COMPARISON OF INFILTRATION AND DETENTION IN THE GEORGIA PIEDMONT USING RECENT HYDROLOGIC MODELS

M. Morgan Ellington and Bruce K. Ferguson

AUTHORS: M. Morgan Ellington and Bruce K. Ferguson, respectively Graduate Student and Associate Professor, School of Environmental Design, University of Georgia, Athens, GA 30602.

REFERENCE: Proceedings of the 1991 Georgia Water Resources Conference, held March 19 and 20, 1991, at The University of Georgia. Kathryn Hatcher, Editor, Institute of Natural Resources, The University of Georgia, Athens, Georgia.

INTRODUCTION

Infiltration is a possible alternative to detention for control of urban stormwater. Infiltration is capable of controlling peak flows as is detention, but also promises the advantages of flow volume control, base flow augmentation, and water quality improvement. However, the feasibility of infiltration in the Georgia Piedmont has been questioned because of the region's combination of high rainfall and slowly permeable soils.

To test the feasibility of infiltration in this region, Patton (1986) designed infiltration systems as hypothetical replacements for existing detention systems on two urban development sites in the Atlanta area. Both the detention and infiltration systems were based on the Rational formula and equivalent design storms. When the two types of systems were compared, Patton found that infiltration, when designed to meet the same hydraulic standards as detention, was surprisingly feasible in terms of construction cost and land area occupied while offering more environmental benefits than detention.

This paper summarizes a study (Ellington, 1991) to update Patton's work. In this study both detention and infiltration systems on Patton's study sites were redesigned using two relatively recent hydrologic models, the Soil Conservation Service (SCS) method of estimating storm runoff, and the long-term water balance as it applies to accumulation of standing water in closed reservoirs. Hydrologic performance was modeled, and cost indicators estimated, for four conditions: undeveloped, developed with no stormwater control, developed with detention, and developed with infiltration.

HYDROLOGIC MODELS

The SCS method was applied using the computer model *On-Site Stormwater Management* by Ferguson and Debo (1990). After generating flood hydrographs, the model also routes flows downstream through channels using the Muskingum method, and through reservoirs using the Puls method.

Infiltration basins are closed reservoirs that accumulate long-term background flows. Infiltration basins designed using only design storm criteria have accumulated standing water, preempting basin capacity before a design storm occurs (Pensyl and Clement, 1987). Ferguson (1990) found that such failures could be due to not taking into account the long-term water balance. Engstrand (1983) suggested that the volume of a selected design storm can be superimposed on the highest monthly level of standing water indicated by the long-term water balance to evaluate a basin's volume for controlling a design storm as well as background flows. Ferguson (1990) adapted Engstrand's method to the design of proposed infiltration basins. In this study Engstrand's method was applied to infiltration basins using a computer implementation of Ferguson's (1990) long-term water balance model and Ferguson and Debo's (1990) implementation of the SCS method for storm flow volume.

DATA

The two study sites are named Riverwalk and GEC Avionics (formerly Marconi). They were selected by Patton for their similarity in having governmentally approved detention systems, and their differences in site and land use characteristics and applicable governmental regulations.

Riverwalk is a multi-family residential development in Fulton County, regulated under the Chattahoochee River Corridor provisions of the Atlanta Regional Commission (ARC). The 26.53 acre site has 70 dwelling units with two parking spaces per unit. The site is steep, with average slope after development of 20 percent. The major soil texture is sandy loam. Runoff enters the property from 11.75 acres in neighboring communities, so the study evaluated a total of 38.28 acres. ARC's regulations required that the 50-year peak flow be suppressed by means of permanent stormwater controls (Patton, 1986, pages 16, 18). The original designers installed four detention basins to control the peak flow of the two watersheds most impacted by development, with the larger watershed controlled by three of the four basins.

In contrast, GEC Avionics is a 15 acre industrial site in Gwinnett County. The site was designed to accommodate 85,000 square feet of building space and parking for 357 cars. The site is gently sloping, with average slope after development of 5 percent. The major soil texture is sandy clay loam. Three acres in an adjacent property drain onto the site, so a total of 18 acres were included in the study. The original designers installed a single detention basin to control the 100-year discharge in compliance with the County's regulations.

Patton (1986) designed hypothetical infiltration systems to replace the existing detention systems. The proposed basins were located primarily underground, constructed of crushed stone with void space of 40 percent. Basins located in parking bays were surfaced with porous concrete block pavers as a means of letting surface runoff into the basins from parking pavements; other basins were located in planted areas.

In this study the location of Patton's basins was considered in order to make results as comparable as possible to Patton's work, and all basins were located underground. For the same reason, porous concrete block paving was considered as basin surfacing. However porous pavement is susceptible to sealing without backup storage capacity, and prevents access for maintenance to the infiltrating soil surface. Therefore an additional construction approach was investigated, in-

Table 1. Hydrologic performance of alternative stormwater management systems (Rational formula data adapted from Patton, 1986).

