AGUA FRIA

WATERCOURSE MASTER PLAN

Final Recommended Plan Report

Prepared for

Flood Control District of Maricopa County

November 2001

Kimley-Horn and Associates, Inc.

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Prepared For:

Flood Control District of Maricopa County
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Acknowledgements

This watercourse master plan was prepared by a group of Maricopa County and Consulting professionals dedicated to improving the way we protect people and property from flood damages while meeting the multiple use needs of a growing population. The commitment to this ideal was demonstrated throughout this project by the Maricopa County Board of Supervisors and by leaders of the Flood Control District of Maricopa County. Finally, the plan for the West Valley Recreation Corridor captures the vision of John F. Long — a man who has spent his entire life trying to improve and promote quality of life for families in the West Valley.

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1. INTRODUCTION

The Flood Control District of Maricopa County (District) is tasked with providing flood protection to the citizens of Maricopa County. During the District's 40-year history, numerous flood control dams and detention basins have been constructed, miles of channel and levee have been built, significant flood hazard areas have been identified, thousands of permits have been reviewed, and significant investment in future plans have been made.

In the past several years, citizens and community leaders have begun to express a modified set of expectations for the District. The message is that the District should not waiver from its mission of flood protection, but that the District should provide flood protection in a manner that minimizes near-term and long-term public expenditures for flood control, while promoting solutions that are consistent with multi-objective visions for river corridors, including developed and open space uses.

In order to meet these expectations, it was necessary for the Flood Control District to embark on an aggressive program of planning for the watersheds and watercourses in Maricopa County. These planning programs are focused on resolving existing problems while developing strategies that reduce the likelihood of creating future problems. To be successful, it is necessary for the District to develop and implement these plans before development occurs.

In the West Valley, many have held a vision of utilizing the Agua Fria and New River corridors as areas where open space could be conserved, and recreation opportunities created. This vision includes the use of trail systems that would link park sites with commerce and neighborhoods. Mr. John F. Long has been a promoter and spokesman for this vision, and has focused individuals, communities, agencies, and civic organizations on an ambitious plan called the West Valley Recreational Corridor.

With increased development pressures in the West Valley, it was necessary to place a high priority on a master plan for the Agua Fria River. The Agua Fria Watercourse Master Plan was envisioned as an opportunity to develop a flood protection strategy before flooding problems became worse. Due to ongoing activities associated with the West Valley Recreation Corridor, it made sense for the District to evaluate how a recreation plan for the river would work in the context of flood protection objectives.

The Agua Fria Watercourse Master Plan takes a comprehensive look at existing and anticipated flooding problems within the watercourse, and develops solutions that meet the long-term flood protection objectives called for by the citizens of Maricopa County.

This Final Recommended Plan Report is one of several technical documents of the Master Plan. The report documents the evaluation of three plans. One plan is a full structural plan, the next being a full non-structural plan, and the final alternative being a plan that blends the best solutions into a joint comprehensive plan.

1.1 Project Background

Like most of Maricopa County's major rivers, the Agua Fria is an ephemeral river that has been dramatically changed in character by the construction of dams and the mining of groundwater. For years, the river has been a divide within the West Valley where occasional floodwaters flow and industrial uses are prevalent. As the West Valley continues to grow and the Agua Fria River Floodplain continues to be encroached, questions have arisen on the sustainability of its flood control function and on its recreational and recharge opportunities.

The Watercourse Master Planning Statutes of the State of Arizona provide the District and communities with a specific authority to develop a master plan that will allow for the long-term management of the hydraulic and sediment system. In addition, the statute authorizes the District to consider groundwater recharge opportunities and allow for the adoption of a specific structural and/or nonstructural management strategy that defines the look and feel of the watercourse for the future. As a result, the District has retained Kimley-Horn and Associates, Inc., to develop a flood control plan that includes evaluation of recreation, riparian restoration, transportation, mining, development, and recharge opportunities, and analyze their impacts on the flood control function of the Agua Fria River.

The primary purpose of the Agua Fria Watercourse Master Plan (Watercourse Master Plan) is to establish a long-term plan for the management of the river. The specific goals of the master plan are flood control and public safety; including existing and proposed developed uses, conservation of habitat; and incorporation of multi-use recreational facilities. The Watercourse Master Plan will identify existing and potential flooding and erosion problems along the Agua Fria River and propose management strategies for reducing the threat to public safety. At the same time, the Watercourse Master Plan will identify opportunities for multiple uses of the river corridor, such as recreation and habitat for wildlife. While not able to directly fund recreational facilities or habitat improvements, the District is interested in identifying and understanding multiple uses of the watercourse that are compatible with the fundamental principles of flood control.

This Alternative Analysis Report is one of many components that make up the Watercourse Master Plan. The Watercourse Master Plan is a series of technical and planning documents that identify the existing conditions within the Agua Fria watershed downstream from New Waddell Dam. The Watercourse Master Plan is being prepared for the Flood Control District of Maricopa County (the District). The mandate of the District is to protect the public from flooding and flooding related erosion hazards. To that end, the District is limited to funding flood and erosion control projects.

1.2 Agua Fria River Watershed

The Agua Fria River is over 100 miles long, extending from central Arizona near the Town of Prescott to the confluence of the Gila River near the City of Avondale. The river's location is shown in Figure 1.2-1 on a State Map. The Agua Fria River watershed is approximately 2,250 square miles in size. The upper reaches of the watershed are located northeast of Prescott on the north slopes of the Granite Dells at an elevation of 5,200 feet. Accepting runoff from the Bradshaw Mountains, the river winds approximately 65 miles to the south/southeast through high desert rangeland. The upper river is perennial and is fed primarily by winter storms. The upper reach of the river discharges to Lake Pleasant, a reservoir created by the New Waddell Dam. The Agua Fria River downstream of the dam is ephemeral. Significant flows are a result of runoff from localized storms or localized seepage just downstream of the dam.

Flooding on the Agua Fria River downstream of the dam is generally the result of runoff collecting in the river downstream of the dam. However, in very large flood events a significant discharge from the dam is possible.

The Watercourse Master Plan encompasses the 32-mile reach from the Gila River to the New Waddell Dam. A Vicinity Map showing the study reach is included as Figure 1.2-2.

Between the New Waddell Dam and the Gila River, the Agua Fria River flows through unincorporated Maricopa County and the Cities and Towns of Peoria, Glendale, Surprise, El Mirage, Youngtown, Phoenix, and Avondale. Land

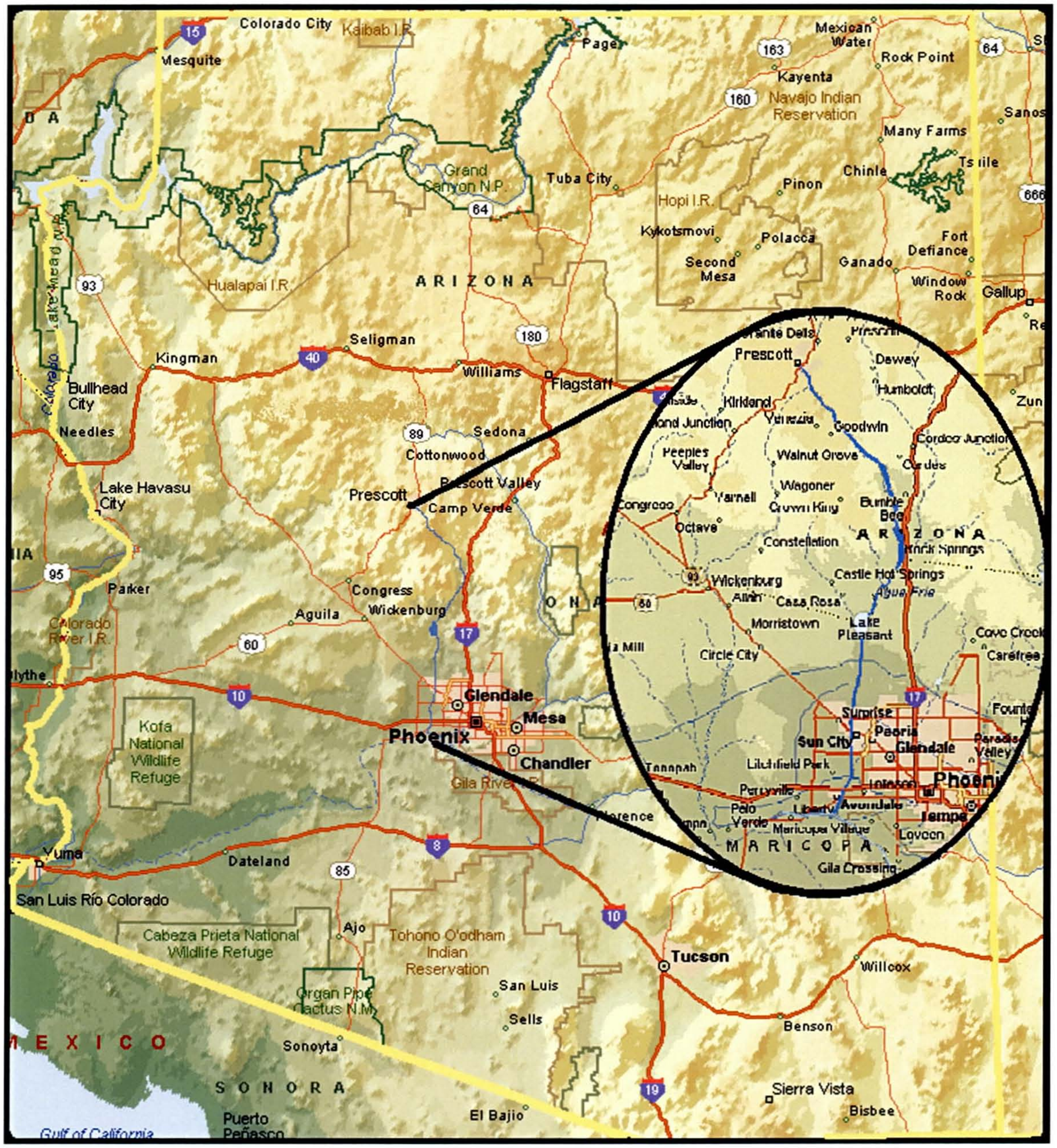

FIGURE 1.2-1
State Map
Agua Fria River

WEST VALLEY RECREATION CORRIDOR
AGUA FRIA WATERCOURSE MASTER PLAN

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FIGURE 1.2-2
Vicinity Map
Agua Fria River

WEST VALLEY RECREATION CORRIDOR
AGUA FRIA WATERCOURSE MASTER PLAN

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uses along the river are varied and include undeveloped desert canyons, residential and commercial properties, sand and gravel mines, and farms.

1.3 New Waddell Dam

The Waddell Dam was constructed in the Agua Fria River in 1927 for water storage purposes. Runoff from the upper two-thirds of the Agua Fria River watershed and water from the Central Arizona Project (CAP) Canal are stored behind the dam in Lake Pleasant. In 1991, the New Waddell Dam was constructed and replaces the Waddell Dam. The new dam was constructed just downstream of the old dam and cuts off the upper 1,459 square miles of the watershed. Although the dam was not constructed for the purposes of flood control, it has excess capacity and the U.S. Army Corps of Engineers (Corps) determined that for a 100-year flood, the dam provides a greater degree of downstream flood protection.

1.4 Significance of Agua Fria Corridor

The Agua Fria River has helped to shape the West Valley. The abundance of archaeological evidence suggests that the river provided for both ancient and historic Native Americans. By redirecting the river's water, the West Valley has enjoyed agricultural production on a commercial scale for 100 years. By mining the river for its sand and gravel, the West Valley has enjoyed home, road, and community building to support a service and manufacturing economy for 50 years.

The river is an historic north/south corridor through the West Valley, but is slowly losing its ability to connect the communities located along its banks. While the Agua Fria has provided much needed resources, the visual characteristics of a river – water, distinct banks, wildlife, riparian habitat, shade, etc. – have all been modified or sacrificed. Consequently, the general public does not perceive the river as a "river," nor can it appreciate the roles the river might play in their lives. Cut off from the source of the river in the upstream Bradshaw Mountains, the public remains largely severed from knowledge about and connection to the river. While crossing it daily, the public largely ignores the river because the river lacks any visual clues to prompt an understanding of how it works. Nevertheless, the river provides the West Valley with its most basic needs: water and shelter.

Although it is normally dry, the river is one of two primary channels for storm water conveyance through the West Valley. The Agua Fria River and the New River drain runoff from the West Valley to the Gila River. The peak flow from the 100-year regulatory storm is 50,900 cubic feet per second (cfs) between the Agua Fria River/New River and the Gila River. The normally dry floodplain is expected to convey a flood wave over 1,000 feet across and approximately 8 feet deep. Given the appearance of the river and the fact that it is normally dry, the public tends to disregard the potential destructive force of the river. Present day development continues to encroach the Agua Fria floodplain.

The master planning process has identified potential uses of the river that are compatible with its primary function of floodwater conveyance. The Watercourse Master Plan presents strategies that will allow for continued uses of the river in a manner that will not lead to extensive public flood control or disaster clean up costs.

1.5 *Purpose of Alternative Analysis*

1.5.1 *Resolve Existing Flooding and Erosion Problems*

The mandate of the District is to protect the public from flooding and erosion hazards. The Alternative Analysis Report documents the investigation of flooding and erosion hazards along the river, examines alternative solutions to reduce the hazards, and provides preliminary recommendations for management of the watercourse. The alternatives considered range from traditional structural flood control alternatives to non-structural flood control through management and policy implementation. These alternatives are based upon system hydrology, hydraulics, lateral migration potentials, and sediment trends of the 32-mile corridor of the Agua Fria River.

1.5:2 *Identify and Incorporate Multiple Use Opportunities*

A secondary objective of the project is to provide opportunities for multiple uses within the Agua Fria Corridor. Traditional single purpose flood control projects generally have ignored other uses within the corridor. The Watercourse Master Plan will identify feasible opportunities for recreational areas, trail systems, habitat enhancement areas, and groundwater recharge throughout the watercourse, in addition to developing strategies that provide for developed uses such as sand and gravel mining using strategies that lead to no adverse impact. The Alternative Analysis Report identifies the overall hydraulic sensitivity of the regulatory floodplain to the addition of trails and vegetation. With the exception of a heavily vegetated area near the I-10 Outlet Channel, site specific multi-use/recreational components of the Watercourse Master Plan are not considered. Site specific hydraulic analysis of proposed recreational features is examined in depth to assure compatibility with existing regulations and the goals of the Watercourse Master Plan.

1.5.3 *Evaluate River Stability*

River channels and floodplains are built and maintained by erosion and deposition of sediments, and are by nature dynamic. Over time, however, channel stability in a given reach occurs from a balance among stream flow, channel form, inflow of sediment from the watershed, and loss of sediment to downstream reaches. This form of stability is called dynamic equilibrium.

The Watercourse Master Plan investigates the dynamic equilibrium in each reach of the Agua Fria River. The analysis examines the potential for changes in channel bed slope, bank erosion, and lateral migration on a reach-by-reach basis. The man-made and natural factors contributing to these processes are considered in the report documentation.

1.6 *Alternatives Considered*

Since the 1920s, the United States has focused almost exclusively on the use of structural flood control solutions. Likewise, the District has historically focused predominantly on structural projects. Examples of these projects include numerous flood control dams, channels, and diversions constructed throughout Maricopa County.

The watersheds of Maricopa County have extensive potential for flash floods and broad sheet flows. Consequently, the District has worked to control watershed-based flooding that can strike at a moment's notice and impact thousands of acres of land and tens of thousands of people. These projects are costly both in the initial investment and in long-term maintenance costs, yet due to the extensive area of flooding they provide significant public benefit.

In contrast, and perhaps due to the abundance of developable land outside the floodplain, there has been less of a need for publicly funded flood control within the floodplains. The rivers of Maricopa County are considerably more confined with more commonly understood flood hazards. However, the District is concerned that, if left unmanaged, the current and future uses in and along the river may be vulnerable to flood damage, and that will lead to significant expenditure of public funds. Land that is isolated from the historic floodplain and developed is generally much more confined, has significantly lower public benefits related to development, and tends to sustain much higher damages if the flood protection measures fail in an extreme event.

Further, the District is aware that the extensive use of structural solutions within the floodplain can lead to adverse impacts on other properties.

Due to these conditions, the District is interested in expanding its "tool kit" to include additional tools, primarily non-structural flood control solutions. Non-structural solutions are those that are focused on three primary objectives. These objectives include:

- Promote uses that are compatible with floodplains
- Regulate construction practices in and around floodplains
- Take steps to minimize flooding damages primarily related to flood-proofing and emergency response activities

1.6.1 *Structural Alternative*

As previously stated, structural flood control alternatives are the traditional approach to flood control. Typical structural alternatives include engineered levees, fill, bank protection, flood control dams, channelization, and grade control structures. Their purpose is to protect existing and future residents from a specified flood event (generally the 100-year flood), and the possible damages associated with potential lateral migration of the river.

Structural means of flood control are popular for resolving flooding or erosion problems in site-specific locations. In some cases, a structure may be the only reasonable means to protect existing structures or other infrastructure.

1.6.2 *Non-structural Alternative*

Non-structural flood control alternatives go beyond traditional flood control tools to protect existing and future residents from the 100-year flood event and the potential lateral migration of the river. This approach defines the land area or watercourse necessary to allow for natural river dynamics to occur over time. The overall strategy of non-structural flood control is to reduce the number of existing structures within this Lateral Migration Erosion Hazard Zone and limit future structural encroachment within this zone. This non-encroachment strategy is implemented through zoning ordinances, land use planning, property acquisition, vegetation management, and drainage management.

Non-structural flood control has several overall advantages: the river is left in a more natural state, up-front costs and maintenance costs are generally low, and the visual/recreational characteristics of the river are left intact or enhanced.

1.6.3 *Recommended Alternative*

This approach allows for the use of both structural and non-structural alternatives. The Agua Fria River has been divided into one to two-mile subreaches with similar characteristics. A particular approach may work well in one river subreach but not in another. Using a subreach-by-subreach approach allows for the evaluation and selection of flood control alternatives in similar areas. Specific areas of existing flooding or erosion hazards were identified in the development of the Alternative Analysis Report. In some cases, a traditional structural solution is required to protect existing structures. In other areas, limiting encroachment of the river by non-structural methods is a more desirable mechanism for protecting the public. The flood/erosion control solutions considered in the Alternative Analysis Report were carried forward for further analysis and refinement in this Final Recommended Plan Report.

2. EXISTING CONDITIONS

2.1 River Reaches

2.1.1 Introduction

For planning purposes, the river is divided into three general reaches. These reaches are further divided into shorter subreaches based on uniformity of land use and uniformity of visual characteristics. Most subreaches are one to two miles long.

Lower Reach - The Confluence of New River to the Confluence of the Gila River

From the New River confluence to Lower Buckeye Road, the Agua Fria River has been extensively channelized. The river is contained by levees from approximately Indian School Road to below MC 85. The levees were designed and constructed by the Corps to contain the standard project flood (SPF). This reach contains several grade control structures. With the exception of some utility crossings, bridges, and power pole bases, there is no development within the levees. Numerous agricultural fields are located within the floodplain downstream of MC 85.

Middle Reach - Bell Road to the Confluence of the New River

Numerous sand and gravel mines within the floodplain and floodway characterize this reach. Residential development is common up to the boundary of the floodplain. New residential subdivisions are planned or under construction within the flood fringe. This reach is constricted and well incised.

Upper Reach - New Waddell Dam to Bell Road

At this time, the upper reach is generally undeveloped desert from the dam to Jomax Road. The area from Jomax Road to Bell Road has several large sand and gravel mines within the floodway and flood fringe. Residential development has occurred in the lower portion of this reach, primarily on the east overbank area. Some of the residential developments have encroached the historic floodplain. Several other residential developments on both sides of the river are in the planning stages.

2.1.2 *Confluence of Gila River to Confluence of New River*

Cultural/Historical

John F. Long was a World War II veteran who started Maryvale, a community that would provide homes for young families and a place for their recreation, employment, and shopping in one given area. He purchased 2,000 acres (in an area near what is now Camelback Road and Grand Avenue) from farmers and created a low cost family housing area at a rapid rate. At one point, Maryvale houses went up at a rate of 20 a day and sold at a rate of 100 a week. His Maryvale subdivision planning, construction methods, tools, and mass production techniques have been adopted by builders and engineers to house people all over the world. With Ronald Reagan and Buster Keaton promoting the homes, John F. Long arguably did more than any other builder to make the American dream available.

2.1.3 *Confluence of Gila River to Broadway Road*

Land Use

Portions of this subreach are located within the City of Goodyear, the City of Avondale, and unincorporated Maricopa County. Land use along the Agua Fria River is entirely agricultural.

Visual Characteristics

The confluence of the Agua Fria River and Gila River represents one of the most scenic areas along the Agua Fria. A portion of the channel is reserved as a retention area. Lush hydric riparian wetlands with reeds, willows, and cattail transition into mesic riparian areas with mesquite bosques and cottonwoods. A large amount of tamarisk is also noted. Vast areas within the floodplain are agricultural areas. The Estrella Mountains form a spectacular background.

Flooding

Both the Agua Fria and the Gila Rivers affect the confluence region. The limits of the Gila River floodplain extend north to the vicinity of Broadway Road. Therefore, the floodplain in this subreach may be inundated by flows from either river. Citizens in this reach are concerned about backwater flooding resulting from the Agua Fria draining into the Gila. Additionally, there are two new flood control channels being proposed that will bring drainage from the east into the Agua Fria River.

Vegetation and Habitat

The confluence area includes significant vegetation, primarily resulting from irrigation tailwater and a generally elevated groundwater table. The vegetation provides habitat for birds and other small mammals. The adjoining land use is predominantly agricultural, most of which is within the Agua Fria or Gila floodplain. Citizens in this reach are concerned about backwater flooding resulting from the Agua Fria draining into the Gila. Additionally, there are two new flood control channels being proposed that will bring drainage from the east into the Agua Fria River.

Groundwater Recharge

Three and one-half miles west of the lower Agua Fria lies the City of Goodyear Soil Aquifer Treatment (SAT) facility. This project is permitted to recharge treated effluent up to 3,360 acre-feet per year for 20 years through basins.

Sand and Gravel

There is one sand and gravel operation within this subreach of the Agua Fria River. This active operation at Broadway Road on the west side of the river is within the regulatory floodway and flood fringe.

2.1.3.1 Broadway Road to MC 85

Land Use

This subreach is located within the City of Avondale and unincorporated Maricopa County. Land use between Broadway and Lower Buckeye Roads is mostly vacant except for some nearby agricultural fields. North of Broadway Road, the river is leveed on the west side. Outside the west levee there are residential developments. On the east side, land use is a mixture of vacant, agricultural, residential, industrial, and commercial.

Flooding

The west side of the river is protected from flooding by the levee. On the east side, development is outside the 100-year floodplain. Lower Buckeye Road is an at-grade crossing and has experienced flooding during heavy storms.

Sand and Gravel

There are no active sand and gravel operations within this reach of the Agua Fria River.

2.1.3.2 MC 85 to I-10

Land Use

This subreach is almost entirely within the City of Avondale. A small portion of the southern end is in unincorporated Maricopa County. Levees extend along the entire subreach on both sides. Land use outside the levees between MC 85 and I-10 is primarily agricultural or vacant. The Southern Pacific Railroad (SPRR) is adjacent to the north side of MC 85/Buckeye Road.

Coldwater Park is located north of MC 85 outside the west levee.

Visual Characteristics

The river has a floodplain area with structured levees along both banks. Large electric pylons on large concrete bases run along the corridor as a dominant feature. Also dominant is the railroad bridge. The floodplain is sparsely vegetated with ephemeral type species. Areas along the riverbed with localized surface run off are more vegetated. Coldwater Park abuts the river corridor and provides relief from the stark character of the levees.

Flooding

The Litchfield detention basins drain from the west to the Agua Fria in the vicinity of Van Buren Street. However, these basins are oversized and are not expected to impact flooding in the Agua Fria River.

The I-10 Outfall Channel drains to the Agua Fria River on the east side. No historic flooding problems have been recorded at these locations, although this area could be subject to flooding from large inflows during heavy storms. Flooding would be limited to within the levees and backwater effects within the I-10 Outfall Channel area.

Sand and Gravel

There are no active sand and gravel operations within this reach of the Agua Fria River.

2.1.3.3 I-10 to Indian School Road

Land Use

This subreach is located within the City of Avondale and unincorporated Maricopa County. It is leveed on both sides of the river. Outside the levees, land use between I-10 and Thomas Road has heavy residential development on the west side and a mix of vacant, agricultural, and residential/commercial development on the east side. Between Thomas and Indian School Roads, there is heavy industrial use (sand and gravel operations) adjacent to the levees. Further east are fully developed residential areas and open space.

Visual Characteristics

This portion of the river is channelized with structural levees on either side. The floodplain is flat and nondescript. Ephemeral channel vegetation is sparse and scattered. An outflow channel leads into the Agua Fria, south of the I-10 freeway. Portions of the channel subject to this flow are well vegetated and show a riparian character. New construction is seen on the west bank of the river.

Flooding

Both sides of the river are protected from flooding by the levees.

Groundwater Recharge

The City of Avondale recharge facility is located north of McDowell Road, just outside the east levee. The facility is permitted to recharge up to 10,000 acre-feet per year for 20 years. This facility is recharging Avondale's allocation of CAP and SRP waters using infiltration basins. The water is delivered though SRP's Grand Canal and purified in the constructed wetlands at the Crystal Gardens subdivision.

Sand and Gravel

There are no active sand and gravel operations within the southern portion of this reach; however, the northern portion is heavily mined. There are two large sand and gravel operations extending from Thomas Road to Indian School Road. These active operations, one on each side of the river, are protected by levees and are outside the 100-year floodplain.

2.1.3.4 Indian School Road to Confluence of New River

Land Use

This subreach is located within the City of Avondale, City of Phoenix, and unincorporated Maricopa County. The west levee terminates north of Indian School Road. Sand and gravel operations are located on the west side of the river outside the 100-year floodplain.

On the east side, the levee extends further north and connects to the Camelback Ranch levee. Outside the east levee, land use includes vacant land, agricultural, open space, and residential development, including the planned Camelback Ranch and the Villa de Paz developments. Additionally, there are sand and gravel operations and agricultural uses on the east side.

Visual Characteristics

The confluence of Agua Fria River and the New River at Camelback Road includes a vast floodplain with scant vegetation. There is indication of heavy ATV use in this area.

Flooding

This subreach is subject to flooding from the New River. In addition, runoff enters the Agua Fria River from Colter Channel just north of Camelback Road. The east side is protected along the entire subreach by the levees; the west side has no levee north of Indian School Road.

Sand and Gravel

This subreach of the Agua Fria River is heavily mined. The active sand and gravel operation, which extends from Indian School Road to Camelback Road on the west side of the river, is outside the 100-year floodplain. However, there are mining pits extending from Indian School Road to Camelback Road within the regulatory floodway. These pits appear to be inactive, but may now be a part of the operation to the west. Additionally, there is a mining pit on the east side of the river just north of Indian School Road that is outside the 100-year floodplain.

There are three active sand and gravel operations at the New River confluence. These operations extend from Camelback Road to Bethany Home Road on the west side of the river and are within the flood fringe.

2.1.4 *Confluence of New River to Bell Road*

Cultural/Historical

As a consequence of the Homestead Act (1862) and the Desert Land Act (1877), 640-acre homesteads were the norm in the West Valley in the early 20th century. Taking advantage of rich alluvial soils, level land, and sophisticated technology to deal with desert conditions, West Valley farm productivity rivaled California in citrus, fruits, and nuts for eastern markets. The desert's unique conditions for cotton production enticed large corporate farmers during World War I when usual supply sources were cut off. Large-scale corporate farming gave rise to the need for farm laborers. Farm labor communities sprinkled throughout the West Valley reflect that demand.

El Mirage, located on the west bank of the Agua Fria River just south of what is now Bell Road, began as a Mexican migrant labor camp. The 1995 population of 5,335 was still three-quarters Hispanic and their heritage is reflected in the town's celebrations. Founders Day is celebrated in March with a parade, fiesta, and carnival. Cinco de Mayo and Fiestas Patrias are both feted.

Before a bumper crop of houses sprouted in Sun City, the area had produced two significant crops of note. In 1908, R.P. Davie began experimental sugar beet production in Marinette. When the soil was found to be inadequate to sustain production, the land was sold to the Southwest Cotton Company for a million dollars. The land was then sold in 1936 to the J.G. Boswell Cotton Company. In 1956, Boswell went into partnership with Del Webb and then sold the land to the Del Webb Corporation. It was the Del Webb Corporation that took a gamble in experimentation with the concept of financing retirement and age segregation. Sun City was built on the retirement community model created by Youngtown, Arizona, and became the first fully master-planned, age-segregated community.

2.1.4.1 Confluence of New River to Glendale Avenue

Land Use

This subreach is located within the City of Glendale, a portion of Luke Air Force Base, and unincorporated Maricopa County. Land uses in this subreach consist of vacant land and sand and gravel operations.

Flooding

Because of lack of development, current flooding concerns in this subreach are limited to localized problems within the sand and gravel operations.

Groundwater Recharge

The City of Glendale West Artificial Recharge Facility is located just north of the confluence with New River, on the east bank. This pilot project was recently constructed and will recharge up to 10,000 acre-feet over a two-year period. This facility will utilize basins, trenches, vadose zone wells, and injection wells to recharge treated effluent. (Vadose zone wells deliver water to the unsaturated interval between the land surface and the water table. Injection wells deliver water directly to an aquifer, below the water table.)

Sand and Gravel

There is one sand and gravel operation just north of Bethany Home Road on the east side of the river. This active operation is within the flood fringe.

2.1.4.2 Glendale Avenue to Olive Avenue

Land Use

This subreach is located within the City of Glendale, the City of El Mirage, and unincorporated Maricopa County. Land use in this subreach is industrial. There are active sand and gravel operations along the entire subreach. Additionally, the City of Glendale's municipal airport, landfill, recycling facility, and wastewater treatment plant are in the vicinity.

Visual Characteristics

A lush riparian area is created along the western edge of the river channel where water flows in from the Airline Canal and Dysart Drain further north. A high occurrence of desert broom and tamarisk is noted along the drainage area. Sand and gravel operations exist on the east floodplain. Apart from the drainage-ways, the river channel is vegetated with scattered ephemeral channel type vegetation. Indications of heavy ATV use and equestrian use are observed.

Flooding

Northern Avenue is an at-grade crossing and is subject to flooding during heavy storms. Because of lack of development, flooding in the remainder of this subreach is limited to localized problems within the sand and gravel operations.

Sand and Gravel

This subreach of the Aguá Fria River is heavily mined. There is a large active operation extending from Glendale Avenue to Northern Avenue that is within the regulatory floodway and flood fringe. There are two active operations midway between Northern Avenue and Olive Avenue, one on each side of the river. The operation on the west side is outside the 100-year floodplain, while the operation on the east side is within the flood fringe.

2.1.4.3 Olive Avenue to Cactus Road

Land Use

This subreach is located within the City of El Mirage, the Town of Youngtown, and unincorporated Maricopa County. Land use in this subreach is mostly residential and vacant. The Pueblo El Mirage Country Club and golf course is located between Peoria Avenue and Cactus Road, as well as the El Mirage Wastewater Treatment Plant.

Visual Characteristics

A residential community (Youngtown) adjoins the river very closely, protected by a steep embankment. The community has been designed in such a way that its recreation areas adjoin the river. However certain design elements like roads, fences, and non-native planting materials deviate from the river's natural landscape character. The river corridor has been used as a continuous uninterrupted space for unattractive power transmission lines that dominate the landscape.

Sand and Gravel

There are no active sand and gravel operations within this subreach of the Agua Fria River.

2.1.4.4 Cactus Road to Grand Avenue

Land Use

This subreach is located within the City of El Mirage on the west side and the Town of Youngtown on the east side. Land use in this subreach is vacant, residential, and industrial. Residential developments, existing and planned, line both sides of the river. The El Mirage Landfill is located on the west side, south of Grand Avenue.

Visual Characteristics

Visual characteristics are similar to those of the previous subreach. Residential areas in Youngtown include adjacent recreation that conflicts with the natural characteristics of the river. Power transmission lines continue to dominate the landscape.

Flooding

As noted below, the El Mirage Landfill has experienced flooding problems from the Agua Fria River in the past, including losing a portion of the landfill during heavy flooding.

El Mirage Landfill

This is easily the most problematic subreach within the study area. The parallel bridges at Grand Avenue and the railroad provide a relatively narrow opening. Flow is constricted through the opening, causing velocity to increase. This leads to increased potential for erosion of the channel bed and the riverbanks downstream of the bridges. The west bank is formed by a closed (not currently in operation) landfill. The landfill embankment rises approximately 30 feet above the channel bed at a steep slope. The landfill embankment is protected to a certain extent from stream erosion by dumped concrete riprap.

Little factual information is known about the landfill. Portions of the landfill washed away during a 1980 storm event. The existing riprap was added after the storm. It is not possible to determine at this time if the riprap is adequate to protect the landfill in a 100-year storm. The adequacy of the riprap will ultimately be dependent on the depth to which it is buried below the channel bed. Definitive records of the riprap construction were not located during a record search. The true footprint of the landfill is also indeterminate. It is possible that portions of the landfill are buried within the main channel. It may be necessary to perform field investigations, such as drilling, to determine the extent of the landfill and the adequacy of the erosion protection.

Sand and Gravel

There are no active sand and gravel operations within this subreach of the Agua Fria River.

2.1.4.5 Grand Avenue to Bell Road

Land Use

This subreach is located within the City of El Mirage, the Town of Youngtown, the City of Surprise, and unincorporated Maricopa County. Sand and gravel mining is the predominant land use in this subreach, heavy residential development, including Sun City, flanks the mining operations.

Visual Characteristics

The west bank is dominated by the El Mirage landfill. The landfill embankment rises approximately 30 feet above the riverbed. It is armored with what consists of broken pieces of concrete rubble. The rubble is easily identified as pieces of pipe, concrete slabs, sections of curbing, and small structures. Power transmission lines continue to dot the landscape.

Flooding

The focus of flooding concerns in this subreach is the constriction of the river at the Grand Avenue and parallel Santa Fe Railroad (SFRR). It is believed that breakout of flow occurs on the west side during the 100-year flood. On the east side, the Sun City Drain conveys runoff from Sun City west of Del Webb Boulevard to the Agua Fria River along the north side of Grand Avenue.

On the west side, Lizard Acres Wash drains to the Agua Fria River north of Greenway Road.

Groundwater Recharge

The City of Surprise's South WWTP lies two miles west of the Agua Fria River between the alignments of Greenway Road and Thunderbird Road. This facility is permitted to recharge up to 3,584 acre-feet per year for 20 years of treated effluent through constructed basins.

Sand and Gravel

This subreach of the Agua Fria River is heavily mined. There is a very large sand and gravel operation extending from Grand Avenue to Bell Road. This active operation, which spans both sides of the river, is within the regulatory floodway and flood fringe.

2.1.5 *Bell Road to New Waddell Dam*

Cultural / Historical

Storing, diverting, channeling, and delivering water to where it is needed has been the major story of West Valley growth. Small amounts of water were diverted from the Agua Fria River for mining operations in the early 1890s in a variety of creek districts (Humbug, Peck, Walker, and Big Bug). The first major plan to use Agua Fria water for irrigated agriculture was hatched in 1888 by the Agua Fria Water and Land Company. Plans called for a series of dams and canals to irrigate 100,000 acres of land. The Agua Fria

Construction Company, headed by William Beardsley, contracted to build the masonry water storage dam and canal.

New Waddell Dam is the primary artifact reflecting the history of watering the West Valley. Beardsley died in 1925, leaving Carl Pleasant as head of the project. Six hundred laborers and their families (perhaps a thousand people) lived in an area nearby called Camp Pleasant. They completed the diversion dam, excavated the rest of the Beardsley Canal, and built a storage dam. The dam was eventually called Waddell Dam to honor Donald Waddell, the dam's financial advisor. Upon completion, Waddell Dam was the largest concrete, multiple arch dam in the world. It functioned for the West Valley for 50 years. When the New Waddell Dam was constructed, the old dam was submerged. New Waddell Dam, with a clay core and layers of sand, gravel, and rock, also added hydroelectric power generation and enlarged the recreational aspects of the lake.

The 33-mile Beardsley Canal required a variety of engineering solutions to carry the water through different terrain, best exemplified by the bridged flume used to carry water across the Agua Fria River. Repairs and maintenance have been conducted since 1935, so only the location remains historic.

2.1.5.1 Bell Road to Beardsley Road

Land Use

This subreach is located within unincorporated Maricopa County, but is flanked on the west side by Sun City West and on the east side by the City of Surprise. Land use in this subreach is residential and includes the Coyote Lakes residential golf course community along the entire east side.

Visual Characteristics

This is an urbanized area. Residential communities are located adjacent to the river. Flood protection embankments are fairly high along the west bank, south of the Bell Road Bridge. The Coyote Lakes subdivision is protected by a levee on the east bank, north of the bridge. The floodplain is very wide and indistinctive with typical xeric/ephemeral type vegetation scattered throughout.

Flooding

On the east side of the river, Coyote Lakes has encroached within the floodplain. It is protected from flooding by a levee, and there is vacant land within the remainder of the flood fringe. On the west side, the McMicken Dam Outfall Channel drains to the river south of Beardsley Road.

Sand and Gravel

There are no sand and gravel operations within this subreach of the Agua Fria River with the exception of one pit located just below Beardsley Road on the east side of the river. This pit, which belongs to the operation located just north of Beardsley Road, is outside the 100-year floodplain.

2.1.5.2 Beardsley Road to Pinnacle Peak Road

Land Use

This subreach is located within unincorporated Maricopa County. The City of Peoria boundary is about one-half mile to the east. Land use is nearly fully developed residential within the Peoria city limits on the east side. The Citizens' Utilities Wastewater Treatment Plant is located near Beardsley Road. On the west side, there are isolated residential developments in the southern portion and vacant land in the northern portion. Within the river, there are large sand and gravel mining operations.

Visual Characteristics

The floodplain is flat and broad with heavy sand and gravel mining activity on the north and south sides. Residential areas adjoin the corridor at a distance. Suburban areas lie towards the east and more rural areas to the west of the river. Typical ephemeral channel vegetation includes snakeweed and creosote.

Flooding

There is an at-grade crossing of the river at Rose Garden Lane. This road is flooded during heavy storms and isolates residents on the west side of the river.

Groundwater Recharge

Two recharge facilities are located on the east side of the river just north of Beardsley Road: the Del Webb Sun City West and City of Peoria Beardsley recharge facilities. Both facilities are outside the Agua Fria River floodplain.

These projects have been permitted for 20 years and recharge effluent through constructed basins. Sun City West and the City of Peoria recharge facilities are permitted to recharge up to 3,042 and 2,470 acre-feet per year, respectively.

Sand and Gravel

The southern portion of this subreach is heavily mined. There is a sand and gravel operation between Beardsley Road and Rose Garden Lane spanning both sides of the river. This active operation is within the regulatory floodway and flood fringe.

There is an operation on the west side of the river extending from Rose Garden Lane to north of Deer Valley Road. This active operation is outside the 100-year floodway. To the west of this operation, there is an active mining operation across the Deer Valley Road Alignment on the west side of the river. This operation is within the regulatory floodway and flood fringe.

2.1.5.3 Pinnacle Peak Road to Jomax Road

Land Use

This subreach is located within unincorporated Maricopa County. The City of Peoria boundary is more than a mile to the east. There is a large sand and gravel mine north of Pinnacle Peak Road on the east side. The area is predominantly undeveloped except for isolated residential areas south of Jomax Road.

Visual Characteristics

The river channel is incised, evident from the eroded banks seen on either side. The riverbed is rocky and is well vegetated by riparian species. Scattered clumps of palo verde and mesquite trees grow with creosote, snakeweed, and desert broom. Saguaros are seen to grow in the higher areas. A wide variety of wildlife is observed. A sand and gravel mine is located south of Jomax Road. Visual variety created by the river alignment, the vegetation and textures make this a very interesting stretch of the river.

Flooding

Twin Buttes Wash drains to the Agua Fria River on the west side, just south of Happy Valley Road. Immediately south of the Twin Buttes Wash confluence, Hatfield Road crosses the river at grade. This road crossing could be impacted by flooding of the Agua Fria or Twin Buttes Wash.

Caterpillar Tanks Wash drains to the Agua Fria River south of Jomax Road.

Sand and Gravel

There is one sand and gravel operation in the southern portion of this subreach. This active operation is north of Pinnacle Peak Road on the east side of the river and is within the flood fringe.

2.1.5.4 Jomax Road to Dixileta Drive Alignment

Land Use

This subreach is located within unincorporated Maricopa County and the City of Peoria. The area is generally undeveloped, with isolated residential housing near Jomax Road and agricultural uses on the east side south of the Dixileta Drive Alignment. There are two sand and gravel mining operations in this subreach.

The Marinette Heading Canal is located on the east side at Jomax Road. Additionally, Calderwood Butte, a highly disturbed rock outcropping with Native American ruins is located north of Jomax Road on the east side of the river.

Visual Characteristics

Wide sandy expanses of the floodplain adjacent to rock outcroppings dominate the immediate vicinity of Calderwood Butte. The rock outcropping is fairly unique in terms of its color and the manner in which it borders the floodplain. Such outcroppings are rare along the river. However, the current usage of the area includes ATV users and an unofficial target range. The target range creates a menace in terms of safety and trash accumulation. Remains of the historic Marinette Heading Canal can be seen at the base of the butte. Dumped concrete rubble was used to reinforce the outer bank of the canal.

Flooding

Jomax Road is an at-grade crossing and would be inundated during a major storm. Several washes drain to the river on the east side within this subreach.

Groundwater Recharge

The Central Arizona Project (CAP) has begun construction of a groundwater recharge facility in the upper reach of the Agua Fria. It is a permitted facility, with managed and constructed components known as the Agua Fria Recharge Project (AFRP). The AFRP will be capable of recharging up to 100,000 acre-feet per year of CAP water for 20 years.

CAP delivers water to the facility through the blow-off structure in the CAP siphon under the Agua Fria River. The water from the siphon flows through the managed portion of this facility for four miles to Jomax Road. The volume of water discharged from the siphon is metered and monitored as it flows downstream and infiltrates into the riverbed. At the southern termination of this managed reach, basins are being built to capture and recharge the water that has not infiltrated or been lost to evapotranspiration through the managed reach. These basins are to be developed within the Agua Fria floodplain, but outside the main flow channel. The facility is anticipated to store excess CAP water for future recovery and use.

Sand and Gravel

There are two sand and gravel operations near the Pinnacle Vista Drive Alignment on the west side of the river. The operation to the south is outside the 100-year floodplain. The active operation to the north is encroaching upon the flood fringe. There is an active operation at the Dixileta Drive Alignment on the west side of the river that is outside the 100-year floodplain.

2.1.5.5 Dixileta Drive Alignment to the CAP Canal

Land Use

This subreach is located within unincorporated Maricopa County and the City of Peoria. The area is undeveloped with some agriculture on the east side north of the Dixileta Drive Alignment. The Beardsley Canal crosses the river just south of the CAP Canal crossing.

Visual Characteristics

The most dominant feature in the vicinity of Jomax Road is a citrus grove. The continuous rows of bright green foliage create an interesting foreground for the mountainous backdrop. The transition to the upland areas is evident from the higher occurrence of rock outcroppings and Saguaros. Beardsley Canal is visible in the foreground as a bench. Metal irrigation pipes greatly contrast with the surrounding landscape.

The river profile is fairly indistinct near the CAP canal, and is more constricted on the north side than on the south. An interesting feature that dominates the area is the Beardsley Canal Bridge crossing over the river via a unique arched metal bridge. Vegetation is typically xeric/mesic. Natural landforms in the vicinity of the bridge are altered by concrete construction related to the bridge crossing. Typical floodplains and flats dominate the field of vision.

Flooding

Flooding concerns are minimal in this subreach due to current undeveloped conditions. Several washes drain to the river on the east side.

Groundwater Recharge

The managed reach of the CAP's recharge facility crosses this subreach. Being a managed reach, it will appear as a natural stream course. At the present time, CAP intends to maintain the reach intensively. Brush and trees are being removed to reduce water loss to evapotranspiration. Removing vegetation from the channel also permits the water to move through the channel more rapidly, reducing infiltration. The objective in any permitted groundwater recharge facility is to maximize the recharge credits. Water recharged in the managed reach is eligible for only half the recharge credits of a constructed facility. The more water transported to the constructed portion of the facility, the higher the recharge credits.

Sand and Gravel

There are no active sand and gravel operations within this subreach of the Agua Fria River.

2.1.5.6 CAP Canal to Cloud Road

Land Use

This subreach is located within the City of Peoria, except for a small portion at the CAP Canal that is in unincorporated Maricopa County. The area is primarily undeveloped. A gravel road extension of the Carefree Highway Alignment crosses the river and ends on the west bank. Canyon Raceway is south of the Carefree Highway extension about one-half mile to the east. Additionally, the Pleasant Valley Airport is located two miles east of the river along the Carefree Highway extension. Finally, an explosives company has leased land along the river within this subreach.

Visual Characteristics

This stretch of the river contains wide floodplains defined by fairly prominent benched banks. Xeric riparian vegetation dominates the floodplains and flats. Occasional interesting rock outcrops occur in the midground. Cowtown and Canyon Raceway are adjacent to the river. Waddell Dam appears to the north.

Flooding

Flooding concerns are few in this subreach due to current undeveloped conditions. Cowtown (along the west bank) is a concern because it could be cut off during active flooding of the Agua Fria River. Several washes drain to the river in this subreach.

Sand and Gravel

There are no active sand and gravel operations within this subreach of the Agua Fria River.

2.1.5.7 Cloud Road to New Waddell Dam

Land Use

This subreach is located within the City of Peoria. The area is primarily undeveloped. SR 74 crosses the river a mile south of the New Waddell Dam. North of the dam are Lake Pleasant, the Maricopa County Lake Pleasant Park, and the Lake Pleasant Visitor Center and Museum. South of the dam on the east side is Hank Raymond Lake. The Beardsley Canal and Waddell Canal straddle the river on the east side.

Visual Characteristics

The river is a deeply incised channel defined by rock cut banks. It is a spectacular area with interesting rock formations interspersed with abundant hydric/mesic riparian vegetation. Pools of water stand within the rocky bed of the river with large rocky boulders in between. Bulrushes, grasses, reeds, and other riparian species are abundant. Saguaros occupy the elevated rocky areas. Increased wildlife activity is observed.

Flooding

Flooding concerns include discharges from the New Waddell Dam and from Morgan City Wash, located on the east side of the river, south of the dam. Morgan City Wash is crossed by the Bypass Road near its confluence with the Agua Fria River.

Sand and Gravel

There are no active sand and gravel operations within this subreach of the Agua Fria River.

3. MULTIPLE USE OPPORTUNITIES

The Agua Fria River was a primary transportation corridor to both Native American and early settlers in the area. Hundreds of years have passed and transportation methods have changed considerably, but the rivers are once again the focal point of the West Valley. The Watercourse Master Plan recognizes both the importance of protecting the public from the hazards of flooding and the recreation potential for current and future residents.

The Agua Fria River supports a range of diverse economic and transportation activities and is a tremendous resource to the West Valley. Each of the seven jurisdictions through which the river passes would benefit from a multiple use corridor that provides flood control, but also allows open space and recreation experiences as well as functional uses such as recharge and sand and gravel mining.

Population within one mile of the Agua Fria River is projected to increase 104% between 2000 and 2020. The largest percentage increases are anticipated as areas in north Peoria and west Glendale develop. Other substantial population increases are projected for Phoenix and Avondale. Litchfield Park, which is not adjacent to the river but within the one-mile boundary of the river, is also projected to experience substantial population increases. In addition to increases in population, increases in retail, service, and industrial employment are also projected within one mile of the river. These employment increases will strengthen the desire to access retail and other destinations from the river, as well as the desire to enhance these types of land uses and more thoroughly integrate them into the community.

A range of multi-use opportunities was evaluated along the river corridor including groundwater recharge, sand and gravel mining, recreation, wildlife habitat, landscape enhancement, and cultural/historical interpretation. These opportunities are summarized below.

3.1 Groundwater Recharge

3.1.1 Introduction

The Watercourse Master Plan identifies and develops alternative plans for providing flood control along the Agua Fria River. An additional aspect of the proposed Master Plan is evaluating the potential development of groundwater recharge facilities along the Agua Fria River corridor. Recharge is the process of adding water to an aquifer system either through the infiltration of water from land surface, or injection into the subsurface via wells. Figure 3.1-1 shows potential water suppliers along the river corridor. Some of the suppliers shown are already providing water to recharge projects.

Groundwater is an important natural resource for domestic drinking water, agricultural irrigation, and industrial uses in the Salt River Valley. Historic pumping has depleted the groundwater system throughout much of central Arizona, including those areas around the Agua Fria River below New Waddell Dam. Water levels have declined significantly, which has resulted in increasingly limited water supplies, the deterioration of water quality, land subsidence, and development of earth fissures. Groundwater replenishment would become a significant attribute of the Watercourse Master Plan if recharge of renewable water sources were possible.

3.1.2 Benefits of Recharge

Groundwater recharge and recovery can be used to increase a water supplier's physical access to water supplies and can also be used to provide administrative access to water within Arizona's Active Management Areas (AMA). Recovery of stored water can provide a well owner with the legal authority to pump wells without having to secure a groundwater right. Recovery of stored water can, depending on its source, serve to alter the legal character of a pumping well from mined groundwater to a renewable water supply such as CAP water or effluent. This can assist a water provider or developer in meeting the Assured Water Supply Rules, which require the use of renewable water supplies.

Recharge/recovery programs may also serve to decrease infrastructure costs. Accounting for recovered water does not require that the molecular water be recovered. Recovery can occur at a distance from the stored water and in closer proximity to the end uses, as long as recovery well criteria are met. For example, a CAP subcontractor could store water in a recharge facility near the Hayden-Rhodes Aqueduct (commonly referred to as the CAP Canal). If the groundwater supplies are still physically available, the stored water could then be recovered at considerable distance from the canal from either existing or new wells within its service area. Under such a program, the cost of constructing the infrastructure to convey raw CAP water to the point of use could be avoided.

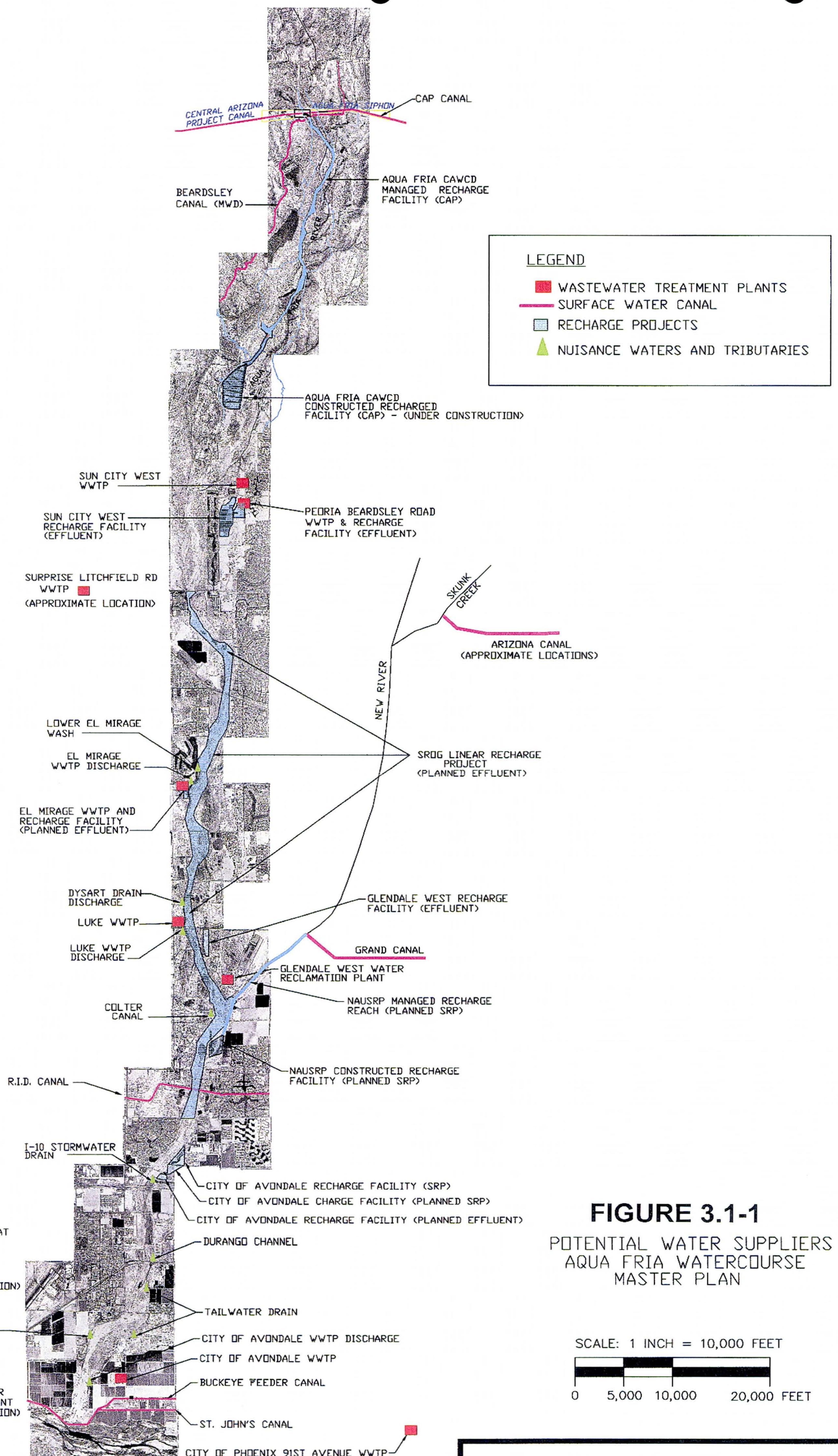

FIGURE 3.1-1

POTENTIAL WATER SUPPLIERS
AQUA FRIA WATERCOURSE
MASTER PLAN

Fluid Solutions
Water, Wastewater, Engineering & Environmental Services
1121 EAST MISSOURI AVENUE ▪ SUITE 100 ▪ PHOENIX ARIZONA 85014

CLIENTS/KIMELY HORN/ACAD/POTENTIAL WATER SUPPLIERS 6/25/01

3.1.3 *Regulatory Framework*

The Arizona Department of Water Resources (ADWR) governs the assessments of water supply, both groundwater and renewable sources, for the state of Arizona. Through its Underground Water Storage, Savings and Replenishment Program (more commonly known as the Recharge Program), ADWR administers the storage and recovery of artificially recharged water within the State. This program is intended to encourage the recharge of renewable water supplies and allow for the efficient, cost-effective management of water supplies.

The District has established a policy and permitting process for groundwater recharge, replenishment, or underground storage activities on land leased from the District. The policy is designed to allow recharge activities, where appropriate, while protecting the District's structures and mission. The program is designed to complement ADWR's permitting process.

3.1.4 *ADWR Permit Requirements*

There are three types of permits that make up the Recharge program: 1) Facility Permits, 2) Water Storage Permits, and 3) Recovery Well Permits. These permits work in unison with one another to create a flexible way to store and recover water.

There are two types of facility permits, Underground Storage Facility (USF) Permits and Groundwater Savings Facility (GSF) permits. A USF can be created anywhere throughout the state of Arizona, but a GSF can only be operated within an AMA or irrigation non-expansion area. Neither facility permit can be used without associated water storage permit(s).

USFs can either be deemed a "constructed" USF or a "managed" USF. A managed USF utilizes a natural stream course for the infiltration of water into an aquifer and cannot contain structures such as berms and levees that impound water to specific areas. Managed USFs must meter the quantity of water that is released to the stream course, but cannot maintain the area to enhance recharge capabilities (except for the removal of macrophytes in some instances). A constructed facility includes structures specifically designed to add water to an aquifer, such as a recharge basin or an injection well, and are maintained to promote infiltration of recharged water. Where space is limited, or in cases where the groundwater aquifer is confined between impermeable layers, recharge may only be achieved by injecting water directly into the aquifer. Metering must also be done on all water entering the facility.

The second type of facility permit is the Groundwater Savings Facility (GSF) Permit, sometimes called "in-lieu" facilities. Under this type of permit, an agricultural irrigator who pumps groundwater agrees to accept a renewable supply of water "in-lieu" of pumping their wells, thereby saving groundwater. The entity providing the renewable water supply to the irrigator is typically credited for the groundwater that remains in storage.

A Water Storage Permit (WS) must be secured at a permitted facility to actually recharge water. A WS permit holder must prove it has legal authority to the water and must comply with the plan of operation of the facility. Multiple water storage permits are allowable at a facility, as long as the sum of all water stored at the facility does not exceed its permitted capacity.

A recovery well (RW) permit provides the authority for recovering recharged water. An RW permit designates wells as recovery wells, and does not limit recovery to the same area as the water was recharged, as long as recovery occurs in the same AMA and its operation does not negatively impact surrounding well owners. Recovery wells can be new or existing wells.

The purpose of obtaining a recharge permit is to accumulate recharge credits. There are two types of recharge credits: annual storage and recovery credit, and long-term storage (LTS) credits. An annual storage and recovery credit is an acre-foot of water that was stored at a permitted facility and was recovered within the same year. LTS credits are those credits that meet the criteria of "water that cannot be reasonably used directly" and water that has not been recovered within the year it was stored. Surface water (Salt, Verde, and Agua Fria water) is not eligible for LTS credit and must be recovered within the month that it was stored.

LTS credits of CAP water provide additional benefits to the aquifer in which water is stored by donating 5% of water stored to the aquifer. Effluent is not subject to this aquifer donation, except when it is stored at a managed facility and then 50% of water stored is donated to the aquifer.

3.1.5 *Existing and Planned Recharge Projects Along the Aqua Fria*

There are a number of existing facilities that are permitted to conduct recharge and underground storage in the vicinity of the Aqua Fria River. These are discussed sequentially from north to south and are listed in Table 3.1-1

Table 3.1-1 – Permitted Recharge Facilities Along the Agua Fria River

Facility name	River Reach[1]	Distance from River (miles)	Facility Type	Type of Construction	Water Source	Permitted Volume (ac-ft/yr)
Agua Fria CAWCD[2]	upper	0	managed		CAP	100,000
Agua Fria CAWCD[2]	upper	0	constructed	basins	CAP	100,000
Sun City West	upper	< 0.5 (east)	constructed	basins	effluent	3,042
Peoria Beardsley	upper	< 0.5 (east)	constructed	basins	effluent	2,470
Surprise South Plant	middle	2 (west)	constructed	basins	effluent	3,584
Glendale West	middle	< 0.5 (east)	constructed	basins, trenches, vadose wells, injection wells	effluent	5,000
Avondale	lower	< 0.5 (west)	constructed	basins	CAP, SRP	10,000
Goodyear SAT	lower	3.5 (west)	constructed	basins	effluent	3,360

(1) The Upper Reach is from New Waddell Dam to Bell Road. The Middle Reach is from Bell R to New River confluence. The Lower Reach is from New River Confluence to Gila Confluen
(2) Facility not yet operational.

Several recharge facilities near the Agua Fria River are in the planning process. The planned facilities are:

- The Sub Regional Operating Group (SROG), the multi-agency entity that owns the 91st Avenue Wastewater Treatment Plant (WWTP), is evaluating recharge of treated effluent along a large portion of the Agua Fria River south of Bell Road. This facility could potentially recharge up to 80,000 acre-feet annually. It is anticipated that this facility will be developed as a managed facility, potentially resulting in significant flows reaching the Agua Fria.
- Salt River Project (SRP) has proposed the development of a recharge facility in the Agua Fria River at the terminus of the Grand Canal near the confluence of the New and Agua Fria Rivers. The New River/Agua Fria Underground Storage and Recovery Project (NAUSRP) is anticipated to be an infiltration basin facility with an expected capacity of 100,000 acre-feet per year. The NAUSRP will be utilized for the long-term storage of waters conveyed by the CAP and SRP to the Phoenix metropolitan area.

- In addition to recharge sites along the Agua Fria, there are a few proposed sites along New River. The City of Glendale is proposing a two-year project using injection or vadose-zone wells to recharge treated effluent from the Arrowhead Ranch WWTP. The City of Phoenix and SRP are also looking at options to recharge along New River.

3.1.6 *Groundwater Recharge Ranking*

Evaluation of recharge potential along the Agua Fria River was limited to that area between Bell Road and the confluence with the Gila River. Twelve issues critical to the assessment of recharge potential were evaluated for each subreach. These issues addressed regulatory ("unreasonable harm", odor, bird strike, and vector) concerns, infiltration rate, aquifer storage, benefit of recharge, proximity to existing water sources, impacts of flooding, and impacts on other watercourse users. For each issue, several subcategories were ranked. A detailed discussion of the ranking criteria and methodology for all subreaches is included in the *Groundwater Recharge Report*. Table 3.1-2 summarizes the potential for groundwater recharge within the river.

Table 3.1-2 – Summary of Recharge Potential In the Agua Fria River By Subreach Confluence of Gila River to Bell Road

Reach	Recharge Potential
Confluence of Gila River to Broadway Road	Unfavorable
Broadway Road to MC 85	Unfavorable
MC 85 to I-10	Potentially Favorable
I-10 to Indian School Road	Favorable
Indian School Road to Confluence of New River	Potentially Favorable
Confluence of New River to Glendale Avenue	Potentially Favorable
Glendale Avenue to Olive Avenue	Potentially Favorable
Olive Avenue to Cactus Road	Favorable
Cactus Road to Grand Avenue	Potentially Favorable
Grand Avenue to Bell Road	Potentially Favorable

3.1.7 *Recharge Design Concept*

Conceptual recharge designs in the Agua Fria are completed for two areas: (1) Thomas to McDowell Roads and (2) Cactus Road to Olive Avenue. Both designs are for constructed, in-channel facilities. These designs shall meet the Floodway Development Standards (Floodplain Regulations for Maricopa County, Article IX, Section 902):

"No structure, excavation or fill material (including fill material for roads, dikes, and levees), deposit, obstruction, storage of material or equipment or other uses shall be permitted which alone or in combination with existing or future uses, in the opinion of the Floodplain Administrator, would cause an increase in the base flood elevations or flood damage potential."

Consequently, in-channel improvements, such as the concepts presented herein, will either need to be constructed below grade or of sacrificial materials that will not increase flood potential.

All recharge techniques required in Article XV, Section 1503 (Floodplain Regulations for Maricopa County) were evaluated:

"All Watercourse Master Plans shall consider recharge techniques including but not limited to gabions, swales, dry wells, sand tanks and small dams."

Both design concepts include excavating sedimentary material from the floodway (creating a swale). A series of T-levees is proposed for the reach between Thomas to McDowell Roads because of the low gradient, 10 feet per mile. In areas where topographic gradient is low, the use of a T- or L-levee design is appropriate (Bouwer, 1999). The location of the T-levees in the floodway was chosen based on the geometry of the wash, and shall accommodate the introduction of additional surface flows from tributaries. An example of the use of T-levees is shown in Figure 3.1-2.

From Cactus Road to Olive Avenue, the gradient is also very low, ~15 feet per mile, and the channel widens. The design concept incorporates modified (curved) L-levees in the floodway and formal, constructed recharge basins in a portion of the flood fringe. Water would be delivered to the channel downstream of Cactus Road. It would cascade downstream through the levees. Diversion works would be constructed in close proximity to Peoria Avenue, which would allow the operator to direct water to either the constructed basins or the levee system.

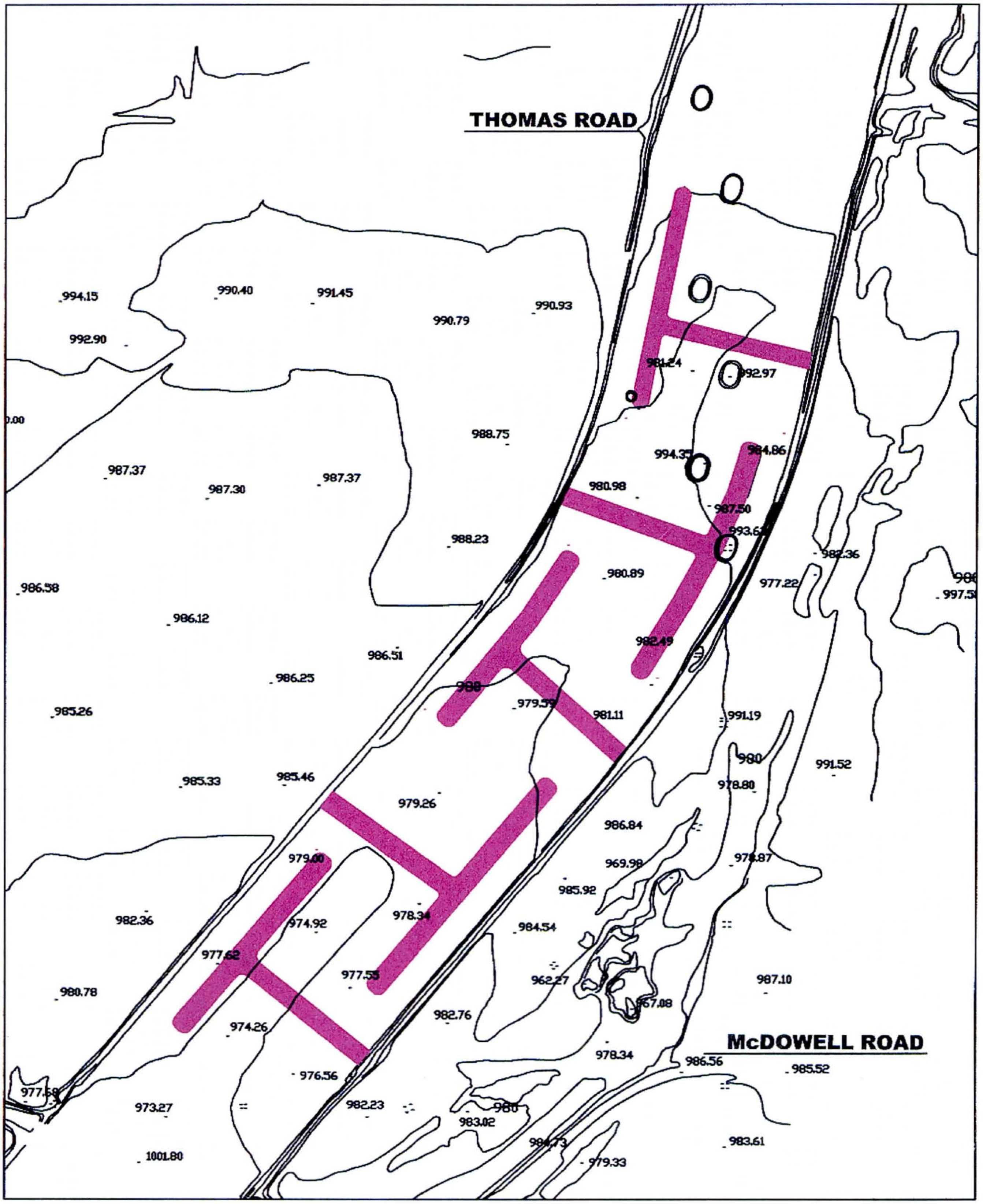

FIGURE 3.1-2

CONCEPTUAL IN-CHANNEL RECHARGE T-LEVEE DESIGN THOMAS RD. TO McDOWELL RD.

SCALE: 1 INCH = 800 FEET

0 800 1600 FEET

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3.2 Mining

3.2.1 Introduction

Mining has played an important role in defining the economy in and around the Agua Fria watershed. Gold, silver, and lead mining activity took place in the upper Agua Fria River watershed (outside the study area) in Yavapai County between 1870 and 1920. However, in 1864 the Vulture Mine was opened about 30 miles west of the Lake Pleasant region, promoting the creation of the boomtown of Wickenburg. From about that time, miners and ranchers began spreading out from this settlement to the present-day Lake Pleasant area. It was not until the 1890s that settlers began to initiate ranching, agricultural, and mining activities within the study area. For example, historical sources document hydraulic mining on Humbug Creek, a tributary to the Agua Fria River in the Lake Pleasant area (Rogge and others, 1987; Tellman and others, 1997). Rogge and others (1987) report a 35-foot high masonry dam that was built in the 1890s on Humbug Creek as part of the Humbug Hydraulic Works to provide water for a mining operation. Some minor gold deposits were discovered, but the operation failed due to lack of water. Mining activities in the lower reaches of the Agua Fria within the study area were limited. The only working mines in Maricopa County near the river were in the vicinity of the town of Pratt. These mines were insignificant; almost all had closed by 1905 (Lacey and others, n.d.).

The watershed downstream of Lake Pleasant has experienced significant urbanization within areas historically irrigated for agriculture, as well as in areas that were relatively undisturbed. The need for adequate utility and transportation infrastructure grew along with the accelerating pace of residential and commercial development in the area. Major bridge and flood control structures were built throughout the study area. Because of the ever-increasing demand for concrete and other rock products, sand and gravel mining became part of the urbanizing landscape. Due to high quality sand and gravel materials, upstream damming, and the ephemeral nature of watercourses; the floodplains became a preferred location from which to mine sand and gravel. Because transportation costs are a major financial component in the cost of sand and gravel products, the Agua Fria's proximity to West Valley growth has partially contributed to controlling the cost of housing and infrastructure (Dallett, 2000). Aerial photographic evidence indicates that active sand and gravel mining has been taking place within the river channel and its floodplain since at least 1949. The consequence is that a significant volume of sand and gravel has been and continues to be extracted from the Agua Fria River.

