5. Channel Flow Status	18
6. Channel Alteration	16
7. Frequency of Riffle	16
8. Bank Stability	14
9. Vegetative Prot.	12
10. Rip Zone Width	18
TOTAL SCORE	**150**

Water Chemistry

Time	0:00
Temp	10.42
Sp Cond	322
Cond	234
DO%	91.3
DO mg/L	10.17
Depth (ft)	0.2
pH	

Downstream end of site, facing upstream

Upstream end of site, facing downstream

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	4	74.83
Plecoptera taxa	2	33.33
Trichoptera	8	61.54
% sens EPT	36.5	69.19
Scraper taxa	6.0	54.55
Biotic Index	3.29	82.4
% dom genus	29.2	76.41
TOTAL SCORE		**64.6**

CE Sample ID: 14-102-14
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Reach Assessment Summary

Site ID: **JB05B**
Stream Name: **Jordan Brook**
Location: Yorkshire Drive @ Fog Plain Road
County, State: New London County, CT
Date sampled: 10/26/2015
Field Personne MBC, RTC

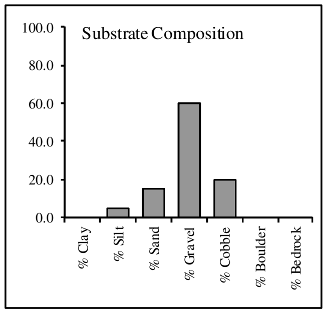
Latitude: 41.35278
Longitude: 72.14408

Physical and Chemical Conditions Summary

Drainge Area: 3.57 mi^2

Instream Physical Characteristics

Wetted Width (m)	17.0
Riffle Depth (ft)	0.3
Run Depth (ft)	1.0
Pool Depth (ft)	1 to 1.5
Pool/Riffle Ratio	80/20
Erosion/Bank Fail?	Yes
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	Yes
Canopy/Shading %	80.0



Substrate

% Clay	0.0
% Silt	5.0
% Sand	15.0
% Gravel	60.0
% Cobble	20.0
% Boulder	0.0
% Bedrock	0.0

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	14
2. Embeddedness	10
3. Vel/Depth Regimes	14
4. Sediment Deposition	11
5. Channel Flow Status	18
6. Channel Alteration	9
7. Frequency of Riffle	10
8. Bank Stability	6
9. Vegetative Prot.	6
10. Rip Zone Width	14
TOTAL SCORE	**112**

Downstream end of site, facing upstream

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	10.51
Sp Cond	296
Cond	214
DO%	76.9
DO mg/L	8.63
Depth (ft)	0.2
pH	

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	4	73.02
Plecoptera taxa	2	33.33
Trichoptera	5	38.46
% sens EPT	11.9	35.02
Scraper taxa	6.0	54.55
Biotic Index	3.39	67.4
% dom genus	15.1	95.8
TOTAL SCORE		**56.79**

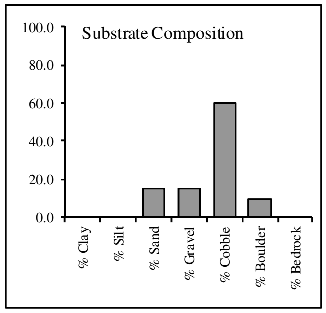
CE Sample ID: 14-102-16
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID: **OM01A**

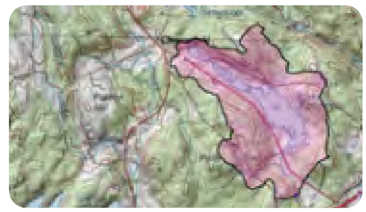
Reach Assessment Summary

Stream Name: **Oil Mill Brook**
Location: behind Speedbowl Race Track
County, State: New London County, CT
Date sampled: 10/26/2015
Field Personne MBC, RTC
Latitude: 41.39787
Longitude: 72.17852

Physical and Chemical Conditions Summary



Drainge Area: 2.99 mi^2



Instream Physical Characteristics

Wetted Width (m)	12.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1.0
Pool/Riffle Ratio	60/40
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	No
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	15.0
% Cobble	60.0
% Boulder	10.0
% Bedrock	0.0

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	17
2. Embeddedness	11
3. Vel/Depth Regimes	17
4. Sediment Deposition	11
5. Channel Flow Status	17
6. Channel Alteration	17
7. Frequency of Riffle	16
8. Bank Stability	18
9. Vegetative Prot.	16
10. Rip Zone Width	14
TOTAL SCORE	**154**

Water Chemistry

Time	0:00
Temp	9.3
Sp Cond	107
Cond	76
DO%	67.3
DO mg/L	7.19
Depth (ft)	0.1
pH	6.54

Downstream end of site, facing upstream

Upstream end of site, facing downstream

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	6	100
Plecoptera taxa	1	16.67
Trichoptera	5	38.46
% sens EPT	2.7	26.87
Scraper taxa	6.0	54.55
Biotic Index	3.68	49.4
% dom genus	50.0	47.95
TOTAL SCORE		**47.7**

CE Sample ID: 14-102-17
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID: **OM02A**
Stream Name: **Oil Mill Brook**
Location: Immediately DS of Rt 395
County, State: New London County, CT
Date sampled: 10/26/2015
Field Personne MBC, RTC

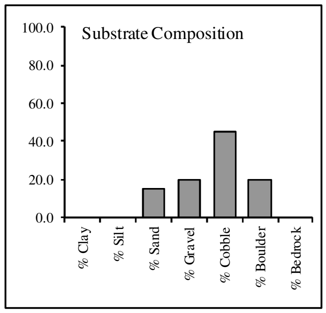
Reach Assessment Summary

Latitude: 41.38852
Longitude: 72.17767

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Wetted Width (m)	15.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1 to 1.5
Pool/Riffle Ratio	50/50
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	No
Canopy/Shading %	65.0



Drainge Area: 3.69 mi²

Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	20.0
% Cobble	45.0
% Boulder	20.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	18
2. Embeddedness	12
3. Vel/Depth Regimes	15
4. Sediment Deposition	12
5. Channel Flow Status	17
6. Channel Alteration	18
7. Frequency of Riffle	12
8. Bank Stability	18
9. Vegetative Prot.	16
10. Rip Zone Width	13
TOTAL SCORE	**151**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	9.29
Sp Cond	132
Cond	94
DO%	86.2
DO mg/L	9.82
Depth (ft)	0.2
pH	

Biological Conditions Summary
CE Sample ID:

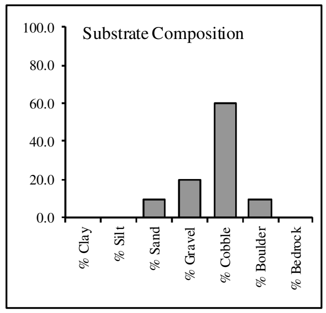
CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	6	95.72
Plecoptera taxa	5	83.33
Trichoptera	11	84.62
% sens EPT	27.8	55.58
Scraper taxa	6.0	54.55
Biotic Index	3.13	75.1
% dom genus	23.4	84.36
TOTAL SCORE		**76.18**

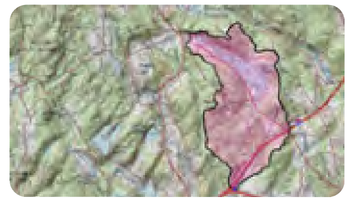
CE Sample ID: 14-102-18
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID:	**OM03A**	**Reach Assessment Summary**		
Stream Name:	**Oil Mill Brook**			
Location:	US of Rt 95			
County, State:	New London County, CT		Latitude:	41.37604
Date sampled:	10/26/2015		Longitude:	72.19077
Field Personne	MBC, RTC			

Physical and Chemical Conditions Summary

Drainge Area: 5.37 mi^2





Instream Physical Characteristics

Wetted Width (m)	15.0
Riffle Depth (ft)	0.2
Run Depth (ft)	0.4
Pool Depth (ft)	1.0
Pool/Riffle Ratio	30/70
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Good
Evidence Scouring	No
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	10.0
% Gravel	20.0
% Cobble	60.0
% Boulder	10.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	18
2. Embeddedness	12
3. Vel/Depth Regimes	13
4. Sediment Deposition	12
5. Channel Flow Status	15
6. Channel Alteration	17
7. Frequency of Riffle	17
8. Bank Stability	16
9. Vegetative Prot.	14
10. Rip Zone Width	17
TOTAL SCORE	**151**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	8.91
Sp Cond	144
Cond	99
DO%	91.4
DO mg/L	10.58
Depth (ft)	0.2
pH	

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	7	100
Plecoptera taxa	4	66.67
Trichoptera	13	100
% sens EPT	42.7	69.9
Scraper taxa	8.0	72.73
Biotic Index	3.11	94.8
% dom genus	13.3	98.22
TOTAL SCORE		**86.04**

CE Sample ID: 14-102-19
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID:	**SB02**		
Stream Name:	**Stony Brook**		
Location:	US of Rte 395		
County, State:	New London County, CT	Latitude:	41.37275
Date sampled:	10/26/2015	Longitude:	72.17317
Field Personne	MBC, RTC		

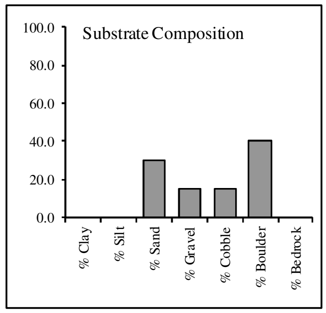
Reach Assessment Summary

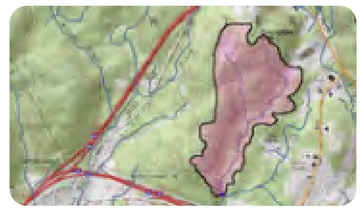
Physical and Chemical Conditions Summary

Drainge Area: 0.42 mi^2

Instream Physical Characteristics

Wetted Width (m)	6.0
Riffle Depth (ft)	0.3
Run Depth (ft)	0.5
Pool Depth (ft)	1.0
Pool/Riffle Ratio	80/20
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Exc
Evidence Scouring	No
Canopy/Shading %	80.0





Substrate

% Clay	0.0
% Silt	0.0
% Sand	30.0
% Gravel	15.0
% Cobble	15.0
% Boulder	40.0
% Bedrock	0.0

Downstream end of site, facing upstream

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	13
2. Embeddedness	10
3. Vel/Depth Regimes	14
4. Sediment Deposition	8
5. Channel Flow Status	13
6. Channel Alteration	19
7. Frequency of Riffle	10
8. Bank Stability	18
9. Vegetative Prot.	18
10. Rip Zone Width	20
TOTAL SCORE	**143**

Upstream end of site, facing downstream

Water Chemistry

Time	0:00
Temp	9.75
Sp Cond	238
Cond	169
DO%	79.9
DO mg/L	8.78
Depth (ft)	0.2
pH	

Biological Conditions Summary

CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	0	96.06
Plecoptera taxa	2	33.33
Trichoptera	5	38.46
% sens EPT	8.4	83.78
Scraper taxa	4.0	36.36
Biotic Index	3.38	65.3
% dom genus	26.2	80.59
TOTAL SCORE		**61.99**

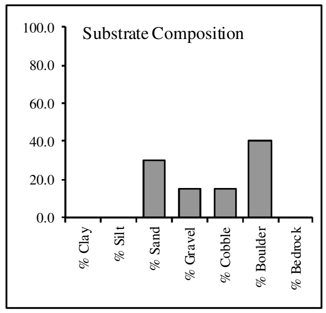
CE Sample ID: 14-102-20
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Site ID: **SB02B**
Stream Name: **Stony Brook**
Location: DS of Rt 95
County, State: New London County, CT
Date sampled: 10/26/2015
Field Personne MBC, RTC

Reach Assessment Summary

Latitude: 41.36675
Longitude: 72.17432

Physical and Chemical Conditions Summary



Drainge Area: 1.3 mi^2

Instream Physical Characteristics

Wetted Width (m)	9.0
Riffle Depth (ft)	0.2
Run Depth (ft)	0.4
Pool Depth (ft)	1 to 2
Pool/Riffle Ratio	40/60
Erosion/Bank Fail?	No
Water Clarity	Clear
Aesthetic Rating	Exc
Evidence Scouring	No
Canopy/Shading %	80.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	10.0
% Gravel	20.0
% Cobble	65.0
% Boulder	5.0
% Bedrock	0.0

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	17
2. Embeddedness	11
3. Vel/Depth Regimes	17
4. Sediment Deposition	12
5. Channel Flow Status	16
6. Channel Alteration	15
7. Frequency of Riffle	17
8. Bank Stability	13
9. Vegetative Prot.	13
10. Rip Zone Width	20
TOTAL SCORE	**151**

Water Chemistry

Time	0:00
Temp	7.59
Sp Cond	318
Cond	213
DO%	83.8
DO mg/L	9.97
Depth (ft)	0.2
pH	

Downstream end of site, facing upstream

Upstream end of site, facing downstream

Biological Conditions Summary
CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	1	100
Plecoptera taxa	2	33.33
Trichoptera	4	30.77
% sens EPT	18.5	97.17
Scraper taxa	4.0	36.36
Biotic Index	3.23	76.4
% dom genus	27.5	78.78
TOTAL SCORE		**64.69**

CE Sample ID: 14-102-21
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

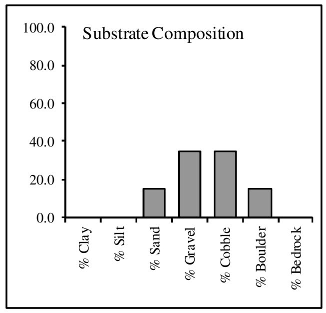
Site ID: **SB03**

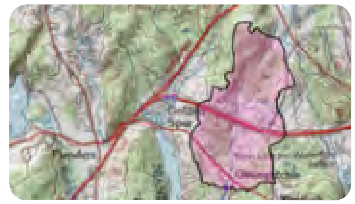
Reach Assessment Summary

Stream Name: **Stony Brook**
Location: Below Rte 1 immed US of tidal section
County, State: New London County, CT
Date sampled: 10/26/2015
Field Personne MBC, RTC
Latitude: 41.35739
Longitude: 72.17608

Physical and Chemical Conditions Summary

Drainge Area: 1.96 mi^2





Instream Physical Characteristics

Wetted Width (m)	10.0
Riffle Depth (ft)	0.2
Run Depth (ft)	0.4
Pool Depth (ft)	1 to 2
Pool/Riffle Ratio	50/50
Erosion/Bank Fail?	Yes
Water Clarity	Clear
Aesthetic Rating	Fair
Evidence Scouring	Yes
Canopy/Shading %	75.0

Substrate

% Clay	0.0
% Silt	0.0
% Sand	15.0
% Gravel	35.0
% Cobble	35.0
% Boulder	15.0
% Bedrock	0.0

Rapid Habitat Assessment Scores

1. Epifaunal Substrate	17
2. Embeddedness	10
3. Vel/Depth Regimes	17
4. Sediment Deposition	10
5. Channel Flow Status	18
6. Channel Alteration	14
7. Frequency of Riffle	16
8. Bank Stability	18
9. Vegetative Prot.	14
10. Rip Zone Width	6
TOTAL SCORE	**140**

Water Chemistry

Time	0:00
Temp	9.21
Sp Cond	291
Cond	200
DO%	76.3
DO mg/L	8.18
Depth (ft)	0.2
pH	

Downstream end of site, facing upstream

Upstream end of site, facing downstream

Biological Conditions Summary
CE Sample ID:

CT DEEP Multimetric Index		
Metric	Metric Value	
Ephemeroptera ta	1	66.93
Plecoptera taxa	2	33.33
Trichoptera	6	46.15
% sens EPT	6.1	49.62
Scraper taxa	7.0	63.64
Biotic Index	3.03	75.0
% dom genus	35.8	67.33
TOTAL SCORE		**57.42**

CE Sample ID: 14-102-22
Sample Method: CT DEEP 2m2 Kick Net
Habitat(s) Sampled: Riffles

Appendix 3. List of macroinvertebrates sampled during the 2014 Town of Waterford Bioassessment.

					2014 Sample Site								
Class	Order	Family	TAXON	Common Name	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB03
Oligochaeta			Oligochaeta	Aquatic worm	1	6	23		13	8	15	74	7
Arachnida			Aracnida	Aquatic mite	10	7	6	1	2		3	7	2
Insecta	Coleoptera	Elmidae	Elmidae	Riffle beetle	24	10	37	15	23	23	31	66	85
		Psephenidae	Psephenidae	Water Penny	6	2	1	10		1	1	2	1
		Ptilodactylidae	Anchytarsus bicolor	Aquatic Beetle	2		1		2	3			
	Diptera	Ceratopogonidae	Ceratopogoninae	Biting midge	5			1	3			19	2
		Chironomidae	Chironomidae	Midge	89	63	102	110	38	28	57	7	57
		Empididae	Hemerodromia	Dance fly	4		4				2	3	
		Simuliidae	Simuliidae	Black fly	3	1	2	2	2	2	1	4	1
		Tabanidae	Tabanidae	Horse/deer fly	1								
		Tipulidae	Tipulidae	Cranefly	4	1	1	3		1	1	7	
	Ephemeroptera	Baetidae	Acerpenna macdunnoughi	Mayfly				1	1				
		Ephemerellidae	Ephemerella	Mayfly		36	15	4	1	23	24		
			Ephemerella subvaria	Mayfly		1	1	1			1		
			Ephemerellidae	Mayfly	9								
			Eurylophella	Mayfly	1	1		6	1	1			
			Serratella deficiens	Mayfly	18		1	2	4	35	19		
		Heptageniidae	Epeorus	Mayfly							7		
			Heptageniidae	Mayfly	4	3							
			Maccaffertium	Mayfly	2	2	4	15	15	7			
			Maccaffertium modestum group	Mayfly				1	32				
		Leptophlebiidae	Paraleptophlebia	Mayfly	11			3	4	7			1
	Megaloptera	Corydalidae	Nigronia serricornis	Fish fly	3	1			6	1	3	1	
	Odonata	Calopterygidae	Calopteryx	Damsefly	1								
		Gomphidae	Gomphidae	Dragonfly		2		1					
			Ophiogomphus	Dragonfly		1							
	Plecoptera	Capniidae	Allocapnia	Stonefly	1				1	3	1	4	3
			Paracapnia	Stonefly	1								
		Leuctridae	Leuctra	Stonefly	1				9	2			1
		Peltoperlidae	Tallaperla maria	Stonefly						1			
		Perlidae	Acroneuria	Stonefly					1			1	
			Acroneuria abnormis	Stonefly		1	2			1			
			Eccoptura xanthenes	Stonefly									1
		Perlodidae	Perlodidae	Stonefly				1					
		Taeniopterygidae	Taeniopterygidae	Stonefly							1	1	
			Taeniopteryx	Stonefly		6	3	9	1	4	7	12	
	Trichoptera	Apataniidae	Apatania	Caddisfly		5		4		1			1
		Brachycentridae	Micrasema	Caddisfly	1							4	
		Glossosomatidae	Glossosoma	Caddisfly		2	1	1		1	14		
		Goeridae	Goera	Caddisfly									2
		Hydropsychidae	Ceratopsyche	Caddisfly						1			

Appendix 3. Continued

Class	Order	Family	TAXON	Common Name	2014 Sample Site								
					JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB03
			Ceratopsyche sparna	Caddisfly		1				2	12		
			Cheumatopsyche	Caddisfly		5	3	10	4	2	2		
			Diplectrona	Caddisfly	1						1	1	3
			Hydropsyche betteni	Caddisfly	1	4	2	5	9	1	4		1
		Hydroptilidae	Palaeagapetus celsus	Caddisfly	1								
		Lepidostomatidae	Lepidostoma	Caddisfly		13	7	14		4	15		
		Leptoceridae	Ceraclea	Caddisfly									1
			Leptoceridae	Caddisfly	2		2						
			Mystacides	Caddisfly			1						
			Oecetis	Caddisfly		1				1			1
		Limnephilidae	Limnephilidae	Caddisfly	1	1	1			4		8	
		Molannidae	Molanna	Caddisfly	1								
		Odontoceridae	Psilotreta	Caddisfly								4	4
		Philopotamidae	Chimarra aterrima	Caddisfly			2	5	12				6
			Dolophilodes	Caddisfly	2					3	3		
		Polycentropodidae	Polycentropus	Caddisfly	1	1	1				1		
		Psychomyiidae	Lype diversa	Caddisfly						1			
		Rhyacophilidae	Rhyacophila	Caddisfly	2	2		1			1	1	2
			Rhyacophila fuscula	Caddisfly					1				
		Uenoidae	Neophylax	Caddisfly		16	3	18	1	11	2		5
Malacostraca	Amphipoda	Gammaridae	Gammarus	Scud		2							2
	Isopoda	Asellidae	Caecidotea	Sow bug									3
Bivalvia		Pisidiidae	Pisidiidae	Fingernail clam	13	1	3	4	50	21	1	5	4
Gastropoda		Hydrobiidae	Hydrobiidae	Snail									15
			Nemata	Round worm					1			2	1
Enopla	Hoplonemertea	Tetrastemmatidae	Prostoma	Proboscis worm			2		2	2		1	
Turbellaria			Turbellaria	Flat worm				1	1				

Appendix 4. List of macroinvertebrates sampled during the 2015 Town of Waterford Bioassessment.

					2015 Sample Site									
Class	**Order**	**Family**	**Taxon**	**Common Name**	**JB02**	**JB04**	**JB05A**	**JB05B**	**OM01A**	**OM02A**	**OM03A**	**SB02**	**SB02B**	**SB03**
Clitellata	Arynchobdellida	Erpobdellidae	Erpobdellidae	Leech						1				
	Lumbriculida	Lumbriculidae	Lumbriculidae	Aquatic Worm	5	3	8	1	7	10	11	24	30	6
Oligochaeta	Tubificida	Naididae	Naididae	Aquatic Worm						1		2		
			Nais	Aquatic Worm		11		4	1				1	7
Arachnida	Trombidiformes	Clathrosperchonidae	Clathrosperchon americanus	Water Mite			1							
		Lebertiidae	Lebertia	Water Mite		2	4	2				3		2
		Limnocharidae	Limnochares	Water Mite	1									
		Sperchonidae	Sperchon	Water Mite								2	2	1
			Sperchonopsis	Water Mite	2		1		1	1	2		5	1
		Torrenticolidae	Torrenticola	Water Mite	2	5	9	2	1	2	3			1
Insecta	Coleoptera	Dytiscidae	Agabus	Predaceous Diving Beetle								1		
		Elmidae	Elmidae	Riffle Beetle			5	8	4				9	19
			Macronychus glabratus	Riffle Beetle			2							
			Optioservus	Riffle Beetle		4	16	5	4		2		8	9
			Optioservus ovalis	Riffle Beetle		1	1	3						2
			Oulimnius latiusculus	Riffle Beetle	22	13	39	33	15	11	22	38	58	76
			Promoresia tardella	Riffle Beetle	11		11		2	8	21		4	3
			Stenelmis	Riffle Beetle		1	1				1	24	2	7
		Psephenidae	Ectopria nervosa	Water Penny	2	4	1		1	2		2	5	1
			Psephenus herricki	Water Penny				8						
		Ptilodactylidae	Anchytarsus bicolor	Aquatic Beetle	14				3	2			3	2
	Diptera	Ceratopogonidae	Ceratopogoninae	Biting Midge	1				1	3		7	2	2
		Chironomidae	Chironomidae	Midge	57	39	8	43	21	29	27	11	13	20
		Empididae	Hemerodromia	Dance Fly					1					1
		Simuliidae	Prosimulium	Black Fly			3					12	7	2
			Simulium	Black Fly			3			1				
		Tabanidae	Tabanidae	Horse/Deer Fly	3									
		Thaumaleidae	Thaumaleidae	Solitary Midge									1	
		Tipulidae	Antocha	Crane Fly										1
			Dicranota	Crane Fly	1	2		3	1			7	1	2
			Pseudolimnophila	Crane Fly	1									
			Tipula	Crane Fly						1				
	Ephemeroptera	Baetidae	Acerpenna macdunnoughi	Mayfly					1	5	1			
			Baetis pluto	Mayfly							1			
			Diphetor hageni	Mayfly	1					1				
			Pseudocloeon frondale	Mayfly		1								
		Ephemerellidae	Ephemerella	Mayfly		20	1	3	1	2	6			
			Ephemerella subvaria	Mayfly							1			
			Ephemerellidae	Mayfly		5								
			Eurylophella	Mayfly	3	4	2	12	4				8	
			Serratella deficiens	Mayfly	4		1		1	24	29			
		Heptageniidae	Epeorus	Mayfly							1			
			Maccaffertium	Mayfly		2	1	2	4	2	4			
			Maccaffertium modestum group	Mayfly	4			1	6	3				
		Leptophlebiidae	Paraleptophlebia	Mayfly	8			2	2	8	13			1

Class	Order	Family	Taxon	Common Name	2015 Sample Site									
					JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB02B	SB03
	Megaloptera	Corydalidae	Nigronia serricornis	Fish Fly	1	1			3	3	12			1
		Sialidae	Sialis	Fish Fly	2									
	Odonata	Calopterygidae	Calopteryx	Damselfly					1					
		Cordulegastridae	Cordulegaster	Dragonfly								3		
		Gomphidae	Gomphidae	Dragonfly	1	1	1	1	1		1		1	
			Ophiogomphus	Dragonfly							1			
	Plecoptera	Capniidae	Allocapnia	Stonefly	9	6	8	3	7	1		56	3	11
			Paracapnia	Stonefly	3									
		Leuctridae	Leuctra	Stonefly	1						1			
		Perlidae	Acroneuria	Stonefly						1				
			Acroneuria abnormis	Stonefly		3					2			
			Eccoptura xanthenes	Stonefly	2					1				2
		Perlodidae	Isoperla	Stonefly						1				
			Perlodidae	Stonefly							2			
		Taeniopterygidae	Taeniopteryx	Stonefly	1	18	64	18		4	11	5	34	
	Trichoptera	Apataniidae	Apatania	Caddisfly		1		2	1	2	3	1		2
		Brachycentridae	Brachycentrus appalachia	Caddisfly						2	4			
			Micrasema	Caddisfly	3		2				1		2	
		Glossosomatidae	Glossosoma	Caddisfly		10	1				2			
		Hydropsychidae	Ceratopsyche sparna	Caddisfly		2	2			5	2			
			Cheumatopsyche	Caddisfly	3	4	1	7	1	1	2		7	
			Diplectrona	Caddisfly	6		1		1		7	6		1
			Hydropsyche betteni	Caddisfly	2	21	2	6	3		3			4
		Lepidostomatidae	Lepidostoma	Caddisfly	1	6	10	1		6	8		2	
		Leptoceridae	Oecetis	Caddisfly							2			
		Limnephilidae	Hydatophylax argus/victor	Caddisfly	1									
			Limnephilidae	Caddisfly						4		1		
		Molannidae	Molanna	Caddisfly						1				
		Odontoceridae	Psilotreta	Caddisfly								3		2
		Philopotamidae	Chimarra aterrima	Caddisfly		1		6	4					6
			Dolophilodes	Caddisfly	5		1			1	2		1	
		Polycentropodidae	Nyctiophylax	Caddisfly						1				
			Polycentropus	Caddisfly						4	1			
		Psychomyiidae	Lype diversa	Caddisfly						1				
		Rhyacophilidae	Rhyacophila	Caddisfly										1
			Rhyacophila nigrita	Caddisfly								3		4
		Uenoidae	Neophylax	Caddisfly	2						1			
Malacostraca	Amphipoda	Gammaridae	Gammarus	Scud										
Ostracoda			Ostracoda	Seed Shrimp						1				
Bivalvia	Unionoida	Unionidae	Unionidae	Mussel							1			
	Veneroida	Pisidiidae	Pisidium	Fingernail Clam	19	1	2	19	38	21	3	2	2	2
			Sphaeriidae	Fingernail Clam		3	4	18	77	27				3
Gastropoda	Basommatophora	Planorbidae	Micromenetus dilatatus	Snail		1		2						
			Planorbidae	Snail										
	Neotaenioglossa	Hydrobiidae	Hydrobiidae	Snail				1	2					4
		Nemata		Round Worm			1				1			
Enopla	Tetrastemmatidae	Prostoma		Proboscis Worm	1	3	2							1
Turbellaria		Turbellaria		Flat Worm	1			2	1		1			2
					206	199	219	219	222	205	218	214	211	212

Appendix 5. Summary tables for habitat and water quality data collected in fall 2014.

Select physical habitat attributes recorded from stream reaches sampled during the Town of Waterford macroinvertebrate assessment survey in fall 2014.

	Jordan Brook				Oil Mill Brook			Stony Brook	
Attribute	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB03
Width (ft)	5	15	15	18	12	15	15	6	10
Pool/Riffle Ratio	40/60	60/40	60/40	80/20	60/40	50/50	30/70	80/20	50/50
Erosion/Bank Fail	No	No	Yes	Yes	No	No	No	No	Yes
Canopy/Shading %	80	90	75	70	80	70	80	80	70

Summary of stream substrate conditions at sites included in the Town of Waterford macroinvertebrate assessment survey in fall 2014.

	Jordan Brook				Oil Mill Brook			Stony Brook	
Description	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB03
% Bedrock	0	0	0	0	0	0	0	0	0
% Boulder	20	5	5	0	10	20	10	35	15
% Cobble	40	20	15	15	60	45	60	20	35
% Gravel	20	60	50	60	15	20	15	15	35
% Sand	20	15	25	20	15	15	15	30	15
% Silt	0	0	5	5	0	0	0	0	0
% Clay	0	0	0	0	0	0	0	0	0

Summary of rapid habitat assessment scores of sites included in the Town of Waterford macroinvertebrate assessment survey in fall 2014.

	Jordan Brook				Oil Mill Brook			Stony Brook	
Description	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB03
Epifaunal Substrate	18	16	16	14	17	18	18	14	17
Embeddedness	15	12	11	11	13	12	11	10	10
Velocity/Depth Regimes	15	15	16	15	17	15	13	15	17
Sediment Deposition	14	12	12	12	12	12	11	8	10
Channel Flow Status	17	19	19	19	18	18	17	16	18
Channel Alteration	16	16	16	9	17	18	17	19	14
Frequency of Riffles	17	16	15	10	16	12	16	10	16
Bank Stability	18	15	14	6	18	18	17	18	18
Vegetative Prot.	14	12	12	6	16	16	14	18	14
Riparian Zone Width	20	20	18	14	15	13	17	20	6
TOTAL SCORE	164	153	149	116	159	152	151	148	140

Summary of stream water quality measured at sites included in the Town of Waterford macroinvertebrate assessment survey in fall 2014.

	Jordan Brook				Oil Mill Brook			Stony Brook	
Description	JB02	JB04	JB05A	JB05B	OM01A	OM02A	OM03A	SB02	SB03
Date	10/28	10/28	10/28	10/28	10/28	10/29	10/28	10/29	10/29
Time	1200	1100	1000	900	1620	745	1530	1030	935
Temperature (^{o}C)	10.93	10.64	9.66	10.76	12.49	12	12.02	12.26	11.56
Specific Cond (µS/cm)	90	320	208	227	97	123	116	331	273
DO (% sat)	86.3	90	97.7	62.4	72.4	95.2	105.5	89.5	69.5
DO (mg/L)	9.53	10	11.12	6.92	7.72	10.25	11.37	9.58	7.56
pH	6.72	6.63	6.78	6.5	6.54	6.79	6.89	6.67	6.49

Downhill from a solar project, concerns mount

Published October 18. 2019 5:55PM | Updated October 19. 2019 6:19PM

By **Lee Howard** Day staff writer

l.howard@theday.com KingstonLeeHow

East Lyme — Retired construction worker John Bialowans Jr. has a solar array on the roof of his garage, so he says his concern with the 24-acre solar field near his Walnut Hill Road home has nothing to do with fighting the tide of green energy.

The problem, he said during a tour of his 45-acre property last month, is that virtual "clear-cutting" of the forest by a Greenskies Renewable Energy subsidiary to make way for the Antares Solar Field just up the hill has left the watercourses on his land a silted mess, killing off the freshwater trout that once made the streams a haven for fishermen.

"There's erosion any place you look," the 70-year-old Bialowans said, glancing around as he perched over a stream bank. "I just wish somebody would take this serious."

Unsatisfied with the response from Greenskies, the state Department of Energy and Environmental Protection or the town Inland Wetlands Commission, Bialowans filed a lawsuit two years ago against the solar field owner, GRE 314 East Lyme LLC, claiming that lack of water runoff controls had affected the value of his property.

Bialowans, who is representing himself, did not specify any damage amount in the suit, though he said one person estimated it would cost about $400,000 to restore streams on his property to their original state. The civil suit, which he said already has cost him more than $100,000 in legal and other fees, will be going to trial Tuesday in New London Superior Court before Judge Cynthia K. Swienton.

"They thought I was going to roll over," Bialowans said, referring to Greenskies.

Greenskies, a Connecticut company co-founded by former state Sen. Art Linares, a Republican from Westbrook, was acquired in December 2017 by Sunnyvale, Calif.-based Clean Focus Yield Limited.

In a December 2018 summary of problems resulting from construction of the East Lyme solar field, Southbury-based civil engineer Steven D. Trinkaus, hired by Bialowans, said that peak runoff volumes from the Grassy Hill Road site were "grossly" underestimated by Greenskies, partly because of changes in the soil resulting from the project's clearing of trees and partly because the effect of solar panel runoff was not taken into account.

He also cited, in an earlier report, stormwater-management and erosion-control "inadequacies" and the solar company's failure in some cases to follow through on its own engineering plans.

GRE is expected to call its own witnesses, including Jeffrey Peterson, a Wethersfield-based wetland and soil scientist for Vanasse Hangen Brustlin Inc., who according to court documents is expected to dispute the extent of damage seen on Bialowans' property. He and another expert also will be questioning some of Trinkaus' technical findings, as well as the extent and cost of runoff damage.

Problems with the solar field started even as it was being constructed in 2014. According to articles in The Day, a downpour that brought several inches of rain in late March of that year led to the overflow of sediment-control basins and flooding downhill in the wetlands off Grassy Hill and Walnut Hill roads.

The town immediately issued a cease-and-desist order against Greenskies and Centerplan Construction Co., which built out the solar field, to force GRE to solve the problem. The order cited "sedimentation ... as a result of stormwater management system failures and failures of erosion and sedimentation controls."

GRE reportedly addressed retention-basin problems and erosion issues, but Bialowans said that whatever mitigation efforts Greenskies made after the order proved inadequate. Runoff after storms still sends water cascading down from the solar farm onto his property, mucking up the streams, he said.

"The stream is silted in; the trout are all gone," said John Jasper of East Lyme, a member of the Niantic River Watershed Committee, former Pfizer Inc. scientist and avid fisherman, who toured the site Sept. 17 with Bialowans.

The problem, he said, is that trout cannot spawn in streams with excessive runoff because they need gravelly areas to deposit their eggs, and silt covers over such sites.

"They're turning trout streams to drainage ditches," said Jasper, a longtime member of Trout Unlimited. "Once they're gone, they're gone."

Don Danila of East Lyme, a retired Dominion Energy fisheries biologist who worked for many years at the Millstone nuclear power plant in Waterford and is a member of the watershed committee, said his group, which is tasked with protecting the area's watercourses, was aware of the solar field application shortly before a 2014 public hearing. He and one other member of the panel testified at a state Siting Council hearing, but they didn't have much time to do their homework, he said.

"We were naive," Danila said in an Oct. 15 interview at Starbucks in East Lyme. "We thought their stormwater plan was kind of sketchy, but we didn't know enough to say anything."

Danila said the Siting Council, without any expertise on staff to analyze the engineering plan, essentially rubber-stamped the project. But when problems arose with water runoff, environmentally minded people in the region started to take notice.

Among them was Deb Moshier-Dunn of Waterford, vice president of Save the River-Save the Hills, an organization that formed initially to oppose development in the Oswegatchie Hills area of East Lyme. A few years after approval of the East Lyme solar field, she led a successful effort to stop a proposed solar field in Waterford that would have been three times larger than the one in East Lyme and could have done much more damage to the environment, she said.

"We shouldn't have to trade off water quality for having solar put in," she said at Starbucks.

Moshier-Dunn's group came late to the East Lyme solar field controversy, but she now supports Bialowans in his efforts to have GRE address the situation.

"They're being litigious instead of fixing the problem," Moshier-Dunn said. "If they fixed the problem, they'd have goodwill."

In his lawsuit, Bialowans accuses GRE of polluting Latimer Brook, Cranberry Meadow Brook, the Niantic River, Long Island Sound and a small unnamed stream that runs through his property. He said that during "appreciable rain events," GRE's water-containment system has either failed or proved inadequate due to "faulty construction" and "negligent monitoring."

The Antares Solar Field, according to the suit, has about 17,000 solar panels designed to supply nearly 5 megawatts of renewable energy. But Trinkaus, for one, questions whether solar fields placed in a state not known for long stretches of sunny days is good policy, pointing to extremely low efficiency rates of about 25 percent initially predicted by Greenskies for its East Lyme solar field.

Moshier-Dunn wonders why companies don't pick less environmentally risky places to put their solar arrays, such as the new Costco building in East Lyme.

"We're not against solar at all," she said. "We want to put it in the most environmentally responsible areas."

Bialowans, who remembers picking blueberries as a boy on his grandmother's farmland and later made hay on the fields now occupied by solar panels, said he just wants Greenskies to fix the drainage problems instead of dragging everything out in court.

"They should have just fixed it five years ago," he said. "This was one of the best freshwater streams in all of Connecticut."

l.howard@theday.com

Niantic River Watershed Plan

... a treasure worth protecting

Niantic River Watershed Protection Plan

~~~

Guided Summary

March 2009

The Guided Summary of the Niantic River Watershed Protection Plan was prepared by the Eastern Connecticut Conservation District and funded in part by the CT DEP through the US EPA Nonpoint Source grant under section 319 of the Clean Water Act.

Printed on Recycled Paper
~~~

Niantic River scallops were abundant during the days of the Nehantic Indians, for the shoreline property soil is well-sprinkled with their shells. Again in the 1930's the scallops flourished. This was the time of "The Great Depression" and many of the jobless earned a scant living scalloping. Great trucks from Boston, Providence and New York backed up to the several town landings especially at the foot of Grand St. – to buy directly from the individual scallopers. Those of us who enjoyed the bounty of the scallops still remember the tender sweetness of those tiny morsels. We remember as well the chapped hands and the hands encased in band-aids from the horrendous task of opening those razor-sharp shells. We all learned at an early age that pleasure usually comes with a price! ***-Olive Chenaldi, (Town Historian)***

Excerpt from "Stories of East Lyme"
Reprinted with permission by the East Lyme Library

Did You Know?
Niantic River ~ Quick Facts

Did you know?

- **The Niantic River does not currently meet state water quality standards because of observed degradation of aquatic life and shellfish harvesting.**
- **Nitrogen and bacteria are the two greatest water quality concerns for the Niantic River.**
- **Rain carries bacteria into the river where it is filtered by shellfish rendering them unsafe for consumption. The shellfish beds in the River are closed after every rainfall event of at least one inch.**
- **Excess nitrogen entering the river enriches the brackish Niantic River water, like fertilizer on a lawn, increasing algal and plant growth**
- **Polluted runoff accounts for approximately half (50%) of the nitrogen inputs into the Niantic River.**
- **Beginning in the 1980s, there was a sharp decline in eelgrass and in subsequent years eelgrass populations have shown annual variation. Scallops and winter flounder, which rely on eelgrass as nursery habitat, are practically missing from the Niantic River.**
- **New species like green crabs and grubby, which are more tolerant of polluted waters, appear to be on the rise in the river.**
- **The Niantic River Watershed covers 31.3 square miles, or approximately 20,000 acres, and includes areas from the four towns of Salem, East Lyme, Waterford, and Montville. Watershed management boils down to *land use management* and will depend on participation of all four communities.**
- **There is a direct relationship between increased impervious surfaces in a watershed and degradation of water quality.**
- **Oswegatchie Hills is one of the last large stretches of undeveloped waterfront land in Connecticut.**

Table of Contents

Acknowledgements

This document would not be possible without the dedication and contributions from the following individuals:

***Chief Executive Officers**: We* would like to express our appreciation to Paul Formica, East Lyme First Selectman, Joseph Jaskiewicz, Mayor of Montville, Bob Ross, Salem First Selectman, and Dan Steward, Waterford First Selectman for their time and contributions.

Original Consulting Team and Steering Committee: The Niantic River Watershed – Plan Refinement Group would like to acknowledge the contributors of the full Niantic River Watershed Protection Plan, funded by the National Oceanic and Atmospheric Association (NOAA) of Ocean and Coastal Resource Management (OCRM). These organizations and individuals include:

> ***Consulting Team:*** Kleinschmidt Associates
> ***The Original Project Steering Committee:*** Marcia Balint, CTDEP OLISP, Colleen Bezanson, Town of Montville, Allison Branco, UCONN Avery Point, Marine Sciences Mary Ann Chinatti, Town of Salem, Maureen Fitzgerald, Town of Waterford John Gaucher, CTDEP OLISP, Fred Grimsey, Save the River, Save the Hills Mary-Beth Hart, CTDEP OLISP, Kristal Kallenberg, CTDEP OLISP, Dr. Jim Kremer, UCONN Avery Point, Marine Sciences, Don Landers, East Lyme Harbor Management/Shellfish Commission, John Mullaney, USGS, Meg Parulis, Town of East Lyme, Sally Snyder, Town of Salem, Paul Stacey, CTDEP Nonpoint Source Program Eric Thomas, CTDEP Watershed Management Program, Jamie Vaudrey, UCONN Avery Point, Marine Sciences and Tom Wagner, Town of Waterford

Funding and DEP Support: The Guided Summary of the Niantic River Watershed Protection Plan was funded in part by the CT DEP through the US EPA Nonpoint Source grant under section 319 of the Clean Water Act. The following DEP individuals have provided invaluable support: Jessica Morgan, MaryAnn Nusom-Haverstock, Paul Stacey, Eric Thomas and Stan Zaremba

The Niantic River Watershed – Plan Refinement Group: The Guided Summary of the Niantic River Watershed Protection Plan was only possible through the vital suggestions and recommendations of the following individuals: Colleen Bezanson, Town of Montville, Mary Ann Chinatti, Town of Salem, Richard Dalkowski, Town of Salem, Maureen Fitzgerald, Town of Waterford, Don Landers, East Lyme Harbor Management/Shellfish Commission, Creig Peterson, Town of East Lyme, Joel Stocker, UCONN, Eric Thomas, CTDEP Watershed Management Program, Pat Young, Watershed Coordinator, and George Ziegra, Town of Salem

Review Comment Contributors:
Joe Mingo, A. V. Polhemus, Montville Planning and Zoning, Christie Hayes, Mark Nickerson, Chairman, E. Lyme Zoning Commission, Doug Brush, Chairman, Montville Inland Wetland Commission, Salem Inland Wetland Commission, John Mullaney, USGS, Don Landers, Chairman, EL Harbor Management, Frank Morelii, Public Utilities Administrator, City of New London, Salem Planning and Zoning Commission Comments, Rich Muckle, Member of the Waterford Conservation Commission, Mary E. Becker, Bureau of Water Protection and Land Reuse, CT Department of Environmental Protection, Fred Grimsey, President, Save the River-Save the Hills, Inc.

Introduction:

The Guided Summary of the Niantic River Watershed Protection Plan was produced for the purpose of providing town officials, commission members, business owners, homeowners and the general public a shortened account of the highlights of the full plan. It has been organized in a format that describes the watershed management concerns then outlines the goals, objectives and recommendations. Throughout the text, references to sections in the full plan are included, so that the reader may conduct further research into an area of interest. To a great extent most of the wording, tables and maps are taken directly from the original plan, with editing, updates or clarifications included, as warranted.

Niantic River Watershed Protection Plan
Guided Summary

The Niantic River Watershed Protection Plan was produced for the communities and advised by a Steering Committee with the vision to improve water quality throughout the watershed, eliminate shellfish bed closures, support fish and wildlife habitat and provide safe and healthy recreational areas.

Executive Summary

This plan takes a *watershed approach* to addressing the problems of nonpoint source pollution associated with the Niantic River, rather than a site specific approach. It considers the hydrologic, or watershed, boundaries of the Niantic River to characterize pollution sources and to develop strategies to address them. Through this scope, the characteristics and land uses of the watershed were examined to better understand the current and potential risk of nonpoint source pollution. Based on these risk assessments, it can then be determined what measures should be taken to decrease nonpoint source pollution to protect the Niantic River and its tributaries.

Full Watershed Management Plan

The full version of the watershed management plan, entitled *Niantic River Watershed Protection Plan*, was completed in 2006. This plan was completed under a consulting team, headed by Kleinschmidt Associates. It offers detailed information on environmental issues specific to the Niantic River, a Vulnerability Analysis of key parcels within the watershed and strategies aimed at addressing identified water quality impairments. Copies of the full plan were forwarded to each watershed town's Public Library and Planning Department. The plan may also be viewed on-line at the following link:

http://www.ct.gov/dep/cwp/view.asp?a=2719&q=379296&depNav_GID=1654

Purpose of the "Guided Summary"

The Guided Summary of the *Niantic River Watershed Management Plan* was produced for the purpose of offering commission members and the general public a concise description of the water quality impairments affecting the watershed and to provide a focused directory of recommendations aimed at reducing those impairments. With this condensed version as a tool, it is anticipated that stakeholders will have a better understanding of the relevant issues, be able to determine their role in the decision-making process and take appropriate actions.

Description of the Niantic River Watershed

A watershed consists of all the land that drains to a waterbody, in this case, the Niantic River. Local water features such as Fairy Lake, Horse Pond, Barnes Reservoir, Bogue Brook Reservoir, Lake Konomac, Darrow Pond, Latimer Brook, Oil Mill Brook, Stony Brook as well as the Niantic River itself, are all part of what is called the Niantic River Watershed, (Fig. I). The watershed covers 31.3 square miles, or approximately 20,000 acres and includes areas from the four towns of East Lyme, Waterford, Salem and Montville.

The Niantic River is an estuary. Fresh water drains from a small coastal watershed to a tidal embayment where fresh water mixes with the salt water of Long Island Sound. Many people relate to the Niantic River as a body of saltwater that provides access to the Sound and to a rich variety of marine resources. Others make connections to local freshwater streams and ponds through recreational activities such as fishing and swimming. For citizens of Waterford, including Quaker Hill, and New London, the freshwater resources in the watershed provide drinking water to 13,000 homes and businesses.

According to Min Huang, CT DEP Migratory Game Bird Program Leader, the Niantic River harbors relatively large concentrations of resident mallards, Canada geese, and feral mute swans throughout the year. The largest concentrations of resident waterfowl are typically found in the upper reaches of the river. These birds will stay in the upper reaches of the river until ice forces them further downstream. In the fall, winter, and early spring the lower river holds large numbers of wintering diving ducks such as hooded mergansers, bufflehead, and red-breasted mergansers. The bay, south of RT 156, attracts large flocks of Atlantic brant and, to a lesser extent, common goldeneye during the winter months.

The shallow marine estuary of the Niantic River was formed when sea level was at an elevation high enough to flood the low lying coastal valley. The river has historically supported healthy populations of shellfish, crustaceans, and finfishes and also provides excellent bird habitat as ospreys, herons, kingfishers, and cormorants may be observed at various times throughout the year. A fish ladder installed in Latimer Brook just north of I-95, allows the passage of species such as alewives and sea-run trout to spawning areas upstream.

In East Lyme, the area known as Oswegatchie Hills consists of over 700 acres of valuable land that offers great recreational potential because of its interesting terrain, and diverse wildlife. It is also one of the last large stretches of undeveloped waterfront land in Connecticut. The Waterford shoreline along this reach consists mainly of sandy beaches and gradual wooded slopes with moderate density residential development.

For additional information on Niantic River resources please refer to Section 3 of the full Niantic River Watershed Protection Plan.

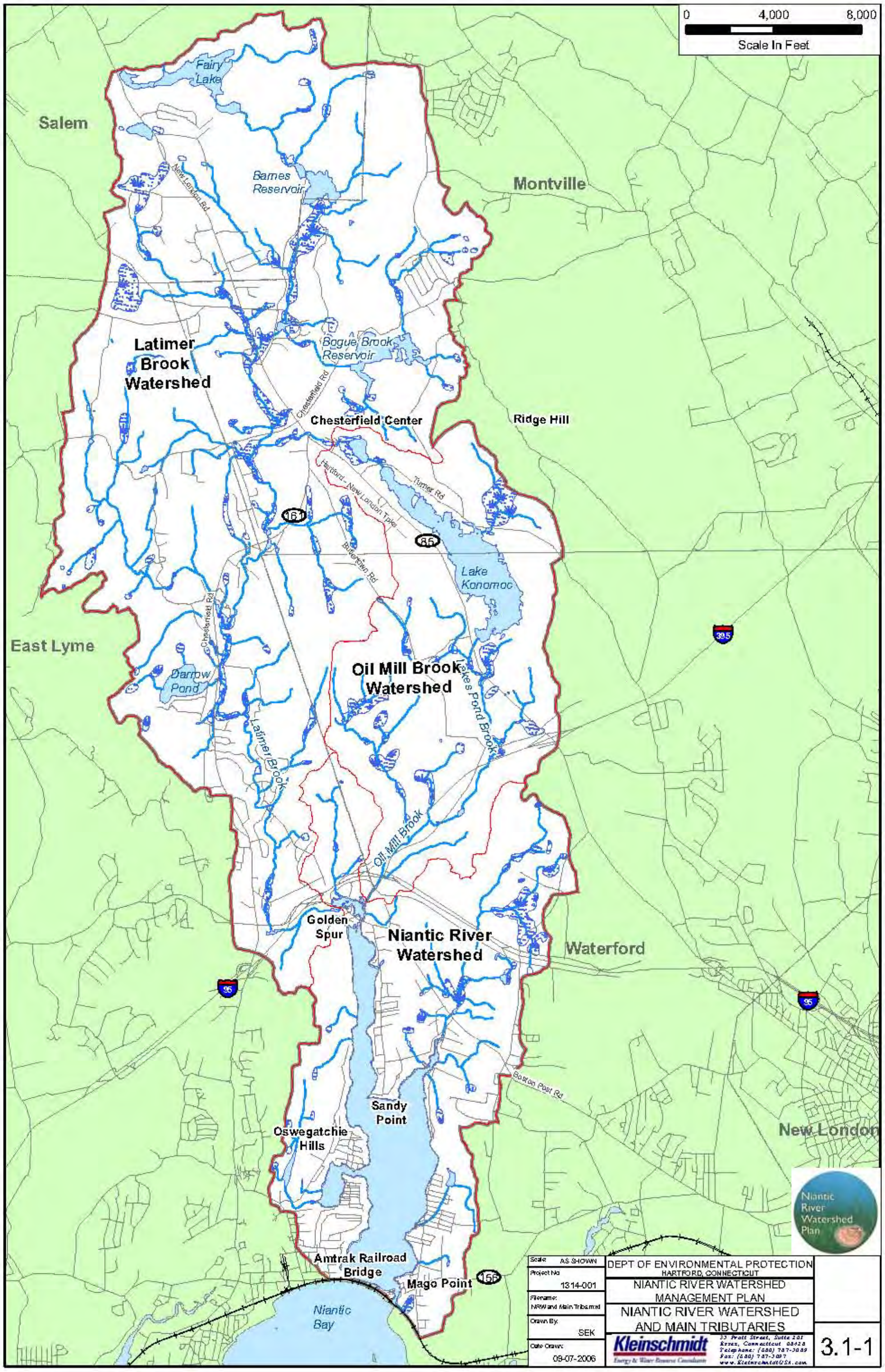


Figure I - Niantic River Watershed

Water Quality Issues in the Watershed

The Niantic River does not currently meet state water quality standards because of observed degradation of aquatic life. A map of the water quality classifications for the watershed based on 2006 data is shown on the following map (Fig. II). Table I describes the surface water quality classifications.

The Niantic River does not currently meet state water quality standards because of observed degradation of aquatic life

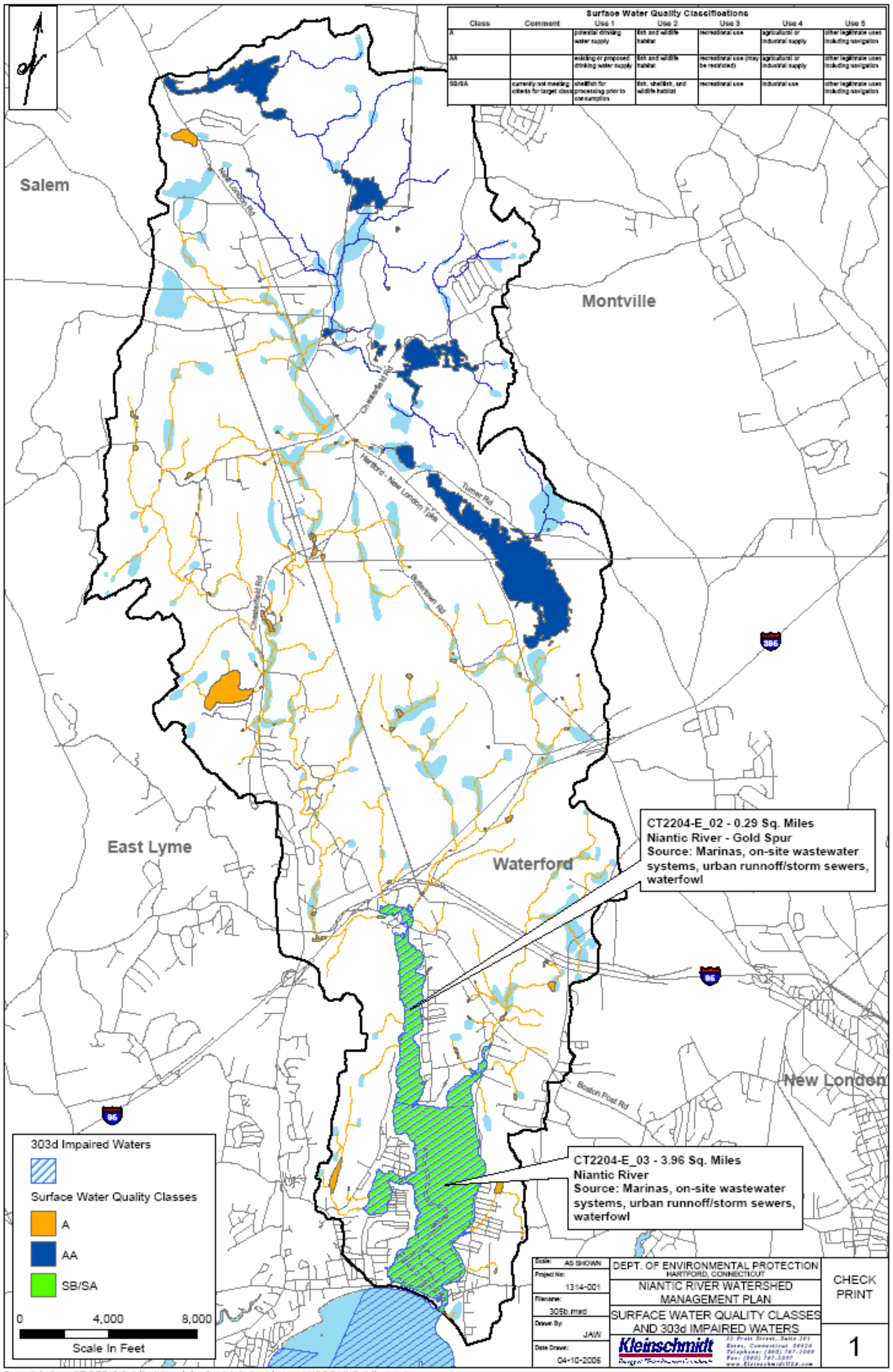
There are two active shellfish beds in the Niantic River. The upper bed remains open year round, while the lower bed is closed during boating season. Following one inch of rainfall, the State of Connecticut, Department of Aquaculture, is required to close both of the shellfish beds, regardless of the time of year. Rain carries bacteria into the river where it is filtered by shellfish rendering them unsafe for consumption. Normally it would take 14 to 28 days for shellfish to cleanse themselves (depurate) so that potentially harmful bacteria are no longer a concern (until the next 1"rainstorm).

The *§303(d) List of Impaired Waters* states that the water quality of the Niantic River is not supporting the aquatic life known to inhabit the estuary. Symptoms of this condition include, algal blooms, seasonal variations in eelgrass populations, loss of scallop populations and changes to the fish communities.

Table I Surface Water Quality Classifications for the Niantic River and its Tributaries

Class	Comment	Use 1	Use 2	Use 3	Use 4	Use 5
A	Known, or presumed, to meet criteria which support designated uses	Potential drinking water supply	Fish and wildlife habitat	Recreational use	Agricultural or industrial supply	Other legitimate uses including navigation
AA	Known, or presumed, to meet criteria which support designated uses	Existing or proposed drinking water supply	Fish and wildlife habitat	Recreational use (may be restricted)	Agricultural or industrial supply	Other legitimate uses including navigation
SA	Uniformly excellent	Direct consumption of shellfish	Designated swimming	All other recreational uses		
SB/SA	Currently not meeting criteria for SA target	Shellfish for processing prior to consumption	Fish, shellfish, and wildlife habitat	Recreational use	Industrial	Other legitimate uses including navigation

Populations of marine plants and animals commonly found in the Niantic River have decreased over the past 4 decades (Millstone Environmental Laboratory (MEL), 2005). Beginning in the 1980s, a sharp decline in eelgrass (*Zostera marina*) was documented (Marshall, 1994) and in more recent years, eelgrass in the Niantic has shown annual



Base data from CT DEP GIS (http://dep.state.ct.us/gis/index.htm) and USGS NHD (http://nhd.usgs.gov/).
303d and Surface Water Quality Classes data from CT DEP, 2004 and 2003.

Figure II – Surface Water Quality Classification

variation (MEL, 2005). Continued threats to eelgrass populations in the Niantic River include nutrient input from domestic septic systems, disease, increased turbidity, competitive interactions with macroalgae, and herbivory. Scallops and winter flounder rely on eelgrass as nursery habitat and are practically missing from the Niantic River (Heck, *et al.*, 1995; MEL, 2005). Meanwhile, new species like green crabs and grubby, appear to be on the rise in the River (MEL, 2005).

The cause of this impairment to aquatic life is not completely understood; however, there is a building body of scientific evidence that states that the river is overloaded with nutrients, primarily nitrogen. Nitrogen enriches the brackish Niantic River water, like fertilizer on a lawn, increasing algal and plant growth. Like bacteria, nutrients flow to the river with stormwater and are considered a problem of nonpoint source pollution.

This widespread, nonpoint source pollution is the greatest threat to the water quality and ecological health of the Niantic River.

Bacteria and nitrogen enter the Niantic River from several sources. Historically, marine vessels, inadequately functioning septic systems and stormwater runoff have been cited as the primary sources of these and other pollutants to the Niantic River. Table II lists nonpoint sources of pollutants their characteristics and impacts. Polluted runoff, illegal marine discharges and sewer line accidents are the most probable sources of bacteria to the Niantic (CT DA/BA, 2005).

Nitrogen associated with polluted runoff, atmospheric deposition and groundwater inputs are critical water quality concerns for the Niantic River (Marshall, 1994; Mullaney, 2006; Stacey and Mullaney, 2004). For instance, we know that polluted runoff accounts for approximately half (50%) of the nitrogen inputs into the Niantic River. Atmospheric deposition of nitrogen accounts for approximately 10% of the nitrogen making its way to the river (Marine Biological Laboratory, 2006). The remaining nitrogen is most likely coming from sources such as septic systems and fertilizer, through groundwater discharge (Mullaney, 2006).

As East Lyme and Waterford continue to extend domestic wastewater sewers to homes along the river, Salem and Montville enforce their surface water protection areas and marine vessels are prohibited from dumping sanitary wastewater into the river, stormwater runoff has become the primary target for protecting the Niantic River. Stormwater runoff transports pollutants of the land into the many drainage systems and tributaries feeding the Niantic River. This widespread, *nonpoint source pollution* is the greatest threat to the water quality and ecological health of the Niantic River.

Without the continued maintenance of existing water quality conditions, or attempts to reduce nonpoint source inputs, the health of the Niantic River ecosystem will deteriorate further.

In recent times, changes in river ecology believed to be associated with nitrogen loading include the loss of commercially important shellfish species, in addition to eelgrass stands and indicate a need for further water quality protection. Measures to protect water quality include land use and development controls to help reduce the influx of nonpoint source pollution. Additionally, the designation of the river and near-shore waters of Long Island Sound as a No Discharge Area may help eliminate potential sewage discharges from vessels, and eliminate another source of nutrient enrichment (CTDEP, 2005). Without the continued maintenance of existing water quality conditions, or attempts to reduce nonpoint source inputs, the health of the Niantic River ecosystem will deteriorate further.

Table II - Nonpoint Source Pollutants, Characteristics and Impacts

Nonpoint Source Pollutants	Pollution Characteristics	Impacts
Sediments	• Produced by natural and anthropogenic erosion of streams. • Generated by particulates settled on impervious surfaces. • Constitutes the largest mass of pollutant loadings to surface waters. • Provide transport for other pollutants like nutrients and bacteria.	*Short term*: increased turbidity, reduced light penetration, decreased submerged aquatic vegetation (SAV), respiration impacts to fish and wildlife, reduced fecundity in fish. *Long term*: Smothered benthic habitat, siltation, channel shoaling, aesthetic impacts.
Nutrients	• Introduced to the watershed by the burning of fossil fuels, use of fertilizers and detergents and the deposit/disposal of human and animal wastes. • Phosphorus and nitrogen are the primary nutrients of concern.	• Eutrophication and low dissolved oxygen in marine ecosystems.
Oxygen-Demanding Substances	• Organic matter enters fresh and coastal waters and then is decomposed, depleting dissolved oxygen. • Organic matter is washed off impervious surfaces with runoff.	• Depletes dissolved oxygen. • Exacerbates the negative impacts of eutrophication.
Pathogens	• Associated with the feces of warm-blooded animals. • Elevated levels typically found in urban runoff. • Leading cause of water quality impairments in the United States.	• Beach and shellfish bed closures. • Contaminated drinking water sources.
Road Salts	• Primarily in northern climates. • Major pollutant in urban areas. • Produces high salt/chlorine concentrations in surface and ground water.	• Contaminated surface waters and ground water. • Toxic to benthic organisms. • Ecological effects pronounced in freshwater systems.
Petroleum hydrocarbons	• Derived from oil and other petroleum products. • Introduced into the watershed from vehicles. • Accumulates on impervious surfaces. • Bind to sediments and often collect in the benthic region.	• Toxic to aquatic life at high and low levels depending on compound. • Accumulate and persist in the benthic environment.
Heavy Metals	• Common in urban runoff: cadmium, chromium, copper, lead, and zinc. • Copper, lead, and zinc are the most prevalent in nonpoint source pollution from urban areas. • Deposit from vehicles and the atmosphere (particulate matter).	• Produce toxic effects on aquatic life. • Bioaccumulate in fish and marine mammals.
Toxics	• Various toxic compounds (USEPA “priority pollutants”) can be found in urban runoff.	• Acute and chronic impacts to aquatic life.

For additional information on Water Quality concerns please refer to section 4.0 of the full Niantic River Watershed Plan – Bacteria (4.2.1), Nitrogen Loading (4.2.2), Niantic River Ecosystem (4.3), and Fish Community and Macroinvertebrates (4.4)

Land-Use and Water Quality

The Niantic River Watershed exhibits a settlement pattern similar to other coastal watersheds in the Northeast United States. Older, denser development occurred along the coast in association with shipping and commercial centers while forestry and agriculture were the predominant land uses inland (Marshall, 1994 and Civco, *et. al*., 2002). This land use pattern continues, by and large, with the exception that the upper portions of the watershed have converted back to forest land now that agricultural uses have diminished or are being developed for residential or commercial uses as a result of sprawl from the coastal areas. In the lower portions of the watershed – East Lyme and Waterford – new development is restricted to infill areas with the exception of Oswegatchie Hills in East Lyme. In the upper reaches of the watershed - Montville and Salem – there remain sizeable areas of land that could be developed.

It is the cumulative impacts of years of development with which we are concerned.

Figures III and IV on the following pages, illustrate the land cover changes in the Niantic River Watershed between 1985 and 2006. Table III below gives the acreages per land use cover for 1985 to 2006. This characteristic of land use change is probable cause for nonpoint source pollution and related water quality problems. Note that there has been significant increase in developed land and a substantial decrease in forest land acres.

Table III - Area in Acres of Land Cover Type

Description	Change in Acres	1985	2006
Developed	+653.3	1969.1	2622.4
Turf and Grass*	+274	607.0	881.0
Other Grasses	+104.6	264.5	369.1
Agricultural Fields	-109.5	758.0	648.5
Deciduous Forest	-984.3	12245.8	11261.5
Coniferous Forest	-38.5	905.8	867.3
Water	-77.6	1536.9	1459.3
Non-forested Wetland	+1.1	63.3	64.4
Forested Wetland	-63.6	938.4	874.9
Tidal Wetland	0	0.3	0.3
Barren	+248.2	338.5	586.7
Utility Corridors	-7.6	129.5	121.9
Totals		19757.3	19757.3

(*includes golf course greens)

Satellite Derived Land Cover data version 2.02, J. Stocker, UCONN, 10/03/08

Generally, no one development will cause, in and of itself, the degradation of a stream. It is the cumulative impacts of *years* of development with which we are concerned. Development in the Niantic River Watershed has occurred and will occur incrementally over time. From year to year, changes in the landscape, as a result of development, are negligible with the possible exception of relatively large developments (*e.g.* “big box” retail outlets, large residential, or road projects) on large parcels of land. But, after many years, landscape changes are obvious. The same holds true for nonpoint source pollution; the gradual development of the watershed will cause water quality concerns over time unless protective actions are taken.

Civco and others (2002) have described land use as, “the common denominator underlying many of the issues that our communities face from nonpoint source water pollution and open space preservation to sustainable economic development and community character”. Changes in land use are the result of community decision-making with regard to all of these community objectives. Development converts vegetated land to mostly impervious surfaces. When the pattern of development emanates from urban areas to suburban and rural areas, we call this pattern ‘urban sprawl’. Therefore, as settlement expands into rural areas, building and road density increases in these areas increasing the area of impervious surfaces.

***Impervious surfaces not only increase the total volume of runoff, but also transmit pollutants readily and can even contribute to thermal pollution*.**

The area of impervious surfaces in a watershed is essential to understanding nonpoint source pollution potential and consequent management requirements (Schueler, 1994; Sleavin *et al.*, 2000). Impervious surfaces include any surface that water cannot infiltrate, such as parking lots, paved roads, sidewalks, buildings, rooftops, and highly compacted earth. Impervious surfaces not only increase the total volume of runoff, but also transmit pollutants readily and can even contribute to thermal pollution. Therefore, much of the impervious surface we recognize in our community is associated with transportation or buildings. Schueler (1994) noted that the transportation system typically contributes the most to total impervious area in a watershed.

