

Green Cities: Beijing Water Resources Beneficial Uses of Stormwater

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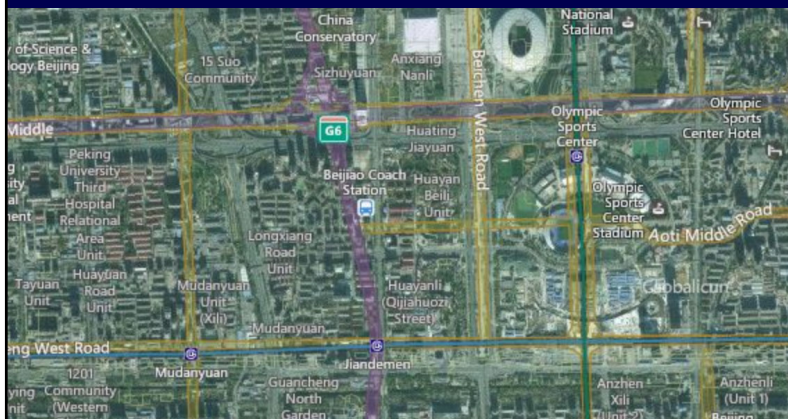
Stormwater Issues in Beijing

- High seasonal flows, long dry periods
- High nutrient discharges
- First flush investigations
- Distributed infiltration to:
 - Reduce flow discharges to drainage system to reduce overflows and other drainage issues
 - Decreased discharges of nutrients to surface waters
 - Enhance water supply

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Typical Dense Urbanized Area in Central Beijing



Aerial photo from Google maps

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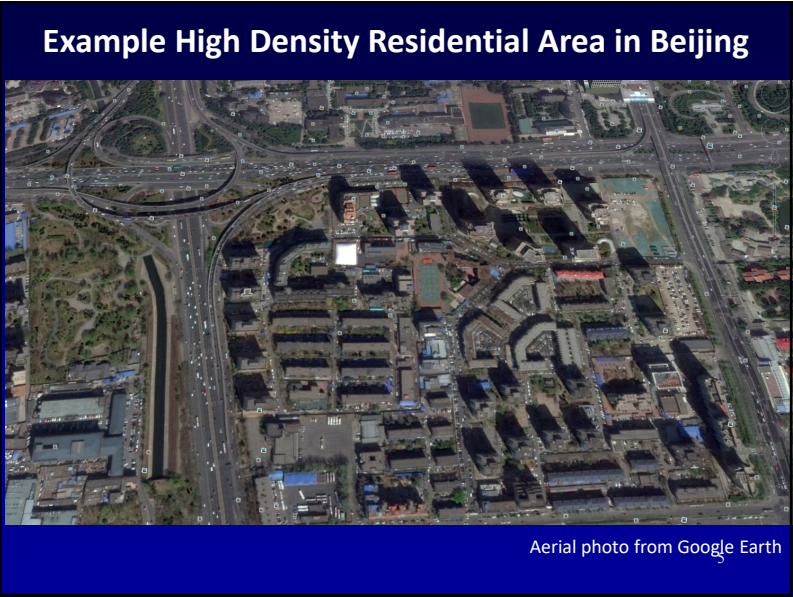
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Example Downtown Commercial and High-Rise Residential Area in Beijing

