CDM Camp Dresser & McKee

City of Chandler

1998 Stormwater Master Plan Update

Final Report
June 1999

Prepared For:
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Executive Summary

The City of Chandler (City), Arizona, while located in an arid region, does occasionally experience significant rain storms. Rapid urbanization of agricultural lands has increased rates of stormwater runoff. The area's flat topography and lack of natural drainageways tend to promote accumulation of runoff after storms. Sheet flows tend to pond at elevated railroad and canal berms. Localized ponding concerns have been particularly prevalent in the older part of Chandler that was developed prior to implementation of drainage standards. In addition, the City only has one drainage channel, the Gila Drain, located at the western edge of the City.

In 1975, the City Council initiated on-site stormwater retention requirements that have significantly reduced drainage concerns in recently developed areas. However, stormwater management concerns continue to impact the management of stormwater in Chandler. They include the flat slope of City terrain and the lack of easily accessible stormwater outfalls in the City.

In 1986, Camp Dresser & McKee Inc. (CDM) completed the first of three stormwater management master plan studies for the City. The plan was based on projections made in the mid-1980s for buildout conditions. A major factor affecting possible stormwater management options for Chandler in 1986 was the lack of easily accessible stormwater outfalls for the area. The plan recommended a regional drainage system in the downtown area with retention basins and a regional drainageway.

In 1992, CDM updated the original plan based on revised land use buildout projections, and on preliminary designs of drainage for the Arizona Department of Transportation's (ADOT) Price Freeway and Santan Freeway. The 1992 update recommended three improvements: connecting the downtown regional basins to ADOT's future drainage systems, requiring on-site retention for new developments, and planning future outfalls for west Chandler. For other areas in the City, the plan recommended on-site retention of the 100-year, two-hour storm runoff in each development. CDM also evaluated stormwater models and recommended design criteria.

Since the last update, the western portion of Chandler has been developed and ADOT has constructed a large retention basin in the downtown area for the Price Freeway and Chandler's downtown regional drainage system. ADOT has also constructed portions of the Price Freeway and drainage system. The agency is continuing to design and construct the freeway drainage systems with the City's financial and project management participation. In addition, the City has constructed numerous storm drains in the downtown area to reduce ponding concerns.

In 1998, the City contracted with CDM to update the City stormwater management master plan based on final design of the future freeways, recently completed storm drains and basins, growth that has occurred, pending federal stormwater regulations under the National Pollutant Discharge Elimination System (NPDES), and local ponding concerns. Also included in the update was a review of stormwater flows from outside the City, recommendations for west Chandler, and improvement of existing City stormwater design criteria.

Plan Summary

The existing Technical Manual No. 3 City drainage design standards were reviewed and compared to the existing City Development Services Department requirements, the Flood Control District of Maricopa County's design manual, and design criteria for other local communities. The City's Manual No. 3 will be updated in the next few months. The items being considered for change include retention basin, storm drain, street, drywell, and pump station design standards, construction and maintenance standards.

For each area of the City, ponding and regional drainage concerns were identified, alternatives carefully studied, and solutions recommended. For Area A, the downtown portion of the City, regional basins and storm drains were constructed between 1987 and 1997 to minimize areas of ponding, however, ponding still occurs at several locations. To minimize the remaining localized ponding concerns and drain the regional basins within 36 hours after a storm, CDM recommends constructing a system of storm drains and pump stations connecting to the Price and Santan Freeway drainage systems. Local improvements are also recommended. The total estimated cost for the Area A recommended plan is $12,914,000 over ten years. The City previously contributed a total of $11,980,000 to ADOT, $3,880,000 for the freeway drainage systems and $8,100,000 for accelerating the freeway construction. This brings the total cost to $24,894,000.

In Areas B (West and North Chandler) and C (South Chandler) CDM recommends that the City continue requiring that new development provide on-site retention of runoff from the 100-year, 2-hour storm. To reduce localized ponding concerns, improvements are required at a cost of $580,000 to expand basins, install temporary basins and drywells, and construct storm drains. Regional retention basins and outfalls are not necessary in Areas B and C since there have been no reported concerns with on-site retention and percolation. The only exception is an outfall for the 56th Street/Chandler Blvd. ponding concern.

The total cost for improvements for all three areas is $13,500,000. This 1998 updated plan reduced the cost for facilities from the 1992 Update by $4,500,000 in Area A and $34,800,000 in Area B, West Chandler. If the Denver Basin is pumped directly south to the freeway drainage channel, the cost will be reduced by an additional $4,900,000 for a total savings of $9,400,000 in Area A.

CDM recommends that the City coordinate with FCDMC, Mesa, and Gilbert to develop regional solutions to address predicted overtopping of canals in southeast Chandler as a result of runoff from the 100-year, 24-hour storm. This recommendation includes attending project meetings and providing input to the FCDMC during the development of the Higley Area Drainage Master Plan.

The City will be required to apply for both municipal and industrial stormwater Phase II National Pollutant Discharge and Elimination System (NPDES) permits for the municipal separate stormwater system and City-owned industrial-type facilities. The permits will be required based on the proposed Environmental Protection Agency (EPA) Phase II rules published in January 1998. The final EPA stormwater rules applicable to Chandler are expected October 29, 1999 and should stipulate that Chandler must submit a municipal permit application by May 31, 2002. Implementation of the pollution prevention programs is expected by 2007. The programs include public information best management practices, and other pollution prevention type activities. They are expected to cost $341,000 to implement and $305,000 in annual program maintenance costs.

Annual operating and maintenance costs for the regional storm drain system in Chandler will be expected to increase from $247,000 in 1998 to an estimated $780,000 in 2007. The increases include maintenance of additional storm drains, pump stations, and streets, and maintenance of the NPDES stormwater pollution prevention programs.

To fund the rising annual operation and maintenance programs for the new infrastructure and NPDES program, CDM recommends that either the sewer fee be increased or a stormwater utility be implemented.

ES. 1 Project Area

The area covered by this study and the previous stormwater master plans is shown in Figure ES-1 and encompasses the entire 71-square-miles within the City's boundaries and county land outside the City boundaries. The area under investigation was divided into three separate study areas (A, B, and C) based on the state of development, drainage standards in effect during development, and location relative to possible runoff conveyance routes. Study Area A consists of the older downtown part of the City. Study Area B consists of the recently developed areas of the City north of Pecos Road. Study Area C consists of the area south of Pecos Road and east of Price Road where development is now occurring. With the growth in the City, agricultural land is being replaced with residences and businesses. At buildout, no agricultural land is predicted to remain in the City.

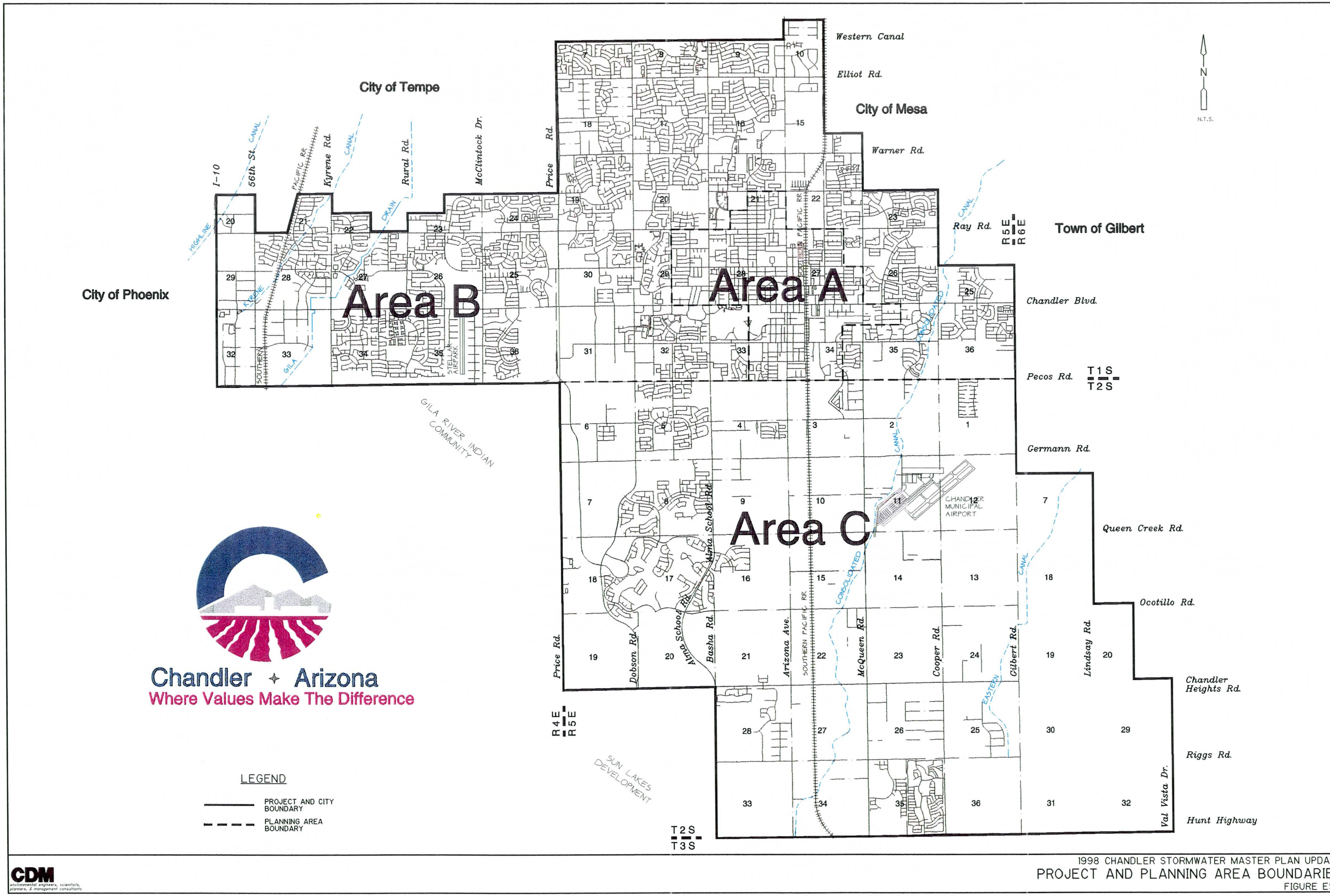
The topography in Chandler is relatively flat: slopes vary between one and two feet per thousand feet. In the north and west portions of the City, the land slopes to the west toward the Gila Drain except for the portion west of the drain, which generally slopes toward the east. The southern part of the City slopes southwest toward the Gila River Indian Community and the Gila River. Local flooding in areas smaller than 100-square-miles tends to occur during July through September as a result of local thunderstorms.

The following sections discuss the concerns addressed by the updated plan:

- Design standards requiring updates
- Localized ponding and regional drainage of Area A (downtown)
- Localized ponding in Areas B and C
- Stormwater flows from outside the City

Each concern is discussed in the following format:

- Concern
- Previous Recommendation
- Current Status
- Alternatives Evaluation
- Recommended Solution



1998 CHANDLER STORMWATER MASTER PLAN UPDATE
PROJECT AND PLANNING AREA BOUNDARIES
FIGURE ES-1

ES. 2 Design Standards

Concern

The City's drainage design standard manual (Technical Manual No. 3, 1987) does not include all the standards currently required by the City Development Services Department. In addition, the manual was written before the Flood Control District of Maricopa County's (FCDMC) design manual (last updated in 1996) and ADEQ drywell recommendations were published.

Previous Recommendations

The 1992 Update recommended on-site retention of stormwater runoff, one foot of freeboard for retention basins, detailed percolation tests, and maintenance of basins and drywells to keep them functioning properly.

Current Status

CDM reviewed and compared Technical Manual No. 3, handouts provided to developers by Development Services, the FCDMC design manual, recommendations from the 1992 Update, and ADEQ recommendations. CDM is currently updating Technical Manual No. 3 based on discussions with the City.

Recommended Solution

The City of Chandler was adopted the FCDMC design manuals with exceptions that the City requires. The following exceptions to the FCDMC design manuals have already been incorporated by the Development Services Department and will be added to Technical Manual No. 3:

- Retention Basins:
  - The maximum side slope shall be 4:1.
  - The maximum water depth allowed in parking lots with retention shall be six inches. The maximum area shall be 2/3 of the parking spaces.
  - Landscaping and mounding must be provided in and around basins per the City zoning code.
  - A maximum of 50% of the frontage property may be used for retention.
  - The Intensity-Duration-Frequency curve derived for Chandler must be used for retention basin sizing.
  - The maximum water surface elevation shall be lower than the minimum street pavement elevation.

- Storm Drains:
  - Only Rubber Gasketed Reinforced Concrete Pipe (RGRCP) is allowed for storm drains.
  - The City furnished D load chart must be used to determine the depth of cover for storm drains.
  - New City standard details for bubbler boxes, catch basins, handrail, catch basin grates, and frames must be met.
  - The weir equation for calculating capacity of inlets to storm drains shall be used.

— The method shown in the FCDMC manual for junction loss calculations shall be used.
— The drains must provide ten-year, six-hour storm capacity in the storm drain system.
— They must also provide 100-year, two-hour storm runoff capacity if storm drains sized for the ten-year, six-hour storm runoff would flood nearby properties or arterial streets.

■ Streets:

— Final floor elevations of buildings must be 14-inches above the lowest outfall elevation.
— No slotted drains are allowed.

■ Other:

— Developments within 100-year flood areas require FCDMC approval.
— Lot grading shall have positive drainage at 0.5 percent slope away from the buildings.
— Existing ditches shall be abandoned, piped, or improved when the surrounding land is developed.
— The FCDMC pump station design standards shall be used.

■ Drywells:

— ADEQ registration, drilling logs, and certified percolation tests must be submitted to the City.
— Oil interceptors following the standard detail are required near gas or service stations or other fuel storage facilities.

■ Construction:

— Lightweight equipment shall be used for the construction of retention basins.
— Certified as-built plans shall be submitted to the City.

■ Maintenance:

— Basin sediment shall be scarified or scraped as needed to prevent buildup of an impermeable soil layer.
— Drywells shall be inspected annually and maintained as needed.
— Performance bonds shall be set up for maintenance of private basins and drywells.

Additional standards CDM recommends be added to Technical Manual No. 3 include:

■ Retention Basins:

— Basins must provide one foot of freeboard above the elevation of the runoff from the 100-year, two-hour storm.
— Rain falling on the top of the basin berm shall drain to a channel with erosion protection.
— Install Catch Basins prior to retention basin bubbler box inlet.
— Conduct percolation tests before and after construction of the retention basin to verify permeability of the completed basin.

- Streets:
  - When calculating flows, use reduction factors from the FCDMC manual for parked cars and debris in the street.
- Pump Stations:
  - Dual pumps, a small pump for nuisance flows, and a backup power source to stormwater pump stations shall be additional requirements.
- Drywells:
  - The revised City Drywell standard detail (dated November 1998) must be met. For drywells draining parking lots and service stations oil/water separators are required. A standard detail that shows the separator and drywell will be added to Technical Manual No. 3.
  - Inlet grates must be two-inches above the bottom of landscaped basins; for drywells in other locations, the grate must be level with the ground.
  - 100-foot separation is required between drywells, or between drywells and underground storage tanks, fuel areas, or water wells.
  - Drywells shall be 20 feet from the inlets of landscaped basins.
  - Drywell drillers shall be registered with ADEQ.
  - Petrochemical absorbents shall be provided in all drywells.
  - Drywells in the zone of perched groundwater must be sealed.
  - The bottom of drywells shall be at least 10-feet above the water table.

ES. 3 Area A Evaluation of Alternatives and Recommendations

Concerns

Localized ponding concerns have been particularly prevalent in the downtown area. Previously, the City constructed storm drains which now convey runoff to regional basins in the downtown area to reduce ponding. These existing regional basins are limited in size, do not hold the 100-year, 2-hour storm, and may not drain in 36 hours, as required by the City to prevent mosquitoes from breeding. The basins can currently discharge to the SRP (Salt River Project) irrigation system if needed; however, SRP would like to discontinue this practice. Localized ponding occurs at several locations between Alma School Road and Arizona Avenue where there are no storm drains or inlets to the existing storm drain system.

Previous Recommendations

In the 1986 Master Plan five alternatives for discharges of stormwater runoff from the downtown area were evaluated:

- Retention and a regional drainageway
- Retention with drywells for percolation
- Stormwater treatment and reuse

- Stormwater utilization in a lake system
- Detention and drainageway through the Gila Indian Community to the Gila River

Based on feasibility and costs, detention and the drainageway to the Gila River was recommended. To reduce ponding in the downtown area, storm drain systems emptying to regional retention basins were recommended.

The 1992 master plan update revised and re-evaluated the 1986 recommendation of detention and discharge to a drainageway. This plan recommended connecting the regional basins to the planned ADOT highway drainage system for an outfall and discharge within 36 hours. It also recommended additional storm drains to further reduce ponding in the downtown area.

Current Status

Freeway Drainage Systems

ADOT is designing and constructing the Price and Santan Freeways and drainage systems. Along Price Road, the future Price Freeway will have a series of basins, pumps, and pipes to collect stormwater and convey it to either the Gila or Salt River. North of Knox Road, the runoff will be drained to ADOT Basin F, with a gravity outlet to ADOT Basin E and a forcemain to the Tempe/ADOT Carriage Lane Basin and outfall to the Salt River (see Figure ES-2). South of Knox Road the runoff along the freeway will drain to ADOT Basin G, which will have gravity outlets to the Santan Freeway drainage channel, and will drain to the Gila River. The Santan Freeway drainage channel will convey stormwater west with pumps at Dobson Road, McClintock Road, and ADOT Basin B. At Basin B, first flush runoff will be retained for settling of particles and treatment in a vegetated cell. Discharge from ADOT Basin B will be pumped to the Gila Floodway and Gila River on Gila River Indian Community land.

City Drainage Systems

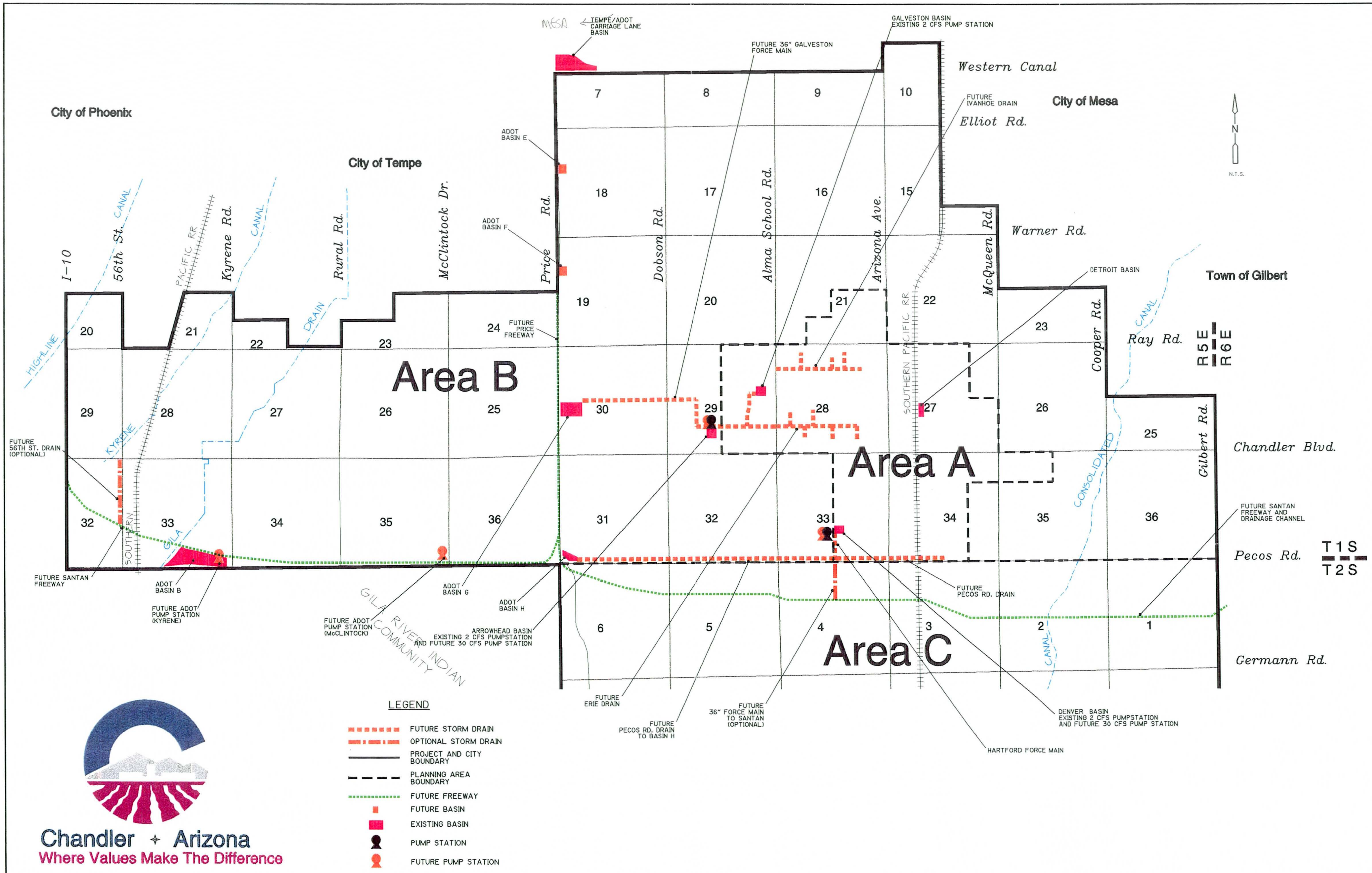
To help speed up the freeway construction and implement the drainage system, the City has maintained active involvement and has contributed $3,880,000 toward drainage systems and $8,100,000 toward freeway acceleration. The drainage projects will allow the City to discharge stormwater from regional basins to the Salt River north of the City and Gila Floodway southwest of the City via the freeway drainage systems. Ponding in the downtown area has been reduced by the construction of storm drains to the regional basins.

Alternatives Evaluation

Localized Ponding

Streets in Area A that have problems with water ponding and lack of drainage during and after storms were identified. In the Denver Basin drainage area, ponding occurs on Delaware Street from Erie Street to Chandler Boulevard. The Chandler Boulevard storm drain is located in this area so catch basins could be installed and connected to it.

In the Galveston Drainage area, several alternatives were identified to reduce multiple ponding areas and to reduce the volume of stormwater runoff conveyed in the streets.



CDM
environmental engineers, scientists, planners, & management consultants

1998 CHANDLER STORMWATER MASTER PLAN UPDATE
RECOMMENDED MASTER PLAN FACILITIES
FIGURE ES-2

Alternatives to drain ponding areas to Galveston Basin included:

- Install a storm drain along Ray Road and connect it to the Alma School Road Drain
- Install a storm drain along Ivanhoe Street and connect it to the Alma School Road Drain
- Install a storm drain along Galveston Street, replace the Chandler Drain, and connect the new drain to Galveston Basin
- Install storm drain along Erie Street and connect it to the Alma School Road Drain. Ultimately, extend this drain to Arrowhead Basin.

Based on feasibility, ease of construction, and reduction or elimination of disturbances to traffic and neighborhoods, storm drains were recommended along Erie and Ivanhoe Streets with laterals extending to ponding areas in Hartford Street, and to Oakland and Cheri Lynn Streets (See Figure ES-2).

Regional Drainage

The 1992 recommendation to connect regional basins to the freeway drainage system was reviewed and carefully analyzed. Alternatives that were studied are listed below. For the three alternative costs shown below, the cost to install storm drains along Erie and Ivanhoe streets to the Arrowhead Basin and for the NPDES program implementation was not included because it is the same for all three options..

- Discharge stormwater from the downtown regional basins to the ADOT freeway system and eventually the Gila River. Prior costs: $3,880,000 for freeway drainage system and $8,100,000 for freeway acceleration. Future estimated costs: $9,955,000. Total estimated costs: $21,935,000 (1998 Plan).
- Implement recharge program in the downtown area using the San Marcos golf course for underground storage and percolation in drywells. Preliminary cost estimate: $22,060,000.
- Implement recharge program in the South Chandler Area, pumping the water south of Pecos Road to 75 acres of retention basins for storage and percolation. Preliminary cost estimate: $24,587,000.

Based on the limited land available, estimated costs for the alternatives, and amount spent for the freeway drainage system, connection to the ADOT freeway system was recommended for implementation. The planned system to connect the existing regional basins to the freeway drainage system was re-evaluated to maximize the use of the retention basin capacities, reduce pipe sizes, compare using pump stations to drain the basins, and minimize the disturbance to neighborhoods during construction. Several options were evaluated using a SWMM model of the existing and proposed system to size pipes and pump stations for peak flows. The options studied are listed below. They are detailed options for the regional drainage plan discussed above. The recommended option was used to determine the $9,955,000 cost.

Table ES-1 Options for Galveston and Arrowhead Basins	
Gravity storm drains (1992 SWMP Update Plan recommendation)	$7,365,900
Gravity storm drain through Galveston and Arrowhead Basins	$7,025,000
Routing stormwater through the basins with pump station at Arrowhead Basin	$6,358,000
Routing stormwater through the basins with pump stations at Arrowhead and Galveston Basins	$8,969,000
Routing stormwater only through Arrowhead Basin with one pump station at Arrowhead*	$5,427,000

* recommended

Table ES-2 Options for Denver Basin	
Gravity drain to Pecos Road and Basin H	Not feasible: Large diameter pipe size or dual pipes required at available slope
Pump station and force main to Pecos Road, gravity storm drain along Pecos Road to Basin H* (1992 recommendation and Current Plan)	$6,740,000
Pump station and force main along Pecos Road to Basin H	$5,356,000
Gravity drain south to ADOT Santan freeway drainage channel	Not feasible: Large diameter pipe size or dual pipes required at available slope
Pump station and forcemain south to ADOT Santan freeway drainage channel**	$1,865,000

* recommended
** optional recommendation

Recommended Plan for Area A

From the alternative evaluation a revised plan was developed. This revised stormwater plan uses pump stations at Arrowhead and Denver Basins and smaller outlet pipes than shown in the 1992 plan.

The revised plan for Area A is outlined below and illustrated in Figure ES-2.

Table ES-3 ***Galveston and Arrowhead Basins Drainage Areas Ponding Concerns and Recommended Solutions***		
Concern	***Solution***	***Cost Estimate***
Erie Street fills with stormwater during significant storm events	Install Erie Drain to convey stormwater (page ES-7 to ES-8)	$1,972,000
Hartford Street fills with water during significant storm events	Install lateral to the Ivanhoe Drain to improve Hartford Street Drainage	Included in Ivanhoe Drain cost below
Ponding at Ivanhoe and Evergreen Street during significant storm events	Install Ivanhoe Drain (page ES7 to ES-8)	$961,000
Ponding at Dublin Street and Hartford Street	Install catch basins and a lateral to the Erie Drain	Included in Erie Drain cost above
Ponding at Oakland Street and Cheri Lynn Street	Install catch basins and a lateral to the Erie Drain	Included in Erie Drain cost above
Galveston Basin drainage within 36 hours after the end of the 100-year, two-hour storm	Install outlet drain to the Erie Drain and Arrowhead Basin (page ES-8)	$340,000
Arrowhead Basin drainage within 36 hours after the end of the 100-year, two-hour storm	Install Arrowhead Basin pump station, 30 cfs	$917,000
	Install force main from Arrowhead Basin to Basin G: 36-inch diameter, Anderson Blvd to Galveston Street and west to Basin G (page ES-8)	$1,958,000
Pleasant Lane: ponding near basin	Two drywells	$12,000

Table ES-4 ***Detroit and Denver Basins Drainage Areas*** ***Ponding Concerns and Recommended Solutions***		
Concern	***Solution***	***Cost Estimate***
Ponding in Delaware Street from Erie Street to Chandler Boulevard	Install catch basins along Delaware Street: Erie Street to Chandler Boulevard; connect to Chandler Boulevard storm drain	$14,000
Denver Basin drainage within 36 hours after the end of the 100-year, two-hour storm	Install pump station and force main to Pecos Road; gravity storm drain along Pecos Road to Basin H (1992 recommendation) (page ES-9) OR Install pump station and force main south to ADOT Santan freeway drainage channel (option)	$6,740,000 OR $1,865,000

Total Estimated Cost for Area A Recommended Plan: $12,914,000. The regional system of storm drains makes up $9,955,000 of the cost, and the localized ponding improvements cost the remaining $2,959,000. The $2,959,000 cost breaks down into $26,000 for local improvements, and $2,930,000 for the Erie and Ivanhoe Drains.

The other alternative to drain the Denver Basin would be to pump the stormwater directly south to the drainage channel as shown above. This option is now feasible since ADOT has moved up the Santan Freeway and drainage channel construction date for the section from Arizona Avenue to Price Road. CDM recommends that the City pursue with ADOT the option of pumping water from the Denver Basin directly south to the freeway drainage channel. This would save approximately $4,900,000 in capital costs, reducing the total cost for the regional system to $8,000,000. Until an agreement is reached with ADOT and final costs are known, the plan to pump water from the Denver Basin to Pecos Road and a gravity storm drain along Pecos Road to ADOT Basin H should be kept.

ES. 4 Areas B and C Evaluations and Recommendations

Concerns

Overall, the on-site drainage and retention systems have functioned well without major concerns. The recently developed west area, north area, and developing south areas of the City have on-site retention basins to collect street runoff, allowing it to infiltrate or percolate in drywells. For City-owned basins with drainage problems, the City installs a new drywell and regrades basins as needed. For City-owned drywells, a drywell maintenance program has been started to increase effectiveness.

However, several locations within Areas B and C have been identified with localized ponding concerns. They include intersections that floods during significant storm events due to undersized on-site retention, locations adjacent to vacant lots where no on-site retention is provided, and a location in south Chandler (Alma School Road/Ocotillo Road) where a lake overflows after significant storm events.

Previous Recommendations

West Chandler

The 1992 Master Plan Update recommended connecting existing on-site basins to new regional retention basins, with outfalls to the Santan freeway drainage system, once this freeway is constructed. The plan was estimated to cost $34,800,000 in 1992, including costs to developers for land and storm drain systems.

CMX Engineers completed a study of a localized ponding concern near 56th Street and Chandler Boulevard. The study recommended expanding local basins to reduce runoff and constructing additional retention basins.

North Chandler

The 1992 Update recommended continued enforcement of retention of the 100-year, two-hour storm and drainage of basins within 36 hours. Improvement of construction and maintenance practices by establishing a regular inspection schedule, with cleaning as required, was also recommended. Local ponding concerns were identified and solutions recommended.

South Chandler

The 1992 Update recommended keeping runoff dispersed in South Chandler by requiring on-site retention of the 100-year, 2-hour storm and seeking an agreement with GRIC to allow discharge onto reservation land. If an agreement had been reached, a drain system with detention was recommended.

Current Status

Localized ponding concerns in Area B previously identified were reduced by the City's construction of new on-site retention basins and storm drain connections to existing basins. Other areas were developed with on-site retention that reduced ponding concerns.

West Chandler

Most of West Chandler has been developed with on-site retention for the 100-year, 2-hour storm and disposal of stormwater by percolation in basins and/or drywells. The freeway drainage system is being designed; the section from the Price Freeway to 56th Street is scheduled for completion in September 2000.

The City modified the Crafco Basin near 56th Street and Chandler Boulevard to capture more runoff from 56th Street and reduce the ponding concern. Additional retention volume is required to eliminate the concern. An outfall or adequate drywells and retention basins are also required to drain the area within 36 hours.

North Chandler

Infill development is occurring and the City requires retention and percolation of the runoff from the 100-year, 2-hour storm. The Price Drain is being constructed north of Knox Road and is scheduled for completion in the next few months.

South Chandler

Development is continuing south of Pecos Road. Retention of runoff from the 100-year, 2-hour storm and percolation disposal is required for each development.

Alternatives Evaluated

Localized Ponding

West Chandler

The CMX report was reviewed and alternatives were evaluated for the ponding concern near 56th Street and Chandler Boulevard. The ponding is caused by undersized basins, inlets with flat slopes, and street runoff not retained on-site. Additional storage capacity with infiltration discharge or an outfall is required. Alternatives evaluated are listed below:

Table ES-5
Options for Eliminating 56th Street/Chandler Boulevard Ponding Concern

Concern	***Solution***	***Cost Estimate***
56th Street and Chandler Boulevard Ponding after significant Storm Events	Obtain permission from Universal Forest Products concerning resloping their drive & parking to retain stormwater; complete resloping.*	$15,000
	Obtain permission from the owner of private basin near Galveston Street and 56th Street concerning increasing its size and capacity; complete improvements.*	$43,000
	Modify the Basha's warehouse retention basin located south of Chandler Blvd. and install a drain along 56th Street	Not feasible: No outlet to drain within 36 hours
	Construct basins on the corner properties on the south side of Chandler Blvd. at 56th Street	Not feasible: Property alone costs >$300,000 ($7-8 per square foot)
	Modify the Crafco Basin to provide more capacity	Not feasible: Property owners do not want to sell more land to the City, no outlet.
	Construct a basin on vacant property on the west side of the railroad tracks	Not feasible: High property costs and gas line.
	Install catch basins and inlets and 3/4 mile of 18-inch diameter storm drain south to the future Santan Freeway drainage channel.*	$278,000
	Install catch basins and inlets and 3/4 mile of 18-inch diameter storm drain west to the Interstate 10 drainage system.	$298,000

*recommended

North and South Chandler

Localized ponding concerns in North and South Chandler were identified. Options identified to reduce or eliminate them are listed below.

Table ES-6
Evaluation of Other Localized Ponding Concerns in Areas B and C

Concern	Solution	Estimated Cost
North Chandler		
McClintock Road: Ponding from Galveston Street to Monterey Street	Install a temporary basin*	$12,000
	Provide on-site retention when the parcel develops	Developer Cost
Cooper Road: Chandler Blvd. to Ray Road	Improve road*	Street Funding
Oregon Street: Palomino Street to Nopal Street	Install scupper into basin on west side of Oregon Street	$6,000
Temporary Basin at Dobson Road and Elliot Road	Deepen temporary basin*	$1,000
	Provide On-site retention when the parcel develops	Developer Cost
Basins not draining in 36 hours or Overtopping after significant storms		
■ White Glove Car Wash Warner Road	Install seven new drywells in basins*	$42,000
■ Warner Road, in front of K Ball		
■ N. Warner Rd. and Comanche St.		
■ S.E. corner of Warner and Alma School		
■ E. Oregon Street: Palomino Street to Nopal Street		
■ Pleasant Drive: Knox Road to Pleasant Drive		
■ Pleasant Drive: Pleasant Lane to Orchid Lane		

Table ES-6 Evaluation of Other Localized Ponding Concerns in Areas B and C		
Concern	**Solution**	**Estimated Cost**
South Chandler		
West Alma School Road/Ocotillo Road Lake overflows to road after significant storms	Install overflow retention basin*	$144,000
Basha's Road/Ocotillo Road Ponding Concern after significant storms	Add a temporary basin*	$12,000
	Provide on-site retention when the property develops	Developer Cost
Willis Road/Alma School Road Ponding Concern after significant storms	Deepen the temporary basin near the intersection;*	$1,000
	provide on-site retention when parcels develop	Developer Cost

*recommended

Regional Drainage

In North, West, and South Chandler, on-site retention and percolation or infiltration discharge have been required for developments as they were constructed. Alternatives evaluated for these areas were no action and regional basins with outfalls.

Recommended Plan for Areas B and C

CDM recommends that the City continue requiring new development in Areas B and C to provide on-site retention of the 100-year, 2-hour storm runoff. Design criteria must be strictly followed. The drywell and retention basin maintenance program should be continued to enhance the system's effectiveness. Percolation-only retention basins must drain within the recommended time. Slow draining basins must have drywells installed, be regraded, or expanded to meet City requirements. Regional retention basins and outfalls are not necessary since there have been no reported problems with on-site retention and percolation.

To reduce ponding concerns, miscellaneous projects to reduce ponding are recommended. They include expanding basins, installing drywells and temporary basins, and a storm drain. The Table below lists the recommended improvements. The cost for West Chandler is $336,000. The cost for north Chandler is $61,000. The cost for South Chandler is $157,000. The total cost is $554,000.

Table ES-7 Areas B and C Ponding Concerns and Recommended Solutions		
Area B West Chandler		
Concern	**Solution**	**Cost Estimate**
56th Street and Chandler Boulevard Ponding after significant Storm Events	Obtain permission from Universal Forest Products and reslope their drive & parking area.	$15,000
	Obtain permission from the owner of private basin near Galveston Street and 56th Street and increase its size and capacity.	$43,000
	Install catch basins and inlets and 3/4 mile of storm drain south to the future Santan Freeway drainage channel.	$278,000
	Subtotal	$336,000
Area B North Chandler		
Concern	**Solution**	**Cost Estimate**
McClintock Road: Ponding from Galveston Street to Monterey Street	Install a temporary basin; provide on-site retention when the parcel develops	$12,000
Cooper Road: Chandler Blvd. to Ray Road	Improve road	Street Funding
Oregon Street: Palomino Street to Nopal Street	Install scupper into basin on west side of Oregon Street	$6,000
Temporary Basin at Dobson Road and Elliot Road	Deepen temporary basin; provide On-site retention when the parcel develops	$1,000
Basins overtop or do not drain within 36 hours	Install seven new drywells in basins	$42,000
	Subtotal	$61,000
Area C South Chandler		
Concern	**Solution**	**Cost Estimate**
West Alma School Road/Ocotillo Road Lake overflows to roadafter significant storms	Install overflow retention basin	$144,000
Basha's Road/Ocotillo Road Ponding Concern after significant storms	Add a temporary basin; provide on-site retention when it the property develops.	$12,000
Willis Road/Alma School Road Ponding Concern after significant storms	Deepen the temporary basin near the intersection; provide on-site retention when parcels develop	$1,000
	Subtotal	$157,000

ES. 5 Ponding and Runoff From Outside Chandler

Concern

Several studies by the FCDMC and others have predicted overtopping of railroad and canal berms during 100-year, 24-hour storm events under current and future conditions as a result of sheet flows from outside Chandler. Areas affected are located in the southeast portions of the City, near the Consolidated and Eastern Canals, where development is starting to occur.

Previous Recommendations

This potential overtopping has not been addressed in previous stormwater master plans for Chandler.

Alternative Evaluation

Because this is a regional concern, FCDMC and the upstream communities of Mesa and Gilbert should be involved in developing regional solutions. The FCDMC is studying the area and developing a plan to address flooding issues under the Higley Area Drainage Master Plan. Possible improvements to discuss with the upstream communities and the FCDMC include:

- Request that FCDMC construct a drainage channel along the eastern side of the Eastern and Consolidated Canals and adjacent railroad tracks that will drain ponded water south to the East Maricopa Floodway or a new drainageway onto GRIC.
- Request that FCDMC construct a series of retention basins along the canals and railroad to provide percolation and recharge of stormwater. This area could also be developed for multi-recreation use.
- Study options to redesign or design drainage system on roads affected that will pass the water through the community.
- Improve on-site retention in upstream communities to prevent runoff from reaching Chandler.

Recommended Plan

CDM recommends that the City take the following measures to address predicted overtopping of canals in southeast Chandler:

- Coordinate with FCDMC, Mesa, and Gilbert to develop regional solutions to stormwater flows from outside the City.
- Attend project meetings and provide input to the FCDMC during the development of the Higley Area Drainage Master Plan.
- Continue requiring final floor elevations to be 14 inches above low outfall elevations.

- Continue requiring developers to address off-site flows in drainage reports.
- Restrict building in floodplains and areas predicted to flood.

ES. 6 Federal Stormwater Regulations

Concern

The City will be required by the EPA to apply for a stormwater Phase II National Pollutant Discharge and Elimination System (NPDES) permit for the municipal separate stormwater system based on a review of the proposed Environmental Protection Agency (EPA) rules published in January 1998. The City discharges stormwater from the downtown area to the Salt River Project irrigation canals that drain to the Gila Drain and Gila River, a water of the U.S. In the future, the downtown area will discharge to the Price Freeway and Santan Freeway drainage system that will drain into a treatment cell and also discharge to the Gila Floodway and Gila River. On-site retention in other areas prevents runoff from discharging to waters of the U.S.

City-owned industrial-type facilities such as vehicle yards and filling stations will be required to apply for Phase II permits or, if stormwater runoff does not come into contact with materials or facilities, a "no exposure" exemption.

For the municipal separate storm drain system, the City will be required to implement programs that address six minimum control measures to reduce stormwater pollution as part of the permitting process, unless the programs already exist. The six measures include:

- Public Education and Outreach
- Public Involvement/Participation
- Illicit Discharge Detection and Elimination
- Construction Site Stormwater Runoff Control
- Post-Construction Stormwater Management
- Pollution Prevention/Good Housekeeping

For each measure, the City must implement a minimum program, as described above, and set quantifiable goals. Additional recommended programs will likely be negotiated with the EPA during the permitting process.

Previous Recommendations

The proposed Phase II rules were not published until 1998. The 1992 Master Plan update discussed the requirements of the Phase I rules, which cover municipalities with populations more than 100,000 by the 1990 Census. The final Phase II rules are expected to focus on best management practices and programs.

Recommendations

The following items will meet the EPA requirements for a minimum pollution prevention program:

- Public Education and Outreach: Set up a Stormwater Pollution Prevention program to create and mail fliers, water bill inserts, and document the program.

- Public Involvement/Participation: Continue public notices and public information meetings, City bond committee review of projects, and document programs.

- Illicit Discharge Detection and Elimination: Continue City household hazardous waste collection, City oil recycling program, spill response by fire department. Adopt an ordinance against illicit discharges, map areas likely to have problems, set up a public reporting process, inspect and enforce ordinance, and document program.

- Construction Site Stormwater Runoff Control: Continue plan review for erosion control as is currently done. Adopt an ordinance requiring construction site BMPs, inspect and enforce BMPs for construction sites, set up a public reporting process, and document the program.

- Post-Construction Stormwater Management: Continue requiring on-site retention, prevention of flood damage, drainage design standards. Inspect stormwater facilities, require certified as-built plans, and document the program.

- Pollution Prevention/Good Housekeeping: Continue City recycling program, maintaining streets and storm drain systems, use certified pesticide appliers, keep chemicals stored in containment structures, train employees, and document programs.

The estimated cost for the minimum programs is $192,000 in capital costs and $149,000 in labor costs or a total of $341,000 initial costs. After implementation, the annual maintenance cost is estimated to be $305,000 for salaries and running programs.

CDM recommends that the City take the steps required to prevent stormwater runoff from contact with equipment and facilities at City-owned industrial-type locations in the downtown area. These steps include installing storm-resistant shelters and providing on-site retention. The estimated cost for review of the facilities and improvements totals $31,600 (included in the $341,000 listed above). This cost includes $6,600 for labor to review the sites and apply for the exemptions and $25,000 for capital costs. To apply for a NPDES permit for the landfill and develop a Stormwater Pollution Prevention Plan (SWPPP) to comply with Phase II, an additional $25,000-35,000 is required.

In addition to planning programs, setting goals, and applying for a permit for the City's stormwater system, it is recommended that the City complete the following tasks:

- Contact ADEQ to request the latest information on the Total Maximum Daily Loads (TMDLs) planned for the Gila and Salt Rivers. Review the information and provide feedback to the agency.

- Update the Stormwater Master Plan as needed to address changing issues and growth in the City.

The final EPA stormwater rules applicable to Chandler are expected October 29, 1999 and should stipulate that Chandler must submit a municipal permit application by May 31, 2002. The programs should be implemented within five years. Specific program development tasks and schedule are shown in Table ES-2.

Table ES-8 *NPDES Program Development, Tasks, and Schedule*	
Program Development Task	***Date***
Review final Phase II Rules	November 1999 - January 2000
Advertise and negotiate contract	January - July 2001
Review EPA General Permit	August 2001 - April 2002
Permit Application and Background Report	August 2001 - April 2002
Submit application	May 31, 2002
Complete permit negotiations	May 2003
Implementation	March 2007

Over the first five years, program implementation will follow the schedule outlined in the permit application. Following implementation, the City will incur costs to maintain the program and renew the permit every five years.

ES. 7 Recommended Stormwater Plan and Estimated Costs

The recommended stormwater management infrastructure system in Chandler is on-site retention basins sized for the 100-year, 2-hour storm with drainage by percolation within 36 hours after the storm ends. The downtown area of Chandler will be served by new and existing City storm drain systems and four regional basins. To drain the regional basins within 36 hours, pump stations will discharge to the future ADOT freeway drainage systems.

The following table lists the projects, a summary of items required, and estimated costs.

Table ES-9 *Recommended Projects and Costs (1998 Dollars)*				
Description	***Item***	***Unit***	***Quantity***	***Total Cost***
Ivanhoe Drain - Phase I	24-42-inch Pipe	lf	1,530	$300,000
Ivanhoe Drain - Phase II	24-42-inch Pipe	lf	1,020	$152,000
Ivanhoe Drain - Phase III	24-36-inch Pipe	lf	3,700	$509,000
Erie Drain - Phase I	18-54-inch Pipe	lf	4,750	$871,000
Erie Drain - Phase II	24-30-inch Pipe	lf	2,450	$337,000
Erie Drain - Phase III	60-inch Pipe	lf	2,600	$764,000
Galveston Basin Discharge Pipe	33-inch Pipe	lf	2,190	$340,000

Table ES-9 Recommended Projects and Costs (1998 Dollars)				
Description	***Item***	***Unit***	***Quantity***	***Total Cost***
Arrowhead Basin Pump Station	Pumps Wetwell Piping and Valves Electrical/Instrum Standby Power	ls	1	$917,000
Arrowhead Basin to Basin G Force main	36-inch Pipe	lf	11,300	$1,958,000
Denver Basin Pump Station	Pumps Wetwell Piping and Valves Electrical/Instrum Standby Power	ls	1	$828,000
Denver Basin force main to Pecos Road and Pecos Road Drain to Basin H	36-54-inch Pipe	lf	26,000	$5,912,000
56th St./Chandler Blvd. Catch basins, inlets, and storm drain to Santan Freeway Drainage Channel	Basin Modifications Driveway Mods 18-inch Pipe	lf	2,800	$336,000
Miscellaneous Ponding Concern Improvements			Area A Area B Area C	$26,000 $61,000 $157,000
NPDES Stormwater Pollution Prevention Program				$341,000
TOTAL ESTIMATED COST (including NPDES costs)				***$13,800,000***

If a force main from Denver Basin to the Santan Freeway drainage channel is constructed, the cost would be $1,037,000 instead of $5,912,000 to discharge to Basin H (Denver Basin pump station and pipes to Basin H). The total cost for all projects would then be $8,900,000, a savings of $4,900,000. It is recommended that Chandler pursue the feasibility of connecting the Denver Basin to the Santan Freeway with ADOT.

This 1998 updated plan reduced the cost for facilities from the 1992 Stormwater Management Master Plan by $4,500,000 as shown in Table ES-5. If the Denver Basin is pumped directly south to the freeway drainage channel, the cost will be reduced by $4,900,000 for a total of $9,400,000. The recommendation to require only on-site retention and percolation in West Chandler reduced the cost by $34,800,000.

Table ES-10 Cost Savings			
1992 SWMP Update		**1998 SWMP Update**	
Items Recommended	***Estimated Cost***	***Items Recommended***	***Estimated Cost***
30- to 72-inch Storm Drains Pump Station Improvements at Denver, Galveston, and Arrowhead Basins, force mains and Pecos Road Drain	$17,400,000 (1998 Costs)	Ivanhoe, Erie Drains, Pump Stations at Galveston, Arrowhead, and Denver Basins, force mains, and Pecos Road Drain	$12,900,000 (1998 Costs)
		If Denver Basin is pumped directly south to the Santan Freeway drainage channel	$8,000,000 (1998 Costs)
West Chandler 18- to 72-inch Storm Drains, Retention Basins	$34,800,000 (1992 Costs)	On-site Retention and Percolation	Developer pays for construction

ES. 8 Operation and Maintenance Costs

In addition to capital costs to install storm drains, force mains, and pump stations, the City will have operational costs to clean and maintain the systems. In 1998, the estimated operation and maintenance costs were $247,000, excluding landscape maintenance. Retention basin landscaping maintenance is included with each mile of street landscaping maintenance in most areas of the City. The following table (Table ES-6) summarizes the estimated future operational costs at a total of $475,000, an increase of $228,000 in annual costs. This additional amount is expected to be reached by 2004. NPDES program maintenance costs were estimated to be an additional $305,000, bringing the total annual cost to $780,000, an increase of $533,000.

Table ES-11
Future Estimated Annual Stormwater Operation and Maintenance Costs (in 1998 Costs)

Description	Unit	Unit Cost	Quantity	Total Cost
Street Sweeping	mile curb	$1,065	95	$101,000
Pipeline, Inlet, and Basin Inlet Inspection/Maintenance (three Full-time employees)				$130,000
Pump Station Maintenance/ Repairs (2 - 35 cfs pump stations): Pull pumps, inspect, maintain, repair				$ 5,000
Pump Operating Costs (Power)				$ 140,000
Drywell Maintenance	each	$500	40/year	$20,000

Table ES-11 Future Estimated Annual Stormwater Operation and Maintenance Costs (in 1998 Costs)				
Description	**Unit**	**Unit Cost**	**Quantity**	**Total Cost**
Subtotal				$ 396,000
Contingencies (20%)				$ 79,200
Total Estimated Annual Costs for infrastructure				$ 475,000
Estimated NPDES Program Maintenance				$305,000
Total Estimated Annual Costs				***$780,000***

ES. 9 Implementation Plan

Tables ES-7, ES-8, ES-9 summarize capital projects, NPDES program costs, and operational costs by year of implementation. Projects are spread across the next six years for implementation. Erie Drain, Phase III, precedes Erie Drain, Phase II, because the connection of the Erie Drain from Alma School Road to the Arrowhead Basin should be completed before connecting additional pipe to the Erie drain. The Galveston Basin is not sized to handle all the runoff from the 100-year, 2-hour storm through the entire Erie Drain.

ES. 10 Financing Options

Concern

Increasing costs for maintaining new infrastructure and implementing the NPDES program will raise the annual cost from $247,000 in 1998 to an estimated $780,000 per year by 2004, an increase of $533,000. Annual capital costs are expected to range from $898,000 to $4.34 million over the next five years.

Previous Recommendations

The 1992 Update listed a variety of methods to obtain funding for capital and annual expenses. These funding sources could be used alone or in combination. They included:

- Federal Loans/Grants
- State and County Cost Sharing
- Bonds: Assessment, Revenue, and General Obligation
- Nonprofit corporations
- Reserve Funds
- Taxation
- Developer Fees
- User Fees
- Redevelopment
- Privatization

Current Status

The City currently finances stormwater capital projects through sewer revenue bonds and most annual operation and maintenance costs through the City's general fund. With the decrease in Highway and Urban Funds (HURF) monies, more of the City's street program will be funded from the general fund.

Alternative Evaluation

Financing options available to the City include using the sewer fees and general fund (existing funding program), increasing the sewer fee, and adding a stormwater utility. By increasing the monthly residential sewer service charge by $1 to $2 per month, the sewer fund could generate $500,000 to $1,000,000 per year. A stormwater utility could also generate similar annual income.

Recommendation

Capital project funding from the sewer and general obligation revenue bonds are authorized at $16,700,000 which is sufficient to carry out the proposed improvements. The alternative force main to drain the Denver Basin should be negotiated with ADOT. This alternative would save the City at least $4,900,000. Also, the City will be pursuing funding from FCDMC for projects of regional significance. To fund the rising annual operation and maintenance programs for the new infrastructure and NPDES program, CDM recommends that either the sewer fee be increased or a stormwater utility be implemented.

Table ES-12
Phasing of Capital Projects
(1998 Dollars)

Project	***1998-99***	***1999-2000***	***2000-01***	***2001-02***	***2002-03***	***2003-04***
Ivanhoe Drain Phase I	$300,000					
Ivanhoe Drain Phase II	$152,000					
Ivanhoe Drain Phase III				$509,000		
Erie Drain Phase I	$871,000					
Erie Drain Phase II				$337,000		
Erie Drain Phase III			$764,000			
Galveston Basin Discharge Pipe			$340,000			
Arrowhead Basin Pump Station		$917,000				
Arrowhead Basin to Basin G Force main		$1,958,000				
Denver Basin Pump Station					$828,000	
Hartford Force main and Pecos Road Drain					$2,912,000	$3,000,000
Area A Ponding Improvements		$26,000				
56th St/Chandler Blvd Storm Drain					$336,000	
Ponding Concerns in Area B		$61,000				
Ponding Problems in Area C					$157,000	
NPDES Program Development			$40,000	$52,000		
NPDES Program Implementation					$100,000	$59,000
NPDES Industrial-type Facilities					$6,000	$26,000
Involvement in TMDL Process				$2,000	$2,000	$2,000
Update Stormwater Management Plan						$50,000
Total Capital/Initial Costs	***$1,323,000***	***$2,962,000***	***$1,144,000***	***$900,000***	***$4,341,000***	***$3,137,000***

Table ES-13 *Phasing of Operational Annual Cost* *(1998 Dollars)*							
Project	***1998-99***	***1999-2000***	***2000-01***	***2001-02***	***2002-03***	***2003-04***	***2004-05***
Infrastructure Operation and Maintenance Cost	$247,000	$285,000	$323,000	$361,000	$399,000	$437,000	$475,000
NPDES Maintenance Cost					$500	$27,000	$305,000
Total Operation and Maintenance Cost	***$247,000***	***$285,000***	***$323,000***	***$361,000***	***$400,000***	***$464,000***	***$780,000***

Table ES-14 *Summary of Total Phased Cost* *(1998 Dollars)*							
Project	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05
Capital/Initial	$1,323,000	$2,962,000	$1,144,000	$900,000	$4,341,000	$3,137,000	$2,000
Annual	$247,000	$285,000	$323,000	$361,000	$400,000	$464,000	$780,000
Total Phased Cost	***$1,570,000***	***$3,247,000***	***$1,467,000***	***$1,261,000***	***$4,741,000***	***$3,601,000***	***$782,000***

Galveston Basin

Section 1
Introduction

Section 1
Introduction

1.1 Overview

The City of Chandler (City), Arizona, while located in an arid region, does experience occasional significant storms. Rapid urbanization has greatly increased rates of runoff from formerly agricultural and desert lands. The area's extremely flat topography and lack of natural drainageways tends to allow accumulation of runoff after storms. Localized ponding concerns have been common in the older part of the City, which was developed prior to implementation of drainage standards. In 1975, on-site stormwater retention requirements were instituted and have greatly reduced drainage problems in newer developed areas. Major factors affecting stormwater management options for the City have been the flat slope of the terrain, the lack of easily accessible stormwater outfalls for the area, and type of soils for percolation.

In 1986 Camp Dresser & McKee Inc. (CDM) completed the first Stormwater Management Master Plan study for the City. It was undertaken to provide a comprehensive cost-effective approach to stormwater management in the City. The primary goals of this plan included the reduction of existing drainage concerns, and the anticipation and prevention of drainage concerns that might be experienced as the City developed further. The plan was intended to be flexible, implementable in stages, and able to respond to conditions different from those assumed for the purpose of the study.

CDM completed an update to the plan in 1992 to evaluate: the 1986 recommendations not yet implemented; the Arizona Department of Transportation's (ADOT) drainage plans for the future Price and Santan Freeways and possible interfaces with proposed ADOT facilities; the evolving development picture within the City; and emerging National Pollutant Discharge Elimination System (NPDES) stormwater discharge permitting requirements. In addition, appropriate design storm frequencies for storm drainage systems and retention basins and several stormwater models were evaluated.

The City hired CDM in early 1998 to update the Stormwater Management Master Plan. This, the latest update, includes: evaluating the City's design criteria based on the Flood Control District of Maricopa County (FCDMC) standards and City design review procedures; providing a base map of existing stormwater facilities; updating the computer model; evaluating recommended storm facilities; evaluating storm flows from outside the City; evaluating impacts of growth and future permitting requirements; preparing detailed design plans for the downtown area; and updating the Management Master Plan.

1.2 Scope of Work

The following tasks have been completed to update the Stormwater Management Master Plan:

- Current information for freeways, land use, utilities, benchmarks, drainage studies, City design guidelines, problem areas, base map, and design criteria for other cities have been collected.

- Detailed "as-built" information concerning stormwater drains, basins, and pump stations have been added to the City base map and the information has been listed in tabular form.
- The City stormwater drainage design criteria have been reviewed and compared to design criteria for other southwestern communities, ADOT, and FCDMC. Changes have been recommended.
- The City retention/detention basin design standards have been reviewed. Recommendations have been made to update City standards with construction methods, operation and maintenance procedures, and policies for homeowner association operation and maintenance of private basins to satisfy NPDES requirements. Maintenance procedures have been compared with standards for other southwestern cities, ADOT, and FCDMC, and improvements have been recommended.
- The hydrology developed for the 1992 report has been updated with the Flood Control District's revised storm data and latest Chandler General Plan and Land Use Element Plan. Flow concentration points in south Chandler have been calculated at each quarter section.
- Drainage studies for flows from outside the City area have been reviewed. Areas of potential flooding have been identified and the severity predicted. Potential adverse impacts have been assessed and solutions recommended.
- Recommendations for storm drainage improvements have been reviewed and revised, and the best alternatives for the City were proposed. Preliminary cost estimates were developed. After reviewing the recommended alternatives with the City, the final recommendations were selected.
- The existing City of Chandler Stormwater Improvement Financing Program has been reviewed and changes have been recommended.
- A phased implementation plan for short-, medium-, and long-range projects has been developed.

1.3 Approach

In each of the sections of the report where the existing City storm drain systems, ponding concerns, design criteria, and other items are discussed, the following approach is used:

- Concern: Definition of the concern.
- Previous Recommendations: Solutions recommended in previous reports or master plan updates.
- Current Status: How the City has addressed the concern and existing status.

- Alternatives Evaluation: Alternative solutions are listed and compared based on feasibility, cost, and public acceptance.

- Recommended Plan: Solution is recommended and cost is estimated.

Detroit Basin and Street Inlet

Section 2
Background

Section 2
Background

2.1 Project Area

The City encompasses approximately 71-square miles of east Maricopa County in south-central Arizona. The Town of Gilbert borders the City on the northeast, the City of Mesa on the north, the City of Tempe on the northwest, an unincorporated County area on the southeast, the City of Phoenix on the west and the Gila River Indian Community on the south.

