KINGMAN AREA DRAINAGE MASTER PLAN REPORT

CITY OF KINGMAN, ARIZONA

PREPARED BY

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.
3111 N CADEN CT., STE. 180,
FLAGSTAFF, AZ 86004

Registered Professional Engineer (Civil)
CERTIFICATE NO. 45648
JOSEPH BERNARD LOVERICH
Date Signed 8/3/2020
ARIZONA U.S.A

AUGUST 2020

TABLE OF CONTENTS

Registered Professional Engineer (Civil)
CERTIFICATE NO. 45648
JOSEPH BERNARD LOVERICH
Date Signed 8/3/2020
ARIZONA U.S.A.

Table of Figures


Registered Professional Engineer (Civil)
CERTIFICATE NO.
45648
JOSEPH BERNARD
LOVERICH
Date Signed 8/3/2020
ARIZONA U.S.A

List of Tables

Appendices

Registered Professional Engineer (Civil)
CERTIFICATE NO.
45648
JOSEPH BERNARD
LOVERICH
Date Signed 8/3/2020
ARIZONA U.S.A

1 INTRODUCTION

1.1 PROJECT PURPOSE

The Kingman Area Drainage Master Plan (KADMP) project was performed by JE Fuller Hydrology and Geomorphology, Inc. (JE Fuller) with the authorization of the City of Kingman. The KADMP was developed to meet four primary objectives:

- Evaluate and identify flooding hazard and drainage problems within the project area by the implementation of a work plan which includes data collection, review of previous studies, information gathering from public agencies and residents, hydrologic and hydraulic modeling
- Develop a series of alternatives to either partially or wholly mitigate the hazards identified in the first objective
- Conduct a desktop cultural and environmental analyses for the conceptual solutions to identify their potential impacts on the drainage problems
- Provide stakeholder coordination and public outreach of the project through a public meeting and multiple project stakeholder meetings

Each major task of the project is presented herein with a description of the technical approach, analysis results, interpretation of results, and applicability to the overall project purpose. The results of this study can be used as a planning tool and as input to the design of potential future drainage infrastructure and flood mitigation measures that are appropriate for the physical environment for both existing and future development.

1.2 PROJECT LOCATION

The KADMP study area is approximately 84.6 square miles and is located in Mohave County. A location map is shown in Figure 1-1. This study focuses on the City of Kingman and its surrounding watershed. The general vicinity is shown in Figure 1-2.

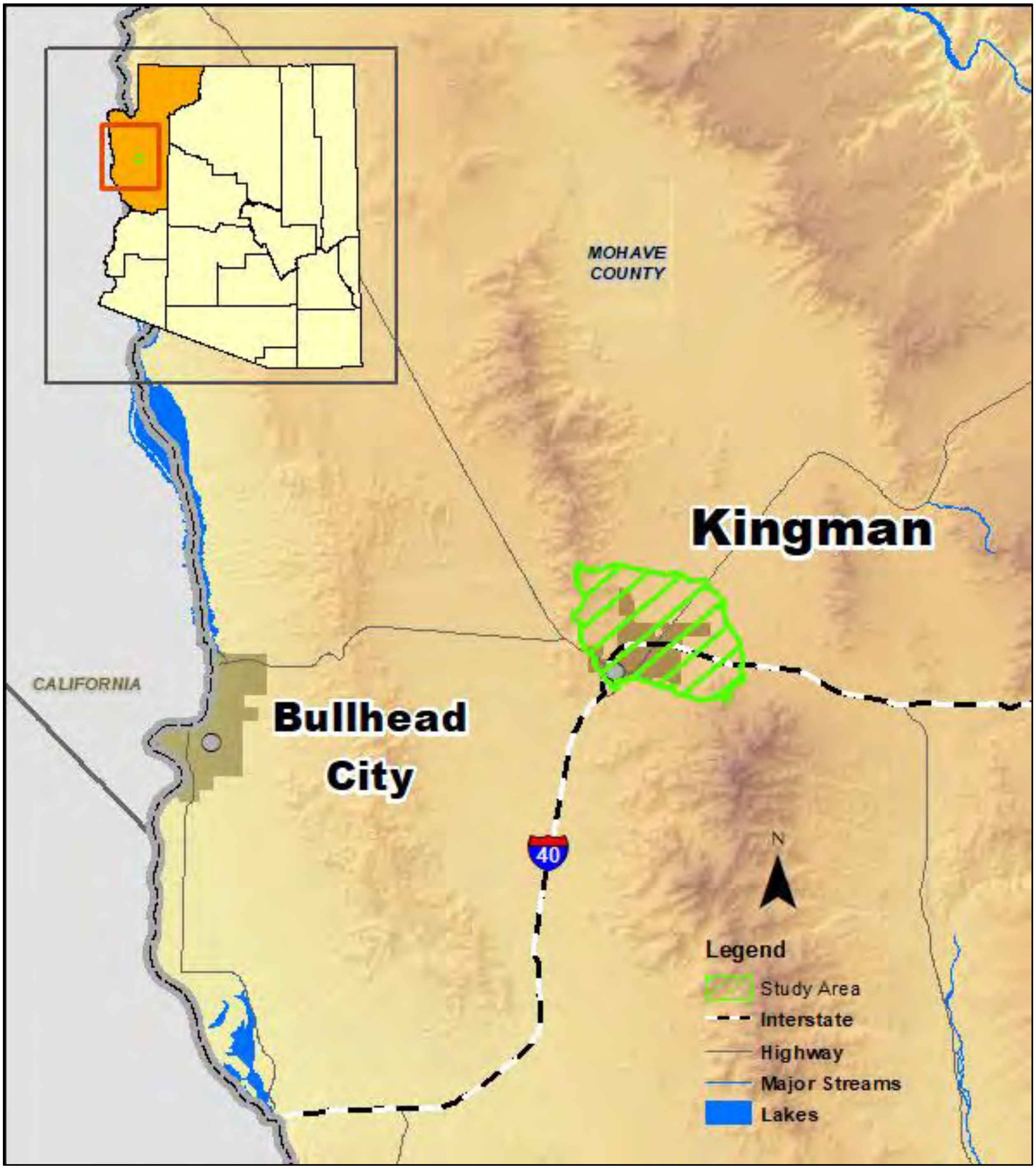

Figure 1-1. Location Map (not to scale)

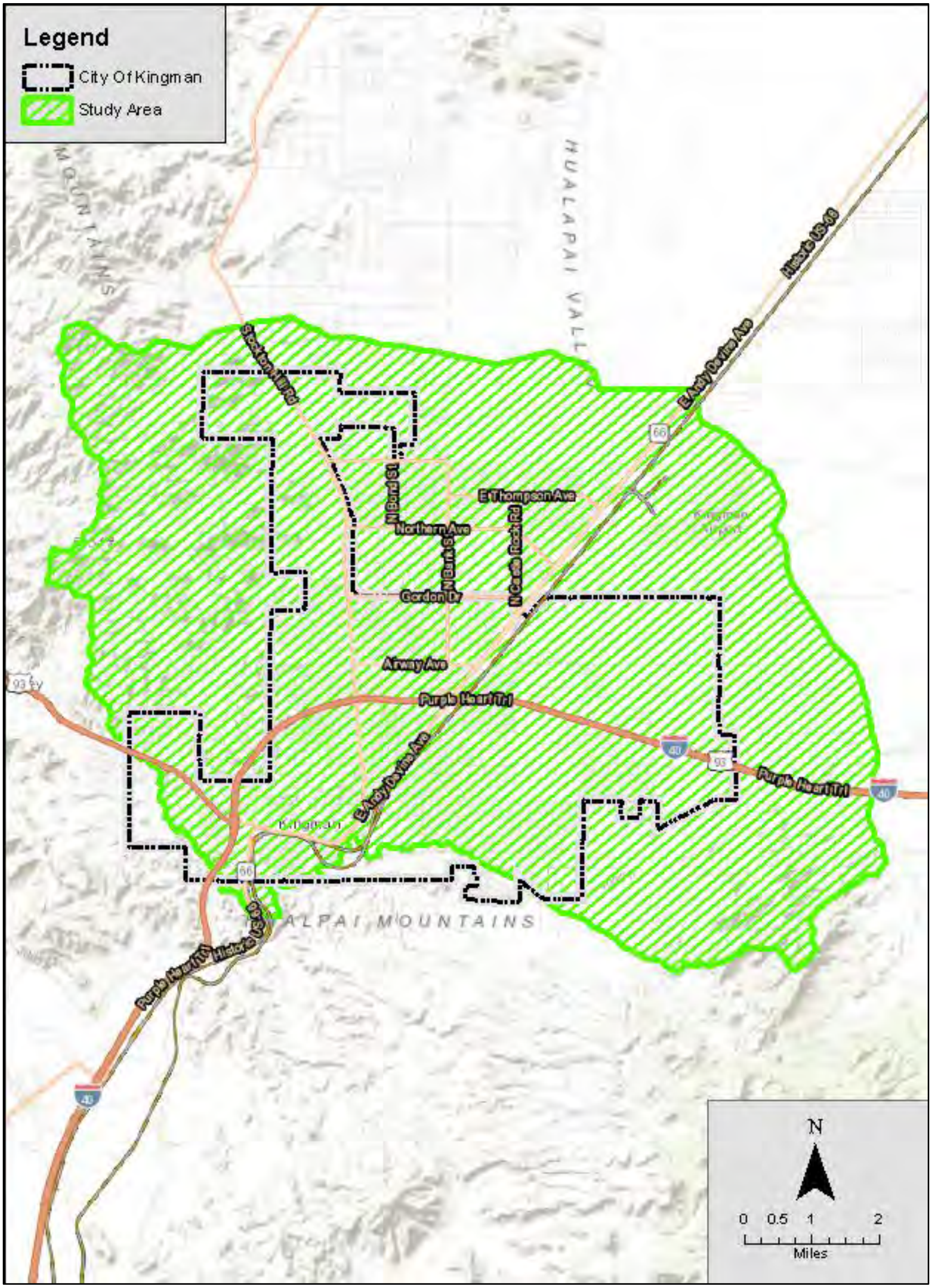

Figure 1-2. Vicinity Map

1.3 Project Approach and Report Organization

1.3.1 Project Approach

Due to the complex nature of the planning process, this project required a multi-step process (shown in Figure 1-3) that is explained in greater detail in Section 3 of this report.

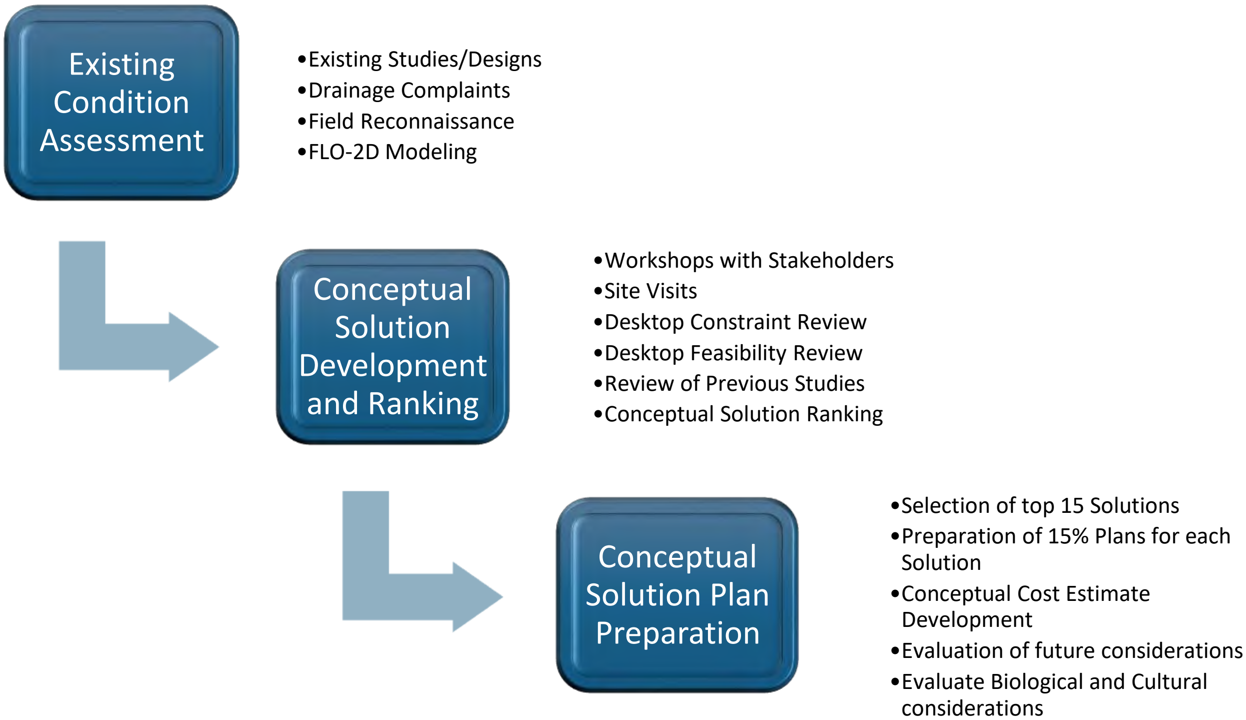

Figure 1-3. Project Approach

1.3.2 Report Organization

Section 2 of this report provides an assessment of the existing conditions and issues within the KADMP study area. Included in this section are reported drainage complaints and the methods, results, and summary of the hydrologic and hydraulics modeling. Section 3 contains the methods and results of the solution development and ranking process including stakeholder outreach, solution development and brainstorming, and solution refinement and ranking. Section 3 contains a list of fifteen (15) solutions that were moved forward into conceptual plan preparation. Section 4 contains the conceptual planning methods and results for the final solutions from Section 3. Finally, Section 5 contains cost estimates for each of the solutions presented in Section 4.

2 EXISTING CONDITIONS ASSESSMENT

2.1 INTRODUCTION AND PURPOSE

In order to fully understand drainage problems within the study area, it is critical to view both modeling data and anecdotal records. Flood modeling, as described in the previous sections is one way to gain an understanding of drainage problems within the City and can help determine the severity, complexity, and extent of drainage problems. Anecdotal records such as citizen drainage complaints, city maintenance crews experience, and records of flooded buildings both help validate the modeling data and gain additional perspective on the impacts of flooding within the study area. Throughout the planning process, the project team also constantly monitored the ever-changing drainage conditions within the City and ongoing studies, design, and construction projects.

2.2 EXISTING STUDIES/DESIGNS

The project team began the Existing Conditions Assessment by reviewing all relevant reports and studies within and in the vicinity of the KADMP study area to ensure that they were knowledgeable of the data that was already available.

The following studies and designs were referenced at the beginning of the conceptual solution development process to gain a full understanding of the data that was already available:

- Preliminary Drainage Report for Bull Mountain Basin (Channel Design), 90% and 60% Progress Prints (Mohave Engineering Associates, Inc., 2009) (Mohave Engineering Associates, Inc, 2010).
- Final Design Concept Report for Kingman Railroad Diversion Channel (URS Corporation, 2012)
- Design Report Steamboat Drainage Improvements (City of Kingman Engineering Department, 2014)
- Southern Vista Tract 1980-A Drainage Easement Report (Bull Mountain Engineering, LLC, 2015)
- Drainage Improvement Project for Fairgrounds Boulevard, 100% Final Plans (City of Kingman Engineering Department, 2016)
- Final Drainage Report Eastern Street Improvements – Pasadena Ave. to Airway Ave. (RPA, 2017)
- West Kingman Flood Control / Recharge Basin Study (JE Fuller / Hydrology & Geomorphology, Inc., 2018)

2.3 DRAINAGE COMPLAINTS

The project team analyzed the drainage complaints that were gathered within the KADMP study area before 2018, during and after the large storm in 2018, and when buildings flooded in 2018. These drainage complaints were compiled into spreadsheets and entered spatially into GIS to provide a visual representation of the issues and complaints throughout the study area.

2.3.1 Existing Drainage Complaints

Records of existing drainage complaints were provided by the City of Kingman and their location was digitized. The majority of complaints stem from the October 3, 2018 storm, but some are from previous years. Drainage complaints and their locations are included in Appendix A and shown on Figure 2-1.

2.3.2 Flooded Buildings

Several buildings were flooded during the 2018 storm. A summary of the event and the locations are shown in Appendix A. Refer to Figure 2-1.

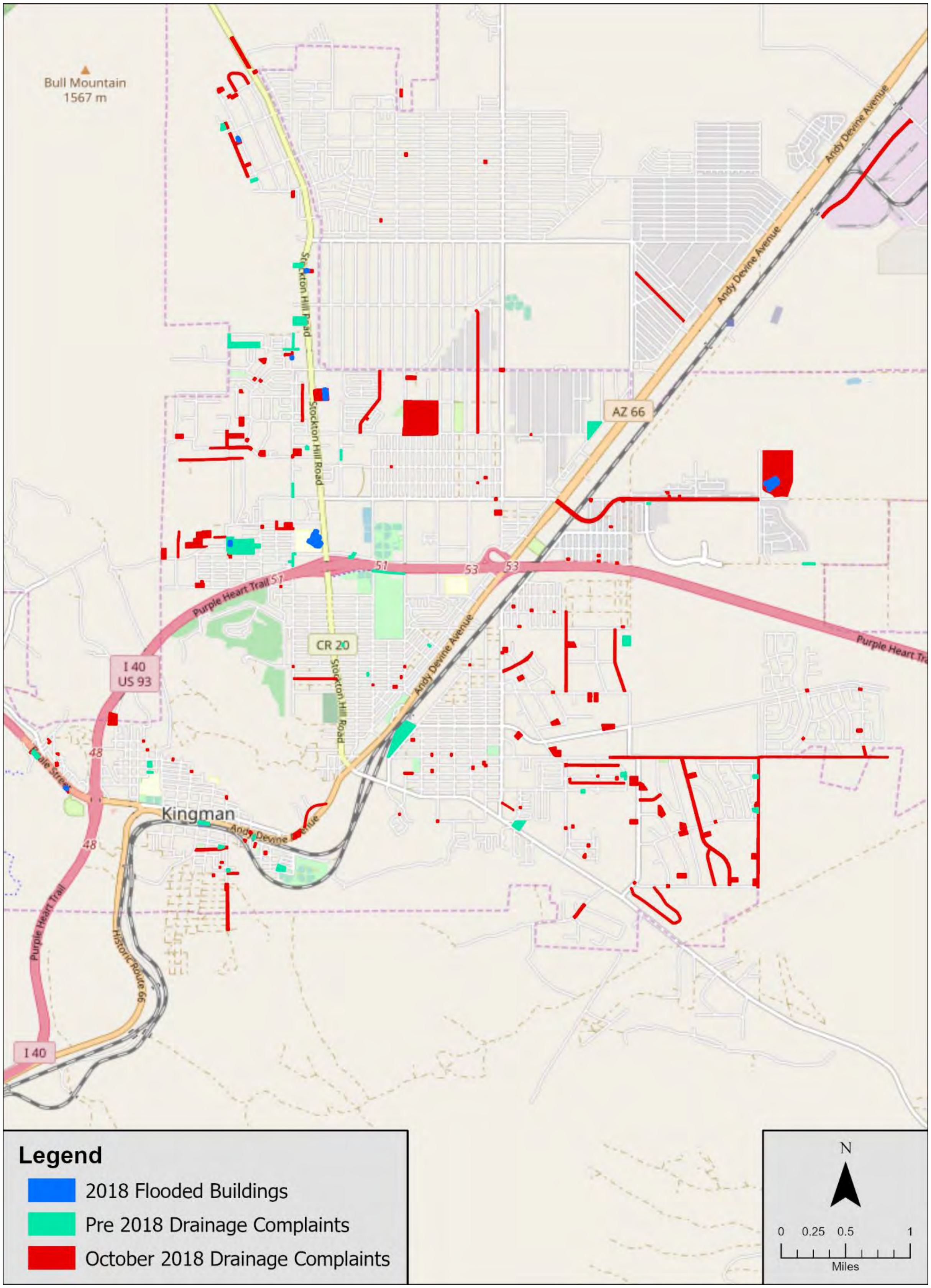

Figure 2-1. Drainage Complaints and 2018 Flooded buildings

2.3.3 Field Reconnaissance

The project team conducted field reconnaissance of the "problem" areas within the KADMP study area to obtain ground-level information and bolster understanding of the on-site conditions. Members of the project team visited both problem areas like those shown in Figure 2-1 above and potential solution areas.

2.4 Public Meeting

A public meeting was held at the City Council chambers on October 29, 2019 from 5:00 to 6:30 PM. The meeting was formatted as an open house and was attended by 10 members of the public and the purpose was to gain insight into existing drainage problems that exist within the City. Members of the project team were able to listen to concerns and all in attendance were encouraged to fill our comment response forms. One comment response form was returned and is included in Appendix A.

2.5 Hydrologic And Hydraulic Modeling

Hydrology and hydraulics for the KADMP Project area have been modeled using a single software package FLO-2D (FLO-2D Software, Inc.). FLO-2D is a dynamic two-dimensional (2D) hydrologic and hydraulic model that conserves volume as it routes hydrographs over a system of square grid elements. The model routes runoff over the grid using the full dynamic wave momentum equation and a central finite difference routing scheme. The floodwave progression is affected by the surface topography and roughness values (Manning's n-values) associated with land use characteristics. The FLO-2D version used for this study is the Pro Version Build No. 16.06.16 with an executable dated February 28, 2017. This version was used to maintain consistency with the previous FLO-2D studies in the same area – the Kingman Flood Risk Study and the East Kingman Risk Map study.

FLO-2D model development was based on the guidelines set forth in the *Mohave County Drainage Design Manual* (Mohave County Flood Control District, 2018), which is herein referred to as the *Design Manual*. Models were developed for the 2-, 10-, and 100--year return frequency, 6-hour storm duration events. The FLO-2D models were used to identify flood hazard areas and to investigate the impact of flood mitigation alternatives.

2.5.1 Model Development

2.5.1.1 Spatial Reference System

All data was generated for the KADMP projected in Arizona State Plane West, the horizontal datum is North American Datum of 1983 (NAD 83) while the vertical datum was the North American Vertical Datum of 1988 (NAVD 88). The units of measure were feet.

2.5.1.2 Grid Size

In order to leverage the excellent resolution of the LiDAR (Light Detection and Ranging) mapping, a grid size of 20-feet was chosen for this study. This grid size resulted in a total of five submodels that cover 86.3 square miles and are shown in Figure 2-2.

2.5.1.3 Grid Element Elevations

The limits of all topographic mapping sources used in the FLO-2D modeling are shown in relation to the model domains in Figure 2-3. There were two mapping sources – 1) LiDAR and 2) NEXTMap 5-meter digital terrain model (DTM). These mapping sources are discussed in detail below.

2.5.1.3.1 LiDAR Mapping

LiDAR mapping of the primarily undeveloped portion of the Project Area (approximately 68.6 square miles) was completed by Quantum Spatial, Inc. (QSI) in November 2015 (Quantum Spatial, Inc., 2016). Refer to the Kingman Area Flood Risk Study report (JE Fuller / Hydrology & Geomorphology, Inc., 2016) and East Kingman Risk Map Study Technical Support Data Notebook (JE Fuller / Hydrology & Geomorphology, Inc., 2018) for a detailed description of the LiDAR mapping, including the accuracy of the LiDAR data and LiDAR data mapping deliverable.

2.5.1.3.2 NEXTMap Data

The LiDAR data did not cover the entire watershed. For these areas, the topography was taken from the NEXTMap 5 (INTERMAP Technologies, 2019) . Approximately 16 square miles of the study area was not included in the LiDAR mapping area. NEXTMap 5-meter DTM was purchased from INTERMAP (INTERMAP Technologies, 2019) for the 16 square mile gap area. This DTM product has a 5-meter (16.4-feet) resolution with elevation values in meters, a horizontal spatial reference of GCS North American 1983, and a vertical spatial reference of NAVD 88. Initial FLO-2D results from the NEXTMAP data were reasonable and compared well with observed flow patterns on aerial photography. The model area that used the NEXTMap data is shown in Figure 2-3.

2.5.1.3.3 Seam between Mapping Sources

During initial model runs, some erroneous ponding was observed at the seams between the LiDAR and NEXTMap data due to the differences in elevation between mapping data sets. These differences are expected since the topographies are from two different sources with differing resolutions (e.g., the LiDAR data has much better resolution).

In areas where ponding was observed, the model results were reviewed, and the elevations were adjusted to provide a smoother transition between mapping data sets where the ponding was inappropriate. In the final model runs, there are some isolated areas where ponding is observed but the stored volume is not significant, and the downstream area is near the downstream model boundary – away from the main areas of interest (see example in Figure 2-3).

Finally, since the NEXTMap data does not have the same level resolution as the LiDAR data (i.e., the LiDAR is much more accurate), the flow patterns and peak discharges in areas within the NEXTMap limits should be verified before being used for future projects.

2.5.1.4 Model Inflow/Outflow

In general, outflow nodes were placed along the entire boundary of the model domains to let water free-flow out of the domain. However, the FLO-2D inflow/outflow routine was used to automatically transfer flow from the West and East models to the Central model, from the Central model to the Beale model, and from the Central and East models to the South model. This means that the boundaries between these five models are coincident. The outflow nodes from the West and East models provided the inflow hydrographs for the inflow nodes in the Central model. The outflow nodes from the Central model provided the inflow hydrographs for the inflow nodes in the Beale model. The outflow nodes from the Central and East models provided the inflow hydrographs for the inflow nodes in the South model. These inflow nodes are symbolized in orange along the boundaries of these three modes in Figure 2-4.

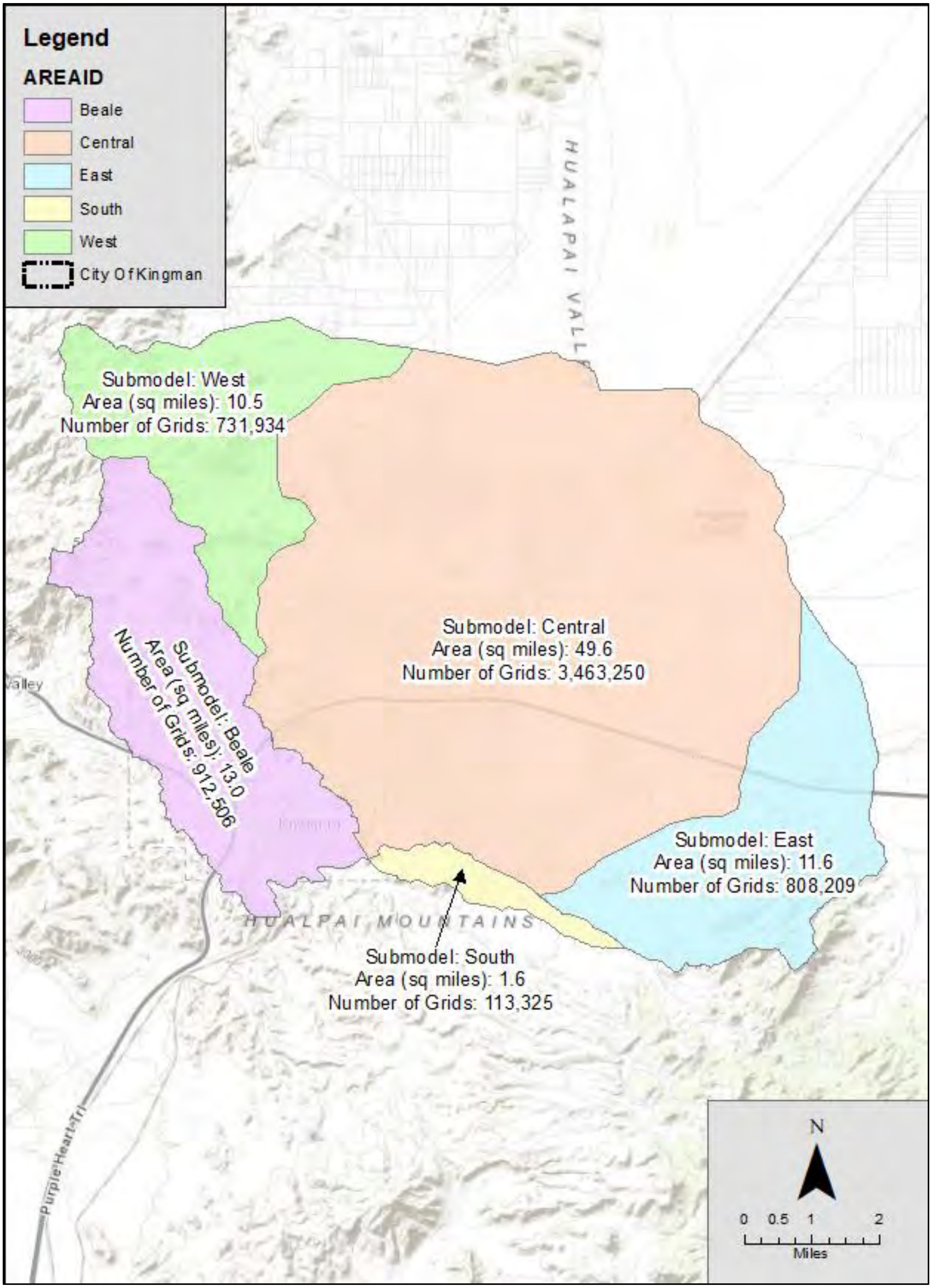

Figure 2-2. Submodel boundaries and characteristics

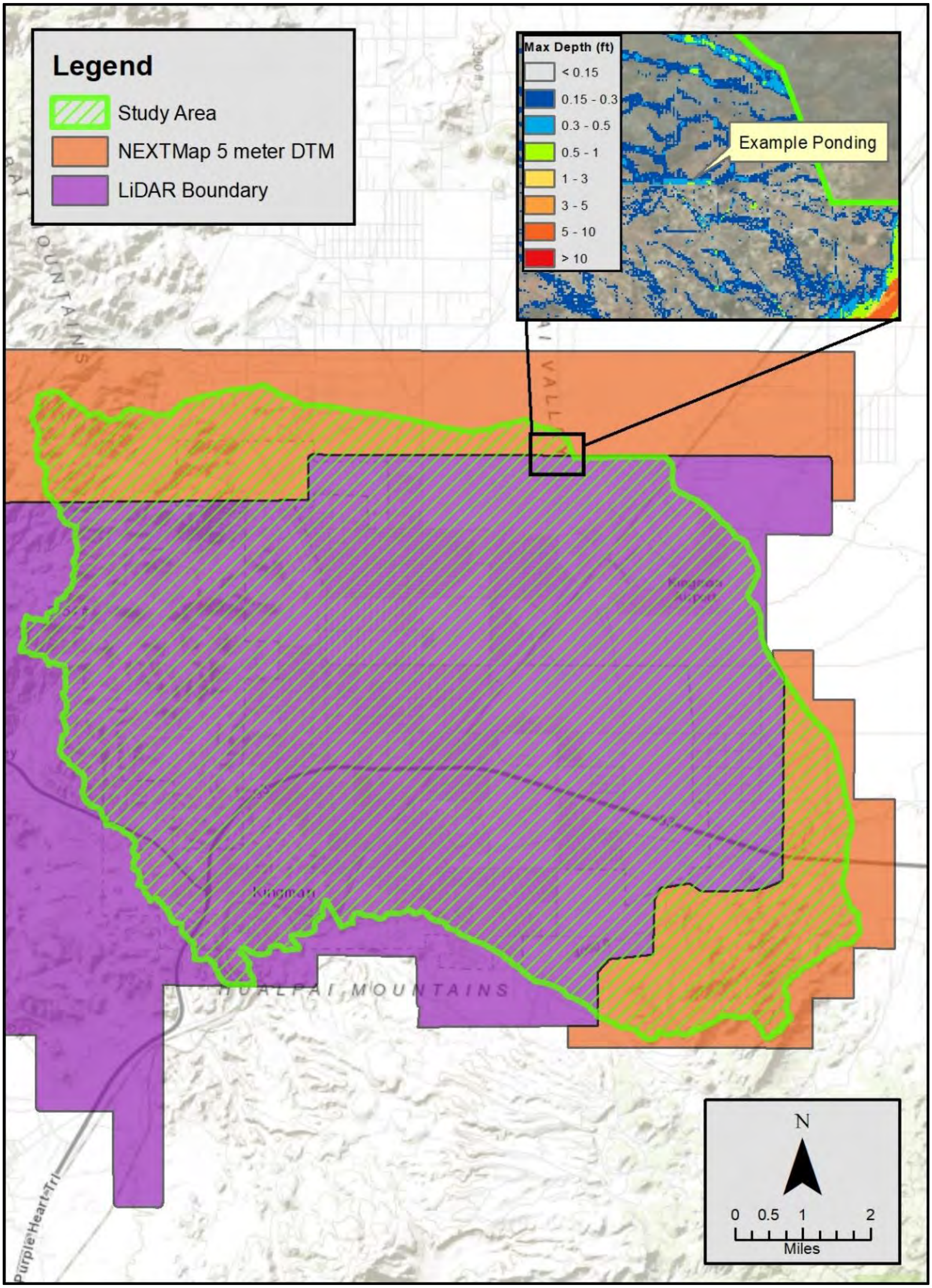

Figure 2-3. Limits of Topographic Mapping Data

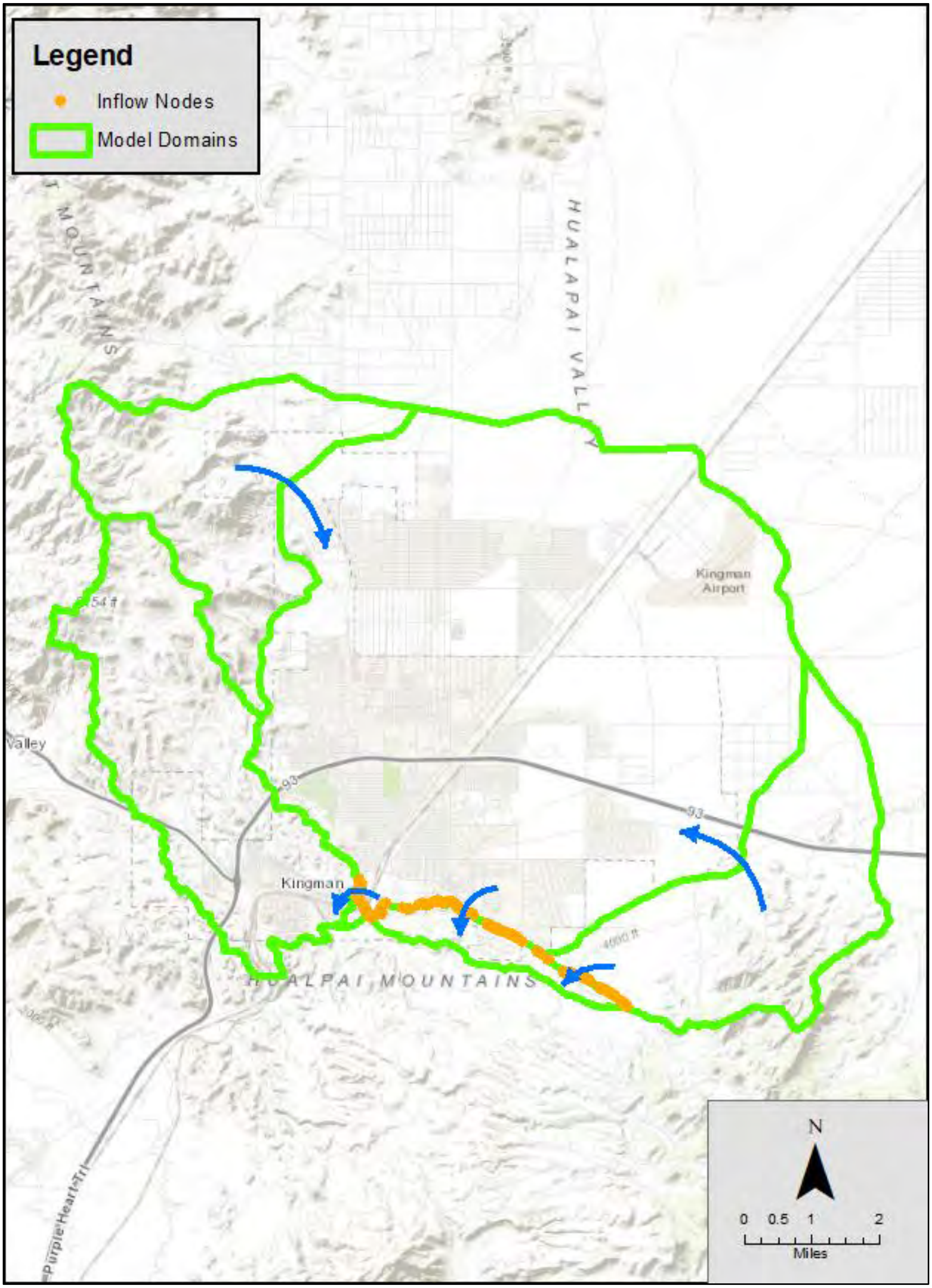

Figure 2-4. Hydrograph flow transfer between FLO-2D Models

2.5.1.5 *Precipitation*

As a part of the KADMP, three design storms were simulated:

- 2-year, 6-hour storm
- 10-year, 6-hour storm
- 100-year, 6-hour storm

The Mohave County Drainage Design Manual (Mohave County Flood Control District, 2018) recommends the use of 6-hour duration storms for watersheds up to 20 square miles in size, and the greater of the 6-hour or 24-hour storm for watersheds between 20 and 100 square miles in size. With the exception of Mohave Wash, none of the watersheds generally tributary to the primary watercourses exceed 20 square miles in size. Accordingly, the 2-, 10-, and 100-year, 6-hour storms were simulated for this study.