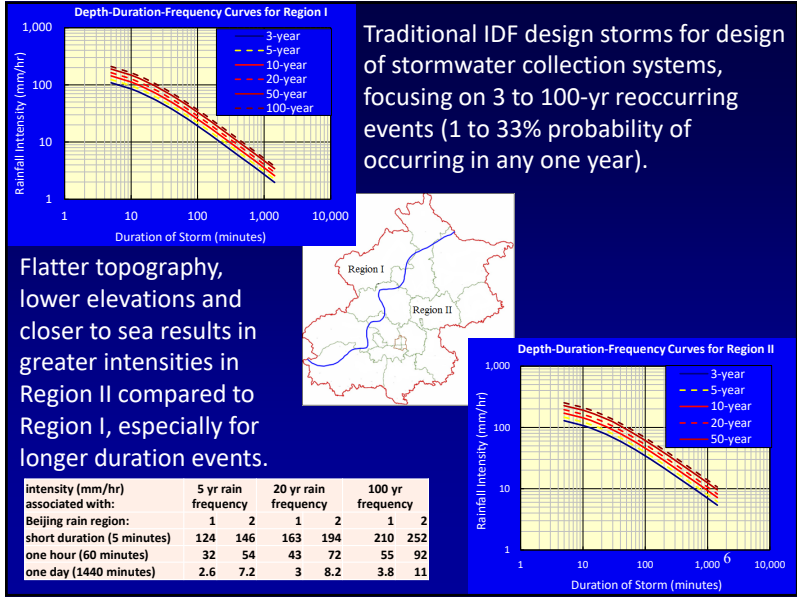


Aerial photo from Google Earth

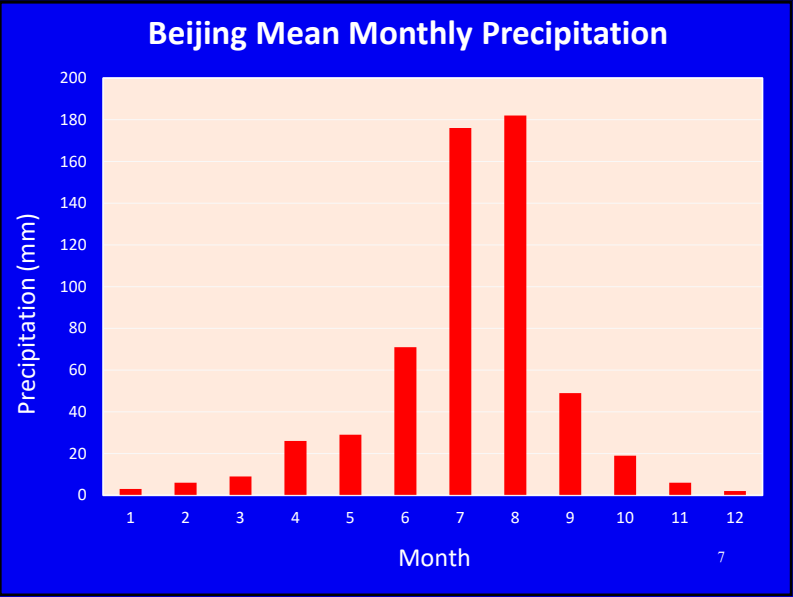
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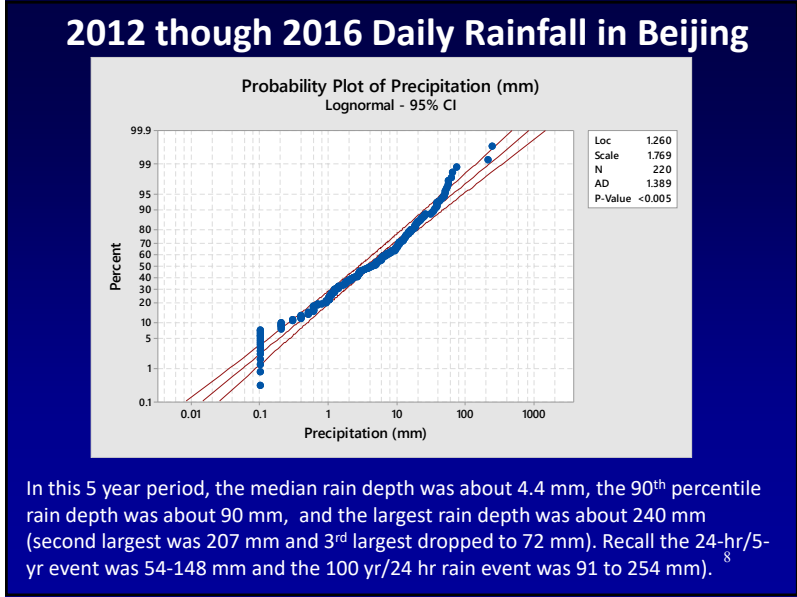
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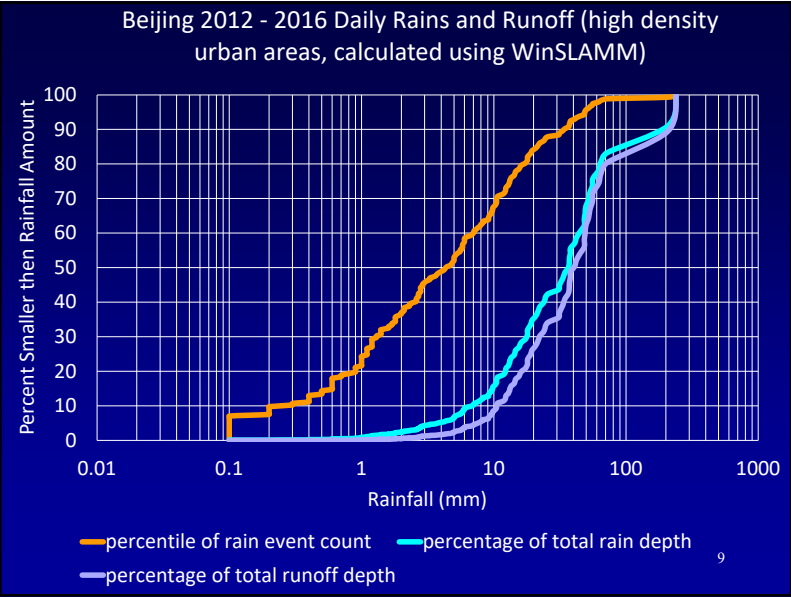
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Importance of Small and Intermediate Sized Rains

