Hazen

Green Infrastructure Right-of-Way Inlet Type Selection: Hydraulic and Siting Factors to Consider to Optimize Design

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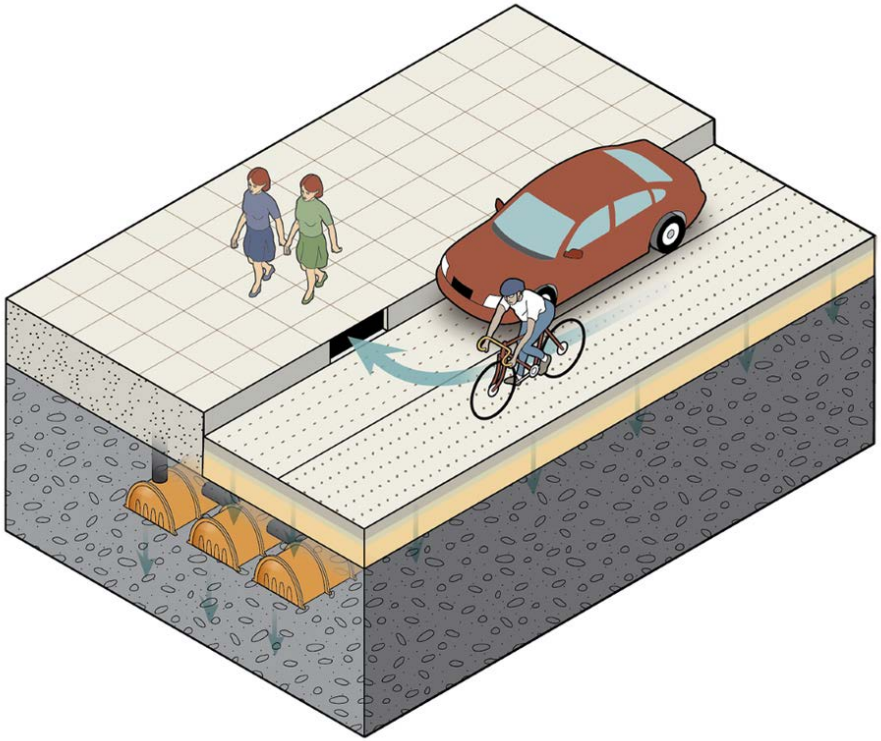
How does a green infrastructure system capture water in urban areas?



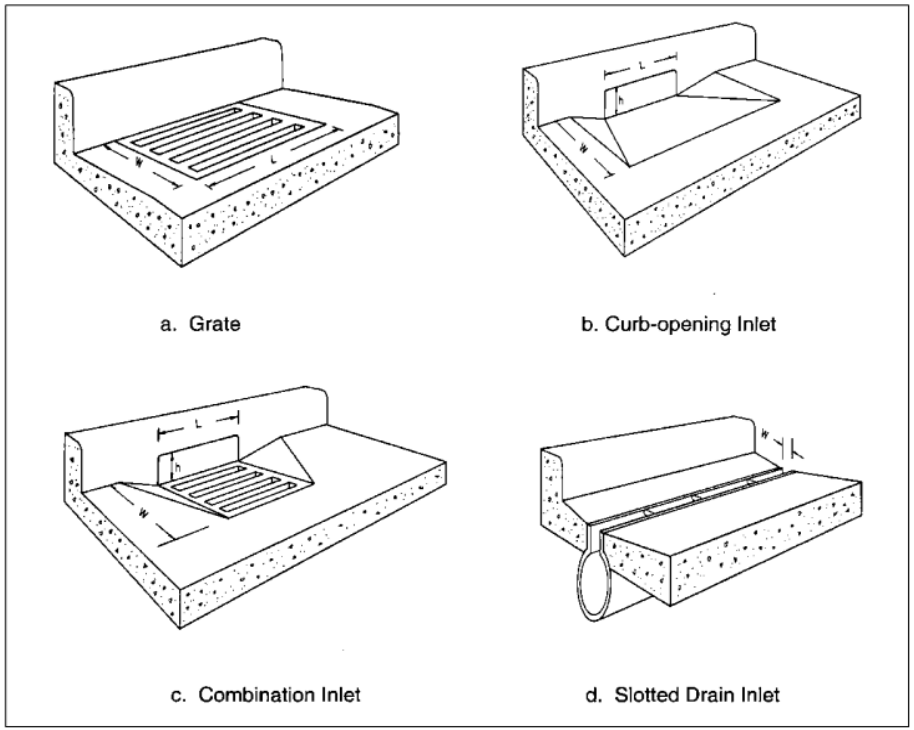
Capture Water Through Green Infrastructure Inlets

