FLOOD HAZARD NEWS

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IMPLEMENTATION OF STORMWATER DETENTION POLICIES IN THE DENVER METROPOLITAN AREA

By Bruce Prommersberger, Denver Engineering Corporation

This article is a condensation of a report prepared for completing a master's degree in civil engineering at the University of Colorado at Denver.

Purpose of the Study

As a practicing civil engineer for a consulting firm, the writer is regularly engaged to prepare drainage reports for clients who are developing land in various communities in the Denver metropolitan area. This work exposes one to a variety of city and county policies regarding stormwater collection, control, and disposal. One is also exposed to many clients whose projects vary in size and type, such as single-family residential, multi-family residential, commercial, and industrial. Their attitudes with regard to control of stormwater runoff also vary considerably.

The extent to which these attitudes vary was first realized when the writer received a telephone call from a municipality regarding a recently installed stormwater detention system which the writer had designed. The local official asked questions which led the writer to the conclusion that the system which had been installed was not the system which had been designed.

How could this have happened? The consulting firm's policy up until that time had been to stamp original mylar drawings with the seal of the professional engineer responsible for the design. Most standard forms of contract between engineer and client state that all work prepared by the engineer is owned by the client. Some clients request that they receive all original drawings and calculations, but most leave all records with the engineer. In this particular case, the client requested a reproducible copy of the original drawing, which is not an unusual request. What happened, however, was that the client took the liberty of revising the design on the reproducible drawing, and submitted the revised design to the municipality. The drawing, of course, had the engineer's seal on it.

This act by the client was clearly in violation of the State's laws regarding the practice of professional engineering. It also sparked a question: How often does something similar to this happen? A great many stormwater detention systems are constructed in the Denver metropolitan area every year. How many are constructed the way they are designed? How many are maintained to operate in the manner for which they were designed?

Scope of the Study

A study was conducted to examine how stormwater detention if utilized by municipalities in the Denver metropolitan area. Ten municipalities were contacted and stormwater policies were discussed. Random samples of stormwater detention facility designs were taken from three of the municipalities and measurements were taken in the field to determine how the facility was constructed and how it has been maintained.

Determination of Local Policies

The stormwater management policy for each of ten Denver metropolitan area communities was documented. The information collected was based on interviews with the person directly responsible for administration of the stormwater program for the city or county.

Special attention was given to the stormwater detention portion of the community's policy. The method of determination of detention volumes and release rates was documented. The procedure for verification of proper installation of stormwater facilities was discussed, as was the community's approach to insuring proper maintenance of stormwater facilities.

All of the ten communities interviewed require drainage reports for all developments, with minor exceptions. Stormwater detention is almost always required. A growing trend is to require detention for the initial storm, as well as the 100-year storm. Only two communities required that the constructed facility be certified by a professional engineer. Only two communities have special storm drainage funding programs. None of the communities have a regular maintenance program. A summary of the policies of the ten communities is shown on Table 1.

Field Investigation

The interviews of community officials indicate that the least monitored aspect of almost all stormwater management programs is maintenance after construction.

For a community's stormwater management program to function in accordance with its policy, maintenance of stormwater facilities is essential. A field investigation was made to review existing conditions in stormwater detention facilities installed in the Denver metropolitan area within the last few years. The objective was to compare designs as presented on final drainage plans with actual conditions in the field to evaluate the success of stormwater management programs.

Communities A, B, and C provided random samples of approved drainage plans. During the field trip, outlet structures were visually checked for size, configuration, materials, restrictor plates, and general maintenance. Detention volumes were not as carefully scrutinized. The general configuration shown on the drainage plan was checked by visual inspection, pacing distances, a one hundred foot tape, a six foot folding ruler, and a hand level. No volumetric calculations were made.

Study Results

This study indicates that little attention has been paid to main-

(Continued on Page 10)

VEGETATION STUDY

The District has recently completed a drainageway vegetation study. The study primarily covers topics such as seed bed and soil preparation, soil types, natural grass seed mixtures, planting, weed control, fertilizer and routine maintenance of drainageway vegetation. The study includes using natural grasses in conjunction with "hardscape" materials, i.e., riprap and interlocking concrete blocks.

The study also investigates other aspects of the District's vegetation management procedures such as site construction guidelines, maintenance standards, erosion control methods and construction inspection procedures. This study produces a sound vegetation management program from which the District can expect consistent results. It will also be a valuable source of information to which consultants and other agencies could refer in developing seeding specifications for a specific site or in developing their own set of standards and procedures.

Anyone interested in obtaining a copy of this vegetation study can write to the District and enclose a check for $20.00 plus 1.50 for postage and handling.

NEWS NOTE

Papers Published and/or Presented by District Staff in 1984

Hunter, M.R.; "Maintenance of Stormwater Detention Facilities"; International Public Works Congress & Equipment Show, Philadelphia, PA; September, 1984.

Urbonas, Ben; "Report on the Task Committee's Scope and Findings"; Task Committee for the Design of Detention Outlet Control Structures; Proceedings of ASCE Hydraulics Division Specialty Conference, Cour d'Alene, Idaho; August, 1984.

Urbonas, Ben; "Effectiveness of Stormwater Detention"; Proceedings of the Sixty Fourth Annual Meeting of the Transportation Research Board; Washington, D.C.; January, 1984.

Urbonas, Ben; "Summary of Findings by ASCE Task Committee on Detention Outlets"; Proceedings of the Third International Conference on Urban Storm Drainage; Goteborg, Sweden; June, 1984; Vol. 2, pp. 733 - 742.

Urbonas, Ben; "Report on 1982 Engineering Foundation Conference on Stormwater Detention Facilities"; Proceedings of the Third International Conference on Urban Storm Drainage; Goteborg, Sweden; June, 1984; Vol. 2, pp. 743 - 748.

Urbonas, Ben; Discussion Paper on the Session Titled "Technology Transfer in the USA"; Proceedings of the Third International Conference on Urban Storm Drainage; Goteborg, Sweden; June, 1984; Vol. 2, pp. 1652 and 1653.

Scott Tucker, Mark Hunter, Dave Lloyd, Bill DeGroot, and Ben Urbonas made presentations to the "Drainage, Flood Control and Floodplain Management — Update" seminar sponsored by the Professional Engineers of Colorado, Denver, September, 1984.

FLOODPLAIN MANAGEMENT PROGRAM

by Bill DeGroot
Chief, Floodplain Management

Maintenance Eligibility

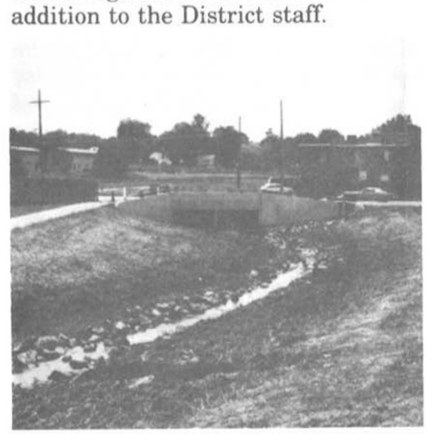
In 1979, the Colorado General Assembly authorized the Urban Drainage and Flood Control District to levy up to 0.4 mill for the maintenance and preservation of floodplains and floodways within the District for the years 1981 through 1983. That authorization was extended indefinitely by the General Assembly in 1983. The District's initial investigation of maintenance needs revealed many instances in which substantial restoration or remedial work was required due to the inadequate design and/or construction of flood control facilities by private parties and local governments. The District did not want to be placed in the position of always having to devote a large portion of its maintenance funds to correcting design and/or construction defects. Consequently, the Board of Directors of the District adopted a policy statement in 1979 (which was reaffirmed in 1983) which establishes criteria which must be met in order for a project to be eligible for District maintenance assistance.

The District policy requires that drainage and flood control facilities constructed by, or approved for construction by, local public bodies on or after March 1, 1980 will not be eligible for District maintenance assistance unless: a) the design of the facility is in accordance with the *Urban Storm Drainage Criteria Manual,* b) the design of the facility is approved by the District, c) a certification acceptable to the District has been provided that certifies the construction of the completed facility has been accomplished in accordance with the approved design, and d) satisfactory maintenance access is provided in order to adequately maintain the facility.

The Flood Plain Management Program has staff responsibility for carrying out this District policy. We feel that this policy is proving to be quite effective, and in future years will result in tremendous savings in maintenance costs, thereby allowing District maintenance funds to be stretched much further than at present, where we are still in a repair mode.

New Staff Member

Kevin Stewart has joined the District staff as a Project Engineer, Flood Plain Management Program. Kevin came to us from Muller Engineering Company, Inc. Prior to that he was with the Floodplain Management Section of the Iowa Natural Resources Council. Kevin's experience in both the public and private sectors, as well as his knowledge of both technical and administrative aspects of floodplain management (including the National Flood Insurance Program) make Kevin a valued addition to the District staff.