	Beijing 2012 through 2016 rains
% of rain events <10 mm depth:	70%
Rain depths associated with 10% of annual runoff:	<10 mm
Rain depths associated with 50% of annual runoff:	<40 mm
Rain depths associated with 80% of annual runoff:	<70 mm
Large rains >70 mm therefore contributed about 20% of the annual runoff for this 5 year monitoring period (unusually large?)	

10

Summary for Beijing Rainfall and Stormwater Conditions

- Beijing has highly seasonal rains with long interevent periods. Literature suggests nutrient discharges are the greatest concern. First flush investigations of local stormwater, and sources of stormwater pollutants are also described in the literature. Desire to use distributed infiltration to reduce discharges.
- First flushes are not consistent for all land uses and pollutants. Most important for simple drainages that are mostly paved; less obvious for complex drainages with separate source areas.

11

Summary for Beijing Rainfall and Stormwater Conditions, cont.

- Beijing drainage design events indicate a significant trend across the city, with more severe conditions to the east.
- Conventional drainage design approaches do not work well for the smaller rains that are of most significance in annual pollutant and flow discharges.
- Most of the Beijing rains (by number) are less than 10 mm in depth, while those rains only result in about 10% of the annual runoff. About 80% of the runoff occurs for rains less than 70 mm in depth.

12

Neighborhood- Scale Stormwater Beneficial Uses	
Main sources of stormwater	Mixed runoff from all sources in the neighborhood, usually a single land use, such as an institution or residential area, but may be a mixture.
Main uses of stormwater	Could be used for irrigation or toilet flushing at individual buildings, but would require significant infrastructure. Large-scale irrigation of adjacent parks or public gardens, or storage of firefighting water at institutional areas suitable uses. Medium-scale groundwater recharge possible.
Treatment options	Sedimentation in larger stormwater facilities. Possible to add available small-scale treatment systems, as needed.
Special considerations	Storage would be larger than possible with on-site options and could include small ponds. Can be integrated with conventional underground storage in combined sewer areas as part of CSO control program.

13

National Academy of Sciences 2015

13

Retrofitted curb-cut biofilters in commercial areas in Kansas City.

Large stormwater park at 18th and Broadway in downtown Kansas City integrating underground storage for beneficial irrigation use along with surface water features and infiltration.

14

Curb-cut biofilter monitored at Kansas City during the EPA's National Demonstration Project of Green Infrastructure.

