Sustainable Water Issues
as applied to buildings

Eric Adams

Outline for Discussion in

Design for Sustainability (1.964)

November 15, 2006

Outline

- Introduction (brief)
- Context: Boston area's water supply and wastewater treatment (brief)

  (Is current system sustainable?)
- Water-related sustainability measures applicable to buildings

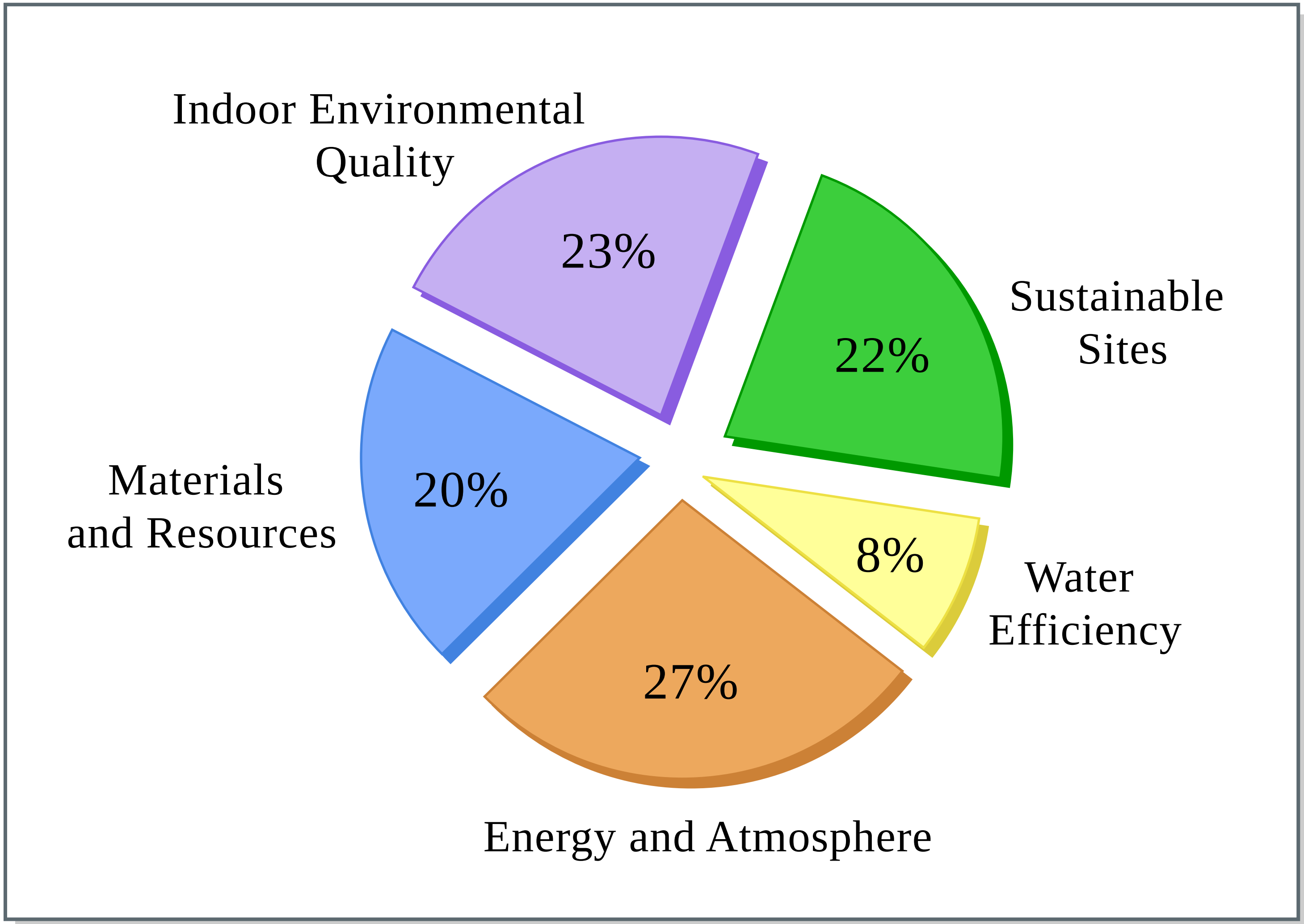


Figure by MIT OCW.

LEED™ Certification Categories

Water and Sustainablity

- Sustainability => keeping consumption within limits of natural replenishment
- Broader view includes
  - Environmental
  - Economic
  - Social

Water vs Materials & Energy

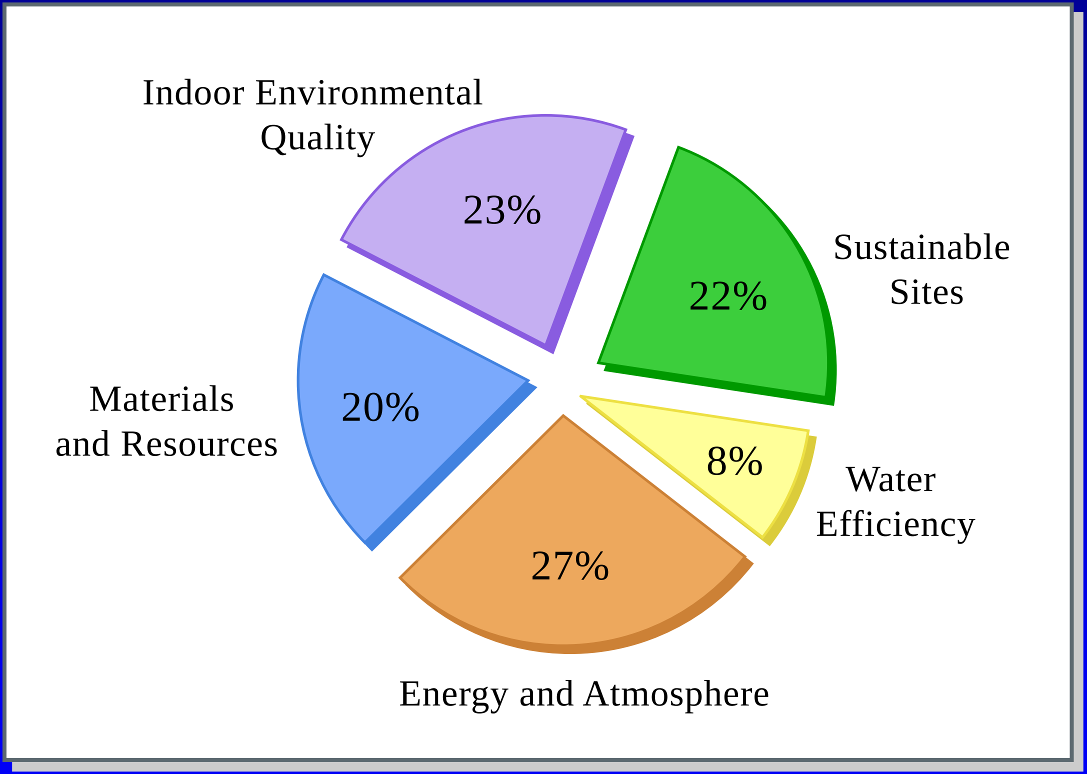


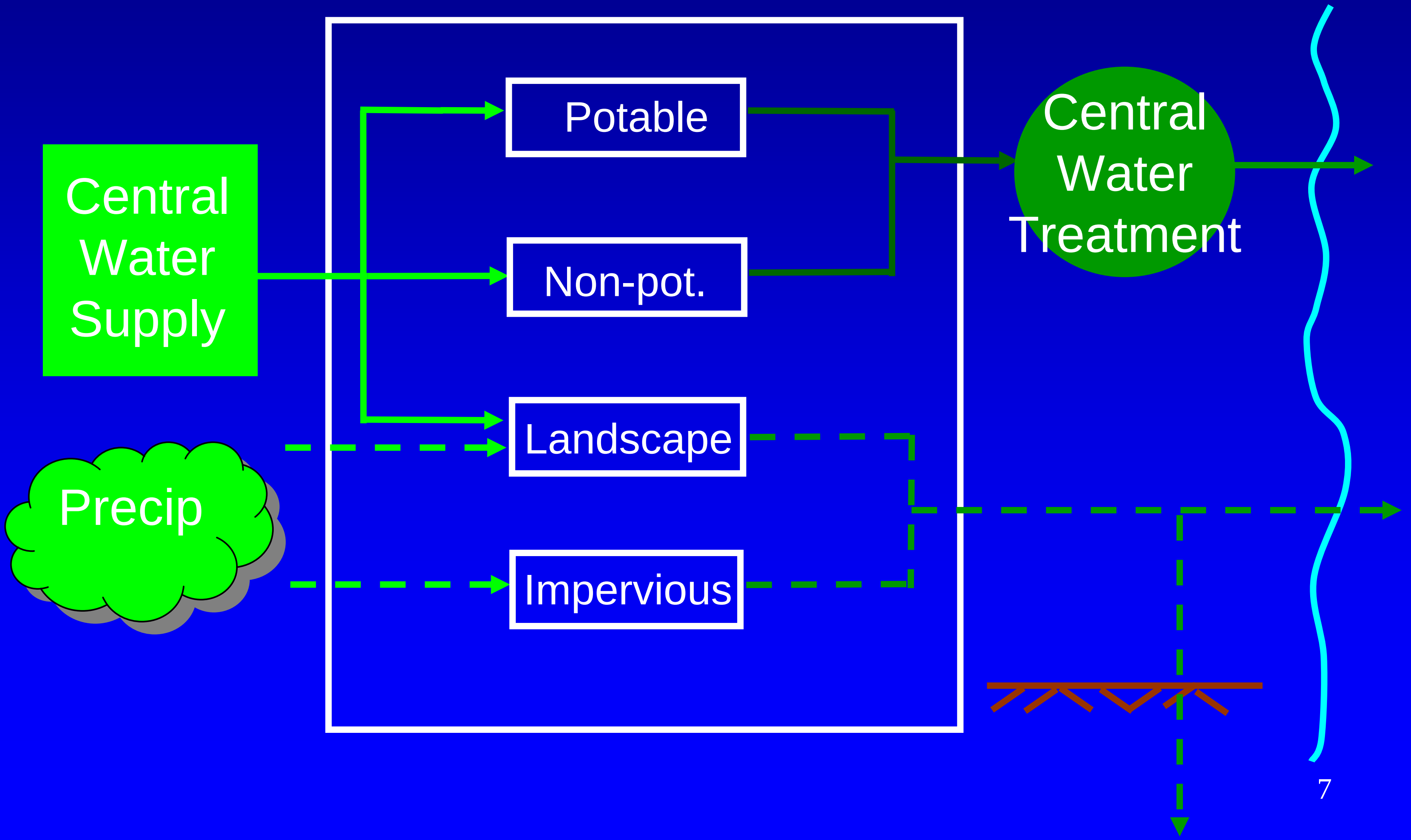
Figure by MIT OCW.

- Largely renewable
  - Time scales of months to few years => we've had plenty of practice
  - Sustainability measures driven more by extremes than averages (droughts, floods, peak demand)
- Multiple uses
  - Different levels of treatment
- More site specificity

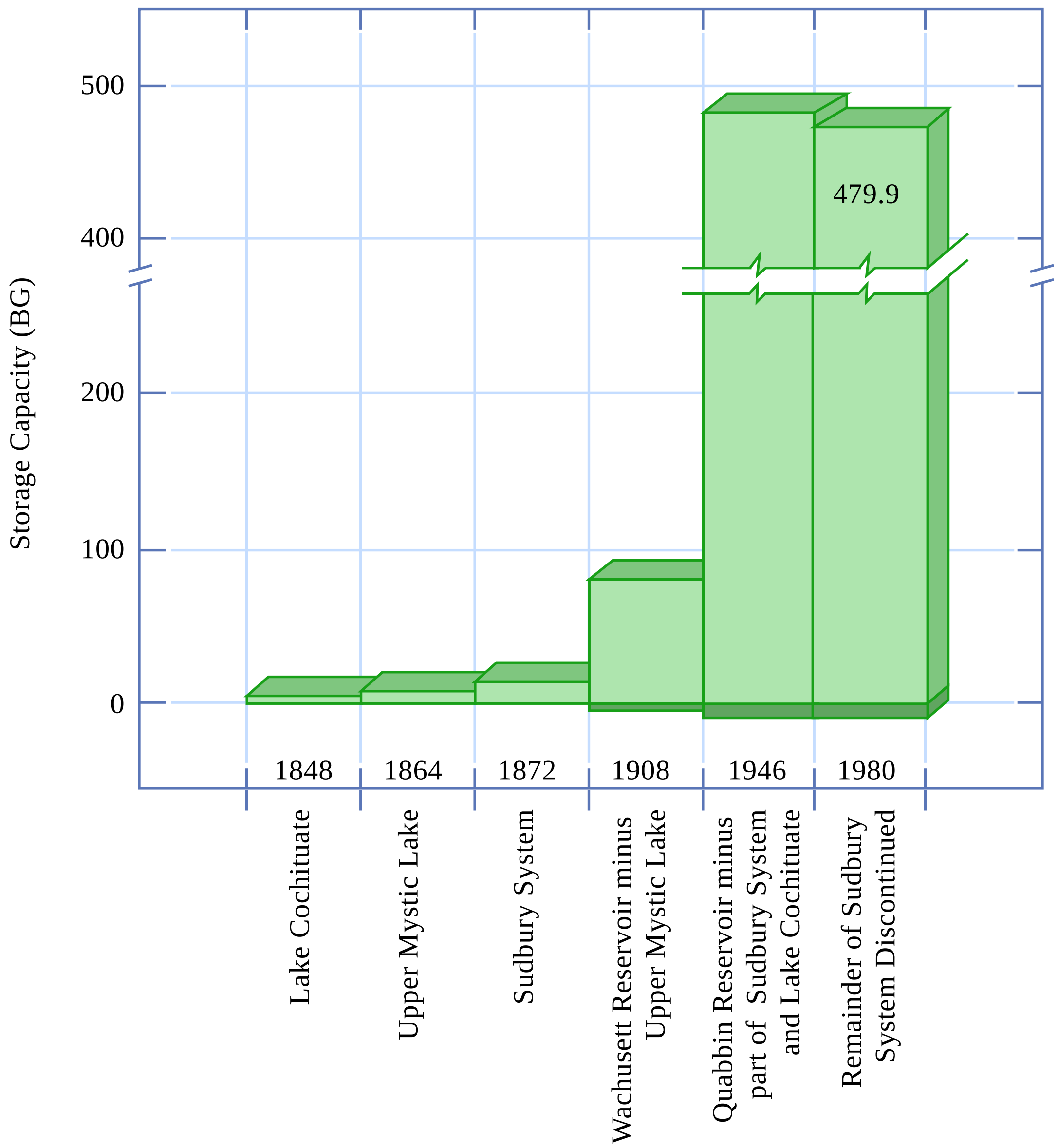
A Building's Impact on Water

- Impacts associated with occupants' water use
  - Water supply
  - Generation of wastewater
- Impacts on hydrology
  - Reduced recharge, increased storm water runoff, altered WQ
  - Construction, operation, demolition phases

Water supply, wastewater, stormwater



Boston's Water Supply



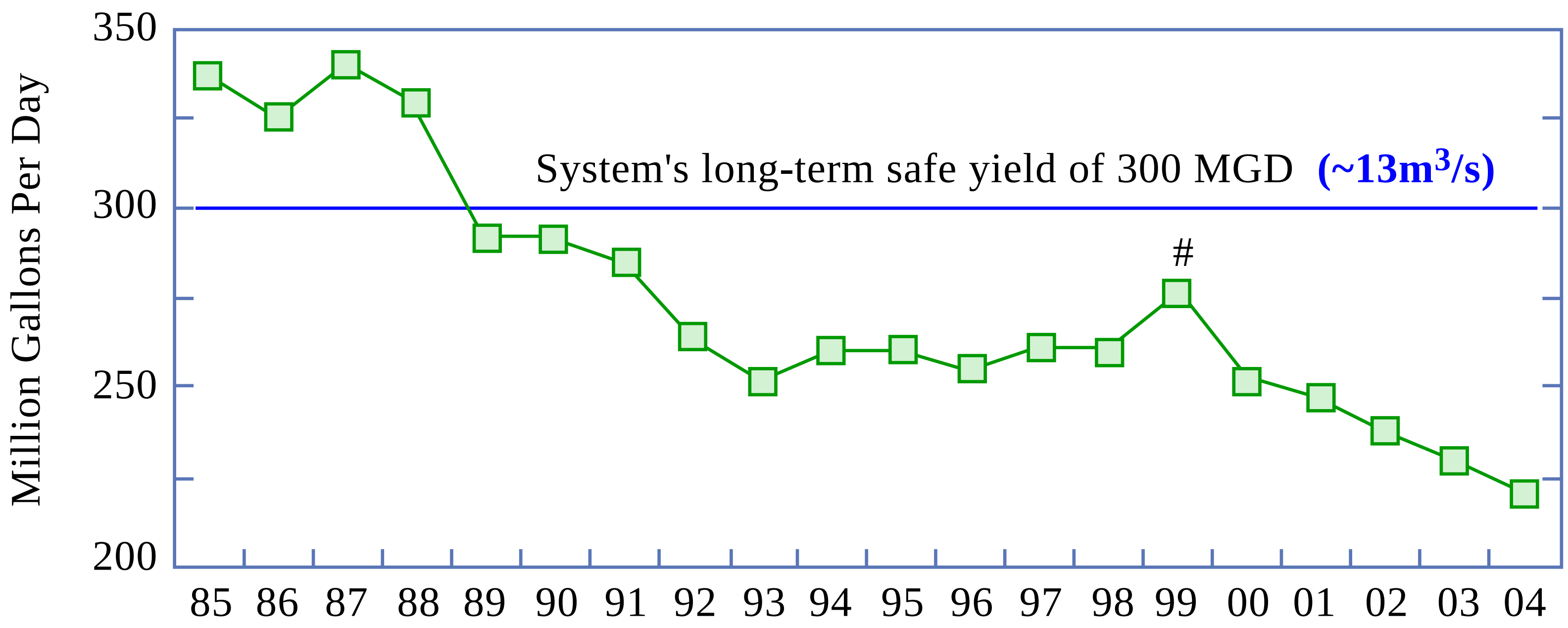
- 1795-1870: Local ponds & reservoirs
- 1875-78: Sudbury Aque-duct & Chestnut Hill Res
- 1895: Wachusett Res
- 1926: Quabbin Res.
- 1946-78: Pressure Aqueducts
- 1996-present: Integrated water system improvements
- Many towns supplement MWRA with local wells

Figure by MIT OCW.

