Combined Sewers

Regulations and Emerging Technology

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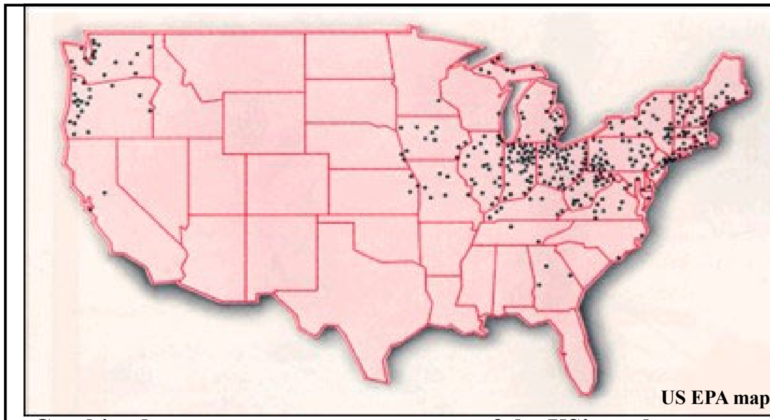

US EPA map

Combined sewer systems are remnants of the US's early infrastructure and are therefore usually found in older communities. Combined sewer systems serve almost 800 communities having about 40 million people (and about 10,000 CSO outfalls). Most are located in the Northeast and Great Lakes regions, and the Pacific Northwest

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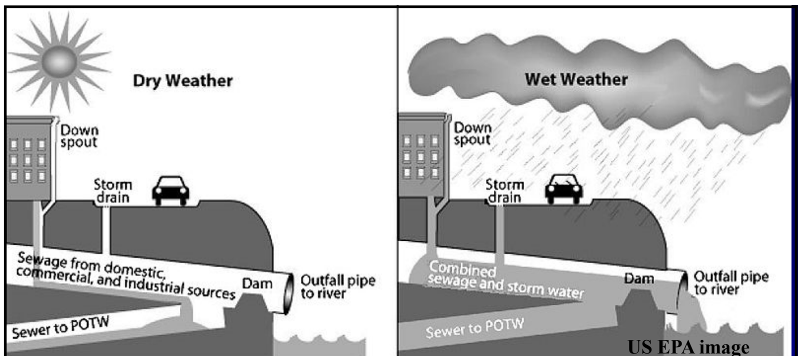

US EPA image

Simple combined sewer and overflow controlled by an outfall weir as commonly found in the U.S.

POTW: Public Owned Treatment Works

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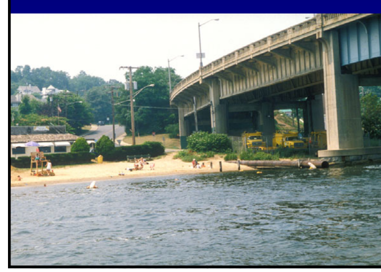
Sanitary Sewer Overflow (SSO)

SSO water mixing with receiving water



CSO discharge location at a public swimming beach

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Report to Congress: *Impacts and Control of Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)* (2004)

http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm

- EPA estimates that about 850 billion gallons of untreated wastewater and stormwater are released as CSOs each year in the United States.
- Because CSOs contain raw sewage along with large volumes of stormwater and contribute pathogens, solids, debris, and toxic pollutants to receiving waters, CSOs can create significant public health and water quality concerns. CSOs have contributed to beach closures, shellfish bed closures, contamination of drinking water supplies, and other environmental and public health concerns

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What recommendations does the Report to Congress make?

- Providing adequate funding for maintenance and improvement of the nation's wastewater infrastructure;
- integrating of wastewater programs and activities at the watershed level;
- improving monitoring and reporting programs to provide better data for decision-makers; and
- supporting stronger partnerships among federal and state agencies, municipalities, industry, non-governmental organizations, and citizens.

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Combined Sewer Overflows Nine Minimum Controls (1994)

http://cfpub.epa.gov/npdes/cso/ninecontrols.cfm?program_id=5

1) Proper operation and regular maintenance programs for the sewer system and the CSOs

2) Maximum use of the collection system for storage

3) Review and modification of pretreatment requirements to assure CSO impacts are minimized

4) Maximization of flow to the publicly owned treatment works for treatment

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Combined Sewer Overflows Nine Minimum Controls (1994) (continued)

5) Prohibition of CSOs during dry weather

6) Control of solid and floatable materials in CSOs

7) Pollution prevention

8) Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts

9) Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls

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Nine Minimum Controls

The nine minimum controls (NMCs) are technology-based controls, applied on a site specific basis to reduce the magnitude, frequency, and duration of CSOs and their impacts on receiving water bodies.

In addition, “ability to pay” guidance and significantly reduced overflows (usually to about 3 or 4 per year) are also part of the CSO control programs.

