ELECTRIC POWER RESEARCH INSTITUTE

Solar Stormwater Nexus: An Overview of Regulatory and Permitting Issues Related to Developing Utility-Scale Solar Projects

Technical Brief — *Program on Environmental Aspects of Renewables*

Summary

Utility-scale solar projects are capable of offsetting emissions from fossil-fuel power plants, but they cover large tracts of land with infrastructure (i.e., solar photovoltaic [PV] panels, access roads, transformers) that can increase stormwater run-off and disrupt natural hydrology. Under natural conditions, rainfall seeps into the soil and the soil can absorb it; excess rainfall (that cannot be absorbed) flows over the surface to rivers and lakes. Overland flow causes brief, high peak flow rates that erode surface soils and increase sediment loading in downstream water bodies. This issue brief summarizes a literature review that was conducted to develop a reference for understanding the solar-stormwater nexus. Key findings are listed below:

- **Solar Stormwater Nexus:** The propagation of utility-scale solar projects has brought increased scrutiny of land use and related environmental impacts across multiple states. Large fields of solar PV panels have the potential to produce increased stormwater run-off that may lead to adverse impacts on local water quality through soil erosion and sedimentation. Proper selection and implementation of temporary and permanent best management practices (BMPs) is critical to achieving regulatory compliance.
- **Stormwater Regulations:** The Clean Water Act does not contain specific requirements for utility-scale solar facilities. All construction projects that disturb at least one acre of land are required to obtain and adhere to the conditions of a construction general permit (CGP) requiring the development and implementation of a Stormwater Pollution Prevention Plan (SWPPP).
- **Best Management Practices:** Each state surveyed in this review has a field manual that describes the recommended suite of stormwater BMPs for all types of construction projects. Additionally, Maryland, Minnesota, and North Carolina have developed specific guidance for solar project site development that include minimizing site disturbance and soil compaction and limiting the height of solar panels.

Background and Overview

Solar energy capacity has expanded throughout the United States with 67 GW of installed capacity in the United States through the first quarter of 2019 (SEIA, 2019) with utility-scale projects larger than 1MW being built in multiple states. Increasing electricity generation from solar and

other renewable energy sources is a key objective of state and federal policy initiatives aimed at reducing greenhouse gas (GHG) emissions and the impacts of climate change. Although utility-scale solar projects generate electricity without GHG emissions, past and future development of large solar farms can cause other adverse environmental impacts due to the large amount of land area required to support them.

Utility-scale solar projects cover large tracts of land with impervious surfaces (i.e., solar PV panels, access roads, transformers) that can increase stormwater run-off and disrupt natural hydrology. The capacity-weighted average land use for solar projects larger than 1MW ranges from 3.1 acres/MW for dual-axis tracking systems to 4.4 acres/MW for fixed axis systems (Ong, 2013). Under natural conditions, rainfall infiltrates into the soil to the extent that the soil can absorb it, while excess rainfall flows over the surface to rivers and lakes. Overland flow causes brief, high peak flow rates that erode surface soils and increase sediment loading in downstream water bodies.

Although this phenomenon occurs naturally, the development of natural lands and placement of impervious surfaces can exacerbate these issues by increasing the frequency and magnitude of peak flows during heavy precipitation events. To mitigate these potentially negative impacts, stormwater runoff is regulated by multiple government agencies at the federal, state and local levels. Stormwater runoff that occurs during the construction phase of a project is regulated through the National Pollution Discharge Elimination Program (NPDES), while post-construction stormwater quantity and quality may or may not be regulated by state and/or municipal stormwater management regulations.

A full report on *Solar-Stormwater Nexus* (EPRI Report 3002014508, 2018) was developed to consolidate information about stormwater management regulations, permitting requirements and BMPs designed to minimize the risk of erosion and sedimentation at utility-scale solar projects. This issue brief provides a summary of the main subject areas covered in the full report: *Stormwater Hydrology, Stormwater Regulations and Permitting Requirements, Stormwater BMPs, and Case Studies*.

