FLOOD HAZARD NEWS

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RANDOM DETENTION COMPUTER MODEL STUDY

by Ben Urbonas, Chief, Master Planning Program;
and L. Scott Tucker, Executive Director

INTRODUCTION

Those of us in the business of drainage and flood control have been arguing for a long time about the potential effects of on-site detention on the flows along major drainageways. Some argue that on-site detention can maintain stormwater runoff flows, after a watershed urbanizes, to levels that existed before urbanization. Therefore, we need to floodplain zone only for the flows resulting from existing basin conditions. Others argue that random on-site detention effects are uncertain and, it is unwise to assume that flows along major drainageways will remain at existing levels in the future. Still others are saying that random on-site detention can hold back the runoff until the peak flow arrives from upstream, thereby increasing the peak flows downstream and actually causing more harm than good.

Amongst all this confusion, the local policy makers and public works officials have a hard time trying to decide if detention has to be required and, if it is required, what effects it will produce. In the meantime, drainage studies for individual land development projects are being turned in for review and approval by local public works officials without the benefit of clear policies or criteria to follow regarding effects of on-site detention. Many of these drainage studies assume that all off-site runoff to their development site will be maintained at existing undeveloped levels. The validity of such assumptions, particularly when only the 100-year detention policy is being considered, needs to be determined. It was the intent of this study by the District to provide some insight into the potential effectiveness of on-site detention as a drainage and/or flood control technique.

The random on-site detention study was originally conceptualized by the writers about four years ago and a computer modelling effort was begun. Unfortunately, other duties and responsibilities caused the progress to be excruciatingly slow. About a year ago Mark Glidden, an engineer with Merrick and Company, was looking for a Masters thesis topic and took on the task of moving this study along. In October of 1981, the writers and Mark Glidden had an opportunity to present a paper describing the study and some of the findings at ASCE Water Forum '81 where it was received with great interest by the session audience. This article summarizes the information contained in the Water Forum '81 presentation. A copy of the original paper is available upon request.

STUDY APPROACH

An urbanizing watershed in the Denver metropolitan area having a 7.85 mi^2 area was chosen for the study (see Figure 1). The watershed was subdivided into 56 sub-catchments and its major drainageways were segmented into 52 individual channel reaches. Within this watershed, we randomly identified 27 detention sites that intercepted 91 percent of the watershed. The physical, hydrologic and hydraulic characteristics of each watershed and drainageway element were defined and set up on EPA's Storm Water Management Model (SWMM) Runoff Block. The model was approximately calibrated against a version of Colorado Urban Hydrograph Procedure currently under development by UD&FCD. This version of CUHP is being developed with the help of rainfall/runoff data collected within the District since 1970. We used a version of SWMM's Runoff Block that contains modifications by the Omaha District of the U.S. Army Corps of Engineers and permits the use of a large number of detention sites.

Runoff simulation was performed using 2-hour design storms. These design storms are also under development by UD&FCD utilizing a local rainfall/runoff data base collected since 1970 and a long term, 73-year, rainfall data base at the Denver Raingage. The 2-hour storm duration was selected because it is representative of intense storms observed in the area. Initial tests of the effects of random on-site detention were done using the 2-, 10- and 100-year design storms. Additional simulation was performed using three rainstorms recorded at the Denver Raingage which verified the trends discovered using the synthesized design storms.

Base line conditions were simulated for the historic (i.e., 1.9 percent

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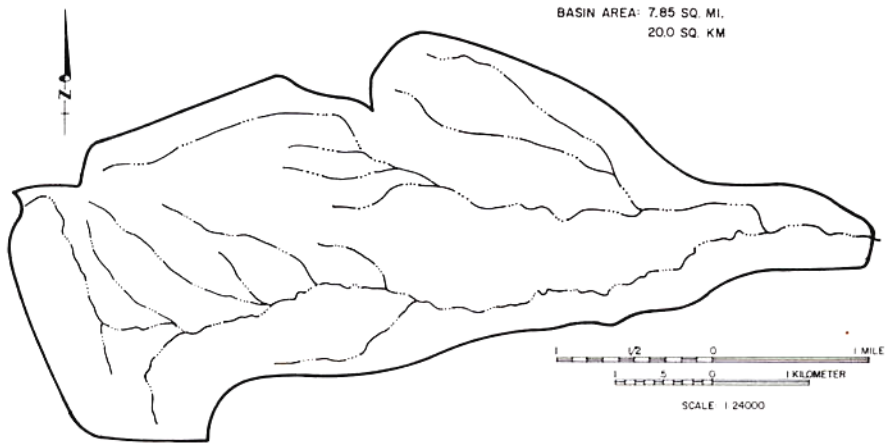

FIGURE 1. STUDY BASIN

(Continued from Page 1)

impervious) and the fully developed watershed (i.e., 38% impervious). Then the effects of using 27 randomly distributed detention ponds were compared against this base line. To establish the base line conditions runs were made using the 2-, 10- and 100-year design storms. Similarly, base line conditions were also established for the three recorded rainstorms.

After the base line runs were completed, the model was modified by adding in 27 detention sites. Each detention pond size was based on inflow hydrographs from its tributary sub-catchment. The required control volume for each pond was estimated by a process illustrated in Figure 2, where the control volume is the shaded portion of the runoff hydrograph. This volume sizing procedure recognizes that the maximum controlled pond discharge will occur on the recession limb of the inflow hydrograph. Although the actual pond discharge will not be a straight line up to this point, it was assumed that the shaded area above the straight line is representative of the needed pond volume.

In addition to estimating volume requirements, a procedure was developed to relate the pond volume to outlet flow rates. The details of how this was done are somewhat involved and are presented in the Water Forum '81 paper. All we will say here is the outlet was assumed to function as an orifice (pipe outlet) until the full controlled volume is reached. When the pond capacity is exceeded, it was assumed that excess flow went over an emergency weir type spillway.

RESULTS AND OBSERVATIONS

Figure 3 summarizes the relative trends of how peak flows vary within the study watershed under three conditions: 1) historic, 2) developed without detention, 3) developed with a uniformly applied 100-year detention pond system within the watershed. The results presented in Figure 3 are in a non-dimensional form. All flow values have been divided by the flows resulting from an undeveloped (historic) site. Thus, the numbers on the ordinate of Figure 3 represent the ratios of peak flows when compared to the historic peak flows. In other words, a ratio of ten represents a tenfold increase in the runoff peaks over the undeveloped basin condition.

A uniformly implemented 100-year random detention pond system looks to be somewhat effective. The net result of having these ponds in the system is that the peak flows along major drainageways are maintained to

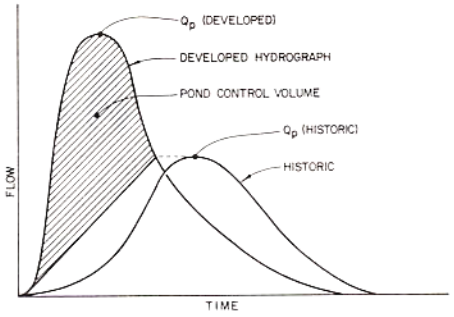

FIGURE 2. DETERMINATION OF DETENTION POND VOLUME

near historic or undeveloped levels. However, the effectiveness of such a pond system diminishes as the area becomes larger and larger. When the watershed is 10 mi^2 in area the flows along the drainageway are 30 percent higher than historic watershed would produce. At the same time, an urbanized watershed without detention would produce 85 percent higher flows then historic. Little or no reduction in peak flows from 2- or 10-year storms is indicated from a 100-year random detention pond system. This is understandable because pond outlets are sized for much larger flows and do not hold back the smaller runoff peaks resulting from the more frequently occurring smaller storms.

