LID Application Review and FLO-2D Modeling

Jeff Holzmeister, P.E.
Shimin Zou, Ph.D., P.E., CFM
Daniel Selk, P.E., CFM
J2 Engineering and Environmental Design

Spring 2016
Presentation Outline

- Introduction to LID
- LID Controls, Accessories, and Systems
- Review of LID Simulation Methods
- FLO-2D Modeling Methods of LID Controls
- FLO-2D Modeling Results of LID Controls
- Questions
Introduction to LID

Low Impact Development (LID) is an innovative stormwater management approach whose basic principle is modeled after nature: manage storm runoff at the source using distributed micro-scale controls. The goal of LID is to mimic and/or restore a site's predevelopment hydrology using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source.
Typical LID Applications in Tempe
Benefits of LID

- LID is a more environmentally sound technology and a more economically sustainable approach to addressing the adverse impacts of urbanization.

- LID can enhance the local environment, protect public health, and improve community livability - all while saving developers and local governments money.
LID vs. Traditional Drainage Structures

LID Facilities Menu

from mechanical to biological

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LID Controls, Accessories, and Systems

- LID controls (tools, practices, techniques, methods, facility, concept, practice, application or similar names) have been developed and applied with similar hydrologic and hydraulic functions, but different shapes, materials, locations, and sometimes, with and or without add-ons (accessories).
- LID accessories are structures that are added or connected to LID basic controls to improve their hydrologic and hydraulic functions and capabilities.
- LID systems are combinations of one or more LID basic controls and accessories to improve and expand their hydrologic and hydraulic functions and capabilities.
LID Controls

<table>
<thead>
<tr>
<th>Similar names</th>
<th>Similar names</th>
<th>Similar names</th>
<th>Similar names</th>
<th>Similar names</th>
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</thead>
<tbody>
<tr>
<td>Bioretention cell</td>
<td>Downspout disconnection</td>
<td>Pervious concrete</td>
<td>Active rainwater harvesting</td>
<td>Vegetated roof</td>
</tr>
<tr>
<td>Chicane</td>
<td>Grass swale</td>
<td>Pervious paving</td>
<td>Above ground cistern</td>
<td>Rooftop garden</td>
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<tr>
<td>Flow-through planter box</td>
<td>Linear vegetated swale</td>
<td>Porous asphalt</td>
<td>Below ground cistern</td>
<td></td>
</tr>
<tr>
<td>In-ground planter box</td>
<td>Meandering vegetated swale</td>
<td>Soft paving</td>
<td>Rain cistern</td>
<td></td>
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<tr>
<td>On-site bioretention basin</td>
<td>Vegetated channel</td>
<td>Stabilized aggregate</td>
<td>Rain tank</td>
<td></td>
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<tr>
<td>Planter box</td>
<td></td>
<td>Structural grid system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain barrel</td>
<td></td>
<td>Permeable paver system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain garden</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raised planter box</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional bioretention basin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention basin</td>
<td></td>
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## LID Controls and Hydrologic Functions

<table>
<thead>
<tr>
<th>Basic LID Control Name</th>
<th>Hydrologic Functions</th>
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<tbody>
<tr>
<td></td>
<td>Retention</td>
</tr>
<tr>
<td>Bio Retention</td>
<td>X</td>
</tr>
<tr>
<td>Bio Swale</td>
<td></td>
</tr>
<tr>
<td>Pervious Pavement</td>
<td>X</td>
</tr>
<tr>
<td>Rainwater Harvesting</td>
<td>X</td>
</tr>
<tr>
<td>Green Roof</td>
<td>X</td>
</tr>
</tbody>
</table>
## LID Systems

<table>
<thead>
<tr>
<th>LID Systems, Basic Controls, and Accessories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical LID Systems</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Accessories</td>
</tr>
</tbody>
</table>
On-Lot Treatment System Concept along Concorda Drive
Green Parking System Concept along Concorda Drive
Green Street System Concept along Concorda Drive
General Concepts of Basic LID Controls

