Landscape and Urban Planning 106 (2012) 326–335

Contents lists available at SciVerse ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Comparing the adaptability of infiltration based BMPs to various U.S. regions

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ARTICLE INFO

Article history:
Received 29 June 2011
Received in revised form 6 April 2012
Accepted 10 April 2012
Available online 4 May 2012

Keywords:
Best management practice
Stormwater management
Portland
Simplified Sizing Approach
Sizing factor

ABSTRACT

The Pacific Northwest, specifically Portland, OR, has become a recognized leader in using small, vegetated best management practices (BMPs) such as infiltration basins for stormwater management. Landscape Architects around the United States often point to Portland's successes as to what could be achieved elsewhere. However, is stormwater management in the Pacific Northwest different from the rest of the country, and is it practical or even possible to replicate these practices somewhere else? To answer these questions, the authors re-created Portland's Simplified Sizing Model and then calibrated it for several major U.S. cities in various regions of the country. This approach allowed for a direct, side-by-side comparison of a hypothetical site, using the same design variables with different rainfall inputs depending on the city being studied. The results indicated that while small scale BMPs are effective in all regions of the country in managing small events, large rain events are much more difficult to manage as compared to Portland. However, by understanding the differences, opportunities arise that allow for practices to be adapted to a region's specific climatic conditions.

1. Introduction

Portland, OR, is considered a leader in progressive and creative stormwater management practices in the United States (Grewe et al., 2002; Hottenroth, Harper, & Turner, 1999; Thompson, 2004; Tunney, 2000; WERF, 2008). Research has shown that many projects in the Pacific Northwest have done more than meet stormwater quality and quantity requirements. Projects have been able to use stormwater management facilities to educate the public, create visual amenities, add value, and have become art features unto themselves (Echols, 2007; Echols & Pennypacker, 2006; Echols & Pennypacker, 2008; Pennypacker & Echols, 2008; Thompson, 1999). However, is there something other than better design that makes sustainable stormwater management different or more feasible in the Pacific Northwest than in other areas in the United States?

According to a case study by Echols (2007), many of the projects in the United States that focus on innovative and artful stormwater management are located in the U.S. Pacific Northwest – specifically Seattle, WA, and Portland, OR. Echols claims that:

> This is likely a reflection of some combination of the nature of rainfall in these areas that may encourage designers to transform excess runoff from a common nuisance to a design asset and the establishment of strict stormwater regulations in these municipal regions. It is not surprising that most of the suggested artful rainwater design projects are in the U.S. Pacific Northwest; however, it is likely that many of the projects' attributes will prove adaptable for use in other regions (Echols, 2007, p. 5).

This paper addresses how well a small-scale stormwater planter BMP can be adapted to other regions by sizing the same type of BMP for several U.S. cities including Portland, OR. By shedding light on climatic differences, this study allows designers to understand how BMP sizing requirements vary by region and allows municipalities to gauge the potential for adapting more progressive stormwater regulations that encourage more innovative and artful stormwater management.

1.1. Portland's stormwater approach

Portland's 2008 Stormwater Management Manual (BES, 2008) is unique in that it encourages a comprehensive application of small- to moderate-scale BMPs to capture precipitation, and retain, cleanse, detain, and/or convey stormwater runoff. This allows designers to use vegetated facilities to not only manage small water quality events but also large flow control events (i.e. 2-, 5-, and 10-year, 24-h storm events in most cases).

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http://dx.doi.org/10.1016/j.landurbplan.2012.04.004

> Traditional stormwater management tended to respond to each concern independently (e.g. filters reduced pollution, storage tanks provided detention and pipes conveyed and discharged the stormwater). The City's current stormwater management approach relies on the use of vegetated surface infiltration facilities to comprehensively meet multiple requirements. Vegetated facilities allow the applicant to meet pollution reduction, flow control, and infiltration requirements (BES, 2008, pp. 1–8).

The city has combined this unique management approach with an innovative application process called the Simplified Sizing Approach, which relies on sizing factors to simplify the design process. Steve Fancher, a previous employee of Portland's Bureau of Environmental Service (BES) who assisted in the development of the Simplified Sizing Approach, believes the approach allows designers to confidently incorporate stormwater management facilities early in the design process without the need for complex stormwater formulas (communication with author).

1.2. Climatic differences

There are two primary aspects of stormwater management: quality and quantity control (Ferguson & Debo, 1990). Regardless of location, water quality events are much smaller than water quantity events (Field & Sullivan, 2003). Therefore, the overall size of a BMP designed to manage both quality and quantity is driven by the quantity requirements. For this reason, this study focuses on the quantity requirement as the more important sizing criterion.