3.2.2 *Sand and Gravel Mining*

Historical records indicate that prior to the 1950s the Agua Fria was relatively stable. However, before the introduction of sand and gravel mining into the watercourse, the channel has narrowed and degraded (lowered). Degradation of the Agua Fria has been noted by other studies as well (SLA, 1983; ADOT, 1989). In 1989, ADOT collected data relative to sand and gravel mining in a portion of the Agua Fria River that extends from Buckeye Road to Camelback Road. The data were used to study the impacts of in-stream sand and gravel mining on channel stability. The volume of sand and gravel extraction in this study area was estimated at 11.8 million tons for the period from 1972 to 1981. Aerial photo interpretation indicated mining activity was concentrated near Indian School Road. Mining proceeded uniformly, with episodic disruption due to floods and significant impacts from extensive channelization of the river during the 1980s. The change in bed topography in the reach averaged 1.5 feet during this period. Observed changes in the local bed profile at bridge sites were reported to be four to five feet. In one report, aggradation of about 3 feet at the Buckeye Road bridge site was noted following the 1980 flood.

As part of this investigation, hydrologic investigations were undertaken to estimate whether there was sufficient floodplain storage to regulate or attenuate floodwaves as they moved downstream. It was noted that significant attenuation occurred at locations with large overbank sand and gravel pits. The conclusion was that the overbank storage including sand and gravel pits were providing a measure of flood attenuation for downstream reaches.

Historical data from the past 100 years indicate the following:

- Historically, heavy mineral mining activities in the lower reaches of the Agua Fria River were limited. The only working mines in Maricopa County near the river were in the vicinity of the town of Pratt, upstream of the study reach. These mines were insignificant, and almost all of them had closed by 1905.
- Active sand and gravel mining has been taking place within the river channel and its floodplain since at least 1949, causing a significant volume of sand and gravel to be extracted from the river and increasing the potential for significant degradation of the river bed.

- The sand and gravel resources of the Agua Fria are considered to be of a very high quality, and their abundance has led to significant positive impacts on the local economy. The Arizona Rock Products Association estimates that the total economic impact in 2001 from all mining in Maricopa County was $1.4 billion.

3.2.3 *Current Regulatory Control of Mining by the Flood Control District of Maricopa County*

Current regulations require sand and gravel operations to obtain a floodplain use permit for excavations within the regulatory floodplain. Applicants submit requests to the floodplain administrator for the community in which the proposed operation is located. The District administers the floodplain in unincorporated areas of Maricopa County, as well as for the towns of El Mirage, Surprise, and Youngtown. Additionally, some communities may refer a sand and gravel permit application to the District for technical review. Upon acceptance of the application, either the District or the floodplain administrator issues a floodplain use permit. Applicants are required to renew permits every two to five years.

Applications for excavations limited to 10 feet in depth require minimal engineering analysis. For larger operations, permit applications require an engineering analysis of the local impact of the proposed mining operation. The current permitting process is focused more on localized site impacts rather than evaluating the cumulative mining impact along the river. The District is currently evaluating the effectiveness of the permitting process on a countywide basis.

Several sediment transport models were created as part of the Watercourse Master Plan. The models are discussed in greater detail in Section 7 of this report. One set of models was developed to specifically examine the impact of sand and gravel mining on sediment movement. The base model was adjusted to include existing and proposed pits as described in the floodplain use permit applications. The revised model depicts the mines as excavated to the limits proposed in the floodplain use permit. Given the fully mined scenario, the models predict additional bed degradation.

In the past, at the end of the economic life of the gravel mine, the mine has been abandoned or refilled with inert waste. This practice led to a landscape that was visually unattractive and hazardous. As a result, the District has been requiring the incorporation of a reclamation plan as part of the permit application. These plans traditionally have been focused on actions taken when the pit is to be abandoned. Currently, the District is working with operators to develop reclamation strategies that may promote a more orderly introduction of phased reclamation, as well as mitigating the long-term impact to the visual landscape. Demand for this type of mitigation is increasing within Maricopa County. Some operators in the sand and gravel industry are recognizing the need to incorporate these strategies within their operations.

3.3 Vegetation, Habitat, and Wildlife

3.3.1 Vegetation

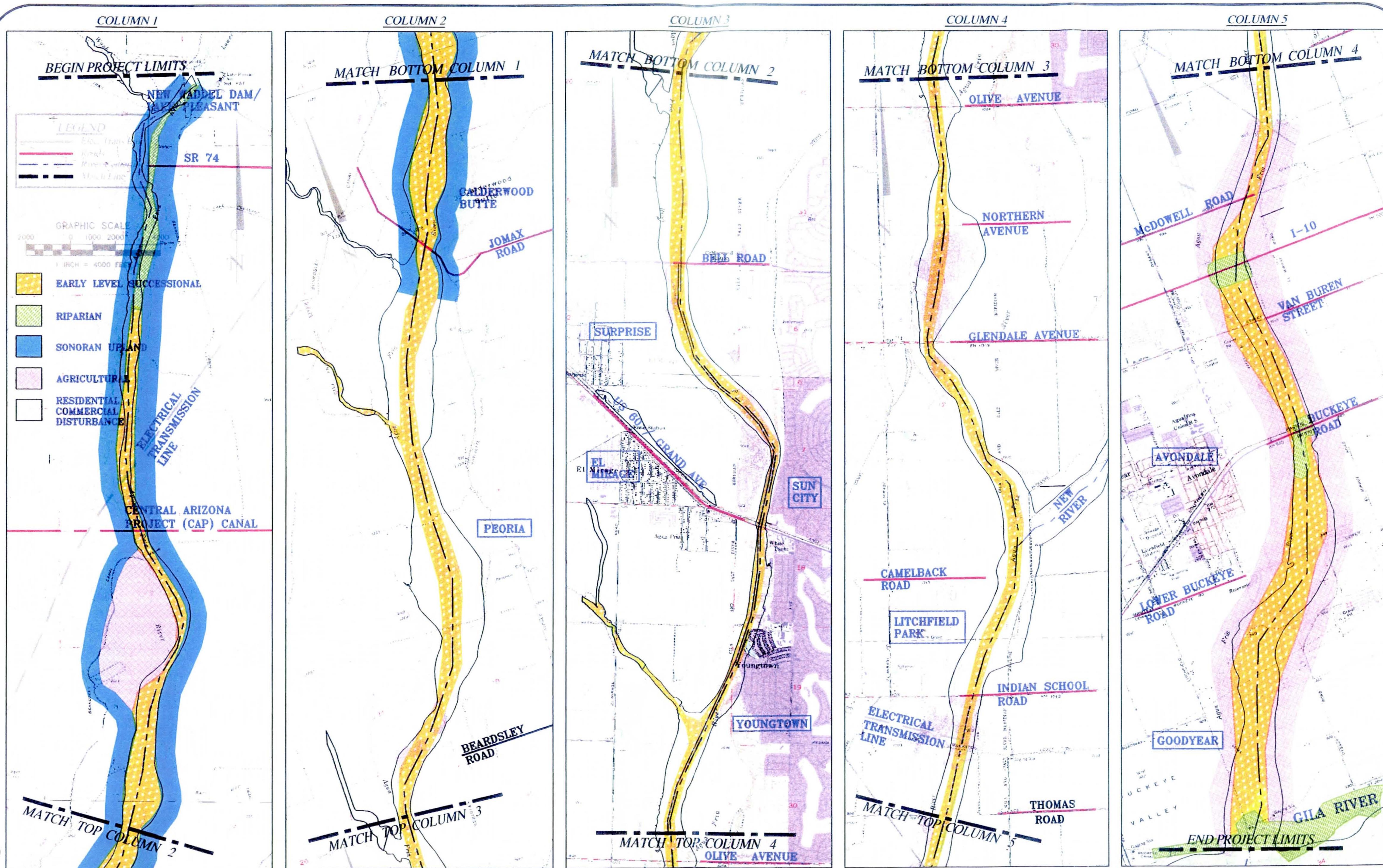
Field reconnaissance revealed five vegetation communities throughout the Agua Fria River Corridor:

- Early Level Successional
- Sonoran Upland
- Agricultural
- Commercial/Residential
- Mesic/Hydric Riparian

Each community is composed of several physiognomic and floristic groups. Several communities share numerous common species. See Figure 3.3-1.

The Early-Level Successional community is located within the low terrace banks of the Agua Fria River channel from south of the State Route 74 bridge crossing to near the confluence with the Gila River. This community is relatively heterogeneous throughout the corridor with the exception of areas where the sand and gravel mining operations exist. It is also interspersed with small inclusions of the mesic/hydric riparian community in several areas. This community is composed of ruderal, invasive or early level successional species with isolated inclusions of mid-level successional species and dominated by annual/perennial herbaceous and low-growth shrub species. In areas of recent or repeated disturbance, the vegetation community is dominated by annuals or is barren. The transition zone between this community and the adjacent communities is relatively abrupt and is driven by the moisture regime and the development of hard-pack desert soils along the terrace banks.

The Sonoran Upland Community includes both the Arizona Upland Subdivision and Lower Colorado River Valley vegetation sub-divisions since the transition between these two communities is not well defined within the project corridor. Vegetation densities within the Sonoran Upland Community vary as a function of the surrounding landform. The northern portion of the



WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

VEGETATIVE COMMUNITIES

NEW WADDELL DAM TO CONFLUENCE OF GILA RIVER

FIGURE 3.3-1

Agua Fria corridor has numerous incised, ephemeral washes that exhibit some of the highest vegetation cover densities along the corridor. These communities consist of woody desert scrub vegetation that is concentrated along the margins of the washes. The surrounding upland areas also contain some of the same woody species but are primarily dominated by succulents.

The agricultural community includes areas that are currently or historically under crop production or structured pasture areas. The majority of these active areas are in the southern portion of the corridor, south of the I-10 Bridge. Orchards were identified in the upper reach of the corridor north of Calderwood Butte and south of the CAP crossing. The agricultural species consist of cotton, alfalfa, and citrus. Most of the agricultural areas have been cleared of native vegetation and have been graded to promote irrigation.

The Mesic/Hydric riparian community consists of vegetation along the intermittent or perennially wet portions of the Agua Fria River corridor. It is found in the northernmost portion of the corridor from the New Waddell Dam to below the SR 74 crossing. It is also noted in several areas where near permanent surface discharge outfalls to the Agua Fria channel such as I-10, wastewater treatment facilities, and sand and gravel mining operations. It includes woody vegetation as well as the herbaceous vegetation associated with the ponded areas.

The commercial/residential vegetation communities include golf courses, landscaped medians, buildings, and paved areas. Most of the landscaped areas are irrigated and maintained.

3.3.2 *Wildlife and Habitat*

Field reconnaissance of the Agua Fria River corridor revealed wildlife usage through sightings, animal signs, and habitat potential. Several animal species were identified throughout the corridor; however, no threatened or endangered species were sited.

The functional habitat value within the Agua Fria River corridor was assessed based upon the following factors: wildlife cover habitat, wildlife forage habitat, and wildlife travel habitat. All five vegetation communities provided moderate to excellent nesting and forage habitat for most avian and small mammal species. The agricultural and commercial/residential vegetation communities had fair to poor cover habitat for all species. Overall, Sonoran Upland and Mesic/Hydric Riparian communities were good to excellent in all habitat functions for all species.

3.4 *Visual/Interpretive Features*

3.4.1 Introduction

As part of the Watercourse Master Plan, it is important to establish the current overall impression of the river landscape. This assists in the formulation of flood control solutions and future planning policies that take into account the character of the river. Such an analysis also facilitates the identification of key points along the river that have unique scenic attraction, wildlife habitat quality, historical/cultural significance, and/or recreational potential.

3.4.2 Visual Resources Inventory & Analysis

An inventory of areas of natural scenic quality is an important step towards their integration into future planning solutions for the river corridor. Future recreational activities proposed along the river corridor will need to take into account the existing and proposed land uses, as well as the existing types of recreational activities along the river corridor that best satisfy planning demands. The river landscape character provides an insight into the type and quality of both passive and active recreational space that can be incorporated into the Watercourse Master Plan while preserving ecologically critical zones and rich historic traditions. Ecologically less critical areas of the floodplain with little wildlife habitat, as well as degraded areas that result from mining activity, provide great potential for reclamation into active recreational spaces.

3.4.3 Intrinsic Qualities

The National Scenic Byway Program administered by the Federal Highway Administration has identified six intrinsic qualities that distinguish scenic byways. These qualities represent the scenic, historic, cultural, recreational, natural, and archaeological aspects of scenic byways. While these were developed in conjunction with the national highway program, they represent qualities that distinguish any scenic corridor. The Agua Fria River corridor contains a wide variety of intrinsic qualities that contributes to the visitor's experience. These intrinsic qualities are summarized below.

3.4.3.1 Scenic Qualities

The Agua Fria River corridor has areas of spectacular scenic beauty, especially along its northern reach near Lake Pleasant. In the otherwise dry and sparse expanses typical of the southwest, sections of the riverbed stand out in their lush vegetated state. Dramatic stands of Saguaro and Cholla dot the uplands through which the river carves its way. Panoramic mountain views are visible from almost the entire length of the river. The river corridor contains vast expanses of open land in an otherwise urban stretch providing relief from the noise, pollution, and fast-paced quality of urban life.

3.4.3.2 Recreational Qualities

The diverse landscape provides opportunities for recreational activities such as hiking, horse riding, jogging, mountain biking, and bird watching. Much of the recreational potential of the Agua Fria River Corridor is yet to be realized.

3.4.3.3 Natural Qualities

Exposed geologic formations exist in rich pattern and variety along the Agua Fria River corridor. The lower slopes of many hill ranges flank the river channel in its northern reach. The river floodwaters have deeply incised these rocky slopes and have created eroded banks that are unique in texture and color. Stratified bands along the banks contrast with the granular quality of the riverbed and its lush vegetation. Calderwood Butte and Twin Buttes are two conspicuous hills that dominate the river corridor in the northern reach.

3.4.3.4 Historic and Cultural Resources

The Agua Fria River corridor is replete with archaeological sites, many of which have been recorded. A special archaeological assessment carried out specifically for this project details 20 sites that best represent the general cultural, chronological, and functional variability of this locale. The study discusses the general activity patterns and briefly describes a series of interesting cultural resources found chiefly along the Agua Fria River. Collectively, the sites represent cultural themes of prehistoric and historic influences. These influences include water transportation and canal systems, prehistoric villages, natural resource exploitation, rock, vehicular transportation, homesteading, and commercial farming.

3.4.3.5 Archaeological Qualities

Many artifacts of Hohokam cultural development exist along and adjacent to the corridor. These include intricate systems of local irrigation of a predominantly agricultural society, remnants from habitations that constitute pithouses, and semi-subterranean houses. Hohokam People were also known for their prolific rock art and preoccupation with craft products of pottery, stone, bone and shell, as evidenced at many interesting sites along the corridor. More detailed information regarding the historical qualities of the project area can be obtained from The West Valley Archeological Sites Assessment Project of Central Maricopa County, Arizona, which has been completed as a part of the Watercourse Master Plan.

3.4.4 Planning Process

In order to understand the visual context of the project area, an inventory and assessment of the project vicinity was conducted using planning concepts identified in the Scenery Management System (SMS), developed by the U.S. Department of Agriculture (USDA) Forest Service (USFS) (USFS, 1995). SMS-based analyses consider both physical and social/cultural conditions and provide resource planners with information related to the broader aesthetic/visual conditions in the project vicinity.

3.4.5 SMS-Based Inventory Considerations

The aesthetic visual resource inventory procedures followed the concepts and methods of the USFS's SMS. Very simply, this process considers a range of physical conditions (natural processes and land uses) and social/cultural conditions that form our perceptions, attitudes, and expectations of the lands around us. The sequence of documentation of the principal considerations in this process is described below.

3.4.5.1 Landscape Character

Starting at a broad (regional or sub-regional) scale, landscape character is documented to understand the visual and cultural image of a geographic area. It consists of the physical, biological, and cultural attributes that make each landscape identifiable and unique.

3.4.5.2 Scenic Attractiveness

Within a particular Landscape Character type, a smaller breakdown of landscape units is delineated to assess the relative scenic value of the land based on specific conditions of landform, vegetation, water, and cultural features present.

3.4.5.3 Scenic Integrity

Scenic Integrity is a measure of the intactness or wholeness of the Landscape Character, or, conversely, a measure of the degree of visual disruption or discordant visual relationships. Landscape modifications may range from disruptive, such as disturbance that has left the land scarred, or enhancing, such as an attractive bridge over a channel.

Scenic Attractiveness and Scenic Integrity values were extensively used to assess the scenic quality of the corridor. The level of importance attached to scenic areas (Scenic Classes) was further determined in conjunction with use levels associated with each area.

3.4.6 Visual Resources Inventory

The Visual Resources Inventory identified points of interest along the river that define the character and quality of the corridor that contribute to the visitor's experience. Also identified were the major view sheds along the river corridor.

The inventory process included a number of separate site visits to document field conditions. In addition to site visits, interviews with public and agency representatives identified additional sites of aesthetic value. Information available from past publications as well as information from this multidisciplinary effort was consulted extensively in the development of the Visual Resources Inventory and Scenic Assessment.

3.4.7 Scenic Attractiveness

Scenic Attractiveness represents the inherent scenic beauty of a landscape. Commonly held perceptions of the beauty of landform, vegetation pattern, composition, surface water characteristics, and land use patterns and cultural features all contribute to create a general feeling of well being in the viewer. Scenic Attractiveness determines the potential of a landscape to evoke a positive response in people.

To enable an evaluation of Scenic Attractiveness, contrast ratings, scenic quality inventory, and the perceived landscape were individually analyzed to obtain a total score that would correctly and consistently classify sites along the river corridor. Scenic Attractiveness is determined by a composite score of the contrast ratings, scenic quality, and perceived character of a site.

The *Visual Resources Inventory & Scenic Quality Assessment* discusses the rating process in detail. Landscapes were rated in each of these categories. Scores were totaled and stops that fell within the top 33% were classified as Distinctive (Class A). The next 33% were classified as Typical (Class B), while the lower 33% were classified as Indistinctive (Class C). Scenic attractiveness classifications are defined as follow:

Class A—Distinctive

Areas where landform, vegetation patterns, water characteristics, and cultural features combine to provide unusual, unique, or outstanding scenic quality. These landscapes have strong positive attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance.

Class B—Typical

Areas where landform, vegetation patterns, water characteristics, and cultural features provide ordinary or common scenic quality. These landscapes have generally positive, yet common, attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance.

Class C—Indistinctive

Areas where landform, vegetation patterns, water characteristics, and cultural land use have low scenic quality. Often water and rock formations of any consequence are missing in class C landscapes. These landscapes have weak or missing attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance.

3.4.8 Existing Scenic Integrity

Existing scenic integrity is defined as the current state of the landscape, considering previous human alterations. The frame of reference for measuring achievement of scenic integrity levels is the valued attributes of the existing landscape character being viewed. The scenic integrity levels are:

Very High

The landscape scenery appears unaltered. Deviations to the landscape are insignificant. The existing landscape character and sense of place is expressed at the highest possible level.

High

The scenery appears unaltered. Alterations to the landscape do exist but repeat the form, line, color, texture, and pattern of the surrounding landscape so completely and at such scale, that the alteration is not evident.

Moderate

The scenery appears slightly altered. Deviations in the landscape are noticeable; however they remain visually unobtrusive when viewed within the general landscape character.

Low

The scenery is moderately altered. Man-made deviations begin to dominate the valued landscape character being viewed. They borrow valued attributes such as size, shape, edge effect, and pattern of natural openings, vegetative type changes, or architectural styles outside the landscape being viewed. However, introduced landscape character appears compatible or complementary to the character within the natural landscape.

Very Low

The landscape character is heavily altered. Modifications to the landscape may strongly dominate the valued landscape character. Deviations to the landscape do not borrow from valued attributes such as size, shape, edge effect, and pattern of natural openings, vegetative type changes, or architectural styles within or outside the landscape being viewed. However, deviations are made to shape and blend with the natural terrain (landforms) so elements such as unnatural edges, roads, landings, and structures do not dominate the composition.

Unacceptably Low

Scenic integrity refers to landscapes where the valued landscape character being viewed appears extremely altered. Deviations are extremely dominant and borrow little if any attributes from surrounding character. Landscapes at this level of integrity need rehabilitation.

3.4.9 *Scenic Inventory Summary*

Fifteen stops along the river were selected for a detailed analysis. Thirty-seven separate rating units based on particular characteristics of landform, vegetation, water, and land use/cultural conditions were determined. A detailed descriptive narrative was prepared in the field, a number of visual components were rated, and photographs were taken of each unit. At each stop, all visually evident landscape modifications were rated for Scenic Attractiveness and Scenic Integrity. The ratings were documented on special field forms and in photographs. Results of the inventory and analysis are summarized in Evaluation of Attractiveness on the following pages.

Table 3.4-1 - Evaluation of Attractiveness

Subreach	Location	Contrast Score	Scenic Quality Score	Perceived Character Score	Total Score	Scenic Integrity	Class
Gila River to Broadway	Confluence	84	24	16	124	medium	A
Broadway to MC 85							
MC 85 to I-10	Buckeye Road	24	4	3	31	Very low	C
I-10 to Indian School	McDowell Road	27.5	4.5	4	36	Very low	C
Indian School to New River	Camelback Road	28	3	0	31	Very low	C
New River to Glendale	Glendale Avenue	63.5	10.5	5	69		B
Glendale to Olive							
Olive to Cactus	Lakeshore Drive	29	8	0	37		C
Cactus to Grand							
Grand to Bell	Bell Road	31.5	2	3	36.5	Low	C
Bell to Beardsley							
Beardsley to Pinnacle Peak	Rose Garden Lane	27.5	3	3	33.5	unacceptably low	C
Pinnacle Peak to Jomax	Hatfield Road	47.5	14	3	64.5	Low	B
Jomax to Dixileta	Calderwood Butte	66	13	6	85	Very low	B
	Citrus Grove	59.5	17	4	80.5	Low	B

Table 3.4-1 - Evaluation of Attractiveness

Subreach	Location	Contrast Score	Scenic Quality Score	Perceived Character Score	Total Score	Scenic Integrity	Class
Dixileta to CAP Canal	Beardsley Canal	13	31	0	38	unacceptably low	C
CAP Canal to Cloud							
Cloud to New Waddell Dam	Cowtown Road	45.25	9.5	8	62.5	Very low	B
	South of Hwy 74	90.5	21	17	128.5	Low	A
	North of Hwy 74	121.25	20.75	20	162	high	A

Scores<54 = C
Scores>54<108 = B
Scores>108 = A

3.4.10 *Desired Landscape Character*

Landscapes are not static, but are always undergoing change as a result of natural environmental processes or external modification. The Watercourse Master Plan promotes the preservation of wildlife habitat areas and the enhancement of areas of scenic beauty and cultural/historic significance while supporting controlled development and recreational use. Changes in land use types and modifications to the landscape brought about as a result of the implementation of the Master Plan indicates consequential changes to the existing landscape character.

Changes to the existing landscape character as a result of development extend to the physical, biological, and cultural components that make up the landscape. Physical changes include topographical modifications or structural installations as a result of development and/or flood control implementation. Hydrologic changes are a direct result of physical changes in the landscape. Additional water inflow points cause modification to the water table and alternative flow channels. A direct, indirect, or cumulative effect of these changes is the modification of the vegetation and habitat character.

Landscape character descriptions establish the current overall visual impression of the existing landscape. Scenic quality assessments determine the scenic values and the extent to which those values are intact. These evaluations promote the improvement of indistinct areas as well as provide a reference for comparison between the existing and desired landscape character. This facilitates the progression toward a character found more appropriate to changed uses in a manner that is consistent and legitimate.

It is recognized that much of the existing landscape character along the Agua Fria River may not be sustained. However, certain parameters have been considered to develop a strategy by which a desired landscape character may be achieved. Also, in conjunction with the team biologists, an enhanced planting palette based on the existing vegetation types seen in each character zones has been prepared. The planting pallet is documented in *Visual Resources Inventory & Scenic Quality Assessment, EDAW, 2001* and *Habitat Enhancement Opportunities/Techniques on the Agua Fria River – New Waddell Dam to Confluence with Gila River, Kimley-Horn and Associates, Inc., 2001.* These, along with topographical modification (determined from the character studies) can be used to achieve the desired landscape character.

3.4.11 Landscape Transition Strategies

As stated earlier, landscapes are not static and are always undergoing change as a result of natural processes and human modifications. As a part of the Watercourse Master Plan study, two planning studies accompanied the Visual Resource Analysis: a Recreation Plan and a Water Recharge Plan. These plans, referred to as overlay plans, when combined with the plans prepared in this report reflect probable modifications that in turn will affect the future landscape character.

It is acknowledged that as water recharge projects are developed, recreational opportunities are realized, and flood control measures are implemented, that the landscape character will also need to be modified to match future land uses.

The structure for the landscape character recommendations in this report is envisioned as a dynamic process over the next 20-30 years. The recreational, biological, and engineering studies contained in the Watercourse Master Plan, combined with the findings of this Visual Assessment, provide a set of tools to respond to the changing landscape of the Agua Fria River.

The tools provided follow the natural landscapes found within the corridor, along with modified landscapes that allow active recreation. Also, as a critical element of flood control, hydraulic modeling of vegetation densities as landscapes are proposed will greatly influence the placement of plant material types and densities within the corridor.

3.5 Recreation

Existing and planned recreation features shown in Table 3.5-1 were inventoried to identify opportunities where they could be preserved, enhanced, or improved, and to serve as a basis for establishing a linked system of recreational opportunities throughout the project area. The recreation resources included in this inventory include open spaces, natural areas, interpretive opportunities, active play areas, sports fields, trails, and passive sites. Table 3.5.1 lists the existing and planned recreational features located within the one-mile buffer along the Agua Fria from the New Waddell Dam in north Peoria to the Confluence with Gila River in Avondale. The information is subdivided by jurisdiction.

3.5.1 Parks, Trails, and Open Space Inventory and Recreation Needs Analysis

An open space and parks inventory, and a recreation needs analysis were conducted to ascertain the extent to which demand for recreation facilities is being met, as well as to identify the existing facilities that could be woven into an interconnected recreation system along the river. The inventory and analysis includes all recreation facilities within one mile of the floodplain. This distance is coincident with the service area radius of a community park.

Parks

There are many improved neighborhood, community, and regional parks within each of the municipalities located within one mile of the Agua Fria River. These parks serve the community and regional needs of populations along the river.

Parks under development include Avondale's Regional Park II north at McDowell Road on the east bank of the river and the City of Phoenix Camelback Ranch Park. Regional Park II will include sports fields, a soccer facility, picnic areas, gardens, restrooms, and ramadas. The City of Phoenix Camelback Ranch Park is a community park and will include an equestrian trail and trailhead, sports fields, restrooms, picnic areas, and a ramada. A planned community park will be located at Deer Valley Road on the east side of the river.

Table 3.5-1 – Existing Recreational Features

Agua Fria River Watercourse Master Plan

City/Recreation Feature	Amenities	Status	Location	River Reach
Avondale				
Coldwater Park	Baseball Fields, Ramadas, Picnic Facilities, Parking	Developed	West of Agua Fria & Buckeye Road	Lower Reach
Regional Park II	Japanese Garden, sports fields, soccer facilities, restrooms, picnic areas, ramadas	Under construction	East of Agua Fria & McDowell Road	Lower Reach
City of Avondale Trails	Shared use trail	Partially completed		Lower Reach
Estrella Mountain Park	Rodeo and equestrian facilities, parking, picnic areas, hiking trails, restrooms	Master plan to be updated in 2001-2002	South of Gila River Confluence area	Lower Reach
Agua Fria Union High School	Sports fields	Complete	West of Agua Fria at Dysart & Riley Drive	Lower Reach
Rancho Santa Fe Park	Tot lot, open grass play area, barbecue area, on street parking	Complete	North of McDowell Road	Lower Reach
Garden Lake Parks (2)	Tot lots, picnic areas	Complete	East side of Agua Fria River at Thomas & 115th Avenue	Lower Reach

Table 3.5-1 – Existing Recreational Features

Agua Fria River Watercourse Master Plan

City/Recreation Feature	Amenities	Status	Location	River Reach
El Mirage				
Existing Bike lanes	Street bicycle lane	Complete; additional lanes planned	El Mirage Road between Thunderbird Road and Canal	Middle Reach
Pueblo El Mirage Country-Club	Golf course, club house, private residential lots	Golf course complete, residential lots available	West of Agua Fria River between Peoria & Cactus Roads	Middle Reach
Dysart High School	Sports Fields	Complete	Dysart Road	Middle Reach
Glendale				
Luke AFB Horse Stables	Stables	Complete	West side of Agua Fria River, north of Glendale Road	Middle Reach
Phoenix				
Camelback Ranch Park and Equestrian Access	Sports fields, grass areas, ramadas, restrooms, parking, equestrian facilities	Under design	East side of Agua Fria River just north of Camelback Road	Middle Reach
Sun City				
Sun City Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria/ South of Peoria Avenue	Middle Reach
South Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria / North of Peoria Avenue	Middle Reach
North Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria/ South of SR 60	Middle Reach

Table 3.5-1 – Existing Recreational Features

Agua Fria River Watercourse Master Plan

City/Recreation Feature	Amenities	Status	Location	River Reach
Lakes West Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria / North of SR 60	Middle Reach
Willow Creek Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria/ North of Bell Road	Upper Reach
Sun City West				
Briarwood Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria & north of SR 60	Upper Reach
Star Dust Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria & north of SR 60	Upper Reach
Pebblebrook Golf Course	Golf Course and Clubhouse	Complete	East of Agua Fria & north of SR 60	Upper Reach
Gaines Park	Ramadas, picnic areas	Complete	East of Agua Fria & north of SR 60	Upper Reach
Bicentennial Park	Ramadas, picnic areas	Complete	East of Agua Fria & north of SR 60	Upper Reach
Youngtown				
Maricopa Lake Park	Lake, picnic areas	Complete	East side of Agua Fria River at Lakeshore Drive	Middle Reach
Surprise				
Coyote Lakes Golf Course	Golf Course	Complete	East of Agua Fria & north of Bell Road	Upper Reach

Table 3.5-1 – Existing Recreational Features

Agua Fria River Watercourse Master Plan

City/Recreation Feature	Amenities	Status	Location	River Reach
Peoria				
Country Meadow Golf Course	Private golf course, clubhouse	Complete	East of Agua Fria/ North of Northern Avenue	Middle Reach
Conceptual Neighborhood Park		Identified in City of Peoria General Plan	Union Hills Road and Agua Fria River	Upper Reach
Conceptual Community Park		Identified in City of Peoria General Plan	Beardsley Road and Agua Fria River	Upper Reach
Conceptual Neighborhood Park		Identified in City of Peoria General Plan	Deer Valley Road & Agua Fria River	Upper Reach
Conceptual Neighborhood Park		Identified in City of Peoria General Plan	Cloud Road and Agua Fria River	Upper Reach
Conceptual Neighborhood Park		Identified in City of Peoria General Plan	Joy Ranch Road and Agua Fria River	Upper Reach

Developed parks include Coldwater Community Park on the west bank of the river on the north side of Buckeye Road in Avondale, the Maricopa Lake Community Park on the east bank of the Agua Fria River in Youngtown, and the Rancho Santa Fe Private Community Park on the west bank just north of McDowell Road.

Several existing and planned parks located outside the study area serve residents of the Agua Fria corridor. These include the City of Surprise funded Cactus League facility and regional park in conjunction with its new town core, the Sunshine Mountain community park south of Jomax Road, and the Las Legas Community Park in Avondale, and several unnamed community parks identified in the City of Peoria General Plan.

To determine the extent to which existing and planned facilities meet current and future needs an analysis of existing and planned park facilities based on population and service area was conducted. The analysis shows that the existing populations along the river are generally well served by either community or neighborhood parks, and that park development has generally followed residential development. Some gaps in service exist on the east side of the river between Olive Avenue and Thunderbird Road as well as north of Bell Road on the east side of the River. However, these areas are either not generally residential in character (as with the Olive to Thunderbird areas) or are served by open space and golf courses (as with the Sun City West area north of Bell Road) appropriate to surrounding demographic patterns. Finally, the analysis demonstrates no recreation facilities are currently provided for the largely undeveloped area in Peoria north of Pinnacle Peak Road. However, planned facilities for this area are included in the City of Peoria General Plan. In addition, the City of Peoria has identified the area on both sides of the river as open space (discussed below) and generally requires developed parks as part of private development. Consequently, as this area develops, its recreation service needs will most likely be met.

<u>Trails</u>

Several existing and planned trails intersect with or terminate at the river. These trails include bicycle lanes and routes and shared use paths.

Although the City of Avondale has no adopted trails plan, several trails constructed through private developments cross or are adjacent to the river. The City of Phoenix designates all arterial streets for bicycle lanes, including Camelback and Indian School Roads. Glendale similarly designates arterial streets for bicycle lanes. The New River is also a planned shared use corridor. Maricopa County is currently working to designate a countywide, shared use trail that would include the Agua Fria River corridor. While east/west routes provide a variety of connections from the river to other destinations, the Sun Circle Trail is the only designated north/south connection identified along the river.

Open Space

Substantial designated open space exists along the Agua Fria Corridor. In the southern areas of the River, the City of Avondale has designated the confluence with the Gila River as an opportunity to promote eco-tourism. While the City is currently revising its general plan, it is likely that the commitment to conserving this area will remain. In the northern areas of the river, the City of Peoria has identified both sides of the Agua Fria River as an open space buffer. In addition, slopes over 14% and most major washes in Peoria have been designated open space.

In the more urbanized areas (between I-10 and Bell Road), several golf courses provide private open spaces. These include the Coyote Lakes golf course in the Town of Surprise and the Pueblo El Mirage Country Club in El Mirage. Both Sun City and Sun City West provide golf courses for their residents. The Coldwater Springs golf course is located within Avondale.

In summary, a variety of public and private open space resources are located near or adjacent to the Agua Fria River. These open spaces are dispersed along the corridor and are not connected by any direct street routes.

As discussed previously in this section of the report, planned recharge along the river could return it to a more vegetated state and may support the development of new riparian and wildlife habitats. Although current mining activities limit recreational opportunities in certain areas of the river, there may be the potential to reclaim these pits as a recreation amenity once their resources are spent. Finally, the rich culture and history of the West Valley, including the Agua Fria River, also influence the future use of the river through development of interpretative areas in significant historical and pre-historical areas.

3.5.2 Recreation Opportunities and Planning Issues

As shown in Figure 3.5-1, there are many opportunities for open spaces, interpretive areas, shared use facilities, and recreation facilities along the

WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

PLANNING INFLUENCES

Figure 3.5-1

This map shows the factors that may influence recreation uses along the Agua Fria River.

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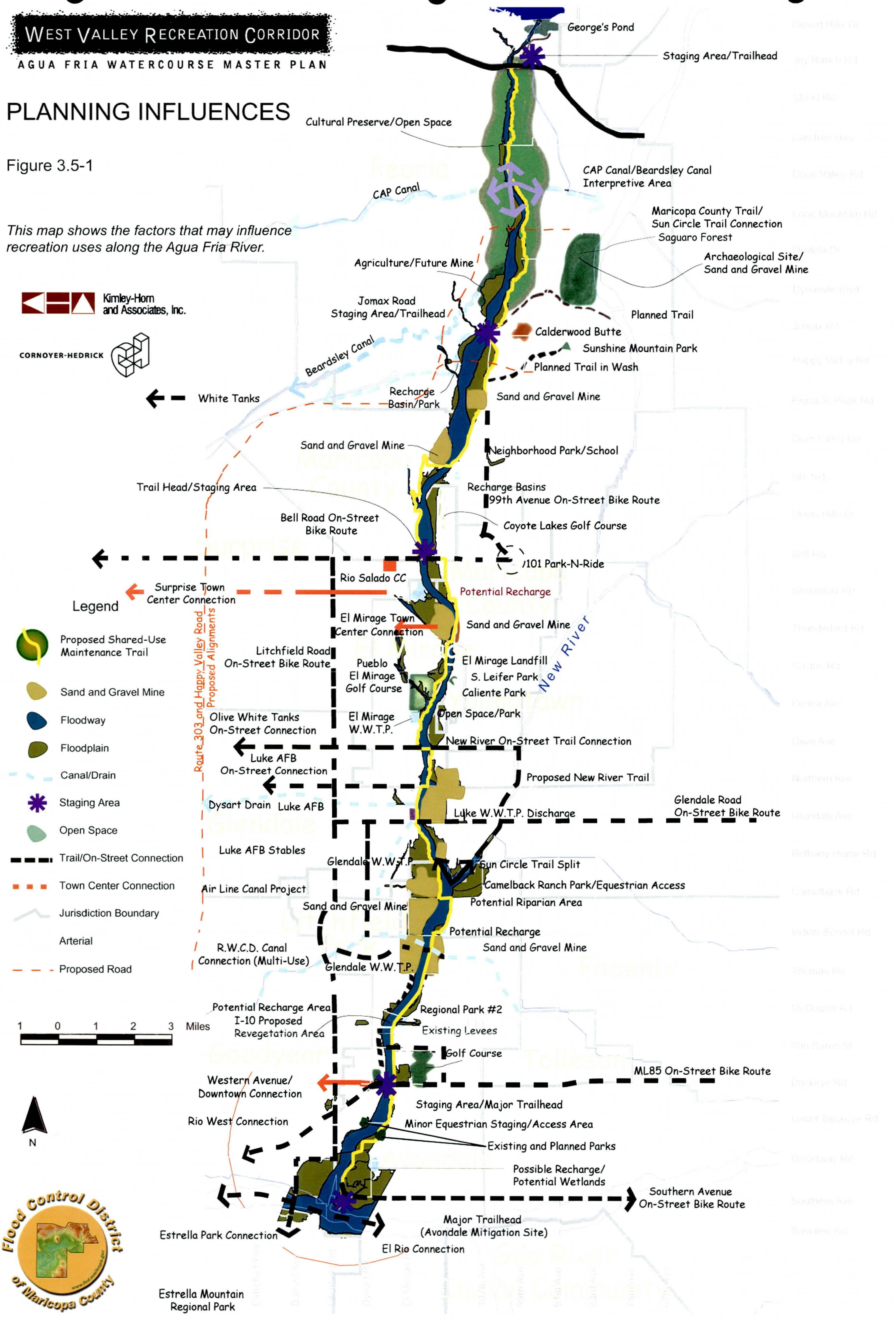


Flood Control District of Maricopa County

Agua Fria River. These opportunities are summarized below by type of facility.

3.5.2.1 Parks

Parks could be developed to serve residential areas between Union Hills and Joy Ranch roads. These include parks at the El Mirage Treatment Plant and at the McMicken Dam Outfall. Additionally, interpretive sites could reinforce the history of the river as a resource for mining, agriculture, and water. Interpretive sites could also be integrated with recharge facilities. Finally, several archaeological areas from the Hohokam period could be developed as interpretive parks including Calderwood Butte, Casa de las Piedras (north of Calderwood Butte), and pit houses throughout the northern reach.

3.5.2.2 Maintenance Road

An access road would be needed to monitor and maintain the river for flooding and erosion activities. At the same time, it is desirable to link recreational resources. Therefore, it is proposed that an access and maintenance road be constructed that would also allow non-motorized recreational use. A continuous stabilized surface trail could be constructed along the river from Southern Avenue (extended) to Camelback Road. North of Camelback Road to approximately Bell Road, mining makes passage within the river difficult. Consequently, the trail could continue along the New River to Olive Avenue or agreements with mining operators could provide access through their operations. North of Olive Avenue, the in-river trail could be continued to SR 74, where on-street access would be necessary to enter Lake Pleasant Park.

3.5.2.3 Levee Trails

Along the levee reach of the river, a shared use trail along both sides of the river could be constructed. This trail would be directly accessible to residents along the river and could offer amenities such as lighting, benches, and rest areas outside the floodplain.

3.5.2.4 Trailheads

Several trailheads are proposed to connect to existing trails that intersect the river and to provide access to the river. Two general types of trailheads are proposed. The major trailhead would include horse trailer parking and other equestrian facilities, restrooms, shade areas, and water. These facilities would be co-located with parks whenever possible. The minor trailhead is intended as a parking area and access point, and would offer directional signing and limited amenities.

3.5.2.5 Natural Areas and Passive Open Spaces

Open space, interpretive, and passive recreation facilities could be preserved or developed at the northern and southern ends of the river. At the I-10 crossing, a proposed mitigation site could be developed into an open space interpretive area with in-channel trails. Other natural open spaces are proposed at Rose Garden Lane and between Patton Road and Dixileta Drive.

3.5.2.6 Recreation Planning Constraints

In conjunction with recreational potential along the river, there are many issues that may affect their inclusion in the recommended plan. These issues include regulations that may restrict the uses of some areas, the need to preserve the river as a stormwater conveyance, access, environmental hazards, existing development patterns, current land use, and cost of implementation and maintenance.

Recreation

- The industrial feel of the Middle Reach and current mining activities limit access and continuous recreation use.
- Existing and planned parks along the corridor that are developed privately reduce the incentive for public agencies to provide potentially redundant facilities along the river.
- Access to the river is difficult in many places due to the design of existing developments, flood control improvements, mining, or natural topography.
- Flooding events could potentially result in the damage or loss of recreation improvements placed within the river.
- Because of access constraints, policing is more difficult, and safety may be an issue. The braided character of the main channel limits the opportunity to create developed recreation connections between the east and west side of the river.
- Regulatory agencies should continue to work with new development along the river to ensure opportunities for access and conservation of

recreation, and to see that open spaces, environment, habitat and cultural resources are maintained.

Recharge

- Recreation activities adjacent to recharge channels and basins may affect the class of water and the amount of water being recharged. Some recharge (i.e., effluent) may have undesirable characteristics that could impact recreation use.
- The type of conveyance (constructed or in-channel natural flows).
- Some recharge facilities are underway, requiring retrofit if these facilities are to be designed in a manner that promotes multiple or interpretive uses.

Archaeological

- Additional research is needed to fully document these sites.
- Most of the northern sites are underground.
- Most sites do not lend themselves to public interpretation.
- One rock art site may have religious association.
- While some sites contain valuable information, the resources are not readily visible.
- Many sites are on private land.
- Sites could be open to the public only when adequate protection is in place.

Cultural

- Most of the cultural/interpretive sites are not focused on the river itself, but on getting people across the river.
- The story of the river is one of how it was exploited whichever group was using it at the time.
- Many of the resources and sites are not adjacent to or within the project boundaries.

Environmental

- With the exception of the northern end and the restoration of the southern end of the corridor, the Agua Fria River has marginal environmental value.

- Water quality issues may impact the potential for mitigation banking within the river.

3.5.3 *Proposed Recreation Plan*

The vision of the recreation plan is to complement the flood control functions of the Agua Fria River by creating a dynamic open space and recreation corridor that remembers landscapes of the river and the people who lived along it. In order to achieve this vision, the following goals are identified:

- Create activity within the Agua Fria River while minimizing the impact of recreation on the landscape.
- Use the river as a bridge to connect to the cultural history of the West Valley.
- Connect the open space recreation resources along the river to each other, adjacent neighborhoods, and other recreation and open space resources in the West Valley, the region, and the state.
- Provide access to the river.
- Educate the public about the history of the people who lived along the river and role of the river in the development of the West Valley and the region.
- Integrate ecological values with recreation concepts.
- Integrate recreation functions with flood control facilities.

To implement this vision of enhancing the character of the river, three broad management areas were identified. The purpose of these areas is to guide the types of activities that could occur along the river to realize this vision. Table 3.5-2 describes the types of activities appropriate to the management areas.

Table 3.5-2 - West Valley Recreation Corridor Planning Matrix
West Valley Multi-Modal Transportation Corridor Plan

DEVELOPMENT ACTIVITIES	Management Goals & Intensity		
	RURAL (HABITAT/ WILDLIFE CONSERVATION)	SUBURBAN (PASSIVE)	URBAN (ACTIVE)
Transportation	Access restricted to protect sensitive desert areas; trails will skirt such areas	Link with community open space systems and residential areas	Links between residential, commercial, recreational, etc. areas; bypass routes to separate more intensive users from pedestrians
Flood Control	Natural, generally non-structural low flow channels integrated into environment	Non-structural with structural elements to protect road crossings and existing development or to preserve natural features	Structural to stabilize banks; protect planned and existing development and desired natural features
Recreation	Fitness, observation, restricted hiking/packing, equestrian routed around fragile areas. Stabilized surfaces	All activities in Conservation Wildlife Management Goal and picnicking, camping, restricted bicycling, restricted blading, restricted horseback, concessions, fitness, hiking/packing, touring, climbing, non-motorized boating, services	All activities in Conservation Wildlife and Passive Management Goals and motorized activities, shooting, bicycling, blading, field oriented sports, rodeo, large group (>10 people) activities, fitness, festivals, concessions, services
Interpretation/Education	Controlled access; viewing platforms and elevated pathways for observation of protected habitat, especially in areas near New River Dam	Numerous opportunities on proposed trails with informational signs on bridges, and structures; linkages also serve as educational opportunities, identification of historic sites	Numerous opportunities on proposed trails with informational signs; links also serve as educational opportunities

Table 3.5-2 - West Valley Recreation Corridor Planning Matrix
West Valley Multi-Modal Transportation Corridor Plan

DEVELOPMENT ACTIVITIES	Management Goals & Intensity		
	RURAL (HABITAT/ WILDLIFE CONSERVATION)	SUBURBAN (PASSIVE)	URBAN (ACTIVE)
Extraction/Mining	None	None	Revegetation and restoration plans required, time limits placed on activities, buffering during activities required
Economic	No development or alteration of floodplain; buffer floodplain from adjacent uses	Incorporate floodplain into development without altering shape or characteristics, restore floodplain and floodway to enhance land uses	Incorporate trails or river amenities into land uses adjacent to the floodplain; some alteration of the floodplain to encourage desired uses
Trailhead	Outside the floodplain	Limited facility trailheads inside the floodplain. Compacted parking areas, restrooms, small picnic areas	Full facility trailheads. Paved parking areas, restrooms, picnic areas, play fields (if appropriate).
Land Use	Residential (buffered from the floodplain). Open Space, Resort	Residential outside the floodplain, neighborhood commercial, community (i.e., library, park, low intensity administrative or doctors office)	All in Passive Management Goal Category and mixed use, high intensity areas, including mixed use Cores and/or nodes, industrial
Recharge	Natural (wetlands) only	Revegetated areas, soft surface basins and/or channels integrated into surrounding environment	All in Passive Management Goal Category and landscaped hard surface basins, pipes, hard surface, and landscaped channels.
Others/Special Areas			

3.5.4 Recreation Plan Summary by Recreation Component

This section of the report summarizes the planned recreation elements for the Agua Fria Watercourse Master Plan. The development of the Agua Fria Watercourse Master Plan culminates the planning process, which involved collaborative planning and design with multi-jurisdictions. Figure 3.5-2 shows how the proposed recreation plan components connect to existing and planned recreation facilities along the River.

3.5.4.1 Parks

Two developed parks associated with the El Mirage Wastewater Treatment Plant and the McMicken Dam outfall, are proposed.

3.5.4.2 Trails and Trailheads

Two trails are proposed to travel the extent of the river. The primary trail is planned as a shared use recreation trail intended to serve pedestrians and bicyclists. This facility is planned for use by bicycles, walkers, joggers, and skaters, and is generally located outside the floodway or adjacent to the levees between Buckeye and Camelback Roads. An in-channel secondary trail is planned as a stabilized surface facility that would include equestrian use. The secondary trail would merge with the primary trail from time to time. When the trails are merged, they are planned as either paved or unpaved, depending on their location (in channel or on street). When the merged or secondary trail is in-channel, it is to be incorporated into a vegetated area proposed as part of the Landscape Character Plan element of the Watercourse Master Plan. Trailheads are proposed at several locations in conjunction with trail crossings, arterial streets, and parks.

3.5.4.3 Equestrian Facilities

Two existing horse stables include the private Lower Buckeye horse corrals on the east side of the River below Lower Buckeye Road and the Luke Air Force Base horse corrals north of Glendale Avenue. A planned equestrian access is located at Camelback Ranch Park. Equestrian facilities are recommended at Lower Buckeye Road.

3.5.4.4 Environmental/Habitat/Open Space Areas

Riparian interpretive areas and trails adjacent to recharge basins and channels are recommended to be associated with recharge facilities underway or planned by the Central Arizona Project and the Southwest

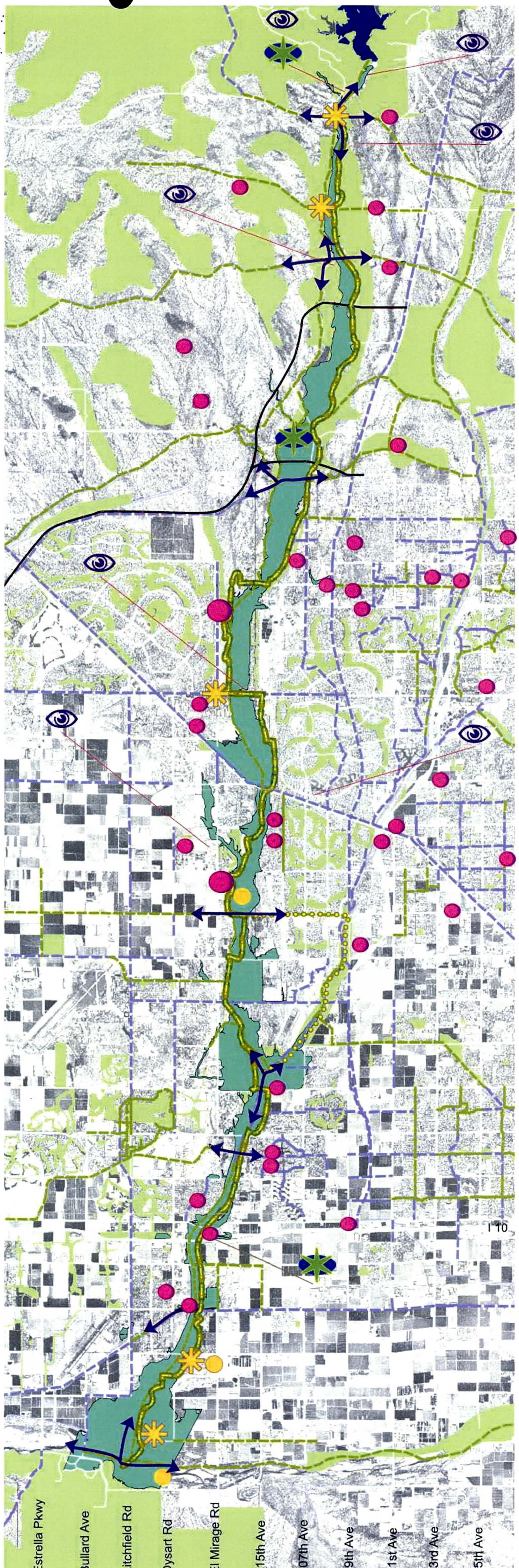
WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

PROPOSED RECREATION CORRIDOR PLAN

Figure 3.5-2

This map shows the proposed recreation features, in addition to existing and planned recreation facilities in the vicinity of the Agua Fria River.



Legend

- Floodplain
- Upland/Open Space
- Proposed Corridor Park
- Planned and Existing Community/Neighborhood Park
- Trailhead/Staging Area
- Equestrian Facility
- Interpretive/Cultural Point
- Riparian Area
- Connections
- Planned and Existing Multi-Use Trails
- Planned and Existing Bike Lanes
- Proposed Route 303 and Happy Valley

Sources: Maricopa Association of Governments (1995), Flood Control District of Maricopa County (2000), Arizona Land Resource Information System, and Jurisdictional Plans.

NORTH

1 0 1 2 3 Miles

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Regional Operating Group. In addition, a mitigation site is proposed for the I-10, and open spaces are identified throughout the corridor.

3.5.4.5 Interpretive Historic and Cultural Resources

The rich history of the Agua Fria River has been incorporated as part of the Agua Fria Master Plan. The historic Akimel Au Authm inhabited and farmed the area at the confluence of the Gila River and the Salt River, and the Yavapai's traditional homeland was along the middle and upper reaches of the Agua Fria River (ACS report). These historic sites are preserved as part of the Agua Fria Master Plan by creating interpretive areas at the Casa de Piedras prehistoric ruins and Calderwood Butte. The Master Plan also includes conceptual interpretative areas at the Beardsley and Central Arizona Project Canals, Calderwood Stage Site, at master planned developments, and other important sites and crossings.

3.5.5 Recreation Components in the Lower Reach (Gila River Confluence to New River Confluence)

The southern reach of the river consists of two types of planning management areas. The lower portion is rural in character and transitions to suburban between approximately Lower Buckeye Road and the New River Confluence at Camelback Road. Plan elements are identified below by subreach. Figure 3.5-3 is an illustrative showing various recreational components of the master plan. The numbers in parenthesis refer to the locations shown in the illustrative.

3.5.5.1 Confluence of Gila River to Broadway Road

It is recommended that the Avondale Mitigation Site be restored as a park with a major trailhead and the initiation/terminus of a stabilized surface trail along the eastern edge of the river **(36)**. The riparian area at the confluence is recommended to be restored as a habitat/interpretive area. Interpretive signs describing the Agua Fria as a resource and a seam, created via the many river crossings, that joins the West Valley from east to west and via the course of the river north to south are recommended here as well.

3.5.5.2 Broadway Road to MC 85 (Buckeye Road)

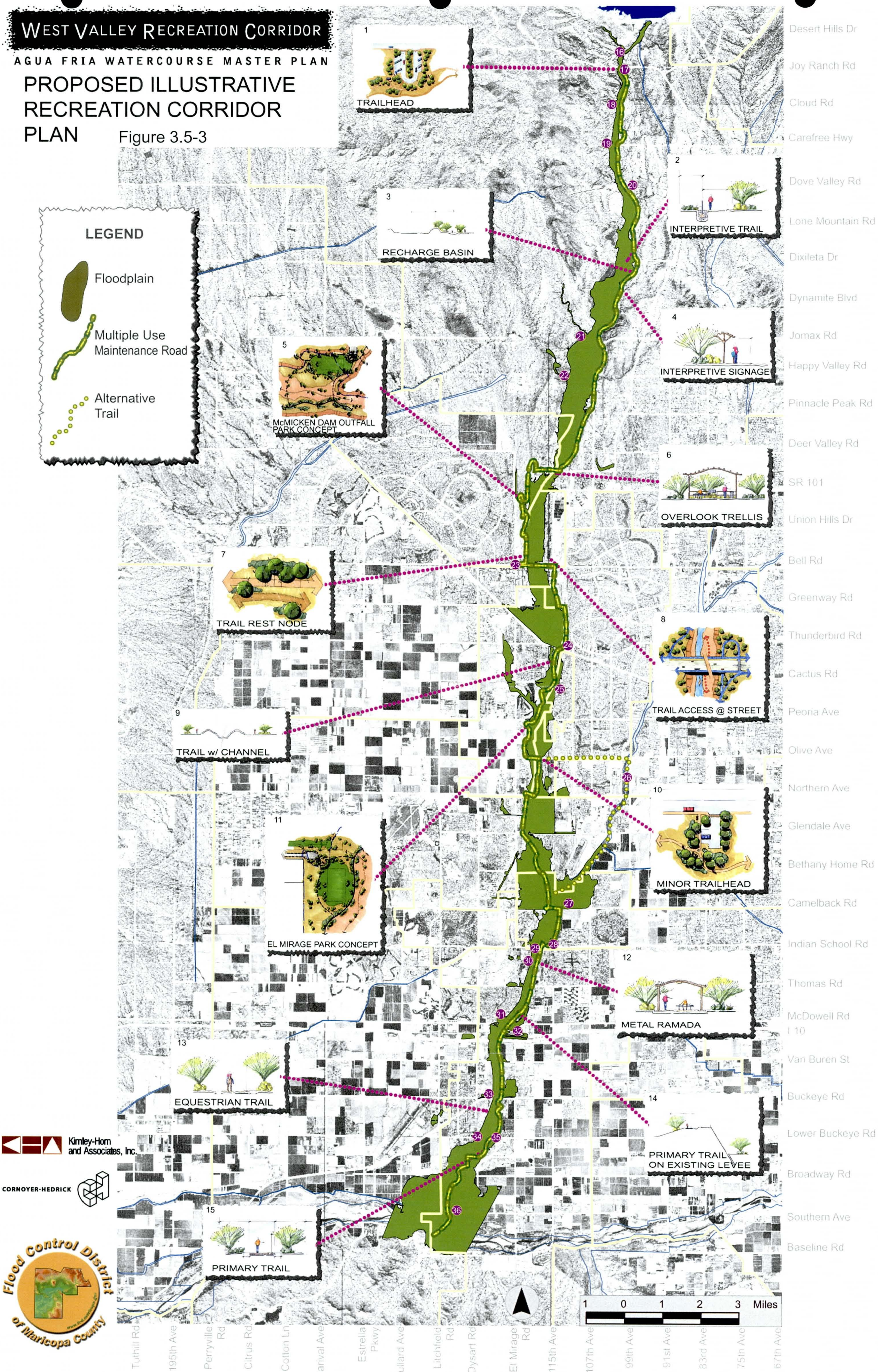
An equestrian trailhead **(35)** is proposed at Lower Buckeye Road on the east side of the river. This trail will provide access for residents in the mostly rural areas adjacent to the river. Within this reach, the stabilized surface trail splits into two trails: a primary, paved surface trail **(15)** along the levee, and a

WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

PROPOSED ILLUSTRATIVE RECREATION CORRIDOR PLAN

Figure 3.5-3



stabilized surface secondary trail **(13)** that provides equestrian use in the river channel.

Shopping, dining, and strolling have become a form of recreation and entertainment. The Agua Fria River offers a tremendous opportunity to blend these types of recreation activities with more traditional recreation uses. To complement traditional recreation uses, a mixed use river-oriented development (**34**) is recommended on the west side of the River at Lower Buckeye Road on the City owned property, once the City vacates its offices and moves to a new facility.

3.5.5.3 MC 85 (Buckeye Road) to I-10

South of Coldwater Park on the north side of Buckeye Road, an interpretive facility associated with the Santa Fe and Southern Pacific Railroad is recommended. This facility could include information about rail and its role in moving agricultural products that have been important throughout the development of the West Valley. A mixed use, river-oriented node is recommended on the vacant land just west of Coldwater Park **(33)**. The City of Avondale owns the land. This would provide a second commercial/entertainment venue within Avondale along the River.

The primary levee and secondary in-channel trails are recommended to continue through this reach. A trailhead associated with the proposed rail interpretive facility north of Buckeye Road and Coldwater Station is recommended within this reach to provide access to the primary and secondary trails.

3.5.5.4 I-10 to Indian School Road

Connections from the private park associated with the Rancho Santa Fe master planned community to the primary west levee trail are recommended **(31)**. These connections would provide a direct route to Regional Park II on the east side of the river.

On the north side of I-10, at the Arizona Department of Transportation Outfall Channel, a habitat area with trails and open space interpretation is recommended **(32)**. Access under McDowell Road and across the River to Regional Park II is also important to provide users of the trail on the west side with access to Regional Park II.

A trail adjacent to the levee is planned to continue here along both sides of the river **(14)**.

A park associated with the reclaimed mine located south of the Roosevelt Water Conservation District Canal is also included in the plan **(30)**. A connection from the primary and secondary trails to the canal, and inclusion of the canal as a trail in the Avondale General Plan, is also recommended **(29)**.

3.5.5.5 Indian School Road to the Confluence of the New River

Connections at Indian School Road will provide on-street bicycle route and sidewalk access to residents of Villa De Paz on the east side of the river **(28)**. The planned Camelback Ranch Park **(27)** will provide equestrian access and an open space node at the northeast intersection of Camelback Road and the river. North of the park, open space associated with the planned Camelback Ranch community is planned.

Because the levees end in this subreach, the primary and secondary trails are recommended to merge at Camelback Road and continue along the New River to Olive Avenue to avoid existing mining operations.

3.5.6 Recreation Components in the Middle Reach (Confluence of New River to Bell Road)

The middle reach of the Agua Fria River currently consists of urban activities in close proximity to general industrial uses such as sand and gravel mining, the Glendale airport, landfill, and wastewater treatment plant, and the El Mirage landfill. Recreation Plan elements are summarized in detail in the following subreaches.

3.5.6.1 Confluence of New River to Olive Avenue

Due to heavy industrial activities that span the entire reach of the river, no recreation activities are recommended. Alternative trail access is recommended along the New River **(26)** to Olive Avenue. On-street bicycle routes and sidewalks will provide bicycle and pedestrian access from the New River back to the Agua Fria River corridor. A trailhead at Olive Avenue **(10)** could mark re-entry to the Agua Fria River trail.

3.5.6.2 Olive to Cactus Road

The primary and secondary trails are proposed to continue along the west side of the river to Cactus Road. Within this reach, a park associated with the existing vegetation at the El Mirage Wastewater Treatment Plant is proposed **(11)**. Connections to the Youngtown Maricopa Lake Park, constructed as part of bank stabilization on the east side of the river, are also recommended **(25)**. At Grand Avenue, the primary and secondary trails are recommended to merge and continue on-street on the east side of the river to Bell Road.

3.5.6.3 Cactus Road to Bell Road

No recreation facilities are proposed here. The merged trail is recommended to continue on street to Bell Road **(24)**.

3.5.7 Recreation Components in the Upper Reach (Bell Road to New Waddell Dam)

For the most part, the northern reach of the river remains pristine Sonoran Desert open space. The land use zone transitions to suburban zone approximately at Dove Valley Road down to approximately Deer Valley Road. The area below Deer Valley Road transitions to the urban zone. Plan elements within this reach of the river are summarized in detail by the following subreaches:

3.5.7.1 Bell Road to Beardsley Road

A vacant parcel owned by the Arizona State Land Department located at the northwest corner of Bell Road and the Agua Fria River offers an opportunity to provide a trailhead with equestrian access to the river **(23)**. North of Bell Road, the primary trail could continue on the western bank and the secondary trail could continue in the river along the west edge of the floodplain **(8)**. Both trails could converge **(7)** at a park proposed for the McMicken Dam Outfall, located just north of the Union Hills Drive Alignment on the west side of the river **(5)**.

3.5.7.2 Beardsley Road to Twin Buttes Wash

North of Beardsley Road, the merged trail continues from the McMicken Dam outfall park through an elevated creosote flat with views of the floodplain. The flat is located on the western bank of the river bordering the north side of the McMicken Dam Outfall (6). The trail crosses the river at Rose Garden Lane, and continues north along the east bank of the river. A trailhead on the west side of the river at Beardsley Road is recommended.

3.5.7.3 Twin Buttes Wash to Calderwood Butte

A connection from the merged trail is recommended to Twin Buttes Wash **(22)**. Besides the merged trail and associated markers and vegetation, no developed recreation improvements are recommended in this portion of the river. A riparian area is recommended in association with planned recharge basins south of Jomax Road **(21)**.

3.5.7.4 Calderwood Butte to the CAP Canal

The plan recommends working with property owners to create interpretive areas at Calderwood Butte, Casa de Piedras, the CAP Canal, and Beardsley Canal (4). Within this area of the river, the primary and secondary trails would stay merged until north of Calderwood Butte. South of Casa de Piedras, the trails are recommended to split, with the primary trail on the east terrace and a secondary trail in the river at the east edge of the floodplain **(2, 3)**. An open space area is recommended north of Casa de Piedras **(20)**.

3.5.7.5 CAP Canal to Cloud Road

Connections to the three major washes on the west side of the river in this area should be created from the secondary trail **(18)**. The river would remain an open space corridor accessed by the secondary trail. The primary trail would continue on the east terrace above the river. A trailhead in conjunction with the proposed City of Peoria Regional Park is proposed at Lake Pleasant Road south of SR 74 and on the west side of the river at SR 74 **(19)**.

3.5.7.6 Cloud Road to the New Waddell Dam

A connection to the planned Maricopa County on-street bicycle route along SR 74 and to the Lake Pleasant Park is recommended at the SR 74 Bridge **(17)**. A trailhead is also recommended at this location **(1)**. Interpretive areas on the west side of the River north of SR 74 are also recommended.

The George's pond area is recommended to be conserved as a habitat/open space/interpretive area with access trails and connections to Morgan City Wash **(16)**.

Table 3.5-3 – Opinion of Probable Costs for Recreational Components

Component	Location	Description	Construction Cost ($Million)	Comments
Recreational Components of Maintenance Road	Gila Confluence to Lake Pleasant	Primary Trail		
Park/Major Trailhead	Gila Confluence to Broadway Road	Avondale Mitigation Site		
Equestrian Facilities	Lower Buckeye Road	Trail head with parking/loading facilities		
River Theme Development	Lower Buckeye Road	Commercial Redevelopment of current City offices	$ -	Private development-No cost to public sector
Interpretive Ramada/ Open Space/Trailhead	Buckeye Road	Interpretive site with railroad theme and minor trailhead	$ 0.250	
Interpretive Ramada/ Open Space/Trails	I-10	Interpretive site, habitat area, trails, open space	$ 0.250	
10-Acre Park Site	El Mirage	Recreational Park in Flood Fringe- No Structures	$ 0.470	
Interpretive Ramada/ Open Space	RID Canal	Interpretive site, trail connection	$ 0.250	
10-Acre Park Site	McMicken Dam Outlet Channel	Recreational Park in Flood Fringe- No Structures	$ 0.470	
Major Trailhead	Bell Road	Equestrian Trailhead		
Minor Trailhead	Beardsley Road			
Interpretive Ramada/ Open Space	Jomax Road	Interpretive site associated with CAP recharge project	$ 0.250	
Interpretive Ramada/ Open Space	Associated with SROG Recharge Facilities (location to be determined)		$ 0.250	

Table 3.5-3 – Opinion of Probable Costs for Recreational Components

Component	Location	Description	Construction Cost ($Million)	Comments
Interpretive Ramada/ Open Space	Associated with SROG Recharge Facilities (location to be determined)		$ 0.250	
Interpretive Ramada	Calderwood Butte	Interpretive site	$ 0.250	
Interpretive Ramada/ Open Space	Casa de Piedras	Interpretive site	$ 0.250	
Interpretive Ramada	CAP Canal	Interpretive site	$ 0.250	
Interpretive Ramada	Beardsley Canal	Interpretive site	$ 0.250	
Major Trailhead/ Interpretive Area	SR 74	Trailhead, habitat conservation areas and interpretive areas in the vicinity of SR 74 and George's Pond		
Minor Trailhead	Lake Pleasant Road south of SR 74	Trailhead in association with City of Peoria Regional Park		

3.6 *Transportation Corridors*

Many conventional transportation corridors, roads and bridges, currently cross the Agua Fria River. At-grade or dip crossings are simply roads across the bottom of the river. These roads become inundated during storms that produce flow in the river. Bridges have been constructed at most crossings to provide all-weather access. As shown in Figure 3.6-1 and Figure 3.6-2 on the next few pages, two new bridges are anticipated in the near future near Happy Valley Road and Lone Mountain Road. These bridges are in the latter stages of planning. Local and regional transportation planners have identified additional transportation corridors across the river, to be developed in the future. At this time, these corridors have been identified only as potential crossing sites. The type of crossing (bridge or at-grade) and precise location are unknown at this time. The corridors identified could possibly shift as much as one-quarter mile or more during detailed roadway design.

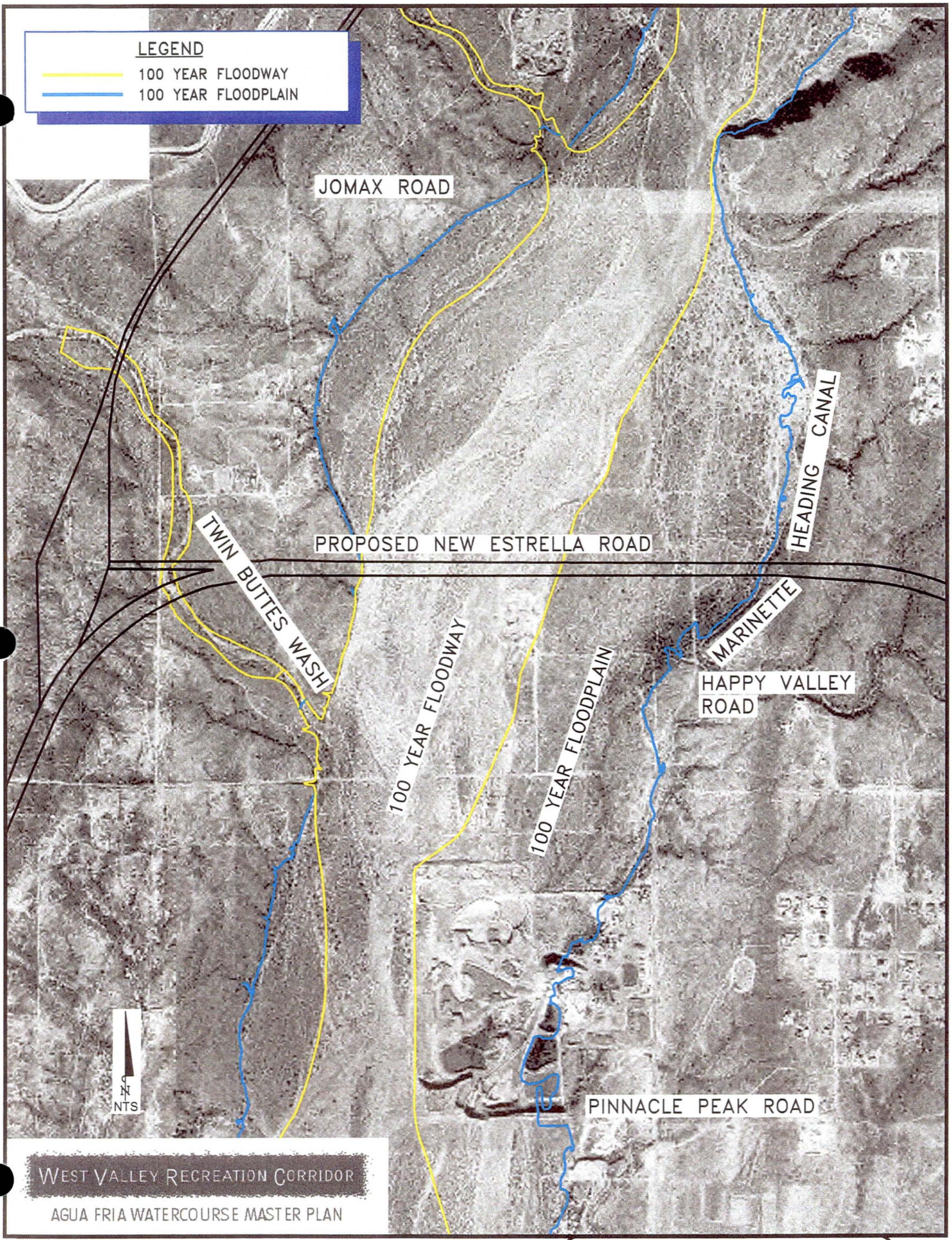
As the West Valley continues to grow and expand, the existing transportation corridors will be modified to meet new needs. At-grade crossings will be replaced with bridges, existing bridges will be widened and the proposed facilities will become a reality. Existing, proposed, and future transportation facilities are presented in Table 3.6-1.

