FLOOD HAZARD NEWS

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Flash Flood Warning for Lena Gulch

*by Kevin G. Stewart, **Project Engineer***
Floodplain** Management **Program

Introduction

In June of 1980, the Urban Drainage and Flood Control District, in cooperation with the cities of Lakewood and Wheat Ridge, Jefferson County and The Consolidated Mutual Water Company, began a program to develop an early flood detection network and flood warning plan for Lena Gulch. The Lena Gulch basin, located in central Jefferson County, drains approximately 13.8 square miles at its confluence with Clear Creek near Kipling Street. The Lena Gulch headwaters are located in the Apex Gulch area of Lookout Mountain. Apex Gulch and Jackson Gulch join to form Lena Gulch just below Heritage Square near the intersection of U.S. Highway 40 and State Highway 93. Numerous developed areas downstream from this point are considered highly flood prone. Lena Gulch flooding will impact numerous major highways and arterial streets in addition to the developed areas within unincorporated Jefferson County and the cities of Lakewood and Wheat Ridge.

One major water supply reservoir (Maple Grove Reservoir), which is owned and operated by The Consolidated Mutual Water Company, provided further impetus for implementing the $100,000 Lena Gulch flood warning plan and early detection network. The dam and reservoir, located near West 27th Avenue and Youngfield Street, performs an important flood control function for storm runoff events through the 100-year flood. Improvements to the dam and spillway were completed in 1977 to comply with the dam safety requirements of the State Engineer. These improvements included the installation of two Fabridams on the spillway crest which are operated in a manner to protect the dam from failure in the event of floods exceeding the 100-year magnitude. UDFCD participated in the construction of one of these Fabridams as part of a major channel improvement project for Lena Gulch through the City of Wheat Ridge. The downstream flood control improvements, totaling more than $5,000,000 in construction costs, rely heavily on the flood control benefit provided by Maple Grove Reservoir. Should Fabridam deflation be required in a severe emergency, discharges well in excess of downstream channel capacity can be expected with the loss-of-life potential being extremely high.

In consideration of the numerous problem areas within the Lena Gulch floodplain and the special warning needs with respect to Maple Grove Reservoir, an automated real-time detection network was selected by the project sponsors for implementation. The 1986 flood season represents the first full year operation of the Lena Gulch detection network which employs state-of-the-art micro-computer technology, real-time data collection, advanced meteorological forecasting and hydrologic modelling.

The remainder of this article will deal primarily with the telemetry system and data processing components which comprise the "Lena Gulch Flood Detection Network." The reader should keep in mind that this real-time data collection system represents only one element of the overall "Flood Warning Plan" for Lena Gulch. Other elements, including meteorological support, communications, warning dissemination and emergency response should not be given lesser importance. Failure of any one or combinations of these elements could cause the entire warning plan to fail.

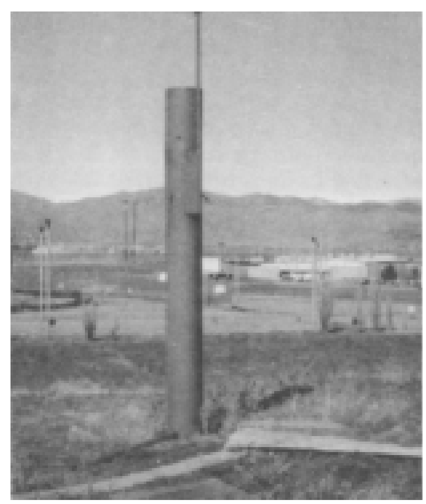
The Flood Detection Network

The flood detection network for Lena Gulch, modelled after a similar system for Boulder Creek, consists of six self-reporting rain gages, three automated steam gages and two base stations. All remote gages report data using standard formats (ASCII or binary) through battery powered VHF radio transmitters. The base stations receive radio signals from each gage, decode the transmitted data and process the data with the aid of a microcomputer. The following paragraphs provide a more detailed description of the telemetry equipment, remote sensors and base station features.

Rain Gages

All six self-supporting rain gages are standard tipping bucket gages. Each bucket tip represents 1.0 mm of rain or approximately 0.04 in. Each bucket tip trips a magnetic switch which causes the weather data transmitter to power-up and transmit the Gage I.D. and an accumulator value of 0 to 99. Each bucket tip causes the accumulator value to increase by one.

The tipping buckets are housed in the top section of a 12-inch diameter standpipe assembly which stands approximately 10 feet above the ground surface. The weather data transmitter is housed in the lower portion of the standpipe assembly approximately 2 feet below the ground surface. A side mounted antenna mast supports an omni-directional antenna.



A rain gage at Jefferson County Fairgrounds.

Stream Gages

All three stream gage sensors are pressure transducers (PT.) capable of sensing minor changes in stream stage (less than 0.1 feet). The PIN are calibrated to measure a stream stage

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George M. Wallace Park Dedication

by Dave Lloyd, Project Engineer

July 23, 1986, marked the official opening of George MacKenzie Wallace Park. The park opening marked the culmination of $4^{1}/2$ years of cooperative effort between the Goldsmith Metropolitan District, Denver Wastewater Management Division and the Urban Drainage and Flood Control District.

The park land was given to the City of Denver in 1971 by Mr. George Wallace, Executive Vice President and Chief Operations Officer of the Denver Technological Center (DTC), when he voluntarily annexed a portion of DTC to the City of Denver. The land lay unused for several years due to the unavailability of funding to develop it.

Basic to the development of the park was the resolution of the drainage and flood control problems associated with Goldsmith Gulch which flows in a northerly direction through the heart of the park property between Belleview and 1-225. The Goldsmith Gulch drainageway master plan prepared in 1977 called for major channel improvements along this reach including a detention pond at Temple Drive.

In March of 1982, an Agreement was signed between the three sponsoring agencies for the purpose of design and construction of improvements on Goldsmith Gulch through the park area. Greenhorne & O'Mara, Inc. was selected to design the facilities with careful attention being paid to the visual aesthetics of the overall design and emphasis on utilization of the detention area as a park. In addition to the flood control function, the Temple Drive Detention facility was sized to handle the on-site detention requirements of developments within the Denver Technological Center.

Construction of the facility commenced in August of 1983, and was completed by late summer of 1985. Total cost of the drainage and flood control improvements, including engineering, came to approximately 2.3 million dollars. These costs were near evenly divided amongst the three sponsoring agencies with the exception of certain park improvements, Temple Drive roadway construction, and water line construction which were paid for in their entirety by Goldsmith Metropolitan District.

Prior to completion of construction, the Goldsmith Metropolitan District commenced construction of landscape improvements throughout the park. These improvements were completed in the summer of 1986 at a cost of approximately 1.2 million dollars.

Approximately 200 people attended the park opening. Among those present were Denver Mayor Federico Pena, former Denver Mayor William McNichols, Greenwood Village Mayor Freda Poundstone, Denver Councilwoman Stephanie Foote, Councilman Paul Swalm, Arapahoe County Commissioners Bob Brooks and Tom. Eggert, and Denver Manager of Parks and Recreation Ruth Rodriguez.

In response to Mayor Pena's acknowledgement, Wallace expressed appreciation for what can be accomplished when businessmen, politicians, and homeowners cooperate in the spirit of "honest, effective, astute leadership."

George Wallace at the podium. Seated (L to R): Bill McNichols, Mayor Pena, Councilwoman Foote, Ruth Rodriguez, Pat Gallavan and Ray Bullock.

Professional Activities of District Staff

Bill DeGroot presented "Flash Flood Warning in the Denver Metro Area" and "South Platte River Greenway in Denver" at the Western States High Risk Flood Areas Symposium.

Bill DeGroot presented "Successful Flood Management on a Regional Basis" at the 1986 Association of State Floodplain Managers Conference and at the Big Thompson Symposium. Scott Tucker was co-author.

Kevin Stewart, Ben Urbonas and Bill DeGroot were lecturers at two short courses, one on the HEC-2 program and the other on storm runoff hydrology, which were sponsored by the University of Colorado at Denver.

Mark Hunter presented "Inspection and Maintenance of Drainageway Systems" at a short course on "Planning and Preliminary Design for Flood Hazard Mitigation" which was sponsored by Colorado State University and FEMA.

Ben Urbonas chaired a conference co-sponsored by ASCE, APWA, EPA and The Engineering Foundation on "Urban Runoff Quality, Its Impact and Quality Enhancement Technology." He also co-edited the conference proceedings with Larry Roesner and co-authored two papers, one with D. Earl Jones and the other with Larry Roesner.

Scott Tucker chaired the sessions on Institutional Issues and presented a paper in the same session at the above conference.

Scott Tucker presented a summary of the Engineering Foundation Conference on "Urban Runoff Quality" at the APWA annual meeting in New Orleans in September.

Scott Tucker and Bill DeGroot prepared an article on the impact of drainage and flood control requirements on industrial and office park developments. The article is scheduled to appear in a late 1986 issue of *Development* magazine, a quarterly publication of the National Association of Industrial and Office Parks.

Scott Tucker made a presentation at the Colorado Trails Symposium on the District's approach to trails along rivers and drainageways. The symposium was held in April, 1986 at the Viscount Hotel in Denver.

Scott Tucker gave a talk at the APWA Mid America Conference and Exhibit Show in Kansas City in April, 1986 on "The Denver Experience."

Dave Bennetts made a presentation at the Seventh Annual Pedestrian Conference on the cooperative effort between the District and local governments in building multi-use trails. The conference was held in Boulder in September, 1986.

Tucker-Talk

by L. SCOTT TUCKER

Timely Comment from the District's Executive Director

The President has signed the "Water Resources Development Act of 1986" (H.R. 6) and has vetoed the "Water Quality Act of 1986," the Clean Water Act reauthorization bill (S. 1128).

The Water Resources Development Act ends nearly 10 years of controversy over policy issues including cost sharing. The bill authorizes many water resource projects including flood control projects. More importantly, however, it establishes cost sharing policies that both the Congress and the Administration support. With regard to flood control the minimum non-federal share of the total cost of a project is 25%. Local sponsors will have to continue to furnish all lands, easements, rights-of-way, and relocations, but in addition local sponsors must contribute a 5% cash payment. The non-federal contribution is capped at 50%.

The approach to federal flood control projects may also change dramatically. Non-federal interests in a project, under H.R. 6, must contribute 50% of the cost of feasibility studies. Not more than one-half of the non-federal contribution may be made by the provision of in-kind services. This will make the local sponsor a full partner in the development of the project. Costs of feasibility studies will have to be held in check because local participants will be paying one half the bill. Review procedures of the Corps will have to be reconsidered, because if the local sponsor and the Corps at the District level develop and prepare a feasibility study, higher authority will have less basis to demand more information that will drive up the costs of the study. Previously the Corps was the sole party in control of the feasibility study phase and local sponsors were not involved in a partnership relationship. The Corps will now have to be willing to consider lower design standards and other factors. Will established and adopted procedures be in conflict with local sponsor needs and desires?

The Water Resources Development Act of 1986 marks a turning point in the way the Corps will have to do business. How successful the Corps will be in taking advantage of this opportunity to move flood control projects forward in a true federal/local partnership will depend on the Corps' ability to shed some of their old established ways and develop new approaches and attitudes.

One of the many items which was addressed in the Water Quality Act of 1986 (S.1128) was the adoption of an alternative to the National Pollutant Discharge Elimination System (NPDES) permitting process required under previous legislation. The previous and still existing legislation resulted in the interpretation that all municipal storm sewer discharges must obtain NPDES permits. There are by the most conservative estimates over one million separate municipal storm sewer outlets in the U. S. The cost of merely obtaining the required permits would be unreasonable. Congress in the passage of S.1128 adopted a procedure for addressing stormwater pollution problems in a more realistic manner. President vetoed S. 1128, the previous law remains in effect and municipalities will have until December 31, 1987, to apply for permits for all their storm sewers.

