From Rain Tanks to Catchments: Use of Low-Impact Development to Address Hydrologic Symptoms of the Urban Stream Syndrome

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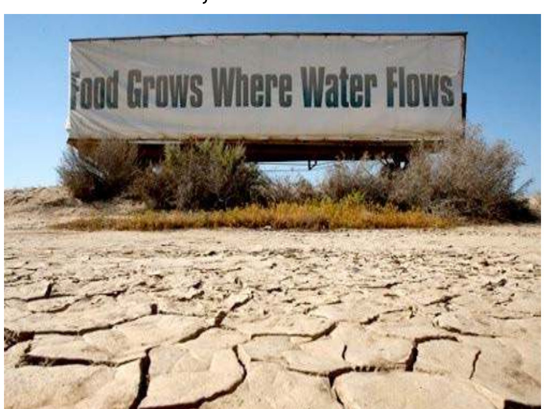
University of California, Irvine

Water Resource Sustainability Issues on Tropical Islands
December 2, 2015

California, USA



SE Australia

UCI Water PIRE: "Low Energy Options for Making Water from Wastewater"

http://water-pire.uci.edu/

The Urban Stream Syndrome

The Urban Stream Syndrome

Environmental Science & Technology

Critical Review

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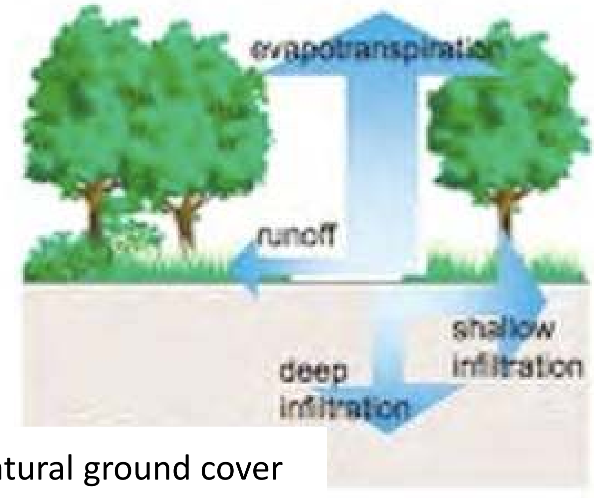
From Rain Tanks to Catchments: Use of Low-Impact Development To Address Hydrologic Symptoms of the Urban Stream Syndrome

Asal Askarizadeh,[†] Megan A. Rippy,[†] Tim D. Fletcher,[‡] David L. Feldman,[§] Jian Peng,[⊗] Peter Bowler,[#] Andrew S. Mehring,[‖] Brandon K. Winfrey,[⊥] Jasper A. Vrugt,[†] Amir AghaKouchak,[†] Sunny C. Jiang,[†] Brett F. Sanders,[†] Lisa A. Levin,[‖] Scott Taylor,[∇] and Stanley B. Grant[*,†,○,¶]

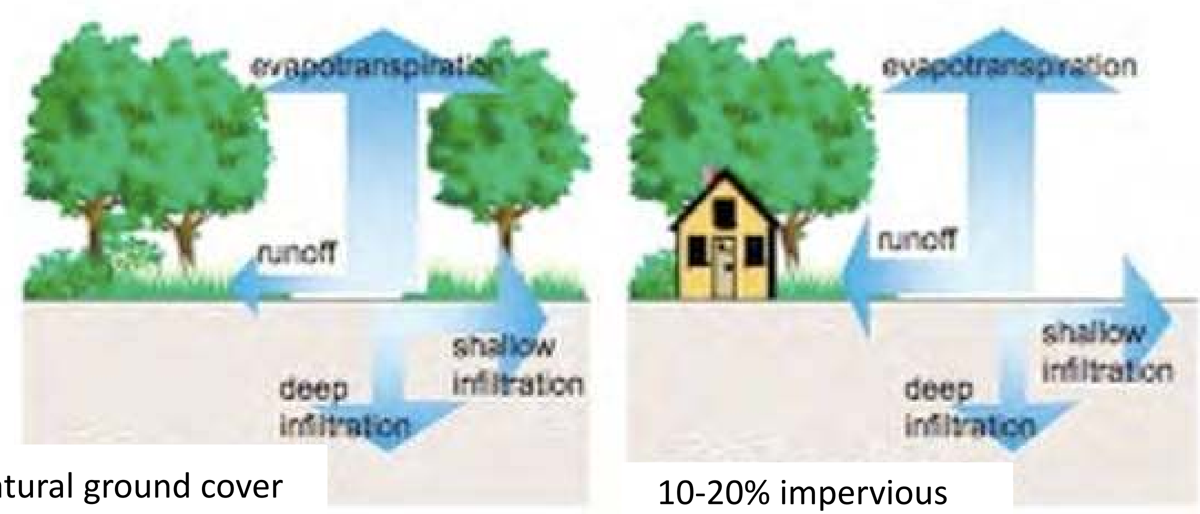
Urban Stream Syndrome



Natural ground cover

From National Research Council (2008) “Urban stormwater management in the US”

Urban Stream Syndrome



Natural ground cover

10-20% impervious

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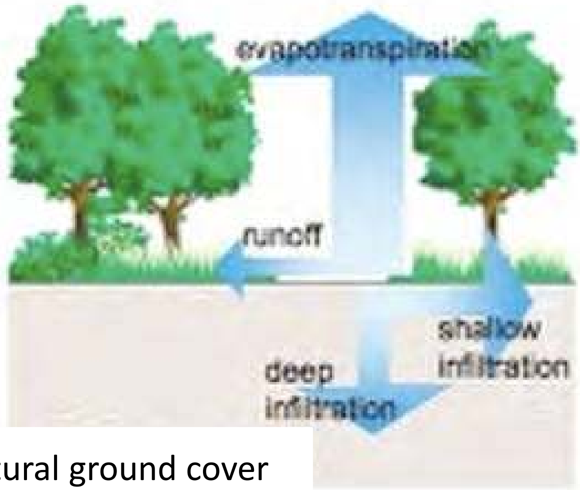
Urban Stream Syndrome



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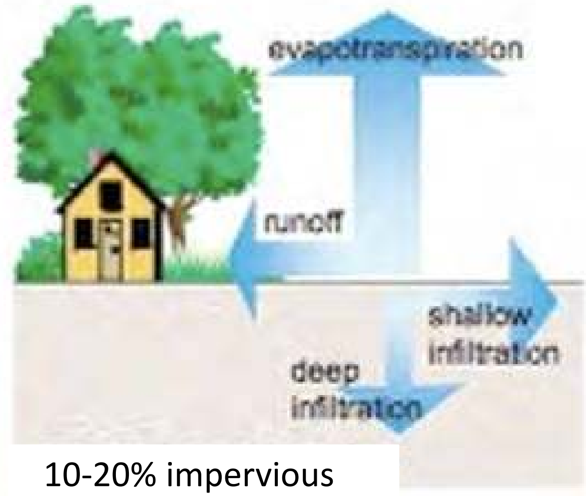

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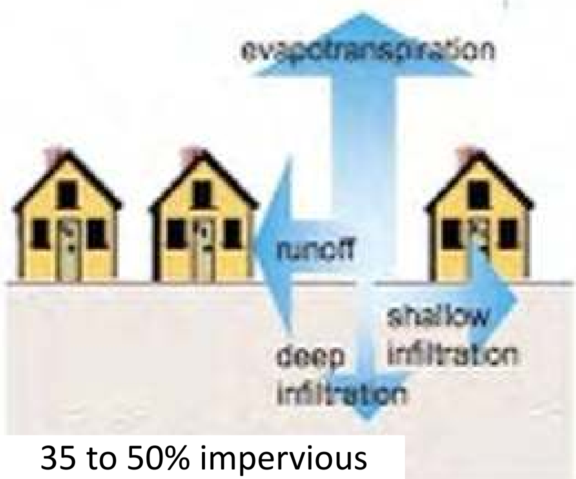
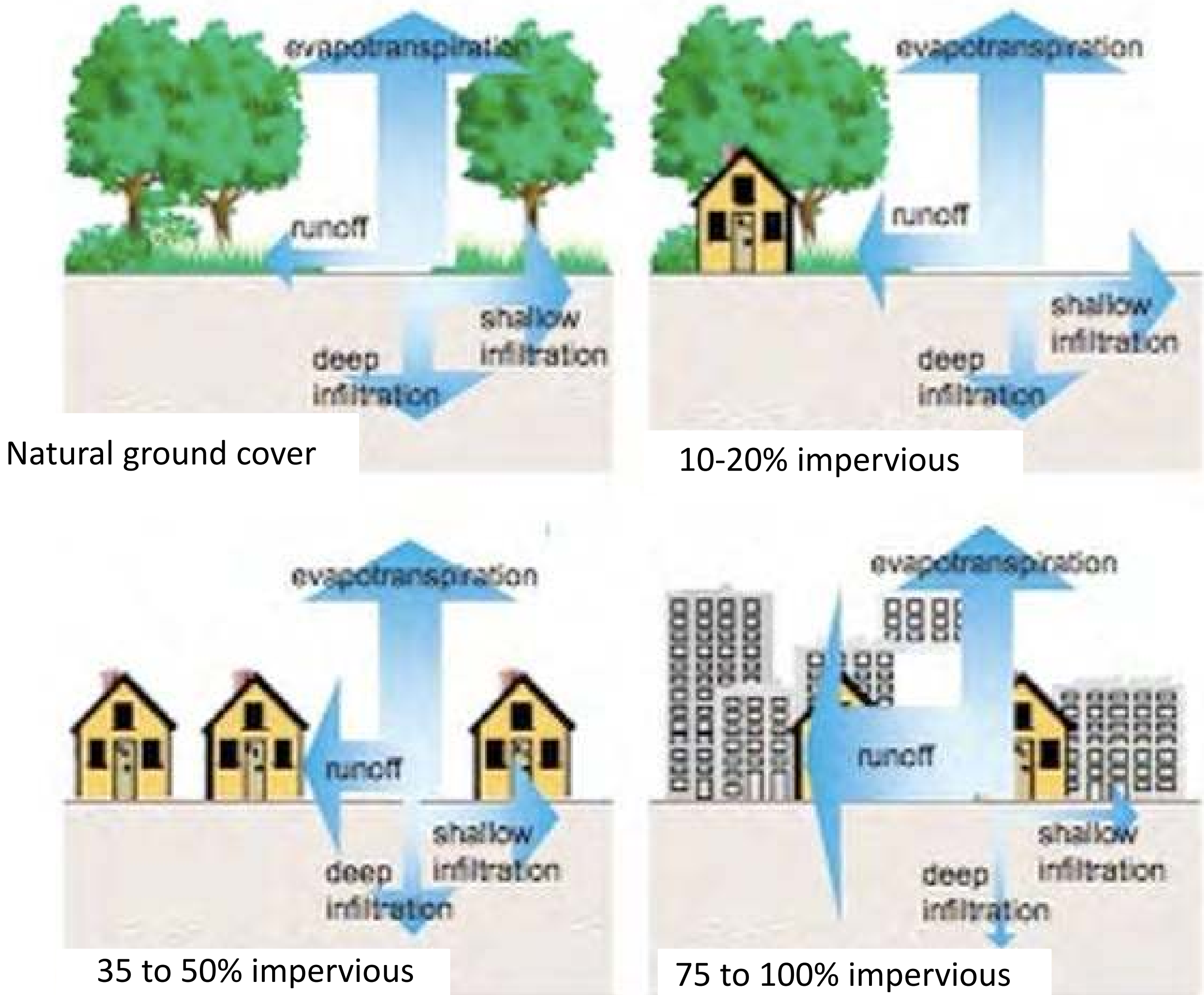