- Bio Retention
- Bio Swale
- Pervious Pavement
- Rainwater Harvesting
- Green Roof
General Concepts of Basic LID Controls
- Bio Retention

Bio Retentions are shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets.
General Concepts of Basic LID Controls
- Bio Retention

Bioretention cells fit into constrained urban site.
General Concepts of Basic LID Controls - Bio Retention

Bioretention planters provide stormwater storage and promote healthy growth of trees and plants.
General Concepts of Basic LID Controls
- Bio Swale

Bioswales are vegetated, mulched, or "xeriscaped" channels that provide treatment and retention as they move stormwater from one place to another.
General Concepts of Basic LID Controls
- Bio Swale
General Concepts of Basic LID Controls - Pervious Pavement

Pervious pavements are paved surfaces that infiltrate, treat, and/or store rainwater where it falls.

Permeable paving is an attractive way to provide runoff reduction in paving and pedestrian areas.

Structural grid paving reduces runoff in parking areas and fire lanes.
General Concepts of Basic LID Controls - Pervious Pavement

Stabilized aggregate reduces storm runoff from low-traffic paving areas.

Porous asphalt paving is a runoff-reducing in paving areas and driveways.
General Concepts of Basic LID Controls
- Rainwater Harvesting

Rainwater harvesting systems collect and store rainfall for later use. When designed appropriately, rainwater harvesting systems slow and reduce runoff and provide a source of water.
General Concepts of Basic LID Controls
- Green Roof

Green roofs are covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water.
General Concepts of Basic LID Accessories

- Standard Curb Cut
- Curb Cut with Sidewings
- Grated Curb Cut
- Curb Cut with Sediment Capture
- Concrete Flush Curb
- Wheelstop Curb
- Downspout
- Roof Drain
- Underdrain
General Concepts of Basic LID Accessories
- Standard Curb Cut

Curb cuts are openings created in a curb to allow stormwater from an impervious surface, such as roads, parking lots, or hardscape areas, to flow into a lower landscaped storage and LID control area.

Curb cuts control stormwater flow from streets to LID facilities.
General Concepts of Basic LID Accessories
- Curb Cut with Sidewings

The sidewing addition to curb cut conveys stormwater a greater distance, and can reduce the potential for erosion behind the curb or close to the paved surface.
General Concepts of Basic LID Accessories - Grated Curb Cut

Grated curb cuts allow stormwater to be conveyed into LID area under a pedestrian walkway.

Grates allow stormwater to pass through while proving an acrossing pedestrian route.
General Concepts of Basic LID Accessories
- Curb Cut with Sediment Capture

Sediment catchments capture and collect sand and fine soils at the entrance to bio retention areas, removing them from stormwater and allowing periodic removal. Sediment removal can significantly extend the functional life of these features.
General Concepts of Basic LID Accessories
- Concrete Flush Curb

Concrete flush curbs allow stormwater to runoff impervious surfaces directly into LID control areas and stormwater facilities.
General Concepts of Basic LID Accessories - Wheelstop Curb

Wheelstop Curbs are formed sections of curb with gaps between them. They allow stormwater from adjacent impervious surfaces, like parking lots, to flow into adjacent LID control areas.
General Concepts of Basic LID Accessories - Downspout

Downspout is used to direct rainwater from the rooftop into a LID control instead of into a piped system or into the street.
General Concepts of Basic LID Accessories  
- Roof Drain

Roof Drain is used to help collect and convey runoff from green roof LID control area into rain tanks, cisterns above/below ground or piped systems.
General Concepts of Basic LID Accessories - Underdrain

A perforated pipe, typically 4-6 inches in diameter placed longitudinally at the invert of a bio retention, bio swale, or pervious pavement LID control for the purposes of achieving a desired discharge rate or runoff volume reduction.
Review of LID Simulation Methods

- Hydrologic and Hydraulic Modeling
- Benefit/Cost Estimation Programs
- General Help Tools
Review of LID Simulation Methods
- Hydrologic & Hydraulic Modeling