Boston's Water Supply cont'd

Flickr image courtesy of pjmorse.

- Prim. Disinfection: O_3
  Res. Disinfection: Chloramine
- Corrosion Control
- Fluoridation
- Modular for expansion/contingency
  - Filtration
- $0.34 billion



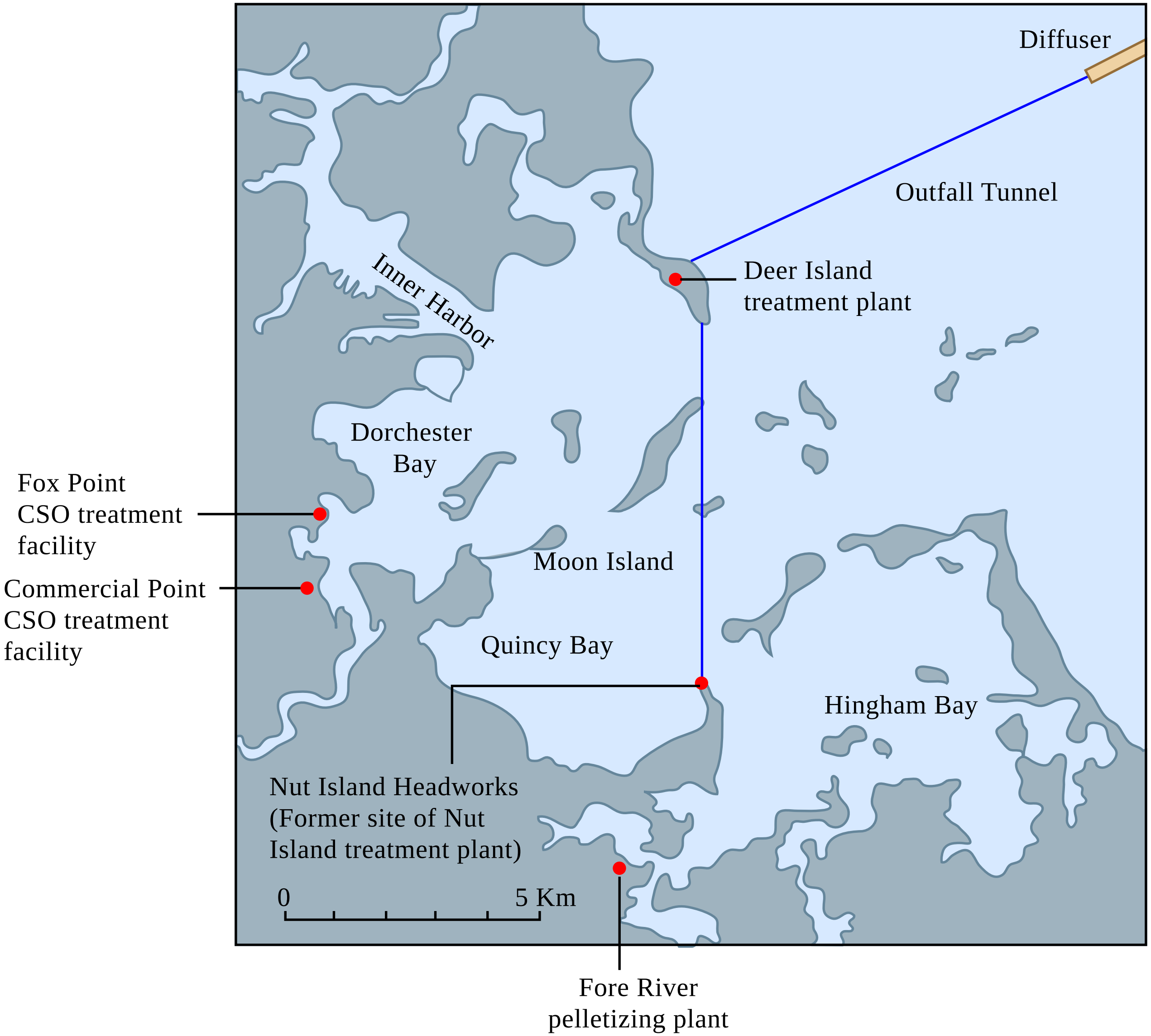
Includes temporary supply to Cambridge during construction of local water treatment plant

MWRA Water Demand vs. System Safe Yield

Figure by MIT OCW.

Sustainable?

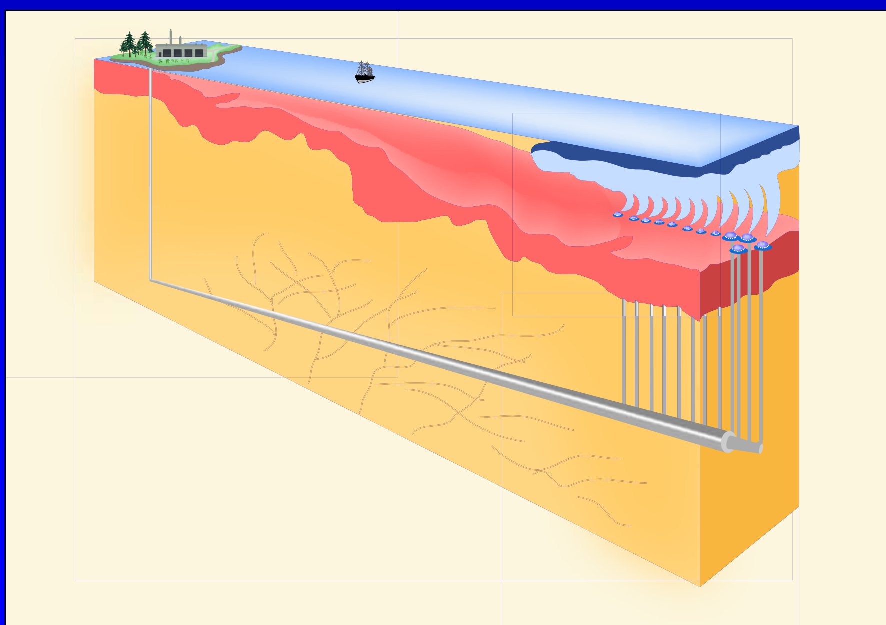
Boston's Wastewater



- 1700s-mid 1800s: Convey WW to nearest water body
- 1876 First sewer system -> Moon Is
- 1952 Nut Is TP
- 1968 Deer Is TP
- 1997 New Deer Is TP

Figure by MIT OCW.

Boston's Wastewater cont'd

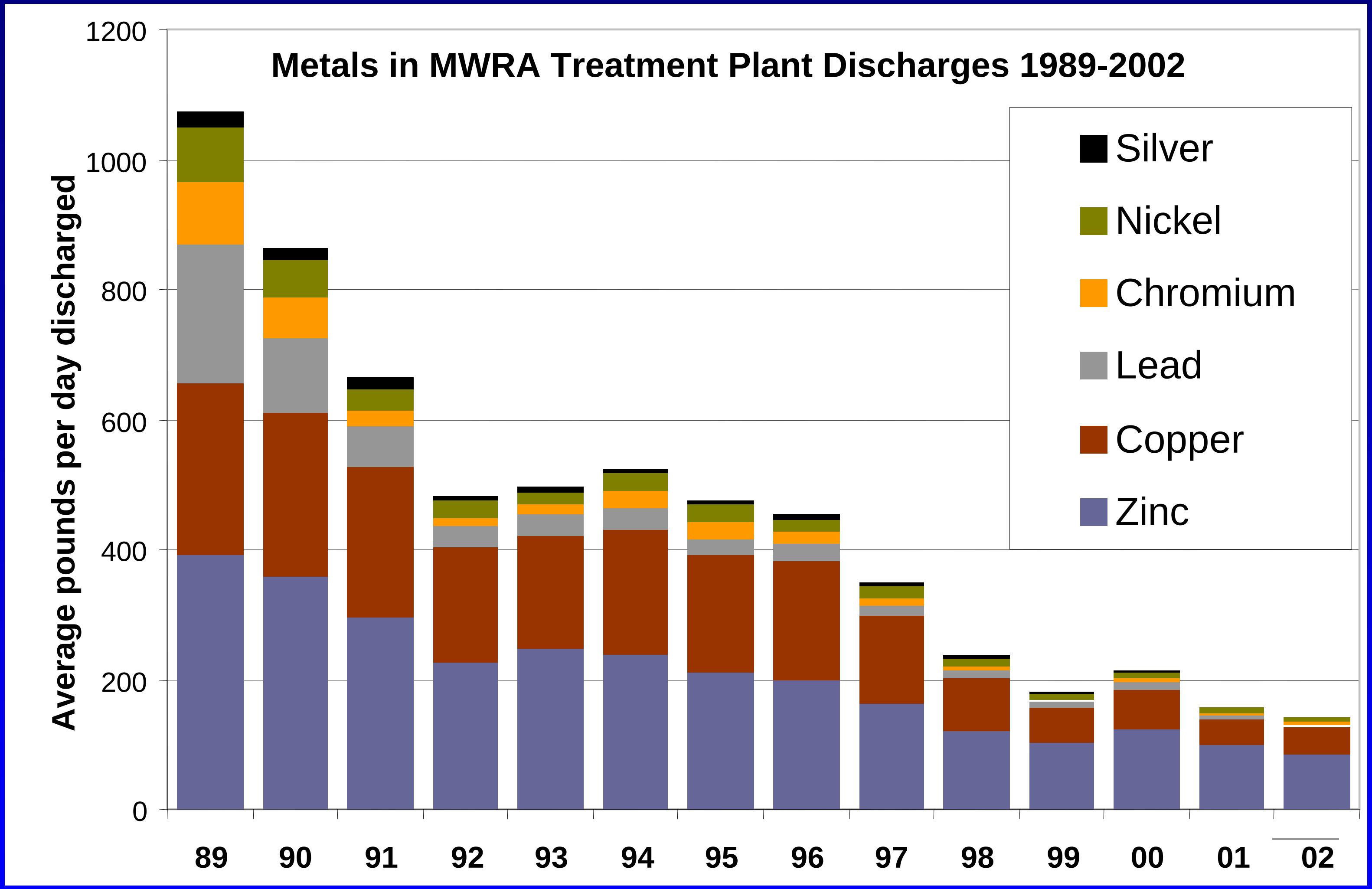


SCHEMATIC VIEWS OF OUTFALL AND DIFFUSERS

- Modern 2º TP (Activated Sludge)
- 20 m^3/s (ave); 50 m^3/s (peak)
- Room for Expansion
  - AWT for Nitrogen
- 15 km ocean outfall
  - Contingency plan

Figure by MIT OCW.

Should wastewater be returned to watershed rather than discharged to ocean?



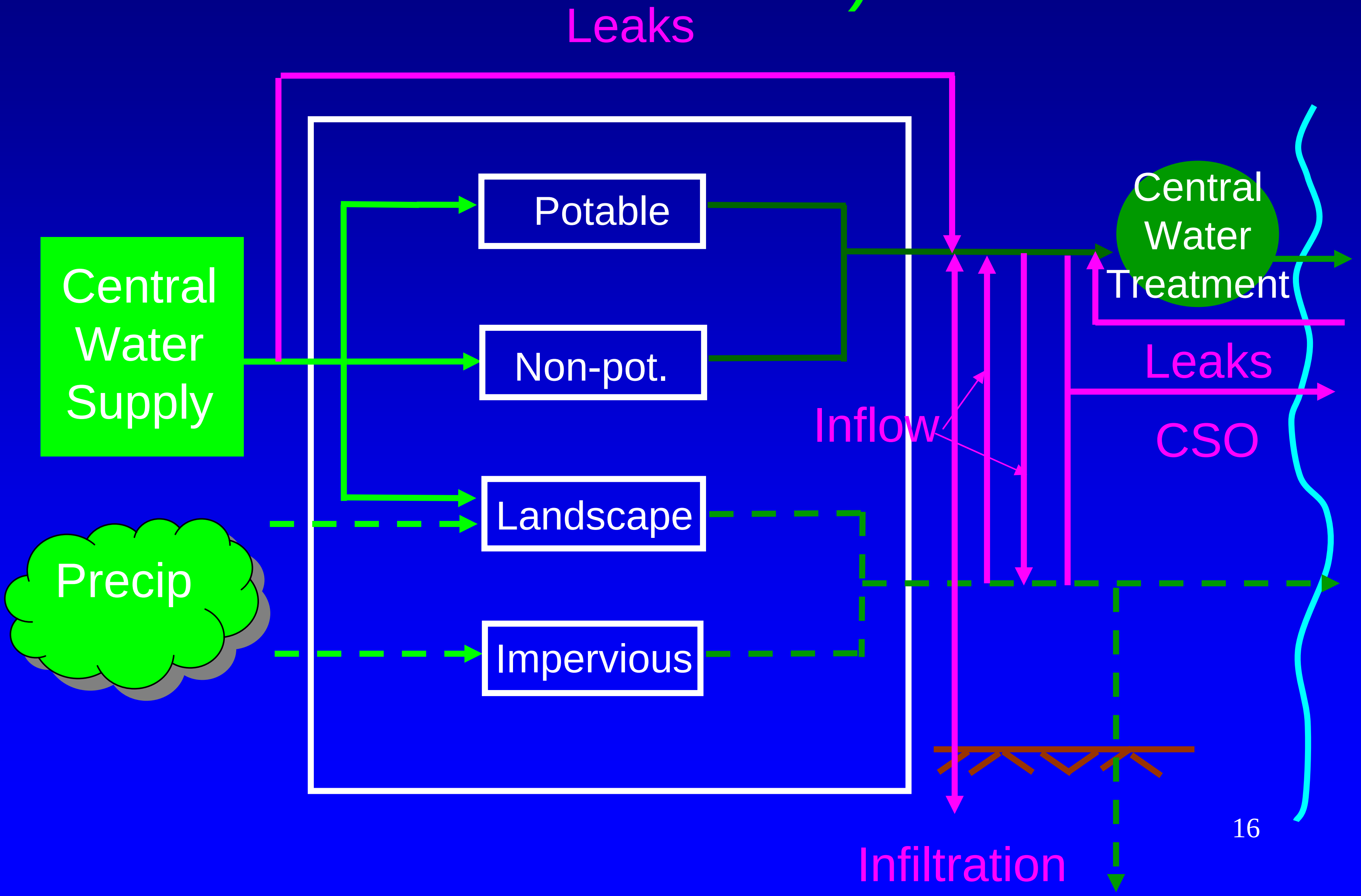
Data from mwra.state.ma.us

Boston's Wastewater cont'd

- Aggressive Source Control
- Sludge recycling at Quincy
  - New England Fertilizer Co.
  - Bay State Fertilizer Co.
- Total cost: $3.8 billion

Sustainable?

