

Sustainable Drainage Techniques in antiquity for efficient water management, a review

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Sustainable Drainage (SuDS) in context

Mimics natural processes: encourages

infiltration

detention

conveyance

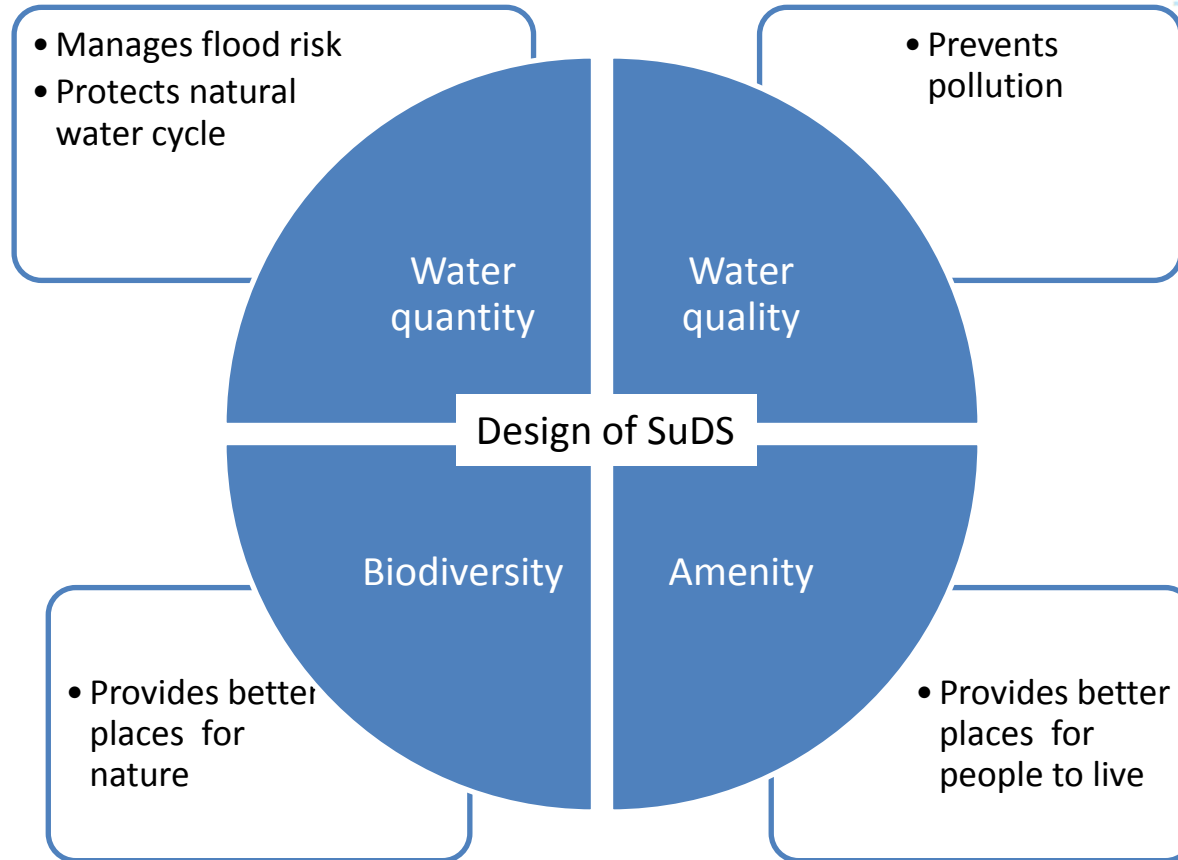


Permeable paving



Swales and filter strips

The modern role of SuDS



Water management in antiquity

Political motivation:

Maintain power: eg all aspects of Mayan life were rainfall-dependent

Maintain borders:

Droughts during Byzantine, ruling Empire gave state subsidies to maintain stable frontier, encouraged peripheral settlement

Seasonality: cope with climate fluctuations: droughts

Ancient Greece lack of water and high evaporation rates, particularly during summer

Negev desert



Sustainability of water resource management

“the ability to use water in sufficient quantities and qualities to meet the needs of humans and ecosystems” (Mays, 2014)



Hadrian Aquaduct, Athens, completed 140 AD
in use until 1920s, partially until 1950s

Peisistratean Aquaduct built ca. 510 BC
irrigates National Garden central Athens



Modern *combined* sewers carry foul and stormwater, CSOs have significant health implications.



