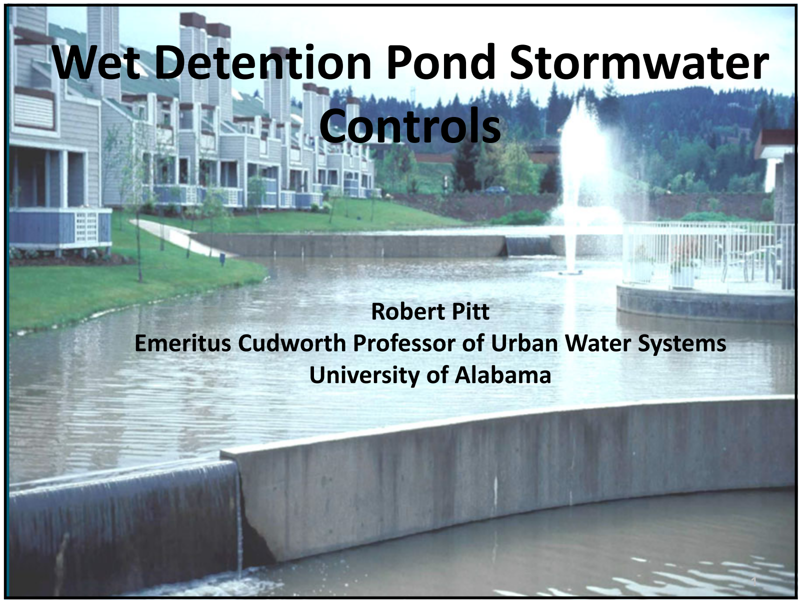

Wet Detention Pond Stormwater Controls
Robert Pitt
Emeritus Cudworth Professor of Urban Water Systems
University of Alabama

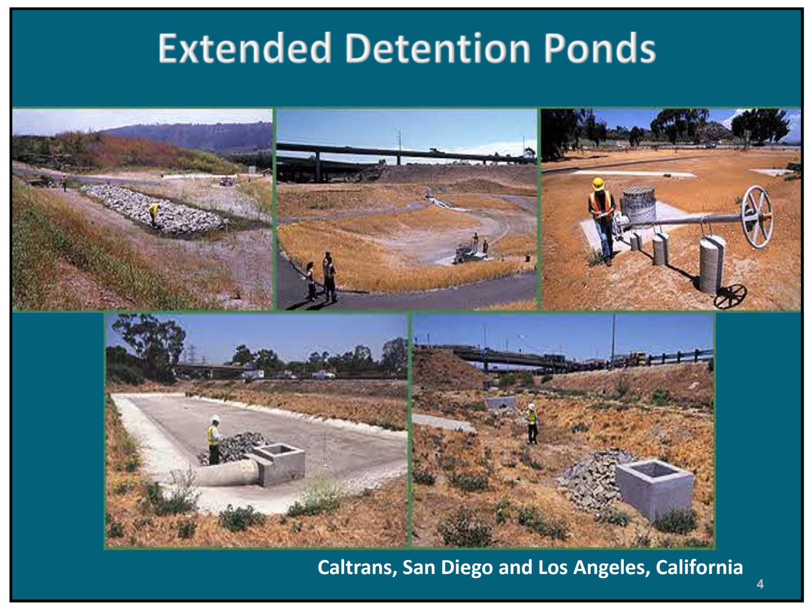
1


Presentation Topics
Types of stormwater sediment ponds
Pond performance
Sedimentation theory
Design and sizing of ponds and examples
Conclusions
2

2


Wet Basins
Caltrans, San Diego, California
3

3


Extended Detention Ponds
Caltrans, San Diego and Los Angeles, California
4

4

Wet Detention Pond Advantages

- Very good control of particulate pollutants
- Opportunity to utilize biological processes
  - Protozoa as bacteria predators
  - Aquatic plants enable higher levels of nutrient removal
- Outfall ponds capture and treat all storm sewer discharges
  - Wet weather stormwater runoff
  - Dry weather baseflows
  - Snowmelt
  - Industrial spills
  - Illegal discharges

5

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Typical Dry Detention Ponds, with Pilot Channels

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Unusual Dry Detention Pond Located on Hillside to Meet Peak Flow Rate Criterion

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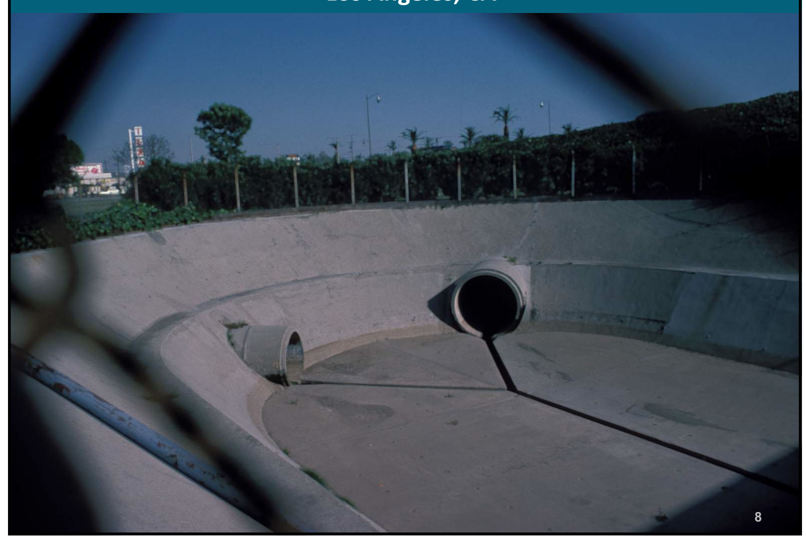
Dry Detention Pond Forebay for Stormwater Pump Station, Los Angeles, CA



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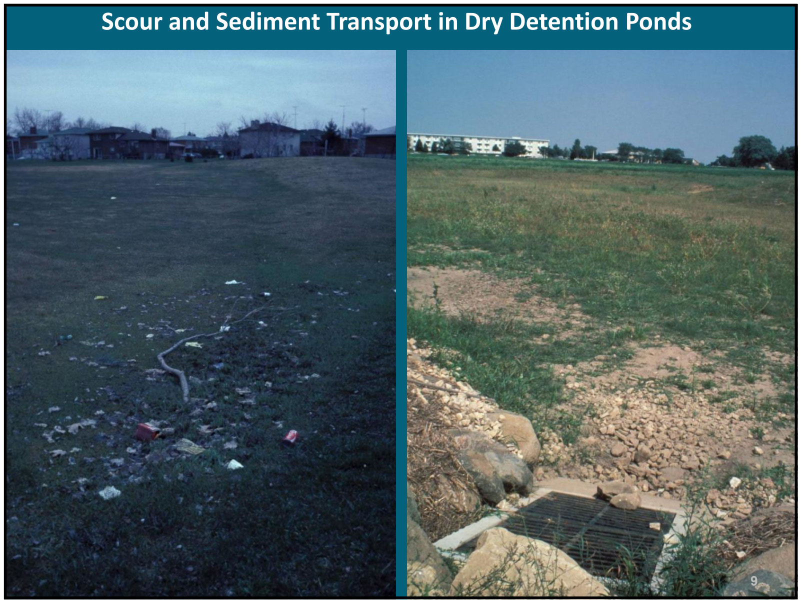
Tab 4b - Wet Detention Control Practices