35 to 50% impervious

From National Research Council (2008) “Urban stormwater management in the US”

Urban Stream Syndrome



From National Research Council (2008) “Urban stormwater management in the US”

Increased Imperviousness alters stream hydrology in two ways*

*Walsh et al (2005) *J. N. Am. Benthol. Soc* **24**:706-723

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- During wet weather, water is delivered directly to the stream as overland flow (i.e., runoff). Overland flow is rare in natural catchments.

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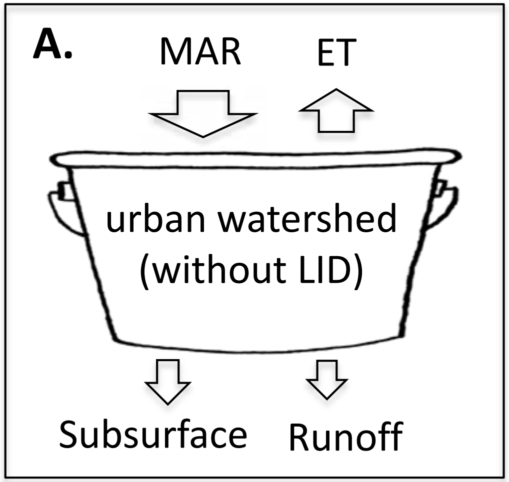
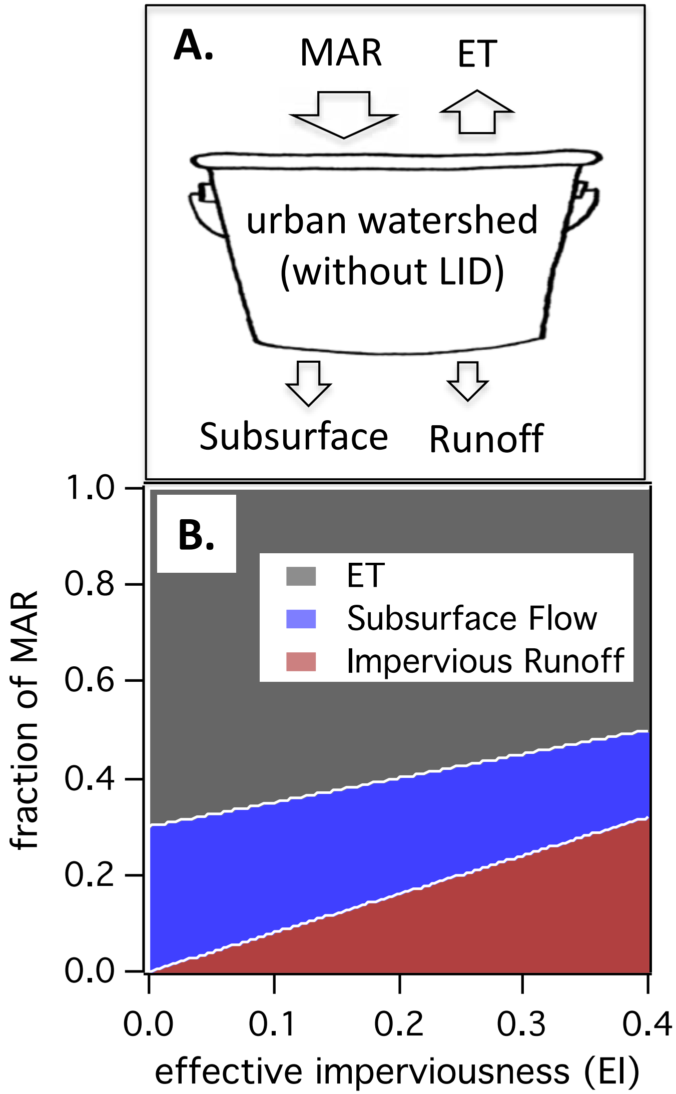
- During dry weather, stream baseflow is reduced because impervious surfaces prevent infiltration and resupply of the shallow groundwater
- These two changes are a primary cause of the so-called "urban stream syndrome"

*Walsh et al (2005) *J. N. Am. Benthol. Soc* **24**:706-723

Annual Catchment Water Balance



Annual Catchment Water Balance



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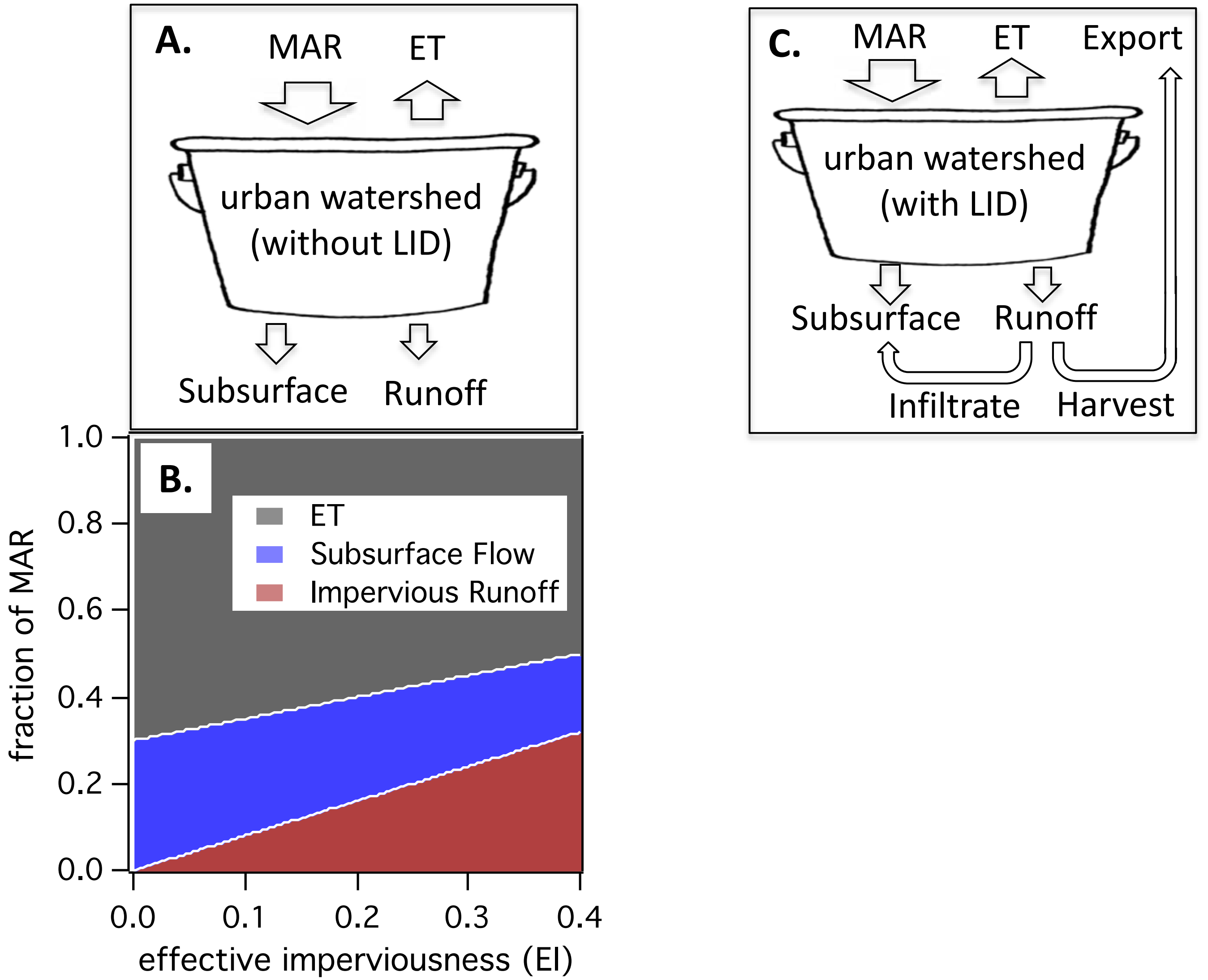
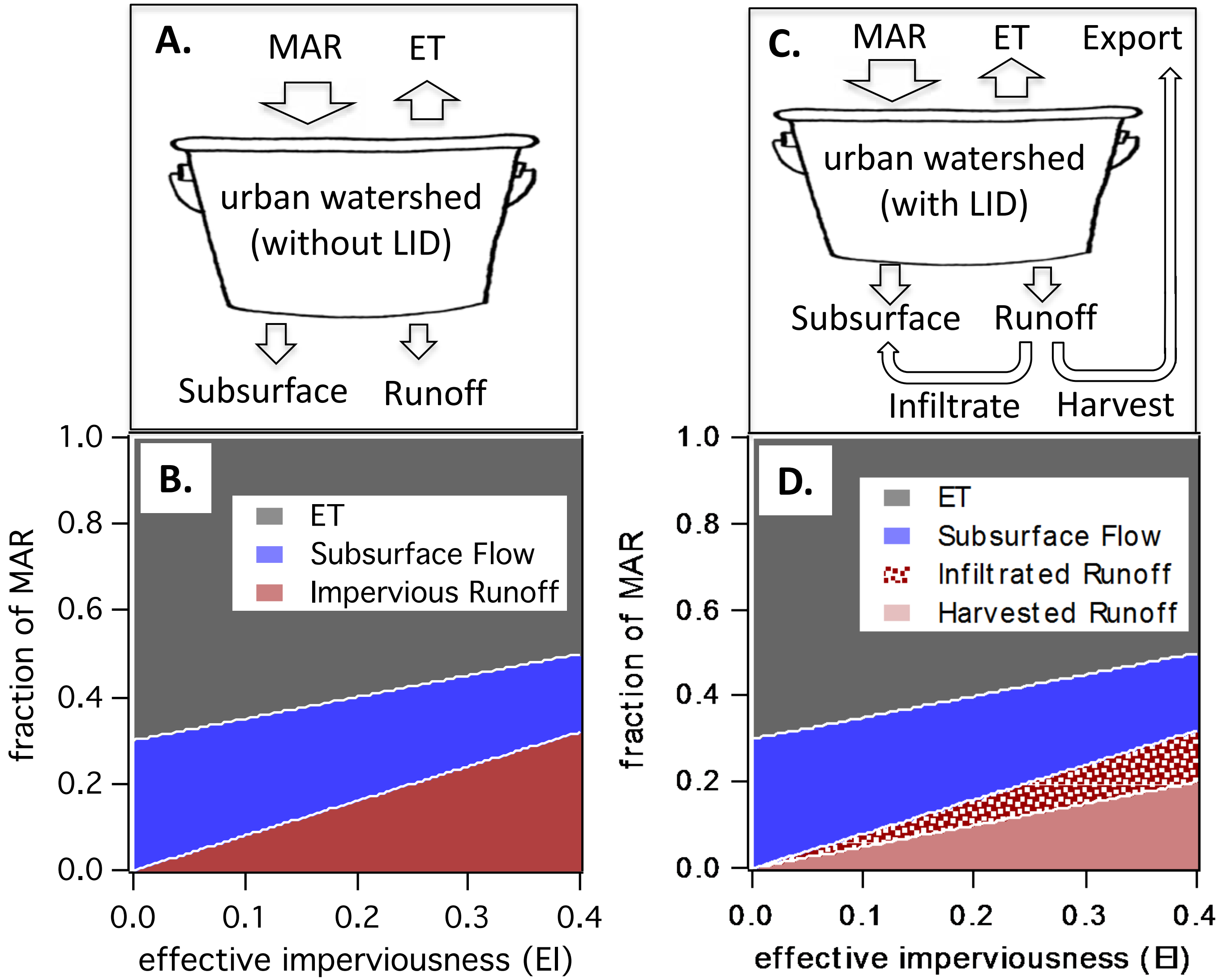