Hazen

Types of Green Infrastructure Inlets

Four Types of Inlets

Roadway Drainage

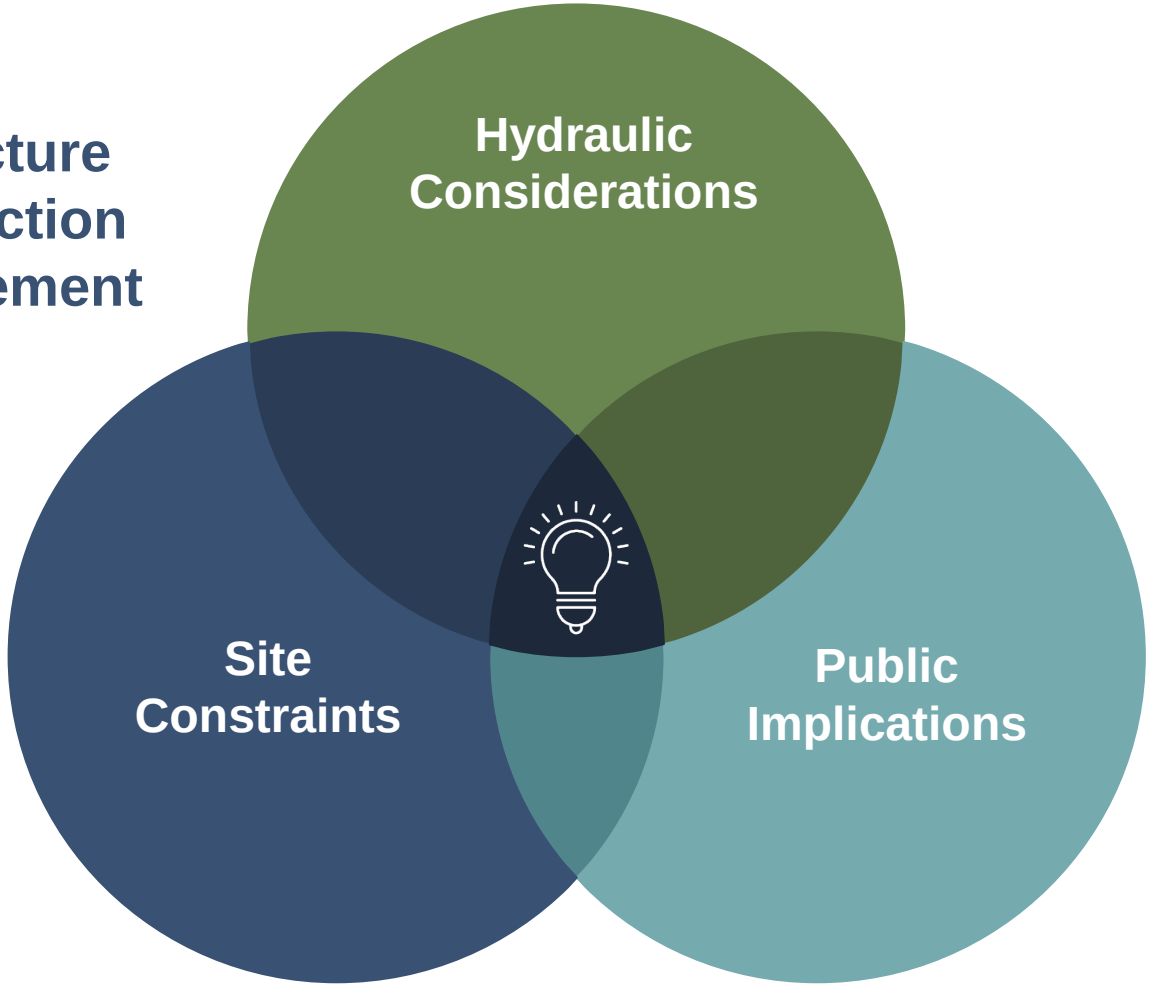


Source: FHWA Urban Drainage Design Manual

Source: Hazen

Siting and Sizing Factors

Green Infrastructure Inlet Selection and Placement

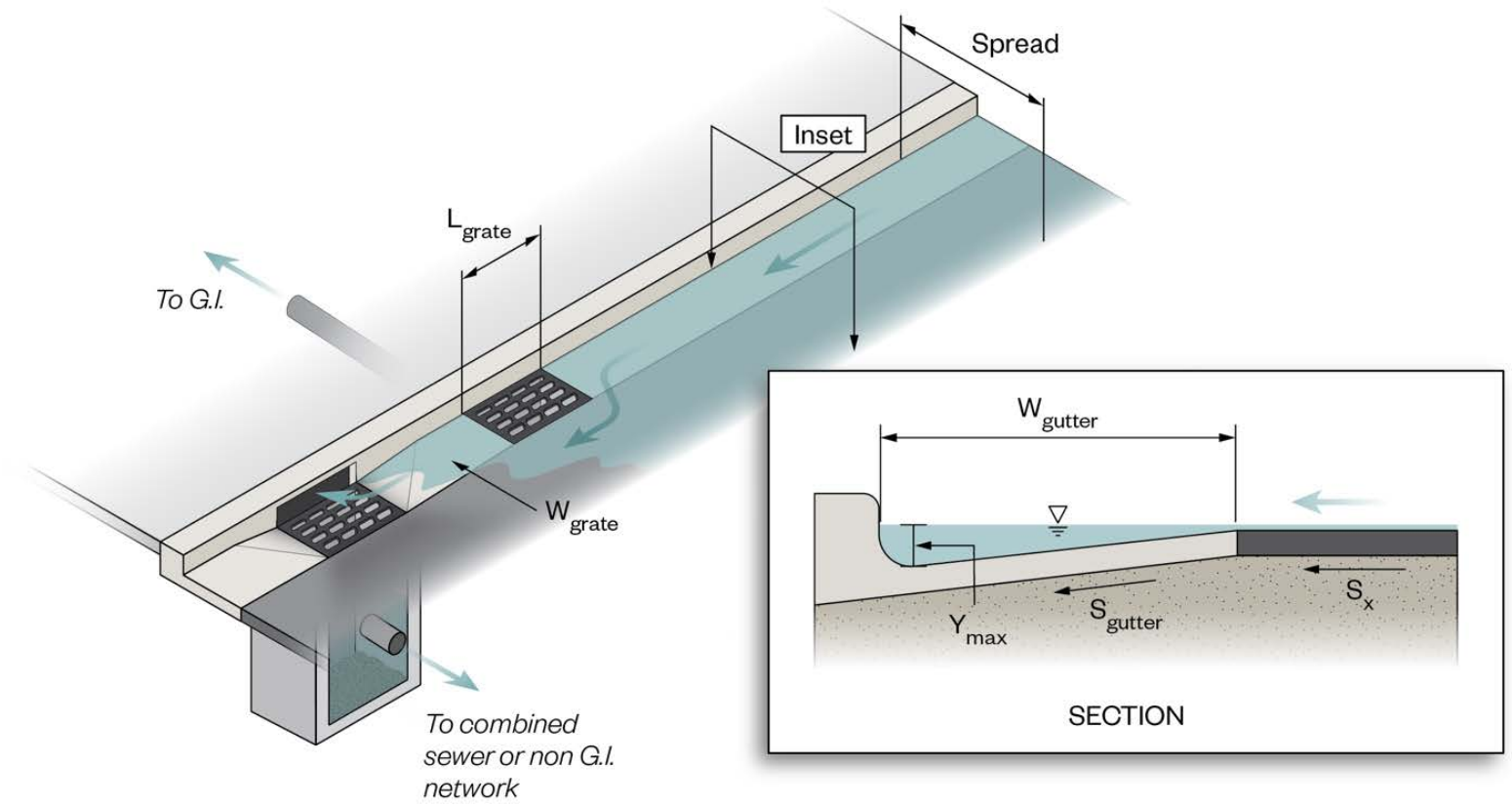


How can we optimize the capture efficiency of a green infrastructure inlet?