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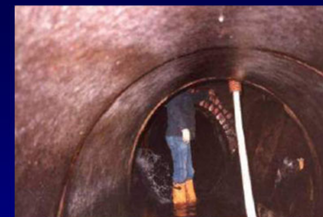
1) Proper operation and regular maintenance programs for the sewer system and the CSOs



Sealing and inspections to ensure minimal infiltration and inflow (I&I)

EPA photos

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Re-lining of a large sanitary sewer to reduce infiltration.

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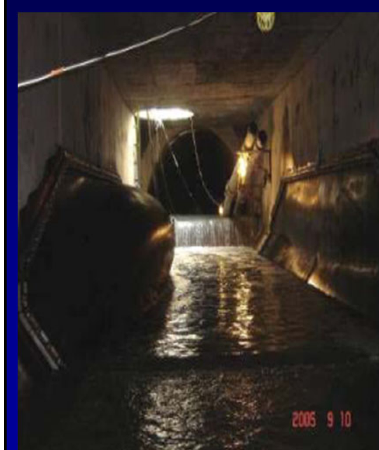
2) Maximum use of the collection system for storage



In-system storage with inflatable dams

US EPA photos

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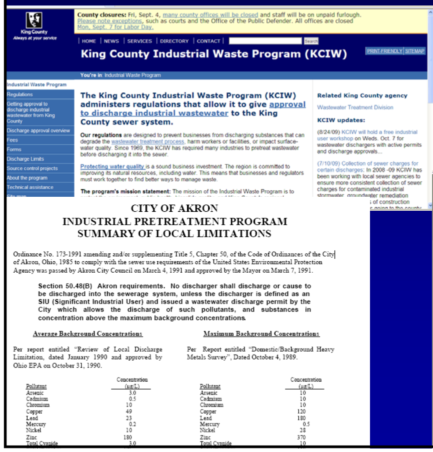
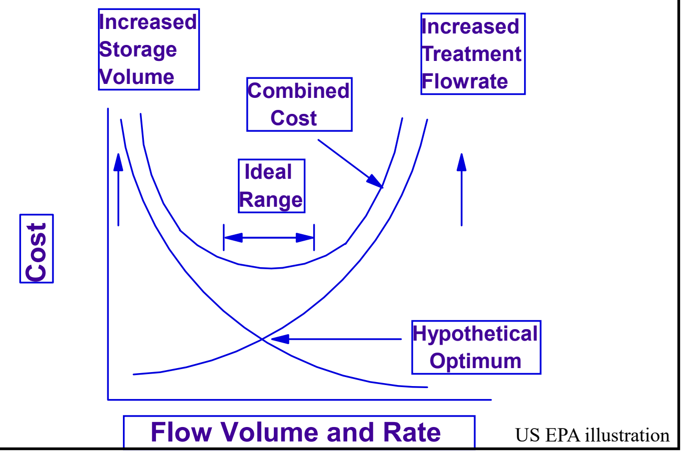
3) Review and modification of pretreatment requirements to assure CSO impacts are minimized



King County, Washington and Akron, Ohio, web pages describing industrial pre-treatment and local hazardous waste management programs

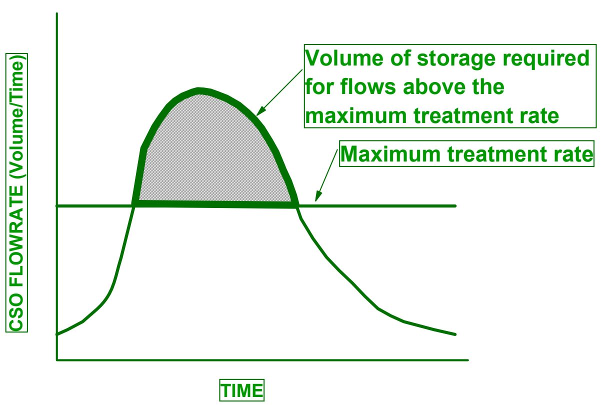
4) Maximization of flow to the publicly owned treatment works for treatment

Classical Optimization Curve



US EPA illustration

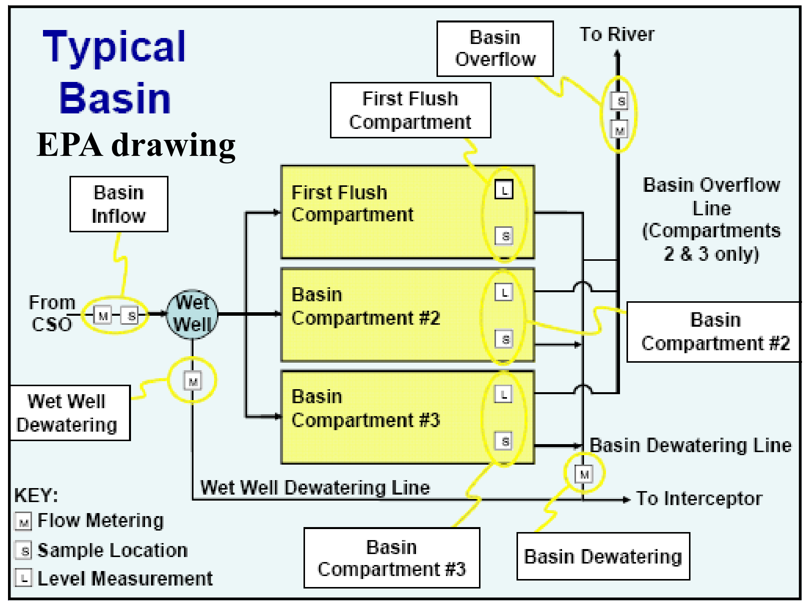
Representation of Storage Volume above Treatment Rate

