Advancing Stormwater Beneficial Uses: ET Mapping in Urban Areas

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ET and Disturbed Urban Lands

Evapotranspiration has long been noted as an important component in urban water mass balances. The loss of ET (along with decreased infiltration) with conventional development has lead to increased runoff volumes and flow rates. Enhancing ET can help restore the urban water mass balances and minimize many receiving water problems.

- One of the WA test sites studied by Pitt, et al. (1999) for the EPA that examined the benefits of adding large amounts of compost to glacial till soils at the time of land development for increased ET.

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Changes in Mass Discharges for New Plots having Amended Soil Compared to Unamended Soil

Constituent	Surface Runoff Mass Discharges (ratio compared to unamended site)	Subsurface Flow Mass Discharges (ratio compared to unamended site)
Runoff Volume	**0.09**	**0.29 (due to ET)**
Phosphate	0.62	3.0
Nitrate	0.28	1.5
Copper	0.33	1.2
Zinc	0.061	0.18

Increased mass discharges for many constituents in subsurface water observed at these new plots due to compost leaching, but also 70% reduction in subsurface flow volume due to increased ET from the increased water holding capacity of the soil-compost mixture.

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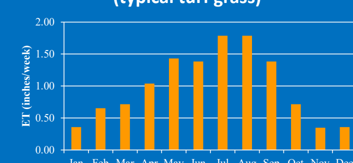
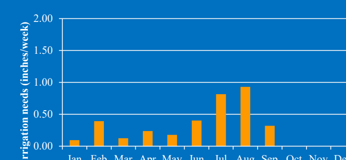
Kansas City Green Infrastructure Demonstration Project: Calculations of Water Harvesting Potential of Roof Runoff to Closely Match ET Requirements

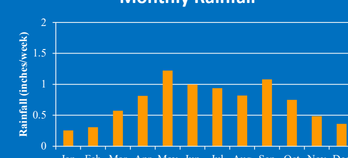
Evapotranspiration per Month (typical turf grass)



Supplemental Irrigation Needs per Month (typical turf grass)



Monthly Rainfall



Irrigation needs for the landscaped areas surrounding the homes were calculated by subtracting long-term monthly rainfall from the regional evapotranspiration demands for turf grass.

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The expected per household water use (gallons/day) from cisterns for toilet flushing and outside irrigation (ET deficit only) for the Kansas City study :

January	113 gal/day/house	July	428
February	243	August	479
March	126	September	211
April	175	October	71
May	149	November	71
June	248	December	71

Examples of water harvesting storage tanks in New Zealand and Australia (where they are experts in modern roof runoff harvesting):

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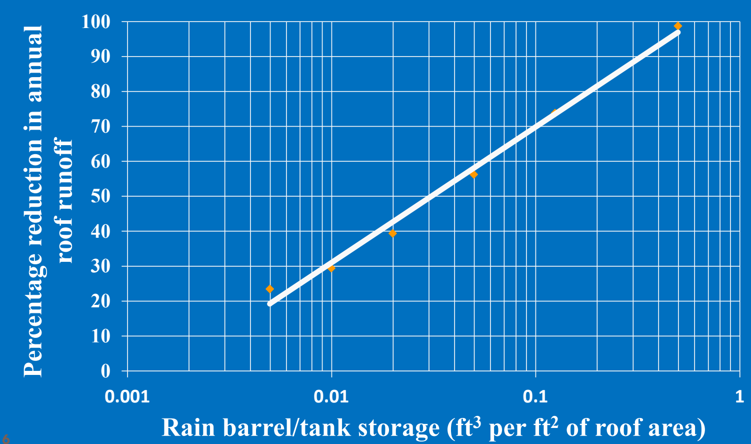
Reductions in Annual Flow Quantity from Directly Connected Roofs with the Use of Rain Barrels and Water Tanks for Irrigation to meet ET (Kansas City CSO Study Area)



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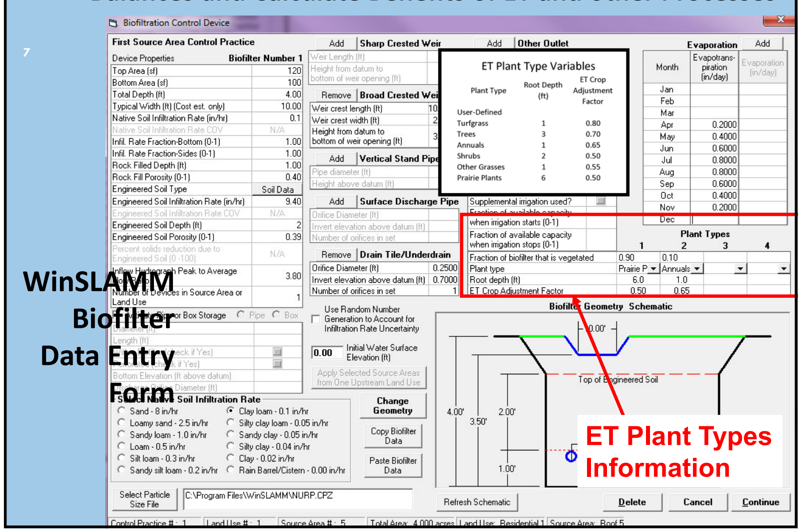
Stormwater Models Can be used to Quantify Urban Water Mass Balances and Calculate Benefits of ET and other Processes