2.5.1.5.1 Precipitation Depths

The rainfall depths were taken from the NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 1: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico, Utah), while the temporal distributions were taken from simplified HEC-1 models per the Drainage Design Manual. The 6-hour distribution is shown in Figure 2-5 while the maximum rainfall point values for each submodel are shown in Table 2-1.

The RAIN.DAT file for each of these storms was developed with the same procedure. The general NOAA 14 rainfall shapefile was obtained from the software, DDMSW (KVL Consultants, Inc., 2009). This shapefile was converted to a global 20-foot raster where each cell was an area-weighted average of the rainfall depths within that cell. This global raster was then used to assign rainfall depths for each grid for each submodel, and finally the rainfall depths were normalized by the maximum rainfall in each submodel (using RAINARFs) to produce the RAIN.DAT file in the correct format.

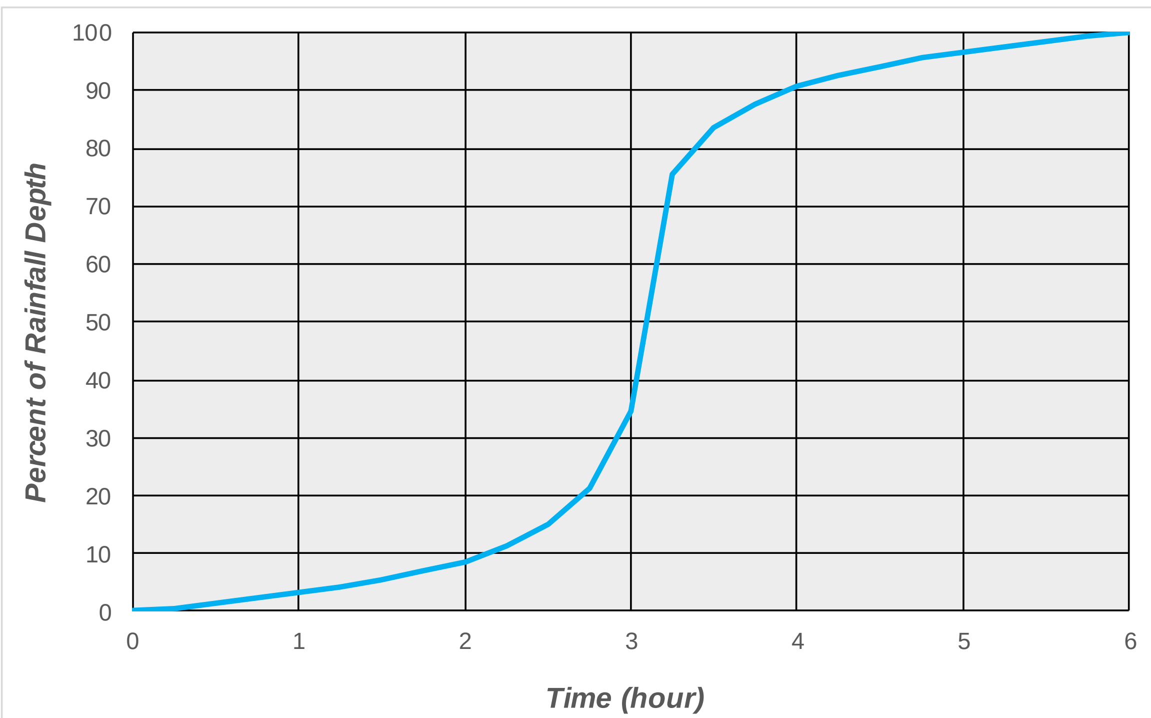

Figure 2-5. FLO-2D 6-hour Rainfall Temporal Distribution

Table 2-1. Maximum NOAA14 Point Rainfall Estimates (inches) by Recurrence Interval

Storm Events	Precipitation (inch)				
	West	Center	East	South	Beale
2-year, 6-hour storm	1.133	1.158	1.192	1.165	1.113
10-year, 6-hour storm	1.896	1.920	1.968	1.931	1.867
100-year, 6-hour storm	3.234	3.254	3.336	3.275	3.202

2.5.1.6 Infiltration Development

Green-Ampt method was used to calculate infiltration for this study. To develop the infiltration files, the entire study area needs to be spatially classified by both land use and soils. The land use shapefile was developed using the zoning shapefiles for both Mohave County and the City of Kingman. These two zoning shapefiles were merged, and then shapes were manually corrected using the latest available aerial photography. The final spatial distribution of the estimated land use is shown in Figure 2-6, and the land use parameters for each land use type, as estimated by the *Design Manual* (Mohave County Flood Control District, 2018), is shown in Table 2-2. The final FLO-2D infiltration parameters were not adjusted for vegetative cover, and therefore these values are all zero. The initial saturation (DTheta Condition) was also estimated as normal for the entire study area to prevent over infiltration.

The most recent soils shapefile was downloaded from the Mohave County website and clipped to the study area. The soil parameters that were used are shown in Table 2-3, while the spatial distribution of the soils within the study areas is shown in Figure 2-7. With the parameters of Table 2-2 and Table 2-3, the INFIL.DAT file was developed using the procedures outlined in the *Design Manual*.

Table 2-2. Land Use Parameters

Land Use Type	Initial Abstraction (in)	Percent Impervious (%)	DTheta Condition	XKSAT Condition	Vegetative Cover (%)
Commercial	0.1	75	normal	developed	0
Industrial	0.2	70	normal	developed	0
Mountain	0.25	0	normal	natural	0
Multi-Family Residential	0.25	50	normal	developed	0
Non-irrigated Landscape	0.1	10	normal	developed	0
Pavement	0.05	90	normal	developed	0
Rangeland flat slopes	0.35	0	normal	natural	0
Rangeland hill slopes	0.15	0	normal	natural	0
Residential large lot	0.3	15	normal	developed	0
Residential small lot	0.25	40	normal	developed	0
Wash	0.1	0	normal	natural	0

The FLO-2D models for this study were calibrated by modifying the limiting infiltration depth. The depth was set to match two criteria:

1) Closely approximate the infiltration volume from the previous HEC-HMS modeling for Unnamed Wash 6 and 10 (which are in and are representative of the East Kingman Risk Map study area). Based on HEC-HMS model results from the 2006 Technical Support Data Notebook (Map IX-Mainland, 2006) the total infiltration volume was in the range of 50-60%. Initially, the limiting infiltration depth (limiting depth) was set to 0.3333 feet (4 inches), but these preliminary runs were only showing about 28% infiltration by volume.
2) Produce flow peaks from representative watersheds within the study area that reasonably compare to results from the USGS regression equations for this region (see Section 2.5.4).

The final limiting infiltration depth was set as 16 inches to meet these two criteria. With this value, 63% of the volume was lost to infiltration during the 100-year event, and the flow peaks were comparable to results from the regression equations (discussed in Section 2.5.4). The Infiltration volume was calculated using the Summary values in the SUMMARY.OUT file with the equation:

$$\frac{(W_{\mathrm{II}} + TOL)}{VOL_R} \times 100 \qquad (1)$$

where:

W_{II} is water lost to infiltration and interception (acre-feet)

TOL is TOL floodplain storage (acre-feet)

VOL_R is total rainfall volume (acre-feet)

Table 2-3. Soil Parameters

Soil ID	Rock (%)	XKSAT N (in/hr)	XKSAT D (in/hr)
AZ697100	0	0.3	0.15
AZ697101	0	0.05	0.01
AZ697104	0	0.04	0.01
AZ697112	0	0.02	0.01
AZ697117	20	0.21	0.1
AZ697150	0	0.23	0.1
AZ697155	0	0.52	0.28
AZ69719	0	0.47	0.23
AZ69732	0	0.66	0.36
AZ69734	20	0.29	0.15
AZ69757	0	0.67	0.36
AZ69759	20	0.22	0.09
AZ6976	0	0.79	0.46
AZ69770	0	0.21	0.08
AZ69776	0	0.45	0.23
AZ69790	0	0.39	0.18
AZ69799	20	0.06	0.02

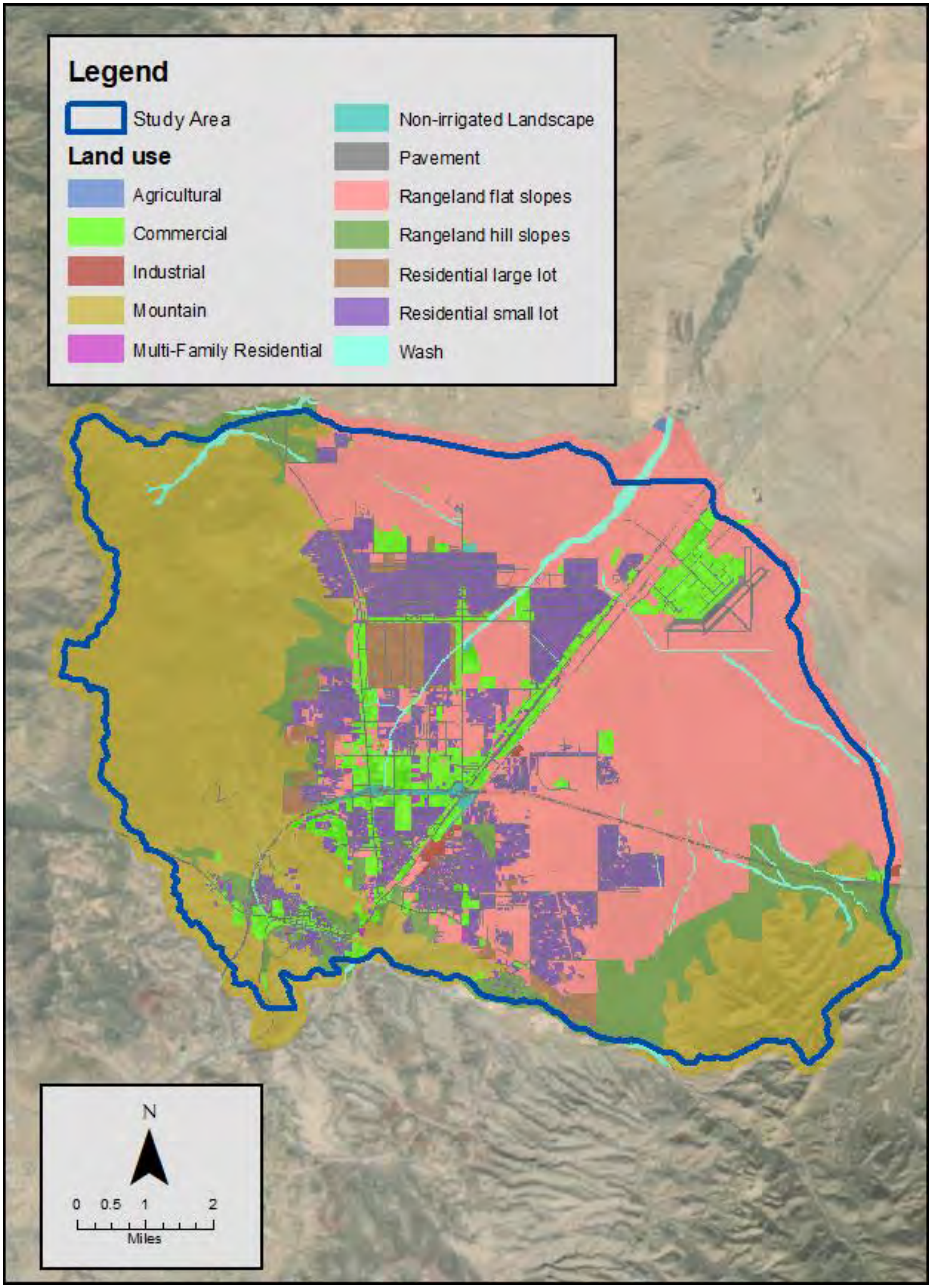

Figure 2-6. Spatial Distribution of Land Use Types within the FLO-2D Model

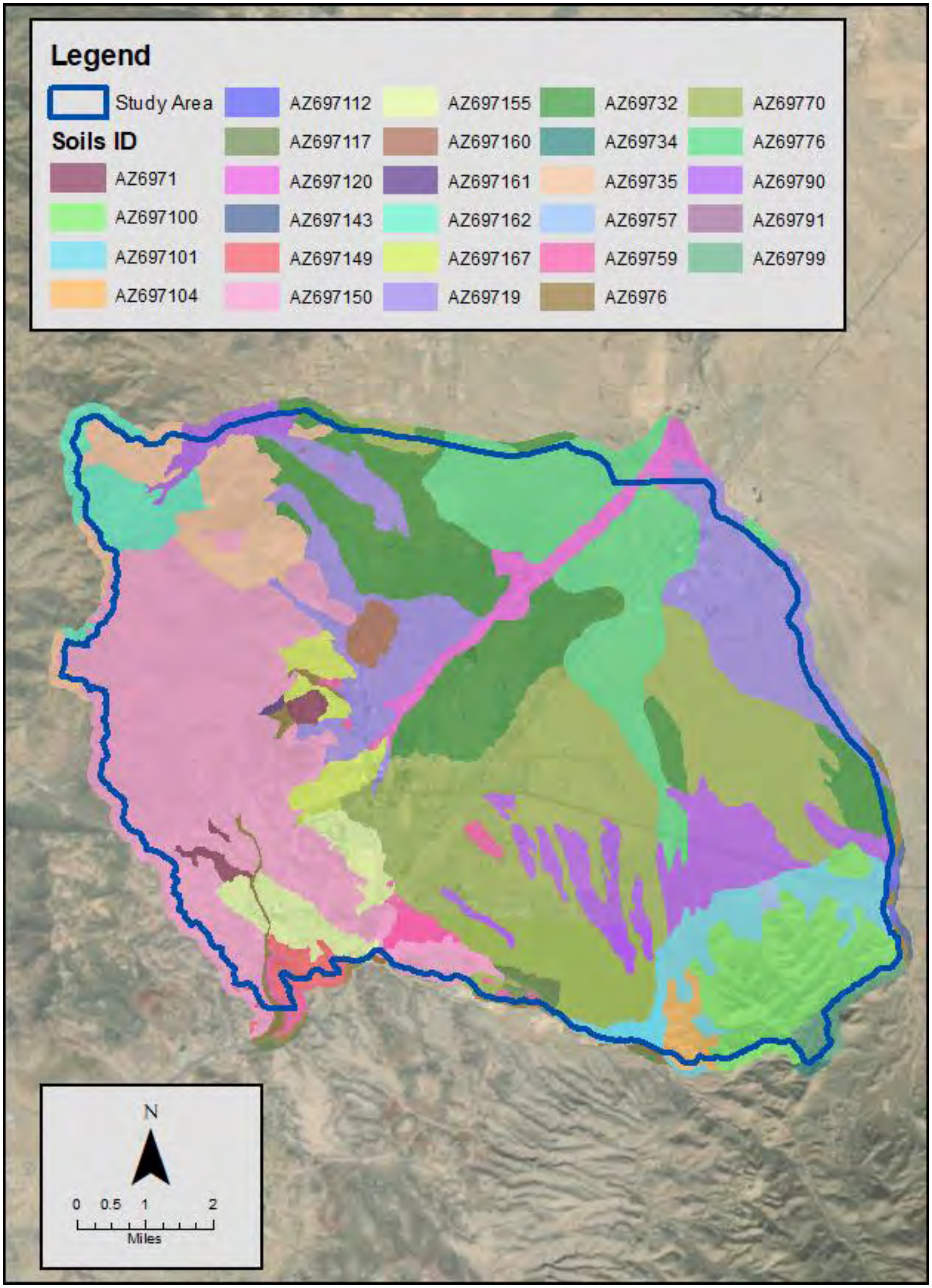

Figure 2-7. Spatial Distribution of Soil Types within the FLO-2D Model

2.5.1.7 Grid Element Roughness (Manning's n Values)

Since the land use classification is a rough estimate based on initial zoning shapefiles, the procedure for estimating n values was twofold. First, it was decided that FLO-2D's shallow n value option was to be used in order to control depths below 3 feet. Please see the *Data Input Manual* (FLO-2D Software, Inc., 2016) for a detailed discussion about shallow n value. Second, the urban land use types (Residential large lot, Residential small lot, Commercial, Pavement, etc.) were set to lower n values so that in the depth values between 0.5 feet and 3 feet these lower n values would have more control. For this study, the shallow n value was set to 0.18, and the general n values for each land use type are shown in Table 2-4.

Table 2-4. Surface Classification and Corresponding Manning's n Value

Land Use	Manning's n
Commercial	0.035
Industrial	0.035
Mountain	0.045
Multi-Family Residential	0.035
Non-irrigated Landscape	0.035
Pavement	0.020
Rangeland flat slopes	0.055
Rangeland hill slopes	0.050
Residential large lot	0.035
Residential small lot	0.035
Wash	0.033

2.5.1.8 Hydraulic Structures

2.5.1.8.1 Culverts

Based on the results of two large FLO-2D studies in mountainous regions of Maricopa County, the Laveen Area Drainage Master Study/Plan Update (JE Fuller / Hydrology & Geomorphology, Inc., 2017) and the Ahwatukee Foothills Area Drainage Master Study (T. Y. Lin International, 2017), it was assumed that all culverts would be under inlet control. With this assumption, the only difference between culverts were the inlet geometries. This helped simplify the development of the rating tables for two reasons:

1) a single rating table is needed for each type of structure, and
2) a surveyed invert elevation is not necessary.

However, if tailwater was high enough to effect flow in the culvert, FLO-2D has an option (the INOUTCONT variable) that would allow adjustment of the rating table during runtime to better characterize the hydraulics of the culvert. This option was used for some culverts where tailwater effects may be expected.

For each structure type (characterized by Kingman and JEF staff field investigations), depth-discharge rating tables were developed using Appendix A of the Federal Highway Administration's Hydraulic Design Series Number 5 (FHWA, 2012). The rating tables accounted for both unsubmerged and submerged inlet conditions using the equations from the manual. For simplicity, Form (2) of the unsubmerged equations was used since the barrel slope of each structure was not critical to the development of the rating tables. However, the submerged equation did require a barrel slope to solve. Being consistent with the above-referenced studies, a constant two percent slope was assumed for all structure types. All the culverts were assumed to be completely free of sediment in order to assess their maximum efficiency at flow conveyance. All modeled culverts are shown in Figure 2-8.

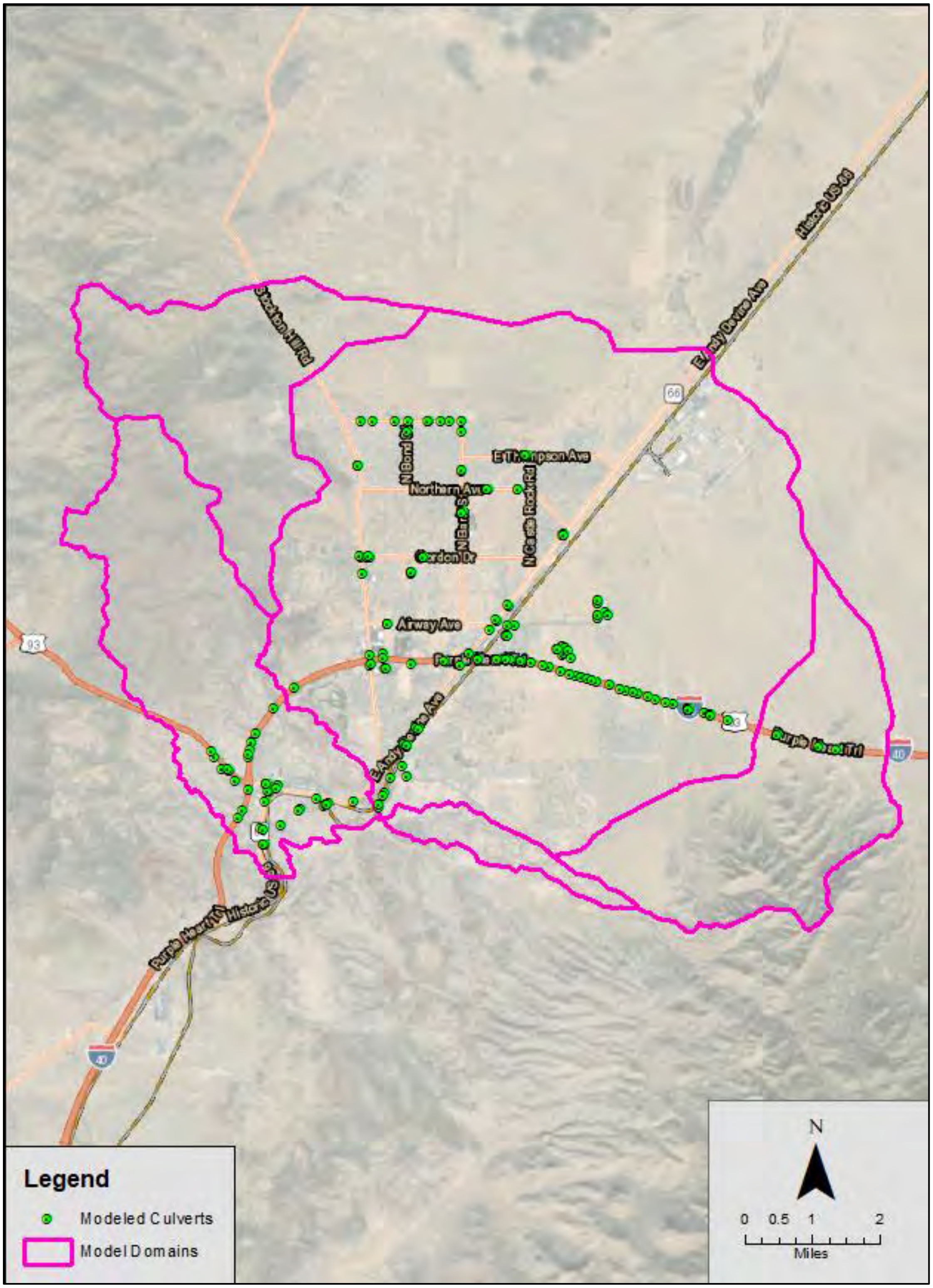

Figure 2-8. Modeled Culvert Locations

2.5.1.8.2 Storm Drains

The major stormdrain systems were input into the FLO-2D model using the SWMM model component of FLO-2D Pro. A total of 24,777 feet (4.69 miles) of stormdrain, including 109 inlets, manholes, and junctions were included in the model Figure 2-9. The SWMM model input is reflected in the SWMM.INP, SWMMFLO.DAT, SWMMFLORT.DAT and SWMMOUTF.DAT files.

2.5.1.9 Buildings

As a part of the final deliverable, Quantum Spatial, Inc. (Quantum Spatial, Inc., 2016) developed a buildings polygon shapefile for the LiDAR mapping area (see Figure 2-3). This shapefile was the input to create a global area-weighted 20-foot raster. This raster was then used to extract the percentage of area obstructed by buildings for each grid, and this percentage assigned as an area reduction factors (ARF) for the appropriate grid in each submodel. The totally blocked grid element routine ("T Line") was not used in order to simplify file development. Totally blocked grids were rather assigned 1 in the partially blocked grid attribute (i.e., the IDG column). Width reduction factors (WRF) were not used in this study and were assigned a 0 value in the ARF.DAT file.

To facilitate model runtime and reduce volume conservation error, all ARF values that were greater than 0.93 were modified to a value of 1.0. This change was necessary because a large number of timestep decrements were occurring on ARF values between 0.93 and 0.95 near the boundary. This occurs because even though there is a small flow in this grid elements the change in depth can be large due to the small remaining area. This is only a slight deviation from an assumption in the model engine itself, where the model automatically raises any ARF values greater than 0.95 to 1.0 at run time.

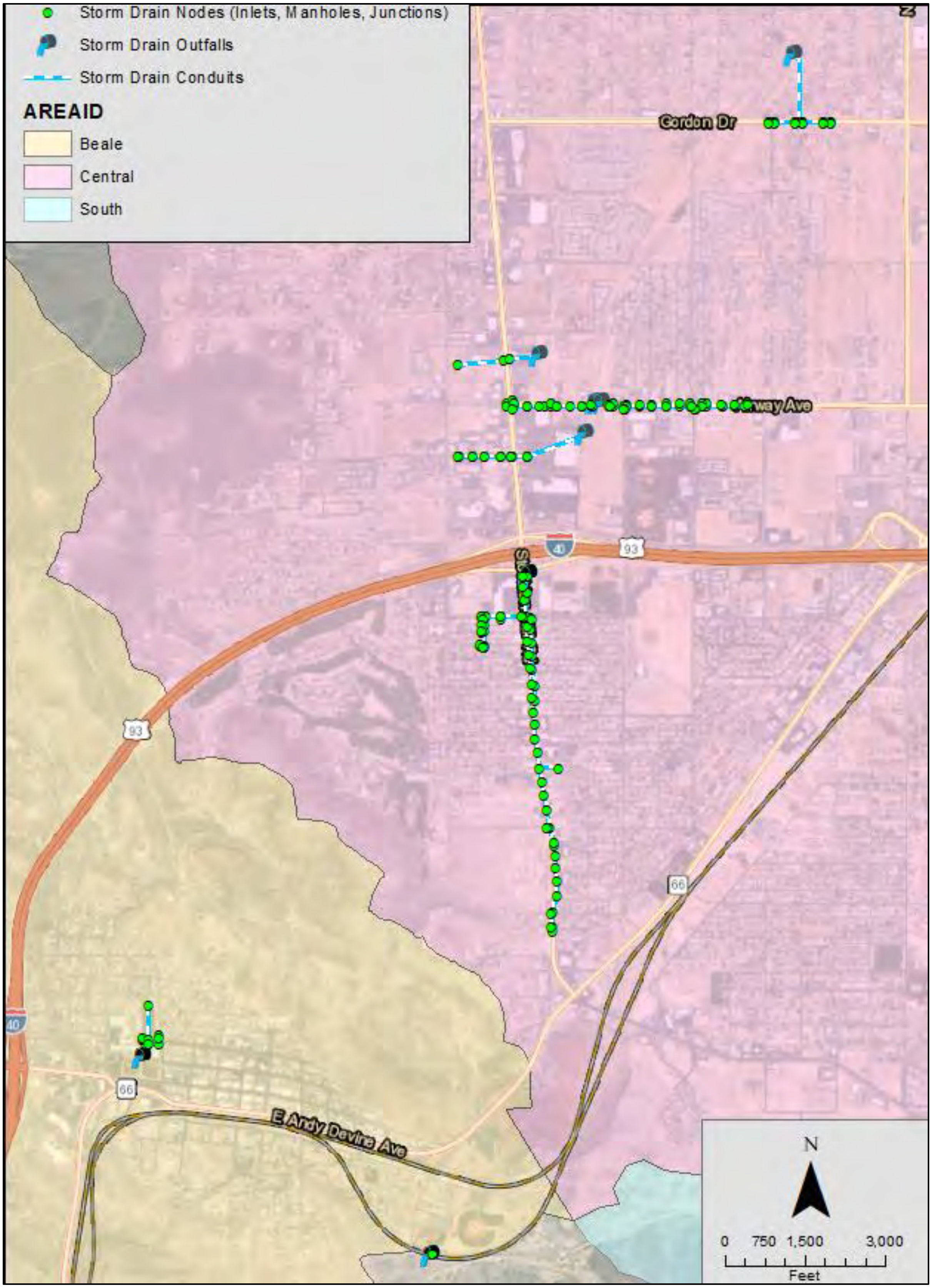

Figure 2-9. Storm Drain Networks that Are Simulated with SWMM

2.5.1.10 Model Control Parameters

CONT.DAT and TOLER.DAT contain numerical stability and simulation controls for the FLO-2D model. The CONT.DAT file controls simulation time, output report time interval, some numerical controls and model switches, such as infiltration and rain. The total simulation time was set to 12 hours for the 6-hour storm. These times were sufficient to ensure the floodwave has traveled through the entire study area.

In the CONT.DAT file, the global Manning's n value adjustment factor (AMANN) and the limiting Froude number (FROUDL) were the numerical controls that were used in the KADMP study. For this study, these controls were set to:

- AMANN = 0
- FROUDL = 0.95
- SHALLOWN = 0.18

For the limiting Froude number, a value of 0.95 was used to ensure the model ran in subcritical conditions and avoided critical locations (by keeping the Froude number slightly lower than 1). In FLO-2D, "when the limiting Froude number is exceeded, the floodplain n-value is increased by 0.001 for that grid element for the next timestep. During the hydrograph recessional limb when the Froude number is less than 0.5 and the flow is shallow, the n-value decreases by 0.0005 until the original n-value is reached" (FLO-2D Software, Inc., 2016).

The TOLER.DAT file contains the numerical tolerance settings specified for the model. These settings are: the flow exchange tolerance (TOL), percent allowed change in flow depth (DEPTOL), dynamic wave stability criteria (WAVEMAX), and Courant-Friedrich-Lewy numerical stability parameter for floodplain grid element flow exchange (COURANTFP). For the KADMP model, the settings applied were:

- TOL = 0.004 feet (the depth at which FLO-2D begins to route flow)
- DEPTOL = 0 (not used, model uses Courant number as stability criteria)
- WAVEMAX = 0 (not used, model uses Courant number as stability criteria)
- COURANTFP = 0.6 (main stability criterion used by FLO-2D)

These values have been used in similar studies (JE Fuller, 2016, 2018), which yielded reasonable results. For this project, these values have produced good model stability and reasonable results.

