Infiltration BMPs: Managing Stormwater Runoff in the Los Angeles River Watershed

ENE 510 – Spring 2020

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Background Information

Types of Infiltration BMPs

Los Angeles River Watershed

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Application of Case Studies to LA River Watershed

Acronyms

- BMP: Best Management Practices
- LID: Low-Impact Development
- CEC: Chemicals of Emerging Concern
- MAR: Managed Aquifer Recharge
- GWT: Groundwater Table
- LADWP: Los Angeles Department of Water and Power
- SWRCB: State Water Resources Control Board
- TMDL: Total Maximum Daily Load
- TSS: Total Suspended Solids
- TDS: Total Dissolved Solids
- AF: Acre-Feet
- AF: Acre-Feet per Year
- GAC: Granular Activated Carbon

Stormwater BMPs

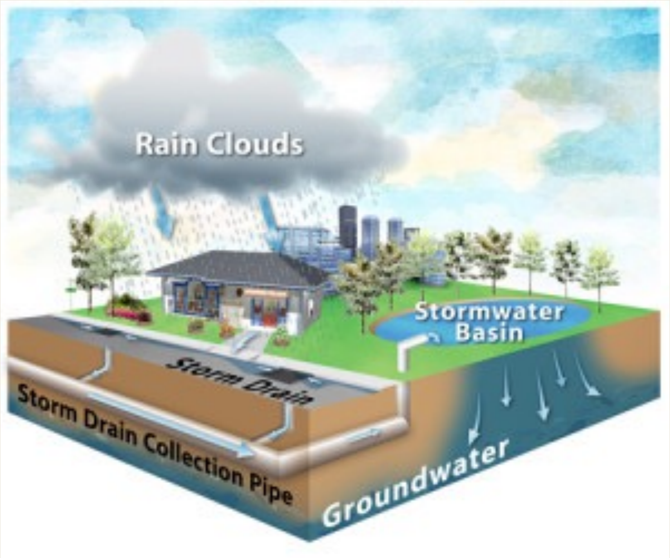
- **Traditional Approach:** Conveyance of surface runoff to a storm drain system which quickly diverts stormflows off-site, to the ocean or a nearby waterway.

- **Low Impact Development (LID) Approach:** A stormwater management method which promotes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls. LID practices more closely reflect hydrologic functions prior to development.

NUISANCE

RESOURCE

https://www.industrialdistrictgreen.org/la_river



http://www.fresnofloodcontrol.org/water-resources/groundwater-recharge/

LID Stormwater BMP Control Measures

- **Infiltration – Topic of this presentation**
- Evapotranspiration/Biofiltration – Stormwater planters, vegetated swales, vegetated buffer strip
- Detention – Constructed wetlands, detention basins

Structural Treatment BMPs

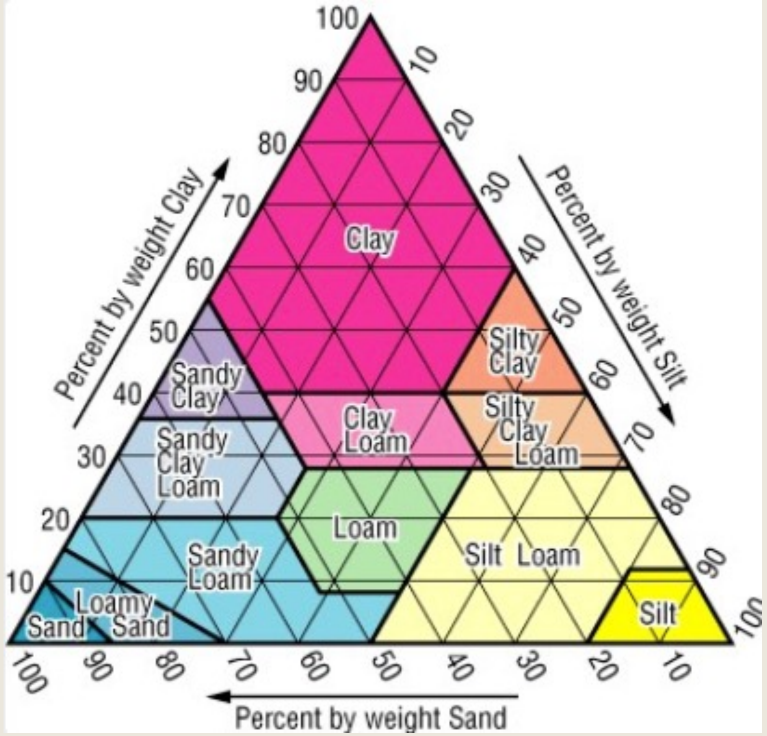
- Pollution Prevention– source control measures
  - *Regulatory Controls*
  - *Education & Participation Programs*

Non-structural BMPs

Hydrologic Soil Groups

Group	Runoff Potential	Types
A	Low runoff potential when thoroughly wet	sand, loamy sand or sandy loam types of soils
B	Moderately low runoff potential when thoroughly wet	silt loam or loam
C	Moderately high runoff potential when thoroughly wet	sandy clay loam
D	High runoff potential when thoroughly wet	clay loam, silty clay loam, sandy clay, silty clay or clay

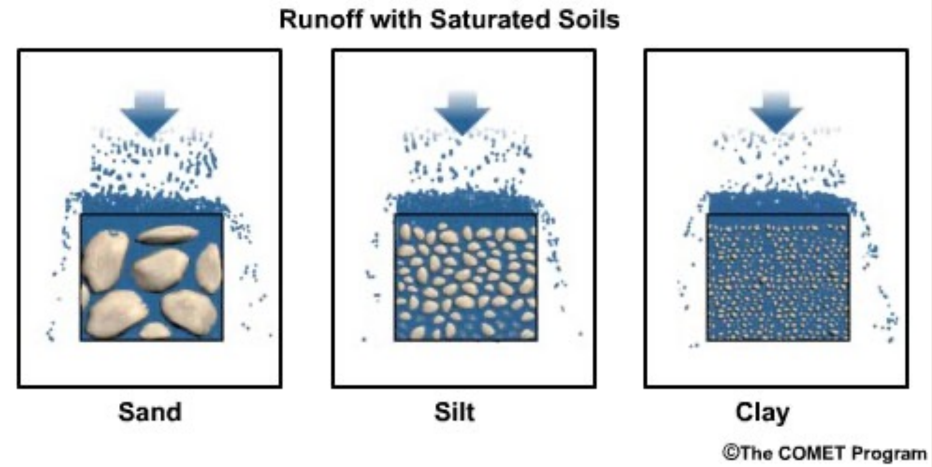
https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba



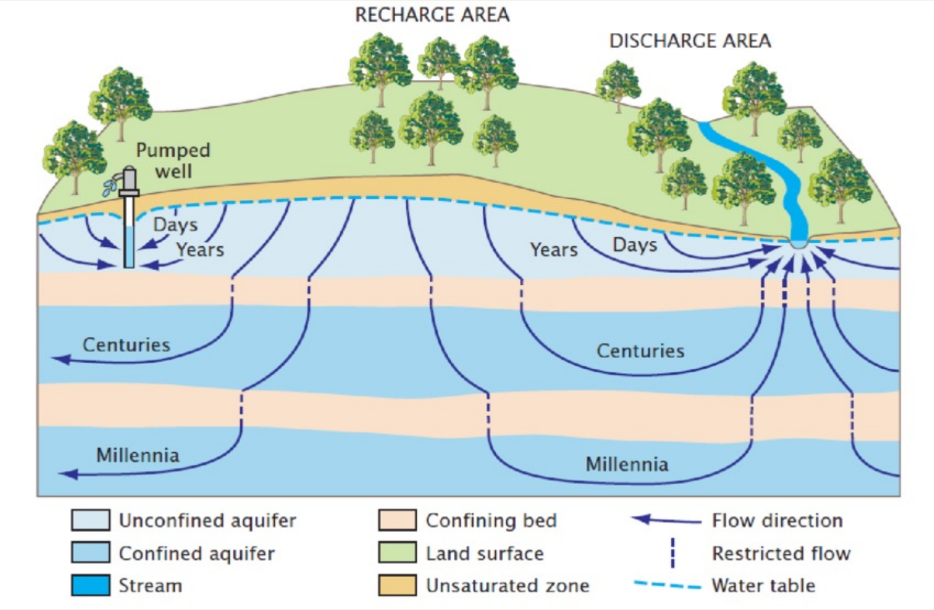
https://margulis-group.github.io/teaching/

Groundwater Hydrology

- Hydraulic conductivity (K) is defined as the ease with which water can travel through the pores in soil or rock
  - *Water will flow easily through soils with a high hydraulic conductivity*
  - *Units of K are [distance/time]*
- Unconfined aquifers
  - *Underground layers with extremely low hydraulic conductivity, block the passage of water*
- Aquifers lacking a confining layer are best suited for infiltration



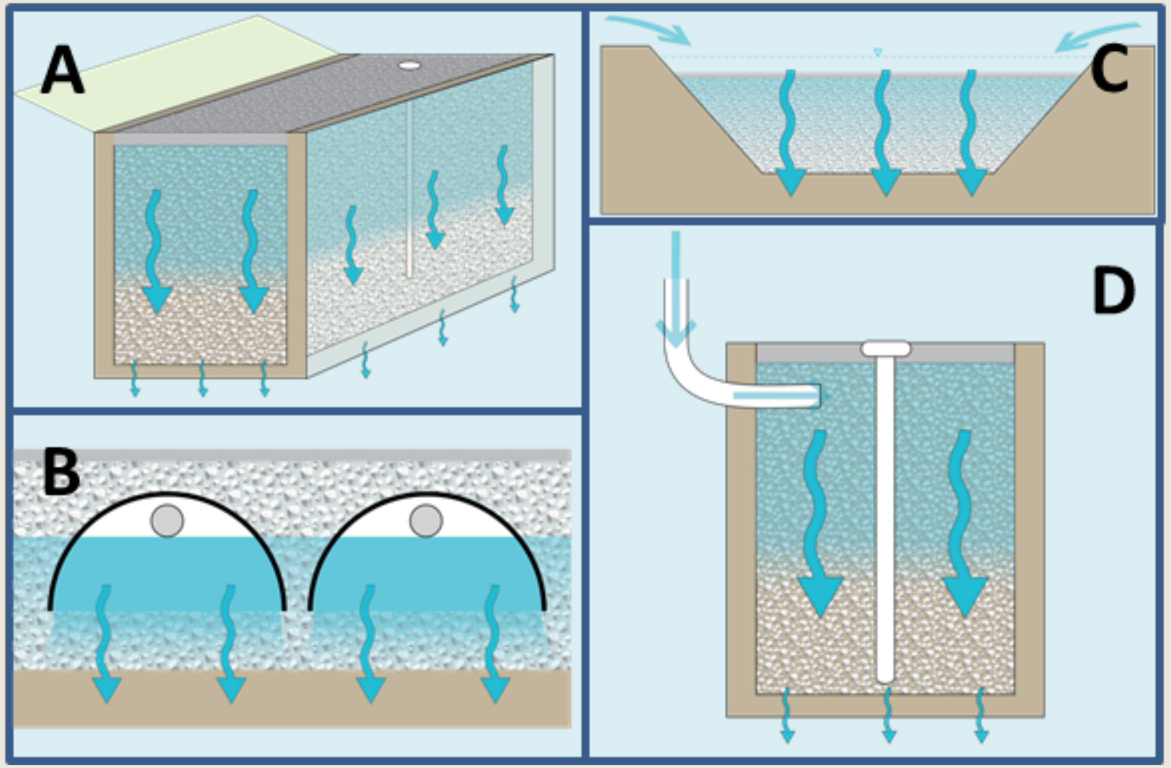
http://portal.chmi.cz/files/portal/docs/poboc/CB/runoff_cz/print.htm



DOI: 10.13140/RG.2.1.4533.3360

Criteria for Stormwater Infiltration Control Measures

- Soil must have a high hydraulic conductivity (K)
- Generally only recommended for **Type A or Type B** soils (not clay)
- Groundwater aquifers need to be accessible (i.e. no impermeable layers blocking infiltration)
- Infiltration isn't typically appropriate for industrial sites due to the potential for groundwater contamination
- Not suitable for regions where the groundwater table (GWT) is near the surface
  - *A groundwater table too close to the surface does not allow enough retention time to benefit from the natural filtering of percolation*
  - *Minimum depth recommendation: >10 ft.*
- Removal mechanisms typically include filtration, flotation/skimming, and sedimentation

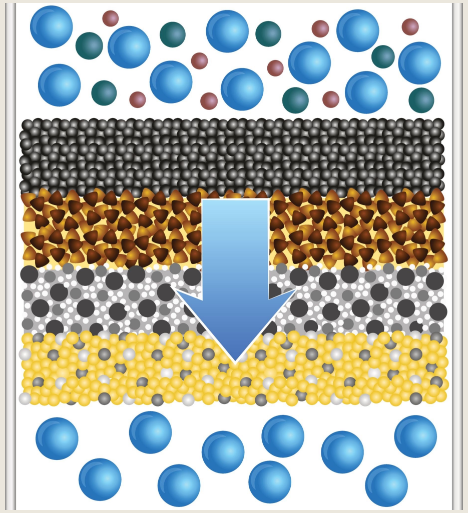


A- Infiltration Trench, **B**- Infiltration Gallery, **C**- Infiltration Basin, **D**- Dry Well

https://stormwater.pca.state.mn.us/index.php?title=Overview_for_infiltration

Infiltration Treatment Mechanisms

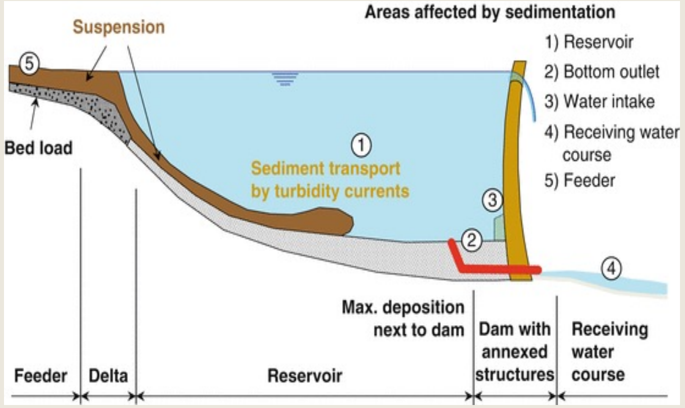
- **Filtration**
  - *Water is naturally treated by movement through soil and sand layers*
  - ***Targets:***
- Nutrients, pathogens, and metals



- **Flotation/Skimming**
  - *Collect insoluble contaminants that stay at water surface*
  - ***Targets:***
- Oils/greases

https://stormwater.pca.state.mn.us/index.php?title=File:Floating_skimmer.jpg

- **Sedimentation**
  - *Contaminants suspended in water are settled out of the water and deposited into a basin*
  - ***Targets:***
- Sediment, solids, debris



https://link.springer.com/referenceworkentry/10.1007%2F978-1-4020-4399-4_312

Infiltration and Contaminants of Emerging Concern (CECs)

- Several studies have found that infiltration may be effective in removing or attenuating contaminants of emerging concern
- Attenuation is most successful when the travel time to the aquifer is the longest
- The table on the following slide summarizes the decrease in concentration of several CECs at different test locations of the San Gabriel Spreading Grounds

www.yourdictionary.com

https://cropaia.com
https://fmidr.com/bpa-affect-health/

Table 2
Trace organic contaminant concentrations in the research basin (RB) and subsurface sampling locations. Travel times noted in parentheses. Average concentrations for MLS 8–PR 11 representative of upper aquifer. Average values for PR 8, PR 10 representative of lower aquifer.