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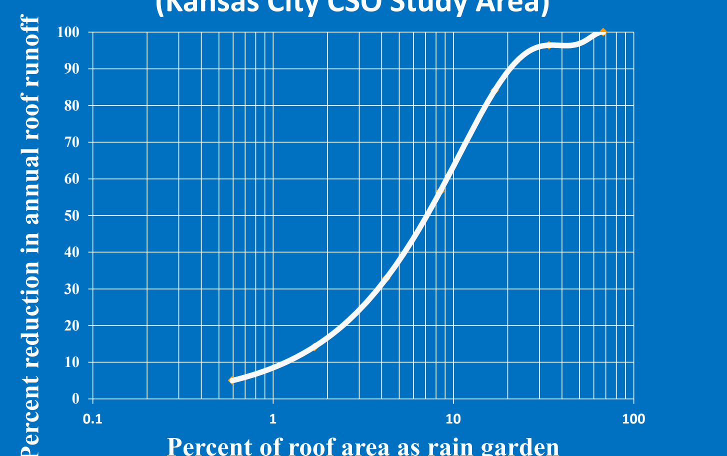
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Gardens (Kansas City CSO Study Area)



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Determining Actual ET for Urban Settings has been Difficult:

- Available ET data is mostly for agricultural settings, far from urban areas
- Actual ET measurements in urban areas are rare, with much data for crops, and few for landscaping plants
- Urban microclimates can be much different from agricultural areas where the reference ET and plant needs data were obtained

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ET Components of WERF Stormwater Beneficial Use Project

- Explore some available ET resources by type, current standards for recording ET data, and expectations for recovering publicly available data.
- Examine the Remote Automated Weather Stations (RAWS) Climate Archive and the differences between the data it houses compared to agriculturally based ET data.
- Map these locations for use in conjunction with associated rainfall information to calculate irrigation requirements in urban areas as part of a WERF-sponsored project on the beneficial uses of stormwater.

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Traditional ET Uses and Data Sources

- In agriculture, maximizing crop growth depends on the ability to monitor ET and developing an appropriate irrigation schedule
  - Irrigation depends on each crop’s ET requirements
  - The estimated ET will change with each different crop and its stages of growth
  - An approximation of this water loss helps form an irrigation schedule for the duration of a crop’s growing season
  - Therefore, most ET available data and plant coefficients are developed for plant species associated with agriculture and not urban landscaping

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Traditional ET Uses and Data Sources

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- In wildland and rangeland areas, ET is used for drought monitoring and land management, and if in a water supply area, for forecasting water supplies.
- One example of rangeland ET sources are the Remote Automated Weather Stations (RAWS) that are placed in rural locations to constantly monitor ambient conditions and communicate the data by satellite. This ET data is critical in wildfire prediction and management.

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Traditional ET Uses and Data Sources

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- Most of the publicly available ET data is from the western U.S.
- Very sparse coverage in the eastern U.S. or in heavily urbanized areas
- There is limited information relating urban ET data needs to the available agricultural and wildland ET data

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ET Data Resources

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- Selection criteria:
  - Regional coverage
    - Objective to cover all 50 states
  - Web accessibility and non-proprietary
  - Ease of access
  - Distance to urban zones
  - Station density
- Other Resources Considered*
  - California Irrigation Management Information System (CIMIS)
  - Texas ET Network
  - AgriMet
  - Florida Automated Weather Network (FAWN)
  - RainMaster®

*ET Resources list only includes some of the available sources for ET data

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RAWS USA Climate Archive

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- Maintained by the Western Regional Climate Center (WRCC), Reno, NV
- Coverage for all 50 states
- Includes ET estimates using two calculation methods:
  - Kimberly-Penman 1982 (alfalfa reference)
  - ASCE Reference Equation (grass reference)
- RAWS site conditions vary
  - Instrument age and maintenance
  - Tree canopy coverage and distance from station
  - Groundcover varies in density and type

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Landscape Coefficient Method

Can be used for determining water needs in urban areas

17 Estimated Values of Landscape Coefficient Factors	Very Low	Low	Moderate	High
Species Factor	<0.1	0.1 to 0.3	0.4 to 0.6	0.7 to 0.9
Density Factor	-	0.5 to 0.9	1	1.1 to 1.3
Microclimate Factor	-	0.5 to 0.9	1	1.1 to 1.4

Landscape Coefficients Method Equation

$$K_L = k_S * k_d * k_{mc}$$

$$k_s = \text{Species Coefficient}$$

$$k_d = \text{Plant Density Factor}$$

$$k_{mc} = \text{Microcimate Factor}$$

Example calculation for a RAWS site in the Oakmulgee National Forest, near Brent, AL

k values	Observed Site Conditions	Assessed Category	Estimated Coefficient
Species Factor	cool season grasses	High	0.9
Density Factor	Low density groundcover	Low	0.75
Microclimate Factor	Shaded with wind protection	Low	0.65
Calculated Landscape Coefficient for Site	$K_L = k_S * k_d * k_{mc}$		0.43