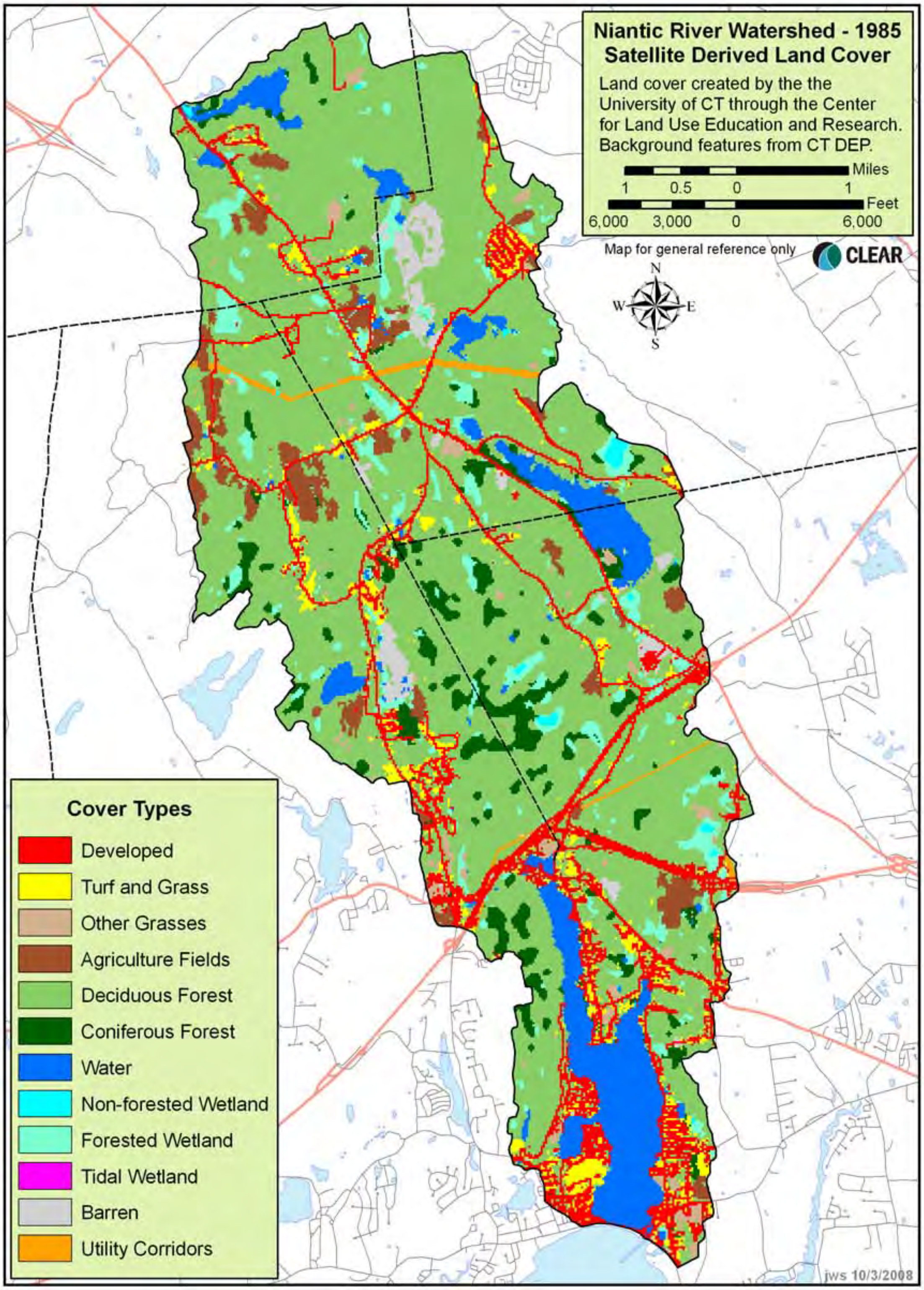


Figure III – Land Use Cover - 1985

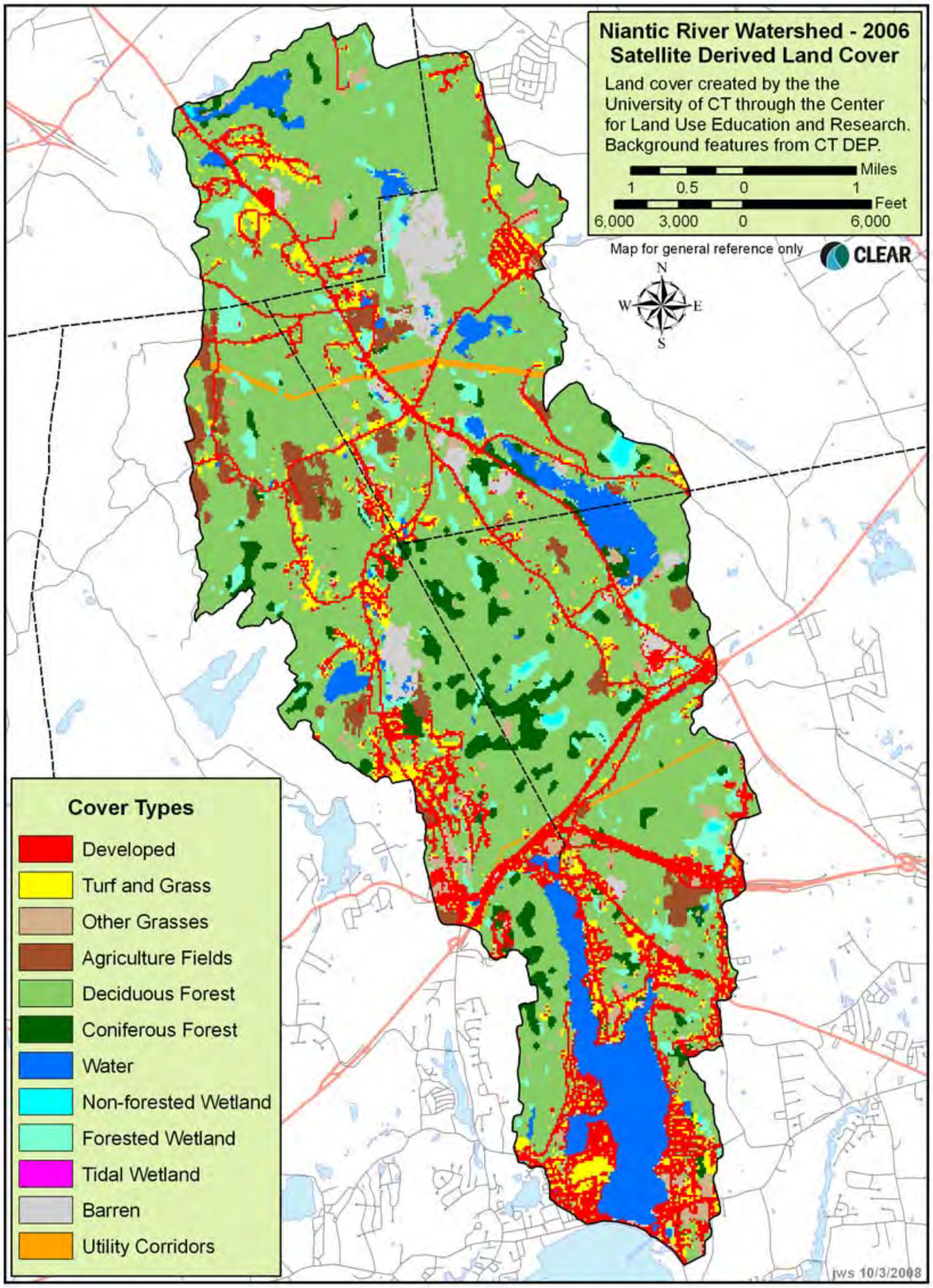


Figure IV - Land-Use Cover-2006

Impervious surfaces lead to four major impacts to a watershed. In no particular order, these are *altering the natural flow of water*, *aquatic habitat loss*, *decreasing water quality*, and *loss of biological diversity*. As a watershed's imperviousness increases, the quality of its streams decreases**.** Early and recent work by the Center for Watershed Protection (CWP) in the Chesapeake Bay Watershed established a close relationship between a watershed's imperviousness and the state of water and habitat quality degradation in streams (CWP, 2003). Figure V illustrates this relationship and reflects the degree of stream degradation as *degraded, impacted,* and *protected.*

As a watershed's imperviousness increases, the quality of its streams decreases.

(adapted from UCONN NEMO, 2006 and Schueler, 2002)

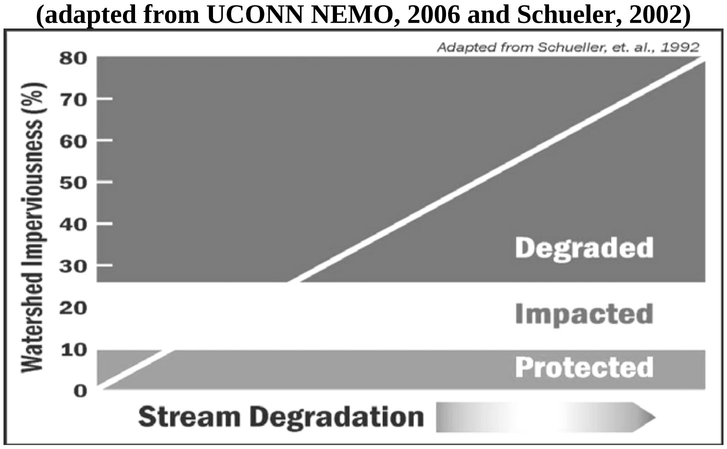


Figure V – Relationship between Watershed Imperviousness and Stream Degradation

Full build-out scenarios were developed for each of the sub-basins in the watershed to predict the amount of impervious surface coverage based on current zoning. Impervious surface percents were calculated for current conditions and were estimated under full-buildout conditions. Basins at less than 10% impervious are shaded green, between 10 and 25% impervious are shaded yellow and above 25% impervious are shaded red. Maps of estimated current and future percent impervious surface area for basins are shown on Figures VI and VII.

Based on existing conditions approximately 90% of the sub-basins in the Niantic River Watershed have less than 10% impervious surface coverage. The remaining 10% falls between the 10-25% range. Under the projected build-out analysis approximately 69% of the of sub-basins will have less than 10% impervious coverage, 29% would then be in the 10-25% range and 2% of the sub-basins would have impervious surface coverage over 25%. Referring to the graph above, this would mean that based on current land development practices over 30% of the sub-basins will fall into the impacted or degraded category.

For additional information on Land-Use in the Niantic River resources please refer to sections 4.5 of the full Niantic River Watershed Plan.

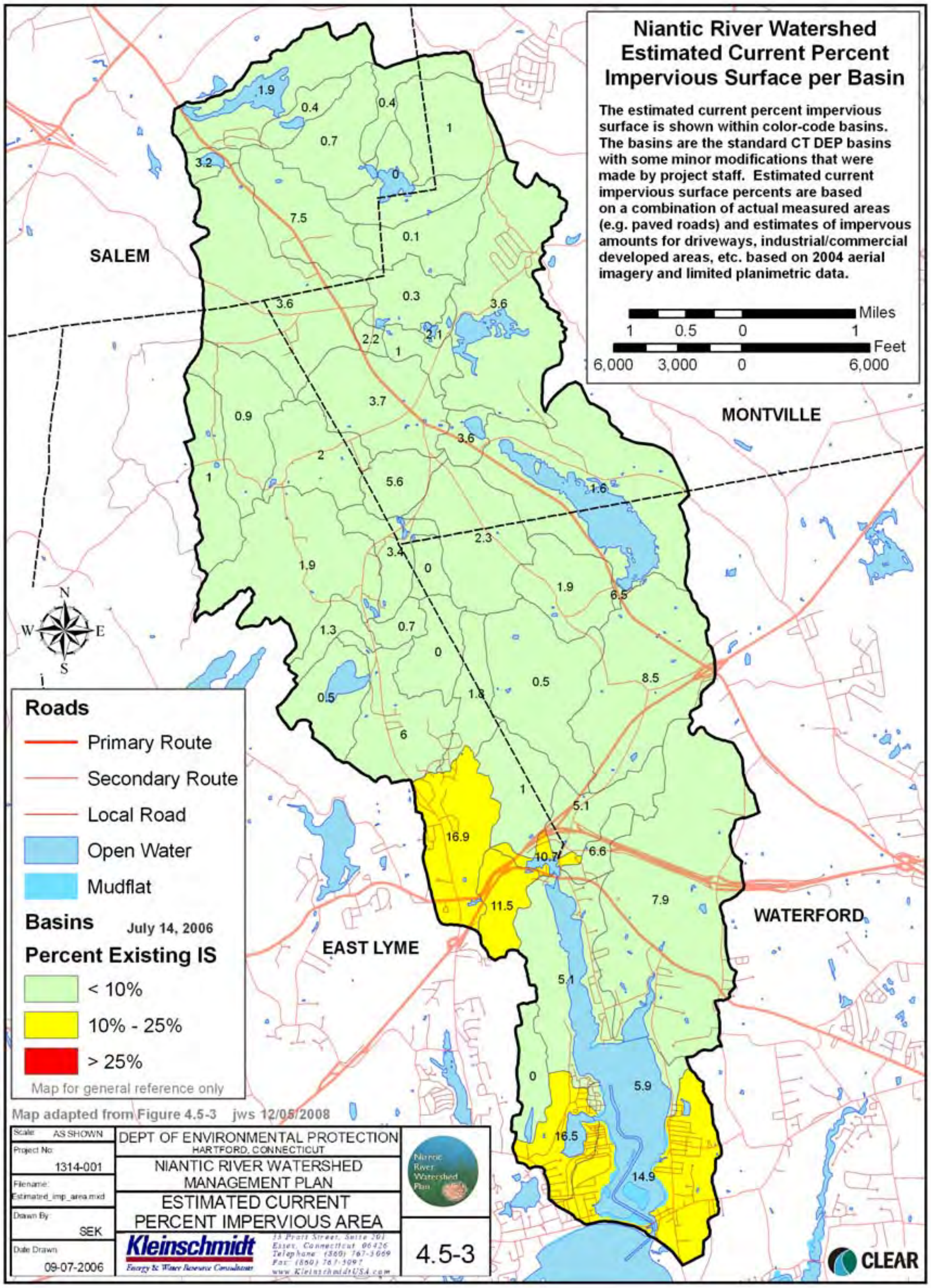


Figure VI – Estimated Current Impervious Area per Basin

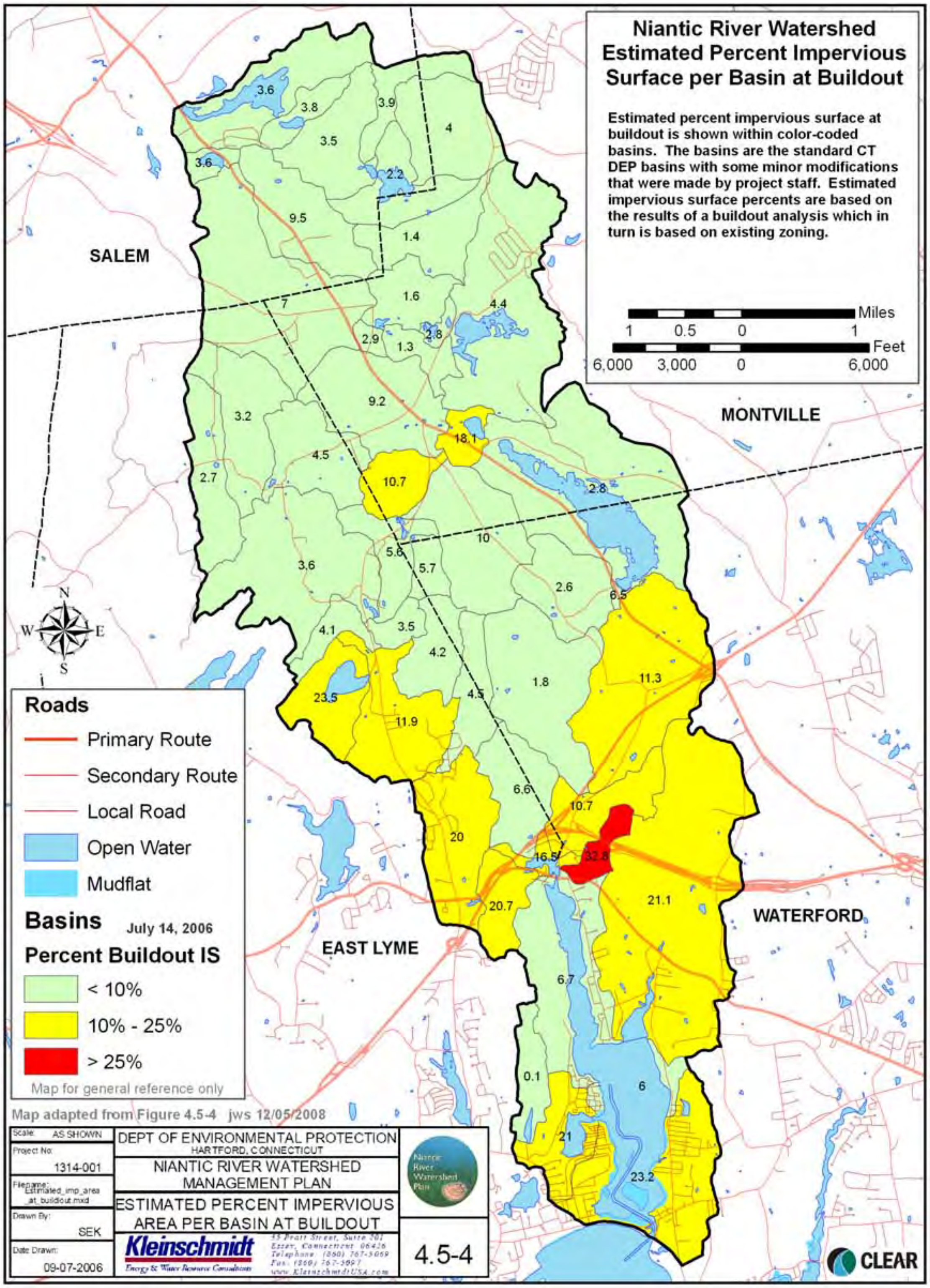


Figure VII – Estimated Current Impervious Area per Basin at Buildout

What Needs to be Done?

Significant investments have been made to control pollution to the Niantic River. East Lyme and Waterford have sewered many of the neighborhoods along the shores of the river to eliminate the risk of bacterial and nutrient pollution from septic systems. The Niantic boating community is being encouraged to observe the No Discharge Zone on the river to control sewage from marine vessels. These efforts, combined with advances in stormwater management, offer hope that impacts from historic activities can be turned around. However, the impacts and management of nonpoint source pollution (*i.e.* polluted runoff and stormwater) remain.

The nature of nonpoint source pollution makes it extremely challenging to manage.

The nature of nonpoint source pollution makes it extremely challenging to manage. It is decentralized (sources vary and are scattered), cumulative (pollution results not from one, voluminous event; rather, it occurs over time in regular, periodic rain/runoff events), and systematic (an entire hydrologic unit [watershed] is both the scope and scale of the problem). In the case of the Niantic River, pollution is transported to the main stem via several smaller streams, each carrying pollutant loads emanating from sources somewhere else in the watershed. Hence, effectively managing nonpoint source pollution issues relies on an approach that is comprehensive and watershed-based, *i.e.* scaled according to the natural system to be managed.

…watershed boundaries are not political boundaries

Although watershed-based management plans have been recognized as the approach to dealing with nonpoint source pollution, they are not without their own set of challenges. For instance, watershed boundaries are not political boundaries; therefore several jurisdictions often have a stake in watershed management. The Niantic River Watershed includes portions of four towns – East Lyme, Montville, Salem, and Waterford. Therefore, watershed management relies on participation and execution from all four communities.

Watershed management boils down to land use management.

Watershed management boils down to *land use* management. By and large, land use planning and regulation, including the management of runoff (*i.e.* stormwater), lies with the municipalities. Current nonpoint source pollution problems are linked to historic development and stormwater management in these four communities. Like all coastal watershed communities in Connecticut, population and development pressure will continue to yield more full-time residents, housing and other developments, thereby increasing the potential for nonpoint source pollution problems. (NOAA, Spatial Trends in Coastal Socioeconomics (STICS), 2006).

…there is real hope and possibility to prevent further degradation of the Niantic River and to restore it to an improved condition

As the last remaining parcels of developable land are converted to commercial, industrial, and residential uses, the quantity and quality of stormwater runoff can be expected to change. Therefore, it is central to this plan that polluted runoff be considered the greatest water quality management challenge for the Niantic River, primarily because it is considered the most *manageable* of all potential sources of pollution to the river. That is to say there is real hope and possibility to prevent further degradation of the Niantic River and to restore it to an improved condition. This plan is needed to establish a coherent and practical approach to dealing with nonpoint source pollution in the Niantic River Watershed.

Key Watershed Findings

In completion of the full Niantic River Watershed Plan, several key project findings emerged which spearheaded the recommendations for future management efforts in the watershed. Table IV on the following page summarizes those findings.

Watershed Stakeholders—Where Do You Fit In?

There are four categories of watershed plan stakeholders. The categories are defined by the role the stakeholders play in moving the plan forward. In Table V the stakeholder roles are defined by the questions listed in the left column and the stakeholders in the right column. Many of these stakeholders were involved in the planning process and all play a role in plan implementation.

Table IV – Key Watershed Findings

Data Assembly & Results	• Fifteen or more storm sewer outfalls discharge untreated runoff directly into the Niantic River. These outfalls collect runoff from several drainage areas of various sizes along the Niantic River shoreline. • As a watershed's imperviousness increases, the quality of its streams decreases – a relationship well-established in scientific literature. Five drainages of the Niantic River are currently covered by over 10% impervious surfaces such as roads, parking lots, sidewalks and roofs. At fully developed conditions (maximum development allowed by current planning and zoning regulations), ten drainages in the watershed will be covered by 10% or more imperviousness and one drainage will be over 30% impervious surface cover. • Stormwater modeling showed increased loading to the Niantic River from existing development, but drainages adjacent to the lower river are fairly developed with respect to the remainder of the watershed. Any areas that may be considered developable pose a risk for direct discharge to the lower river by increasing the pollutant loading through its tributaries. • Undeveloped areas further upstream in the watershed pose a great risk to increasing loads to town water supply reservoirs. Preservation of lands abutting receiving waterbodies is as much a key component to water quality protection as is stabilizing and treating existing development. • Tracked development of the watershed has steadily increased since monitoring using aerial images was implemented in 1985. Since that time, over a thousand acres of forest has been converted into either developed, barren or grassed lands.
Zoning	• Each of the towns is making great efforts to do their part in protecting the waters of their communities. A more effective approach may be to match wetland protection requirements for a consistent watershed wide approach to protecting water quality. For example, the towns of East Lyme and Waterford each have a 100-foot upland review for wetlands and watercourses, where the towns of Montville and Salem have different buffer areas.
Environmental	• Eelgrass populations plummeted in 1999, but experienced a rebound in 2003 and 2004. The future of the grass is still questionable and requires regular protection and monitoring. It is believed that continued growth of the eelgrass populations will also aid in restoring shellfish populations, although the increased predation by an overall increase in fish species may limit growth opportunities.
• *Monitoring*	• Measurement of water quality throughout the watershed is not currently a standard practice. Improvements may be made through BMP and planning changes, but without practical measurement techniques, it becomes difficult to measure, monitor and adjust. • Monitoring and inspection programs, which are making great progress, are underway in the Towns of Waterford and East Lyme, but the potential for future development is the greatest in the upper reaches of the watershed.

Table V – Stakeholder Roles

Who is responsible for implementing the plan?	Property Owners and Managers (e.g. Home & Business) Developers, contractors and realtors Local government: • Local boards and commissions • Directors of Department of Public Works – East Lyme, Montville, Salem, Waterford • Directors of Planning – East Lyme, Montville, Salem, Waterford • Environmental Planner/Wetland Officer – East Lyme, Montville, Salem, Waterford • Zoning Officers • East Lyme-Waterford Shellfish Commission • Niantic River Gateway Commission • Ledge Light Health District State agencies: • CTDEP Bureau of Water Protection and Land Reuse – OLISP, Nonpoint Source Pollution Program, Coastal Management • CTDEP Bureau of Natural Resources – Fisheries, Wildlife • Connecticut Department of Transportation (ConnDOT) • Connecticut Department of Health Local environmental groups • Save the River, Save the Hills & Friends of Oswegatchie Hills	
Who is affected by the implementation of the plan?	Property owners, Water supply customers, Local businesses, Visitors	Recreational users, Boaters, Marinas, Anglers
Who can provide information on the issues and concerns in the watershed?	Property owners Anglers Boaters Local government: • Boards of Selectman, planning, zoning, wetland commissions in East Lyme, Montville, Salem, Waterford. East Lyme-Waterford Shellfish Commission State agencies: • CT Department of Agriculture/Bureau of Aquaculture, CTDEP Bureaus of Natural Resources & Outdoor Recreation, Office of the Commissioner Non-profit organizations	
Who can provide technical and financial assistance in developing and implementing the plan?	State agencies and institutions: • CTDEP Bureau of Water Protection and Land Reuse – OLISP, Nonpoint Source Pollution Program, Coastal Management • CTDEP Bureau of Natural Resources – Fisheries, Wildlife •ConnDOT • CT Department of Agriculture/Bureau of Aquaculture, (DA/BA) • University of Connecticut Cooperative Extension System Federal agencies: • NOAA, USEPA, USGS, USDA NRCS, USFWS	

Goals and Objectives

Overarching Goal

To restore and preserve the Niantic River and its tributaries so that they fully support all uses, including shellfishing, fishing, swimming and habitat for aquatic-life.

Main Goals and Objectives

Support Designated Uses for Shellfishing and Primary Contact Recreation

- Reduce bacterial loads from stormwater outfalls, runoff and direct discharges

Support Designated Uses for Aquatic Life

- Reduce nutrient loading from stormwater outfalls and runoff

Protect and Restore Natural Stream Channels

- Minimize flooding impacts by improving peak and volume controls from impervious surfaces
- Preserve and restore critical wetland and watercourse vegetative buffers

Raise Stakeholder Awareness and Involvement by Implementing a Watershed Management Information and Education Campaign

- Educate stakeholders about the Niantic River and its tributaries and watershed management.

Establish a Sustainable Coalition of Partners to Manage the Niantic River Watershed

- Create a coalition of watershed stakeholders to take a leadership role for the implementation of this plan

Improve Water Quality and Biological Monitoring for the Niantic River and its Tributaries

- Establish a comprehensive long-term water quality monitoring program for the Niantic River Watershed

Key Recommendations

The following recommendations were adopted from the full version of the *Niantic River Watershed Protection Plan.* They have been organized to present an edited version of the original recommendations to facilitate implementation.

Establish a Watershed Coalition

- **Support establishment of a sustainable watershed board**
    1. The coalition, which may be formed by modifying an existing board, would include appointed representatives from each of the four towns. This may include town officials, town board members, local environmental and non-profit organizations, business owners and landowners. Liaison representation from; environmental organizations with an interest in the watershed, local, state, and federal government, utilities, educational institutions and local businesses should be encouraged.
    2. Responsibilities would include putting into action the recommendations of the watershed management plan, with periodic plan reviews and updates.

Continued Support for a Watershed Coordinator Position

- **Support a Watershed Coordinator Position**
    1. This position would be dedicated to assisting the watershed board in implementing the Watershed Management Plan including conducting the inter-jurisdictional coordination activities, grant-writing and evaluation of plan achievements.

Develop and Implement Education and Outreach Programs

- **Increase stakeholder awareness about the link between shellfish closures and sources of bacterial pollution in the Niantic River.**
- **Increase stakeholders' level of knowledge about nutrient loading and the health of the Niantic River Estuary.**
- **Educate land use decision makers about the value of vegetated riparian buffers in the protection of water quality.**
- **Establish an outreach and tracking program for landowners about on-site septic system maintenance.**
- **Partner with other local groups to develop and implement a comprehensive education and outreach program addressing water quality and watershed management issues**
    1. Identify existing programs and target audiences
    2. Develop targeted outreach activities and materials- See Table VI on following page.*(and Chapter 7 of the full plan)*
    3. Annual evaluations on program(s) effectiveness
    4. Include public updates on municipal participation, local business efforts, development changes, monitoring results, changing technology and open space preservation.

Table VI – Outreach Activities

Targeted Group	Outreach Activities
Marinas and boat owners	✓ Support incentive and recognition programs for marinas to become Certified Connecticut Clean Marinas ✓ Support and assist in boat owner education programs ✓ Support pump out program conducted by Save the River-Save the Hills and improve awareness of availability land based pumpout facilities at Niantic Dockominiums, Three Belles, and Port Niantic in addition to the dump station at Niantic Bay Marina.
Homeowners and business owners	✓ Periodically complete a public outreach campaign for shoreline neighborhoods about potential sources of bacterial pollutants ✓ Conduct ongoing outreach on topics such as lawn care practices, pet waste management, and impervious surface run-off. Support MS4 requirements wherever feasible. ✓ Encourage and participate in programs such as storm drain stenciling, river and beach clean-ups and household hazardous waste disposal ✓ Promote the protection of riparian buffers for the benefit of water quality and habitat protection. Encourage public participation in habitat restoration and riparian revegetation projects ✓ Promote good “housekeeping” practices
Contractors and developers	✓ Sponsor on-going workshops to promote topics such as management of nitrogen loading during the development process, best management practices during construction
Municipal staff and appointed and elected officials	✓ Partner with organizations such as CT-NEMO, NRCS and CT Sea Grant to provide ongoing education on topics including; LID practices, riparian buffers, land conservation, stormwater regulations, housekeeping BMPs and management of nitrogen loading during the development process
Local Schools and youth organizations	✓ Work with local schools, education facilities and youth groups to promote outreach opportunities on water quality programs

Develop Design Standards for Local Implementation

- **Mitigate the impacts of increased/increasing impervious surfaces from development through Low Impact Development (*LID*) design and Best Management Practice (*BMP*) implementation. Apply to new and redeveloped sites, both public and private.**
    1. Incorporate low-impact site preparation and development techniques.
    2. Wherever feasible, eliminate curb requirements and mandatory sidewalks, reduce road widths and require pervious surfaces.
    3. Adopt new or modify existing cluster and/or conservation subdivision ordinances that promote density allowances with minimum footprints and limit rezoning that will result in more impervious surface and/or less wetlands in critical sub-drainage basins.
    4. Encourage and enforce non-structural, non-piped stormwater handling techniques wherever possible, avoid short-circuiting of stormwater discharges and incorporate effective vegetative buffers in site design.
    5. Carefully consider any rezoning that would allows an increase or high percentage of impervious surface on a lot.

> ***<u>What does it mean</u>?***
> ***LID****- design strategy using small scale controls integrated throughout a site to manage stormwater run-off and replicate pre-development hydrology*
> ***BMP****-a measure used to mitigate changes to the quality and quantity of runoff due to development*
> ***Cluster Subdivisions****-subdivisions that promote the preservation of natural resources while allowing similar densities as a conventional subdivision.*

- **Encourage and support municipal approaches to land-use planning, development reviews and site inspections that protect watershed resources. For uniformity within the watershed, the following management tools should be considered in land-use regulations and review of development proposals.**
    1. Conduct assessments of tributaries to establish stream preservation and restoration priority locations and needs. Assess value and functions of resources, (i.e. wetland and watercourses) as part of preliminary planning and design.
    2. Use an Upland Review Area from inland wetlands and watercourses boundaries in Inland Wetland and Watercourse Regulations. The DEP and *Niantic River Watershed Protection Plan* recommended guideline is 100 feet.
    3. Regulate activities in any other non-wetland or non-watercourse area that will likely impact inland wetland or watercourses.
    4. A minimum 50 foot wide vegetated buffer beyond wetland and watercourse boundaries, within which no alteration or vegetative removal is permitted, to the extent feasible.

Encourage vegetative buffer restoration where needed.

5. A riparian buffer overlay zoning district based on delineation of perennial and associated wetlands with associated widths of 100 feet for larger streams and 50 feet for smaller, headwater streams.
6. Protect existing wetlands, vernal pools and watercourses to maximum extent practicable (i.e. no alteration of areas with good existing functions and values). Mitigate for any and all wetland/riparian impacts, with emphasis on re-establishing vegetated buffers (water quality filtration zones) in appropriately placed locations (even if uplands locations are the only option*)*
7. Focus on stormwater treatment at beginning of site design. Design stormwater management treatment and controls that can and will be maintained, are suited to the site, maximize pollutant removal and minimize flooding impacts. Consider soils, hydrology, peak flows, stormwater volume, wetland and watercourse values and function, receiving waters, topography and vegetation. Develop checklists for stormwater design and, construction inspection and long-term maintenance. Table VII below lists management objectives and targets for bacteria, nitrogen and peak stormwater volume controls.
8. Use resources including *2004 Connecticut Stormwater Quality Manual*, *2002 Guidelines for Sediment and Erosion Contro*l, and full version of the *Niantic River Watershed Protection Plan* for plan and site reviews.
9. Apply development restrictions on steep slopes or adopt a steep slope overlay zone.
10. Develop incentive based programs where appropriate to promote resource protection.

> ***What does it mean?***
> ***2004 CT Stormwater Manual***-Standards adopted by the State of CT to address stormwater control design and maintenance
> ***2002 Guidelines for Sediment & Erosion Control***-Standards adopted by the State of CT to address soil erosion and site stabilization

Table VII - Watershed Management Objectives and Targets

Management Objective	Target
Reduce bacterial loads from stormwater outfalls, runoff, and direct discharges.	Fecal coliform: Geometric Mean less than 14/100ml; 90% of Samples less than 43/100ml (CTDEP, 2002).
	Enterococci: Geometric Mean less than 35/100ml; Single Sample Maximum 500/100ml
Reduce nutrients loading from stormwater outfalls and runoff.	Nutrient criteria for eelgrass is currently being developed by CT-DEP. Suggested Dissolved Inorganic Nitrogen (DIN) for LIS is <0.03mg/L (Vaudrey, 2008)
Minimize flooding impacts by improving peak and volume [stormwater] controls from impervious surfaces.	Peak flow volume and velocity: Minimized peak velocity for 1-yr, 24-hr storm events (CTDEP, 2004).

(Adapted from Table 6.1 of the Niantic River Watershed Protection Plan, updated to reflect input from DEP on nutrient loading)

Further reference on these management tools may be found in Section 6 of the Niantic River Watershed Protection Plan.

Develop a Comprehensive Watershed Monitoring Plan

- **Support the establishment of a Total maximum Daily Load** (TMDL) **for the Niantic River and its tributaries to establish water quality goals.**
- **Establish a repository system for monitoring data for the Niantic River and its tributaries to promote periodic water quality assessments**
- **Integrate existing watershed monitoring programs to address water quality restoration, tracking of indicator bacteria and nitrogen, status of riparian zones and impervious surfaces, to measure management performance.**
    1. Develop a water quality and biological integrity baseline for the tributaries including, Latimer, Oil Mill and Stony Brooks
    2. Evaluate monitoring data against performance measures (*e.g.* indicators, targets) to evaluate the effectiveness of the watershed protection plan.
    3. Monitor impervious surface cover/land use and net loss of wetlands and riparian corridors on a watershed and local basin basis.

<u>What does it mean?</u>
TMDL-establishes the maximum amount of a pollutant that a waterbody can take in without adverse impact

- **Support monitoring efforts conducted by town, state, federal and private organizations.**
    1. Support continued monitoring efforts by organizations including, Town Public Works Departments, Local and Regional Departments of Health, Shellfish Boards, CT-DEP, CT-Dept. of Agriculture, University of Connecticut, USGS, Dominion, City of New London Water Dept. and Save the River-Save the Hills, Inc.
- **Support training sessions for municipal officials and volunteers on water quality monitoring parameters specific to the watershed.**
    1. Support citizen–based water quality monitoring programs**.**
- **Produce annual/biennial "*State of the Watershed--Progress Report Card*", including the Niantic River and its tributaries as well as the watershed as a whole.**
    1. Track the implementation of the management strategies and monitoring parameters to determine status and effectiveness and identify trends. Levels of indicator bacteria and nitrogen should be tracked to measure management performance.
    2. Determine changes needed in monitoring protocol
    3. Report progress and recommendations to inform planning and management decision-makers.

> ***<u>What does it mean?</u>***
> ***Vulnerability Analysis***- An assessment completed as part of the full Watershed Mgt. Plan to identify areas of the watershed that demand the most priority for management.

Define, Adapt and Implement Open Space Initiatives

- **Key Resource Protection Recommendations:**
    1. Set watershed land preservation goals and targets based on available (undeveloped) land and priority watershed areas
    2. Protect acres of priority watershed areas every year as identified in the Vulnerability Analysis
    3. Maintain no-disturb buffers around wetlands and waterbodies and provide demarcation in key areas
    4. Preserve continuous wildlife corridors
- **Funding:** Work with legislative and funding organizations to obtain monies to purchase lands for preservation.

Develop and Support a Stormwater Utility Partnership

- **Support development of a municipal stormwater partnership for purpose of facilitating effective stormwater management, meeting Municipal Separate Storm Sewer System (MS4) requirements and implementing Stormwater Management Program Plans (SWMPPs)**
    1. Identify and prioritize maintenance schedules including, street sweeping, and stormwater structure inspection, maintenance

and repair
2. Identify and prioritize stormwater retrofits
3. Coordinate stormwater monitoring
4. Identify and coordinate cooperative agreements for cost-sharing of equipment and services
5. Identify and apply for funding sources
6. Provide outreach and education for staff, regulated community and general public

What does it mean?

MS4- system of pipes, ditches, or gullies, that is owned or operated by a governmental entity and used for collecting and conveying storm water

SWMPPs-plans prepared by a municipality to address stormwater issues

Stormwater retrofits-a series of structural stormwater practices designed to mitigate erosive flows, reduce pollutants in stormwater run-off, and promote conditions for improved aquatic habitat

Form Working Relationships with Public and Utility Organizations Impacting the Watershed

- **Identify organizations and contacts for all groups that impact the watershed.**
- **Establish a communication system with organizations to promote opportunities for coordinating and commenting on construction proposals and state and federal permits**

Seek Grant Funding Opportunities

- **Identify and apply for grants that address the Watershed Management Plan goals and recommendations.**
- **Partner with other organizations for coordinated grant efforts**

Where are we Now?

Periodically an assessment or progress report should be conducted to determine what has been accomplished and to direct future focus area activities. It will document what has been implemented on a town by town basis and will be used to make town-specific recommendations as part of watershed management implementation.

References:

Civco, D.L., J.D. Hurd, E.H. Wilson, C.L. Arnold, and S. Prisloe. 2002. Quantifying and describing urbanizing landscapes in the Northeast United States. Photogrammetric engineering and Remote Sensing 68(10):1083-1090.

CT DA/BA. 2005. 2003 Annual assessment of shellfish growing areas for the Town of East Lyme, Date 1/31/05. State of Connecticut Department of Agriculture, Bureau of Aquaculture (DA/BA). Milford, CT. 33 pp.

CTDEP. 2002. Water quality standards for the State of Connecticut (Surface water quality standards effective December 17, 2002. Ground water quality standards effective April 12, 1996).

CTDEP. 2004. 2004 Connecticut stormwater quality manual. Connecticut Department of Environmental Protection, Hartford, CT.

CTDEP. 2005. Application for Federal approval of no discharge area designation, Guilford to Groton, July 2005. Connecticut Department of Environmental Protection, Hartford, CT.

CTDEP OLISP. 2006. Niantic River Watershed Protection Plan - Watershed-wide Strategies to Prevent Nonpoint Source Pollution Connecticut Department of Environmental Protection, Office of Long Island Sound Programs, Hartford, CT. September 2006, 180 pp.

Center for Watershed Protection (CWP). 2003. Impacts of impervious cover on aquatic systems. Ellicott City, MD. 150 pp.

Heck, K.L. Jr., K.W. Able, C.T. Roman, and M.P. Fahay. 1995. Composition, abundance, biomass and production of macrofauna in a New England estuary: comparisons among eelgrass meadows and other nursery habitats. Estuaries 18(2):379-389.

Marine Biological Laboratory (The Ecosytem Center at). 2006. Changing land use and estuaries – Nitrogen in coastal waters. Woods Hole, MA. Website accessed on Aug. 10, 2006: http://ecosystems.mbl.edu/Research/Clue/

Marshall, N.E. 1994. The scallop estuary: The natural features of the Niantic River. Th'Anchorage Publisher, St. Michaels, MD.

MEL (Millstone Environmental Laboratory). 2005. Annual Report 2004: Monitoring the marine environment of Long Island sound at Millstone Power Station, Waterford, CT.

Mullaney, J.R. 2006. Presentation to Niantic River watershed protection project steering committee, May 31, 2006: Project to determine nitrogen discharge from ground water to the Niantic River funded in part with funds from the Long Island Sound Study Connecticut Department of Environmental Protection and U.S. Geological Survey. Unpublished data, USGS, Hartford, CT.

NOAA (National Oceanic and Atmospheric Administration). 2006. Spatial trends in coastal socioeconomics. NOAA STICS. Website accessed June 23, 2006. http://marineeconomics.noaa.gov/socialeconomics/welcome.html

Schueler, T.R. 1994. The importance of imperviousness. Watershed Protection Techniques. 1(3)100-111.

Sleavin, W., S. Prisloe, L. Giannotti, J. Stocker, and D.L. Civco. 2000. Measuring impervious surfaces for nonpoint source pollution modeling. Proc. 2000 ASPRS Annual Convention, Washington, D.C. 11pp.

Stacey, P. and J.R. Mullaney. 2004. Long Island Sound grant proposal: Nutrient loading to the Niantic River from tributaries above the fall line. Connecticut Department of Environmental Protection (DEP) in cooperation with the U.S. Geological Survey (USGS).

USEPA. 2000. Ambient water quality criteria recommendation information supporting the development of State and Tribal nutrient criteria for rivers and streams in nutrient ecoregion XIV Eastern Coastal Plain including all or parts of the States of South Carolina, North Carolina, Georgia, Virginia, Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Maine and the authorized Tribes within the ecoregion (EPA 822-B-00-022). USEPA Office of Water, Office of Science and Technology Health and Ecological Criteria Division, Washington, D.C. October 2001. http://www.epa.gov/waterscience/criteria/nutrient/guidance/index.html

Vaudrey, J. 2008. Establishing Restoration Objectives for Eelgrass in Long Island Sound, Part II: Case Studies. Final Grant Report to the Connecticut Department of Environmental protection, Bureau of Water Protection and Land Reuse and the U.S. Environmental Protection Agency.

IER INSTITUTE FOR ENERGY RESEARCH

The Levelized Cost of Electricity from Existing Generation Resources

JULY 2016 | THOMAS F. STACY | GEORGE S. TAYLOR, PH.D.

Table of Contents

Introduction

In this paper, we analyze publicly available data to establish the average levelized cost of electricity from existing generation sources, or "LCOE-E." This new measure is a crucial piece of information that has been missing from the electricity policy discussion. The LCOE-E data and framework we introduce in this report offer policymakers a powerful tool as they make decisions that affect the cost of electricity in the U.S.

What is the levelized cost of electricity? The approach taken by the federal Energy Information Administration (EIA) to answer that question ignores the cost of electricity from all of our existing resources and publishes LCOE calculations for new generation resources only. If no existing generation sources were closed before the end of their economic life, EIA's approach would provide sufficient information to policymakers on the costs of different electricity policies.

However, in the current context of sweeping environmental regulations on conventional generators—coupled with mandates and subsidies for intermittent resources—policies are indeed forcing existing generation sources to close early. Federal policies alone threaten to shutter 110 gigawatts of coal and nuclear generation capacity.[1] The LCOE-E we introduce in this paper allows for much-needed cost comparisons between existing resources that face early closure and the new resources favored by current policy to replace them.

First, our findings show the sharp contrast between the high cost of electricity from new generation resources and the average low cost from the existing fleet. Existing coal-fired power plants, for example, generate reliable electricity at an LCOE-E of $39.9 per megawatt-hour on average. Compare that to the LCOE of a new coal plant, which is $95.1 per megawatt-hour according to EIA estimates. This analysis also shows that, on average, continuing to operate existing natural gas, nuclear, and hydroelectric resources is far less costly than building and operating new plants to replace them. Existing generating facilities produce electricity at a substantially lower levelized cost than new plants of the same type. This analysis uses forward-looking LCOE based on estimates by EIA to compare with our estimates of LCOE from existing facilities.

Second, we adjust the LCOE estimates provided by EIA to reflect the average real-world capacity factors of different generation resources on the power grid. We find that EIA's estimates of the LCOE for new generation resources are low, because EIA provides these estimates at high levels of utilization relative to historical levels. For our LCOE estimates, we use the most recent delivered fuel price data instead of EIA estimates of future fuel prices.

Third, we estimate the amount intermittent resources increase the LCOE for conventional resources by reducing their utilization rates without reducing their fixed costs. We refer to these as "imposed costs," and we estimate them to be as high as $25.9 per megawatt-hour of intermittent generation when we model combined cycle natural gas energy displaced by wind, and as high as $40.6 per megawatt-hour of intermittent generation when we model combined cycle and combustion turbine natural gas energy displaced by PV solar.[2]

The LCOE-E framework allows for cost comparisons that are relevant for today's energy policymakers. For example, when all known costs are accurately included in the LCOE calculations, we find that existing coal ($39.9), nuclear ($29.1), and hydroelectric resources ($35.4) are about one-third of the cost of new wind resources ($107.4) on average and one-fourth of the cost of new PV solar resources ($140.3).[3] By increasing the transparency of the costs associated with policies favoring new resources over existing conventional resources, we hope to inform policymakers with the best available data and raise the level of the electricity policy debate.

About the Authors

Tom Stacy

Tom Stacy has dedicated the past eight years to education and research in electricity generation, wholesale market design and public policy with a focus on the dynamics of grid-scale wind electricity; has served on the ASME Energy Policy Committee; has testified before Ohio energy policy related legislative committees numerous times, many by invitation from their chairpersons. He continues to help state lawmakers come to terms with the electricity system's complex economic and technical issues and base the state's electricity related laws and regulations on conservative economic, sound engineering, and prudent land use principles. He holds a B.A. in Industrial Marketing from the Ohio State University's Fisher College of Business.

George Taylor

George Taylor is a former Silicon Valley engineer and executive; the director of Palmetto Energy Research, an educational non-profit devoted to the future of electricity generation; the author of a report on "The Hidden Costs of Wind Electricity" released by the Energy and Environment Legal Foundation; and a participant in Energy Information Administration workshops on the cost of (and costs avoided by) new generation options. He received a Ph.D. in Computer Architecture from U.C. Berkeley.

Executive Summary

The purpose of this report is to compare the cost of electricity from existing generation resources with the cost from new generation resources that might be constructed to replace them. To date, the Levelized Cost of Electricity from new generation resources (LCOE) has been the primary focus of "cost of electricity" comparison studies and debates. Our calculation of levelized cost from existing resources (LCOE-E) offers policymakers a more accurate depiction of the tradeoffs involved in decisions affecting the electricity industry. LCOE-E is based on data from two government sources – Federal Energy Regulatory Commission (FERC) Form 1 and Energy Information Administration (EIA) Form 860.

Decision-makers often compare levelized cost of electricity from various types of new power plants that might be built to serve society in the future. One such comparison, a part of the EIA's Annual Energy Outlook (AEO) includes a projection for the LCOE from new generation facilities that could be brought online in the future. EIA defines LCOE as "the per-megawatt-hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle."[4] EIA's estimates of LCOE are the most widely accepted and commonly used version of the LCOE methodology.

LCOE comparisons can be quite useful if they encompass a wide range of likely alternatives. However, one of the clear deficiencies of most LCOE reports has been the absence of any information about the cost of electricity from existing generation resources, even though those resources supply all of our electricity today and most of them could continue to supply reliable electricity at the lowest cost for years – even decades to come.

On the other hand, if regulators or lawmakers force power plants to retire earlier than they would have otherwise, the price of electricity must increase to pay for the incremental cost of replacement capacity. Because electricity is an essential input to nearly all goods and services, the cost of replacing operationally sound, least cost electricity-producing power plants with new ones that produce electricity at a higher levelized cost ripples throughout the domestic economy.

This report provides a baseline from which policymakers can assess the cost of replacing existing plants with new ones.

Our analysis is based on data reported to federal government agencies, EIA and FERC. The data suggest that on average each resource category's existing power plants have lower fixed costs and similar variable costs compared to their most likely replacements. The primary reason new power plants have higher LCOE is because they begin their operational lives with a full burden of construction debt and equity investment to repay. Since existing power plants have already repaid some or all of those obligations, their fixed costs going forward are lower. To the extent power plants of the same type outlive their "mortgages," they enjoy far lower fixed costs of operation, and thus are likely to be capable of supplying electricity at a lower cost overall.

Data sources mined for this report indicate that for all major generation resources, the fleet-average cost of electricity from existing power plants is less than the fleet-average cost of electricity from new power plants of the same type. We also examine a best-case scenario for new plants using a hypothetically achievable capacity factor that, in most cases, is higher than observed data.

Table 1A *Table 1A*

EXISTING VS. NEW (2013 $/MWh)

GENERATOR TYPE	LCOE of Existing Generation (at actual 2015 Capacity Factors and Fuel Costs)	LCOE of New Generation (at actual 2015 Capacity Factors and Fuel Costs)
DISPATCHABLE FULL-TIME-CAPABLE RESOURCES		
Conventional Coal	39.9	N/A[4]
Conventional Combined Cycle Gas (CC gas)[1]	34.4	55.3
Nuclear	29.1	90.1
Hydro	35.4	122.2
DISPATCHABLE PEAKING RESOURCES		
Conventional Combustion Turbine Gas (CT gas)	88.2	263.0
INTERMITTENT RESOURCES - AS USED IN PRACTICE	N/A[3]	
Wind including cost imposed on CC gas	N/A[3]	107.4 +other costs[5]
PV Solar including cost imposed on CC and CT gas[2]		140.3 +other costs[5]

Table 1B *Table 1B*

NEW VS. NEW (2013 $/MWh)

GENERATOR TYPE	LCOE of New Generation (at actual 2015 Capacity Factors and Fuel Costs)	LCOE of New Generation (at EIA-Assumed Capacity Factors and Fuel Costs)
DISPATCHABLE FULL-TIME-CAPABLE RESOURCES		
Conventional Coal	N/A[4]	95.1
Conventional Combined Cycle Gas (CC gas)[1]	55.3	75.2
Nuclear	90.1	95.2
Hydro	122.2	83.5
DISPATCHABLE PEAKING RESOURCES		
Conventional Combustion Turbine Gas (CT gas)	263.0	141.5
INTERMITTENT RESOURCES - AS USED IN PRACTICE	N/A[3]	
Wind including cost imposed on CC gas	107.4 +other costs[5]	73.6 +other costs[5]
PV Solar including cost imposed on CC and CT gas[2]	140.3 +other costs[5]	125.3 +other costs[5]

[1] Fuel costs derived using most recent (2015) delivered fuel price and heat rate data from EIA.

[2] PV solar LCOE based on EIA 860 reported capacity factor of 25.9% and adding back imposed costs of 3rd % PV market share

[3] Lack of sufficient FERC Form 1 data prevented us from producing estimates of LCOE-E for wind and PV Solar.

[4] Regulations from the Environmental Protection Agency currently prevent new construction of coal-fired power plants. Specifically, the EPA's New Source Performance Standards for CO2 are a de facto mandate for carbon capture and sequestration (CSS) for coal plants, and CCS is not a commercially viable technology.

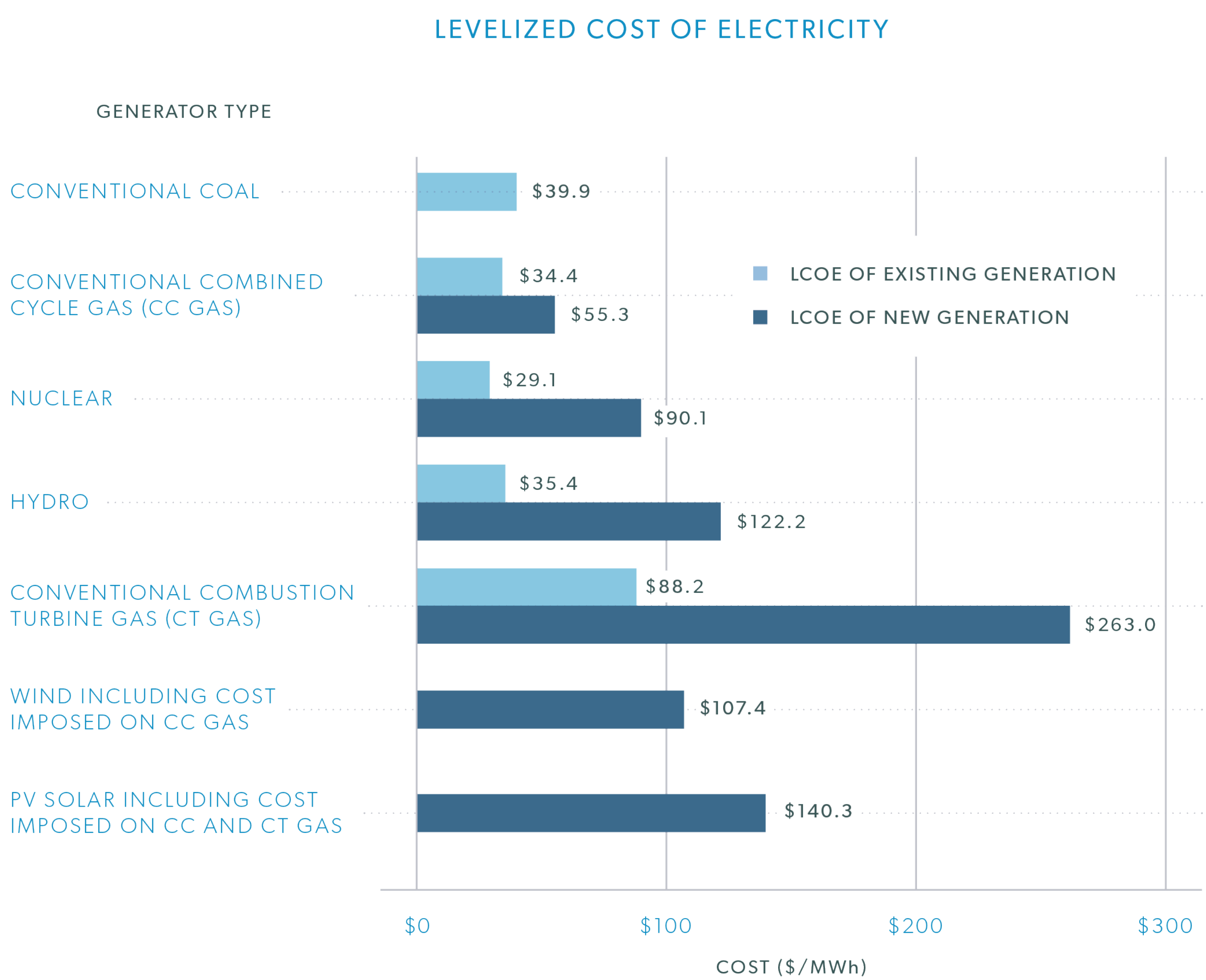
[5] "Other Costs" could add $25 - $50 per MWh and include transmission costs and subsidies not considered by EIA in their calculation of LCOE. Further, EIA makes no distinction between the 20-25 year expected lifespans of win and solar facilities vs. the 50+ year lifespans of most other technologies. See the following publications: *http://www.nrel.gov/docs/fy11osti/47078.pdf* , *http://eelegal.org/?page_id=1734*

Table 1A shows the levelized cost of electricity (LCOE) for existing resources--as derived using the FERC Form 1 database--and compares that to the LCOE for new resources. As Table 1A makes clear, the cost advantage of existing resources over new sources is pronounced. For both columns in Table 1A, we use 2015 fuel cost and capacity factor data from the Energy Information Administration (EIA). This allows us to make the most direct, apples-to-apples comparison between the LCOE of existing and new resources.

Table 1B highlights our adjustments to EIA's methodology in reporting the LCOE of new resources. Two key adjustments have substantial impacts on LCOE: 1) replacing EIA's fuel cost projections with 2015 data significantly lowers the LCOE of natural gas-fueled generation resources (CC gas and CT gas), and 2) using actual capacity factor data from 2015 (as opposed to EIA's "best-case" capacity factor assumption) affects all resources, but in different directions.[5] For example, it raises the LCOE for CC gas, CT gas, hydro, and wind while it lowers the LCOE for nuclear and solar.

Environmental Regulations + Subsidies and Mandates for Renewables are Driving Most New Generating Capacity Construction, Not New Electricity Demand

The reason the cost of generation from existing sources is so important is that government mandates, regulations and subsidies (not additional demand) are driving the construction of new generation resources.



FERC Form 1 and EIA 860 show that, in the absence of mandates, subsidies and regulatory compliance costs, the cost of electricity from almost all existing generation resources will remain less than the cost of electricity from their likely replacements for at least the next 10 to 20 years.

In fact, in their 2014 State of the Market report to FERC, grid operator PJM's Independent Market Monitor stated that: "Subsidies in the form of additional out of market revenue is not consistent with the PJM market design. The result would be to artificially depress prices in the PJM capacity market. This would negatively affect the incentives to build new generation and would likely result in a situation where only subsidized units would ever be built."[6]

From 2004 through 2014, electricity demand in the United States increased by an average of 0.3% percent per year.[7] Absent mandates for new generation and the onset of new federal environmental regulations forcing some coal fired generating capacity to retire, almost no new generation capacity would have been necessary over that ten-year period.

Longevity of the Existing Fleet

Forms 1 and 860 data indicate that most existing power plants could remain economically viable for years or decades beyond their current age. While existing resources remain our lowest cost option, regulatory compliance costs and artificial "wholesale price suppression" brought about by subsidizing and mandating higher cost and lower value technologies (for example, through the wind production tax credit, solar investment tax credit, and renewable energy mandates) combined with wholesale price caps cause low-cost existing dispatchable resources to operate at a financial loss. These external influences are not consistent with cost-minimizing market design. The result is that some existing resources may be operating at a net financial loss even while their likely replacements would produce electricity at a substantially higher cost.[8] The lowest possible electricity rates will only be achieved by keeping existing generating resources in operation until their product becomes uneconomic– not relative to suppressed wholesale market clearing prices, but rather *relative to the levelized cost of electricity from new sources that would replace them.*[9]

Conclusion

Most existing coal, natural gas, nuclear, and hydroelectric generation resources could continue producing electricity for decades at a far lower cost than could any potential new generation resources. At a typical coal-fired power plant, for example, when a component wears out, only the component must be replaced, not the entire plant. The same is true for nuclear plants, until they reach their regulatory end of life, which is currently defined to be 60 years, but could be extended to 80 years.[10] Under current laws, rules, and regulations, large amounts of generating capacity are slated to retire and will be replaced with new generating capacity, which will produce electricity at a far higher average levelized cost. The Institute for Energy Research identified more than 110 gigawatts of coal and nuclear generation capacity set to close as a direct result of federal regulations.[11]

When electricity from an existing electric generating plant costs less to produce than the electricity from the new plant technology expected to be constructed to replace it—and yet we retire and replace the existing plant despite the higher costs—ratepayers must expect the cost of future electricity to rise faster than it would have if we had instead kept the existing power plants in service.

An unprecedented amount of generating capacity is set to close due to ongoing renewable policies, undervalued capacity markets, currently low natural gas prices, and additional environmental regulations. In the absence of even some of these factors, most existing power plants would remain operational, helping keep electricity costs low for many years or decades into the future.

[1] This estimate was made before finalization of the Clean Power Plan, which will increase the amount of coal-fired power plants shuttered by federal policy tremendously.

[2] At six percent PV solar energy market share modeled vs. CAISO load profile and sunlight profiles.

[3] At three percent energy market share for PV solar and capacity factor adjusted US average PV solar LCOE, based on CAISO load and solar resource availability profiles.

[4] Energy Information Administration, Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2014, Apr. 17, 2014.

[5] Capacity factor is the average output of a plant or fleet over time divided by the theoretical maximum output of that plant or fleet, and is listed as a percentage. For example, EIA's best-case capacity factor for CC gas used in its LCOE estimates is 87 percent, and the actual capacity factor observed for the CC gas fleet in 2015 was 56.3 percent.

[6] Testimony of Monitoring Analytics, Dr. Joe Bowring, to the Ohio Electricity Mandate Costs Legislative Study Committee, April 16th, 2015 available through the office of the committee chairman, 131st Ohio General Assembly Senator Troy Balderson.

[7] Energy Information Administration, www.eia.gov/electricity/monthly Monthly Energy Review, Table 7.2a Electricity Net Generation: Total (All Sectors), February 2015, http://www.eia.gov/totalenergy/data/monthly/pdf/sec7_5.pdf

[8] http://www.monitoringanalytics.com/reports/Reports/2011/IMM_Comments_to_MDPSC_Case_No_9214_20110128.pdf Section 1 B, page 5

[9] Low-cost natural gas is another factor influencing the retirement of coal (and even some nuclear) capacity. Competitive marginal prices for CC gas energy place downward pressure on clearing prices, which in turn reduce the revenues accruing to all technologies. A properly valued and functioning capacity market should result in capacity market clearing prices sufficient to carry existing capacity contributors (in this case coal and nuclear) through any short-term reduction in gross margin and/or capacity factor.

[10] Katherine Tweed, APS Argues to Extend Lifespan of Nuclear Reactors to 80 Years, IEEE Spectrum, Dec. 12, 2013, http://spectrum.ieee.org/energywise/energy/nuclear/aps-argues-to-extend-lifespan-of-nuclear-reactors-to-80-years . The American Physical Society argues that there are no technical barriers to run nuclear power plants for up to 80 years—20 years beyond the current maximum 60-year life of nuclear power plants.

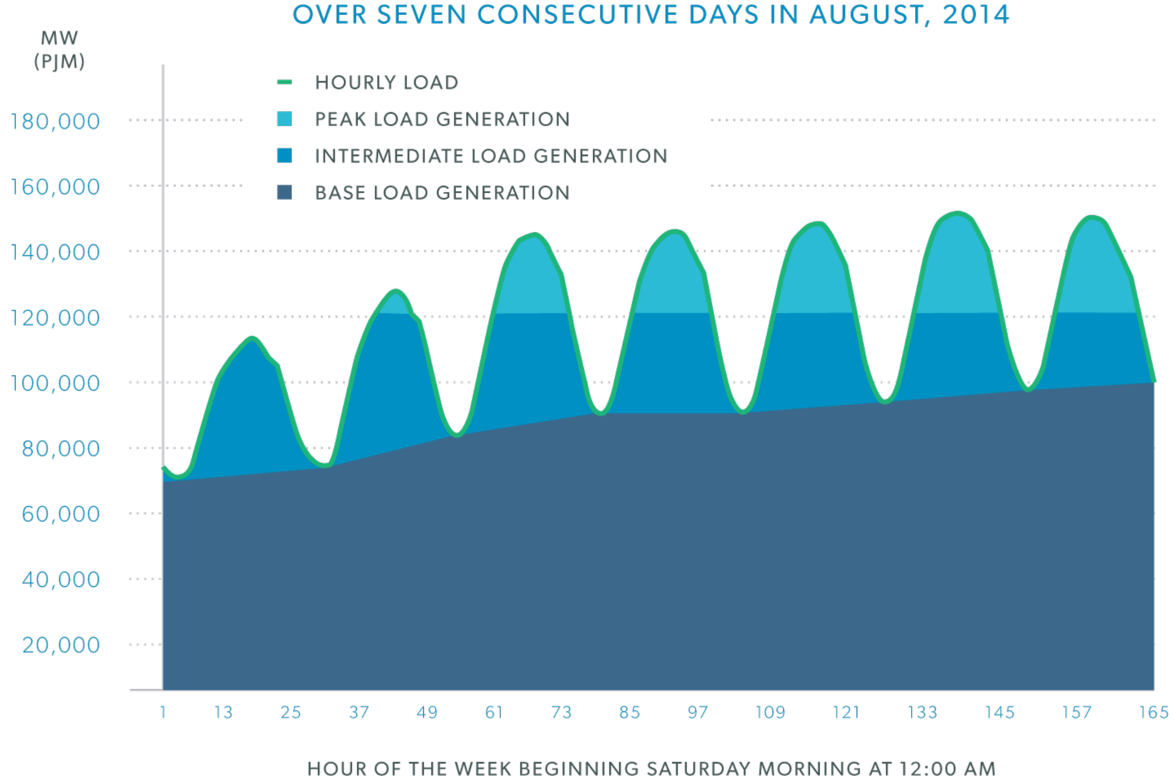
[11] Travis Fisher, Assessing Emerging Policy Threats to the U.S. Power Grid, Institute for Energy Research, Feb. 24, 2015, http://instituteforenergyresearch.org/wp-content/uploads/2015/02/Threats-to-U.S.-Power-Grid.compressed.pdf . The estimate was made based on federal policies, not including EPA's Clean Power Plan, which was not finalized at the time of the study.

I. IDENTIFYING VALUE-COMPARABLE GENERATION RESOURCE CATEGORIES

Valid LCOE Comparison Must Be Limited to Generation Resources with Similar Performance Capabilities/Characteristics

One of the most commonly overlooked aspects of comparing the cost of electricity from different sources is that different generating resources play different roles in keeping the electricity grid in balance. Some are designed to run almost all the time at a fairly steady level (base load) while others run part of the time (load following). Still others are designed to run only a few hours per day or year, and must adapt quickly to changes in demand or supply (peaking resources). For this reason, peaking resources should not be electricity-cost compared with nuclear designed for base load operation, or with coal or CC gas units designed for base load and load following. That is why this report lists peaking resources in a separate section from base load generators; in the same way, EIA lists non-dispatchable resources in a separate section of its LCOE Table 1.

HOURLY ELECTRICITY LOAD: PJM INTERCONNECTION OVER SEVEN CONSECUTIVE DAYS IN AUGUST, 2014



It would be convenient for cost comparison purposes if all types of electricity generators could serve the entire demand market, but that is not realistic. Electricity has no shelf life. It is instantaneously perishable, so it cannot be produced now and used several hours, days, weeks or months later without large scale “batteries” or other mass electricity storage devices that convert the electricity to some other form of energy (such as chemical or kinetic potential), store it, and then convert it back into consumable electricity.

Because most bulk electricity storage options add more cost than the potential savings, fuel storage (where possible) remains the most prudent choice. For technologies whose fuel cannot be stored and will not always be available in accordance with electricity demand, the cost of necessary storage capacity to bring it to the same dispatchability standards as conventional generators must be counted as part of the cost of those technologies.

Another option is to force dispatchable generators to “back down” relative to their previous levels whenever non-dispatchable generators produce electricity. As with electricity storage, there are both potential costs and savings in doing so. The savings are in the form of lower variable costs (including some fuel savings) of the dispatchable fleet. The costs are more complicated and stem from the unchanged fixed costs of dispatchable generators having to be recovered through the sale of less electricity long-term (because the dispatchable generators are backing down to accommodate non-dispatchable resources). In this report, we refer to these costs as “imposed costs.”

If we could build fewer dispatchable resources as we add non-dispatchables, these imposed costs would not exist. Unfortunately the “replacement value” of some nondispatchable resources for dispatchable resources is very low–close to zero–as measured by their guaranteed performance across the hours of the year society requires the greatest amount of electricity.

We are fortunate to have the means to store electricity-generating fuels and deliver them to the generators in the amounts and at the times electricity is needed. These fuels—primarily coal, natural gas and uranium—provide prompt and consistent generation of electricity in accordance with electricity demand, which is integral to electricity’s value proposition. For that reason, LCOE comparisons are valid only between resources with similar performance characteristics: that is, between technologies that are able to consistently and reliably serve the same segments of electricity demand. EIA partially represents this by listing non-dispatchable technologies such as wind and solar in a separate section of its LCOE Table 1, making special note just prior to its summary tables: “The duty cycle for intermittent renewable resources, wind and solar, is not operator controlled, but dependent on the weather or solar cycle (that is, sunrise/sunset) and so will not necessarily correspond to operator dispatched duty cycles. As a result, their LCOE values are not directly comparable to those for other technologies (even where the average annual capacity factor may be similar) and therefore are shown in separate sections within each of the tables.”[12]

Table 1 of EIA’s LCOE lists the high end of achievable annual capacity factors for each technology for dispatchable resources and a simple estimate of average capacity factors expected for the next non-dispatchable resources to be built in each region of the United States. The latter may be optimistic for wind, given that some U.S. regions have extraordinarily weak wind resources. An exploration of estimated capacity factors for marginal wind and solar resources is beyond the scope of this report, but merits further study. Nevertheless, these high end and estimated-marginal-average capacity factors may have been displayed in EIA Table 1 to assist readers in further distinguishing between the capabilities of different dispatchable technologies in order to avoid an invalid LCOE comparison between full-time-capable and part-time-capable dispatchable resources which serve different market segments. EIA says: “In Table 1 and Table 2, the LCOE for each technology is evaluated based on the capacity factor indicated, which generally corresponds to the high end of its likely utilization range.”

But natural gas and coal resources tend to operate at capacity factors significantly lower than “the high end of their utilization range” as shown in Table 2 of this report.[13] Capacity factors directly impact levelized cost calculations because the present value of fixed costs over a unit’s cost recovery period is converted to a fixed cost per MWh when calculating LCOE. In other words, a lower capacity factor means fewer operating hours and hence a higher fixed cost per MWh and higher overall LCOE.

Therefore, EIA's LCOE estimate is biased in favor of those technologies for which EIA's assumed capacity factor is higher than the actual capacity factor. As discussed, this report makes a further distinction within EIA's category "Dispatchable Technologies," dividing them into two separate categories: "Dispatchable Full Time Capable Resources," and "Dispatchable Peaking Resource," Combustion Turbine (CT) gas, which is expected to be called on and to run reliably, primarily at times of high electricity demand.

Base Load (Full-Time-Capable) Resources

Nuclear, coal, and CC gas electricity are commonly deployed through facilities designed to produce:

- at or near full nameplate capability
- for sustained periods of time from several days to several months

Many hydroelectric resources operate the same way, although their capacity may vary from one time of the year to another. These operating characteristics promote the highest fuel efficiencies and lowest variable costs, as well as the lowest emissions intensities.

Peak Demand Resources

CT gas facilities are designed to minimize fixed costs in anticipation of the low utilization rate associated with serving peak demand. The trade-off is lower fuel efficiency, higher variable costs and higher emissions intensity. Because CT gas units produce relatively small amounts of energy on an annual basis, low fixed costs take precedence over low fuel cost and emissions. While EIA lists a possible 30 percent capacity factor for CT gas, FERC Form 1 and EIA 923 data indicates that CT gas units typically have capacity factors in the mid to high single digits. A report prepared under contract to EIA assumes a 10 percent capacity factor for CT gas units in its calculation of fixed costs per MWh, while Electric Power Monthly shows real world capacity factors for CT gas units average 6.7 percent.[14] Since CTs were not intended to be full time resources, they are not direct replacements for nuclear, coal or CC gas units.

Intermittent Fuel Resources

EIA refers to hydroelectric, wind and solar as "Non-Dispatchable Resources" because they consume fuels whose availability is not under human command. Such units can be turned down or off, ("downward dispatchable") but they cannot produce more electricity than their fuel streams permit. Wind generation is particularly problematic, because across most of the United States its season of lowest production corresponds with the season of highest demand (summer).

Solar photovoltaic (PV) has the advantage of producing during daytime hours when demand is high. However, electricity demand remains high for several hours after solar radiation has declined in late afternoon. Therefore, even though solar generation's correlation with demand is higher than wind generation's, solar still has limited value as a replacement for "peaker" power plants whose fuel can be consumed precisely and only at peak demand times. Because combustion turbines (peaker plants) are less fuel-efficient than other dispatchables, solar PV saves more fuel per MWh of generation than wind. Neither solar PV nor wind, however, are good substitutes for base or intermediate load power plants.