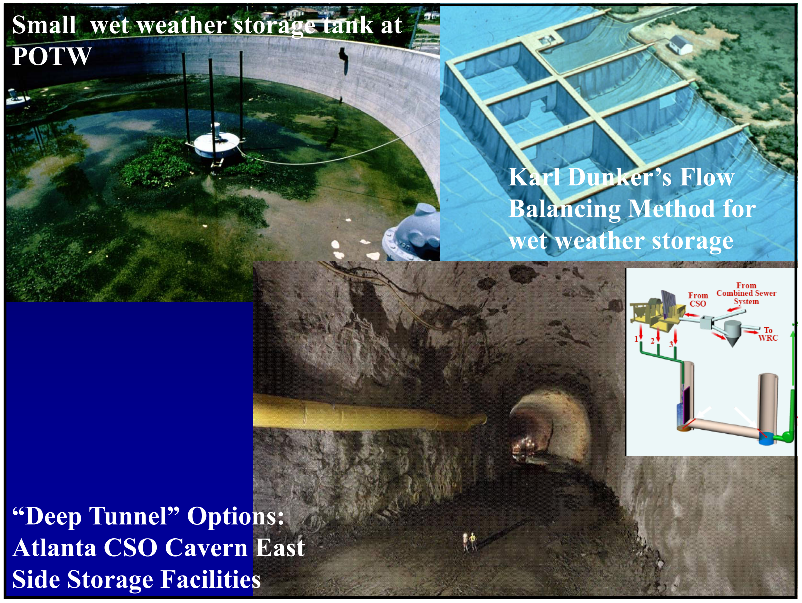


US EPA illustration

Typical Basin

EPA drawing




Small wet weather storage tank at POTW
Karl Dunker's Flow Balancing Method for wet weather storage
"Deep Tunnel" Options: Atlanta CSO Cavern East Side Storage Facilities

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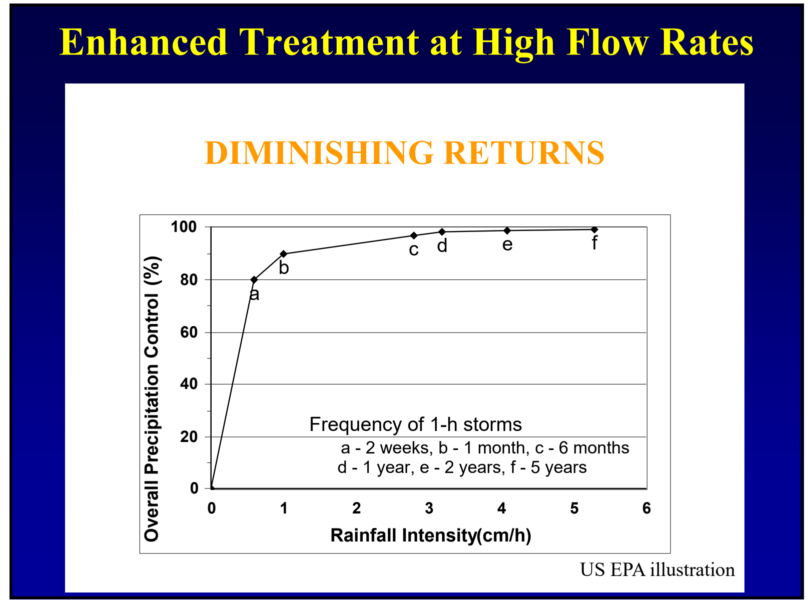
Enhanced Treatment at High Flow Rates
DIMINISHING RETURNS
Overall Precipitation Control (%)
100
80
60
40
20
0
0
1
2
3
4
5
6
Rainfall Intensity(cm/h)
a
b
c
d
e
f
Frequency of 1-h storms
a - 2 weeks, b - 1 month, c - 6 months
d - 1 year, e - 2 years, f - 5 years
US EPA illustration