Of critical importance in S.1128 was that the NPDES permit application deadline of December 31, 1987 was removed. EPA would have had two years to establish regulations setting forth permit application requirements for stormwater discharges associated with industrial activity and from municipal separate storm sewer systems serving populations of 250,000 or more. Local governments would not have been off the hook by any means. The new law proposed that, "Permits for discharges from municipal storm sewers (i) may be issued on a system or jurisdiction wide basis; (ii) shall include a requirement to effectively prohibit non-stormwater discharges into storm sewers; and (iii) shall require controls to reduce the discharge of pollutants to their maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants."

What this would have meant to municipalities would have depended on the regulatory requirements developed by EPA. S. 1128 at least gave municipalities some breathing room in terms of time, but permits would still eventually be required. Most important the onus of "controls to reduce the discharge of pollutants to the maximum extend practical" would still be hanging over the heads of local government for some time to come. Although probably an obvious conclusion, local governments would still have to bear the cost of preparing the permits and for what ever controls the feds in their infinite wisdom eventually decide to require.

Because the President vetoed the bill, local interests will have to begin the process of submitting permit applications, while at the same time lobbying the new 100th Congress for legislative relief during 1987.

Joe Shoemaker and Cathy Reynolds

Friend of the River Awards

Board Chairman Cathy Reynolds and Executive Director Scott Tucker have been awarded "Friend of the River" Awards by the South Platte River Greenway Foundation. In remarks made at the awards ceremony Greenway Chairman Joe Shoemaker expressed his gratitude for the longtime cooperation of the Urban Drainage and Flood Control District with the Greenway Foundation and he acknowledged the leadership provided by Cathy and Scott. The awards ceremony, which was held at Confluence Park, was followed by an informal dinner at My Brother's Bar.

RECENT PLANNING PROGRAM ACTIVITIES

by Ben Urbonas, Chief, Master Planning Program

Planning Projects

In the last issue of Flood Hazard News we announced the completion of a master plan for the South Platte River. Since then we have completed one additional drainageway plan and five outfall system master plans. All of these are tabulated, along with the ongoing and anticipated projects, in the "Status of Planning Projects" table. As you can see, 1986 was a rather hectic year for planning. The District local sponsors and the consultants can be proud of what was accomplished during the year. At the same time, the planning pace is expected to continue through 1987.

Technology Transfer

Again we had the pleasure of cooperating with Dr. James Guo and the University of Colorado of Denver to put on two short courses. One was held in January of 1986 and was a repeat of the course given in 1985. The course covered urban storm runoff hydrology methods as contained in the *Urban Storm Drainage Criteria Manual* (USDCM). The second was held in August of 1986 and was co-sponsored by the Federal Emergency Management Agency. This course covered the use of HEC-2 for open channel water surface profile calculations. Both courses were attended by about 50 professionals and we received many favorable comments about them.

In response to the comments received at earlier short courses, Dr. Guo is preparing to organize two additional short courses. Both are tentatively scheduled for the summer of 1987. One will address urban storm sewer design and the other will concentrate on the design of urban stormwater detention facilities. If you wish to obtain early information on either course, call Dr. Guo at UCD (Tele. No. 629-2871).

Software

We announced in the last issue of this newsletter that the District contracted with the University of Colorado at Denver (UCD) to develop a storm sewer design program. A draft version of this program has been delivered to the District and has undergone field testing by several "volunteer" organizations. It is being modified at this time to incorporate many of the comments received from the evaluators. We expect the working program to be ready for distribution early in 1987.

This program, called UDSEWER, is designed to duplicate the Rational Method described in the USDCM. It will not only calculate runoff peaks, but will also size or analyze a storm sewer network, check for surcharging, minimum and maximum velocities and include an approximation of manhole losses. The program will handle 100 sub-basins and 100 storm sewers and is fully interactive. We will notify all owners of CUHPE/PC and UDSWM2-PC by mail when it is finally released.

STATUS OF PLANNING PROJECTS

PROJECT	LOCAL SPONSOR	CONSULTANT	STATUS
Adams County/Commerce City-Irondale Area	Adams County, Commerce City	McLaughlin Water Engineers, Ltd.	Completed in 1986
Broomfield & NE Area	Broomfield, Westminster	Greenhorne & O'Mara, Inc.	Completed in 1986
Direct Flow 0056 & Basin 4100	Thornton, Adams County	Project Consultants	Completed in 1986
Lower Ralston & Van Bibber Cr.	Arvada, Jefferson County	Wright Water Engineers, Inc.	Completed in 1986
Quincy Drain/Shop Creek	Aurora, Colo. Div. of Parks	Boyle Engineers	Completed in 1986
Interim Lowry Detention	Denver, Aurora	Simons, Li & Assoc., Inc.	Completed in 1986
Boulder & Adjacent County	Boulder, Boulder County	Greenhorns & O'Mara, Inc.	
Big Dry Creek (ADCO)	Westminster, Broomfield, Adams, Jefferson Airport	Muller & Assoc., Inc.	90% Complete
Gunbarrel Area	Boulder County, Boulder	Boyle Engineers	60% Complete
Thornton Criteria	Thornton	WRC Engineers, Inc.	Draft 80% Complete
Jefferson County Criteria	Jefferson County	WRC Engineers, Inc.	In Hearings
Adams County Criteria	Adams County	WRC Engineers, Inc.	In Review by County
City of Boulder Criteria	Boulder	WRC Engineers, Inc.	In Review by City
Westminster Criteria	Westminster	WRC Engineers, Inc.	In Review by City
Littleton Criteria	Littleton	WRC Engineers, Inc.	Final Printing
Lone Tree, Windmill, Dove Creeks	Arapahoe County	WRC Engineers, Inc.	80% Complete
Bear & Mt. Vernon Creeks	Morrison, Lakewood, Jefferson County	n/a	Begin in 1987
Cottonwood Creek-Arapahoe County	Arapahoe County	n/a	Selecting Consultant
Cottonwood Creek-Douglas County	Douglas County	n/a	Begin in 1987
Happy Canyon Creek	Douglas County, Arapahoe County	n/a	Begin in 1987
Lower Big Dry Creek (ADCO)	Thornton, Adams County	n/a	Begin in 1987
52nd & Pecos to S. Platte & Clear Creek	Adams County	n/a	Waiting for Local Funding
First, Second, Third Cr. Hydrology	Adams, Aurora, Brighton, Denver, Commerce City	n/a	Begin in 1987

Foreign Visitors

The District was visited in October by eight stormwater management professionals from France and West Germany. Some of them heard about

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Wetlands and Hard-lined Low Flow Channels Can Co-exist

by Mark R. Hunter
Chief, Maintenance Program

In the fall of 1983, two homeowners groups contacted Foothills Metropolitan Park District and the Urban Drainage and Flood Control District (District) regarding their concerns over the erosion and deposition problems on Lilley Gulch. The portion of Lilley Gulch they were concerned with is in Jefferson County southwest of the Denver metropolitan area and is between Wadsworth Boulevard and Kipling Streets.

Boyle Engineering Corporation was selected in the spring of 1984 to design the project. Their design was limited to arresting the erosion in the low flow channel and to reduce local deposition. They were also called upon to design a low flow channel for the reach. This was designated a maintenance project and as such, major improvements such as grade control, drop structures, and major channel reshaping were not included. Since the overbank areas of the creek were in good condition, the longitudinal channel slope was left as it was, which ranged from 1.2% to 1.6%. This cost reducing decision has the trade-off that after major storm flows there may be channel maintenance and erosion repair to be done. None-the-less the low flow channel installation was critical and will be a definite advantage in maintaining the existing cross-section and flood capacity of the creek.

Four alternate low flow channel cross-sections were considered. They were as follows:

1. Dumped riprap
2. Grouted riprap
3. Formed concrete
4. Formed concrete bottom with rock sidewalls.

Boyle Engineering analyzed all four options and after several discussions with District staff, the choice was made to build the concrete bottom with rock sidewalls alternate. Listed below are the reasons for making that selection:

1. Easier maintenance than the dumped riprap or the grouted riprap.
2. Easier construction than the formed concrete channel.
3. Better aesthetics than any of the other options.
4. Built-in weep holes between the rocks to reduce the differential uplift pressure that is present due to the high groundwater.
5. It is more efficient to get the desired capacity in a low flow channel with vertical sidewalls than with the sloped sidewalls which are necessary with the dumped riprap or grouted riprap channel.
6. Reduced velocities at the outer edges of the low flow channel are expected because of the roughness value of the rock. This will reduce the local erosion at the interface between the low flow channel and the vegetated channel banks beyond.

The selected low flow channel has a depth of about 2-feet and a bottom width of 6- to 8-feet for a capacity of approximately 100 cfs. The 100-year design flow through this reach is 1300 to 1350 cfs. The 2-year flow ranges from 300 to 350 cfs.

Early in 1985 the District contracted with Randall Blake Incorporated to construct a little over 2000-feet of the low flow channel with accompanying facilities. The portion that was built is located between Estes Street and Holland Way where there were several pockets of local erosion with the remainder of the reach being flat enough that cattails had established. Lilley Gulch is similar to many suburban streams in the Denver area in that it was historically an intermittent stream, but it now has a continual base flow due to land development within its basin. With the continual base flow has come accelerated erosion in some locations, and in other reaches the development of cattails and local wetland areas. Most of this has occurred within the last ten years. In the middle of the reach, a 1.3-acre pocket of land was left undeveloped. That pocket of land had filled with cattails in the meantime with the gulch wandering along one edge of it. It is in a fairly wide area of the drainageway so the cattails did not appear to be a threat to the flood conveyance through his short portion of the gulch. The design called for installing the rock-lined low flow channel throughout the linear reach of the creek as well as through the 1.3-acre pocket area. Through the 1.3-acre pocket the design was to run the low flow channel on one side of the area leaving the cattails virtually intact.

There are three potential sources of water for this particular cattail area. They are:

1. Occasional surface water whenever the stream flows are high enough to inundate the area.
2. Recharged groundwater that is moving from the channel area into the surrounding soil.
3. Groundwater that is flowing from the surrounding area toward the stream.

The District did not analyze the situation to determine the exact water movement, but it is felt that only one potential source may have been impacted. The cattails will still receive surface water when the stream flows are high enough, and groundwater will continue moving toward the stream (if such is the case) through the cattail area. On the other hand, putting in a 2-foot deep low flow channel may have lowered the level of the water that leaves the low flow channel and recharges the surrounding area, assuming that is what happened historically.

Since completion of this project in late spring of 1985, the District has monitored the low flow channel and the wetland area. The low flow channel is performing as designed in controlling the erosion and sedimentation and the cattails are showing no signs of stress. One and one-half years after the completion of the project the cattails still look green and healthy. The District acknowledges that long-term changes will always occur, but the intent is not to accelerate those changes. The District will continue watching this area, hoping that the cattails will remain as intended. At this time, the hard-lined low flow channel and the cattail area are co-existing nicely.

Eighteen months after the low flow channel in the foreground was constructed the wetlands in the background remain healthy.

DESIGN AND CONSTRUCTION NOTES

B. H. Hoffmaster
Chief, Design and Construction Program

During 1986 there were 31 drainage and flood control projects in some stage of development. These projects are listed in the two tables, "Status of District Design Projects" and "Status of District Construction Projects." These projects represent projects designed under the supervision of the District in cooperation with other local entities and construction that was either administered by the District or a co-sponsoring local agency.

The City of Boulder and the District began the construction of the Goose Creek, Wonderland Creek and Boulder Slough Project during the year and the project is expected to be completed before the end of the year. The project consists of construction of two channels for Goose Creek from Foothills Parkway downstream to the confluence with Boulder Creek. Wonderland Creek enters the north channel just east of 49th Street. Boulder Slough joins the south branch at 47th Street. Before Goose Creek empties into Boulder Creek, it flows through a pond to be used for scientific studies by the University of Colorado. Because of this use and the U.S. Environmental Protection Agency concerns, a siltation area was constructed just upstream of the pond and Boulder Creek. This siltation area consisted of a series of dikes to provide temporary storage of stormwaters to allow time for precipitation of materials and chemicals. Also, the area is to serve as part of the mitigation area required under the Clean Water Act Section 404 and will be established as wetlands. There was a 9-month delay of construction of the project while mitigation plans were developed before the Corps of Engineers issued the 404 permit. The project was designed by Simons, Li and Associates and constructed in three phases by National Construction Company and Loveland Excavating, Inc.

