FLOOD HAZARD NEWS

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1988 FLOOD WARNING EFFORTS

By Kevin G. Stewart, Project Engineer
Floodplain Management Program

Expansion of ALERT Network Continues

ALERT flood detection networks are becoming widely used throughout the United States and many other parts of the world. ALERT is a National Weather Service acronym which stands for "Automated Local Evaluation in Real-Time." This concept was developed in the late 1970's by the National Weather Service and was first implemented in the State of California. The evolution of micro-computers and the availability of ALERT equipment and software through private vendors have contributed to the affordability and popular appeal of ALERT Systems.

The first ALERT network in the Urban Drainage and Flood Control District was installed in Boulder County in 1979 for the Boulder Creek drainage basin. This network, which is owned and operated by the Boulder County Sheriff's Department, has expanded since 1979 to now include a total of 41 rain gauges and 12 stream stage gauges covering the South Boulder Creek, Four Mile Canyon Creek, Left Hand Canyon/James Creek, and the St. Vrain drainage basins.

In 1985, an ALERT network was installed for Lena Gulch in central Jefferson County, Colorado. This network, comprised of six rain and three stage gauges, was originally designed with future system expansion in mind. Due to its successful operation, expansion efforts began in 1987 and continued through this year. ALERT gauges have now been installed on six regional detention facilities constructed by the District to monitor both rainfall and stage. This "District Wide" network covers a large area from as far north as Louisville to as far south as Englewood Dam in Arapahoe County. Three additional gauging sites have recently been identified and are scheduled for installation in early 1989.

Two additional basin flood detection networks have also been added to the system this year. The Ralston Creek project, affecting Arvada and Jefferson County, and the Westerly Creek project, affecting Aurora and Denver, have added an additional 23 sensors to the ALERT system. Plans for future system expansion in 1989 include additional rain and stage gauges for the Ralston network, a new flood detection network for the Toll Gate Creek basin in Aurora and the partial implementation to a flood detection network for Bear Creek in Jefferson County.

As of November 1988, the District's ALERT system consisted of 26 rain gauges and 17 stage gauges. With the addition of the new flood detection networks next year and the continued expansion of the "District Wide" gauging network for flood control facilities, it has been estimated that a total of 48 rain gauges and 30 stage gauges will be on-line by mid-summer 1989. Plans are also being considered to integrate the Boulder County network with the District's ALERT system. By the end of 1989, real-time ALERT data may be centrally collected from more than 130 remote sensors.

Three micro-computer base stations are currently in service. The primary base station is located with the contract meteorologist (Henz Kelly and Associates) and consists of a Compaq 386 processor with ALERT software, Okidata 393 printer, radio receiver, data decoder and backup power supply. The second base station, located at District offices, consists of an IBM PC-AT 286 processor and is configured for remote access. The third base station is located at The Consolidated Mutual Water Company and is dedicated as a back-up for the Lena Gulch Flood Detection Network. Additional base stations will be added in the near future. The National Weather Service is currently working on integrating the ALERT data with a new computer driven work station currently in operation at the Weather Service Forecast Office at Stapleton International Airport. The City of Aurora is also considering base station needs in conjunction with the Toll Gate Creek project scheduled for implementation in 1989.

It is apparent that what was once a small network of gauges serving a 10-square mile watershed in central Jefferson County has quickly evolved into a much larger and sophisticated monitoring network. The real-time data generated by these ALERT networks provide the means for observing rainfall and stage fluctuations as events occur. By combining this information with other data sources (i.e. satellite

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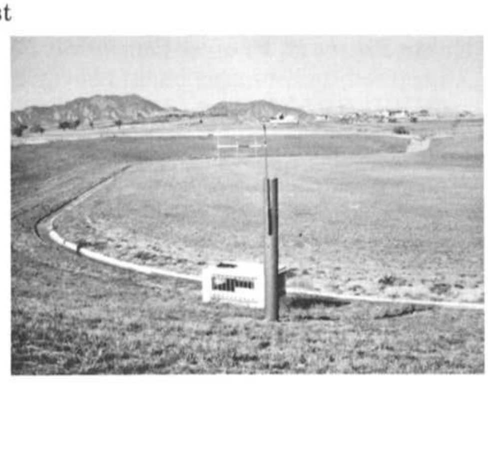

A District rain and stage ALERT gauge at Drainageway Detention in Louisville.

Professional Activities of District Staff

Scott Tucker, Executive Director

- Presented "A View from the Bottom, Challenges and Prospects" at the Engineering Foundation Conference on Current Practices in Urban Stormwater Quality Control Facility Design at Trout Lodge, Potosi, Missouri in July, 1988.
- Spoke at the ASCE, APWA, AWRA and UDFCD sponsored conference on Urban Runoff Quality. Presented views on NPDES permitting of storm sewers in September, 1988, in Denver, Colorado.
- Wrote article "Permits to be Needed for Storm Sewers," for *Colorado Municipalities,* March-April 1988.
- Spoke at a conference on "Stormwater Management at the Crossroads" sponsored by the City of Tulsa and the Association of State Floodplain Managers. Talked about "State and National Programs Affecting Stormwater Management."
- Spoke to Fort Lewis College Engineering/Physics Club Seminar on "Basic Elements of an Urban Draining and Flood Control System," February, 1988.
- Presented "Summary of the Proposed Stormwater NPDES Permit Program Required by the Water Quality Act of 1987" at the Northern California Chapter APWA Workshop on Non-Point Source Discharges and NPDES in Oakland, California in May, 1988.

Ben Urbonas, Chief, Master Planning and South Platte River Programs

- Lectured on the development of the Colorado Urban Hydrograph Procedure (CUHP) 1984 Version at a CUHP/SWMM Short Course sponsored by the University of Colorado, Denver in March.
- Co-chaired an Engineering Foundation Conference held in Potasi, Missouri in July. Topic: Current Practices in Urban Stormwater Quality Control Facility Design.
- Attended an ASCE Technical Committee meeting in St. Louis in July to review the development of a manual of practice on urban stormwater drainage and management.
- Presented a paper titled "The Big Picture" at an urban stormwater quality seminar held in September in Aurora, Colorado jointly sponsored by the local chapters of ASCE, APWA and AWRI.
- Participated in a panel discussion in September on the topic of separate stormwater NPDES permits at the annual APWA Convention held in Toronto.
- Presented a paper in October with Mike Jansekok (District student intern) on rainstorm hyetograph compositing effects on stormwater runoff modelling at EPA's Stormwater Modelling Conference held in October in Denver, Colorado. Ben assisted Dr. James Guo in organizing this conference.

Bill DeGroot, Chief, Flood Plain Management Program

- Participated in a panel discussion on the quantification of benefits of floodplain information at the Association of State Floodplain Managers (ASFPM) annual conference in Nashville in May.
- Participated in a panel discussion on Floodplain Management in the Year 2000 at the ASFPM Arid West Conference in Las Vegas in October.
- Recorder for a research discussion at the 1988 Workshop on Hazards Research and Applications at the University of Colorado in Boulder in July.
- Made a presentation on flood plain management to a University of Wisconsin short course titled, "Understanding and Applying Storm Water Management Techniques".

Kevin Stewart, Project Engineer, Flood Plain Management Program

- Lectured on drainage basin characteristics and the rational method at a CUHP/SWMM Short Course Sponsored by the University of Colorado at Denver in March.
- Presented a paper entitled, "Effecting Timely Response to Urban Flash Floods" at the ASCE Water Resources Operations and Management Workshop: Computerized Decision Support Systems for Water Managers at Colorado State University in June.
- Elected Secretary of the Southwestern Association of ALERT Systems at the annual conference in Austin in September.
- Presented the ASCE paper listed above to the National Weather

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PROJECT WINS AWARD

Siegrist Construction Company has been named 1988 Contractor of the Year by the American Public Works Association, in the $2-Million and Under category, for construction of the 49th Avenue bridge over Sand Creek. The bulk of the project was funded by Commerce City and the Colorado Department of Highways with the District participating in the flood control aspects of the project.

The project, consistent with the District's Sand Creek master plan, consisted of replacing a 130-foot-long, 3-span bridge with a 200-foot, 2-span, concrete girder bridge, along with channel bank stabilization and wetland protection and/or re-establishment. The project was finished two weeks ahead of schedule and 2.4% under budget. City Engineer Don Wuerz directed the project.

BID TABS DATA BASE

by Robert Norick, Student Intern

The Urban Drainage and Flood Control District has tabulated the bid items from past District projects into a database file (Dbase III Plus). This aids in estimating the cost of various construction items. The database file contains the following information for each bid item:

- The name of the construction project;
- The lowest, highest, and average cost for the bid item;
- The applicable standard specifications;
- What is included and excluded from the bid item.

The database file can be conveniently accessed by using one program, BIDS.PRG. The BIDS program uses a collection of fourteen database files and subprograms. These files and programs can only be used with Dbase III Plus.

The database file will be updated with each new construction and maintenance project. The updated database files along with the instructions for use can be obtained by submitting a 5¼", double sided, double density floppy disk to the District during the months of January and February each year. The disk will be formatted using DOS 3.20. The user must supply a self addressed stamped envelope with the disk.

The programs and database files are given free of charge, and neither the District nor the author warrantee their results. If you use them, you must assume all responsibility. If you have any questions, feel free to contact Robert Norick or Paul Hindman at 455-6277.

Tucker-Talk

by L. SCOTT TUCKER

Timely Comment from the District's Executive Director

Westerly Creek Dam Project Underway

The Urban Drainage and Flood Control District and the Corps of Engineers signed a Local Cooperative Agreement (LCA) in August 1988, culminating many years of effort on obtaining Federal support for the project. The LCA commits the District to being local sponsor for the project. As local sponsor, the District will have maintenance responsibility for the completed project, and had to provide the local sponsor's share of project costs.

The project involves construction of a large detention facility on Lowry Air Force Base. Construction of this facility will allow Denver and Aurora to complete needed upstream drainage work, while at the same time providing valuable protection downstream of Lowry Air Force Base. I have been working on this project since coming with the District in 1972. The files indicate that Congressman Byron Rogers was involved prior to that time in seeking the Federal assistance needed for the effort. A major hurdle was crossed when Congress included the Westerly Creek project in the 1986 Water Resources Development Act. This provided the necessary authorization for the project, but funds still needed to be appropriated to pay for the work. The Corps of Engineers is the Federal agency responsible for the project and they requested funds in their 1988 and 1989 budgets for the project. Congress appropriated the necessary funds and the project finally got underway.

The Corps of Engineers bid the first phase of the work in August, 1988, which involved primarily utility relocations. The Corps plans to bid the work for the construction of the embankment in January, 1989. Construction will probably take from 18 to 24 months.

The local cost of the project is being split between Denver, Aurora and the Urban Drainage and Flood Control District. The Corps gave the local entities over $4,000,000 in credit for work previously completed on downstream channel work. This reduced the local share for the Westerly Creek dam project to $850,000. The District's share of that is $425,000 and Denver and Aurora are sharing the remaining balance on a 50/50 basis.

This project shows that perseverance does pay off. Hopefully, the big flood will wait another couple of years until the detention project is completed.