Stormwater (and freshwater and stormwater)



Combined Sewer Overflow

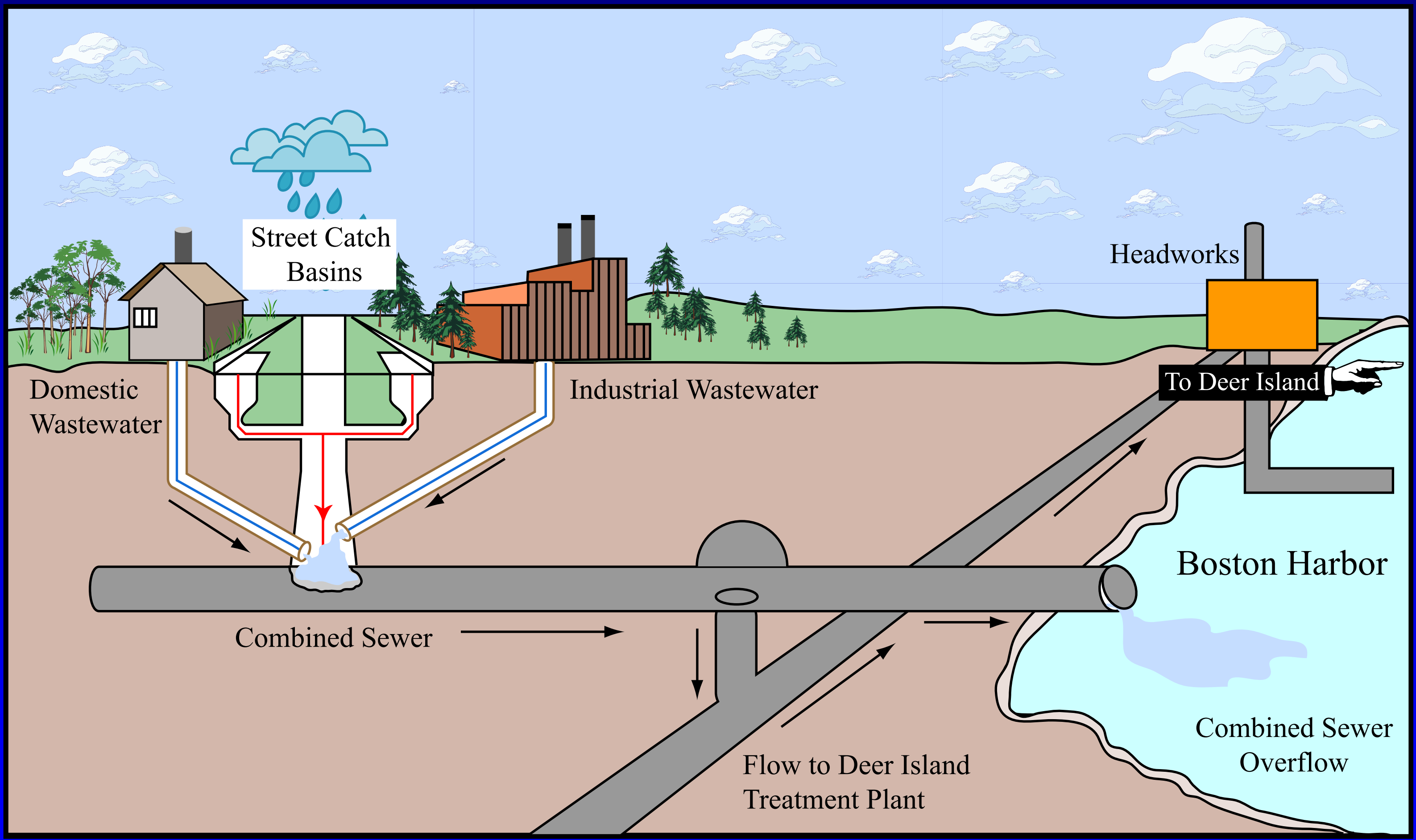
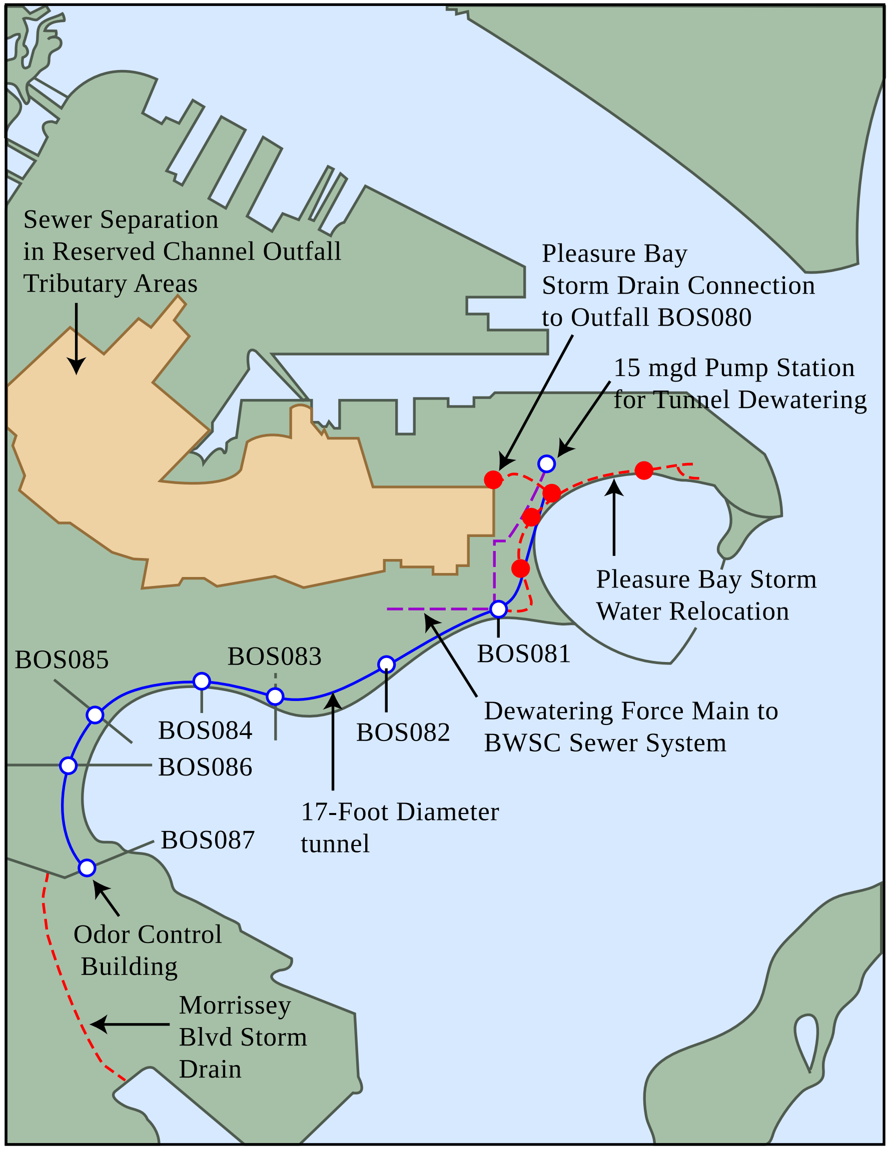


Figure by MIT OCW.

mwra.state.ma.us

Boston's CSOs



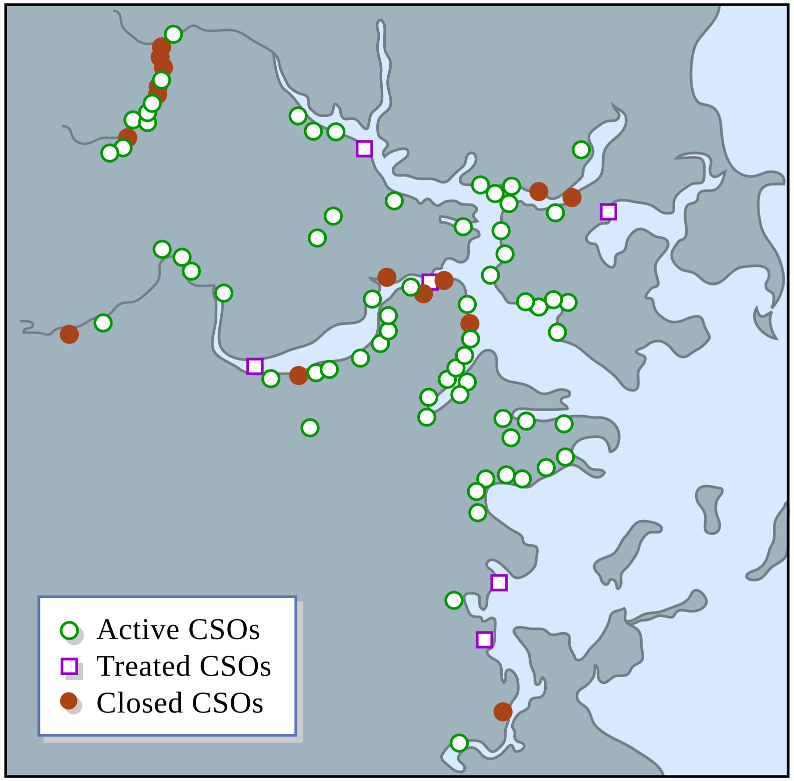


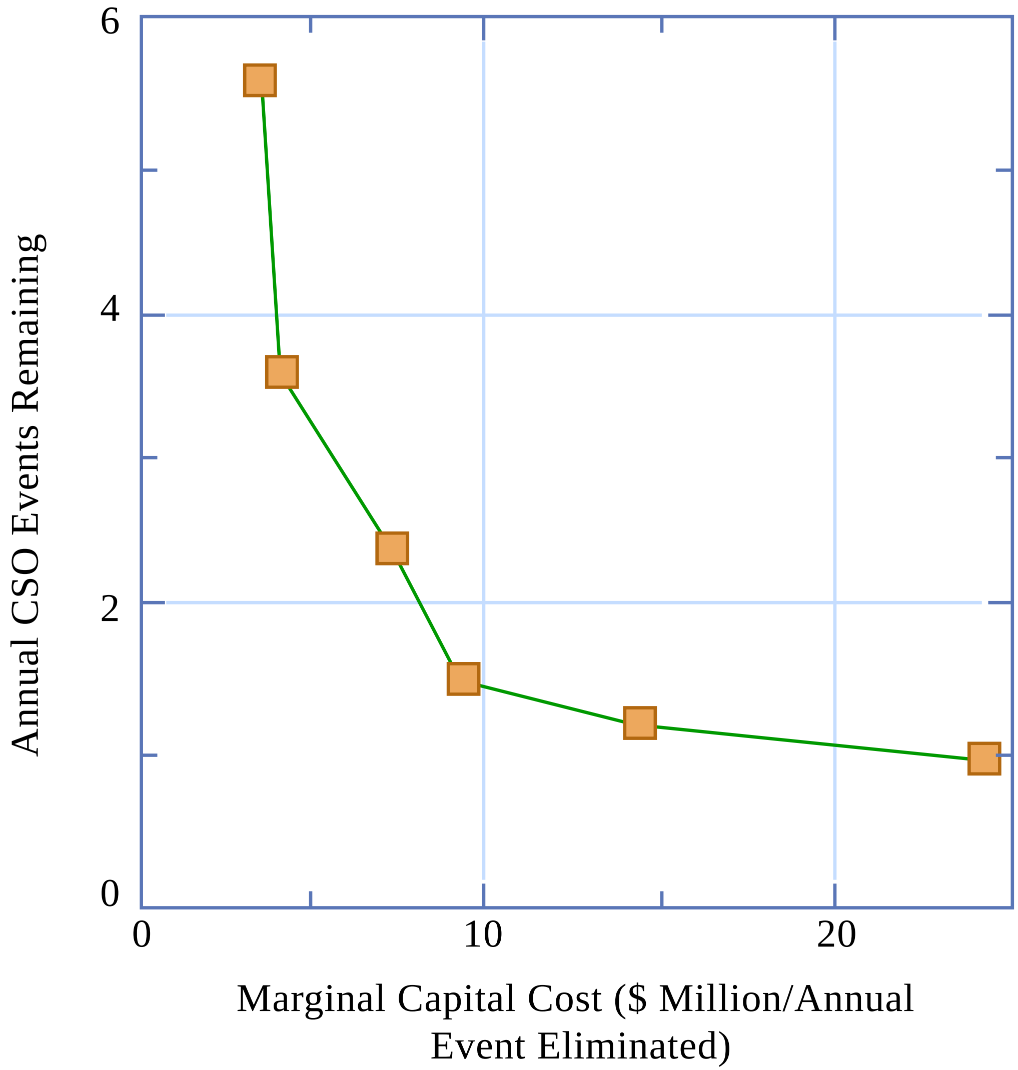
Figure by MIT OCW.

Figure by MIT OCW.

CSOs (cont'd)

- 85% reduction in CSO volume since 1988 (3.3 -> 0.5 bgy).
- 95% of CSO will receive some treatment (4 plants)
- Not 100% because marginal cost of CSO storage/ treatment increases as event frequency decreases
- And stormwater will never be clean
- Boston Harbor & Charles River will never be completely swimmable
- Total cost = $0.9 billion

Sustainable?



Marginal Capital Cost of Near-Surface Storage for Alewife/Mystic River Basin

Figure by MIT OCW.

Central vs Distributed Systems

Advantages

- Investment/sharing in existing infrastructure & professionals
- Stability under transient water demand/availability
- Cheap!

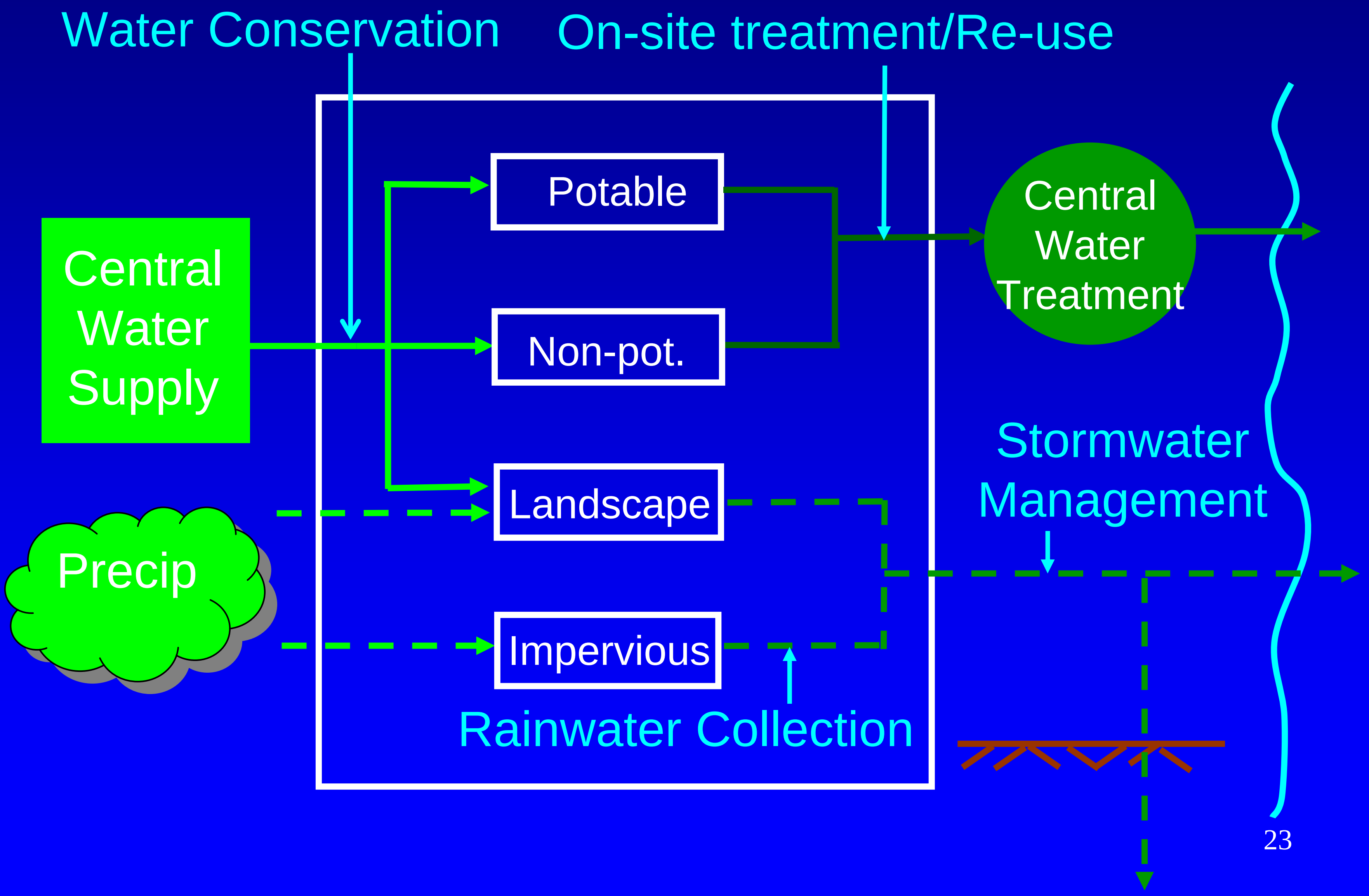
Disadvantages

- Disrupts hydrology, people
- Encourages waste
- High energy costs
- Large sludge production
- More vulnerability
- Complex, hard to monitor
- Hard to expand

System Expansion

- Not all or nothing.
- Most urban/suburban systems are centralized but there is room (indeed need!) for local systems: new hook-ups mean greater distances & flow rates (hence pressure losses), implying greater marginal costs

Sustainability measures

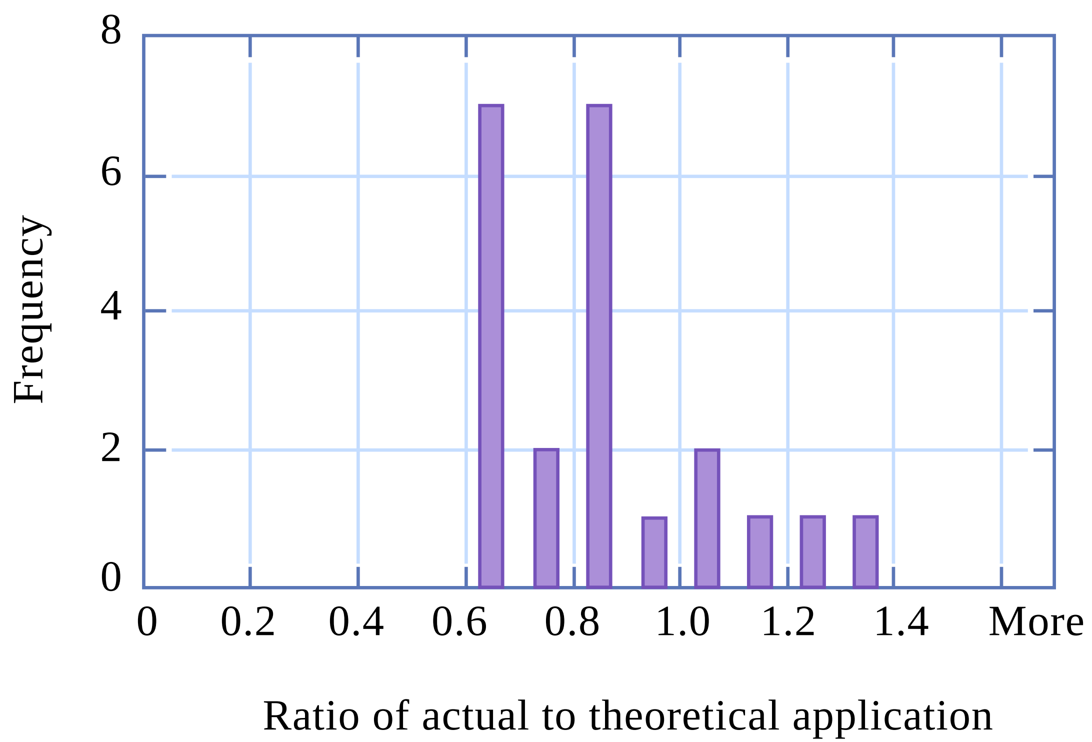


1. Water Conservation

- Mainly for non-potable and landscaping flows
- Low flow faucets, shower heads
- Low flow, dual flush toilets, waterless urinals, separation/dry toilets
- Smart irrigation (and landscaping)
- Greatest potential for institutional sources