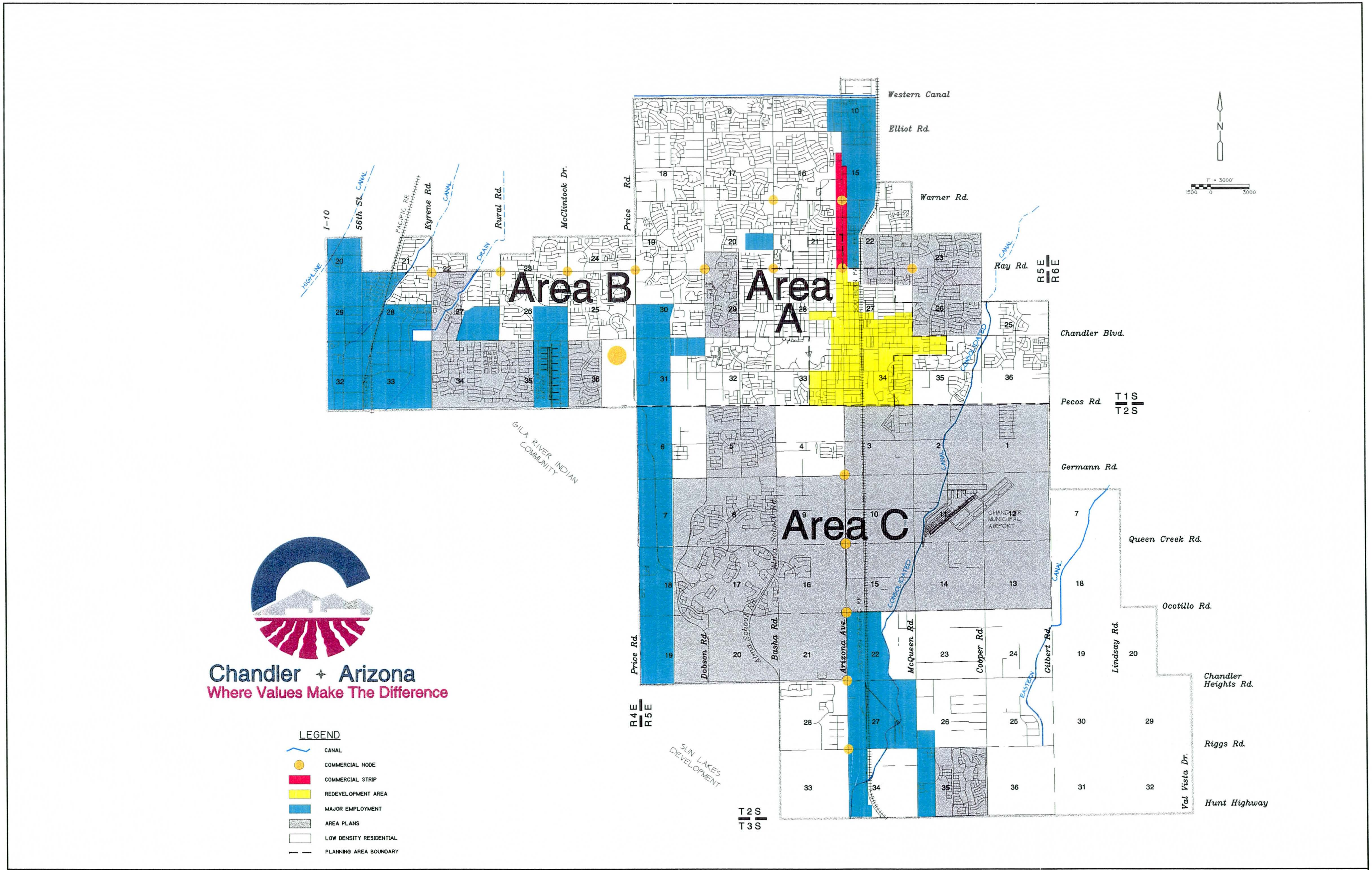
The project area addressed by the Stormwater Management Master Plan update is bounded by Chandler's City limits, as shown on Figure 2-1, and includes unincorporated county areas within the City's strip-annex boundaries. Figure 2-1 also shows the boundaries for three separate planning areas. Study Area A consists of the downtown portion of the City bounded roughly by Ray Road, Arrowhead Drive, Pecos Road, and McQueen Road. Area A was mostly developed before the City required storm design criteria. The north and west portions of the City outside of Area A make up Area B which has been developed since storm design criteria were required or is currently being developed. The area south of Pecos Road is Area C, which is currently vacant or under development.

2.2 Land Use

For a number of years, Chandler was an urban area of approximately 4-square miles surrounded by irrigated farmland. Census records show that Chandler had a population of 13,763 within its limits in 1970. Since the mid-1970's, the rate of growth in Chandler has accelerated rapidly increasing by 115 percent to 29,673 between 1970 and 1980, by 212 percent to 92,484 between 1980 and 1990, and to 168,000 by 1998. By the year 2000, the City's population is expected to reach 176,000. Development has been in industrial, commercial, and residential land use, while agricultural use has declined.

The current Circulation and Land Use Element (CLUE) of the Chandler General Plan was developed in 1990 to guide development in the City and was adopted by the City Council in late 1998. The CLUE projects that industrial and commercial growth will be concentrated in west Chandler along West Chandler Boulevard, in south Chandler along South Price Road, and in north Chandler along North Arizona Avenue. As shown on the Chandler Land Use Element (Figure 2-1) and General Plan (Figure 2-2), regional shopping centers are planned along the west side of Price Road between Chandler and Pecos Roads, at Price and Queen Creek Road, and east of I-10 on Ray Road. Major retail centers are projected along Ray Road and Arizona Avenue. For residential land uses, the General Plan encourages the neighborhood concept, which consists of developing a section of land with mixed residential subdivisions and concentrating commercial land uses at section corners.

The current General Plan anticipates that no land will remain in agricultural use at ultimate development conditions. Revisions to the land use plan were made prior to the 1992 Stormwater Management Plan Update for south Chandler, where runoff is expected to increase several



CDM
environmental engineers, scientists, planners, & management consultants

1998 CHANDLER STORMWATER MASTER PLAN UPDATE
CITY OF CHANDLER LAND USE ELEMENT
FIGURE 2-1

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Chandler Municipal Planning Area General Plan Land Use

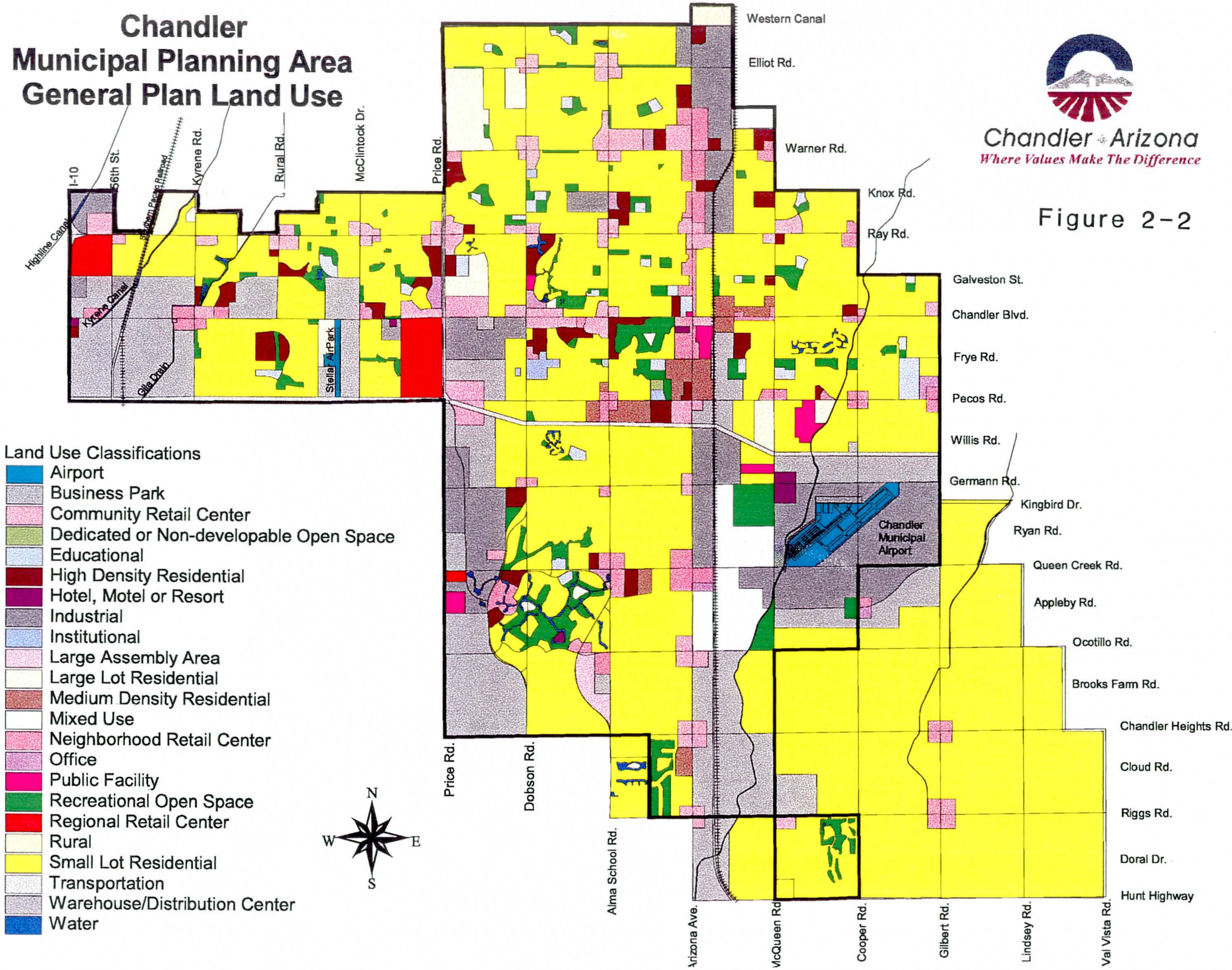


Figure 2-2

hundred percent compared to original runoff estimates from the 1986 Stormwater Management Master Plan. Recent revisions to housing densities in south Chandler did not affect the Stormwater Management Master Plan since on-site retention will continue to be required for all new construction.

2.3 Topography

Chandler is located in the Gila Floodway Drainage Basin which is shown in Figure 2-3. Except for a short piece of the Gila Drain, no water courses run through the City. The only other water course in the basin is Queen Creek which is located east of Chandler. Queen Creek flows west from the Whitlow Ranch Dam to the Roosevelt Water Conservation District (RWCD) Floodway and south to the Gila River.

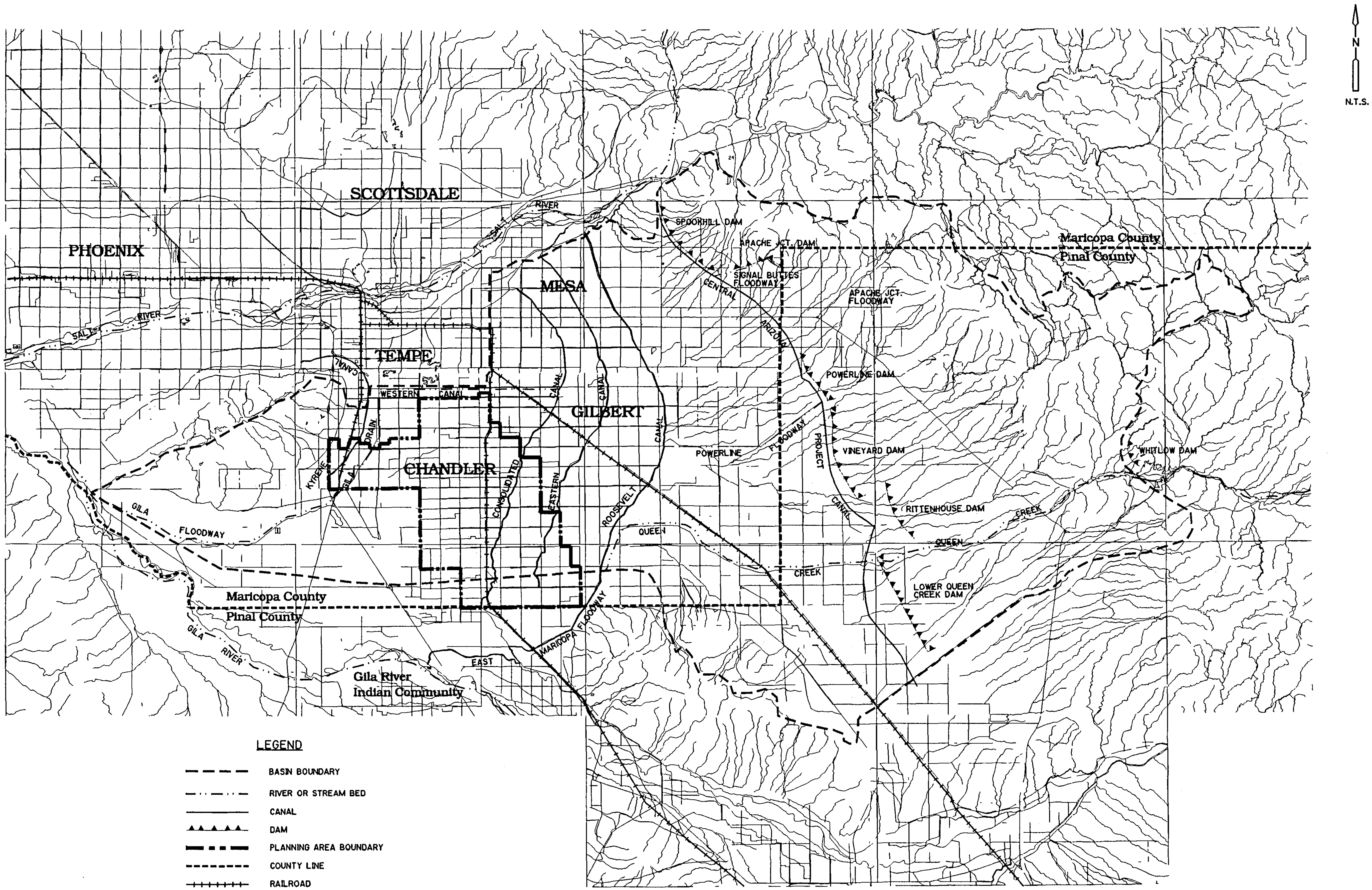
The Gila River waterway is south and west of the City. A natural drainage feature named the Gila Drain flows through west Chandler where the South Mountain slopes on the west meet the alluvial plains on the east. Salt River Project (SRP) improved this natural watercourse and has been using it since the early 1920's as a drainage way flowing south and then west to the Gila River through the Gila River Indian Community. Six miles north of the City the Salt River drains portions of Mesa and Tempe. On the west side of Phoenix, the Salt and Gila Rivers join.

The land surface in the north and west portion of the City slopes moderately to the west toward the Gila River and Gila Drain, except for the area west of the Gila Drain which slopes to the east toward the Gila Drain. The southern part of the City slopes southwest to the Gila River. Slopes vary between one and two feet per thousand and elevation contours run primarily north-south. Prior to development, the area drained by sheet flow west and southwest; however, development in the area has affected natural drainage patterns. Barriers to sheet flow include the SRP canals and irrigation laterals, and the Southern Pacific Railroad (SPRR) which is elevated on an earthen berm. As areas urbanize, stormwater generally flows over City streets with the arterials (section and half-section streets) providing the backbone of the system. Ponding can occur at obstructions to flow and localized low spots. However, the overall flow direction in Chandler is still west-southwest.

2.4 Rainfall

Rain storms that occur in the Chandler area can be either widespread or localized storms. Widespread storms in the area tend to be of a frontal type covering large areas and resulting in the flooding of major water courses. Winter storms occurring from October through May result in light to moderate rainfall which may last several days. Summer storms from June through October are the result of tropical storms originating in the Pacific Ocean south of Mexico. These tend to result in locally heavy rain cells within a larger area of light to moderate rain.

Localized storms are the result of convective activity and are usually referred to as thunderstorms or cloud bursts. They may last up to 6 hours and cover up to 500-square miles. Heavy rain from these storms tend to last less than 60 minutes. Localized storms are most frequent from July through September and often result in short duration flooding for local areas, including flash floods. For areas of 100-square miles or less, local storms are the ones which most often produce local and regional flooding.



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GILA FLOODWAY BASIN
FIGURE 2-3

2.5 Geology

The geology in the Chandler area consists of alluvial (water-borne) sediments deposited by the Salt and Gila Rivers and their tributaries. Surface sediments are fine-grained sands, silts, and clays. In the northern part of the City, sediments were formed by the Salt River as floodplain deposits. In the central part, Queen Creek has been the major contributor of alluvium transported from the east. Sediment deposits in the southern portion of the City contain eolian (wind-borne) sand was most likely transported from the Gila River floodplain to the south. The depth of the Salt River and Queen Creek alluvium throughout the area is estimated to be 300 to 400 feet.

Some aspects of the geology in the Chandler area which can affect stormwater management options include the presence of caliche, the depth to permeable sand and cobbles layer, and the depth to groundwater. Caliche deposits are commonly found in north, central, and west Chandler. Caliche is a calcareous material found in layers in soils of arid and semi-arid regions and is formed when water evaporates from the soil leaving carbonate deposits. This process eventually forms impermeable carbonate layers, generally found in the upper 10 to 25 feet of the soil, which impede water percolation to lower depths.

The depth to a sand and cobbles (river gravel) layer suitable for dry well percolation varies throughout the area, but ranges generally from 70 to 120 feet. The depth to the regional groundwater table ranges from approximately 100 to 130 feet in west Chandler to approximately 140 to 250 feet in south, central, and north Chandler. However, perched groundwater does occur at shallower depths (approximately 50 feet) in some areas. According to a local drilling company (McGucken Drilling), a perched groundwater zone generally extends from I-10 to Cooper Road between Chandler Boulevard and Pecos Road.

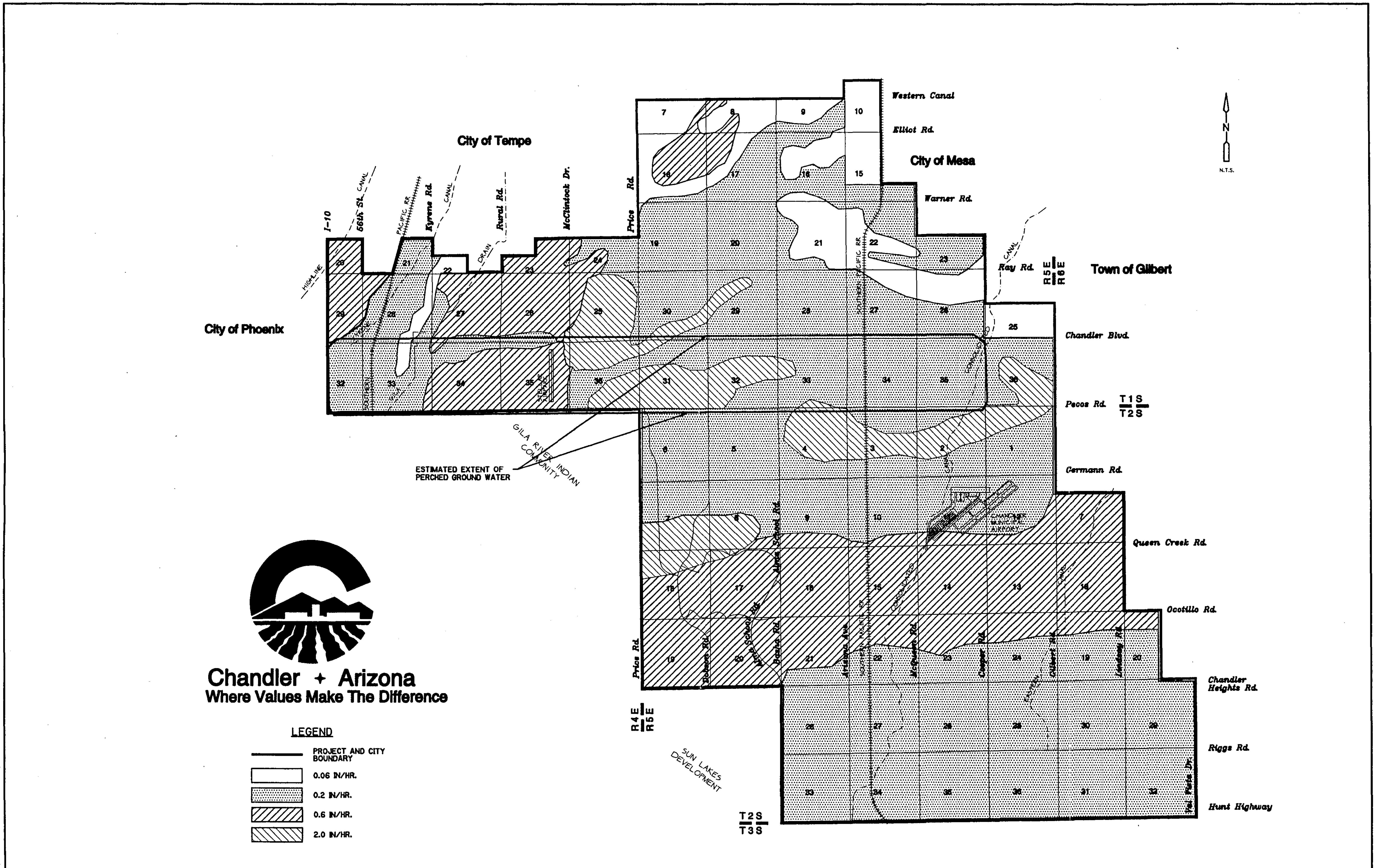
Two studies completed by the Geology Department at Arizona State University evaluated the Chandler area's geology. The studies generally indicated that dry wells could be installed with moderate difficulty and function adequately throughout Chandler. However, the studies cautioned against installing dry wells too close to the groundwater table which would preclude adequate filtering of surface runoff through alluvial sediments to remove pollutants. ADEQ recommends drywells be at least 10 feet above the groundwater elevation. Table 2-1 presents additional information concerning groundwater depth within the City.

Table 2-1 Groundwater Depth City of Chandler	
Location	***Depth (ft.)***
West Chandler (West of Alma School Road) - Alma School/Elliot Road Intersection	110-130 216
North Chandler (North of Ray Road, East of Alma School) - City limits ½ mile east of McQueen Road	160-180 211
East Chandler	170-190
Downtown Chandler	160-175
Southwest Chandler (west of Arizona Avenue)	90-160
Southeast Chandler (east of Arizona Avenue) - Roosevelt Canal, ½ mile north of Queen Creek Road	140-250 257

2.6 Soil Characteristics

The major surface soil types within the project area have been mapped by the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS). Most soils in the central downtown portion of the City are Mohall series consisting of stratified clay loam and loam soils which generally have moderately slow permeability. The north Chandler area is characterized by Mohall-Contine soils consisting of loams, clay loams, and sandy clay on old alluvial fans. The Mohall series soils have moderately slow permeability and the Contine series soils have slow permeability. In west Chandler soils are typically Laveen clay loam, Laveen loam, and Gilman loam soils which are interspersed and generally have moderate permeability. The major soil types found in the portion of the project area south of Pecos Road have been divided into two groups according to permeability. The first group consists of Antho series, Gilman series, and Vint series soils which are the major soil types found in the following vicinities: the area bounded by Alma School, Gilbert, Pecos, and Germann Roads; and the area bounded by Price, Gilbert, Queen Creek, and Ocotillo Roads. These soils are all characterized by moderate to moderately rapid permeability. The second group consists of Mohall series, Valencia series, and Trix series soils which are the major soil types found in the remainder of the area and have moderate to moderately slow permeability.

Soils vary in their potential to generate runoff from rainfall, and permeability is one parameter used to predict possible runoff rates for storm events. Generally, the greater a soil's permeability, the faster stormwater can infiltrate into the soil and the slower the runoff rate. Figure 2-4 shows the pattern of infiltration rates over the Chandler planning area. It also shows the approximate location of the perched groundwater.



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GENERAL PATTERN OF INFILTRATION RATES

FIGURE 2-4

Residential Basin with Drywell and Landscaping

Section 3 Design Criteria

Section 3
Design Criteria

3.1 Existing City Design Standards

Since 1975 design criteria for storm water conveyances and facilities in the City have in large part evolved to match the requirements of the Flood Control District of Maricopa County (FCMCD) and other neighboring communities. Currently the City Development Services Department requires projects within the City to follow the design criteria found in the City's "Technical Design Manual No. 3, Storm Drainage System Design 1987," which included FCDMC policies and standards in effect at that time. The 1987 FCDMC "Uniform Drainage Policies and Standards for Maricopa County, Arizona" was included as an Appendix to the 1987 Technical Design Manual No. 3. The policies included master drainage planning at early project stages, basinwide master drainage planning by the governments involved, avoidance of transferring adverse affects downstream, and minimizing flood damage and inconvenience. Since the 1992 Stormwater Management Master Plan Update, the FCDMC has published the Drainage Design Manual for Maricopa County, Volume I Hydrology and Volume II Hydraulics (last update 1996) to describe county design criteria for runoff predictions and storm drainage systems. It which superseded the 1987 FCDMC policies and Standards.

As part of the Stormwater Management Master Plan Update, the Development Services Department requested CDM to prepare an update to the City's "Technical Design Manual No 3". The revisions to Manual No. 3 are to address these major concerns:

1. To determine which County Standards should be adopted by the City of Chandler and to clearly define City design standards that differs from the FCDMC manual.

2. To update City Policy regarding storm drainage issues and concerns encountered with new development.

3. To incorporate various design standards and criteria that are already being used by plan reviewers at the Development Services Department but which do not appear in the existing manual.

4. To develop standard details for storm water facilities and structures where the City has indicated that MAG or FCDMC details are inadequate.

5. To define standards for testing and maintenance of storm water facilities to address chronic concerns with infiltration at retention basins and dry wells.

Specific issues which impact future storm water facility design include:

Hydrologic Issues

- Compare FCDMC hydrologic requirements to City requirements and recommend new standards if needed.
- Prepare Chandler specific rainfall intensity-depth-frequency (IDF) curves.
- Compare runoff coefficients between Chandler and FCDMC and recommend new standards if needed.

Drainage Conveyance and Facility Design Issues

- Compare Chandler and FCDMC street drainage design criteria.
- Compare Chandler and FCDMC storm drain inlet and pipeline drainage design criteria.
- Compare Chandler and FCDMC lot development grading requirements.
- Compare Chandler and FCDMC retention basin design standards.
- Develop design standards for storm water pump stations.
- Standardize percolation testing requirements for retention basin design.
- Revise retention basin side slope requirements to eliminate slopes steeper than 4:1.
- Develop standards for minimum pipe strength (D-Load) for Rubber Gasketed Reinforced Concrete Pipe (RGRCP).
- Require that FCDMC review and approve developments located within a 100 year flood plain prior to City Development Services Review.
- Develop standard details for:
  - Bubbler box inlets to retention basins
  - Catch basins and headwall hand railings
  - Drywell details (Update Existing detail)

Drainage Facility Operation and Maintenance Issues

- Develop standards for maintaining retention basins and dry wells including silt removal.
- Develop as-built standards and submission requirements for drainage facilities.

3.2 Design Criteria Evaluation

Hydrology - Rainfall Intensity and Depth

Volume I of the FCDMC Drainage Design Manual describes criteria for defining the 100-year, 2-hour rainfall used to size retention basins. Rainfall data used for the manual was taken from the "NOAA Precipitation-Frequency Atlas of the Western United States" except for short duration storms. Isopluvial maps show the rainfall for various frequency storms in the county. For storms of duration less than one hour, the manual used rainfall ratios published by Arkell and Richards (1986). CDM used FCDMC maps and the calculation method shown in the Arizona Department of Transportation's "Highway Drainage Design Manual, Final Report, March 1993" to generate rainfall depth and intensity for storms in the City. The 100-year, 2-hour storm rainfall depth was calculated to be 2.6 inches. The values for different storms and Intensity-Duration-Frequency curves are shown in Appendix A along with calculations. The 2.6 inch depth is a minor increase from the 2.5 inch depth given in existing City Technical Manual #3. The newly calculated 100-year, 2-hour storm depth and IDF curves are to be added to the revised 1998 Technical Design Manual No. 3.

FCDMC Drainage Design Manual Volume 1 also describes the storm distribution for the 2-hour and 6-hour storms and patterns of rainfall which should be used for different sizes of drainage areas. This information is useful for modeling areas larger than 160 acres and for routing peak flows through a drainage system. This information was not previously provided in Technical Design Manual No. 3. This information from the FCDMC Drainage Design Manual was used for modeling the storm drain system in Area A for this Master Plan Update, as discussed in Section 4.

Runoff Coefficients

An important factor of the Rational Method, required to calculate runoff for areas smaller than 160 acres, is the runoff coefficient. Volume I of the FCDMC Drainage Design Manual lists runoff coefficients for different storm frequencies. A comparison of City and FCDMC runoff coefficients is shown in Table 3-1. The FCDMC runoff coefficients differ from the City coefficients in that FCDMC coefficients increase as the frequency of the design storm decreases. The FCDMC runoff coefficients for the 2- to 10-year frequency storms are lower than the City runoff coefficient values. However, the City runoff coefficients fall within the range of the FCDMC runoff coefficients for the 50- and 100-year frequency storms. Given the success that the city has had using their existing coefficients and because the city requires roadway drainage calculations for both 50- and 100-year storms, CDM recommends that the City maintain their current runoff coefficients but add a runoff coefficient for cluster developments. City staff suggests the cluster development runoff coefficient be 0.75.

Table 3-1 *Comparison of Runoff Coefficients for the Rational Method*				
Land Use	**Chandler**	**FCDMC**		
		2-10 year	**50 Year**	**100 Year**
Farmland	0.10	0.10-0.20	0.12-0.24	0.13-0.25
Grass Lawn (slope 0-7%)	0.20	0.10-0.25	0.12-0.30	0.13-0.31
Bare Ground (undeveloped vacant lots)	0.25	0.20-0.30	0.24-.036	0.25-0.38
Grass Lawn (slope >7%)	0.35	0.25-0.40	0.30-0.48	0.31-0.50
Undeveloped Desert	0.50	0.30-0.40	0.36-0.48	0.38-0.50
Playgrounds	0.60	0.40-0.50	0.48-0.60	0.50-0.63
Desert or Rock Landscaping	0.50	Not	Listed	
Impermeable Surfaces (pavement, roofs, etc.)	0.95	0.75-0.85	0.90-0.95	0.94-0.95
Gravel Roadways and Shoulders	Not Listed	0.60-0.70	0.72-0.84	0.75-0.88
Commercial or Industrial	0.90	Not	Listed	
Heavy Industrial Areas	Not Listed	0.70-0.80	0.84-0.95	0.88-0.95
Light Industrial Areas	Not Listed	0.60-0.70	0.72-0.84	0.75-0.88
Downtown Business Areas	Not Listed	0.75-0.85	0.90-0.95	0.94-0.95
Neighborhood Business Areas	Not Listed	0.55-0.65	0.66-0.78	0.69-0.81
Multi-Family	0.80	0.50-0.60	0.60-0.72	0.63-0.75
Apartments	Not Listed	0.60-0.70	0.72-0.84	0.75-0.88
Detached Single Family	0.65	0.45-0.55	0.54-0.66	0.56-0.69
Suburban	Not Listed	0.30-0.40	0.36-0.48	0.38-0.50

Drainage Facility and Conveyance Design Criteria

Volume 2 of the FCDMC Drainage Design Manual describes the street drainage, storm drain, open channel, detention basin, and pump station design criteria. These recommendations were compared to the existing City design criteria.

Street Drainage Criteria

Requirements for street drainage design for the City and FCDMC are shown in Table 3-2. The FCDMC does not require calculating the 50-year storm flow, and the allowable water depth over the curb varies. The City's specific requirements for 50-year storm flows in streets indicates that flow should be limited to the width of the right of way, whereas FCDMC allows the width of a 100-year storm flow to extend to the adjacent building lines. Both of the width limitations require that the designer make assumptions about the actual width available for calculating flows and to reassess the runoff coefficient for flow paths that include areas outside the roadway limit. To simplify flow calculations in a conservative manner it is recommended that flow calculations limit the wetted perimeter to the back of the sidewalk for 50 and 100 year flow calculations. City staff has further recommended that the FCDMC roadway design requirements for the 10- and 100-year storm be adopted but that maximum flow depth above the curb be limited to 6 inches for both the 50- and 100-year storm. An additional exception to the FCDMC criteria is that the City requires finished floor elevations to be at least 14 inches above the development's low outfall elevation.

Table 3-2
Current Design Storm Frequencies and Requirements for Street Drainage

Frequency (Years)	***City of Chandler***	***Flood Control District Maricopa County 1993 Drainage Design Manual***
	Longitudinal Street Flow	
10	No curb overtopping. (For streets with 4 or more lanes, at least one traffic lane must be free of water in each direction.) Manning's Equation for flow capacity	No curb overtopping. Maintain one dry 12 foot driving lane in each direction for collector and arterial streets. Use modified Manning's Equation to calculate gutter flow capacity with reductions for debris and parking. n = 0.015 or 0.016
50	Flow shall be contained in the right-of-way ■ 0.3 feet maximum depth over curb ■ 100 cfs maximum flow ■ 10 fps maximum velocity	N/A
100	Flow to be calculated such that the lowest finished pad elevation is free of inundation. Finished floor elevation will be required to be 14 inches above development low outfall elevation. If located within a FEMA 100-year floodplain, submit plans to FCDMC.	Flow to be calculated assuming contained between buildings with: ■ 100 cfs maximum flow ■ 10 fps maximum velocity ■ 8 inches maximum depth Finished floor elevation 12 inches above 100-year flood level, and retention basin 100-year water level and overflow elevations. Use 100-year runoff for storm drain design if 100-year storm runoff is higher than the 10-year storm runoff.

Table 3-2 Current Design Storm Frequencies and Requirements for Street Drainage		
Frequency (Years)	**City of Chandler**	**Flood Control District Maricopa County 1993 Drainage Design Manual**
Longitudinal Street Flow		
Cross Street Flow		
50	No flow shall cross the street.	N/A
100	Maximum Depth 0.5 feet at the street crown or in the valley gutter crossing the street.	N/A

Storm Drain Systems and Inlet Sizing

Due to the cost and size of storm drains sized to convey the runoff from a 10-year, 6-hour storm at the minimum slopes existing in the downtown areas of the City, the 1992 Storm water Management Master Plan Update recommended using the 2-year, 6-hour storm runoff to size storm drains in Area A. The existing City criteria requires using the 10-year, 6-hour design storm for sizing scuppers, catch basins, and pipe. The FCDMC requires storm drains to be sized for the 10-year, 6-hour storm flow or 100-year flow, whichever is larger. The existing City criteria does not address situations where the storm drain pipe is the principal storm water conveyance from a development to a retention basin. It is desirable for the pipe to be sized for the 100-year storm flow to prevent flooding from being transferred from one development to another. To resolve this concern it is recommended that the FCDMC design criteria for storm drain pipe be adopted with the exception that the Area A design storm remain as the 2-year, 6-hour storm.

Existing design criteria for storm drains are compared in Table 3-3.

Table 3-3 Storm Drain Design Comparison	
City of Chandler	**Flood Control District Maricopa County 1993 Drainage Design Manual**
Inlets: Use weir equation for capacity and clogging reduction factor.	**Inlets:** Use weir or orifice equation and clogging reduction factor.
Pipes: RGRCP Only Capacity for the 10-year, 6-hour storm flow except in the downtown area where the 2-year, 6-hour storm flow applies Manning's Equation to calculate capacity Thompson Equation to calculate junction losses.	**Pipes:** Capacity for the 10-year, 6-hour or 100-year storm, whichever is greater. 2 fps minimum pipe velocity. 0.001 minimum slope Hydraulic grade line no higher than 6 inches below inlet. Minimum sizes 15-inch diameter for laterals, 24-inch diameter for main drain pipes. Manning's Equation to calculate capacity, n = 0.011 to 0.015 for concrete pipe.

A few minor modifications to the FCDMC Manuals have been requested by the City. The City requires the Weir Equation for calculating capacities of inlets along roadways whereas the FCDMC Drainage Design Manual also allows the Orifice Equation.

The City further requires drain pipe to be rubber gasketed reinforced concrete pipe (RGRCP) while the FCDMC manual does not specify the pipe material, but refers to the local requirements. The Development Services Department intends to keep the RGRCP only requirement until such time as an engineering evaluation can be performed on alternate materials.

Open Channel Design Criteria

In addition to storm drain design criteria, the FCDMC Drainage Design Manual describes design criteria for open channels including linings, maximum velocities, natural channels, roughness, and backwater calculations. Design criteria for hydraulic structures such as channel drops, conduit outlets, and stilling basins are also discussed. Because the City does not have any natural drainage channels, and new storm drains tend to be pipes under roadways, no design criteria has been listed for open channels and hydraulic structures by the City. CDM recommends the City adopt the FCDMC design criteria for open channels, drops, stilling basins, etc.

Lot and Development Grading

The City Development Services Department is already requiring that building finished floor elevations (FFE) be 14 inches above the lowest outfall elevation of the development.
The department plans to add this requirement to the 1999 Updated Technical Design Manual No. 3. Additionally if the development is within the FEMA 100-year flood area, the developer is required to submit plans to the FCDMC, which requires that the FFE be 12-inches above the 100-year flood elevation. The building must not be flooded by the 100-year storm. The FCDMC also requires the FFE to be 12-inches above the water surface elevation and emergency outfall elevations of any nearby retention basin. The City and FCDMC standards are similar for keeping building FFEs above the 100-year flood level, therefore, no changes are recommended. The City requirements will to be added to Technical Manual #3.

The City requires lot grading to provide a slope which prevents ponding on a development or a site. The FCDMC does not have lot grading requirements, but requires drainage master planning.

The City requires that existing irrigation ditches be abandoned or piped when a new development is built across or around them. The FCDMC does not have requirements for canals, but does not allow irrigation canals to be used for storm drainage. The FCDMC does require developers to maintain the same drainageway entrance and exit points at the edges of a development as existed prior to development. CDM recommends the City adopt the FCDMC requirement.

Retention Basin Design Standards

The City and the FCDMC require that retention basins be sized to store the 100-year, 2-hour storm runoff, however, the City requires an additional 10 percent volume to account for losses due to sedimentation, sloughing of side slopes, and weed growth. The FCDMC does not recommend that off-site flows be routed to a retention basin. The City requires that the developer discuss how the off-site flows will be handled in the Drainage Design Report and it is the responsibility of the design engineer to pass it through or store it.

Basin Design Criteria

For safety reasons, both the City and the FCDMC limit the maximum water depth in any basin to 3 feet for the volume of runoff from a 100-year, 2-hour storm with some exceptions granted for older existing basins. The FCDMC requires a minimum of 1-foot of freeboard above the 3-foot water depth and it is recommended that the City add this requirement to its updated design manual. The 1-foot of freeboard above the required volume, including the extra 10 percent, will provide a safety factor to better handle back-to-back storms or the gradual decrease in capacity over time due to sedimentation. Additional freeboard, if added for aesthetic or recreational reasons, also offers a greater factor of safety. The City also requires that the maximum water surface in the basin for the design storm be below the minimum street pavement elevation at basin inlets to ensure that storm water does not pond in streets at inlets. The City also requires retention basins used for recreation to have the playing fields above the 10-year storm ponding elevation. A typical cross section for a multi-use retention basin is shown in Figure 3-1. Nuisance flow channels are recommended for low flows to direct them to the low flow channel. For bubbler box inlets, it is recommended that the City require a catch basin upstream of the inlet to prevent sediment buildup in the bubbler box and allow easier maintenance. The City requires that a minimum of 6-inches and a maximum of 12-inches be left between the bottom of the basin and the invert of basin discharge pipes or the bottom of scuppers to allow for build-up of debris and sediment over time in sediment traps. The FCDMC requires outlet pipes to be at least 12-inches in diameter and should have trash racks. The City requires that a riprap or concrete apron be installed to prevent erosion at pipes and scuppers.

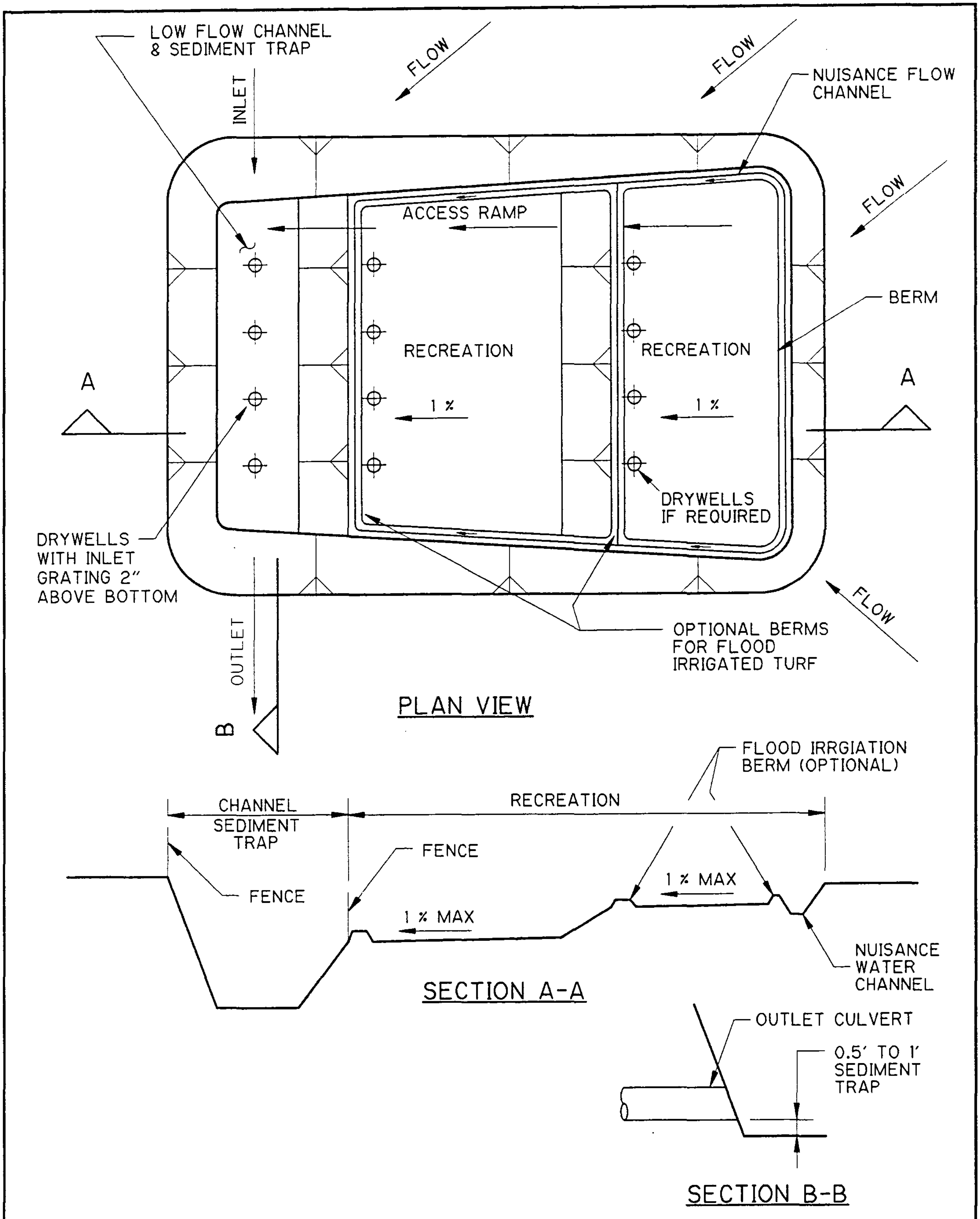
To reduce side slope erosion and deposition of sediments in retention basins the City requires the maximum side slopes to be 4 horizontal to 1 vertical however existing Technical Manual #3 allows steeper slopes that vary according to the depth of the basin. The FCDMC allows rock, riprap, or shrub landscaped slopes up to a maximum slope of 3:1 and 4:1 for grass slopes or basins adjacent to rights-of-way. CDM recommends that the revisions to Technical Manual #3 require 4:1 maximum side slopes. To further prevent side slope erosion, drainage of rain falling on the top of the basin should be directed away from the basin or to protected channels into the basin.

Regarding the shape of retention basins, the FCDMC recommends curvilinear, irregularly shaped basins to provide a more natural look. FCDMC further recommends provisions for a low flow channel to direct nuisance flows to the lowest point or outlet for the basin. CDM recommends adoption of the FCDMC recommendations.

Where parking lots are used for storm water retention, FCDMC limits the maximum water depth to 1-foot and the City limits the depth to 6-inches, which is more stringent. The City also requires that two-thirds of the parking spaces remain above the maximum water surface elevation. No changes are recommended to the City criteria.

Retention Basin Discharge and Dewatering

In most cases, retention basins within the City drain by means of percolation through the soil surface. The City and FCDMC require water to drain from a basin within 36 hours after the end of the storm event through percolation or discharge. The soils within the City vary in their permeability, which affects the rate that rainfall can percolate through the soil. Percolation tests are



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TYPICAL CROSS SECTION OF RETENTION BASIN/SEDIMENT TRAP

FIGURE 3-1

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required for retention basins as shown in Figure 3-2. Percolation through drywells is allowed by the City if surface percolation is not effective to drain the basin within 36 hours. The 1992 update recommended extending this time limit depending on the size of storm. This was based on the number of drywells which may be required to drain a retention basin within 36 hours if the surface soil has low permeability. The City has indicated they prefer to keep the 36 hour discharge requirement.

Regional retention basins in the downtown area will be connected to the future freeway drainage channel. The required pump stations will be sized to drain the basins within 36 hours. Most of the vacant areas remaining in the City are located in areas with percolation rates estimated to be 0.2 to 2.0 inches/hour as shown in Figure 2-3 and discussed in Section 2. No changes are recommended to the existing discharge requirements.

Overflow

Drainage facilities should address an appropriate overflow spillway for the basin to meet City requirements. The City requires the drainage design report to address the effect of a basin overflow due to back-to-back storms or a storm greater than the design storm (where will overflow go, what damages might occur). No more than nuisance damage to adjacent or downstream facilities shall be allowed to occur from such an event. The FCDMC also requires that flooding concerns not be moved farther downstream and recommends master planning. CDM recommends the City adopt the FCDMC requirements also.

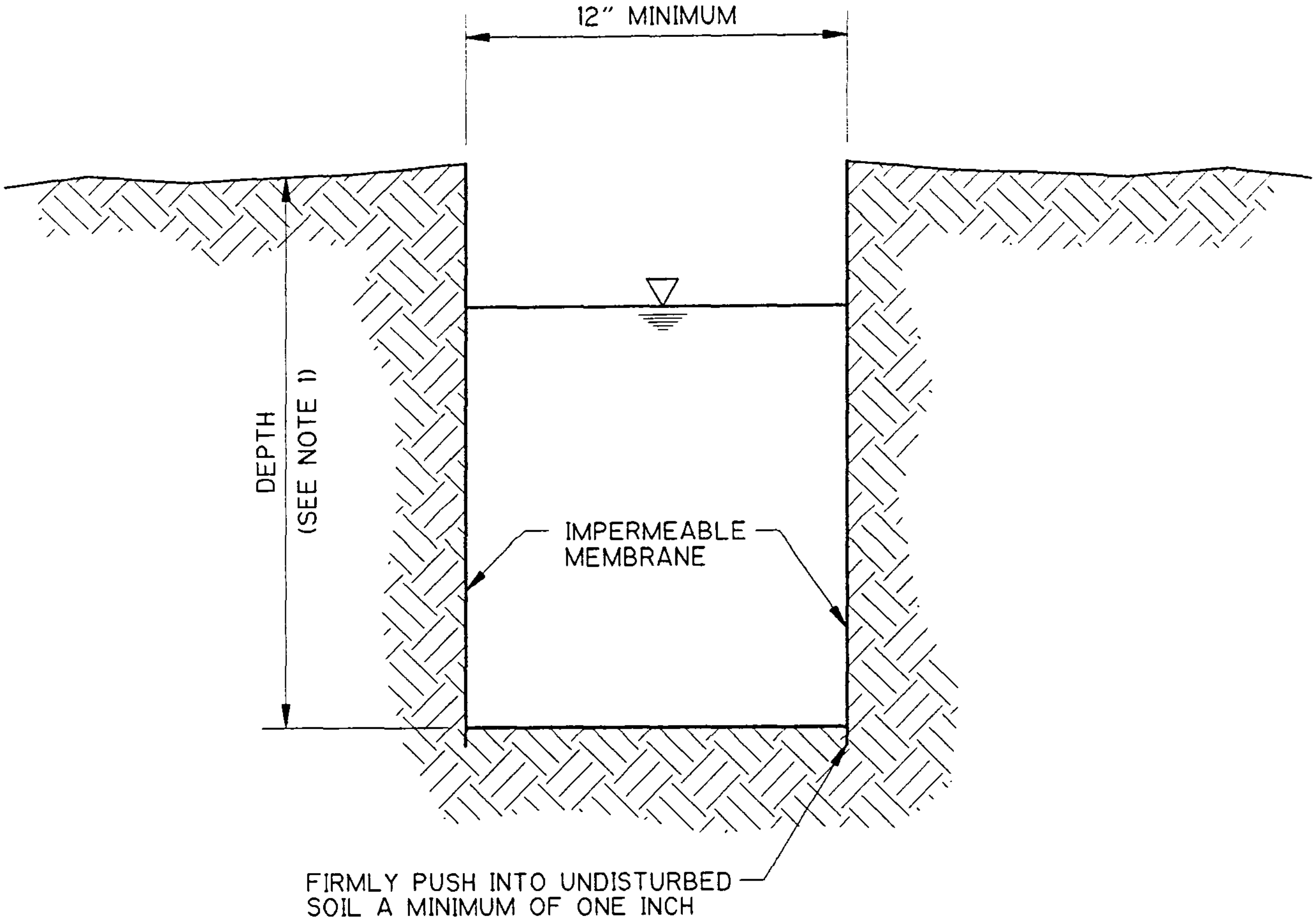
Temporary Retention Basins

The City requires the installation of temporary retention basins along improved arterial roads with vacant lots to collect the 100-year, 2-hour storm runoff from one-half of the adjacent right-of-way until the site is developed and on-site retention is provided. The area for the basins is included within the right-of-way of the street. In some areas, the temporary basins have been filled in by erosion or have on-site runoff filling them, leading to ponding concerns in the roadway. To prevent this, CDM recommends sizing temporary basins for the street runoff plus an additional 25 percent. Berms along the edge of the basin should prevent on-site runoff from draining to the temporary basin.

Pump Stations

The City design manual does not cover pump stations, however, the FCDMC manual lists several criteria for pump station design. They include:

- Pumping facilities shall be set at an elevation at or above the anticipated level of the 100-year event, considering that a total power failure may occur.
- Pumps shall be capable of handling solids up to a maximum of 3 inches.
- Screening devices will not be used at the entrances to the pump stations. Grates will be used on each catch basin.



NOTES:

1. THE TEST SHALL BE PERFORMED AT THE SAME DEPTH AS AS THE BOTTOM OF THE BASIN OR THREE FEET BELOW GROUND, WHICHEVER IS LOWER.
2. THE TEST HOLE SHALL BE PRE-WETTED FOR 24 HOURS, OR UNTIL A STABILIZED PERCOLATION RATE IS ACHIEVED.
3. THE TEST HOLE SHALL BE REFILLED DURING THE PRE-WETTING PERIOD AS NECESSARY TO MAINTAIN A FREE WATER SURFACE. IF AT ANY TIME A FREE WATER SURFACE IS NOT MAINTAINED, THE PRE-WETTING PROCESS SHALL BE RESTARTED.
4. THE TEST RESULTS ARE TO BE EXPRESSED IN THE UNITS OF CUBIC FEET PER HOUR PER SQUARE FOOT OF PERCOLATION AREA.

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SHALLOW PIT PERCOLATION TEST REQUIREMENTS

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FIGURE 3-2

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- Required calculations include:

  - Total Dynamic Head
  - Net Positive Suction Head
  - Head Capacity Curves
  - Mass Flow Curves

- Controls will provide for automatic and manual operation and will have communications to permit transmission of failure signals to a designated reporting location.

- A potable water supply with back-flow prevention and hose bibs should be provided to aid in removal of silt and trash.

- A ventilation system will provide ventilation of wetwells.

- Plugging factors will be used on inlets of pipe systems that are tributary to pump stations.

- Facilities not associated with retention facilities will provide storage to the maximum practical extent to aid in efficient operation of the system.

- A backup pump will be required, particularly at small installations.

- Generally, storm water pump stations should not be privately maintained.

CDM recommends the City adopt the FCDMC design manual requirements for pump station design with the following additions to provide greater system reliability:

1. A minimum of two pumps will be required at any station to allow a backup pump. Each station should also have a small pump to handle "nuisance" water in the system.

2. A backup power source will be provided at all stations.

Drywell Standards

The City allows drywells if a retention basin will not percolate storm water within 36 hours. Drywells are also regulated by the ADEQ as potential groundwater pollution sources, and must be designed accordingly. All drywells must be registered with ADEQ within 30 days unless they are located on golf courses. ADEQ recommends that an ADEQ licensed installer drill and construct new drywells. Currently the City requires the drywell installer to submit a copy of the ADWR approved drywell registration, drilling logs, and certified percolation testing data.

ADEQ and City Drywell Requirements

An application form and fee are submitted to the state agency to register a drywell. An Aquifer Protection Permit from ADEQ is required if the drywell is in an industrial or commercial area where hazardous chemicals may be used within its catchment area. ADEQ has recommendations for estimating the number of drywells needed, but the City prefers to maintain the existing City criteria. CDM recommends that drywells taken out-of-service be decommissioned following the ADEQ requirements which are shown in Table 3-4. Statewide drywell rules have not been written, but the

Arizona State Legislature has passed statutes regarding drywells. ADEQ is in the process of writing the drywell rules.

Table 3-4 *Drywell Decommissioning*
Experienced drilling contractor shall: ■ Remove sediment, pipes, screens from chamber, top of drywell to 6 feet below ground. ■ Fill in with silt, clay, or ABC slurry to plug the zone from 4 to 6 feet below the surface with cement grout. ■ Backfill top 4 feet with silt, clay, etc., and compact. ■ Following decommissioning, notify ADEQ and the City in writing.

The City and the FCDMC require the number of drywells to be estimated using 0.1 cubic feet/second per drywell. If the soil percolation is faster, the drywell disposal rate may be estimated as 50 percent of the tested rate, not to exceed 0.5 cfs per drywell. The rate reduction by 50 percent is intended to compensate for infiltration deterioration over time.

Drywell Location Restrictions

City staff recommends that drywells be located a minimum of 100-feet from any water well, underground storage tank, fuel area, or other drywell, as recommended by ADEQ. CDM recommends that the City also adopt ADEQ's recommendations regarding drywell depth and sealing :

1. If perched groundwater is encountered, the drywell should be sealed in the perched water zone of the well.

2. The drywell bottom should be at least 10-feet above the water table.

ADEQ and the City require that the drywell be drilled 10-feet into a permeable porous soil layer. The FCDMC and the City's Standard Detail require a sediment trapping settling chamber. Drywells in Chandler will be required to follow the updated City Standard Detail shown in Figure 3-3 which incorporates ADEQ recommendations that drywells include a minimum settling capacity of 1,000 cf per chamber, oil separation, and a petrochemical absorbent.

CDM recommends that the City require that drywells installed in landscaped basins have the inlet grate 2-inches above the basin bottom. In other areas the grate shall be at ground level. The ADEQ and FCDMC require the inlet grate to be 3-inches and 4-inches, respectively, above the ground if silt and sedimentation may be a concern. The City will require that drywell inlets be installed at least 20 feet from retention basin surface inlets in the 1999 Technical Design Manual No. 3 update.

Operation and Maintenance Requirements

Retention Basin Maintenance

As discussed in the 1992 update, retention basin bottoms should not be turfed in areas of high sediment buildup (near inlets and drywells). These areas should be scarified and scraped when accumulated silt and other sedimented materials such as oils and greases form an impenetrable crust and impede surface percolation. Depressed sediment traps at inlets and drywells should also be provided to facilitate maintenance.

If basin landscaping makes scarifying or scraping impractical and the basin is not draining adequately, drywells should be installed to drain the basin within the required time without relying on surface percolation. Material removed from retention basins should be deposited in a landfill. The City has already implemented this course of action for City-maintained basins.

CDM recommends that maintenance of private retention basins be through a maintenance agreement, enforced by a performance bond, between the City and the developer or Homeowner's Association. Such a performance bond would be for an amount equal to the cost for the City to either maintain the basin with City forces, or to contract the work through the private sector, presently estimated at $80/acre. CDM also recommends passing an ordinance which requires maintenance of basins within 15 days of a City request. For example, the City of Albuquerque, New Mexico, performs the maintenance and bills the owner if the owner does not complete work within 15 days of the request.

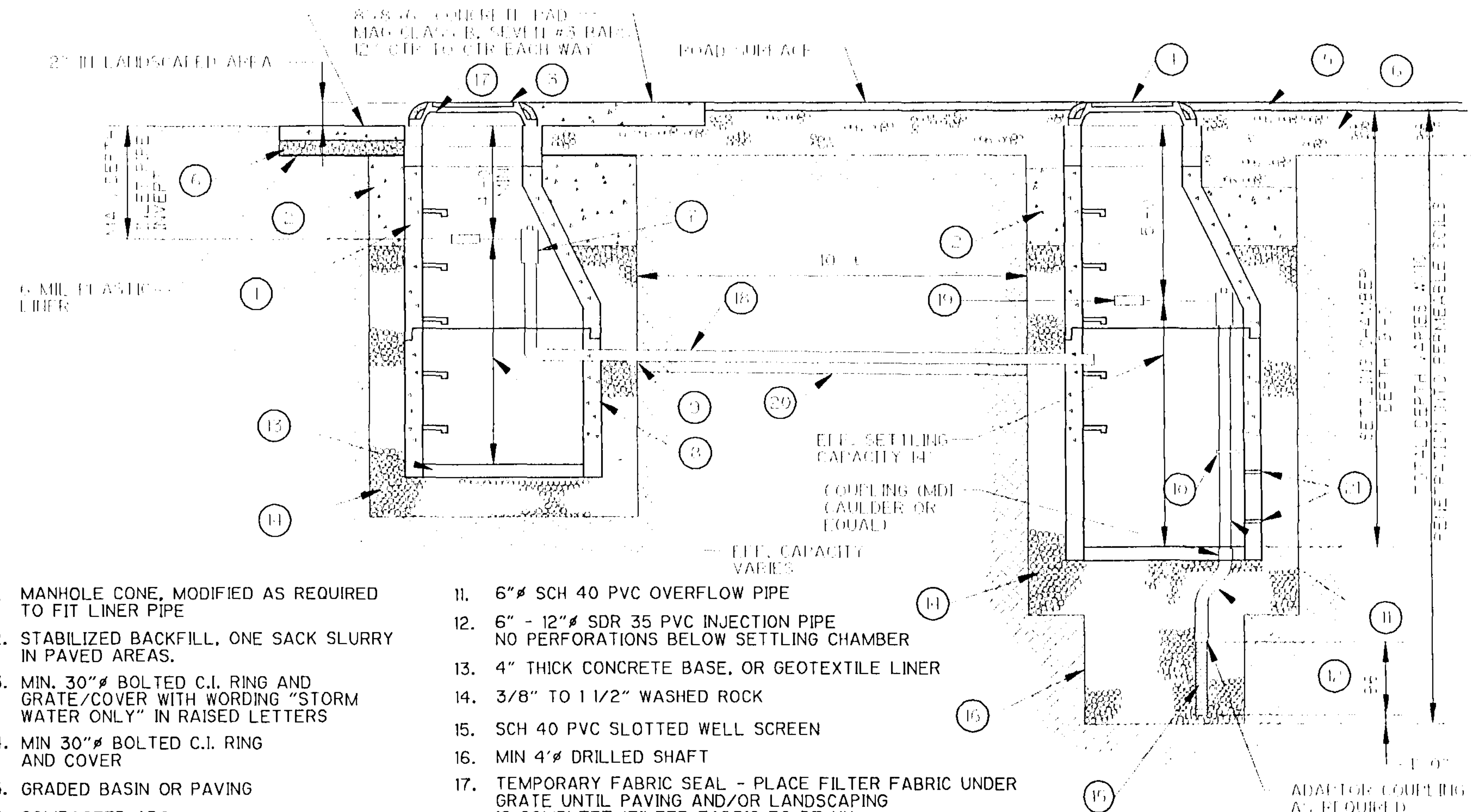
Drywell Inspection and Maintenance Criteria

A drywell's effectiveness and useful lifetime is affected by many variables including soil strata, construction practices, and maintenance procedures. Drywells have a limited effective life span due to silting and must be maintained or replaced periodically. Since drywells are an important element of the City's drainage system, it is important that they are maintained properly. Figure 3-4 shows the City-owned drywells throughout the City. Both public and private drywell inspection should be performed on an annual basis and more often if there is ponding. ADEQ provides an inspection checklist and recommends looking for evidence of chemical use, non-storm water discharges, sediment, and debris.