Board Seeks Changes to District Statutes

The Board of Directors at their meeting on October 20, 1988, made the decision to seek several changes in the District's statutes during the 1989 session of the Colorado General Assembly. One change includes expanding the District's boundaries. When the Adams County voters approved the annexation of the land needed for the proposed new Denver airport, the boundaries of Denver were suddenly extended beyond those of the Urban Drainage and Flood Control District. Also, recent annexations by the City of Aurora have led to portions of Aurora being outside of the District. A similar situation exists in Douglas County where the City of Parker has annexed territory resulting in part of Parker being within the District and part of Parker being outside the District. The Board and the local governments involved agree that it would be appropriate for the entire cities to be located within the District. This will provide consistency in drainage and flood control planning, design and construction, maintenance, and for other services such as early warning for the entire metro area. Annexation of these areas would add 402 square miles to the District's present size of about 1208 square miles.

The second area is in the composition of the Board of Directors. The Board decided to ask the legislature to add a Board member from any city larger than 100,000 population. This presently includes Lakewood and Aurora. This would increase the size of the Board from 15 to 17.

Finally, the Board agreed to ask the legislature to give the District the authority to address stormwater quality problems. The present District statutes are silent on this issue. In their deliberations, the Board expressed concern about potential liability that this might create for the District as well as the cost implications. The Board in the end, however, came to the conclusion that you cannot separate stormwater quantity and quality, and that because of the NPDES regulations being prepared by the EPA for municipal storm sewers, local jurisdictions were going to have to deal with stormwater quality issues. Since stormwater, by its nature, is a multi-jurisdictional problem, the District should initiate the process of involvement which will begin with a clarification of the District statutes regarding its ability to assist local governments with stormwater quality problems.

The decision by the Board to seek these legislative changes is certainly a big step. However, there is a long way to go and one can certainly not take for granted that the legislative process will not be without its lumps and bumps.

NPDES Creeping Closer and Closer

As this article is written the proposed rules for permitting municipal separate storm sewer systems have not been published by EPA. Last indications are that the proposed rules will be published in the Federal Register in early November, 1988. Once the proposed regulations are published in the Federal Register, a 30- or 60-day comment period will begin. Following the comment period, EPA will consider the comments provided and publish final rules, probably towards the end of 1989. Once final rules are published, the clock will start ticking for local governments to apply for permits for their municipal storm sewer systems.

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DESIGN AND CONSTRUCTION NOTES

B.H. Hoffmaster
Chief, Design and Construction Program

The year 1988 saw the start of three, and the completion of nine, design projects and the start of seven, and completion of fifteen, construction projects. The projects are listed in accompanying tables, "Status of District Design Projects" and "Status of District Construction Projects". The design projects were completed under District management in cooperation with other public agencies. The construction projects were generally managed by the local sponsor with some exceptions in which the District managed construction.

Since the District's design and construction program was initiated in 1973, the District has expended or committed, as its share of capital improvement projects, approximately $35.8 million. During 1988 the District expects to expend or commit through the District and/or local agencies $21.8 million, of which the District's share will be $4.7 million or 22 per cent.

The design of Goldsmith Gulch from Cherry Creek to Dartmouth/Cornell is a classic public works project involving the public. The detention pond portion of the project would require 75% of the expenditure and is surrounded by homes that are not in a flood hazard area. Those homes that are in the flood hazard area have 25% of the construction cost. Without the detention pond, the costs down stream for the same level of protection are much greater than the project now recommended. After several months of examining upstream detention and downstream improvement scenarios a decision should be reached soon on an acceptable plan such that the District and Denver Wastewater Management Division can proceed with final design with construction to start in the fall of 1989.

An improvement district to finance the Town of Columbine Valley's share of the project cost for Dutch Creek Project failed to be formed in 1988 before a new town council was elected. The new council is studying the project and the means to finance it.

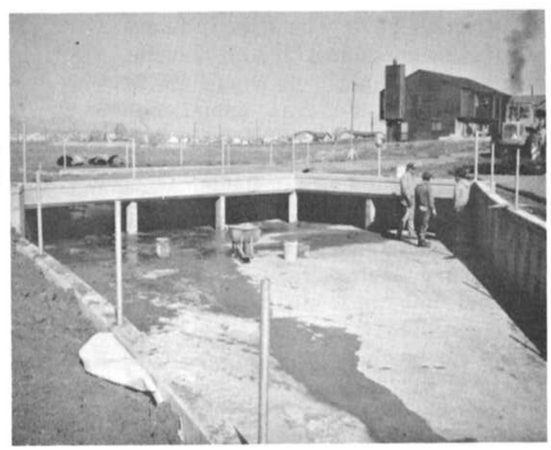
The District, in cooperation with Aurora and Denver, has entered into a Local Cooperation Agreement with the U.S. Army Corps of Engineers for the construction of Westerly Creek Dam on Lowry Air Force Base. The agreement designates the District as the local sponsor. The District has also signed a Memorandum of Understanding with Lowry Air Force Base for maintenance of the facility.

Marston Lake North, Phase II channel, located in the southwest part of Denver has been completed by Kiewit Western Co. The project extends from the upstream end of Schedule I, which was completed in 1987, to Old Wadsworth, south of Quincy. The Denver Water Board redesigned the project and included moving and realigning the Marston Lake Dam so that a grass-lined channel could be used. In addition to providing the Water Board with a structurally updated embankment, it also precluded having to construct a more costly concrete-lined channel.

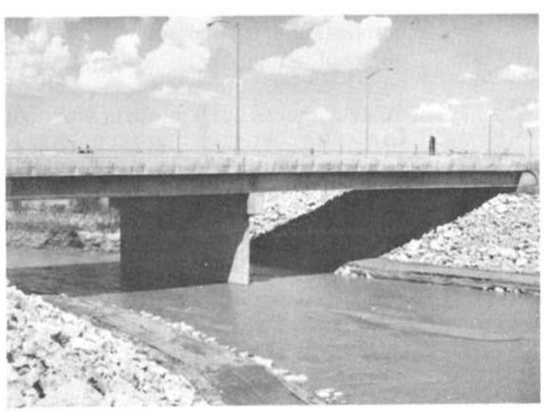
The Upper Sloan Lake Project, Phase II from Ingalls Street and 20th Avenue to Reed Street and 25th Avenue is complete. This project is an improved storm drain system with detention at Jefferson High School at 20th Avenue and Pierce Street. The contractor was Trainor Construction Company and the design engineer was URS Corporation. The last phase of this project from Wadsworth near 25th Avenue to the Rocky Mountain Ditch is now designed and is expected to go to construction this winter. The work in the Rocky Mountain Ditch must be complete by April.

A construction contract let by Aurora to Randle and Blake, Inc., for the Sand Creek Project from the confluence of Sand Creek and Toll Gate Creek to east of Chambers Road was completed this year. The project was designed by Greenhorne & O'Mara, Inc. This project required the placement of approximately 32,000 cubic yards of soil cement as an alternate to rip-rap for bank protection. The use of soil cement as bank protection was a cost savings of approximately $600,000 over the use of rip-rap. The channel bottom has been returned to native vegetation which was included in the design.

Little Dry Creek from Broadway to Clarkson in Englewood was completed by Randle and Blake, Inc. The channel improvements were designed by McLaughlin Water Engineers, Inc., with EDAW, Inc., serving as landscape architect. The overall project is an excellent



Construction on the North Branch of Massey Draw at Carr St. in Jefferson County.



The new 49th Ave. bridge over Sand Creek in Commerce City (see story on page 2).

example of how park amenities can be blended with a flood control facility. The City of Englewood and the Englewood Urban Renewal Authority have also completed improvements including a lake with water falls between Broadway and the Cinderella City Box Culvert.

On another Little Dry Creek, in Westminster, a section of channel was completed from Tennyson Street to Winona Street. This is basically a trapezoidal concrete channel for the 10-yr flood with grass-lined banks extended to contain the 100-yr flood. This is the fourth phase of this project. Lillard and Clark Construction Co. was the contractor and Sellards and Grigg, Inc., was the design engineer. The next phase, from 75th Avenue to 76th Avenue is expected to go to construction in 1989.

A project with Jefferson County was completed on Massey Draw, North Branch, in southern Jefferson County. The project included a rectangular concrete channel between Carr and Allison Streets between Meadow and Brook Drives. New box culverts were constructed for Carr and Allison Streets.

Two phases of construction were completed on the East Fork of Kennys Run in 1988. This is a joint project with the City of Golden with engineering provided by Muller Engineering Company. The first phase of construction was the installation of a flow separation structure by L & M Enterprises, Inc. where the Welch Ditch crosses the East Fork of Kennys Run. This had long been a problem for the City of Golden as flood waters previously entered the Welch Ditch from the drainageway creating problems for residents along the ditch. The second phase of construction included installation of storm sewer improvements by Diamond Contracting along Ford Street to alleviate frequent flooding along this reach of drainageway.

Rehabilitation of an existing pond, construction of a new detention pond, and construction of storm sewer improvements on Basin 3207 Drainageway were completed in 1988 in cooperation with the City of Broomfield. The project was designed by Sellards and Grigg, Inc., and constructed by L & M Enterprises. Preservation of existing wetlands was a key element in the design and construction of this project.

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdiction(s)	Status
Marston Lake North	Denver, DWB	Complete
Dutch Creek, Platte River to Platte Canyon Road	Columbine Valley	Complete
Goldsmith Gulch, Cherry Creek to Dartmouth	Denver	Preliminary Design Is Complete
Gunbarrel Area	Boulder County	40% Complete
Hays Lake Outfall	Arvada	80% Complete
Kennys Run, East and West Forks	Golden	Complete
Lena Gulch - 20th Ave to Youngfield	Lakewood	40% Complete
Little Dry Creek (ADCO), Clear Cr to Lowell	Adams County	95% Complete
Little Dry Creek (ADCO), Lowell to Sheridan	Westminster	Complete
Marston Lake North	Denver, Denver Water Board	Complete
Sloan Lake - Schedule IV	Lakewood, Denver	Complete
South Jefferson County Drainages	Arapahoe Co., Nevada Ditch, Last Chance Ditch	30% Complete
Weir Gulch - Depew St. Design - Phase I	Lakewood	Complete
Weir Gulch - First Ave. Trib. - Schedule II	Lakewood	Complete
Westerly Creek Dam	Denver, Aurora, U.S. Army Corps of Engineers	Complete

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Jurisdiction(s)	Cost	Status
Basin 3207 Detention, 10th St. to Ash St.	Broomfield	$370,412	Complete
Cherry Creek, at Cottonwood Road	Parker	$1,878,034	Complete
Clear Creek at Pecos	Adams Co., CO Dept. of Highways	$650,000	0% Complete
Goldsmith Gulch, at Wallace Park	Goldsmith Metro Dist.	$67,636	Complete
Goldsmith Gulch, Hampden to Quincy	Denver	$661,294	Complete
Kennys Run, East Fork	Golden	$560,011	Complete
Lena Gulch - Schedule V	Wheat Ridge	$227,500	0% Complete
Little Dry Creek (ADCO) Phase B2	Westminster	$1,384,625	Complete
Little Dry Creek (ARAP) Belleview to Clarkson	Cherry Hills Village	$59,498	Complete
Little Dry Creek (ARAP) Broadway to Clarkson	Englewood	$2,871,100	Complete
Little Dry Creek (ARAP) Santa Fe to Cinderella	Englewood, CO Dept. of Highways	$125,000	0% Complete
Louisville Drainageway 'D'	Louisville	$270,519	Complete
Lower Three Lakes @ Bowles	Littleton	$60,000	Complete
Marston Lake North - Sch II	Denver, Denver Water Board	$882,362	Complete
Massey Draw North	Jefferson County	$461,458	Complete
Parker/Mexico	Arapahoe Co., Aurora	$1,536,900	95% Complete
Sand Creek - Schedule I	Aurora	$3,598,407	Complete
Slaughterhouse Gulch	Littleton, Arapahoe Co.	$804,379	Complete
Sloan Lake - Schedule II	Edgewater, Lakewood	$1,994,549	Complete
South Jefferson County Drainages - North (Basin 6100)	Jefferson County	$60,000	20% Complete
Weir Gulch 1st Ave. Tributary - Schedule III	Denver	$290,000	0% Complete
Westerly Creek Dam - Lowry AFB	Denver, Aurora, Corps of Engineers	$12,100,000	5% Complete

PLANNING PROGRAM ACTIVITIES

by Ben Urbonas
Chief, Master Planning Program

PLANNING PROJECTS

There was a very active master planning program at the District during 1988 and we expect the pace to pick up in 1989. The accompanying table titled "STATUS OF PLANNING PROJECTS" summarizes what is being done at this time and what we expect for next year. As always, we appreciate the continued support of this program by the various local governments and the fine work by the many consultants helping us to plan for the future.