Smart Irrigation

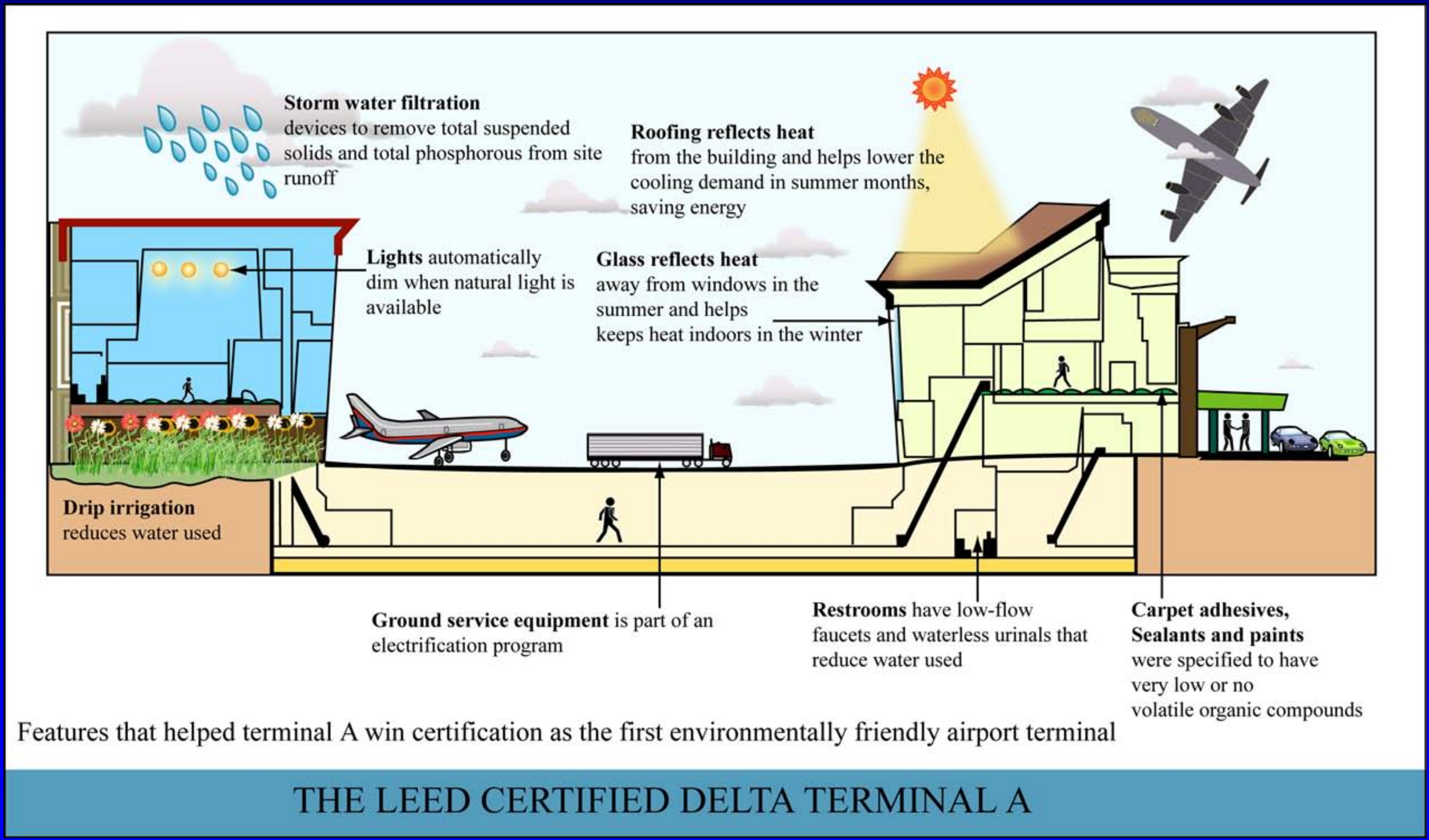
- 30-70% of residential water use is for landscaping; homeowners over-water by 2X
- Method of delivery
  - Drip irrigation
- Timing/quantity
  - Timers
  - Local weather reports
  - Rainfall, solar sensors (theoretical ET)
  - Moisture sensors



Sensor Based Irrigation Efficiency

Figure by MIT OCW.

DeOreo, et al., Boulder CO



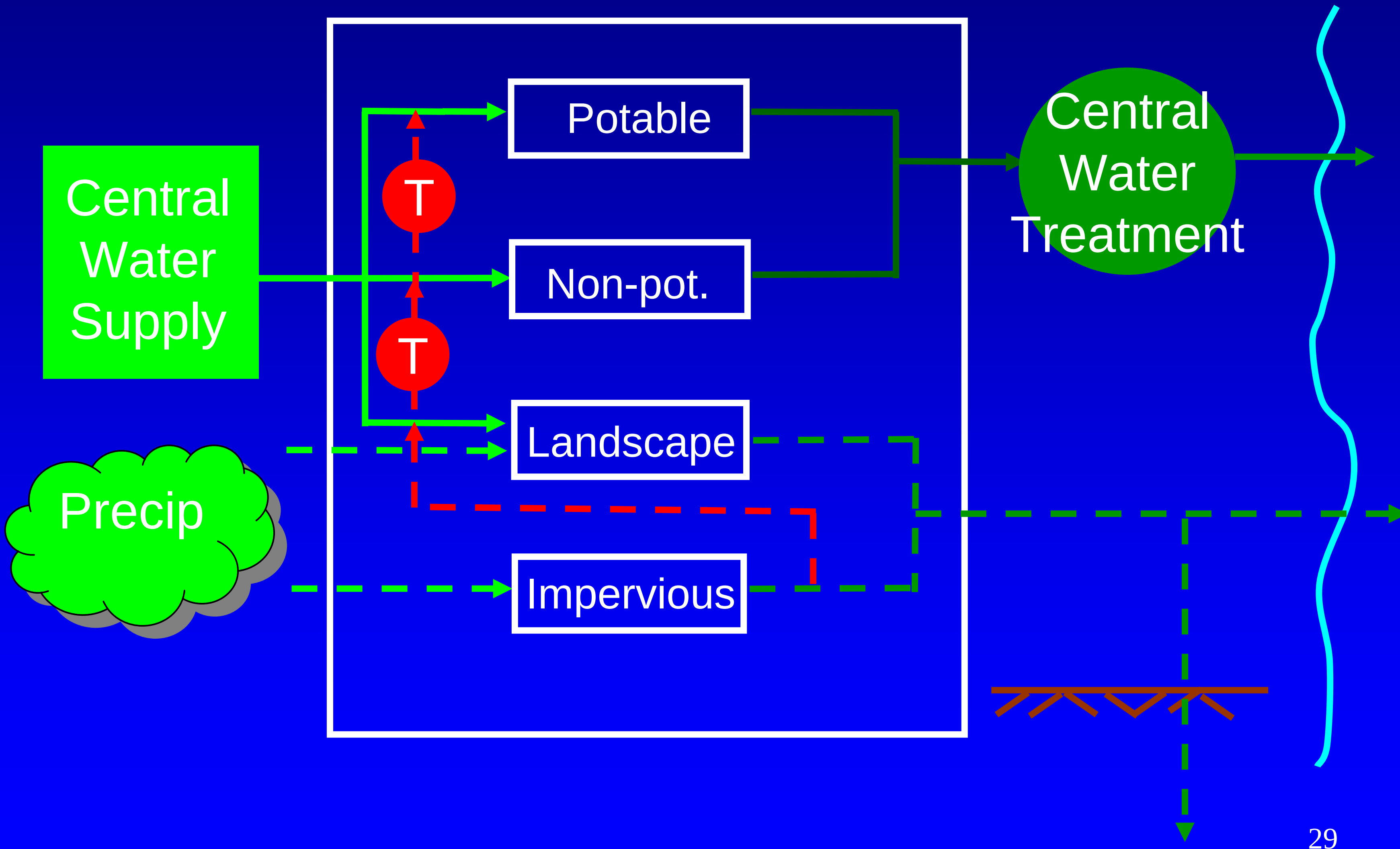
- Opened March 2005; Design by Hellmuth, Obata and Kassabaum
- Annual water savings: 1.7 million gallons
- Storm water filtration reduces pollution to Boston harbor

Figure by MIT OCW.

Synthetic Lawns

- E.g., Residential Field Turf
- No water (or mowing, fertilizer, pesticides…)
- Drains through turf to underground pipes (permeability approaches grass)
- Comparable cost to sod
- Trace metals, pathogens vs nutrients, pesticides
- Aesthetics? (Monet effect)

2. Rainwater Collection/Use



Rainwater collection systems

- Order of increasing quality requirements
  – Landscaping, (rain barrels, SmartStorm)
  – Non-potable water (e.g., new MIT buildings)
  – Potable water (Toronto Healthy House)

Fit for use quality/downcycling

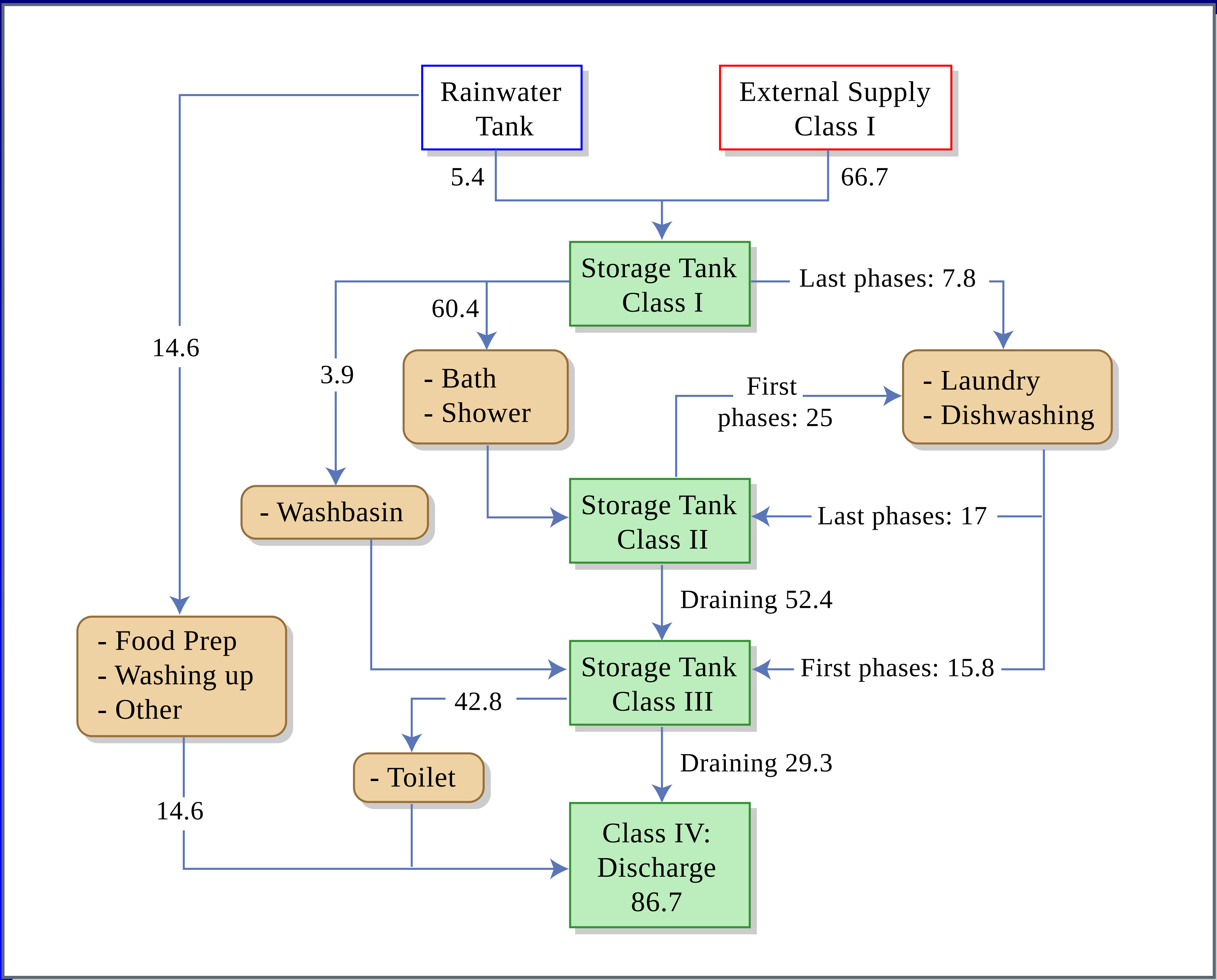


Figure by MIT OCW.

Coombes, 2005

Toronto Healthy House

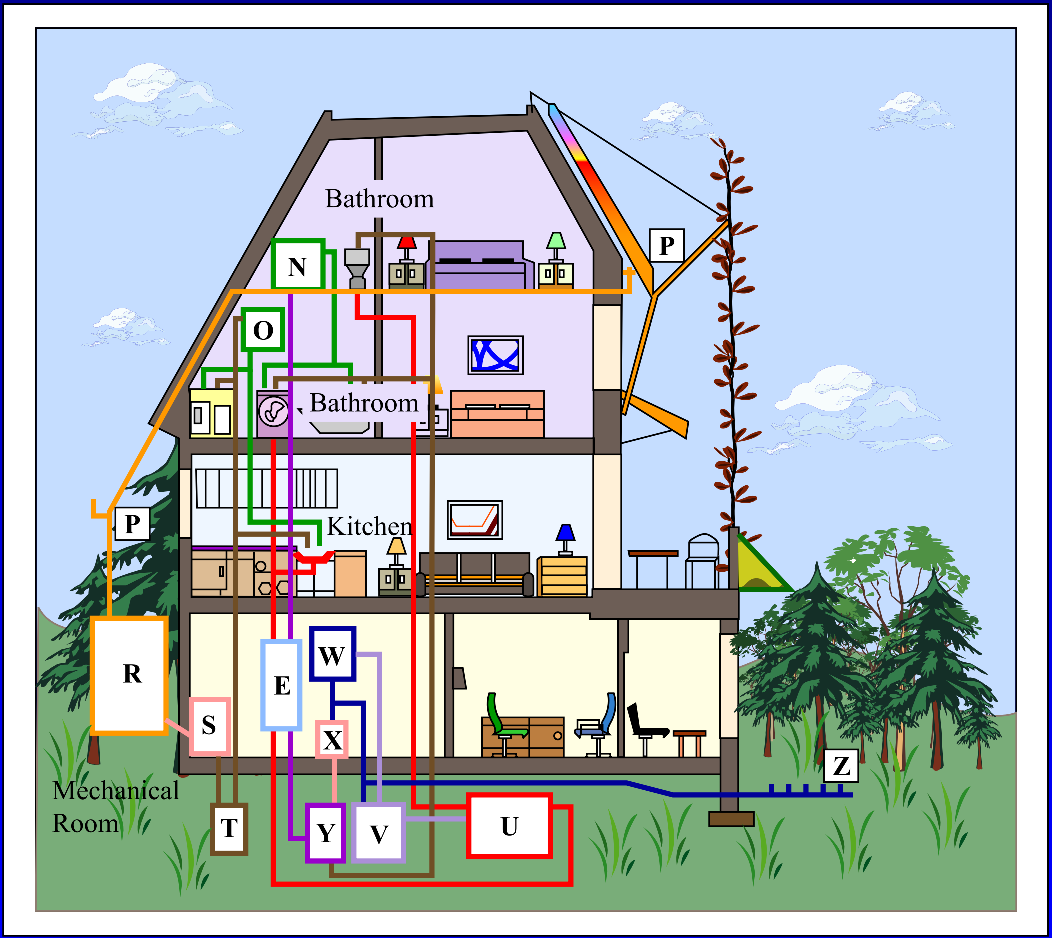


Figure by MIT OCW.

P—gutters
R—rain water cistern
S—combination filter
T—drinkable cold water tank
O—drinkable hot water tank

E—grey water heat exchanger
N—reclaimed hot water tank
U—septic tank
V—recirculation tank
W—Waterloo biofilter
X—twin combination filters
Y—reclaimed cold water tank
- Z—garden irrigation

Toronto Healthy House

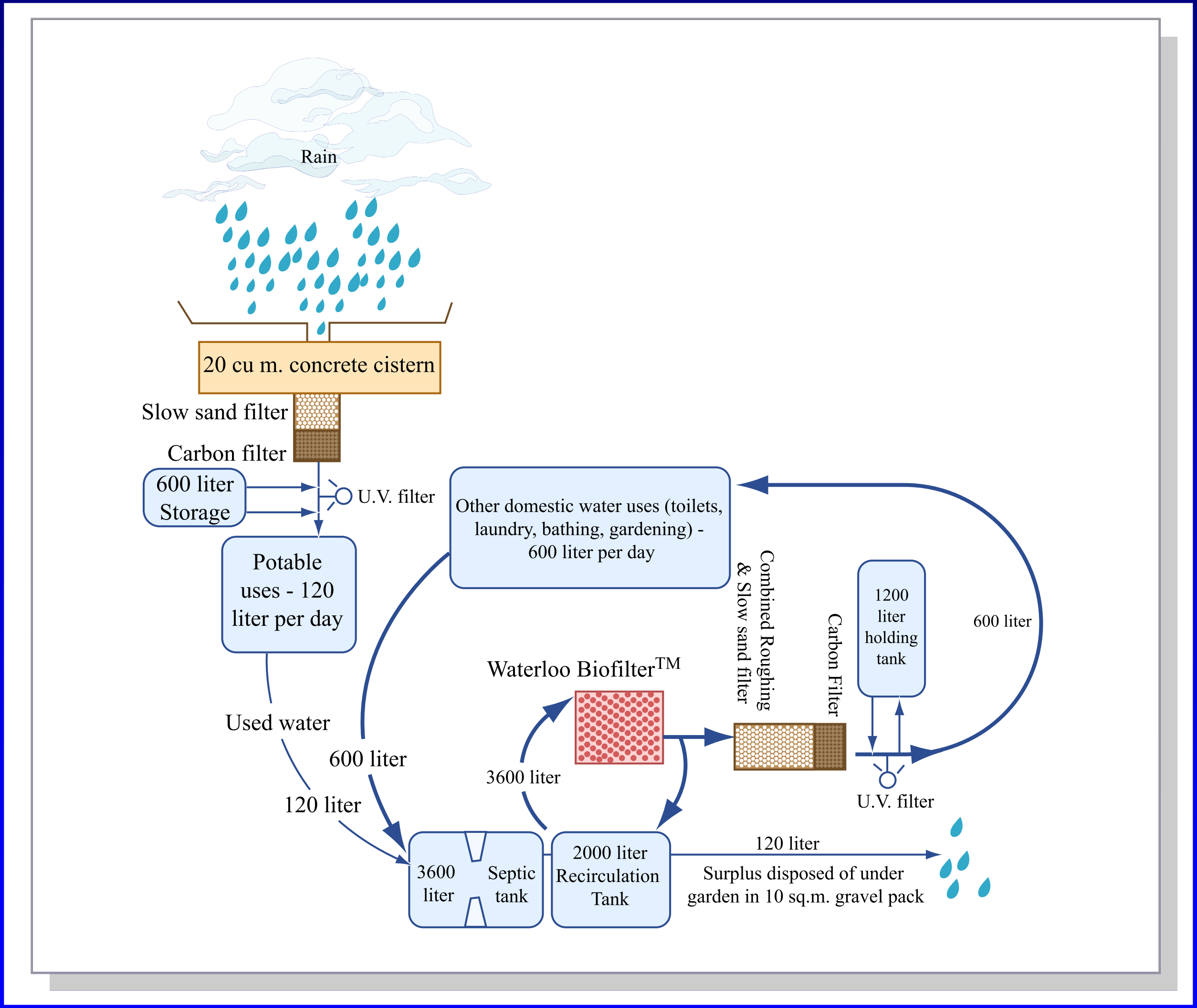


Figure by MIT OCW.