The range of different hydroelectric facility capabilities means hydro does not fit neatly in any particular segment of a LCOE table. "Run of river" hydroelectric power could be shown in the intermittent or dispatchable category depending on the water resource feeding any given hydroelectric facility. Many current hydro facility locations and designs offer some fuel supply certainty over time (or "storage") in the form of regular precipitation, melting snow pack and/or ground saturation over a facility's feedstock watershed, or through impoundment capability (deep water stored behind tall dams), which allows them to operate much like dispatchable generators for weeks or even months at a time. Periodic shortages of water for hydro develop gradually and are far more foreseeable than shortages in wind velocity.

Due to untimely changes and low availability of their fuels during hours of peak demand, wind and solar resources are not direct or complete substitutes for dispatchable resources. They are instead "supplemental" options that reduce the fuel consumption and utilization rates of "dispatchable" units without replacing the need to build and maintain those units. Wind and solar therefore can be thought of as "energy only" resources that save a portion of the variable costs (fuel and variable operations and maintenance or O&M), but little or no fixed costs.

To make it possible for policymakers to compare the cost of electricity from all available technologies, the body of this report examines each intermittent resource as part of a fulltime-capable "combination" of resources composed of the intermittent resource and a full-time-capable dispatchable resource, the combination of which can deliver approximately the same levels of capacity and energy as the dispatchable resource by itself. Namely, we examine two hybrid sources of firm capacity: 1) CC gas plus wind, and 2) CC and CT gas plus PV solar. The LCOE of these two combinations is derived from the costs of the two components.

FOOTNOTES: IDENTIFYING VALUE-COMPARABLE GENERATION RESOURCE CATEGORIES

[12] *http://www.eia.gov/forecasts/aeo/electricity_generation.cfm*

[13] *http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_a* ***and*** *http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b*

[14] ***"..assumed 10 percent annual capacity factor and an operating profile of approximately 8 hours of operation per CT start."*** *http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf* ***(8-5) Actual class average CT capacity factor across the system in 2015 was 6.7%*** *http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_a*

II. LCOE-E DATA SOURCES AND METHODOLOGY

Determination of LCOE from Existing Resources

This report uses data from two federal databases to calculate the levelized cost of electricity from existing power plants (LCOE-E). The first is the Federal Energy Regulatory Commission's (FERC's) Form 1 database.[15] Form 1 filings include annual fuel consumption, electricity generation and cost data from all non-government-owned power plants. Data for the past twenty years' filings are available to the public with some exceptions. The second data source is EIA's Form 860. Form 860 contains much of the same information as Form 1 (except cost and generation data), but also identifies the technology employed at each power plant, the types of fuel consumed, and unit capacity ratings.

All commercial electricity generators are required to file Form 1 annually. This form is "a comprehensive financial and operating report submitted for Electric Rate regulation and financial audits."[16] To produce this report, we collected, sorted and evaluated data from each of the 20 years of FERC Form 1 filings available on line. Specifically, nameplate capacity (MW), annual generation (KWh/yr.), ongoing capital expense (nominal $ since inception), annual operating expense including fuel (nominal $/YR) and fuel expense (nominal $/YR).

EIA Form 860 "collects generator-level specific information about existing and planned generators and associated environmental equipment at electric power plants with 1 megawatt or greater of combined nameplate capacity."[17] While Form 1 is the only public source of financial data from commercial power plants, it allows open text responses in some fields such as unit name, generator technology and fuel type. Form 860 limits respondents' entries regarding plant name, unit name, fuel type and generator technology (prime mover) to specific ID numbers and codes, restrictions which facilitate sorting and disambiguation. Form 860 also serves as a cross reference for other generator attributes and facts such as physical address, nameplate capacity, grid control region and RTO/ISO interconnection.

Most wind and solar facilities have either not submitted Form 1, have been permitted to complete the form only partially, or have requested their entries be redacted from the public record. Of those that did report, more than half were incomplete or unusable. This resulted in a sample that could not be used to estimate levelized cost. As a result, the cost of existing sources of wind and solar versus the other sources of electricity generation could not be calculated using a consistent methodology. For these reasons, this report does not estimate LCOE-E for wind or solar.

FERC Form 1 Data

FERC Form 1 is maintained as 20 databases--one for each of the past twenty years. For this report we collected data for each plant for all twenty years. All thermal sources (Coal, CT Gas, CC Gas, nuclear and dual fuel and dual output plants) report as steam plants. Hydro plants report on a separate page. The fields used to calculate LCOE from existing sources are highlighted in the following figure.

Name of Respondent	This Report Is: (1) ☐ An Original (2) ☐ A Resubmission	Date of Report (Mo, Da, Yr)	Year/Period of Report End of ______

STEAM-ELECTRIC GENERATING PLANT STATISTICS (LARGE PLANTS)

1. Report data for plant in Service only.
2. Large plants are steam plants with installed capacity (name plate rating) of 25,000 Kw or more. Report in this page gas-turbine and internal combustion plants of 10,000 Kw or more, and nuclear plants.
3. Indicate by a footnote any plant leased or operated as a joint facility
4. If net peak demand for 60 minutes is not available, give data which is available, specify period.
5. If any employees attend more than one plant, report on line11 the approximate average number of employees assignable to each plant.
6. If gas is used and purchased on a therm basis report the Btu content or the gas and the quantity of fuel burned converted to Mct.
7. Quantities of fuel burned (Line38) and average cost per unit of fuel burned (Line41) must be consistent with charges to expense accounts 501/507 (Line42) as shown on Line 20.
8. If more than one fuel is burned in a plant furnish only the composite heat rate for all fuels burned.

Line No.	Item (a)	Plant Name: (b)		Plant Name: (c)	
1	Kind of Plant (Internal Comb, Gas Turb, Nuclear)				
2	Type of Constr (Conventional, Outdoor, Boiler, etc)				
3	Year Originally Constructed				
4	Year Last Unit was Installed				
5	Total Installed Cap (Max Gen Name Plate Ratings-MW)				
6	Net Peak Demand on Plant - MW (60 Minutes)				
7	Plant Hours Connected to Load				
8	Net Continuous Plant Capability (Megawatts)				
9	When Not Limited by Condenser Water				
10	When Limited by Condenser Water				
11	Average Number of Employees				
12	Net Generation, Exclusive of Plant Use - KWh				
13	Cost of Plant: Land and Land Rights				
14	Structures and Improvements				
15	Equipment Costs				
16	Asset Retirement Costs				
17	Total Cost *Reported as an aggregate figure since inception				
18	Cost per KW of Installed Capacity (line 17/5) Including				
19	Production Expenses: Oper, Supv & Engr				
20	Fuel * Reported as an annual expense				
21	Coolants and Water (Nuclear Plants Only)				
22	Steam Expenses				
23	Steam From Other Sources				
24	Steam Transferred (Cr)				
25	Electric Expenses				
26	Misc Steam (or Nuclear) Power Expenses				
27	Rents				
28	Allowances				
29	Maintenance Supervision and Engineering				
30	Maintenance of Structures				
31	Maintenance of Boiler (or reactor) Plant				
32	Maintenance of Electric Plant				
33	Maintenance of Misc Steam (or Nuclear) Plant				
34	Total Production Expenses * Annual				
35	Expenses per Net KWh				
36	Fuel: Kind (Coal, Gas, Oil or Nuclear)				
37	Unit (Coal-tons/Oil-barrel/Gas-mcf/Nuclear-indicate)				
38	Quantity (Units) of Fuel Burned * Annual				
39	Avg Heat Cont - Fuel Burned (btu/indicate if nuclear)				
40	Avg Cost of Fuel/unit, as Delvd f.o.b. during year				
41	Average Cost of Fuel per Unit Burned				
42	Average Cost of Fuel Burned per Million BTU				
43	Average Cost of Fuel Burned per KWh Net Gen				
44	Average BTU Per KWh Net Generation				

FERC Form 1 Field Name Visual FoxPro Databases	Reason Field Collected
RESPONDENT_ID	Sorting field used to aggregate each plant's 20 years of data
REPORT_YEAR	Sorting field for chronological arrangement of values for each plant. To establish each plant's sample vintage and number of contiguous years in final sample.
PLANT_NAME	Name of plant. Used to sort polled database by plant. used to cross reference Form 1 data with EIA Form 860
PLANT_KIND	Used to preliminarily distinguish between nuclear, coal, and other types of primary units at each plant
YR_CONST	Used to track the age of the plant
YR_INSTALLED	Indicates the most recent year units were added
TOT_CAPACITY	Nameplate capacity of reported unit or entire plant. Used to calculate plant capacity factor.
PEAK_DEMAND	Not used in this report
PLNT_CAPABILITY	Not used in this report
NET_GENERATION	Annual generation figure. Used to convert annual expenses figures to $/MWh for each year for each round
COST_OF_PLANT_TO	Cumulative Capital Cost since inception reported annually. Includes construction cost. Subtracting each year's figure from the following year's reported figure yields annual capital expense.
EXPNS_FUEL	Annual fuel expense. Used to calculate the cost of fuel per MWh for each year in a plant record. Subtracting this from the tot_prdctn_expns yields Fixed + Variable O&M excluding fuel.
TOT_PRDCTN_EXPNS	Annual production expenses (includes fuel)(includes both fixed & variable operations expense)

Eliminating Plants and/or Years with Flawed or Incomplete Fields

The Form 1 database included some records in which fields were missing or contained erratic values. Records with data missing in fields required to calculate LCOE were discarded, as were records with erratic or unintelligible numbers and records where the plant name or specific unit in the plant could not be reconciled with the 2012 EIA 860 database.

For example, if a plant reported cumulative production expense figures that implied large negative values for some specific years, these might represent the correction of a previous error, but it is impossible to know which previous year or years were corrected. In this case, calculation of capital expense per MWh for any year would not be reliable. So for the plant in question, all years of and prior to any negative result(s) were omitted from the chronological plant record.

Discrimination of Useful from Incomplete/ Invalid Form 1 Records

In cases of missing data: if at least three consecutive years of complete data were available in the years prior to or following the missing data, we included as many consecutive years with complete data as possible—and in some cases, included more than one (but not more than two), sample windows for the same plant. Dual windows for the same plant were treated as two separate samples.

When a plant record reported a change in nameplate capacity of 5% or more, we divided the chronological data for the plant into two independent samples where three or more years of data were available before and after the nameplate capacity change. Because such uprates were optional, and historical learning might incorporate such uprates for new plants, the year(s) of the uprate were omitted from the former and latter samples for that plant. In that sense we calculate LCOE-E under the assumption no additional downtime and capital expense will occur over the remaining lifespan of that plant.

The year of a plant's retirement was often marked by a steep reduction in annual capacity factor. Where these reductions were significant, we omitted the final year from a plant's sample window. Assuming a thirty year lifespan, omitting the final year of operations created at most a 3.3% opportunity for error and on average about half that. Since very few plants retired during the Form 1 data window, the average error due to omitting the final year of operation over our entire sample was even less.

Furthermore, since the final year could have been a partial year of operation, but the month of retirement was not often reported, inclusion of the final year also represented an opportunity for error. The same reasoning applies to omission of initial year data for plants which began operation within the 20-year span of the database.

Form 1 suggests categories and names for respondents to use in the "plant_kind" field found on page 402, but then allows respondents to enter open-ended text responses in the field. As a result, our confidence in the accuracy of data was low. Misspellings, multiple names for the same technology, and inaccurate information were entered into this field. Inconsistencies appeared not only from one plant to another, but sometimes from year to year at the same plant. This lack of data certainty and sortability necessitated cross referencing Form 1 "plant_kind" data for each plant with the more reliable EIA 860 generator level and plant level databases, as explained in the EIA 860 section below.

EIA 860 Data

As indicated above, in the Form 1 filings FERC allowed open ended text for the "plant_kind" field. We found that in the EIA 860 generator level database, the fields "prime mover" and "fuel type" were consistently filled out. The public database contained complete, reliable annual records for all power plant facilities, and for the generators or units within those facilities.

The following table shows fields collected from the 2012 plant level and generator level EIA 860 databases.

Once data were collected from both plant level and generator level 860 data sets, each facility's data were sorted and merged into a single row/record, similar to the procedure used with the Form 1 data.

Field Retrieved	EIA Plant Data	EIA Generator Data	FERC Form 1 Data
Utility ID	x	x	
Utility Name	x	x	
Plant Code	x	x	
Plant Name	x	x	INCS
Plant/Unit Ownership			x
County	x		
State	x	x	x
ISO RTO	x		
Prime Mover (generator technology)		x	INCS
Energy Source 1		x	INCS
Energy Source 2		x	
Operational Status		x	x
Nameplate Capacity	x	x	x
Summer Capacity	x	x	x
Unit Initial Operating Year	x		x
Annual Generation			RDCT
Annual Fuel Expense			RDCT
Annual Total Operations Expense			x
Annual Aggregated Plant Capital Spending			x

x	Reported Consistently	INCS	Reported Inconsistently	RDCT	Partially Redacted

Cross-Referencing Form 1 and 860 Records

Form 1 records for each plant were cross-referenced with 2012 EIA 860 plant and unit records, ascertaining/verifying the generating technology and fuel used at each plant. Plants and units we could not cross reference between Form 1 and 860 data sets were searched individually on the internet for utility industry and general news stories in an effort to create as complete and fully cross referenced Form 1 / EIA 860 data set as possible. Plants whose prime mover and/or fuel were still ambiguous were omitted from the sample.

Applying a Uniform Fuel Price to LCOE-E and LCOE-New

EIA publishes average delivered fuel prices by state for each month and year and a weighted average national annual figure for each fuel. In our calculations, we applied 2015 delivered fuel prices for natural gas and coal to both existing and new generation resources. Because future fuel price fluctuations will impact LCOE from both new and existing plants similarly, 2015 fuel prices were applied to both. We also note that fuel prices for natural gas were at historic lows in 2015 and have fluctuated considerably in the past decade. Hence the current very low LCOE for new and existing CC gas hinges critically on fuel price.

FOOTNOTES: LCOE-E DATA SOURCES AND METHODOLOGY

[15] *Federal Energy Regulatory Commission, Form 1 – Electric Utility Annual Report, Dec. 18, 2014,* *http://www.ferc.gov/docs-filing/forms/form-1/data.asp*

[16] *Federal Energy Regulatory Commission, Form 1 – Electric Utility Annual Report, Dec. 18, 2014,* *http://www.ferc.gov/docs-filing/forms/form-1/data.asp*

[17] *Energy Information Administration, Form EIA-860 detailed data, Feb. 17, 2015,* *http://www.eia.gov/electricity/data/eia860/*

III. DATA ANALYSIS

According to EIA, LCOE is "- the per-megawatt-hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle."[18] Components of LCOE include:

- **Construction cost, typically paid using a blend of debt and owner equity with a repayment term for all technologies over the first 30 years of operation.**
- **Ongoing capital expenditures for upgrades and major overhauls**
- **Operations and maintenance expenses, which have fixed and variable components**
- **Fuel**
- **New transmission investment. Note that EIA's number for transmission investment does not take into account the likely physical location of any of the technologies examined in their report. Instead, EIA treats all technologies the same with regard to transmission investment.**

Because of the running total reported for cost of plant, construction cost is not independently reported in Form 1 records, except where the facility was constructed within the past 20 years. For the younger plants, we used the reported costs. For older plants, we used EIA's capital cost value for new plants of the same or similar technology, deflated to the year of the existing plant's construction as a proxy for actual construction cost.

Ongoing capital cost is reported as "Cost of Plant Total" in Form 1. This is a cumulative figure beginning with the year construction was commenced. For plants older than 20 years, the first year of available data for cost of plant total is a blended value of construction cost and ongoing annual capital expenditures through 1994.

An estimated adder for taxes, insurance and real cost of borrowing of 34 percent has been added to all capital costs per tables received from particular power plant financial officers.

Form 1 records show a total figure for operations and maintenance in each year's forms, showing both fixed and variable operations and maintenance expense and fuel. Fuel expense is reported in a separate field, allowing the derivation of total O&M excluding fuel. Fuel expense is then added back using 2015 delivered fuel prices. This was done because current fuel price is a better indicator of future fuel price than its historical fuel price.

Initial transmission costs for existing power plants were excluded because these costs are either fully repaid (in the case of older facilities) or are likely to be recovered through the rate base—even if the associated power plant retires prematurely.[19]

Next we converted historical year annual capital and O&M figures to 2013 dollars for every record[20] in the sample. We then divided annual capital and operations spending by annual net generation for each plant for each year to convert the figures into $/MWh.

U.S. average delivered cost of fuel per MWh was added at an assumed standard heat rate for each technology.

The remaining construction debt was calculated based on 30-year term from date of construction over the coming 30 years. Remaining debt and expected return on equity obligations make up a small fraction of levelized cost for existing resources.

The average of the coming thirty years' capital, O&M and fuel costs per MWh sum to the final levelized cost figure.

Present Value and Other Cost Adjustments

We applied an annual average rate of inflation to historical year reported data for O&M, construction cost and ongoing capital spending.[21] Only real rate of interest is implicit in the addition to capital cost described in the following section.

Applying Cost of Capital Adjustment to Ongoing Capital Expense per MWh

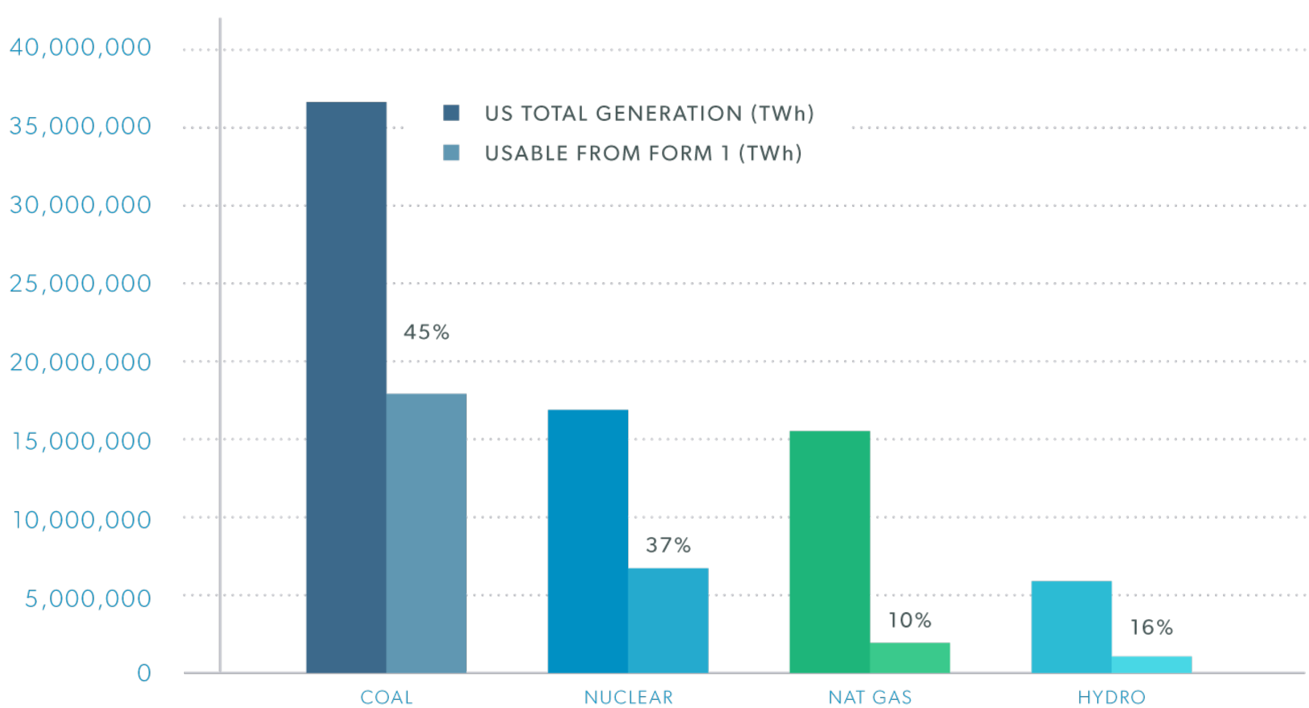
In the initial calculations of LCOE, we applied several factors:

- Inflation/present value factor: Using a table of historical inflation rates, we applied a present value calculation based on the mean age of each plant's sampled time window to bring all the figures to 2012 equivalent dollars.

- Real Cost of Capital, Insurance and Property Tax Multiplier: Based on recommendations from industry officials, we applied a fixed 34 percent adder to reported annual capital expense. While this may not be accurate for all plants or across technologies, using this average figure does not represent a significant error in the final results.

LCOE-E Form 1 Sample Size

The FERC Form 1 public database includes only data from non-government owned power plants. This represents a considerable limitation of our sample size compared to the entire grid-connected power plant fleet in the entire United States. The Form 1 database allows respondents open text entry of the name of the type of generating unit or units the respondents refer to in each form. For this reason, this report cross-referenced Form 1 records with the most recently available EIA Form 860 records.[22] The Form 860 records require respondents to choose from a specific list of fuel and prime mover (technology) codes. The EIA maintains Form 860 data for facilities generating units in separate files, with common fields across files so merging can be automated. Additionally, the 860 records make clear the nameplate capacity and age of each unit within each facility as well as the physical address, FERC market region and ISO/RTO (where applicable) of each plant. While the Form 1 data provided the necessary financial and electricity generation data, the 860 data provided a well-organized crosscheck as to what was actually being reported in FERC Form 1. The following figure shows the usable sample size in the Form 1 database over the years 1994 – 2013 vs. the installed capacity in the U.S. by generating technology.

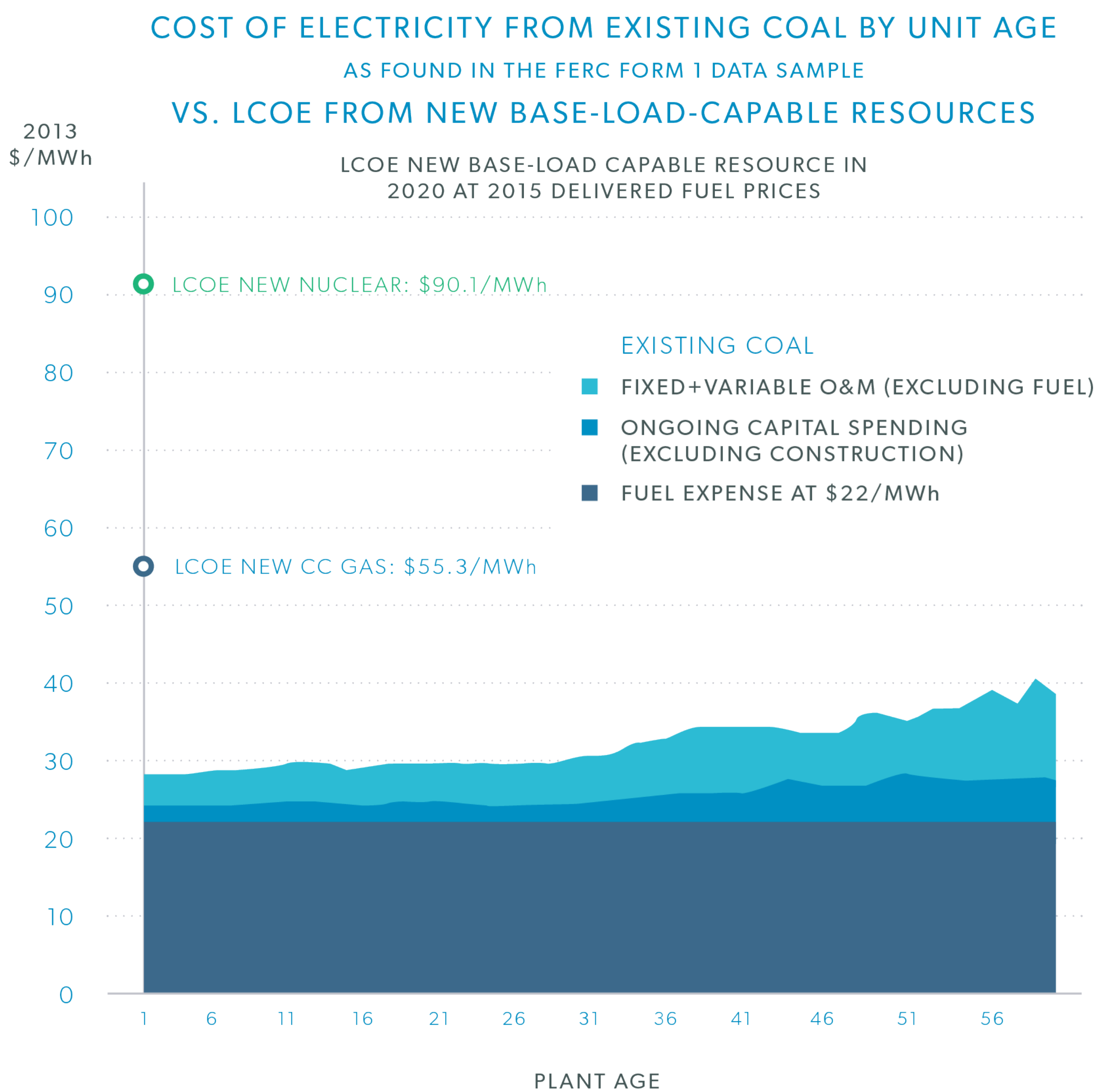


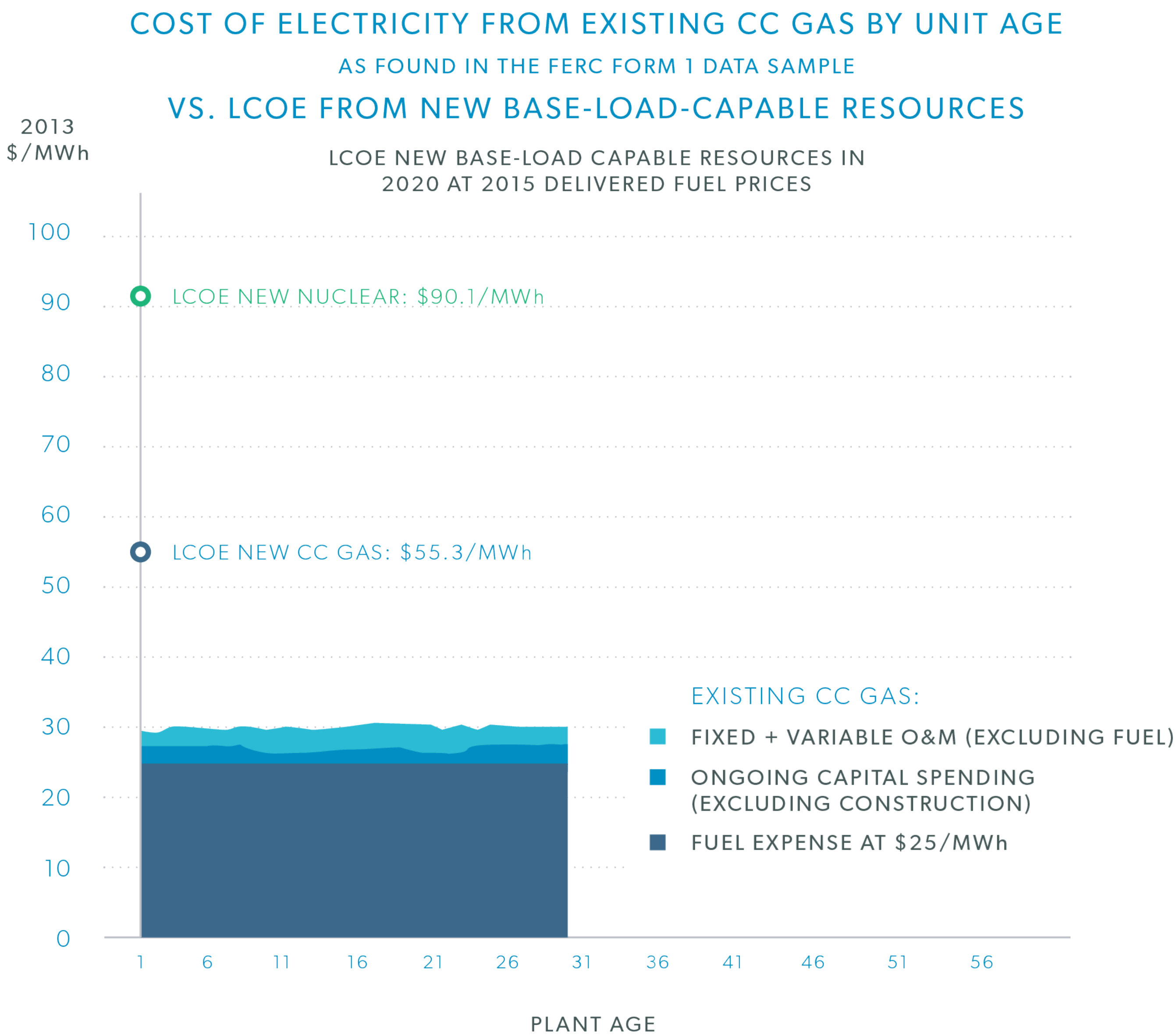
Capital Reinvestment and Operations Expense Trends by Technology by Plant Age

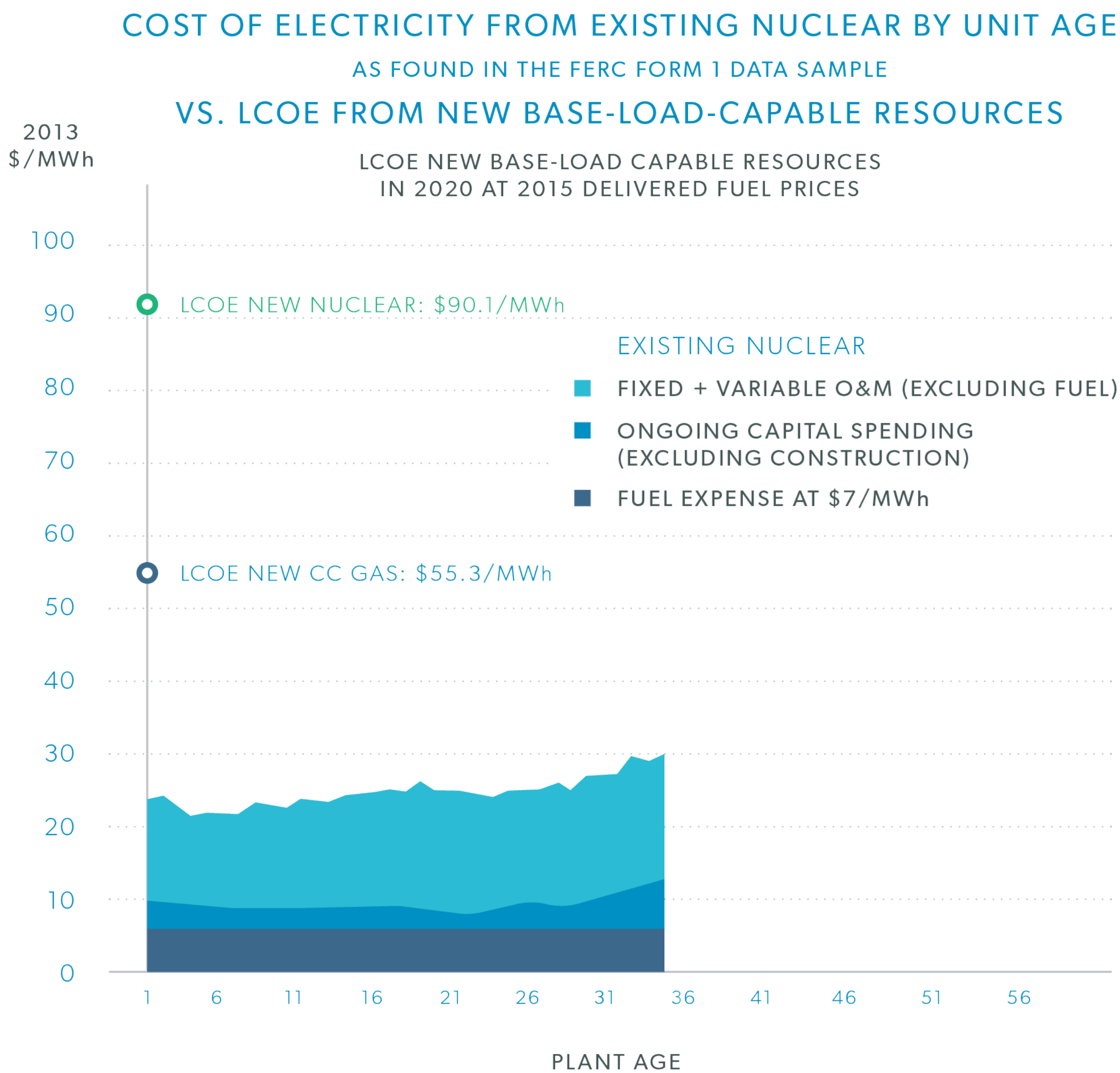
In addition to the "static" cost comparisons between various electricity resource choices, it is helpful to illustrate trends by plant age. The FERC Form 1 sample offers a cross section of plants by plant age in two ways:

1. **It considers each plant's annual generation costs for up to the past twenty years.**
2. **It considers operating plants constructed over the entire history of the electricity sector.**

We illustrate these plant age trends by unit age within each major technology below. The shaded areas of the three graphs illustrate the average levelized cost of electricity from existing full-time-capable resources by generating technology by plant age, excluding outstanding construction debt repayment obligation and at 2014 delivered fuel prices. These values are derived from the usable FERC Form 1 sample. The stripes above each shaded area represent LCOE from new resources, at the same delivered fuel price used for existing resources. The vertical distance between the shaded area and the stripe above represents the opportunity cost of replacing the existing resource with the corresponding new resource.




COST OF ELECTRICITY FROM EXISTING CC GAS BY UNIT AGE
AS FOUND IN THE FERC FORM 1 DATA SAMPLE
VS. LCOE FROM NEW BASE-LOAD-CAPABLE RESOURCES
2013 $/MWh
LCOE NEW BASE-LOAD CAPABLE RESOURCES IN 2020 AT 2015 DELIVERED FUEL PRICES
100
90
80
70
60
50
40
30
20
10
0
LCOE NEW NUCLEAR: $90.1/MWh
LCOE NEW CC GAS: $55.3/MWh
EXISTING CC GAS:
FIXED + VARIABLE O&M (EXCLUDING FUEL)
ONGOING CAPITAL SPENDING (EXCLUDING CONSTRUCTION)
FUEL EXPENSE AT $25/MWh
1
6
11
16
21
26
31
36
41
46
51
56
PLANT AGE



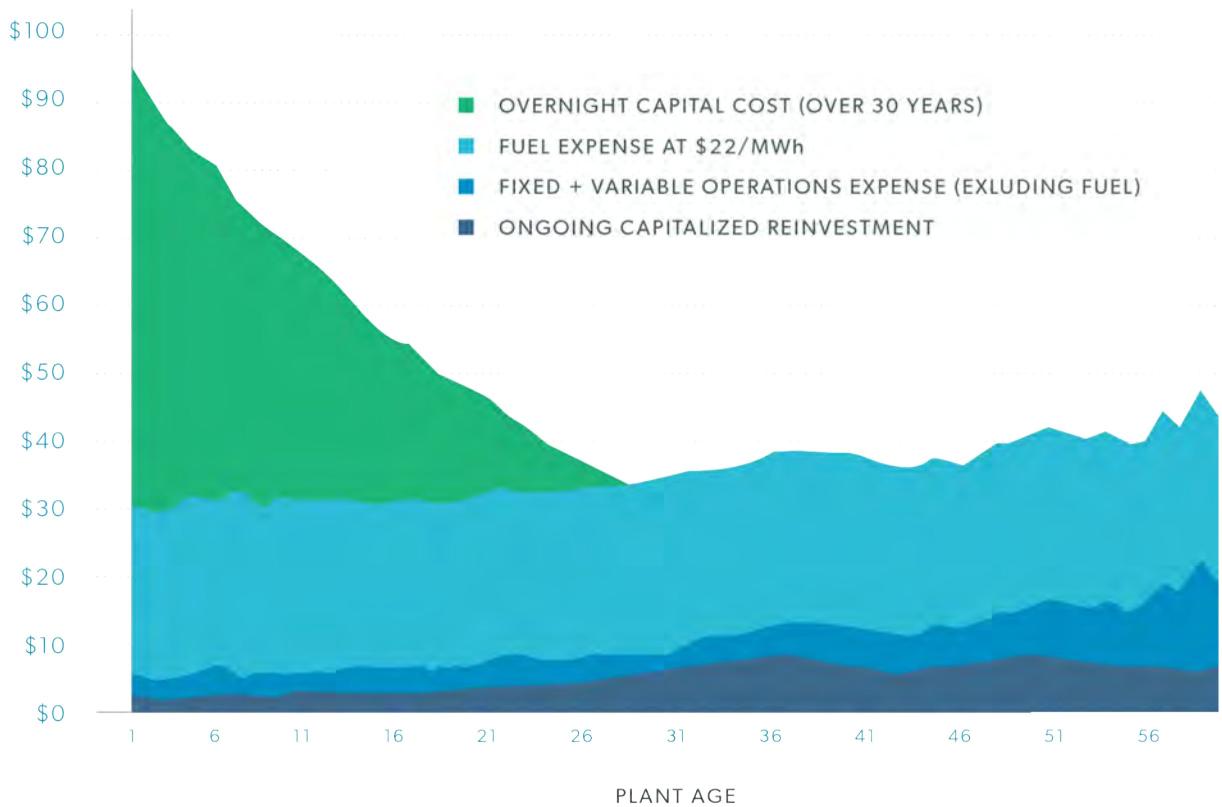
The shaded blocks for new full-time-capable technologies in the previous graphs show the range of expected LCOE based on the range of fleet-average capacity factors between actual (as reported by EIA in Electric Power Monthly) and "best case" (which were used by EIA to calculate LCOE).

These graphs indicate that, on average, existing full-time capable plants of any age will have a lower LCOE than their likely replacements for the foreseeable future—even at "best case" capacity factors. Of course, some existing units do not achieve their same-age technology's average LCOE. Some of those may be approaching or have reached the end of their competitive lifespans.

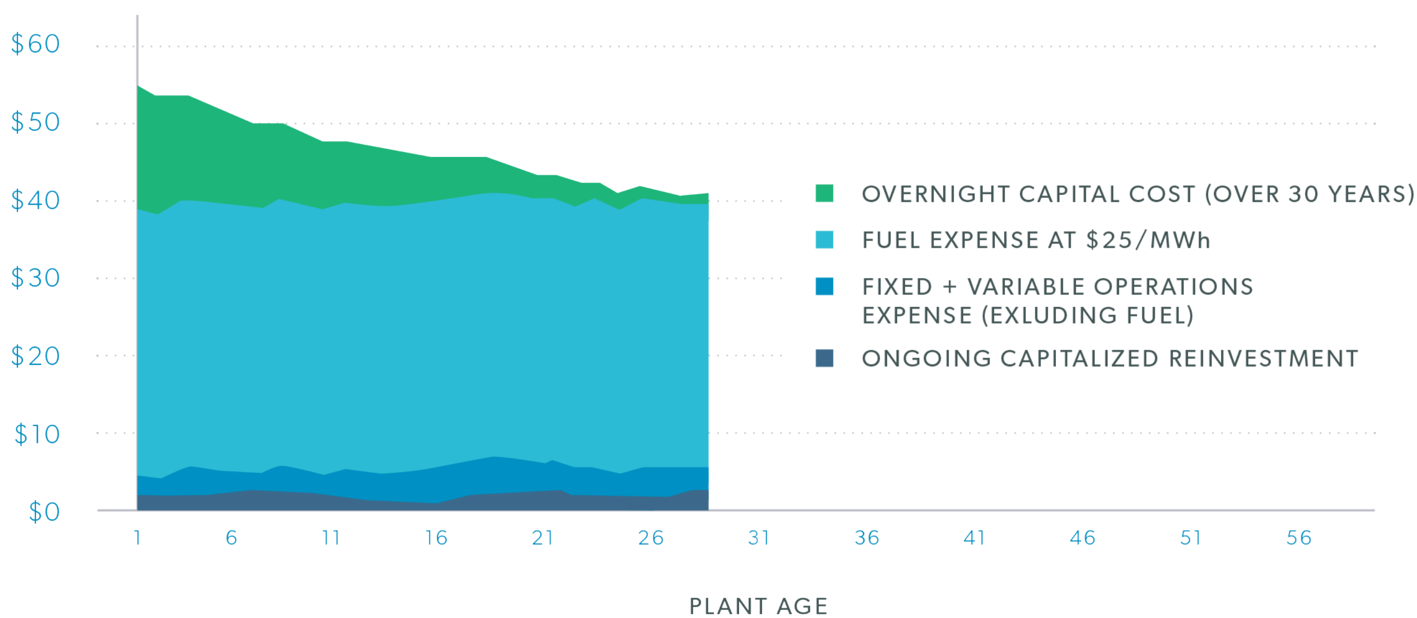
Reinvestment and Operations Expense by Unit Age vs. Remaining Fixed Costs Recovery for Base Load Capable Resources

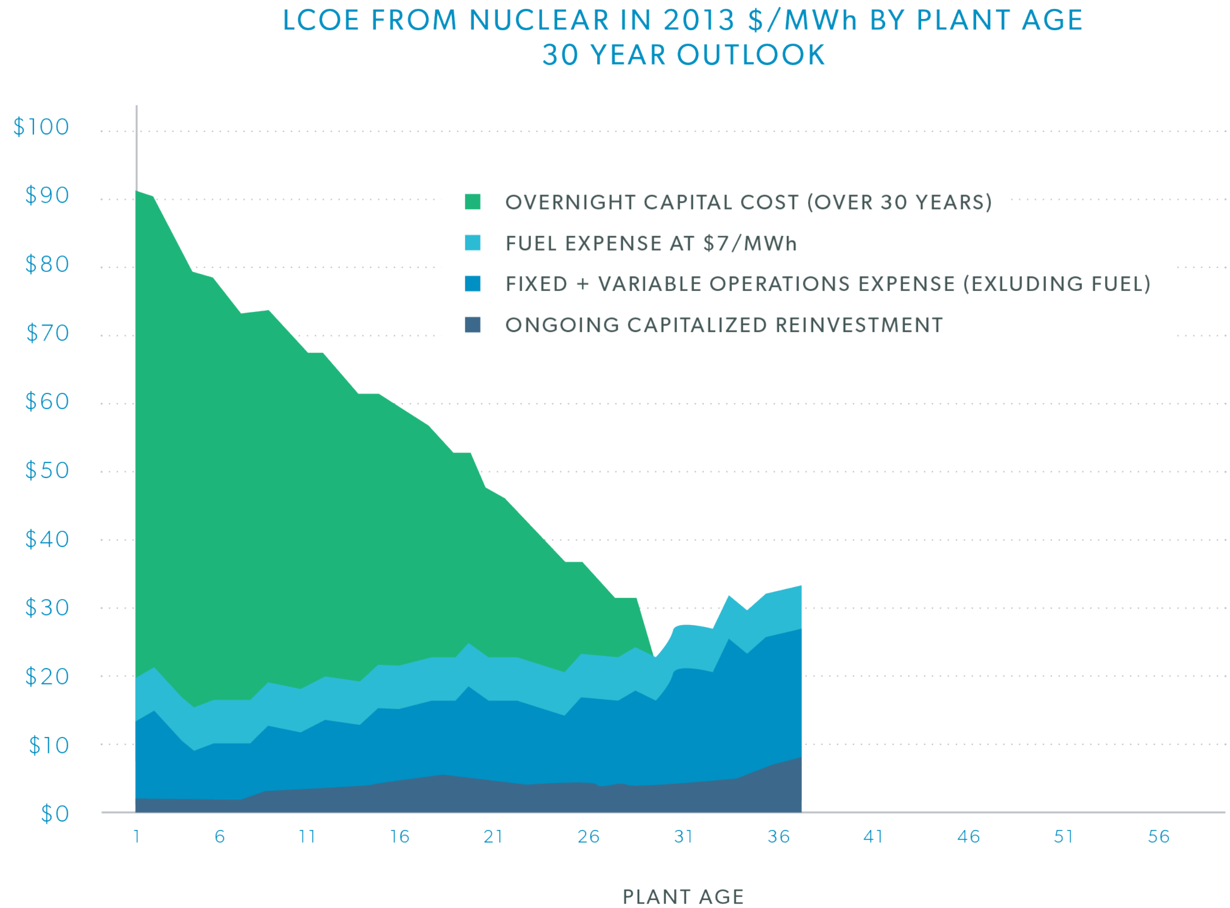
Data from Form 1 show ongoing expenses rise gradually over time as plants age. From a second perspective similar to that shown in the graphs above, some outstanding debt repayment and return on equity obligations do exist for all new and some existing units, but decline over an assumed 30-year financial repayment term. The purple shaded areas on the following charts represent the decline of remaining construction cost repayment obligation and the rising operations expense across their current lifespans. The height of the entire shaded area at any year represents the "going forward" LCOE for the next 30 years.

LCOE FROM COAL IN 2013 $/MWh BY PLANT AGE 30 YEAR OUTLOOK



LCOE-E CC GAS UNITS IN 2013 $/MWh 30 YEAR OUTLOOK





Observation: Going forward LCOE is at its lowest for plants which have just retired construction debt and equity obligations (at 30 years of age).

Observation: For plants within any generation resource category, per-MWh operations expenses rise gradually over their lifespans, but do not exceed the rate of decline in construction repayment obligations over a 30-year repayment term. On average, therefore, going-forward LCOE-E falls steadily until plants reach age 30, then rises gradually as operations and capital expenditures accrue due to facility and component age. Regulatory changes imposed on existing generators after they are constructed and in operation also force new capital expenditures.

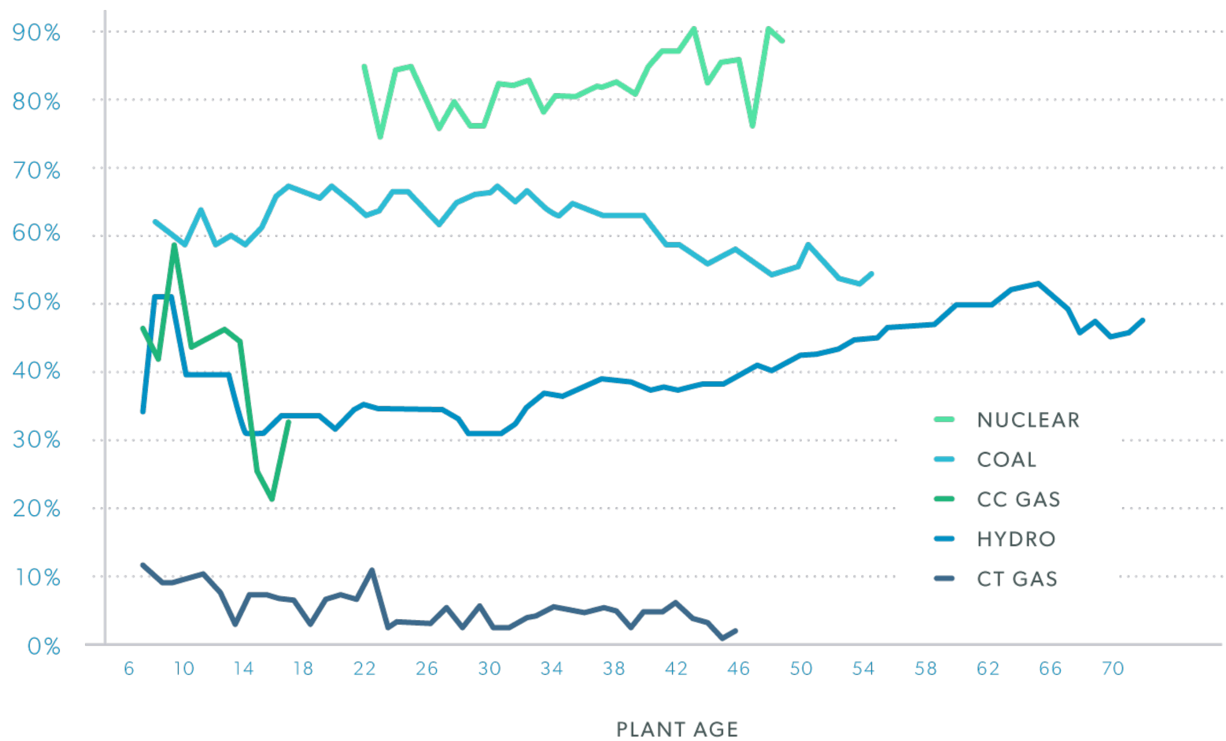
On average, even for the oldest plants of each generation resource category sampled, rising operations capital reinvestment expenses do not appear to force LCOE-E to the level of LCOE from new resources for several years to several decades. This suggests the US could enjoy lower cost electricity for the foreseeable future by continuing to operate existing power plants with levelized costs lower than their possible replacements.

Observation: Older power plants with lower fixed costs and lower LCOE are of the highest value to electricity consumers.

Capacity Factor by Generating Technology by Plant Age

Capacity factor, listed as a percent, is the measured historical (or assumed future) utilization rate of a unit or technology over an average calendar year relative to theoretical maximum (running at nameplate capacity for all hours). The following graph indicates that capacity factors for older plants are not markedly lower than those for younger plants of the same type (except for hydroelectric).

HISTORICAL CAPACITY FACTOR BY PLANT AGE IN 2019
FROM 1994 - 2013 FERC FROM-1 DATA SET



Applying Real-World Capacity Factors to EIA LCOE-New

For new resources, EIA lists "best case scenario" capacity factors for each technology, based on an absence of market competition throughout a year. Capacity factors are de-rated based only on manufacturer suggested maintenance down time (all resources) seasonal fuel efficiency derates (nuclear and combustion technologies) and estimated average annual fuel source unavailability (wind, solar and hydro).

Historical capacity factors for fossil fueled resources are considerably lower than best case scenario levels for most technologies. As such, EIA's calculation of fixed costs per MWh likely underestimates actual fixed costs per MWh in competitive markets and fluctuating load conditions from day to night, weekday to weekend and season to season.

Table 2 lists real capacity factor ranges vs. the capacity factors used by EIA to calculate LCOE for new resources. The product of the sum of fixed cost components of LCOE-New and the adjustment multiplier for each resource yields LCOE-New under the assumption that average utilization rates for new resources would match average utilization rates of existing generators in the real world.

Table 2

Table 02 Generator Type	2015 Real World Capacity Factors	EIA LCOE 2020 Capacity Factor Assumptions	Fixed Cost Adjustment Factor
DISPATCHABLE FULL-TIME-CAPABLE RESOURCES			
Conventional Coal[1]	54.6%	85%	1.56
Conventional Combined Cycle Gas (CC Gas)	56.3%	87%	1.55
Nuclear	92.2%	90%	0.98
Hydro	35.9%	54%	1.50
DISPATCHABLE PEAKING RESOURCE			
Conventional Combustion Turbine Gas (CT Gas)	6.7%	30%	4.48
INTERMITTENT RESOURCES			
Wind[3]	32.5%	36%	1.11
PV Solar[3]	28.6%	25%	0.87

Table 3

Table 03 New Generator Type	Sum of Fixed Costs of LCOE-New as reported by EIA LCOE 2020 (2013 $/MWh)	Adjustment Factor	Adjusted Fixed Cost per MWh	Variable Costs inlcuding fuel at 2015 delivered price	EIA LCOE-New 2020 at Real-World Capacity Factors (2013 $/MWh)
Dispatchable Full-Time-Capable Resources					
Conventional Coal[1]	N/A	N/A	N/A	N/A	N/A
Conventional Combined Cycle Gas (CC Gas)	17.3	1.55	26.7	28.6	55.3
Nuclear	83.0	0.98	81.0	9.1	90.1
Hydro	76.6	1.50	115.2	7.0	122.2
Dispatchable Peaking Resource					
Conventional Combustion Turbine Gas (CT Gas)	47.0	4.48	210.4	52.5	263.0
Intermittent Resources – as used in practice					
Wind including cost imposed on CC gas[3]	73.6	1.11	81.5	+ $25.9 Imposed cost on new CC gas	107.4
PV Solar including cost imposed on CC and CT gas[3]	125.3	0.87	109.5	+ $30.8 Imposed cost on new CT and CC gas	140.3

Table 3 shows the sum of per-MWh fixed cost components of LCOE and applies the real world adjustment multiplier. The right hand column shows LCOE at real world capacity factors.

Table 4

Table 04 Generator Type	LCOE Existing at 2015 Real World Capacity Factors (2013 $/MWh)	EIA LCOE New at Real World Capacity Factors (2013 $/MWh)	Premium for Replacing Existing with Same Resource New
DISPATCHABLE FULL-TIME-CAPABLE RESOURCES			
Conventional Coal[1]	39.9	N/A	N/A
Conventional Combined Cycle Gas (CC Gas)	34.4	55.3	61%
Nuclear	29.1	90.1	210%
Hydro	35.4	122.2	245%
DISPATCHABLE PEAKING RESOURCE			
Conventional Combustion Turbine Gas (CT Gas)	88.2	263.0	198%
INTERMITTENT RESOURCES – AS USED IN PRACTICE			
Wind including cost imposed on CC gas[3]	--	107.4	--
PV Solar including cost imposed on CC and CT gas[3]	--	140.3	--

Table 4 compares LCOE-E to LCOE at equivalent capacity factors.

Calculation of Cost Imposed by Wind on Base Load Capable Resources

As we discussed on page 9 above, non-dispatchable resources impose costs on dispatchable resources by causing them to run fewer hours without substantially reducing their fixed costs.

Thus, with an increase in non-dispatchable generation, the fixed costs of dispatchable resources are levelized over fewer units of production. Below, we provide the methodology for calculating the cost wind imposes on CC gas. The result of the calculation is that each additional MWh of wind imposes a cost of $25.9 per MWh under real-world capacity factors in 2013 dollars and based on EIA's Annual Energy Outlook 2015 levelized costs. Appendix A provides examples of this methodology based on 2012 dollars and EIA's Annual Energy Outlook 2014 levelized costs. We leave the example in Appendix A unchanged from the original report but note that the imposed cost of wind fell slightly due to the higher capacity factor for CC gas in 2015.

Intermittent resources do not always displace natural gas generation. In practice, they also displace generation from coal and perhaps nuclear power plants, among others. But for simplicity and the purposes of this report, we make the following assumptions about how intermittent resources are integrated onto the electric grid:

- We compare two scenarios in a snapshot in time (load growth and fuel prices are held constant).
- The base line scenario assumes no intermittent generation. In this simple baseline scenario, CC gas provides all needed electricity.
- The alternate scenario includes an intermittent resource (wind) combined with CC gas, where the two resources combine to produce the same constant output as in the baseline scenario.
- CC gas as a fleet offers 87% of its nameplate capacity as summer peak demand capacity credit[23] regardless of capacity factor.
- CC gas as a fleet offers base load capacity. That is, at whatever capacity factor it operates, it operates at the same level all the time.

- Intermittent resources (wind) are "paired" with CC gas to create the same flat generation profile, capacity factor and capacity value in the pairing as achieved by CC gas alone in the base line scenario.

- Capacity values for intermittent resources are determined using the "mean of lowest quartile output across summer peak hours" method recommended by Midcontinent ISO's market monitor, Potomac Economics[24] and using hourly wind data from MISO and PJM for calendar year 2013.

- Installed capacity of CC gas in the hybrid pairing with wind is equal to capacity value of CC gas in the baseline scenario minus the capacity value of the intermittent resource (wind) in the pairing divided by the capacity value of CC gas (0.87).

- Installed capacity of the intermittent resource is equal to the nameplate of the CC gas prior to the addition of the intermittent resource times the CC gas capacity factor prior to the pairing.

- The annual energy from the new CC gas capacity in the pairing is the remainder of CC gas energy prior to the intermittent resource minus the energy that can be produced at the best-case capacity factor of the installed capacity of the intermittent resource.

- The new capacity factor of the new installed capacity of CC gas in the pairing is the new CC gas energy divided by the new CC gas capacity required to meet the capacity and energy levels of CC gas prior to the pairing.

- Fixed costs per MWh of CC gas are altered by multiplying the prior fixed costs per MWh by the prior capacity factor of CC gas divided by the new capacity factor of CC gas.

- The imposed cost per MWh of the intermittent resource is the increase in fixed cost per MWh of CC gas times the percentage of CC gas in the pairing divided by the percentage of the intermittent energy in the pairing.

Calculation of Cost Imposed by PV Solar on Base Load Capable and Peaking Resources

The methodology for determining wind's imposed cost assumes uncurtailed wind is part of a full time base load hybrid with CC gas. We cannot assume that PV solar is part of a base load hybrid because it does not produce at night and it does produce some energy across many of the peak hours of the daytime, especially in summer, when CT gas is often the marginal resource. PV also produces electricity during "shoulder" load hours when CC gas is often on the margin. Instead of using the same methodology we applied to wind, we developed a scenario that assumes solar displaces two resources: CC gas and CT gas, and that it reduces their capacity factors at equal rates. That is, we assume that if the capacity factor of CC gas started at 50% without PV solar and falls by 10% to 45% with PV solar, then if CT gas started at 5% it would drop to 4.5% (also 10%). We do not know the exact ratio in each electricity market because grid operators do not release recent-year hourly and monthly marginal fuel reports due to the competitively sensitive nature of that data. The ratio does have an impact on imposed cost because CT gas starts at a relatively low capacity factor and corresponding high fixed cost per MWh. As its utilization rate falls to zero, its fixed cost per MWh goes up exponentially. As a result, if we assume CT gas is displaced more than CC gas, then the imposed cost is larger. If we assume solar primarily displaces CC gas and very little CT gas, then the imposed cost is lower.

Under this set of assumptions, we estimate the capacity value of PV solar at incremental capacity additions. After a few percentage points of energy market share gain, the residual peak load hours shift from late afternoon to mid-evening. At mid-evening solar is not producing, so its ability to further reduce the required system capacity falls to zero. For this reason, solar PV's capacity value falls as its market share rises, creating a "diminishing returns" scenario that drives up imposed cost at each incremental addition of solar capacity. The same is not necessarily true for wind, because wind produces across a full spectrum of hours of the year and those generating hours can shift substantially from day to day, season to season and year to year. That is why we believe wind's capacity value stays about the same as more capacity is added to the system.

The analysis is based on real world hourly PV generation and hourly system electricity demand (load) data reported by California Independent System Operator (CAISO) for calendar year 2014. Six percent PV energy market share is expected to be achieved in California in 2015 or 2016. From the CAISO analysis, and using additional information provided by the U.S. Department of Energy's Energy Information Administration (EIA), we estimate the U.S. average levelized cost of electricity from PV for the entire United States in 2020.

The CAISO hourly data allow estimation of the replacement value of PV capacity for dispatchable capacity, or PV's relative "capacity value" (CV). Because the CV of PV is lower than the CV of the resources from which it gains market share, dispatchable resources cannot "retire" at the same rate as PV capacity is added, assuming CAISO will (or must) maintain its current level of system peak demand reserve capacity. Instead, more generating resources must remain operational in the system to achieve the same system peak reserve margin.[26] It is elementary, then, that on average, generators must achieve a lower market share and utilization rate (capacity factor [CF]) than prior to the PV capacity additions. At a lower average CF, the breakeven fixed cost per MWh of the system generator fleet necessarily rises. We term this effect "imposed cost" of PV energy.

The analysis shows that as PV gains energy market share beyond the first few percent, its CV falls to zero.[26] As capacity value falls, imposed cost rises. We believe imposed costs are not recognized or represented in EIA's LCOE forecast.[27]

We adjust EIA's US LCOE 2020 in two ways:

- For real world US average capacity factor in 2015 of 28.6% of nameplate (vs. EIA LCOE 2020 estimate of 25%),
- For an estimated imposed cost (based on capacity factors, capacity value and energy market share achieved)

According to data gathered from the CAISO web site, in 2014, PV attained 4.48% energy market share across the CAISO control region, with enough new PV capacity added across the year to ensure more than 5% energy market share in 2015.[28] For this reason, we report the LCOE from new PV capacity capturing its sixth percentage point of energy market share:

California ISO / NERC Region 20

EIA LCOE 2020 Regional Estimate (at 31% CF) $111.1

Imposed Cost From 6th Percent Market Share $35.8

Total Estimated Cost of New PV $146.9

PV installed capacity at the beginning of 2014 and monthly capacity additions across the year could not be verified because data from EIA and CAISO sources does not match. Therefore, it was impossible to determine the annual CF of PV in CAISO for 2014. We assume the CF for new PV capacity in 2020 assigned for NERC region 20 in the EIA's National Electricity Modeling System (NEMS) is 31%.

We note here that CF, when used to estimate total PV nameplate capacity on the system from known generation data, affects total PV CV (in MW) on the system. CF and CV therefore have an inverse relationship, as do CF and imposed cost.

Applying Model Results to National Average LCOE from PV

According to industry growth estimates released by the solar trade group Solar Energy Industries Association, PV will have captured more than 2% energy market share in the US in 2020.[29] Consistent with our reasoning for evaluating the next (sixth) percentage market share gain for PV on the CAISO system, we utilize imposed cost of the next percent of energy market share for PV for the national imposed cost estimate in our LCOE estimate for the United States. For the U.S., the estimated CV of the capacity sufficient to capture a three percent energy market share for PV would be 16.2% of nameplate and would impose a cost of $30.8 (2013 $/MWh) of PV generation onto new combined cycle and combustion turbine generators, as shown here.

US Average

EIA LCOE 2020 (at 28.6% CF) (2013 $/MWh)[30] $109.5

US Estimated Imposed Cost From 3% Mkt. Share $30.8

Total Estimated Cost of New PV[31] $140.3

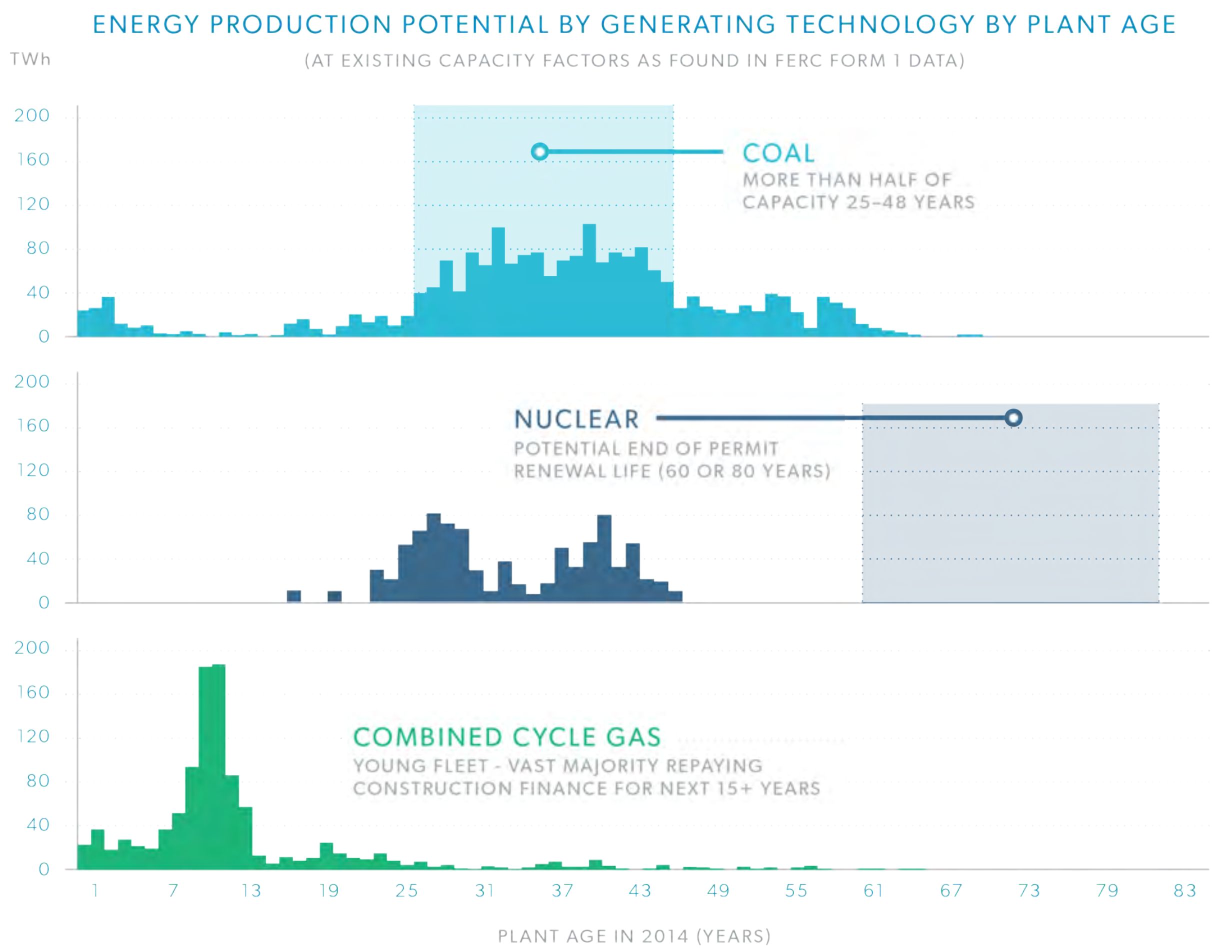
Appendix B provides the methodology for determining solar PV's imposed cost on CC gas and CT gas in more detail and provides examples of the calculation.

U.S. Generating Capability by Generating Technology by Unit Age

The following bar chart shows installed capacity times 8,760 hours (the number of hours in one year) times the highest capacity factors achievable for each respective technology as reported in EIA LCOE Table 1, herein referred to as "generating capability." The figure is shown for all US plants from newly commissioned through 83 years of age, as reported in EIA Form 860.

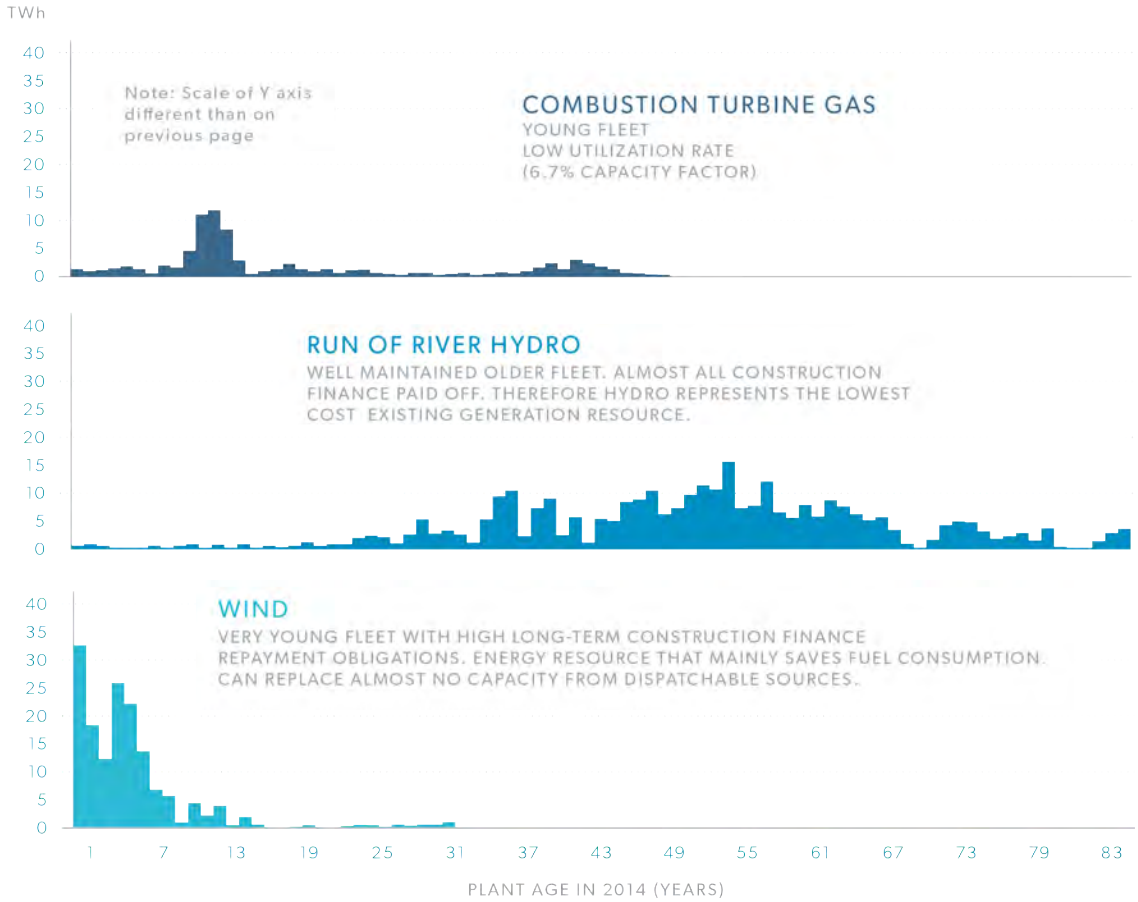
The three technologies shown in the first chart are full-time-capable resources that make them reasonable substitutes for each other. The technologies shown in the second group of three charts include sources that are not substitutes for one another or for any of the full-time-capable resources.

The vertical scale is different between the first and second set of charts—specifically, the scale is five times greater for the first compared with the second.



