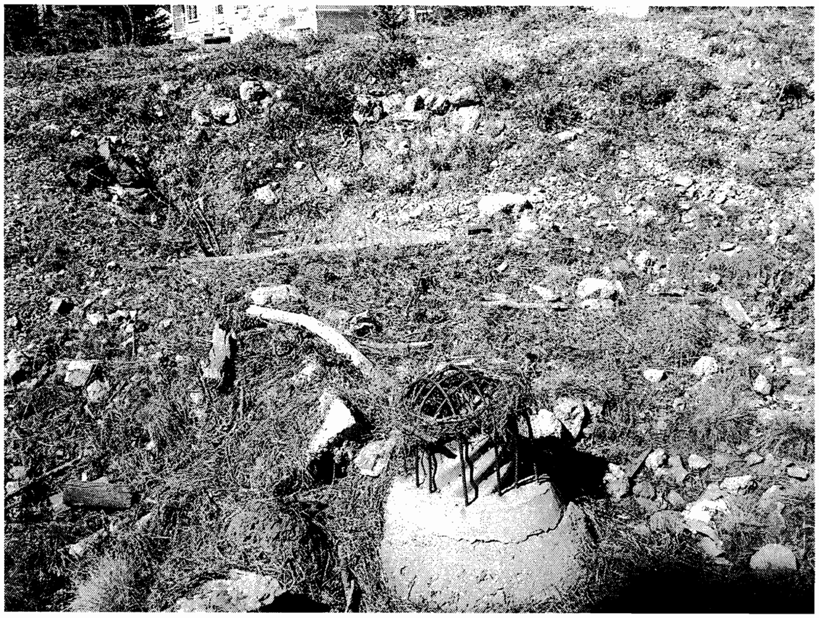
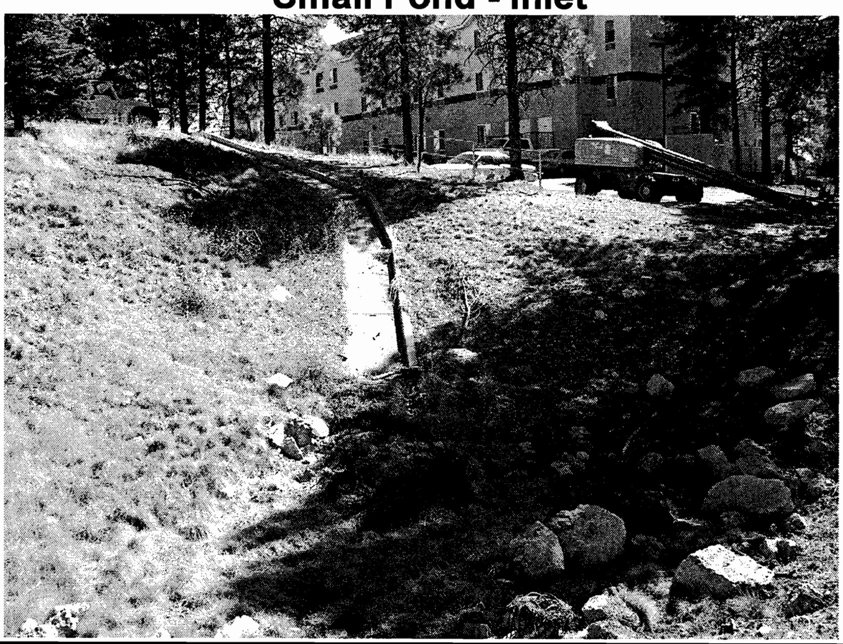
Small Outlet - maintenance