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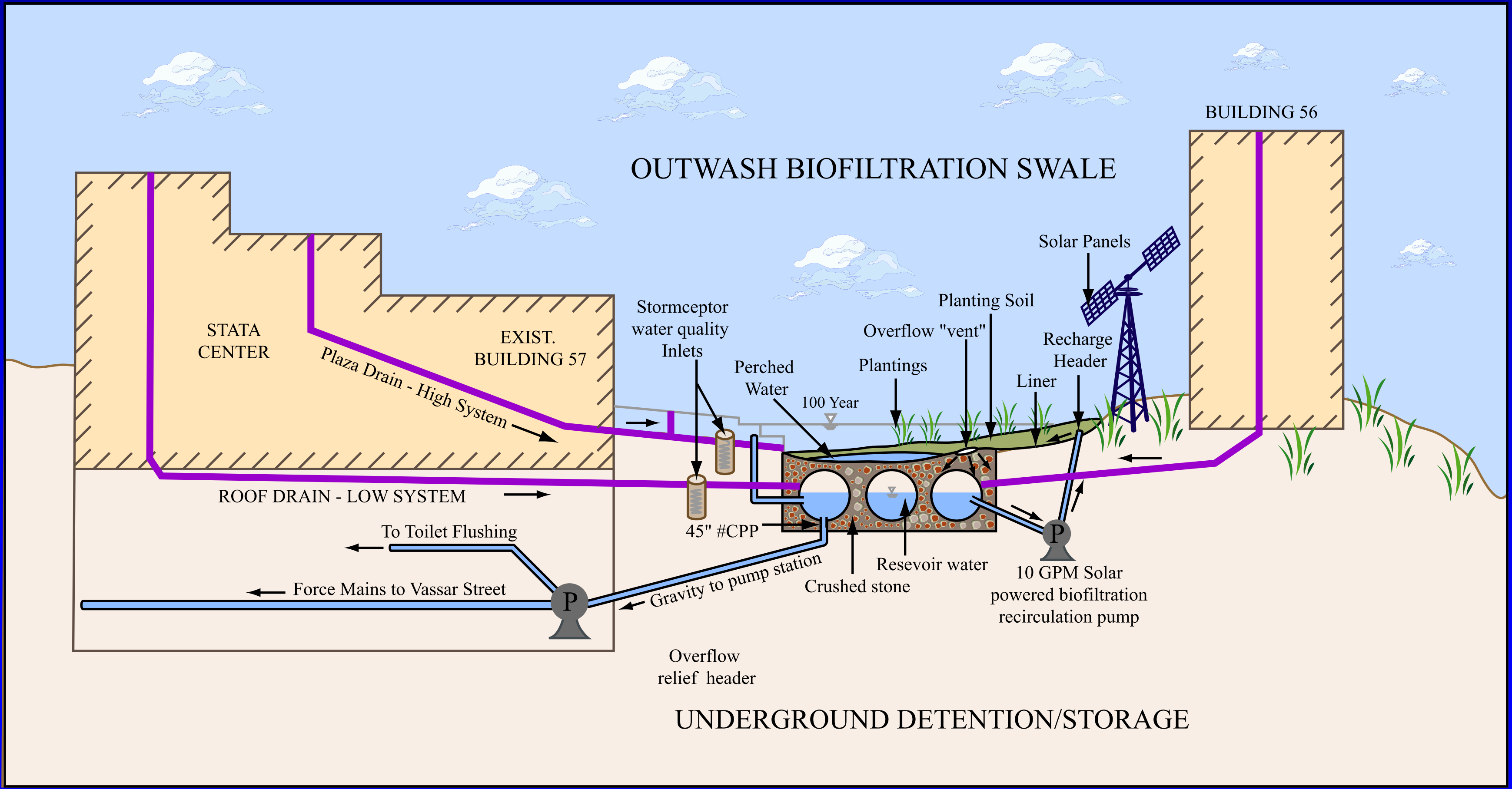
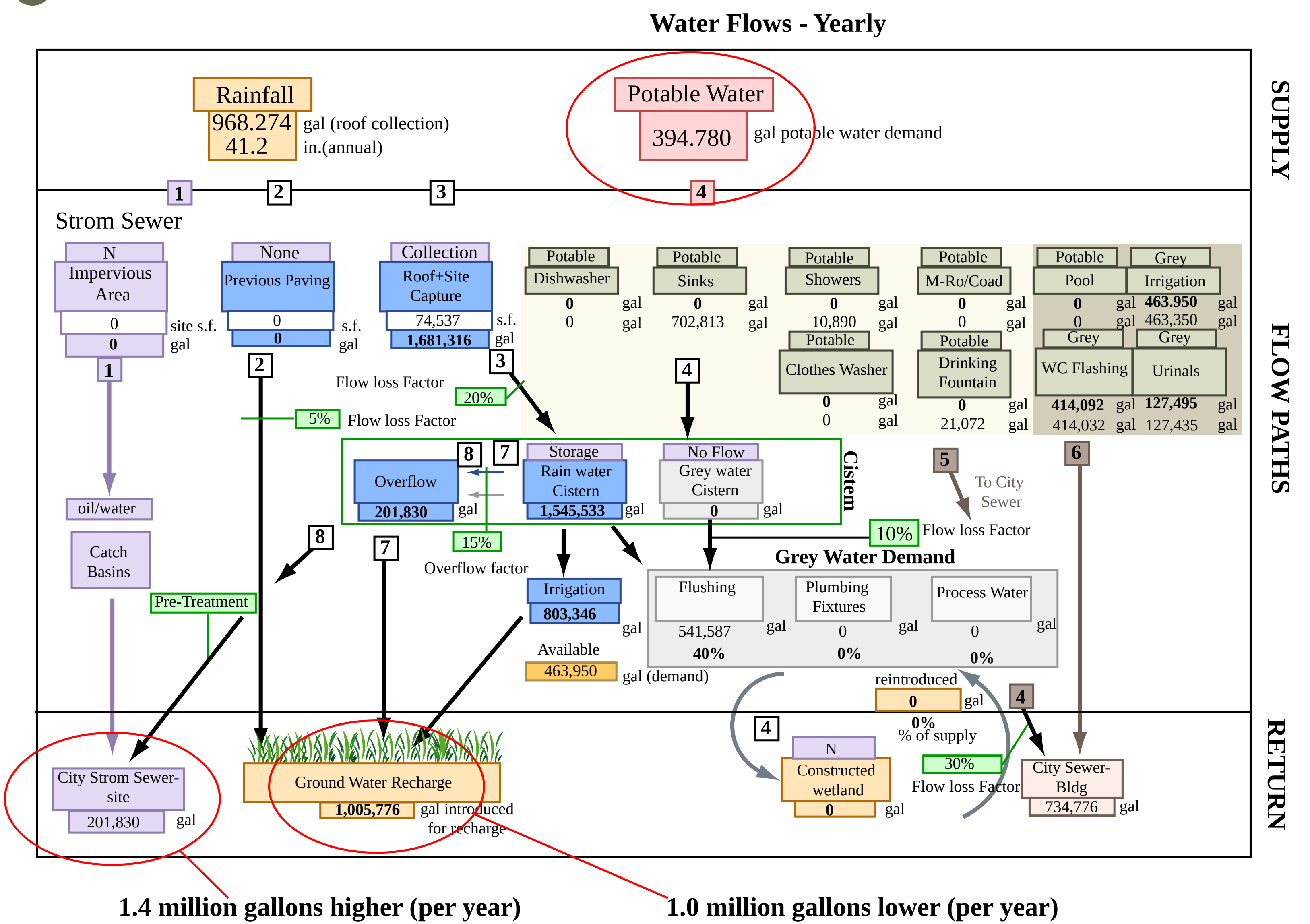


Eden Project

❶ Rainwater Collection Roof + Site

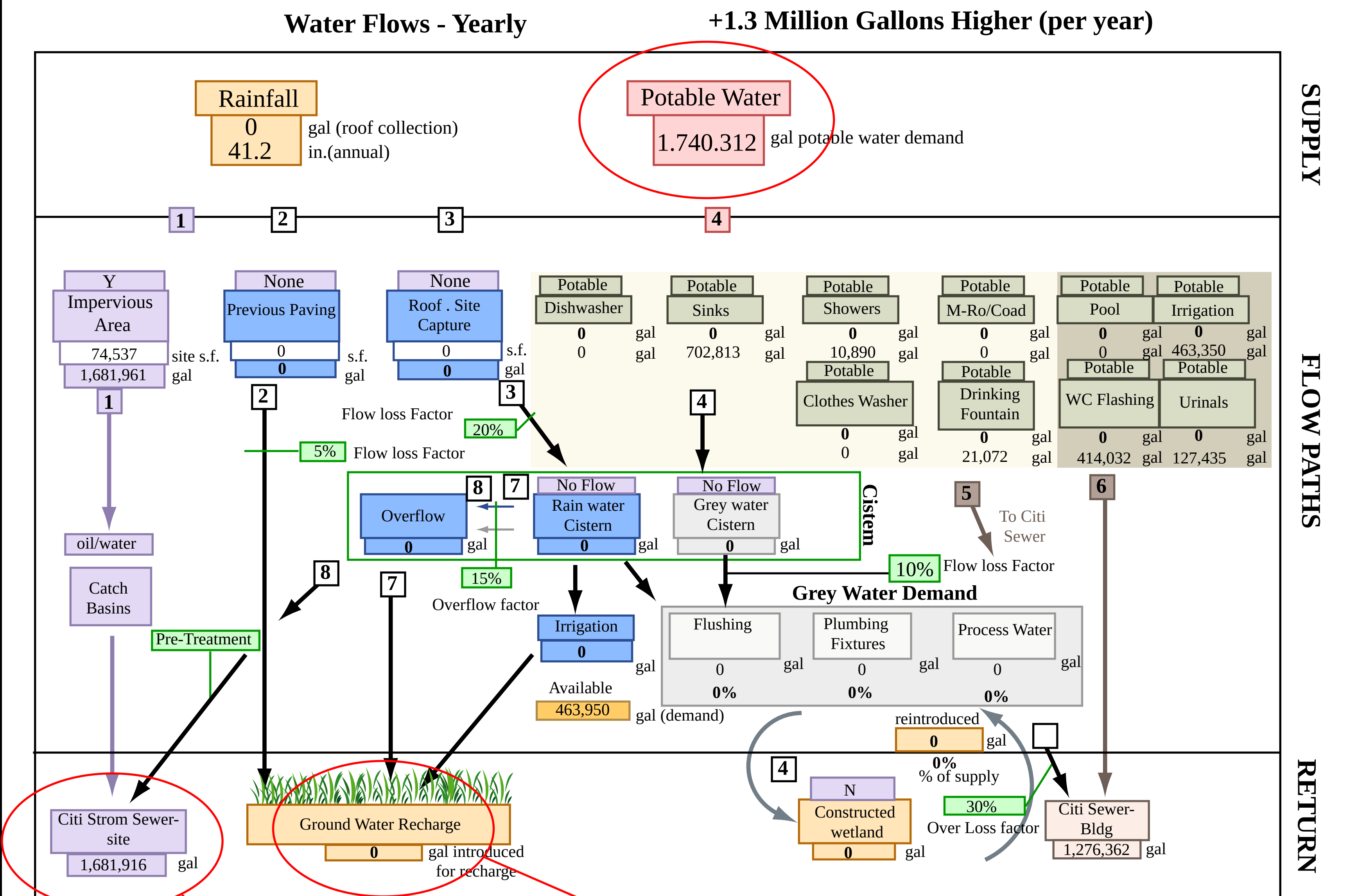


Water Profile Tool

www.greenroundtable.org

Figure by MIT OCW.

2 If no water mesaure included



1.4 million gallons higher (per year)

1.0 millon gallons lower (per year)

Figure by MIT OCW.

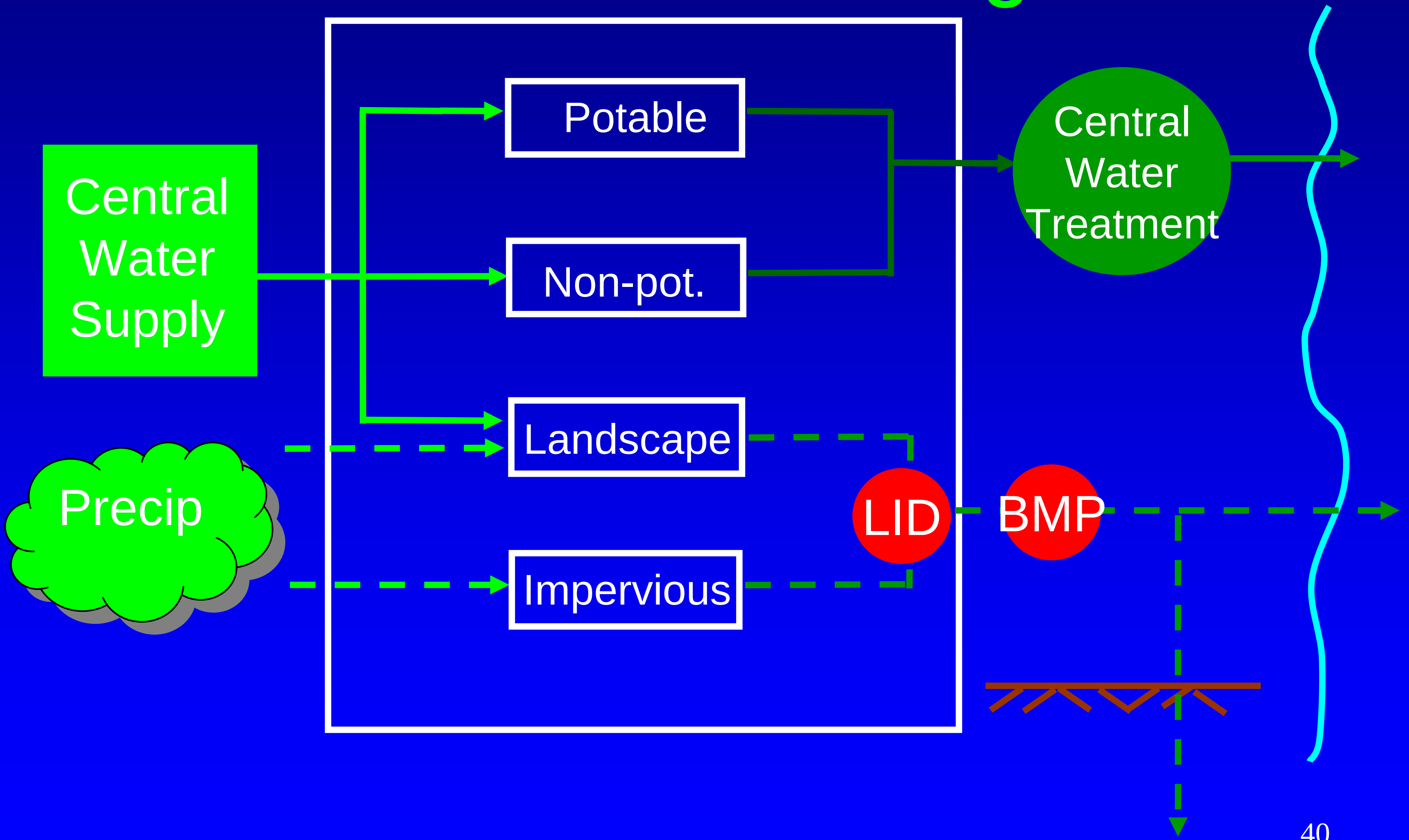
One Bryant Park (Bank of America Bldg NYC)

- Cook and Fox, 54 stories, $1billion, const. start: 2008
- First LEED platinum skyscrapper
- Rainwater, condensate, groundwater & greywater collection, treatment and re-use (flushing, cooling)
- Waterless urinals
- Zero discharge to storm sewer (irrigation instead)
- Also:
  - On-site wind turbine, heat pumps
  - Low-e glass and daylight dimming lights\
  - Displacement ventilation, filtering
  - Digest cafeteria scraps -> CH_4
  - 90% recycling of construction debris, blast furnace slag in place of cement