Hydraulic Considerations

- Inlet Geometry
- Storm Intensity and Duration
- Drainage Area
- Roadway Design
- Gutter Characteristics
- Inlet Aprons
- Debris Clogging
- Conveyance to Green Infrastructure

Hydraulic Considerations for a Grate Inlet

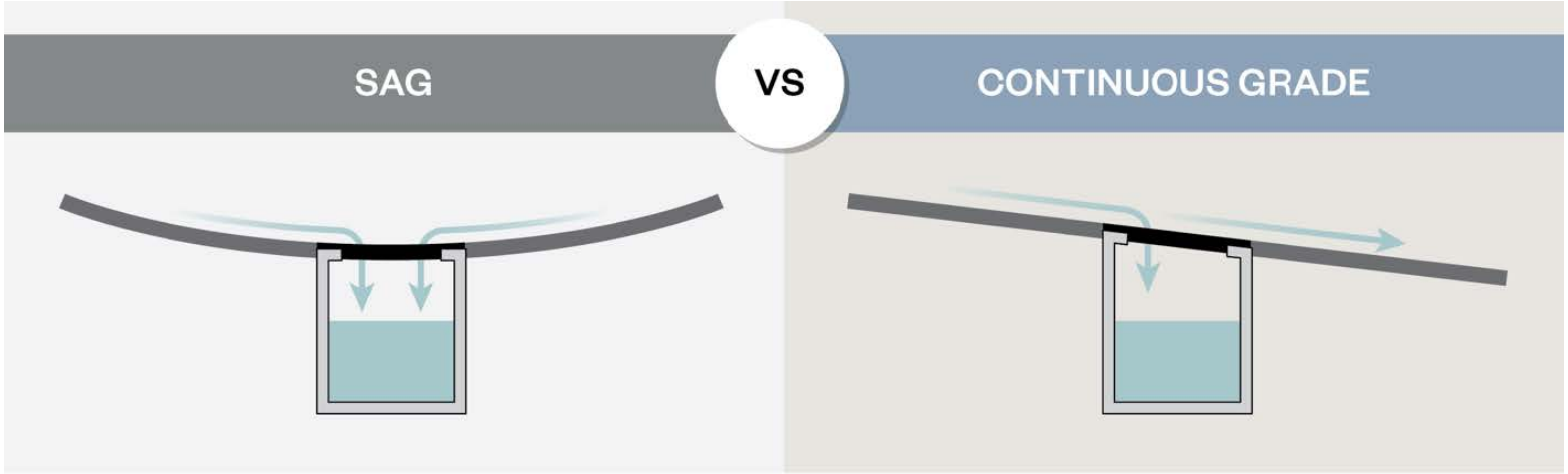


Site Constraints and Other Factors

- Presence and type of curbing
- Proximity to buildings, utilities, streetscape, trees, ADA ramps, etc.
- Conveyance to green infrastructure system
- Pretreatment
- Maintenance and access
- Constructability
- Allowable spread
- Pedestrian and driver impacts
- Cost