Compound	MRL[a]	RB	RB-dup	MRL[b]	MLS 8 (10 h)	WP Z (12 h)	MLS 14 (26 h)	MLS 20 (42 h)	PR 9 (51 h)	PR 11 (70 h)	Avg. (MLS 8–PR 11)	PR 8 (60 days)	PR 10 (60 days)	PR 10-dup (60 days)	Avg. (PR8, PR10)
Herbicide															
Atrazine	5	<MRL	<MRL	0.25	5.5	5.8	5.4	5.1	5.1	5.2	5 ± 0.2	4	3.9	4.1	4.0 ± 0.1
Flame retardants															
TCEP	200	400	400	10	390	410	400	420	410	380	402 ± 15	83	150	150	128 ± 39
TCPP	2000	7200	7300	1000	6000	7000	6700	7800	6100	5300	6,483 ± 875	580	910	900	797 ± 188
Personal care products															
Benzophenone	1000	<MRL	<MRL	50	67	<MRL	<MRL	68	120	55	68 ± 27	<MRL	<MRL	<MRL	<MRL
DEET	20	320	310	10	130	230	260	300	280	230	238 ± 60	36	57	56	50 ± 12
Musk Ketone	25	<MRL	<MRL	25	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL
Triclosan[c]	1	6.5	8.2	1	1.6	8.4	7.1	8.9	2.9	9.1	6 ± 3	<MRL	<MRL	<MRL	<MRL
Pharmaceuticals															
Atenolol	20	830	830	1	3.2	14	15	95	19	45	31 ± 34	<MRL	<MRL	<MRL	<MRL
Atorvastatin	10	<MRL	<MRL	0.5	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL
Carbamazepine	10	330	340	5	280	330	320	280	270	330	302 ± 28	170	170	170	170 ± 0
Diazepam	5	<MRL	<MRL	0.25	2.1	2.4	2.6	2.5	2.9	2.4	2 ± 0.3	1.2	1.6	1.8	1.5 ± 0.3
Diclofenac	0.5	24	20	0.5	7	9.8	9.7	10	13	9.5	10 ± 2	<MRL	<MRL	<MRL	<MRL
Fluoxetine	10	13	17	0.5	<MRL	0.89	<MRL	<MRL	<MRL	<MRL	0.57 ± 0.16	<MRL	<MRL	<MRL	<MRL
Gemfibrozil	5	880	900	0.25	6.3	28	20	130	75	160	70 ± 63	35	30	30	32 ± 2.9
Ibuprofen[d]	1	10	11	1	6.3	10	1.7	6.1	4.6	4.8	12 ± 8	<MRL	1.3	1.3	1.3 ± 0
Meprobamate	5	430	420	2.5	300	360	400	420	360	410	375 ± 45	97	150	150	132 ± 31
Naproxen	0.5	32	32	0.5	1.9	8.2	5.3	23	12	20	6 ± 3	2.4	2.4	2.4	2.4 ± 0
Phenytoin	20	150	170	1	130	100	99	94	97	98	103 ± 13	94	78	84	85 ± 8
Primidone	10	150	160	5	140	180	120	220	130	220	168 ± 45	92	91	87	90 ± 2.6
Sulfamethoxazole	5	460	440	2.5	180	390	330	550	490	400	390 ± 129	220	200	200	207 ± 12
Trimethoprim	5	54	54	0.25	29	26	83	99	29	81	58 ± 33	6.5	1.9	2.1	3.5 ± 2.6
Plasticizer															
Bisphenol A	5	<MRL	<MRL	5	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL
Preservative															
BHA	1	<MRL	<MRL	1	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL
Stimulant															
Caffeine	100	<MRL	<MRL	5	<MRL	17	<MRL	<MRL	5.8	<MRL	7 ± 5	<MRL	<MRL	<MRL	<MRL
Surfactant															
Octylphenol	25	<MRL	<MRL	25	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL	<MRL
X-ray contrast media															
Iopromide	200	2700	3100	10	25	84	20	130	44	59	60 ± 41	110	77	81	89 ± 18

[a] Minimum reporting level for research basin.
[b] Minimum reporting level for subsurface locations.
[c] Detected in travel blank at 1.3 ng/L.
[d] Detected in travel blank at 3.1 ng/L.

https://www-sciencedirect-com.libproxy2.usc.edu/science/article/pii/S0048969710012520

https://www.sandiegocounty.gov/content/dam/sdc/dpw/

Types of Infiltration BMPs

Types of Infiltration BMPs

- Surface BMP Controls
  - *Infiltration Trenches*
  - *Infiltration Basins*
  - *Dry Swales with Check Dams*

- Subsurface BMP Controls
  - *Permeable Pavements*
  - *Infiltration Wells/Galleries*
  - *Dry Wells*

Infiltration Trenches

https://www.casqa.org/sites/default/files/BMPHandbooks/TC-10.pdf

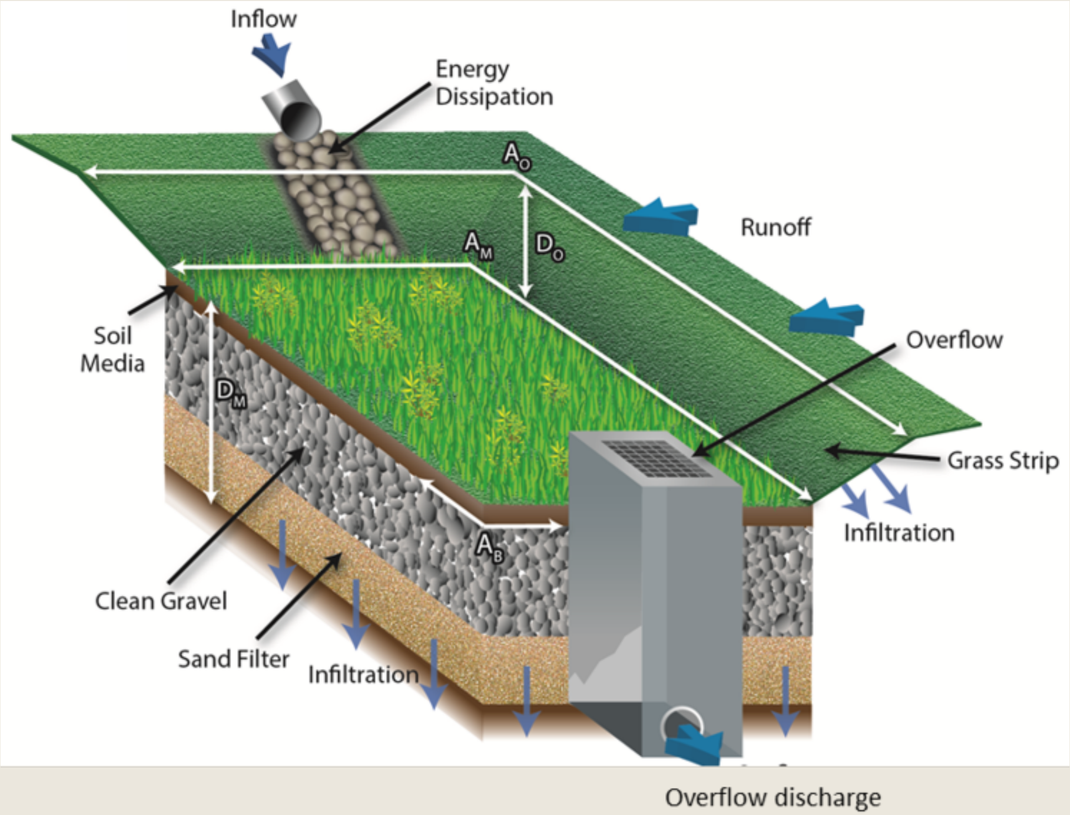
- Infiltration trenches are rock filled trenches that are generally long, narrow, and shallow in depth.
- Runoff from nearby impervious areas is diverted into the trenches for infiltration into underground groundwater basins. There is no outlet to a storm drain.
- Treatment is especially effective at removing fine sediment and associated pollutants.
- This treatment method often requires pretreatment to remove large sediment to avoid clogging of the trenches.

Constituent Removal

Sediment	Nutrients	Chloride	Metals	Pathogens	Oil and Grease	Organics
▲	▲	▥	▲	▲	▲	▲

▥ Low (<30%) ✚ Medium (30-65%) ▲ High (>65%)

Infiltration Trenches



https://stormwater.pca.state.mn.us/index.php?title=File:Infiltration_trench_Detailed_Cross_Section_2.png

- Advantages
  - *High load and volume reduction in discharge to surface waters*
  - *Reduces channel erosion*
  - *Easily installed on roadsides or incorporated into landscaping*
  - *High removal of pollutants*

- Disadvantages
  - *High failure rate if soil conditions are unsuitable (require Soil Type A or B conditions only)**
  - *Unsuitable for steep slopes or catchment areas over 5 acres*
  - *High clogging potential and difficult restoration once clogged*

*Refer to Slide 4 for soil types

Infiltration Basins

https://stormwater.pca.state.mn.us/index.php?title=BMPs_for_stormwater_infiltration

- Infiltration basins are large shallow impoundments designed to infiltrate water
  - *Typical drainage area: 5-50 acres*
  - *Typical depth: 2-6 feet*
- Used throughout California for the mitigation of stormwater peak runoff and for groundwater recharge

Constituent Removal

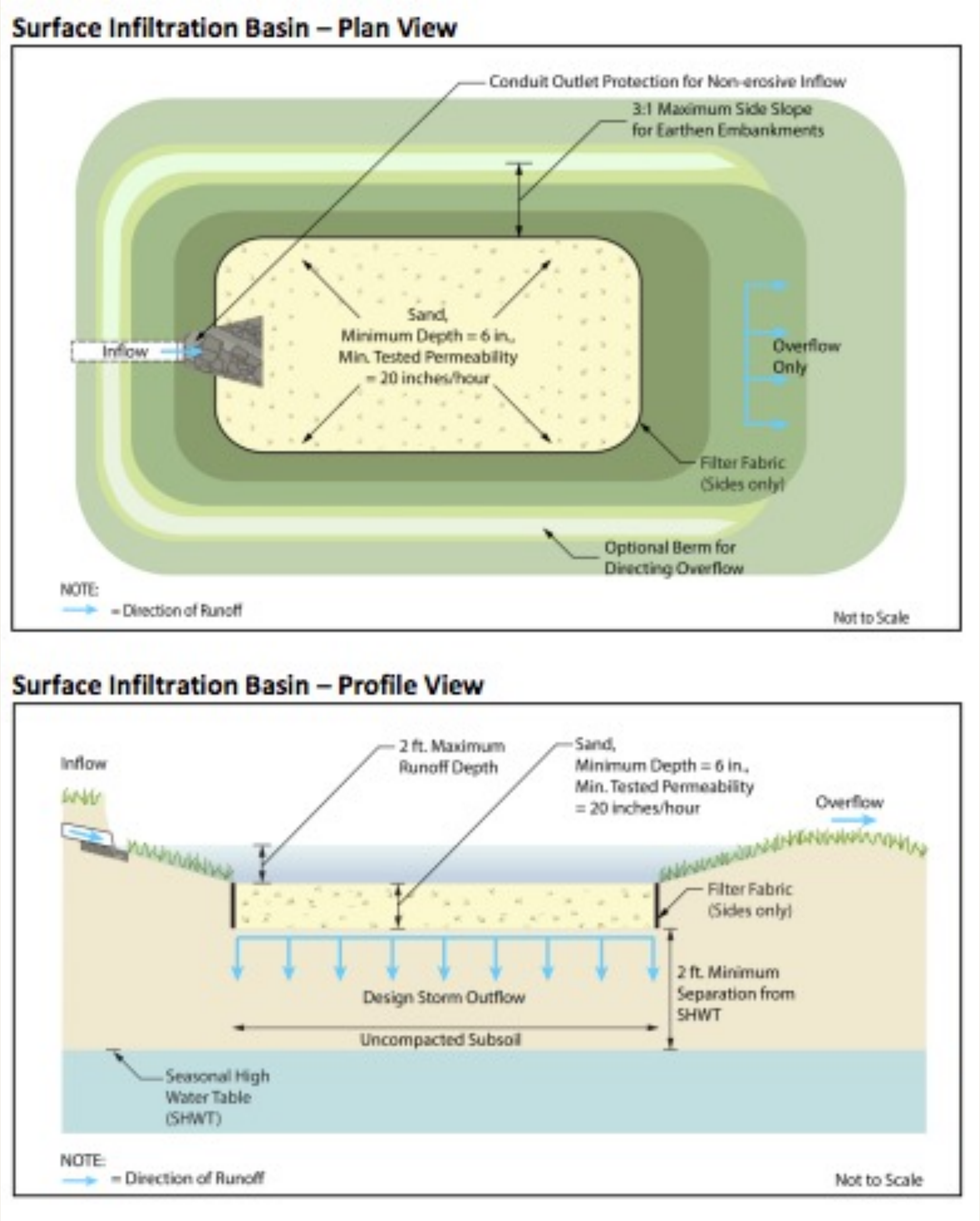
Sediment	Nutrients	Chloride	Metals	Pathogens	Oil and Grease	Organics
▲	✚	▥	▲	▲	▲	▲

▥ Low (<30%) ✚ Medium (30-65%) ▲ High (>65%)

Infiltration Basins

- Advantages
  - *Can help to reduce channel erosion and can capture volume from lower frequency events (i.e. hydrological events with a lower return frequency)*
  - *Easily incorporated into parks or fields*
  - *High pollutant removal*

- Disadvantages
  - *Unsuitable for steep slopes*
  - *High clogging potential and difficult restoration once clogged*
  - *Large area of standing water could breed mosquitoes*



https://www.nj.gov/dep/stormwater/bmp_manual/NJ_SWBMP_9.5.pdf

Dry Swales
with Check Dams

https://chesapeakestormwater.net/events/webcast-advanced-stormwater-design-grass-swales-and-channels/

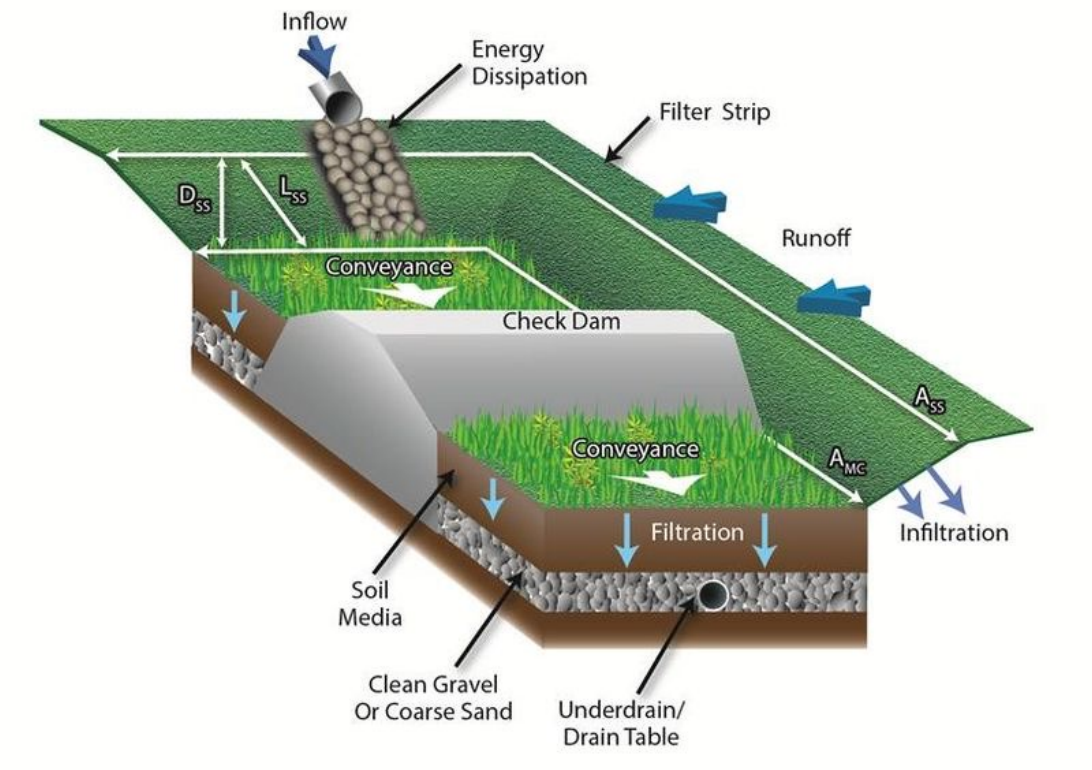
- Dry swales are typically used to slow down peak runoff and convey stormwater to a downstream infiltration basin or a storm drain
  - *Dry swales with check dams place intermediate dams along the swale channel, so that water can infiltrate into each smaller basin created by the dam structures*
- Typically installed alongside long roadways or near impervious parking lots
- Best for lots that are < 1 acre