Site Condition	Simple Additive Peak Discharge (cfs)	Hypothetical Single Peak Discharge (cfs)	Velocity Released (fps)	Volume Released (af)	Volume Infiltrated (storm only) (af)
Riverwalk (38.28 acres, 50 year storm)					
Sized and Evaluated with Rational Formula Design Storm:					
Undeveloped	125	—	—	—	0.00
Developed, Detention	110	—	11.5	2.04	0.00
Developed, Infiltration	97	—	—	1.37	1.54
Sized and Evaluated with SCS Method Design Storm:					
Undeveloped	166	159	12.6	4.08	0.00
Developed, No Control	205	193	13.8	4.38	0.00
Developed, Detention	162	149	12.9	4.38	0.00
Developed, Infiltration	161	147	12.5	3.64	0.74
Sized and Evaluated with Long-term Water Balance and SCS Design Storm:					
Developed, Infiltration	161	147	12.5	3.64	0.74
GEC Avionics (18 acres, 100 year storm)					
Sized and Evaluated Rational Formula Design Storm:					
Undeveloped	26	—	—	—	0.00
Developed, Detention	26	—	0.6	0.45	0.00
Developed, Infiltration	31	—	—	0.28	0.32
Sized and Evaluated SCS Method Design Storm:					
Undeveloped	82	77	7.2	2.06	0.00
Developed, No Control	139	136	8.6	2.72	0.00
Developed, Detention	75	70	5.4	2.72	0.00
Developed, Infiltration	79	74	5.6	1.56	1.24
Sized and Evaluated Long-term Water Balance and SCS Design Storm:					
Developed, Infiltration	79	74	5.6	1.56	1.24

volving conventional impermeable asphalt paving and a grate drop inlet with perforated walls to let surface runoff into the void space of the stone and to allow access for maintenance such as pumping out sediment or standing water if the need occurs.

RESULTS

The hydrologic effects predicted by the various models are listed in Table 1.

To calculate representative peak flows for meeting governmental flood control requirements, the original designers of both sites simply added the peak flows from all discharge points as if they occurred simultaneously in a single stream. The same method was used by Patton and in this study. In addition in this study the flows at the various discharge points from each site were combined in an artificial composite hydrograph as if each site had a single point of discharge. The results by both methods, reflected in Table 1, show that all stormwater control systems, as intended, were capable of reducing peak discharge below the required predevelopment levels.

Velocity of discharge is relevant to downstream erosion and bank stability. The velocities reported in Table 1 are in hypothetical swales at the largest discharge point of each site, at the peak discharge of the applicable design storm. The results show that the velocities released from the infiltration systems were the lowest of the management alternatives at Riverwalk, but at GEC Avionics infiltration resulted in a velocity slightly higher than detention, but still less than the undeveloped condition.

The length of time that the velocity of discharge exceeds the maximum noneroding velocity of the assumed downstream conditions is relevant to downstream stability and water quality. The velocity discharged from the watershed was calculated in three minute intervals based on the discharge hydrographs during the applicable design storms. Results for both sites indicated that infiltration shortened the time of erosive velocity in comparison to the other two conditions, thereby reducing the possibility of stream bank erosion is reduced.

Volume of storm runoff is relevant to downstream flood and loss of subsurface recharge. Table 1 shows that infiltration using the SCS method decreased the volume of runoff from the undeveloped condition; detention, being a surface discharge approach, did not affect volume from the developed site.

The smaller two-year storm was also modeled for both sites, to examine effects of smaller, more frequent storms, to

Table 2. Cost indicators of alternative stormwater management systems (Rational formula data adapted from Patton, 1986).

Site Condition	Basin Surface Area (ac)	Basin Capacity (water only) (af)	Total Basin Volume (water and stone) (af)	Percent of Site Dedicated to Stormwater (%)	Construction Cost (pavers) ($)	Construction Cost (inlets) ($)
Riverwalk (38.28 acres, 50 year storm)						
Sized with Rational Formula Design Storm						
Detention	0.26	0.77	0.77	1.0	183,051	183,051
Infiltration	0.11	1.54	3.86	0.4	133,718	128,162
Sized with SCS Method Design Storm						
No Control	0.00	0.00	0.00	0.0	198,603	198,603
Detention	0.30	0.92	0.92	1.0	215,433	215,433
Infiltration	0.00	0.74	1.85	0.0	128,582	89,441
Sized with Long-term Water Balance and SCS Design Storm						
Infiltration	0.00	0.74	1.85	0.0	128,582	89,441
GEC Avionics (18 acres, 100 year storm)						
Sized with Rational Formula Design Storm						
Detention	0.64	2.39	2.39	4.0	100,274	100,274
Infiltration	0.00	0.42	1.04	0.0	58,480	34,868
Sized with SCS Method Design Storm						
No Control	0.00	0.00	0.00	0.0	144,231	144,231
Detention	0.55	1.07	1.07	3.7	121,146	121,146
Infiltration	0.00	1.24	3.09	0.0	187,835	94,990
Sized with Long-term Water Balance and SCS Design Storm						
Infiltration	0.00	1.32	3.30	0.0	255,968	103,062

which stream morphology may be adapted and impacts to which may be more damaging in the long run. During this storm infiltration was able to reduce the peak rate of flow to equal or below the predevelopment condition, while the detention systems were ineffective. Infiltration reduced the volume of discharge while detention did not affect it. The velocity discharged from the site under the assumed conditions also showed infiltration more favorable, with a shorter duration of erosive velocity.