Properly designed and constructed facilities make maintenance easier and cheaper.

Tucker-Talk

by L. Scott Tucker

Timely Comment from the District's Executive Director

An Emerging Issue: Detention and Major Drainageway Design Criteria

An issue is developing regarding design criteria for major drainageways in developing areas. It has been the District's position since the early 1970's that new drainageway facilities should have a capacity to handle flows from fully developed basins. The fully developed condition is based on existing zoning and comprehensive plans of the local governments located in the drainage basin. Depending on the type of development, 100-year flow rates can increase from 1½ to 3 times the historic or undeveloped flow rates.

In the Urban Drainage and Flood Control District area, when a developer proposes to develop along a major drainageway, he is required to provide for the future flow rates. The justification is that for the health, safety and welfare local governments are required at a minimum to assure that the public is protected from the 100-year flood. Future flows must be used, otherwise, the channel or floodplain capacity would soon be inadequate and buildings that were once out of the floodplain would be located within the 100-year floodplain.

Developers are raising the issue that it is not their responsibility to provide for the additional flow difference between historic and future basin conditions. They argue that developers located throughout the basin should be required to provide detention that will limit flows to historic 100-year rates.

The problem with this argument is that there is no way of guaranteeing that detention can be provided on a development by development basis that will, in fact, result in limiting flows in the major drainageway to historic rates. Also, indications are that random on-site detention facilities are often not constructed in conformance with their designs, nor are they maintained in a condition to insure their continued function. The only way that detention sites can be guaranteed to perform in the way that they were designed is for them to be owned and maintained by a public body.

We find ourselves in the position wherein detention could possibly maintain flows at historic levels if constructed in conformance with a carefully developed plan, if designed and constructed in accordance with good design practice and if maintained on a regular basis. In terms of public policy the "ifs" are overwhelming and the only logical answer is to require developments that are built to handle 100-year flow rates based on fully developed basin conditions. If a developer wants to develop his property in a timely manner, his only recourse is to provide that capacity at his own cost. It does not make sense for the public to be put in the position where they are required to provide funds to help the developer with a facility that is being constructed to provide the developer with more developable property.

If the developer does not wish to provide such a capacity, then the other alternative is to wait until a master plan can be developed for the basin that includes detention that will be constructed in a planned way to insure that the historic flows are maintained, and that a system of public ownership is arranged that will guarantee the operation and maintenance of those facilities in the future. The master plan could also take the approach of using no detention but having all development in the basin share in the cost of the increased capacities that are required downstream. Again, this takes the preparation of a master plan and then establishment of some sort of basin fee to pay for either the entire cost of the facilities or for the incremental costs of the facilities to handle the difference between the historic and future flow rates. The practical problem arises, however, in how to "front end" the necessary improvements. Development does not always occur in a downstream to upstream pattern. If a developer builds in the middle of the basin then it is necessary to provide some sort of outlet. How can the local government raise the necessary monies to "front end" the cost of that while the rest of the basin develops and the fees are generated over a long period of time?

We keep coming back to the most straight-forward, and what we consider best approach. That is to require a developer to provide for the 100-year flood for future basin conditions when the property is developed. He must do so in such a manner that it does not adversely impact upstream or downstream property owners. In this way, facilities are provided as development occurs.

All is not perfect with this system either. A major problem is the linking of the facilities as they are implemented over a period of years. It is possible to end up with a variable system consisting of grass-lined channels, concrete-lined channels, open floodways, and so on. However, it is better to have facilities that provide for the future 100-year capacity than to be stuck with facilities that are too small with no way to make necessary improvements.

DISTRICT STAFF IN LEADERSHIP ROLES

Members of the District's staff have been honored by their selection to important leadership positions within the profession. Executive Director L. Scott Tucker is President of the Water Resources Institute of the American Public Works Association. He is also a member of the Executive Committee of the National Association of Urban Flood Management Agencies.

Ben Urbonas; Chief, Master Planning Program; has been re-elected Chairman of the American Society of Civil Engineers (ASCE) Urban Water Resources Research Council. Ben has also been chairing the ASCE Task Committee on Stormwater Detention Outlet Structures. Ben is also a member of the Colorado Water Quality Control Commission.

MAINTENANCE OF STORMWATER DETENTION FACILITIES

by Mark R. Hunter

Introduction

In the last 15 years stormwater detention ponds have been introduced as the foundation of the "storage detention approach" in urban stormwater management. This contrasts with the previous "conveyance approach" which used curb and gutter, inlets, pipes, and channels to quickly carry the water away. When water travels faster than it used to from one place to another as is the result of implementing the conveyance approach in a development it will "pile up" someplace. Typically that someplace was on someone else's property where it became their problem. Under the Modified Civil Law Rule our justice system has since established in case law that when one person's actions regarding drainage cause damage to another person the first person has incurred the liability for the damage. The eventual result was the "storage detention approach" in order to reduce the liability for damage. The manifestation of that approach has taken the shape of the detention pond. The idea is to capture and temporarily detain all or part of the runoff generated by rainfall or snowmelt and then release it at controlled rates to the receiving stream. By so doing, damage can sometimes be reduced or prevented. (1)

The widespread endorsement and use of detention ponds has created another set of needs. As early as 1866 the House of Lords in England in the case of Fletcher vs. Rylands. L. R. 1, Ex. 265 found that a dam owner was responsible for all consequences of the accidental release of the water from his impoundment. In the opinion of the House of Lords it was stated:

> "If a person brings, or accumulates, on his land anything which, if it should escape, may cause damage to his neighbor, he does so at his peril. If it does escape, and cause damage, he is responsible, however careful he may have been, and whatever precautions he may have taken to prevent the damage."

The findings of this case have been applied throughout the United States under English Common Law. (1)

Recognize that drainage systems in general and detention facilities specifically co-exist with nature in such a way that some of the maintenance needs are not predictable and are subject to nature's whim. A detention pond is an unnatural feature when you realize that the drainageway on which it's located is still responding to the natural forces that control storm water in an open system. It is a unique relationship for storm drainage systems when compared to other publicly operated utilities. No other utility is in the position of having to contend with, manage, and improve (by man's definition) a pre-existing naturally occurring facility. Storm drainage is unique in this regard. Sanitary sewer, potable water, transportation, electric service, telephone, cable TV, gas, and street lights are all services that fall under the utility category. The common feature of all these services is that their facilities are 100% man-made and man-operated. The utilities mentioned above have another common feature; they all require periodic maintenance. A storm drainage system requires maintenance too, but, no matter how many drop structures, inlets, pipes, detention ponds, box culverts, riprap protected banks and other improvements are constructed on a drainageway it still exists as a combination of manmade and naturally occurring features and factors. For this reason a detention pond must be regularly maintained with the knowledge that Mother Nature may call again tomorrow requiring the work to be done a second time. The design concepts discussed earlier in this paper must be accompanied by a flexible responsive maintenance program or the detention facility could rapidly fall into disrepair. Maintenance of detention facilities should be standard operating procedure or Mother Nature could quickly reclaim its territory with weeds, trees, marshy areas, sloughing banks, erosion and scour holes.

The burden on a detention pond owner is obvious. In order to reduce his liability exposure he must do all that he can to insure the pond continues to function as it was designed and built. The key to doing so is to be conscious of maintenance needs starting with the design of the facility.

There are two major components to the maintenance of a detention facility. The first is to design a facility that is maintainable and the second is the physical work required to keep the detention pond operating as designed and built. Ideally maintenance design considerations and maintenance work are inseparable, but all too often the maintenance work needs are not given the priority they require. It is not uncommon for maintenance to be deferred on many of our public systems. The strain shown by the infrastructure of our country is a prime example.

Design Considerations

A detention pond can be squeezed onto almost any back lot in a development where it will be out of the way. When a detention facility is relegated to such a location it is likely that maintainability was not a concern during design. Journalist George Will said "A mature society is measured not by how much it can build, but by how well it can maintain." To fulfill its purpose and its design life a detention facility must be designed with consideration for the following details: (1) sufficient bottom cross-slope to insure good drainage after use; (2) underdrains to help dry the pond bottom to quickly make it available for secondary use; (3) trickle channels to contain the nuisance flows and reduce boggy areas; (4) inlets and outlets to the outlet works need to be child safe, resistant to local erosion, and accessible by vehicles for maintenance; (5) trash racks with sufficient surface area and individual opening area to pass small debris, but catch large debris without clogging; (6) maintenance access to the inlet and outlet of the outlet works and any other control structures to allow easy access even while the facility is in use; (7) multiple use of a detention facility which greatly increases the visibility, appeal, public use, and justification for regular maintenance; (8) vegetative cover which helps prevent erosion and improves the appearance of the area.