STATUS OF PLANNING PROJECTS

Project	Sponsors	Consultant	Status
Big Dry Creek (ADCO) Update	Westminster, Broomfield, Adams Co., Jefferson Co. Airport	Muller Engineering	30% Complete
Gunbarrel Area	Boulder Co., Boulder	Boyle Engineers	Completed in 1988
Thornton Criteria	Thornton	WRC Engineers, Inc.	In Review by City
Adams Co. Criteria	Adams Co.	WRC Engineers, Inc.	In Review by County
Boulder Criteria	Boulder	WRC Engineers, Inc.	In Review by City
Westminster Criteria	Westminster	WRC Engineers, Inc.	In Review by City
Bear & Mt Vernon Creeks	Morrison, Lakewood Jefferson Co.	Muller Engineering	90% Complete
Cottonwood Creek - Arap. Co.	Arapahoe Co.	HCE, Inc.	70% Complete
Dry Creek (ADCO) - North	Thornton, Adams Co.	Wright Water Engineers, Inc.	Getting started
52nd & Pecos to S. Platte & Clear Creek	Adams Co.	Hydro-Triad, Ltd.	90% Complete
First Cr. & Irondale Hydrology	Adams, Co., Aurora, Brighton, Denver, Commerce City	Wright Water Engineers, Inc.	Completed in 1988
Second & Third Cr. Hydrology	Adams, Aurora, Brighton, Denver, Commerce City	Kiowa Engineering, Inc.	Completed in 1988
First Cr. & Irondale M.P.			40% Complete
Second & Third Cr. M.P.			30% Complete
Clear Creek Update	Adams Co.	David J. Love & Assoc.	Completed in 1988
Leyden Dam Feasibility Study	Arvada & Farmers Highline Canal & Irrigation Co.	McCall, Ellingson, & Morrill, Inc.	90% Complete
Little Dry & Piney Cr. (Arap Co) Stability Plan	Arapahoe Co.	Greenhorne & O'Mara	90% Complete

TECHNOLOGY TRANSFER

Early in 1988 we participated in sponsoring a short course with the University of Colorado at Denver on the use of CUHPE and UDSWM. Course attendance exceeded 30 and included many from outside the Denver area and some even came from outside of Colorado. Drs. Guo and Hughes are at this time developing a new course on advanced uses of CUHPE/PC and UDSWM2-PC. If there is an interest in this type of short course, the District will continue to support their development. For further information call Dr. Guo at his UCD office (tel. no. 556-2831) or his answering service (798-4936).

SOFTWARE

The District, Arapahoe County, Adams County, Aurora, Boulder County, Greenwood Village, Jefferson County and Littleton are contributing funds in 1988 toward a project that will eventually translate all the technical sections of the Urban Storm Drainage Criteria Manual into Menu driven PC software. We are negotiating the development of this software with the Colorado Water Resources Research Institute and the University of Colorado at Denver. Other local governments will contribute funds towards this effort in 1989 and possibly in 1990.

Each of the sponsoring governments will participate in a technical advisory committee and provide practical guidance and feedback to the software writers. Because of this broad local government involvement and the practical experience this represents, this software should be truly user oriented. Despite widespread local funding support, the work will be done with a modest budget. It is the intent, however, to make this software available to any engineer or organization practicing within the District for a relatively small cost to encourage its use.

Activities *(continued from page 2)*

Association annual meeting in Denver in October.

Mark Hunter, Chief, Maintenance Program

- Participated in a 4-day short course, "Understanding and Applying Storm Water Management Techniques" sponsored by the University of Wisconsin. Presentation was titled, "Storm Water Management Facility Maintenance".
- Contributed a paper titled, "Maintenance of Storm Conveyance Structures" to the *Manual of Practice for the Design and Construction of Storm Drainage Systems,* to be published by ASCE in 1989.
- Gave a presentation titled "Creative Channel Stabilization and Flood Protection" at the 1988 Colorado Trails Symposium in Boulder in May.

Paul A. Hindman, Project Engineer, Maintenance Program

- Represented the District and ASCE as sponsors in organizing and presenting a two-day Urban Runoff Water Quality Seminar in September titled, "Reality in the Face of Chaos".
- Chaired the 1988 Water Resources Group.
- Contributed to preparation of the *ASCE Manual of Practice for the Design and Construction of Storm Drainage Systems.*

DISTRICT FLOOD CONTROL FACILITIES PUT TO TEST THE GOLDSMITH GULCH FLOOD OF AUGUST 17, 1988

By Kevin G. Stewart, Project Engineer
Floodplain Management Program

Introduction

During the late afternoon of August 17, 1988, very intense rainfall occurred in the vicinity of the Denver Tech Center forcing a rush hour closure of southbound I-25. The storm also caused significant flooding along Goldsmith Gulch through Denver and received a considerable amount of news media attention.

The thunderstorm was centered near the intersection of I-25 and East Belleview Avenue and dumped between 2- and 3-inches of rain within a 1-hour period. This article focuses on the events of that day by highlighting weather forecasting activities, evaluating how existing flood control facilities performed, reporting actual flood damages and providing a retrospective look at what might have happened if conditions had been different.

Location

Goldsmith Gulch is a left bank tributary to Cherry Creek with its confluence point located just upstream of Monaco Boulevard. The Goldsmith Gulch drainage basin is approximately 7-miles long and 1-mile wide. The basin parallels I-25 on the east with I-225 essentially bisecting the basin on the north side of the Denver Tech Center. Goldsmith Gulch drains approximately 3.5 square miles at its crossing with I-225 and 8.0 square miles at its confluence with Cherry Creek.

The headwaters of the drainage basin are located within unincorporated Arapahoe County just south of East Arapahoe Road. The drainage basin is almost entirely developed and has numerous major road crossings. Goldsmith Gulch floodplains impact Arapahoe County, Greenwood Village and the City and County of Denver.

Drainage and Flood Control Facilities

The majority of the drainage basin is urbanized and collects storm runoff through a network of streets and storm sewers. Due to the nature of these storm drainage facilities and the narrowness of the drainage basin, surface runoff is rapidly conveyed to the Goldsmith Gulch channel.

Numerous drainage and flood control facilities exist along the major drainageway. In addition to major street crossings, certain reaches of Goldsmith Gulch have been channelized. George Wallace Park is located between East Belleview Avenue and I-225 and represents one of the most attractive features along the watercourse. A major flood control facility known as Temple Pond is located within George Wallace Park immediately upstream of where Union Avenue crosses the gulch. This facility was completed in 1986, and was jointly funded by the Goldsmith Metropolitan District, the City and County of Denver and the Urban Drainage and Flood Control District. In 1987, a self-reporting rain and stage gauge was installed at Temple Pond as part of the District's ALERT flood detection network. This automated gauge was operating on August 17, 1988.

Downstream of I-225, Goldsmith Gulch crosses Quincy Avenue and flows through Rosamond Park. Downstream from this point, an improved open channel carries flows to the Hampden Avenue crossing. A short distance downstream, Dartmouth Avenue and the Highline Canal cross the gulch. Storm drainage is conveyed by a 36-inch RCP beneath the Highline Canal. Flows frequently exceed the capacity of this 36-inch concrete pipe and discharge directly into the canal, which also has limited hydraulic capacity.

Downstream of the Highline Canal, Goldsmith Gulch flows through Bible Park. Yale Avenue crosses the gulch and runs adjacent to the northern boundary of Bible Park. Between Yale and Iliff Avenues, Goldsmith Gulch is comprised of a limited capacity open channel. Between Iliff and Evans Avenues, the gulch is confined to a limited capacity box culvert underneath an apartment complex and shopping center area. An improved grass-lined channel conveys flows between Evans and Jewell Avenues. From Jewell to Monaco the gulch flows through a combination of grass-lined and concrete rectangular channels having very limited capacity. From Monaco to the Cherry Creek confluence, Goldsmith Gulch consists of an unimproved channel.

The Flood

Special efforts were made by the District following the August 17 flood to document the experience. Leonard Rice Consulting Water Engineers (LRCWE) was contracted to survey the flooded area, take photographs, and document their findings. During the event, data was collected in real-time via radio transmissions from the Temple Pond rain/stage gauge. Also, a District staff member videotaped the flood as it occurred at various points along the gulch. Numerous newspaper accounts and television coverage also provided valuable documentation of the event.

The flood forecasting activities which preceded the event are also of interest. The consulting meterorological firm of Henz Kelly and Associates (HKA) is contracted by the District to provide area-wide flash flood predictions for events such as this. HKA forecast services are intended to supplement

Surveying high water marks after the flood.

National Weather Service activities by maintaining contacts with the various local emergency response agencies. HKA is also responsible for updating the District's Weather Bulletin Board which is accessible to the agencies involved with the District's Flash Flood Prediction Program.

The following paragraphs highlight the events of August 17 preceding and during the flood:

9:55 a.m. — The first Bulletin Board message was received from HKA. The message indicated that there was adequate low level moisture to cause potential problems later in the day. A quantitative precipitation forecast (QPF) was included in the morning message calling for possible rainfall amounts of 1-inch in 20-minutes, 2½-inches in 1-hour with peak rainfall totals of 3- to 4-inches possible. Storms could last for 1½-hours at any one location.

2:30 p.m. — HKA updated the Bulletin Board noting that temperatures were remaining cool and that the flooding risk had significantly diminished from the earlier outlook. HKA also indicated that they were not ready to totally rule out the possibility of an event.

3:14 to 3:55 p.m. — HKA telephoned internal alert messages (MESSAGE 1, TYPE 2) to local government contact points within Douglas, Arapahoe, Denver and Jefferson Counties. Messages were not issued for Adams or Boulder Counties but monitoring would be continued for these areas. Lowry Air Force Base, the City of Aurora and the National Weather Service were also notified. A MESSAGE 1, TYPE 2 is a standard UDFCD message calling for possible flash flooding of intersections, low-lying areas and small streams.