Solar-Stormwater Hydrology

The goal of stormwater management at large solar projects typically focuses on controlling sedimentation during construction and mitigating excess runoff due to increased impervious surfaces on large swaths of land (i.e., from solar panels and access roads). Stormwater runoff flows overland during heavy precipitation events and can impact water quality in downstream lakes, rivers and streams. The rate by which water flows through soil can vary by several orders of magnitude depending on soil type and conditions. Because the soil has storage volume and water moves through soil more slowly than it flows over the surface, one day of rainfall may drain to surface water for days, or weeks in extreme cases.

Utility-scale solar facilities present a unique situation with respect to stormwater, soil erosion, and sedimentation because solar panels constitute an elevated impervious surface. Utility-scale solar facilities cover many acres of land, and therefore, have the potential to substantially alter the dynamics of local hydrology and storm event hydrographs. Solar PV panels, access roads, support structures, and other associated infrastructure can generate increased overland flow, decreased infiltration, and concentration of runoff leading to soil erosion and downstream sedimentation. Fortunately, there are many design alternatives that engineers can employ to mitigate the risks to local waterways that construction of utility-scale solar projects may pose.

Obtaining and understanding detailed soil survey maps for proposed solar project sites can provide valuable insights for identifying erosion and sedimentation risks. Understanding the soil type and characteristics at the project site can also help guide selection of appropriate seed mixes to quickly re-establish robust ground cover vegetation. The erosion factor (denoted by K) indicates the susceptibility of a particular soil to sheet and rill erosion by water. Soil erodibility estimates are based primarily on the percentage of silt, sand, and organic matter, and on soil structure and saturated hydraulic conductivity. Values of K range from 0.02 to 0.69 (all other factors being equal) with higher values being more susceptible to sheet and rill erosion by water. The basic factors that affect stormwater run-off at solar projects are shown in Figure 1.

Stormwater Regulations and Permitting

The process of obtaining the appropriate stormwater permits for any construction project can be complicated and requires coordination with multiple permitting agencies. Permitting requirements can vary significantly depending on the proposed project location and the authority having jurisdiction in that area. Stormwater is regulated at the federal level under Section 402(p) of the Clean Water Act (CWA). This section provides a framework for regulating stormwater under the NPDES. Most states have developed stormwater and point source pollution policies that have received authorization from the U.S. EPA to administer the NPDES program.

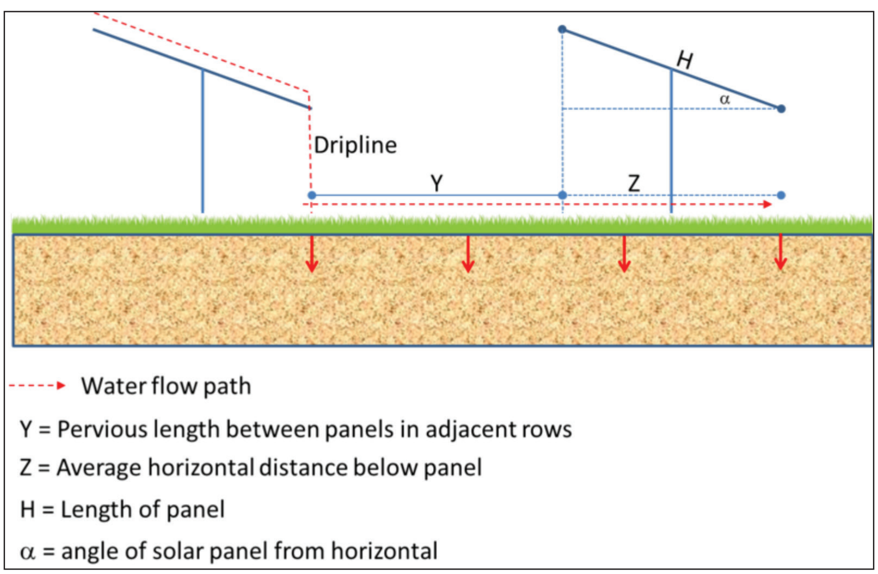

Figure 1: Basic illustration of factors affecting solar hydrology

All construction projects that will disturb more than one acre of land must apply for a general construction permit under the NPDES or EPA-authorized state program. The land use requirements for utility-scale solar projects larger than 1MW exceed this threshold and therefore, require the developer to obtain a CGP before construction activities can begin. Coverage under all CGPs, regardless of administering authority, is granted after several requirements are met, including the development and approval of a SWPPP. The major steps involved with developing and obtaining an NPDES permit are shown in Figure 2.