Water supply

Rainwater harvesting: main source of water in antiquity, transported by canals and aqueducts

Terracotta pipes, Pompeii, Italy, 79AD



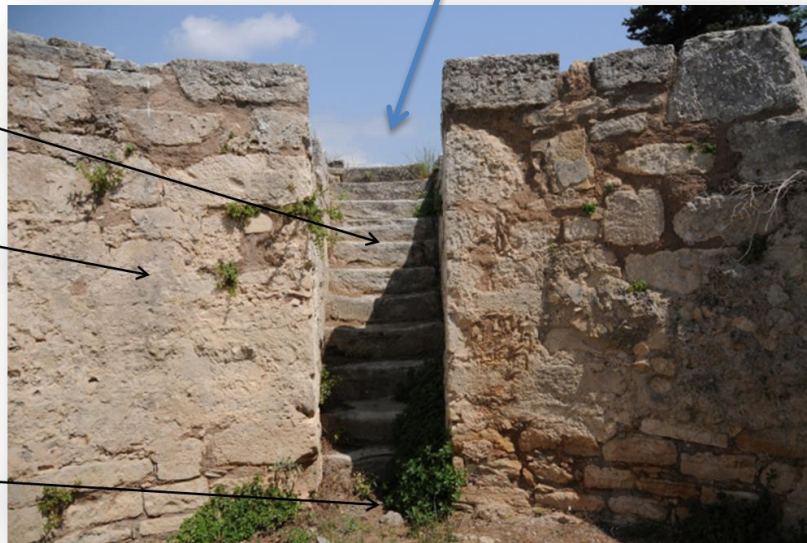
Little Petra, Nabatean 586BC

Cisterns

Stairs leading down into cistern

plaster on the cistern walls

inside the cistern



Water quality management

Maintained/ improved by:

bioretention



filtration

settling



Petra, Jordan

Biological treatment

1. Reduce evaporation;
2. Prevent disease vectors eg mosquitoes breeding by covering the surface of the stored water;
3. Water hyacinth, water lilies and ferns can clean/polish water;
4. Provide compost when harvested regularly, ie maintained;
5. Macrophytes eg water lily only thrive in clean water, thus indicate water quality.