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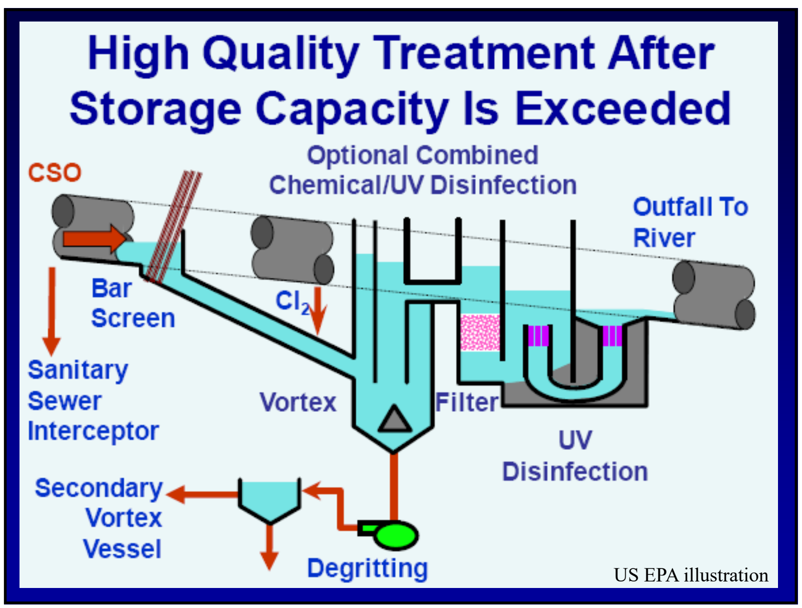
High Quality Treatment After Storage Capacity Is Exceeded
CSO
Optional Combined Chemical/UV Disinfection
Outfall To River
Bar Screen
Cl2
Sanitary Sewer Interceptor
Vortex
Filter
UV Disinfection
Secondary Vortex Vessel
Degritting
US EPA illustration

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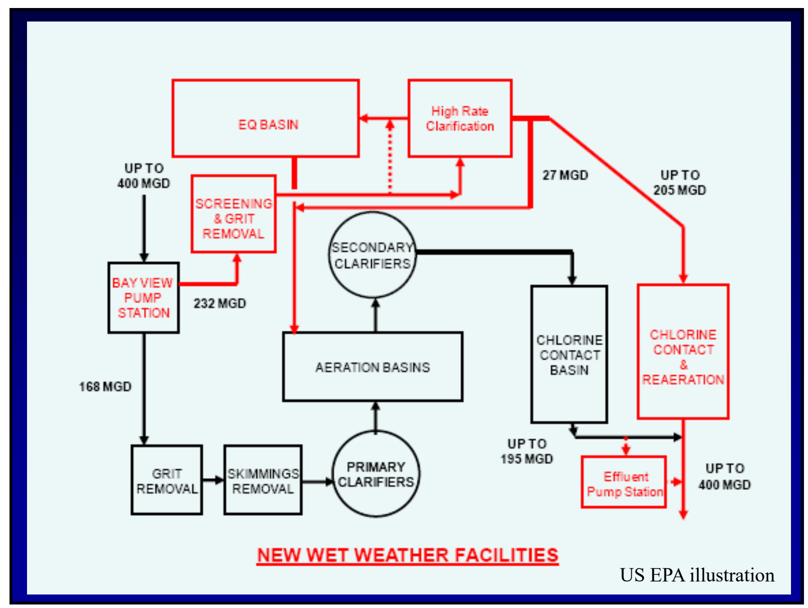
EQ BASIN
High Rate Clarification
UP TO 400 MGD
SCREENING & GRIT REMOVAL
27 MGD
UP TO 205 MGD
SECONDARY CLARIFIERS
BAY VIEW PUMP STATION
232 MGD
AERATION BASINS
CHLORINE CONTACT BASIN
CHLORINE CONTACT & REAERATION
168 MGD
GRIT REMOVAL
SKIMMINGS REMOVAL
PRIMARY CLARIFIERS
UP TO 195 MGD
Effluent Pump Station
UP TO 400 MGD
NEW WET WEATHER FACILITIES
US EPA illustration

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Wetland Treatment of CSO discharges; Rouge River National Demonstration Project, Detroit, Michigan

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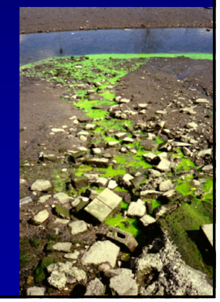
5) Prohibition of CSOs during dry weather

Dry weather sanitary sewage source and outfall

Outfall chemical screening, followed by dye testing and TV surveys to locate specific sources



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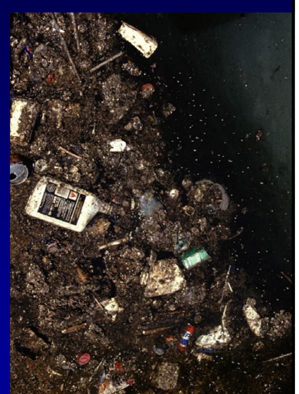
6) Control of solid and floatable materials in CSOs

Large-scale CSO screening facility



Typical CSO floatables in receiving water

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Floating booms and screening nets to capture CSO floatables