Table 3.6-1 – Agua Fria River Transportation Corridors

Location	Crossing Type	Status
Litchfield Road (Gila River Confluence area)	Unknown	Future
Southern Avenue/ Broadway Road	Unknown	Future
Lower Buckeye Road	At-grade	Existing
Buckeye Road	Bridge	Existing
Van Buren Road	Bridge	Existing
Interstate 10	Bridge	Existing
McDowell Road	Bridge	Existing
Thomas Road	Bridge	Future
Indian School Road	Bridge	Existing
Camelback Road	Bridge	Existing
Bethany Home Road	Unknown	Future
Glendale Avenue	Bridge	Existing
Northern Avenue	At-grade	Existing

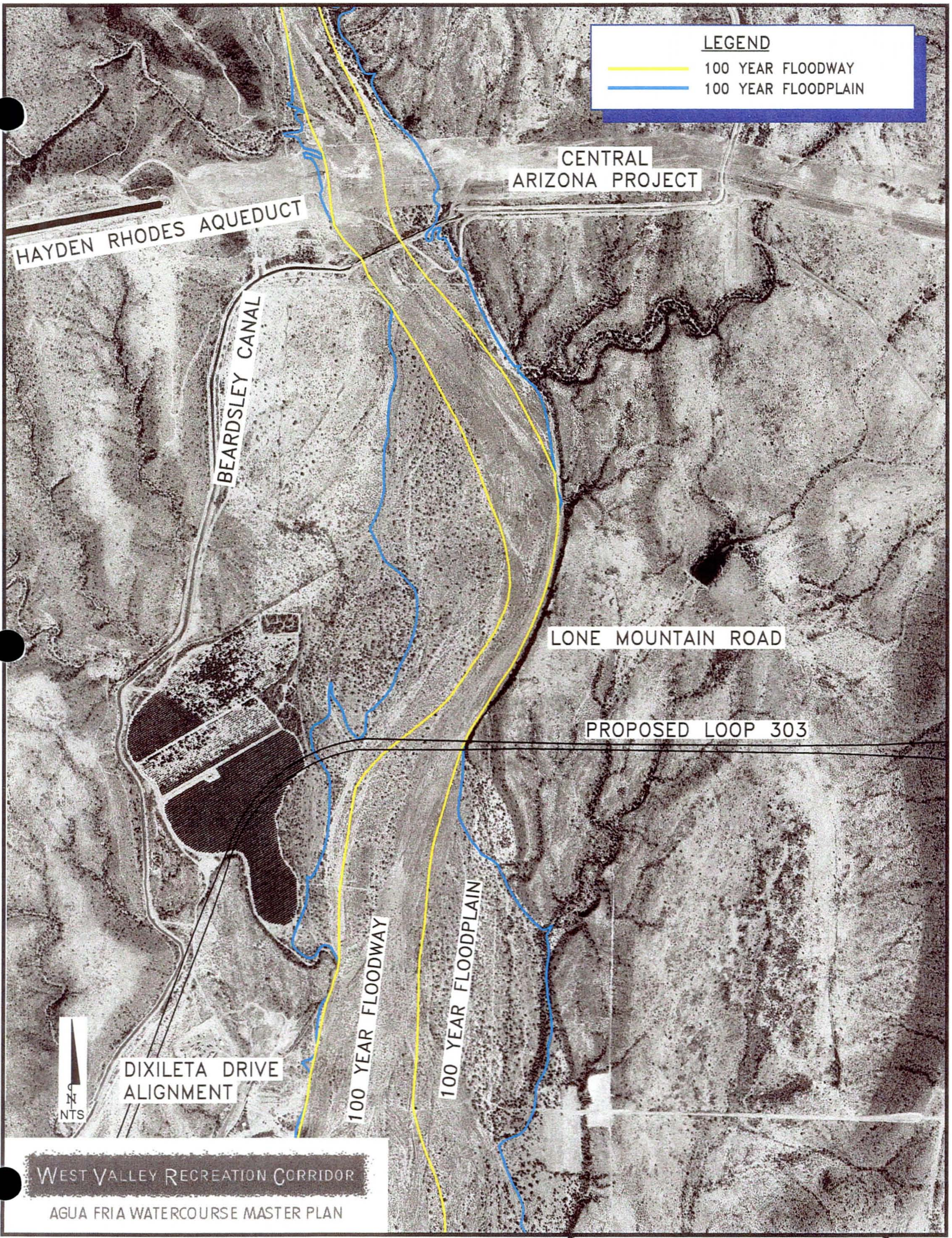
Table 3.6-1 – Agua Fria River Transportation Corridors

Location	Crossing Type	Status
Olive Avenue	Bridge	Existing
Peoria Avenue	Unknown	Future
117th Avenue- Peoria Avenue to Olive Avenue	Unknown	Future
Grand Avenue - U.S. 60	Bridge	Existing
Santa Fe Railroad	Bridge	Existing
Bell Road	Bridge	Existing
Rose Garden Lane	At-grade	Existing
New Estrella Roadway (Happy Valley Road)	Bridge	Proposed
Jomax Road	At-grade	Existing
Dixileta Road / Dynamite Boulevard	Unknown	Future
Loop 303	Bridge	Proposed
Beardsley Canal	Canal Bridge	Existing
Pass Road / Carefree Highway	Unknown	Future
SR 74	Bridge	Existing



Kimley-Horn and Associates, Inc.

FIGURE 3.6-1
NEW ESTRELLA ROAD



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and Associates, Inc.

FIGURE 3.6-2
LOOP 303

4. HYDROLOGY

4.1 *Introduction*

As part of the master planning process, KHA created supplemental hydrologic models to evaluate two important conditions that affect the river response during large floods:

- The effectiveness of the existing retention policies within the watershed, and
- Floodwave attenuation in the river as it relates to encroachment of the floodplain.

The models are intended for planning uses only and should not be used for regulatory purposes.

4.2 *Corps' Hydrologic Models*

The Los Angeles District U.S. Army Corps of Engineers established the regulatory hydrology for the River in July 1995. The hydrology is documented in the report "*Hydrologic Evaluation of New Waddell Dam on Downstream Peak Discharges in the Agua Fria River.*" The Corps' hydrology is the basis for current regulatory discharges on the Agua Fria River. The Corps has performed several analyses of the Agua Fria River. Another study, "*Hydrology for Evaluation of Flood Reduction by New Waddell Dam, Agua Fria River below New Waddell Dam to the New River Confluence*", 1988, describes the hydrologic design parameters of the river and New Waddell Dam.

For purposes of comparison, results of this study are compared to the 100-year flow rates established by the Corps.

4.3 *Tributary Flows*

Local runoff drains to the upper reach of the Agua Fria River in numerous locations such as Morgan City Wash, Caterpillar Tank Wash, and Twin Buttes Wash. These washes are uncontrolled and drain generally undeveloped desert areas.

Below the uncontrolled drainage area is the McMicken Dam outlet channel, a potentially major tributary. According to the Corps' 1988 study, "no contributing flow from McMicken Dam was included in the discharge-frequency evaluation of Agua Fria River because it either occurs at a different time than local flow due to longer time of concentration, or a different season than New Waddell Dam." The design storm for New Waddell Dam is a general winter storm, as compared to a summer thunderstorm for McMicken Dam.

The next major tributary is the New River. The New River accepts runoff from the Arizona Canal Diversion Channel (ACDC), which was constructed to divert floodwaters from north central Phoenix to the New River. Flood control dams located on the New River, Skunk Creek, Cave Creek, and Dreamy Draw play an integral role in the functioning of this system. In the 1995 report, the Corps considered the inflow from the New River for estimating peak discharges, although documentation of the specific hydrographs used was lacking. The hydrographs developed for the New River were based on the SPF rather than the 100-year event.

Flood Routing

The 100-year flood routing model of the Agua Fria River has been undertaken as a general evaluation of floodwave attenuation as impacted by floodplain encroachment. In general, floodwaves can be attenuated where significant floodplain storage exists. The question being evaluated is whether floodplain encroachment as allowed under the floodplain regulation would lead to loss of attenuation and increasing flood peaks.

4.3.1 Methodology

Due to the presence of levees in the lower reach, the analysis was terminated at the New River Confluence. Separate models were created for the remaining upper and middle reaches. For these reaches, hydrographs from the Corps' 1995 study were directly input into the model.

The 9,000-cfs outflow expected from the New Waddell Dam during large storms was not included in this analysis since it is understood that its release would not coincide with flows occurring in the uncontrolled lower watershed. Combined probability computations were performed by the Corps to determine a discharge-frequency relationship. The evaluation found "that for a specific frequency, the local runoff value was much larger than that for the routed dam flow."

The flood routing investigation was accomplished using the modified Puls routing method in HEC-1 to route the Corps regulatory hydrographs. The modified Puls method is ideal for this evaluation because it assumes that the river corridor is a linear reservoir, thus accounting for floodplain storage.

4.3.2 *Floodplain Storage*

Floodplain storage occurs naturally in floodplains. The impact of storage on floodwave attenuation tends to be most pronounced in wide floodplains and less pronounced in narrow floodplains. The Agua Fria River upstream of the New River has both confined reaches and wide reaches. Sand and gravel pits are scattered throughout the River both inside and outside the floodway. Some of these pits can provide significant storage volume that assist in the attenuation of floodwaves.

A key aspect of the hydrologic model was estimating the stage-storage-discharge relationships for the watercourse. Stage-storage curves were developed on a reach-by-reach basis using HEC-RAS to compute total volumes. These total volumes were then used as initial conditions in the HEC-1 models. In order to simplify the model, direct channel losses and additional inflow were assumed to be negligible.

To estimate floodplain storage at various flow rates, a multiple-profile analysis was developed in HEC-RAS. At each flow rate, an estimate of reach storage was obtained from the HEC-RAS output. Since this analysis was for hydrologic purposes, the ineffective flow records of the HEC-RAS model were modified to include hydraulically connected areas. However, some encroachment records were added to the model to separate the hydraulically continuous channel from the sand and gravel pits.

The addition of encroachment records does not eliminate the impact that sand and gravel mines have on the river; rather it clarifies the limits of the channel. All sand and gravel mines within the floodplain were modeled unless they were considered hydraulically disconnected.

For the floodway analysis, storage volume estimates were obtained directly from the floodway run of the HEC-RAS model. The Floodway model is independent of the location of sand and gravel mines. Encroachment records are placed at the floodway line without regard to the sand and gravel mines.

4.3.3 *Results of Flood Routing Analysis*

Two conditions were modeled for this investigation. The first was the Floodplain model depicting the existing non-encroached floodplain. The second was the Floodway model, which is the floodplain encroached to the regulatory floodway line. The floodplain model was developed to establish a baseline flow condition from which to compare the impacts of future encroachments. Due to the significant variation between the routing methods used by the Corps (Muskingum Routing) and Modified Puls, it had been unclear as to how closely the Corps' results would match with the floodplain model. However, the results of the floodplain model for all practical purposes matched the published results of the Corps. However, one significant variation is the timing differential between KHA's and the Corps' floodplain models. The peak flow rate for the KHA models occurs about two hours later than the Corps' model. In evaluating the issue of timing, it was concluded that this delay in timing in part represented the time for floodwaters to fill up channel storage, most notably sand and gravel pits.

The Floodplain model shows a significant amount of flow attenuation through the river reach. In general, the more narrow incised upper reaches had less attenuation than the wider southern reaches. However, flood attenuation was most dramatically impacted in the reaches with significant sand and gravel mining activity. Three areas in particular stand out: south of Jomax Road to Beardsley Road, north of Grand Avenue to Bell Road, and near Northern Avenue.

Comparison of the Floodplain and Floodway models in Table 4.3-1 confirms the assumption that encroachments on the flood fringe will increase peak flows downstream and decrease the time it takes for the river to peak.

Table 4.3-1 - Peak Flow Comparison

Location	Corps Q (cfs)	KHA Floodplain Q (cfs)	KHA Floodway Q (cfs)
D/S New Waddell Dam	22,000	22,200	22,200
Jomax Road	N/A	20,000	20,500
U/S Bell Road	N/A	15,300	19,700
CP1037 (Bell Rd.)	37,500	37,500	37,500
CP1038 (Grand Ave.)	34,500	34,400	36,600
CP1039U (U/S New River)	30,000	30,300	35,200

The subreach from New Waddell Dam to Jomax Road originates at the upper end as a canyon-like reach with minimal overbank storage. Near the CAP siphon, the River broadens into a wider floodplain. Currently, there is no significant in-channel mining activity upstream of Jomax Road. In the subreach between Jomax and Bell Road, several large sand and gravel mines characterize the River. The Floodway model demonstrates that peak flow rates would increase by approximately 30% upstream of Bell Road if the floodplain were encroached to the floodway line.

The middle subreach, between Bell Road and the New River confluence, is also impacted by sand and gravel mines. Encroachment to the Floodway causes a 16% increase over the Floodplain model just north of the New River confluence. While it is not possible to precisely evaluate the percentage of attenuation that can be attributed to sand and gravel mining versus floodplain storage, it is apparent that attenuation is significantly impacted in those areas with large pits in the flood fringe.

4.3.4 *Conclusions*

The objective of modeling the hydrologic routing was to determine how much floodwave attenuation occurs in the River under existing conditions and ultimate conditions (encroachment to the floodway line). The Floodplain model produced results similar to the regulatory flow rates established by the Corps between Bell Road and the New River confluence. Sand and gravel pits, like those north of Grand Avenue, provide a significant amount of storage volume that accounts for some of the attenuation in the Floodplain model. Further, the floodway model demonstrates that downstream flood peaks will increase significantly (up to 30%).

It was noted that floodplain encroachment led to a decrease in the time to peak by approximately two hours. Based on existing studies, it was not possible to determine if flow rates downstream of the New River confluence would be adversely impacted by this shift in timing.

4.4 ***RETENTION MODELING***

The retention investigation, which encompassed the entire river downstream of New Waddell Dam, was based on simplified retention and future condition assumptions. The purpose of the analysis was to evaluate the effectiveness of retention policies in reducing flood peaks along the Agua Fria River from New Waddell Dam to the Gila River confluence.

Maricopa County and many of the municipalities in the Phoenix metropolitan area established storm water retention policies in the mid to late 1980s to ensure that future development would not adversely impact downstream areas of the watershed. The majority of municipalities require onsite retention of runoff from the 100-year, 2-hour rainfall. Although not all municipalities have the same retention criteria, they all have a retention requirement of no less than the 100-year, 1-hour rainfall.

The City of Surprise is the largest municipality with the less stringent 100-year, 1-hour rainfall criteria. The majority of the City is in subbasin 35, which drains to McMicken Dam. Subbasins 36 and 39 are both influenced by the City's criteria. Approximately 50 percent of Subbasin 36 and 60 percent of Subbasin 39 are in the City of Surprise. Less than five percent of any other subbasin was affected by the lesser criteria.

4.4.1 *Hydrologic Retention Models*

An existing condition model was created by KHA to provide the framework to develop three future condition models. The existing condition model is a reconstruction of hydrology originally presented in the Corps' 1995 study. The model was reconstructed using input parameters from the Corps' model including rainfall curves, loss rates, percentage of impervious area, and physical basin parameters such as slope, area, and roughness.

The Corps transformed the existing condition hydrologic model to a future condition model by increasing the percentage of impervious area in the watershed. The Corps had developed a land use map that projected future development in the Agua Fria River watershed for the year 2071. The Corps used the mapping to estimate the increase in impervious area due to future development. The percentage of impervious area was the only parameter that changed between the existing and District's future models presented in the 1995 study.

Based on the foundation of the existing condition model, KHA created three hydrologic retention models to compare the impact of retention regulations. As with the Corps hydrology, the fundamental difference between the existing condition model and the future condition models is an increase in the percentage of impervious area within the watershed. This difference is reflected in the diversion records. All models use 6 and 24-hour storms to compare the effectiveness of retention policies during larger storms.

4.4.2 *Methodology*

The Corps' HEC-1 program was used to create the existing drainage runoff model throughout the watershed. This model was created by inputting the Corps' parameters directly into the MCUHP2 program and HEC-1. It is noted that the results of the KHA existing conditions model indicated that peak flow rates were slightly higher than those used in the Corps' regulatory model. This was expected since the Corps' 100-year results are a function of the SPF event. The differences were not a concern since the objective of the modeling is to evaluate the effectiveness of the retention policies, not duplicate peak flows produced by the Corps' modeling.

As described below, the three future condition models were created based on the KHA existing condition model. In all, the percentage of impervious area was increased to match the Corps' future condition models.

<u>No Retention Model</u>

The percentage of impervious area was increased to future condition levels to create the No Retention Model. This is considered to represent the worst case scenario. No other modifications were made to this model.

<u>Retention Model I</u>

The Retention I Model incorporated retention into the watershed by using a simplified assumption that all runoff was retained at the end of the major drainage basins. Diversion records were added to the HEC-1 model at the end of the major drainage basins to represent retention of a calculated volume of runoff. Once the retention volume was satisfied, runoff was no longer diverted out of the model. The retention volume was calculated using Equation 8.1 of the District's Drainage Design Manual, Volume I:

$$V = C * A * P / 12$$

Where

V = Volume Required, ac-ft

C = Runoff coefficient (assumed to be 0.6 for single family homes)

A = Contributing Drainage Area, acres

P = Rainfall depth, in. (determined from the PREFRE program)

The rainfall depth used to calculate retention volumes was adjusted to reflect the difference in retention criteria within the City of Surprise. See Table 4.4-1 for a volume calculation summary.

The amount of available retention storage from each subbasin was determined based on the difference in impervious area between existing and future condition land uses. It was assumed that retention would be provided in areas developed in the future. The increase in the percentage of impervious area in each subbasin was multiplied by the area of the subbasin to determine the area developed in the future condition. The developed area and runoff coefficients were then used to determine the amount of potential storage.

Table 4.4-1 - Retention Volumes

Basin	A (ac)	Vol (ac-ft)
1036	5,811	755
1037	17,229	2,240
1039	16,979	2,054
1040	26,112	3,395
1042	5,709	742

Retention Model II

The Retention II Model recognized that only a portion of the runoff would be diverted to retention storage since part of the watershed was developed prior to the implementation of a retention policy. Therefore, diversion records within the HEC-1 model were configured to allow a portion of flow to bypass to the river while retaining the remainder of the flow up to the specified volume.

4.4.3 *Results of Retention Analysis*

The existing condition model produced results higher than anticipated, but reasonable enough to serve as a basis for the future condition model and retention models. The increase in percentage of impervious area increased the future condition flows over existing conditions by varied amounts. In the Retention I model, the time to peak lengthened and the peak flows decreased at the concentration points. The retention volume had no effect on peak flows exiting the subbasins.

The Retention II model used a modified approach to the diversion records. This model showed longer times to peak and decreased peak flows, confirming that retention basins have a positive effect on the peak flows out of the subbasins and in the river.

See Table 4.4-2 for a comparison between models for the 100-year, 6-hour storm.

Table 4.4-2 - Comparison between Retention Models

Location	Existing	Future	Retention I	Retention II
	Qpeak(cfs)	Qpeak(cfs)	Qpeak(cfs)	Qpeak(cfs)
Sub-basin 1036	21,500	22,100	22,100	22,100
Sub-basin 1037	24,800	26,400	26,400	26,400
CP1037 @ Bell Rd.	43,800	45,900	45,700	36,500
Sub-basin 1039	21,600	23,100	23,100	23,100
CP1039 @ New River	39,800	41,600	39,200	33,600
Sub-basin 1040	28,300	31,900	31,900	31,900
CP1040 @ I-10	41,500	48,300	38,300	35,200
Sub-basin 1042	5,500	6,400	6,400	6,400
CP1042 @ Avondale	40,000	48,000	37,600	33,300

4.4.4 *Conclusion*

The objective of the retention model was to evaluate the effect of current retention policies on a fully developed watershed. Based on simplified assumptions, the current retention policy will effectively control inflows to the Agua Fria River and no additional increase in retention storage is necessary to account for watershed development.

Assuming a standard retention basin depth of three feet, the one-foot freeboard requirement provides an additional 30-40% capacity in each basin. Although this is a significant volume, it is not incorporated in any of the retention models.

4.5 *Summary of Hydrologic Modeling*

The results of the hydrologic evaluation of retention policies and floodplain storage indicate the following:

- There is a significant amount of attenuation in certain stretches of the Agua Fria River, which can be positively influenced by properly placed sand and gravel mines, while other areas pass flows through with very little attenuation.
- Results from the Floodway model indicate that encroachment on the floodplain by development or through flood control structures would increase flows in certain river sections by nearly 30%.
- The results from the retention models showed that current retention policies are effective in controlling the peak flow rates from subbasins.

5. HYDRAULICS

5.1 Introduction

A key criterion for evaluating the feasibility of alternatives for the Watercourse Master Plan is the hydraulic response of the river. It is the District's intent to avoid adversely impacting the river's conveyance capacity. Therefore, any structural elements or changes to the vegetation within the river must be evaluated and, if necessary, mitigated. The hydraulic evaluation was performed by LTM Engineering, Inc. (LTM, 2001) and is presented herein.

5.2 Current Planning Model

The District's current Flood Insurance Study (FIS) model was used to form the basis of comparison between current and potential future conditions (CVL, 1996). This model was developed by others using the Corps' HEC-2 Water Surface Profiles program. Peak flow rates from the FIS model shown in Table 5.2-1 were unchanged for the converted model.

Table 5.2-1 - Peak Flow Rates
For the Hydraulics Evaluation of the Agua Fria River

River Station	Peak Flow (cfs)	Approximate Location of Flow Change
33.82	9,000	4,000 ft. below dam
33.41	19,000	Morgan City Wash
31.86	21,000	1 mi. S. of SR74
30.46	23,000	
29.04	25,000	
27.77	27,000	
26.37	29,000	
25.098	31,000	0.5 mi. S. of Jomax Road
23.692	33,000	
22.273	35,000	
20.675	37,500	1.7 mi. N. of Bell Road
17.548	36,000	
16.385	34,500	Below Grand Avenue
11.428	30,000	
9.696	54,400	New River
5.305	52,000	I-10
3.77	50,900	Buckeye Road

This HEC-2 model was imported into HEC-RAS and the results of both models were compared. The model conversion, while straightforward, exhibited minor variations compared to the HEC-2 model due to differences in computational methods. As a result, the HEC-RAS model was adjusted to better represent conditions within the river. The primary differences were in-channel velocities at bridge crossings and in top widths, typically at locations with sand and gravel operations.

It is noted that the focus of the conversion and subsequent adjustments was not to duplicate the current FIS model, but to form a basis for analysis of alternatives in this planning study.

The converted model was then used as a basis for developing a practical, updated planning model that was used to develop and compare alternative solutions for the Watercourse Master Plan. As described below, this modified Current Planning Model includes recent development and minor modifications to the existing levee portions of the study area.

5.2.1 Recent Development

Aerial photographs, LOMR data, discussions with local jurisdictions, and field investigations were used to identify post-1996 development. Additionally, known proposed developments as of April 2001 were included. Two methods were used to represent the encroachments. For developments based on fill, blocked obstruction records were added to the HEC-RAS model at an assumed elevation of one foot above the floodway water surface elevation. For developments protected by levees, levee records were added. A list of the new developments and their locations is presented in Table 5.2-2.

Table 5.2-2 - Agua Fria Watercourse Master Plan
Inventory of Post-1996 Developments

Name of Development	Approximate Location
Unnamed	N. of Greenway, west side
Arizona Brisas Ph. 2 & 3	NW cor Cactus & 115th Ave., west side
Sundial IV (Planned)	SW cor Cactus & 117th Ave., west side
Suncliff	N. of Northern, east side
Glendale Landfill	SE cor Northern & 115th Ave. east side
Unnamed	S. of Glendale east side
Glendale Airport	At New River Confluence east side
Camelback Ranch	South of Camelback Rd., east side

5.3 *Hydraulic Response to Alternatives*

The hydraulic response of the Agua River focuses on several components of the Watercourse Master Plan:

- Structural Alternative
- Non-structural Alternative
- Multi-Use Opportunities
- Recommended Alternative

The methodologies and results are presented below.

5.3.1 *Structural Alternative*

The structural alternative consists of completing the existing levee system for the entire river between New Waddell Dam and its confluence with the Gila River. This scenario is hydraulically equivalent to encroachment of the floodplain up to the floodway. Therefore, the effect on the river would be identical to that already evaluated in the floodway run of the HEC-RAS model. Since this condition is the basis of regulation for development, no further analysis was required. Therefore, a purely structural alternative would not hydraulically impact the Agua Fria River above what is allowed under current regulations and practices.

5.3.2 *Non-structural Alternative*

The focus of the non-structural alternative is to reduce property damages and loss of life by preserving the natural floodplain and preventing development from encroaching. While the structural alternative represents the upper boundary of impacts of development on the floodplain, the non-structural alternative reflects the lower boundary where the floodplain is allowed to function naturally. The effect is typically lower floodwater depths and velocities since the water is allowed to spread over the floodplain rather than being artificially constricted within the floodway.

Because the river corridor is already partially developed and has existing structures such as bridges and levees, the hydraulic effect of implementing a non-structural alternative would lie somewhere between purely structural and non-structural approaches. Therefore, negative impacts of development (increased water surface elevation, higher velocities) on the system are reduced but not eliminated.

5.3.3 *Multi-Use Opportunities*

Several elements of the multi-use components of the study include changing the vegetative character of portions of the river. The methodology used to evaluate the effects of these changes focuses on corresponding changes to the roughness coefficient, Manning's n, used in the evaluation. A procedure was developed to modify the roughness coefficient in the channel where changes to the vegetation were being considered. The procedure was based on the U.S. Geological Survey's "Estimating Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona" (Thomsen and Hjalmarson, 1991). The USGS' procedure requires the selection of a base n value assuming a straight, uniform channel of a given bed material. The base value is then increased according to the degree of channel irregularity, obstructions, and vegetation to create a composite n value.

Using the USGS' methodology, adjustments to the n values could be made to reflect increases of individual components. For this analysis, adjustments were made to reflect increased vegetation (ground cover such as grasses, bushes, and tree seedlings) and obstructions (trees). Trees were not included in the vegetation component because their effect on the river hydraulics fits the USGS definition of obstructions better.

5.3.3.1 Trapezoidal Channel (Grand Avenue to the CAP Canal)

A trapezoidal channel was assumed along the Agua Fria River from Grand Avenue to the CAP Canal. The "low flow" portion would accommodate about half of the 100-year flow. The remaining flow would be contained by a larger cross section that contains a flat "bench" portion. A 50-foot wide landscaped trail would be located along the bench section. It was assumed that ground cover and trees would occupy about 40% of the trail. Of this, 2/3 would be ground cover and 1/3 would be trees.

A base n value of 0.30 was selected to represent this constructed trail along the bench. Using the USGS procedures, the n value was then increased to 0.052.

5.3.3.2 Landscaped Trail

To account for additional vegetation in a trail setting, a 100-foot wide landscaped section was analyzed extending along the entire length of the Agua Fria River. Vegetative treatment was assumed to be similar to that used in the trapezoidal channel described above. Therefore, the n value for the landscape associated with the landscaped trail would also be 0.052.

5.3.3.3 Plated Levee

Another element of the non-structural alternative was to plate the existing levee in a portion of the lower reach of the Agua Fria with soil at a gentler slope to allow pedestrian access from adjacent neighborhoods. The plate would extend approximately 0.5 mile, from Coldwater Park near Buckeye Road north to the I-10 Riparian section 0.5 mile south of Van Buren Street. The plated levees were modeled by moving the toe of the existing levees inward so that the side slope was decreased to about 6 (horizontal) to 1 (vertical). Additionally, vegetative treatment was assumed to be added similar to that used in the trapezoidal channel and landscaped trail described previously. Therefore, the n value for the landscape within the plated levee would also be 0.052.

5.3.3.4 Hydric Riparian Habitat Near I-10

Others are proposing tree plantings in areas upstream and downstream of I-10. Therefore, a hydric riparian section was assumed to extend from 0.5 mile south of Van Buren Street to McDowell Road. The channel cross section is uniform in this section and was modeled in the 1996 FIS study with an n value of 0.03. To accommodate the additional trees, the n value was increased to 0.067.

5.3.4 Results of Multi-Use Analysis

The Watercourse Master Plan allows for non-flood overlays that would meet its multi-use goals. However, the non-flood overlays must be evaluated to determine their effects on the hydraulic response of the river. Therefore, the n values in the HEC-RAS model were modified according to the procedures identified above and the model was re-run to evaluate their effects. Separate runs were made in order to evaluate river response to each of the components. Hydraulic response for each component is described below.

5.3.4.1 Effects of Trapezoidal Channel

A trapezoidal channel from Grand Avenue to the CAP Canal would include a bottom section that would contain about half of the 100-year flow. The top portion, which includes a benched section to accommodate a trail, would contain the remainder of the 100-year flow. Because the channel would contain all of the 100-year flow, it was not necessary to perform further analysis on the hydraulic impacts from a regulatory standpoint. Rather, criteria such as economics and public safety were considered to be overriding factors and are evaluated separately. Therefore, no further hydraulic evaluation was performed for this component.

5.3.4.2 Effects of Landscaped Trail

The effect of a 100-foot wide landscaped trail on the floodplain was analyzed. It was found that within the lower reach of the study area (Gila River confluence to New River confluence), increases in the water surface elevation were limited to 0.20 feet or less and increases in top width were insignificant except at the confluence with the Gila River.

Increases in flow depth in the middle reach were consistently between 0.2 and 0.5 foot with several locations exceeding a 1-foot rise north of Glendale Avenue and south of Grand Avenue. Increases in top widths of more than 100 feet were noted at several locations between Glendale and Olive Avenues.

In the upper reach, increases in water surface elevation between 0.20 and 0.50 occurred fairly consistently, with top widths exceeding 100 feet north of Grand Avenue and at several locations between Jomax Road and the Beardsley Canal.

5.3.4.3 Effects of Plated Levee

It was established that the computed water surface elevation must match pre-landscape conditions (to within 0.10 feet) at Camelback Road in order to be considered feasible. Camelback Road is about 4.5 miles upstream of the proposed plated and landscaped levee. Results of the analysis showed that computed water surface elevations rose within the plated section by as much as 0.6 feet, and met the 0.10-foot rise criterion within 0.5 mile upstream of the plated section. This is well below the 4.5-mile distance to Camelback Road.

The channel velocities generally decreased, typically by 1-2 feet per second (fps). However, velocities in this portion of the river under existing conditions are typically 7 to 9 fps. Therefore, it may be difficult to anchor plantings under the increased velocity conditions without additional low-flow protection and the understanding that vegetation would be lost under high-flow conditions.

5.3.4.4 Effects of I-10 Riparian Habitat

As with the plated levee scenario, it was established that the computed water surface elevation must match pre-riparian conditions (to within 0.10 feet) at Camelback Road in order to be considered feasible. Camelback Road is more than three miles upstream of the proposed riparian section. Results of the analysis showed that computed water surface elevations rose within the riparian section by as much as 5.3 feet, but met the 0.10-foot rise criterion within 0.8 mile upstream of the riparian section. This is well below the 3-mile distance to Camelback Road.

Channel velocities in this section were reduced significantly in the riparian section, ranging typically from 6 to 11 fps to 6 to 7 fps.

5.3.4.5 Effects on Levee Operations

Another feasibility criterion was that the computed water surface elevation could not violate the freeboard requirements of three feet within the levees under the flow regime of the 1989 Standard Project Flood (SPF). The 1989 SPF flow rates within the levees are as follow in Table 5.3-1:

Table 5.3-1 - Agua Fria River
Post-Waddell Standard Project Flood Flows

River Station	Approximate Location	Flow Rate
8.03	Indian School Road	102,000
5.305	I-10	99,000
3.77	Buckeye Road	97,000
0.16	Confluence with Gila River	92,000

During the analysis, it was discovered that the levees do not meet the 3-foot freeboard requirements under existing conditions at two locations:

- East levee at Buckeye Road (freeboard ~ 2.7 feet)
- East and west Levee downstream of Indian School Road (freeboard ~ 1.9 feet)

The effect on SPF conditions of a plated levee and a riparian section near I-10 was analyzed. Results of the analysis showed that the freeboard requirement would be exceeded due to the potential landscape features in most places between Buckeye Road and Van Buren Street, and from McDowell Road extending about one-half mile north.

A second scenario was analyzed of riparian habitat only (no plating of the levee at Coldwater Park). This scenario was developed to evaluate the effect on freeboard of a less dense, or isolated riparian habitat. A palate similar to that used in the plated levee scenario was assumed. Additionally, the isolated riparian section was terminated just upstream of the I-10- channel instead of just north of McDowell Road assumed in the hydric riparian scenario.

- The modified vegetative palate and shortened section resulted in the elimination of compromised freeboard south of Van Buren Street. In addition, compromised freeboard at McDowell Road was essentially eliminated. Only one cross section fell below the 3-foot freeboard requirement at 2 feet. In general, this modified restoration reach would appear to be feasible.

5.3.4.6 Comparison of Levee Elevation Data

An approximate comparison was made of elevations of the top of levee due of the 1996 FIS levee elevation data versus recent elevation data provided by the District. Differences in elevations were found, both positive and negative. It was found that freeboard was compromised at two additional locations:

- East levee immediately upstream of I-10
- West levee immediately downstream of McDowell Road

At both of these locations, the difference in elevation between the 1996 FIS model and recent spot elevation data is about 8 feet. It is noted that this significant difference in elevation could be explained by the proximity of I-10 and McDowell Road where changes in elevation can be dramatic depending on the location of the cross section versus the spot elevations.

5.4 Sand and Gravel Mining Hydraulics

It is proposed to adopt a No Adverse Impact policy toward sand and gravel mining within the Agua Fria floodplain. Miners will be required to limit the impact of their operation to the boundaries of the parcel being mined. It is anticipated that the implementation of the policy may result in:

- Reduction or elimination of mining within the regulatory floodway
- Limiting floodway mining to the depth of the thalweg that was established in 1987
- Construction of levees at the edge of the pits
- Require that the pits accept floodwaters in excess of the 50-year flood

A HEC-RAS model was prepared to establish the limits of the 50-year flood requirement and was compared to the regulatory (encroached 100-year) floodway. It was assumed that the 100-year flow is contained within the floodway and that the mines would be continuous on both sides of the river between Camelback Road and the CAP Canal.

Peak 50-year flow rates were taken from the Corps' "*Agua Fria River Study, New Waddell Dam to Gila River Confluence, Arizona*" (Corps, 1996). However, the Corps peak flow rates did not take into account significant flow contributions in the upper reaches of the Agua Fria River such as from the Morgan City Wash watershed. Therefore, between Bell Road and New Waddell Dam, a ratio of the Corps' peak 50- and 100-year flow rates at the Gila River confluence was applied:

$$\frac{\text{Peak 50-Year}}{\text{Peak 100-Year}} = \frac{35{,}000}{48{,}000} = \mathbf{0.73}$$

Using this combined methodology of Corps flows and ratios, peak flow rates within the study area were estimated and are presented in Table 5.4-1. The resulting 50-year and 100-year water surface elevations were tabulated and graphed in approximately two-mile segments. The tables and graphs are included in "*Hydraulic Analysis for the Agua Fria Watercourse Master Plan, LTM Engineering Inc., 2001*" and in *"Aqua Fria River Watercourse Implementation/Maintenance Strategy, Kimley-Horn and Associates, Inc., 2001"*.

Table 5.4-1 - Peak Flow Rates for the Sand & Gravel Evaluation

River Station	100-Year Peak Flow (cfs)	Corps 50-Year Peak Flow (cfs)	Interpolated 50-Year Peak Flow * (cfs)	Approximate Location of Flow Change
33.82	9,000	9,000		4,000 ft. below dam
33.41	19,000		13,680	Morgan City Wash
31.86	21,000		15,120	1 mi. S. of SR74
30.46	23,000		16,560	
29.04	25,000		18,000	
27.77	27,000		19,440	
26.37	29,000		20,880	
25.098	31,000		22,320	0.5 mi. S. of Jomax
23.692	33,000		23,760	
22.273	35,000		25,200	
20.675	37,500	29,000		Bell Road
16.385	34,500	26,500		Below Grand Ave.
11.428	30,000	23,000		
9.696	54,400	39,000		New River
5.305	52,000	38,000		I-10
3.77	50,900	37,000		Buckeye Rd.

* Interpolated flow derived as a ratio of 0.73 times the 100-year peak flow.

5.5 Recommended Alternative

As described in this report, portions of the structural and non-structural alternatives were analyzed to establish the feasibility of potential master plan elements. The results of the hydraulic analysis are being incorporated in developing the Watercourse Master Plan. The Current Planning Model documents the hydraulic effects associated with implementing the Recommended Plan.

6. LATERAL MIGRATION

6.1 Project Background

6.1.1 *Lateral Migration Analysis Report*

A variety of analyses were performed to assess the potential for future lateral migration of the Agua Fria River from New Waddell Dam to the Gila River. Detailed descriptions of these analyses are provided in the Agua Fria River Lateral Migration Report prepared by JE Fuller/ Hydrology & Geomorphology, Inc. (JEF, 2001).

Base data on the watershed, hydrology, geology, and geomorphology of the study reach establish the context for the assessment of lateral stability. These data were also used to define fifteen stream reaches with relatively uniform geomorphic and geographic characteristics. The stream reaches defined for the lateral stability assessment vary from natural-appearing reaches that are significantly impacted by upstream dams to highly disturbed reaches with active in-stream sand and gravel mining, channelization, and floodplain encroachments. The physical and visual characteristics, landscape character, and geomorphic characteristics vary significantly over the length of the study reach.

Despite minimal historical changes in most of the Agua Fria River watershed upstream of New Waddell Dam, the hydrology of the study reach has been significantly modified over the past century due to the following:

- New Waddell Dam. Together with its historical predecessor, Waddell Dam, the New Waddell Dam has impounded most of the natural low flow runoff from the upper watershed since 1927. Therefore, the natural low flow hydrology has little impact on the existing channel morphology. Currently, floods up to the 10-year event are completely impounded behind the dam. Depending on the pre-flood storage capacity, even less frequent floods could be totally retained in Lake Pleasant.
- Other Dams. Other dams in the Agua Fria watershed include the New River Dam (New River), Adobe Dam (Skunk Creek), Cave Creek and Cave Buttes Dams (Cave Creek), McMicken Dam (Trilby Wash), and White Tanks Flood Retarding Structure (FRS) #3. These flood control dams further reduce the low flows, peak flood discharges, and sediment supply delivered to the study reach. Only 17 percent of the 2,700 square mile watershed is not controlled by dams.

- Diversions. The Arizona Canal Diversion Channel (ACDC), McMicken Dam, and the I-10 Outfall Channel expand the watershed area that ultimately drains to the study reach, potentially increasing the volume of water delivered within the study reach during large floods.
- Urbanization. Urbanization of the West Valley downstream of New Waddell Dam has changed the natural hydrology in the study reach in conflicting ways. Urbanization typically results in more frequent runoff, higher peak flows, higher flow volumes, reduced sediment supply, and "flashier" floods compared to non-urbanized watersheds due to less infiltration and other losses. However, enforcement of storm water retention requirements in areas that were developed in the past 15 years may have reduced flood volumes and peak discharges in some watersheds. Of the 460 square miles of watershed not controlled by dams, more than half are highly urbanized or will be within 10 years.
- Return Flows. Irrigation return flows, discharge from water and wastewater treatment plants, and other point sources of manmade runoff supply water to the study reach at different rates, locations, durations and seasons than the natural water supply.

These changes in the natural hydrology of the Agua Fria River complicate the assessment of lateral stability. Clearly, historical (pre-dam & urbanization) stream behavior in response to periods of low flows has little applicability to future channel behavior. However, lateral channel movement during floods may be similar to historical flood responses, but will be complicated by changes in peak discharge, flow duration, and sediment supply. It is likely that floods will be the dominant cause of significant lateral channel movement in the study area.

The geologic record indicates that the Agua Fria River has experienced net degradation at about 0.02 to 0.06 mm/year over the past two million years. Given that shorter cycles of aggradation undoubtedly occurred within this time period, much higher rates of degradation are implied over shorter time periods. Net degradation of the Agua Fria River created a series of older, stable terraces that effectively define the limits of long-term lateral channel movement. These geologic estimates of long-term degradation and lateral movement may be used as boundary conditions for predictions of channel response within engineering time scales. Other geologic impacts on the study reach include base level adjustments to the Gila River and land subsidence due to groundwater withdrawal. Geomorphic stream classification data indicate that the Agua Fria River is subject to rapid bank erosion rates, except where the banks are stabilized by carbonate-cemented soils, bedrock, or engineered stabilization measures.

Field observations and spatial data were collected that describe the existing conditions of the Agua Fria River study reach. Extensive field visits to the study area, conducted over a period of several months, consisted of walking the entire 36-mile study reach, photographing and mapping key features, and recording descriptions of existing channel conditions. Specifically, stream reaches with evidence of recent or historical lateral erosion, degradation or aggradation, human impacts or structures, and points of natural grade control were identified. These data included the following:

- Evidence of active erosion – locations of cut banks, headcuts, slope breaks, unstable bank heights.
- Evidence of lateral erosion limits – locations of bedrock and caliche outcrops, terrace boundaries, armor layers, natural grade control, permanent bank vegetation, and manmade structures.
- Evidence of channel and floodplain processes – bank heights, channel and floodplain particle sizes, bank material composition and stratigraphy, and tributary confluences.
- Evidence of human activities – sand and gravel mines, bridges, at-grade road crossings, levees, grade controls, bank protection, utility crossings, irrigation and water supply crossings, residential or commercial development, illegal dumping, and a sanitary landfill.

Field data indicate that the Agua Fria River study reach has been significantly impacted by development and in-stream mining, and that, despite historical decreases in peak discharges, it is subject to high rates of lateral channel movement during floods. The direct impacts by humans on the channel and floodplain have the potential of completely overshadowing the potential changes due to natural processes.

Historical information was synthesized to illustrate the types of channel changes that have occurred in the past. Archaeological records imply that channel erosion has affected the Agua Fria River for at least 2,000 years. That is, lateral erosion is not caused solely by human impacts on the channel and watershed. Natural cycles of stream degradation, local aggradation, lateral migration, and climate change must be accounted for in development of the erosion hazard zones and the watercourse management plan. Climatic changes have been significant factors in long-term lateral erosion and channel development.

An inventory of changes to the Agua Fria River based on historical maps and aerial photographs indicates that human impacts have been substantial in the past 100 years. These impacts include construction of 11 major bridges, three dedicated at-grade road crossings, the Beardsley Canal flume, the CAP and RID siphons, numerous in-stream and floodplain sand and gravel mines, overhead and buried utility crossings, floodplain encroachments, a major sanitary landfill, residential and commercial subdivisions, recreational facilities, illegal dumping, off-road vehicle use, water treatment facilities, groundwater recharge facilities, an airport, and several major flood control dams. Additional bridges, at-grade crossings, and utility corridors are proposed for the future. The existing river bears little resemblance to its prehistoric ancestor. Except for the decrease in low flows and reduction of flood peaks due to construction of New Waddell and other dams, human impacts tend to destabilize stream channels and lead to increased rates of lateral erosion due to reduced sediment supply, increased flood flow durations, and direct excavation of the channel for mining.

Although historical changes in watershed hydrology imply that use of pre-New Waddell Dam channel changes may lead to conservative estimates of future channel movement due to decreased peak flows, historical data do provide the most reliable physical basis for such predictions. That is, while the future lateral movement of the Agua Fria River may be somewhat muted compared to past lateral movement, the historical data changes at a minimum represent the upper boundary of predictions of future changes. Furthermore, given the uncertainty in flood storage conditions in Lake Pleasant, the potential for large, sustained, erosive outflows from New Waddell Dam still exists. The scale of lateral erosion during such a large flood would be analogous to the scale of erosion during historical, pre-New Waddell Dam floods. Therefore, measurements of long-term and single event lateral and vertical erosion were made for the Agua Fria River from historical maps and aerial photographs to establish a baseline of potential channel movement.

Historical aerial photographs for the entire study reach were available as early as 1949 and extended through 1999. Thirteen individual years of coverage for various extents of the river were evaluated, digitized, and catalogued. Historical topographic maps dating to 1903 were available for most of the study reach, although 1957/1962 was the earliest topographic coverage of the entire reach. Six individual years of topographic coverage were used to estimate historical vertical changes along the river. GLO survey data extended the record of channel position back to the late 1800s. The types of channel changes documented by the historical maps and aerial photographs included channel avulsions, bank collapse, channelization, scour, headcutting, channel width changes, formation of multiple channels, braiding, and sediment deposition.

Historical channel width and channel position has changed significantly during the past 100 years. Overall, the average channel width decreased from 1,696 feet in 1953 to about 968 feet in 1999, except in the levee reach where the channel was artificially widened during levee construction. Despite this historical narrowing trend, significant lateral movement was observed. The maximum-recorded channel movement during the period of record was more than 2,200 feet. During the 1980 flood alone, the channel near Indian School Road widened by more than 1,100 feet. Avulsions were the primary mechanism for the largest long-term channel movements in the study reach. Bed elevations fluctuated throughout the study reach, with an overall decrease (degradation) during the period of record. The maximum measured degradation between 1903 and 1995 was 13 feet, with most of the degradation occurring after 1957. No reaches experienced net aggradation during the period of record, including the reaches nearest the Gila River confluence. The scale of lateral channel change observed on historical maps and aerial photographs is not significantly different than the scale of the changes estimated by interpreting the age and characteristics of geomorphic surfaces along the river corridor. The rate of lateral movement has been fastest on the youngest, less indurated surfaces and slowest along the margins of the older, more indurated surfaces. Therefore, the older terrace margins serve as a practical limit for predicted future rapid channel change, although the older terraces are also subject to (slower) lateral erosion where abutted by the main channel.

Mathematics-based engineering and geomorphic analyses were used to predict future channel behavior and to assess the potential for lateral channel migration. Hydraulic data used in the mathematical analyses were obtained from the HEC-RAS model prepared for this study. Modifications were made to the -HEC-RAS model to better depict the full range of discharges considered, to focus on bank-full discharge conditions, and to improve the input data. Sediment sampling data were used to develop representative sediment distributions for each of the reaches defined for the lateral stability assessment.

Bank-full discharge varies significantly within the study reach, but averages about 14,000 cfs, which has a post-New Waddell recurrence interval of about the 15-year event in the Upper Reach, a 20-year event in the Middle Reach, and a 10-year event in the Lower Reach. The average bank-full characteristics for the main (low flow) channel are 700 feet wide and 7 feet deep, with a velocity of about 5 feet per second. The main channel appears to be adjusted to the geometry left by the 1980 flood, the most recent large discharge to be conveyed through the study reach. The expected channel pattern is braided, given the existing slope, sediment characteristics, and dominant discharge. The actual channel pattern is compound, with a braided high flow channel and a slightly sinuous to sinuous low flow channel. Post-New Waddell Dam discharges from the urbanizing watershed downstream of the dam may have controlled formation of the more sinuous low flow channel.

Regime geometry equations indicate that the Agua Fria River is over-widened and under-deepened, and will continue to narrow in the future. Concentration of floods within a narrower, deeper channel will result in higher flow velocities, erosion of the main channel banks, and continued long-term degradation, but decreased potential for avulsions, except during the largest floods. Flood velocities in the main channel generally exceed allowable velocity limits for non-cohesive sediments, even for the 2-year flood. However, where the channel abuts more cohesive, older surfaces, the channel velocities generally are less than the allowable velocity thresholds. Overbank velocities are generally considered erosive, especially for overbank areas dominated by finer-grained sediments and areas of local flow concentrations.

The longitudinal profile and equilibrium slope analyses indicate that the Agua Fria River will continue to degrade during large floods. During smaller floods, the middle reaches (Reach 4-10) will be stable or will aggrade slightly, according to the equilibrium slope equations. These predictions do not account for the effects of in-stream sand and gravel mining, which tends to accelerate long-term degradation and induce headcutting. In general, the bed material of the Agua Fria River is not large enough to form an armor layer that would prevent long-term degradation. Predicted single-event scour depths are moderate, ranging from about 1 foot for the 2-year event, to about 5 feet for the 100-year event. The mathematical analyses indicate that lateral erosion and degradation will occur during large floods. Minimal erosion will occur during small floods, except where the channel has been disturbed by human activity.

The erosion hazard zones are defined as follows:

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-term Erosion Hazard Zone

The Severe Erosion Hazard Zone is comprised of the active stream channels and the channel margin areas likely to be eroded during a single 100-year flood, or the area likely to be removed if the bank angle were to be reduced to the natural angle of repose. Areas within the limits of existing sand and gravel mining operations were considered to be in the severe erosion hazard zone, since no engineered erosion protection was observed near the mines during field visits.

The Lateral Migration Erosion Hazard Zone consists of the channel margin area likely to be eroded by a "typical" series of floods over a 60-year period, plus the erosion that would be caused by a 100-year flood. The Lateral Migration Erosion Hazard Zone also includes the natural channel movement due to geomorphic processes such as meander migration or channel avulsion. The Lateral Migration Erosion Hazard Zone includes portions of the floodplain that had been occupied by the main channel during the period of historical record, unless clear and convincing evidence of future stability was available. In general, the Lateral Migration Erosion Hazard Zone included areas outside the regulatory floodway of the Agua Fria River. The Lateral Migration Erosion Hazard Zone is recommended for adoption as the regulatory erosion zone for the Watercourse Master Plan.

The Long Term Erosion Hazard Zone consists of the channel margin area defined by geologic evidence of channel movement over the past 100 to 1,000 years, and represents expected or potential channel movement over the next 60 to 1,000 years in the future. The boundary of the expected Long Term Erosion Hazard Zone envelops the results of all the predictive methods used to assess channel stability, in addition to application of engineering judgment and interpretation of the site geomorphology. Portions of areas mapped as older geomorphic surfaces, but adjacent to active channels and floodplains, were generally included in the long-term Erosion Hazard Zone. Areas protected by engineered levees or other bank protection were considered to be the outside limit for the Long Term Erosion Hazard Zone.

The results of the lateral migration analysis were compared to previously completed channel stability assessments of the Agua Fria River. Like the previously completed studies, this analysis concluded that human impacts, especially in-stream sand and gravel mining and impoundment of natural runoff in upstream reservoirs, have been the dominant cause of channel change along the Agua Fria River. High rates of single-event and long-term erosion should be expected, except where structural flood control measures are provided.

7. SEDIMENTATION AND SCOUR

7.1 Introduction

The purpose of the Sediment Trend Analysis was to study and evaluate the long-term and flood response of the streambed profile of the Agua Fria River based on existing, proposed, and alternative development conditions along and within the river. The sediment trend analysis is used as an analytical tool to evaluate the impact of future plans, including sand and gravel mining operations, on the response of the streambed profile. The sediment trend analysis is sufficient to predict trends and impacts of the river response on local infrastructure, but is not intended to be a site specific management tool for regulation of activity or the analysis and design of infrastructure.

The Sediment Trend Analysis is a complementary analysis to a broader investigation of the Agua Fria River as part of the Agua Fria Watercourse Master Plan. Other technical and engineering studies conducted on behalf of the Master Plan include hydrology, river hydraulics, and geomorphology studies. All of these studies, together with their results and interpretations, provide an understanding of the behavior of the ephemeral Agua Fria River in an arid, urbanizing environment.

The sediment trend analysis for the Agua Fria River will attempt to predict anticipated river channel response to long-term channel forming discharges and to short-term flood events such as the 100-year flood. The sediment trend analysis uses a sediment transport computer model developed by the U.S Army Corps of Engineers. The computer model is known as HEC-6 "Scour and Deposition of Rivers and Reservoirs". The HEC-6 model was developed to predict anticipated riverbed channel responses to changes in river hydrology, sediment characteristics, and channel morphology. These responses take the form of changes in riverbed channel elevations through aggradation or degradation of sediment in river subreaches and through changes in channel cross section geometry.

7.2 Climatology and Geomorphology

The Agua Fria River is characterized as an ephemeral alluvial desert stream due to the impact of the water storage capabilities of the New Waddell Dam and local climatology. The presence of a significant amount of water is only apparent in the river during storm events on the upstream watershed. When flooding does occur in the river, the duration of the flooding is relatively short in duration. The duration of the 100-year flood event in the Agua Fria River is predicted to be less than several days according to flood studies conducted by the U.S Army Corps of Engineers.

The Agua Fria River is also characterized as a sand and gravel stream. The moveable bed materials in the river are comprised primarily of sands and gravels with finer and coarser materials interspersed throughout the study reach. The bed material of the upper reach of the river is coarser than the lower reaches of the river. This characteristic is primarily due to the sediment trapping capability of the New Waddell Dam and the local geology of the upper reach (narrow canyon/channel and presence of bedrock). The lower reach of the Agua Fria River is predominately sand with some gravel lenses.

The overall general behavior of the Agua Fria River stream profile in response to long-term channel forming flows or short-term floods, such as the 100-year flood, is to degrade and move sediment from the upper reaches to the lower reaches. It is anticipated that flood flows in the upper reach of the river are relatively devoid of sediment load compared to the lower reach of the river. This relatively sediment hungry floodwater in the upper reaches of the river tends to obtain sediment from the bed and banks of the river. The acquisition of sediment from the bed and banks of the river tends to lower the streambed channel profile and widen the river through lateral erosion. Some of the sediment accumulated in the upper reaches of the river tends to settle out or deposit in the lower reaches of the river or be transported out of the Agua Fria River into the Gila River. This change in bed material from coarse to finer materials in the upper reaches to the lower reaches is readily observable on the Agua Fria River today.

Several tributaries exist along the study reach of the Agua Fria River. The most notable tributary is the New River, which joins the Agua Fria River south of the Glendale Airport. New River is incorporated into the sediment trend analysis of the Agua Fria River. Previous hydrologic and hydraulic studies of the Agua Fria River/New River system indicate that the New River has more of a influence on the Agua Fria River south of the New River confluence than does the Agua Fria River itself.

7.3 *Hydrology*

The short-term flood flow selected to evaluate the river response is the 100-year flood event as developed by the Corps of Engineers. The long-term channel forming discharge selection was based on the potential discharge from the New Waddell Dam under the 100-year flood event. The Corps of

Engineers have estimated that the New Waddell Dam may discharge a flood flow of approximately 9,000 cubic feet per second into the Agua Fria River. The duration of this flood flow to simulate long-term behavior was set at 30 days by KHA in concurrence with the District.

7.4 Sediment Transport Modeling

The sediment trend analysis begins at the confluence of the Agua Fria River with the Gila River. The upstream limit of the sediment trend analysis is approximately at the diversion outlet downstream of New Waddell Dam. The total length of the study reach of the river is approximately 33.8 river miles.

Four HEC-6 models were created to analyze different aspects of sediment transport within the river system:

- Existing Condition Model
- Sand and Gravel Model
- Full Encroachment Condition Model
- Grade Control Structure Model

7.4.1 *Existing Condition Model*

The first HEC-6 model is based on existing river conditions as depicted by the sum of the Corps of Engineers 1995 hydrology study of the river, the 1996 Flood Insurance Study (FIS) of the Agua Fria River, and the sediment gradation data developed for the sediment trend analysis. The flood event simulated in the existing condition model is a long-term flow of 9,000-cfs for 30-days followed immediately by the 100-year flood. The peak discharge in the lower Agua Fria River during the 100-year flood is 54,400 cfs.

The existing condition model indicates that there is a general trend toward degradation for the reach of the Agua Fria River north of Jomax Road. The maximum ending degradation was 6.1 feet, downstream of the State Route 74 Bridge.

The reach from Jomax Road to Bell Road indicates a slight aggradation condition with some degradation at a few river cross sections. The maximum ending aggradation of 3.54 feet occurs upstream of Happy Valley Road.

The reach from Bell to Grand Avenue appears to be degrading. The channel bed is degrading at the Grand Avenue Bridge with a small aggradation along the El Mirage landfill.

The channel is degrading just downstream of the confluence with the New River and aggrading at the beginning of the Corps' levees. The contributing flow from New River may be causing the Agua Fria channel to degrade at the confluence.

Within the levee reach of the lower Agua Fria, the grade control structures appear to be causing aggradation in the channel. The maximum ending condition degradation in the levee reach is 3.61 feet. The maximum event deposition is 3.97 feet, near Van Buren Street.

The reach of the Agua Fria downstream of the levees to the Gila River indicates a slightly degrading condition. The maximum degradation occurs near Broadway Road with a depth of 3.56 feet.

7.4.2 Sand and Gravel Model

The second HEC-6 model developed in this analysis is the full sand and gravel model. The term "full sand and gravel" is used to depict the sand and gravel mines that have an existing or pending Floodplain Use Permit as operating to their full mining extents and limits. In other words, the sand and gravel mines are built to their full mining plan limits in regards to pit depths, lengths and widths of pits. The full build-out limits of the sand and gravel mines were incorporated into the existing condition model to develop the sand and gravel model. The sand and gravel model results were then compared to the existing condition HEC-6 model results.

The sand and gravel model includes the same hydrology event, sediment inflow curve, transport function, and bed sediment gradations as used in the existing condition model. The modifications incorporated in the sand and gravel model include establishing the limits of the mining pits through the use of the dredge routine of the HEC-6 model, establishing conveyance limits, and review of the moveable bed limits.

The sand and gravel model indicates the potential for development of headcuts in the river channel, through the initiation of invert degradation upstream of sand and gravel mines. The riverbed channel upstream of the sand and gravel mines appears to degrade during the simulation of the passing of the flood event. The degradation exhibited upstream of the sand and gravel mines could potentially initiate local headcuts. Those headcuts located near bridged crossings may impact the performance of scour countermeasures located at the bridges (e.g. Olive Avenue).

The model shows a general degradation of the channel invert upstream of the sand and gravel mines. This is particularly evident at cross section 18.962, which indicates a channel degradation of 6.38 ft at the Bell Road Bridge. Other bridge and at-grade crossings potentially exposed to channel degradation include Indian School Road Bridge (cross section 8.105, -1.78 ft), Camelback Road Bridge (cross-section 8.992, -0.55 feet), and the Northern Avenue at-grade crossing (cross section 12.42, -9.20 feet).

The sand and gravel model indicates minor degradation and deposition occurring from cross sections 8.105 through 10.846. This reach of the river is mined from downstream of Indian School Road to upstream of the Glendale airport area (Bethany Home Road and New River confluence). Within this reach, an average pit depth was assumed for each model cross section that included a mine. Average pit depths were used because the HEC-6 model is not capable of individually distinguishing separate mines within a cross section when using the dredging option. It should be noted that the average pit depth is not necessarily the maximum pit depth. Future sediment studies of this reach of the river should include a sensitivity analysis on maximum pit depth to evaluate the impact of the mines located in this reach of the river.

The bed channel profile in the downstream reach of the Agua Fria River (between Indian School Road to Buckeye Road), which includes the Corps of Engineers levees, appears to be relatively stable during the passage of the 100-year hydrograph. This is anticipated since this reach contains five grade control structures, has no active sand and gravel mines, and the banks of the river are stabilized with levees.

From the Gila River confluence to the beginning of the Corps levees, the Agua Fria River indicates scour during the passage of the 100-year flood flows. There is a small sand and gravel mine (permit pending) located at Roser Road (between river stations 1.10 to 1.25) near the west bank. The impacts of this mine at full extraction is to lower the invert of the river locally by a much as 10.3 feet during the 100-year flood.

The results of the full sand and gravel model of the Agua Fria River indicate the need for management of potential headcutting. Although HEC-6 cannot directly predict the degree and amount of headcutting, HEC-6 can predict precursors for headcutting. The headcutting may be attributable to the extensive sand and gravel extraction activities in the river. The management of potential headcuts may take the form of grade stabilization structures, set-back limits on sand and gravel mines, limitations on the depths of extraction within the floodway/floodplain, and scour countermeasures at existing and proposed river crossings. Grade control structures may be located downstream/upstream of sand and gravel mines, and near bridge crossings. At-grade crossings should be reviewed for scour countermeasures

7.4.3 *Full Encroachment Condition Model*

The third HEC-6 model prepared for the Agua Fria River was the full encroachment model. This model evaluates the river response caused by encroachment to the floodway limits. The purpose of the model was to examine the effects on the bed profile of a future management policy for encroachment of the river. The encroachment may take several forms including the filling of the flood fringe for development or the construction of levees to provide a measure of flood protection to sand and gravel operations. The policy would potentially allow utilization of the flood fringe and exclude extraction of sand and gravel within the regulatory floodway.

KHA updated the original encroachment model as part of this investigation. The updated encroachment model indicates that the average range of aggradation and deposition for the Agua Fria River under encroachment conditions is from zero feet to plus or minus three feet. This is the same result that was observed in the original encroachment model. There is a notable exception, however, at river station 13.396 where the degradation was estimated at 9.3 feet. This depth is attained during the 9,000 cfs flow (at hydrology day 15) with a maximum of 9.7 feet and a recovery back to 9.3 feet at the end of the 100-year hydrograph. This river station is located downstream of the Olive Avenue Bridge. It is one of the river stations added to the updated encroachment model.

The model indicates that the average bed change during the flood event ranges between zero to plus or minus 3 feet from the Gila River confluence to Cloud Road. Upstream of Cloud Road, the bed elevation decreases by as much as 6 feet at the end of the hydrology simulation.

The 30 days of 9,000 cfs flow in the Agua Fria River has more of a channel forming impact on the riverbed profile than the subsequent 100-year event. The maximum range of deposition and scour are nearly attained with the 30-day flow with minor additional contribution of deposition or scour attributable to the 100-year event. The maximum degradation occurs within the river subreach from Cloud Road to just downstream of State Route 74. This may or may not occur to this extent at all locations within this subreach due to the shallow presence of bedrock. The degradation seen within this subreach may be caused by the relatively narrow floodway limits. The flow velocity within this reach is greater than in downstream reaches, allowing higher sediment transport capacity.

The riverbed profile of the encroached floodway model generally mirrors the behavior of the existing condition riverbed profile at the peak of the 100-year event, and at the end of the 100-year flood. This could be attributable to the river floodplain hydraulics and the floodway hydraulics being nearly the same at many cross sections in the river.

The HEC-6 encroachment model indicates that the Agua Fria may be encroached to the FIS floodway limits without significant impacts on sediment transport above those demonstrated under existing conditions. Encroachment, however, should be examined in more detail on a reach by reach basis of the river. Encroachment is not advisable to the limits of the FIS floodway in the upper reach (upstream of Cloud Road) due to the predicted depths of degradation and the close proximity of important existing or proposed infrastructure.

7.4.4 *Grade Control Structure HEC-6 Model*

The fourth HEC-6 model prepared for the sediment trend analysis is the grade control structure model. The purpose of this model was to evaluate the impact of proposed grade control structures on the riverbed and to assist in the selection and recommendation of the locations of proposed grade control structures.

Four proposed grade control structures were recommended for evaluation as a result of preliminary sediment trend results. These are located downstream of Olive Avenue (at river station 13.395), Bell Road (river station 18.962), upstream of Rose Garden Lane (river station 21.893) and downstream of the proposed New Estrella Parkway (at river station 24.543). These grade control structure locations were selected for investigation after joint discussions and concurrence with JE Fuller Hydrology and Geomorphology, the consulting firm responsible for the geomorphic and lateral migration analysis and investigation of the river. The reasons for these locations are presented below.

The grade control structure downstream of Olive Avenue Bridge would be located between the bridge and a major sand and gravel operation. The purpose of the grade control is to help stabilize the invert of the channel upstream of the grade control and to arrest potential headcuts from the sand and gravel mine that may develop over time or during a major flood event. The encroachment model indicates a significant degradation at this location.

The purpose of the grade control structure downstream of Bell Road Bridge is to arrest several existing headcuts that have been identified downstream from the bridge. There is an existing sand and gravel mine located in the left overbank area between Bell Road and Greenway Road. The existing headcuts appear to be propagating upward from the mine.

The grade control structure upstream of Rose Garden Lane (river station 21.893) would be located about ½ mile downstream of the Deer Valley Road Alignment. The purpose of the grade control is to arrest potential headcuts from an in-stream sand and gravel operation. Three headcuts have been located in the river channel at the Deer Valley Road Alignment.

The fourth grade control structure is proposed just downstream of the proposed New Estrella Parkway, near the Happy Valley Road Alignment. The purpose of the grade control structure is to stabilize the river invert, benefiting the Parkway Bridge foundation. An existing headcut is located approximately ¼ mile upstream of the Pinnacle Peak Road Alignment that could potentially promulgate over time towards the proposed bridge. There is also a large sand and gravel mine approximately ½ mile downstream of the proposed grade control structure on the east side of the river channel. The mine is within the floodplain limits of the Agua Fria River.

7.5 Grade Control Structure Evaluation

The HEC-6 models incorporating the proposed grade control structures show local aggradation at the structures. The largest difference is exhibited at the proposed grade control at Olive Avenue. There is an aggradation of approximately 2.8 feet at this location. At the other three grade control structure locations, the grade controls have aggraded the river channel locally.

At the Olive Avenue Bridge (Station 13.395), the HEC-6 updated encroachment model indicated a degradation of 9.3 feet. When the same location was modeled as having a grade control structure, the model indicated that the river channel would aggrade to 2.8 feet above existing conditions. It should be noted that the grade control structures in the HEC-6 grade control model are allowed to have local aggradation but not degradation. The grade control at Olive Avenue appears to be warranted due to the change from minus 9.3 feet to plus 2.8 feet. The structure would serve to protect the bridge and arrest the existing headcut just downstream of the bridge.

The grade control structure at Bell Road (river station 18+962) appears not to be warranted at this time from interpretation of the HEC-6 results. Examination of the encroachment model indicates local aggradation at the Bell Road grade control location. The grade control model also indicates local aggradation at the proposed grade control location at Bell Road. However, due to the extensive in-channel mining downstream, a potential headcut could occur which could propagate upstream in a flood event. It is recommended at this time that the District monitor and inspect the river at this location after flood events and observe for propagation of headcuts.

The updated encroachment model results indicated that the river will degrade at Rose Garden Lane (river station 21.893) by approximately 1.0 to 1.2 feet. The grade control model results also indicates a slight aggradation at this location. Therefore, this grade control structure may be warranted based on strict interpretation of the HEC-6 results. However, providing a grade control structure for a local river degradation of 1.2 feet appears unnecessary at this time. But, due to the extensive in-channel mining downstream, a potential headcut could occur which could propagate upstream during a flood event. Field evidence upstream of the proposed grade control indicates the existence of several headcuts. It is recommended at this time that the District monitor and inspect the river at this location after flood events and observe for propagation of headcuts.

Both the encroachment model and the grade control model indicate that aggradation would occur at the grade control structure at the New Estrella Parkway Bridge (river station 24.543). The aggradation would occur to a depth of approximately 2.0 feet. Based on the results of the HEC-6 models, a grade control at this location may not be warranted at this time. However, the close proximity of an existing headcut and a large downstream sand and gravel mine may cause locally sever erosion. Designers of the proposed bridge should consider foundation modifications, erosion stabilization or scour countermeasures.

7.6 Conclusions and Recommendations

The findings of the Sediment Trend Analysis indicate that there may still be a need, on a case by case basis, for stabilization of the riverbed profile and/or bank stabilization. Riverbed stabilization may take the form of grade control structures. These may be located downstream/upstream of sand and gravel mines and near bridge crossings.

As a result of the HEC-6 analysis, only one grade control structure is warranted at Olive Avenue. An existing headcut downstream from the bridge should be monitored until the grade control structure is built. Foundation modifications, erosion stabilization or scour countermeasures are recommended at the proposed New Estrella Parkway Bridge. Monitoring and inspection are recommended for the river channel in the vicinity of Bell Road and Rose Garden Lane after flood events. These monitoring activities should take the form of estimating the rate of headcut propagation and dimensions of headcuts that form. Monitoring should include surveys and time sequence aerial photographs of the river channel and ground inspections. Distance measurements of the upstream end of the headcut to infrastructure should be recorded on an annual basis.

Finally, it should be noted that these recommendations are premised on existing river conditions as depicted in the study topography, and an understanding that future sand and gravel permits will require that pits be isolated from the main flow of the river. Significant new instabilities in the watercourse, whether induced by human activity or naturally occurring, will change the way the river responds. In five to ten years the District should evaluate river management practices that might influence river stability. This evaluation should include a field check for conditions that would suggest instabilities are developing; and if sufficient evidence exists, consider updating this analysis.

8. SAND AND GRAVEL MINING

8.1 Introduction

This summary presents an overview of the findings of the *Sand and Gravel Mining Summary, Kimley-Horn and Associates, Inc., 2001.* Mining for rock products within the river has been ongoing for the past 50 years. Numerous mines are in operation today and permits are currently pending for the opening of new pits.

