Flood Control District of Maricopa County

Pinnacle Peak West Area Drainage Master Study
Work Assignment #3
Flood Hazard, Risk, Prioritization, and Alternatives

July 2015

FINAL

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Date Signed 7-8-2015
ARIZONA, U. S. A.
Expires 09/30/2017

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Memorandum

DATE: December 15, 2014

TO: Theresa Pinto, FCDMC

FROM: Patricia K. Quinn, PE, RLS, AVS

RE: Pinnacle Peak West ADMS Work Assignment 3, Tasks 12 through 15 – Hazards, Risks, Prioritization, and Alternatives
Executive Summary

The purpose of this summary memorandum is to present and summarize the results of the Flood Hazard Classification, Flood Risk Determination, Flood Problem Prioritization, and Alternatives to Reduce Flood Risk tasks performed for the Pinnacle Peak West (PPW) Area Drainage Master Study (ADMS). The report summarizes the conclusions and findings of Work Assignment Number 3, Tasks 12 through 15 for contract FCD 2011C024. Two parts of Task 15 are provided under separate cover as described below – 1) alternatives for Rawhide Wash and 2) redelineation of the Fan 5 & 6 floodplains.

The following briefly summarizes the Task 12 through 15 memoranda and key results.

Task 12 & 13 – Flood Hazard Classification & Flood Risk Determination

Flood hazard classification and risk assessment were performed using the FLO-2D model results for the 10-, 25-, and 100-year storm events. The methodologies and hydraulic results of these models are presented in the Technical Study Data Notebook. Flood hazards to pedestrians, passenger vehicles, and structures were quantified. For each category, flood hazard levels from Low to Very High were designated and quantified. About 8 percent of buildings were found to be subject to some level of flood hazard during the 100-year event. Of the buildings subject to flood hazards, over 60 percent lie outside of delineated FEMA floodplains. About 18 percent of roadways exhibit greater than a moderate hazard to passenger vehicles during the 100-year event. Just less than half of these roadway segments are subject to flood hazards during the 10-year event. Of the total study area, about 16 percent has greater than moderate flood hazards to child pedestrians. The methods and results of the hazard and risk assessment are presented in the Tasks 12 and 13 - Hazard and Risk Memo provided in the binder accompanying this summary.

Task 14 – Flood Problem Prioritization

Observed flooding issues throughout the study area and analytically identified potential risks from Tasks 12 and 13 were collected and organized into a geodatabase. The goal of this task was to understand the collective story told with all of the data presented in one location on a big picture basis. The result of the effort was an identification of several key areas and themes where further examination and alternatives would be beneficial as presented in the Task 14 Prioritization Memo. The high priority problems describe in the Task 14 memo are vetted in greater detail in Task 15.

Task 15 – Alternatives to Reduce Flood Risk

Alternatives to address prioritized flooding risks were investigated. Separate memoranda or reports were produced. Three classes of alternatives were considered – Build, No Build, and No Action.

Buildings

For the 2230 buildings with flood risks identified in Tasks 12 and 13, those with greater than a moderate risk level (i.e. flow depth in house greater than 1.5 feet) were examined for potential solutions to reduce flood risks. For half of the 272 buildings, half were assigned to the No Action alternative. The flood risk was found to be an artifact of the GIS analysis 20-foot raster resolution and no flood mitigation measures are needed. In a number of cases, the buildings were not reflected in the topography used for the modeling. Of the remaining half, one third were identified as potentially benefiting from some kind of Build alternative. Structural mitigation solutions such as culvert upgrades, local channel improvements, or major structural measures would be needed to reduce flood risk. Another third might benefit from floodwall certification. To the extent that the existing walls can be shown to provide adequate safe flood protection, these could be categorized as No Build alternatives. The remainder require some additional investigation to confirm the flood risk and/or develop some specific Build alternative mitigation measures. The methods and results of the alternatives evaluation for buildings with flood hazards are presented in the Task 15 - Buildings w Hazards Alternatives Memo provided in the binder accompanying this summary.

Transportation

The flood hazard and risk to passenger vehicles analyses from Task 12 and 13 plus input from stakeholders and public input indicated the need for all-weather transportation access through the study area. Other than the Loop 101, there are currently no major arterial streets with all-weather access across the study area. Transportation system improvements fall into the Build alternative category. Development of a transportation access plan for the area could help coordinate and prioritize future transportation improvements. Additional details are provided in the Task 15 - Transportation Improvements Memo provided in the binder accompanying this summary.

Rawhide Wash Alluvial Fan

Flood hazards associated with the Rawhide Wash alluvial fan were well-recognized and reflected in the analytical results as well as the feedback and input from stakeholders and the general public. A more detailed alternatives development and process was performed for the Rawhide Wash alluvial fan area. That process included consideration of Build, No Build, and No Action alternatives. Detailed discussion is provided under separate cover in the Rawhide Wash Conceptual Alternatives Report. The Task 15 - Rawhide Executive Summary Table is provided in the binder accompanying this summary.

Fan 5 & 6 Floodplain Redelineation

Another area of flood hazard revealed by the FLO-2D modeling and public input was the so-called Fan 5 and Fan 6 area. Floodplains within the northwest portion of the study area had been previously delineated by FEMA as active alluvial fans. Due to improved modeling methods, updated topography and modeling parameters, and new development in the area, the current FEMA

regulatory floodplain delineations for Fans 5 & 6 no longer represent the actual flood hazards. The FLO-2D modeling results produced as part of Work Assignment 3 show a much smaller flood prone area than the current effective FEMA floodplains for Fan 5 and 6. As part of Work Assignment 5, the FLO-2D model results will be refined to meet FEMA requirements and submitted following FEMA approval of Stage 1 and Stage 2 analyses previously conducted by the District. The result should be a new revised floodplain delineation that more accurately depicts the true flood hazards in this part of the study area. This should also allow for better management of the floodplain in the future. This process is on-going and is expected to be completed next year. The floodplain redelineation falls into the No Build alternative solution for the Fan 5 & 6 area.

Other Areas

Besides the Rawhide Wash and Fan 5 and 6 areas, a number of other areas of flood risks were recognized from the analytical results and stakeholder and public input. Additional discussion is provided in the Task 15 – Alternatives to Reduce Flood Risk - Other Areas Memo. The alternatives for these other areas are predominantly Build alternatives to reduce those flood risks.

Flood Hazard Classification & Flood Risk Determination Memorandum

Memorandum

DATE: December 31, 2014

TO: Theresa Pinto, Project Manager, FCDMC

FROM: Pat Quinn, PE, RLS, AVS
Reed Blochberger, EIT

RE: Pinnacle Peak West ADMS Work Assignment No. 3
Task 12.0 Flood Hazard Classification and
Task 13.0 Flood Risk Determination

Introduction & Purpose

During a 100-year storm, flood waters flow throughout the Pinnacle Peak West (PPW) Area Drainage Master Study (ADMS) watershed. Not all flood hazards pose a risk to people or their properties. Flood risk depends on the co-location of a flood hazard with a person or their property. As an example, flow in a constructed flood control channel does not present a risk until someone enters the channel. Identifying where flood waters do cause risks that potentially harm people or their properties is an important objective of the PPW ADMS. Identification of potential flood risks in the study area helps the project team determine which of the flood problems should be addressed in the future.

For the purposes of the PPW ADMS, 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 10-year, 25-year, and 100-year 24-hour storm events.

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

Flood hazards were determined by modeling three scenarios for the PPW ADMS which were combined to depict a 'worst case' scenario. Therefore, four sets of modeling results were considered during the flood hazard classification, delineation, and quantification process as follows:

- *Without Walls Model (WOW):* None of the walls in the PPW watershed were included in the levee.dat file.
- *Walls with Failure (WF):* The influence of walls in the watershed was accounted for as levees in the levee.dat file. The walls were programed to fail at a 2-foot ponding depth.
- *Walls with No Failure (NF):* The influence of walls in the watershed was accounted for as levees in the levee.dat file. The walls were not programed to fail at any point.
- *Worst Case (WC):* This set of results is not directly from a modeled scenario, but is a composite of the worst case scenario results at each grid element from the previous three modeling scenarios.

After evaluating the four scenarios, the project team decided that flood hazards from the WC scenario would be used because the other three scenarios do not fully capture all of the potential risks arising from a flooding event in the watershed. Flood risk assessments were made for the 100-year, 25-year, and 10-year events.

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

Flooding Risks to Pedestrians

Above certain water depths and velocities, flood water can knock a person off their feet. Identifying areas were this can occur can help reduce flooding risk to pedestrians that live or walk in these areas. In addition, areas of risks to pedestrians near homes may also experience damages to landscaping and other outdoor improvements.

Pedestrian flood risks were classified using the depth-velocity relationship outlined in the United States Bureau of Reclamation (USBR) Technical Memorandum 11 (TM 11) (1988). The depth-velocity relationships presented in TM 11 were used for the flood risk classification because the criteria are scientifically founded and widely accepted. TM 11 presents two possible classifications for pedestrians; flood danger levels for adults and for children. The option of using the flood danger classification for children in the area around schools and the flood danger classification for adults elsewhere was discussed. In order to simplify the methodology and be conservative, the project team decided to use the flood danger classification for children throughout the entire watershed. The depth-velocity flood danger level relationship from TM 11 is shown as **Figure 1**.

Pedestrian flooding risks were classified into the following three categories:

- *Low:* These are areas with depths and velocities corresponding to the Low Danger Zone as shown in **Figure 1**. Low pedestrian risks are not displayed on the PPW map exhibits because, according to TM11, low danger zones do not present a threat to children of almost any size (excluding infants).
- *Moderate:* Areas with depths and velocities corresponding to the Judgment Zone in **Figure 1** were classified as having a moderate potential flood risk to pedestrians.
- *High:* Areas with depths and velocities corresponding to the High Danger Zone in **Figure 1** were classified as having a high potential flood risk to pedestrians.

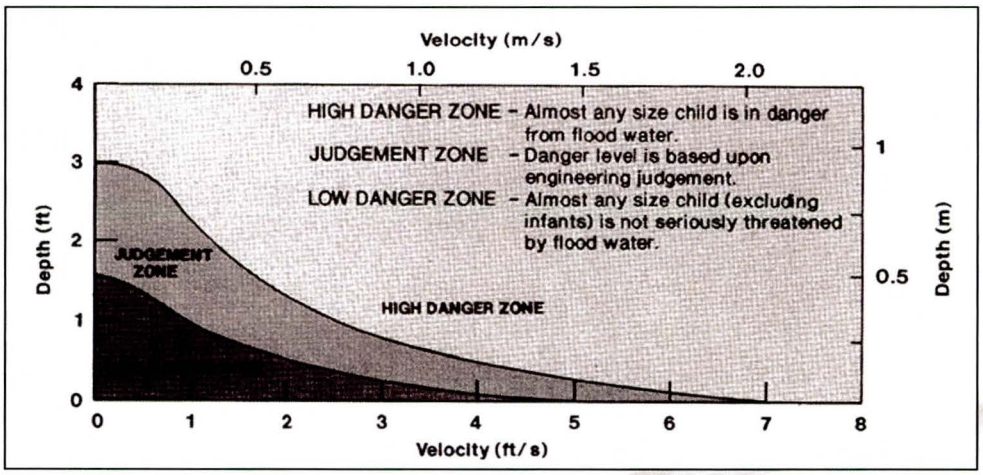


Figure 1 - Depth-Velocity Flood Danger Level Relationship for Children (USBR, 1988)

The pedestrian flood risks were 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 correlate to a low, moderate, and high risk classification, respectively. A visualization of the potential risks to pedestrians for the entire study area is shown in **Exhibit A** at the end of this technical memorandum. The following electronic data for the potential risks to pedestrians are provided along with this technical memorandum:

- Potential risk to pedestrians (raster) (example nomenclature for all storm events: wc_ped_100)

Potential Risks to Passenger Vehicles

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

- *Low*: This risk category is based solely on minimum depth criteria and is for roadway crossings with depths less than 0.5 feet. Low passenger vehicle risks are not displayed on the PPW map exhibits because almost any size passenger vehicle can pass through safely. Also, this risk classification covers all areas not classified as a higher flood risk.
- *Moderate:* This risk 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** that also have greater than 0.5 feet depth. The threshold depth of 0.5 feet was chosen because 0.5 feet 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** were classified as having a high potential flood risk for passenger vehicles.
- *Very High:* Roadway crossings with depths and velocities corresponding to the High Danger Zone in **Figure 2** were classified as having a very high potential flood risk for passenger vehicles.

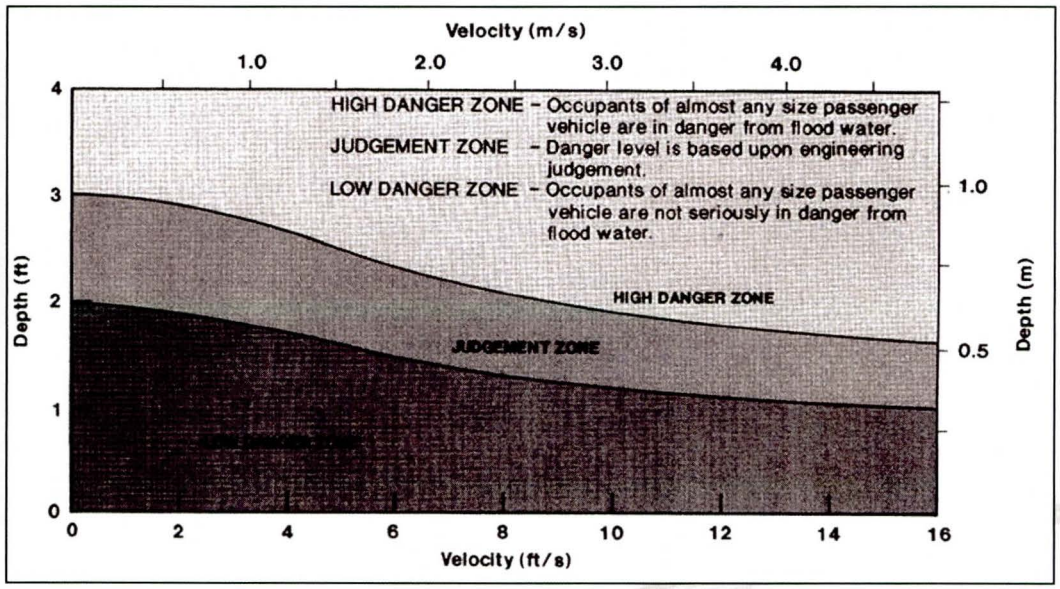


Figure 2 - Depth-Velocity Flood Danger Level Relationship for Passenger Vehicles (USBR, 1988)

The resulting passenger vehicle flood hazard layer was intersected with a polyline shapefile containing the centerline all of the roads in the PPW watershed. The flood layer rasters provided with this memorandum for documentation contain values of 1, 2, 3, and 4 correlating to the flood risk classifications low, moderate, high, and very high, respectively. Two different methods for displaying and quantifying potential flood risks to passenger vehicles were developed.