Another project in Boulder was a flood wall at the County Justice Center. This project, undertaken in cooperation with Boulder County, consisted of a flood wall adjacent to the south wall of the building. The wall was constructed of materials that blend into the architectural design of the building. There was also grading on the north and east sides of the Justice Center to create a berm to hold out floodwaters. The building, which contains the courts, jail, communications center and emergency operations center for Boulder and Boulder County, was within the 100-year floodplain. The building is now protected up to the 100-year flood. The project was constructed by National Construction Company.

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdiction(s)	Status
Basin 3207	Broomfield	30% Complete
Depew St. Basin-Weir Gulch	Lakewood	30% Complete
Dutch Creek	Columbine Valley	5% Complete
Goose Cr., Wonderland Cr. Boulder Slough	City of Boulder	Complete
Greenwood Gulch- Big Dry Creek (ARAP)	Greenwood Village	Complete
Goldsmith Gulch-Denver Evans to Mexico	5% Complete	
Kenney's Run	Golden	5% Complete
Louisville Drainageway D	Louisville	5% Complete
Little Dry Creek (ARAP)	Cherry Hills Village	15% Complete
Little Dry Creek (ADCO) Westminster	Adams County	95% Complete
Marston Lake North Schedule II	Denver	95% Complete
Massey Draw	Jefferson County	Complete
Parker/Iliff-Huntington Estates	Arapahoe County	Complete
Parker/Mexico	Arapahoe County Aurora	Complete
Sand Creek	Aurora	Complete
Sand Creek	Commerce City	Complete
Shaw Heights	Adams County Westminster	Complete
Slaughterhouse Gulch	Arapahoe County Littleton	30% Complete
South Jefferson County Drainages	Arapahoe County Last Chance Ditch Company Nevada Ditch Company	95% Complete
Upper Sloans Lake Schedules I, it and III	Edgewater Lakewood	Complete
Westerly Creek-Interim Lowry Detention	Denver	80% Complete
Westerly Creek-Dayton St.	Denver	Complete

A bridge was constructed at Lowell Boulevard on Little Dry Creek (ADCO). Cooperating with the District were Adams County and the City of Westminster. This project helped to reduce the flooding problem in the immediate area where flooding had occurred several times each year. The 86-foot span replaced an 84-inch diameter corrugated metal pipe. Sellards and Grigg, Inc. designed the project and it was constructed by Lillard and Clark Construction Company. This is one of several projects that have been designed for Little Dry Creek from Clear Creek to Sheridan Boulevard, a distance of three miles. The District and Westminster have completed 1100 feet of channel at 72nd Avenue. The City of Westminster currently has under construction another 600-feet near Tennyson Street. A fourth project of 1,420 feet of channel will be constructed this next year.

Another section of Lena Gulch was completed at the beginning of the year. Schedules III and IV, constructed in cooperation with the City of Wheat Ridge, extended the improved channel from Moore Court to above Parfet Street, a distance of 2,195 feet. The project included two box culverts, a prestressed Double The bridge, a European type channel, grass-lined channels and several grouted rock drop structures. As a result of construction and the proximity to private residences, landscaping was an important element in the construction of this project. The design was by Wright-McLaughlin Engineers and construction was by Wycon Construction Company.

Construction of Marston Lake North, Denver, started this fall. This work is the first phase of a two phase project. The length of construction,

DESIGN NOTES
Supplement to Flood Hazard News (December, 1986)

Design of Channels With Wetland Bottoms

By Ben Urbonas
Chief, Planning Program

Introduction

Ever since the U.S. Army Corps of Engineers promulgated the new Sectioon 404 permit regulations in 1985, we at the Urban Drainage and Flood Control District, along with everyone who works with drainageways, found ourselves having to deal with a new set of unfamiliar rules. First, the reporting requirements changed so that anyone filling or grading one or more, but less than ten, acres of "wetland" or channel needs to notify the Corps of Engineers and ask for their determination if a permit will be required.

Second, if more than 10-acres of "wetland" or channel are being filled or graded, or filling of a "navigable" stream or river is to take place, a Section 404 permit is required. Third, we found ourselves having to pay much more attention to the preservation of "wetlands" and riparian habitat along the drainageways in the Denver region.

To cope with the issues now facing us as a result of the current Section 404 requirements, the District contracted with WRC Engineers, Inc. to help the District re-examine its approach to trickle channel sizing and design and to help us develop "wetland" channel criteria. The draft proposed revisions to the District's *Urban Storm Drainage Criteria Manual* (USDCM) that follow are the result of several interactions between the consultant and the District's staff. These revisions consist of the revised Part 2.1 and a new Section 2.6 of the Major Drainageways chapter of the USDCM.

In the revisions to Part 2.1, an evaluation procedure is suggested to help the designer, developer or the public works administrator with the selection of the channel type for use as a drainageway. This section, particularly Figure 2-1, guides the user through a series of questions includeing the Section 404 concerns. It has to be emphasized that Section 404 requirements are, in fact, Federal Law. The revised Part 2.1 of USDCM attempts to interpret what Section 404 requirements are; however, when working with drainageways or "wetlands" be sure to study the regulations yourself and reach your own conclusions.

The proposed Part 2.6 of the USDCM contains a recommended approach for the design of a channel with a "wetland" bottom. This approach recognizes that, when the channel is new, it will have a much lower roughness factor that a mature condition. The procedure is intended to provide a stable channel when it is new and for adequate capacity when the wetland vegetation matures. Both conditions are important and need to be recognized in design.

These draft criteria, after a six-month evaluation period may be incorporated into the USDCM. We ask all the users of the USDCM to use the "interim" criteria that follow and to report to us on any successes, problems, concerns, etc. within the next six months. We will consider all your comments before finalizing these criteria. Please forward all your comments before June 1, 1987 to:

Ben Urbonas, Chief
Master Planning Program
Urban Drainage and Flood Control District
2480 West 26th Avenue, Suite 156B
Denver, CO 80211

Draft Criteria

2.1 Choice of Channel (Proposed Revised Section of USDCM)

The choices of channel available to the designer are almost infinite, depending only upon good hydraulic practice, environmental design, sociological impact, and basic project requirements. However, from a practical standpoint, the basic choice to be made initially is whether or not the channel is to be a lined one for higher velocities, a grassed channel, a channel with a wetland bottom or a natural channel already existing.

The actual choice must be based upon a variety of multi-disciplinary factors and complex considerations which include, among others:

Hydraulic
- Slope of thalweg
- Right-of-way
- Capacity needed
- Basin sediment yield
- 'Ibpography
- Ability to drain adjacent lands

Structural
- Costs
- Availability of material
- Areas for wasting fill

Environmental
- Neighborhood character
- Neighborhood aesthetic requirements
- Need for new green areas
- Street and traffic patterns
- Municipal or county policies
- Wetland mitigation

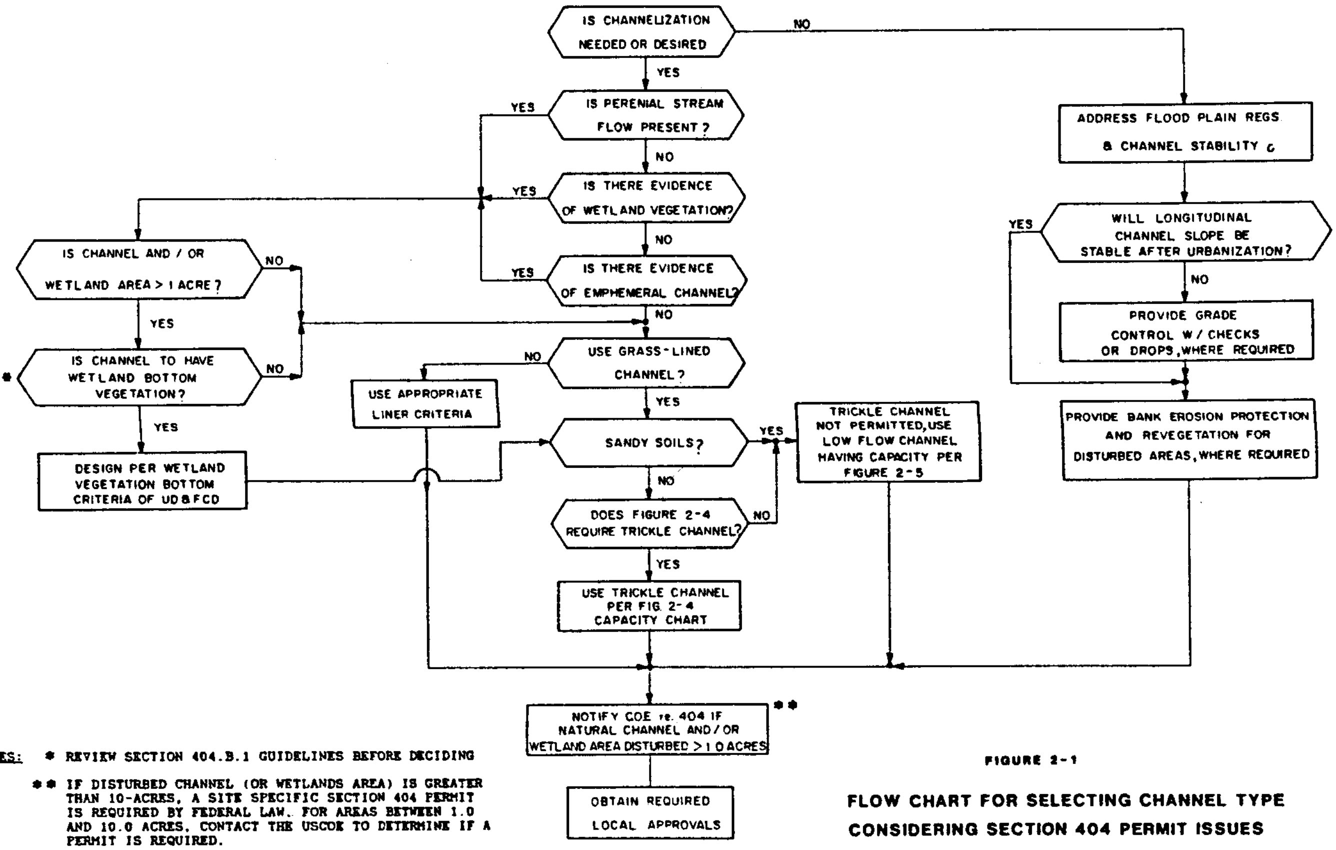
Sociological
- Neighborhood social patterns
- Neighborhood children population
- Pedestrian traffic
- Recreational needs

Prior to choosing the channel type the planner should be sure to consult with experts in related fields in order that the channel chosen will create the greatest overall benefits. Whenever practical, the channel should have slow flow characteristics, be wide and shallow, and be natural in its appearance and functioning (2).

To assist with the selection of type of channel or drainageway improvements to be used, the flow chart in Figure 2-1 was prepared. It contains a series of questions one may wish to consider in light of the requirements in this criteria manual and the recent Federal Section 404 requirements. Following the chart, the first step is to determine if channelization is needed or desired. In many cases a well established natural drainageway and its associated floodplain can be preserved. Therefore, before deciding to channelize, ask if the value of reclaimed lands will justify the cost of channelization.

If the decision is not to channelize, investigate the stability of the natural drainageway and its banks, selectively stabilize the longitudinal grade and banks and obtain, if necessary, Section 404 permits and other approvals.

If the decision is to channelize, then determine if the existing natural drainageway has a perennial flow, or if there is evidence of wetland vegetation, or if there is evidence of an ephemeral channel. If any of these items are present, then you *may* be subject to Section 404 regulations. Under the regulations in existence in 1986, when wetland area or the normal annual high water area in a channel exceeds one acre, the project may require a Corps of Engineers permit. It is the responsibility of the proponent to comply with all applicable Federal and State laws and regula-



NOTES: * REVIEW SECTION 404.B.1 GUIDELINES BEFORE DECIDING

** IF DISTURBED CHANNEL (OR WETLANDS AREA) IS GREATER THAN 10-ACRES, A SITE SPECIFIC SECTION 404 PERMIT IS REQUIRED BY FEDERAL LAW. FOR AREAS BETWEEN 1.0 AND 10.0 ACRES, CONTACT THE USCOE TO DETERMINE IF A PERMIT IS REQUIRED.