ENERGY PRODUCTION POTENTIAL BY GENERATING TECHNOLOGY BY PLANT AGE

(AT EXISTING CAPACITY FACTORS AS FOUND IN FERC FORM 1 DATA)



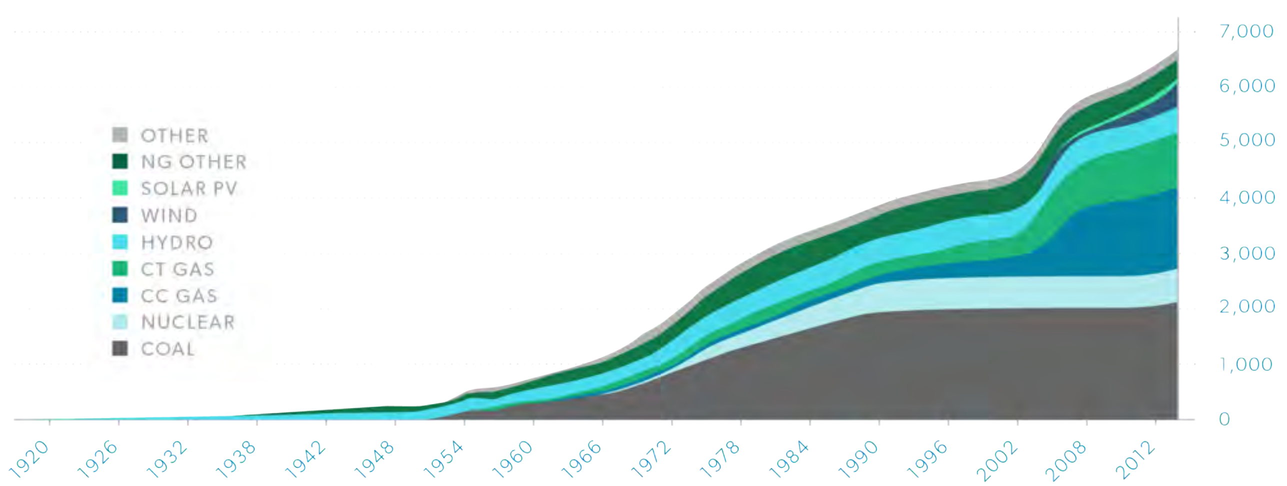
The histograms above indicate that almost the entire existing fleet would have a decade or more of remaining economic life relative to their likely replacements if not for the impacts imposed by new existing source environmental regulations, coupled with the profit and market share erosion associated with subsidies and mandates for non-dispatchable (renewable) generation.

The following illustration shows the generating capability of the existing fleet by year at best-case capacity factors. Generating capability exceeds total demand by almost 65%, and capacity was sufficient to meet peak demand (peak demand and summer capacity not shown).

Source Data for Graph Below: EIA 860, 2013[32] and AEO 2015[33]

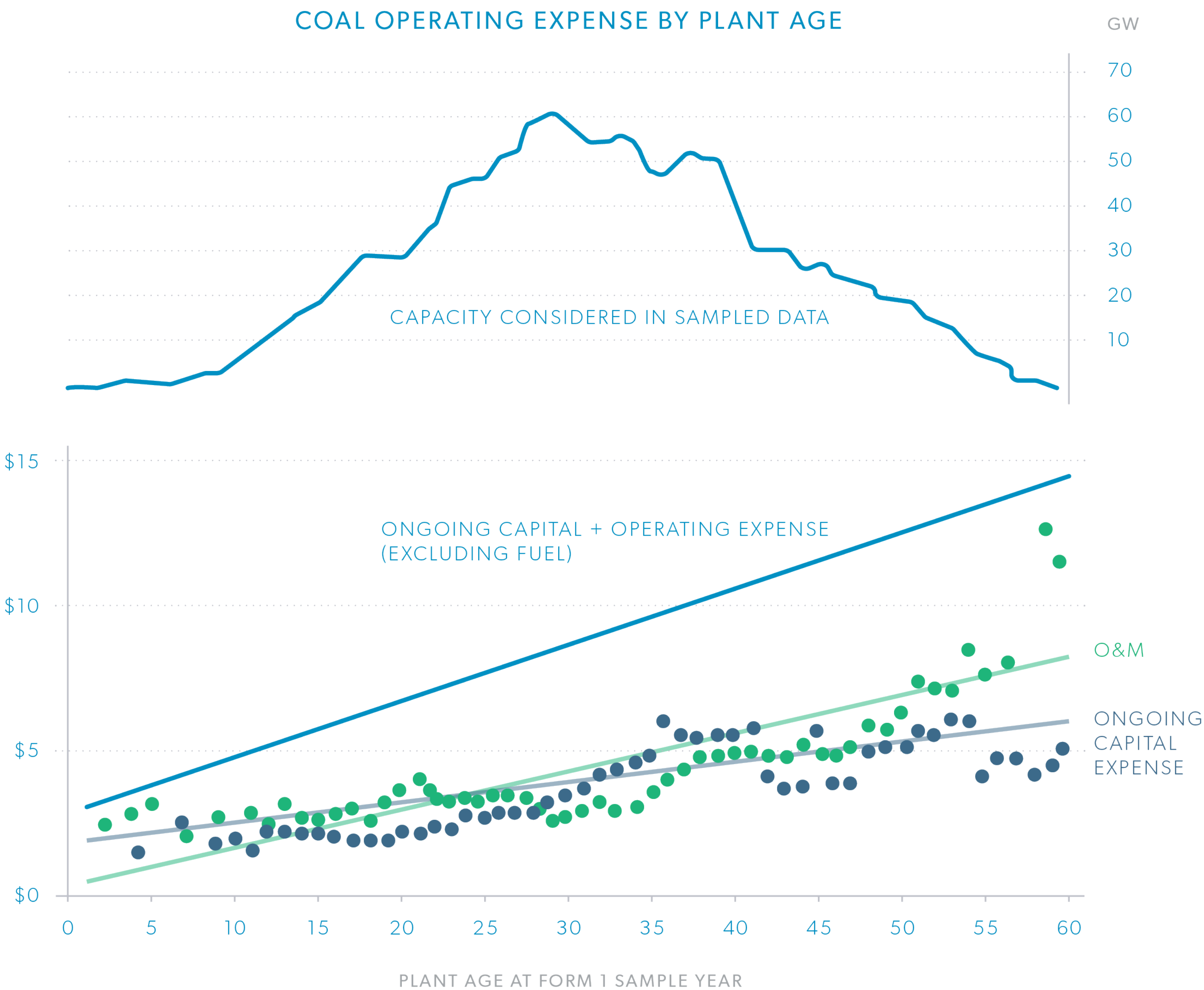
CUMULATIVE OPERATIONAL GENERATING CAPABILITY BY YEAR BY FUEL TYPE AT EIA FORECAST CAPACITY FACTORS (TWh/YEAR)

ANNUAL ELECTRICITY DEMAND 2014: 4,089 TWh

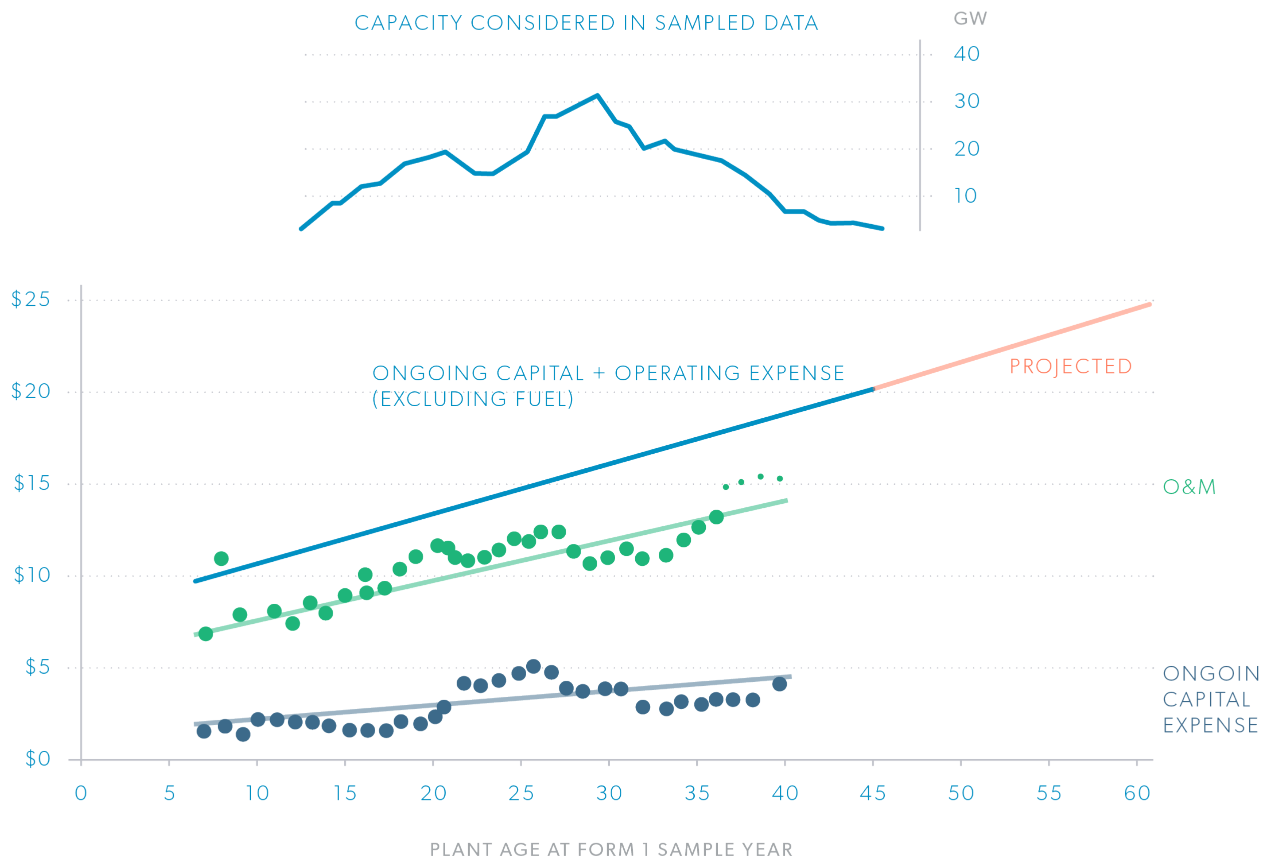


Sample Size by Plant Age by Major Generating Technology

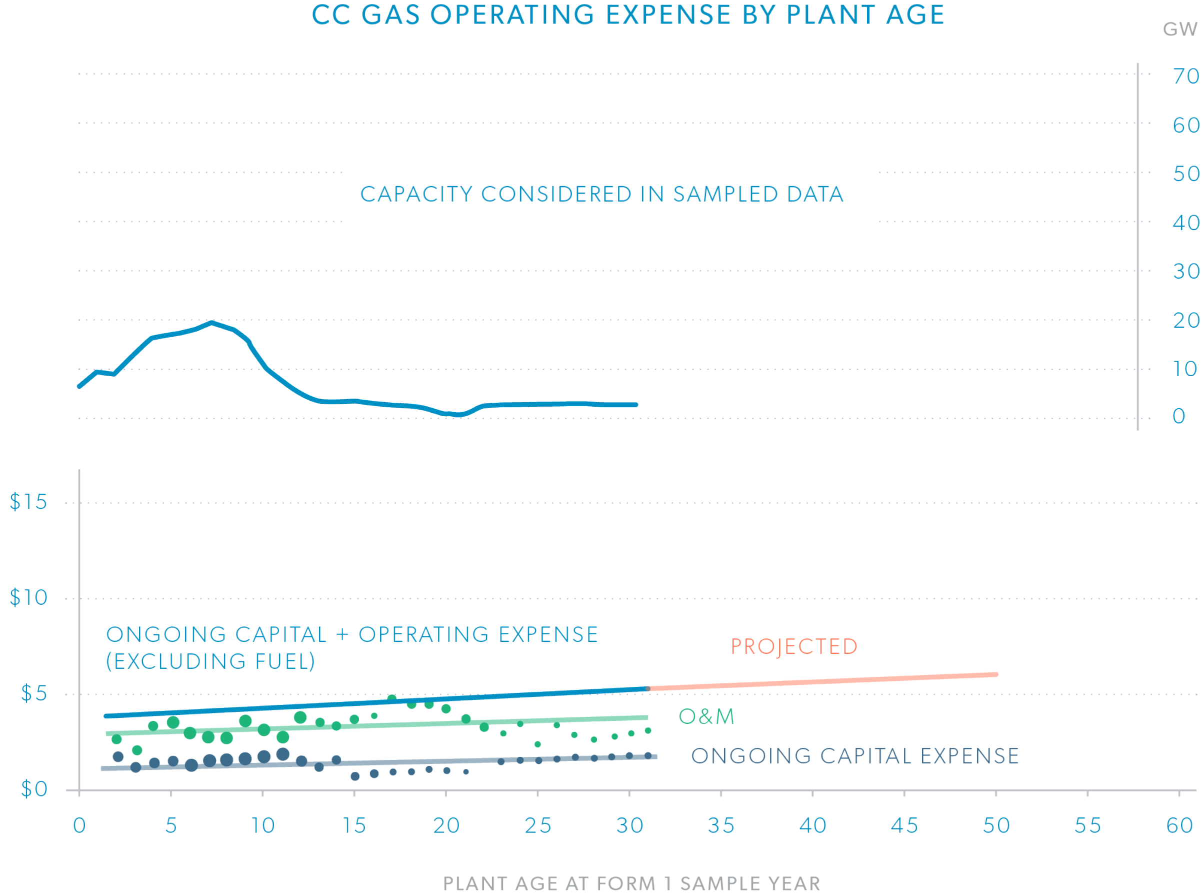
The following bubble charts show fleet-average operations and ongoing capital reinvestment expenses by plant age for each considered technology. Bubble size as well as the line graph above each bubble chart represent the FERC Form 1 sample size by technology by plant age.



NUCLEAR OPERATING EXPENSE (2013 $/MWh) BY PLANT AGE



CC GAS OPERATING EXPENSE BY PLANT AGE



EIA's Calculation of the Components of LCOE

There are important limitations to the application of EIA's LCOE figures when evaluating the costs of electricity from and between new resources:

- EIA applies "best case" (high end) capacity factors in calculating fixed cost per MWh. As a result fixed costs per MWh and LCOE are understated for technologies whose capacity factors in real world application fall short of "best case." For example, EIA applies a 30% capacity factor to fixed costs of combustion turbines, while those resources realize only a 6.7% capacity factor in application today. This means fixed costs per MWh for CT are underestimated by nearly five fold.

- EIA assumes a 30-year lifespan for all technologies in their LCOE report for new generation resources, giving no credit to the value of the electricity produced by new units surviving beyond that age, and applying no penalty for technologies with operational lives of less than 30 years.

- EIA transmission investment figures do not recognize the additional cost of transmission associated with onshore wind, which must be sited near the best fuel availability locations. These locations are many hundreds of miles from primary load centers of the continental US. Therefore EIA either sharply underestimates transmission expense for wind or grossly overstates its achievable capacity factor. In either case, LCOE for new onshore wind is underestimated by EIA.

- Special accelerated depreciation available to wind and solar is not considered a "cost" in EIA's calculation of those technologies' LCOEs. It should be, however, because it represents advanced cash flows to wind developers and postponed cash flows to the treasury, which is funded primarily by all taxpayers.

- EIA divides its LCOE Table 1 into two sections attempting to separate resources which are not performance (and cost) comparable. In practice, combustion turbines are not performance comparable to full-time-equivalent resources and should be separated into their own section of the table to avoid confusion.

- Graph above each bubble chart represent the FERC Form 1 sample size by technology by plant age.

[18] *Energy Information Administration, Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015, June 3, 2015,* http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

[19] *However, when an existing power plant is induced to retire and is replaced with a new one constructed at a a different site, the existing transmission serving the retiring generation unit may become underutilized, while new transmission must be constructed for the new generator. These circumstances add additional cost to the system that would otherwise be unnecessary. That would clearly be the case when wind energy capacity is added to the system because of the remote siting requirement for that technology. But in addition, some new natural gas fired power plants would also require either new gas or electricity transmission. While we maintain EIA's direct transmission cost estimates for new generation resources, estimates of imposed transmission cost are beyond the scope of this report.*

[20] *The number of records in the sample is equal to the number of "plant years" collected. This is the number of power plants reporting to Form 1 times the average number of years of complete data across all power plants. Due to some missing data and significant nameplate capacity changes at some plants, the average sample period was approximately 11 years.*

[21] http://data.bls.gov/pdq/SurveyOutputServlet

[22] *At the time of original publication, June, 2015*

[23] *At the time of original publication, June, 2015*

[24] https://www.potomaceconomics.com/uploads/reports/2012_SOM_Report_final_6-10-13.pdf *Section II C, page 16*

[25] ftp://ftp.pjm.com/operations/wind-web-posting/2013-hourly-wind.xls *&* https://www.misoenergy.org/Library/Repository/Market%20Reports/20131231_hwd_HIST.csv

[26] *We determine capacity through a calculation that considers the technology's stand-alone capability to meet peak loads in a recent historical year.*

[27] *We do not adjust EIA's PV LCOE to account for the difference between the 30-year financial lifespan EIA assumed and the actual lifespan of PV facilities, the cost of long-distance transmission, accelerated depreciation subsidies or regulatory costs. However, we note that EIA did not fully consider these costs, which are likely in the range of $25 to $40 per megawatt-hour. The basis is physical lifespan, long distance transmission costs (infrastructure and losses) and "subsidies" recognized but not counted as costs in EIA's "fixed charge factor* http://www.eia.gov/renewable/workshop/gencosts/ *and other subsidies such as state mandates, loan programs and other incentives, and impact of net metering laws.*

[28] http://www.caiso.com/Documents/2014AnnualReport_MarketIssues_Performance.pdf

[29] http://www.seia.org/research-resources/us-solar-market-insight *(Estimated based on SEIA projected installed capacity at 25% CF)*

[30] *EIA forecast LCOE for PV is 125.3 (2013 $/MWh) at a 25% CF. US Average real world CF for PV in 2014 was 25.9%.* http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b *We adjust the LCOE estimate to reflect a 25.9% CF: 125.3 x 25% / 25.9% = 120.9.*

[31] *EIA published a national average figure of 125.3 (2013 $/MWh) for LCOE from PV in 2020, but does not offer the methodology or regional weightings by which the average is calculated. This report uses the LCOE for NERC region 20, CASIO (received in email from EIA, ibid), from EIA's Annual Energy Outlook 2015, calculates the imposed cost for that region using data from CASIO, and then applies that methodology to the average LCOE for the nation from EIA's report found at* http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

[32] http://www.eia.gov/electricity/data/eia860/ *(Generator/Unit level data set)*

[33] http://www.eia.gov/forecasts/aeo/MT_electric.cfm

IV. SUMMARY & RECOMMENDATIONS

Electricity from the existing generating fleet is less expensive than from its available new replacements, and existing generators whose construction costs repayment and recovery obligations have been substantially or entirely met are often the least-cost producers in their resource fleet. Cost trends extracted from Form 1 indicate the fleet average cost of electricity from existing resources is on track to remain a lower cost option than new generation resources for at least a decade—and possibly far longer.

However, wholesale energy and capacity market price suppression caused by external subsidies can drive lowest-cost generators toward earlier retirement than otherwise. This negative incentive is compounded as units face capital reinvestment decisions to comply with additional environmental or other regulations.

When low-cost electricity generators retire, they must be replaced with capacity sources whose electricity may be substantially more expensive. Recognizing these costs now could help avert poor policy and regulatory decisions in the near term.

A combination of current public policies drive the current retire/replace, trend including:

- Subsidies; making the construction and operation of energy-only "renewable" generation resources the least-cost entry even though they may offer a significantly lower capacity value than the sources they displace.
- Mandates; requiring significant increases in the market share of renewable electricity over several years. Increases in market share for renewable energy erodes the market share and capacity factor of marginal high capacity value resources.
- Environmental and other regulations, both pending and finalized, add new fixed costs to existing units.

The levelized cost of electricity from existing resources (LCOE-E) is a vital piece of information that has been missing from the public policy discussion. The framework we introduce in this report offers policymakers a powerful tool as they make decisions that affect not only the cost structure of the U.S. electricity industry but, by extension, a large sector of the domestic economy and a fundamental part of Americans' well-being.

Appendix A: Levelized Cost of Electricity from Wind

This appendix uses the methodology explained in Section III of this report to provide examples of the calculation for determining wind's imposed cost on CC gas. These examples are based on EIA's levelized cost from its Annual Energy Outlook (AEO) 2014 and are quoted in 2012 dollars. As such, the numbers will not match those provided in the main body of this report which are based on EIA's levelized costs from AEO 2015 and quoted in 2013 dollars. These examples are for illustrative purposes.

Example 1: Base Load CC Gas + Wind at Best-Case Capacity Factors

In this example, the CC gas fleet runs at an 87% annual capacity factor. For simplicity, we assume the CC gas fleet runs at a steady state 24/7/365.

1 MW of CC gas on the system works to provide 0.870 MWs of constant power 24/7/365. Its capacity factor is: 0.870MW / 1MW= 87%. 0.870 MW of wind is then "installed" and operates at a 35% capacity factor with no curtailment. Its output ranges from a minimum of 2.7% of nameplate (using the mean of lowest quartile output across peak hour calculation method) to 100% of nameplate.[34]

To create the identical generation and capacity profile as the 1 MW of CC gas, we will require slightly less CC gas summer capacity by the amount of summer capacity offered by the 0.870 MW of wind. Specifically: 0.870 MW x 2.7% = 23.49 KW. 0.870 MW CC gas summer capacity – 0.02349 MW = 0.84651 MW of CC Gas summer capacity required. To achieve that level of summer capacity we must divide by the capacity value of the CC Gas facility: 0.84651 / 87% = 0.973 MW.

We have now established that the pairing includes 0.870 MW of wind nameplate capacity and 0.973 MW of CC gas nameplate capacity.

The CC gas system will back down in synchronously as wind generation increases so that the pairing produces 0.870 MWs continuously throughout the year.

The wind energy produces an average of 0.870 MWs x 35% capacity factor = 0.3045 average MWs of power. The CC gas produces 0.8700 MW – 0.3045MW = 0.5655 MWs from its installed 9,730MWs.

The new CC gas capacity factor in the pairing is: 5,655MW / 9,730MW = 58.1%

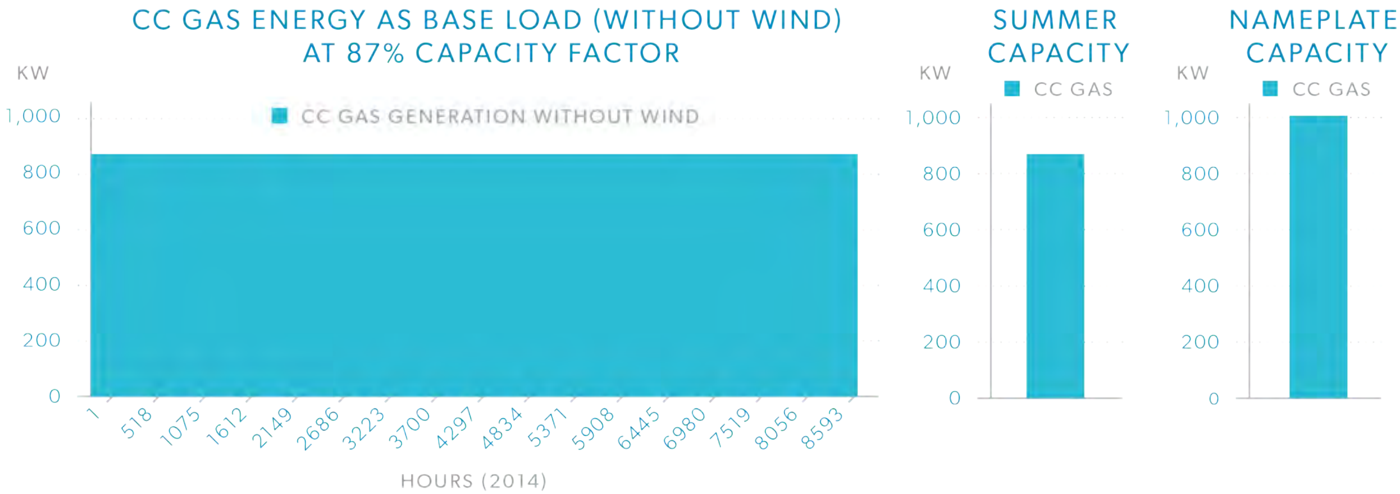
The fixed cost per MWh from the CC gas was $17.20/MWh at an 87% capacity factor. The new fixed cost per MWh is $17.20 x 87%/58.1% = $25.75/MWh.

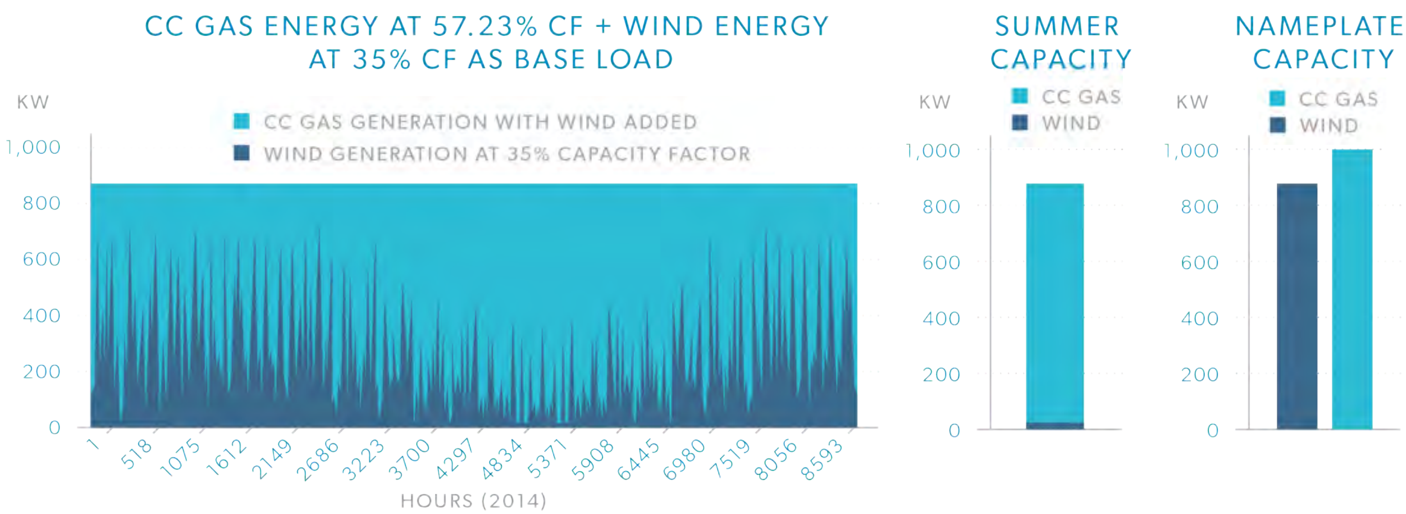
Each unit of gas in the pairing costs $25.75 - $17.20 = $8.55/MWh more than it used to.

Every MWh of wind energy in the pairing requires: 65% / 35% = 1.86 units of CC gas energy.

The imposed cost of wind on CC gas in the pairing is $8.55 x 65%/35% = $15.87 per MWh of wind in the pairing. The natural gas fuel and capital cost savings in the pairing are integral to these figures. The figures in the following spreadsheet table reflect the example above. All Excel worksheets are available on request.[35]

Model to serve a full time slice of 870KW demand and 870KW of UCAP	
CC GAS SERVING MODEL REQUEST BY ITSELF	
Fixed Cost ($/MWh) of CC Gas at 87% CF	$17.2
Variable Cost ($/MWh) of CC Gas	$42.1
Capacity Factor of CC Gas	87.0%
Capacity Value (UCAP) of CC Gas	87.0%
ADD MAXIMUM WIND CAPACITY TO REPLICATE MODEL SCENARIO (WITHOUT CURTAILMENT)	
KIND OF INTERMITTENT	WIND
Nameplate Capacity of wind to build (MW)	0.870
Summer Capacity From wind (KW)	23.49
Average energy from 0.87MW of wind at 35% CP (KW)	304.50
Residual energy to be generated from CC Gas (KW)	565.50
Residual Summer Capacity Required from CC Gas (KW)	845.51
Nameplate Capacity of CC Gas required to meet new summer capacity requirement (KW)	973.00
Fixed Cost ($/MWh) of Intermittent	$80.3
Variable Cost ($/MWh) of Intermittent	$ --
Capacity Factor of Intermittent	35.0%
Capacity Value of Intermittent	2.7%
RESULTING RATIOS AND COSTS WHEN PAIRING WIND WITH CC GAS	
LCOE CC Gas Alone	$59.3
LCOE Intermittent Alone (Invalid Choice)	$80.3
CC Gas nameplate required to meet 870KW of summer capacity and 870KW of energy (KW)	1,000.0
Gas nameplate required to meet 0.65% of PREVIOUS energy and 846.51KW of summer capacity	973.0
Energy from 973 KW of CC gas in combination with wind	565.50
Old CC Gas capacity factor	87.0%
New CC Gas Capacity Factor After Backing Down for Intermittent	58.1%
Fixed Cost ($/MWh) of CC Gas in Combination with Intermittent	$25.75
LCOE CC Gas in Combination with Intermittent	$67.85
Percent of Energy from CC Gas	65.0%
Percent of Energy from Wind	35.0%
LCOE of combination new CC Gas + new wind	$72.21
Imposed cost on new CC Gas per unit of new wind	$15.87
LCOE new wind including imposed cost	$96.17
Imposed cost on CC Gas per unit of CC Gas in Pairing	$8.55





Example 2: "Base Load" CC Gas + Wind at Real-World Capacity Factors:

In this example the CC gas fleet runs at a 47.8% annual capacity factor. For simplicity, we assume the CC gas fleet runs at a steady state 24/7/365.

1 MW of CC gas on the system works to provide 0.478 MWs of constant power 24/7/365. Its capacity factor is: 0.478MW / 1MW= 47.8%.

0.478 MW of wind is then "installed" and operates at a 33.9% capacity factor with no curtailment. Its output ranges from a minimum of 2.7% of nameplate (using the mean of lowest quartile output across peak hour calculation method) to 100% of nameplate.

To create the identical generation and capacity profile as the 1 MW of CC gas, we will require slightly less CC gas summer capacity by the amount of summer capacity offered by the 1 MW of wind. Specifically: 0.478 MW wind nameplate x 2.7% = 12.91 KW of summer capacity from wind. 0.870 MW CC gas summer capacity – 0.01291 MW = 0.85709 MW of CC Gas summer capacity required. To achieve that level of summer capacity we must divide by the capacity value of the CC Gas facility: 0.85709 / 87% = 0.98517 MW.

We have now established that the pairing includes 0.478 MW of wind nameplate capacity and 0.98517 MW of CC gas nameplate capacity.

We assume the CC gas system will back down synchronously as wind generation increases so that the pairing produces 0.478 MWs continuously throughout the year.

The wind energy produces an average of 0.478 MWs x 33.9% capacity factor = 0.16204 average MWs of power. The CC gas is left to produce 0.478 MW – 0.16204MW = 0.31596 MWs from its installed 0.98517 MWs.

The new CC gas capacity factor in the pairing is: 0.31596 MW / 0.98517 MW = 32.07%

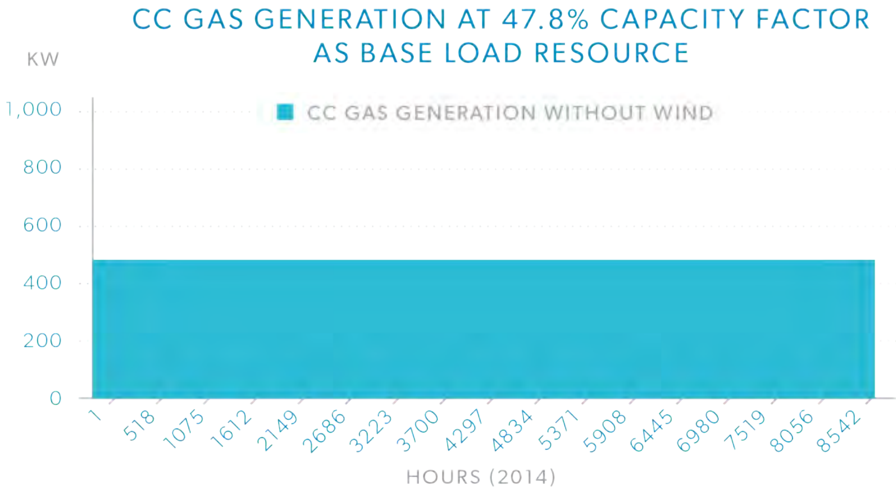
The fixed cost per MWh from the CC gas was $31.12/MWh at a 47.8% capacity factor. The new fixed cost per MWh is $31.12 x 47.8%/32.07% = $46.39/MWh.

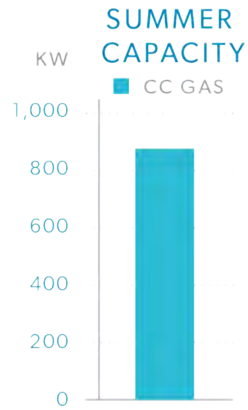
Each unit of gas in the pairing costs $46.39 - $31.31 = $15.26/ MWh more than it used to.

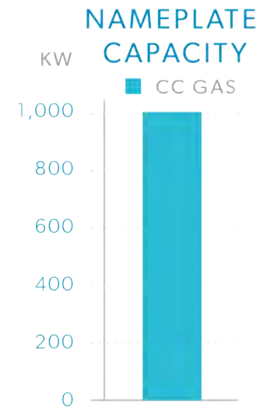
Every MWh of wind energy in the pairing requires: 66.1% / 33.9% = 1.95 units of CC gas energy.

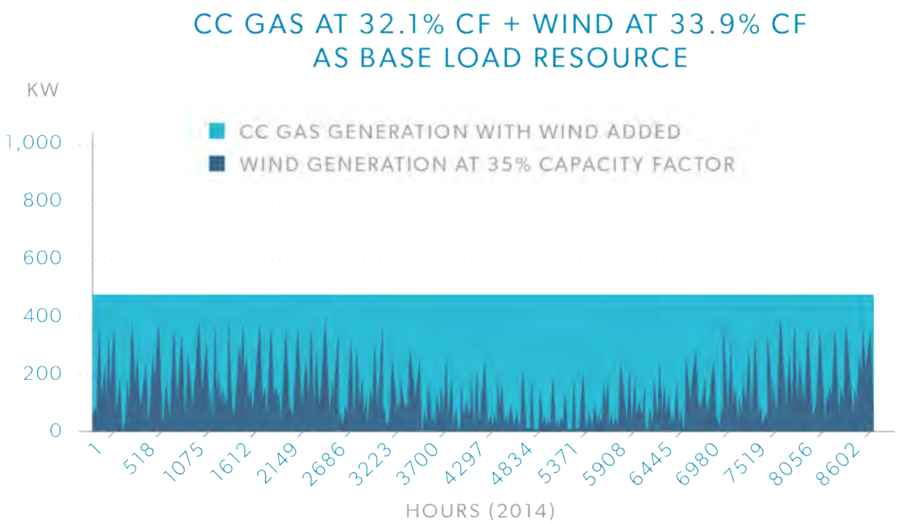
The imposed cost of wind on CC gas in the pairing is $15.26 x 66.1%/33.9% = $29.76 per MWh of wind in the pairing. The natural gas fuel and capital cost savings in the pairing are integral to these figures. The figures in the following spreadsheet table reflect the example above. All Excel worksheets are available on request.[36]

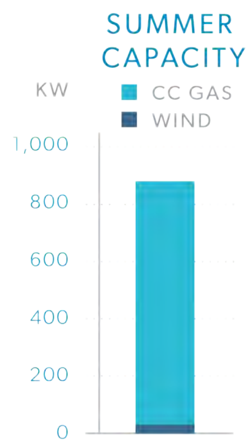
Model to serve a full time slice of 478KW demand and 870KW of UCAP	
CC GAS SERVING MODEL REQUEST BY ITSELF	
Fixed Cost ($/MWh) of CC Gas at 47.8% CF	$31.12
Variable Cost ($/MWh) of CC Gas	$42.10
Capacity Factor of CC Gas	47.8%
Capacity Value (UCAP) of CC Gas	87.0%
ADD MAXIMUM WIND CAPACITY TO REPLICATE MODEL SCENARIO (WITHOUT CURTAILMENT)	
KIND OF INTERMITTENT	WIND
Nameplate Capacity of wind to build (MW)	0.478
Summer Capacity From wind (KW)	12.91
Average energy from 0.498MW of wind at 33.9% CF (KW)	162.04
Residual energy to be generated from CC Gas (KW)	315.96
Residual Summer Capacity Required from CC Gas (KW)	857.09
Nameplate Capacity of CC Gas required to meet new summer capacity requirement (KW)	985.17
Fixed Cost ($/MWh) of Intermittent	$78.16
Variable Cost ($/MWh) of Intermittent	$ --
Capacity Factor of Intermittent	33.9%
Capacity Value of Intermittent	2.7%
RESULTING RATIOS AND COSTS WHEN PAIRING WIND WITH CC GAS	
LCOE CC Gas Alone	$73.22
LCOE Intermittent Alone (Invalid Choice)	$78.16
CC Gas nameplate required to meet 870KW of summer capacity and 478KW of energy (KW)	1,000.0
Gas nameplate required to meet 0.661% of PREVIOUS energy and 857.09KW of summer capacity	985.17
Energy from 985.2 KW of CC gas in combination with wind	315.96
Old CC Gas capacity factor	47.8%
New CC Gas Capacity Factor After Backing Down for Intermittent	32.1%
Fixed Cost ($/MWh) of CC Gas in Combination with Intermittent	$46.4
LCOE CC Gas in Combination with Intermittent	$88.5
Percent of Energy from CC Gas	66.1%
Percent of Energy from Wind	33.9%
LCOE of combination new CC Gas + new wind	$84.99
Imposed cost on new CC Gas per unit of new wind	$29.76
LCOE new wind including imposed cost	$107.92
Imposed cost on CC Gas per unit of CC Gas in Pairing	$15.26

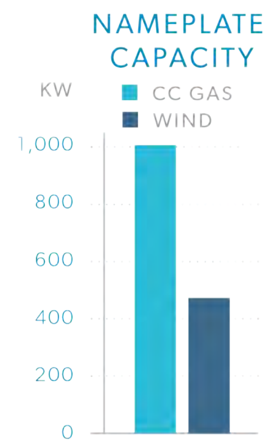












FOOTNOTES: APPENDIX A

[34] *https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/BOD/Markets%20Committee/2013/20130724/20130724%20Markets%20Committee%20of%20the%20BOD%20Item%2005%202012%20SOM%20Report.pdf (Page 16)*

[35] *Contact Tom Stacy at (937) 407-6258 or tfstacy@gmail.com*

[36] *Contact Tom Stacy at (937) 407-6258 or tfstacy@gmail.com*

Appendix B: Levelized Cost of Electricity from PV Solar

This appendix estimates the levelized cost of electricity (LCOE) from new photovoltaic solar power (PV). Imposed cost (defined later) rises as the PV energy market share increases. We examine LCOE at one percent increments of energy market share in a regional grid system from zero percent through fifteen percent.

Methodology for Calculating Imposed Cost of Solar PV

Refer back to pages 27-28 for our discussion regarding PV solar. The calculations in Appendix B are intended to be illustrative. The final figures below do not match the figures on page 28 of the report because we used EIA 2014 real world capacity factors for all applicable resources in Appendix B. The figures above rely on the more recently released 2015 national average capacity factors. Further, one data set underlying the imposed cost figures above and in Appendix B is the set of solar generation data published by CAISO, which was difficult to compile. Due to the format of the CAISO data, it was impractical to regather and recalculate load, solar generation, and residual peak load for 2015 in the course of finalizing this report. Hence all calculations in Appendix B reflect 2014 data.

We estimate the US average LCOE of PV in 2020 at 153.7 and the LCOE of PV in the California region at 151.7 (2013 $/MWh) including imposed cost for the next one percent energy market share gain in their respective jurisdictions. This is higher than estimated by EIA in their LCOE 2020 forecast,[37] and indicates PV solar electricity is four to five times more expensive than electricity from most existing dispatchable resources.

CCGT and CT as Proxy for Actual Marginal Resources Displaced by PV

Because hourly marginal resource reports for CAISO were not found in the public domain, we are not able to verify which generating technologies PV generation displaces or in what ratio. We therefore estimate imposed cost under a model case where only new combustion turbine (CT) and combined cycle (CCGT) units experience reductions from their previous annual generation totals as PV capacity is added, and experience them at an equal percentage reduction from their previous capacity factors.[38] This assumption does not consider the likely increase in upward ramping requirements placed on gas generators due to rapidly declining PV generation across hours of fairly steady, near peak demand. That circumstance has been widely reported to require an increase in the use of CT (or CCGT in heat recovery steam generator (HRSG) bypass mode) capacity as PV capacity increases.

Real world circumstances certainly vary by region of the country and by local transmission constraints. Even though our displaced resource and ratio assumption may not hold true in specific regions of the country, we argue that all capacity-bearing generator technologies carry fixed costs, and operate at some CF prior to PV capacity being added to the system, and that resources displaced will achieve lower capacity factors once PV energy gains market share. Imposed costs are therefore present at some level even if our best assumption cannot rely on actual marginal resource data. The calculations used for this report yield a marginal fixed cost per unit of energy curve (i.e. change in $/MWh) as a result of incremental one percent PV energy market share gains.

Imposed Cost Should be Allocated to its Source

Imposed cost increases as more and more PV capacity is added to a system. This is because energy produced by early PV installations reduces original gross peak demand at late afternoon hours to levels below demand levels occurring at evening hours. Once that happens, no amount of additional PV capacity can reduce the new daily peaks in the residual load curve (net of solar energy already being produced by previously installed PV capacity) which now occur after PV stops producing in the evening. This is illustrated in Figures 1A and 1B later in this report. Therefore, PV's value as a capacity resource falls away as market share increases and residual daily load peaks shift to evening hours.

Because "imposed cost" does not accrue directly to intermittent generators in wholesale energy markets or through the value of renewable energy credits (RECs), most lawmakers, regulators and electricity consumers do not recognize its existence, let alone allocate it correctly, even though imposed cost is very real in a "conservation of matter" sense. We believe imposed cost should be considered and shown as an expense on the policy, LCOE and wholesale market "ledgers" of the intermittent generators which induce them.

Estimating Capacity Value (CV) of PV

This report utilizes hourly PV generation and hourly electricity demand data for 2014 across the CAISO system as reported by CAISO.

We model the minimum availability of PV energy from incremental capacity additions across the highest 900 net electricity demand hours in CAISO (net of PV generation from previously installed capacity) of the year in "1% market share increments" from zero to fifteen percent PV market share. These calculations were made at various confidence levels. That is, a 75% confidence level would return the lowest hourly generation that could be expected from incremental PV capacity across 75% of the 900 highest net load hours of the year. After each 1% energy market share addition of PV generation we re-calculate net load and re-sort the 8,760 hourly net load figures highest to lowest. Of the new ordered net load data we consider the 900 hours of greatest net demand in analyzing the next 1% market share addition of PV contribution to "peak load" fulfillment. Then, for the 900 greatest net load hours, we sort PV generation lowest to highest. The 225th lowest PV generation hour of the 900 highest demand hours is considered the "75% confidence level." In other words, 75% of the time PV is expected to generate at some percent of nameplate capacity or above across the 900 highest net demand hours of the year. This is repeated through 15% PV energy market share.

CV was also estimated using the "mean of lowest quartile generation" method (MLQG). This is the average expected generation of the lowest one fourth of generating hours of the highest 900 electricity net demand hours of the year. The analysis allowed us to calculate the CV and resulting system imposed cost for each successive percentage gain of PV energy market share. Because the 75 percentile method yielded results more favorable to PV CV than the MLQG method, we base our imposed cost estimates on the more generous 75 percentile method. Imposed cost would be higher under the alternative calculation method. All worksheets are available upon request of the author.

The CV determination method in this report differs significantly from the effective load carrying capability (ELCC) convention. This is because we believe a proper long term capacity planning metric must measure each technology's dependability at high demand periods independent of:

- **system or regionally constrained area load profile dynamics over time,**
- **point-in-time system or regional reserve margins, and**
- **the uncertain future ratio of dispatchable to intermittent fueled generators across a system or within any transmission constrained region on the system.**

While ELCC is a valid statistical measure of an intermittent generating technology's capability to address new load under static generating resource blend and load profile assumptions, resource blend is not constant in the real world across capacity planning time horizons, nor are increasing loads of the existing use profile a certainty.

PV's CV is therefore calculated for purposes of this report based on its stand-alone ability to reduce existing peak system demand across the 900 greatest peak demand hours of 2014. We do not, however, assign CV based on the absolute peak load hour of the year. Instead, we measure PV's expected contribution at and above various percentages of the top 900 ordered peak demand hours of the sampled year. Our methodology answers the question, "What minimum percentage of PV's nameplate capacity is that capacity expected to generate across (75%) of the highest peak demand hours of a year?"

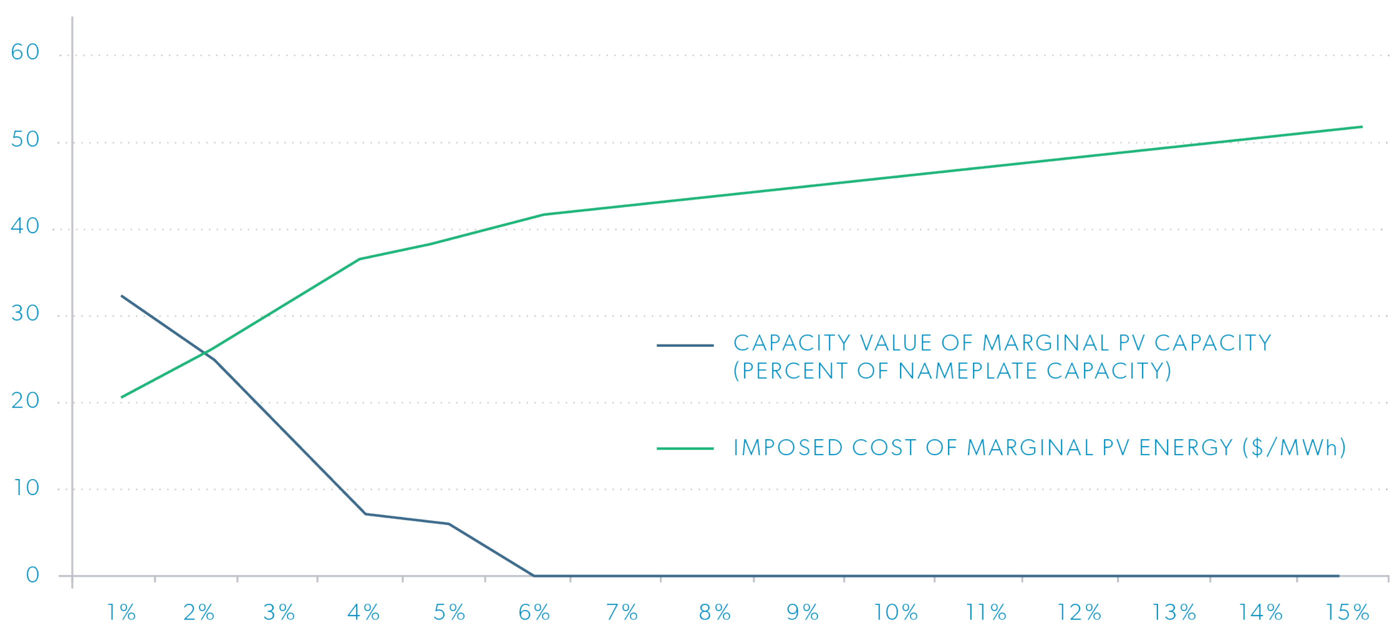
We base our definition of "peak demand hours of the year" on the highest 900 hours, because this is likely to capture most or all of the highest 360 load hours across typical load and weather years--even as PV might achieve very optimistic market share--and because 360 is approximately the number of hours considered in several other RTO/ISO regions in their determination of CV (also termed by some regulators and regional market organizations as "capacity credit").[39] Those regions, however, specify a set of hours they consider to contain most of the highest demand hours of a year (e.g. "2 PM to 6PM across June, July and August") which "misses" a significant number of peak demand hours in CAISO in 2014, and likely in many other years and regions. Furthermore, that set of hours fails to include most of the peak demand hours net of higher market penetrations of PV. For this reason, we chose to evaluate the specific 900 highest demand hours, rather than a set of hours that "might" contain "most" of them.

We calculate net system demand after adding each 1% market share gain for PV for the top 900 demand hours of 2014. We then sort by net demand at each percent market share gain and evaluate the top 900 net load hours of the 8,760 total hours in a calendar year. The highest demand hour in 2014 consumed an average of 44,671 MW and the 900th highest demand hour consumed an average of 33,970 MW, a range of almost 11,000 MW. The highest hourly PV generation at (extrapolated) 15% market share was 10,267 MW, making our inclusion of 900 hours sufficient to minimize skewed results due to an insufficient sample size.

The statistically appropriate confidence level necessary to maintain system reliability at current reserve margin levels is not determined by this report.[40] Peak load hours are defined here as the highest 900 electricity demand hours of a calendar year. That is, the net load hour of the year ranking 225th highest represents the 75% confidence level. The average generation from the lowest 225 generating hours of the highest 900 net load hours is the MLQG confidence level. Our expectation is that the appropriate confidence level falls within the range we consider for this report.

ESTIMATED CAPACITY VALUE AND IMPOSED COST OF PV SOLAR: CAISO AT 31% CF

PV ENERGY MARKET SHARE	CAPACITY VALUE OF MARGINAL PV CAPACITY (PERCENT OF NAMEPLATE CAPACITY)	IMPOSED COST OF MARGINAL PV ENERGY
1%	32.6%	21.0
2%	25.3%	25.1
3%	16.2%	30.2
4%	7.1%	35.3
5%	4.7%	37.4
6%	0.0%	40.6
7%	0.0%	41.6
8%	0.0%	42.7
9%	0.0%	43.8
10%	0.0%	45.0
11%	0.0%	46.2
12%	0.0%	47.6
13%	0.0%	49.0
14%	0.0%	50.4
15%	0.0%	52.0

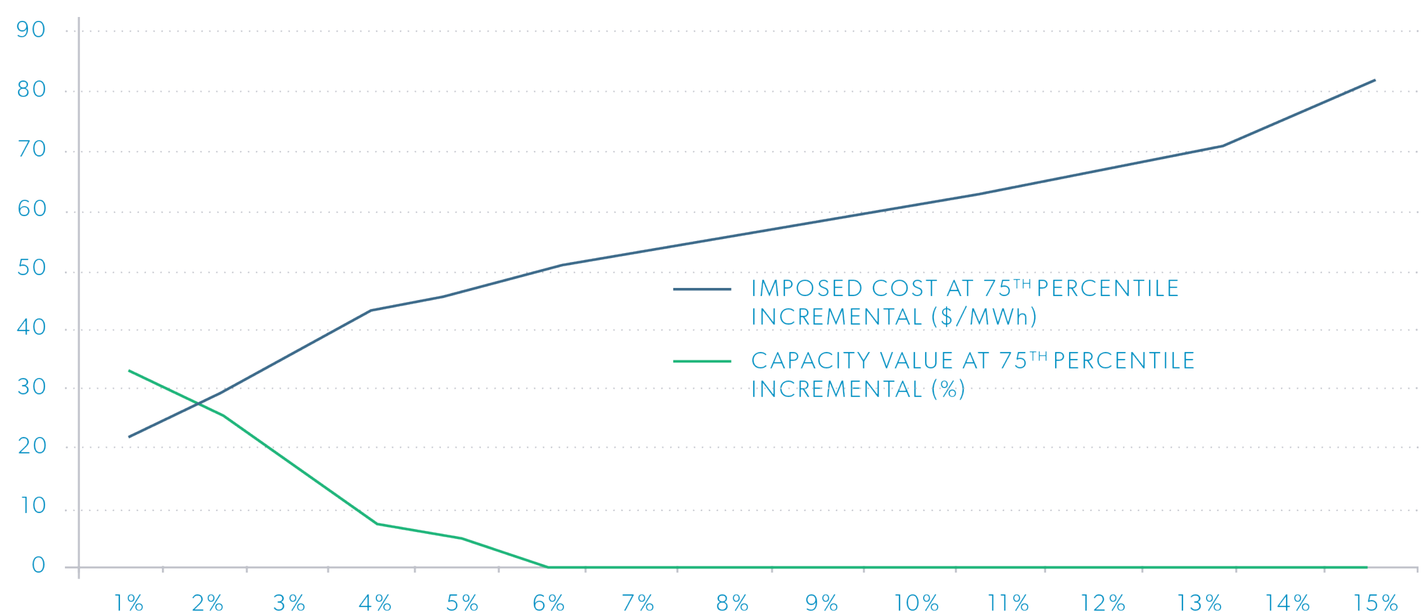


At each incremental market share level, the MLQG confidence level returns the lowest CV, and the 75th percentile confidence level returns the highest CV. The range of CVs for these two confidence levels turns out to be narrow, but the 75th percentile method yields the more generous capacity value result. We present only the 75th percentile figures in this report.

The following pairs of tables and graphs demonstrate how the CV of PV capacity additions fall and imposed costs rise for each successive energy market share gain in CAISO and for the US, respectively. Costs vary slightly between the two, based on differing CF assumptions used in the calculations. CVs are identical in the two cases because they are listed as a percent of nameplate capacity. CVs (in MWs) would vary inversely with CF assumptions.

ESTIMATED CAPACITY VALUE AND IMPOSED COST OF PV SOLAR: US AVG. AT 25.9% CF

PV ENERGY MARKET SHARE	CAPACITY VALUE AT 75TH PERCENTILE INCREMENTAL (%)	IMPOSED COST AT 75TH PERCENTILE INCREMENTAL ($MWh)
1%	32.6%	20.9
2%	25.3%	26.1
3%	16.2%	32.8
4%	7.1%	39.7
5%	4.7%	42.9
6%	0.0%	47.8
7%	0.0%	50.0
8%	0.0%	52.5
9%	0.0%	55.3
10%	0.0%	58.4
11%	0.0%	61.8
12%	0.0%	65.7
13%	0.0%	70.1
14%	0.0%	75.1
15%	0.0%	80.8



What Imposed Cost (as Defined in this Report) Does Not Include

Imposed cost as used in this report does NOT include additional costs borne by dispatchable resources such as lost fuel efficiency from "cycling" and steep "ramping" nor the higher maintenance costs associated with those more demanding operating dynamics.

Imposed cost also does not include higher transmission investment costs for remotely sited PV. It does not include an adjustment for a likely shorter physical lifespan of PV systems relative to the lifespans of conventional generators.

Finally, while imposed cost monetizes the indirect cost of intermittent and "outside operator control" renewable "fuel" resource behavior, we do not intend to imply PV technology on the whole is a direct substitute for any dispatchable resource. Clearly it is not, as dispatchable resources are available to operate 24/7/365 and can be scheduled by the system operators.

The sum of these unconsidered factors could increase the cost of PV significantly. Reliable quantitative data were not readily available and as such, such estimates were not appropriate for this analysis.

Capacity Value (CV) Calculations Using CAISO 2014 Hourly Load

Our analysis suggests that incremental additions of PV capacity offer steeply declining CV. PV fleet-average CV for the first 5% energy market share in CAISO is 17.2% of nameplate capacity and the resulting imposed cost spread across all PV is 28.6 (2013 $/MWh) as shown in Table 3 of this report, while the six percent incremental market share has CV of 0%. It is important to note that PV provides some CV at low market penetration, but as residual peak load hours[41] shift to evening, additional capacity contribution to meeting net peak load falls sharply. We label this effect PV's "capacity value cliff." The imposed cost of energy from the capacity required to attain the six percent incremental market share rises significantly to $40.6, a 42% imposed cost increase over the previously existing 5% average market share bearing installed PV capacity.[42]

In our example we assume the resources displaced by PV are new combined cycle natural gas (CC gas) and new combustion turbine natural gas (CT gas) generators, with their respective forecast levelized fixed costs at real-world CFs.[43]

Fleet average CVs and imposed costs are simply an averaging function of preceding incremental CVs as shown below:

CAISO MARGINAL AND FLEET AVERAGE CAPACITY VALUES (%) AND IMPOSED COSTS ($/MWh)

CAPACITY VALUE OF MARGINAL CAPACITY	FOR (NTH % PV ENERGY MARKET SHARE)	IMPOSED COST OF MARGINAL CAPACITY	FLEET AVERAGE CAPACITY VALUE	FLEET AVERAGE IMPOSED COST
32.6%	1%	$21.0	32.6%	21.0
25.3%	2%	$25.1	28.9%	22.8
16.2%	3%	$30.2	24.7%	24.9
7.1%	4%	$35.3	20.3%	27.1
4.7%	5%	$37.4	17.2%	28.6
0.0%	6%	$40.6	14.3%	30.0
0.0%	7%	$41.6	12.3%	31.0
0.0%	8%	$42.7	10.7%	31.8
0.0%	9%	$43.8	9.5%	32.4
0.0%	10%	$45.0	8.6%	32.9
0.0%	11%	$46.2	7.8%	33.2
0.0%	12%	$47.6	7.2%	33.6
0.0%	13%	$49.0	6.6%	33.8
0.0%	14%	$50.4	6.1%	34.1
0.0%	15%	$52.0	5.7%	34.3

Assumptions to the Calculation of PV Imposed Cost

We provide a step by step calculation of estimated capacity value and imposed cost of PV for its first five, and its sixth percent energy market share. The analysis indicates the presence of a fleet average imposed cost of PV for the first five percent PV market share, and a larger incremental imposed cost for the sixth incremental percent of energy market share.

PV often displaces natural gas generation. We chose to model that dynamic in this report.[44] In the following example, we make the following assumptions about how PV resources are integrated onto the electricity grid:

- Hourly PV generation in CAISO totaled 10,435,675 MWh for 2014 against 232,734,274 MWhs of load, equating to a 4.483% energy market share for PV.
- EIA estimates a 31% CF for PV in NERC region 20 (California) in LCOE assumptions for 2020. We assume that same CF for existing California PV. At 31% CF, PV installed capacity for 2014 would have been 3,843 MW (nameplate).[45]
- Example assumes zero load growth.
- CV estimates use the 900 greatest electricity demand hours in CAISO for 2014. We chose 900 hours because several prominent ISO/RTOs estimate CV across a smaller set of approximately 360 hours of the year that do not capture early evening hours. In PJM, for example, CV for intermittent generators is determined using the hours between 2PM and 6PM across the months of June, July and August.[46] However, as PV attains market share, many of the 360 residual peak load hours (net of PV generation) shift from late afternoon when PV is often productive, to twilight hours with little to no PV generation. This causes the fixed window of peak demand hours to miss the mark and over-value additional PV's contribution to meeting future peak demand. We therefore examine a larger and more flexible sample size (the 900 highest net demand hours) which we feel more accurately reflects incremental PV capacity's contribution to meeting peak electricity demand.
- As PV is added, we reduce the annual energy from the remaining CCGT and CT facilities equally, estimated based on the hours of day PV is generating and which technologies are likely "on the margin" at those hours of the year. This is not meant to be a perfect representation of the resources displaced by PV but rather a reasonable facsimile of the fixed costs and CFs of the resources actually displaced. Real world data based on an hourly marginal resource report (which we could not obtain from CAISO) would yield more precise imposed costs.
- PV installed capacity is added in increments sufficient to capture one additional energy market share gain in a system with annual load and load profile held constant.
- System capacity reserve margin is held constant by "retiring" CT gas, CC gas capacity with CV (in MWs) equal to the CV in MWs of PV added. In the real world retirements and capacity additions take time to evolve, which masks the gradually accruing costs. Our calculations and this example shine light on the need to maintain system reserve capacity while adding low CV resources to the generation mix.
- CT gas and CC gas each and as a combined "natural gas fired fleet" offer 87% of their nameplate capacity as net summer capacity[47] regardless of either resource's estimated real-world or "best case" CFs. We use net summer capacity as CV because no other published values for natural gas generator CV by any calculation method could be attained.
- CT gas and CC gas together offer a blend of base load, load following and peak load following at estimated respective CFs of 6.6% and 51.9% in the 0% PV base scenario.[48]
- CVs for PV use the 75th percentile highest net load hour methodology, the most lenient of the confidence levels we considered. The 75th percentile mark means PV is permitted to fall short of its CV 25% (90) of the highest 900 load hours of 2014 (net of generation from modeled previously existing PV capacity). It is the 225th highest PV generation of the highest 900 net load hours of 2014.
- The annual energy from the CT gas and CC gas

capacity with the 6th percentage of PV added to them is the remainder of CT gas and CC gas energy prior to the PV energy minus the energy produced by incremental PV capacity.

- The new CF of the residual installed capacity of CT gas and CC gas with the incremental PV is the new CT gas and CC gas energy divided by the new CT gas and CC gas capacity required to meet the capacity and energy levels of CT gas and CC gas prior to the addition of the incremental PV resource.
- Fixed costs per MWh of CT gas and CC gas are then recalculated by multiplying their new fixed costs per MWh in the base line scenario by the ratio of their base line CFs divided by their new CFs.
- The imposed cost per MWh of the incremental PV energy is the increase in fixed cost per MWh of CT gas and CC gas times the percentage of CT gas and CC gas energy in the resulting system divided by the incremental PV energy.

Imposed Cost Calculation Example for CAISO

CAISO 0% PV ENERGY MARKET SHARE CASE

The base case scenario assumes no PV exists on the CAISO system. In this case, we estimate the CT gas fleet, (consisting of approximately 12,000 MWs of nameplate capacity), runs at 6.6% annual CF. Similarly, the CC gas fleet is estimated to consist of approximately 22,000 MWs of installed capacity and achieves a 51.9% annual CF. In this scenario, together CT and CC gas would have generated 46% of CAISO system energy in 2014.[49]

CT gas:
12,000 MW X 6.6% X 8,760 hours per year = 6.98 Million MWhs per year

CC gas:
22,000 MW X 51.9% X 8760 hours per year = 100.08 Million MWhs per year

Total = 107.06 Million MWhs

Absent PV, gas aggregated CF would have been 35.9%:

107.06 Million MWhs / ((22,000 MWs + 12,000 MWs) X 8,760) = 35.9%

CAISO 5% PV ENERGY MARKET SHARE CASE

In 2014, PV actually achieved 4.484% energy market share in CAISO according to published data. (10,435,675 MWhs). We adjust this to 5% (11,639,164 MWhs) for this example. Assuming the PV fleet average CF was 31%, average PV nameplate capacity across 2014 would have been approximately 4,286 MW:

11.639 Million MWhs / (31% X 8,760) = 4,286 MWs

CAISO 2014 TOTAL GENERATION (MWh) = 232,734,000

TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
FLEET AVERAGE PV SOLAR	0%					
CV%	87.0%	87.0%	87.0%	0.0%	N/A	N/A
SUMMER CAP (CV)(MW)	19,140	10,440	29,580	N/A		29,580
ENERGY MKT SHR%	43.0%	3.0%	46.0%	0.0%	0.0%	46.0%
ANNUAL ENERGY (MWh)	100,075,620	6,982,020	107,057,640	N/A	-	107,057,640
CAPACITY FACTOR (%)	51.9%	6.6%	35.9%	N/A	31.0%	N/A
EST. NAMEPLATE CAP (MW)	22,000	12,000	34,000	N/A	0.0	34,000
FIXED COST ($/MWh)	$29.0	$153.57	$37.11	N/A	N/A	N/A

According to our analysis, the fleet average CV of the first 4,286 MWs of PV is 17.2%.[50] Therefore, 736 MW of CV was provided by 5% energy market share for PV:

4,286 MWs X 17.2% = 736 MW

The CV of the gas fleets is 87% of nameplate capacity.[51] The remaining installed gas fired capacity required to maintain the same system capacity reserve margin as prior to PV is 33,154 MWs:

22,000 MWs + 12,000 MWs – (736 MW / 87%) = 34,000 MWs – 846 MWs = 33,154 MW

Energy produced by the remaining gas fleet in the presence of 5% PV was 95.42 Million MWhs:

107.06 Million MWhs – 11.64 Million MWhs = 95,418,476 MWhs

The new CF of the gas fleet is 32.9%:

95.42 Million MWhs / (33,154 MW X 8,760 hours per year) = 32.9%

The new fixed cost per MWh for gas is 40.60 ($/MWh) of gas energy produced. This is calculated by energy market share weighted average for CT and CC gas:

($31.71 x 89,195,532 MWh / 95,418,476 MWh + $168.0 x 6,222,944 MWh / 95,418,476 MWh) = 40.6

Fleet Average imposed cost per unit of gas energy at 5% PV energy market share is 3.49 ($/MWh) of gas energy:

$40.60 - $37.11 = $3.49 per MWh of gas energy

Fleet average imposed cost per unit of PV energy at 5% energy market share is $28.6/MWh of PV energy:

$3.49 X 95.42 Million MWhs / 11.64 Million MWhs = $28.6 / MWh of PV energy

CAISO 2014 TOTAL GENERATION (MWh)	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
232,734,000						
TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
FLEET AVERAGE PV SOLAR	5%					
CV%	87.0%	87.0%	87.0%	N/A	17.2%	0.0%
SUMMER CAP (CV)(MW)	18,664	10,180	28,844	N/A	736	29,580
ENERGY MKT SHR%	38.3%	2.7%	41.0%	N/A	5.0%	43.0%
ANNUAL ENERGY (MWh)	89,195,532	6,222,944	95,418,476	N/A	11,639,164	107,057,640
CAPACITY FACTOR (%)	47.5%	6.1%	32.9%	N/A	31.0%	N/A
EST. NAMEPLATE CAP (MW)	21,453	11,701	33,154	N/A	4,286	37,440
FIXED COST ($/MWh)	$31.71	$168.0	$40.6	N/A	N/A	N/A

CAISO CASE OF INCREASING PV ENERGY MARKET SHARE FROM 5% to 6%

Beginning with the ratios, CFs and fixed costs per MWh figures for CT and CC gas at 5% market penetration, we add an additional 857 MWs of PV capacity – enough to capture a six percent energy market share at 31% CF based on 2014 CAISO load conditions. The annual energy yield of the added PV capacity would be 2.33 Million MWhs under these assumptions.

The six percent market share for PV reduces gas energy to 93.09 Million MWhs:

95.42 Million MWhs – 2.33 Million MWhs = 93.09 Million MWhs

The CV of the marginal PV capacity offers no CV.

Gas CV required to maintain the same reserve margin does not change:

33,154 MW – 0 MW / 87% = 33,154 MW

This yields a lower CF for gas of 32.1%:

93.09 MM MWhs / (33,154 MW * 8760) = 32.1%

The fixed cost per MWh impact on the gas fleet of the incremental 1% PV market share gain is therefore $1.0/MWh of gas energy:

$41.6 - $40.6 = $1.0/MWh of gas.

The estimated imposed cost per incremental unit of PV is therefore $40.6/MWh of incremental PV:

$1.0/MWh of gas X (93.09 Million MWhs gas energy / 2.33 Million MWhs of incremental PV energy) = $40.6[52]

CAISO 2014 TOTAL GENERATION (MWh)	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
232,734,000						
TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
FLEET AVERAGE PV SOLAR	5%					
CV%	87.0%	87.0%	87.0%	N/A	17.2%	0.0%
SUMMER CAP (CV)(MW)	18,664	10,180	28,844	N/A	736	29,580
ENERGY MKT SHR%	38.3%	2.7%	41.0%	N/A	5.0%	43.0%
ANNUAL ENERGY (MWh)	89,195,532	6,222,944	95,418,476	N/A	11,639,164	107,057,640
CAPACITY FACTOR (%)	47.5%	6.1%	32.9%	N/A	31.0%	N/A
EST. NAMEPLATE CAP (MW)	21,453	11,701	33,154	N/A	4,286	37,440
FIXED COST ($/MWh)	$31.71	$168.0	$40.6	N/A	N/A	N/A

TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
MARGINAL PV SOLAR ADDED	6%					
CV%	87.0%	87.0%	87.0%	0.0%		
SUMMER CAP (CV)(MW)	18,664	10,180	28,844	-	736	29,580
ENERGY MKT SHR%	37.4%	2.6%	40.0%	1.0%	5.0%	46.0%
ANNUAL ENERGY (MWh)	87,019,514	6,071,129	93,090,643	2,327,833	11,639,164	107,057,640
CAPACITY FACTOR (%)	46.3%	5.9%	32.1%	31.0%	31.0%	N/A
EST. NAMEPLATE CAP (MW)	21,453	11,701	33,154	857	4,286	38,297
FIXED COST ($/MWh)	$32.5	$172.2	$41.6	N/A	N/A	N/A
PERCENT OF GAS CAPACITY	64.7%	35.3%				
PERCENT OF GAS ENERGY	93.5%	6.5%				
MARGINAL PV SUMMARY						
NAMEPLATE CHANGE (MW)	-	-	-	857	N/A	857
IMPOSED COST PER UNIT OF GAS ($/MWh)	$0.8	$4.2	$1.0	N/A	N/A	N/A
IMPOSED COST PER UNIT OF PV ($/MWh)	$29.6	$11.0	$40.6	N/A	N/A	$40.6

IMPOSED COST CALCULATION EXAMPLE FOR US TOTAL

For this example, we estimate installed capacity and energy market share for CC and CT gas resources nationally using EIA Forms 860 and 923 data (2014) and other sources. EIA's reported U.S. total net electricity generation in 2014 is used for annual system load. While exact input figures can be debated, the example output is not significantly altered.

Table 4 shows the marginal and fleet average capacity values and imposed costs of PV at one percent increments of energy market share for the United States, at EIA LCOE 2020 estimated PV capacity factor in 2020 of 25%.