Constituent Removal

Sediment	Nutrients	Chloride	Metals	Pathogens	Oil and Grease	Organics
▲	▥	▥	▲	✚	▲	▲

▥ Low (<30%) ✚ Medium (30-65%) ▲ High (>65%)

Dry Swales with Check Dams



https://stormwater.pca.state.mn.us/index.php?title=File:Dry_swale_credit_picture_1.jpg

- Advantages
  - *Reduction in peak runoff and channel erosion*
  - *Low capital cost*
  - *Pollution and blockages are easily identified*
  - *Reduce driving hazards by keeping stormwater flows away from street surfaces*
- Disadvantages
  - *Limited to smaller runoff areas*
  - *Not suitable for steep slopes*
  - *Placement next to roadways and parking often leads to damage from off-street parking, deicing, or snow removal*

Permeable Pavement

https://www.mass.gov/service-details/demonstration-3-permeable-paving-materials-and-bioretention-in-a-parking-lot

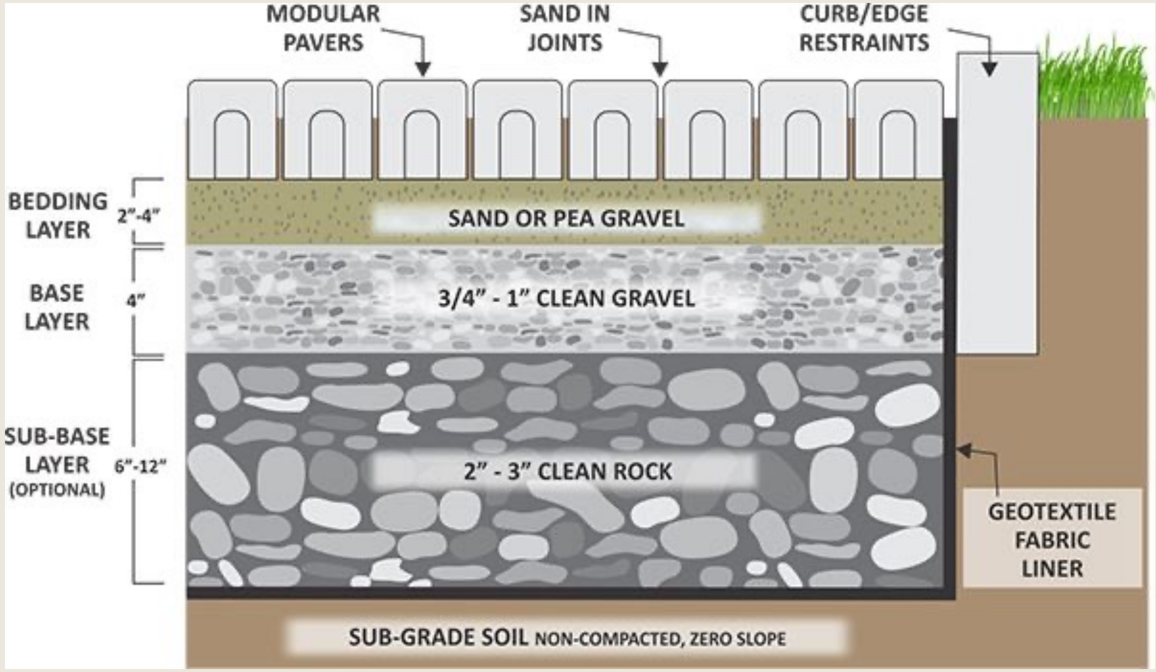
- Permeable pavements are porous surfaces which allow stormwater to filter through the surface into an underlying stone reservoir for infiltration
- Types of material that can be used for permeable pavement include:
  - *Pervious concrete*
  - *Porous asphalt*
  - *Permeable interlocking concrete pavers*
- Underdrains can divert high volume storm events that cannot infiltrate fast enough to storage basins or storm drain systems

Constituent Removal

Sediment	Nutrients	Chloride	Metals	Pathogens	Oil and Grease	Organics
▲	✚	▥	▲	unknown	▲	▲

▥ Low (<30%) ✚ Medium (30-65%) ▲ High (>65%)

Permeable Pavement



https://snohomishcountywa.gov/776/Permeable-Pavement

- Advantages
  - *Functionally and aesthetically pleasing*
  - *Reduces peak runoff for smaller storm events*
  - *Space can be used for dual-purposes (i.e. parking and for stormwater infiltration)*
- Disadvantages
  - *Cost of maintenance or restoration can be high when pores are clogged by sediment*
  - *Installation can result in uneven surfaces that may be difficult to traverse on foot or may do damage to vehicles*
  - *It is not applicable for high-traffic areas or for heavy automobiles/equipment*

Infiltration Galleries

https://wiki.sustainabletechnologies.ca/index.php?title=Infiltration_chambers&mobileaction=toggle_view_desktop

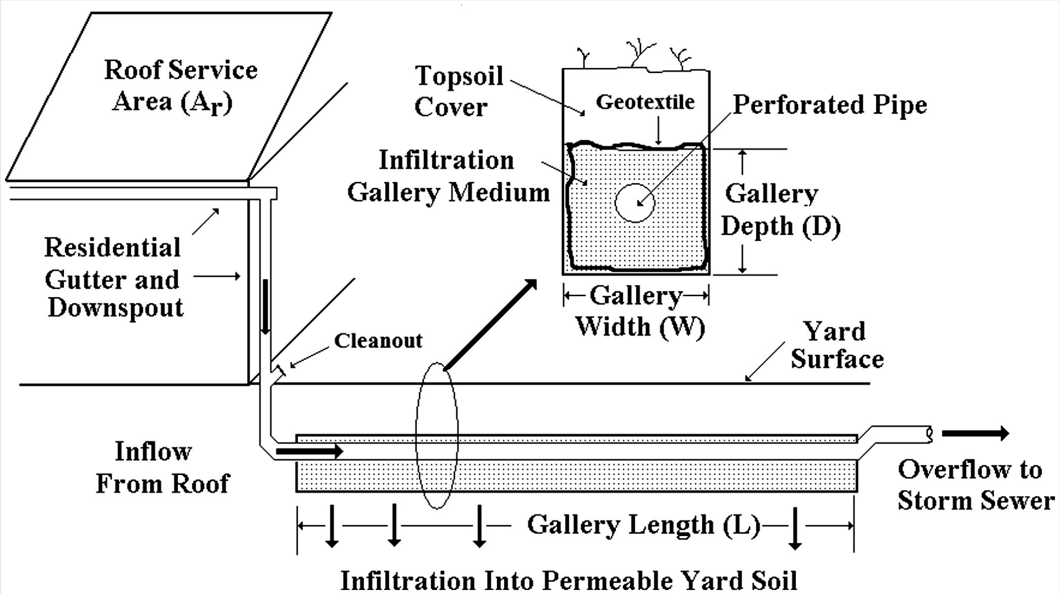
- Infiltration galleries are underground perforated vaults, pipes, or arches that temporarily store stormwater then allow it slowly infiltrate into the surrounding pervious soil
- Stormwater can be diverted from households, street surfaces, or commercial businesses to be stored and treated in galleries offsite
- Galleries can be (and often are) pre-fabricated for relatively easy installation

Constituent Removal

Sediment	Nutrients	Chloride	Metals	Pathogens	Oil and Grease	Organics
▲	▥	▥	▲	✚	▲	▲

▥ Low (<30%) ✚ Medium (30-65%) ▲ High (>65%)

Infiltration Galleries



https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29EE.1943-7870.0001063

- Advantages
  - *Low cost*
  - *Simple construction and modular design for easy installation*
  - *Underground location means surface can be used for other purposes (i.e. parking)*
- Disadvantages
  - *High clogging potential and difficult restoration once clogged*
  - *Maintenance can be difficult if proper access is not included in design plans*

Dry Wells

https://alphaenvironmental.net/drywell/

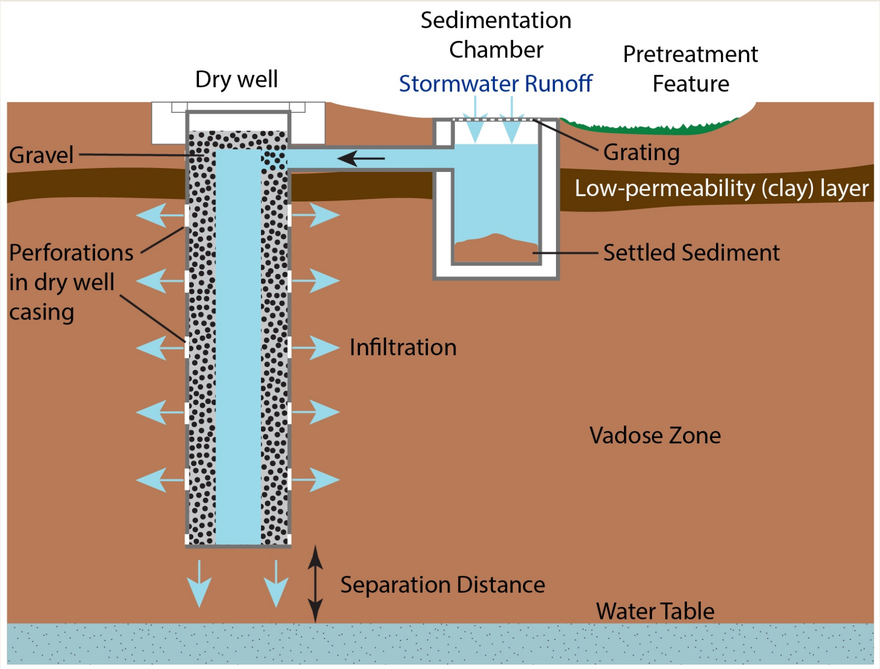
- Dry wells are shafts or bores which are drilled into the soil, and are longer than they are wide
  - *Most are 30-70 ft. deep and approximately 3 ft. wide*
- Most often installed as a means for residences or commercial businesses to infiltrate rooftop stormwater on-site
- Sized and designed to drain over a period of hours or days, typically between 24-72 hours

Constituent Removal

Sediment	Nutrients	Chloride	Metals	Pathogens	Oil and Grease	Organics
▲	✚	▥	▲	▲	▲	▲

▥ Low (<30%) ✚ Medium (30-65%) ▲ High (>65%)

Dry Wells



https://www.americangeosciences.org/geoscience-currents/dry-wells-stormwater-management

- Advantages
  - *Reduction of stormwater flow during light, low-frequency storm events*
  - *Easy installation*
  - *Underground location means surface can be used for other purposes*

- Disadvantages
  - *Usually require pretreatment*
- Most modern dry wells incorporate a sedimentation chamber to avoid premature clogging
- Even with pretreatment, there is a high potential for clogging— restoration is difficult once clogged
  - *Regulations - the differentiation between an injection well and a dry well is not well-defined. Injection wells are heavily regulated, and it is often unclear whether dry wells are subject to the same regulatory frameworks governing injection well use. Regulatory roadblocks may discourage dry well use.*

Los Angeles River Watershed

https://www.thenation.com/

LA River Watershed: Background

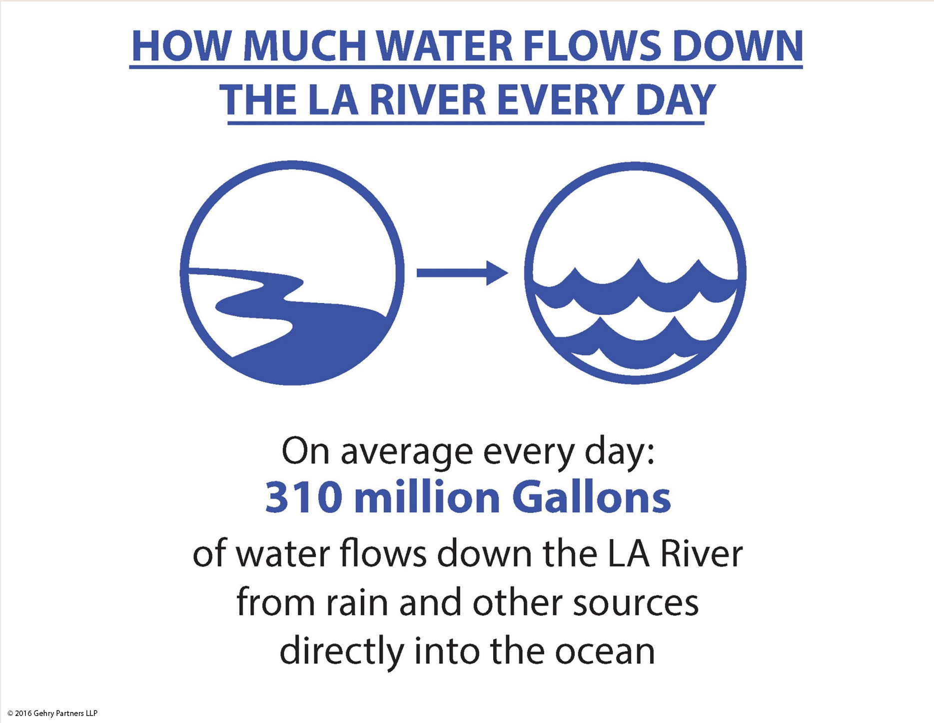
- 834 square miles (533,800 acres)
- 9-million+ population served
- Over 40 communities exist in the region
- Management is overseen by state and local authorities
  - *California State Water Resources Control Board (SWRCB)*
  - *Los Angeles Department of Water and Power (LADWP)*
  - *Los Angeles Department of Sanitation*

www.kcet.org

LA River Watershed: Relevant Facts

- Los Angeles River's main sources of water are 3 treatment plants
- Increasing reliance upon groundwater recovery and other sources, to supplement city's growth
- Mediterranean Climate
  - *Annual rainfall: 14 inches*
  - *Mean annual temperature:*