8.2 Background

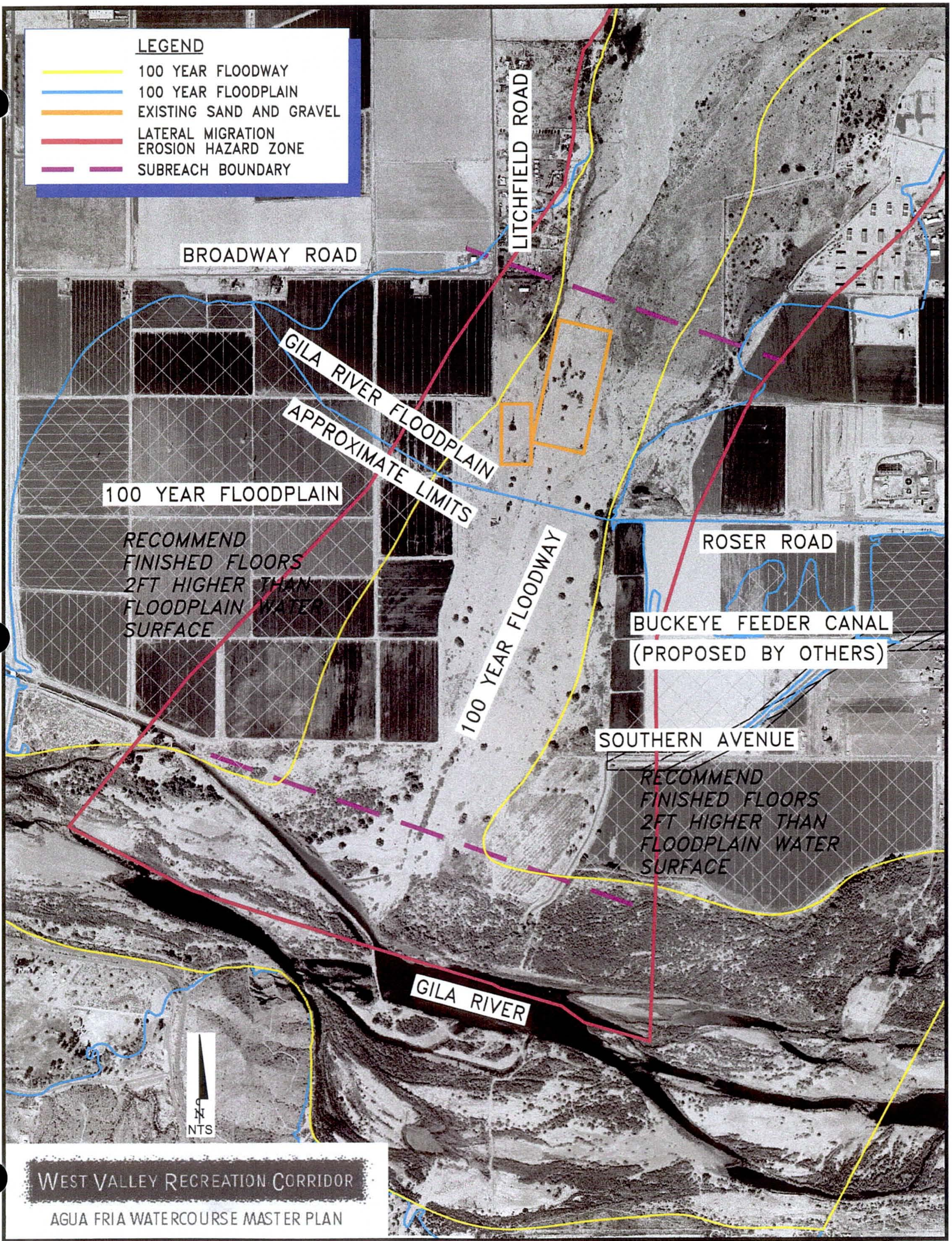
The availability of abundant, high quality sand and gravel resources within the region's floodplains has led to affordable building materials which has played a critical role in the economic growth of the Phoenix metro area. Per information provided by the Arizona Rock Products Association, the sand and gravel resources of the Agua Fria River are of the highest quality. Based on some independent market research, it was determined that within the Phoenix market place that rock products, especially aggregate, is about ½ the cost of other major southwest markets. It is understood that moving outside of the region's floodplains would lead to both loss of quality, and increased production cost for the region's rock products.

The challenge with sand and gravel mining in floodplains is to identify and find solutions that balance public safety and protection, and protection of adjacent properties from erosive impacts while continuing to extract the high quality resources of the river.

The fluvial geomorphologists associated with the Watercourse Master Plan have concluded that the Agua Fria is a degrading river that is still approaching equilibrium slope conditions. Two factors have primarily contributed to this imbalance. These factors are the damming of the Agua Fria and the sand and gravel mining that has occurred in the riverbed over the past 50 years.

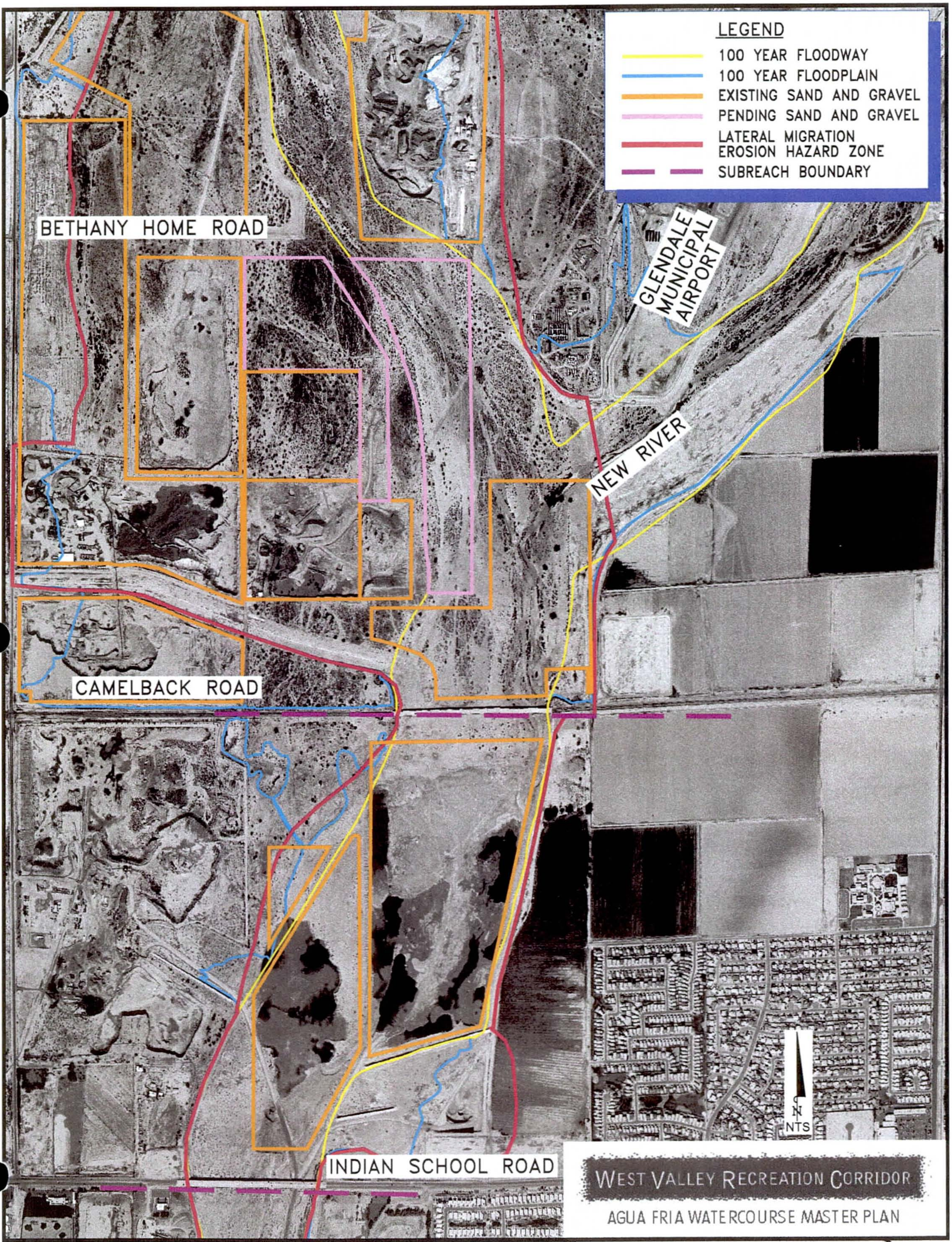
The Agua Fria River's sediment supply was interrupted with the construction of the Waddell Dam in the late 1920s and early 1930s. While this clearly impacted sediment inflow to the river, data do not indicate any significant or widespread response from the river. This could be due to sufficient sediment being available in the river reaches below the dam that allowed for continued transport of sediment downstream.

Sand and gravel mining was first noted in the 1950s with demand being driven by some of the first developments in the West Valley. Today, sand and gravel mining can be found throughout the river. Figure 8.2-1 through Figure 8.2-10 shows existing and proposed sand and gravel mines within the study corridor. Two significant clusters of mining pits are found between Camelback Road and Olive Avenue, and between Grand Avenue and Jomax Road. Future operations are proposed within these reaches as well as the reach north of Jomax Road and south of the CAP Canal.



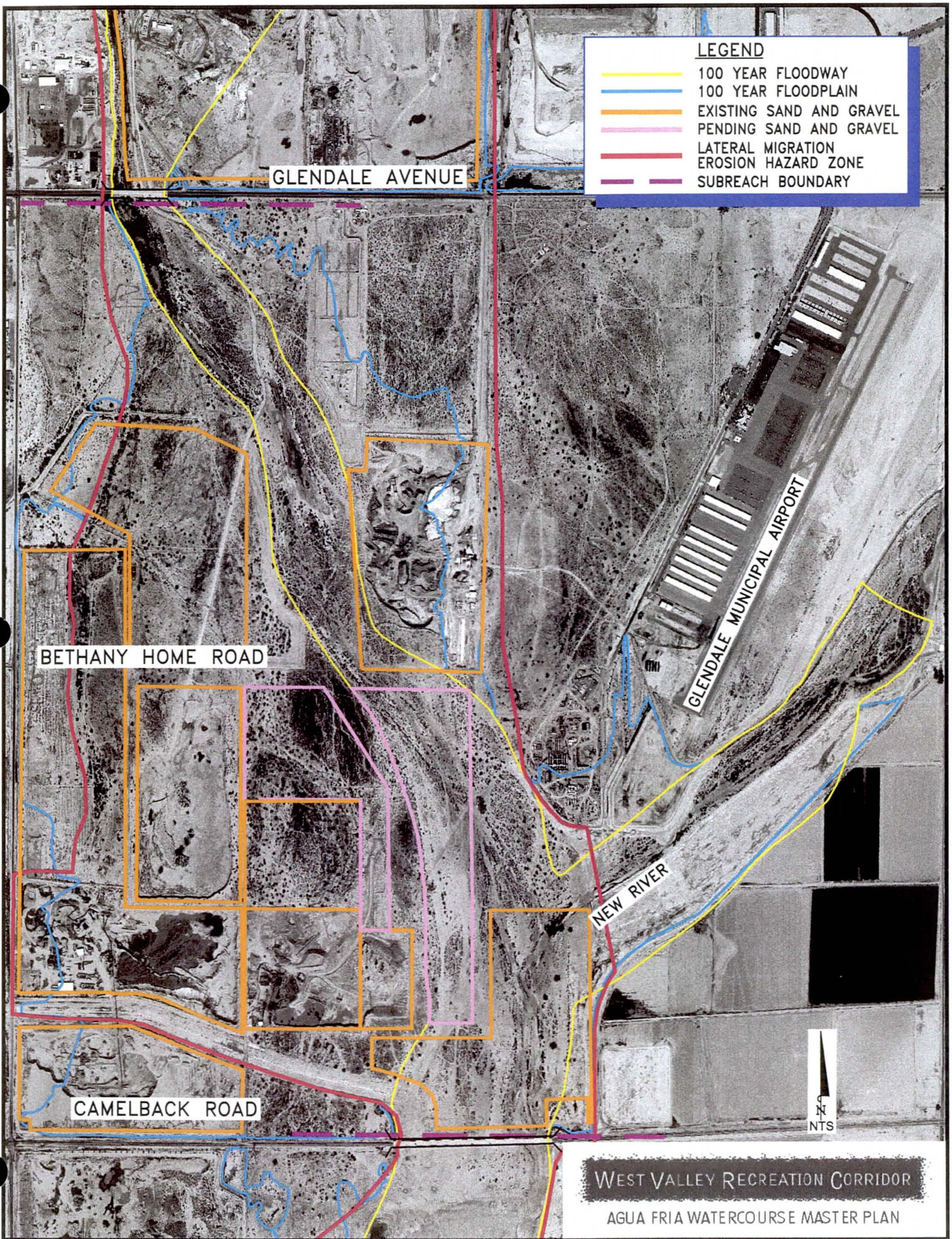
Kimley-Horn and Associates, Inc.

FIGURE 8.2-1
SAND AND GRAVEL MINING
CONFLUENCE OF GILA TO BROADWAY ROAD



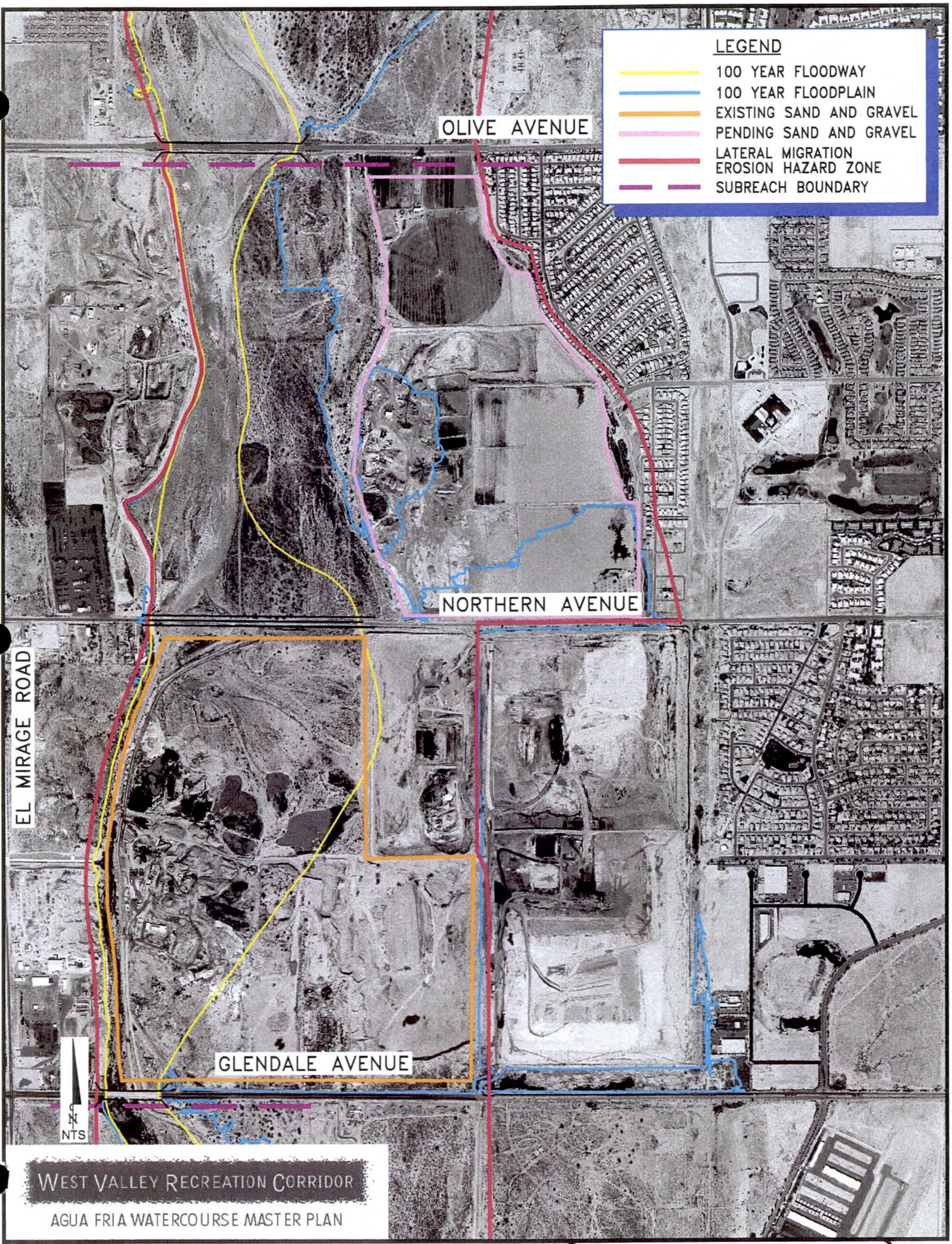
Kimley-Horn and Associates, Inc.

FIGURE 8.2-2
SAND AND GRAVEL MINING
INDIAN SCHOOL RD TO CONF OF NEW RIVER



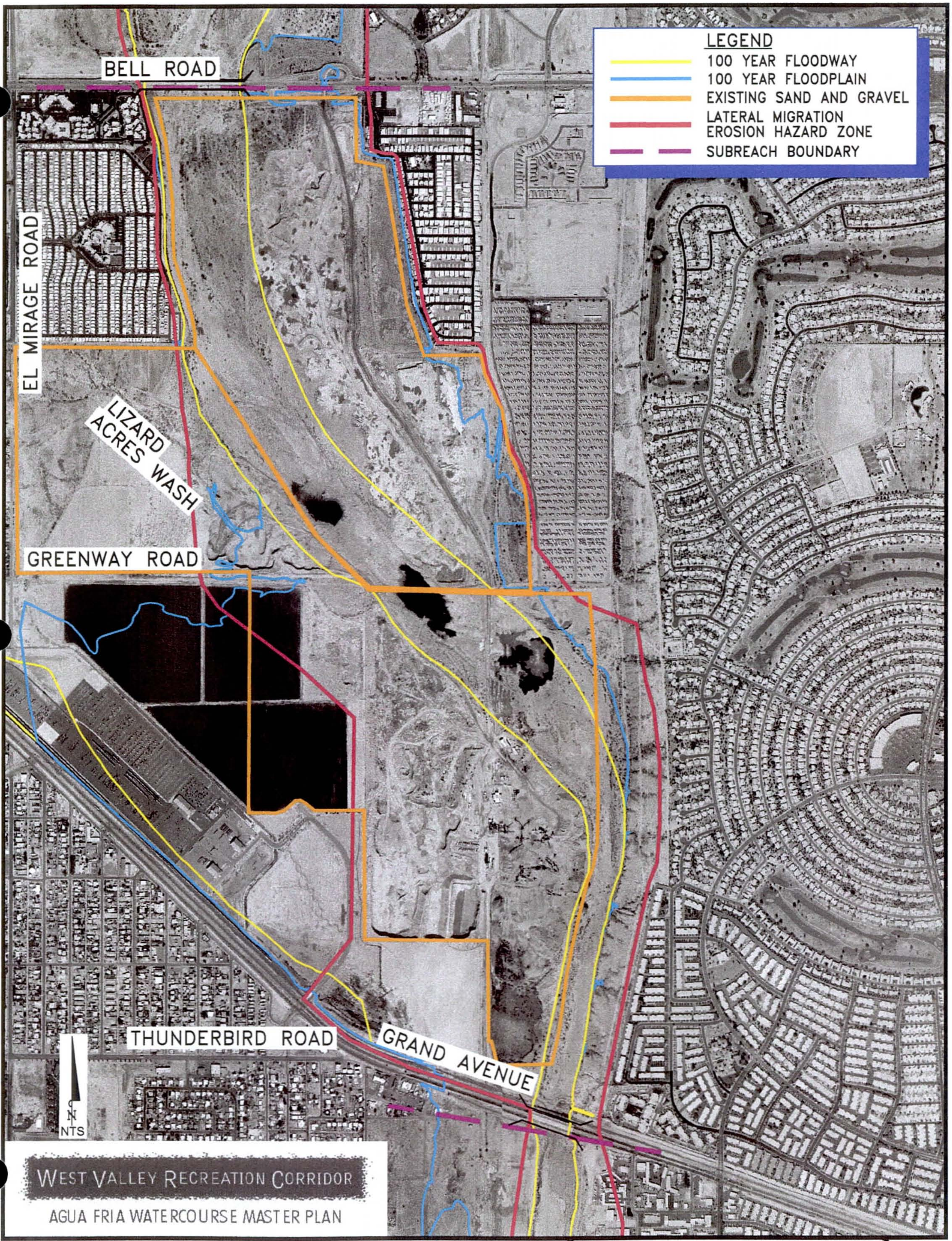
Kimley-Horn and Associates, Inc.

FIGURE 8.2-3
SAND AND GRAVEL MINING
CONF OF NEW RIVER TO GLENDALE AVE



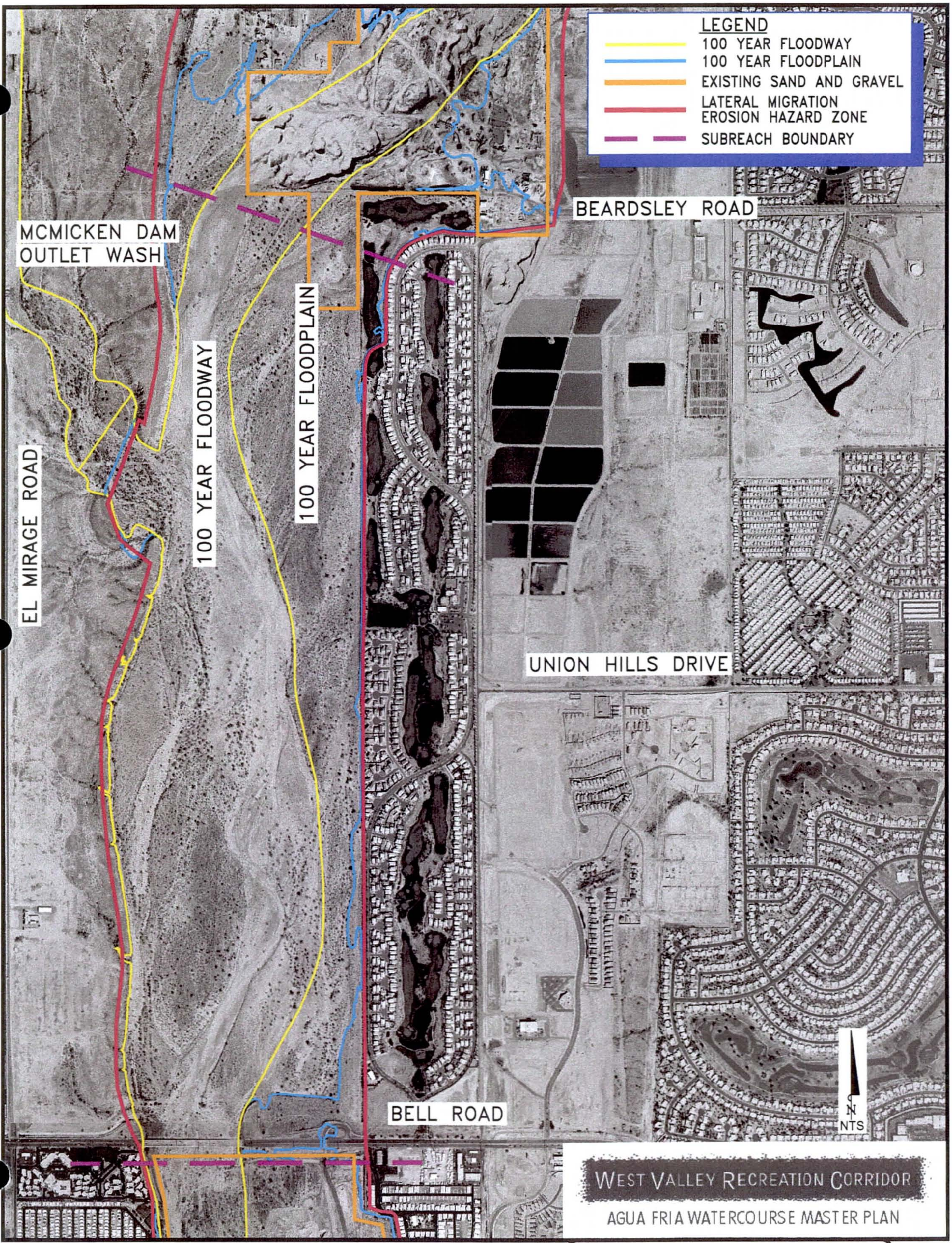
Kimley-Horn and Associates, Inc.

FIGURE 8.2-4
SAND AND GRAVEL MINING
GLENDALE AVENUE TO OLIVE AVENUE



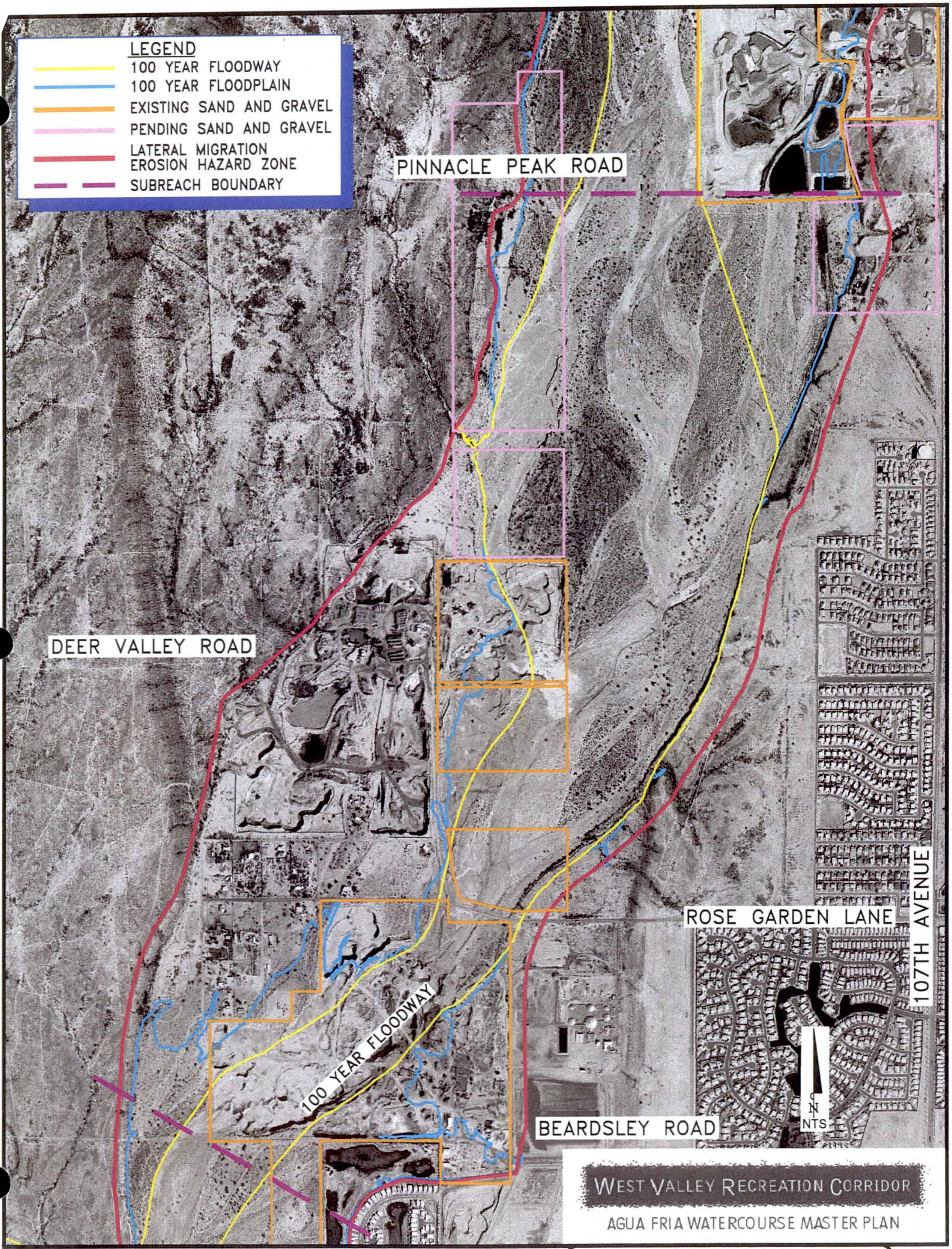
Kimley-Horn and Associates, Inc.

FIGURE 8.2-5
SAND AND GRAVEL MINING
GRAND AVENUE TO BELL ROAD



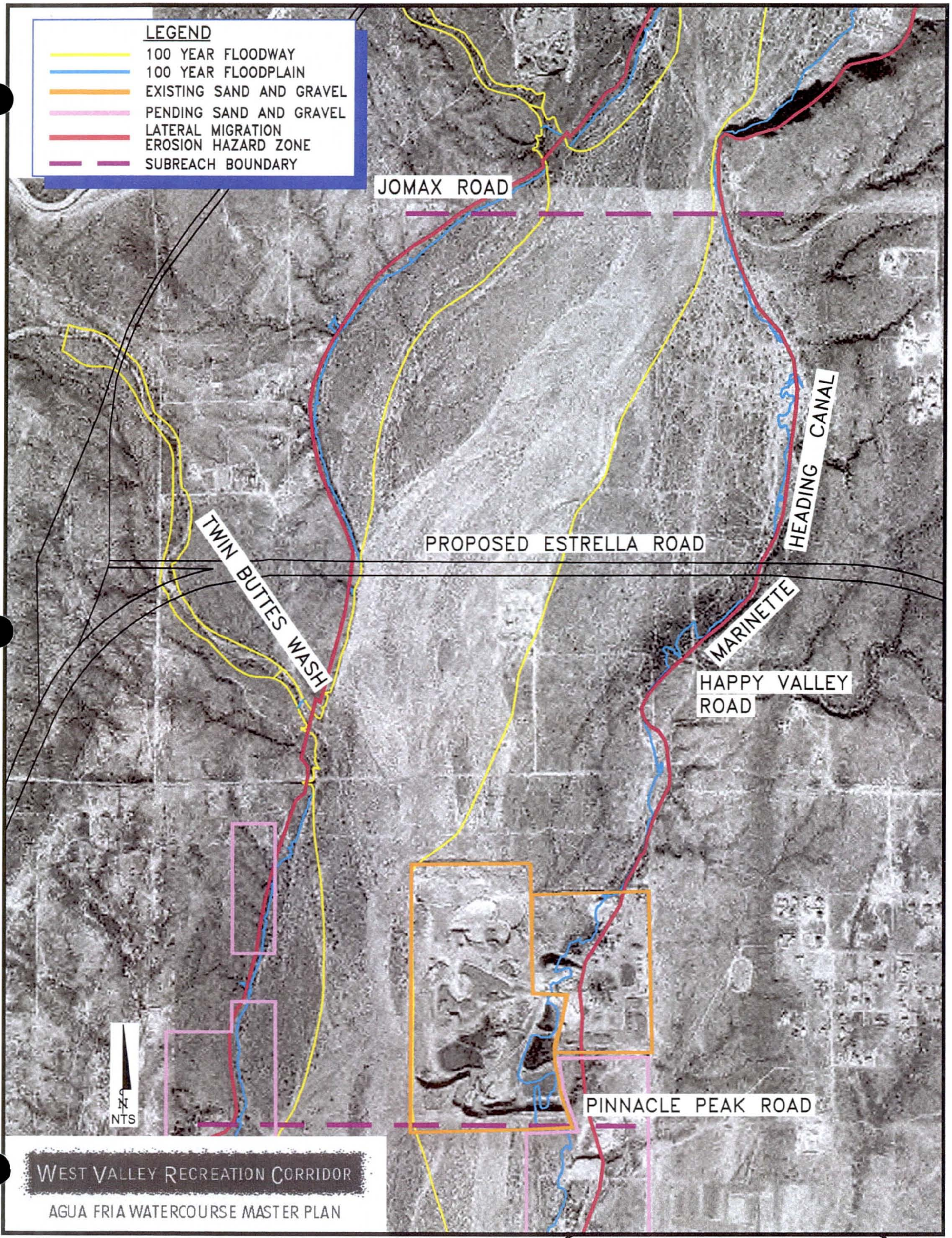
Kimley-Horn and Associates, Inc.

FIGURE 8.2-6
SAND AND GRAVEL MINING
BELL ROAD TO BEARDSLEY ROAD



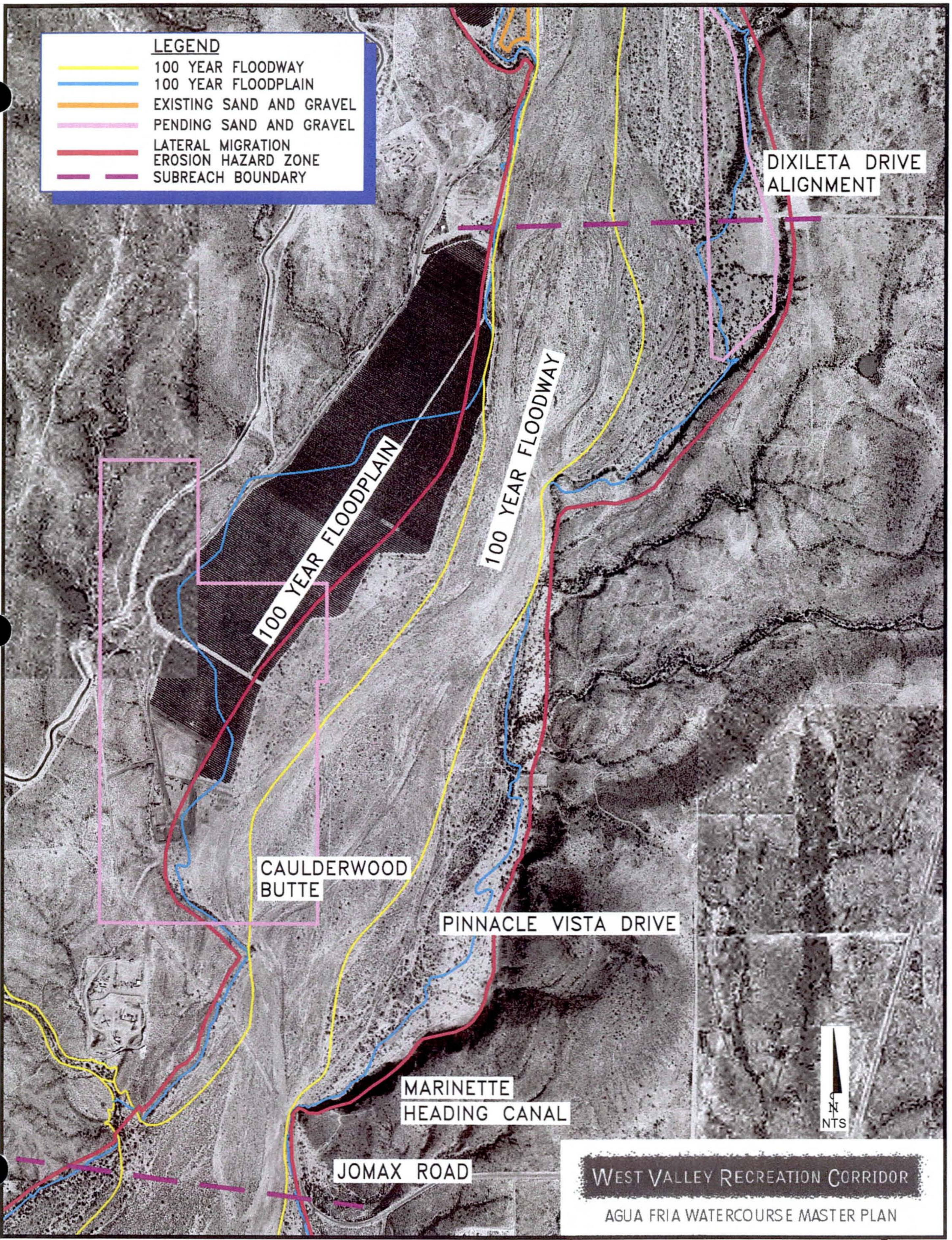
Kimley-Horn and Associates, Inc.

FIGURE 8.2-7
SAND AND GRAVEL MINING
BEARDSLEY ROAD TO PINNACLE PEAK ROAD



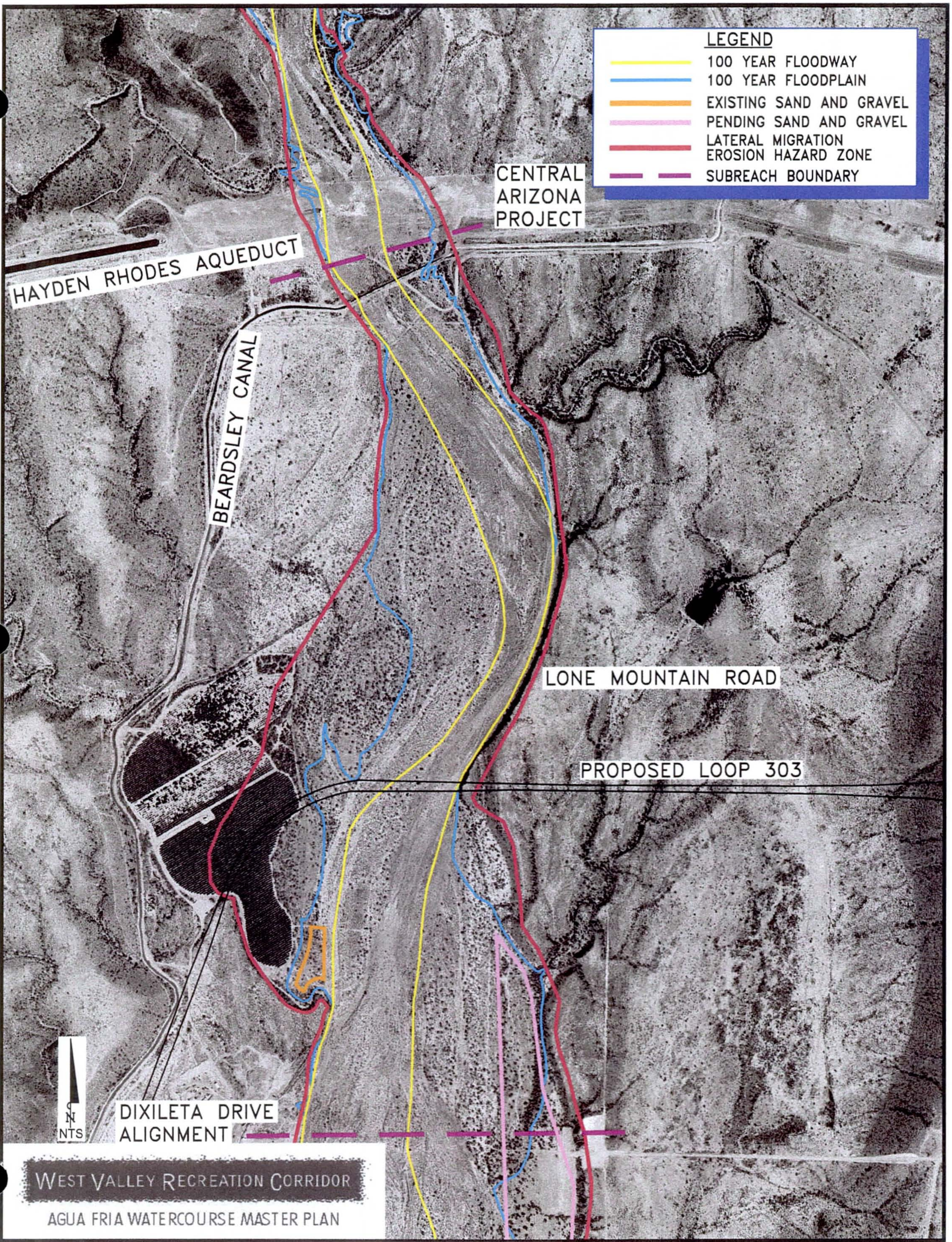
Kimley-Horn and Associates, Inc.

FIGURE 8.2-8
SAND AND GRAVEL MINING
PINNACLE PEAK ROAD TO JOMAX ROAD



Kimley-Horn and Associates, Inc.

FIGURE 8.2-9
SAND AND GRAVEL MINING
JOMAX RD TO DIXILETA DRIVE ALIGNMENT



WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

Kimley-Horn and Associates, Inc.

FIGURE 8.2-10
SAND AND GRAVEL MINING
DIXILETA DRIVE ALIGNMENT TO CAP CANAL

In order to predict the impacts that sand and gravel mining might have on the river, sediment trend investigations were performed as part of the master planning process. Sediment movement was modeled using a single flood hydrograph approximating the runoff from a 100-year storm. Sediment transport was evaluated in both the existing condition (assumes little or no mining) and in the proposed condition (incorporates existing and proposed mines). The existing condition model demonstrated that without the influence of mining, the river would be relatively stable, with some isolated points of degradation. The proposed condition model indicated the river would respond to mining by lowering the watercourse, with some areas experiencing more than 5 feet of degradation. It is anticipated that if this investigation were performed using a hydrograph that represented flows from multiple storm events, the river would continue to degrade significantly.

Simply stated, the problem is that the sand and gravel mining is truly removing portions of the riverbed and there is no obvious source of sediment replenishment. As such, the river can only respond by shifting upstream sediment into downstream holes, causing a general lowering of the river. It is possible that localized degradation or scour may be severe, causing the loss of a bridge or other infrastructure. At the very least, long-term degradation would be expected to cause a general lowering of the river.

As the river lowers, erosion may impact infrastructure and lead to bank instabilities, potentially threatening land and developed areas on the banks of the river.

8.3 Regulatory Controls

Currently, the Flood Control District's authority is limited to regulation of land use within the 100-year floodplain. The District's ability to regulate sand and gravel mining within the river is limited to that of the floodplain regulation and Watercourse Master Plan. The title of the regulation might suggest that the regulation only applies to the "watercourse". The limits of a "watercourse" are currently undefined, but it appears that it might approximate the areas of jurisdiction for Waters of the United States as defined by Section 404 of the Clean Water Act.

The District currently exercises its authority to regulate land use by requiring a Floodplain Use Permit for mining activities within the 100-year floodplain. The permit process requires the submittal of a plan of the proposed mine.

Historically, regulation of sand and gravel has been accomplished using standards of care that approximate no offsite impact by either limiting pit depth, incorporating "safe" side slopes, using property setbacks, or using techniques to fill the pit with water in order to reduce the potential for headcutting. In most cases, compliance with these guidelines has led to permits being approved based on the assumption that mining impacts are kept on site.

However, the Agua Fria River has such an overwhelming sediment imbalance, that past standards of care are probably not containing impacts onsite. In the long term, the cumulative impact of numerous pits in the river is likely to lead to significant degradation of the river system.

In the mid-1990s it was determined that activities such as sand and gravel mining would fall under Section 404 of the Clean Water Act. In Maricopa County and in other parts of the state, there were significant requirements associated with obtaining 404 Permits from the US Army Corps of Engineers. Due to the vagaries of the law and challenges with applying 404 regulations to gravel mining, the permit process was arduous and time consuming. In many cases, continuation of mining operations was allowed via time extensions or other administrative devices. Under these interim operating conditions, mining was curtailed significantly, but operations did not necessarily shut down.

In parallel with these activities, a lawsuit was filed in Washington District court by the national rock products trade organizations against the Corps. In part, what was being challenged was the Corps' authority to regulate excavation activities, since 404 regulations governed the placement of fill. The Corps had premised its authority on the fact that even an excavation process will cause a disturbance of adjacent material or that spillage in the process constituted a fill (incidental fall back). In this case, the court did not rule on the Corps' authority to govern mining activities, but it did rule that the regulation was not proper as previously written.

Recently the Corps has reissued regulations related to what constitutes "incidental fallback", and it is believed that excavation activities once more are regulated under Section 404, along with other activities such as road building that are clearly within its authority.

8.4 *Management Strategies*

Current development of the Watercourse Master Plan has been premised on the District adopting a management strategy toward in-stream mining activities that would lead to a reduction in impact caused by material extraction. This decision-making process was being guided in part by sand and gravel policy investigations that are independent of this Watercourse Master Plan. To date, these investigations have not yielded a clear direction.

A key philosophy of the Watercourse Master Plan is that activities should not be undertaken if they would result in a windfall to private interests. Construction and maintenance of flood control structures at the expense of the public to correct degradation caused by mining or to allow future extraction appears to be at odds with this philosophy.

In order to implement the components of the Master Plan, it will be necessary for the District to adopt a management strategy. Three alternative management strategies toward in-stream sand and gravel mining were considered as part of the master planning process. The alternative strategies are outlined below.

8.4.1 No Change Strategy

The No Change Strategy proposes to allow sand and gravel operators to extract sand and gravel based on the design assumptions currently employed. However, erosion and lateral migration analyses completed in conjunction with the Master Plan indicate it is not likely that mine operators will be able to limit the cumulative impact of their activities to their property. Significant degradation of the riverbed is anticipated. Due to the sporadic spacing and random depth of pits, it is not practical to assume that grade control structures can be implemented in any meaningful fashion since it is not feasible to control mining activities between pits. This plan assumes that the existing bridges north of Camelback Road and south of the CAP Canal ultimately will be replaced, and that bank stabilization for the entire reach of the floodplain would need to be constructed. These actions are anticipated more on a demand basis rather than on a programmed basis.

Estimated Cost: $140,000,000

8.4.2 No Adverse Impact Strategy

The No Adverse Impact Strategy is premised on truly limiting the impact of mining operations to the boundary of the property being mined. The strategy would be implemented when mine owners attempt to renew their Floodplain

Use Permits. In order to renew the permit, a mine owner would have to show that the engineering design of the pit limits the impact of the 100-year storm to his property boundary.

It is anticipated that this strategy will lead to movement of the mining activities away from the floodway; mitigation of reflective erosion; construction of protective works to separate mines from the river; and incorporation of features that would allow mine pits to drown out during major floods to replace channel storage.

Mining within the floodway is expected to be extremely limited. The Corps LA District published the *Sand and Gravel Mining Guidelines, 1987*, to provide recommendations related to in-stream mining near Corps structures. These include:

- Incorporation of set back from bridges and utilities of 500 feet, and maximum pit depths no deeper than that allowed by a 1% slope (a pit initiated 500 feet downstream from the structure would be no deeper than 10 feet deep at a point 1,000 feet downstream from the bridge or utility).
- Pit depths would not be lower than the existing thalweg elevation.
- Pits would be set back from channel banks 500 feet, and pit depths would be limited to being no deeper than a 10:1 slope as measured from the setback.
- Mining operations should be continuous and not be set up to promote skipping over land areas.

It is anticipated that similar guidelines will be adopted to minimize riverbed degradation due to mining, assuming the floodway boundary line is equivalent to a bank line.

Mine owners would be expected to provide the infrastructure necessary to limit mining impacts to their property line. However, the current state of the river indicates that grade stabilization will be required to arrest further degradation of the riverbed. A grade control structure is recommended downstream from the Olive Road Bridge to protect the existing bridge and utility crossings. The structure could be programmed into the District's construction budget based on project priority.

Miners are not currently required to isolate mine pits from the floodway with engineered levees. Adding this requirement would increase the capital improvements required to operate a mine. The placement of levees could trigger 404 permitting issues, and for this strategy to be viable it is recommended that the District pursue a river-wide 404 Permit from the Corps. The permit would encompass the entire reach from New Waddell Dam to the confluence of the Gila River. The District would then assist individual miners to obtain site-specific 404 Permits for their mines.

Estimated Cost $2,000,000

8.4.3 *River Channelization Strategy*

The River Channelization Strategy is premised on restricting the Agua Fria floodplain to a constructed channel. The channel would be approximately 800 feet wide, stabilized with rip-rap, and include a 150-foot wide bench that could be used for linear recreation features and buffering. Excavated materials from the channel either could be moved onto the immediate overbank, minimizing haul costs, or could be dumped into existing sand and gravel pits for future processing and sale. While the sale of the material may lead to some potential financial return, the reality is that an extended haul distance would quickly exceed the return on the raw material. Sand and gravel mining would then be excluded from the channel. Sand and gravel mining activities outside of the channel would be set back a distance of 200 feet with a pit depth not exceeding a depth of 5:1 as measured from the set back in accordance with the Corps *Guidelines*. The *Guidelines* suggest that pit depth would be limited to the depth of the thalweg although this is not totally clear. Limiting excavation depth to the thalweg appears to be very conservative in this channel configuration.

Estimated Cost: $186,000,000 to $248,000,000

8.5 Recommendations

It is recommended that the District adopt the No Adverse Impact Strategy. Implementation of the strategy would require the District to construct a grade control structure downstream from the Olive Road Bridge to stabilize the riverbed. This strategy will require miners to limit the impact of mining operations to the boundaries of the property being mined. In order to meet the requirements of the No Impact Strategy, miners will be required to provide additional infrastructure to isolate mines from the floodway and allow the pits to drown out during larger storms. Figure 8.5-1and Figure 8.5-2 show schematic plans of infrastructure improvements that may be required to limit mining impacts to the boundary of the parcel being mined.

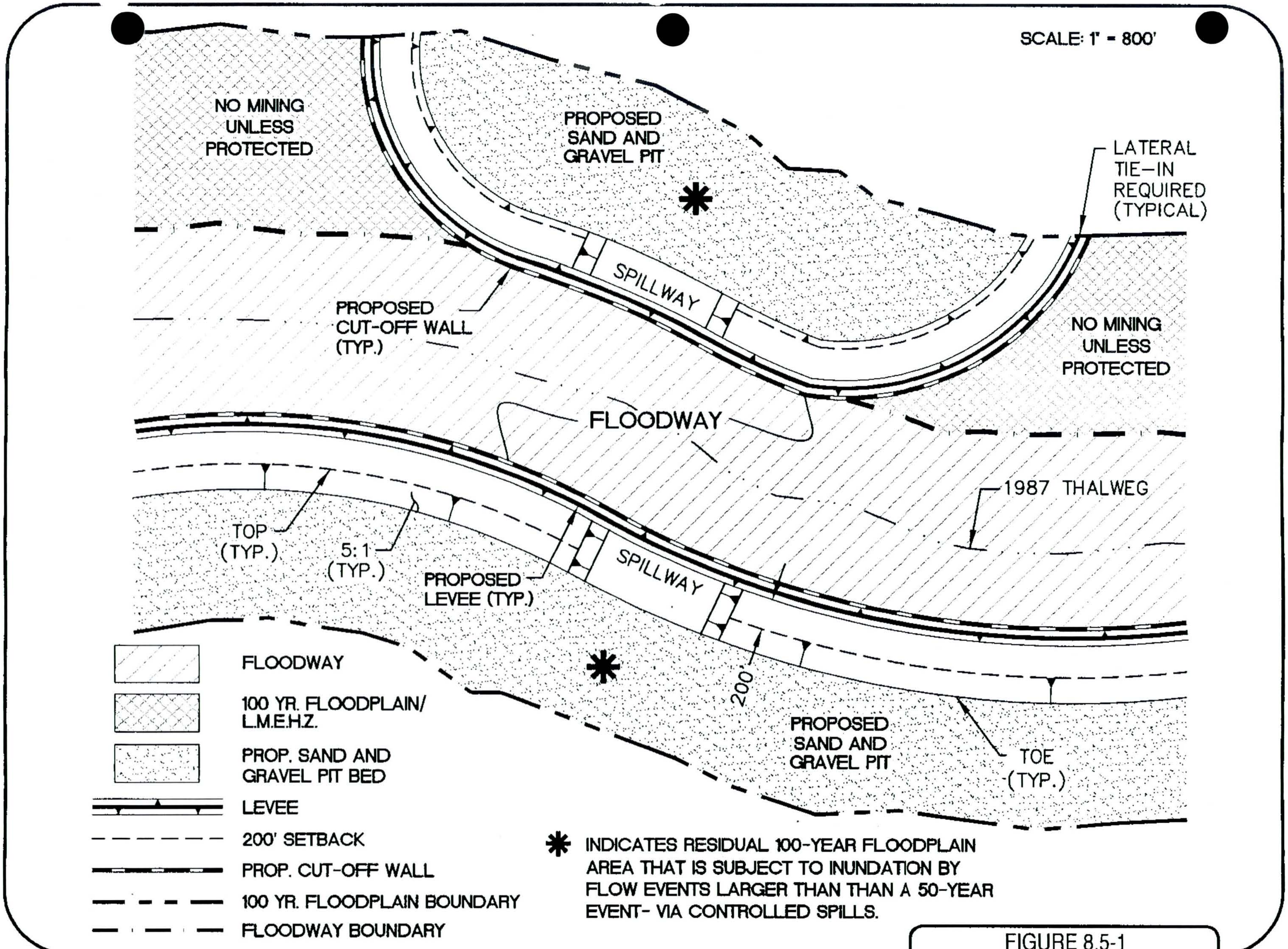


FIGURE 8.5-1
SCHEMATIC MINING PLAN

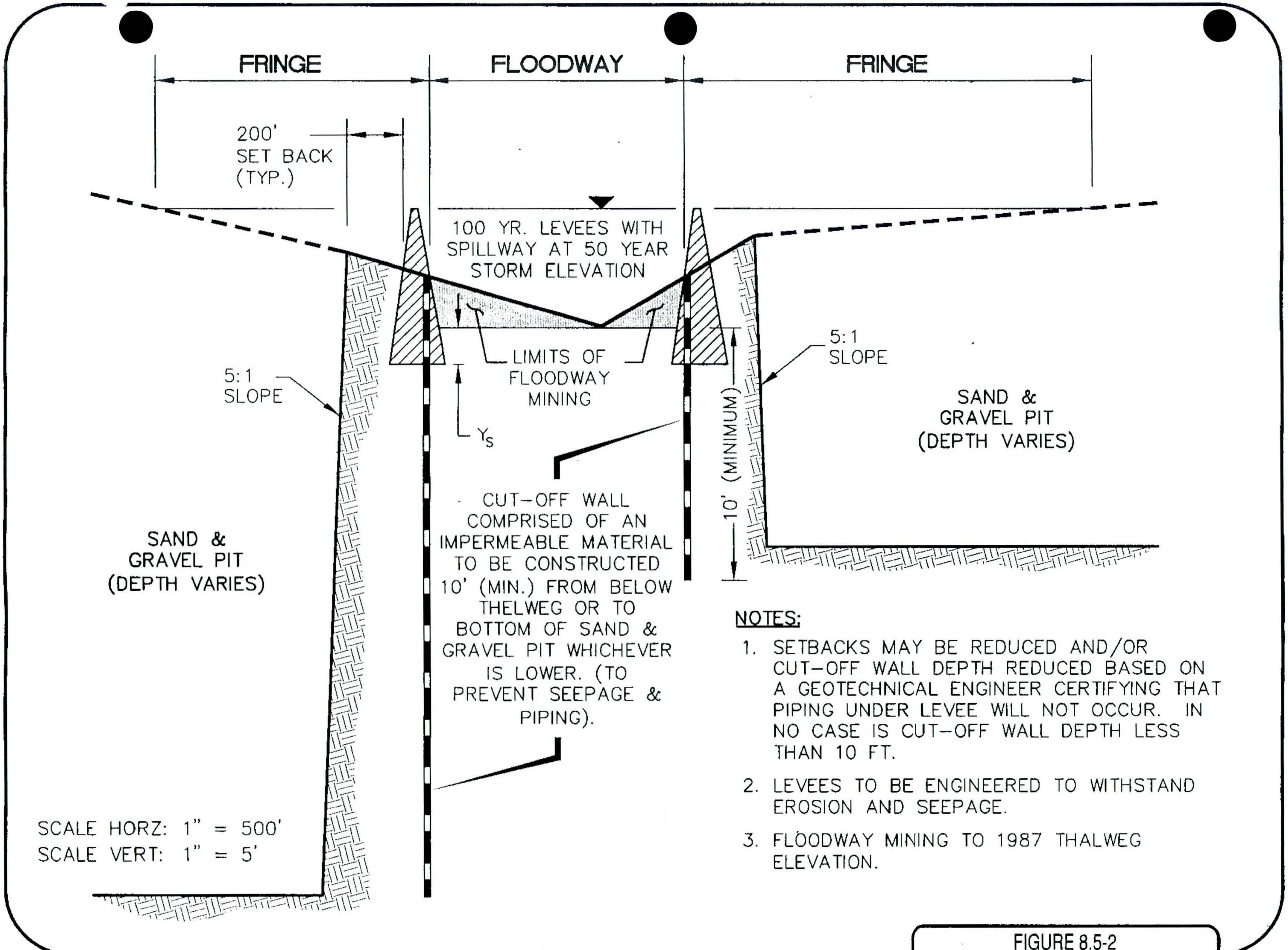


FIGURE 8.5-2
SCHEMATIC MINING CROSS SECTION

In order to facilitate the implementation of this strategy, it is recommended that the District pursue a 404 Permit for the Agua Fria River from New Waddell Dam to the confluence of the Gila River. The District would then assist sand and gravel miners to comply with the requirements of the 404 Permit. In return, the miners would limit mining impacts to their property boundaries.

In the event that a public/private partnership could be developed that included entities such as the Flood Control District, the sand and gravel industry, the development community and others, then the river channelization alternative should be reexamined. In order for this alternative to be consistent with the rest of the Watercourse Master Plan, it will be essential that incorporation of offline channel storage facilities be included to not cause excessive increases in downstream flood peak. It is also essential that the management plan developed with this alternative consider management strategies that would prevent the piping of waters from the channel into adjacent sand and gravel pits. Finally, it would be recommended that land use zoning within the historic floodplain adequately consider access and emergency evacuation of lands adjacent to the channel. Due to the landforms of the floodplain, unlike most other areas, a channel failure or flow event slightly larger than the design could lead to inundation of significant areas, and potentially the temporary displacement of significant populations.

9. STRUCTURAL ALTERNATIVE

9.1 Introduction

Traditional flood control strategies protect development within floodplains with levees, channels, or elevation on fill. The downside to this methodology is that quite often encroachment of the floodplain leads to adverse impacts to other properties. Also, development within the floodplain can greatly increase the potential of catastrophic flood damages in the event that a structure fails or overtops.

Structural flood and erosion control measures are generally the preferred solution to an existing site-specific problem. Although they may be costly to build and maintain, structures may be the most appropriate solution to protect existing development, to correct unforeseen consequences of other activities within the river, and to manage natural degradation or erosion of the channel bed and banks.

It is recognized that a purely structural solution for the Agua Fria River is neither practical nor advisable given the study objectives. Rather, the structural alternative presented here represents the "upper bracket" of costs and impacts to the river. Instead, elements of the structural alternative that best protect existing structures and meet other objectives are combined with non-structural elements to form a cohesive approach to managing the river corridor.

This discussion of proposed structures for flood/erosion control measures is limited to protecting the public from inundation or avulsion due to flood flows. It does not consider aggradation or degradation of the streambed due to the movement of sediment within the system. The need for grade control structures to arrest bed degradation is discussed in Section 7. The suitability of structural methods for flood protection or control of bank erosion discussed below is independent of grade control structures.

9.2 Existing Flood Control Structures

There are numerous flood and erosion control structures within the study reach of the Agua Fria River. This discussion is limited to existing engineered levees, grade control structures, and bank protection not associated with bridges. The District does not own or maintain bridges; therefore, it is not responsible for evaluating their vulnerability to scour and overtopping during flood events. Non-engineered levees, such as those associated with sand

and gravel mines or agricultural fields, are not recognized as flood control structures by the FEMA. Therefore, these structures are not considered adequate protection against the regulatory 100-year flood.

9.2.1 *Levees*

Existing levee locations are summarized below in Table 9.2-1, and Figure 9.2-1 through Figure 9.2-17 on the following pages show the proposed levees.

Table 9.2-1 - Location of Existing Levees

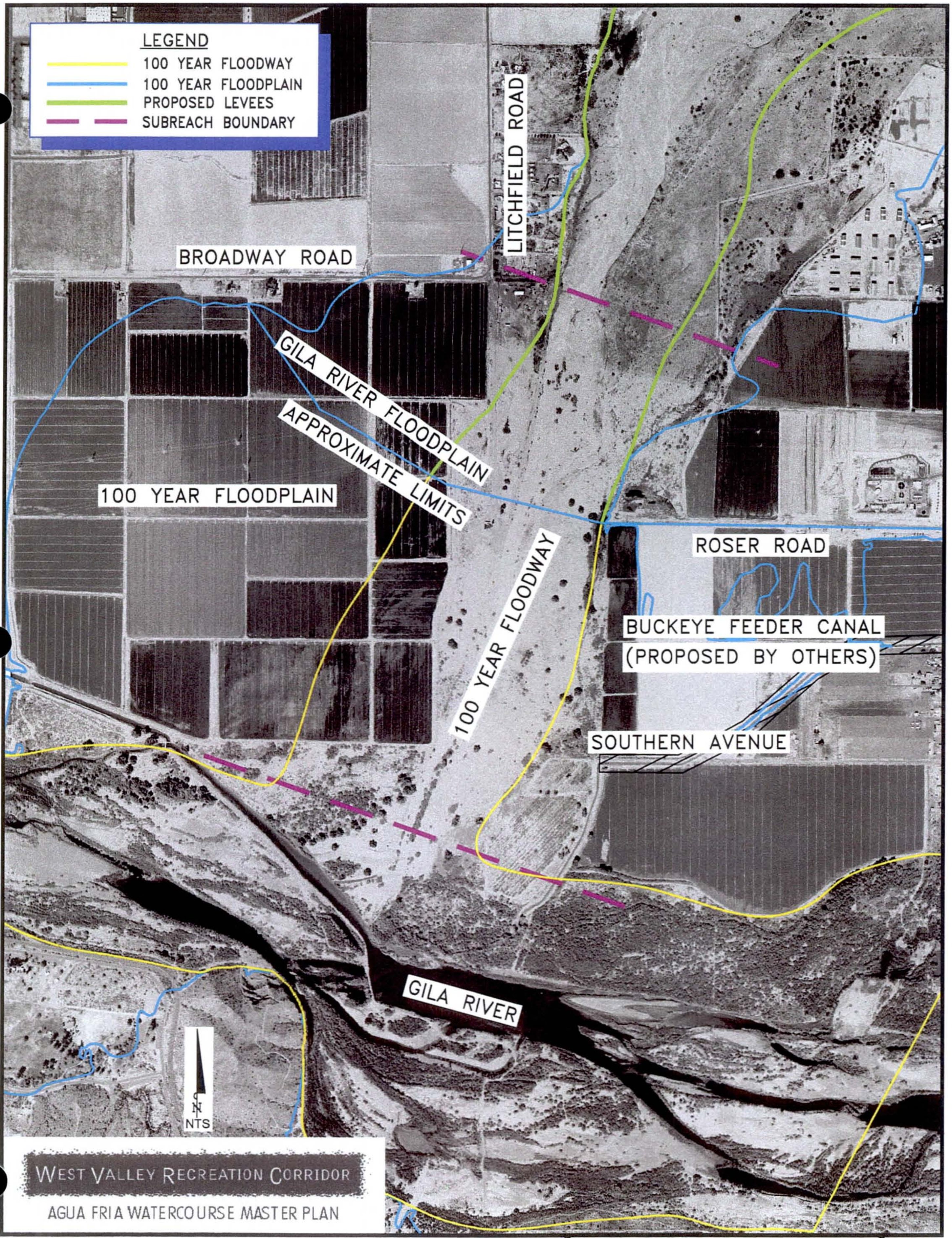
Reach	Bank	Protecting
Broadway Road to MC85	West	Avondale
MC85 to Indian School Road	East/West	Avondale
Indian School Road to Confluence of New River	East	Camelback Ranch
Confluence of New River to Glendale Avenue	East	Glendale WWTP
Glendale Avenue to Northern Avenue	East	Glendale landfill and Glendale recycling facility
Bell Road to Beardsley Road	East	Coyote Lakes

9.2.2 *Grade Control Structures*

There are five existing grade control structures between Indian School Road and MC85. The grade control structures were constructed in conjunction with the levees.

9.2.3 *Bank Protection*

There are approximately 700 linear feet of bank protection along the west bank of the river south of the Bell Road bridge. The bank protection consists of gabion baskets protecting an apartment complex on the south side of Bell Road at the river.



WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

Kimley-Horn and Associates, Inc.