2.5.1.11 Model Warning and Error Messages

The following warnings and error messages are reported in FLO-2D output files, ERROR.CHK (Table 2-5), HYDRAULIC STRUCTURE_RUNTIME WARNINGS.OUT (Table 2-6), and DEPRESSED_ELEMENT S.OUT (Table 2-7). Some messages are repeated multiple times if the applicable situation occurs multiple times during a single simulation. For example, the warning message appears quite often that the downstream water surface is higher than the upstream water surface for a hydraulic structure. However, each warning is only discussed once in the list below. The warnings that were reported for the final model run include the following:

Table 2-5. ERROR.CHK Messages

FLO-2D Message	JEF Description
WARNING: THE IMPERVIOUS AREA REPRESENTED BY THE RTIMP PERCENTAGE IS LESS THAN THE ARF VALUE FOR AT LEAST ONE GRID ELEMENT.THE IMPERVIOUS AREA ASSIGNED BY THE RTIMP VARIABLE MUST INCLUDE THE BUILDING AREA, STREET AND ALL OTHER IMPERVIOUS AREAS WITHIN THE GRID ELEMENT.IF THE RTIMP PARAMETER IS LESS THAN THE BUILDING ARF VALUE, YOU MAY HAVE GLOBALLY UNDERESTIMATED THE RTIMP PARAMETER.FOR THIS SIMULATION THE RTIMP IS RESET TO THE ARF VALUE, HOWEVER, YOU SHOULD REVIEW ALL THE RTIMP ASSIGNMENTS	This message occurs because the maximum RTIMP assigned to grid elements in the INFIL.DAT file is 98 percent for impervious surfaces (e.g. roof tops, concrete). However, FLO-2D assigns an RTIMP of 100 percent to grid elements that have an ARF value of 1.0 (completely blocked) at runtime and there is currently no control for this. Therefore, a slight increase in rainfall runoff will occur on roofs for example. This error is considered conservative but will likely be imperceptible in the model results.
THERE ARE POTENTIAL DATA ERROR(S) IN FILE ARF.DAT	This general warning occurs when other warning messages that are related to ARF values are generated, such as the small surface area message that is shown below. Nothing was specifically done to eliminate this message.
THE FOLLOWING GRID ELEMENT ARF VALUES WERE ADJUSTED TO 1.0 TO ELIMINATE THE POTENTIAL FOR INSTABILITY RELATED TO SMALL SURFACE AREA	This is the warning that lets the modeler know that some ARF values were adjusted to 1.0 to eliminate potential instability in the model due to small available surface area that is left on those grids for flow. This message does not warrant the need to modify the model. No action was taken to eliminate this message.
THE INITIAL ABSTRACTION VALUE IS GREATER THAN THE TOL VALUE (DEPRESSION STORAGE) FOR AT LEAST ONE GRID ELEMENT. CONSIDER (NOT REQUIRED) LOWERING THE TOL VALUE OR ADJUSTING THE IA VALUE.	This general warning occurs when the initial abstraction is greater than the TOL value. Since the TOL value is very low (0.004 feet) and assigned based on guidance and experience from other FLO-2D studies, it is expected that the initial abstraction will be larger than the TOL value. Since the infiltration results were calibrated to generally match previous HEC-HMS modeling infiltration volumes and this TOL value has been used in multiple FLO-2D studies, this warning message was ignored. This message does not warrant the need to modify the model.
THERE ARE POTENTIAL DATA ERROR(S) IN FILE HYSTRUC.DAT	This general warning occurs when other warning messages that are related to hydraulic structures are generated, such as the adverse slope message that is shown below. Nothing was specifically done to eliminate this message.

FLO-2D Message	JEF Description
WARNING: THE HYDRAULIC STRUCTURE: NO. INLET ELEMENT: OUTLET ELEMENT: HAS AN ADVERSE BED SLOPE. THE OUTLET INVERT IS HIGHER THAN THE INLET INVERT. PLEASE CHECK TO ENSURE THIS IS CORRECT	This warning indicates that the outlet grid elevation is higher than the inlet grid elevation. The two hydraulic structures with this warning were reviewed to ensure that conditions coded in the model represented physical conditions reasonably well, and the resulting hydrographs were reasonable. Since the hydraulic structure results appeared reasonable, no action was taken to eliminate this message. This message does not warrant the need to modify the model.
THERE ARE POTENTIAL DATA ERROR(S) IN FILE FPXSEC.DAT	This general warning occurs when other warning messages that are related to floodplain cross-sections are generated, such as the grid element message that is shown below. Nothing was specifically done to eliminate this message.
THE CROSS SECTION ELEMENT: CAN ONLY BE ASSIGNED ONCE IN THE FPXSEC.DAT FILE	This warning occurs when a grid element is specified in two (or more) floodplain cross-sections. Since a reasonable hydrograph was generated for the cross-sections and the cross-sections were located where a hydrograph was desired, no action was taken to eliminate this message. This message does not warrant the need to modify the model.
WARNING: THE RATE OF CHANGE IN THE FOLLOWING HYDRAULIC STRUCTURE RATING TABLES MAY BE UNREASONABLE - RATE OF CHANGE = 10 TIMES PREVIOUS STAGE RATE OF CHANGE	This warning occurs when the discharge increases between consecutive points past a threshold based off of the previous two points. This error was reviewed and only occurs at the hydraulic structures (RttlSnkBrdUS_A through G) that simulate the bridge over Unnamed Wash 1.1a (or Rattlesnake Wash) where the rating table was developed in HEC-RAS and for the last two points in the table. Since the HEC-RAS model can more precisely model the interaction of flow through the bridge opening (only) as the depth reaches the low chord, the rating table was not adjusted. Additionally, the depth results were reviewed, and it was found that the maximum depth results do not get deep enough where this point is used. Therefore, the last point could be removed without any change in the final results. This message does not warrant the need to modify the model. No action was taken to eliminate this message.
WARNING: THE FOLLOWING HYDRAULIC STRUCTURES HAVE ARF VALUES IN EITHER THE INLET OR OUTLET ELEMENTS: (THIS WOULD ONLY BE A PROBLEM IF THE REMAINING SURFACE AREA WAS RELATIVELY SMALL (< 50%).)	The culverts inlet or outlet elements that have ARF values are located near buildings. Since the remaining surface area are greater than 90%, this warning does not warrant the need to modify the model. No action was taken to eliminate all instances of this message.

FLO-2D Message	JEF Description
WARNING: THE RATING TABLE FOR HYDRAULIC STRUCTURE: WAS ADJUSTED TO BETTER MATCH THE STREAM FLOW CONDITIONS	This warning informs the modeler that the rating curve has been adjusted to stabilize the model/structure and that a portion of the rating table has been written to a separate output file, REVISED_RATING_TABLES.OUT. The REVISED_RATING_TABLES.OUT file was reviewed; and since the suggested revisions were minor and the INOUTCONT value was assigned according to expected tailwater conditions during the entire simulation, the original rating tables were not adjusted. This warning does not warrant the need to modify the model. No action was taken to eliminate all instances of this message.

Table 2-6. HYDRAULIC STRUCTURE_RUNTIME WARNINGS.OUT Messages

FLO-2D Message	JEF Description
THE HYDRAULIC STRUCTURE: NO. RATING TABLE WAS REVISED. RATING TABLE WAS REVISED. REVIEW THE SUGGESTED REVISIONS TO THE RATING TABLE IN REVISED_RATING_TABLE.OUT FILE	This warning informs the modeler that the rating curve has been adjusted and written to a separate output file, REVISED_RATING_TABLES.OUT. The REVISED_RATING_TABLES.OUT file was reviewed; and since the suggested revisions were minor or involved structures that were calculated with HY-8 and the INOUTCONT value was assigned appropriately according to expected tailwater conditions during the entire simulation, the original rating tables were not adjusted. This warning does not warrant the need to modify the model. No action was taken to eliminate all instances of this message.
WARNING: THE DOWNSTREAM WATER SURFACE GETS HIGHER THAN THE UPSTREAM WATER SURFACE AT TIME: THERE IS POTENTIAL FOR UPSTREAM FLOW THROUGH THE STRUCTURE: CONSIDER SETTING THE UPSTREAM FLOW SWITCH INOUTCONT = 1	This warning indicates that the water surface elevation is higher at the outlet than the inlet. When a hydraulic structure had the potential to be affected by tailwater conditions, such as small pipes (e.g., ~20-30 inches in diameter) that drain to retention basins or grate inlets that drain to culverts, the INOUTCONT value was assigned accordingly. Each hydraulic structure was also reviewed to ensure that its resulting hydrograph was reasonable. Since these results appeared reasonable, no further action was taken to eliminate this message. This warning does not warrant the need to modify the model. No action was taken to eliminate all instances of this message

FLO-2D Message	JEF Description
WARNING: AT TIME (HR) HYDRAULIC STRUCTURE NO. AND NAME DISCHARGE (CFS OR CMS) EXCEEDS THE INFLOW DISCHARGE (CFS OR CMS) TO THE INLET NODE BY 50% (1.5 X)	This warning informs that modeler that inflowing stream conditions at the identified hydraulic structures may cause excessive timestep decrements (increasing total run time) due to grid elements at structure inlets having rapid drawdown in depths at certain timesteps. The structures that were listed in the warning messages were reviewed to ensure that they matched physical conditions in the field and expected tailwater conditions throughout the simulation. Since the structures seemed to represent physical conditions and their resulting hydrographs and local depth results appeared reasonable and total model run time was not excessive, the final warnings were considered reasonable. This warning does not warrant the need to modify the model. No action was taken to eliminate all instances of this message

Table 2-7. DEPRESSED_ELEMENTS.OUT Messages

FLO-2D Message	JEF Description
THE FOLLOWING GRID ELEMENTS ARE DEPRESSED BY AT LEAST 3.0 (FT OR M) BELOW ALL CONTIGUOUS NEIGHBORS	The grid elements were reviewed, and most elements are isolated ponding areas that can be seen in the LiDAR hillshade surface. This warning does not warrant the need to modify the model. The instances specified in the warning messages appear to be reasonable representations of the surface.

2.5.2 Model Results

2.5.2.1 Depth, Velocity, and Discharge Results

Flow depth, velocity and discharge results from the existing conditions FLO-2D modeling are shown on Figure 2-10, Figure 2-11, and Figure 2-12 , respectively. These figures are for general illustrative purposes and not practical for obtaining detailed information at site-specific locations. For more detailed results, FLO-2D workmaps, included in Appendix B, have been generated and contain grid-based data for the maximum flow depth, maximum peak discharge, and maximum velocity.

2.5.2.2 Floodplain Cross-Sections

Floodplain cross-sections were developed and included in the FPXSEC.DAT file to query flow hydrographs, peak discharges, and flow volumes from the FLO-2D model at key locations, such as:

- Major flow concentration locations, and
- Areas near potential mitigation sites

Major floodplain cross-section locations and the peak flow volumes at each floodplain cross-section for each storm event are shown on Workmaps 10 through 21.

2.5.2.3 Storm Drain Flooding and Utilization

After a FLO-2D model has been run, the SWMM component flags each node (i.e., a junction or inlet) that has had a hydraulic grade line above the rim (ground) elevation as being flooded For the 100-yr, 6-hour storm event, 61 nodes out of 169 were flooded (with total flooding volume of 2.68 acre-feet) for the Central model, while 5 nodes out of 12 were flooded (with total flooding volume 0.11 acre-feet) for the Beale model. These flooding volumes are much smaller than either the overall rainfall volume (8,243 acre-feet for the Central model during the 100-year, 6-hour event) or even the volume that enters the stormdrain system (233 acre-feet for the Central model during the 100-year, 6-hour event).

In SWMM, manholes (or pipe connections) are modeled as junctions. If these manholes are not connected to the FLO-2D surface with a Type 5 inlet in SWMMFLO.DAT, any flow volume that is lost by flooding through these nodes leaves the model and is not returned. To eliminate this potential lost flow, an additional surcharge depth was added to these manholes to prevent flooding. This additional surcharge depth was added instead of connecting these nodes to FLO-2D surface as a Type 5 inlet because this version of FLO-2D had minor stability problems when manholes popped, and water could reenter the stormdrain through the open manhole. All flooding volumes from the SWMM results are shown in Figure 2-12.

SWMM also records the maximum flow and depth in a conduit during simulation. For each conduit, design flow is calculated using the Manning's formula and is supposed to be an indication of the conduit's design flow. Since this calculation is based on an assumption of steady capacity flow and does not account for pressure flow, the flow through the pipe can exceed this value under a number of circumstances.

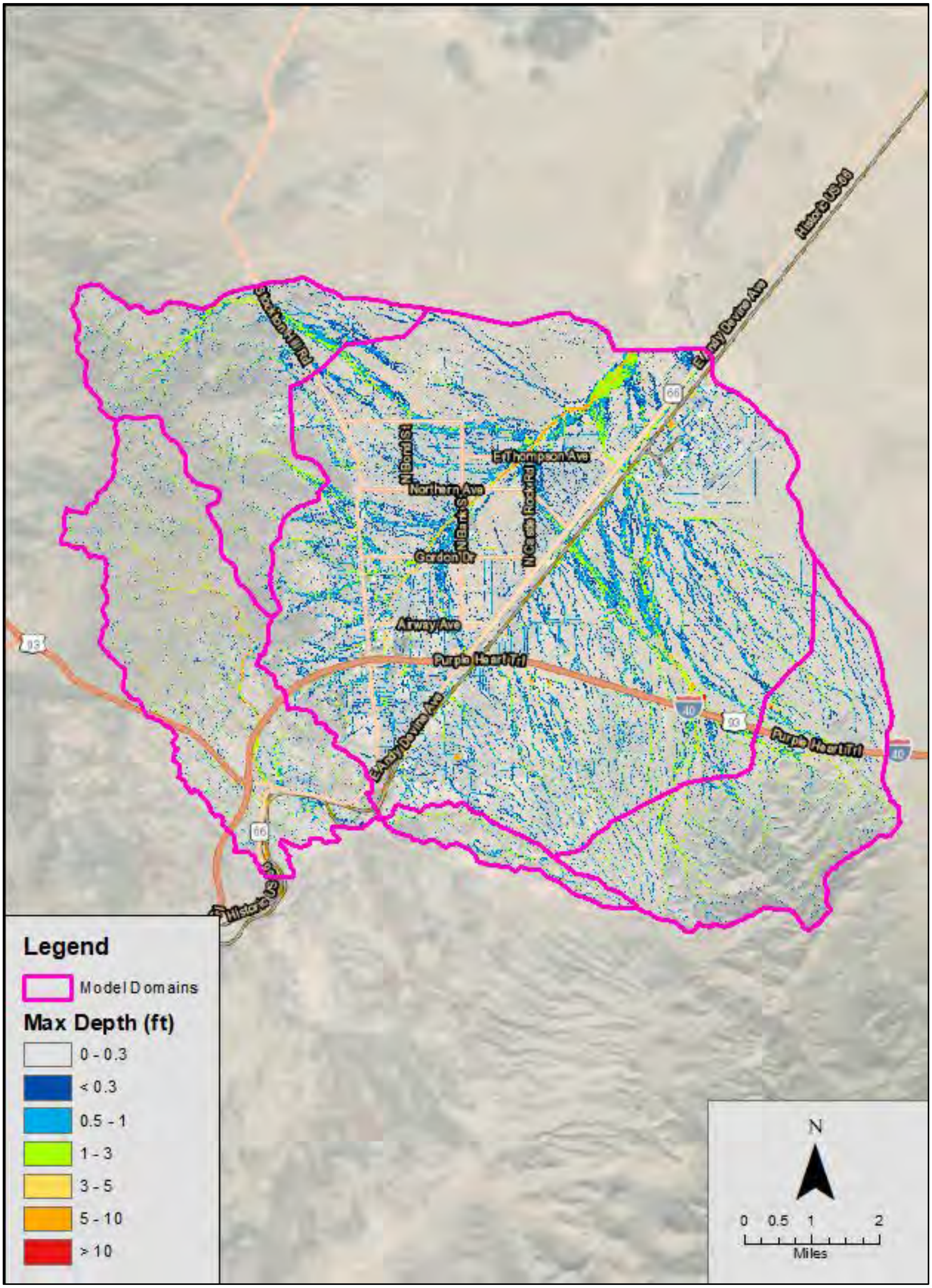

Figure 2-10. FLO-2D Maximum Depth Map for 100-year, 6-hour Storm Event

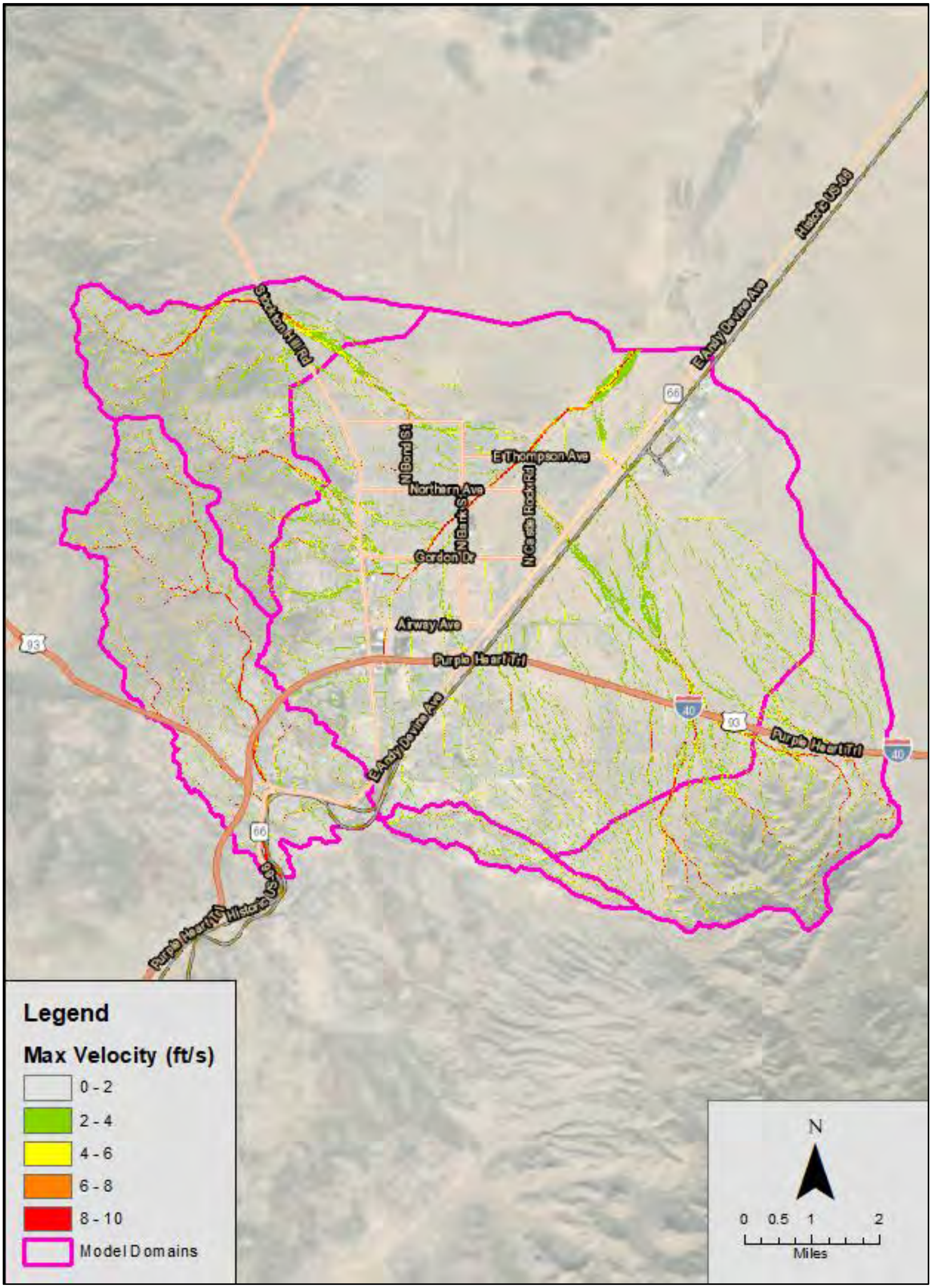

Figure 2-11. FLO-2D Maximum Velocity Map for 100-year, 6-hour Storm Event

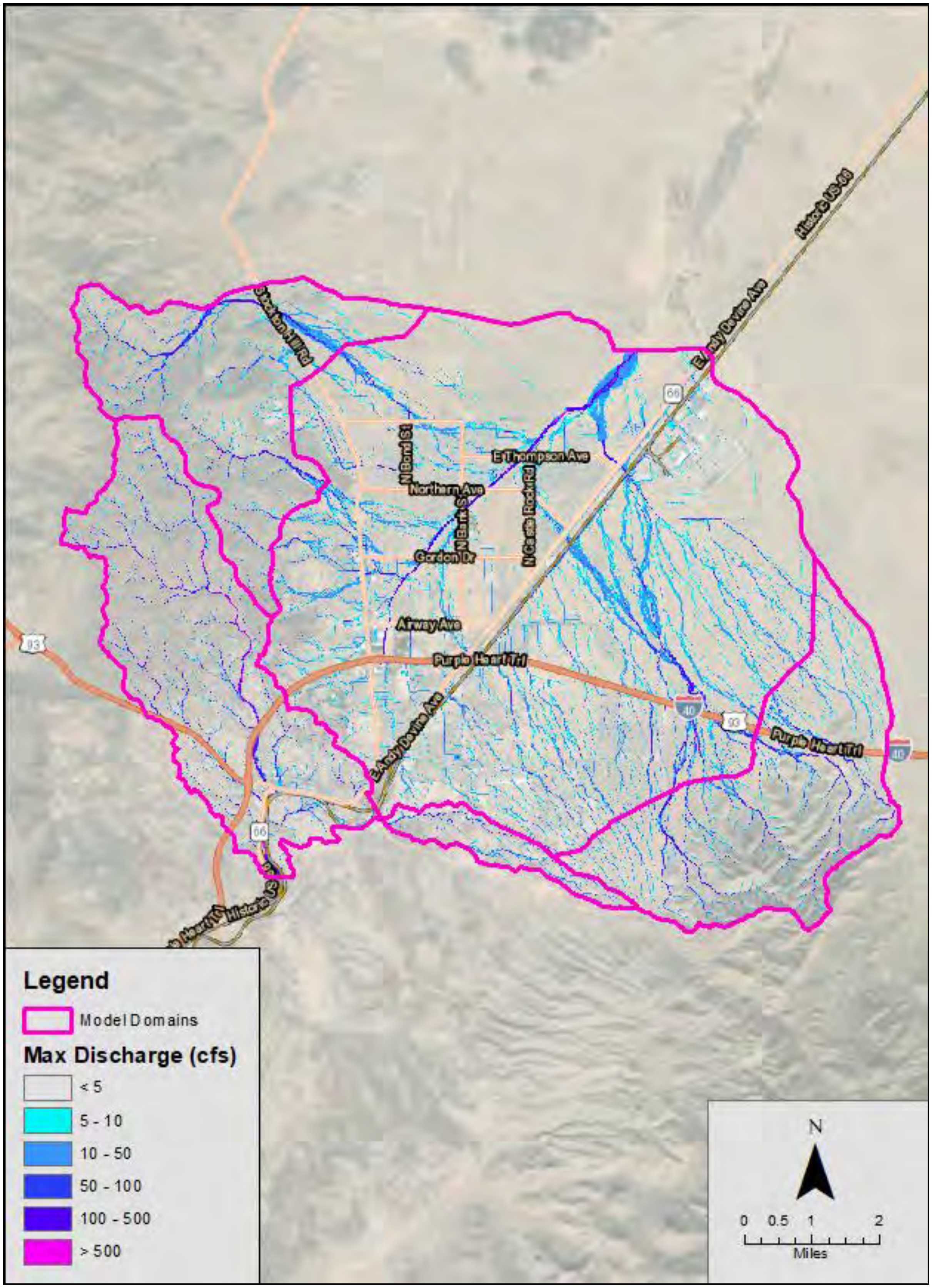

Figure 2-12. FLO-2D Maximum Discharge Map for 100-year, 6-hour Storm Event

2.5.3 Flood Hazard Classification

During severe storm events flood waters flow throughout the KADMP study area. However, not all flood hazards pose a risk to people or their properties. Flood risk depends on the presence of both a flood hazard and a person or their property in the flooding area. For example, flow in a constructed flood control channel does not present a risk until someone enters the channel. Identifying areas where flood waters may cause potential to harm people or their properties is an important objective of the KADMP study. Identification of potential flood risks in the study area helped the project team determine which flood problems should be addressed in the future.

For the purposes of this study, flood hazards were defined based on the physical characteristics of the flood water – that is, the location, depth, and velocity associated with those flood waters. The hydrology and hydraulic modeling results were used to define flood hazards for three storms:

- The 2-year, 6-hour event
- The 10-year, 6-hour event
- The 100-year, 6-hour event

The flood risk assessment involved selecting criteria and quantifying flood risks throughout the study watershed using the FLO-2D model results. Three types of potential flood risks were assessed – flooding risks to pedestrians, passenger vehicles, and structures.

In addition to the flooding risks, building inundation assessment was conducted. The building inundation assessment is planning level analyses to estimate the number of habitable structures and associated damage costs by flow depths greater than six inches. Since this analysis will be done for both the base (i.e., existing) and the with-alternatives conditions, it gives a quantitative estimate of the effectiveness of the potential alternative structures. This analysis was performed for all three storm events.

The following sections describe the flood classification criteria, methodology, and description of provided electronic files for each potential flooding assessment.

2.5.3.1 Flooding Hazard to Pedestrians

Pedestrian flood hazards were classified using the depth-velocity relationship outlined in the United States Bureau of Reclamation (USBR) Technical Memorandum 11 (TM 11) (U.S. Department of the Interior, Bureau of Reclamation, 1988). The depth-velocity relationships presented in TM 11 are a good basis for flood hazard classification since the criteria are widely accepted. TM 11 presents two possible classifications for pedestrians; flood danger levels for adults and for children. It was decided to use the flood danger classification for children throughout the entire watershed to simplify the methodology and to be conservative. The depth-velocity flood danger level relationship from TM 11 is shown as Figure 2-13.

The following three categories exist for pedestrian flood hazards:

- *Low*: These are areas with depths and velocities corresponding to the Low Danger Zone as shown in Figure 2-13. Low pedestrian hazards are not displayed on the PPW map exhibits because, per TM 11, low hazard zones do not present a threat to children of almost any size (excluding infants) and cover all areas not classified with a higher flood hazard.
- *Moderate*: Areas with depths and velocities corresponding to the Judgment Zone in Figure 2-13 have been labeled as having a moderate potential flood hazard to pedestrians.

- *High*: Areas with depths and velocities corresponding to the High Danger Zone in Figure 2-13 have been labeled as having a high potential flood hazard to pedestrians.

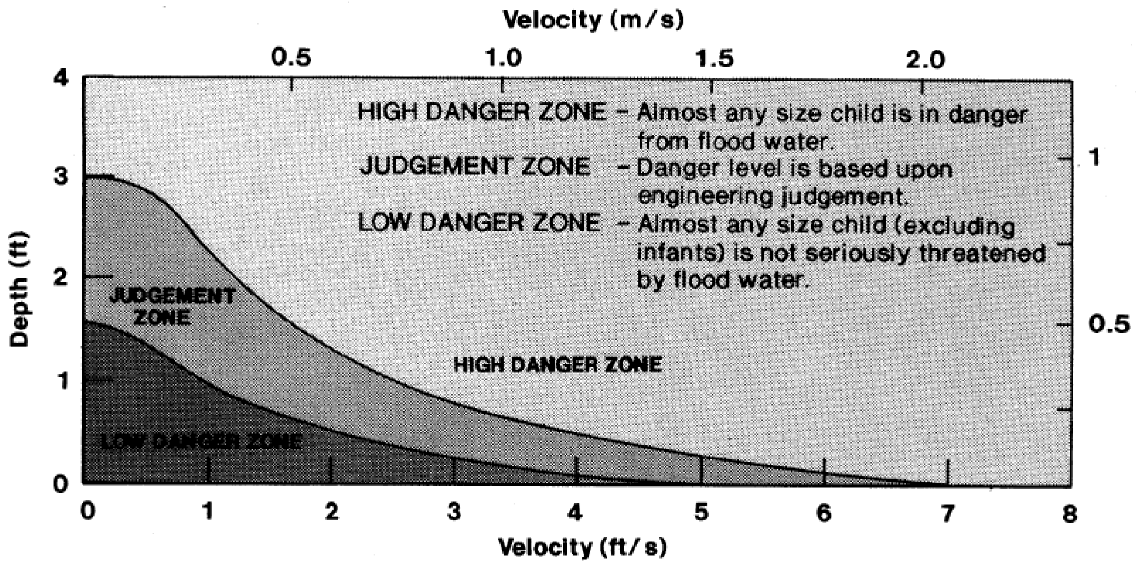

Figure 2-13. Depth-Velocity Flood Danger Level Relationship for Children (U.S. Department of the Interior, Bureau of Reclamation, 1988)

The flood hazards to pedestrians have been digitized in GIS in the form of a raster. The rasters generated for the risk analysis coincide with the FLO-2D grid elements with a 20-foot by 20-foot pixel size. The raster contains values of 1, 2, and 3 which correlates to a low, moderate, and high hazard classification, respectively. Since the 100-year, 6-hour storm produces the largest peak runoff, the flooding hazard from this storm event is shown as Figure 2-14.

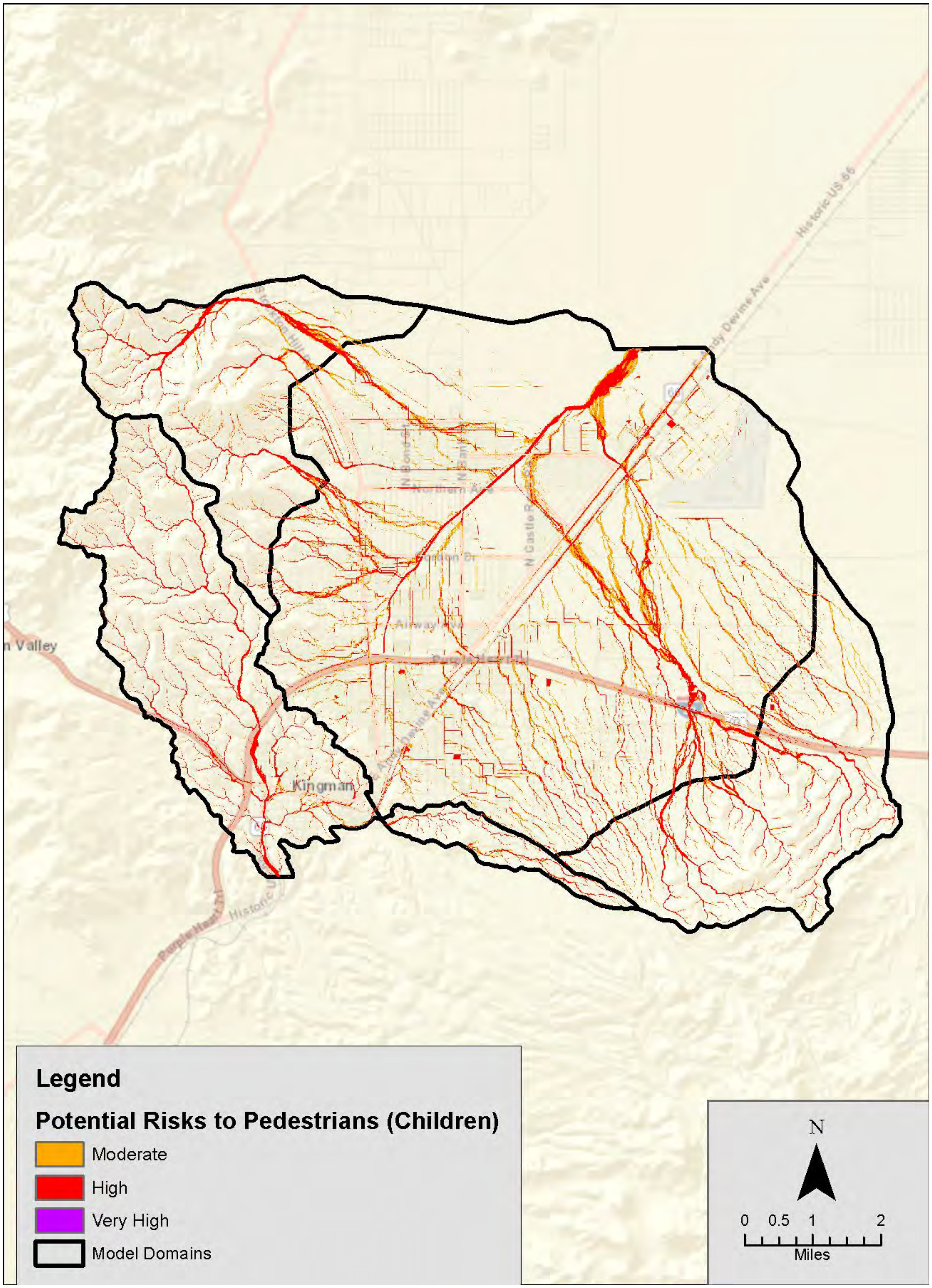

Figure 2-14. Flooding Hazards to Children Based on the 100-Year, 6-Hour FLO-2D Results

2.5.3.2 Flooding Hazards to Passenger Vehicles

Potential hazards to passenger vehicles were classified using a combination of minimum depth criteria and depth-velocity relationship in TM 11 as shown in Figure 2-15. The following four categories exist for passenger vehicle flood hazards:

- *Low*: This hazard category is based solely on minimum depth criteria and is for roadway crossings with depths less than half a foot. Low passenger vehicle hazards are not displayed on the map exhibits because low hazard zones indicate areas where vehicles “are not seriously in danger” and, as such, almost any size passenger vehicle can safely pass. Also, this hazard classification covers all areas not classified with a higher flood hazard.
- *Moderate*: This hazard category is based on a combination of minimum depth criteria and the depth-velocity relationship in TM 11. Specifically, these are roadway crossings with depths and velocities falling into the Low Danger Zone (as shown in Figure 2-16) that also have greater than a half a foot of depth. The threshold depth of half a foot was chosen because half a foot of water will reach the bottom of most passenger cars and can cause loss of control and possible stalling.
- *High*: Roadway crossings with depths and velocities corresponding to the Judgment Zone in Figure 2-16 have been labeled as having a high potential flood hazard for passenger vehicles.
- *Very High*: Roadway crossings with depths and velocities corresponding to the High Danger Zone in Figure 2-16 have been labeled as having a very high potential flood hazard for passenger vehicles.

