

Bringing Resilience to Stormwater Management – Updating the Pennsylvania (USA) Post-Construction Stormwater Management Manual.

Renforcer la résilience de la gestion des eaux pluviales – Mise à jour du manuel de gestion des eaux pluviales post-construction de Pennsylvanie (États-Unis)

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RÉSUMÉ

Robert Traver est professeur au département de génie civil et environnemental de l'Université Villanova, ingénieur professionnel, ingénieur en ressources hydriques certifié et membre de l'ASCE. Il a fondé et dirigé le Centre Villanova pour les systèmes d'eau résilients et mène depuis plus de trente ans des recherches sur les infrastructures vertes de gestion des eaux pluviales. M. Traver a créé le parc de démonstration et de recherche sur les infrastructures vertes de gestion des eaux pluviales à Villanova et est rédacteur associé de la revue de l'ASCE, *Sustainable Water in the Build Environment*, qu'il a contribué à fonder. Il a été membre du comité du Conseil national de la recherche qui a rédigé le rapport « Gestion des eaux pluviales urbaines aux États-Unis » (2009) et co-auteur du manuel *Green Stormwater Infrastructure Fundamentals and Design* (Wiley). M. Traver est titulaire d'une licence en génie civil (BSCE) de l'Institut militaire de Virginie, d'une maîtrise en génie civil (MCE) de l'Université Villanova et d'un doctorat (Ph.D.) de l'Université d'État de Pennsylvanie.

ABSTRACT

The authors will present the results of a multiyear effort, to create a Post-Construction Stormwater Management Manual for the Commonwealth of Pennsylvania in the United States, replacing a 2006 version. Major changes include: an emphasize on resilience, inclusion of climate change considerations, updated analysis methods involving Stormwater Control Measure (SCM) unit processes (infiltration, evapotranspiration, and water quality treatment), consideration of temporal distribution of the rainfall, and a lifecycle approach (that considers long term maintenance of SCMs).

Les auteurs présenteront les résultats d'un projet pluriannuel visant à élaborer un manuel de gestion des eaux pluviales après construction pour le Commonwealth de Pennsylvanie, aux États-Unis, en remplacement de la version de 2006. Les principales modifications comprennent : une importance accrue accordée à la résilience, la prise en compte des effets du changement climatique, des méthodes d'analyse actualisées intégrant les processus unitaires des dispositifs de gestion des eaux pluviales (infiltration, évapotranspiration et traitement de la qualité de l'eau), la prise en compte de la distribution temporelle des précipitations et une approche de cycle de vie (qui prend en compte l'entretien à long terme des dispositifs de gestion des eaux pluviales).

KEYWORDS

Climate, Infiltration, Regulatory, Resilience, Stormwater Control Measure

1 INTRODUCTION

The Commonwealth of Pennsylvania has contracted with Villanova to spearhead the revamp of the Pennsylvania Post-Construction Stormwater Management Manual (PCSM) to guide industry professionals in meeting the Pennsylvania Department of Environmental Protection regulatory requirements. Since the original document was published in 2006 (PaDEP 2006), there has been a huge advancement of stormwater knowledge. The current state of the art is reflected by the over 1500 Journal articles that include the term “Stormwater” published by the American Society of Civil Engineers since 2006 (which does not include many other worldwide refereed journal sources). The authors have been tasked to update the manual, to address the advancements in the field, and to enable a resilient approach to meeting the Commonwealth’s stormwater management requirements. What started out as a revision has morphed into a completely new document, addressing the design, analysis, construction, inspection and maintenance of stormwater systems. Innovations that promote resilience such as design using continuous simulation (which better account for SCM unit processes and water use to promote sustainable systems) have been brought to the process.

2 CURRENT STORMWATER MITIGATION REQUIREMENTS

It has long been recognized that stormwater runoff and local flooding are related to changes in land cover associated with construction and development activities, which often result in an increase of impervious surfaces in the form of roads, pavements, and buildings. From a hydrologic perspective, this can result in a domino effect through the watershed. An increase in the amount of impervious surface in a watershed causes an increase in the volume and rate of site stormwater runoff, which, in turn, increases the frequency and severity of downstream flooding and destructive, accelerated erosion and sedimentation in the receiving waterbody. Additionally, increases in impervious surfaces in a watershed adversely affects groundwater recharge and the quality of the stormwater runoff. These effects have been amplified in recent years due to high rainfall intensities attributed to climate change.

Since 1978, in the aftermath of Hurricane Agnes, Pennsylvania (PA) has required new development to reduce postconstruction peak flows (associated with extreme events) to preconstruction or lower levels. The chief approach to meet this requirement has been a central-peaking 24-hour design storm. Specifically in PA, the 2-, 10-, 50- and 100-year frequency storms are used to meet peak rate criteria. Stormwater requirements in the US were augmented around 2000, as it was recognized that only considering peak rate was not addressing water quality impacts, recharge, or channel erosion/geomorphology concerns. Around this time, PA added volume and water quality requirements for all new development, specifically that postconstruction volume and water quality expected from the 2-year 24-hour storm could not exceed preconstruction. The 2006 PA guidance manual relies on the design storm approach for volume analysis and assumed percent removals per SCM type for water quality (Davis et al, 2022).

