ABSTRACT & POWERPOINT PRESENTATION

A Role for Dispersed Groundwater Recharge Systems to Balance the Effects of Hydromodification

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By Daniel B. Stephens, Mark Miller, and Stephanie J. Moore

Storm water capture for groundwater recharge at the lot, subdivision, or commercial site deserves to receive consideration from groundwater managers as a means to replenish aquifers, as there is increasing pressure to find new sources of water, especially in metropolitan areas which rely to a significant extent on groundwater. Studies show the significant quantity of water which is potentially available and that this water may have a very positive effect on increasing water table elevations or offsetting water level declines. For example, a field investigation in a semi-arid area of New Mexico found that capturing runoff from a hardscape area and diverting it into unlined retention ponds increased the recharge from about 1% to about 50% of mean annual precipitation, creating a groundwater mound beneath the ponds. Nationwide, existing investigations of groundwater recharged by storm water suggest there has been no significant decline in water quality. Planners and managers who recognize the new hydrologic conditions created by progressive urbanization and climate change have an opportunity to adapt to these conditions and re-engineer new systems which capture storm water runoff for recharge, while at the same time fulfilling storm water runoff permit requirements under the Clean Water Act. An approach to achieve both groundwater recharge and storm water control is to implement at the local or neighborhood scale, low-impact development (LID) methods which favor infiltration in lieu of evapotranspiration.

There are numerous potential challenges to implementing a decentralized recharge program using stormwater. Some issues pertain to infiltrability of local soils, impacts of excess local water on geotechnical stability, and flushing natural salts from the soil profiles. In some water-short States, existing surface water rights are incompatible with approaches to capture runoff for groundwater recharge, in spite of the potential benefits to augmenting water supplies. Costs to implement decentralized systems seem to be favorable in comparison to centralized and heavily engineered systems, but there are few incentives currently in place to encourage public support; consequently, implementation is likely to be a slow process, on the order of decades to be an important component of a water management portfolio. Recent EPA regulations of federal facilities which require returning site runoff to the pre-development condition, if adopted by municipalities, would potentially lead to mandates for local-scale, decentralized recharge systems.
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Hardscaping In Urban Environment

- Curb and gutter
- Impervious pavement
- Concrete lined channels
- Increases discharge to stream, lake, ocean
Urbanization Increases Runoff (RO) and Decreases Evapotranspiration (ET), Runoff (R)
Runoff Capture Also For Artificial Recharge

- Large scale; centralized
  - Basins, channels
- Generally are conducted by public entities:
  - Cities
  - Counties
  - Water Agencies
- Example of in-channel recharge with levees on the Santa Ana River, CA
Usually The Main Driver For Capturing Storm Water is Regulations: CWA

- Improved water quality
  - **Clean Water Act** requires that the quality of water discharged to receiving bodies should be improved
NM Example: Local Storm Water Capture Produces 10 m Groundwater Mound Beneath Ponds
Recharge Increased from 1 to 50% P

- MODFLOW-Surfact: 40% of Precipitation
- UNSAT-H: 60% of Precipitation
- Consistent with volume in mound
- 25% of subdivision needs at 5 homes/ac
Greatest Potential Stormwater Recovery is from the Lot (Roof)

\[ y = 0.0738e^{-0.5992x} \]
\[ R^2 = 0.9075 \]

\[ y = 0.033e^{0.3357x} \]
\[ R^2 = 0.8368 \]

City of Tucson and Pima County, 2009
Lot Scale Rainwater Harvesting Is Catching On as a Green Technology
Low Impact Development (LID)

- For compliance w/CWA
- Micro-scale storm water retention areas
- Reduces impervious hardscape
- Lowers peak discharge
- Lengthens duration of runoff
Green (ET) Roofs
LID is A Trend in Storm Water Management

- Water retention for on-site use
  - Landscape modification to enhance vegetation
  - Providing habitat and recreation
- Afford some improvement in runoff water quality
- Some designed to recharge groundwater
Permeable Pavers Promote Recharge
Underground Infiltration Basins

- Can be installed under Athletic Fields, Parking Lots, etc.
- Crushed Stone Cover Layer
- Stone Backfill around Perimeter
- Compacted Base
- Geotextile Fabric
- Storm Tank Modules (Slate Panels used on Perimeter Modules)
- PVC Liner for Detention Basin
- Geotextile for Infiltration Basin

Controlled Outflow (when system is used as a Detention Basin)
Infiltration Gallery
Emerging Trends in Water and Land Use Again Are Modifying Hydrologic Balance

- Landscape development occurring at local scale
  - Homes
  - Subdivisions
  - Offices
  - Shopping malls (e.g., Annapolis, MD; Ecosite, Inc., 2003)

- LID ET Enhancers Do Not Promote Recharge
  - Green Roofs
  - Rain Gardens

Source: Hall and Clar
Recent Modeling Results of Decentralized Recharge Applying LID at Watershed Scale

- Los Angeles and San Gabriel River Basins
- Capture first 3/4” rainfall
- 384,000 AFY
- 1.5 M people
- $311 M value of water
A Recent Federal Driver May Lead to Increased Recharge Opportunity

  - Interprets the 2007 Energy Independence and Security Act for redeveloped and new facilities
    - **Maintain pre-development hydrology** (RO, ET, R)
  - Key: Retain up to the 95 percentile storm on-site

- May Become a Model for States and Municipalities
Local Mandates for Recharge Have Begun and Are Expanding