3:56 p.m. — Bulletin Board update was received from HKA stating that internal alert messages valid until 10:00 p.m. were issued for Douglas, Arapahoe, Denver and Jefferson Counties calling for thundershowers with potential rainfall amounts of 1- to 2-inches in 1-hour.

4:00 p.m. — Rainfall was occurring within the District east of Cherry Creek Reservoir, but no rain was being reported within the Goldsmith Gulch drainage basin. Only traces of rain were reported by the District's ALERT gauging network with the first rainfall report of 0.04-inches coming from the Utah Park gauge at 3:17 p.m. Utah Park is located within the Westerly Creek drainage basin which is located generally north and east of the Goldsmith basin.

4:30 p.m. — The Temple Pond rain gauge reports the first trace of rainfall. Only three other ALERT gauges in the upper Westerly Creek basin had reported rainfall by this time. No intense rainfall activity was occurring in the area monitored by ALERT gauges. The most intense rainfall at this time was east of I-225 in Aurora and Arapahoe County.

4:45 p.m. — Intense rainfall activity picks up at Temple Pond with 0.20-inches reporting in the last five minutes.

4:51 p.m. — First rainfall rate alarm is triggered at the District's ALERT Base Station by the Temple Pond gauge. Rainfall rate alarm criteria has been user specified at 0.5-inches per hour.

5:00 p.m. — The National Weather Service issues a Special Weather Statement noting that thunderstorms with locally heavy rain have developed over southeast Denver and that the heavy rain will be spreading throughout the rest of metro Denver area within the next two hours. The statement notes that 1- to 2-inches of rain has fallen in about 1-hour over Aurora which caused flooding of intersections, underpasses and low-lying areas making driving difficult.

5:02 p.m. — Second rainfall rate alarm is triggered at Temple Pond and rapid increases in flows are being reported by the stage gauge. Since rainfall began at 4:30 p.m., the water surface has risen 3.8-feet and the detention facility is discharging a flow rate of 390 cubic feet per second (cfs).

5:13 p.m. — The flow rate at Temple Pond has just doubled in the past 10-minutes and is now discharging approximately 800 cfs.

5:30 p.m. — The heaviest rainfall activity is over at Temple Pond. Within the last 50-minutes, 1.95-inches of rain had fallen at the gauge with a peak 10-minute rainfall of 0.63-inches occurring between 4:55 and 5:05 p.m.

5:39 p.m. — The Temple Pond stage gauge peaks at a discharge of 1250 cfs and a stage of 12.6-feet above the invert of the twin 96-inch culverts.

5:46 p.m. — Temple Pond stage gauge fails. Pressure transducer electronics get wet and erroneous reports begin.

The Morning After

The automated rain and stage gauge at Temple Pond did an excellent job of reporting the flood event up to the point where the stage sensor (pressure transducer) failed. The accompanying figure shows the discharge hydrograph for Temple Pond with a peak discharge of approximately 1250 cfs. The figure also shows incremental rainfall for 10-minute periods reported by the gauge. The storm lasted for approximately 90-minutes with the peak rainfall activity occurring within a 40-minute period. The point rainfall frequency at Temple Pond was estimated to be a 25-year event (4% chance of occurring annually). The table which accompanies the figure shows the peak rainfall intensities forecast by HKA compared with the actual rainfall amounts reported by the gauge. The 10-, 30- and 60-minute rainfall amounts noted for the 9:55 a.m. forecast were calculated using a numerical model developed by HKA based on data available the morning of August 17. The 20-minute and 90-minute amounts were taken from the morning Bulletin Board message.

From the field data collected by LRCWE, and from news media reports, the District estimates that the heaviest rainfall likely occurred west of the Temple Pond gauge. The District is in the process of having radar film loops evaluated to identify the heaviest portions of the storm and its location relative to the Goldsmith Gulch drainage basin. National Weather Service archiving procedures have delayed making such information available for this article.

A general synopsis of the August 17 event has been compiled from the documentation available. For the most part, only a limited amount of flooding occurred south or upstream of East Belleview Avenue. No major damages were reported in this area. Evaluation of the radar data is expected to show that the rainfall in the upper portion of the drainage basin was of a much lesser magnitude and that the storm was very localized in the Denver Tech Center area.

Below I-225, a District maintenance construction project was damaged through the Rosamond Park area. Erosion damages occurred and losses were sustained by the contractor.

Further downstream, at least two residences had water in their basements and received peripheral property damage. Parking lots were flooded at a condominium complex and the floodwaters came very close to damaging a number of units.

Flows entered the Highline Canal just downstream of the East Dartmouth Avenue crossing of Goldsmith Gulch. Overtopping of the Highline Canal occurred at five locations but minimal damage was noted. Since the Highline Canal was essentially empty at the time of the flood, significant benefits were provided by the canal carrying away potentially damaging flows.

Flows leaving the Bible Park area came within 6-inches of overtopping Yale Avenue. The channels, conduits and crossing structures downstream of Bible Park flowed very close to maximum capacity and no major damages were reported.

In Retrospect

Floodplain occupants along Goldsmith Gulch can consider themselves most fortunate on August 17. If Temple Pond had not existed, and if the Highline Canal had been carrying irrigation water at the time of the storm, flood losses would have been much higher. Also, floodplain occupants can be thankful that the storm was localized and not widespread. If the event had covered more of the basin, the flood losses would have been substantially greater, given the same hydraulic conditions.

Denver is fortunate that the August 17 event was not more serious. The lessons learned from that day will prove beneficial in handling future flooding situations. The District would like to recognize the contributions made by the various agencies and individuals involved with flood warning, emergency operations, damage documentation and technical evaluation for the August 17 flood. This experience will lead to improved flood warning capabilities and future flood control improvements for Goldsmith Gulch and other major drainageways within the District.

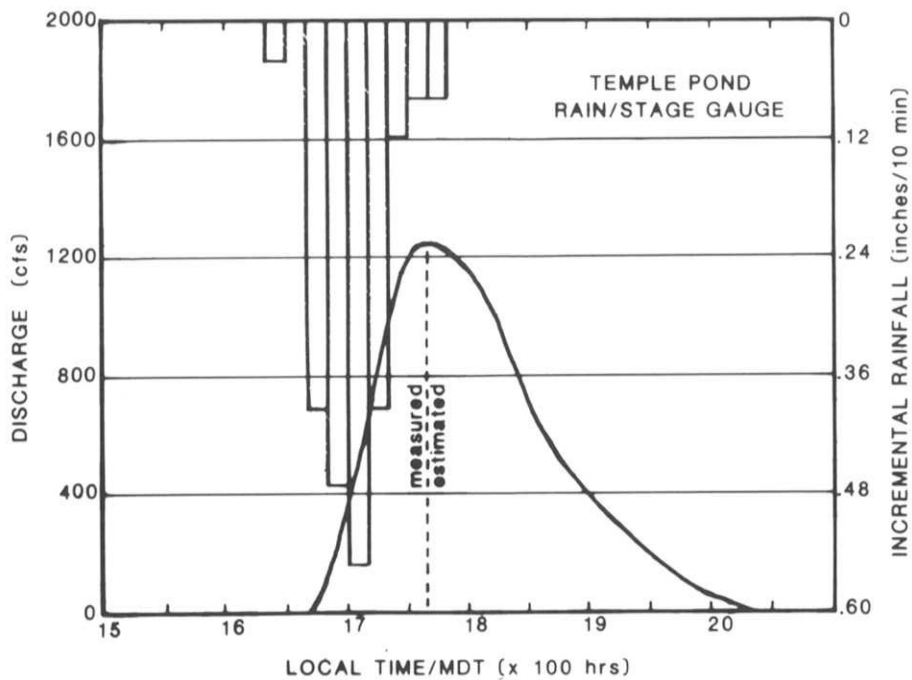
The Jersey barriers along I-25 caused a major obstruction to drainage forcing southbound traffic to be halted and rerouted. Serious drainage problems occurred west of I-25 as a result of the locally intense rain. While flood damages were reported, it should be noted that this area is not within any identified floodplain or along any major drainageway. The heavily developed land west of I-25 represents a remote area tributary to Goldsmith Gulch which must drain across the freeway. Existing storm drainage facilities were inadequate to handle the storm runoff.

Along Goldsmith Gulch between East Belleview Avenue and I-225, existing facilities performed well with only minor erosion damage occurring. Clean-up activities in George Wallace Park began the next morning. By noon that day, there was little evidence that a flood had occurred through the park area.

The Temple Pond detention facility performed well, releasing an estimated peak discharge of 1250 cfs. The peak stage was confirmed by field survey on August 18 with floodwaters reaching an elevation 3.3-feet above the headwall of the outlet structure (twin 96-inch CMPs). Calculations indicate that the facility received a peak inflow of more than twice its release rate.

Downstream of Temple Pond, the I-225 box culvert flowed very close to its maximum capacity. The I-225 culvert is capable of handling approximately a 10-year discharge. It is obvious that Temple Pond proved its worth on August 17 and that damages downstream would have been much worse if the detention facility had not existed.

Event of August 17, 1988



QUANTITATIVE PRECIPITATION FORECAST FOR AUGUST 17, 1988

Duration	Forecast Time: 0955L	Forecast Time: 1543L	Measured Rain Start: 1640L End: 1735L
10 min.	0.7"		0.67"
20 min.	1.0"		1.11"
30 min.	1.8"		1.50"
60 min.	2.5"	1" to 2"	2.07"
90 min.~	3" to 4"		2.17"

MAINTENANCE OF STORM DRAINAGE FACILITIES

By Mark R. Hunter
Chief, Maintenance Program

Introduction

It can be done now or it can be done later, but it's inevitable. Storm drainage systems must be maintained. They are not self-healing. A well-maintained storm drainage system will be ready to convey the runoff from the next storm with minimal damage to the storm drainage facilities. A poorly maintained drainage system may not be able to function at its design capacity and could be damaged by the runoff. For example, an unmaintained drainageway can quickly become overgrown with vegetation or littered with urban debris. The loss of conveyance and possibility for plugging are evident. The increases in potential repair costs and liability exposure are less obvious, but no less serious.

Because storm drainage systems function intermittently and seldom at full capacity it is all too easy to defer maintenance activities. If a storm drainage program is to fulfill its purpose it must include active maintenance of the drainage system. It is too late to repair the damage from the last storm or to do preventive maintenance if storm clouds are again gathering over the basin.

Maintenance Objectives

A thorough drainage system maintenance program will provide for scheduled maintenance activities and will also accommodate unscheduled work that is necessary after Mother Nature tests the system. Staff from the maintenance department should be involved in all aspects of a drainage system; from planning and design through construction. Maintenance considerations may not receive adequate attention if maintenance personnel are not involved in the design, review, and construction phases of a drainage project. The general goals of a maintenance program should include the following:

1. Have a voice in drainage project planning and in design review in order to facilitate maintenance activities.
2. Participate in construction progress meetings to determine if maintenance-oriented facilities are being built as called for in the design.
3. Regularly inspect facilities to monitor their effectiveness and need for repairs.
4. Keep drainage systems from falling into visual disrepair. Aesthetics is important within the community. A respectable-looking drainage facility is less likely to attract vandalism and garbage dumping.
5. Reduce life-cycle costs through effective design review, timely maintenance activities, documentation of crew and equipment productivity, and analysis of repair costs and longevity.
6. Repair deteriorated facilities before major damage or failure occurs.
7. Have drainage systems repaired, cleaned, and ready to function before the next rainy season arrives.
8. Repair and maintain facilities as necessary in order to insure that they are capable of operating at full design capacity.