The above stated results and observations are indicative of trends only. It is important to remember that the results were obtained from a computer modeling effort and represent, to a large extent, the mathematical prejudices inherent in such models. We feel they represent only relative trends and should not be treated as absolute truth. However, as "ballpark" estimates, we consider them to be reasonable. Also, the study tested only the effects of a well-designed operational detention system. The study did not consider the effects of design criteria, design practices, construction quality control, and/or operation and maintenance practices, all of which can have a significant impact on how successfully random, on-site, detention will control flows along major drainageways.

CLOSING REMARKS

Although the study indicates that a system of random detention ponds to control a 100-year runoff can be effective for smaller watersheds, their effectiveness decreases as the watershed size increases. On the other hand, the 100-year detention system is not effective in controlling runoff from more frequently occurring storms of 2- or 10-year return period.

As a follow-up for this study, the UD&FCD plans to test the effectiveness of 2-year and 10-year detention pond systems and combinations such as 2-year and 100-year peak flow control. In addition, there is need to answer the following questions: 1) What are the relative effects of detention when the storms are moving (i.e., not uniformly applied over the total watershed)? 2) What are the relative effects when storms are applied in a continuous time series mode (i.e., a series of recorded storms)? 3) How do different design criteria and design practices affect the results? 4) What are the effects of detention policies now being implemented in the Denver area? Without answers to these questions, it is not possible to conclusively determine how effective on-site detention policies are, or can be, in controlling flows along major drainageways.

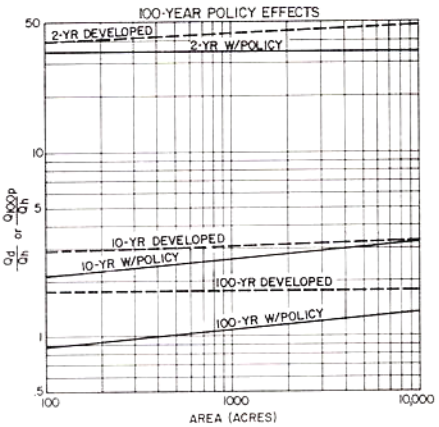

FIGURE 3. NORMALIZED EFFECT OF 100-YR DETENTION POLICY

LATE NEWS ITEMS

Scott Tucker, Ben Urbonas and Bill DeGroot are co-chairing an Engineering Foundation Conference concerning on-site detention. The conference will be held in Rindge, New Hampshire, the week of August 1, 1982. If you would like to be added to the mailing list for the conference please drop us a note.

Scott Tucker was recently elected President of the National Association of Urban Flood Management Agencies (NAUFMA).

Westminster Mayor Fred Allen has just been appointed to the District's Board of Directors by Governor Richard Lamm. Mr. Allen replaces Vi June on the Board.

Tucker-Talk

by L. Scott Tucker

Timely Comment from the District's Executive Director

Some Thoughts on Federal Flood Control Assistance

The Federal agencies that are primarily involved with flood control projects are the Soil Conservation Service, Corps of Engineers, Tennessee Valley Authority and Bureau of Reclamation. The agency with the largest and most wide spread responsibility for flood control is the Corps of Engineers. In terms of urban flood control the Corps of Engineers is the principal agency involved, except for the area covered by the TVA.

Those of us in the urban drainage and flood control business have always been frustrated with the present system of obtaining Corps of Engineers' approval for a project, subsequent Congressional authorization, and finally the actual appropriation of funds. This is particularly true for smaller type projects in the $2-$10,000,000 range, which take the same amount of time to wend their way through the system as does a larger project.

The frustration with the system, however, has not led to any significant positive changes, at least to date. Senators Domenici and Moynihan have proposed a block grant system that would send money directly to states on a formula basis for the states to distribute for projects they select. The Senate bill introduced by Senators Domenici and Moynihan, however, has not advanced too far in the Congress. The present system involves a Congressional approval for every Corps project costing in excess of $2,000,000. I quite frankly do not see Congress giving up the prerogative to approve a project and show the folks back home what a good job they have done.

The Principals and Standards May Be On Their Way Out

Most recently the Water Resources Council has proposed to repeal the rules known as "principals and standards" which set forth detailed procedures for planning water projects. The Water Resources Council's proposal is set forth in the Federal Register, Volume 46, No. 176, dated Friday, September 11, 1981. The proposed rule change is based on a recent policy review which has led to the conclusion that the principals, standards and procedures are too complicated, too rigid, and too cumbersome as legally binding formal rules.

It is indicated in the Federal Register that it is anticipated that a newly formed cabinet council on natural resources and the environment will prepare guidelines that will be established by executive order. The guidelines would have a single national planning objective of National Economic Development (NED) which means that planning would be oriented to maximizing economic benefit. The guidelines would, however, have flexibility to address other concerns, such as from local governments, that are related to the planning setting. The guidelines would emphasize the avoiding or mitigating of the adverse affects of alternative plans and on protecting the nation's environment pursuant to national environmental statutes and executive branch policies.

This proposed change would appear to greatly simplify the project authorization process. This is definitely a step in the right direction. On the down side it would appear that the benefits would be oriented more towards national economic objectives as opposed to local or regional benefits which could mean that local governments would have to fund proportionately larger shares of the project. With today's rate of inflation, however, a project that is brought on line one year sooner can save in the neighborhood of 10% of project costs. I certainly support simplification of the procedures, particularly for the smaller projects that involve urban areas and urban problems.

The Corps of Engineers 800 cfs Rule

Flood control in urban areas has been an area of interest of the Corps of Engineers under its flood control authorities. However, improvements to urban storm sewer systems has not been an area of Corps interest; it is the Corps' position that such improvements are to be accomplished by local interests. I agree with the Corps' decision not to involve itself in developing urban storm sewer systems. To me local storm sewers are local problems and it would take a massive Federal program to address all of the urban storm drainage problems on any type of comprehensive basis.

The Corps has had problems, however, in identifying the cutoff point between an urban flood control problem and an urban storm drainage problem. The Corps has issued rules and regulations which provide guidance for the Corps of Engineers in participating in urban flood control projects. Firstly, urban flood control is eligible for Corps of Engineers' assistance. Secondly, the Corps in their regulation has stated that "urban water damage problems associated with a natural stream or modified natural waterway may be addressed under the flood control authorities downstream from the point where the flood discharge of such a stream or waterway within an urban area is greater than 800 cfs for the 10% flood (one chance in ten of being equalled or exceeded in any given year) under conditions expected to prevail during the period of analysis." The Corps' regulations do provide for exceptions to the 800 cfs/10% flood discharge criterion when certain additional criteria are met.

There has been concern from some that the 800 cfs/10% criterion is too arbitrary and limits the Corps' involvement in some worthwhile flood control projects. I believe, however, that some definite cutoff is warranted and that the 800 cfs/10% criterion seems to be reasonable. My conclusion is of course based on the premise that the Corps of Engineers, or the Federal Government for that matter, should not get involved in urban storm drainage.

The Corps of Engineers has recently confirmed its position that its current procedure for distinguishing between "urban drainage" and "flood control" needs is the "fairest and most appropriate for use at this time." The restatement of the Corps' position came in a letter to the Executive Director of the National League of

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FLOODPLAIN MANAGEMENT PROGRAM

by Bill DeGroot
Chief, Floodplain Management

In its broadest sense, floodplain management includes all measures for planning and action which are required for the wise utilization of our floodplain lands. A comprehensive floodplain management program will consist of the following elements:

1. Delineation of the flood hazard area or 100-year floodplain.
2. Control of activities in the flood hazard area through the use of floodplain regulations, zoning, subdivision regulations, building codes, etc.
3. Availability of flood insurance by community participation in the National Flood Insurance Program.
4. Master planning of flood control projects.
5. Design and construction of flood control facilities.
6. Routine and remedial maintenance of floodplains and flood control facilities.
7. Design and implementation of flood detection networks and flood warning plans.
8. Public information with particular emphasis on floodplain occupants.