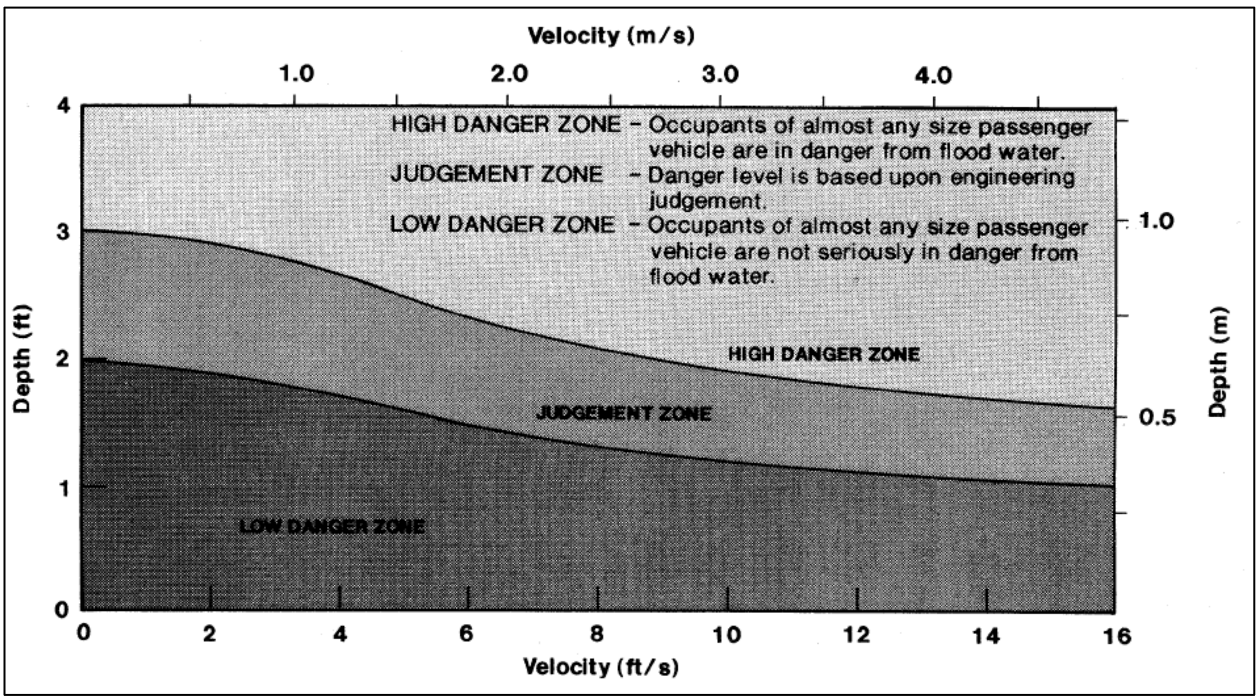

Figure 2-15. Depth-Velocity Flood Danger Level Relationship for Passenger Vehicles (U.S. Department of the Interior, Bureau of Reclamation, 1988)

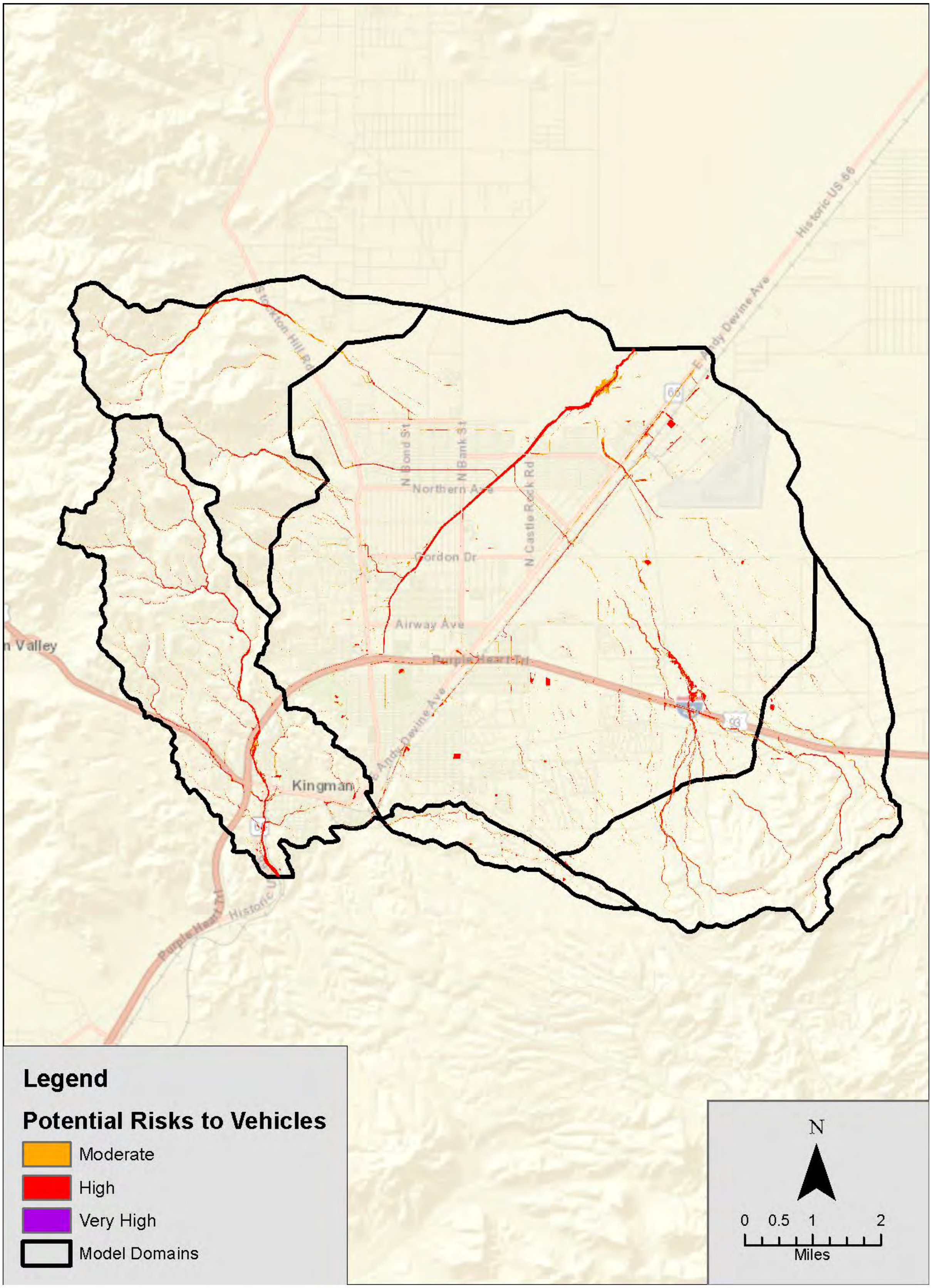

Figure 2-16. Flooding Hazards to Passenger Vehicles during the 100-Year, 6-Hour Event

2.5.3.3 Flooding Hazards to Structures

Potential hazards to buildings were classified using the depth-velocity relationship from TM 11. The depth-velocity relationship from TM 11 is shown as Figure 2-17. The following three categories exist for potential flood hazards to structures:

- *Low*: Buildings that have contact with at least one FLO-2D grid element that has a depth-velocity relationship corresponding to the low danger zone in Figure 2-18 have been designated as having a low potential flood hazard.
- *Moderate*: Buildings that have contact with at least one FLO-2D grid element that has a depth-velocity relationship corresponding to the judgment danger zone in Figure 2-18 have been designated as having a moderate potential flood hazard.
- *High*: Buildings that have contact with at least one FLO-2D grid element that has a depth-velocity relationship corresponding to the high danger zone in Figure 2-18 have been designated as having a high potential flood hazard.

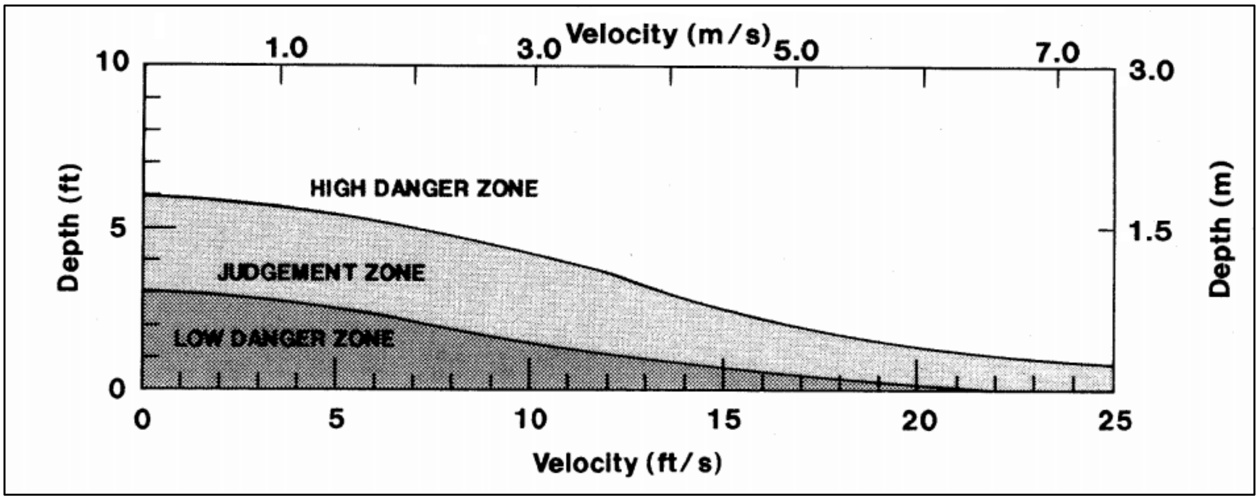

Figure 2-17. Depth-Velocity Flood Danger Level Relationship for Structures Built on Foundations (U.S. Department of the Interior, Bureau of Reclamation, 1988)

The flood hazard layer was intersected with a polygon shapefile containing all the buildings in the watershed using GIS software tools. The procedure is to first create a raster from the building polygon shapefile, then check if the centroid of any grid from the building raster intersects a grid from the flood hazard layer. If it does, that hazard classification is assigned to the building polygon in an attribute table. If a building intersects the hazard layer multiple times, the maximum hazard classification is assigned to the building. Buildings with less than 600 square feet (mostly secondary outbuildings) were not considered because they were assumed to be uninhabited due to their size. The result is a building polygon shapefile with a hazard attribute classifying low, moderate, or high flood hazards. Figure 2-19 shows buildings classified as having a low or moderate potential hazard. There were no buildings classified as having high potential hazard within the study area.

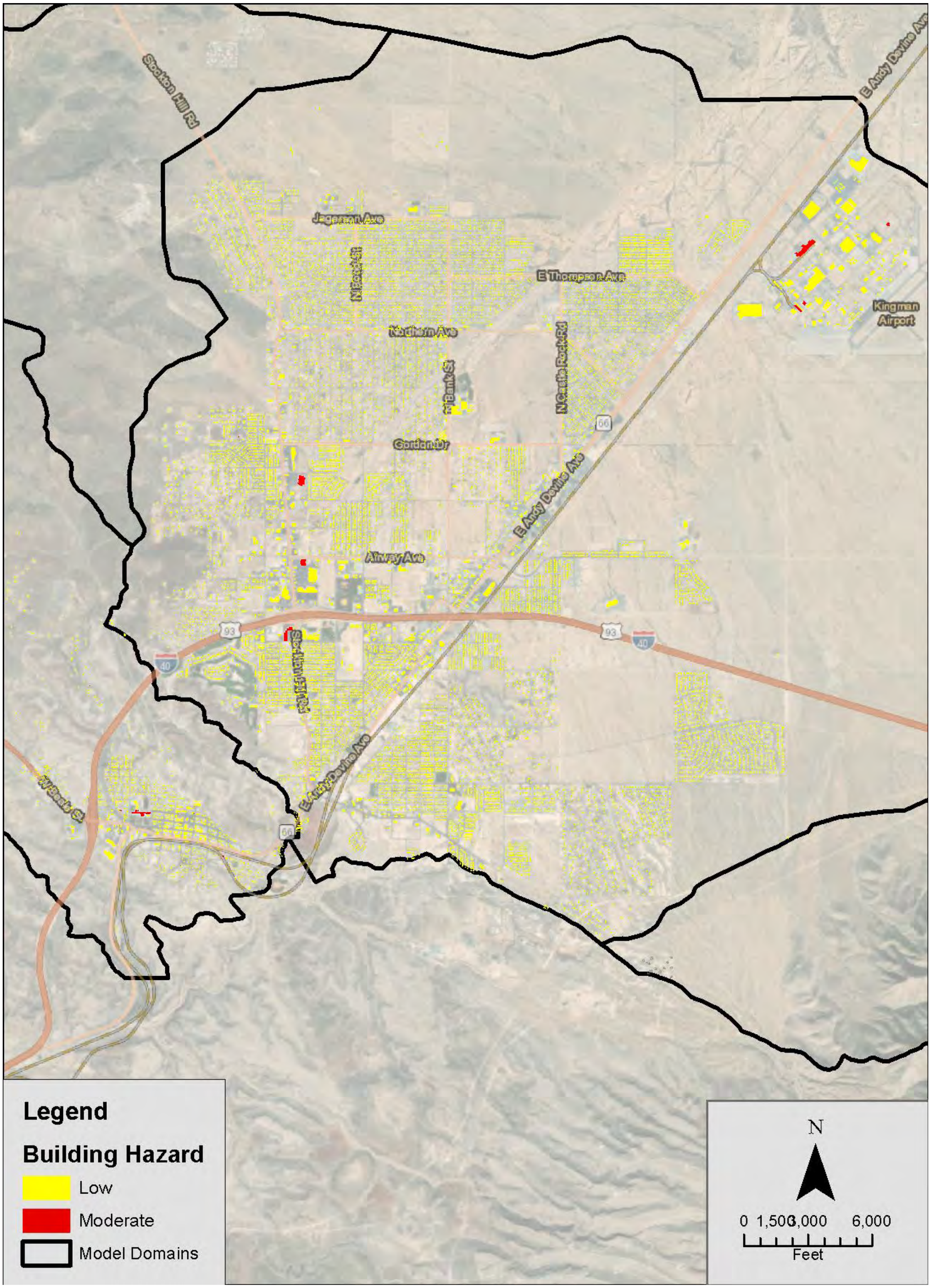

Figure 2-18. Building Flooding Hazard Classification for the 100-Year, 6-Hour Event

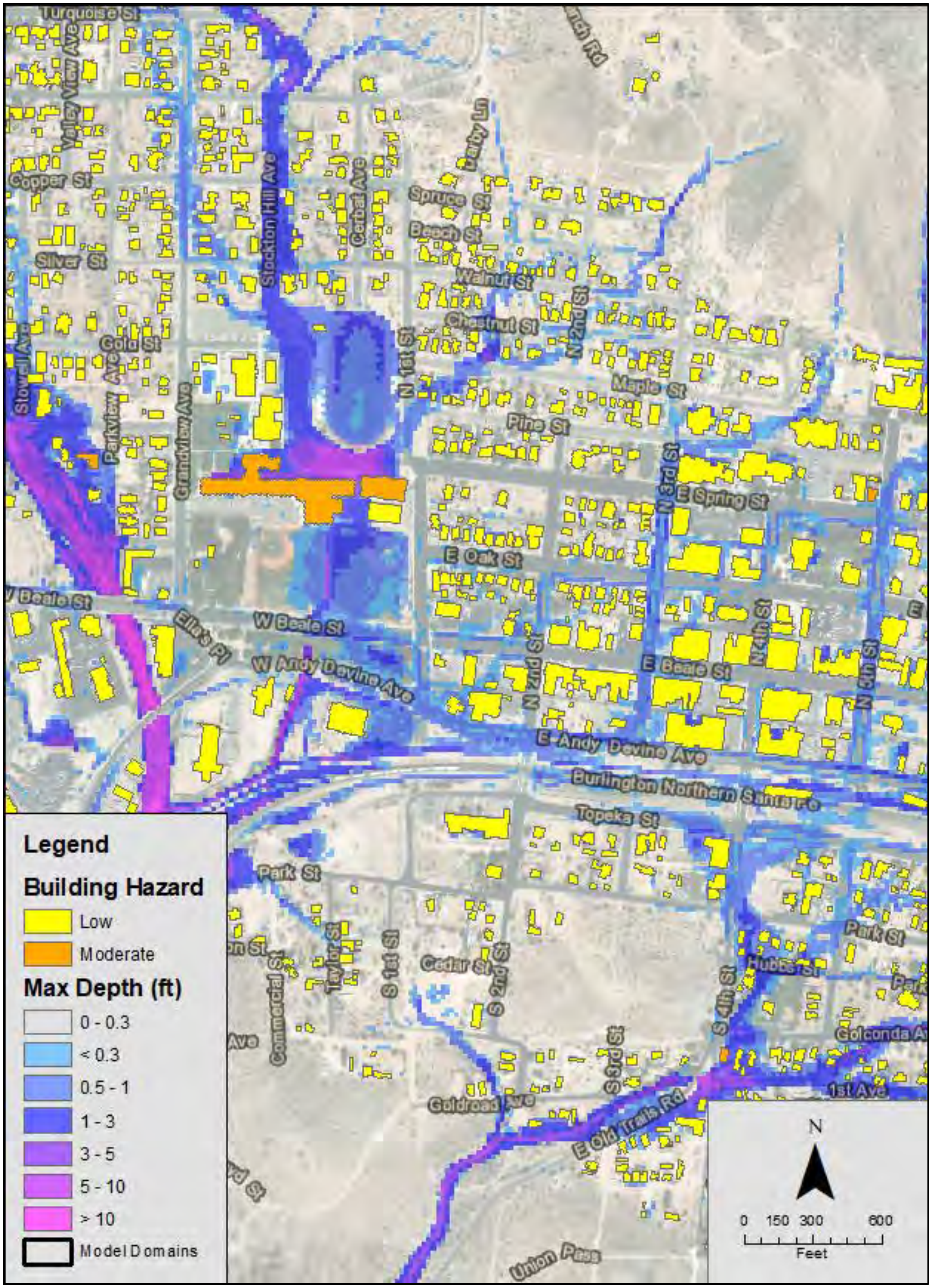

Figure 2-19. Building Flooding Hazard Classification Example in the Beale Model for the 100-Year, 6-Hour Event

2.5.4 Verification of Results

To validate the FLO-2D peak flows and check that the infiltration and overland storage estimates were reasonable, the FLO-2D results were compared with the 100-year regional regression equations provided by the United States Geological Survey (USGS) Scientific Investigations Report (SIR) 2014-5211 (Paretti, Kennedy, Turney, & Veileux, 2014).

USGS developed a method for estimating flood peak discharges for ungauged sites on watercourses in the Southwestern US by using regional regression equations. The regression equations were developed for five regions in Arizona. The project site is located within Region 3 (Western Basin and Range) according to the mapping provided in the reference. The regression equations for the study area require two variables: drainage area and mean annual precipitation 100-year peak discharge (Q_{100yr}), and can be expressed as:

$$Q_{100\mathrm{yr}} = 183 \times A^{0.516} \times P^{0.812} \qquad (2)$$

where:

A is drainage area (square mile)

P is mean annual precipitation (inches)

For this study, total mean annual precipitation data for the sub-basins were collected from 30-Year Normal developed by PRISM Climate Group (2018). The normals are baseline datasets describing average annual conditions over the most recent three full decades (1981-2010).

The sixteen locations that were used in the comparison are shown in Figure 2-20, while the results are shown in Table 2-8. As seen in Table 2-8, the FLO-2D results are generally higher than the results from the two regression equations. To better view the data with discharge results that were used in developing the regression equations, the FLO-2D results were plotted with the USGS's frequency curve for 100-year return period and Crippen Envelope curve for Region 3 (shown in Figure 2-21). In the figure, Crippen Envelope Curve represents the largest flood that can be expected in a period comparable to the period of record.

Figure 2-21 shows that the FLO-2D results are generally below the envelope curves for the study area. However, in most cases, the FLO-2D results are greater than the Q_{100yr} derived from the regression equation. In general, the results are in line for smaller drainage areas but become more conservative (i.e., larger) as the drainage area increases excepting C1. These results are consistent with previous studies (JE Fuller / Hydrology & Geomorphology, Inc., 2013) and show that the infiltration and overland storage estimates are reasonable.

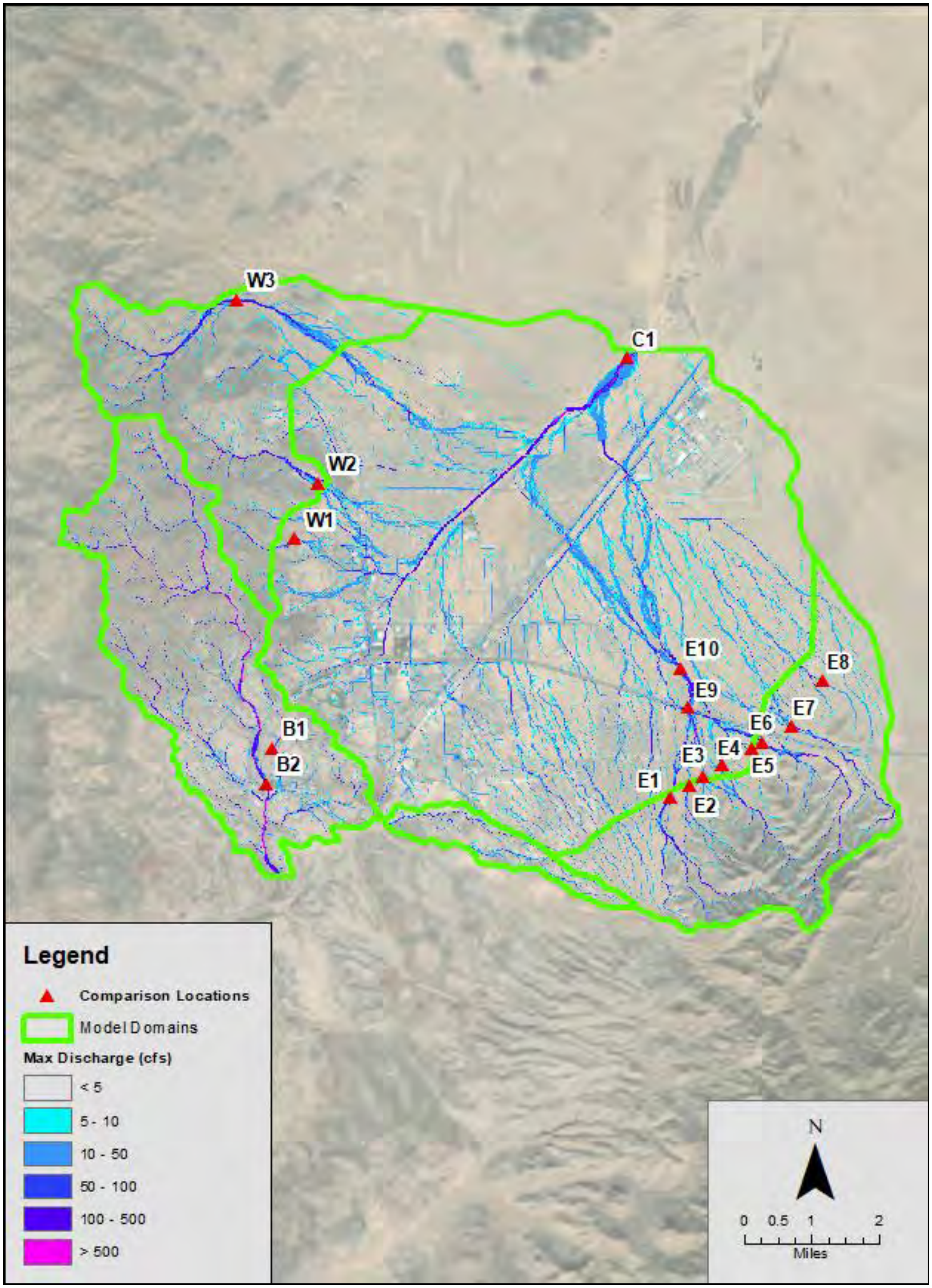

Figure 2-20. Locations for Comparison with Regional Regression Equations

Table 2-8. Comparison with 100-Year Regional Regression Equations

Location ID	*A* (mi^2)	*P* (in)	Q_{100yr} Regression Equation (cfs)	$Q_{100\ yr}$ FLO-2D (cfs)
B1	0.59	10.19	921	1,013
B2	6.86	11.35	3,553	7,309
W1	0.51	10.36	863	1,006
W2	1.92	11.11	1,808	3,118
W3	3.25	11.90	2,511	4,546
E1	1.67	12.10	1,806	2,935
E2	0.61	10.98	990	1,200
E3	1.32	11.25	1,510	1,207
E4	0.12	10.72	424	503
E5	0.15	10.72	471	279
E6	1.93	10.96	1,794	2,316
E7	1.04	11.06	1,315	1,157
E8	0.22	10.37	565	244
E9	4.22	10.98	2,691	4,112
E10	7.48	10.72	3,547	4,991
C1*	65.04	9.34	9,680	9,560

*With a drainage area greater than 20 mi^2, the 24-hour storm event would most likely control for ID C1. The 24-hour storm event was not simulated in this study.

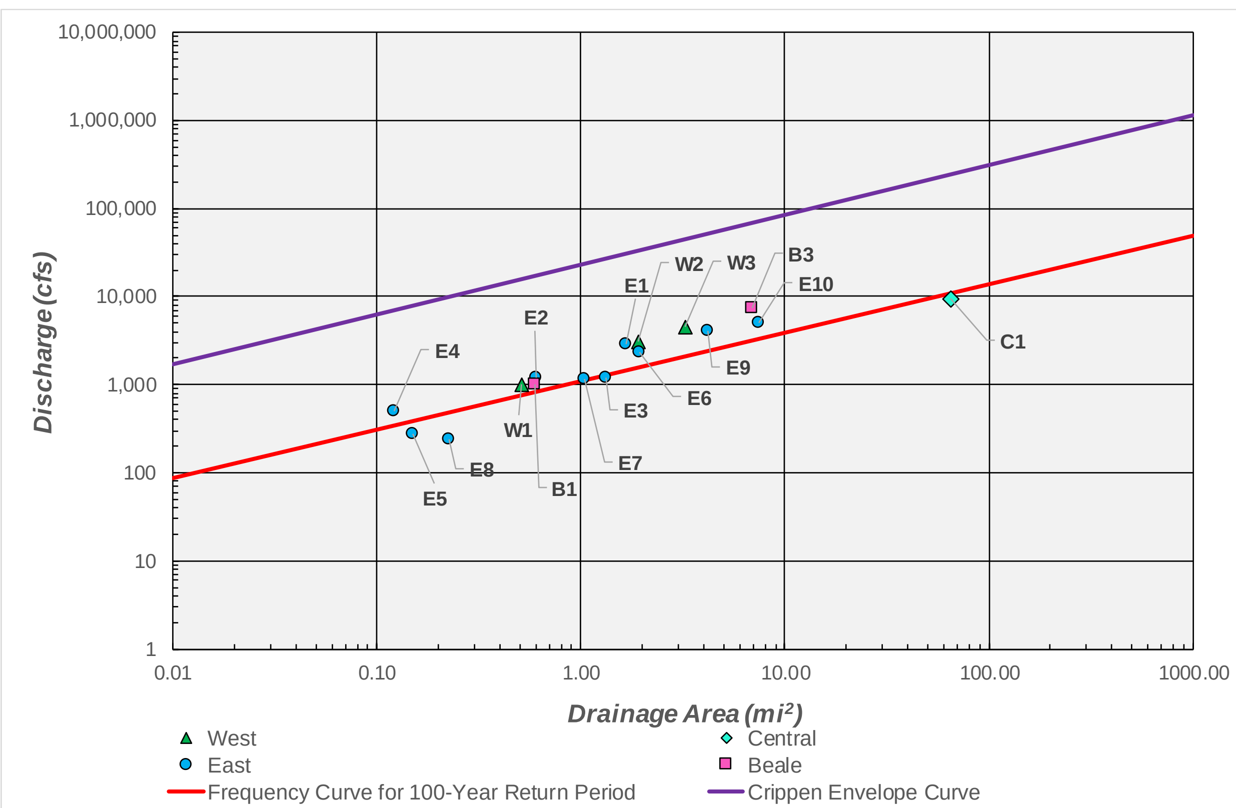

Figure 2-21. 100-Year Peak Discharge Relation for Flood Region 3 with FLO-2D Results

2.5.5 Modeling Summary

The existing conditions FLO-2D models were created using the best available information for land cover, land use, topography, and hydrology. Every effort was made to ensure the models represented existing conditions as of the date of the LiDAR survey and NextMAP DTM. Like all models, the KADMP FLO-2D models are a simulation of potential conditions that could occur during a range of storm events. The models cannot duplicate actual, observed storm events at all locations within the community due to the vast number of variables that change with each unique storm event.

The modeling results reflect a complex suite of flooding hazards that exist within the KADMP study area. The results provide valuable, quantitative, detailed information from which future planning and development decisions can be based.

The existing conditions models also serve as a foundation from which potential mitigation alternatives can be assessed.

Although the KADMP FLO-2D modeling effort was not intended to replicate an actual historical flood event, the comparison of the modeling results with USGS regression equations indicate the project FLO-2D models suitably depict storm runoff conditions, which is an indicator that model input parameters are reasonable. Given the distributary nature of the flooding within the community, flooding characteristics (depth, discharge, location) are likely to change from one flood event to the next. Even small anthropogenic changes to the landscape (e.g. dirt piles, berms, construction of outbuildings, landscaping debris piles, etc.) will result in sediment accumulation, channel scour, and changes in flow path directions that may not be represented in the project FLO-2D modeling. In other words, the results of the modeling represent potential flooding conditions as of the date of the project topographic mapping. Updated mapping and FLO-2D modeling are recommended if major changes to the landscape occur in the future.

3 CONCEPTUAL SOLUTION DEVELOPMENT AND RANKING

3.1 INTRODUCTION AND PURPOSE

An important element to any area drainage master plan is an assessment of potential mitigation alternatives. The previous sections of this report described the overall watershed setting, discussed the development of offsite and onsite hydrology, explained the development and results of two-dimensional hydraulic modeling, and outlined flooding hazards for pedestrians, vehicles, and structures. In summary, all the analyses leading up to this section have identified the locations and magnitudes of flooding and sedimentation hazards for a range of frequency storms. Identifying the hazards is a critical first step. The second step is to evaluate potential drainage solutions that could mitigate the hazards.

Conceptual solutions were developed through a multi-step process that involved the following steps:

Detailed descriptions of the steps shown in Figure 3-1 are included in Sections 3.2 – 3.5 below.

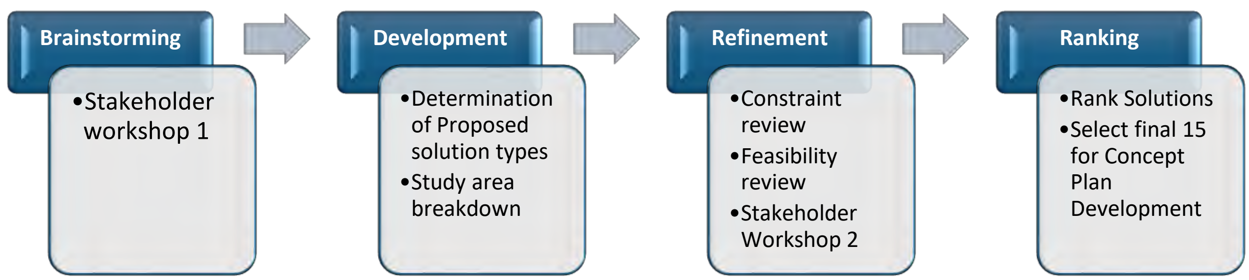

Figure 3-1. Solution Development

3.2 CONCEPTUAL SOLUTION BRAINSTORMING

During the conceptual solution brainstorming process, the study area was split into seven (7) areas (see Figure 3-2):

- Area 1 – Old Downtown
- Area 2 - New Kingman
- Area 3 – Hualapai
- Area 4 – Airway
- Area 5 - Andy Devine
- Area 6 - Stockton Hill Road
- Area 7 - North Kingman

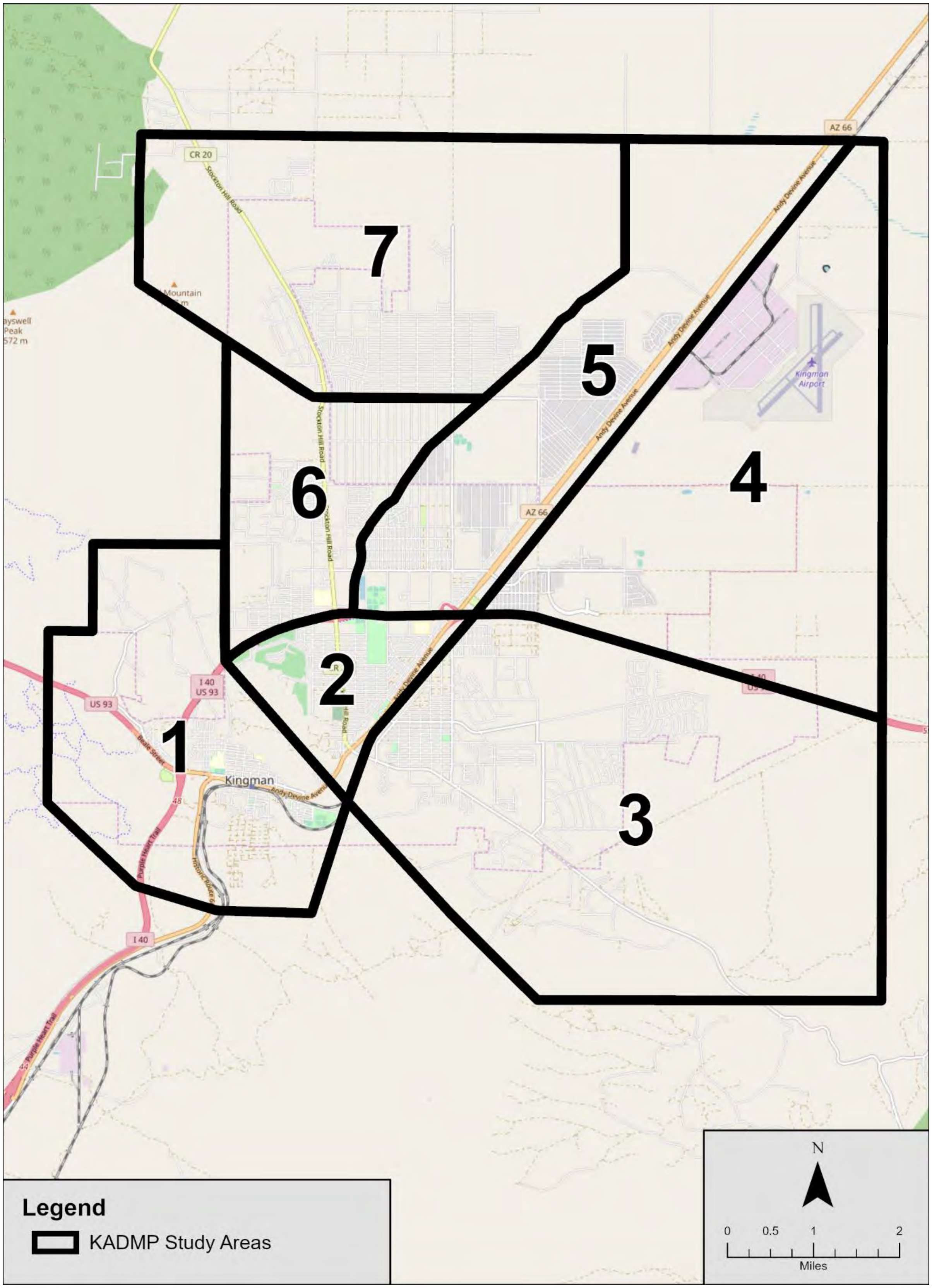

Figure 3-2. KADMP Study Areas for Concept Solution Development

3.2.1 Workshop 1

The initial stakeholder workshop was held on November 20 and 21, 2019 in the City of Kingman and was designed to address the following questions:

- What are the major drainage problems?
- Where are the major problem areas?
- What are some ways to address them?