    63 degrees Fahrenheit



riverlareports.riverla.org

LA River Watershed: Threats to System

Rapid growth and urbanization

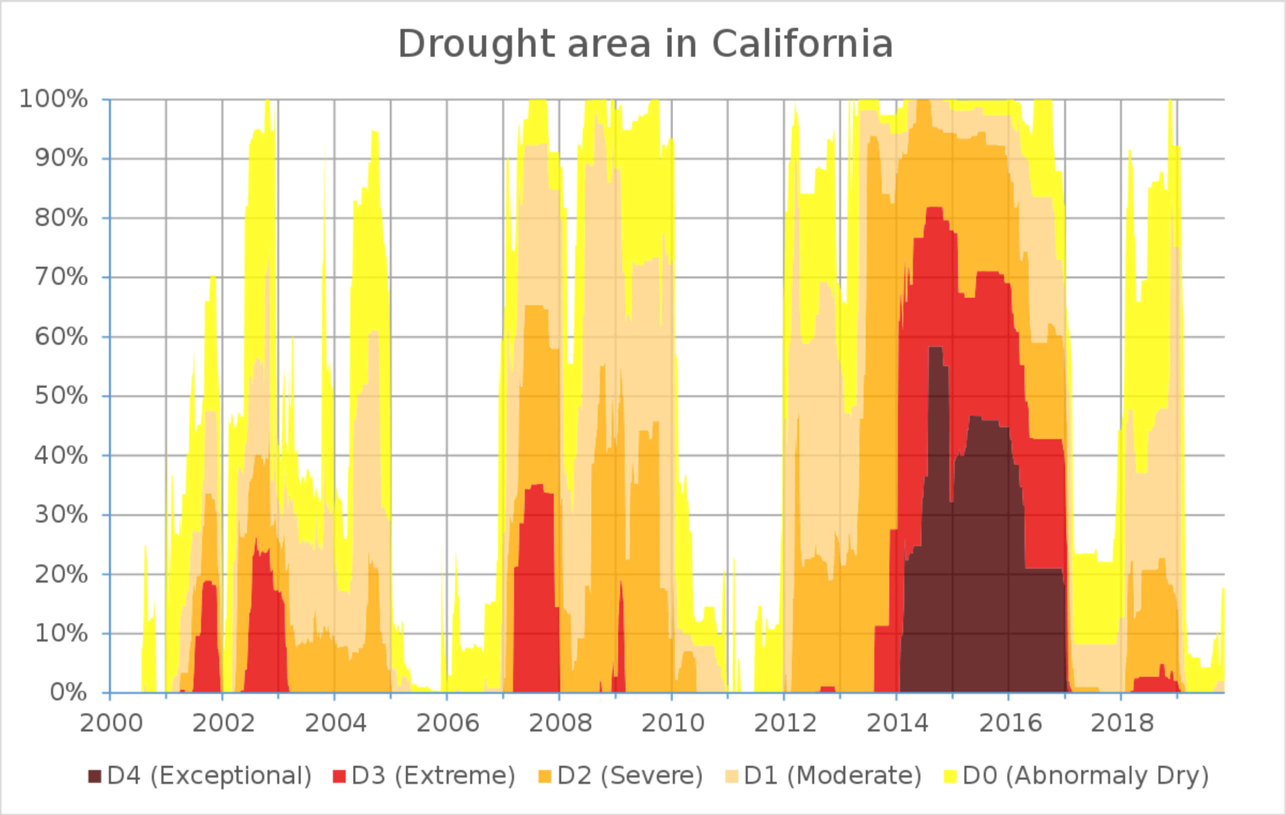
Extreme climate variability

- Periods of extended drought
- Flooding during wet years

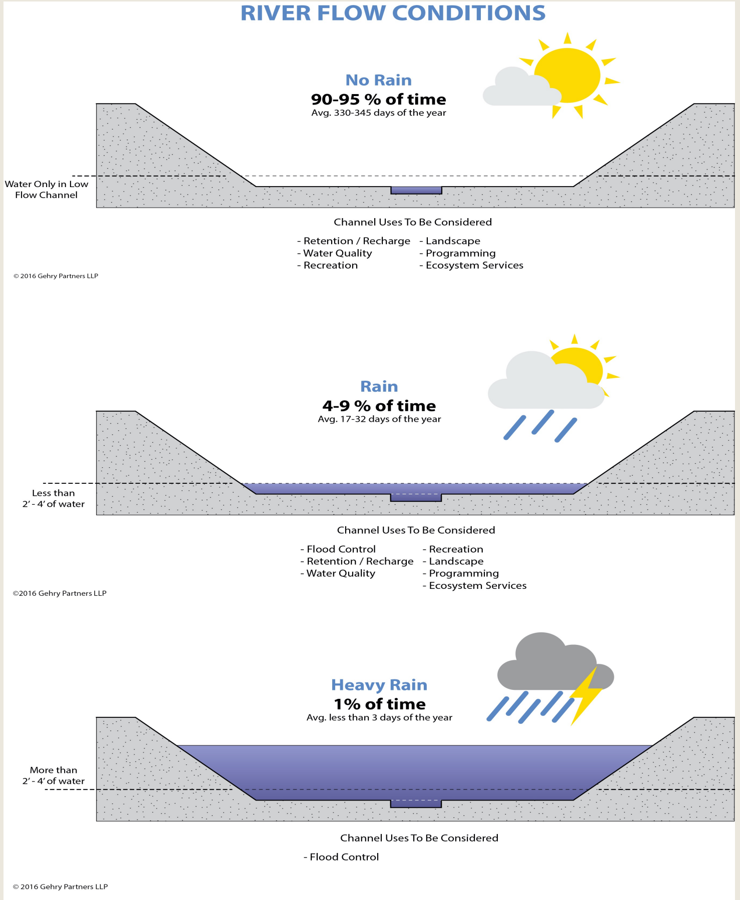
Climate change forcing on sources of imported water

- Sierra Nevada snowpack is decreasing
- Snowpack peak runoff shifts to earlier in year
- Decreasing volume of Colorado River

LA River Watershed: Threats to System



http://droughtmonitor.unl.edu/Data/DataTables.aspx

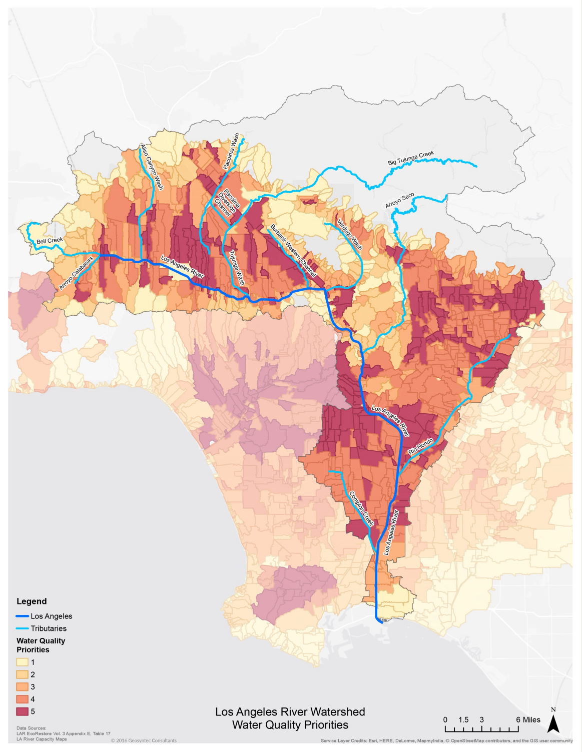


http://riverlareports.riverla.org/flood-risk-management/

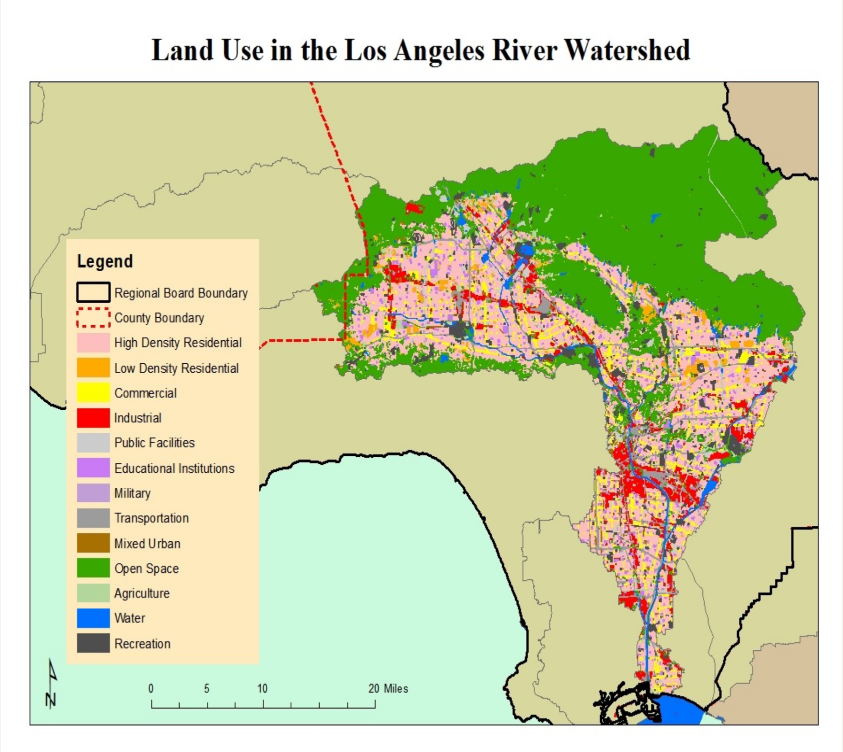
LA River Watershed: Focal Points

- Side-by-side comparison of regions with diminished groundwater quality vs. land use regions shows that primary areas of concern are residential

- Managed aquifer recharge (MAR)
- Increase groundwater table (GWT) levels
- Mitigate contamination



http://riverlareports.riverla.org/



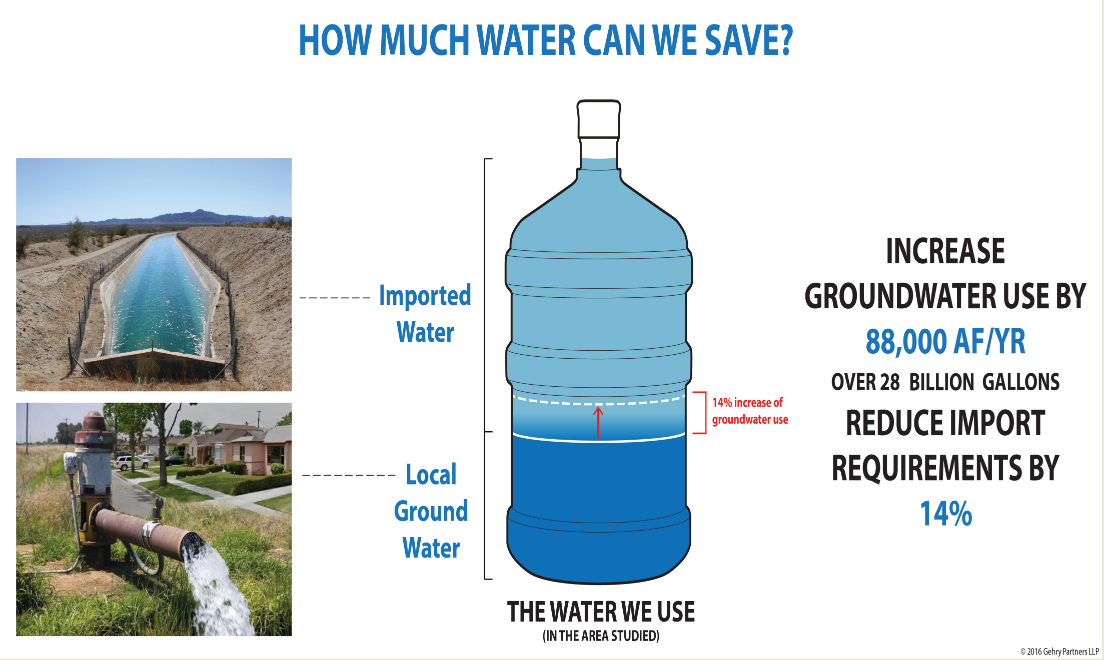
https://www.waterboards.ca.gov/losangeles/water_issues/

LA River Watershed: Stormwater Capture and Management

- **Objectives:**
  - *To reduce, capture, infiltrate and/or treat stormwater runoff for 0.5 to 0.75-inch storms on developed land*
  - *Improve water quality and meet TMDLs*
  - *A portion of this treated stormwater could be applied to augment water supplies*

- **Opportunities for Improvement:**
  - *Develop multipurpose TMDL solutions including treatment, filtration, and natural treatment modalities*
  - *Retrofit existing publicly owned lands for stormwater capture either above or below ground*
  - *Develop joint-use capture facilities and joint-use recharge facilities*
  - *Expand river corridors to include more area for riparian habitat and stormwater storage*

LA River Watershed: Opportunities for Improvement

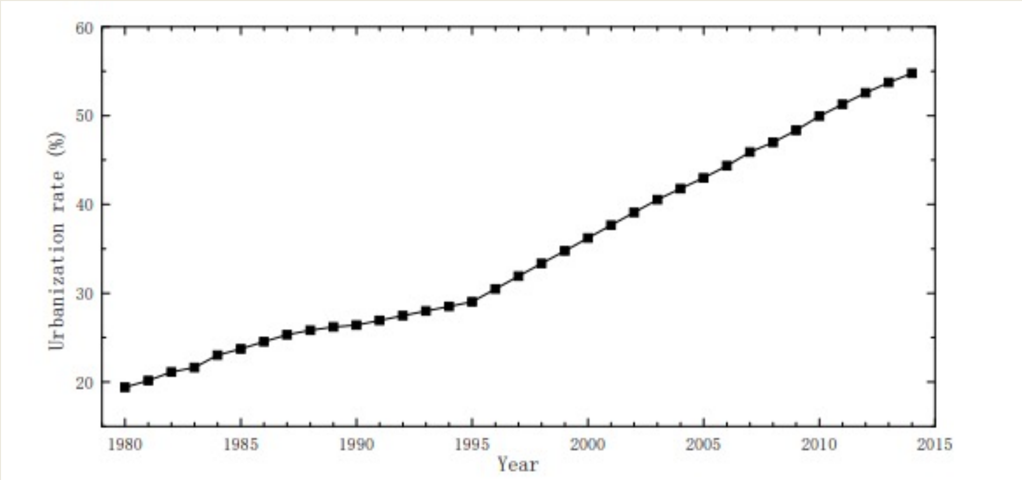


http://riverlareports.riverla.org/water-quality/water-quality-improvements/

Case Studies

“Sponge Cities”, China

- Over the past 30+ years, southeast China has undergone rapid urban development
- – *Development increased impermeable surfaces*
- – *Groundwater aquifers across the country were showing signs of depletion due to population increases*

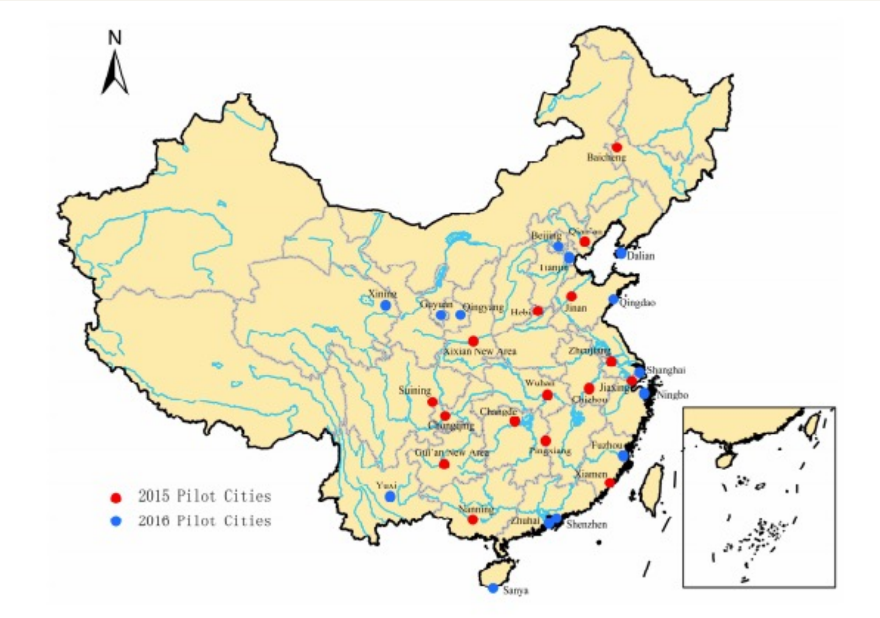


https://www.mdpi.com/2073-4441/9/9/594

Sponge City, China

- Wuhan, Hubei, China is in a low-lying area and is subject to frequent storms during monsoon season
  - *In the mid-2000's, 14 people died from flooding. An economic crisis later followed because portions of the city were completely inundated by stormwater, and flooding blocked transportation routes for goods, services, and people.*
  - *Wuhan was the first of the 16 cities in China to join the Sponge City Program*
- Sponge Cities are used to evaluate new stormwater control measures