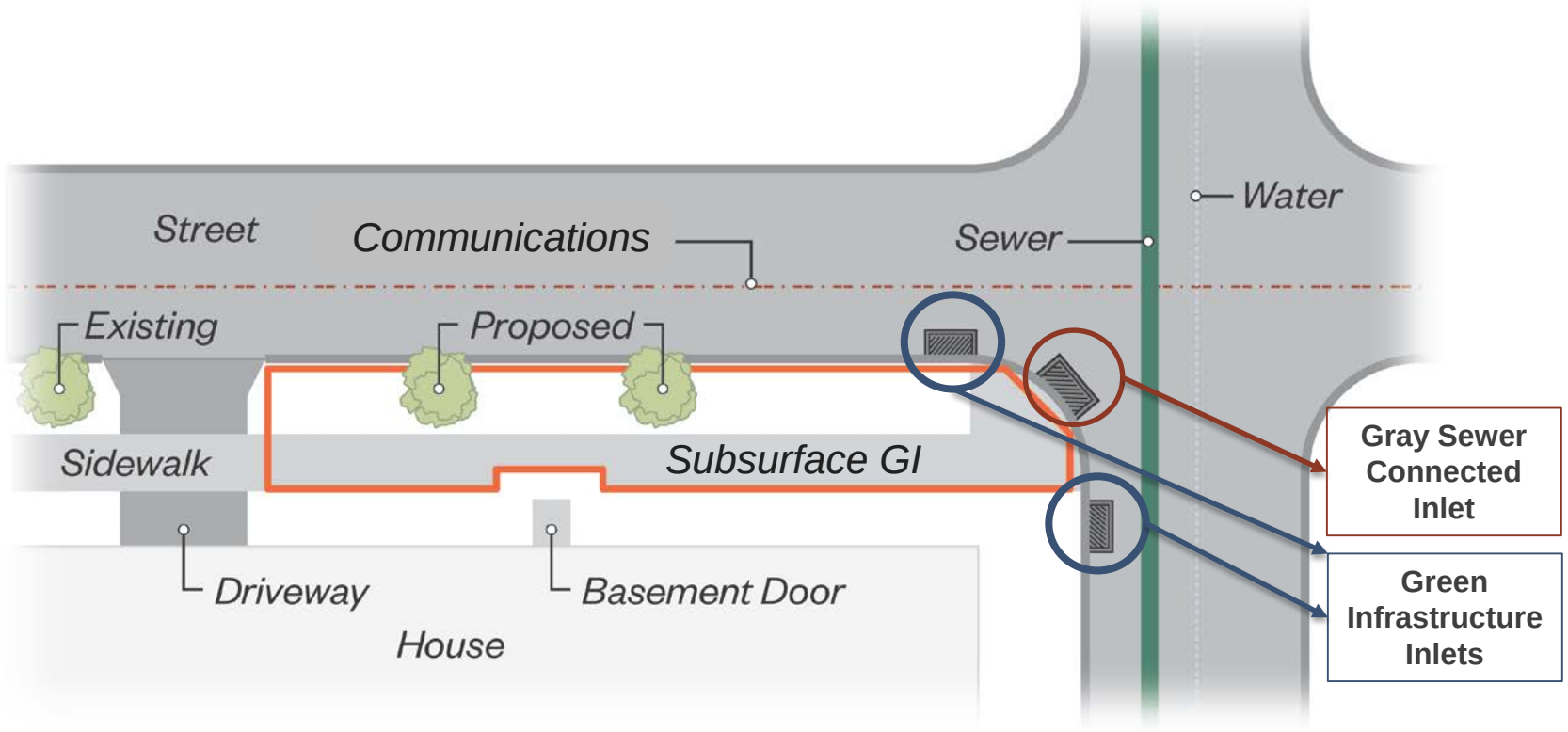
Site Constraints and Other Factors

Green Infrastructure Inlet Site Placement



- Low point inlets – “online” GI and capacity risk/consequence
- Continuous grade inlets not as efficient by definition (e.g. splash-over)
- Clogging implications are different (e.g. curb opening litter more easily dislodged in sag)

Green Infrastructure Inlet Site Placement in Urban Environments



Controllable Factors

Hydraulic Considerations

- Inlet Type Selection
- Inlet Size
- Presence of Inlet Apron
- Presence of Gutter

Siting and Other Constraints

- Inlet Type Selection
- Proximity to GI System
- Pretreatment
- Public Implications

Green Infrastructure Inlet Analysis

Design Factors

- Select number of factors and some implications
  - Drainage area
  - Longitudinal slope (good direct surrogate for velocity, splash-over, bypass)

$$V = (K_u/n)\, S_L^{0.5}\, S_x^{0.67}\, T^{0.67}$$

$$(d/D) = K_u\, [(Qn) / (D^{2.67}\, S_L^{0.5})]^{0.488}$$

$$Q_i = C_o\, A_g\, \{2g\, [d_i - (h/2)]\}^{0.5}$$

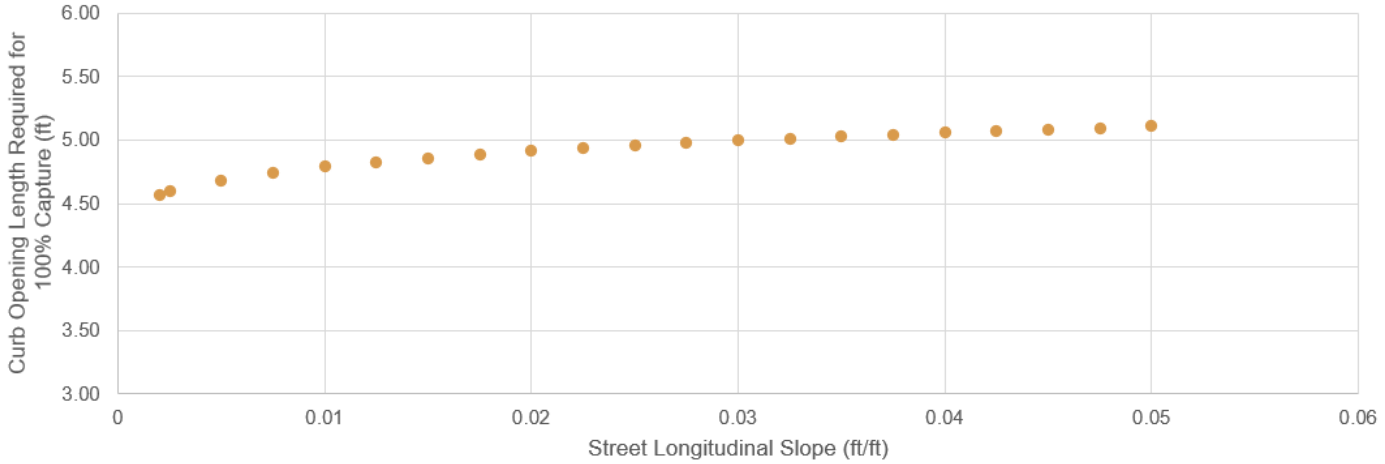
$$Z_1 + y_1 + \frac{V_1^2}{2g} = Z_2 + y_2 + \frac{V_2^2}{2g} + h_L$$

$$E_o = 1/\left\{1+\frac{S_w/S_x}{\left[1+\frac{S_w/S_x}{\frac{T}{W}-1}\right]^{2.67}-1}\right\}$$