All of these activities are currently being pursued by the Urban Drainage and Flood Control District. The activities fall into the four basic categories of Planning, Design and Construction, Maintenance and Floodplain Management. The first three areas of activity are fairly self explanatory. The fourth, Floodplain Management, includes the other areas of activity listed above. The purpose of this article is to discuss the District's activities in the area of public information, which is one element of the Floodplain Management Program.

The District uses several techniques to increase public knowledge of flood hazards. Each spring the District's Board of Directors adopts a "Flood Awareness" resolution which recommends that the District's citizens check for flood hazards where they live and work, recommends certain mitigative actions for those citizens who do have a flood hazard problem, and also recommends that local governments coordinate with their local emergency preparedness units to prepare for potential flood problems. The resolution is sent to the local governments and the news media. This usually results in one or two radio interviews which receive heavy play during the morning and evening drive times.

Another technique used by the District is to hold ground breaking and dedication ceremonies in conjunction with the beginning or end of major flood control construction projects. Media coverage ranges from zero to excellent. When good coverage is obtained, the ceremonies tend to make the public aware that flood hazards do exist.

The major public information activity of the District is floodplain occupant notification. This is an effort to mail an informational brochure to every occupant of every District defined 100-year floodplain. Several reasons motivated the District to take this unusual step.

We wanted to reach the actual floodplain occupants, those who live and/or work in the floodplain. Normal public information methods, such as those described above, did not provide the blanket coverage we felt was needed to get the message to every occupant. We wanted the floodplain occupant to know that a flood hazard existed which could affect him, not just somebody somewhere as generally described on a radio news show.

We recognized that there are many actions individuals can take to mitigate the flood hazard, once they realize they have a potential problem. These actions, if widely implemented, can significantly reduce the effects of a flood as that flood affects both the flood victims and government disaster response and long range recovery efforts. For example, an individual with flood insurance who suffers flood damage receives an insurance payment to cover the loss (within the limits of the policy, of course). This makes that individual less of a burden on the recovery process. The flood insurance coverage also opens up opportunities for use of "Section 1362" or "constructive total loss" provisions of the National Flood Insurance Program to mitigate future flood damages by acquiring flood damaged properties (if they meet the necessary criteria). The key point here is that the individual must purchase the flood insurance; and the brochure encourages him to do so. The actions listed in the brochure are described later.

A third reason we decided to undertake this effort was one of liability. The District's legal counsel felt that, although it had yet to happen, a local government would eventually be held liable for not warning occupants of a floodplain of an identified flood hazard even though the local government knew of the hazard.

The makeup of the brochure was carefully considered; and the current brochures have the following characteristics. Separate, individually tailored brochures are developed for each major drainageway or portion thereof (for the longer drainageways). Each brochure contains a map at a scale of 1"=2000' which shows the 100-year floodplain. USGS quadrangle maps are used for the base map. The text of the brochure states that the brochure has been mailed to addresses located in or near the flood hazard area, it gives the source of the floodplain delineation, an office and phone number in each affected local government where the source can be seen, a definition of the 100-year flood, a brief description of flood insurance, and a list of actions floodplain occupants can take to mitigate the flood hazard.

The suggested mitigative actions are:

"1. Know the flood hazard exists.
2. Plan escape routes to high ground.
3. Obtain flood insurance.
4. During times of heavy rainfall, monitor the level of water in the drainageway. Also stay tuned to radio or television for possible flood warnings.
5. Evacuate the flood hazard area in times of impending flood or when advised to do so by an official agency such as a police or sheriff's department.
6. Consider flood proofing options (structural changes to buildings should be designed by a professional engineer).
7. Be a good neighbor to yourself. Help keep drainageways clean. Report potential problems such as blocked culverts or people dumping debris in the drainageway."

The brochures may also contain information on special situations such as an unsafe dam or the existence of a flood warning plan.

The brochures are mailed by bulk mailing rate to all addresses in the 100-year floodplain and the first address outside the floodplain if it appears that a portion of the lot the building is on is in the floodplain. The address lists were compiled by driving the floodplain and taking the addresses of the buildings and putting them on the 1"=200' scale flood hazard area delineation study maps of the District. Apartment buildings are handled by mailing a brochure to each apartment number. The only exception to the mailing policy is that we have one of our student helpers deliver the brochures to large office buildings.

In 1981, the District mailed 39 different brochures totaling approximately 22,000 pieces and covering 31 drainageways. The cost of printing, affixing mailing labels and

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MAINTENANCE PROGRAM NOTES

by Steve Hogoboom
Chief, Maintenance Program

During the October, 1980 Board of Directors' meeting the 1981 Maintenance Program budget was approved. This budget reflected the Board's commitment to implement a maintenance program that would aggressively pursue the maintenance problems on major drainageways that have plagued all of the thirty-four local government entities within the District.

The 1981 Maintenance Program budget totaled $2,835,000. These funds were divided between several line items; program operating costs and administration - $167,000, floodplain preservation - $300,000 emergency - $150,000, and maintenance services $2,218,000. Each of the budget line items was carefully studied to assure that the Colorado General Assembly charge "to establish a comprehensive program of drainageway maintenance and floodplain preservation administered by the District's Board of Directors" was met.

The costs associated with program operation, personnel cost, general, legal and engineering costs, and new equipment required to implement the program were included as a line item in the budget. This allows the Board to monitor the true operating costs of the program, thereby evaluating the total cost of maintenance service.

The floodplain preservation budget item was authorized specifically to respond to the General Assembly language in the enabling legislation. These funds are to be used to purchase property in or adjacent to 100-year floodplains that if developed would adversely affect the implementation of a Master Plan, proposed capital improvement project or, as a last resort, to prevent improper and potentially hazardous development.

Emergencies associated with major drainageway flooding are impossible to accurately budget for. Therefore, the Board felt it was necessary to establish a "contingency fund" so that if an emergency occurred the District would be in a position to provide assistance. The Board is currently discussing criteria that would constitute an "emergency", and thereby establish guidelines for assistance eligibility. The tornadoes and severe thunderstorms that occurred in early June in the northern portion of the District have prompted the Board to establish a Policy Resolution.

The maintenance services budget is the "operation" portion of the Maintenance Program. Expenditure of these funds was based on the Board's policy that the funds shall be spent in each of the 6 counties in the District in proportion to the tax revenues received from each county. In reviewing this portion of the budget the Board again emphasized its policy of not developing a public works department but of relying on private sector contractors to perform the actual field maintenance services.

The maintenance services portion of the budget was based on a Work Program that was presented to the Board. This Work Program was based on meetings with local government public works directors and city engineers, maintenance needs studies on 74 miles of major drainageways in the District, and District staff input. The Board, keenly aware of the need for flexibility in providing maintenance services, decided that the Work Program was to be used only as a guide and could be changed and modified to respond to the continually changing maintenance needs and priorities.

After approval of the Maintenance Program budget, Resolutions were approved levying the full 0.4 mill. Subsequent to the Board's action the Executive Director proceeded to implement the Board's directions. First, the authorized Maintenance Program staff positions were filled. I was assigned the responsibility for the overall Maintenance Program management. Shortly thereafter the remainder of the staff was hired. First, Jerry Corder was brought aboard to handle construction/maintenance field inspection duties. Sally Peterson and Frank Rosso were next to arrive. Both are project engineers assigned geographic responsibility to develop and administer county-wide maintenance programs. Mark Hunter, last to join the staff, arrived in February, also to handle project engineer responsibilities for the maintenance program within two counties.

Activity has been fast paced; a total of fifty-one separate major projects have been undertaken. Of these fifty-one, twenty were rehabilitation projects requiring engineering design services by outside consulting firms. The remaining projects were routine in nature and, if engineering was necessary, it was handled in-house.

