UNIFORM DRAINAGE POLICIES AND STANDARDS EVALUATION

VOL. 1

EXECUTIVE SUMMARY AND APPENDICES

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NOVEMBER, 1986

Flood Control District
of
Maricopa County

Boyle Engineering Corporation
consulting engineers / architects

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of
Maricopa County

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ACKNOWLEDGEMENTS

These Urban Drainage Policies and Standards for Maricopa County, Arizona have been prepared by Boyle Engineering Corporation under the direction of Mr. Kenneth Lewis, assisted by Mr. Jim Davey and Dr. Young Yoon. They were prepared following interviews with the Flood Control District of Maricopa County and 23 of the cities and towns within the County. A review of policies and standards in numerous other cities and counties in the United States was also conducted. Regular and constant review, as well as guidance, was provided by a Task Force which included the following:

Kebba Buckley	Flood Control District of Maricopa County
John Baldwin	City of Phoenix
Dick Schaner	City of Scottsdale
Ken Reedy	City of Glendale
Keith Nath	City of Mesa
Tom Ankeny	City of Tempe
Skip Blunt	Town of Wickenburg
Joe Kissel	Salt River Project
Dave Bixler	Homebuilders Association of Arizona
Lindy Bauer	Maricopa Association of Governments
Collis Lovely	Arizona Consulting Engineers Association
Joe Tram	Flood Control District of Maricopa County
Doug Plasencia	Flood Control District of Maricopa County

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EXECUTIVE SUMMARY

1. INTRODUCTION

The governmental agencies of Maricopa County desire to establish a common basis for drainage management in all jurisdictions within Maricopa County. To accomplish this, a Task Force was formed to prepare a scope of work. It was concluded that the effort should be planned in three phases:

PHASE I — Research, evaluate, develop and produce uniform policies and standards for drainage of new development within Maricopa County.

PHASE II — Establish a Stormwater Drainage Design Manual for use by all jurisdictions and agencies within the County.

PHASE III — Prepare an in-depth evaluation of regional rainfall data and establish precipitation design rainfall guidelines and isohyetal maps for Maricopa County.

This report summarizes the results of Phase I and comprises two Volumes. Volume 1 is an executive summary of the work performed and contains detailed appendices of various sections of the project. Volume 2 contains the report on Evaluation of Hydrologic and Hydraulic Methods.

The primary functions necessary to produce the policies and standards included:

- Interviewing 24 Maricopa County jurdisdictional agencies; ranking their drainage policies and standards and comparing their standards with other western metropolitan areas.
- Evaluating hydrologic methods for their applicability for use in Maricopa County.
- Assessing the existing regional rainfall data and collection network and proposing the requirements for updating the data.
- Preparing design examples and inventorying computer usage.

Regular and constant review was provided by the Task Force, which included the following:

Kebba Buckley	Flood Control District of Maricopa County
John Baldwin	City of Phoenix
Dick Schaner	City of Scottsdale
Ken Reedy	City of Glendale
Keith Nath	City of Mesa
Tom Ankeny	City of Tempe
Skip Blunt	Town of Wickenburg
Joe Kissel	Salt River Project
Dave Bixler	Homebuilders Association of Governments
Lindy Bauer	Maricopa Association of Governments
Collis Lovely	Arizona Consulting Engineers Association
Joe Tram	Flood Control District of Maricopa County
Doug Plasencia	Flood Control District of Maricopa County

2. DRAINAGE POLICIES AND STANDARDS

During the course of the study, nine draft documents on Drainage Policies and Standards were prepared for review by the Task Force. The final draft prepared by Boyle Engineering Corporation is dated November 19, 1985, and is contained in Appendix A. Subsequent drafts are currently being prepared by the Flood Control District of Maricopa County for adoption by the various jurisdictional agencies.

3. DATA COLLECTION AND QUESTIONNAIRES

The initial task was to collect drainage ordinance and practices data from the 24 jurisdictional agencies within Maricopa County and from selected agencies outside the County. A list of the agencies is summarized in Table 1. The published data was supplemented by completing questionnaires from interviews. Details of the questionnaires are given in Appendix B.

Table 1 Agencies and Personnel Interviewed

Agency	Contact	Position	Phone	Persons Interviewed
FCDMC	Kebba Buckley	Proj Eng	262-1501	J Tram, D Plasencia
Phoenix	John Baldwin	Eng Supr	262-6824	J Baldwin, P Johnson
Scottsdale	Dick Schaner	Pub Wks Adm	994-2326	D Schaner, C Connett
Mesa	Keith Nath	Eng Supr	834-2512	H Kent, K Nath
Glendale	Ken Reedy	City Engr	435-4155	K Reedy
Chandler	Alfred Pfahl	Engr Mgr	899-9797	A Pfahl
Tempe	Howard Hargis	Sup Engr	968-8200	H Hargis
Goodyear	Eric Grendell	Pb Wks Dir	932-3910	E Grendell
Peoria	Eldon Johansen	City Engr	979-6121	E Johnson
Gilbert	Lonnie Frost	Engr	892-0800	L Frost
Paradise Vly	Joe Jason	Town Engr	948-7411	J Jason
Surprise	P Murphy	Engineer	977-8369	
Apache Jnct	Dennis Eckert	Bldg Inspect	982-8002	D Eckert
Avondale	Larry Ramirez	Pb Wks Dir	932-1909	L Ramirez
El Mirage	Cecil Skaggs	Pb Wks Dir	972-8116	C Skaggs
Wickenburg	Skip Blunt	Fl Pl Mgr	252-4672	S Blunt, G Bush
Buckeye	Stephen Villa	Pb Wks Dir	386-2487	S Villa, T Rockwell
Gila Bend	R McComb	Town Mgr	256-7856	R McComb
Tolleson	Ralph Velez	City Mgr	936-7111	R Velez
Youngtown	J Detheridge	City Engr	933-8286	S Wise
Guadalupe	R Guttierrez	Town Mgr	839-2415	R Guttierrez
Carefree	Art Lucas	Town Engr	488-3686	A Lucas
SRP	Joe Kissel	Sn Engr	236-2978	J Kissel, D Roach, T Phillips
El Paso			9155414200	
Clark Cty	Gill Suko	Hydrolog	7023864621	
Albuquerque		City Clerk	5057667410	
LACFCD	D Donavon	Pb Wks	2132264111	
Pima Cty FCD	Dan Yersabich		882-2622	
Denver FCD	Ben Urbonas		3034556277	
ADOT	Marv Sheldon			M Sheldon

4. EVALUATION OF HYDROLOGIC AND HYDRAULIC METHODS

A report was prepared (Volume 2 bound separately) evaluating current and proposed hydrologic and hydraulic methods to be used in Maricopa County. The hydrologic methods evaluated included:

Methods used in Maricopa County

- Rational Method
- Soil Conservation Service Method (TR-20/TR-55)
- Arizona Department of Transportation Method
- Corps of Engineers HEC-1
- Storm Water Management Model (SWMM)

Other methods

- Albuquerque Metropolitan Arroyo Flood Control District
- Denver Urban Drainage and Flood Control District
- City of El Paso
- Clark County, Nevada
- Los Angeles County Flood Control District
- Illinois Urban Drainage Area Simulator (ILLUDAS)
- Santa Barbara Urban Hydrograph (SBUH)
- Penn State Run-off Model (PSRM)

It was recommended:

<u>For areas up to 160 acres:</u>

- The rational method be used for computing peak discharges.

- A uniform method of determining run-off coeffecients and time of concentration be established.

- A procedure to define hydrographs, when needed, be established.

<u>For areas greater than 160 acres:</u>

- SCS curve numbers be used to determine effective rainfall (run-off). These should be checked for their applicability to local conditions.

- A unit hydrograph method be established for computing peak discharge and synthesizing hydrographs.

- A hydrologic computer program be developed which can run on both personal computers and mainframes. This can be achieved by modification to subroutines of TR-20 and HEC-1.

- The kinematic wave method be used for channel routing.

- Hydrologic simulation parameters should be established to provide for consistent results in Maricopa County.

5. MARICOPA COUNTY REGIONAL RAINFALL

A report was prepared (Appendix C) assessing existing isohyetal data and characterization of the Maricopa County rainfall networks. In the paper it was recommended that:

1. Existing 6-hour and 24-hour storm precipitation-frequency relations should be updated. New precipitation frequencies should be developed for stations with greater than 25 years of record.

2. The isohyetal maps should be updated using the data now available.

3. For storms up to 6 hours, revised rainfall-intensity-duration-frequency curves should be established using regression equations based on Maricopa County data.

4. In conjunction with the rainfall frequency analysis, consideration should be given to the evaluation of area rainfall reduction curves.

6. DESIGN EXAMPLES AND COMPUTER USAGE

To further aid in formulating drainage policies and standards, design examples were prepared. These examined the costs of providing longitudinal street drainage, retention, and flow capacity in open channels. The design examples are in Appendix D.

An inventory of computer usage by the jurisdictional agencies of Maricopa County was conducted. It was found, however, that most usage of computers was by consultants rather than by the jurisdictional agencies.

APPENDIX A

DRAINAGE POLICIES AND STANDARDS
for
MARICOPA COUNTY, ARIZONA

NOVEMBER 19, 1985 DRAFT

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1 INTRODUCTION

The governmental agencies of Maricopa County seek to establish a common basis for drainage management in all jurisdictions within Maricopa County. The Flood Control District of Maricopa County, in April 1985 invited all interested entities to a meeting to establish an agreement in principle. At that meeting a Task Force was formed to prepare a Scope of Work for consultants to carry out the project.

The Task Force concluded that the effort should be planned in three phases. They are:

Phase 1	Research, evaluate, develop and produce uniform policies and standards for drainage of new development within Maricopa County.
Phase 2	Establish a Stormwater Drainage Design Manual for use by all jurisdictional agencies within the County.
Phase 3	Prepare an in-depth evaluation of regional rainfall data and establish precipitation design rainfall guidelines and isohyetal maps for Maricopa County.

These policies and standards have been prepared to fulfill the requirements of Phase 1 of the effort. Their adoption by all agencies involved in urban drainage will result in a common standard of drainage design and will reduce the time and effort by both designers and government review staff for submitted drainage proposals and designs.

2 POLICIES

1. The jurisdictional agencies within Maricopa County (AGENCIES), through the Flood Control District of Maricopa County (DISTRICT), will establish and publish criteria for drainage planning and design. Guidance relative to construction, operation, and maintenance of urban drainage systems will also be provided. The AGENCIES will adopt criteria relevant to all public and private drainage interests. Such criteria will be periodically reviewed and revised in the light of new knowledge, changing circumstances, and adjustments in overall comprehensive goals and objectives.

2. Drainage planning shall involve concerned publics.

3. Master drainage planning for developments should be carried out in the earliest stages of the planning process. They should include the proposed methods of managing urban drainage and associated land use.

4. Drainage planning and design shall be based on the principle of not increasing or transferring detrimental drainage effects to other areas.

5. Basinwide master drainage planning by the AGENCIES is necessary, has started and should be continued. The plans are being prepared on a priority basis and will be continued subject to need and available financing.

6. Plans for drainage basins will be periodically reviewed and revised in the light of new knowledge, changing circumstances, and adjustments in overall comprehensive goals and objectives. Unless otherwise determined, such reviews will be at intervals of about 5 years.

7. The cooperation of the AGENCIES and other relevant drainage interests, including the land development industry, will be sought to coordinate individual development and drainage schemes with the basinwide plans.

8. Urban drainage planning is for the purpose of reducing flood damage and potential loss of life. The benefits of planning will reduce overall public and private costs, including the long and short term cost of new housing.

9. Uniform drainage policies and standards will improve processing of development requests and equitable application of regulations.

10. Development and basinwide master drainage plans will consider a full range of preventive and corrective approaches, including the following:

    . Maintaining the integrity of existing drainage patterns;

    . Establishment of selected major drainage routes by the use of purchase, dedication, development rights, and easements;

    . Storage and attenuation of urban stormwater runoff; and

    . Construction of urban drainage works.

    The combination of strategies will balance engineering, economic, environmental, and social factors in relationship to stated comprehensive goals and objectives.

11. Multiple use of drainageways is encouraged provided the use does not adversely impact the functional design of the system.

12. In accordance with priorities and fiscal capabilities, the AGENCIES will develop and implement corrective drainage plans that will mitigate existing drainage problems. Such plans will be coordinated with comprehensive goals and objectives, and will consider a combination of structural and nonstructural measures. The level of protection will be determined on the basis of economic analyses, availability of funds and physical constraints.

3 PLANNING

Drainage planning helps to achieve an orderly, efficient, pleasant and diverse area. Accomplishment of the comprehensive goals and objectives can be assisted by a broad drainage planning process. Such a process should be considered within the context of the total environmental system and should be compatible with comprehensive regional plans.

The design team should think in terms of natural drainage easements and street drainage patterns and should coordinate its efforts with drainage engineers. Drainage measures are costly when planning is poor or mediocre, whereas good planning results in lower cost drainage facilities.

It is vitally important that planning precede development for the following reasons: to ensure drainage problems are not transferred from one location to another, multiple use opportunities are not lost, and the cost for overall drainage facilities are kept to a minimum. This is best accomplished with comprehensive master drainage plans.

3.1 MASTER PLAN

A master drainage plan describes in detail the recommended plan for drainage and the courses of action for implementation in terms of priorities. It shows sizes, types and location of drainage facilities on maps in sufficient detail to allow for planning new development.

Each AGENCY in Maricopa County will be responsible for master planning drainage facilities in their jurisdiction. Cooperation between governmental units is desirable, and joint efforts between cities and the DISTRICT are particularly encouraged. Coordination of efforts will be made by the DISTRICT.

The preparation of detailed master drainage plans for Maricopa County are in process by both the DISTRICT and individual cities and towns. They are primarily focused on areas of rapid development and areas with existing problems.

3.2 TRANSFER OF PROBLEMS

Planning and design of storm water drainage systems are to ensure that problems are not transferred from one location to another. This includes upstream channel modifications which can transfer problems downstream if not planned properly. The diversion of storm runoff from one drainage area to another introduces significant legal and social problems and will be avoided unless specific reasons justify such a transfer and the affected jurisdictions agree on the transfer.

3.3 IRRIGATION FACILITIES

Irrigation facilities are not to be used as outfalls for drainage systems unless such use is shown to be without unreasonable hazard substantiated by adequate hydraulic engineering analysis, and is approved by the owner and the AGENCY.

Irrigation facilities cannot, as a general rule, be used as a direct or indirect outfall for additional storm drainage. Exceptions to the rule are when the capacity of the irrigation facility is adequate to carry the maximum irrigation flow plus the design storm runoff with an adequate margin of safety. When irrigation facilities are used for stormwater drainage, written permission from the owner/operator must be provided indicating the volume of drainage permitted and location of acceptance.

Irrigation facilities are sometimes abandoned in urban areas. If these facilities are to be used for stormwater drainage, then their capacity must be established. The capacity analysis must include evaluation of the facility and all conduits to its unrestricted outfall. The owner of any abandoned facility must approve all transfer of uses.

3.4 OPEN CHANNELS

Open channels have advantages in cost, capacity, multiple use for recreational and aesthetic purposes, and potential for detention storage. However, disadvantages exist in right-of-way needs, maintenance costs and hazards to traffic and pedestrians. Careful planning and design are needed to minimize the disadvantages and to maximize the benefits.