The first method for visualizing and quantifying potential flood risks to passenger vehicles is a polyline shapefile showing all locations where the passenger vehicle flood risk layer intersected a road. An example of this method is shown in **Figure 3**. Visually, this displays the extents of a potential flood risk on any given roadway. Quantitatively, this method is used to determine what percentage of roads are affected by each of the potential risk categories. Affected roadways are further broken down by their type (arterial, secondary roadway, ADOT roadways). A summary of results is provided in **Table 1**.

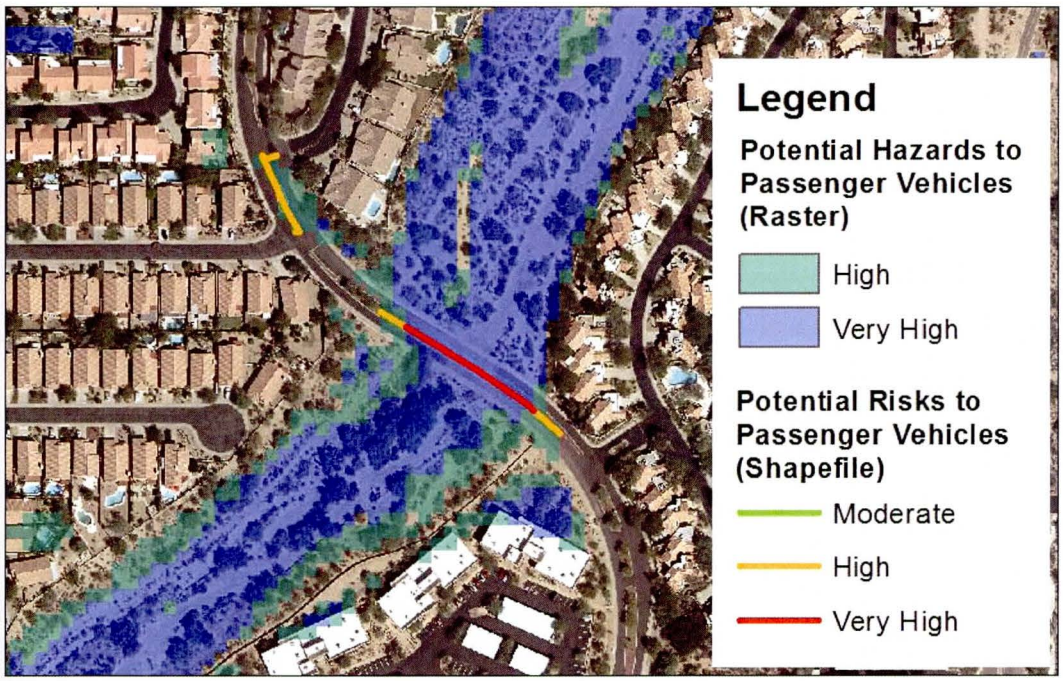


Figure 3 – Example of Raster and Polyline Shapefiles for Passenger Vehicles Flood Hazard

The second method for visualizing and quantifying potential flood risks to passenger vehicles is a point shapefile showing street segments that are affected by a moderate, high, or very high potential flood risk. For the purpose of this method, a roadway segment is defined as a stretch of roadway between two intersections.

Figure 4 is an example of how flood risks to passenger vehicles is shown visually for this method. Displaying information in this way might be useful in determining if there are any clusters of roadways with significant risks that might be addressed in the prioritization stage of the PPW ADMS. Quantitatively, this method provides a total number of roadway segments effected by high and very high potential risks. A summary of results is provided in **Table 2**.

During the modeling effort, 50 culvert and bridge crossings were modeled by decreasing the elevation of the grid element(s) at the crossing rather than coding a structure into the model.

Potential risks at these locations were analyzed in more detail. An estimation was made for the capacity of the culvert based on the culvert size and number of barrels. A weir calculation was performed to estimate the depth of any discharge in excess to the estimated capacity of the culvert. Three crossings had an overtopping depth between 0.5 and 2 feet and were therefore reassigned to a moderate risk classification.

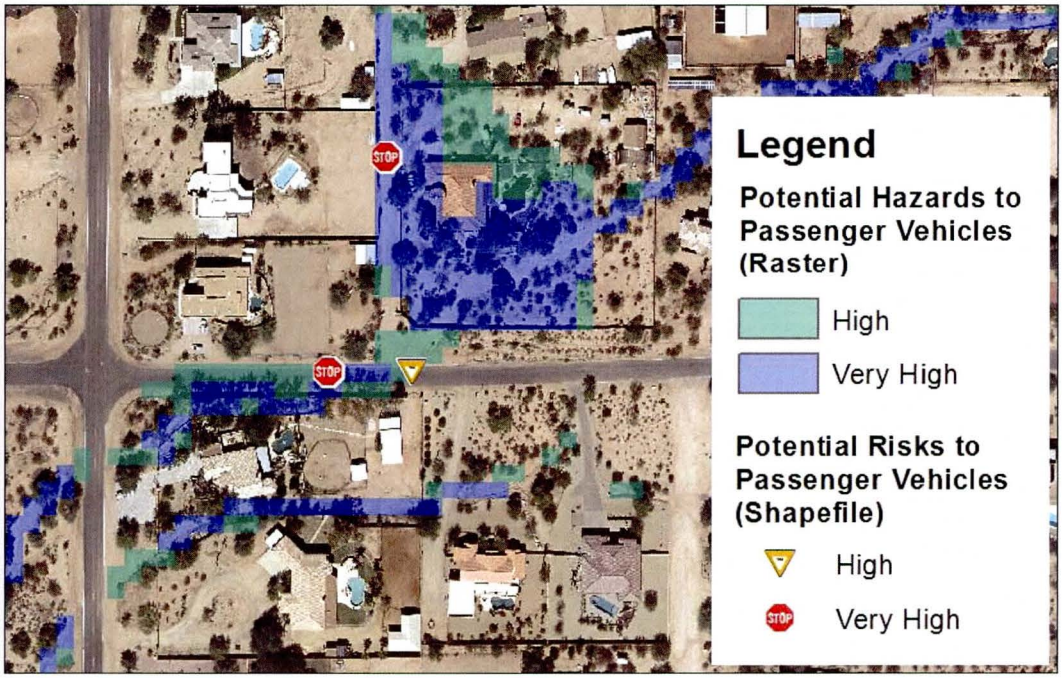


Figure 4 - Example of Raster and Point Shapefile for Passenger Vehicle Risks

A visualization and summary of results for the polyline and point road risks for the entire study area are provided in **Exhibit B** and **Exhibit C**, respectively. The following electronic data for the potential risks to passenger vehicles are provided along with this technical memorandum:

- Potential risk to passenger vehicles as a polyline (shapefile) (example nomenclature for all storm events: WC_VehicleLine_100)
- Potential risk to passenger vehicles as a point (shapefile) (example nomenclature for all storm events: WC_VehiclePoint_100)
- Potential hazard to passenger vehicles layer (raster) (example nomenclature for all storm events: wc_vehicle100) (for documentation)

Potential Risks to Buildings

Potential risks to buildings were classified using a combination of minimum depth criteria and the depth-velocity relationship from TM 11. The depth-velocity relationship from TM 11 is shown as **Figure 5**. The following four categories exist for potential flood risks to structures:

- *Low:* Buildings that have contact with at least one FLO-2D grid element that has a depth ranging between 0.5 feet and 1.5 feet and a velocity of at least 1 foot per second (fps) have been designated as having low potential flood risk. The minimum 0.5 foot depth assumes that the average finished floor elevation for a structure is 0.5 feet above grade. The 1.5-foot maximum depth criterion assumes that average electrical outlets are one foot above

the finished floor elevation (therefore 1.5 feet above grade). The 1 fps minimum velocity is added to the depth criteria to eliminate structures that might only have localized ponding.

- *Moderate:* Buildings that have contact with at least one FLO-2D grid element that has a depth ranging between 1.5 feet and 2.5 feet and a velocity of at least 1 fps have been designated as having a moderate potential flood risk.
- *High:* Buildings that have contact with at least one FLO-2D grid element where one of the following criteria is true have been designated as having a high potential flood risk.
    - *Depth:* A depth greater than 2.5 feet and a velocity of at least 1 fps.
    - *TM 11:* A structure with a velocity-depth relationship corresponding to the TM 11 Judgment Zone shown in **Figure 5**.
- *Very 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 5** have been designated as having a very high potential flood risk.

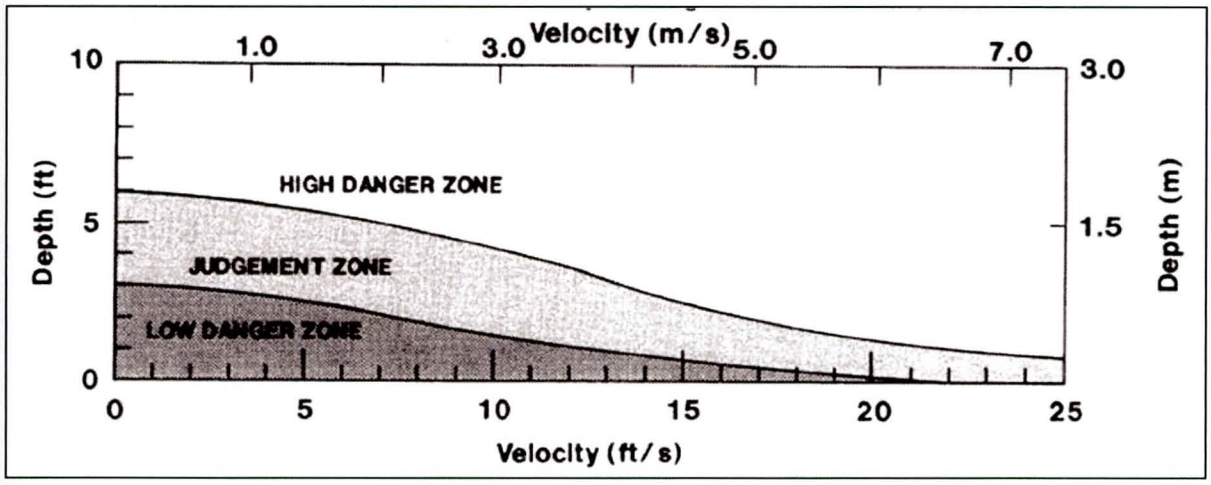


Figure 5 - Depth-Velocity Flood Danger Level for Buildings

A flood hazard layer was intersected with a polygon shapefile containing all of the buildings in the watershed using the 'Zonal Statistics as Table' tool in ArcMap. The 'Zonal Statistics as Table' tool works by first creating a raster from the building polygon shapefile. It should be noted that the raster generated by the building polygon is based on a 20 foot grid size and therefore does not match the building footprint exactly. The tool then checks if the centroid of any grid from the building raster intersects a grid from the flood hazard layer. If it does, that risk classification is assigned to the building polygon in an attribute table. If a building intersects the hazard layer multiple times, the maximum risk classification is assigned to the building. Buildings with less than 600 square feet (mostly secondary outbuildings) were not considered because they are assumed to be uninhabited due to their size. The result is a building polygon shapefile with a risk attribute classifying low, moderate, high, or very high flood risks.

Commercial buildings with ponding due to a truck dock or the geometry of the building blocking the flow of runoff were removed from the flood risk designation. An example of ponding caused by the geometry of a building is shown in **Figure 6**. The assumption that buildings falling into these categories should be treated as anomalies is that commercial developments should have engineered onsite drainage features to relieve ponding in truck docks or against the building.

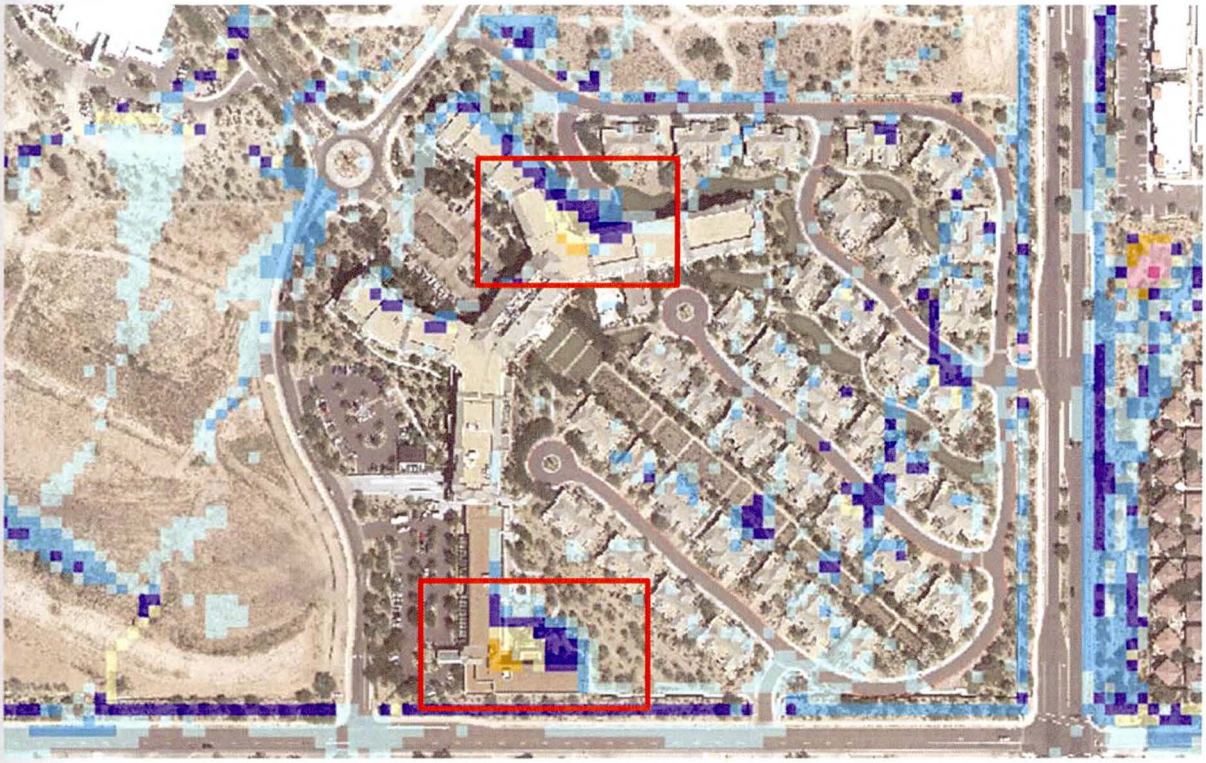


Figure 6 - Ponding Due to Building Geometry

An assessment was also done to determine the maximum potential hazard to pedestrians around buildings. This assessment was completed using the same 'Zonal Statistics as Table' tool as described earlier in this section. The potential hazard to pedestrians around buildings assessment is pertinent because the area around buildings is where pedestrians are most likely to be if outside during a storm event. The results reinforce the idea that people should stay indoors during a flood. This assessment can also be used to evaluate the damage to landscaping around houses during a storm event.