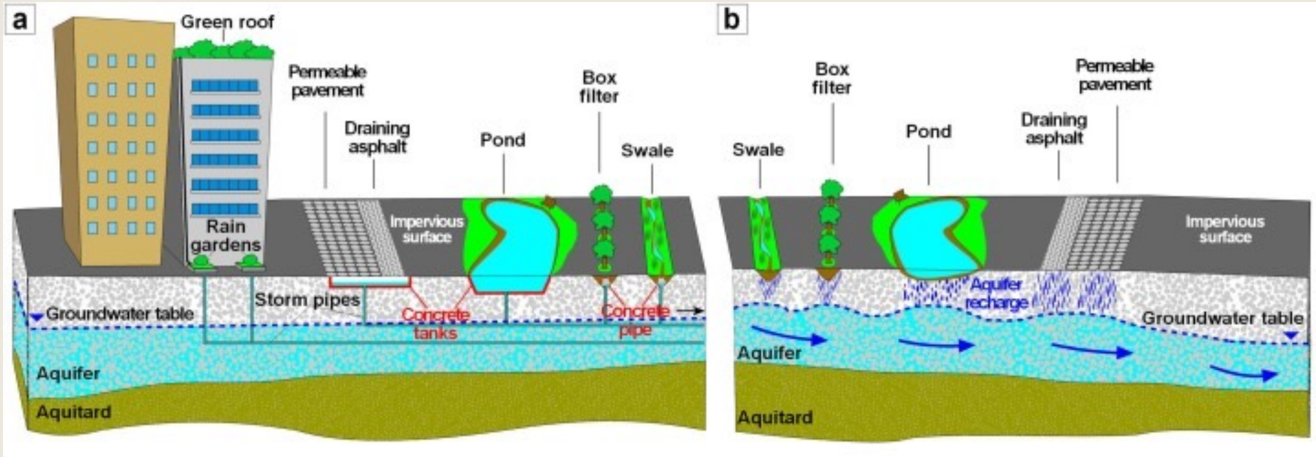
https://www.theguardian.com/cities/2019/jan/23/inside-chinas-leading-sponge-city-wuhans-war-with-water



https://www.mdpi.com/2073-4441/9/9/594

Sponge City, China

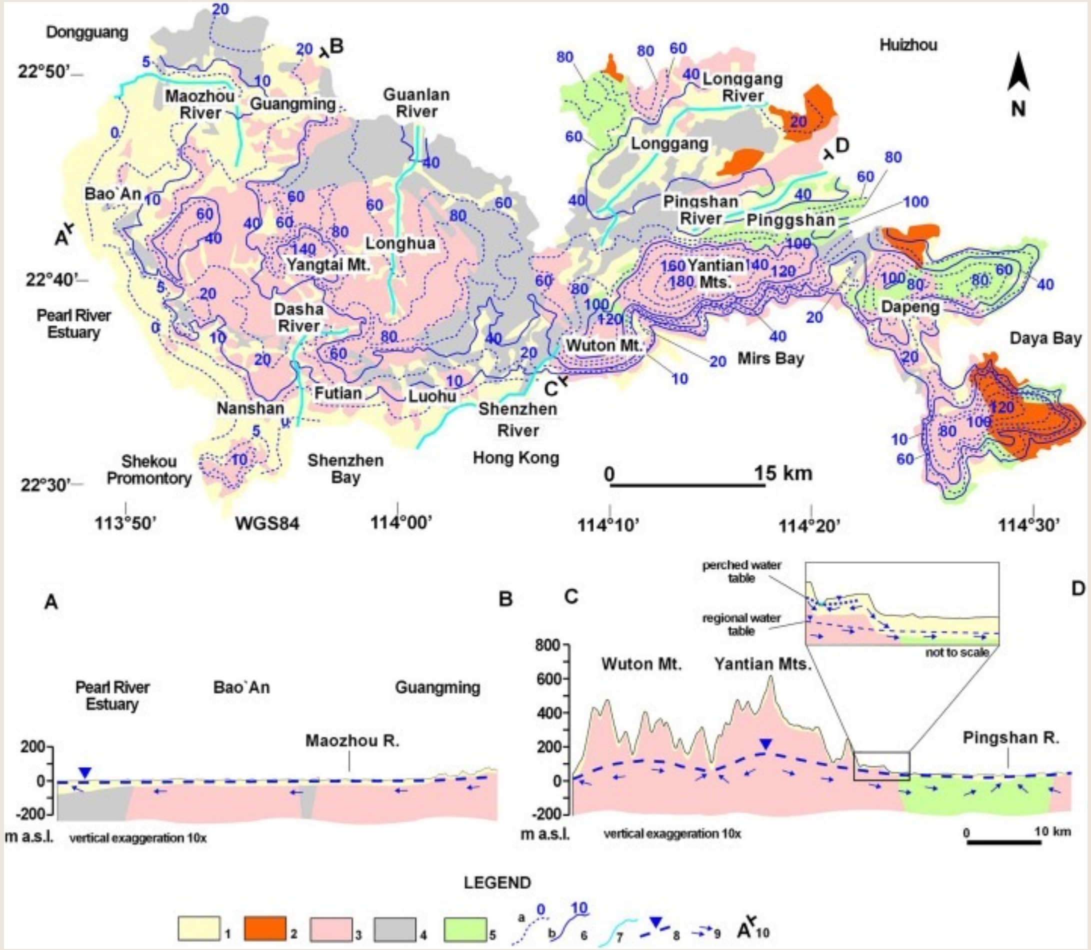
- Researchers (Lancia et al.) investigated the use of infiltration BMPs, to reduce the cost of the overall project and determine if groundwater recharge was a viable option
- Urban areas close to the coastal plain or built upon reclaimed land developments require above-ground measures. Infiltration cannot be used. However, geological studies showed there were several Sponge Cities that had the potential for groundwater recharge. These cities are currently piloting infiltration BMPs.



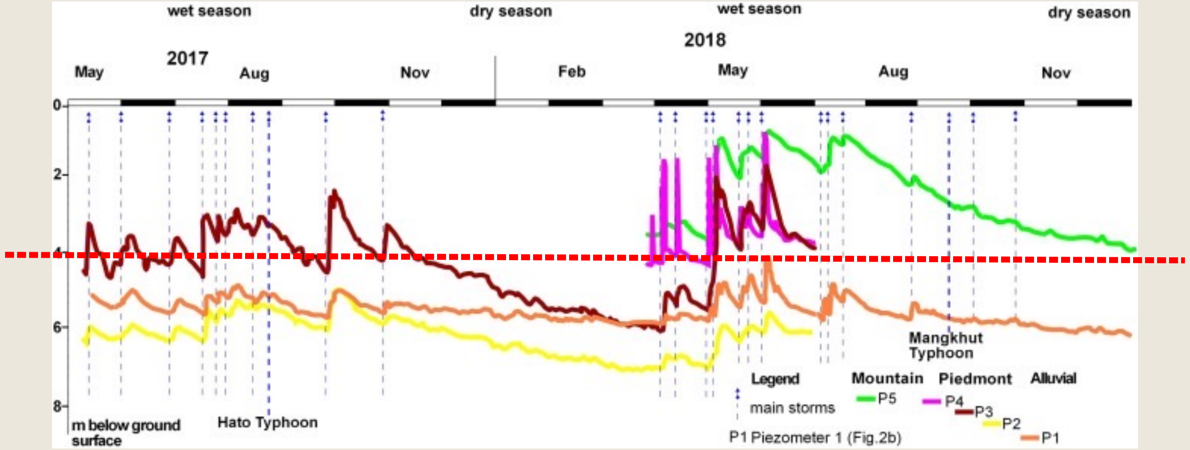
a – Original Sponge City concept without Infiltration BMPs, **b** – modification to Sponge City concept to cities with appropriate geology

https://www.sciencedirect.com/science/article/pii/S2214581819303222

Sponge City, China



https://www.sciencedirect.com/science/article/pii/S2214581819303222



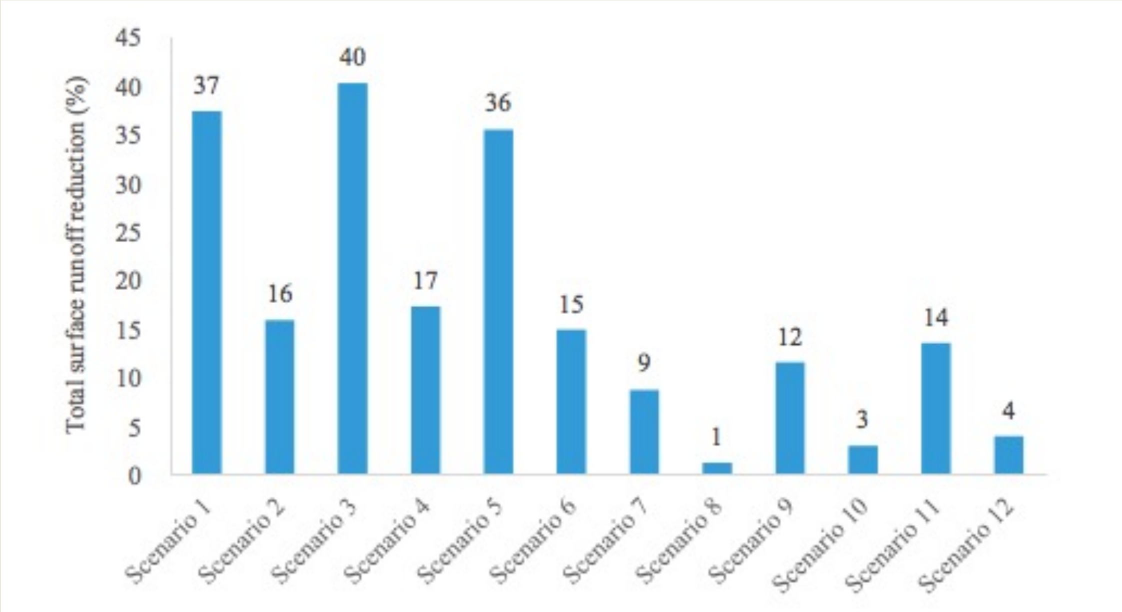
https://www.sciencedirect.com/science/article/pii/S2214581819303222

- A significant limiting factor for groundwater recharge potential was the groundwater level. Regions with high GWT levels are likely inappropriate for infiltration BMPs
  - Recommended minimum water table depth is 4 meters (~13 feet)

Sponge City, China

- To date, the preferred infiltration method for Chinese Sponge Cities is **permeable pavement**
  - *Permeable pavement has begun to show promising results in the reduction of runoff throughout several of the pilot cities*

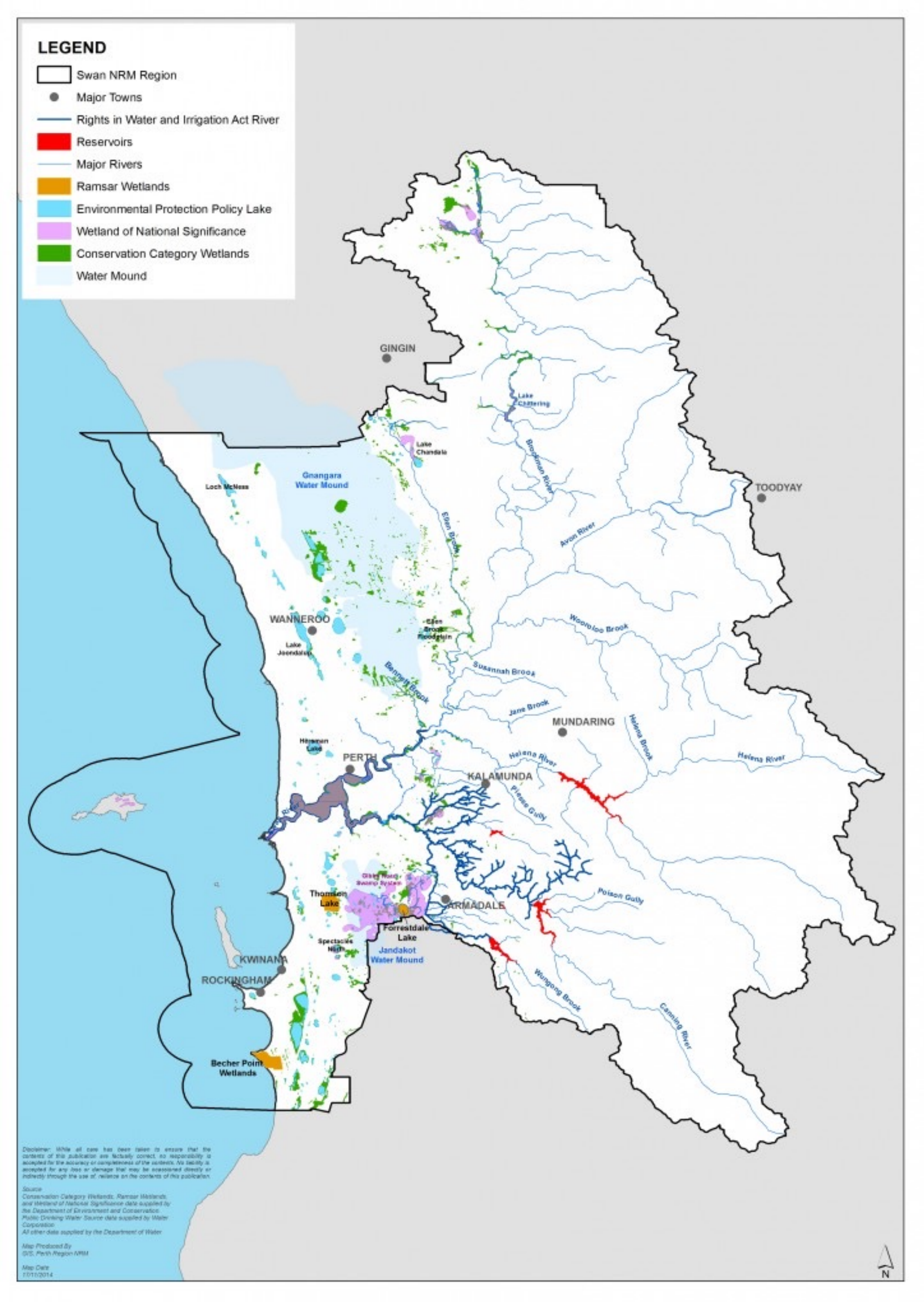
https://e2designlab.com.au/blog/i_2017-12-05-sponge-cities-chinas-green-blue-approach-to-urban-water-management



https://www.mdpi.com/2073-4441/10/2/172

Perth, Western Australia

Watershed	Swan-Canning Catchment
Surface Area	807 sq. miles (516, 500 acres)
Population Served	2.6 million people
Land Use	• Residential & Business • Agriculture & Farming
Pollutants of Concern in Stormwater	Coarse Sediment, TSS, Nutrients, Metals, Pathogens



http://www.swanregionstrategy.com.au/assets/water

City Water Stories:
Perth

Population

- Current population 24,244 (ABS ERP 2015).
- By 2031, Perth is forecast to have an additional 14,452 new residential dwellings (based on 2006 figures) and 1.2 million m2 of non-residential space, with close to 60% population growth by 2036.

Geography

- Located on the Swan Coastal Plain.
- Local government area of 19.37km^2.

Main challenges

- Water scarcity; extreme weather events; excessive urban heat; and sea level rise.