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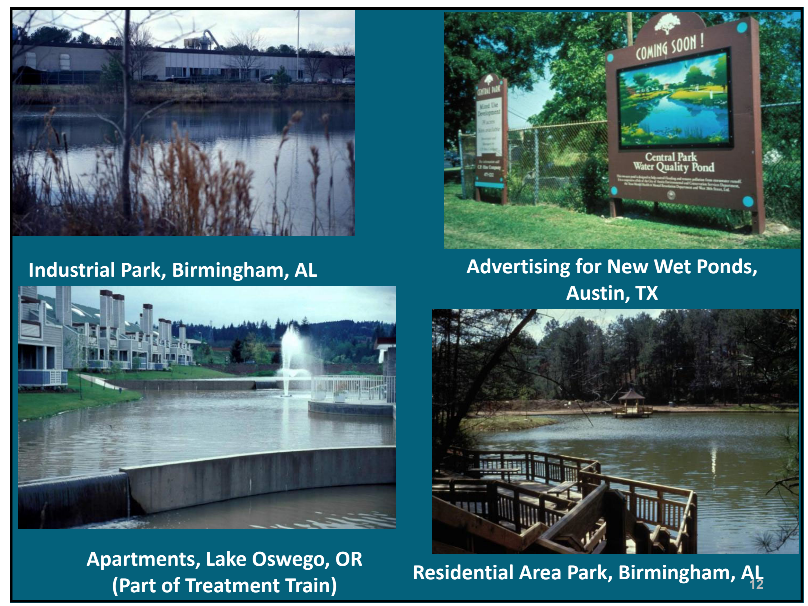

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Wetlands for Stormwater Control
Low water levels in wetlands, exposing sediment to potential scour.
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Wetlands in Malmo, Sweden (under construction and mature)
Watch your step Eric!
14

14


Mature Wetlands and Wet Detention
Pond Facility for CSO control, Malmo, Sweden

15


New Wetlands being
Planted by Volunteers,
Malmo, Sweden
16

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Necessary Harvesting of Aquatic Plants from Wetland used for Treatment of Municipal Wastewater

Lemna Systems

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Observed Wet Pond Performance (when constructed and operated according to best guidance)

- Suspended solids: 70 to 95%
- COD: 60 to 70%
- BOD_5: 35 to 70%
- Total Kjeldahl nitrogen: 25 to 60%
- Total phosphorus: 35 to 85%
- Bacteria: 50 to 95%
- Copper: 60 to 95%
- Lead: 60 to 95%
- Zinc: 60 to 95%

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- NURP (1983) found particulates reduced by between 0% (for small ponds and large drainage areas) and 90+% for large ponds. For well designed ponds BOD and COD removals were 70%, and heavy metals between 60 – 95%.
- Oliver (1981) reported 88% reductions in SS and 54% and 60% reductions for COD and total phosphorus.
- Yousef (1986) found 85% removal of soluble nutrients due to plant uptake.

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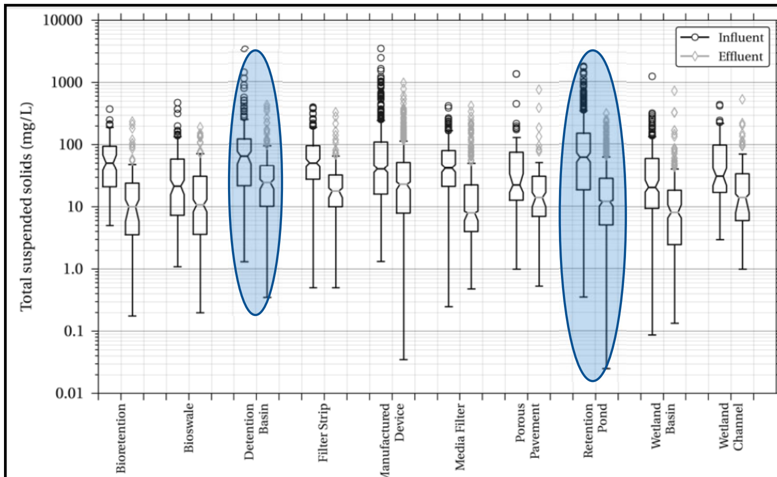

TSS influent and effluent for different stormwater practices

International Stormwater BMP Database

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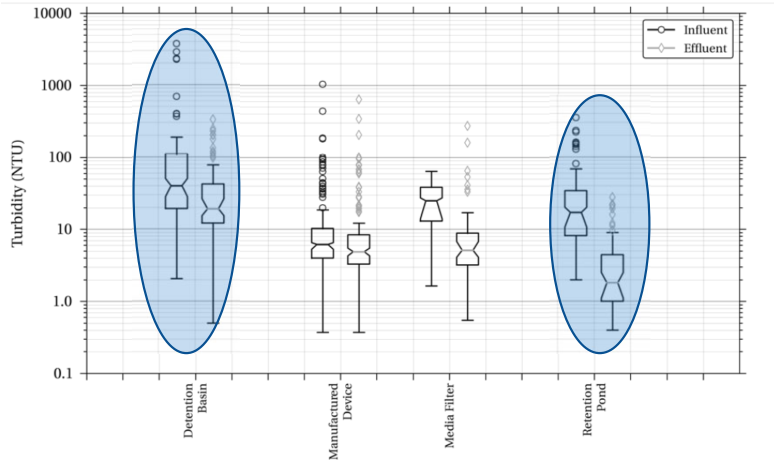

Turbidity influent and effluent for different stormwater practices

International Stormwater BMP Database

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Why is there such a large difference in performance between a dry and a wet pond?

- Usually due to scour
  - Need at least 3 ft for wet ponds to protect previously captured silt
  - Grass filters look like dry ponds (and the grass filters can work well, but require lengthy sheetflows with level spreaders, low slopes, good grass stands, no pilot channels, etc.)
  - Terminology issues (in many areas, dry ponds are actually percolation ponds or infiltration ponds with no surface discharges). HIGs

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The Monroe St. detention pond in Madison has been monitored by the WI DNR and USGS for many years. The data have been used to verify the wet detention pond routines in WinSLAMM and Detpond (amongst other ponds). Retrofitted to result in 90% SS control, the long-term monitored results were 87%.

23

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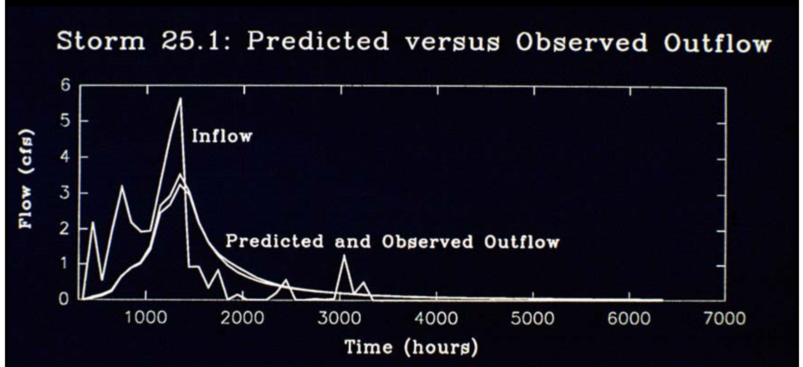

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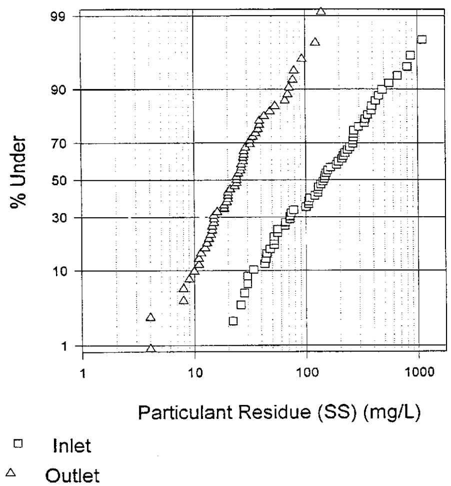
Suspended Solids Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)