A visualization and summary of results for the potential risks to buildings is provided in **Exhibit D** at the end of this technical memorandum. A summary of potential risks to buildings is provided in **Table 3**. A summary of the potential hazard to pedestrians around buildings is provided in **Table 4.** The following electronic data for the potential risks to buildings are provided along with this technical memorandum:

- Potential risks to buildings (shapefile) (example nomenclature for all storm events: WC_BuildingRisks_100)
- Potential hazard layer based on depth (raster) (example nomenclature for all storm events: wc_depth_100) (for documentation)
- Potential hazard layer based on TM 11 criteria (raster) (example nomenclature for all storm events: wc_tm11_100) (for documentation)
- Overall potential hazard layer combined to include depth and TM 11 criteria (raster) (example nomenclature for all storm events: wc_comb_100) (for documentation)

Potential Risks Impacting Schools

There are 14 schools in the study area. An analysis was done to assess the potential risks associated with transporting children to and from school via passenger vehicles and walking. The potential risks associated with transporting students to and from schools in a passenger vehicle was assessed by counting the number of arterial roadway segments impacted by a moderate, high, or very high potential risk to passenger vehicles within a 1.5 mile radius of a school. The potential risks associated with children walking to and from school was assessed visually by comparing the pedestrian hazard raster with the location of each school. If the majority of pedestrian walkways from the school to surrounding neighborhoods are impacted by pedestrian hazards, the school was determined to have a risk for children walking to and from school.

The results for potential passenger vehicle and pedestrian risks impacting schools are provided in **Table 5** and **Table 6** respectively. A visualization of the potential risks impacting schools are provided in **Exhibit E** and **Exhibit F**.

Summary

A summary of the hazard and risk assessment for the watershed is presented in the following tables:

Table 1 - Summary of the Road Polyline Risks (WC Scenario)

Storm Event	Street Classification	Rawhide Wash (UR, LR)				Northwest Area (LT, WR, TR, DR, CB)				Overall Total
		Moderate	High	Very High	Rawhide Wash Total	Moderate	High	Very High	Northwest Area Total	
100-Year	ADOT	0.9%	0.0%	0.0%	0.9%	0.6%	0.0%	0.0%	0.6%	0.8%
	Arterial	21.9%	2.7%	6.0%	30.6%	19.3%	1.4%	0.3%	21.0%	23.1%
	Secondary	20.4%	3.8%	1.9%	26.2%	14.2%	0.6%	0.2%	14.9%	16.7%
25-Year	ADOT	0.4%	0.0%	0.0%	0.4%	0.2%	0.0%	0.0%	0.2%	0.3%
	Arterial	9.5%	1.0%	1.0%	11.5%	4.3%	0.2%	0.0%	4.6%	6.1%
	Secondary	14.5%	1.6%	0.4%	16.4%	10.0%	0.3%	0.1%	10.5%	11.4%
10-Year	ADOT	0.3%	0.0%	0.0%	0.3%	0.0%	0.2%	0.3%	0.7%	0.5%
	Arterial	6.7%	0.7%	0.5%	7.8%	2.7%	0.1%	0.0%	2.8%	3.9%
	Secondary	10.2%	0.8%	0.2%	11.2%	6.2%	0.2%	0.0%	6.4%	7.2%

**Percentages represent the percent of the total length of street for a given classification effected by the respective risk classification.*

Table 2 - Summary of the Road Point Risks (WC Scenario)

Storm Event	Street Type	Rawhide Wash (UR, LR)				Northwest Area (LT, WR, TR, DR, CB)				Overall Total
		Moderate	High	Very High	Total	Moderate	High	Very High	Total	
100-Year	Arterial	37	9	11	57	184	15	11	210	267
	Secondary	272	66	46	384	1573	171	58	1802	2186
25-Year	Arterial	38	1	6	44	130	12	4	146	191
	Secondary	243	27	13	282	1263	106	26	1395	1678
10-Year	Arterial	22	4	2	26	99	9	0	108	136
	Secondary	189	17	8	214	1070	51	16	1137	1351

Table 3 - Summary of Potential Risks to Buildings (WC Scenario)

Storm Event	Rawhide Wash (UR, LR)					Northwest Area (LT, WR, TR, DR, CB)					Overall Total
	Low	Moderate	High	Very High	Rawhide Wash Total	Low	Moderate	High	Very High	Northwest Area Total	
100-YR	683	98	28	4	813	1000	78	21	4	1103	1916
25-YR	337	37	16	1	391	472	31	14	2	519	910
10-YR	245	18	10	1	274	249	14	10	2	275	549

Table 4 - Summary of the Hazards to Pedestrians around Buildings (WC Scenario)

Storm Event	Rawhide Wash (UR, LR)			Northwest Area (LT, WR, TR, DR, CB)			Overall Total
	Moderate	High	Total	Moderate	High	Total	
100-YR	453	318	771	674	257	931	1702
25-YR	228	140	368	361	102	463	831
10-YR	172	82	254	193	63	256	510

Table 5 - Summary of Potential Roadway Risks Impacting Schools (WC Scenario)

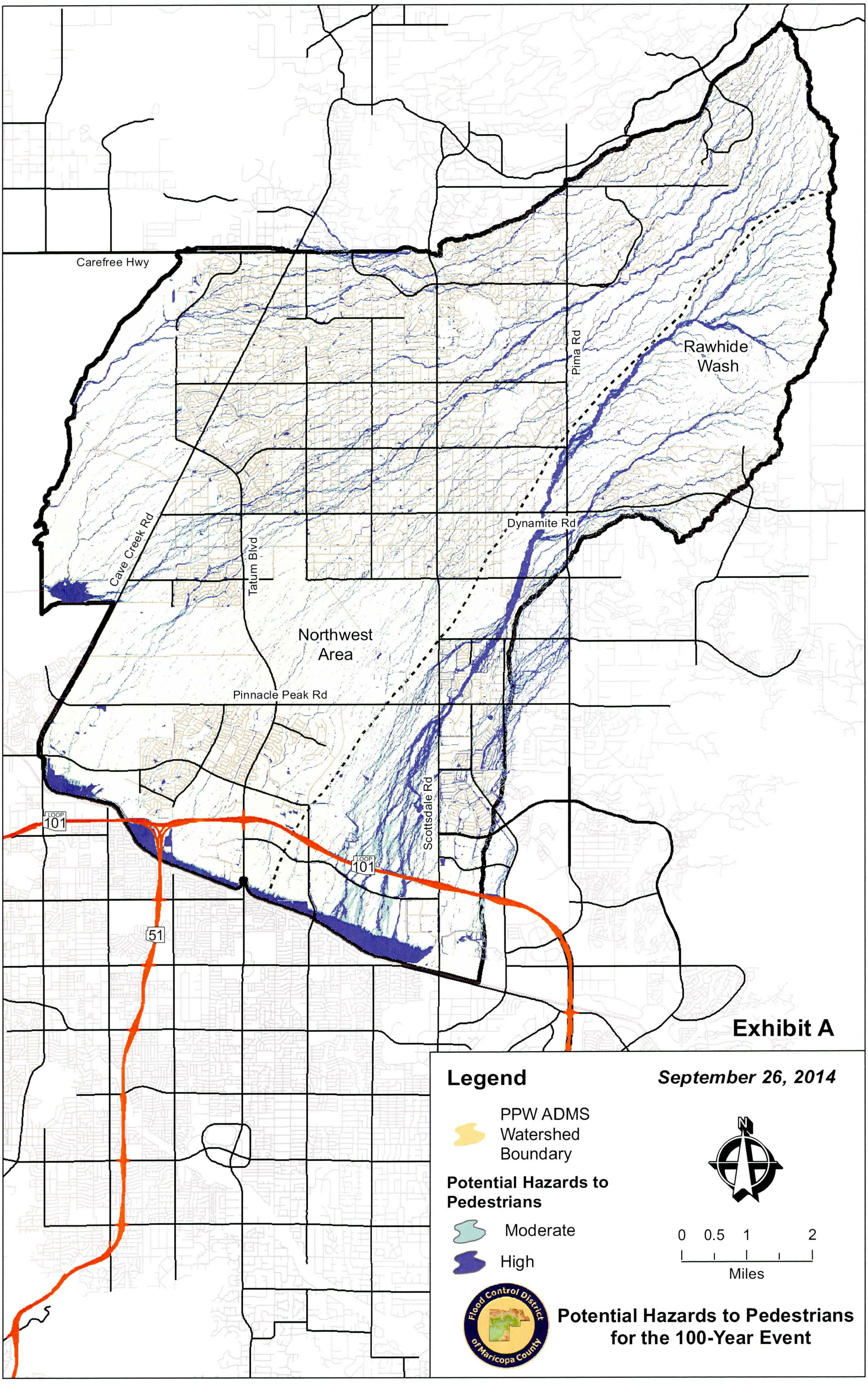
Storm Event	Hazard Classification	Elementary School	Middle School	High School	Total*
100-Year	Very High	15	5	3	16
	High	18	4	9	19
	Moderate	153	37	24	157
25-Year	Very High	9	2	0	9
	High	9	4	7	10
	Moderate	121	23	17	122
10-Year	Very High	2	0	0	2
	High	10	4	3	11
	Moderate	91	19	15	95

**The total represents the total number of potential risks to passenger vehicles within a 1.5 mile radius of all schools. For example, a potential risk might impact both an elementary school and middle school, but is only counted once for the total.*

Table 6 - Summary of Potential Pedestrian Risks Impacting Schools (WC Scenario)

Storm Event	Elementary School	Middle School	High School	Total
100-Year	8	1	1	10
25-Year	7	1	1	9
10-Year	6	0	0	6

Exhibits


Carefree Hwy
Pima Rd
Rawhide Wash
Dynamite Rd
Cave Creek Rd
Tatum Blvd
Northwest Area
Pinnacle Peak Rd
Scottsdale Rd
LOOP 101
LOOP 101
51
Exhibit A
Legend
September 26, 2014
PPW ADMS Watershed Boundary
Potential Hazards to Pedestrians
Moderate
High
N
0 0.5 1 2
Miles
Flood Control District of Maricopa County
Potential Hazards to Pedestrians for the 100-Year Event

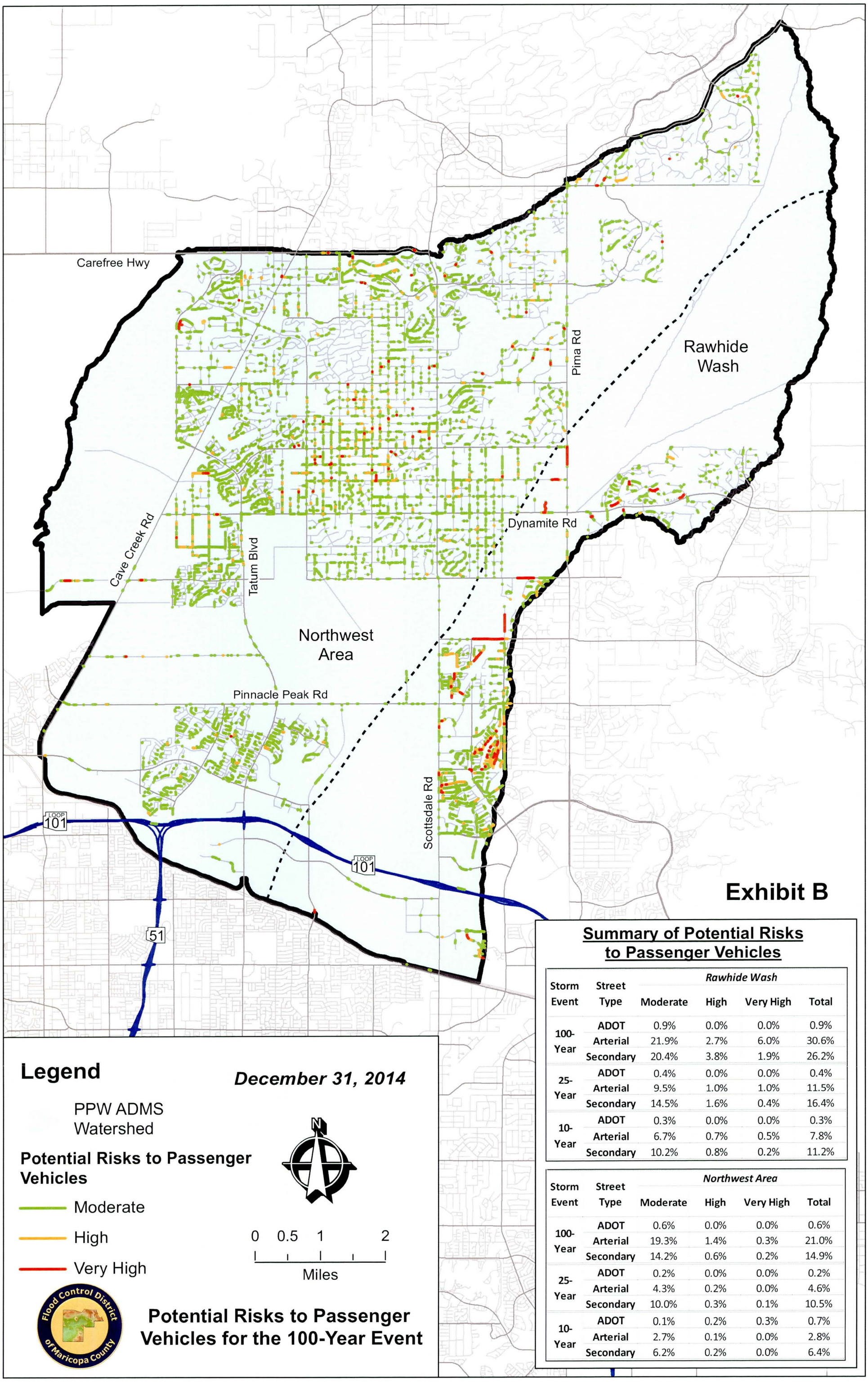
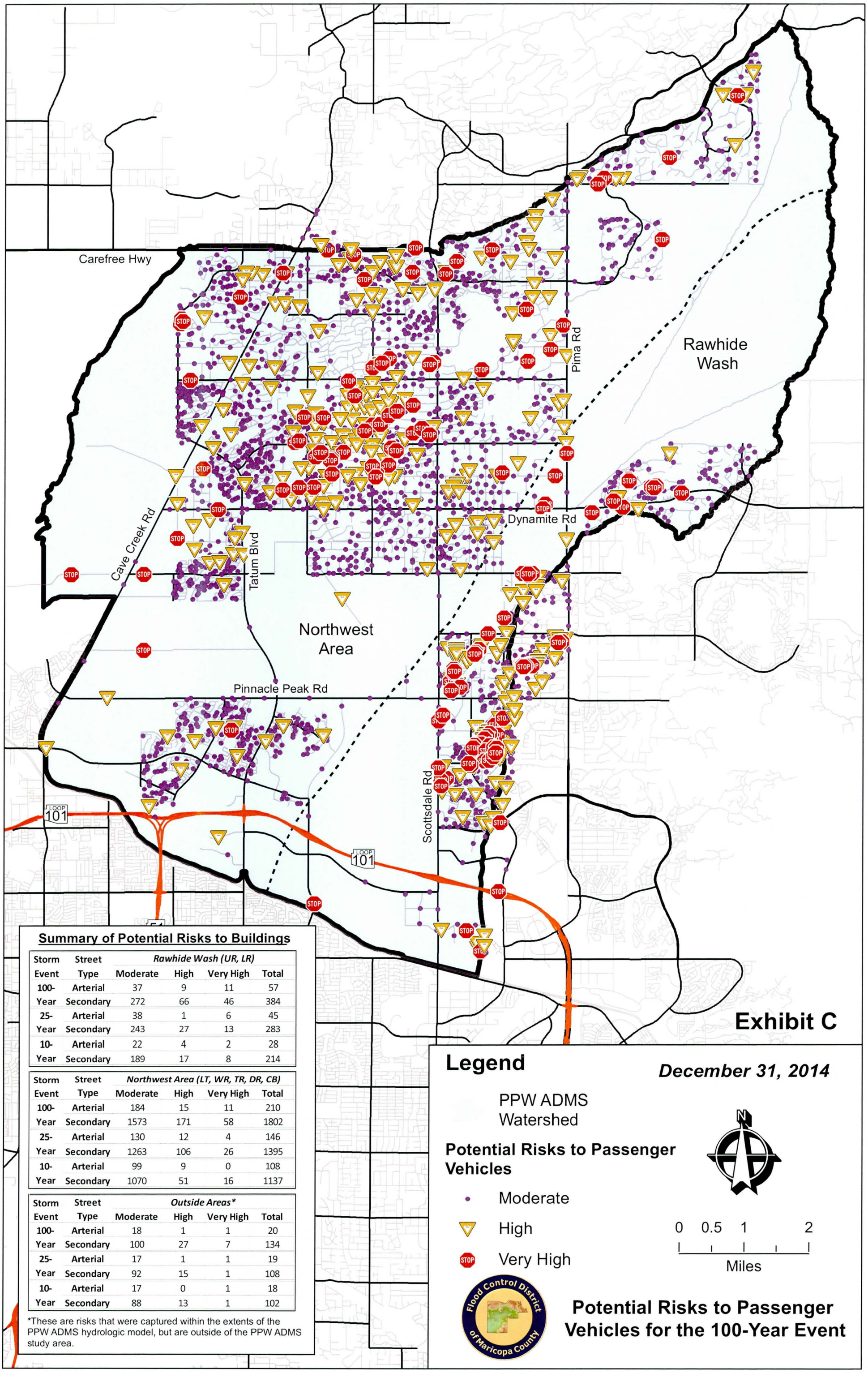