Planning is currently underway for the 1982 Work Program. At this time, forty-six projects are scheduled, 15 rehabilitation and 31 routine. During the October, 1981, Board of Directors meeting the 1982 Maintenance Program Budget was approved. The Board will be reviewing the 1982 Work Program in November with spending authorization scheduled for December.

(Continued from Page 4)

bundling and bagging for the post office was about $2900.00. The mailing costs were $2270.00.

Every new program should be evaluated to determine if it is having the intended effect. The floodplain occupant notification program was so evaluated in a study by the Institute of Behavorial Science, University of Colorado, under contract to the District. The primary purpose of the study was to determine if the brochure was successful in increasing awareness of flood hazards and in motivating mitigative actions on the part of the floodplain occupant. To do the study, the researchers selected three groups of respondents for telephone interviews. The first group, from Lena Gulch, had received brochures approximately a year before the interviews. The second group, from Ralston Creek, had not received a brochure at the time of the interviews. The third group, also from Ralston Creek, was interviewed 4-6 weeks after the brochure was mailed to their area.

The results of the study demonstrated that members of the two groups who had received the brochure prior to being interviewed were more aware of the flood hazard and a significantly higher percentage had taken some form of mitigative action than was true for the third group. This was very encouraging to the District and convinced us to continue the notification effort. An executive summary of the report "Mitigation Behavior of Urban Flood Plain Residents" by Marvin Waterstone, dated 1978, is available from the District upon request.

In summary, just imagine a major flood in an urban area where all the flood victims knew about the hazard, had an escape route planned, evacuated when told to do so and had flood insurance to help cover their financial losses. The effects of that flood would be much less severe and the recovery process would be easier. The floodplain occupant notification effort will not obtain the above idealized situation but it is a move in the right direction. It is a low cost effort which has the potential to provide substantial benefits. It encourages action by the individuals at risk. In this period of tightening budgets and competing demands for limited tax dollars, individual actions may be the only flood damage reduction alternative available. The notification effort helps stimulate that individual action.

DESIGN AND CONSTRUCTION NOTES

B.H. Hoffmaster
Chief, Design and Construction Program

The District recently completed and released on a preliminary basis Volume 2, Major Drainage, Section 5, Rip Rap of the *Urban Storm Drainage Criteria Manual.* The purpose of the revision was to review actual failures and implement the latest state of the art in the design of bank protection. The basic preparation was performed by William Hughes, Professor at the University of Colorado, Denver. Hughes had done considerable research on the subject before being retained by the District. The work defines the criteria to be used and provides tables for solution. Also examples have been prepared for the user to follow and gain experience.

The design of projects has slowed this year as many moved from the drawing board to construction. In the construction area, several projects had ground breakings this past year. These projects include Westerly Creek, Schedule II; Lena Gulch, Schedule I; Harlan Street Storm Drain, Schedule I; Little Dry Creek (Englewood), Schedule I; and Little's Creek, Schedule I.

A Big Year For Construction Starts

The last 12 months have been busy ones as far as the start of new construction projects is concerned. Six major projects have been started in that time frame. The largest construction contract of $2,306,000 was awarded to Northern Contracting Company for Westerly Creek Schedule II in Aurora. Two projects in Wheat Ridge were awarded to Pascal Construction Company. The Lena Gulch Schedule I contract was for $1,045,000 and the Harlan Street Storm Drain Schedule I contract was for $1,632,000.

A&R Concrete Construction Company was awarded an $830,500 contract for Weir Gulch Schedule V in Denver. A $561,000 contract for Little Dry Creek, South Platte River to Sante Fe Drive was awarded to Bebo Construction Company. The smallest contract; $278,000; was awarded to Arvada Excavating Company for Little's Creek Schedule I. The design frequencies range from 5-year for the Harlan Street project to 10-year for Westerly Creek and 100-year for the other three projects.

Accompanying this article are pictures of ground-breaking ceremonies for two of the projects.

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdictions	Status
Little Dry Creek	Englewood, Greenwood Village	Feasibility of Alternative Oct. 81
Upper Sloans Lake Schedule II	Lakewood, Edgewater, Denver	80% Completed
Lena Gulch Schedules III-VI	Wheat Ridge	95% Completed
Hidden Lake	Adams County	Original Design Complete-Changes Required Due To Development
Little Creek Schedule II	Littleton	Complete
Van Bibber Creek Detention Reservoir	Arvada, Jefferson County	Awaiting State Engineer Comments
South Jefferson County Drainage Flow Separation	Arapahoe County, Nevada Ditch Company, Last Chance Ditch Company	90% Completed

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Participating Jurisdictions	Cost	Status
Westerly Creek			
Schedule I	State of Colorado, Denver, Aurora	$1,087,650	Complete
Schedule II	Aurora	2,444,300	60% Complete
Schedule III	Denver	2,094,000	Advertise Early 1982
Weir Gulch			
Schedule III	Denver	1,652,445	Complete
Schedule IV	Denver	1,008,949	Complete
Schedule V	Denver	753,000	30% Complete
Upper Sloans Lake			
Schedule I	Denver, Edgewater, Lakewood	1,453,000	Construction Advertising by end of 1981
Lena Gulch			
Schedule I	Wheat Ridge	1,141,300	95% Complete
Schedule II	Wheat Ridge	1,590,600	Bid Opening Oct. 1981
Brighton Southeast Drainage	Brighton	135,800	Completed
Little's Creek			
Schedule I	Littleton	363,800	90% Complete
Schedule II	Littleton	1,000,000	Advertise Late 1981
Little Dry Creek			
Schedule I	Englewood	691,500	50% Complete
Harlan Street Storm Drain	Wheat Ridge	1,644,900	50% Complete
Cherry Creek			
Wazee to Champa	Denver	373,000	Advertise Nov. 1, 1981
Sanderson Gulch at Jewell	Lakewood	222,000	Advertise Nov. 1, 1981
Wonderland Creek at 26th Ave.	Boulder	109,900	Complete Nov. 1, 1981

Ground-breaking ceremonies for Westerly Creek (left) and Lena Gulch

TRICKLE CHANNELS REVISITED

The last issue of *Flood Hazard News* (September, 1980) contained a "Design Notes" supplement on trickle channels. Many more trickle channels have been constructed throughout the District area in the last year. Several of them are shown here, along with a brief description and their location. Anyone involved with trickle channels is encouraged to visit these locations to see first hand both how they look and how they work. Please note that all of the projects pictured here were still under construction at the time the photos were taken.

Little's Creek south of Bowles and west of Santa Fe in Littleton. This channel has a concrete bottom with rock sides which results in a pleasing appearance.

Lone Tree Creek south of Arapahoe Road. This is a trapazoidel concrete channel.

Lena Gulch at its confluence with Clear Creek in Wheat Ridge. This is another channel with a concrete bottom and rock sides.

SJCD (S) north of intersection of Depew and Platte Canyon Dr. in Jefferson County. A rectangular concrete channel.

Lake Park drainageway at Griffith and Lincoln in Louisville. This is a trapazoidal grouted riprap channel.

Little Dry Creek at confluence with the South Platte River in Englewood. This is a trapazoidal concrete channel.

MEET THE NEW BOARD MEMBERS

HAROLD V. COOK

Manager of Public Works and Deputy Mayor City and County of Denver

Harold Cook is no stranger to the District's Board of Directors, having represented Mayor Bill McNichols at many Board meetings. However, until this year he has been unable to vote. The 1981 Colorado Legislature changed that by passing legislation which allows the Mayor or Deputy Mayor to be a director, and Mr. Cook has now assumed that role.

Mr. Cook was born in Denver and attended Denver public schools. He holds a Bachelor of Science Degree in Mechanical Engineering from the University of Colorado and a Master's Degree in Meteorology from California Institute of Technology. He is a registered professional engineer.