Monitored large biofilters in Cincinnati at a community college.

Large biofilter series at St. Francis apartments, Cincinnati.

15

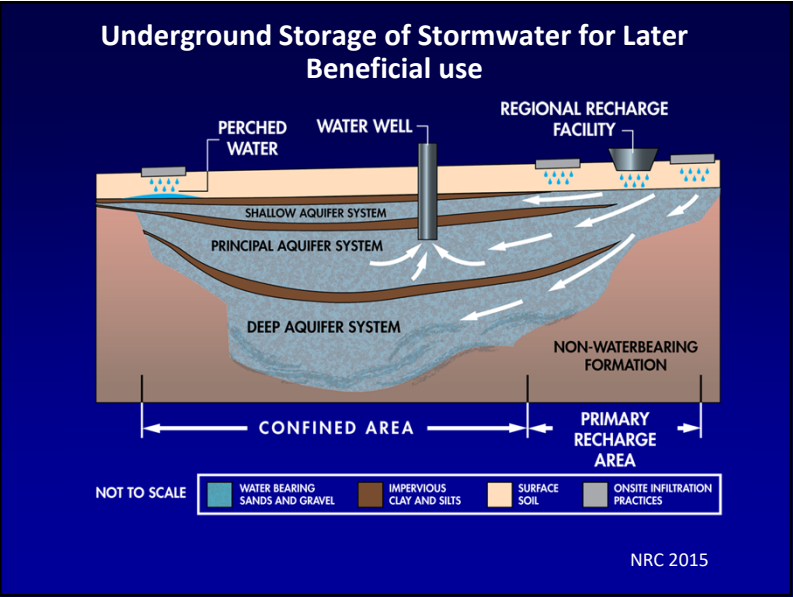
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Community-Scale Stormwater Beneficial Uses	
Main sources of stormwater	Mixed runoff from the community, including all land uses in the area, plus possible adjacent non-urban areas.
Main uses of stormwater	Small-scale reservoirs with collected water used for possible water supplies (after normal water treatment), groundwater recharge in spreading basins, or for ornamental/recreational lakes.
Treatment options	Sedimentation in larger storage facilities. If entering public water supply, water would be further treated at community water treatment facility.
Special considerations	Water contact recreation and consumptive fishing not recommended, but park water features for aesthetics possible. Groundwater recharge may be safe depending on land uses in area, effectiveness of soil-aquifer treatment, and groundwater uses.

16

National Academy of Sciences 2015

16



17

- ### Findings for Beneficial Uses of Stormwater (from NRC 2015 report)
- Public water supplies are being stressed with increasing populations and diminishing available supplies.
 - With suitable storage, stormwater can supply most/all of these non-consumptive needs, reducing water demands from the public water supply by significant amounts.
 - Availability vs. demand time-series, water quality, necessary treatment, and costs currently restrict the wide-spread use of beneficial use of stormwater.
 - The safest beneficial uses of stormwater are mainly for purposes having low potentials for human contact, such as irrigation.

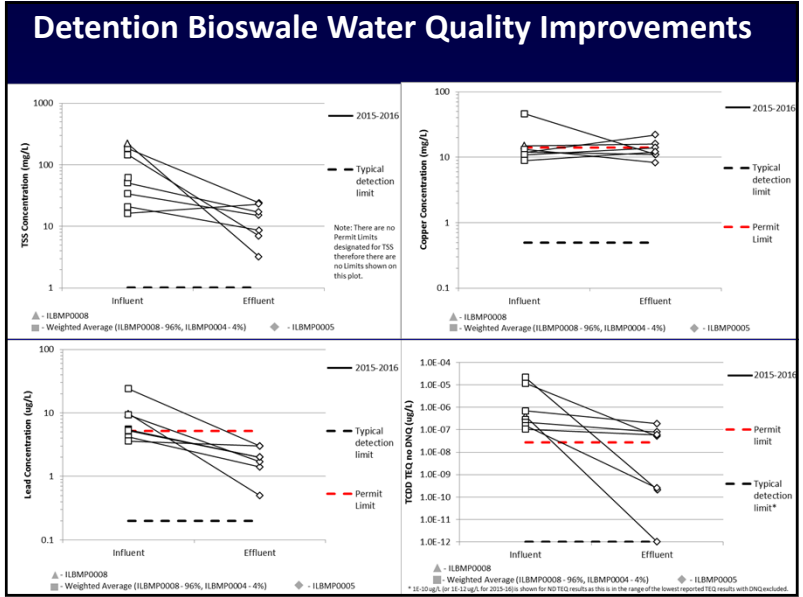
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Performance of Stormwater Bioinfiltration Facilities during Full-Scale Monitoring