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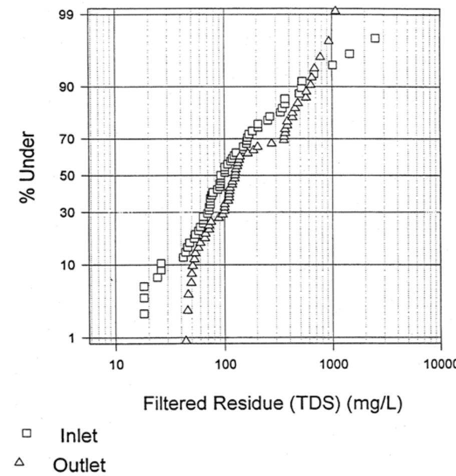
Total Dissolved Solids Control at Monroe St. Detention Pond, Madison, WI (USGS and WI DNR data)



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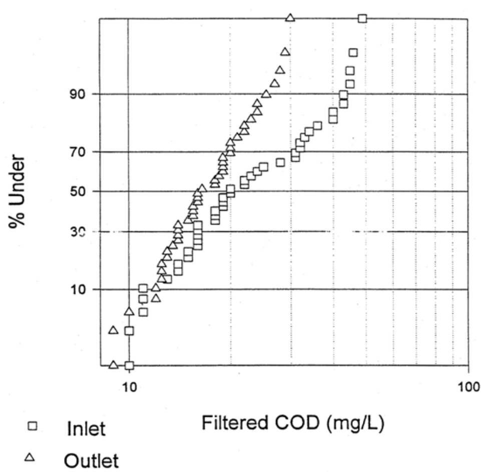
COD Control at Monroe St. Detention Pond, Madison, WI

(USGS and WI DNR data)



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Retrofitted to result in 90% SS control, the long-term monitored results were 87%.

PROBABILITY IN % UNDER	10%	50%	90%
Suspended solids	35	87	97
Total Residue	<0	52	86
Volatile Residue	<0	41	76
Filtered Residue	<0	<0	56
Particulate COD	15	80	95
Total COD	29	60	84
FilteredCOD	<0	24	80
Particulate Phosphorus	-20	60	80
Total Phosphorus	<0	47	81
Filtered Phosphorus	<0	43	83
Particulate TKN	-40	40	80
Total TKN	<0	45	75
Filtered TKN	<0	12	68
Particulate Zinc	-117	70	95
Total Zinc	<0	31	69
Filtered Zinc	<0	<0	59

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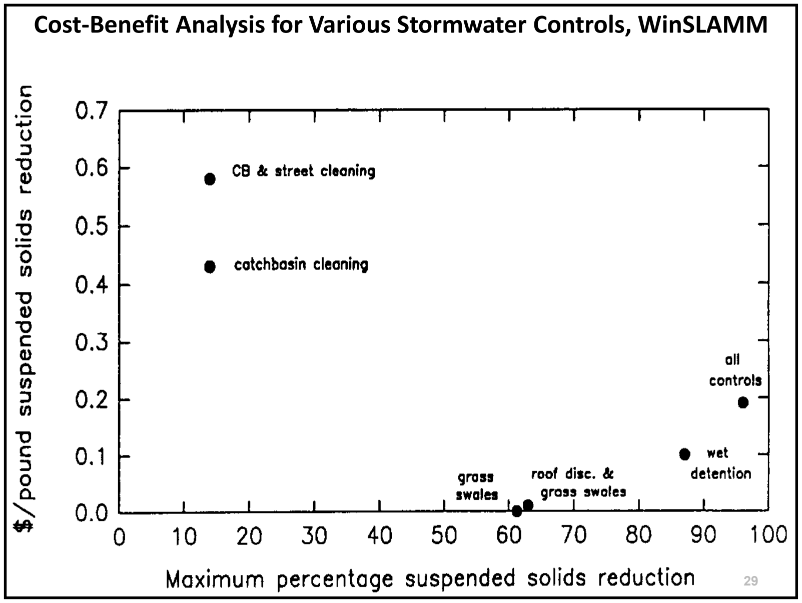

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Pond Problems

- Safety
- Nuisance conditions
- Maintenance
- Poorly known site conditions
- Critters

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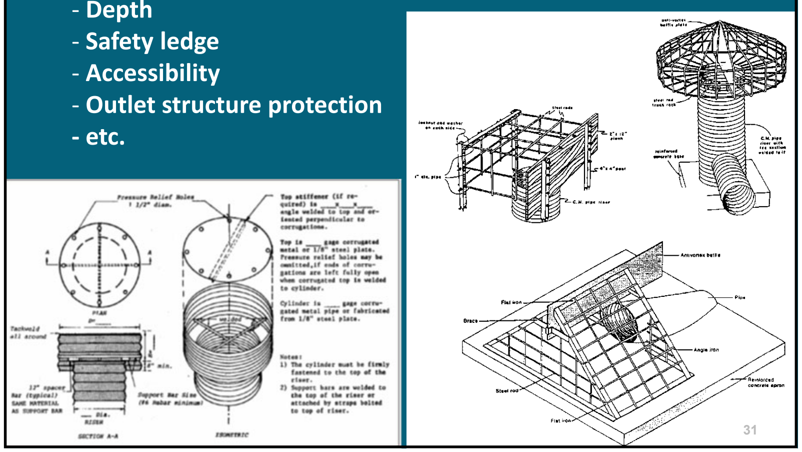
Safety of Detention Ponds

Numerous design features to maximize pond safety:
- **Side slopes**
- **Depth**
- **Safety ledge**
- **Accessibility**
- **Outlet structure protection**
- **etc.**



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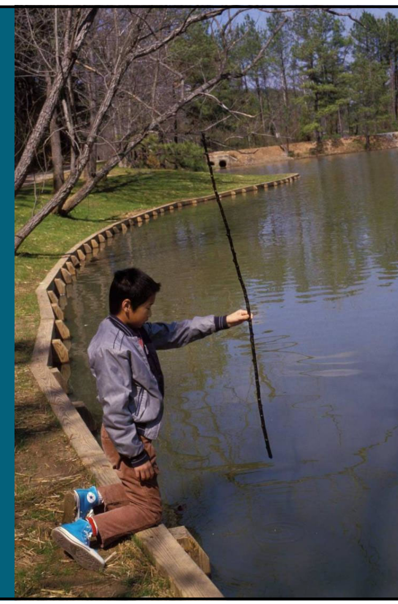

Deep Water Too Close To Shore

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Thin Ice Near Shore
DANGER
THIN
ICE
Steve Auger photo
2002 02 13 11:19

33


Children are Attracted to Urban Waters
Wisconsin DNR

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Frequent Maintenance and Adjustments to Outlets may be Needed
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Sometimes the pond wins!
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Wet Ponds Located in Areas of Karst Geology may have Sinkholes

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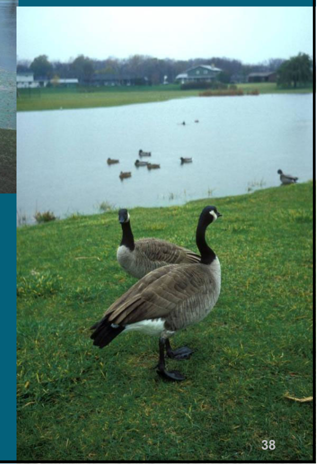

Ponds can be attractive and in some areas they actually encourage contact recreation, but water quality is usually poor. Birds and other wildlife are also frequently attracted to ponds.

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However, they may be mutually exclusive uses

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Other critters also attracted to ponds (no geese at this pond!)