ADEQ recommends maintenance of drywells when inspection shows 10 (paved area) or 25 (landscaped) percent of the capacity of the drywell is filled with sediment; it is performing inadequately as demonstrated by increased draining time; non-storm water enters the drywell; or ownership changes.

Maintenance should include cleaning out dirt and debris; replacing filter fabric and petrochemical absorbent; cleaning screens; drilling out weep holes in liner, if plugged; and using a high-pressure hose, compressed air jetting, or surging and pumping to force accumulated silt out of the aggregate backfill. Sediment, debris, fabric, and absorbent should be disposed at an acceptable landfill.

According to the City, maintenance of private drywells is the responsibility of the owning party. Maintenance should be enforced with a performance bond between the City and the developer or Homeowner's Association or by an ordinance in a similar fashion to retention basin maintenance bonds. A bond would require increases in homeowner's fees, and would likely require the City to enact new ordinances to enforce the requirement. To inform homeowners and other private drywell owners of the requirements and inspection and maintenance requirements, CDM recommends a packet of information be made available to property owners from the City.

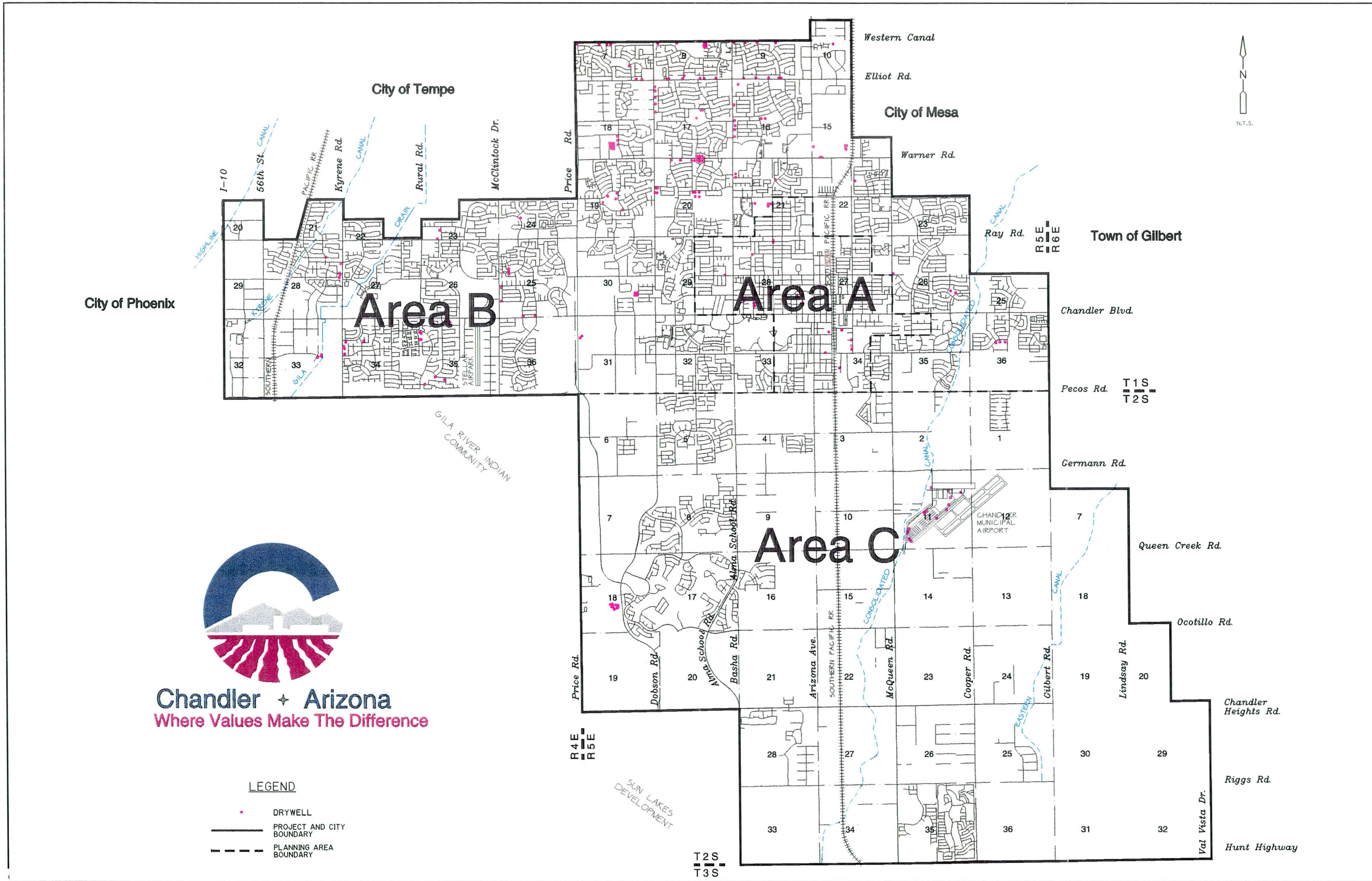


1. MANHOLE CONE, MODIFIED AS REQUIRED TO FIT LINER PIPE
2. STABILIZED BACKFILL, ONE SACK SLURRY IN PAVED AREAS.
3. MIN. 30"ø BOLTED C.I. RING AND GRATE/COVER WITH WORDING "STORM WATER ONLY" IN RAISED LETTERS
4. MIN 30"ø BOLTED C.I. RING AND COVER
5. GRADED BASIN OR PAVING
6. COMPACTED ABC
7. DEBRIS SCREEN (ROLLED 16 GUAGE x 24" LENGTH x 0.265" MAX SWD FLATTENED EXPANDED STEEL, GALVANIZED OR COALTAR EPOXY COATED)
8. PRECAST CONCRETE LINER RING, 4000 PSI 48" ID. 54" OD
9. MIN 6"ø DRILLED SHAFT
10. SUPPORT BRACKET (TYP) STEEL FUSION BONDED EPOXY COATED STEEL, MIN 3/8" AT 5'-0" ON CENTER.
11. 6"ø SCH 40 PVC OVERFLOW PIPE
12. 6" - 12"ø SDR 35 PVC INJECTION PIPE NO PERFORATIONS BELOW SETTLING CHAMBER
13. 4" THICK CONCRETE BASE, OR GEOTEXTILE LINER
14. 3/8" TO 1 1/2" WASHED ROCK
15. SCH 40 PVC SLOTTED WELL SCREEN
16. MIN 4'ø DRILLED SHAFT
17. TEMPORARY FABRIC SEAL - PLACE FILTER FABRIC UNDER GRATE UNTIL PAVING AND/OR LANDSCAPING IS COMPLETE (FILTER FABRIC TO BE UV RESISTANT)
18. 4"ø CONNECTOR PIPE W/FLOW REGULATOR
19. MIN 4 QT CAPACITY HYDROPHOBIC PETROCHEMICAL ABSORBANT PER ADEQ REQUIREMENTS. (TYP)
20. SLURRY BACKFILL
21. 8 PERFORATIONS PER LINEAR FOOT FOR BOTTOM 3 FEET OF CHAMBER

(DRAFT JULY 1998)

FIGURE 3-3

DETAIL NO.	CITY OF CHANDLER STANDARD DETAIL AUGUST 1998	DRY WELL SYSTEM DETAIL	APPROVED: ______ DATE: ______	DETAIL NO.
43 NTS				43 NTS



CDM
environmental engineers, scientists, planners, & management consultants

1998 CHANDLER STORMWATER MASTER PLAN UPDATE
CITY MAINTAINED DRYWELLS IN CHANDLER
FIGURE 3-4

New drywells are recommended to be installed when existing drywells or surface percolation become ineffective as demonstrated by annual inspection, or by failure of the well to comply with drainage time requirements.

As-Built Plan Requirements

CDM recommends that developers be required to submit As-Built plans of storm water facilities to the City, including:

1. The plans shall be 24" by 36" sized sheets.
2. An engineering scale shall be included.
3. A north arrow shall be included.
4. The plans shall be sealed by a registered Civil Engineer. They shall be marked "As-Built" with changes noted.
5. Approved ADEQ drywell registration, drilling logs, and certified testing results shall be included with the As-Built plans. Certified percolation test results shall be included with the As-Built plans, both the pre construction and the post construction percolation tests should be submitted.
6. Certify retention basin dimensions, grades, and volumes match As-built drawings.
7. Show the "As-Built" maximum water depth of the retention basin for a 100-year, 2-hour storm.
8. Show the "As-Built" finished floor elevation of buildings constructed and the "As-Built" elevation of the development low outfall.
9. If the development is located in a FEMA 100-year flood zone, show the limits of the zone and submit approval from the Flood Control District of Maricopa County.
10. Verify compliance with City standard details for new drywells.
11. Verify that sediment from construction has been removed or prevented from entering drywell.
12. If the drywell is installed near a gas service station or in a vehicle storage yard, verify that an oil separator was installed and is operational.

3.3 Standards for Other Cities

Table 3-5 outlines the standards recommended or in effect in Chandler and surrounding communities. In general, Chandler's criteria matches those required by other local communities. Exceptions include the Town of Gilbert's retention basin sizing for runoff for the 50-year, 24-hour storm, and directing outlets to drain to riverbeds in Tempe and Scottsdale.

3.4 Recommendations

The changes requested by the Development Services Department and recommended to be included in the 1999 Technical Design Manual No. 3 update include:

City Policy

Existing City policy as written in the 1987 Technical Manual #3 to be retained with the following additions and modifications.

- Storm runoff from the 100-year, 2-hour storm shall be changed from 2.5 inches, as noted in the existing design manual, to 2.6 inches.
- Storm drainage facility designers should be required to verify dimensions, grades, and volumes of constructed basins with approved plans. They are also recommended to verify that drywells comply with the City Standard Detail, verify that sediment has been removed, and verify that an oil separator was installed if it is near a gas or service station.
- Certified As-Built drawings of storm water facilities shall be provided to the City.
- Development within the 100-year flood areas require FCDMC approval prior to City Development services project reviewer.
- Lot grading shall be graded to drain away from buildings at 0.5 percent slope.
- Existing irrigation and drainage ditches shall be abandoned, piped, or improved when the land is developed around it.
- Storm water facility designers shall discuss how off site flow from up stream of the development will be handled.

Table 3-5
Design Criteria for Southwestern Cities Storm Drain Systems

Requirements	*Chandler*	*FCDMC*	*Phoenix*	*Mesa*	*Tempe*	*Glendale*	*Scottsdale*	*Gilbert*
Street Drainage								
Design Storm	10-year, 6-hour or 50-year, 6-hour	10-year, 6-hour or 100-year, 2-hour	10 year between sidewalks	10-year peak storm	5-year storm between curbs	10 year storm	10 year peak storm	10 year 6-hour
Dry Lanes for multilane streets	1 each direction	1 each direction		Runoff concentrated to one lane		As designated in Drainage Master Plan	1 each direction for major streets	1 each direction for major streets
Drain Pipes								
Required	If street capacity exceeded by design storm	If street capacity exceeded by design storm	If street capacity exceeded	If street capacity exceeded	If street capacity exceeded by design storm	If street capacity exceeded by design storm	If street capacity exceeded by design storm	If street capacity exceeded by design storm capacity required for inlet
Design Storm	10-year, 6-hour or 2-year, 6-hour in downtown	10-year, 6-hour or 100-year for flow routing	10 year	10-year peak storm flow		10-year storm		10 year, 6-hour
Inlet Sizing	10-year, 6-hour Weir equation only	10-year, 6-hour or 100-year for flow routing		10-year peak or storm-year near ret. basin		10 year	10 year	10 year, 6-hour
Pipe Material	RGRCP			RGRCP or RCP		Not PVC in Public ROW	Not listed	RGRCP or RCP
Minimum Slope	0.001	0.001		not listed			Not listed	
Minimum Size	18" main, 15" lateral	18" main, 15" lateral		not listed		12" minimum	24 " main, 18" lateral	15" minimum

Table 3-5
Design Criteria for Southwestern Cities Storm Drain Systems

Requirements	*Chandler*	*FCDMC*	*Phoenix*	*Mesa*	*Tempe*	*Glendale*	*Scottsdale*	*Gilbert*
				Retention Basins				
On-site required	yes	yes	yes, unless direct to major drainage	yes	yes, unless outlet to Salt River	yes, unless drain or channel approved	yes, unless waiver approved	yes
Design Storm	100-year, 2-hour	100-year, 2-hour	100 year, 2-hour	100 yr, 2 hour	100 yr 1 hr	100 year, 2 hour	100 year, 2 hour	50 year, 24 hour
Maximum depth	3 feet	3 feet	3 feet	not listed	3 feet	3 feet or other for aesthetics	not listed	2 feet frontage, 3 feet other
Maximum Side Slope	4:1	4:1 where grass will be added	2:1 on private property	6:1 by ROW 4:1 other locations	4:1	6:1 pedestrian access 4:1 next to walls, hedges		4:1 and vary to eliminate "bowl"
Freeboard	1 foot	1 foot		3.5 feet total		1 foot	not listed	0.5 feet
Time to Drain	36 hours	36 hours	36 hours	36 hours	36 hours	36 hours	36 hours	36 hours
Positive Discharge	Preferred	Preferred	Permitted	Required	Reqd if deeper than 1 ft	Reqd if deeper than 1 foot	Permitted	Reqd if deeper than 1 foot
ROW runoff	½ of all adjoining streets	To centerline of adjoining streets	Yes, if required for continuity of wash	½ of adjacent ROW unless in exempt area	Not from arterials	To centerline of adjoining streets	To follow natural drainage	½ of ROW adjacent to development
Drywells	Permitted if no other means available	Only with approval	Permitted	With City approval; no pavement runoff	Permitted	Permitted	Permitted	Permitted if no other means available
Percolation Test Required	Yes three feet below basin bottom	Yes	Yes if not drilled a minimum of 5 feet into porous strata	Yes where it is unclear if sand or gravel layer is penetrated	no	To support use of >0.1 cfs per well	no	Yes where it is unclear if sand or gravel layer is penetrated
Drywell Installer	ADEQ licensed	not listed		ADEQ License		not listed	not listed	not listed
Drywell Separation	100 feet c/l to c/l	not listed		not listed		not listed	not listed	75 ft c/l to c/l
Drainage Plan Approval Req'd	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Hydrology

Adopt the FCDMC "Design Manual for Maricopa County, Arizona Volume 1 Hydrology" with the following exceptions.

- Use Chandler specific IDF curves as shown in Appendix A.
- Retain existing Chandler Runoff Coefficients and add a corfficiect of 0.75 for cluster developments.
- Use 2-year, 6-hour design storm for storm drain facility and roadway drainage design in Area A.

Drainage and Conveyance Facility Design

Adopt the FCDMC "Design Manual for Maricopa County, Arizona Volume 2 Hydraulics" with the following exceptions.

Street Drainage Design

- Require Finished Floor Elevations to be 14-inches above lowest outfall elevation in the drainage area.
- Disallow use of slotted drains.
- Require 50-year storm flow calculations.
- Wetted perimeter calculations extend only to the back of the sidewalk for 50- and 100-year storm flow calculations. Maximum depth over the curb shall be 6 inches.
- Require FCDMC approval for developments within the 100 year floodplain prior to City Development Services Department review.
- Flooding concerns should not be moved downstream by a new development.

Storm Drain Design

- Require installation of a catch basin upstream of the inlet to a bubbler box to prevent sediment buildup and allow easier maintenance.
- Require storm drain pipe to be RGRCP only. This may be changed after the City reviews alternate materials.
- Add D Load chart to indicate minimum required pipe strength.
- Add standard details for bubbler boxes, catch basins, handrail, catch basin grates, and frames.

- Use only the Weir equation for design of inlets to storm drains.
- Size storm drains to convey the 10-year, 6-hour storm except in the downtown area where a 2 year 6 hour design storm is recommended.
- Disallow use of the Papadaki s and Kazan equation for calculating time of concentration. Require use of Manning equation to calculate flow time.

Retention Basin Design

- Continue to require retention of 100-year, 2-hour storm runoff.
- Limit retention basin side slope to 4:1 for all conditions. (Previously, deeper basins were allowed to have steeper side slopes).
- Require One foot of freeboard above the high water depth of 3-feet for retention basins. Also require an additional 10% of storage capacity to allow for losses due to sedimentation etc.
- Where commercial or retail parking areas are used for storm water retention (parking not allowed in residential basins)the maximum water depth in a parking area shall be 6 inches. Two-thirds of the parking spaces shall be above the maximum water surface elevation.
- The maximum water surface in the basin for the 100-year, 2-hour storm shall be below the minimum street pavement elevation at inlets to ensure that storm water does not pond in the streets at the inlets.
- Rain falling on the top edge of a retention basin should be directed away from the basin or into protected channels to prevent erosion of the sides.
- Recommend curvilinear, irregularly shaped basin with low flow channels *per Figure 3-1.*
- Temporary basins should be sized for street runoff plus 25 percent extra.
- Limit property frontage used for retention to 50%.

Drywell Design.

- Require use of the Chandler standard drywell detail (in Tech. Manual 3 Update) to reflect current construction techniques including petrochemical absorbents.
- Require drywells to be 100-feet away from any water well, underground storage tank, fuel area, or other drywell.
- If perched groundwater is encountered, the drywell is required to be sealed within the perched water zone of the well.

- The drywell bottom is required to be at least 10-feet above the water table.
- Oil interrupters/separator should be is required to be installed in drywells near a gas or service station or vehicle storage yard.
- The inlet grates for drywells installed in landscaped basins are required to be 2-inches above the basin bottom. In other areas they are required to be at ground level.
- Drywells are required to be installed at least 20-feet away from retention basin surface inlets.
- Driller is required to be registered with ADEQ.
- Submit ADEQ registration, drilling logs, and certified percolation tests to the City.
- Decommission drywell following ADEQ recommendations.
- Drywell inlet grates shall be 2 inches above the bottom of a landscaped basin. They shall be at ground level in other areas.

Pump Station Design

Adopt the FCDMC manual design criteria for pump station design with the following inclusions:

- At least 2 pumps shall be installed in a pump station. In addition, a small pump shall be required to handle small nuisance flows.
- Backup power shall be provided, unless pumps are direct driven by gasoline, diesel or natural gas powered generators.

Drainage Facility Operation and Maintenance

Retention Basin Maintenance Requirements

- Detention basin silt removal should occur when the accumulated depth exceeds 6 inches in basins without sediment traps and 4 inches in basins with sediment traps.
- Non-vegetated retention basin surfaces shall be scarified to breakup silt deposits and surface crusting annually. Use of heavy equipment for basin maintenance is discouraged because it can cause excessive compaction of the basin surface.
- Sediment in basins shall be scarified or scraped.

Drywell Maintenance Requirements

- Drywells shall be annually inspected and maintained as needed.
- City shall set up performance bonds for maintenance of drywells and retention basins.
- Ineffective drywells shall be decommissioned and replaced.

Detroit Basin and Street Inlet

Section 4 Stormwater Modeling

Section 4
Stormwater Modeling

4.1 Methodology

For the 1986 and 1992 Master Plans, U.S. Environmental Protection Agency Storm Water Management Models (SWMM) were used to size future storm drain pipes in Areas A and B, the downtown and northern portions of the City as shown in Figure 2-1. The SWMM model was also used to calculate the flow at points of concentration in Area C. The model assumed that the stormwater would accumulate downstream. However, most of north and west Chandler have been developed using on-site retention without major storm drain systems. Based on the City's requirement to provide on-site retention for new construction, the southern portions of Chandler are expected to develop in the same manner.

For hydrologic analysis of subareas of 160 acres or less, the FCDMC has adopted the Rational Method. As a result, the SWMM models are no longer valid for Areas B and C. This Master Plan Update used the Rational Method for areas that are served primarily by on-site retention without major storm drain systems. The stormwater runoff calculations in this report for quarter sections and vacant parcels are for subbasins of 160 acres or less. The Rational Method was used to calculate retention volumes required for vacant lots in north and west Chandler and partially developed or vacant quarter sections of south Chandler. The only area where the SWMM model was used was Study Area A, where regional detention basins will eventually discharge to the Price Drain, Price Freeway, and Santan Freeway drainage systems.

4.2 Modifications to 1992 SWMM Model for Area A

For the 1992 Update, CDM updated the SWMM model developed in 1986 for the Stormwater Management Master Plan to reflect current conditions, and to utilize the model's capabilities for simulating runoff and routing subsequent hydrographs for overland, open channel, and pipe flow. The runoff module of the SWMM was used to determine peak flows for sizing the recommended drainage improvements in Area A.

General Description of SWMM Model for Area A

Since the original release of the EPA SWMM model in the early 1970's, EPA has continuously maintained and funded periodic updates and improvements to the model. The most recent update to the SWMM model was completed in 1988 (Huber, 1988; Roesner, 1988). The model simulates both hydrographs and water surface profiles at intermediate points throughout both closed conduit and open channel networks. The SWMM RUNOFF module was the first watershed model to be designed exclusively for urban stormwater studies, and will automatically re-size pipes to convey the modeled design stormwater flow. Over the years, SWMM's ability to handle urban systems was significantly enhanced by the addition of the TRANSPORT and EXTRAN blocks which handle surcharge flow in storm sewers (i.e., full pipes) and backwater effects in open channels. The SWMM model relies upon a dynamic instream routing simulation (i.e., based on routing of complete streamflow hydrographs at each location) through a direct solution of the equations for conservation of mass and momentum. Because the SWMM model provides a dynamic simulation with complete hydrographs throughout the watershed, it can be used to simulate the downstream interactions and impacts of outflows from detention ponds, stream crossings (e.g., culverts), and channel improvements.

Specific Characteristics of the Chandler Model

For this update, the SWMM model revised to reflect current conditions in Study Area A. Key model parameters used in this study, based on FCDMC recommended methods, are shown in Table 4-1.

Table 4-1
Model Parameters

A. Percent Impervious Land Use	
Single family residential	
Low density (1-2 units/acre)	25%
Medium density (3-5 units/acre)	35%
High density (over 5 units/acre)	45%
Multi-family residential	65%
Commercial/Offices	90%
Industrial	75%
Agricultural/Open Vacant Land/Parks	5%
Educational/Government	50%
B. Resistance Factors - Manning's n	
1. Overland Flow	
Impervious Surface Flow	0.013
Pervious Surface Flow	0.25
2. Channels	
Pipe Flow (Concrete)	0.012
Gutter/Street Flow	0.015
C. Surface Storage	
Pervious	0.062 in./hr.
Impervious	0.18 in./hr.

The SWMM Model simulates the runoff pattern from a specific storm event by applying a rainfall pattern to a drainage area and calculating the path of the water based on the physical characteristics of the drainage area. Each drainage area was divided into subdrainage areas, and a flow routing structure and collection points were defined.

The SWMM Model requires input of an entire rainfall pattern for a storm rather than just a peak rainfall intensity or a total precipitation amount. The relative placement of the peak rainfall within a storm is an important factor. For the 1992 update, the FCDMC rainfall distribution for a 6-hour storm was used as shown in Table 4-2. Peak flows were higher than with the previously used rainfall distribution curves for the 1992 update, and the peak rainfall occurs at hour four rather than in the first hour. The rainfall depths for the design storms were obtained from the FCDMC rainfall maps (hyetographs).

Table 4-2
Design Storm Distribution

Time (Hours)	Percent Depth of Rainfall — FCDMC Pattern 1
0:00	0.0
0:15	0.8
0:30	1.6
0:45	2.5
1:00	3.3
1:15	4.1
1:30	5.0
1:45	5.8
2:00	6.6
2:15	7.4
2:30	8.7
2:45	9.9
3:00	11.8
3:15	13.8
3:30	21.6
3:45	37.7
4:00	83.4
4:15	91.1
4:30	93.1
4:45	95.0
5:00	96.2
5:15	97.2
5:30	98.3
5:45	99.1
6:00	100.0

Input data for the SWMM Model was developed for each of the selected subdrainage areas. An idealized rainfall pattern was determined for each design storm to be analyzed. The drainage area, slope, and width of each subdrainage area were estimated from topographic maps. The amount of impervious area was estimated from land use maps, applying appropriate factors for each land use type. Infiltration rates were estimated from soils maps of the area and known characteristics of the various soil types. Roughness values and surface storage parameters are estimated from typical technical literature values and from site visits. Future land use conditions were simulated by adjusting the percent impervious parameters to reflect the estimated changes in the land use type. The land use information from the most recent Chandler Land Use Element (Figure 2-2), which has not changed since 1992 and the General Land Use Plan (Figure 2-3).

The model computes a runoff hydrograph for each subcatchment and then routes flow through an idealized channel system to specified concentration points. Hydraulic data such as size, slope, and roughness factors were input for the channel system. Concentration and channel connections were defined so that runoff hydrographs for the subareas could be combined at appropriate locations. The runoff hydrograph generated by the model provided information on the maximum flows that might occur. The model also generated data for facility sizing through use of a surcharge option, which indicates that the modeled gutter and/or pipe capacity is exceeded and stores excess flow (ponding) until capacity becomes available, or a resize option that automatically resizes pipes to carry the computed peak flows. SWMM analyzes the hydraulics for large drainage areas (greater that 60/acres), but is inappropriate to model flow and calculate hydraulics for smaller drainage areas. For design of the Erie and Ivanhoe drains, CDM used the Rational Method.

4.3 The Rational Method for Area B

In west Chandler (Area B), the Rational Method was used to calculate the 10- and 50-year peak flows and the 100-year retention volumes for vacant subareas of 160 acres or less. The vacant lots remaining in Area B were identified and field verified. The zoning and land use predicted by the Chandler Land Use Element and General Plan (Figure 2-3) were compared to current City zoning for each vacant lot. The developed land use which was likely to generate more runoff was used for the calculations.

To calculate the 10-year and 50-year peak flows, the Rational Method Equation was used:

$$Q = C*i*A$$

where

Q	=	Peak Discharge in cubic feet per second
C	=	Runoff Coefficient from Chandler Technical Design Manual No. 3
i	=	Rainfall intensity in inches/hour
A	=	Tributary drainage area in acres

To calculate the 100-year, 2-hour on-site retention volume, the following equation was used, which was derived from the Rational Method:

$$V_R = (\frac{D}{12}) * A * C(1.1)$$

where

V_R	=	Retention volume required in acre-feet
D	=	100-year, 2-hour depth of rainfall in inches
A	=	Tributary drainage area in acres
C	=	Runoff Coefficient from Chandler Technical Design Manual No. 3
1.1	=	Additional 10 percent as required by the City

For each subarea, the drainage areas and longest flow paths were estimated. The longest flow path was estimated to be along the south and west lengths of the property. Results are found in Section 7 and Appendix D, Table D-1 of this Technical Master Plan Update.

4.4 The Rational Method for Area C

A spreadsheet model based on the Rational Method was used to calculate the 10-year and 50-year peak flows and the 100-year, 2-hour retention volumes for Area C (south Chandler). The equations used for the spreadsheet calculations are the same as those described for Area B.

Similar to Area B, quarter sections of vacant land and vacant parcels in developed quarter sections in south Chandler were identified. For each quarter section, the zoning from the City zoning maps and land uses planned by the Chandler Land Use Element and General Land Use Plan (Figures 2-2 and 2-3) were compared. Results are discussed in Section 7 and shown in Appendix D of this Technical Master Plan Update.

ADOT Basin G

Section 5 Freeway Drainage Systems

Section 5
Freeway Drainage Systems

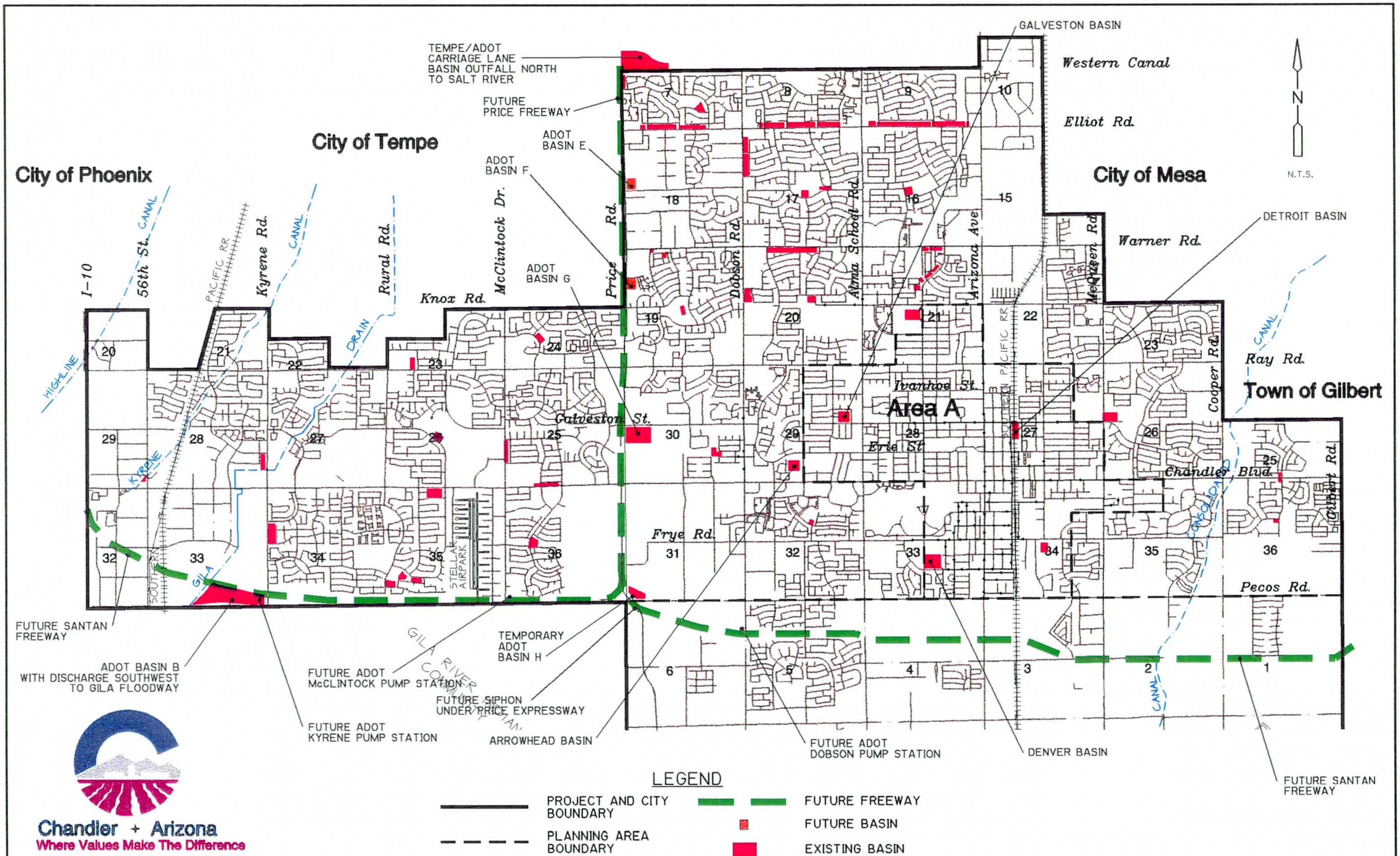
Since the 1992 Master Plan Update, portions of the drainage system for the Price Freeway have been installed and design has started on other portions of the Price Freeway as well as portions of the Santan Freeway. As shown in Figure 5-1, Basins B, G, and H have been constructed. The freeway drainage system north of Knox Road is being installed and other portions are being designed. Table 5-1 shows the January 1998 ADOT schedule for freeway completion. The City of Chandler has contributed funding towards the drainage portions of the freeways and to complete the system faster than originally planned.

Table 5-1
ADOT Schedule for Freeway Completion, January 1999

Section of Price Freeway	***Scheduled Completion Date***
Superstition Freeway (I-60) to Baseline Road	Completed Spring 1999
Baseline Road to Guadalupe Road	Completed Spring 1999
Guadalupe Road to Warner Road	December 2000
Warner Road to Frye Road	December 2000
Section of Santan Freeway	***Scheduled Completion Date***
56th Street to Price Freeway-Drainage	September 2000
Kyrene Road to McClintock Drive	September 2004
Price/Santan Traffic Interchange - West ½	September 2004
I-10/Santan Traffic Interchange - East ½	December 2004
Price/Santan Traffic Interchange - East ½	November 2005
I-10/South Mountain Traffic Interchange - West ½	December 2005
Dobson Road to Arizona Avenue	December 2005

5.1 Storm Drains Along the Price Freeway

The ADOT Price Freeway drainage system will drain and pump community stormwater runoff from Chandler and other communities to the Salt or Gila River. Runoff originating north of Knox Road and east of Price Road could flow north through a system of basins to the Carriage Lane Basin at Price Road and the Western Canal. From there it would be pumped north to the outfall into the Salt River. South of Knox Road stormwater will drain to basins and south to the Santan Freeway drainage system. The Santan Freeway drainage channel will drain west through basins and pump stations to the Gila Floodway of the Gila River Indian Community and eventually the Gila River. ADOT's original hydrology for the drainage systems used a 100-year, 24-hour design storm to size the channels and basins for runoff from communities on the upstream side of the freeways. The City would need to install storm drains connecting on-site basins to the freeway drainage system to use the capacity provided. Except for the downtown regional basins, the adequate existing on-site retention and high costs for drains make the connection to ADOT's system unfeasible at this time.



1998 CHANDLER STORMWATER MASTER PLAN UPDATE

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A.D.O.T. FREEWAY DRAINAGE SYSTEM

FIGURE 5-1

Price Drain to Carriage Lane Basin

The following paragraphs describe retention basins and pump stations (shown in Figure 5-1) which will direct freeway stormwater runoff north to the Carriage Lane Basin and Outfall to the Salt River. The City has reserved 100 cfs capacity in this system in case it is needed in the future.

Tempe/ADOT Carriage Lane Basin

This existing basin is located on the north side of the Western Canal adjacent to Price Road, which will be the future East Frontage Road. The basin pumps runoff to the Carriage Lane Outfall and the East Valley Tunnel to the Salt River.

Basin E

Located at the intersection of Mesquite Street and the East Frontage Road, this future basin will be midway between Warner and Elliot Roads. It is planned to cover 15.5 acres, contain 150 acre-feet (ac-ft) with a total capacity of 189 ac-ft, and have a depth of 16 feet. The north, south, and east sides will have 1:6 slopes and the west side will have a 1:3 slope with shotcrete or gunite. The basin will be joint use for recreation. Its drainage area will be bounded by Price Road, the railroad (with overflows during significant rainfall events), the Western Canal, and Warner Road. Runoff sources include Elliot Road off-site runoff, Mesquite Road runoff, Warner Road off-site runoff, freeway runoff, and discharge from Basin F. The road runoff will include sheet flows which enter the freeway right-of-way. Because the freeway will be depressed beneath both Elliot and Warner Roads, large diameter pipes at both low points of the freeway will collect pavement drainage. Pump stations will pump the collected runoff to Basin E. Basin E will discharge by either gravity or under pressure to the Carriage Lane Basin through a 90-inch pipe with a flow of 50 to 150 cfs. If under pressure, flow will be through one to three 50 cfs pumps.

Basin F

Located at the southeast corner of Highland Street and the East Frontage Road of the Price Freeway, midway between Warner and Ray Roads, future Basin F will collect runoff from the surrounding area and the East Frontage Road. The drainage area is bounded by Price, the railroad, Warner Road, and Ivanhoe Street. It is planned to hold 32 ac-ft and have an outfall pipe 60-inches in diameter. Basin F will drain north by gravity under the East Frontage Road to Basin E as soon as the water reaches the discharge pipe.

Status

ADOT is currently constructing the drainage system to the existing Tempe/ADOT Carriage Lane Basin. Basins E and F are part of this project.

Price Freeway Drain to Santan Freeway

South of Knox Road the drainage will be directed south to Basin G, and temporary Basin H. After construction of the future pump station and siphon under the Price Expressway to the Santan Freeway drainage system, the drainage will be routed west to the Gila Floodway.

Basin G

The existing Basin G is located at the southeast corner of Galveston Road and the East Frontage Road. The basin covers 17.4 acres, holds 108 ac-ft of water, and is 16 feet deep. Stormwater from Galveston Street and Chandler Boulevard is directed to this basin. Area A will drain to this basin when the City installs discharge pipes from Arrowhead Basin. The discharge from Basin G is designed to flow to the West Frontage Road and south to temporary Basin H at a rate of 193 cfs through 84- and 90-inch diameter pipes. Currently, the pipes are plugged and will remain so until the next phase of the freeway, from Warner Road to Hunt Highway, is constructed. As part of the freeway, an emergency overflow for Basin G will be constructed at an elevation of 1185, which is 1 foot below the lowest point on the Basin G perimeter road (top of basin berm). The overflow pipe will connect to mainline storm drainage along the Price Freeway and will be sized for 100 cfs.

Basin H

This is an existing temporary basin located north of Pecos Road and east of Price Road. It will receive stormwater from the downtown area, the Price freeway south of the Chandler Boulevard overpass, and the East and West Frontage Roads. There is no outlet for this basin. Basin H was designed to cover 23.3 acres, store 370 ac-ft of water, with a depth of 26 feet.

ADOT will allow the City to discharge 60 ac-ft from the downtown area to Basin H and the future pump station after the peak flows from the freeway have dissipated. When the Price/Santan Interchange is constructed, Basin H will be replaced by a pump station and the storm water will be directed west into the Santan drainage channel to the McClintock pump station, Basin B, and the Gila Floodway.

Status

The Price Freeway is currently under construction from Interstate 60 south to Warner Road. Basins G and H have been constructed. The drainage system in the portion of the project between Warner Road and Frye Road is being designed to drain the local and off-site runoff to the retention basins as described above.

5.2 Santan Freeway Drainage System

The Santan Freeway drainage channel from Chandler will be a collector channel parallel to and north of the freeway. It will run west through a series of basins and pump stations, and end up in Basin B which is located north of Pecos Road between Kyrene Road and the Gila Drain in the future Santan Freeway right-of-way. Another channel will run east from the future I-10 and Santan Freeway Interchange to the basin. Basin B, partially constructed in November 1997, consists of three components: equalization, treatment, and the main Basin B storage. It will drain to a new channel outlet to the Gila Floodway on Gila River Indian Community land. The drainage system from Price Road to the floodway is called the South East Valley Regional Drain System (SEVRDS).

The system from the Price Freeway to the west will include two pump stations. One will be located at McClintock Road and the other near Basin B at Kyrene Road. The Kyrene Road pump station will normally pump freeway stormwater to the equalization basin, but will also pump stormwater treated by the basins. Stormwater will enter the equalization basin which will contain the "first flush," up to 27.6 ac-ft, with additional flows bypassing the equalization and treatment basins to Basin B storage. Sediment, debris, and possible contaminated particles will be allowed to settle in the equalization basin. The retained flow will then be discharged to vegetated treatment cells. Effluent from the treatment cells will be discharged to Basin B. Basin B will have two 54-inch outlet pipes to the Kyrene Pump station, which will pump the treated stormwater to the outflow channel leading to the Gila Floodway.

The SEVRDS portion west of Price Road is being designed and constructed in four phases. Phase 1, excavation of Basin B and its associated basins, was completed in November 1997. Phase 2, the outfall channel from Basin B to the Gila Drain and the piping for Basin B is under construction and scheduled for completion in September 2000. Phase 3A consists of the drainage channel from the Stellar Airpark to Basin B, details for Basin B, and the Kyrene Pump Station and force main. Phase 3A is also under construction and scheduled for completion in September 2000. The channel from Price Road to the Stellar Airpark, from 56th Street to Basin B and the wetlands treatment for Basin B are Phase 3B. Design began in early 1998 and construction is scheduled to begin in 1999.

By December 2005, the Santan Freeway is scheduled to be completed to Arizona Avenue. The portion from Price Road to Arizona Avenue will include a pump station at Dobson Road and a siphon under the Price Freeway.

5.3 Intergovernmental Agreements

Several Intergovernmental Agreements (IGAs) have been signed relative to stormwater discharge from the City of Chandler through the Price Drain and South East Valley Regional Drainage System. The following summaries discuss the tasks each participant agreed to in the IGAs relative to intent, costs, monitoring, quantity, and quality of stormwater discharge.

Price Drain

On January 25, 1988, an agreement was signed by the City, Mesa, the ADOT, and FCDMC for the Price Drain from the Carriage Lane Basin to the Salt River along the Price Expressway and Pima Freeway. The intent of the agreement was to define the responsibilities for the Arizona Department of Transportation, the Flood Control District of Maricopa County, the City of Mesa, and the City of Chandler for the Price Drain. The project costs were shared by the ADOT (68.5 percent), FCDMC (31.5 percent), Chandler (6.19 percent and no more than $2.78 million), and Mesa (8.26 percent and no more than $3.71 million). The agreement allotted 230 cfs peak discharge capacity in the system for stormwater from the Carriage Lane Basin. Of the total 230 cfs capacity, Chandler was allotted a peak flow capacity of 100 cfs and Mesa was allotted 30 cfs. The remaining 100 cfs was unallotted and could be sold to another entity. Off peak capacity was divided among the four agencies as follows:

- State 70.7 percent
- FCDMC 5.2 percent
- Chandler 10.3 percent
- Mesa 13.8 percent

ADOT agreed to design and construct the facilities, obtain rights-of-way and retain titles, operate and maintain the Price Drain, and establish an operating and scheduling agreement with Chandler and Mesa for controlled releases and maintenance. The FCDMC agreed to handle payments from the cities and review plans and specifications. Chandler and Mesa agreed to construct, operate, and maintain all facilities built to convey their stormwater to the Price Drain inlet at the Carriage Lane Basin or to pipelines constructed by ADOT. Water quality and monitoring were not mentioned in the IGA.

Price Freeway Acceleration

On February 13, 1991, the City of Chandler and ADOT signed an agreement to accelerate construction of the Price Freeway from Galveston Street to Frye Road including drainage facilities. ADOT agreed to acquire the rights-of-way, design, bid, and administer the project, and provide 100 cfs capacity to Chandler. ADOT also agreed to allow Chandler to use the detention basins until completion of the drainage system. The City agreed to advance $5,000,000 for the project, with an additional $1,600,000 in July 1991, and an additional $1,500,000 in July 1992. After construction, Chandler agreed to maintain the project until the mainline section of the Price Freeway is completed. Maintenance was to include sweeping, debris removal, street drainage system maintenance, pavement surface repairs, etc. There was no mention of water quality in the agreement.

Gila Floodway Improvements and Stormwater Discharge

ADOT and the Gila River Indian Community (GRIC) signed an agreement on July 3, 1991, concerning the Gila River floodway/greenbelt (as shown in the GRIC Gila Borderlands Conceptual Master Plan in the historic Queen Creek floodplain), borrow material, and stormwater discharge related to the Santan and Price Freeways. GRIC agreed to allow ADOT to purchase borrow material from the floodway, allow ADOT to perpetually discharge stormwater runoff from the watershed intercepted by the Price and Santan Freeways drainage system into the floodway, review and approve design plans for the floodway, and facilitate and coordinate inter-agency cooperation in design and implementation of the floodway.

ADOT agreed to improve the Gila Drain along the Santan Freeway alignment to the beginning of the floodway channel on GRIC lands, coordinate with SRP and FCDMC, design the floodway greenbelt on the reservation, provide storage volume in the floodway greenbelt to contain the runoff volume from the Price and Santan Freeways before discharging, obtain federal approvals and permits, and "meet any State, Federal, and GRIC water quality standards and requirements which are now or may be in place in the future, including development of a water quality monitoring plan approved by respective agencies." ADOT also agreed to revegetate all areas, prepare environmental statements, archaeological surveys, acquire GRIC permits and approvals, give water rights for the discharged stormwater to GRIC, coordinate with GRIC during development of South Mountain and Santan freeways, provide freeway access to the new freeways for the GRIC lands at no cost to GRIC, and pay $360,000 to GRIC to "secure a perpetual drainage easement to outfall stormwater from the Price and Santan Freeways into the new Gila Drain Floodway."

South East Valley Regional Drainage System

An agreement signed May 14, 1997, defined responsibilities for ADOT, FCDMC, and Chandler for permitting, design, acquisition of right-of-way, utility relocations, construction, construction management and administration, and operations and maintenance of the South East Valley Regional Drainage System (SEVRDS) project. The SEVRDS project consists of the drainage system for the portion of the Santan Freeway (SR-202L) between I-10 and Price Expressway (SR-101L).

ADOT agreed to acquire right-of-ways and permits, serve as lead agency and pay costs for design and utility relocations, conduct public meetings or other public involvement activities, remove structures or utilities requiring demolition, fund 100 percent of non-drainage features, monitor construction, fund landscaping and aesthetics, and assume operation and maintenance responsibility. FCDMC agreed to participate in the design selection committee, review and comment on utility relocations, fund construction costs for part of the project, manage the bidding and construction administration, acquire and have installed the equipment necessary to establish a monitoring station to collect water samples and data for discharges to the project outfall channel, and operate and maintain the monitoring station and have samples analyzed for 5 years. Chandler agreed to provide City permits and City-owned right-of-way at no cost, fund $1.1 million, review and comment on the design, reroute private utilities from the right-of-way, monitor construction, participate in public involvement, and fund any additional Chandler requested facilities. After 4 years ADOT, FCDMC, and the City will determine who will operate the water quality monitoring station, if necessary.

Detroit Basin

Section 6 Area A Evaluation

Section 6
Area A Evaluation

This Master Plan encompasses the entire 71-square miles of the City of Chandler. However, the City has been divided into three separate study areas (A, B, and C) to allow a more in-depth study of the prevalent conditions common to each individual study area. The study area boundaries are shown on Figure 2-1. Area A consists of the older part of the City which was initially developed prior to the establishment of drainage standards or criteria. Area A contains approximately 4-square miles, which includes the downtown part of Chandler containing the City Hall complex and the San Marcos Hotel. This section describes the concerns, previous recommendations, current status, alternatives evaluated, and recommended solutions for the following items:

- Area A - localized ponding
- Area A - Regional Stormwater Management
- Area A - Discharge to ADOT Basin G
- Area A - Discharge to ADOT Basin H

6.1 Area A Localized Ponding

Concerns

Localized ponding concerns has been prevalent in the older downtown area, which was developed before drainage standards were implemented. The existing storm drainage systems in this area were developed in response to these concerns rather than as a planned overall system. Streets in Area A that have concerns with water ponding and lack of drainage during and after storms (shown in Figure 6-1 in the pouch) were identified:

- Erie Street between Arizona Avenue and Alma School Road carries large amounts of stormwater west to the Galveston Basin. The street floods during storms and water can remain ponded in the front lots of some buildings after a storm.
- Hartford Street between Ray Road and Galveston Road carries large amounts of stormwater, and the intersections flood during storms.
- An interim drywell has been constructed, however, ponding still occurs at the western-most end of Ivanhoe Street at Evergreen Street.
- Ponding occurs at Dublin and Hartford Streets and at Oakland and Cheri Lynn Streets.
- Ponding occurs along portions of Pleasant Drive and Delaware Street in Area A after significant storms.

6.1.2 Previous Recommendations

The 1992 Master Plan Update recommended installing a drain along Hartford Street to Erie Street and west to the Arrowhead Basin. This drain was recommended to reduce ponding and the amount of runoff flowing in Galveston, Erie, and Hartford Streets. Solutions were identified for other miscellaneous ponding concerns for other portions of Area A.

6.1.3 Current Status

Since 1992 the City has constructed numerous storm drains in Area A as a part of redevelopment in the downtown area and to reduce ponding concerns. Two sections of pipe were abandoned when recent drainage improvements were constructed as a part of the A.J. Chandler Park improvements. The following drains were replaced in the City Center area and new pipes were connected to the Arizona Avenue storm drain:

- A 24-inch line originating just west of Arizona Avenue previously flowed west on Chandler Boulevard to Hartford Street. This pipe no longer conveys stormwater; inlets to this pipe were removed during the repavement of Chandler Boulevard.
- A 15-inch line originating at Chicago Street previously drained north on Dakota Street to the 24-inch line at Chandler Boulevard. Prior to the paving and storm drain improvements on Arizona Avenue in the early 1980's, this line received runoff from west-flowing storm drains (15-inch diameter or less) along Buffalo Street and Boston Street that originally began east of Arizona Avenue. However, when Arizona Avenue was improved, these old lines were cut and portions removed.

Drains, scuppers, and on-site basins were installed to reduce localized flooding in the Detroit Basin drainage area as shown in Table A-1 in Appendix A:

- 18-inch diameter pipe in Hamilton Street from Detroit Street to Flint Street and south to the pipe in the Hamilton-Detroit intersection.
- 18-inch diameter pipe in Exeter Street from Erie to Galveston Street and south to the Detroit Basin.
- Scuppers and retention basins were installed along the north and west sides of Hamilton and Harrison Streets for a new development and to reduce ponding at the intersection.

In the Denver drainage area the City has installed a number of new catch basins and drains to reduce ponding. The sizes and pipe materials for these improvements are listed in Table A-2 in Appendix A. The projects included:

- Catch basins and pipe were installed to drain the City Center pedestrian mall area near Commonwealth Street and Colorado Street to the Arizona Avenue storm drain.
- Existing catch basins at Buffalo Street and Arizona Place were repaired and connected to the Arizona Avenue storm drain.

- Catch basins and pipe were installed to drain the intersection of Dakota Street and Chicago Street to the San Marcos storm drain in Frye Road.
- 24-inch diameter pipes were installed, running west along Kesler Lane, Morelos Street, and Saragosa Street to Arizona Avenue.
- The Arizona Avenue improvements reduced ponding at Arizona Avenue and Saragosa Street, Arizona and Morelos Street, and Arizona and Kesler Lane.
- A 24-inch diameter pipe was installed along Frye Road from Alma School Road to Nebraska Street. The pipe drains into the 84-inch diameter pipe to the Denver Basin.
- Improvements to Arizona Avenue from Pecos Road to Frye Road addressed ponding concerns at the intersections of Pecos Road and Arizona Avenue, Elgin Street and Arizona Avenue, and Fairview Lane and Arizona Avenue. A 24-inch diameter pipe was installed at Pecos Road and Arizona Avenue which drains north to Frye Road, enlarges to 48-inches, and empties into the 72-inch pipe in Frye Road which drains to the Denver Basin.
- A new drain pipe system was installed to reduce ponding on Dakota, Commonwealth, California, Chicago and Boston Streets.
- Catch basins were installed at the intersections of Palm Lane and Kesler, Geronimo, Saragosa, Frye, and Elgin to reduce ponding.
- Catch basins were installed at the intersection of California and Kesler connecting to an 18-inch diameter storm drain.
- Catch basins were installed at the intersections of Elgin Street and California, and Elgin and Nebraska connecting to an 18-inch storm drain.
- Catch basins were installed along Nebraska Street between Elgin Street and Frye Road.

Since 1992, the City has completed miscellaneous other drainage improvements in Area A to resolve localized concerns. They are shown on Figure 6-1 and include:

- Pleasant Drive and Oakland Street: Junction box with flap gate and drywell were installed to mitigate flooding at the intersection.
- Detroit Street and Evergreen Street: Two drywells were installed.
- Hartford Street and Shannon Street: Two new drywells were installed to replace old non-functioning wells.

As shown by the number of improvements completed in Area A, the City has significantly reduced localized ponding in Area A since 1992. The remaining ponding concerns are located between Ray Road and Chandler Boulevard and between Arizona Avenue and Alma School Road.

Alternatives Evaluated

Erie-Hartford Area

Alternatives were identified and reviewed to reduce or eliminate the ponding concerns east of Alma School Road. Since no land is available for retention, installing storm drains in several streets were identified. All of the alternatives would connect to the Alma School Road storm drain and drain to the Galveston Basin. They included:

- The Ray Road Drain, an extension of the Alma School Road Drain in Ray Road farther east.
- The Ivanhoe Drain, a drain in Ivanhoe Street connecting to the Alma School Road Drain.
- The Galveston Drain, replacing the Chandler Drain in Galveston Street.
- The Erie Drain, a drain west along Erie Street.

Ray Road is a major arterial street, and the ponding concerns are located south and downstream from this location. In addition, the City prefers not to disrupt traffic. For these reasons, the Ray Road alternative was discarded.

Ivanhoe Street is near several of the ponding locations. This street will be extended towards Alma School Road by the developer of a new housing development. As a part of the street construction and to drain the new area, a storm drain will be installed west of Jay Street in Ivanhoe Street. The Ivanhoe Drain will help reduce ponding concerns farther east and is a feasible option.

The Galveston Drain would replace the Chandler Drain, which provides limited drainage along Galveston Street. SRP may still use the drain for tailwater discharges. As a result, the Chandler Drain is not recommended to be replaced by a larger drain.

The Erie Drain is located near several other ponding locations. This drain was recommended in 1992 to reduce ponding concerns and to drain the areas with ponding west to the Arrowhead Basin. The Erie Drain will be connected to the Alma School Road Drain until the regional system is completed.

Based on feasibility, ease of construction, and reduction or elimination of disturbances to traffic and neighborhoods, storm drains were recommended along Erie and Ivanhoe Streets with laterals extending to ponding areas in Hartford Street, and to Oakland and Cheri Lynn Streets.

Other Areas

Ponding occurs along portions of Pleasant Drive and Delaware Street in Area A after significant storms. Options to solve these concerns include:

- Enlarge retention basins or install drywells on Pleasant Drive between Knox Road and Pleasant Lane, and between Pleasant Lane and Orchid Lane to prevent ponding. Estimated cost is $12,000.

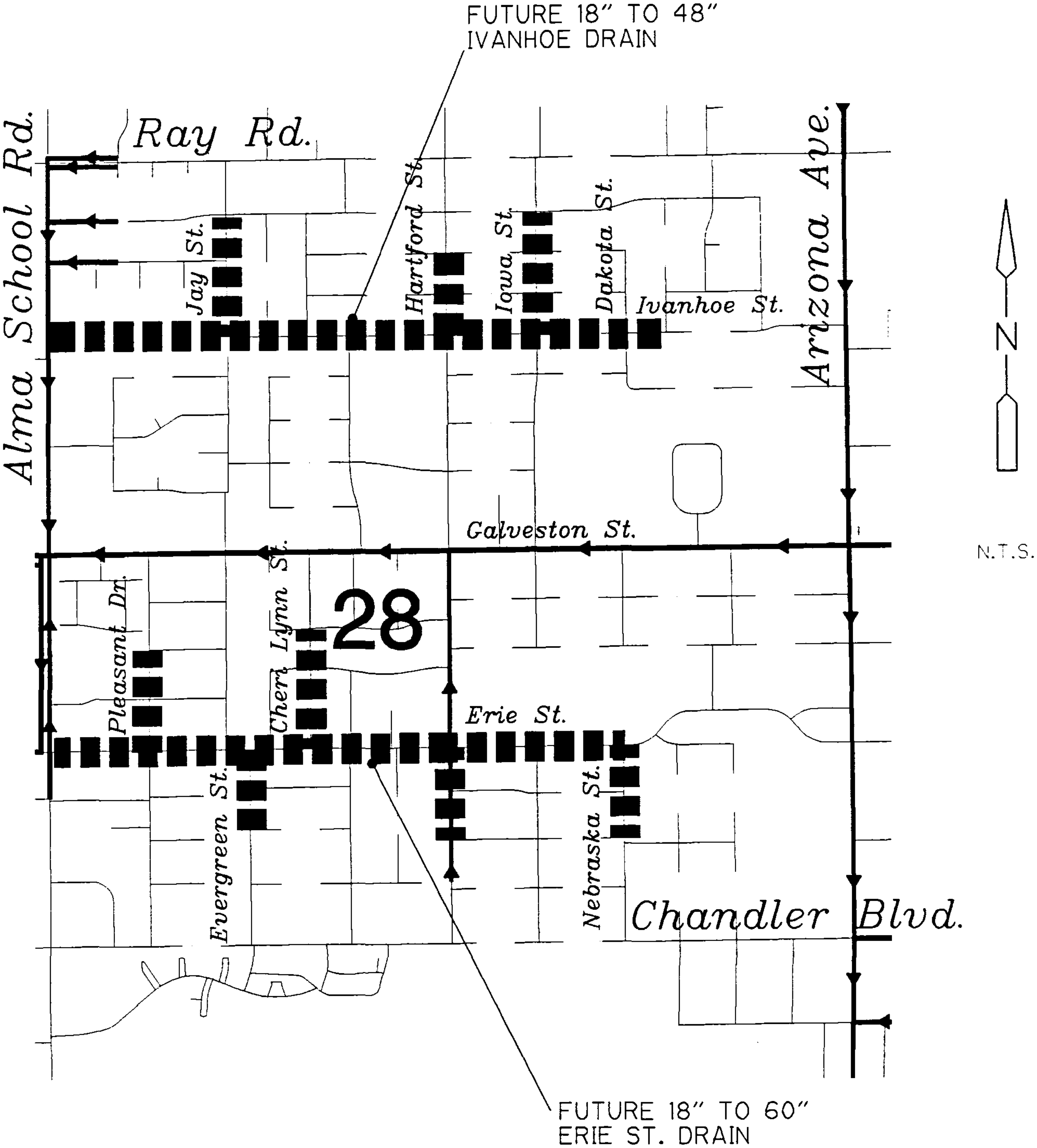
- Install catch basins along Delaware Street between Erie Street and Chandler Boulevard to connect to the storm sewer and reduce ponding. Estimated cost is $14,000.