- NRCS Curve No. Method
- SWMM or PCSWMM
- HSPF (Hydrologic Simulation Program in FORTRAN) Model Function Tables
- EPA National Stormwater Calculator
- Statistical Method
- FLO-2D/SWMM
Review of LID Simulation Methods
- Benefit/Cost Estimation Programs

The Pima County Regional Flood Control District & Pima Association of Governments with the Cooperation of the City of Tucson

AutoCASE™

Business Case Evaluator
A Value and Risk Based Enhancement to Envision™
Review of LID Simulation Methods
- General Help Tools

Envision™ was developed in joint collaboration between the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure.
FLO-2D/SWMM Modeling of LID Controls - Why FLO-2D/SWMM?

- LID practices are known to reduce area flooding, but quantification of LID flood impacts has been minimal to date;
- Grid-base (20’x20’ or smaller) provides necessary level of detail;
- Dynamic – accounts for spatial and temporal effects of distributed LID;
- Physical parameter modeling reduces dependence on assumptions;
- Model can track storm water volumes, peak flows, quality, and other parameters at the grid level;
FLO-2D/SWMM Modeling of LID Controls
- Why FLO-2D/SWMM?
How To Model LID with FLO-2D?

- Grid elevation adjustment-to mimic the volume storage of a specific LID application;
- Initial loss abstraction (IA) adjustment-to approximate rainfall depth/volume reduction;
- Infiltration rate & maximum soil depth adjustment;
- Diversion by a structure;
- Storm drain systems;
- Use artificial levees around the grids to control the flow locations and directions;
- Spatially variable rainfall data.
FLO-2D/SWMM Integration
Modeling of Storm Drain Systems
### FLO-2D Modeling Parameters for LID Basic Controls

<table>
<thead>
<tr>
<th>Method No.</th>
<th>Parameter Name</th>
<th>Bio Retention</th>
<th>Bio Swale</th>
<th>Pervious Pavement</th>
<th>Rainwater Harvesting</th>
<th>Green Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Grid elevation adjustment</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>B</td>
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<td></td>
<td></td>
<td>X</td>
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<tr>
<td>C</td>
<td>TOL value adjustment</td>
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<td>X</td>
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<tr>
<td>D</td>
<td>Infiltration rate adjustment</td>
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<td>E</td>
<td>Limiting soil depth</td>
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<td>F</td>
<td>Spatially variable rainfall</td>
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<td>X</td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>G</td>
<td>Diversion by structure</td>
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<tr>
<td>H</td>
<td>Boundary outflow grid</td>
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<td>X</td>
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<tr>
<td>I</td>
<td>Use of artificial WRF</td>
<td>X</td>
<td>X</td>
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<tr>
<td>J</td>
<td>Use of artificial levee</td>
<td>X</td>
<td>X</td>
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<td></td>
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<tr>
<td>K</td>
<td>Use of artificial storm drain</td>
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<td>X</td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>L</td>
<td>Others/IRAIN-BUILDING</td>
<td></td>
<td></td>
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</table>

*Note: X denotes the parameter is considered for the respective control.*
## FLO-2D Modeling of LID Basic Controls

- **Recommended Modeling Parameters**

### FLO-2D Modeling Methods for LID Basic Controls

<table>
<thead>
<tr>
<th>LID Basic Control</th>
<th>Possible Modeling Methods</th>
<th>Grid elevation adjustment</th>
<th>Initial loss IA adjustment</th>
<th>Infiltration rate/Soil depth adjustment</th>
<th>Use of artificial storm drain</th>
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<tbody>
<tr>
<td>Bio Retention</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bio Swale</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pervious Pavement</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rainwater Harvesting</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Green Roof</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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</tbody>
</table>
FLO-2D Modeling of LID Basic Controls
- Bio Retention

LID Focus Modeling Area - Bio Retention Control Grids
FLO-2D Modeling of LID Basic Controls

- Bio Retention
FLO-2D Modeling of LID Basic Controls
- Bio Retention

LID Focus Model - Bio Retention Max Depths

100 yr Storm Max Depth (ft)
- 0.04 - 0.10
- 0.11 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 +