Exhibit B

Summary of Potential Risks to Passenger Vehicles

Storm Event	Street Type	Rawhide Wash Moderate	High	Very High	Total
100-Year	ADOT	0.9%	0.0%	0.0%	0.9%
	Arterial	21.9%	2.7%	6.0%	30.6%
	Secondary	20.4%	3.8%	1.9%	26.2%
25-Year	ADOT	0.4%	0.0%	0.0%	0.4%
	Arterial	9.5%	1.0%	1.0%	11.5%
	Secondary	14.5%	1.6%	0.4%	16.4%
10-Year	ADOT	0.3%	0.0%	0.0%	0.3%
	Arterial	6.7%	0.7%	0.5%	7.8%
	Secondary	10.2%	0.8%	0.2%	11.2%

Storm Event	Street Type	Northwest Area Moderate	High	Very High	Total
100-Year	ADOT	0.6%	0.0%	0.0%	0.6%
	Arterial	19.3%	1.4%	0.3%	21.0%
	Secondary	14.2%	0.6%	0.2%	14.9%
25-Year	ADOT	0.2%	0.0%	0.0%	0.2%
	Arterial	4.3%	0.2%	0.0%	4.6%
	Secondary	10.0%	0.3%	0.1%	10.5%
10-Year	ADOT	0.1%	0.2%	0.3%	0.7%
	Arterial	2.7%	0.1%	0.0%	2.8%
	Secondary	6.2%	0.2%	0.0%	6.4%



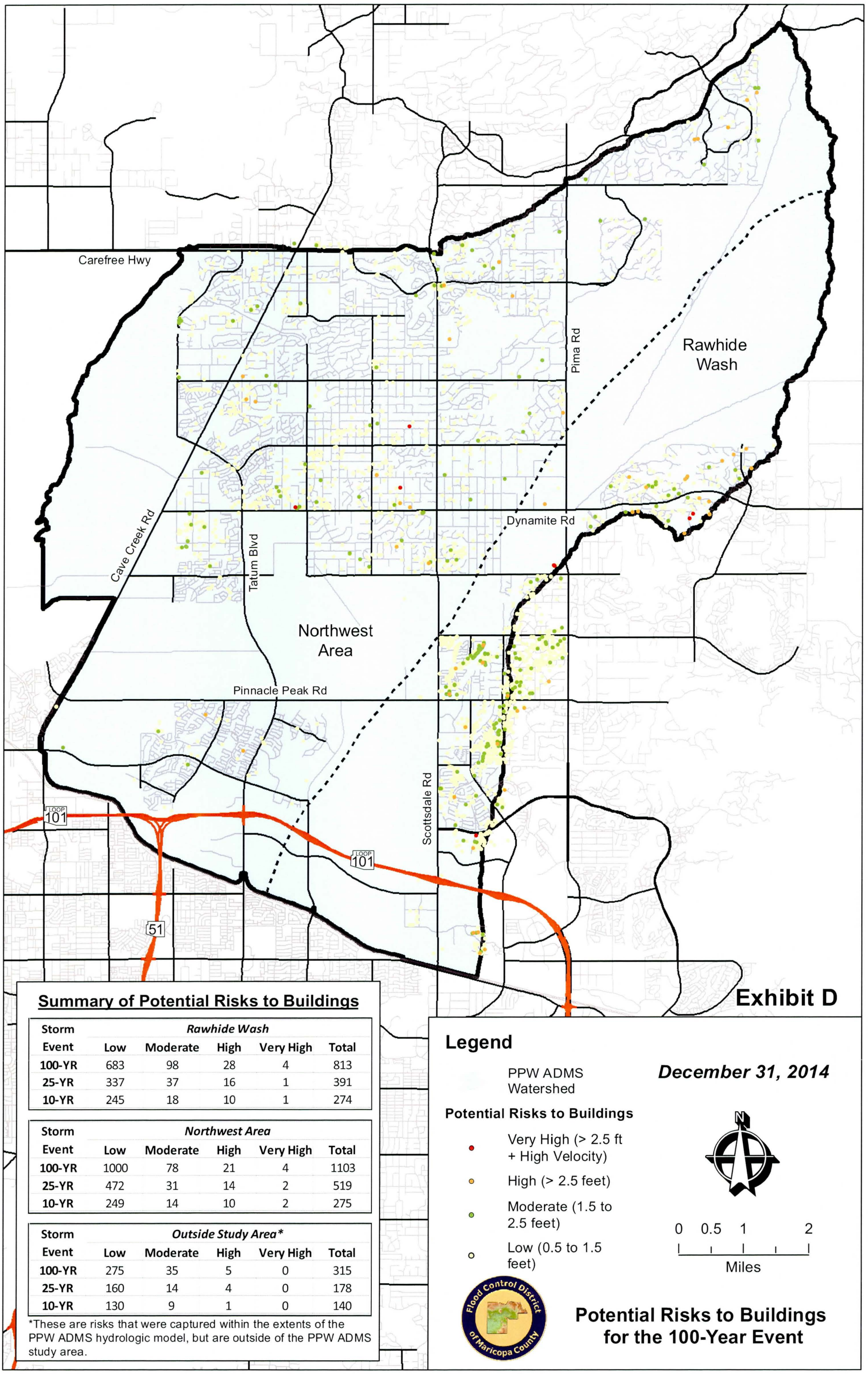
Summary of Potential Risks to Buildings

Storm Event	Street Type	*Rawhide Wash (UR, LR)* Moderate	High	Very High	Total
100-Year	Arterial	37	9	11	57
	Secondary	272	66	46	384
25-Year	Arterial	38	1	6	45
	Secondary	243	27	13	283
10-Year	Arterial	22	4	2	28
	Secondary	189	17	8	214

Storm Event	Street Type	*Northwest Area (LT, WR, TR, DR, CB)* Moderate	High	Very High	Total
100-Year	Arterial	184	15	11	210
	Secondary	1573	171	58	1802
25-Year	Arterial	130	12	4	146
	Secondary	1263	106	26	1395
10-Year	Arterial	99	9	0	108
	Secondary	1070	51	16	1137

Storm Event	Street Type	*Outside Areas** Moderate	High	Very High	Total
100-Year	Arterial	18	1	1	20
	Secondary	100	27	7	134
25-Year	Arterial	17	1	1	19
	Secondary	92	15	1	108
10-Year	Arterial	17	0	1	18
	Secondary	88	13	1	102

*These are risks that were captured within the extents of the PPW ADMS hydrologic model, but are outside of the PPW ADMS study area.



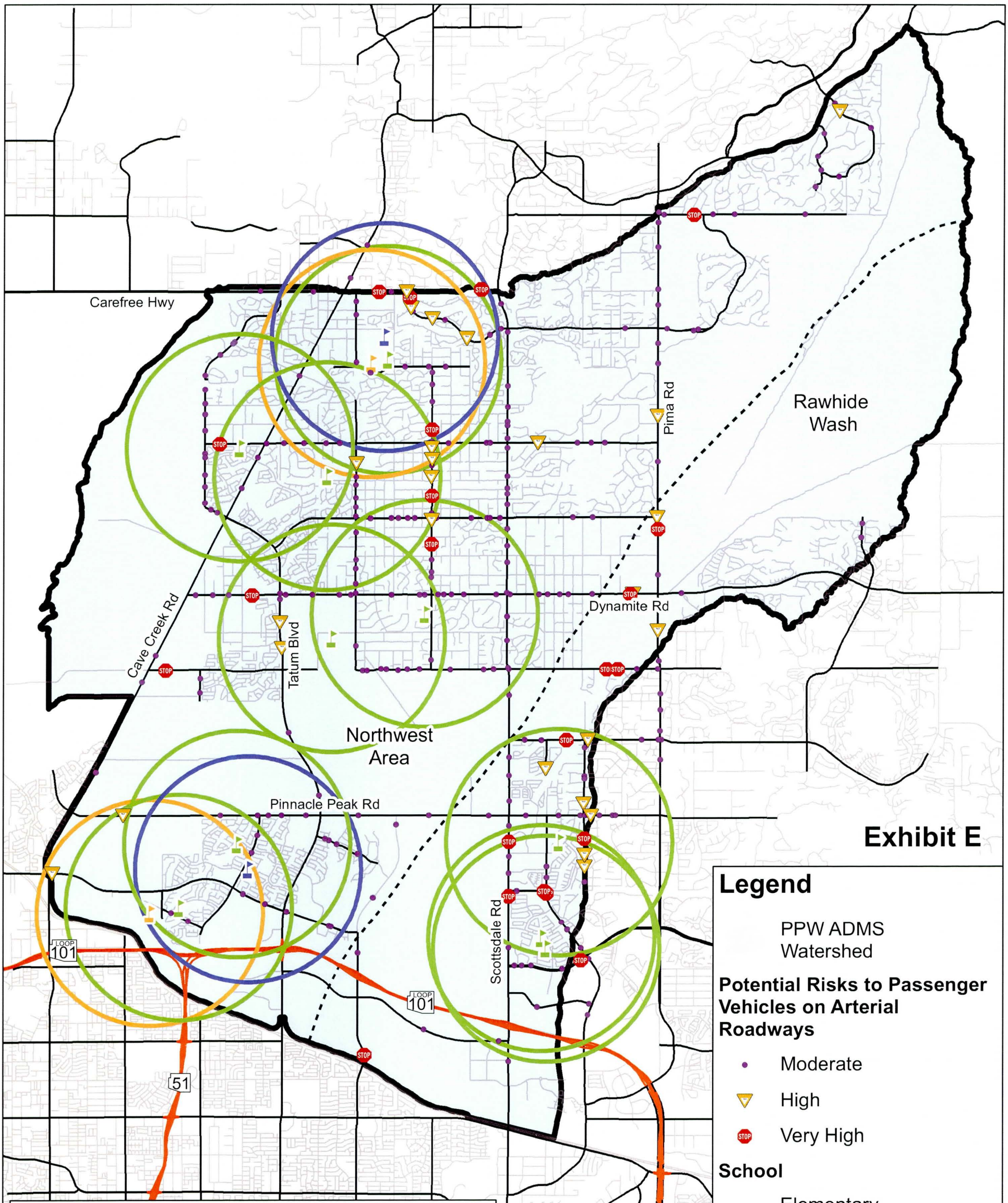
Summary of Potential Risks to Buildings

Storm Event	Rawhide Wash				
	Low	Moderate	High	Very High	Total
100-YR	683	98	28	4	813
25-YR	337	37	16	1	391
10-YR	245	18	10	1	274

Storm Event	Northwest Area				
	Low	Moderate	High	Very High	Total
100-YR	1000	78	21	4	1103
25-YR	472	31	14	2	519
10-YR	249	14	10	2	275

Storm Event	Outside Study Area*				
	Low	Moderate	High	Very High	Total
100-YR	275	35	5	0	315
25-YR	160	14	4	0	178
10-YR	130	9	1	0	140

*These are risks that were captured within the extents of the PPW ADMS hydrologic model, but are outside of the PPW ADMS study area.