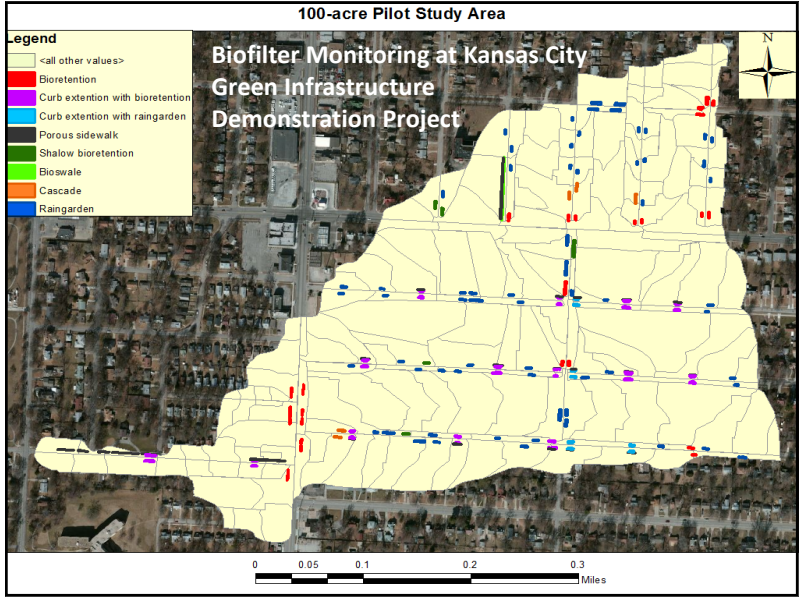
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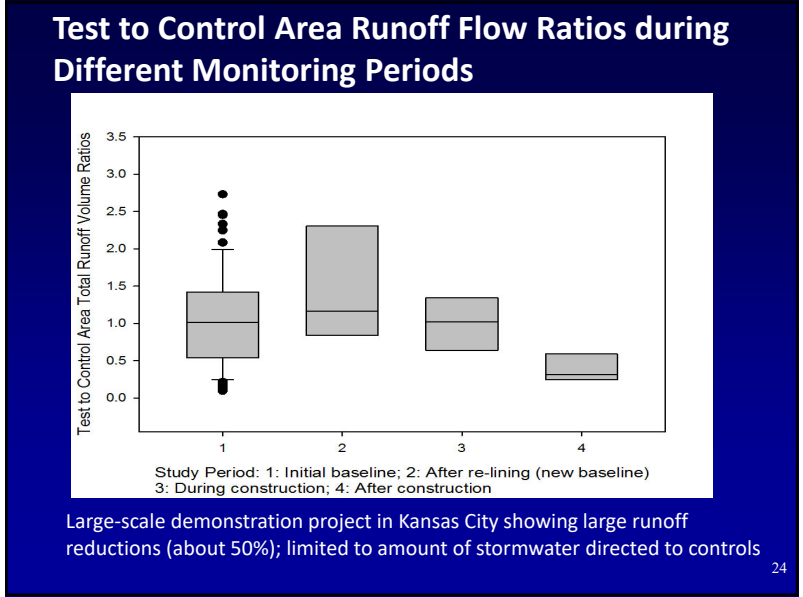
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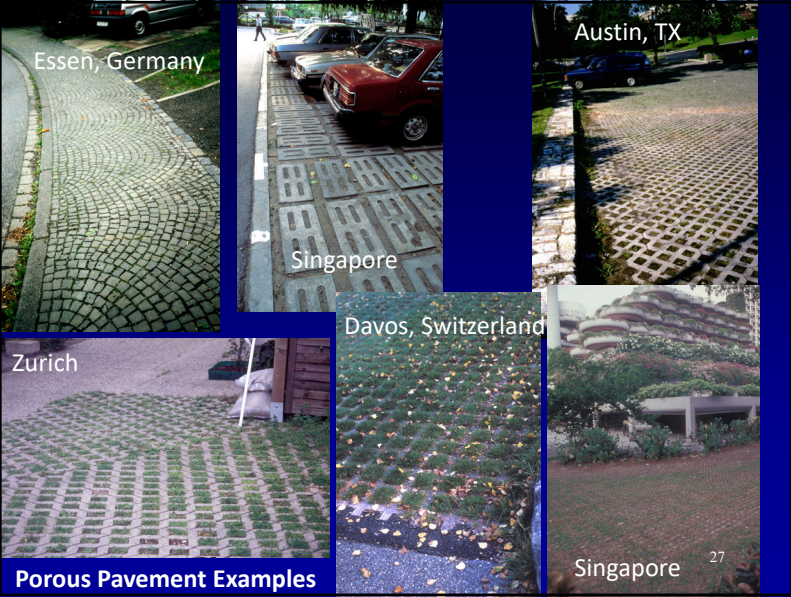
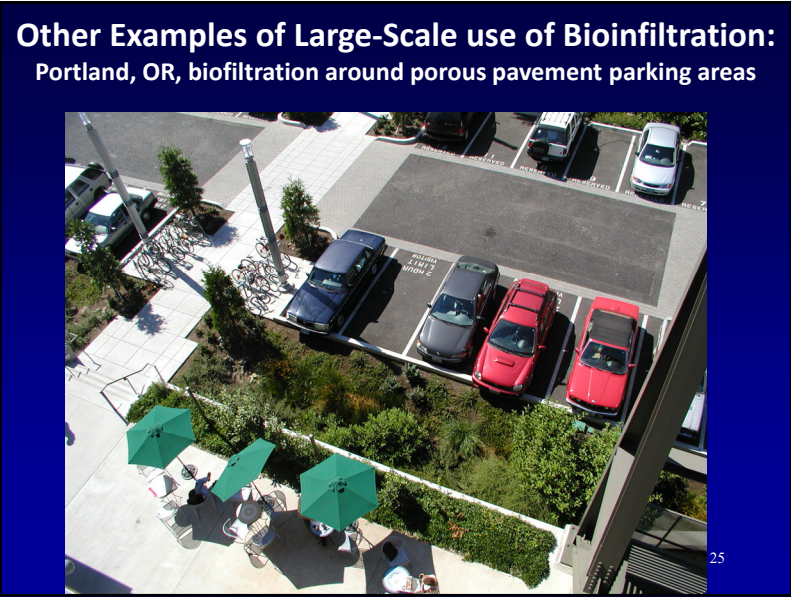
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Large-scale beneficial use projects can use stormwater ponds for both pre-treatment and for storage for later use.