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Existing Ponds can be Modified for Improved Performance

- Change outlet device
- Reshape pond
- Add internal berms to prevent short-circuiting

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Modification of Outlet for Improved Performance

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Modification of Pond Outlet at Epcot Center, Orlando, FL

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Re-building Pond (Re-shaping and Dredging), Moscow, Russia

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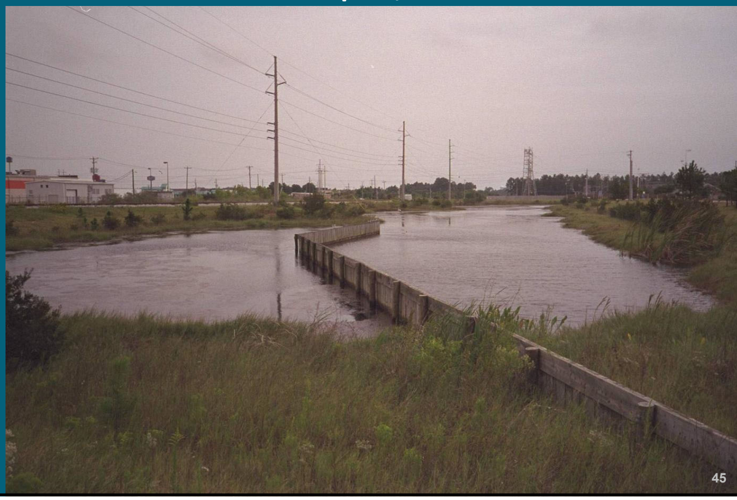
Berm Located in Pond to Minimize Short-Circuiting, Gulfport, MS



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Design Suggestions to Enhance Pollutant Control and to Minimize Problems

Composite list from literature and experience

- Locate and size ponds to minimize hydraulic interferences.
- Keep pond shape simple to minimize short-circuiting.
- Slope ground leading to pond between 5 and 25%.
- Use shallow perimeter shelf as a safety ledge.
- Plant dense emergent vegetation on shelf.
- Plant thick vegetation barrier around pond perimeter.
- Provide at least 3 ft. of permanent pool depth for scour protection.
- Provide at least 2 more feet as sacrificial storage.

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Design Suggestions (cont.)

- Use sub-surface outlets to minimize clogging and to retain floatables.
- Discourage water contact recreation and consumptive fishing.
- Stock mosquito eating fish.
- Minimize water level fluctuations to reduce mosquito problems.
- Place rocks at inlet and outlet areas to minimize scour.
- Use anti-seep collars around outlet pipes to minimize piping.
- Provide trash and safety racks, plus baffles on outlets.
- Provide emergency spillway.

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Special Stormwater Control Considerations in Areas having Harsh Winters

- Snowmelt can contribute the majority of the annual pollutant loads from urban areas that experience heavy winter snowfalls.
- Summer runoff is typically only considered in the design of stormwater controls
- Cold weather hinders all stormwater control processes (such as infiltration, settling, and plant uptake)
- Deicing salts are a special threat to urban groundwater quality

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Stormwater Design Considerations for Cold Climates

- "Oversize" wet ponds to accommodate reduced settling rates (can be one-half of the summer rates)
- Protect sediment from scour during snowmelt
- "Oversize" infiltration areas due to reduced soil infiltration rates, but substantial infiltration does occur under snowpacks during long winters
- Divert snowmelt from infiltration areas
- Do not rely on wetlands and other controls utilizing plants during long dormant season
- Follow good snow removal practices
- Reduce the use of deicing salts
- Prevention is especially important in design of land development

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Use of Sedimentation in Conjunction with other Controls

- Effluent can be directed to infiltration or wetland area.
- Sedimentation is a common pre-treatment option for filtration and chemical treatment
- Sedimentation can better handle large flows and serves to protect downstream more "fragile" devices, such as wetlands or infiltration areas.

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Infiltration Swale in Office Park Area, Downstream of Wet Pond, Lake Oswego, OR, Part of Treatment Train

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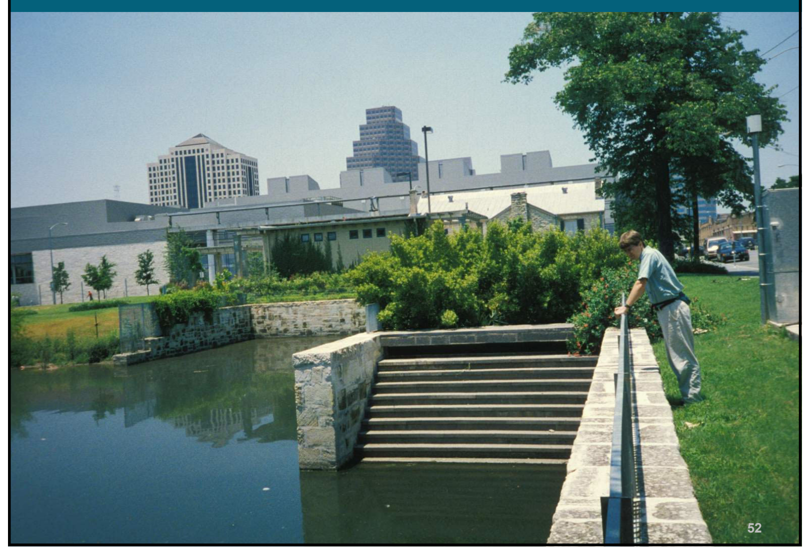
Wet Pond after Oil and Grease Trap and Step Aerator, Austin, TX



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Settling Pond after Alum Injection, Orlando, FL

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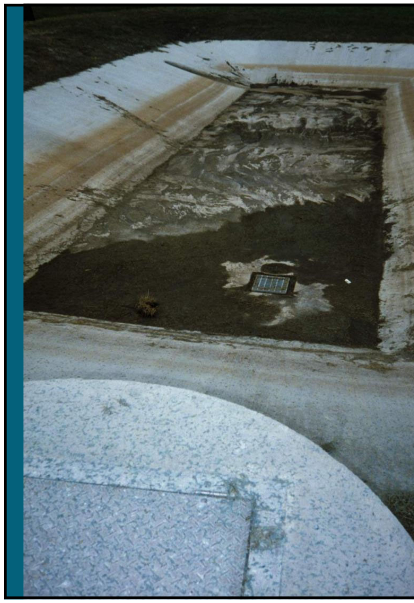

Dry Pond to Equalize Flows before Sand Filter, Austin, TX

54

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Equalizing Dry Pond to Control SSO Problems, Moody, AL

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Wet Detention Pond Performance Calculation Data Requirements

- Surface area of pond
- Water quality volume (live storage above lowest pond water surface elevation, usually the pond volume between the water quality outlet and the emergency spillway)
- Depth of water over the sediment to prevent scour
- Stage-discharge relationship for all outlets
- Particle size distribution of inflowing particulates
- Hydrograph of influent flows

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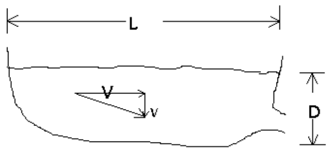
Particulate Settling

- Ideal Settling: Particle path is vector sum of particle velocity through pond and settling (upflow) velocity



$$\frac{V}{v} = \frac{L}{D} \rightarrow v = \frac{Q_{out}}{A}$$

As shown on pages 23-25 of detention pond design.pdf and outlined on the following ppts

- **L = Pond Length**
- **D = Outlet Depth**
- **V = Water Velocity through Pond**
- **v = Settling Velocity**
- **Q_{out} = Outflow from Pond**
- **A = Pond Surface Area**

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Particle Settling Derivation

$$\frac{V}{v} = \frac{L}{D}$$

$$V = \frac{Q}{a}$$

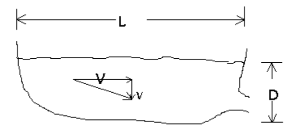
$$V = \frac{Q_{out}}{DW}$$

- **L = Pond length**
- **D = Outlet depth**
- **V = Water velocity through pond**
- **v = Settling velocity**
- **Q_{out} = Outflow from pond**
- ***a* = Pond cross sectional area**
- **W = pond width**

Substituting this relationship of V into the first equation:

$$\frac{Q_{out}}{DWv} = \frac{L}{D}$$

$$\frac{Q_{out}}{Wv} = L$$



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Particle Settling Derivation (cont.)

$$\frac{Q_{out}}{v} = LW$$

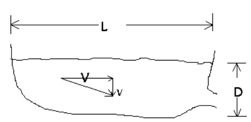
$$\frac{Q_{out}}{v} = A \quad \text{where } A = \text{Pond Surface Area}, LW$$

$$v = \frac{Q_{out}}{A}$$

where Q_{out} = Pond Outflow Rate (ft^3/s)

v = Particle Settling Velocity (ft/s)

Therefore, particle settling is a function of the pond outflow rate and the pond surface area only. This can be applied to changing flows entering the pond during continuous modeling.