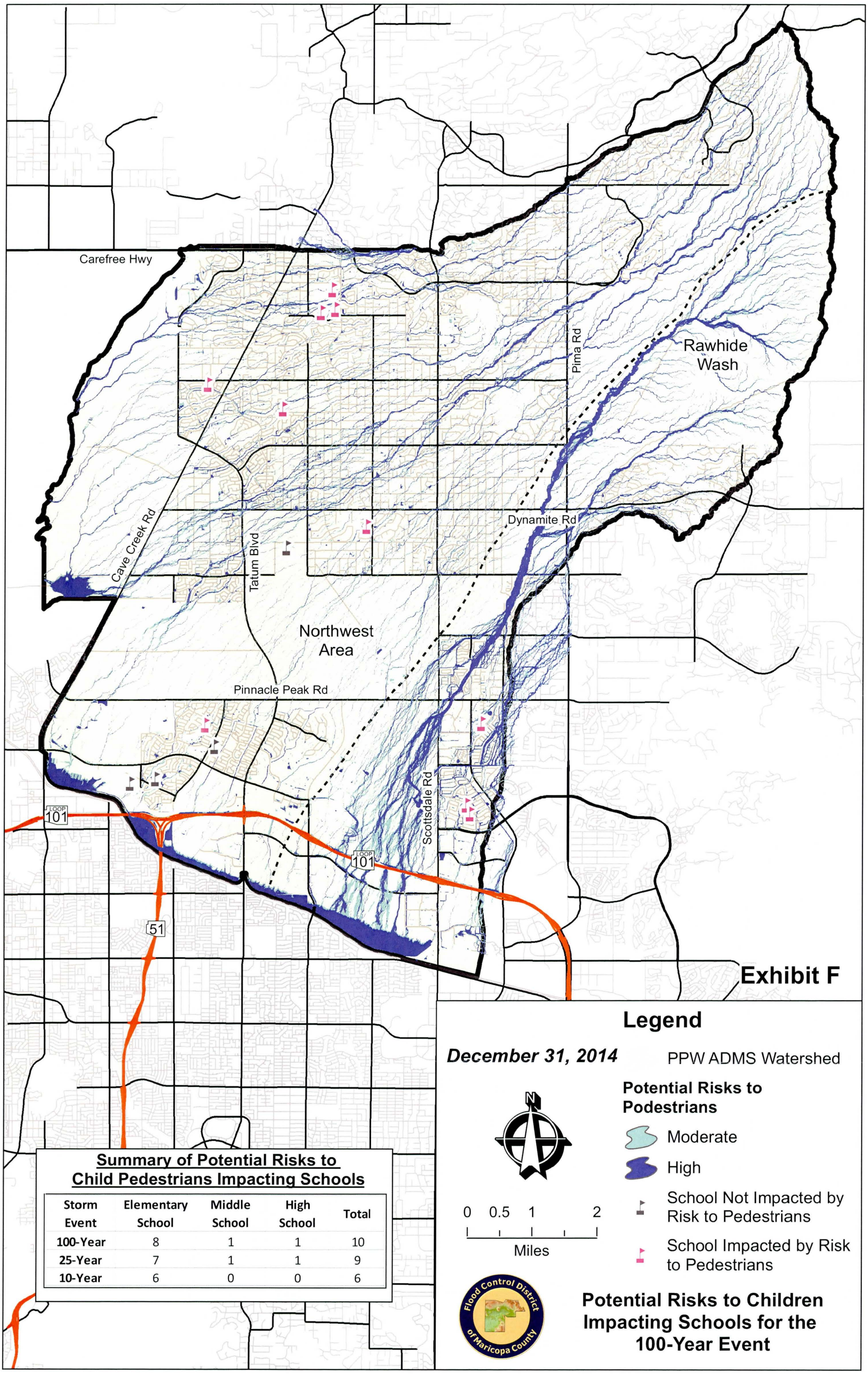


Summary of Potential Risks to Passenger Vehicles Impacting Schools

Storm Event	Hazard Classification	Elementary School	Middle School	High School	Total*
100-Year	Very High	15	5	3	16
	High	18	4	9	19
	Moderate	153	37	24	157
25-Year	Very High	9	2	0	9
	High	9	4	7	10
	Moderate	121	23	17	122
10-Year	Very High	2	0	0	2
	High	10	4	3	11
	Moderate	91	19	15	95

*The total represents the total number of potential risks to passenger vehicles within a 1.5 mile radius of all schools. For example, a potential risk might impact both an elementary school and middle school, but is only counted once for the total.

Potential Risks to Passenger Vehicles Impacting Schools for the 100-Year Event



Summary of Potential Risks to Child Pedestrians Impacting Schools

Storm Event	Elementary School	Middle School	High School	Total
100-Year	8	1	1	10
25-Year	7	1	1	9
10-Year	6	0	0	6

Flood Problem Prioritization Memorandum

Memorandum

DATE: December 31, 2014

TO: Theresa Pinto, Project Manager, FCDMC

FROM: Pat Quinn, PE, RLS, AVS
Reed Blochberger, EIT

RE: Pinnacle Peak West ADMS Work Assignment No. 3
Task 14.0 Flood Problem Prioritization

Purpose of Flood Problem Prioritization

The flood problem prioritization assessment involved using the results of the Flood Hazard Classification and Flood Risk Determination (hazard and risk assessment) as well as public and stakeholder input to identify areas in the Pinnacle Peak West (PPW) Area Drainage Master Study (ADMS) watershed that possess especially critical flooding issues.

A geodatabase was created for the flood problem prioritization task to organize all observed issues from public and stakeholder input and potential issues from the hazard and risk assessment. The following three datasets are contained within the geodatabase.

- *Infrastructure_All:* This dataset contains all of the observed and potential issues.
- *Transportation_Only:* This dataset contains any issues from the Infrastructure_All dataset that relate specifically to transportation flooding issues.
- *Source_Data*: This dataset contains all of the raw data received from the various sources.

The following sections described the data contained within each of the three datasets in greater detail.

Infrastructure_All

The Infrastructure_All dataset is composed of seven feature classes. Each of the feature classes fits into a category which generally describes the data source. The three category options are public input, stakeholder input, or analytical identification.

Public Input

The feature classes that fit into the public input category include public meetings (Meeting_Input) and data from the reportaflood.org website (Report_A_Flood). The data collected for the public meetings feature class came from two sources. The first public meeting source is the input from the home owner's association (HOA) meetings. The HOA meetings included a series of meetings between Flood Control District of Maricopa County (FCDMC) staff, JE Fuller project members, and various HOAs throughout the study area. These meetings were conducted throughout a six month period and provided an opportunity for community members and leaders to give input of observed flooding issues in and around their neighborhoods while learning more about the study. The second source of data for the public meetings feature class is the PPW ADMS Public Meetings which included the PPW Rawhide public meeting (09/16/2014) and the northwest watershed

public meeting (09/18/2014). At both public meetings, attendees had the opportunity to record flooding issues by writing on hard copy maps, or by digital input using computer stations at the meetings. Attribute fields within this feature class include meeting type (MeetingTyp), a description of the drainage issue (Descrip), source, and category. The second feature class in the public input category is data collected from the reportaflood.org website. The website is hosted by the FCDMC and allows the public to upload flooding issues, flood dates, and pictures or videos. The data in the feature class includes all items posted to the website before November 3rd, 2014. Attribute fields within the report a flood feature class include date of the storm that caused the complaint (StormDate), location of the issue (Location), description of the issue (Descrip), source, and category.

Stakeholder Input

The feature classes that fit into the stakeholder input category include drainage complaints (Drainage_Complaints) and operations and maintenance (Operations_and_Maintenance). The data for these two feature classes was provided directly by one of the three municipalities located in the study area; City of Phoenix, City of Scottsdale, and Maricopa County. Attribute fields within the drainage complaints feature class include the applicable municipality (Municipalty), date of the storm that caused the complaint (StormDate), a description of the drainage issue (Descrip), a location of the issue (Location), source, and category. Attribute fields within the operations and maintenance (O&M) feature class also include the municipality, storm date, description, source, and category. In addition, the O&M feature class contains an attribute describing whether the feature represents a maintenance issue, or a barricade that was put up during the storm event. Barricade information provided by Maricopa County originally came as line features. So that this data could be included with the other municipality O&M data, the line features were converted into point features. Some O&M issues provided by the stakeholders outside of the study area were included in the geodatabase to help understand the bigger picture of drainage issues impacting the study area.

Analytical Identification

The feature classes that fit into the analytical identification category include potential risks to passenger vehicles and buildings from the hazard and risk analysis. The potential risk to passenger vehicles includes a feature class for both the point (RoadPointRisks_WC_10yr) and line segment (RoadLineRisks_WC_10yr) features from the hazard and risk analysis. The potential risk to buildings were identified in the hazard and risk assessment as polygon features. These polygon features were imported into the Source_Data dataset. To better visualize the buildings with the other data, the polygon features were converted into point features. Out of the three storm events analyzed in the hazard and risk assessment, potential risk from the 10-year event were included in the geodatabase. The reason for using the potential risk from the 10-year event is to help highlight the more common flooding issues.

A visual summary of the Infrastructure_All dataset is shown as Figure 1.

Transportation_Only

Flooding issues related specifically to transportation within the study area has been a consistent theme throughout all facets of data collection and flooding issue identification. Transportation issues, however, get lost within all of the other infrastructure issues when viewing the Infrastructure_All dataset as a whole. The Transportation_Only dataset was created to help clarify transportation specific flooding issues. Any features from the Infrastructure_All dataset that related specifically to transportation were copied into the Transportation_Only dataset. All

feature classes in the Transportation_Only dataset have the extension "_Transpo" added to their name and maintain all of the same attribute fields.

A visual summary of the Transportation_Only dataset is shown as Figure 2.

Source_Data

All features within the prioritization geodatabase were imported from various shapefiles into their respective datasets so that they would have uniform attributes and structure. The original shapefiles used to create the Infrastructure_All and Transportation_Only datasets were imported into the Source_Data dataset as a reference. The feature classes in the Source_Data dataset maintain all of the same attributes and format as the original shapefiles.

Prioritization Outcome

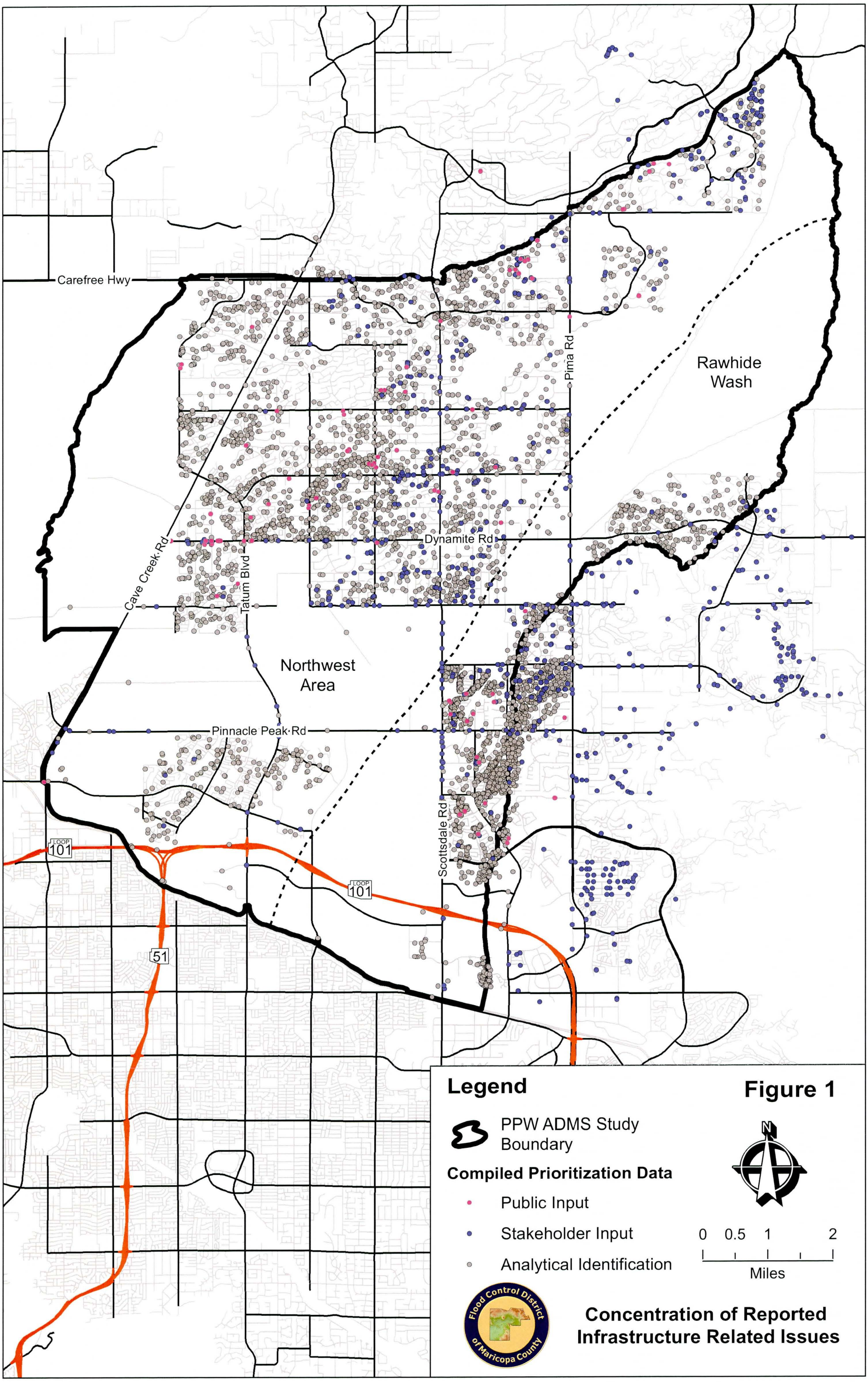
The following candidate alternatives were highlighted from the prioritization effort.