US TOTAL MARGINAL AND FLEET AVERAGE CAPACITY VALUES (%) AND IMPOSED COSTS ($/MWh)

CAPACITY VALUE OF MARGINAL CAPACITY	FOR (NTH % PV ENERGY MARKET SHARE)	IMPOSED COST OF MARGINAL CAPACITY	FLEET AVERAGE CAPACITY VALUE	FLEET AVERAGE IMPOSED COST
32.6%	1%	$20.9	32.6%	20.9
25.3%	2%	$26.1	28.9%	23.1
16.2%	3%	$32.8	24.7%	25.7
7.1%	4%	$39.7	20.3%	28.4
4.7%	5%	$42.9	17.2%	30.3
0.0%	6%	$47.8	14.3%	32.1
0.0%	7%	$50.0	12.3%	33.4
0.0%	8%	$52.5	10.7%	34.3
0.0%	9%	$55.3	9.5%	35.0
0.0%	10%	$58.4	8.6%	35.6
0.0%	11%	$61.8	7.8%	36.1
0.0%	12%	$65.7	7.2%	36.5
0.0%	13%	$70.1	6.6%	36.8
0.0%	14%	$75.1	6.1%	37.1
0.0%	15%	$80.8	5.7%	37.4

0% PV ENERGY MARKET SHARE CASE

In this case, we scale our example to the entire US. We change the levelized costs of CT and CC gas using a capacity factor adjustment from the LCOE 2015 report released by IER in June, 2015, which concluded that the CT fleet achieved a capacity factor of 4.8%, down from the 6.6% CF assumption in CAISO, and that the CC fleet achieved a capacity factor of 47.8%, down from the 51.9% assumed for CAISO. This adjustment raises the levelized fixed costs of those resources to 212.5 and 31.5 $/MWh, respectively.

We estimate the US average energy market share for CT to be 1.4% and for CC to be 25.6% based on EIA summary statistics[53] and the ratio of CT to CC energy estimated for CAISO using EIA 860 data. We note that energy market share does not affect imposed cost calculations.

US average PV capacity factor is set at 25%: the level estimated by EIA in its LCOE 2020 forecast. This increases the installed capacity of PV per percent energy market share for the US to 18,566 MW.[54] We do not decrease PV CV with the decrease in CF so the increased installed capacity per MWh increases effective CV (in MWs), lowering imposed cost (per MWh).

CT gas
135,377 MW X 4.8% X 8,760 hours per year = 56,923,496 MWhs per year

CC gas:
248,583 MW X 47.8% X 8760 hours per year = 1,040,886,784 MWhs per year

Total = 1,097,810,280 MWhs per year

Absent PV, gas aggregated CF would have been 32.6%:

1,097,810,280 MWhs / ((248,583 MWs + 135,377 MWs) X 8,760) = 32.6%

TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
FLEET AVERAGE PV SOLAR	0%					
CV%	87.0%	87.0%	87.0%	0.0%	N/A	N/A
SUMMER CAP (CV)(MW)	216,267	117,778	334,046	N/A		334,046
ENERGY MKT SHR%	***25.60%***	***1.4%***	***27.0%***	0.0%	0.0%	27.0%
ANNUAL ENERGY (MWh)	1,040,886,784	56,923,496	1,097,810,280	N/A	-	1,097,820,280
CAPACITY FACTOR (%)	47.8%	4.8%	32.6%	N/A	25.0%	N/A
EST. NAMEPLATE CAP (MW)	248,583	135,377	383,960	N/A	0.0%	383,960
FIXED COST ($/MWh)	$31.5	$212.5	$40.87	N/A	N/A	N/A

US TOTAL 2% PV ENERGY MARKET SHARE CASE

Here we raise US PV solar energy market penetration in the US to 2% (81,319,280 MWhs) in this example. Assuming the PV fleet average CF was 25%, average PV nameplate capacity at 2% energy market share would have been approximately 37,132 MW:

81,319,280 Million MWhs / (25% X 8,760) = 37,132 MWs

From our analysis, the fleet average CV of the first 37,132 MWs of PV is 28.9%[55] of installed nameplate capacity. Therefore, 10,745 MW of CV was provided by 2% energy market share for PV:

37,132 MWs X 28.9% =10,745 MW

The CV of the gas fleets is 87% of nameplate capacity.[56] The remaining installed gas fired capacity required to maintain the same system capacity reserve margin as prior to PV is 371,610 MWs:

248,583 MWs + 135,377 MWs – (10,745 MW / 87%) = 383,960 MWs – 12,350 MWs = 371,610 MW

Energy produced by the remaining gas fleet in the presence of 2% PV was 1,016,491,000 MWhs:

1,097,810,280 MWhs – 81,319,280 MWhs = 1,016,491,000 MWhs

The new CF of the gas fleet is 31.2%:

1,016,491,000 MWhs / (371,610 MW X 8,760 hours per year) = 31.2%

The new fixed cost per MWh for gas is $42.72/MWh of gas energy produced, derived using a weighted average:

($32.9 x 963,784,059 MWh + $222.1 x 52,706,941 MWh) / 1,016,491,000 MWh = $42.72

Imposed cost per unit of gas energy for the first 2% PV energy market share is $1.85 / MWh of gas energy:

$42.72 - $40.87 = $1.85 per MWh of gas energy

40.87 is the levelized fixed cost of gas energy in the zero percent PV base case.

Fleet average imposed cost per unit of PV energy at 2% energy market share is $23.1 / MWh of PV energy as shown in Table 4 above:

$1.85 X 1,016,491,000 MWhs / 81,319,280 MWhs = $23.12 / MWh of PV energy

TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
FLEET AVERAGE PV SOLAR	0%					
CV%	87.0%	87.0%	87.0%	0.0%	N/A	N/A
SUMMER CAP (CV)(MW)	216,267	117,778	334,046	N/A		334,046
ENERGY MKT SHR%	***25.60%***	***1.4%***	***27.0%***	0.0%	0.0%	27.0%
ANNUAL ENERGY (MWh)	1,040,886,784	56,923,496	1,097,810,280	N/A	-	1,097,820,280
CAPACITY FACTOR (%)	47.8%	4.8%	32.6%	N/A	25.0%	N/A
EST. NAMEPLATE CAP (MW)	248,583	135,377	383,960	N/A	0.0%	383,960
FIXED COST ($/MWh)	$31.5	$212.5	$40.87	N/A	N/A	N/A

US TOTAL FUTURE CASE OF INCREASING PV ENERGY MARKET SHARE FROM 2% TO 3%

Beginning with the ratios, CFs and fixed costs per MWh figures for CT and CC gas at 2% market penetration, we add an additional 18,566 MWs of PV capacity – enough to capture three percent energy market share at 25% CF based on 2014 US Total net generation.[57] The annual energy yield of the marginal PV capacity would be 40,659,640 MWhs under these assumptions.

The three percent market share for PV reduces gas generation to 975,831,360 MWhs:

1,016,491,000 – 40,659,640 MWhs = 975,831,360 MWhs

The CV of the marginal PV capacity is 16.2% of marginal PV nameplate capacity, or 3,000 MW.

18,566 MW x 16.2% = 3,000 MW

Total gas nameplate capacity required to maintain the same reserve margin is:

371,610 MW – 3,000 MW / 87% =
371,610 MW – 3,448 MW = 368,162 MW

This yields a lower CF for gas of 30.3%:

975,831,360 MWhs / (368,162 MW * 8760) = 30.3%

The fixed cost per MWh impact on the gas fleet of the incremental 1% PV market share gain is therefore $1.4/MWh of gas energy:

$44.09 - $42.72 = $1.37/MWh of gas.

The estimated imposed cost per incremental unit of PV is therefore $32.8/MWh of incremental PV:

$1.37/MWh of gas X (975,831,360 MWhs gas energy / 40,695,640 MWhs of incremental PV energy) = 32.8 ($/MWh)

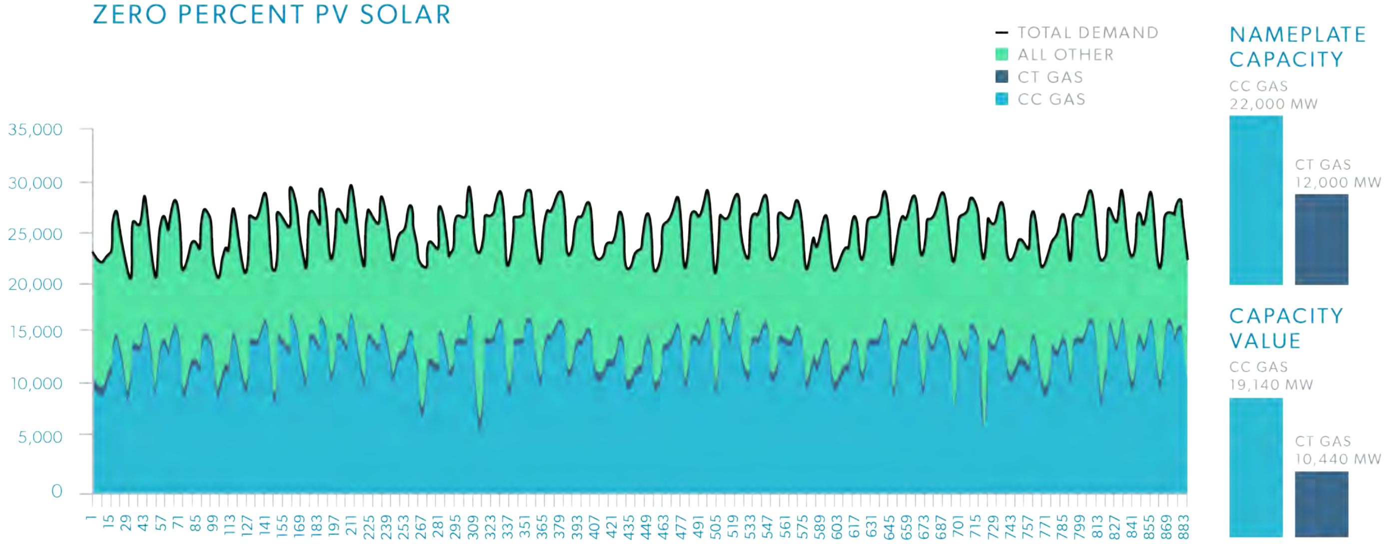
US TOTAL 2014 NET GENERATION (MWh)	2%	2%	2%	2%	2%	2%
4,065,964,000	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL GAS + PV
FLEET AVERAGE PV SOLAR	2%					
CV%	87.0%	87.0%	87.0%	N/A	28.9%	0.0%
SUMMER CAP (CV)(MW)	209,311	113,990	323,301	N/A	10,745	334,046
ENERGY MKT SHR%	23.7%	1.3%	25.0%	N/A	1.0%	27.0%
ANNUAL ENERGY (MWh)	968,784,059	52,706,941	1,016,491,000	N/A	81,319,280	1,097,810,280
CAPACITY FACTOR (%)	45.7%	4.6%	31.2%	N/A	25.0%	N/A
EST. NAMEPLATE CAP (MW)	240,587	131,023	371,610	N/A	37,132	408,742
FIXED COST ($/MWh)	$32.9	$222.1	$42.72	N/A	N/A	N/A

TECHNOLOGY	CC GAS	CT GAS	NAT GAS TOTAL	NEW PV	EXISTING PV	TOTAL
MARGINAL PV SOLAR ADDED	3%					
CV%	87.0%	87.0%	87.0%	16.2%		
SUMMER CAP (CV)(MW)	207,368	112,932	320,301	3,000	10,745	334,046
ENERGY MKT SHR%	22.8%	1.2%	24.0%	1.0%	1.0%	26.0%
ANNUAL ENERGY (MWh)	925,232,697	50,598,663	975,831,360	40,659,640	81,319,280	1,097,810,280
CAPACITY FACTOR (%)	44.3%	4.4%	30.3%	25.0%	25.0%	N/A
EST. NAMEPLATE CAP (MW)	238,354.52	129,807.00	368,162	18,566	37,132	423,860
FIXED COST ($/MWh)	$34	$229.2	$44.09	N/A	N/A	N/A
PERCENT OF GAS CAPACITY	64.7%	35.3%				
PERCENT OF GAS ENERGY	94.8%	5.2%				
MARGINAL PV SUMMARY						
NAMEPLATE CHANGE (MW)	(2,333)	(1,216)	(3,449)	18,566	N/A	15,117
IMPOSED COST PER UNIT OF GAS ($/MWh)	$1.1	$7.1	$1.37	N/A	N/A	N/A
IMPOSED COST PER UNIT OF PV ($/MWh)	$24.0	$8.8	$32.8	N/A	N/A	$32.8

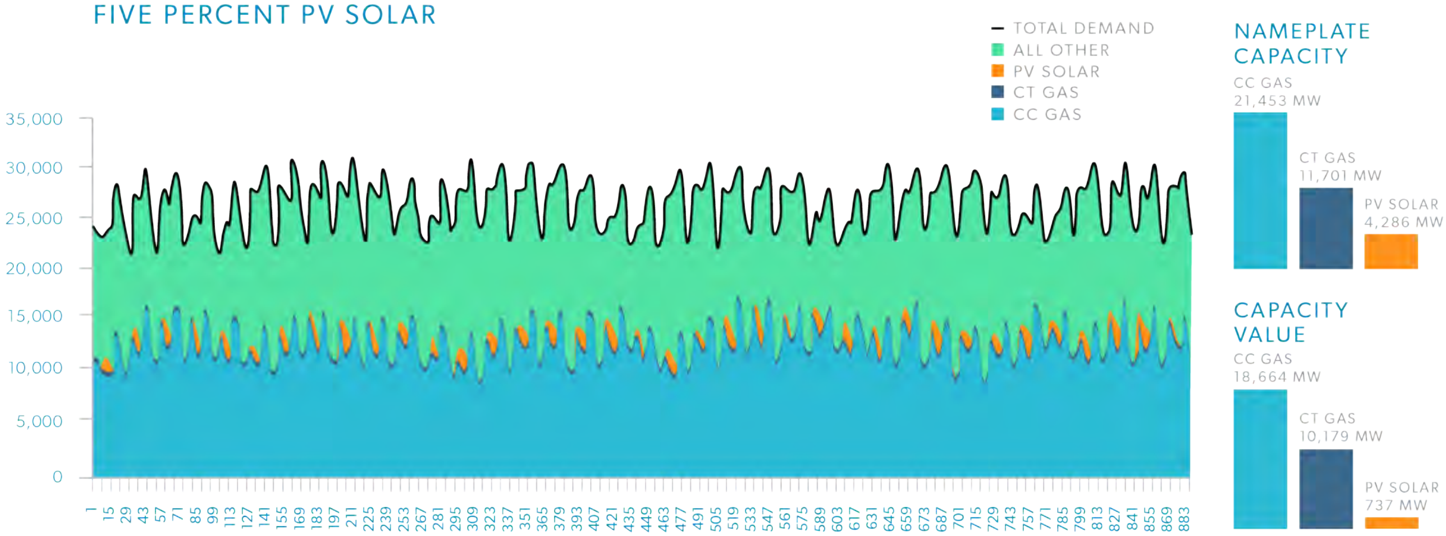
All Excel worksheets with formulas are available on request.[58]

Example Generation and Load Curves for CC and CT Gas With/Without PV Solar

CC AND CT GAS ON REGIONAL SYSTEM WITH ZERO PERCENT PV SOLAR



CC AND CT GAS ON REGIONAL SYSTEM WITH FIVE PERCENT PV SOLAR



The graphic above illustrates the energy, nameplate capacity and capacity value substitute of PV solar for natural gas CC and CT technologies considered in this report. The capacity value of the PV solar installed capacity is shown at 17.2% of nameplate capacity at 5% energy market share using the 75th percentile generation CV calculation methodology.

PV Declining Value as Replacement for Residual Peak Load Generation

We depict hourly electricity demand in CAISO for September 15th, 2014 as the wide blue line in figure 1 below. This was near annual peak demand day of that year. Demand net of several increments of PV capacity is shown in the thinner lines of various colors. The figure illustrates that PV contributes to a reduction of daily peak demand until PV capacity achieves a 5% energy market share. After that, peak demand net of previously operating PV occurs at hour 20 - after useful sunlight is no longer available.

As a result, additional PV capacity beyond 5% market share increasingly forces other dispatchable resources to stand down while it is sunny, without allowing those dispatchable resources to retire, as they are needed for system adequacy at hour 20. This lowers the CFs of the displaced dispatchable fleet technologies, raising their break-even fixed costs per MWh. We label this effect "imposed cost" of PV energy.

Two possibilities exist to avoid imposed cost at higher PV energy market shares. Excess electricity could be produced at hours just preceding peak load hours of the day, and converted to chemical or kinetic/potential energy (battery, compressed air or hydro pumped storage). The stored energy can then be converted back to electricity at hour 20. The other alternative is to force society to use less electricity at hour 20.

The former is prohibitively expensive, and is likely to remain so for most of the US due to infrastructure costs and conversion losses both into and out of the storage form of energy. The latter involves a paradigm shift away from the conventional idea that the electricity system is designed to serve consumers' convenience at whatever time energy consuming needs arise.

Figure 1A

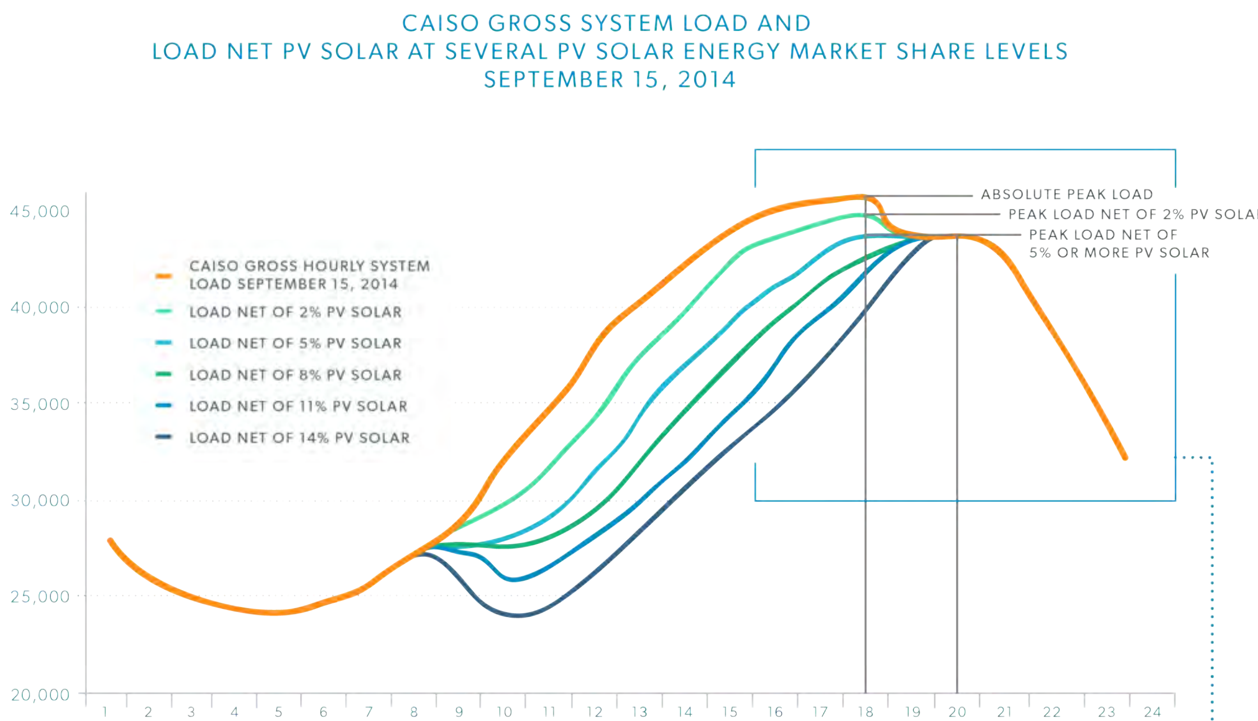


Figure 1B

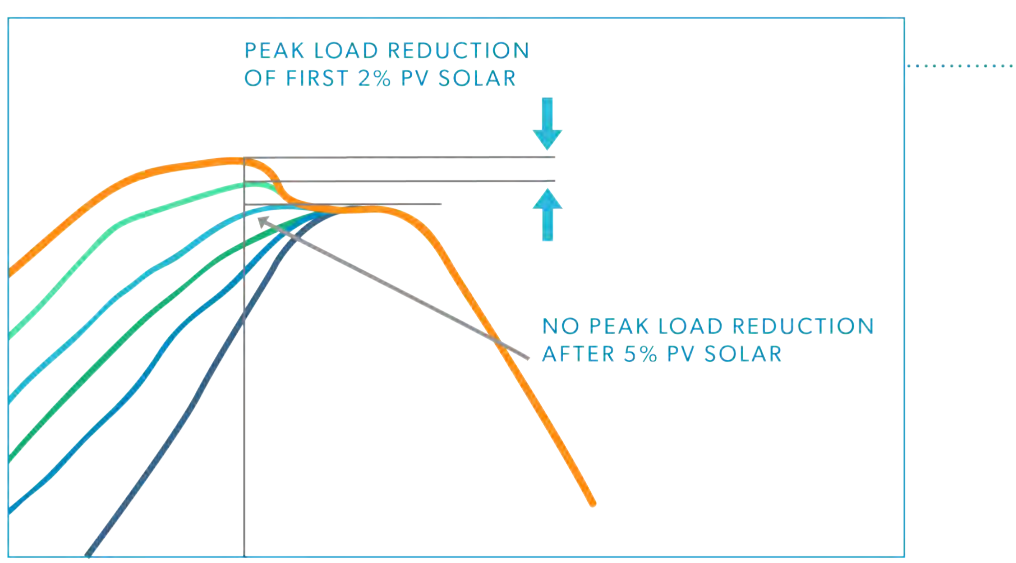


Figure 2

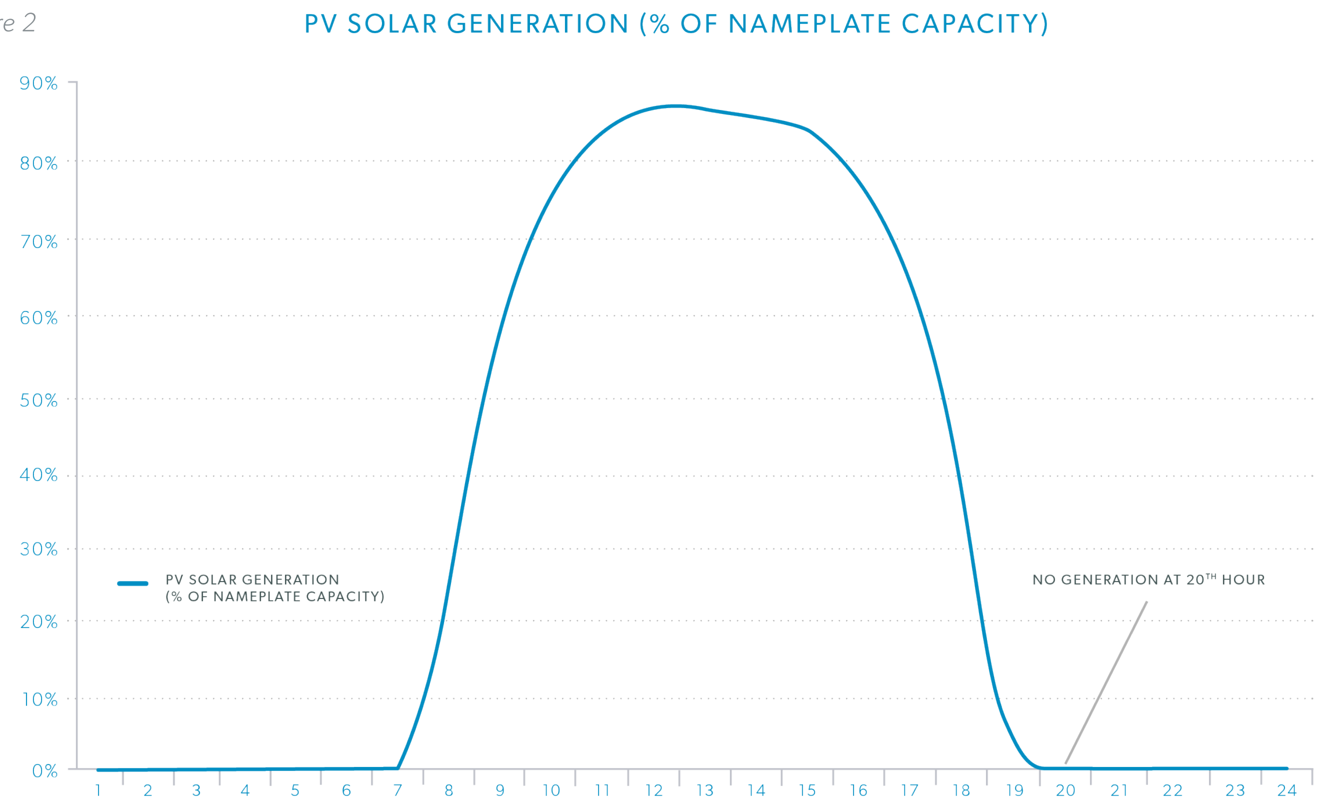


Figure 2 shows reported hourly PV generation in CAISO for September 15th, 2014, corresponding to the net load curves represented in figures 1A and 1B, above.

Figures 3 and 4 illustrate a full week of modeled hourly natural gas generation and PV generation.[59]

Figure 3

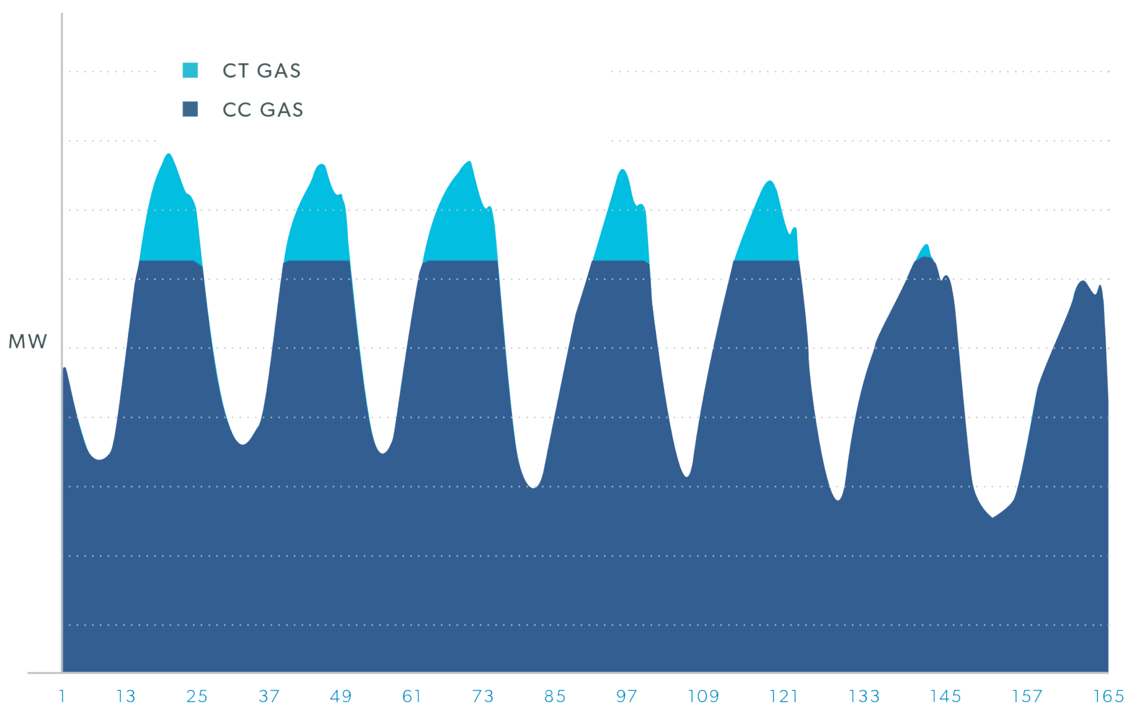
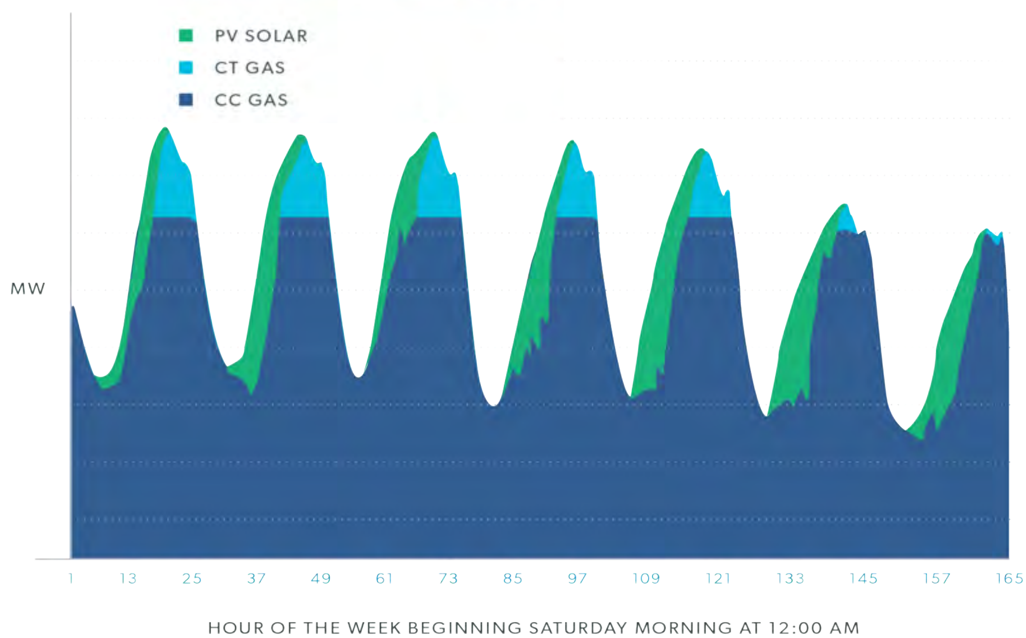


Figure 4

HOURLY LOAD MET BY CC GAS, CT GAS & PV SOLAR

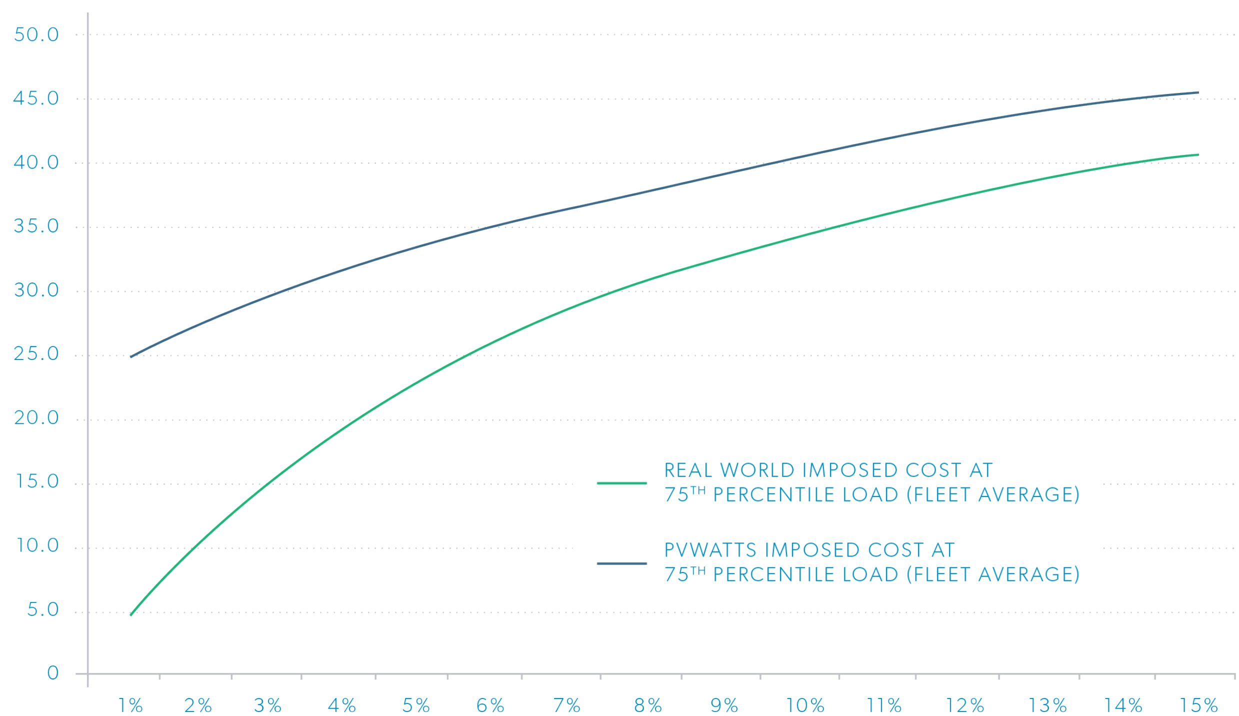


Levelized Cost of PV Calculations Using the US DOE's PVWATTS Model

We repeated the calculations of CV and imposed cost of PV using hourly outputs of the National Renewable Energy Laboratory's "PVWATTS" modeling software against CAISO hourly demand.

Calculated CVs using the PVWATTS data started lower and fell more sharply than for CAISO reported hourly PV generation data. This is not surprising, because the PVWATTS data had more uniform and slightly earlier evening decline than the real world data, causing it to miss evening residual peak loads sooner.

As a result, imposed costs were higher with modeled data than for real world data. The following graph expresses the differences in fleet average imposed cost between modeled generation and normalized CAISO published data at both 75% and 95% load confidence levels. Fleet average looks at the entire PV installed fleet rather than incremental capacity additions.



Appendix B Discussion

EIA forecasts new PV to have among the highest levelized cost of electricity of any new resource is 2020. With consideration of imposed cost included LCOE for PV is estimated to be over $150/MWh both in California and for the US. Moreover, new PV comes at an astronomical premium relative to existing dispatchable generators.

The total levelized cost electricity from capacity constructed which increases PV energy market share in CAISO from 5% to 6% is estimated at $151.7 MWh, which includes imposed cost of $40.6MWh at EIA's estimated 31% CF and at EIA's $111.1 LCOE estimate for NERC Region 20.[60]

On a national average basis, we estimate the levelized cost of electricity from PV in 2020 at 153.7 (2013 $/MWh) including imposed cost under the assumption PV solar is capturing three percent of energy market share in 2020. The estimated cost of electricity from new PV in CAISO ($151.7) represents a cost up to five times the average LCOE from least-cost existing dispatchable resources.

In regional systems such as CAISO where incremental additions of PV capacity offer no reduction in system peak loads, the minimum installed capacity of dispatchable generators required to meet peak system load cannot be reduced at all, while additional PV generation continues to drive down their CF while driving up their going-forward levelized costs.

We believe PV has lower than advertised guaranteed contribution to peak load fulfillment at increasing market penetrations when using CV calculations that consider PV's stand-alone capabilities (rather than metrics such as ELCC that "borrow" CV from other resources in the fleet). At 6% energy market share, which PV will achieve in CAISO in 2015, CV falls to zero while imposed costs alone rise above $40 per MWh, nearing recent year national average wholesale energy market clearing prices.

For states and regions where electricity cost is important to manufacturing competitiveness, caution should be exercised in setting renewable energy policies that induce PV capacity growth. Lawmakers and regulators should consider indirect costs such as imposed cost, which are additive to subsidy the costs of other policies that induce PV capacity expansion.

FOOTNOTES: APPENDIX B

[37] *http://www.eia.gov/forecasts/aeo/electricity_generation.cfm*

[38] *There are services available to help determine the causes of generator cycling such as those offered by Renewable Impacts, LLC. http://www.renewableimpacts.com/*

[39] *PJM and MISO both use a range of hours in certain "summer months." MISO staff admitted in a telephone conversation that this set of hours is recognized by MISO as inappropriate for determining accurate CV for PV.*

[40] *We do feel, however, that whatever "confidence level" is chosen for PV should be applied to all generation technologies in a calculation of the appropriate confidence level to maintain system adequacy.*

[41] *Net of generation from previously installed PV capacity*

[42] *Our analysis considers the highest 900 net load hours of 2014 in CAISO (net of existing PV). Of these hours, the 225th lowest PV generation hour equates to a 75% confidence level and the average of the lowest 225 PV generation hours equates to the MLQG confidence level. That is, marginal PV capacity will generate at or above its respective CV 75 percent of those 900 hours, respectively. In hours where PV fails to meet its capacity CV, other generating technologies will be required to achieve system adequacy, intruding into system reserve margin.*

[43] *Eventually all existing resources are replaced with new. Reporting the imposed cost on existing resources would mask the high imposed cost of low CV resources upon that eventuality.*

[44] In practice, PV from time to time may also displace generation from coal and hydro. It is also possible but less likely that PV might reduce the productivity of nuclear power plants. The major impetus for adding PV is to reduce the consumption of fossil fuels and their associated air emissions, so it is important to note that when PV displaces (run of river) hydro or nuclear generation, there is no reduction in fossil fuel consumption or the associated air emissions. For this reason we evaluate PV's impact on natural gas generation only.

[45] (10,435,675 MWhs / 8,760 hours in the year) / 31% CF

[46] We found that in CAISO, annual peak load hours often occurred outside of such a strict pattern of hours. We therefore gathered load and real PV generation data across CAISO for the highest 900 load hours of 2014 for this analysis. From those 900 hours we determined the net peak load hours (net of PV generation) at each 1% energy market share of PV from zero to 15% energy market share. From each result we sorted the 900 hours highest to lowest by load, and then based our evaluation on the highest 360 of 900 net peak load hours. http://www.pjm.com/~/media/documents/manuals/m21.ashx (Appendix B, Section B2, Line Items 7, 8, 9)

[47] http://www.eia.gov/electricity/data/state/plancapacity_annual.xls

[48] This is based in part on data reported by CAISO: http://www.caiso.com/Documents/2014AnnualReport_MarketIssues_Performance.pdf , in part on data from The US Energy Information Administration: http://www.eia.gov/electricity/data/eia860/xls/eia8602014.zip and in part on typical CFs reported for CC and CT gas facilities in other ISO/RTOs such as MISO and PJM. A breakdown of energy market shares and/or CFs for CT and CC gas was not evident on the CAISO public web site.

[49] CAISO reports natural gas held 41% energy market share for 2014 while PV held 5% energy market share for the same year. Because the initial scenario assumes 0% PV that scenario includes 46% energy market share for natural gas generation, or about 5% above what CAISO reports for natural gas fueled generation in 2014.

[50] The average of the CVs of the first five percent incremental additions of PV at 75% confidence level, shown in Table 3.

[51] Based on EIA Net Summer Capacity. http://www.eia.gov/electricity/annual/html/epa_04_02_a.html , http://www.eia.gov/electricity/annual/html/epa_04_06.html , http://www.eia.gov/electricity/annual/html/epa_04_03.html

[52] Estimated imposed cost per incremental unit of PV replacing existing CC gas and CT gas capacity instead of new would be less due to the lower estimated going-forward levelized fixed costs per MWh of existing CC gas and CT gas resources.

[53] https://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3

[54] 4.066 Billion MWhs times one percent divided by the quantity 25% capacity factor times 8,760 hours per calendar year. See: http://www.eia.gov/electricity/annual/html/epa_01_01.html

[55] ibid. (Footnote 6)

[56] Based on EIA Net Summer Capacity. http://www.eia.gov/electricity/annual/html/epa_04_02_a.html , http://www.eia.gov/electricity/annual/html/epa_04_06.html , http://www.eia.gov/electricity/annual/html/epa_04_03.html

[57] Because forecast US Total system load in 2020 is not much greater than US Total system load in 2014, and because imposed cost is a function of ratios and not scale, we provide this example using 2014 load, capacity and generation data rather than 2020. Modeling US Total generation forecast for 2020 would increase total generation, gas generation and capacity, PV generation and capacity all proportionally.

[58] Contact Tom Stacy at (937) 407-6258 or tfstacy@gmail.com

[59] These figures should not be construed to sum to the total system demand curve and are provided only to illustrate that if PV displaces only energy from CC and CT gas facilities, it does not reduce the maximum generation from the total gas fleet on some days of the year which might be the days which induce the highest gas generation days of a year.

[60] EIA provided a table of levelized costs for PV by NERC region via email. No URL has been found which reports these figures. Please contact the authors of this report for more information.

Will Solar Power Be at Fault for the Next Environmental Crisis?

IER instituteforenergyresearch.org/uncategorized/will-solar-power-fault-next-environmental-crisis

August 15, 2017

Solar panel waste will become a major issue in the coming decades as old solar panels reach the ends of their useful lifespans and require disposal. Last November, Japan's Environment Ministry issued a warning that the amount of solar panel waste Japan produces each year is likely to increase from 10,000 to 800,000 tons by 2040, and the country has no plan for safely disposing of it.[i] China has more solar power plants than any other country, operating roughly twice as many solar panels as the United States and also has no plan for the disposal of the old panels. In China, there could be 20 million metric tons of solar panel waste, or 2,000 times the weight of the Eiffel Tower, by 2050.[ii] California, another world leader in deploying solar panels, likewise has no plan for disposal, despite its boasts of environmental consciousness. Only Europe requires solar panel manufacturers to collect and dispose of solar waste at the end of their useful lives.[iii]

Environmental Issues with Solar Panels

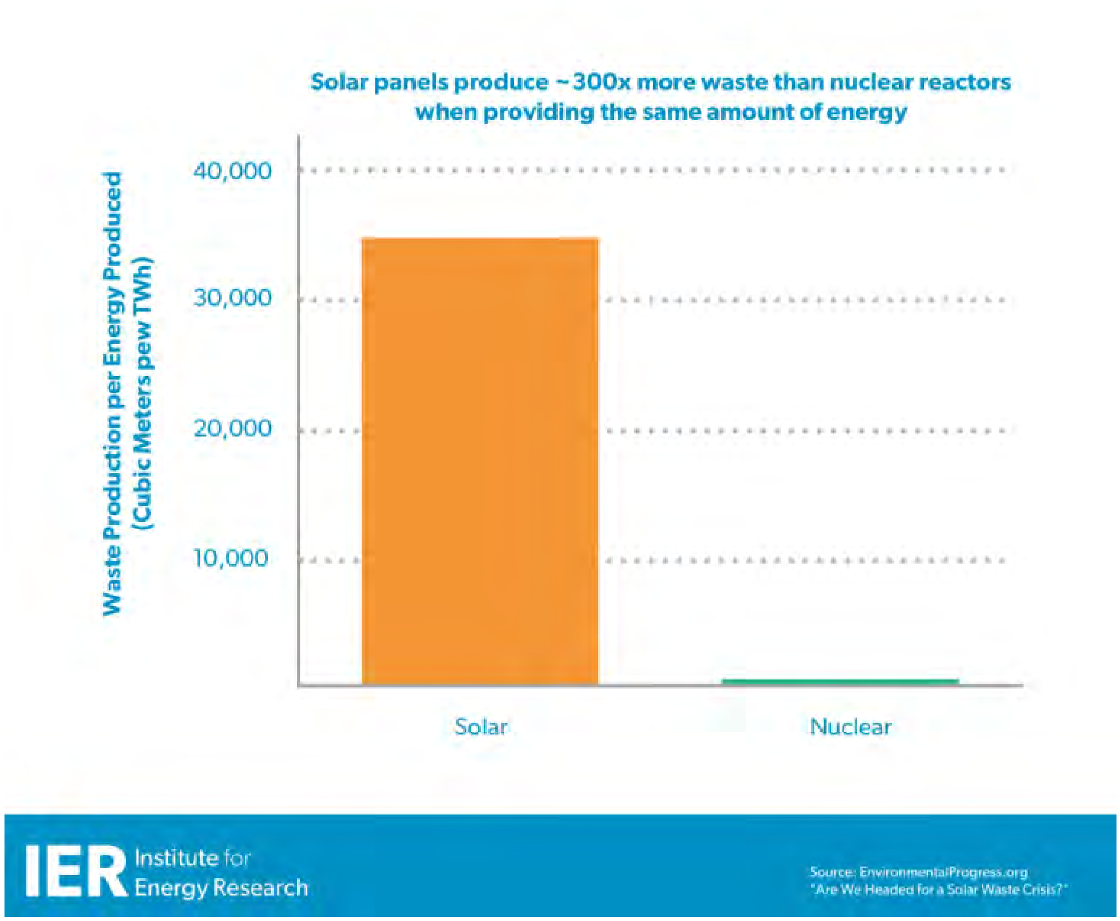
Solar panels are manufactured using hazardous materials, such as sulfuric acid and phosphine gas, which make them difficult to recycle. They cannot be stored in landfills without protections against contamination. They contain toxic metals like lead, which can damage the nervous system, as well as chromium and cadmium, known carcinogens that can leak out of existing e-waste dumps into drinking water supplies.

A study published last December determined that the net impact of using solar panels actually temporarily increases carbon dioxide emissions, because of the amount of energy needed in the construction process. But, because newer solar panels have a smaller adverse environmental impact than older models and as their time of operation increases to mitigate the construction effects, some scientists believe the solar industry could develop a net positive environmental impact by 2018.[iv]

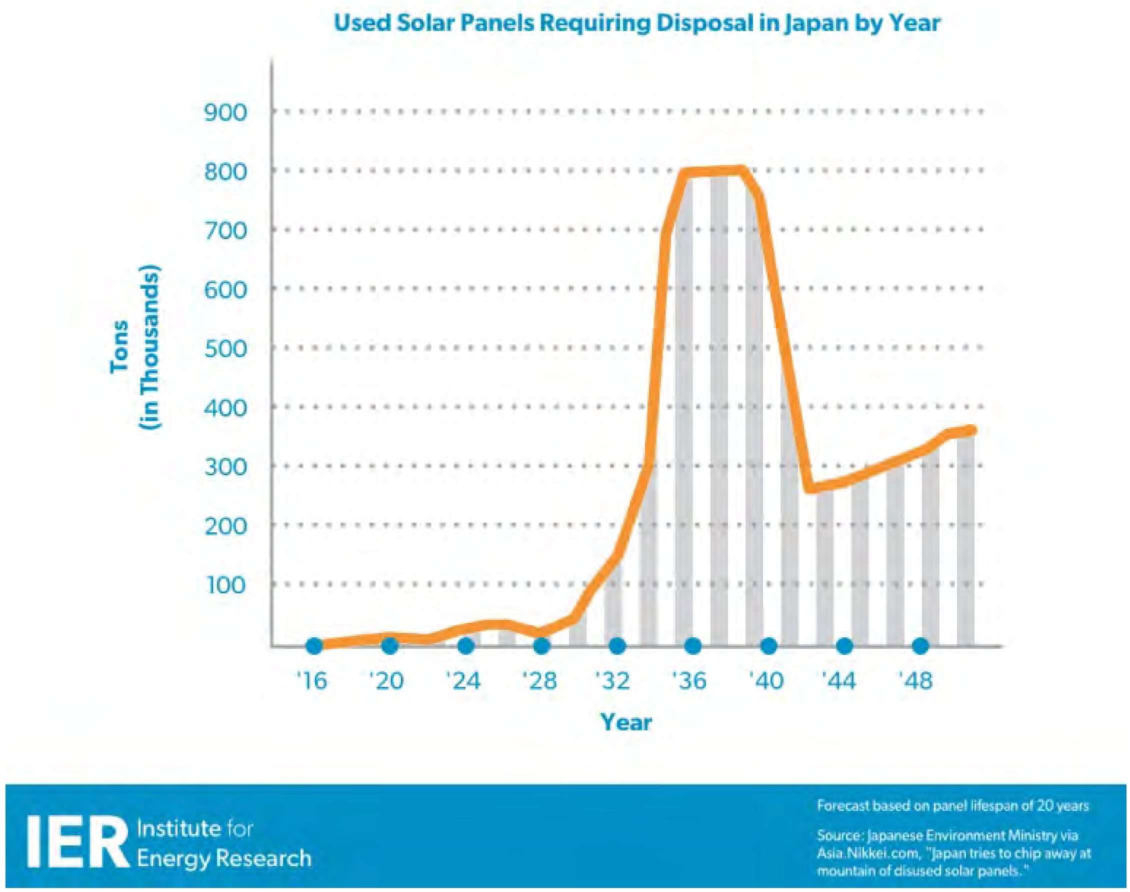
According to federal data, however, building solar panels significantly increases emissions of nitrogen trifluoride (NF3), which is 17,200 times more potent than carbon dioxide as a greenhouse gas over a 100-year time period.[v] NF3 emissions increased by 1,057 percent over the last 25 years. In comparison, U.S. carbon dioxide emissions only increased by about 5 percent during that time period.

Regardless, the waste disposal issues regarding solar panels are enormous. According to an analysis by Environmental Progress, solar panels create about 300 times more toxic waste per unit of electricity generated than nuclear power plants. For example, if solar and nuclear produce the same amount of electricity over the next 25 years that nuclear produced in 2016, and the wastes are stacked on football fields, the nuclear waste would reach 52 meters (the height of the Leaning Tower of Pisa), while the solar waste would reach 16 kilometers (the height of two Mt. Everests).

Further, while nuclear units can easily operate 50 or 60 years, solar panels have relatively short operational lifespans (20 to 30 years), so their disposal will become a problem in the next few decades. While nuclear waste is contained in heavy drums and regularly monitored, very little has been done to deal with solar waste. Solar waste outside of Europe tends to end up in a large stream of electronic waste.



A report determined that it would take 19 years to recycle all of the solar waste that Japan is expected to produce by 2020. By 2034, the annual waste production will be 70 to 80 times larger than that of 2020. (See graph below.) The projected annual peak of 810,000 tons of solar waste in Japan is equivalent to 40.5 million panels. To dispose of that amount of solar waste in a year would mean getting rid of over 110,000 panels per day.[vi]



Conclusion

Solar photovoltaic energy is not as environmentally conscious a choice as many think it is. Besides being an intermittent source of energy and more expensive than traditional technologies[vii], it has serious waste disposal issues that few countries are tackling. The hazardous materials used in their construction are not easy to recycle and can contaminate drinking water if solely discarded with other electronic waste.

---

[i] Environmental Progress, Are We Headed For a Solar Waste Crisis?, June 21, 2017, http://www.environmentalprogress.org/big-news/2017/6/21/are-we-headed-for-a-solar-waste-crisis

[ii] Daily Caller, Old Solar Panels Causing An Environmental Crisis In China, August 1, 2017, http://dailycaller.com/2017/08/01/old-solar-panels-causing-an-environmental-crisis-in-china/

[iii] Solar Waste/ European WEEE Directive, http://www.solarwaste.eu/faq/

[iv] Daily Caller, Solar Power Actually Made Global Warming Worse, Says New Study, December 7, 2017, http://dailycaller.com/2016/12/07/solar-power-actually-made-global-warming-worse-says-new-study/

[v] Daily Caller, Solar Panels Increased Emissions Of A Gas 17,200 Times More Potent Than CO2, March 1, 2017, http://dailycaller.com/2017/03/01/solar-panels-increased-emissions-of-a-gas-17200-times-more-potent-than-co2/

[vi] Nikkei Asian Review, Japan tries to chip away at mountain of disused solar panels, November 8, 2016, https://asia.nikkei.com/Tech-Science/Tech/Japan-tries-to-chip-away-at-mountain-of-disused-solar-panels?page=1

[vii] Institute for Energy Research, The Levelized Cost of Electricity from Existing Generation Resources, July 2016, https://www.instituteforenergyresearch.org/wp-content/uploads/2016/07/IER_LCOE_2016-2.pdf

Controversial solar project is back on the table

Published February 16. 2020 8:00PM | Updated February 16. 2020 10:11PM

By **Mary Biekert** Day staff writer

Waterford — The developers who proposed a 75-acre solar project off Oil Mill Road that state officials rejected two years ago have asked the state to reconsider its decision.

Opponents, including town leaders and a local environmental group, say they are again ready to speak against the project and remain concerned about its potential environmental impacts. The developers, though, say they've revised the project to better address those concerns.

Originally proposed by Greenskies Clean Energy in 2018, the proposal's application was denied by the state Siting Council after the town and Save the River-Save the Hills raised concerns ranging from the potential impact on wildlife to clearcutting dozens of acres of forest.

Greenskies, a Connecticut company co-founded by former state Sen. Art Linares, a Republican from Westbrook, was acquired in December 2017 by Sunnyvale, Calif.-based Clean Focus Yield Limited.

Greenskies submitted a request to reopen the effort in late January, as well as a new petition outlining details of the project. The Siting Council is scheduled to decide Feb. 27 on whether to reopen Greenskies' application and hold a public hearing on the plan.

Greenskies' petition argues that its developers and newly hired engineering consultants VHB of Massachusetts have carefully addressed the issues brought forward by both the town and STR-STH by redesigning the project to lessen the impact on wildlife and the impact of a poor stormwater management design.

The new plan decreases the size of the project from 55,692 solar panels to 45,976. According to Greenskies VP of Marketing Jeff Hintzke, the project would generate 16 megawatts of energy, which can power more than 3,000 homes, helping Connecticut meet its emissions-reduction targets of 45% below 2001 levels by 2030.

“We have been going through what I would say is a very rigorous process,” Hintzke said. “One of the reasons we are petitioning is that we believe we have gone above and beyond what's required to get approval this time. If we didn't think we would get approval, we wouldn't bother.”

Over the next 35 years, the panels would sit on a 152-acre parcel owned by Rosalie Irene Maguire and Todd Carl Willis. The land is located between the Oil Mill and Stony brooks, both of which are “critically important” to maintaining the health and functions of the surrounding watershed area, according to town officials. Both brooks drain into what they've described in 2018 letters sent to the Siting Council as “the already impaired Niantic River.”

First Selectman Rob Brule wrote to the Siting Council last week requesting it hold a public hearing on the proposal. The town did not comment on the contents of Greenskies' application in that letter, but Brule wrote that town officials would if Greenskies' application were reopened.

In the letter sent to the Council in 2018 advising against the project, Town Planner Abby Piersal wrote, “Maintaining conditions in the tributary watersheds that support the biodiversity and water quality in these streams is a critical concern of the town.”

Protecting those brooks is paramount, said Southbury-based civil engineer Steve Trinkaus, who has worked closely with the STR-STH group to raise awareness statewide about the importance of well-planned stormwater mitigation techniques associated with solar installations.

Trinkaus said he believes Greenskies' new proposed stormwater plan is still inadequate and "has not materially changed from the original application."

Trinkaus argued that the newly submitted plans "are interchangeable" with those Greenskies submitted to the Siting Council in 2014 when proposing to build a 24-acre solar project in East Lyme, a third of the size of the project proposed in Waterford.

"It's a disaster waiting to happen," Trinkaus said, explaining that Greenskies has not adequately planned for the amount of runoff that could be produced by the project and claimed the company is not planning to follow standard erosion-control guidelines.

In a recent letter that STR-STH submitted to the Siting Council, Trinkaus and STR-STH Vice President Deb Moshier-Dunn argue that Greenskies has a particularly "poor track record of creating solar installations that don't have a substantial adverse environmental effect in the state." The letter specifically points to the company's history on its 24-acre East Lyme site, built in 2014 by a Greenskies Renewable subsidiary and which is known as the Antares Solar Field.

That same year, East Lyme resident John Bialowans Jr.'s property, which sits downstream from the Antares Solar Field on Walnut Hill, was heavily damaged by large amounts of stormwater runoff coming from the solar installation, he claims, destroying stream habitats for trout.

"The (new) plans are still grossly underestimating the amount of runoff that will be generated by the panels – just like they did in the East Lyme construction disaster," wrote Trinkaus and Moshier-Dunn. "STR-STH is very disappointed that the Petitioner has not studied the stormwater failure that occurred in East Lyme at their Antares Solar Farm. Much can be learned from reviewing the damage done there."

Don Danilla, a STR-STH fisheries biologist and former environmental consultant for Dominion, agreed, saying, "We are not against green power and we're not against solar energy power. I put solar panels on the roof of my house last year. I just think there has been a big rush to develop these multiple megawatt projects in Connecticut, and its easy for them to find undeveloped land, clear cut forest, take over productive farmlands and put up thousands and thousands of solar panels. And we just don't think this is the right place for them."

Danilla, also an East Lyme representative on the Niantic River Watershed Committee, worried how eel grass in the Niantic River, which support scallops and fish, might be affected by increases in stormwater runoff that might come rushing down both Oil Mill and Stony brooks. He noted that additional runoff could bring increased nitrogen levels and other organic matter that could "smother the eel grass."

"It's a unique estuary in Connecticut and we want to keep it healthy," Danilla said. "This is a very large development, very close to the Niantic River. And this thing is going to be here for 35 years."

"But this is the problem, we have to rely on our state agencies," he continued. "It takes a lot of things out of local control. We have to hope that DEEP will ensure these guys are doing the right thing."

According to state statutes, the Siting Council has final jurisdiction over whether the project can proceed. With council approval, Greenskies would not need to obtain any land-use permissions from the town. Though the Siting Council does evaluate stormwater management plans as part of its review process, stormwater management falls exclusively under DEEP's jurisdiction through a General Permit process, Siting Council Director Melanie Bachman said.

The project developer is required to submit an application for a General Permit to DEEP prior to commencement of construction if the Siting Council approves the project, she said.

Responding to worries brought up by STR-STH, Hintzke, speaking on behalf of Greenskies, said, “We are following all the guidelines and regulations around how DEEP has specified for (stormwater management).” He added that Greenskies has been meeting with DEEP employees and curbing its project to meet updated, stricter stormwater regulations. “We are a local company — almost all of our employees live in Connecticut and typically the employees that work here are environmentally conscious and very much want to support local environmental causes. And that includes everything from stormwater runoff to renewable energy, as well as conserving watersheds. We don’t want to slash and burn and cut down trees for no reason. We are local, and our workers are local, and we want to do the best we can for our local community.”

Siting council will consider scaled back Waterford solar project

Published March 02. 2020 7:09PM By **Mary Biekert** Day staff writer

Waterford — The Connecticut Siting Council is again considering an application to build a 75-acre solar project off Oil Mill Road after developers submitted revised plans.

The new plan reduces the size of the project by 23 acres, eliminates more than 9,600 of the panels and according to the developer, improves the project's stormwater management system.

Two years ago, state officials denied an application to build the array after town leaders and members of the Save the River-Save the Hills environmental group raised concerns about the environmental fragility and location of the project and its stormwater management plan.

The developer, GRE Gacrux LLC, a subsidiary of the Greenskies Power Group, now says it has addressed those concerns.

GRE Gacrux asked the Siting Council in January to reopen its application, proposing the project now be located over 75 acres which is part of a larger 152-acre site owned by Rosalie Irene Maguire and Todd Carl Willis between the Oil Mill and Stony brooks.

The developer has also stated it has hired VHB, an engineering firm from Massachusetts, to revise the application to decrease its impact on wildlife and improve the stormwater management design.

The new plan also proposes to decrease the size of the project from 55,692 solar panels to 45,976. According to Greenskies VP of Marketing Jeff Hintzke, the project would generate 16 megawatts of energy, which can power more than 3,000 homes, helping Connecticut meet its emissions-reduction targets of 45% below 2001 levels by 2030.

The array was originally brought forward to the siting council in 2018 by Greenskies Clean Energy, a Connecticut company co-founded by former state Sen. Art Linares, a Republican from Westbrook, before it was acquired in December 2017 by Sunnyvale, Calif.-based Clean Focus Yield Limited.

In its most recent letter submitted to the Siting Council opposing the project, Save the River-Save the Hills said the installation would be detrimental to wildlife, the Oil Mill and Stony brooks and the forest that would have to be clearcut for the installation. Both brooks are considered "critically important" to maintaining the health and functions of the surrounding watershed area, according to STR-STH and the town, as they drain into the Niantic River.

STR-STH Vice President Deb Moshier-Dunn argued that Greenskies has a "a bad track record" when it comes to developing solar projects, pointing to a East Lyme project developed by a company subsidiary in 2014.

Because of a deficient stormwater management system, resident John Bialowans Jr. alleged his property, which sits downstream from the Walnut Hill Road development, was damaged by large amounts of stormwater runoff, destroying stream habitats for trout.

Bialowans sued in New London Superior Court in 2017, but a judge dismissed the case last December.

Moshier-Dunn said she is worried what a potentially ill-planned stormwater management system and clearcutting dozens of acres of land could mean for the health of the brooks and the river, which lies just 4,000 feet downstream from the proposed development. Steve Trinkaus, a civil engineer hired by STR-STH, has said he does not believe Greenskies has adequately calculated the amount of stormwater runoff that would be generated by the development.

GRE Gacrux attorney Lee Hoffman wrote in a Feb. 26 letter to Siting Council Executive Director Melanie Bachman that STR-STH's claims are baseless and "troubling."

"The vast majority of the statements made in its February 12, 2020, letter are unsupported and in many instances are incorrect," Hoffman wrote. "… Suffice it to say that GRE disagrees with what has been proffered by Save the River-Save the Hills, and GRE will set the record straight if the Council sees fit to re-open the Petition."

Waterford has not yet submitted comments to the Siting Council on the matter but First Selectman Rob Brule said town officials would if the application is reopened.

A public hearing on the matter has been scheduled for March 31 at the Waterford Town Hall Auditorium. An evidentiary session, giving the involved parties an opportunity to present their positions is scheduled for 3 p.m. followed by a public comment section at 6:30 p.m.

East Lyme Project Walnut Hill Project Pics - Stormwater Failure

Figure: 2014 Photos of erosion in East Lyme, Connecticut solar installation on Walnut Hill Road

TITLE: Solar Array Construction in the Niantic River Watershed – Turning Native Trout Streams into Drainage Ditches.

Deborah Moshier-Dunn and John P. Jasper

Save the River-Save the Hills would like to inform the public about an ongoing threat to the water quality of the Niantic River and two of its major tributaries (Oil Mill Brook and Stony Brook) in Waterford. The developer of a proposed solar array installation which was "denied without prejudice" by the Connecticut Siting Council (CSC) last December largely because of the negative effects it would have on the two native trout streams on each side of it, has indicated they will be moving forward with the installation. A “denial without prejudice” allows the developer to return with another plan under the same request for proposal. We feel it is important to write this article to let the public know since no public hearing was held for this project. The public has a right to know because if this project is allowed to move forward, prospective adverse impacts will detrimentally affect not only the water quality of the adjacent brooks, but the Niantic River and ultimately the Long Island Sound as the tidal river drains directly into it.

The current proposal is to install 55,000 solar panels on approximately 90 acres of hilly terrain off Oil Mill Road in Waterford, Connecticut. Installing a solar array of this size on the hilly terrain between two streams that currently support native brown and brook trout is irresponsible development. The developer already has a record of destroying a tributary to the Niantic River in East Lyme (see photo of East Lyme watershed above) resulting in a lawsuit against the developer by downstream landowners. Looking at the photographs of the devastation after sequential two-inch rain events on the Walnut Hill Road solar installation gives a daunting forecast for the proposed Waterford site which is three times the size (*viz*., approximately 90 acres). The CSC wisely denied the developer's petition to develop the Waterford site because it felt the project <u>would</u> adversely affect the environment. The hardscape of such a large array would very likely cause huge amounts of runoff on both sides of the property and the runoff needs to be treated like it would for any other large building. These are not "solar fields”, they are industrial structures made of glass, metal and concrete which are installed on soil that has been physically compacted during the installation process. As seen in at the East Lyme site, these ground-mounted solar arrays have a record of destroying water quality around them. The stormwater systems in the solar installations in East Lyme were inadequate to handle the actual volume of runoff generated. The proposed site in Waterford uses the same faulty engineering and will likely cause similar issues – on a scale three times larger than the one in East Lyme, adversely affecting two different native-trout-stream tributaries to the Niantic River. The Waterford site is a mere 4,000 feet from the Niantic River. There is no margin for error for proper stormwater mitigation. The river will suffer if this project goes forward.

In 2014, the design of the solar array installation in East Lyme involved marked earth disturbance over an approximately 30-acre area. Topsoil was stripped and removed from the site and does not appear to have been replaced after mass grading was performed. Site disturbance compacted the native soils to such a degree that rainfall even from the grassed areas runs off and does not infiltrate into the soil. The engineering design incorrectly considered the solar panels in the array to be "pervious" and thus grossly underestimated the volume of runoff generated from the site. Even after completion, increased runoff volumes continue to cause adverse impacts to the stream channel morphology on the unnamed brook which runs into Cranberry Meadow Brook and ultimately the Niantic River. These same issues existed in a ground-mounted solar installation in Pomfret which has resulted in the Connecticut Department of Energy and Environmental Protection (CT DEEP) fining the developer $575,000 for non-compliance with the DEEP General Permit and the resulting destruction to wetlands by "sediments from the Site going off-site and blanketing thousands of square feet of adjoining wetlands…" (*viz*., CSC Consent Order COWRSW18003). A much smaller proposed solar installation in Killingworth was totally denied approval this past May with the CSC citing water quality issues as the main reason for denial. Current engineering standards used for ground-mounted solar are inadequate here because they are based on the incorrect assumption that the solar arrays are on liquid pervious sites. In most cases, however, they are not. The construction of ground-mounted solar arrays creates an *impervious* site and should be required to have Low Impact Development (LID) engineering to protect the surrounding wetlands and water courses. And it should not be allowed at all in a core forest surrounded by trout streams.

Also, cutting 90 acres of core forest to install 55,000 solar panels - thus replacing nature's free carbon recycling and storage with hardscape, metal and glass - does NOT result in a net decrease in carbon emissions in New England. The conversion of active cropland, farm meadow, and forests to a solar array is environmentally irresponsible as these green areas are very effective carbon sinks. The vegetations takes in carbon dioxide to grow and release oxygen to the air. Carbon is sequestered in the woody material and in the soil in these areas and remain there unless disturbed for decades to millennia. In 2017 the Connecticut State Legislature passed a law that effectively bans cutting core forest to put in solar arrays. PA 17-218—SB 943 states: "The act requires the DEEP commissioner, when considering proposals received after July 1, 2017 in response to certain energy-related solicitations, to consider (1) their environmental impact, including the impact on prime farmland and core forests, and (2) the reuse of sites with limited development opportunities, such as brownfields and landfills." Unfortunately for the Waterford forest, the developer petitioned the CSC on a request for proposal that was applied for prior to the new law. That is the only reason this proposal to cut down a core forest has been allowed to continue. We recommend that it be stopped.

While the installation of solar arrays has a seemingly appealing environmental and certainly federal-tax abatement appeal, each solar panel only converts only about 26% of the sun's energy into power every year, with this efficiency decreasing by roughly 0.5% per year. Additionally, when the lack of sunny days in Connecticut is accounted for on a yearly basis, the power generated by one of these large arrays is only 22% of the stated power output. Finally, there is currently no present method for the recycling of solar panels. Panels, with all their toxic materials, simply end up in landfills.

Brook and brown trout populations are on the decline in Connecticut because of habitat destruction such as siltation caused by solar field installation. Let's protect those we have left and not turn them into drainage ditches. Let's be Smart about Solar and put solar panels where they belong - on already developed property like a large warehouse rooftop or even a landfill that's been properly capped. Let's keep the forests surrounding our rivers thriving so we can keep our rivers clean. #SmartSolar

Deb Moshier-Dunn is the Vice President of Save the River-Save the Hills, Inc. John P. Jasper is a Board Member of the Niantic River Water Committee, and a member of both the Nitrogen Working Group and Trout Unlimited.

Solar project poses threat to Niantic River

8
3

Published September 17. 2018 12:01AM

Fred Grimsey and Deb Moshier Dunn

Save the River Save the Hills (STRSTH) has recently discovered that the 55,000 solar-panel project in Waterford is proposed to be on 93 acres in a currently forested area between two tributaries − Oil Mill Brook and Stony Brook − to the Niantic River, not at the original site of the old Waterford Airport or the landfill. While we are a strong supporter of renewable solar energy, we feel that this site off Old Mill Road in Waterford is an inappropriate place to install it.

Waterford has spent taxpayer's money to study the tributaries to the Niantic River and to create plans to protect the water quality of this estuary. In 2009, the town paid for the creation of The Stony Brook Watershed Management Plan. In 2006, the state of Connecticut, with the help of the four towns in the watershed and some Clean Water Act federal monies, produced the Niantic River Watershed Protection Plan. Both documents contain guidelines and recommendations to reduce stormwater runoff, the number one cause of pollution in the Niantic River. The proposed plans supporting the petition for the solar installation ignore these two plans.

STRSTH has officially requested to be an intervener in the solar company's Petition for a Declaratory Ruling from the Connecticut Siting Counsel to start the work on the installation this fall without a public hearing or environmental review. We have hired a professional engineer to review the plans of the proposed installation and have confirmed our fears that the company proposing the solar project has not learned from the devastating results from the installation they created on Walnut Hill Road in East Lyme. (In 2014, the East Lyme site discharged silt and destroyed area wetlands on another tributary to the Niantic River. There is currently a lawsuit from downstream property owners against the same company.) The Waterford plans do not have sufficient stormwater mitigation built into the construction or the final product. STRSTH has worked too hard for too long on water quality in the Niantic River to allow it to be potentially destroyed by stormwater runoff from this proposed solar farm.

It makes no sense to deforest an area and degrade water quality in the Niantic River to provide solar energy. We have been fighting for 15 years to keep development from happening in the Oswegatchie Hills which overlook the Niantic River, so that the ecosystem of the river won't be destroyed. This solar installation, as proposed, could do the same damage as developing the Hills, especially given the track record of the company in East Lyme.

Save the River Save the Hills is for solar energy, but not at the expense of water quality. This should not be a trade-off. The town and the state should find an area that creates a win for everyone. #SMARTSOLAR

Fred Grimsey is president of Save the River Save the Hills and Deb Moshier Dunn the vice president.