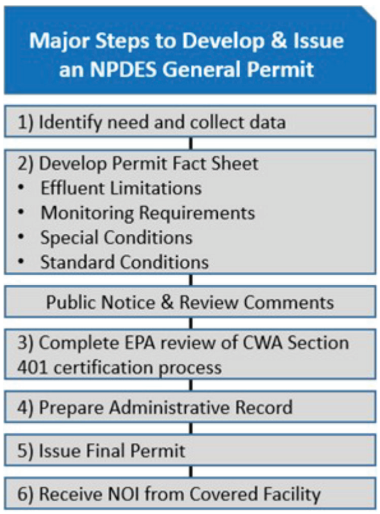

Figure 2: Steps to obtain an NPDES permit

Authorization for states to administer the NPDES program within their jurisdictional boundaries is granted through a process defined by the CWA, whereby states can assume responsibility for administering all, or portions of, the NPDES program. State regulatory agencies, regional water control boards, and local government bodies (i.e., municipal planning and zoning boards) may implement additional stormwater management requirements for utility-scale solar projects. Some notable differences across 11 states surveyed in the full *Solar-Stormwater Nexus* report (EPRI Report 3002014508, 2018) includes the promulgation of solar-specific provisions and the designation of solar panels as impervious or pervious surfaces. Table 1 provides a summary of stormwater policies in these 11 states.

Maryland, Minnesota, and North Carolina have each drafted stormwater management regulations and guidance documents that are specifically tailored to the construction of utility-scale solar projects. The design considerations that are common among these three states include the following concepts:

- Ensuring that there is an adequate permeable space between rows of solar panels so that runoff from the panels remains hydrologically disconnected
- Selecting a construction site with a slope of less than 5%, or terracing the site to maintain sheet flow conditions
- Minimizing site compaction during construction or tilling and amending soil following construction to maintain the natural infiltration capacity of the soils
- Limiting the vertical distance between the ground and the panel drip edge to limit soil erosion
- Establishing native groundcover that will help prevent erosion, promote infiltration, and support ecological function

In addition to enacting solar-specific stormwater regulations and guidelines, Minnesota has also implemented pollinator-friendly solar development guidelines that emphasize the use of native low growth flowering plant species to support robust pollinator habitats that benefit nearby agricultural lands. Voluntary pollinator-friendly guidelines and standards were enacted by Minnesota State Legislature (bill number HF 3353) following near unanimous votes in the Minnesota state legislature. The bill codified a one-page scorecard that is used to rate solar projects seeking a pollinator-friendly designation.

Table 1: Summary of state level stormwater policies

State	State Level Stormwater Management Policy	Solar PV Specific Stormwater Policy	Solar Panel Designation for Stormwater Design
Arizona			Not Specified
California	✓		Pervious
Florida	✓		Site Specific
Georgia	✓		Impervious
Massachusetts	✓		Site Specific
Maryland	✓	✓	Pervious
Minnesota	✓	✓	Impervious
New Jersey	✓		Pervious
North Carolina	✓	✓	Pervious
Texas			Not Specified
Virginia	✓		Pervious

Best Management Practices (BMPs)

Many state environmental agencies have produced stormwater and erosion/sedimentation control guidelines and handbooks that describe the suite of BMPs applicable to a variety of construction projects including large solar arrays. Best management practices that are applied during the construction phase of a project are designed to control the erosion and resulting sedimentation that can occur when natural land surfaces are disturbed. These BMPs include mats that are placed over exposed soil, silt fences, stone filters, and drainage swales among other methods commonly used across all types of construction projects. Each of these BMPs reduce surface erosion and/or promote the settlement of sediment particles that have been dislodged.