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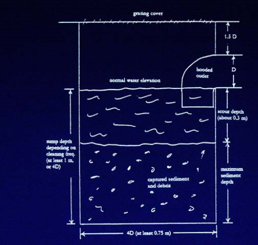
7) Pollution prevention

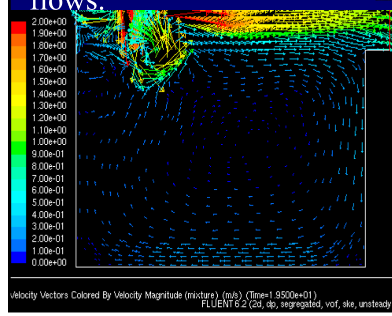
Street cleaning, inlet screening, materials substitution, and stormwater controls are included under this category.

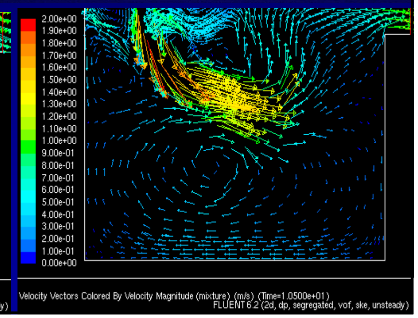
Street and catchbasin cleaning, and inlet controls most effective for smaller rains in heavily paved areas.

We have studied the performance of hydrodynamic devices for inlet control, most recently investigating scour potential of captured sediment during high flows.

Dimensions of Optimally-Designed Catchbasin



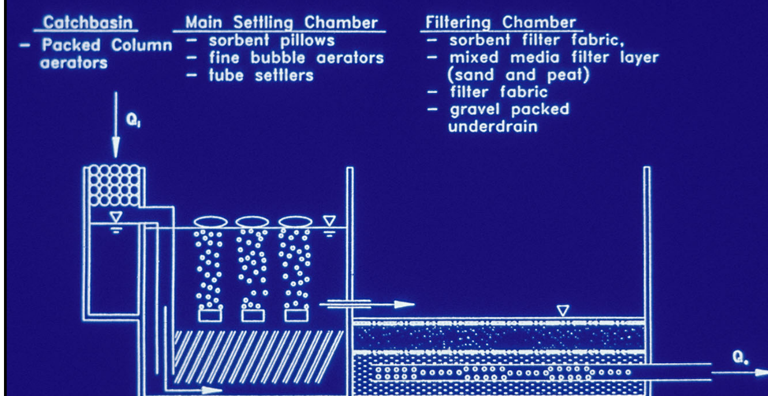




Critical Source Area Controls are Needed to Pretreat Stormwater before Entering Combined Sewerage

Contech Solutions Storm Filter, the most commonly used stormwater filter in the US, is used to treat runoff from roof drains to airports.

The Multi-Chambered Treatment Train (MCTT) was developed by R. Pitt as part of an EPA research contract to provide very high levels of control of toxicants in stormwater. This device, or similar devices based on the treatment concepts, is in the public domain and has been constructed in several countries.



Minocqua, WI, MCTT Installation

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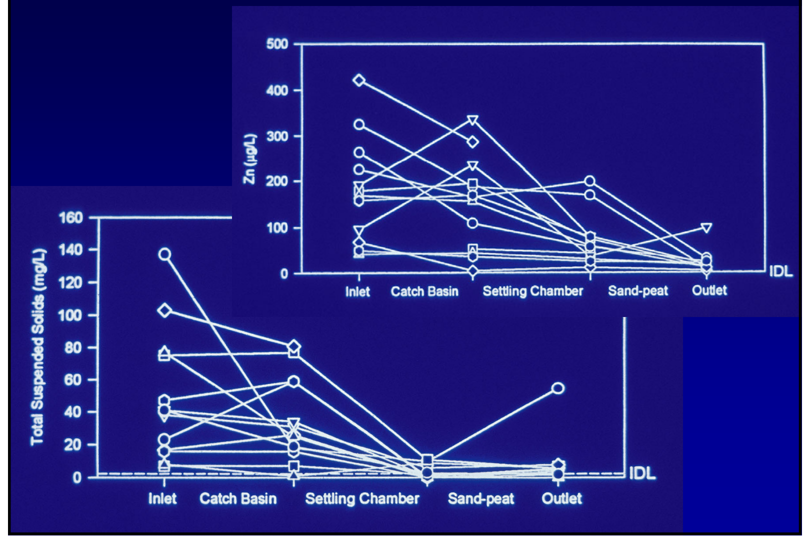
MCTT Test Results