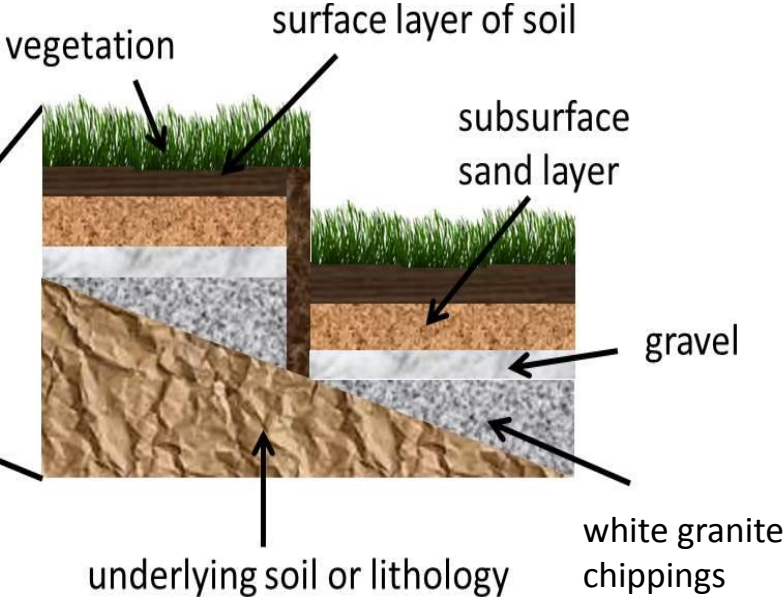


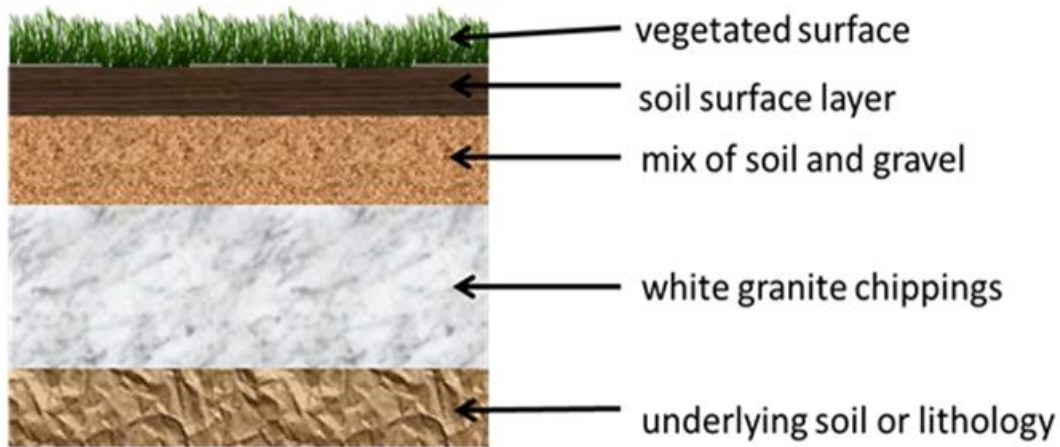
Water lilies and water hyacinth, Angkor Wat, Cambodia (late 12 century)

Water quantity management

Ancient infiltrating pavements, Machu Picchu, built 1450, abandoned 1572

Terraces





Storage/ storm attenuation

Barays Angkor Wat and Angkor Thom, Cambodia



Reducing water velocity to reduce the storm peak



Meanderings cut into Pre-Incan aqueduct, Cumbe Mayo, Peru

Pompeii: raised kerbs and *pondera*



Stepping stones

Cart wheel ruts

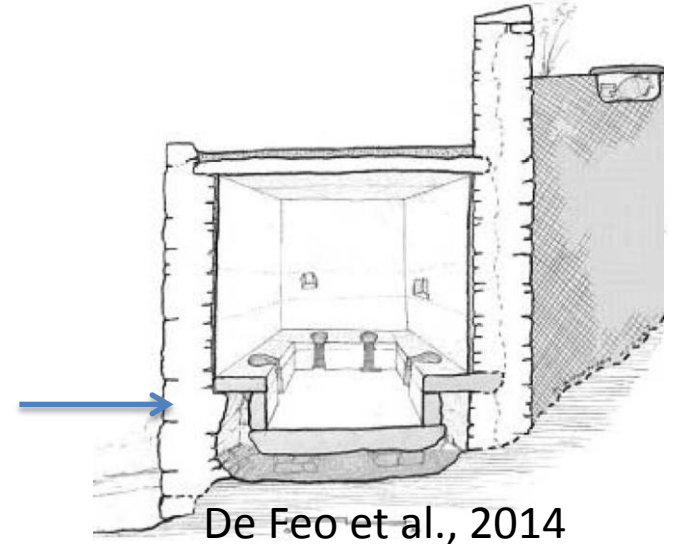
Raised kerbs

Greywater recycling

Due to: semi-arid climates eg eastern Mediterranean, ancient Greece

Greywater from kitchens or baths used to bucket flush toilets eg Minoan toilets on Amorgos (10th century BC-4th century AD).

Indoor water-flushing toilets 3180 BC–2500 BC Skara Brae, Orkney, Scotland.



Minoan: cooking/ bathing water for domestic animals, indoor plants, washing floors
eg Hagia Triadha villa stormwater + greywater for irrigation built 2000-1550 BC
Leftover water from ceremonial purposes in shrines, eg the Asklepieion, Kos.

Non-structural SuDS: policy and governance

Maintenance and ownership

5th century BC Plutarch:
Institutional water efficiency measures in Athens:
election of 'superintendent of fountains' to ensure
equitable distribution of water

ἐπιμελητής τῶν κρηνῶν

Citizens maintained stormwater cisterns, providing
resilience against flooding and efficient water
resource provision



Conclusions

Will “our modern sewerage systems still be functioning after even one thousand years”
Mosso (1907)



Modern infrastructure design life = 50 years

Parts of the sanitary and storm
sewerage systems in Hagia Triadha
still working after 4000 years

Water was valuable and valued, not wasted
It was harvested, stored, treated and recycled
Rainwater harvesting prominent, also used for drinking
Greywater recycling used

Engagement of the citizens in efficient water management

Smaller populations
Less impermeable areas

Industrial and urban emissions
Water hidden 'out of sight, out of mind'
Disconnected from water

Great Drain of the Agora, Athens
Early 5th century BC
1m x 1m