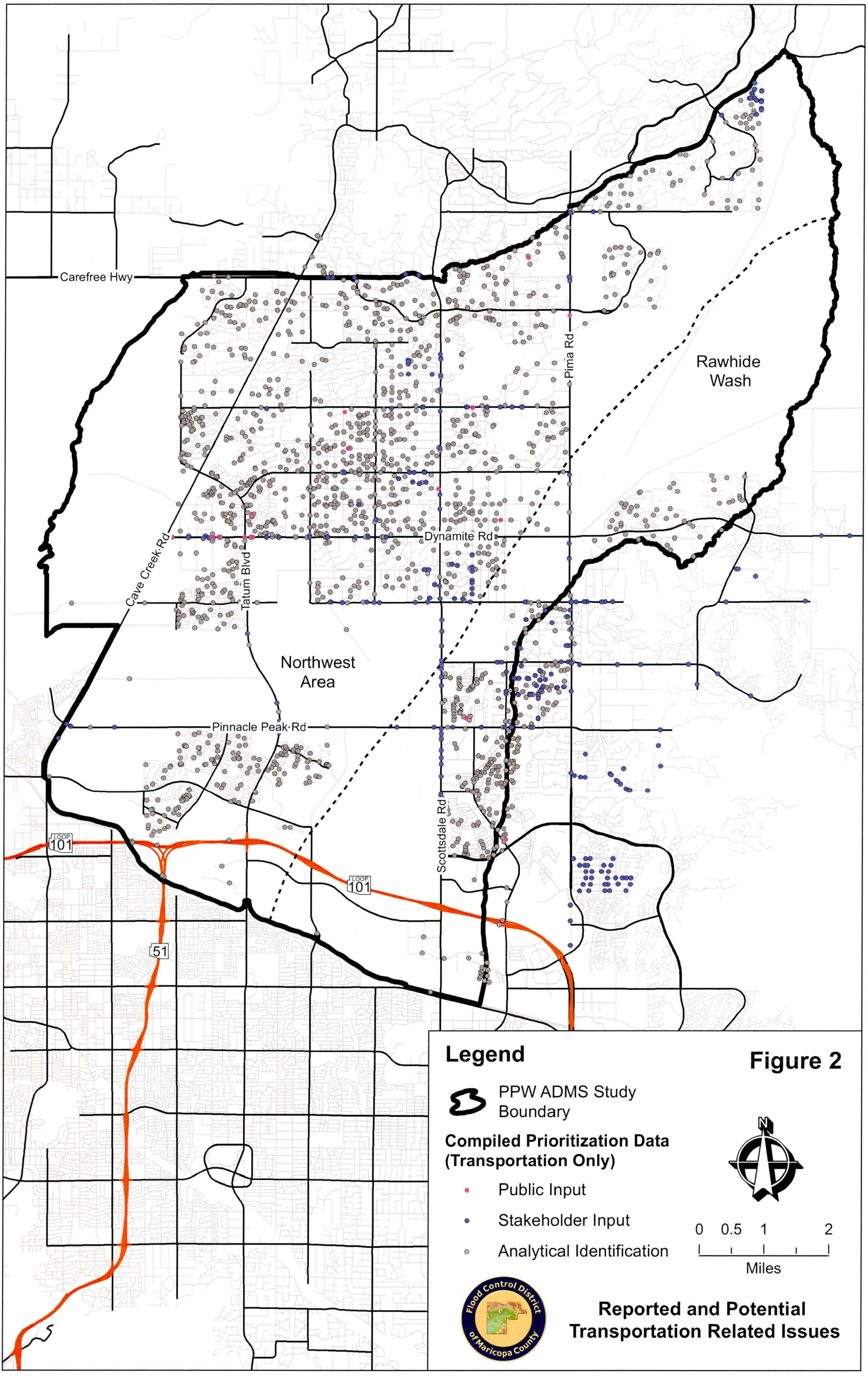
- *Refinement of Risk Assessment for Buildings*: Potential flood risks to buildings makes up a large portion of the potential risks identified by analytical methods. It is noted from the FCDMC Flood Tolerance Survey Results (tolerance survey), that flood risk to buildings is a major concern to community members in the study area. To better understand the potential flooding issues impacting buildings, as well as possible solutions, it is recommended that the buildings identified as having a potential risk in the hazard and risk assessment be further assessed on an individual basis. This alternative is discussed more in the Task 15 - Buildings w Hazards Alternatives Memo.
- *Transportation Access Plan*: As mentioned in the Transportation_Only section of this memorandum, transportation issues within the study area has been a major concern in every phase of the data collection effort. This concern is further reflected in the feedback from the tolerance survey. As seen in Figure 2, one of the most severe transportation issues, even in smaller storm such as the 10-year event, is unreliable (and sometime no) north-south transportation routes. This issue is not only of concern to resident's mobility during storms, but also emergency responder access. It is recommended than an all-weather transportation access plan be developed. This alternative is discussed more in the Task 15 - Transportation Improvements Memo.
- *Rawhide Report*: As seen in Figure 1, the area surrounding Rawhide Wash downstream of the Rawhide fan apex has a very high concentration of observed and potential flooding issues. This area is also of specific concern due to the unpredictable, alluvial nature of the wash. It is recommended that several alternatives for alleviating flooding issues related to Rawhide Wash be examined. This alternative is discussed more in the Rawhide Wash Conceptual Alternatives Report (under separate cover).
- *Other Areas Memo*: Aside from the major themes mentioned, it is apparent that there are other more localized area with flooding issues. Other areas within the study area that exhibit adverse flooding conditions include Grayhawk basin overflows, Pinnacle Peak piedmont, Cave Creek Road area, 44th Street and Dynamite Road area, and Terravita Way area. Localized flooding issues vary in severity and cause and should be examined more thoroughly for acceptable mitigation approaches. This alternative is discussed more in the Task 15 - Other Areas Memo.

In addition to the issues highlighted during the prioritization effort, the following issue will also be an important consideration moving forward:

- *Re-delineation of Fans 5 and 6*: Inactive Fans 5 and 6 have existing floodplain delineations that do not adequately represent the actual floodplain limits nor flood hazards and risks in the area. Because of this, some residences have unneeded restrictions and flood insurance while other residents are likely located in areas of greater risk than they realize. It is recommended that the PPW FLO-2D modeling results be used to re-delineate the floodplain in these areas.

Figures


Carefree Hwy
Cave Creek Rd
Tatum Blvd
Dynamite Rd
Pima Rd
Rawhide Wash
Northwest Area
Pinnacle Peak Rd
Scottsdale Rd
LOOP 101
LOOP 101
51
Legend
Figure 1
PPW ADMS Study Boundary
Compiled Prioritization Data
Public Input
Stakeholder Input
Analytical Identification
N
0 0.5 1 2
Miles
Flood Control District of Maricopa County
Concentration of Reported Infrastructure Related Issues


Carefree Hwy
Cave Creek Rd
Tatum Blvd
Dynamite Rd
Pima Rd
Rawhide Wash
Northwest Area
Pinnacle Peak Rd
Scottsdale Rd
LOOP 101
LOOP 101
51
Legend
Figure 2
PPW ADMS Study Boundary
Compiled Prioritization Data (Transportation Only)
Public Input
Stakeholder Input
Analytical Identification
N
0 0.5 1 2
Miles
Flood Control District of Maricopa County
Reported and Potential Transportation Related Issues

Alternatives to Reduce Flood Risk – Buildings Memorandum

Memorandum

DATE: January 8, 2014

TO: Theresa Pinto, Project Manager, FCDMC

FROM: Pat Quinn, PE, RLS, AVS
Ted Lehman, PE

RE: Pinnacle Peak West ADMS Work Assignment No. 3
Task 15 Alternatives To Reduce Flood Risk - Buildings

Alternatives for Buildings with Elevated Flood Risk

Flood risks for buildings throughout the Pinnacle Peak West (PPW) Area Drainage Master Study (ADMS) watershed were previously identified and quantified. The methods and results of the hazard and risk assessment are presented in the Tasks 12 and 13 - Hazard and Risk Memo. Four levels of flood risks were delineated: Low, Moderate, High, and Very High for three storm events.

- *Low:* depth between 0.5 feet and 1.5 feet and a velocity of at least 1 ft/sec.
- *Moderate:* depth between 1.5 feet and 2.5 feet and a velocity of at least 1 ft/sec
- *High:* depth greater than 2.5 feet and a velocity of at least 1 ft/sec OR a depth-velocity in TM 11 Judgment zone
- *Very High:* depth-velocity in TM 11 High danger zone

Table 1 summarizes those previous results.

Table 1 - Summary of Potential Risks to Buildings (Worst Case Scenario)

Storm Event	*PPW ADMS Totals*			
	Low	Moderate	High	Very High
100-YR	1958	**210**	**53**	**9**
25-YR	1053	**87**	**33**	**4**
10-YR	624	**41**	**21**	**3**

For the 272 buildings with moderate or greater flood risk in the 100-year event, alternatives to reduce their flood risk were determined. Each individual building with a moderate or higher flood risk was examined. Flow depths and velocities were looked at along with the local topography and the building footprints. Alternatives to reduce flood risk at each were then determined based on the nature of the flooding, the flood source, the flood scenario, the flood probability, and the physical setting of the building.

Of the 272 total potential at-risk structures with greater than moderate hazard (i.e. flow depth in house greater than 1.5 feet). No Action, No Build, and Build categories of alternatives were identified as shown in **Table 2**. Additional specifics for each group are also provided in the comments column.

Table 2 – Summary of Alternatives for Buildings with Greater Than Moderate Flood Risk

	Number of Buildings	Alternative	Comments
No Action	136	No Action	False positive risk identified. Closer examination revealed low or very low risk. Usually a raster/analysis resolution or topo issue.
No Build	43	Investigate further	Potential issues/risks, but the level of detail of modeling, topo uncertainties, etc. may reveal 'No Action' or some specific structural recommendation.
	30	Flood wall investigation	Located along Rawhide Wash. Flooding may be prevented by walls along Rawhide Wash downstream of apex.
	18	Flood wall investigation	Located primarily in the Sonoran Hills development. Flooding may be prevented by walls that might be certifiable or sufficient to stand up to flows if verified.
Build	12	Structural	Located along Rawhide Wash. Flooding could be prevented if containment were provided at Los Portones Drive.
	17	Structural	Buildings potentially benefiting from some kind of diversion of PPP flows along Pima, Happy Valley, and/or Pinnacle Peak Roads.
	16	Structural	Structural and other possible solutions including culvert upgrades, buyout, etc.

No Action

As presented in **Table 2**, for half of the buildings the No Action alternative was identified. In most instances, though these buildings were captured by the GIS analysis, upon closer examination, the flood risk was an artifact of the 20-foot raster resolution. Deep and/or fast water does exist near the building, but the nature of the rasterization of the topography and/or the building footprint result in a 'false positive'. In other cases, the building post-dates the topographic mapping or the topography does not represent the building pad grading very well.

No Build

The second largest group of buildings are identified as needing further investigation. In many of these instances, the small scale features in the immediate vicinity of the buildings may not be well represented by the 20-foot grid. Further analysis may reveal genuine flood problems. Further investigation might require supplemental HEC-RAS modeling, surveying, and/or field visits.

Forty-two of the buildings lie along Rawhide Wash between Happy Valley and Pinnacle Peak Roads downstream of the alluvial fan apex. Thirty of these experience flood risks only if the walls fail (With Walls With Failure Scenario) or are not modeled (Without Walls Scenario). This suggests that if the walls along Rawhide Wash are floodwalls and could withstand the 100-year flows without failure, then these 30 buildings would have a low or very low risk of flooding.

Eighteen buildings at various locations were also identified as having flood risks that only occur in the Without Walls Scenario. Many of these 18 are located within the Sonoran Hills subdivision north of Deer Valley Road and west of Hayden Road. Again, investigation of the integrity of the walls protecting these properties may reveal that the flood risks are not significant.

Build

Twelve of the 42 buildings along Rawhide Wash between Happy Valley and Pinnacle Peak Roads are at risk of flooding from water flowing out of Rawhide Wash at the Los Portones Drive at-grade crossing. Modifications to Los Portones Drive in this area could result in reducing flood risk to these twelve buildings.

Seventeen buildings with moderate or greater flood risks lie along the east side of the Rawhide Wash Zone AO floodplain south of Happy Valley Road and west of Pima Road. Runoff from the Pinnacle Peak South ADMS model enters the PPW modeling area spreading out broadly through a wide area of relatively large lot residences. Capturing and diverting these flows in a controlled fashion along Happy Valley Road and/or Pima Road would significantly reduce flooding in this area. However, the outflow for such diversion channels could increase flooding elsewhere downstream.

There are sixteen additional buildings with greater than moderate flood risks scattered throughout the PPW study area. Several of these may be reduced via improvements to roadway drainage crossings located nearby. One area with a cluster of buildings adversely affected by undersized culverts is located along the west side of the Dove Valley Ranch subdivision near 40th Street and the Cave Creek Landfill.

Each building with the identified alternative and additional comments are also provided as a shapefile (WC_BuildingRisks_all.shp) for all buildings identified with greater than a moderate flood risk.

Alternatives to Reduce Flood Risk – Other Areas Memorandum

Memorandum

DATE: May 14, 2015

TO: Theresa Pinto, Project Manager, FCDMC

FROM: Pat Quinn, PE, RLS, AVS
Ted Lehman, PE

RE: Pinnacle Peak West ADMS Work Assignment No. 3
Task 15 Alternatives To Reduce Flood Risk – Other Areas

Introduction

Review of the FLO-2D results and the building risks analyses indicated a number of areas within the study area that exhibited adverse flooding conditions. One of those areas was the Rawhide Wash alluvial fan area. Alternatives for the Rawhide Wash area are addressed separately in the Rawhide Wash Conceptual Alternatives Report. This memo addresses a number of other priority problem areas within the study area. Figure 1 shows an overview of the other problem area locations within the study area.

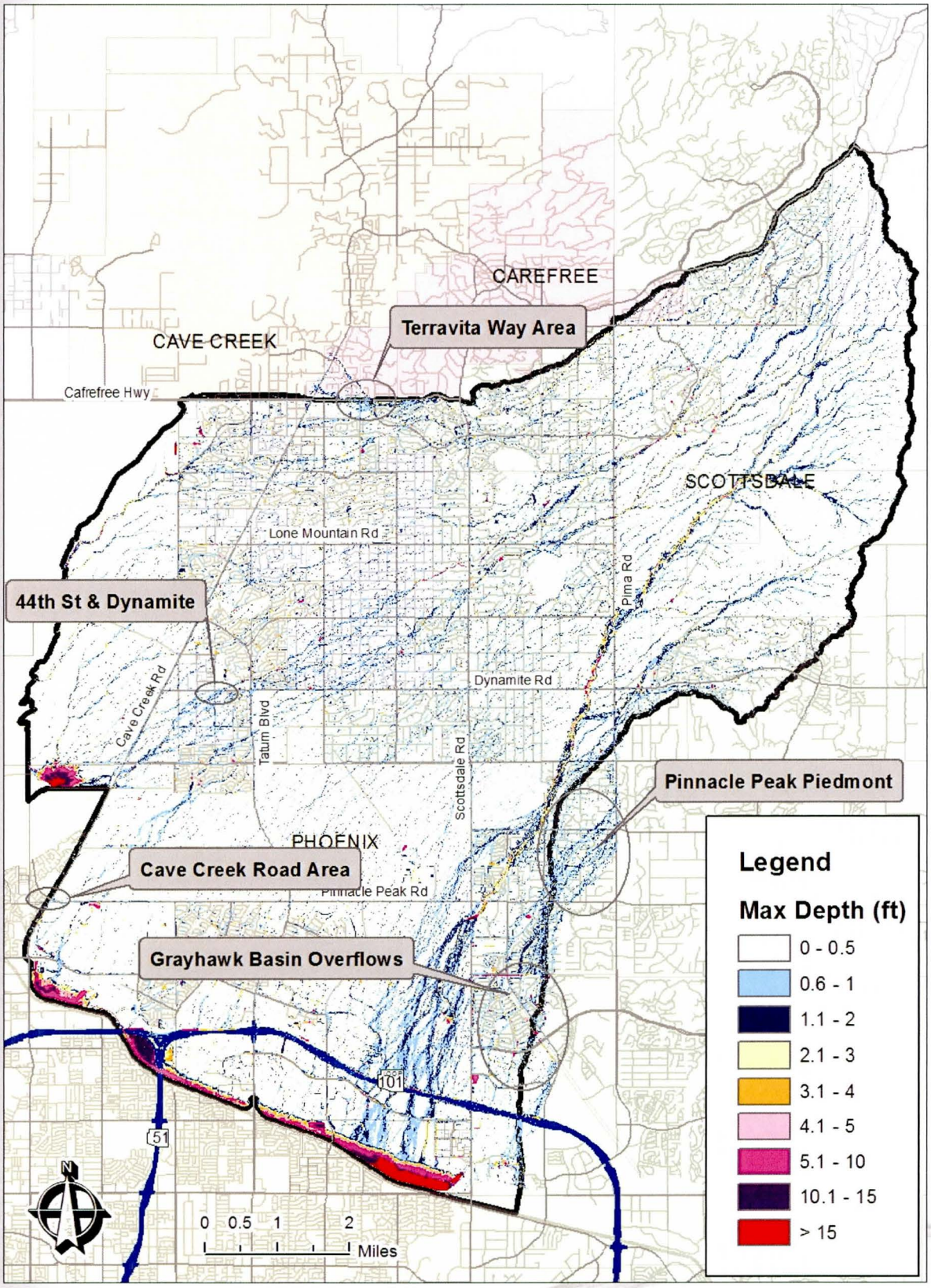


Figure 1. Overview Map of Other Problem Areas

Grayhawk Basin Overflows

Model results indicate several problems downstream of a dead-end basin along Deer Valley Road at about the Hayden alignment (Figure 2).