During this workshop, the stakeholders were asked to think about solutions from different perspectives, large-scale, green infrastructure, maintenance, conveyance, access, emergency restrictions, etc.

From this initial stakeholder meeting, issue and potential solution areas were identified throughout the study areas. This information provided the basis of conceptual solution development.

3.3 Conceptual Solution Development

3.3.1 Proposed Solution Types

For each of the solutions the project team assessed, the design, feasibility, benefit, and applicability was considered. This information was then summarized on individual concept solution exhibits that were presented to the stakeholders.

Each of the types of solutions shown in Figure 3-3 were assessed as part of the KADMP:

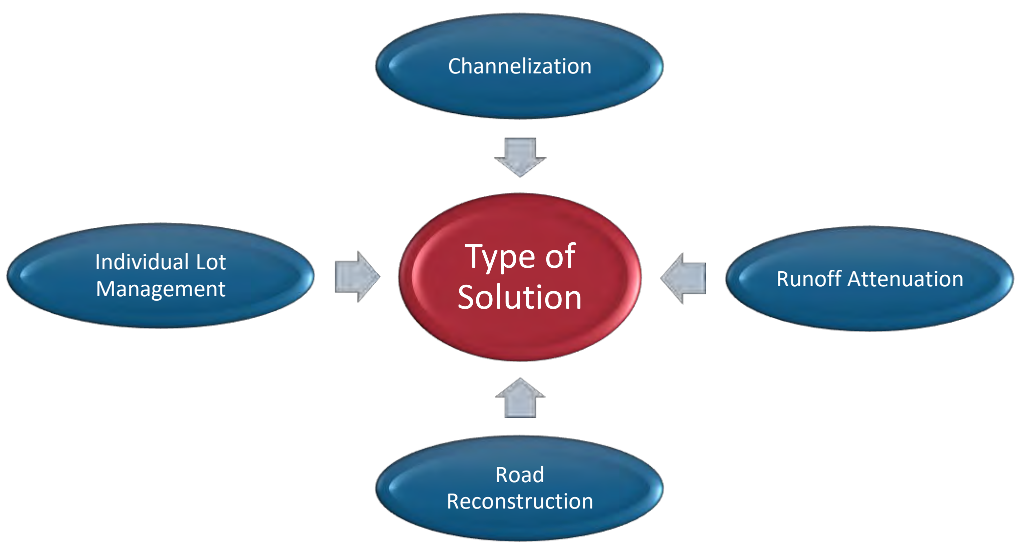

Figure 3-3. Solution Type Consideration

- **Individual Lot Management** – This concept explored whether flooding hazards within the community could be mitigated though implementation of an individual lot management plan rather than regional mitigation structures.
- **Roadway Conveyance** – This analysis was performed to determine maximum allowed roadway conveyance with inverted crowns or normal crowns.
- **Channelization** – This analysis identified interceptor channels and conveyance channels that could be implemented to reduce flooding.

- **Runoff Attenuation** – This analysis explored the potential reduction in flooding and sedimentation hazards through construction of a series of Infiltration/retention basins or detention basins.

3.3.2 Study Area Breakdown

After the types of solutions were determined, the project team prepared eighty-seven (87) solution sheets for each individual potential solution to share with the stakeholders. Table 3-1 contains a comprehensive list of the potential solutions organized by study area. Appendix C includes descriptions of all solutions.

Table 3-1. Eighty-Seven (87) Conceptual Solutions in each Area of KADMP Study

Solution Number	Solution Name
Area 1 – Old Downtown	
1	City Land Basins
2	Channelize Clack Canyon Channel
3	White Cliffs Detention
4	Stockton Hill Avenue Stormdrain (High School Stormdrain)
5	Maple Street Stormdrain
6	3rd Street Reconstruction
7	Stockton Hill Avenue Retention
8	Detention Upstream of 8th Street
9	South Downtown Channelization
10	Southside Park Retention/Detention
11	4th Avenue Basin
12	Beale Street Stormdrain
13	Spring Street Crossing
Area 2 – New Kingman (I-40 S)	
1	Golf Course Retention
2	Miami Street Stormdrain Extension
3	Main Street Stormdrain Extension
4	Fairgrounds Boulevard Stormdrain
5	Andy Devine Retention
6	Harrison Street Stormdrain Extension
7	Fairgrounds Detention
8	Post Office Area Curb and Gutter
9	Harrison Street Detention
10	Cemetery Detention
11	Neighborhood Road Reconstruction
Area 3 – Hualapai	
1	Harrod Avenue Basin Upgrades
2	Cherokee Street Regional Channel
3	Hualapai Neighborhood Improvements
4	Louise Avenue Zuni Bowls
5	Southern Vista Drainage Improvements
6	Franklin Drive/Eastern Street Reconstruction

Solution Number	Solution Name
7	I-40 Regional Retention
8	Dry Wells - Green Hole and School basins
9	Southern Avenue/Eastern Street Reconstruction and Stormdrain
10	Yavapai Drive Improvements
11	Apache Drive Improvements
12	Eastern Street Improvements
13	Railroad Diversion Channel
14	BLM Basins
15	State Land Channel
16	State/City Land Master Plan
17	Southern Avenue Erosion Protection
18	Hualapai Mountain Road Retention
19	Cherokee Street Basin
Area 4 – Airway	
1	Airway Avenue Retention
2	Airway Drainage
3	Airport Berm Reinforcement/Channel
4	Prospector Channel Outlet
5	Rattlesnake Regional Retention
6	Rattlesnake Wash Drainage Master Plan
7	Heather Ave Dry Wells
8	Castle Rock Channel
9	Berry Collector Channel
10	Hualapai Medical Center Dry Wells
11	TI Drainage Improvements
12	Berry Road Basin
Area 5 – Andy Devine	
1	Pinal Street Basin
2	Airway Basin
3	Harrison Basin
4	Kino Avenue Basin
5	Bank Street Channel
6	Diagonal Channel Improvements
7	Mohave Channel DCR for Future Extension
8	High School Retention Basin
Area 6 – Stockton Hill	
1	Anson Smith Road Collector Channel
2	Anson Smith Basin
3	Harvard Street Improvements
4	Harvard/Sycamore Basins
5	Western Avenue Stormdrain
6	State Land Basins

Solution Number	Solution Name
7	Vista Basin
8	Lower Crestwood Channel
9	Canyon Hills Road Reconstruction and Downstream Channel
10	Bull Mountain Channel
11	BLM Basins
12	Gordon Basin
13	Riata Valley Neighborhood Road Reconstruction
14	West Basin
15	Walleck Ranch Stormdrain
16	Hospital Basin
Area 7 – North Kingman	
1	College Trails Channel Reinforcement
2	Grace Neal Channel
3	Stockton Hill Channel
4	Camelback Basin
5	Camelback Channel
6	Shane Channel
7	Devlin Channel Lining
8	Suffock Channel

Figure 3-4 through Figure 3-10 show all of the conceptual solutions within each of the seven (7) study areas.

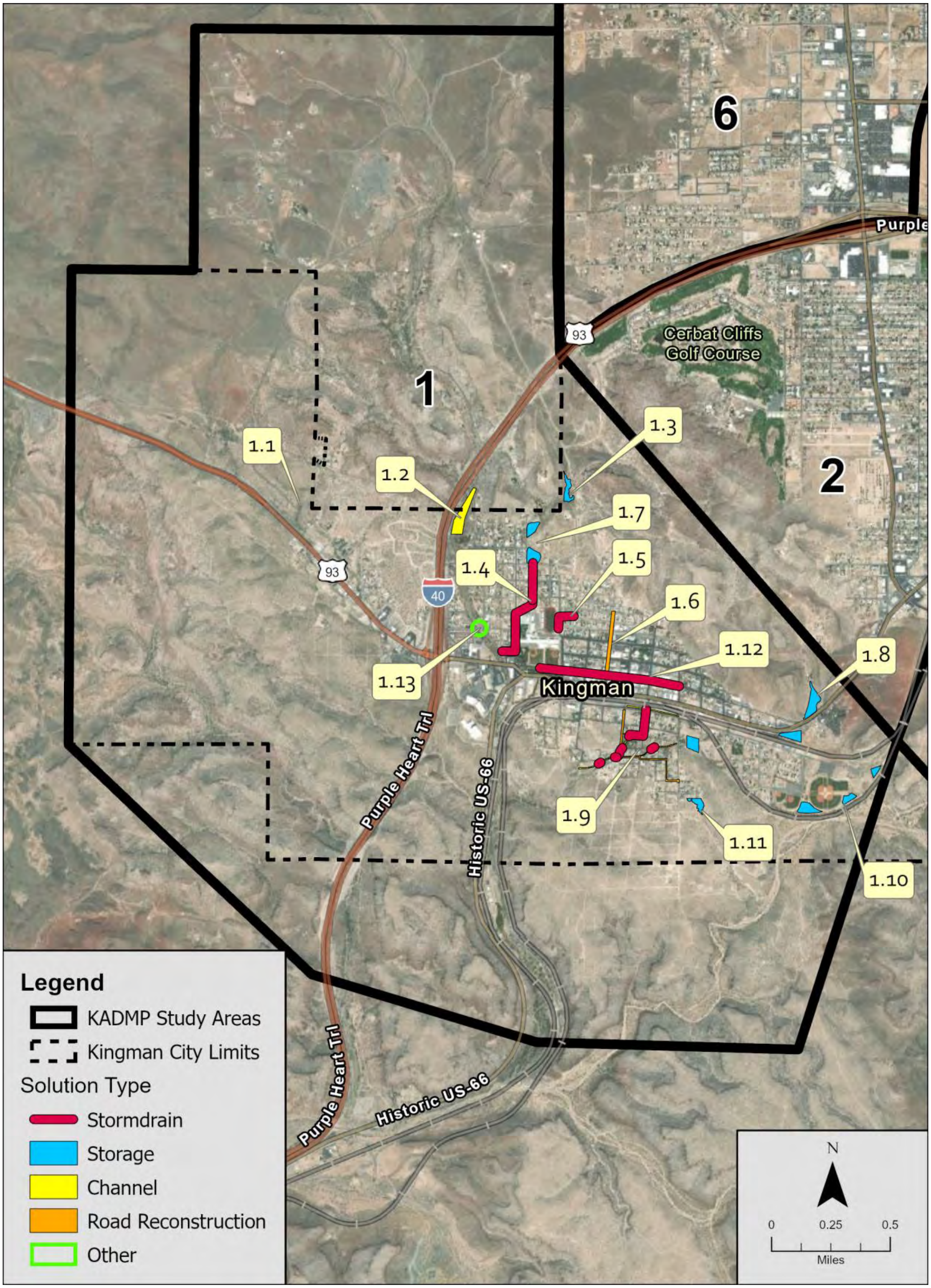

Figure 3-4. Study Area 1 with Initial Conceptual Solutions

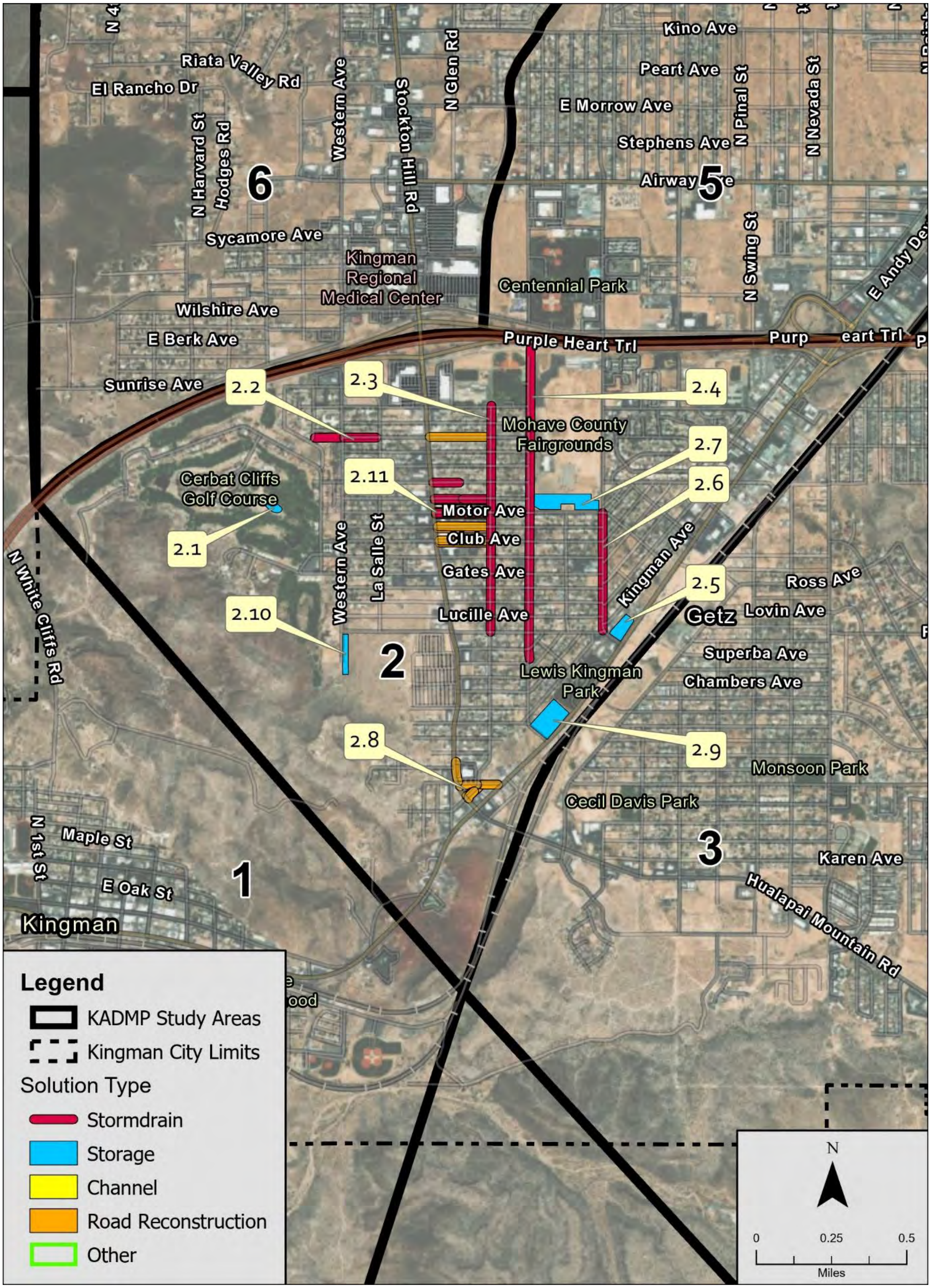

Figure 3-5. Study Area 2 with Initial Conceptual Solutions

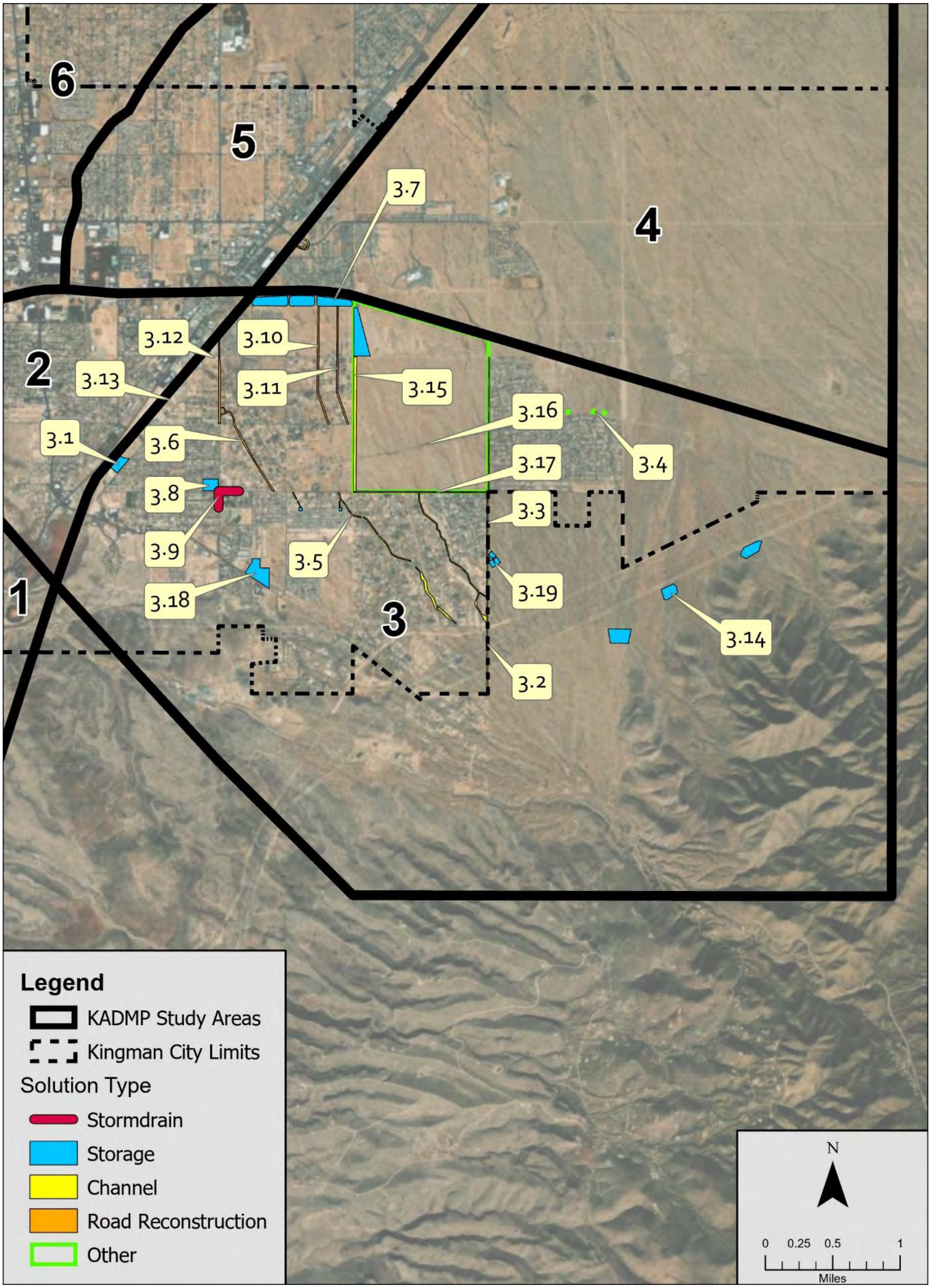

Figure 3-6. Study Area 3 with Initial Conceptual Solutions

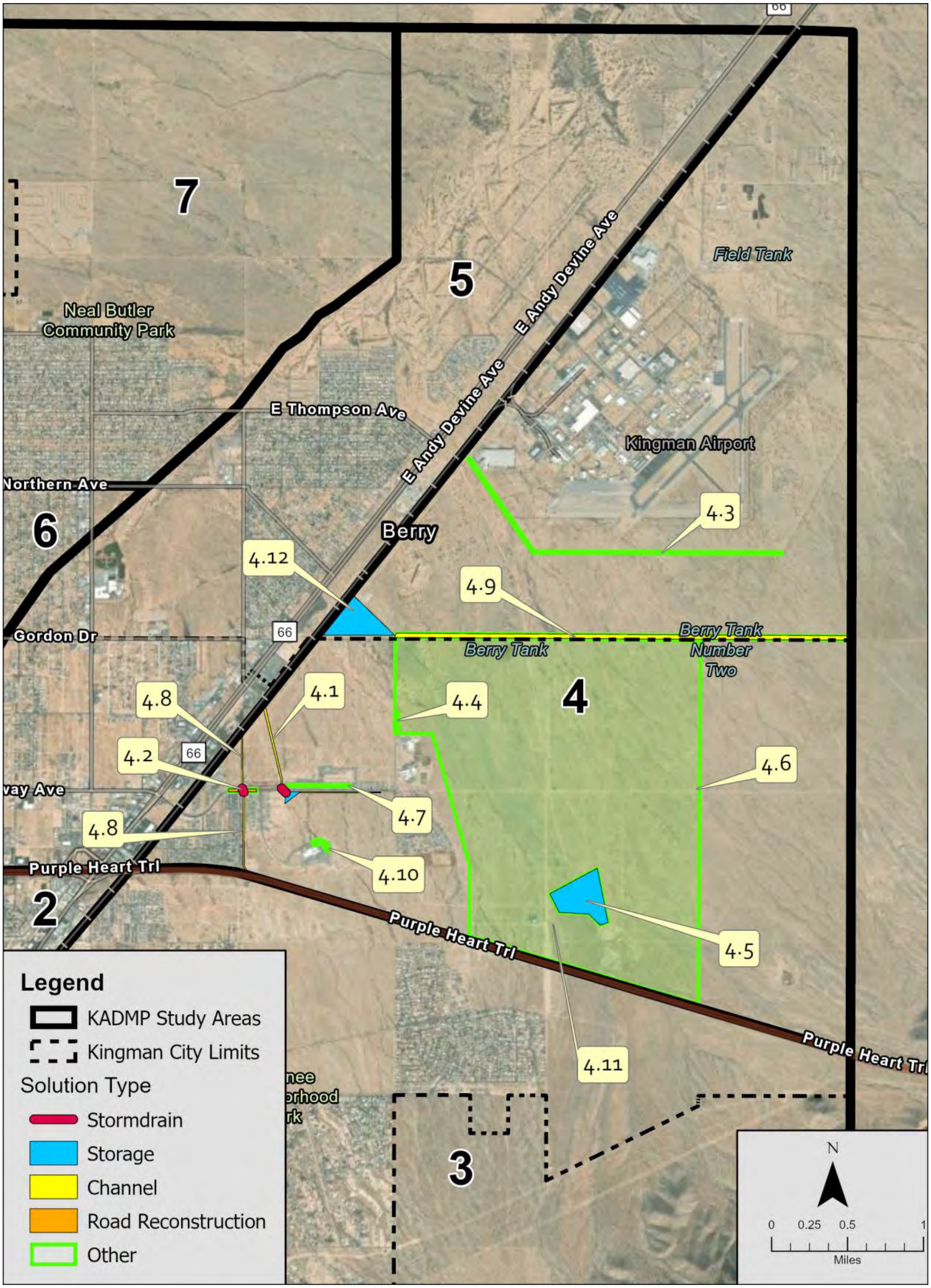

Figure 3-7. Study Area 4 with Initial Conceptual Solutions

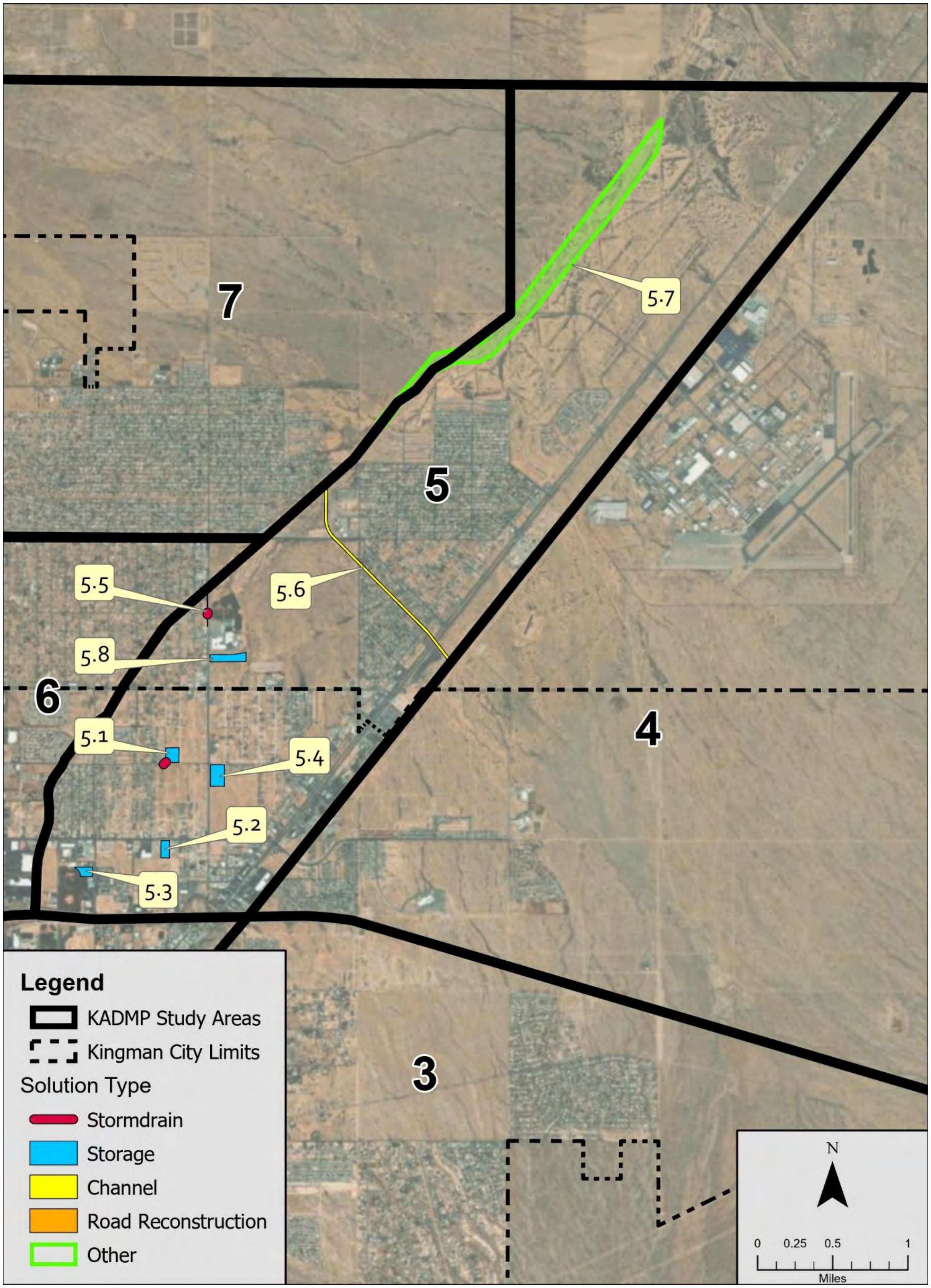

Figure 3-8. Study Area 5 with Initial Conceptual Solutions

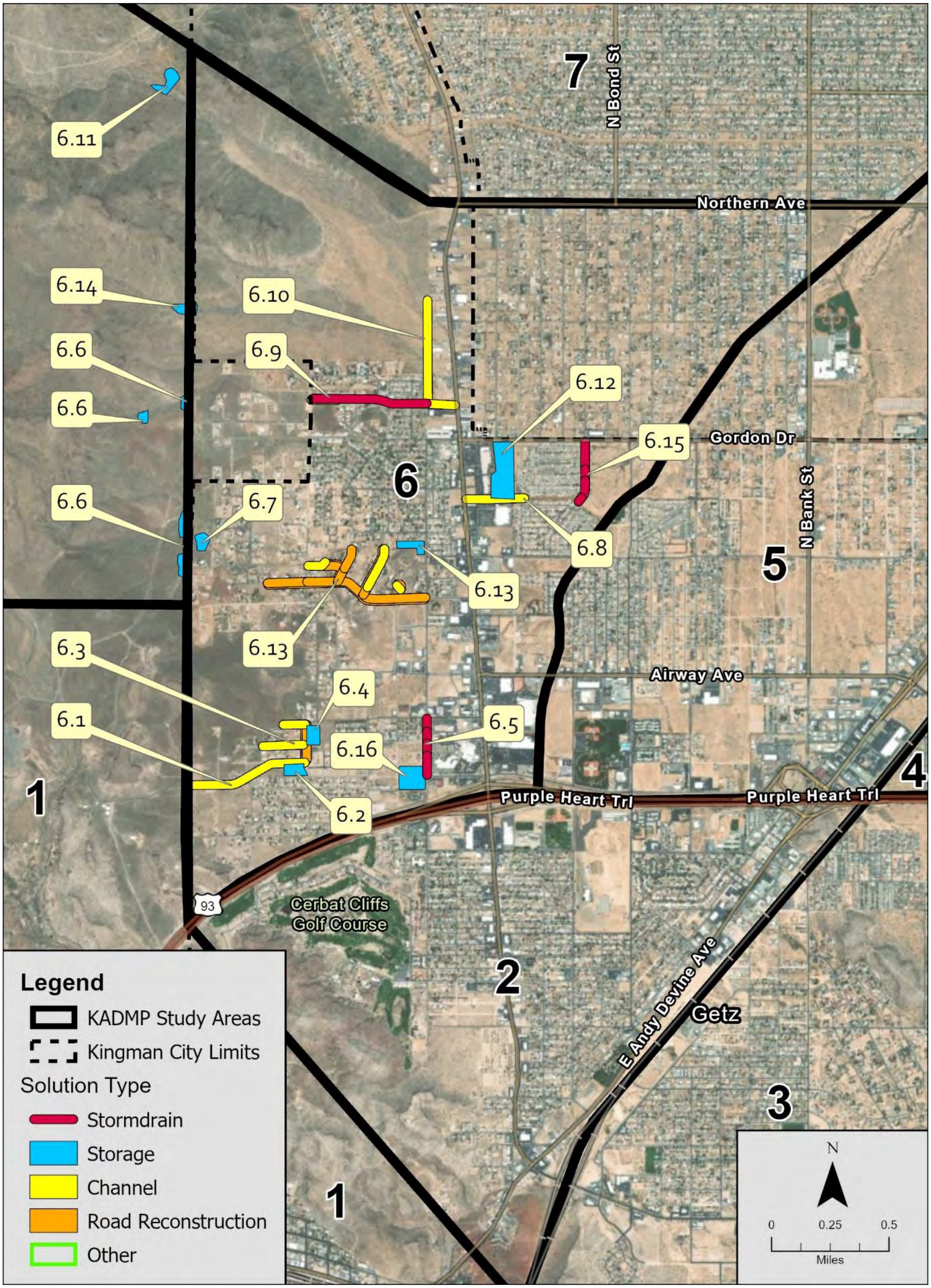

Figure 3-9. Study Area 6 with Initial Conceptual Solutions

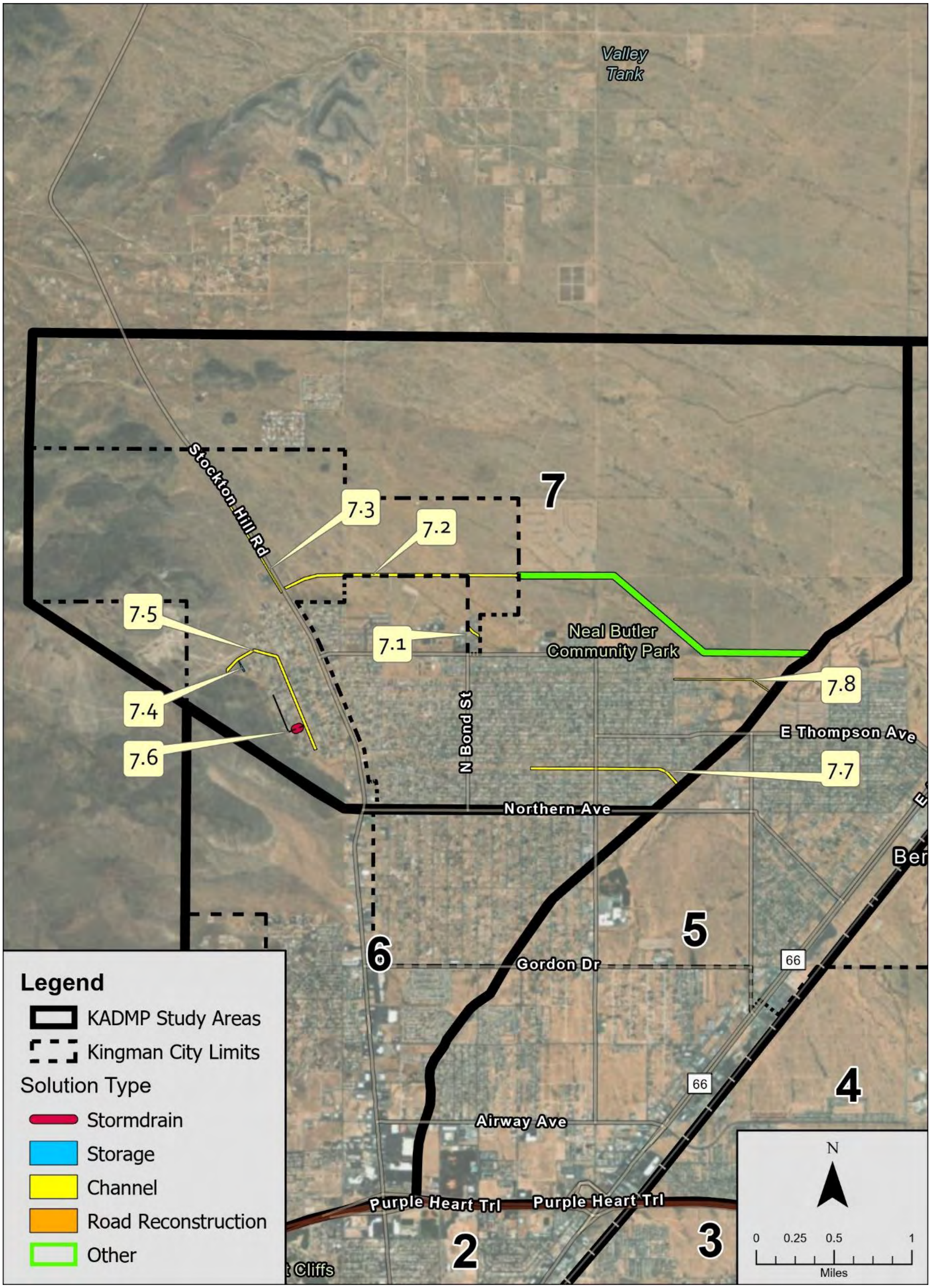

Figure 3-10. Study Area 7 with Initial Conceptual Solutions

3.3.3 Workshop 2

A second stakeholder workshop occurred on January 23, 2020. During this meeting, stakeholders were asked to review the eighty-seven (87) solution sheets that were prepared by the project team after the initial workshop in November 2019. They were then tasked to develop ranking criteria to help select the most reasonable and feasible solutions with which to proceed forward into planning.