FIGURE 2-1

FLOW CHART FOR SELECTING CHANNEL TYPE CONSIDERING SECTION 404 PERMIT ISSUES

tions. Approvals by the local authorities do not supercede or waive compliance with these Federal laws.

At this point you also need to decide if the new channel will have wetland vegetation at its bottom. If the channel is to have wetland vegetation in its bottom, then follow the design requirements of Section 2.6 "Channels With Wetland Bottoms," obtain necessary Corps of Engineers permits and also obtain all local government and, if necessary, other approvals. If the channel is not to have a wetland vegetation bottom, then follow the guidelines for the appropriate channel liner and obtain the necessary approvals.

If, on the other hand, there is no evidence of perennial flow, wetland vegetation or ephemeral channel, then the channelization being proposed is probably outside of the "Waters of United States" and is likely not subject to Section 404 regulations. In such cases any conventional grass-lined, concrete-lined or rock-lined channel may be considered. As appropriate, use either a trickle channel or a low flow channel in conjunction with the selected channel type.

When considering a channel in a street right-of-way located in the middle of opposing lanes, it is often attracttive to pursue a parkway approach where a parklike or greenbelt effect is achieved. However, to narrow down the channel width and perhaps line the channel with concrete is basically undesirable. The hydraulic demands are usually incompatible with street and traffic demands. Furthermore, this combination tends to require many storm inlets and connecting pipes because of the street crown barriers on each side of the channel, over which initial drainage flows generally must not pass to get into the channel. Maintenance considerations, traffic needs, hydraulic complications at tee intersections, and the general incomepatibility of major drainage channels with street requirements make median strip lined channels unsuitable in the Denver Region. See Part on Streets.

2.6 Channels With Wetland Bottoms (New Section)

Under certain circumstances, particularly when existing wetland areas are affected or natural channels are modified, the Corps of Engineers Section 404 permitting process may mandate the use of channels with wetland vegetation in their bottoms. These types of channels are in essence grass-lined channels, with the exception that wetland type vegetation is encouraged to grow in their bottom. The easiest way to achieve this is to replace the concrete-lined trickle channel with a trickle channel lining which permits free exchange of water between the trickle flow channel and the soils in the adjacent channel bottom.

There are potential benefits associated with a wetland bottom channel. These include habitat for aquatic, terrestial and avian wildlife and possible water quality enhancement as the water moves through the marshy vegetation.

The down side of this practice is that the channel bottom becomes "boggy" and overgrown with wetland type vegetation. As a result, it is virtually impossible to mow the bottom grasses. The more abundant bottom vegetation traps sediments and channel capacity is lost with time as the bottom fills with sediments. Eventually, depending on the sediment loads being carried by the flows, the channel bottom will have to be dredged to restore the drainageway's flood carrying capacity. In addition, the problems with a wetland bottom channel located in a close proximity of urban residences include habitat for mosquito breeding, odors, channel agradation, hazard to small children, aesthetics, potential increase in water table, difficult maintenance and an increased potential for blockage of drainageway crossing structures.

Since wetland bottoms will cause

an increase in friction to flow and will accelerate channel bottom agradation due to entrapment of sediments, the channel cross-section for flood conveyance needs to be enlarged to provide an additional initial flow capacity. This will require more right-of-way than is needed for a well groomed grass-lined channel. In areas where urbanization has already occurred wetland channels may not be feasible. In cases where right-of-way in urbanized areas is limited, mitigating flood damages should take precedence over other considerations during project design. In some of these instances, off-site wetland mitigation may be required by the Corps of Engineers.

2.6.1 Preliminary Design

The design of channels with wetland bottoms can be a complicated, iterative process. In order to simplify the design procedure, assumptions had to be made concerning how the flow depth in a channel interacts with the wetland vegetation and affects the channel roughness and the rate of sediment deposition on the bottom. These assumptions were based on state-of-the-art literature, observed sediment loads in stormwater (1) (2) and locally observed sediment buildup (3) in several wetland bottom channels in the Denver area.

The recommended design parallels the procedures for grass-lined channels (i.e. Section 2.3.1. of USDCM). The main differences are in the design of the trickle and flow channels and the need to account for two channel flow roughness conditions. To assure longitudinal stability, the design channel slope should be established assuming there is no wetland vegetation on the bottom (i.e. "New Channel"). To ensure that the channel will have adequate flow capacity after the vegetation matures and some siltation occurs, the channel's freeboard is calculated using roughness coefficients for the "Mature Channel" condition. More specifically, the minimum design requirements are as follows:

2.6.1A Flow Velocity. The maximum normal depth flow velocity for the 100-year flood peak for the "New Channel" condition shall not exceed 7.0 feet per second in non-sandy soils and 5.0 feet per second for sandy soils. The Froude number for the "New Channel" condition at the design flow shall be less than 0.8. No minimum velocities are specified for the low flow condition. The flow velocities will be less after the wetland vegetation on the channel bottom matures.

2.6.1B Longitudinal Channel Slope. Set the longitudinal channel slope using the Manning Roughness Factor given in Section 2.6.1E for a "New Channel" condition to limit the 100-year design flood velocities so they do not exceed those specified under 2.6.1A above.

2.6.1C Freeboard. Provide freeboard of one foot above the 100-year design water surface for the "Mature Channel" condition. This will require that the channel cross-section determined using the "New Channel" will be modified to carry the design flow using "Mature Channel" Manning's "n." After the "Mature Channel" cross-section is finalized and the 100-year water surface for the "Mature Channel" is calculated, add one foot of freeboard to determine the top of the channel bank.

2.6.1D Curvature. The centerline curvature of the channel shall have a radius of at least twice the top width of the 100-year flow for the "New Channel" condition, but not less than 100 feet.

2.6.1E Roughness Coefficient. To determine the longitudinal slope and the initial cross-section area of the channel, use a Manning's "n" for a "New Channel" condition. To determine the design water surface, the final cross-section area, and freeboard use the "Mature Channel" condition. Use the following Manning's "n" for the design of Wetland Bottom Channels:

a. Newly Built Channel condition: $n = 0.035$

b. Mature Wetland Channel w/ Trickle Flow Channel: n = (See Fig. 2-2)

c. Mature Wetland Channel w/Low Flow Channel:

(1) Low Flow Channel Area: $n = 0.055$

(2) Grass-lined Areas Above Low Flow Channel Area: $n = 0.35$

(3) Composite "n" per following Equation:

$$n_c = (n_o p_o + n_w p_w)/(p_o + p_w)$$

in which,

n_c = Manning's "n" for the composite channel

n_o = Manning's "n" for areas above the low flow channel

n_w = Manning's "n" for the low flow channel

p_o = Wetted perimeter of channel above the low flow channel area

p_w = Wetland perimeter of the low flow channel.

2.6.1F Cross-Section. The cross-section has to fit the location, the community setting and the environmental conditions of the site. Figures 2-3 and 2-3A illustrate possible cross-section configurations of wetland bottoms. One is a suggestion for channels conveying floods from smaller tributary watersheds and the other is intended for channels serving larger tributary watersheds and for channels located in sandy soils regardless of watershed size.

a. Sub-Channels

As with grass-lined channels, the base flow must be carried in either a trickle channel or a low flow channel. Use Figure 2-4 to determine if a trickle channel or a low flow channel should be used. The minimum capacity for a trickle channel should be determined using Figure 2-4 and for a low flow channel using Figure 2-5. Trickle channels should be constructed of riprap lining (see Figure 2-6 for acceptable sections) to provide free exchange of groundwater in the channel with the adjacent wetland bottom.

Low flow channels shall be at least 3-feet deep, but no more than 5-feet deep, have 2:1 to 2.5:1 riprap lined side slope banks and their bottom will be reserved for wetland vegetation. The 5-foot normal depth limitation for the 100-year flood shall not apply to the low flow channel area of the total channel cross-section. See Figures 2-3 for an example cross-section of a channel with a low flow channel. Figure 2-7 was prepared to help the designer determine the bottom width of the low flow channel.

b. Bottom Width

Bottom width shall be consistent with the velocity and depth criteria, but shall not be less than four feet wide to accommodate a trickle channel.

c. Right-of-Way Requirements

Provide sufficient right-of-way to accommodate the cross-section, freeboard and maintenance access.

d. Flow Depth

For the "New Channel" condition, use the limits set forth under Section 2.3 Grass Lined Channel (Artificial) of this

Urban Storm Drainage Criteria Manual (USDCM).

e. Maintenance Access

Provide a stabilized flat 12-foot wide access area for maintenance equipment. If a portion of this area is to be paved, the pavement should be at least 8-feet wide.

f. Side Slopes

Side slopes of the grass-lined channel shall be 4:1 or flatter.

2.6.1G. Vegetation. The grassed areas of all channels shall be revegetated with native grasses using the Urban Drainage and Flood Control District revegetation guidelines contained in "Guidelines for Development and Maintenance of Natural Vegetation."

The "wetland" portions of the channel should be revegetated using wetland species vegetation such as cattail and wetland reed grasses.

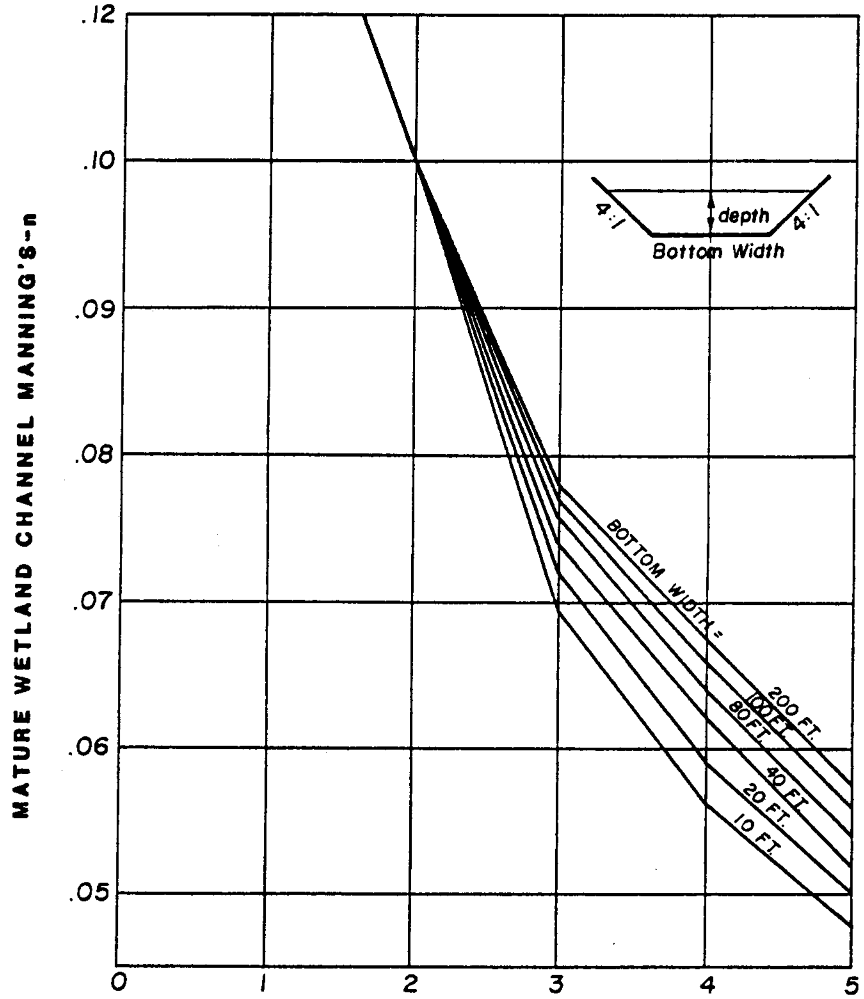
2.6.1E Erosion Control. To assure a reasonable life of a wetland bottom channel before it has to be dredged, erosion control has to be enforced in the tributary watershed. Without such controls the channel will loose its flood carrying capacity very rapidly.