Current Maintenance Practice

So far we've been concerned with design considerations that will make detention ponds more maintainable and better able to fulfill their design intent. The second major maintenance component is the physical work, both scheduled and unscheduled, required to properly operate the facility.

The following services must be built in to the scheduled maintenance program: (1) grass mowing to improve aesthetics and safety and to make the area more inviting for secondary use; (2) weed control to improve aesthetic appeal and to be a good community neighbor; (3) cleaning outlet works to help insure their functional ability when called upon; (4) sediment removal to maintain pond capacity, to keep the outlet works from plugging and to reduce the growth of unwanted vegetation; (5) debris removal to improve safety, to reduce the potential for blocking the outlet works, and to limit the habitat for undesirable rodents and pests; and (6) regular inspection to watch for both overnight and long-term changes that affect function and safety of the facility.

In addition to the scheduled program discussed above, the following unscheduled maintenance work should be anticipated: (1) embankment repair to keep erosion or sloughing of rock riprap or earth fill from weakening the structure of the detention pond; (2) debris removal following heavy storms; (3) rodent control to help insure the structural integrity of earth embankments and to improve health conditions; (4) inlet and outlet channel repairs to stop erosion and to maintain hydraulic capacity; and (5) outlet works repair to insure that the structure will function as designed when called upon.

The maintenance work described above may seem like low priority work, but because of a detention pond's close relationship with nature it is a vital program. If this maintenance isn't performed the changes in a pond will seem to be gradual, almost unnoticeable, but in a matter of a couple wet seasons nature can effectively gain control of an unmaintained detention pond and severely reduce its value as a drainage facility.

Periodic inspection is one of the most important activities that can be done in the maintenance program of a detention facility. This includes facilities that are publicly owned and maintained as well as those local detention systems that may be the result of development regulations and are owned and maintained by the private property owner.

A report from a regular inspection of a detention pond will give one of the following summaries; (a) a statement that no maintenance work is needed at this time, (b) a recommended list of repairs and work items to be done to correct deficiencies or potential problems and to restore the aesthetics, (c) a list of changes that have occurred that alter or eliminate some of the design features and affect the level of service of the detention system. The last item is the most alarming. It's not uncommon for changes, manmade or natural, to occur that have such a severe impact. Examples of such changes are: (1) remodelled traffic control barriers or islands that divert water from parking lot detention ponds; (2) restricted outlet pipes or inlets that have had the restrictors removed; (3) restricted outlets that have become ineffective because they were vandalized or run over by automobile traffic; (4) asphalt overlaying that changed the contours or flow patterns in a parking lot detention pond; and (5) breached pond embankments caused by man or by storm flow erosion. It requires an aggressive conscientious public works staff to recognize such changes, particularly in small local detention systems. If the pond is privately owned repairs to the problems listed above may be difficult to achieve without an assertive local floodplain regulation.

A recent study of 10 Denver area communities revealed that they all require drainage reports and they all require on site stormwater detention with only a few special cases not needing detention. As important as it is to routinely inspect and maintain detention facilities to insure their integrity the same 10 communities had no regular maintenance programs and only one community field reviews detention ponds when construction is complete. (3)

Periodic inspection of detention facilities is not often a high priority for local governments. At the same time, the local governments have a fundamental responsibility to protect the health and welfare of the public. Maintaining stormwater detention facilities is one step that can benefit the public. Regular inspection provides the basis for effective maintenance of detention facilities and regular maintenance is the link from initial construction to long service life.

References

1. Findings of the Task Committee on Stormwater Detention Outlet Control Structures, prepared by ASCE Task Committee on the Design of Outlet Control Structures, ASCE, May 1984.
2. Jones, Jonathan, and Jones, D. Earl, "Interfacing Considerations in Urban Detention Ponding", presented at the conference on Stormwater Detention Facilities, ASCE, 1982.
3. Prommersberger, Bruce D., "Implementation of Stormwater Detention Policies in the Denver Metropolitan Area", Masters Degree Report, Dept. of Civil and Urban Engineering, University of Colorado, 1984.

TRI-LAKES INFORMATION

The following information concerning the Tri-Lakes (Chatfield Dam, Cherry Creek Dam and Bear Creek Dam) was provided by Colonel John I. Coats, Rocky Mountain Area Engineer for the Corps of Engineers.

FLOOD DAMAGE PREVENTED (BENEFIT)

DAM	COST	DAMAGE PREVENTED
Bear Creek	$ 61,700,000	$ 450,000 in 6 years
Chatfield	$101,130,000	$ 1,880,000 in 10 years
Cherry Creek	$ 14,670,000	$163,256,000 in 35 years
Total	$177,500,000	$165,586,000

SOUTH PLATTE RIVER 1983 SUMMARY STREAMFLOW BELOW CHATFIELD DAM

GAGING STATION	MAY - JULY FLOW IN ACRE-FEET	PEAK DISCHARGE CFS	PEAK DISCHARGE DATE
Littleton	320,000	2,900	5 July
Henderson	597,000	12,300	27 June
Kersey	1,786,000	17,650	14 June

1983 SUMMARY RESERVOIR REGULATION

	CHATFIELD	BEAR CREEK	CHERRY CREEK
Max. Inflow - CFS	3,400	1,000	10,500
Max. Outflow - CFS	3,000	600	330
Max. Flood Pool	15.8 Ft (13%)	23 Ft (13%)	7.9 Ft (9%)
Encroachment Rank	2nd - 10 YRS	1st - 6 YRS	3rd - 35 YRS

RECENT PLANNING PROGRAM ACTIVITIES

by Ben Urbonas Chief, Master Planning Program

South Platte Phase A Report Completed

The Phase A report for the South Platte River major drainageway planning study was completed by Wright Water Engineers, Inc. and submitted to the District for distribution to twelve cities and counties and the Greenway Foundation that are helping to sponsor this project. The report addresses flood control and recreational issues for 41 miles of the river between Chatfield Dam and Baseline Road at Brighton, Colorado.

The 41 miles of the South Platte River were subdivided into eight reaches representing differences in the existing and projected character of the river. After evaluating several flood control and recreation alternatives for each reach, the consultant recommended the following:

Reach 1, Chatfield Dam to Columbine Valley. Preserve a natural channel and floodplain. Provide erosion protection in selected locations and continue floodplain regulation. Retain Littleton Floodplain Park as a primarily passive recreation and wildlife refuge facility in accordance with long term goals of City of Littleton.

Reach 2, Columbine Valley to Oxford. The U.S. Corps of Engineers is constructing a flood control channel in this reach. Along with this channelization, develop a trail system and boating improvements.

Reach 3, Oxford to Bates. Retain the existing channel with erosion protection at selected locations and continue floodplain regulation. Complete the linear park and trail system begun by the South Suburban Foundation, Greenway Foundation, and the cities of Denver and Englewood.

Reach 4, Bates to Colfax. Provide limited structural improvements to eliminate or reduce damages by a 100-year flood. These include: modify the bridge at Evans; modify drop structures for safe kayak and raft passage; lower channel bottom in selected sub-reaches; widen channel in selected sub-reaches; raise bridges at 6th and 13th Avenues; modify or remove 14th Avenue bridge; and modify or replace the pedestrian bridge at Colfax.

Reach 5, Colfax to Cherry Creek. Excavate the right overbank area to convey floods exceeding the 10-year flood to carry larger floods up to the 100-year flood. Also, relocate or lower an 18-inch sanitary sewer crossing the river and modify the 15th Street diversion and the channel under I-25.

Reach 6, Cherry Creek to Franklin. Provide limited structural improvements, primarily to some drop structures, and continue with floodplain regulation. Add to the existing recreational facilities.

Reach 7, Franklin to Sand Creek. Continue to regulate the relatively undeveloped floodplain in this reach and provide limited structural improvements to the diversion structures and to some of the bridges. Provide for a linear park and trail in this reach.

Reach 8, Sand Creek to Baseline Road. Provide a 10-year flood capacity stabilized channel, continue to regulate and manage the floodplain. Also recommended is the construction of parks, trails, boating improvements and fishing access to adjacent gravel pits.

A more detailed description of the Phase A report is contained in the project's newsletter *South Platte Currents*, Issue #5. This newsletter describes briefly the alternatives considered and the basis for master planning of the South Platte River. It also discusses river management, flood hydrology, water quality, water rights and low flows, geomorphology and sedimentation, groundwater, and recreational inventory. If you wish to receive a copy of this newsletter, call or write Cindy Griego at the District's office.