Recommendations

To reduce localized ponding concerns in Area A, CDM recommends installing storm drains along Ivanhoe and Erie Streets. In addition, improvements are recommended for retention basins on Pleasant Drive and catch basins in Delaware Street to reduce ponding. The following sections describe the Ivanhoe and Erie Drains.

Ivanhoe Storm Drain

The Ivanhoe Drain is recommended to drain runoff from Ivanhoe Street west to the Alma School Road Drain. The drain will be sized to collect runoff from the new development between Evergreen and Alma School Road in addition to the portions farther east. The Ivanhoe Street Drain will consist of a trunk line in Ivanhoe Street from Alma School Road to Dakota Street. Laterals running to the north from the trunk line are proposed for Jay, Cheri Lynn, Hartford, and Iowa Streets. See Table 6-1 for pipe sizes. The pipe will be connected to the Alma School Road storm drain and drain to the Galveston Basin as shown in Figure 6-2. The estimated cost for the Ivanhoe Drain is $961,000.



LEGEND

EXISTING STORMDRAIN

FUTURE STORM DRAIN

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ERIE ST./IVANHOE ST. STORM DRAINS

FIGURE 6-2

Table 6-1 Ivanhoe Drain Pipe Sizing			
Phase	**Pipe Section**	**Length (ft)**	**Pipe Diameter (in.)**
I	Ivanhoe Street: Alma School Road to Evergreen Street	1,350	42
I	Jay: Ivanhoe Street to Linda Lane	180	24
II	Jay: Linda Lane to Shannon Street	620	24
II	Ivanhoe Street: Evergreen Street to Cheri Lynn Street	400	42
III	Ivanhoe: Cheri Lynn Street to Hartford Street	940	36
III	Ivanhoe Street: Hartford Street to Iowa Street	600	36
III	Ivanhoe Street: Iowa Street to Dakota Street	850	24
III	Hartford Street: Ivanhoe Street to Dublin Street	510	24
III	Iowa Street: Ivanhoe Street to Shannon Street	800	24

Erie Storm Drain

The Erie Drain is recommended to reduce ponding by providing drainage to the Alma School Road Drain and Galveston Basin. The limited capacity of the Alma School Road storm drain and its inlet elevation will dictate how fast the area drains to Galveston Basin. The Erie Street system will consist of a storm drain trunk line in Erie Street extending from Alma School Road to Nebraska Street. Lateral pipelines connecting to the trunk line are proposed for Pleasant Street and Cheri Lynn Street between Erie Street and Oakland Street, and for Evergreen, Hartford and Nebraska Streets between Erie Street and Detroit Street. See Figure 6-2. The existing storm drain lines in Hartford Street south of Erie Street will be replaced with new larger pipe. The pipe sizes for the proposed Erie Drain are shown in Table 6-2. The estimated cost for the Erie Drain is $1,972,000.

The Chandler Drain in Galveston Street will remain in place, as is, with the exception that a portion of the Hartford Street Drain line will be disconnected from the Chandler Drain and replaced with a drain connecting to the Erie Street trunk line. The location of the Erie Street storm drain will significantly reduce the amount of runoff being carried by the existing Chandler Drain.

The Erie Drain is recommended to be disconnected from the Alma School Road Drain and extended west to Arrowhead Basin when Arrowhead Basin is connected to ADOT Basin G and funding is available. This is discussed in more detail later in this section.

Table 6-2 *Erie Drain Pipe Sizing*			
Phase	***Pipe Section***	***Length (ft)***	***Pipe Diameter (in.)***
I	Erie Street: Alma School Road to Pleasant Drive	600	54
I	Erie Street: Pleasant Drive to Evergreen Street	600	48
I	Erie Street: Evergreen Street to Cheri Lynn Street	400	48
I	Erie Street: Cheri Lynn Street to Sunset Drive	300	48
I	Erie Street: Sunset Drive to Hartford Street	700	42
I	Pleasant Drive: Erie Street to Oakland Street	700	30
I	Cheri Lynn Street: Erie Street to Oakland Street	800	18
I	Evergreen Street: Detroit Street to Erie Street	500	30
II	Erie Street: Hartford Street to Nebraska Street	1150	30
II	Hartford Street: Detroit Street to Erie Street	650	30
II	Nebraska Street: Detroit Street to Erie Street	650	24
III	Erie: Alma School to Central	1,300	60
III	Erie: Central to Arrowhead Basin	1,300	60

Other Ponding Concerns

To reduce ponding on Pleasant Drive and Delaware Street, several items are recommended. Existing retention basins should be expanded and have drywells installed on Pleasant Drive between Knox Road and Pleasant Lane, and between Pleasant Lane and Orchid Lane. In addition, catch basins should be installed along Delaware Street between Erie Street and Chandler Boulevard to connect to the existing storm drain. The estimated cost is $26,000 for the improvements.

6.2 Area A Regional Stormwater Management

Concern

There are four regional retention basins in Area A. The existing system is shown in Figure 6-1 in the pocket. The existing drainage areas for each regional basin are shown in Figure 6-3. Runoff from the 100-year, 2-hour storm from the drainage areas will result in more water than the basins are sized to hold and dispose of by infiltration within 36 hours. As a result, the Detroit Basin drains to the Denver Basin and the Denver, Galveston and Arrowhead Basins have permits to discharge to the SRP irrigation system. The maximum discharge rate is 2 cfs from each basin. These permits are revocable and SRP is trying to phase out municipal drainage connections to its system due to the following concerns:

- SRP's system will be unable to provide the necessary capacity to meet the increasing needs for municipal stormwater drainage;
- SRP may be held liable for damages due to its inability to accept discharges from permitted basins or due to flooding if its structures overflow during storms;
- Municipal storm runoff in SRP's irrigation system might adversely affect water quality for downstream users.

The SRP irrigation system is not well suited to function as a drainage system. In irrigation systems, the lines become smaller as water is distributed downstream. For an effective stormwater drainage system, the lines must become larger as stormwater is collected and conveyed downstream for ultimate disposal.

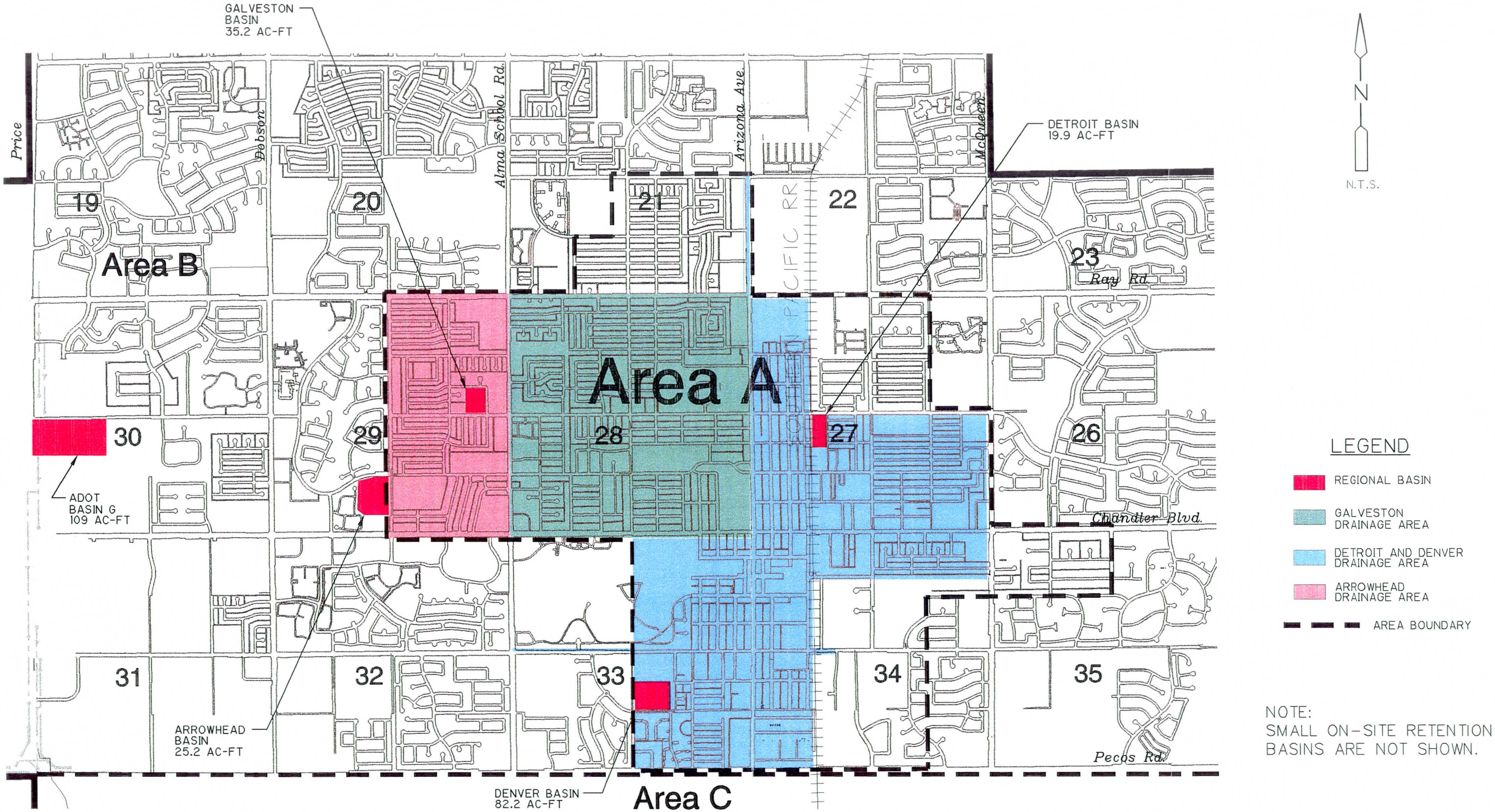
In the older part of Chandler (Area A), there are also isolated instances of catch basins or street drains which are directly connected to SRP lines and SRP lines which drain into the Chandler storm drain system. One example is the SRP pipe which discharges into the Arrowhead Drain at Ivanhoe Street.

Previous Recommendations

1986 Master Plan

The original Stormwater Master Plan (1986) evaluated five alternatives for discharges of stormwater runoff from Area A. They included:

- Retention and a Regional Drainageway: basin discharges would discharge through a gravity and force main pipe system with ultimate disposal to the Salt River.
- Retention with Drywells: Basin discharges into drywells for disposal into the groundwater table.



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AREA A DRAINAGE BASINS - EXISTING
FIGURE 6-3

- Stormwater Treatment and Reuse: Collection and treatment of stormwater at the Ocotillo WWTP.

- Stormwater Utilization in a Lake System: Collect and use stormwater in artificial lakes.

- Detention and Drainageway through the Gila River Indian Community: Gravity drain south and west across GRIC land to the Gila River.

Based on feasibility and costs, the regional drainageway was recommended in the 1986 Master Plan. The 1986 recommended plan would drain stormwater from the downtown area to a channel along Pecos Road, which would connect to the Price Road Drain and discharge into the Salt River.

1992 Master Plan Update

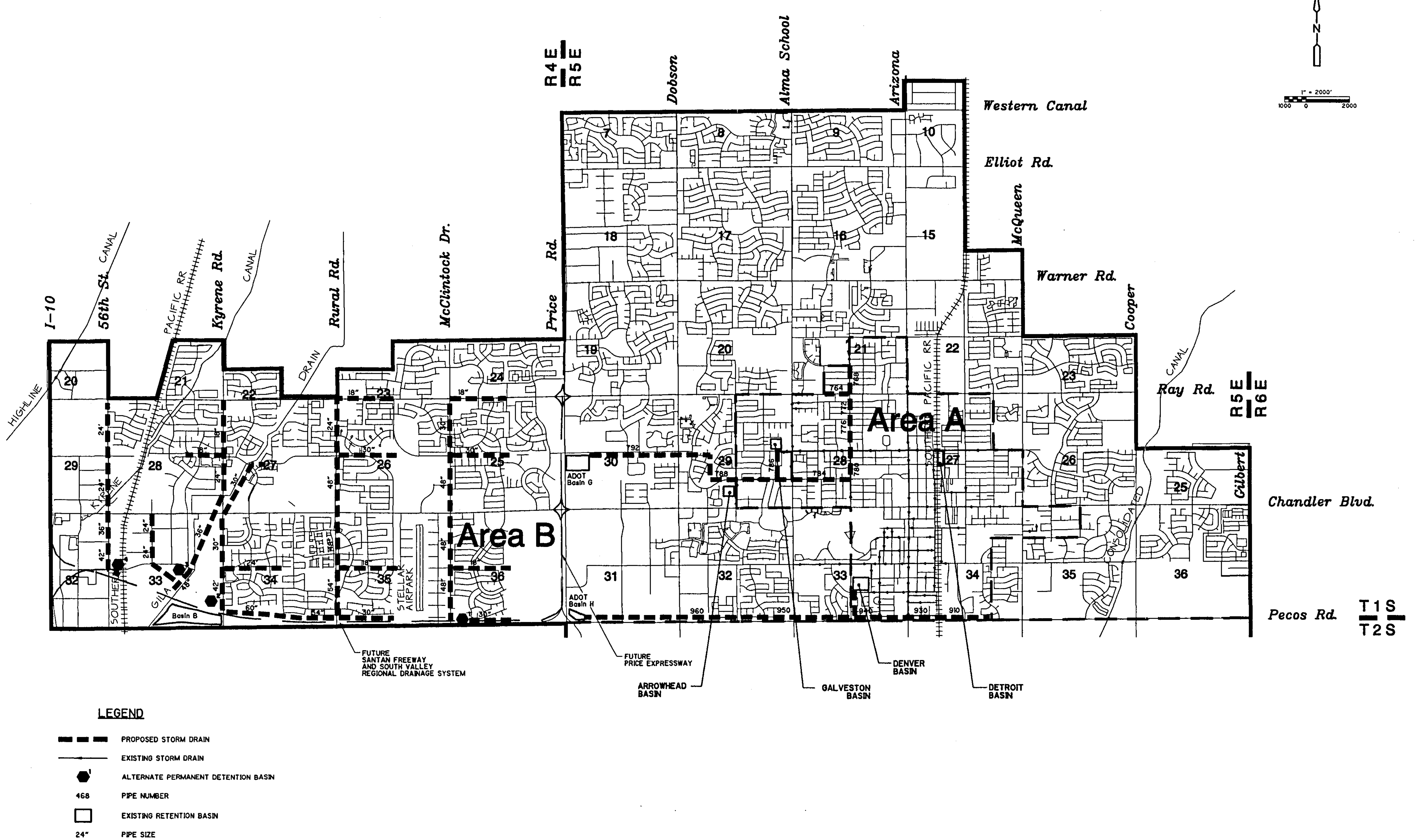
The 1992 Master Plan update revised and re-evaluated the 1986 recommendations to integrate with the future freeway drainage system, which had been revised to drain to both the Salt and the Gila Rivers. The 1992 update recommended several improvements to connect the downtown drainage system to ADOT Basins G and H and the proposed freeway drainage channels, and to provide the required flood protection for the downtown area. The 1992 recommendations are listed in Table 6-3 along with their status in 1998. They are also shown on Figure 6-4.

Table 6-3
Area A 1992 Recommendations and Current Status

1992 Recommendation	*1998 Status*
Reserve 100 acre-feet storage for Downtown Chandler in Basin G as preliminarily agreed to by ADOT	Basin G was designed and constructed by ADOT with a total volume of 108 acre-feet. Drywells and outlet pipes will drain the basin. Until the drainage system downstream from the basin is constructed, the outlet pipes are blocked. Only local runoff is routed to Basin G at this time.
Review the ADOT plans for the construction of the 60 ac. ft. temporary retention basin (Basin H) at Price and Pecos Roads	Basin H was constructed by ADOT. Only local runoff is routed to this basin now.
In the interim condition, no outlet will be provided for Basins G and H, thus ADOT will maintain and control nuisances/hazards	In the ADOT/FCDMC/Chandler IGA, the City agreed to maintain the project until the mainline section of the Price Freeway is completed. Maintenance includes sweeping, debris removal, street drainage, system maintenance, pavement surface repairs, etc. ADOT agreed to allow Chandler to use the detention basins until completion of the drainage system.

Table 6-3
Area A 1992 Recommendations and Current Status

1992 Recommendation	1998 Status
Install a new storm drain system in Hartford and Erie Streets ending with a 72-inch pipe along Galveston Street to convey 140 cfs into Basin G from the drainage area east and south of the Galveston Basin (pipes 767 through 792 in Figure 6-3).	The size and cost of this project have prevented the City from constructing it. The first portion, storm drains in Erie and Ivanhoe Streets, is currently being designed.
Install a new storm drain system (pipes 910 through 960 in Figure 6-3) ending with a 54-inch pipe along Pecos Road to convey 90 cfs from the Denver Basin into temporary Basin H in the interim. In the long term, connect the 54-inch storm drain along Pecos Road to a proposed ADOT siphon under Price Road which will replace Basin H.	The pipes have not been installed. The size and cost of this project will require phasing to complete it. The ADOT siphon has not been constructed.
Increase outlet rates from downtown retention basins from 2 cfs to 35 cfs for the Denver Basin, and 10 cfs each for the Galveston and Arrowhead Basins.	The discharge piping and pump station upgrades have not been installed.



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1992 MASTER PLAN UPDATE RECOMMENDED PLAN

FIGURE 6-4

Current Status

Existing Systems

The existing drainage systems consists of storm drain conveyance lines draining to four stormwater basins, which retain the water and allow infiltration. The existing configuration of regional basins, drainage areas, and major storm drain lines in Study Area A are shown in Figure 6-1 (in the pocket). The existing basins include: Galveston Basin, Arrowhead Basin, Detroit Basin, and Denver Basin.. Smaller on-site basins are also shown in Figure 6-1.

Galveston Basin

The Galveston Basin is located just west of Alma School Road on Galveston Street as shown in Figure 6-1 (in the pocket). It was constructed by the City and was not designed to hold a particular design storm but rather to fit the area available for a basin. Design calculations indicated that the basin can hold a volume corresponding to the 2-year, 24-hour storm runoff (35.2 acre-feet) from its drainage area. Its drainage area is bounded approximately by Ray Road on the north, Arizona Avenue on the east, Chandler Boulevard on the south, and Alma School Road on the west. The Galveston Basin is grassed and landscaped on the berms and slopes, but does not serve as a neighborhood park. The City plans to install playing fields in the bottom of the Galveston Basin.

The basin has pumped discharge to SRP Lateral 13.0 by means of an 8-inch PVC force main to a junction box located at Alma School Road and Galveston Street which allows discharge to a 24-inch concrete pipe abandoned by SRP, which is the downstream portion of the Chandler Drain. The Chandler Drain flows south along Alma School Road to Erie Street, then west on Erie to an SRP drainage ditch at Arrowhead Drive. The ditch drains to existing SRP Lateral 13.0 (48-inch concrete pipe) at Chandler Boulevard. The discharge is permitted by SRP, and limited to a maximum rate of 2 cfs.

The storm drain collection lines feeding this basin are the Alma School storm drain and the Chandler Drain. The Alma School Drain runs from Ray Road south to Galveston Street to the basin and from Flint Street north to Galveston Street to the basin. Catch basins were installed at Pleasant Drive and Ray Road with pipe to the Alma School storm drain. The Chandler Drain originates at Galveston Street and McQueen Road by means of a 12-inch pipe to Arizona Avenue, then a 16-inch pipe to Hartford Street, and a 24-inch pipe to Alma School Road. Catch basins at Sunset Drive,

Cheri Lynn Street, Evergreen Street, Jay Street, Galveston Street, and Alma School Road are inlets to the Chandler Drain. At Alma School Road, flow in the Chandler Drain is diverted to the Galveston Basin. The Chandler Drain still collects irrigation tailwater during dry periods. The Galveston Basin also collects runoff from Galveston Road which drains from Hartford Street to Alma School, and in Hartford Street from Galveston Street to Detroit Street. The map of the existing storm drain system in Study Area A, which is included as Figure 6-1, shows the location of the basin and the location, size, and direction of flow of the storm drain lines. A tabular description of the Alma

School storm drain is included in Appendix A as Table A-3. The Chandler Drain is listed in Table A-4 in Appendix A.

One older pipeline exists in the Galveston drainage area. It is a line of 24-inch diameter which flows north on Hartford Street to the Chandler Drain at Galveston Street. Table A-5 in Appendix A lists the details of this drain. The catch basins at Oakland and Hartford Street are reported to be connected to this Hartford Drain. It improves drainage locally, but does not resolve all concerns along its alignments due to inadequate capacity of lines and inadequate number of catch basins.

Arrowhead Basin

The Arrowhead Basin is located at the southwest corner of Arrowhead Drive and Erie Street. It was designed to contain the 100-year, 6-hour storm runoff (25.2 acre-feet) from its 320-acre drainage area. Its drainage area is bounded approximately by Ray Road to the north, Alma School Road to the east, Chandler Boulevard to the south, and Arrowhead Drive to the west. A storm drain collection line is located along the west side of Arrowhead Drive between Ray Road and Chandler Boulevard. SRP has agreed to allow the Arrowhead Basin to pump into SRP lateral 13.0 at a maximum rate of 2 cfs. See Appendix A, Table A-6 and Figure 6-1 for the details of the Arrowhead Drive storm drains.

Detroit Basin

The Detroit Basin is located just east of the Southern Pacific Railroad between Galveston and Erie Streets. It has been designed to contain the 100-year, 6-hour storm (19.9 acre-feet) runoff from its drainage area. Its drainage area is bounded approximately by Galveston Street on the north, McQueen Road on the east, Chandler Boulevard on the south, and the Southern Pacific Railroad on the west. The Detroit Basin discharges to the Chandler Boulevard storm drain at a rate of 5 cfs. The flow then drains south along Delaware Street to the Denver Basin.

Storm drain lines to convey stormwater to the Detroit Basin consist primarily of a 18-inch x 24-inch corrugated metal pipe arch (CMPA) originating at the intersection of Detroit Street and Hamilton Street, running west on Detroit Street to Nevada Street and then north on Nevada Street to the basin. A concrete sump catch basin exists at the terminus of Detroit Street at the Southern Pacific Railroad where runoff collects due to the railroad berm. The sump is connected to the 18-inch x 24-inch CMPA at Nevada Street by a 12-inch concrete pipe. Nevada Street is drained by a slotted 18-inch storm drain pipe installed along each gutter line and connected to the 18-inch x 24-inch CMPA. Additional scuppers and catch basin inlets exist along the Detroit Basin boundaries along Exeter Street and Erie Street. A tabular description of the Detroit Basin discharge line to Arizona Avenue is included in Appendix A as Table A-7. For a description of the drains to the Detroit Basin see Table A-1 in Appendix A.

Denver Basin

The Denver Basin is located west of Nebraska Street and south of Frye Road adjacent to the San Marcos School as shown on Figure 6-1. It was built by ADOT for retention of stormwater from ADOT's Arizona Avenue storm drain. The basin was designed to hold the 2-year, 24-hour storm runoff volume of 35.6 acre-feet below an elevation of 1194.2, and the 50-year, 24-hour storm (which is equivalent to the 100-year, 6-hour) runoff volume of 82.2 acre-feet below the elevation of 1202.5. The basin was designed with substantial freeboard and can contain 103 acre-feet below the elevation of 1206. Due to the depth and steep side slopes necessary to provide the design capacity, the basin has no function other than stormwater detention.

Discharge from the Denver Basin is pumped to SRP Lateral 13.4 near Pecos Road (a concrete-lined open channel) by means of a 10-inch PVC force main. The discharge is permitted by SRP and is limited to a rate of 2 cfs, which can begin only upon SRP approval.

The storm drain collection lines feeding this basin consist of the Arizona Avenue storm drain, the Chandler Boulevard storm drain, and the Delaware and Fairview storm drains. They are shown on Figure 6-1. The Arizona Avenue storm drain originates at Knox Road and runs south in Arizona Avenue to Frye Road, then west in Frye Road to Nebraska Street, then south in Nebraska Street to the basin. The Chandler Boulevard storm drain, installed by the City east of Arizona Avenue, originates just west of McQueen Road and conveys stormwater runoff west to the Arizona Avenue storm drain at Chandler Boulevard. The Delaware and Fairview storm drains originate on Boston Street east of Colorado Street and run east on Boston Street to Delaware Street, then south on Delaware Street to Fairview Street, then west on Fairview Street to the basin. A lateral to this system conveys flow from the Palm Lane/Pecos Road intersection north along Palm Lane to the drain in Fairview Street.

The map of the storm drain system in Study Area A, Figure 6-1, shows the location of the basin and the locations, sizes, types, and direction of flow of the storm drain lines. A tabular description of the Arizona Avenue storm drain is included in Appendix A as Table A-8 and of the Chandler Boulevard storm drain as Table A-9 in Appendix A. Other, older storm sewers are shown in Table A-10 (Appendix A).

Other Basins in Area A

As shown in Figure 6-1, there are several on-site retention areas in Area A. They include A.J. Chandler Park near City Hall, Folley Park, Tyson Manor, and Apache Park. They do not drain to regional basins, but discharge stormwater through infiltration and percolation.

Freeway System

Since 1992, Basins G and H have been constructed by ADOT to provide stormwater storage capacity. Basin G will be the only available stormwater basin with a gravity outlet in Area A, and the only basin not dependent on SRP canals for drainage. The Erie-Hartford Drain, the outlet from the Denver Basin, and the pump stations at Arrowhead, Galveston, and Denver Basins were not constructed due to project costs and concerns of the City.

The concerns include:

- Pipe size and depth: The City has a goal to minimize pipe size and depth to reduce costs. The 1992 plan showed large diameter 72- and 78-inch gravity pipes draining portions of Area A.

- Full utilization of existing regional basin capacity: The previous plan also showed gravity pipe draining a large portion of Area A directly to Basin G. The City wanted to investigate conveying the water to the regional basins to maximize the use of the existing system.

- The proposed pipeline route through existing residential areas to Basin G: Since 1992 major portions of the land west of Area A have been developed and additional areas are currently being developed; the proposed route should minimize disturbance to existing residences and streets.

These concerns are addressed as a part of this update by evaluating the 1992 update recommendations and other possible alternatives. The following sections discuss regional storm systems, whether to discharge to the freeway systems, and draining to ADOT Basins G and H.

Alternatives Evaluation

Alternatives evaluated for this update included other methods of discharge for Area A instead of discharge to the freeway system, and other methods to drain to the freeway system instead of using ADOT Basin G. These options were studied to verify the 1992 recommendation to discharge to the regional freeway drainage system.

Alternatives to Freeway Discharge

The 1992 recommendation to connect regional basins to the freeway drainage system was reviewed and carefully analyzed. Alternatives to the discharge were developed and studied as listed below. For the three alternatives, the costs to install storm drains along Erie and Ivanhoe streets to the Arrowhead Basin and for the NPDES program implementation were not included.

- Discharge stormwater from the downtown regional basins to the ADOT freeway system and eventually the Gila River. Prior costs: $11,980,000 Future estimated Costs: $9,615,000. Total estimated costs: $21,595,000 (Existing Plan).

- Implement recharge program in the downtown area using the San Marcos golf course for underground storage and percolation in drywells. Preliminary cost estimate: $22,060,000.

- Implement recharge program in the South Chandler Area, pumping the water south of Pecos Road to 75 acres of retention basins for storage and percolation. Preliminary cost estimate: $24,587,000.

Based on the limited land available, estimated costs for the alternatives, and amount spent for the freeway drainage system, connection to the ADOT freeway system was recommended for implementation.

Alternatives to Basin G

To verify that use of ADOT Basin G is the best solution to drain the Arrowhead and Galveston regional basins within 36 hours and to prevent overtopping, several alternatives were evaluated. The alternatives included keeping the existing system and taking no action, adding local retention basins, draining to the freeway channel along another route, and using other existing retention basins. Potential new detention basins should be located south and west of Area A due to the existing roadway and ground slopes. New basins should have a gravity outlet if possible. Alternatives reviewed included:

1. No Action: Not constructing additional storm drains in the downtown area.

2. Installing new basins and drains south and west of Area A. Available locations included (see Figure 6-4):

   — Northeast corner of Chandler Boulevard and Dobson Road
   — Convert Arrowhead Meadows Park to a retention basin
   — Install underground storage pipes and drywells in the San Marcos golf course

3. Expand Arrowhead Basin onto the surrounding property.

4. Construct a drain south to the future Santan Freeway drainage system from Arrowhead and Galveston Basins.

5. Construct a drain to the Denver Basin from the Arrowhead and Galveston Basins.

None of these alternatives offer any significant advantages over using the existing Basin G. The alternatives would require purchasing land, construction of a new basin or enlargement of an existing one, a significant length of new storm drain to drain to the freeway drainage system or other basin, or rely on percolation for disposal. The City has already contributed to the costs for ADOT Basin G and the freeway infrastructure. Basin G is complete and construction is pending for the Price and Santan Freeway drainage systems west of Price Road.

Recommendation

Based on the evaluation of the alternatives to discharge to the freeway drainage system, and the amount of money already invested into this option, CDM recommends continuing with the regional plan to drain the Galveston and Arrowhead Basins to ADOT Basin G. Further refinement of this option is considered in the next section.

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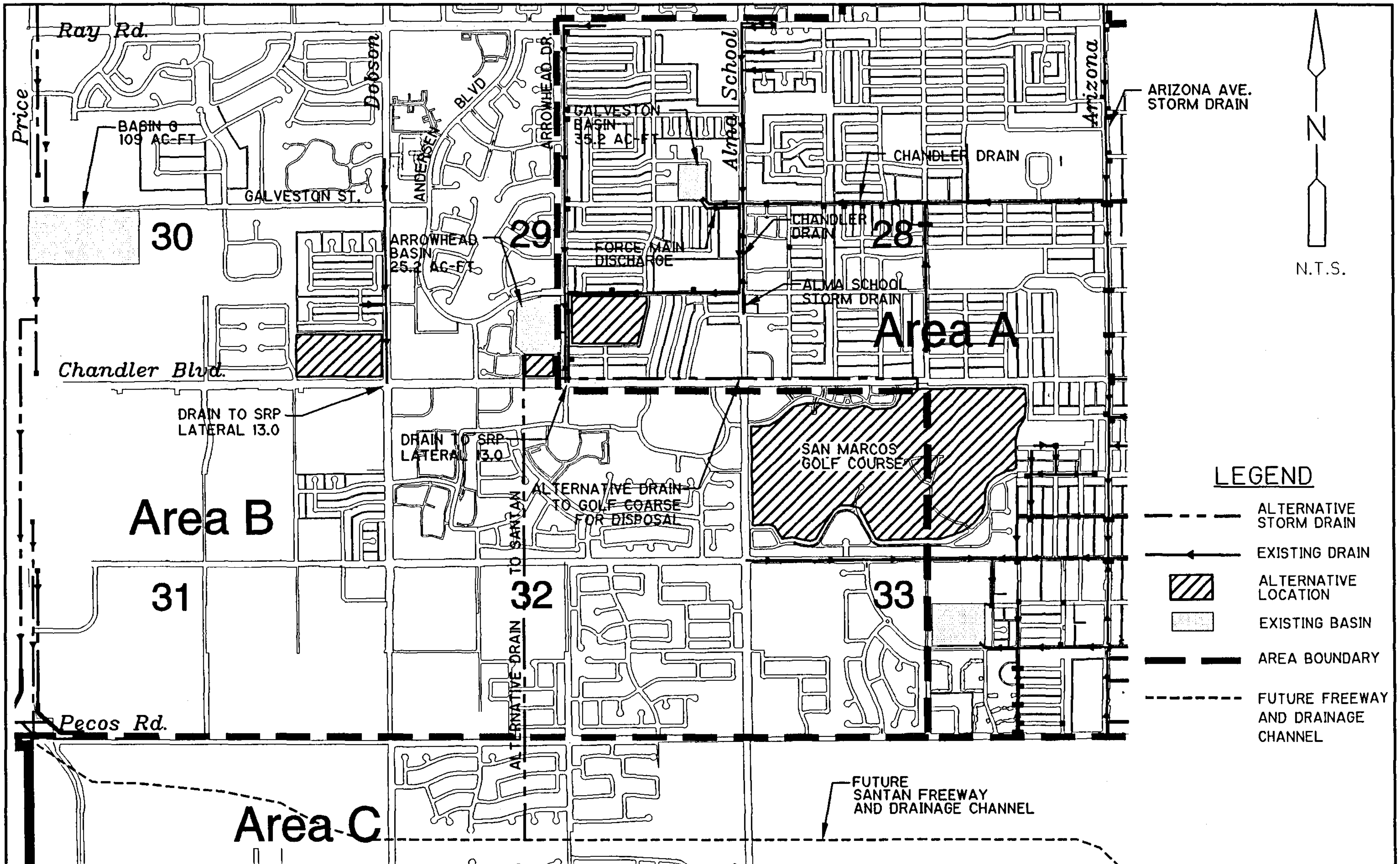

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ALTERNATIVE LOCATIONS FOR RETENTION INSTEAD OF BASIN G

FIGURE 6-5

6.3 Discharge to ADOT Basin G

Concern

The existing regional retention basins do not drain within 36 hours and they are currently connected to the SRP irrigation system. SRP would like to discontinue this discharge, as mentioned in Section 6.2.

Previous Recommendations

The 1992 Update recommended installing a large diameter gravity drain system to convey water south on Hartford Street and west on Erie and Galveston Streets to ADOT Basin G at Price Road. Details of the 1992 recommendations are discussed in Section 6.2.2 and shown on Figure 6-4 and Table 6-1.

Current Status

The City is concerned that the 1992 recommendation for the Erie-Hartford Drain is not the best alternative for connecting to ADOT Basin G. Large pipelines would likely shut down the narrow streets during construction and disrupt the residents. Long lengths of north-south pipe would require deep invert elevations because the north-south topography is flat. The deep inverts would increase installation costs, would not allow connection to the existing Alma School Road Drain, and would preclude using the Galveston Basin as an interim outlet for the Erie-Hartford area. There would also be no alternatives for an interim outlet for the large pipe until the pipe is connected to Basin G.

Alternatives Evaluated

The following sections describe the alternatives evaluated to find the best solution for draining Arrowhead and Galveston Basins to ADOT Basin G. Alternatives to maximize the use of the existing regional basins and minimize pipe sizes were compared. Maximizing basin use meant routing water through the existing basins for peak attenuation to reduce pipe sizes. Pipe sizes were reduced further by adding pump stations and force mains. A preliminary route study was completed for the storm drain pipe to Basin G.

Alternatives to Discharge to Basin G and Maximize Use of Existing System

Five options for draining stormwater from the western portion of Area A to Basin G were developed and modeled using the SWMM model. The model showed the peak flows for the basins and drains for sizing for different design storms. The alternatives included combinations of gravity and force main pipes, pump stations at the basins, and bypassing or routing water through the regional basins. A site survey by CDM determined that gravity drains could connect the regional basins to Basin G with approximately a 0.001 ft/ft slope. See Appendix B for details. The alternatives are as follows:

1. Gravity Storm Drains (1992 Recommendation). East of Alma School Road runoff would be directed into a pipe along Erie Street to the Arrowhead Basin. An outlet from the Arrowhead

Basin would drain to ADOT Basin G. An outlet from the Galveston Basin would also drain to the Arrowhead Basin. (Figure B-1)

2. Routing Water Through the Arrowhead and Galveston Basins by Gravity. A drain pipe would direct the runoff east of Alma School to the Galveston Basin. An outlet from the Galveston Basin would drain to the Arrowhead Basin. An outlet from the Arrowhead Basin would drain to ADOT Basin G. (Figure B-2)

3. Routing Water Through the Two Basins with One Pump Station at Arrowhead Basin. This alternative adds a pump station to drain the Arrowhead Basin to Option 2. (Figure B-3)

4. Routing Water Through the Two Basins with Two Pump Stations, One at Arrowhead Basin and One at Galveston Basin. This alternative adds a pump station to drain the Galveston Basin to Option 3. (Figure B-4)

5. Routing Water Through the Arrowhead Basin with One Pump Station at Arrowhead Basin (Figure 6-6). This option drains the area east of Alma School Road and south of Galveston Street west to the Arrowhead Basin in the Erie Drain. Galveston Basin is drained by gravity to the Erie Drain and into Arrowhead Basin. A pump station and force main discharge the water from the Arrowhead Basin to ADOT Basin G.

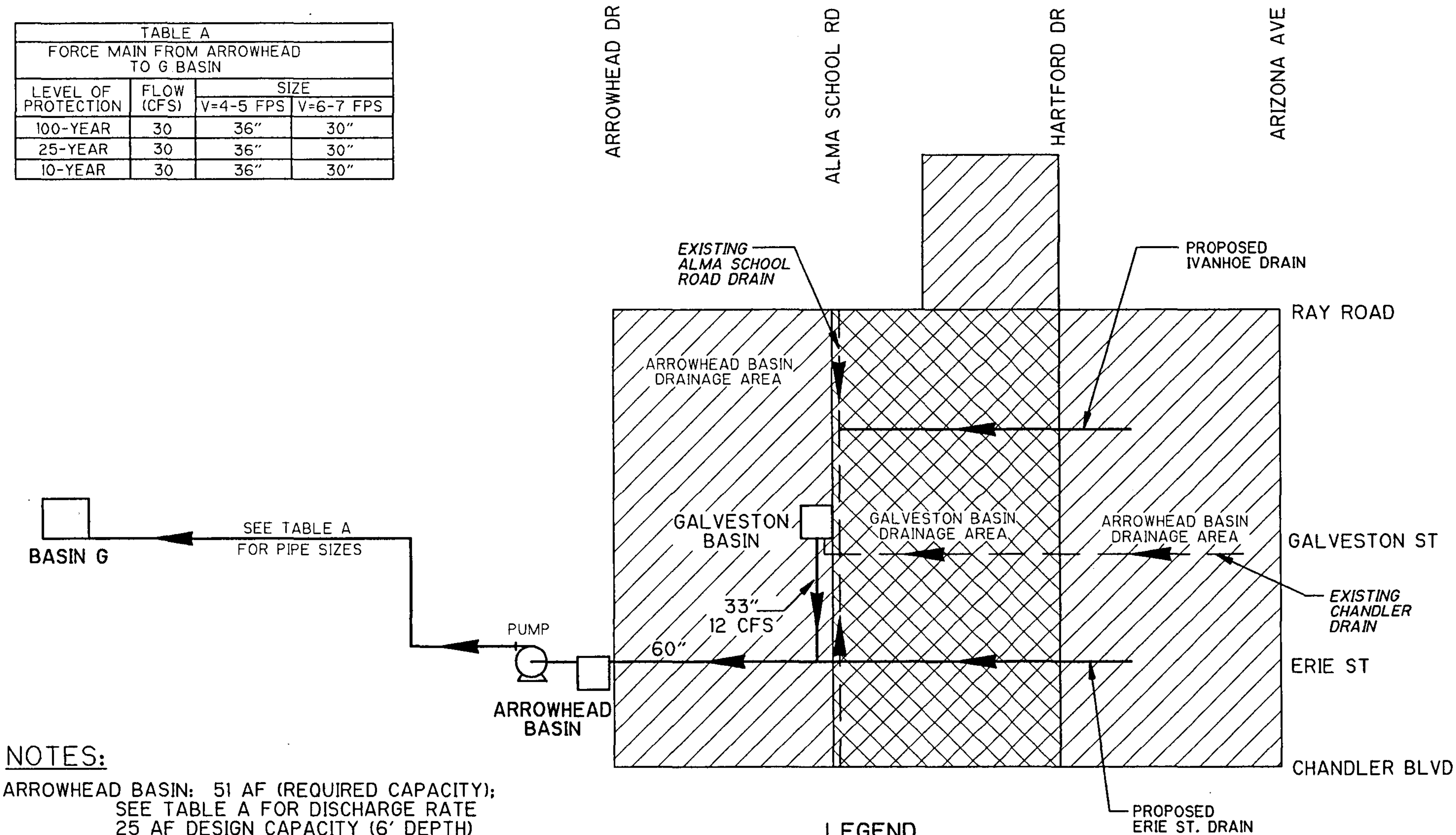
The options are listed in Table B-1 in Appendix B with descriptions, modeling results, pipe sizes, estimated costs, advantages, and disadvantages. Figures for each option are also shown in Appendix B. The development of the options considered the following factors:

- The size of the tributary area for the Galveston and Arrowhead Basins from which the 100-year runoff could be contained within their maximum storage capacities.

- For larger tributary areas where the 100-year runoff exceeded the maximum capacity of the basins, the required discharge rate to avoid overtopping the basins.

Cost estimates were prepared for each of the five options. Pipe unit costs were based on the 1998 Means Construction Data and local project costs. Unit prices include miscellaneous items associated with drainage projects such as manholes, catch basins, pavement replacement, etc. Operation and maintenance costs were neglected since they would not appreciably affect the cost analysis. An additional cost for sewer utility conflicts was added to the options which rely on deep, large diameter gravity pipelines to drain from Arrowhead Basin to Basin G. Table 6-4 shows the costs for the alternatives with three levels of protection. Levels of protection refers to the sizing of the system for a particular sized storm. For the 100-year storm, larger pipes are required than for the 25-year storm. For a gravity system, it was assumed that the system would be sized for the 100-year storm.

TABLE A			
FORCE MAIN FROM ARROWHEAD TO G BASIN			
LEVEL OF PROTECTION	FLOW (CFS)	SIZE V=4-5 FPS	SIZE V=6-7 FPS
100-YEAR	30	36"	30"
25-YEAR	30	36"	30"
10-YEAR	30	36"	30"



NOTES:

ARROWHEAD BASIN: 51 AF (REQUIRED CAPACITY);
SEE TABLE A FOR DISCHARGE RATE
25 AF DESIGN CAPACITY (6' DEPTH)
51 AF MAX CAPACITY (10' DEPTH)

GALVESTON BASIN: 35 AF; 12 CFS DISCHARGE
35 AF MAX CAPACITY (9-10' DEPTH)

LEGEND

PROPOSED STORM DRAINS
EXISTING STORM DRAINS

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OPTION 5 THROUGH ARROWHEAD BASIN WITH ONE PUMP STATION

FIGURE 6-6

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Table 6-4 ***Chandler Basin G Force Main and Pipe Sizing Alternatives*** ***1998 Design and Construction Cost Estimates***					
Cost Summary by Level of Protection					
Design Storm Level of Protection	***Option 1 Gravity System***	***Option 2 Gravity Routing through both basins***	***Option 3 Routing through both basins with Arrowhead pump station***	***Option 4 Routing through both basins with two pump stations***	***Option 5 Routing through Arrowhead Basin with one pump station***
100-year	$7,365,900	$7,025,000	$6,358,000	$8,969,000	$5,427,000
25-year	N/A	$6,477,000	$6,067,000	$8,165,000	$5,427,000
10-year	N/A	$5,938,000	$5,740,000	$6,783,000	$5,427,000

Option 1, the 1992 Update recommendation for gravity drains, is not recommended because the City wants to reduce the pipe size to Basin G to minimize trench size, reduce costs and reduce disturbance during construction.

Option 2, Routing the water through the two basins with gravity pipes, also in not recommended because it requires larger pipes. It also includes a large pipe down Alma School Road to the Galveston Basin. Alma School Road is a main arterial road.

Option 3, Routing the water through both basins with a pump station at Arrowhead Basin also results in a large pipe down Alma School Road.

Option 4, Routing the water through the two basins with two pump stations, costs more than the other options. It also results in a large pipe down Alma School Road.

Option 5, Routing the water through the Arrowhead Basin with one pump station, is the least expensive and takes advantage of the capacity in the Galveston Basin for a 100-year storm for its drainage area without installing a pump station to drain it. It also reduces the pipe sizes from Arrowhead Basin to ADOT Basin G. Installation of a pipe in Alma School Road is avoided.

CDM recommends Option 5, Routing stormwater through Arrowhead Basin with one pump station and a force main to ADOT Basin G. See Figure 6-6.

Pipe Alignment Alternatives from Arrowhead Basin to Basin G

After choosing Option 5, Routing stormwater through the Arrowhead Basin with one pump station, alternatives for routing the force main from Arrowhead Basin to Basin G were evaluated. Several alignments are discussed below and shown on Figure 6-7.

1. Anderson Boulevard: The east end of the forcemain starts at Arrowhead Basin and goes west and north along Anderson Boulevard to Galveston Street. It continues west along Galveston Street, crosses Dobson Road and continues west to Basin G near Price Road.

2. Anderson Boulevard west to Dobson Road: A second option is to follow Anderson Boulevard to approximately Pennington Drive and then head directly west. The land west of Anderson Boulevard is presently undeveloped and a storm drain could be constructed between Anderson Boulevard and Dobson Road along the Detroit Street alignment. Once the line reaches Dobson Road it would turn north and follow Dobson Road to Galveston Street. Then it would follow Glaveston Street west to Basin G.

3. Chandler and Dobson Roads: From the Arrowhead Basin the forcemain would follow Arrowhead Drive south to Chandler Boulevard and from there it would follow Chandler Boulevard west to Dobson Road. At Dobson Road the forcemain would turn north and follow Dobson Road to Galveston Street and turn west to Basin G.

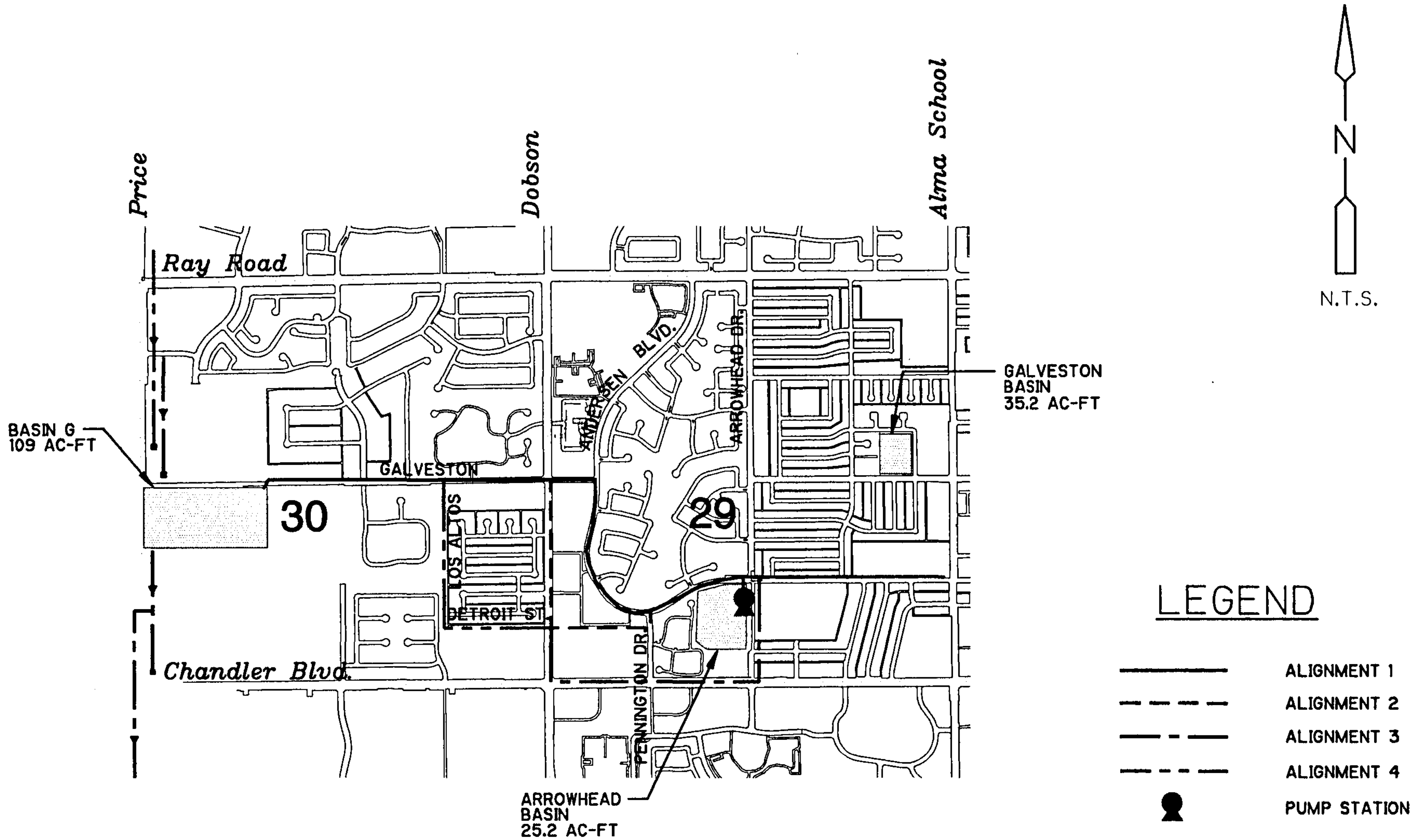
4. Detroit Street west of Dobson Road: This alignment is a continuation of Alignment 2. The forcemain would follow Anderson Boulevard to Pennington Drive, and then the Detroit Street alignment to Dobson Road. At Dobson Road the forcemain will continue west along Detroit Street to Los Altos Drive where it turns north. It would follow Los Altos Drive to Galveston Street and then turn west to Basin G.

Option 1, Anderson Boulevard, is feasible with the drain being constructed in wide residential streets. Sewer lines and house connections are located in Anderson Boulevard which may conflict. Option 2, the Anderson-Dobson alignment, results in the construction of a large diameter storm drain in one-half mile of a busy arterial street (Dobson Road). Option 3, the Chandler-Dobson alignment, has approximately one mile of drain in two major arterial streets. Option 4, Detroit Street West of Dobson Road would result in construction in very narrow residential streets west of Dobson.

To minimize construction along arterial streets or narrow residential streets, CDM recommends Alignment 1 - Anderson Boulevard to connect the Arrowhead Basin to Basin G with a force main. Detailed design and utility routing studies will be required to confirm this recommendation.

Recommendations

To provide an outfall for the area west of Arizona Avenue between Ray Road and Chandler Boulevard, CDM recommends routing the water to ADOT Basin G through the Arrowhead Basin with one pump station at Arrowhead Basin. The Galveston Basin will drain to the Erie drain and Arrowhead Basin by gravity. The Arrowhead Basin pump station will discharge to ADOT Basin G for ultimate discharge to the freeway drainage system and the Gila River. The pipe from Arrowhead Basin is recommended to follow Anderson Boulevard to Galveston Street and then turn west and continue along Galveston Street to Basin G, as shown for Alignment 1 in Figure 6-7.



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PIPE ALIGNMENT ALTERNATIVES
FROM ARROWHEAD BASIN TO BASIN G

FIGURE 6-7

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6.4 Basin H

Concern

In order to drain the Denver Basin within 36 hours, it is connected to the SRP irrigation system. SRP would like to stop this practice, as discussed in Section 6.2.

Previous Recommendations

The 1992 Update recommended installing a pump station and force main to Pecos Road. A drain in Pecos Road was recommended to convey the water west along Pecos Road to ADOT Basin H near Price Road. Section 6.2.2 lists the detailed 1992 recommendations for the Denver Basin and they are shown in Figure 6-3.

Current Status

Denver Basin Drainage Area

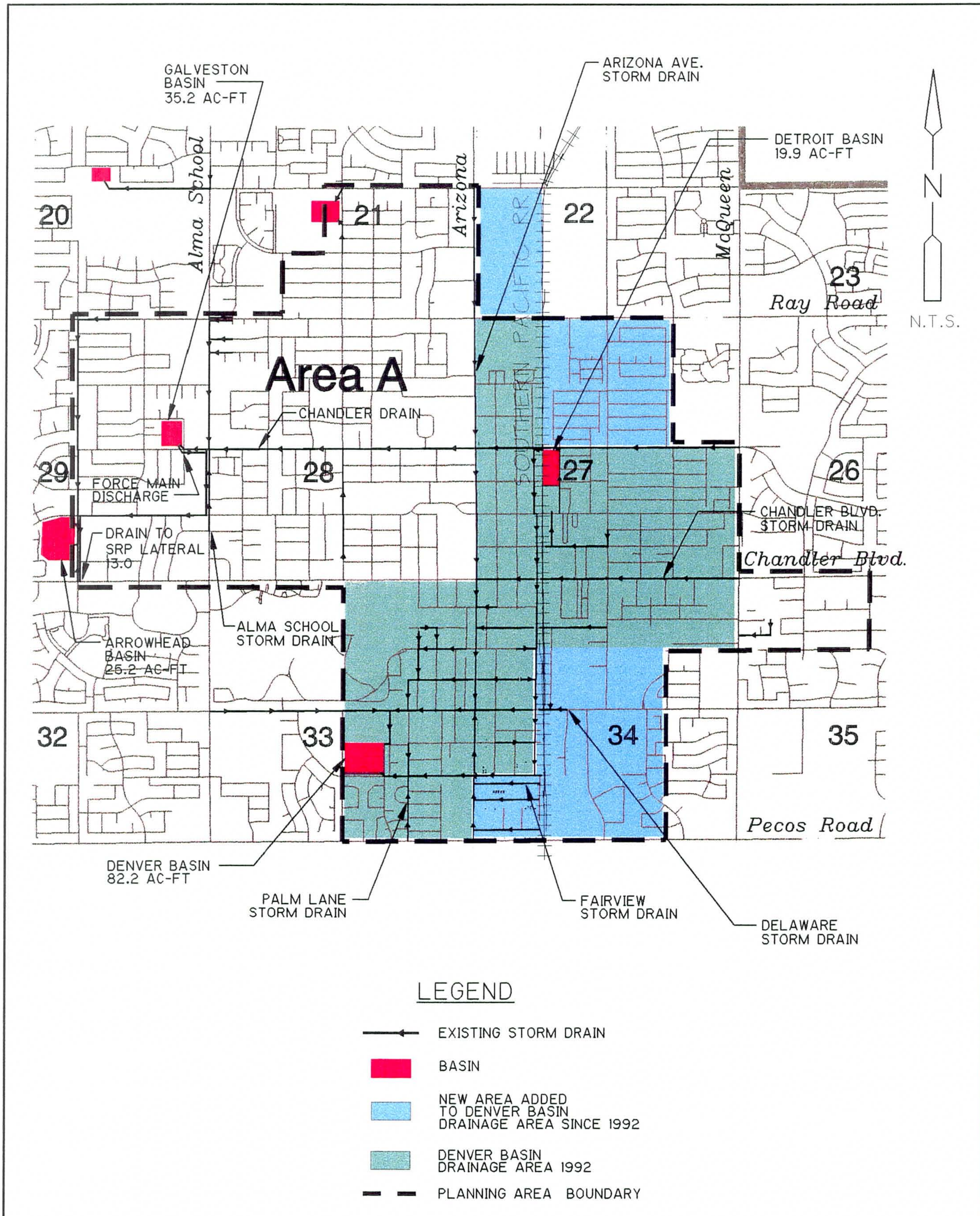
Since 1992, additional storm drains have been constructed that add additional acres to the Denver Basin tributary area. In the 1992 update, the Denver Basin drainage area was identified as being between Knox Road, Pecos Road, Nebraska and Arizona Avenue, and the Southern Pacific Rail Road (SPRR) on the east as shown in green in Figure 6-8. Since 1992 the City has constructed storm drains to the Denver Basin which have enlarged the drainage area (shown in Blue in Figure 6-8) to include 3/4-mile of street drainage west of Palm Lane along Frye Road, and drainage from east of the SPRR at Frye Road, Commonwealth Street, and Chandler Boulevard. The total drainage area has increased to 1,520 acres (blue and green in Figure 6-8). The Denver Basin drainage area includes all of Area A east of Arizona Avenue and south of Chandler Boulevard. The 100-year runoff volume from this large drainage area exceeds the maximum storage volume of 103 acre-feet in the Denver Basin. Therefore, a discharge outlet is required during storms to avoid over-topping the basin or flooding areas upstream and at the same elevation as the basin. Currently the Denver Basin has a 2 cfs pump to drain the basin to the SRP irrigation system. A connection to the freeway system is needed to provide a permanent discharge.

Freeway System

Since the 1992 update, Temporary Basin H has been constructed and the portion of the Santan Freeway drainage channel west of Price Road is being designed. ADOT has scheduled completion of the Santan Freeway and Drainage Channel from Price Road to Arizona Avenue in December 2005. Previously, the freeway drainage system was not to be constructed until 2007 or later.

Alternatives Evaluated

The updated freeway schedule suggests that a potential option may be available for the City to drain the Denver Basin by a gravity pipe or force main directly south to the freeway channel rather than along Pecos Road to Basin H. This option was developed and compared to the 1992 recommendation.



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DENVER BASIN DRAINAGE AREA

FIGURE 6-8

Denver Basin Outlet to ADOT Drainage System Alternatives

Several options for draining the Denver Basin west to temporary Basin H by gravity and force main pipes and south to the Santan Freeway drainage channel were reviewed. They included:

1. Gravity Drain to Pecos Road and Basin H.

2. Force main to Pecos Road, Gravity Along Pecos Road to Basin H (1992 recommendation).

3. Force Main Along Pecos Road to Basin H.

4. Gravity Drain South to the Santan Freeway drainage channel.

5. Force Main South to the Santan Freeway drainage channel.

These options are shown in Figure 6-9 and shown in Table B-2 in Appendix B.

The gravity drain alternatives south from the Denver Basin (Options 1 and 4) are not feasible based on the depth of the Denver Basin, flat ground slope, and required pipe size or dual pipes required to drain the basin in 36 hours.

Options 2 and 3, the options discharging the water to Basin H, require approximately 2-1/2 miles of pipe. In comparison, pumping to the drainage channel (Option 5) would only require about one mile of pipe. The pump station at the Denver Basin, included for Options 2, 3, and 5 would also require less total dynamic head to counteract headloss in a shorter length of pipe in Options 2 and 5. Connecting to the freeway channel (Option 5) will require coordination with ADOT. Until this occurs, the City is recommended to plan to construct the 1992 recommended plan, Option 2, which is a force main south to Pecos Road, and a gravity drain along Pecos Road to Basin H.

Option 2, Force main to Pecos Road and gravity drain west on Pecos Road to Basin H, and negotiating with ADOT for Option 5, Force main south to the future Santan Freeway drainage channel, are viable.

Denver Basin Discharge Pipe Sizing

The system including the force main pipe discharge to the freeway channel was modeled using the updated SWMM model and the assumptions that the entire 1520 acres (south and west of Arizona Avenue and Chandler Boulevard) would ultimately drain to the Denver Basin and flows would reach the basin via the existing storm drain pipes. The SWMM model was used to account for the travel time in the existing system before peak flows reach the Denver Basin. The results are shown in Table 6-3. The required discharge rate from Denver Basin assumes that pumping begins during the storm, as soon as water enters the basin, so that the basin will not overtop.