9900 Wilshire Bldv (luxury condos in Beverly Hills)

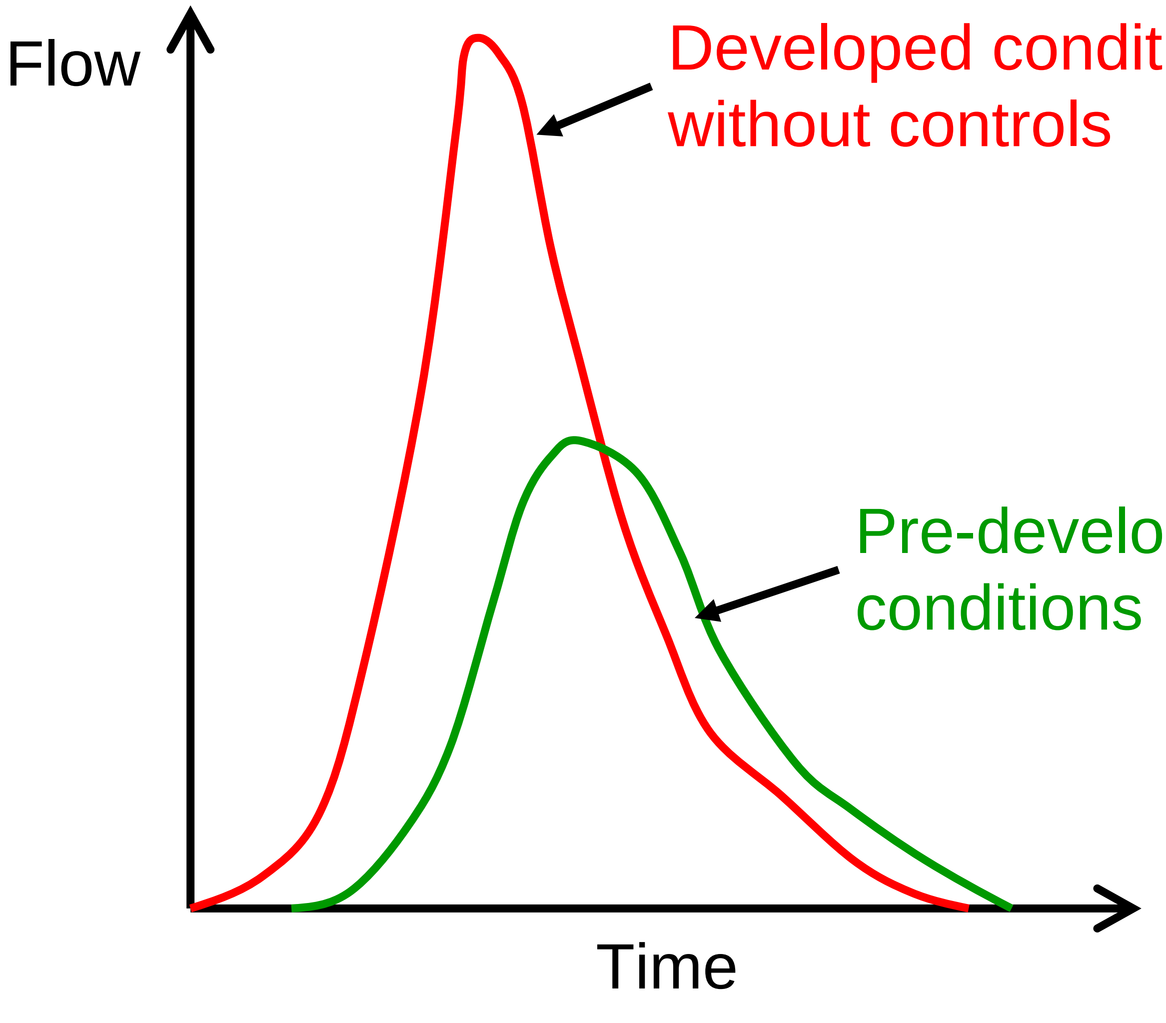
- Architect: Richard Meier; 252 units, average = 3300 sq ft.
- First LEED Gold condo development in West
- On-site WW treatment: 1) methane from sludge -> co-generation, effluent -> Vegetative treatment (Living Machines) -> toilet flushing, irrigation, cooling
- Also on-site wind turbines, heat recovery, passive solar features

3. Stormwater Management

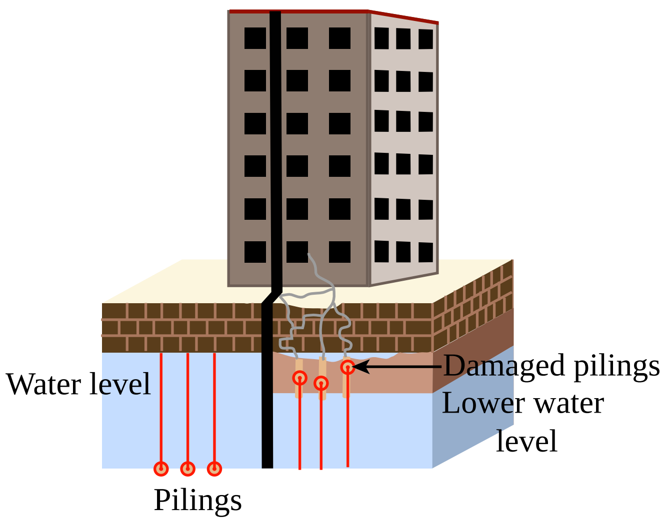


Effect of development: more runoff, leaving site more quickly

(P. Shanahan)



Consequences



* Wood pilings bathed in ground water do not rot.

** If water level drops, the wood is exposed to oxygen, allowing fungi and bacteria to attack

How Drops in Ground Water Damage Wooden Pilings

Figure by MIT OCW.

- Flooding
- Poor water quality
- Reduced long-term ground water storage
- Fluctuating ground water table

Boston Globe May 16, 2005

Detention Ponds

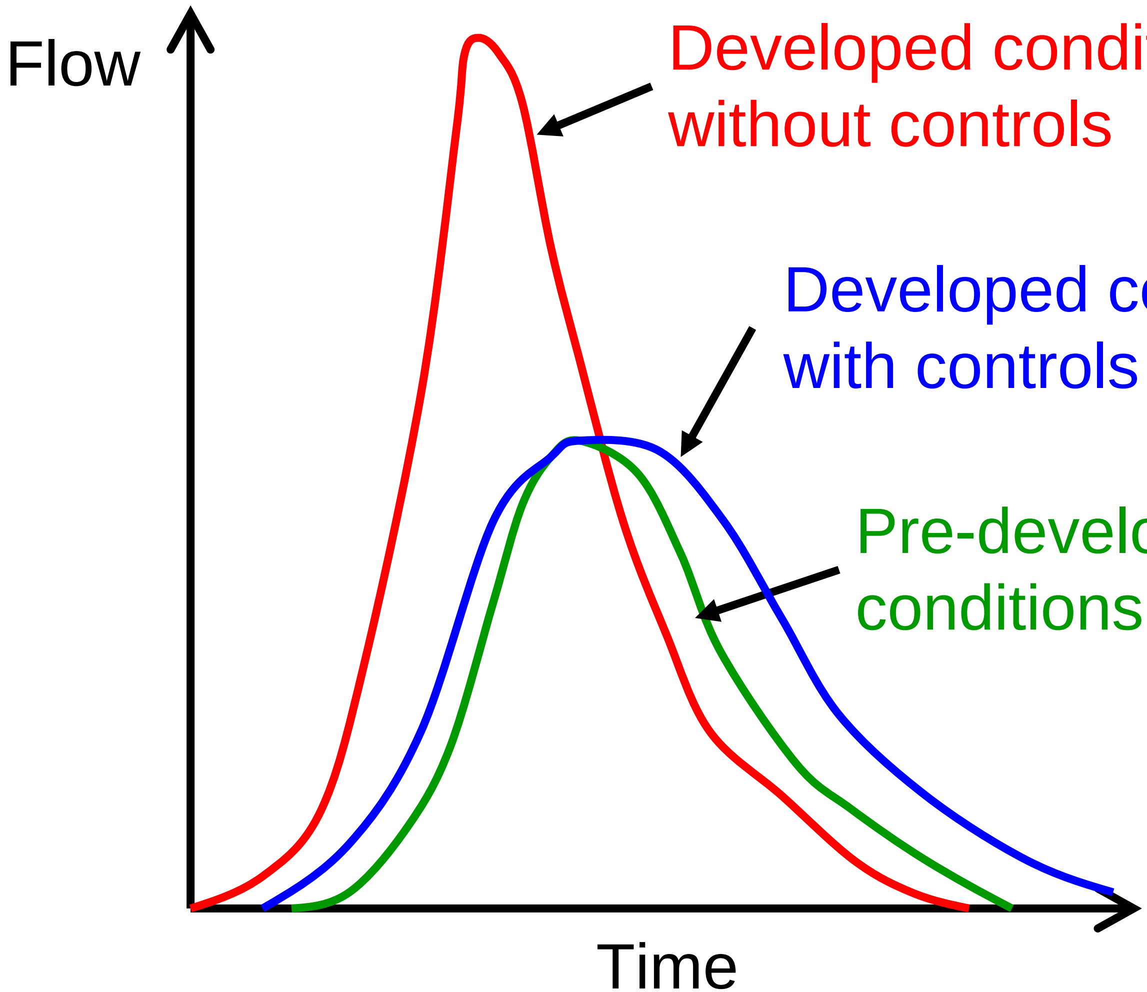
Courtesy of Peter Shanahan.
Used with permission.

Detention Ponds

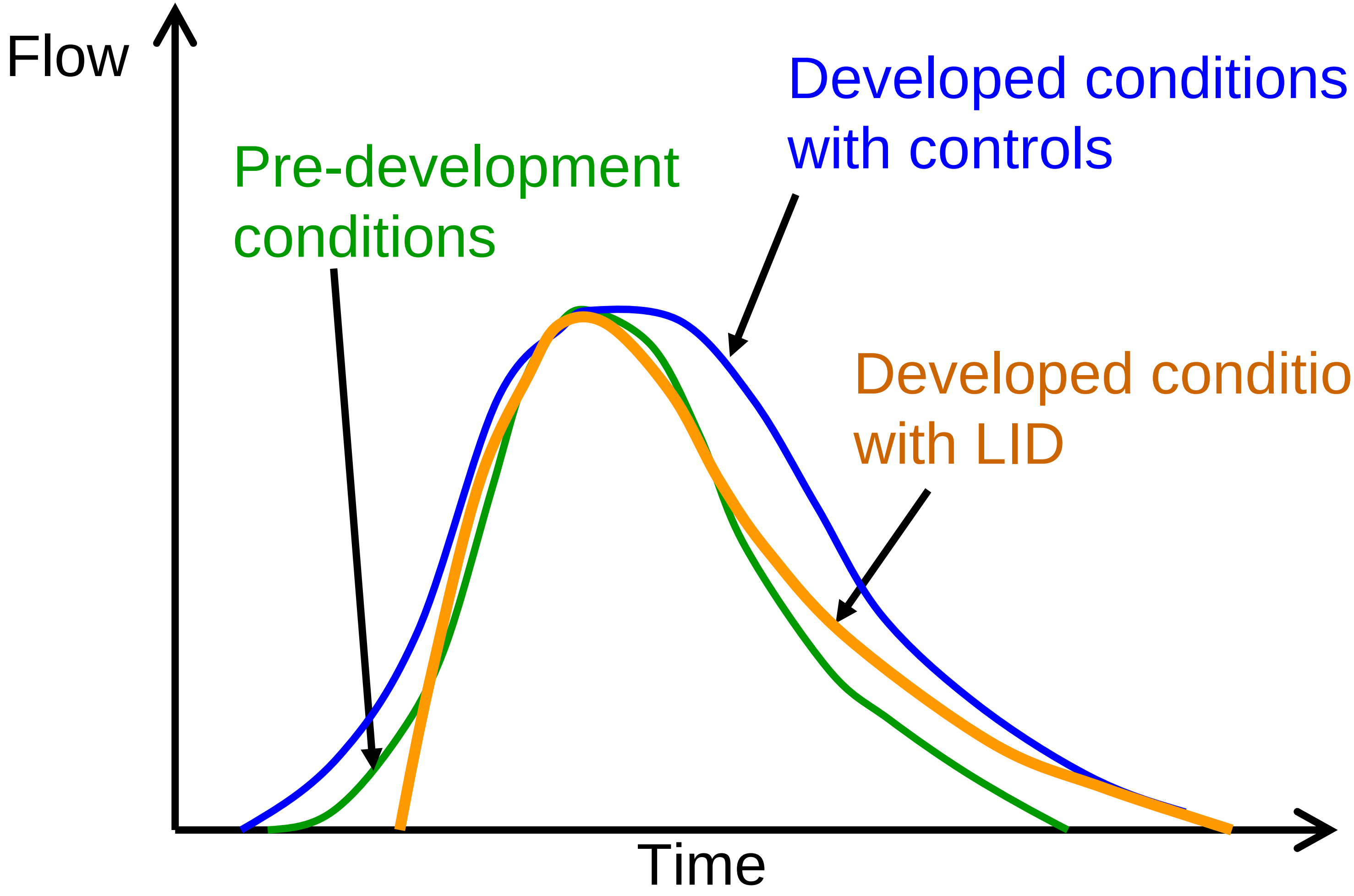
Courtesy of Peter Shanahan.

Used with permission.

Effect of site controls (detention ponds)



Effect of low-impact development



Low-Impact Development

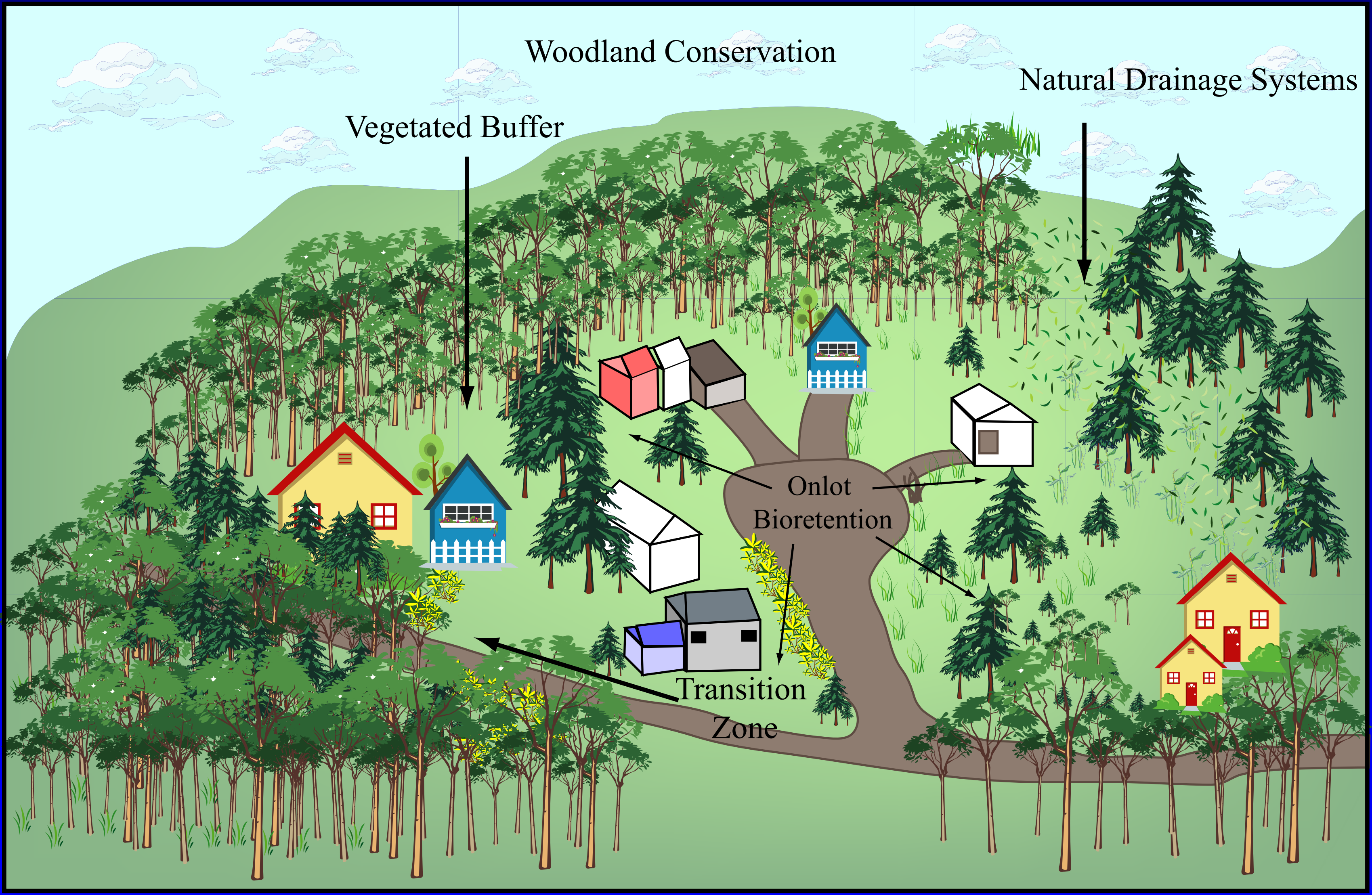
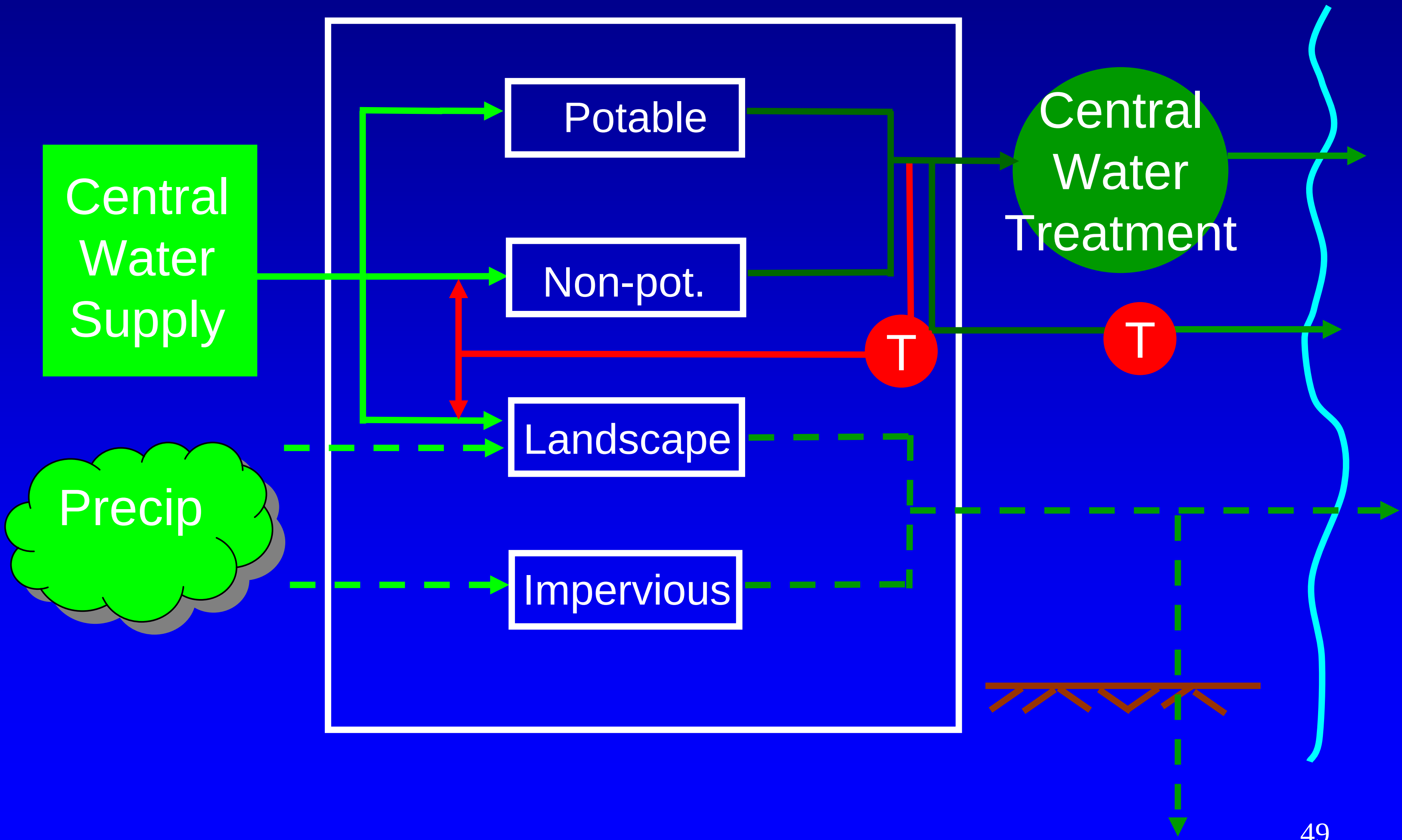


