Designing Urban Retrofits:  
Or Getting as Much as You Can  
(in the Space Available)  


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Bioretention has a very substantial capability to not only treat runoff, but to also retard and delay flows.

These flow effects require a modeling approach that addresses the various compartments that comprise the bioretention system:

- the surface pond,
- the media,
- the underdrain stone.

These different compartments have very different responses.

By modeling the dynamics of and interactions between these compartments, it is possible to obtain a better prediction of actual performance.

Such an approach is very useful in retrofit situations where space is limited, and the goal is to treat as much runoff as possible.

The following will present two case studies on how bioretention systems can be modeled dynamically to meet discharge objectives.
Route 72 and Garden State Parkway

- Site is shopping center and parkway interchange retrofit.
- Total area of subwatershed treated is 55 acres.
Due to overlapping jurisdictions between the Pinelands Commission, Ocean County Soil Conservation District (OCSCD) and NJDEP, the following discharge and routing criteria were to be met in the design of the project:

<table>
<thead>
<tr>
<th>OCSCD</th>
<th>Pinelands Commission</th>
<th>NJDEP Conditions</th>
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</thead>
<tbody>
<tr>
<td>•2, 10-Year Events, no reductions</td>
<td>•2, 10, 100-Year Events 50-, 25- &amp; 20% reductions</td>
<td>•Water Quality Event no reduction</td>
</tr>
<tr>
<td>•No infiltration</td>
<td>•No infiltration</td>
<td>•Infiltration</td>
</tr>
<tr>
<td>•Basins in failure mode</td>
<td>•Basins not in failure mode</td>
<td>•Basins not in failure mode</td>
</tr>
</tbody>
</table>

Design goal is to also treat as much runoff from Route 72 and Recovery Road as possible, as well as all onsite runoff to preceding criteria.

Therefore, to improve capture and treatment volumes for Rt. 72, the 2-foot isolation distance to groundwater along Route 72 was waived by Pinelands Commission.
Total impervious area treated is 34.3 acres, or 62% impervious.

Runoff treated in 5 bioretention cells and two bioretention swales.
A GIS is used to derive the various combinations of soil group and land cover.

Pivot table in Excel used to collate data according to subarea, pervious classification, land cover, HSG, and applicable CN.

Method rapidly develops accurate composite CN, weighted to tenth of a CN. (Since runoff differences between integer CN values often exceed 5%).

Subareas segregated into pervious and impervious nodes, with different Tc’s for each.

Data then directly entered into HydroCAD for routing.
Route 72 and Garden State Parkway

Roadside swale section designed to intercept as much flow as possible, and convey treated runoff via underdrain to existing inlets.
Route 72 and Garden State Parkway

- Roadside bioretention section also designed to intercept as much flow as possible, and convey treated runoff via underdrain to existing inlets.
- Note elevated standpipe inside outlet to ensure no groundwater discharge.
- Tailwater inside inlet accounted for in the routing of surface flows.
- Flows through compartments modeled dynamically during events.
Drainage diagram for proposed conditions shows subareas and pipe network.

Existing wetland basin treats cleaner flows from roof and disconnected areas.

Roadside swales modeled as surface nodes, media nodes, and underdrain nodes. Surface flows in swales routed by conventional reach nodes.

Same approach used for Route 72 bioretention basins, without surface flow reach node.

To meet discharge criteria of no increase at point of discharge, diversion used to convey flows from A-3 system up to A-2 system.
OCSCD Routing for the 2-year event (no infiltration turned on.)

Starting elevation is lowest outlet from underdrain stone.

Even though groundwater observed 5-6 feet down by creek surface, mottling at shallow depths used to allocate SHWT.

Therefore, underdrain outlets turned up inside inlet so as to ensure no groundwater discharge.

Media flow shown as red, while surface outflows shown in blue.

Able to meet no increase from Route 72 pond node since existing flows already high.

No surface flow from Entrance West.
The SPAW model is used to obtain estimates of saturated and unsaturated hydraulic conductivities. Note the dramatic reduction in rates under unsaturated conditions. This is applied as a rating curve in the models.
Routing for the 2-year event, with infiltration.
Starting elevation is system empty.
Media discharge into underdrain stone (in blue) is delayed according to the rating curve derived from SPAW routines. Since never saturated, peak outflow less than peak inflow.
Underdrain flow shown as blue is absent in stone node.
This is due to routing infiltration at 2.5 in./hr. (in brown).
Modeled under “actual” criteria, the bioretention cell eliminates all surface discharge in the 2-year event.
Organic fill require excavation through restricting zone and replacement of insitu soils with porous media so treated runoff can infiltrate.
Route 72 and Garden State Parkway

Media placed in layers, and manipulated from edge. **NO** tracked vehicles on media. Overplace by 20% to allow for settlement.
Springfield Retrofit