Life-Cycle Stage of a Storm Drainage System

All improved storm drainage systems pass through three stages in their life-cycle. Those stages are:

1. Design and Construction
2. Drainage Service
3. Rehabilitation

If a drainage system includes many structures and man-made features, the stages are quite separate and distinct. The stages are less obvious and less important for streams that have been only slightly modified by man. The higher the degree of improvement to be done to a drainage channel the more imperative it is that maintenance personnel be involved in every stage. A natural stream requires nothing from man. It is only when man requires something from the stream, usually in the form of right-of-way encroachment and floodplain modifications, that he becomes responsible for future impacts caused by the stream.

The "design and construction stage" is short but it is a period of much activity with far-reaching affects. It is the beginning of the life-cycle for the drainage system. The maintenance-oriented decisions made during this stage will dictate much of what happens during the other two stages.

The "drainage service stage" will be long and uneventful if maintenance concerns are given full consideration during design. During the drainage service stage the drainage system will be functioning as designed. Maintenance activities will be motivated by the desire to extend the service life as much as possible. Little or no modification is made to the drainage system during this stage.

All drainage systems will eventually pass through a "rehabilitation stage." Facilities that are storm-damaged or simply worn out will need repair. As long as the hydrology and hydraulics are still valid the system can be rehabilitated and returned to the drainage service stage. The more comprehensive and maintenance-oriented the original design, the more likely it is that the system will need only rehabilitation rather than complete re-design and capital construction.

Maintenance of Open Channel Drainage System

Many factors contribute to making open channel drainage systems desirable when compared with other systems. Those same factors need careful attention from maintenance personnel during the three life-cycle stages of a drainage system. The stages are shown below with an associated list of maintenance factors that should be examined.

Design and Construction Stage

1. Access — Vehicle accessibility is vital to the maintainability of a drainage system. Ramps leading into channels and/or all-weather trails paralleling the system are frequent multi-purpose designs. Access ramps and trails should have traffic control barriers to keep unwanted traffic from using the trails while still allowing pedestrian movement.
2. Side slopes — Grass-lined channels must have slopes that are steep enough to drain toward the channel and yet are gentle enough to allow vegetation to be established and to permit mowing and clean-up activities.
3. Vandalism — Drainage facilities can be attractive nuisances and can be damaged by those who use the area. Preventive measures may be necessary to keep graffiti off walls, to keep rock riprap from being relocated, or to keep gabion baskets from being cut open.
4. Trickle channel — Base flow

erosion damage continues day after day. The cumulative effect can be dramatic. If the soils are erodible it may be justified to install a trickle channel to halt the erosion. Pay attention to the potential for erosion immediately outside the trickle channel during intermediate runoff events.

5. Localized erosion — There are several locations that can suffer erosion and subsequently need increased maintenance work. Design calculations will give some guidance in solving erosion problems. A practical review of the design plans may reveal the need for additional erosion protection in the following places:
   a. All transitions, such as changes in cross-section or changes in channel lining material.
   b. At the outside of curves where flow velocities are higher.
   c. At the outlet of all tributary storm sewer pipes.
   d. On the bank opposite all tributary pipes and channels.
   e. Downstream from drop structure energy dissipation basins.
   f. Downstream of bridges and box culverts.
6. Toe protection — Localized scour or general degradation can quickly lower the bottom of a channel. Erosion protection facilities must have deep toe protection or they can fail by being undermined.
7. Rundowns — All drainage systems have many small capacity tributaries. Runoff events can damage these tributary connections as well as the main channel if the connections aren't built to withstand the erosion impact.
8. Trash racks — These structures do exactly what they are designed to do—catch debris. For that reason the trash rack should have a clear opening area equal to at least four times the area of the pipe being protected. The bars should be spaced to allow small debris to pass through yet catch large material. Arrange the bars to facilitate cleaning and to allow the debris to float out of the way as the water level rises.
9. Sediment traps — If called for in the design they will certainly need regular silt removal in order to protect the downstream facilities. Sediment traps can effectively reduce downstream maintenance needs.

Drainage Service Stage

1. Mowing — In urbanized areas the drainage channel should be mowed often enough to control weeds and to show community responsibility. For native grass vegetation in a semi-arid climate three to six cuttings per year is satisfactory.
2. Debris control — Debris blockage at drainage structures often contributes to flooding problems. Trash racks and debris traps help reduce the problem if they function properly and are regularly cleaned. Regular debris removal along the length of the drainage system also helps. This should include trimming and thinning of trees if they encroach on the drainage channel or if they have become overgrown.
3. Inspection — An annual inspection of drainage facilities will detail long term changes in the system and will highlight needed maintenance work.
4. Silt removal — Some silt accumulation in stilling basins and around channel obstructions is inevitable. It does no harm in limited amounts. Silt should be removed if it is severe enough to alter the water surface or affect the function of drainage facilities such as drop structures. Silt accumulations can also cause trouble by supporting undesirable vegetation.
5. Trail repair — An annual effort to repair damaged trail sections will result in guaranteed maintenance access and better pedestrian use. The best time for repairs is right after the cold/rainy season.

Rehabilitation Stage

With regular inspection reports a drainage maintenance department will be aware of it when a drainage system is in need of repairs. If the problems are repaired promptly the facility can be returned to service with little threat of complete failure. It is usually less expensive to repair a facility today than to rebuild it tomorrow. Listed below are many of the typical problem areas that signal the need for rehabilitation.

1. Hard-lined trickle/low flow channels — local undermining of the structure or secondary channel erosion parallel to the main channel.
2. Soft-lined trickle/low flow channels — Random bank failure and bottom degradation that is unsafe or threatens other improvements.
3. Tributary channels and pipe outlets — Erosion from the receiving channel leading back to the tributary outlet and/or erosion under the outlet structure.
4. Drop structures and grade control structures — Frequent problems include erosion damage in and around the energy dissipation basin and around the outside edges of the structure. Physical damage can occur to the structure in the form of uplifted or depressed concrete, broken gabion baskets, and displaced riprap.
5. Channel banks — Bank protection such as riprap, slope paving, or retaining walls can be undermined by local scour or general degredation if not "toed-in" deep enough. Grass-lined banks can lose vegetative cover and can suffer spot erosion which may quickly worsen.

In summary, maintenance of drainage and flood control facilities is a must. Participation of maintenance personnel in the design and construction of facilities can assure a more easily maintainable system.

A recently rehabilitated channel in Westminster.

South Platte River Program Notes

by Ben Urbonas, Chief
Master Planning Program

Maintenance of South Platte River

Good news! The U.S. Army Corps of Engineers issued a General 404 permit to the District which covers certain restorative maintenance activities. Since its issuance, individual work authorizations are being received with no delays and we have been able to respond to badly needed bank repairs and grade stabilization in a timely manner. Barbara Evans led the effort on our behalf to obtain this General permit and I refer you to her article on this topic in this newsletter for futher details.

This was a productive year for the South Platte River maintenance program. This year we provided routine maintenance assistance (i.e., mowing along trails, trash pickup, debris removal from the channel and tree and shrub pruning along the trails) between Niver Creek on the north and Bowles Avenue on the south. We expect to expand this service further south and north to cover a total of 25 miles. In addition, we contracted for the installation of two grade control "riffle type" structures, and 1000-feet of bank restoration and stabilization in Adams County; one utility crossing buttress, trail repairs and trail drainage improvements in Denver; and the installation of a 10-foot wide maintenance access bridge across Lee Gulch in Littleton. The demand for maintenance assistance on the river is overwhelming and our $470,000 budget in 1988 was only able to address items in greatest need of attention. Nevertheless, the needs on the river are being and will continue to be addressed.

Cooperative Activities

Private and public partnerships have been utilized by many communities to provide for infrastructure needs as development occurs. In our last issue of this newsletter, we reported on such a cooperative project to construct a major drop structure near 88th Avenue. This year the District executed three cooperative agreements: one with Cooley Gravel Company; another with Albert R. Frei and Sons, Inc., also a gravel operator; and a third with Esther Miller for repair of a levee along Mrs. Miller's property. The right-of-way dedications that resulted from these cooperative activities in 1988 totaled 80.8 acres.

In most of the cooperative agreements, the owner also agrees to provide riprap installation with the District buying the rock and working with the owner to revegetate the banks with native riparian vegetation. We are very enthused about this program and the wonderful cooperation we have received from the above listed property owners. Their contribution of easements to this program assures continued maintenance of the river and unobstructed flowage area for the floods that occur.

Capital Improvement Activities

Finishing touches were completed on the 88th Avenue drop structure this year. Although the structural work was finished in 1987, site revegetation with native grasses, willow plantings, and cottonwood trees was completed this year. We received a real shot in the arm when Volunteers for Outdoor Colorado selected the South Platte River as one of their projects this year. These dedicated individuals spent a day last spring planting native flowers, willow and cottonwood to beautify the 88th Avenue site. They did a marvelous job and the District Board passed a resolution acknowledging their unselfish contribution.

The District also contributed funds to a joint project with Denver Parks to replace the maintenance/hiker/biker trail between 8th and 13th Avenues. This section of the trail is very narrow with part of it being timber decking. It not only is too narrow for maintenance access, but is in desparate need of replacement. Thanks to the leadershhip and persistence of Neil Sperandeo of Denver Parks, the replacement project is funded and now is awaiting the outcome of the Central Platte Preliminary Design Study.

The Central Platte Valley is a portion of Denver loosely defined as being between 13th Avenue on the south and 23rd Street on the north. A large portion of area between 13th Avenue and Speer Boulevard is in the 100-year floodplain. The District and Denver are funding a preliminary design study to identify the most appropriate flood control alternative. We expect this study to be completed by mid-1989. The next step will then be to find a way to fund this very significant flood control project.

MEET THE NEW BOARD MEMBERS

SUSAN C. VAN DYKE

Mayor, City of Englewood

Susan began her political career unknowingly in 1983 when she volunteered for a position on the Englewood Urban Renewal Commission. Two years later, she found herself elected to city council for a four year term. Running for mayor was simply a natural progression from her role on city council.

In addition to her mayoral position, Susan teaches in the sports medicine program at Chapman College in Denver, tutors Kinesiology, and is a sport science consultant.

Susan has always been conscientious about volunteering. She has been active in several professional organizations which includes; co-founder and past president of Professionals Against Fitness Fraud, Educators for Athletic Equity, and a recent board member for the Colorado Association for Health, Physical Education, and Recreation.

Life may not change drastically for the citizens of Englewood, but Van Dyke hopes to improve government efficiency and put greater controls on the budget. Maintenance of a traditional quality of life plus the revitalization and positive redevelopment of Englewood's downtown area are her major goals as mayor.

Flood Plain Management Program Notes

by Bill DeGroot, Chief, Flood Plain Management Program

The past year has been a very slow one as far as new development in the Denver area is concerned. Consequently, there have been many fewer requests for us to review development proposals and fewer requests to approve design or construction projects for maintenance eligibility. This development slowdown has given us the opportunity to address a few other areas which had been somewhat neglected during the last development boom.