Main solutions

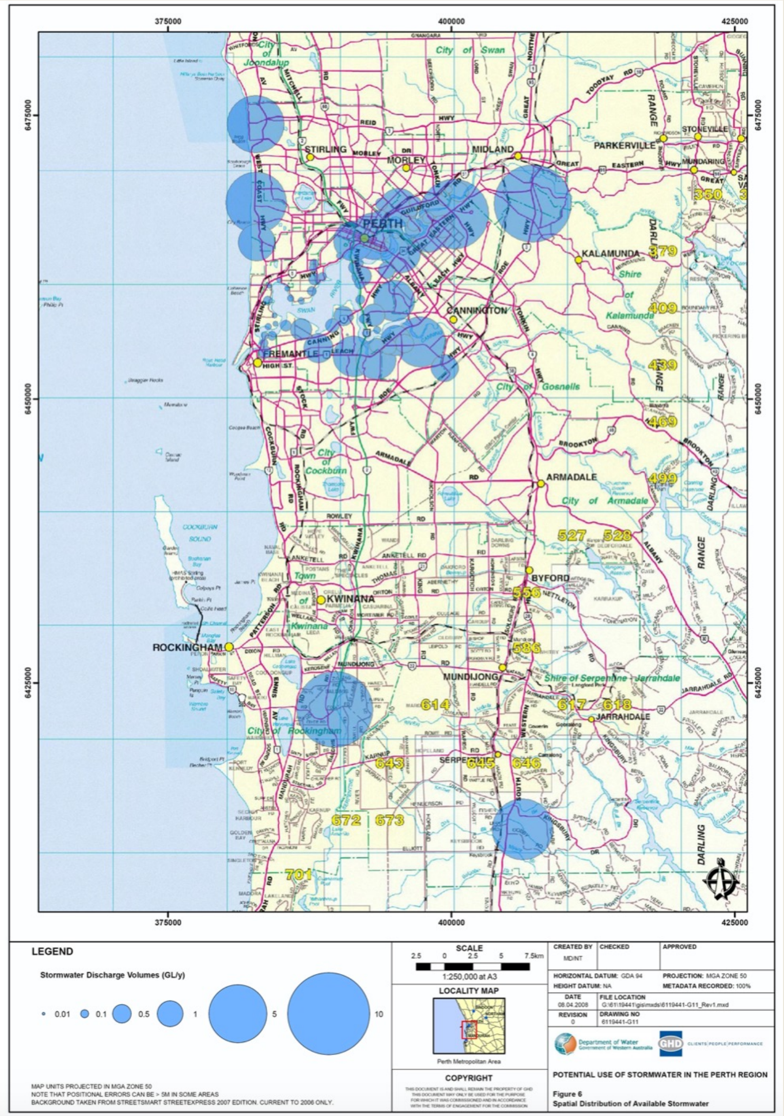
- Promote the reduction of potable water use; identifying fit for purpose opportunities; investing in stormwater capture and reuse infrastructure; identifying alternative water sources; integrating green infrastructure; and employing a treatment train to manage nutrients and pollution.

https://iwa-network.org/

Background & Relevant Facts

- Perth—Western Australia's capitol—is heavily urbanized and growing
- Groundwater aquifers supply nearly half of region's water demands
- Bound to the west by Indian Ocean, to the east by the arid Australian Outback
- Mediterranean Climate
  - *Annual rainfall: 15-25 inches*
  - *Mean annual temperature:*

    65 degrees Fahrenheit



https://www.water.wa.gov.au/planning-for-the-future/

Threats to Perth's Water System

- Rapid *population growth* and *urbanization*
- The region sees extended periods of *drought* on a decadal basis, with intermittent *flooding*
- Land subsidence due to excessive extraction from aquifers
- Rainfall has declined almost 20% since the 1970s
- Projected further *decrease* in annual rainfall amounts
- Projected *increase in evapotranspiration* rates
- *Sea level rise* increases threat of saltwater intrusion into groundwater

Perth's Action Plan

Basin Connected Cities

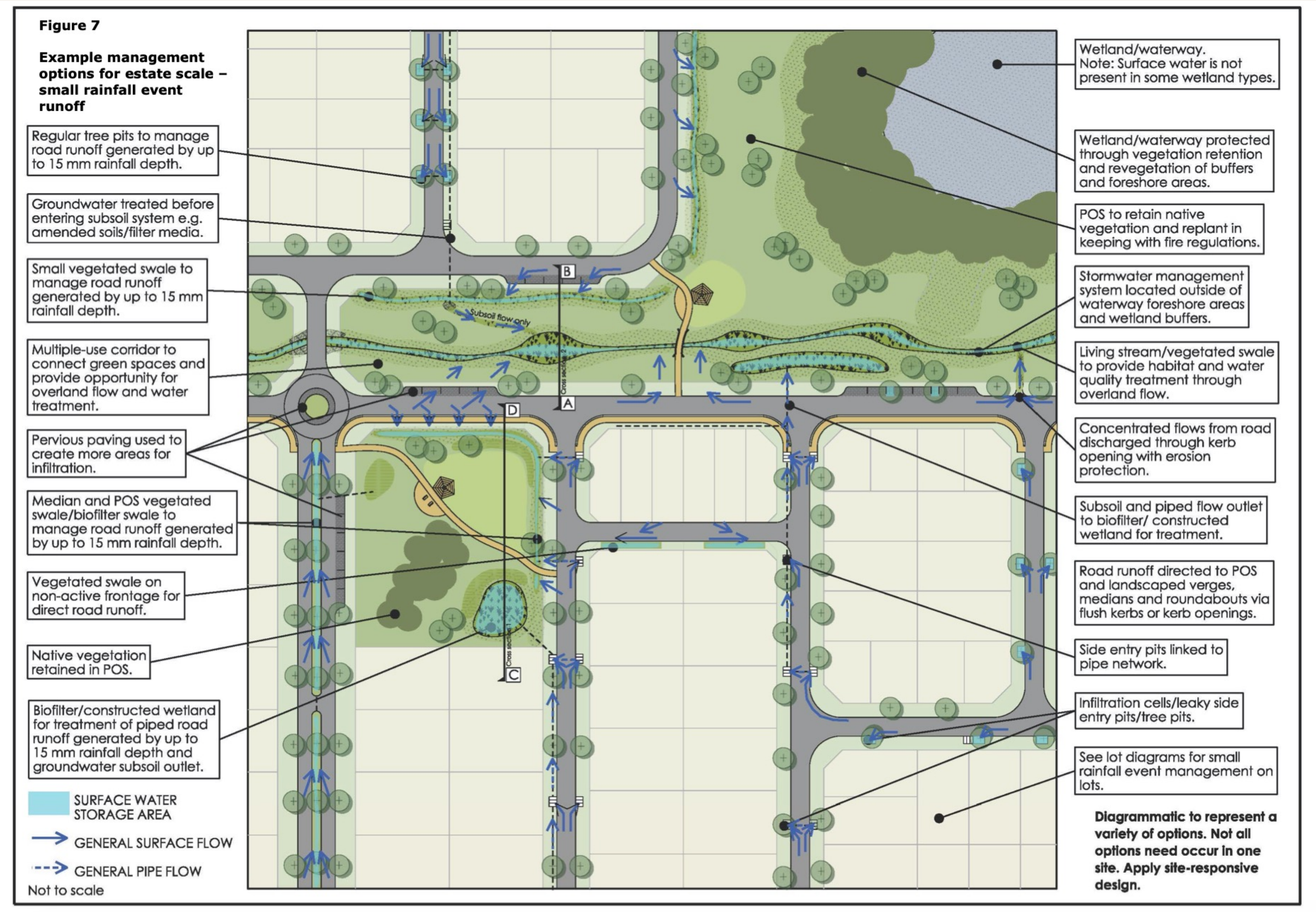
- Complete a Water Sensitive City Transition Study
- Monitor and improve water quality discharging into the river and wetlands
- Construction of Point Fraser water quality treatment wetland
- Signatory to the WALGA Declaration on Climate Change and Compact of Mayors

Water Sensitive Urban Design

- Review and improve design guidelines, approvals processes, incentives and compliance mechanisms to facilitate environmentally sustainable design and improve environmental performance of new buildings
- Work with stakeholders to prepare for, and positively adapt to, climate change risks through creation of natural spaces, facilitation of climate responsive built form, and risk mitigation strategies
- Strengthen community connection and increase community access to the natural environment
- Implement an Urban Forest Plan

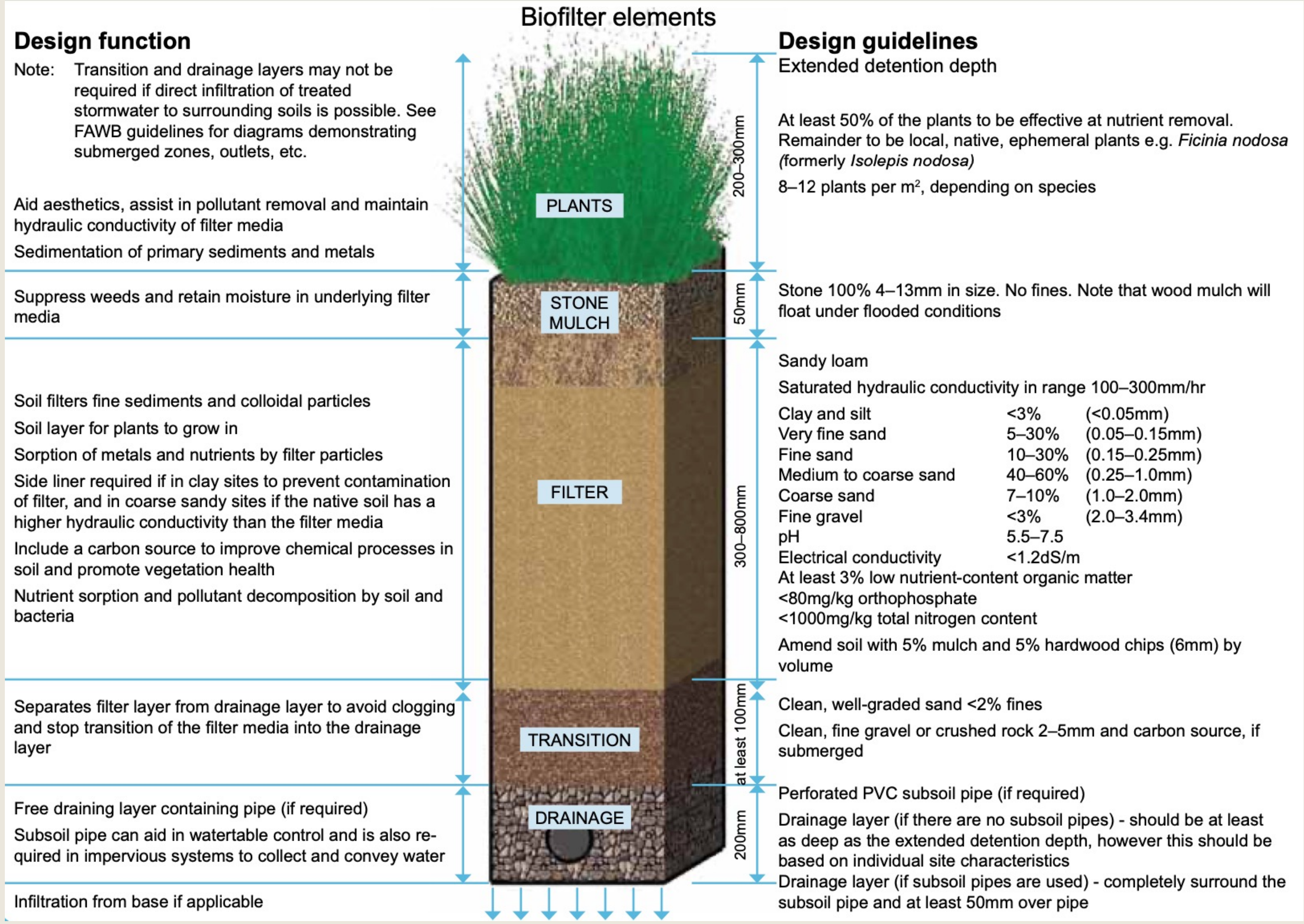
https://iwa-network.org/city/perth/

Managing rainfall events at source



https://www.watercorporation.com.au/

Perth Methods: Biofiltration

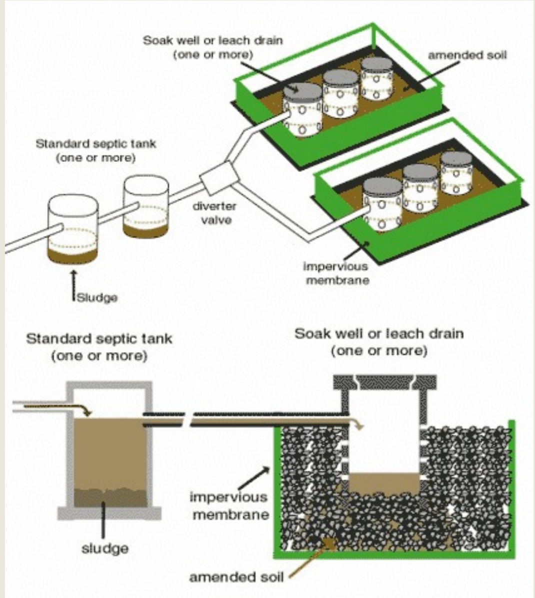


https://www.water.wa.gov.au/

- Systems are integrated into LID schemes
- Allow nutrient stripping and sedimentation prior to infiltration
- Excellent for urban areas and/or those prone to prolonged dry spells
- Includes swales, rain gardens, and bioretention basins
- Can be combined for more effective treatment and peak runoff prevention, e.g. rain garden draining into bioretention basin

Perth Methods: Dry wells

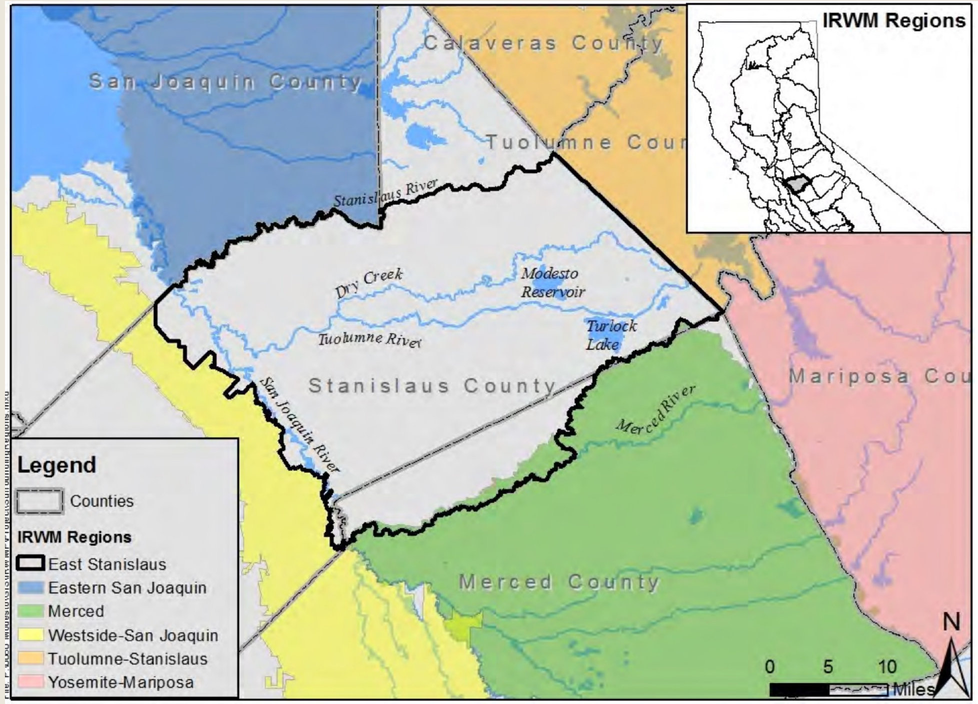
- Widely used in Western Australia
- Can be incorporated into small-scale residential and commercial developments or installed by retrofitting
- Standard design incorporates use of a septic tank
- Usually amended with geofabrics or geotextile layers to maximize treatment abilities and soil separation
- Encourages infiltration of small rainfall events (<1 inch) at or near source