$$Q_W = Q - Q_s$$

$$Q = Q_s / (1 - E_o)$$

Single Factor Analysis: Roadway Longitudinal Slope for Curb Opening Inlets

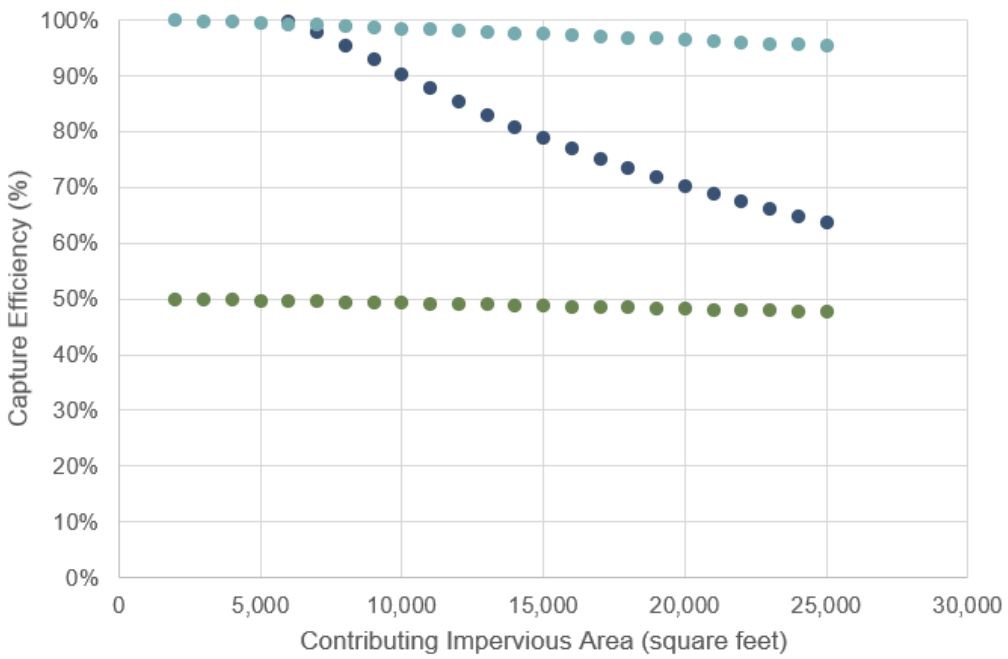


Assumptions for both
Drainage Area = 5,000 SF
1-year, 10 min storm
Road cross slope = 2%
Gutter cross slope = 4%
Gutter width = 2 feet

GI Takeaways:

- Require less throat length for flatter streets, is not as large an effect as spread across range of slopes—may need to add duplicate inlets to capture 1-year storm intensity, added costs for GI piping configuration and excavation

Grate Inlet vs. Curb Opening Inlet – Capture



Grate Inlet, No Clogging Factor

Curb Opening Inlet

Grate Inlet, 50% Clogging Factor

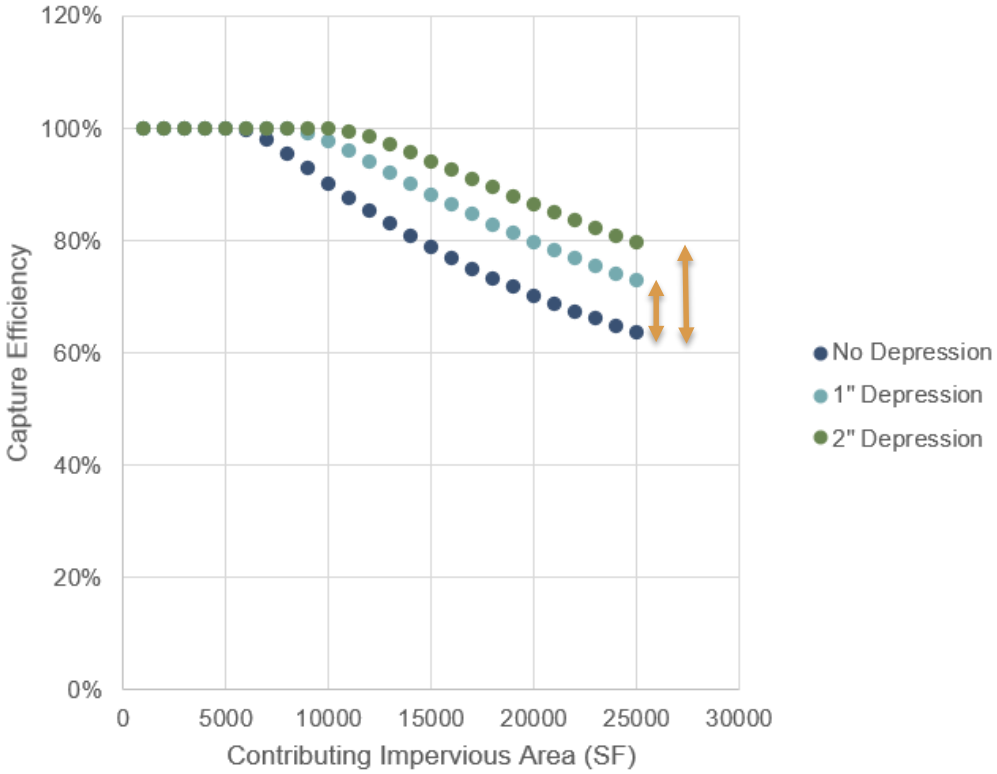
GI Implications

- Grate inlets theoretically perform well over much larger range of drainage area
- Assuming heavy clogging, can reduce drastically, may need to consider adding additional inlets

Assumptions
1-year, 15 min storm
Road cross slope = 2%
Gutter cross slope = 4.2%
Gutter width = 2.5 feet
Curb inlet length = 4.5 feet
Grate length = 4 feet
Grate type = CDOT/Denver 13 Valley Grate

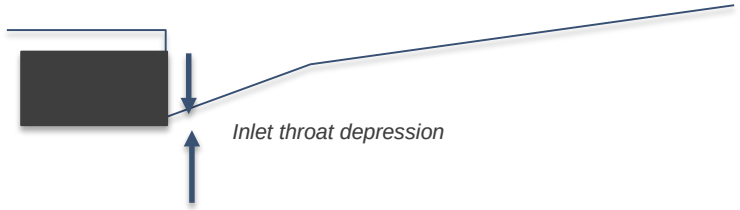
But where is the design storm in this efficiency?

Curb Opening: Depressed Inlet Throat or At-Grade?



GI Implications

- GI system and pipe utilization may increase with a small depression in the throat
- More capture at higher contributing areas can stretch GI dollars farther (but don't forget spread!)