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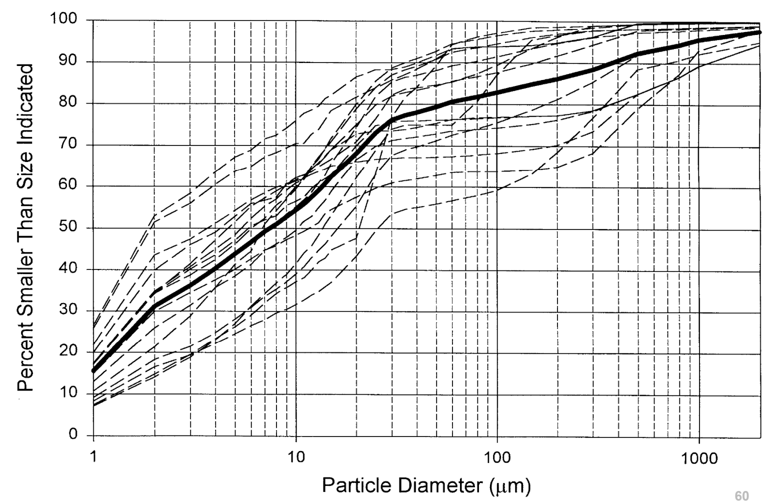
Measured Particle Sizes, Including Bed Load Component, at Monroe St. Detention Pond, Madison, WI



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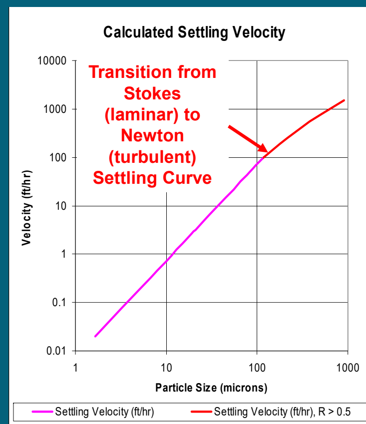
Particulate Settling

- Ideal settling is modeled
  - Using Stokes Law (laminar flow) for smaller particles
  - Settling velocity as a function of Reynolds number and particle size for larger particles under turbulent flow conditions
  - Water temperature (can vary monthly) and particle density also affect settling rates and can be changed in WinSLAMM



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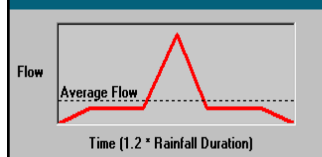
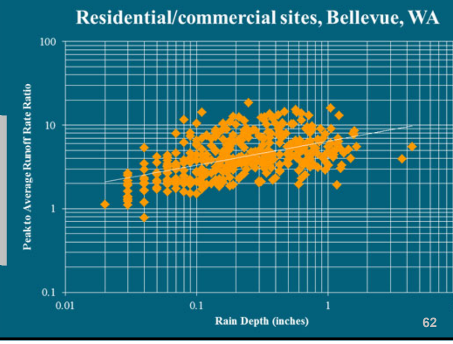
Complex Hydrograph Creation by WinSLAMM

- Flow rate calculated using Complex Triangular Hydrograph, based on statistical analysis of hundreds of monitored events throughout North America and for different land uses
  - Runoff Volume calculated from WinSLAMM
  - Runoff Duration = 1.2 times rainfall duration
  - Peak to average flow rate ratio user defined, but usually about 3.8





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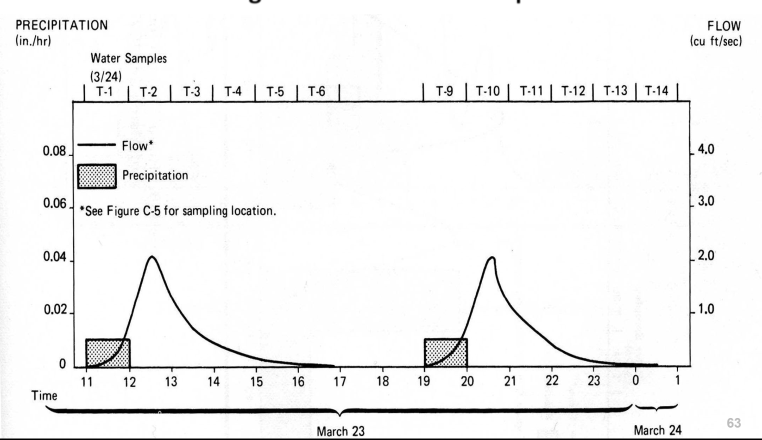
Urban Hydrology Simplifications for Small to Intermediate Storms

Examined about 550 monitored urban hydrographs that ranged from small and simple:



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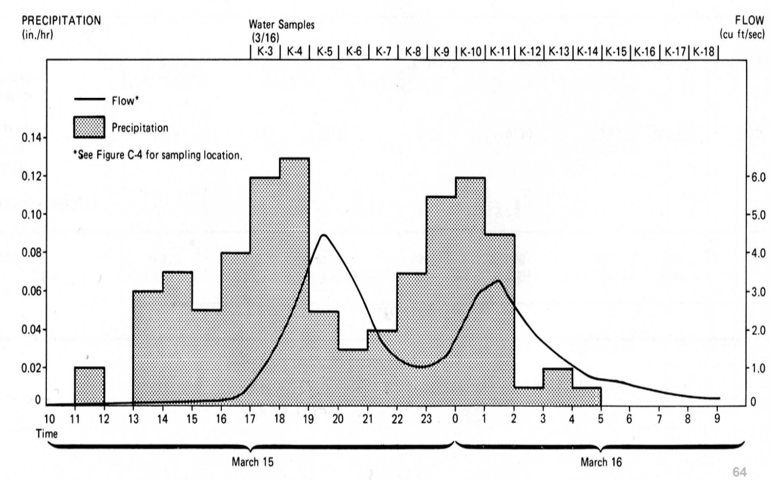
to complex:



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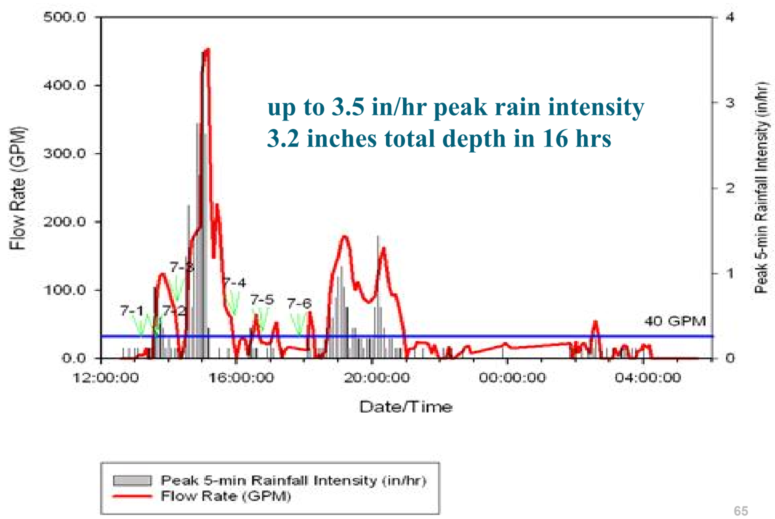
including large and intense (Hurricane Katrina):



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Observed Urban Hydrographs

Evaluated about 550 different urban area hydrographs from 8 watersheds (1, 1a, 2, and 3 rain distributions and B soils to pavement)