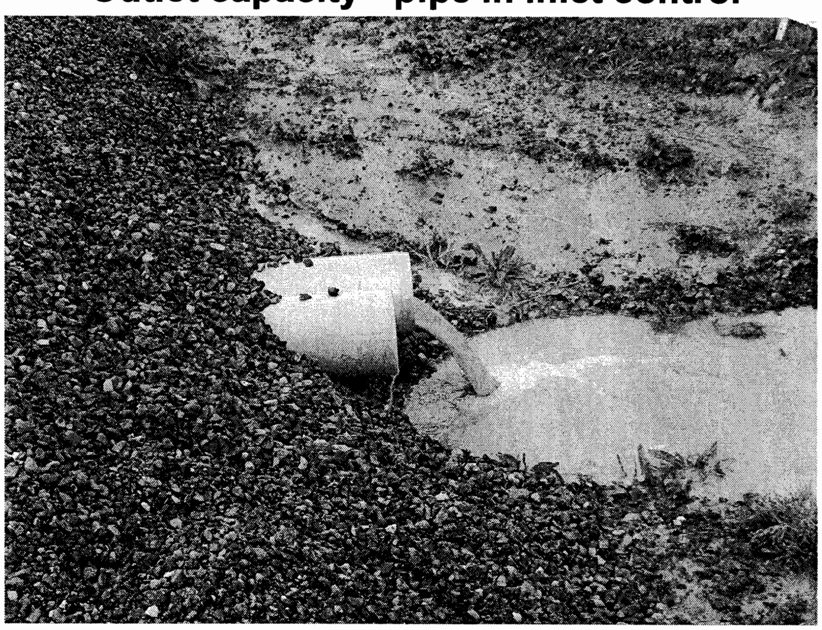


Small Pond - Inlet



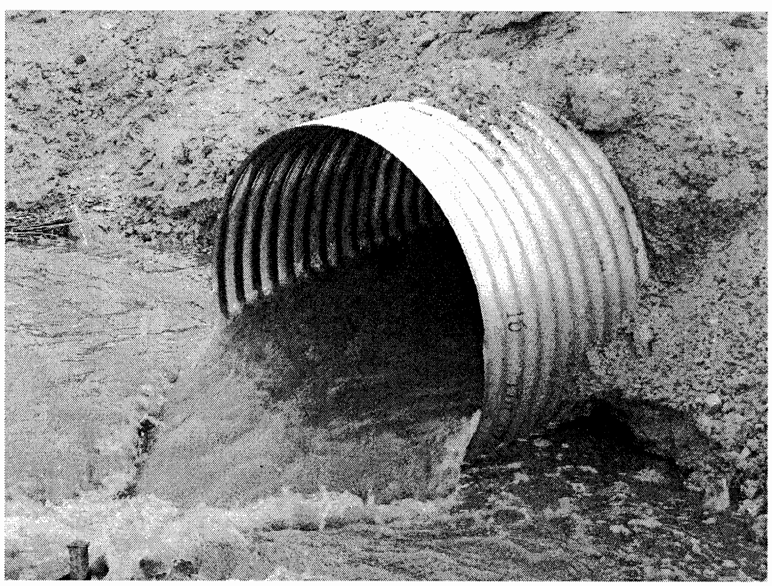
Outlet capacity - pipe in inlet control

Outlet capacity - pipe in inlet control



Outlet capacity - pipe in inlet control

Outlet capacity - pipe in inlet control

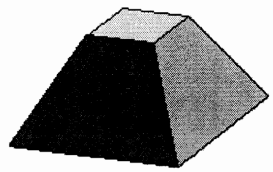


Outlet capacity - pipe in inlet control

Pond Volumes - Frustum

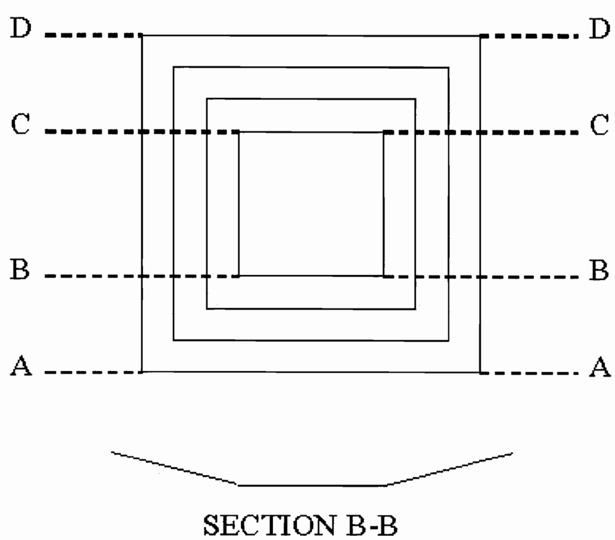
- For a square pond with uniform side slope - three methods:
  - Frustum of a pyramid (exact)
  - Average end area
  - Area of contours
- Volume of frustum of a pyramid
  - $V = h(B1+B2+[B1*B2]^{0.5})/3$
  - For 40' x 40' base, 4' deep pond, with 4:1 side slopes
    - B1 = 40 * 40 = 1600 sq ft
    - B2 = (40+16+16) * (40+16+16) = 5184 sq ft
    - $V = 4(1600+5184+[1600*5184]^{0.5})/3$
  - V = 12,885 cu. ft.

Pond Volumes - Average end area



- Average end area (4 cross-sections)
  - Section A-A = 0 sq ft
  - Section B-B = 0.5 * 4 * (40 + 72) = 224 sq ft
  - Section C-C = Section B-B = 224 sq ft
  - Section D-D = 0 sq ft

Pond Volumes - Average end area



Pond Volumes - Average end area

Distance	Area	Volume	Total Volume
0	0		
		1792	1792
16	224		
		8960	10752
56	224		
		1792	12544
72	0		

- V = 12,544 cu. ft. difference of -2.65%

Pond Volumes - 1-foot contours

- Area of contours
  - 1 foot contours:

Depth	Length	Width	Area	Avg. Area	Incr. Vol	Total Vol
0	40	40	1600			
				1952	1952	1952
1	48	48	2304			
				2720	2720	4672
2	56	56	3136			
				3616	3616	8288
3	64	64	4096			
				4640	4640	12928
4	72	72	5184			

  - V = 12,928 cu. ft. difference of +0.33%

Pond Volumes - 2-foot contours

- Area of contours
  - 2 foot contours:

Depth	Length	Width	Area	Avg. Area	Incr. Vol	Total Vol
0	40	40	1600			
				2368	4736	4736
2	56	56	3136			
				4160	8320	13056
4	72	72	5184			

  - V = 13,056 cu. ft. difference of +1.32%

Pond Volumes - 4-foot contours

- Area of contours
  - 4 foot contours:

Depth	Length	Width	Area	Avg. Area	Incr. Vol	Total Vol
0	40	40	1600			
				3392	13568	13568
4	72	72	5184			

  - V = 13,568 cu. ft. difference of +5.30%

Pond Volumes - method comparison

- Frustum of a pyramid (exact), V = 12,885 cu. ft.
- Average End Area, V = 12,544 cu. ft. difference of -2.65%
- Area of contours
  - 1 foot contours, V = 12,928 cu. ft. difference of +0.33%
  - 2 foot contours, V = 13,056 cu. ft. difference of +1.32%
  - 4 foot contours, V = 13,568 cu. ft. difference of +5.30%

Hydrograph Routing

- Inflow - Outflow = Change in Storage

  $Q_{in} * \Delta t - Q_{out} * \Delta t = \Delta S$
- Required Information:
  - Inflow Hydrograph
  - Outlet Stage-Discharge Curve
  - Pond Stage-Storage Curve
- Example: Using Rational Method Hydrograph developed previously for 10-year, one-hour event for a 10-acre parking lot in Ottumwa, IA, an 18-inch diameter discharge pipe at the bottom of the pond, and a 100' x 100' square pond with 4:1 side slopes, route the hydrograph through the pond

Hydrograph Routing - Inflow

- Inflow Hydrograph

Clock time minutes	Q, cfs
0	0.0
10	8.7
20	24.1
30	56.4
40	18.6
50	8.7
60	8.7

Pond Volumes - Size approximation

- Inflow Hydrograph

Clock time minutes	Q, cfs	Volume cubic feet
0	0.0	0
10	8.7	5,220
20	24.1	14,460
30	56.4	33,840
40	18.6	11,160
50	8.7	5,220
60	8.7	5,220
	Total	75,120

- Upper limit: total flow = 75,120 cubic feet
- Lower limit: total flow - maximum discharge
  If max. discharge=14 cfs: 75,120-(14)(60)(60)=24,720 cf

Hydrograph Routing - pond volume

- Volume of frustum of a pyramid
  - $V = h(B1+B2+[B1*B2]^{0.5})/3$
  - For 100' x 100' base, 4' deep pond, with 4:1 side slopes
    - B1 = 100 * 100 = 10,000 sq ft
    - B2 = (100+16+16) * (100+16+16) = 17,424 sq ft
    - $V = 4(10000+17424+[10000*17424]^{0.5})/3$
  - V = 54,165 cu. ft.
  - Solving for depth at 0.5 foot increments yields the stage-storage curve for the pond

Hydrograph Routing - Stage-Storage-Discharge

- Stage-Storage-Discharge Curve for 100' x 100' pond, 4 foot deep with 4:1 sides:

Depth	Flow	Storage	Depth	Flow	Storage	Depth	Flow	Storage
0.1	0.1	1008	1.5	5.1	16872	2.9	9.5	36248
0.2	0.1	2032	1.6	5.6	18135	3.0	9.7	37776
0.3	0.2	3073	1.7	6.1	19417	3.1	9.9	39324
0.4	0.5	4129	1.8	6.6	20716	3.2	10.1	40891
0.5	0.7	5203	1.9	7.0	22034	3.3	10.3	42479
0.6	1.0	6293	2.0	7.3	23371	3.4	10.5	44086
0.7	1.3	7399	2.1	7.6	24726	3.5	10.7	45715
0.8	1.7	8523	2.2	7.8	26099	3.6	10.9	47363
0.9	2.1	9664	2.3	8.1	27492	3.7	11.1	49033
1.0	2.6	10821	2.4	8.3	28903	3.8	11.3	50723
1.1	3.0	11996	2.5	8.5	30333	3.9	11.5	52433
1.2	3.5	13189	2.6	8.8	31783	4.0	11.7	54165
1.3	4.1	14399	2.7	9.0	33252			
1.4	4.6	15627	2.8	9.3	34740			

Hydrograph Routing - First time increment

- Time increment 10 minutes:
  - Inflow = 8.7 cfs
  - Inflow = 8.7 * 60 (sec/min) * 10 min = 5220 cubic feet
  - Trial volume = 5220 cubic feet
  - Trial depth = 0.5 ft
  - Average depth = 0.25 ft
  - Outflow = 0.2 cfs
  - Outflow = 0.2 * 60 * 10 = 120 cubic feet
  - Cumulative Storage = 5220 - 120 = 5100 cubic feet
  - Depth at this volume ~ 0.5 ft, = Trial depth, continue with next time increment

Hydrograph Routing - Second time increment

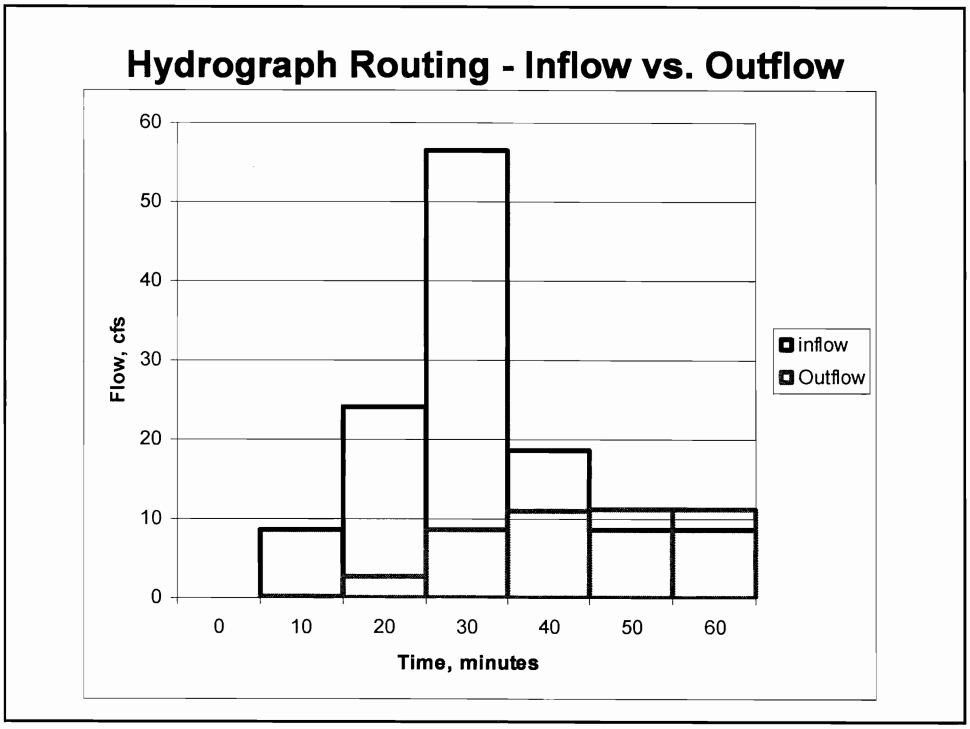
- Time increment 20 minutes:
  - Inflow = 24.1 cfs
  - Inflow = 24.1 * 60 * 10 = 14,460 cubic feet
  - Trial volume = 14460 + 5100 = 19,560 cubic feet
  - Trial depth = 1.7 ft
  - Average depth = (1.7 + 0.5)/2 = 1.1 ft
  - Outflow = 3.0 cfs
  - Outflow = 3.0 * 60 * 10 = 1800 cubic feet
  - Cumulative Storage = 19,560 - 1800 = 17,760 cubic feet
  - Depth at this volume ~ 1.6 ft < Trial depth, continue with another iteration

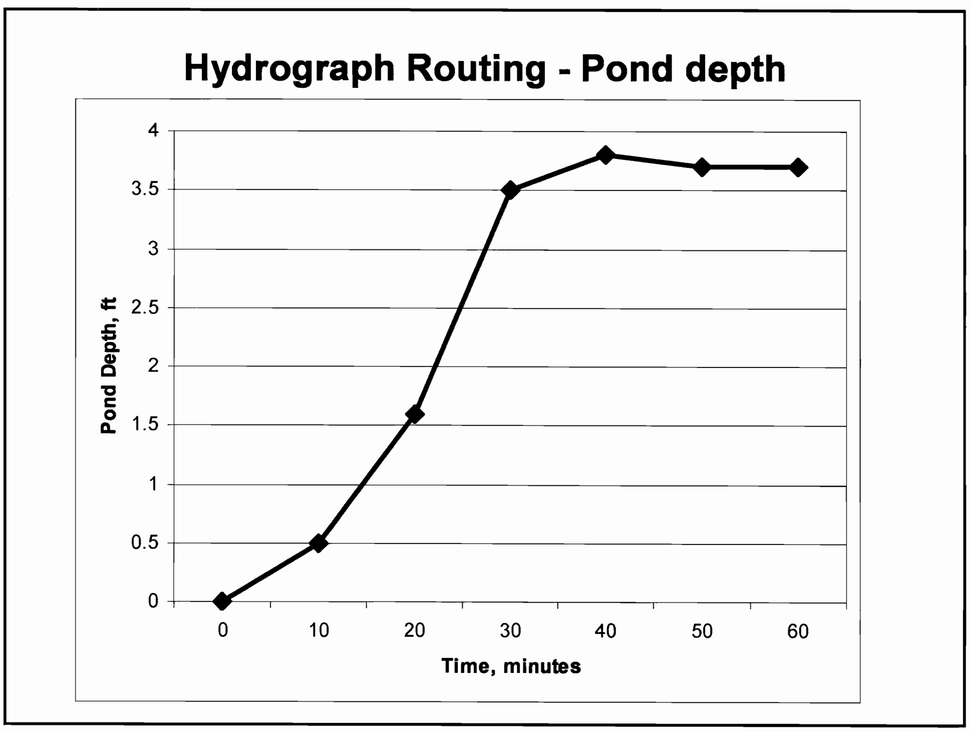
Hydrograph Routing - Second time increment