- Local governments in Maricopa County, AZ
  - Since early 1970s
  - Runoff control with infiltration basins and dry wells

- Santa Ana Regional Water Quality Control Board
  - 2009 Orders re: NPDES Permits to Counties
  - New residential, commercial, and industrial
    - Developments and redevelopments
    - Implement LID with infiltration as first priority
State Mandates

• New Jersey in 2004
  • Stormwater management rules for new development
    • Either maintain all the pre-construction recharge volume
    • Or, infiltrate the increase in post-development runoff volume for the 2 year storm
Artificial Recharge with Roof Water Mandated in Some Provinces in India

Rooftop rainwater harvesting

Recharge Through abandoned dug well
Canvas Pipe Dia mm
Clay Layer
Abandoned Well
Aquifer

ROOFTOP RAIN WATER RECHARGE

SECTION

152 mm JHONSON V WINE SCREEN (1 mm SIZE)
10.5 m
SLATTED PIPE SLAB
COARSE SAND 10-20 CM
GRANULAR SAND 10-20 CM
ROULDER 10-20 CM
MS PIPE
MS PIPE
Extension To Urban Watershed

• Recognize needs to reduce runoff while not impairing downstream surface water users

• **Capture RO above pre-development flow and the lost ET**
  • Current regulatory focus has been on storm RO control
  • Some land development is necessary and will cover native plants, thus eliminating the pre-development ET
  • ET is typically the largest natural output in water balance
Capture Evapotranspiration (ET) and Restore Runoff (RO) for Improved Sustainability: Baseline Condition

Precipitation (P) = 20”
ET = 12”
Native vegetation
Vadose zone
Recharge (R) = 4”
Infiltration (I)
RO = 4”
Groundwater
Choose Infiltration-Based LID Methods (not ET-Based)

RO = 4"

ET = 10"

Infiltration basin

Permeable pavement

I

DP

DP

I

R = 6"

Groundwater
Benefits of Decentralized Artificial Recharge

Bear, 1978

K = 100 ft/d
P = 1.25 ft/yr
R_{recharge} = 100 ft

Bear, 1972
Harvest Roof Water, Recharge the Excess

- Roof water collection
- Storage tank
- Pumping well
- Infiltration structure
- Soil treatment zone
- Naturally treated and stored roof water
- Impaired water

Roof water collection, naturally treated and stored, can be directed to recharge the excess impaired water through infiltration structures and soil treatment zones.
Large Urban Area

- Assume:
  - 400 square mile area
  - Precipitation is 12 inches per year
  - 25% of precipitation becomes recharge through a decentralized system

- Then,
  - Potential New Recharge = 64,000 AFY
Cost for Indirect Potable Reuse

- 72,000 AFY
- 600,000 People

- $481M Capital Cost
- $30M/yr Operating
“The New Mexico Office of the State Engineer supports the wise and efficient use of the state's water resources; and, therefore, encourages the harvesting, collection and use of rainwater from residential and commercial roof surfaces for on-site landscape irrigation and other on-site domestic uses.”
New Mexico Rainwater/Snowmelt Harvesting Policy (cont.)

• “The collection of water harvested in this manner should not reduce the amount of runoff that would have occurred from the site in its natural, pre-development state”

• There is no guidance from NM OSE on how to calculate natural runoff and obtain approval
“Harvested rainwater may not be appropriated for any other uses.”

No rainwater harvesting for artificial recharge?
Potential State Engineer Concerns

- *Diverting rainfall runoff* with roof harvesting may affect:
  - Downstream senior surface water rights
  - Surface water delivery obligations per the Rio Grande Compact

- *Diverting surface runoff* to recharge will cause:
  - Same as above plus,
  - Issuing a water right for the recharged water (salvaged ET)
  - Incentivizing local scale artificial recharge:
    - May set a precedent for septic system users to request same
A Decentralized Approach to Groundwater Sustainability and Runoff Control

- Consistent with sound water conservation practices
- Supports CWA requirements
- Off-sets need for alternative water supplies
- Utilizes existing potable supply infrastructure
- Avoids land purchases for large scale, centralized basins
Water Quality Benefits

- Local roof runoff systems
  - Capture runoff before it flows far off property
  - Avoids industrial-chemicals, petroleum hydrocarbons on land surfaces
  - Does not mix with other waste water discharge streams
  - Uses natural soil-aquifer treatment processes in LID
    - Filtration through lawns and gardens
    - Biodegradation
    - Volatilization
    - Sorption
Studies Show No Significant Impact to Groundwater Quality

- USGS: 2100 stormwater ponds on Long Island
- USGS/USDA: 100 stormwater ponds in Fresno
- U of A: dry wells in Phoenix area
- LAR/ SGR Watershed Council: 6 LID sites
- EPA:
  - “…runoff from residential areas (the largest component of urban runoff in most cities) is generally the least polluted urban runoff flow and should be considered for infiltration.”
Some Concerns With Enhancing Recharge at Local Scale

- Fast flow in gravels or karst sites with little chemical attenuation
- Perched conditions on impervious soil horizons
- Shallow water tables afford little storage potential and offer lower treatment with thinner vadose zone
- Collapsible soils; geotechnical instability
Conclusions

• Decentralized artificial recharge systems can add significantly to groundwater reserves without depleting pre-development runoff

• Nationally, local artificial recharge with roof water and runoff is likely to be increasingly considered in water management planning

• In NM, clarity and consistency are needed in regulations to encourage a decentralized artificial recharge approach to augment groundwater supplies