2.6.2 Channel Design. Channels with bottoms containing wetland vegetation shall be designed to be stable when the channel is new and the vegetation has not been firmly established, and to have sufficient capacity to carry the 100-year flood after the wetland channel vegetation has matured. Briefly, the procedure is as follows:

a. Using the 100-year design flow and the channel velocity and depth limitations, determine the longitudinal channel slope using the Manning's "n" for a "New Channel," (i.e. item 2.6.1E above).

b. Adjust the channel depth, the width or both to contain the 100-year design flow within the channel's banks using the slope set for the "New Channel," but now using the Manning's "n" for a "Mature Channel."

c. Add one foot of freeboard to determine the total channel cross-section depth and adjust the cross-section details to show a trickle channel or a low flow channel. Check final results using final geometry and the composite roughness coefficient. Adjust the cross-section as needed to meet the minimum re-



NEW CHANNEL DESIGN DEPTH (FEET) *

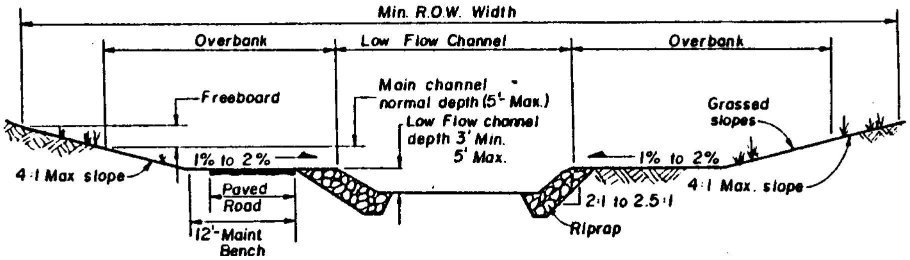
*** DEPTH OF CHANNEL BEFORE WETLAND VEGETATION MATURES**

MANNING'S W FOR WETLAND BOTTOM CHANNELS

NOTES:, 1. FOR DESIGN, USE MANNING'S n = 0.035 FOR A NEW (IMMATURE) CHANNEL TO SET THE CHANNEL'S LONGITUDINAL SLOPE. USING THIS LONGITUDINAL SLOPE, ADJUST THE DEPTH OR WIDTH FOR THE WETLAND MANNING'S n IN THIS CHART

2. FOR CHANNEL DESIGN DEPTH GREATER THAN 5-FEET, USE THE DEPTH OF 5-FEET IN ABOVE CHART.

FIGURE 2-2



NOTES: 1. THIS SECTION IS REQUIRED FOR CHANNELS IN SANDY SOILS, OR FOR CHANNELS AS CALLED FOR IN FIGURE 2-4.

2. LOW FLOW CHANNEL: CAPACITY TO BE AS DETERMINED USING FIGURE 2-5. DEPTH SHALL BE BETWEED 3- AND 6- FEET

3. NORMAL DEPTH: FLOW DEPTH FOR THE 100-YEAR FLOW OUTSIDE THE LOW FLOW CHANNEL AREA SHALL NOT EXCEED 5-FEET.

4. FREEBOARD: FREEBOARD TO BE A MINIMUM OF 1-FOOT.

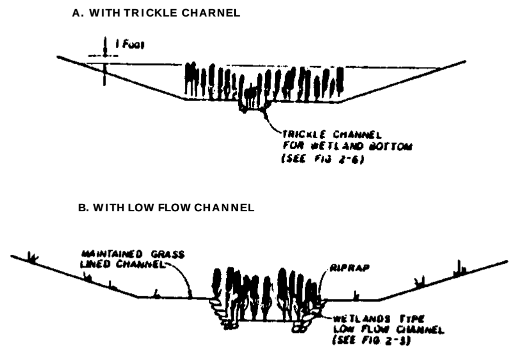
5. MAINTENANCE ACCESS ROAD: MINIMUM WIDTH OF THE FLAT SURFACE TO BE 12-FEET. LOCAL GOVERNMENT MAY REQUIRE THE ROAD TO BE PAVED. MAINTENANCE ROAD HAY BE LOCATED AS SHOWN ABOVE OR ON TOP OF MAIN CHANNEL BANK.

6. RIGHT-OF-WAY: MINIMUM WIDTH TO INCLUDE FREEBOARD AND MAINTENANCE ACCESS ROAD.

7. MAIN CHANNEL:FLOW IN EXCESS OF LOW FLOW CHANNEL SHALL BE CARRIED IN THE MAIN CHANNEL. THIS AREA MAY BE USED FOR RECREATION PURPOSES.

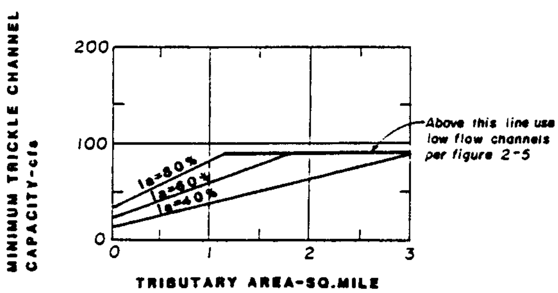
GRASS LINED CHANNEL WITH A WETLAND LOW FLOW CHANNEL

FIGURE 2-3



WETLAND BOTTOM CHANNELS

FIGURE 2 - 3A

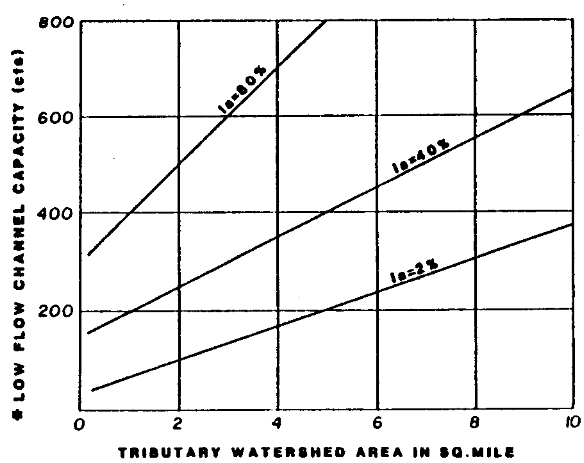


MINIMUM CAPACITY REQUIREMENTS
FOR TRICKLE CHANNELS
(EROSION RESISTANT SOILS ONLY)

NOTES: 1. **Ia =** TRIBUTARY BASIN IMPERVIOUS AREA PERCENTAGE USING FULL BASIN DEVELOPMENT CONDITION.

2. TRIBUTARY AREA CALCULATION WILL DISCOUNT ALL DETENTION DAMS UPSTREAM.

FIGURE 2-4



*FOR SANDY SOILS, DOUBLE THE REQUIRED MINIMUM LOW FLOW CHANNEL CAPACITY DETERMINED FROM THIS CHART

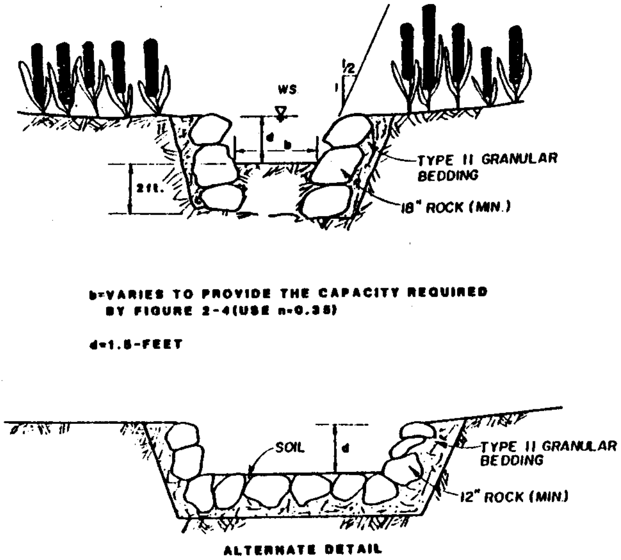
MINIMUM LOW FLOW CHANNEL CAPACITY
FOR A COMPOSITE CHANNEL SECTION

NOTES: 1. USE FIGURE 2-4 TO DETERMINE THE CAPACITY OF A TRICKLE CHANNELAND TO DETERMINE I A LOW FLOW CHANNEL SHOULD BE USED

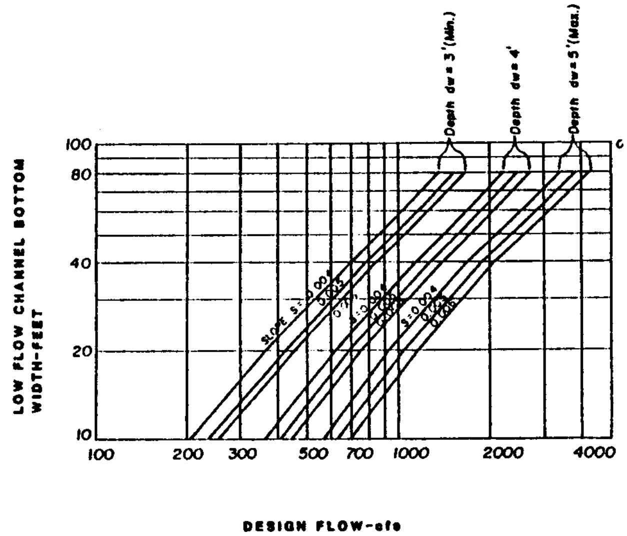
2. **Ia =** TRIBUTARY BASIN IMPERVIOUS AREA PERCENTAGE USING FULL BASIN DEVELOPMENT CONDTION.

3. TRIBUTARY WATERSHED AREA CALCULATION WILL DISCOUNT ALL DETENTION DAMS UPSTREAM.

FIGURE 2-5



TRICKLE CHANNELS FOR WETLAND VEGETATION BOTTOMS



LOW FLOW CHANNEL BOTTOM WIDTH vs. DESIGN FLOW

FIGURE 2-6

FIGURE 2-7

quirements of this Section of the manual.

2.6.3 Design Examples.

Example *1. Wetland Bottom Channel With a Tickle Flow Channel.* This example will illustrate the basic steps needed to design a flood control channel for a relatively small watershed that will encourage the development of wetland vegetation in the channel bottom. Because the tributary area is relatively small and the channel is not in sandy soils, a porous trickle flow channel will be used to control channel bank erosion during low flows. For starters we know the following:

Tributary Basin Area:	1.09 mi^2
Projected Future Basin Imperviousness:	40 Percent
Projected 100-year Flow For Fully Developed Watershed:	1400 cfs
Designed Channel Shape:	Basically Trapezoidal With 4:1 Side Slopes

Step 1: Determine Channel Cross-Section.

a) Limits for a new grass-lined channel are,
Maximum Velocity = 7 ft/s
Maximum Channel Depth = 5 ft

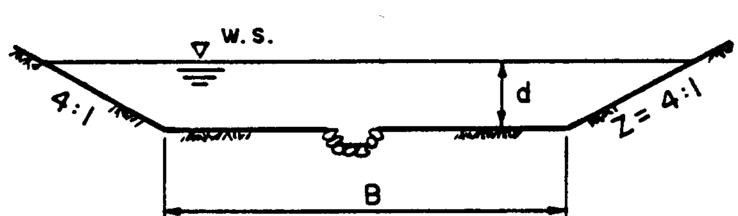
b) Calculate Needed Channel Cross-Section Area:
$A = Q/v = (1{,}400\ ft^3/s)/(7 ft/s)$
$A = 200\ ft^2$

c) Calculate Bottom Width:
$A = dB + zd^2$
or
$$B = \frac{A - zd^2}{d}$$
in which,
B = Bottom Width in feet
Z = Channel side slope = 4
A = Cross-Sectional Area = 200 ft²
d = Channel Depth = 5 ft
then,
$B = (200 - 4(5)^2)/5 = 20$ ft

Step 2: Determine Longitudinal Slope ("New Channel" Condition).
$S = n^2Q^2/(2.22\ R^{4/3}\ A^2)$
in which,
S = Longitudinal Slope in ft/ft
n = Manning's "n" = 0.035 (Section 2.6.E)
Q = Design Discharge = 1400 cfs
R = Hydraulic Radius = A/WP = 3.27 ft
A = Flow Area = 200 ft²
then,
S = 0.0056 ft/ft

Step 3: Estimate Final Geometry

There are two options available. One option is to increase channel depth to convey the design flow at the Mature "Wetland Channel" Manning's "n." Since the initial design depth was 5 feet, use Figure 2-2 to find that the "Mature Channel" n = 0.050 for a bottom width of 20 feet. Using the normal depth calculation



Example 1.

procedure described in the Major Drainageway Section, Vol. 2 of this USDCM, for the above channel geometry and slope we find:

Mature d = 6.2 feet.