Flood Warning

One area where we have devoted a great deal more attention in the last year is in flood warning. Project engineer Kevin Stewart has spent almost full time working on the installation of a number of ALERT gauges and the formulation and implementation of new flood warning plans for Westerly Creek and Ralston/Leyden/Van Bibber Creeks. Kevin also developed simplified decision making procedures for identifying critical rainfall thresholds and responding to urban flash floods, which he presented to an ASCE conference this year.

Construction Observation

The construction slowdown also gave us the opportunity to test a new procedure for determining the eligibility for District maintenance assistance of projects constructed by others (usually developers or local governments). We have retained the consulting engineering firm of Merrick and Co. to provide periodic construction observation services of construction projects for which the designs have been approved by the District. Basically, when construction is in full swing, an engineer from Merrick will visit the construction site once or twice a week, observe construction, point out problems to us and the local government representative, and eventually recommend to us whether or not construction has been accomplished in accordance with the approved plans and specifications and should be accepted for District maintenance eligibility.

Although there have been few construction projects to observe, we have found the process to be very worthwhile. Our observers have prevented numerous serious construction errors and have made it much more likely that we will accept a given construction project for maintenance eligibility.

Inadvertent Detention

In the early years of the District, several master plans, flood plain delineations, and even a construction project were completed where credit was taken for inadvertent detention provided by non-flood control reservoirs not controlled by any public agency for flood control purposes. Over the last 18 months we have been identifying every District project where this was done, and formulating for each case, to either revise the project so that the detention is no longer relied upon or to take steps toward obtaining sufficient control of the detention facility to assure its flood routing benefit.

One of the approaches we have used is what we call the "adequate assurances" agreement. This agreement, between the District and the local governments benefitting from the inadvertent detention, commits the parties to take whatever steps are available to them to protect the flood routing capability of the facility should the owner attempt to make changes which would reduce or eliminate the flood routing benefit. There were several reasons for devising the adequate assurances agreement approach. Some of these reservoirs and embankments are so large and so permanent that it is hard to "pretend" that they don't exist, and, as long as they do exist the local governments get what is, in effect, free flood control benefits. On the other hand, spillways are revised, and reservoirs and embankments do disappear from time to time. In fact, Colorado Revised Statutes specifically allow reservoir owners to pass flood inflows without diminution.

The genesis for the agreement concept was two actual cases in which the District and local governments were able to protect flood routing benefits which were endangered. The first case was Englewood dam. This was a privately owned dam and the owner was under order to either enlarge the spillway or breach the dam. The owner/developer gave the dam to the District in return for a waiver of on-site detention requirements and other considerations, and the District and the benefitting local governments built an enlarged spillway.

The other case was Maple Grove Reservoir, a water supply facility where again the owner (The Consolidated Mutual Water Company) was under order to enlarge the spillway. Consolidated agreed to work with the District and the benefitting local governments to revise the spillway design to maintain the same flood routing characteristics up through the 100-year flood, with the District and the local governments paying the additional costs.

Based on these two cases, we felt that we had demonstrated that the adequate assurances concept would work. The Colorado Water Conservation Board has accepted this approach in their rules and regulations, and has designated and approved a 100-year flood plain which has an adequate assurances agreement in place.

Another approach we are using is to request that the State Engineer "tag" the records of each reservoir under his jurisdiction so that the District and benefitting local governments are notified whenever an owner submits a proposal which would adversely affect flood routing capability. This will give us the opportunity to approach the owner to attempt to work out a way to preserve the flood routing capability. We are also sending an annual notice to all owners requesting that they notify us if the are contemplating changes to their facilities so that we can work with them on a mutually beneficial alternative.

Finally, we are talking to several owners on specific proposals to formalize flood routing benefits of reservoirs and embankments. We are encouraged by our progress to date, although it will be a few years before we will really feel that we have this particular problem under control.

What's in a Name?

When the District and the City of Broomfield started construction of a flood control project earlier this year, a sign was erected at the project site. The sign indicated construction of a "detention facility." Broomfield City Hall was inundated (pardon the expression) with phone calls protesting the construction of a jail in the neighborhood.

The objectionable phrase was quickly painted over, construction proceeded, and the project is now complete and ready to "detain" flood waters and not hardened criminals.

imagery, weather radar, upper air soundings, other surface data, etc.) early flood warning capabilities are greatly enhanced.

Generalized Urban Flash Flood Guidance Developed and Tested

As the District's ALERT gauging system continued its expansion with new flood detection networks and warning plans coming on-line, special focus was given in 1988 concerning other elements of flood warning and response. With new data sources rapidly increasing, it is clear that efficient ways of managing the data are needed and that the communications aspect of flood warning deserves much more attention. Emergency managers and technical support personnel can become overwhelmed by the excessive amount of available data. This can lead to confusion and delays in making critical decisions. Communication methods must be improved by focusing on specific user needs. Confusing terms and unnecessary dialog need to be avoided by technical personnel when working with sheriff and police dispatchers.

In addition to improving communications, it also became apparent that technical personnel involved with flood warning activities needed simplified procedures for recognizing serious situations. As a first step, small urban watersheds were targeted for developing such procedures. Critical rainfall thresholds capable of producing various types of flooding events were identified. Emphasis was placed on how to recognize flash flood potentials and maximize warning lead times. The ultimate goal in developing such criteria is for emergency managers to become more proactive in responding to urban flash floods as opposed to being forced into a reactive mode of operation. Due to the nature of flash floods on small urban streams, this concept presents a difficult challenge.

The results of this year's efforts have been presented in a paper entitled: "Effecting Timely Responses to Urban Flash Floods" authored by Kevin Stewart. This paper was presented at two conferences this year, an ASCE conference at Colorado State University in Fort Collins and a National Weather Association meeting held in Denver. The paper

Table 1

2-HOUR CONVECTIVE STORM CHARACTERISTICS
FREQUENCY/DEPTH/DURATION BREAKDOWNS
(INCHES)

Freq.	Total 2-hr Rain	10-min. maxs. Low-Avg-High	30-min. maxs. Low-Avg-High	60-min. maxs. Low-Avg-High
2-YR	1.2	0.3-0.4-0.5	0.6-0.8-1.1	0.8-1.0-1.2
5-YR	1.6	0.4-0.5-0.7	0.8-1.0-1.4	1.1-1.4-1.6
10-YR	1.9	0.5-0.6-0.8	1.0-1.2-1.7	1.3-1.6-1.8
25-YR	2.2	0.6-0.7-0.9	1.1-1.4-1.9	1.5-1.9-2.1
50-YR	2.6	0.7-0.8-1.1	1.3-1.6-2.3	1.8-2.2-2.5
100-YR	3.0	0.8-1.0-1.3	1.5-1.9-2.6	2.0-2.6-2.9

describes the dilemma of evaluating and disseminating timely flash flood information and the importance of meterorological forecasts on a mesoscale level. A simplified decision aide was developed for identifying critical rainfall thresholds (see Table 1).

Table 1 can be used in two operational modes, the forecast mode and the observation mode. In the forecast mode relative flood magnitudes can be recognized on a preliminary basis. If an early outlook provides quantitative precipitation forecasts (QPF's) of smaller magnitudes (say less than 1-inch), serious problems are not likely and projected flood conditions will be limited to streets, intersections, and other frequent nuisance areas. Forecasts of greater magnitudes would prompt different states of readiness and permit emergency resource planning to begin at an early stage. In order to effectively use the decision aide in a forecast mode, QPF's must be provided which specify total rainfall amounts, storm duration estimates, and probably peak intensities (e.g. 10-, 30- and 60-minute periods).

During the observation mode, data is collected and displayed in real-time by the ALERT base station. The same decision aide can be used to identify the occurring storm magnitude at any point where an ALERT gauge exists. The data received can be evaluated and extrapolated to other ungauged areas through the use of weather radar and satellite. By recognizing a storm's "signature" in terms of rainfall frequency, expected flood magnitudes can be predicted in real-time. For a given drainage basin and associated watercourse, flood arrival times can be estimated for various hydrologic forecast points and known problem areas using data from previous hydrologic modeling efforts or actual measured runoff events. Combining this knowledge with proper communications, people and equipment resources can be positioned to prevent possible loss-of-life and in some cases, prevent unnecessary property damage.

The paper referenced in this article is available from the District upon request and contains the methodology used to develop the decision making procedures. The paper discusses meteorological forecasting requirements and provides an overview of how to do site specific forecasting by using an actual flood example. ALERT data management and electronic communications are also presented in the paper along with recommendations addressing the "cry wolf" syndrome and other critical aspects of urban flash flood warning programs.

In 1989, the District plans to build on the concept presented in the Urban Flash Flood paper by developing similar procedures for large drainageways and in particular, the major mountain canyon streams affecting the District. In addition, the flash flood decision making process may be automated in 1989 by developing computer accessible text keyed to specific local jurisdictions and major drainageways. Training programs are also being developed to orient public safety officials to the flash flood prediction services being provided. Emphasis will be made on obtaining input from these public safety officials regarding their specific needs for effecting timely emergency responses.

Electronic Bulletin Board Established

Since 1985, the Urban Drainage and Flood Control District has been using electronic mail to obtain hard copies of weather forecasts in conjunction with the District's Flash Flood Prediction Program. Through the 1987 flood season, these messages were relayed by Henz Kelly and Associates (HKA) to a dedicated computer (IBM PC-jr) located at District offices. The messages provided a daily synopsis of the flood potential for areas within the District. For this 3-year period, the HKA communication served to notify District staff of the possibility of a flood occurring later in the day. These messages were typically received a number of hours before standardized internal alert messages were issued to local public safety officials.

In April of 1988, the electronic mail concept was expanded to begin exchanging weather forecasts with the National Weather Service on a routine basis and to make these messages available to the various contact points served by the program (i.e. sheriff's departments, police departments, fire departments, etc.). The District's ALERT Base Station provided the means for the Weather Bulletin Board service at minimal expense. Two phone lines and modems were added making a total of three lines available. The multi-tasking capabilities of the ALERT Base Station were ideal for developing customized access procedures. The Bulletin Board was established for communicating early outlooks and internal alert messages only. User access is restricted to public safety organizations within the District. The intent of the Bulletin Board is to serve the emergency management community by providing critical weather information before situations develop. This allows emergency managers to take early actions such as recognizing resource needs and positioning personnel and equipment well in advance of an actual emergency.

This year, 181 weather messages were relayed by Henz Kelly and Associates through the Weather Bulletin Board. Primary users of the Bulletin Board included Boulder County, Denver, Aurora, Arvada, The Consolidated Mutual Water Company and the National Weather Service. Other public safety organizations were unable to access the Bulletin Board due to the lack of available computer facilities at their respective communication centers. These individual limitations and needs are being recognized and efforts will be made to accommodate all users involved with the District's Flash Flood Prediction Program.

The response to the Bulletin Board service this year has been overwhelming. Processes are currently being refined to include National Weather Service special weather statements, urban flood statements, flash flood watches and warnings as available products through the District's Bulletin Board. These products are currently not available to many local emergency managers since very few organizations currently subscribe to NOAA Weather Wire.

Through the winter season, procedures will be refined for the 1989 Bulletin Board service including standardized messages, dissemination times, customized products for more sophisticated users and specifications for user access restrictions. The District would appreciate any comments or recommendations regarding operational procedures for message dissemination. It is the District's desire to continue improving capabilities in this area, thereby, providing better flood prediction services to local emergency managers.