Location	Land use	area (acres)	directly connected impervious	# of events monitored
Bellevue, WA				
Surrey Downs	Resid, med. den.	95	17 %	196
Lake Hills	Resid, med. den.	102	17	201
San Jose, CA				
Keyes	Resid, med. den.	92	30	6
Tropicana	Resid, med. den.	195	25	8
Toronto, Ontario				
Thistledowns	Resid, med. den.	96	21	35
Emery	Industrial	381	42	60
Tuscaloosa, AL				
City Hall	Institutional/com	0.9	100	31
BamaBelle	Commercial	0.9	68	17

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Observed Runoff Characteristics

	Monitored rains (inches, range)	Observed Rv (average)	Observed CN (range)	peak/avg flow ratio (average)
Bellevue, WA				
Surrey Downs	0.03 - 4.38	0.18	64 - 100	4.4
Lake Hills	0.02 - 3.69	0.21	73 - 100	5.4
San Jose, CA				
Keyes	0.01 - 1.06	0.10	88 - 100	3.2
Tropicana	0.01 - 1.08	0.59	95 - 100	3.8
Toronto, Ontario				
Thistledowns	0.03 - 1.01	0.17	84 - 99	4.0
Emery	0.03 - 1.0	0.23	87 - 99	3.1
Tuscaloosa, AL				
City Hall	0.02 - 3.2	0.60	95 - 99	4.2
BamaBelle	0.1 - 1.9	0.80	94 - 100	5.5

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Wet Pond Design Criteria for Water Quality

- Surface area should have a minimum area based on land use and desired pollutant control.
- Pond freeboard storage (water quality volume) equal to runoff associated with 1.25 inches of rain for the land use and development is a good value to start with.
- Select outlet device to obtain desired pollutant control for all pond stages based on stage-discharge relationship.
- Incorporate special features for harsh winters and snowmelt loads, if needed

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1. Pond Area as a Percentage of Drainage Area (assuming "standard" development conditions)

	5 micrometer (about 90% SSC control)	20 micrometer (about 65% SSC control)
Totally paved	2.8	1.0
Industrial	2.0	0.8
Commercial	1.7	0.6
Institutional	1.7	0.6
Residential	0.8	0.3
Open space	0.6	0.2
Construction	1.5	0.5

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2. Design of Wet Detention Ponds (cont.)

The pond freeboard storage (water quality volume) should be equal to the runoff associated with 1.25 inches of rain for the land use and development type. For example:

Example site	Land Area (acres)	Pond WQ Volume Factor	Pond WQ Volume
Paved area	0.6	1.1 inches	0.66 ac-in
Undeveloped area (clayey soils)	3.8	0.3	1.14
Construction site (clayey soils)	27.6	0.6	16.56
Total	32.0		18.36 ac-in (1.53 ac-ft)

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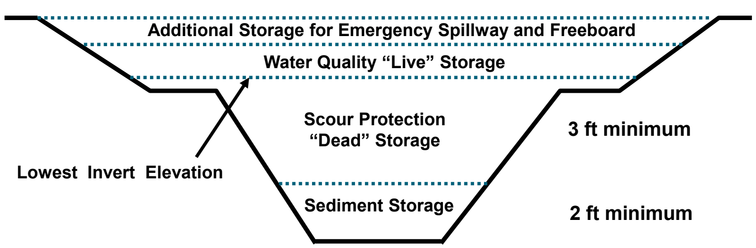

3. The "dead" storage is needed to prevent scour of previously deposited material and should be at least 3 ft. deep over the sediment. Sediment storage volume is also needed and can be estimated based on sediment accumulation; it should be at least 2 ft. deep.

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Runoff Depth Corresponding to 1.25 Inches of Rain

Based on small storm hydrology

	Sandy	Clayey
Freeways	0.35	0.40
Totally paved	1.1	1.1
Industrial	0.85	0.9
Commercial	0.75	0.85
Schools	0.2	0.4
Low density residential	0.1	0.3
Medium density residential	0.15	0.35
High density residential	0.2	0.4
Developed parks	0.5	0.6
Construction sites	0.5	0.6

Pitt 1987

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4. Selection of Outlet Control Device (only showing two small V-notch weirs here)

Head (ft)	Flow (cfs)	22.5° Storage (ac-ft)	Reqd. min. area (acres)	Flow (cfs)	30° Storage (ac-ft)	Reqd. min. area (acres)
0.5	0.1	<0.01	0.01	0.1	<0.01	0.02
1	0.5	0.03	0.1	0.7	0.05	0.1
1.5	1.4	0.1	0.2	1.9	0.2	0.3
2	2.8	0.3	0.5	3.8	0.3	0.7
3	7.8	1.2	1.4	11	1.6	1.8
4	16	3.3	2.8	22	4.4	3.8
5	28	7.2	4.9	38	9.6	6.6
6	44	14	7.7	60	18	10

If have 3 ft of head over the water quality outlet below the emergency spillway and the pond surface area at that depth is 2 acres, then use 30° V-notch weir. 73

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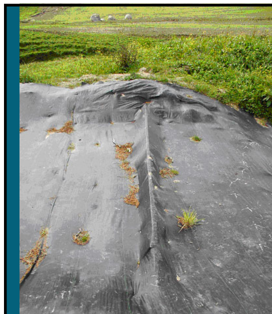
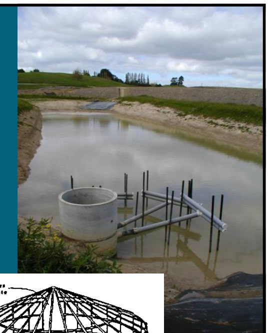
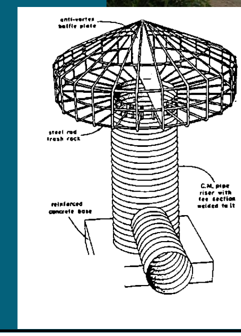



Temporary and permanent pond outlet structures

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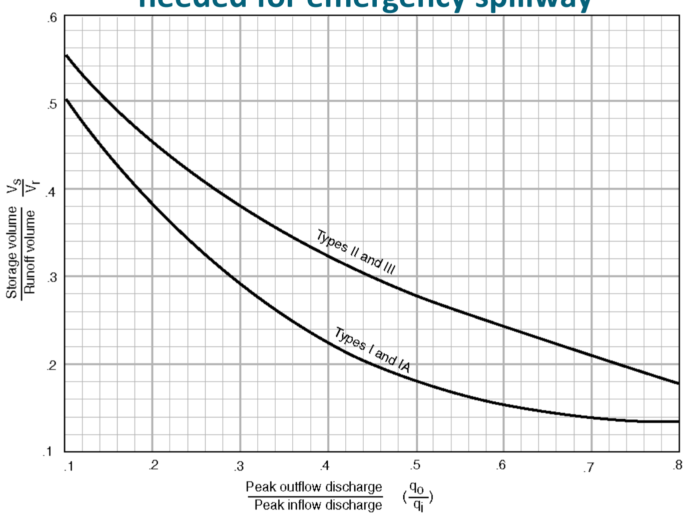
SCS TR-55 plot used to size additional freeboard needed for emergency spillway



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Vs = 1.53 acre-ft
Vr = 7.5 acre-ft
and Vs/Vr = 0.20

for type II or III rain categories:
qo/qi = 0.72

if the calculated peak discharge rate entering the pond (qi) = 8.7 cfs, the resulting peak discharge rate leaving the pond, qo, (through the water quality primary outlet plus the emergency spillway) is therefore: 0.72 (8.7) = 6.3 cfs

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Rain and watershed characteristics for the emergency spillway design:

P = 8 inches
CN = 86; therefore the Ia = 0.0366
Q = 6.2 inches and Ia/P = 0.041
Area (Am) = 0.021 mi^2 (13.2 acres)
Tc = 20 min (0.3 hr)

The peak unit discharge rate from the tabular hydrograph method is 498 csm/in, and the peak discharge is therefore:
Q_{peak} = (498 csm/in)(0.021 mi^2)(6.2 in) = 63.7 ft^3/sec

Also, the volume of runoff for this event is:
V_r = [(6.2 in)(13.2 ac)]/12 in/ft = 6.82 ac-ft

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The maximum desired discharge rate for this pond (for both the water quality outlet plus the emergency spillway) is given as 46.5 ft^3/sec.