Figure by MIT OCW.

Vegetative Roofs

Flickr photograph courtesy of birdw0rks.

4. Wastewater treatment/re-use



(On-site) Wastewater Treatment

- Order of increasing quality requirements
  - Recharge to GW or discharge to surface water
  - Landscaping/irrigation
  - Non-potable water
- Natural or mechanical
  - Large area vs High Energy

Small Footprint WWTPs

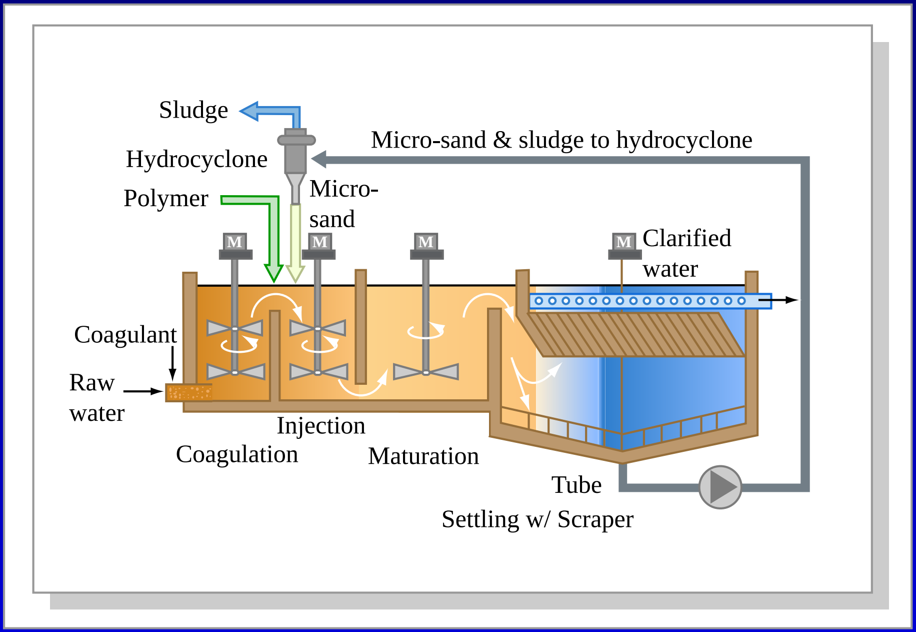
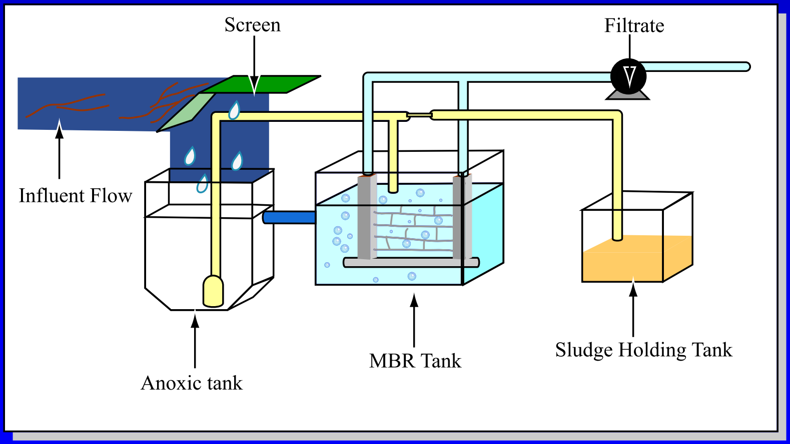


Figure by MIT OCW.

Ballasted flocculation (BF);
(www.brentwoodindustries.com)

Figure by MIT OCW.

Biological aerated Filter (BAF)
(www.vertmarkets.com)



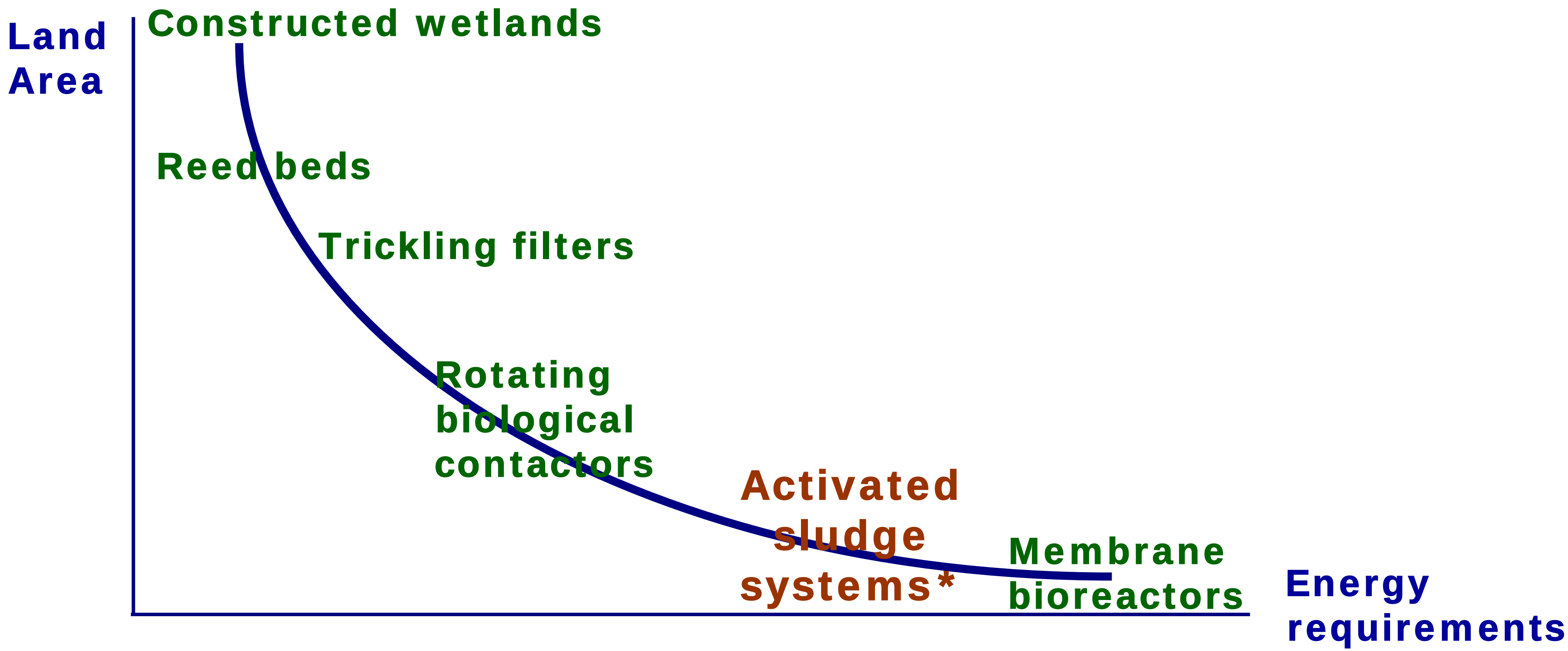
Integrated fixed-film activated sludge (IFAS)
(www.brentwoodindustries.com)

Membrane Bio Reactor (MBR)
(www.brentwoodindustries.com)

Sandino, et al., Civil Engineering, 2003

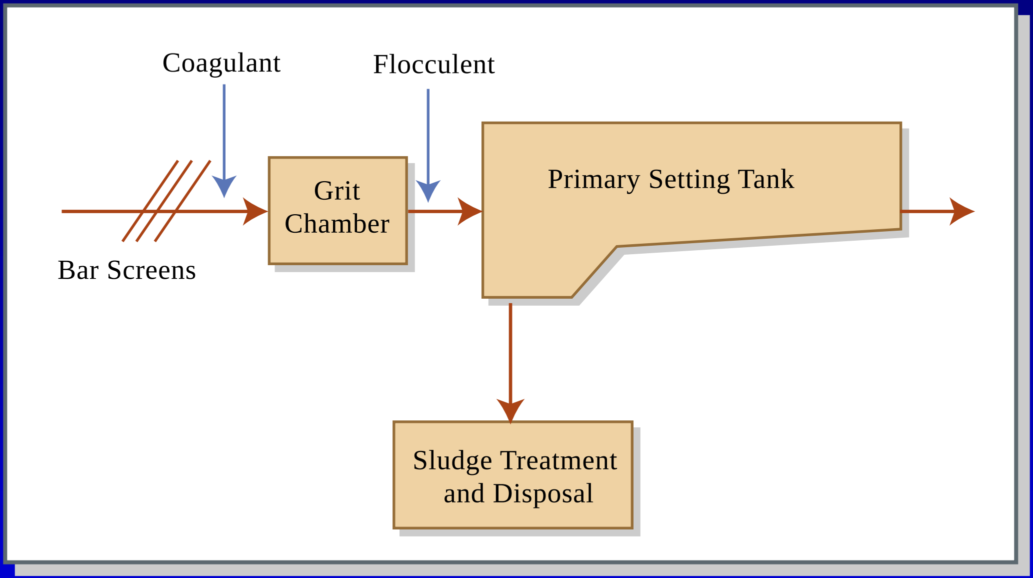
Sustainable Sewage Treatment

(R. Fenner)



Chemically Enhanced Primary Treatment

(D. Harleman, et al.)



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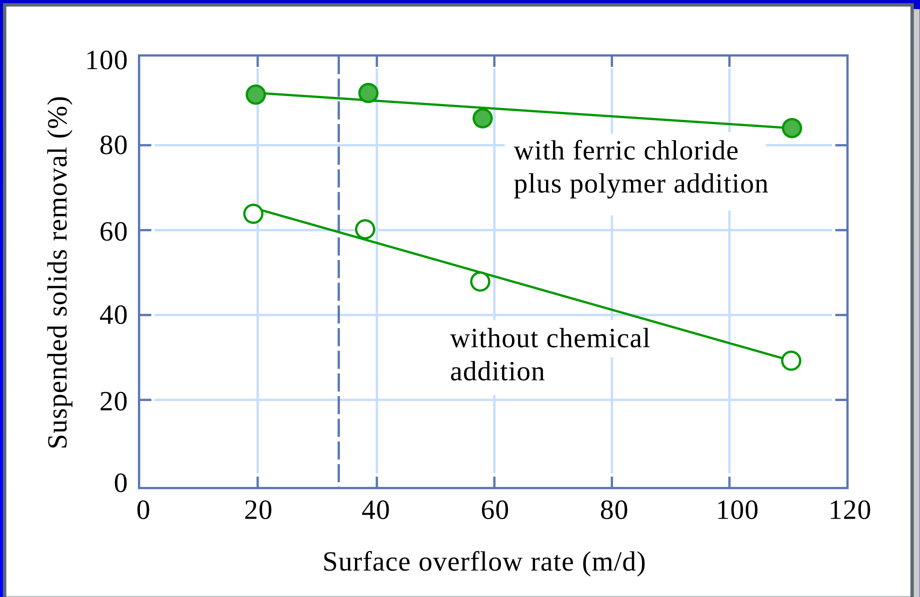

TSS Percent Removal vs. Surface Overflow Rate

Figure by MIT OCW.

Stonecutters Island: world's largest and most efficient CEPT plant

Hong Kong uses seawater to flush toilets

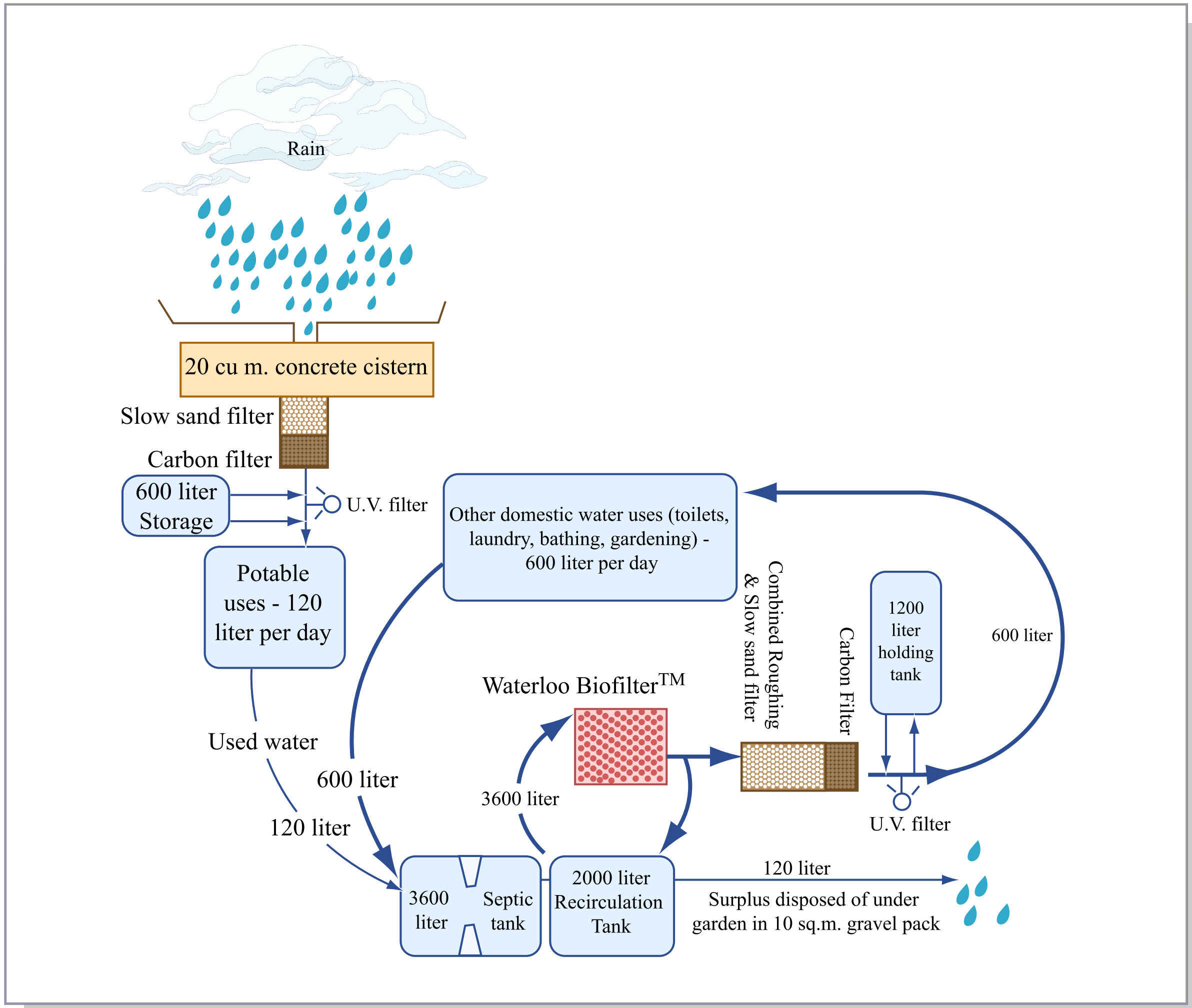

Figure by MIT OCW.