Table 2 compares the costs associated with each of the alternative stormwater control systems. Basin surface area is the area of the development site dedicated exclusively to single-purpose stormwater facilities. Considering the high cost of urban land, it is economically beneficial not to dedicate large amounts of land exclusively to stormwater basins. In this regard infiltration basins were more favorable than detention; they involved no surface area because the surface over them was reclaimed for parking or planting.

Basin volume is an indicator of construction costs associated with quantities of earthwork and construction materials, independent of specific unit costs at any moment in time. The total volume of a stone-filled basin is 2.5 times its hydraulic capacity, because only 40 percent of the volume is void space holding water. At Riverwalk the total infiltration basin volume using the long-term water balance gave the same result as using the SCS method, but at GEC Avionics an increase in basin volume was necessary to the accommodate background flows indicated by the water balance analysis. At Riverwalk the higher soil infiltration rate (.18 ft/day vs. .10 ft/day at GEC) and areas available for large level basin floors combined to produce infiltration basins that did not accumulate background flows before the design storm occurred.

The estimated construction costs listed in Table 2 are based on reasonable assumptions of construction methods and 1989 unit costs (Kerr 1989). For stormwater management systems designed using the Rational method, the cost analysis of Patton (1986) was updated to 1989 unit costs. At Riverwalk infiltration was estimated to be less expensive than detention when porous concrete pavers were used; replacement of the pavers with conventional asphalt and inlets resulted in further cost reduction. At GEC Avionics the Rational-based costs reflect infiltration with concrete pavers less expensive than detention for both types of construction while use of the SCS method and the long-term water balance resulted in an increase in cost. Nevertheless, with asphalt paving and inlets replacing the concrete pavers, both methods showed infiltration lower in cost than detention.

Although future maintenance costs cannot be quantified, they can be discussed qualitatively. A moderately intense monitoring program for both detention and infiltration basins would include checking the basins annually or less than annually in months (October through December) when the long-term water balance predicts that the lowest stage would occur. If upon checking it is found that the depth of water or sediment in a basin detracts excessively from basin storage capacity or an inlet or outlet is clogged, it is possible to pump out the standing water and sediment through the inlet or to dredge an open detention basin.

Alternative stormwater management facilities can also be evaluated aesthetically. The infiltration basins assumed in this study are underground basins, incorporated under parking lots and planted areas. They are out of public view. The location of the inlets is the only reminder that they exist. In contrast, the dry detention basins are located on the ground surface, a utilitarian intrusion upon landscapes that ought to be designed to be viewed, enjoyed or used.

CONCLUSIONS

The results suggest that, while both detention and infiltration were able to satisfy applicable peak-flow requirements, infiltration had the added advantages of reducing the volume of discharge, reducing the time of erosive velocity in stream channels, and reclaiming the surface of basins for dual purposes. Despite the cost of stone for underground infiltration basins, properly planned infiltration systems cost less than detention systems due to the high cost of conveyances and outlet structures associated with detention.

These results confirm that infiltration is physically and economically feasible as an alternative to detention in the Georgia Piedmont. In a region concerned about water quality and quantity and experiencing rapid urbanization, infiltration deserves to be more widely practiced. In addition, the results point out the importance of taking into account the long-term water balance as a supplement to the design-storm approach when sizing infiltration basins.

LITERATURE CITED

Ellington, M. Morgan. 1991. Comparison of Infiltration and Detention in the Georgia Piedmont Using Recent Hydrologic Models. MLA Thesis, University of Georgia, Athens.

Engstrand, D. 1983. Retention Ponds, Design and Analysis of Ponds without Outlets. Minnesota Department of Transportation, St. Paul

Ferguson, Bruce K. 1990. Role of the Long-term Water Balance in Management of Stormwater Infiltration. Journal of Environmental Management 30: 221-233.

Ferguson, Bruce K. and Thomas N. Debo. 1990. On-Site Stormwater Management, Applications for Landscape and Engineering, Second Edition. Van Nostrand Reinhold, New York.

Kerr, Kathleen. 1989. Cost Data for Landscape Construction. Kerr Associates, Inc., Minneapolis.

Patton, Stacy R. 1986. Infiltration Basins as a Stormwater Management Alternative for the Piedmont Region of Georgia. MLA Thesis, University of Georgia, Athens.

Pensyl, L. Kenneth, and Paul F. Clement. 1987. Results of the State of Maryland Infiltration Practices Survey. Presented at the State of Maryland Sediment and Stormwater Management Conference. (Available from Maryland Department of Natural Resources, Water Resources Administration, Stormwater Management Division, Annapolis, Maryland.)