Satellite Downlink System Aids in Flash Flood Predictions

In July of this year, a VISTA satellite downlink system became the latest asset in the District's Flash Flood Prediction Program. This system was purchased from Kavouras, Inc. of Minneapolis, Minnesota and provides for data ingest of multiple western satellite sectors. The imagery is a high-resolution 64 level gray scale with data being transmitted every 30-minutes in infra-red and visible pictures. The VISTA computer can store up to 24 hours of images which can be played back, a single frame at a time or at animation speeds ranging from one frame every five seconds to thirty frames per second. The VISTA can have up to five satellite sectors for animation. Numerous base maps are available with the largest scale being a 2-mile resolution map covering an approximate 4-state area. The infra-red imagery can be colorized to highlight critical cloud top and ground surface temperatures.

The VISTA system has proven to be a valuable asset in tracking storm systems, estimating arrival times, and providing data for longer range forecasting. Moisture sources and disturbances from the Pacific Ocean, the Gulf of Mexico and inland systems can be easily tracked with this satellite system. Cold fronts, lines of active thunderstorms, probable severe weather systems, and other features can be identified and used in conjunction with other available surface and upper air data to improve forecasting capabilities. Ground features such as the major river valleys and the Colorado front range are recognizable from the system's visible imagery. From this year's limited experience, it is anticipated that the VISTA satellite downlink system will continue to prove its value as future storms and floods inevitably occur.

MORE CONSTRUCTION PHOTOS

Constructing a low flow channel consisting of concrete bottom and boulder sides at Slaughterhouse Gulch.

Sand Creek drop structures incorporate pedestrian crossings.

Tucker Talk *(from page 3)*

Current indications are that the preferred option of EPA will be to limit the initial permit requirement to incorporated jurisdictions larger than the threshold populations of 250,000 and 100,000. In the Denver area, this will mean that only the cities of Aurora, Denver and Lakewood will initially have to apply for storm sewer system permits. The Federal law however, requires EPA to promulgate regulations by October, 1992, that will address all the other municipal storm sewer systems. The net result is that sooner or later all of the metropolitan area will have to respond.

Colorado is a "NPDES" state. That means that Colorado administers the NPDES program instead of EPA. The NPDES program in Colorado is administered through the Water Quality Control Commission (WQCC). The State Department of Health acts as staff support to the WQCC. Since the program will be administered by the WQCC, they also will have to promulgate regulations for the operation of the program. How the timing of the WQCC regulatory adoption process coordinates with the promulgation of EPA remains to be seen. What may create a dilemma for local governments is that the clock will start ticking as far as when applications need to be submitted when EPA promulgates regulations. Will local governments be able to wait until the State also publishes regulations, which may make it difficult or impossible for local governments to meet the Federal time requirements. The failure to submit applications within Federal time limits will place local governments in the position of possibly being sued for violating Clean Water Act requirements.

I have been writing about the NPDES permitting system in the Flood Hazard News for several years; 1988 is no exception and it looks like it will go on for a few years beyond 1988 as a topic of considerable interest.

District Enters Its Twentieth Year in 1989

It does not seem like it, but 1989 will be the 20th year of existence of the Urban Drainage and Flood Control District. Twenty years have taken the District from limited activity in planning to programs dealing with maintenance, design and construction, flood warning systems, a South Platte River Program and many activities associated with those major areas of endeavor. A basic principal of operation still remains. That is, the District does not seek to become a large public works organization in terms of a large staff, owning lots of equipment, having its own maintenance crews, and so on. The District's approach has been and probably will continue to be contracting with the private sector for its needed services. These include engineering, design and planning services, maintenance activities, meteorological consulting, library maintenance and so on. This concept has served us well and I expect the Board will want to continue contracting for the vast majority of the District services.

When the Board of Directors first met in 1969 they had no staff at all. Since that time, the staff has gone from an Executive Director and Secretary to 16 full-time people and 5 part-time student interns. The District's budget for the first full year of operation in 1970 was $290,000. This compares with the 1989 total budget adopted by the Board in October, 1988, of $15,371,800. This reflects active construction, maintenance, master planning, flood plain management and South Platte River programs. If the District becomes involved in stormwater quality that will probably change the direction of some of those program expenditures.

In its 20 years of operation, the District has been fortunate to have an excellent Board of Directors, well-qualified staff and a little bit of luck in terms of avoiding difficult pitfalls. Hopefully, our luck will hold and the District will continue to be a positive and contributing factor in the growth and vitality of the Denver metropolitan area.

NEW STAFF MEMBER

Mike Koger was transferred from a student intern position to a full-time permanent staff member as an Inspector/Technician in the Maintenance Program. The change took place April, 1988. His main activity will be to conduct field inspections for District restoration projects. Restoration work consists of small projects that are done to repair local damage to drainageways. Mike will also manage some of the restoration projects, prepare the supporting documentation, and handle some of the contacts with local governments.

MEET THE NEW BOARD MEMBERS

RAMONA MARTINEZ

Councilwoman, City of Denver

Ramona Martinez was elected to the Denver City Council in May, 1987. She had previously served as administrative assistant to Councilman Sam Sandos, a longtime member of the District's Board. Ramona is a life long resident of Denver. She grew up in west Denver and attended West High School. Ramona continued her education and along with her husband Lawrence, raised three children while being actively involved in community and church affairs.

As a member of the American GI Forum, Ramona was awarded the Outstanding Member for her chapter, and the State of Colorado. She has received the Woman in Community Services Award; Catechist Award, and numerous other certificates of merit. Ramona found the time over the years to serve as a counselor for Job Corp. She taught Religious Education Classes at Presentation Parish, along with serving on several community Boards and committees. Ramona has also worked on a number of political campaigns. She also served as the State of Colorado Democratic Voter Registration Chairperson in 1974.

In 1986, Ramona and her sister started their own business, Uniglobe Advance Travel Agency, which is located in Cherry Creek. Ramona, along with her full time staff, are members of GCIU Local 440. Her husband Lawrence Martinez is an International Representative for GCIU. She is a third generation union member.

Ramona and Lawrence have been married since 1959. They have three grown children and two grandchildren.

THE EFFECT OF RAIN GAGE DISTRIBUTION IN HYDROLOGIC COMPUTER MODELING

by
Michael Jansekok, Civil Engineer
Kiowa Engineering Corporation
and
Ben Urbonas, Chief,
Master Planning Program
Urban Drainage and Flood Control District

INTRODUCTION

Over the last two year period the authors investigated the effects of rain gage density on the accuracy of hydrologic modelling. The basis for this study was the rainfall and runoff data collected in the Harvard Gulch basin, a 3.08 square mile urban watershed in Denver, Colorado. This semi-arid region urban watershed continues to be instrumented with five recording rain gages and two recording flow gages. The data collected since 1979 was used to calibrate the Urban Drainage and Flood Control District's UDSWM2 model. The calibrated model was then used to examine the effects on runoff calculations using a single composite hyetograph for each storm as input instead of using the rainfall data from all five gages as independent input. The calibrated UDSWM2 model was also used to estimate the effects of rain gage density on simulated volumes of runoff and peak flows.

Much of what is written about the effects of gage density and hyetograph compositing methods in computer modelling revolves around synthetically manufactured hyetographs. The authors were fortunate to have access to several years of rainfall and runoff records for a relatively small and stable urban watershed with a high rain gage density. The work by the authors, to be reported in detail in a Master of Science thesis by Mike Jansekok at University of Colorado, attempts to show the variance in runoff calculations that can occur when rain gage density is increased or decreased, and the effects of hyetograph compositing on hydrologic modelling.

Rainfall/runoff data recorded between 1979 and 1987 for the Harvard Gulch drainage basin was obtained from the U.S. Geological Survey (USGS) at the Denver Federal Center in Lakewood, CO. The data were collected under a cooperative agreement between the Urban Drainage and Flood Control District and USGS. Data from two flow gages and five rain gages were used in the investigations. The locations of all gages are shown in Figure 1.

SELECTION AND PREPARATION OF DATA

Seventeen storms were selected for this study based on the following criteria:

1) 5 rain gages and 2 flow gages must be reporting during the storm (i.e., no malfunctioning gages at the time).
2) Minimum recorded rainfall at any rain gage must equal or exceed 0.08 inches during at least one 5 minute period within the storm (i.e., larger storms only).
3) The recorded peak flow at one of the two gages must equal or exceed 50 cubic feet per second.

For hydrologic modelling purposes, the Harvard Gulch Basin was divided into 59 sub-basins, 23 of which comprised the upper basin upstream of Colorado Boulevard. Average values for imperviousness, perviousness, slope, tributary width, Manning's n, etc. were calculated for each sub-basin and entered into the UDSWM2 model. The drainage conveyance system was modelled using a total of 78 conveyance elements, 35 providing drainage for the upper basin. The Thiessen Polygon Method was used to assign each sub-basin in UDSWM2 to each of the five specific rain gages.

EFFECTS OF RAIN GAGE DENSITY ON MODELLING RESULTS

For the total basin, five combinations of rain gage reporting conditions were created to show the effects of rain gage density on peak flow and runoff volumes in computer modelling. Two different scenarios of these five gage combinations were run. One of these rain gage combination scenarios used in this investigation is summarized in Table 1. For the upper basin, three combinations of rain gages were also simulated, but are not described here for sake of brevity in this newsletter. The Thiessen Polygon Method was again applied to assign each sub-basin to each rain gage for each of the Table 1 rain gage combinations.

RESULTS FOR THE TOTAL BASIN ANALYSIS

Effect of Rain Gage Density

To present the variation in modelling results for various combinations of rain gages used, the simulated peak flows and volumes were normalized using the results from the calibrated five rain gage UDSWM2 model. The normalizing method is described by the following equation:

$$V_i = [(R_i - R_{ci})/R_{ci}]\ 100$$

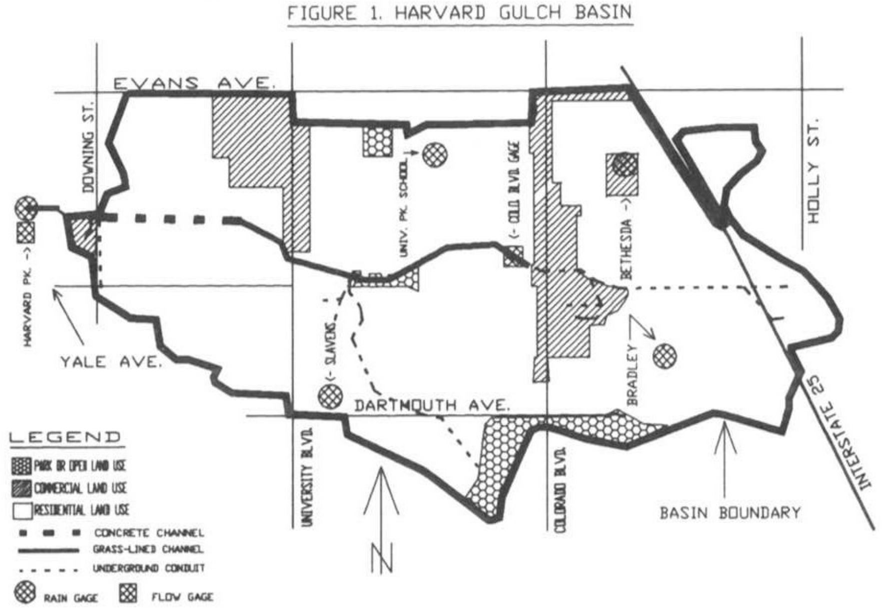
in which, V_i = variance from the calibrated five rain gage peak flow or volume for storm i,

R_i = runoff peak or volume for the test run for storm i,

R_{ci} = runoff peak or volume for the calibrated five gage model for storm i.