The total inflows to this basin vary some by scenario but range in peak discharge from about 1,100 to 1,400 cfs. The inflow volume is about 270 ac-ft. The existing basin at the end of the channel has a surface area of less than 2 acres and a depth of about 6 feet. Excess flows enter the golf course and continue south toward the powerlines. Downstream culverts near Hayden Road have capacities of about 400 to 600 cfs. The volume of the basin overflow hydrograph shows about 110 to 140 ac-ft of volume above 500 to 600 cfs. Therefore, the size of a basin to capture excess flows would be very large. Increasing the existing basin would not realistically work within the current footprint or immediately open adjacent area.

Much of the inflow to the channel along Deer Valley originates from a channel along Pima Road in the Pinnacle Peak South (PPS) ADMS study area. Potential solutions for the downstream Grayhawk area would best be addressed as part of a more integrated solution in the PPS study area.

Figure 2 – Basin overflows from Deer Valley Channel into Grayhawk

Pinnacle Peak Piedmont Area

The square mile area bounded by Happy Valley Road on the north, Pima Road on the east, Pinnacle Peak Road on the south and Hayden Road on the west exhibits a broad area of complex divided flow interweaving its way through large lot residential development. The building hazard/risk assessment identified numerous structures with some level of flood risk. Input from the public also validated model results of widespread flood hazards in this area (Figure 3).

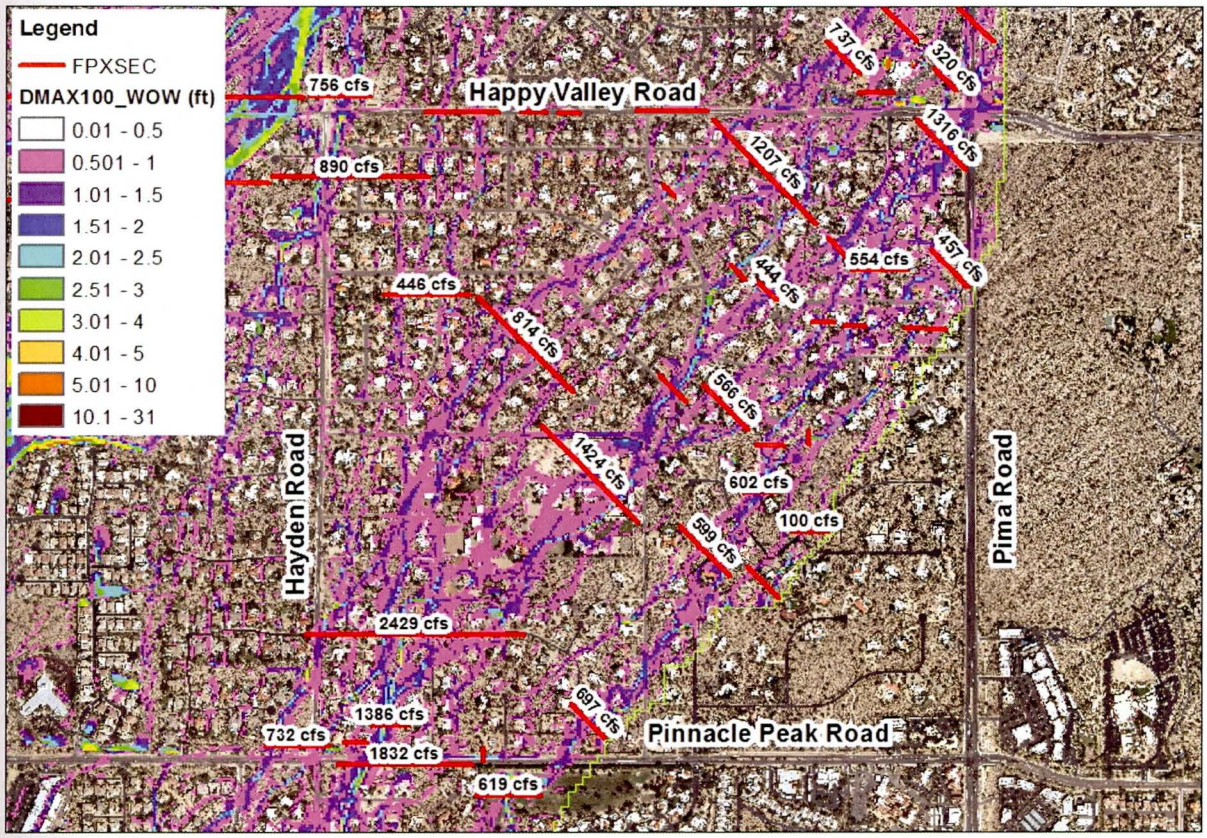


Figure 3 - Pinnacle Peak Piedmont flooding

Flood risks in this area could be potentially reduced by construction of significant diversion channels along Pima and/or Happy Valley Roads. Flow rates for the 100-year storm are relatively large (see labeled cross sections in Figure 3). However, given these are major arterial road corridors, obtaining adequate continuous right-of-way and potential utility conflicts to provide this level of conveyance may restrict implementation. In addition, determining the potential outfall location, especially of any diversion along Pima Road, presents additional challenges. Diversions along Happy Valley Road to Rawhide Wash might also increase flows in Rawhide beyond an acceptable level.

Localized improvements through the subdivision might also be possible to reduce flood risks in the area. Such improvements would require significant ROW acquisition across multiple lots and require significant coordination. Objection by one or more affected property owners could prevent successful implementation. Adverse downstream consequences due to changed flow distribution would also require careful attention.

Cave Creek Road Area

At the public meetings in September 2014, the public reported significant water in Cave Creek Road somewhere approaching Loop 101, perhaps at Pinnacle Peak Road (FLO-2D hydraulic structure ID S005-04) or somewhere between there and the highway. The FLO-2D model shows overflows at Pinnacle Peak Road (Figure 4). The field inventory showed significant sediment in culverts as of June 2012.

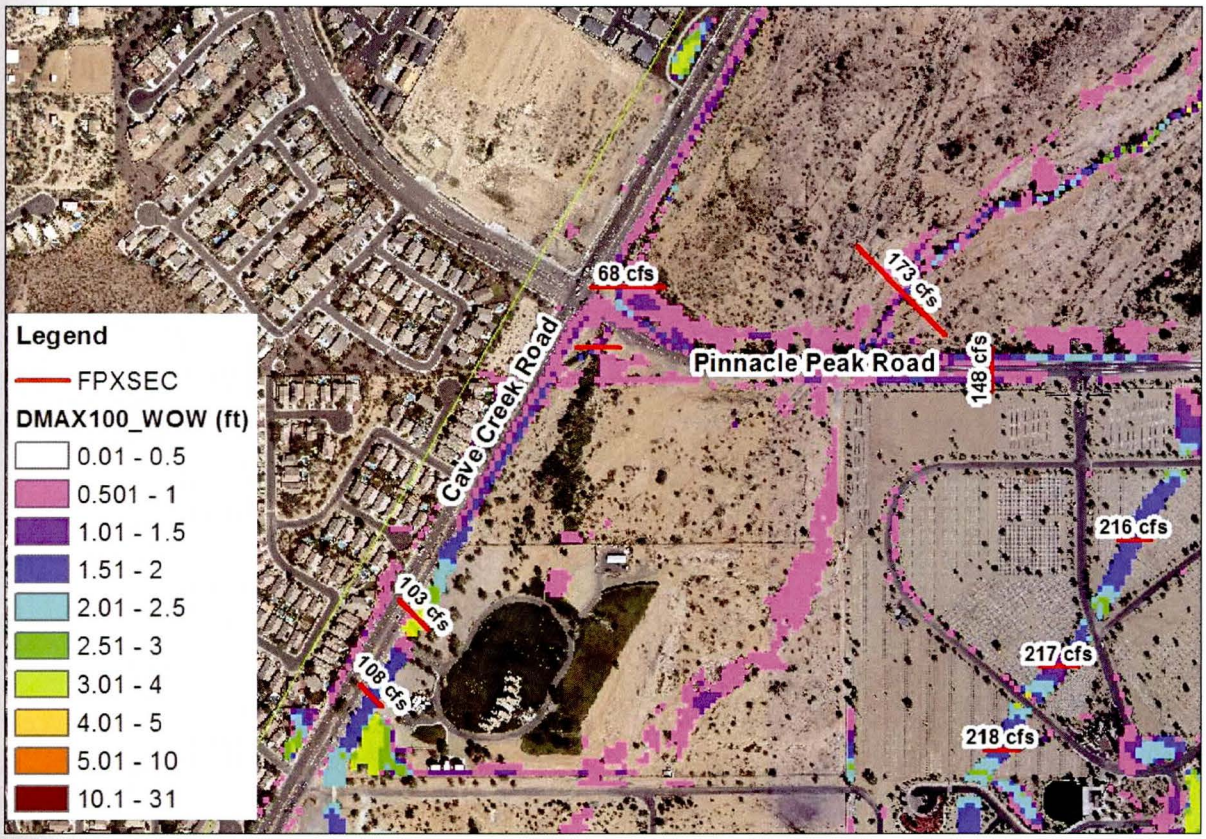


Figure 4 - Flooding near Cave Creek and Pinnacle Peak Roads

Total flow rates approaching Pinnacle Peak Road are about 70 cfs. Just downstream of the culvert crossing, flow rates increase to about 100 cfs. Recent Google street view appears to show significant maintenance as of July 2014. Nevertheless, apparently flooding of Cave Creek Road caused problems during the storms later in the monsoon season of 2014 as reported by the public at the meetings in mid-September. Improvements to the culvert crossings and/or the roadside drainage may be required to deal with sedimentation issues and provide all-weather access along Cave Creek Road to the Loop 101.

44th Street & Dynamite Area

Another area of concern arose from input at the public meetings in September 2014. Homeowners in the vicinity of 44th Street and Dynamite Road expressed significant concern regarding flooding and changes in flooding resulting from development and new drainage facilities under Dynamite Road east of 44th Street. The situation is complicated by cross-jurisdictional challenges between City of Phoenix and unincorporated Maricopa County along Dynamite Road. The issue is further complicated by the fact that flow divides into several separate flow paths downstream of Dynamite Road (Figure 5). Changes to flow distribution from one of these paths to another need to be carefully evaluated when examining potential solutions to reduce flood risk in this area.

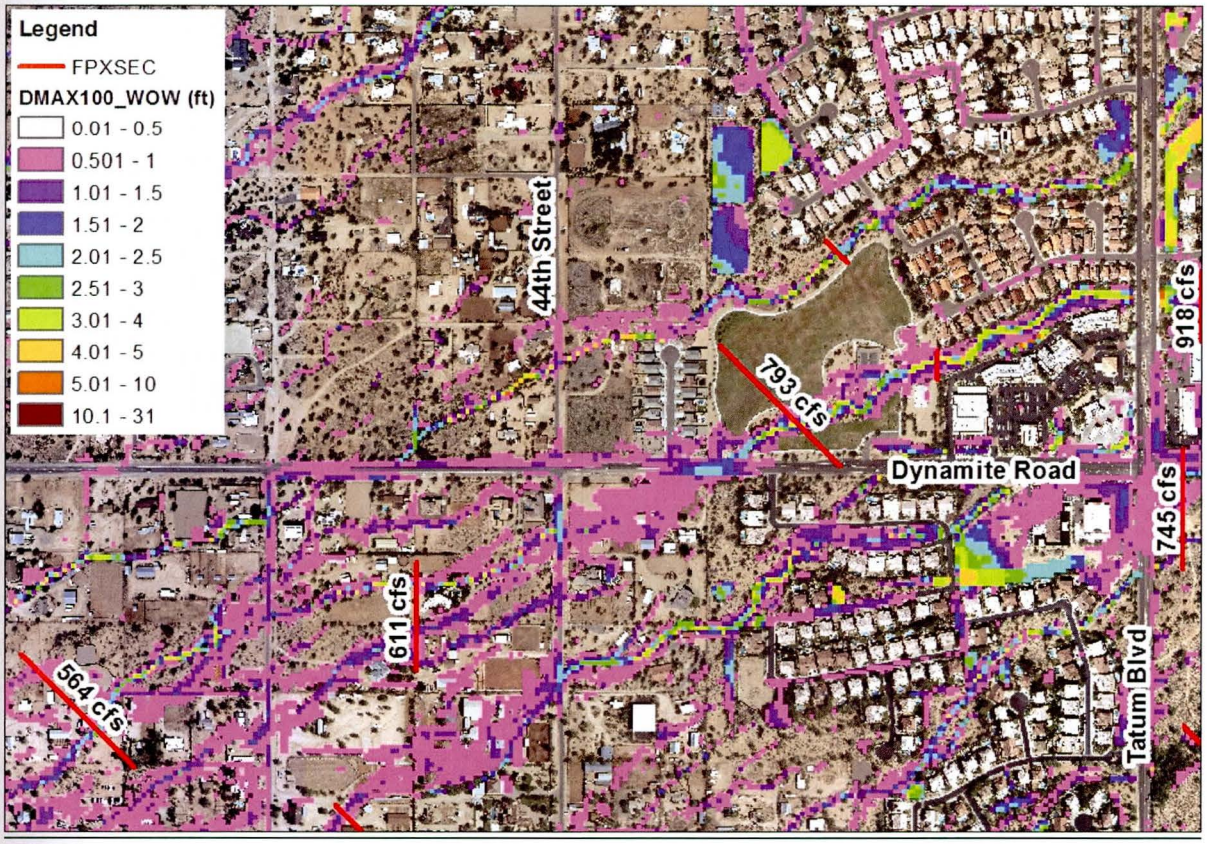


Figure 5 - Flooding near 44th Street & Dynamite Road

Terravita Way Area

Culvert performance issues, especially due to sedimentation, create overflows and divided flow downstream impacting Terravita Way, Carefree Highway, and surrounding buildings (Figure 6). Structural modifications could provide for a more predictable split of flows and provide all-weather access on Carefree Highway and Terravita Way. Careful consideration of sediment should be part of the design of modifications. The current culvert and drop inlet have performed poorly in the past, filling with sediment. Like the area near 44th Street and Dynamite, solutions to flooding in this area is complicated by the fact that flow divides into several separate flow paths downstream of Terravita Way. Changes to flow distribution from one of these paths to another need to be carefully evaluated when examining potential solutions to reduce flood risk in this area.