Photograph courtesy of Brett Paci.

Gillette Stadium: Water and sewer issues

- Water supply
  - Limited municipal supply (100 gpm) vs. Peak demands (3,500 gpm)
  - Summer water bans
  - No municipal water allowed for irrigation
- Wastewater disposal
  - 30 yr old treatment system
  - No municipal sanitary sewers

The solution

- Develop a regional high pressure district
- Construct on-site WWTP (MBR, UV, O_3)
- Utilize a water reuse system
- Daylight Neponset River

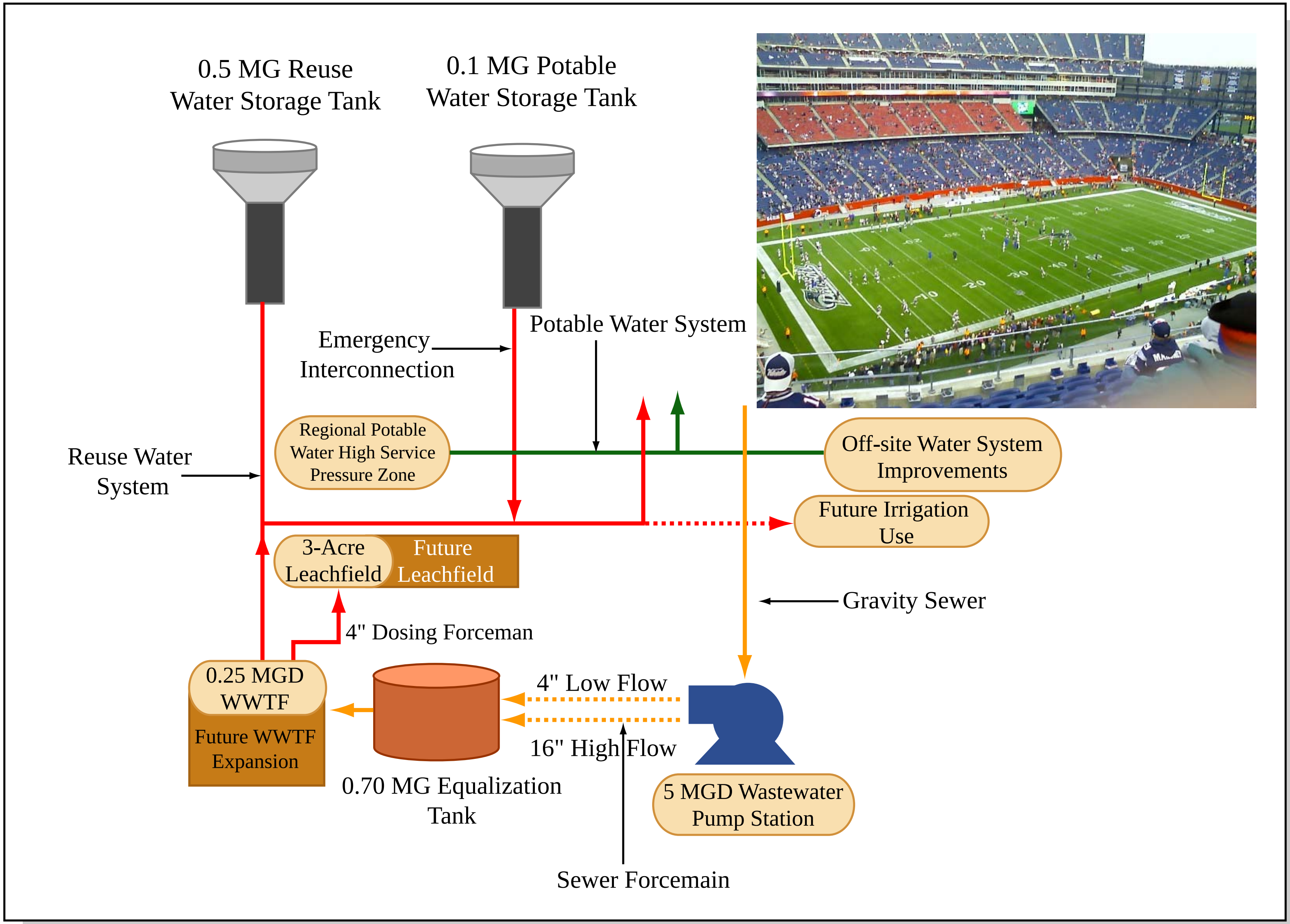

Figure by MIT OCW.

Projected Stadium event water use

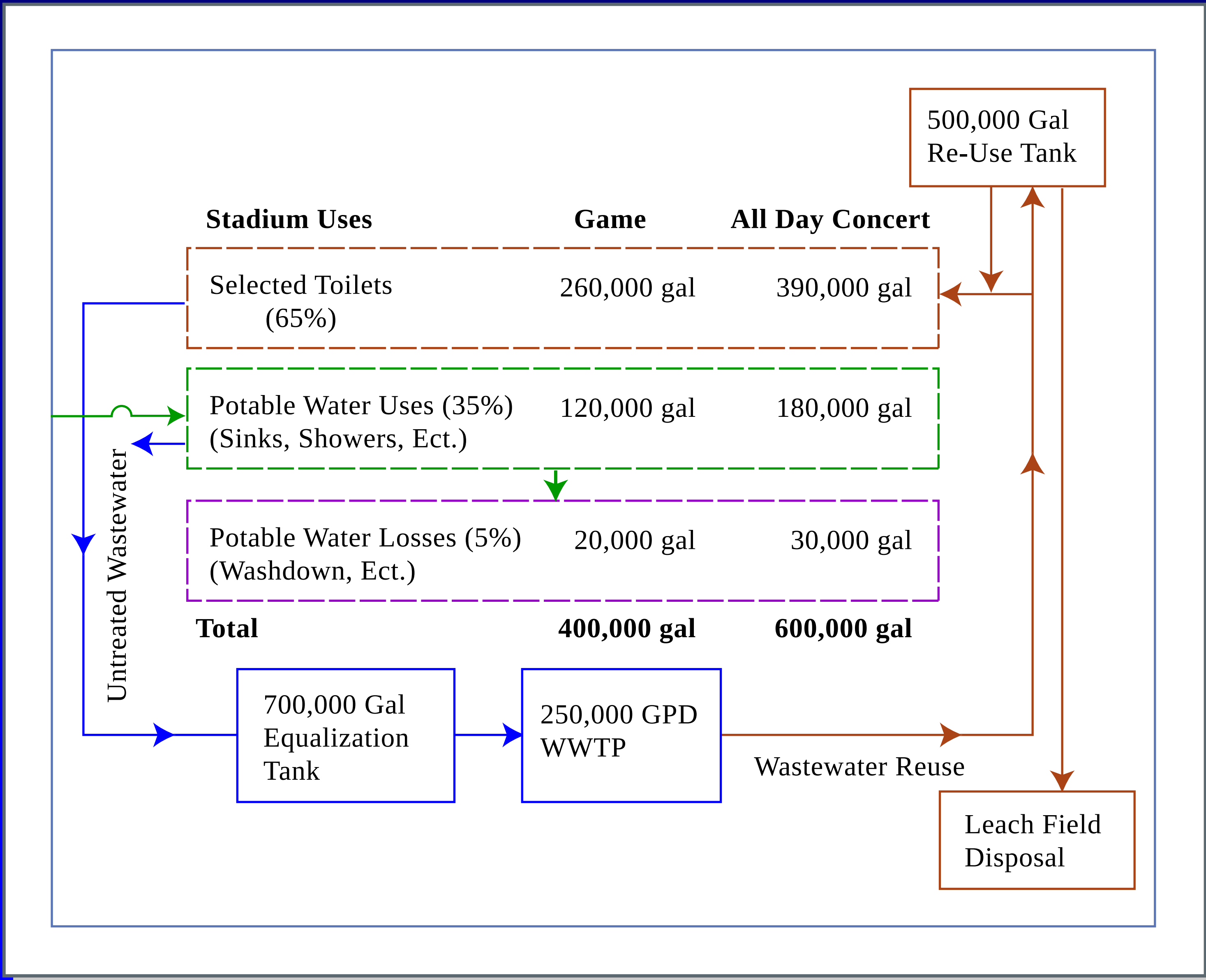

Figure by MIT OCW.

Living Machines, Inc.

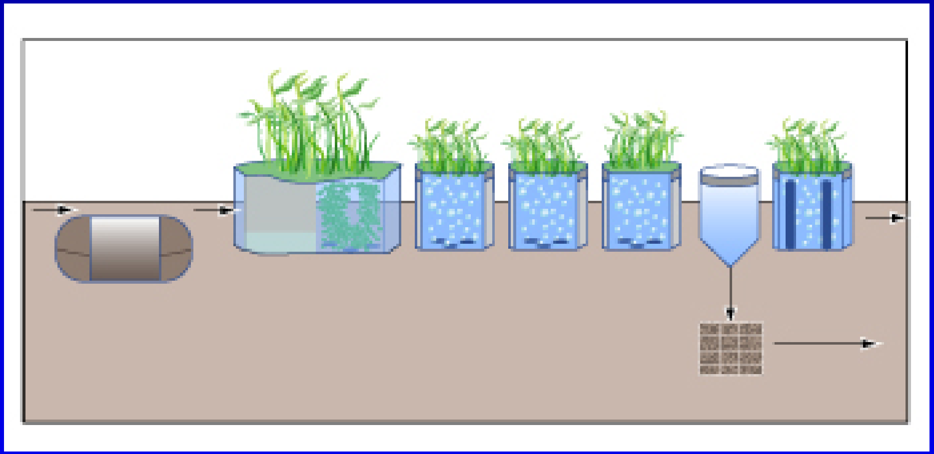

Figure by MIT OCW.

- Household to small town
- Tertiary treatment
  - TSS (5 mg/L)
  - BOD (5 mg/L)
  - NH_3-N (2 mg/l)
- Landscaping & N-P water
- Anaerobic reactor -> Closed aerated reactor -> aerated bioreactors (floating plant racks) -> clarifier -> Ecological Fluidized Beds -> disposal

Living Machines, Inc.

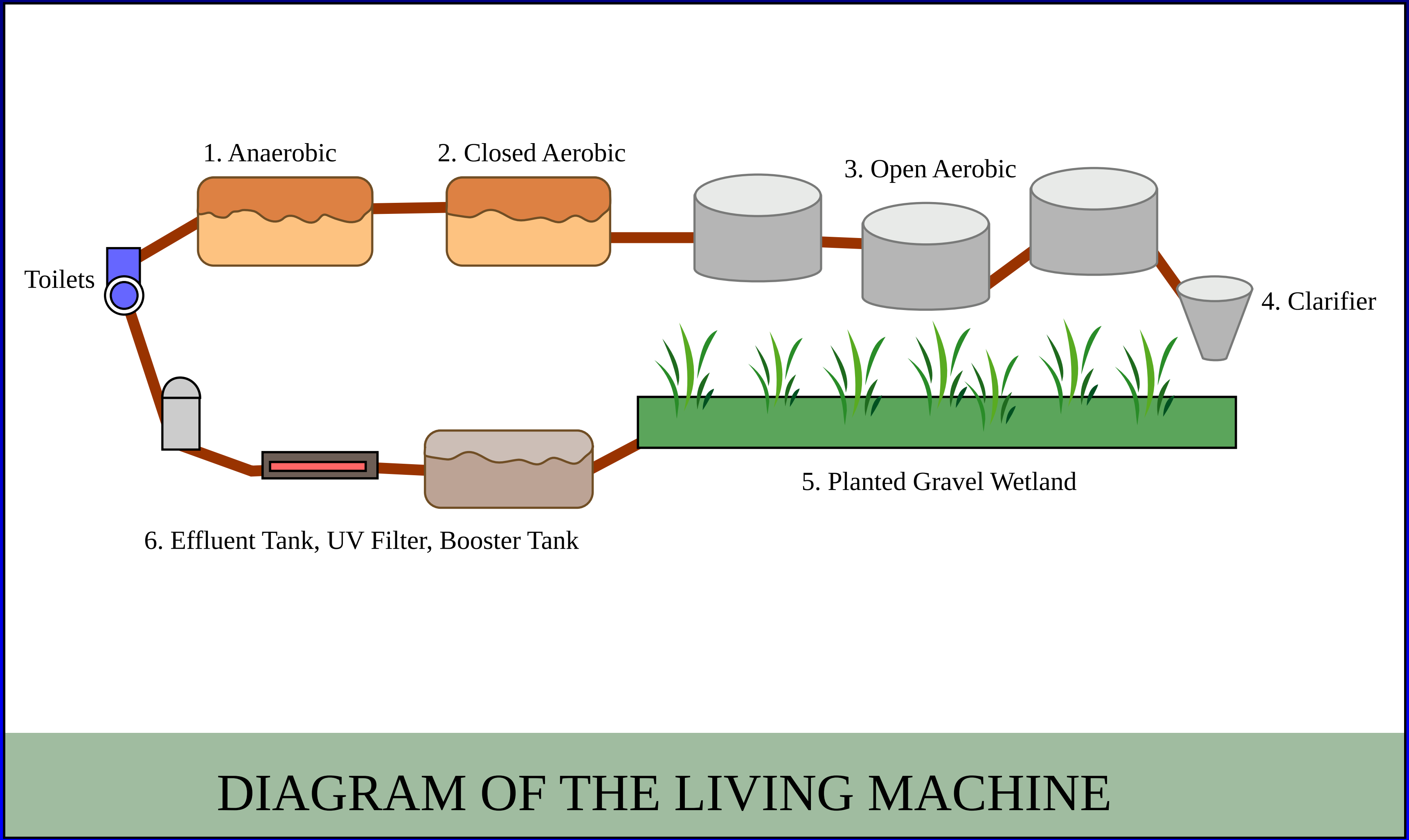

Figure by MIT OCW.

System designed for re-use

Wolverton Engineering, Inc

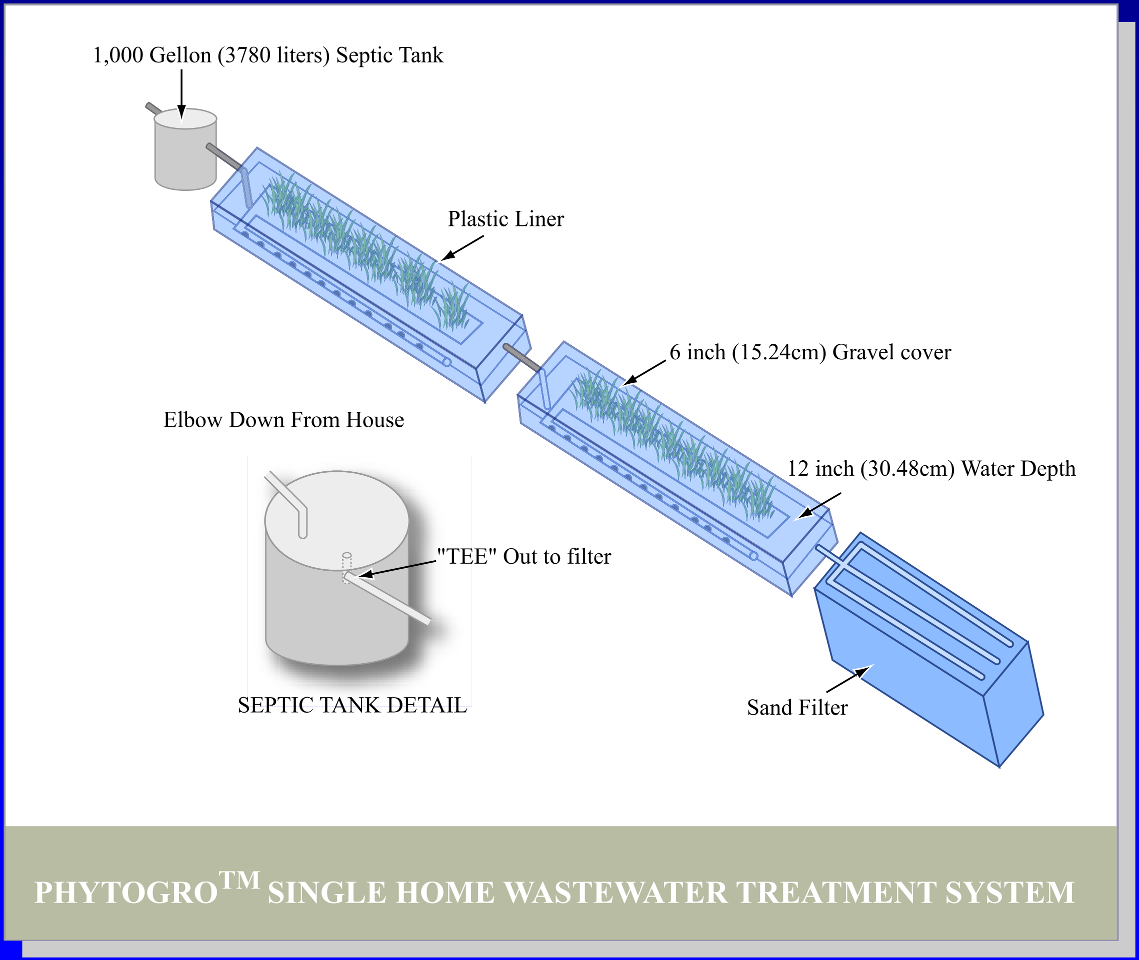

Figure by MIT OCW.

- Household to small town
- Concentrated in rural South (mainly outdoor systems)
- Mainly for discharge back to environment, but some re-use
- Evolved from NASA
- Septic tanks -> rock/plant filters (PhytoGro™ System) -> sand filters

The role for LCA