The ratio of the outlet to the inlet flow rate is therefore: q_o/q_i = 46.5/63.7 = 0.73

The ratio of the storage volume (V_s) to the runoff volume (V_r), for Type II rains is 0.2, for this ratio of outlet to inlet peak flow rates. Therefore the storage for the pond to meet this peak discharge rate goal is:
V_s = 0.2 (6.82 acre-ft) = 1.34 acre-ft

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The length (LW in feet) of a rectangular weir, for a given stage (HW in feet) and desired outflow rate (qo in ft^3/sec) can be expressed as:

$$L_w = \frac{q_o}{3.2H_w^{1.5}}$$

The desired q_o for the rectangular weir is 46.5 – 2.2 = 44.3 ft^3/sec. If the maximum stage for the emergency spillway is 1 ft, then length for the emergency spillway is:

$$L_w = \frac{q_o}{3.2H_w^{1.5}} = \frac{44\,ft^3/\sec}{3.2(1\,ft)^{1.5}} = 13.8\,ft$$

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Example Sizing of Wet Detention Pond

- the basic pond area,
- the "live" storage volume,
- the pond side slopes, top surface area, and "dead storage" volume,
- the selection of the primary discharge device,
- the additional storage volume needed for the emergency spillway,
- the sizing of the emergency spillway, and
- the sacrificial storage volume for sediment accumulation.

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the basic pond area and "live" storage volume

The following are the areas associated with each surface in the drainage area:
- paved areas: 0.2 acres
- undeveloped areas: 1.2 acres
- construction area: 32 acres
- total site area: 33.4 acres

Site Subarea	Pond Surface Area (acres)	Pond "Live" Volume, runoff from 1.25 inches of rain fall (acre- inches of runoff)
paved area (0.2 acres)	3% of 0.2 acres = 0.006 acres	1.1 inches x 0.2 acres = 0.22 ac-in
undeveloped area (1.2 acres)	0.6% of 1.2 acres = 0.007 acres	0.3 inches x 1.2 acres = 0.36 ac-in
construction area (32 acres)	1.5% of 32 acres = 0.48 acres	0.6 inches x 32 acres = 19.2 ac-in
Total:	0.49 acres	19.8 ac-in = 1.65 ac-ft

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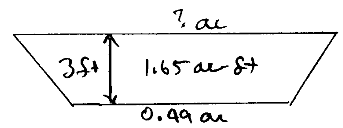
pond side slopes, top surface area, and "dead storage" volume

1) If 3 ft deep:

Top area:

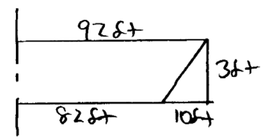


$$\frac{(0.49 acres + X)3\,ft}{2} = 1.65 ac-ft$$

$$X = 0.61 acres$$

at 0.61 acres: $\pi r^2 = 26{,}570\,ft^2$ r = 92 ft

at 0.49 acres: $\pi r^2 = 21{,}340\,ft^2$ r = 82 ft



side slope = 3 ft/(92-82 ft) = 3 ft/10 ft = 0.3 = 30% too steep

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Therefore try different pond depths and calculate diameters and slopes:

If 1 ft deep; top area = 2.81 acres and r = 197 ft and side slope = 1.2% too shallow

If 2 ft deep; top area = 1.16 acres and r = 126 ft and side slope = 4.5% suitable, but on the low side

etc.....

The "pond sizer" spreadsheet does this (and evaluates different outlet devices) for you.

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the selection of the primary discharge device

At the top of the live storage volume, this pond will have 2 ft of stage and 1.16 acres maximum pond area:

45° V-notch weir requires at least 1.0 acres of pond surface at 2 feet of stage in order to provide about 90% control of sediment.

30° V-notch weir would require only 0.7 acres, 60° V-notch weir would require 1.4 acres.

None of the rectangular weirs would be suitable, as the smallest 2 ft weir requires at least 2.6 acres at 2 feet of stage.

The 45° weir is closest to the area available and is therefore selected for this pond.

Another suitable outlet structure would be an 18" drop tube structure which requires at least 1.1 acres.

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the sacrificial storage volume for sediment accumulation

Using RUSLE, calculate the sediment loss for the complete construction period for the site area draining to the pond:

R = 350
LS = 1.28 (based on typical slope lengths of 300 ft at 5% slope)
k = 0.28
C = 0.24 (assuming that 5 of the 32 acres of the construction area is being actively worked with a C=1, and the other 27 acres of the construction area is effectively protected with a C=0.1)

A = (350)(1.28)(0.28)(0.24) = 30 tons per acre per year.

Since the construction period is for one year and the active construction area is 32 acres, the total sediment loss is estimated to be about 960 tons. For a loam soil, this sediment volume is about 980 yd^3, or 0.8 acre-ft. At least 1 or 2 ft should be used for stabilized areas. 85

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The pond water surface is about 0.5 acres. With a three feet deep dead storage depth to minimize scour, the surface area at the bottom of this 3 ft scour protection zone (and the top of the sediment storage zone), can be about 0.35 acres (about 25% underwater slope).

The sacrificial storage zone can be about 3 ft deep also, and the bottom pond area would be about 0.18 acre, as shown in the following calculations:
Top of sacrificial storage area is 0.35 acres,
at 0.35 acres:

$$\pi r^2 = 15{,}250\, ft^2 \qquad r = 70 \text{ ft}$$

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Therefore, the area of the bottom of the sacrificial storage area needed to provide 0.8 acre-ft of storage, if 3 feet deep can be approximated by:

$$\frac{(0.35 acres + X)3\,ft}{2} = 0.8 ac - ft$$

$$X = 0.18 acres$$

at 0.18 acres, r = 50 ft
side slope = 3 ft/(70-50 ft) = 3 ft/20 ft = 0.15 = 15%

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the additional storage volume needed for the emergency spillway

Therefore, this example will only consider the capacity of the emergency spillway to meet the design storm flow rate, the 25-year event. Other watershed characteristics are:

- watershed area: construction area (32 acres), paved area (0.2 acres), and undeveloped area (1.2 acres) = 33.4 acres = 0.052 mi^2
- clayey (hydrologic soil group D) soils (weighted curve number = 94)
- time of concentration (Tc): 12 minutes (0.2 hours). Since the pond is at the bottom of this watershed, there is no “travel time” through down-gradient subwatershed areas.
- rain intensity for a “25-year” rain for the Birmingham, AL, area, with a 15 minute time of concentration (from the local IDF curve): 6.6 inches/hour (type III rain)

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- Ia for this curve number is 0.128 inches.
-24-hour, 25-year rain has a total rain depth (P) of 6.9 inches.
-Ia/P ratio is therefore: 0.128/6.9 = 0.019, which is much less than 0.1.

Therefore the tabular hydrograph table to be used would be Exhibit III, corresponding to a Tc of 0.2 hour. The top segment of "csm/in" (cubic feet per second per square mile of watershed per inch of direct runoff) values are therefore used, corresponding to Ia/P values of 0.1, or less. The top row is also selected as there is no travel time through downstream subwatersheds. Examining this row, the largest value is 565 csm/in, occurring at 12.3 hours. The amount of direct runoff for a site having a CN of 94 and a 24-hr rain depth of 6.9 inches is 6.2 inches. The AmQ value (area in square miles times the direct runoff in inches) for this site is: (0.052 mi^2)(6.2 inches) = 0.32 mi^2-in. This value is multiplied by the csm value to obtain the peak runoff rate for this design storm: (0.32 mi2-in)(565 csm/in) = 182 ft^3/sec.