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Landscape Coefficient Method Data Adjustment Example

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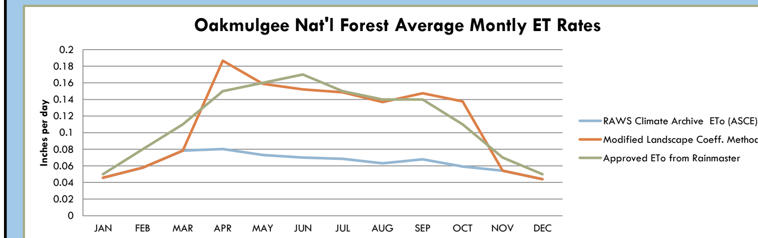
- After RAWS data were adjusted using the K_L coefficient (0.43), the modified rate was similar to other data sources, as shown below. The unadjusted values are likely about half the actual reference values for this example.
- The large number of sites and lack of site information makes this method difficult to use for large scale coverage.
- It may be possible to automate these corrections using high resolution aerial photography and other remote sensing information.



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WERF Project ET Mapping Products

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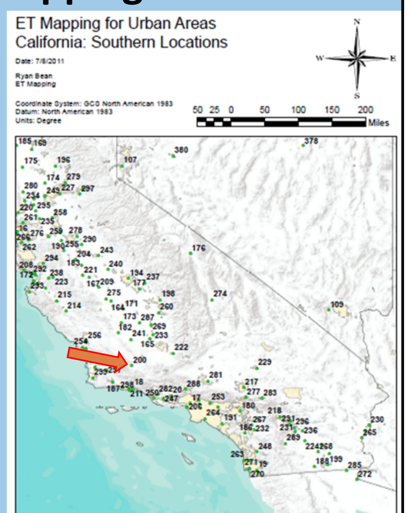
- All locations were assigned an ID number and shown on many regional maps
- Corresponding tabular monthly ET values for each site
- Two tables provided:
  - Grass reference (ET_o)
  - Alfalfa reference (ET_r)



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WERF Project ET Mapping Products

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Example monthly ET_o grass reference values from CIMIS data for different stations:

ET_o California Irrigation Management Information System (CIMIS)

Station Map ID	State	Lat	Long	Elev	Station Name	CIMIS Average Monthly Rates (ET_o) ($\frac{in}{day}$) Years of Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
200	CA	34.942525	-119.673800	2290	Cuyama	N/A	0.07	0.09	0.12	0.18	0.22	0.26	0.27	0.25	0.20	0.15	0.09	0.06
201	CA	36.609444	-121.529300	120	Salinas South	N/A	0.04	0.06	0.11	0.16	0.18	0.21	0.20	0.19	0.14	0.11	0.06	0.04
202	CA	41.438214	-120.480308	4405	Alturas	N/A	0.03	0.05	0.09	0.12	0.16	0.21	0.24	0.21	0.15	0.09	0.04	0.02
203	CA	41.958869	-121.472372	4035	Tule Lake	N/A	0.02	0.05	0.09	0.13	0.17	0.21	0.23	0.21	0.16	0.09	0.03	0.02
204	CA	37.231861	-120.880819	75	Kesterson	N/A	0.03	0.06	0.11	0.18	0.24	0.27	0.28	0.24	0.18	0.12	0.06	0.03
205	CA	34.471333	-119.869294	640	Goleta Foothills	N/A	0.07	0.09	0.12	0.18	0.17	0.19	0.18	0.19	0.15	0.13	0.09	0.08
206	CA	34.044311	-118.476886	340	Santa Monica	N/A	0.06	0.08	0.11	0.15	0.15	0.17	0.17	0.17	0.13	0.11	0.08	0.07
207	CA	38.526336	-122.829297	85	Windsor	N/A	0.03	0.06	0.10	0.15	0.18	0.22	0.21	0.19	0.15	0.10	0.05	0.03
208	CA	36.997444	-121.996758	300	De Laveaga	N/A	0.04	0.07	0.11	0.16	0.16	0.18	0.16	0.16	0.12	0.10	0.05	0.04

• The data on these mapped stations is used in conjunction with associated rainfall information to calculate irrigation requirements in urban areas, as illustrated previously.

• part of a WERF - sponsored project on the non - potable beneficial uses of stormwater:

Pitt, R., Talebi, L., Bean, R., and Clark, S., *"Stormwater Non-Potable Beneficial Uses And Effects On Urban Infrastructure"*, Water Environment Research Foundation. WERF INFR3SG09, Alexandria, VA. 234 pages. (Final Draft Report) December 2011.

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Conclusions

- ET literature relating urban rates to agricultural and wildland data are sparse.
- More research applying the large amounts of agricultural and wildland area ET rates to disturbed urban environments is required to effectively use these data for various urban stormwater management needs.
- RAWS ET data provided by the WRCC ET models are for naturally occurring conditions and require significant adjustments to match artificial urban conditions.
- The Landscape Coefficient Method could be a useful tool for converting WRCC data following a site visit.

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