Annual Catchment Water Balance



Q: What is the best mix of distributed LID for a Specific Catchment?

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A: Depends on your end goal!

Say the goal is to restore pre-urban stream hydrology, then*…

*Walsh,C.J.; Fletcher, T.D.; Burns, M.J. (2012) "Urban Stormwater Runoff: A New Class of Environmental Flow Problem", *PLoS ONE* 7(9):e45814

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- All stormwater should be captured (i.e., no stormwater should be allowed to flow directly to the stream)
- A portion of the captured stormwater should be **infiltrated** to restore shallow groundwater and baseflow in the stream
- The rest should be **harvested**; i.e., used for any purpose that keeps it out of the stream

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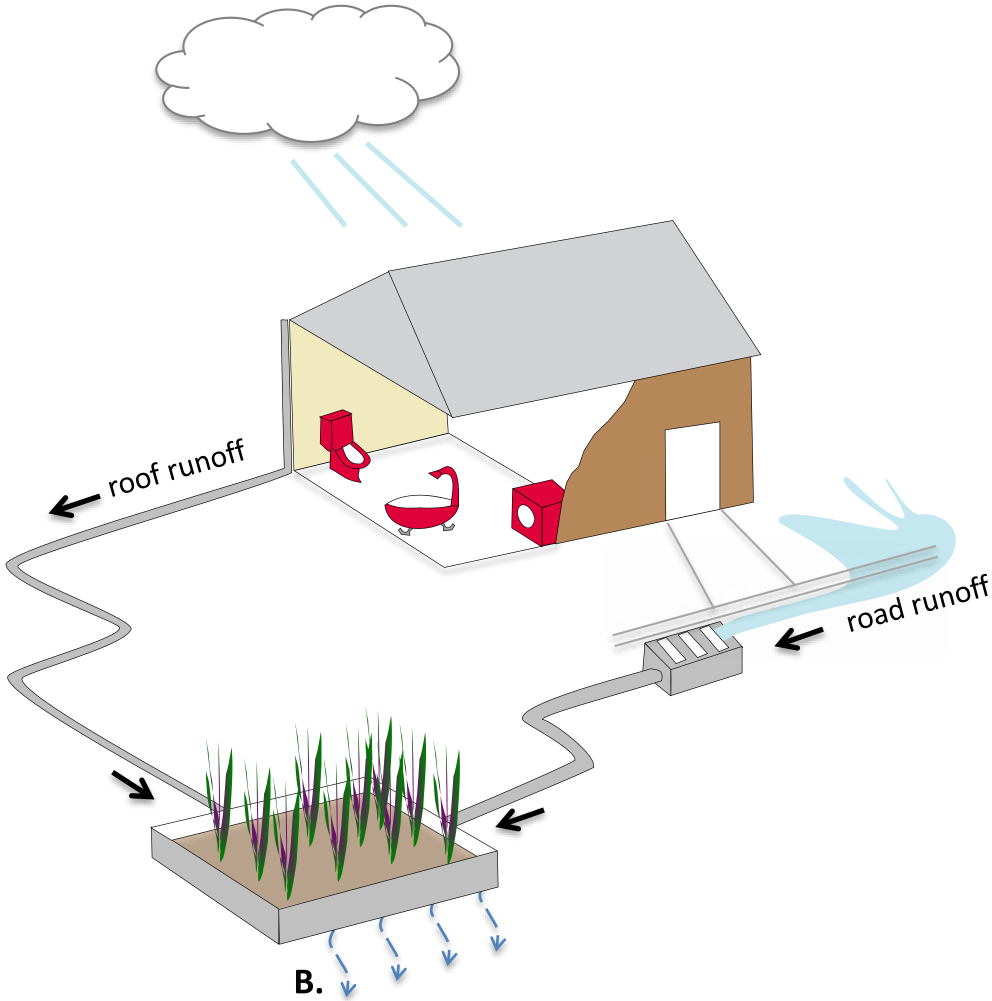
Stormwater Infiltration Technologies



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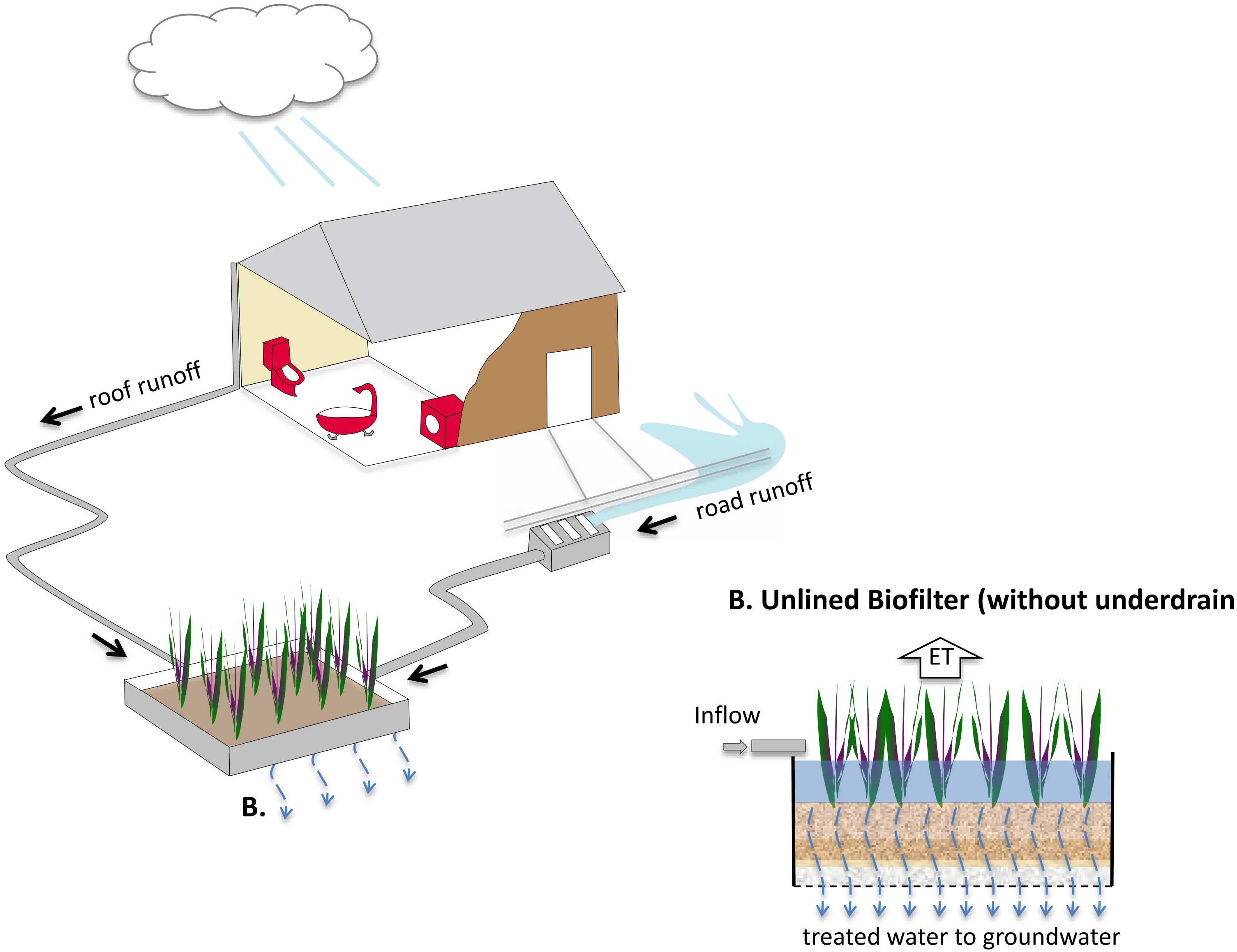
Stormwter Infiltration Technologies