Add one foot of freeboard to this depth and summarize the channel design as follows:

Bottom Width:	**B = 20 feet**
Total Depth w/ Freeboard:	**D = 7.2 feet**
Longitudinal Slope:	**S = 0.0056 ft/ft**
Side Slope: (H:V):	**Z = 4**
Mature Channel Velocity:	**V = 6 ft/s**
Top Width Including Freeboard and 10′ maintenance road:	**W = 87.6 ft**

The second option is to widen the channel bottom and maintain a lower design depth. For this example let's examine what will happen if the bottom is widened to 30 feet. Using a bottom width of 30 feet and the corresponding Manning's n=0.052 (from Figure 2-2) we find:

Mature d = 5.3 ft

Again, add one foot of freeboard and summarize the channel design as follows:

Bottom Width:	**B = 30 feet**
Total Depth w/ Freeboard:	**D = 6.3 feet**
Longitudinal Slope:	**S = 0.0056 ft/ft**
Side Slope: (H:V):	**Z = 4**
Mature Channel Velocity:	**V = 5.2 ft/s**
Top Width Including Freeboard and 10′ maintenance road:	**W = 90.4 ft**

Example 2. *Channel With Wetland Bottom Low Flow Channel.* This example illustrates the basic steps needed to design a flood control channel for a larger tributary watershed. In this example, the wetland is confined to a stabilized low flow channel. For starters we know the following:

Tributary Basin Area:	**3.5 mi²**
Projected Future Basin Imperviousness:	**39 Percent**
Projected Future 100-year Flow:	**3500 cfs**
Desired Channel Slope:	**As Illustrated**

Step 1: Determine Preliminary Cross-Section For Channel.

a) Using limits for velocity and depth specified for a new channel, make a first estimate using a trapezoidal section that ignores the low flow channel:

$A = Q/v = (3{,}500\ ft^3/s)/(7 ft/s)$

$A = 500\ ft^2$

b) Find the corresponding bottom width:

$B(A-zd^2)/d$

$=(500-4(25))/5$

$B = 80$ ft

Step 2: Determine Longitudinal Slope

$S = n^2Q^2/(2.22R^{4/3}A^2)$

With

$A = 0.035$, $Q = 3500$ cfs, $R = 4.12$, $A = 500$

$S = 0.0041$ ft/ft

Step 3: Determine the Width of the Low Flow Channel

Using Figure 2-5 we determine that the low flow channel needs to have a minimum capacity of 320 cfs. Thus, using the Manning's Equation and the geometry of a trapezoidal section we know that

$$Q = \frac{1.49}{n} AR^{2/3}S^{1/2}$$

and

$$R = d(b_w+Z_d)/(b_w+2d\sqrt{1+Z^2})$$

These two equations need to be solved simultaneously and obviously this is a difficult set of equations to solve. Figure 2-7 was developed to help solve these equations for a typical range of design conditions. With the help of Figure 2-7 we find, for a "New Channel" slope of 0.0041 ft/ft that

$b_w = 17$ feet

$d_w = 3$ feet

Then, for side slope $Z = 2$ and depth $d_w = 3$ feet,

$T_w = 29$ feet

Step 4: Configure Preliminary Cross-Section and Check Results.

Referring to the cross-section shown for this example we now have:

$S_o = 0.0041$ ft/ft	$S_w = 0.0041$ ft/ft
$B = 80$ feet	$b_w = 17$ feet
$d_o = 5$ feet	$d_w = 3$ feet
$Z = 4$	$Z_w = 2$
$T = 120$ feet	$T_w = 23$ feet
$p = 127$ feet	$p_w = 30$ feet
$p_o = 97$ feet	$A_w = 184\ ft^2$
$A_o = 385\ ft^2$	

Using the Equation for a composite section given in Section 2.6.1E, we find

$n_c = (n_op_o+n_wp_w)/(p_o+p_w)$

$n_c = [(0.035)(97)+(0.055)(30)]/(127)$

$n_c = 0.040$

Now check the capacity of the composite cross-section using the Manning's Equation

$$Q = \frac{1.49}{0.40}(385+184)\left(\frac{385+184}{127}\right)^{2/3}(0.0041)^{1/2}$$

$Q = 3690$ cfs

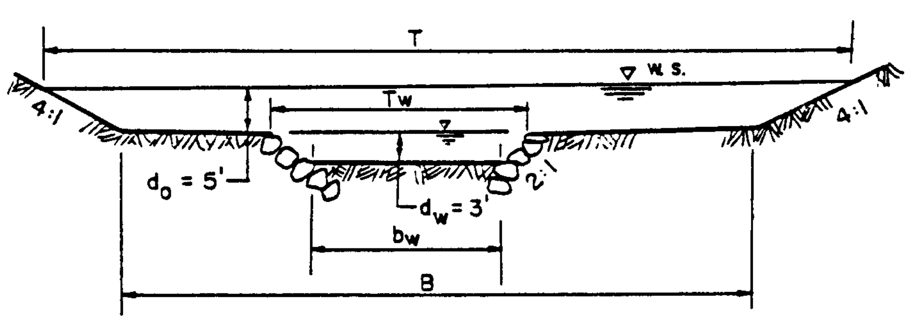
Note that this flow is only 190 cfs higher than the design flow. As a result, further refinement of the cross-section is not justified, and the above design can become final. If, on the other hand, the check of the flow capacity revealed that it is less than 3500 cfs or is excessively high, the cross-section should then be modified and again checked against the design flow

To complete the design, add one foot of freeboard which would result in,

Top Width Including Freeboard and 10' maintenance road: W = 138 feet

2.6.4. Channel Crossings. Whenever a wetland vegetation bottom channel is crossed by a road, railroad or a trail requiring a culvert or a bridge, a drop structure should be provided immediately downstream of such a crossing. This is needed to reduce the silting in of the crossing with sediments. A minimum of a 2-foot drop is recommended on the downstream side of each culvert and bridge that is built to cross a wetland bottom channel (see Figure 2-8).

2.6.5. Life Expectancy. Wetland vegetation bottom channels are expected to fill with sediment in time as the bottom vegetation entraps sediments carried by urban runoff. The life ex-



Example 2.

pectancy of such a channel will depend primarily on the land use of the tributary watershed and could range anywhere from 20 to 60 years before major channel dredging is needed. However, this life expectancy can be dramatically reduced to as little as one or two years if erosion in the watershed tributary to the channel is not controlled during the land development phase. Therefore, erosion needs to be strictly controlled during the construction phase of land development in the watershed to maintain a reasonable economic life of a wetland bottom channel.

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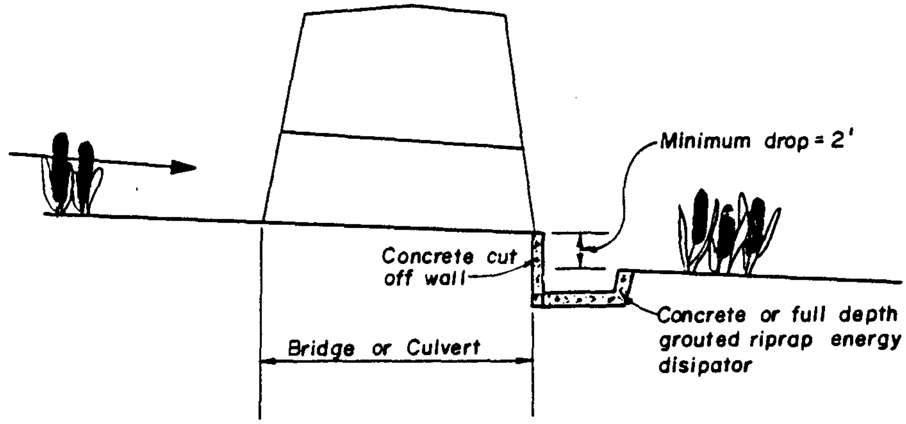
1. *Environmental Protection Agency, Results of the Nationwide Urban Runoff Program, Final Report, Washington, D.C., 1983.*
2. *Denver Regional Council of Governments, Urban Runoff Quality in the Denver Region, Denver, CO, 1983.*
3. WRC *Engineering, Inc., Comparisons of Measured Sedimentation With Predicted Sediment Loading, Draft Technical Memorandum in response to requirements of UDFCD Agreement No. 85-02.07B. 1986.*



WETLANDS BOTTOM CHANNEL, BRIDGE, OR CULVERT CROSSING

FIGURE 2-8

Errata

Page S-3, Left Column Bottom Line
"the wetland vegetation on the" should be "the wetland vegetation as the"

Center Column
n = 0.35 should be n = 0.035

Page S-4, Left Column
2.6.1E should be 2.6.1H

Page S-7, Left Column
Desired Channel Slope should be Desired Channel Shape

Center Column:
In Step 2: A = 0.035 should be n = 0.035
In Step 3: $R = d(b_w + Z_d)/(b_w + 2d\sqrt{1+Z^2})$ should be
$R = d(b_w + Zd)/(b_w + 2d\sqrt{1+Z^2})$; and
T = 29 feet should be T = 23 feet.

which begins in Pinehurst Country Club, is 2630-feet long. Included in this work is reconstruction of Viele Lake in Pinehurst Country Club where a plunge pool at the outlet of a box culvert is required. This necessitated the relocation of the golf cart path across the lake rather than around the lake. In the re-design of Viele Lake, a new landing area for one of the holes on the course was created. Previously there was very little flat area to land on after hitting over the lake. The project consists of 586-feet of 10-feet x 5-feet double box culvert that crosses Quincy and the entrance road to the Marston Water Treatment Plant and 1835-feet of grass-lined channel with 8 concrete grade stabilization structures. Scheduling is critical for this project in order not to interfere with the golf course use, and the Denver Water Department's new $32 million water treatment plant expansion to begin construction adjacent to the channel in February 1987. The flood control project was designed by WRC Engineers, Inc. and construction is by Lillard and Clark Construction Company.

The Parker/Mexico Project was constructed during the year. This project consisted of 10,205 feet of reinforced concrete pipe ranging from 36-inches to 60-inches in diameter. The project began at Cherry Creek at about Jewell Avenue (extended) and extended eastward to Havana and Jewell in Aurora. The project was a cooperative effort between the District, Arapahoe County and the City of Aurora. Of particular interest was the design of 71-feet of 54-inch diameter pipe at 25% slope. There was concern about the energy of the water and potential erosion of the pipe. The energy is to be dissipated by a baffle placed within a special junction box. The pipe is a 54-inch diameter 5/16-inch thick steel pipe lined with a 50-millimeter thickness of PCL membrane. The design engineer was WRC Engineering, Inc. and Kelran Construction Company of Salida, CO was the contractor.

The City of Aurora and the District started the Sand Creek Project in Aurora that extends from the confluence with Tollgate Creek to above Chambers Road. The project is a major channel construction project. It has been on hold for about a year as details of a plan to mitigate lost wetlands were worked out. The plan now calls for about 4-acres of new wetlands to be created at Four Star Park adjacent to Sand Creek above Chambers Road. It is also expected, since the channel will have a sandy bottom, to return certain native vegetation to the bottom following construction. The favored alternate is soil cement for the lower 8 feet of the channel side slopes. It is expected that advertising for the project will be underway before January, 1987. The project was designed by Greenhorne & O'Mara, Inc.