To adequately consider each potential solution, the project team needed to answer several questions:

- Does the solution adequately mitigate a current problem?
- Does the solution provide flood protection for homes or critical facilities?
- Does the solution improve emergency access?
- Does the solution reduce high vehicle risk?
- Does the solution reduce high building risk?
- Does the solution reduce pedestrian risk?
- What is the existing land ownership?

The process of solution selection included project workshops with the team, analysis of existing drainage complaints, and current existing conditions flood modeling. Based on answers and ideas generated during the second workshop with the project team, forty-eight (48) solutions were selected to move forward to a numerical ranking process (see Table 3-2).

Table 3-2. Refined Forty-Eight (48) Solutions Selected for Ranking in each Area of KADMP Study

Solution Number	Solution Name
Area 1 – Old Downtown	
4	Stockton Hill Avenue Stormdrain (High School Stormdrain)
8	Detention Upstream of 8th Street
9	South Downtown Channelization
10	Southside Park Retention/Detention
11	4th Avenue Basin
Area 2 – New Kingman (I-40 S)	
1	Golf Course Retention
2	Miami Street Stormdrain Extension
3	Main Street Stormdrain Extension
4	Fairgrounds Boulevard Stormdrain
6	Harrison Street Stormdrain Extension
10	Cemetery Detention
11	Neighborhood Road Reconstruction
Area 3 – Hualapai	
1	Harrod Avenue Basin Upgrades
2	Cherokee Street Regional Channel
3	Hualapai Neighborhood Improvements
5	Southern Vista Drainage Improvements
7	I-40 Regional Retention
8	Dry Wells - Green Hole and School Basins
12	Eastern Street Improvements
13	Railroad Diversion Channel

Solution Number	Solution Name
15	State Land Channel
16	State/City Land Master Plan
Area 4 – Airway	
1	Airway Avenue Retention
8	Castle Rock Channel
9	Berry Collector Channel
12	Berry Road Basin
Area 5 – Andy Devine	
1	Pinal Street Basin
2	Airway Basin
3	Harrison Basin
4	Kino Avenue Basin
5	Bank Street Channel
Area 6 – Stockton Hill	
1	Anson Smith Road Collector Channel
2	Anson Smith Basin
3	Harvard Street Improvements
4	Harvard/Sycamore Basins
5	Western Avenue Stormdrain
6	State Land Basins
7	Vista Basin
8	Lower Crestwood Channel
10	Bull Mountain Channel
11	BLM Basins
12	Gordon Basin
14	West Basin
16	Hospital Basin
Area 7 – North Kingman	
2	Grace Neal Channel
4	Camelback Basin
5	Camelback Channel
6	Shane Channel

3.4 Conceptual Solution Refinement

3.4.1 Solution Constraint and Feasibility Review

The project team conducted a constraint review and a feasibility review for each of the forty-eight (48) conceptual solutions that was developed during the stakeholder meetings and brainstorming sessions. Some of the many factors that were considered during these reviews are presented in Figure 3-11. These reviews were designed to compile enough information to successfully support the concept solution ranking process that is described in Section 3.5.1.

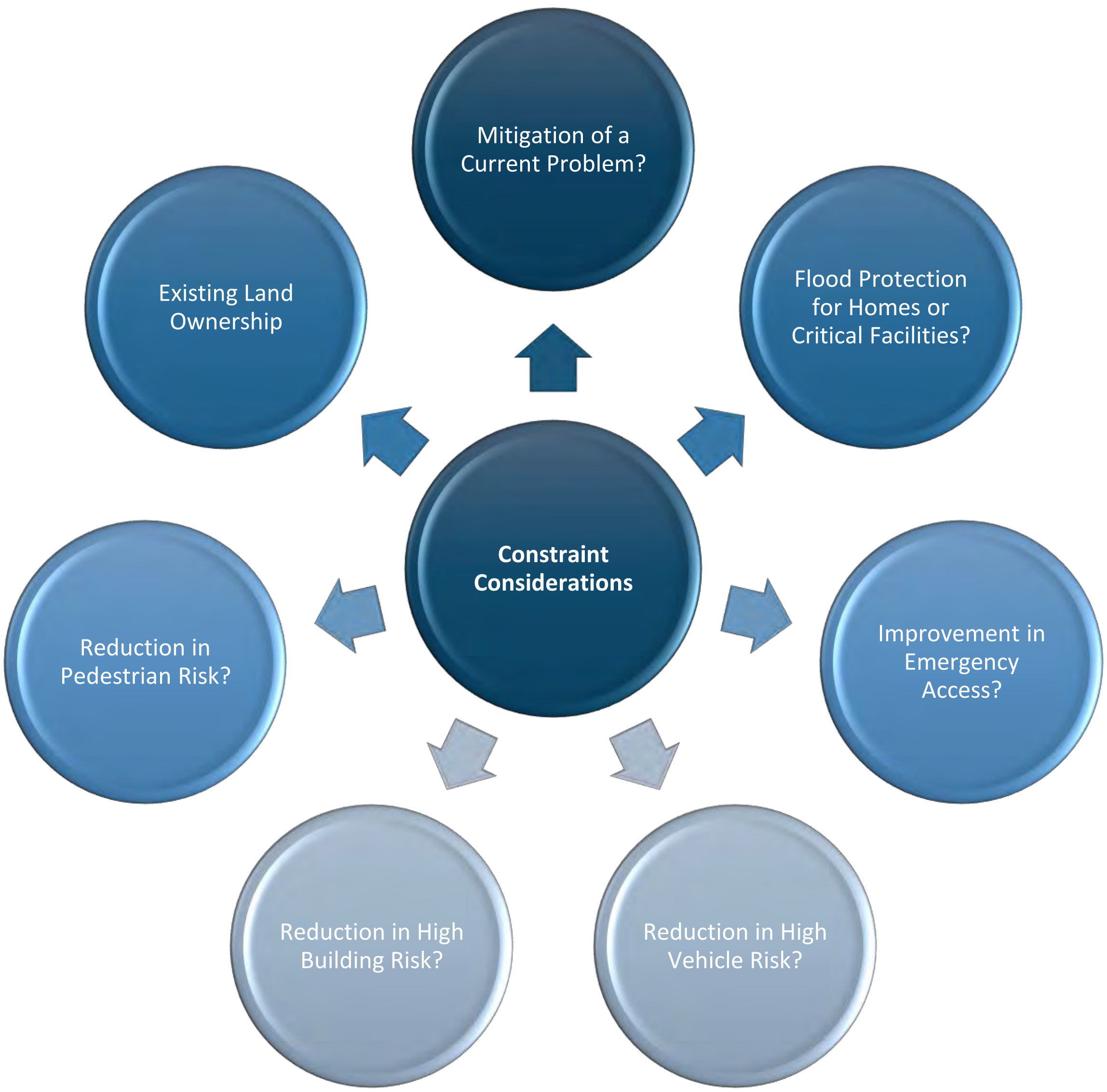

Figure 3-11. Solution Constraint Considerations

3.5 CONCEPTUAL SOLUTION RANKING

3.5.1 Solution Ranking Process

While each of the solutions would have provided some level of benefit to the community and can be used as a reference for future projects, the team was tasked with identifying fifteen (15) concept solutions to slate for preliminary engineering design and eventually development. The numerical ranking process included an evaluation of each drainage solution for its benefit to the community. A generalized summary of the ranking criteria is noted below:

- Urgency – How urgent is the solution based on hazards or funding issues?
- Severity – How severe is the flooding in relation to public safety, people, or structures?
- Feasibility – Will it be difficult to implement in terms of support and complexity? Does it benefit long term maintenance efforts?
- Community Benefits – Does the solution improve the quality of life in Kingman? Does the solution provide for groundwater recharge opportunities?

The stakeholder group was tasked with ranking the potential solutions based on solution ranking criteria that was developed during the stakeholder meeting that occurred on January 23, 2020. All solutions were assigned a score of 0 to 10 for each category and those scores were summed and weighted per Table 3-3 to determine a final score from 0 to 100.

Table 3-3. Conceptual Solution Score Weighting.

		Feasibility		**Community Benefit**	
Urgency	**Severity**	Implementation	Long-Term Maintenance	Quality of Life	Groundwater Recharge Benefits
Weight = 30	Weight = 25	Weight = 15	Weight = 15	Weight = 10	Weight = 5

During the solution ranking period, there was a total of 14 stakeholder respondents including six (6) from the City of Kingman, three (3) from Mohave County, and five (5) from JE Fuller. The scores were summed and averaged, and the solutions were ranked as shown in Table 3-4. Considering the ranking and overall benefit to the City, the City of Kingman Engineering Department made the final selection of the highlighted solutions in Table 3-4 to proceed forward with into concept solution development.

Table 3-4. Conceptual Solution Ranking Selections.

Solution Number	Drainage Solution	Rank
Area 1 - Old Downtown		
1.4	Stockton Hill Avenue Stormdrain (Grandview Ave Stormdrain)	23
1.8	Detention Upstream of 8th Street	9
1.9	South Downtown Channelization	36
1.10	Southside Park Retention/Detention	25
1.11	4th Avenue Basin	16
Area 2 - New Kingman (I-40 S)		
2.1	Golf Course Retention	47
2.2	Miami Street Stormdrain Extension	45
2.3	Main Street Stormdrain Extension	18
2.4	Fairgrounds Boulevard Stormdrain	21
2.6	Harrison Street Stormdrain Extension	37
2.10	Cemetery Detention	44
2.11	Neighborhood Road Reconstruction	20
Area 3 - Hualapai		
3.1	Harrod Avenue Basin Upgrades	14
3.2	Cherokee Street Regional Channel	42
3.3	Hualapai Neighborhood Improvements	31
3.5	Southern Vista Drainage Improvements	24
3.7	I-40 Regional Retention	3
3.8	Dry Wells - Citywide	34
3.12	Eastern Street Improvements	11
3.13	Railroad Diversion Channel	12
3.15	State Land Channel	46
3.16	State/City Land Master Plan	43
Area 4 - Airway		
4.1	Airway Avenue Retention	38
4.8	Castle Rock Channel	41
4.9	Berry Collector Channel	40
4.12	Berry Road Basin	27
Area 5 - Andy Devine		
5.1	Pinal Street Basin	26
5.2	Airway Basin	33
5.3	Harrison Basin	32
5.4	Kino Avenue Basin	39
5.5	Bank Street Channel	48
Area 6 - Stockton Hill		
6.1	Anson Smith Road Collector Channel*	30
6.2	Anson Smith Basin*	2
6.3	Harvard Street Improvements**	17
6.4	Harvard/Sycamore Basins**	6
6.5	Western Avenue Stormdrain	5

Solution Number	Drainage Solution	Rank
6.6	State Land Basins	15
6.7	Vista Basin	7
6.8	Lower Crestwood Channel	35
6.10	Bull Mountain Channel	1
6.11	BLM Basins	13
6.12	Gordon Basin	19
6.14	West Basin	22
6.16	Hospital Basin	4
Area 7 - North Kingman		
7.2	Grace Neal Channel	8
7.4	Camelback Basin	29
7.5	Camelback Channel	28
7.6	Shane Channel	10

* Solutions 6.1 (Anson Smith Road Collector Channel), and 6.2 (Anson Smith Basin) are combined to be one solution.
** Solutions 6.3 (Harvard Street Improvements), and 6.4 (Harvard/Sycamore Basins) are combined to be one solution.

3.5.2 Final Conceptual Solution Selection

As shown in Table 3-4, there was a total of 21 solutions identified, several of which were combined as noted to be a single solution. Solutions 1.4 and 1.8 were renamed to describe their locations more-appropriately. Three of the solutions (3.12 – Eastern Street Improvements, 3.13 – Railroad Diversion Channel, and 6.10 – Bull Mountain Channel) have been designed previously and will not be re-designed as a part of this area drainage master plan. Solution 3.8 – City Wide Drywells will serve as a placeholder for potential drywell projects across the City and a specific design will not be developed for this solution. A summary of the excluded solutions is presented at the end of Section 4.

The fifteen (15) solutions listed in Table 3-5 were the final selected solutions that were officially moved forward with into conceptual design planning during Phase 3 of the KADMP.

Table 3-5. Final Conceptual Solution Selections.

Solution Number	Drainage Solution
1.4	Grandview Avenue Stormdrain *(formerly named Stockton Hill Avenue Stormdrain)*
1.8	Detention Upstream of Andy Devine *(formerly named Detention Upstream of 8th Street)*
1.11	4th Avenue Basin
2.3	Main Street Stormdrain Extension
2.4	Fairgrounds Boulevard Stormdrain
3.1	Harrod Avenue Basin Upgrades
3.7	I-40 Regional Retention
5.1	Pinal Street Basin
6.1/6.2	Anson Smith Road Collector Channel and Basin
6.3/6.4	Harvard Street Improvements and Basin
6.5	Western Avenue Stormdrain
6.7	Vista Basin
6.8	Lower Crestwood Channel
7.2	Grace Neal Channel
7.6	Shane Channel

Conceptual design plan summaries for each of these solutions are provided in Section 4 of this report. They are listed in their order of appearance in Table 3-5.

4 CONCEPTUAL PLAN SUMMARIES

Conceptual design plans have been developed for each of the fifteen (15) solutions selected in Section 3. The purpose of the plan development is to determine solution feasibility, proposed design elements, potential planning level construction costs, and future design and implementation considerations.

Each of the Conceptual Plan summaries include the following sections:

*Problem description - S*ummarizing the need for the solution

Summary of Solution – Discussing the primary design elements and overall intent

Future Planning Considerations – Items that should be investigated during the final design of the solution. This includes a summary of the biological and cultural desktop evaluations that were completed for each solution. Full biological and cultural reports are included in Appendix D.

Refer to Appendix E for the conceptual plans prepared for each solution. Some items to note for each solution are below:

- The solutions are drawn based on the 2016 LiDAR data and aerial imagery. Individual detailed field surveys have not been completed.
- Each plan has been drawn to approximately a 15% level and show the main design elements. Each of these elements must be verified and fully designed if a solution is to move forward. In addition, the plans do not fully detail every design element required for each solution and those must be developed if a solution moves forward.
- Typically, property impacts are not shown or quantified and must be fully investigated.
- An adverse impact analysis has not been completed. This analysis should be completed for each solution if it moves forward to design.

4.1 GRANDVIEW AVENUE STORMDRAIN

4.1.1 Problem Description

There are several flood hazard zones in the area which converge upon the Lee Williams High School (LWHS) campus creating potential safety and maintenance issues with debris removal and cleanup. Upstream of the high school at the intersection of Turquoise St. and Hibbert Ave., several properties adjacent to the main channel are prone to scour and have been damaged by historic flooding causing wall/foundation undermining.

The main flood zone is north of LWHS and a tributary extends northeast from the high school. The FLO-2D model shows that the approximate 100-year discharge at the north end of Stockton Hill Ave. is 1,005 cfs and 1,147 cfs at the north entrance to the high school. The approximate 10-year discharge at the north end of Stockton Hill Ave. is 252 cfs and 280 cfs at the north entrance to the high school. The northeast tributary has a 100-year discharge of 300 cfs per the FEMA FIS. The tributary flow and the main flow from the north concentrate at the high school campus and are forced into a 6 footx6 foot concrete box culvert between two of the school buildings. A drainage study for new improvements at the high school was conducted by another firm (SWI, 2010) in 2010, and the report states that the 6 footx6 foot box culvert has capacity for approximately 285 cfs.

4.1.2 Summary of Solution

This solution includes the construction of a new 100-year capacity stormdrain beginning on Hibbert Ave., north of Turquoise St. The proposed 84-inch to 96-inch stormdrain would continue south on Hibbert Ave. to Turquoise St., then south on Grandview Ave. to Oak St. where it would transition into a double barrel 8-foot by 6-foot box culvert to its outlet in Clack Canyon. The west end of Oak St. would be reconstructed and raised to allow for the stormdrain. The downstream impacts of routing the flow from Stockton Hill Ave. to Clack Canyon have not been analyzed.

See Figure 4-1 for an overview map of the Grandview Avenue Stormdrain conceptual plans.

4.1.3 Future Planning Considerations

- Outlet into Clack Canyon requires significant road reconstruction.
- Utility conflicts and significant trench depths are anticipated.
- Downstream impacts would need to be analyzed.
- FEMA coordination is expected based on changing the hydrology and potentially the hydraulics of Clack Canyon.
- If maintenance is to be provided by the City, then easements would be required for areas not within City ROWs.
- Six historic structures have been identified in close proximity to the solution area, and no cultural resource surveys have been conducted within the solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for Gila monster, Sonoran desert tortoise, burrowing owl, and freckled milkvetch.

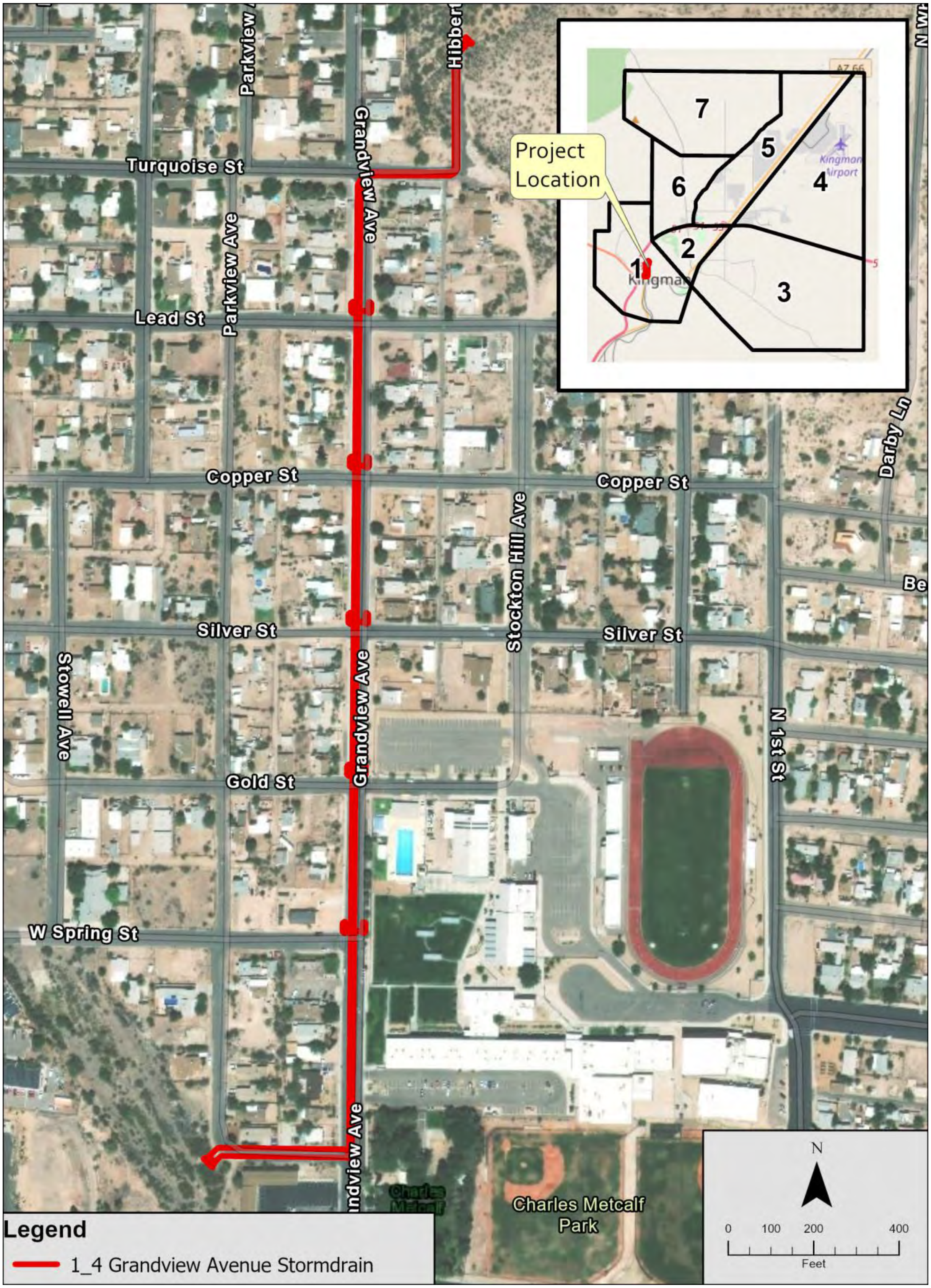

Figure 4-1. Grandview Avenue Stormdrain Solution Overview

4.2 DETENTION UPSTREAM OF ANDY DEVINE

4.2.1 Problem Description

Deep ponding of runoff at the 8th St. underpass creates a significant hazard for accessing the south side of downtown Kingman. There are three railroad crossings which provide access to this section of downtown, two at grade crossings and one underpass. The two at-grade crossings are close enough to each other where one train can block both. If an emergency occurs during a large storm, there is a potential for this section of town to be cut-off from emergency services. Ponding at the underpass also creates maintenance issues with removal of debris and damage to the roadway.

Runoff that impacts the 8th St. trestle is from a small drainage area to the north and a larger drainage area approaching from the east. The large contributing drainage from the east originates north of Andy Devine Ave. and flows under the road through a 72-inch culvert east of 8th St. Once the flow crosses Andy Devine Ave., it proceeds west towards 8th St. in the channel confined by the Burlington Northern Santa Fe (BNSF) Railroad and Andy Devine Ave.

The culvert that passes under Andy Devine Ave. currently provides some attenuation to both the 10-year and 100-year events. Under existing conditions, the 100-year inflow is 615 cfs, and outflow through the 72-inch culvert is 334 cfs. The 10-year inflow is 156 cfs, and current outflow is approximately 115 cfs.

4.2.2 Summary of Solution

The solution includes construction of an outlet structure on the north end of the 72-inch CMP under Andy Devine Ave. The outlet would be optimized for the 10-year event and in doing so would have a minimal impact on the 100-year discharge. The area north of Andy Devine Ave. currently detains approximately 1.7 acre-feet in the 10-year event and 10.3 acre-feet in the 100-year event. The proposed headwall would include a 2-foot diameter opening at the base with weir at 8.0 feet above the bottom of the basin. It would allow for approximately 14.3 acre-feet of detention in the 100-year storm. This would have the effect of reducing the 100-year peak below Andy Devine Ave. from 334 cfs to 318 cfs and the 10-year peak from 115 cfs to 40 cfs.

See Figure 4-2 for an oveview map of the Detention Upstream of Andy Devine conceptual plans.

4.2.3 Future Planning Considerations

- An inundation easement is needed to preserve the detention basin ponding area.
- The proposed ponding limits and water surface elevation needs to be compared to surveyed finished floor elevations of the upstream homes.
- This option only involves detention storage. Detention would reduce the flow rate to 8th St. but would not reduce the runoff volume.
- A Geotechnical Investigation of the Andy Devine Ave. roadway embankment for its use as a basin embankment would be required.
- Construction of a maintenance roadway may be required.
- Historic Route 66 runs immediately south of the solution area, and no cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for Gila monster, Sonoran desert tortoise, burrowing owl, and freckled milkvetch.

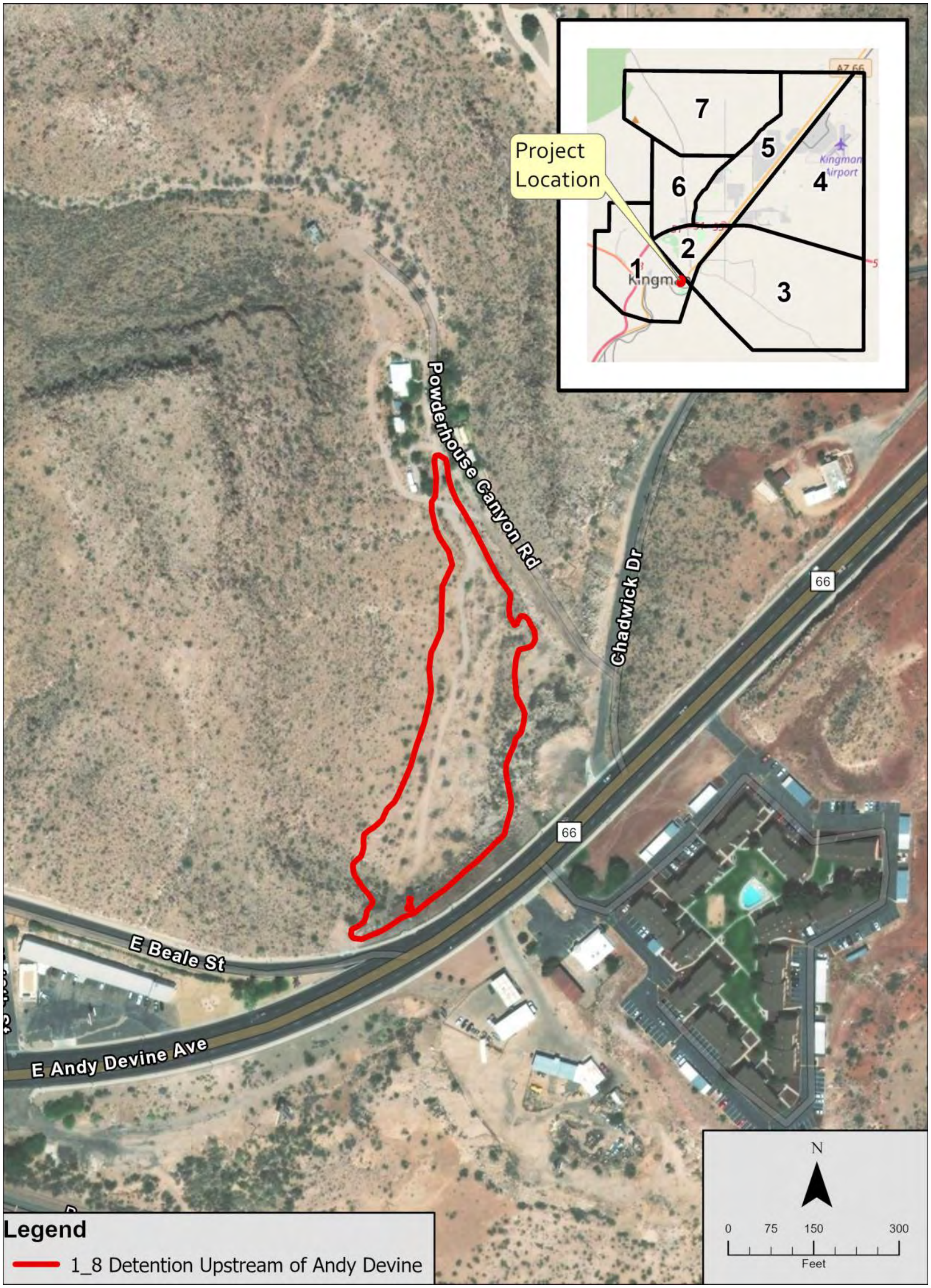

Figure 4-2. Detention Upstream of Andy Devine Solution Overview

4.3 4TH AVENUE BASIN

4.3.1 Problem Description

Runoff from a small watershed impacts the homes on 4th Ave., east of 6th St., and contributes to the regional flood problems along Old Trails Rd. The watershed drains directly into the back yard of the 4th Ave. homes and there are no conveyance channels or structures in-place to carry the runoff from 4th Ave. to Old Trails Rd.

4.3.2 Summary of Solution

This solution involves constructing a basin largely on City-owned parcels that lie north and south of 4th Ave. The basin has been designed to contain the full 100-year runoff volume by providing approximately 6.6-acre feet of storage at the 100-year pool elevation. The basin would be drained with a 12-inch outlet pipe. A spillway is designed to contain the 100-year event in the case that the basin does not drain prior to a flow event.

See Figure 4-3 for an overview map of the 4th Avenue Basin conceptual plans.

4.3.3 Future Planning Considerations

- The basin spillway outlets directly into the back yards of the homes along 4th Ave. While the basin provides storage for the 100-year event, there is inherently risk created by placing a berm and spillway upstream. An operation and maintenance plan should be developed and implemented.
- The 12-inch outlet pipe outlets into the back yard of a home along 4th Ave. The full routing of this pipe and downstream channels would need to be evaluated during the design.
- Property acquisition would be required.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for Gila monster, Sonoran desert tortoise, and burrowing owl.

Figure 4-3. 4th Avenue Basin Solution Overview

4.4 Main Street Stormdrain Extension

4.4.1 Problem Description

As a result of the existing terrain and configuration of the adjacent street network, urban runoff is directed toward Main St. such that the street serves as one of the primary conveyances for stormwater flowing north. Recent hydrologic models indicate the runoff conveyed within the Main St. traffic corridor, specifically at Main St. and Davis Ave., could be as great as 474 cfs and 134 cfs during the 100-year storm and 10-year storm events, respectively.

While an existing stormdrain, which consists of a transverse grate and 3-36-inch reinforced concrete pipes, captures runoff at the intersection of Detroit Ave. and Main St., the system does not extend to the south. As a result, the depth of flow south of Detroit Ave. and extending as far south as Robinson Ave. exceeds 1 foot, making the roadway a safety hazard. In addition, the amount of the discharge during these storms is greater than the conveyance capacity of the roadway and adjacent right-of-way, resulting in the potential flooding of homes within the surrounding neighborhoods.

4.4.2 Summary of Solution

To capture runoff upstream and mitigate the flooding hazards along Main St., the stormdrain system that terminates at Detroit Ave. and Main St. would be extended to Lucille Ave. The system would consist of 3 -36-inch reinforced concrete pipes and capture runoff via a series of roadway grates constructed within the inverted crown roadway. The required maintenance access would be provided with grated manhole covers. During small events, these grates would capture local street runoff. During the larger events, the manholes would surcharge. Grated manhole covers were selected because they do not need to be bolted to the manhole frame. The system is designed to capture the 10-year storm event. However, because of the available capacity, flow in the street and adjacent properties would be significantly reduced during the 100-year event.

See Figure 4-4 for an overview map of the Main Street Stormdrain Extension conceptual plans.

4.4.3 Future Planning Considerations

- Stub out pipes are provided south of Lucille Ave. should the City desire to extend the stormdrain further south.
- Roadway improvements and local stormdrain systems could be constructed within the local side streets (e.g. Club Ave., Motor Ave., Hope Ave.), though it is recommended that these lateral systems be designed to capture and convey the 2-year event only as the flow would be discharged into only one of the 3-pipes.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- No biological resource concerns have been identified for this solution.

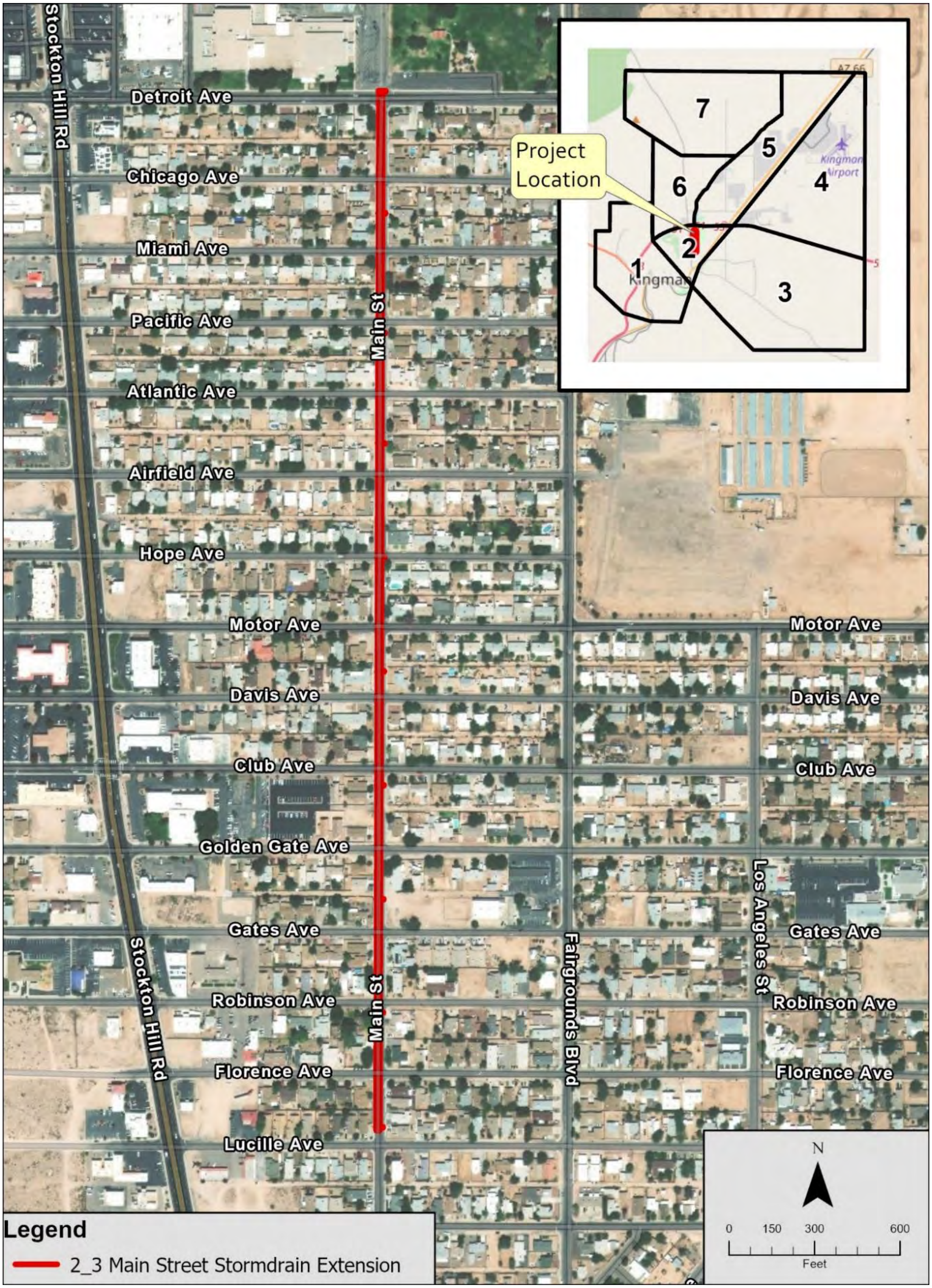

Figure 4-4. Main Street Stormdrain Extension Solution Overview

4.5 FAIRGROUNDS BOULEVARD STORMDRAIN EXTENSION

4.5.1 Problem Description

As a result of runoff generated by the watersheds south of Andy Devine Ave. and the configuration of the adjacent street network, Fairgrounds Blvd. serves as one the primary conveyances for urban runoff flowing north. Recent hydrologic models indicate that the majority of the runoff conveyed within the roadway originates from the contributing area south of Mullen Ave. At this location, the models report that the peak discharges could be as great as 278 cfs and 85 cfs during the 100-year storm and 10-year storm events, respectively.