The District, in cooperation with the 12 local governments and the Greenway Foundation co-sponsoring this project held three public meetings in November to introduce the Phase A findings. The goal of these meetings was to receive public comment on the recommendations so that the public's desires are considered before a decision is made on what the final South Platte Master Plan will recommend to the metropolitan area.

STATUS OF PLANNING PROJECTS

PROJECT	COMPLETED 1984	UNDERWAY	PLANNED FOR 1985
Boulder & Adjacent County		*	
Boulder Cr/S. Boulder Cr. Confl.	*		
Henry's Lake Basin	*		
Lower Ralston & Van Bibber Cr.		*	
Sand Creek	*		
Sheridan Outfall	*		
South Platte River		*	
Quincy Drain/Shop Creek		*	
Adams County, Commerce City		*	
Direct Flow 0056 & 4100		*	
Interim Lowry Detention		*	
Columbine Valley/Littleton/Bow Mar		*	
Four Square Mile (ARAPCO)		*	
Arapahoe County Criteria		*	
Big Dry Creek (ADCO)			*
Broomfield NE		*	
Boulder County Gunbarrel Area			*
Jefferson Co/Adams Co/Boulder Criteria			*

Flood control and recreation key the South Platte River master plan.

Modifications of Dams for Recreational Boating

William C. Taggart, John M. Pflaum, & Jon H. Sorensen
Engineers, McLaughlin Water Engineers

Problem Description

Many existing diversion dams and other river structures create vertical or near vertical drops across channels which create hazards to recreational activities. These structures require modification, and new structures may need to include features to allow safe white water boating activities. The basic problem is safety, with a long list of other concerns including expense, stability, technical difficulty, utility or hydropower relationships, aesthetics, and aquatic passage.

The fundamental issue with regard to safety is the formation of dangerous hydraulic jumps including submerged jumps, of the type with reverse (or upstream) surface current and very abrupt vertical differentials. This paper is oriented toward solution of this problem. Recreational craft, safety devices and people are likely to be trapped in certain jumps. Once involved, escape from such a man-made feature is difficult because of the uniformity (linearity) of the structure across the entire channel. Figures 1(a), 1(b), and 1(c) illustrate some classic examples. Jumps (often called holes or keepers) also occur in natural rivers, but they are usually dispersed and nonuniform such that escape is often possible by reaching to the side and using an adjacent current to pull oneself out.

Kayaks or canoes entering such an area are often turned sideways and flipped over by the strong surface current. Figure 2 illustrates a kayaker in a normal attitude where both his boat and his paddle action use natural current patterns to maneuver. In Figure 3 a kayaker is shown in a very modest 6 to 12-inch jump and his dilemma becomes evident. The slightest exposure of the deck or paddle to the upstream will cause an upstream flip. The kayaker is unable to rely on the downstream current if the surface water is moving upstream because the current will flip his boat downstream if his deck or paddle is exposed. The kayaker is therefore trapped and will probably be rolled under water.

Basic Approach Concepts and Theory

Ideally, a white water bypass could be a channel around the obstruction with a variety of constructions, eddies and undulating bottom and side configurations. Its overall slope only needs to be ½ to 1-¼% slope to be of world class competition level. One of the first South Platte River Greenway Projects in Denver included a long white water bypass which is in excess of 360 feet in length and drops 8 ft. (See Photo 1). It has many low-notched weirs and constructions which prevent the formation of any major jumps (although there are many small holes and keepers depending on flow levels).

The authors have designed numerous other white water improvements which use construction structures, large boulders, small drops, flow deflectors, and bottom sills. Some of these include Kayak (Riverfront Park) Park, a semi-natural white water reach on the South Platte River in Denver, and modifications of several utility crossings that formed high sills and obstructions.

The challenge to the engineer is that of creating a hydraulic jump that can be safe from a recreational viewpoint. Fortunately there are a number of bypass configurations and components

Photo 1 - Kayak course at Confluence Park on the South Platte River.

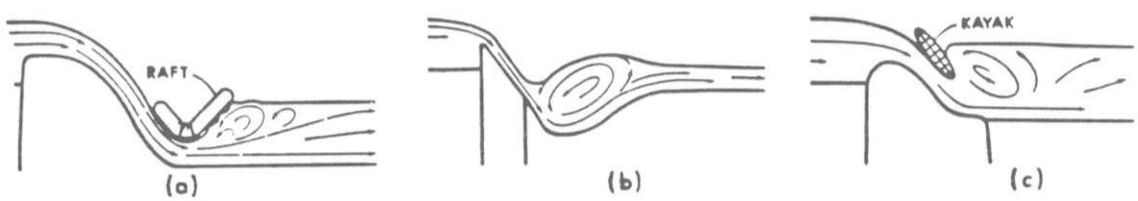


Figure 1: Examples of Dangerous Hydraulic Jumps

Fig. 2: Kayaker Using Normal Surface Currents

Fig. 3: Kayaker's Dilemma in a Small Hydraulic Jump

which can be combined to deal with this problem.

The fundamental guideline concepts used to develop a rapid drop chute are:

1. Any supercritical flow must make the transition to subcritical flow with the supercritical discharge on the surface, and in a horizontal direction.
2. Any sort of submerged jump, that is, where supercritical flow traveling down a slope enters a downstream pool in a fashion where it continues vertically downward and then the jump occurs with a reverse (or upstream) current, should be avoided.

This type of jump is referred to as a hydraulic jump at an abrupt drop. Hsu[3] presented the results of studies at Iowa State University for the situation which is depicted in Figure 4. Specific Force Analysis leads to the basic solution of the problem which was documented experimentally. Hsu noted 5 zones: 1) where the tail water forces the jump to move upstream, 2) where the jump begins just in the area of the end of the supercritical flow chute, 3) where an undulating jump without a breaking front occurs, 4) where there is insufficient specific force downstream such that the supercritical flow must first expand (and fall) before forming the jump and 5) where the tail water is so low that the jump must wash downstream. Generally speaking, the authors desire to achieve the lower portion of Zone 2, Zone 3, and the upper portion of Zone 4. Zone 4 has to be dealt with at lower flows to minimize any keeping tendencies. Zone 2 borders on causing a submerged jump upstream and thus is to be considered carefully. The undular surface of Zone 3 is not unlike that of major river rapids. Any design is usually augmented with deflectors and other features to help keep downstream velocity vectors on the surface and provide a nonuniform wave or jump as one moves laterally. The real problem is dealing with the range of flows anticipated. Hsu presents theoretical relationships for Zone 2 and 4 and a useful graph incorporating experimental results which illustrates these relationships and the transition between (Zone 3). Chow et al[2] contains this same graph.

Moore et al[4] present an extensive study of the same phenomena and documentation illustrating the same zones for various relative drops. Figure 5 illustrates an example of the results of that effort, where Jump A is Hsu's Zone 2, Wave W is Zone 3, and Jump B is Zone 4. The study has excellent photographs which agree with the observations and results of the authors' projects where Zone 3 and the upper part of Zone 4 are the most desirable (with the provision that the actual installation may require further improvements for safety performance). Also documentation on bottom velocities is given. Figure 6 is an example of velocity relationships for various types of jump configurations and Froude Numbers (assumed). Bottom velocities are often in the upstream direction, illustrating the upside down jumps and low magnitude. One notation made is that wave heights on the order of 50% of the downstream depth y_2 can occur.

Whenever a condition of flow and tail water is identified such that a submerged jump must occur on the downstream face of the structure, then modifications or use restrictions must be made. A number of concepts are available, such as moving a portion of the drop upstream so that the flow/tail water combination will completely inundate the lower portion of the drop at