He served five years in the Army Air Corps during World War II where he rose to the rank of Lieutenant Colonel. After the war, he worked for the U.S. Bureau of Reclamation and then as an executive of Louis Cook Plumbing and Heating Company. He also served as Chairman of the Denver Planning Board.

Mayor McNichols appointed him Manager of Public Works and Deputy Mayor on December 30, 1971. In that role, he also serves as Chairman of the Board of County Commissioners, Chairman of the Board of Equalization and Denver's representative on the Metropolitan Sewage Disposal District.

Mr. Cook is a member of Tau Beta Pi, national engineering honor society, Sigma Tau and Pi Sigma fraternities. He is a Master Mason and Shriner and a member of the Hebrew Educational Alliance. He and his wife, Lee, have two children.

MARGARET MARKEY

Commissioner, Boulder County

Maggi Markey has served as Boulder County Commissioner for seven years and is presently chairing the Board for the third time. She was one of the three women commissioners elected to Boards of Commissioners in Colorado in 1974—the first time women had served.

Commissioner Markey is former president of the Boulder League of Women Voters, has served as a member of the Boulder County Board of Health, and is presently a member of the Governor's Blue Ribbon Committee on Rocky Flats and of the Front Range Project.

She is a native of Maine but has lived in Boulder County for 20 years. Her husband, Joe, is a neurologist and they have two children.

T.J. "TED" HACKWORTH

Councilman, City and County of Denver

Councilman Hackworth is a Denver native, as is his wife Doris. They have three children and two grandchildren. He is a graduate of the Denver Public Schools and Denver University.

He served six years on the Denver Board of Education between 1971 and 1977. He was elected to City Council in May, 1979. Mr. Hackworth serves as the City Council Representative on the Denver Regional Council of Governments. He is Chairman of the City Council's General Government Committee and Vice Chairman of the Health and Hospitals Committee. Additionally, he serves on the Intergovernmental Relations, Public Safety, Public Works, and Zoning and Land Use Committees.

WALT TOMSIC

Commissioner, Jefferson County

Walt Tomsic is serving his first term as a Jefferson County Commissioner. He had previously worked for the county as Chief Building Official, Zoning Administrator, Director of Traffic and Safety., Planning Director and Director of Purchasing and Accounting. He has also worked for the State of Colorado as Program Administrator for the Division of Housing and Director of the Division of Local Government.

Mr. Tomsic is a graduate of Arvada High School and the University of Denver. He is a member of the Arvada Methodist Church, Arvada Elks Club, Arvada Masonic Lodge and Rocky Mountain Consistory No. 2. He and his wife, Dorothy, have one daughter, Nancy.

RECENT ACTIVITIES IN THE PLANNING PROGRAM

by Ben Urbonas
Chief, Master Planning Program

In the last issue of *Flood Hazard News*, I reported to you on a new trend in the type of master planning projects with which the District is becoming involved. We see an increase in requests for community and basinwide drainageway system planning. These types of projects address the interceptor and outfall needs for communities on a sub-basin by sub-basin basis. We also have had requests from a few local governments to assist them with the development of their own storm drainage criteria.

We have recently completed a basinwide major outfall system plan for the City of Lafayette and surrounding Boulder County. It was the first attempt by the District at this type of a plan. Included in the work was the preparation of local storm drainage criteria that addressed the specific needs of the City and the surrounding area in Boulder County. With their own drainage criteria and a major drainageway plan, the City of Lafayette is in a very strong position to have the drainage system grow in an orderly fashion with individual pieces fitting together when the city has fully developed. The Lafayette project is not the only master planning activity being worked on this year. The accompanying table summarizes the status of all the planning projects funded by the District that have been recently completed, are underway or are planned by 1982.

Another major area of activity in recent months has been in the development of new technology. We have completed the development of a revised Riprap section for the *Urban Storm Drainage Criteria Manual.* The draft of this section was passed out at a recent two-day short course the District and City of Aurora sponsored on the design of channels and hydraulic structures in sandy soils. After we have accumulated some working experience with the draft, it will be released as a revision to the *Manual.* The short course I mentioned was attended by well over one hundred people. It was taught by Simons, Li and Associates and was intended to introduce a new publication entitled "Design Guidelines And Criteria For Channels And Hydraulic Structures On Sandy Soils." It is a document that deals with a very technologically complicated topic; namely, how to design stable channels and structures when erosion and/or deposition keep trying to destroy such facilities.

With the help of Dr. M.A. Stevens, we were also able to develop, for the first time, sound riprap drop structure guidelines. As soon as we have reasonable experience in their use and have put them in a format that is readily understood by others, they also will be released as a change to the *Criteria Manual.* And last, but not least, we are now ready to begin finalizing a revision of the entire Hydrology section of the *Criteria Manual.* Since 1978, we have been analyzing rainfall/runoff data collected for the District by the U.S.G.S. We now understand the rainfall/runoff process sufficiently to modify the Colorado Urban Hydrograph Procedure and the Rational Formula so that these tools will produce more reliable urban runoff estimates in the District.

STATUS OF PLANNING PROJECTS

PROJECT	COMPLETED IN '80-'81	UNDERWAY	PLANNED FOR 1982
Brantner Gulch		*	
City of Lafayette Outfall System and Criteria	*		
City of Louisville Outfall System and Criteria		*	
Clear Creek-Youngfield thru Golden		*	
Greenwood Village Drainage Criteria			*
Hayes Lake Outfall in Arvada		*	
Lower Clear Creek		*	
Parker and Mexico Outfall		*	
Sand Creek			*
South Platte River			*
Tucker Gulch and Kenney Run			*
Upper Slaughterhouse Gulch		*	
Upper Westerly Creek Tributary		*	

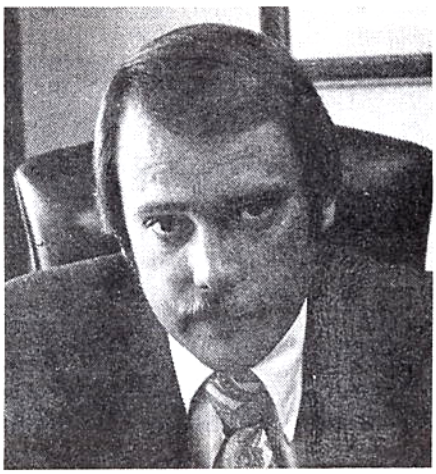
MEET THE NEW BOARD MEMBERS

STEPHEN E. CRAMER

Commissioner, Adams County

Commissioner Cramer is a Colorado native and an 18-year resident of Adams County. He was elected to the Board of Adams County Commissioners in 1980.

Commissioner Cramer received his B.S. Degree in Business from the University of Colorado in 1971. He is Broker-Owner of ReMax Northwest Realtors in Westminster. He is a past president of the Westminster Kiwanis, North Suburban Board of Realtors and the Adams County Mental Health Board. He was chosen



the "Outstanding Young Coloradoan" in 1980 by the Colorado Jaycees.

FEMA HIKES FLOOD INSURANCE RATES

The Federal Emergency Management Agency's Federal Insurance Administration has raised its federally-subsidized flood insurance rates. The rate increase is an effort to put the flood insurance program on a self-supporting basis as soon as possible.

The new rates are $0.40 per $100.00 of coverage for residential structures and $0.50 per $100.00 for non-residential structures. Contents coverage will cost $0.50 per $100.00 for residential and $1.00 per $100.00 for non-residential. There is also a flat $20.00 fee for all policies to defray operating expenses.