FIGURE 9.3-1
STRUCTURAL PLAN
CONFLUENCE OF GILA TO BROADWAY ROAD

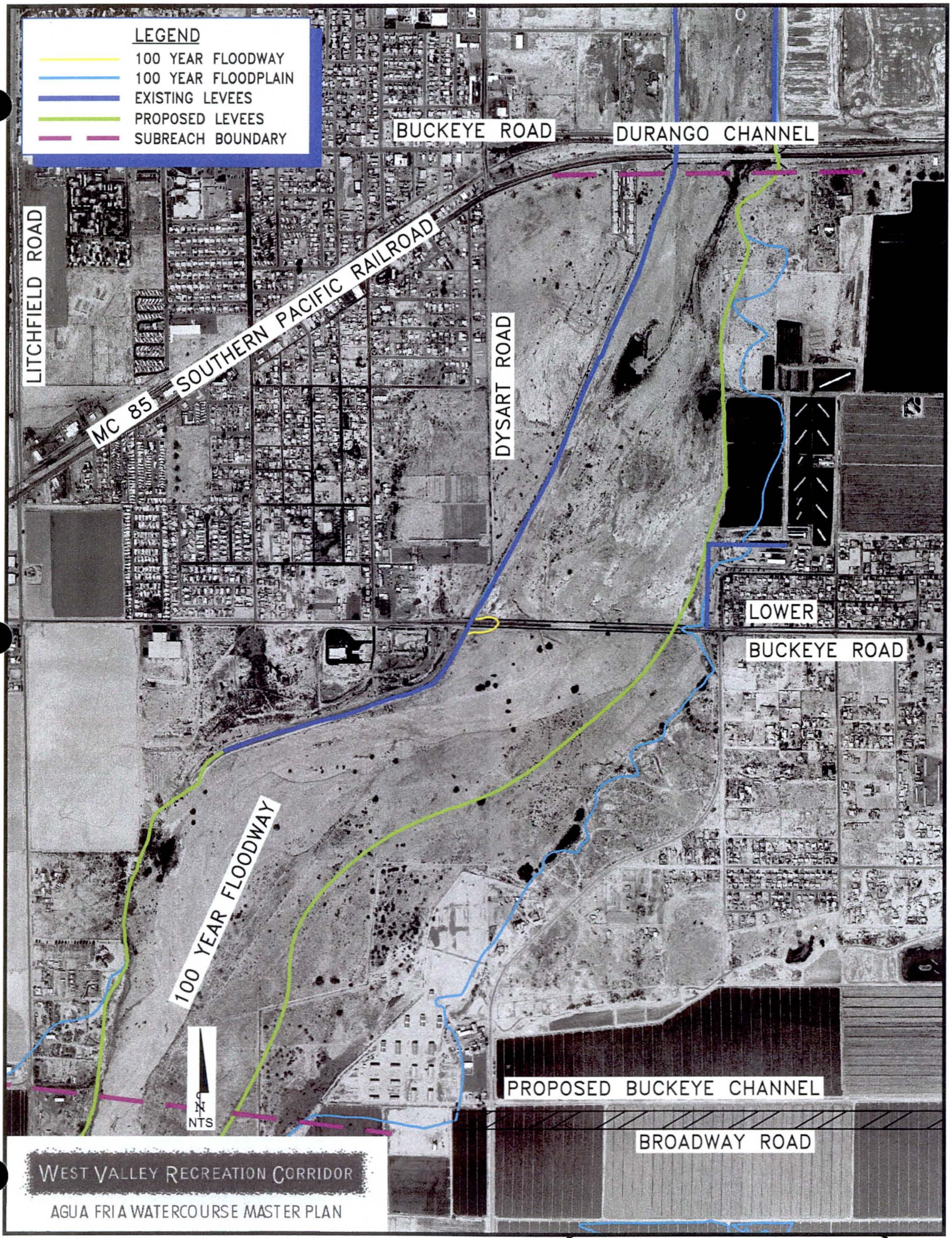


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FIGURE 9.3-2
STRUCTURAL PLAN
BROADWAY ROAD TO MC 85

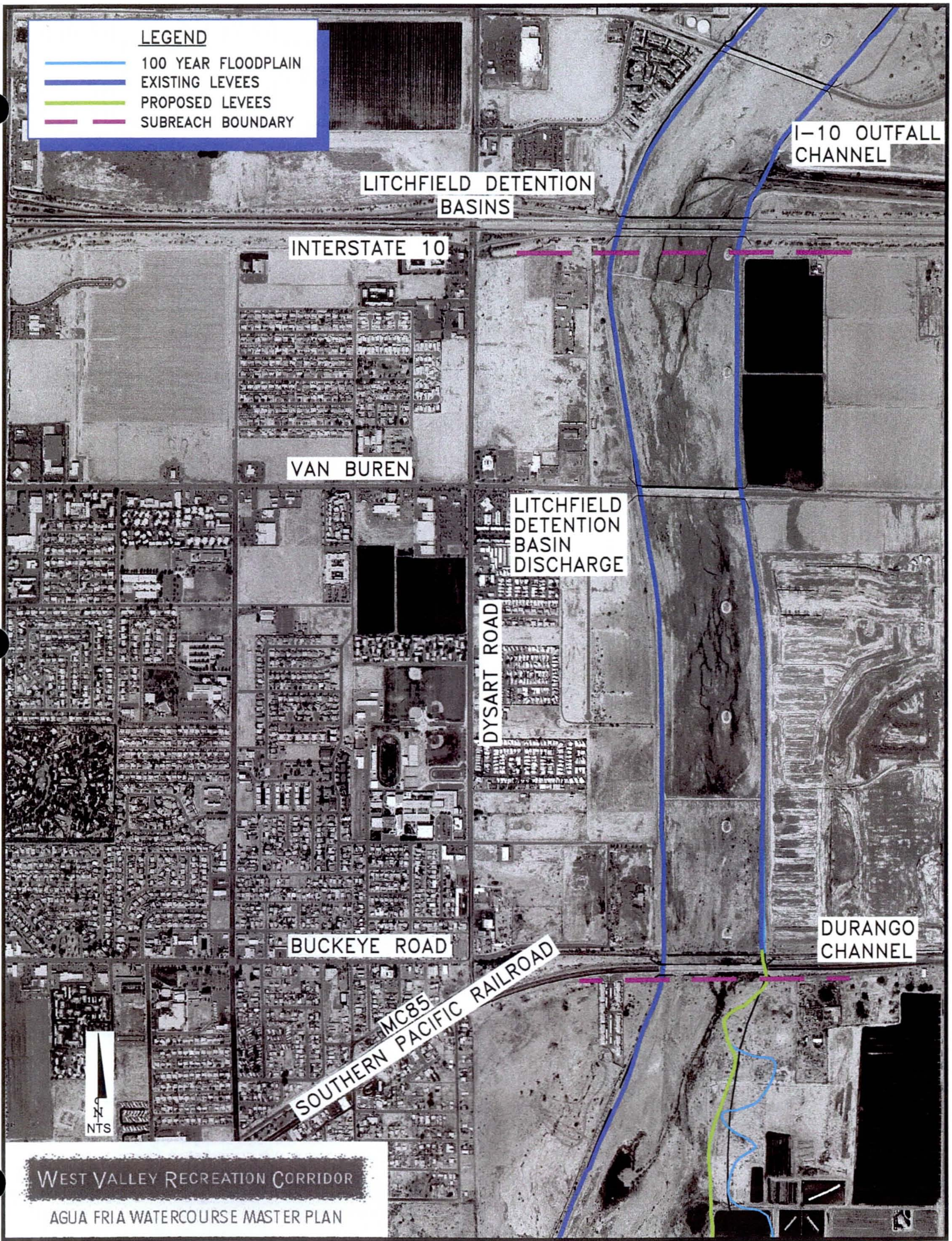

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FIGURE 9.3-3
STRUCTURAL PLAN
MC 85 TO INTERSTATE 10

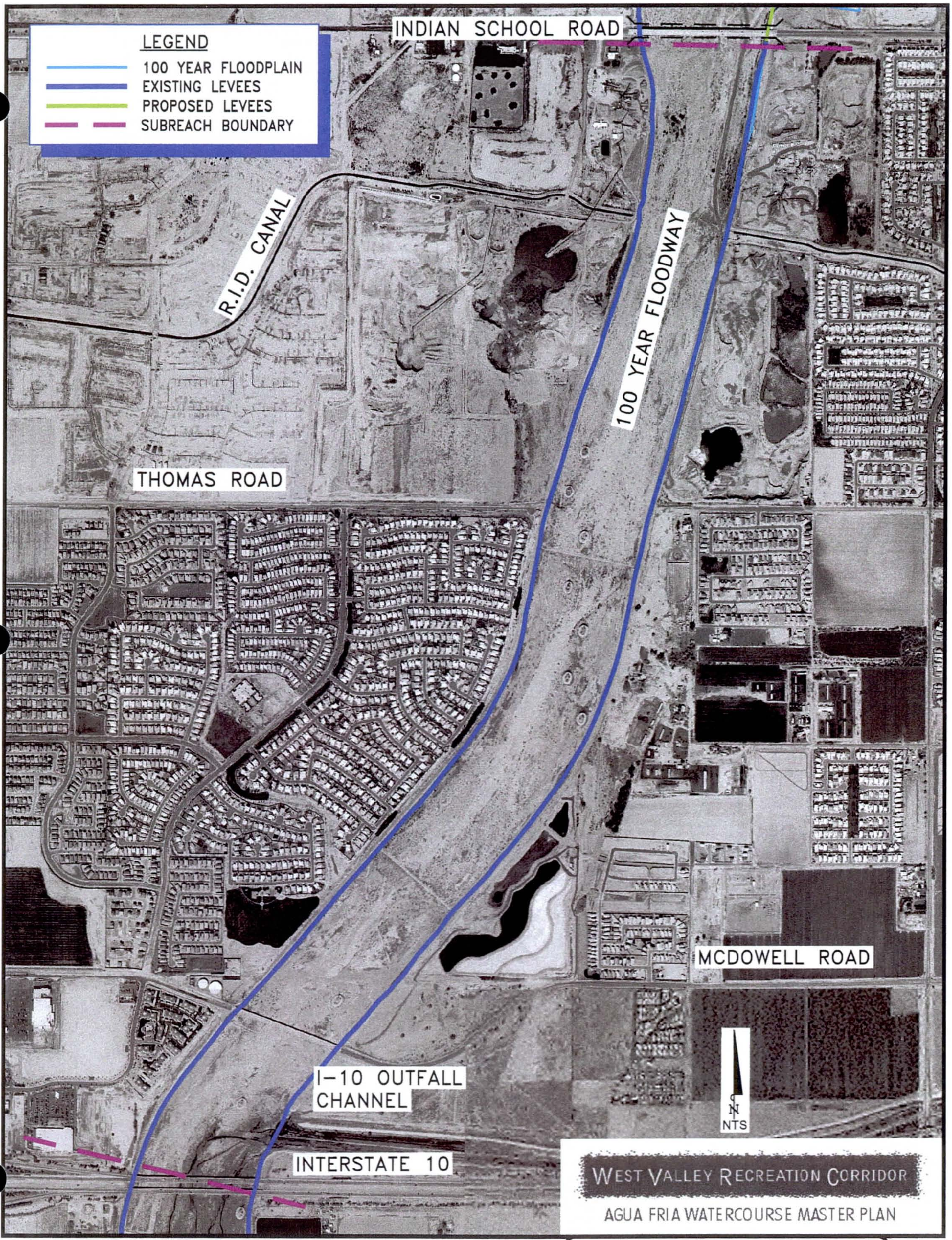

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FIGURE 9.3-4
STRUCTURAL PLAN
INTERSTATE 10 TO INDIAN SCHOOL ROAD

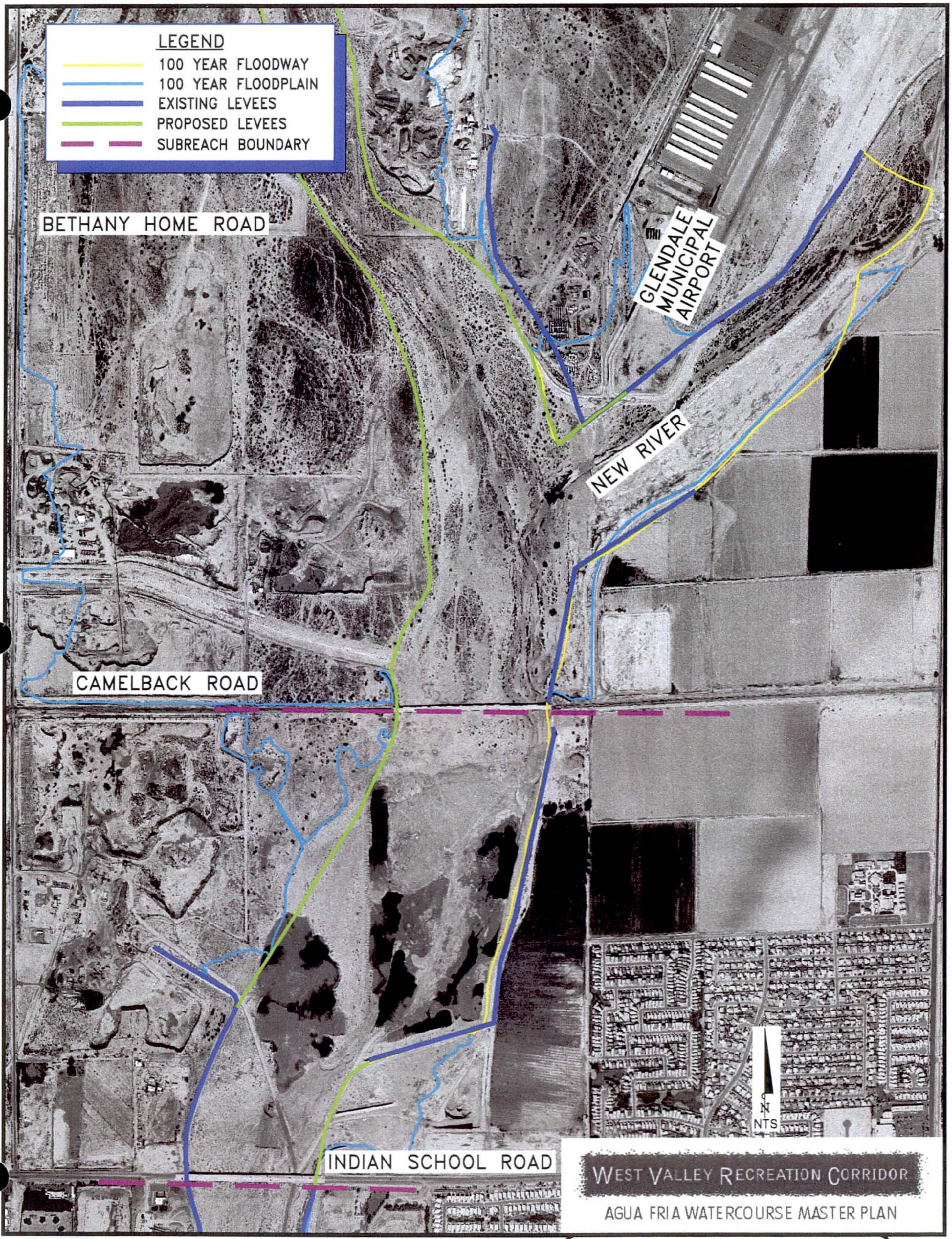

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FIGURE 9.3-5
STRUCTURAL PLAN
INDIAN SCHOOL RD TO CONF. OF NEW RIVER

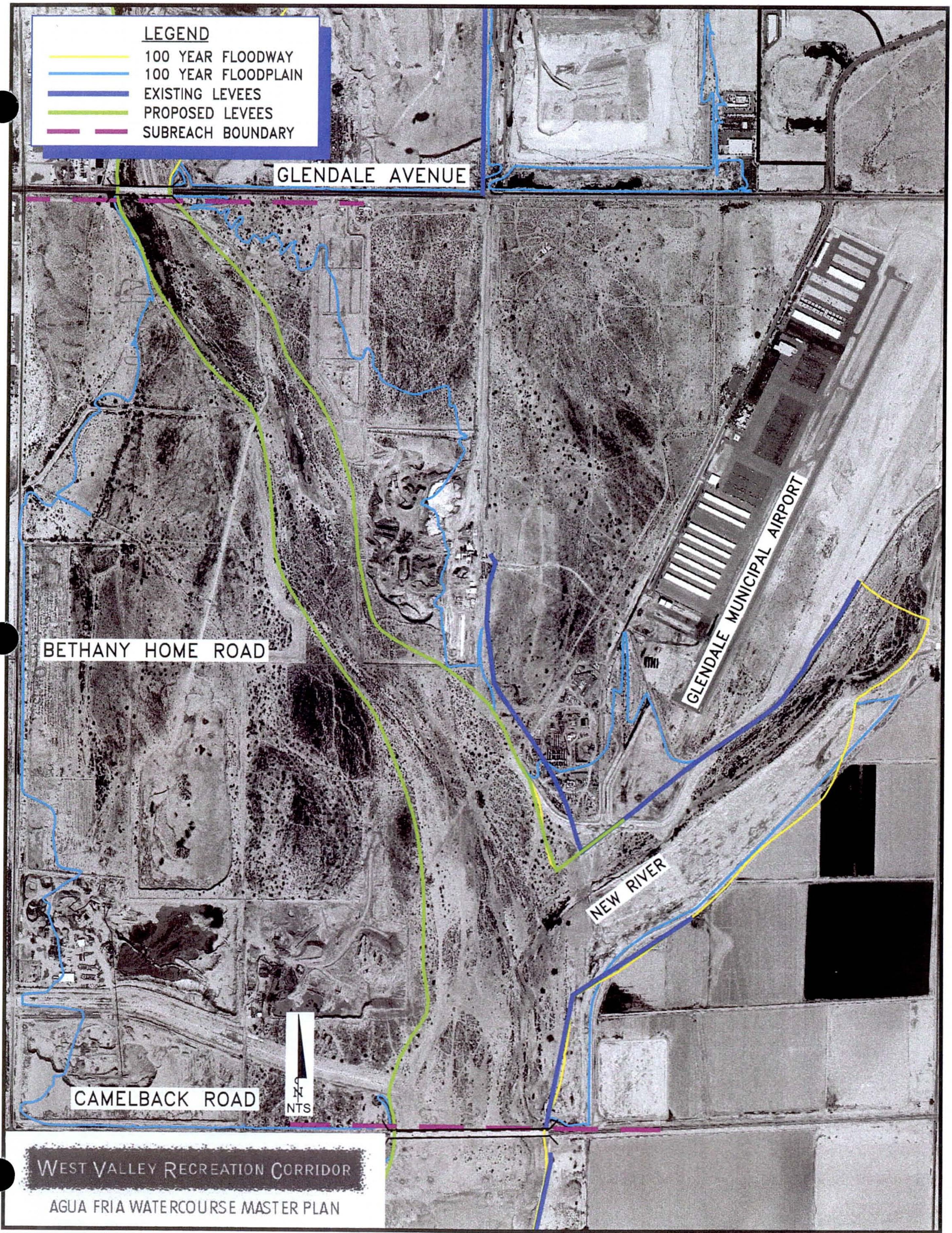

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FIGURE 9.3-6
STRUCTURAL PLAN
CONF OF NEW RIVER TO GLENDALE AVE

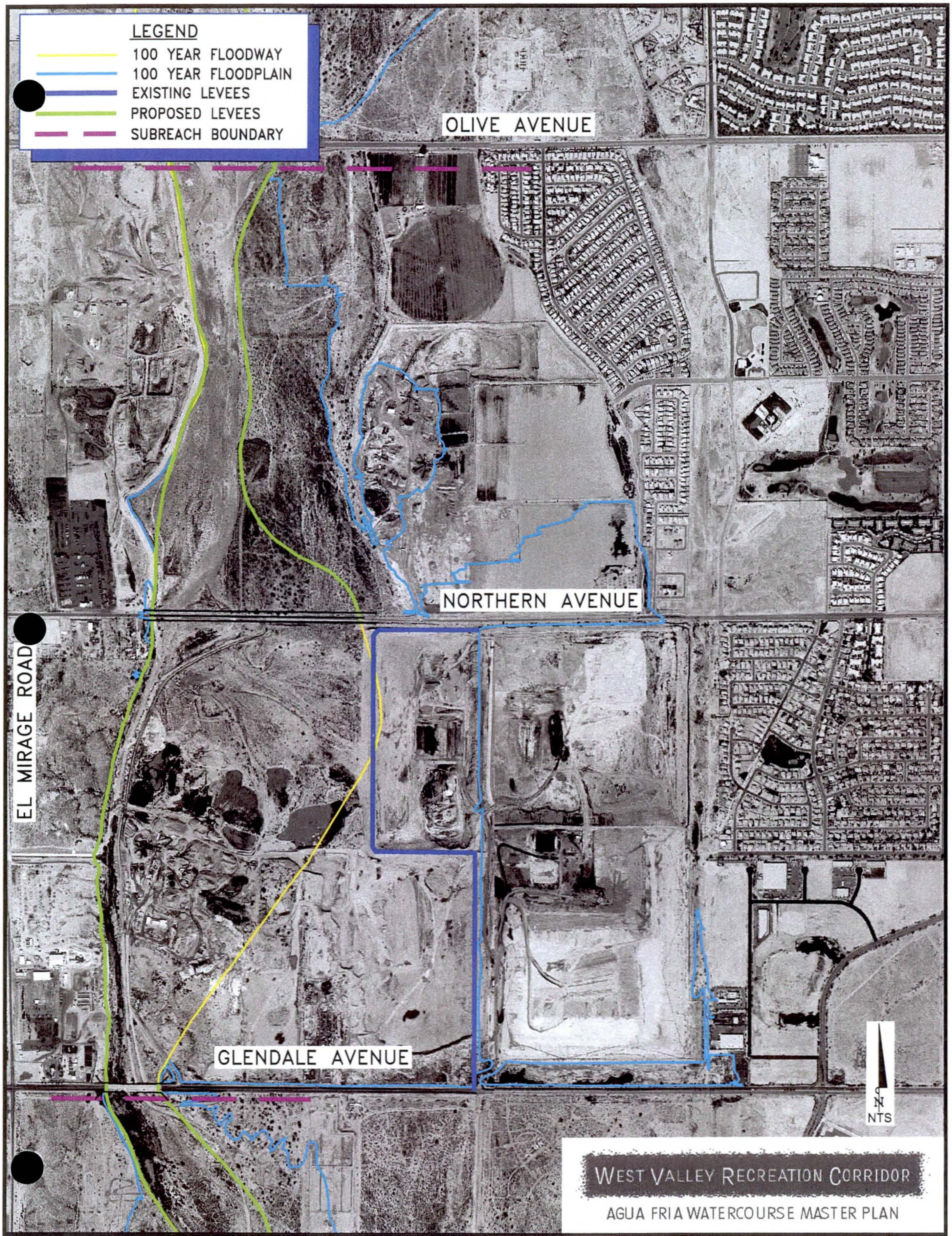

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FIGURE 9.3-7
STRUCTURAL PLAN
GLENDALE AVE TO OLIVE AVE

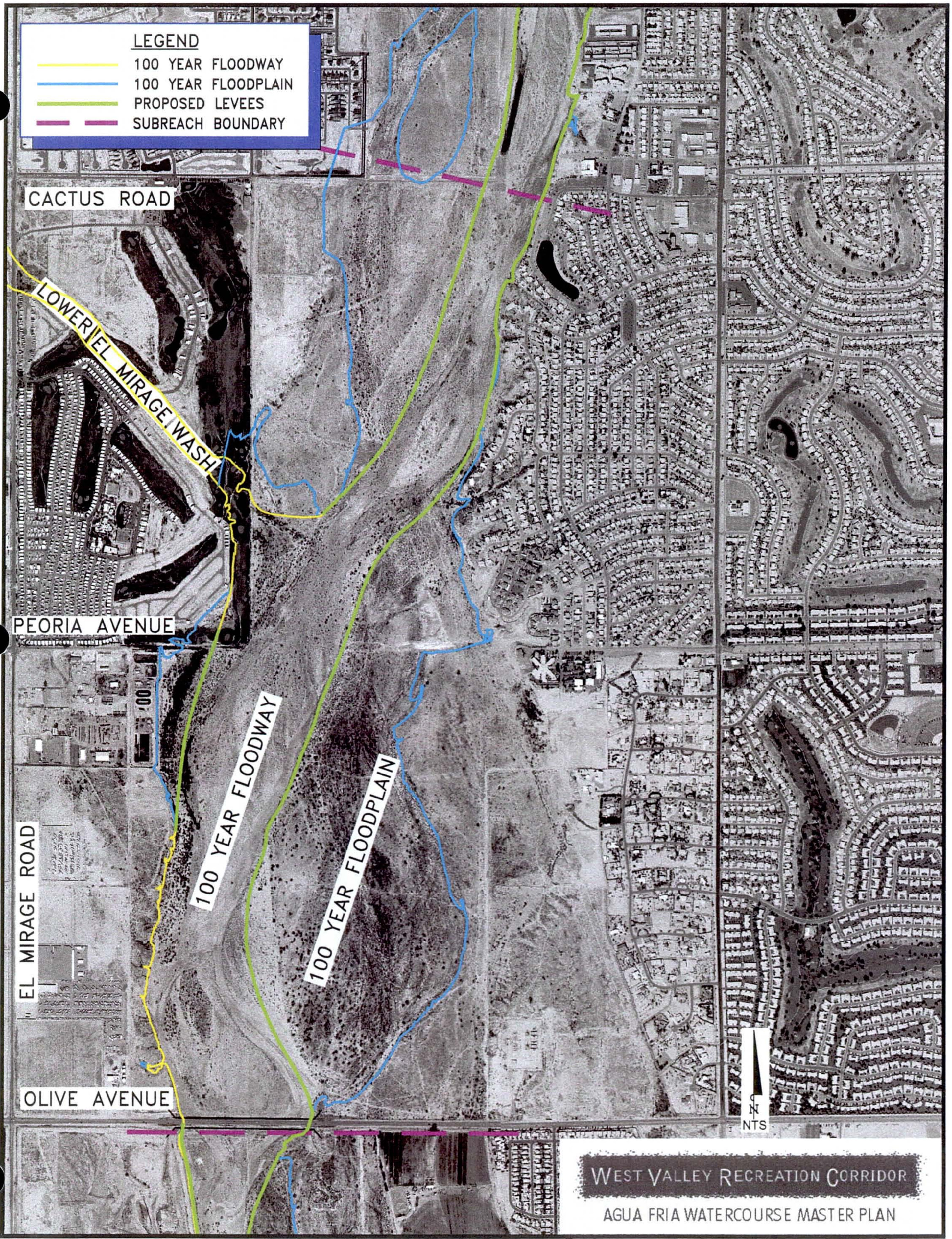

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FIGURE 9.3-8
STRUCTURAL PLAN
OLIVE AVENUE TO CACTUS ROAD

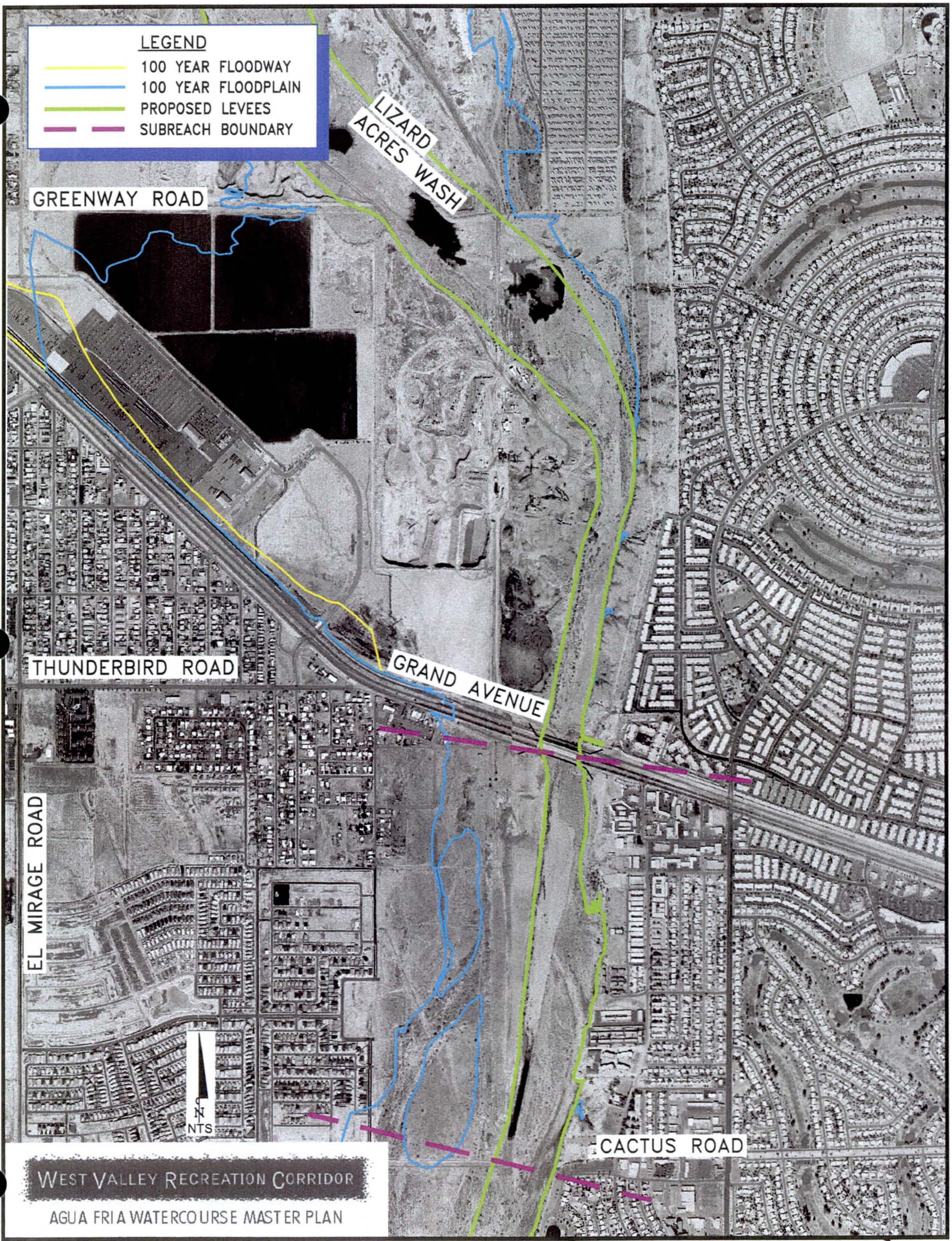

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FIGURE 9.3-9
STRUCTURAL PLAN
CACTUS ROAD TO GRAND AVENUE

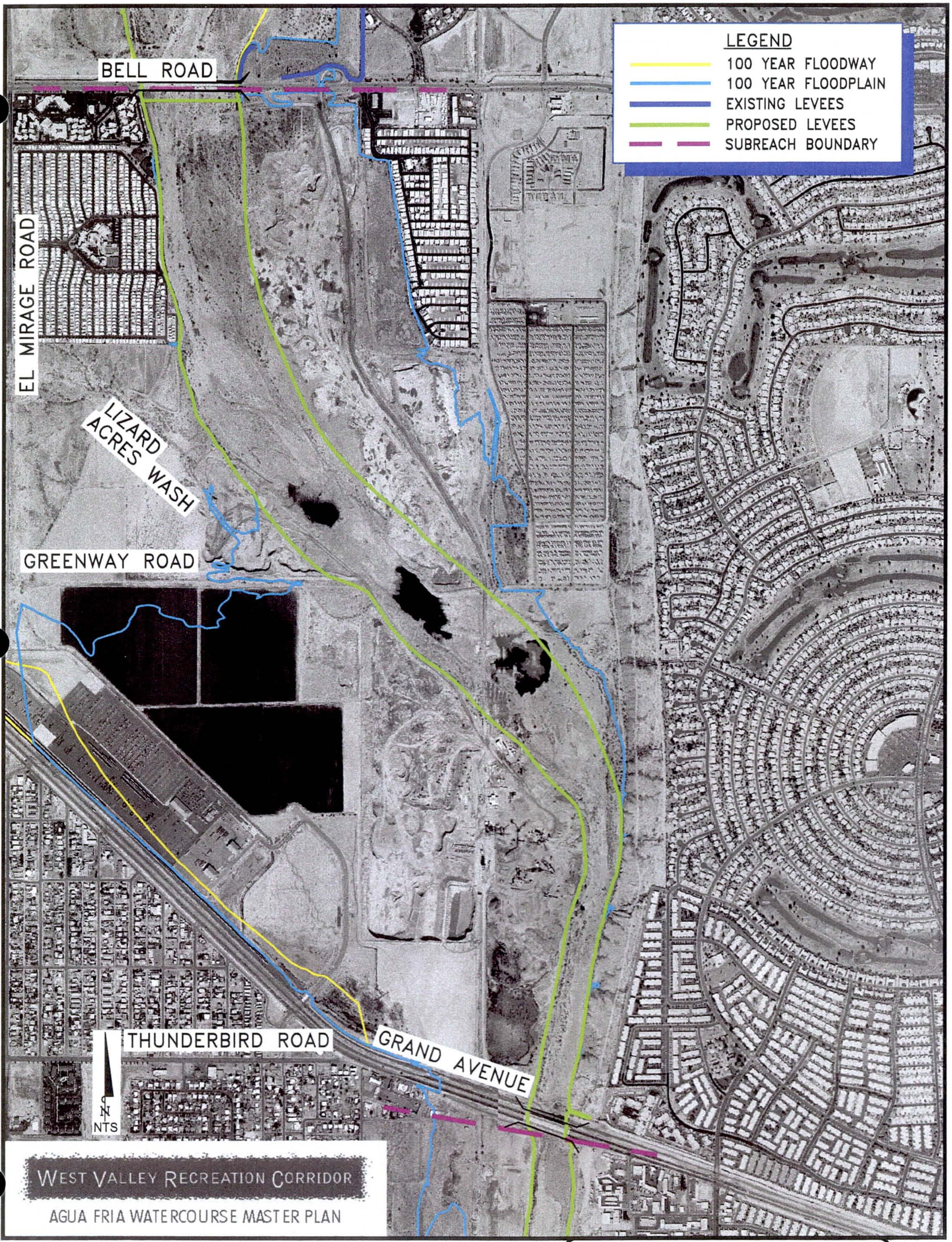

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FIGURE 9.3-10
STRUCTURAL PLAN
GRAND AVENUE TO BELL ROAD

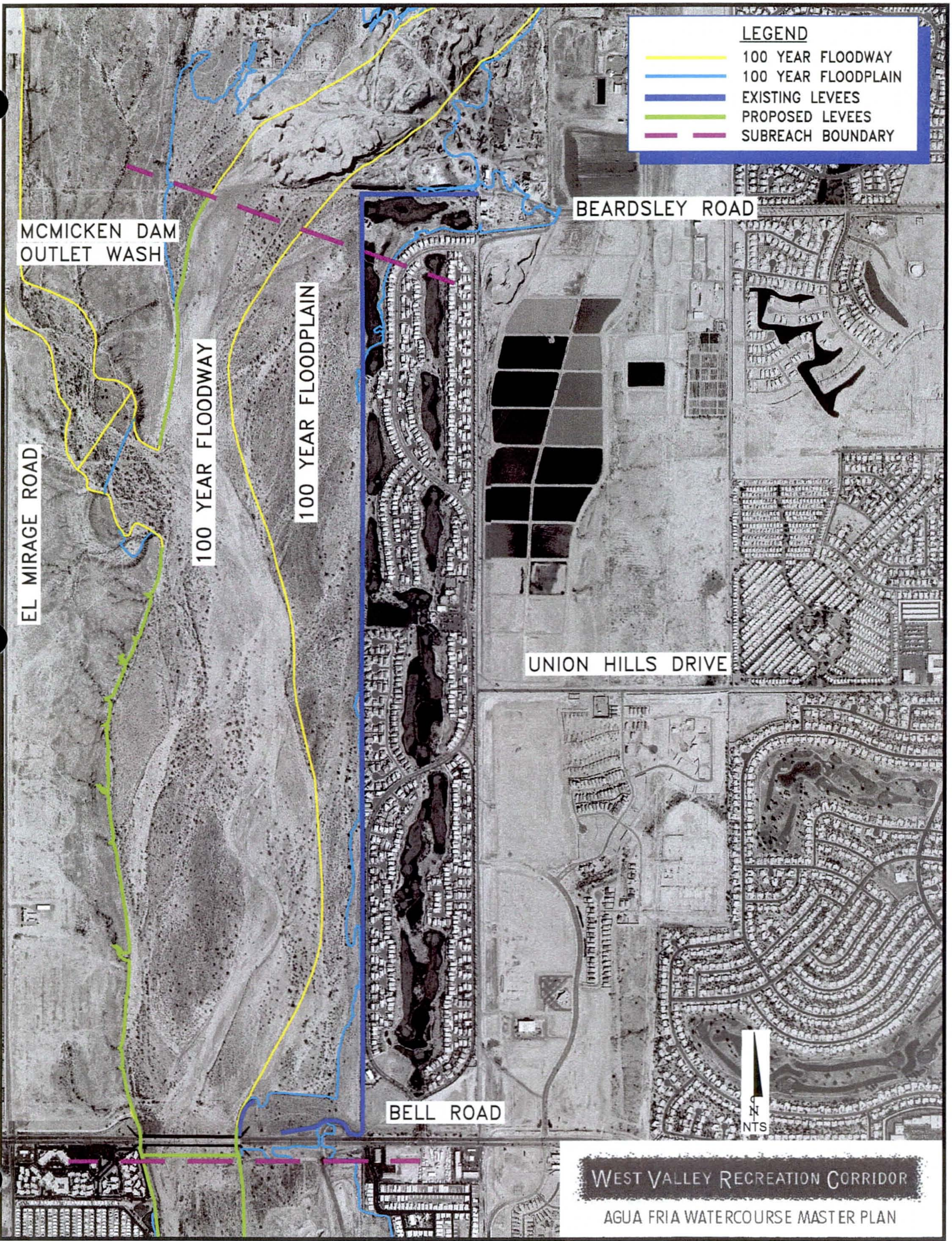

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FIGURE 9.3-11
STRUCTURAL PLAN
BELL ROAD TO BEARDSLEY ROAD

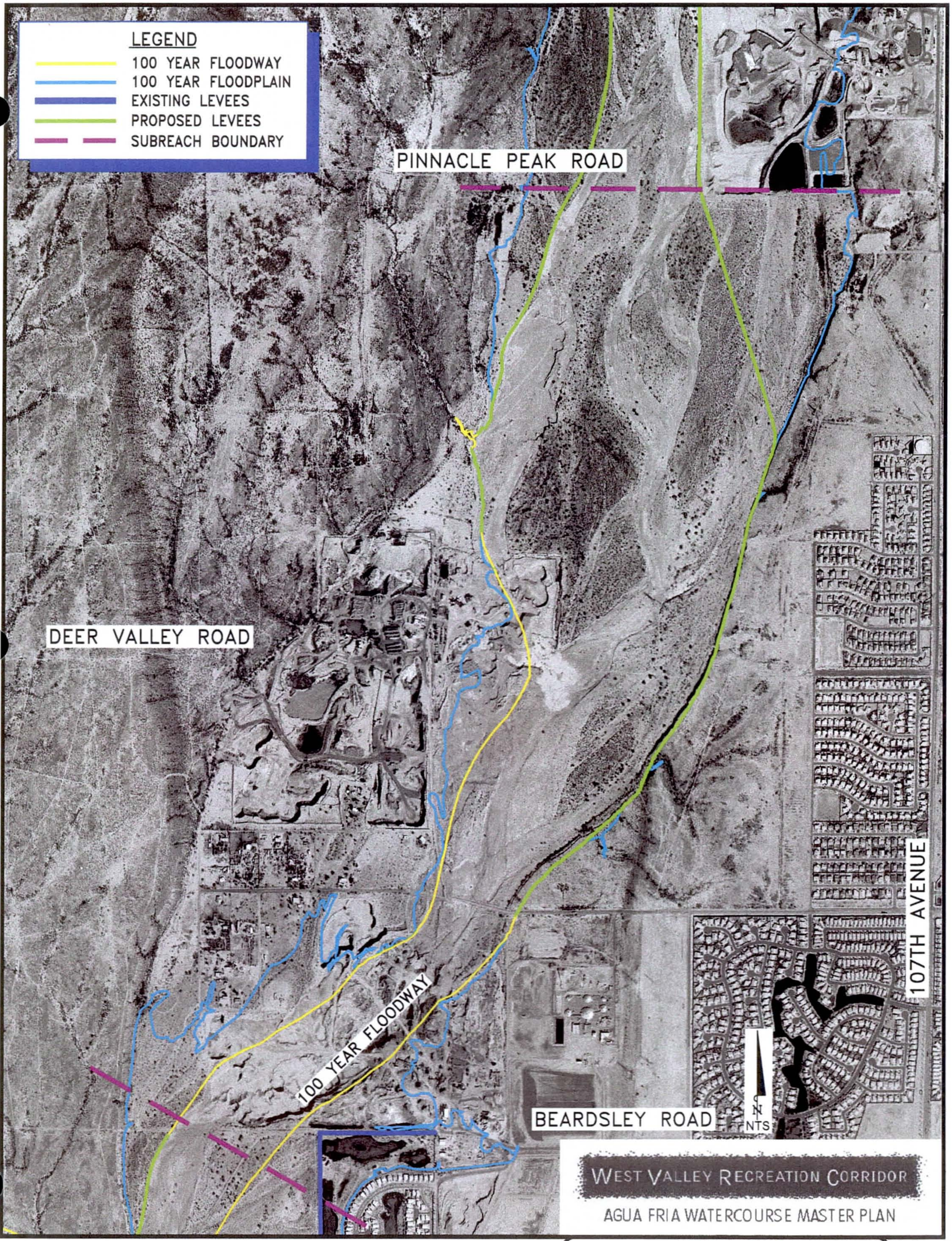

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FIGURE 9.3-12
STRUCTURAL PLAN
BEARDSLEY RD TO PINNACLE PEAK RD

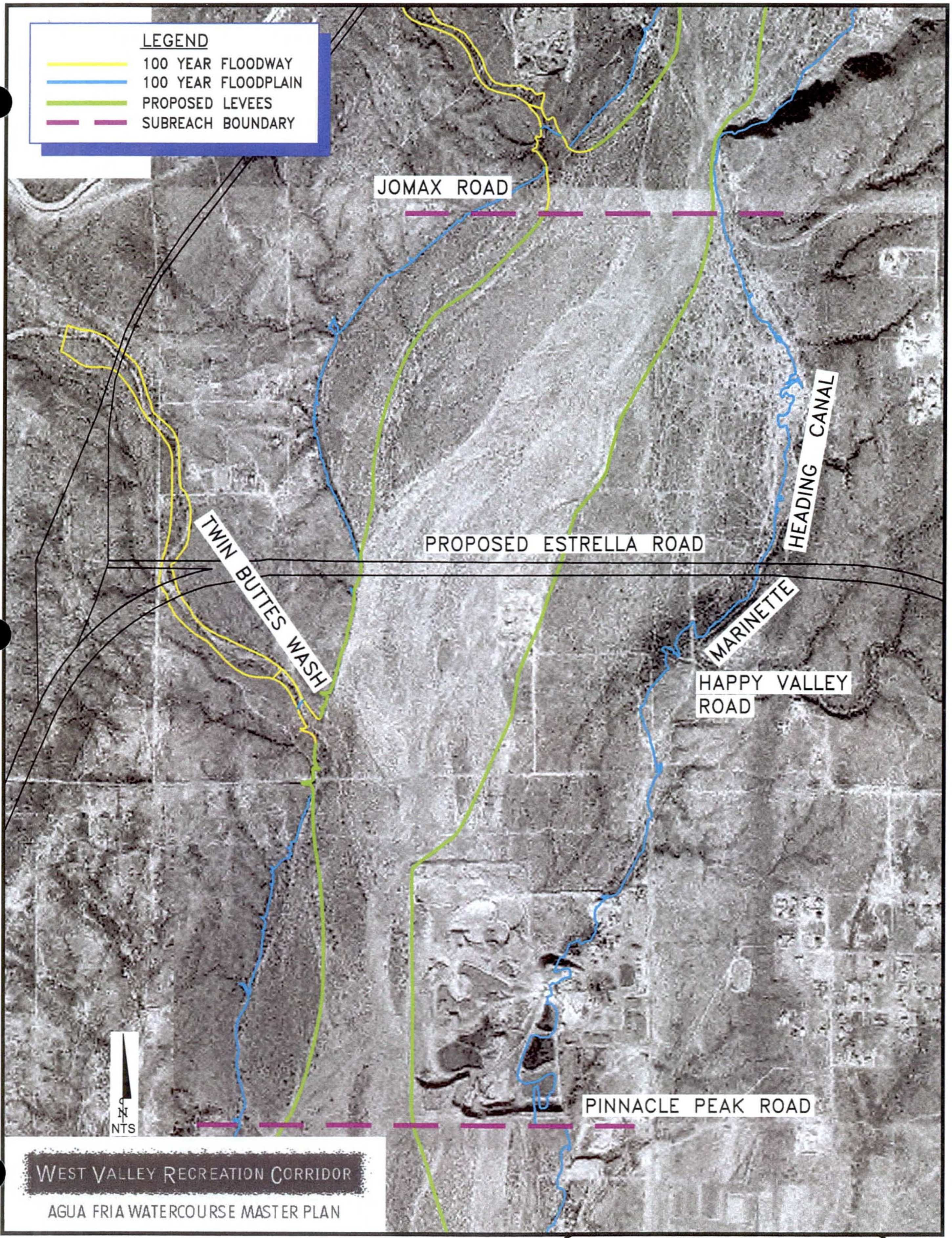

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FIGURE 9.3-13
STRUCTURAL PLAN
PINNACLE PEAK ROAD TO JOMAX ROAD

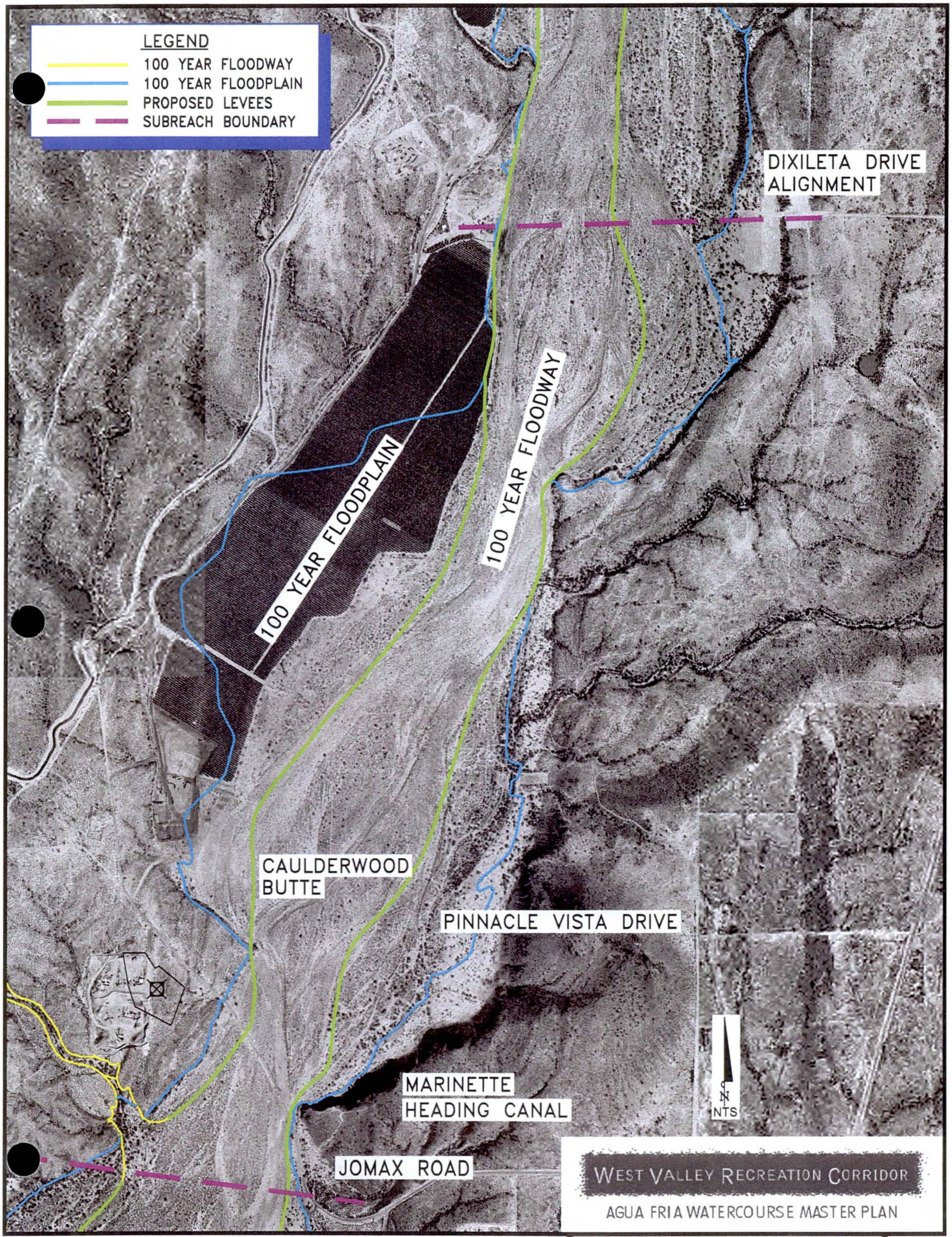

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FIGURE 9.3-14
STRUCTURAL PLAN
JOMAX ROAD TO DIXILETA DRIVE ALIGNMENT

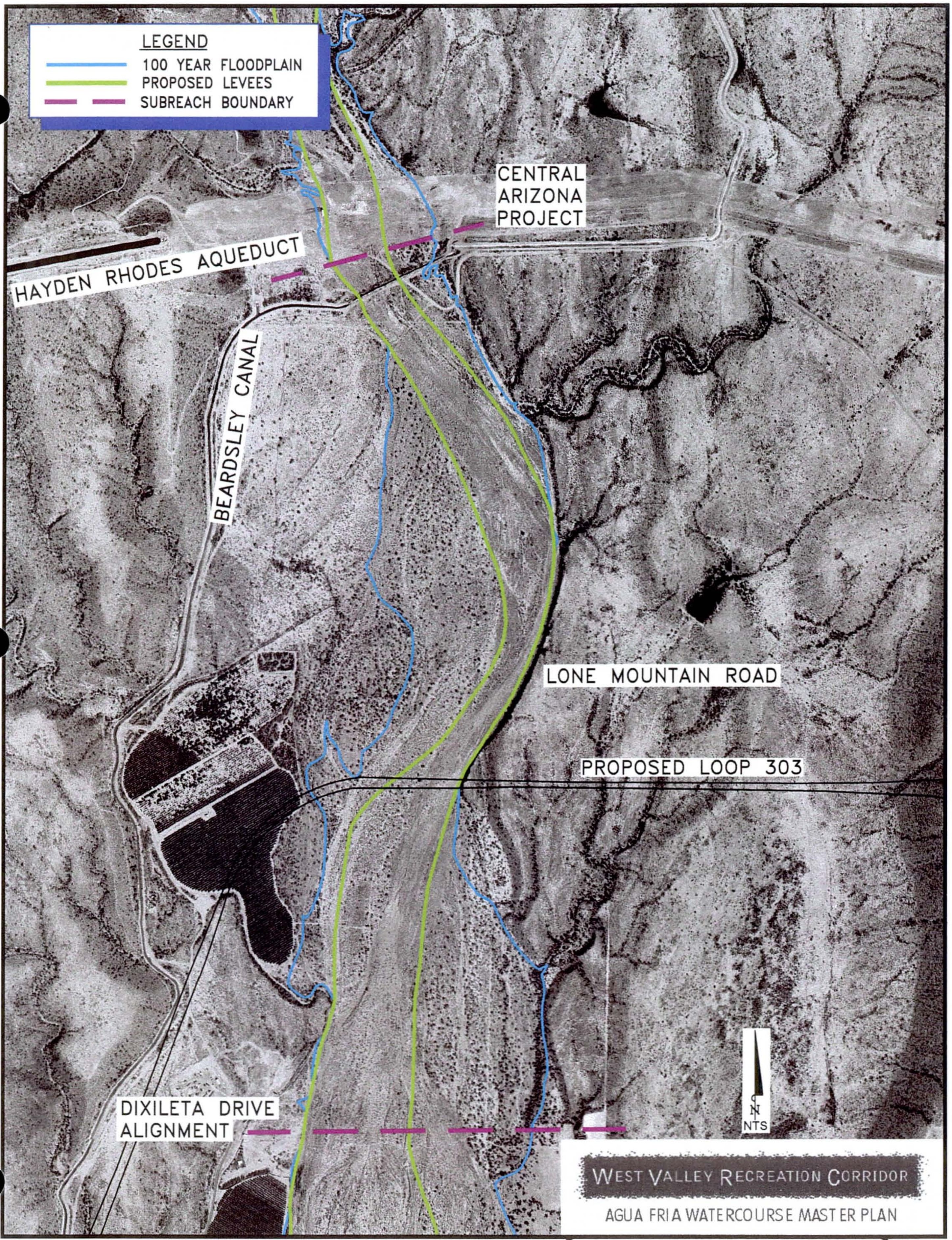

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FIGURE 9.3-15
STRUCTURAL PLAN
DIXILETA DRIVE ALIGNMENT TO CAP CANAL

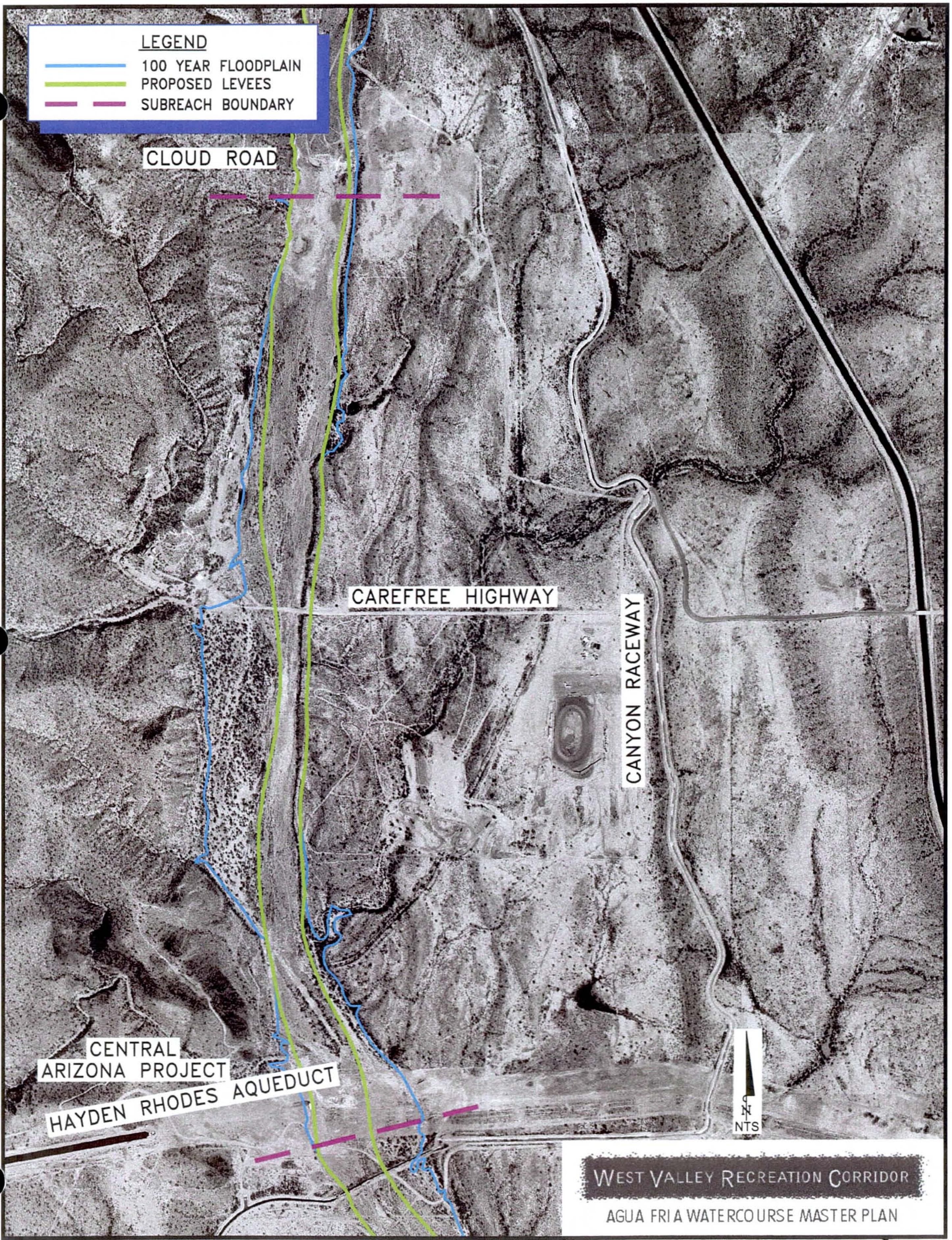

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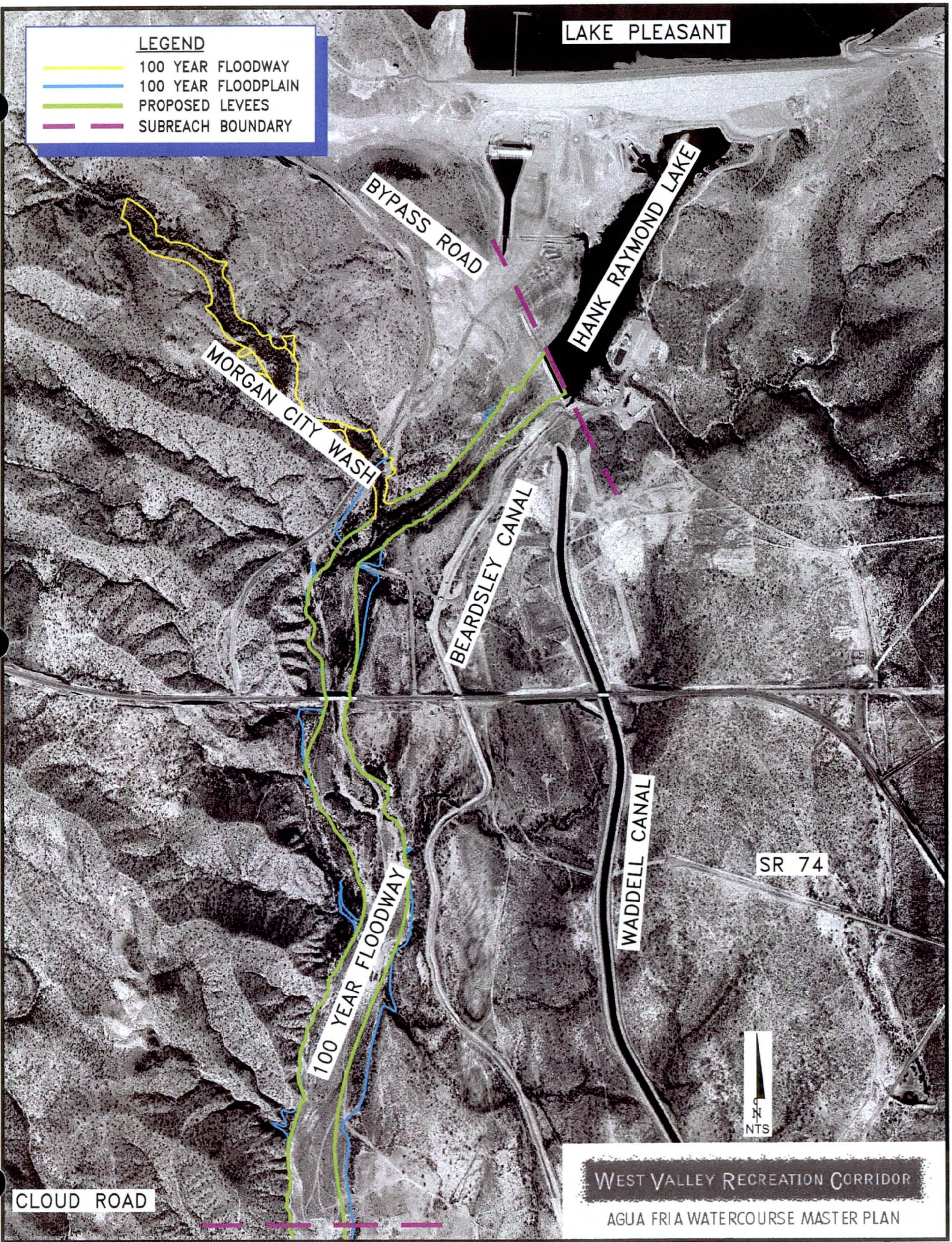
FIGURE 9.3-16
STRUCTURAL PLAN
CAP CANAL TO CLOUD ROAD



WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

Kimley-Horn and Associates, Inc.

FIGURE 9.3-17
STRUCTURAL PLAN
CLOUD ROAD TO NEW WADDELL DAM

9.3 *Description of Structural Alternative*

The first major structural element considered would extend along the entire study area from the floodplain of the Gila River to New Waddell Dam. This element would consist of new levees tying into the existing levees along both banks. The levees are assumed to be constructed along the current regulatory floodway boundary line. As stated previously, the primary reason for considering a full-length structural solution is to establish an upper boundary limit for potential project costs and impacts.

A second structural element was considered at the District's request. Channelization of the river was analyzed from Jomax Road to Grand Avenue in lieu of levees. The channel would be constructed to convey the 100-year regulatory discharge with one foot of freeboard. The purpose of the channel is to make land available for development within the existing floodplain.

In addition to the two major structural elements considered, specific flood and erosion concerns have been identified at various locations within the watercourse. Isolated flood/erosion control structures were considered to mitigate these specific concerns.

A detailed description of the structural elements is presented below by subreach.

9.3.1 Confluence of Gila River to Broadway Road

<u>Full Length Levees</u>

Both the Agua Fria and the Gila Rivers affect the confluence region. The limits of the Gila River floodplain extend north to the vicinity of Broadway Road. South of Broadway Road, the floodplain may be inundated by flows from either river. Levees along the east bank of the Agua Fria were considered at the request of area residents. However, due to potential flooding from the Gila, levees in this subreach are ineffective unless levees are also constructed along the north bank of the Gila. Another study, Tres Rios, is being performed by others to evaluate the installation of a levee along the Gila River. Therefore, a levee along the east bank of the Agua Fria is assumed to tie into the proposed Tres Rios levee.

As is the case on the east bank, levees along the west bank of the Agua Fria would not provide protection unless a second levee is constructed along the north bank of the Gila River. At the present time, there are no levees under consideration on this reach of the Gila River. A detailed study is required to adequately assess the situation. Therefore, levees were not considered for the west bank of the Agua Fria in this subreach.

It appears that there are no existing buildings within the Agua Fria floodplain in this subreach.

Isolated Structures

Isolated flood control structures were not considered necessary in this subreach.

9.3.2 *Broadway Road to MC85*

Full Length Levees

Much of the west bank and a subdivision on the east bank are protected by existing levees. Additional levees were considered to provide continuous levees along the subreach. The proposed levees would tie into the existing levees.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.3 *MC85 to I-10*

Full Length Levees

The entire subreach is protected by existing levees. No additional levees were considered.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.4 *I-10 to Indian School Road*

Full Length Levees

The entire subreach is protected by existing levees. No additional levees were considered.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.5 *Indian School Road to Confluence of New River*

Full Length Levees

The east bank is protected by existing levees. The levees extend north to protect the Glendale airport, the Glendale wastewater treatment plant, and the Camelback Ranch development. Several sand and gravel mining operations occupy the west bank. A new west levee would extend from the existing levee north of Indian School Road to the New River.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.6 *Confluence of New River to Glendale Avenue*

Full Length Levees

Sand and gravel mines are in operation within the floodplain on both sides of the river. New levees would extend on both sides of the river for the entire subreach.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.7 *Glendale Avenue to Olive Avenue*

Full Length Levees

The east bank is protected by existing levees from Glendale Avenue to Northern Avenue. The levees protect the Glendale landfill and municipal recycling facility. A large sand and gravel mining operation occupies the floodway and portions of the east bank within this subreach. New levees would be located from Northern to Olive Avenue on the east side and from Glendale to Olive Avenue on the west side.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.8 *Olive Avenue to Cactus Road*

Full Length Levees

Numerous developments are located outside the floodplain on both sides of the Agua Fria in this subreach. New levees would be located from Olive Avenue to Cactus Road on both sides of the river.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.9 *Cactus Road to Grand Avenue*

Full Length Levees

The El Mirage Landfill occupies the west bank of this subreach. The landfill embankment is protected by riprap. The level of protection provided by the riprap is unknown. The opposite bank of the river is a high, nearly vertical bluff with existing development along the top edge. New levees would extend along both sides of the entire subreach.

Isolated Structures

Bank protection is needed to protect the existing landfill, although it is difficult to determine its scope and cost. The extent of the landfill is not clearly defined in the records available for review.

The opposite bank of the river is a high, nearly vertical bluff in this subreach. Protecting the landfill embankment makes the opposite bank of the river more susceptible to erosion. Flow velocities in this area are high enough to cause erosion. Therefore, the east bank would also need to be protected.

9.3.10 *Grand Avenue to Bell Road*

Full Length Levees

There is no existing development within the regulatory floodplain from Grand Avenue to Greenway Road. However, existing homes abut the floodplain/floodway on the west bank, south of Bell Road at the top of a nearly vertical 25-foot bluff. New levees would extend along both sides of the river in this subreach.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

River Channelization

In lieu of levees, a channel that would contain the 100-year flood was considered. The configuration is a compound trapezoidal section with a low flow channel and a 150-foot bench above the low flow channel. The low flow channel would contain half of the 100-year flood. The bench in the upper portion of the channel was assumed to have a vegetated trail along the full length.

9.3.11 *Bell Road to Beardsley Road*

Full Length Levees

The east bank of this subreach is defined by an engineered levee protecting the Coyote Lakes subdivision. A new levee would extend along the west bank of the Agua Fria.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

River Channelization

In lieu of levees, the 100-year channel and landscaped trail was considered in this subreach.

9.3.12 *Beardsley Road to Pinnacle Peak Road*

Full Length Levees

A large sand and gravel mine occupies the lower half mile of the subreach. The mine is located within the floodway and within the floodplain along both banks. It is not possible to construct a levee or other flood control structure in this area due to the presence of the mine. The remainder of the subreach is undeveloped with smaller sand and gravel operations west of the floodplain. The remainder of the subreach could be protected by levees on both sides of the river.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

River Channelization

In lieu of levees, the 100-year channel and landscaped trail were considered in this subreach.

9.3.13 *Pinnacle Peak Road to Jomax Road*

Full Length Levees

A large gravel mine is located immediately north of Pinnacle Peak Road within the flood fringe and east of the floodplain. The CAP is currently constructing groundwater recharge ponds within the flood fringe along the west bank, south of Jomax Road. Levees would be located along both sides of the river.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

River Channelization

In lieu of levees, the 100-year channel and landscaped trail were considered in this subreach.

9.3.14 *Jomax Road to Dixileta Drive Alignment*

Full Length Levees

In the future, water will flow through this subreach along the natural channel bottom from the CAP Canal to the recharge ponds south of Jomax. Also, proposed gravel mines may be located in the flood fringe along the west bank. Levees would be located along both sides of the river.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

River Channelization

In lieu of levees, the 100-year channel and landscaped trail were considered in this subreach. The channel must be modified to accommodate the CAP recharge project, but the details of this modification were not analyzed.

9.3.15 *Dixileta Drive Alignment to the CAP Canal*

Full Length Levees

There are two existing structures within the subreach: the CAP Canal siphon and the Beardsley Canal bridge. A proposed bridge will carry the Loop 303 across the river in the vicinity of Lone Mountain Road.

As previously noted, water will flow from the CAP Canal to the recharge ponds south of Jomax. Also, proposed gravel mines may be located in the flood fringe along the west bank. Levees would be located along both sides of the river.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

River Channelization

In lieu of levees, the 100-year channel and landscaped trail were considered in this subreach. The channel must be modified to accommodate the CAP recharge project, but the details of this modification were not analyzed.

9.3.16 *CAP Canal to Cloud Road*

Full Length Levees

The subreach is generally undisturbed desert. There are no existing buildings within the regulatory boundaries. Levees would be located along both sides of the river.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.3.17 *Cloud Road to New Waddell Dam*

Full Length Levees

The subreach is generally undisturbed desert. There are no existing buildings within the regulatory boundaries. Levees would be located along both sides of the river.

Isolated Structures

Additional flood control structures do not appear to be necessary within this subreach.

9.4 Analysis of Structural Alternative

9.4.1 *Full Length Levees*

Design Assumptions for Levees

At this stage of the planning process, the full structural alternative must be quantified by developing general assumptions and approximate estimates of structure size, shape, and cost. The following design assumptions form the basis for calculating quantities and ultimately estimating costs:

- Levee height was calculated from data produced by the HEC-RAS Current Planning Model. Total levee height is equal to maximum channel depth plus 10 feet for toe down plus 3 feet of freeboard.
- Levee length is equal to left and right reach lengths between HEC-RAS cross sections.
- Levees were assumed to be 8 feet wide at the top and constructed of soil cement placed at a 1:1 slope.
- Embankment behind the levee was assumed to be tall, medium, or short, depending on existing bank condition. Embankment side slopes were assumed to be 8:1.
- Land costs for area under levees and embankments were included in the cost estimate. Land cost for construction easement or floodway area was not included.
- New levees would not be constructed if there are existing levees present.

Results of Levee Analysis

The length, height, and quantity of soil cement are estimated for each subreach. The quantities are shown in Table 9.4-1.

Table 9.4-1 - Levee Quantities

Subreach	Length of West Levee (ft)	Length of East Levee (ft)	Average Height of Levee (ft)	Quantity of Soil Cement (cy)	Embankment Quantity (cy)	Land Area (ac)
Confluence of Gila River to Broadway Road	2,830	2,910	21.4	36,433	119,545	16.76
Broadway Road to MC 85	3,635	12,165	21.7	101,503	377,743	48.77
MC 85 to I-10	0	0	0	0	0	0
I-10 to Indian School Road	0	0	0	0	0	0
Indian School Road to Confluence of New River	10,104	645	22.4	71,318	264,350	33.26
Confluence of New River to Glendale Avenue	6,175	6,510	22.9	86,168	355,874	41.93
Glendale Avenue to Olive Avenue	11,240	5,090	25.7	124,101	82,191	29.50
Olive Avenue to Cactus Road	9,390	10,650	23.9	141,881	166,629	45.17
Cactus Road to Grand Avenue	4,925	4,860	27.1	78,698	29,693	18.01
Grand Avenue to Bell Road	10,612	12,752	25.1	173,620	225,634	55.09
Bell Road to Beardsley Road	9,905	0	22.2	65,246	14,867	14.27
Beardsley Road to Pinnacle Peak Road	8,680	9,380	21.0	112,389	20,680	23.84
Pinnacle Peak Road to Jomax Road	11,050	10,930	20.4	132,878	396,618	60.28
Jomax Road to Dixileta Drive Alignment	11,110	12,545	21.2	148,321	493,519	64.43
Dixileta Drive Alignment to the CAP Canal	10,075	11,220	22.3	140,899	134,573	43.20
CAP Canal to Cloud Road	10,530	10,180	22.6	138,625	34,541	30.93
Cloud Road to New Waddell Dam	10,840	10,510	26.0	164,572	55,901	36.73
Total	**131,101**	**120,347**		**1,716,652**	**2,772,358**	**562.17**

9.4.2 *River Channelization, Grand Avenue to Jomax Road*

Design Assumptions for Channelization

The channelization alternative is quantified by developing general assumptions and approximate estimates of the channel dimensions. The following assumptions form the basis for quantities and costs:

- Channel begins at Grand Avenue and continues north to Beardsley Road. A large sand and gravel mine occupies the floodway at this location. The channel would be discontinuous through the mine pit. The channel would resume from the mine in the vicinity of Rose Garden Lane and continue north to the CAP Canal.
- Impacts to at-grade road crossings and bridges are not considered.
- The accuracy of estimates is consistent with a conceptual or planning level of detail.
- The channel is assumed to be within the floodplain, but a precise location is irrelevant to this level of analysis. Therefore, the horizontal location of the channel within the river bottom is not established.
- The channel is to convey the regulatory 100-year discharge with one foot of freeboard.
- The maximum flow depth is limited to approximately 8 feet.
- The sides of the channel are to be armored with dumped riprap, preferably native material.
- The channel cross section is assumed to be uniform throughout the project length. The channel configuration is a compound trapezoidal section with a low flow channel and a 150-foot bench above the low flow channel. The bench is assumed to have a vegetated trail along the full length.
- The low flow channel has sufficient capacity to convey approximately one-half the 100-year flow.

Results of Channelization Analysis

HEC-RAS was used to perform hydraulic calculations. The channel modification routine in HEC-RAS was used to estimate earthwork quantities. AutoCAD was used to measure the land encompassed by the floodplain boundary. The gross land area made available for development was calculated by subtracting the area needed to construct the channel from the total floodplain area. The suitability of this land for development was not considered as part of this analysis.

Table 9.4-2 shows the calculated quantities for the channel.

Table 9.4-2 - Channelization Analysis

Total Channel Length	73,554	**Ft**
Excavation	17,400,000	**Cy**
Riprap	163,500	**Cy**
Floodplain Area	4,166	**Ac**
Channel Area	1,323	**Ac**
Net Developable Area	2,743	**Ac**
Cost	$136 to $196 million	
Cost per Developable Acre	$49,000 to $71,000	

9.4.3 *Isolated Structures*

The site-specific structures identified would be installed as erosion protection for existing riverbanks. It is anticipated that the bank protection would be installed in essentially the same place as the existing riverbank. Therefore, the proposed structures would not have a significant impact on river hydraulics. The only calculation associated with these structures is estimating quantities to provide a cost estimate.

10. NON-STRUCTURAL ALTERNATIVE

10.1 Introduction

The overlying principal to non-structural flood control is to adjust occupancy and land use in the floodplain so as to minimize the potential for loss of life or property. This is accomplished by encouraging occupancy outside of hazardous flood areas, encouraging uses that are somewhat more compatible with flooding, or regulating how individual buildings are constructed or modified to provide a level of property protection. Currently, the District's non-structural flood control policy is primarily implemented via the floodplain management ordinance or on occasion via specific project actions. The District regulates "development" activities within the 100-year floodplain, where development constitutes activities associated with construction, placement of fill, and other land disturbing actions. The regulatory floodplain/floodway boundaries are determined by FEMA methodology. Under current ordinances and regulations, buildings in the flood fringe must be elevated above the 100-year flood elevation or removed from the floodplain via fill or structural measures. Development within the floodway is permitted to the extent that it does not further increase the floodway water surface elevation, a policy that has discouraged most floodway development.

Current floodplain management practices have worked reasonably well to protect new development from the current 100-year flood. However, nationally and locally there are concerns as to whether the current standards provide sufficient long-term protection. Current standards do not fully consider the impacts that may result to other properties when a floodplain is encroached. The potential impacts include floodwaters being pushed onto other properties, loss of floodplain storage resulting in higher downstream flow rates, increased erosion on other properties, and other factors. Additionally, just as the structural program has encouraged at-risk development, floodplain encroachment based on filling the flood fringe is leading to significant developed land areas that will be prone to flood damage from future flood flows.

The hazards associated with the lateral migration of rivers has been recognized as a problem, but not adequately addressed in management policy. It is an issue that has been taken up by FEMA, ADWR, and several local agencies including the District. Rivers in the southwest United States are prone to significant lateral shifts during major flood events. On the Agua

Fria, as much as 1,000 to 2,000 feet of shift has been documented in a single flood event. The problem is that this erosion potential is not widely understood or known, leading to the construction of buildings within areas that could be washed away. This type of loss may not be insurable with conventional hazard insurance. Bank protection and armoring may provide a level of protection if properly designed; however, bank protection can also contribute to accelerated erosion on other properties.

Potential flood and erosion damage costs would be greatly reduced if occupancy of areas historically prone to flooding or lateral migration of the stream channel were managed and regulated. The management strategy could be based on both structural and non-structural solutions to the extent that damage potential is not increased offsite.