- Time increment 20 minutes, second iteration:
  - Inflow = 24.1 cfs
  - Inflow = 24.1 * 60 * 10 = 14,460 cubic feet
  - Trial volume = 14460 + 5100 = 19,560 cubic feet
  - Trial depth (from first iteration) = 1.6 ft
  - Average depth = (1.6 + 0.5)/2 = 1.05 ft
  - Outflow = 2.8 cfs
  - Outflow = 2.8 * 60 * 10 = 1680 cubic feet
  - Cumulative Storage = 19,560 - 1680 = 17,880 cubic feet
  - Depth at this volume ~ 1.6 ft = Trial depth, continue with next time increment

Hydrograph Routing - Table

Time	Inflow cfs	Inflow cu ft	Trial Volume cu ft	Trial Depth ft	Average Depth ft	Outflow cfs	Outflow cu ft	Volume cu ft
0	0	0	0	0	0	0	0	0
10	8.7	5220	5220	0.5	0.25	0.2	120	5100
20	24.1	14460	19560	1.7 1.6	1.1 1.05	3.0 2.8	1800 1680	17760 17880
30	56.4	33840	51720	3.9 3.5	2.75 2.55	9.1 8.6	5460 5160	46260 46560
40	18.6	11160	57720	4.0 3.8	3.75 3.65	11.2 11.0	6720 6600	51000 51120
50	8.7	5220	56340	4.0 3.7	3.9 3.75	11.5 11.2	6900 6720	49440 49620
60	8.7	5220	54840	4.0 3.6 3.7	3.85 3.65 3.7	11.4 11.0 11.1	6840 6600 6660	48000 48240 48180


Hydrograph Routing - Inflow vs. Outflow
60
50
40
30
20
10
0
Flow, cfs
0
10
20
30
40
50
60
Time, minutes
inflow
Outflow


Hydrograph Routing - Pond depth
4
3.5
3
2.5
2
1.5
1
0.5
0
Pond Depth, ft
0
10
20
30
40
50
60
Time, minutes

Hydrograph Routing - Class Problem

- Class Problem: Using Rational Method Hydrograph developed previously for 5-year, one-hour event for a 5-acre parking lot in Red Wing, MN, an 18-inch diameter discharge pipe at the bottom of the pond, and a 100' x 100' square pond with 4:1 side slopes, route the hydrograph through the pond

Routing Problem - Inflow

- Inflow Hydrograph, Class Problem

Clock time minutes	Q, cfs
0	0.0
10	3.2
20	8.7
30	20.5
40	6.6
50	3.2
60	3.2

Routing Problem - Stage-Storage-Discharge

- Stage-Storage-Discharge Curve for 100' x 100' pond, 4 foot deep with 4:1 sides:

Depth (ft)	Volume (cu.ft.)	Discharge (cfs)
0.0	0	0.0
0.5	5203	0.7
1.0	10821	2.5
1.5	16872	5.1
2.0	23371	7.7
2.5	30333	8.7
3.0	37776	9.8
3.5	45715	10.8
4.0	54165	12.2

Hydrograph Routing - Stage-Storage-Discharge

- Stage-Storage-Discharge Curve for 100' x 100' pond, 4 foot deep with 4:1 sides:

Depth	Flow	Storage	Depth	Flow	Storage	Depth	Flow	Storage
0.1	0.1	1008	1.5	5.1	16872	2.9	9.5	36248
0.2	0.1	2032	1.6	5.6	18135	3.0	9.7	37776
0.3	0.2	3073	1.7	6.1	19417	3.1	9.9	39324
0.4	0.5	4129	1.8	6.6	20716	3.2	10.1	40891
0.5	0.7	5203	1.9	7.0	22034	3.3	10.3	42479
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0.8	1.7	8523	2.2	7.8	26099	3.6	10.9	47363
0.9	2.1	9664	2.3	8.1	27492	3.7	11.1	49033
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1.2	3.5	13189	2.6	8.8	31783	4.0	11.7	54165
1.3	4.1	14399	2.7	9.0	33252			
1.4	4.6	15627	2.8	9.3	34740			

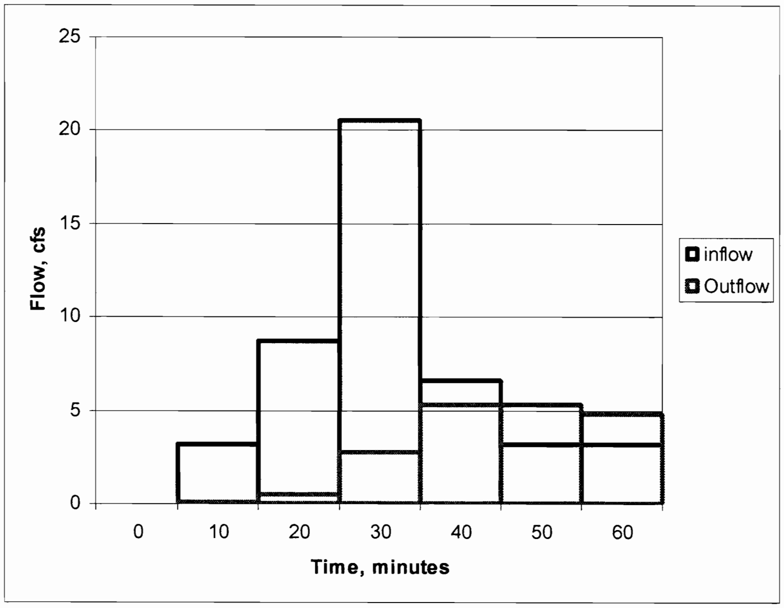
Routing Problem - Table

Time	Inflow cfs	Inflow cu ft	Trial Volume cu ft	Trial Depth ft	Average Depth ft	Outflow cfs	Outflow cu ft	Volume cu ft
0	0	0	0	0	0	0	0	0
10	3.2							
20	8.7							
30	20.5							
40	6.6							
50	3.2							
60	3.2							