Natural channels have velocities that are usually low, resulting in longer concentration times, increased storage and generally lower downstream peaks. If flows in natural channels are increased, consideration must be given to maintaining their stability. Channels in hillside development areas are to be retained in their natural state unless otherwise required by the AGENCY.

If right-of-way is limited requiring higher velocities to convey the design discharges, then channel lining is required to prevent scour. The choice of lining is subject to allowable velocities, cost and aesthetics. Man made channel alignments for drains are to coincide with the natural watercourse locations, except as approved by the AGENCY. They are to discharge runoff as nearly as possible in the location and with the same velocities which existed prior to construction. If diversion within a proposed development is required, sufficient work is to be done upstream and/or downstream of the diversion to provide affected properties at least the same level of flood protection as existed prior to the diversion.

Open channels adjacent to public streets are discouraged and require approval from the AGENCY. When it is necessary to locate a channel adjacent to a street, it will be placed a safe distance from traffic.

3.5 DRAINAGE REPORTS

Drainage reports are required for the following reasons: to analyze the effect that a proposed development would have upon the rainfall runoff in the vicinity of the development; to provide data to insure that the development is designed to be protected from flooding; and to provide data supporting the design of facilities to be constructed for the management of rainfall runoff. When a drainage report is required, it must be prepared and sealed by a civil engineer registered as a professional engineer in the State of Arizona. A drainage report will be submitted to the AGENCY in accordance with its requirements.

4 BASIS OF DESIGN

4.1 DRAIN CLASSIFICATION

The following classification of drains into minor, major and regional drains is presented as an aid for system analysis.

Minor drains serve areas up to 160 acres and are normally the drains associated with subdivision development.

Major drains include natural and man-made channels, conduits and washes, and serve areas from 160 acres to about 10 square miles.

Regional drains are the main outfalls for drainage. They serve areas generally greater than 10 square miles, and include rivers and washes.

4.2 HYDROLOGICAL ANALYSIS

Hydrological procedures for general application in Maricopa County shall:

- Provide reliable and consistent results;
- Be capable of estimating peak discharges for various return periods and degrees of urban development;
- Produce a hydrograph corresponding to the peak discharge;
- Utilize input data which is readily available;
- Be workable for main frame, microcomputer and hand calculations.

For Maricopa County two procedures will be developed: one for areas less than 160 acres and one for areas greater than 160 acres. The primary differences between the two are ease of use and range of applicability. The specific input parameters required for each procedure will be established and published in the Design Criteria Manual and will be periodically updated as required.

For drainage areas less than 160 acres the Rational Method will be used. This method is the simplest and most widely used procedure for small urban basins.

For drainage areas greater than 160 acres, the SCS dimensionless unit hydrograph procedure will be used at this time. A new procedure, to be called the Maricopa County Urban Hydrograph Procedure (MCUHP), will be developed for this area. The procedure will be described in the Stormwater Drainage Design Manual. In the interim, excess rainfall will be computed using the SCS curve number method; runoff will be determined by the SCS dimensionless unit hydrograph method, and the resultant hydrographs routed, where necessary, by such methods as those available in SCS TR-20 or HEC-1.

The peak discharges determined by either of the methods are approximations. Emphasis should be placed on the design of practical and hydraulically balanced works based on sound logic and engineering, as well as on dependable hydrology.

4.3 HYDRAULIC ANALYSIS

4.3.1 Storm Sewers

Manning's formula is to be used for calculating the capacity of continuous stormwater drains, with appropriate allowances for headloss at inlets, bends, junctions and manholes. Manning's "n" factors and minor energy loss coefficients will be published in the Design Criteria Manual. The maximum capacity for circular sections under open channel flow conditions is not to exceed full flow conditions. Uniform flow assumptions may be used in calculating the capacities of minor drains. For major drains, or where a higher degree of accuracy is required, backwater or drawdown curves should be calculated using the Standard Step method. Pressure and momentum theory can be used at bends, junctions, and manholes.

For systems flowing under pressure, the maximum pressure allowed must consider the structural limitations of both the pipe and joint. The hydraulic grade line must be maintained below ground level unless special consideration is taken to prevent water from escaping from sewers or to handle it once it does escape. Whether the system is under pressure or in open channel flow conditions, the hydraulic controls are to be clearly indicated.

4.3.2. Open Channels

Open channels should maintain subcritical flow conditions. Any channel that is not designed for subcritical conditions will require approval from the AGENCY. Open channels should be designed with the tops of the banks or levees at or below the adjacent ground to allow interception of surface flows. If it is unavoidable to construct the channel without creating a barrier to surface flow, a means of draining must be indicated.

In preliminary layouts of the routing of proposed channels, it is desirable to avoid sharp and reversed curvatures, and closely spaced series of curves. If this is unavoidable, design considerations are to include the reduction of superelevations and the elimination of initial and compounded wave disturbances.

Manning's formula is to be used for uniform flow computations in open channels. Water surface profile calculations are to be calculated using the Standard Step method and confluences and bridge piers are to be analyzed using pressure and momentum theory.

Unlined channels should have side slopes of 3 (horizontal) to 1 (vertical)or flatter. A minimum Manning's "n", applicable for the channel under design, is to be used for checking sections susceptible to scour, and the normal or maximum value used for determining the required cross section. Where the channel roughness changes significantly with depth, a composite Manning's "n" is to be used.

4.4 STREETS

Design standards for the collection and conveying of runoff water on public streets is based on an acceptable frequency of traffic interference. That is, depending on the street classification, certain traffic lanes can be fully inundated after exceeding the design storm frequency. Streets have been classified into local, collector, arterial and expressway.

A local street is a minor traffic carrier within a neighborhood. There is no direct through traffic from one neighborhood to another and they are primarily used for direct access to residential, commercial, industrial, or other abutting property.

A collector street collects and distributes traffic between arterial and local streets.

An arterial street permits rapid and relatively unimpeded traffic movement throughout a city.

An expressway is a roadway that expedites movement of large volumes of through traffic between areas and across the city.

Street drainage will be governed by the following:

Design Storm Frequencies for Street Drainage (Years)

	STREET CLASSIFICATION		
	Local	Collector	Arterial
A. LONGITUDINAL STREET FLOW			
No curb overtopping. * (For 4 or more laned streets at least 1 traffic lane free of water in each direction.	10	10	10
Flow to be calculated assuming contained in ROW with: . 0.3 feet maximum depth over curb * . 100 cfs maximum flow . 10 fps maximum velocity	50	50	50
Flow to be calculated assuming no inundation within 1 foot of the lowest finished floors.	100	100	100
B. CROSS STREET FLOW			
No flow across street	10	10	10
0.5 feet depth at crown or in valley gutter *	25	25	50
1.0 feet of depth at crown	100	100	100

* Where no curb exists, maximum depth to be 0.5 feet over crown.

Drainage design for expressways shall be governed by ADOT standards.

Regardless of the size of the culvert or bridge, the street crossing is to be designed to convey the 100-year storm runoff under and/or over the road to an area downstream of the crossing to which the flow would have gone in the absence of the street crossing.

For flows crossing broad shallow washes where the construction of a culvert is not practical or desirable, the road should be dipped to allow the entire flow across the road. The pavement through the dip should have a one way slope and curbing and medians must not be raised. For these situations approval is to be obtained from the AGENCY.

4.5 STORAGE FACILITIES

4.5.1 Requirements for Storage

To reduce the significant cost of handling stormwater runoff and to control increased peaks and volumes from development areas, all development will make

provisions to retain runoff from rainfall events up to and including the 100-year 2-hour duration storm falling within the boundaries of the proposed development. The 100-year 2-hour event should be established using ADOT procedures.

The development will be considered to extend to the centerline of all existing and/or future streets on the exterior boundaries, and will include all property within the development. In some areas it may be required to retain runoff generated from adjacent arterial streets. These areas will be designated by the AGENCY during the preliminary planning stages.

Offsite flows may not be routed through the storage facilities unless approved by the AGENCY.

Storage facilities are to be located so they can intercept the flow from the entire development area. If portions of the area cannot drain to a primary storage facility, then additional facilities are to be added for these areas as approved by the appropriate AGENCY. Wherever possible, the facilities are to be located in parks or other recreational facilities to offset the cost of open space and to encourage improved maintenance.

4.5.2. Conditions When Storage May Be Waived

If the downstream drainage system is adequate, storage requirements may be waived by the AGENCY under the following circumstances:

1. The runoff has been included in a storage facility at another location;

2. The runoff can be directly carried to a regional drain;

3. Development of an existing parcel under one-half acre in an area where it can be demonstrated that no significant increase in the potential for flood damage will be created by the development.

If onsite storage is waived, the development may be required to contribute to the cost of drainage works on the basis of runoff contribution.

4.5.3. Method of Storage

The use of common storage facilities is encouraged

Residential developments will have no single lot storage unless approved by the AGENCY, and the design of common facilities will not assume any individual lot onsite storage. Developments with Homeowners Associations will locate their facilities in private drainage tracts or public park sites dedicated by the developer, in accordance with requirements determined by the AGENCY. The private facilities will be maintained by the Homeowners Association. Public parks will be maintained by the AGENCY. Common storage facilities for single family developments without a Homeowners Association and with public streets will have maintenance determined by the AGENCY. The number and location of storage facilities within a development is to be approved by the AGENCY.

Non-Residential Developments that are not included in a public storage facility, will provide the required storage on the lot itself without depressing the right-of-way area. Asphalt parking areas, landscape areas and underground tanks may be used for storage purposes.

4.5.4 Drainage of Storage Facilities

Storage facilities are to be drained within a period of 36 hours by either controlled bleed-off, discharge pump, infiltration or drywell.

Controlled bleed-off or pumping is the preferred method and may be required if the AGENCY considers a public nuisance would be created by surface spreading or drywells. Responsibility for maintenance and operation of the bleed-off and/or pumping system will be determined by the AGENCY.

Drywells may be used with the approval of the AGENCY. The maximum disposal rate is not to exceed 0.1 cfs per well unless supported by a detailed certified soils report. Should the soils report indicate a higher rate, a conservative value of 50% of the higher rate (not to exceed 0.5 cfs) will be used to compensate for deterioration over time. Drywells that cease to drain a project area in a 36-hour period are to be replaced by the maintenance authority with new ones, unless an alternate method of drainage becomes available.

APPENDIX A DEFINITIONS

AGENCY	The governmental authority in whose jurisdiction an aspect of the drainage system is regulated.
Arterial Street	An arterial street permits rapid and relatively unimpeded traffic movement throughout a city.
Channel	A natural or artificial watercourse with definite bed and banks for conducting flowing water.
Collector Street	A collector street collects and distributes traffic between arterial and local streets.
Detention System	A system which delays runoff in a controlled manner through the combined use of temporary storage facilities and an open outlet. The duration of downstream runoff is increased and the flow peak immediately downstream is reduced.
DISTRICT	The Flood Control District of Maricopa County.
Drainage Basin	The contributing area to a single point of drainage concentration. Also called catchment area, watershed, and river basin.
Drywell	A shaft or hole, covered and designed to allow the percolation of drainage water into the ground.
Expressway	An expressway is a roadway that expedites movement of large volumes of through traffic between areas and across the city.
Irrigation Facilities	Channels, pipes and hydraulic structures through which irrigation water flows.
Local Street	A local street is a minor traffic carrier within a neighborhood. There is no direct through traffic from one neighborhood to another and they are primarily used for direct access to residential, commercial, industrial, or other abutting property.
Minor Drains	Drains that serve areas up to about 160 acres and are normally the drains associated with subdivision development.
Major Drains	Major drains include natural and manmade channels, conduits and washes and serve areas from 160 acres to about 10 square miles.
Outfall	The point, location or structure where drainage discharges from a channel, conduit or drain.
Regional Drains	Regional drains are the main outfalls for drainage. They serve areas generally greater than 10 square miles and include rivers and washes.

Retention System	A system which retains runoff in a controlled manner through the use of storage facilities. Stored water is evacuated either by percolation or released to the downstream drainage system after the storm event.
Storage Facilities	Reservoir, tank, pipes or other space for either the detention or retention of drainage.

APPENDIX B REFERENCES

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APPENDIX B

POLICIES AND STANDARDS QUESTIONNAIRES

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Uniform Policies and Standards
DATA COLLECTION AND INTERVIEWS

Ref Page		Contact	Position	Phone	Persons Interviewed
2	FCDMC	Kebba Buckley	Proj Eng	262-1501	J Tram, D Plasencia
4	Phoenix	John Baldwin	Eng Supr	262-6824	J Baldwin, P Johnson
6	Scottsdale	Dick Schaner	Pub Wks Adm	994-2326	D Schaner, C Connett
9	Mesa	Keith Nath	Eng Supr	834-2512	H Kent, K Nath
11	Glendale	Ken Reedy	City Engr	435-4155	K Reedy
13	Chandler	Alfred Pfahl	Engr Mgr	899-9797	A Pfahl
14	Tempe	Howard Hargis	Sup Engr	968-8200	H Hargis
15	Goodyear	Eric Grendell	Pb Wks Dir	932-3910	E Grendell
16	Peoria	Eldon Johansen	City Engr	979-6121	E Johnson
18	Gilbert	Lonnie Frost	Engr	892-0800	L Frost
19	Paradise Vly	Joe Jason	Town Engr	948-7411	J Jason
20	Surprise	P Murphy	Engineer	977-8369	
20	Apache Jnct	Dennis Eckert	Bldg Inspect	982-8002	D Eckert
21	Avondale	Larry Ramirez	Pb Wks Dir	932-1909	L Ramirez
22	El Mirage	Cecil Skaggs	Pb Wks Dir	972-8116	C Skaggs
22	Wickenburg	Skip Blunt	Fl Pl Mgr	252-4672	S Blunt, G Bush
23	Buckeye	Stephen Villa	Pb Wks Dir	386-2487	S Villa, T Rockwell
23	Gila Bend	R McComb	Town Mgr	256-7856	R McComb
23	Tolleson	Ralph Velez	City Mgr	936-7111	R Velez
23	Youngtown	J Detheridge	City Engr	933-8286	S Wise
24	Guadalupe	R Guttierrez	Town Mgr	839-2415	R Guttierrez
24	Carefree	Art Lucas	Town Engr	488-3686	A Lucas
24	SRP	Joe Kissel	Sn Engr	236-2978	J Kissel, D Roach, T Phillips
26	El Paso			9155414200	
26	Clark Cty	Gill Suko	Hydrolog	7023864621	
27	Albuquerque		City Clerk	5057667410	
29	LACFCD	D Donavon	Pb Wks	2132264111	
29	Pima Cty FCD	Dan Yersabich		882-2622	
31	Denver FCD	Ben Urbonas		3034556277	
	ADOT	Marv Sheldon			M Sheldon

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.1	Planning	Master Plan basis established, planning for 10-12 basins with drains designated. No enforcement available--not approved yet. Master plans preempt standards.
2.2	Drainage Reports	Yes, for residential, commercial and industrial development.
2.3	Drainage Patterns	Maintain same ingress and egress of washes crossing properties. Path can be varied across property.
2.4, 2.5	Retention/Detention	Detain difference between pre- and post-development levels of peak flows for residential developments and both peak flows and volume for commercial and industrial developments.
2.6	Use of Streets	Not used. County Highway Department against inverted streets.
2.7	Floor Levels of Buildings	FEMA in regulated areas or 14" above low outfalls of lot or 8" above top of curb.
2.8	Channels	Maintain pre-development hydrological conditions so no adverse conditions are caused either upstream or downstream, with respect to areas of inundation and velocities.
2.9	R.O.W.	Area designated for design discharge adjacent to washes. County accept no dedications.
2.10	Multiple Use	Indirect encouragement for flood prone land to be used for non intensive development.
2.11	Hillside Area	Maintain dip sections at crossing. Back cut required to protect houses from sheet flow (part of Uniform Building Code). No current intense urbanization on hillside sites.
2.12	Maintenance	Homeowners Association responsible until City annexes land.
2.13	Erosion Sediment Control	No policies or standards.
2.14	Enforcement	Minimal. Based on follow up on construction plans.
3.	DRAINAGE STANDARDS	
3.1	Drain Classification	Accept rivers, trunk drains (including major washes), and infrastructural drains.