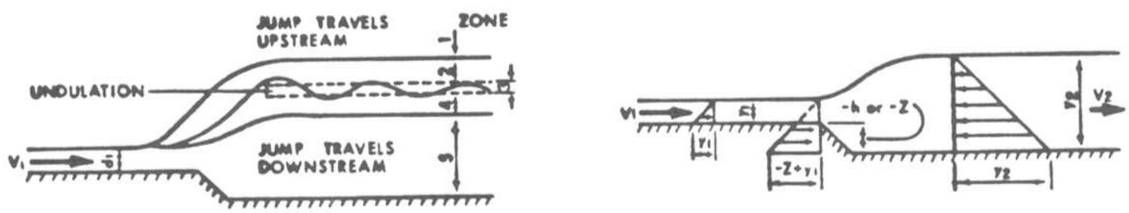


Figure 4: Hydraulic Jump at an Abrupt Drop

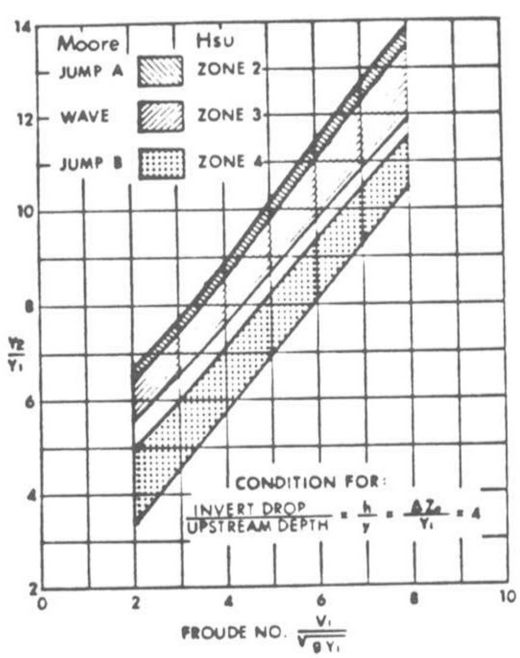


Figure 5: Froude No. vs. Relative Depth

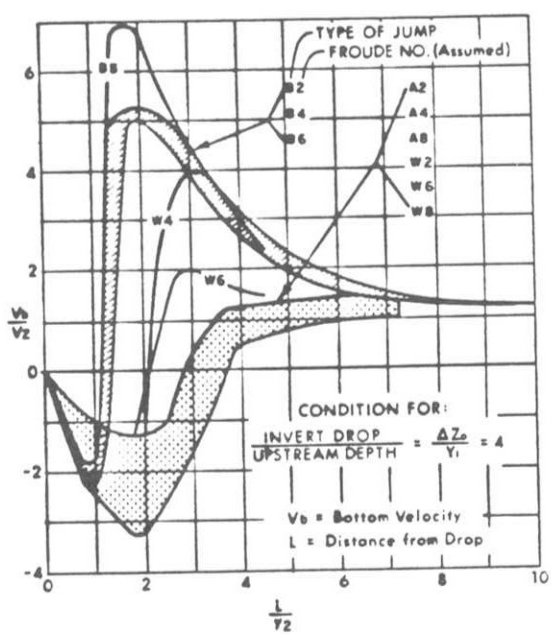


Figure 6: Bottom Velocity vs. Distance

the troublesome flow regime. Basically this means interrupting the drop by creating a number of pools and chutes/weirs/constrictions which are totally submerged at certain flows.

The energy dissipation characteristics of this type of jump appear to be adequate in the projects completed by the authors and for the range documented by Moore et al, but the reader is warned to take precautions as it seems possible to carry harmful velocity currents downstream in certain circumstances. The energy loss through a hydraulic jump at an abrupt drop is basically the same as a conventional jump. The authors use a minimum guideline pool length of 6 y_2 to ensure the jump occurs within the pool and then also consider room for maneuvering, boulders and eddies.

3rd Avenue Dam, South Platte River, Denver. Figure 1b depicts the general situation. The scour hole extended 10 feet below the surrounding channel to bedrock. Design discharges for the modification ranged from 150 cfs to 5,000 cfs. Design constraints limited construction to 260 feet. A boating bypass off channel was not possible because of right-of-way constraints. The design that was chosen, Figure 7, involved modifying the existing dam to successfully control the tail water for a chute upstream. The modified existing dam and upstream chute were separated by a 75 foot long stilling pool. A second smaller chute was then placed in the modified existing dam to make a safe transition to the tail water in the river. The 50 foot long chute and the pool were placed in the river upstream of the existing dam allowing water to enter the chute and pool from the side (See Photo 2). The net result was a lowering of the 100-year water surface elevation.

The upstream chute was designed as a trapezoidal section with a 10% slope. A high "n" value was used to achieve minimum depths for boating under low flow conditions. Alternative methods for producing high "n" values are limited because the roughness element utilized cannot be hazardous to boats or people. The roughness element chosen for the chute was 6-inch diameter polyethylene pipe which was filled with grout and structurally tied to the reinforced concrete chute.

Placement of large boulders at strategic locations within the project area is used to adjust tail water immediately downstream of the chutes, to create desirable eddies for kayakers and to provide a degree of excitement to other boaters. Boulders used for these purposes ranged in size from 4 to 17 tons.

Zuni White Water Bypass. This structure is located at a power plant diversion dam on the South Platte River in Denver (See Photo 3). A 6-foot high self-modulating fabridam (essentially a water pressurized rubber tube) presented an obstacle to recreational boating. A combination structural steel and concrete chute was designed to bear directly on the Fabridam and rotate around a hinge point located on

Photo 2 - Looking upstream at the Third Avenue Dam Bypass.

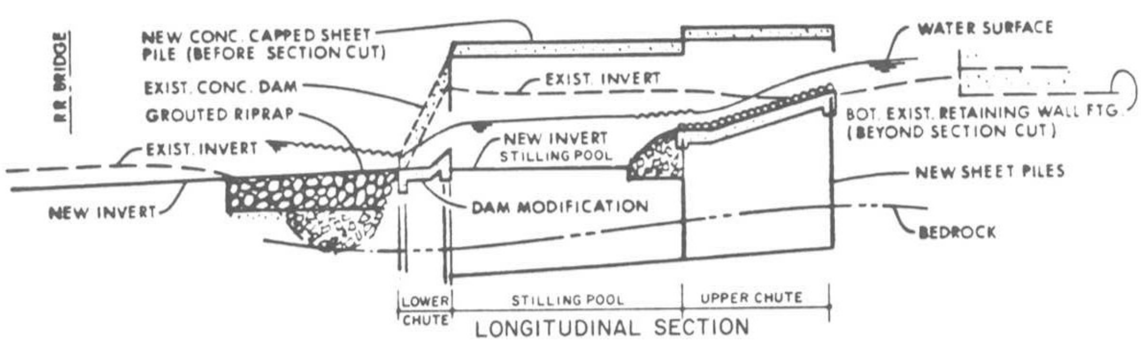


Figure 7: 3rd Avenue Dam Bypass, Denver

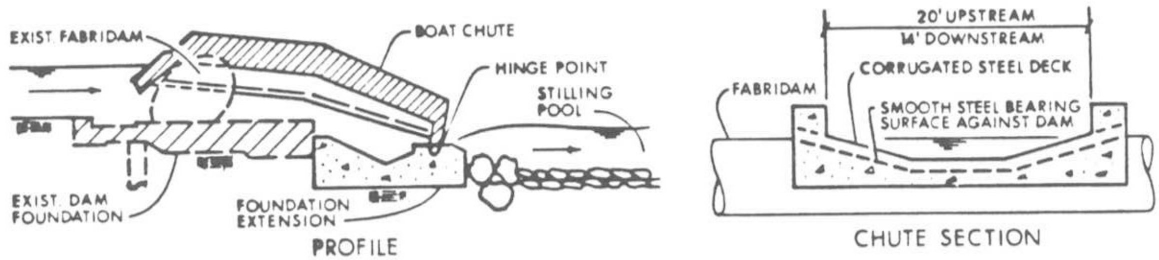


Figure 8: Zuni White Water Bypass, Denver

an extension of the existing dam foundation. By virtue of its weight (an estimated 40 tons) the chute depresses the Fabridam to allow flow through the chute. (Figure 8).

Model studies were conducted to verify the hydraulic calculations and to document the contact area of the Fabridam to determine weight requirements of the bypass. The chute is 20 feet wide at the upstream end and 14 feet (4.3m) wide at the downstream end. This narrowing, coupled with the use of heavy gauge corrugated structural steel plate to achieve a high "n" value, enables flows as minimal as 100 cfs to be conveyed through the chute with sufficient depth for recreational boats. Reinforced concrete walls form the sides of the chute and make up the required weight of the structure. One particular advantage of this system is that as flood flows increase, the fabridam deflates, the relative drop decreases and the chute lies flatter, thus increasing safety and ease of boating.