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The first trial for an emergency spillway will be a rectangular weir, with one foot of maximum stage. At the one foot of stage on this weir, the 45° V-notch weir will have 3 feet of stage. The V-notch weir will discharge 16 ft^3/sec at this stage. Therefore, the rectangular weir will need to handle: 182 – 16 ft^3/sec = 166 ft^3/sec. The rectangular weir can be sized from the rectangular weir equation:

$$L_w = \frac{q_o}{(3.2)(H_w)^{1.5}} = \frac{166\,ft^3/\sec}{(3.2)(1)^{1.5}} = 52\,ft$$

This may be large for this pond, so another alternative is to try for a rectangular weir having 2 ft of maximum stage.

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Another alternative is to try for a rectangular weir having 2 ft of maximum stage. At this elevation (4 ft total), the 45° V-notch weir will discharge 33 ft^3/sec. Therefore, the rectangular weir will need to handle: 182 – 33 ft^3/sec = 149 ft^3/sec. The rectangular weir can be sized from the rectangular weir equation:

$$L_w = \frac{q_o}{(3.2)(H_w)^{1.5}} = \frac{149\,ft^3/\sec}{(3.2)(2)^{1.5}} = 16\,ft$$

This is a suitable length, but does result in an additional foot of pond depth. For this example, the 52 foot long weir is selected.

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Final pond profile and expected performance

Pond Depth (ft from bottom of pond, the datum)	Surface Area at Depth (acres)	Pond Storage below Elevation (calculated by Detpond) (acre-ft)	Pond slope between this elevation and next highest noted elevation	notes
0	0	0	-	the pond bottom (datum) must be 0 acres for the routing calculations
0.1	0.18	-	15%	the area close to the bottom can be the calculated/desired pond bottom area. This is the bottom of the sacrificial storage area for the sediment
3	0.35	0.8	25%	this is the top of the sacrificial storage area for the sediment
6	0.49	2.0	4.5%	this is the bottom of the "dead" storage area, at least 3 feet above the pond bottom (this is 6 feet above the absolute bottom, but is 3 feet above the top of the maximum sediment accumulation depth)

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Final pond profile (continued)

Pond Depth (ft from bottom of pond, the datum)	Surface Area at Depth (acres)	Pond Storage below Elevation (calculated by Detpond) (acre-ft)	Pond slope between this elevation and next highest noted elevation	notes
8	1.16	3.7	4.5%	this is the bottom (invert) of the water quality outlet structure (and live storage volume), a 45º V-notch weir
9	1.5	5.0	4.5%	this is the top of live storage volume, and the bottom of the emergency spillway, a 52 ft long rectangular weir
10	1.8	6.7	-	1 foot of freeboard above maximum expected water depth, the top of the pond

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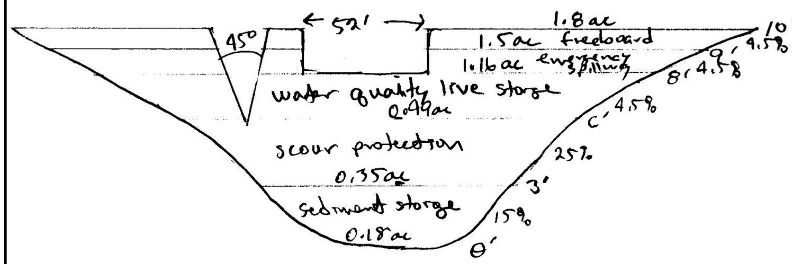
Example pond profile and expected performance



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The pond performance for a 30 year period of rain (3,346 events, ranging from 0.01 to 13.6 inches) was calculated using DETPOND. During these 30 years, the expected maximum pond stage is slightly more 8 ft. The emergency spillway was used a total of four times in this period. The flow-weighted particulate solids removal rate was about 92%.

	Max. Pond Stage (ft)	Event Inflow Volume (ac-ft)	Event Flushing Ratio	Flow-weighted Particle Size (µm)	Partic. Solids Removed (%)
Maximum	8.1	23	11	6.8	100
Flow-weighted avg.	n/a	n/a	1.4	2.6	92
Median	6.1	0.012	0.0057	0.39	99.6
COV	0.035	5.1	5.1	1.1	0.019

The pond design was sized for a target 80 to 90% SSC removal rate. Therefore, the calculated SSC removal in the pond surpasses the goal, and the emergency spillway was infrequently used. The pond is therefore somewhat over-sized.

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Pond Sizer and Shaper Spreadsheet Aid for Wet Ponds

1) Enter the areas of each land use in the appropriate section corresponding to the general soil type, for 5 or 20 µm control objectives. This example is for 5 µm control in an area having silty soils and has 10 acres of commercial and 95 acres of medium density residential land use areas:

soil	land use and area:	area (acres)	pond surface area (ac)	wet storage volume (ac-ft)
silty	Totally paved areas	0	0.00	0.000
silty	Freeways	0	0.00	0.000
silty	Industrial	0	0.00	0.000
silty	Commercial	10	0.17	0.667
silty	Institutional	0	0.00	0.000
silty	Low den resid	0	0.00	0.000
silty	Med den resid	95	0.76	1.979
silty	High den resid	0	0.00	0.000
silty	Open space/parks	0	0.00	0.000
silty	Construction sites	0	0.00	0.000
	Total:	105	0.93	2.646

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2) Select the pond depth corresponding to an average side slope of between about 10 to 25%. In this example, 2.5 ft depth for the water quality volume section has a side slope of about 17% (the pond surface area is about 0.9 to 1.2 acres over this depth):

pond surface area (acres):			0.93	radius (ft):
pond wet storage volume (acre-ft):			2.646	114
pond storage depth (ft)	top surface area (acres)	radius of top area (ft)	average side slope (%)*	max discharge for 5 um (cfs)
0.25	**20.237**	530	**0.1**	114.6
0.5	**9.653**	366	**0.2**	54.7
0.75	**6.126**	291	**0.4**	34.7
1	**4.362**	246	**0.8**	24.7
1.5	**2.598**	190	**2.0**	14.7
2	**1.716**	154	**4.9**	9.7
2.5	**1.187**	128	**17.0**	6.7
3	**0.834**	108	**-49.8**	4.7
3.5	**0.582**	90	**-14.7**	3.3
4	**0.393**	74	**-10.1**	2.2

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3) For the selected water quality volume depth, find an outlet structure that matches the needed discharge rate. This table shows the minimum surface area needed at the depth, and also compares this to the available surface area. Therefore, select an outlet that has the smallest positive "delta" value. In this case, that is a 30º V-notch weir.

Pond storage depth (ft)	max weir length (ft)	max orifice dia (ft)	min surface area (ac) required for v-notch weirs:					
			22.50	22.5 delta	**30**	30 delta	**45**	45 delta
0.25	275.4	2.73	0.00	20.23	0.00	20.23	0.01	20.23
0.50	46.5	1.58	0.02	9.64	0.02	9.63	0.03	9.62
0.75	16.2	1.14	0.04	6.08	0.06	6.07	0.09	6.04
1.0	7.6	0.89	0.09	4.27	0.12	4.24	0.18	4.18
1.5	2.7	0.62	0.24	2.36	0.33	2.27	0.50	2.09
2.0	1.4	0.47	0.50	1.22	0.68	1.04	1.03	0.68
2.5	1.0	0.37	0.87	0.32	1.18	0.01	1.81	-0.62

4) Continue to size the remaining pond attributes for the full profile.

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Conclusions

- Wet detention ponds have been used and studied longer than most other stormwater quality practices.
- Wet detention ponds are robust and provide excellent control of particulate-bound pollutants for a wide range of conditions.
- Wet detention ponds can be used in conjunction with other controls for broader water quality objectives.
- Wet detention pond performance can be calculated using traditional pond routing and sedimentation procedures.

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