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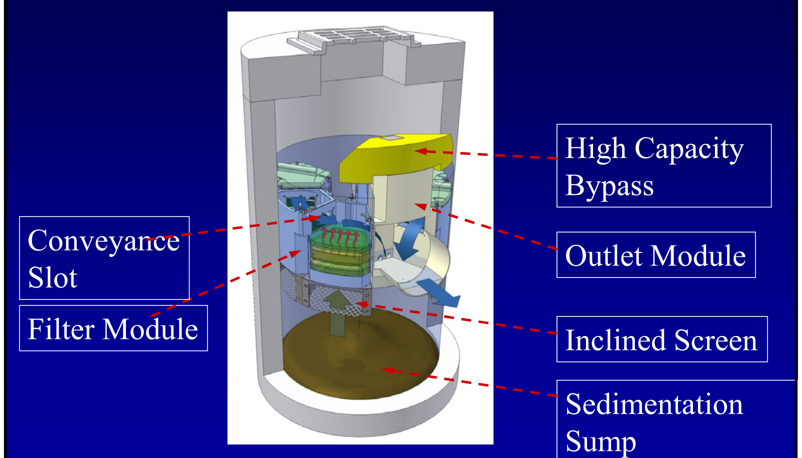
The Up-Flo® filter was developed by R. Pitt as part of an EPA SBIR research project. It was commercialized by HydroInternational.



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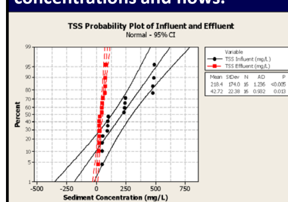
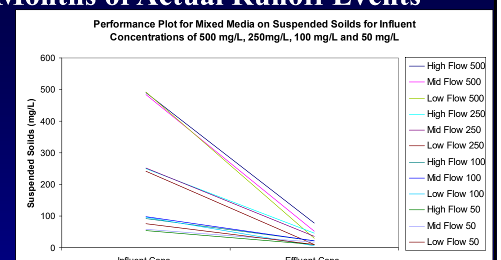
Flow rate has very little effect on effluent quality. Effluent quality is relatively constant over broad range of influent concentrations and flows.

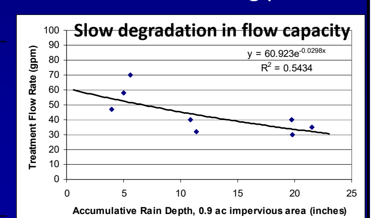
Pilot-Scale Tests, Controlled and 10 Months of Actual Runoff Events





Performance during actual rains over a 10 month monitoring period:

particle size range (µm)	SS influent mass (kg)	SS effluent mass (kg)	SS removed (kg)	% reduction
0.45-3	9.3	2.8	6.6	71
3-12	18.7	6.4	12.3	66
12-30	22.4	7.7	14.7	66
30-60	26.7	6.8	19.9	75
60-120	4.6	1.8	2.9	63
120-250	19.8	4.3	15.5	78
250-425	11.5	0.0	11.5	100
425-850	17.1	0.0	17.1	100
850-2,000	10.5	0.0	10.5	100
2,000-4,750	4.8	0.0	4.8	100
>4,750	3.5	0.0	3.5	100
sum	148.9	29.8	119.2	80



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High Zinc Concentrations have been Found in Roof Runoff for Many Years at Many Locations

- Typical Zn in stormwater is about 100 µg/L, with industrial area runoff usually several times this level.
- Water quality criteria for Zn is as low as 100 µg/L for aquatic life protection in soft waters, up to about 5 mg/L for drinking waters.
- Zinc in runoff from galvanized roofs can be several mg/L

- Other pollutants and other materials also of potential concern.
- A cost-effective stormwater control strategy should include the use of materials that have reduced effects on runoff degradation.

Penn State – Harrisburg test facility

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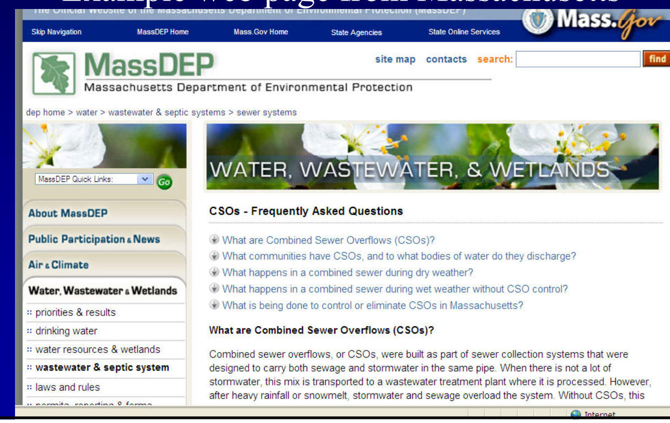
8) Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts

Example web page from Massachusetts



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Public Education Activities

Fish consumption warning

Presentations at schools

Aquarium exhibit

Signage at in-stream aeration system

Volunteer stream monitoring

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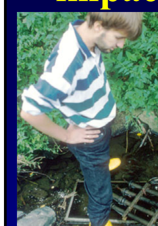
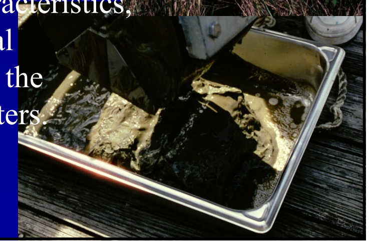
9) Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls



Many in-stream and CSO discharge attributes need to be monitored, including rainfall and runoff quantity, chemical and physical characteristics, and biological conditions in the receiving waters.