EMERGENCY RESPONSE IN THORNTON

By Steve Hogoboom and Sally Peterson
Chief and Project Engineer, Maintenance Program

The 1981 Maintenance Program budget includes money designated for an "Emergency Contingency Fund". The Board of Directors approved this budget item to initiate an "Emergency Fund" to be developed using revenues received pursuant to Colorado General Assembly authorization for the District to levy 0.4 mills property tax to develop a comprehensive District-wide maintenance program. Even before these funds were to be transferred to the "Emergency Fund" account, tornado and thunderstorm events on June 2 and 3 in the northern portion of the District required an emergency response as described below.

Sally Peterson, the project engineer with regional responsibility for the Adams and Boulder County area, was inspecting major drainageways in this region for flood damage. On June 3, while inspecting a portion of Tributary L on Niver Creek, she noted damage to a large sloped riprap drop structure (see Figures 1 and 2). As shown in Figure 1, taken on June 3, damage to the structure was concentrated at the north abutment. Over the following five days, damage increased as the low flows eroded the clay foundation material (see Figure 2). Major portions of the heavy riprap which made up the crest were washed from the crest and deposited along the sloping face of the drop (see Figure 2).

On June 4 the District contacted Eric Pahlke, Director of Public Works, City of Thornton, to inform him of the conditions at Tributary L and to determine if the City staff had discovered any other major drainageway problems that the District should inspect. He identified two areas that involved major drainageway damages: Grange Hall Creek from Colorado Boulevard downstream to 108th Avenue, and Basin 0054 from 112th Avenue downstream to Holly Street. Damage on Grange Hall Creek consisted of side slope erosion (Figure 3), with silt from the eroded area blocking the box culverts under 108th Avenue (Figure 4). In Basin 0054 a small local detention pond embankment was breached (Figure 5). This breaching over-stressed the capacity of the adjacent downstream detention pond which overtopped the roadway embankment at Holly Street causing erosion of the downstream face of the roadway embankment and flooding downstream.

After field inspection of these areas the District staff met on June 8 to develop the District's response to the damage. At that meeting it was determined that Tributary L was the most critical problem requiring immediate repairs to check erosion that threatened six and twelve inch water lines on the north side slope. So serious were the problems that it was decided to commit funds from the Adams County portion of the maintenance services budget to proceed with repairs. Although the damages to Grange Hall Creek and Basin 0054 detention were significant, it was decided to delay decisions regarding these two areas until meeting with Thornton.

On June 10 District staff met with Thornton officials to develop strategy and to address the problems on all three major drainageways. Emergency repairs in the 0054 Basin were assigned to Thornton because a majority of the work involved road and street repairs. The District assumed responsibility to clean up problems on Tributary L and Grange Hall Creek.

Subsequent to this meeting with Thornton the District contacted Siegrist Construction Company to determine their interest in and availability to make the repairs on Tributary L. A meeting with Bill Yearsley from Siegrist Construction Company on June 12 culminated in authorization to proceed with repairs on a force account basis. Siegrist moved on to the job site on June 17 and completed repairs by June 23 at a cost of approximately $8,000.

The box culvert blockage on Grange Hall Creek also required an immediate response. Ditch Cleaning Specialists, Inc. was contracted to clean the 108th Avenue box culverts. Tom Fisher of Ditch Cleaning Specialists, Inc. initiated work on July 7 and completed cleanup by the next week at an approximate cost of $9,000. No effort was made to address the erosion problems upstream of 108th Avenue since this portion of Grange Hall Creek was the subject of a detailed hydraulic study and design by John S. Griffith of Project Consultants under contract to the City of Thornton. Aware of this design effort, the District began studying the possibility of a jointly funded rehabilitation project to repair the damage.

On July 6, the State of Colorado

(Continued on page 11)

Figure 1 - Niver Creek Tributary L drop structure.

Figure 2 - Niver Creek Tributary L drop structure.

Figure 3 - Grange Hall Creek

Figure 4 - Grange Hall Creek at 108th Ave.

(Continued from Page 10)

Division of Disaster Emergency Services (DODES), proceeding under Governor Lamm's proclamations dated June 30, which declared the City of Thornton a disaster area and authorized State financial assistance, held a meeting with affected State agencies to coordinate the disaster assistance and to develop Damage Survey Reports (DSRs). The Colorado Water Conservation Board (CWCB) and the District were assigned joint responsibility to develop DSRs for Tributary L and Grange Hall Creek. The damage investigation on Basin 0054 was divided between the Colorado Department of Highways and the District - CWCB investigation teams. The DSRs required additional field investigation and were submitted to DODES and the City for approval on July 10.

The DSRs not only summarized emergency repair costs but mitigation cost estimates. On Tributary L mitigation costs were estimated to be $15,000. On Basin 0054 mitigation costs were not estimated since such repairs were considered so extensive that Thornton, in cooperation with Adams County, was undertaking a design to address the problems which caused the damage. Grange Hall Creek mitigation costs were estimated to be $150,000. This estimate was based on reconstruction costs developed during the John Griffith design on this portion of the Creek.

The District and Thornton met again on July 14 to discuss the status of the repair efforts and to develop strategy to accomplish the mitigation repairs. On Grange Hall Creek it was decided to present to the District's and Thornton's governing bodies a plan to jointly fund the mitigation repairs essentially in accordance with the John Griffith design. This plan was approved by the District Board and Thornton City Council. The Board authorized the expenditure of funds for this project from the "Emergency Contingency Fund" in the 1981 Maintenance Program budget. On Tributary L it was concluded that additional engineering study was necessary before any decisions could be made. The Muller Engineering Company was retained to investigate the cause of the failure of the drop structure and to recommend mitigation alternatives. District and Thornton staffs are reviewing the Muller report and a decision is pending.

The problems in Basin 0054 were not so easy to put a finger on. Thornton and Adams County were jointly working on a design to upgrade Holly Street. Thornton is

Figure 5 - Basin 0054 detention pond.

working with Wood Brothers to construct a 24-acre-foot detention pond as part of a new subdivision in the basin. The ownership of the detention pond that was breached is in question and may involve court action. Because of this complex situation it was decided to wait before deciding on the mitigation repairs.

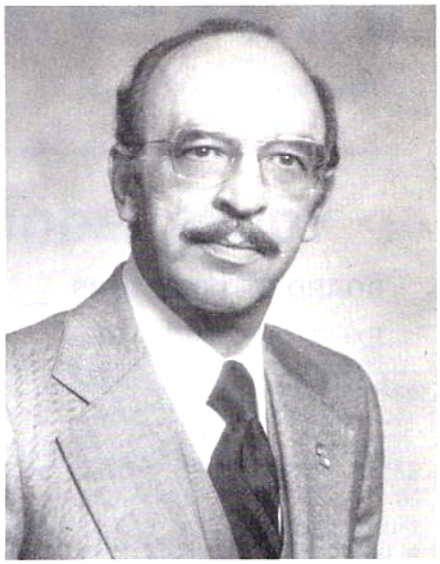
In summary, the District's response to flooding in Thornton was as follows:

1. Emergency repairs were made to the Tributary L drop structure to protect two water lines.
2. Emergency cleaning of the 108th Ave. culverts was completed.
3. Cooperative efforts were made with DODES, CWCB and Thornton to estimate damages and mitigation expenses; and to determine how the needed repairs would be accomplished.
4. The District and Thornton agreed to jointly fund the Grange Hall Creek mitigation project, which will be under construction by the end of the year.
5. The District will complete additional repairs to the south rundown on Tributary L in 1982.

This flooding event showed the value of having an emergency fund available, and also gave the District's staff valuable experience in dealing with an emergency situation.

CHERRY CREEK DEDICATION—Denver Mayor Bill McNichols cuts a ribbon to open the Cherry Creek channel improvements. Looking on are Councilwoman Cathy Reynolds, District Board Chairman, Harold Cook and Bud Ruppert.