1 inch = 400 feet
FLO-2D Modeling of LID Basic Controls

- Bio Retention

Graph: Floodplain XS 1 - Bala Dr

- Base Q
- Bio Retention Q

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FLO-2D Modeling of LID Basic Controls
- Bio Swale

LID Focus Modeling Area - Bio Swale Control Grids
FLO-2D Modeling of LID Basic Controls
- Bio Swale

100 yr Storm
Max Depth (ft)

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Color</th>
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<tbody>
<tr>
<td>0.04 - 0.10</td>
<td>Light Gray</td>
</tr>
<tr>
<td>0.11 - 0.50</td>
<td>Light Blue</td>
</tr>
<tr>
<td>0.51 - 1.00</td>
<td>Blue</td>
</tr>
<tr>
<td>1.01 - 2.00</td>
<td>Light Green</td>
</tr>
<tr>
<td>2.01 - 4.00</td>
<td>Green</td>
</tr>
<tr>
<td>4.01 - 6.00</td>
<td>Yellow</td>
</tr>
<tr>
<td>6.01 - 8.00</td>
<td>Orange</td>
</tr>
<tr>
<td>8.01 - 10.00</td>
<td>Pink</td>
</tr>
<tr>
<td>10.01 +</td>
<td>Red</td>
</tr>
</tbody>
</table>

1 inch = 400 feet

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FLO-2D Modeling of LID Basic Controls

- Bio Swale

**Floodplain XS 1 - Bala Dr**

![Graph showing flow rates over time for Floodplain XS 1 - Bala Dr with two lines: one for Base Q and another for Bioswale Q.](image)

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FLO-2D Modeling of LID Basic Controls
- Pervious Pavement

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FLO-2D Modeling of LID Basic Controls
- Pervious Pavement

LID Focus Model - Pervious Pavement Max Depths

100 yr Storm Max Depth (ft)
0.04 - 0.10
0.11 - 0.50
0.51 - 1.00
1.01 - 2.00
2.01 - 4.00
4.01 - 6.00
6.01 - 8.00
8.01 - 10.00
10.01 +

1 inch = 400 feet
FLO-2D Modeling of LID Basic Controls

- Pervious Pavement

![Graph](Floodplain XS 1 - Bala Dr)
FLO-2D Modeling of LID Basic Controls
- Rainwater Harvesting

LID Focus Modeling Area - Rainwater Harvesting Control Grids

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FLO-2D Modeling of LID Basic Controls

- Rainwater Harvesting

LID Focus Model - Rainwater Harvesting Max Depths

100 yr Storm Max Depth (ft)

- 0.04 - 0.10
- 0.11 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 +
FLO-2D Modeling of LID Basic Controls

- Rainwater Harvesting
FLO-2D Modeling of LID Basic Controls
- Green Roof

LID Focus Modeling Area - Green Roof Control Grids
FLO-2D Modeling of LID Basic Controls

- Green Roof

LID Focus Model - Green Roof Max Depths

100 yr Storm
Max Depth (ft)

- 0.04 - 0.10
- 0.11 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 +

1 inch = 400 feet
FLO-2D Modeling of LID Basic Controls

- Green Roof

Floodplain XS 1 - Bala Dr

![Graph showing floodplain analysis with green roof effect]

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# FLO-2D Modeling of LID Basic Controls