As can be seen from Figures 2 and 3, the variations of the simulated peak flows and volumes increased as the rain gage density decreased

FIGURE 1. HARVARD GULCH BASIN



(i.e., data from fewer gages were used as input to model). The variation in the results are summarized in Tables 2 and 3. The largest variations occurred when only one rain gage was used to represent the rainfall over the entire basin. The calculated peak flow and runoff volumes varied by as much as +150 and -100 percent from the calibrated five gage model runs. However, the mean for the 17 storms investigated was found to be within 25 percent of the average obtained from the five gage calibrated model runs, or for that matter from the field recorded data.

Effect of Compositing Rain Gage Records

Rain gage records from two or more gages are often composited into a single input hyetograph as input to hydrologic studied by the authors to see how they may affect runoff simulation results. The five hyetographs were composited directly using the recorded rainfall depth at each clock time interval (i.e., "simple linear"). In addition, the hyetographs were composited using a technique that first shifted the five gage records so the peak rainfall producing time increments were aligned (i.e., "peak preservation compositing"). The rain gage records were composited using both the peak preservation method and the simple linear compositing method and both composite type hyetographs were then used to simulate runoff. The Thiessen Polygon method was employed to assign an area weighting factor to each rain gage hyetograph to come up with composite hyetographs for each storm.

The most notable trend found in this study is the tendency for the composite hyetographs to underestimate peak flows and runoff volumes. The results are summarized in Tables 4 and 5. The variations of peak flows from the calibrated five gage model were observed to be as low as -65 percent and for runoff volumes were observed as low as -20 percent. There was very little difference observed in the results between the two compositing methods investigated. This, however, may be because of the population of rainstorms used in the study (see SELECTION AND PREPARATION OF DATA above).

CONCLUSIONS

Very little difference was found in peak flows and runoff volumes between the two rainfall compositing methods tested, namely the peak preservation method or the simple linear method. Both methods tended to underestimate both the simulated peak flows and volumes when compared to the simulation results using the calibrated five gage model, or when compared to field recorded data.

It is also clear that rain gage density plays a very important role in the accuracy of hydrologic modelling. It was observed that the variations in simulated results increased as gage density decreased. At the same time, it appears that if a sufficient number of rainfall events are used, the averages of peak flows and runoff volumes can be reasonably close to the averages obtained using either multi-gage simulations or the observed data. What is a sufficient number of rainfall events to insure that the averages are realistic has yet to be determined and will probably depend on the type of storms experienced at the site.

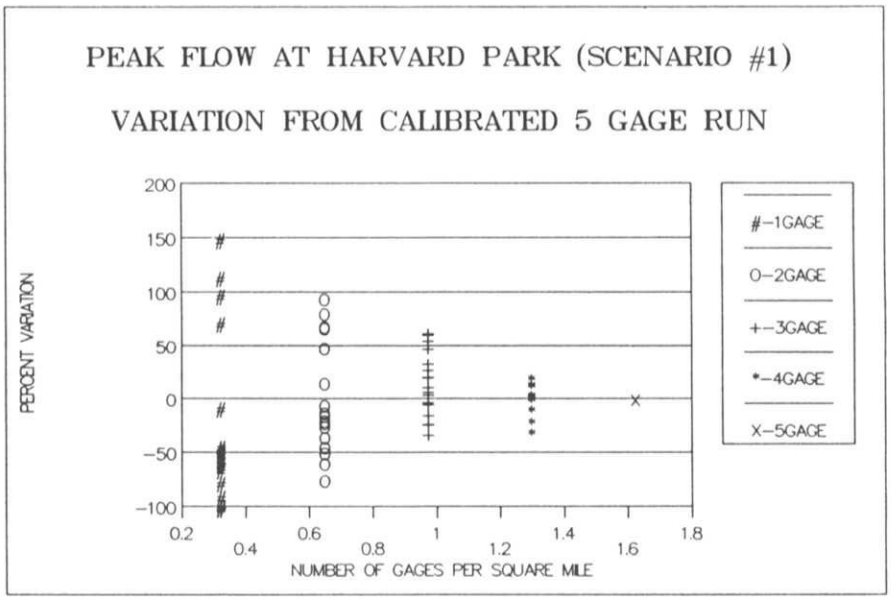


Figure 2

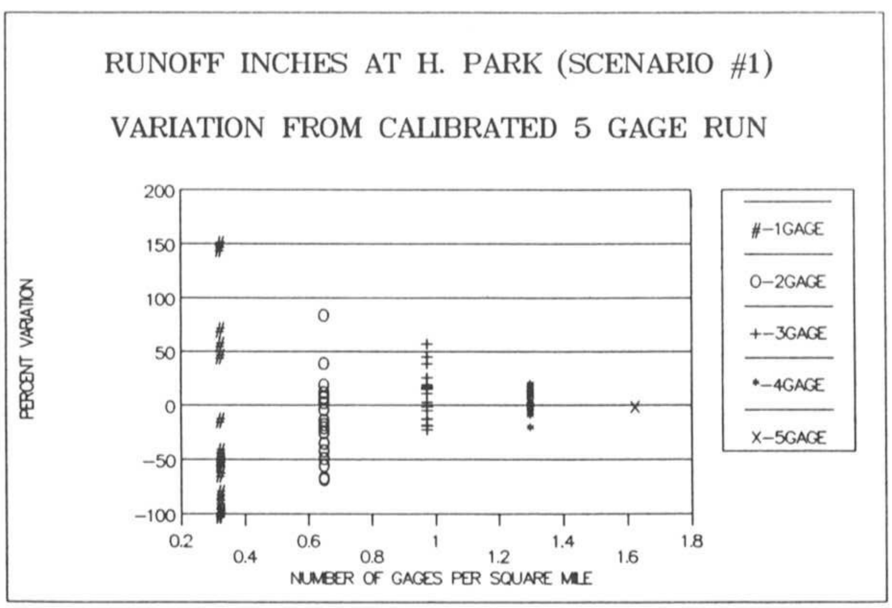


Figure 3

TABLE 1
COMBINATIONS OF RAIN GAGES USED IN MODELLING TOTAL BASIN

1. Harvard Park only
2. Harvard Park, Bradley only
3. Harvard Park, Bradley, University Park only
4. Harvard Park, Bradley, University Park, Slaven only
5. Harvard Park, Bradley, University Park, Slaven,Bethesda

TABLE 2
HARVARD GULCH AT H. PARK — PEAK FLOW
PERCENT VARIATION FROM THE FIVE GAGE CALIBRATED RUN

NO. OF GAGES REPORTING	RANGE OF VARIATION	MEAN	STANDARD DEVIATION
1	-100.00 to 150.00	-24.2	78.5
2	75.3 to 94.5	0.5	51.0
3	32.2 to 63.6	15.8	29.4
4	32.2 to 18.8	-0.9	11.6
5	0.0 to 0.0	0.0	0.0

TABLE 3
HARVARD GULCH AT H. PARK — RUNOFF VOLUME
PERCENT VARIATION FROM THE FIVE GAGE CALIBRATED RUN

NO. OF GAGES REPORTING	RANGE OF VARIATION	MEAN	STANDARD DEVIATION
1	-98.6 to 152.8	-16.5	79.9
2	-66.7 to 185.2	-12.4	38.4
3	-32.2 to 59.4	11.3	22.8
4	-20.8 to 19.1	4.6	10.5
5	0.0 to 0.0	0.0	0.0

TABLE 4
HARVARD GULCH AT H. PARK — PEAK FLOW COMPOSITING RESULTS
PERCENT VARIATION FROM THE FIVE GAGE CALIBRATED RUN

COMPOSITE TYPE	RANGE OF VARIATION	MEAN	STANDARD DEVIATION
Peak Preservation	-65.1 to 4.9	-17.4	18.1
Simple Linear	-60.5 to 9.7	-16.7	18.0

TABLE 5
HARVARD GULCH AT H. PARK — RUNOFF VOLUME COMPOSITING RESULTS
PERCENT VARIATION FROM FIVE GAGE CALIBRATED RUN

COMPOSITE TYPE	RANGE OF VARIATION	MEAN	STANDARD DEVIATION
Peak Preservation	-18.8 to 9.0	-3.3	7.7
Simple Linear	-20.1 to 9.0	-2.8	7.6

An energy dissipater on Little Dry Creek in Westminster.

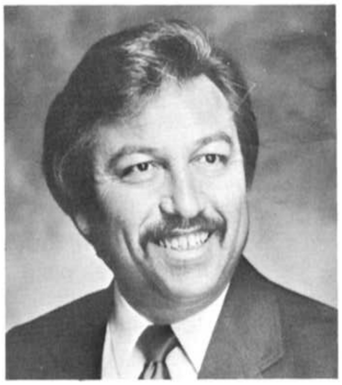
District Assists Boulder County in Fire Fighting Efforts

While the Yellowstone Park fire of 1988 received the attention of the news media as the worst national park forest fire on record, firefighters around the country fought numerous other fires within forested areas of the western United States. Boulder County, Colorado experienced its share of fire fighting activities over a two-week period in mid-September of this year. Firefighters in Boulder County deserve credit and recognition for saving both lives and property.

During the peak of the Boulder County firefighting efforts, the District was asked to assist the County by making the Electronic Bulletin Board available for relaying fire-related weather information. Boulder County was one of the primary users of the Bulletin Board during the 1988 flood season and found that it was a very quick and efficient way of relaying critical weather information. Henz Kelly and Associates (HKA) were contacted by Boulder County to assist with fire-related forecasting and weather reporting. The District's Bulletin Board was used as a means of disseminating hard copy information directly to the Boulder County Sheriff's Department. Wind, temperature and rainfall forecasts were considered essential for positioning equipment and human resources. Captain Charles Pringle, of the Boulder County Sheriff's Department, was responsible for making the arrangements and deserves special recognition for his contributions.

The District appreciates the confidence expressed by Boulder County in the Bulletin Board service. If future emergency situations arise, the District stands ready to assist local governments in whatever way possible. Considering the response the District received from Boulder County and others concerning the Bulletin Board, such services can be expected to continue in the future.

MEET THE NEW BOARD MEMBERS



SAMUEL V. GOMEZ

Mayor, City of Brighton

Sam Gomez became mayor of Brighton on January 1, 1988, and was appointed to the District Board shortly thereafter by Governor Roy Romer.

Sam has also served on the Brighton City council, Brighton Parks and Recreation Advisory Board, Brighton Housing Authority Board of Directors, Denver Regional Council of Governments, Colorado Municipal League Policy Committee, National League of Cities and Hispanic Elected Local Officials Board of Directors.

He is married to Eva and they have three children. He has been employed in the Civil Engineering Department of Adams County since 1971. Sam served in the Marine Corps from 1966-68, including a tour of duty in Viet Nam.

Mayor Gomez is a member of the Brighton Veterans of Foreign Wars, Brighton Eagles Lodge, Brighton Lions Club and St. Augustine Church.

THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
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