The year saw the completion of a detention pond at 26th Avenue and Wadsworth Boulevard for the Upper Sloans Lake Project. This project was sponsored by the Cities of Edgewater and Lakewood and the District. There still remains some landscaping work to complete the job. The project consisted of constructing a 24 acre-foot detention pond and 1,585-feet of 48-inch diameter storm drain downstream of the detention pond. The design engineer was URS, Inc. and the contractor was Trainor Construction Company. The next phase of the project, a storm drain from 25th Avenue and Reed Street to 20th Avenue and Ingalls Street has now been designed. The District and the Cities of Edgewater and Lakewood have the funding set aside and the project should be advertised shortly after the first of the year. The project is expected to include another detention pond on the Jefferson High School grounds for flows in excess of five year frequency.

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Participating Jurisdiction(s)	Cost	Status
Boulder Co. Justice Center Flood Barrier	Boulder County	$ 526,500	Complete
Dakota Tributary to Weir Gulch	Denver Lakewood	$ 769,900	Complete
Greenwood Gulch Newland Detententíon Pond	Greenwood Village	$ 238,900	Complete
Goldsmith Gulch Detention at Union	Denver	$2,230,300	Complete
Goose Cr., Wonderland Cr., Boulder Slough	City of Boulder Goldsmith Metropolitan District	$1,753,800	70% Complete
Lena Gulch Schedule III & IV	Wheat Ridge	$2,376,500	Complete
Lena Gulch Schedule V	Wheat Ridge	$ 227,500	0% Complete
Little Dry Creek (ADCO) Lowell Bridge	Adams County Westminster	$ 598,900	Complete
Little's Creek Schedule IV	Littleton	$ 100,400	Complete
Marston Lake North-Schedule I	Denver	$1,609,200	15% Complete
Monaco Street Storm Drain	Greenwood Village	$ 239,100	Complete
Parker/Iliff Huntington Estates	Arapahoe County	$ 359,900	Complete
Parker/Mexico	Arapahoe County	$1,620,000	75% Complete
Upper Sloans Lake Schedule III	Edgewater	$ 957,000	Complete
Sand Creek Schedule I	Aurora	$3,305,800	0% Complete
Sand Creek @ 49th Avenue	Commerce City	$ 518,300	0% Complete

Planning *(from page 4)*

the District's use of weather radar, along with weather forecasting, to help forecast flash floods. After talking to yours truly, Bill DeGroot, Kevin Stewart, and to the District's meteorologic consultants (i.e., Henz, Kelly and Associates) the visitors felt that we were indeed pushing the state-of-the-art frontiers. Although their use of radar technology was in some ways more advanced than ours, some of the concepts used by the District were not yet developed in France and Germany. The exchange of technical and operational ideas between the District and our European visitors was judged a success. It is gratifying to us that the Urban Drainage and Flood Control District enjoys international recognition as a leader in the field of stormwater management.

CONTRACTING FOR DRAINAGE WAY MAINTENANCE WORK

by
Mark R. Hunter
Chief, Maintenance Program

Contracting for work has been a very popular concept over the last five years. Many local governments have used the concept to acquire services from the private sector either to replace services originally performed by their staff or to supplement services where the need exceeds the in-house capabilities. Many agencies can point to contracting for services as a way of saving staff time, reducing direct expenses, and improving service to the community. On the other hand other local governments have turned from contracting to staffing up and increaseing their own equipment and inventtory supplies to meet all their anticipated demands. Obviously the choice to contract for work is not black or white. It depends on the specific needs of the local government as well as factors within the local community.

The Urban Drainage and Flood Control District (District) was established in 1969 by the Colorado State Legislature. Since that time all flood hazard area delineation studies, all master planning studies, all design engineering for the Construction Program and Maintenance Program, all construction for the Construction Program and Maintenance Program, and all routine and restoration work in the Maintenance Program has been accomplished through contracts with private engineering, construction, and maintenance contracting firms. Contracting for services has worked well for the District. The purpose of this article is to discuss how it works in the District's Maintenance Program.

The Maintenance Program of the District was begun in 1981 with an administrative staff of five full time employees and two part time temporary workers. The present staff level of the Maintenance Program is the same, and current funding generates 3.6 million dollars per year through property taxes. Of that money approximately 3.2 million dollars per year is available for actual maintenance field work which includes engineering, construction, and routine and restoration activities. By the end of this year the 1986 Maintenance Work Program will list approximately 180 different work items. The range in cost for these work items is from $250 up to $200,000. Of those 180 items only ten to fifteen are above the $100,000 level.

To accomplish the maintenance activities three different levels of field work have been defined. Those levels are called routine, restoration, and rehabilitation. One process has been developed by which contractors are selected for routine and restoration work, and another process by which engineers and contractors are selected for rehabilitation work.

The District's method of contracting for routine and restoration work is competitive but does not rely completely on cost. Cost is the primary ingredient in determining which contractor is selected to do the work, but the contractor's experience and past performance are also considered. The process by which these characteristics are evaluated is fairly detailed. In early spring of each year the process of selection of contractors for the coming year is accomplished. These contracts then run for the remainder of the calendar year.

The District's rehabilitation projects are designed by consultants and constructed by contractors. A detailed selection process has been developed for acquiring engineering services. Once a consultant has completed a design he prepared a bid package and the contractor is selected through a typical bidding process.

Since the Maintenance program began in 1981, all engineering, rehabilitation construction, and routine and restorative work has been accomplished through contracting with private firms. Several hundred projects, both big and small, have been accomplished during that time. Listed below are the advantages and disadvantages the District has found for contracting for drainageway maintenance activities.

ADVANTAGES

1. Can avoid "building an empire" of office equipment, telephones, office space, warehouse space, material inventory, support staff, and construction equipment. It is not necessary to gear up to provide what is already available.
2. Tax generated revenue is returned to the private sector through the local engineering and construction community in exchange for their services.
3. State-of-the-art drainage and flood control thinking is tapped within the local engineering community and blended with District needs and staff expertise.
4. There is no fill-in or standby time for labor or equipment. All time that is paid for is productive time. This is true for day-to-day work loads for seasonal variations.
5. By providing regular work to the engineering and construction community they are stimulated to be prepared and available to provide a high quality product to accomplish District needs. Just as important is the fact that the consultants and contractors can then transfer their drainage and flood control capabilities to their work with other local governments and land developers.
6. The quality control manager (District staff) is independent of the work manager (consultant or contractor) and is therefore able to judge the quality of the work being done without being critical of himself or his crews.
7. The program manager is relieved from having to deal with equipment, control of personnel duties, materials purchasing, and inventtory and is able to concentrate on program planning and long term solutions to provide the best product with the taxpayer's money.
8. The local engineering and construction community is large enough that the District benefits from the resulting competition for the work.
9. The consultant selection process and negotiations, and the construction bidding process provide barometers by which to compare project costs and work productiveity. This gauge is not available to local governments that perform the same work with in-house staff and crews.
10. Budget fluctuations are easier to handle when contracts are at issue versus changes in staff and equipment levels.

DISADVANTAGES

1. It is more difficult to maintain strict uniformity in planning, design, and construction since there is a variety of consultants and contractors performing the projects.
2. The contractors are required to be available on short notice, however the District does not have the capability of responding quickly and frequently to emergency needs.
3. With different consultants and contractors performing each project a higher level of project management, project inspection and record keeping is necessary. This requires more administrative effort and staff time.

(Continued on page 9)

South Platte River Program

By L Scott Tucker and Ben Urbonas

The Colorado Legislature authorized the Board of Directors of the Urban Drainage and Flood Control District to levy up to 0.1 mill for maintenance of improvements on the South Platte River within the District. The General Assembly provided this authority in legislation passed during their 1986 session. The District is in the process of putting together a South Platte River Program pursuant to the Legislature's authorization.

The District sought this authorization because, in a recently completed master plan for the South Platte River, about $69,000,000 of flood control improvement costs were identified. In addition, annual operation and maintenance needs were estimated to cost $636,000. It became apparent to the District that a dependable long range funding source was needed if the maintenance of and improvements to the South Platte River were to be realized.

In 1987 1/10 of a mill will generate slightly less than $900,000. While this seems small compared to the identified need, it is felt that much can be accomplished if a program is developed and oriented specifically towards the South Platte River. The steady annual revenue of about $900,000 from the District will permit long-term implementation plans to proceed. The Board of Directors of the District at their meeting on October 16, 1986, adopted a budget for the South Platter River Program and authorized the levying of 0.1 mill.

The South Platte River is the primary and largest drainageway in the Urban Drainage and Flood Control District. All of Denver County, the major parts of Douglas County, Arapahoe County, Jefferson County and Adams County are tributary within the District to the South Platte River as well as areas extending west to the Continental Divide and south to the Palmer Divide. All of the waters from these tributary areas flow into the South Platte River and through the District. In addition to serving as a channel for conveyance of runoff and flood waters, the South Platte River is a metro-wide resource in terms of its trail system, as a water recreation corridor, as a carrier and diluter of wastewater effluent, as a water supply corridor, and for fish and wildlife habitat. Because the river is a metro-wide facility serving and benefiting the citizens of the entire Urban Drainage and Flood Control District area, the Board adopted policies regarding the South Platte River Program from a metro-wide perspective.

At its October 1986, meeting the Board adopted specific policies regarding the South Platte River Program. The Board of Directors decided it will allocate the funds available from the 0.1 mill on an annual basis to projects all along the River. Such allocations will be based on consideration of the timing of projects, availability of matching funds, relative need and priority of improvements, compatibility with the master plan, and distribution of revenues to the various counties. However the Board decided to not adopt a rigid formula for the allocation of funds as is the case for our Capitol Improvement Program and the Maintenance Program.

The Board decided to adopt a cost sharing policy for capitol improvement type projects on a basis of a minimum contribution of 25 percent from the local governments and/or other parties. This is a minimum contribution and it may be appropriate in some cases for the local interests to provide a greater portion of the cost than the 25 percent minimum.

The Board directed that an annual work program for activities relating to the South Platte River be adopted. Primary activities in the work program will include maintenance, construction of improvements, obtaining maintenance access all along and on both sides of the River, stabilization of the banks, and other activities that may be approved by the Board. The Board anticipates that a portion of the South Platte revenues will be allocated each year to maintenance. The amount allocated to maintenance each year will depend on identified needs. The cost sharing policy for maintenance is that the District may contribute up to 100 percent of the cost of maintenance activities.

The South Platte River has great potential as a resource to the residents of the Denver area. Over a period of time this new District program will allow the potential of the South Platte River as a community asset to be realized.

Contracting *(from page 8)*

4. Since each project is constructed by a different contractor there will be times when the construction quality falters and is inconsistent with what is ideal. The project inspector's responsibility is to see that the functional capacity of the project is not compromised; none-the-less there are times when the contractor is not conscientious about the details. This same criticism can often be made of in-house constructed projects as well.
5. There will be more staff travel time in monitoring projects because of the need to travel from job to job.

The District has found that contracting for engineering and construction is a very productive and efficient way to operate. Each situation differs and before a decision is made to contract for engineering or construction services the following questions should be considered:

1. Is there enough work to support full time in-house design crews and full time in-house construction crews and equipment facilities?
2. Does the work either engineering or construction, occur year round, or is it quite seasonal? Seasonal work typically benefits from contracting for the services.
3. Is the engineering technology and/or construction capacity already available in the local community and can it be hired through contracts?
4. Can the work be scheduled such that it would fit a consultant's or contractor's program or is the work frequently needed on short notice or are there frequent emergency calls, that might require in-house capabilities?
5. Is there a technical, financial, or productivity advantage in developing a design staff and/or field crews in-house?
6. If construction is contracted can the work be quantified so that it can be competitively bid?
7. If the work is to be contracted but can't be quantified are there processes by which to select a contractor and by which to monitor his work and pay only for what he satisfactorily completes? In the District's case a detailed process has been developed in which a contractor's labor rates, equipment rates, staff personnel, appropriate experience, and past performance are reviewed and measured.