The current strategy of managing the 100-year floodplain is a good start, but does not adequately address potential impacts to other properties. Most significant to downstream property owners is the cumulative impact on flow rates resulting from encroachment of the flood fringe. This practice currently meets District, State, and FEMA policy, but could ultimately lead to flow rate increases of 10% or more in the downstream reaches of the Agua Fria River. The current policy allows property owners to encroach into the flood fringe or construct bank protection. These types of activities have the potential to increase the water surface elevation up to one foot, force floodwaters from one side of the floodplain to the other, increase erosion on the opposite bank, or increase erosion in the main channel. In very flat floodplains, this could actually make the floodplain significantly wider, increasing the hazard to properties that are considered to be outside the 100-year floodplain.

As part of the non-structural general strategies for the Watercourse Master Plan, it is proposed that development within the 100-year floodplain only be allowed to the extent that the development can demonstrate mitigation for adversely impacting downstream flood flow or for pushing floodwaters onto others.

Further, it is proposed to adopt a lateral migration setback based on the recommended Lateral Migration Erosion Hazard Zone (LMEHZ) developed as part of this plan. Due to the difficulties in managing offsite impacts, the area within the LMEHZ would be considered a no encroachment zone. Construction would not be allowed within this zone unless an individual can demonstrate mitigation techniques that do not increase the erosion potentials for other properties.

It should be understood that the LMEHZ is an estimate of erosion based on a significant flood and reflects an imminent hazard. This plan also developed the Long Term Erosion Hazard Zone that consists of the channel margin area defined by geologic evidence of channel movement over the past 100 to 1,000 years, and represents expected or potential channel movement over the next 60 to 1,000 years. The boundary of the Long Term Erosion Hazard Zone was determined by predictive methods used to assess channel stability, the interpretation of the site geomorphology, and application of engineering judgment. Portions of areas mapped as older geomorphic surfaces, but adjacent to active channels and floodplains, were generally included in the Long Term Erosion Hazard Zone. Areas protected by engineered levees or other bank protection were considered to be outside the limits of the long-term erosion hazard zone. The Long Term Erosion Hazard Zone is not proposed as regulatory boundary, but those that develop in and around the Agua Fria floodplain should consider it.

10.2 Existing Non-structural Flood Control

When considering non-structural flood control systems, it is often easy to forget past projects or on-going efforts, especially in our arid climate. A structure by its very nature provides an ongoing point of reference from which to be reminded of flood protection. When a flood occurs, media attention is frequently drawn to the structure whether it is working or failing. Non-structural flood control provides a more subtle form of protection, quite often functioning behind the scenes. Removing flood-prone buildings or not allowing them to be constructed in the first place is an action that is quickly forgotten. During subsequent flooding, there is no physical reminder of the sound management decision that prevented damage from occurring.

The entire Agua Fria Watercourse is currently regulated by non-structural flood control methods, although approximately one third of the watercourse contains levees or other flood control structures. Current floodplain regulations remain effective within structural reaches because they regulate development that might be prone to occur on the riverside of these protective works. The public is partially protected from flooding by enforcement of FEMA regulations. With the exception of sand and gravel mines and agriculture, there are no present encroachments into the floodway of the Agua Fria River between New Waddell Dam and the confluence of the Gila River. Existing floodplain encroachments not related to agriculture or mining operations are limited to the fringe areas.

Up to this time, there has been little residential land development within the historic flood fringe. However, the West Valley is developing rapidly and there is increasing pressure to build homes along the river. Coyote Lakes, north of Bell Road, is an example of development that has encroached into the floodplain. Two housing developments are either being designed or are under construction along the west bank between Olive Avenue and Grand Avenue. Both developments have phases that will be constructed in the flood fringe. The homes will be protected by elevating them on an embankment or by constructing levees.

In the 1980s, a buy-out of homes was implemented in the vicinity of Hatfield Road and 109th Avenue (near the east bank, just south of Happy Valley Road). Due to significant flooding and erosion damages, evacuation of the floodplain was determined to be the best mitigation action. This action eliminated the flood damage potential on this property.

As part of local cooperative agreements with the Corps for the construction of the Phoenix and New River Vicinity project, the District purchased flowage easement and purchased land in fee title within the Agua Fria River Floodplain. While this action was taken for other project purposes, it has contributed significantly to non-structural flood control in the lower Agua Fria River.

10.3 Proposed Non-structural Flood Control

The non-structural alternative considers both flooding and erosion hazards. This discussion of proposed flood/erosion control measures is limited to protecting the public from inundation or lateral migration. Floodplain boundaries and the LMEHZ boundary are shown on Figure 10.3-1 through Figure 10.3-17. This discussion of proposed non-structural flood/erosion control measures is limited to protecting the public from inundation or avulsion due to flood flows. It does not consider aggradation or degradation of the streambed due to the movement of sediment within the system. The suitability of non-structural methods for flood protection or control of bank erosion discussed below are independent of grade control structures. Grade control structures do not change the suitability of non-structural methods for flood or erosion control.

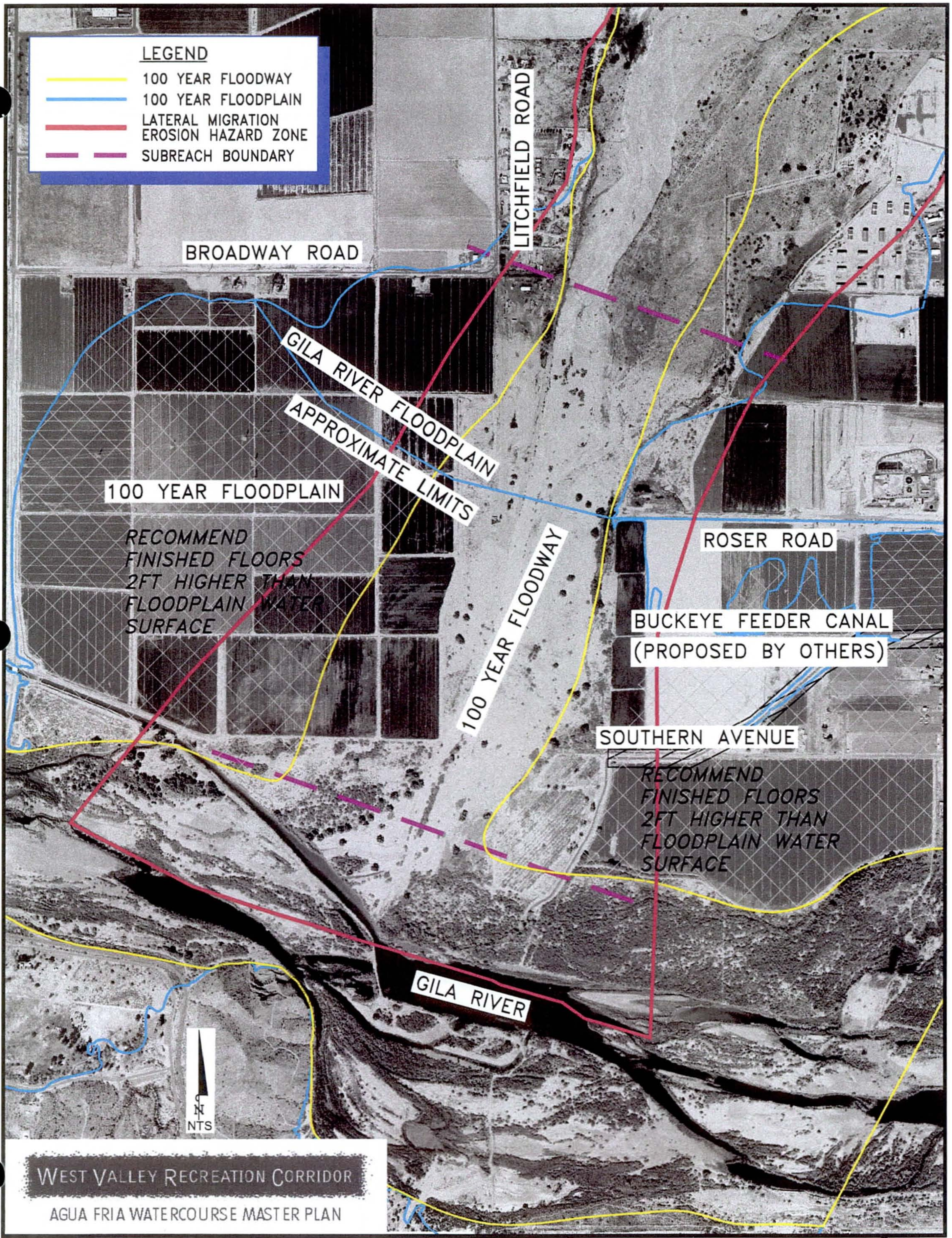


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FIGURE 10.3-1
NON-STRUCTURAL PLAN
CONFLUENCE OF GILA TO BROADWAY ROAD

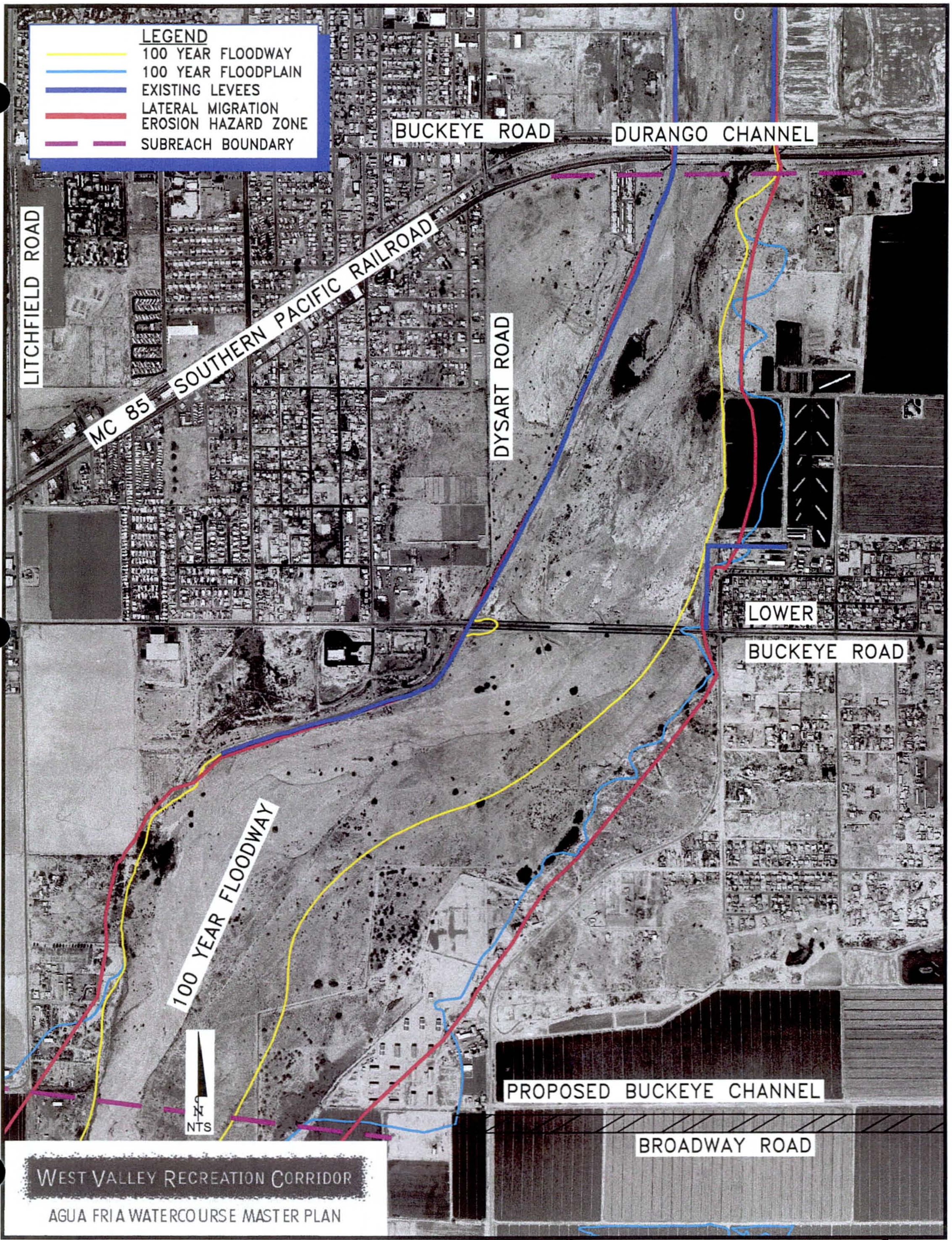

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FIGURE 10.3-2
NON-STRUCTURAL PLAN
BROADWAY ROAD TO MC 85

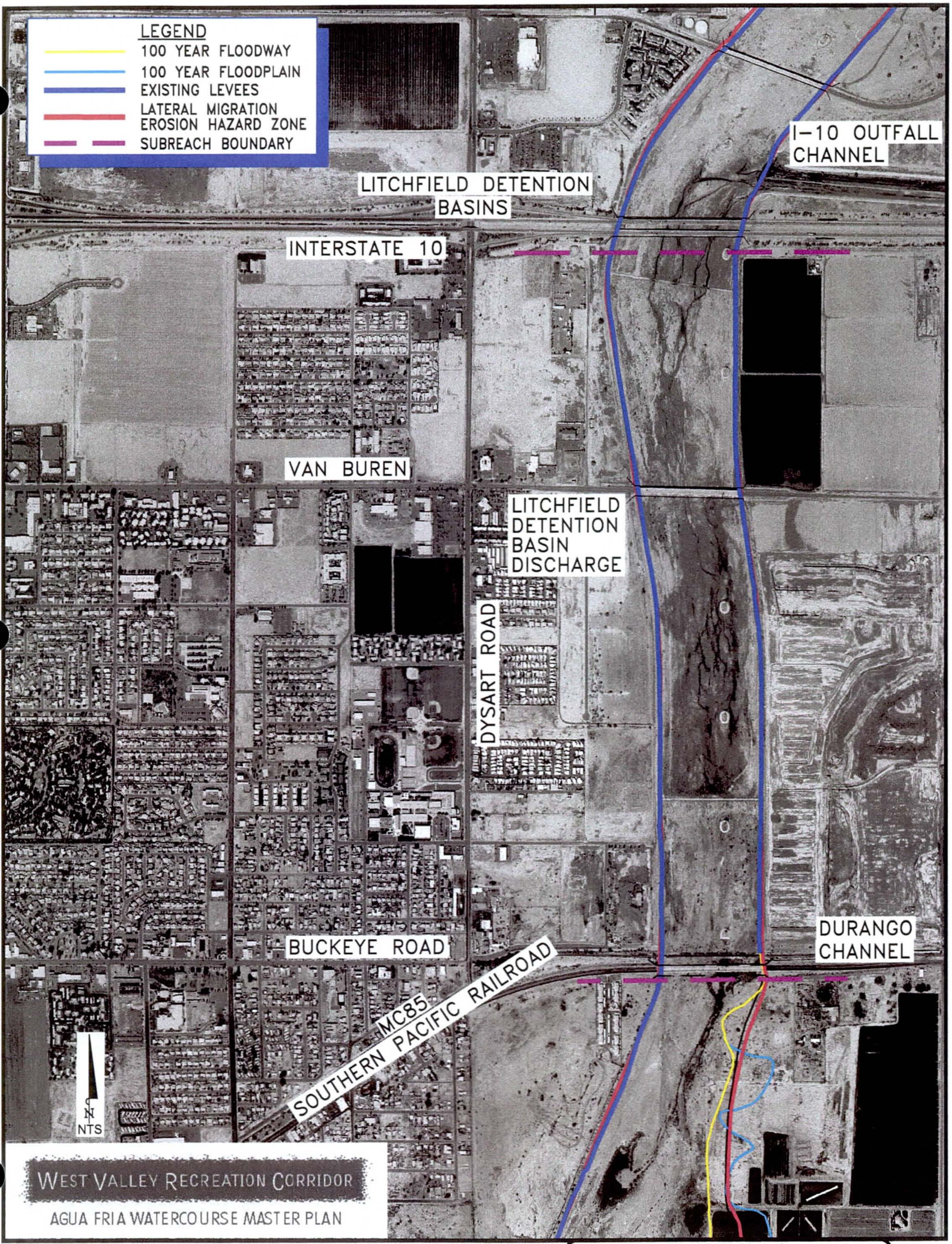

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FIGURE 10.3-3
NON-STRUCTURAL PLAN
MC 85 TO INTERSTATE 10

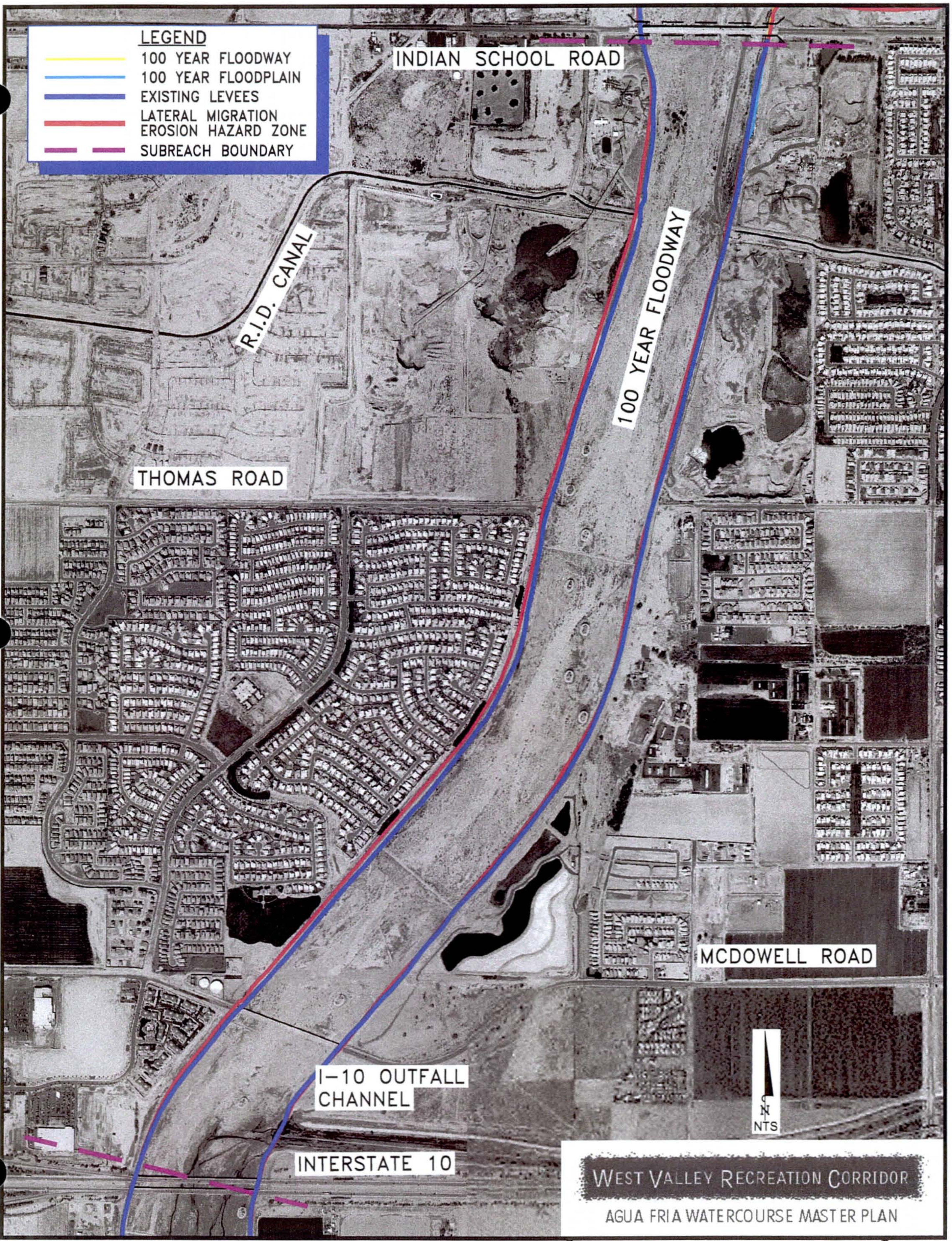

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FIGURE 10.3-4
NON-STRUCTURAL PLAN
INTERSTATE 10 TO INDIAN SCHOOL ROAD

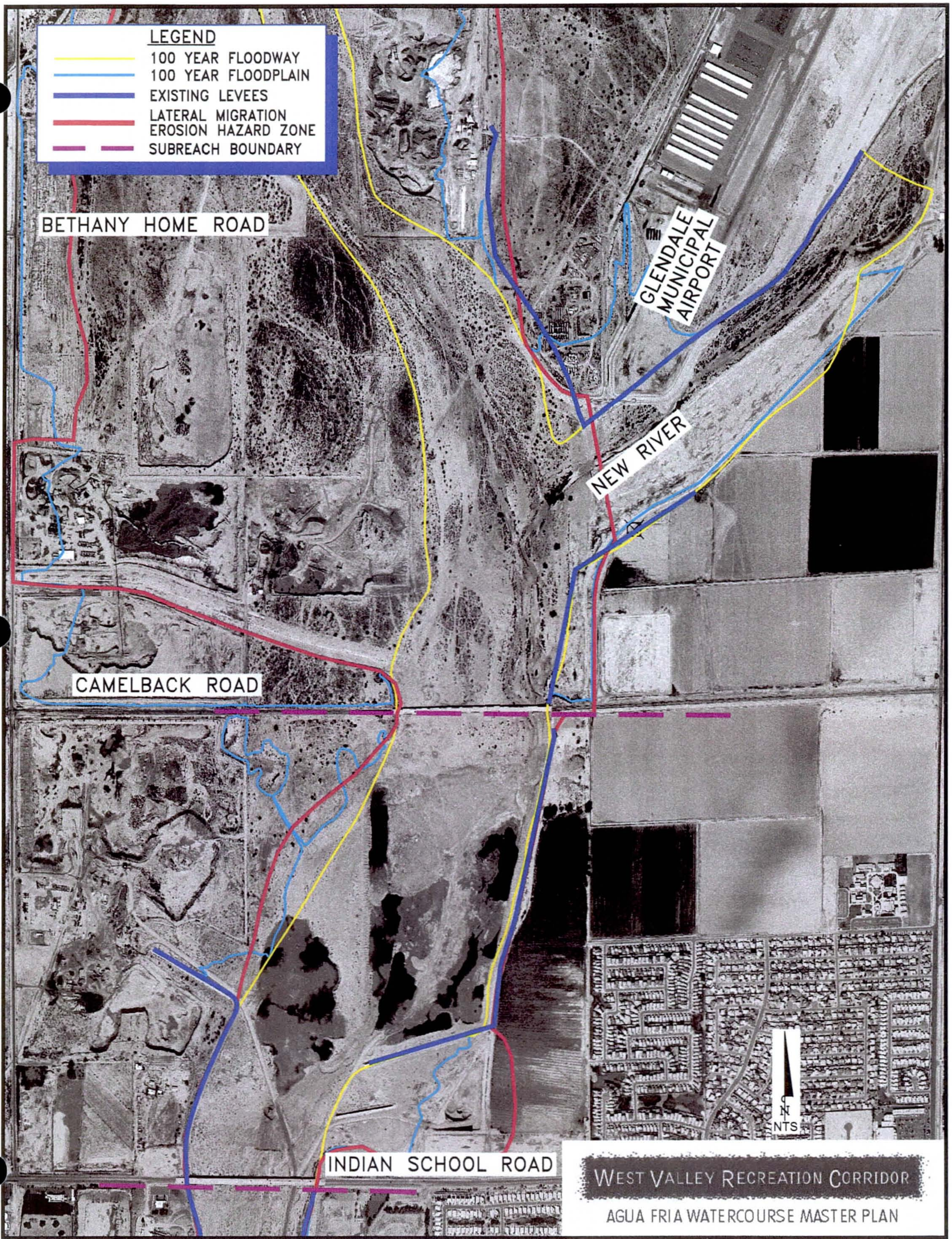

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FIGURE 10.3-5
NON-STRUCTURAL PLAN
INDIAN SCHOOL RD TO CONF. OF NEW RIVER

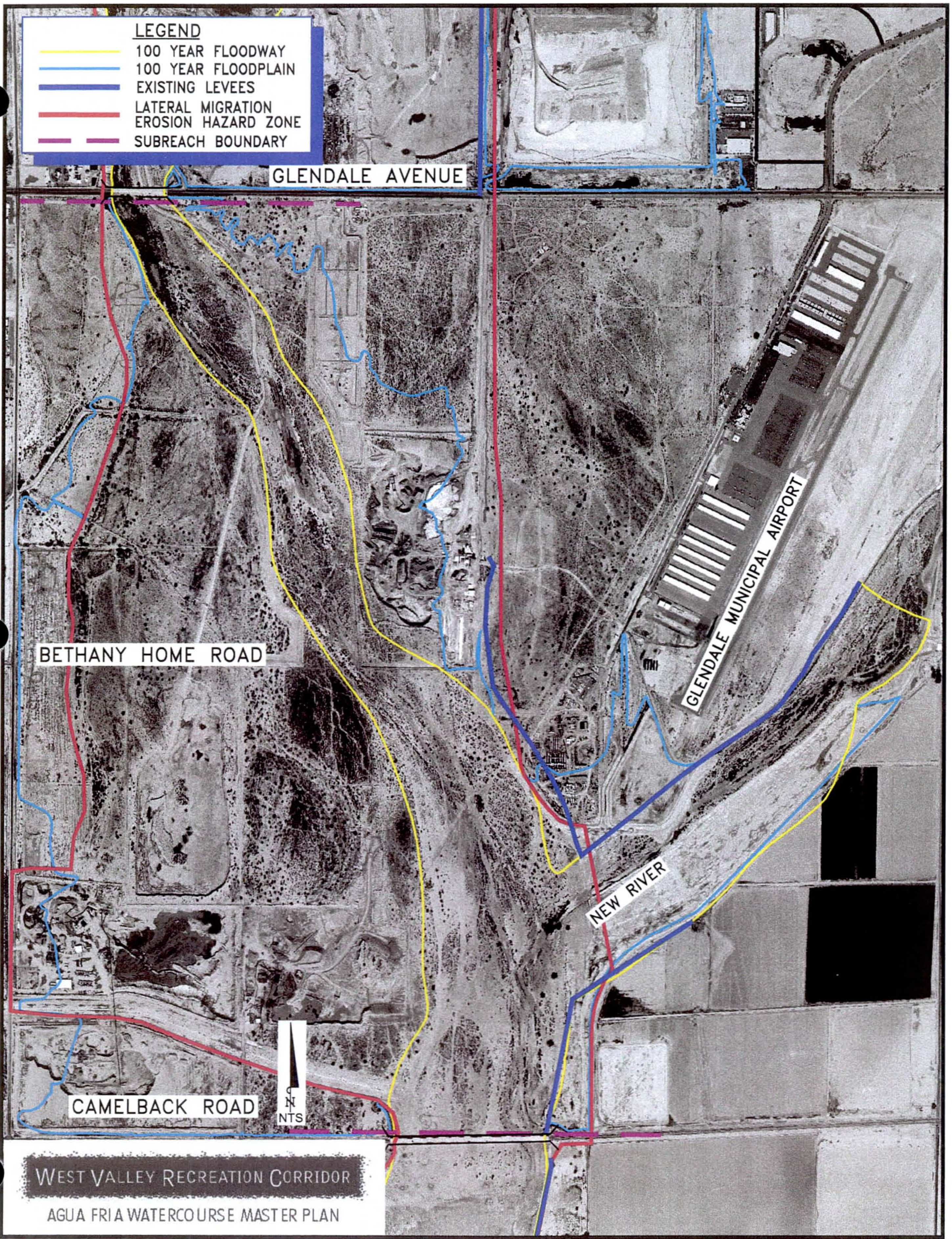

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FIGURE 10.3-6
NON-STRUCTURAL PLAN
CONF OF NEW RIVER TO GLENDALE AVE

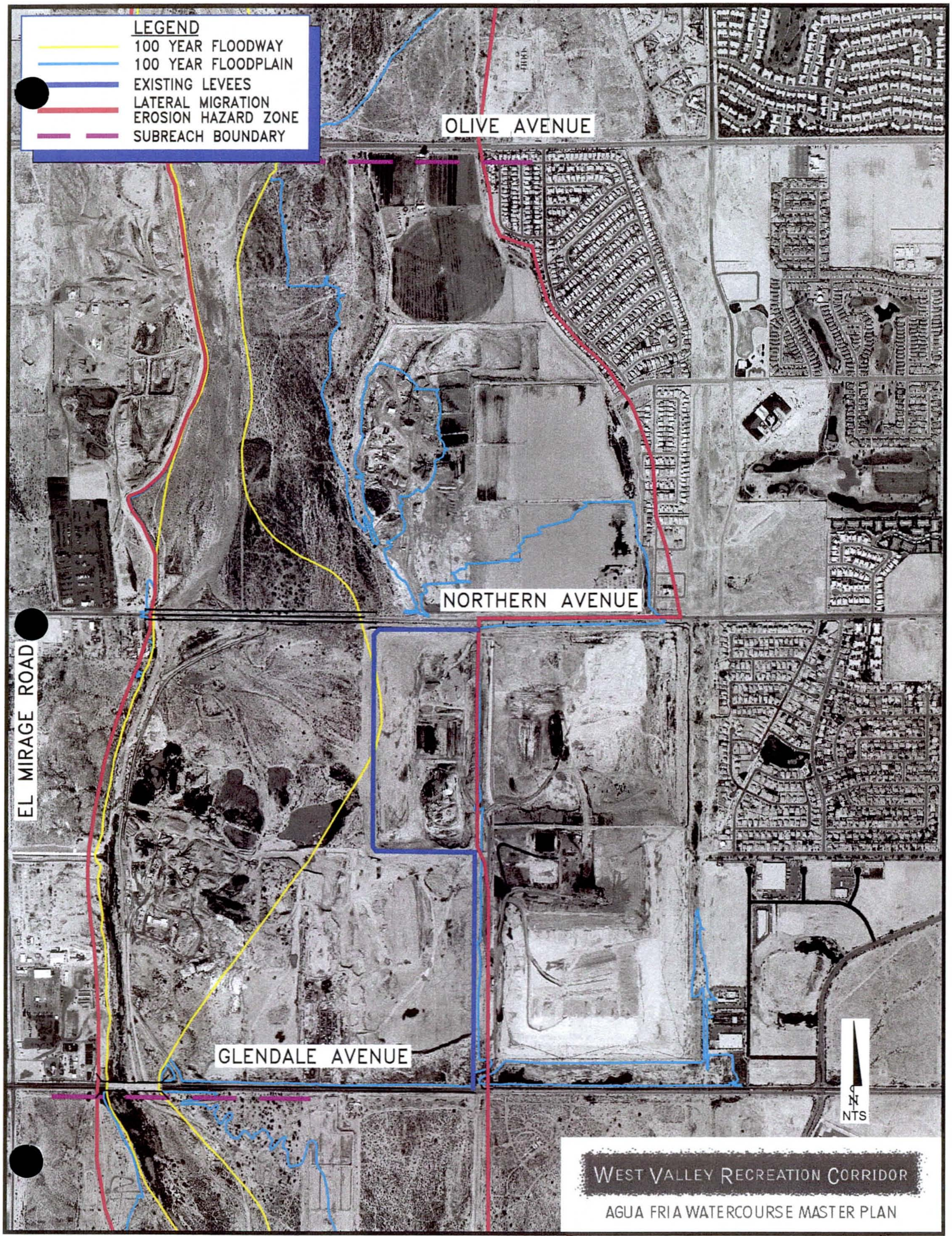

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FIGURE 10.3-7
NON-STRUCTURAL PLAN
GLENDALE AVE TO OLIVE AVE

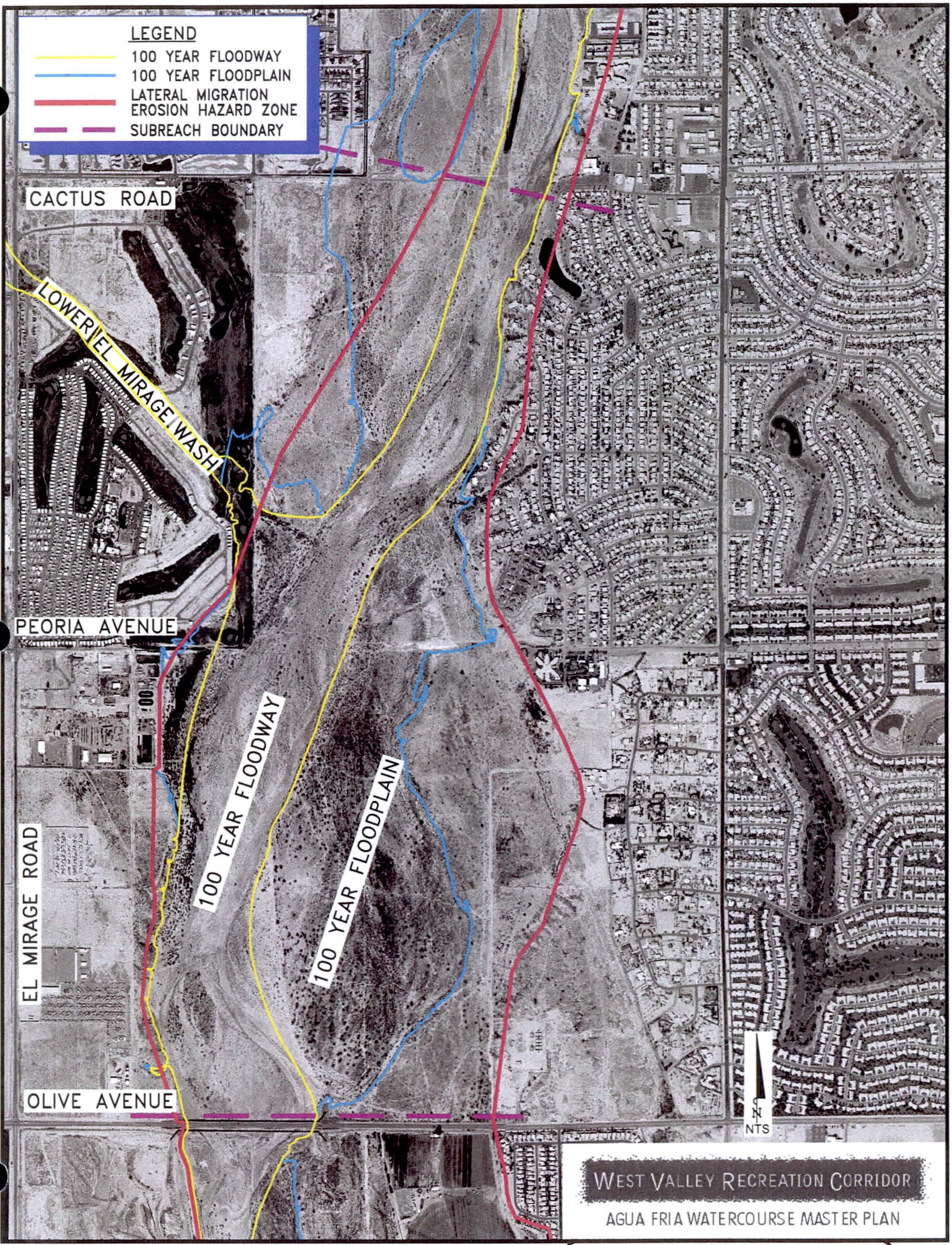

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FIGURE 10.3-8
NON-STRUCTURAL PLAN
OLIVE AVENUE TO CACTUS ROAD

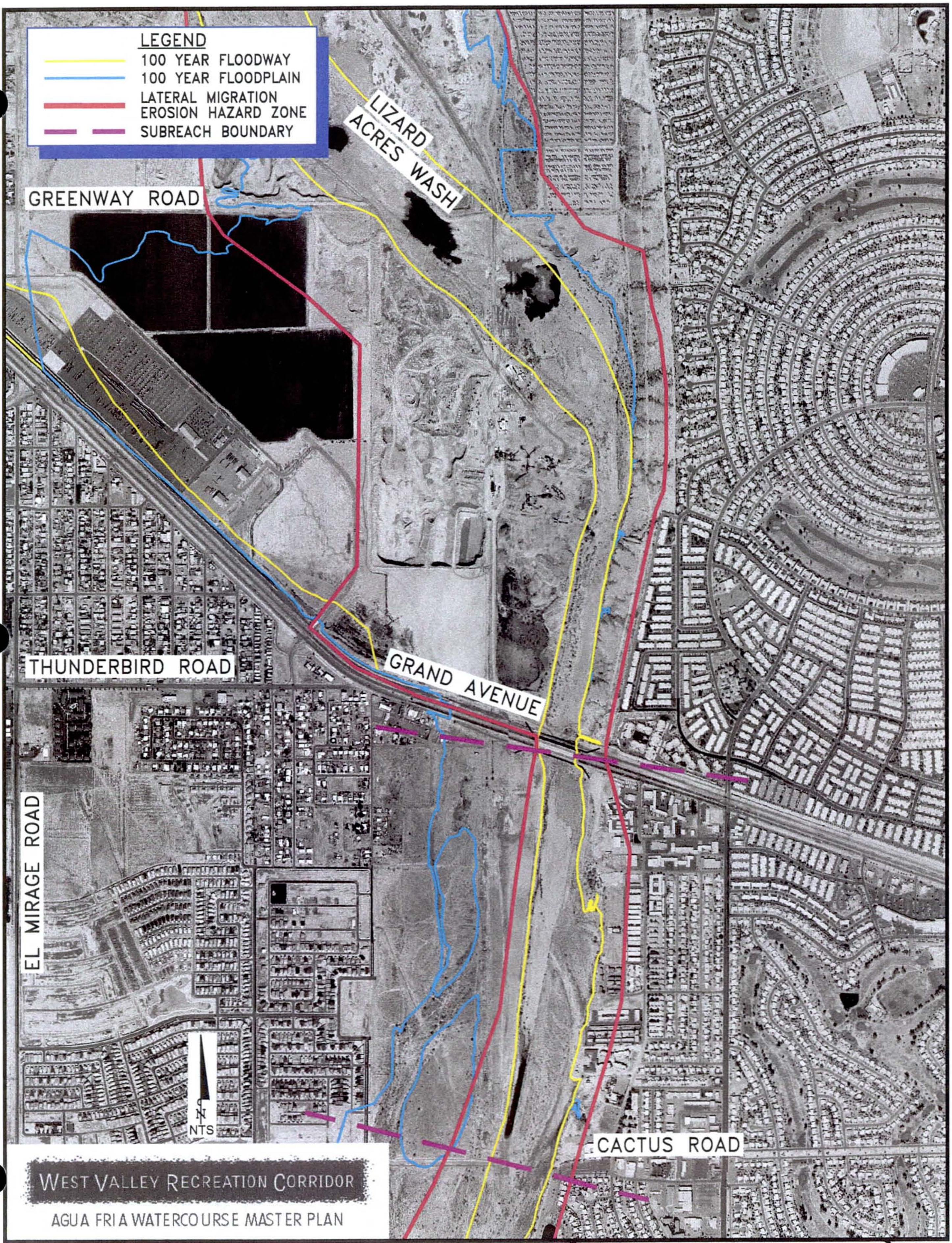

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FIGURE 10.3-9
NON-STRUCTURAL PLAN
CACTUS ROAD TO GRAND AVENUE

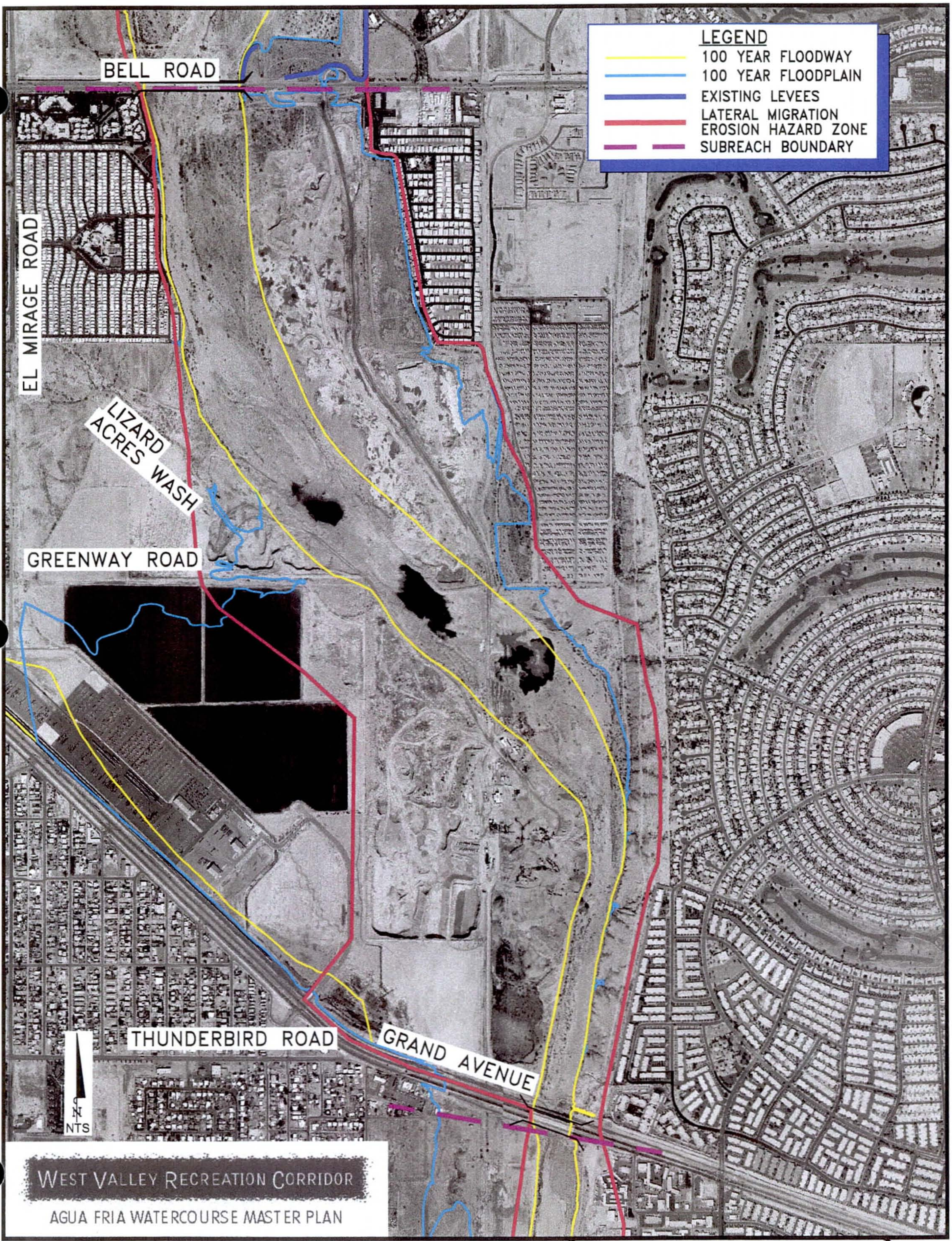

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FIGURE 10.3-10
NON-STRUCTURAL PLAN
GRAND AVENUE TO BELL ROAD

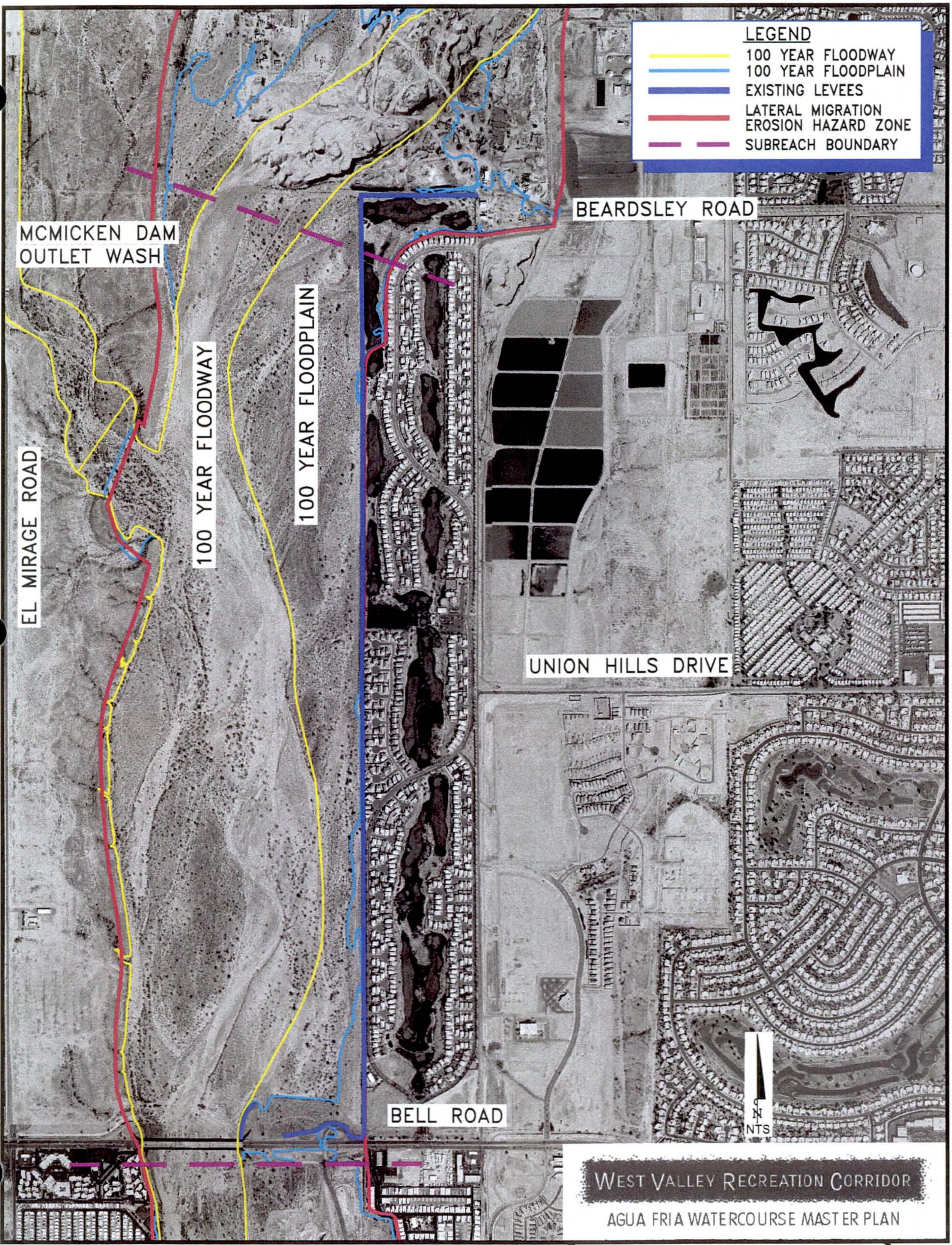

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FIGURE 10.3-11
NON-STRUCTURAL PLAN
BELL ROAD TO BEARDSLEY ROAD

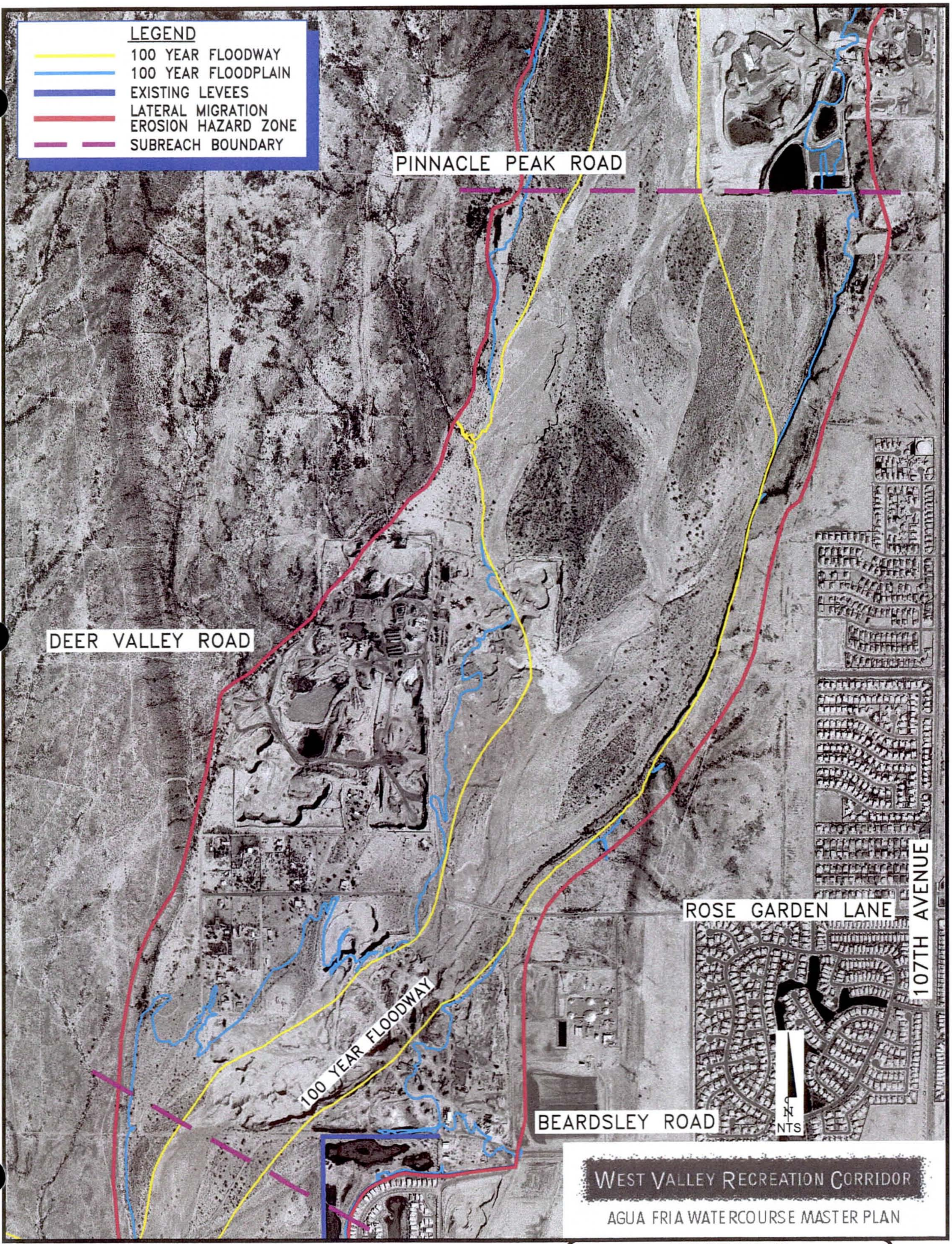

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FIGURE 10.3-12
NON-STRUCTURAL PLAN
BEARDSLEY RD TO PINNACLE PEAK RD

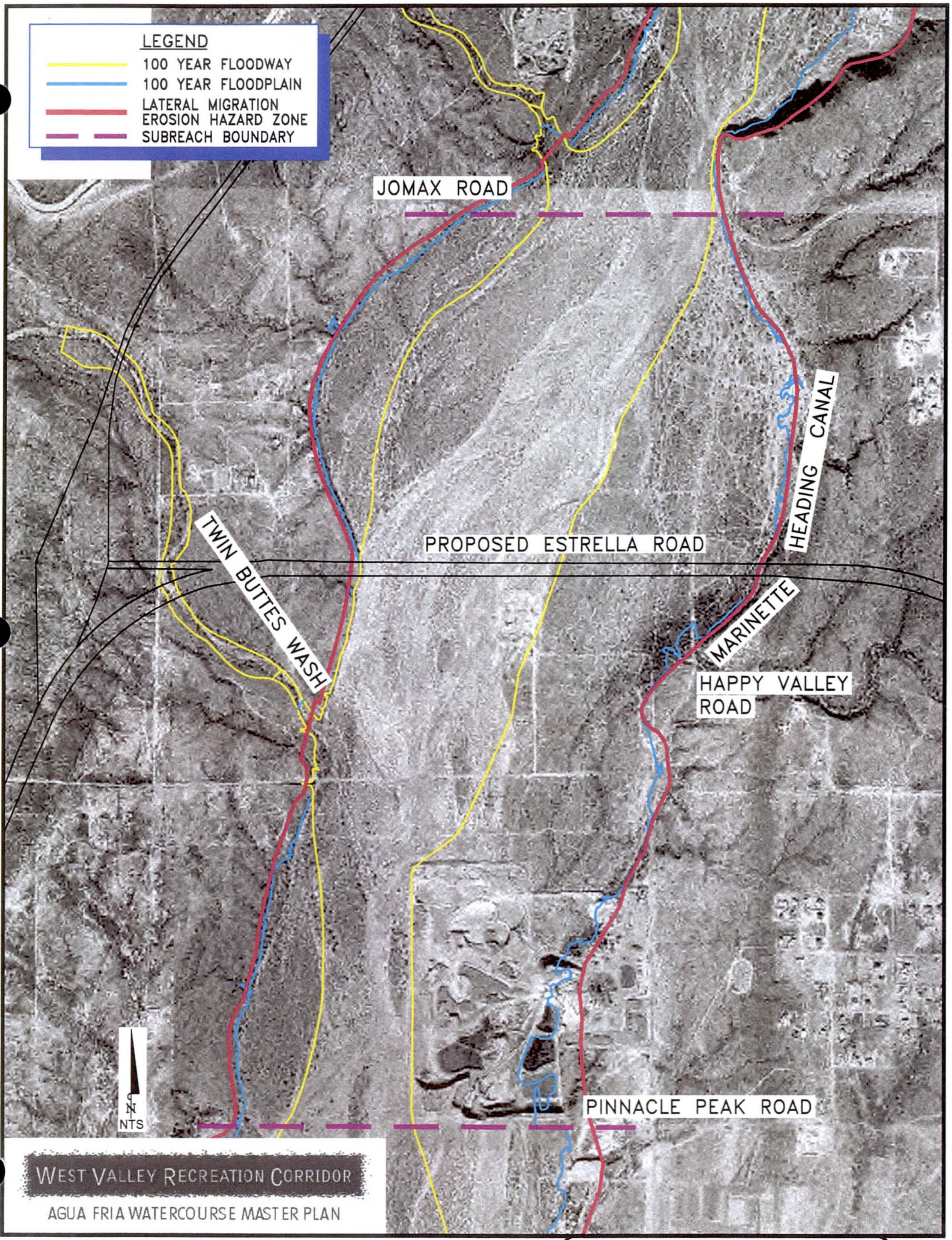

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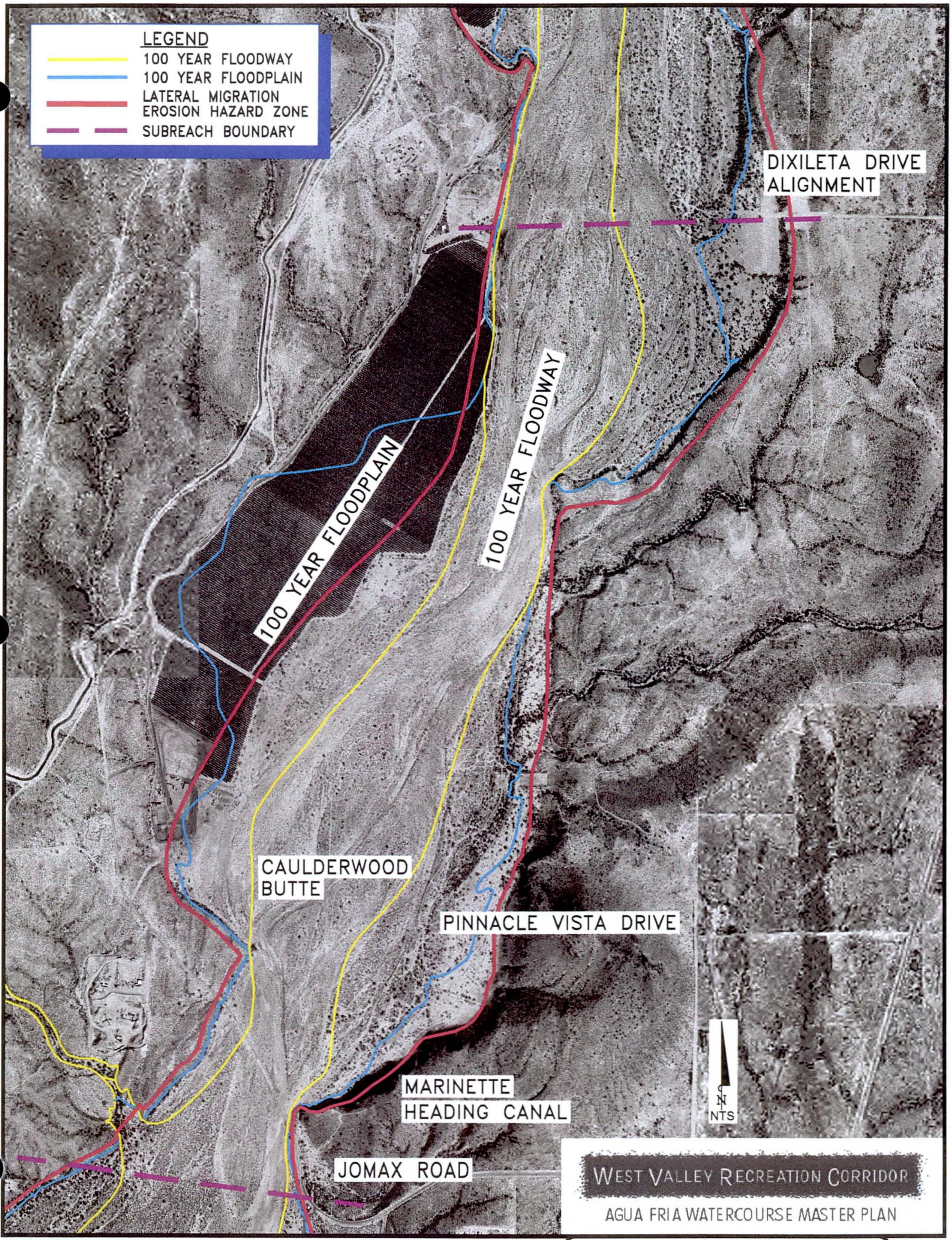
FIGURE 10.3-13
NON-STRUCTURAL PLAN
PINNACLE PEAK ROAD TO JOMAX ROAD



Kimley-Horn and Associates, Inc.

FIGURE 10.3-14
NON-STRUCTURAL PLAN
JOMAX ROAD TO DIXILETA DRIVE ALIGNMENT

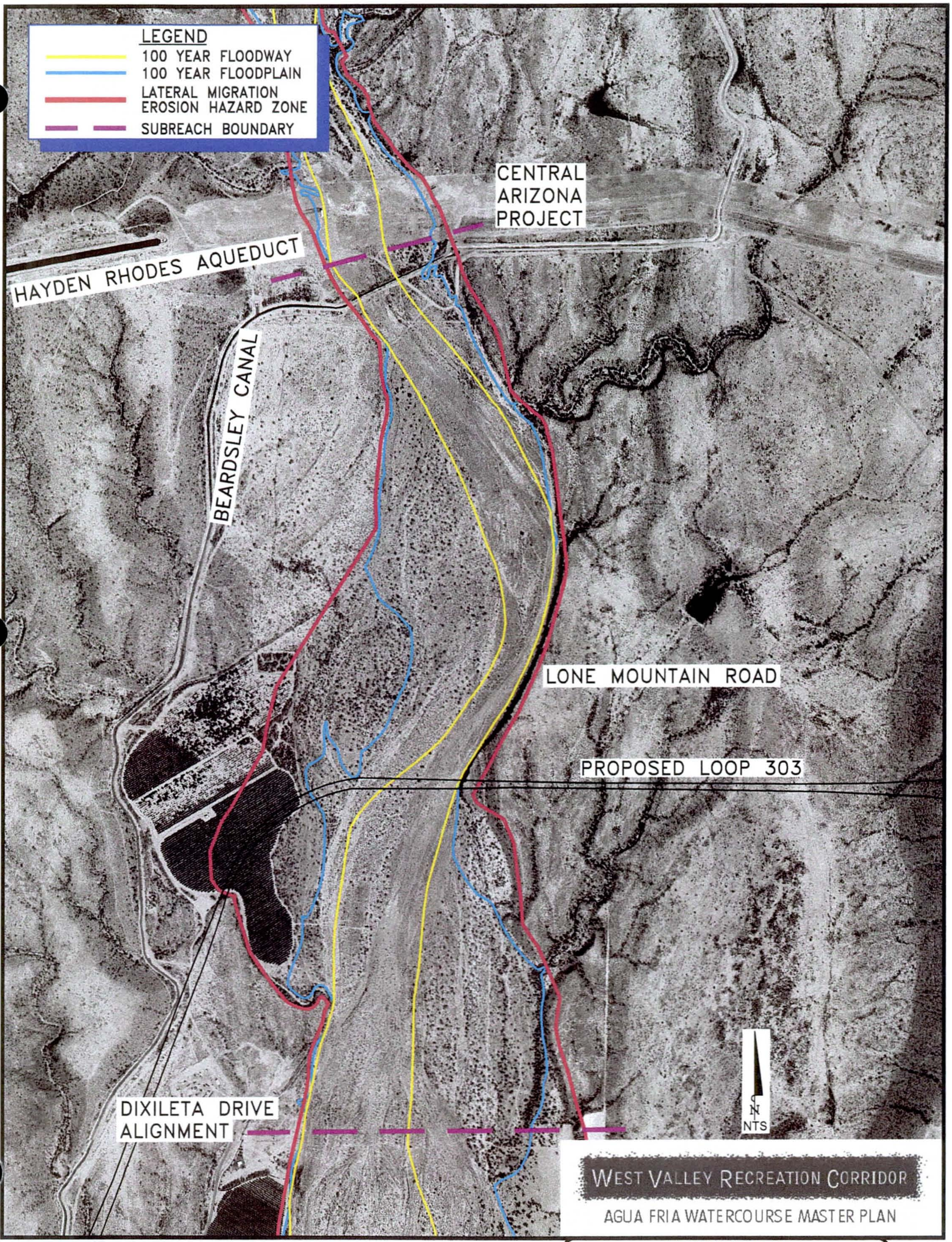


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FIGURE 10.3-15
NON-STRUCTURAL PLAN
DIXILETA DRIVE ALIGNMENT TO CAP CANAL

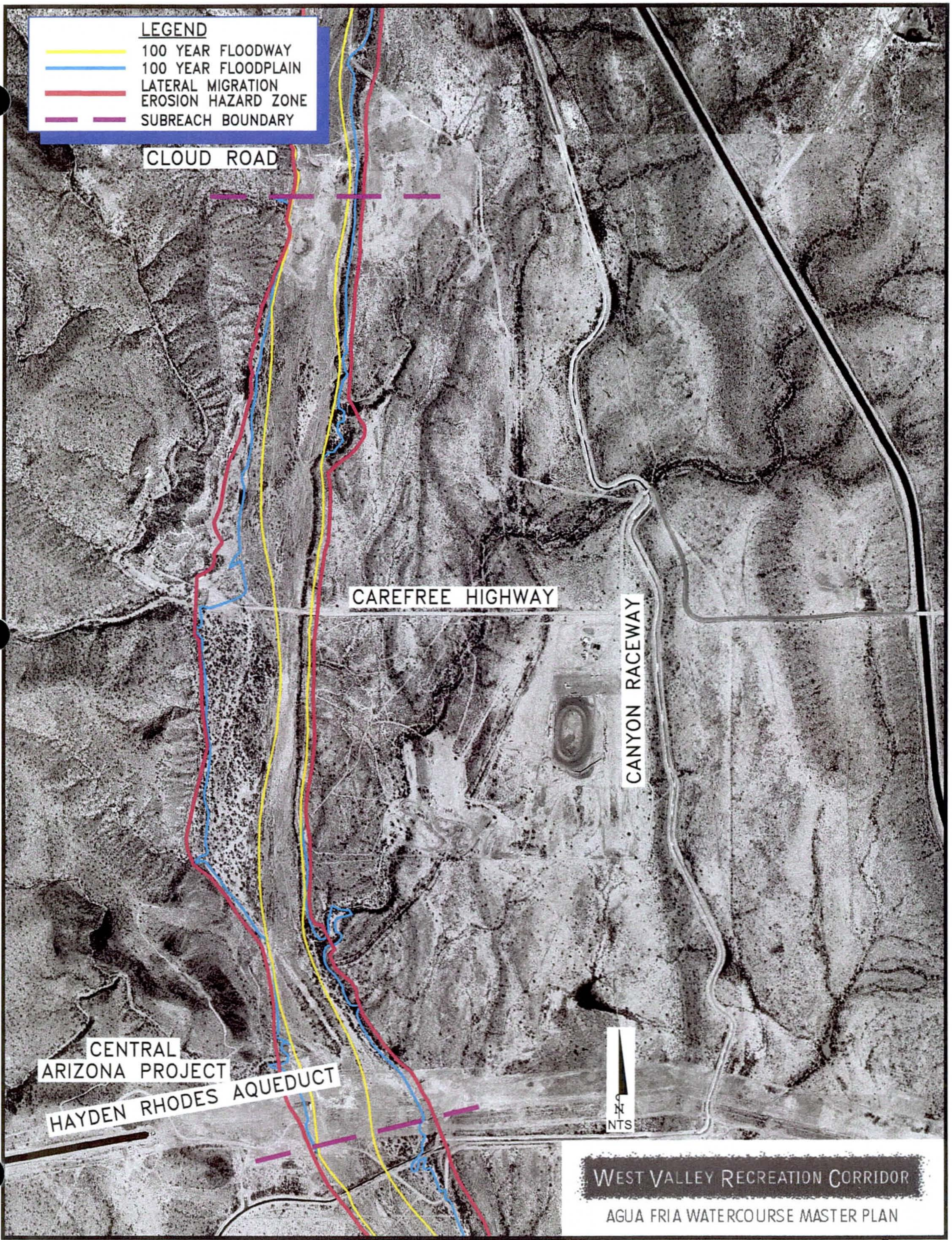

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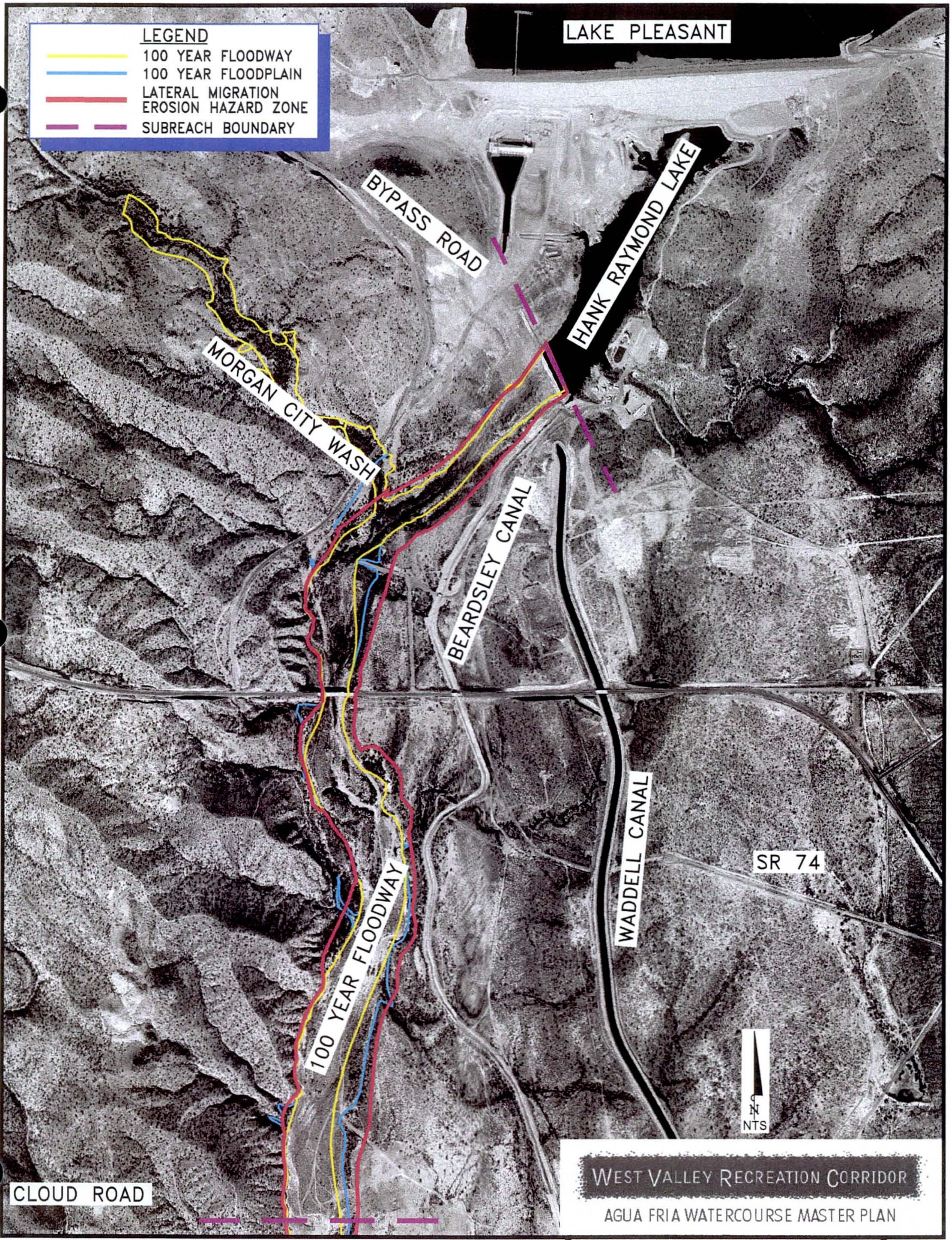
FIGURE 10.3-16
NON-STRUCTURAL PLAN
CAP CANAL TO CLOUD ROAD



Kimley-Horn and Associates, Inc.