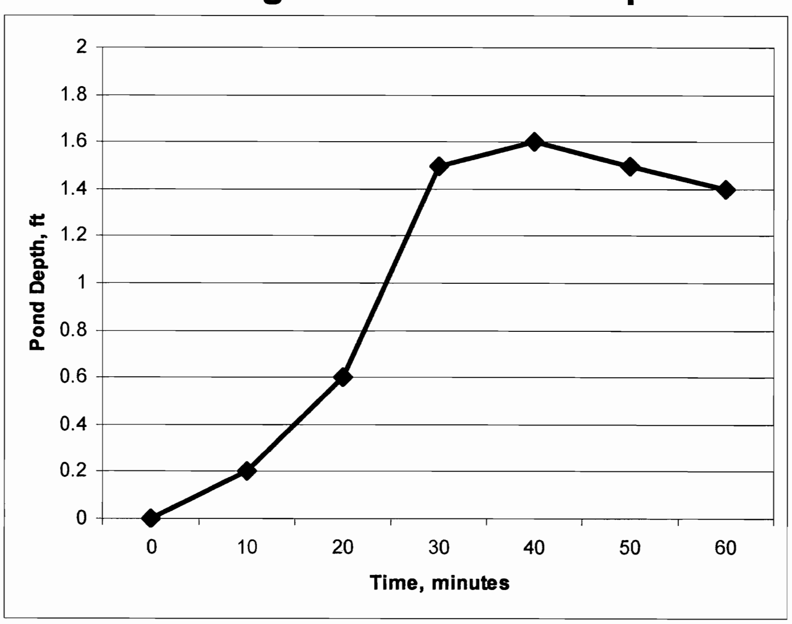
Routing Problem - Table

Time	Inflow cfs	Inflow cu ft	Trial Volume cu ft	Trial Depth ft	Average Depth ft	Outflow cfs	Outflow cu ft	Volume cu ft
0	0	0	0	0	0	0	0	0
10	3.2	1920	1920	0.2	0.1	0.1	60	1860
20	8.7	5220	7080	0.7 0.6	0.45 0.4	0.6 0.5	360 300	6720 6780
30	20.5	12300	19080	1.7 1.5	1.15 1.05	3.2 2.8	1920 1680	17160 17400
40	6.6	3960	21360	1.8 1.6	1.65 1.55	5.8 5.3	3480 3180	17880 18180
50	3.2	1920	20100	1.8 1.5	1.7 1.55	6.1 5.3	3660 3180	16440 16920
60	3.2	1920	18840	1.7 1.4	1.6 1.45	5.6 4.8	3360 2880	15480 15960

Routing Problem - Inflow vs. Outflow



Routing Problem - Pond depth



Pond Geometry

- Generally constrained by site topography or development
- For better treatment, length should be 2 times width or more
- Rectangular may be most efficient and easiest to construct, but not aesthetically pleasing
- Outlet should be as far away from inlet as physically possible
- Side slopes:
  - 2H:1V minimum for stability, but people can't traverse when wet
  - 4H:1V probably minimum for mowing and walking
  - Flatter better for aesthetics, but not efficient use of land area and may create too much shallow water (WNV)

Water Quality Impacts

- Detention for water quality often requires substantial time of detention for "first flush" (often first 0.5 to 1.0 inch of runoff) or frequent return periods (6-months to 2-years)
- Parking lot pollutants include TSS, Cadmium, Copper, Lead, Zinc, Oil and Grease
- Wet Ponds
  - Generally require 12-48 hours of "hydraulic residence time" to achieve significant treatment
  - 90% of pollutant removal occurs during the quiescent period (period between rainfall events)
  - Improper design/location/maintenance can result in adverse effects on water quality, groundwater, cold water fisheries or wetlands

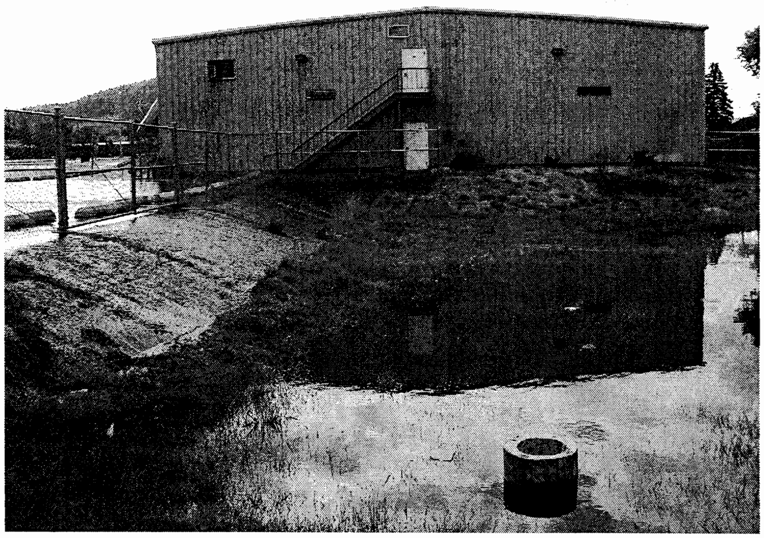
Water Quality - Wet Ponds

- Wet Ponds
  - Rectangular shapes subject to short-circuiting of flow
  - Must be able to maintain a permanent pool of water
    - Insufficient precipitation
    - Permeable soils
    - Small drainage areas
  - Land requirements can be a constraint, especially in developed areas
  - Poor maintenance can substantially reduce performance – Pollutant storage vs. pollutant removal