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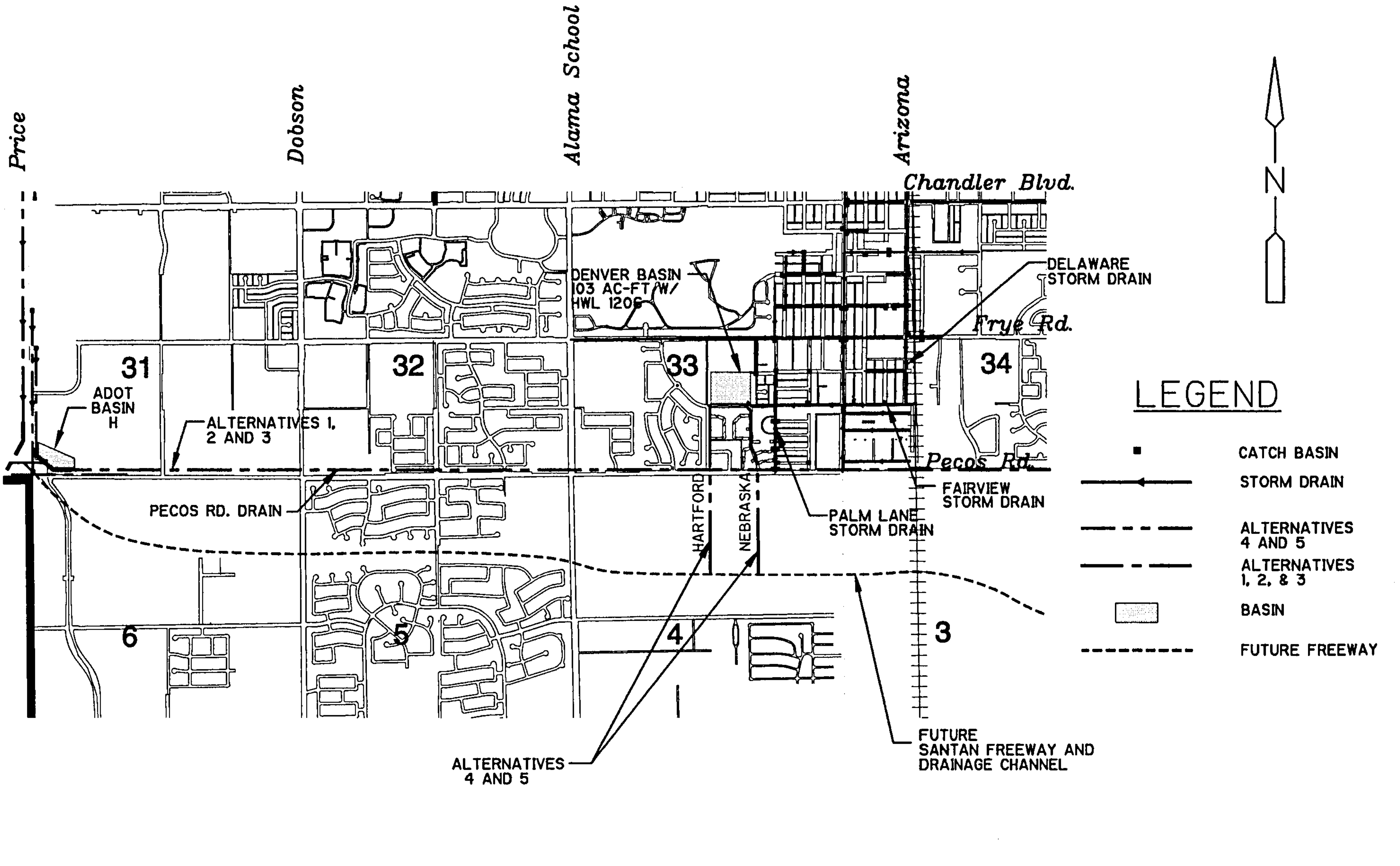

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DENVER BASIN DISCHARGE ALTERNATIVES

FIGURE 6-9

Table 6-5 **SWMM Model Results for Denver Basin Drainage Area Alternative D-5**		
Storm Event	***Maximum Storage Volume in Denver Basin (acre-feet)***	***Required Discharge Rate [1] During Storm (cfs)***
2-year	Basin can contain the 2-year runoff without discharge.	
10-year	103	9
25-year	103	20
100-year	103	35

1. The 100-year, 2-hour storm was assumed to have 2.6 inches of rainfall.

In order to meet the Chandler design criteria of draining the Denver Basin within 36 hours after a storm and provide capacity for the 100-year, 2-hour storm, a discharge rate of 35 cfs is required. A 36-inch diameter pipe will also provide adequate capacity for discharge during storm events, so that the basin does not overtop. A 36-inch diameter pipe would allow a velocity of 4 fps at the 35 cfs flowrate.

A pump station with a 36-inch diameter pipe is recommended to drain the Denver Basin within 36 hours for either Option 2 (force main to Pecos Road drain) or Option 5 (force main to the future Santan Freeway drainage channel).

Denver Basin Discharge Pipe Route Alternatives

In addition to reviewing probable pipe sizing, possible pipe routes south from the Denver Basin were identified. For the recommended force main discharge alternatives (Options 2 and 5), there are two possible routes south from the Denver Basin (Alternatives 4 and 5) as shown in Figure 6-8.

- One option would take the stormwater down Hartford Street,
- the second option down Nebraska Street.

For the Pecos Road drain connection, either street could be used to route the force main south to Pecos Road.

For Option 2, draining along Pecos Road to ADOT Basin H, there are also two options.

- The pipe could be routed along Pecos Road
- The pipe could be routed along Fairview Street then south to the basin.

Pecos Road is the best alignment to drain the water west to Basin H because it has not been improved and is less expensive to cut for pipe installation. The Fairview Street alignment goes along curving residential streets and Frye Road has been improved to a four lane arterial.

For the freeway drainage channel connection (Option 5), the pipe route south of Pecos Road also has the two options of Hartford and Nebraska Street. The area south of Pecos Road is not yet developed, so either Hartford or Nebraska Street is feasible at this time. The Chandler General Plan shows a 20-acre parcel with a land use of High Density Residential east of Hartford. The Nebraska Street alignment would cut through the middle of this parcel; therefore, the Hartford Street alignment is recommended for the freeway channel option until further development plans have been made or a further detailed route study is completed.

Recommendations

The recommended plan for the south and east portion of Area A is to maintain the Detroit and Denver Basins and drainage systems, add a pump station at Denver Basin, and a force main south along Hartford Street to Pecos Road where it will drain into a new Pecos Road drain to Basin H. This is estimated to cost $6,740,000.

As an alternate, CDM recommends negotiation with ADOT and the possibility of connecting the force main south to the future freeway system. ADOT would need to include the Denver drainage capacity in the design of the Santan Freeway drainage channel from Hartford Street to ADOT Basin H/future siphon. The estimated pipe construction and design cost for this option is $1,850,000, a savings of $4,900,000.

6.5 Summary of Area A Recommendations

Recommendations for Area A include improvements to existing basins, storm drains, pump stations and force main pipes. Recommendations are summarized as follows:

- Route stormwater from the Galveston Basin and Arrowhead Basin drainage areas through the Arrowhead Basin with one pump station and a force main to ADOT Basin G. Route the force main from Arrowhead Basin to ADOT Basin G along Anderson Boulevard to Galveston Street and west along Galveston Street to Basin G. Estimated cost for the force main is $1,958,000 and for the Arrowhead Pump Station is $917,000. Estimated Cost for the Galveston Basin Discharge Pipe which drains to the Erie Drain is $340,000. See Appendix B for detailed cost information.

- Proceed with the Denver Basin pump station, 36-inch forcemain to Pecos Road, and Pecos Road drain to ADOT Basin H. Estimated cost is $6,740,000.

- Initiate negotiations with ADOT to connect the forcemain to the Santan freeway drainage system instead of a drain along Pecos Road. Estimated cost is $1,850,000, a saving of $4,900,000.

- Install the Erie and Ivanhoe Drains to improve drainage. Estimated cost for the Ivanhoe Drain is $961,000 and for the Erie drain is $1,972,000.

- Enlarge retention basins or install drywells on Pleasant Drive between Knox Road and Pleasant Lane, and between Pleasant Lane and Orchid Lane. Estimated cost is $12,000.

- Install catch basins along Delaware Street between Erie Street and Chandler Boulevard to connect to the storm drain from the Detroit Basin to the Chandler Boulevard storm drain. Estimated cost is $14,000.

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STUDY AREA A - EXISTING STORM DRAINAGE FACILITIES

FIGURE 6-1

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Street Inlet Into Residential Basin

Section 7 Evaluation Of Areas B and C

Section 7
Evaluation of Areas B and C

Area B consists of the northern part of Chandler, with the exception of Area A, as shown in Figure 7-1. It is divided into North Chandler, the area north of Pecos Road and east of Price Road, and West Chandler, the area west of Price Road. Area C consists of the area south of Pecos Road as shown in Figure 7-2.

Areas B and C have been developed with on-site retention of stormwater runoff. As a result, the existing City drainage systems in Areas B and C consist of retention basins with runoff collection usually handled by surface (street) flow or, in a few cases, by a limited subsurface system (storm drain pipe). The only storm drains in these areas are short pipes for the Apache and Brooks Crossing Basins.

In these areas, residential subdivision retention basins were built by developers, then deeded over to the City and incorporated into the City's maintenance program, unless the subdivision has a homeowner's association. In such cases, the association normally retains ownership and maintenance responsibility for the retention basin. The City does not accept industrial or commercial retention areas into its system; such basins must be privately maintained.

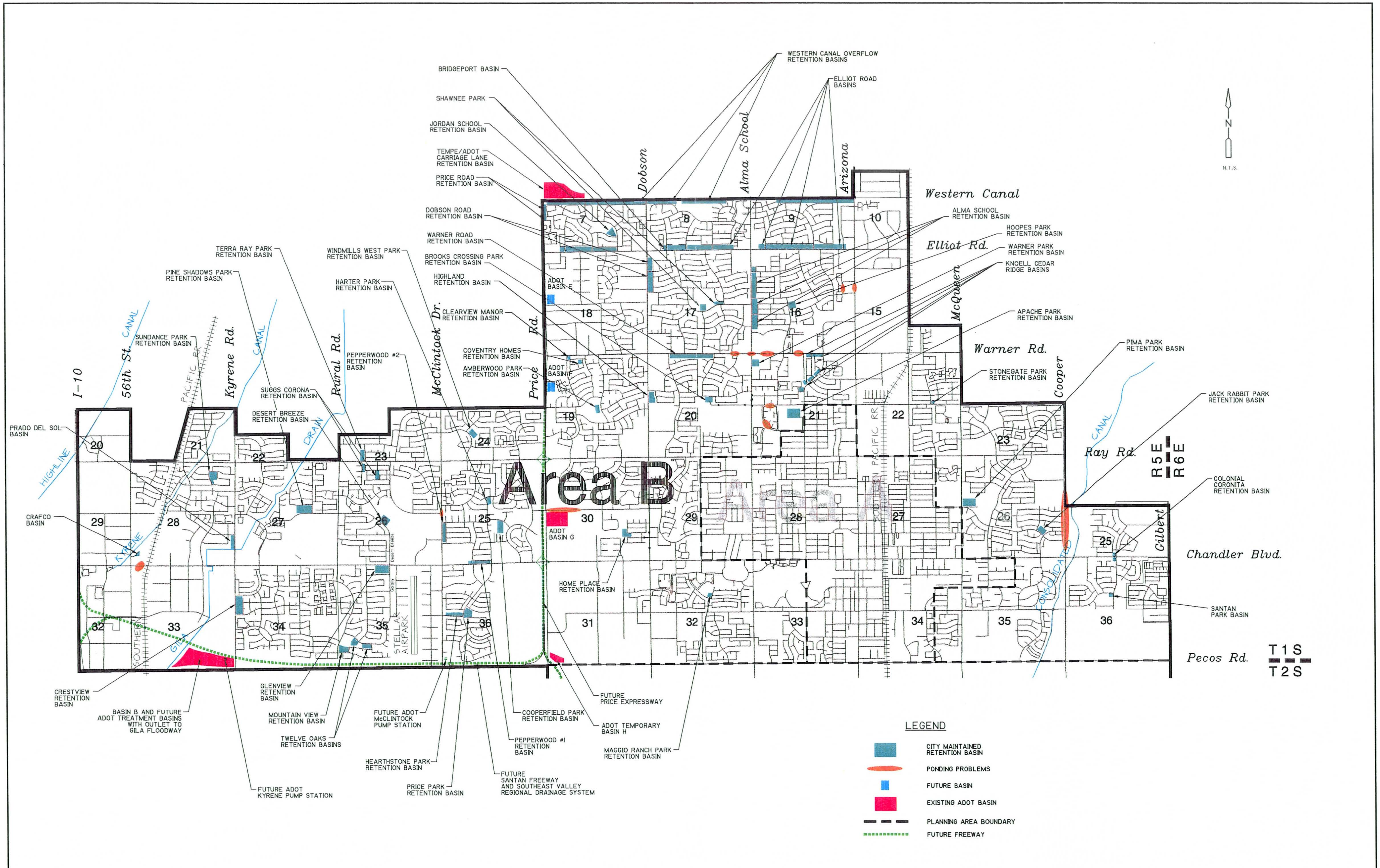
Methods of incorporating basins into the community include: locating desert-landscaped basins along major streets between the street and the development wall; grassed basins within the development which also provide for some open space; or joining the retention area to a City park or school adjacent to the development to provide a large community area.

In the majority of cases, retention basins are constructed for individual developments, however, some joint facilities have been constructed to serve larger areas (up to a square mile). Figure 7-1 and Table C-1 in Appendix C show the retention basins maintained by the City in Areas A, B, and C. Table C-2 lists the public park facilities that include retention basins. Not listed are the numerous developer constructed, on-site retention basins, nor the private artificial lake systems that serve as retention basins.

This section describes the concerns, previous recommendations, current status, alternatives evaluated, and recommended solutions for the following parts of Areas B and C:

- Area B - West Chandler
- Area B - North Chandler
- Area C - South Chandler

In addition, vacant parcel and Quarter Section storm runoff calculations and retention volumes are included at the end of this section.



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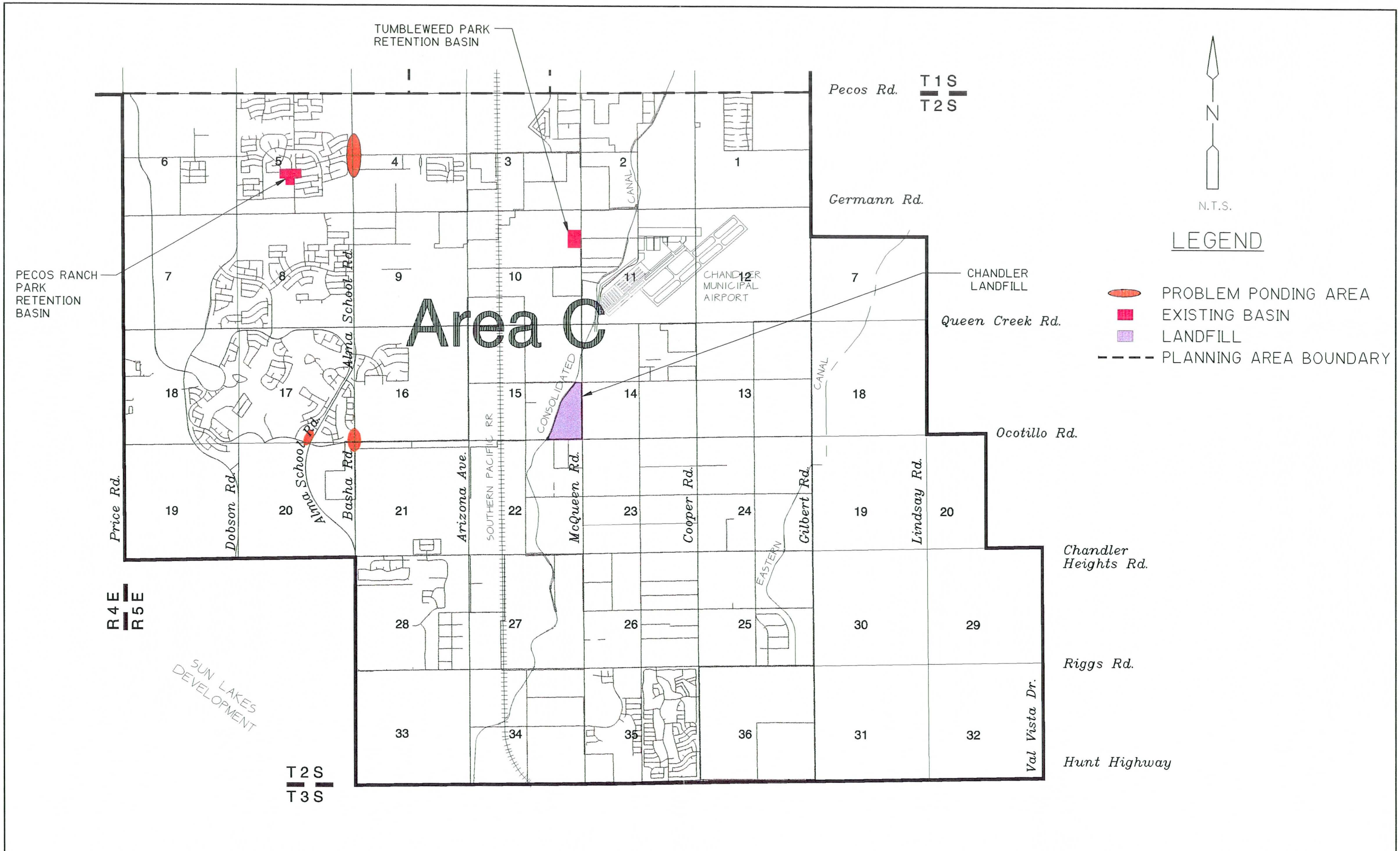
EXISTING RETENTION BASINS AND PONDING PROBLEMS IN STUDY AREA B

FIGURE 7-1



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EXISTING RETENTION BASINS AND PONDING PROBLEMS IN STUDY AREA C

FIGURE 7-2

7.1 Area B - West Chandler

Concerns

Regional

Overall the on-site retention systems in West Chandler have functioned well to handle storm runoff, without major concerns with basins draining. If a basin maintained by the City experiences draining problems, the current procedure is for the City to install a new drywell and regrade as necessary. Concerns are resolved on a case-by-case basis. The City Streets Department has instituted a drywell maintenance program which should increase their effectiveness and useful lifetime.

Localized

A ponding concern occurs east of 56th Street on the north side of Chandler Boulevard where there is a low point in Chandler Boulevard at a scupper into a temporary basin. The temporary basin is undersized for the amount of street drainage reaching this low spot. See Figure 7-1 for the location. During storms, the water ponds deep enough to cross the median to the south side of the street.

7.1.2 Previous Recommendations

1992 Master Plan Update

In the 1992 Master Plan Update, a series of regional retention basins for the 100-year, 2-hour storm and an off-peak discharge of 260 cfs to the Santan Collector Channel (see Table 7-1) was the recommended alternative for West Chandler. The basins were recommended to be constructed once the Santan Freeway drainage channel was constructed and recommended to be sized for West Chandler stormwater runoff. No action other than on-site retention was recommended as an interim plan until that time. The regional plan was recommended before the majority of development had occurred or arterial streets had been improved. The connection to the Santan Channel would have provided a discharge outlet for areas that had concerns with percolation discharge. The improvements recommended in 1992 are shown in Figure 6-3 and listed in Table 7-1.

Table 7-1 1992 Recommended Alternatives for Area B, West Chandler	
	Current Status
On-Site Retention: 1,150 acre feet	No Action
Pipe system sized to convey: 5% of the 2-yr, 6-hr storm See Figure 6-3	No Action
260 cfs discharge to Santan Channel: off peak	No Action
60 hours to drain basins McClintock Road - 50 cfs Kyrene Road - 90 cfs Gila Drain - 60 cfs 56th Street - 60 cfs	No Action

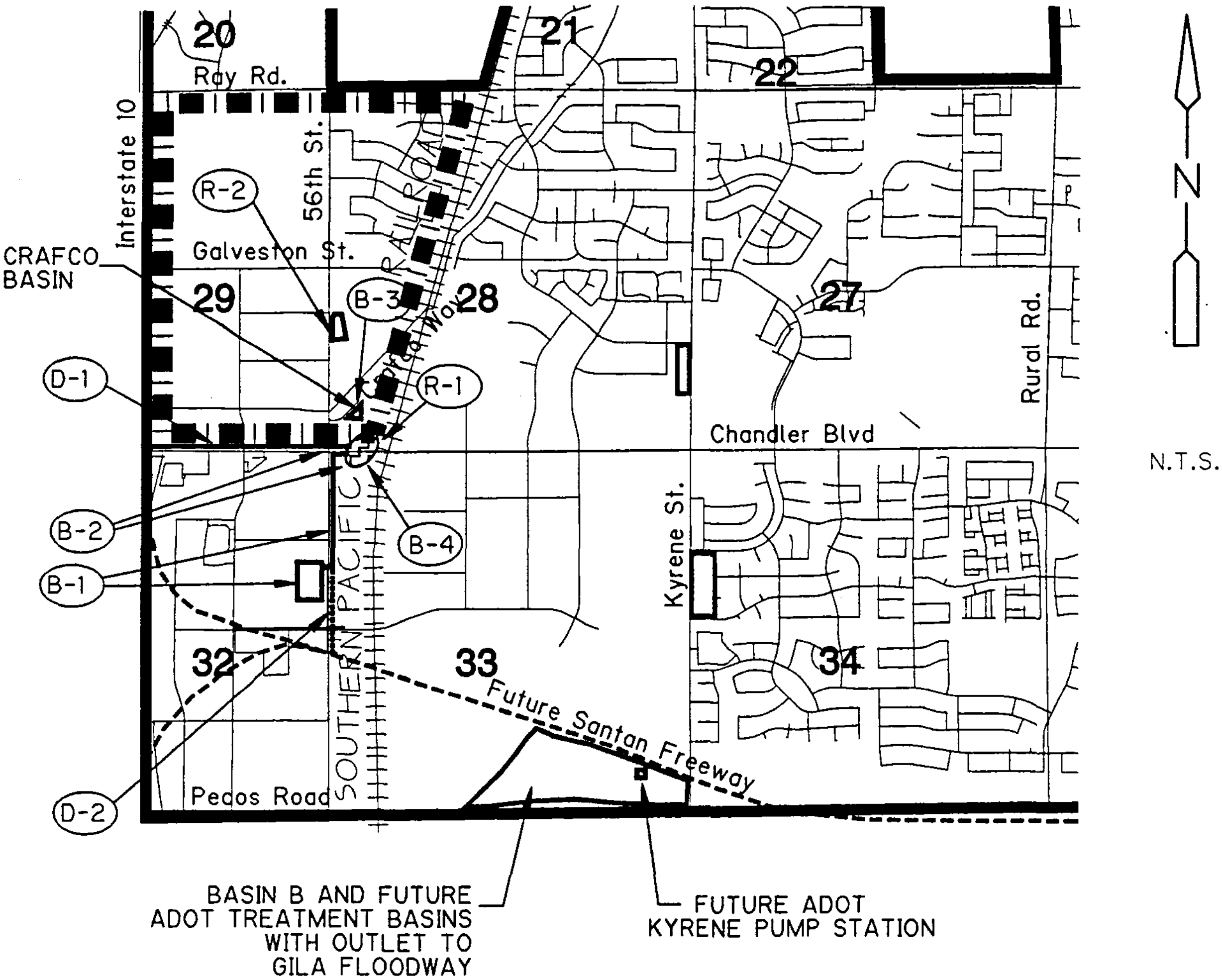
The 1992 Update also emphasized maintenance of existing basins and drywells to insure the percolation rates are maintained.

1997 56th Street/Chandler Boulevard Study

A drainage study by CMX Engineers for the concern identified at 56th Street and Chandler Boulevard (Figure 7-3) was completed in 1997. The area studied was bounded by Ray Road, Chandler Boulevard, Interstate 10, and the Southern Pacific Railroad. The area drains to the south. Along I-10 the runoff drained into the freeway drainage channel.

Concerns identified in the CMX report which caused ponding in Chandler Boulevard at 56th Street included:

- Temporary retention basins along the south side of Ray Road and west side of 56th Street were undersized because silt had partially filled them in and no berms prevented on-site water from the farm fields from draining into them.
- One scupper at Galveston Street and 56th Street was inoperable.
- Street runoff was not captured by vacant property in the industrial park at the northwest corner of 56th Street and Chandler Boulevard. Only on-site runoff drained into the two existing retention basins.
- Street runoff was not captured on the east side of 56th Street south of Galveston Street. Existing industries retain the stormwater on-site.



LEGEND

ADOT AND CITY MAINTAINED RETENTION BASIN

PONDING PROBLEMS

MODIFY EXISTING BASIN

or — ALTERNATIVE STORM DRAINS

STUDY AREA BOUNDARY

CMX STUDY AREA BOUNDARY

RUNOFF REDUCTION ALTERNATIVES

- (R-1) Universal Forest Products -reslope drive and parking
- (R-2) Private basin expand, inlets

BASIN ALTERNATIVES LOCATIONS

- (B-1) Basha's Basin drain pipe
- (B-2) Corner properties Install basins
- (B-3) Crafco Basin modify
- (B-4) Install basin next to railroad tracks

DISCHARGE ALTERNATIVES

- (D-1) Pipe to I-10 drainage channel
- (D-2) Pipe to Santan Freeway drainage channel

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56th ST./CHANDLER BLVD.
PONDING PROBLEM ALTERNATIVES

FIGURE 7-3

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- The parking area and front drive on the lot adjacent to the ponding concern, the site of Universal Forest Products, drains into the Chandler Boulevard.

- The City reported the concern to be caused by runoff from the I-10 on-ramp, undersized scuppers and basins along both 56th Street and Chandler Boulevard, and inlets with flat slopes.

A HEC-1 model was developed for the study area in the 1997 CMX report. It showed that 7.0 ac-ft of stormwater runoff would drain to Chandler Boulevard and 56th Street from the 10-year, 6-hour storm (3 inch rainfall depth). Subtracting 0.9 acres of existing retention, the report predicted 6.1 ac-ft of retention (2.21 acres at 3.0 feet deep) was needed to correct the ponding concern for the 100-year, 6-hour storm. Runoff from the 10-year, 2-hour storm is the City's retention requirement. Using the 6-hour storm, the HEC-1 model calculated 15 percent more retention than the City requires. The report identified possible retention basin sites and recommended that the City acquire retention at the northwest corner of 56th Street and Galveston Street, at the northwest corner of 56th Street and Chandler Boulevard, and vacant Crafco property north of Chandler Boulevard and 56th Street.

One item the CMX report did not address is drainage of retention basins within 36 hours, as the City requires. To dispose of 6.8 ac-ft of stormwater, 23 drywells with 0.1 cfs rates of discharge (assuming no infiltration discharge in the basins) are required. Enough land area to separate the drywells 100 feet apart, 5.3 acres, is also a consideration.

Current Status

Regional Drainage

Much of West Chandler has been developed since 1992. The major storm drains recommended for West Chandler have not been constructed, however, since the Santan Freeway drainage channel has not been constructed. The developed portions of West Chandler have been built with on-site retention basins sized for the 100-year, 2-hour storm. Drywells have been installed, even with perched groundwater, by sealing the drywell discharge pipe in the region of the perched water. The main roads where the pipes were to be installed have been completed without the drain pipes. Since 1992, land in West Chandler has been developed with on-site retention and arterial streets have been improved. The remaining development will be infill of vacant parcels.

ADOT has been designing the South East Valley Regional Drainage System (SEVRDS), the portion of the Santan drainage channel from Price Road to Basin B and the Gila Floodway. Portions of it are scheduled to start construction this year. It was sized to accept the runoff from West Chandler and could provide a discharge outlet if sole reliance on stormwater retention proves ineffective in West Chandler, in the future.

Localized Ponding

Since the 1997 CMX report about the 56th Street/Chandler Boulevard ponding concern was completed, some of the sources of the concern were corrected by the City and others:

- The temporary basins were excavated to original size.
- The extra fill was used to create berms.
- The broken scupper at Galveston Street and 56th Street was repaired.
- The western portion of the vacant farmland west of 56th Street and south of Ray Road was recently developed with on-site retention which prevents stormwater and street runoff from draining to 56th Street and south to Chandler Boulevard.
- The basin on the northwest corner of Galveston Street and 56th Street was expanded by the developer. The remainder of the property is also expected to be developed.
- The City purchased 0.9 acres of the Crafco property and enlarged the Crafco retention basin. The depth of the basin is 4-feet deep to provide 3 feet of water depth and 1 foot of freeboard for a total volume of 2.7 ac-ft.

Alternatives Evaluated

Regional Drainage

Because there have been no major ponding concerns in the area other than undersized temporary basins, it is recommended that the City continue to require on-site retention and drywells as the remaining parcels are developed. Installation of major drains would be a significant disruption to streets and existing residences and businesses now in West Chandler, and the pipes required to connect the on-site retention would be costly. However, this option would be a last resort if percolation is no longer effective.

The current situation does not warrant the cost of installation of a storm drain system, as envisioned in 1992, since on-site retention is functioning adequately with percolation discharge only. In the future, if the extensive industrial development in West Chandler must face stringent ADEQ drywell permitting requirements, which precludes their use for drainage, installation of drains to the SEVRDS may become necessary.

Localized Ponding

Based on the HEC-1 model in the previous report, and the changes described in Section 7.1.3, an additional 2.4 acre-ft (6.1 ac-ft required minus the 2.7 ac-ft in the Crafco Basin, minus 1 acre foot from the newly developed area), or 1.13 acres with a 3-feet deep retention basin are required to alleviate the ponding in Chandler Boulevard.

Runoff Reduction

The runoff which ponds in Chandler Boulevard was reported to flow south on 56th Street and east on Chandler Boulevard. To reduce the volume of water, several alternatives were evaluated:

R-1. Reslope Universal Forest Products parking lot and drive to contain stormwater on-site.

R-2. Enlarge the private basin without landscaping, which is located on the east side of 56th Street south of Galveston Street. Install additional scuppers and catch basins to route water into this basin. This should prevent street runoff north of Galveston Street from flowing south into Chandler Boulevard.

Both alternatives are feasible, but require the property owners' approval.

Additional Retention Basin Locations

Several alternatives to provide retention for the runoff near the area of the ponding were evaluated for costs and feasibility. They are shown in Figure 7-3 and include:

B-1. Modifying the Basha's warehouse retention basin located south of Chandler Boulevard, and installing a drain pipe along 56th Street.

B-2. Installing basins on the corner properties on the south side of Chandler Boulevard at 56th Street.

B-3. Modifying the existing Crafco Basin to provide more capacity.

B-4. Installing a basin on vacant property on the west side of the railroad tracks.

One of the concerns with the alternatives which require purchasing land is the high property costs in this area. The corner properties in Alternative B-2 were estimated to cost $7 to $8 per square foot or $300,000+ per acre. The high cost makes this option unfeasible. Alternative 4, a basin near the railroad tracks, also is unfeasible because it requires purchasing land and there is a gas line crossing adjacent to the railroad, which cuts through the property. Alternatives 1 and 3, modifying existing basins, require cooperation of the property owners, and an outlet to dispose of the water within 36 hours. The Crafco owned property adjacent to the basin owned by the City was not sold to the City previously because it has frontage property on Chandler Boulevard which Crafco prefers to sell to a commercial property owner. Once a developer buys the property, the City could pursue expanding the basin if the developer agrees. If the retention basins do not drain within 36 hours, drywells or an outfall will be required.

Discharge Alternatives

The location of the ponding suggests that outfall drain pipes (Alternatives D-1 and D-2) to freeway drainage systems may be feasible options. Interstate 10 and the future Santan Freeway rights-of-way are within 3/4-mile west and south, respectively, of the ponding location. Interstate 10 west of the problem area has an existing drainage channel, however, it was not sized for additional flow from Chandler Boulevard. Chandler Boulevard was recently upgraded so tearing it up to install a drain pipe west to Interstate 10 would be expensive and likely unfeasible. Installing a drain to the Santan Freeway drainage channel, scheduled for completion in 2004, is feasible because the channel was sized to drain West Chandler. 56th Street has not been improved and the City may be able to use existing rights-of-way for a drain pipe south. This alternative does not require land purchase or drywells for disposal.

Recommended Solutions

The following items are recommended to prevent, reduce, or solve ponding concerns in West Chandler:

- Continue requiring on-site retention of the 100-year, 2-hour storm including one-half of the adjacent street for new development in the City as discussed in Section 3.

- Contact the property owners of the Universal Forest Products and the private, unlandscaped basin near Galveston and 56th Street to discuss modifications to reduce drainage to Chandler Boulevard. These are the two runoff reduction alternatives for reducing stormwater draining to 56th Street/Chandler Blvd. Estimated cost to deepen the basin, provide landscaping, and reslope the parking lot is $58,000. See Section 10 and Appendix B for detailed costs.

- Install catch basins, inlets, and a 18 inch diameter storm drain south along 56th Street to the Santan Freeway drainage channel, scheduled for completion in 2000. Estimated Cost for 2,800 feet of pipe and a 20% contingency is $278,000. See Section 10 and Appendix B for detailed costs.

7.2 Area B - North Chandler

7.1.1 Concerns

Regional Drainage

Similar to West Chandler, the on-site retention basins with percolation discharge have worked adequately to contain and dispose of stormwater in North Chandler.

Localized Ponding

Several areas where ponding occurs after significant storm events have been identified in North Chandler. The ponding is caused by undeveloped property without retention or retention basins that overtop or do not drain fast enough. The areas with ponding include the following:

- McClintock Drive at Desert Breeze Drive.
- Cooper Road between Chandler Boulevard and Ray Road.
- Oregon Street between Palomino and Nopal Streets.
- 750 W. Warner Road, west of Evergreen Street, north side of street, in front of White Glove Car Wash.
- Warner Road, north, in front of SRP substation, west of Hartford.
- Warner Road, south, in front of K-ball site.
- Warner Road, north, at Comanche Street.
- Southeast corner of Warner and Alma School Roads.
- East side of Oregon Street between Palomino and Nopal Streets.
- Pleasant Drive between Knox Road and Pleasant Lane.
- Pleasant Drive between Pleasant Lane and Orchid Lane.
- Northeast corner of Dobson and Elliot Roads.

Previous Recommendations

Regional Drainage

The 1992 Update did not recommend connecting to the Carriage Lane Basin and outfall because of the cost to construct a storm drain system to connect the numerous North Chandler on-site retention basins to the proposed ADOT system. Instead, the update recommended the on-site drainage policy be retained with additional retention basin design and maintenance requirements.

Local Ponding

Localized ponding areas were identified in the 1992 Update.

Current Status

Regional Drainage

Most of the North Chandler area is already developed with on-site retention of the 100-year, 6-hour storm, which was the City's previous criteria from 1975 to 1992. The 1992 Master Plan recommended that Chandler adopt a policy requiring retention of the 100-year, 2-hour storm to be consistent with the requirements of neighboring communities. Chandler has since adopted this policy and in-fill development must conform to it.

Under the current ADOT plan, a portion of the original Price Road Drain design will be constructed from Knox Road, north to the Carriage Lane Basin, and eventually to the Salt River. This system is designed to detain the 100-year, 24-hour runoff from areas north of Knox Road (North Chandler) and east of Price Road and discharge the stormwater at a reduced rate after the peak. Chandler has reserved 100 cfs discharge into this system.

Localized Ponding

The City has corrected several ponding concerns in Area B since 1992 including:

- New basins reduced the ponding concern at Galaxy Street and Desert Breeze Drive.
- New basins were installed on the east side of McQueen Road and Commonwealth Street.

The area within the boundaries of Knox Road to the north, Arizona Avenue to the east, Ray Road to the south, and Evergreen Street to the west was subject to ponding concerns. Extensive ponding occurred during storms along Orchid Lane, particularly between Hartford and Evergreen Streets, and along Evergreen Street from Orchid Lane south to Ray Road. The City corrected this concern by installing catch basins and a pipe to Apache Park from Orchid Lane and Hartford Street. Apache Park retention basin was also graded. See Figure 7-1.

Two areas have been developed in the north portion of Area B and the new on-site retention has reduced ponding:

- Ponding at the Northwest corner of Alma School and Elliot Roads has been reduced since the corner was developed and on-site retention constructed.
- Ponding in the street at the northwest corner of Dobson and Elliot Roads has been reduced since the corner was developed and on-site retention constructed.

Alternative Evaluation

Ponding occurs at several locations in North Chandler after storms. Options to solve these concerns include:

- Install a temporary basin on vacant land near the ponding concerns at the southwest corner of McClintock Drive and Desert Breeze Drive. Future development of the vacant lot will include on-site retention which will eliminate the problem. Other options to reduce ponding include installing a drywell, or storm drain to a local retention basin. These options would be more costly and are not needed since the long-term solution will be development of the vacant lot.

- To reduce ponding along Cooper Road between Chandler Boulevard and Ray Road, the City has plans to improve the road to provide channeling along the curb and scuppers into on-site retention areas. Other options to reduce ponding include installing drywells, or storm drains to a local retention basin. These options would be more costly and are not needed since the long-term solution will be roadway improvements.

- Expand the temporary basin at Dobson and Elliot Roads to provide more capacity.

- Ponding along Oregon Street could be reduced by installing a scupper into the retention basin on the west side of Oregon Street between Palomino and Nopal Streets. The other option to install a drywell, but the basin is close to the ponding area.

- In several locations existing retention basins are undersized or not draining properly. Options include installing drywells or expanding the basins. The basins are located on lots that are fully developed with little room for expansion. As a result, drywell installation is recommended for the following basins:

  — 750 W. Warner Road, west of Evergreen Street, north side of street, in front of White Glove Car Wash.

  — Warner Road, south, in front of K-Ball site.

  — Warner Road, north, at Comanche Street.

  — Southeast corner of Warner and Alma School Roads.

  — East side of Oregon Street between Palomino and Nopal Streets.

  — Pleasant Drive between Knox Road and Pleasant Lane.

  — Pleasant Drive between Pleasant Lane and Orchid Lane.

Recommended Solutions

Regional Drainage

The 1992 recommendations remain valid for North Chandler given ADOT's current plans. Chandler has capacity to drain retention basins into the Price Drain and Carriage Lane Outfall to the Salt River. However, the cost of installing the storm drains from the basins to the Price Drain is not warranted at this time, since on-site retention with percolation discharge is functioning adequately.

Ponding Concerns

In North Chandler, improvements recommended to reduce the local ponding concerns include:

- Install a temporary basin and scuppers at the southwest corner of McClintock Drive and Desert Breeze Drive to reduce ponding along McClintock Drive west between Galveston and Monterey. On-site retention will reduce ponding when this property is developed. Estimated cost is $12,000. See Section 10 and Appendix B for detailed costs.

- Improve Cooper Road between Chandler Boulevard and Ray Road to provide channeling of stormwater and reduce ponding.

- Install scupper into the retention basin on the west side of Oregon Street between Palomino and Nopal Streets. Estimated cost is $6,000.

- Temporary basin at Dobson and Elliot Roads should be deepened for more capacity. Estimated cost is $1,200.

- Install seven new drywells in the following basins:

  — 750 W. Warner Road, west of Evergreen Street, north side of street, in front of White Glove Car Wash.

  — Warner Road, south, in front of K-ball site.

  — Warner Road, north, at Comanche Street.

  — Southeast corner of Warner and Alma School Roads.

  — East side of Oregon Street between Palomino and Nopal Streets.

  — Pleasant Drive between Knox Road and Pleasant Lane.

  — Pleasant Drive between Pleasant Lane and Orchid Lane.

Estimated cost for 7 new drywells is $42,000.

7.3 Area C - South Chandler

7.3.1 Concerns

A few locations in Area C experience localized ponding after significant storms and they are shown in Figure 7-2. Causes include vacant land with small temporary basins and a lake system overflowing. The locations include the following:

- Ponding in the west side of Alma School Road at Ocotillo Road when lake has a high level.
- Ponding in the road at Bashas Road and Ocotillo Road.
- Ponding in the road at Willis Road and Alma School Road.

7.3.2 Previous Recommendations

In the 1986 Master Plan and 1992 Update, on-site retention with additional design, construction, and maintenance requirements for basins was the recommended alternative for South Chandler (Area C). Other alternatives evaluated included no action, regional retention basins, and regional detention basins with outlets to drainage outfalls. The alternatives did not include the major planned area developments in South Chandler (i.e., Ocotillo, Sun Lakes, and Pecos Ranch) that were already under development and included lake systems for stormwater storage.

The 1992 update indicated that outfall options in South Chandler are currently not implementable without an agreement with the Gila River Indian Community to accept additional runoff from the City. ADOT has an agreement to discharge the Santan Freeway drainage system into the Gila Floodway, but it does not include Area C. The 1992 update cautioned that regional retention basins within South Chandler would contain large volumes, and may be difficult to drain within 36 hours relying on percolation and drywells. Therefore, on-site retention similar to Study Area B was the recommended alternative for Area C.

Local ponding concerns were not identified in the 1992 Update because the area was undeveloped.

7.3.3 Current Status

In Area C the Ocotillo, Pecos Ranch, and Amstar developments retain stormwater runoff in their lake systems. Other recent developments have also been constructed with on-site retention. Development in the near future will also be required to meet the on-site retention requirements under the City's drainage ordinance. The Chandler Municipal Airport located in the vicinity of Queen Creek and McQueen Roads has its own master drainage plan and will provide on-site retention basins. The Chandler sanitary landfill located near the airport has one retention basin and uses a vacant cell as a second retaining area. When this landfill cell is placed into operation, a second basin will be constructed. The landfill provides on-site retention and will continue to do so after closure.

The location of Area C (to the south of Areas A and B, and bounded to the south and west by the Gila River Indian Community) affects its possible drainage options. Depth to groundwater is approximately 90-250 feet. A study conducted by Professor Pewe of Arizona State University ("Environmental Geology - Chandler Quadrangle, Maricopa County, Arizona," 1985) indicates that dry well usage would be acceptable for the area.

7.3.4 Alternatives Evaluation

Ponding occurs in three locations in Area C after significant storms. Options to solve these concerns include:

- Ponding occurs on the west side of Alma School Road at Ocotillo Road when heavy rains cause a high water level in the lake. Options to prevent the ponding that were reviewed included the following:
  -- Provide an overflow and retention basin for high water levels in the lake
  -- Deepen the lake to provide more capacity. This option is not feasible since the lake would have to be emptied and the lining replaced.

- Ponding occurs in the road at Basha Road and Ocotillo Road. A development is being constructed on the northeast corner which should help the problem. Future development on the southeast corner should eliminate the concern. In the meantime, a temporary basin should be installed on the southeast corner of Bashas Road and Ocotillo Road. Installing a drywell or storm drains to a retention basin are other options, but not feasible if the long term solution is development with on-site retention.

- Ponding occurs near Willis Road and Alma School Road where the temporary basin is undersized. This should be corrected when development occurs at the northeast and southeast corners. In the meantime, deepen the temporary basin to provide more capacity. Installing a drywell or storm drains to a retention basin are other options, but not feasible if the long term solution is development with on-site retention.

7.3.5 Recommended Solutions

Regional Drainage

The 1992 recommendation for an on-site retention system in South Chandler is still valid. Without adequate outfalls for South Chandler, the best course to take is to keep runoff as dispersed as possible by requiring on-site retention of the 100-year, 2-hour storm. Available information indicates that percolation drainage should function adequately. Development in Area C should meet the same requirements as new development in Area B (North and West Chandler). These requirements are as specified in the City's revised drainage design standards.

Localized Ponding

As discussed in the previous section, three areas with ponding were identified in Area C. The lake overflow can be routed to a retention area.

Proposed solutions for the ponding include:

- Install an overflow and retention basin near Alma School Road at Ocotillo Road to remove water from the lake when heavy rains cause a high water level and prevent overflow into the street. Estimated cost for a one-half acre basin is $144,000.

- Ponding in the road at Basha Road and Ocotillo Road. Until the corners are developed, a temporary basin should be installed on the southeast corner of Basha Road and Ocotillo Road. Estimated Cost for 25 foot square temporary basin is $12,000.

- Ponding in the road at Willis Road and Alma School Road because the temporary basin located nearby is undersized. Until the corners develop, deepen the temporary basin to provide more capacity. Estimated cost for excavation is $1,000.

Care must be taken to ensure that the temporary basins are adequately sized to drain the intersection during major storms and that the basins are regraded when soil or silt has reduced their capacity.

7.4 Summary of Recommendations for Areas B and C

In summary, CDM recommends the following:

General

- Keep an on-site retention requirement for the 100-year, 2-hour storm requiring drainage of basins within the time established by the City, using surface percolation and drywells, if needed.

- Improve construction and maintenance practices by establishing a regular inspection schedule, with cleaning as required.

- Install temporary basins, enlarge existing basins, install scuppers, and complete other tasks to reduce ponding at several locations:

West Chandler

- Install a 30-inch pipe south from Chandler Boulevard and 56th Street south to the Santan Freeway drainage channel.

- Request permission to modify private basin at Galveston and 56th Street. Estimated cost is $43,000.

- Request permission to reslope the Universal Forest products parking lot. Estimated cost is $15,000.

North Chandler

- Install scupper drain to the retention basin on Oregon Street, north of Palomino Street. Enlarge the basin. Estimated cost is $6,000.

- Install a temporary basin and scuppers at the southwest corner of McClintock Drive and Desert Breeze Drive to reduce ponding along McClintock Drive west between Galveston and Monterey. Estimated cost is $12,000.

- Enlarge, or install new drywells in the following basins:

  — 750 west Warner Road, west of Evergreen St, north side of street, in front of White Glove Car Wash

  — Pleasant Drive from Knox Road to Pleasant Drive

  — Pleasant Drive from Pleasant Lane to Orchid Lane

  — Warner Road, south, in front of K-Ball site

  — Warner Road, north, at Comanche Street

  — Southeast corner of Warner and Alma School Roads

  — East side of Oregon Street between Palomino and Nopal Streets

  Total estimated cost for 7 drywells is $42,000.

- Deepen the temporary basin at the northeast corner of Dobson and Elliot Roads. Estimated cost is $1,000.

- Improve Cooper Road between Chandler Boulevard and Ray Road to provide channeling of stormwater and reduce ponding.

South Chandler

- Provide an overflow with retention basin to prevent the lake from overflowing into the street near Alma School Road and Ocotillo Road. Estimated cost is $144,000.
- Install a temporary basin on the southeast corner of Basha Road and Ocotillo Road. Estimated cost is $12,000.
- Deepen the temporary basin at the intersection of Willis Road and Alma School Road. Estimated cost is $1,000.

7.5 Quarter Section and Vacant Parcel Flows and Retention Calculations

Area B

As described in Section 4, for each vacant parcel in Area B (north and west Chandler) the runoff for 10-year and 50-year storms, and the retention volume for a 100-year, 2-hour storm were calculated using a spreadsheet. Land uses were taken from the City's zoning map, General Plan Land Use, or Land Use Element. The results are listed in Table D-1 Appendix D and shown on Figure 7-4 in the pocket. This information will allow the City's development services plan reviewers to compare a developer's calculations for retention and flow to this baseline.

Area C

Similar to Area B, runoff from vacant land in Area C, South Chandler, was calculated using the Rational Method and land use from the City's zoning maps, General Plan Land Use, or Land Use Element. The peak runoff was calculated for the 10-year and 50-year storms along with the retention volume required for the 100-year, 2-hour storm. See Appendix D, Table D-2 and Figure 7-5 for the results.

LEGEND

UNDEVELOPED PARCELS

7/10/1.2 — Q_{10} = 10-year Storm Runoff, cfs

Q_{50} = 50-year Storm Runoff, cfs

$V_{retention}$ = 100-year, 2-hour Runoff Volume, acre-feet

SLR — SLR = Small Lot Residential = Zoning

CDM environmental engineers, scientists, planners, & management consultants

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STUDY AREA B UNDEVELOPED PARCELS AND RETENTION VOLUMES

FIGURE 7-4

CDM
environmental engineers, scientists, planners, & management consultants

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STUDY AREA C - PARCEL AND QUARTER SECTION FLOWS AND RETENTION VOLUMES

FIGURE 7-5

P:\2141-232.28\Dwg\ 2141-4xx 05/26/99 10:09 tsarkmk XREFS: XBASE, COCLBNO1, COCLBNO2, COCLBSO1, COCLBSO2, COCLBW1, COCLBW2, COCCITY

Residential Basin with Drywell and Landscaping

Section 8 Runoff Originating Outside

Section 8
Runoff Originating Outside of Chandler

As part of the Master Plan Update, sources of stormwater entering the City from outside of Chandler were investigated. Stormwater from outside Chandler will enter the City planning area by sheet flows or through the irrigation canals since there are no streambeds running through the City. The cities of Mesa and Gilbert are directly upstream of the City. This section discusses predicted ponding and flooding concerns in Chandler as a result of runoff from outside the City during or after an extreme storm event such as a 100-year, 24-hour or larger storm.

8.1 Concern

Runoff from outside Chandler consists of sheet flows across vacant land and along roadways, or overflows from canals and retention basins outside Chandler during a larger storm event. Because the topography slopes gradually to the south and west, sheet flows pond on the east side of barriers such as canals and railroads. After enough water collects, it may flow over the canal berm or road or through openings in the railroad berm and result in flooding. Upstream and east of Chandler and the Central Arizona Project (CAP) canal, runoff from the 100-year storm is stored or diverted and never reaches Chandler. Sheet flows reaching the east side of the Roosevelt Canal are contained in the East Maricopa Floodway and directed south onto Gila River Indian Community land and the Gila River and also never reach Chandler as shown in Figure 2-2. An earthen tailwater ditch directs stormwater along the east side of the Eastern canal from Interstate 60 to 1/4 mile north of Pecos Road, where it drains into the Eastern Canal extension. Part of the sheet flows from the area west of the Eastern Canal and northeast of Chandler are blocked by the barriers to flow within Mesa and Gilbert. These include the Roosevelt Canal on the east, the Western Canal and Lateral 9.5 on the north and Rittenhouse Southern Pacific Railroad, which runs southeast across Mesa and Gilbert.

In Chandler the barriers to sheet flows include the following:

- The Southern Pacific Railroad between Kyrene Road and 56th Street
- The Kyrene Canal between Kyrene Road and 56th Street
- The Chandler Southern Pacific Railroad east of Arizona Avenue
- The Consolidated Canal between Cooper Road and Arizona Avenue
- The Eastern Canal between Lindsay and Cooper Roads

Figure 8-1 shows these barriers and illustrates the predicted ponding and flooding from stormwater entering the City from outside Chandler. The next section, Section 8.2, discusses the predicted flooding and ponding locations in more detail.

8.2 Previous Recommendations

Several agencies have modelled stormwater flows in the Chandler area. Each study predicted overtopping of canals or flooding through railroad berm openings, but did not address solutions to prevent ponding or overtopping. The following sections summarize each study.

8.2.1 1989 Freeway Drainage Study

A 1989 study for the Price and Santan Freeways predicted overflows under current conditions at the Eastern Canal and Pecos Road which is east of the Chandler City limits. The study also predicted that the Consolidated Canal would overtop at four locations, but did not list them.

The Chandler SPRR has openings at Chandler Boulevard and Ray Road which may allow stormwater sheet flows to cross the embankment. The Chandler Boulevard opening was predicted to be a major overflow concentration point in the Price/Santan freeway study for current conditions. For the overflow, the study predicted a peak flow of 644 cfs and a volume of 540 ac-ft. Less overflow was also predicted at the SPRR and Elliot Road.

8.2.2 1991 Federal Emergency Management Agency Study

A flood insurance study for the Federal Emergency Management Agency (FEMA) dated September 1991 identified overtopping and ponding locations along the Eastern and Consolidated canals, Southern Pacific Railroad embankment, and Kyrene canal under current conditions in the event of a 100-year, 24-hour storm. See Table 8-1. Overtopping was predicted to occur when the water elevation reached 6 inches above the canal road elevation in the model.

Table 8-1
Ponding and Overtopping Locations Predicted by the FEMA study (1991)

Location	Volume (ac-ft)	Note
Eastern Canal: ■ 1/4 mile to 3/4 mile North of Chandler Heights Road ■ Downstream side of Ocotillo Road ■ Southside, centerline, and 1/8 mile to ½ mile north of Queen Creek Road		Overtopping at three locations
Consolidated Canal		Ponding 1 to 3 feet deep
Chandler SPRR	790 cfs Peak Flow	Ponding 1 to 3 feet deep Breakout predicted near Ray Road at railroad bridge

The flood insurance study did not predict the Consolidated Canal would overflow. According to the FEMA study, it is anticipated that ponding from 1 to 3 feet deep could occur along the upstream (eastern) side of the east branch of the Consolidated Canal, the Southern Pacific Railroad embankment, and the Kyrene Canal. The FEMA study expected a breakout along the SPRR embankment near Ray Road at the bridge location. The peak flow was given as 790 cfs for this location for the 100-year, 24-hour storm.

Although it is anticipated that runoff from storms of lesser magnitude will not pond as deeply, it could flow beneath the SPRR track at breakout locations. However, according to FEMA, most of Chandler is classified as Zone B. Zone B areas lie outside the limits of the 100-year flood. Localized ponding in the event of the 100-year flood may cause flooding of properties adjacent to the features causing the ponding.

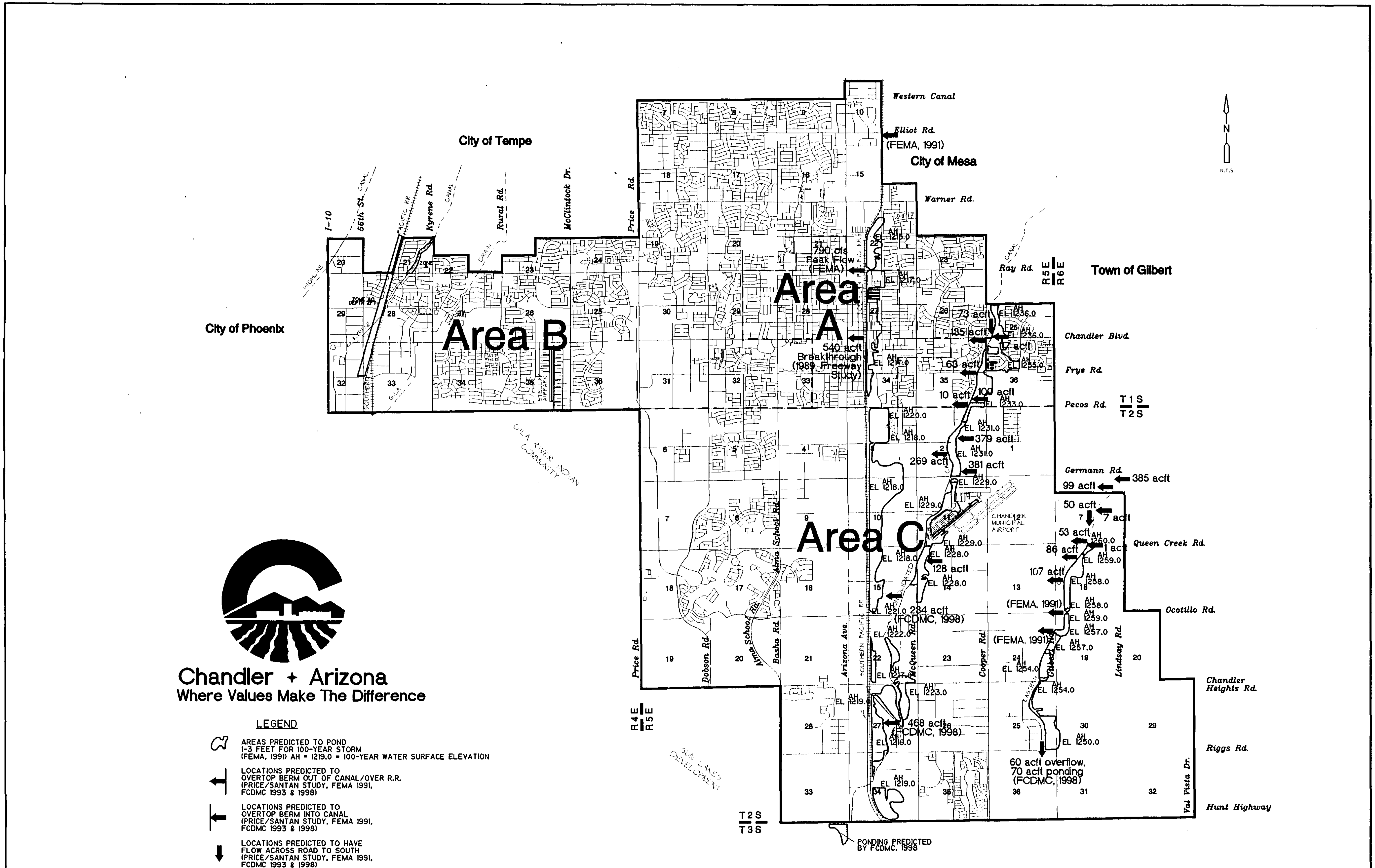
The FEMA study also anticipated that the Eastern and Consolidated canals will convey storm water flows from north of I-60, which is north of the City and parallel to Warner Road, during the 100-year event. In addition, stormwater runoff from scattered developments located in an unincorporated area east of Gilbert Road flows west to the Eastern Canal extension and the two RWCD retention basins located adjacent to Gilbert Road at Riggs Road and Chandler Heights Road. The only outlet for the basins is back into the RWCD system which ultimately drains to an area in South Chandler bounded by the Consolidated Canal and Hunt Highway.

In West Chandler, stormwater flow from streets was predicted to converge at the Gila Drain at I-10 and Maricopa Road.

FCDMC Modeling North of Queen Creek Road

The Flood Control District of Maricopa County modeled stormwater flows in the Gilbert and Chandler area north of Queen Creek Road in 1993 and 1994. The area consisted of the 120 square miles between I-10, the Roosevelt canal, the Western Canal, I-60, and Queen Creek Road. Based on existing land uses, overtopping could occur along both the Eastern and Consolidated Canals; there would likely be outflows from the Eastern Canal; and ponding along the SPRR. The FCDMC modeled both the 100-year, 6-hour storm and the 100-year, 24-hour storm. The topography was based on a limited amount of available data: USGS topographical maps; smaller areas with 2 foot contours; and field investigations.

The Eastern canal tailwater ditch controls flooding of the Eastern canal. The results of the FCDMC study for existing land uses showed that the ditch prevents floodwaters from entering the canal and overtopping westward except outside the Chandler City Limits. Under future conditions, overflows were predicted to be at Germann and Queen Creek Roads, south of the terminus of the ditch, as shown in Table 8-2 and Figure 8-1.