3 MAIN TENENTS OF THE NEW MANUAL

To make it clear that this is a significant departure (not a small change) from the previous guidance, the term Stormwater Control Measure (SCM) was adopted. In addition, the movement from the previously used term Best Management Practice, which is poorly defined, to a science-based approach to stormwater management requires a clear definition. Introduced by the report Urban Stormwater Management in the United States (NRC 2009), SCM is defined as: *Physical, structural, and/or managerial measures that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater.*

Early in the manual writing process, it was evident that a mere revision was unsatisfactory to bring in the advances gained in the profession over the last 20 years. At the start of the rewrite process, the authors embraced several guiding principles which are to base guidance on: 1) best available science, and 2) resiliency.

3.1 Best Available Science

As the knowledgebase will continue to grow, it was imperative to have a mechanism for revision to the manual to reflect this continued growth. As such, strategic structural choices were made to enable this agility for the most likely to change sections.

Considerable advances to date in stormwater management including accounting for SCM unit processes such as infiltration, evapotranspiration, and water quality treatment have been brought to the manual. For example, the

manual includes 15-year continuous simulation approach to meet water volume goals and mass loading (i.e., effluent concentration tied to volume reduction) approach to meet the water quality criteria. From long term research, it is evident that the design storm approach does not properly account for the time-dependent benefits of SCM infiltration and evapotranspiration as it ignores inter- and intra-storm recovery periods and local rainfall patterns which leading to potential over-sized systems and false prioritization of less resilient SCM types over others (Traver and Ebrahimian, 2017).

3.2 Resilience

The concept of resilience is used by many profession, each of which tailors this term to the specific vocation. For stormwater management professionals, resiliency is part of all aspects of PCSM guidance – its ultimately holistic approach that is more than the sum of its components, though some new or specific considerations are worth mention. Specific resilience considerations in the update of the manual include: incorporating climate change, valuing of natural landscapes (whether existing or newly created), including water quantity and quality unit processes, focusing on diversion of erosive flows from large storm events to volume and water quality SCM, and developing SCMs where infiltration is impractical (Karst, high water tables, etc.) All aspects including site selection, design, analysis, construction and maintenance life cycle need to consider resiliency.

SCMs themselves must be resilient; in other words, SCMs must meet their design intent despite changing rainfall volumes, variable rainfall patterns, seasonal temperature changes, and exposure to the variety of challenges associated with urban environments (e.g., incoming debris/sediments, heat island, clogging, etc.). A resilient SCM has a long lifespan (multiple decades) and returns to its expected performance with routine, minimal maintenance or repair even after extreme storm events thus inherently sustainable. Expected performance and design of resilient SCMs considers and acknowledges the variability of natural systems (which can be better accomplished through continuous simulation modeling compared to design storm). Consider a simple rain garden (or bioinfiltration): its performance depends on climate, rainfall patterns, underlying soil conditions, vegetation, geometric configuration, and maintenance. When a specific SCM is designed (considering the variability of the previously mentioned elements), constructed, and maintained correctly, it is expected to provide continuous and long-term performance. A benefit to resilience-informed design of infiltration SCMs is the reduction of significant volumes during larger extreme events.

SCM need to fit within the context of their larger watershed. A resilient SCM is designed specifically to the contributing drainage area and site conditions, and its contribution to the protection of the overall watershed. The design must recognize that SCM performance needs to contribute to the protection of waters from both an individual storm and from a broader hydrologic cycle perspective.

Resiliency ultimately includes all the tools in the toolbox (i.e., all SCM types) but may look different for different types of SCMs. Understanding the complex relationship between climate, soils and plants is important for resiliency in infiltration and evapotranspiration SCMs. Soil supports plant health, and the root system maintains infiltration pathways that maintain and increase SCM function. Resiliency is achieved in non-infiltrating SCMs through proper selection of plants and by limiting the duration and magnitude of erosive runoff velocities to protect water quality treatment processes and promote evapotranspiration. Of course, non-vegetated SCMs, such as pervious pavements and detention basins, can play a role in resiliency when designed as a system in partnership with other SCMs.

4 SUMMARY

The task of updating a close to twenty year old stormwater guidance manual is daunting, as is the task of creating a manual that can be updated, with a framework to allow innovation and improvements as knowledge allows within the regulatory structure. At the time of the writing the first review of the manual based upon public comment is underway, and is expected to be completed before the symposium. It is the attention of the authors to present key innovations that have been included in the manual, framed around representative SCM

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