EXHIBIT B
(responsive to Interrogatory #2)

Curriculum Vitae of Donald J. Danila

Home & Present Work Address: 24 Pattagansett Drive, East Lyme, CT 06333

Place and Date of Birth: Hartford, Connecticut; November 4, 1947

Education: B.S., Cornell University, 1969, Biological Sciences (concentration in Ecology and Systematics)
M.S., Rutgers University, 1978, Biology

Professional Work Experience:

2011-16	Senior Environmental Scientist, ASA Analysis & Communication, Inc., East Lyme, CT
2009-10	Biological Consultant, Dominion Env. Laboratory, Millstone Power Station, Waterford, CT
2001-2009	Biologist III, Dominion Environmental Laboratory, Millstone Power Station, Waterford, CT
1986-2000	Senior Scientist, Northeast Utilities Environmental Laboratory, Millstone Power Station
1980-86	Scientist, Northeast Utilities Environmental Laboratory, Millstone Power Station, Waterford, CT
1979-80	Senior Research Biologist, Ichthyological Associates, Inc. (IA), Absecon, NJ
1978-79	Project Director, Oyster Creek and Forked River Generating Stations Ecological Studies, IA, Forked River, NJ
1978	Assistant Project Director, Oyster Creek Generating Station Ecological Studies, IA., Forked River
1976-78	Fish Section Leader, Oyster Creek Generating Station Ecological Studies, IA., Forked River
1972-76	Research Biologist, Atlantic Generating Station Ecological Studies, IA, Absecon, NJ
1969-71	Officer, United States Navy, *USS Maury* (AGS-16), Honolulu, Hawaii and *USS Diamond Head* (AE-19), Norfolk, Virginia
1968 (summer)	Junior Research Biologist, Delaware River Ecological Studies, IA, Middletown, DE
1967 (summer)	Junior Research Biologist, Peach Bottom-Muddy Run Ecological Studies, IA, Holtwood, PA

Professional or Industry Associations:

1967-present	Member, American Fisheries Society (AFS)
1996-2017	Board of Directors (Publicity Officer), Southern New England Chapter of AFS [SNEC-AFS]; presented Chapter's Irwin Alperin Outstanding Member Award in June 2000; presented Special Achievement Award in January 2008; presented Award of Excellence in June 2011.
1988-92	Co-Principal Investigator for Electric Power Research Institute Winter Flounder Key Species Program (in conjunction with Oak Ridge National Laboratory, Oak Ridge, TN)
1989-present	Member, Fisheries Advisory Council to the Connecticut Department of Energy and Environmental Protection (CT DEEP) representing SNEC-AFS; Recording Secretary of FAC during 2001-2009
2010-present	East Lyme representative to Niantic River Watershed Committee; volunteer - Latimer Brook water quality monitor and Rapid Bioassessment Volunteer stream biota monitoring
2015-present	Board of Selectman appointed member, East Lyme Commission for the Conservation of Natural Resources

Other Voluntary Activities:

Board of Directors, Friends of Oswegatchie Hills Nature Preserve (2013-present); Stewardship Committee; represent
this body on the Nitrogen Work Group (a body set up as a condition of the Millstone Power Station National Pollutant Discharge Permit)

Flatfish Biology Conference Steering Committee (1986-2014)

Coastal Connecticut Cornell Club, Board of Directors (2008-present); Treasurer (2011-present)

Relevant Work Experience and Knowledge:

Identification and ecology of freshwater and marine fishes

Life history and age and growth studies of fishes

Comprehensive studies of fishes and macroinvertebrates to determine effects of proposed or operating electrical generating stations and petrochemical plant operations on aquatic organisms

Population abundance studies of fishes and macroinvertebrates

Ichthyoplankton power plant entrainment and field studies of abundance and distribution

Power plant thermal plume studies and effects of temperature on aquatic organisms
Movements and migratory behavior of fishes
Screening and water intake studies, including impingement survival studies
Hydroelectric station FERC licensing studies and report preparation
Statistical analyses of biological data using SAS and other computer-based software
Technical report and scientific paper writing and editing
Provided expert testimony in civil court and CT DEEP NPDES Permit proceedings for Millstone Power Station

Scientific Publications and Presentations at Professional Meetings

Danila, D.J. 1978. Age, growth, and other aspects of the life history of the winter flounder, *Pseudopleuronectes americanus* (Walbaum), in southern New Jersey. M.S. Thesis. Rutgers University, New Brunswick, NJ. 79 pp.

Danila, D.J., and M.J. Kennish. 1982. Tagging study of winter flounder (*Pseudopleuronectes americanus*) in Barnegat Bay, New Jersey. Pages 759-764 *in* Proc. Ocean 82 Conf., Boston, MA.

Kennish, M.J., D. J. Danila and R. J. Hillman. 1982. Assessment of blue crab, *Callinectes sapidus*, in Barnegat Bay, New Jersey. Bull. N.J. Acad. Sci. 27:59-71.

Kennish, M.J., J.J. Vouglitois, D.J. Danila, and R.A. Lutz. 1984. Shellfish. Pages 171-200 *in* M.J. Kennish and R.A. Lutz, eds. Ecology of Barnegat Bay, New Jersey. Lecture Notes in Coastal and Estuarine Studies 6, Springer-Verlag, New York.

Tatham, T.R., D.L. Thomas, and D.J. Danila. 1984. Fishes of Barnegat Bay, New Jersey. Pages 241-280 *in* M.J. Kennish and R.A. Lutz, eds. Ecology of Barnegat Bay, New Jersey. Lecture Notes in Coastal and Estuarine Studies 6, Springer-Verlag, New York.

Danila, D.J., and J.A. Castleman. 1984. Population studies of the Niantic River, Connecticut stock of winter flounder (*Pseudopleuronectes americanus*). Poster presented at the 114th Annual Meeting of the American Fisheries Society, Aug. 12-16, 1984, Ithaca, NY.

Danila, D.J., and E. Lorda. 1985. Mortality of post-larval juvenile winter flounder in the lower Niantic River, Connecticut during 1983 and 1984. Proceedings of the 1985 Northeast Fish and Wildlife Conference, May 5-8, 1985, Hartford, CT.

Danila, D.J. 1986. Abundance, growth, and mortality of juvenile winter flounder in the lower Niantic River, CT from 1983-1986. Workshop on Winter Flounder Biology, Dec. 2-3, 1986, Mystic, CT.

Lorda, E., D.J. Danila, J.D. Miller, L.E. Bireley, and P.M. Jacobson. 1987. Assessing power plant impacts on fish populations at Northeast Utilities sites: winter flounder studies at Millstone Nuclear Power Station. Pages 5-1 to 5-56 *in* Mechanisms of Compensatory Response of Fish Populations; Workshop Proceedings. EPRI EA5202, Proj. 1633, Airlie, VA.

Danila, D.J. 1989. Our ability to measure and evaluate fisheries impacts for mitigation. 119th Annual Meeting of the American Fisheries Society, Sep. 4-8, 1989, Anchorage, AK.

Danila, D.J. 1989. Movements and exploitation of the Niantic River stock of winter flounder. Workshop on Winter Flounder Biology, Dec. 5-6, 1989, Mystic, CT.

Danila, D.J. 1991. Estimation of winter flounder spawning stock abundance in the Niantic River. Winter Flounder Biology Workshop, Dec. 3-4, 1991, Mystic, CT.

Danila, D.J. 1992. Differences in growth and survival of metamorphosed age-0 winter flounder (*Pleuronectes americanus*) between Niantic River and Niantic Bay, CT. 16th Annual Larval Fish Conference, Early Life History Section of the American Fisheries Society, June 16-20, 1992, Kingston, RI.

Danila, D.J., and J.D. Miller. 1994. Critical periods in the formation of winter flounder (*Pleuronectes americanus*) year-class strength. 18th Annual Larval Fish Conference, Early Life History Section of the American Fisheries Society, June 26-28, 1994, St. Andrews, NB, Canada.

Rose, K.A., J.A. Tyler, R.C. Chambers, G. Klein-MacPhee, and D.J. Danila. 1995. Simulating winter flounder population dynamics using coupled individual-based young-of-the-year and age-structured adult models. Can. J. Fish. Aquat. Sci. 53:1071-1091.

Jacobson, P.M., E. Lorda, D.J. Danila, J.D. Miller, C.A. Tomichek, and R.A. Sher. 1998. Studies of cooling water intake effects at two large coastal nuclear power stations in New England. *In* Proceedings of a workshop on Clean Water Act Section 316(b) Technical Issues held at the Coolfont Conference Center, Berkeley Springs, WV, September 22-23, 1998. Electric Power Research Institute, Palo Alto, CA. EPRI Technical Report.

Danila, D.J. 1998. Monitoring the population abundance of winter flounder in the Niantic River. Long Island Sound Research Conference, Nov. 13-14, 1998, Purchase, NY.

Danila, D.J. 1998. Estimating the abundance of winter flounder spawning in the Niantic River, Connecticut. Flatfish Biology Conference, Dec. 1-2, 1998, Mystic, CT.

Danila, D.J. 1999. Estimating the abundance of winter flounder spawning in the Niantic River, Connecticut. Env. Sci. & Policy 3:S459-S469.

Lorda, E., D.J. Danila, and J.D. Miller. 1999. Application of a population dynamics model to the probabilistic assessment of cooling water intake effects of Millstone Nuclear Power Station (Waterford, CT) on a nearby winter flounder spawning stock. Env. Sci. & Policy 3:S471-S482.

Danila, D.J., E. Lorda, and J.D. Miller. 2000. Correlations among stage-specific abundances of larval and juvenile winter flounder near Millstone Point, CT and their relation to year-class strength. Flatfish Biology Conference, Dec. 5-6, 2000, Mystic, CT.

Saila, S.B., E. Lorda, B. Moran, and D. Danila. 2000. Larval winter flounder stock identification using microelements: first-year (2000) analysis and preliminary results. Flatfish Biology Conference, Dec. 1-2, 1998, Mystic, CT.

Crivello, J.F., J.D. Miller, D. Danila, M. Keser, E. Lorda, and S. Saila. 2000. An examination of winter flounder (*Pseudopleuronectes americanus*) larvae genetic stock structure in Long Island Sound. Flatfish Biology Conference, Dec. 1-2, 1998, Mystic, CT.

Danila, D.J. 2000. Comparison between two methodologies for batch-marking adult winter flounder: preliminary results. [poster.] Flatfish Biology Conference, Dec. 1-2, 1998, Mystic, CT.

Danila, D.J., and E.F. Roseman. 2002. Formation of year-class strength of the Niantic River, CT stock of winter flounder – when and where variation occurs and suggestions on how and why. Flatfish Biology Conference, Dec. 10-11, 1998, Westbrook, CT.

Roseman, E.F., and D.J. Danila. 2002. Genetic stock identification and mass-balance modeling determine contribution of Niantic River winter flounder larvae to power plant entrainment. Flatfish Biology Conference, Dec. 10-11, 1998, Westbrook, CT.

Crivello, J.F., D.J. Danila, E. Lorda, M. Keser, and E.F. Roseman. 2002. The genetic stock structure of larval and juvenile winter flounder (*Pseudopleuronectes americanus*) in Connecticut waters of eastern Long Island Sound and estimations of larval entrainment. Flatfish Biology Conference, Dec. 10-11, 1998, Westbrook, CT.

Crivello, J.F., D.J. Danila, E. Lorda, M. Keser, and E.F. Roseman. 2004. The genetic stock structure of larval and juvenile winter flounder in Connecticut waters of eastern Long Island Sound and estimations of larval entrainment. J. Fish. Biol. 65:62-76.

Jacobson, P.M., C. Tomichek, and D.J. Danila. 2004. Twenty years of impingement history: Connecticut Yankee Haddam Neck Nuclear Power Plant. Pages 455-473 *in* P.M. Jacobson, D.A. Dixon, W.C. Leggett, B.C. Marcy, Jr., and R.R. Massengill, eds. The Connecticut River ecological study (1965-1973): ecology of the lower Connecticut River 1973-3003. American Fisheries Society Monograph 9.

Taylor, D.L., and D.J. Danila. 2005. Predation on winter flounder (*Pseudopleuronectes americanus*) eggs by the sand shrimp (*Crangon septemspinosa*). Can. J. Fish. Aquat. Sci. 62:1611-1625.

Danila, D.J., and D.L. Landers. 2007. Changes in the assemblage of fishes and macroinvertebrates near Millstone Point, CT over the past 30 years. Southern New England Chapter of the American Fisheries Society Summer Meeting, June 27, 2007, Kingston, RI.

Danila, D.J., and D.L. Landers. 2007. Changes in the fish and macroinvertebrate assemblage near Millstone Point, CT over the past 30 years. Estuarine Research Society Annual Meeting, November 5-8, 2007, Providence, RI.

Danila,D.J., and J.F. Foertch. 2008. Niantic River winter flounder studies: transition between larval and juvenile life stages and factors affecting the growth and abundance of settled juveniles. Flatfish Biology Conference, Dec. 3-4 2008, Westbrook, CT.

Danila,D.J. 2010. 30 years on the Niantic River: looking back at Millstone winter flounder studies. Flatfish Biology Conference, Dec. 1-2 2010, Westbrook, CT.

Electric Power Research Institute (principal investigators: D. Danila, W. Dey, and J. Wier). 2011. Potential entrainment of dead or moribund fish eggs and larvae at cooling water intake structures. Tech. Rep. 1019860. EPRI, Palo Alto, CA.

Current Resume of Steven D. Trinkaus, PE of Trinkaus Engineering, LLC

Steven D. Trinkaus, PE
Trinkaus Engineering, LLC
114 Hunters Ridge Road Southbury, Connecticut 06488
Phone: +1-203-264-4558
Website: http://www.trinkausengineering.com
Email: strinkaus@earthlink.net

Qualifications	B.S. / Forest Management/1980 University of New Hampshire
Licenses/Certifications	Licensed Professional Engineer- Connecticut (1988) Licensed Professional Engineer – Maryland (2017)
Professional Societies	American Society of Civil Engineers Connecticut Society of Professional Engineers Soil and Water Conservation Society of America International Erosion Control Association
Professional Awards	Steve was named an Industry Icon by Storm Water Solutions in July 2015 http://editiondigital.net/publication/?i=263831&p=16 for his work in the Low Impact Development field.

International Experience

South Korea – July 2017, June 2016, April 2015, October 2014, April 2014, October 2013 and June 2013

- Steve was invited by Dr. Leeyoung Kim of Kongju University to make a presentation at the Seoul International Symposium for water cycle held on July 27, 2017 at Seoul City Hall. Steve's presentation was entitled "Sustainable Urban Water Cycle Management, Low Impact Development Strategies for Urban Retrofits". Steve also made a presentation to Master and PhD Engineering students at Kongju University on designing LID treatment systems. He also visit the research office of Land & Housing Institute in Daejeon to inspect recent LID retrofits consisting of Bioretention systems, Bioswales and Permeable Paver systems.
- Steve was invited by Dr. Shin to visit the Korean GI/LID research center in July of 2017. The purpose of the visit was to inspect the LID research systems which had been in place for a year to observe how well they were functioning and also to observe the current research on infiltration of LID systems and evaportranspiration of green roof systems.
- Steve was an invited attendee to the official opening of the Korean GI & LID Research Center recently constructed at the Yangsam Campus of Pusan National University. Steve was a consultant on the design of the research center for Dr. Hyunsuk Shin of Pusan National University.

- Steve was an invited presenter at the World Water Forum by Dr. Hyunsuk Shin of Pusan National University. He presented case studies of GI/LID applications in the United States.
- Steve was invited by Dr. Yong Deok Cho of Kwater to participate in the Water Business Forum at the World Water Forum. Steve presented an overview of his business and expertise in Low Impact Development.
- Steve was invited by Dr. Hong-Ro Lee of Kunsan National University and made a presentation entitled "Understanding Low Impact Development in the Urban-Rural Interface" for the **Ariul Brainstorming Working Group** on April 16, 2015 in Gunsan, South Korea. He also toured portions of the proposed land reclamation area to assess how Low Impact Development strategies could be incorporated to address water quality issues from the proposed agricultural, residential, commercial and industrial land uses for this area.
- Steve was a Contributing Author as well as an Advisory Reviewer for a report prepared by Land & Housing Institute (LHI) entitled " Pyeongtaek Godeok New City Low Impact Development techniques (LID), A study on the introduction of measures (I) " dated: January 2015. This report by LHI also cited the Town of Tolland LID Design Manual as a foreign LID Manual to be used as a reference document.
- Steve was an invited presenter at the International Water Forum 2014 held in conjunction with the Nakong River International Water Week in Gyeongju, South Korea sponsored by DaeGyeong Water Foundation & the International Hydrologic Environmental Society. His presentation focused on urban stormwater and the benefits of LID in these areas.
- Steve was an invited presenter at the IWA Water Reuse & Energy Conference 2014 held in Daegu, South Korea. His presentation was on the regulatory barriers to implementation of LID and how to overcome these barriers. He also participated in a panel discussion with other presenters.
- He also made a presentation at The 1st GI & LID Technical Education Workshop held at Pusan National University on October 22nd on an overview of LID and the application of LID concepts. He was invited by Dr. Kyung Hak Hyun of Land & Housing Institute (LHI) to make two presentations of LID case studies at Sangyung University and at a seminar hosted at LHI along with Kwater.
- Steve met with Jong-Pyo Park, Director and Kyoung-Do Lee, CEO of HECOREA, a water resource consulting firm to discuss LID in dense urban areas. Steve signed a MOU with HECOREA to provide consulting services on LID monitoring approaches and maintenance protocols for the Go-Deok International Planning District near Pyeongtaek, South Korea.
- Steve was invited by Dr. Kyung Hak Hyun of Land & Housing Institute to present at the 2nd Low Impact Development Forum in Daejeon, South Korea on October 31, 2013. He also inspected the site of Asan-tangjeong which is an expansion of residential housing for the city of Asan. This expansion will incorporate LID stormwater strategies.
- Steve was invited to make a presentation of the implementation of LID on commercial sites by Dr. Reeho Kim of the Korea Institute of Construction Technology in Seoul.
- Steve met with Dr. Sangjin Lee of Korean Water and Dr. Woo Young Heo, CEO of LID Solution Co, Ltd to review the initial concept plans for the Eco-Delta City project. Eco-Delta City is a new city located near the Gimhae International Airport of 13 square kilometers and will incorporate LID concepts throughout the new city.

- Steve signed a MOU with Dr. Shin of Pusan National University to provide consulting services for the Smart GI/LID Research Facility at Pusan National University. Steve was asked by Dr. Shin to review the design plans for the GI/LID research facility to be constructed at Pusan National University with a focus on the exterior LID research facilities. He provided a written comprehensive review for consideration by PNU.
- Steve was invited by Dr. Hyunsuk Shin of Pusan National University in South Korea to present a workshop on Low Impact Development on June 24, 2013. The presentation was made to research professors, graduate engineering students and practicing engineers at K-water headquarters in Daejeon, South Korea. He also met with representatives of other agencies tasked with the development of a new city, called Eco-Delta City which will implement LID practices from the ground up and comprises approximately 3,500 acres.

Nanjing, China, September 2018
Steve was invited by the organizing committee for the third China Sponge City International Exchange Conference to make three presentations on LID. The presentations were entitled: "LID: The Good, the Bad and the Ugly", "Permeable Pavement Case Studies" and "The regulatory framework to adopt LID". The conference was held September 27th and 28th in Nanjing, China.

Beijing/Zhenjiang, China – August 2017
Steve was invited to make a presentation entitled "Urban LID in China and South Korea" at the 2017 Second China Sponge City International Exchange Conference held in Beijing on August 16-1, 2017. He also made a presentation for Dr. Nian She, Director of Smart Sponge City Planning and Construction Research Institute in Zhenjiang, China on modeling approaches for LID treatment systems as well as inspecting some recent LID retrofits currently under construction in Zhenjiang.
Steve also made a presentation at Reschand entitled "LID Case Studies from US" at the request of Yuming Su of Reschand.

Nanjing, China – September 2016
Steve was invited to present at the 2016 First China Sponge City International Exchange Conference held in Nanjing, China. The presentation focused on several case studies of LID systems in the US.

Zhenjiang, China – June 2015
Was retained by Dr. Nian She to design Urban LID retrofits for a 2.5 hectare (6.5 acres) dense residential area in the city of Zhenjiang. The LID retrofits had to fully treat runoff from the existing impervious areas (building roofs, driveways and parking areas) for 65 mm (2.6") of rainfall in 24 hours. The LID systems also had to attenuate the peak rate of runoff for a rainfall event of 150 mm (5.9") rainfall event. A combination of Bioretention systems, and permeable pavers with a filter course and reservoir layer were used to meet these stormwater requirements.

Zhenjiang, China – May 2015
Steve was invited by Professor Nian She of Shenzhen University to make a presentation entitled "Using LID to Attenuate Large Rainfall Events and Reduce Flood Potential" at the 2015 First

Sino US Sponge City LID Technology Practice Conference held on May 4-5, 2015 in Zhenjiang, China organized by Zhenjiang Water Supply and Drainage Management Office. (http://www.c-water.com.cn/2015lid/en/index_e.html). In addition to the presentation, field inspections were made of several new LID installations in the city consisting of Bioswales, permeable pavement systems and rainwater harvesting.

Guangzhou, China – December 2012

- Steve was an invited attendee at the 15th Annual Guangzhou Convention of Chinese Scholars in Science and Technology in Guangzhou, China on December 17 – 21, 2012 to present a project narrative on how Low Impact Development and sustainable development can be applied to address water quality issues in urban and rural areas of China to implement sustainability concepts and conservation of resources. He attended with Dr. Jim Su, PE of Golder Associates of Mt. Laurel, New Jersey. While at the convention he met with representatives from Sichuan University, Chang'an University, Guangdong University of Technology, Shenzhen University and the South China Institute of Environmental Sciences, MEP to discuss LID being incorporated into their engineering programs.
- Steve also met Dr. Hongbin Cheng of New China Times Technology which is located in Stellenbosch, South Africa. Steve has signed a three year partnership agreement with New China Times Technology to introduce LID concepts to the west cape area of South Africa.

Taiwan – December 2011

- Steve was invited by Hung Kwai Chen, Director of the Water Resources Planning Institute, Water Resource Agency, Ministry of Economic Affairs of Taiwan and Dr. Yong Lai of the US Bureau of Reclamation to present a 12-hour presentation on Low Impact Development on December 8th and 9th, 2011 in Taichung, Taiwan. The presentation focused on applying LID strategies in both urban and rural environments to address runoff volumes and water quality issues.
- Steve is an invited consultant to a project team headed up by Xiaoyan Zhou, PhD of the Institute for Taiwan Water Environment Research (TIIWE) along with The National Taiwan Ocean University, Hohai Engineering Professor Liao Chaoxuan, Ting Engineering Consultants Co., Ltd and University of Colorado professor Guo Chunyuan to develop a LID demonstration project in New Taipei City along with LID policy strategies to further the use of LID in New Taipei City, Taiwan.

Low Impact Development

- Review of existing municipal land use regulations to identify barriers to the implementation of Low Impact Development

- Preparation of regulatory language changes to facilitate the adoption of Low Impact Development

- Preparation of design manuals for the implementation of Low Impact Development strategies and processes with an approach that simplifies the design process

- Application of environmental site design strategies to focus development concepts on land most suitable for development while enhancing the protection of environmentally sensitive areas

- Design of Low Impact Development treatment systems, such as Bioretention areas, wet/dry swales, vegetated level spreaders, vegetated filter strips, subsurface gravel wetlands, constructed wetlands and/or pond systems, infiltration basins & trenches

- Hydrologic analyses of current and post-development conditions to assess impacts of proposed development on storm water flows

- Design of storm water control systems including detention and water quality basins and appropriate planting plans

- Perform hydrologic modeling of stormwater management systems to demonstrate compliance with regulatory benchmarks

- Prepare Pollutant loadings analyses to evaluate the effectiveness of stormwater treatment designs in reducing pollutant loads

Wastewater Management:

- Soil testing to determine suitability of land to support on-site sewage disposal systems for residential and commercial projects and assistance with identifying optimal location for both small and large scale system

- Perform necessary calculations to model and design large scale subsurface sewage disposal systems under CT DEEP criteria and State Department of Public Health

- Design of on-site sewage disposal systems in accordance with state and local health codes

- Perform construction oversight of both small and large scale subsurface sewage disposal systems and provide certifications of compliance

Site Engineering:

- Development feasibility studies

- Layout concepts to maximize development, while preserving environmentally sensitive areas

- Design of horizontal and vertical road geometry

- Preparation of grading, drainage and erosion and sedimentation control plans

- Use AutoCAD Land Development, Civil3D, HydroCAD and Pondpack software packages

- Layout and design of sanitary sewers

- Bid estimates

- Construction oversight

- Third party technical reviews

- Expert testimony

Professional Committees

- Chairman and primary author of EWRI/ASCE LID Model Ordinance Task Committee (goal is to create a National LID Guidance document to further the adoption of LID)
- Chairman of EWRI/ASCE LID Task Committee on Filter Strips and Bioswales (goal is to review & evaluate literature and design specifications for filter strips and Bioswales and create uniform design standards for different geographical regions)
- Member of EWRI/ASCE LID National Guidelines Task Committee

Published Articles

- **"Easier Said Than Done – Overcoming common errors when installing bioretention systems"** – October 2018 edition of Storm Water Solutions by Scranton Gillette Communications.
- **"Large-scale LID Design for urban expansion in South Korea**" with co-author, Dr. Kyung Hak Hyun of South Korean Land and Housing Institute – Volume 3/Issue 4, August/September 2015 – Worldwater Stormwater Management by the Water Environmental Federation.
- "**Research team leads LID deployment in South Korea**" – Volume 2/Issue 1, Spring 2014 – Worldwater Stormwater Management by the Water Environmental Federation.
- "**Low Impact Development, Sustainable Stormwater Management**" **–** English article converted to Chinese and published in the Chinese Edition of Global Water Magazine, July 2013.
- "**A Case Study: Southbury Medical Facility and Low Impact Development**" **-** January/February 2014 issue of Land and Water.
- "**A True Pioneer of Low Impact Development – Member Spotlight**" – January/February 2014 Issue of Erosion Control – Official Journal of the International Erosion Control Association.
- "**Low Impact Development: Changing the Paradigm**" published in the March 2012 edition of PE, The Magazine for Professional Engineers by the National Society of Professional Engineers. Article was also republished in the Spring 2012 addition of EWRI Currents (with permission of NSPE).
- "**Stormwater Retrofit of Existing Detention Basins**" published in the March/April 2012 Land and Water, The Magazine of Natural Resource Management and Restoration with co-author Sean Hayden of the Northwest Conservation District.
- "**Out in the Open; Creating a Stormwater Park in the Heart of a Community**" published in the April 2013 issue of WaterWorld by Pennwell Corporation.
- "**Creating a Stormwater Park in the City Meadow of Norfolk, Connecticut**" published in the July/August 2013 edition of Land and Water

Volunteer Organizations

- President (elected 11/2013) and Connecticut Representative to the Board of Directors for the Northeast Chapter of IECA,
- Alternate member of Inland Wetlands Commission Town of Southbury (served three years),
- Northwest Conservation District Board of Directors (served 18 months)

Software Development

Developed a proprietary software application called **A**ssessment of **P**ollutant **L**oads and **E**valuation of **T**reatment **S**ystems (**A.P.L.E.T.S.**). This application calculates the pollutant loads for current and future land use conditions for the seven most common pollutants in non-point source runoff (TSS, TP, TN, Zn, Cu, TPH, & DIN) for a total of twenty two different types of land uses. The application then allows the evaluation of the effectiveness of thirty four Conventional and Low Impact Development treatment systems in removing these pollutants. Up to four treatment systems can be used in a row as a treatment train to achieve water quality goals.

Future Presentations

- Steve will be making presentations on the following topics: "LID Retrofits to Address Nutrient Loads in Lake Pocotopaug in East Hampton, Connecticut" and "A Study on the Introduction of Low Impact Development for Widespread Applications in South Korea" at the 2020 International Low Impact Development Conference in Bethesda, Maryland on July 19th to 22nd, 2020. (https://www.lidconference.org/).

Invited Speaker Presentations:

- Steve made two presentations at the IWA Dipcon 2019; The 19th IWA International Conference on Diffuse Pollution and Eutrophication being held in Jeju, South Korea in October 2019. The presentations were entitled "How Low Impact Development strategies can mitigate high intensity rainfall events" and "If LID is so easy to implement, how come we keep getting it wrong". (http://iwadipcon2019.org/dipcon/about.asp)

- Steve made the following presentations at **St. Andrews University in Scotland** on October 19th , 2017 for the Sustainable Development program. The first presentation is entitled "Improving the environment with Low Impact Sustainable Development Strategies". The second presentation is entitled "Addressing Water Quality and Runoff Issues in a changing weather world".

- Steve was invited by Dr. Jae Ryu of the University of Idaho Water Center to make a presentation entitled "Designing Low Impact Development treatment systems for **Urban & Agricultural Environments" at the Annual US-Korea Conference on Science, Technology, and Entrepreneurship** being held in Atlanta, Georgia on July 29 to August 1, 2015. (http://www.ukc.ksea.org/UKC2015/)

- Steve was invited by the Lake George Waterkeeper to make a presentation entitled "Applying LID Concepts in the Real World" at the 5th Annual Low Impact Development Conference being held in Lake George, NY on May 7, 2015. (http://fundforlakegeorge.org/2015LID)

- Steve was invited by Dr. Hyunsuk Shin and made a presentation entitled "Real Adaptation and Implementation of GI and LID Technology in USA" at the **World Water Forum** (http://eng.worldwaterforum7.org/main/) being held in Daegu, South Korea on April 14, 2015.

- Steve prepared a presentation for a workshop to civil and environmental engineering students at **Pusan National University** (http://www.pusan.ac.kr/uPNU_homepage/kr/default.asp) in Busan, South Korea on April 17, 2015 entitled "Designing LID System, What do you need to know and why".

- Steve was invited by Dr. Hong-Ro Lee of Kunsan National University and made a presentation entitled “Understanding Low Impact Development in the Urban-Rural Interface” for the **Ariul Brainstorming Working Group** on April 16, 2015 in Gunsan, South Korea. It will focus on how Low Impact Development concepts can be applied to made land areas filled in off the west coast of South Korea to address water quality issues.

- Steve was an invited speaker at the **2014 Low Impact Development Conference** sponsored by the Lake George Waterkeeper and the Fund for Lake George in Lake George, NY on May 1, 2014 for land use professionals and regulatory agencies. He will be presenting case studies focusing on the application of LID concepts for commercial and residential projects.

- Steve was invited by Justin Kenney, Green Infrastructure Coordinator of the Vermont Department of Environmental Conservation Watershed Management Division to present an eight hour workshop entitled “From Bioretention to Permeable Pavement: An In-depth Introduction to Low Impact Development and Green Stormwater Infrastructure” in Montpelier, Vermont on December 5, 2013. The presentation was hosted by the **Vermont Green Infrastructure Initiative** with support from the following Vermont Agencies and Divisions; **Building and General Services, Ecosystem Restoration Program and Agency of Transportation.**

- Steve was invited to attend and present on the Application of LID Concepts for the Urban Environment and LID Case Studies at the 2nd Low Impact Development, Stormwater Management Forum hosted by the **Land & Housing Institute, Korean Land & Housing Corporation** to be held in South Korea in on October 31, 2013. He also made presentations at the **Korean Institute of Construction Technology** and **Pusan National University** on various aspects of LID during this time.

- Steve was an invited speaker at the **2013 Low Impact Development Conference** sponsored by the Lake George Waterkeeper and the The Fund for Lake George in Lake George, NY on May 2, 2013 for land use professionals and regulatory agencies. Over 80 design professionals and regulatory people were in attendance. He made a presentation entitled “Barriers to the implementation of LID”.

- Steve was an invited presenter at a closed-meeting of the **National Association of Home Builders (NAHB) and the Water Environment Federation (WEF)** on October 10, 2012 focusing on progressive stormwater management. The presentation focused on the application of LID strategies on actual development projects and discussed the hydrologic performance and cost effectiveness of LID design.

- Steve was the invited presenter for a 1-hour long webinar presented by **Stormwater Solutions and Stormwater USA** on Low Impact Development and the Basics of Bioretention held on September 18, 2012. Over 760 individuals watched the webinar.

- Steve was an invited speaker at and **EPA/WEF Stormwater Technical Meeting** on July 18, 2012 in Baltimore, MD to discuss the application of Low Impact Development strategies for actual projects with a focus on cost effectiveness when compared to conventional stormwater management as well as field performance of the LID designs. The purpose of this meeting was to assist EPA in the development of a National Stormwater Rule.

- Site Design using Low Impact Development Strategies and What are the impacts of Impervious Cover on Water Quality and Quantity were presented at a workshop entitled “Challenges and Solutions using Low Impact Development”, sponsored by the **Lake George Waterkeeper** in Lake

George, NY on May 5, 2011 for land use professionals and regulatory agencies. 90 design professionals and regulators in attendance.

- Steve was an invited speaker at the **2012 Low Impact Development Seminar** sponsored by the Lake George Waterkeeper in Lake George, NY on April 25, 2012 for land use professionals and regulatory agencies. 100 design professionals and regulatory people were in attendance. He made a presentation entitled "The Hydrologic Benefits of Vegetation in Site Design".

Conference Presentations:

- Steve made one presentation at UKC 2019 by The Korean-American Scientists and Engineers Association in Chicago, IL in August 2019. The presentation is entitled "Designing Low Impact Development Treatment Systems for Agricultural Environments". (https://ukc.ksea.org/ukc2019/about/about-ukc-2019/)

- Steve made two presentations at the 2019 Annual Conference of IECA being held in Denver, CO in February 2019. The presentations were entitled "A Study on Introduction Plan of Low Impact Development Techniques for Widespread Application in South Korea" and "If LID is so easy to implement, how come we keep getting it wrong".

- Steve made a presentation entitled "LID in China and South Korea" at the 2018 Annual Conference of the Northeast Chapter of IECA in Concord, NH on October 1, 2018.

- Steve made a presentation entitled "If LID is so easy to implement, how come we keep getting in wrong" at the **2018 International Low Impact Development** conference being held in Nashville, TN on August 12 – 15, 2018. The conference is sponsored by ASCE and EWRI. (https://www.lidconference.org/)

- Steve made two presentations at the **2018 TRIECA Conference** being held on March 21 & 22, 2018 at the Pearson Convention Center in Brampton, Ontario. The presentations are entitled "Addressing Stormwater in China with Low Impact Development" and "Implement Low Impact Development in South Korea." This conference is sponsored by the Toronto and Region Conservation Authority and the Canadian Chapter of the International Erosion Control Association.

- Steve made the following presentations at the **2018 IECA Annual Conference** being held in Long Beach, CA in February of 2018. The presentations are entitled "How Low Impact Development strategies can mitigate high intensity rainfall events" and Designing Low Impact Sustainable Development treatment systems for Agricultural Environments".

- Steve was invited by the Dylan Drudul, President of the Mid-Atlantic Chapter of IECA to present the keynote address at a one day event called "Sediment Control Innovations Roadshow on July 14th in Columbia, Maryland. The keynote is entitled **"A Worldwide Perspective on Municipal Stormwater Issues".**

- Steve made a presentation entitled **"Designing LID Systems: What do you need to know and why"** at the 27th Annual Nonpoint Source Pollution Conference being held in Hartford, CT on April 20-21, 2016 as sponsored by the New England Interstate Water Pollution Control Commission.

- Steve will be presenting four one-hour long webinars through Halfmoon Seminars on Low Impact Development. The first entitled **"Introduction to Low Impact Development"** will be on May 10, 2016 at 12 pm. The second entitled **"Bioretention System Design"** will be offered on May 10, 2016 at 1:30 pm. The third entitled **"Applying LID Concepts to Residential Development"** will be offered on May 12, 2016 at 12 pm. The fourth entitled **"LID Case Studies"** will be offered on May 12, 2016 at 1:30 pm.

- Steve will be making a presentation entitled **"Designing LID Systems: What do you need to know and why**" at the UKC2016 conference, sponsored by KSEA (Korean-American Scientists and Engineers Association) at the Hyatt Regency DFW in Dallas, Texas, August 10 – 13, 2016.

- Steve made five presentations at the **2016 Environmental Connection** conference by IECA (www.ieca.org) being held in San Antonio, Texas on February 16 – 19, 2016. The presentations were entitled "Designing LID Systems: What do you need to know and why", "Construction Site Stormwater: The Ignored Problem", "Solving Construction Stormwater Problems in the Field", "Developing Effective LID Municipal Regulations", and "LID Demonstration Projects in Connecticut, a study of Contrasts".

- Steve made two presentations at the **EPA Region Stormwater Conference 2015** (http://epa.gov/region6/water/npdes/sw/ms4/2015conference/index.html) being held in Hot Springs, AR on October 18-23, 2015. The presentations are entitled "Designing LID systems: What do you need to know and why" and "Designing LID treatment systems for Urban and Agricultural Environments."

- Steve made a presentation entitled "Applying LID strategies to residential and commercial developments to address water quality and runoff volumes" at the KSEA Northwest Regional Conference 2015 held at the Idaho Water Center in Boise, Idaho on October 11, 2015.

- Steve made a presentation entitled "Solving Construction Stormwater Problems in the Field" at **WEFTEC 2015** (http://www.weftec.org) in Chicago, IL on September 29, 2015.

- Steve made three presentations entitled: "Korean GI/LID Research Facility", Applying LID concepts to High Density Residential Developments, and Municipal LID Regulations" at the 2015 Environmental Connection IECA Annual Conference being held in Portland, Oregon on February 16 – 18, 2015. He also presented a half day workshop entitled: "Designing LID Projects". He moderated an Expert Panel on Low Impact Development with Seth Brown, (Water Environment Federation), Bob Adair (Construction Ecoservices, Inc.) and Roger Sutherland (AMEC)

- Steve made two presentations at International Low Impact Development Conference 2015 in Houston, Texas which is sponsored by ASCE-EWRI. The presentations are entitled "Korean GI/LID Research Facility", and "LID Demonstration Projects in Connecticut: The Good and the Bad".

- Steve made presentations entitled "Overview of Low Impact Development" and "The Application of Low Impact Development Strategies for Land Development Projects" along with Dr. Jae Ryu of the University of Idaho and Dr. Hyun-Suk Shin of Pusan National University at the annual meeting of the **American Water Works Association** in Tyson Corners, VA on November 6, 2014.

- Steve made two presentations entitled "Construction Site Stormwater: The Ignored Problem" and "Applying LID Concepts to High Density Residential Development" at the **2014 Annual Conference and Trade Show of the Northeast Chapter of IECA** held at Lake Morey, Vermont on November 4 – 5, 2014.

- Steve made the following presentations entitled: "A Case Study – Southbury Medical Facility and Applying LID concepts on undeveloped land and in the urban environment" at Municipal Wet

Weather Stormwater Conference, hosted by the **Southeast Chapter of IECA** in Charlotte, NC on August 18th and 19th, 2014.

- Steve made the following presentations: "The Incorporation of LID on Affordable Housing Projects, A Case Study – Southbury Medical Facility and LID' and Municipal LID Regulations" at the **16th Annual EPA Region 6 Stormwater Conference** sponsored by the South Central Chapter of IECA in Fort Worth, TX on July 27th through August 1st, 2014.

- Steve made oral presentations at the **2014 Environmental Connection** sponsored by the International Erosion Control Association in Nashville, Tennessee on February 25 – 18, 2014. The presentations were entitled "A Case Study – Southbury Medical Facility and LID", "The Implementation of the Highland Estates Detention Basin Retrofit water quality impairment in Northfield Lake", and "Creating Effective Municipal LID Regulations".

- Steve co-presented an all day workshop on Low Impact Development with Jamie Houle of the University of New Hampshire Stormwater Center at the **2013 International Erosion Control Association Northeast Chapter Conference and Trade Exposition** on November 19 – 21, 2013 in Warwick, RI.

- Steve made three oral presentations at the **2013 International Low Impact Development Symposium** held at the Saint Paul RiverCentre in Saint Paul, Minnesota on August 18 – 21, 2013. The presentations were entitled "A Case Study – Southbury Medical Facility and LID", "LID regulations in Connecticut: The Long and Tortured Road", and "Creating a Stormwater Park in the City Meadow of Norfolk, Connecticut."

- Steve presented two papers at the **2013 EWRI World Environmental and Water Resources Congress** held in Cincinnati, Ohio on May 19- 23, 2013. The papers are entitled: "Municipal LID Regulations - What is important to include to be successful?" and "Creating a Stormwater Park in the City Meadow of Norfolk, Connecticut". http://content.asce.org/conferences/ewri2013/index.html

- Steve made a presentation at the **Soil and Water Conservation Society Winter Conference** held in Berlin, Connecticut on February 15, 2013. The presentation focused on erosion and sedimentation control issues with Low Impact Development treatment systems.

- Steve presented two papers at the **2013 Environmental Connection** held in San Diego, CA on February 10 – 13, 2013. The papers are entitled "LID Demonstration Project for Seaside Village in Bridgeport, Connecticut" and "Creating a Stormwater Park in the City Meadow of Norfolk, Connecticut". He also presented a full day LID workshop entitled "Next Generation Low Impact Development and Meet Today's Needs" and a half day workshop on Low Impact Development covering Environmental Site Design, Water Quality Issues, Pollutant Loading Analyses, Designing different types of LID treatment systems and actual case studies.

- Steve made three presentations at the **2012 Annual Conference of the Northeast Chapter of IECA** in Fishkill, NY on November 7, 8, & 9, 2012. The presentations are entitled: "LID Demonstration Projects in Connecticut, A Study of Contrasts, Environmental Site Design and LID Hydrologic Issues, and Siting and Designing LID Treatment Systems with Case Studies"

- Steve made two oral presentations entitled "Applying Environmental Site Design Strategies to Design a Residential Subdivision" and "The incorporation of LID on Affordable Housing Projects" at the

2012 Ohio Stormwater Conference in Toledo, Ohio sponsored by the Ohio Stormwater Association on June 7th and 8th, 2012.

- Presented two papers at the **ASABE Watershed Technology Conference** in Bari, Italy, May 28 – 30, 2012. The papers were entitled "LID Demonstration Project for Seaside Village in Bridgeport, Connecticut" and "The creation of a Stormwater Park in the City Meadow of Norfolk, Connecticut".

- Steve made one oral presentation entitled "LID Demonstration Project for Seaside Village in Bridgeport, Connecticut" and presented one poster entitled "The Incorporation of LID on Affordable Housing Projects" at the **2012 World Environmental & Water Resources Congress** in Albuquerque, New Mexico sponsored by EWRI/ASCE on May 20 - 24, 2012.

- "Stormwater Retrofit of Highwood Estates Detention basins to address Water Quality Issues and How the application of Environmental Site Design Strategies can provide a resource for carbon sequestering" were presented at the **2011 International Erosion Control Associated Northeast Chapter Annual Conference** on December 1 – 3, 2011 at the Crowne Plaza Hotel in Natick, Massachusetts.

- Stormwater Retrofit of Highwood Estates Detention Basins to enhance Water Quality Benefits; A Low Impact Development (LID) Model Ordinance and Guidance Document and The Farmington River Enhancement Grants: A tale of three towns and the path to Low Impact Development were presented at the **Philadelphia Low Impact Development Symposium "Greening the Urban Environment"** in Philadelphia, PA (September 2011) sponsored by EWRI, Villanova University, North Carolina University and the University of Maryland.

- Stormwater Retrofit of Highwood Estates Detention Basins to enhance Water Quality Benefits; The Farmington River Enhancement Grants: A tale of two towns and the path to Low Impact Development and A Low Impact Development (LID) Model Ordinance and Guidance Document was presented at the **EWRI/ASCE 2011 World Environmental & Water Resources Congress** in Palm Springs, CA (May 2011).

- Stormwater Retrofit of Highwood Estates Detention Basins to enhance Water Quality Benefits was presented at the "Annual Nonpoint Source Pollution Conference", sponsored by the **New England Interstate Pollution Control Commission** in Saratoga Springs, NY, on May 17-18, 2011.

- Stormwater Pollutant Load Modeling presented at the **Northeast Chapter of IECA Annual Conference** at the University of New Hampshire Stormwater Center in Durham, NH (December 2010).

- How the application of Environmental Site Design Strategies and Low Impact Development Storm Water Treatment Systems can mimic the Natural Hydrologic Conditions in a watershed and provide a resource for carbon sequestering and The Importance of Assessing Pollutant Loads from Land Development Project and the Design of Effective Storm Water Treatment Systems at the **EWRI/ASCE Watershed Management Conference** in Madison, WI (August 2010).

- The Tolland Low Impact Development Design Manual: The Changing Paradigm for Land Development, The application of Environmental Site Design Processes to design a residential subdivision and A Low Impact Development (LID) Model Ordinance and Guidance Document at the **ERWI/ASCE 2010 World Environmental and Water Resources Congress** in Providence, RI (May 2010).

- The application of Form-Based Zoning and Low Impact Development for the Revitalization of the Town Center of Simsbury, Connecticut and The Integration of Low Impact Development to enhance the application of Smart Code Zoning to create a Gateway District to the Historic Town Center of Tolland, Connecticut at the **EWRI/ASCE 2010 International Low Impact Development Conference** in San Francisco, CA (April 2010).

- The application of Environmental Site Design Processes to design a residential subdivision and Assessing Pollutant Loads and Evaluation of Treatment Systems to achieve Water Quality Goals for Land Development Projects at the **EWRI/ASCE 2009 World Environmental & Water Resources Congress** in Kansas City, Missouri (May 2009).

- Ahead of the Curve – Tolland, CT adopts Low Impact Development Regulations and Preparing a Pollutant Loading Analysis for Land Development Projects at the **Urban Water Management Conference** in Overland Park, KS sponsored by National Association of Clean Water Agencies (NACWA) and the City of Independence Water Pollution Control Department (March 2009).

- Ahead of the Curve – Tolland, Connecticut adopts Low Impact Development Regulations and Trade Winds Farm – Winchester, Connecticut – How to create a LID subdivision along with the preparation of a poster on Preparing a Pollutant Loading Analysis for Land Development Projects at **EWRI/ASCE 2008 International Low Impact Development Conference** in Seattle, WA (November, 2008).

- Trade Winds Farm – Winchester, Connecticut – How to create a LID subdivision and Preparing a Pollutant Loading Analysis for Land Development Projects at the **IECA Northeast Chapter's Annual Conference & Trade Exposition** in Portland, ME (October, 2008).

- The Preparation of a Valid Pollutant Loading Analysis at the **National StormCon 2008 Conference** in Orlando, FL (August, 2008).

- Panelist with Linda Farmer, AICP for Profiles of Partnerships for Addressing NPS Pollution at **NEIWPCC Annual Non-point Source Pollution Conference** in Groton, CT (May, 2008).

Workshop Presentations:

- Steve presented an all-day workshop on Low Impact Development for continuing education for design professionals in Little Rock, Arkansas on February 28, 2020 which is sponsored by Halfmoon Seminars. (https://www.halfmoonseminars.org/seminars/133069/low-impact-development-seminar/north-little-rock-ar)

- Steve presented an all-day workshop on Low Impact Development for continuing education for design professionals in Nanuet, NY on December 19, 2019 which is sponsored by Halfmoon Seminars. (https://www.halfmoonseminars.org/seminars/132909/low-impact-development-seminar/nanuet-ny)

- Steve presented a webinar entitled "Construction Stormwater Regulation Strategies: Best Practices to Assure NPDES Compliance" on Thursday, November 12, 2015 at 2:00 pm to 3:00 pm eastern time. The webinar is sponsored by Business and Legal Resources (www.blr.com).

- Steven presented a full day workshop entitled "Stormwater Management 2015" in Columbia, Maryland on August 13, 2015 which focused on applying the State of Maryland Stormwater Manual. The workshop was sponsored by Halfmoon Seminars, LLC and 113 people attended the workshop.

- Steve presented a full day workshop on "Stormwater Regulations in Connecticut", sponsored by Halfmoon Seminars, LLC in North Haven, Connecticut on June 25, 2014. More than 30 engineers and landscape architects attended the workshop.

- Steve was the facilitator in a live chat as part of the Stormwater Solutions Virtual Trade Show on April 2, 2014. The topic of the live chat will be LID with a focusing on Bioretention systems.

- Steve made a presentation entitled "What is Low Impact Development and how do you apply it to residential projects" for the Connecticut Chapter of the American Institute of Architects in New Haven, Connecticut on April 22, 2014.

- Steve made a presentation entitled "Wastewater to Stormwater; Designing a subsurface flow gravel wetlands" at the annual meeting of the Connecticut Association of Wetland Scientists on March 20, 2014 in Southbury, Connecticut.

- Steve made a presentation entitled " Low Impact Development and the Connecticut General Stormwater Permit" at the annual meeting of the Southern New England Chapter of the Soil and Water Conservation Society on March 14, 2014 at Eastern Connecticut State University.

- He co-taught an ASCE Short Course entitled, "Introduction to Low Impact Development" with Mike Clar at the 2013 Low Impact Development Symposium held in St. Paul, Minnesota on August 18, 2013.

- Steve presented a workshop on Low Impact Development to the Town of Naugatuck Inland Wetlands Commission on June 5, 2013 to demonstrate how the implementation of LID can reduce stormwater impacts in the urban area of the community.

- Steve presented a webinar entitled "The Basics of Low Impact Development on Wednesday, April 17, 2013. More information is available at http://www.ieca.org/education/webinar/livewebinars.asp

- Steve presented a webinar entitled "Changing the Regulatory Framework to Adopt LID Strategies" on Thursday, March 7, 2013 and on Thursday, August 8, 2013 from 11:30 am to 1:00 pm through **ASCE and EWRI.** Link for more information: http://www.asce.org/Continuing-Education/Brochures/Webinars/ChangingRegulatoryFrameworkLIDStrategies/#Purpose

- Steve presented a three hour workshop on Low Impact Development on June 5, 2012 at the Oxford town hall for municipal land use staff and officials at the request of the **Oxford Inland Wetlands and Watercourses Commission**. Approximately 20 individuals attended the workshop.

- Steve presented an eight hour short courses on Low Impact Development at the **EWRI/ASCE 2011 World Environmental & Water Resources Congress** in Palm Springs, CA (May 2011). The following topics will be covered: Understanding and Implementing Principles of Low Impact Development, Applying LID Strategies to a Site, Low Impact Development Hydrologic Considerations, The Regulatory Framework and LID, LID Integrated Management Practices, Erosion and Sedimentation Controls for the Implementation of LID Practices and Case Studies (Applying LID and Regulations). 12 attendees took the course, including professors from Mississippi State University, Oklahoma State University, Adelaide University (Australia) and Pusan National University (South Korea).

- Understanding and Implementing Principles of Low Impact Development, Applying Low Impact Development to a Site, Low Impact Development Hydrologic Considerations, Low Impact Development Integrated Management Practices, Erosion and Sediment Control for the Implementation of Low Impact Development Practices, and Case Studies of LID (Residential and Commercial) at workshops on Low Impact Development sponsored by **HalfMoon, LLC** (https://www.halfmoonseminars.com) in Albany, NY, Ronkonkoma, NY, North Haven, CT, Manchester, NH, Nanuet, NY, Cleveland, OH, Natick, MA, Portland, ME Fort Washington, PA, Springfield, MA, Wilmington, DE, White River Junction, VT, Somerset, NJ, and White Plains, NY for continuing education credit for design professionals. A total of 322 land use professionals have attended these workshops.

- Pollutant Loads and the Design of Effective Stormwater Treatment Systems was presented at the Virtual H2O conference on February 22, 2011 as presented by **PennWell Publishing**. 25 professionals in attendance.

- LID Stormwater Treatment Systems: Siting, Design and Installation for Maximum Environmental Benefit. What are the aesthetic, financial and maintenance implications? presented at a seminar for the **AIA Connecticut, Committee on the Environment** in New Haven, CT (December 2010). 70 architects in attendance.

- Low Impact Development and the Environmental Site Design process to create sustainable sites at a seminar for the **AIA Connecticut, Committee on the Environment** in New Haven, CT (September 2010). 40 architects in attendance.

- Workshop entitled Using Environmental Site Design Strategies and LID stormwater systems for commercial development at the **Connecticut Conference on Natural Resources** at the University of Connecticut (March 2010). 10 design professionals and regulatory staff in attendance.

- Implementing Low Impact Development in Your Community for the **Connecticut Technology Transfer Center** in Glastonbury, CT (November, 2009). 40+ professionals in attendance.

- What towns can do to encourage LID at the "Low Impact Development Forum" presented by the **Housatonic Valley Association** in Shelton, CT. (October 2009). 12 professionals in attendance.

- Town of Tolland, CT; Low Impact Development Regulations and Design Manual at the **Community Builders Institute** for the workshop entitled: "Swift, Certain & Smart: Best Practices in Land Use" (May 2009). 30+ professionals in attendance.

- Low Impact Development, Environmental Site Design and Water Quality issues and strategies to local municipalities (**Greenwich, and Old Lyme**) to provide an educational opportunity about the many benefits of Low Impact Development in 2009. 30+ design professionals, regulatory commissioners and staff in attendance for each presentation.

- Low Impact Development, Environmental Site Design and Water Quality issues and strategies to local municipalities (**Bolton, Farmington, and Guilford** to date) on a pro bono basis to provide an educational opportunity about the many benefits of Low Impact Development in 2009. 25+ design professionals, regulatory staff and commission members in attendance for each presentation.

- Workshop entitled Using Environmental Site Design Strategies to create a residential subdivision at the **Connecticut Conference on Natural Resources** at the University of Connecticut (March 2009). 20 design professionals and regulatory staff in attendance.

- The Need for Pollutant Loading Analyses for Land Development Projects to storm water engineers at **CT DEP** (March 2009). 6 DEP staff in attendance.

- A review of existing land use regulations and storm water management issues for the Middle Quarter Districts in Woodbury, CT and how the implementation of Environmental Site Design and Low Impact Development strategies can improve water quality of storm water runoff for the Woodbury land use agencies (August 2008). 15 regulatory commission members in attendance.

- Low Impact Development at meeting of the **Connecticut Association of Zoning Enforcement Officers** (October 2007). 30+ professionals in attendance.

- Low Impact Development and adoption of LID regulations by municipalities at workshops of the **Land Use Leadership Alliance (LULA)** (2007, 2010 and 2011). 20+ professionals in attendance at each presentation.

- Stormwater management and Low Impact Development at workshop sponsored by the **Northwest Conservation District** held for land use officials (March 2006). 20+ professionals in attendance.

Conferences Attended

- Bioretention Summit: Ask the Researcher – Annapolis, MD by the University of Maryland (Dr. Alan Davis), North Carolina State University (Dr. Bill Hunt) and Villanova University Stormwater Partnership (Dr. Rob Traver) – (July 2010).

- Workshop at the University of New Hampshire Stormwater Center on permeable pavements. This full-day training included field visits to a variety of on-the ground porous pavement installations throughout the region. Participants learned key design principles necessary to successfully design, evaluate, specify, and install porous pavement for stormwater management. (December 2009).

- Two workshops at the University of New Hampshire Stormwater Center in Durham, NH to observe conventional and Low Impact Development storm water treatment systems in operation. The Stormwater Center is independently verifying the effectiveness of the various treatment systems to remove pollutants from runoff and reduce impacts associated with storm flows. (March 2006 and May 2007).

- 2ND National Low Impact Development Conference – North Carolina State University held in Wilmington, NC, (March 2007).

- Designing Bio/Infiltration Best Management Practices for Stormwater Quality Improvement – University of Wisconsin (Madison, WI) (November 2005).

- Stormwater Design Institute – Center for Watershed Protection (White Plains, NY), (December 2004).

- Engineering and Planning Approaches/Tools for Conservation Design – University of Wisconsin (Madison, WI) (December 2003).

- Law for Design Professionals in Connecticut – Lorman Education Services in Trumbull, CT (September 2002).

- On-site Wastewater Facility Design – University of Massachusetts in Amherst, MA (May 2002).

- The Northeast Onsite Wastewater Short Course & Equipment Exhibition – New England Interstate Water Pollution Control Commission in Newport, RI (March 2002).

- Designing On-site Wetland Treatment Systems, University of Wisconsin, (Madison, WI) (October 1999).

- Cost Effective Drainage System Design – University of Wisconsin (Atlanta, GA) (November 1997).

- Treatment Wetlands, University of Wisconsin, (Madison, WI). "Creating and Using Wetlands for Wastewater Disposal and Water Quality Improvement" (April 1996).

- Alternative On-site Wastewater Treatment Systems, New England Intrastate Pollution Control Commission's On-Site Wastewater Task Force in Westford, MA (November 1994).

- Stormwater Quality, University of Wisconsin, (Portland, ME). "Designing Stormwater Quality Management Practices" (June 1994).

LOW IMPACT SUSTAINABLE DEVELOPMENT PROJECTS

<u>LID Regulations and Design Manuals</u>

- **Town of Tolland. CT –** Prepared amendments to Town of Tolland Zoning, Subdivision, Inland Wetland regulations and Road Design Manual to incorporate Low Impact Development standards. Wrote "Design Manual – Low Impact Development – Storm Water Treatment Systems – Performance Requirements – Road Design & Storm Water Management" prepared for the Town of Tolland; October 2007. The Town of Tolland was awarded the Implementation Award by the CT-APA for the LID regulations and design manual in December 2008.

- **Town of Plainville, CT –** Planimetrics was the lead consultant on this project. This office performed the technical regulatory audit to identify barriers to the implementation of LID. These barriers were removed from the regulations to provide for the implementation of LID. A LID design manual was written by Steve Trinkaus to address specific development/stormwater issues for the Town of Plainville. The regulatory changes and LID manual were adopted by the Planning and Zoning Commission in September 2010. This work was funded by the Farmington River Enhancement Grants from CT DEP.

- **Town of Harwinton, CT –** In conjunction with Planimetrics of Avon, CT, the existing land use regulations were evaluated for barriers to the implementation of Low Impact Development (LID). The project team suggested changes to the land use regulations to encourage the application of LID in the community. Steve Trinkaus defined design processes and strategies to encourage the implementation of LID in the town. This work was funded by the Farmington River Enhancement Grants from CT DEP.

- **Town of East Granby, CT –** Planimetrics was the lead consultant on this project. This office performed the technical regulatory audit to identify barriers to the implementation of LID. These barriers were removed from the regulations to provide for the implementation of LID. Steve Trinkaus prepared a LID Design Manual and LID Educational document for the town working with Gary Haynes, the town planner. This work was funded by the Farmington River Enhancement Grants from CT DEP.

- **Town of Morris, CT -** This office performed the technical regulatory audit to identify barriers to the implementation of LISD. These barriers were removed from the regulations to provide for the implementation of LISD. A LISD design manual was written by Steve Trinkaus to address specific development/stormwater issues for the Town of Morris. The regulatory changes and LISD manual were adopted by the Planning and Zoning Commission in January 2020.

<u>LID Projects</u>

- **Garden Homes Management –** Westport, Connecticut – 19 unit residential apartment building being developed under 8-30g (affordable housing) on 1 acre site directly tributary to West Branch of the Saugatuck River. All construction activities are located outside regulatory setbacks to tidal wetland and 100-year flood boundary. Stormwater management system was designed to fully infiltrate the runoff for all storm events up to and including the 100-year event and reduce pollutant loads to existing levels as wooded parcel.

- **Jelliff Mill, LLC** – New Canaan, Connecticut: Redesigned the site layout to create ten single family residential units on a site overlooking the restored historic Jelliff Mill dam on the Noroton River. The site design uses two sections of permeable pavement and a Bioretention system to infiltrate the runoff from the proposed impervious areas on the site. Due to the presence of sand and gravel soils, all runoff from the impervious areas will be infiltrated up to and including the 25-yr storm event (5.7" of rain/24 hrs). Fully constructed and occupied.

- **SRG Family, LLC** – Southbury, Connecticut: Design final site grading for 38,000+ sq.ft. Medical services building and approximately 225 parking spaces in order to maintain overland flow patterns. Designed multiple LID treatment systems consisting of bioswales with weirs, Bioretention systems and Permeable Pavement (asphalt) to handle runoff from all impervious area on the project site. The LID treatment systems are capable of fully infiltrating the runoff from a 50-yr storm event will virtually eliminating the discharge of any pollutants to the adjacent wetland area. Currently pending before Inland Wetlands Commission for modification of original approval.

- **Farmington River Watershed Association** – Winchester, Connecticut: Designed stormwater retrofit for existing 1 acre paved parking area at the science building of the Northwest Community College to treat runoff prior to discharge into the Still River. Retrofit consists of forebay and Bioswale to treat runoff from parking area and building roof. Currently at Bid stage.

- **Garden Homes Management –** Southport, Connecticut: Designed site to support 96 unit apartment building and 115 parking spaces. Site contains both freshwater and tidal wetlands. Stormwater management design required to provide Groundwater Recharge Volume & Water Quality Volume in addition to reducing the post-development peak rate of runoff from the 10-yr rainfall event to the pre-development peak rate of runoff from the 2-yr rainfall event. The stormwater management design includes grassed swales, Bioretention systems and underground concrete galleries to meet all of these stormwater requirements. Due to favorable soils on the site, the site will likely be a zero discharge site. Court Approved.

- **Garden Homes Management** – Milford, Connecticut: Designed site to support 257 unit apartment building with 295 parking spaces. Stormwater management design required to provide Groundwater Recharge Volume & Water Quality Volume in addition to reducing the post-development peak rate of runoff from the 25-yr rainfall event to the pre-development peak rate of runoff from the 25-yr rainfall event. The design utilizes a Bioretention system, two underground galleries systems as well as a small detention basin to meet all of the stormwater requirements. Court Approved.

- **Garden Homes Management** – Milford, Connecticut: Designed site to support 21,888 sq.ft. building (three stories) containing 36 studio apartments and 45 parking spaces. Permeable pavement and Bioretention will be used on the site to treat runoff for water quality improvements along with reducing runoff volume from the 1-yr to 100-yr storm event. Construction complete and project occupied.

- **Quickcomm, Inc. –** Newtown, CT**:** Design a parking facility for approximately 140 vehicles to serve an existing corporate use. Runoff from the entire parking facility will be directed to one of seven Bioretention systems. Water quality of the runoff will be improved by the filtration through a specialized soil media and will then infiltrate into the underlying soils. Due the presence of sand and gravel soils, the Bioretention systems will fully infiltrate all runoff up to and including a fifty-year design storm (6.5” of rain/24 hours). Land use approvals obtained in the fall of 2012 and work completed in the fall of 2013.

- **Garden Homes Management** – Fairfield, Connecticut: Designed site to support 32,592 sq.ft. building (three stories) containing 54 studio apartments and 68 parking spaces. Permeable pavement will be used for majority of parking facility. Roof drains will also be directed to permeable pavement system for water quality improvement. Reservoir layer was sized to fully contain 1.7” of runoff from contributing impervious area. By using a raised underdrain an anaerobic condition will be maintained in the bottom of the reservoir, thus providing denitrification of Total Nitrogen prior to discharge to tidal section of Rooster River. Construction complete and occupied.

- **Garden Homes Management** – Oxford, Connecticut: Design site plan for 126 units of manufactured housing on 41+ acres. Stormwater management is achieved by the use of linear Bioretention systems (Bioswales) along both sides of all interior roads. After treatment in Bioswales, all runoff is directed to standard detention basins to provide peak rate attenuation from the 2-year to 100-year rainfall event. Approved by Inland Wetlands Agency, Denied by Planning and Zoning Commission. Court Approved and under construction.

- **Compton Family Trust** – New Hartford, Connecticut: Design two wet swales systems to convey and filter runoff from road which is currently discharged into West Hill Lake via a paved swale. West Hill Lake has very good water quality and the owner desires this work on this property to become a template for other homeowners on West Hill Lake to prevent adverse impacts of stormwater on the water quality of the lake. Received all necessary land use approvals. Construction to commence in the summer of 2012.

- **Highwood Estates** – Thomaston, Connecticut: Design retrofits for two existing failing detention basins serving existing 50 lot residential subdivision. Retrofits were designed using LID techniques to improve water quality reaching Northfield Brook, an impaired waterway. The larger basin was converted to an Extended Detention Shallow Wetlands to significantly reduce pollutant loads. Due to a limited area, only a forebay and deep pool could be designed for the smaller basin, thus providing measurable improvements in water quality.

- **Farmington River Watershed Association** – Winchester, Connecticut: Design stormwater retrofits consisting of a Bioretention system at the Town of Winchester Wastewater Treatment Plant and a Bioswale at the Town of Winchester Public Drinking Supply facility. These projects are being funded as LID demonstration projects to increase public awareness of LID. The systems were installed in June 2012 and were featured in articles in the Republican American and Register Citizen newspapers.

- **Harwinton Sports Complex** – Harwinton, Connecticut: Redesign stormwater management system for indoor sports facility to use vegetated swales and Bioretention systems. Redesign site grading to eliminate all structural drainage in parking facility. Client saved over $ 40,000 on infrastructure costs by the use of LID treatment systems.

- **Holland Joint Venture, LLC –** Bridgewater, Connecticut: Prepared site plan for 28,000 sq.ft. industrial/light assembly use and 140 parking spaces on 10.94 acres. Utilize Environmental Site Design strategies to preserve large portions of site in natural condition, minimize impacts due to site disturbance, and minimize impacts to wetland/watercourse system by access driveway. Designed five Bioretention systems for storm water management and pollutant removal from all impervious areas.

- **Goodhouse Flooring, LLC** – Newtown, Connecticut: Design site to accommodate 8,800 commercial building and associated driveway and parking areas on 1.0 acre site. Designed eight Bioretention systems to handle runoff from all impervious surfaces. Analyze and demonstrate that State of Connecticut water quality goals will be achieved for the site design.

- **Trade Winds Farm** – Winchester, Connecticut: 24 lot Open space subdivision on 104+ acres of land. Performed all civil engineering design work for project. Notable feature of project is the preservation of 64+ acres of the site as dedicated Open Space. Many LID strategies such as Environmental Site Design, site fingerprinting, volumetric reduction and water quality improvements were incorporated into site design. Storm water treatment systems utilized vegetated basins, vegetated swales with gravel filter berms, emergent marsh, Bioretention systems, linear vegetated level spreader, and meadow filter strips.

- **Northern View Estates** – Sherman, Connecticut: Five lot subdivision with private road. Design has no direct wetland impacts and only minor intrusions into defined 100’ upland review area. Low Impact Development systems, such as vegetated swales and Bioretention were used to treat post-development runoff while maintaining existing drainage patterns to the maximum extent possible.

- **Mill River –** New Milford, Connecticut: Designed 14 lot open space subdivision on 68 acre site. Performed all civil engineering services for project. .LID treatment systems such as a permanent pond/emergent marsh system, linear biofiltration swale, and rain gardens were designed for the site.

- **Byron Avenue Cluster Development –** Ridgefield, Connecticut: Seven lot cluster subdivision on 4 acres. The Stormwater management system consisted of a road with no curbs, grassed swales and constructed wetland with detention to reduce pollutant loads and increases in the peak rate of runoff.

- **The Estates on the Ridge** – Ridgefield, Connecticut: 32 lot open space subdivision on 152+ acres. Over 80 acres of the site will be preserved as Open Space as part of this project. Stormwater will be treated by the use of rain gardens for roof drains, infiltration trenches for footing drains, emergent marsh systems and vegetated swales for conveyance and treatment of road runoff. Designed over 1 mile of proposed road for project. Designed bottomless culverts over several wetlands crossing to minimize direct impact on wetland areas.

- **G & F Rentals, LLC** – Oxford, Connecticut: By utilizing LID stormwater concepts such as grass filter strips, Bioretention in parking islands, Bioretention for roof drains, and infiltration trenches, a total of 54,000 sq.ft. of commercial office space along with 140+ parking spaces was placed on 10 acre site. The project also restored previously degraded inland wetlands on the site.

- **Dauti Construction – Edona Commons** – Newtown, Connecticut: Designed 23 unit affordable housing plan to minimize impacts on delineated wetland areas. Designed three construction wetland systems for the treatment of storm water runoff for water quality renovation.

- **American Dimensions, LLC** – New Milford, Connecticut: Redesigned the storm water treatment systems for a 7 lot residential subdivision. Rain gardens were designed to handle the runoff from all roof areas and proposed driveways. Each rain garden provided the required Water Quality Volume and Groundwater Recharge Volume as specified in the 2004 Storm Water Quality Manual. A Subsurface Gravel Wetland was designed to treat the full Water Quality Volume for runoff from adjacent roads network which drained through the subject property.

- **Molitero Residence** – New Fairfield, CT: Designed five Bioretention systems to mitigate both volumetric increases of runoff and address water quality issues for large building addition to single family residence on Candlewood Lake. Also designed landscape filter strip above lake edge to filter runoff from up gradient lawn area. Bioretention systems fully infiltrated 5" of rain in 24 hours from Hurricane Irene in August of 2011. Project was featured in newsletter of Candlewood Lake Authority to demonstrate the effectiveness of LID treatment systems in a lake environment.

- **Multiple single family residences** – Design Bioretention systems to mitigate volumetric increases of runoff due to increases of impervious cover on the lot for large building additions and new construction including the reduction of volumetric increases up to the 25-yr event (5.7" of rain in 24 hours).

Residential Subdivisions

- **Stone Ridge Estates**, 59 lot residential open space subdivision, Ridgefield, Connecticut (Town of Ridgefield)
- **Oak Knoll**, 14 lot open space subdivision, Ridgefield, Connecticut (Mike Forbes)
- **Ward Acres Farm**, 12 lot open space subdivision, Ridgefield, Connecticut (Sturges Brothers, Inc.)