MEET THE NEW BOARD MEMBERS



CHARLES A. PITTS

Commissioner, Arapahoe County

Commissioner Pitts retired from the U.S. Army in May, 1973. He was then engaged in the office supply field for eleven years before joining the Board of County Commissioners. He has served on the Denver Regional Council of Governments as a member and as Vice Chairman of its Executive Committee. He has also served on the Jail Advisory Committee and is Past President of the North East District of Colorado Counties.

Mr. Pitts has served on the Vestry of St. Stephens Church in Aurora. He is an active Life Member of Sertoma International, where he has held the offices of Lt. Governor, Governor, State Director and International Director. Commissioner Pitts is in his second elected term and is currently Chairman of the Board of Commissioners.

He and his wife, Jean, have one daughter, Lisa.

Tucker Talk

Continued from page 3)

Cities. The League had asked the Corps to consider modifying the procedure as part of its regulatory reform effort. The Corps continues to maintain that there is a need for uniform criteria to distinguish between flood control and urban drainage system components and that the present criterion was selected after exhaustive consideration of alternatives. It would appear that the Corps will stick with the 800 cfs/10% criterion.

DESIGN NOTES - RIPRAP

Supplement to Flood Hazard News (December, 1981)

INTRODUCTION

The Urban Drainage and Flood Control District (UD&FCD) has developed a revision of the *Urban Storm Drainage Criteria Manual* (USDCM) regarding riprap. Riprap refers to a protective blanket of stones, which are placed by machine to a specified configuration to control erosion. The USDCM revision addresses the design problems associated with the use of riprap to reduce erosion along channel banks, in channel beds, upstream and downstream from hydraulic structures and at bridges. The design concepts and aids presented in the revision are straight forward, following procedures that were developed after years of research and field experiments on a world wide basis. This article discusses the physical properties of riprap and construction practices that will yield aceptable riprap erosion protection.

The hydraulic forces that affect riprap include velocity, current direction, eddy action and waves. The basic hydraulic parameters of velocity and hydraulic radius are used to determine the riprap classification. With the class of riprap known, tables are provided outlining the specific physical requirements within each class. The designer often times overlooks or, due to contractual limitations, cannot inspect the riprap that has been specified for the particular project. The critical physical properties of the individual stones that comprise the riprap mass include the size and weight of the individual stones and their shape. The individual stones should be graded and proportioned in a manner that when placed to the specified depth will produce a compact and tight mass of rock. The individual rocks should interlock with a minimum of void space, resulting in a rock mass with a nested appearance.

The riprap must be placed on a filter material and/or fabric. This filter should be specially designed for the soil conditions that will be encountered on the project site. The filter material or fabric also has specific physical requirements which are discussed below. These materials are as important to the durability, maintainability and operational effectiveness of the channel protection as the riprap itself.

Experience has shown that a majority of riprap failures are caused by improper bedding material gradation or placement which allows leaching of channel particles through the riprap blanket. Other failures result from

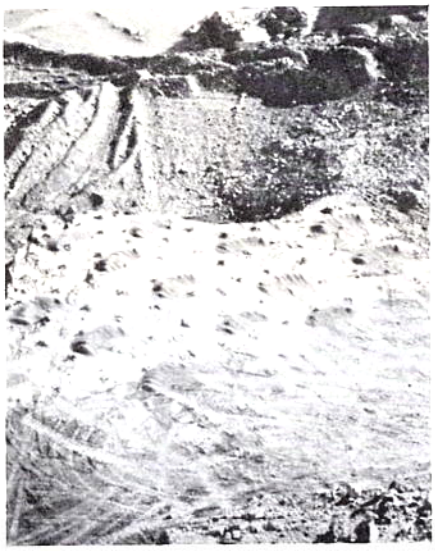


Figure 1 - Looking down on a rock ledge that has been drilled, had explosives inserted and is ready for blasting.

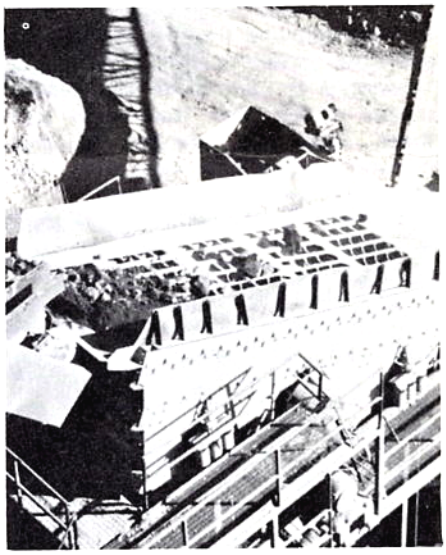


Figure 2 - A large screen used to develop the Light (L) and Very Light (VL) riprap specifications.

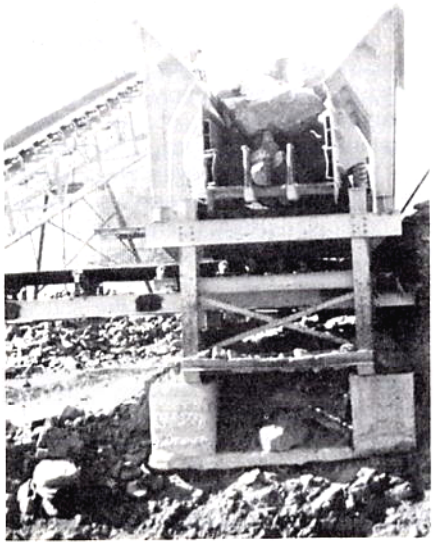


Figure 3 - A "grizzly" which is used to develop the riprap gradation. Rocks less than 6 inches drop through the grizzly on to the conveyor system. Rocks greater than 6 inches fall forward and are used for riprap.

undersized individual rocks in the maximum size range and improper gradation of the rock mass which reduces the interlocking of the individual particles.

This issue of *Design Notes* discusses the experience that has been gained by the District over the past three years regarding the construction of riprap channel lining and erosion protection. The design criteria presented in the USDCM revision will be sent out to all *Criteria Manual* holders in the spring of 1982.

PHYSICAL PROPERTIES AND SIZE

The rock used for riprap should be hard, durable, angular in shape, free from cracks, overburden, shale and organic matter. Three tests are used to determine the durability and hardness of the rock: abrasion, freeze-thaw and specify gravity tests. These tests are used on a national basis and the procedures for these tests are described by ASTM and AASHTO. The rock suppliers should supply information to the potential buyer regarding the results of these tests. If recent tests for abrasion and freeze-thaw are not available, service records should be investigated to determine the acceptability of the rock. Remember that these tests are intended to give general indications regarding the physical properties of the rock.

The physical properties of rock from a single quarry will vary. All rock should be visually inspected before it is accepted. The durability and hardness of the rock is affected by the location of the rock strata that will be blasted in the quarry and the manufacturing technique used to obtain the rock fragments from the rock strata. In most cases the rock is extracted from a hillside or ledge. This usually means that unwanted material covers the rock formation that will be used to produce the riprap. This material or overburden must be stripped or it will be found at the proposed riprap stock pile making it unacceptable. Due to the hardness of the rock formation, rock fragments can only be obtained by blasting with black powder or high explosives. In order to place the explosives, holes must be drilled. The diameter, spacing and depth of holes and the amount of explosives used are factors that influence the final product. It can be surmized from this short discussion on the manufacturing process for riprap that the time the designer spends to size the riprap blanket may all be wasted if quarry operations are not considered. The acceptability of some rock fragments from a particular quarry site does not mean all rock from that quarry is acceptable.