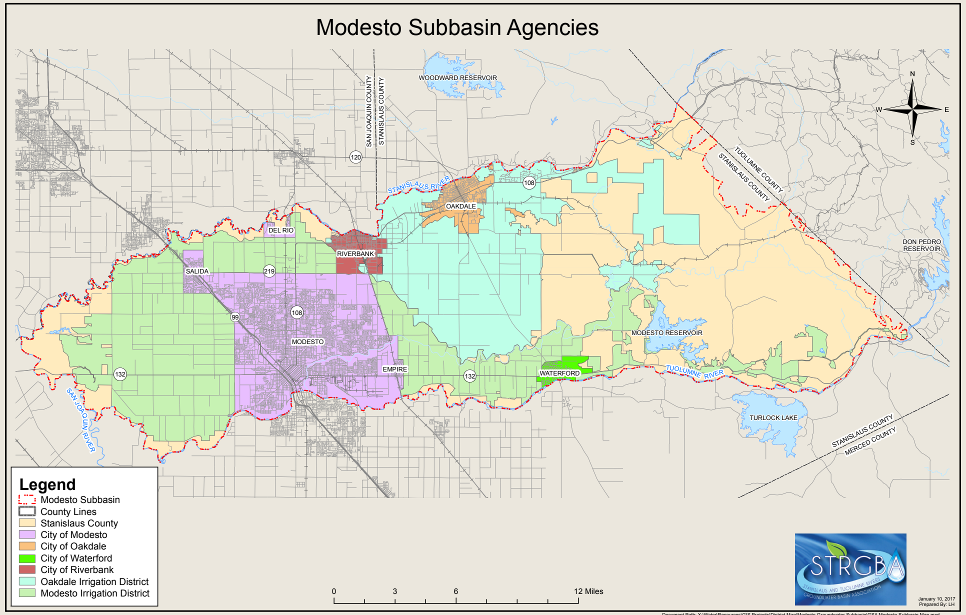


https://www.water.wa.gov.au/
https://www.researchgate.net/

Modesto, California

Watershed	San Joaquin Hydrologic Region – Modesto Sub basin
Surface Area	392 sq. miles (250, 850 acres)
Population Served	300,000
Land Use	• 56% Irrigated • 15% Urban • 29% Non-Irrigated
Pollutants of Concern in Stormwater	Toxic Metals, TDS, Nutrients, Diazinon, Pathogens



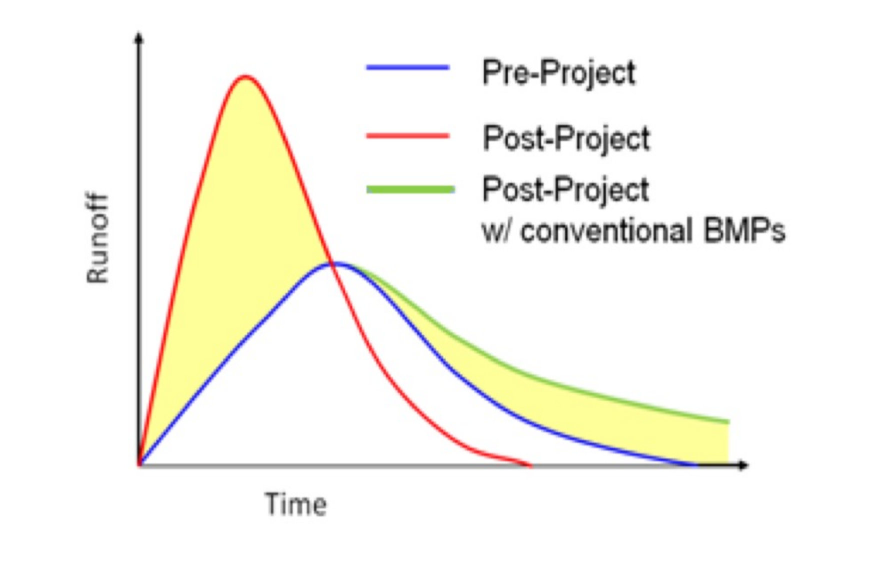


http://www.stancounty.com/publicworks/pdf/water-atlas.pdf
https://www.modestogov.com/

Background & Relevant Facts

- Modesto is densely-populated and its population is rapidly growing
- The urban landscape of Modesto is nearly surrounded by agricultural land use areas
- Bound to the north and south by the Stanislaus and Tuolumne Rivers, to the west by the San Joaquin River
- Semi-arid climate
  - *Annual rainfall: 13 inches*
  - *Mean Annual Temperature:*
    64 degrees Fahrenheit

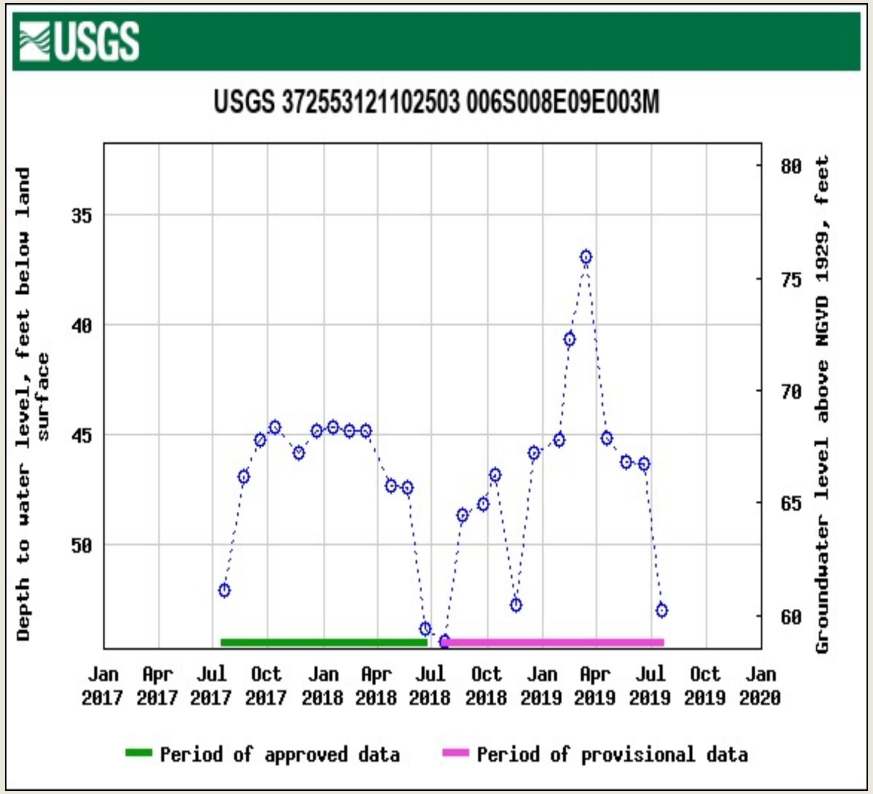
The goal of Modesto's stormwater management is to mimic the natural (pre-project) hydrograph—reduction in peak runoff volume and flow.

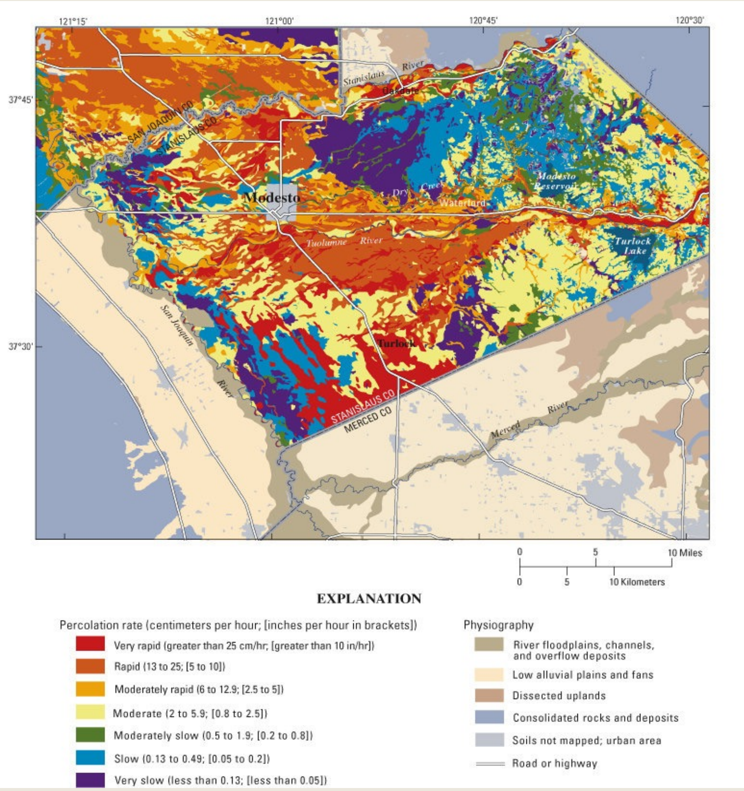


https://www.modestogov.com/

Water Table & Soil Characteristics

The water table is sufficiently low for multiple infiltration modalities





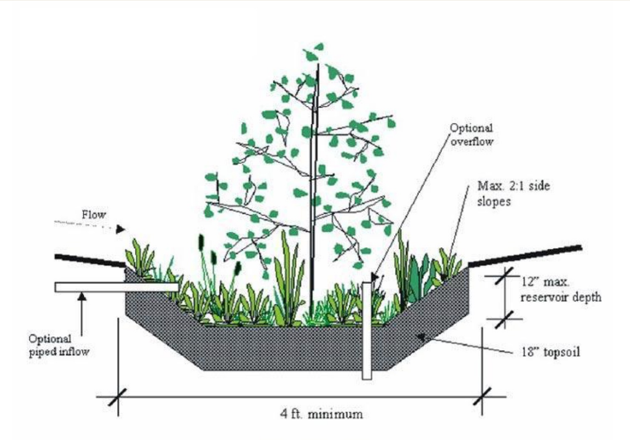
The soil in the region promotes moderate-to-rapid percolation

https://nwis.waterdata.usgs.gov/ca/

https://www.researchgate.net/

Bioretention without an Underdrain

- Designed to receive, retain, and infiltrate stormwater runoff from downspouts, piped inlets, or sheet flow from adjoining paved areas
- Advantages
  - *Low installation cost*
  - *Enhances site aesthetics*
  - *Easy maintenance*
- Disadvantages
  - *Not appropriate for industrial sites or locations with contaminated soils or where spills may occur*
  - *Will require individual owner/tenants to perform maintenance*

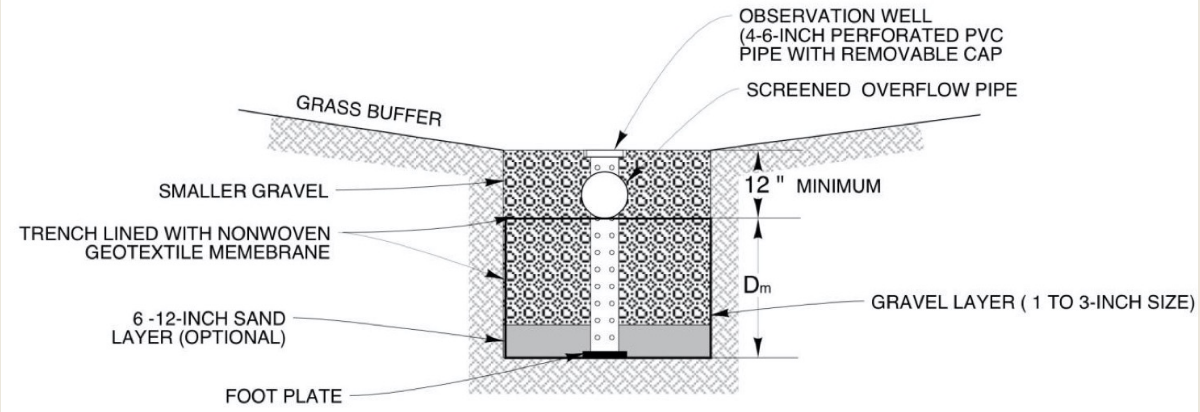


Design Parameter	Design Criteria	Notes
Ponding zone depth (D_{pz})	12 in	Maximum depth above top mulch layer
Top mulch layer depth	2-3 in	Mulch, softwood, or shredded hardwood
Planting media depth	12-24 in	Mix 60-65% loamy sand + 35-40% compost; or 30% loamy sand + 30% course sand + 40% compost
Excavation side slope (H:V)	2:1	Maximum steepness

https://www.modestogov.com/

French Drains

Design Parameter	Design Criteria	Notes
Tributary drainage area	≤ 5 acres	
Design volume	WQV	See Fact Sheet C-2
Drawdown time for WQV	48 hr (maximum)	
Soil permeability range	0.6-2.0 in/hr	Saturated vertical permeability
Groundwater separation	10 ft (minimum)	Between water quality infiltration trench bottom and historical seasonally high groundwater table
Trench surcharge depth (D_{max})	10 ft (maximum)	
Setbacks	100 ft	From wells, tanks, springs
	20 ft	Down slope from foundation
	100 ft	Up slope from foundation
Trench media material size/type	1-3 in	Washed gravel or manufactured percolation tank modules
Trench lining material	–	Geotextile fabric (see Table 8-8) prevents clogging
Observation well size	4-6 in	Perforated PVC pipe with removable cap
Pretreatment vegetated buffer strip length	10 ft (minimum)	Length in flow direction
Pretreatment vegetated buffer strip slope	5% (maximum)	Slope in flow direction



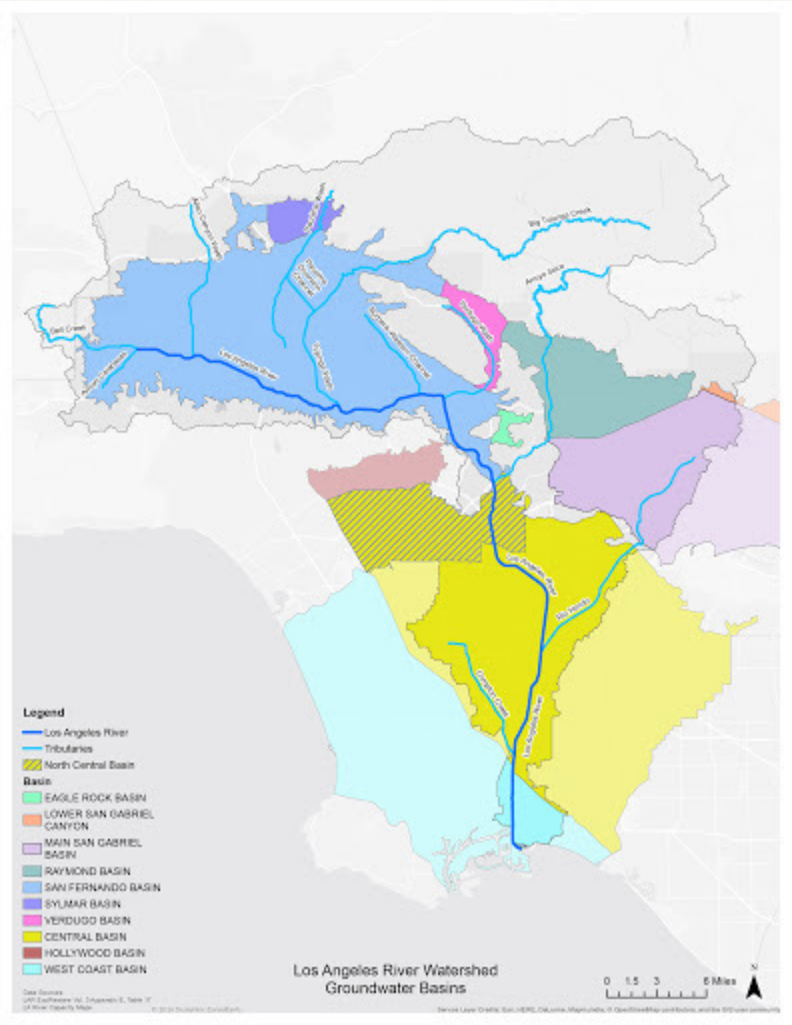
https://www.modestogov.com/

- Can be modified with use of manufactured percolation tank modules in place of gravel fill
- Can also be installed below the surface (infiltration gallery)
- Pretreatment is required using grassy channels, vegetated buffer strips, or swales is required to protect water quality infiltration trenches from high sediment loads