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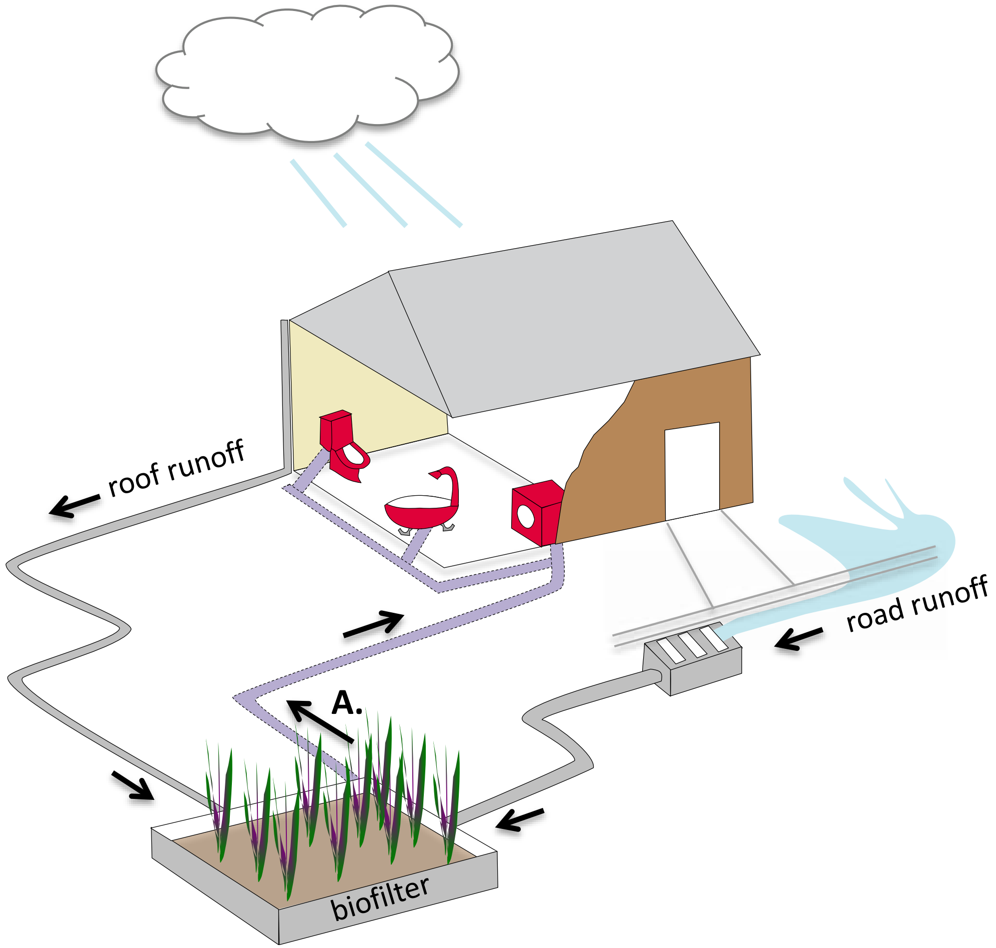
Stormwater Harvesting Technologies



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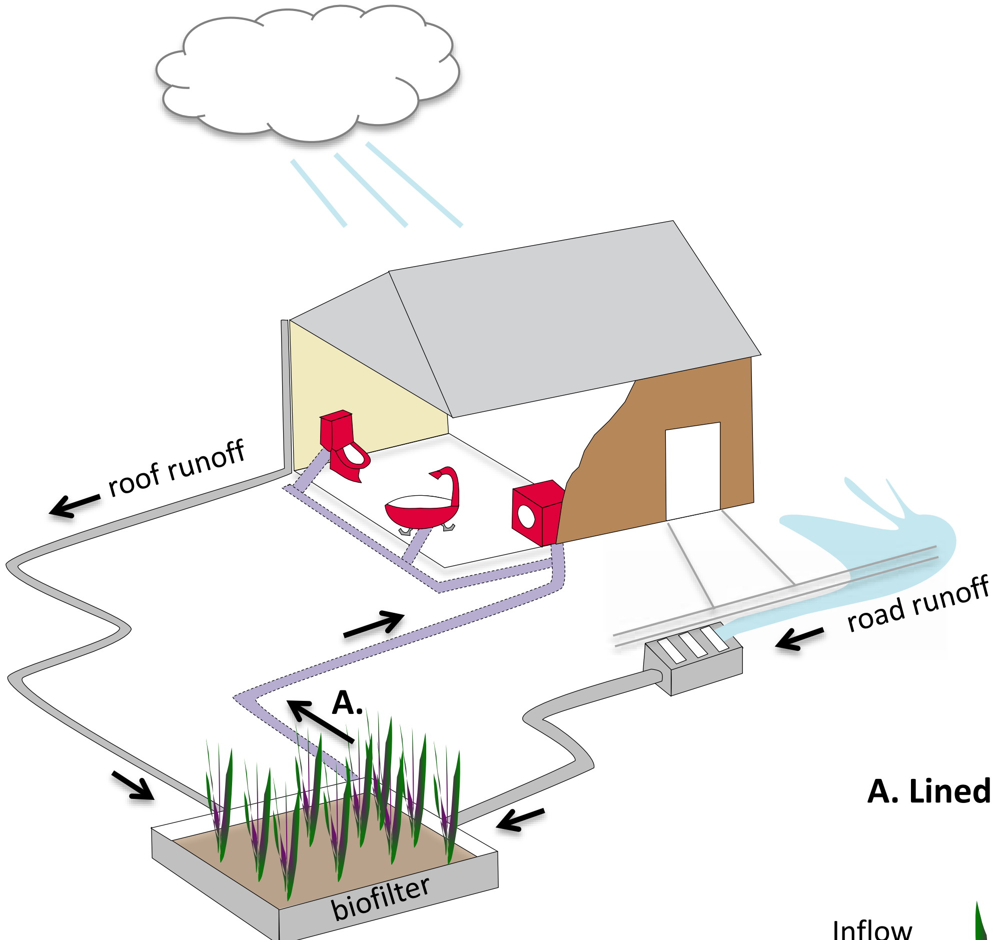
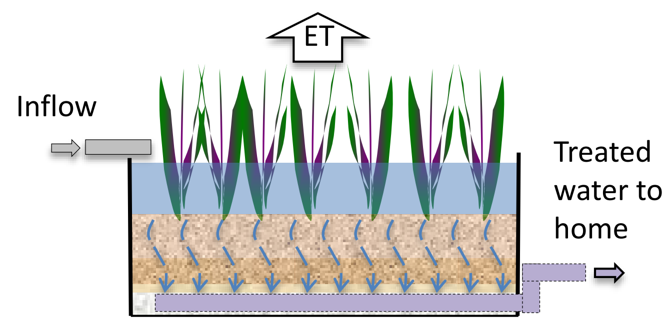


A. Lined Biofilter (with underdrain)



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Q: If we want to restore pre-urban hydrology, how much stormwater runoff should be infiltrated versus harvested?

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A: Depends on the local mean annual rainfall and fraction of pre-urban land area covered with forest*.

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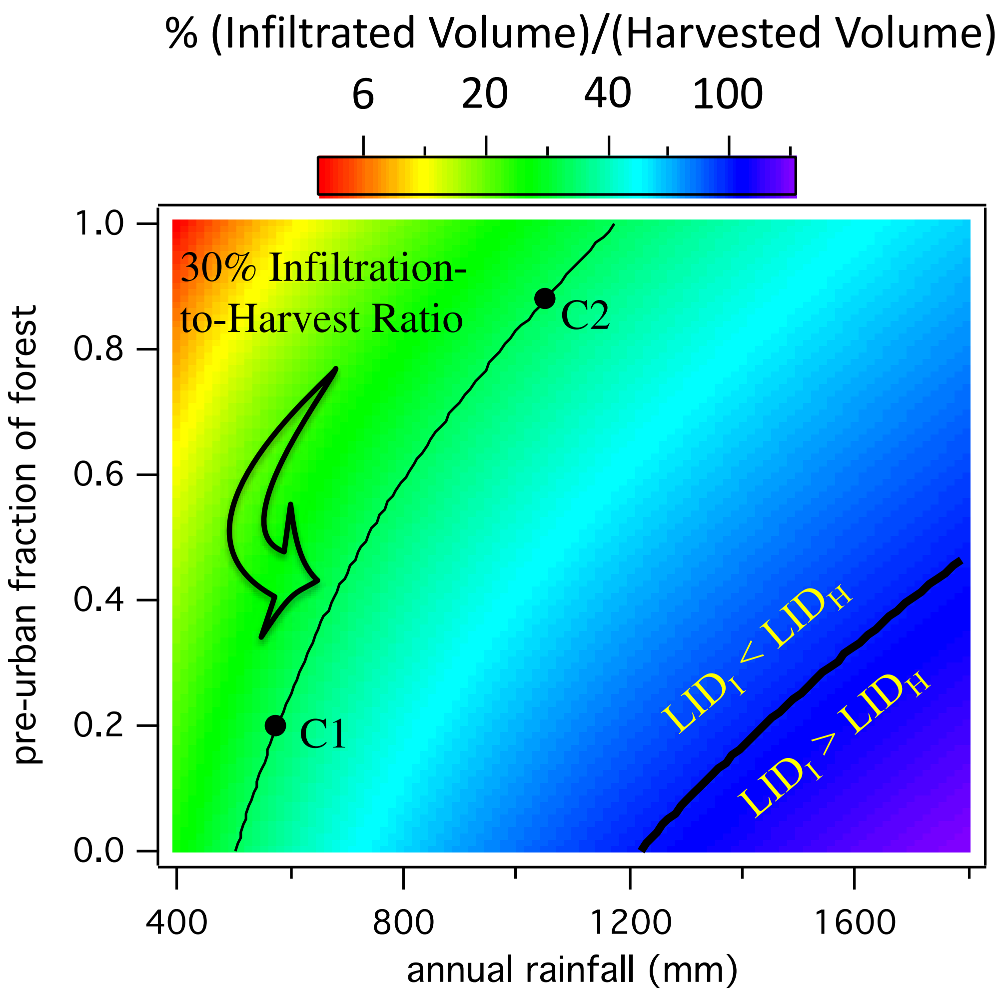
Right Mix of Infiltration and Harvest



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How might we choose Low Impact Development (LID) technologies to achieve a given harvest/infiltration ratio?