3.2	Design Recurrence Intervals	100 year peak from offsite flows. 100 year - 2 hour runoff for determination of retention volumes.
3.3	Cross Street Flow	Must maintain predevelopment conditions in crossings (no backwater allowed).
3.5,6	Retention/Detention	Difference in peaks and volumes of 100 year 2 hour runoff event to be detained for commercial and industrial developments. Only peak difference to be detained for residential developments.
3.7	Freeboard	No requirements.
3.8	Drywells	No standards except for refrain ing from using them in industrial areas.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Accept SCS TR-20/TR-55, HEC1, HEC2, ADOT and Rational Methods. Any that is technically sound and can be substantiated. Runoff coefficients must be accept able.
4.2	Hydraulic	Using accepted n-values.
5.	DRAINAGE DATA	
5.1	Rainfall	Use NOAA.
5.2	Networks	Gauges established in new areas. High intensities seen. new data available for revision.
5.3	Soils	SCS
6.	COMPUTERS	
6.1	Hardware	Data General MB4000
6.2	Software	HEC1, HEC2, Minor channel programs.
7.	GENERAL	
7.1	Problems	1. Finished floor design criteria upstream and downstream of building site. 2. Modification to natural drainage system. 3. Lack of hydrology and hydraulic data.
7.2	Concepts	Prefer planning to be developed around drainage but usually see drainage developed around planning.
7.4	Development	Most frequently 5-100 acres.
7.5	Built up Areas	Try to rectify existing problems.
7.6	Performance or Standards Oriented	Meet Standard or exceed by performance
7.7	Flexibility	Yes

CITY OF PHOENIX

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.1	Planning	Drainage planned around subdivision except where natural channels will be kept.
2.2	Drainage Reports	For grading permits.
2.3	Drainage Patterns	Runoff to enter and depart in essentially the same manner, unless new storm drain facilities constructed.
2.4	Retention	Required unless major channels or natural drainageways with adequate capacity available or unless justified (small, isolated developments).
2.6	Use of Streets	For drainage, including allowing natural washes to flow into streets.
2.7	Floor Levels of Buildings	Above runoff expected from 100-year storm. Minimum of 14 inches above top of low curb and 6 inches above top of high curb.
2.8	Channels	Natural channels shall have 50-year runoff capacity and freeboard. Channels may be used for excess runoff from streets. Flow must be below natural ground level, levees unacceptable (except fill for freeboard). If quantity is greater than 2,000 cfs, lining must be reinforced. Channelization within floodplain must be so the 100-year water surface is not raised by more than 1 foot.
2.9	Right-of-Way	Open channels shall be on dedicated right-of-way (on easement if Homeowners Association accepts maintenance responsibility). Single family development retention facilities on public tracts. Minimum 10-foot easement for drainage ROW for underground drainage on Drainage easement to ROW required for lot-to-lot drainage.
2.10	Multiple Use	No parking within washes or selected floodways.
2.11	Hillside Areas	Use curve number of 95 if ground slope is greater than 10% regardless of zoning.
2.12	Maintenance	Of retention facilities - by Homeowners Association if there is one; if not, by Phoenix.
2.13	Erosion and Sediment Control	Culvert exit velocity greater than 5 fps will require soil stabilization. Channel lining required for velocities greater than 5 fps, or tractive force analysis requirements. Provisions shall be made to prevent surface water erosion of faces of excavations or fills.

2.14	Enforcement	Floor elevations not approved until paving plans approved.
3.	DRAINAGE STANDARDS	
3.2	Design Recurrence Intervals	100-year flood for floor elevations, 10-year for street capacity with provi sions for 100- year runoff. Culverts for 50-year storm, culverts and dip crossings together for 100-year, 50-year storm for natural wash capacities.
3.3	Cross Street Flow	If washes terminate in street, then calculations required to determine if the water can be turned to stay within street section.
3.4	Longitudinal Street Flow	Capacity of runoff from 10-year storm to top of sidewalks. Maximum street flow of 100 cfs and 12 fps in 100-year storm. When runoff leaves streets at dead-ends, channels or underground facilities required to get it back to public ROW or drainage easements. Inverted crowns not permtted unless concrete.
3.5	Retention	Retain runoff from 100-year, 2-hour storm falling within development. If average slope of property exceeds 5% retention requirements may be waived. 36- hour drain time. Overflow to adjacent streets.
3.7	Freeboard	Channel must contain 50-year runoff and additional 20% capacity. Freeboard can be satisfied with fill sections.
3.8	Dry Wells	Allowed for retention basins. One-half of theoretical capacity of dry wells shall be used for design to allow for sitting and/or grate obstruction. Dry well tests required.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Up to 1/10 square mile, use rational method (c & i values included), SCS TR-20/TR-55 for greater than 1/10 square mile.
4.2	Hydraulic	No supercritical junctions. Tractive force (preferred) or limiting velocity (5 fps) for lining channels or not. Manning's Equation used for all culverts and open channels. Open channel convergence, divergence standards. Momentum analysis for pier loss.
5.	DRAINAGE DATA	
5.1	Rainfall	Rainfall Intensity: Duration-frequency relation for Phoenix used; based on U.S. Weather Bureau Technical Papers #28 and #40; Revised 6/75 with new information from WR-44.
5.3	Soils	USDA SCS General Soil Map of Maricopa County

5.4	Maps	Drainage map required with quantities at points of concentration, drainage areas outlined, and showing how flow is to be routed.
6.	COMPUTERS	
6.2	Software	HEC-2 and WSPII for water surface profiles. Other programs acceptable if documentation provided. TR-20 may be used for SCS hydrograph computations, requires additional documentation.
7	GENERAL	
7.2	Concepts	To increase retention of runoff. Open channel hydraulics given much attention.

CITY OF SCOTTSDALE

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.1	Planning	No area master drainage plans available. Must consider drainage problems that will occur during construction. Phased developments must provide a Master Drainage Report; provide for supplemental reports and demonstrate how the drainage system will work.
2.2	Drainage Reports	Basically required for any development area other than single-family residential structure.
2.3	Drainage Patterns	Runoff to enter and depart in same manner unless justified. Manmade channel locations should coincide with natural channels. Must not violate Hillside District or Natural Developments.
2.4	Retention	Not for Hillside District unless justified. Detain to prevent increase in runoff with development. Retain runoff if there is no suitable outlet. No detention/retention for greater than 36 hours unless justified. Detention/retention not required for: single-family residence, development adjacent to a floodway or channel if justified, or for development less than 1/2 acre if justified.
2.6	Use of Streets	For drainage.
2.7	Floor Levels of Buildings	Use base flood of 100-year flood with floodplain determined by FEMA, City of Scottsdale, or by Drainage Engineer, depending on location. Elevation of floor depends upon location, type of structure and amount of flood proofing.
2.8	Channels	Manmade channels should follow natural channel. Location of channels next to public streets discouraged.

2.9	Right-of-Way	Big enough for natural channel and adequate access. Retention/detentionbasins not to be constructed on public ROW or easement.
2.10	Multiple Use	Encourage recreation.
2.11	Hillside Areas	No detention/retention unless justified. Channels with quantities greater than 50 cfs to be natural unless justified.
2.12	Maintenance	Retention basin maintenance must be considered.
2.13	Erosion and Sediment Control	Channel bank protection required for high velocities and bends of a significant angle. Bank and bottom protection required where flows pass over spillways of exit culverts, particularly where hydraulic jump may occur. Calculations required for protection measures. Erosion and sedimentation problems must be prevented during construction.
2.14	Enforcement	Ordinance
3.	DRAINAGE STANDARDS	
3.2	Design Recurrence Intervals	Up to 100-year runoff must be considered. 100-year flood for lowest floor elevation. 100-year for channel capacity.
3.3	Cross Street Flow	Street Crossings: Flexible if justified. Local: 2-year through structure, 10-year less than 6" on road. Major Collector: 10-year through structure, 25-year less than 6" on road. Major Arterial: 10-year through structure, 25-year less than 6" on road. Minor Arterial: 10-year through structure, 25-year less than 6" on road.
3.4	Longitudinal Street Flow	Maximum 8 inches in 100-year storm. Confined to right-of-way.
3.5	Retention	Required if detention facilities prove unfeasible. 36-hour drainage time. 100-year storm.
3.6	Detention	Detention to reduce peak flows to predevelopment conditions required. 36-hour drainage time.
3.7	Freeboard	2.5-foot minimum for levees. For channels, ADOT Training Session of October 16-18, 1972 Standards used, with a 1-foot minimum.

3.8	Dry Wells	Design at 1/2 capacity to account for loss of capacity with age. 1 cfs maximum.
3.9	Water Quality	Dry wells not closer to a water well than 500 feet, unless justified.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	ADOT "Hydrologic Design for Highway Drainage in Arizona" and "Hydrologic and Hydraulic Training Session October 16-18, 1972" SCS TR-20 and HEC-1 also accepted. Rational Method for urban and developed areas less than 1 square mile.
4.2	Hydraulic	Manning's Equation.
5.	DRAINAGE DATA	
5.1	Rainfall	NOAA Atlas. City of Scottsdale provides 1-, 2-, 3- and 6-hour storm data.
5.2	Networks	No rainfall network.
5.3	Soils	SCS soil groups (soil map included). City provides Curve numbers for urban development.
5.4	Maps	Watersheds to be delineated. Aerial photos recommended. Show areas to be flooded (e.g. along streets) during 100-year storm.
6.	COMPUTERS	
6.2	Software	TR-20 and HEC-1 acceptable; need version of program, assumptions and coefficients and well organized data output. HEC-2 water surface profiles accepted. Routing programs for detention basins accepted.
7.	GENERAL	
7.1	Problems	1. Lack of area master plans. 2. Existing infrastructure capabilities. 3. Road maintenance people cutting drains and changing flow patterns.
7.3	Administration	Knowledgeable.
7.4	Development	Where diversion occurs, affected properties should be provided with same degree of flood protection as before.
7.5	Existing Built-up Areas	Must not be adversely affected.
7.6	Performance or Standards Oriented	Performance oriented.
7.7	Flexibility	If justified, the use of other methods and data are encouraged.

CITY OF MESA

1. DRAINAGE CODE

2. DRAINAGE POLICIES

2.1	Planning	Development drainage to be planned. A phased development requires a master drainage study and then a report for each phase.
2.2	Drainage Reports	Preliminary and final reports for subdivision plat, grading, right-of-way, improvements and structures.
2.3	Drainage Patterns	Show existing patterns for 100-year storm and what will be done with them, including offsite and street drainage. Sub-areas to be identified.
2.4	Retention	Retain runoff from subdivisions and adjacent arterial streets (depending on development location). On-lot retention only allowed on some commercial and suburban ranch developments (although discouraged). Require certification for volume of retention basin.
2.6	Use of Streets	Streets to drain design flows, with storm drains and catch basins used when street capacity insufficient.
2.7	Floor Levels of Buildings	In designated flood hazard areas elevated floors and floor protection required. (100-year flood plain, as determined by FEMA)
2.8	Channels	Generally approve redefined channel. Most channels in Mesa are not well defined. To the east are more defined channels and the integrity of these channels is being kept.
2.9	Right-of-Way	Detention basins must not include City ROW's. Minimum 20 feet. Additional ROW needed for channels to be dedicated as part of plat or other dedications prior to improvements.
2.10	Multiple Use	Asphalt parking areas and landscape areas may be used for retention basins on a restrictive basis. Encourage recreational use.
2.12	Maintenance	City maintains single-family subdivision retention basins only. Avoid dry wells wherever possible.
2.13	Erosion and Sediment Control	No policy during construction.
2.14	Enforcement	Certification required on retention basins. Investigations through citizens complaints.

3.2	Design Recurrence Intervals	100-year flood for flood plains and floor elevations. Retention designed for 50-year, 24-hour storm. 10-year and 50-year storms used for street capacity.
3.4	Longitudinal Street Flow	Streets must carry runoff from 10-year storm between curbs (any excess must be carried by underground pipes). Intersections not to have more than 10-year flow. Peak flow from a 50-year storm must be carried within the cross section between buildings (front yards and streets). 100-year storm to be reviewed if 50-year is close.
3.5	Retention	Runoff from 50-year, 24-hour storm. Asphalt parking areas, landscape areas, underground tanks, and dry wells may be used. 36-hour drain time. Maximum depth of 3-1/2 feet for non-paved areas. Limit to less than one (1) foot for paved areas.
3.8	Dry Wells	Permitted if no other means of draining basins are available. Additional wells must be added if existing wells lose capacity to drain basin in 36 hours. Allow one (1) dry well to drain 9300 cubic feet (about 0.1-0.2).
4.1	Hydrologic	Rational Method used for all areas.
5.1	Rainfall	Rainfall intensity-duration-frequency relation developed for Mesa from U.S. Weather Bureau Technical Paper No. 40, Technical Memorandum WBTM WR-44, and rainfall data from pages 37c through 39 of the Arizona Highway Department Hydrologic Design Manual (1970 revision).
7.1	Problems	Major problems include: offsite drainage, both from within and outside jurisdiction; maintenance of retention basins.
7.2	Concepts	Retention areas and their maintenance a large portion of designs. Open channels require improvement (lining).
7.3	Administration	Preliminary and final plans reviewed by City of Mesa.
7.5	Existing Built-up Areas	Treated same as new developments No requirements for considering eventual development of upstream areas.
7.6	Performance or Standards Oriented	Oriented towards eliminating runoff from developed land.
7.8	Effect of Drainage on Other Utilities	Improvement plan submittal routed to Maricopa County Flood Control District, ADOT, SRP and other utilities. ROW's cannot be excavated for retention area.

CITY OF GLENDALE

1.	DRAINAGE CODE	Grading and Drainage Ordinance
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Preliminary and final reports required.
2.3	Drainage Patterns	Prefer channels to be left in natural state. Off-project and runoff volumes to be routed through the retention/detention facilities. Drainage between lots or buildings is discouraged.
2.4	Retention	Shall provide sufficient retention to minimize adverse impact of development on downstream neighbors. Retain on-site 10-year, 2-hour storm. Maximum 36 hour retention time.
2.7	Floor Levels of Buildings	Residential - lowest floor elevated above base flood level (according to FEMA maps). Nonresidential - lowest floor elevated or flood proofed above base flood level. 14" above lowest curb or 12" above crown.
2.8	Channels	Manmade channels should have "natural" appearance.
2.9	Right-of-Way	Drainage easement required for each retention/detention area; must not encroach in public ROW. All storm drains and open channels in public ROW or dedicated easements. 100-year flood plain shall be drainage easement or ROW for natural channels.
2.10	Multiple Use	Retention/detention basins should present an aesthetically pleasing appearance, possibly used as parks. No parking lots in residential development retention/detention basins. Retention/detention runoff in commercial/ industrial parking lots allowed.
2.12	Maintenance	Of retention/detention facilities by property owner or City, depending on type of development. Water courses that are altered or relocated shall be maintained by City.
2.13	Erosion and Sediment Control	Channel protection required if scouring velocity of soil (with natural cover) is exceeded.
2.14	Enforcement	As-constructed building floor elevations must be submitted and approved prior to any vertical construction if in critical drainage area, or prior to acceptance of project if in non-critical areas. A department has been established for Code Enforcement (Branch of Police Dept.).