- **Horblitz Subdivision**, 13 lot open space subdivision, Ridgefield, Connecticut (John Sturges)
- **McKeon Subdivision**, 14 lot conventional subdivision, Ridgefield, Connecticut (McKeon Family Trust)
- **High Ridge Estates**, 5 lot subdivision in historic district, Ridgefield, Connecticut (Scandia Construction)
- **Millstone Court**, 7 lot conventional subdivision, Ridgefield, Connecticut (Sturges Brothers, Inc.)
- **Cricklewood Subdivision** – 12 lot conventional subdivision, Redding, Connecticut (Jay Aaron)
- **Spruce Meadows Subdivision –** 12 lot conventional subdivision, Wilton, Connecticut (Piburo Builders)
- **Noroneke Estates** – 12 lot open space subdivision, Ridgefield, Connecticut (John Sturges)
- **Lynch Brook Lane** – 7 lot open space subdivision, Ridgefield, Connecticut (Sturges Brothers, Inc.)
- **Ledgebrook Subdivision** – 27 lot conventional subdivision, Southbury, Connecticut (Conte Family Trust, LLC**)**
- **Seven Oaks** – 19 lot open space subdivision, Ridgefield, Connecticut (Basha Szymanska)
- **Applewoods** – 29 lot conventional subdivision, Bethel, Connecticut (Gene & Joe Nazzaro)

Third Party Engineering Reviews

- **Groton Open Space Association** – Wal-Mart Super center, Mystic Woods Age Restricted Development, and changes to stormwater standards in the Town of Groton regulations – Groton, Connecticut. Focus of review was on stormwater management plans to address water quality and runoff volumes per the CT DEP 2004 Storm Water Quality Manual as well as the adequacy of the erosion and sedimentation control plan for the proposed development. Project approved with modifications to stormwater management system to address water quality.
- **Town of Tolland Planning & Zoning Commission** – Star Hill Athletic Complex with focus on water quality impacts on existing impaired waterway. Focus was on suggesting changes to stormwater management system to comply with recently adopted Low Impact Development requirements in the Town of Tolland. Project approved and built with modifications to stormwater management system to address water quality of post-development runoff.
- **Town of Newtown Inland Wetlands Commission** – Sherman Woods – 38 lot residential Subdivision with focus on stormwater management and water quality. Review stormwater management plan for compliance with CT DEP 2004 Storm Water Quality Manual to address water quality issues being directed to high quality wetland systems. Also review erosion & sedimentation control plan for adequacy and compliance with CT DEP 2002 Guidelines for Soil Erosion & Sediment Control. Project withdrawn and not resubmitted.
- **Town of Winchester Inland Wetlands Commission** – 30,000 sq.ft. Commercial building with grading and stormwater management within 100-yr flood plain. Plan reviewed focused on impacts to floodway and 100-year flood plain as a result of the placement of significant fill within the flood plain. Project approved with modifications to stormwater management system.
- **Town of Southbury Inland Wetlands Commission** – 35,000 sq.ft. Medical office building proposed in close proximity to inland wetlands & watercourses. Review focus on the adequacy of the stormwater management plan to address water quality and runoff volumes prior to discharge into on-site wetland areas.
- **Friends of Litchfield** – Stop & Shop proposal on existing retail site proposing an increase of impervious area of 1 acre directly draining into an aquifer protection area. Focus of review was on adequacy of stormwater management system to address water quality of runoff and prevent further off-site adverse impacts. Project approved with minor modifications to stormwater management system.

- **The Regency at Ridgefield** – Proposal for contractor's yard on steep slope immediately uphill of existing pond and wetlands. Project proposed removal of over 45,000 cubic yards of earth and rock to facilitate construction of building. Focus of review was on adequacy of erosion control and stormwater management plan to prevent discharges of pollutants to receiving pond. Project denied citing impacts of stormwater on existing pond.
- **Friends of Oswegatchie Hills Nature Preserve, Inc. and Save the River, Save the Hills, Inc**. – Review of preliminary site plan for 840 unit of affordable housing on a 230+ acre site directly adjacent to the Niantic River submitted for a zone change to the Planning and Zoning Commission. Focus of review was on stormwater management and impacts to down gradient wetlands, including the Niantic River. Preliminary site plan approval granted with conditions of approval requiring final plans to address stormwater issues raised by Trinkaus Engineering, LLC.
- **Save the River, Save the Hills, Inc**. – Review of the erosion control plans and stormwater management plans for 90-acre solar array proposed on core forest in Waterford, Connecticut which drained directly to first order cold water fishery streams. Provide written comments to Connecticut Siting Council on behalf of Save the River, Save the Hills (Intervenor). Siting Council denied project citing erosion and stormwater management issues with the plan.
- **Town of Brookfield Inland Wetlands Commission** – The Enclave at Brookfield, an affordable housing project with 187 units on 9.8 acres proposing filling of wetland, locating stormwater basin within inland wetland area and a significant increase of impervious. Review focused on adequacy of stormwater management system to address water quality, runoff volume and peak rate changes due to development in accordance with CT DEP 2004 Storm Water Quality Manual and local land use requirements; review of erosion & sedimentation control plan for compliance with CT DEP 2002 Guidelines for Soil Erosion & Sediment Control and local land use requirements. Offer modifications to plans to address water quality and runoff volume which applicant accepted resulting in approval of project.
- **Town of Brookfield Inland Wetlands Commission and Zoning Commission** – The Renaissance, an affordable housing project with 156 units of 5+ acres adjacent to the Still River replacing existing development on the site. Review focused on adequacy of stormwater management system to address water quality, runoff volume and peak rate changes due to development in accordance with CT DEP 2004 Storm Water Quality Manual and local land use requirements; review of erosion & sedimentation control plan for compliance with CT DEP 2002 Guidelines for Soil Erosion & Sediment Control and local land use requirements. Additionally, reviewed issues of development in the floodway and 100-year flood plain of the Still River. Provided modifications to plans to address water quality and runoff volume which applicant accepted resulting in approval of project.
- **Town of Brookfield Inland Wetlands Commission** – Brookfield Village – Phase II – 12/23 Station Road proposing commercial space and residential apartments in the "Four Corners of Brookfield"; 70 Stony Hill Road proposing 26 units of affordable housing served by private water and on-site sewage disposal systems; 468 Federal Road – 280-unit affordable housing project. In all applications, the review focused on the probable adverse impacts to inland wetlands and watercourse as well as the adequacy of the erosion control plan and stormwater management plan to treat non-point source pollutants and runoff volumes to minimize adverse impacts to the receiving inland wetlands and watercourses. Original application withdrawn after initial review. Provide sketch of modifications to improve water quality of post-development runoff and minimize direct impacts on inland wetlands. Application not resubmitted at this time.
- **Town of Salisbury Inland Wetlands Commission** – Review of multiple applications for residential development and/or improvements on existing lakes. Issues reviewed were stormwater management to ensure that water quality of post-development runoff was improved prior to entering lake and that erosion control plans were appropriate and adequate to prevent eroded material from reaching the lake or shoreline wetlands.

- **Branford Citizens for Responsible Development** – Review of development plans for Costco Store and other commercial development on 45 acres in Branford, CT. Review focuses on stormwater management issues, particularly increased runoff volumes and pollutant loads to be generated by development and whether the proposed stormwater management proposal would adequately address the impacts of these two issues. Both the 2004 CT DEP Storm Water Quality Manual and the Branford Inland Wetland Regulations were used to determine if the plans were compliant with the applicable standards. The erosion control plan was evaluated for compliance with the CT DEP 2002 Guidelines for Soil Erosion & Sediment Control. Project withdrawn and not resubmitted.
- **Save our Shelton** – Review of development plans for large-scale mixed-use development on 120+ acre site on Bridgeport Avenue. Site contained core forest and high-quality wetland/watercourse systems. Review focused on stormwater management issues, particularly increased runoff volumes and pollutant loads to be generated by development and whether the proposed stormwater management proposal would adequately address the impacts of these two issues. Both the 2004 CT DEP Storm Water Quality Manual and the Shelton Inland Wetland and Stormwater Regulations were used to determine if the plans were compliant with the applicable standards. The erosion control plan was evaluated for compliance with the CT DEP 2002 Guidelines for Soil Erosion & Sediment Control. Project still in land use process.
- **Concerned Citizen Group - Roxbury, CT** – Review of proposed residential 12-lot subdivision on steeply sloping site with high quality wetlands and watercourses. Review of all aspects of civil engineering (site layout, grading, erosion/sediment control, stormwater management, stream crossing methodology) using the CT DEP 2004 Storm Water Quality Manual and CT DEP 2002 Guidelines for Soil Erosion and Sediment Control as well as the Town of Roxbury land use regulations and ordinances and evaluate impacts to wetlands and watercourses. Stormwater management system and erosion control plans were found to be inadequate to protect the high-quality wetlands and watercourses from adverse impacts by the Inland Wetlands Commission. Project denied by Inland Wetlands Commission citing findings from the Trinkaus Engineering, LLC review and other consultants.
- **Par Arbors, LLC – Bloomfield, CT –** Review of truck storage and dispatch center on agricultural land with numerous delineated inland wetland/watercourses on the site. Focus of review was on stormwater management and the adverse effects of increased pollutant loads and runoff volumes on wetland. Also review adequacy of erosion control plans. Provided testimony at two public hearings in front of Inland Wetlands Commission. Application to conduct regulated activities was denied by the commission in July 2019.

Commercial Site Plans

- **Cannondale Corporation Headquarters -** Bethel, Connecticut
- **Village Bank Headquarters** – Danbury, Connecticut
- **Newtown Hardware -** Newtown, Connecticut
- **Amicus Healthcare Living Centers –** Rocky Hill, Connecticut
- **Nathan Hale Office Building** – Fairfield, Connecticut
- **Ridgefield Recreation Center** – Ridgefield, Connecticut
- **Silver Spring Country Clubhouse & Pool house renovations -** Ridgefield, Connecticut
- **Tiger Hollow Athletic Complex at Ridgefield High School -** Ridgefield, Connecticut

On-site sewage disposal systems

- **Candle Hill Mobile Home Park** – Design Subsurface Sewage Disposal Systems for individual mobile home units. New Milford, Connecticut.

- **Hemlock Hills Camp Resort** – Expansion of campground, design of gravity sanitary sewer and design of subsurface sewage disposal system to handle 4,800 gpd. Litchfield, Connecticut.
- **Old Field Condominiums** – long term inspection & reporting on the condition of multiple subsurface sewage disposal systems serving 40 unit condominium complex with design flows in excess of 15,000 gpd. Southbury, Connecticut.
- **Thorncrest Farm** – Design of on-site sewage disposal system to handle wastewater from milking operation. Goshen, Connecticut.
- **Silver Spring Country Club** – Design of multiple subsurface sewage disposal systems for private country club with average daily flow of 7,000 gpd during peak usage season.
- **Richter Park Golf Course** – Design subsurface sewage disposal system to replace existing failed system for golf club house and year round restaurant with average daily flow of just under 5,000 gpd.
- **Redding Country Club -** Performed soil testing to design a repair to an existing wastewater management system that was experiencing periodic effluent discharges during high use on very marginal soil conditions. Utilized oversized grease tanks for kitchen waste and septic tanks to increase the clarity of the effluent which was discharged by force main to the subsurface sewage disposal system increase the long term functionality of the system. Discharge rate 4,900 gpd.

General Civil Engineering Projects

- **Montgomery Residence**, 10,000 sq.ft. residence with 2.5 acre pond, Redding, Connecticut.
- **Neils Different,** Design 1 acre pond, Ridgefield, Connecticut.
- **Anthony DeLuca**, Design 2 acre pond**,** Redding, Connecticut.
- **Barrett Cram**, Design 0.5 acre pond, Redding, Connecticut.
- **Jay & Eileen Walker Residence**, 27,000 sq.ft. residence, Ridgefield, Connecticut.
- **Lodestar Energy – Winchester, Connecticut:** Design 8 acre ground mounted solar array, access driveway, stormwater management system and erosion/sedimentation control plan.

Athletic Facilities

- **Kingdome – East Fishkill, NY,** Prepare comprehensive site plan for the construction of an air-supported structure covering 7.96 acres of land area. Project also includes the design of 303 parking spaces, two full size artificial turf baseball fields and three 54-80 artificial turf baseball fields. Designed all site grading and stormwater management facilities to address water quality volume, channel protection volume as well as peak rate attenuation for the 1-yr, 2-yr, 10-yr, 25-yr, 50-yr and 100-yr rainfall events.
- **Tiger Hollow – Ridgefield High School – Phase I**, Design and site artificial turf competition field and track complex. Design access road to provide access to new building containing locker rooms, concessions, media room, and equipment storage areas. Design all utility connections and obtain local permits.
- **Tiger Hollow – Ridgefield High School – Phase II**, Prepare Conceptual Development plan for reconfiguration of existing athletic fields adjacent to the Tiger Hollow stadium.
- **Joel Barlow High School – Redding, CT**, Provide preliminary Master Plan on pro bono basis for reconfiguration and improvement of existing athletic fields at Joel Barlow in response to Falcon Pride stadium proposal. Plan was provided to Region 9 Board of Education for general discussion purposes.

APPENDIX "B"
Letter from Trinkaus Engineering, LLC to Leslie King, Esq. of Murtha Cullina of December 18, 2018 regarding the Antares Solar Array in East Lyme, Connecticut

LOW IMPACT SUSTAINABLE DEVELOPMENT
TRINKAUS ENGINEERING

Trinkaus Engineering, LLC
114 Hunters Ridge Road
Southbury, Connecticut 06488
203-264-4558 (office & fax)
+1-203-525-5153 (mobile)
E-mail: strinkaus@earthlink.net
http://www.trinkausengineering.com

December 19, 2018

Ms. Leslie King, Esq.
Murtha Cullina
One Century Tower
265 Church Street
New Haven, Connecticut 06510

Re: Solar Farm – Grassy Hill Road
East Lyme, Connecticut

Dear Ms. King,

At your request, I have reviewed the following additional documents for the solar farm which was constructed on Grassy Hill Road in East Lyme.

1. Site plans prepared for Antares Solar Field by BL Companies, dated: October 9, 2012 and revised to July 16, 2013.
2. Stormwater Management Report prepared for Antares Solar Field by BL Companies, dated: July 16, 2013 (Stormwater Management Report)

None of the information found in these documents changes my conclusions and professional opinions regarding issues with the design of the stormwater management and erosion control plan for the East Lyme solar farm.

Executive Summary of Opinions:

1. The stormwater management report grossly under estimates both the peak rate and runoff volumes which are being generated by the project as it does not consider the solar panels to be impervious. The panels are situated above the ground surface, thus every raindrop which falls on a panel instantly becomes runoff.
2. The applicant failed to account for changes in soil compaction and porosity which resulted from the considerable regrading of the site. The substantial cuts and fills of the

site resulted in a soil surface which will not infiltrate and thus will generate more runoff than the undisturbed pre-development conditions.

Developers Stormwater Management Plan and Report:

To further support the professional opinions stated in the executive summary regarding the increases in the peak rate and runoff volumes, I have performed calculations to show the significant increases in the peak rate of runoff and runoff volume are being generated by the existing solar farm on Grassy Hill Road in East Lyme.

I have calculated the changes in both the peak rate of runoff and runoff volumes for that portion of the solar farm which is tributary to the Bialowans property. Based upon the plans and Stormwater Management Report prepared by BL Companies, sub-watershed areas A-1, A-2, A-3, A-4, A-5 and B-1 identified therein were analyzed.

The Time of Concentration value used by BL Companies as well as their total sub-watershed area was used in my analysis. I made three modifications compared to the BL analysis. First, the area of the solar panels was considered as pervious by BL Companies and I considered them to be impervious as all rainfall which falls on the panels is converted to runoff. An impervious surface has a Runoff Curve Number (RCN) of 98. Each panel was shown on the site plan by BL Companies as a separate unit and measured 10' x 35'. To determine the impervious area, I counted the number of solar panels within each sub-watershed area.

The approved site plans BL Companies showed a gap between each panel in a row; however, in the field there is no gap between each panel, so the actual peak rate of runoff and runoff volumes would be higher than the values stated in Table #1 and #2 for Trinkaus #1 and Trinkaus #2. The calculated values for Trinkaus #1 and Trinkaus #2 are based upon a gap existing between the individual panels as shown on the BL Company site plans.

Secondly, the RCN for the gravel roads was changed from 89 to 96. In the HydroCAD Version of TR-55, there are two categories for a gravel road. First, a gravel road (with right of way) has an RCN of 89. This is the value used by BL Companies in their stormwater management plan and is not applicable in this case as the gravel road is simply located within the limits of the solar farm. A gravel road (w/o right of way) has a RCN of 96 according to the HydroCAD program and this condition reflects what was actually proposed by BL Companies and constructed in the field at the Antares Solar Farm.

Lastly, one analysis (Trinkaus #1) was done using a RCN for Lawn in Good Condition on a Class C soil (74) and the second analysis (Trinkaus #2) was done using a RCN for Lawn in Good Condition on a Class D soil (80). The Class D soil designation more accurately reflect the disturbed soil conditions on the site as a result of the regrading and compaction specifications on the approved plans by BL Companies.

Applying these three modifications, the peak rate of runoff for the 2-year rainfall event (3.4" per 24 hours as stated in the Stormwater Management Report by BL Companies) was analyzed; the results are shown in Table #1 below. Peak Rate of runoff is shown as cubic feet per second (cfs). Runoff volume for the two-year rainfall event is shown in Table #2. Runoff volume is measured in acre-feet. (An acre-foot is 1 foot of water over 1 acre of land (43,560 cubic feet of water).)

Table #1

Post-Development Watershed Area	BL Companies	Trinkaus #1	**Net Change/ Percent Change**	Trinkaus #2	**Net Change**
Peak Rate	cfs	cfs		cfs	
A-1	5.36	5.63	**+0.27/5.0%**	7.66	**+2.30/22.9%**
A-2	5.52	6.49	**+0.97/17.6%**	8.25	**+2.73/49.4%**
A-3	7.12	8.35	**+1.23/17.3%**	10.60	**+3.48/48.9%**
A-4	5.11	5.97	**+0.86/16.8%**	7.53	**+2.42/47.3%**
A-5	7.43	14.32	**+6.89/92.7%**	18.13	**+10.70/144.0%**
B-1	3.40	4.15	**+0.75/22.0%**	4.97	**+1.57/46.2%**

Table #2

Post-Development	BL Companies	Trinkaus #1	**Net Change/ Percent Change**	Trinkaus #2	**Net Change**
Runoff Volume	cubic feet	cubic feet		cubic feet	
A-1	0.530	0.556	**+0.026/4.9%**	0.732	**+0.202/38.1%**
A-2	0.545	0.629	**+0.084/15.4%**	0.786	**+0.241/44.2%**
A-3	0.715	0.826	**+0.111/15.5%**	1.032	**+0.317/44.3%**
A-4	0.542	0.624	**+0.082/15.1%**	0.776	**+0.234/43.4%**
A-5	0.774	0.898	**+0.124/16.0%**	1.121	**+0.347/44.8%**
B-1	0.312	0.375	**+0.063/20.2%**	0.446	**+0.134/42.9%**

The results shown in both Table #1 and Table #2 clearly show that both peak rate and runoff volumes are substantially higher when the solar panels are considered impervious.

The engineering standard for the design of a stormwater management is to consider any hard surface above ground or on the ground surface as impervious. The stormwater manuals of the States of Massachusetts, Minnesota, North Carolina and Maryland have sections which specifically address how to handle stormwater from large scale solar farms. Links to these sections are provided below.

State of Massachusetts: https://www.mass.gov/guides/massdep-wetlands-program-policy-17-1-photovoltaic-system-solar-array-review

State of Minnesota:
https://stormwater.pca.state.mn.us/index.php?title=Fact_sheet_on_stormwater_guidance_for_solar_farm_projects

State of North Carolina:
https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Stormwater/BMP%20Manual/E-6%20%20Solar%20Farms.pdf

State of Maryland:
https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/ESDMEP%20Design%20Guidance%20Solar%20Panels.pdf

The common features in these four manuals is that solar panels themselves could be considered pervious if all of the following conditions are met. If any of conditions are not met, then the solar panels must be considered as impervious.

a. Minimize site disturbance,
b. Prevent compaction of the soils on the solar farm, particularly in the area of the panels and vegetated strips,
c. Prevention the removal of topsoil from the site or replace the topsoil prior to seeding,
d. Maintain or restore infiltrative capacity of the soil,
e. Prevent concentrated flow from occurring,
f. Establishment of a dense vegetated cover on the soil surface.

The Antares Solar Farm on Grassy Hill Road in East Lyme does not meet any of the conditions stated above, therefore the solar panels must be considered impervious in the design of the stormwater management systems.

At the field inspection of the site on October 5, 2018, it did not appear that topsoil was replaced on the site after being removed to permit the mass grading of the site to occur. This observation is based on a visual inspection of the ground surface which did not show dark brown organic soil on the surface. The ground under the rows of panels and between the rows was light brown and very compacted, whereas if topsoil was present, the surface would not be compacted due to the higher organic content found in topsoil.

There is clear evidence in the field that runoff from the solar panels are not infiltrating into the disturbed soils under the entire solar farm. This evidence of erosion and resultant sedimentation is shown in Figure 1 and Figure 2 below.

Figure 1 – Concentrated flow from runoff off solar panel

Figure 2 – Erosion & Sedimentation resulting from concentrated flow

On Sheet GN-1 by BL Companies with a revision date of 7/16/13 under Grading and Utility Notes, note #5 states the following: "The contractor shall compact fill in 8" maximum lifts under all building areas to 95% of the maximum dry density as determined by ASTM D1557 (Modified Proctor Test), or as directed by the Geotechnical Engineer." In my professional opinion, the term "all building areas", mean the entirety of the solar farm. The natural soils were cut and filled substantially on the site, compacted to the ASTM D1557 standard, which easily and clearly explains why there is no infiltration occurring within the grass areas on the solar farm and more runoff is being created for all rainfall events.

Information on the ASTM D1557 standard can be found at this link: https://www.astm.org/Standards/D1557.htm . The following language was taken from this link and the sentence shown in bold is how the properties of the natural soil would be changed. NOTE 3: The degree of soil compaction required to achieve the desired engineering properties is often specified as a percentage of the modified maximum dry unit weight as determined using this test method. If the required degree of compaction is substantially less than the modified maximum dry unit weight using this test method, it may be practicable for testing to be performed using Test Method D698 and to specify the degree of compaction as a percentage of the standard maximum dry unit weight. Since more energy is applied for compaction using this test method, the soil particles are more closely packed than when D698 is used. **The general overall result is a higher maximum dry unit weight, lower optimum moisture content, greater shear strength, greater stiffness, lower compressibility, lower air voids, and decreased permeability.** However, for highly compacted fine-grained soils, absorption of water may result in swelling, with reduced shear strength and increased compressibility, reducing the benefits of the increased effort used for compaction **(2)**. Use of D698, on the other hand, allows compaction using less effort and generally at a higher optimum moisture content. The compacted soil may be less brittle, more flexible, more permeable, and less subject to effects of swelling and shrinking. In many applications, building or construction codes may direct which test method, D698 or this one, should be used when specifying the comparison of laboratory test results to the degree of compaction of the in-place soil in the field.

Corrective Action to Remediate the Stormwater Management System:

In order to reduce the runoff being discharged from the solar farm, the existing stormwater management systems must be remediated to provide the Channel Protection Volume (CPV) as specified in the CT DEP 2004 Storm Water Quality Manual. The CPV requires developers to reduce the post-development peak rate of runoff from the 2-year rainfall event to 50% of the pre-development peak rate for the 2-year storm event. The intent of the CPV is to reduce the post-development peak rate, which will significantly increase the duration of flow directed to a receiving stream. By reducing the peak rate, the nominal flow depth in the receiving streams is lowered for the all rainfall event up to and equal to the 2-year rainfall event to the more naturally stable cross-sectional area of the stream, thus preventing adverse changes to the morphology of the stream channel. The following work must be done to the Antares Solar Field in order to have a stormwater remediation plan which provides the CPV:

1. An As-built survey of the entire solar farm done conforming to the following standards.

    a. Boundary work and survey location performed to a Class A-2 standards locating all buildings, solar panels, gravel roadways, stormwater management practices (ponds and swales),
    b. A two-foot topographic survey of the solar farm which meets Class T-2 standards. The area of the topographic survey needs to encompass all those areas within the fenced area of the solar farm, including the detention ponds and swales. The

limit of topographic survey must extend a minimum of fifty (50) feet beyond the eastern and southern limit of grading of the solar farm.

2. A revised stormwater management analysis and design encompassing the following parameters.
    a. All solar panels, all buildings or above ground equipment identified as impervious,
    b. The grass on all disturbed areas within the limits of the solar farm shall be considered as Grass (good condition on a Class D soil),
    c. Post-development watershed boundaries shall be established by the design engineer based upon current as-built conditions,
    d. Times of concentration shall be determined by the current field conditions,
    e. Runoff Curve Numbers (RCN) will be determined based upon current field conditions and the parameters stated above,
    f. Post-development peak rates of runoff and runoff volumes shall be determined by HydroCAD or a similar hydrologic model for the two-year rainfall event (3.4"/24 hours),
    g. The size and hydrologic outlets of all the existing stormwater ponds shall be redesigned to provide the Channel Protection Volume (CPV) as specified in the CT DEP 2004 Storm Water Quality Manual as well as attenuate the peak rate of runoff for the 10-year rainfall event. An appropriate overflow spillway shall be incorporated into the design of all stormwater ponds for all rainfall events larger than the 10-year event up to and including the 100-year rainfall event,
    h. A revised site plan showing the modifications to all the stormwater ponds shall be prepared. The site plans shall include all construction details for each stormwater pond and their respective outlet structures,
    i. An erosion control plan, conforming to the CT DEP 2002 Guidelines for Soil Erosion and Sediment Control shall be prepared for the modifications of the stormwater ponds,
    j. A revised stormwater management report shall be prepared with all calculations and pond routing analyses.

The above modifications to the stormwater management plan for the solar farm must be reviewed and approved by a third-party engineering consultant which expertise in stormwater management prior to its implementation. No cost for the implementation of the stormwater pond modifications can be determined until an actual design has been made.

Respectfully Submitted,
Trinkaus Engineering, LLC

Steven D. Trinkaus, PE

Appendix "C"
Engineering Review letter by Trinkaus Engineering of April 3, 2020 concerning the applicant's solar farm proposal in Waterford, Connecticut

Trinkaus Engineering, LLC
114 Hunters Ridge Road
Southbury, Connecticut 06488
203-264-4558 (ph & fax)
E-mail: strinkaus@earthlink.net
http://www.trinkausengineering.com

April 3, 2020

Ms. Melanie Bachman
Connecticut Siting Council
Ten Franklin Square
New Britain, Connecticut 06051

Re: Proposed Photovoltaic Installation
177 Old Mill Road – Waterford, CT
CT Siting Council Petition No. 1347

Dear Ms. Bachman and Members of the Connecticut Siting Council,

I have been retained by Save the River-Save the Hills, Inc. to review submitted documentation for the above referenced project. In addition to being a licensed Professional Engineer in Connecticut and Maryland, I am an expert in the field of Low Impact Development which has a major focus on stormwater, particularly water quality and runoff volume. I also have a Bachelor of Science in Forest Management from the University of New Hampshire which makes me a qualified expert in the Forestry field and I will be making some specific comments on the forestry aspects of this application.

Stormwater Report by VHB, Inc.:

1. On page 1, it is stated that a selective timber harvest was conducted on the site over 66 acres of the site. Based upon Google Earth, the operation conducted on the subject property was not a selective timber harvest but is a clear cut of large portions of the site. A selective timber harvest does not remove all the trees in a particular location which is the case on this site. It is clearly visible in Figure 1 that whole swatches of trees were removed from many portions of a site. A selective timber harvest is defined as follows *"Selection cutting, also known as **selective** cutting, is the silvicultural practice of **harvesting trees** in a way that moves a forest stand towards an uneven-aged or all-aged condition, or 'structure'."* This is clearly not what occurred on the subject property.

Figure 1 - Google Image of Timber Harvest on subject parcel

2. On page 2, the applicant states that most soils are Class B and thus have a moderate infiltration rate. This statement does not take in account the compaction which occurred by the movement of tree clearing and hauling equipment used in the timber removal operation.
3. On page 2, it is stated that the stormwater management system was designed to incorporate measures found in the CT DEP 2004 Storm Water Quality manual. It is further stated that post-development peak rates are less than pre-development peak rates and meets the Channel Protection Volume per the manual. These are false and incorrect statements and will be demonstrated below that the design does not achieve any of these requirements.
4. On page 3, it is stated that most of the site is wooded. This is a false statement as it was noted on page 1 that a timber removal operation was done on the site. Question: Can the applicant explain how and why large extents of forest were removed from the site, when a selective harvest was supposed to have been done?
5. On pages 3 to 6, it is noted that the all the site ultimately drains to either Stony Brook or Oil Mill Brook, both of which are cold water fishery streams. There is no mention of the environmental sensitives of these brooks in the stormwater report.
6. There is no discussion or proposed mitigation for the thermal impacts of runoff from the site which will be directed to Stony Brook or Oil Mill Brook.
7. On page 6, it is stated that the only new impervious areas proposed on the site are the access roads and concrete pads. This is a false and misleading statement by the engineer.
8. On page 6, it is also stated that the vegetated buffers and proposed stormwater basins with crushed stone access path and the wetland systems will provide water quality treatment in all portions of the site. No evidence has been provided how this improved water quality will be met.

a. If the crushed stone access paths are considered impervious, how will they provide water quality treatment? No computations or analyses are provided to document this statement.
b. As all the runoff from the area of the array is being directed to one of the many stormwater basins, will the vegetated buffers see any untreated runoff?
c. How will the vegetated buffers provide treatment of the runoff if they are located below the stormwater treatment basins?
d. How will the proposed stormwater basins provide water quality treatment? No computations or other analyses have been provided.

9. It is the DEEP policy to use wetlands to provide treatment for stormwater runoff. How does the applicant intend to have the wetlands provide stormwater treatment? No analysis has been provided. Figure 3 in the report depicts the post-development drainage boundaries do not show the extent of solar panels in each watershed. Figure 3 is not an accurate representation of the post-development conditions.
10. On page 9, it is shown that post-development peak rates of runoff will be less than pre-development rates. This is a false statement by VHB and voids all the conclusions found in the stormwater report by VHB. The applicant is not considering the solar panels to be impervious and thus the post-development peak rates and volumes of runoff are under-estimated by approximately 40% based upon my review of other large-scale ground mounted solar arrays. The solar panels are set upon a metal racking system which place them between 3' and 10' above grade. The applicant's argument is that there is vegetation under the panels and runoff will infiltrate, thus the panels basically do not change the runoff characteristics. This is a false statement. The elevated solar panels are no different than a car port, which is a roof supported by four or more posts and open on all four sides. The roof of the car port is impervious and thus the elevated solar panels are impervious. At the solar array in East Lyme also developed by Greenskies, there is clear evidence that runoff from the solar panels is not infiltrating at all, but occurring as concentrated flow, causing erosion and resultant sedimentation. See Figures 2 and 3.

Figure 2 - Concentrated flow from Solar Panels (East Lyme)

Figure 3 - Sedimentation of eroded soil from concentrated flow (East Lyme)

11. On page 10, it is stated that neither the panels nor the concrete pads will produce any pollutants. It is a false statement. Atmospheric deposition of pollutants on an impervious surface are a substantial component of the discharge of non-point source pollutants. According to published literature anywhere between 27% and 40% of nitrogen in non-point source runoff is from atmospheric deposition. This is a significant

concern as both Stony Brook and Oil Mill Brook discharge to the Niantic River (a tidal estuary). It is well documented that increased nitrogen loads in tidal areas have a significant adverse impact on tidal wetland grasses, causing die offs of these plants. Additionally, particulate bound trace metals such as Chromium, lead, and zinc are also found in atmospheric deposition. No evaluation of the pollutant loads to be generated by this site has been provided. Also, there is no assessment as to how well the proposed stormwater treatment practices will reduce these non-point source pollutant loads which will occur on this site.

12. On page 10, it states that the Water Quality Volume (WQV) is being provided in each of the basins, however the area of the solar panels is not included in the impervious area determination for each basin according to the actual WQV computations. Therefore, the WQV is grossly under-estimated and is not in compliance with the CT DEP 2004 Storm Water Quality Manual. Furthermore, the applicant is misapplying the language from the Minnesota Stormwater Standards for ground mounted solar arrays as there are very specific criteria in the Minnesota Manual which are not present on this site. According to CT DEP Stormwater Division, the Minnesota standards have NOT been adopted in any shape or form by the DEEP in Connecticut.
13. On page 11, it is stated that the Channel Protection Volume (CPV) is being provided. This is a false, unsupported statement. By not considering the solar panels to be impervious, the post development runoff rates and volumes are substantially less and thus the claim of meeting the CPV is false.
14. On page 11, it is stated that outlet protection is provided at the discharge point of each permanent stormwater basin in accordance with the guidance found in the 2004 Manual. The controlling document for energy dissipation of runoff is the CT DEP 2002 Guidelines for Soil Erosion and Sediment Control, not the 2004 Manual.
15. Appendix C uses a generic erosion control inspection sheet. It does not define what are the “Minimum Maintenance and Key Items to Check” so this form is useless to the contractor and does nothing to ensure that the erosion control proposed by the applicant will actually be installed properly and maintained over the construction period.
16. Appendix D provides the hydrologic computations for the complete design of the temporary and permanent stormwater basins and comments are as follows:

Temporary Diversion Swale Sizing:

a. There is no way to correlate the sizing calculations with the site plans as none of the swales are labeled on the erosion control plans.
b. No boundaries of the contributing area to each swale are provided so the applicant’s calculations cannot be verified.
c. The applicant is using the CT DOT Manual for sizing of the swale. This is incorrect, the 2002 Guidelines by CT DEP are the controlling document for the design of swales to be used as temporary or permanent diversion systems.
d. It appears that an average slope was used for the sizing of the swales, however, a review of the plans shows that the slope is variable and thus the calculations appear to be only applicable to the flattest portion of the swale. This is not correct, if the swale has variable slopes, the swale design must evaluate all conditions to ensure that non-erosive velocities will be achieved in all locations. It is obvious that steeper sections will have higher flow velocities than flatter

sections and additional measures may be necessary to ensure non-erosive flow velocities are present at all locations.

e. No grading for the temporary diversion swales is shown on the plan.

Temporary Sediment Trap Sizing:

a. It appears that the applicant is not using the 2002 Guidelines for the sizing of the temporary sediment traps. This is the controlling document, not the CT DOT Drainage Manual.
b. There is no way to correlate the sizing calculations with the site plans as note of the temporary sediment basins are labeled on the erosion control plans.
c. No boundaries of the contributing area to each temporary sediment trap are provided, so the applicant's calculations cannot be verified.
d. To be effective and allow sediments to settle out, temporary sediment traps must have a minimum 2:1 length to width ratio (inlet to outlet). This condition is not met for many of the basins shown on the plans.
e. No spillway is shown for the temporary sediment traps. It appears that the spillway for the permanent stormwater basins will be used. If the permanent spillways are to be used for the temporary sediment traps, in many cases they are not located the minimum 2:1 length to width ratio requirement noted above.

Water Quality Volume:

a. The calculations submitted for each drainage area are not valid. Only the gravel driveway and concrete pads are considered impervious, thus the WQV is grossly under-estimated. The solar panels are impervious and thus must be factored into the WQV calculation.
b. The applicant has separated various soil classifications out for the calculation of the WQV. This is incorrect. The soil types have no bearing on the calculation of the WQV.

Stormwater Basins for Post-Development Runoff:

a. The post-development watershed mapping does not show land cover types and associated areas for the determination of peak runoff rates. Based upon the HydroCAD summaries in the report, it cannot be verified that one lower soil classification is being used for those portions of the site where the array will be located.
b. In the analyses of each watershed area which includes portions of the array, the applicant is using the ground cover, Grass cover (>75%) in good condition. Under TR-55 Methodology (used by the applicant), in order for grass ground covers to be considered in "Good Condition" certain conditions must be met. Grass cover must cover the entire soil surface with no bare spots; the height of the grass needs to be a minimum of 3" tall and the depth of the root system must be equal to or longer than the height of the grass. If these conditions are not met, then the "Good Condition" designation cannot be used. Based upon information found elsewhere in the application, it is stated that the area of the array will be stumped and seeded, then the following year, the array will be installed. This means that newly established grass cover will be driven over by the equipment

used to deliver the panels and racking systems to the site, install the racking system, and to install underground conduit. The movement of this equipment over the newly established grass will adversely affect its growth and thus the extent of cover with the area of the array. In addition to adversely affecting the growth of the grass, this will also result in compaction in some areas of the site further reducing the infiltrative capacity of the soil. This will have the effect of reducing the amount of infiltration into the ground and increase the volume and rate of runoff.

c. The area of solar panels is not considered impervious in the post-development analysis; thus, the peak rate and runoff volumes are grossly under-estimated.

17. The hydrologic analyses only looked at the 2-year, 25-year, 50-year and 100-year rainfall events. Why wasn't the analysis done for the WQ storm as well as the 1-year rainfall events?
18. The proposed stormwater management systems consist of either Ponds, Infiltration Basins or Sand Filters. What type of pond is being proposed on this site (Number 1, 4, 6, 9, 11, 12 and 16)?
19. As proposed none of the proposed stormwater ponds are not in compliance with the requirements found in the DEP 2004 Manual for stormwater ponds.
20. Without knowing the specific type of pond (Wet Pond, Micro pool Extended Detention Pond, Wet Extended Detention Pond or Multiple Pond System), the design and compliance with the requirements of the DEP 2004 Manual cannot be determined.
21. None of the proposed stormwater ponds have forebays or other appropriate pre-treatment systems which will contain a minimum of 10% of the required WQV or treat the Water Quality Flow (WQF).
22. There are several infiltration basins proposed (Number 2, 5, 13, and 14) for this project. None of them provide a pre-treatment system containing between 10% and 25% of the required WQV.
23. The DEP 2004 Manual strongly recommends that Infiltration basins be designed as off-line systems to only accept runoff generated by the water quality storm with a by-pass system for larger rainfall events. None of the proposed infiltration basins are designed as off-line systems with a bypass. The result of these infiltration basins being subject to the runoff from all rainfall events is that they will prematurely fail due to clogging of the surface of the infiltration soil surface. This condition has been well documented at professional conferences.
24. There are several sand filter systems proposed (Number 3, 8, and 10). The DEP 2004 Manual requires that a 36" vertical separation from the bottom of the sand filter to SHGW be provided. This requirement has not been met for any of the three proposed sand filters.
25. Sand Filters also require the same level of pre-treatment as do Infiltration Basins and this pre-treatment has not been provided by the applicant.
26. There is a singular detail on sheet C-6.2 for Permanent Stormwater Basins whereas three different types of stormwater practices are proposed with different design requirements. Additionally, this detail appears to show that the downhill side of the embankment will solely consist of modified riprap and other stones. If this is the case, then there will

continually flow through the stone which has not be modeled in the routing analyses of the proposed practices.

27. The following bullet points (#28 to #43) evaluate each proposed stormwater practice and provides a statement as to whether it will function as intended by the applicant.
28. Basin #1: Type – Pond, Depth to SHGW = 24" (avg), depth of pond below existing grade = 3' to 7', bottom of pond = 190', elevation of spillway = 193', available storage volume is over-estimated as there will be a permanent pool below the spillway elevation 193'.
29. Basin #2: Type – Infiltration, depth of pond below existing grade = 3' to 7', bottom of pond = 227.5', elevation of spillway = 231', infiltration rate is based upon approximately 42" below grade not at or below bottom pond elevation; percolation tests over-estimates vertical permeability when compared to Double Ring Infiltration tests; infiltration basin not designed per DEP 2004 Manual.
30. Basin #3: Type – Sand Filter, Depth to SHGW = 46" (avg), depth of pond below existing grade = 3' to 8', bottom of pond = 184', elevation of spillway = 188', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 188', design does not provide 36" vertical separation to SHGW, thus design is not in compliance with DEP 2004 Manual.
31. Basin #4: Type – Pond, Depth to SHGW = 22" (avg), depth of pond below existing grade = 3' to 7', bottom of pond = 184', elevation of spillway = 188', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 188'.
32. Basin #5: Type – Infiltration, Depth to SHGW = 26" (avg), depth of pond below existing grade = 0' to 4', bottom of pond = 216', elevation of spillway = 218', no infiltration will occur as the bottom of the infiltration basin is below seasonal groundwater, design conclusions are not valid. Design is not in compliance with DEP 2004 Manual.
33. Basin #6: Type – Pond, Depth to SHGW = 23" (avg), depth of pond below existing grade = 4' to 7', bottom of pond = 205', elevation of spillway = 209', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 209'.
34. Basin #7: Type - Infiltration, depth of pond below existing grade = 2' to 5', bottom of pond = 223', elevation of spillway = 226', infiltration rate is based upon approximately 42" below grade not at or below bottom pond elevation; percolation tests over-estimates vertical permeability when compared to Double Ring Infiltration tests; infiltration basin not designed per DEP 2004 Manual.
35. Basin #8: Type – Sand Filter, ledge was encountered between 24" & 43", depth of pond below existing grade = 0' to 5', bottom of pond = 187', elevation of spillway = 188.5', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 188.5', there is not a 36" vertical separation from the bottom of the sand filter to ledge per DEP 2004 Manual, thus design is not in compliance with the Manual.
36. Basin #9: Type – Pond, Depth to SHGW = 27" (avg), depth of pond below existing grade = 4' to 8', bottom of pond = 186', elevation of spillway = 190', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 190'.

37. Basin #10: Type – Sand Filter, Depth to SHGW = 36" (avg), depth of pond below existing grade = 0' to 1.5', bottom of pond = 166.5', elevation of spillway = 168.5', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 168.5'. Design does not provide 36" vertical separation to SHGW per DEP 2004 Manual and thus is not in compliance.
38. Basin #11: Type – Pond, Depth to SHGW = 24" (avg), depth of pond below existing grade = 3' to 4', bottom of pond = 148', elevation of spillway = 152', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 152'.
39. Basin #12: Type – Pond, Depth to SHGW = 34" (avg), depth of pond below existing grade = 5' to 7', bottom of pond = 1155', elevation of spillway = 158.5', available storage volume is over-estimated as there will be a permanent pool below elevation spillway 158.5'.
40. Basin #13: Type – Infiltration, depth of pond below existing grade = 6' to 8', bottom of pond = 184', elevation of spillway = 188', infiltration rate is based upon approximately 42" below grade not at or below bottom pond elevation; percolation tests over-estimates vertical permeability when compared to Double Ring Infiltration tests; infiltration basin not designed per DEP 2004 Manual. There is a routing analysis for Pond 13.1 in the stormwater report, but no Pond 13.1 is shown on the site plans.
41. Basin #14: Type – Infiltration, depth of pond below existing grade = 3.5' to 5.5', bottom of pond = 186.5', elevation of spillway = 190', infiltration rate is based upon approximately 42" below grade not at or below bottom pond elevation; percolation tests over-estimates vertical permeability when compared to Double Ring Infiltration tests; infiltration basin not designed per DEP 2004 Manual. Basin #16: Type – Pond, Depth to SHGW = 26" (avg), depth of pond below existing grade = 5' to 9', bottom of pond = 189', elevation of spillway = 195.5', available storage volume is over-estimated as there will be a permanent pool below spillway elevation 195.5'.
42. Portions of the embankment for Ponds 3, 5, 8, 10, 12, 13, and 16 are all greater than four (4) feet above existing grade. This means that the embankments must be designed as a dam per CT DEP requirements as the ponds will impound water behind the embankment. This has not been done by the applicant.
43. In front of several stormwater basins, a rectangle with no grading is shown on the plans and is called a "Proposed Pre-Treatment Basin". What type of pre-treatment system is this? Is this device listed within the DEP 2004 Manual.
44. The Energy Dissipator shown on sheet C-6.2 is basically a depressed hole lined with some type of stone, but the stone type and size are not defined. It appears the intent of this design is to result in overland flow from the basins to the undisturbed upland areas downhill of the system. Overland flow will not result from this design as runoff will find low points in the downgradient edge of the stone and this will result in a concentrated flow path. The concentrated flow will cause erosion of the undisturbed upland soils on the downhill side of the basins. There are no sizing calculations for the energy dissipator which ensures that non-erosive flow velocities (< 3.00 feet per second) will be met.
45. No grading is shown for any of the proposed swales proposed on the plans.
46. According to the Testimony of Jean-Paul La Marche (page 2), he states that infiltration testing was done and incorporated into the hydrologic modeling of the site. This is an

incorrect statement as VHB used percolation testing and not double ring infiltration tests in the hydrologic models. See comment #29 above.

47. La Marche's statement on page 3 that the design provides the Channel Protection Volume is invalid as the VHB hydrologic analysis did not consider all the solar panels to be impervious.
48. La Marche further states it their plan to clear the site in 2020, hydroseed the site and begin construction in 2021 after the site has achieved some level of stabilization. What is "some level of stabilization"? As noted above in comment 16.b for more information.
49. Based upon the above analyses, the stated conclusions found in the stormwater report are simply inaccurate.

Erosion Control Plans – Sheets C-5.1 to C-5.12:

d. The applicant proposes to use what they call an E-Fence. This is a proprietary product by Ertec Environmental Systems. On the sheet C-6.1 it calls out EFB20, ERTEC E-Fence20", yet on the company website, there is no such product listed. No performance data was found on the website for any of their products, so it cannot be verified if this product is a suitable sediment control product for this site.
e. The Ertec system barrier is shown around the perimeter of the solar array. In many locations, the system is perpendicular to the contours which violates the requirements found in the DEP 2002 Guidelines that control barriers must be parallel to the contours. Perpendicular barriers will concentrate flow and cause erosion and downhill sedimentation.
f. There are no erosion control barriers located below all the areas to be regraded on this site. This is in violation of the requirements of the DEP 2002 Guidelines.
g. No phasing plan has been provided which limits site disturbance to five (5) acres or less at one time.
h. No comprehensive erosion and sediment control plan have been provided; thus, the plan is not in compliance with the DEP 2002 Guidelines.
i. No construction narrative has been provided; thus, the plan is not in compliance with the DEP 2002 Guidelines.
j. There are no maintenance provisions for the post-development stormwater practices.
k. The applicant is ignoring how long slope length on disturbed sites effects all types of erosion.
l. It appears that all temporary sediment traps (TSTs) are in the same locations as the permanent stormwater basins. Infiltration Basins and Sand Filters are infiltrative practices and per the DEP 2004 Manual should not be used as temporary sediment basins due to clogging issues.
m. As no additional spillways are shown for the TSTs, it must be assumed that the permanent spillways will be used as the outlet system for the TST.
n. For Basin #1, the majority of the runoff is entering the TST on the east side and the outlet is on the west side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.

o. For Basin #2, the majority of the runoff is entering the TST on the west side and the outlet is on the east side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
p. For Basin #3, the majority of the runoff is entering the TST on the north side and the outlet is on the south side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
q. For Basin #4, the majority of the runoff is entering the TST on the west side and the outlet is on the south side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
r. For Basin #5, the majority of the runoff is entering the TST on the west side and the outlet is on the east side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
s. For Basin #6, the majority of the runoff is entering the TST on the west side and the outlet is on the east side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
t. For Basin #7, the majority of the runoff is entering the TST on the east and south sides and the outlet is in the southwest corner, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
u. For Basin #8, the majority of the runoff is entering the TST on the north side and the outlet is on the south side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
v. For Basin #9, the majority of the runoff is entering the TST on the east side and the outlet is on the west side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
w. For Basin #10, the majority of the runoff is entering the TST on the east side and the outlet is in the southwest corner, this might meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines, however the basin shape itself does not. This basin is 50’ x 70’ thus it does not meet the 2:1 ratio.
x. For Basin #11, the majority of the runoff is entering the TST on the south side and the outlet is on the north side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
y. For Basin #12, the majority of the runoff is entering the TST on the south side and the outlet is on the north side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
z. For Basin #13, the majority of the runoff is entering the TST on the south side and the outlet is on the north side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.
aa. For Basin #14, the majority of the runoff is entering the TST on the east side and the outlet is on the south side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.

bb. For Basin #16, the majority of the runoff is entering the TST on the east side and the outlet is on the west side, thus the TST does not meet the minimum 2:1 length to width ratio from inlet to outlet which is required by the DEP 2002 Guidelines.

Conclusion:

Based upon the invalid information used in the design of the stormwater management system, the proposed stormwater basins will not function as intended and will result in increased flow rates, volumes and pollutant loads to cold water fisheries streams and undisturbed wetlands. The design of the stormwater practices is not in compliance with the CT DEP 2004 Manual and will fail as noted above. The erosion control plan is inadequate to protect the site from erosion and resultant downgradient sedimentation during the construction period. The erosion control plans are not in compliance with the required approaches defined in the CT DEP 2002 Guidelines. These will cause a multitude of adverse environmental impacts as described above.

Please contact my office with any questions. A copy of my professional CV is included for the record and found in Appendix A of this report.

Sincerely,
Trinkaus Engineering, LLC

Steven Trinkaus, PE

EXHIBIT C
(responsive to Interrogatory #14)

Trinkaus Engineering, LLC
114 Hunters Ridge Road
Southbury, Connecticut 06488
203-264-4558 (office & fax)
+1-203-525-5153 (mobile)
E-mail: strinkaus@earthlink.net
http://www.trinkausengineering.com

December 19, 2018

Ms. Leslie King, Esq.
Murtha Cullina
One Century Tower
265 Church Street
New Haven, Connecticut 06510

Re: Solar Farm – Grassy Hill Road
East Lyme, Connecticut

Dear Ms. King,

At your request, I have reviewed the following additional documents for the solar farm which was constructed on Grassy Hill Road in East Lyme.

1. Site plans prepared for Antares Solar Field by BL Companies, dated: October 9, 2012 and revised to July 16, 2013.
2. Stormwater Management Report prepared for Antares Solar Field by BL Companies, dated: July 16, 2013 (Stormwater Management Report)

None of the information found in these documents changes my conclusions and professional opinions regarding issues with the design of the stormwater management and erosion control plan for the East Lyme solar farm.

Executive Summary of Opinions:

1. The stormwater management report grossly under estimates both the peak rate and runoff volumes which are being generated by the project as it does not consider the solar panels to be impervious. The panels are situated above the ground surface, thus every raindrop which falls on a panel instantly becomes runoff.
2. The applicant failed to account for changes in soil compaction and porosity which resulted from the considerable regrading of the site. The substantial cuts and fills of the site resulted in a soil surface which will not infiltrate and thus will generate more runoff than the undisturbed pre-development conditions.

Developers Stormwater Management Plan and Report:

To further support the professional opinions stated in the executive summary regarding the increases in the peak rate and runoff volumes, I have performed calculations to show the significant increases in the peak rate of runoff and runoff volume are being generated by the existing solar farm on Grassy Hill Road in East Lyme.

I have calculated the changes in both the peak rate of runoff and runoff volumes for that portion of the solar farm which is tributary to the Bialowans property. Based upon the plans and Stormwater Management Report prepared by BL Companies, sub-watershed areas A-1, A-2, A-3, A-4, A-5 and B-1 identified therein were analyzed.

The Time of Concentration value used by BL Companies as well as their total sub-watershed area was used in my analysis. I made three modifications compared to the BL analysis. First, the area of the solar panels was considered as pervious by BL Companies and I considered them to be impervious as all rainfall which falls on the panels is converted to runoff. An impervious surface has a Runoff Curve Number (RCN) of 98. Each panel was shown on the site plan by BL Companies as a separate unit and measured 10' x 35'. To determine the impervious area, I counted the number of solar panels within each sub-watershed area.

The approved site plans BL Companies showed a gap between each panel in a row; however, in the field there is no gap between each panel, so the actual peak rate of runoff and runoff volumes would be higher than the values stated in Table #1 and #2 for Trinkaus #1 and Trinkaus #2. The calculated values for Trinkaus #1 and Trinkaus #2 are based upon a gap existing between the individual panels as shown on the BL Company site plans.

Secondly, the RCN for the gravel roads was changed from 89 to 96. In the HydroCAD Version of TR-55, there are two categories for a gravel road. First, a gravel road (with right of way) has an RCN of 89. This is the value used by BL Companies in their stormwater management plan and is not applicable in this case as the gravel road is simply located within the limits of the solar farm. A gravel road (w/o right of way) has a RCN of 96 according to the HydroCAD program and this condition reflects what was actually proposed by BL Companies and constructed in the field at the Antares Solar Farm.

Lastly, one analysis (Trinkaus #1) was done using a RCN for Lawn in Good Condition on a Class C soil (74) and the second analysis (Trinkaus #2) was done using a RCN for Lawn in Good Condition on a Class D soil (80). The Class D soil designation more accurately reflect the disturbed soil conditions on the site as a result of the regrading and compaction specifications on the approved plans by BL Companies.

Applying these three modifications, the peak rate of runoff for the 2-year rainfall event (3.4" per 24 hours as stated in the Stormwater Management Report by BL Companies) was analyzed; the results are shown in Table #1 below. Peak Rate of runoff is shown as cubic feet per second (cfs). Runoff volume for the two-year rainfall event is shown in Table #2. Runoff volume is measured in acre-feet. (An acre-foot is 1 foot of water over 1 acre of land (43,560 cubic feet of water).)

Table #1

Post-Development Watershed Area	BL Companies	Trinkaus #1	**Net Change/ Percent Change**	Trinkaus #2	**Net Change**
Peak Rate	Cfs	cfs		cfs	
A-1	5.36	5.63	**+0.27/5.0%**	7.66	**+2.30/22.9%**
A-2	5.52	6.49	**+0.97/17.6%**	8.25	**+2.73/49.4%**
A-3	7.12	8.35	**+1.23/17.3%**	10.60	**+3.48/48.9%**
A-4	5.11	5.97	**+0.86/16.8%**	7.53	**+2.42/47.3%**
A-5	7.43	14.32	**+6.89/92.7%**	18.13	**+10.70/144.0%**
B-1	3.40	4.15	**+0.75/22.0%**	4.97	**+1.57/46.2%**

Table #2

Post-Development	BL Companies	Trinkaus #1	**Net Change/ Percent Change**	Trinkaus #2	**Net Change**
Runoff Volume	cubic feet	cubic feet		cubic feet	
A-1	0.530	0.556	**+0.026/4.9%**	0.732	**+0.202/38.1%**
A-2	0.545	0.629	**+0.084/15.4%**	0.786	**+0.241/44.2%**
A-3	0.715	0.826	**+0.111/15.5%**	1.032	**+0.317/44.3%**
A-4	0.542	0.624	**+0.082/15.1%**	0.776	**+0.234/43.4%**
A-5	0.774	0.898	**+0.124/16.0%**	1.121	**+0.347/44.8%**
B-1	0.312	0.375	**+0.063/20.2%**	0.446	**+0.134/42.9%**

The results shown in both Table #1 and Table #2 clearly show that both peak rate and runoff volumes are substantially higher when the solar panels are considered impervious.

The engineering standard for the design of a stormwater management is to consider any hard surface above ground or on the ground surface as impervious. The stormwater manuals of the States of Massachusetts, Minnesota, North Carolina and Maryland have sections which specifically address how to handle stormwater from large scale solar farms. Links to these sections are provided below.

State of Massachusetts: https://www.mass.gov/guides/massdep-wetlands-program-policy-17-1-photovoltaic-system-solar-array-review

State of Minnesota:
https://stormwater.pca.state.mn.us/index.php?title=Fact_sheet_on_stormwater_guidance_for_solar_farm_projects

State of North Carolina:
https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Stormwater/BMP%20Manual/E-6%20%20Solar%20Farms.pdf

State of Maryland:
https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/ESDMEP%20Design%20Guidance%20Solar%20Panels.pdf

The common features in these four manuals is that solar panels themselves could be considered pervious if all of the following conditions are met. If any of conditions are not met, then the solar panels must be considered as impervious.

a. Minimize site disturbance,
b. Prevent compaction of the soils on the solar farm, particularly in the area of the panels and vegetated strips,
c. Prevention the removal of topsoil from the site or replace the topsoil prior to seeding,
d. Maintain or restore infiltrative capacity of the soil,
e. Prevent concentrated flow from occurring,
f. Establishment of a dense vegetated cover on the soil surface.

The Antares Solar Farm on Grassy Hill Road in East Lyme does not meet any of the conditions stated above, therefore the solar panels must be considered impervious in the design of the stormwater management systems.

At the field inspection of the site on October 5, 2018, it did not appear that topsoil was replaced on the site after being removed to permit the mass grading of the site to occur. This observation is based on a visual inspection of the ground surface which did not show dark brown organic soil on the surface. The ground under the rows of panels and between the rows was light brown and very compacted, whereas if topsoil was present, the surface would not be compacted due to the higher organic content found in topsoil.

There is clear evidence in the field that runoff from the solar panels are not infiltrating into the disturbed soils under the entire solar farm. This evidence of erosion and resultant sedimentation is shown in Figure 1 and Figure 2 below.

Figure 1 – Concentrated flow from runoff off solar panel

Figure 2 – Erosion & Sedimentation resulting from concentrated flow

On Sheet GN-1 by BL Companies with a revision date of 7/16/13 under Grading and Utility Notes, note #5 states the following: "The contractor shall compact fill in 8" maximum lifts under all building areas to 95% of the maximum dry density as determined by ASTM D1557 (Modified Proctor Test), or as directed by the Geotechnical Engineer." In my professional opinion, the term "all building areas", mean the entirety of the solar farm. The natural soils were cut and filled substantially on the site, compacted to the ASTM D1557 standard, which easily and clearly explains why there is no infiltration occurring within the grass areas on the solar farm and more runoff is being created for all rainfall events.

Information on the ASTM D1557 standard can be found at this link: https://www.astm.org/Standards/D1557.htm . The following language was taken from this link and the sentence shown in bold is how the properties of the natural soil would be changed.
NOTE 3: The degree of soil compaction required to achieve the desired engineering properties is often specified as a percentage of the modified maximum dry unit weight as determined using this test method. If the required degree of compaction is substantially less than the modified maximum dry unit weight using this test method, it may be practicable for testing to be performed using Test Method D698 and to specify the degree of compaction as a percentage of the standard maximum dry unit weight. Since more energy is applied for compaction using this test method, the soil particles are more closely packed than when D698 is used. **The general overall result is a higher maximum dry unit weight, lower optimum moisture content, greater shear strength, greater stiffness, lower compressibility, lower air voids, and decreased permeability.** However, for highly compacted fine-grained soils, absorption of water may result in swelling, with reduced shear strength and increased compressibility, reducing the benefits of the increased effort used for compaction **(2)**. Use of D698, on the other hand, allows compaction using less effort and generally at a higher optimum moisture content. The compacted soil may be less brittle, more flexible, more permeable, and less subject to effects of swelling and shrinking. In many applications, building or construction codes may direct which test method, D698 or this one, should be used when specifying the comparison of laboratory test results to the degree of compaction of the in-place soil in the field.

Corrective Action to Remediate the Stormwater Management System:

In order to reduce the runoff being discharged from the solar farm, the existing stormwater management systems must be remediated to provide the Channel Protection Volume (CPV) as specified in the CT DEP 2004 Storm Water Quality Manual. The CPV requires developers to reduce the post-development peak rate of runoff from the 2-year rainfall event to 50% of the pre-development peak rate for the 2-year storm event. The intent of the CPV is to reduce the post-development peak rate, which will significantly increase the duration of flow directed to a receiving stream. By reducing the peak rate, the nominal flow depth in the receiving streams is lowered for the all rainfall event up to and equal to the 2-year rainfall event to the more naturally stable cross-sectional area of the stream, thus preventing adverse changes to the morphology of the stream channel. The following work must be done to the Antares Solar Field in order to have a stormwater remediation plan which provides the CPV:

1. An As-built survey of the entire solar farm done conforming to the following standards.

    a. Boundary work and survey location performed to a Class A-2 standards locating all buildings, solar panels, gravel roadways, stormwater management practices (ponds and swales),
    b. A two-foot topographic survey of the solar farm which meets Class T-2 standards. The area of the topographic survey needs to encompass all those areas within the fenced area of the solar farm, including the detention ponds and swales. The

limit of topographic survey must extend a minimum of fifty (50) feet beyond the eastern and southern limit of grading of the solar farm.

2. A revised stormwater management analysis and design encompassing the following parameters.
   a. All solar panels, all buildings or above ground equipment identified as impervious,
   b. The grass on all disturbed areas within the limits of the solar farm shall be considered as Grass (good condition on a Class D soil),
   c. Post-development watershed boundaries shall be established by the design engineer based upon current as-built conditions,
   d. Times of concentration shall be determined by the current field conditions,
   e. Runoff Curve Numbers (RCN) will be determined based upon current field conditions and the parameters stated above,
   f. Post-development peak rates of runoff and runoff volumes shall be determined by HydroCAD or a similar hydrologic model for the two-year rainfall event (3.4"/24 hours),
   g. The size and hydrologic outlets of all the existing stormwater ponds shall be redesigned to provide the Channel Protection Volume (CPV) as specified in the CT DEP 2004 Storm Water Quality Manual as well as attenuate the peak rate of runoff for the 10-year rainfall event. An appropriate overflow spillway shall be incorporated into the design of all stormwater ponds for all rainfall events larger than the 10-year event up to and including the 100-year rainfall event,
   h. A revised site plan showing the modifications to all the stormwater ponds shall be prepared. The site plans shall include all construction details for each stormwater pond and their respective outlet structures,
   i. An erosion control plan, conforming to the CT DEP 2002 Guidelines for Soil Erosion and Sediment Control shall be prepared for the modifications of the stormwater ponds,
   j. A revised stormwater management report shall be prepared with all calculations and pond routing analyses.

The above modifications to the stormwater management plan for the solar farm must be reviewed and approved by a third-party engineering consultant which expertise in stormwater management prior to its implementation. No cost for the implementation of the stormwater pond modifications can be determined until an actual design has been made.

Respectfully Submitted,
Trinkaus Engineering, LLC

Steven D. Trinkaus

Steven D. Trinkaus, PE

EXHIBIT D
(responsive to Interrogatory #23)

STATE OF CONNECTICUT :

v. :

WOODS HILL SOLAR, LLC; :
RES AMERICA DEVELOPMENTS INC., :
RES AMERICA CONSTRUCTION INC., and :
ENEL GREEN POWER NORTH :
AMERICA, INC. :

CONSENT ORDER # COWRSW18003

Date Issued: November 27, 2018

A. With the agreement of Woods Hill Solar, LLC ("Woods Hill"), RES America Developments Inc. ("RES Developments"), RES America Construction Inc. ("RES Construction"), and Enel Green Power North America, Inc. ("Enel"), (collectively the "Respondents" and each, as individual entities, a "Respondent" to this Order), The Commissioner of Energy and Environmental Protection ("the Commissioner") finds:

1. Woods Hill Solar, LLC ("Woods Hill") is a Delaware limited liability company with a business address of 100 Brickstone Square, Suite 300, Andover, Massachusetts 01810.

2. RES America Developments Inc., ("RES Developments") is a Delaware corporation with a principal place of business at 11101 W. 120th Avenue, Suite 400, Broomfield, Colorado, 80021. Woods Hill was formerly a subsidiary of RES Developments.

3. RES America Construction Inc., ("RES Construction") is a Delaware corporation with a principal place of business at 11101 W. 120th Avenue, Suite 400, Broomfield, Colorado, 80021.

4. Enel Green Power North America, Inc., ("Enel") is a Delaware corporation with a principal place of business at 100 Brickstone Square, Suite 300, Andover, Massachusetts, 01810. Woods Hill is currently a subsidiary of Enel.

STORMWATER VIOLATIONS

5. The Respondents are constructing a solar ground-mounted solar photovoltaic facility ("the Solar Array") located at 90 Woods Hill Road and 101 Woods Hill Road in Pomfret, Connecticut. The two properties encompass approximately 228 acres and, collectively, are referred to as "the Site".

6. Construction of the Solar Array has or will disturb greater than one acre at the Site and as such, requires, among other requirements, compliance with the General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities

("the General Permit"), or an individual stormwater discharge permit issued by the Commissioner.

7. On August 11, 2017, Woods Hill submitted to the Department of Energy and Environmental Protection ("DEEP") a registration application under General Permit. This application included a Stormwater Pollution Control Plan ("SWPCP") required under the General Permit. On August 23, 2017, Wood Hill's registration was approved by the Commissioner, as registration No. GSN003215.

8. While RES Construction undertook construction of the Solar Array at the Site in late August 2017, throughout construction, all four Respondents have been involved in construction activities at the Site.

9. On or about November 22, 2017, Enel acquired Woods Hill from RES Developments and, along with RES Construction, Enel remains involved in construction of the Solar Array at the Site.

10. Since the approval of registration No. GSN003215, the Respondents have violated the requirements of the General Permit, including the SWPCP approved by the Commissioner for the Site. These violations have resulted in non-compliance with the General Permit and the SWPCP, unpermitted discharges from the Site, sediments from the Site going off-site and blanketing thousands of square feet of adjoining wetlands, sediments from the Site being discharged off-site into an adjoining watercourse a threat to the continued existence of threatened species listed pursuant to section 26-306 of the Connecticut General Statutes, and the destruction of habitat essential for a species listed as threatened under Conn. Gen. Stat. § 26-306. These violations are described in the following paragraphs.

11. Under section 5(b)(2)(A)(i) of the General Permit, regarding Soil Stabilization and Protection, the Respondents shall ensure, among other things, that disturbed sections of the Site are both minimized and stabilized. Under Section 5(b) of the General Permit, the Respondents shall maintain compliance with the soil stabilization measures in the SWPCP approved by the Commissioner.

12. The Respondents disturbed over a hundred acres at the Site and failed to both minimize disturbed areas and stabilize any areas of the Site that were disturbed, including, but not limited to, failing to take stabilization measures in the SWPCP approved by the Commissioner. Despite the violations that occurred and the ensuing erosion - both on and off-site - construction and disturbance of the Site continued.

13. Under section 5(b)(2)(A)(ii) of the General Permit, regarding Structural Measures, points of discharge from disturbed sites with a total contributing drainage area of between two to five acres require the installation of a temporary sediment trap. For points of discharge from disturbed sites with a total contributing drainage area greater than five acres, a temporary basin must be installed. Any sediment trap, basin, or other structural measure to divert the flow of stormwater at the Site must be designed and installed in accordance

with the 2002 Connecticut Guidelines for Soil Erosion and Sediment Control and must be maintained until final stabilization of the contributing area. In addition, under Section 5(b) of the General Permit, the Respondents are required to maintain compliance with the provisions of the SWPCP approved by the Commissioner regarding sediment traps, basins, and other temporary structural measures for diverting the flow of stormwater.

14. The Respondents disturbed over a hundred acres at the Site without installing any of the required sediment traps, basins, and other temporary structural measures to divert the flow of stormwater or complying with the requirements of the SWPCP approved by the Commissioner regarding such sediment traps, basins, and other structural measures. Even though the failure to install such traps, basins or other structural measures and the ensuing erosion - both on and off-site – was obvious, construction and disturbance of the Site continued.

15. Under the General Permit, the Respondents are responsible for ensuring that inspections are conducted during construction activities. A primary purpose of these inspections is to ensure that any non-compliance with the General Permit can be identified and corrected. Section 5(b)(4)(A) of the General Permit requires that "Plan Implementation Inspections" be conducted within the project's first 90 days to ensure compliance with the General Permit and proper implementation of all stormwater control measures in the SWPCP approved by the Commissioner. In addition, under Section 5(b)(4)(B) of the General Permit, "Routine Inspections" are to be conducted on a weekly basis and after any rain event that generates a discharge. The areas to be inspected include, at a minimum, disturbed areas of the construction activity that have not been finally stabilized, all erosion and sedimentation control measures, all structural control measures, soil stockpile areas, washout areas and locations where vehicles enter or exit the Site. The effectiveness of erosion and sediment controls, structural controls, stabilization practices and any other controls implemented to prevent pollution, are evaluated through these routine inspections so it can be determined if it is necessary to install, maintain, or repair such controls and/or practices to improve the quality of stormwater discharges.

16. Section 5(b)(4)(B)(iii) of the General Permit requires that the routine inspection reports include a statement about whether a site that is being inspected is, or is not, in compliance with the terms and conditions of the approved SWPCP for the site and the General Permit. Certain of the Plan Implementation Inspections submitted to the Commissioner did not include this statement.

17. In addition, Section 5(b)(4)(B)(iii) of the General Permit requires that if a site inspection indicates that a site is out of compliance, the inspection report shall include a summary of the remedial actions required to bring the site back into compliance. While certain Plan Implementation Inspections for the Site have been submitted to the Commissioner, no inspection noted any non-compliance with the General Permit or the SWPCP approved by the Commissioner, nor did any of these reports include a summary of remedial actions required to bring the Site into compliance, despite the fact that the temporary structural measures, such as sediment traps, swales and check dams, had not been installed and the Site was not properly stabilized. Also, on one or more occasion, the Respondents failed

to inspect the Site within twenty-four hours after a storm event that generated a discharge.

18. Under section 3(b) of the General Permit, construction activity can be authorized, provided it does not threaten the continued existence of any threatened or endangered species listed pursuant to section 26-306 of the Connecticut General Statutes and shall not result in the destruction or adverse modification of habitat essential to such species.

19. The Respondents, through its own consultant and through communication with the Department, were aware that threatened or endangered species had been documented at the Site and that the Site contained suitable habitat for other threatened species. In letters from the Department dated February 2, 2016 and June 17, 2017, the Department indicated that the Frosted Elfin, a threatened butterfly, had been documented within the proposed project area at the Site. The Department's letter noted that since the Respondents had not performed surveys of the plant species favored by the Frosted Elfin, an invertebrate biologist or plant ecologist should be retained to implement a habitat expansion plan along the forested edge and in open areas of the Site not covered by the Solar Array.

