WATER INFILTRATION & POLLUTANT REMOVAL EFFICIENCIES OF THE BALLONA CREEK RAIN GARDENS

JOHN DORSEY, PH.D.; JAMIE BURKHARD; STEPHANIE KAWECKI, & JOSE SAEZ, PH.D.

DEPT. CIVIL ENGINEERING & ENVIRONMENTAL SCIENCE
LOYOLA MARYMOUNT UNIVERSITY

SMBRF BOARD OF GOVENORS MEETING
FEBRUARY 16, 2017

LMU|LA Frank R. Seaver College
LMU|LA Center for Urban Resilience

LOS ANGELESWATER QUALITY ISSUES

CLIMATE CHANGE IMPACTS

DRINKING WATER SUPPLY

- SHRINKING SNOW PACK
- COASTAL GROUNDWATER CONTAMINATED (SALT)

RUNOFF

- INCREASED RUNOFF FLOWS
- CONTAMINATED COASTAL WATER
- IMPACTS TO RECREATION, MARINE BIOTA

BALLONA CREEK: DRY VS. WET WEATHER

DRY WEATHER FLOWS:
~16 MILLION GAL/DAY

WET WEATHER FLOWS:
>162 MILLION GAL/DAY

MAIN RUNOFF CONTAMINANTS:
FECAL INDICATOR BACTERIA
PESTICIDES (Chlordane, DDT, PCBs, PAHs)
METALS (Zn, Cu, Pb, Se)
TRASH

SOURCE FOR CONTAMINANT INFORMATION: Multi-Pollutant TMDL Implementation for the Unincorporated County Area of Ballona Creek. Appendices. County of Los Angeles.
http://www.swrcb.ca.gov/rwqcb4/board_decisions/basin_plan_amendments/technical_documents/2006-011/10_0224/County%20of%20LA%2026Oct09/2ND_Draft_Ballona_Creek_TMDL_IP_Appendices.pdf

LOW IMPACT DEVELOPMENT: DEALING WITH URBAN RUNOFF

U.S. EPA DEFINITION OF LOW IMPACT DEVELOPMENT:

- FOCUSES ON RUNOFF
- PRINCIPLES AND PRACTICES TO MIMIC NATURAL PROCESSES
- MAIN GOAL ➔ PROTECT WATER QUALITY
- PROJECTS DESIGNED TO INFILTRATE RUNOFF
  - ➢ INCREASE GROUNDWATER SUPPLY
  - ➢ REDUCE CONTAMINATED RUNOFF IMPACTING DOWSTREAM AREAS
- ESSENTIAL COMPONENT OF GREEN INFRASTRUCTURE
- LID PROJECTS REALIZE MANY ECOSYSTEM SERVICES

SOURCE: U.S. EPA, Urban Runoff: Low Impact Development
https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/urban-runoff-low-impact-development

LID MEASURES PROMOTE ECOSYSTEM SERVICES

ASSOCIATED PLANTS AND ANIMALS BOTH SUPPORT AND PROVIDE ECOSYSTEM SERVICES

SUPPORTING
- NUTRIENT CYCLING
- SOIL FORMATION
- PRIMARY PRODUCTION
- …

PROVISIONING
- FOOD
- FRESH WATER
- WOOD & FIBER
- …

REGULATING
- CLIMATE
- FLOOD
- DISEASE
- WATER PURIFICATION
- …

CULTURAL
- AESTHETIC
- SPIRITUAL
- EDUCATIONAL
- RECREATIONAL
- …

SOURCE: World Health Organization
http://www.who.int/globalchange/ecosystems/en/

BIOFILTRATION SYSTEMS: KEY LID STRATEGY

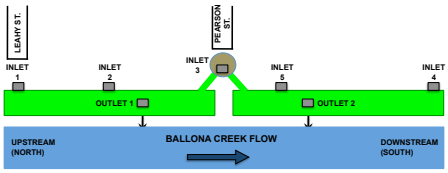
- CAPTURING & INFILTRATING STORM AND DRY WEATHER RUNOFF ACROSS VEGETATED AREAS
- BACKBONE OF THE LOW IMPACT DEVELOPMENT (LID) STRATEGY
- SYSTEMS IMPLEMENTED THROUGHOUT WATERSHEDS FROM HOMES TO LARGE MUNICIPAL PROJECTS

GREEN STREET

BALLONA CREEK RAIN GARDEN (CULVER CITY)