3.	DRAINAGE STANDARDS	
3.1	Drain Classification	Use a major and minor system - minor for drainage up to 10-year storm, and major for up to 100-year storm.
3.2	Design Recurrence Intervals	10-year, 2-hour storm for retention; 10-year storm for street drainage.
3.3	Cross Street Flow	Low water crossings passing a 10-year storm (through a culvert) shall be provided.
3.4	Longitudinal Street Flow	Arterial and secondary - flow as per City's Master Drainage Plan. Collector and interior streets - 10-year flow between curbs, 50-year flow between property lines, 100-year flow between finished floor elevations. Underground or open channel drainage where street capacity exceeded.
3.5	Retention/ Detention	Retain 100% of 10-year, 2-hour storm, from area including exterior streets and ROW's. Retain 100% of 100-year, 2-hour storm if adequate drainage outfall does not exist. 36-hour drainage time. 3-foot depth of water average maximum on private land and 1-1/2-foot depth maximum within 10 feet of public ROW.
3.8	Dry Wells	Drilled 10 feet into permeable strata or else percolation test required. Maximum rate of 0.1 cfs per well or 50% of any higher value from a soils report.
3.9	Water Quality	Retention/detention facilities must not be within 20 feet of an active septic system or within 100 feet of an active water well.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational Method primary method. Other methods such as TR-55/TR-20 may be used if approved.
4.2	Hydraulic	Manning's Equation for storm drainage, pipes and open channels. Single-step backwater method preferred. Street capacity formula from City of Phoenix's Drainage Manual, as well inlet capacities from same manual. Other formulas may be used if referenced.
5.1	Rainfall	Intensities from USWB.
6.	COMPUTERS	
6.1	Hardware	IBM-AT
6.2	Software	SWMM Model (CDM Modified Version 3)

7.	GENERAL	
7.1	Problems	1. No drainge system. - Master plan in process. - Joint Regional Plan with Peoria. 2. SRP has served as drainage system by dumping into agricultural areas. - Fewer agricultural areas remaining, get more water.
7.2	Concept	To provide adequate retention to minimize impacts downstream and to provide adequate drainage facilities to insure structures to be reasonably free from flooding and allow access by emergency vehicles.

CITY OF CHANDLER

1.	DRAINAGE CODE	
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Required.
2.3	Drainage Patterns	Point at which natural drainage flows from a property will remain the same.
2.4	Retention	Retain all runoff from 100-year, 6-hour storm (approximately 3 inches).
2.7	Floor Levels of Buildings	Finish floor elevations should be a minimum of 14 inches above point of outfall - above 100-year runoff level.
2.10	Multiple Use	Encouraged. Use of retention basins for recreation.
2.12	Maintenance	Basins privately maintained.
2.14	Enforcement	Problems from within, not generated from outside.
3.	DRAINAGE STANDARDS	
3.4	Longitudinal Street Flow	5-year storm runoff between curbs, if storm runoff exceeds street capacity then storm drains required. 50-year storm runoff within yards and streets with 100-year runoff below finished floors. Gutters will be tested for proper drainage.
3.5	Retention	Currently pump into SRP laterals. No certification. New developments encouraged to use large central basins. 36-hour disposal time. On-lot retention permissible for some single family lots.

3.8	Dry Wells	Permitted when no other means of disposal is available. Lack of maintenance, silting problems. Drilled 10 feet into permeable strata or percolation test required.
7.	GENERAL	
7.1	Problems	Adoption of master plans. Flat terrain with lack of outlet (pumping required). Soils do not drain (lack of percolation).
7.6	Performance or Standards Oriented	Performance oriented.
7.7	Flexibility	Flexible when warranted.
7.8	Effect of Drainage on Other Utilities	Use of SRP laterals for retention water disposal.

CITY OF TEMPE

1.	DRAINAGE CODE	Ordinance available.
2.	DRAINAGE POLICIES	
2.1	Planning	South part of Tempe drainage is major element in planning. Master plans cover most areas.
2.2	Drainage Reports	Required for subdivisions. For commercial, industrial and other developments not requiring a subdivision map, a "Grading and Drainage Plan" can be submitted with necessary calculations.
2.3	Drainage Patterns	Maintain flows in existing regime.
2.4	Retention	Required when existing outlet does not have adequate capacity to receive runoff from development. Require retention unless suitable outlet available.
2.6	Use of Streets	For drainage.
2.7	Floor Levels of Buildings	Buildings must not be damaged by 100-year runoff.
2.9	Right-of-Way	Retention basin requires easement if in private ownership or dedicated to City. 5- to 6-foot clearance on both sides of pipe encouraged.
2.10	Multiple Use	Public use of retention basins.
2.12	Maintenance	Maintenance of basins is responsibility of owner, if in private ownership may require seeding and irrigation/sprinkler systems. If City accepts dedication of property, City will assume maintenance. Most maintained by City; private in parking lots; major subdivisions turned over to City.

2.14	Enforcement	Dry well drillers logs and certification of compliance required prior to acceptance.
3.	DRAINAGE STANDARDS	
3.2	Design Recurrence Intervals	100-year runoff needed at critical points of subdivision. 5-year only when suitable outfall available.
3.4	Longitudinal Street Flow	10-year flow allowed up to top of curve. excess flow to underground drainage. 100-year runoff in streets and yards.
3.5	Retention	New areas require 100-year/1-hour storm (2.40"). Minimum of 5-year/1-hour in any area. 36-hour drain time.
3.7	Freeboard	1-foot freeboard in central retention basins.
3.8	Dry Wells	May be required for nuisance water in retention basins. Permitted for retention basin water disposal - no absorption factor, however, allowed to reduce retention volume.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational Method for runoff. C values included. SCS TR-20 used on major drains.
4.2	Hydraulic	Manning's Equation for pipes and channels.
5.	DRAINAGE DATA	
5.1	Rainfall	Based on USWB Technical Paper #40.
5.4	Maps	For drainage report, a map showing existing drainage and a map showing drainage and drainage structures after development are required.
6.	COMPUTERS	
6.2	Software	Rely on consultants.
7.	GENERAL	
7.1	Problems	1. Lack of outlet in south part of Tempe. 2. A lot of water coming from outside areas (outside jurisdiction).
7.6	Performance or Standards Oriented	Performance oriented, especially where designs exceeding standards may be necessary.
7.8	Effect of Drainage on Other Utilities	Discharge into SRP, MCFCD, etc. ditches requires their approval.

TOWN OF GOODYEAR

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.1	Planning	Beginning master planning.

2.2	Drainage Reports	Yes
2.3	Drainage Patterns	Agua fria River and two manmade channels.
2.4	Retention	Retain on-site or use drains if available.
2.6	Use of Streets	For conveying runoff to storm drains.
2.7	Floor Levels of Buildings	14 inches above outfall.
2.8	Channels	Provide channelized areas for drains.
2.9	Right-of-Way	Along drainage channels.
2.10	Multiple Use	Use of retention basin for recreation.
2.11	Hillside Areas	Expecting future hillside development.
2.12	Maintenance	Maintained by owner.
2.13	Erosion and Sediment Control	Not a problem
2.14	Enforcement	No occupancy until retention basin complete.
3.	DRAINAGE STANDARDS	
3.1	Drain Classification	River, channels and storm drains, and lots.
3.3	Cross Street Flow	Very little cross street flow.
3.5	Retention	Retain approximately 3 inches (100-year, 1-hour storm), 36-hour disposal time.
3.8	Dry Wells	Allowed, but not encouraged. Subject to ADWR permits.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Any accepted if reasonable.
6.	COMPUTERS	
6.2	Software	Computer mapping of storm drain system.
7.	GENERAL	
7.1	Problems	No major problems.
7.6	Performance or Standards Oriented	Performance oriented.

CITY OF PEORIA

1.	DRAINAGE CODE	Yes

2.	DRAINAGE POLICIES	
2.1	Planning	Street drainage master plan
2.2	Drainage Reports	Required
2.3	Drainage Patterns	Points of entrance and exit to remain unchanged, but alright to move within development.
2.4	Retention	Retain 10-year/2-hour runoff onsite; 36-hour drain time; rear yards of single family homes depressed 3 inches.
2.7	Floor Levels	14 inches above outfall
2.8	Channels	Only Agua Fria and New Rivers
2.11	Hillside Areas	None
2.12	Maintenance	Private maintenance
2.13	Erosion and Sediment Control	None
3.	DRAINAGE STANDARDS	
3.2	Design Recurrence Intervals	100 years for safety
3.4	Longitudinal Street Flow	10-year storm capacity
3.5	Retention	Percolation tests required if greater than 1 foot depth and no outfall
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Phoenix subdivision manual. SCS used for both city and rural. SWMM used in developed areas.
5.1	Rainfall	NOAA
6.	COMPUTERS	
6.1	Hardware	Mini computers
7.1	Problems	. Developing storm drains . Maintenance of retention basins . Localized flooding
7.6	Performance or Standards Oriented	Performance oriented
7.8	Effects of Drainage on Other Utilities	None

TOWN OF GILBERT

1.	DRAINAGE CODE	Flood Plain Ordinance
2.	DRAINAGE POLICIES	
2.1	Planning	Some drainage plans. Pilot central retention basin in town.
2.2	Drainage Reports	Required for new development.
2.3	Drainage Patterns	All water to enter and leave in same manner.
2.4, 2.5	Retention/Detention	Provide 100% retention for all runoff from 50-year, 24-hour storm (aproximately 3"). Area includes 1/2 of street ROW.
2.6	Use of Streets	Must contain: 10-year storm curb to curb 50-year storm in ROW 100-year storm below floor elevation
2.7	Floor Levels of Buildings	Above 100 year flows in streets. In flood plains, in accordance with Town of Gilbert flood plain ordinance.
2.8	Channels	Not applicable - only canals.
2.9	Right-of-Way	Half of remaining ROW, after street and sidewalk, can be used for retention. Maximum 2 feet depth in ROW.
2.10	Multiple Use	Recreational use of detention areas encouraged.
2.12	Maintenance	Town will not accept, for mainte nance, any basins less than 4 acres. Others on a case by case basis. Owner maintains all drywells.
2.13	Erosion Sediment Control	Street have to be maintained & cleaned during construction.
2.14	Enforcement	Certification required on basins.
3.	DRAINAGE STANDARDS	
3.1	Drain Classification	Not applicable.
3.2	Design Recurrence Intervals	50-year, 24-hour storm for retention. 10-, 50- & 100-year for streets.
3.5, 3.6	Retention/Detention	On lot retention acceptable for commercial and suburban ranch developments. 4:1 standard side slopes. 3-foot maximum depth. Must provide positive drainage if deeper than 1 foot, percolation test if less than 1 foot. 36-hour evacuation time.

3.8	Drywells	Considered temporary only. Standard drywell is Maxwell III. 1 drywell/acre ft. to be drained. Keep in area where there will be no direct sediment. Having good luck with properly designed drywells.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational method for areas less than 100 acres. Also accept SCS TR-20/TR-55 methods.
6.	COMPUTERS	
6.2	Software	T-20 accepted.
7.	GENERAL	
7.1	Problems	Lack of outfall on property. Areas developed prior to standards.
7.2	Concepts	All development shall be designed so that the runoff produced by storms greater than the 50-year, 24-hour storm will not adversely affect them or increase the risk to any downstream development.

TOWN OF PARADISE VALLEY

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.1	Planning	Several master planned basins.
2.2	Drainage Reports	Grading and drainage plan required.
2.3	Drainage Pattern	Rerouting of channels is acceptable.
2.4	Retention	No policy.
2.6	Use of Streets	For drainage.
2.11	Hillside Areas	Hillside ordinance.
3.4	Longitudinal Street Flow	10-year flow contained within curbs. 100 year flow within right-of-way.
3.5	Retention	Evaluated on a project by project basis.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Any valid method acceptable.
7.	GENERAL	
7.2	Concepts	Preserve capacity of natural drainages.

TOWN OF SURPRISE

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Required
2.4	Retention	Required for 100-year/1 hour storm (2.4")
2.6	Use of Streets	For drainage
2.7	Floor Levels of Buildings	14" above low outfall and above 100-year.
2.11	Hillside Areas	None
2.12	Maintenance	By owners, town has right to assess owners for maintenance performed by them.
3.	DRAINAGE STANDARDS	
3.4	Longitudinal Street Flow	10-year between curbs, 50-year in yards. 100-year below finished floors.
3.5	Retention	100-year/1 hour (2.4"), 3' maximum depth, 36 hour drain time. On lot retention possible.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational method
7.	GENERAL	
7.1	Problems	Lack of defined drainage patterns.

CITY OF APACHE JUNCTION

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Yes - preliminary and final
2.4	Retention	Required for all new buildings; Retain 10-year/24-hour storm
2.6	Use of Streets	Carry 10-year runoff between tops of curbs
2.7	Floor Levels of Buildings	Above 100-year flow
2.8	Channels	Enter and leave property at same point; must be large enough to accommodate maintenance vehicle.
2.9	Right-of-Way	Drainage easement may be required for retention basins.
2.12	Maintenance	By homeowners associations

3.	DRAINAGE STANDARDS	
3.2	Design Recurrence Intervals	10-year storm for most uses
3.3	Cross Street Flow	10-year event passed through culvert
3.4	Longitudinal Street Flow	10-year storm between curbs or in storm sewer.
3.5	Retention	Retain 10-year/24-hour storm with method of retention left up to developer; 36-hour drain time
3.8	Dry Wells	Not desirable, but may be acceptable with approval and percolation test
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Use Rational Method
4.2	Hydraulic	Manning's equation
5.	DRAINAGE DATA	
5.1	Rainfall	NOAA
7.	GENERAL	
7.8	Effect of Drainage on Other Utilities	Policy on use of SRP transmission line rights-of-way for detention basins

AVONDALE

1.	DRAINAGE CODE	Yes, based on Phoenix standards.
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Required
2.4	Retention	Retain 10-year/2 hour runoff.
2.6	Use of Streets	For drainage.
2.7	Floor Levels of Buildings	Above 100-year level.
2.11	Hillside Areas	None
2.12	Maintenance	By owner.
2.13	Erosion and Sediment Control	Not a problem.
3.	DRAINAGE STANDARDS	
3.5	Retention	10-year/2 hour storm, 36 hour drain time.
3.8	Dry Wells	Used for retention basins.
3.9	Water Quality	Potential dry well problems a concern.

4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational method
5.	DRAINAGE DATA	
5.1	Rainfall	NOAA Atlas
7.	GENERAL	
7.1	Problems	Offsite flows from other cities, county.

TOWN OF EL MIRAGE

1.	DRAINAGE CODE	No. All drainage work performed by Mozecki-Royden Engineering, based on ADOT standards and judgement of engineers.