## - Storm Water Volume Reduction

### Summary Table for LID Basic Control Modeling Results

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>LID 2.1</th>
<th>LID 6.5</th>
<th>LID 13</th>
<th>LID 7.3</th>
<th>LID 9.3</th>
<th>LID 9.6</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Base</td>
<td>Bio Retention</td>
<td>Bio Swale</td>
<td>Pervious Pavement</td>
<td>Rainwater Harvesting</td>
<td>Green Roof</td>
<td></td>
</tr>
<tr>
<td><strong>Outflow (Outfall node I338)</strong></td>
<td>Qp (cfs)</td>
<td>8.58</td>
<td>4.70</td>
<td>8.45</td>
<td>7.52</td>
<td>8.62</td>
<td>7.85</td>
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<tr>
<td>Wet weather inflow</td>
<td>V (acft)</td>
<td>1.19</td>
<td>0.64</td>
<td>1.11</td>
<td>1.02</td>
<td>1.15</td>
<td>0.93</td>
</tr>
<tr>
<td>Return flow</td>
<td>V (acft)</td>
<td>0.04</td>
<td>0.00</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
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<tr>
<td><strong>Rainfall volume (2.52&quot; depth)</strong></td>
<td>V (acft)</td>
<td>4.37</td>
<td>4.37</td>
<td>4.37</td>
<td>4.37</td>
<td>4.37</td>
<td>4.37</td>
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<tr>
<td>Infiltration &amp; interception</td>
<td>V (acft)</td>
<td>0.93</td>
<td>1.32</td>
<td>0.99</td>
<td>1.67</td>
<td>1.05</td>
<td>1.54</td>
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<tr>
<td></td>
<td>%</td>
<td>21</td>
<td>30</td>
<td>23</td>
<td>38</td>
<td>24</td>
<td>35</td>
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<tr>
<td>Floodplain storage</td>
<td>V (acft)</td>
<td>1.47</td>
<td>1.83</td>
<td>1.5</td>
<td>1.09</td>
<td>1.44</td>
<td>1.27</td>
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<tr>
<td></td>
<td>%</td>
<td>34</td>
<td>42</td>
<td>34</td>
<td>35</td>
<td>33</td>
<td>29</td>
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<tr>
<td>TOL storage</td>
<td>V (acft)</td>
<td>0.07</td>
<td>0.07</td>
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<tr>
<td></td>
<td>%</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Floodplain outflow</td>
<td>V (acft)</td>
<td>0.76</td>
<td>0.58</td>
<td>0.79</td>
<td>0.59</td>
<td>0.73</td>
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<tr>
<td></td>
<td>%</td>
<td>17</td>
<td>13</td>
<td>18</td>
<td>14</td>
<td>17</td>
<td>15</td>
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<tr>
<td>Stormdrain (FLO-2D to SWMM)</td>
<td>V (acft)</td>
<td>1.23</td>
<td>0.64</td>
<td>1.1</td>
<td>1.02</td>
<td>1.17</td>
<td>0.92</td>
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<tr>
<td></td>
<td>%</td>
<td>28</td>
<td>15</td>
<td>25</td>
<td>23</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td>Return flow (SWMM to FLO-2D)</td>
<td>V (acft)</td>
<td>0.03</td>
<td>0.00</td>
<td>0.02</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
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<tr>
<td><strong>Vol Comparison</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum of volumes</td>
<td>V (acft)</td>
<td>4.36</td>
<td>4.37</td>
<td>4.36</td>
<td>4.37</td>
<td>4.37</td>
<td>4.36</td>
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<tr>
<td>LID volume captured</td>
<td>V (acft)</td>
<td>-</td>
<td>0.75</td>
<td>0.99</td>
<td>0.74</td>
<td>0.12</td>
<td>0.61</td>
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<tr>
<td>LID design volume capacity</td>
<td>V (acft)</td>
<td>-</td>
<td>0.89</td>
<td>0.31</td>
<td>0.85</td>
<td>0.12</td>
<td>0.63</td>
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<tr>
<td>Utilization of LID volume</td>
<td>%</td>
<td>-</td>
<td>84</td>
<td>29</td>
<td>87</td>
<td>98</td>
<td>96</td>
</tr>
</tbody>
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FLO-2D Modeling of LID Basic Controls
- Peak Flow Reduction at CS

LID Floodplain Cross Section Peak Flows

![Graph showing LID floodplain cross section peak flows with different LID controls: Base Model, Bio Retention, Bio Swale, P. Pavement, Rainwater Harvesting, Green Roof. The graph compares flow rates across various LID systems, highlighting peak flow reduction at different Control Sections (CS).]