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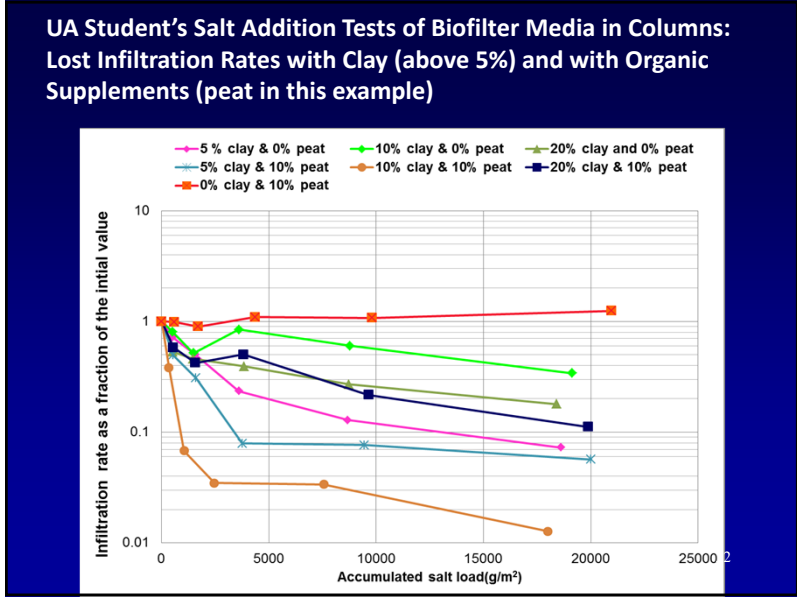
Important Areas of Concern Affecting Infiltration Devices