FIGURE 10.3-17
NON-STRUCTURAL PLAN
CLOUD ROAD TO NEW WADDELL DAM

10.3.1 *Confluence of Gila River to Broadway Road*

Both the Agua Fria and the Gila Rivers affect the confluence region. The limits of the Gila River floodplain extend north to the vicinity of Broadway Road. South of Broadway Road, the floodplain may be inundated by flows from either river. Area residents have expressed concerns related to backwater flooding in and around the confluence of the two rivers. Additional concerns were expressed as to whether upstream activities such as levee plating might lead to additional sediment being deposited at the confluence. Those that expressed concerns have homes that lie outside the LMEHZ but are within the floodplain. Levees along the east bank of the Agua Fria were considered at the request of area residents and are discussed in more detail under the structural alternative.

The non-structural alternative for this reach includes the continued enforcement of the floodplain regulation, adoption of the LMEHZ, and the adoption of a local standard that would require elevating finished floors at least 2 feet higher than the regulatory (floodway) water surface elevation. In this subreach, the LMEHZ is outside the floodway but within the floodplain due to the influence of the Gila River. This solution provides future protection for the uncertainty associated with construction in the confluence area, and recognizes the potential for lateral migration. Further, any upstream placement of fill in the floodplain should consider stabilization techniques that prevent wash out.

10.3.2 *Broadway Road to MC85*

This reach represents the southern end of the Agua Fria levees. Much of the west bank and a subdivision on the east bank are protected by the existing levees. Existing buildings are located just north of Broadway Road on the west bank. They are on the outer edge of the LMEHZ. It is proposed that a monitoring and acquisition program be considered in this reach. For the entire reach, the non-structural alternative would include both floodplain and LMEHZ regulations.

10.3.3 *MC 85 to I-10*

The entire subreach is protected by existing levees. Additional non-structural solutions were not viewed as necessary.

10.3.4 *I-10 to Indian School Road*

The entire subreach is protected by existing levees. Additional non-structural solutions are not necessary.

10.3.5 *Indian School Road to Confluence of New River*

The east bank is protected by existing levees. The levees extend north to protect the Glendale airport, the Glendale wastewater treatment plant, and the Camelback Ranch development. Several sand and gravel mining operations occupy the west bank. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.6 *Confluence of New River to Glendale Avenue*

Sand and gravel mines are in operation within the floodplain on both sides of the river. The LMEHZ stays within the floodplain but significantly departs from the floodway. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation. There are no existing flood control structures in this reach.

10.3.7 *Glendale Avenue to Olive Avenue*

The east bank is protected by existing levees from Glendale Avenue to Northern Avenue. The levees protect the Glendale landfill and Glendale's municipal recycling facility. A large sand and gravel mining operation occupies the floodway and portions of the east bank within this subreach. The LMEHZ conforms to the floodplain line on the west bank. On the east bank, north of Northern Avenue, the LEMHZ extends outside the floodplain to the east. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.8 *Olive Avenue to Cactus Road*

This reach transitions from relatively open space to numerous developments located outside the floodplain on both sides of the Agua Fria. The LMEHZ on the west bank primarily conforms to the floodplain boundary. The LMEHZ on the east bank is outside the floodplain. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.9 *Cactus Road to Grand Avenue*

The El Mirage Landfill occupies the west bank of this subreach. The landfill embankment is protected by riprap. The level of protection provided by the riprap is unknown. The opposite bank of the river is a high, nearly vertical bluff with existing development along the top edge.

The current floodplain map shows the potential for inundation of the land area west of the landfill; however, it was assumed during mapping that this area provided non-significant conveyance. Non-structural solutions in this reach could include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation. However, the non-structural solution would not meet project objectives in this area.

10.3.10 *Grand Avenue to Bell Road*

There is no existing development within the regulatory floodplain from Grand Avenue to Greenway Road. Existing homes abut the floodplain/floodway on the west bank, south of Bell Road at the top of a nearly vertical, 25-foot bluff. The LMEHZ primarily conforms to the floodplain boundary. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation. In the area south of Bell Road, a monitoring and acquisition program may be feasible.

10.3.11 *Bell Road to Beardsley Road*

The east bank of this subreach is defined by engineered bank protection protecting the Coyote Lakes subdivision. The floodway, floodplain, and the LMEHZ conform to the west bank. On the east bank, there is an area of land between the floodway and the existing bank protection. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.12 *Beardsley Road to Pinnacle Peak Road*

A large sand and gravel mine occupies the lower one-half mile of the subreach. The mine is located within the floodway and within the floodplain along both banks. It is not possible to construct a levee or other flood control structure in this area due to the presence of the mine.

Due to the disturbance of the sand and gravel mine, the LMEHZ extends outside of the floodplain in the area south of Deer Valley Road. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.13 *Pinnacle Peak Road to Jomax Road*

A large gravel mine is located immediately north of Pinnacle Peak Road within the flood fringe and east of the floodplain. The CAP is currently constructing groundwater recharge ponds within the flood fringe along the west bank, south of Jomax Road. The LMEHZ and floodplain boundary are contiguous for most of the reach. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.14 *Jomax Road to Dixileta Drive Alignment*

In the future, water will flow through this subreach along the natural channel bottom from the CAP Canal to the recharge ponds south of Jomax Road. Also, proposed gravel mines may be located in the flood fringe along the west bank. Land development has been proposed within an area adjacent to Calderwood Butte that would be within the LMEHZ.

10.3.15 *Dixileta Drive Alignment to the CAP Canal*

There are two existing improvements within the subreach: the CAP Canal siphon and the Beardsley Canal bridge. A proposed bridge will carry the Loop 303 across the river in the vicinity of Lone Mountain Road.

As previously noted, water will flow from the CAP Canal to the recharge ponds south of Jomax Road. Proposed gravel mines may be located in the flood fringe along the west bank. The LMEHZ primarily conforms to the east bank in this reach. On the west bank, the LMEHZ also conforms to the floodplain boundary, with the exception of a 1,000-foot reach at Lone Mountain Road. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.16 *CAP Canal to Cloud Road*

The subreach is generally undisturbed desert. There are no existing buildings within the regulatory boundaries. The LMEHZ primarily conforms to the floodplain line. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

10.3.17 *Cloud Road to New Waddell Dam*

The subreach is generally undisturbed desert. There are no existing buildings within the regulatory boundaries. The floodway, floodplain, and LMEHZ are contiguous. Non-structural solutions would include continued enforcement of the floodplain regulation and adoption of a LMEHZ regulation.

11. COMBINED ALTERNATIVE

11.1 Introduction

The Combined Alternative detailed the result of the Alternative Analysis investigation. The recommendations and conclusions reached as a result of the investigation were presented at three public meetings in May 2001. Comments arising from the public meetings and comments made by District staff have been incorporated into this report. The following is a summary of the Combined Alternative. It is presented here to provide documentation of the process and procedures used to develop the Recommended Plan.

11.2 Combined Alternative

The Structural and Non-structural Alternatives were examined as all-or-nothing methods of managing the Agua Fria Watercourse. This was done to evaluate the potential cost of the alternatives, estimate the impact to existing infrastructure, and estimate the land area impacted. Both of these alternatives have been objectively rated along each subreach to identify the most suitable management tool for the subreach. The Combined Alternative is a suggested mix of structural and non-structural flood control policies within the Agua Fria River. By and large, the components of the Combined Alternative have been moved forward as the Recommended Plan. Therefore, the subreach by subreach descriptions of the components of the Combined Alternative have been deleted from this section. See Section 12, Recommended Plan, for a discussion of the alternatives that were included in the Combined Alternative.

The management policies suggested in the Combined Alternative were presented at three public meetings in the latter part of May 2001. The public had a chance to review the Combined Alternative and offer its input. Public comments were noted and incorporated into the Recommended Plan.

11.3 Proposed Flood/Erosion Control Methods

Non-structural flood control policies appear to be well suited to most subreaches of the Agua Fria River corridor. Non-structural policies maintain open space, increase access to the river, provide opportunities for recreation, and allow creation of habitat zones. Evaluation shows that non-structural methods of flood management tend to meet the stated goals and objectives of the Watercourse Master Plan. Structures appear to be required in specific locations to mitigate localized hazards.

With the exception of sand and gravel mining operations, there are few encroachments into the regulatory floodplain or the LMEHZ. These encroachments are generally protected by engineered levees. Several unprotected encroachments have been identified that may be subject to future flooding or losses due to erosion. It is recommended that these areas be protected by structures to reduce damage due to flooding or that they be monitored to evaluate the likelihood of imminent erosion damage.

This discussion of proposed flood/erosion control measures is limited to protecting the public from inundation or avulsion due to flood flows. It does not consider aggradation or degradation of the streambed due to the movement of sediment within the system.

12. RECOMMENDED PLAN

12.1 Introduction

The components of the Combined Alternative were carried forward for further evaluation as the Recommended Plan. The results of the additional evaluation are documented in the final versions of *Hydraulic Analysis for the Agua Fria Watercourse Master Plan, LTM Engineering Inc., 2001*; *Sedimentation/Scour Report, Kimley-Horn and Associates, Inc., 2001*; and *Sand and Gravel Mining Summary, Kimley-Horn and Associates, Inc., 2001*. The Recommended Plan incorporates the results of the additional evaluation and comments received from the public and District Staff regarding the Combined Alternative.

The primary difference between the Recommended Plan and the Combined Alternative is the inclusion of a strategy toward the regulation of sand and gravel mining in the Agua Fria floodplain. Section 8 of this report and *Sand and Gravel Mining Summary, Kimley-Horn and Associates, Inc., 2001* discuss the details of this strategy. The following discussion provides greater detail regarding the implementation of the strategy on a reach by reach basis.

The management strategies suggested in the Recommended Plan were presented at three public meetings in October 2001. The public had a chance to review the Recommended Plan and offer its input. Public comments were noted and incorporated into the Final Recommended Plan Report.

12.2 Deviations from the Combined Alternative

Only one component of the Combined Alternative is to be removed as the process moves forward. This is the recommendation to block the culverts at Grand Avenue and divert flow to the main channel. Further investigation shows that this recommendation is not practical at this time. Existing culverts west of the bridge at Grand Avenue convey flows under Grand Avenue. The flows discharging from the culverts are diverted around the west side of the El Mirage Landfill and join the main channel of the river south of the landfill. The area west of the landfill has undergone recent residential development. The development accommodates the design discharges from the culverts. During the development of the Combined Alternative, it was suggested that the culvert be blocked and the flow from the culvert diverted to the river on the north side of the Grand Avenue Bridge. Diverting the flow to the north side of the bridge was perceived as a benefit given the unanswered questions concerning the landfill and the close proximity of the residential development. However, the railroad tracks immediately north of and parallel to Grand Avenue preclude the installation of drainage infrastructure within the existing right-of-way. Diverting the flows on the north side of the railroad is impractical. A spur line from the railroad turns to the north along the west bank of the Agua Fria. Diverted flows from the culverts would have to be conveyed under the spur line. Given the infrastructure required to cross the spur line, there is little or no financial benefit to this project. Therefore, this component of the Combined Alternative was not carried forward in the Recommended Plan.

As noted in the Alternative Analysis Report, this report makes recommendations regarding grade control structures based on sediment trend analysis. A grade control structure is needed to arrest bed degradation and stabilize the river system at Olive Avenue. It is also recommended that existing headcuts be monitored in two areas. The first area is downstream from the Bell Road Bridge, the second is near the Deer Valley Road Alignment.

It is recommended that the District adopt a No Adverse Impact Strategy toward sand and gravel mining in the floodplain. Implementation of this strategy would require miners to show that their operations do not cause adverse impacts beyond the boundary of the parcel being mined. The District would obtain a river-wide 404 Permit from the Corps and assist miners to bring their operations into compliance with the stipulations of the 404 Permit.

12.3 Recommended Plan Components

These proposed flood/erosion control measures are recommended to protect the public from inundation or avulsion due to flood flows, arrest bed degradation, and reduce the cumulative impact of mining operations within the river system.

12.3.1 Confluence of Gila River to Broadway Road

Existing buildings are within the LMEHZ along the west bank at Broadway Road. The buildings are over 100 feet from the existing bank. It is proposed to monitor the location of the existing riverbank. Future action may be required in the event of bank loss due to erosion.

The area south of Broadway Road is affected by flood flows in both the Gila River and the Agua Fria River. The confluence area is shown in Figure

12.3-1. It is proposed that future buildings in this area be protected by elevating them two feet above the regulatory (100-year) water surface elevation.

12.3.2 Broadway Road to MC 85

Much of the west bank and a subdivision on the east bank are protected by existing levees, therefore, implementing non-structural management policies within the remainder of the subreach is proposed. Additional flood control structures or monitoring do not appear to be warranted within this subreach.

12.3.3 MC 85 to I-10

The entire subreach is protected by existing levees. Additional flood control structures or monitoring do not appear to be warranted within this subreach. The addition of wetland vegetation/habitat is being considered at the I-10 Outfall Channel. Preliminary hydraulic analysis shows this to be a potentially viable use of the river if an isolated riparian palate is implemented. A more dense hydric riparian palate would not be suitable due to freeboard constraints of the levees.

12.3.4 I-10 to Indian School Road

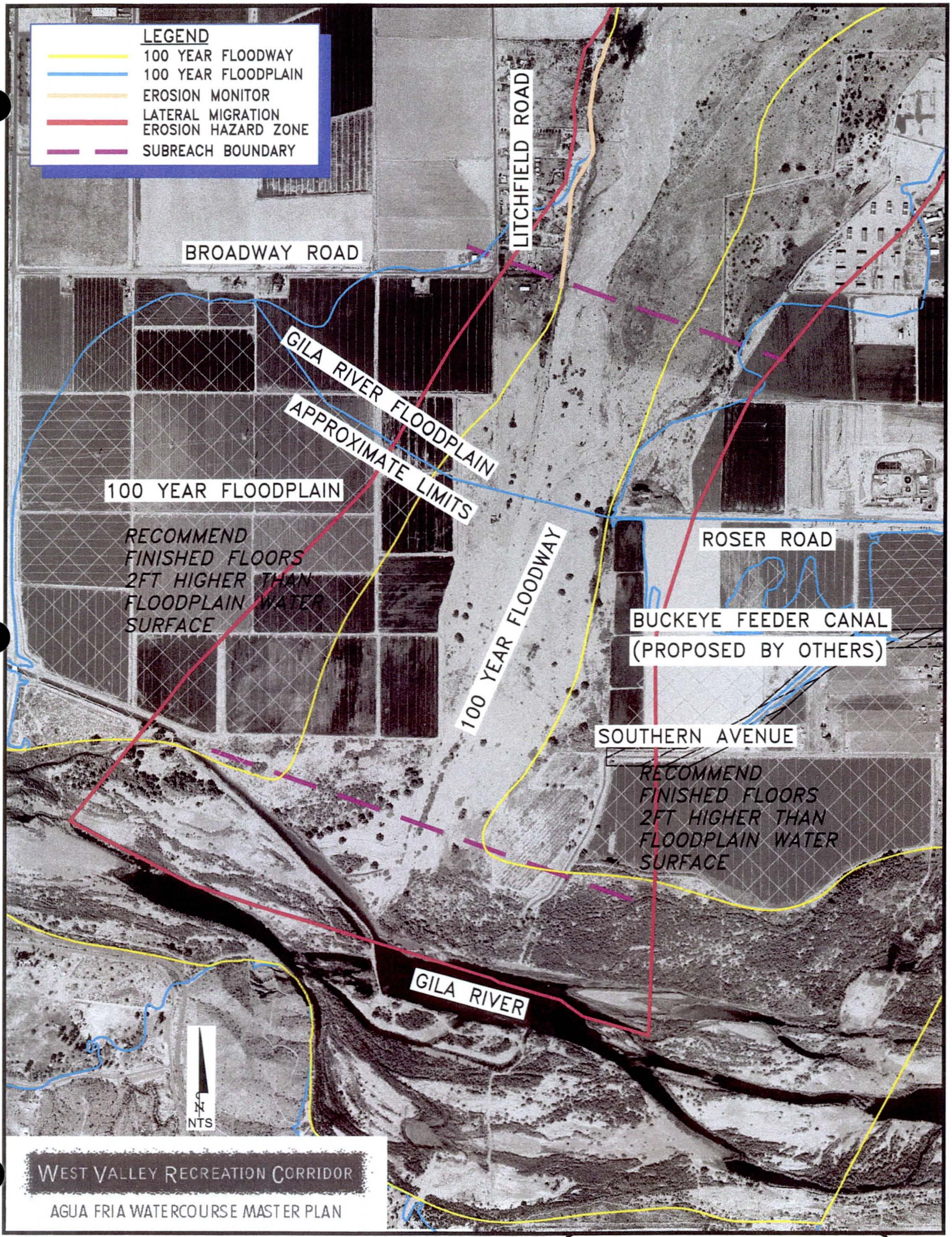
The entire subreach is protected by existing levees. Additional flood control structures or monitoring do not appear to be warranted within this subreach.

12.3.5 Indian School Road to Confluence of New River

The east bank is protected by existing levees. The levees extend north to protect the Glendale airport and wastewater treatment plant. The west bank is occupied by several sand and gravel mining operations. Implementation of non-structural management policies within the remainder of the subreach appears to provide adequate flood protection. Additional flood control structures or monitoring do not appear to be warranted within this subreach.

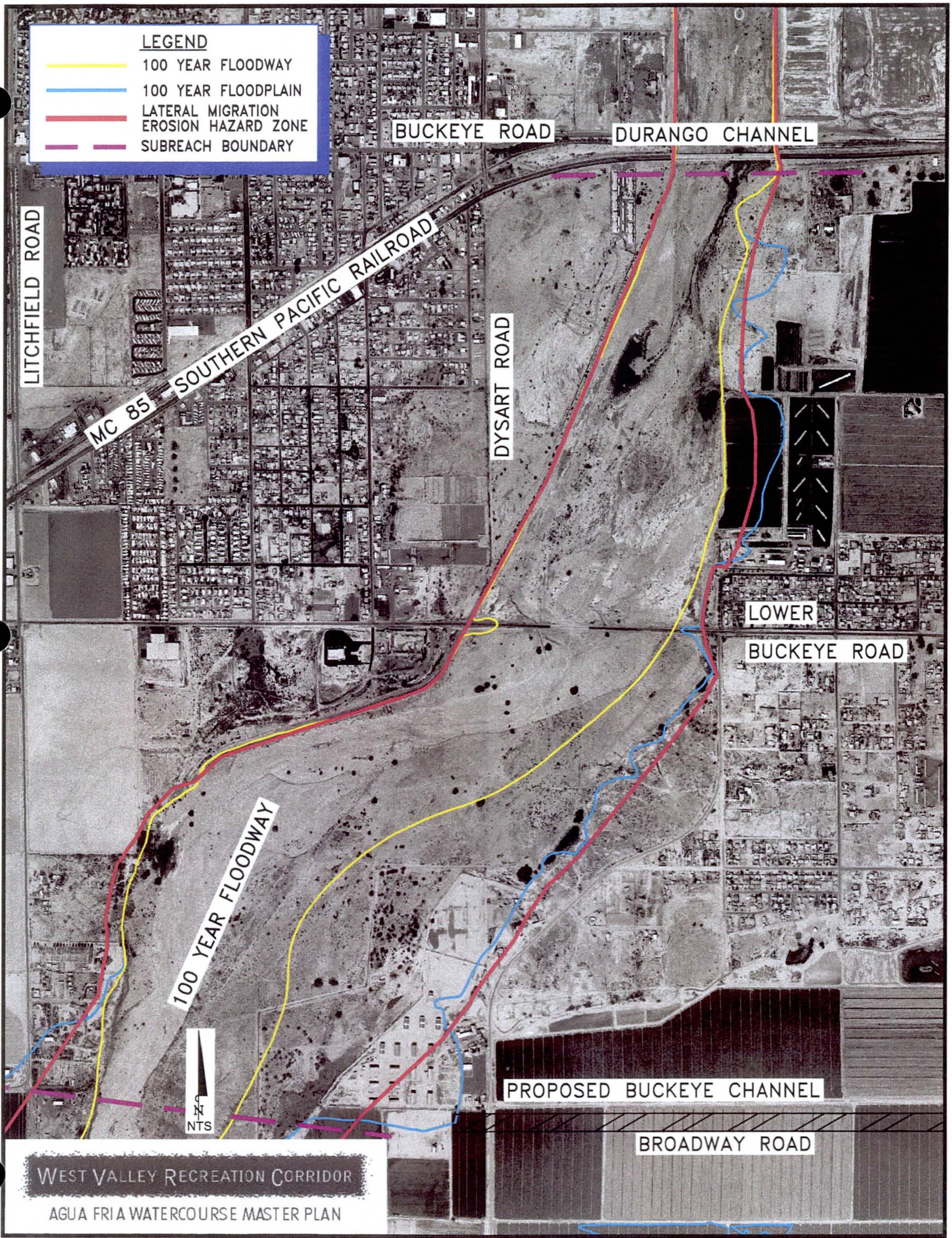
12.3.6 Confluence of New River to Glendale Avenue

Sand and gravel mines are in operation on both sides of the river. Implementing non-structural management policies within the remainder of the subreach is proposed. Additional flood control structures or monitoring do not appear to be warranted within this subreach.



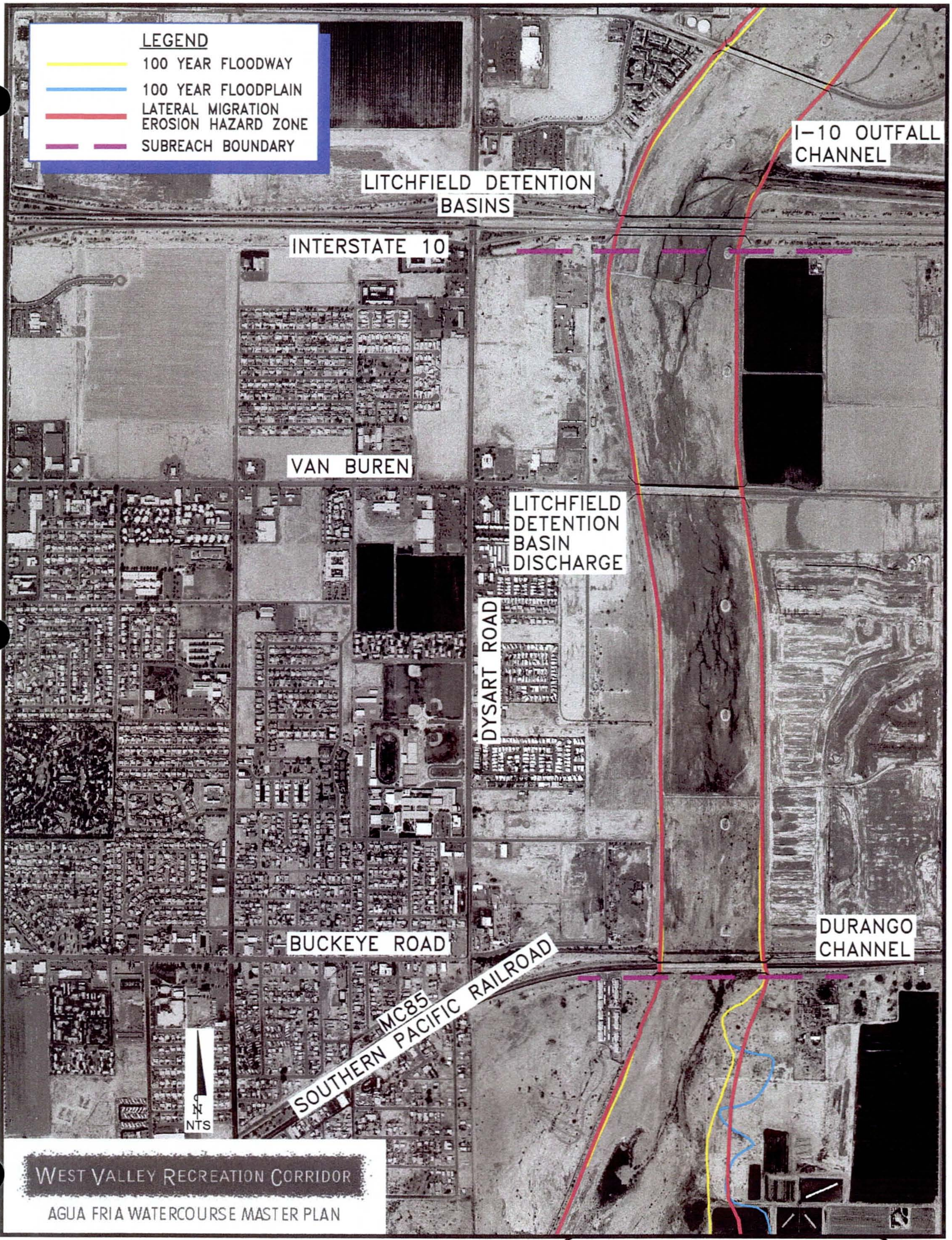
Kimley-Horn and Associates, Inc.

FIGURE 12.3-1
RECOMMENDED PLAN
CONFLUENCE OF GILA TO BROADWAY ROAD



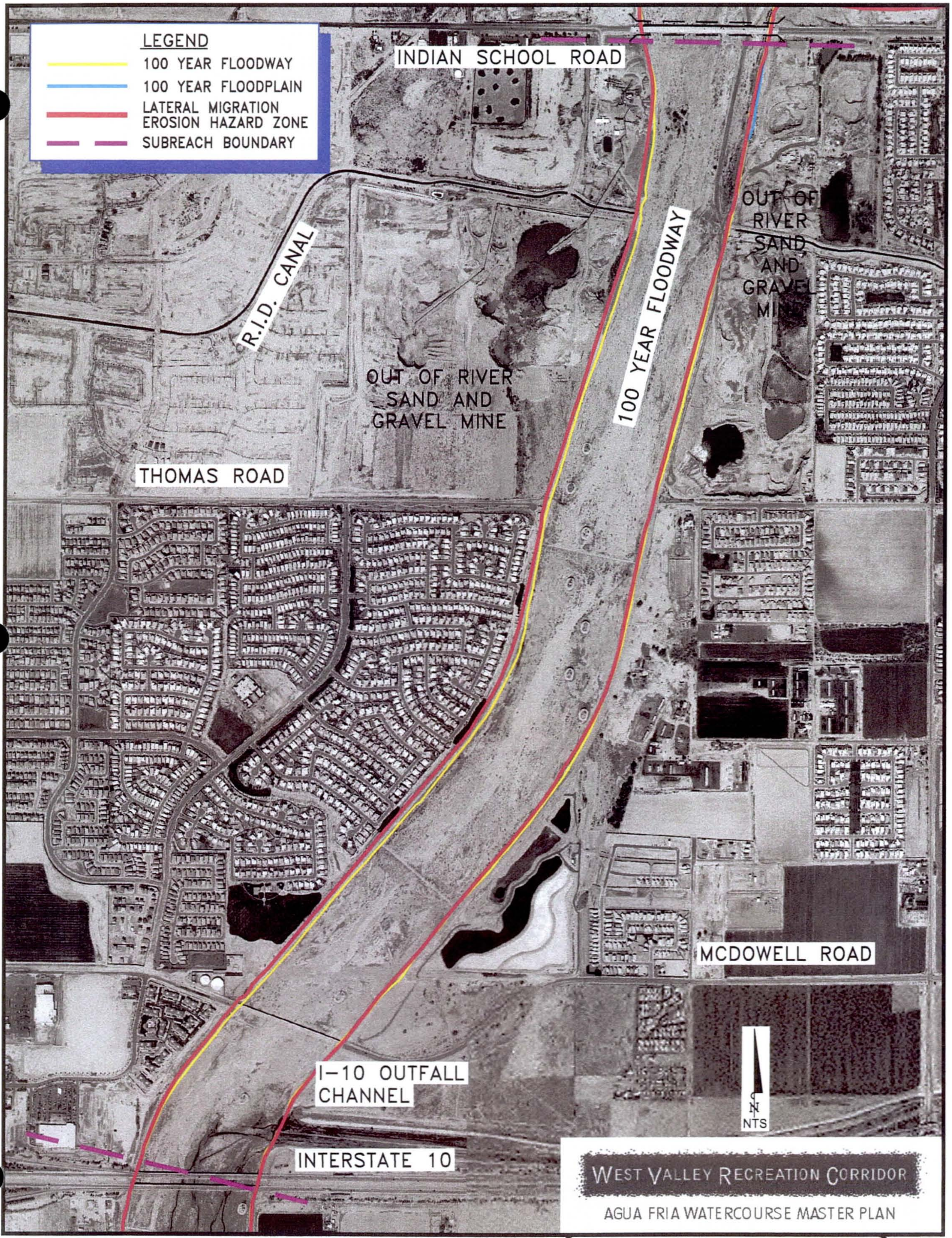
Kimley-Horn and Associates, Inc.

FIGURE 12.3-2
RECOMMENDED PLAN
BROADWAY ROAD TO MC 85



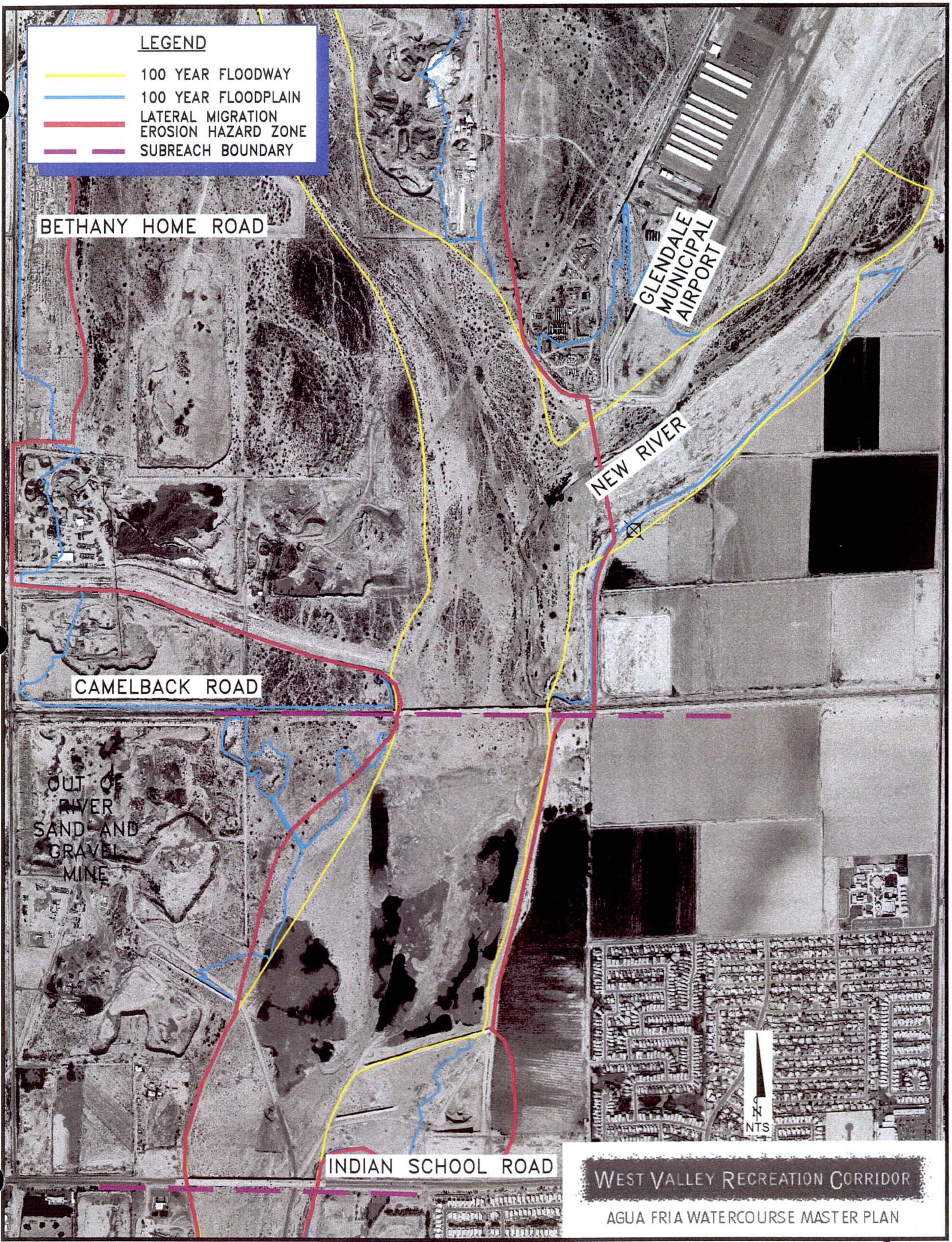
Kimley-Horn and Associates, Inc.

FIGURE 12.3-3
RECOMMENDED PLAN
MC 85 TO INTERSTATE 10



Kimley-Horn and Associates, Inc.

FIGURE 12.3-4
RECOMMENDED PLAN
INTERSTATE 10 TO INDIAN SCHOOL ROAD



Kimley-Horn and Associates, Inc.

FIGURE 12.3-5
RECOMMENDED PLAN
INDIAN SCHOOL ROAD TO CONF OF NEW RIVER

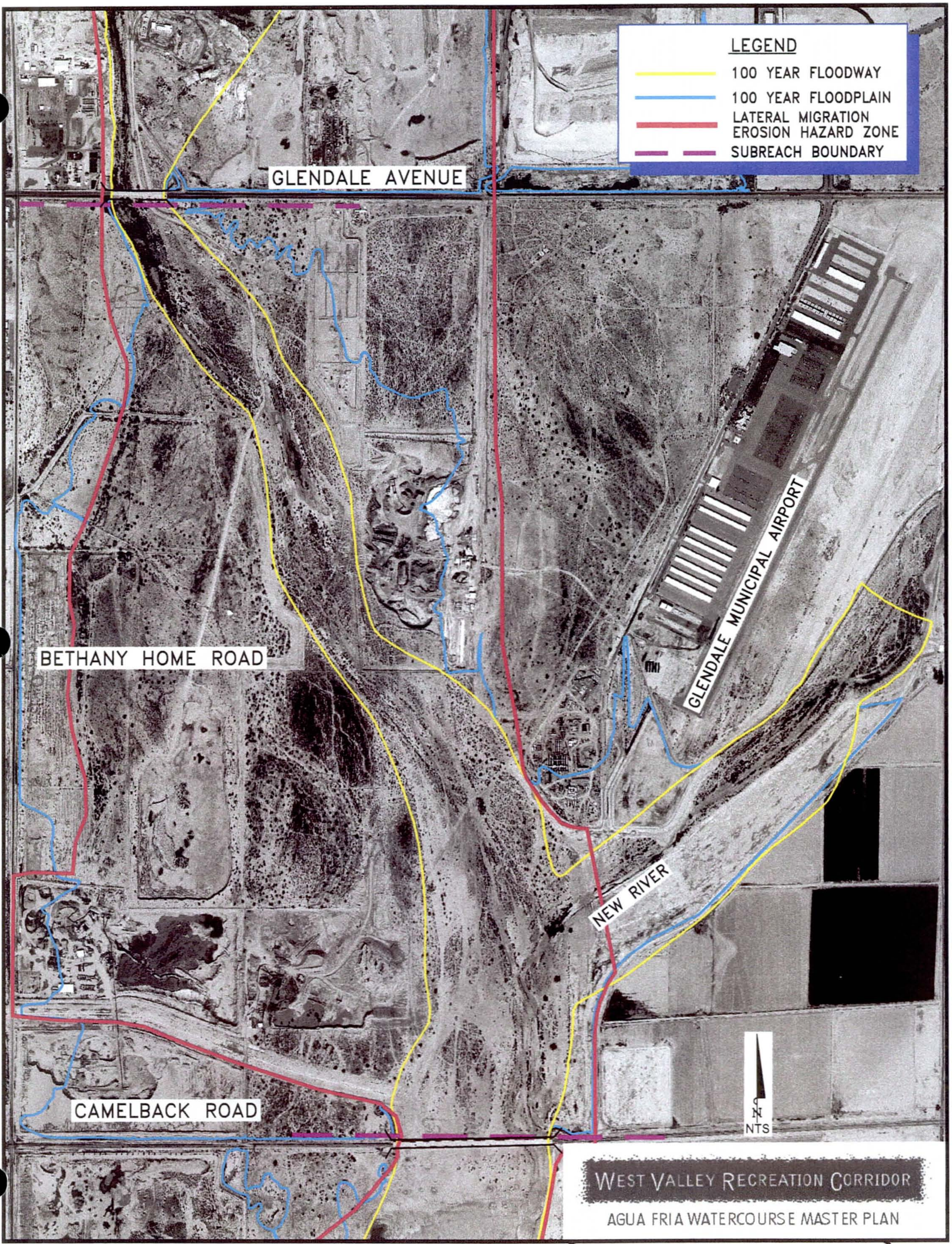


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FIGURE 12.3-6
RECOMMENDED PLAN
CONFLUENCE OF NEW RIVER TO GLENDALE AVE

12.3.7 *Glendale Avenue to Olive Avenue*

The east bank is protected by existing levees. The levees protect the Glendale landfill and municipal recycling facility. A large sand and gravel mining operation occupies the floodway and portions of the east bank within this subreach.

The encroachment model indicates significant riverbed degradation at this location. A grade control structure is recommended downstream of the Olive Avenue Bridge. It would be located between the bridge and a major sand and gravel operation. The purpose of the grade control is to help stabilize the invert of the channel upstream of the grade control and to arrest the existing headcut downstream. Bed degradation and propagation of the headcut should be monitored until the grade control structure is built.

12.3.8 *Olive Avenue to Cactus Road*

The east bank of the river is a high, nearly vertical bluff from the vicinity of Olive Avenue to Grand Avenue. The bluff is subject to the effects of hillside erosion from the top and to the effects of stream erosion from the bottom. Figure 12.3-8 shows the LMEHZ is located east of the bluff. Numerous buildings are located within the LMEHZ. It is proposed to monitor the rate of slope erosion of the east bank between Olive Avenue and Cactus Road. Future action may be required if erosion threatens the existing buildings, but a structural solution does not appear to be necessary at this time.

Non-structural flood management without additional monitoring or flood control structures appears to provide adequate protection along the west bank.

12.3.9 *Cactus Road to Grand Avenue*

The El Mirage Landfill occupies the west bank of this subreach. A review of the records associated with the landfill was conducted as part of the master planning process. The results of the record search are documented in *El Mirage Landfill Site, Summary of Status, Kimley-Horn and Associates, 2001*. Unfortunately, there are gaps in the available records and many questions pertaining to the landfill remain unanswered. Further investigation is required before the issues associated with the landfill are resolved. The reader is referred to the above report for a detailed discussion of the situation.

The landfill embankment is protected by riprap made of dumped concrete rubble. The level of protection provided by the riprap is not known. Further

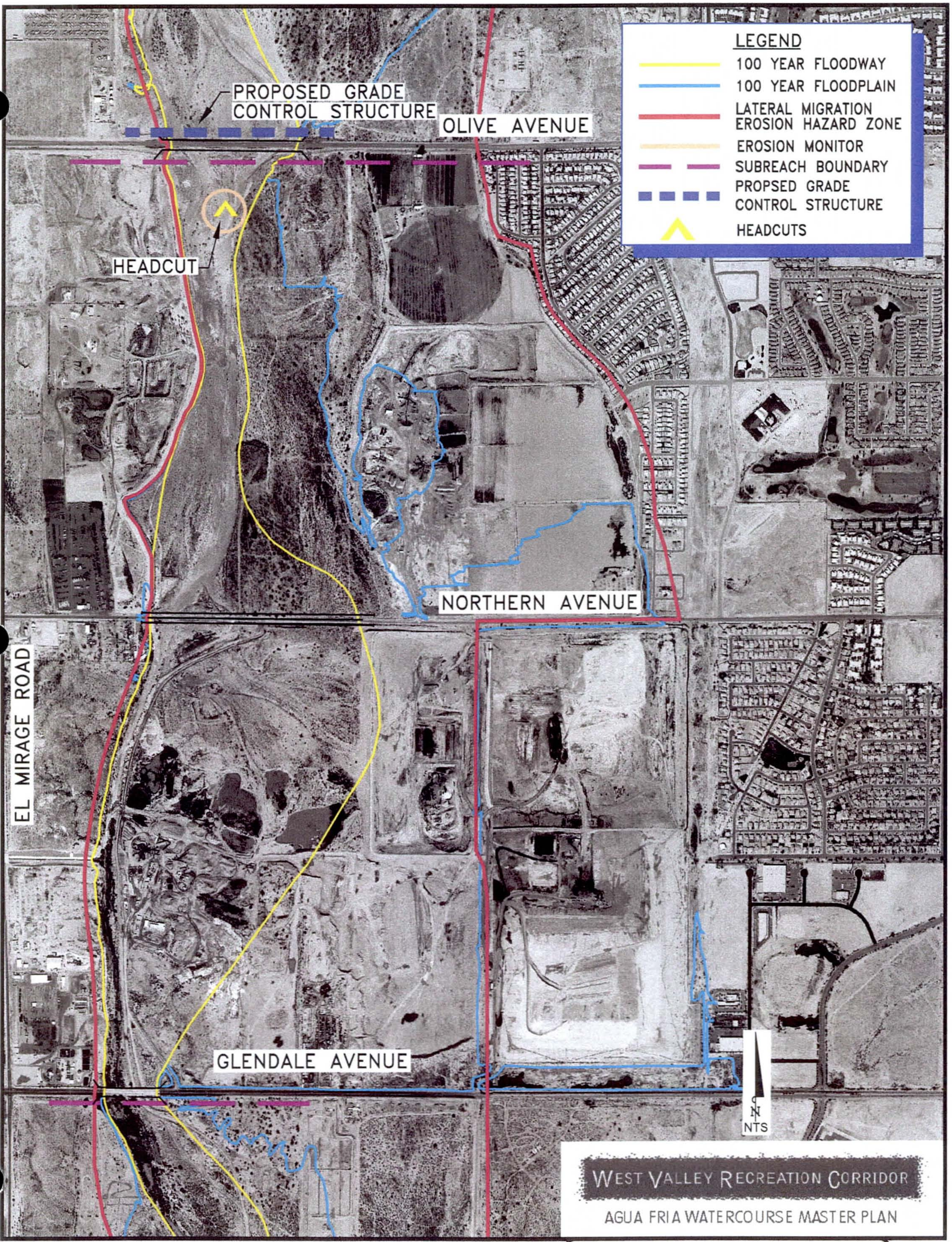

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FIGURE 12.3-7
RECOMMENDED PLAN
GLENDALE AVENUE TO OLIVE AVENUE

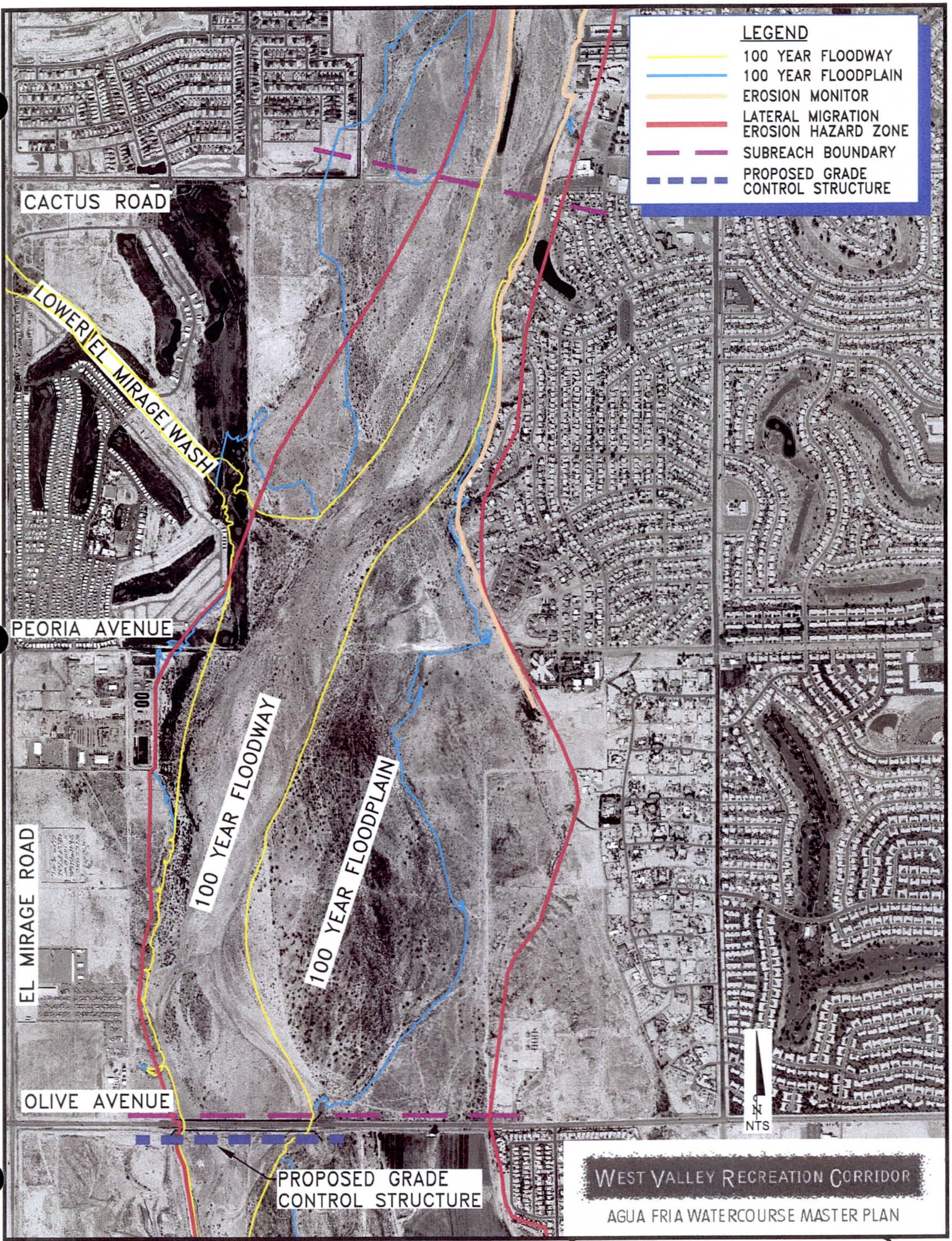

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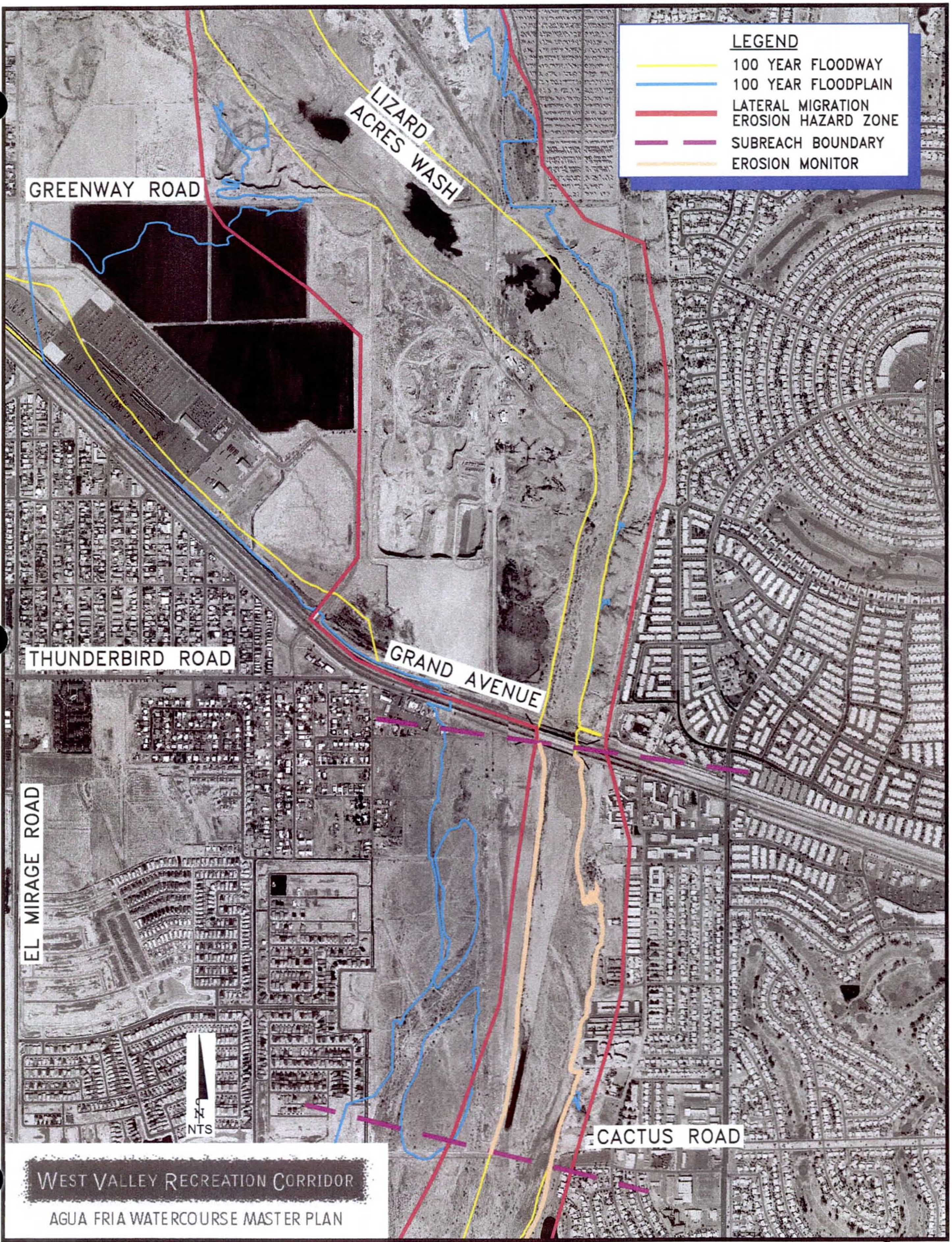
FIGURE 12.3-8
RECOMMENDED PLAN
OLIVE AVENUE TO CACTUS ROAD



WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

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FIGURE 12.3-9
RECOMMENDED PLAN
CACTUS ROAD TO GRAND AVENUE

investigation of the landfill is required to determine the level of protection offered by the riprap. The size of the riprap and the depth to which the riprap is buried determine the erosive forces the riprap is able to withstand. The riprap visible above the riverbed is simply broken pieces of concrete of varying sizes. Careful investigation by a qualified engineer is required to estimate the adequacy of the riprap to withstand a 100-year storm. The depth to which the riprap is buried (toe down) determines the amount of scour that may occur before the protection is undermined. A potential scour depth of the riverbed may be estimated, but the toe down depth is unknown.

It is difficult to determine the scope and cost of augmenting the bank protection. The extent of the landfill is not clearly defined in the records available for review. Further investigation is necessary to determine the eastern boundary of the landfill. At some point, the investigation will involve excavation or drilling in the vicinity of the landfill. There is a high potential cost and high liability associated with a physical investigation of the landfill, but installation of additional riprap will require excavation to install the toe down for the new riprap. The extent of the landfill must be known before a contractor can begin excavating to construct bank protection or channelization. It is conservatively estimated that the river will require soil cement bank protection along both banks and across the bottom of the channel throughout the subreach.

The east bank of the river is a high, nearly vertical bluff in this subreach. Protecting the landfill embankment makes this bank more susceptible to erosion. Flow velocities in this area are high enough to cause erosion. The landfill embankment is stabilized (to some extent) and unable to erode, so the opposite bank and the channel bottom must supply the sediment load to the flow. This reflective erosion has been ongoing since the placement of the existing riprap. It will continue unless the east bank is also protected.

As shown in Figure 12.3-9, monitoring of the area is recommended until more is known about the landfill. Non-structural flood control measures may not provide adequate protection in the long term, but additional information is required before a reasonable and feasible solution can be considered.

12.3.10 Grand Avenue to Bell Road

There are no existing buildings within the regulatory boundary from Grand Avenue to Greenway Road. Non-structural policies appear to offer the most suitable means of flood protection through this section of the subreach.

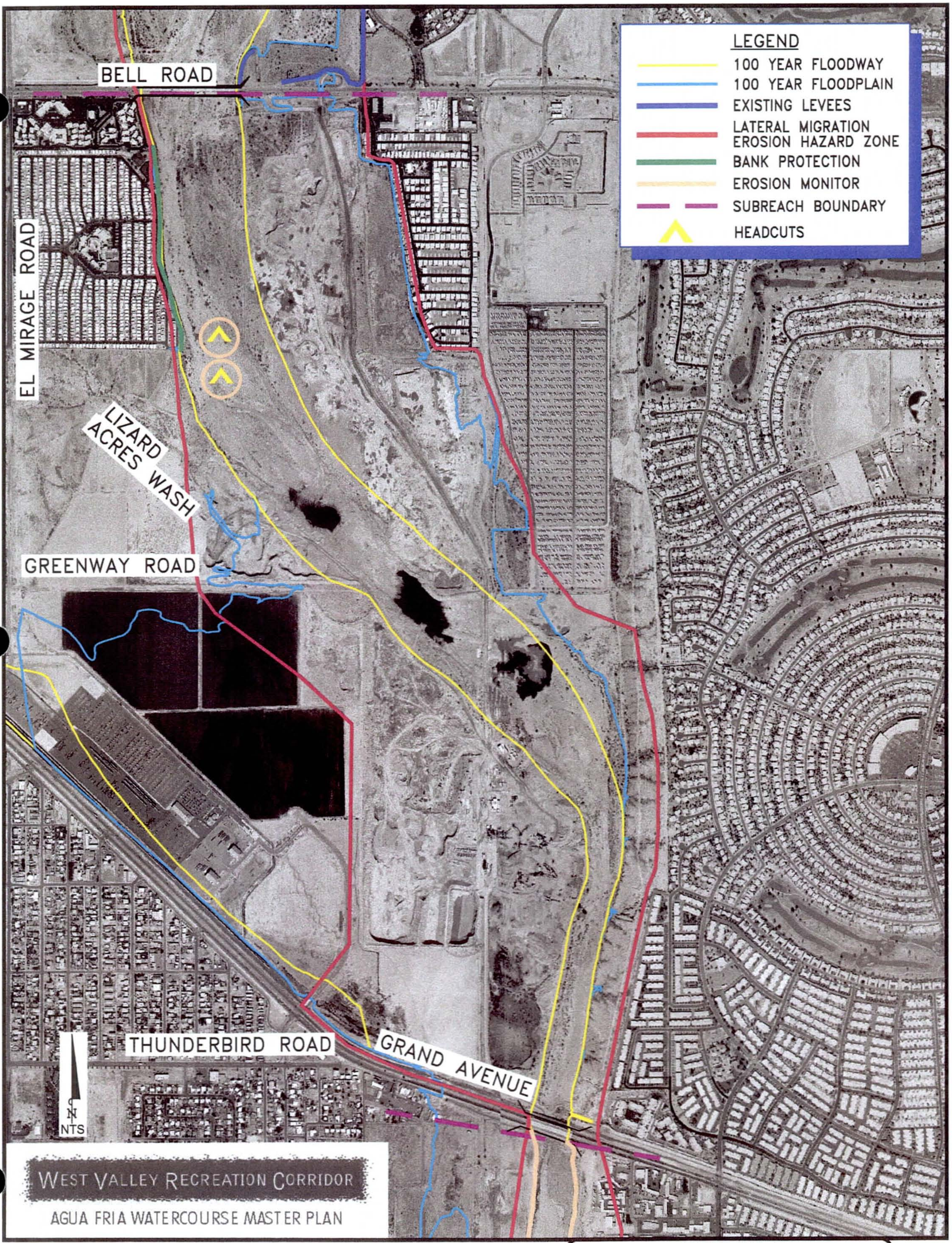

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FIGURE 12.3-10
RECOMMENDED PLAN
GRAND AVENUE TO BELL ROAD

Existing homes abut the floodplain on the west bank, south of Bell Road at the top of a nearly vertical 25-foot bluff. The homes are pre-manufactured units on small lots. Many of the homes have been placed quite close to the edge of the bluff. It forms the boundary of the floodway, floodplain, and LMEHZ. Although the homes are outside the regulatory boundaries, sudden failure of a small portion of the bank would cause homes to fall into the floodway. Bank protection is proposed to prevent loss of life. Figure 12.3-10 shows the location of the proposed bank protection.

Extensive sand and gravel mining operations occupy this subreach. In order to comply with the No Adverse Impact strategy, it is anticipated that nearly continuous levees will be required on both sides of the river to isolate the mine from the floodway. The owners of the mine would construct the levees.

Existing headcuts have been identified downstream from the Bell Road Bridge. It is recommended that the existing size and location of the headcuts be accurately documented. Monitoring of the area monitored is recommended after flow events to track progression of head cuts or development of new ones. A future grade control structure may be required at this location.

12.3.11 Bell Road to Beardsley Road

This subreach is ideally suited to non-structural regulation. There are no buildings within the proposed regulatory boundary. The west bank is quite high and steep. The area west of the river is an undeveloped strip one-quarter mile wide throughout the subreach. The only exception is a building on El Mirage Road, north of Bell Road.

The east bank is defined by the levee protecting the Coyote Lakes subdivision. The levee is an engineered levee. The levee forms the boundary for the LMEHZ and the floodplain. Preventing encroachment beyond the regulatory line would prevent construction in a sizeable tract of undeveloped land along the east bank. The tract is a narrow strip west of the Coyote Lakes subdivision.

This strip is currently in the floodplain, between the Coyote Lakes levee and the floodway. Under current regulations, it is permissible to construct in this area by raising the building on an embankment or by building a levee to protect the building. However, development in this area would be in immediate danger if a storm event exceeds the level of protection provided by

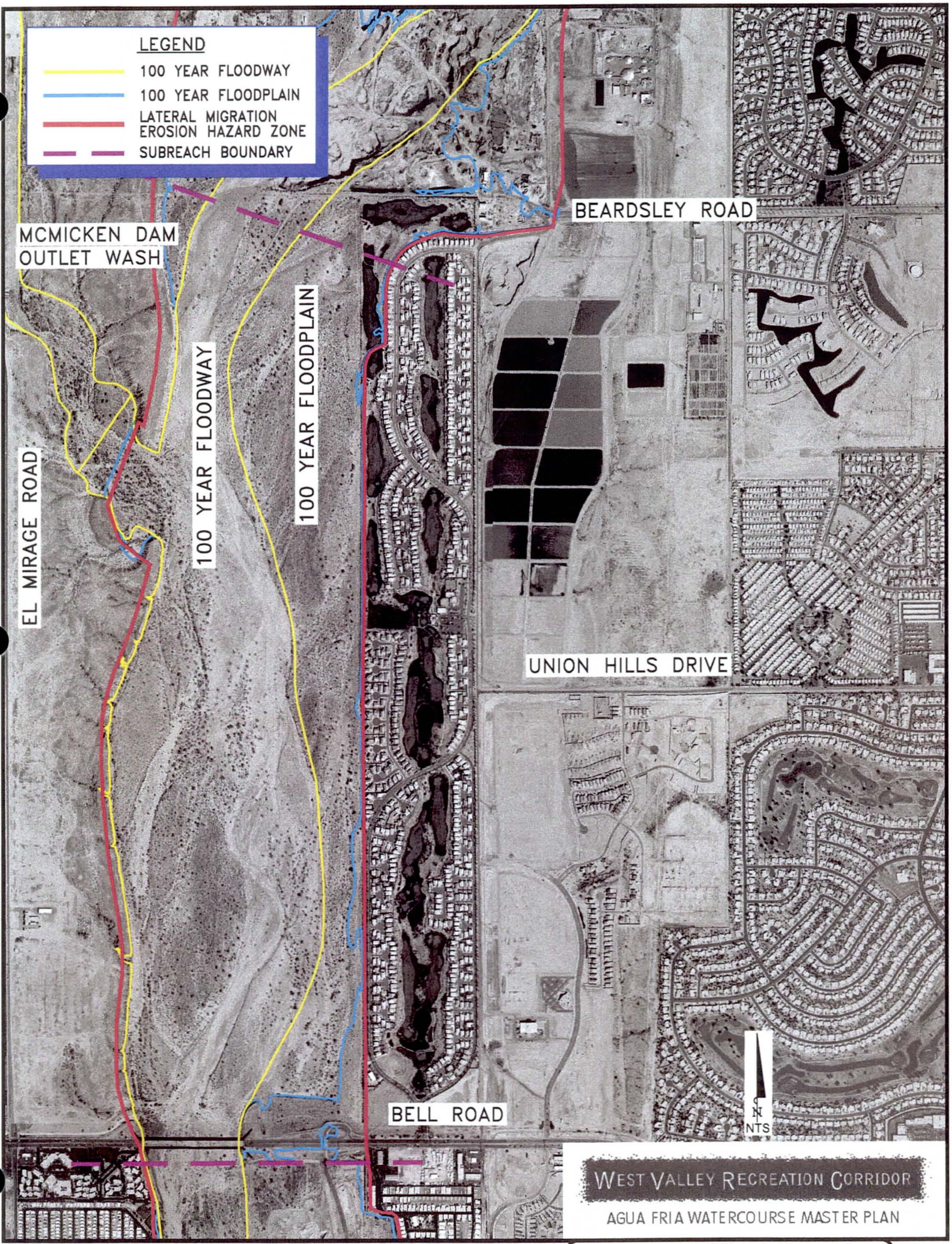

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FIGURE 12.3-11
RECOMMENDED PLAN
BELL ROAD TO BEARDSLEY ROAD

a levee or embankment. Damage to buildings could be significant due to depth of flow and velocity of flow. Preventing development of this strip helps reduce losses due to large storms.

12.3.12 *Beardsley Road to Pinnacle Peak Road*

A large sand and gravel mine occupies the lower half mile of the subreach. The mine spans the floodway and also occupies large portions of the flood fringe along both banks. It is not possible to construct a levee or other flood/erosion control structure in this area due to the presence of the mine.

Existing headcuts have been identified upstream from the mine in the vicinity of the Deer Valley Road Alignment. It is recommended that the existing size and location of the headcuts be accurately documented. Monitoring of the area is recommended after flow events to track progression of head cuts or development of new ones. A future grade control structure may be required near Rose Garden Lane.

Existing homes along the west bank are located within the LMEHZ. It is proposed to monitor the rate of bank erosion along the west bank . Future action may be required if erosion threatens the existing buildings, but a structural solution does not appear to be necessary at this time.

The remainder of the subreach is undeveloped with smaller sand and gravel operations west of the floodplain. The owners of the mines may be required to construct levees to meet the requirements of the No Adverse Impact Strategy toward mining within the floodplain. Bank protection might be required along the east bank to arrest reflective erosion if the west bank is armored.

Non-structural regulation of the floodplain is a practical method of protecting the public in this subreach.

Infrastructure required to meet the requirements of the No Adverse Impact Strategy would be constructed by gravel miners.

12.3.13 *Pinnacle Peak Road to Jomax Road*

A large gravel mine is located immediately north of Pinnacle Peak Road along the east bank. The mine occupies the flood fringe and a considerable area east of the floodplain. The owners of the mine may be required to construct levees to meet the requirements of the No Adverse Impact Strategy toward mining within the floodplain.

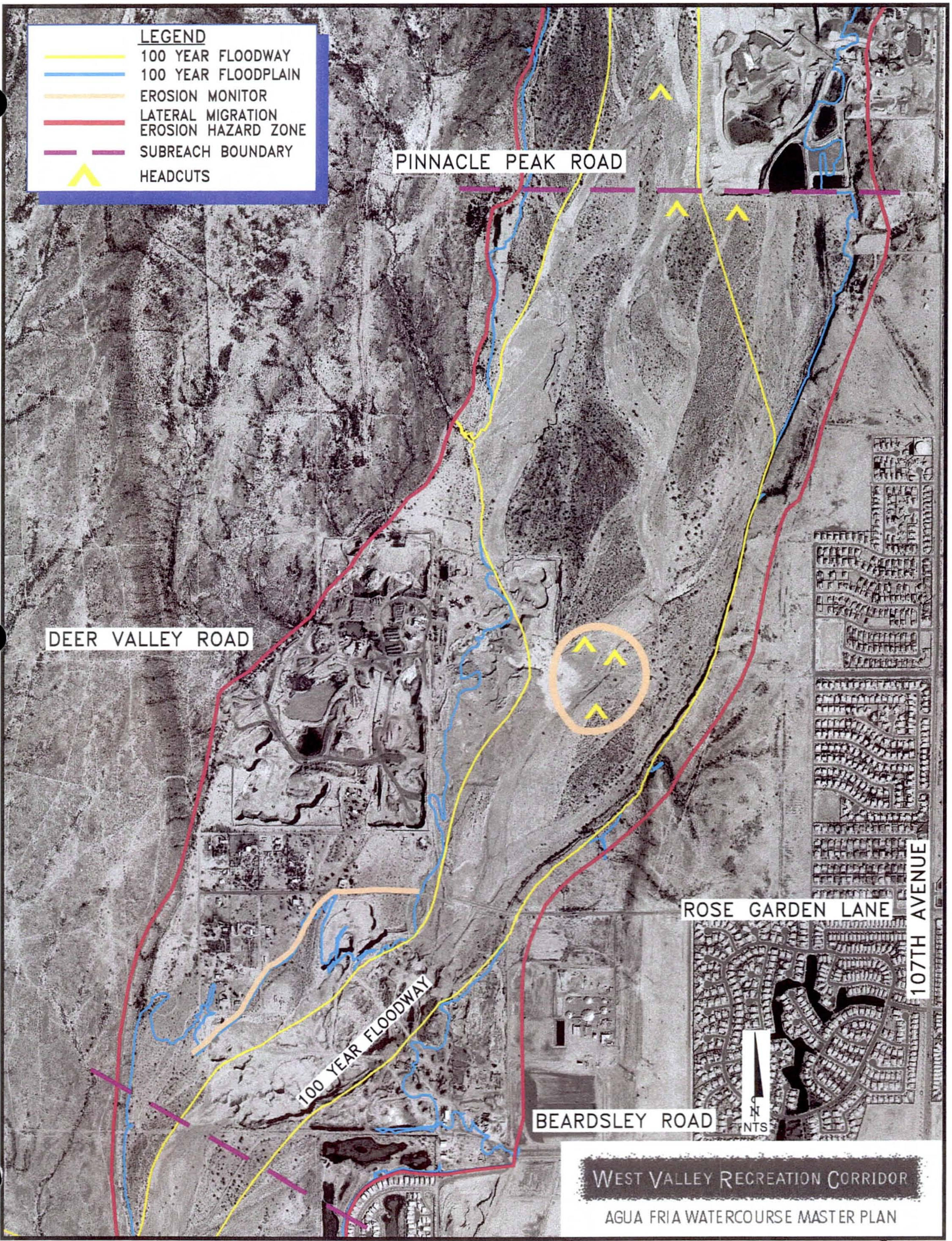

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FIGURE 12.3-12
RECOMMENDED PLAN
BEARDSLEY ROAD TO PINNACLE PEAK ROAD

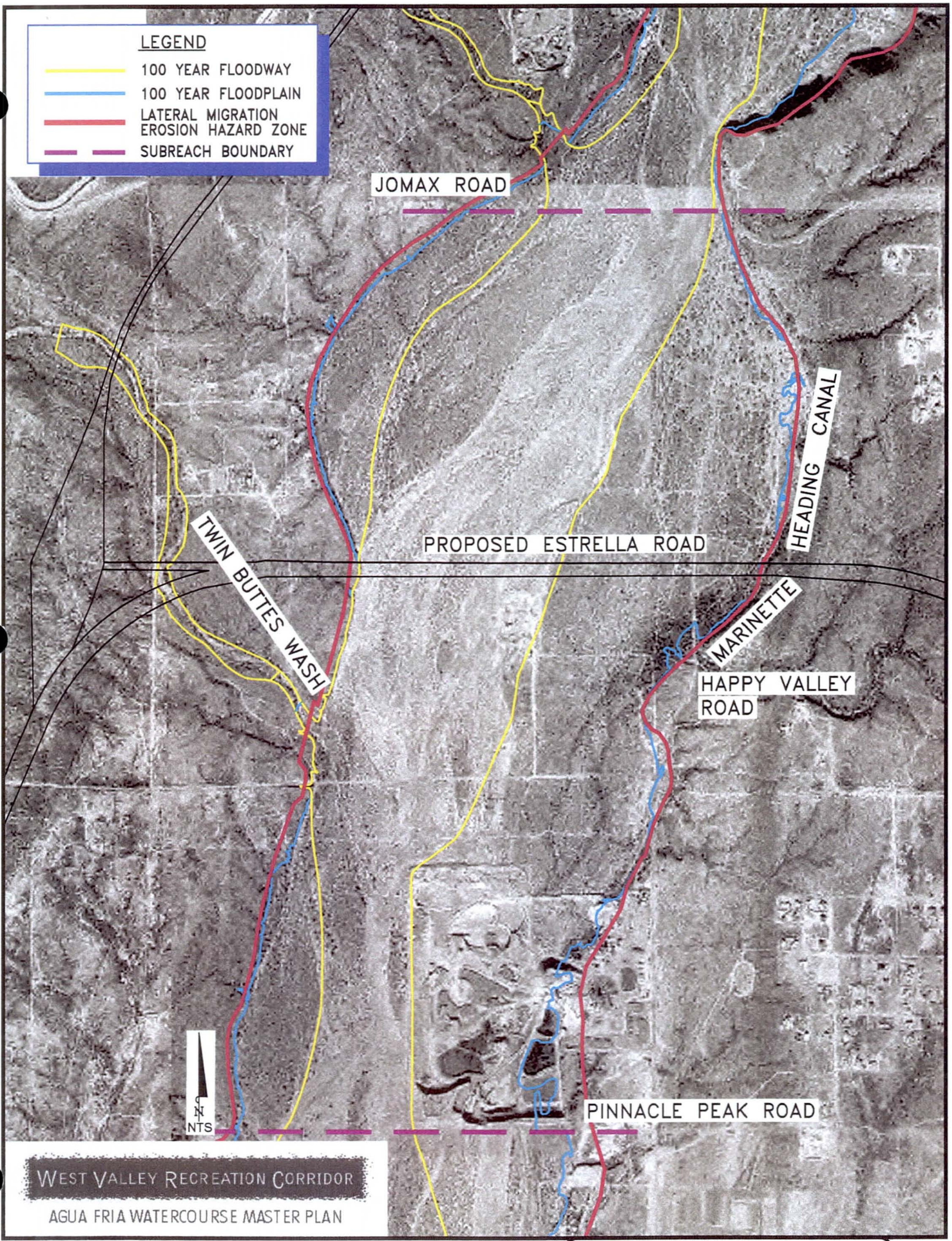

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FIGURE 12.3-13
RECOMMENDED PLAN
PINNACLE PEAK ROAD TO JOMAX ROAD

CAP is currently constructing groundwater recharge ponds within the floodplain along the west bank, south of Jomax Road. The ponds are to be located outside the floodway.