At largest contributing area modeled, throat can increase inlet capacity 14% and 25%

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Road cross slope = 2%
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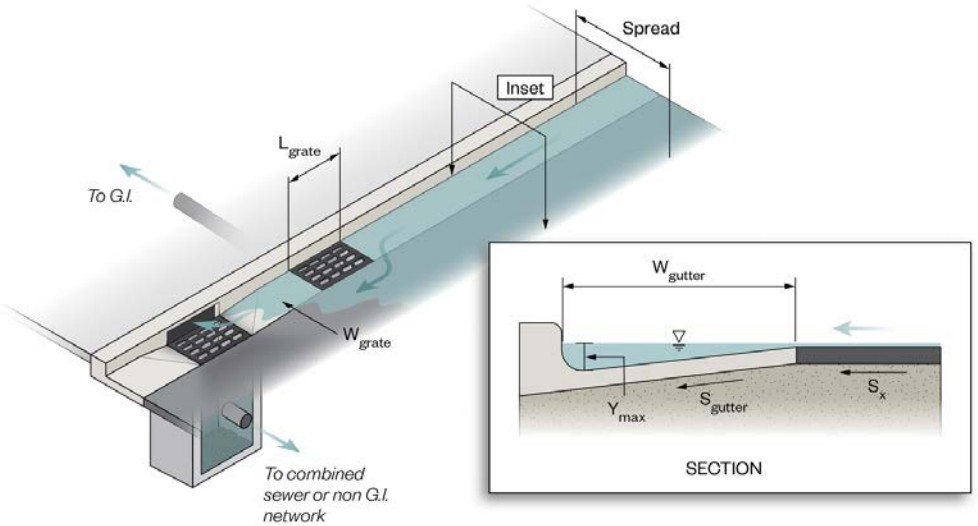
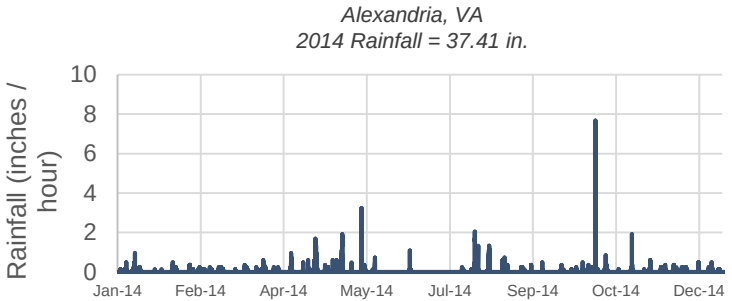
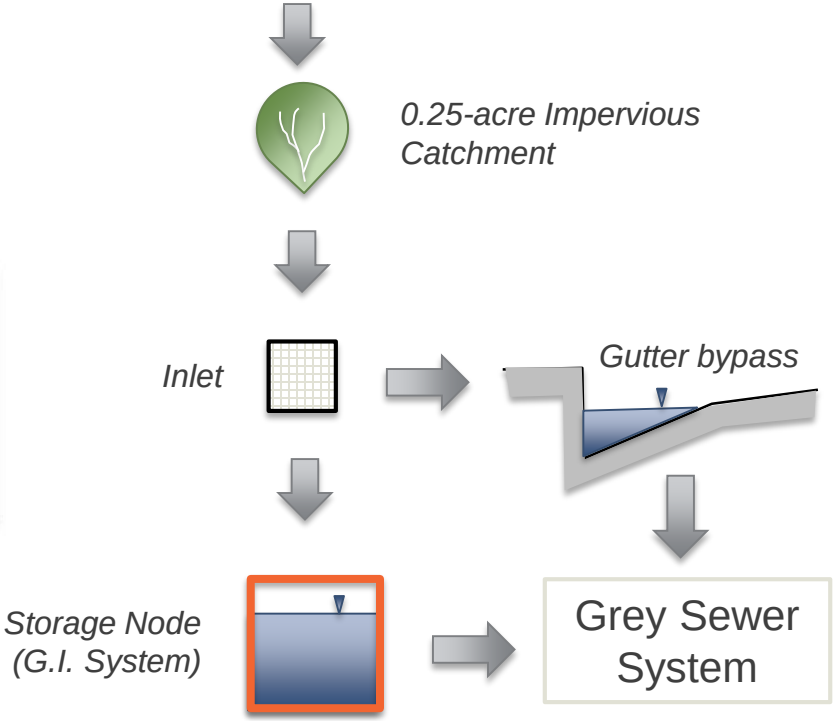
Annual Runoff Analysis