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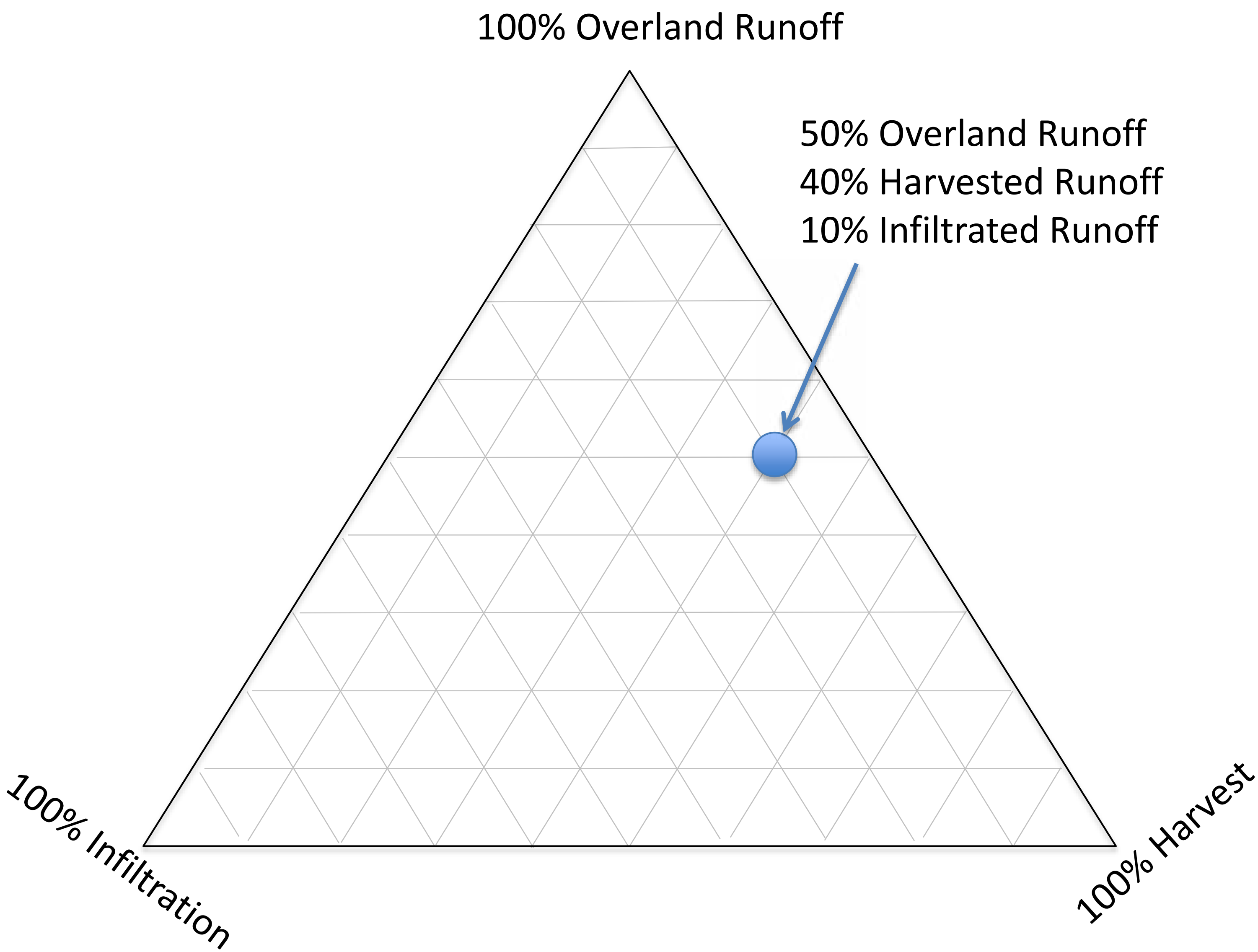
All LID technologies can be categorized according to the percentage of runoff they harvest, infiltrate, or leave as runoff

The LID Universe



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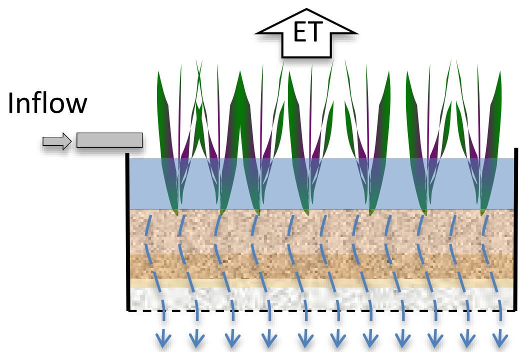

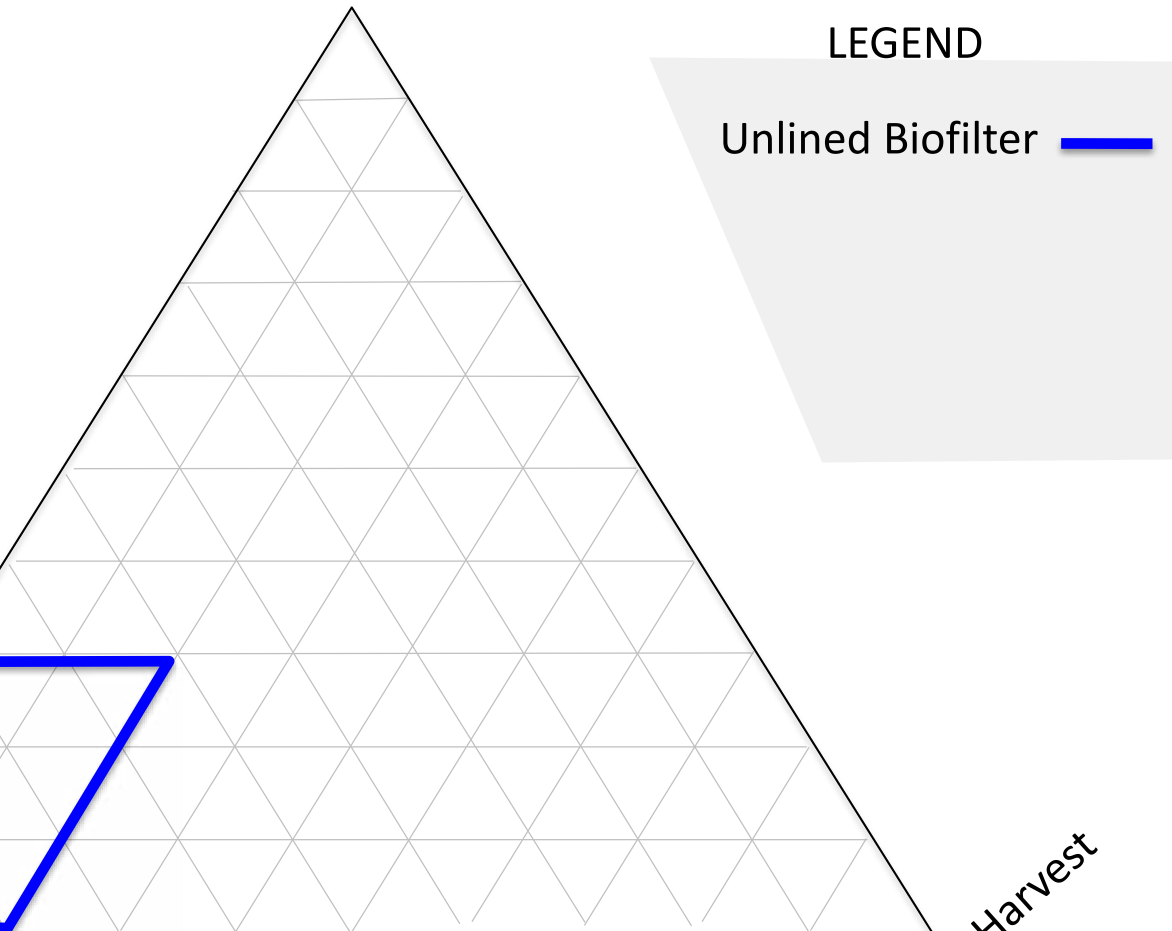

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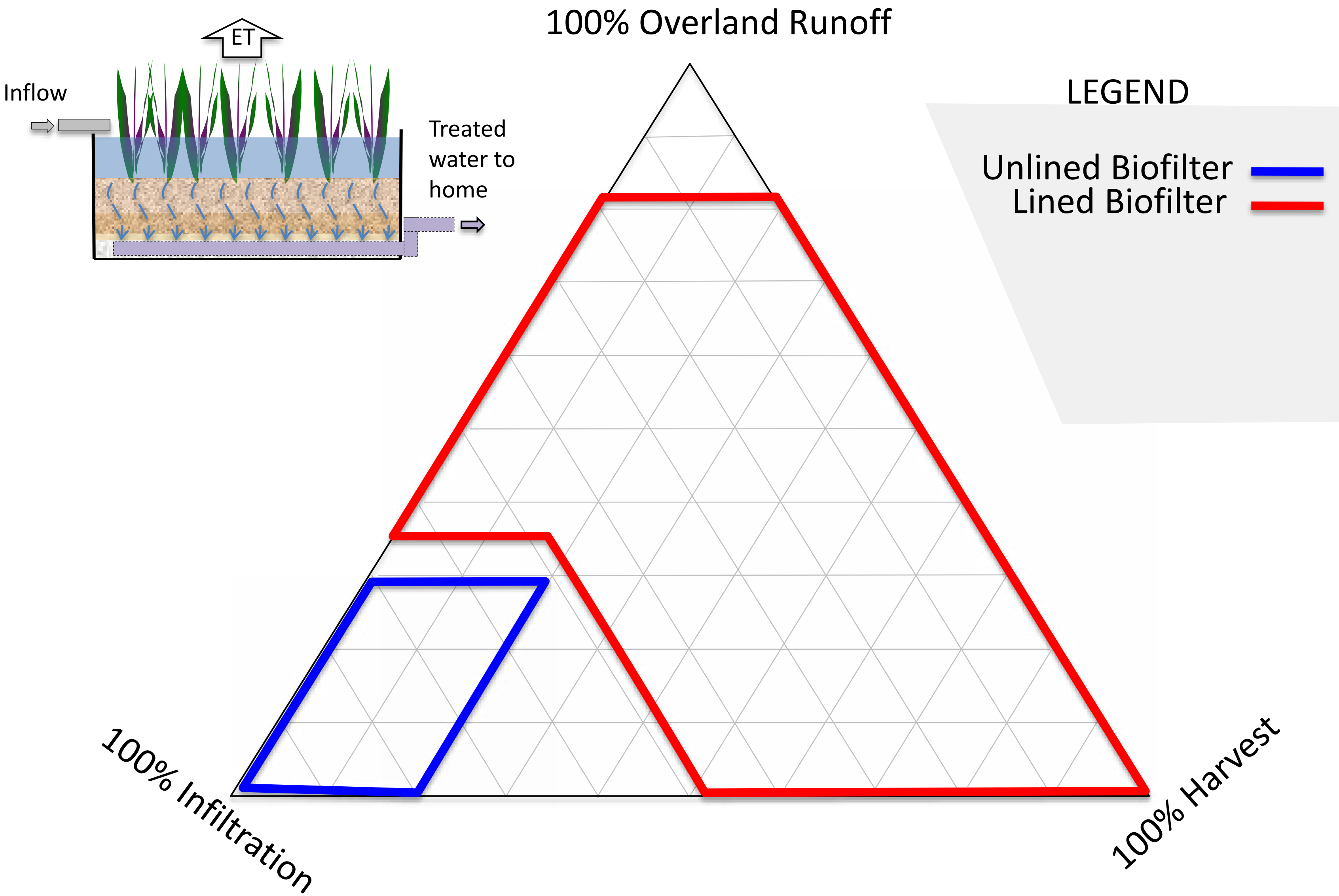