TOWN OF WICKENBURG

1.	DRAINAGE CODE	No
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Only required in floodway.
2.3	Drainage Patterns	Maintain same ingress and egress of washes crossing properties. Path can be varied across property.
2.4, 2.5	Retention/Detention	No current policies. Not too much need at present.
2.6	Use of Streets	Currently used for drainage.
2.7	Floor Levels of Buildings	Regulated by FEMA.
2.8	Channels	Natural drainage ways protected through review process.
2.9	Right-of-Way	Up to now ROW not required. This is desired for maintenance.
2.10	Multiple Use	Encouraged in right situation.
2.11	Hillside Area	No policy.
2.12	Maintenance	City maintains own property. Not much maintenance required.
2.13	Erosion Sediment Control	Have asked developer to provide control along drainage.
3.	DRAINAGE STANDARDS	
3.1	Drain Classification	None

3.7	Freeboard	No requirements.
3.8	Drywells	No standards except for refrain ing from using them in industrial areas.
4.1	Hydrologic	Any accepted methods.
6.	COMPUTERS	
6.1	Hardware	IBM Main Frame - Financial Recorder
7.	GENERAL	
7.1	Problems	Lack of direction for future development.
7.2	Concepts	Improvement of existing drainage system.
7.3	Administration	Through consulting firm.

BUCKEYE, ARIZONA

1.	DRAINAGE CODE	No. Consultant on retainer reviews plans.
2.	DRAINAGE POLICIES	Based on MCFCD drainage code.

GILA BEND

1.	DRAINAGE CODE/ POLICIES	No drainage policy. Developments handled on an individual basis by Town manager and reviewed by a consultant. No current drainage problems.

CITY OF TOLLESON

1.	DRAINAGE CODE/ POLICIES	Drainage work performed by Anderson-Nichols Engineers using standards from various county jurisdictions.

TOWN OF YOUNGTOWN

1.	DRAINAGE CODE	No.
2.	DRAINAGE POLICIES	
2.1	Planning	City is mostly developed.
2.2	Drainage Reports	Required for new developments.
2.4	Retention	Not required - Agua Fria River provides drain.
2.11	Hillside Areas	None.
2.12	Maintenance	By Town.
3.	DRAINAGE STANDARDS	Have adopted ADOT Standards or use judgment of town engineer.

4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Use ADOT Procedures
7.	GENERAL	
7.1	Problems	Channel erosion problems.

TOWN OF GUADALUPE

1.	DRAINAGE CODE	No - drainage work done by Dava Assoc., Prescott.
2.	DRAINAGE POLICIES	
22.1	Planning	Town is almost fully developed.
2.4	Retention	No existing requirements.
2.6	Use of Streets	For drainage - no storm sewers.
2.11	Hillside Areas	None.
2.12	Maintenance	By City.
7.	GENERAL	
7.1	Problems	Ponding caused by inflow to the City property.

CAREFREE

1.	DRAINAGE CODE	No - drainage work done by MCFCD.

SRP

Purpose

The purpose of this policy is to encourage long range storm drain planning based on an integrated system that optimizes use of SRP's system while minimizing storm drainage impacts to the SRP system.

Background

For many years, SRP has had an informal policy that allowed connection of storm drain to SRP facilities to temporarily help governmental agencies drain storm water from public right-of-way.

Continued urbanization of agricultural lands has created more and faster runoff of storm water, while severely reducing the number and locations where SRP can divert storm water to open fields or established drain ways.

Although many governmental agencies have installed storm drains to the river and have allowed SRP facilities to be connected to these storm drains, there are not enough locations available to remove all storm water being received. Also, since SRP's system is not designed to transport urban storm runoff (canals and laterals decrease in capacity as they progress downstream), it is apparent that SRP must modify its policy to minimize and/or curtail any type of storm drain connections to SRP facilities.

Policy

1. All requests for new or modified storm drain connections are to be submitted to the Manager, Operational Support, for processing. Calculations of the volume and flow rate of discharges to the SRP system must be provided.

2. All new storm drain connections will require an outlet of equal flow rate to a governmental storm drain, river bed, or other facility that can adequately dispose of the storm runoff.

3. Existing drains that are moved, modified or adjusted due to street widening, intersection improvements, etc., will require an outlet of equal flow rate to a governmental storm drain, river bed, or other discharge facility.

4. New, or replacement of existing, drain connections will not exceed 12 inches in diameter at any site or discharge at a combined flow rate greater than the outlet unless otherwise justified (case by case).

5. All drain connections and discharge rates of storm water into SRP facilities must be approved by the Manager of Water Operations and the Assistant General Manager-Water prior to issuance of license.

6. Water quality impacts on shareholders are to be considered.

7. All governmental agencies are encouraged to reduce dependence on SRP for storm water discharge and to plan for storm drainage facilities to handle existing and future storm runoff. All drains should have an outlet of equal flow rate to a governmental storm drain or to a river bed by January 1, 1995, or be scheduled for removal from the SRP system.

8. Distance from inlet to outlet will be a function of the available capacity for the transportation of storm flow between the inlet and outlet.

9. Storm drain outlet currently in design should be reviewed in an effort to have the design meet the guidelines established in this policy whenever possible.

10. Retention basin discharge pumping to the SRP system will require an outlet of equal flow rate based on the maximum pumping capacity and SRP's ability to transport storm water will be function of the available capacity in the canal or lateral.

11. Exceptions to the guidelines outlined above may be reviewed on a case-by-case basis with the Manager of Water Operations and the Assistant General Manager-Water.

CITY OF EL PASO, TEXAS

1.	DRAINAGE CODE	Yes, subdivision design standards.
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Required
2.4	Retention	Retain 4" rainfall from 3-hour storm.
2.7	Floor Levels of Buildings	Above 100-year.
2.11	Hillside Areas	Design to follow good engineering practice.
2.13	Erosion and Sediment Control	Provide capacity for sediment in detetion basins.
3.	DRAINAGE STANDARDS	
3.3	Cross Street Flow	Provide valley gutters for collector streets with less than 0.5% slope.
3.5	Retention	Retain 4" of rainfall from 3 hour storm. Additional 25% emergency capacity and capacity for 10 years of sediment.
3.7	Freeboard	5' freeboard for detention basins.
3.8	Dry Wells	Require percolation test.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational method used for all areas, with rainfall reduction curves for areas over 200 acres.
4.2	Hydraulic	Manning's equation and channel velocity-slope chart for arroyos.
5.	DRAINAGE DATA	
5.1	Rainfall	NOAA Atlas

CLARK COUNTY, NEVADA

1.	DRAINAGE CODE	Yes.
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Yes.
2.3	Drainage Patterns	Locations of a channel entering and leaving a property must be maintained and the hydraulic characteristics of the channel must be maintained the same or improved.
2.4, 2.5	Retention/Detention	Developer shall assure drainage of property by utilizing existing drainage facilities and natural washes. Onsite retention allowed. Provide detention volume for zero increase in peak discharges.

2.7	Floor Levels of Buildings	If within a designated flood hazard area, floor levels shall be 18 inches above the higher of either street curb or centerline.
2.8	Channels	Development shall not cause natural drainage channel to be filled in, obstructed or diverted.
2.9	Right-of-Way	ROW's or drainage easements required for structures and other improvements needed to carry runoff. Easements required for drainage and maintenance of natural washes.
2.13	Erosion Sediment Control	During grading or construction on any property (including offsite construction), the contractor shall control completely construction water and storm runoff in such a manner as to not affect any adjoining properties nor add silt or debris to any existing storm drain, wash, channel or roadway.
3.	DRAINGE STANDARDS	
3.1	Drain Classification	Major (100-year runoff or greater than 1000 cfs) and minor channels.
3.2	Design Recurrence Intervals	Determine 10-, 25- and 100-year storms for major drainage.
3.4	Longitudinal Street Flow	Determine discharges and show flood levels of 10- and 25-year floods.
3.7	Freeboard	In channels, one foot of freeboard above the 100-year flood level.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	For single homogenous drainage areas under 2,000 acres, use SCS TR-55. For drainages exceeding 2,000 acres or containing multiple subbasins and travel time, use SCS TR-55 tabular method or computer programs of equal or greater sophistication may be used. Rational method for small drainages. Use sediment bulking factor.
5.	DRAINAGE DATA	
5.1	Rainfall	NOAA
5.3	Soils	SCS
7.	GENERAL	
7.5	Existing Built-up Areas	Effect of development on downstream property owners relative to increase flood potential and nuisance water shall be considered.

CITY OF ALBUQUERQUE, NEW MEXICO

1.	DRAINAGE CODE	Yes

2.	DRAINAGE POLICIES	
2.1	Planning	Albuquerque Master Drainage Plan
2.2	Drainage Reports	Required
2.4	Retention	May be required
2.6	Use of Streets	May be used for drainage and flood control purposes if such use does not interfere with safe transportation.
2.9	Right-of-Way	May be credited for open space
2.10	Multiple Use	Encouraged for rights-of-way and easements
2.12	Maintenance	By City unless on private property where public access is denied
2.13	Erosion and Sedimentation	Erosion control plan needed to prevent erosion during the 10-year storm
2.14	Enforcement	By City
3.	DRAINAGE STANDARDS	
3.1	Drain Classification	Major arroyo - greater than 320 acres. Major facility - facility which will carry more than 50 cfs. Minor facility - facility which will carry less than 50 cfs.
3.2	Design Recurrence Intervals	10-year and 100-year
3.3	Cross Street Flow	Crossings of major arroyos will pass the 100-year flow. Some dip crossings allowed.
3.4	Longitudinal Street Flow	Maximum depth of 0.87' or 0.2, above top of curb. The 10-year storm shall not exceed 0.5' in an arterial street and a 12' lane in each direction will remain free of water. For collector streets, a depth of 0.5 feet will be the maximum for a 10-year storm.
3.5	Retention	Required if basin has inadequate capacity for increased runoff. 24-hour drain time.
4.1	Hydrologic	Rational Method used for less than 320 acres and SCS method used for greater than 320 acres.
5.1	Rainfall	NOAA 100-year/6-hour and 100-year/24-hour storms used.

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Required
2.3	Drainage Pattern	May be modified
2.8	Channels	Subject to detailed design criteria.
3.	DRAINAGE STANDARDS	
3.2	Design Recurrence Intervals	50-year storm runoff for major drains 10-year storm runoff for all others.
3.3	Cross Street Flow	To pass 10-year flow under road and pass 50-year flow without damage to culvert.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Capital Flood Hydrology based on 4 day storm.
4.2	Hydraulic	Hydraulic manual with design criteria for open channel and pipe flows.
5.	DRAINAGE DATA	
5.1	Rainfall	Based on analysis of locally operated and NWS rain gauges.
5.2	Networks	Local network.
6.	COMPUTERS	
6.2	Software	Have developed programs for runoff calculations and flood routing, culvert design and storm drains.

PIMA COUNTY FLOOD CONTROL DISTRICT

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.2	Drainage Reports	Required
2.3	Drainage Pattern	Must not divert from one drainage basin to another.
2.4	Retention	Required depending upon drainage characteristics of basin.
2.6	Use of Streets	Minimize adverse affects to adjoining property while maintaining traffic safety. All weather access must be provided to a subdivision.
2.7	Floor Levels of Buildings	Minimum of 1.0 feet above 100-year water surface elevation.

2.8	Channels	Not to be constructed next to roadway without approval.
2.9	Right-of-Way	Dedicated right-of-way or easement required for major watercourses.
2.11	Hillside Areas	Special hydraulic considerations
2.13	Erosion and Sediment Control	Channels to be designed to minimize erosion. Erosion and sediment control measures required.
3.	DRAINAGE STANDARDS	
3.1	Drain Classification	Minor Watercourses - including Major Wash, Minor Wash and Local Flows
		Major Watercourses - with 100-year discharge over 5,000 cfs.
3.3	Cross Street Flow	Arterials - Q50 under roadway, Q100 in dip section.
		Collectors - Q25 under roadway, Q50 with less than 1 foot, and Q100 in dip sections.
		Local -10-year under roadway, 25-year with less than 1 foot depth and 100-year in dip section.
3.4	Longitudinal Street Flow	Limited to right-of-way, 1.0 foot depth, and 10 fps for 100-year storm on local streets. Limited to one lane inundated each direction for 10-year storm on collectors and arterials.
3.5	Retention	Varies, depending upon drainage properties of basin, from retaining portions of 100-year discharge to retaining difference in volumes and peak for a 2-year discharge.
3.7	Freeboard	Required for channels.
3.9	Water Quality	Drywells a concern
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational Method based method used for up to 10 square miles. SCS Method used for greater than 10 square miles.
4.2	Hydraulic	Detailed hydraulic analysis required.
5.	DRAINAGE DATA	
5.1	Rainfall	Local data used (reanalyze NOAA data)
5.2	Networks	Several local raingages
5.3	Soils	SCS
7.	GENERAL	
7.1	Problems	Erosion of channel banks and beds

DENVER URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

1.	DRAINAGE CODE	Yes
2.	DRAINAGE POLICIES	
2.1	Planning	A master plan shall be developed and maintained for each urbanizing basin.
2.2	Drainage Reports	Required
2.3	Drainage Patterns	Encouraged to keep natural
2.4	Retention	Encouraged in upstream areas
2.6	Use of Streets	Primary use of streets is for transportation, drainage is a secondary use.
2.8	Channels	Designed to prevent damage during 100-year flood.
2.9	Right-of-Way	Natural or 100-year floodway
2.10	Multiple Use	An urban drainage policy should be a multi-purpose multi-means effort. Multiple use of retention basins especially encouraged.
2.12	Maintenance	Required
2.13	Erosion and Sediment Control	Provisions for sediment deposition encouraged
3.	DRAINAGE STANDARDS	
3.1	Drain Classification	Major and minor drains
3.2	Design Recurrence Intervals	100-years for major storms, 2-10 for initial storm.
3.3	Cross Street Flow	Local, Collector - 6" in minor storm, 18" maximum on street for major storm. Arterial, Freeway - None in minor storm, 6" maximum on street for major storm.
3.4	Longitudinal Street Flow	For initial storm: Local - no curb overtopping, flow to crown Collector - one lane free Arterial - one lane free each direction Freeway - no lane encroachment

3.9	Water Quality	Removal of sediment by detention/retention basins.
4.	DRAINAGE PROCEDURES	
4.1	Hydrologic	Rational Method used up to 160 acres. For over 90 acres, Colorado Urban Hydrograph Procedure, a unit hydrograph developed for the Denver area.
4.2	Hydraulic	Manning's Equation; modified Manning's Equation used for gutters.
5.	DRAINAGE DATA	
5.1	Rainfall	Use NOAA Atlas. 2-hour design storm developed
5.3	Soils	SCS hydrologic soil types.
6.	COMPUTERS	
6.2	Software	CUHP and CUHP/SWMM programs developed.
7.	GENERAL	
7.6	Performance or Standards Oriented	Performance oriented.
7.7	Flexibility	Yes
7.8	Effect of Drainage on Other Utilities	Use of irrigation ditches not allowed.

APPENDIX C

MARICOPA COUNTY REGIONAL RAINFALL

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SUMMARY AND RECOMMENDATIONS

The assessment of isohyetal data commonly used for drainage analysis within Maricopa County and characterization of the Maricopa County rainfall networks has resulted in the following conclusions and recommendations.