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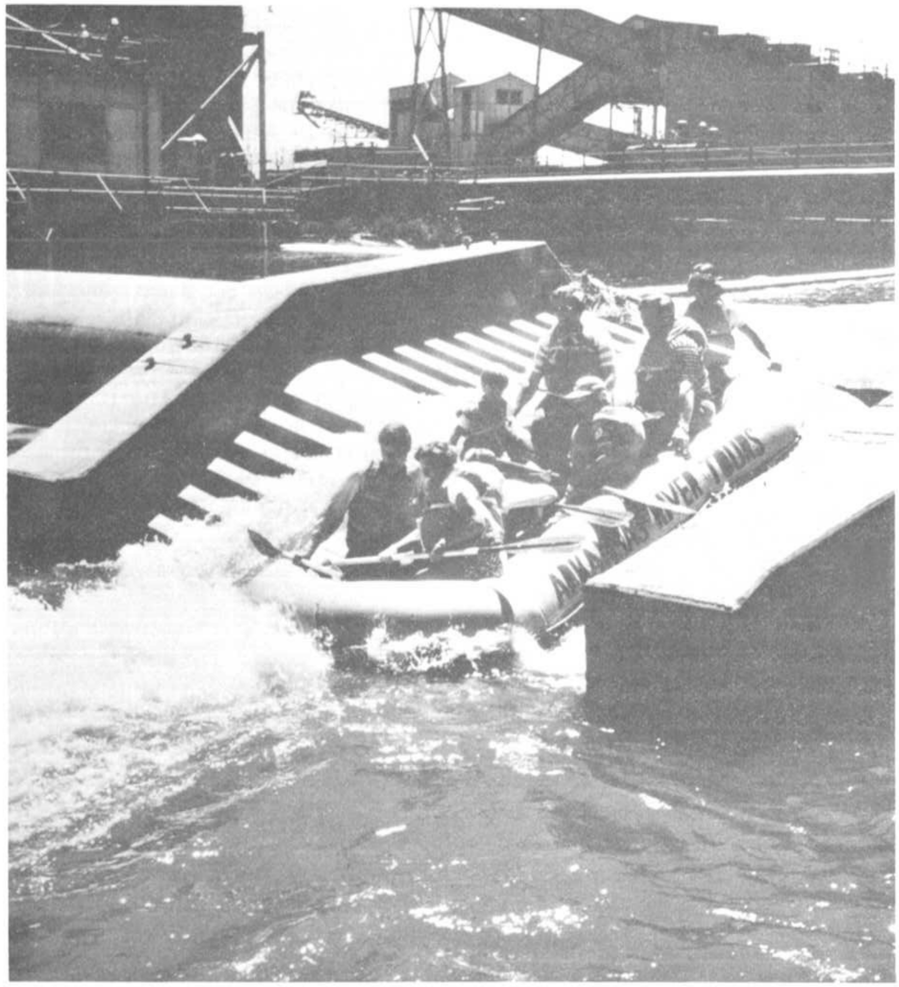

Photo 3 - Zuni White Water Bypass. Note the corrugated plate used to achieve the high roughness value.

DESIGN AND CONSTRUCTION NOTES

B.H. Hoffmaster
Chief, Design and Construction Program

A large design contract for Sand Creek in Aurora was initiated this year. The design concern is the sandy nature of the soils. Because of this, bank revetments may be constructed with soil cement. A review of the use of soil cement is being conducted before a final decision is made. The alternative for bank protection is riprap at a flatter slope and a possible increase in cost. Also involved in the design are recreation and landscape considerations. The cooperative agency with the District is Aurora. Greenhorne and O'Mara, Inc. is the design engineer.

Another design contract started this year is Marston Lake North. The project is located from Quincy to upstream of State Highway 121 (new Wadsworth). The project will protect the homes along the north side of Marston Lake, the water supply stored in Marston Lake and some proposed facilities of the Denver Water Board. The cooperating agencies with the District are Denver Wastewater Management and Denver Water Board. The Engineer for the job is WRC Engineering, Incorporated.

The District in cooperation with Adams County and Westminster have in progress a design for Little Dry Creek (ADCO) from Sheridan to the mouth (approximately 15,000 feet). The design work is on the order of 80% complete. Construction has already commenced in the vicinity of 72nd Avenue where 622 feet of grasslined channel, an additional box culvert under 72nd Avenue and 450 feet of concrete lined channel are being constructed. The Contractor is Lillard and Clark. The neighborhood upstream of this work experiences considerable flooding each year. This construction, along with the next phase, will go a long way to solving this problem. The design engineer is Sellards and Grigg, Inc.

In the last *Flood Hazard News,* the construction of an off channel detention facility for Little Dry Creek on the Englewood High School grounds was discussed. The project is now complete and dedication took place May 22, 1984. The detention facility is fully landscaped and has several soccer and baseball fields. The baseball diamond has bleachers and snack stand with a press room. The facility demonstrates how multi-use facilities can be created. The Englewood School District has been most cooperative with Englewood and the District on this project. The contractor was Palasades Construction Company.

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdiction(s)	Status
Goose Cr., Wonderland Cr., Boulder Slough to Bldr. Cr.	City of Boulder	10% Complete
Lafayette Drainageway #4	Lafayette	Complete
Little Dry Creek (ADCO)	Westminster Adams County	85% Complete
Marston Lake North	Denver	1% Complete
Parker/Iliff - Huntington Estates	Arapahoe County Aurora	90% Complete
Sand Creek	Aurora	20% Complete
South Jefferson County Drainages	Arapahoe County, Last Chance Ditch Co.	95% Complete
Upper Sloans Lake Schedule II	Edgewater Lakewood	60% Complete

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Participating Jurisdiction(s)	Cost	Status
Goldsmith Gulch Detention at Union	Denver	$1,553,500	45% Complete
Harlan Street Storm Drain Sch. III	Mountain View	$ 253,900	Start 1/85
Hidden Lake	Adams County	$1,335,000	Complete
Lafayette Drainageway 4	Lafayette	$ 281,400	25% Complete
Little Dry Ck. (ADCO) Phase A	Westminster	$1,313,800	85% Complete
Little Dry Ck. (ARAP) Detention & Channel	Englewood	$3,500,000	Complete
Weir Gulch Schedule I	Denver	$2,100,700	50% Complete
Weir Gulch 1st Ave. Trib. Box Culvert	Denver	$1,249,000	Complete
Weir Gulch 1st Ave. Trib. Newland Detention Pond	Lakewood	$ 130,000	75% Complete
Weir Gulch 1st Ave. Trib. Benton Detention Pond ROW	Lakewood	$ 175,000	Complete
Westerly Ck. Sch. IV	Denver	$ 600,000	Complete

Westerly Creek Schedule IV looking upstream toward the Kelly Dam Spillway.

Task Committee on the Design of Detention Outlet Control Structures

by Ben Urbonas

Introduction

The American Society of Civil Engineers Hydraulics Division set up a Task Committee to study the Design of Detention Outlet Control Structures and to report on the state-of-the-art. Its task was to address: 1) hydraulic function, 2) water quality, 3) public safety, 4) maintenance, and, 5) aesthetic aspects of outlet controls. It was my pleasure to be named the Chairman of this task committee and want to share with you its goals and some of its initial findings.

Traditionally, the prevention of flooding and other drainage related problems in urban areas has been accomplished by a "conveyance approach", which relied on a system of swales, curbs and gutters, inlets, storm sewers and channels to quickly carry water away. In contrast, the last fifteen years has seen an introduction of the "storage detention approach" in urban stormwater management. In recent years, the idea of using detention facilities for water quality enhancement has also been gaining wider acceptance.

Outlet control structures are an important component of stormwater detention facilities since they control rates of release from the pond and the water depth and storage volume in the pond. Outlet control structures are often called upon to perform several functions in an urban area, some of which may conflict. An urban setting for detention outlet controls also increases the complexity of the task faced by a designer. Although practicing engineers have developed a variety of outlet control works, very little can be found in technical literature about this topic.

The Committee was tempted to expand its scope to address stormwater detention in its entirety because it is difficult to address outlet controls autonomously. They are a part of the detention system as a whole and interrelate with tributary watershed hydrology and storage basin geometry. To avoid an excessively narrow focus, the Committee decided to include in its final report to ASCE a limited discussion of general stormwater detention concepts, which will hopefully clarify where and how outlet controls intermesh with the overall system.

Literature Search

A search revealed little on the topic of urban detention pond outlet control structures in the English language literature. Practically all available literature addressed structures associated with larger water resources projects and flood control reservoirs. The primary references for design of small structures were found to have been developed by the Soil Conservation Service (SCS). Although the SCS guidelines are comprehensive, their emphasis is on non-urban settings. SCS treatment of factors such as safety, aesthetics, and maintenance do not consider the special constraints and needs imposed by urban settings. Nevertheless, the SCS publications (8)(9) offer the urban stormwater detention outlets designer considerable guidance in hydraulic and hydrologic design techniques and should be a part of every designer's library.

Comprehensive references regarding stormwater detention are available (1) (2) (7), but even these publications contain only limited information on outlet structures. Other references which provide background information on hydrology, hydraulics and hydraulic structures, dam construction and other factors inextricably related to detention ponding are provided as references (3) (4) (5) (6) for the reader seeking general information. In summary, the committee found a lack of helpful technical literature and had to draw upon experiences of its members and their colleagues in the urban stormwater management field.