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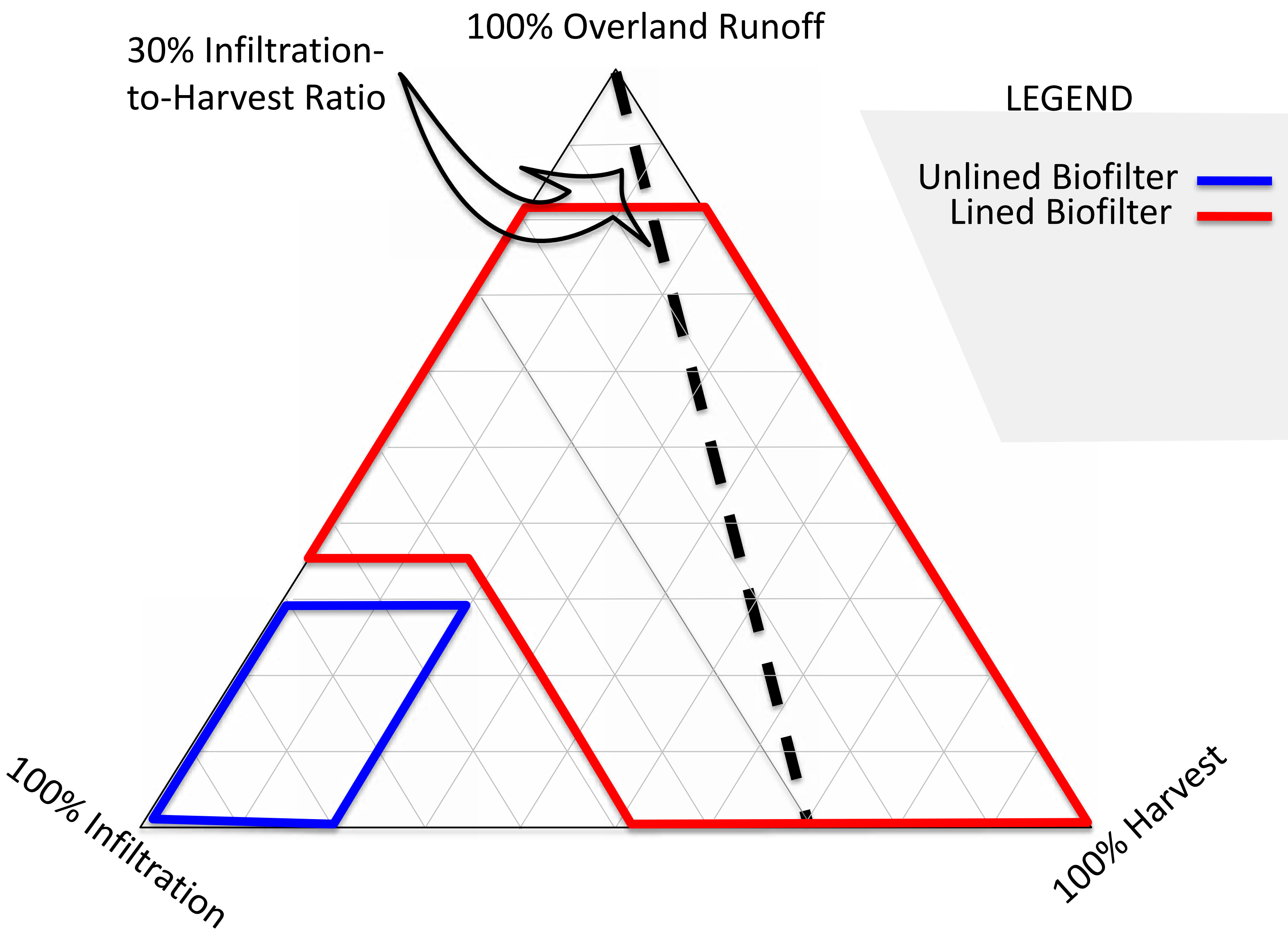

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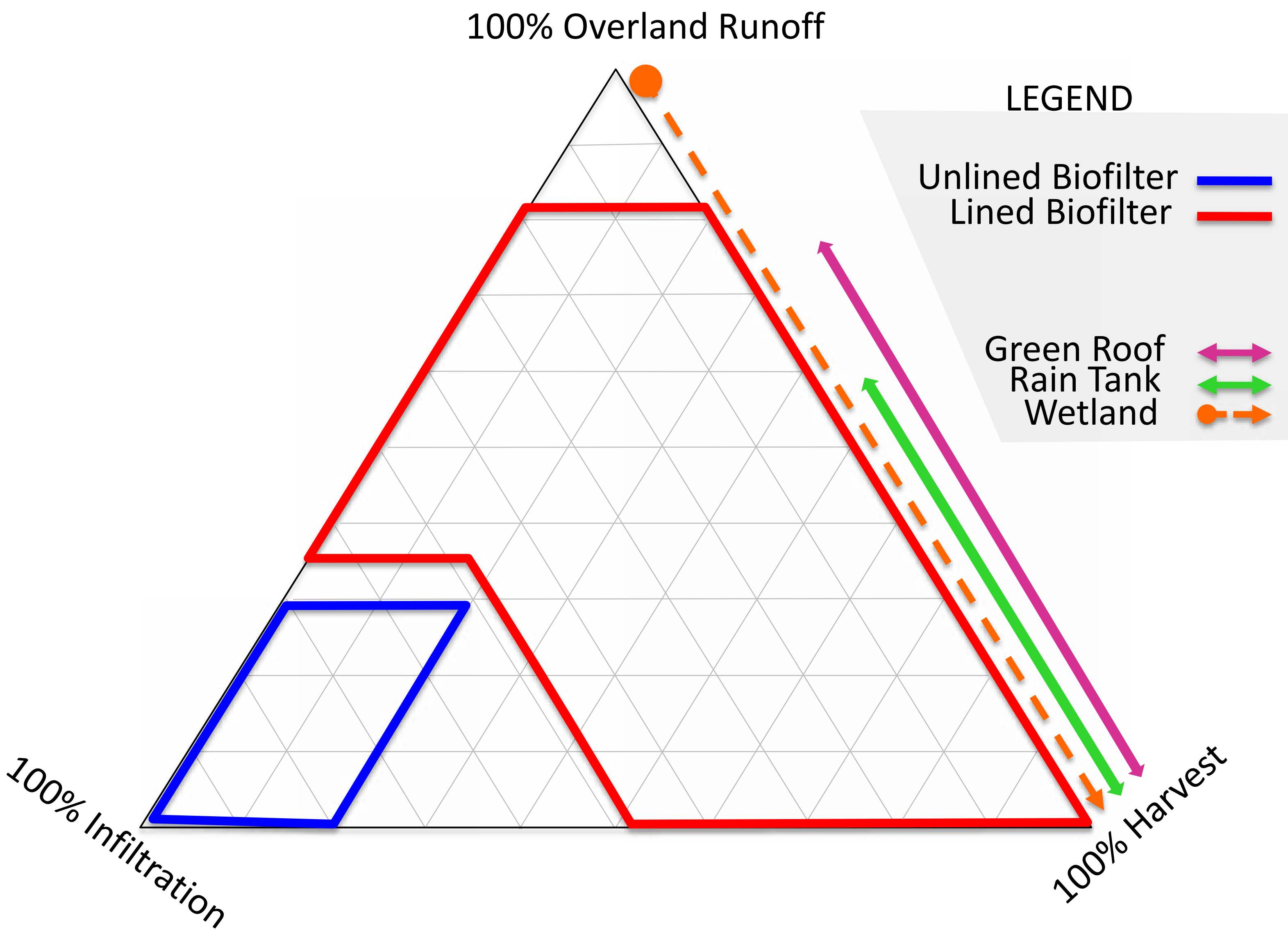