The mine and the recharge ponds are both located within the LMEHZ. These are acceptable land uses within the LMEHZ. Structural protection of these facilities at the taxpayer's expense is not necessary. Non-structural flood control measures provide adequate protection throughout the subreach.

12.3.14 Jomax Road to Dixileta Drive Alignment

In the future, water will flow through this subreach from the CAP canal to the recharge ponds south of Jomax. The water will flow along the natural channel bottom. Except for maintenance to remove excessive vegetation, the channel will not be improved.

Proposed gravel mines may be located in the floodplain along the west bank. The limits of the mines are undetermined at this time.

There are no existing buildings within the subreach that require structural protection. The subreach is well suited to non-structural flood control.

12.3.15 Dixileta Drive Alignment to the CAP Canal

In the future, water will flow through this subreach from the CAP canal to the recharge ponds south of Jomax. The water will flow along the natural channel bottom. Except for maintenance to remove excessive vegetation, the channel will not be improved.

Proposed sand and gravel mines may be located in the floodplain along the west bank. The limits of the mines are undetermined at this time.

There are two existing structures within the subreach: the CAP Canal Siphon and the Beardsley Canal Bridge. A proposed bridge will carry the Loop 303 across the river in the vicinity of Lone Mountain Road. The Loop 303 Alignment is well into the planning phase at this time, but a precise alignment has not been finalized.

The subreach is well suited to non-structural flood control. There are no existing buildings within the regulatory boundaries.

12.3.16 CAP Canal to Cloud Road

The subreach is well suited to non-structural flood control. The area is generally undisturbed desert. There are no existing buildings within the

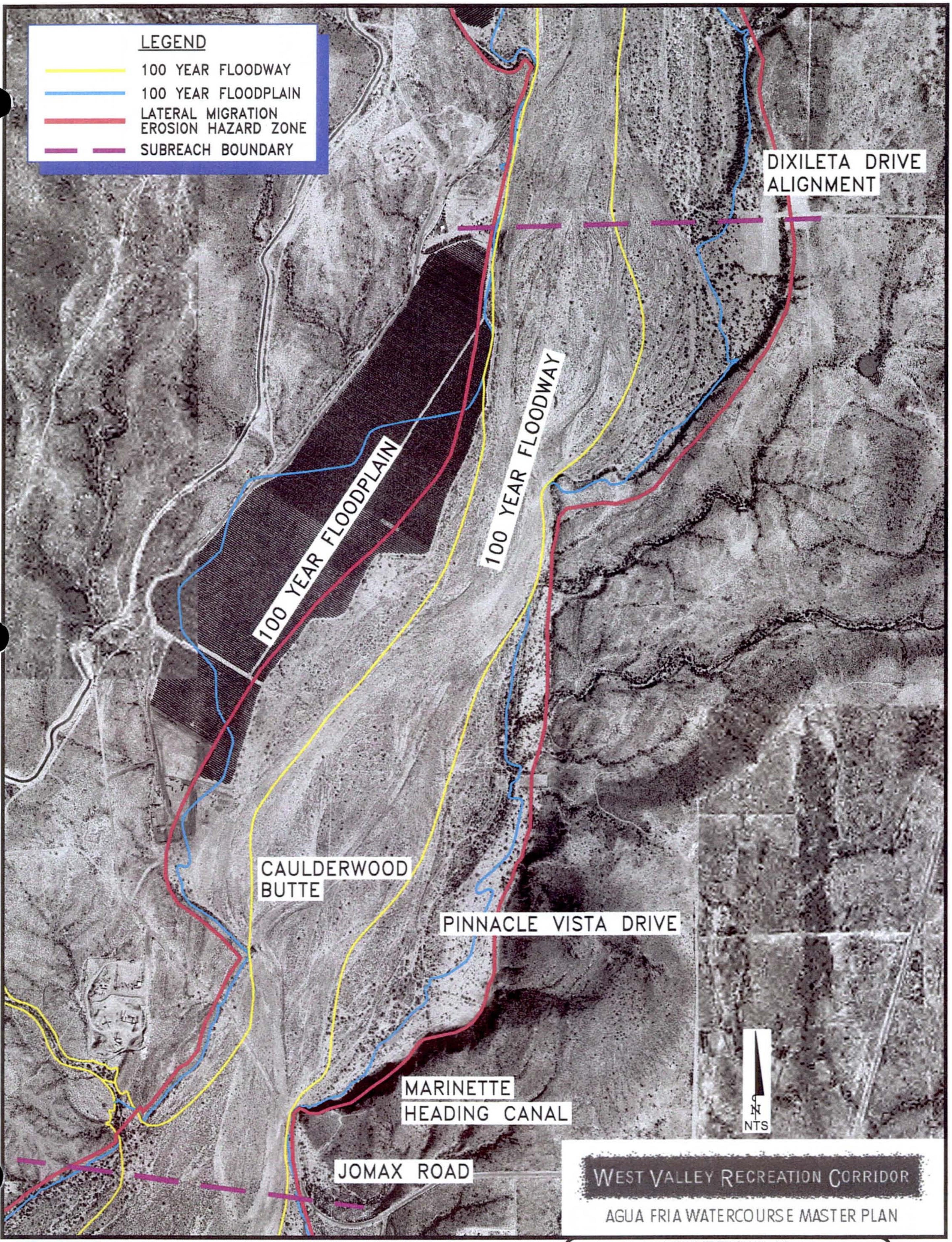

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FIGURE 12.3-14
RECOMMENDED PLAN
JOMAX ROAD TO DIXILETA DRIVE ALIGNMENT

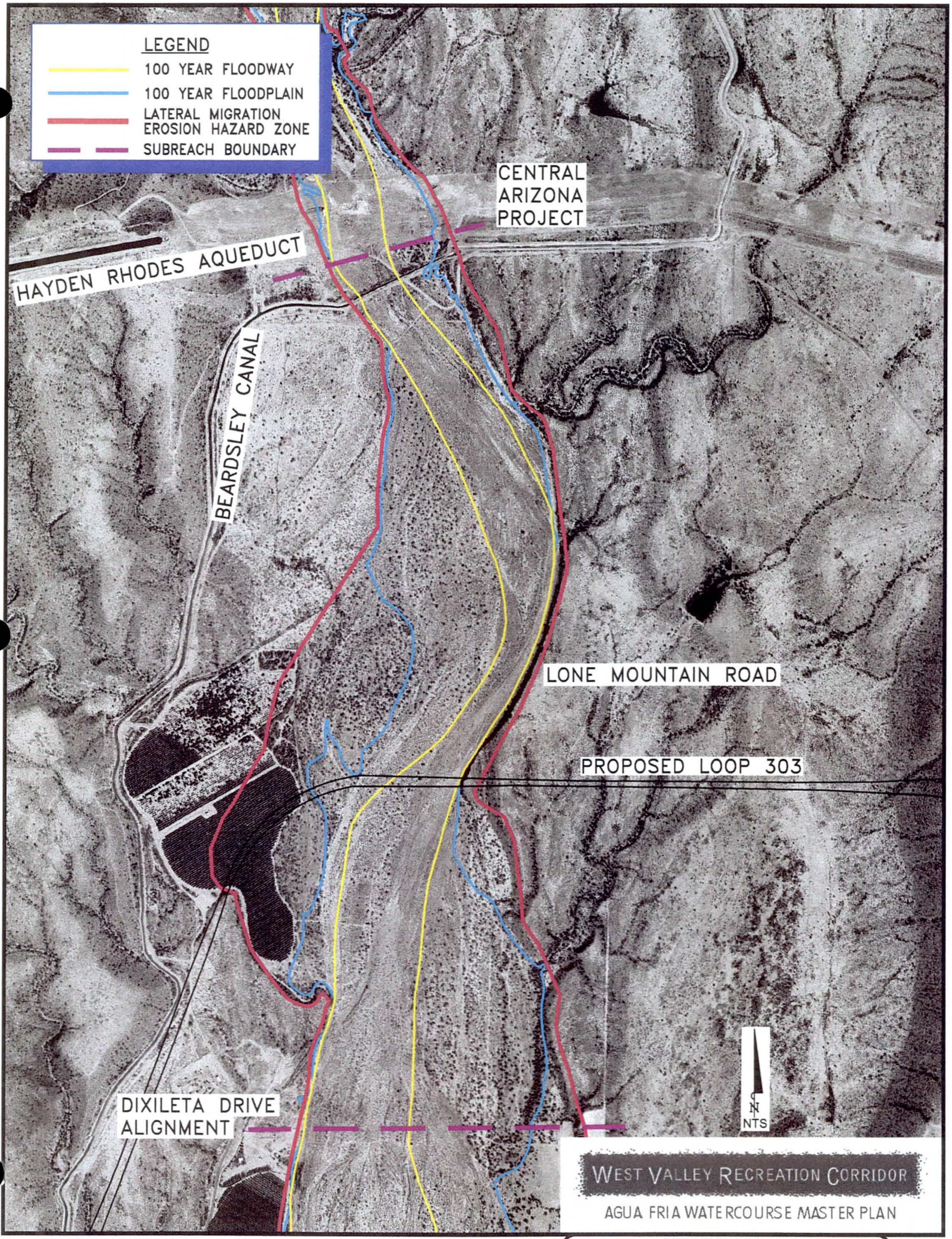

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FIGURE 12.3-15
RECOMMENDED PLAN
DIXILETA DRIVE ALIGNMENT TO CAP CANAL

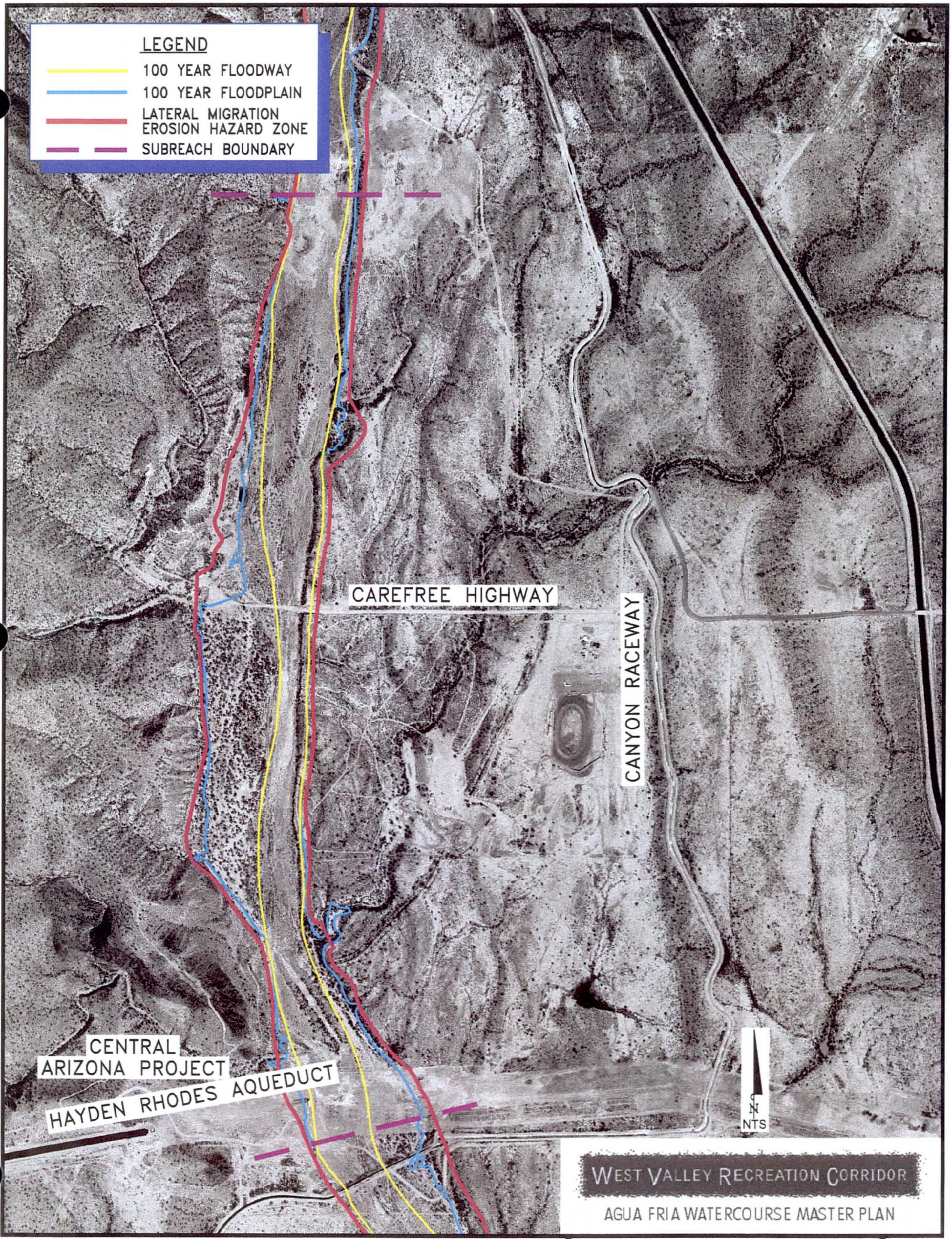

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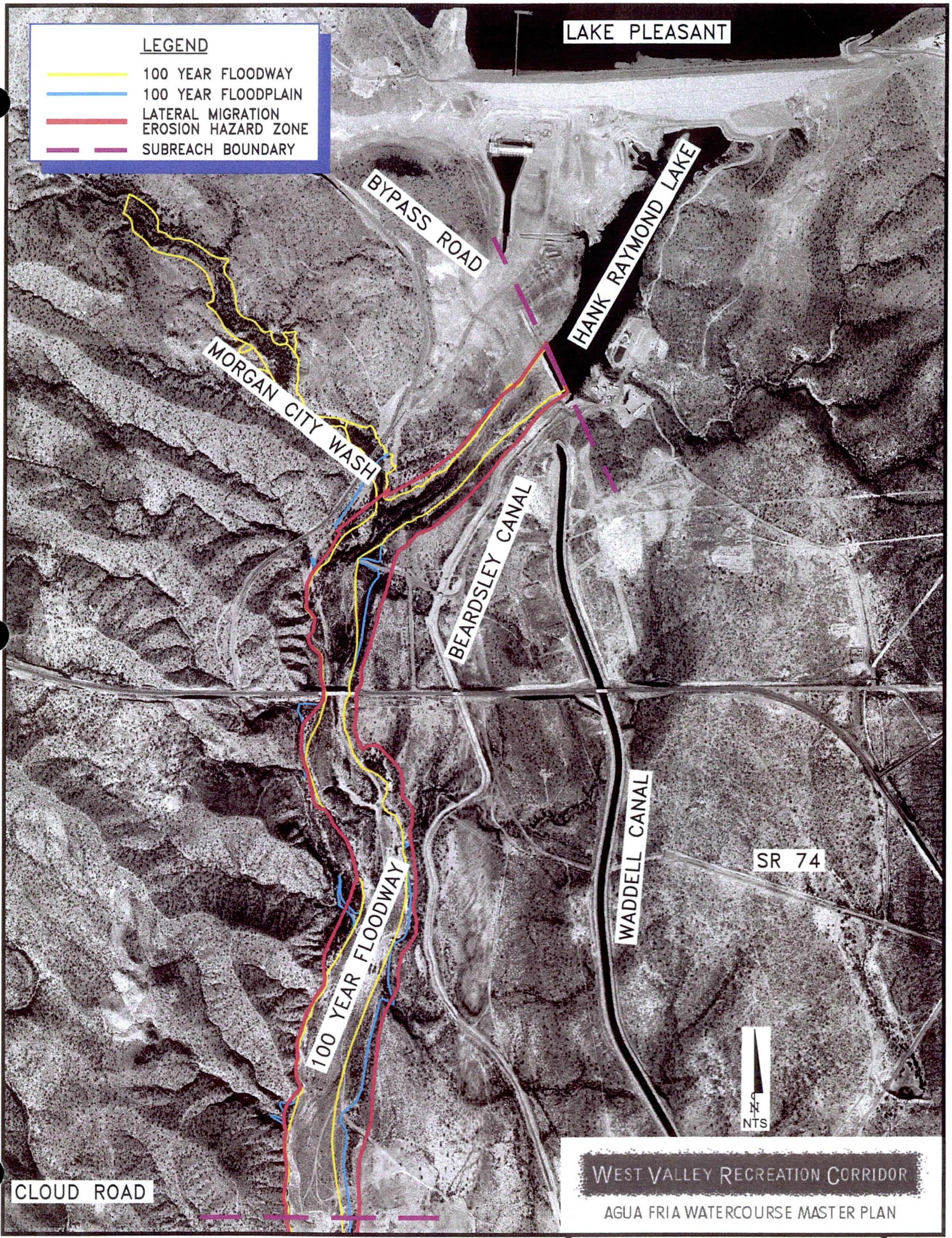
FIGURE 12.3-16
RECOMMENDED PLAN
CAP CANAL TO CLOUD ROAD

regulatory boundaries. The river is well incised with the floodway line, floodplain line and LMEHZ all being nearly coincidental with one another.

12.3.17 Cloud Road to New Waddell Dam

The subreach is well suited to non-structural flood control. The area is generally undisturbed desert. There are no existing buildings within the regulatory boundaries. The river is well incised with the floodway line, floodplain line and LMEHZ all being nearly coincidental with one another.



WEST VALLEY RECREATION CORRIDOR

AGUA FRIA WATERCOURSE MASTER PLAN

Kimley-Horn and Associates, Inc.

FIGURE 12.3-17
RECOMMENDED PLAN
CLOUD ROAD TO NEW WADDELL DAM

13. PUBLIC SAFETY

13.1 Introduction

Floodplains are a valuable resource in creating multi-use opportunities and open space for communities. However, locating these facilities in and around a major watercourse makes them vulnerable to periodic flooding and exposes users to weather-related hazards. The District wishes to minimize public safety concerns and is addressing them as part of the planning process.

LTM Engineering, Inc evaluated public safety issues related to the proposed multi-use plan for the Agua Fria River corridor. Existing flood hazards were identified and current emergency management procedures along the river were investigated. Results of this evaluation and recommendations for minimizing safety hazards are discussed in the *Evaluation of Public Safety Issues, LTM, 2001*, and are summarized below.

13.2 Existing Public Safety Hazards

A number of city, county, state, and federal agencies were interviewed to identify existing flood hazards along the Agua Fria River. A number of potential hazards were identified, including houses near the dam, locations where access would be cut off during active flooding, at-grade road crossings, and an adjacent landfill that could be undercut by flooding.

13.3 Current Emergency Response Procedures

The CAP and USBR have prepared an Emergency Action Plan (EAP) for New Waddell Dam. The CAP is responsible for maintaining the dam and implementing the EAP. The CAP regularly participates in flood drills with MCDEM, downstream municipalities, USBR, Corps, Red Cross, and local fire departments.

13.3.1 *Maricopa County Department of Emergency Management*

The Maricopa County Department of Emergency Management (MCDEM) coordinates emergency management activities in unincorporated areas of the county and interfaces with local jurisdictions as well. If releases are made at New Waddell Dam, the CAP notifies the MCDEM. In turn, MCDEM notifies MCDOT, the Maricopa County Sheriff, and the District. In addition to internal notification of other county agencies, MCDEM contacts a number of federal, state, and local agencies as well as sand and gravel operators.

13.3.2 *Flood Control District of Maricopa County*

The District operates an automated network of precipitation, stage, and weather gages to monitor real-time information about rainfall, stormwater runoff, and weather conditions in Maricopa County. The District also monitors meteorological conditions and provides forecast products for a large portion of the county, including the Agua Fria River corridor. The District coordinates closely with other county and local agencies to keep them informed of developing severe weather and associated flooding.

13.3.3 *Municipalities*

Most of the municipalities rely on the CAP and MCDEM for information on developing flood conditions in the Agua Fria River. Direct monitoring of the river is not done routinely; rather, action is taken when notified of a problem or potential problem. It is challenging for the municipalities to monitor activity along the middle and upper reaches of the river because the terrain prevents easy sighting of people. Also, there is little or no motorized access, so it is difficult to respond to an emergency in the channel or to warn people to leave the area.

13.4 *Public Safety Considerations of Future Recreational Facilities*

Potential facilities identified in the Recommended Plan were evaluated with respect to public safety. A summary of the evaluation is provided herein.

13.4.1 *Parks and Interpretive Areas*

Several parks and interpretive areas are envisioned along the river corridor. Public safety may not be compromised if the parks are located outside the floodplain. However, if portions of the park allow access to or recreation in the river channel, special hazard conditions would need to be addressed. Any facilities should be located above the regulatory flood elevation and would need to be monitored during a flood threat. An EAP should be prepared that includes monitoring of the park during storms and closure during flooding.

13.4.2 *Trails*

The proposed trail system is largely envisioned to be outside or on the fringes of the floodplain and away from immediate contact with sand and gravel operations and haul routes. However, the trails may cross the river at several locations, and in some cases, would be located along the bottom of the Agua Fria or its tributaries. In general, where a trail crosses the river or is located within it, special safety issues must be considered. Minimal safety precautions would include proper signage identifying the flood hazard at all access points and periodically along the trail itself. If signs also incorporate flashing lights to signal imminent flooding, they should be installed at a height that reduces the chances of startling horses when activated.

If a trail is developed in a wash, the District may wish to install precipitation and stage gages on the watershed. The monitoring of gages could then be tied to an EAP for the recreational facilities. Installing gages on large tributaries to the river has additional advantages at downstream facilities and unbridged road crossings.

13.5 *Public Safety Considerations for Future Flood Control Facilities*

Several types of structural flood control facilities were analyzed in considering potential future changes to the river and in developing alternatives for the Watercourse Master Plan. These facilities include grade control structures, river channelization, and bank protection. Of these, grade control structures and river channelization can directly affect public safety and are discussed below.

13.5.1 *Future Grade Control Structures*

Grade control structures may be constructed at various locations within the river to mitigate channel bed erosion. However, events that occurred in the past decade have shown that grade control structures can be hazardous. During a major flood in 1993, two people illegally entered the Salt River in a kayak and were pulled underwater at a grade control structure. It was believed that the accident and resulting deaths were caused by a submerged hydraulic jump. In a submerged hydraulic jump, the water appears stable on the surface. However, under the surface considerable turbulence occurs and the current is dangerous to unsuspecting boaters.

Even though boating is not allowed in the Agua Fria River and would not likely be allowed in the future, the potential exists for people to enter the river illegally during a flood. Therefore, it is important to avoid submerged hydraulic jumps when designing any future grade control structures.

13.5.2 *Future River Channelization*

It is possible that portions of the Agua Fria River could be channelized in the future to contain the regulatory flow. However, the floodplain in some areas is broad and the historic channel embankment is steep and high. If the 100-

year flow is contained in a channel, the adjacent area would no longer be within the floodplain under existing regulations. Therefore, it is conceivable that the surrounding area could then be allowed to develop. This area may not be subject to flooding from the regulatory flow; however, it would still be at risk to flooding in the event of a failure or overtopping of New Waddell Dam. If this occurs, the ensuing property damage and loss of life would be catastrophic. This special hazard should be recognized and addressed before development of the historic floodplain occurs.

13.6 Public Safety Recommendations

Public safety issues must be considered at all stages of river restoration and management, from planning through implementation. It is important to avoid locating recreational facilities at points of concentrated flow, to coordinate emergency management and response activities, and to address specific hazards on individual projects. Recommendations for incorporating public safety elements into future facilities are summarized below.

13.6.1 Public Recreational Facilities Design

Recommendations for guiding the design of public recreational facilities include:

- Modify the floodplain use permit application process to include a formal review of public safety. Permit application requirements could include an evaluation of flood safety concerns and the requirement of a mitigation plan as warranted.
- Require signage of flood hazards wherever public amenities are constructed within in corridor and at all access points to the river.
- Encourage benched or tiered recreational areas; passive recreation on lower tiers, active on higher tiers.
- Locate structures and parking lots above the regulatory flood elevation. If structural recreational facilities are allowed within the regulatory floodplain, require that they be secured.
- Disallow amenities within any designated low-flow drainageways.
- Coordinate with appropriate agencies to develop wetlands or habitat zones that allow for periodic maintenance of the drainage facilities.
- Incorporate access points for emergency response into the design of recreational facilities. Access points (e.g., trailheads and staging areas)

must be large enough for emergency vehicles and related equipment to enter and exit the area.

- Incorporate park rangers into emergency management and response plans where parks are constructed in or adjacent to the river.
- Install a light system such as blue-light stations that would be visible at night from the river and where users could safely get out of the river or to a telephone.

13.6.2 *Flood Control Facilities Design*

Recommendations for designing grade control structures include:

- Require stepped or cascade designs that prevent the formation of a hydraulic jump, particularly a submerged hydraulic jump.
- Where channelization occurs in a broad, flat floodplain, restrict adjacent development to areas above the historic river banks in order to avoid catastrophic damage in the event of a dam failure.

13.6.3 *Flood Threat Recognition*

As recreational amenities are constructed and public use increases, the District's ALERT system should be expanded accordingly. Suggested enhancements could ultimately include:

- Install precipitation gages in the Morgan City Wash watershed and a stage gage at Bypass Road.
- Evaluate the need for installing additional monitoring equipment in the Twin Buttes and three unnamed washes downstream of New Waddell Dam.
- Expand the District's Meteorological Services Program to include all interested communities along the Agua Fria River in the distribution of flood threat information.

13.6.4 *Emergency Management & Response*

Emergency management and response activities should be designed to be site-specific to maximize their effectiveness:

- Develop EAPs or Flood Response Plans as appropriate for individual facilities.
- Keep the CAP informed of recreational development as it occurs so than the New Waddell Dam EAP can be updated.

- Develop and maintain a complete inventory of critical facilities along the Agua Fria River.
- Encourage/require critical facilities to prepare an EAP.
- Routinely (at least annually) exercise the EAPs.

14. ALTERNATIVE EVALUATION METHODOLOGY

14.1 *Comparison Criteria*

The alternative flood control strategies were evaluated using a point-based scoring methodology. A rating matrix was developed based on similar evaluation criteria used on other watercourses in Maricopa County. The matrix assigns maximum potential point values to various aspects of flood control strategy such as public safety, economics, and multi-use/habitat opportunities. The maximum point values of the elements vary to assign a potentially higher score to more important aspects of the alternative. The matrix allows an impartial comparison of structural and non-structural flood control methods on a subreach by subreach basis. The methodology is sufficiently flexible to allow localized structures that target specific problems be included in the evaluation.

14.2 *Alternative Comparison*

Special circumstances or conditions were encountered in some subreaches. These special circumstances are described below.

14.2.1 *Confluence of Gila River to Broadway Road*

It appears that a continuous levee from the north bank of the Gila River to the east bank of the Agua Fria is impractical due to local drainage concerns. The Buckeye Feeder Canal and the proposed Buckeye Channel discharge 100-year peak flows in excess of 3,000 cfs (combined). This large volume of water would cause local flooding east of the Agua Fria if the channels were not allowed to discharge to the river.

The Gila River Floodplain overlaps the Agua Fria River floodplain south of Broadway Road. Both watercourses would be expected to be flowing in an extreme storm event, even if the storm generates more runoff in one watershed than another. Due to the difficulty in estimating the coincidental discharges, there is uncertainty in estimating water surface elevations in this area. Elevating proposed buildings 2 feet above the estimated water surface affords additional protection in this area.

14.2.2 *Broadway Road to MC 85*

There are existing agricultural sheds (hay barns) within the floodplain on the east bank. These sheds were not considered in the evaluation of the non-structural alternative.

14.2.3 *MC 85 to Indian School Road*

The I-10 Outfall Channel has been identified as a reliable source of irrigation water for the development of localized vegetation/habitat enhancement. A hydraulic analysis was conducted to determine the effect of vegetation on the water surface elevation. The analysis assumed that a hydric riparian environment would be created in the channel from McDowell Road to one-half mile south of Van Buren Street. The hydric riparian habitat is considered to be the densest vegetation that this water source is capable of supporting. To simulate the effect of vegetation, the Manning's n-value of this subreach was increased to 0.052. The results of the analysis indicate that vegetation of this density causes an encroachment of the required freeboard during the Standard Project Flood (SPF). Further analysis of less dense vegetation indicated that some type of vegetation/habitat enhancement is feasible, although the density of the habitat has yet to be determined.

14.2.4 *Cactus Road to Grand Avenue*

The non-structural alternative does not provide adequate protection to the El Mirage Landfill. A structural solution will be required if the existing riprap is inadequate. Armoring the embankment of the landfill is likely to cause reflective erosion of the east bank of the river. This erosion would be likely to occur due to existing conditions and if the armoring of the landfill is modified.

14.3 *Evaluation Matrix*

The alternatives were rated (see Table 14.3-1) in regard to their impact on Public Protection, Economics and Social/Environmental considerations. These three categories were given weighting factors of 10, 8 and 9, respectively, to emphasize their importance in relationship to the goals of the Watercourse Master Plan. Each alternative was then scored from one to five to reflect its value in each category. The score of one to five was multiplied by the weighting factor to obtain an adjusted score in each category. The adjusted scores are then added. The alternative with the higher total score best meets the goals of the Watercourse Master Plan.

For purposes of this evaluation of *flood control alternatives*, public safety is limited to considering the level of protection provided to improved property, utilities, and transportation infrastructure by an alternative. It should be understood that virtually any modification in the floodplain, whether a flood

Table 14.3-1 - Agua Fria Watercourse Master Plan Evaluation Matrix

Reach	Public Safety Weighting Factor = 10		Economics Weighting Factor = 8		Social/Environmental Weighting Factor = 9		Total Score
Weighting Factor	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	
Gila River to Broadway Road							
Structural	1	10	1	8	2	18	**36**
Non-structural	3	30	5	40	5	45	**115**
Broadway Road to MC 85							
Structural	3	30	1	8	3	27	**65**
Non-structural	5	50	4	32	4	36	**118**
MC 85 to I-10							
NA							
I-10-Indian School Road							
NA							
Indian School Road to New River Confluence							
Structural	1	10	1	8	4	36	**54**
Non-structural	4	40	5	40	4	36	**116**
Transverse Levee	3	30	2	16	4	36	**82**
New River Confluence to Glendale Avenue							
Structural	1	10	1	8	3	27	**45**
Non-structural	4	40	5	40	3	27	**107**
Glendale Avenue to Olive Avenue							
Structural	1	10	1	8	3	27	**45**
Non-structural	4	40	5	40	4	36	**116**
Grade Control	4	40	2	16	4	36	**92**
Olive Avenue to Cactus Road							
Structural	1	10	2	16	2	18	**44**
Non-structural	4	40	4	32	5	45	**117**
Grade Control	4	40	2	16	5	45	**101**
Purchase Buildings	4	40	2	16	5	45	**101**
Cactus Road to Grand Avenue							
Structural	3	30	4	32	4	36	**98**

Table 14.3-1 - Agua Fria Watercourse Master Plan Evaluation Matrix

Reach	Public Safety Weighting Factor = 10		Economics Weighting Factor = 8		Social/Environmental Weighting Factor = 9		Total Score
Weighting Factor	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	
Non-structural	3	30	2	16	4	36	**82**
Channel	4	40	2	16	4	36	**92**
Grand Avenue to Bell Road							
Structural	4	40	1	8	3	27	**75**
Non-structural	4	40	5	40	4	36	**116**
Bank Protection	4	40	2	16	4	36	**92**
Grade Control	4	40	3	24	4	36	**100**
Bell Road to Beardsley Road							
Structural	2	20	1	8	2	18	**46**
Non-structural	4	40	3	24	5	45	**109**
Beardsley Road to Pinnacle Peak Road							
Structural	3	30	3	24	3	27	**81**
Non-structural	4	40	2	16	4	36	**92**
Pinnacle Peak Road to Jomax Road							
Structural	1	10	1	8	2	18	**36**
Non-structural	4	40	4	32	5	45	**117**
Grade Control	4	40	3	24	4	36	**100**
Jomax Road to Dixileta Drive Alignment							
Structural	1	10	1	8	2	18	**36**
Non-structural	4	40	4	32	2	18	**90**
Dixileta Drive Alignment to CAP Canal							
Structural	1	10	1	8	2	18	**36**
Non-structural	4	40	4	32	2	18	**90**
CAP Canal to Cloud Road							
Structural	4	40	1	8	2	18	**66**
Non-structural	4	40	5	40	6	54	**134**
Cloud Road to New Waddell Dam							
Structural	4	40	8	8	2	18	**66**
Non-structural	4	40	5	40	6	54	**134**

control structure or a multi-use feature, will have design considerations associated with protecting people that venture temporarily into the floodplain. It is the responsibility of future designers to fully consider the safety of these temporary users in their design.

14.4 *Opinion of Probable Construction Cost of Flood Control Components*

A planning level cost estimate in 2001 dollars of the flood control components of the Recommended Plan was prepared (see Table 14.4-1) to compare and rank the alternatives. Costs were estimated throughout the study area using the following assumptions:

- Levees and grade control structures are assumed to be constructed of soil cement
- Levees and grade control structures are assumed to have a similar configuration as the levees in Avondale
- Levees are assumed to have 10 feet of toe down and 3 feet of freeboard in the 100-year storm
- Continuous embankments with 6:1 slopes are assumed behind the levees
- Embankment height is estimated as high (equal to levee height), medium (equal to half of levee height) or low (equal to one –quarter levee height) based aerial photos
- Levee costs include the embankment behind the levee, the land under the footprint of the levee and embankment
- Land costs for the channel between the levees are not included
- Land costs for the areas under the footprint of grade control structures, levees and embankments are included
- Physical parameters such as channel depth and length of levee were calculated from information obtained from the HEC-RAS model
- Land cost is estimated at $32,500 per acre
- Soil cement cost is estimated at $30.00 per cubic yard
- Embankment cost is estimated at $3.00 per cubic yard

- Estimated prices were increased 10% for design costs and 30% for contingencies

Prices of buildings were estimated based on size, use, type of construction (i.e. mobile home or stationary building). Table 14.4-1 shows the estimated cost for purchasing the buildings in the event of a buyout. However, the Recommended Plan does not recommend purchasing buildings at this time. It is proposed to protect buildings that are immediately threatened using flood control structures and to monitor bank erosion in areas that do not appear to be immediately threatened. The costs shown are future costs that may be incurred as a result of non-structural flood control management.

Table 14.4-1 – Opinion of Probable Construction Cost of Flood Control Components For the Agua Fria Watercourse Master Plan (Recommended Plan Components Shown in Bold Text)

River Reach	Structural Alternative	Construction Cost ($Million)	Non-structural Alternative	Construction Cost ($Million)	Addition of 100-ft. Vegetated Trail	Comments
Gila Confluence to Broadway	5,740 ft levee above Gila	$2.8	**Regulatory line/ +2 feet fill**		Probable	
Broadway to MC 85	12,200 ft levee	$8.1	**Regulatory/Monitor**		Probable	Monitor 4 buildings in erosion zone on west bank
MC85-I 10	Levee in Place		Levee in Place		Probable	
I-10 to Indian School	Levee in Place		Levee in Place		Probable	
Indian School To New River	10,800 Ft of Levee	$5.6	**Regulatory**		Probable	
Indian School To New River	Close Transverse Levee	$0.3			Probable	Negligible benefit to project
New River to Glendale	12,700 ft of levee	$7.0	**Regulatory**		No	
Glendale to Olive	16,300 ft of levee	$6.8	**Regulatory**		Uncertain	
Glendale to Olive	**Olive Road Grade Control Structure**	**$2.0**			Uncertain	
Olive to Cactus	20,000 ft of levee	$8.8	**Regulatory/Monitor**		Probable	Monitor 6 homes in erosion zone on east bank
Olive to Cactus			Buy Floodplain	$10.0	Probable	
Cactus to Grand	*9,800 ft of levee*	*$4.2*	*Regulatory/monitor*	*$5.0*	*Probable*	*Typical levees, both banks. Monitor east bank.*
Cactus to Grand	*Channel*	*$24.0*			*Probable*	*Assumes full channel lining- both banks and bottom*
Grand to Bell	24,800 ft of levee	$10.7	**Regulatory**		Uncertain	Vegetation OK in upper half

Table 14.4-1 – Opinion of Probable Construction Cost of Flood Control Components For the Agua Fria Watercourse Master Plan (Recommended Plan Components Shown in Bold Text)

River Reach	Structural Alternative	Construction Cost ($Million)	Non-structural Alternative	Construction Cost ($Million)	Addition of 100-ft. Vegetated Trail	Comments
Grand to Bell	**2,650 Bank Protection**	**$0.8**	Buy out 50	$5.0	Uncertain	
Grand to Bell	Bell Road Grade Control Structure	$1.3			Uncertain	Not necessary at this time
Bell to Beardsley	9,900 ft of levee	$3.4	**Regulatory Line**		Probable	
Beardsley to Pinnacle Peak	18,000 ft of levee	$5.7	**Regulatory/monitor**		Uncertain	Monitor 22 structures in erosion zone, west bank
Pinnacle Peak to Jomax	22,000 ft of levee	$10.0	**Regulatory**		Probable	
Pinnacle Peak to Jomax	Happy Valley Road Grade Control Structure	$2.7			Probable	Not necessary at this time
Jomax to Dixileta	24,000 ft of levee	$11.2	**Regulatory**		No	
Dixileta to CAP	21,000 ft of levee	$8.4	**Regulatory**		No	
CAP to Cloud	21,000 ft of levee	$7.4	**Regulatory**		No	Need to buy State Land
Cloud to New Waddell	21,000 ft of levee	$8.7	**Regulatory**		No	Need to buy State Land
El Mirage Landfill- Flood Control Improvements from Cactus Road to Grand Avenue		**$4.2 to $24 Million**				Structural mitigation likely to be required- scope of project unknown at this time
Other Flood Control Structures		**$2.8 Million**				
Maintenance Road (Gila to New Waddell)		**$17.5 to $20.0 Million**				
Anticipated Cost of Recommended Plan		***$24.5 to $46.8 Million***				

14.5 *Opinion of Probable Construction Cost of Recreational Components*

A planning level cost estimate, in 2001 dollars, of the proposed recreational features of the Recommended Plan was prepared to compare and rank the alternatives (see Table 14.5-1). The cost for non-flood control features of the Watercourse Master Plan must be funded by entities other than the District. Costs were estimated throughout the study area using the following assumptions:

- Levees and grade control structures are assumed to be constructed of soil cement.
- Land cost is estimated at $32,500 per acre.
- Estimated prices were increased 10% for design costs and 30% for contingencies.
- Trail costs reflect additional signs and other features required to open the maintenance road as a non-motorized trail. Land and surface treatment of the trail are included in the maintenance road costs.

Table 14.5-1 - Opinion of Probable Construction Cost of Recreational Features for the Agua Fria Watercourse Master Plan

Location	Component	Description	Construction Cost (Millions)	Comments
Gila Confluence to Lake Pleasant	Recreational Components of Maintenance Road	Primary Trail	$1.500	
Gila Confluence to Broadway Road	Park/Major Trailhead	Avondale Mitigation Site	$0.500	
Lower Buckeye Road	Equestrian Facilities	Trail head with parking/loading facilities	$0.750	
Lower Buckeye Road	River Theme Development	Commercial Redevelopment of current City offices	-	Private development- No cost to public sector
Buckeye Road	Interpretive Ramada/ Open Space/Trailhead	Interpretive site with railroad theme and minor trailhead	$0.150	
I-10	Interpretive Ramada/ Open Space/Trails	Interpretive site, habitat area, trails, open space	$0.150	
El Mirage	10-Acre Park Site	Recreational Park in Flood Fringe- No Structures	$1.600	
RID Canal	Interpretive Ramada/ Open Space	Interpretive site, trail connection	$0.150	
McMicken Dam Outlet Channel	10-Acre Park Site	Recreational Park in Flood Fringe- No Structures	$1.600	
Bell Road	Major Trailhead	Equestrian Trailhead	$0.500	
Beardsley Road	Minor Trailhead		$0.250	
Jomax Road	Interpretive Ramada/ Open Space	Interpretive site associated with CAP recharge project	$0.250	
Associated with SROG Recharge Facilities (location to be determined)	Interpretive Ramada/ Open Space (1of 2)	To be determined	$0.250	

Table 14.5-1 - Opinion of Probable Construction Cost of Recreational Features for the Agua Fria Watercourse Master Plan

Location	Component	Description	Construction Cost (Millions)	Comments
Associated with SROG Recharge Facilities (location to be determined)	Interpretive Ramada/ Open Space (2 of 2)	To be determined	$0.150	
Calderwood Butte	Interpretive Ramada	Interpretive site	$0.150	
Casa de Piedras	Interpretive Ramada/ Open Space	Interpretive site	$0.150	
CAP Canal	Interpretive Ramada	Interpretive site	$0.150	
Beardsley Canal	Interpretive Ramada	Interpretive site	$0.150	
SR 74	Major Trailhead/Interpretive Area	Trailhead, habitat conservation areas and interpretive areas in the vicinity of SR 74 and George's Pond	$0.500	
Lake Pleasant Road south of SR 74	Minor Trailhead	Trailhead in association with City of Peoria Regional Park	$0.250	

15. MAINTENANCE ROAD

Access to District facilities for the purpose of operations and maintenance is typically a critical design consideration and a significant construction cost. The District operates many miles of access road along channels, dams, and levees. The purpose of these roads is to allow for maintenance and observation, often during storm events. It also facilitates access by emergency response vehicles.

Maintenance and observation of flood control structures are required on a regular and emergency basis. Regular maintenance and observation are necessary in order to document maintenance requirements, to observe trespassing or encroachments that might threaten the system, to install and operate flood safety related monitoring systems, and to evaluate conditions in the general vicinity that might alter the function of the system.

Emergency maintenance and monitoring activities relate to the need to safely move personnel into areas where staff can evaluate how the system is performing during a flood. Based on that information, staff can call for necessary emergency repairs, call for flood fighting activities or in extreme circumstances, recommend evacuations of populated areas.

Managing a watercourse has many of the same operation and maintenance requirements inherent to other District projects. The need for a maintenance road includes the:

- Ability to access remote structures such as grade controls, levees, and bank stabilization for maintenance activities.
- Ability to monitor in-channel development that would threaten the flood carrying capacity function of the floodplain.
- Ability to monitor illegal dumping that would reduce capacities or promote debris blockages.
- Ability to monitor areas prone to lateral migration in order to implement evacuations or other project activities.
- Ability to monitor and gain access to multiple-use functions in the floodplain that could impact the flood protection system.

During the development of the Watercourse Master Plan, the Agua Fria was traversed from Lake Pleasant to Camelback Road in order to identify a preliminary alignment for a maintenance road. Factors considered in selecting this alignment included:

- Continuous access
- Placement of the road outside or toward the outer edge of the floodplain
- Selecting a route that allows access to critical river features
- Minimizing disturbance
- Avoiding vehicular conflict with sand and gravel operations

The estimated cost for land acquisition, design, and construction for an asphalt maintenance road covering approximately 35 miles was $17.5 million to $21 million. This expenditure would be beneficial in the implementation of a non-structural management approach and would provide access to grade control structures and other project features. On a cost-per-mile basis, the maintenance road was approximately 1/5 the cost of implementing a traditional structural project such as a levee.

During the development of the Watercourse Master Plan, the District considered a policy change that would open up existing and future maintenance roads to multi-use, non-motorized access. This approach would be similar to that used along the levee at Tempe Town Lake. As part of the recreation considerations, the maintenance road was also evaluated from a recreational trail perspective.

The dual purpose of such a facility has several inherent conflicts or incompatibilities that must be resolved through innovative design or operational guidelines. Some of the incompatibilities identified at the planning level include:

- Use of the maintenance road by District vehicles for purposes of maintenance or monitoring vs. prevention of trail use by unauthorized vehicles.
- Providing vegetation along a trail for shade and ambiance vs. clearing the channel to improve hydraulic conveyance.
- Encouraging people to enter the floodplain for recreational purposes vs. keeping people out of the floodplain during floods.
- Additional construction and maintenance costs associated with trails vs. costs associated with a maintenance road.

- Increased recreational use of corridor vs. current industrial use of corridor (mining).

These incompatibilities were examined as part of the Watercourse Master Plan. Analysis shows these issues can be resolved satisfactorily in some locations, but dual uses remain incompatible some areas. It is recommended that dual use be allowed to the extent that it is feasible and practical. The Watercourse Master Plan provides a planning-level answer as to the feasibility and compatibility of these uses. It is up to the designers to establish the requirements of safe multi-use facilities.

16. SUMMARY AND RECOMMENDATIONS

16.1 Summary

The primary purpose of the Watercourse Master Plan is to establish a long-term plan for the management of the Agua Fria River. The specific goals of the master plan are flood control and public safety, conservation of habitat, and incorporation of multi-use recreational facilities. The Recommended Plan has identified existing and potential flooding and erosion problems along the Agua Fria River and proposed management strategies for reducing the threat to public safety. At the same time, the master planning process has identified opportunities for multiple uses of the river corridor such as recreation and habitat for wildlife. While not able to directly fund recreational facilities or habitat improvements, the District is interested in identifying and understanding multiple uses of the watercourse that are compatible with the fundamental principles of flood control.

16.2 Recommendations

The following recommendations are made concurring non-flood and erosion issues. These recommendations are made to:

- Identify direction of future policy decisions.
- Identify policies that promote the goals of the Watercourse Master Plan.
- Facilitate the implementation practices that promote the goals of the Watercourse Master Plan.
- Identify opportunities for multiple-use facilities within the River.

Brief summaries of recommendations concerning flood control are presented here. See Section 12, Recommended Plan, for a detailed discussion of the recommended flood control improvements.

16.2.1 Policies Affecting Stormwater Runoff and Conveyance

- Retention policies as currently crafted must diligently be implemented since they reduce watershed flows resulting from the 100-year, 2-hour storm.
- Current floodplain regulations are leading to the loss of floodplain storage by allowing encroachment into the floodplain. Floodplain

storage has the hydraulic effect of attenuating (reducing) flow rates. Decreasing storage volume by encroaching into the floodplain creates the potential for higher flow rates in the future. Management strategies must begin to reduce or eliminate encroachment into the floodplain or the cumulative effect of encroachment may reduce the protection offered by flood control structures designed for lower peak flows. The alternative is to require a higher standard of design for future structures and a reevaluation of existing structures to determine if they offer adequate protection under fully encroached conditions.

16.2.2 *Adoption of Lateral Migration Erosion Hazard Zone*

Adoption of the Lateral Migration Erosion Hazard Zone (LMEHZ) as a regulatory boundary will help achieve the three goals of the Watercourse Master Plan:

- Regulating land use within this zone protects public interests by reducing development in areas prone to the hazards of flooding and erosion.
- It increases the potential area available for recreation.
- It increases opportunities for habitat enhancement and open space.

16.2.3 *Non-structural Flood Control*

Except in the locations noted below, it is recommended that non-structural methods be used to protect the public and reduce flood damages. The District is extremely fortunate that development in the vicinity of the floodplain has been limited up to this point. Managing land use within the LMEHZ is expected to reduce future development of areas that are intrinsically hazardous. This reduces the need to spend public dollars to protect private property, reduces the need to maintain structures and decreases the overall cost to society caused by flood damage.

Non-structural methods of flood control have the added benefit of reducing cumulative impact often associated with flood control structures. As identified in this report, encroachment of the floodway (as allowed under current regulations) reduces channel storage and increases peak flows. Non-structural flood control will prevent or reduce encroachment of the floodway, maintaining channel storage and allowing attenuation of peak flows.

Due to the uncertainty of the determination of a floodplain at the confluence of two major rivers, it is recommended that future development at the confluence of the Gila River be subject to more stringent building requirements. Current regulations require buildings within the floodplain to be protected by a levee or elevated 1 foot above the estimated water surface elevation. As discussed herein, it is not feasible to protect this area with levees at this time. Therefore, elevating buildings 2 feet above the water surface would provide additional flood protection at a relatively low cost.

16.2.4 *Erosion Monitoring*

Monitoring the effects of bank erosion is recommended in three locations:

- On the west bank, north of Broadway Road
- On the east bank, between Cactus Road and Peoria Avenue
- On the west bank, between Beardsley Road and Pinnacle Peak Road

At these locations, existing buildings are within the LMEHZ, but are not immediately threatened by bank erosion. Monitoring is recommended to determine if structural protection is necessary.

Monitoring of the area downstream from the Bell Road Bridge, the Olive Avenue Bridge and the area near Rose Garden Lane is recommended. Existing headcuts have been identified in these areas. Progression of the headcuts may eventually threaten existing infrastructure.

It is recommended that the District begin monitoring the river bed elevations at bridges. Bridges provide a fixed reference point from which to monitor changes in bed elevations. Over time, changes in bed elevation can be compared to the changes predicted as a result of this study. Monitoring should begin in the near future to establish baseline data. Once a baseline is established, bed elevations should be recorded after significant storm events.

16.2.5 *Flood Control Structures*

Structural methods of flood and erosion protection are considered necessary in the following locations:

- Between Grand Avenue and Cactus Road to protect the El Mirage Landfill and the opposite riverbank
- South of Bell Road, along the west bank to protect existing homes

16.2.6 *Grade Control Structures*

A grade control structure is recommended downstream from the Olive Avenue Bridge.

16.2.7 *Sand and Gravel Mining*

Sand and gravel mining is well established within the Agua Fria River. The mines provide an economical source of the rock products required for the growth and development of the West Valley. The District needs to find ways to partner with the industry in three principle areas:

- Mitigate and reclaim mine pits to protect the public and allow for future use of the land.
- Limit the adverse impact of mining operations to the boundary of the property being mined, through adoption of the Management Practices recommended as part of this plan; or through the joint implementation of river channelization efforts that are consistent with the goals of the master plan.
- Cooperation between District and miners to obtain river-wide 404 Permit and bring mines into compliance with the requirements of the permit.

16.2.8 *Environmental*

Several recommendations associated with the Watercourse Master Plan provide opportunities for habitat enhancement and preservation of open space within the river corridor. It is specifically recommended to preserve, where practical, the existing vegetation and landscape forms of the river between the CAP Canal and New Waddell Dam. At present, this area is relatively undisturbed desert with little or no existing development. Within this reach, the riverbed is relatively narrow and the banks are quite steep. As a result, the banks are nearly coincidental with the LMEHZ, the floodplain boundary and the floodway boundary. This gives the District considerable regulatory control within the channel. The challenge will be to preserve the character of the land adjacent to the waterway.

16.2.9 *Groundwater Recharge*

Encouraging groundwater recharge projects within the river corridor has the potential to allow establishment of vegetation. Vegetation, in turn, enhances recreational opportunities, provides habitat and improves the visual characteristics of the river. While there are benefits to allowing vegetation in the river, it must be undertaken with caution.

A key function of the river is to convey flood flows. Vegetation retards stream flow to a certain degree, regardless of the vegetation type or size. Large trees can become dislodged during storms and become entangled in bridge piers, causing disruption of flow and increasing the potential for damage. However, populating the river with a prudent selection of plant species in appropriate locations reduces many of these concerns.

While recharge projects are a potential source of irrigation water, current regulations discourage using recharge water to develop stands of vegetation. Water lost to evapotranspiration will not be recharged. Current regulations aim to maximize the amount of water that reaches the aquifer. The District's challenge in this arena will be to work with ADWR, ADEQ and other agencies to change the regulations to allow the development of multi-purpose projects incorporating vegetation in concert with groundwater recharge. If the benefits of establishing habitat, encouraging recreational opportunities, and enhancing open space can be shown to outweigh the impacts of additional water usage, it becomes possible to change the existing regulations.

16.2.10 Landscape Character

The Agua Fria River is a dynamic resource. Rivers in the Valley have traditionally been viewed as a resource for industrial uses. Using rivers for open space and wildlife habitat creates a longer lasting resource that will serve the neighborhoods and the communities of the Valley. How we implement future projects both in and along the banks of the river in the coming years will determine if the Agua Fria River is valued as an open space asset to the community. This report, in combination with the entire Watercourse Master Plan, sets in place a vision and the tools to create a recreational, scenic and biologically enhanced corridor that works in concert with flood control. The implementation of this vision resides in the projects that will come after this study and the support by individuals, cities, county agencies and the overall community.

16.2.11 Recreation

- Allowing and encouraging recreation within the Agua Fria River corridor is one of the primary goals of the Watercourse Master Plan. Many recreational opportunities have been identified within the master planning process. Private groups and adjacent political jurisdictions are encouraged to work with the District to develop recreational facilities within the corridor that will be compatible with the conveyance of flood waters.

16.2.12 Public Safety

Public safety issues must be considered in all stages of river restoration and management, from planning through implementation. It is important to avoid locating recreational facilities at points of concentrated flow, coordinate emergency management and response activities, and address specific hazards on individual projects.

16.2.12.1 Public Recreational Facilities Design

Recommendations for guiding the design of public recreational facilities include:

- Require signage of flood hazards wherever public amenities are constructed within in corridor and at all access points to the river.
- Encourage benched or tiered recreational areas; passive recreation on lower tiers, active on higher tiers.
- Locate structures and parking lots above the regulatory flood elevation.
- If structural recreational facilities are allowed within the regulatory floodplain, require that they be secured.
- Disallow amenities within any designated low-flow drainageways.
- Coordinate with appropriate agencies to develop wetlands or habitat zones that allow for periodic maintenance of the drainage facilities.
- Incorporate access points for emergency response into the design of recreational facilities. Access points (e.g., trailheads and staging areas) must be large enough for emergency vehicles and related equipment to enter and exit the area.
- Incorporate park rangers into emergency management and response plans where parks are constructed in or adjacent to the river.
- Install a light system such as blue-light stations that would be visible at night from the river and where users could safely get out of the river or to a telephone.

- Modify the floodplain use permit application process to include a formal review of public safety. Permit application requirements could include an evaluation of flood safety concerns and the requirement of a mitigation plan as warranted.

16.2.12.2 Flood Control Facilities Design

- Recommendations for designing grade control structures include:
- Require stepped or cascade designs that prevent the formation of a hydraulic jump, particularly a submerged hydraulic jump.
- Where channelization occurs in a broad, flat floodplain, restrict adjacent development to areas above the historic river banks in order to avoid catastrophic damage in the event of a dam failure.

16.2.12.3 Flood Threat Recognition

As recreational amenities are constructed and public use increases, the District's ALERT system should be expanded accordingly. Suggested enhancements could ultimately include:

- Install precipitation gages in the Morgan City Wash watershed and a stage gage at Bypass Road.
- Evaluate the need for installing additional monitoring equipment in the Twin Buttes and three unnamed washes downstream of New Waddell Dam.
- Expand the MSP to include all interested communities along the Agua Fria River in the distribution of flood threat information.

16.2.12.4 Emergency Management & Response

Emergency management and response activities should be designed to be site-specific to maximize their effectiveness:

- Develop EAPs or Flood Response Plans as appropriate for individual facilities.
- Keep the CAP informed of recreational development as it occurs so than the New Waddell Dam EAP can be updated.
- Develop and maintain a complete inventory of critical facilities along the Agua Fria River.

- Encourage/require critical facilities to prepare an EAP.
- Routinely (at least annually) exercise the EAPs.

17. SUPPLEMENTAL PROJECT STUDIES

17.1 Introduction

The information contained in the Recommended Plan Report is based on numerous technical analyses and investigations. The details of the analyses and investigations are documented in a series of supplemental reports associated with the master planning process. The Final Recommended Plan Report merely summarizes the findings of the supplemental reports. The reader is directed to the original reports for additional detail. The following is a brief summary of the contents of the supplemental reports.

17.2 Report Summaries

Hydrology Report for the Agua Fria Watercourse Master Plan, Kimley-Horn and Associates, Inc., 2001

The U.S. Army Corps of Engineers, Los Angeles District established the regulatory hydrology for the River in July 1995. The hydrology is documented in the report "*Hydrologic Evaluation of New Waddell Dam on Downstream Peak Discharges in the Agua Fria River*." The Corps' hydrology is the basis for current regulatory discharges on the Agua Fria River.

As part of the master planning process, KHA created supplemental hydrologic models to evaluate two important conditions that affect the river response during large floods:

- The effectiveness of the existing retention policies within the watershed
- Floodwave attenuation in the river as it relates to encroachment of the floodplain

Hydraulic Analysis for the Agua Fria Watercourse Master Plan, LTM Engineering Inc., 2001

A key criterion for evaluating the feasibility of alternatives for the Watercourse Master Plan is the hydraulic response of the river. It is the District's intent to avoid adversely impacting the river's conveyance capacity. Therefore, any structural elements or changes to the vegetation within the river must be evaluated and, if necessary, mitigated.

The District's current Flood Insurance Study (FIS) model was used to form the basis of comparison between current and potential future conditions

(CVL, 1996). This model was developed by others using the Corps' HEC-2 Water Surface Profiles program. This HEC-2 model was imported into HEC-RAS and the results were updated to better represent current conditions within the river. The results then became a basis for developing a practical, updated planning model that was used to develop and compare alternative solutions for the Watercourse Master Plan.

Sedimentation/Scour Report, Kimley-Horn and Associates, Inc., 2001

The purpose of the sedimentation analysis is to simulate the long-term streambed profile response of the Agua Fria River based on development conditions within and along the river corridor. The limits of the sediment transport study are from the diversion outlet south of the New Waddell Dam downstream to the confluence of the Agua Fria River with the Gila River. The sediment trend analysis is used as an analytical tool to evaluate the impact of future plans, including projected sand and gravel activities. The sediment trend analysis is sufficient to project trends and impacts on infrastructure, but is not intended to be a site specific management tool for regulating individual sand and gravel operations.

Sand and Gravel Mining Summary, Kimley-Horn and Associates, Inc., 2001

The Agua Fria River is a rich source of rock products. The acceleration of development in the West Valley in recent years has caused an increase in the demand for concrete, aggregate, gravel and sand. A significant percentage of these materials have been mined from the Agua Fria. Mining activities are currently taking place within the floodplain, effecting river flow patterns, sediment movement and floodplain storage capacity. The Summary looks at these effects and proposes strategies for reducing the impact of mining operations.

Agua Fria River Lateral Migration Report, JE Fuller/ Hydrology & Geomorphology, Inc., 2001

A variety of analyses were performed to assess the potential for future lateral migration of the Agua Fria River from New Waddell Dam to the Gila River. Detailed descriptions of these analyses are provided in the Agua Fria River Lateral Migration Report prepared by JE Fuller/ Hydrology & Geomorphology, Inc. (JEF, 2001).

Base data on the watershed, hydrology, geology, and geomorphology of the study reach establish the context for the lateral stability assessment (Chapter

2 of the Lateral Migration Report). These data were also used to define 15 stream reaches with relatively uniform geomorphic and geographic characteristics. The stream reaches defined for the lateral stability assessment vary from natural-appearing reaches that are significantly impacted by upstream dams to highly disturbed reaches with active in-stream sand and gravel mining, channelization, and floodplain encroachments. The physical and visual characteristics, landscape character, and geomorphic characteristics vary significantly over the length of the study reach.

Visual Resources Inventory & Scenic Quality Assessment, EDAW, 2001

As part of the Watercourse Master Plan, it is important to establish the current overall impression of the river landscape. This will assist in the formulation of flood control solutions and future planning policies that take into account the character of the river. Such an analysis will also facilitate the identification of key points along the river that are unique in terms of their scenic attraction, wildlife habitat quality, historical/cultural significance and/or recreational potential. An inventory of areas of natural scenic quality is an important step towards their integration into future planning solutions for the river corridor. Future recreational activities proposed along the river corridor will need to take into account the existing and proposed land uses, as well as the different types of recreational activities along the river corridor that best satisfy planning demands. The river landscape character provides an insight into the type and quality of both passive and active recreational space that can be incorporated into the Watercourse Master Plan while preserving ecologically critical zones and those areas with rich historic traditions. Ecologically less critical areas of the floodplain with little wildlife habitat, as well as degraded areas that result from mining activity, provide great potential for reclamation into active recreational spaces.

Recreation Corridor Master Plan, Cornoyer-Hedrick, 2001

The Recreation Corridor Plan identifies resources along the Agua Fria that could be linked into a continuous corridor, highlights the potential for flood control facilities to connect or enhance these existing resources, and identifies those areas where flood control facilities provide opportunities to further enhance existing recreation opportunities. This plan is intended to complement existing plans and to be used as a tool for the County and local jurisdictions to provide flood control that protects the health and safety of

Maricopa County residents without compromising the potential for multiple uses of the Agua Fria River.

Evaluation of Public Safety Issues for the Agua Fria River Watercourse Master Plan, LTM Engineering Inc., 2001

Floodplains are a valuable resource in creating multi-use opportunities and open space for communities. However, locating these opportunities in and around a major watercourse makes them vulnerable to periodic flooding and exposes users to weather-related hazards. The District wishes to minimize public safety concerns and has addressed them as part of the planning process.

Existing flood hazards were identified and proposed facilities were evaluated with respect to public safety. Recommendations were made for the design of future improvements to minimize safety hazards. Also, emergency management procedures along the river were evaluated and recommendations were made to improve coordination and response and to maximize use of the District's current flood detection and data collection program.

Aqua Fria River Watercourse Implementation/Maintenance Strategy, Kimley-Horn and Associates, Inc., 2001

The District is limited by statute to regulation of floodplains and providing flood control infrastructure. Providing the public with recreational amenities is beyond the authority of the District. Therefore, the District needs to partner with local jurisdictions or citizens groups to obtain funding for the proposed multi-use features.

The implementation section of the *Implementation/Maintenance Plan* will address possible funding sources for non-flood control aspects of the Watercourse Master Plan. The maintenance section will address requirements associated with the flood control features of the plan. The plan is scheduled for completion in November 2001.

Groundwater Recharge- Alternative Analysis Report, Fluid Solutions, 2001

The Aqua Fria River Watercourse Master Plan identifies and develops alternative plans for providing flood control along the Aqua Fria River. An additional aspect of the proposed Master Plan is evaluating the potential development of groundwater recharge facilities along the Aqua Fria river corridor. Recharge is the process of adding water to an aquifer system either through the infiltration of water from land surface, or injection into the subsurface via wells.

Groundwater is an important natural resource for domestic drinking water, agricultural irrigation, and industrial uses in the Salt River Valley. Historic pumping has depleted the groundwater system throughout much of the West Salt River Valley, including those areas around the Agua Fria River below New Waddell Dam. Water levels have declined significantly, which has resulted in increasingly limited water supplies, the deterioration of water quality, land subsidence, and development of earth fissures. Groundwater replenishment would become a significant attribute of the Agua Fria Watercourse Master Plan if recharge of renewable water sources was possible.

Environmental Reports

Several environmental reports or evaluations were prepared as support documentation in the development of the Agua Fria Watercourse Master Plan. An initial biological evaluation of the corridor was conducted to develop an understanding of the biotic and abiotic resources along the river. This initial data was used to characterize the ecological and cultural significance of the corridor. The master plan development process utilized this initial data, along with supplemental information from the numerous additional studies to develop the Watercourse Master Plan.

The following Natural and Cultural Resource Reports were prepared as a part of the master planning process:

Initial Ecological Evaluation of Agua Fria Watercourse, Kimley-Horn and Associates, Inc., 2001

This evaluation was conducted as part of the initial Agua Fria Watercourse Master Plan process. It includes a description of the biotic and abiotic resources along the river corridor from New Waddell Dam to the confluence with the Gila River. The evaluation was conducted to provide the study team with an understanding of the various resources along the corridor.

Jurisdictional Determination for Agua Fria Watercourse – New Waddell Dam to Confluence with the Gila River, Kimley-Horn and Associates, Inc., 2001

This documentation was prepared and submitted to the U.S. Army Corps of Engineers (Corps) Arizona Field Office for compliance with Section 404 of the Clean Water Act. The proposed jurisdictional determination established the approximate ordinary high watermark (OHWM) for the river channel, thus establishing the limits of Corps jurisdiction (waters of the U.S.). It was submitted along with a request for authorization under the Nationwide Permit program to conduct sediment sampling within the channel.

The evaluation included documentation regarding compliance with the Endangered Species Act and Section 106 of the Historic Preservation Act.

Environmental Assessment of the Agua Fria Watercourse Master Plan, Kimley-Horn and Associates, Inc., 2001

An Environmental Assessment document was prepared based on the evaluation of the potential affects on the human and natural environment from the development and implementation of the proposed Agua Fria Watercourse Master Plan. This document includes a summary of the various other Technical Reports and studies developed for the project. It also documents the public involvement process.

Habitat Enhancement Opportunities/Techniques on the Agua Fria River – New Waddell Dam to Confluence with Gila River, Kimley-Horn and Associates, Inc., 2001

The Watercourse Master Plan included the identification and development of enhancement techniques for wildlife habitat areas along the corridor. Utilizing historical and current aerial photography, geographic information system (GIS) data and field evaluations, the study team identified areas for potential habitat enhancement. The criteria utilized for the identification included juxtaposition, vegetation integrity, and parcel size, hydrologic regime and other criteria. The report also details enhancement strategies for multiple use areas and provides recommended vegetation species lists for in-channel and adjacent areas.

El Mirage Landfill Site, Summary of Status Review, Kimley-Horn and Associates, Inc., 2001

The El Mirage Landfill forms the west bank of the Agua Fria River between Grand Avenue and Cactus Road. Portions of the landfill washed out during the floods of 1979/1980. Many questions surround the landfill including adequacy of rip rap erosion protection, exact location of landfill footprint, contents of landfill, adequacy of landfill closure and potential environmental threats posed by the landfill, to name a few. A search of available records was undertaken as part of the master planning process to attempt to a answer some of these questions. This report summarizes the results of the record search and makes recommendations for future actions to be taken in regards to the landfill regarding flooding and erosion issues.

Cultural Studies of the Agua Fria River Corridor

The cultural (historical and archaeological) resources of the corridor were evaluated during the initial phases of the master planning process. Qualified archaeologists or historians conducted record searches with applicable state agencies to determine the extent of identified and potential for additional resources along the corridor. Information from several reports was compiled and presented to the master plan study team for use during the field-testing phase. The individual reports are: *The Agua Fria: A Working River for the West Valley Themes and Historic Sites, Dallett, September 11, 2000; Historic Resources of the Agua Fria River, Watercourse Master Plan Area, A Selected Sample of Prehistoric and Historic Sites of the Western Salt River Valley, Arizona, Rodgers and Dallett, 2000; West Valley Common Ground: The Agua Fria as a Corridor of Natural, Historic, Cultural, and Recreational Resources, Dallett, 2001; and Historic Cultural Resources Along the Agua Fria River Between the Gila River and Waddell Dam, Archaeological Consulting Services, Ltd., 2000.* This information was further developed into the recreational, landscape, and habitat enhancement portions of the Master Plan.

18. REFERENCES

18.1 Supplemental Agua Fria Watercourse Master Planning Studies

1. *Hydrology Report for the Agua Fria Watercourse Master Plan, Kimley-Horn and Associates, Inc., 2001*

2. *Hydraulic Analysis for the Agua Fria Watercourse Master Plan, LTM Engineering Inc., 2001*

3. *Sedimentation/Scour Report, Kimley-Horn and Associates, Inc., 2001*

4. *Sand and Gravel Mining Summary, Kimley-Horn and Associates, Inc., 2001*

5. *Agua Fria River Lateral Migration Report, JE Fuller/ Hydrology & Geomorphology, Inc., 2001*

6. *Visual Resources Inventory & Scenic Quality Assessment, EDAW, 2001*

7. *Recreation Corridor Master Plan, Cornoyer-Hedrick, 2001*

8. *Evaluation of Public Safety Issues for the Agua Fria River Watercourse Master Plan, LTM Engineering Inc., 2001*

9. *Aqua Fria River Watercourse Implementation/Maintenance Strategy, Kimley-Horn and Associates, Inc., 2001*

10. *Groundwater Recharge- Alternative Analysis Report, Fluid Solutions, 2001*

11. *Initial Ecological Evaluation of Agua Fria Watercourse, Kimley-Horn and Associates, Inc., 2001*

12. *Jurisdictional Determination for Agua Fria Watercourse – New Waddell Dam to Confluence with the Gila River, Kimley-Horn and Associates, Inc., 2001*

13. *Environmental Assessment of the Agua Fria Watercourse Master Plan, Kimley-Horn and Associates, Inc., 2001*

14. *Habitat Enhancement Opportunities/Techniques on the Agua Fria River – New Waddell Dam to Confluence with Gila River, Kimley-Horn and Associates, Inc., 2001*

15. *El Mirage Landfill Site, Summary of Status Review, Kimley-Horn and Associates, Inc., 2001*

16. *The Agua Fria: A Working River for the West Valley Themes and Historic Sites, Dallett, September 11, 2000*

17. *Historic Resources of the Agua Fria River, Watercourse Master Plan Area, A Selected Sample of Prehistoric and Historic Sites of the Western Salt River Valley, Arizona, Rodgers and Dallett, 2000*

18. *West Valley Common Ground: The Agua Fria as a Corridor of Natural, Historic, Cultural, and Recreational Resources, Dallett, 2001*

19. *Historic Cultural Resources Along the Agua Fria River Between the Gila River and Waddell Dam, Archaeological Consulting Services, Ltd., 2000.*

18.2 Additional References

1. *A Selected Sample of Prehistoric and Historic Sites of the Salt River Valley, Arizona, James B. Rodgers and Nancy Dallett, November 22, 2001*

2. *Estimating Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona, Thomsen and Hjalmarson, April 1991.*

3. *Agua Fria River Floodplain Delineation Re-Study Between the Gila River Confluence and the New Waddell Dam, Coe & Van Loo Consultants, Inc., October 1996.*