The District's experience with contracting for work has been very positive. We are confident we have made the best use of the taxpayers' money and that our relationship with the consulting field and the construction industry is productive, fertile and always improving.

Lena *(from page 1)*

range of 0 to 15 feet. The calibration curve is linear and represents measurements in terms of volts (range 0 to 5 volts). The weather data transmitters are set to report stage in an event-time (ET) mode. This type of reporting is accomplished in the following manner:

1. Approximately every 4 minutes the transmitter logic board sends a specified voltage to the PT.
2. The PT returns a voltage to the transmitter logic board (0 to 5 volts) dependent upon static pressure at the PT orifice.
3. If the logic board senses a voltage change from the previous 4 min. reading, the transmitter powers up and sends the corresponding data.
4. The data consists of the Gage I.D. number and a data value (range 0 to 255) representing stage. For the 15-foot calibration range, each data value increment represents 0.058 feet of stage.

Each PT is housed in a sealed 4 inch PVC pipe with end caps and can be mounted to almost any solid object. One end of the PVC housing contains a 1/4 inch diameter orifice which allows fluids to reach the PT. Watertight flexible plastic tubing is attached to the other end of the PVC housing to protect the electronics portion of the PT and house the wire cable leading to the weather data transmitter. The flexible conduit connects to a vertical PVC sewer pipe which houses the transmitter approximately 2 feet below the ground surface. Antenna types and mountings are site dependent, varying from a short wire whip to an omni-directional antenna mounted on an aluminum chain link fence. Low profile installations were selected to help prevent vandalism.

Base Stations

The base stations consist of micro-computers operating database software with various display routines and multi-tasking capabilities. The data collection software is the ALERT package originally developed by the National Weather Service (ALERT-"Automated Local Evaluation in Real Time"). Base station hardware includes; VHF radio receiver, weather data decoder, micro-computer, printer and backup power supply.

The primary base station is located at the offices of Henz Kelly and Associates (HKA), near 1-25 and Colorado Blvd. HKA is a private meteorological firm under contract to perform specific services for the District. The secondary or backup base station is located at the Jefferson County Office of Emergency Preparedness. A third base station (not part of the Lena Gulch system) is located at UDFCD offices to function as areawide support and provide for remote access by other authorized users such as the National Weather Service. Special features of the primary base station are outlined in the following paragraphs:

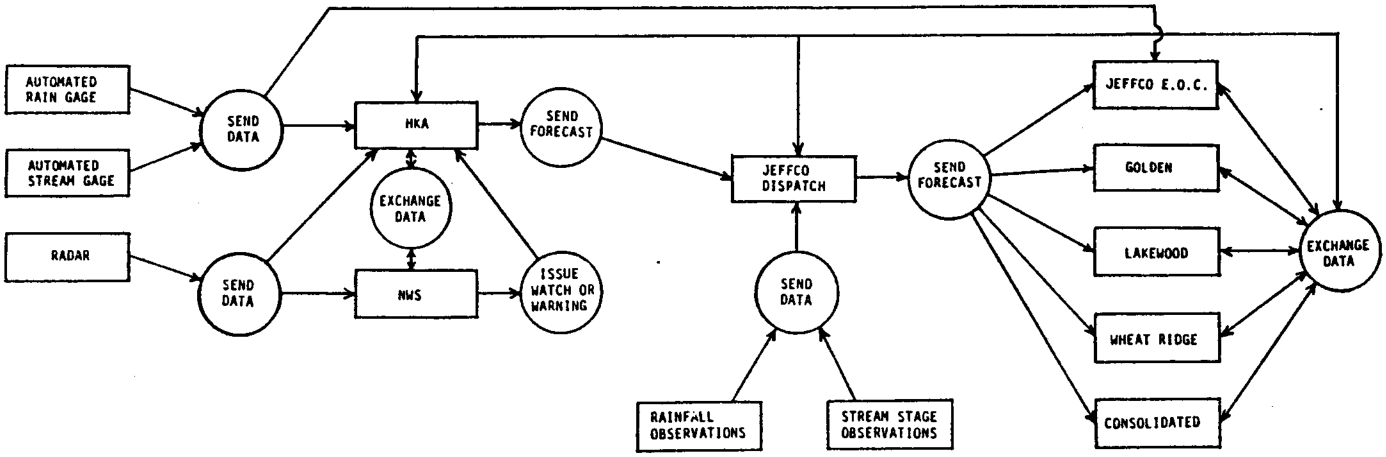
1. The processing unit is an IBM PC/XT with a color monitor and graphics capability.
2. The software package is an upgraded version of the NWS ALERT program which was developed by International Hydrological Services, a California based company and subsidiary of Sierra-Misco, Inc.
3. The Enhanced ALERT software runs on a QNX operating system which provides a multi-user, multi-tasking environment. The basic function of the software is to collect data and provide the means to display data in a variety of formats.
4. The data collection function is performed by a database manager program which dates and time-stamps the decoded data and files the data electronically on the computer's 10 MB hard disk.
5. The display functions constitute the primary "Enhanced" features of the ALERT software. For example, data can be displayed for a single sensor or as a user-defined group of sensors. Both alpha and graphics map displays can be defined for precipitation sensors allowing quick viewing of total rainfall accumulation in real-time for any specified time period. Stream gage data can also be displayed in a variety of manners such as tabular displays for single sensors or sensor groups. Hydrographs can be viewed in graphical format along with time-plots of rainfall intensity for any specified time interval. Other display features include: active alarm viewing, automatic display of incoming data, listing of sensor names defined in the database and others.
6. A hydrologic package has also been developed to run concurrently with the ALERT data collection and display software. The procedure was originally developed by the California-Nevada River Forecast Center of the NWS. This hydrologic model is an adaption of the Sacramento Soil Moisture Accounting (SSMA) Model which is used to forecast runoff hydrographs for user-defined catchments or drainage basins. The model has been calibrated for selected forecast points by adjusting various input parameters and defining model connectivity for routing channel flows. Since only a limited amount of runoff data has been collected to date, the initial model was calibrated to previous hydrology developed for the 1975 Lena Gulch Master Drainage Plan. The originnal hydrology was developed using the Colorado Urban Hydrograph Procedure (CUHP) and the MIT-CAT model. The District contracted with McLaughlin Water Engineers to perform the initial model calibration.
7. A reservoir routing package runs concurrently with the previously described software. This program allows pre-event and real-time evaluation of the operation of Maple Grove Reservoir with the ability to simulate up to 25 gated outlet configurations. The reader will recall that the Maple Grove spillway involves the operation of two Fabridams which require careful monitoring.

The preceding presents a general overview of the key components which make up the Lena Gulch Flood Detection Network. The total system design and costs, which total $100,000, include other items such as radio repeaters, antennas, a duplexer and maintenance related equipment. While the total system design may be considered as over-kill where Lena Gulch is concerned, this system was selected to allow future detection networks to be added on with minimal effort. A buy-in procedure has been proposed to pay back some of the costs borne by the sponsors of the Lena Gulch project. Future systems are currently being considered for Bear Creek, Clear Creek and for the Ralston/Van Bibber/Leyden Creek area affecting the City of Arvada.

Meteorological Support and Real-Time Application

The responsibility for monitoring the Lena Gulch Flood Detection Network currently falls upon the private meteorological firm of Henz Kelly & Associates (HKA). Procedures and decisions aids for disseminating flood forecasts are presented in a document entitled: LENA GULCH FLOOD WARNING PLAN. Timely flood warning for Lena Gulch relys heavily on early meteorological predictions. Various rainfall scenarios can be looked at using the hydrologic and routing procedures of the Lena Base Station well in advance of rainfall. During an actual storm event, real-time data can be observed, predictions adjusted, earlier notifications updated and deci-

LENA GULCH FLOOD WARNING PLAN
COMMUNICATIONS FLOW CHART



LEGEND

AGENCY

ACTION TAKEN

FLOW OF INFORMATION

NOTES:

1. PRIMARY BASE STATION P HKA
2. SECONDARY BASE STATION B JEFFCO E.O.C.
3. PRIMARY VOICE COMMUNICATIONS BY TELEPHONE

sions made with respect to appropriate emergency responses.

The meteorological component, while not the emphasis of this article, should not be underestimated. In a real emergency, certain developed areas along Lena Gulch have less than 30 minutes to evacuate from the time of peak rainfall. Too heavy reliance on real-time data, in such areas, could prove disastrous. On the other hand, real-time data and proper interpretation should reduce the false alarm rate and increase confidence in effecting emergency operations, particularly for affected areas in the lower portion of the basin and below Maple Grove Reservoir.

Putting It All Together

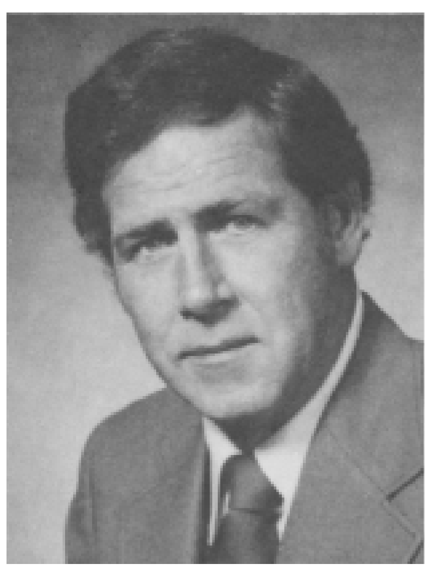
The Lena Gulch Flood Warning Plan is a document which is updated annually and spells out the responsibilities of all parties involved with responding to a flood emergency. Critical elements of the plan include: 1) detection and evaluation; 2) dissemination of the warnings; and 3) warning response. All elements of the warning plan must function properly or the plan will fail. Standard operating procedures (SOPs) for the various response agencies are detailed in the document. Procedures are also described for disseminating warnings to the public, informing the news media of the potential flood hazard and conducting annual exercises.

Communications is one aspect of the plan which needs special emphasis. The accompanying Flow Chart illustrates the complexity of the communications network for Lena Gulch. Dispatch operators are not well versed in the areas of meteorology and hydrology. Care must be taken to make certain that the correct communication occurs and critical messages are not delayed. Timely response to an emergency relies much more heavily on proper communications than the accessibility of real-time weather data.

The Bottom Line

Since the installation of the Lena Gulch Early Flood Detection Network, no emergency situation has developed nor for that matter has any significant rainfall event occurred. The inevitability of this project is that one day, the Lena Gulch Flood Warning Plan will be tested and a real emergency will develop. The success of this program will be evaluated at that time and the public will be the judge.

MEET THE NEW BOARD MEMBERS



WILLIAM A. SCHEITLER
Councilman, City of Denver

Councilman Scheitler is president and part owner of the Hires-Royal Crown Bottling Company in Denver and has been a member of the Denver City Council since July, 1979. Bill ran unopposed for a second term on Council in 1983, and is serving as Council President this year. Bill represents District 1 in Denver which is the northwest part of the city.

Bill also serves on the Board of the Denver Center for the Performing Arts and many other civic organzations and neighborhood groups. He loves to travel, fish and play golf.

Bill was married to Lucille "Dutchess" Iacino in 1958. They are both alumni of Holy Family High School where Bill was Senior Class President. He has a B.A. in Psychology from CU-Denver.

Bill and Dutchess have five children, one grandchild and another one expected soon.

MEET THE NEW BOARD MEMBERS

LINDA S. JOURGENSEN
Mayor, City of Boulder

Linda Jourgensen was born in Fort Morgan, CO. She attended Wellesley College before receiving a B.A. in English Literature from the University of Colorado in 1956. She has been a Boulder resident since 1969.

Mayor Jourgensen has been a member of the Boulder City Council since 1978. She was Deputy Mayor from 1980 to 1986, when she was elected Mayor. She has been a member of the Denver Regional Council of Governments Board of Directors from 1980 to 1986, and a member of the U.S. Conference of Mayors in 1986.

She has one daughter and two sons.

THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
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