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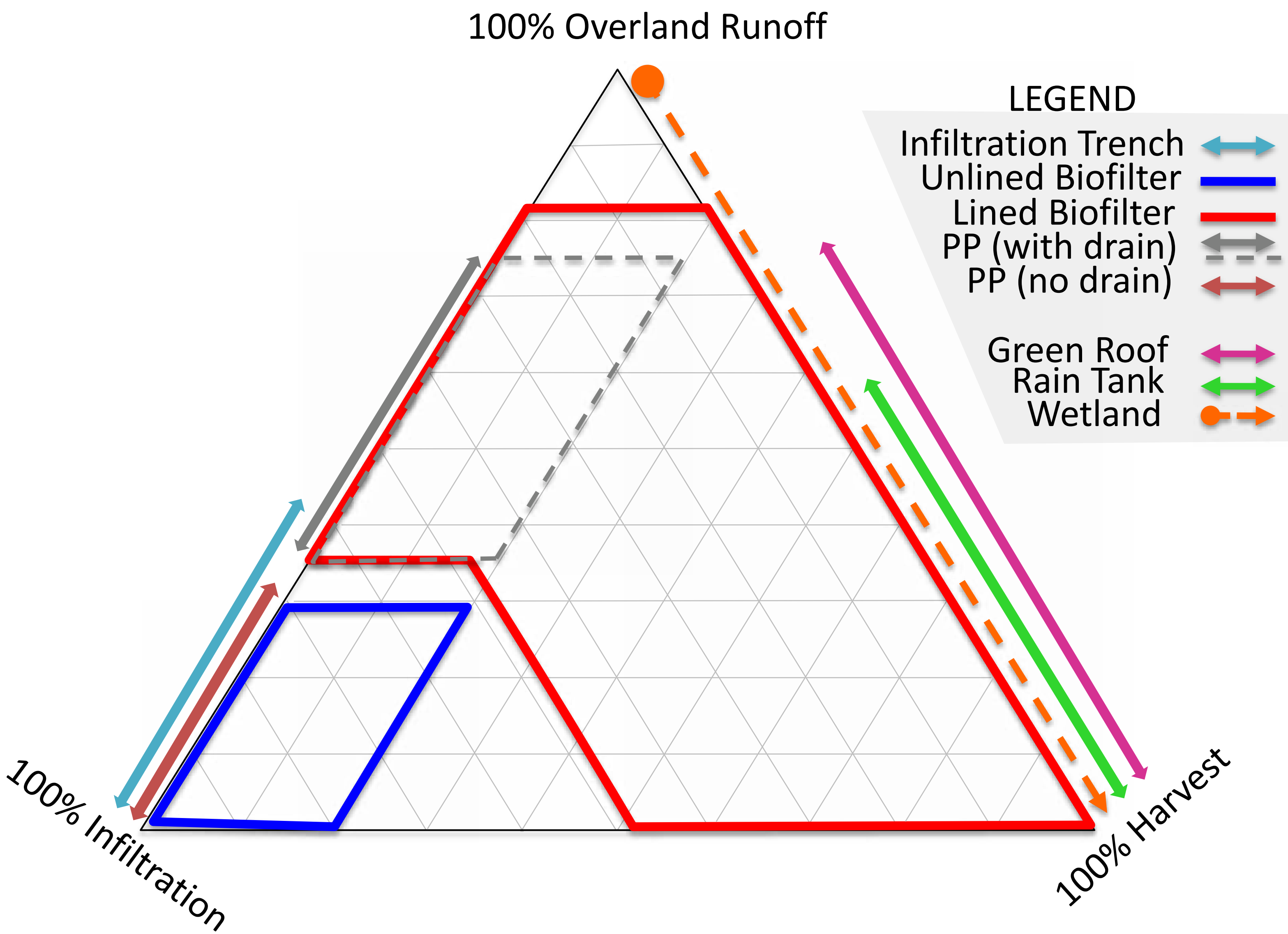

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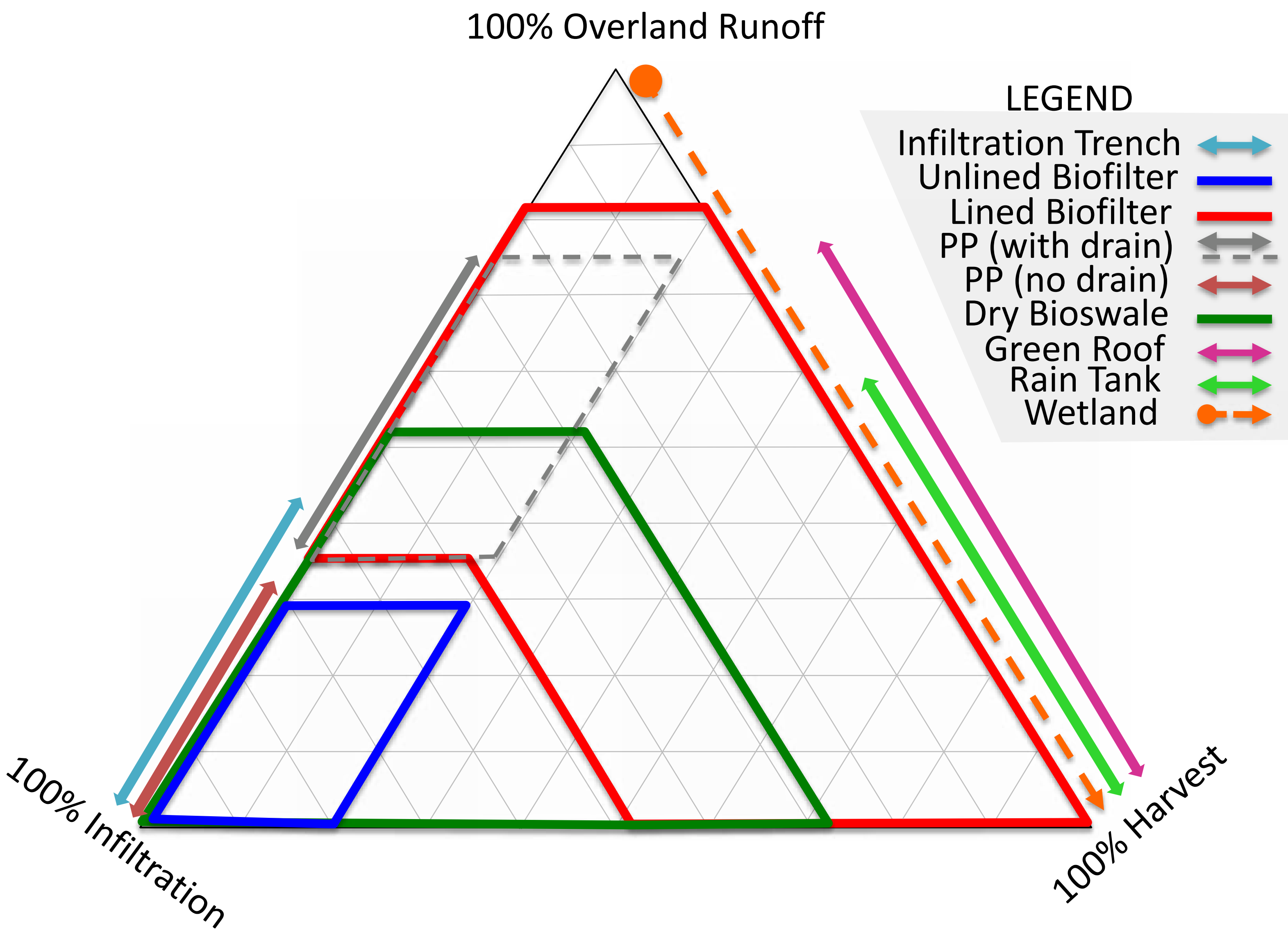

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Conclusions

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- Distributed LID have can restore pre-urban hydrology provided all stormwater is harvested and infiltrated
- The infiltration-to-harvest ratio depends on:
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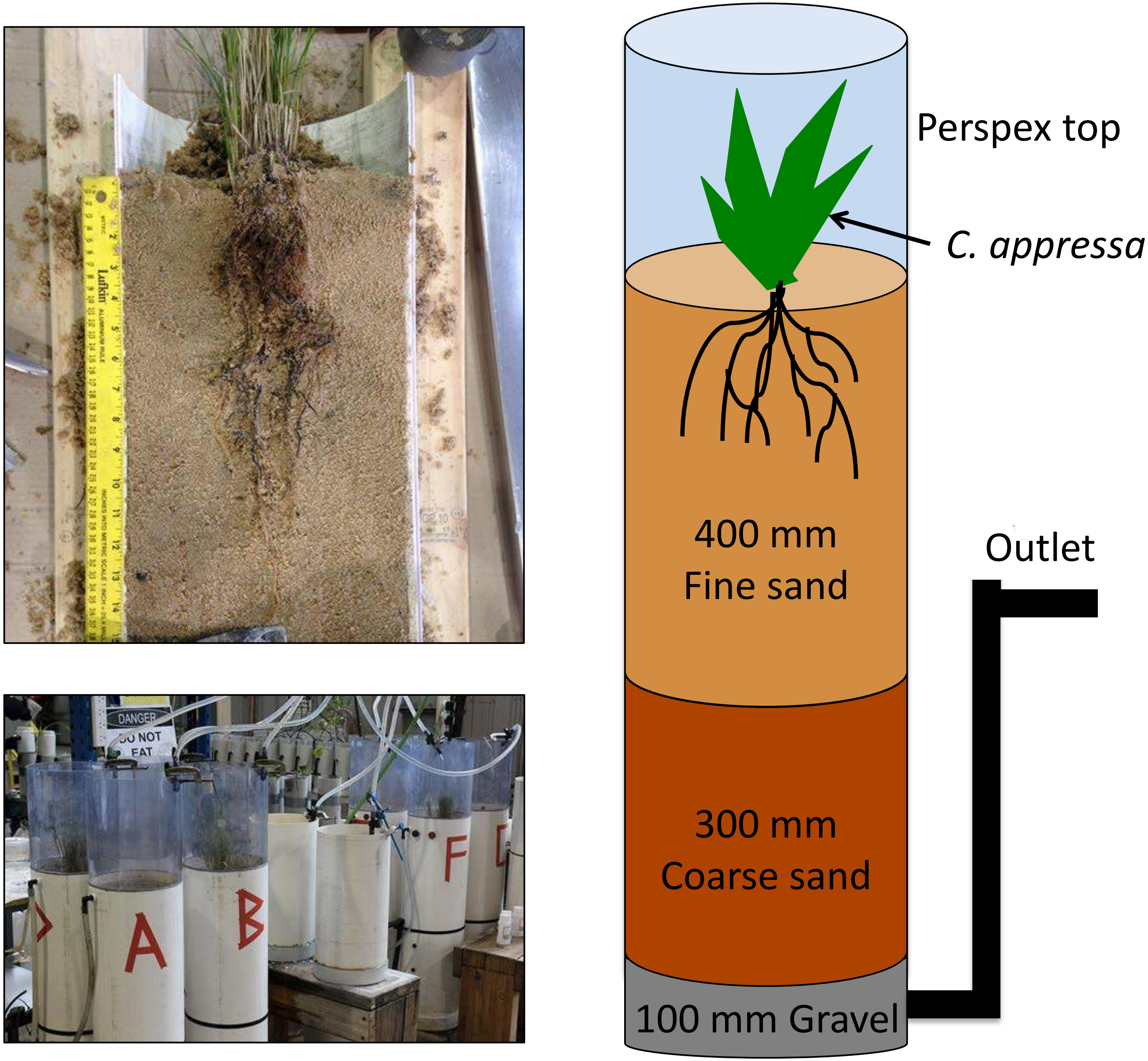
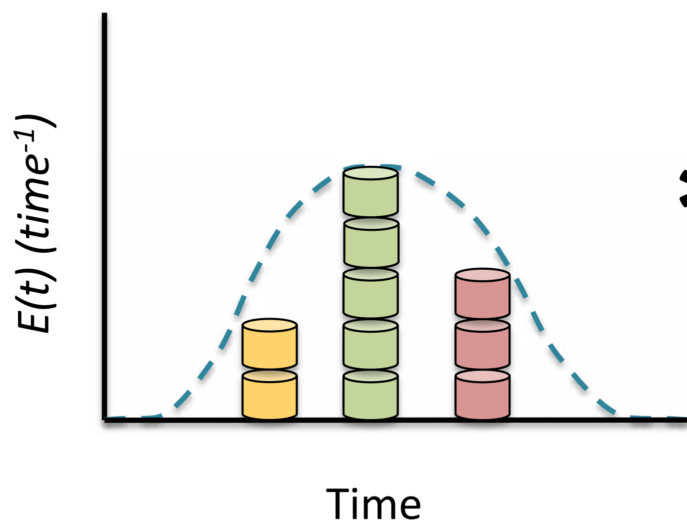
- For most regions of the world (including So Cal), much more water should be harvested than infiltrated