Currently there is no subterranean conveyance under Fairgrounds Blvd., though plans for a stormdrain system extending from Detroit Ave. to the ADOT channel located north of the Firefighters Memorial Park have been completed. Due to the lack of a drainage system, the peak discharges conveyed within the right-of-way exceed 1 foot in depth, making the roadway a safety hazard. In addition, the amount of the discharge during these storms is greater than the conveyance capacity of the roadway which causes the surface flow to breakout to the west and results in the potential flooding of homes within the surrounding neighborhoods.

4.5.2 Summary of Solution

To capture runoff upstream and mitigate the flooding hazards along Fairgrounds Blvd., a stormdrain system that extends from the ADOT Channel to Sunset Blvd. is proposed. The system would consist of a single 60-inch reinforced concrete pipe, and runoff would be captured via a series of roadway grates constructed within the inverted crown roadway. The required maintenance access would be provided with grated manhole covers. During small events, these grates would capture local street runoff. During the larger events, the manholes would surcharge. Grated manhole covers were selected because they do not need to be bolted to the manhole frame. The system is designed to capture the 10-year storm event. During the 100-year event runoff in the street and onto the adjacent properties is significantly reduced.

See Figure 4-5 for an overview map of the Fairgrounds Boulevard Stormdrain Extension conceptual plans.

4.5.3 Future Planning Considerations

- Roadway improvements and local stormdrain systems could be constructed within the local side streets to reduce the flow conveyed to Main St. Because the slope of these roads is away from Fairgrounds Blvd., the design would be working against grade. The system does have sufficient fall to accommodate this fact, though it is recommended that these lateral systems should use 18 inch or 24-inch pipes.
- A basin located north of Andy Devine Ave., which could serve to capture runoff upstream of the grate at Sunset Blvd., would allow for metering the off-site runoff to levels and would allow the 100-year peak discharge to be conveyed with a combination of subsurface and surface flow.
- It is understood that transitioning from a larger pipe to a smaller pipe is a not a standard design. However, the original design of the Fairgrounds Stormdrain used a 48-inch RCP which was sufficient to accommodate the runoff calculated at this location. Because runoff is being captured upstream, additional flow is captured within the system. The additional flow facilitated the need

for a larger pipe. Because revising the existing plans was not part of this scope, the concept design used a 60-inch pipe transitioning to a 48-inch pipe.

- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- No biological resource concerns have been identified for this solution.

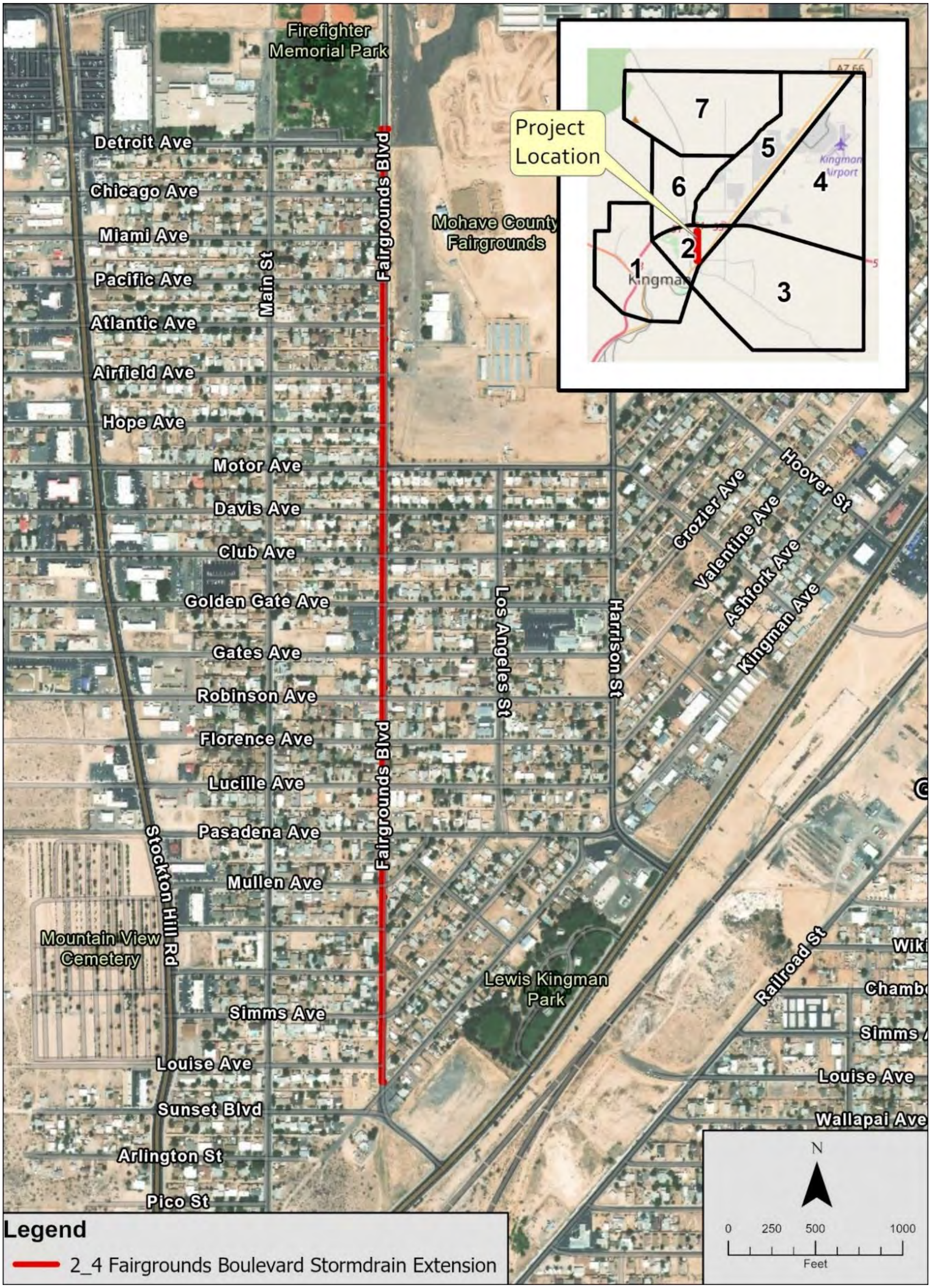

Figure 4-5. Fairgrounds Boulevard Stormdrain Extension Solution Overview

4.6 HARROD AVENUE BASIN UPGRADES

4.6.1 Problem Description

There is an existing basin northwest of Railroad St. and west of Harrod Ave., with the railroad forming the downstream outlet embankment. FLO-2D modeling and personal accounts suggest that the west basin does the bulk of the work while the east basin is not fully utilized. The outlet configuration has a single 24-inch pipe draining the west basin with a single 18-inch pipe draining the east basin. A small weir connects the basin with the weir elevation approximately 4 feet above the west outlet culvert.

4.6.2 Summary of Solution

The proposed solution would construct a weir structure upstream of the west outlet to restrict flow entering the culvert. This structure would be elevated 2 feet above the interconnecting weir so that flow enters the east basin before it flows into the culvert.

The interconnecting weir would be reconstructed to be 25 feet long and 1 foot lower than it currently is. This configuration would allow for approximately 200 cfs to flow into the east basin before it exits the west basin. This configuration should not increase the west basin water surface elevation while potentially increasing the storage volume in the east basin by 8 acre-feet and reducing the potential for the west basin to overtop its embankment.

See Figure 4-6 for an overview map of the Harrod Avenue Basin Upgrades conceptual plans.

4.6.3 Future Planning Considerations

- A site survey needs to be conducted to verify potential conflicts with the existing sewer line in the embankment.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for burrowing owl.

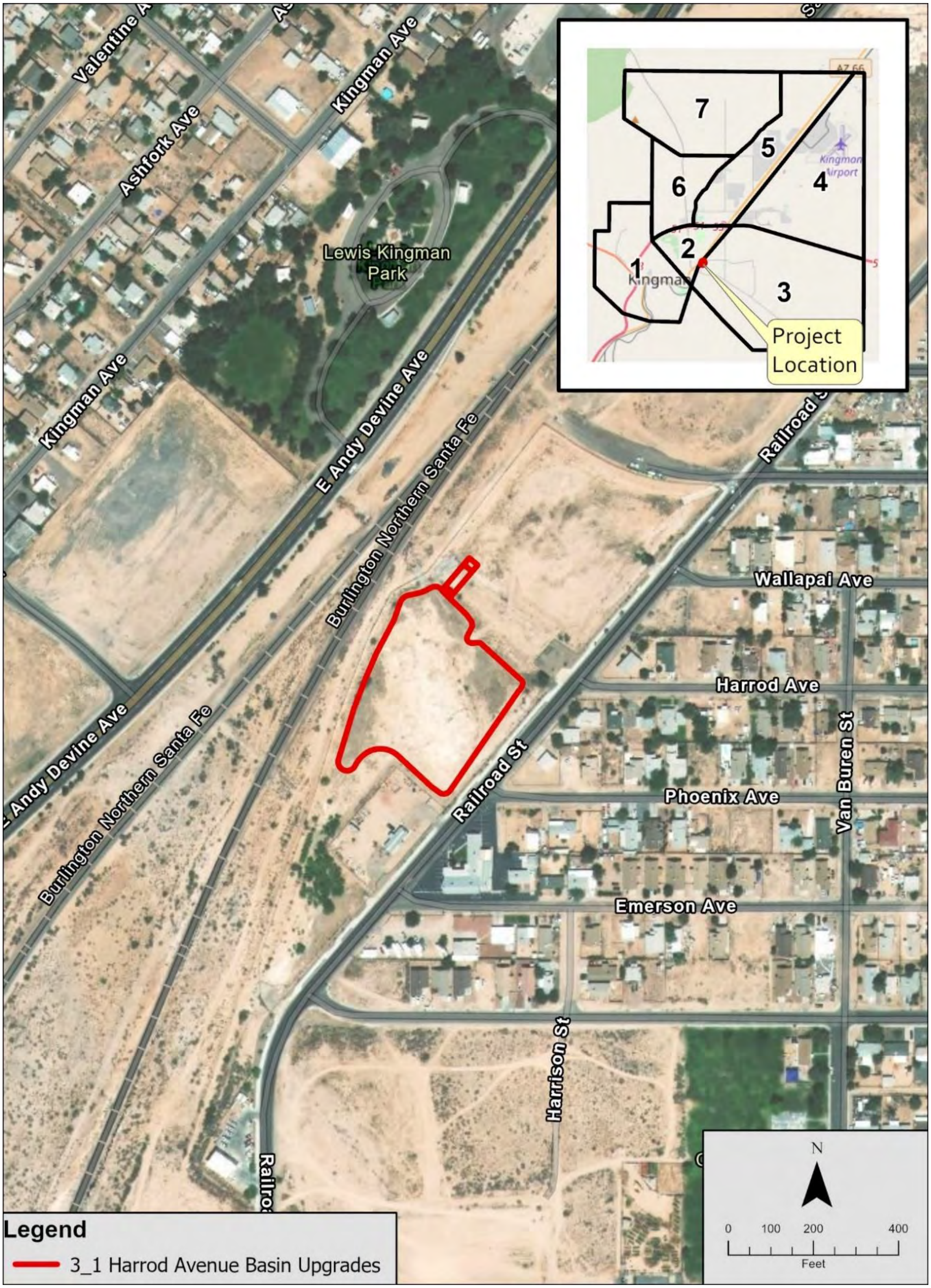

Figure 4-6. Harrod Avenue Basin Upgrades Solution Overview

4.7 I-40 Regional Retention

4.7.1 Problem Description

Several flow paths are interrupted and impounded by the I-40 alignment to the east of the railroad and west of the Castle Rock Rd. alignment. The flow patterns in this area are naturally from south to north, although the I-40 embankment produces some flow through the I-40 via culverts with overflow draining west towards Eastern Ave. and the railroad. Flow that drains north under I-40 enters residential subdivision areas with flows conveyed in the streets and in the lots. The flow that drains west along the south side of I-40 makes its way to the underpass where it is eventually captured in a channel and conveyed towards Andy Devine Ave.

In the current condition there is a strip of undeveloped land bounded by I-40 to the north, the railroad to the west, Windsor Ave. alignment to the south, and Castle Rock Rd. to the east. This strip of land is impacted by flow crossing it from the south and from impounded floodwater behind I-40.

4.7.2 Summary of Solution

This solution consists of constructing several detention/retention basins along Windsor Ave. and east of Sage St. The basins along Windsor Ave. have been previously considered as a part of the Railroad Diversion Channel and could be constructed independent of that solution to reduce flooding downstream. The basin to the east of Sage St. could be constructed in various locations and might provide a place to drain the State Land Channel and/or the Cherokee St. Channel.

See Figure 4-7 for an overview map of the I-40 Regional Retention conceptual plans.

4.7.3 Future Planning Considerations

- Basin outlet and downstream impacts need to be analyzed.
- These basins need to be coordinated with development of adjacent land.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for Gila monster, Sonoran desert tortoise, and burrowing owl.

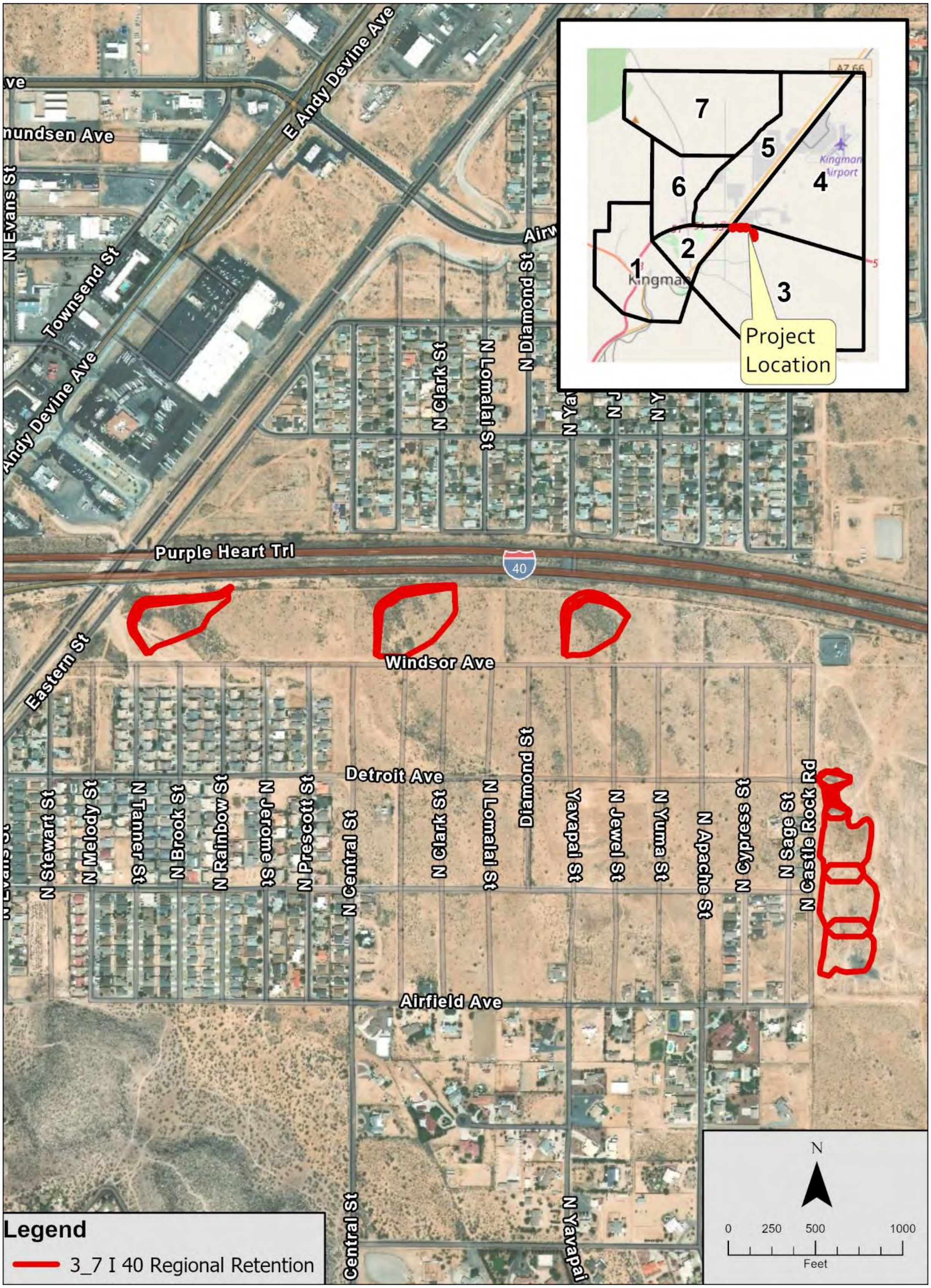

Figure 4-7. I-40 Regional Retention Solution Overview

4.8 PINAL STREET BASIN

4.8.1 Problem Description

Runoff originating south of I-40, combines with runoff from the area north of I-40 and east of Andy Devine Ave. and sheet flows north through the neighborhood. The flooding is generally shallow and based on information from the City, significant volumes of sediment can be deposited on the primary east and west roadways. At the proposed location for the Pinal Basin, the 100-year discharge is approximately 520 CFS and the 10-year is approximately 170 CFS.

4.8.2 Summary of Solution

This solution involves construction of a series of detention basins south and north of Kino Ave. The proposed location is on 7 acres of vacant, but privately owned land.

At a depth of 6 feet, there is approximately 30.1 acre-feet of storage available. Construction of the basin would include grading a 400-foot channel on the south side of Kino Ave. and the east side of Pinal St. to direct flow into a culvert crossing Kino Ave. and empty into the proposed basin.

The basin would capture most of the 10-year volume crossing Kino Ave. at this location. A second basin could also be constructed to the north providing additional storage and a location that could serve as a sediment basin that would be easily maintainable. The basins would significantly reduce the 10-year flow to be approximately 45 cfs and only slightly reduce the 100-year flow to 490 cfs. The benefits are not only a reduction in flow but also a reduction in downstream sediment collection during all events.

See Figure 4-8 for an overview map of the Pinal Street Basin conceptual plans.

4.8.3 Future Planning Considerations

- The primary benefits are related to the solution as it is not designed to retain the 100-year storm.
- Property acquisition is required.
- The basins would require maintenance after all large events to stay functional.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for burrowing owl.

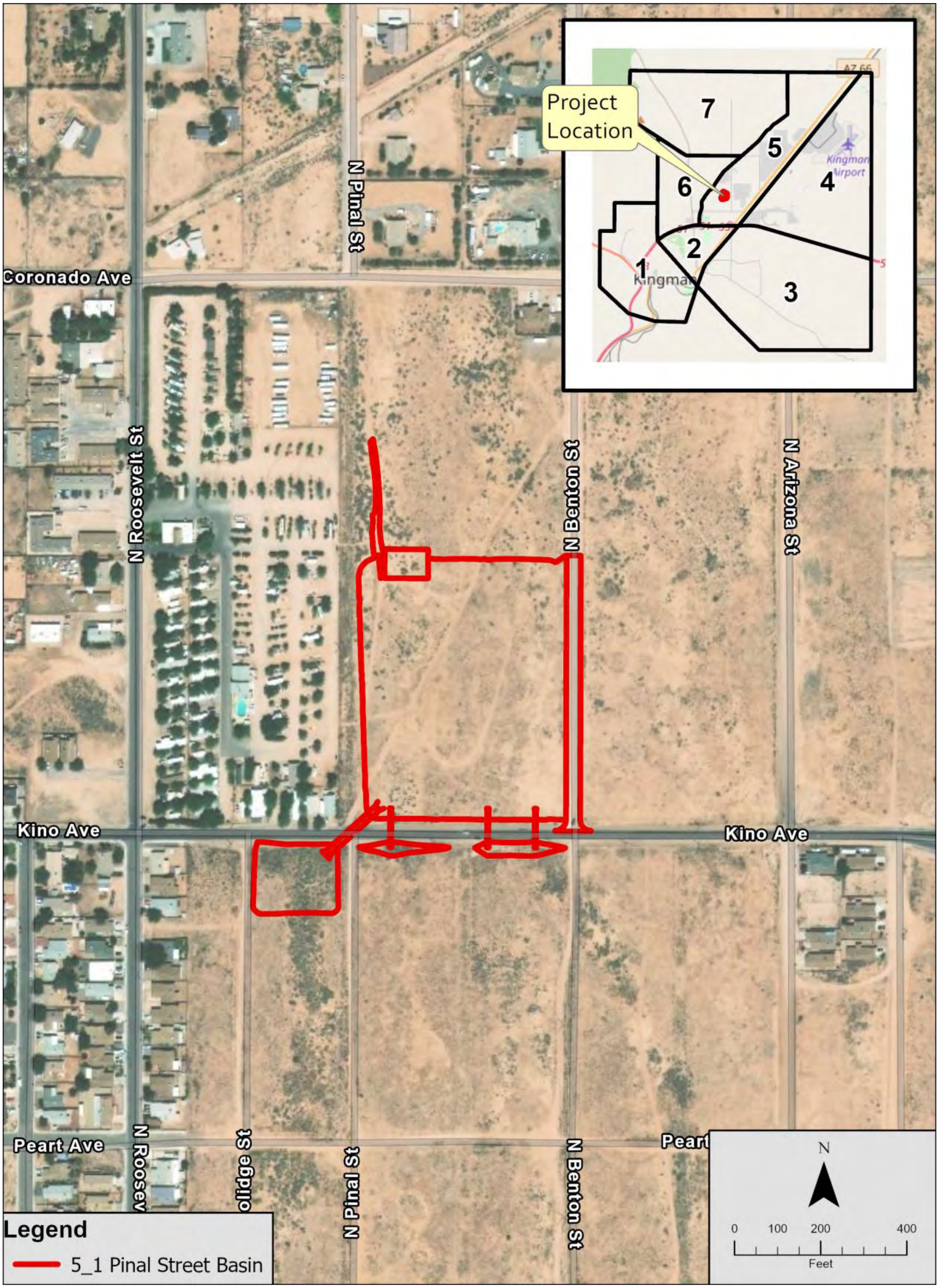

Figure 4-8. Pinal Street Basin Solution Overview

4.9 Anson Smith Road Collector Channel and Basins

4.9.1 Problem Description

Under existing conditions, runoff from regional watersheds located north of Anson Smith Rd. flows southwest across the roadway. Recent hydrologic models indicate that runoff crossing Anson Smith Rd. primarily as sheet flow, reaches depths of about 1 foot. Based on the models, flow along the Anson Smith Rd. alignment could be as great as 331 cfs during the 100-year storm event and 104 cfs during the 10-year storm event.

Due to a lack of defined surface-water drainage corridors, the runoff enters the neighborhoods that lie south and east of Anson Smith Rd., resulting in the potential for flooding. In addition, the current flow path conveys the runoff as far east as the Kingman Medical Center, which has experienced flooding in the past.

4.9.2 Summary of Solution

To reduce the flooding potential directly south of Anson Smith Rd., a drainage system comprising of a constructed channel and a series of detention basins is proposed. The channel, constructed along the south side of Anson Smith Rd., would have trapezoidal cross-section with 2:1 side-slopes. The channel would have a maximum depth of 5 feet and have maximum top width of 25 feet. The channel might require the acquisition of additional right-of-way. The channel would discharge flow into a series of detention basins that are designed to attenuate runoff until it would be released downstream into Wilshire Ave. via a single 36-inch RCP. In addition to detaining runoff entering from the channel, the basin would accept flow from the stormdrain located within Astor Rd. (See Section 4.10). The basins would vary in size and depth as a result of the natural terrain but would provide a combined storage volume of 11 ac-feet. The basin would be located on City of Kingman property. As a result of the drainage improvements, the 100-year peak discharge would be reduced from 393 cfs to 60 cfs. During the 10-year event, the peak discharge would be reduced from 97 cfs to 2 cfs.

See Figure 4-9 for an overview map of the Anson Smith Road Collector Channel and Basins conceptual plans.

4.9.3 Future Planning Considerations

- An inundation easement is needed to preserve the ponding area associated with the detention basin.
- This option only involves detention storage. Detention would reduce the flow rate downstream but would not reduce the runoff volume. As such the flow exiting the basin would occur over an extended period of time (12 plus hours).
- An operation and maintenance plan for the basin would need to be prepared and implemented.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for burrowing owl.

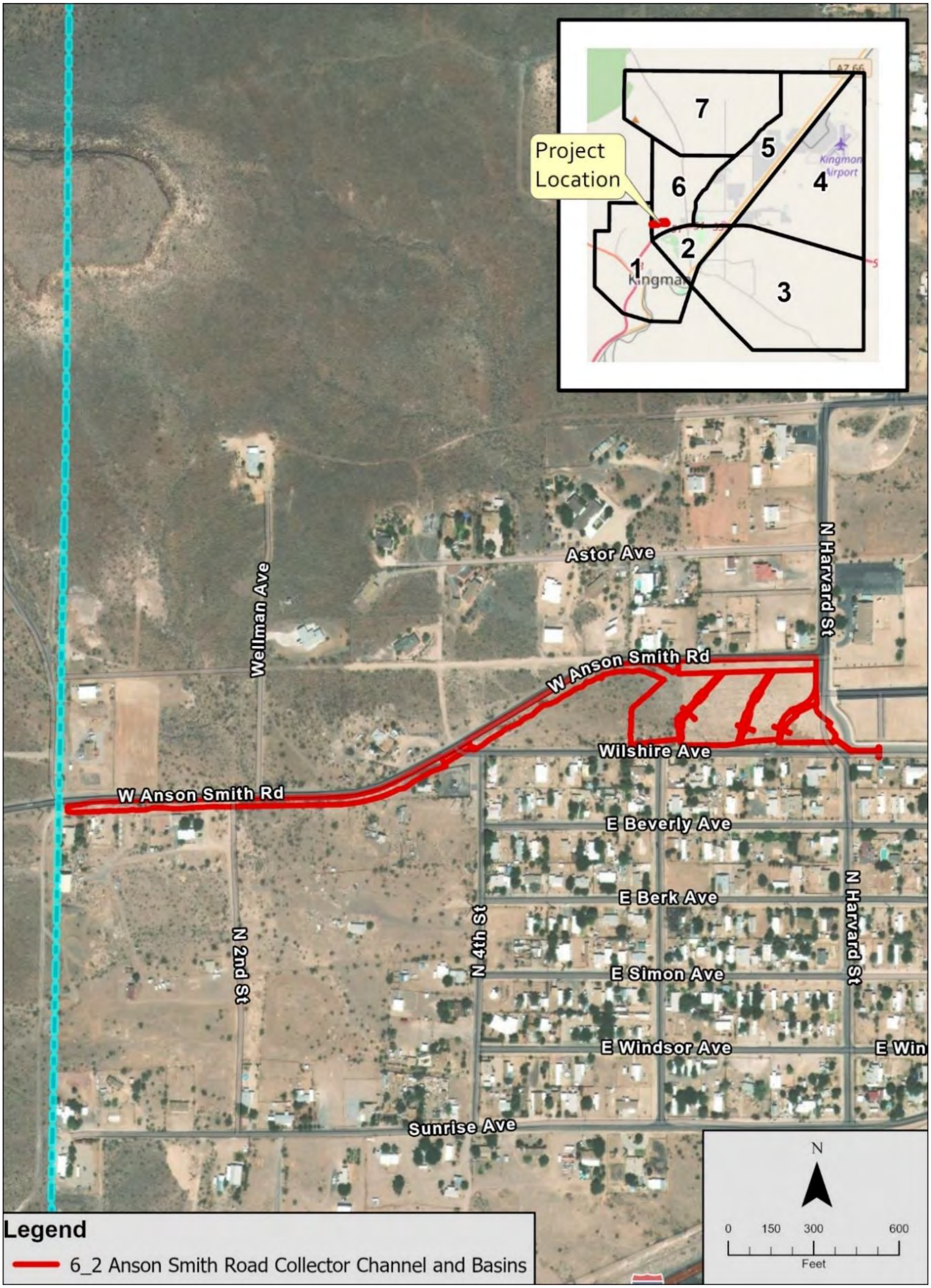

Figure 4-9. Anson Smith Road Collector Channel and Basins Solution Overview

4.10 HARVARD STREET IMPROVEMENTS AND BASINS

4.10.1 Problem Description

Runoff from upstream watersheds north of the Sycamore Ave. alignment flows southeast, impacting Harvard Rd. The runoff, which is conveyed in two distinct flow paths crosses both Sycamore Ave. and Astor Ave., prior to being discharged on Harvard St. Recent hydrologic models indicate that runoff from these two sources could be as great as 234 cfs during the 100-year storm event and 87 cfs during the 10-year storm event.

Due to a lack of defined surface-water drainage corridors, the runoff that enters the neighborhood west of Harvard St. could potentially inundate private residences. This potential extends to the east side of Harvard St., which have been developed to contain high-density housing developments.

As previously discussed, watersheds north of the Astor Ave. contribute to the surface water drainage conveyed to Harvard St. Recent hydrologic models indicate that runoff crossing Sycamore Ave. could be as great as 147 cfs during the 100-year storm event and 55 cfs during the 10-year storm event.

Due to a lack of defined drainage corridors along Astor Ave. and further downstream, the runoff crossing Astor Ave. is combined with runoff crossing Sycamore Ave. The combined flow directly impacts the subdivisions east of Harvard Rd., with the combined effects extending as far east as the Kingman Medical Center.

Also as previously discussed, watersheds north of the Sycamore Ave. contribute to the surface water drainage conveyed to Harvard St. Recent hydrologic models indicate that runoff crossing Sycamore Ave. could be as great as 87 cfs during the 100-year storm event and 32 cfs during the 10-year storm event.

Due to a lack of defined drainage corridors along Sycamore Ave. and further downstream, the runoff crossing Sycamore Ave. is combined with runoff crossing Astor Ave. The combined flow directly impacts the subdivisions east of Harvard Rd., with the combined effects extending as far east as the Kingman Medical Center.

4.10.2 Summary of Solution

By constructing a detention basin on the City of Kingman Property located at the southeast corner of Harvard St. and Sycamore Ave., the flow currently being conveyed east can be detained such that the flooding potential is substantially reduced. The basin would receive runoff captured within defined drainage systems constructed within Sycamore Ave. and Astor Ave. (See Section 4.9). The basin would be created by excavating a 5-foot deep impoundment area to detain the incoming flow and then allowing the captured runoff to be metered out through two (2) 18-inch RCP. Given the existing terrain, the total excavation depth would be 15 feet such that a total storage volume of a 2.9 acre-feet could be achieved. In combination with the construction of the basin, Harvard St. would be reconstructed such that the roadway cross-section would be warped towards the basin. This would allow local runoff within Harvard St. to be conveyed to the basin. As a result of the drainage improvements, the 100-year peak discharge is reduced from 160 cfs to 31 cfs. During the 10-year event, the peak discharge is reduced from 55 cfs to 11 cfs.

To reduce the flooding potential and capture the runoff such that it can be conveyed directly to the Harvard Basin and the Anson Smith Basin, roadway and drainage improvements would be constructed within the right-of-way of Astor Ave. The improvements would consist of warped roadway section bounded by curbs along the southern edge combined with a concrete channel constructed within the street right-of-way. The channel would terminate at an open-ended catch basin that would be covered by a transverse grate. Flow entering the channel would be conveyed into the Harvard basin via a stormdrain system consisting of 2-36-inch RCP. A separate stormdrain system also consisting of the 2-36-inch RCP would convey runoff to the Anson Smith Basin. As a result of the roadway improvements, the 100-year peak discharge of 147 cfs would be captured within the new roadway section. Freeboard in the channel would be provided such that flow into the stormdrain would not result in the required headwater exceeding the capacity of the channel upstream.

To reduce the flooding potential and capture the runoff such that it can be conveyed directly to the Harvard Basin, roadway improvements to Sycamore Ave. would be constructed. Improvements would consist of a warped roadway section bounded by curbs along the southern edge combined with a concrete channel constructed within the street right-of-way. Flow entering the channel would be conveyed into the basin via 2-36-inch RCP. As a result of the roadway improvements, the 100-year peak discharge of 87 cfs would be captured within the new roadway section. Freeboard in the channel would be provided and the channel would be designed such that the pipes would not result in the required headwater exceeding the capacity of the channel upstream.

See Figure 4-10 for an overview map of the Harvard Street Improvements and Basins conceptual plans.