CDM environmental engineers, scientists, planners, & management consultants

1998 CHANDLER STORMWATER MASTER PLAN UPDATE

PREDICTED FLOODING IN CHANDLER FROM STORMWATER RUNOFF FROM OUTSIDE OF CITY AT BUILDOUT

FIGURE 8-1

Table 8-2
Overtopping Locations for Future Conditions, 100-year, 24 hour storm (FCDMC 1993)

Location	Volume (ac-ft)	Note
Consolidated Canal		
Chandler Boulevard	77 117 135	Over Chandler Boulevard Into Canal South and East
Frye Road, ½ mile south of Chandler Boulevard	63	South
Pecos Road	10 100	West Into canal
Willis Road	379	Into canal
½ mile South of Pecos	269	Over canal West
Germann Road	381	North
1/4 mile South of Queen Creek Road	128	Into canal
3/4 mile South of Queen Creek Road	234	Out or over canal
½ mile South of Chandler Heights Road	468	West
Eastern Canal		
Germann Road	385 99	Into canal Over canal
Ryan St, ½ mile South Of Germann Road	7 50	Into Canal South
Queen Creek Road	53 1 86	Over canal Into canal Into Queen Creek Road
Appleby Road, ½ mile South of Queen Creek Road	107	Outflows in QC Road and Runoff down QC Road

As shown in Table 8-2, the Consolidated Canal was predicted to have inflows of stormwater at the Phoenix mainline railroad crossing, and at nearly every road. Overtopping of the canal was predicted to occur at Pecos, Germann, Chandler, and Ocotillo Roads.

Ponding was also predicted to occur along the Chandler branch of the SPRR from Detroit Basin to Frye Road and near Germann Road.

The FCDMC also modeled future conditions with the freeway drainage systems installed and land fully developed with on-site retention. The total flows to the Gila Drain and Floodway increased as a result of the direct drainage in the freeway drainage channels. Inflows to the Eastern canal decreased because on-site retention for future development areas contained stormwater. Overall peak overflows and runoff decreased by about half as a result of on-site retention. This suggests buildout conditions should decrease the overflows predicted to occur, by about one-half.

FCDMC Modeling South of Queen Creek Road for Future Conditions

The FCDMC is currently studying the southern parts of Chandler and Gilbert and modeling the area bounded by Roosevelt Canal on the East, Queen Creek Road on the north, Hunt Highway to the south, and Arizona Avenue from Hunt Highway to Chandler Heights Road, and Price Road from Chandler Heights Road to Queen Creek Road on the West. The study addresses both the 100-year, 6-hour and 100-year, 24-hour storms as well as existing and future conditions.

Preliminary results for future conditions included:

- At Riggs Road and Gilbert Road, the stormwater flow from a 100-year, 24-hour storm will not overtop the Eastern Canal, but it will cross Riggs Road to the south. Preliminary results showed 60 ac-ft escaping south over the road and 70 ac-ft ponding in that area.
- At McQueen Road and Cloud Road (½ mile south of Chandler Heights Road) there will be a concentration point. A sugar factory has a berm next to the Consolidated Canal which will trap sheet flows that have ponded along the canal. The canal will overtop during a 100-year, 24-hour storm onto adjacent land to the west where a lake and golf course are planned. The preliminary results showed a volume of 468 ac-ft.
- At the end of the Consolidated Canal at Hunt Highway and Arizona Avenue, ponding may occur at the southeast corner next to the SPRR because there is no outlet. A 24-inch concrete pipe allows drainage from the northeast corner of Hunt Highway and Arizona Avenue to flow under Hunt Highway. This water as well as sheet flows trapped north of the SPRR flow under the highway through three culverts to the southeast corner, which has no outlet.

8.3 Current Status

The Chandler Development Services Department has existing general requirements for new developments to prevent flooding from off-site flows. Developers must address off-site flows in the drainage report for a proposed development. Developments located within the FEMA 100-year floodplain must obtain approval from the Flood Control District of Maricopa County. Finished Floor Elevations must be 14 inches above the low outfall elevation of the development. Predicted concerns for each planning area of the City are discussed below.

Area A

As discussed previously, FEMA has classified a narrow strip along the east embankment of the SPRR in Study Area A as being within the 100-year floodplain with a Zone AH designation which indicates ponding to depths between 1 and 3-feet. The U.S. Army Corps of Engineers (COE) in a "Summary Report for Flood Control for the Gila Floodway" which covers the Chandler area also defined the same area as subject to ponding in a 100-year flood.

For the 100-year storm, breakouts from the ponding along the SPRR is expected at Chandler Boulevard, Ray Road, and south of Ray Road based on the 1991 FEMA flood insurance study and Price/Santan Freeway study. Figure 8-1 identifies the 100-year flood areas and predicted overflows. In addition, the COE evaluated a "Standard Project Flood" (SPF) which represents the flood that would result from the most severe combination of meteorologic and hydrologic conditions characteristic of the region and could generally be expected to exceed any storm of record. A SPF would cause ponding over a larger portion of Study Area A.

Area B

The 1991 FEMA Flood Insurance Study for Chandler classifies most of Study Area B as Zone B which indicates that these areas are outside the limits of the 100-year flood. The exceptions are narrow strips along the SPRR embankment, the Consolidated Canal, and the Kyrene Canal which are subject to ponding to depths less than three feet on the upstream sides. Generally, inflow into Study Area B from adjacent communities will only occur if a storm were to cause overloading of adjacent drainage systems and overtopping of canals and embankments. Figure 8-1 identifies the 100-year flood areas and predicted inflows and overflows.

The Gila Drain is a drainage ditch which does not trap street flows, but rather accepts them and directs flows to the southwest to the Gila River. It is operated by SRP, and according to SRP is not likely to overflow.

Stormwater inflow from adjacent communities into the western portion of Study Area B between the Western Canal and Pecos Road is limited. Runoff in Mesa is intercepted by the storm drain and retention basin systems adjacent to the Superstition Freeway and the Western Canal. Runoff from Tempe is intercepted by a 36-inch storm drain in Warner Road.

Runoff from Gilbert generally ponds east of the Consolidated and Eastern Canals. In addition, developments in Gilbert are required to provide on-site retention for the 50-year, 24-hour storm (3-inches of rainfall). Based on the 1994 FCDMC study, the Consolidated Canal is expected to overflow at Chandler Boulevard, Frye Road, and Pecos Road and cause local flooding for a 100-year, 24-hour storm.

Area C

Ponding from sheet flows in Study Area C is also minimized by the barriers of berms along the Eastern and Consolidated Canals and the SPRR. In the event of a 100-year, 24-hour storm the Eastern canal is predicted to overtop south of Gilbert Road, at Ocotillo Road, south of Ocotillo Road, at Chandler Heights Boulevard, and at Riggs Road where the canal ends. The Consolidated Canal is predicted to overtop at Germann Road, Queen Creek Road, Ocotillo Road, and Cloud Road (½ mile south of Chandler Heights Boulevard). This area is under development and may be subject to flooding based on the FCDMC studies. Figure 8-1 identifies the 100-year flood areas and predicted inflows and overflows.

8.4 Alternative Evaluation

Alternatives to prevent flooding and ponding from runoff from outside of the City limits should be addressed on both a regional and local level. Reducing, preventing, or controlling the runoff from outside the City needs to be addressed by regional solutions with the participation of Mesa and Gilbert. Local solutions to minimize local impacts within the City planning area are also discussed.

Regional Alternatives

Because this is a regional concern, FCDMC and the upstream communities of Mesa and Gilbert should be involved in developing regional solutions. The FCDMC is studying the area and developing a plan to address flooding issues under the Higley Area Drainage Master Plan. Possible improvements to discuss with the upstream communities and the FCDMC include:

1. Request that FCDMC construct a drainage channel along the eastern side of the Eastern and Consolidated Canals and adjacent railroad tracks that will drain ponded water south to the East Maricopa Floodway or a new drainageway onto GRIC.

2. Request that FCDMC construct a series of retention basins along the canals and railroad to provided percolation and recharge of stromwater. This area could also be developed for multi-recreation use.

3. Improve on-site retention in upstream communities to prevent runoff from reaching Chandler.

A channel could be added along the Eastern Canal to Gilbert Road (Option 1) and south to discharge into the East Maricopa Floodway (EMF) drainage channel owned by the FCDMC. The Roosevelt Water Conservation District owns land along the canal right-of-way which could be used. To reduce construction costs, this project would need to be installed before the area is developed and streets are improved. In order to reach the EMF, the drainage channel would have to cross the GRIC land south of Hunt Highway shown in Figure 2-2. The EMF was not designed with extra capacity so it would likely be undersized for additional flows. Also, GRIC has indicated to the FCDMC that they do not want additional stormwater draining to their land.

Development of multi-use retention basins along the canals and railroad where ponding is predicted (Option 2) would contain the ponding and prevent flooding. Further study of the land uses, amount of water that may pond, and location and amount of retention required would be needed.

Local Alternatives

Besides pursuing regional solutions to off-site flows, alternatives for local action by the City were evaluated. The options included:

1. Improve infrastructure at the road and berm locations predicted to overtop. Further study of the breakthrough and overtopping locations could identify whether channels or pipes to convey the water through Chandler would be a feasible option.

2. Restrict building in potential flood areas.

3. Continue requiring developments in FEMA 100-year flood areas to obtain FCDMC approval, as discussed in Section 3.

4. Continue requiring Finished Floor Elevations to be 14 inches above the low outfall elevation of the development, as discussed in Section 3.

5. Continue requiring developers to address off-site flows in the drainage report, as discussed in Section 3.

At the locations where canals and the railroad berm are predicted to overtop and cause flooding, infrastructure improvements (Option 1) could be added. The improvements would include additional street capacity, open channels along the road or pipes in the right-of-way to essentially pass the flows through the City.

Linear parks could be developed on the eastern sides of the canals and railroad to catch the floodwaters and allow them to infiltrate by providing retention areas. The areas could also be used for recreation and open space in the community (Option 2).

The City Development Services Department already requires new developments to take steps to prevent concerns. As listed above, alternatives 3 through 5 recommend continuing the requirements.

8.5 Recommended Solutions

CDM recommends the following actions to reduce the impacts of canals and railroad berms overtopping as a result of runoff from outside Chandler ponding on the upstream side of the canals and berms:

- Coordinate with FCDMC, Mesa, and Gilbert to develop regional solutions to stormwater flows from outside the City.

- Attend meetings, review draft reports, and provide input for possible regional solutions to prevent flooding in South Chandler from offsite flows as part of the FCDMC's Higley ADMP.

- Restrict building in the areas along the canals and railroad berm predicted to have ponding and flooding.

- Study the predicted overtopping locations for ways to improve the infrastructure. Possible options may be to add additional street capacity, channels or pipes to convey the water through the City.

- Continue requiring developments in FEMA 100-year flood areas to obtain FCDMC approval, Finished Floor Elevations to be 14 inches above the low outfall elevation of the development, and developers to address off-site flows in the drainage report. These requirements have been developed to minimize the impacts of flooding within Chandler.

Denver Basin

Section 9 Permitting

Section 9
Stormwater Permitting

In January 1998, proposed rules for the National Pollutant Discharge Elimination System (NPDES) Stormwater Phase II were published. The rules require discharges of stormwater from construction sites from 1 to 5 acres, small municipal separate storm sewer systems, and commercial and industrial sources to be permitted by the Environmental Protection Agency (EPA) if they reach waters of the U.S.. Camp Dresser & McKee Inc. (CDM) was hired to review the Phase II proposed rules; evaluate their effect on the City of Chandler (City) and the stormwater management master plan; and identify future tasks, products, schedules, and costs.

9.1 NPDES Program

The goal of the NPDES program is to reduce pollution entering surface waters in the U.S., eliminate non-stormwater discharges, and apply best available technology to remove pollutants in runoff from industrial areas. In 1990 the Phase I rules required medium and large municipalities, many industries, and construction sites with more than five acres of land being disturbed to apply for permits and apply best management practices (BMPs), to prevent pollution of stormwater runoff discharges. Chandler was exempt from Phase I because the population was less than the cutoff for a medium municipality, which is 100,000 people based on the 1990 Census. The City's industrial-type activities were exempt from Phase I because the Intermodel Surface Transportation and Efficiency Act (ISTEA) of 1991 restricted EPA from requiring municipalities with population less than 100,000 from applying for permits for most industrial type facilities.

9.2 Applicability to Chandler

Chandler was specifically listed in the Federal Register to meet the Phase II rules. As listed in the proposed rules, the City will be required to apply for a Phase II stormwater NPDES permit from the EPA for its municipal separate storm sewer system which discharges to the Salt River Project (SRP) irrigation system, which is designated a water of the U.S.. The proposed rules freeze the Phase I cutoff to the 1990 Census even though the population will be above 100,000 for the 2000 Census. Under the proposed rules the City will also be required to apply for stormwater NPDES permits from the EPA for industrial type facilities such as vehicle maintenance yards and for construction sites which disturb between one and five acres.

9.3 City Stormwater System

Existing Stormwater Discharges

The downtown area of the City has four existing regional retention basins which capture runoff and discharge it by surface infiltration and pumping to SRP irrigation laterals in order to meet a 36 hour discharge requirement. The SRP irrigation system drains into the Gila Drain, which flows south and west to the Gila River on the Gila River Indian Community's (GRIC) reservation.

Future Stormwater Discharges

To alleviate existing flooding concerns in the downtown area and to reduce the reliance on the SRP drain, the City is undertaking an expansion of its downtown storm drain system. Once the system is designed and constructed, the western portion of the downtown area will be connected to the Arizona Department of Transportation (ADOT) Basin G for discharge of stormwater from regional basins after a storm instead of discharging to the SRP irrigation system. Stormwater from the rest of the downtown area will drain to regional basins and be discharged to the Santan Freeway Drainage Channel and Southeast Valley Regional Drainage System (SEVRDS). Basin G will drain into the Price Freeway Drainage system and the SEVRDS, which will end up in ADOT Basin B. Basin B will detain "first flush" waters, allow particles to settle, and treat the stormwater in vegetated cells before it is discharged to the Gila Floodway and the Gila River. The City also has an allotment to discharge stormwater north to the Salt River, but there are no plans to use the capacity at the current time.

Agreements

The City has signed several agreements with the ADOT and the Flood Control District of Maricopa County (FCDMC) to discharge stormwater to the future Price and Santan Freeway Drainage systems. The agreements allot the City 100 cubic feet per second (cfs) in the Price Drain and Carriage Lane Outfall to the Salt River, 160 acre-feet (ac-ft) in Basin G at Price Road and Galveston Street, and allows use of the future Price Freeway drainage facilities. The City also is participating in the SEVRDS project. For the SEVRDS, the FCDMC agreed to install a water sample monitoring station for discharges to the project channel, and operate it for five years. After four years ADOT, FCDMC, and Chandler will determine who will operate the monitoring station, if necessary. ADOT agreed to "meet any State, Federal, and GRIC water quality standards and requirements which are now or may be in place in the future, including development of a water quality monitoring plan approved by respective agencies" in an agreement with GRIC for discharge of stormwater from the Price and Santan Freeway drainage areas to the Gila Floodway.

On-Site Retention

In the other areas of the City, on-site retention with surface infiltration and drywell percolation disposal are used to capture and dispose of stormwater runoff. Future developments will also provide on-site retention. This policy is considered a best management practice for controlling stormwater pollution discharges to waters of the U.S.

9.4 NPDES Phase II Rules

Permit Types

The proposed Phase II rules provide industries and municipalities with three options for applying for stormwater permit coverage: General, Group, and Individual permit coverage. General permit coverage, recommended for most industries and municipalities regulated by the proposed Phase II rules, requires submission of a Notice of Intent (NOI) to be covered by the EPA's general permit for Arizona or a particular watershed. Group permits allow several similar entities to apply for a permit together or for a Phase I permit to be modified to include another party. Individual permits are not likely to be required for Phase II unless there is a concern about pollution. The proposed rules discussed the possibility of combining municipal storm sewer, construction, and industrial permits into one permit. Most likely the City will apply for a General Permit for the municipal separate storm sewer systems (MS4). The City should review the final rules and General Permits when they are issued by the EPA before making the final decision about which kind of permit to pursue.

Permits will be renewed every five years, and annual status reports will be required. Record keeping is required for three years. No water sampling will be required for the first permit term.

Table 9-1 lists the expected rule publication date and proposed deadlines for permit applications.

Table 9-1
NPDES Phase II Rules Schedule

Date	Item
October 29, 1999	Final Phase II Rules Published
August 7, 2001	Permit Applications Due for ISTEA Facilities
March 1, 2002	EPA Issues General Permits
May 31, 2002	Permit Applications Due for Small Municipalities
May 31, 2002	Permit Applications Due for Small Construction Sites
March 1, 2007	Municipal Programs Implemented

Six Minimum Control Measures

As part of the permit application, the City will be required to implement six minimum control measures based on measurable goals. They include:

1. Public Information and Outreach
2. Public Participation/Involvement
3. Illicit Discharge Detection and Elimination
4. Construction Stormwater Control
5. Post-Construction Stormwater Control
6. Pollution Prevention/Good Housekeeping

For each control measure, the City will be required to implement a minimum program and is recommended by EPA to implement additional programs.

9.5 Existing City Programs and New Rule Requirement Impacts

Input from City departments, existing City programs, and ordinances related to stormwater pollution control were compared to the six minimum control measures requirements and recommended programs. Changes which are required to be implemented and those which are recommended or optional were identified along with their implementation costs are summarized in Table 9-2.

In addition to implementing and maintaining the above NPDES Stormwater program, the City must also undertake the following tasks:

- Program Development - It is assumed that the City will hire a consultant to assist them in reviewing the proposed rules, reviewing the EPA General Permit, preparing the application and negotiating with EPA for a final plan.
- Review and implement a program for mitigation of stormwater runoff from City-owned industrial facilities; be involved in the State's Total Maximum Daily Load (TMDL) process and in five years update the Stormwater Management Plan.

9.6 Impacts on Stormwater Master Plan Update

The impact on the Stormwater Master Plan Update will be to add funding for staffing requirements and programs to meet the minimum control measures. For City-owned industrial-type facilities, funding will be required to install shelters where stormwater may come into contact with material, equipment, or facilities in the downtown area and subsequently discharge to waters of the U.S.

9.7 Program Development and Implementation

The final rules are expected in March 1999 and should stipulate that Chandler should submit a municipal permit application by May 31, 2002. The programs should be implemented five years later. Specific program development tasks and schedule are listed in Table 9-2:

Table 9-2
NPDES Program Development, Tasks, and Schedule

Task	*Date*
1. Review final Phase II Rules	October 1999 - December 1999
2. Advertise and negotiate contract	January - July 2001
3. Review EPA General Permit	August 2001 - December 2001
4. Outline programs, prepare permit application, and background report	August 2001 - April 2002
5. Submit application	May 31, 2002
6. Complete permit negotiations	May 2003
7. Complete program compliance	March 2007

Table 9-3 (Page 1 of 3) Summary of Existing, Required, and Optional NPDES Programs				
Minimum Control Measure	***Existing City Programs***	***Required Program and Costs***	***Options and Costs (Initial/Annual)***	
1. Public Education and Outreach	Water Conservation, Solid Waste, and Fire Safety have programs to set up booths, visit classrooms. Existing household hazardous waste program.	Set up Stormwater Pollution Prevention Program: -Create and mail fliers -Create water bill inserts -Document program Initial Costs:$5,500 Annual Costs:$600	-Set up public display -Give presentations -Film a video -Tape radio commercials -Create and maintain website -School Program -Speakers Burau -Develop Stakeholders Program	$20,200/$8,300 $1,050/$2,100 $15,400/0 $10,400/0 $6,250/$5,000 $15,400/$2,100 $15,400/$2,500 $15,400/$2,500
2. Public Involvement/ Participation	City follows state/local public notice requirements. City storm drain projects hold public information meetings. City bond committee reviews overall stormwater projects.	Document public participation program Initial Costs:$300 Annual Costs:$600	-Set up Volunteer Program -Coordinate with Cities, county -Set up Citizens Advisory Committee -Set up Technical Advisory Committee -Set up Adopt a Basin Program -Set up Informal Public Opinion Survey -Develop Stencil Program	$2,100/$10,000 $1,050/$5,000 $1,050/$10,000 $1,050/$10,000 $1,570/$5,000 $25,200/0 $5,600/$2,500
3. Illicit Discharge Detection and Elimination	Map of stormwater system completed under master plan. Household hazardous waste program exists. City recycling program for oil, batteries, antifreeze exists. City departments contain spills. Fire Dept. takes steps to notify other departments if chemicals enter storm drain.	- Adopt Ordinance -Add areas likely to produce stormwater pollution to map -Set up public reporting process -Set up Inspection/enforcement inspections -Document program. Initial Costs:$43,000 Annual Costs:$113,000	-Educate City Employees -Set up Stormwater Hotline -Set up Used Oil Turn-in -Adopt Spill Management Plan	$6,300/$62,400 $15,200/$2,500 $6,200/$1,700 $10,400/$5,000

Table 9-3 (Page 2 of 3) ***Summary of Existing, Required, and Optional NPDES Programs***				
Minimum Control Measure	***Existing City Programs***	***Required Program and Costs***	***Options and Costs (Initial/Annual)***	
4. Construction Site Runoff Control	Plan reviewers assess erosion control in the review process. Federal law covers sites larger than 5 acres. County design manual lists BMPs.	-Adopt Ordinance -Construction Inspectors enforce BMPs -Set up Public Reporting Process -Document program Initial Costs:$43,000 Annual Costs:$163,000	-Modify Design Manual -Set up Training Program	$10,400/0 $10,400/$200
5. Post Construction Stormwater Management	On-site retention required by City code. Flood damage prevention required by City code. Stormwater retention calculations and layouts required by City code. Design manual lists drainage design criteria. Discharges to SRP system are stored in basins first, providing settling time for contaminants. Planning department has General Land Use Plan, Land Use Element Plan.	-Inspect stormwater facilities after construction -Document program Initial Costs:$5,000 Annual Costs:$25,000	-Set up and update retention basin and drywell database. -Study BMPs for basins.	$42,000/$12,500 $30,200/0

Table 9-3 (Page 3 of 3) ***Summary of Existing, Required, and Optional NPDES Programs***				
Minimum Control Measure	***Existing City Programs***	***Required Program and Costs***	***Options and Costs (Initial/Annual)***	
4. Construction Site Runoff Control	Plan reviewers assess erosion control in the review process. Federal law covers sites larger than 5 acres. County design manual lists BMPs.	-Adopt Ordinance -Construction Inspectors enforce BMPs -Set up Public Reporting Process -Document program Initial Costs:$43,000 Annual Costs:$163,000	-Modify Design Manual -Set up Training Program	$10,400/0 $10,400/$200
5. Post Construction Stormwater Management	On-site retention required by City code. Flood damage prevention required by City code. Stormwater retention calculations and layouts required by City code. Design manual lists drainage design criteria. Discharges to SRP system are stored in basins first, providing settling time for contaminants. Planning department has General Land Use Plan, Land Use Element Plan.	-Inspect stormwater facilities after construction -Document program Initial Costs:$5,000 Annual Costs:$25,000	-Set up and update retention basin and drywell database. -Study BMPs for basins.	$42,000/$12,500 $30,200/0

The estimated costs for the four phases of the overall program for the City are shown in Table 9-4. Costs are based on the City implementing only the required items identified in Table 9-2. As shown in Table 9-4 it will cost the City about $341,000 to develop and implement the NPDES program. It will also cost the City about $305,000 per year to maintain the program. The actual costs will depend upon the permit finally negotiated with EPA in the year 2002. Other programs include City-owned industrial activities that are subject to stormwater permits and participating in the TMDL process of ADEQ.

Table 9-4
NPDES Summary of Costs
(In 1998 Dollars)

Phase	*Labor*	*Capital*	*Total*
Program Development	$40,000	$52,000	$92,000
Implementation	$94,000	$65,000	$159,000
Other Programs	$16,000	$75,000	$90,000
Subtotal	$149,000	$192,000	$341,000
Maintenance (Annual)	$305,000	--	$305,000

Private Retention Basin and Inlet

Section 10 Recommended Plan

Section 10
Recommended Plan, Implementation and Estimated Costs

This section itemizes the recommended storm system facilities and improvements for each area of the City discussed in Sections 6 through 9. The infrastructure recommended is shown in Figure ES-2. The estimated construction costs and land required for the recommended alternatives are presented below. The costs are based on similar construction project costs and the 1997 Means Costing Data. Unit prices include miscellaneous items associated with drainage projects such as manholes, catch basins, pavement replacement, etc. and are shown in Appendix B. The costs are 1998 costs with the ENR Construction Cost Index at 5921. The cost estimates include: an additional 20 percent for engineering, legal, and administration; and an additional 20 percent for contingencies, including the relocation of utilities.

10.1 Assumptions and Limitations

In the development of this plan, certain conditions and limitations have been in place. These include:

1. The plan has been based upon information about the existing stormwater system, topography and land uses obtained from the City of Chandler, Arizona Department of Transportation, the U.S. Geologic Survey and other agencies. The only field surveys performed were to determine the basin depths and for the Erie and Ivanhoe drain design.

2. No field measurements of rainfall or stormwater runoff rates were made for the preparation of this plan.

3. It was assumed that all existing stormwater system components will be adequately maintained so that their existing flow carrying capacity will not be diminished.

4. It was assumed that inlet grates are capable of allowing estimated quantities of stormwater to enter the inlets and that manholes and inlets along pipelines do not restrict flow.

5. Prior to final design and construction, preliminary designs and field surveys will be needed to verify basin sizing, pipe sizes, alignments, elevations, tributary areas and other details about the overall system.

6. Studies regarding the structural adequacy of existing stormwater facilities and water quality are beyond the scope of this plan.

10.2 Area A Recommendations and Costs

The recommended storm drains, improvements, and pump stations for the downtown area include the system of storm drains, pump stations, and pipes from the Galveston and Arrowhead Basins to

ADOT Basin G; and from the Denver Basin to the future Santan Freeway drainage channel. Costs are also included for an alternative system of storm drains, a pump station, and pipes from the Denver Basin to temporary ADOT Basin H. The following sections discuss specific portions of the projects recommended.

Basin G Drainage Area Projects

Ivanhoe Drain

As discussed in Section 6, a storm drain is recommended along Ivanhoe Street to drain into the Alma School Road drain. The phases of the project will take into account the volume of storage available in the Galveston Basin, and the severity of the ponding. The costs and phases are shown below:

- Phase I: Evergreen Street to Alma School Road: A gravity storm drain along Ivanhoe Street from Evergreen Street to the Alma School Road drain. A short lateral north in Jay Street from Ivanhoe Street to Linda Lane. See Table 10-1 for estimated cost. (Detailed costs are shown in Appendix B.)
- Phase II: Cheri Lynn Drive to Evergreen Street including laterals: A gravity storm drain along Ivanhoe Street from Cheri Lynn Drive to the pipes installed for Ivanhoe Drain Phase I. Extend lateral in Jay Street north to Shannon Street. See Table 10-2 for estimated costs.
- Phase III: Extend Ivanhoe Drain to Dakota Street including laterals: A gravity storm drain along Ivanhoe Street from Dakota Street to Cheri Lynn Drive. Laterals in Iowa and Hartford Streets to collect runoff north of Ivanhoe Street. See Table 10-3 for estimated costs.

Table 10-1
Ivanhoe Drain Phase I Estimated Costs (1998)

Phase	Pipe Section	Length (ft)	Pipe Diameter (in.)	Unit Cost ($/ft)	Total Cost
I	Ivanhoe Street: Alma School Road to Evergreen Street	1,350	42	$144	$194,00
I	Jay: Ivanhoe Street to Linda Lane	180	24	$78	$14,000
I	Subtotal	1,530			$208,000
I	Engineering/Legal/Admin (20%)				$42,000
I	Subtotal				$250,000
I	Contingencies (20%)				$50,000
	Total Ivanhoe Drain Phase I				***$300,000***

Table 10-2
Ivanhoe Drain Phase II Estimated Costs (1998)

Phase	Pipe Section	Length (ft)	Pipe Diameter (in.)	Unit Cost ($/ft)	Total Cost
II	Jay: Linda Lane to Shannon Street	620	24	$78	$48,000
II	Ivanhoe Street: Evergreen Street to Cheri Lynn Drive	400	42	$144	$58,000
II	Subtotal	1,020			$106,000
II	Engineering/Legal/Admin (20%)				$21,000
II	Subtotal				$127,000
II	Contingencies (20%)				$25,000
	Total Ivanhoe DrainPhase II				***$152,000***

Table 10-3
Ivanhoe Drain Phase III Estimated Costs (1998)

Phase	Pipe Section	Length (ft)	Pipe Diameter (in.)	Unit Cost ($/ft)	Total Cost
III	Ivanhoe: Cheri Lynn Street to Hartford Street	940	36	$120	$113,000
III	Ivanhoe Street: Hartford Street to Iowa Street	600	36	$120	$72,000
III	Ivanhoe Street: Iowa Street to Dakota Street	850	24	$78	$66,000
III	Hartford Street: Ivanhoe Street to Dublin Street	510	24	$78	$40,000
III	Iowa Street: Ivanhoe Street to Shannon Street	800	24	$78	$62,000
III	Subtotal	3,700			$353,000
III	Engineering/Admin/Legal (20%)				$71,000
III	Subtotal				$424,000
III	Contingencies (20%)				$85,000
	Total Ivanhoe Drain Phase III				***$509,000***

Table 10-4
Ivanhoe Drain Estimated Cost Summary (1998)

Phase I (Table 10-1)	$300,000
Phase II (Table 10-2)	$152,000
Phase III (Table 10-3)	$509,000
Total Ivanhoe Drain	***$961,000***

Erie Drain

The Erie Drain is recommended to drain excess stormwater along Erie Street to the Alma School Road drain until Phases II and III extend it and connect it to Arrowhead Basin. The phases take into account the storage available and future regional drainage plans. The phases and costs include:

- Phase I: Hartford Street to Alma School Road: A gravity storm drain along Erie Street from Hartford Street to the Alma School Road drain. Laterals to the north in Cheri Lynn Drive, Evergreen Street, and Pleasant Drive. See Table 10-5 for estimated costs.

- Phase II: Nebraska Street to Hartford Street: A gravity storm drain along Erie Street from Nebraska Street to Hartford Street to the pipe installed for Erie Drain Phase I. Lateral in Hartford to replace Hartford Drain south of Erie Street. Lateral to the north in Nebraska Street. See Table 10-6 for estimated costs.

- Phase III: Disconnect Erie Drain from the Alma School Road drain, gravity storm drain in Erie Street to the Arrowhead Basin. Includes stub out for the Galveston Basin gravity outlet pipe. See Table 10-7 for estimated costs.

Table 10-5
Erie Drain Phase I Estimated Costs (1998)

Phase	Pipe Section	Length (ft)	Pipe Diameter (in.)	Unit Cost ($/ft)	Total Cost
I	Erie Street: Alma School Road to Pleasant Drive	600	54	$186	$112,000
I	Erie Street: Pleasant Drive to Evergreen Street	600	48	$165	$112,000
I	Erie Street: Evergreen Street to Cheri Lynn Street	400	48	$165	$66,000
I	Erie Street: Cheri Lynn Street to Sunset Drive	300	48	$165	$50,000
I	Erie Street: Sunset Drive to Hartford Street	700	42	$144	$101,000
I	Pleasant Drive: Erie Street to Oakland Street	700	30	$102	$71,000
I	Cheri Lynn Street: Erie Street to Oakland Street	800	18	$78	$62,000
I	Evergreen Street: Detroit Street to Erie Street	500	30	$102	$51,000
I	Subtotal	4,750			$605,000
I	Engineering/Legal/Admin (20%)				$121,000
I	Subtotal				$726,000
I	Contingencies (20%)				$145,000
	Total Phase I				***$871,000***

Table 10-6
Erie Drain Phase II Estimated Costs (1998)

Phase	Pipe Section	Length (ft)	Pipe Diameter (in.)	Unit Cost ($/ft)	Total Cost
II	Erie Street: Hartford Street to Nebraska Street	1150	30	$102	$117,000
II	Hartford Street: Detroit Street to Erie Street	650	30	$102	$66,000
II	Nebraska Street: Detroit Street to Erie Street	650	24	$78	$51,000
II	Subtotal	2,450			$234,000
II	Engineering/Legal/Admin (20%)				$47,000
II	Subtotal				$281,000
II	Contingencies (20%)				$56,000
	Total Phase II				***$337,000***

Table 10-7
Erie Drain Phase III Estimated Costs (1998)

Phase	Pipe Section	Length (ft)	Pipe Diameter (in.)	Unit Cost ($/ft)	Total Cost
III	Erie: Alma School Road to Central Drive	1,300	60	$204	$265,000
III	Erie: Central Drive to Arrowhead Basin	1,300	60	$204	$265,000
III	Subtotal	2,600			$531,000
III	Engineering/Legal/Admin (20%)				$106,000
III	Subtotal				$637,000
III	Contingencies (20%)				$127,000
III	***Total Erie Drain Phase III***				***$764,000***

Table 10-8 Erie Drain Estimated Cost Summary (1998)	
Phase I (Table 10-5)	$871,000
Phase II (Table 10-6)	$337,000
Phase III Table 10-7)	$764,000
Total Erie Drain	***$1,972,000***

Facilities to Discharge to Basin G

An outlet from Galveston Basin is recommended to drain into the Erie Drain and drain to the Arrowhead Basin. In addition to the Erie Drain, a pump station at Arrowhead Basin and a forcemain to ADOT Basin G are recommended. Details are shown below:

- Galveston Basin Discharge Pipe: A gravity pipe from the Galveston Basin west on Galveston Street to Central Drive, south on Central Drive to Erie Drain. See Table 10-9 for estimated costs.
- Arrowhead Basin Pump Station: 35 cfs pump station to drain the Arrowhead Basin within 36 hours. See Table 10-10 for estimated costs. This pump station should be constructed before the Erie Drain is connected to the Arrowhead Basin to prevent overtapping.
- Forcemain from the Arrowhead Basin Pump Station to Basin G: A forcemain from the Arrowhead Basin, following Anderson Boulevard through the Anderson Springs development to Galveston Street and then west along Galveston Street to Basin G near Price Road. See Table 10-11 for estimated costs. This forcemain should also be constructed before the Erie Drain is connected to the Arrowhead Basin.

Table 10-9
Galveston Basin Discharge Pipe Estimated Costs (1998)

Pipe Section	***Length (ft)***	***Pipe Diameter (in.)***	***Unit Cost ($/ft)***	***Total Cost***
Galveston: Basin to Central Drive	780	33	$108	$84,000
Central: Galveston Street to Erie Street	1,410	33	$108	$152,000
Subtotal	2,190			$236,000
Engineering/Legal/Admin (20%)				$47,000
Subtotal				$283,000
Contingencies (20%)				$57,000
Total Galveston Basin Discharge Pipe				***$340,000***

Table 10-10 Arrowhead Basin Pump Station Estimated Costs (1998)	
Item	***Cost***
Pumps, 35 cfs	$127,000
Wetwell/structure	$130,000
Piping and Valves	$70,000
Electrical and Instrumentation	$62,000
Standby Power	$150,000
Building	$85,000
Landscaping, etc. (½ acre)	$13,000
Subtotal	$637,000
Engineering/Legal/Admin (20%)	$127,000
Subtotal	$764,000
Contingencies (20%)	$153,000
Total Arrowhead Pump Station	***$917,000***

Table 10-11 Forcemain to Basin G Estimated Costs (1998)				
Pipe Section	***Length (ft)***	***Pipe Diameter (in.)***	***Unit Cost ($/ft)***	***Total Cost***
Erie Force Main: Pump Station to Arrowhead Drive	150	36	$120	$18,000
Anderson Blvd. Force Main: Arrowhead Drive to Galveston Street	5,880	36	$120	$707,000
Galveston Street Force Main: Anderson Blvd. to Basin G	5,280	36	$120	$635,000
Subtotal	11,300			$1,360,000
Engineering/Legal/Admin (20%)				$272,000
Subtotal				$1,632,000
Contingencies (20%)				$326,000
Total for Arrowhead Basin Discharge Force Main				***$1,958,000***

Table 10-12 Facilities from Galveston Basin to Basin G Estimated Cost Summary (1998)	
Galveston Basin Discharge Pipe (Table 10-9)	$340,000
Arrowhead Pump Station (Table 10-10)	$917,000
Arrowhead Basin Discharge Forcemain (Table 10-11)	$1,958,000
Total Galveston Basin to Basin G	***$3,215,000***

Recommended Alternative for Denver Basin

The 1992 plan to drain the Denver Basin to ADOT Basin H includes the following components:

- Denver Basin Pump Station: A 35 cfs pump station to drain the basin in 36 hours. See Table 10-13 for estimated costs.
- Hartford forcemain from the Denver Basin to the Pecos Road Drain: A force main from the Denver Basin pump station south on Hartford Street to the future Pecos Road Drain. See Table 10-14 for estimated costs.
- Pecos Road Drain: A storm drain pipe from 1/4 mile west of McQueen Road west along Pecos Road to temporary ADOT Basin H at Price Road. See Table 10-14 for estimated costs.

Table 10-13
Denver Basin Pump Station Estimated Costs (1998)

Pipe Section	Length (ft)	Pipe Diameter (in.)	Unit Cost ($/ft)	Total Cost
Pumps				$141,000
Wetwell/Structure				$135,000
Piping and Valves				$72,000
Electrical and Instrumentation				$64,000
Standby Power				$150,000
Landscaping, etc (½ acre)				$13,000
Subtotal				$575,000
Engineering/Legal/Admin (20%)				$115,000
Subtotal				$690,000
Contingencies (20%)				$138,000
Total Denver Pump Station				***$828,000***

Table 10-14 Hartford Forcemain and Pecos Road Drain Estimated Costs (1998)				
Pipe Section	**Length (ft)**	**Pipe Diameter (in.)**	**Unit Cost ($/ft)**	**Total Cost**
Hartford Force Main: Fairview Street to Pecos Road	6000	36	$120	$720,000
Pecos Drain: Basin H to Arrowhead Drive	7920	54	$186	$1,475,000
Pecos: Arrowhead Drive to Hartford Street	5280	48	$165	$872,000
Pecos: Hartford Street to Nevada Street	4365	48	$165	$721,000
Pecos: Nevada Street to Ithica Street	2640	36	$120	$318,000
Subtotal	26,200			$4,106,000
Engineering/Legal/Admin (20%)				$821,000
Subtotal				$4,927,000
Contingencies (20%)				$985,000
Total Hartford Forcemain and Pecos Road Drain to Basin H				***$5,912,000***

Table 10-15 Facilities to Drain Denver Basin to Basin H Estimated Cost Summary (1998)	
Denver Basin Pump Station (Table 10-13)	$828,000
Hartford Forcemain and Pecos Road Drain (Table 10-14)	$5,912,000
Total Denver to Basin H	***$6,740,000***

Alternative Force Main to Drain the Denver Basin

Instead of a force main to Pecos Road and a gravity drain to ADOT Basin H, the Denver Basin is recommended to have a pump station and forcemain to the ADOT Santan Freeway drainage channel if ADOT agrees. The project would include:

- Denver Basin Pump Station: A 35 cfs pump station to drain the basin in 36 hours. See Table 10-13 for estimated costs.

- Hartford force main from the Denver Basin to the Santan Freeway Drainage Channel: A force main from the Denver Basin pump station to the future Santan Freeway drainage channel, routed along the Hartford Street alignment. See Table 10-16 for estimated costs.

Table 10-16
Alternative Hartford Forcemain to the Santan Freeway Drainage Channel Estimated Costs (1998)

Pipe Section	Length (ft)	Pipe Diameter (in)	Unit Cost ($/ft)	Total Cost
Hartford Force Main: Denver Basin to Santan Freeway drainage channel	6000	36	$120	$720,000
Engineering/Legal/Admin (20%)				$144,000
Subtotal				$864,000
Contingencies (20%)				$173,000
Total Hartford Forcemain				***$1,037,000***

Table 10-17
Facilities to Drain Denver Basin to the Santan Freeway Drainage Channel Cost Summary (1998)

Denver Basin Pump Station (Table 10-13)	$828,000
Hartford Forcemain (Table 10-16)	$1,037,000
Total Denver to Santan drainage channel	***$1,865,000***

Ponding Concern Improvements

In a few areas of Area A stormwater ponds in the street after significant rainfall. Improvements to existing basins and drains to reduce the ponding include:

- Install two dry wells in the basins near Pleasant Drive between Knox Road and Pleasant Lane, and near Pleasant Lane and Orchid Lane.
- Install catch basins along Delaware Street between Erie Street and Chandler Boulevard to connect to the storm sewer.

Estimated costs are shown in Table 10-18.

Table 10-18 ***Area A Modifications to Reduce Ponding Concerns (1998)***				
Description	***Items***	***Quantity***	***Unit Cost***	***Total Cost***
Pleasant Lane Basin Improvements	Drywells	2	$5000	$10,000
Delaware Street Catch Basins	Catch basins	4	$3,000	$12,000
Subtotal				$22,000
Admin/Legal/Contingencies (20%)				$4,000
Total Area A Ponding Improvements				***$26,000***

Summary of Costs for Area A

The total costs for the projects in Area A summarized above are shown in Table 10-19.

Table 10-19 ***Summary of Area A Projects and Estimated Costs (1998)***	
Project	***Total Cost***
Ivanhoe Drain Phase I (Table 10-1)	$300,000
Ivanhoe Drain Phase II (Table 10-2)	$152,000
Ivanhoe Drain Phase III (Table 10-3)	$509,000
Erie Drain Phase I (Table 10-5)	$871,000
Erie Drain Phase II (Table 10-6)	$337,000
Erie Drain Phase III (Table 10-7)	$764,000
Galveston Basin Discharge Pipe (Table 10-9)	$340,000
Arrowhead Basin Pump Station (Table 10-10)	$917,000
Arrowhead Basin Discharge Forcemain (Table 10-11)	$1,958,000
Denver Basin Pump Station (Table 10-13)	$828,000
Hartford Forcemain and Drain to Basin H (Table 10-14)	$5,912,000
Ponding Area Improvements (Table 10-18)	$26,000
Total Cost for Area A	***$12,914,000***

Thus, the total estimated cost for the projects recommended to reduce ponding and provide a long-term outfall for Area A is $12,900,000. If the ***alternative Denver Basin forcemain to the Santan***

Freeway drainage channel replaces the drain along Pecos Road to Basin H, the total estimated cost would be *$8,039,000,* a savings of about $4,900,000 in piping costs.

10.3 Area B Recommendations and Costs

To reduce local ponding in North and West Chandler, the following items are recommended:

- Obtain permission from the owner of the private basin on the east side of 56th Street near Galveston Street concerning increasing its size and capacity.
- Obtain permission from Universal Forest Products concerning resloping their driveway and parking lot towards an on-site basin.
- Install catch basins and storm drain pipe to drain the 56th Street and Chandler Boulevard area south along 56th Street to the Santan Freeway drainage channel.

Estimated costs to perform these modifications are listed in Tables 10-20 though 10-22.

Table 10-20
Facilities to Reduce Ponding near 56th Street and Chandler Boulevard Estimated Costs (1998)

Pipe Section	***Item***	***Quantity***	***Unit Cost***	***Total Cost***
Private Basin Modifications	Deepening, landscaping and inlets	1	$35,400	$35,400
Universal Forest Products Entrance Modifications	Excavation, Repaving	1	$12,620	$12,620
Subtotal				$48,000
Admin/Legal/Contingencies (20%)				$10,000
Total Stormwater Reduction Projects				***$58,000***

Table 10-21
Facilities to Retain or Discharge Stormwater near 56th Street and Chandler Boulevard Estimated Costs (1998)

Pipe Section	***Length (ft)***	***Pipe Diameter (in)***	***Unit Cost ($/ft)***	***Total Cost***
56th Street Storm Drain	2800	18	$69	$193,200
Engineering/Admin/Legal (20%)				$38,640
Subtotal				$232,000
Contingencies (20%)				$46,000
Total 56th Street Storm Drain				***$278,000***

Table 10-22 Facilities to Reduce Ponding near 56th Street and Chandler Boulevard Summary of Estimated Cost (1998)	
Reduction Measures	$58,000
56th Street Storm Drain	$278,000
Total 56th Street/Chandler Blvd. Ponding	*$336,000*

Ponding Concerns

A few ponding concerns were identified in Area B which will require minor improvements to reduce the ponding. They include:

- Install temporary basin along McClintock Drive west between Galveston and Monterey.
- Improve Cooper Road between Chandler Blvd and Ray Rd. These costs were assumed to be part of the street improvement project and are not included here.
- Install scupper into the retention basin on the west side of Oregon Street between Palomino and Nopal Streets.
- Enlarge the temporary basin at Dobson and Elliot Roads.
- Install new drywells in the following basins:
  - 750 W. Warner Road, west of Evergreen St, north side of street, in front of White Glove Car Wash
  - Warner Road, south, in front of K-ball site
  - Warner Road, north, at Comanche Street
  - Southeast corner of Warner and Alma School Roads
  - East side of Oregon Street between Palomino and Nopal Streets
  - Pleasant Drive between Knox Road and Pleasant Lane
  - Pleasant Drive between Pleasant Lane and Orchid Lane

Estimated costs for the minor improvements are shown in Table 10-23.

Table 10-23
Facilities and Modifications to Reduce Area B Ponding Concerns

Pipe Section	Item	Quantity	Unit Cost	Total Cost
Temporary Basin 25 ft x 25 ft	Excavation, grading, haul spoils, etc.	1	$10,000	$10,000
Enlarge Temporary Basin	Grading	1	$1,000	$1,000
Oregon Street Scupper and Basin Improvements	Scupper Grading	job	$5,000	$5,000
New Drywells		7	$5,000	$35,000
Subtotal				$51,000
Legal/Admin/contingencies (20%)				$10,200
Total Area B Ponding Concerns				***$61,000***

CDM recommends continuing the policy of on-site retention including runoff from one-half of adjacent streets for new development. Existing retention basins and drywells are recommended to be maintained to extend the life of drywells and keep the rate of percolation in the basins as fast as the soil will allow. Maintenance of private basins and drywells are enforced by City ordinance.

Summary of Costs for Area B

The total costs for the Area B projects summarized above are shown in Table 10-24.

Table 10-24
Area B Summary of Estimated Costs

Project	Total Cost
56th Street/Chandler Blvd Ponding (Table 10-22)	$336,000
Ponding concerns (Table 10-23)	$61,000
Total Cost for Area B	***$397,000***

10.4 Area C Recommendations and Costs

To reduce local ponding in South Chandler, the following items are recommended:

- Provide an overflow with retention basin near Alma School and Ocotillo Roads to prevent the lake overflowing into the street.
- Install temporary basin on the Southeast corner of Bashas Road and Ocotillo Road.

- Deepen the temporary basin at the intersection of Willis Road and Alma School Road.

Estimated Costs are shown in Table 10-25.

Table 10-25
Area C Facilities and Modifications to Reduce Ponding Concerns (1998)

Pipe Section	***Item***	***Quantity***	***Unit Cost***	***Total Cost***
Lake Overflow Basin (½ acre)	Land, Excavation, Haul Spoils, Grading, Landscaping	1	$120,000	$120,000
Temporary Basin (25 ft x 25 ft)	ROW Acquisition Excavation Grading	1	$10,000	$10,000
Temporary Basin Modifications	Excavation Grading	1	$1,000	$1,000
Subtotal				$131,000
Legal/Admin/contingencies (20%)				$26,000
Total Cost for Area C				***$157,000***

10.5 Operational Costs

The 1998 costs for maintaining the streets, inlets, catch basins, storm drains, and basin inlets for the City are summarized in Table 10-26. Not included is the landscaping maintenance cost which the City contracts out by the square mile, including City-maintained basins, medians, and rights-of-way.

Table 10-26 1998 Annual Operation and Maintenance Costs (1998)				
Description	**Unit**	**Unit Cost**	**Units**	**Total Cost**
Street Sweeping	mile curb	$1,065	80	$85,200
Pipeline, Inlet, and Basin Inlet Inspection/Maintenance (2 Full-time employees)				$87,000
Pump Station Maintenance/ Repairs (3 - 2 cfs pump stations): Pull pumps, inspect, maintain, repair				$ 1800
Pump Operating Costs				$ 12,000
Drywell Maintenance	each	$500	40/year	$20,000
Subtotal				$ 206,000
Contingencies (20%)				$ 41,000
Total Annual Costs				***$ 247,000***

After the addition of the recommended storm drains and pump stations in Area A and the improvement of remaining streets within the City limits, the annual operation and maintenance costs are expected to increase as shown in Table 10-27.

Table 10-27 Future Annual Operation and Maintenance Costs (in 1998 costs)				
Description	**Unit**	**Unit Cost**	**Units**	**Total Cost**
Street Sweeping	mile curb	$1,065	95	$101,000
Pipeline, Inlet, and Basin Inlet Inspection/Maintenance (3 full-time employees)				$130,000
Pump Station Maintenance/ Repairs (2 - 35 cfs pump stations): Pull pumps, inspect, maintain, repair				$ 5,000
Pump Operating Costs				$ 140,000
Drywell Maintenance	each	$500	40	$20,000
Subtotal				$ 396,000
Contingencies (20%)				$ 79,000
Total Future Annual Operational Costs				***$475,000***

10.6 NPDES Permitting Requirements and Costs

The City will be required to apply for a Phase II Stormwater Permit for the municipal separate storm sewer system (MS4) and industrial-type facilities owned by the City. As discussed in Section 9, the permit application for the MS4 must include programs and measurable goals for six minimum measures. Optional additional programs for the measures will likely be negotiated with the EPA during the permitting process.

In addition to the programs for the six minimum control measures, the City will be required to apply for permits for any industrial-type facilities which may come into contact with stormwater. CDM recommends that the City take steps required to prevent stormwater runoff from contact with equipment and facilities at City-owned industrial-type locations in the downtown area. This would include on-site retention (as exists at many sites) and construction of storm resistant shelters for uncovered facilities. Once any modifications are complete, the City will be eligible to apply for "no exposure exemptions."

The required programs are summarized in the Table 10-28. Estimated costs are shown in Table 10-29.

10.7 Project Phasing

The recommended projects to connect the downtown area to the freeway drainage system and required programs for the NPDES permit will be implemented in phases to spread the costs over several years. Tables 10-30 to 10-32 summarize the phases, projects, and costs.

Table 10-28
NPDES Required Programs

Minimum Control Measure	***Required Programs Descriptions***
Program Development	Advertise and Negotiate Contract Review final Phase II Rules Review General Permit Permit Application Negotiation
Implementation	
1. Public Education and Outreach	Set up Stormwater Pollution Prevention Program: - Create and mail fliers - Create water bill inserts - Document program - Develop school program
2. Public Involvement/ Participation	Document public participation program
3. Illicit Discharge Detection and Elimination	- Ordinance - Add areas likely to produce stormwater pollution to map - Public reporting process - Inspection/enforcement inspections - Document program.
4. Construction Site Runoff Control	- Ordinance - Construction Inspectors enforce BMPs - Public Reporting Process - Document program
5. Post Construction Stormwater Management	- Inspect stormwater facilities after construction - Document program
6. Pollution Prevention/Good Housekeeping	Document existing programs.
Industrial-Type Activities	Review Installation Document and Apply for No Exposure Exemption
Other Programs	Follow TMDL Process Stormwater Masterplan Update

Table 10-29
NPDES Estimated Costs (1998)

Phase	***Total Estimated Cost***
Program Development	$92,000
Implementation	$159,000
Other Programs	$90,000
Annual Maintenance	$305,000
Totals	Initial: $341,000 Annual: $305,000

Table 10-30 ***Phasing of Capital Projects (1998 costs)***						
Project	***1998-99***	***1999-2000***	***2000-01***	***2001-02***	***2002-03***	***2003-04***
Ivanhoe Drain Phase I	$300,000					
Ivanhoe Drain Phase II	$152,000					
Ivanhoe Drain Phase III				$509,000		
Erie Drain Phase I	$871,000					
Erie Drain Phase II				$337,000		
Erie Drain Phase III			$764,000			
Galveston Basin Discharge Pipe			$340,000			
Arrowhead Basin Pump Station		$917,000				
Arrowhead Basin to Basin G Forcemain		$1,958,000				
Denver Basin Pump Station					$828,000	
Hartford Force main and Pecos Road Drain					$2,912,000	$3,000,000
Area A Ponding Improvements		$26,000				
56th St/Chandler Blvd Storm Drain					$336,000	
Ponding Concerns in Area B		$61,000				
Ponding Concerns in Area C					$157,000	
NPDES Program Development			$40,000	$52,000		
NPDES Program Implementation					$100,000	$59,000
NPDES Industrial-type Facilities					$6,000	$26,000
Involvement in TMDL Process				$2,000	$2,000	$2,000
Update Stormwater Management Plan						$50,000
Total Capital/Initial Costs	***$1,323,000***	***$2,962,000***	***$1,144,000***	***$900,000***	***$4,341,000***	***$3,137,000***

Table 10-31 *Phasing of Operational Annual Cost*							
Project	***1998-99***	***1999-2000***	***2000-01***	***2001-02***	***2002-03***	***2003-04***	***2004-05***
Infrastructure Operation and Maintenance Costs	$247,000	$285,000	$323,000	$361,000	$399,000	$437,000	$475,000
NPDES Maintenance Cost					$500	$27,000	$305,000
Total Operation and Maintenance Cost	***$247,000***	***$285,000***	***$323,000***	***$361,000***	***$400,000***	***$464,000***	***$780,000***

Table 10-32 *Summary of Total Phased Cost (1998 costs)*							
Project	***1998-99***	***1999-2000***	***2000-01***	***2001-02***	***2002-03***	***2003-04***	***2004-05***
Capital/Intial	$1,323,000	$2,962,000	$1,144,000	$900,000	$4,341,000	$3,137,000	$2,000
Annual	$247,000	$285,000	$323,000	$361,000	$400,000	$464,000	$780,000
Total Phased Cost	***$1,570,000***	***$3,247,000***	***$1,467,000***	***$1,261,000***	***$4,741,000***	***$3,601,000***	***$782,000***

Residential Basin with Drywell and Landscaping

Section 11 Financing Options

Section 11
Financing Stormwater Systems

Currently Chandler finances its stormwater capital projects through the use of sewer revenue bonds. For annual operation and maintenance costs, the City utilizes its General Fund monies. In 1998, the estimated annual stormwater operation and maintenance cost was $247,200. If the proposed stormwater improvements are constructed with connections to Basins G and H, the estimated annual operations and maintenance costs are expected to rise to nearly $475,000 per year, an increase of approximately 90 percent. If the NPDES program is implemented as identified, this will increase the annual costs to the City by another $305,000 per year. Combining these costs results in an annual operation and maintenance cost of $780,000 per year. If other minor annual costs are also included, the total annual cost for stormwater will be approximately $780,000 per year by the year 2004. Annual capital costs during the next five years are estimated to range from $898,000 to $4,340,000.

11.1 Financing Options

For financing the stormwater costs there are many options available including general fund, general obligation bonds, revenue bonds, utility fees, improvement districts, and developer fees. For Chandler however, three options have been identified:

- Existing Program using Sewer Fees and General Fund
- Existing Program with Increased Sewer Fee
- Stormwater Utility

Existing Program

As stated above, the existing annual operation and maintenance cost is approximately $247,200 per year. This amount appears to be within the City's General Fund capabilities. However, there are several concerns in continuing with this approach for operation and maintenance. First, the annual operation and maintenance costs are going to increase which will put an additional strain on the General Fund monies. Second, the street HURF funds to the City are anticipated to be cut which will mean the City will have to fund more of the street program from the General Fund. As a result of these facts, continuing to use the General Fund for the stormwater annual operating and maintenance monies will become increasingly more difficult.

The continued use of sewer revenue bonds for the stormwater capital improvements appears to be a satisfactory solution as long as the cheaper option for discharge to Basin H (forcemain directly south to the Santan Freeway drainage channel) can be implemented. This could reduce the anticipated capital costs for the pipeline from $5,920,000 (Table 10-14 in Section 10) to $1,037,000 (Table 10-16).

Table 11-1 Advantages/Disadvantages of Existing Program	
Advantages	**Disadvantages**
■ Easy way to finance storm water funding ■ No new council authorization required ■ Repayment of capital costs are spread citywide	■ Higher O&M costs could have big impact on General Fund monies ■ May have impact on other projects funded through the General Fund ■ Current sewer service charge does not identify storm sewer charges

Existing Program with Increased Sewer Service Fee

The current monthly sewer service charge covers the sewer system annual operation and maintenance costs; repayment for bonds sold for sewer projects; and repayment for bonds sold for stormwater projects. If the monthly residential sewer service charge was increased by $1 to $2 per month, the sewer fund could generate an additional income between $500,000 to $1,000,000 per year. This additional money could be used for O&M costs and/or bond repayment.

Table 11-2 Advantages/Disadvantages of Increased Sewer Fee	
Advantages	**Disadvantages**
■ Utilizes an existing funding mechanism ■ Monies can be used for both capital and O&M ■ Dedicated funding source ■ Eliminates or reduces General Fund support for O&M.	■ Single rate may not be acceptable ■ Requires identification of additional charges ■ Could impact any planned increases for sanitary sewer related projects ■ Will require special assessment study ■ Council will have to approve

Stormwater Utility

In this option, a separate stormwater utility would be established to fund all stormwater related expenditures. A mechanism would be developed to establish an equitable user fee based upon the average impervious area for a single family residence (equivalent residential unit - ERU). All other developments would be based on the number of ERUs.

Table 11-3
Advantages/Disadvantages of Stormwater Utility

Advantages:	*Disadvantages:*
▪ Monies can be used for both capital and O&M ▪ Dedicated funding source ▪ Eliminates General Fund support	▪ Since the fee is a user charge, tax exempt facilities will pay ▪ Will need special council authorization ▪ Will need to go through public acceptance ▪ Will require special ERU study

11.2 Recommendations

With respect to the capital costs, CDM recommends Chandler to continue to utilize sewer revenue bonds for construction of the stormwater system.

For the additional operation and maintenance costs, CDM recommends the City look at either increasing the sewer service fee or implementing a stormwater utility. Both options should include the development of ERU charges in order for the applicable stormwater charges to be fair and equitable.