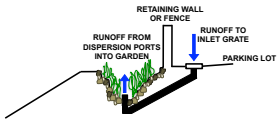
THE BALLONA CREEK RAIN GARDENS

CONFIGURATION OF COMMERCIAL GARDEN (NOT TO SCALE)

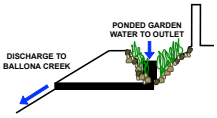


- CONSTRUCTED 2011, MODIFIED 2014.
- DESIGNED TO CAPTURE AND RETAIN POLLUTED RUNOFF
- EXCESS RUNOFF FLOWS INTO BALLONA CREEK
- 300 m LONG X 3 m WIDE = 900 m^2
- RUNOFF FROM 11.1 ac COMMERCIAL, LIGHT INDUSTRIAL BUILDINGS AND PARKING LOTS
- DESIGNED FOR A ¾-in STORM
- LARGE COBBLE-BOULDERS TO DISSAPATE ENERGY
- NATIVE VEGETATION, BUT MAINTENANCE REQUIRED TO REMOVE NON-NATIVES
- TOTAL COST OF CONSTRUCTION : $1,669,148

RAIN GARDEN DESIGN DIAGRAMS



INLET CROSS SECTION



OUTLET CROSS SECTION

MEASURING FLOWS: WEIRS

GARDEN FILLING DURING STORM

WEIR NO. 3 IN PLACE BENEATH GRATE

MEASURING FLOW

DETAIL—WEIR NO. 1

HOBO WATER LEVEL LOGGER; PLACED AT BOTTOM OF PVC PIPE

CONVERTING WATER HEIGHT (ft) TO FLOW (gpm)

FLOW (GPM) CALCULATIONS FOR A 90° V-NOTCH WEIR DISCHARGE STRUCTURE:

- If Water Height (WH) > H2 ➔ Flow = $1122*H3^{2.5} + 3985.3*(WH-H2)^{1.5}$
- If Water Height (WH) > H1, <H2 ➔ Flow = $1122*(WH-H1)^{2.5}$
- If Water Height (WH) < H1 ➔ Flow = 0

From: Douglas M. Grant & Brian D. Dawson. 1995. *Isco Open Channel Flow Measurement Handbook.* 4th Edition

POLLUTANTS MEASURED

POLLUTANT	UNITS	METHOD	LAB
Fecal indicator Bacteria (*E. coli*, Enterococci)	MPN/100 ml	Standard Methods 9223, 9230	LMU
Total Suspended Solids	mg/L	Standard Methods 2540D	LMU
Metals (Cu, Zn, Pb)	ppb	ICP/MS (EPQ 1640)	LMU
Polyaromatic Hydrocarbons (PAHs)	ng/L	EPA 625m	CSULB-IIRMES*
Total Petroleum Hydrocarbons-Diesel, Gas	ng/L	EPA 625m	CSULB-IIRMES*

* Institute for Integrated Research in Materials, Environments & Society

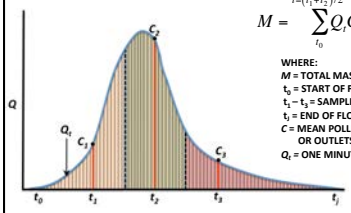
SAMPLING/LAB WORK

- SAMPLING OVER TWO RAINY SEASONS (2015-16, 2016-17)
- FOUR STORMS/SEASON
- COLLECT HYDROGRAPHS FOR EVERY STORM THIS 2016-17 SEASON
- COLLECT 2-3 SETS OF SAMPLES/STORM EVENT DEPENDING ON DURATION
- BACTERIA SAMPLES PROCESSED WITHIN 6-hr OF COLLECTION

COLD & SOGGY WORK

BUT OUR STUDENTS LOVE IT!