Storm and Sanitary Analysis

Simple Inlet, Gutter Bypass, and Green Infrastructure Setup

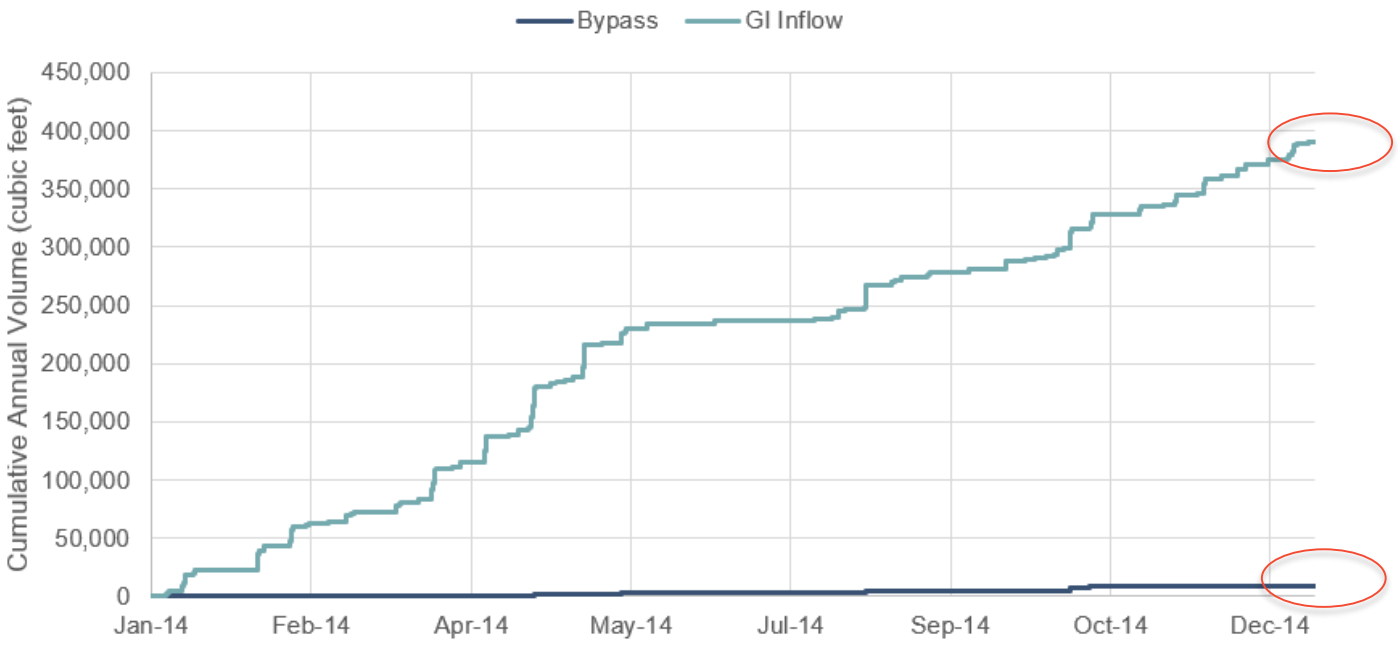




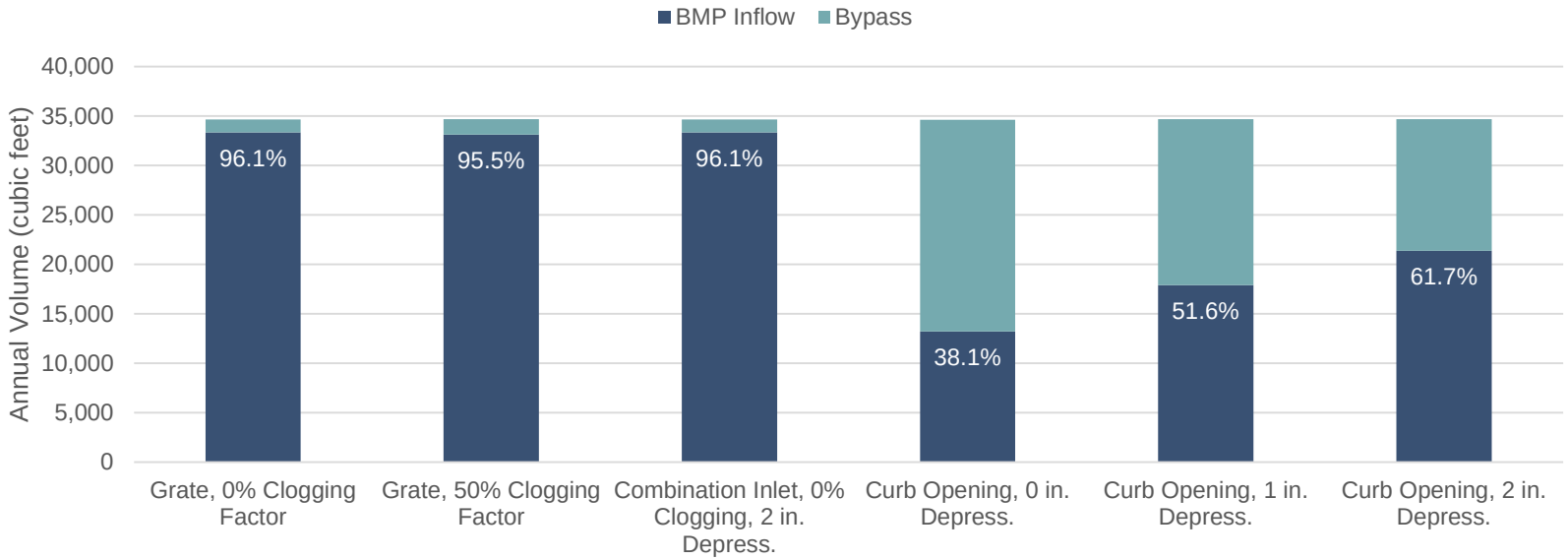


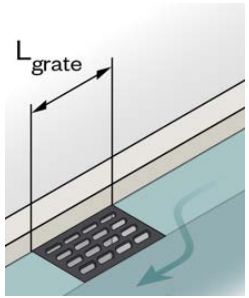
Storm and Sanitary Analysis

Cumulative Capture vs Bypass



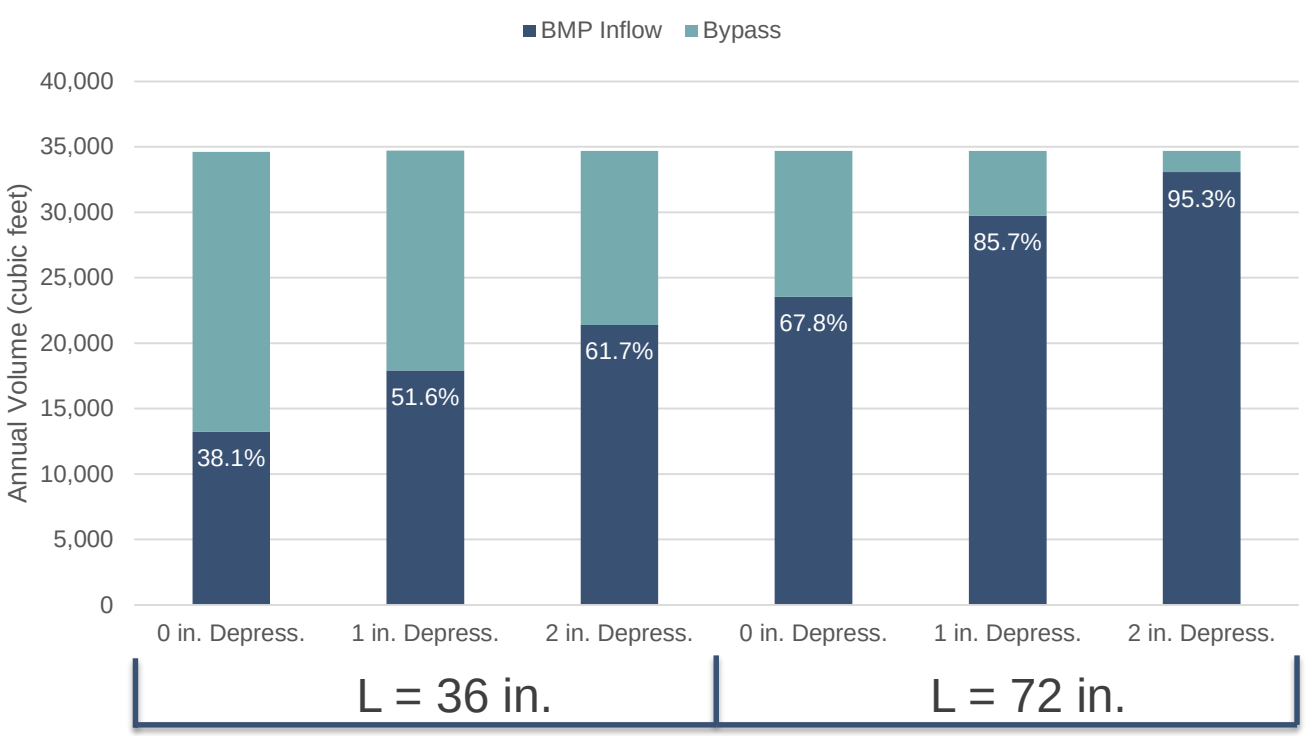
Inlet Types – Annual Performance

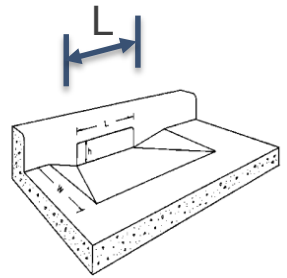




Frontal vs side flow of grate?

GI Capture and Curb Opening Length



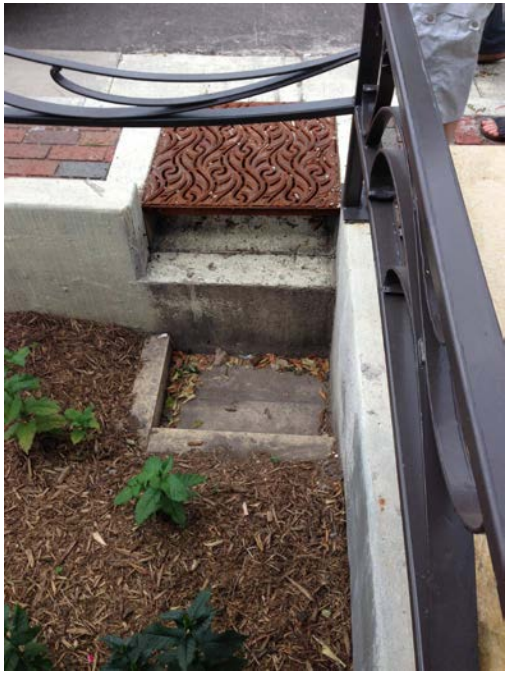


Capture Implications

- Increased depression is better for annual capture, balance with traffic and bike safety
- Grates are better at capture in most apples-to-apples scenarios
  - Lowers hydraulic grade line at inlet = more excavation or reduces surface filtration opportunity
  - Cost vs. curb cut / curb opening

Portland, OR. Photo by: A. Anderson 2014

Capture Implications



St. Paul, MN. Photo by: A. Anderson 2013

Summary of Cumulative Capture Implications

- Tradeoff between what's good in perfect world of placing inlets vs reality on the ground—what is there room for