Requirements for post-construction stormwater management vary by location, but typically include BMPs designed to reduce erosion, reduce off-site sediment transport, and mitigate alteration of the natural hydrologic response (volume and timing of runoff). These BMPs include site grading and terracing to reduce run-off flow velocity, soil stabilization through effective re-vegetation, constructed and natural depressions to promote stormwater infiltration, vegetated swales (with or without check dams), and retention ponds.

Perhaps the most effective approach for minimizing adverse stormwater impacts is to prevent stormwater concentration from occurring in the first place. Minimizing the potential for stormwater concentration can lead to reduced construction, operation, and maintenance expenses. Utilities wishing to add solar projects to their generation portfolio can limit their exposure to potential stormwater management expense by analyzing a suite of environmental variables that can be used to estimate potential stormwater volume. Mean annual precipitation and soil erodibility are two examples of datasets that can be used to inform site selection decisions during the planning and design phase of project development. Choosing a site with low annual precipitation and/or low soil erodibility, minimizes the potential for adverse stormwater impacts. Soil erodibility factors across the continental United States are shown in Figure 3.

Summary of Case Studies

The full *Solar-Stormwater Nexus* report (EPRI Report 3002014508, 2018) includes several case studies to compare and contrast stormwater permitting requirements, challenges, and innovative approaches to implementing successful stormwater management BMPs. The case studies included solar projects from California, Georgia, Maryland and Pennsylvania and are summarized here.

California Antelope Valley Solar Ranch: The 242 MW solar project was developed on 5,175 acres of land in Kern County, California that drains from the northwest to the southeast with an elevation decrease of approximately 20 feet over a span of six miles. Soils found throughout the project site are alluvium derived from granite and are primarily loamy sands that allows precipitation to percolate before forming desert wash drainage features.