MEASURING POLLUTANT LOAD FROM THE HYDROGRAPHS



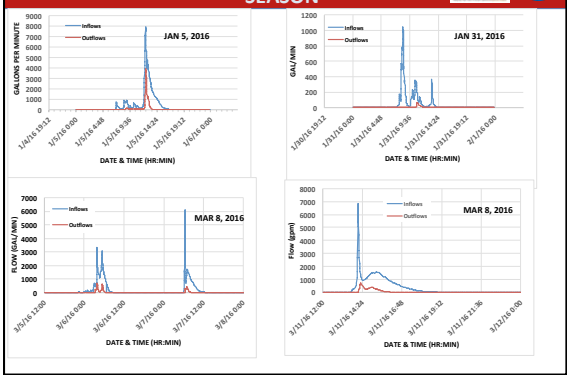
$$M = \sum_{t_0}^{t=(t_1+t_2)/2} Q_t C_1 + \sum_{t=(t_1+t_2)/2}^{t=(t_2+t_3)/2} Q_t C_2 + \sum_{t=(t_2+t_3)/2}^{t=(t_f)} Q_t C_3$$

WHERE:
M = TOTAL MASS LOADING OF POLLUTANT
t_0 = START OF FLOW
$t_1 - t_3$ = SAMPLING TIMES
t_f = END OF FLOW
C = MEAN POLLUTANT CONCENTRATION AMONG INLETS OR OUTLETS
Q_t = ONE MINUTE FLOW SEGMENT (L/min)

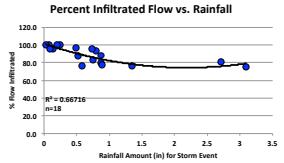
% POLLUTANT REMOVAL EFFICIENCY = $\left(1 - \frac{M_O}{M_I}\right) \times 100$

WHERE:
M_O = TOTAL MASS LOADING OF ALL OUTLETS/EVENT
M_I = TOTAL MASS LOADING OF ALL INLETS/EVENT

HYDROGRAPHS FROM 2015-16 SEASON

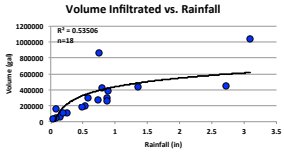


RUNOFF RETAINED: 2016-2017



AVERAGE % FLOW RETAINED:
89.0 ± 9.5 %

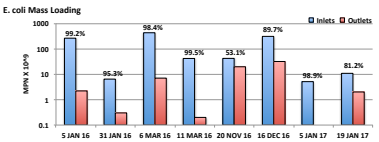
RANGE OF PERCENTAGES:
75.4-100.0 %



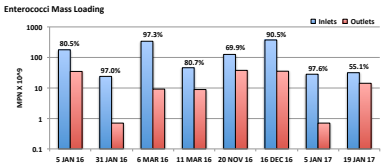
AVERAGE VOLUME RETAINED:
313,214 ± 268,477 gal/storm

RANGE OF RETAINED VOLUMES:
43,646–1,033,571 gal

POLLUTANT MASS REMOVAL EFFICIENCIES: FIB

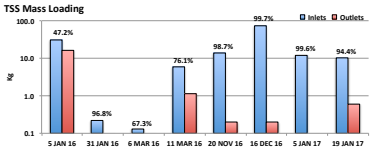


***E. coli* AVERAGE % REMOVAL:**
89.4 ± 16.0 %



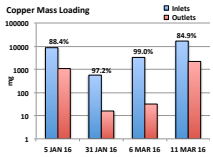
ENTEROCOCCI AVERAGE % REMOVAL:
83.6 ± 15.3 %

POLLUTANT MASS REMOVAL EFFICIENCIES: TOTAL SUSPENDED SOLIDS

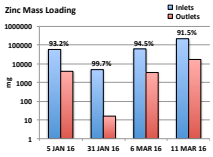


TSS AVERAGE % REMOVAL:
85.0 ± 19.5 %

POLLUTANT MASS REMOVAL EFFICIENCIES: METALS



COPPER AVERAGE % REMOVAL:
92.4 ± 6.8 %



ZINC AVERAGE % REMOVAL:
94.7 ± 3.5 %

CONCLUSIONS & FUTURE WORK

THE GARDEN IS DOING ITS JOB:

- **GREATER THAN 75% OF FLOWS ARE RETAINED DEPENDING ON NATURE OF THE STORM**
- **AVERAGE POLLUTANT REMOVALS ARE GREATER THAN 84%**

WILL BE SAMPLING ADDITIONAL STORMS THIS SEASON FOR FLOWS AND POLLUTANT LOADS

IN ADDITION TO LOADING ESTIMATES, WILL BUILD REGRESSION MODEL OF WATER RETENTION BASED ON RAINFALL AMOUNT, RAINFALL RATE, AND STORM DURATION

FATE OF METALS SEQUESTERED IN GARDEN WILL BE STUDIED BY GRADUATE STUDENTS FROM CSULA