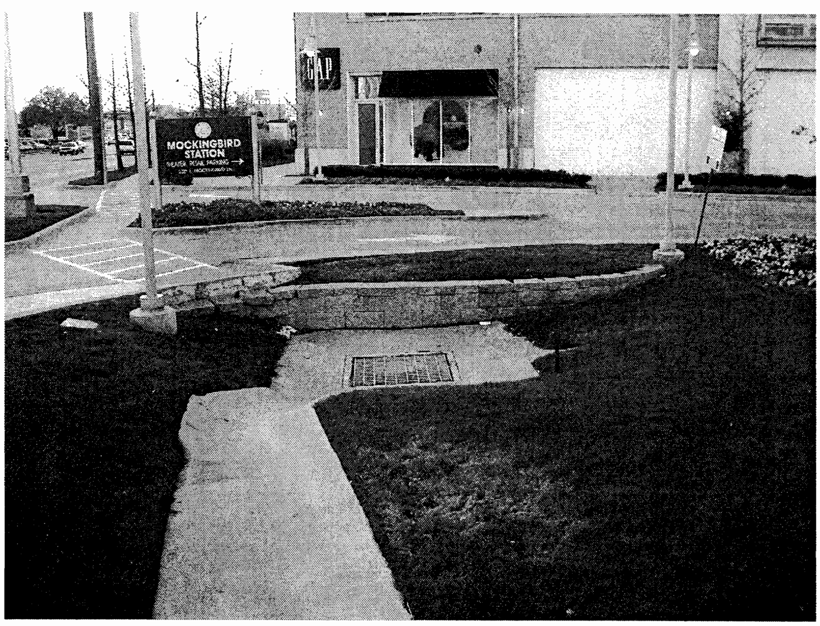
Water Quality - Dry Ponds

- Dry Detention Ponds
  - Provide very little pollutant removal, primarily due to short HRT
  - Can provide some limited reduction of larger sediments (sands and gravels)
  - Effective for flood control
- Dry Extended Detention Ponds
  - Land requirements can be a constraint, especially in developed areas
  - Maintenance can substantially reduce performance
  - Moderate pollutant removal and ineffective at removing soluble pollutants, though removal rates are highly variable