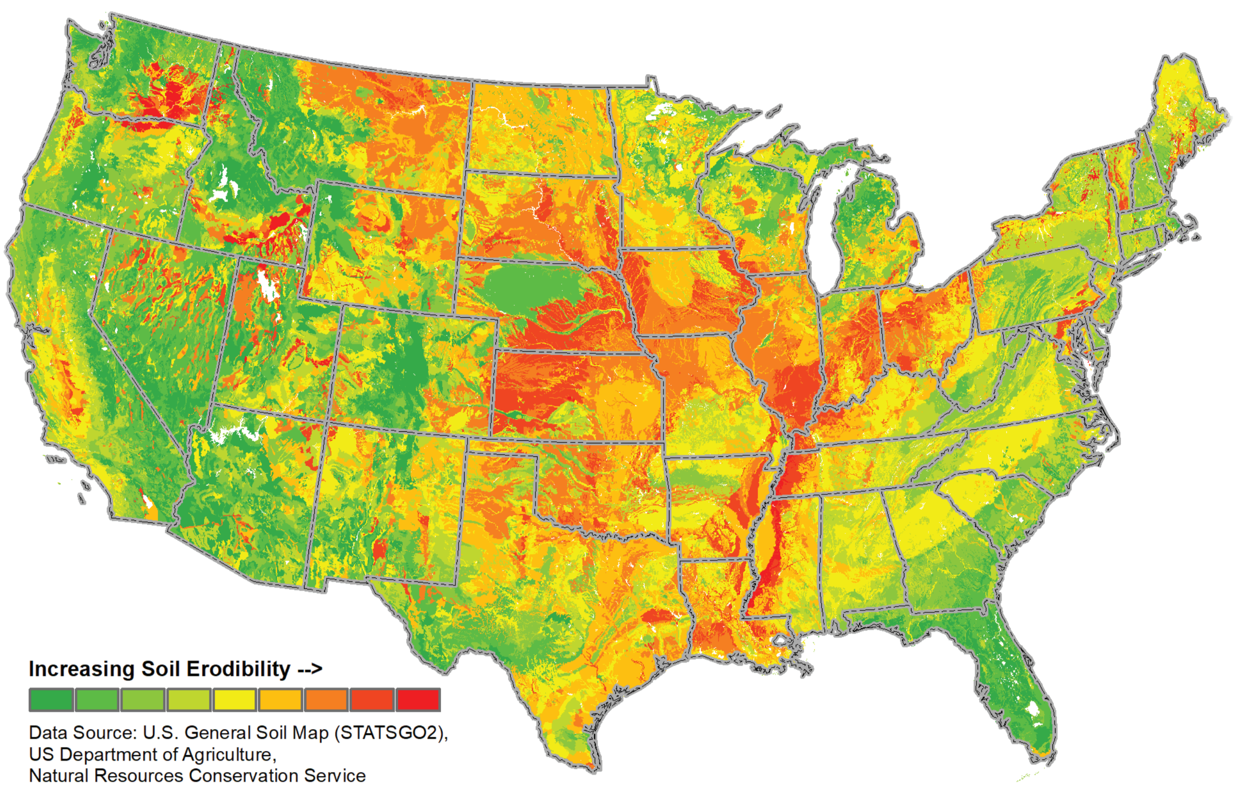

Figure 3: Soil erodibility for the contiguous U.S.

Infiltration basins were installed to function as a series of detention basins that detain the excess stormwater runoff flow and volume on-site to promote stormwater percolation into the soil instead of draining into downstream water bodies. This approach also allowed the project to meet the Los Angeles County Department of Public Works requirements for balancing pre- and post-development runoff volume. The project was also designed to coexist with the Antelope Valley groundwater recharge basin to minimize interference and increase in impervious surfaces that would require additional stormwater mitigation measures.

Georgia Decatur County Solar Facility: The 19MW solar project was developed at an out-of-service airfield that was already part of the regional stormwater detention system that includes pre-existing retention ponds and drainage infrastructure to reduce costs. Developing the solar project at the airfield minimized the need to clear tree or grade land, which would have resulted in greater risk of erosion and sedimentation.

The warm climate, fertile soil, long growing season and annual rainfall in Decatur County makes for favorable growing conditions for all types of vegetation. The solar project is covered in naturalized Bahia grass that grows quickly and has a substantial root system, which works well for erosion control. There has been notable erosion beside the main access road that was repaired and addressed with stone and secured hay bales.

Longwood Gardens, Pennsylvania: The 1.6 MW solar project was developed on varying terrain with significant elevation changes in some areas. Stormwater management systems included planting a dense meadow to promote infiltration, rain gardens, and utilization of an existing detention basin. Concerns over erosion in winter led to the development of a meadow to facilitate construction in densely planted areas. The pre-established meadow allowed for a fast and clean installation of solar PV panels.

The project was compliant with zoning and the Township waived land development permitting requirements. Chester County Conservation District in conjunction with the Pennsylvania Department of Environmental Protection issued an NPDES permit for the property. Construction costs were reduced by planting the meadow and implementing stormwater BMPs ahead of all other construction activities.

Area for Future Research

Systematic quantification of stormwater runoff, rainfall infiltration, and sedimentation from demonstration sites at operational solar facilities are necessary to enhance the industry's understanding of vegetation stabilization and other measures for long-term erosion control. Evaluation of different types of ground cover, vegetation and other BMPs that deliver ecological co-benefits (i.e., pollinator habitat or row crop agriculture) also warrant further study. Future research activities that can help solar developers and project owner/operators implement effective stormwater, erosion and sedimentation control strategies include the following:

- Quantify the performance of different plant species for stormwater management (i.e., infiltration, soil erodibility, flow velocity) in different geographic regions
- Evaluate the cost-effectiveness of low-impact solar design principles both for initial investment and long-term operations and maintenance costs
- Evaluation of existing solar projects to measure stormwater run-off coefficients to inform future design principles that will be most effective in reducing on-site and downstream flooding

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