White Paper: Green Streets

Stormwater management is a critical infrastructure issue, with direct vulnerability to flooding from rainwater being compounded by vulnerability to the aboveground and underground stormwater management facilities being overwhelmed by floodwaters. The green streets concept is an approach to using green infrastructure to manage stormwater at the point where it falls rather than managing it through channels, drains, and other routing. Green streets use the natural processes associated with soils and vegetation to capture, slow down, and filter runoff, often allowing it to recharge ground water. This approach to managing stormwater runoff in a natural way can significantly reduce reliance on construction of additional infrastructure.

The green streets approach is an engineering efficiency approach. It recognizes that streets form a large part of the surface area of cities, and that surface can be used positively to manage stormwater with natural infiltration strategies, rather than merely channeling it to other infrastructure which can become overwhelmed. The green streets approach is detailed in several reference guides with many examples of implementation. Primary references are:

- *City Green: Innovative Green Infrastructure Solutions for Downtowns and Infill Locations*, published by the US Environmental Protection Agency (EPA) in 2016. This document cites twelve case studies of completed projects.
- *Stormwater Infiltration in the Highway Environment: Guidance Manual*, published by the National Cooperative Highway Research Program (NCHRP) in 2019 as Research Report 922. This report provides guidance on when it is appropriate to use, siting, and design of infiltration approaches to manage stormwater in the highway environment.
- *Urban Street Stormwater Guide*, a 2017 publication from the National Association of City Transportation Officials (NACTO).
- *City of Philadelphia Green Streets Design Manual*, published by the city in 2014 to define standards for the construction of green streets for stormwater management.

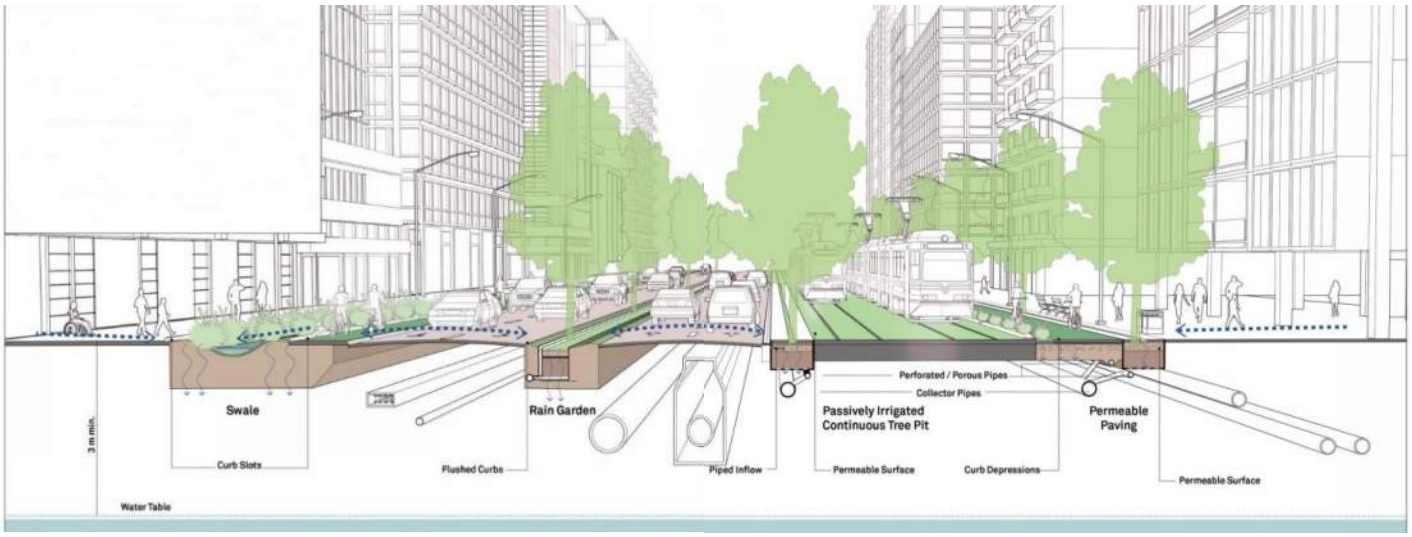
These design guides and their referenced case studies identify successful strategies and lessons learned for overcoming common problems in implementing a green streets approach. In general, the references have found that although green streets can be more challenging to implement, the barriers can be overcome and the results are effective. Particular issues which were found with green streets are:

- A green streets approach can be cost-effective, particularly when compared to subsurface infrastructure.
- Careful site planning may be needed to allow green streets techniques to work in sites with poor soil infiltration.
- There may be regulatory barriers at the municipal level which have to be overcome.
- Long-term maintenance must be addressed.

A secondary effect of green streets relies on its being a natural strategy. Efficient infiltration treatments are therefore more likely to be seen as beautiful. The result is a stormwater management system that efficiently uses available street right-of-way, functions well, and provides a safe and pleasant environment for road users.

The nature-based green street strategies are not restricted only to rural and suburban environments. **Figure 1** shows a conceptual green street cross-section designed for an intense urban example. The strategies which are shown include tree trenches, rain gardens, streets directing runoff to infiltration areas, and permeable underground piping.

Figure 1: NACTO Conceptual Urban Green Street Cross Section



A detail of a bioretention planter from the *City of Philadelphia Green Streets Design Manual* is shown as **Figure 2**. This is just one type of device that can be incorporated into roadway design as a strategy to increase stormwater infiltration to prevent flooding.

Figure 2: Stormwater Planter Cross Section

These types of retention planters and tree wells or trenches are envisioned as natural-based treatments that are an integral part of the street, streetside, or median. They are not isolated treatments in dispersed places, but are continuous elements of the street ecosystem. **Figure 3** shows samples of how these green streets elements can be constructed on the streetside, curb bulb-out, or median.

Figure 3: Samples of Bioretention Elements

These elements are predominantly natural filtration swales, which are relatively slight modifications of the grassy ditches which are in common use. More extensive treatments are also listed in the NACTO guide, such as tree wells and continuous tree trenches, with engineered subsurface infiltration and drainage. Illustrations of these elements from the Bagby St reconstruction in Houston are shown in **Figure 4**.

Figure 4: Tree Trenches on Bagby St, Houston

Pervious pavement are another approach that increases the surface area where water can infiltrate into the ground. Pervious pavement has typically been used in parking lots, since their strength to handle traffic loads and their impacts on ride quality and tire-pavement noise has been questioned However, more recent applications of pervious concrete have demonstrated its suitability for low-volume roads. A seven-year pilot application of pervious concrete pavement was conducted in Shoreview, Minnesota, as reported in *Local Road Research Board Report 2017-47*, found that:

- Water infiltration was high, but can decline over time because of material clogging the pores unless the street is regularly cleaned. Pressure-washing or vacuuming twice a year is recommended.
- Construction costs were higher than for impervious asphalt, but life-cycle costs are lower.
- Ride quality and noise were superior to typical concrete or asphalt pavements.
- In general, pervious pavement is a cost-effective alternative for low-volume city streets.

Interlocking pervious pavers are suitable for parking lots, parking lanes and sidewalks, but the ride quality for bicycles and strollers should be considered before using them for bicycle lanes or shared-use paths. Pervious asphalt or concrete paving can be used for any of these applications and also for low-volume streets. Pervious asphalt or concrete paving can also be used as paved shoulders alongside impervious pavements. **Figure 5** shows samples of interlocking pervious pavers and pervious pavement.

Figure 5: Sample Applications of Pervious Pavements