1. Rainfall data commonly used for drainage analysis within Maricopa County is based upon the NOAA Atlas, in which isohyetal maps and equations for producing design event guidelines were produced and formulated.

2. 33 nonrecording stations and 2 recording stations were used to produce the Maricopa County isohyetal maps for 6- and 24-hour storms. Regression equations were developed to relate precipitation from storms of shorter durations to the 6- and 24-hour precipitation value.

3. The recording stations averaged 20 years of record up to 1970. The nonrecording stations had 15-70 years of data up to 1970.

4. 2-year, 6-hour and 2-year, 24-hour precipitation value for individual stations are the most accurate. 100-year precipitation values are less accurate, especially for 6-hour storms.

5. Due to the large scale of the maps and few stations used, the isohyetals are not as accurate as could be possible with the data now available. This is especially true of the 6-hour isohyetal maps.

6. The regression equations for short duration storms are averages for the entire Colorado River basin. They may not adequately represent precipitation in Maricopa County.

7. Rainfall data collection networks are operated by the Flood Control District of Maricopa County, the City of Phoenix, the U.S. Geological Survey, and the National Weather Service. An approximate total of 79 telemetered gages, 23 recording gages, and 142 nonrecording gages are currently in operation.

8. Since the preparation of the NOAA atlas, more stations and longer periods of record are available which can be used to improve the accuracy of current rainfall data used for drainage analysis within Maricopa County.

It is recommended that:

1. Existing 6-hour and 24-hour storm precipitation-frequency relations should be updated. New precipitation frequencies should be developed for stations with greater than 25 years of record; shorter records may be used in some cases.

2. The isohyetal maps should be updated using the data now available.

3. For storms up to 6 hours, revised rainfall-intensity-duration-frequency curves should be established using regression equations based on Maricopa County data.

4. In conjunction with the rainfall frequency analysis, consideration should be given to the evaluation of area rainfall reduction curves.

1. INTRODUCTION

For economical design of drainage facilities, good quality hydrologic data are required. Towards this goal the existing rainfall data of Maricopa County was evaluated and procedures for updating the data were examined. These steps included:

1. Assessing the adequacy of existing regional rainfall isohyetal data.

2. Describing and characterizing the rainfall data collection networks utilized by various jurisdictions within Maricopa County.

3. Describing the necessary steps to perform an in-depth evaluation and synthesis of isohyetal maps and design event guidelines.

The completion of these procedures provides guidance for obtaining the needed hydrologic data.

2. ADEQUACY OF EXISTING REGIONAL RAINFALL ISOHYETAL DATA

2.1 EXISTING ISOHYETAL DATA

Most of the rainfall isohyetal data used within Maricopa County are based upon the National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Volume VIII - Arizona(1). The atlas updates the earlier U.S. Weather Bureau Technical Paper 40(2) and is the basis for the Arizona Department of Transportation precipitation maps(3). Figure 1 is an example isohyetal map from reference (3).

The NOAA Atlas contains isohyetal maps of 6-hour and 24-hour storms for return periods of 2, 5, 10, 25, 50 and 100 years. For each storm duration base maps of the 2-year and 100-year events were constructed. Maps for the intermediate frequencies were derived from the base maps. Precipitation records up to 1970 were used.

Weather Bureau Technical Memorandum WBTM WR-44, Estimated Return Periods for Short Duration Precipitation in Arizona (4), is also used by some Maricopa County communities for rainfall data. It contains tabulations of rainfall data at point locations for Apache Junction, Buckeye, Carefree. Gila Bend, Phoenix and Wickenburg. While published at about the same time as NOAA Atlas II, it is based on precipitation records only up to 1960 as analyzed in Technical Paper 40.

2.1.1 Data Used

The 24-hour precipitation values were obtained from nonrecording and recording rain gages. (Nonrecording gages are those which give only total rainfall for a time period. Recording gages record the time distribution of rainfall.) These represented the largest available data set, and therefore, the 24-hour precipitation maps are the most accurate of the NOAA maps. The records from a total of 229 stations were used in Arizona, including 33 in Maricopa County. The nonrecording stations used are shown in Figure 2 and the recording stations are shown in Figure 3. Table 1 shows the breakdown of the lengths of record used.

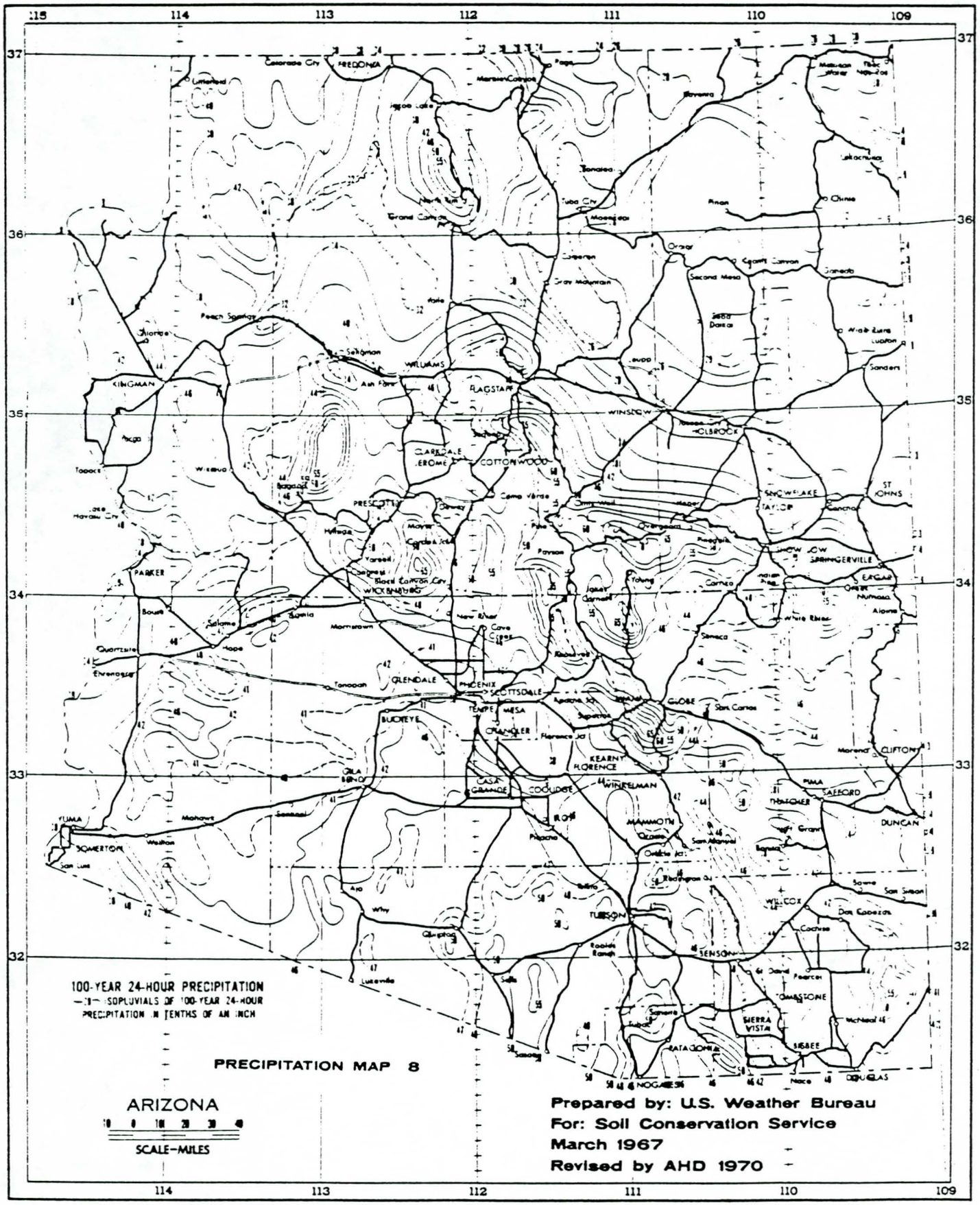
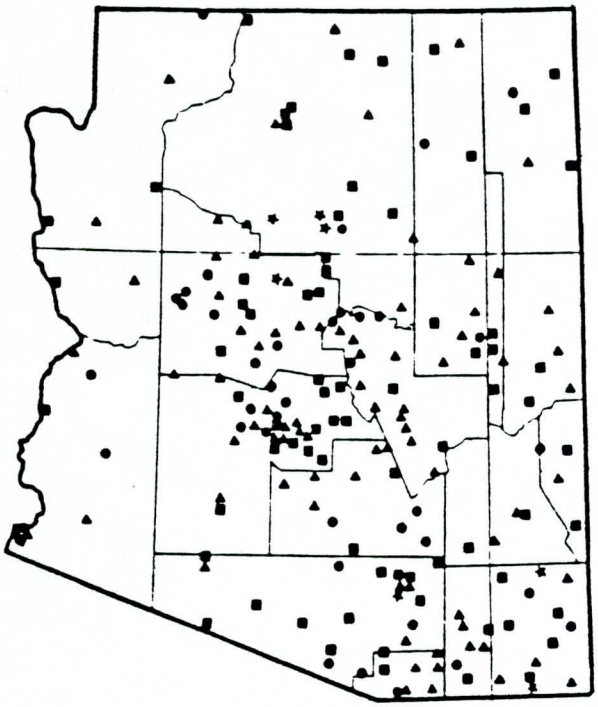
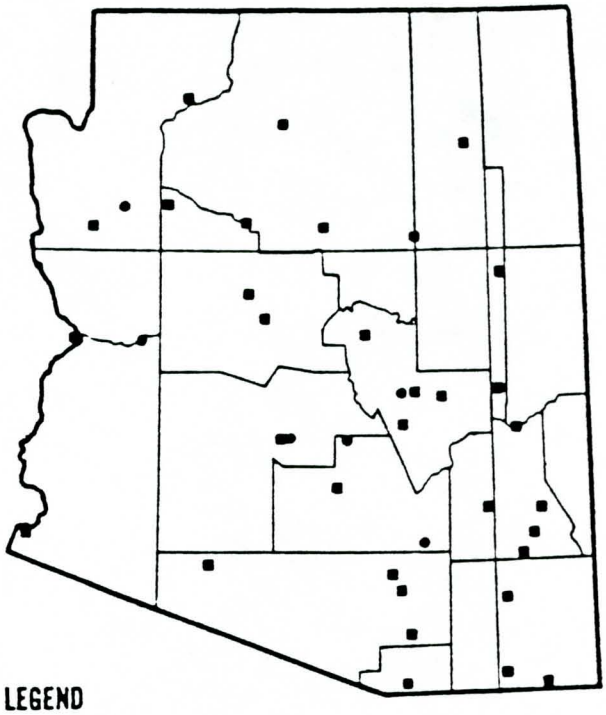


Figure 1 Typical Isohetal Map





LEGEND
● 10-14 YEARS
■ 15-29 YEARS
▲ 30-49 YEARS
★ 50 YEARS OR MORE

Figure 2 Nonrecording Rainfall Data Collection Stations used for NOAA Atlas 2 24-hour precipitation maps.

Figure 3 Recording Rainfall Data Collections Stations used for NOAA Atlas 2 6-hour and 24-hour precipitation maps.

Table 1. Stations Used for the Arizona NOAA Atlas II Maps.

Years of Record (up to 1970)	Arizona Stations RG	TR	NR
10-14	6	5	38
15-19	9	8	28
20-24	23	12	30
25-29		1	15
30-34		1	9
35-39		2	10
40-44		6	53
45-49		0	1
50-54		1	1
55-59		1	4
60-64		0	1
65-69		1	1

Totals:

Recording gage stations	38
Nonrecording gage stations	191
Total number of stations	229

Note: RG - stations having recording gage record.
TR - stations having a recording gage for some part of the record; total record includes both recording and nonrecording gage record.
NR - stations having only nonrecording gage record.

The 6-hour precipitation values were obtained from 38 recording gages in Arizona, only 2 of which were in Maricopa County. These were the Phoenix Airport Station, which had less than 25 years of record, and the Downtown Phoenix Station, which had less than 15 years of record.

2.1.2 Isohyets

The isohyet patterns were drawn based upon the precipitation frequency values calculated for the various stations and considered topographic, geographic and meteorologic features. The 2-year, 24-hour isohyetal map was drawn first and used as the base map in construction of the isohyetal maps for the other combinations of return periods and durations. This was due to the large amount of 24-hour data available and the greater accuracy with which 2-year events can be determined.

Due to the large areas covered by the maps, features considered were very generalized and the amount of local detail that could be shown was limited.

2.1.3 Other Duration Storms

Data from storms of durations other than 6 or 24 hours are often required. To obtain this data, regression equations were developed to relate the 6- and 24-hour precipitation value to storms of durations of 1, 2, 3 and 12 hours and of 5, 10, 15 and 30 minutes.

The equations for 1, 2, 3 and 12 hour storms were based upon precipitation records for an area roughly corresponding to the Colorado River Basin (including Arizona, and parts of California, Utah, Colorado and New Mexico). Because of the large area involved, the equations are fairly general. The equations used to relate the 5, 10, 15 and 30 minute duration precipitation value to 1 hour precipitation value are even more general as they are the ones developed for Technical Paper 40 and represent nationwide average values. The commonly used frequency-duration-precipitation curves are derived from the regression equations. Figure 4 shows typical curves for the City of Phoenix. Frequency-duration-precipitation data developed from the equations is given in tabular form in WBTM-44(4), Table 2.