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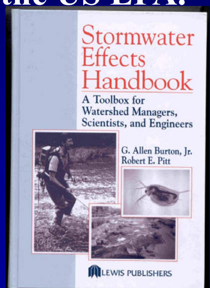
Monitoring guidance is provided in the following book that was prepared with partial assistance from the US EPA.



Burton, G.A. Jr., and R. Pitt. *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*. ISBN 0-87371-924-7. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages.

Due to partial EPA support, this book is also available at:
http://www.epa.gov/ednnrmrl/publications/books/handbook/index.htm

Suggestions for New Sewerage Systems (Richard Field, US EPA)

- Larger diameter sewers to add in-line storage
- Steeper-sloped sewers/more effective bottom cross-sections/sediment traps to reduce sediment deposition
- Treatment plant capacity sized for CSO
- Larger interceptors
- Beneficial use of stormwater
- Blackwater-graywater separation/graywater recycling
- Integrate green & gray infrastructure

What Does EPA Mean by "Green Solutions"?

- Green Solutions use natural or engineered systems – e.g., green roofs, bioretention/rain gardens, swales, wetlands, & porous pavement
- These systems mimic natural processes and direct stormwater to areas where it can infiltrate, evapotranspirate, be slowed, and beneficially used
- Green Solutions generally are a subset of sustainable infrastructure
- Green Solutions can provide many environmental benefits

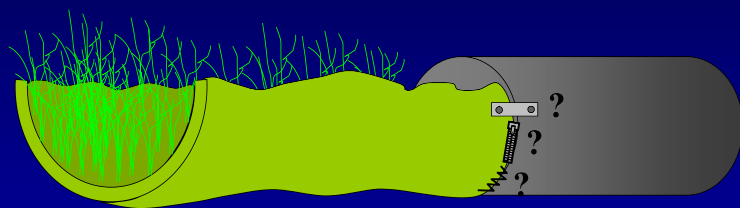
Green Solutions Can Have Multiple Community Benefits

- Water quality
- Flood and hydromodification control
- Rainwater capture and use
- CSO/SSO control
- Increased groundwater recharge and baseflow
- Improved air quality
- Reduced energy consumption

– Cost savings
– Community identity
– Recreational greenspace
– Reduced urban heat island effect
– Wildlife habitat
– Enhanced property values
– Carbon sequestering
– Aesthetics

(from Ben Grumbles, US EPA March 5, 2007 memo)

How does Green integrate with Gray?



US EPA graphic

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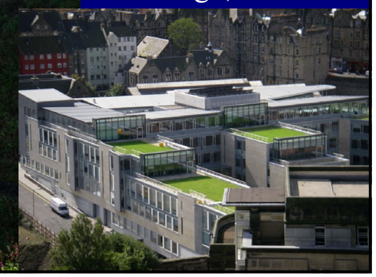
Examples of Green Infrastructure:

Green roofs function by reducing roof runoff through evapotranspiration losses.

San Francisco Academy of Science

Edinburgh, Scotland



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Examples of Green Infrastructure:

Large storage tanks capture roof runoff that is then used on site for toilet flushing or landscaping irrigation, amongst other uses.

Roof runoff storage tanks at the LandCare main research centre in Auckland, New Zealand. Water is used to flush urinals and to irrigate research greenhouses.

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Examples of Green Infrastructure:

Parking lot and roof bioinfiltration areas reduce discharges from these areas through plant evapotranspiration and infiltration into the soil.

Bioinfiltration area capturing roof and parking lot runoff in downtown Portland, Oregon. This parking lot also has porous asphalt pavement.

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National Demonstration of Advanced Drainage Concepts Using Green Solutions for CSO Control

Collaborations in Kansas City:

- EPA: National Risk Management Research Laboratory (NRMRL), Region 7, Office of Wastewater Management (OWM), and Office of Enforcement and Compliance Assurance (OECA)
- Kansas City, MO, Water Services Department (KCMO WSD), Tetra Tech, Univ. of Missouri-Kansas City UMKC), Univ. of Alabama (UA), Mid-America Regional Council (MARC), Bergmann Associates
- Partnerships at neighborhood, watershed & regional levels

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Selection of Kansas City for National Demonstration Project

- Approximately 56 mi^2 within Kansas City served by combined sewers
- Many opportunities for stormwater management
- The City has implemented at least 8 engineered bioretention systems and developed national recognition through the "10,000 Rain Gardens" program
- Kansas City willing to dedicate in-kind & direct funds for analyses, planning, design, and construction

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Selection of Kansas City (cont.)