Arrowhead Basin

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Section 12
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Arrowhead Basin

Appendix A

Appendix A
IDF Curves and Area A
Existing Storm Drains

Appendix A Contents

Figure A-1 Chandler Intensity-Duration-Frequency Curves
Based on FCDMC Isopluvial Maps

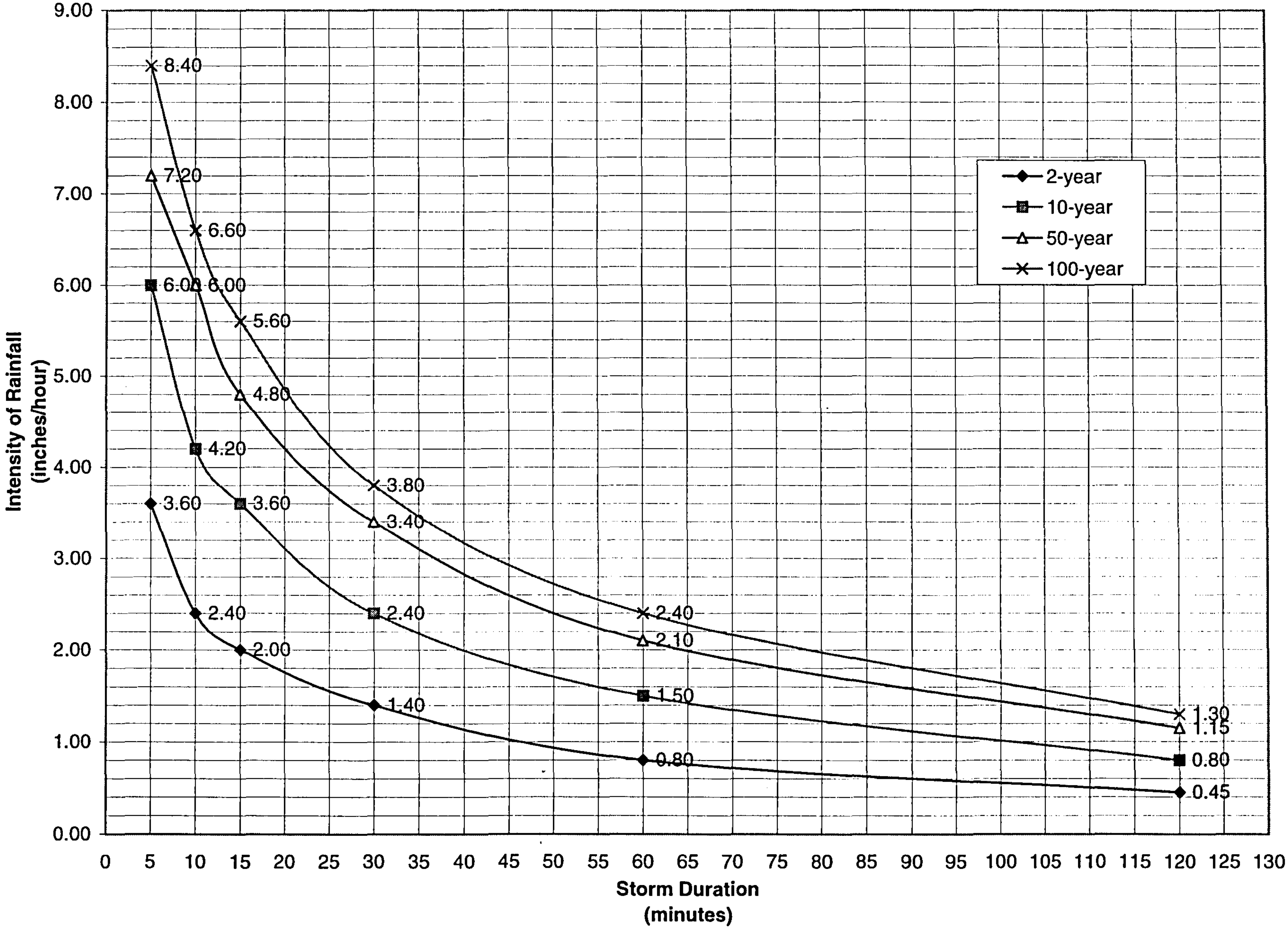


Figure A-2 Chandler Depth of Rainfall
Based on FCDMC Isopluvial Maps

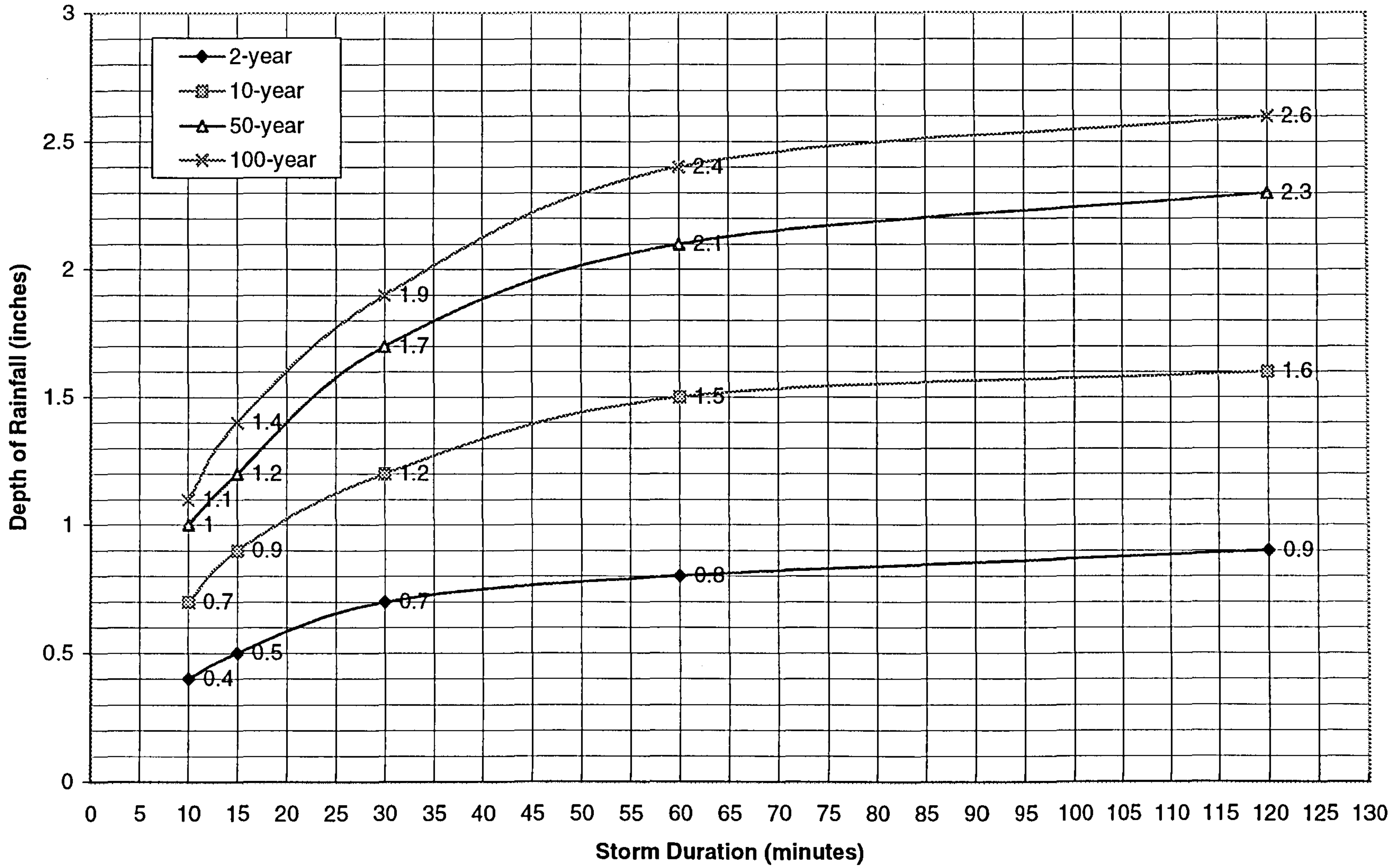


Table A-A - Data for IDF and Rainfall Depth Charts				
City of Chandler		From FCDMC Isopluvial Maps		
Stormwater Master Plan Update				
Depth of Rainfall (inches)				
Duration	Storm Frequency (years)			
(mins)	2-year	10-year	50-year	100-year
5	0.3	0.5	0.6	0.7
10	0.4	0.7	1	1.1
15	0.5	0.9	1.2	1.4
30	0.7	1.2	1.7	1.9
60	0.8	1.5	2.1	2.4
120	0.9	1.6	2.3	2.6
180	1	1.7	2.4	2.7
360	1.1	1.9	2.7	3
720	1.2	2.1	2.9	3.3
1440	1.35	2.3	3.2	3.6
Intensity of Rainfall (in/hr)				
Duration	Storm Frequency (years)			
(mins)	2-year	10-year	50-year	100-year
5	3.60	6.00	7.20	8.40
10	2.40	4.20	6.00	6.60
15	2.00	3.60	4.80	5.60
30	1.40	2.40	3.40	3.80
60	0.80	1.50	2.10	2.40
120	0.45	0.80	1.15	1.30
180	0.33	0.57	0.80	0.90
360	0.18	0.32	0.45	0.50
720	0.10	0.18	0.24	0.28
1440	0.06	0.10	0.13	0.15

Table A-1 *Drains to Detroit Basin*			
Reach	***Type***	***Size***	***Direction of Flow***
Detroit Street: Hamilton to Nevada St.	CMPA	18x24"	West
Nevada Street: Detroit Street to Detroit Basin	CMPA	18x24"	North
Detroit Street: Railroad to Nevada Street	CP	12"	East
Hamilton Street: Flint Street to Detroit Street	CP	18"	South
Exeter: Erie Street to Galveston Street and into Detroit Basin	CP	18"	North

Table A-2 Recently Installed Drain Pipes to Denver Basin			
Reach	**Type**	**Size**	**Direction of Flow**
Commonwealth Avenue: Dakota Street to California Street	CP	18"	East
California Street: Commonwealth Avenue to Boston Street	CP	18"	South
Park Street: Colorado Street to Delaware Street	CP	24"	West
Elgin Street: Washington Street to Delaware Street	CP	18"	West
Commonwealth Avenue: Hamilton To Railroad	CP	30"	West
Commonwealth Avenue: Railroad to Arizona Avenue	CP	24"	West
Dakota Street: Commonwealth Avenue To Boston Street	CP	18"	South
Dakota Street: Boston Street to Chicago Street	CP	24"	South
Chicago: Colorado Street to Palm Lane	CP	24"	West
Buffalo: Washington Street to Arizona Avenue	CP	18"	West
Arizona Avenue: Pecos Road to Fairview Avenue	CP	24"	North
Arizona Avenue: Fairview Avenue To Frye Road	CP	48"	North
Kesler Street: Delaware Street to Arizona Avenue	CP	24"	West
Morelos Street: Delaware Street to Arizona Avenue	CP	24"	West
Saragosa Street: Delaware Street to Arizona Avenue	CP	24"	West
Frye: Alma School Road to Nebraska Street	CP	24"	East

Table A-3 Alma School Storm Drain: Discharges to Galveston Basin			
Reach	**Type**	**Size**	**Direction of Flow**
Alma School Road: Flint Street to Erie Street	R.G.R.C.P. Class III	30"	North
Alma School Road: Erie Street to halfway to Oakland Street	R.G.R.C.P. Class III	42"	North
Alma School Road: halfway between Oakland and Erie Streets to Galveston Street	R.G.R.C.P. Class III	48"	North
Alma School Road: Ray Rd. to Ivanhoe Street	R.G.R.C.P. Class III	42"	South
Alma School Road: Ivanhoe to West Del Rio Street	R.G.R.C.P. Class III	54"	South
Alma School Road: West Del Rio to Galveston Street	R.G.R.C.P. Class III	54"	South
Galveston Street: Alma School Road to Galveston Basin	R.G.R.C.P. Class III	72"	West

Table A-4 Chandler Drain			
Reach	**Type**	**Size**	**Direction of Flow**
Galveston: Colorado Street to Arizona Avenue	CP	12"	West
Galveston: Arizona Avenue to Hartford Street	CP	16"	West
Galveston: Hartford Street to Alma School Road to Galveston Basin	CP	24"	West
Galveston Basin Pumps to Galveston/Alma School Road	PVC	8"	East
Alma School Road: Galveston Street to Erie Street	CP	24"	South
Erie Street: Alma School to Arrowhead Drive to open ditch	CP	24"	West

Table A-5 ***Galveston Basin Storm Drains - Old***			
Reach	***Type***	***Size***	***Direction of Flow***
Hartford: Toledo to Galveston & Chandler Drain	CP	24" or less	North

Table A-6 ***Arrowhead Basin Storm Drains***			
Reach	***Type***	***Size***	***Direction of Flow***
Ray Road: 500' West of Central to Arrowhead Drive	R.C.P. Class III	24"	West
Arrowhead: Ray Road to Arrowhead Basin	R.C.P.	24 - 48"	South
Arrowhead: Chandler Boulevard to Arrowhead Basin	R.C.P.	24"	North

Table A-7 ***Detroit Basin Storm Drains*** ***- To Denver Basin -***			
Reach	***Type***	***Size***	***Direction of Flow***
Detroit Basin: Galveston Street to Delaware Street	R.C.P. Class III	30"	West
Delaware Street: Galveston Street to Chandler Blvd.	R.C.P. Class III	36"	South

Table A-8 Arizona Avenue Storm Drain: Discharges to Denver Basin			
Reach	**Type**	**Size**	**Direction of Flow**
Arizona Avenue: Ray Road to Ivanhoe Place	R.C.P. Class II	24"	South
Arizona Avenue: Ivanhoe Place to Galveston Street	R.C.P. Class II	48"	South
Arizona Avenue: Galveston Street to Detroit Street	R.C.P. Class II	66"	South
Arizona Avenue: Detroit Street to Chandler Boulevard	R.C.P. Class II	72"	South
Arizona Avenue: Chandler Boulevard to Frye Road	R.C.P. Class II	84"	South
Frye Road: Arizona Avenue to Nebraska Street	R.C.P. Class II	84"	South
Nebraska Street: Frye Road to Denver Basin	R.C.P. Class II	84"	South

Table A-9 Chandler Boulevard Storm Drain (East of Arizona Avenue) Connects to Arizona Avenue Storm Drain which Discharges to Denver Basin			
Reach	**Type**	**Size**	**Direction of Flow**
Chandler Boulevard: Monte Vista to Jackson Street	R.C.P. Class III or CIPP	24"	West
Chandler Boulevard: Jackson Street to Hamilton Street	R.C.P. Class III or CIPP	30"	West
Chandler Boulevard: Hamilton Street to Exeter Street	R.C.P. Class III or CIPP	48"	West
Chandler Boulevard: Exeter Street to Colorado Street	R.C.P. Class III or CIPP	51"	West
Chandler Boulevard: Colorado Street to Arizona Avenue	R.C.P. Class III or CIPP	54"	West

Table A-10 *Other Storm Drains - Drain to Denver Basin*			
Reach	***Type***	***Size***	***Direction of Flow***
Delaware -- Buffalo to Fairview	R.C.P.	24-36"	South
Fairview -- Delaware to Denver Basin	R.C.P.	36-54"	West
Palm Lane -- Pecos Rd. to Fairview	R.C.P.	24"	North
Commonwealth Ave. -- Hamilton St. to Arizona Ave.	R.C.P.	30"	West
100' West of Dakota St. -- Chicago St. to Frye Rd.	R.C.P.	24"	South
Chicago St. -- Dakota St. to 100' West of Dakota St.	R.C.P.	24"	West
Dakota St. -- Boston St. to Chicago St.	R.C.P.	18"	South
California St. -- Commonwealth Ave. to Boston St.	R.C.P.	18"	South
Boston St. -- San Marcos Pl. to Dakota St.	R.C.P.	18"	West
Chicago St. -- Colorado St. to Dakota St.	R.C.P.	18"	West

Arrowhead Basin

Appendix B

Appendix B
Area A
Alternative Analyses

Appendix B Contents

Table B-1
Pipe Sizing and Force Main Alternatives to Basin G

Alternative and Costs	*Description*	*Modelling Results*	*Advantages*	*Disadvantages*
Option A-1- Gravity Storm Drains (1992 Update Recommendation) Estimated Cost: $7,365,900 (Table B-2) 100-Year Level of Protection	Gravity drains: - to Galveston Basin (tributary area 320 acres), - discharge from Galveston Basin to Erie-Hartford drain (after storm is over), - to Arrowhead Basin (tributary area 320 acres), - discharge from Arrowhead Basin to the Erie-Hartford drain (after storm), - Erie-hartford drain (tributary area 360 acres) to Basin G. The Erie drain also conveys discharge from Galveston and Arrowhead Basins after storm has passed. Note: The Erie-Hartford Drain does not flow through Galveston or Arrowhead Basins.	The new Erie Drain from Arrowhead Basin to Basin G is sized from 36 to 72 inches in diameter for 10-year to 100-year storm.	■ Lower operational costs than pump system. ■ No impact on Galveston or Arrowhead Basins, which provide 100 year storage volume for their drainage areas. ■ Safest option for back to back storms.	■ Larger pipe sizes than the pump system(s). ■ Conflict with other utilities. ■ Public acceptability for pipe size and route. ■ Installation requires specific slope and location.
Option A-2 - Routing Water Through the Arrowhead and Galveston Basins by Gravity Estimated Costs: $7,025,000; 100-yr; $6,477,000; 25-yr; $5,938,000; 10-yr.	Gravity drains: - to Galveston Basin (tributary area 680 acres), - discharge from Galveston Basin to Arrowhead Basin (during storm), - to Arrowhead Basin (tributary area 320 acres + Galveston discharge during storm), - discharge from Arrowhead Basin to Basin G.	The sizes of pipe required for 10, 25, and 100-year storm flows were determined from the SWMM stormwater model for Area A. For the gravity pipe from Galveston Basin to Arrowhead Basin, the size varies from 48 to 66 inches in diameter for the 10-year to 100-year storm. It was sized at 66-inches diameter for 100 cfs or 100-	■ Lower operational costs than pump system.	■ Alma School Road may flood. ■ Larger pipe sizes than the pump system(s). ■ Conflict with other utilities. ■ More complex to operate basins in series. ■ Public acceptability

Table B-1 *Pipe Sizing and Force Main Alternatives to Basin G*				
Alternative and Costs	***Description***	***Modelling Results***	***Advantages***	***Disadvantages***
Option A-3 - Routing Water Through the Two Basins With One Pump Station at Arrowhead Estimated Costs: $6,358,000; 100-yr; $6,067,000; 25-yr; $5,740,000; 10-yr.	Gravity drains: - to Galveston (tributary area 680 acres), - discharge from Galveston to Arrowhead Basin (during storm), - to Arrowhead (tributary area 320 acres + Galveston discharge during storm), Force main: - discharge from Arrowhead to Basin G during storm.	The addition of a pump at Arrowhead Basin for discharge to Basin G reduces the pipe size for Option A-2, from 42 to 54-inches diameter to 30 or 36 inches for the 10-year to 100-year storm, depending on the design velocity. This forcemain will drain the Arrowhead Basin within 36 hours with a pipe velocity of 5 to 7 feet/sec. The gravity pipe from Galveston Basin to Arrowhead Basin is the same as for Option A-2.	■ Smaller Pipe west of Arrowhead Basin. ■ Less utility conflicts. ■ Alignment is not a problem. ■ Better public acceptance for smaller pipe. ■ Flexible location and depth.	■ Alma School Road may flood. ■ More expensive to maintain and operate than gravity system. ■ More complex to operate basins in series. ■ 78" pipe runs down Alma School Road.

Table B-1 *Pipe Sizing and Force Main Alternatives to Basin G*				
Alternative and Costs	***Description***	***Modelling Results***	***Advantages***	***Disadvantages***
Option A-4 - Routing Water Through the Arrowhead and Galveston Basins With Two Pump Stations Estimated Costs: $8,969,000; 100-yr; $8,165,000; 25-yr; $6,783,000; 10-yr.	Gravity drains: - to Galveston Basin (tributary area 680 acres), - to Arrowhead Basin (tributary area 320 acres + Galveston discharge during storm), Force main: - from Galveston Basin to Arrowhead Basin during storm, - from Arrowhead Basin to Basin G during storm.	Adding a pump at the discharge of the Galveston Basin reduces the pipe size to Arrowhead Basin. The gravity outlet pipe was sized between 48 to 66 inches diameter for 10-year to 100-year storms for Options A-2 and A-3. This is reduced to a 36-inch to 54-inch diameter pipe, for the 10-year to 100-year storms. These sizes will drain the Galveston Basin in 36 hours. The pipe size for the pump discharge out of Arrowhead Basin is the same as for Option A-3.	■ Smaller pipe west of Galveston Basin. ■ Less utility conflicts. ■ Alignment is not a problem. ■ Better public acceptance for smaller pipe. ■ Part can be installed with road. ■ Flexible location and depth.	■ Alma School Road may flood. ■ More expensive to maintain and operate than gravity system. ■ More complex to operate basins in series.

Table B-1 *Pipe Sizing and Force Main Alternatives to Basin G*				
Alternative and Costs	***Description***	***Modelling Results***	***Advantages***	***Disadvantages***
Option A-5 - Routing water only through Arrowhead Basin With One Pump Station at Arrowhead Estimated Costs: $5,427,000; 100-yr; $5,427,000; 25-yr; $5,427,000; 10-yr.	Gravity drains: - to Galveston Basin (tributary area 320 acres), - discharge from Galveston Basin to Erie-Hartford Drain during storm, - Erie-Hartford drain to Arrowhead Basin (tributary area 360 acres + Galveston discharge during storm), - to Arrowhead Basin (tributary area 320 acres), Force main: - discharge from Arrowhead Basin to Basin G after storm.	The force main from Arrowhead Basin to Basin G is sized at 30 or 36 inches in diameter for the 10 to 100-year storms depending on the assumed flow velocity. A 36-inch diameter is the minimum to drain the basins within 36 hours. See Figure 5-5 for the proposed pipe schematic.	■ Smaller pipe west of Arrowhead Basin ■ Galveston basin contains 100 yr storm runoff from its drainage area ■ Part can be installed with road ■ Alignment is not a problem ■ Public Acceptance for smaller pipe ■ Smaller Alma School Road pipe ■ Flexible location, depth	■ More expensive to maintain and operate than gravity system ■ More complex to operate basins in series.

The following assumptions were made for the options analyzed:

- Arrowhead and Galveston basins remain at their present size. Galveston Basin has a maximum storage capacity of 35 acre-feet when full (no freeboard). If Arrowhead Basin is filled to the top (no freeboard), it can hold up to 51 acre-feet of storage.

- Gravity pipe sizing for the proposed drain is based on the 2-year, 6-hour peak flows. Gravity pipe or force main sizes required for basin discharges (to avoid flooding at basin locations) were calculated for different storm frequencies.

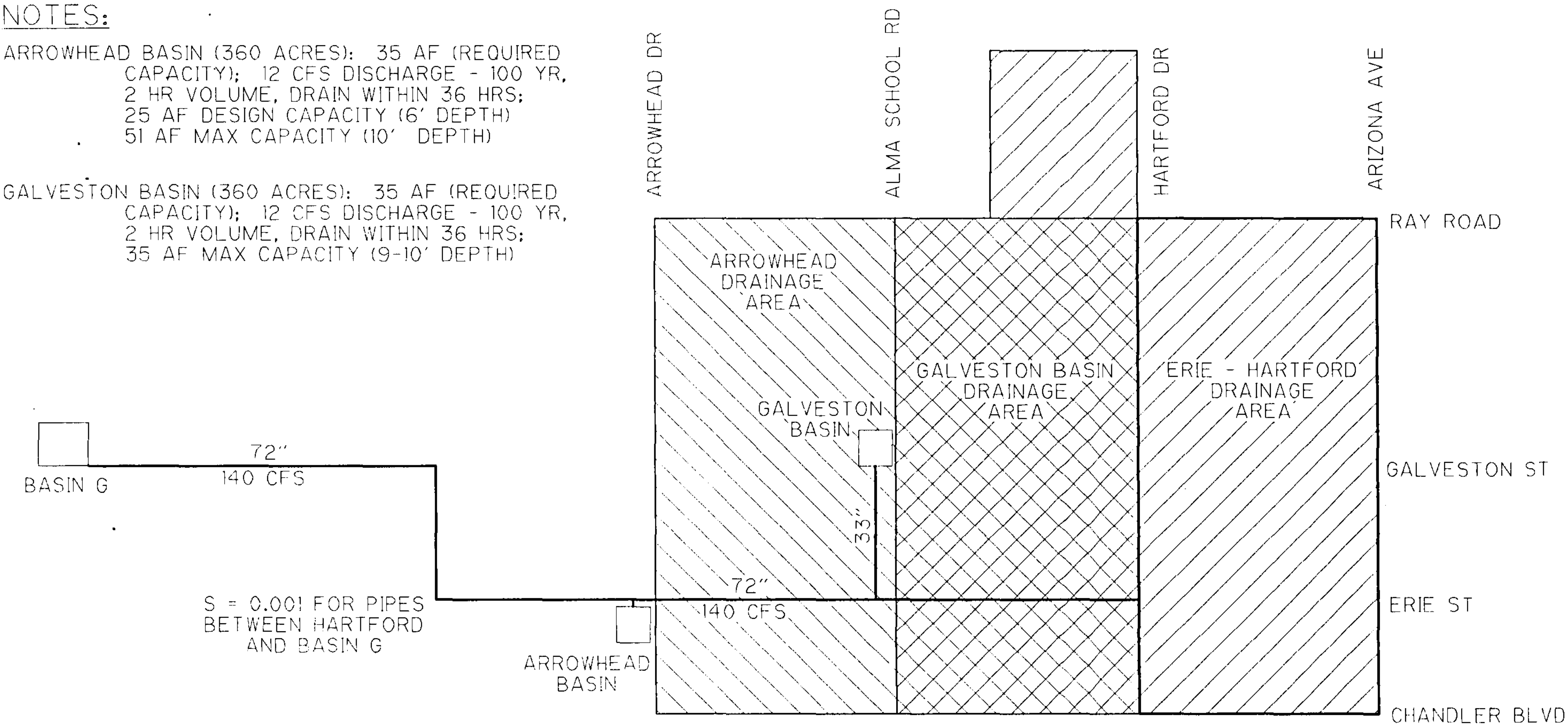
- Rainfall distribution used for modeling was taken from the FCDMC design manual, Volume I Hydrology, page 2-25, Table 2.4. The peak flow was higher than with rainfall distribution curves used for the 1992 Master Plan Update.

- Pipe velocities for force mains were limited to 5 to 7 fps. Pipe slopes west of Galveston Basin averaged 0.0010 feet/foot.

NOTES:

ARROWHEAD BASIN (360 ACRES): 35 AF (REQUIRED CAPACITY); 12 CFS DISCHARGE - 100 YR, 2 HR VOLUME, DRAIN WITHIN 36 HRS; 25 AF DESIGN CAPACITY (6' DEPTH) 51 AF MAX CAPACITY (10' DEPTH)

GALVESTON BASIN (360 ACRES): 35 AF (REQUIRED CAPACITY); 12 CFS DISCHARGE - 100 YR, 2 HR VOLUME, DRAIN WITHIN 36 HRS; 35 AF MAX CAPACITY (9-10' DEPTH)



LEVEL OF PROTECTION: 100-YEAR

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GRAVITY STORM DRAINS
OPTION 1

FIGURE B-1

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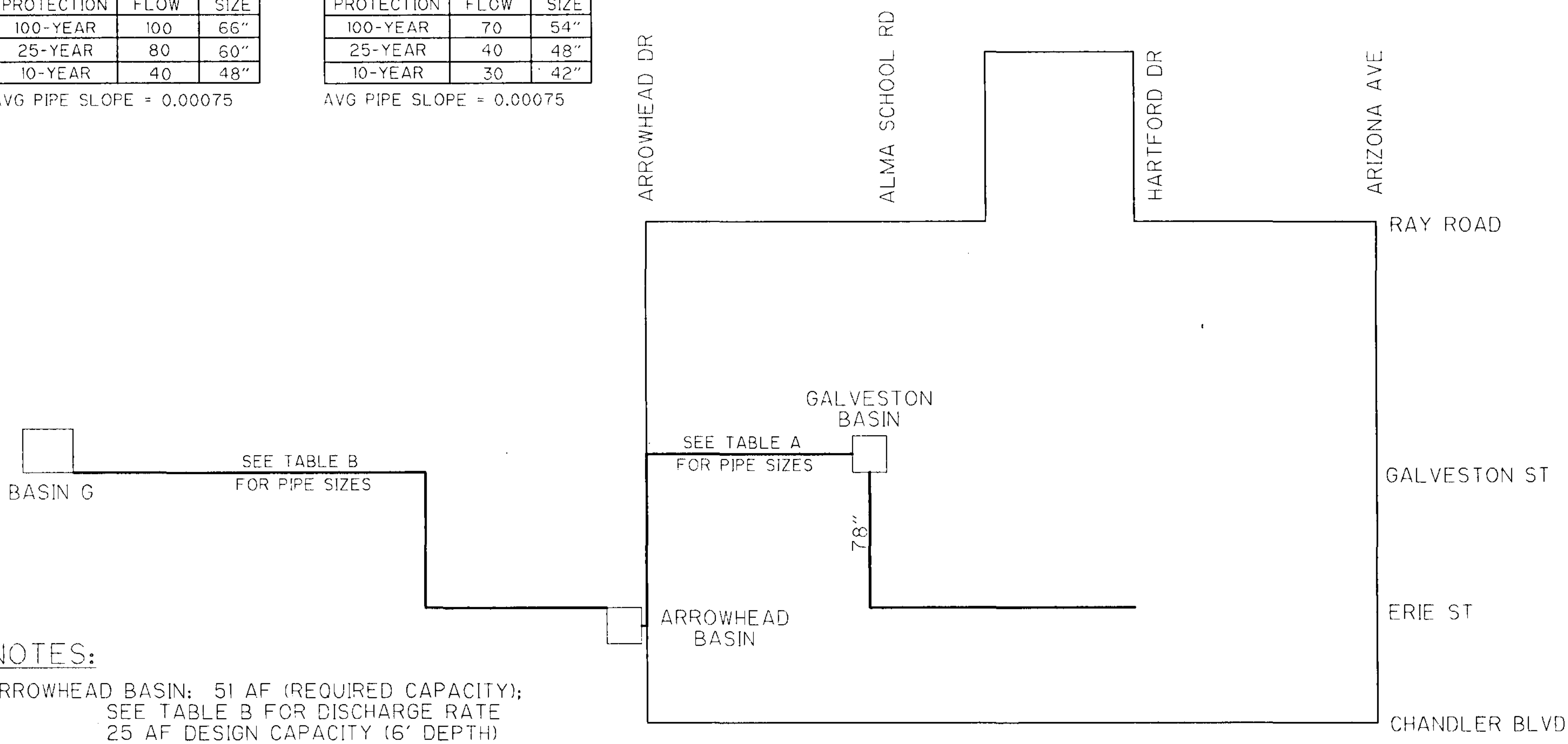
TABLE A		
GRAVITY FROM GALVESTON TO ARROWHEAD BASIN		
LEVEL OF PROTECTION	(cfs) FLOW	SIZE
100-YEAR	100	66"
25-YEAR	80	60"
10-YEAR	40	48"

AVG PIPE SLOPE = 0.00075

TABLE B		
GRAVITY FROM ARROWHEAD TO G BASIN		
LEVEL OF PROTECTION	(cfs) FLOW	SIZE
100-YEAR	70	54"
25-YEAR	40	48"
10-YEAR	30	42"

AVG PIPE SLOPE = 0.00075



NOTES:

ARROWHEAD BASIN: 51 AF (REQUIRED CAPACITY);
SEE TABLE B FOR DISCHARGE RATE
25 AF DESIGN CAPACITY (6' DEPTH)
51 AF MAX CAPACITY (10' DEPTH)

GALVESTON BASIN: 35 AF (REQUIRED CAPACITY);
SEE TABLE A FOR DISCHARGE RATE
35 AF MAX CAPACITY (9-10' DEPTH)

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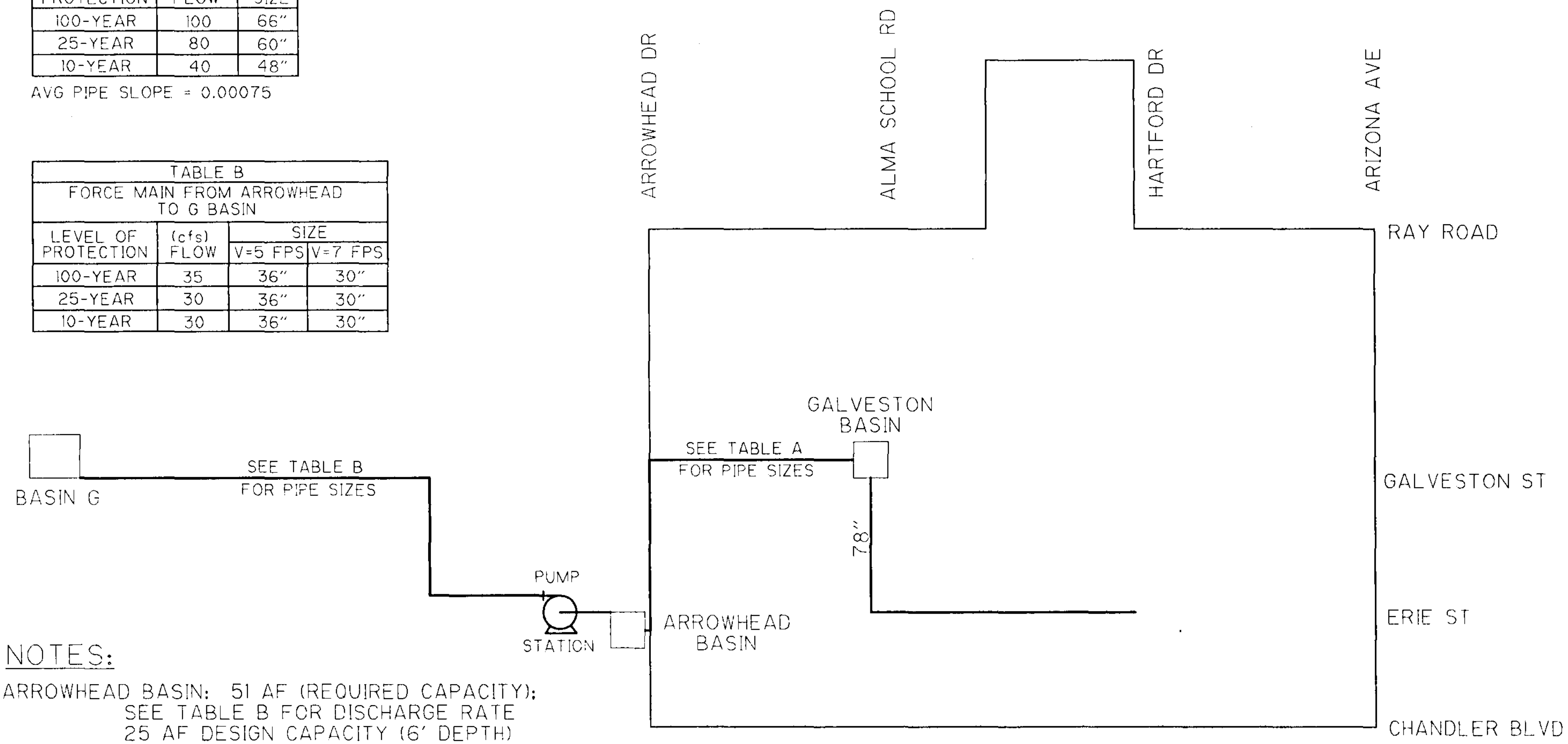
ROUTE THROUGH GALVESTON AND ARROWHEAD BASINS
OPTION 2

FIGURE B-2

TABLE A		
GRAVITY FROM GALVESTON TO ARROWHEAD BASIN		
LEVEL OF PROTECTION	(cfs) FLOW	SIZE
100-YEAR	100	66"
25-YEAR	80	60"
10-YEAR	40	48"

AVG PIPE SLOPE = 0.00075

TABLE B			
FORCE MAIN FROM ARROWHEAD TO G BASIN			
LEVEL OF PROTECTION	(cfs) FLOW	SIZE	
		V=5 FPS	V=7 FPS
100-YEAR	35	36"	30"
25-YEAR	30	36"	30"
10-YEAR	30	36"	30"



NOTES:

ARROWHEAD BASIN: 51 AF (REQUIRED CAPACITY);
SEE TABLE B FOR DISCHARGE RATE
25 AF DESIGN CAPACITY (6' DEPTH)
51 AF MAX CAPACITY (10' DEPTH)

GALVESTON BASIN: 35 AF (REQUIRED CAPACITY);
SEE TABLE A FOR DISCHARGE RATE
35 AF MAX CAPACITY (9-10' DEPTH)

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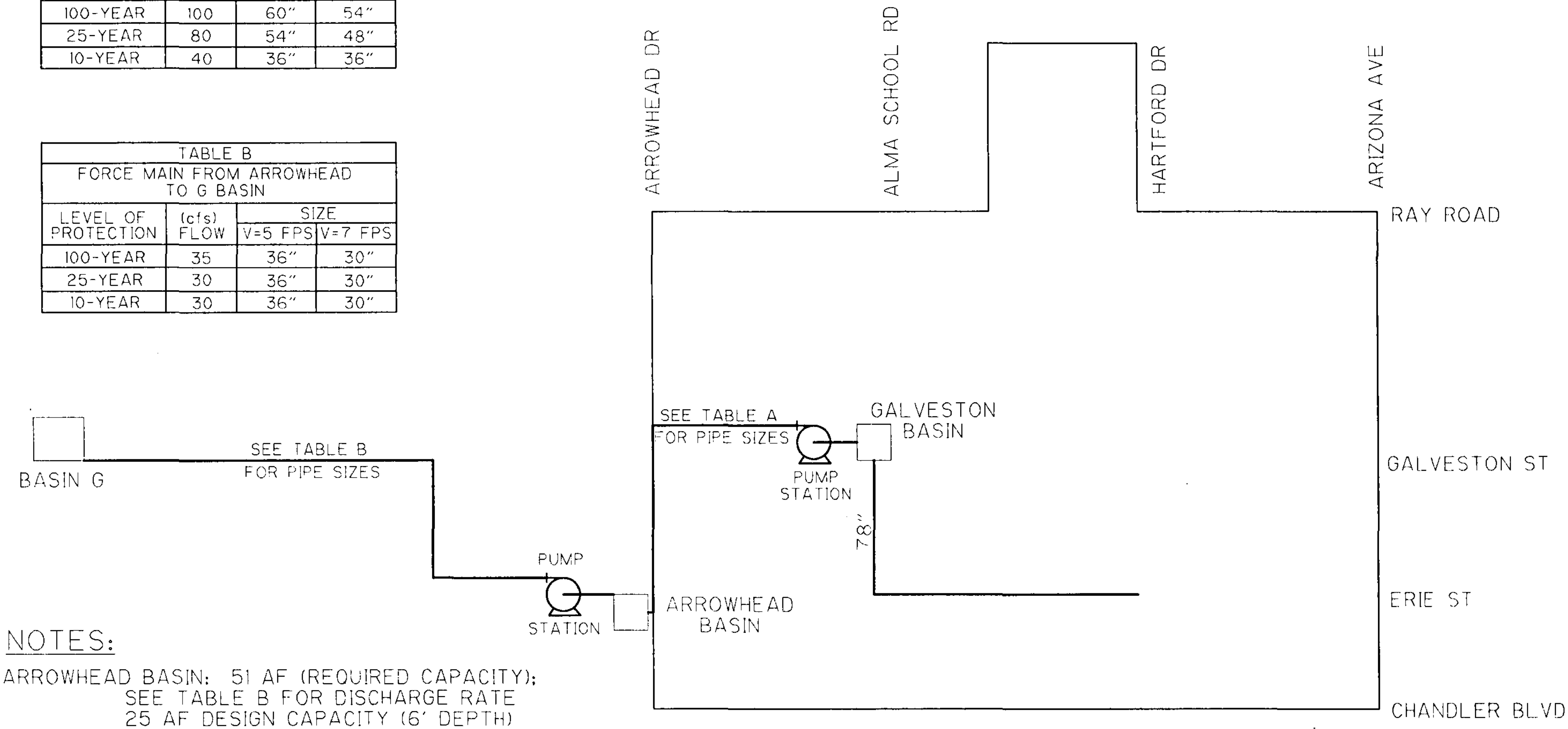
ROUTE THROUGH GALVESTON AND ARROWHEAD BASINS
OPTION 3, ONE PUMP STATION

FIGURE B-3

TABLE A			
FORCE MAIN FROM GALVESTON TO ARROWHEAD BASIN			
LEVEL OF PROTECTION	(cfs) FLOW	SIZE	
		V=5 FPS	V=7 FPS
100-YEAR	100	60"	54"
25-YEAR	80	54"	48"
10-YEAR	40	36"	36"

TABLE B			
FORCE MAIN FROM ARROWHEAD TO G BASIN			
LEVEL OF PROTECTION	(cfs) FLOW	SIZE	
		V=5 FPS	V=7 FPS
100-YEAR	35	36"	30"
25-YEAR	30	36"	30"
10-YEAR	30	36"	30"



NOTES:

ARROWHEAD BASIN: 51 AF (REQUIRED CAPACITY);
SEE TABLE B FOR DISCHARGE RATE
25 AF DESIGN CAPACITY (6' DEPTH)
51 AF MAX CAPACITY (10' DEPTH)

GALVESTON BASIN: 35 AF (REQUIRED CAPACITY);
SEE TABLE A FOR DISCHARGE RATE
35 AF MAX CAPACITY (9-10' DEPTH)

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ROUTE THROUGH GALVESTON AND ARROWHEAD BASINS
OPTION 4, TWO PUMP STATIONS

FIGURE B-4

Design and Construction Cost Estimates

Table B-2

Option 1, 100 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	33' Galveston Basin Outlet	lf	$108	2,190	$236,500
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	72" in Erie East of Alma School	lf	$267	2,760	$736,900
	72" in Erie , Arrowhead to Alma School	lf	$267	2,600	$694,200
	72" , Arrowhead to Basin G	lf	$267	8,400	$2,242,800
					$0
	Pump Stations				$0
	All basin drainage outlets by gravity				$0
	Utility Conflicts Arrowhead to Basin G	ls	$650,000	1	$650,000
					$0
	SUBTOTAL				$5,130,200
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$1,026,000
	CONTINGENCY		20%		$1,026,000
	TOTAL				$7,182,200

Table B-3

Option 2, 100 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	66" from Galveston Basin to Arrowhead basin	lf	$242	3,480	$842,200
	54" , Basin G to Arrowhead	lf	$186	8,400	$1,562,400
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	All basin drainage outlets by gravity				$0
	Utility Conflicts Arrowhead to Basin G	ls	$650,000	1	$650,000
					$0
	SUBTOTAL				$5,005,200
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$1,001,000
	CONTINGENCY		20%		$1,001,000
	TOTAL				$7,007,200

Table B-4

Option 2, 25 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	60" from Galveston Basin to Arrowhead basin	lf	$204	3,480	$709,900
	48" , Basin G to Arrowhead	lf	$165	8,400	$1,386,000
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	All basin drainage outlets by gravity				$0
	Utility Conflicts Arrowhead to Basin G	ls	$650,000	1	$650,000
					$0
	SUBTOTAL				$4,696,500
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$939,300
	CONTINGENCY		20%		$939,300
	TOTAL				$6,575,100

Table B-5

Option 2, 10 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	48" from Galveston Basin to Arrowhead basin	lf	$165	3,480	$574,200
	42" , Basin G to Arrowhead	lf	$144	8,400	$1,209,600
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	All basin drainage outlets by gravity				$0
	Utility Conflicts Arrowhead to Basin G	ls	$650,000	1	$650,000
					$0
	SUBTOTAL				$4,384,400
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$876,900
	CONTINGENCY		20%		$876,900
	TOTAL				$6,138,200

Table B-6

Option 3, 100 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	66" from Galveston Basin to Arrowhead basin	lf	$242	3,480	$842,200
	36" , Basin G to Arrowhead	lf	$120	8,400	$1,008,000
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	Galveston Basin drainage outlet by gravity				$0
	Arrowhead Basin Pump Station, 35 CFS	ls	$803,000	1	$803,000
					$0
	SUBTOTAL				$4,603,800
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$920,800
	CONTINGENCY		20%		$920,800
	TOTAL				$6,445,400

Table B-7

Option 3, 25 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	60" from Galveston Basin to Arrowhead basin	lf	$204	3,480	$709,900
	36" , Basin G to Arrowhead	lf	$120	8,400	$1,008,000
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	Galveston Basin drainage outlet by gravity				$0
	Arrowhead Basin Pump Station, 30 CFS	ls	$710,000	1	$710,000
					$0
	SUBTOTAL				$4,378,500
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$875,700
	CONTINGENCY		20%		$875,700
	TOTAL				$6,129,900

Table B-8

Option 3, 10 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	48" from Galveston Basin to Arrowhead basin	lf	$165	3,480	$574,200
	36" , Basin G to Arrowhead	lf	$120	8,400	$1,008,000
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	Galveston Basin drainage outlet by gravity				$0
	Arrowhead Basin Pump Station, 30 CFS	ls	$710,000	1	$710,000
					$0
	SUBTOTAL				$4,242,800
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$848,600
	CONTINGENCY		20%		$848,600
	TOTAL				$5,940,000

Table B-9

Option 4, 100 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	60" from Galveston Basin to Arrowhead basin	lf	$204	3,480	$709,900
	36" , Basin G to Arrowhead	lf	$120	8,400	$1,008,000
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	Galveston Basin Pump Station, 100 CFS	ls	$1,980,000	1	$1,980,000
	Arrowhead Basin Pump Station, 35 CFS	ls	$803,000	1	$803,000
					$0
	SUBTOTAL				$6,451,500
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$1,290,300
	CONTINGENCY		20%		$1,290,300
	TOTAL				$9,032,100

Table B-10

Option 4, 25 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186.00	960	$178,600
	66" in Hartford	lf	$242.00	1,200	$290,400
	54" from Galveston Basin to Arrowhead basin	lf	$186.00	3,480	$647,300
	36" , Basin G to Arrowhead	lf	$120.00	8,400	$1,008,000
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	Galveston Basin Pump Station, 80 CFS	ls	$1,617,000	1	$1,617,000
	Arrowhead Basin Pump Station, 30 CFS	ls	$710,000	1	$710,000
					$0
	SUBTOTAL				$5,932,900
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$1,186,600
	CONTINGENCY		20%		$1,186,600
	TOTAL				$8,306,100

Table B-11

Option 4, 10 Year Level of Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	78" in Alma School	lf	$294	2,190	$643,900
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	36" from Galveston Basin to Arrowhead basin	lf	$120	3,480	$417,600
	36" , Basin G to Arrowhead	lf	$120	8,400	$1,008,000
	72" in Erie east of Alma School	lf	$267	2760	$736,900
					$0
	Pump Stations				$0
	Galveston Basin Pump Station, 40 CFS	ls	$891,000	1	$891,000
	Arrowhead Basin Pump Station, 30 CFS	ls	$710,000	1	$710,000
					$0
	SUBTOTAL				$4,977,200
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$995,400
	CONTINGENCY		20%		$995,400
	TOTAL				$6,968,000

Table B-12

Option 5, 100 Year Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	33" Galveston Basin Outlet	lf	$108	2,190	$236,500
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186.00	960	$178,600
	66" in Hartford	lf	$242.00	1,200	$290,400
	72" in Erie East of Alma School	lf	$267.00	2,760	$736,900
	72" in Erie , Arrowhead to Alma School	lf	$267.00	2,600	$694,200
	36" , Basin G to Arrowhead	lf	$120.00	8,400	$1,008,000
					$0
	Pump Stations				$0
	Galveston Basin drains by gravity				$0
	Arrowhead Pump Station, 30 CFS	ls	$710,000	1	$710,000
					$0
	SUBTOTAL				$3,955,400
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$791,100
	CONTINGENCY		20%		$791,100
	TOTAL				$5,537,600

Table B-13

Option 5, 25 Year Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	33" Galveston Basin Outlet	lf	$108	2,190	$236,500
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	72" in Erie East of Alma School	lf	$267	2,760	$736,900
	72" in Erie , Arrowhead to Alma School	lf	$267	2,600	$694,200
	36" , Basin G to Arrowhead	lf	$120	8,400	$1,008,000
					$0
	Pump Stations				$0
	Galveston Basin drains by gravity				$0
	Arrowhead Pump Station, 30 CFS	ls	$710,000	1	$710,000
					$0
	SUBTOTAL				$3,955,400
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$791,100
	CONTINGENCY		20%		$791,100
	TOTAL				$5,537,600

Table B-14

Option 5, 10 Year Protection

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Piping				$0
	33' Galveston Basin Outlet	lf	$108	2,190	$236,500
	36" in Hartford	lf	$120	840	$100,800
	54" in Hartford	lf	$186	960	$178,600
	66" in Hartford	lf	$242	1,200	$290,400
	72" in Erie East of Alma School	lf	$267	2,760	$736,900
	72" in Erie , Arrowhead to Alma School	lf	$267	2,600	$694,200
	36" , Basin G to Arrowhead	lf	$120	8,400	$1,008,000
					$0
	Pump Stations				$0
	Galveston Basin drains by gravity				$0
	Arrowhead Pump Station, 30 CFS	ls	$710,000	1	$710,000
					$0
	SUBTOTAL				$3,955,400
	ENGINEERING, LEGAL, ADMINISTRATIVE		20%		$791,100
	CONTINGENCY		20%		$791,100
	TOTAL				$5,537,600

Table B-15

Utility Conflicts, Arrowhead Basin to Basin G

Note: Conflict costs were added to Tables B-3, B-4, and B-5; Gravity System for Option 1

SPEC. DIVISION	WORK ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	SUBTOTAL
					$0
	Parallel Sewers				$0
	15" in Anderson Blvd.	lf	$100	2,800	$280,000
	27" in Galveston St.	lf	$225	1,200	$270,000
	12" Inverted Siphons in Dobson Road	ea	$40,000	1	$40,000
	27" Inverted Siphons in Dobson Road	ea	$60,000	1	$60,000
					$0
	SUBTOTAL				$650,000

Table B-16
Denver Basin Discharge Outfall Alternatives

Alternative	Drainage Alternative Descriptions	Evaluation
D-1- Gravity Drain to Pecos Road and Basin H	A gravity outfall from the Denver Basin would discharge stormwater to a gravity pipe along Pecos Road to Basin H. See Figure 5-8.	This is not feasible because of the depth of the Denver Basin, flat ground slope, and the size of pipe or dual pipes needed to drain the stormwater in 36 hours.
D-2 - Force Main to Pecos Road , Gravity Drain Along Pecos Road to Basin H	A pump station and force main would drain the water from the Denver Basin and discharge it into a gravity pipe to be constructed in Pecos Road. The gravity pipe would drain west and discharge into Basin H. The gravity drain pipe would be from 36-inches to 54-inches diameter along Pecos Road as shown in Figures 5-3 and 5-8. Recommended in 1992.	The pumped discharge from the Denver Basin would require a smaller outlet pipe than Alternative D-1 and be at a shallower depth. The gravity pipe in Pecos Road in the 1992 Update extended within 1/4 mile of McQueen Road and would provide drainage for the southwestern portion of Area A instead of the Denver Basin.
D-3 - Force Main Along Pecos Road to Basin H	Pumped discharge (forcemain) from the Denver Basin south to Pecos Road and west to Basin H and the future siphon.	All of the southwest portion of Area A would drain to the Denver Basin which would then be pumped to Basin H as shown in Figure 5-8.
D-4 - Gravity Drain south to Channel	Gravity outfall south from the Denver Basin to the future Santan Drainage Channel	A gravity outfall would not be feasible because of the elevation of the bottom of Denver Basin, flat ground slope, and size of pipes needed to drain the basin in 36 hours.
D-5 - Force Main south to Channel	Pumped discharge (forcemain) south from the Denver Basin to the Santan Drainage Channel as shown in Figure 6-9.	The pumped discharge will result in a smaller outlet pipe at a shallower depth than Alternative D-4.