- Design storm vs annual capture
- Retrofits of inlets require precision to translate design assumptions to reality

Maintenance and Green Infrastructure

- An improperly functioning inlet is an under-utilized green infrastructure system
- Potential maintenance triggers by inlet type:
  - Curb Opening
    - Structural cave-in of curb opening
    - Sediment build up in depressed apron
    - Large debris build-up in throat
  - Grate Inlet
    - High leaf, organic, and litter clogging on grate can create flooding nuisance
  - Combination Inlet
    - Provides multi-modal flow diversion if one method is ineffective (opening vs. grate)

Implications of Improper Selection and Placement

- Idle Green Infrastructure System
- High Sediment Loading in Green Infrastructure System
- Localized Ponding and Spread
- Driver and Pedestrian Hazards
- Excess Debris and Supplemental Maintenance
- Elevated Costs

Questions?

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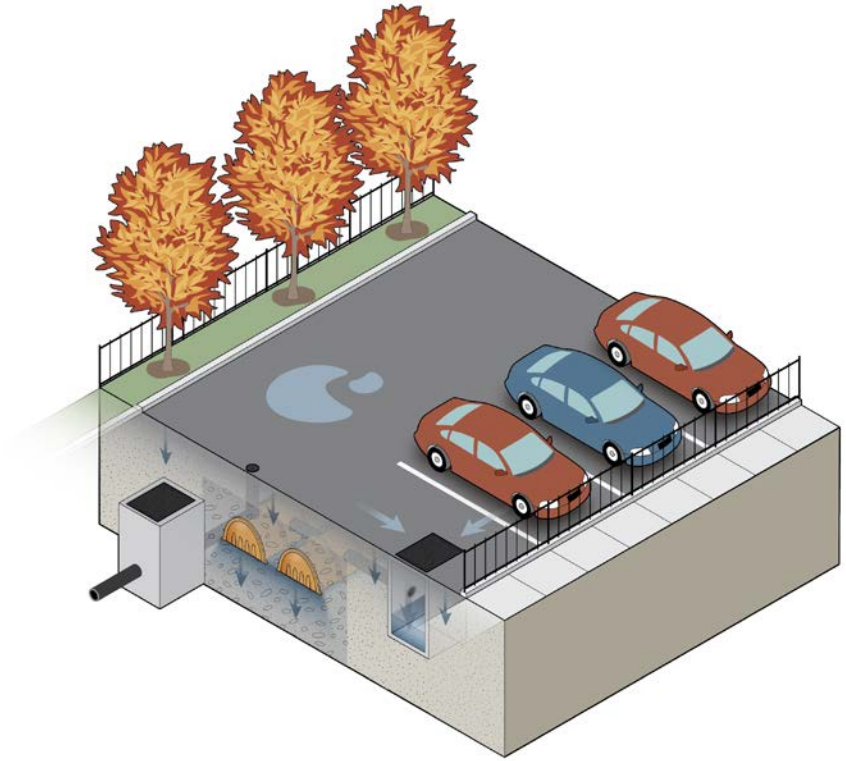

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