Application of Infiltration BMPs on the LA River Watershed

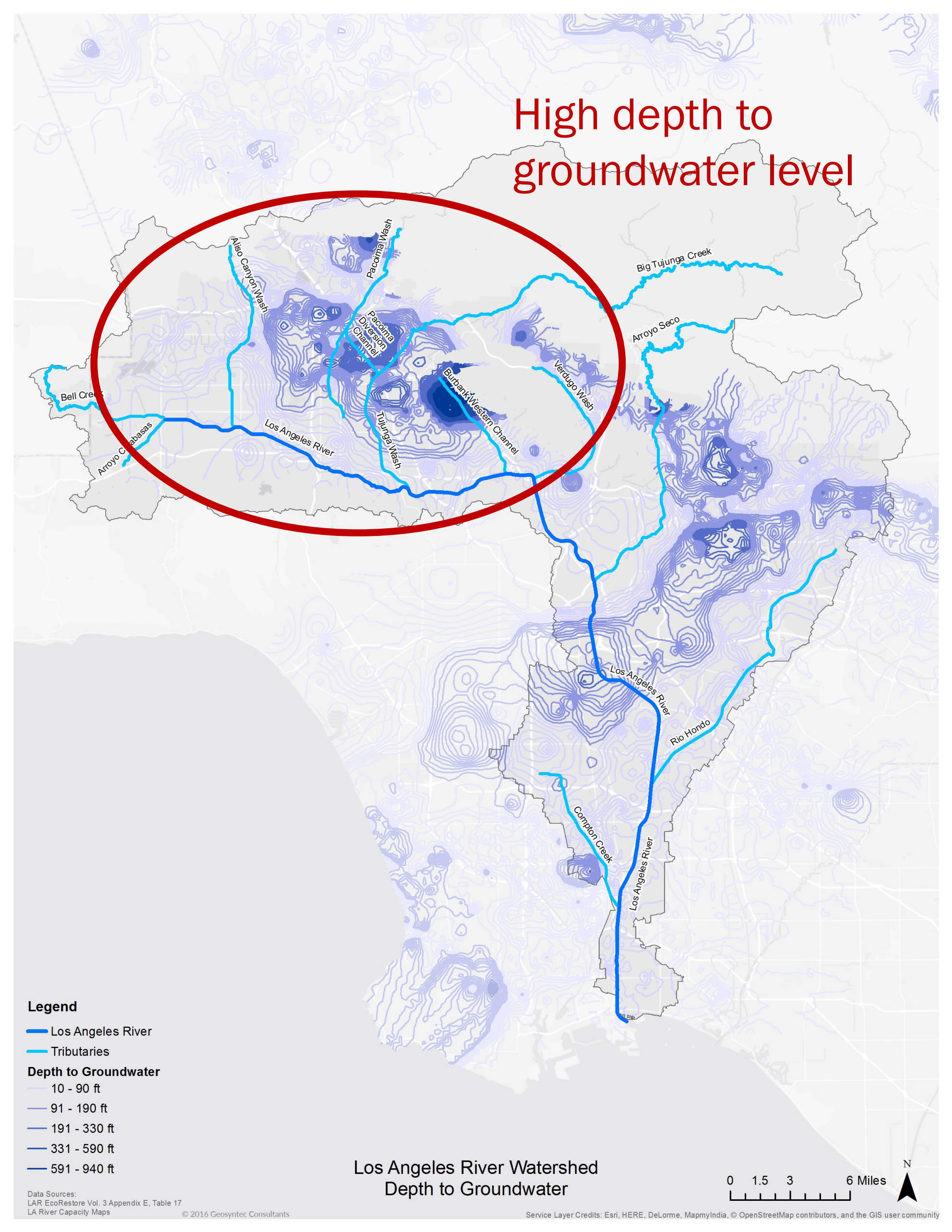
Infiltration BMPs in Los Angeles

- For the past 50 years, groundwater replenishment on the Los Angeles River watershed has averaged approximately 70,000 acre-feet per year (AFY)
- Approximately 50% of stormwater in Los Angeles is diverted to the ocean
- The three largest aquifers on the watershed are the San Fernando, West, and Central Basins and they have a total capacity of 3.1 million AF of storage
- **The San Fernando Basin may be the best location to use infiltration BMPs**
- 1) It is an unconfined aquifer, where water can easily infiltrate to the subsurface
- 2) The basin has a large storage capacity (500 AF)
- 3) Depth to the GWT is generally high
- 4) Soil generally has high hydraulic conductivity

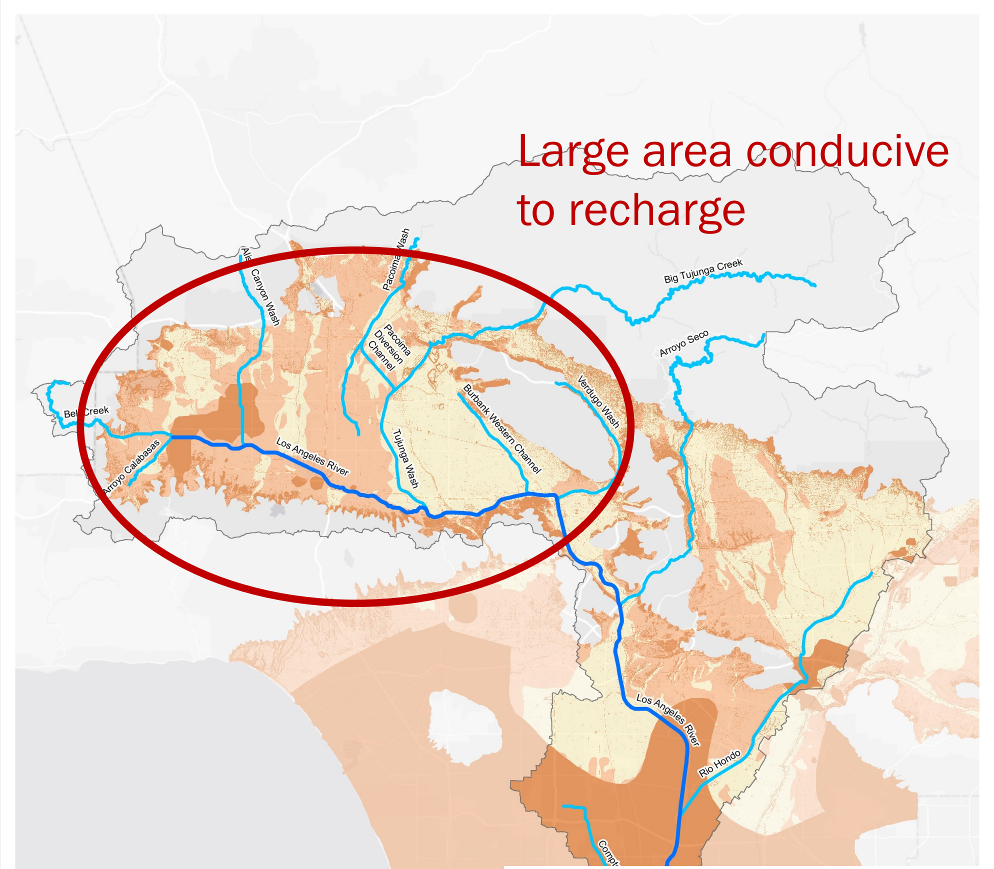


http://riverlareports.riverla.org/water-recharge/aquifers/

High depth to groundwater level



Large area conducive to recharge

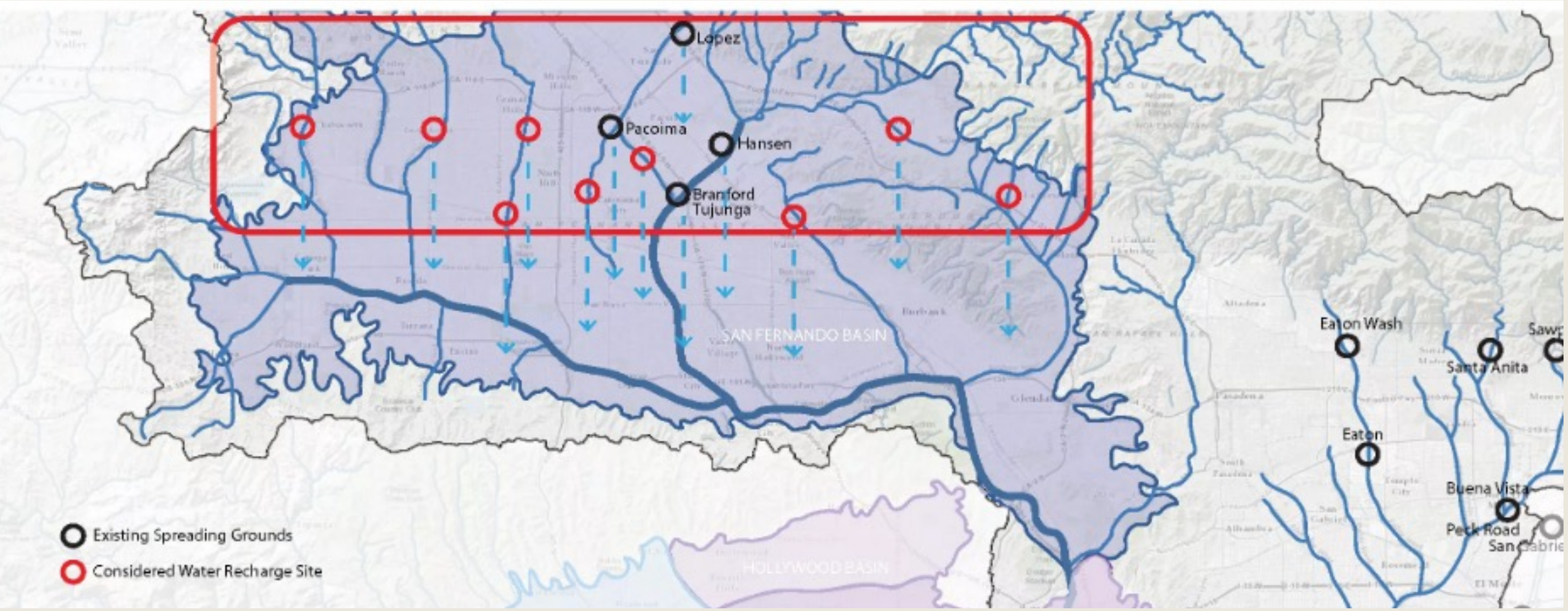


Large capacity

http://riverlareports.riverla.org/water-recharge/where-to-recharge/

San Fernando Basin Infiltration BMPs

- LA County already manages several spreading basins for stormwater infiltration
- Using BMPs on the residential and commercial development scale could further treat stormwater, reduce peak runoff flow, and recharge the basin



http://riverlareports.riverla.org/water-recharge/where-to-recharge/san-fernando-basin-study/

Residential

- Most beneficial options for residential areas include the use of bioretention areas and dry wells
  - *Bioretention areas can be constructed next to driveways and sidewalks, as well as lightly-traveled roadways*
  - *Dry wells can be incorporated into new developments and green home retrofitting*
- Incentives could be provided to homeowners to retrofit their properties, allow individual (non-developer) early adopters to waive certain fees associated with projects

Glenoaks bioswale and drywell system

http://hbteam.org/featured-projects/trees-as-bio-swales/

Commercial

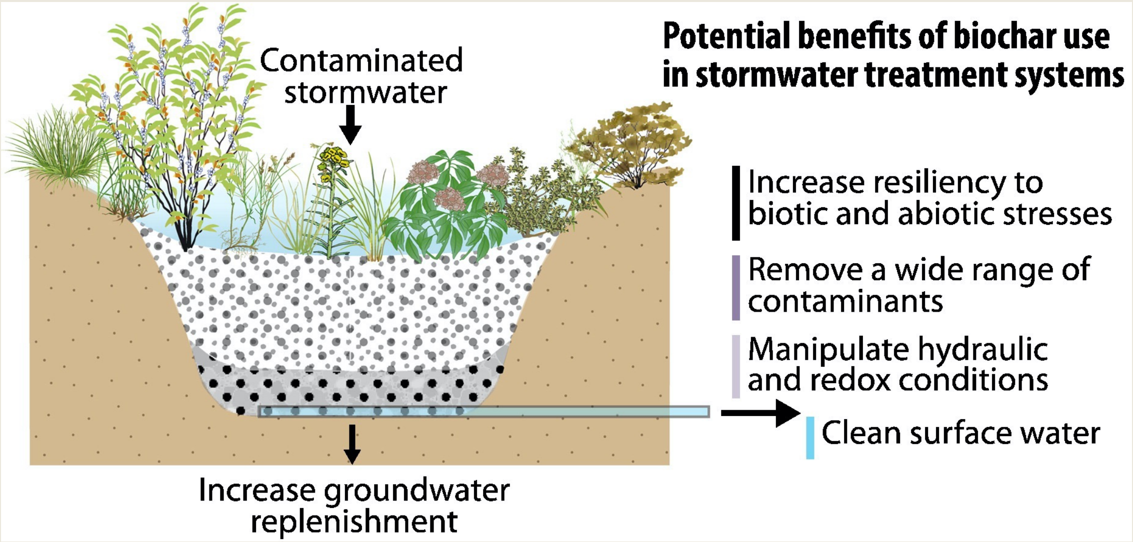
- Most beneficial option for commercial streets and lots in the City include the use of permeable pavement and dry swales—space permitting
  - *Permeable pavement can be used in low-traffic neighborhoods, for sidewalks, and in commercial parking lots*
  - *The Los Angeles Green Streets Program is already seeking to implement permeable pavement in public spaces*
  - *Dry swales can be installed on the edges of parking lots, and surrounding large buildings*
- Incentives could be offered to businesses to install on their properties

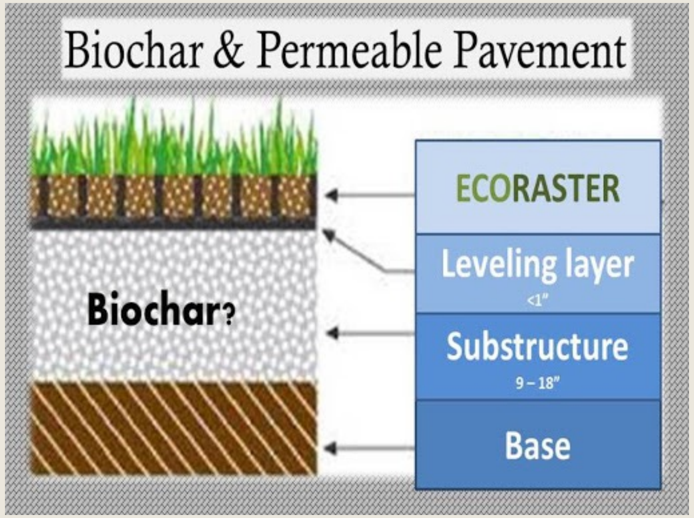
City of Burbank permeable sidewalks

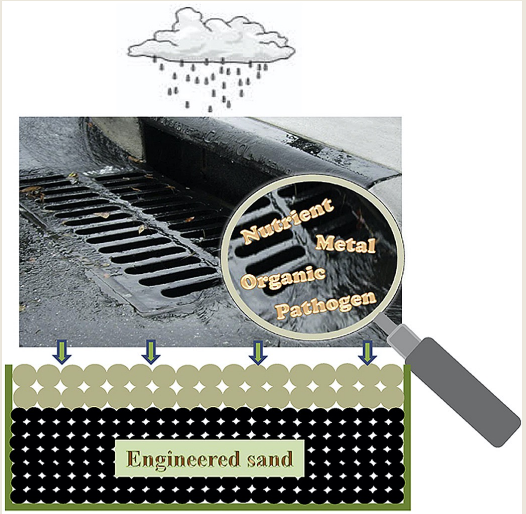
https://ahbelab.com/2015/07/27/helping-los-angeles-become-more-like-a-sponge/

Amendments for Removal of CECs

- Reactive media (e.g. granular activated carbon, biochar, oxide-coated sand) may be incorporated into the design to increase sorption capacity and target specific pollutants
  - *Granular activated carbon (GAC) or biochar aid in removing carbon-based and other hydrophilic compounds*
  - *Oxide-coated sand can be added as a layer of adsorption media to aid in removal of toxic metals*







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