TABLE 1 — CLASSIFICATION AND GRADATION OF ORDINARY RIPRAP

Riprap Designation	% Smaller Than Given Size By Weight	Minimum Dimension Inches	K* m Inches
Type VL	100	9**	
	35-55	6	6
	10	2	
Type L	100	12**	
	35-55	9	9
	10	2	
Type M	100	18**	
	35-55	12	12
	10	3	
Type H	100	24**	
	35-55	18	18
	10	6	
Type VH	100	36**	
	35-55	24	24
	10	6	

* KM = mean particle size

**At least 30% of all stones by weight shall be this dimension

The size and shape of the individual rock fragments should be studied and compared to the size designated in the particular riprap classification. The rock shape should be angular. Round stones, river run rock or boulders are generally unacceptable. Thin slabs of rock or rock with shale seams are also unacceptable. The breadth or thickness of a single rock should not be less than one-third the length of the rock. The dimensions of the rock given in Table 1 are minimum; the maximum dimension is one and one-half times that dimension.

If large amounts of rock are required, the interested parties; contractor, engineer and owner's representatives; should visit the quarry proposed for the rock supply. All quarries maintain stock piles of the various classifications of riprap. The inspection team should physically inspect the riprap that is proposed for use on the particular project. This inspection should include measurement of individual rock size and durability test by using a hammer to test the soundness of the rock.

The inspection team must keep in mind the seriousness of the inspection effort. Measurement of the rock size involves the physical measurement with a tape or rule, not just an educated guess. Careful attention should be given to determining if the rocks required in the maximum size range for each classification are acceptable. These large rocks are the work horses within the riprap mass and at least 30% of all rock by weight should be this minimum dimension. The correlation between weight and size is based on the volume of a sphere or the equivalent spherical diameter or Volume = 1/6 D^3 when D is the minimum dimension in feet. For example, based on a minimum specific gravity of 2.64 the large individual rock fragments in the Type M classification should weigh approximately 700 pounds. With the requirement that 30% of all rock by weight should be this minimum dimension, in a 2,000 pound sample of riprap at least one rock should weigh 700 pounds.

GRADATION

The gradation for each class of riprap is specified in Table 1. The grading and proportioning of the individual rock fragments that make up the total gradation in each class is not an easy or accurate operation. Simplifying, the rock is blasted from rock ledges in the quarry. This blasting operation yields rock, not only for riprap, but for all construction materials requiring rock fragments, such as concrete and asphalt aggregate. The large rock fragments that have size ranges that may be acceptable for riprap are separated and

transported to screening and sizing equipment that are called "grizzlies". The grizzlies are made up of parallel steel rails spaced at given intervals. By using a series of different sized grizzlies the rock fragments are sorted and resorted to develop each classification of riprap. Due to the potential of equipment damage for the heavy (H) and very heavy (VH) classifications of riprap a loader with a rock bucket rather than grizzlies, is often used to sort the rock fragments and develop the required gradation.

If the grading and proportioning of the rock sounds unscientific, it is. This manufacturing process requires the inspection team to be particularly careful in approving the riprap classifications. The four quarries in the Denver Metropolitan area are staffed with professionals that want to meet each and every riprap specification within the physical limitations of their manufacturing equipment and quarry. The District has visited each of these four quarries during the past few months on inspection trips, and has found total cooperation and interest in supplying the specified rocks.

To insure that the riprap specified for your next project is available per specification the owner or his representative should contact the quarries during the final design phase of the project. This is particularly important when specifying heavy (H) or very heavy (VH) class riprap. The quarries will be able to tell you if the specified riprap gradation is manufacturable, if stock piles of the riprap are available and the lead time required to produce the necessary stock pile to satisfy the requirements of your project.

The quality control of the gradation is by visual inspection. Once the inspection team has determined that the given riprap stock pile meets the physical and minimum size requirements of the specification, the gradation can be checked. The District has found it advantageous when inspecting riprap gradation to think in terms of the finished riprap mass that is required. For example, if the minimum thickness of the rock layer of Class M riprap for a particular application is 1.5 times the D_{50} of the gradation or 18 inches. The gradation based on the blanket thickness should yield a tight, compact mass of rock fragments with a minimum of void space. Look at the rock on the edges of the stock pile where the depth is approximately equal to the specified depth in this case 18 inches. It is this area that should be carefully studied in determining if the proposed gradation is acceptable. Keep in mind that during transportation of the riprap to the job site additional rock fragments in the 6" size and less will be formed due to breakage during handling. Also remember that the contractor that has been awarded the construction contract, and not necessarily the quarry, must supply the specified riprap. Therefore if the quarry's riprap stock pile is unacceptable, the contractor may at his discretion choose another supplier or purchase quantities of several classifications of riprap and mix them at his own cost to meet the requirements of the specified gradation.

Assuming that a proposed gradation has been approved at the quarry the next problem that can arise is insuring that the approved gradation is continously supplied. The District has found it advantageous to require the contractor to provide a 10 ton sample of the approved riprap. This sample is stock piled on the construction site. The sample is used as a reference for judging the gradation of the supplied riprap.

Figure 4 - A "rock bucket" which is used to sort out small rock pieces.

Figure 5 - A stock pile of Medium (M) riprap. Note the variation in the size of the rock.

Figure 6 - Riprap can be used in drop structures.

CONSTRUCTION REQUIREMENTS

At the introduction of this article it was pointed out that a majority of riprap failures are caused by improper bedding. This mode of failure extends to placing the filter material on improper subgrade. Therefore, the chan-

nel bottoms and side slopes that will be protected by riprap should be cleared of all brush, trees and trash. This clearing and grubbing operation should remove all organic or trash-like material at least two feet below the finish subgrade. This increased excavation depth should then be backfilled and compacted to 90% Proctor with suitable on-site or imported material. Also, all soft spongy material or muck should be removed and replaced with acceptable material compacted to 90% Proctor. The subgrade should be fine graded to relatively smooth lines free of depressions, mounds or windrows prior to the placement of the filter material and filter fabric.

The design criteria for bedding requirements are discussed in detail in Section 5.3 of the USDCM revision. Therefore, design procedures will not be discussed in this article. Briefly, a properly designed bedding material provides a buffer of intermediate sized material between the subgrade and the riprap to prevent leaching of the channel subgrade particles upward through the voids in the riprap blanket. Generally the quality control regulating the properties of the bedding material is more exacting yet easier to control when compared to riprap. The quality control of bedding materials, either granular filter or plastic/fiber filter blankets, is critical but, because of the nature of these materials, not as hard to supply. The placement of the materials is also critical. The most critical element for the granular filter is the depth. The most critical element for the fabric filter is the overlaping and securing the individual panels with pins.

The stone for the riprap should be placed on the prepared slope in a manner that will prevent damage to the filter material, prevent segregation and produce a well graded mass with a minimum of voids. In order to obtain the desired finished product the rock should not be dropped from a height more than two feet above the filter material. It has been observed that dropping the rock from greater heights reduces the relative depth of the granular material or in the case of filter fabric can actually puncture the fabric. The riprap should be placed to its full design thickness in one operation. This usually requires placing the riprap with a loader having a bucket size greater than two cubic yards. Placing the riprap in layers or using chutes to place the riprap will cause segregation and should be avoided. Remember that the entire riprap blanket should conform to the gradation specified in Table 1. At times in order to reach this specified gradation hand placement of some stones may be required. Working the riprap blanket with heavy equipment should be discouraged since this will disturb the filter material underlaying the rock.

Figure 7 - Riprap used in a trickle channel.

Figure 8 - Riprap used on a tight curve in a grass lined channel.

Figure 9 - Riprap used in a transition from a concrete lined channel to a grass lined channel.

CONCLUSIONS:

The designer can develop the hydraulic parameters in order to size the riprap mass for channel erosion protection but it must be remembered that the manufacturing and construction technologies control the success or failure of a particular design. Owners, engineers and inspectors should not forget this fact and should increase their attention to the manufacturing and construction problems associated with riprap.

COMING NEXT ISSUE

RIPRAP DROP STRUCTURES

The URBAN UD DRAINAGE & FLOOD CONTROL DISTRICT

THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
2480 West 26th Ave., #156-B
Denver, Colorado 80211