Table 2 Frequency-Duration-Precipitation Station Phoenix WBO (Inches)

	RETURN PERIOD (YEARS)						
	1	2	5	10	25	50	100
5 min.	0.17	0.26	0.38	0.47	0.59	0.68	0.77
10 min.	0.27	0.40	0.59	0.72	0.91	1.06	1.20
15 min.	0.34	0.50	0.74	0.92	1.15	1.34	1.52
30 min.	0.47	0.70	1.03	1.27	1.60	1.86	2.10
1 hr.	0.60	0.88	1.30	1.61	2.02	2.35	2.66
2 hr.	0.65	0.94	1.39	1.72	2.15	2.49	2.82
3 hr.	0.69	1.01	1.48	1.82	2.27	2.62	2.97
6 hr.	0.81	1.16	1.70	2.07	2.57	2.96	3.35
12 hr.	0.91	1.30	1.90	2.30	2.84	3.26	3.69
24 hr.	1.02	1.44	2.10	2.53	3.12	3.57	4.04

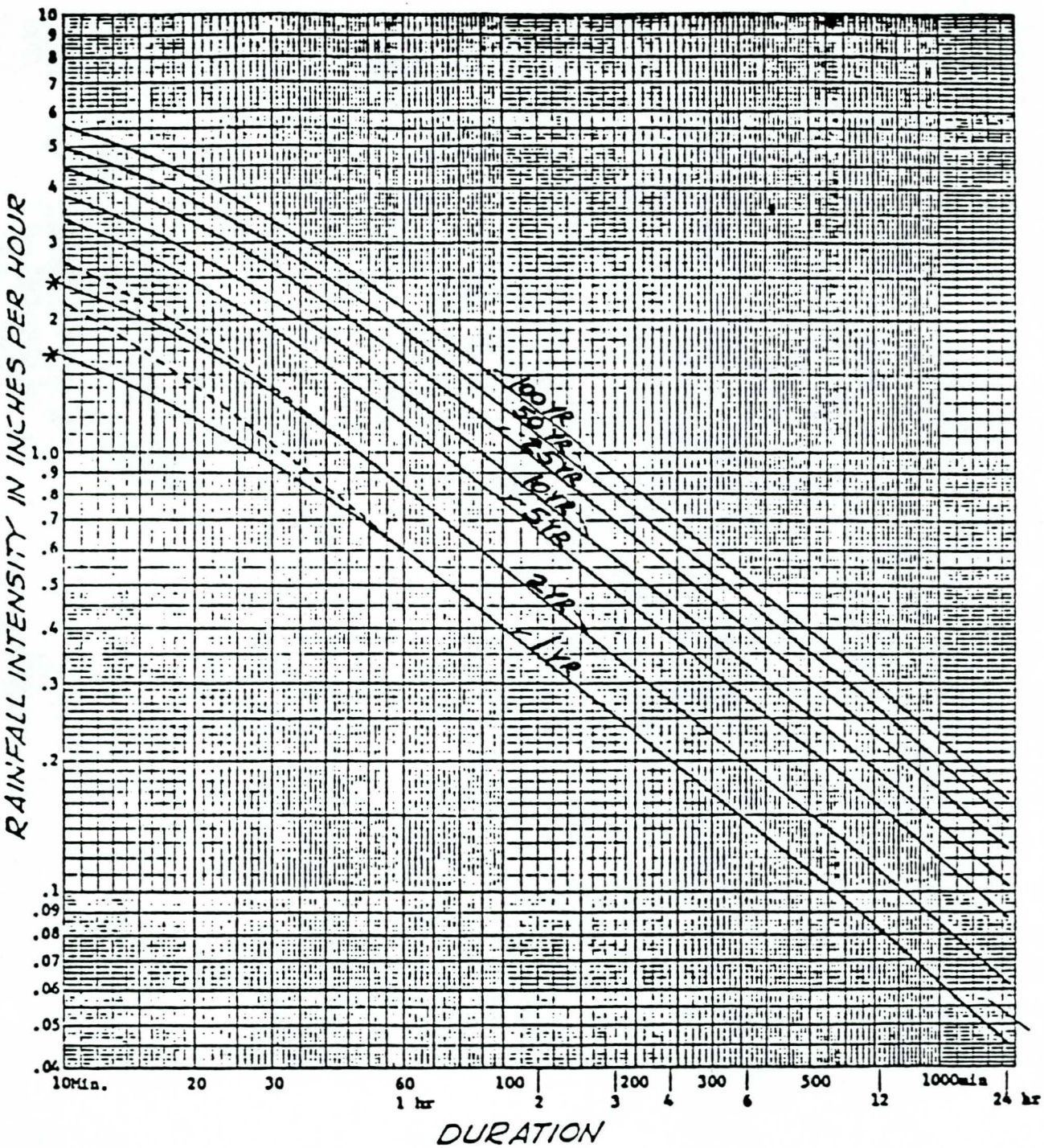
From Weather Bureau Technical Memorandum WBTM WR-44.

2.2 ADEQUACY OF THE ISOHYETAL DATA

The adequacy of the NOAA Atlas maps was assessed qualitatively considering both the precipitation frequency relationships developed for the individual stations and the interpolation of isohyetal lines between stations. The individual station relationships depend primarily on the available length of record. The interpolation of isohyetal lines depends upon the distance between stations. The adequacy of the regression equations used for other duration storms was also assessed.

2.2.1 Length of Record

For the individual rainfall data collection stations, records of sufficient length were required for determination of 2-year and 100-year frequency precipitation value. For determination of 2-year precipitation value, the most recent 15 years of data were used. This was compared with the preceding 15 years of data, and if a significant difference was found, a longer period of record was used. Generally, the most recent 15-year time period was judged to be sufficient. As most all of the stations used had 15 years of record, the 2-year values determined for the 6-hour and 24-hour storms should be adequate.



RAINFALL INTENSITY-DURATION-FREQUENCY RELATION
FOR PHOENIX, ARIZONA
(Partial Duration Series)

Curves are based on methods of U.S. Weather Bureau Technical Papers Nos. 28 and 40 and rainfall data prepared by U.S. Weather Bureau Office of Hydrology for the Soil Conservation Service, March 1967

* Curves revised June 1975 to reflect new information from WR-44.

Figure 4 Rainfall Intensity-Duration-Frequency Curves (from City of Phoenix Drainage Manual)

Much longer periods of record are required for accurate determination of 100-year precipitation value. Even with records of 50 years or more, considerable error can occur (5). Therefore, the entire period of record available should be used.

As none of the recording gages used for the 6-hour maps had greater than 25 years of record available, the predicted 100-year precipitation value is of questionable accuracy.

The 24-hour, 100-year values are considered more accurate in general than the 6-hour, 100-year values, as they are based on nonrecording gage records which generally have longer periods of record.

2.2.2 Isohyet Spacing

The location of the isohyets depends upon the effects of topography and climatic factors on the movement of storms and on the type of storm that produces maximum precipitation value for different areas and durations. The NOAA Atlas maps are small scale with widely spaced stations, which did not allow for much detail and accuracy in spacing the isohyets.

The use of the 2-year, 24-hour isohyet as a base map was based upon 33 Maricopa County nonrecording gage stations. Only the 2 recording gage stations were used for the 6-hour maps, however, and the 24-hour map isohyets had to be used as a guide for the 6-hour isohyets.

By doing so it implies that the same storm patterns produce both the same 6- and 24-hour maximum precipitation value. 6-hour maximum precipitation value is, however, from summer convective storms (thunderstorms), while 24-hour maximums are from both convective and winter frontal storms. Topography has a significant influence on convective storms, but less influence on frontal storms. Therefore, the precipitation isohyet from each storm type may not be the same.

Most precipitation stations in Maricopa County are also located in valley areas which generally have less rainfall than nearby highlands. The NOAA Atlas maps attempted to show this effect, but were generally limited by the amount of detail they could show due to the scale of the maps. Only the larger topographic features were shown but local features of possible significance could not be. Prevailing wind patterns and ground slopes also affect the isohyetal patterns. These effects were considered but, again, over only large areas.

In summary, the isohyetal patterns are inadequate due to the scale of the maps, the need to interpolate data between stations and the need of using the 24-hour isohyetal patterns for the 6-hour storms.

2.2.3 Regression Equations

The regression equations used to estimate precipitation amounts from short duration storms were developed for a large area including Maricopa County. Therefore, they are only approximations of conditions in Maricopa County. There would be close agreement only if Maricopa County represented average conditions for the entire areas.

For equations for the 1, 2, 3 and 12-hour storms which were developed for about the entire Colorado River basin, it seems unlikely that the relationship between these storms and the 6-hour storms would be the same everywhere. If Maricopa County, by chance, had average conditions, then the regression equations would be applicable. This could be determined from analysis of local raingage records. For the 5, 15 and 30 minute durations, which are based on national averages, it seems even more unlikely that the equations would be valid. This has been recently studied by Peterson for Montana (8) and he found considerable deviation from the averages.

The regression equations are also only as good as the 6 and 24-hour precipitation value. The inadequacy of this precipitation value will be refelected in the precipitation values obtained from using the regression equations.

3. EXISTING RAINFALL DATA COLLECTION NETWORKS

Rainfall data collection networks are operated by four agencies within Maricopa County: the Flood Control District of Maricopa County, the City of Phoenix, the U.S. Geological Survey and the National Weather Service. Other raingage records are available, but are not adequate for statistical analysis.

Each of the networks are described below with regards to the number and type of gages, the length of records available, and the type of operating system used. The location of the recording raingages operated by the above agencies are shown in Figure 5.

3.1 THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

The most extensive rainfall data collection network is operated by the Flood Control District of Maricopa County. 188 raingages are currently in use, including 58 telemetry stations and 21 recording stations. Over 30 additional gages have been operated in the past but are now abandoned. New gages are frequently added to the system. Most of the gages have been installed since 1980. The breakdown of gage type and length of record is shown in Table 3.

Table 3 Flood Control District of Maricopa County Raingages
October 1985

Length of Record	Number of gages		
	Telemetry	Recording	Nonrecording
Less than 2 years	11	--	32
2-5 years	47	16	72
5-10 years	--	--	--
10-20 years	--	1	--
Greater than 20 years	--	4	5
Total	58	21	109

Rainfall data is stored by a computer located at the Flood Control District of Maricopa County offices. The telemetry stations relay rainfall quantities by radio and the data is stored at 3-minute intervals. The system has the capacity to accept data from many times the current number of stations. A listing of the currently operated telemetry and recording gages by location and years of record is in Appendix A.

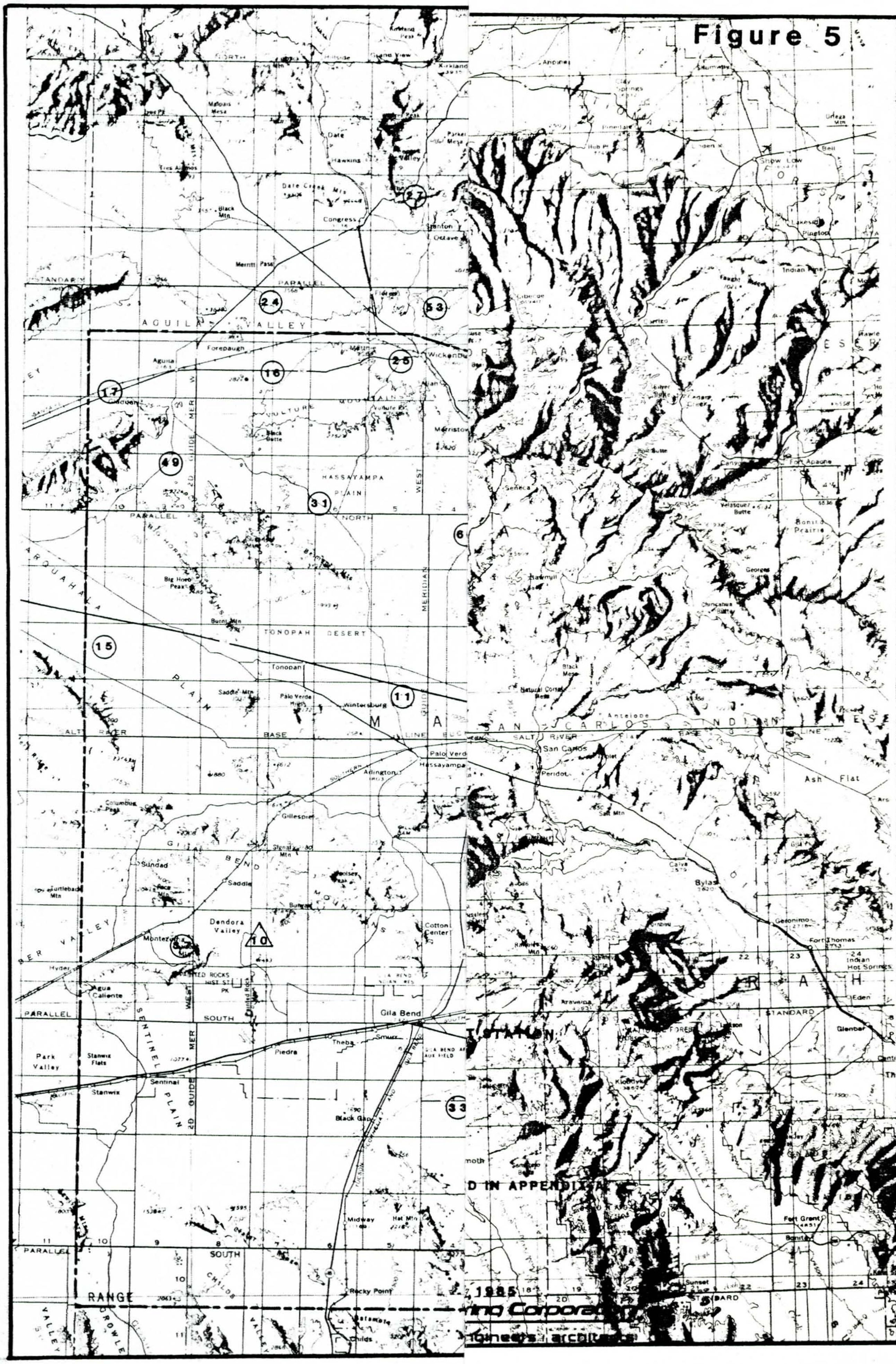

Aguila
Forepaugh
Wickenburg
Congress
Date Creek Mts
Hawkins
Merritt Pass
AGUILA VALLEY
HASSAYAMPA PLAIN
TONOPAH DESERT
Tonopah
Wintersburg
Palo Verde
Hassayampa
Gillespie
Dendora Valley
Gila Bend
Piedra
Theba
Sentinel
Stanwix
Park Valley
Stanwix Flats
Black Gap
Midway
Rocky Point
Childs
San Carlos
Peridot
Calva
Bylas
Geronimo
Fort Thomas
Indian Hot Springs
Eden
Fort Apache
Show Low
Pinetop
Fort Grant
Bonita
Ash Flat
SAN CARLOS INDIAN
D IN APPENDIX
1985

Figure 5

3.2 CITY OF PHOENIX

Phoenix operates 10 raingages within the city limits, as shown in Figure 5. The first of these was installed in 1972.

The network is connected by telephone lines over which the data are sent. The location and years of record for each gage are given in Appendix A. Data is recorded continuously in graphic form. Much data is available but it is not readily usable in its present form. Upgrading of the system is currently under study.

3.3 U.S. GEOLOGICAL SURVEY

A satellite telemetry raingage network is operated by the U.S. Geological Survey. 11 gages in or near Maricopa County are part of the system. They are shown in Figure 5 and are described in Appendix A.

Data from January 1985 is currently being stored in the U.S.G.S. mini-computer system. Additional data may be available on their mainframe computer system, but would have to be confirmed. The Flood Control District of Maricopa County also has some 15 years of U.S.G.S. data on file and on computer tape, although it has not been verified if it is for the same gages currently in use.

The U.S.G.S. operates its raingages for various agencies, including Arizona Department of Water Resources, Salt River Project, the Corps of Engineers, and the National Weather Service. All of their gages are at stream gaging sites.

3.4 NATIONAL WEATHER SERVICE

The National Weather Service has the oldest raingage network in Maricopa County. Most of their gages are nonrecording, (see Figures 2 and 3 for their locations). The Phoenix Airport and Downtown Phoenix recording stations are still operating. Several other stations with recording gages are operated by the U.S.G.S. or others, but are reported by the National Weather Service; these are listed under the operating agency.

Rainfall records of all National Weather Service recording stations in Arizona are available on computer tape at the Arizona State University Laboratory of Climatology.

3.5 SUMMARY OF STATIONS

The Arizona Department of Water Resources maintains a comprehensive listing of raingage locations. This listing includes all agencies collecting rainfall data and is updated periodically.

4. STEPS TO EVALUATE ISOHYETAL MAPS AND DESIGN EVENT GUIDELINES

The precipitation-frequency relationships developed for the stations used in the NOAA Atlas can be evaluated for their accuracy and updated if necessary using the data accumulated since 1970. Precipitation-frequency relationships can also be developed for some of the additional stations now available. The isohyetal maps can be revised to include the new and additional data. For short duration storms the NOAA Atlas regression equations should be revised to reflect more local data.