- Site is township park at base of 39 acre subwatershed.
- Watershed is 38% impervious.
- Flows currently conveyed through site are to be intercepted by diversions.
- Flows then to be treated by bioretention cells.
- Treated flows then to be infiltrated in galleries.
- Design Storm (DS) model used is HydroCAD.
Routing Diagram for subwatershed:
- Each inlet and sump system modeled to partition pipe flow from surcharged flow down street to next inlet.
- Diversions equalize flows between inlet systems, and divert first flush and low flows to bioretention systems.
- Bioretention systems modeled first as pond nodes which discharge through outlets, and into media nodes.
- Media nodes discharge into underdrain stone nodes.
- Underdrain stone nodes discharge to Infiltration gallery nodes, and into ground.
- Infiltration gallery nodes discharge into ground, and seep back into main system.
- Excess flows from Library infiltration diverted to Brookside infiltration.
Springfield Retrofit-DS Routing

- Bioretention pond discharges through outlets (in red), and into media at a constant rate applied to wetted area (shown in blue).
- Media discharge into underdrain stone (in blue) is delayed according to the rating curve derived from SPAW.
- All flows are subject to hydraulic gradient, so when downstream node(s) filled up, the limiting node determines system response.
- Note how flows into and through media are initially as fast as the media can flow (8 in./hr), then drop down to the rate determined by downstream nodes.
- This determines the flow into the media, and the corresponding timing of surface discharge.
Underdrain stone discharges to Infiltration galleries or into ground at constant rate as function of wetted area.

Infiltration rate of 0.5 in./hr is applied to wetted area (shown in brown).

Underdrain discharge (in blue) delayed until stone partially filled.

Infiltration galleries initially fill rapidly when underdrain flow begins, then falls to match outlet response.

Outflows discharge into ground at constant rate as function of wetted area, or seep back into main system (in blue).

By varying outlet parameters, adaptive management of system infiltration response is possible.
Routing List for 39 acre East watershed-proposed conditions:

- List shows important information including inflow rates and volumes, as well as outflow rates and volumes.

- Flows allocated to primary, as segregated from secondary and discarded flows.

- Peak elevations and storage volumes also shown.

- DS model output very useful for both design and review.

- Total volume 29,992 cu.ft.
Routing List for 39 acre East watershed- existing condition and comparison hydrographs to proposed in ±6-month ARI:

- Existing condition volume is 77,314 cu. ft.
- Runoff reduction to 29,992 cu.ft. represents 61% of existing volume.
- Runoff reductions accomplished using less than 0.5% of drainage area for bioretention.
- Good reduction, even when infiltration rate low!
- Peak flows reduced much less, due to the artificially steep hydrograph for runoff volume.
SWMM model input diagram:
- Note impervious area disconnection.
- Same rating curves as DS model used to develop the partially saturated media flow and exfiltration flows.
- Since SWMM does not carry hydraulic grade upward through rating curves (at least smoothly), system set for free discharge (via node 7).
- Dummy infiltration node created to conserve routing.
- SWMM run for 16 years of rainfall data from nearby gauge.
Springfield Retrofit-CS

- Existing condition hydrograph for rainfall event of 5-29-1990:
  - Duration is 18 hours. Depth is 2.36 inches, or roughly 11 month return period for 24 hour event.
  - Runoff Volume is 176,448 cu.ft. and peak flow is 8.07 cfs.
  - Runoff volume for 1.0 year DS event is 192,043 cu.ft. and peak flow is 38.95 cfs.
  - This peak rate does not correspond to CS event at all.
  - Real storm has very different shape from Type-III distribution used in DS model.
Proposed condition hydrograph for rainfall event of 5-29-1990:
- Runoff Volume is 118,791 cu.ft. and peak flow is 7.00 cfs.
- Runoff reduction of 57,618 cu.ft. is 33% of total runoff.
- Reductions in more frequent events would be higher.
Final Results from 16 years of data from 1990 to 2006 (including Hurricane Floyd):

- Total flow volume table shows that infiltrated volume is over 55% of incoming runoff.
- This reduction is similar to the 61% reduction projected from DS analysis of ±6-month recurrence interval event.
- Maximum flow roughly equivalent to 10-year DS event.

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<tbody>
<tr>
<td>MainOutlet</td>
<td>11.81</td>
<td>1.79</td>
<td>96.78</td>
<td>127.032</td>
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<tr>
<td>InfiltrationTotal</td>
<td>65.35</td>
<td>0.25</td>
<td>0.59</td>
<td>155.583</td>
</tr>
<tr>
<td>System</td>
<td>38.58</td>
<td>2.04</td>
<td>97.29</td>
<td>282.615</td>
</tr>
</tbody>
</table>
DS models inherently inaccurate since the DS event designed for flooding is very “peaky”.

However, DS models are overwhelmingly used by designers and reviewers throughout US, also legally required by the courts during litigation.

DS model interfaces show simultaneous display and comparison of multiple hydrographs and summaries. This is useful for detailed design of particular aspects (orifice sizing, pipe sizing) in a complex system.

CS models are the true test of a system. They give flow-duration-frequency curves essential for receiving water impacts.

However, CS modelers need to be experienced to properly allocate, calibrate and validate the parameters, and data needs are extensive.

CS models also suffer from rainfall gauge bias, which can substantially affect results.

CS models can be used to develop DS rainfall distributions, depths and antecedent conditions for BMP designs.