Pond adjacent to Parking Lot

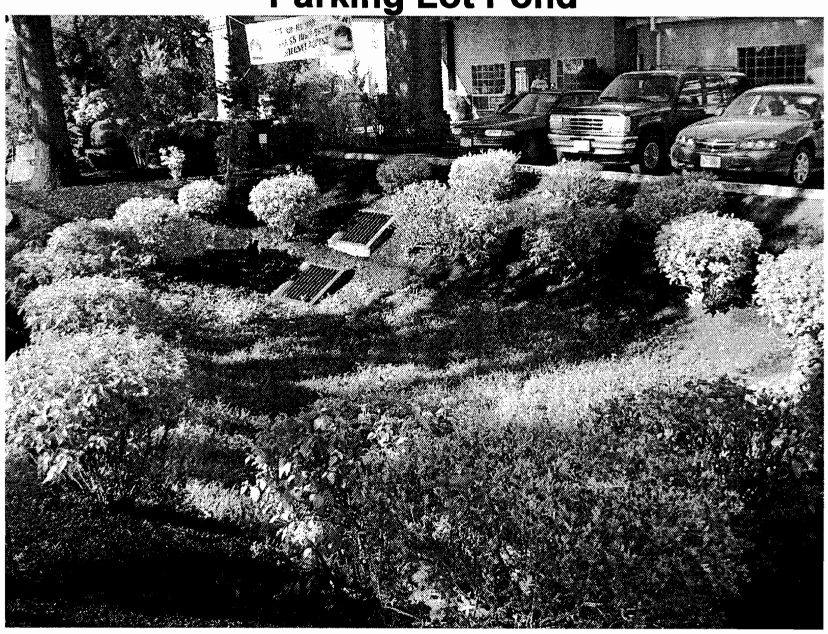


Potential Pond

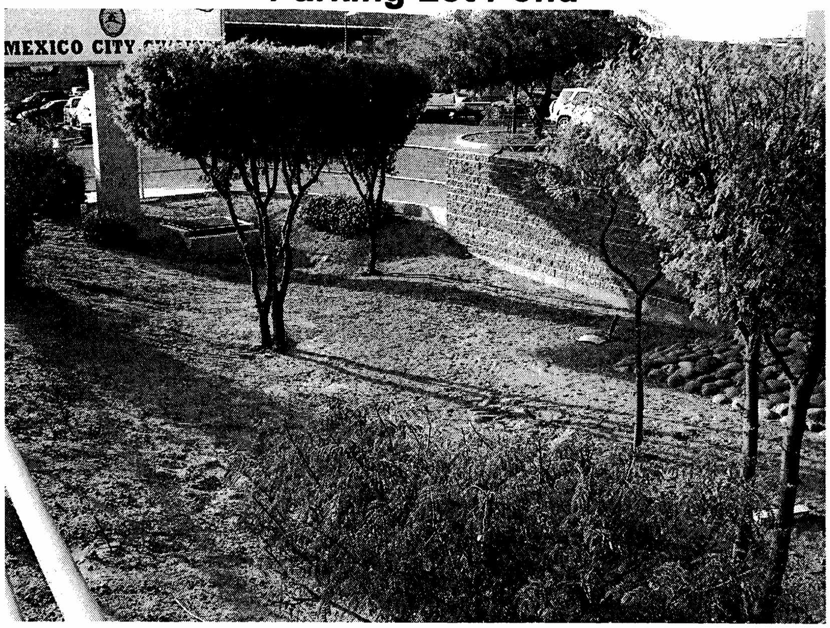


Parking Lot Pond

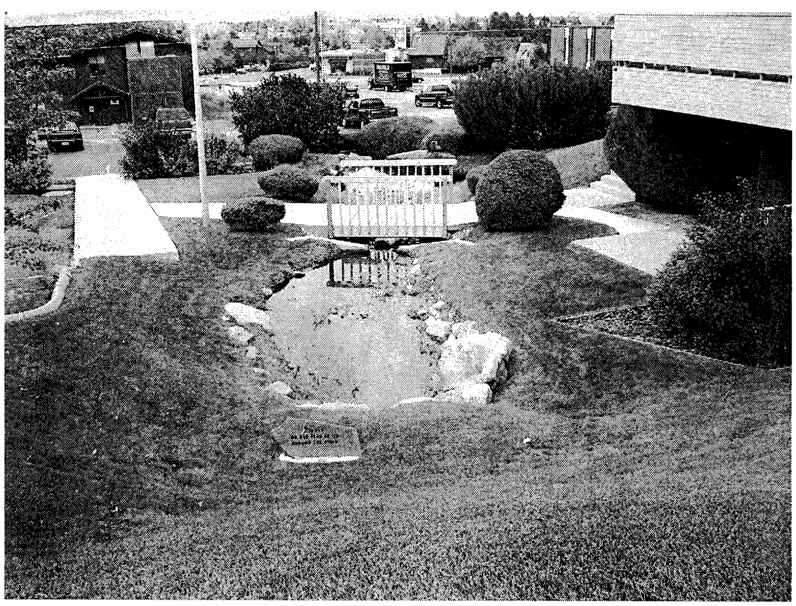
Parking Lot Pond



Parking Lot Pond



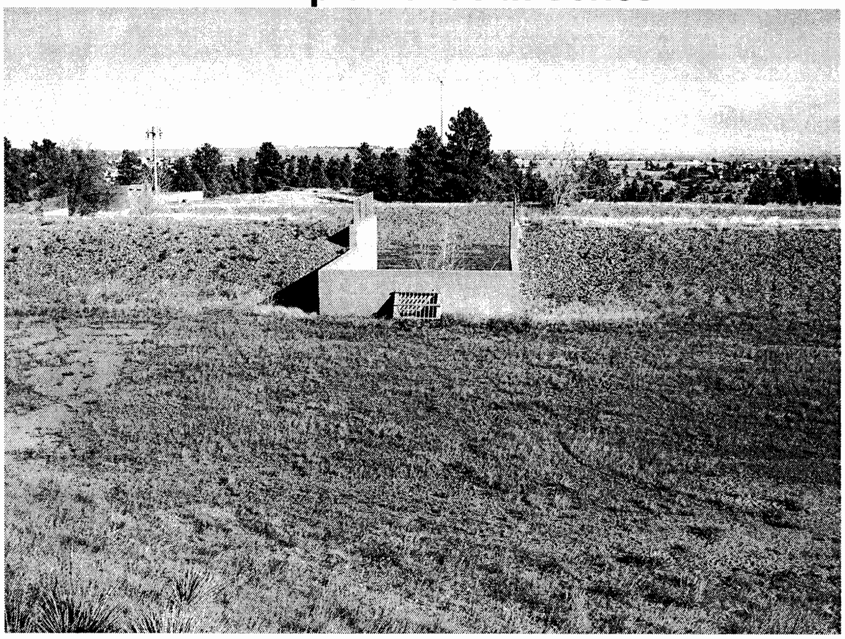
Landscaped Pond



Multiple-function Pond

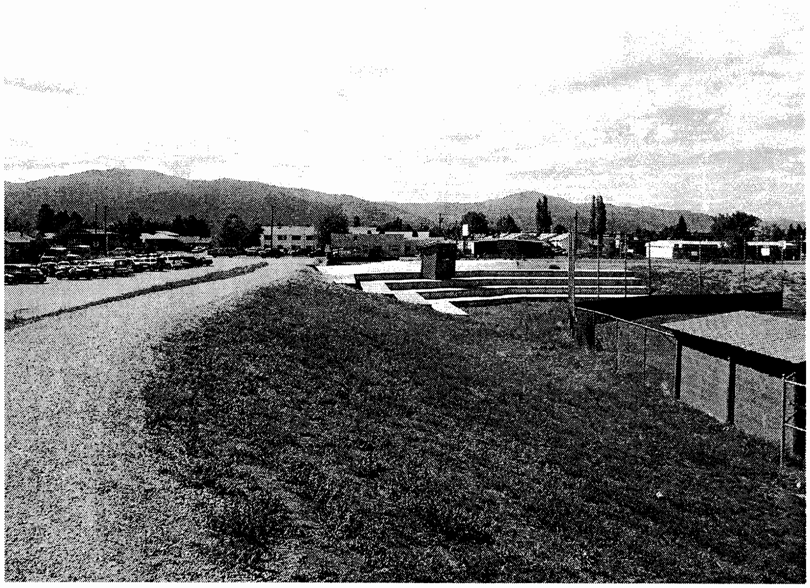
Pond with low-flow channel

Multiple Ponds in Series

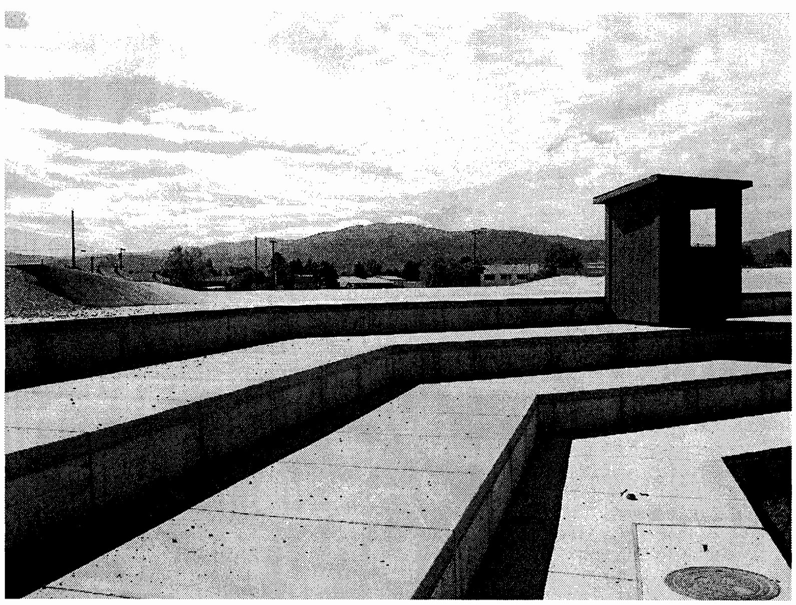


Off-system Pond

Off-system Pond, Outlet