Table B-17	***Estimated Pump Station Costs***			
Arrowhead	**30cfs**			**Est Cost**
Pumps				$127,000
Wetwell/structure				$130,000
Piping & Valves				$70,000
Electrical & Instrumentation				$62,000
Standby Power				$150,000
Building				$85,000
Landscaping, etc (1/2 acre)				$13,000
		Sub Total		$637,000
	Eng/legal/admin		20%	$127,400
	Contingencies		20%	$152,880
	Total Estimated Cost			$917,280
Denver	**35cfs**			
Pumps				$141,000
Wetwell/structure				$135,000
Piping & Valves				$72,000
Electrical & Instrumentation				$64,000
Standby Power				$150,000
Landscaping, etc (1/2 acre)				$13,000
		Sub Total		$575,000
	Eng/legal/admin		20%	$115,000
	Contingencies		20%	$138,000
	Total Estimated Cost			$828,000

Table B-18 - Unit Costs for Storm Drain Installation (1998 Dollars)		
		Construction Costs
Pipe Diameter		1998
(in)	Unit	SUBTOTAL
18	lf	$69
24	lf	$78
27	lf	$82
30	lf	$102
33	lf	$108
36	lf	$120
39	lf	$127
42	lf	$144
45	lf	$156
48	lf	$165
54	lf	$186
60	lf	$204
66	lf	$242
72	lf	$267
78	lf	$294

Arrowhead Basin

Appendix C

Appendix C
Existing
City-Maintained
Retention Basins

Table C-1 *City-Maintained Retention Areas*	*Area*
1.Price Rd. Retention and R-O-W - South & North of Curry on East Side	B
2.Jordan School Retention - North Carriage Ln. at W. Silvergate Dr.	B
3.Elliot Rd. North Side - Between Price & Dobson Rds.	B
4.Elliot Rd. North Side - Between Dobson & Alma School Rds.	B
5.Elliot Rd. North Side - Between Alma School Rd. and Arizona Ave.	B
6.Dobson Rd. - Between Warner and Elliot Rds., Includes North & South of El Monte Pl., North and South of Palomino Dr. (College Park 18). Silvergate #2 at Mesquite & Quail Pl. north of Shawnee to Marlboro St.	B
7.Alma School Rd. - Between Warner and Elliot Rd.	B
8.Warner Rd. North and South - Between Dobson and Alma School Rds. - Includes Knoell Homes, North & South Warner at Arrowhead Dr., Pulte Villas and Brooks Crossing R-O-W, and College Park 16 & 19 at Central St.	B
9.Knoell Cedar Ridge (5 Basins) - Between Alma School & Arizona Ave. Warner Rd. South Side between Hartford and West of Illinois St. also Iowa St East & West at Hartford and Hartford St. West of Ranch St.	B
10.Warner Park and Fire Station #2 - North Alma School & Highland St.	B
11.Bridgeport R-O-W - North Side of Elliot at Pennington St.	B
12.Clearview Manor R-O-W - South side Warner Rd. West of Dobson at Bull Moose Dr.	B
13.Crestview Retention - West Chicago St. to Gila Springs Blvd. and South Kyrene Rd.	B
14.Suggs Corona Retention and R-O-W - West Ray Rd. East & West of Terrace St.	B
15.Glenview Retention and R-O-W - West Chandler Blvd. and Galaxy	B
16.Pepperwood Retention #I - North Side of Chandler Blvd. and North Country Club Way	B
17.Pepperwood Retention #II - On McClintock, North of Chandler Blvd. and West of Lavine	B
18.Home Place Retention - West Erie and North Los Altos	B
19.Coventry Homes (Tiburon) - Warner Rd. at Ellis St. 1/4 mile East of Price Rd.	B
20.Prado Del Sol - West of Kyrene North of Chandler Blvd.	B
21.Crestview Unit V Retention - Kyrene Rd. South of Frye Rd.	B
22.Tyson Manor Retention - West Flint and North Pleasant	A
23.Colonial Coronita - Chandler Blvd., North and South of 132nd St.	B
24.Stonegate Retention and Park - At Ithica St. and North of Knox Rd.	B
25.Highland -Dobson Road, South of Warner at Highland St.	B
26.Brooks Crossing Retention and Park - North Arrowhead Dr. at West Calle Del Norte St.	B
27.Western Canal Retention - Price Rd. to East of Arizona Ave.	B

Table C-1 *City-Maintained Retention Areas*	*Area*
28.Galveston Retention - Galveston St. and Chipawah St.	A
29.Denver Retention - Fairview St. and Nebraska St.	A
30.Crafco Basin - East of 56th St. and North of Chandler Blvd.	B
31.Fann Basin - Arizona Ave. and Germann	C
32.Twelve Oaks Basins	
33.Sommerset - Galveston and Railroad Tracks	A
34.Temporary basins along major arterial roadways	All

Table C-2 City Parks with Retention Basins		
Park Name	***Location***	***Area***
Shawnee	Mesquite and Central	B
Hoopes	Palomino and Evergreen	B
Amberwood	Knox and Bullmoose	B
Apache	Hartford and Knox	B
Pima	McQueen and Galveston	B
Windmills West	Windmills Blvd. and Hazelton	B
Terra Ray	Ray Road and Terrace, north of Cooper Rd.	B
Mountain View	12 Oaks Blvd. and Rita Rd.	B
Hearthstone	Country Club and Frye Road	B
Desert Breeze	Galveston and Galaxy	B
Folley	Fairview and Ithica	A
Maggio Ranch	Maggioway and Arrowhead	B
Cooperfield	Galveston and Country Club	B
Arrowhead	Arrowhead and Erie	A
Detroit / Gazelle Meadows Park	Galveston and Erie, East of Railroad Tracks	A
Harter	Ivanhoe and Club Way	B
Santan	Frye Rd. and 132nd St.	B
Dr. A.J. Chandler	Arizona Ave. and Commonwealth Ave.	A
Price	Frye Rd. and Country Club Way	B
Pecos Ranch	Maplewood and Pennington, North of Germann Rd.	C
Pine Shadows	Galveston St. and Bradley	B
Jack Rabbit	Lakeview and Erie, West of Cooper Rd.	B
Sundance	Roosevelt Ave., South of Ray Road	B
Tumbleweed	McQueen Rd., South of Germann Rd.	C

Arrowhead Basin

Appendix D

Appendix D
Quarter Section and Vacant Parcel Flows and Retention Volumes

Appendix D Contents

Table D-1 *Area B Vacant Parcels Runoff Calculations*								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T1S/R5E	7	SW	Small Lot Residential	2.6	0.65	3	4	0.4
T1S/R5E	8	SW	C - 2	8.9	0.90	12	17	1.9
T1S/R5E	9	SE	Industrial - 1	6.0	0.90	8	12	1.3
T1S/R5E	10	SW	Industrial - 1	8.0	0.90	11	15	1.7
T1S/R5E	10	SW	Industrial - 1	4.2	0.90	6	8	0.9
T1S/R5E	10	SW	Industrial - 1	7.4	0.90	10	14	1.6
T1S/R5E	10	SW	Industrial - 1	16.5	0.90	22	32	3.6
T1S/R5E	10	SW	Industrial - 1	10.6	0.90	14	20	2.3
T1S/R5E	10	SW	Industrial - 1	10.4	0.90	14	20	2.3
T1S/R5E	10	SW	Industrial - 1	6.9	0.90	9	13	1.5
T1S/R5E	18	NW	C-2	6.0	0.90	8	12	1.3
T1S/R5E	18	NW	RRL	18.6	0.50	14	20	2.3
T1S/R5E	18	NW	RRL	9.3	0.50	7	10	1.1
T1S/R5E	18	SW	RRL	18.0	0.50	13	19	2.2
T1S/R5E	18	SE	C-2	9.5	0.90	13	18	2.1
T1S/R5E	17	SE	MF-3	3.3	0.80	4	6	0.6
T1S/R5E	17	SE	MF-2	2.6	0.80	3	4	0.5
T1S/R5E	16	NW	C-2	5.6	0.90	8	11	1.2
T1S/R5E	16	NE	SLR	7.5	0.65	7	10	1.2
T1S/R5E	16	SE	C2	8.6	0.90	12	16	1.9
T1S/R5E	16	SE	CRC	9	0.90	12	17	2.0
T1S/R5E	16	SE	CRC	3.1	0.90	4	6	0.7
T1S/R5E	16	SE	C3	1.5	0.90	2	3	0.33
T1S/R5E	16	SE	HDR	10.1	0.80	12	17	2.0
T1S/R5E	15	SW	IND	86.5	0.90	116	166	18.8

Table D-1 Area B Vacant Parcels Runoff Calculations								
Township and Range	*Section*	*Quarter*	*Land Use*	*Area (acres)*	*Runoff Coefficient*	*10-year Peak Runoff (cfs)*	*50-year Peak Runoff (cfs)*	*100-year Retention Volume (ac-ft)*
T1S/R5E	15	SW	HDR	12.7	0.80	15	22	2.5
T1S/R5E	15	NW	IND	76	0.90	102	146	16.6
T1S/R5E	15	NW	I-1	14.4	0.90	19	28	3.1
T1S/R5E	15	SE	SLR	16.4	0.65	16	23	2.6
T1S/R5E	15	SE	CRC	13.2	0.90	18	25	2.9
T1S/R4E	20	SE	CRC	36.9	0.90	49	71	8.3
T1S/R4E	20	SE	IND	32.5	0.90	44	62	7.3
T1S/R4E	23	SE	C2	15.1	0.90	20	29	3.4
T1S/R4E	24	SW	CRC	21.1	0.90	28	40	4.7
T1S/R4E	24	SE	CRC	15.4	0.90	21	30	3.5
T1S/R4E	24	SE	SLR	7.0	0.65	7	10	1.1
T1S/R5E	19	NW	CRC	11.7	0.90	16	22	2.6
T1S/R5E	19	NW	HDR	2.4	0.80	3	4	0.5
T1S/R5E	19	SW	CRC	22.4	0.90	30	43	4.9
T1S/R5E	19	SE	CRC	17.0	0.90	23	33	3.7
T1S/R5E	20	NW	CRC	14.6	0.90	20	28	3.2
T1S/R5E	20	NE	SLR	2.2	0.65	2	3	0.4
T1S/R5E	20	NE	PCO	0.6	0.90	1	1	0.1
T1S/R5E	20	SW	SLR	10.9	0.65	11	15	1.7
T1S/R5E	21	SW	HDR	9.4	0.80	11	16	1.8
T1S/R5E	22	SW	I2	35.3	0.90	47	68	7.7
T1S/R5E	22	SW	C3	15.9	0.90	21	30	3.5
T1S/R5E	22	SW	IND	36.4	0.90	49	70	7.9
T1S/R5E	23	SW	CRC	30.8	0.90	41	59	6.7

Table D-1 *Area B Vacant Parcels Runoff Calculations*								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T1S/R5E	23	SE	CRC	11.1	0.90	15	21	2.4
T1S/R4E	29	NE	RRC	160	0.90	215	307	35.9
T1S/R4E	29	SE	I1	2.6	0.90	3	5	0.6
T1S/R4E	28	SW	IND	3.4	0.90	5	7	0.8
T1S/R4E	28	SW	I1	2.2	0.90	3	4	0.5
T1S/R4E	28	SW	I2	10.1	0.90	14	19	2.3
T1S/R4E	28	SE	CRC	20.2	0.90	27	39	4.5
T1S/R4E	28	SE	CRC	1.5	0.90	2	3	0.3
T1S/R4E	27	SW	CRC	10.6	0.90	14	20	2.4
T1S/R4E	27	SW	CRC	3.2	0.90	4	6	0.7
T1S/R4E	27	SW	CRC	20	0.90	27	38	4.5
T1S/R4E	27	SW	HDR	9.3	0.80	11	16	1.9
T1S/R4E	26	SW	SLR	21.3	0.65	21	29	3.5
T1S/R4E	26	SE	IND	38.6	0.90	52	74	8.7
T1S/R4E	26	SE	IND	103.6	0.90	139	199	23.3
T1S/R4E	25	NE	SLR	2	0.65	2	3	0.3
T1S/R4E	25	NE	O	1.3	0.90	2	2	0.3
T1S/R4E	25	SW	CRC	15.4	0.90	21	30	3.5
T1S/R4E	25	NE	CRC	2.1	0.90	3	4	0.5
T1S/R4E	25	SE	CRC	21.5	0.90	29	41	4.8
T1S/R4E	25	SE	CRC	5	0.90	7	10	1.1
T1S/R4E	25	SE	CRC	2.9	0.90	4	6	0.7
T1S/R4E	25	SE	O	1.5	0.90	2	3	0.3
T1S/R5E	30	NE	CRC	17.7	0.90	24	34	3.9

Table D-1 *Area B Vacant Parcels Runoff Calculations*								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T1S/R5E	30	SW	RRL	9.7	0.50	7	10	1.2
T1S/R5E	30	SW	RRL	10	0.50	7	11	1.2
T1S/R5E	30	SW	RRL	9.7	0.50	7	10	1.2
T1S/R5E	30	SW	CRC	54	0.90	72	104	11.8
T1S/R5E	27	NE	SLR	14.2	0.65	14	20	2.2
T1S/R5E	26	NW	HDR	7.3	0.80	9	12	1.4
T1S/R5E	26	NW	SLR	3.2	0.65	3	4	0.5
T1S/R5E	26	SW	SLR	20	0.65	19	28	3.2
T1S/R5E	26	SE	SLR	2.3	0.65	2	3	0.4
T1S/R5E	26	SE	HDR	13.6	0.80	16	23	2.6
T1S/R5E	25	SW	CRC	4.9	0.90	7	9	1.1
T1S/R5E	25	SW	SLR	62.5	0.65	61	87	9.8
T1S/R5E	25	SE	CRC	9.5	0.90	13	18	2.1
T1S/R5E	25	SE	CRC	0.6	0.90	1	1	0.1
T1S/R4E	32	NE	C2	11.3	0.90	15	22	2.5
T1S/R4E	32	NE	BP	0.7	0.90	1	1	0.2
T1S/R4E	32	SE	I1	27.8	0.90	37	53	6.2
T1S/R4E	32	SE	I1	40	0.90	54	77	9.0
T1S/R4E	33	NW	BP	9.2	0.90	12	18	2.1
T1S/R4E	33	SW	BP	23.8	0.90	32	46	5.3
T1S/R4E	33	SW	BP	27.6	0.90	37	53	6.2
T1S/R4E	33	SW	BP	59.4	0.90	80	114	13.3
T1S/R4E	33	SE	BP	14.7	0.90	20	28	3.3
T1S/R4E	33	SE	ED	67.5	0.90	91	129	15.2

Table D-1 Area B Vacant Parcels Runoff Calculations								
Township and Range	*Section*	*Quarter*	*Land Use*	*Area (acres)*	*Runoff Coefficient*	*10-year Peak Runoff (cfs)*	*50-year Peak Runoff (cfs)*	*100-year Retention Volume (ac-ft)*
T1S/R4E	33	NE	BP	34	0.90	46	65	7.6
T1S/R4E	34	NW	CRC	11.1	0.90	15	21	2.5
T1S/R4E	34	NW	SLR	4.0	0.65	4	5	0.6
T1S/R4E	34	SW	SLR	18.8	0.65	18	26	3.1
T1S/R4E	35	NE	C2	2.9	0.90	4	6	0.7
T1S/R4E	35	NE	I1	2.6	0.90	3	5	0.6
T1S/R4E	35	NE	I1	8.6	0.90	12	16	1.9
T1S/R4E	35	SE	I1	3.4	0.90	5	7	0.8
T1S/R4E	35	SE	I1	60.4	0.90	81	116	13.6
T1S/R4E	36	NW	I1	11.2	0.90	15	21	2.5
T1S/R4E	36	NE	RRC	103	0.90	138	197	23.1
T1S/R4E	36	SE	RRC	87.5	0.90	117	168	19.6
T1S/R4E	36	SW	SLR	8.7	0.65	8	12	1.4
T1S/R5E	31	NW	IND	40	0.90	54	77	8.7
T1S/R5E	31	NW	I-1	24.6	0.90	33	47	5.4
T1S/R5E	31	NE	I-1	55.5	0.90	74	103	12.1
T1S/R5E	31	NE	SF-8.5	10	0.65	10	14	1.6
T1S/R5E	31	SW	CRC	73.2	0.90	98	140	16.0
T1S/R5E	31	SW	I-1	40	0.90	54	77	8.7
T1S/R5E	31	SE	BP	56.6	0.90	76	109	12.3
T1S/R5E	31	SE	BP	40.4	0.90	54	77	8.8
T1S/R5E	31	SE	SLR	20	0.65	19	28	3.2
T1S/R5E	31	SE	SLR	53.6	0.65	52	74	8.4
T1S/R5E	32	SW	SLR	37	0.65	36	51	5.8

Table D-1 Area B Vacant Parcels Runoff Calculations								
Township and Range	*Section*	*Quarter*	*Land Use*	*Area (acres)*	*Runoff Coefficient*	*10-year Peak Runoff (cfs)*	*50-year Peak Runoff (cfs)*	*100-year Retention Volume (ac-ft)*
T1S/R5E	32	SW	ED	6.4	0.90	9	12	1.4
T1S/R5E	33	SW	SF-8.5	40	0.65	39	55	6.3
T1S/R5E	33	SW	CRC	5.8	0.90	8	11	1.3
T1S/R5E	33	SW	SLR	7.5	0.65	7	10	1.2
T1S/R5E	33	SW	SLR	3.4	0.65	3	5	0.5
T1S/R5E	34	NW	I-2	17.7	0.90	24	34	3.9
T1S/R5E	34	SW	SF-8.5	16	0.65	15	22	2.5
T1S/R5E	34	SW	BP	40.4	0.90	54	77	8.8
T1S/R5E	34	SE	CRC	19	0.90	25	36	4.1
T1S/R5E	35	SW	CRC	12.3	0.90	16	24	2.7
T1S/R5E	35	SW	SLR	107.7	0.65	104	149	16.9
T1S/R5E	35	SE	ED	20	0.90	27	38	4.4
T1S/R5E	35	SE	ROPEN	8.8	0.50	7	9	1.1
T1S/R5E	35	SE	HDR	7.4	0.80	9	13	1.4
T1S/R5E	35	SE	CRC	5.6	0.90	8	11	1.22
T1S/R5E	35	SE	SLR	25.8	0.65	25	36	4.1
T1S/R5E	35	SE	CRC	9.7	0.90	13	19	2.1
T1S/R5E	36	SW	SF-8.5	145	0.65	140	201	22.8
T1S/R5E	36	SW	SLR	8	0.65	8	11	1.3
T1S/R5E	36	SW	CRC	6.4	0.90	9	12	1.4
T1S/R5E	36	SE	SLR	9.2	0.65	9	13	1.5
T1S/R5E	36	SE	CRC	11.4	0.90	15	22	2.5

Table D-1 *Area B Vacant Parcels Runoff Calculations*								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T1S/R5E	36	SE	O	47.7	0.90	64	91	13.4
T1S/R5E	36	SE	SLR	8.8	0.65	9	12	1.4

Note:
C -2 = Commercial
RRL = Rural
MF = Multifamiliary
SLR = Small Lot Residential
CRC = Community Retail Center
HDR = High Density Residential
IND = Industrial
PCO = Planned Commercial Office
O = Office
ED = Education
SF = Single Family
I-1 = Industiral

Table D-2 Area C Vacant Quarter Section and Parcel Runoff Calculations								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T2S/R5E	33	NW NE SW SE	LDR Residential " " "	160 160 160 160	0.65 0.65 0.65 0.65	155 155 155 155	222 222 222 222	25 25 25 25
T2S/R5E	34	NW NE SW SE	Mixed SLR BP SLR	160 160 160 160	0.90, 0.65 0.65 0.90 0.65	211 155 155 155	301 222 222 222	34 25 25 25
T2S/R5E	35	NW NE SW SE	Mixed, partially Built Built Mixed, partially Built Built	100 0 80 0	0.90, 0.65 0.65	108 77	97 111	11 13
T2S/R5E	36	NW NE SW SE	SLR Mixed SLR SLR	160 160 160 160	0.65 0.90, 0.65 0.65 0.65	155 166 155 155	222 237 222 222	25 27 25 25
T2S/R6E	31	NW NE SW SE	Mixed SLR SLR SLR	160 160 160 160	0.90, 0.65 0.65 0.65 0.65	166 155 155 155	237 222 222 222	27 25 25 25
T2S/R6E	32	NW NE SW SE	SLR SLR SLR SLR	160 160 160 160	0.65 0.65 0.65 0.65	155 155 155 155	222 222 222 222	25 25 25 25
T2S/R6E	29	NW NE SW SE	SLR SLR SLR SLR	160 160 160 160	0.65 0.65 0.65 0.65	155 155 155 155	222 222 222 222	25 25 25 25

Table D-2 Area C Vacant Quarter Section and Parcel Runoff Calculations								
Township and Range	**Section**	**Quarter**	**Land Use**	**Area (acres)**	**Runoff Coefficient**	**10-year Peak Runoff (cfs)**	**50-year Peak Runoff (cfs)**	**100-year Retention Volume (ac-ft)**
T2S/R6E	30	NW NE SW SE	Mixed SLR SLR SLR	160 160 160 160	0.65, 0.90 0.65 0.65 0.65	166 155 166 155	237 222 237 222	27 25 27 25
T2S/R5E	25	NW NE SW SE	SLR Mixed SLR Mixed	160 160 160 160	0.65 0.65, 0.90 0.65 0.65, 0.90	155 166 155 166	222 237 222 237	25 27 25 27
T2S/R5E	26	NW NE SW SE	SLR SLR BP SLR	160 160 160 160	0.65 0.65 0.90 0.65	155 155 215 155	222 222 307 222	25 25 35 25
T2S/R5E	27	NW NE SW SE	Mixed BP BP BP	160 160 160 160	0.90 0.90 0.90 0.90	215 215 215 215	307 307 307 307	35 35 35 35
T2S/R5E	28	NW NE SW SE	Mixed, partially Built Mixed, partially Built Built Mixed, partially Built	80 70 0 20	0, 0.50, 0.90 0.65, 0.90 0, 0.90	46 79 13	66 113 13	7 13 2
T2S/R5E	19	NW NE SW SE	BP Mixed, partially Built BP BP	160 140 160 160	0.90 0.65, 0.90 0.90 0.90	215 177 215 215	307 253 307 307	35 29 35 35
T2S/R5E	20	NW NE SW SE	SLR ixed Mixed, partially Built Mixed, partially Built	160 160 50 60	0.65 0.65, 0.90 0.65 0.65	155 207 48 58	222 296 69 83	25 34 8 9

Table D-2 Area C Vacant Quarter Section and Parcel Runoff Calculations								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T2S/R5E	21	NW NE SW SE	SLR Mixed SLR Mixed	160 160 160 160	0.65 0.65, 0.90 0.65 0.65, 0.90	155 166 155 166	222 237 222 237	25 27 25 27
T2S/R5E	22	NW NE SW SE	Mixed Mixed Mixed Mixed	160 160 160 160	0.90 0.65, 0.90 0.90 0.65, 0.90	215 166 215 170	307 237 307 243	35 27 35 28
T2S/R5E	23	NW NE SW SE	SLR SLR SLR SLR	160 160 160 160	0.65 0.65 0.65 0.65	155 155 155 155	222 222 222 222	25 25 25 25
T2S/R5E	24	NW NE SW SE	SLR SLR SLR Mixed	160 160 160 160	0.65 0.65 0.65 0.65, 0.90	155 155 155 166	222 222 222 237	25 25 25 27
T2S/R6E	19	NW NE SW SE	SLR SLR Mixed SLR	160 160 160 160	0.65 0.65 0.65, 0.90 0.65	155 155 166 155	222 222 237 222	25 25 27 25
T2S/R6E	20	NW SW	SLR SLR	160 160	0.65 0.65	155 155	222 222	25 25
T2S/R6E	18	NW NE SW SE	SLR SLR SLR SLR	160 160 160 160	0.65 0.65 0.65 0.65	155 155 155 155	222 222 222 222	25 25 25 25
T2S/R6E	13	NW NE SW SE	Mixed Mixed Mixed SLR	160 160 160 160	0.90 0.90 0.65, 0.90 0.65	215 215 185 155	307 307 264 222	35 35 30 25
T2S/R6E	14	NW NE SW SE	IND Mixed Mixed Mixed	160 160 160 160	0.90 0.50, 0.90 0.65, 0.90 0.50, 0.65, 0.90	215 197 185 167	307 281 264 239	35 32 30 27

Table D-2 *Area C Vacant Quarter Section and Parcel Runoff Calculations*								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T2S/R6E	15	NW NE SW SE	Mixed Mixed Mixed Mixed, Partially Built	160 160 160 125	0.78, 0.90 0.78, 0.90 0.78 0.50, 0.78	194 205 185 114	277 293 264 163	32 33 30 18
T2S/R5E	16	NW NE SW SE	Mixed, Partially Built Mixed Mixed, Partially Built Mixed	160 160 40 160	0.65, 0.78, 0.90 0.65, 0.90 0.65 0.65, 0.90	82 170 39 166	117 243 55 237	13 28 6 27
T2S/R5E	17	All	Built	0				
T2S/R5E	18	NW NE SW SE	Mixed, Partially Built Built BP Built	60 0 160 0	0.90 0.90	81 215	115 307	13 35
T2S/R5E	7	NW NE SW SE	Industrial Mixed, Partially Built Mixed, Partially Built Mixed, Partially Built	160 140 75 50	0.90 0.65, 0.80, 0.90 0.90 0.90	215 174 101 67	307 249 144 96	35 28 16 11

Table D-2 Area C Vacant Quarter Section and Parcel Runoff Calculations								
Township and Range	**Section**	**Quarter**	**Land Use**	**Area (acres)**	**Runoff Coefficient**	**10-year Peak Runoff (cfs)**	**50-year Peak Runoff (cfs)**	**100-year Retention Volume (ac-ft)**
T2S/R5E	8	NW NE SW SE	Mixed, Partially Built Mixed, Partially Built Built Mixed, Partially Built	40 25 0 50	0.65 0.90 0.80, 0.90	39 34 64	55 48 91	6 5 10
T2S/R5E	9	NW NE SW SE	SLR Mixed Mixed Mixed	160 160 160 160	0.65 0.65, 0.90 0.65, 0.90 0.65, 0.90	155 162 166 170	222 232 237 243	25 26 27 28
T2S/R5E	10	NW NE SW SE	Mixed ROPEN Mixed Mixed	160 160 160 160	0.78, 0.90 0.50 0.78, 0.90 0.78	200 119 200 185	285 170 285 264	32 19 32 30
T2S/R5E	11	NW NE SW SE	Mixed Mixed Mixed Mixed	160 160 160 160	0.90 0.90 0.90 0.90	215 215 215 215	307 307 307 307	35 35 35 35
T2S/R5E	12	NW NE SW SE	Mixed Industrial Mixed Industrial	160 160 160 160	0.90 0.90 0.90 0.90	215 215 215 215	307 307 307 307	35 35 35 35
T2S/R6E	7	NW NE SW SE	SLR SLR SLR SLR	80 50 160 20	0.65 0.65 0.65 0.65	77 48 155 19	111 69 222 28	13 8 25 3
T2S/R5E	1	NW NE SW SE	Mixed, Partially Built Mixed Mixed Mixed	80 160 160 160	0.65, 0.90 0.65, 0.90 0.65, 0.90 0.65, 0.90	87 166 200 200	124 237 285 285	9 27 32 32

Table D-2 Area C Vacant Quarter Section and Parcel Runoff Calculations								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T2S/R5E	2	NW NE SW SE	Mixed, Partially Built Mixed, Partially Built Mixed Mixed	140 125 160 160	0.65, 0.90 0.65, 0.90 0.65, 0.90 0.65, 0.90	162 133 209 211	231 190 299 301	26 21 34 34
T2S/R5E	3	NW NE SW SE	Mixed Mixed, Partially Built Industrial Mixed	160 130 160 160	0.90 0.50, 0.65, 0.90 0.90 0.50, 0.65, 0.90	215 111 215 184	307 157 307 263	35 18 35 30
T2S/R5E	4	NW NE SW SE	Mixed Mixed Mixed, Partially Built Mixed, Partially Built	160 160 140	0.65, 0.90 0.65, 0.80, 0.90 0.65	172 186 136	245 266 194	28 30 22
T2S/R5E	5	NW NE SW SE	Built Mixed, Partially Built Mixed, Partially Built Mixed, Partially Built	0 60 50 80	 0.65, 0.90 0.65, 0.90 0.65	 71 56 77	 102 80 111	 11 9 13

Table D-2 Area C Vacant Quarter Section and Parcel Runoff Calculations								
Township and Range	***Section***	***Quarter***	***Land Use***	***Area (acres)***	***Runoff Coefficient***	***10-year Peak Runoff (cfs)***	***50-year Peak Runoff (cfs)***	***100-year Retention Volume (ac-ft)***
T2S/R5E	6	NW NE SW SE	Mixed Mixed Mixed, Partially Built Mixed, Partially Built	160 160 140 120	0.65, 0.90 0.65, 0.90 0.90 0.65, 0.90	211 170 188 131	301 243 269 187	34 28 31 21

Note:

SLR	=	small lot residential
BP	=	business park
LDR	=	low density residential
IND	=	industrial
ROPEN	=	recreational, open area

Table D-3 - Study Area B Rational Method Detailed Calculations										
Runoff Calculated from the Rational Method for Undeveloped Land									$V_R = (D/12)*AC(1.1)$	
Last Update:		6/2/99			10-year storm Intensity = 1.49 in/hr		50-year storm Intensity = 2.13 in/hr		100-year, 2-hour storm Rainfall Depth 2.64 or 2.72 in	
Township and Range	Section Number	Subarea ID	Zoning Land Use	Tributary Area (acres) A	Runoff Coefficient C_{10}	Peak Runoff (ft^3/sec) Q_{10}	Runoff Coefficient C_{50}	Peak Runoff (ft^3/sec) Q_{50}	Runoff Coefficient C_{100}	Retention Volume (ac-ft) V_R
T1S/R5E	7	SW 1/4	SLR	2.6	0.65	3	0.65	4	0.65	0.41
T1S/R5E	8	SW 1/4	C-2	8.9	0.90	12	0.90	17	0.90	1.94
T1S/R5E	9	SE 1/4	I-1	6.0	0.90	8	0.90	12	0.90	1.31
T1S/R5E	10	SW 1/4	I-1	8.0	0.90	11	0.90	15	0.90	1.74
T1S/R5E	10	SW 1/4	I-1	4.2	0.90	6	0.90	8	0.90	0.91
T1S/R5E	10	SW 1/4	I-1	7.4	0.90	10	0.90	14	0.90	1.61
T1S/R5E	10	SW 1/4	I-1	16.5	0.90	22	0.90	32	0.90	3.59
T1S/R5E	10	SW 1/4	I-1	10.6	0.90	14	0.90	20	0.90	2.31
T1S/R5E	10	SW 1/4	I-1	10.4	0.90	14	0.90	20	0.90	2.27
T1S/R5E	10	SW 1/4	I-1	6.9	0.90	9	0.90	13	0.90	1.50
T1S/R5E	18	NW 1/4	C-2	6	0.90	8	0.90	12	0.90	1.31
T1S/R5E	18	NW 1/4	RRL	18.6	0.50	14	0.50	20	0.50	2.25
T1S/R5E	18	NW 1/4	RRL	9.3	0.50	7	0.50	10	0.50	1.13
T1S/R5E	18	SW 1/4	RRL	18	0.50	13	0.50	19	0.50	2.18
T1S/R5E	18	SE 1/4	C-2	9.5	0.90	13	0.90	18	0.90	2.07
T1S/R5E	17	SE 1/4	MF-3	3.3	0.80	4	0.80	6	0.80	0.64
T1S/R5E	17	SE 1/4	MF-2	2.6	0.80	3	0.80	4	0.80	0.50
T1S/R5E	16	NW 1/4	C-2	5.6	0.90	8	0.90	11	0.90	1.22
T1S/R5E	16	NE 1/4	SLR	7.5	0.65	7	0.65	10	0.65	1.18
T1S/R5E	16	SE 1/4	C-2	8.6	0.90	12	0.90	16	0.90	1.87
T1S/R5E	16	SE 1/4	CRC	9	0.90	12	0.90	17	0.90	1.96
T1S/R5E	16	SE 1/4	CRC	3.1	0.90	4	0.90	6	0.90	0.68
T1S/R5E	16	SE 1/4	C-3	1.5	0.90	2	0.90	3	0.90	0.33
T1S/R5E	16	SE 1/4	HDR	10.1	0.80	12	0.80	17	0.80	1.96
T1S/R5E	15	SW 1/4	IND	86.5	0.90	116	0.90	166	0.90	18.84
T1S/R5E	15	SW 1/4	HDR	12.7	0.80	15	0.80	22	0.80	2.46
T1S/R5E	15	NW 1/4	IND	76	0.90	102	0.90	146	0.90	16.55
T1S/R5E	15	NW 1/4	I-1	14.4	0.90	19	0.90	28	0.90	3.14
T1S/R5E	15	SE 1/4	SLR	16.4	0.65	16	0.65	23	0.65	2.58
T1S/R5E	15	SE 1/4	CRC	13.2	0.90	18	0.90	25	0.90	2.87
T1S/R4E	20	SE 1/4	CRC	36.9	0.90	49	0.90	71	0.90	8.28
T1S/R4E	20	SE 1/4	IND	32.5	0.90	44	0.90	62	0.90	7.29
T1S/R4E	23	SE 1/4	C-2	15.1	0.90	20	0.90	29	0.90	3.39

T1S/R4E	24	SW 1/4	CRC	21.1	0.90	28	0.90	40	0.90	4.73
T1S/R4E	24	SE 1/4	CRC	15.4	0.90	21	0.90	30	0.90	3.46
T1S/R4E	24	SE 1/4	SLR	7	0.65	7	0.65	10	0.65	1.13
T1S/R5E	19	NW 1/4	CRC	11.7	0.90	16	0.90	22	0.90	2.55
T1S/R5E	19	NW 1/4	HDR	2.4	0.80	3	0.80	4	0.80	0.46
T1S/R5E	19	SW 1/4	CRC	22.4	0.90	30	0.90	43	0.90	4.88
T1S/R5E	19	SE 1/4	CRC	17	0.90	23	0.90	33	0.90	3.70
T1S/R5E	20	NW 1/4	CRC	14.6	0.90	20	0.90	28	0.90	3.18
T1S/R5E	20	NE 1/4	SLR	2.2	0.65	2	0.65	3	0.65	0.35
T1S/R5E	20	NE 1/4	PCO	0.6	0.90	1	0.90	1	0.90	0.13
T1S/R5E	20	SW 1/4	SLR	10.9	0.65	11	0.65	15	0.65	1.71
T1S/R5E	21	SW 1/4	HDR	9.4	0.80	11	0.80	16	0.80	1.82
T1S/R5E	22	SW 1/4	I-2	35.3	0.90	47	0.90	68	0.90	7.69
T1S/R5E	22	SW 1/4	C-3	15.9	0.90	21	0.90	30	0.90	3.46
T1S/R5E	22	SW 1/4	IND	36.4	0.90	49	0.90	70	0.90	7.93
T1S/R5E	23	SW 1/4	CRC	30.8	0.90	41	0.90	59	0.90	6.71
T1S/R5E	23	SE 1/4	CRC	11.1	0.90	15	0.90	21	0.90	2.42
T1S/R4E	29	NE 1/4	RRC	160	0.90	215	0.90	307	0.90	35.90
T1S/R4E	29	SE 1/4	I-1	2.6	0.90	3	0.90	5	0.90	0.58
T1S/R4E	28	SW 1/4	IND	3.4	0.90	5	0.90	7	0.90	0.76
T1S/R4E	28	SW 1/4	I-1	2.2	0.90	3	0.90	4	0.90	0.49
T1S/R4E	28	SW 1/4	I-2	10.1	0.90	14	0.90	19	0.90	2.27
T1S/R4E	28	SE 1/4	CRC	20.2	0.90	27	0.90	39	0.90	4.53
T1S/R4E	28	SE 1/4	CRC	1.5	0.90	2	0.90	3	0.90	0.34
T1S/R4E	27	SW 1/4	CRC	10.6	0.90	14	0.90	20	0.90	2.38
T1S/R4E	27	SW 1/4	CRC	3.2	0.90	4	0.90	6	0.90	0.72
T1S/R4E	27	SW 1/4	CRC	20	0.90	27	0.90	38	0.90	4.49
T1S/R4E	27	SW 1/4	HDR	9.3	0.80	11	0.80	16	0.80	1.86
T1S/R4E	26	SW 1/4	SLR	21.3	0.65	21	0.65	29	0.65	3.45
T1S/R4E	26	SE 1/4	IND	38.6	0.90	52	0.90	74	0.90	8.66
T1S/R4E	26	SE 1/4	IND	103.6	0.90	139	0.90	199	0.90	23.25
T1S/R4E	25	NE 1/4	SLR	2	0.65	2	0.65	3	0.65	0.32
T1S/R4E	25	NE 1/4	O	1.3	0.90	2	0.90	2	0.90	0.29
T1S/R4E	25	SW 1/4	CRC	15.4	0.90	21	0.90	30	0.90	3.46
T1S/R4E	25	NE 1/4	CRC	2.1	0.90	3	0.90	4	0.90	0.47
T1S/R4E	25	SE 1/4	CRC	21.5	0.90	29	0.90	41	0.90	4.82
T1S/R4E	25	SE 1/4	CRC	5	0.90	7	0.90	10	0.90	1.12
T1S/R4E	25	SE 1/4	CRC	2.9	0.90	4	0.90	6	0.90	0.65
T1S/R4E	25	SE 1/4	O	1.5	0.90	2	0.90	3	0.90	0.34
T1S/R5E	30	NE 1/4	CRC	17.7	0.90	24	0.90	34	0.90	3.86
T1S/R5E	30	SW 1/4	RRL	9.7	0.50	7	0.50	10	0.50	1.17
T1S/R5E	30	SW 1/4	RRL	10	0.50	7	0.50	11	0.50	1.21
T1S/R5E	30	SW 1/4	RRL	9.7	0.50	7	0.50	10	0.50	1.17

T1S/R5E	30	SW 1/4	CRC	54	0.90	72	0.90	104	0.90	11.76
T1S/R5E	27	NE 1/4	SLR	14.2	0.65	14	0.65	20	0.65	2.23
T1S/R5E	26	NW 1/4	HDR	7.3	0.80	9	0.80	12	0.80	1.41
T1S/R5E	26	NW 1/4	SLR	3.2	0.65	3	0.65	4	0.65	0.50
T1S/R5E	26	SW 1/4	SLR	20	0.65	19	0.65	28	0.65	3.15
T1S/R5E	26	SE 1/4	SLR	2.3	0.65	2	0.65	3	0.65	0.36
T1S/R5E	26	SE 1/4	HDR	13.6	0.80	16	0.80	23	0.80	2.63
T1S/R5E	25	SW 1/4	CRC	4.9	0.90	7	0.90	9	0.90	1.07
T1S/R5E	25	SW 1/4	SLR	62.5	0.65	61	0.65	87	0.65	9.83
T1S/R5E	25	SE 1/4	CRC	9.5	0.90	13	0.90	18	0.90	2.07
T1S/R5E	25	SE 1/4	CRC	0.6	0.90	1	0.90	1	0.90	0.13
T1S/R4E	32	NE 1/4	C-2	11.3	0.90	15	0.90	22	0.90	2.54
T1S/R4E	32	NE 1/4	BP	0.7	0.90	1	0.90	1	0.90	0.16
T1S/R4E	32	SE 1/4	I-1	27.8	0.90	37	0.90	53	0.90	6.24
T1S/R4E	32	SE 1/4	I-1	40	0.90	54	0.90	77	0.90	8.98
T1S/R4E	33	NW 1/4	BP	9.2	0.90	12	0.90	18	0.90	2.06
T1S/R4E	33	SW 1/4	BP	23.8	0.90	32	0.90	46	0.90	5.34
T1S/R4E	33	SW 1/4	BP	27.6	0.90	37	0.90	53	0.90	6.19
T1S/R4E	33	SW 1/4	BP	59.4	0.90	80	0.90	114	0.90	13.33
T1S/R4E	33	SE 1/4	BP	14.7	0.90	20	0.90	28	0.90	3.30
T1S/R4E	33	SE 1/4	ED	67.5	0.90	91	0.90	129	0.90	15.15
T1S/R4E	33	NE 1/4	BP	34	0.90	46	0.90	65	0.90	7.63
T1S/R4E	34	NW 1/4	CRC	11.1	0.90	15	0.90	21	0.90	2.49
T1S/R4E	34	NW 1/4	SLR	3.95	0.65	4	0.65	5	0.65	0.64
T1S/R4E	34	SW 1/4	SLR	18.8	0.65	18	0.65	26	0.65	3.05
T1S/R4E	35	NE 1/4	C-2	2.9	0.90	4	0.90	6	0.90	0.65
T1S/R4E	35	NE 1/4	I-1	2.6	0.90	3	0.90	5	0.90	0.58
T1S/R4E	35	NE 1/4	I-1	8.6	0.90	12	0.90	16	0.90	1.93
T1S/R4E	35	SE 1/4	I-1	3.4	0.90	5	0.90	7	0.90	0.76
T1S/R4E	35	SE 1/4	I-1	60.4	0.90	81	0.90	116	0.90	13.55
T1S/R4E	36	NW 1/4	I-1	11.2	0.90	15	0.90	21	0.90	2.51
T1S/R4E	36	NE 1/4	RRC	103	0.90	138	0.90	197	0.90	23.11
T1S/R4E	36	SE 1/4	RRC	87.5	0.90	117	0.90	168	0.90	19.64
T1S/R4E	36	SW 1/4	SLR	8.7	0.65	8	0.65	12	0.65	1.41
T1S/R5E	31	NW 1/4	IND	40	0.90	54	0.90	77	0.90	8.71
T1S/R5E	31	NW 1/4	I-1	24.6	0.90	33	0.90	47	0.90	5.36
T1S/R5E	31	NE 1/4	I-1	55.5	0.90	74	0.90	106	0.90	12.09
T1S/R5E	31	NE 1/4	SF-8.5	10	0.65	10	0.65	14	0.65	1.57
T1S/R5E	31	SW 1/4	CRC	73.2	0.90	98	0.90	140	0.90	15.94
T1S/R5E	31	SW 1/4	I-1	40	0.90	54	0.90	77	0.90	8.71
T1S/R5E	31	SE 1/4	BP	56.6	0.90	76	0.90	109	0.90	12.33
T1S/R5E	31	SE 1/4	BP	40.4	0.90	54	0.90	77	0.90	8.80
T1S/R5E	31	SE 1/4	SLR	20	0.65	19	0.65	28	0.65	3.15

T1S/R5E	31	SE 1/4	SLR	53.6	0.65	52	0.65	74	0.65	8.43
T1S/R5E	32	SW 1/4	SLR	37	0.65	36	0.65	51	0.65	5.82
T1S/R5E	32	SW 1/4	ED	6.4	0.90	9	0.90	12	0.90	1.39
T1S/R5E	33	SW 1/4	SF-8.5	40	0.65	39	0.65	55	0.65	6.29
T1S/R5E	33	SW 1/4	CRC	5.8	0.90	8	0.90	11	0.90	1.26
T1S/R5E	33	SW 1/4	SLR	7.5	0.65	7	0.65	10	0.65	1.18
T1S/R5E	33	SW 1/4	SLR	3.4	0.65	3	0.65	5	0.65	0.53
T1S/R5E	34	NW 1/4	I-2	17.7	0.90	24	0.90	34	0.90	3.86
T1S/R5E	34	SW 1/4	SF-8.5	16	0.65	15	0.65	22	0.65	2.52
T1S/R5E	34	SW 1/4	BP	40.4	0.90	54	0.90	77	0.90	8.80
T1S/R5E	34	SE 1/4	CRC	19	0.90	25	0.90	36	0.90	4.14
T1S/R5E	35	SW 1/4	CRC	12.3	0.90	16	0.90	24	0.90	2.68
T1S/R5E	35	SW 1/4	SLR	107.7	0.65	104	0.65	149	0.65	16.94
T1S/R5E	35	SE 1/4	ED	20	0.90	27	0.90	38	0.90	4.36
T1S/R5E	35	SE 1/4	ROPEN	8.8	0.50	7	0.50	9	0.50	1.06
T1S/R5E	35	SE 1/4	HDR	7.4	0.80	9	0.80	13	0.80	1.43
T1S/R5E	35	SE 1/4	CRC	5.6	0.90	8	0.90	11	0.90	1.22
T1S/R5E	35	SE 1/4	SLR	25.8	0.65	25	0.65	36	0.65	4.06
T1S/R5E	35	SE 1/4	CRC	9.7	0.90	13	0.90	19	0.90	2.11
T1S/R5E	36	SW 1/4	SF-8.5	145	0.65	140	0.65	201	0.65	22.81
T1S/R5E	36	SW 1/4	SLR	8	0.65	8	0.65	11	0.65	1.26
T1S/R5E	36	SW 1/4	CRC	6.4	0.90	9	0.90	12	0.90	1.39
T1S/R5E	36	SE 1/4	SLR	9.2	0.65	9	0.65	13	0.65	1.45
T1S/R5E	36	SE 1/4	CRC	11.4	0.90	15	0.90	22	0.90	2.48
T1S/R5E	36	SE 1/4	O	47.7	0.90	64	0.90	91	0.90	10.39
T1S/R5E	36	SE 1/4	SLR	8.8	0.65	9	0.65	12	0.65	1.38

Table D-4 - Study Area C Rational Method Detailed Calculations

Runoff Calculated from the Rational Method for Undeveloped Land

Last Update: 6/2/99

					10-year storm Intensity = 1.49 in/hr		50-year storm Intensity = 2.13 in/hr		100-year, 2-hour storm Depth of Rainfall = 2.64 in	
Township and Range	Section Number	SubArea ID	Zoning Land Use	Tributary Area (acres) A	Runoff Coefficient C_{10}	Peak Runoff (ft^3/sec) Q_{10}	Runoff Coefficient C_{50}	Peak Runoff (ft^3/sec) Q_{50}	Runoff Coefficient C_{100}	Retention Volume (ac-ft) V_R
T2S/R5E	33	NW 1/4	LDR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	33	NE 1/4	LDR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	33	SW 1/4	LDR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	33	SE 1/4	LDR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	34	NW 1/4	BP	130	0.90	174	0.90	249	0.90	28
			CRC	20	0.90	27	0.90	38	0.90	4
			SLR	10	0.65	10	0.65	14	0.65	2
			TOTAL	**160**	**TOTAL**	**211**	**TOTALS**	**301**		**34**
T2S/R5E	34	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	34	SW 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	34	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	35	NW 1/4	CRC	**30**	0.90	**40**	0.90	**58**	0.90	**7**
PARCELS			Built	60						
			SLR	**70**	0.65	**68**	0.65	**97**	0.65	**11**
T2S/R5E	35	NE 1/4	BUILT							
T2S/R5E	35	SW 1/4	SLR	**80**	0.65	**77**	0.65	**111**	0.65	**13**
PARCELS			Built	80						
T2S/R5E	35	SE 1/4	BUILT							0
T2S/R5E	36	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	36	NE 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			SLR	130	0.65	126	0.65	180	0.65	20
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	36	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	36	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	31	NW 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			SLR	130	0.65	126	0.65	180	0.65	20

			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R6E	31	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	31	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	31	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	32	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	32	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	32	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	32	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	29	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	29	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	29	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	29	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	30	NW 1/4	SLR	130	0.65	126	0.65	180	0.65	20
			CRC	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R6E	30	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	30	SW 1/4	SLR	130	0.65	126	0.65	180	0.65	20
			CRC	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R6E	30	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	25	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	25	NE 1/4	SLR	130	0.65	126	0.65	180	0.65	20
			CRC	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	25	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	25	SE 1/4	SLR	130	0.65	126	0.65	180	0.65	20
			CRC	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	26	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**

T2S/R5E	26	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	26	SW 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	26	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	27	NW 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			BP	130	0.90	174	0.90	249	0.90	28
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	27	NE 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	27	SW 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	27	SE 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	28	NW 1/4	SLR	**40**	0.65	**39**	0.65	**55**	0.65	**6**
PARCELS			WTR	**30**	0.00	**0**	0.00	**0**	0.00	**0**
			RRL	**10**	0.50	**7**	0.50	**11**	0.50	**1**
			Built	80						
T2S/R5E	28	NE 1/4	MDR	**40**	0.65	**39**	0.65	**55**	0.65	**6**
PARCELS			CRC	**30**	0.90	**40**	0.90	**58**	0.90	**7**
		Built	ROPEN	70						
		Built	SLR	20						
T2S/R5E	28	SW 1/4	BUILT							
T2S/R5E	28	SE 1/4	CRC	**10**	0.90	**13**	0.90	**19**	0.90	**2**
PARCELS			Built	140						
			WTR	10	0.00	0	0.00	0	0.00	0
T2S/R5E	19	NW 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	19	NE 1/4	BP	**110**	0.90	**148**	0.90	**211**	0.90	**24**
PARCELS			Built	20						
			SLR	**30**	0.65	**29**	0.65	**42**	0.65	**5**
T2S/R5E	19	SW 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	19	SE 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	20	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	20	NE 1/4	BP	30	0.90	40	0.90	58	0.90	7
			CRC	30	0.90	40	0.90	58	0.90	7
			LAA	80	0.90	107	0.90	153	0.90	17
			SLR	20	0.65	19	0.65	28	0.65	3
			TOTAL	**160**	**TOTAL**	**207**	**TOTALS**	**296**		**34**
T2S/R5E	20	SW 1/4	SLR	**50**	0.65	**48**	0.65	**69**	0.65	**8**
PARCELS			Built	90						

T2S/R5E	20	SE 1/4	Built	120						
PARCELS			SLR	**60**	0.65	**58**	0.65	**83**	0.65	**9**
T2S/R5E	21	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	21	NE 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			SLR	130	0.65	126	0.65	180	0.65	20
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	21	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	21	SE 1/4	SLR	130	0.65	126	0.65	180	0.65	20
			CRC	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	22	NW 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			BP	130	0.90	174	0.90	249	0.90	28
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	22	NE 1/4	SLR	130	0.65	126	0.65	180	0.65	20
			BP	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	22	SW 1/4	BP	130	0.90	174	0.90	249	0.90	28
			CRC	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	22	SE 1/4	BP	40	0.90	54	0.90	77	0.90	9
			SLR	120	0.65	116	0.65	166	0.65	19
			TOTAL	**160**	**TOTAL**	**170**	**TOTALS**	**243**		**28**
T2S/R5E	23	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	23	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	23	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	23	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	24	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	24	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	24	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	24	SE 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			SLR	130	0.65	126	0.65	180	0.65	20
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R6E	19	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	19	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**

T2S/R6E	19	SW 1/4	SLR	130	0.65	126	0.65	180	0.65	20
			CRC	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R6E	19	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	20	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	20	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	18	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	18	NE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	18	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	18	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	13	NW 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			BP	40	0.90	54	0.90	77	0.90	9
			IND	90	0.90	121	0.90	173	0.90	20
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	13	NE 1/4	BP	130	0.90	174	0.90	249	0.90	28
			IND	30	0.90	40	0.90	58	0.90	7
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	13	SW 1/4	SLR	80	0.65	77	0.65	111	0.65	13
			O	30	0.90	40	0.90	58	0.90	7
			BP	50	0.90	67	0.90	96	0.90	11
			TOTAL	**160**	**TOTAL**	**185**	**TOTALS**	**264**		**30**
T2S/R5E	13	SE 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R5E	14	NW 1/4	IND	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	14	NE 1/4	IND	130	0.90	174	0.90	249	0.90	28
			ROPEN	30	0.50	22	0.50	32	0.50	4
			TOTAL	**160**	**TOTAL**	**197**	**TOTALS**	**281**		**32**
T2S/R5E	14	SW 1/4	BP	80	0.90	107	0.90	153	0.90	17
			SLR	80	0.65	77	0.65	111	0.65	13
			TOTAL	**160**	**TOTAL**	**185**	**TOTALS**	**264**		**30**
T2S/R5E	14	SE 1/4	BP	50	0.90	67	0.90	96	0.90	11
			SLR	80	0.65	77	0.65	111	0.65	13
			ROPEN	30	0.50	22	0.50	32	0.50	4
			TOTAL	**160**	**TOTAL**	**167**	**TOTALS**	**239**		**27**
T2S/R5E	15	NW 1/4	O	20	0.90	27	0.90	38	0.90	4
			CRC	30	0.90	40	0.90	58	0.90	7
			MIX	110	0.78	127	0.78	182	0.78	21

			TOTAL	160	TOTAL	194	TOTAL	277		32
T2S/R5E	15	NE 1/4	IND	110	0.90	148	0.90	211	0.90	24
			MIX	50	0.78	58	0.78	83	0.78	9
			TOTAL	160	TOTAL	205	TOTALS	293		33
T2S/R5E	15	SW 1/4	MIX	160	0.78	185	0.78	264	0.78	30
			TOTAL	160	TOTAL	185	TOTALS	264		30
T2S/R5E	15	SE 1/4	OPEN	75	0.50	56	0.50	80	0.50	9
PARCELS			MIX	50	0.78	58	0.78	83	0.78	9
			Built	35						
T2S/R5E	16	NW 1/4	HDR	20	0.80	24	0.80	34	0.80	4
PARCELS			CRC	25	0.90	34	0.90	48	0.90	5
			MDR	25	0.65	24	0.65	35	0.65	4
			Built	90	0.90	121	0.90	173	0.90	20
T2S/R5E	16	NE 1/4	CRC	40	0.90	54	0.90	77	0.90	9
			SLR	120	0.65	116	0.65	166	0.65	19
			TOTAL	160	TOTAL	170	TOTALS	243		28
T2S/R5E	16	SW 1/4	SLR	40	0.65	39	0.65	55	0.65	6
PARCELS			Built	120						
T2S/R5E	16	SE 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			SLR	130	0.65	126	0.65	180	0.65	20
			TOTAL	160	TOTAL	166	TOTALS	237		27
T2S/R5E	17	NW 1/4	BUILT							0
T2S/R5E	17	NE 1/4	BUILT							0
T2S/R5E	17	SW 1/4	BUILT							0
T2S/R5E	17	SE 1/4	BUILT							0
T2S/R5E	18	NW 1/4	RRC	20	0.90	27	0.90	38	0.90	4
PARCELS			IND	40	0.90	54	0.90	77	0.90	9
			Built	100						
T2S/R5E	18	NE 1/4	BUILT							0
T2S/R5E	18	SW 1/4	BP	160	0.90	215	0.90	307	0.90	35
			TOTAL	160	TOTAL	215	TOTALS	307		35
T2S/R5E	18	SE 1/4	BUILT							0
T2S/R5E	7	NW 1/4	IND	160	0.90	215	0.90	307	0.90	35
			TOTAL	160	TOTAL	215	TOTALS	307		35
T2S/R5E	7	NE 1/4	HDR	40	0.80	48	0.80	68	0.80	8
PARCELS			IND	80	0.90	107	0.90	153	0.90	17
			SLR	20	0.65	19	0.65	28	0.65	3
			Built	20						
T2S/R5E	7	SW 1/4	BP	35	0.90	47	0.90	67	0.90	8
PARCELS			IND	40	0.90	54	0.90	77	0.90	9
			Built	85						
T2S/R5E	7	SE 1/4	CRC	30	0.90	40	0.90	58	0.90	7
PARCELS			IND	20	0.90	27	0.90	38	0.90	4
			Built	110						
T2S/R5E	8	NW 1/4	SLR	40	0.65	39	0.65	55	0.65	6

PARCELS			Built	120						
T2S/R5E	8	NE 1/4	CRC	**25**	0.90	**34**	0.90	**48**	0.90	**5**
PARCELS			Built	135						
T2S/R5E	8	SE 1/4	CRC	**25**	0.90	**34**	0.90	**48**	0.90	**5**
PARCELS			HDR	**25**	0.80	**30**	0.80	**43**	0.80	**5**
			Built	110						
T2S/R5E	8	SW 1/4	BUILT							0
T2S/R5E	9	NW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**		**155**	**TOTALS**	**222**		**25**
T2S/R5E	9	NE 1/4	CRC	20	0.90	27	0.90	38	0.90	4
			SLR	140	0.65	136	0.65	194	0.65	22
			TOTAL	**160**	**TOTAL**	**162**	**TOTALS**	**232**		**26**
T2S/R5E	9	SW 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			SLR	130	0.65	126	0.65	180	0.65	20
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	9	SE 1/4	CRC	40	0.90	54	0.90	77	0.90	9
			SLR	120	0.65	116	0.65	166	0.65	19
			TOTAL	**160**	**TOTAL**	**170**	**TOTALS**	**243**		**28**
T2S/R5E	10	NW 1/4	WDC	80	0.90	107	0.90	153	0.90	17
			MIX	80	0.78	92	0.78	132	0.78	15
			TOTAL	**160**	**TOTAL**	**200**	**TOTALS**	**285**		**32**
T2S/R5E	10	NE 1/4	ROPEN	160	0.50	119	0.50	170	0.50	19
			TOTAL	**160**		**119**	**TOTALS**	**170**		**19**
T2S/R5E	10	SW 1/4	MIX	80	0.78	92	0.78	132	0.78	15
			WDC	80	0.90	107	0.90	153	0.90	17
			TOTAL	**160**	**TOTAL**	**200**	**TOTALS**	**285**		**32**
T2S/R5E	10	SE 1/4	MIX	160	0.78	185	0.78	264	0.78	30
			TOTAL	**160**		**185**	**TOTALS**	**264**		**30**
T2S/R5E	11	NW 1/4	HOT	40	0.90	54	0.90	77	0.90	9
			IND	120	0.90	161	0.90	230	0.90	26
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	11	NE 1/4	IND	80	0.90	107	0.90	153	0.90	17
			AP	80	0.90	107	0.90	153	0.90	17
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	11	SW 1/4	AP	90	0.90	121	0.90	173	0.90	20
			IND	70	0.90	94	0.90	134	0.90	15
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	11	SE 1/4	AP	90	0.90	121	0.90	173	0.90	20
			IND	70	0.90	94	0.90	134	0.90	15
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	12	NW 1/4	AP	80	0.90	107	0.90	153	0.90	17
			IND	80	0.90	107	0.90	153	0.90	17
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	12	NE 1/4	IND	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**		**215**	**TOTALS**	**307**		**35**

T2S/R5E	12	SW 1/4	AP	10	0.90	13	0.90	19	0.90	2
			IND	150	0.90	201	0.90	288	0.90	33
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	12	SE 1/4	IND	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R6E	7	NW 1/4	SLR	80	0.65	77	0.65	111	0.65	13
			TOTAL	**80**	**TOTAL**	**77**	**TOTALS**	**111**		**13**
T2S/R6E	7	NE 1/4	SLR	50	0.65	48	0.65	69	0.65	8
			TOTAL	**50**	**TOTAL**	**48**	**TOTALS**	**69**		**8**
T2S/R6E	7	SW 1/4	SLR	160	0.65	155	0.65	222	0.65	25
			TOTAL	**160**	**TOTAL**	**155**	**TOTALS**	**222**		**25**
T2S/R6E	7	SE 1/4	SLR	20	0.65	19	0.65	28	0.65	3
			TOTAL	**20**	**TOTAL**	**19**	**TOTALS**	**28**		**3**
T2S/R5E	1	NW 1/4	CRC	**25**	0.90	**34**	0.90	**48**	0.90	**5**
PARCELS			SLR	**55**	0.65	**53**	0.65	**76**	0.65	**9**
			Built	80						
T2S/R5E	1	NE 1/4	CRC	30	0.90	40	0.90	58	0.90	7
			SLR	130	0.65	126	0.65	180	0.65	20
			TOTAL	**160**	**TOTAL**	**166**	**TOTALS**	**237**		**27**
T2S/R5E	1	SW 1/4	BP	100	0.90	134	0.90	192	0.90	22
			TRANS	20	0.90	27	0.90	38	0.90	4
			SLR	40	0.65	39	0.65	55	0.65	6
			TOTAL	**160**	**TOTAL**	**200**	**TOTALS**	**285**		**32**
T2S/R5E	1	SE 1/4	BP	100	0.90	134	0.90	192	0.90	22
			TRANS	20	0.90	27	0.90	38	0.90	4
			SLR	40	0.65	39	0.65	55	0.65	6
			TOTAL	**160**	**TOTAL**	**200**	**TOTALS**	**285**		**32**
T2S/R5E	2	NW 1/4	PF	**70**	0.90	**94**	0.90	**134**	0.90	**15**
PARCELS			SLR	**70**	0.65	**68**	0.65	**97**	0.65	**11**
			Built	20						
T2S/R5E	2	NE 1/4	PF	**5**	0.90	**7**	0.90	**10**	0.90	**1**
PARCELS			Built	35						
			SLR	**95**	0.65	**92**	0.65	**132**	0.65	**15**
			CRC	**25**	0.90	**34**	0.90	**48**	0.90	**5**
T2S/R5E	2	SW 1/4	BP	90	0.90	121	0.90	173	0.90	20
			TRANS	20	0.90	27	0.90	38	0.90	4
			SLR	15	0.65	15	0.65	21	0.65	2
			HOTEL	35	0.90	47	0.90	67	0.90	8
			TOTAL	**160**	**TOTAL**	**209**	**TOTALS**	**299**		**34**
T2S/R5E	2	SE 1/4	BP	130	0.90	174	0.90	249	0.90	28
			TRANS	20	0.90	27	0.90	38	0.90	4
			SLR	10	0.65	10	0.65	14	0.65	2
			TOTAL	**160**	**TOTAL**	**211**	**TOTALS**	**301**		**34**
T2S/R5E	3	NW 1/4	BP	70	0.90	94	0.90	134	0.90	15
			IND	45	0.90	60	0.90	86	0.90	10

			TRANS	20	0.90	27	0.90	38	0.90	4
			CRC	25	0.90	34	0.90	48	0.90	5
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	3	NE 1/4	SLR	**45**	0.65	**44**	0.65	**62**	0.65	**7**
PARCELS			RRL	**80**	0.50	**60**	0.50	**85**	0.50	**10**
			TRANS	**5**	0.90	**7**	0.90	**10**	0.90	**1**
			Built	30						
T2S/R5E	3	SW 1/4	IND	160	0.90	215	0.90	307	0.90	35
			TOTAL	**160**	**TOTAL**	**215**	**TOTALS**	**307**		**35**
T2S/R5E	3	SE 1/4	IND	30	0.90	40	0.90	58	0.90	7
			PF	35	0.90	47	0.90	67	0.90	8
			SLR	75	0.65	73	0.65	104	0.65	12
			TRANS	15	0.90	20	0.90	29	0.90	3
			RRL	5	0.50	4	0.50	5	0.50	1
			TOTAL	**160**	**TOTAL**	**184**	**TOTALS**	**263**		**30**
T2S/R5E	4	NW 1/4	CRC	25	0.90	34	0.90	48	0.90	5
			MDR	55	0.65	53	0.65	76	0.65	9
			TRANS	20	0.90	27	0.90	38	0.90	4
			SLR	60	0.65	58	0.65	83	0.65	9
			TOTAL	**160**	**TOTAL**	**172**	**TOTALS**	**245**		**28**
T2S/R5E	4	NE 1/4	HDR	40	0.80	48	0.80	68	0.80	8
			CRC	40	0.90	54	0.90	77	0.90	9
			TRANS	20	0.90	27	0.90	38	0.90	4
			SLR	60	0.65	58	0.65	83	0.65	9
			TOTAL	**160**	**TOTAL**	**186**	**TOTALS**	**266**		**30**
T2S/R5E	4	SW 1/4	SLR	**140**	0.65	**136**	0.65	**194**	0.65	**22**
PARCELS			Built	20						
T2S/R5E	4	SE 1/4	CRC	**30**	0.90	**40**	0.90	**58**	0.90	**7**
PARCELS			SLR	**70**	0.65	**68**	0.65	**97**	0.65	**11**
			Built	60						
T2S/R5E	5	NW 1/4	BUILT							0
T2S/R5E	5	NE 1/4	Built	100						
PARCELS			TRANS	**20**	0.90	**27**	0.90	**38**	0.90	**4**
			MDR	**25**	0.65	**24**	0.65	**35**	0.65	**4**
			CRC	**15**	0.90	**20**	0.90	**29**	0.90	**3**
T2S/R5E	5	SW 1/4	CRC	**20**	0.90	**27**	0.90	**38**	0.90	**4**
PARCELS			SLR	**30**	0.65	**29**	0.65	**42**	0.65	**5**
			Built	110						
T2S/R5E	5	SE 1/4	Built	80						
PARCELS			SLR	**80**	0.65	**77**	0.65	**111**	0.65	**13**
T2S/R5E	6	NW 1/4	CRC	40	0.90	54	0.90	77	0.90	9
			BP	90	0.90	121	0.90	173	0.90	20
			TRANS	20	0.90	27	0.90	38	0.90	4
			SLR	10	0.65	10	0.65	14	0.65	2
			TOTAL	**160**	**TOTAL**	**211**	**TOTALS**	**301**		**34**

T2S/R5E	6	NE 1/4	SLR	120	0.65	116	0.65	166	0.65	19
			TRANS	20	0.90	27	0.90	38	0.90	4
			BP	20	0.90	27	0.90	38	0.90	4
			TOTAL	160	**TOTAL**	170	**TOTALS**	**243**		**28**
T2S/R5E	6	SW 1/4	IND	**30**	0.90	**40**	0.90	**58**	0.90	**7**
PARCELS			BP	**110**	0.90	**148**	0.90	**211**	0.90	**24**
			Built	20						
T2S/R5E	6	SE 1/4	CRC	**20**	0.90	**27**	0.90	**38**	0.90	**4**
PARCELS			BP	**20**	0.90	**27**	0.90	**38**	0.90	**4**
			SLR	**80**	0.65	**77**	0.65	**111**	0.65	**13**
			Built	40						