20. The Respondents had an environmental assessment of the Site performed by Tighe & Bond in December of 2015. The results of that assessment were documented in a report entitled "Environmental Assessment" (the "EA") dated March 2016. In that EA, although no bird survey was conducted, the Respondents' consultant noted that the Site contained suitable habitat for another threatened species, the Eastern Meadowlark, although haying at the Site may have limited the Site's suitability as habitat for this species. The EA also noted that Site contained suitable habitat for the Northern Long Eared Bat, a federally threatened species for which the federal government had recently announced special protections. The EA noted that the Department would be contacted to determine if additional information about the Northern Long Eared Bat was available, and if not, that attempts to obtain such information would be documented.

21. The Respondents undertook construction activities at the Site without adequate regard for threatened and endangered species. For example, despite the Department's letter regarding the documented presence of the Frosted Elfin, a threatened species, at the Site, the Respondents took insufficient precautions to either identify whether threatened or endangered species were present on Site, or implement a plan to protect such species. As such, the Respondents' activities at the Site may have threatened the continued existence of threatened or endangered species or resulted in the destruction or adverse modification of habitat essential to such species.

22. Pursuant to Sections 5(c)(1) and 5(c)(2) of the General Permit, turbidity sampling shall be conducted at the Site at least once a month with the results sent to DEEP. Although construction activities have been conducted at the Site since late August 2017, until April of 2018, no turbidity sampling results were sent to DEEP.

23. Under section 5(b)(2)(D)(ii) and (iii) of the General Permit, washout of vehicles shall be conducted in a designated wash-out area and off-site tracking of sediments from vehicles leaving the Site shall be minimized. The Respondents failed to designate an area for washout and, at a minimum, in April and May 2018, off-site tracking of sediments from vehicles leaving the Site was occurring and was not minimized.

24. Under Section 3(b)(8)(B) of the General Permit, the Respondents made an affirmative determination to comply with terms and conditions of the General Permit, maintain such compliance, including, but not limited to, compliance with SWPCP approved by the Commissioner, and properly operating and maintaining all stormwater management systems at the Site. For the reasons noted above, this affirmative determination was repeatedly violated.

25. The General Permit does not authorize the discharge of sediments from the Site into the waters of the State or onto other properties, nor do the Respondents have any such authorization. Yet the Respondents repeatedly failed to take measures necessary to prevent the discharge of sediments from the Site into the waters of the State or onto other properties. On March 8, 2018, RES Construction, at the direction of Enel, contacted the Department to report that on March 1, 2018, there was a discharge of sediment from the Site into adjacent wetlands. The report from RES Construction stated that "lack of stabilization," "lack of temporary sediment basins," and "compounding effects of an extended construction schedule" were the primary contributing factors leading to this sediment release.

26. A subsequent report dated April 15, 2018, prepared by VHB consultants, confirmed that since Site perimeter controls were either non-existent or ineffective, there were at least eight areas where measurable volumes of sediment were discharged into waters of the state or beyond the perimeter controls for the Site. In certain areas these discharges of sediments covered thousands of square feet. The areas into which sediments were discharged included a watercourse, wetlands and areas designated by the Town of Pomfret as upland review areas for wetlands.

27. Section 5(b)(5)(A) of the General Permit requires that the Respondents keep its SWPCP in compliance with the General Permit, including, but not limited to, amending the plan if there is change in the design, construction, operation or maintenance of the Site which has the potential for the discharge of pollutants to the waters of the state and which otherwise has not been addressed in the Plan.

28. The actions taken by Respondents at the Site constituted a change in the design, construction, operation or maintenance of the Site which has the potential for the discharge of pollutants to the waters of the state and which otherwise has not been addressed in the Plan, but the Respondents failed to keep its SWPCP current. For example, not only did the Respondents fail to install temporary sediment traps, the Site was also lacking swales and check dams as depicted and required by the SWPCP approved by the Commissioner. These deviations altered the fundamental assumptions underlying the SWPCP, yet the Plan was not kept current.

ENFORCEMENT SUMMARY

29. As a result of the violations noted above, on March 28, 2018, the Commissioner issued Cease and Desist Order No. 2018001DEEP ("the Cease and Desist Order") to the Respondents prohibiting the Respondents from engaging in, and ensuring that no other person engaged in, any further activities at the Site including, but not limited to, all construction or testing activities related to the Solar Array, vehicular movement on the Site, and any movement of soil, unless such activity is required by or in compliance with the Cease and Desist Order or is otherwise approved by the Commissioner in writing.

30. In response to, and as required by the Cease and Desist Order, the Respondents have taken a number of actions at the Site including:

    a. Applying tackifier, straw matting, and erosion control blankets as well as and hydroseeding to stabilize and prevent erosion of sediments from the Site;
    b. Hiring consultants approved by DEEP to implement certain actions required by the Cease and Desist Order;
    c. Developing a report from a soil scientist regarding remediation of areas impacted by discharges of sediment from the Site. This remediation includes areas on and off-Site;
    d. Constructing sediment traps, swales and check dams to prevent migration of sediments from the Site; and
    e. Providing weekly progress reports on activity at the Site.

31. By virtue of the above, the Commissioner finds that the Respondents have:

    a. Caused, engaged in or maintained a condition or activity which can reasonably be expected to cause or has caused pollution to the waters of the state;

    b. Violated the terms and conditions of the General Permit and registration No. GSN003215 as well as Connecticut General Statutes §§ 22a-37 et seq., 22a-403, 22a-427 and 22a-430. The Respondents are still in the process of correcting these violations.

32. By agreeing to the issuance of this Consent Order, the Respondents make no admission of fact or law with respect to the matters addressed herein, other than the facts asserted in paragraphs A.1 through A.7, inclusive.

B. With the agreement of the Respondents, the Commissioner, acting under Conn. Gen. Stat. §§ 22a-6, 22a-39, 22a-401, 22a-406, 22a-424, 22a-430 and 22a-432, orders the Respondents as follows:

1. Consultants.

a. The Respondents have retained the following consultants or firms to prepare documents and implement or oversee actions required by this Order. Each of these consultants and firms has been approved by the Commissioner for the activity identified next to the consultant.

From Tighe and Bond:
Brian S. Huntley, P.E. - Engineering Design and Implementation
Jean E. Christy, P.E. - Engineering Design and Implementation

From VHB:
Stephen J. O'Neill, P.E. – Site Inspection, Oversite of Construction and Turbidity Monitoring
John McGinn, P.E. – Site Inspection
Jeffrey Peterson – Remediation/Wetlands Restoration

b. The Respondents shall continue to retain the consultants identified in paragraph B.1.a of this Order or other qualified consultants acceptable to the Commissioner, to prepare documents and implement or oversee actions required by this Order, until full compliance with this Order has been achieved. No later than three days after retaining any consultant other than one identified in paragraph B.1.a of this Order, the Respondents shall submit to the Commissioner the identity of such consultant for the Commissioner's review and written approval. Unless otherwise specified in this Order, any consultant(s) retained by the Respondents shall be a professional engineer acceptable to the Commissioner with a current valid license to practice in Connecticut. If requested by the Commissioner, the Respondents shall submit to the Commissioner a description of a consultant's education, experience and training which is relevant to the work required by this Order within ten days after a request for such a description. Nothing in this paragraph shall preclude the Commissioner from finding a previously acceptable consultant unacceptable, nor shall anything in this paragraph preclude an individual who is not a professional engineer, but is reporting to a professional engineer, to assist that professional engineer in the completion of such engineer's work.

c. At least one of the professional engineers identified in paragraph B.1.a of this Order, or another consultant approved in writing by the Commissioner under paragraph B.1.b of this Order, shall be present at the Site during all phases of construction of any stormwater control measures required under this Order.

2. Replacement Stormwater Pollution Control Plan

a. No more than fifteen (15) days from issuance of this Order, the Respondents shall submit for the Commissioner's review and written approval, a revised Stormwater Pollution Control Plan ("the Plan") for the Site. The Plan shall describe how the Site is currently complying with and will maintain compliance with the General Permit and this Order, addressing both current conditions at the Site as well as actions to be taken at the Site. The Plan shall include, but not be limited to, the following:

i. Regarding current conditions at the Site: (1) the Plan shall address site stabilization, perimeter controls, structural measures (traps, basins, swales, plunge pools, or other structural measures), methods for storing soil stock-piled on Site, and any additional matter regarding stormwater at or from the Site; (2) the Plan shall include the measures to achieve Site stabilization, any additional stabilization measures that are in process or that still need to be taken, the criteria used to determine whether Site stabilization has been achieved, any measures to ensure that any portion of the Site that has been stabilized, remains stabilized, whether the perimeter controls installed at the Site are determined to be adequate and the criteria used to make such determination, and a description of, and any maintenance required for, any structural measure installed at the Site; and (3) the Plan shall also address how compliance with the General Permit and this Order will be monitored and maintained until post-construction control measures are in place.

ii. If the Respondents have determined that with respect to current conditions at the Site, no additional action is necessary, the Respondents shall specify that in the Plan. The Plan shall include an explanation for why no further action is necessary, including, but not limited to, the criteria for any such determination, any new design criteria, stormwater calculations, and drainage patterns used that were not described in the SWPCP previously approved by the Commissioner, a photographic record of the Site, and a certification, from a professional engineer approved under paragraph B.1 of this Order, that the Site has been stabilized, including that current controls at the Site are adequate.

iii. Regarding post-construction control measures, the Plan shall include:

I. A description of the post-construction control measures to be implemented, monitored, and maintained at the Site. This shall include the design criteria, stormwater calculations, and drainage patterns used in determining such post-construction controls and a proposal for implementing and maintaining such controls. The Plan shall address what, if any, changes will be made the sediment traps, basins or other structural measure taken at or installed at the Site.

II. A proposed inspection and construction log, including a photograph record of milestones events, so that the Respondents can provide a photographic record demonstrating that the post-construction control measures, including, but not limited to, permanent Site stabilization measures have been implemented in accordance with the Plan approved by the Commissioner;

III. A proposal for monitoring and maintaining the effectiveness of post-construction control measures at the Site. At a minimum, any such proposal shall at a minimum include, for two (2) years, inspections and outfall monitoring at each discharge point at the Site for turbidity to determine whether the permanent stabilizations measures implemented at the Site is working and is preventing erosion, including, but not limited to, the migration or discharge of sediments, at or from all areas of the Site; and

IV. A schedule for installing, monitoring and maintaining the effectiveness of such post-construction control measures.

b. The Respondents shall implement the Plan as approved by the Commissioner. This shall include all actions in the Plan as approved by the Commissioner including any actions required to address current conditions at the Site, post-construction control measures, and post-construction monitoring. Such actions shall be implemented in accordance with the schedule approved by the Commissioner.

c. i. No later than twenty-one (21) days after completing the installation of the post-construction control measures in the Plan approved by the Commissioner, (exclusive of a permanent vegetative cover or other permanent stabilization measure or the maintenance and monitoring required under paragraph B.3 of this Order) the Respondents shall provide the Commissioner a written notification of such completion and submit the following to the Commissioner:

I. As-built drawings of all post-construction control measures at the Site, signed and sealed by a professional engineer approved under paragraph B.1 of this Order; and

II. A photographic record sufficient for the Commissioner to determine if such post-construction control measures comply with the Plan approved by the Commissioner pursuant to paragraph B.2.b of this Order.

ii. After receipt of the documentation required by paragraph B.2.c.i. of this Order, the Commissioner shall determine, in writing, whether the post construction control measures installed by the Respondents' are satisfactorily and comply with the Plan approved by the Commissioner pursuant to paragraph B.2.b of this Order. If the Commissioner deems such implementation to be unsatisfactory, additional work shall be performed by the Respondents in accordance with a supplemental plan and schedule approved by the Commissioner. Unless otherwise specified in writing by the Commissioner, the supplemental plan and schedule shall be submitted by the Respondents for the Commissioner's review and approval on or before thirty (30) days after notice from the Commissioner that additional work is necessary.

d. i. No later than twenty-one (21) days after the establishment of a permanent vegetative cover or other permanent stabilization necessary for stabilization of the entire Site, the Respondent shall provide the Commissioner a written notification of such completion and submit to the Commissioner a photographic record sufficient to demonstrate to the Commissioner that such permanent vegetative cover or other permanent stabilization measure has been established at the Site in accordance with the Plan approved by the Commissioner pursuant to paragraph B.2.b of this Order.

ii. After receipt of the materials required by paragraph B.2.d.i of this Order, the Commissioner shall determine, in writing, whether a permanent vegetative cover, or other permanent stabilization necessary for stabilization of the entire Site, has been established to the satisfaction of the Commissioner. If the Commissioner determines that permanent Site stabilization had not been established, the Respondent shall perform additional work in accordance with a supplemental plan and schedule approved by the Commissioner. Unless otherwise specified in writing by the Commissioner, the supplemental plan and schedule shall be submitted by the Respondent for the Commissioner's review and approval on or before thirty (30) days after notice from the Commissioner that additional work is necessary.

3. Monitoring. After the Commissioner determines, pursuant to paragraph B.2.c.ii and B.2.d.ii, that the post-construction control measures, including, but not limited to, the permanent stabilization measures at the Site, have been implemented to the satisfaction of the Commissioner, the Respondents shall implement the monitoring in the Plan approved by the Commissioner pursuant to paragraph B.2.b of this Order. Such monitoring shall be conducted for not less than two (2) years.

4. Site Stabilization

In addition to any other requirements of this Order, the following shall apply:

a. In the event that during any Site activities the Respondents disturb the tackifier or other measures used to establish stabilization of the Site, the Respondents shall reapply tackifier, or take whatever other measures are necessary to reestablish site stabilization, no later than at the end of each working day, to ensure that the Site remains stabilized and to prevent erosion, including, but not limited to, the migration or discharge of sediments at or from the entire Site.

b. If in the opinion of the Commissioner the Site is not stabilized, including, but not limited to the migration of sediments, at or from any portion of the Site, the Respondents shall take all measures necessary to re-establish stabilization in all areas where, in the Commissioner's opinion, stabilization has failed to occur. Such additional work shall be performed by the Respondents in accordance with a supplemental plan and schedule approved by the Commissioner. Unless otherwise specified in writing by the Commissioner, the supplemental plan and schedule shall be submitted by the Respondents for the Commissioner's review and approval on or before thirty (30) days after notice from the Commissioner that additional work is necessary.

5. Erosion and Sedimentation Control

In addition to any other requirements of this Order, the following shall apply:

a. The Respondents shall not allow sediments from the Site to discharge, migrate or move off the Site. In addition, the Respondents shall prevent erosion from occurring on-Site.

b. The Respondents have installed certain structural measures at the Site, including, but not limited to, sediment traps, a plunge pool, and a level spreader. Unless the removal of such structural measures has been approved in writing by the Commissioner, or the Commissioner specifies otherwise, the Respondents shall maintain such structural measures at the Site in good working order. This includes, but is not limited to, repairing or removing sediment from the sediment traps whenever necessary.

c. If in the opinion of the Commissioner the erosion and sedimentation controls or structural measures at the Site are not adequate, the Respondents shall take all measures necessary to ensure the adequacy of such controls or measures. Such additional work shall be performed by the Respondents in accordance with a supplemental plan and schedule approved by the Commissioner. Unless otherwise specified in writing by the Commissioner, the supplemental plan and schedule shall be submitted by the Respondents for the Commissioner's review and approval on or before thirty (30) days after notice from the Commissioner that additional work is necessary.

6. Site Activity Restrictions and Declaring Commercial Operation:

a. Effective upon the date the Commissioner issues this Order, the Respondents shall not engage in, and ensure that no other person engages in, any activities at the Site including, but not limited to, all construction or testing activities related to the Solar Array, vehicular movement on the Site, and any movement of soil, unless such activity is required by or in compliance with this Order or is otherwise approved by the Commissioner. This requirement shall remain in effect until:

i. The Respondents have completed stabilization of the Site to the satisfaction of the Commissioner, including, but not limited to, installation of perimeter and other erosion and sedimentation controls at the Site and taking the steps necessary to ensure that stock-piles of soil on the Site are not serving as a source of erosion;

ii. The Respondents have submitted a certification, acceptable to the Commissioner, from a professional engineer identified in paragraph B.1 of this Order, demonstrating that the Respondents have completed stabilization of the Site; and

iii. The Respondents have satisfied the requirements of paragraphs 12 of this Order regarding payment of a civil penalty.

b. Effective upon the written determination by the Commissioner that the requirements specified in paragraph B.6.a of this Order have been satisfied, the Respondents may complete construction of and test the Solar Array at the Site, but are prohibited from declaring Commercial Operation at the Site under any power purchase agreement to which the Respondents are a party. This requirement shall remain in effect until the Commissioner has approved, in accordance with paragraph B.2.b of this Order, the Plan submitted by the Respondents and the Respondents have completed implementation of any measures identified in and required by the approval of such Plan regarding current site conditions.

c. Effective upon the written determination by the Commissioner that the requirements specified in paragraph B.6.b of this Order have been satisfied, and upon completion of the supplemental environmental project requirements set forth in paragraph B.14 of this Consent Order, including, but not limited to, the requirements set forth in paragraph B.14.c or, if necessary B.14.e, the Respondents may declare Commercial Operation at the Site under any power purchase agreement to which the Respondents are a party. Any such declaration or operation of the Site shall not excuse the Respondents from complying with any other requirement of this Order.

7. Compliance with General Permit. Unless the Commissioner specifically provides otherwise in writing, the Respondents shall continue to comply with the General Permit and shall ensure that all activities at the Site remain in compliance with the General Permit.

8. Remediation

a. Wetlands

i. No later than December 30, 2018, the Respondents shall implement the remedial actions described in the April 15, 2018 report from VHB. These actions were approved by the Commissioner in a May 31, 2018 letter from Neal Williams of DEEP to Hans P. Van Lingen of Enel. Within fifteen (15) days after completing such actions, the Respondent shall notify the Commissioner in writing that the actions required by the approved remedial plan have been completed.

ii. If, in the Commissioner's judgment, the Respondents fail to reasonably complete the approved remedial actions or fail to reasonably abate erosion and sedimentation impacts from the Site, the Respondents shall undertake additional assessment and remediation in accordance with a supplemental plan and schedule proposed by Respondents and approved in writing by the Commissioner. Unless otherwise specified in writing by the Commissioner, the Respondents shall submit such supplemental plan and schedule for the Commissioner's review and written approval on or before thirty (30) days after notice from the Commissioner that such plan is required.

iii. The Respondents shall use best efforts to obtain access to property not owned or controlled by the Respondents to comply with paragraph B.8 of this Order. If the Commissioner determines that the Respondents cannot obtain access to property not owned or controlled by the Respondents to comply with the requirements of paragraph B.8 of this Order, the Commissioner shall notify the Respondents in writing and the requirements of paragraph B.8 this Order shall not apply to any such property.

iv. The Respondents shall ensure that actions required by paragraph B.8.a. of this Order are undertaken by a Certified Professional Soil Scientist registered in Connecticut, who has been approved by the Commissioner pursuant to paragraph B.1.b of this Order.

b. Threatened and Endangered Species

i. No later than sixty (60) days after the issuance of this Consent Order, The Respondents shall submit for the Commissioner's review and approval a Frosted Elfin, C*allophrys irus,* habitat restoration plan for the Site. This plan shall include, but not be limited to, the following:

I. The identification of a minimum of ten (10) acres at the Site suitable for Frosted Elfin habitat, including being suitable for the establishment of the necessary host plants;

II. Establishment and management of Frosted Elfin habitat, including the planting of host plants using local seeds and potential replanting, if needed. This includes monitoring to ensure that host plants have survived, including removal of competing vegetation, as necessary.

III. A maintenance schedule for the habitat;

IV. Surveys for the Frosted Elfin at the Site and reporting of survey results. The Surveys should identify methods, timing, frequency and locations; and

V. A restoration program that lasts for at least seven (7) years.

ii. The Respondents shall implement the plan submitted under paragraph B.8.b.i. of this Order, including the schedule, as approved by the Commissioner.

iii. The Respondents shall ensure that the development and implementation of the plan required by paragraph B.8.b. of this Order is undertaken by an invertebrate biologist familiar with the requirements of the Frosted Elfin who has been approved by the Commissioner pursuant to paragraph B.1.b of this Order.

iv. Any submission made under paragraph B.8.b of this Consent Order shall be sent to:

Shannon Kearney
Department of Energy and Environmental Protection
Bureau of Natural Resources, Wildlife Division
Natural Diversity Database and Conservation Compliance
Sessions Woods Wildlife Management Area
341 Milford Road (Rte. 69)
Burlington, Connecticut 06013-1550
Shannon.Kearney@ct.gov

9. Financial Assurance:

a. Pursuant to the March 28, 2018 Cease and Desist Order, the Respondents have procured a letter of credit in the amount of $1,000,000.00. See Appendix A attached to this Consent Order. Except for the reductions specified in paragraph 9 of this Order, the Respondents shall maintain this letter of credit in effect until the Commissioner notifies the Respondents, in writing, of the Commissioner's determination that remediation pursuant to paragraph B.8.a of this Order has been satisfactorily completed and that the monitoring required under with paragraph B.3. of this Order has been completed, after which the letter of credit may be terminated.

b. While not required, the amount of the letter of credit in Appendix A may be reduced in accordance with the following schedule:

i. Upon approval by the Commissioner of the Plan pursuant to paragraph B.2.b. of this Order, the amount on the letter of credit may be reduced to $650,000;

ii. Upon approval by the Commissioner of implementation of the Plan, including confirmation of the establishment of permanent stabilization of this Site, pursuant to paragraph B.2.c.i and B.2.c.ii of this Order, the amount on the letter of credit may be reduced to $500,000; and

iii. Upon completion of Remediation pursuant to paragraph B.8.a of this Order and notification from the Commissioner that monitoring has been completed in accordance with paragraph B.3. of this Order, the letter of credit may be terminated.

c. If the amount of the letter of credit in Appendix A is to be reduced in accordance with the preceding paragraph, the Respondents shall first submit a new letter of credit identical in all respects to the letter of credit in Appendix A, except for the reduced amount. Once the new letter of credit is received and the Commissioner determines that it is satisfactory, the Commissioner shall follow any reasonable instructions from the issuing bank regarding the termination or return of the previous letter of credit being cancelled.

10. Progress reports.

   a. Except as provided in paragraph 10.b of this Order or unless another schedule is approved by the Commissioner in writing, on or before the last day of each month following issuance of this Order and continuing until all actions required by this Order have been completed as approved and to the satisfaction of the Commissioner, the Respondents shall submit a progress report to the Commissioner that describes the actions which Respondents have taken during the month of the report to comply with this Order.

   b. During the time that the Respondents are constructing the post-construction control measures, until the Respondents have completed implementation of such controls, the Respondents shall submit weekly progress reports. This weekly report shall identify the work performed during the week preceding the report, including but not limited to, details regarding how construction was performed and the work expected to be completed during the week following the report. Unless specifically requested by the Commissioner, in writing, such weekly reports do not need to be submitted when the post-construction control measures are being monitored or maintained.

   c. Unless otherwise specified by the Commissioner in writing, the Respondents may submit progress reports under this paragraph electronically to Neal Williams at: Neal.Williams@ct.gov.

11. Full compliance. The Respondents shall not be considered in full compliance with this Order until the Respondent's activities at the Site are in compliance with the General Permit, and all other actions required by this Order have been completed as approved and to the Commissioner's satisfaction.

12. Civil penalty. The Respondents shall pay a penalty of $575,00.00 as the total civil penalty to be sought by the Commissioner for those, and only those, violations described in paragraphs A.5 through A.28 of this Order. This penalty is payable as follows: On or before thirty (30) days after issuance of this Order the Respondent shall pay $287,500.00 in accordance with paragraph B.13 of this Order, and Respondent shall pay $287,500.00 as a Supplemental Environmental Project in accordance with paragraph B.14 of this Order.

13. Payment of Penalties. On or before thirty (30) days after the issuance of this Order, the Respondents shall pay $287,500.00 by mail or personally delivery to the Department of Energy and Environmental Protection, Bureau of Financial and Support Services, Accounts Receivable Office, 79 Elm Street, Hartford, CT 06106-5127. Such payment shall be by certified or bank check payable to the "Connecticut Department of Energy and Environmental Protection" The check shall state on its face, "Bureau of Materials Management, Water Permitting and Enforcement Division, civil penalty, Consent Order No. 2018001DEEP.

14. Supplemental Environmental Project. The Respondents shall undertake the following supplemental environmental project ("SEP") "), requiring an expenditure of at least $287,500.00, in accordance with the following:

   a. On or before thirty (30) days after the issuance of this Consent Order, the Respondents shall cause a payment to be made to the Wyndham Land Trust in an amount not less than $287,500.00 to be applied solely towards the purchase of three parcels of land noted on Appendix B of this Order ("the SEP properties") and for no other purpose.

   b. The Wyndham Land Trust shall use the proceeds of this payment to purchase the SEP properties. Upon acquiring the SEP Properties, the Wyndham Land Trust shall record a restrictive covenant and dedication for conservation and public recreation on such properties. The wording of such restrictive covenant and dedication for conservation and public recreation shall be identical to that in Appendix C of this Consent Order.

   c. No later than December 15, 2018, or seven days after the Wyndham Land Trust closes on the purchase of the SEP Properties, whichever comes first, the Respondent shall obtain a letter signed by the President of the Wyndham Land Trust, indicating that the Wyndham Land Trust has received $287,500.00 from the Respondent, has purchased the SEP Properties, has used the aforementioned funds from the Respondent for the purchase of the SEP Properties and for no other purpose and has recorded the restrictive covenant and dedication for conservation and public recreation using language identical to that in Appendix C of this Consent Order.

   d. The Respondent shall not request that the Commissioner approve the use of SEP funds for any purpose other than that identified in paragraph B.14 of this Consent Order.

   e. If paragraph B.14 of this Consent Order is not complied with, regardless of the reason, including that the Wyndham Land Trust did not purchase the SEP Properties or record the required restrictive covenant and dedication for conservation and public recreation, then no later than seven days after such non-compliance, the Respondents shall notify the Commissioner in writing of such non-compliance and shall remit a payment of $287,500.00 to the Department in accordance with paragraph B.13 of this Consent Order.

   f. If and when the Respondent disseminates any publicity, including but not limited to any press releases regarding funding the SEP entered into pursuant to this Consent Order, the Respondent shall include a statement that such funding is in partial settlement of an enforcement action brought by the Commissioner.

   g. The Respondents shall not claim or represent that any SEP payment made pursuant to this Consent Order constitutes an ordinary business expense or charitable contribution or any other type of tax deductible expense, and the Respondents shall not seek or obtain any other tax benefit such as a tax credit as a result of the payment under paragraph B.14 of this Consent Order.

15. Approvals. The Respondents shall use best efforts to submit to the Commissioner all

documents required by this Order in a complete and approvable form. Commissioner shall promptly review and take appropriate action on all submittals as required under this Order. If the Commissioner notifies the Respondents that any document or other action is deficient, and does not approve it with conditions or modifications, it is deemed disapproved, and the Respondents shall correct the deficiencies and resubmit it within the time specified by the Commissioner or, if no time is specified by the Commissioner, within thirty (30) days of the Commissioner's notice of deficiencies. In approving any document or other action under this Order, the Commissioner may approve the document or other action as submitted or performed or with such conditions or modifications as the Commissioner deems necessary to carry out the purposes of this Order. Nothing in this paragraph shall excuse noncompliance or delay.

16. Definitions. As used in this Order, "Commissioner" means the Commissioner of Environmental Protection or a representative of the Commissioner.

17. Dates. The date of "issuance" of this Order is the date the Order is deposited in the U.S. mail or personally delivered, whichever is earlier. The date of submission to the Commissioner of any document required by this Order shall be the date such document is received by the Commissioner. The date of any notice by the Commissioner under this Order, including but not limited to notice of approval or disapproval of any document or other action, shall be the date such notice is deposited in the U.S. mail or personally delivered, whichever is earlier. Except as otherwise specified in this Order, the word "day" as used in this Order means calendar day. Any document or action which is required by this Order to be submitted or performed by a date which falls on a Saturday, Sunday or a Connecticut or federal holiday shall be submitted or performed on or before the next day which is not a Saturday, Sunday, or a Connecticut or federal holiday.

18. Certification of documents. Any document, including but not limited to any notice, which is required to be submitted to the Commissioner under this Order shall be signed by a responsible corporate or municipal officer of the appropriate Respondent or a duly authorized representative of such officer, as those terms are defined in section 22a-430-3(b)(2) of the Regulations of Connecticut State Agencies and by the individual(s) responsible for actually preparing such document, each of whom shall certify in writing as follows: "I have personally examined and am familiar with the information submitted in this document and all attachments thereto, and I certify, based on reasonable investigation, including my inquiry of those individuals responsible for obtaining the information, that the submitted information is true, accurate and complete to the best of my knowledge and belief. I understand that any false statement made in the submitted information is as a criminal offense under Conn. Gen. Stat. § 53a-157b and any other applicable law."

19. Noncompliance. Failure to comply with this Order may subject the Respondents to an injunction and penalties.

20. False statements. Any false statement in any information submitted pursuant to this Order may be punishable as a criminal offense under Conn. Gen. Stat. § 53a-157b or any other applicable law.

21. Notice of transfer; liability of Respondents and others. Until the Respondents have fully complied with this Order, the Respondents shall notify the Commissioner in writing no later than fifteen days after transferring all or any portion of the facility, the operations, the site or the business which is the subject of this Order or after obtaining a new mailing or location address. The Respondents' obligations under this Order shall not be affected by the passage of title to any property to any other person or municipality.

22. Commissioner's powers. Except as provided hereinabove with respect to payment of penalties, nothing in this Order shall affect the Commissioner's authority to institute any proceeding or take any other action to prevent or abate violations of law, prevent or abate pollution, recover costs and natural resource damages, and to impose penalties for past, present or future violations of law. If at any time the Commissioner determines that the actions taken by the Respondents pursuant to this Order have not successfully corrected all violations, fully characterized the extent and degree of pollution, or successfully abated or prevented pollution, the Commissioner may institute any proceeding to require the Respondents to undertake further investigation or further action to prevent or abate violations or pollution.

23. Respondent's obligations under law. Nothing in this Order shall relieve the Respondents of other obligations under applicable federal, state and local law.

24. No assurance by Commissioner. No provision of this Order and no action or inaction by the Commissioner shall be construed to constitute an assurance by the Commissioner that the actions taken by the Respondents pursuant to this Order will result in compliance or prevent or abate pollution.

25. Access to site. Any representative of the Department of Energy and Environmental Protection may enter the Site without prior notice for the purposes of monitoring and enforcing the actions required or allowed by this Order.

26. No effect on rights of other persons. This Order neither creates nor affects any rights of persons who or municipalities which are not parties to this Order.

27. Notice to Commissioner of changes. Within fifteen (15) days of the date the Respondents become aware of a change in any information submitted to the Commissioner under this Order, or that any such information was inaccurate or misleading or that any relevant information was omitted, the Respondents shall submit the correct or omitted information to the Commissioner.

28. Notification of noncompliance. In the event that the Respondents become aware that it did not or may not comply, or did not or may not comply on time, with any requirement of this Order or of any document required hereunder, the Respondents shall immediately notify by telephone the individual identified in the next paragraph and shall take all reasonable steps to ensure that any noncompliance or delay is avoided or, if unavoidable, is minimized to the greatest extent possible. Within five (5) days of the initial notice, the Respondents shall submit in writing the date, time and duration of the noncompliance and the reasons for the noncompliance or delay and propose, for the Commissioner's review

and written approval, dates by which compliance will be achieved, and the Respondents shall comply with any dates which may be approved in writing by the Commissioner. Notification by the Respondents shall not excuse noncompliance or delay, and the Commissioner's approval of any compliance dates proposed shall not excuse noncompliance or delay unless specifically so stated by the Commissioner in writing.

29. Submission of documents. Any document required to be submitted to the Commissioner under this Order shall, unless otherwise specified in writing by the Commissioner, be directed to:

    Neal M. Williams
    Department of Energy and Environmental Protection
    Bureau of Materials Management & Compliance Assurance
    Water Permitting & Enforcement Division
    79 Elm Street
    Hartford, Connecticut 06106-5127
    Neal.Williams@ct.gov

30. Joint and Several Liability. The Respondents are jointly and severally liable for compliance with this Order.

31. Cease and Desist Order Superseded. The Cease and Desist Order issued by the Department to the Respondents on March 28, 2018 (Cease and Desist Order No. 2018001DEEP) shall be superseded by this Order. Once this Consent Order is effective, Cease and Desist Order No. 2018001DEEP shall no longer have any effect or be enforceable by the Department as if such Cease and Desist Order was fully withdrawn.

32. The Parties agree that this Consent Order may be executed in counterparts and that execution of counterparts shall have the same force and effect as if the Parties had signed the same instrument. Any signature made and transmitted electronically or via facsimile for the purposes of executing this Agreement shall be deemed an original signature for purposes of this Agreement and shall be binding on the signing Party.

[Remainder of page left blank. Signature pages to follow.]

Each Respondent consents to the issuance of this Order without further notice. The undersigned certifies that he/she is fully authorized to enter into this Order and to legally bind the Respondent to the terms and conditions of the consent order.

WOODS HILL SOLAR, LLC

By: ______________________________
Name: Georgios Papadimitriou
Title: Chief Executive Officer

____
Date

RES AMERICA DEVELOPMENTS INC.

By: ______________________________
Name: Brian Evans
Title: President

11/16/18
Date

RES AMERICA CONSTRUCTION INC.

By: ______________________________
Name: Christopher Howson
Title: Chief Financial Officer & Treasurer

11/16/18
Date

Each Respondent consents to the issuance of this Order without further notice. The undersigned certifies that he/she is fully authorized to enter into this Order and to legally bind the Respondent to the terms and conditions of the consent order.

WOODS HILL SOLAR, LLC

By: ______________________ 11/20/18
Name: Georgios Papadimitriou
Title: Chief Executive Officer
Date

RES AMERICA DEVELOPMENTS INC.

By: ______________________ ______________________
Name: Brian Evans
Title: President
Date

RES AMERICA CONSTRUCTION INC.

By: ______________________ ______________________
Name: Christopher Howson
Title: Chief Financial Officer & Treasurer
Date

ENEL GREEN POWER NORTH AMERICA, INC.

By: ______________________________
Name: Georgios Papadimitriou
Title: Chief Executive Officer

11/20/18
Date

Issued as a Final Consent Order of the Commissioner of Energy and Environmental Protection.

DEPARTMENT OF ENERGY AND
ENVIRONMENTAL PROTECTION

Robert E. Kaliszewski
Deputy Commissioner

November 27, 2018
Date

ORDER NO.
TOWN OF POMFRET LAND RECORDS

APPENDIX A
IRREVOCABLE LETTER OF CREDIT

MUFG

Bank of Tokyo-Mitsubishi UFJ

New York Branch
1251 Avenue of the Americas
New York, NY 10020
Tel: 201-413-8635
Fax: 201-521-2312
SWIFT: BOTKUS33XXX

Irrevocable
Standby Letter of Credit No.: S517779N

Issuance Date: March 29, 2018

Total Amount: USD 1,000,000.00

BENEFICIARY:
Connecticut Department of Energy and
Environmental Protection Commissioner
79 Elm Street
Hartford, CT 06106-5127

APPLICANT:
Woods Hill Solar, LLC,
100 Brickstone Square
Andover, MA 01810

Dear Sir or Madam:

We hereby establish our Irrevocable Standby Letter of Credit No. S517779N in your favor, at the request and for the account of the Applicant, Woods Hill Solar, LLC, 100 Brickstone Square Andover, MA 01810, up to the aggregate amount of One Million U.S. Dollars (USD 1,000,000.00). We hereby authorize the Connecticut Department of Energy and Environmental Protection Commissioner to draw at sight on us, The Bank of Tokyo-Mitsubishi UFJ, Ltd., New York Branch, 1251 Avenue of the Americas, New York, New York 10020, Attn. Trade Service Operations/Standby LC Section, an aggregate amount up to the total amount available upon presentation of:

(1) your sight draft, bearing reference to this Letter of Credit No. S517779N, and

(2) your signed dated statement reading as follows: "I certify that the amount of the draft is payable after the date of the issuance of this Irrevocable Standby Letter of Credit because I have determined one or more of the following: (a) one or more violations of the requirements or approvals applicable to the management of stormwater at or emanating from 99-101 Woods Hill Road, Pomfret, CT, have occurred, or (b) despite actions taken to manage stormwater at or emanating from the property located at 99-101 Woods Hill Road, Pomfret, CT, such stormwater has become a potential source of pollution (as that term is defined in Conn. Gen. Stat. Par. 22a-423) which the Applicant has been unable to remedy to my satisfaction within five (5) business days of receipt of a written notice from me that a pollution condition exists, or (c) the Applicant no longer owns the property or solar array facility at 99-101 Woods Hill Road, Pomfret, CT or (d) the issuing bank has notified me that it has decided not to extend this letter of credit beyond the current expiration date."

APPENDIX A
IRREVOCABLE LETTER OF CREDIT

MUFG

Bank of Tokyo-Mitsubishi UFJ

This letter of credit is effective as of March 29, 2018 and shall expire on March 29, 2019, but such expiration date shall be automatically extended for a period of one year on March 29, 2019 and on each successive expiration date, unless, at least 120 days before the current expiration date, we notify both you and Applicant, Woods Hill Solar, LLC, by certified mail or nationally recognized courier service that we have decided not to extend this letter of credit beyond the current expiration date. In the event you are so notified, any unused portion of the credit shall be available upon presentation of your sight draft for 120 days after the date of receipt by you, as shown on the signed return receipts or evidence of courier delivery.

Multiple and partial draws on this letter of credit are expressly permitted, up to an aggregate amount not to exceed the total amount available. Whenever this letter of credit is drawn on under and in compliance with the terms of this credit, we shall duly honor such draft upon presentation to us at our address specified in paragraph one above, and we shall deposit the amount of the draft directly into a Connecticut Department of Energy and Environmental Protection dedicated account in accordance with your instructions.

All banking and other charges under this letter of credit are for the account of the Applicant.

This letter of credit is issued subject to the Uniform Customs and Practice for Documentary Credits, published and copyrighted by the International Chamber of Commerce, I.C.C. Publication No. 600.

Very truly yours,

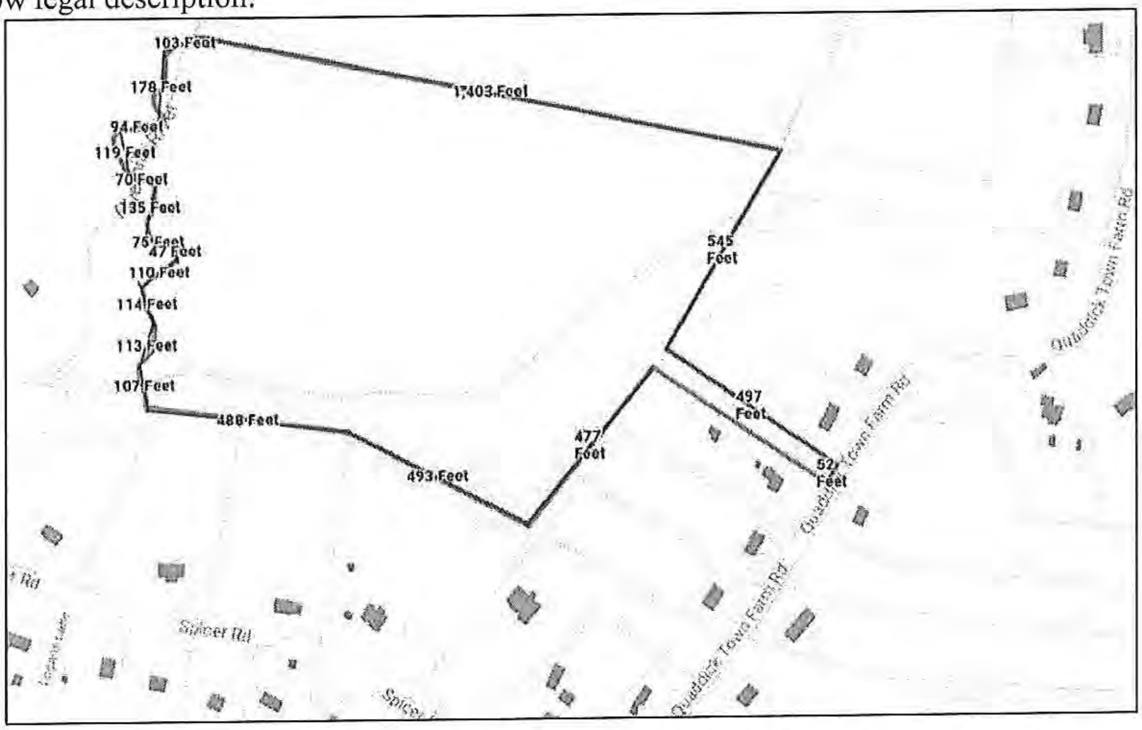
The Bank of Tokyo-Mitsubishi UFJ, Ltd.
New York Branch

Signature(s) of official(s) of issuing institution
Selena Holder-Pierre
Officer
Title(s) of official(s) of issuing institution

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

The SEP Properties are comprised of parcels of approximately 27 acres, 152 acres and 24 acres, for a total of approximately 203 acres. All of the parcels are located in Thompson, Connecticut. A legal description and a map of each parcel follows.

Parcel 1: Is approximately 27 acres located at 0 Quaddick Town Farm Road in Thompson, Connecticut; Volume 525/Page 15, as depicted below, and as described in greater detail in the below legal description:



Two certain tracts or parcels of land located on Quaddick Town Farm Road in the Town of Thompson, County of Windham and State of Connecticut, bounded and described as follows:

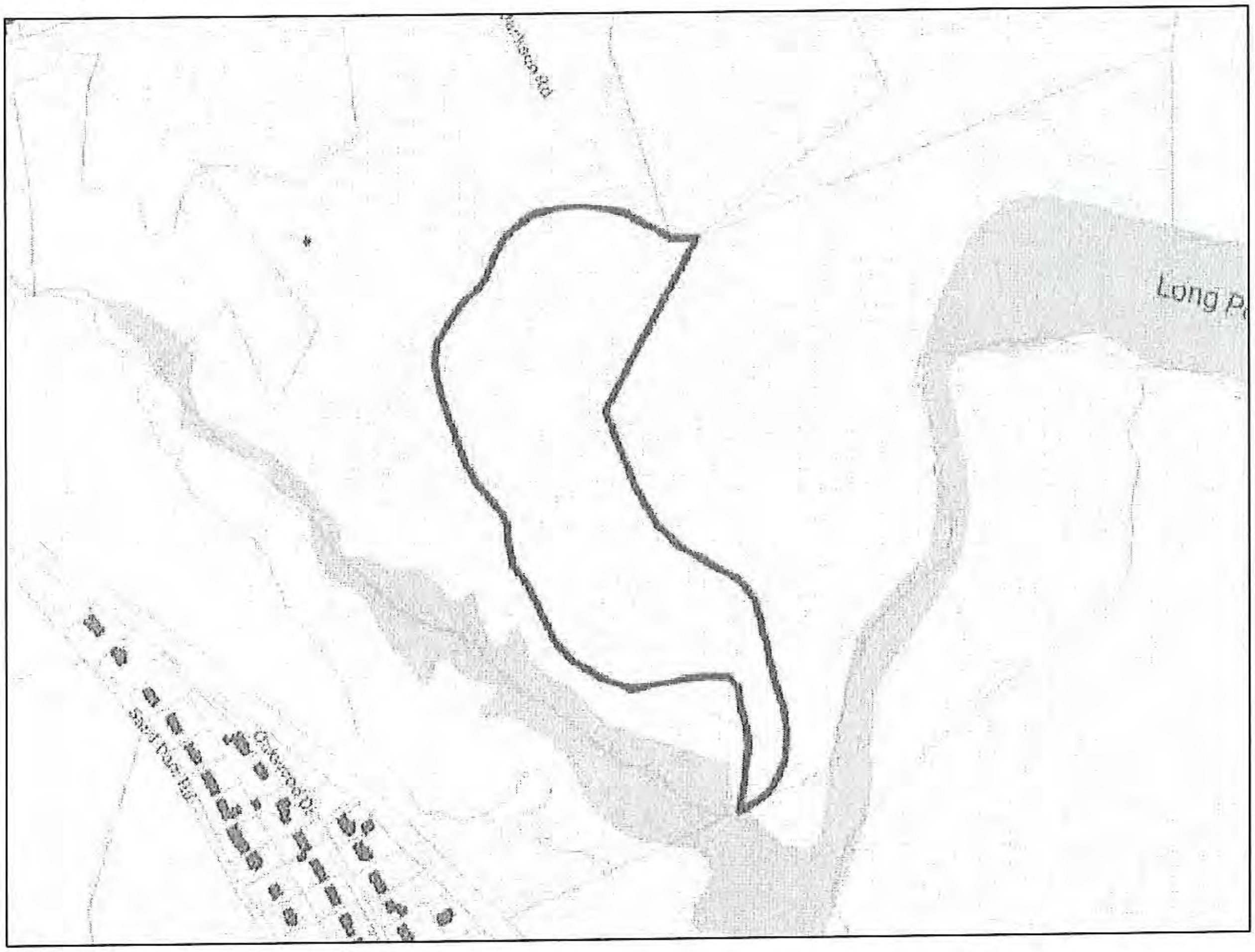
Being the same premises conveyed to Ronald R. Blain by Warranty Deed of Walter E. Dudley a/k/a Walter E. Dudley, Sr. dated March 5, 1979, and recorded in Thompson Land Records, Vol. 131, Pages 172-176.

Being those premises shown on the Assessor's Map for the Town of Thompson as Map 156 Block 7 Lot k9C.

Excluding, however, from the above-described premises all portions of said premises previously conveyed by the releasor.

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

Parcel 2 – Is approximately 24 acres located at 0 South Shore Road in Thompson, Connecticut; Volume 735/Page 86, as depicted below, and as described in greater detail in the attached legal description:



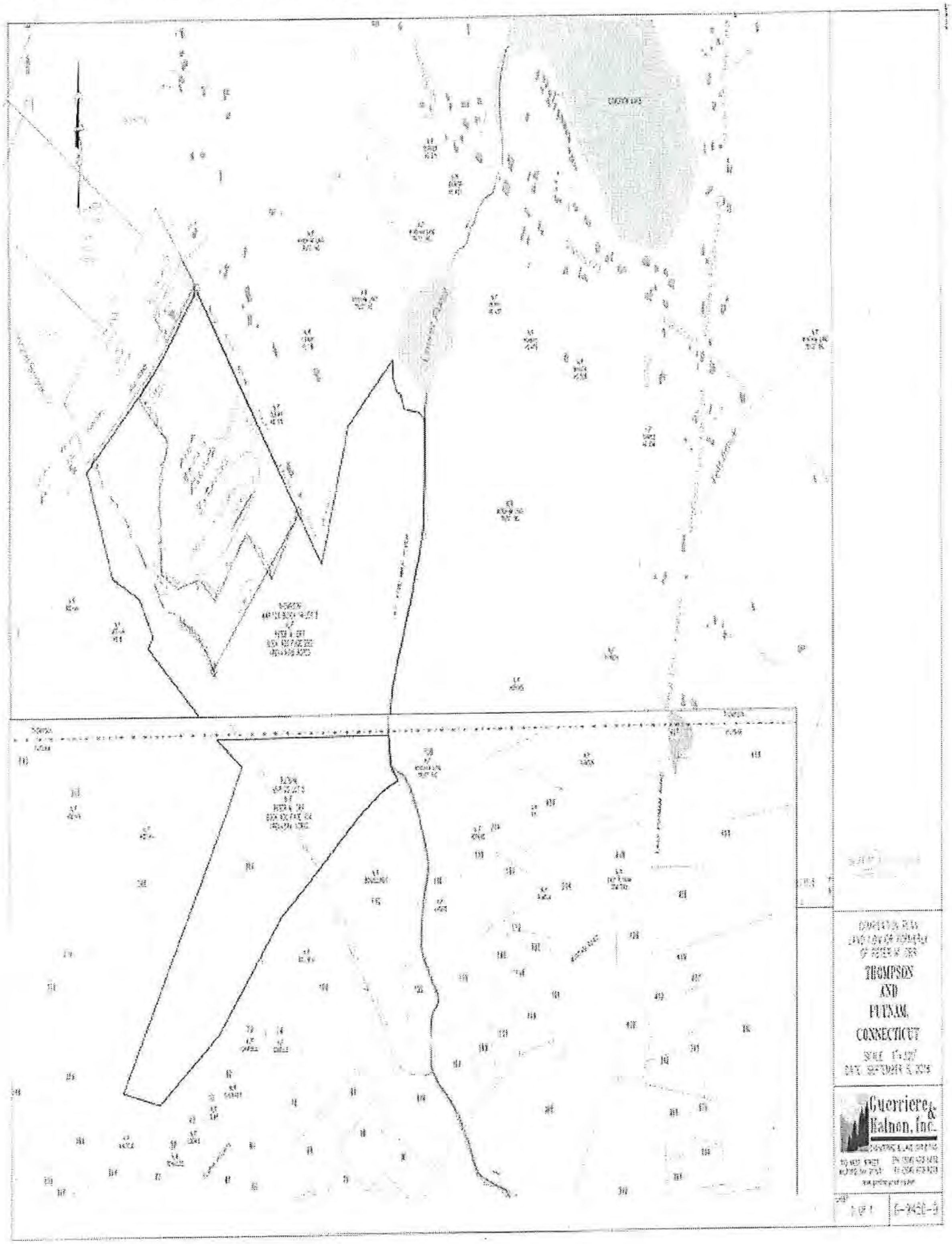
That certain piece or parcel of land with improvements thereon situated on South Shore Road, in the Town of Thompson, County of Windham and State of Connecticut known as 0 South Shore Road, consisting of 24 acres, more or less.

Being the same premises as conveyed by a Warranty Deed dated 1/15/10 and recorded 1/22/10 in Volume 735, Page 86 of the Thompson Land Records.

Further reference is made to a Certificate of Devise recorded in Volume 563, Page 343; see also a Certificate of Devise recorded in Volume 364, Page 79, all of the Thompson Land Records.

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

Parcel 3 – Is approximately 152 acres located at 0 Hill Road in Thompson, Connecticut; and 398 Providence Pike in Putnam, Connecticut, census tract 9032, as depicted below, and as described in greater detail in the attached legal description:



APPENDIX B
DESCRIPTION OF SEP PROPERTIES

1261 BOOK 402 PAGE 304

Warranty Deed - Statutory Form

THAT WE, WINTHROP ROSS MUNYAN and SHIRLEY ANN MUNYAN, of 1 Lexington Avenue, New York, NY 10010, for consideration paid, grant to PETER M. ORR, of the Town of Thompson, County of Windham and State of Connecticut, with WARRANTY COVENANTS.

REFERENCE IS MADE TO SCHEDULE A WHICH IS ATTACHED HERETO AND MADE A PART HEREOF.

Signed this 21st day of MAY, 2002.

Witnessed by:

Jennifer Braithwaite — Winthrop Ross Munyan

Jennifer Braithwaite — Shirley Ann Munyan

State of New York)
) SS.: Manhattan May 21st, 2002
City of New York)

Personally appeared, WINTHROP ROSS MUNYAN and SHIRLEY ANN MUNYAN, signers and sealers of the foregoing instrument, and acknowledged the same to be their free act and deed, before me.

Notary Public, My Commission Expires on: 4/30/2004

Latest mailing address of Grantee:
P.O. Box 447
Thompson, CT 06277

REC'D CLERK PUTNAM
02 MAY 24 PM 2:53

CONVEYANCE TAX RECEIVED
TOWN CLERK PUTNAM, CT

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

BOOK 402 PAGE 305

SCHEDULE "A"

Six (6) certain parcels of land being more particularly bounded and described as follows:

FIRST PARCEL:

A certain lot of land located in the Town(s) of Thompson and Putnam, County of Windham and State of Connecticut, containing two hundred (200) acres, more or less, described as follows, viz:

BEGINNING at a small cedar tree marked at the southwest side of Greens pond, so-called; thence W 29° S 33 ½ rods to a bunch of maple trees, by the side of the swamp; thence S. 31° W 52 ½ rods by land of the late Alpheus Russell to a rock in the wall a corner of said Russell land; thence N 31½° W 143½ rods to a walnut tree where two walls meet in line of Thompson land so-called and southwest corner of land now or formerly of Jacob Wheaton; thence W 43½° S 94½ rods by said Thompson land to a stake by a fence near a small brook a corner of said Jacob Wheaton's land; thence E 31° S. 4 rods, 21 links across said brook to a stake and stones; thence S 26° E 23 rods by said Jacobs land to a stake and stones by the road; thence S 38° E 3 rods across said road to a wall meeting said road; thence S 19° E 22½ rods by a wall to a turn in the same; thence E 39½ S 3¼ rods to a turn in said wall; thence S 50° W 3 rods, 16½ links to a turn in said wall; thence S 7° E 7½ rods to a turn in said wall; thence E 29° S 24 rods to the end of a ditch in the meadow; thence S 30° E 16 rods, 19 links to a stake and stones by said ditch, a corner of said Jacob Wheaton; thence W 44° S 3¼ rods to a stake in said Thompson's line another corner of said Wheaton's; thence E 41° S on line of said Thompson land 80 rods to a [illegible]; thence S 44° W on line of said Thompson land the corner of land of the heirs of Stephen Jackson; thence easterly on said heirs' land until it comes to said heirs' NE corner; thence E 32° N by land Jeremiah Hopkins sold to Joseph Kingsley 145 rods to 5 Mile River (so-called); thence across said river and by said pond to the first mentioned bound with the buildings thereon standing.

EXCEPTING THEREFROM as reserved to Asa Ross, his heirs, successors and/or assigns, from the above-described premises four (4) acres wood land, beginning at the south side of the bog meadow running by the dam and back again to land now or formerly owned by Davis Terry, - Also the burying lot on said farm as laid out and fenced, with the privilege of passing and repassing to the same, and of repairing the ground and fence whenever necessary as set forth in Volume 30 at Page 133 of the Thompson Land Records.

REFERENCE IS HEREBY MADE and BEING THE SAME PREMISES as conveyed to Winthrop Ross Munyan and Shirley Ann Munyan by a Warranty Deed of Charles E. Ross dated December 23, 1953, and recorded December 24, 1953, in Volume 63 at Page 431 of the Thompson Land Records (one-half interest); and as conveyed to Winthrop Ross Munyan by a Certificate of Devise of the Estate of Jerome Ross dated and recorded May 27, 1981, in Volume 144 at Page 264 of the Thompson Land Records (one-half interest).

SAID PARCEL being in part Thompson Assessor's Map 128, Block 14, Lot 3 (149 acres +/-); Thompson Assessor's Map 126, Block 84, Lot 38 (30 acres +/-); and in part Putnam Assessor's Map 102, Parcel 13 (37.8 acres +/-).

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

SAID PARCEL is subject to:

1. Notice (Preservation of Agricultural Land) dated September 17, 1993, and recorded in Volume 287 at Page 65 of the Thompson Land Records.

2. Riparian Rights of others.

SECOND PARCEL:

A certain tract or parcel of land located in the Town of Thompson, County of Windham and State of Connecticut, containing twenty-four and three quarters (24¾) acres, more or less, bounded and described as follows:

BEGINNING at a stake and stones which is the southeast corner of the Allen farm and in the east line of a wood lot belonging now or formerly to the heirs of Abigail Dresser from thence southerly adjoining said heirs' land now or formerly of Joel Deans 44 rods to a stake and stones and in a wall and fence running easterly thence on the same S 34½ E 89 rods to the corner of wall adjoining land now or formerly of Asa Ross; thence on the same N 29 E 43¾ rods to the Allyn land; thence on the same N 55 W 93½ rods to the first bound.

TOGETHER WITH a right and privilege of passing to and from said lot in the usual place to the public highway as set forth in Volume 77 at Page 241 of the Thompson Land Records.

REFERENCE IS HEREBY MADE and BEING THE SAME PREMISES as conveyed to Winthrop R. Munyan by a Warranty Deed of Clarence C. Ballard dated October 28, 1960, and recorded November 23, 1960, in Volume 77 at Page 241 of the Thompson Land Records.

SAID PARCEL being Thompson Assessor's Map 128, Block 34, Lot 29.

THIRD PARCEL:

Three (3) certain tracts or parcels of land, situated in the Town of Thompson, County of Windham and State of Connecticut, and described as follows:

First Tract: A certain tract of wood land situated in said Thompson known as the Joel Deans wood lot containing ten (10) acres, more or less, and bounded and described as follows: COMMENCING at a stake and stones at the northwest corner of said tract adjoining land now or formerly of William H. Chandler on the North; thence on land of said Chandler S 78¾° E, 31 rods 10 links to wall and land now or formerly of Stephen Ballard; thence on said Ballard land S. 42½° W 47 rods to bound and land now or formerly of Lowell Ross; thence on said Ross N. 77° W 26¾ rods to land of George A. Hawkins, thence on said Hawkins land N 10¾ E 41 rods 10 links to place of beginning.

REFERENCE is hereby made to a Quit Claim Deed dated February 24, 1885, and recorded May 10, 1885, in Volume 29 at Page 103 of the Thompson Land Records.

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

BOOK 402 PAGE 307

Second Tract: A certain tract of land with the wood thereon standing bounded and described as follows: BEGINNING at the Elliot Pasture so-called, at the west entrance of said wood land following said cart path about 30 rods, thence at right angles about 3 rods to stake and stones marking southwest bound and bounded by land of George Hawkins and Ellen Chase to land of Elton Ballard and stonewall; thence northeasterly following line of wall and fence to land of Joshua P. Knight, thence following fence of Joshua P. Knight to land of "Parks Heirs" so-called; thence following land of Parks Heirs in westerly direction to stake and stones; thence from stake and stones southwest to first mentioned bound and bordering on land of Ellen Chase, said land with wood thereon standing consisting of about sixteen (16) acres, more or less.

REFERENCE is hereby made to a Warrantee Deed dated and recorded July 26, 1888, in Volume 27 at Page 318 of the Thompson Land Records.

Third Tract: A certain tract or parcel of wood land lying and being in said Thompson and contains six (6) acres, more or less, and is bounded: BEGINNING at a stake and stones at a corner of land now or formerly of Hezekiah Bellows; thence running North 47½ E. about 12 rods to stake and stones; thence westerly about 80 rods to stake and stones; thence southerly about 14 rods to stake and stones; thence easterly to first mentioned bound.

REFERENCE is hereby made to a Warrantee Deed dated February 1, 1814, and recorded February 11, 1815, in Volume 6 at Page 183 of the Thompson Land Records.

REFERENCE IS HEREBY MADE and BEING THE SAME PREMISES as conveyed to Winthrop Ross Munyan and Shirley Ann Munyan by a Warranty Deed of Charles E. Ross dated December 23, 1953, and recorded December 24, 1953, in Volume [illegible] at Page 438 of the Thompson Land Records (one-half interest); and as conveyed to Winthrop Ross Munyan by a Certificate of Devise of the Estate of Jerome Ross dated and recorded May 27, 1981, in Volume 146 at Page 384 of the Thompson Land Records (one-half interest).

SAID PARCEL being Thompson Assessor's Map 107, Block 14, Lot 31 ([illegible] acres +/-).

SAID PARCEL is subject to:

1. Notice (Preservation of Agricultural Land) dated September 17, 1993, and recorded in Volume 287 at Page [illegible] of the Thompson Land Records.

FOURTH PARCEL:

Two (2) certain tracts or parcels of land, situated in the Town of Thompson, County of Windham and State of Connecticut, with a portion possibly situated in the Town of Burrillville, County of Providence and State of Rhode Island, and described as follows:

First Tract: A certain tract or parcel of land, lying and being situated in the easterly part of said Thompson, and containing One Hundred ([illegible]) acres, more or less, and is bounded by land formerly of Erastus Blackmar, easterly by land now or formerly of Sisson Burrill and others; southerly by land formerly of Thomas N. Gleason and others, and westerly by land now or formerly of David Day and others.

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

BOOK 402 PAGE 308

REFERENCE is hereby made to a Warrantee Deed dated July 29, 1916, and recorded August 24, 1916, in Volume 17 at Page 288 of the Thompson Land Records.

<u>Second Tract</u>: A certain tract or parcel of land lying and being situated in the Town of Thompson, County and State aforesaid, bounded and described as follows, viz: BEGINNING at a stake and stones in the Rhode Island line at the southeast corner of land belonging to S. N. Ransome; from thence on said state line S. 32° W 41 rods to a stake and stones to land belonging to Joseph Kinsly; thence N 65½° W 38 rods to a stake and stones in the line of land of Albin Munyan; thence N 22° E, 37 rods and 9 links to a stake and stones it being the southwest corner of lands belonging to said Ransome; thence on the same N 88½° E 44¾ rods to the first-mentioned bound and containing fifteen (15) acres and 13 rods of sprouts land, so-called, more or less.

REFERENCE is hereby made to a Warrantee Deed dated and recorded January 28, 1871, in Volume 23 at Page 424 of the Thompson Land Records.

REFERENCE IS HEREBY MADE and BEING THE SAME PREMISES as conveyed to Winthrop Ross Munyan and Shirley Ann Munyan by a Warranty Deed of Charles B. Ross dated December 23, 1953, and recorded December 24, 1953, in Volume 64 at Page 73 of the Thompson Land Records (one-half interest); and as conveyed to Winthrop Ross Munyan by a Certificate of Devise of the Estate of Jerome Ross dated and recorded May 27, 1981, in Volume 146 at Page 360 of the Thompson Land Records (one-half interest).

SAID PARCEL being in part Thompson Assessor's Map 162, Block 11, Lot 23 (94 acres +/-).

SAID PARCEL is subject to:

1. An Easement to Algonquin Gas Transmission Company dated August 24, 1951, and recorded September 21, 1951, in Volume 62 at Page 105 of the Thompson Land Records.

2. An Easement to Algonquin Gas Transmission Company dated October 31, 1962, and recorded November 21, 1962, in Volume 72 at Page 337 of the Thompson Land Records.

3. An Easement to The Connecticut Light and Power Company dated February 25, 1969, and recorded March 28, 1969, in Volume 80 at Page 24 of the Thompson Land Records.

4. An Easement to The Connecticut Light and Power Company dated February 25, 1969, and recorded March 28, 1969, in Volume 80 at Page 26 of the Thompson Land Records.

5. Notice (Preservation of Agricultural Land) dated September 13, 1983, and recorded in Volume 187 at Page 85 of the Thompson Land Records.

<u>FIFTH PARCEL</u>:

A certain tract or parcel of land situated in the Town of Thompson, County of Windham and State of Connecticut, containing thirteen (13) acres, more or less, and bounded and described as follows: BEGINNING at the northeast corner of land now or formerly of P.O. Barrett; thence S. 6° E seventy-one and one half (71½) rods to land now or formerly of Calvin M. Munyan;

APPENDIX B
DESCRIPTION OF SEP PROPERTIES

BOOK 402 PAGE 309

thence easterly on said Munyan's land twenty-eight (28) rods, more or less, to land now or formerly of Isaac P. Brown; thence on said Brown's land northerly seventy-one (71) rods, more or less, to stake and stones; thence westerly 1° N, on land now or formerly of Lowell D. Ross, twenty-eight (28) rods to a big rock with stones on top of the same; to the first mentioned bound.

REFERENCE is hereby made to a Warrantee Deed dated and recorded June 15, 1914, in Volume 34 at Page 385 of the Thompson Land Records.

REFERENCE IS HEREBY MADE and BEING THE SAME PREMISES as conveyed to Winthrop Ross Munyan by a Certificate of Devise of the Estate of Jerome Ross dated and recorded May 27, 1981, in Volume 148 at Page 366 of the Thompson Land Records.

SAID PARCEL being Thompson Assessor's Map 143, Block 11, Lot 34.

SAID PARCEL is subject to:

1. Notice (Preservation of Agricultural Land) dated September 17, 1992, and recorded in Volume 287 at Page 65 of the Thompson Land Records.

SIXTH PARCEL:

An undivided one-half (50%) percent interest in and to one certain tract or parcel of wood land lying in the northerly part of the Town of Putnam, County of Windham and State of Connecticut, formerly known as the northeasterly part of the Town of Thompson, in School District No. One, containing about 14 3/4 acres, more or less, bounded: BEGINNING at the northwesterly corner of the same adjoining lands now or formerly of Asa Hutchins from thence on said Hutchins and now or formerly of Elisha Brown S 5° W 73 rods to the intersection of two walls by said Brown's north line; thence by said Brown's north line N 82° E, 43 rods to stake in swamp to lands now or formerly of Samuel Pike; thence on said Pike N 42° W 80½ rods to the place of beginning.

REFERENCE is hereby made to a Warrantee Deed dated and recorded March 21, 1851, in Volume 19 at Page 401 of the Thompson Land Records.

REFERENCE IS HEREBY MADE and BEING THE SAME PREMISES as conveyed to Winthrop Ross Munyan and Shirley Ann Munyan by a Warranty Deed of Charles E. Ross dated December 23, 1953, and recorded December 24, 1953, in Volume 39 at Page 381 of the Putnam Land Records.

SAID PARCEL being Putnam Assessor's Map 103, Parcel 43 (18.8 acres +/-).

SAID PARCEL is subject to:

1. Notice (Preservation of Agricultural Land) dated September 17, 1992, and recorded in Volume 287 at Page 65 of the Thompson Land Records.

INTENDING HEREBY TO CONVEY ALL OF THE REAL PROPERTY OWNED BY THE GRANTORS IN THE TOWN(S) OF THOMPSON AND PUTNAM, CONNECTICUT.

APPENDIX C
RESTRICTIVE COVENENAT AND DEDICATION
FOR CONSERVATION AND RECREATION

Please return to: **VOLUME: __________**

State of CT DEEP
Constituent Affairs and Land Management **PAGE: ____________**
79 Elm Street, 6th Floor
Hartford, CT 06106

RESTRICTIVE COVENANT AND DEDICATION FOR CONSERVATION AND PUBLIC RECREATION

This Restrictive Covenant and Dedication for Conservation and Recreation ("Restrictive Covenant and Dedication") is entered into by ______________. The terms, conditions, and restrictions set forth in this Restrictive Covenant and Dedication shall bind and apply to those certain pieces or parcels of land owned by ___________ and more particularly described in Schedule A, attached hereto and made a part hereof (hereinafter "Conservation Area"). The purpose of this Restrictive Covenant and Dedication is to retain forever predominantly in its natural, scenic, forested, and/or open space condition, and to provide opportunities for public recreation on, the Conservation Area, while preventing any use of the Conservation Area that will significantly impair or interfere with the conservation values or interests of the Conservation Area in accordance with the goals and policies set forth in the Connecticut Endangered Species Act (Connecticut General Statutes sections 26-303 through 26-313).

The following specific terms, conditions, and restrictions shall be applicable to the Conservation Area.

There will be no development of any kind within the land described in Schedule A. "Development" is defined as the construction of any building, residential dwelling, structure, parking lot, driveway, road, or other temporary or permanent structure or improvement requiring construction, except that _______ shall be permitted to maintain existing unpaved driveways, footpaths and other minor surface alterations; to excavate and fill as necessary to accomplish permitted building, recreational and silvicultural activities; and to construct, maintain and reconstruct additional unpaved footpaths or unpaved parking areas to assure safe passage, to prevent erosion, to enhance or protect the natural habitat, or to enhance public access to the Conservation Area.

APPENDIX C
RESTRICTIVE COVENANT AND DEDICATION
FOR CONSERVATION AND RECREATION

Any activity on, or use of, the Conservation Area which is inconsistent with or detrimental to the purposes of this Restrictive Covenant and Dedication is expressly prohibited unless authorized by the Department of Energy and Environmental Protection (hereinafter "CTDEEP").

This Restrictive Covenant and Dedication will run with the land in favor of the State of Connecticut, will be binding upon _______________ and its successors and assigns and shall inure to the benefit of the general public and the inhabitants of the State of Connecticut in perpetuity. _____________ agrees that the term, conditions, and restrictions set forth in this Restrictive Covenant and Dedication may not be modified or terminated without the prior written consent of CTDEEP or its successors. ______________further agrees that the terms, conditions, restrictions and purposes of this Restrictive Covenant and Dedication or reference hereto will be inserted by ______________ into any subsequent deed or other legal instrument by which ______________ divests either the fee simple title or other possessory interest in the Conservation Area. ______________ further agrees to notify the CTDEEP in conjunction with any such transfer at least thirty (30) days in advance thereof.

APPENDIX C
RESTRICTIVE COVENANT AND DEDICATION FOR CONSERVATION AND RECREATION

IN WITNESS WHEREOF, the _______ has set its hand.

[PROPERTY OWNER]

WITNESSES Signature
Name in print

____

Name **Date**
Title
Duly Authorized

____
Name

____
Name

STATE OF CONNECTICUT)
) **SS. TOWN OF** _______
COUNTY OF HARTFORD)

The foregoing instrument was acknowledged before me this ____ day of ___________, 20__, by ______________ the ______________ for the ________________.

____
Commissioner of the Superior Court
Notary Public
My Commission Expires____________

SE
AL

APPENDIX C
RESTRICTIVE COVENANT AND DEDICATION FOR CONSERVATION AND RECREATION

Schedule A

[Insert Property Description including a reference to property assessor's parcel identification and the property assessor's map based on such parcel identification]