Survey of Professionals

In the fall of 1982 the Committee prepared a questionnaire concerning stormwater detention practices, observations and opinions, which was mailed to approximately 150 stormwater management professionals including consulting engineers, government officials and university professors. Sixty-five responses (43% response rate) were received, of which 45 percent were from consulting engineers, 37 percent from government officials, 8 percent from universities and 10 percent from unidentified respondents. The 43 percent questionnaire return rate was excellent but easily could reflect a response bias from the more sophisticated practitioners.

The responses to some of these questions are summarized in Table 1. All respondents believed that detention plays an important role in stormwater management. A majority of the respondents evidently adopt a somewhat sophisticated approach to design, as 60 percent of all respondents stated they designed for multi-frequency control and 65 percent have considered water quality enhancement at some time in the past. Most respondents believe the detention ponds not only reduce peak flows, but also help to enhance water

TABLE 1
Partial Summary of Responses to Questionnaire

	Percent Responding Yes by Professional Category			
Question	Consultants	Government	Academic	Unidentified
Percent of all responses by group:	45	37	8	10
Have you designed or analyzed a detention pond?	93	72	75	100
Did you design to control a range of runoff frequencies?	58	59	33	100
Did you consider water quality enhancement?	75	47	67	80
Does detention play an important role in stormwater management?	100	100	100	100
Have you reviewed or inspected detention ponds?	89	88	50	100
Did you feel they functioned properly to reduce peak flows?	84	95	100	75
Did you feel they improved quality by settling solids?	80	76	100	100

quality through settling out sediments.

It was more difficult to summarize the responses to the essay type questions; nevertheless, the following summary provides the general sense gleaned from the 65 responses:

(1) Hydraulic function was considered to be the most important design consideration in design of outlet structures.

(2) Safety, other than assuring prudent design, was not considered to be of great importance by the majority of respondents.

(3) Maintenance and aesthetics were considered of little importance by the majority, except for the local government respondents who overwhelmingly stated that safety and aesthetics deserve much greater attention than is the prevailing practice in design of outlet structures.

(4) Water quality design considerations were deemed relatively unimportant by most respondents, but most felt that ponds improve water quality.

(5) The majority expressed the opinion that multi-frequency outlet controls were especially important in overall stormwater management; at the same time, the overwhelming majority did not consider converting existing single frequency outlet controls into multi-frequency facilities.

The Committee gathered from the responses that there is inconsistency and some confusion among practitioners concerning the design of outlets and ponds intended to control discharges for more than one recurrence frequency. This indicates a need for expanded ASCE training opportunities in multi-frequency design. Most detention pond design for water quality enhancement is reportedly undertaken to satisfy local government requirements and is not otherwise a general practice among designers, despite the fact that the majority believed water quality can be enhanced by stormwater detention.

Finally, the Committee took special note of the responses from local government officials regarding the importance of safety, maintenance and aesthetic considerations in the design of outlet controls. These individuals represent organizations that are ultimately responsible for operation and maintenance of these facilities (i.e. owners of the facilities) and their opinion deserves special recognition.

Summary

A Task Committee for the Design of Outlet Control structures studied the state-of-the-art practices concerning the hydraulic function, water quality, public safety, maintenance and aesthetic aspects of detention outlet control structures. Their findings and suggestions are contained in a report submitted to the Hydraulic Structures Committee of the ASCE Hydraulics Division. A literature search revealed little in the English language literature on this topic. The Committee's survey of professionals revealed a strong belief that detention does play a major role in stormwater management.

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COMPUTER SOFTWARE

by Ben Urbonas

CUHP Program

For the last seven years the District has maintained a computer program for the Colorado Urban Hydrograph Procedure at a large computer service. Recently, they instituted a $500 monthly minimum fee and, as a result, the District no longer has an account with that service. To insure that the CUHP program is available to the engineers working on projects in the Denver metropolitan area, arrangements were made with several consultants and computer service companies. The following firms may be able to provide access to those needing to use the CUHP program: Merrick and Company; Resource Consultants, Ft. Collins; Kirkham, Michael & Assoc.; Costin Engineering; Tri-Consultants, Inc.; Wright Water Engineers; Holland Corporation; Greiner Engineering; Boyle Engineering Corp.; UIS Company (Service Bureau); Fox and Associates, Inc. (Service Bureau); UCC (Service Bureau); Boeing Computer Services (Service Bureau). Also, there is a cooperative group of small accounts headed by WRC Engineers, Inc. that have pooled their resources and use Boeing Computer Services, Inc.

Micro Computer Software

Dr. Young Yoon of Boyle Engineering Corporation, in cooperation with and at the request of the District, has developed a micro computer version of the CUHP. The program is in FORTRAN and has been developed to run on the IBM PC-XT using MS-DOS Version 2.1 and MS FORTRAN compiler Version 3.1.

This IBM PC-XT version of CUHP may be obtained from the District. The cost of preparing a diskette with the source deck and documentation is $75.00. This charge is to cover the handling costs since the District is not selling this program or assuming any responsibility for its use or performance. We will maintain a record of the requests for this program so that every holder of this program can be advised of any modifications in the future.

Future Activities

At this time Boyle and the District are discussing the feasibility of incorporating a channel/pipe/reservoir routing package into the PC version of the CUHP. This looks very promising and we may make this add-on to the CUHP available early in 1985. Dr. Yoon is also working with us to modify the Storm Water Management Model (SWMM) we have been using in our master planning work to also run on the IBM PC-XT. Although this program, which we call UDSWM2-PC, may be operational in the near future, preparation of good user documentation will require several months. All owners of the PC version of the CUHP will be notified when either of the above developments are completed.

tenance of detention ponds. It was found that only one of the ten communities interviewed has performed any field review of a number of existing ponds.

Field investigations of 101 stormwater detention ponds in the Denver metropolitan area revealed that 45.5 percent are not in conformance with design. The degree of deviation ranged from minor differences in outlet diameter to the pond not having ever been installed. The rates of noncompliance for Communities A, B, and C are 46.7 percent, 40.0 percent, and 45.9 percent, respectively. This percentage might increase if detailed topographic surveys were performed to determine if adequate detention volumes were provided.

Clearly, stormwater detention policies are not fully implemented in the communities investigated. It may be assumed that this is probably true in most communities in the Denver metropolitan area. The full impact of this is yet to be determined.

Community stormwater control policies should be fully examined. Initially, the use of detention as a method of stormwater control must be assessed. Most of the literature examined states that detention can be an effective method if properly implemented.

The ten communities interviewed with regard to stormwater control policies generally require random detention. Some of the most recent literature suggests that this may not be an effective policy in all cases. This should be further investigated. If random detention is not the solution, a better policy should be developed and used by communities for their stormwater control programs. This could include regional onstream detention or stormwater conveyance facilities with larger capacities. After such a program has been established, its performance should be evaluated.

Currently, the ten communities interviewed operate on the principle that random detention is the proper way to control runoff. It has been shown by this study, however, that these programs are not being fully implemented. The significance of partial implementation should be analyzed.

Most of the deviations from design found during this investigation were noncomforming outlet structures. This, of course, was due to the fact that topographic surveys of 101 ponds to determine their volumes was beyond the scope of study. The rate of incidence of inadequate storage volumes should also be investigated.

A model study should be performed to determine if outlet nonconformance at the rate of approximately 50 percent causes significant problems in a drainage basin. Storage volume noncompliance at various rates may also be considered. A range of nonconformance rates and the resulting impact should also be studied. The impacts of total nonconformance should be investigated. If total nonconformance does not cause significant problems, then abandonment of community detention policies should be considered.

If partial or total nonconformance causes significant problems, better stormwater controls should be implemented by communities. A proposed logic diagram for analysis of stormwater detention policies is presented in Figure 1.

If the ultimate decision by a community is that individual developers are to be required to provide detention ponds, whether random or otherwise, something must be done to assure compliance with community policy. Better controls must be established.

Design Recommendations

The requirement that developers submit drainage reports which include design for stormwater facilities is normal procedure in most communities. This is easily controlled by normal office procedures.

The communities interviewed all implement stormwater policy through the design phase. Designs are not approved until detention ponds and outlet structures meet community requirements for storage volume and release rate control. In theory, this would provide a functional stormwater detention facility.

What was found, however, was that ponds constructed in compliance with design were not always well maintained. Although they may provide stormwater detention volumes and outlet rates as intended, many ponds are in fair to poor condition as a result of shortcomings in design.

Even lawns that are well maintained in terms of regular mowing, watering, fertilizing, and debris collection may suffer from soggy patches, especially along the flowline of swales. Difficulty in obtaining adequate detention volumes may have necessitated the flattening of slopes on pond bottoms, and the steepening of slopes on the sides of ponds. Alternative designs should be considered to enhance ease of maintenance. Increasing the depth of a pond by deeper or wider excavations or higher berms or retaining walls should be considered.