4.1 UPDATING PRECIPITATION-FREQUENCY RELATIONSHIPS

For the NOAA Atlas maps, precipitation-frequency relationships were developed for each of the gaging stations. As these relationships were based upon pre-1970 data, and as an additional 15 years of data are now available, they can be revised to verify that the values used in constructing the maps are adequate. If the revised values are significantly different (i.e., more than about 10% different), the maps can be updated to include the revised values. 100-year precipitation values should change the most.

4.1.1 Frequency Analysis Method

For frequency analysis of hydrologic data, the data can be treated as either a partial duration series or an annual series. For the precipitation data used in the NOAA Atlas, it was required to express the results in terms of partial duration frequencies. However, the data was arranged and analyzed as an annual series and an empirical relation was used to convert the annual series frequencies to partial duration frequencies. The use of partial duration series and their relation to annual series is discussed by Langbein (5). The frequencies were determined using a modified version the Fischer-Tippet (extreme value) Type I distribution (6). The resulting frequencies should be analyzed to assess how adequately they fit the data.

For accurate analysis of low probability events (e.g., the 100-year precipitation), a minimum of 25 years of data is recommended (7). Shorter records may be used if similar stations with longer records are available for comparison.

4.2 UPDATING THE ISOHYET PATTERNS

Updating the precipitation-frequency relationships for the stations used in NOAA Atlas 2, and analyzing the rainfall records of the additional gages now available may result in the modification of the isohyetal maps. The location of the isohyet between stations should be based on the guidelines in the NOAA Atlas, only applied on a larger scale, as more stations would be used, the generalizations made in the NOAA Atlas would no longer be necessary. These guidelines include how to adjust for topographic features, prevailing wind patterns and other factors influencing storm movements. Based on the qualitative assessments made in Section 2, it is likely that 6-hour duration maps may need major revisions while at least some minor revisions will be necessary for the 24-hour maps.

4.3 UPDATING DESIGN EVENT GUIDELINES FOR SHORT DURATION STORMS

As has been discussed above, the 6-hour and 24-hour precipitation maps need to be evaluated quantitatively and new isohyetal maps may need to be synthesized. For drainage design purposes, however, the most important events in Maricopa County are the short duration storms. For the smaller basins, the short duration storms result in the highest rates of runoff and are, therefore, the basis of drainage facility design. These are also the storms for which data is the least adequate. To evaluate the existing frequency-duration-precipitation curves, the values currently used should be compared to data obtained from stations within Maricopa County.

To update the existing data, two approaches may be taken. The first method would be to develop regression equations specifically for Maricopa County similar to those developed by NOAA for the Colorado River Basin. The second method would be to develop isohyetal maps for each of the storm durations desired based upon available precipitation data.

To develop regression equations for various storm durations, precipitation frequencies need to be calculated for several representative stations and related to the 6 and 24-hour storms. Average equations would be established for use throughout the County using NOAA Atlas or newly developed maps to obtain the local 6 and 24-hour precipitation value. The use of regression equations implicitly assumes that isohyetal patterns for the short duration storms are identical to those of the 6- and 24-hour storms. This assumption is not made if isohyetal maps are made for each of the storm durations.

4.4 DEPTH-AREA CURVES

The NOAA Atlas also contains depth-area curves for using point precipitation value to predict rainfall depths for large-area storms. These are used in various rainfall-runoff models. A more recent National Weather Service publication, Hydrometeorological Report No. 24 (1984) revises the older curves and should be used in Maricopa County.

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E.B.H. London, Bibliography of Precipitation and Runoff in the Arid Region of North America, Climatological Publications Bibliography No. 5, Laboratory of Climatology, Arizona State University, 1978, 77 pp.

Southwest Rangeland Watershed Research Center (Walnut Gulch), Bibliography, USDA SCS Agricultural Research Service, Tucson, Arizona, 50 pp. (continuously updated)

APPENDIX A TELEMETRY AND RECORDING RAINGAGES

A1. FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
October 1985

	gage Location	Telemetry Recording	Years of Record 2	2-5	5-10	10-20	20+
1.	Adobe Dam Precip	T		(82)			
2.	Agua Fria 3	T		(81)			
3.	Agua Fria 4	T/R		(81)			
4.	Agua Fria 5	T		(81)			
5.	Agua Fria 6	T		(81)			
6.	Agua Fria 7	T		(81)			
7.	Agua Fria 8	T		(81)			
8.	Agua Fria 9	T		(81)			
9.	Agua Fria 13	T		(82)			
10.	Agua Fria 14	T	X				
11.	Buckeye FRS1 Precip	T		(83)			
12.	Bulldog Floodway 2	T		(82)			
13.	Cave Creek 15	T		(81)			
14.	Cave Creek 16	T		(81)			
15.	Centennial Levee 1	T		(80)			
16.	Centennial Wash 3	T		(81)			
17.	Centennial Wash 7	T		(82)			
18.	Dreamy Draw Precip	T				(74)	
19.	East Peak Whitetails	T/R		(80)			
20.	Guadalupe 2	T		(82)			
21.	Hassayampa McMicken	T		(81)			
22.	Hassayampa 3 Wilhart	T		(81)			
23.	Hassayampa 2 O'Brien	T		(81)			
24.	Hassayampa 4 Sols	T		(81)			
25.	Hassayampa 5 Sunset	T		(81)			
26.	Hassayampa 6 Mt. Union	T		(82)			
27.	Hassayampa 7 Box Prec.	T	X				
28.	Hssympa 8 Bridge Prec.	T	X				
29	IBW 4	T		(81)			
30.	IBW 7 Precip.	T	X				
31.	Jack Rabbit Wash 2	T		(82)			
32.	Lower Gila 1 Bend	T		(82)			
33.	Lower Gila 2 Sand Tanks	T		(83)			
34.	McMicken 12 Trilby 1	T		(81)			
35.	McMicken 17 Trilby 2	T		(82)			
36.	McMicken Dam Precip	T		(83)			
37.	Mt. Oatman	T/R		(80)			
38.	Mt. Ord	T		(82)			
39.	New River 7	T		(81)			
40.	New River 9	T	X				

T - Telemetry Station
R - Recording Station
(81) - Year Station Installed (if known)

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
Telemetry and Recording Rain gages
October 1985

	gage Location	Telemetry Recording	Years of Record 2	2-5	5-10	10-20	20+
42.	Rittenhouse 2	T		(81)			
43.	RWCD 4	T					
44.	Skunk Creek 7	T		(80)			
45.	Spookhill 8	T					
46.	Spookhill 10	T					
47.	Smith Peak	T/R		(80)			
48.	Thompson Peak	T		(80)			
49.	Tiger Wash 2	T		(81)			
50.	Vineyard 2	T					
51.	Vineyard 4	T	X				
52.	Waterman Wash 10	T		(83)			
53.	Yarnell Hill	T/R		(81)			

(5 additional telemetered stations are installed but their locations were not available.)

59.	Apache Junction	R		X			
60.	Doggy Jones	R					(57)
61.	Foothills	R					(57)
62.	Gila Drain	R		(82)			
63.	Gila E-W 2	R		(82)			
64.	Hydroclimate	R		(80)			
65.	IBW 5	R		(82)			
66.	Below McMicken Dam						(57)
67.	Morristown	R					(57)
68.	Peoria	R		(81)			
69.	Skunk Creek	R		X			
70.	Waterman Wash 4	R		(80)			
71.	Waterman Wash 9	R		(82)			
72.	Wittman	R		(82)			

(3 additional recording stations are installed but their locations were not available)

T - Telemetry Station
R - Recording Station
(81) - Year Station Installed (if known)

A2. CITY OF PHOENIX

Telemetry Rain gages
October 1985

Gage Location	Years of Record 2-5	5-10	10-15
16th St. and Thomas (Fire Station 5)			X
48th St. and Thomas (Fire Station 13)			X
16th St. and Camelback (Fire Station 17)			X
Central Ave. and Southern (Fire Station 22)			X
59th Ave. and Indian School (Fire Station 25)			X
32nd St. and Cactus (Fire Station 27)			X
27th Ave. and Northern (Fire Station 30)			X
Central Ave. and Washington (Municipal Bldg.)		X	
Deer Valley Airport		X	
35th Ave. and Greenway (Fire Station 42)	X		

A3. U.S. GEOLOGICAL SURVEY

Telemetry Rain gages
October 1985

Cave Creek below Cottonwood Creek near Cave Creek, AZ
Sycamore Creek near Fort McDowell
Salt River below Stewart Mountain Dam
New River near Rock Springs
Agua Fria River at El Mirage
Agua Fria River near Mayer
Cotton Wood Creek near Waddel Dam
Turkey Creek near Cleator
Agua Fria River near Rock Springs

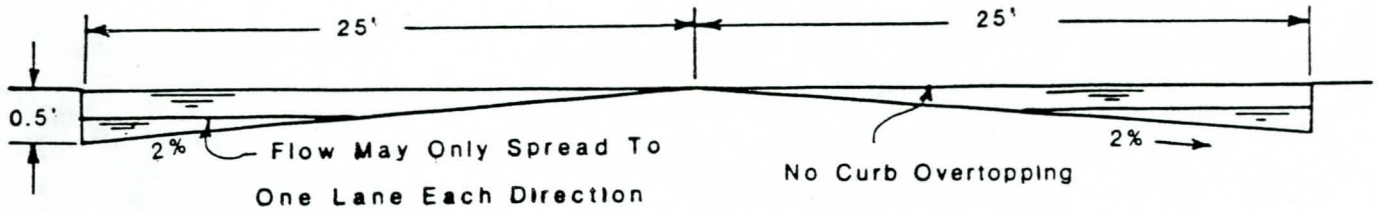
Years of Record: Since January 1985 recorded on USGS Computer System. Previous USGS data available at MCFCD.

APPENDIX D

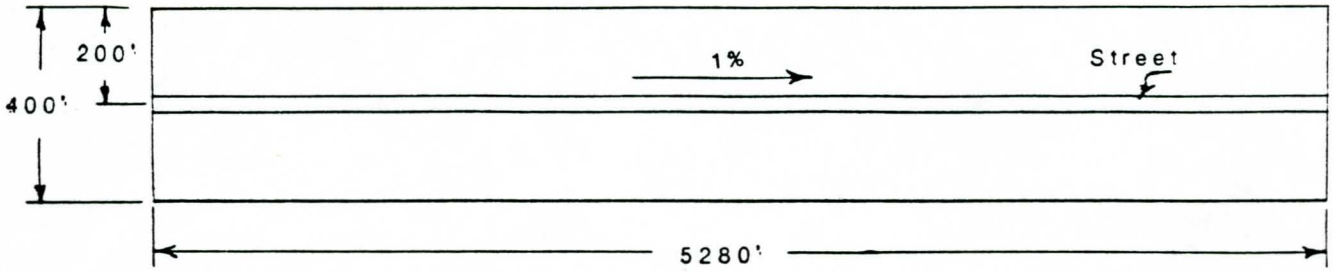
DESIGN EXAMPLES

D1. COLLECTOR STREET DRAINAGE COSTS

Street: 1 mile long
1% slope



Collector Street Section



Drainage Area

Table D1 Drainage Costs per Mile

Design Return Period (Yrs)	Flow May Spread to One Traffic in Each Direction	No Curb Overtopping
1	$340,000	
2	$415,000	
5	$500,000	$335,000
10	$530,000	$370,000
Combination 1 year/1 lane inundated 10 year no curb overtopping	$395,000	

Costs assume $44/foot for 18" dia RCP to $107/foot for 48"dia RCP; catch basins assumed $800/cfs capacity.

The criteria of flow only to one traffic lane in each direction is more restrictive for short street reaches. For longer street reaches, no curb overtopping is the more restrictive criteria.

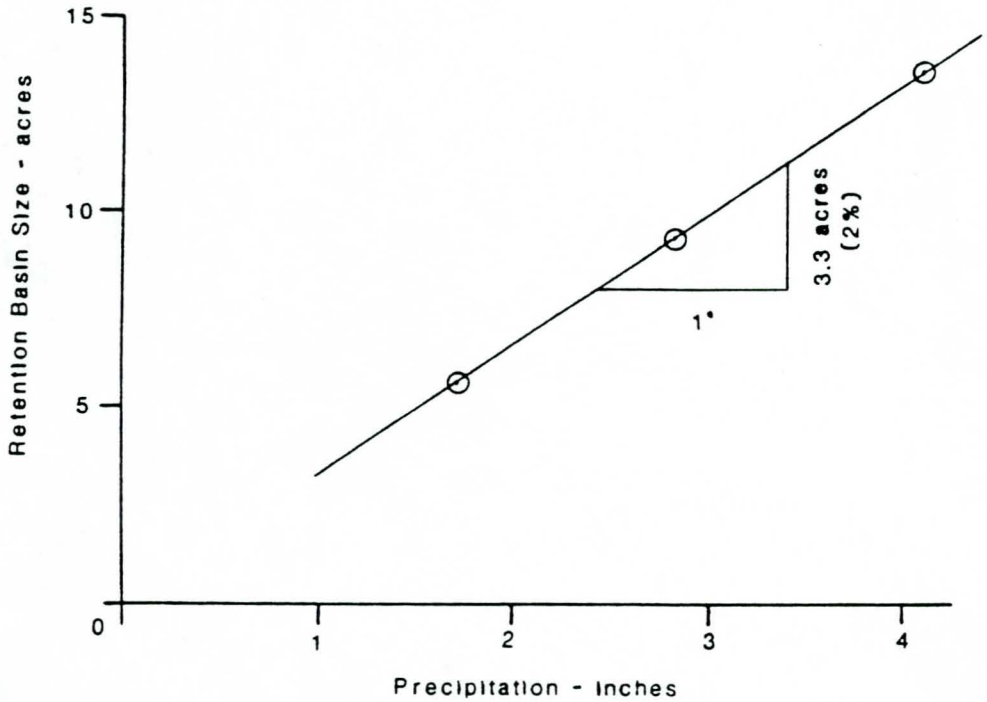
It is recommended that a combination of criteria be adopted, such as flow may only spread to one traffic lane in each direction for the 1 year storm and no curb overtopping for the 10 year storm.

D2. RETENTION BASIN DESIGN EXAMPLE

Retention basin for 160-acre development:

Basin depth = 3 ft.
Runoff coefficient = 0.75

Storm Frequency-Duration	Precipitation (inches)	Runoff Volume (acre-feet)	Retention Basin Size (acres)
10-year/2-hour	1.72	17.2	5.7
100-year/2-hour	2.82	28.2	9.4
100-year/24-hour	4.04	40.4	13.5



Conclusion: Area required for retention increases linearly. Approximately 2% of the total development area required per inch of runoff retained.

D3. CHANNEL DESIGN EXAMPLE

Open channel construction cost:

Channel: 8-foot bottom width, 2:1 side slopes
Lined channel "n" value of 0.015
Unlined channel "n" value of 0.025
Slope of 0.001

Construction Costs: Excavation - $10/c.y.
Lining - $4/sq.ft.

Runoff Frequency (years)	Discharge (cfs)	Lined Channel		Unlined Channel	
		Cost ($/ft)	Top Width (ft)	Cost ($/ft)	Top Width (ft)
5	300	117	22.5	30	26.5
10	370	127	24.0	35	28.5
100	525	148	27.0	45	32.0

Conclusions: Additional cost for 100-year design over 10-year design is 14% for a lined channel and 22% for an unlined channel.

APPENDIX E

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