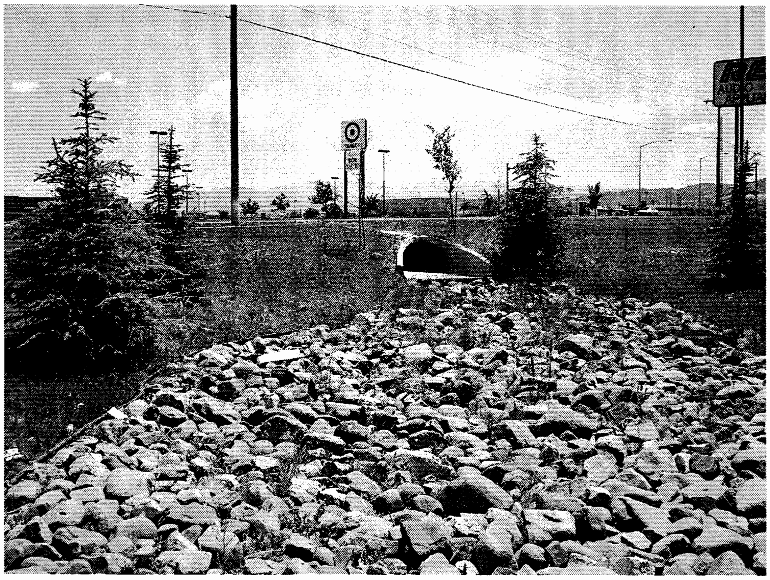
Off-system Pond, Outlet



Off-system Pond, Outlet

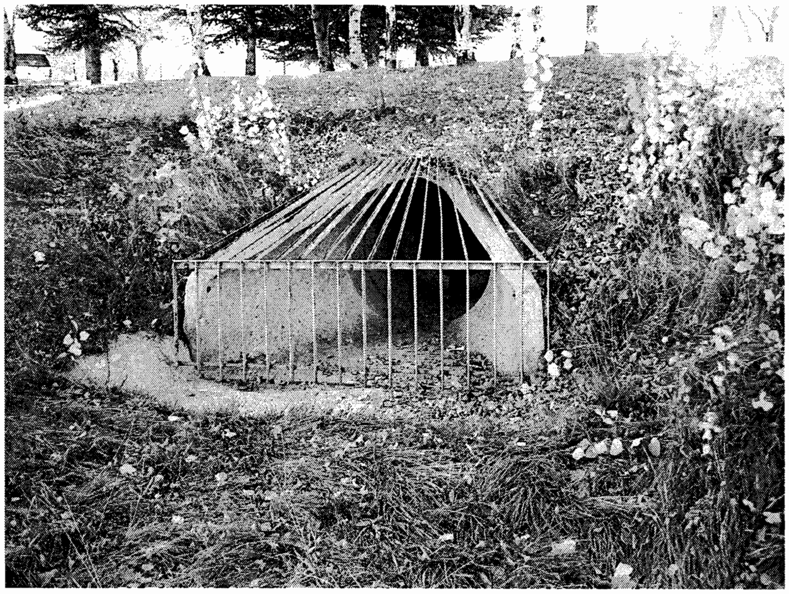
Off-system Pond, Outlet

Pond and Inlet



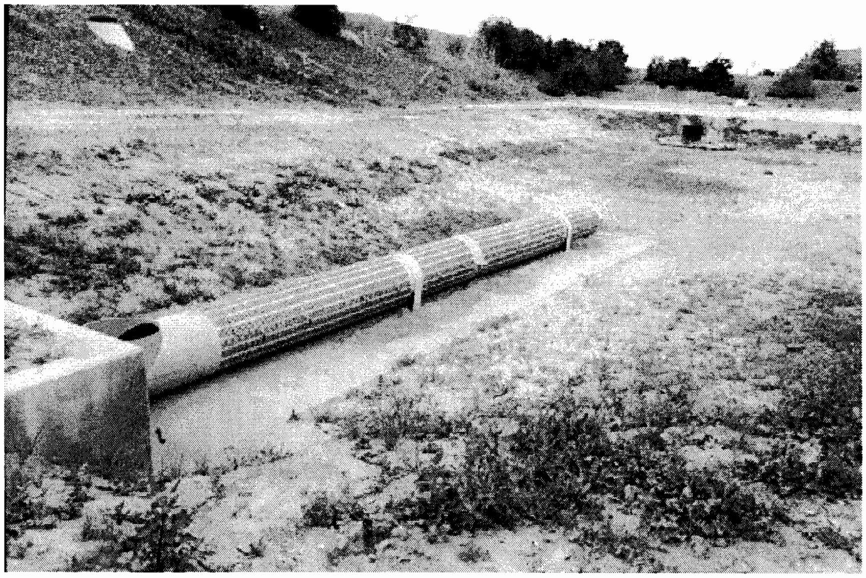
Pond and Inlet - Operating

Inlet pipe with trashrack

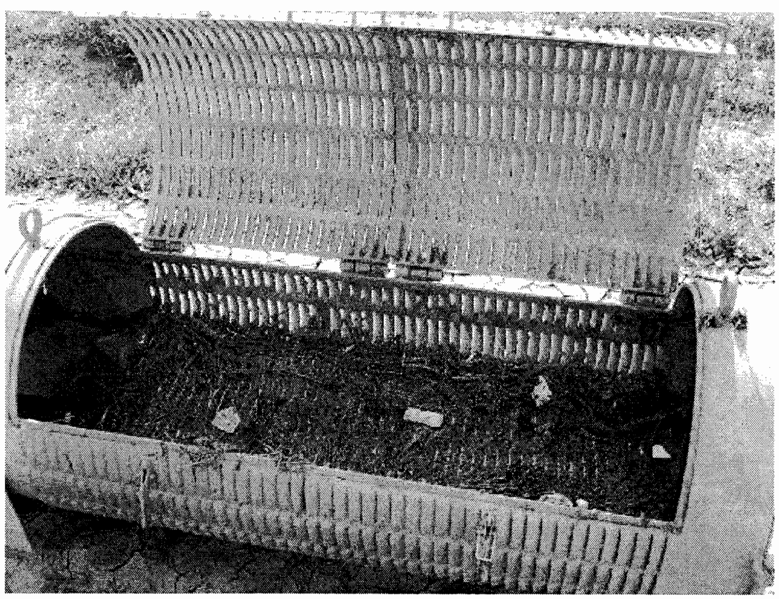


Pond Inlet Structure

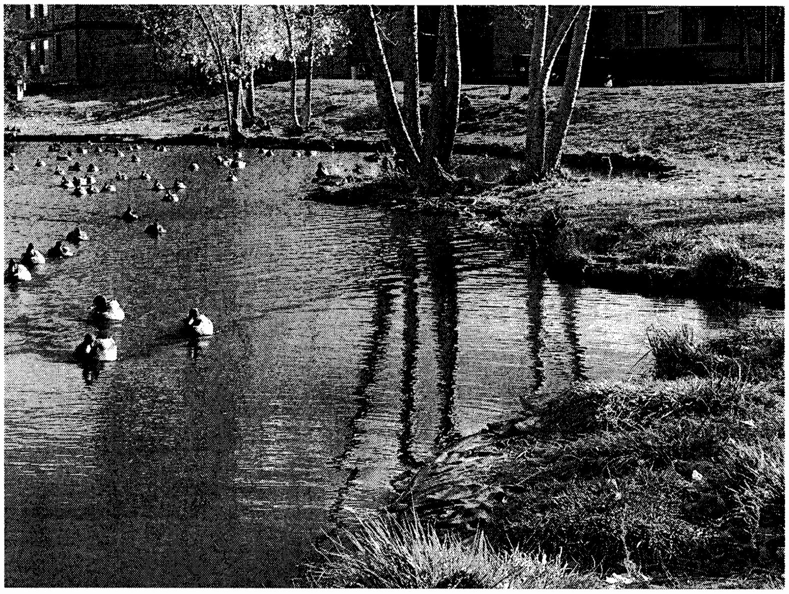
Roscoe-Moss Storm Flo™ Screen



Roscoe-Moss Storm Flo™ Screen



Wet Pond



Inlet to Wet Pond