- Completed preliminary "green filter" technical and economic analysis
- Efforts to create regional "green collar" jobs program as triple-bottom line approach to environmental justice and wet- weather solutions
- Strong commitment to use green solutions
- City Council adopted resolution in August, 2007, "establishing the policy of the City to integrate green solutions protective of water in our City planning and development processes in a comprehensive Wet Weather Solutions Program."

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Project Objectives

Demonstrate value of integrated, green infrastructure-based solutions to WWF pollution problems in a combined sewer system

- **Assess multiple Green Infrastructure practices (include planning, designing, and implementing)**
- **Develop approach to identify & prioritize stormwater micro-control projects**
- **Monitor quantity (flow) and quality (pollutant concentrations) of surface and combined system flows**
- **Determine practice performance**
- **Model performance (quantity and quality) at multiple scales of implementation (WinSLAMM, SUSTAIN)**
- **Conduct economic analyses comparing to traditional approaches**
- **Provide community education, outreach and coordination activities**

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Economic Viability of Green Infrastructure in Kansas City

	Control Component	Est. Capital Cost ($M)	Storage Provided (M gal)	Unit Capital Cost ($/gal Stored)
Gray Controls Only	Outfall 059: 1 M gal Storage Tank 0.5 MGD Pumping Station 17 MGD Screening 2,000 ft 48-in. Sewer 500 ft 8-in. Force Main Odor Control	20.0	1.0	20.00
Green Solutions	Stormwater Inlet Retrofits	0.7	0.1	2.00-7.00
	Porous Pavement Parking Lots	1.9	0.325	5.50
	Curb Extension Swales	4.1	0.30	11.00
	Porous Pavement in Street Right-of-way	3.6	0.40	11.00
	Green Solution Totals	10.3	1.125	9.00

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Preliminary Comparison of Present Worth Costs CSO Control for Kansas City, MO

- Deep-Tunnel Storage: $19-27/gallon stored
- Near-Surface Storage: $17-23/gallon stored
- High-Rate Treatment: $15-25/gallon treated
- Green Solutions: $5-10/gallon stored

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Locating Green Solutions

- Key components of GIS data
  - Topography
    - Digital Elevation Model (DEM) Arc-Hydro model
  - Parcel data
    - Ownership records
  - Remote Sensing/Aerial Imagery
    - Current high quality aerial imagery
    - Natural resources inventory
    - GAP cover analysis
    - Impervious cover

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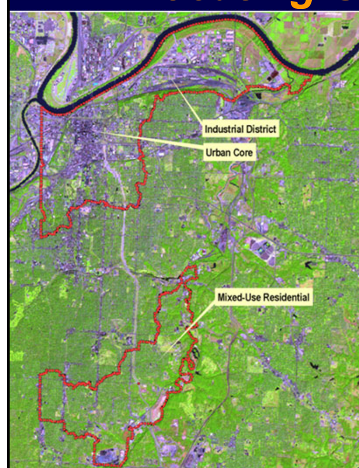
Locating Green Solutions



- **Build a site selection model that will work with varying scales and surface cover**
- **Evaluate several tiers:**
  - **City-owned property**
  - **Vacant private property**
  - **Catchbasin retrofit**
  - **Other open spaces**

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Retention/Detention Ponds
Kansas City, MO

53

Rain Gardens
Kansas City, MO

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Bioretention at Catchbasins
Kansas City, MO

55

Retrofit of Parks & Lakes
Kansas City, MO

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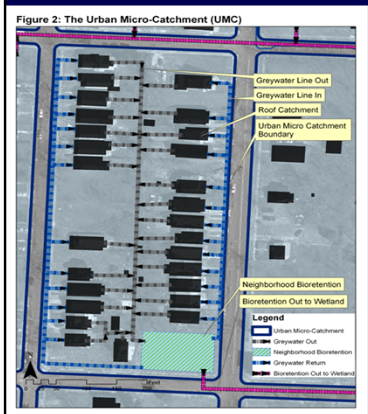
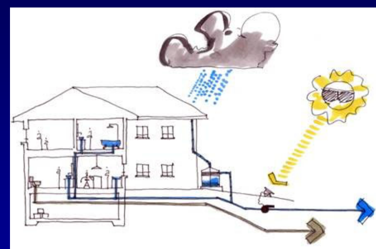
Separate Graywater & Blackwater Systems





Conclusions

- Combined sewer overflows and sanitary sewer overflows have been recognized as significant water pollutant sources in the US for many years.
- Regulations have been in place for several decades describing the minimum efforts needed to reduce these discharges, and the US EPA has prepared associated guidance documents.
- Numerous large-scale CSO and SSO control programs have been conducted throughout the country, documenting their success.
- The large costs of these conventional programs have lead to the current implementation of “green infrastructure” solutions that also promise many social benefits.
- Numerous new projects are demonstrating these benefits of green infrastructure in combined sewered areas.