

Soil Constraints and Low Impact Development

Careful Planning Helps LID Work in Clay Soils

Low impact development (LID) practices, also referred to as green infrastructure, include natural or man-made swales, depressions and vegetated areas that are designed to capture, filter and infiltrate runoff using soils and vegetation. When selecting and designing LID practices, the type of soil underlying the area must be factored into the design process. Designers often incorrectly assume that LID practices should not be sited on clay soils because they are concerned that the clay soils lack sufficient infiltration capacity to manage the runoff and that ponding might occur.

LID practices can be sited on clay soils if the appropriate conditions are present and the infiltrative capacity of the soils has not been significantly altered. Drainage problems tend to occur when the pore spaces in clay soils have been disturbed and compacted by construction activities or previous land uses. In such situations, surficial ponding might occur if the infiltration rate of the clays is too low. Designers should anticipate the challenges that can occur in soils with high clay content. By analyzing the infiltration rates of soils on the site, designers can select the best locations for LID practices and/or identify specific areas that would need remediation (e.g., adding soil amendments) to ensure adequate infiltrative capacity. Compacted soils should be mechanically de-compacted and/or amended to provide the requisite infiltrative capacity that can retain the desired design volume.

Practices That Work With Clay Soils

LID practices such as rain gardens, permeable pavements, and bioretention cells can perform well on sites with clay soils if the practices are sized appropriately, proper drainage is provided, and they are constructed and designed to minimize clogging. Suggested design elements include:

- (1) Design the practice to retain a prescribed volume (e.g., 1 inch of rainfall) that can be infiltrated and/or evapotranspired within a given time frame (e.g., 48 hours) as determined by the capacity of the soils and plants.
- (2) Use soil amendments where necessary to improve soil infiltration rates.
- (3) Design and place overflow, bypass and underdrain systems to prevent ponding and clogging.
- (4) Select plant species that facilitate ongoing infiltration through root structures.
- (5) Include a margin of safety to ensure the system will perform as designed, even with some degree of clogging.

Note: If a practice is designed as a retention/filter system that retains a design volume and filters excess volume, additional design elements such as underdrains, orifice controls and inverted elbows can be incorporated. In high-clay soils, rapid drying can cause the formation of linear cracks in the clay which can reduce the effective retention volume of the practice, especially in designs that include underdrains. Incorporating inverted or upturned elbows in the design of the discharge pipe, as depicted in the figure (above, right), helps to ensure that the requisite design volume is retained and infiltrated.

FAQ

Don't clay-rich soils prevent water infiltration needed for LID?



Barrier Busted!

LID practices can work in clay-rich soils when designed to ensure adequate infiltration.

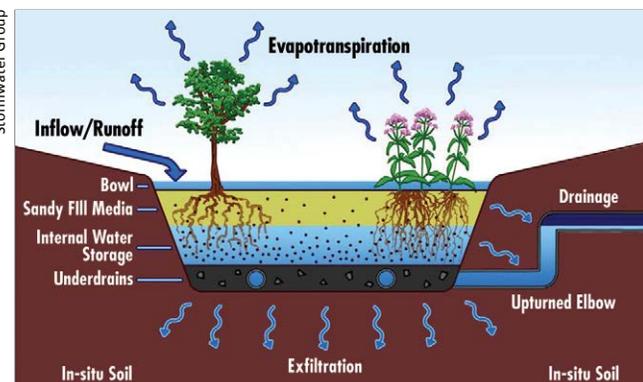
EPA's LID Barrier Busters fact sheet series... helping to overcome misperceptions that can block adoption of LID in your community

Tetra Tech



Roof water drains to this rain garden.

Shawn Kennedy, North Carolina State University Stormwater Group



This bioretention system has an underdrain with an upturned elbow.

Case Studies

Rain Gardens, Madison, Wisconsin

In 2003 the U.S. Geological Survey (USGS) installed four rain gardens next to municipal buildings to test the effect of soil type and plant type on the rain gardens' ability to absorb stormwater. Two rain gardens were installed in sandy soils and two rain gardens were installed in clay soils. For each soil type, one rain garden was planted with turf, and the other with native prairie grasses. Each rain garden was sized to a ratio of approximately 5:1 contributing drainage area to receiving area, resulting in surface areas between 100 to 400 square feet with a 0.5-foot depth. The rain gardens were not equipped with underdrains. The USGS monitored the rain gardens for 4 years, observing inflows, outflows, rainfall amounts and evapotranspiration amounts.



Roof stormwater drains to these monitored rain gardens in Madison, Wisconsin.

Results

- Regardless of vegetation or soil type, the rain gardens were able to store and infiltrate 96 to 100 percent of the stormwater they received over the 5-year study period.
- Under similar soil conditions, rain gardens planted with prairie species had significantly greater median infiltration rates than those planted with turf grass.
- Comparing soil types, the median infiltration for sand was nearly 5 to 9 times greater than the infiltration rates of clay, depending on vegetation type.
- Soil and root investigations indicate that clay soil planted with prairie grass had deeper root growth and appeared well-drained relative to the turf grass, which had limited root growth and a perched water table.

Estimated Median Infiltration Rates (Inches/Hour) for Each Garden across All Water Years (2004–2008)

Rain Garden Type	Soil Texture Type	Median Infiltration Rate
Turf-sand	Silt loam, sandy clay loam and sandy loam	2.50
Prairie-sand		4.20
Turf-clay	Sandy loam to clay-loam, heavily compacted	0.28
Prairie-clay		0.88

Source: Selbig, W.R., and Balster, Nicholas. 2010. Evaluation of turf-grass and prairie-vegetated rain gardens in a clay and sand soil, Madison, Wisconsin, water years 2004–08: U.S. Geological Survey Scientific Investigations

Roadside Bioretention, Toledo, Ohio

In 2009 the city of Toledo installed nearly 800 feet of residential roadside bioretention areas and permeable sidewalks on a site with clay soils to help reduce the occurrence of combined sewer overflows during heavy rainfall events. The bioretention areas were designed with an engineered sandy loam soil and included underdrains to help drain the system if needed. Plants were chosen by the residents adjacent to the bioswales based on how much maintenance they were willing to do in front of their homes. Most chose turf grass, but some chose native plants. Underground water storage was provided beneath the permeable sidewalk. Flow monitors were installed before and after construction to assess the effectiveness of the system.



Stormwater from the road and sidewalks flows into this bioretention system on Maywood Avenue in Toledo.

Results

- Monitoring results comparing pre-construction to post-construction LID implementation indicate greater reductions in peak and total volumes when the underdrain valve is closed as opposed to open (see table at right).
- Long-term modeling for the closed underdrain system indicates an annual average stormwater volume reduction of about 64 percent and peak flow reductions of 60–70 percent.

Average Percent Reductions between Pre-and Post-construction Flows (2010–2011)

Underdrain Status	Open	Closed
Total Flow Volume	-10%	57%
Peak Flow	51%	71%

Source: Tetra Tech. 2009. City of Toledo, OH, Maywood Avenue Stormwater Volume Reduction Project Construction Plan Set. Table shows follow-up monitoring conducted in 2010–2011.