Concrete swales should be used in the flowlines of grassed swales to prevent soggy bottoms. Riprap swales should not be substituted for concrete because in dense urban settings, the riprap tends to collect trash. Concrete swales must be wide enough to handle frequent rainfall events and nuisance flows, and they must be steep enough to prevent silting.

Detention ponds in asphaltic concrete pavement parking lots are generally drier and cleaner than grassed ponds. Parking lots with puddles were usually due to improper paving techniques, rather than improper design. Many parking lot designs, how-

TABLE 1

SUMMARY OF COMMUNITY STORMWATER POLICIES

COMMUNITY	DRAINAGE REPORT REQUIRED	DETENTION REQUIRED	DRAINAGE CRITERIA MANUAL	EVENTS REQUIRING DETENTION	METHOD OF CALCULATION DETENTION VOLUMES & RELEASE RATES	VERIFICATION OF PROPER INSTALLATION	MAINTENANCE PROGRAM	SPECIAL FUNDING
A	Yes	Yes	Community	5-year & 100-year	Simplified Formulas	Certified by Engineer and Community Inspector	None	None
B	Yes	Everything but Single Family	Community	100-year	Determined by Engineer	Community Inspector	None	Fee based on water Tap Size
C	Yes	Yes	USDCM	100-year	Determined by Engineer	Community Inspector	None	None
D	Yes	Yes	Community	2-year & 100-year	Simplified Formulas	Community Inspector	None	None
E	Yes	Selectively	USDCM	100-year	Determined by Engineer	Community Inspector	None	None
F	Yes	Yes	Community	2-yr & 100-yr or 10-yr & 100-yr	Determined by Engineer	Community Inspector	None	None
G	Yes	Unless 30 Minute Lag Time Exists	USDCM	100-year	Determined by Engineer	Community Inspector	None	None
H	Yes	Yes	USDCM	100-year	Determined by Engineer	Certified by Engineer	None	Drainage Utility Based on Impervious Areas
I	Yes	Yes	USDCM	Initial & 100-year	Determined by Engineer	Community Inspector	None	None
J	Yes	Yes	Community	2-year, 10-year, & 100-year	Simplified Formulas	Community Inspector	None	None

ever, did not consider the impact of runoff in asphaltic concrete swales. Portland cement concrete swales of adequate width should be used in this type of design as this material is less susceptible to deterioration.

The design engineer must be aware of all potential implications of alternative designs. It is the engineer's responsibility to recommend the most cost-effective solution compatible with the client's needs.

A design requiring installation of concrete swales or other stormwater control is sometimes rejected by clients due to the additional initial construction expense or the opinion that they detract from the appearance of a project. The client must be shown that initial costs saved may not be as great as long-term maintenance cost savings, and that lack of maintenance detracts from property values. The initial costs saved may be either in construction or in engineering fees which would be required to develop the most effective design. The developer that builds for immediate sale rather than ownership may be more likely to opt for initial cost savings.

The community's staff engineers may live with a project longer than the developer's consulting engineer or the developer. The extent to which they can impose design controls should be analyzed, then carefully weighed against the economic realities of project development.

Construction Recommendations

Once a proper design has been prepared, proper installation must be assured. This has been done only to a limited extent.

Approximately one-third of the ponds investigated require restrictor plates or other restrictions as part of the design to control release rates. Almost two-thirds of the restrictors were not in place. This alone accounts for 20 percent of the ponds investigated being out of compliance with design, or almost half of the total noncompliance. In most of these instances, there was no evidence that the restrictor plates had ever been installed.

Communities have limited budgets for engineering personnel, and are sometimes understaffed to adequately monitor all aspects of construction. Verification of proper installation has been made a responsibility of the developer in some communities. These communities require that a professional engineer certify that stormwater facilities are installed as designed. Topographic surveys are made after construction and pond volumes are calculated. Although currently not used, the requirement for photographs of the installation may be helpful in documenting proper construction.

Another alternative is to require developers to pay an inspection fee. These fees could be used by the community to either add inspection personnel or to hire a consultant to verify that construction on projects in that community is in conformance with the design plans.

One possible problem with installation verification is associated with grassed ponds. Ponds which are not planted immediately are subject to erosion and muddy conditions. It is unfair to delay issuance of a certificate of occupancy if project completion coincides with a season in which seeding would probably not be successful. A conditional certificate of occupancy should be granted which would require the developer to plant in the next seeding season.

Maintenance Recommendations

Ease of maintenance is a function of design. Drainage facility design must be performed with maintenance in mind. Good design and proper construction is not, however, a guarantee of maintenance. It is possible that a detention pond or outlet structure could be altered immediately after certification.

The writer is aware of two cases where detention facilities were modified after certification. In one case, a restrictor plate was removed. In the other, an excavation which was to become a grassed pond was backfilled. No topographic survey, photograph, or sealed certification by a professional engineer can prevent such willful acts.

One possibility, although far from a guarantee, is the requirement for tamper-resistant designs. For example, restrictor plates could be cast into a concrete structure rather than placed on a shelf in a horizontal position or bolted or tack welded into place in a vertical position.

One problem encountered in the field investigation was inaccessibility. Approximately 9 percent of the ponds or outlet structures were inaccessible. Vehicles were often parked over inlet grates in parking lot ponds, making it impossible to view restrictor plates. Building owners were reluctant to allow access to rooftop ponds. Chainlink fences with barbed wire along the top and large dogs are a deterrent to all but the foolhardy. This must be planned for in development of a successful maintenance program.

Parking lot ponds should be designed with the grate in an accessible position, or maintenance inspections must be made during hours of minimum use of the parking lot.

Agreements must be made between the community and the developer for access to rooftops and fenced areas.

Communities must provide proper staffing to assure that stormwater control facilities are properly maintained.

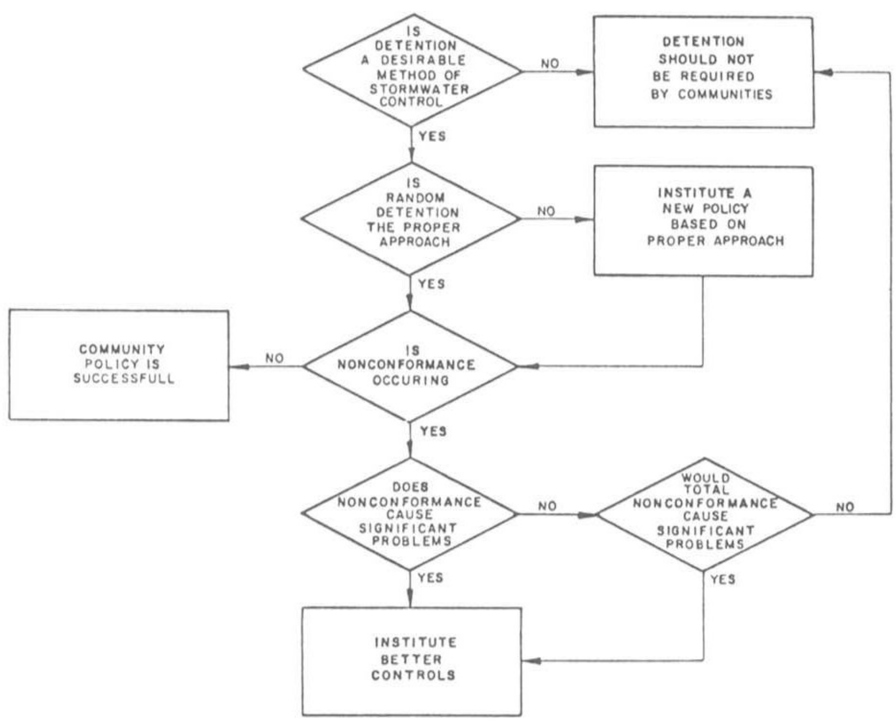

FIGURE 1
POLICY ANALYSIS NETWORK

MEET THE NEW BOARD MEMBERS

PAUL L. SWALM

Councilman, City of Denver

Paul Swalm was born and raised in Idaho, is married to LaVerne, has four grown children and four grandchildren. He has lived in Denver since 1950. He started in real estate development in 1960, started his own company in 1965 and presently owns and manages apartment and warehouse property.

Swalm was elected to the Colorado State House of Representatives in 1976 and served two years. He authored a bill which was signed into law to "index" state income tax rates and brackets. He was elected to Denver City Council District 5 on February 24, 1981 and was re-elected in 1983, unopposed.

He is serving on the following committees: Urban Drainage and Flood Control District, Chairman of Council Airport Committee, Budget and Finance Committee, Health and Social Services Committee, State and Federal Government Committee, The Denver Convention Center and The Denver Symphony.

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