4.10.3 Future Planning Considerations

- While the Harvard Basin is presented as single solution, the drainage improvements within Sycamore Ave. and Astor Ave. are integral to its success. As such, all three should be considered as a single drainage improvement project.
- An inundation easement is needed to preserve the ponding area associated with the Harvard detention basin.
- This option only involves detention storage. Detention would reduce the flow rate downstream but would not reduce the runoff volume. As such, the flow exiting the basin would occur over an extended period of time (12 plus hours).
- The Astor Ave. roadway cross-section fits entirely within the current right-of-way for Astor Ave., which appears to be only 30 feet. However, the channel bank is located at the edge of pavement and the channel. Additional right-of-way could be considered to provide additional clear zone for vehicular traffic heading west.
- The roadway cross-section fits entirely within the current right-of-way for Sycamore Ave., allowing a 5 feet shoulder between the edge of pavement and the channel. Additional right-of-way could be considered to provide additional clear zone for vehicular traffic heading west.
- An operation and maintenance plan for the basin, channel, and stormdrain systems would need to be prepared and implemented.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for burrowing owl.

Figure 4-10. Harvard Street Improvements and Basins Solution Overview

4.11 Western Avenue Stormdrain

4.11.1 Problem Description

Runoff from contributing watersheds from residential and rural areas is conveyed to the west where it is, in part, intercepted by the north-south alignment of Western Ave. Recent hydrologic models indicate the runoff conveyed to Western Ave. at the southern end could be as great as 494 cfs during the 100-year storm event and 110 cfs during the 10-year storm events. At this rate, it has been demonstrated that runoff would overwhelm Western Ave. and impact the Kingman Regional Medical Center to the east.

4.11.2 Summary of Solution

To capture runoff upstream and mitigate the flooding hazards downstream of Western Ave., a stormdrain system that starts north of Calumet Ave. and connects to the existing stormdrain in Sycamore Ave. would be constructed. The main trunk line would consist of a 42-inch reinforced concrete pipe with 36-inch lateral lines constructed within Sheldon Ave. and Astor Ave. The 42-inch pipe would be consistent with the pipe stub constructed as part of the Sycamore Ave. stormdrain system. Transverse grates would be constructed within Western Ave. and the side streets to transition the surface runoff into stormdrain. For the purpose of concentrating the runoff towards the transverse grates, minor roadway improvements to Sheldon Ave. and Astor Ave. would be constructed. In addition, roadway improvements within Western Ave. would also be constructed. The improvements would consist of inverting the crown of Western Ave. and adding a highpoint south of Calumet Ave. The stormdrain and roadway improvements would be designed to capture the 10-year storm event. Given the amount of runoff conveyed to this location, 100-year conveyance is not achievable. However, because there is available capacity within the stormdrain to accommodate the additional flow, the combined effect of the inverted crowned roadway would result in lessening the flooding at the Medical Center.

See Figure 4-11 for an overview map of the Western Avenue Stormdrain conceptual plans.

4.11.3 Future Planning Considerations

- A basin could be constructed in the vacant parcels at the south west corner of the Calumet Ave./Western Ave. Intersection. The basin could be used to capture the flow prior to being discharged into the stormdrain system and as such mitigate the downstream flooding potential.
- Aside from the basin at Calumet, basins are proposed upstream at Anson Smith Rd. and Harvard St. The positive effects of capturing and attenuating the runoff upstream should be evaluated to evaluate if the stormdrain at Western could be reduced or even eliminated.
- Stub out pipes could be provided at the end of the stormdrain system south of Calumet Ave. and at the transverse grates at Sheldon Ave. and Astor Ave. to allow for future expansion of the system.
- An operation and maintenance plan would need to be developed and implemented for the stormdrain and the transverse grates.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- No biological resource concerns have been identified for this solution.

Figure 4-11. Western Avenue Stormdrain Solution Overview

4.12 VISTA DRIVE BASIN

4.12.1 Problem Description

Runoff from a large upstream contributing watershed originating on property owned by the Arizona State Land Department flows from west to southeast through residential neighborhoods within the incorporated City Limits of Kingman. Recent hydrologic models indicate that runoff from upstream watersheds that could be as great as 570 cfs during the 100-year storm event and 111 cfs during the 10-year storm event.

As a result, homes located north of Riata Valley Road have the potential of being flooded by runoff stemming from this watershed. In addition, because the runoff is combined with flow from the south, and conveyed northeast, impacts can extend as far as Stockton Hill Rd.

4.12.2 Summary of Solution

By constructing a detention basin located on City of Kingman Property and on part of the privately-owned parcel to the south, the incoming flow would be detained such that the exiting flow would be substantially reduced. The basin would be created by excavating the existing terrain and constructing a 14-foot earthen berm at the downstream end. A 42-inch RCP would be used to drain the basin. The containment berm would include an emergency spillway and would provide 3 feet of freeboard. The total volume provided by the basin would be 14 acre feet. As a result of the basin, during the 100-year event the peak discharge would be reduced to from 567 cfs to 135 cfs. During the 10-year event, the peak discharge would be reduced from 220 cfs to 82 cfs.

See Figure 4-12 for an overview map of the Vista Drive Basin conceptual plans.

4.12.3 Future Planning Considerations

- This option only involves detention storage. Detention would reduce the flow rate downstream but would not reduce the runoff volume. As such, the runoff exiting the basin would occur over an extended period of time.
- A Geotechnical Investigation of the soils within the parcel should be conducted to determine if the excavated soils can be used for the construction of the berm.
- Downstream erosion mitigation measures would be required to account for the runoff exiting the pipe.
- The parcel to the south is privately owned. All or part would need to be purchased to accommodate the basin.
- An operation and maintenance plan for the berm and basin would need to be prepared and implemented.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for Gila monster, Sonoran Desert tortoise, and burrowing owl.

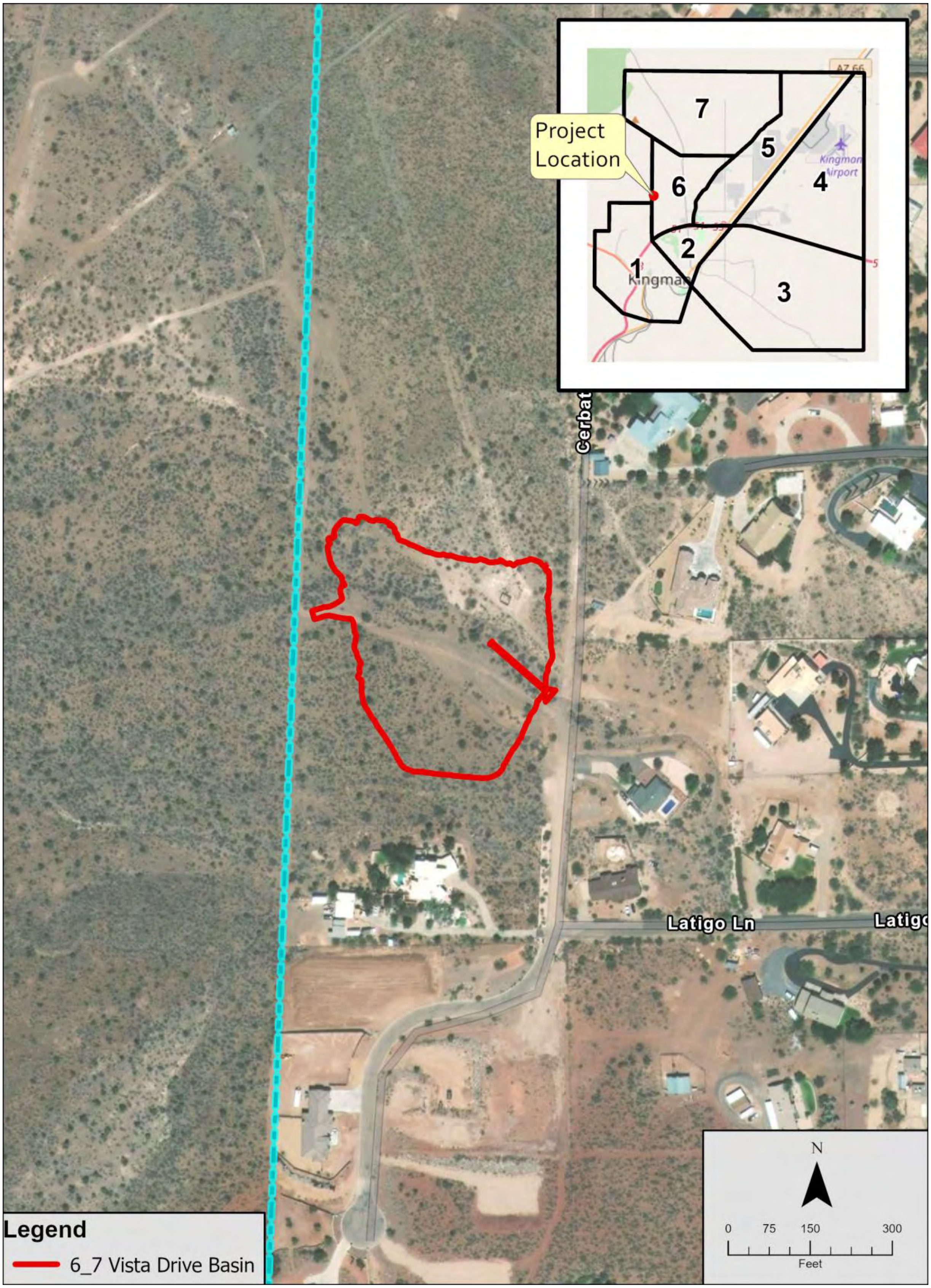

Figure 4-12. Vista Drive Basin Solution Overview

4.13 Lower Crestwood Channel

4.13.1 Problem Description

Runoff originating in the mountains west of the Kingman City Limits is concentrated at a crossing of Stockton Hill Rd., south of Hillcrest Dr. The downstream channel does not have capacity for the full flow reaching the area downstream of Stockton Hill Rd., and the flooding spreads out to the north and south adjacent parcels.

4.13.2 Summary of Solution

This solution would consist of the construction of a new channel within the Coronado Channel alignment. The channel would capture runoff that can impact the Home Depot and the commercial retail complex to the north.

The channel could potentially discharge runoff into a future basin or directly into the existing constructed channel to the east. The channel would be rock-lined with a 20-foot bottom width, 3:1 side-slopes, and a depth of 5 feet (1 foot freeboard).

The channel would have the capacity to convey the 100-year event. It should be observed that that improvements to Hillcrest Dr. and potentially Stockton Hill Rd. should be considered as part of this solution to provide the necessary drainage infrastructure to ensure that the channel is fully utilized.

See Figure 4-13 for an overview map of the Lower Crestwood Channel conceptual plans.

4.13.3 Future Planning Considerations

- The channel is overdesigned for the existing culverts crossing Stockton Hill. Further upgrades to the culvert crossing should be considered to fully utilize the channel capacity.
- Property acquisition or easement acquisition may be required.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for burrowing owl.

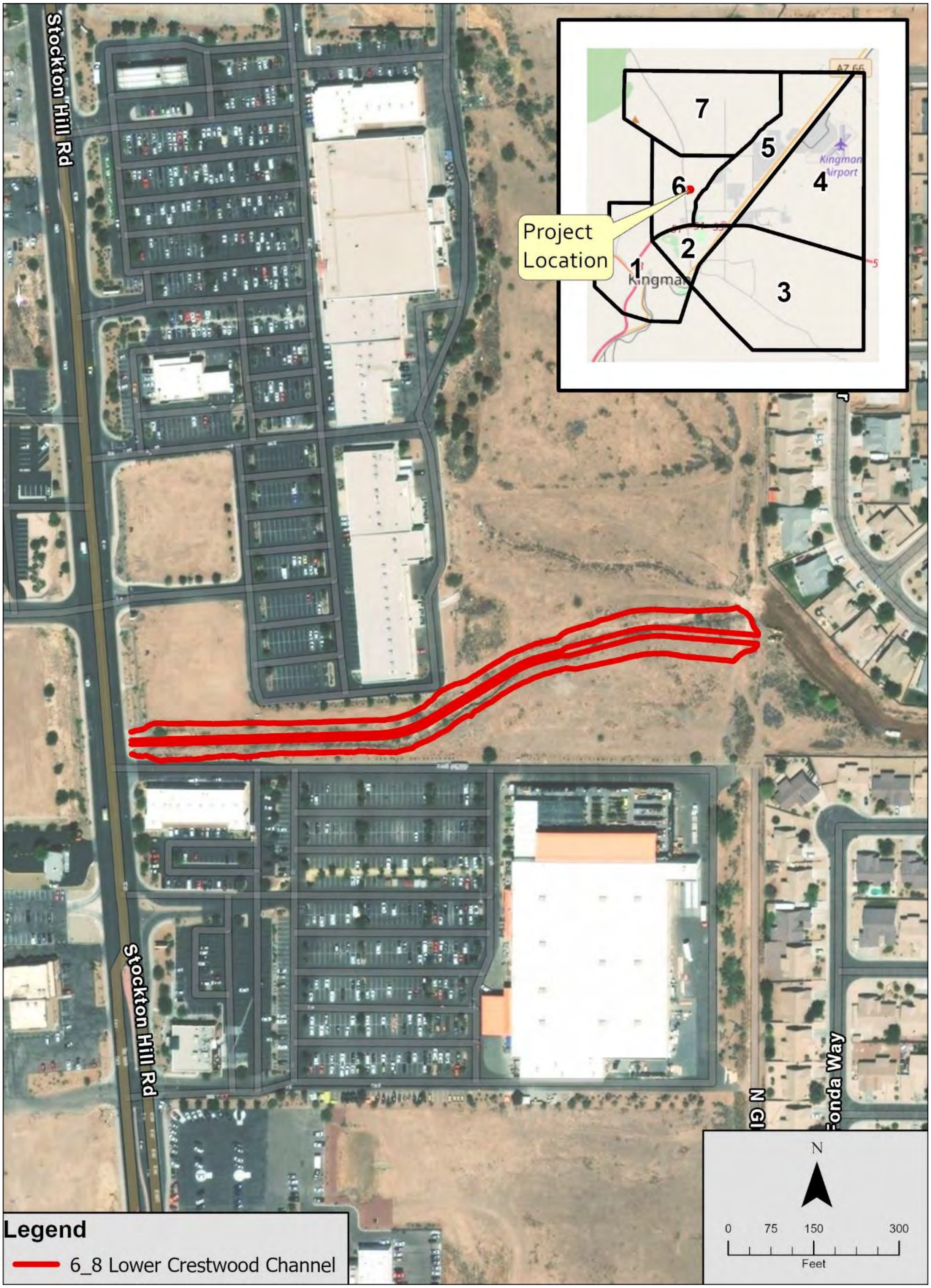

Figure 4-13. Lower Crestwood Channel Solution Overview

4.14 GRACE NEAL CHANNEL

4.14.1 Problem Description

The general flow pattern in this area is from the northwest to the southeast, and runoff from the mountains to the west impairs portions of Kingman and the unincorporated areas along Jagerson Ave. Mohave County has undergone initial planning and installation of a channel downstream of Roosevelt St. which would serve as the downstream portion of the regional Grace Neal Channel. This lower portion of the channel provides a downstream terminus of the Grace Neal Channel proposed in this solution.

4.14.2 Summary of Solution

The Grace Neal Channel system is a long-term regional drainage solution which is intended to divert the runoff impacting the north portion of Kingman, east to the Mohave Wash channel. A portion of the solution has been completed, just east of the city limits. Planning, design and coordination with adjacent developers and landowners is needed to extend the channel west to Stockton Hill Rd. The primary flows are intercepted at Eagle View Rd., and based on the previous design, the channel section from Eagle View to the recently constructed channel should be a trapezoidal channel with 50-foot bottom width and 4:1 side slopes. Upstream of this point, the flows are significantly less, and the channel could have a smaller footprint. Consideration should also be given in regard to the potential of a channel on the east side of Stockton Hill Rd. and how it could influence the channel size across the existing state land. The bulk of the channel is designed to convey the 100-year discharge of approximately 2,300 CFS.

See Figure 4-14 for an overview map of the Grace Neal Channel conceptual plans.

4.14.3 Future Planning Considerations

- A portion of the design and implementation is already underway.
- Significant county/city/landowner coordination would be required.
- The accrual channel cross-section should be customized to the needs of project stakeholder. Various channel cross-sections would function well, and some variations may impact less land, while being more expensive to construct.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for Gila monster, Sonoran desert tortoise, and burrowing owl.

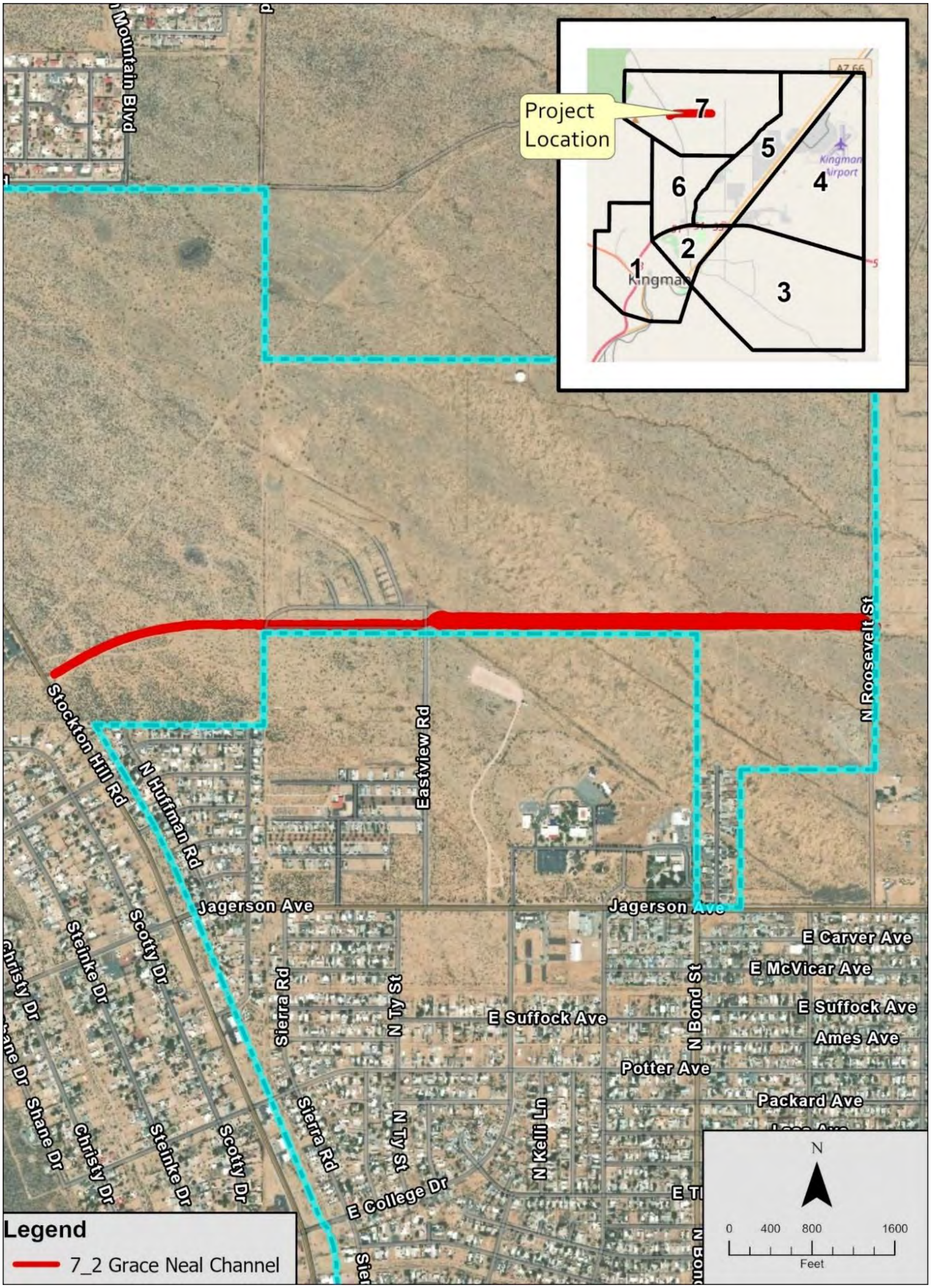

Figure 4-14. Grace Neal Channel Solution Overview

4.15 SHANE CHANNEL

4.15.1 Problem Description

Runoff from watersheds to the west of Shane Dr. impacts homes along Shane Dr. Runoff is conveyed from Shane Dr. to a regional channel east of Christy Dr. Several homes along Shane Dr. were flooded in 2018 because of the lack of infrastructure along the roadway.

4.15.2 Summary of Solution

This solution includes construction of an adequately-designed channel on the east side of Shane Dr. to convey runoff to the Camelback Channel.

The channel would be 4 feet deep with a 4-foot bottom width rock-lined trapezoidal channel and 2:1 side slopes. The channel would have capacity for the 100-year event of approximately 250 CFS and would convey runoff to a box culvert connecting Christy Dr. to the Camelback channel. The box culvert would be a 10 footx3 foot concrete box culvert and would convey the 100-year event. In order for the channel to fit along Potter Ave., the road would need to be shifted south within the right of way and a waterline would need to be relocated.

See Figure 4-15 for an overview map of the Shane Channel conceptual plans.

4.15.3 Future Planning Considerations

- The proposed channel would cut off access to the back yards of the homes to the east.
- There may be property or easement acquisition required.
- An energy dissipator may be required where the box culvert flows into the Camelback channel.
- There may need to be improvements upstream of the intersection of Jagerson Ave. and Shane Dr. to collect runoff into the channel.
- If there are improvements constructed in the upper end of the Camelback Channel, the Shane Channel may be able to be reduced in size.
- No cultural resource surveys have been conducted within the proposed solution area. A Class III cultural resources inventory would be required prior to any ground disturbing activities.
- A biological pre-construction survey is recommended for Gila monster, Sonoran desert tortoise, and burrowing owl.

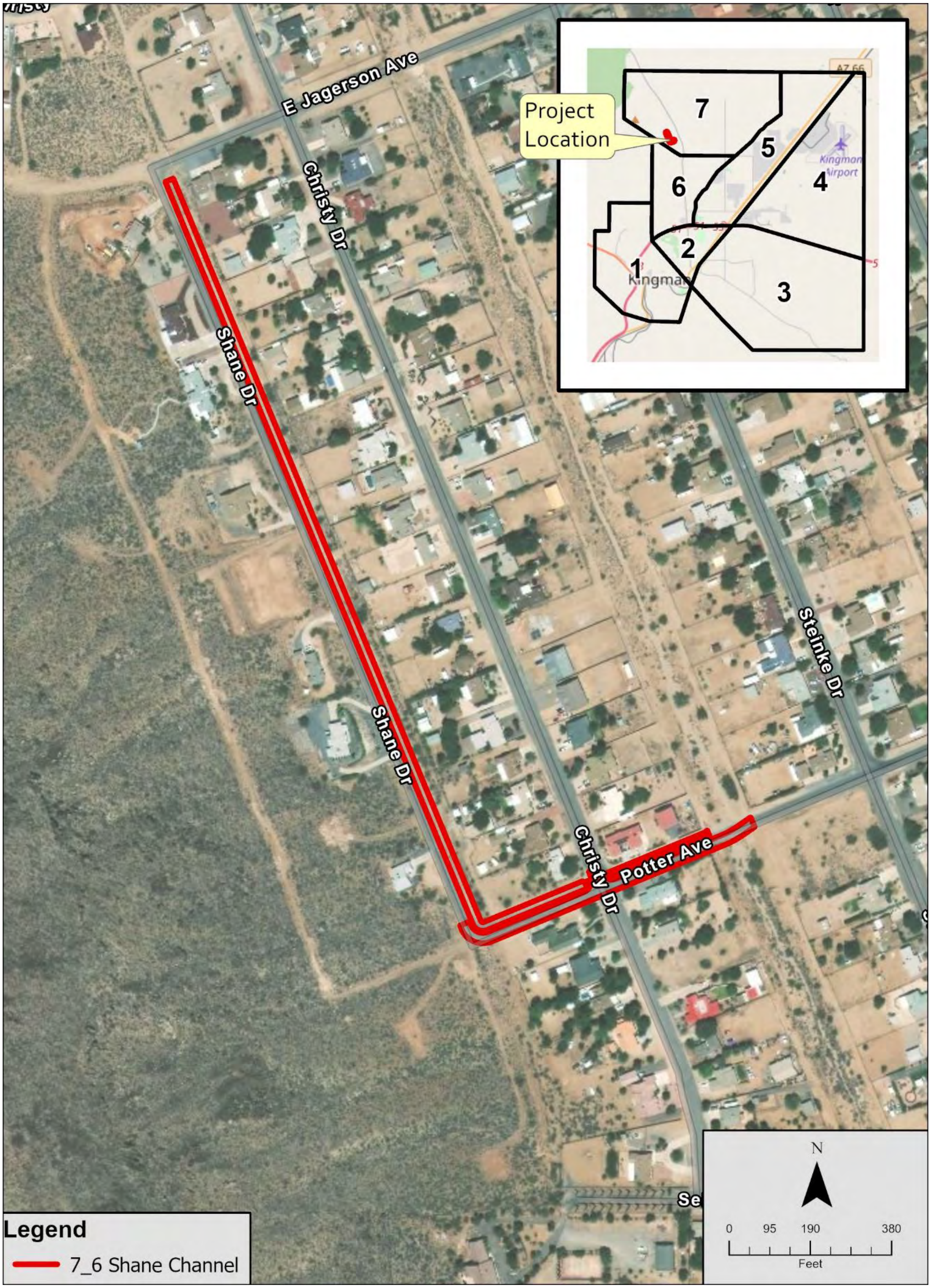

Figure 4-15. Shane Channel Solution Overview

4.16 ADDITIONAL SOLUTIONS

There were several solutions which ranked high during the evaluations but were not developed as a part of this plan. These solutions should be considered for implementation as well: Solution 3.12 - Eastern Street Improvements, Solution 3.13 - Railroad Diversion Channel, and Solution 6.10 - Bull Mountain Channel. Information regarding these solutions can be obtained from the City of Kingman Engineering Department.

4.16.1 City Wide Drywells

There is significant interest within the City of Kingman to promote groundwater recharge and implement elements into proposed projects. While a specific project was not developed, dry wells could potentially be installed in various locations throughout the City depending on need and practicality. Several elements of consideration are:

- Each potential location needs to be analyzed for its suitability and must consider bedrock, soil conditions, and the volume of stormwater disposal required.
- Consultation with a geotechnical engineer should occur in order to properly evaluate existing soil conditions. In practice, the bottom of the drywell should be 2 feet above the seasonal water table and/or bedrock.
- Drywells should be avoided in areas of expansive soils or soils with a high gypsum content. A geotechnical engineer should provide guidance on the depth and dimensions of the drywell.
- Dry wells are not recommended for largely natural watersheds where runoff is sediment laden. The designer should consider implementation in more urban areas.
- Drywells shall drain within 36 hours of a rain event.
- Drywells shall be setback 10 feet from the foundation structures.
- Drywell inlet grates should be set 2-4 inch above the invert of the basin.
- Drywells shall be registered and regulated by the Arizona Department of Environmental Quality.
- Drywells shall be inspected annually at a minimum.
- An operation and maintenance plan should be developed to avoid clogging. Drywell maintenance shall include:
    - Removal of sediment, trash, debris
    - Replacement of filter fabrics (if installed)
    - Cleaning/replacement of screens
    - Opening of liner weep holes
    - Purging of accumulate silt from the aggregate by jetting, surging, or pumping
    - Securing interceptor grates and drywell access covers to the support frame.

5 Conceptual Solution Cost Estimates

Conceptual solution cost estimates were developed for each of the proposed solutions and are presented in Table 5-1. Notes regarding the cost estimates are below and itemized estimates are included in Appendix F.

Table 5-1. Conceptual Solution Cost Estimates

Solution Number	Drainage Solution	Cost
1.4	Grandview Avenue Stormdrain	$8,175,805
1.8	Detention Upstream of Andy Devine	$72,240
1.11	4th Avenue Basin	$565,632
2.3	Main Street Stormdrain Extension	$4,596,148
2.4	Fairgrounds Boulevard Stormdrain	$5,048,091
3.1	Harrod Avenue Basin Upgrades	$242,159
3.7	I-40 Regional Retention	$5,468,680
3.12	Eastern Street improvements	$4,485,000*
3.13	Railroad Diversion Channel	$23,777,000*
5.1	Pinal Street Basin	$2,569,240
6.1/6.2	Anson Smith Road Collector Channel and Basin	$4,117,758
6.3/6.4	Harvard Street Improvements and Basin	$3,150,466
6.5	Western Avenue Stormdrain	$1,074,927
6.7	Vista Basin	$1,141,211
6.8	Lower Crestwood Channel	$937,728
6.10	Bull Mountain Channel	$3,000,000*
7.2	Grace Neal Channel	$12,245,840
7.6	Shane Channel	$1,522,758

*Cost estimates for 3.12,3.13, and 6.10 are approximate and based on previous studies. No adjustments to the cost estimates have been made. The cost estimate for 3.13 is based on the Kingman Railroad Diversion Channel DCR, Option 4A, prepared by URS in January 2012. The estimate includes all components listed in the DCR, some of which have been constructed.

- The opinions of cost shown, and any resulting conclusions on solution financial or economic feasibility or funding requirements, have been prepared for guidance in solution budgeting and implementation from the information available at the time the opinion was prepared. The final costs of the solution will depend on actual labor and material costs, competitive market conditions, actual site conditions, implementation schedule, continuity of personnel and engineering, and other variable factors. As a result, the final solution costs will vary from the opinions of cost presented herein. Construction costs are presented in June 2020 dollars.
- Potential costs of easement or property acquisition have not been calculated.
- All costs include a construction contingency which can be removed as the solution is designed based on the judgement of the City and engineer.
- Potential design and administration costs are included and those may vary per solution.
- As a solution is developed, costs will vary depending on final field conditions and materials used.

6 REFERENCES

Bull Mountain Engineering, LLC. (2015). *Southern Vista Tract 1980-A Drainage Easement Report.*

City of Kingman Engineering Department. (2014). *Design Report for Steamboat Drainage Improvements. City of Kingman Project No. ENG13-049.* City of Kingman, Arizona.

City of Kingman Engineering Department. (2016). *Drainage Improvement Project for Fairgrounds Boulevard, 100% Final Plans. City of Kingman Project No. ENG16-0017.* City of Kingman, Arizona.

FLO-2D Software, Inc. (2016). *FLO-2D Data Input Manual.*

FLO-2D Software, Inc. (n.d.). *FLO-2D Reference Manual.* Nutrioso, AZ.

INTERMAP Technologies. (2019). NEXTMap5 Powerful Elevation Data. Retrieved September 20, 2019, from https://www.intermap.com/hubfs/pdf/NEXTMap%205%20DataSheet%2020180416.pdf

JE Fuller / Hydrology & Geomorphology, Inc. (2013). *Mohave County Flood Control District Request for FEMA Approval of Local Use of FLO-2D for Hydrologic Modeling, Engineering Analysis and Mapping of Special Flood Hazard Areas.* Mohave County, Arizona: Mohave County Flood Control District.

JE Fuller / Hydrology & Geomorphology, Inc. (2016). *Kingman Area Flood Risk Study.* Kingman, Arizona.

JE Fuller / Hydrology & Geomorphology, Inc. (2017). *Laveen Area Drainage Master Study/Plan Update (ADMPSU) Technical Support Data Notebook.* Phoenix, Arizona.

JE Fuller / Hydrology & Geomorphology, Inc. (2018). *East Kingman Risk Map Study Technical Support Data Notebook.* Kingman, Arizona.

JE Fuller / Hydrology & Geomorphology, Inc. (2018). *West Kingman Flood Control / Recharge Basin Study.* Mohave County, Arizona.

KVL Consultants, Inc. (2009). *Drainage Design Management System for Windows (DDMSW) Computer Program.* Scottsdale, Arizona.

Map IX-Mainland. (2006). *Technical Support Data Notebook for Coastal and/or Riverine Flood Insurance Studies/Restudies Throughout Region IX EMF-2003-CO-0047 TASK ORDER 002 (Mohave County, Arizona).*

Mohave County Flood Control District. (2018). *Drainge Design Manual for Mohave County.* Mohave County, Arizona.

Mohave Engineering Associates, Inc. (2010). *Preliminary Drainage Report for Bull Mountain Basin (Channel Design), 90% Progress Print for Review. Job No-09-126.* City of Kingman, Arizona.

Mohave Engineering Associates, Inc. (2009). *Preliminary Drainage Report for Bull Mountain Basin (Channel Design), 60% Progress Print for Review. Job No-09-126.* City of Kingman, Arizona.

Paretti, N. V., Kennedy, J. R., Turney, L. A., & Veileux, A. G. (2014). *Methods for Estimating Magnitude and Frequency of Floods in Arizona, Developed with Unregulated and Rural Peak-Flow Data Through Water Year 2010.* Reston, Virginia: U.S. Geological Survey.

PRISM Climate Group. (2018, 08 21). *Prism Climate Group*. Retrieved from 30-Year Normals: http://prism.oregonstate.edu/

Quantum Spatial, Inc. (2016). *City of Kingman LiDAR Technical Data Report.* City of Kingman, Arizona.

RPA. (2017). *Final Drainage Report Eastern Street Improvements – Pasadena Avenue to Airway Avenue. City of Kingman Project No. ENG15-048. RPA Project No. 215053.* City of Kingman, Arizona.

T. Y. Lin International. (2017). *Ahwatukee Foothills Area Drainage Master Study (ADMS) Final Report.* Phoenix, Arizona.

Thomas, B. E., Hjalmarson, H. W., & Waltemeyer, S. D. (1997). *Method for Estimating Magnitude and Frequency of Floods in the Southwestern United States.* Tucson, Arizona: USGS Water-Supply Paper 2433.

U.S. Department of the Interior, Bureau of Reclamation. (1988). *Downstream Hazard Classification Guidelines, Acer Technical Memorandum No. 11.* Denver, Colorado.

URS Corporation. (2012). *Final Design Concept Report for Kingman Railroad Diversion Channel. Mohave County Contract No. 07-PS-10. URS Project No. 23446047.* City of Kingman, Arizona: Mohave County Flood Control District.

APPENDIX A – DRAINAGE COMPLAINTS

APPENDIX B – FLO-2D WORKMAPS

APPENDIX C – CONCEPT SOLUTIONS AND EVALUATIONS

APPENDIX D – BIOLOGICAL AND CULTURAL RESOURCES EVALUATIONS

APPENDIX E – CONCEPTUAL PLANS

APPENDIX F – CONCEPTUAL PLAN COST ESTIMATES