All site conditions being equal, stormwater modeling techniques for quantity control rely on two climatic variables to determine detention requirements: rainfall amount and intensity. While it rains nearly the same amount over a 24-h period in Portland as it does in other major U.S. cities such as Denver and Detroit, the rainfall is less intense (NRCS, 1986). Portland, like much of the Pacific Northwest, is in the Type 1A rainfall distribution zone as identified by the Natural Resources Conservation Service (NRCS, 1986). So while Detroit and Portland's 25-year, 24-h rain events are between 3.5 in. (9 cm) and 4 in. (10 cm), the rain falls in a more concentrated period of time in Detroit than in Portland.

1.3. Is stormwater management different in Portland?

Portland encourages the use of small, vegetated BMPs to accomplish all aspects of stormwater management including quality and quantity control (BES, 2008). Could both large (quantity) and small (quality) events be managed with these types of facilities in other parts of the United States? Using the sizing factor concept to simplify the relationships between facilities designed in Portland and those designed in other parts of the country, this paper asks two simple questions, and from the results of the two questions, conclusions are drawn regarding the physical design limitations and opportunities of implementing Portland's strategy elsewhere.

First, using Portland's design criteria, how much larger or smaller would a stormwater facility need to be in another part of the United States to manage the same storm event as in Portland? Second, if a facility were designed as if it were to be installed in Portland, what size storm event would that facility manage in another part of the United States?

2. Background

2.1. Sustainable stormwater management

The implementation of on-site stormwater management is typically administered at the municipal level through the use of ordinances or regulations. The first stormwater detention ordinances appeared in the U.S. in the 1970s, and it was not until the adoption of the 1987 Water Quality Act and the subsequent National Pollution Discharge Elimination System that more ordinances began to include a water quality component (Debo & Reese, 2003). Moreover, it was not until the 1980s that hydrologic models and solutions were applied to urban conditions (Booth, 1991).

In the last ten years, stormwater ordinances in some areas of the U.S. have advanced further to encourage a diverse set of goals including creating aesthetic amenities, intervening at the site scale to make cumulative improvements, and treating stormwater as a resource (Debo & Reese, 2003). Additionally, the most successful municipalities have engaged the public to increase awareness and acceptance of stormwater facilities (Roy et al., 2008). These recent changes reflect a more sustainable approach to on-site stormwater management.

A key spatial concept of sustainable stormwater management is managing pollution emissions at the source (Barbosa & Hvitved-Jacobsen, 2001; Boller, 2004), which includes decreasing the overall flow through maximizing infiltration (Hirschman, Collins, & Schueler, 2009; Mikkelsen, Jacobsen, & Fujita, 1996). Management at the source implies the use of small facilities that are able to be integrated into the overall site design. It also allows BMPs to more effectively manage pollutants where they originate (Bannerman, Owens, Dodds, & Hornewer, 1993). While sustainable stormwater management concepts have been extensively explored in literature, only a few municipalities have embraced or been able to regulate and implement widespread sustainable stormwater practices (Roy et al., 2008).

2.2. Artful rainwater design

Holman-Dodds (2007, p. 72) defines sustainable stormwater management as "combining effective and safe pollution control and floodwater conveyance with self-supporting ecological and aesthetic benefits". The latter half of this definition has been expanded by Echols and Pennypacker into the concept of Artful Rainwater Design (ARD) (Echols, 2007; Echols & Pennypacker, 2008). They have defined five overall amenity goals beyond water management that ARD projects strive to achieve: education, recreation, safety, public relations, and aesthetic richness (Echols & Pennypacker, 2008). Echols (2007) also focused on aspects of ARD projects that promote public interaction and appreciation that includes ecological legibility, maintenance strategies, information systems, physical accessibility, multiple use, visual integration, public awareness, perceived value, and municipal commitment. Through their research and examination of case studies, many of the projects that meet these goals have been built in the U.S. Pacific Northwest due to a prolonged wet weather environment and strict stormwater regulations (Echols & Pennypacker, 2008).

2.3. Bioretention facilities

Structural BMPs have been developed in the last few decades to mitigate urban runoff (Braga, Horst, & Traver, 2007; Sample et al., 2003). They have been shown to reduce stormwater volumes, minimize peak flows, and remove pollutants (Barbosa & Hvitved-Jacobsen, 2001; Dietz, 2007). One of the most common small-scale BMPs is the "rain garden", "bioretention facility" or "infiltration basin" (Davis, Hunt, Traver, & Clar, 2009). Bioretention facilities can achieve several sustainable stormwater management objectives including: groundwater recharge, maintaining base flow, pollutant removal, channel protection and peak flow reduction (Davis et al., 2009).

Physical design guidelines for bioretention facilities vary greatly in literature, however they typically include a reservoir or ponding area to collect runoff, a bioretention soil mix to filter water, a