Teaser: Engineering Design of Stormwater Biofilters


DANGER
A
B
F
Perspex top
C. appressa
400 mm
Fine sand
300 mm
Coarse sand
100 mm Gravel
Outlet

Hypothesis: pollutant removal in the biofilter is a **convolution** of the residence time distribution (RTD) and reaction rate

C_{exit} =



$* \quad C = C_0 e^{-kt}$

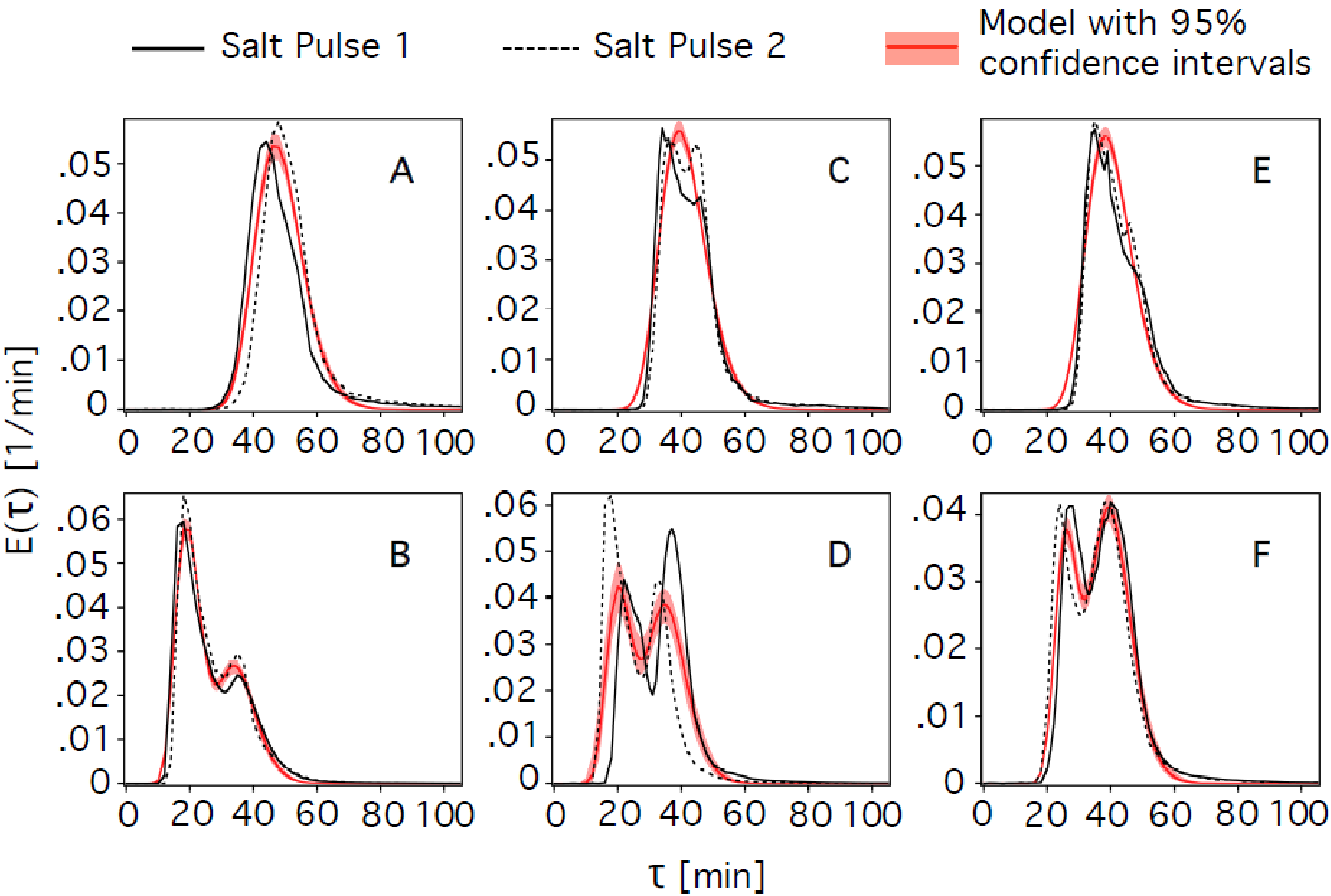
Mathematically, this is what a convolution looks like

$$C_{\text{exit}} = \int_0^{\infty} \underbrace{C_0(t-\tau)e^{-k\tau}}_{\text{First-Order Decay of Pollutant}} \underbrace{E(\tau)}_{\text{RTD}} d\tau$$

First-Order
Decay of Pollutant

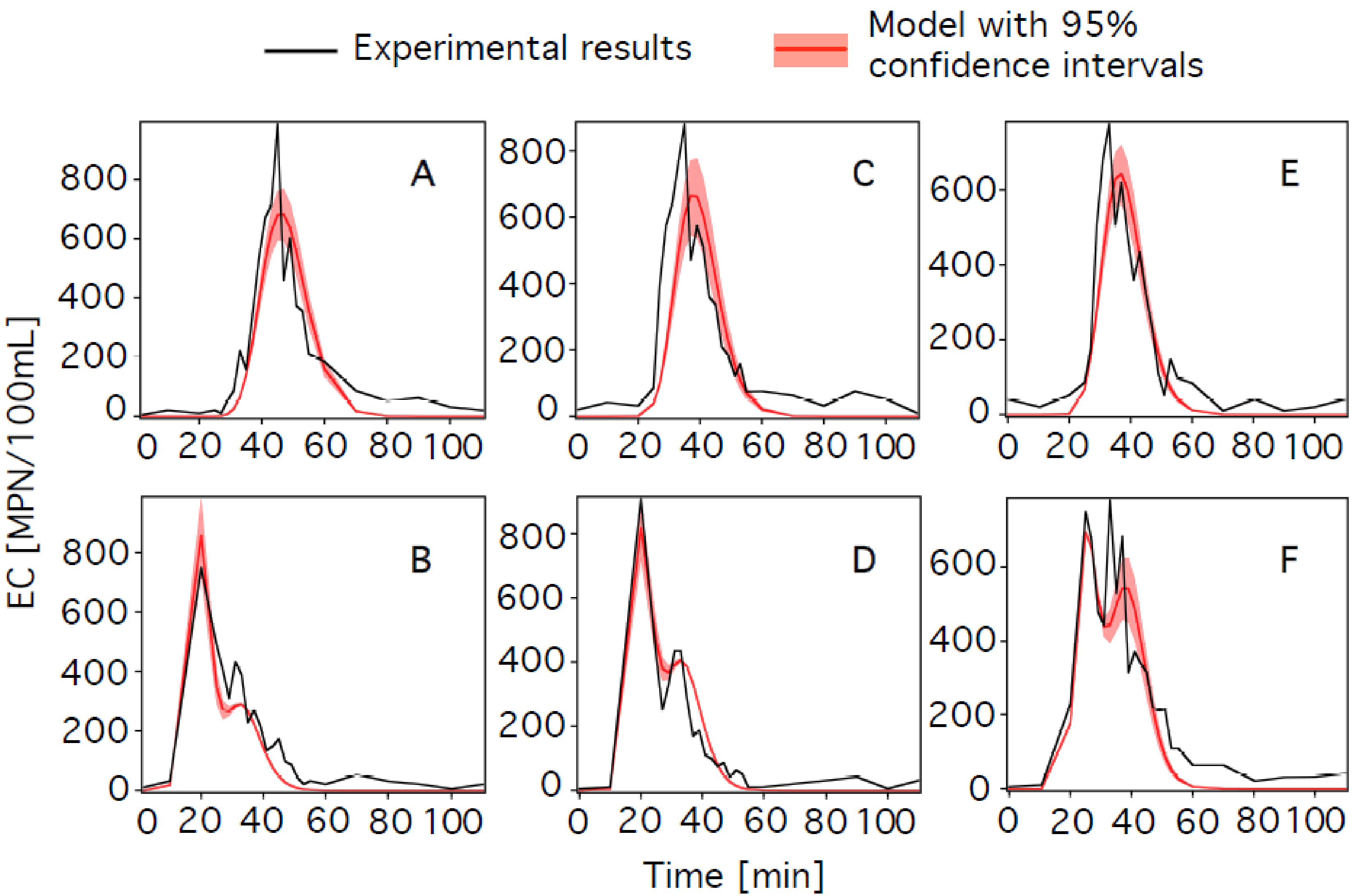
RTD

Integrate over all residence times in the biofilter



Salt Pulse 1
Salt Pulse 2
Model with 95% confidence intervals
A
B
C
D
E
F
E(τ) [1/min]
τ [min]

Figure 2



Experimental results
Model with 95% confidence intervals
EC [MPN/100mL]
Time [min]
A
B
C
D
E
F
0
200
400
600
800
0
20
40
60
80
100

Figure 3

Mathematically, this is what a convolution looks like

$$C_{\text{exit}} = \int_0^\infty \underbrace{C_0(t-\tau)e^{-k\tau}}_{\text{First-Order Decay of Pollutant}} \underbrace{E(\tau)}_{\text{RTD}} d\tau$$

First-Order
Decay of Pollutant

RTD

Thank you for listening!

http://faculty.sites.uci.edu/stanleygrantresearchgroup/