- Improper Modeling and Sizing
- Improper Locations
- Clogging due to High Sediment Loads
- Compaction of Soils and Media
- Chemical Breakthrough
- Sodium Adsorption Ratio due to De-icing Salts in Snowmelt
- Groundwater Interactions and Contamination
- Improper Construction
- Poor Maintenance
- Anaerobic Conditions
- Large Underdrains and Short-Circuiting
- Need Combinations of Controls and Unit Processes

30

A new infiltration pond after first winter; receives snowmelt from adjacent salted parking areas (plus sediment from area construction); lost almost all of the infiltration capacity and is rapidly becoming a (poorly designed) wet pond.

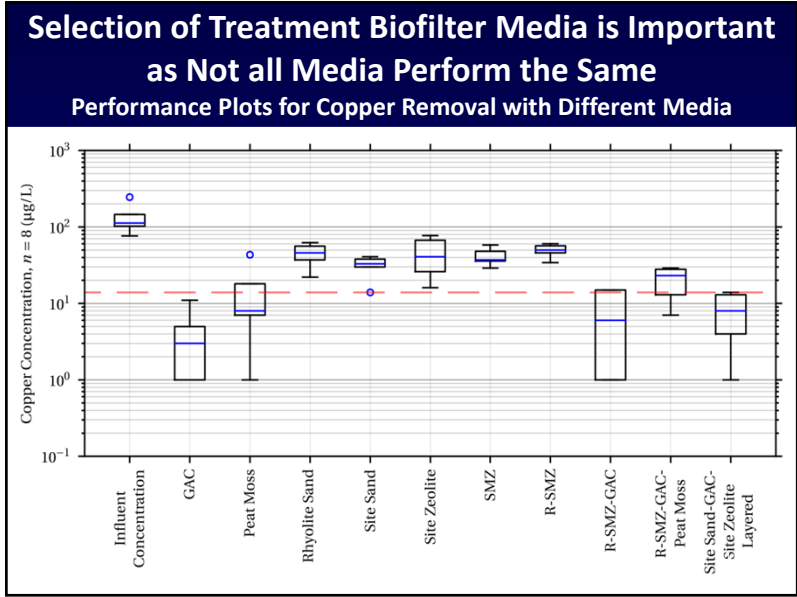
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Conclusions

- Beijing stormwater problems are associated with high rain intensities and long interevent periods, high phosphorus discharges to surface waters, and the need to augment water supplies.
- Beijing rainfall is highly variable throughout the year (wet summers and cold and dry winters). This climate pattern generally matches irrigation needs.
- Most of the stormwater runoff is associated with 10 to 70 mm rains, while the median rain (by number) is about 4 mm.
- Small rains can be easily controlled by simple site infiltration efforts, while larger rains require more elaborate infiltration systems.

35

Conclusions (cont.)

- Neighborhood-scale stormwater beneficial use tools include roof and pavement runoff controls (green roofs, rain gardens, bioinfiltration, porous pavement, etc. Storage tanks in buildings can be used to capture roof runoff and graywater for in-building toilet flushing use, with appropriate treatment).
- Community-scale stormwater beneficial use tools would focus more on regional controls (stormwater ponds or wetlands for treatment and storage, along with underground storage, for later withdrawal for use.
- Careful design and construction of these facilities is critical to prevent problems associated with operation and maintenance.

36