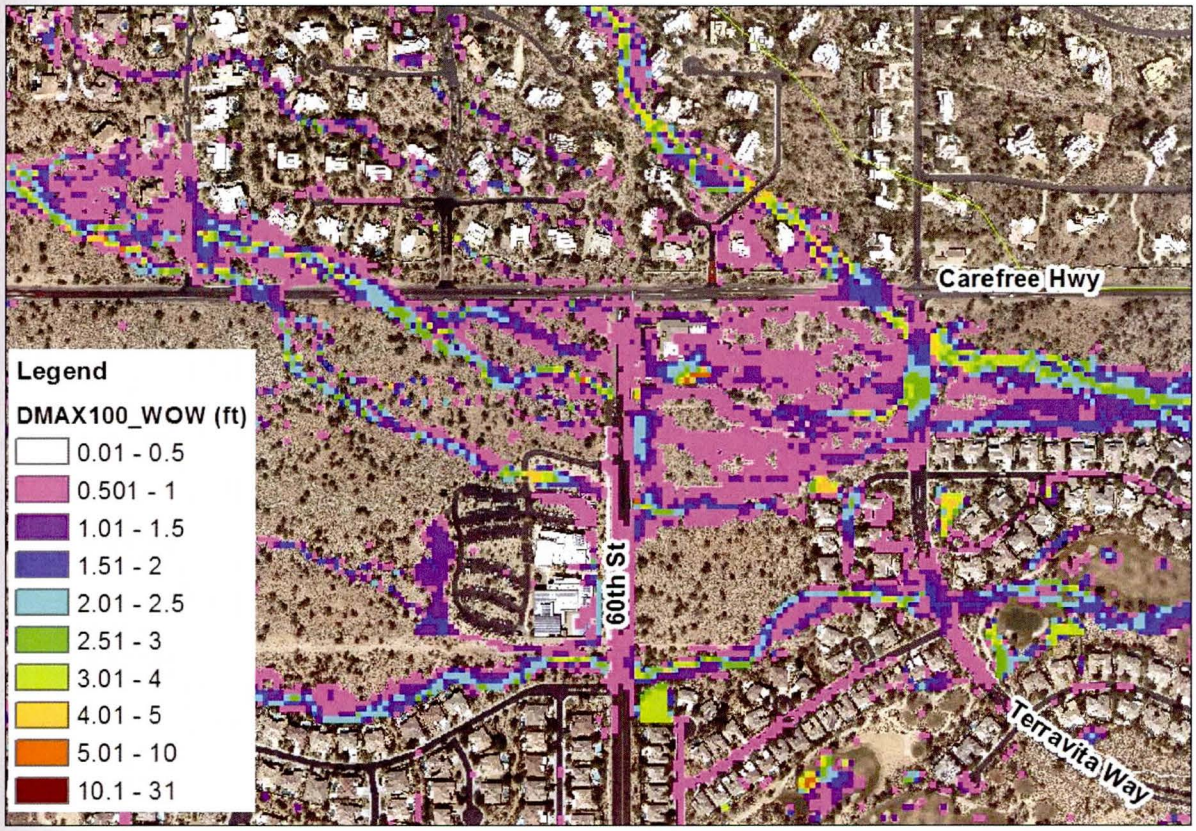


Figure 6 - Flooding in vicinity of Terravita Way

Monterra

Flooding and erosion concerns in the Monterra subdivision were identified by residents attending the May 2015 public meetings. Figure 7 shows a close up of the Monterra subdivision area with flow depths and computed 100-year discharges. Residents expressed concern about erosion and sedimentation. The model results indicated that flows are not getting into and not remaining within the apparent planned drainage corridors. Additional structural measures and/or modifications to existing facilities may improve flooding and erosion within the subdivision.

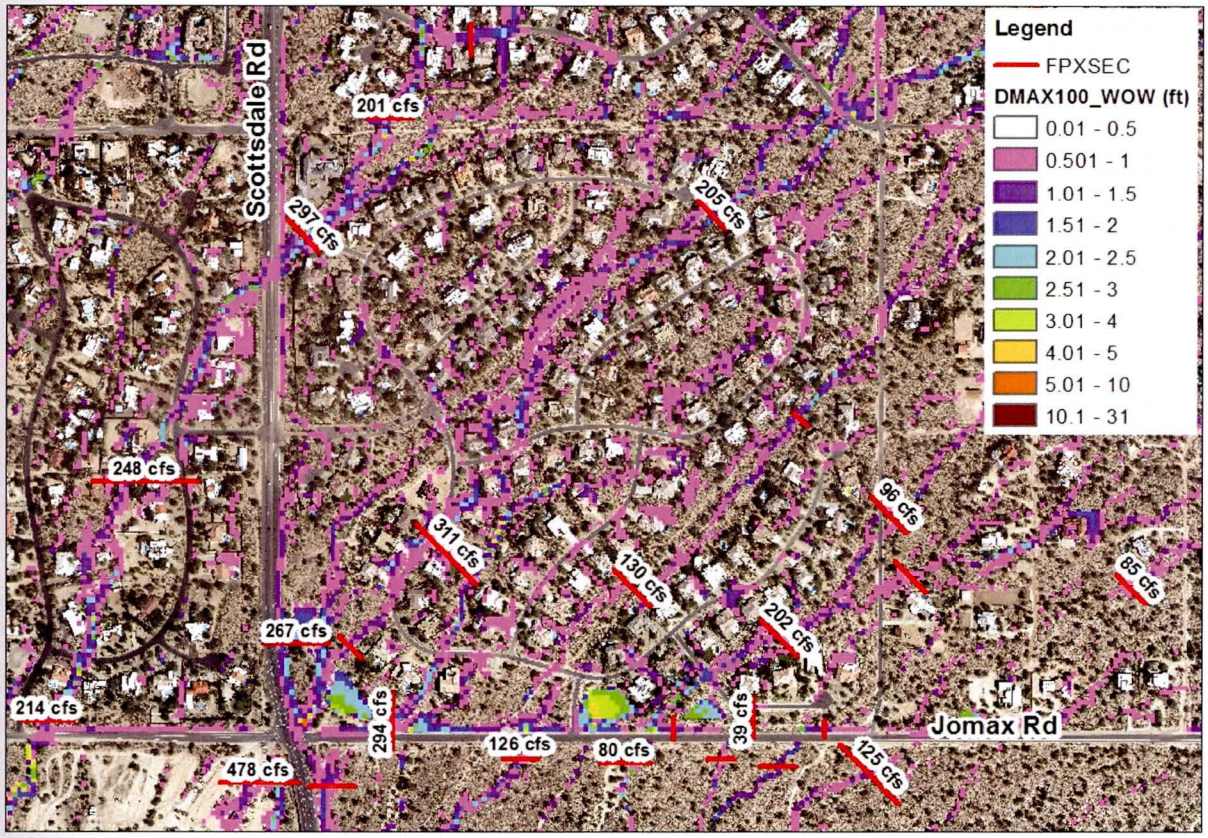


Figure 7 – Flooding in Monterra subdivision area

Alternatives to Reduce Flood Risk – Transportation Memorandum

Memorandum

DATE: January 9, 2014

TO: Theresa Pinto, Project Manager, FCDMC

FROM: Pat Quinn, PE, RLS, AVS
Ted Lehman, PE

RE: Pinnacle Peak West ADMS Work Assignment No. 3
Task 15 Alternatives To Reduce Flood Risk - Transportation

Introduction

Flood risks to passenger vehicles on roadways throughout the Pinnacle Peak West (PPW) ADMS study area were previously evaluated. The methods and results of the hazard and risk assessment are presented in the Tasks 12 and 13 - Hazard and Risk Memo. Four levels of flood risks to vehicles were differentiated: Low, Moderate, High, and Very High for three storm events.

- *Low*: roadway crossings with depths less than 0.5 foot
- *Moderate:* based on a combination depth greater than 0.5 foot and with depths and velocities corresponding to Low Danger Zone in TM 11 for passenger vehicles
- *High:* roadway crossings with depths and velocities corresponding to the Judgment Zone in TM 11 for passenger vehicles
- *Very High:* Roadway crossings with depths and velocities corresponding to the High Danger Zone in TM 11 for passenger vehicles.

Table 1 summarizes the flood risks to vehicles for the study area. The numbers shown are the percentage of roadway segment length for each street classification and hazard level. The results show that 17.5 percent of all roadways in the study area have a greater than moderate flood hazard to vehicles during the 100-year event (see also **Figure 1**). For the 10-year event, just under 8 percent of roadway length has a greater than moderate flood hazard to vehicles. Very high flood hazards are limited to a fraction of one percent of roadway length.

Table 1. Summary of Roadway Flood Risks

Storm Event	Street Classification	PPW ADMS Totals			
		Moderate	High	Very High	Total
100-year	Arterial	17.1%	1.4%	1.3%	19.9%
	Secondary	15.2%	1.1%	0.4%	16.7%
	Total	15.7%	1.2%	0.7%	17.5%
25-year	Arterial	4.7%	0.3%	0.2%	19.9%
	Secondary	10.7%	0.5%	0.1%	11.4%
	Total	9.2%	0.5%	0.1%	9.8%
10-year	Arterial	3.1%	0.2%	0.1%	19.9%
	Secondary	6.9%	0.3%	0.1%	7.2%
	Total	5.9%	0.3%	0.1%	6.2%

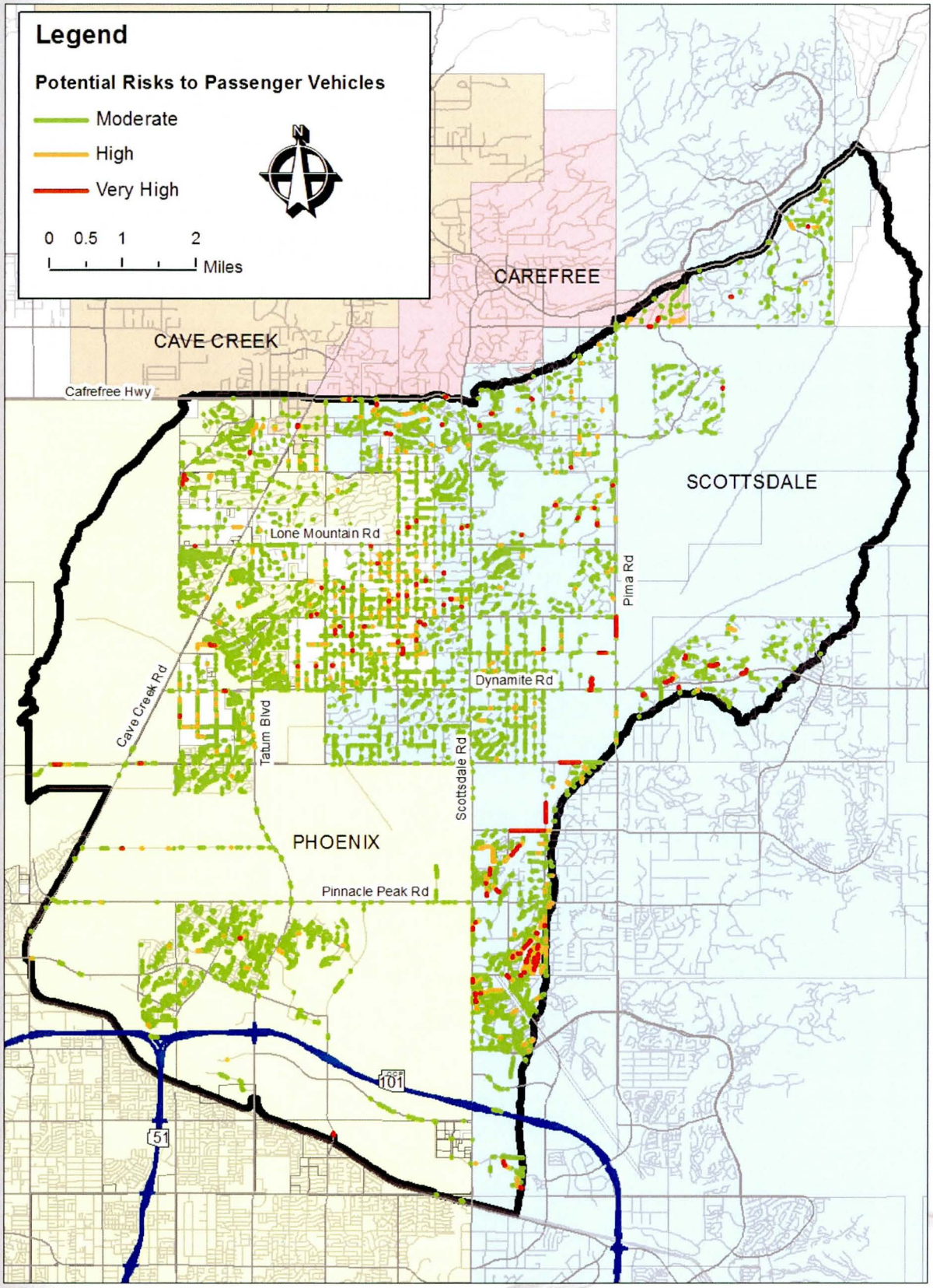


Figure 1. 100-year event flood risks to passenger vehicles

Public input

In addition to the analytical identification of flood hazards on roadways in the study area, the PPW team received numerous, repeated input from public and stakeholders that flooding of streets in the study area was a problem. In particular, the lack of safe, all-weather north-south roadways was identified as an issue that could use improvement. Street flooding on Tatum Boulevard, Cave Creek Road, and Scottsdale Road was identified as adversely affecting transportation access through the study area.

Drainage complaints and maintenance records from county and city street departments collected for the study reinforced the significance of adverse impacts to transportation due to flooding in the area.

Tolerance surveys

Another component of the public outreach process were tolerance surveys. Residents were asked to characterize their tolerance to varying levels of roadway flooding impacts. A large majority (66%) indicated that if a road is flooded causing it to be closed for hours, there is a problem and possible actions should be taken to improve the situation.

As a result of the analytical results and public input, it is clear that a big, important issue for the area with lots of public attention is the need to provide all-weather transportation access.

Solutions

All-weather Access Plan

Currently there is no all-weather access to Loop 101 from within the study area. There is currently no long range transportation plan for the area. MCDOT is currently conducting a Transportation Strategic Plan for the whole County based on forecast traffic demand in the 2020-2025 timeframe.

It is suggested that a transportation plan to upgrade major arterials within the area to provide safe passage during the 100-year storm should be developed. Implementation could be a phased and would require careful coordination between cities, the County, and the State. Cave Creek Road is probably the easiest to achieve as it exhibits the fewest existing flooding issues. Only a few issues near Pinnacle Peak Road and south toward the highway were identified or reported by the public. Other north-south options would include Tatum Boulevard, Scottsdale Road, and Pima Road. East-west roadways might include Carefree Highway, Lone Mountain, Dynamite, and Pinnacle Peak Roads.

Evaluation of which roadways to improve would require traffic analysis with attention to drainage issues and impacts. Many areas along roadways currently result in complex diversions of storm water that would need to be carefully considered when improving the roadway. Cross jurisdictional coordination will also be an important challenge as a number of important roads are coincident with jurisdictional boundaries (e.g. Phoenix/Scottsdale, Phoenix/County, or Scottsdale/County).

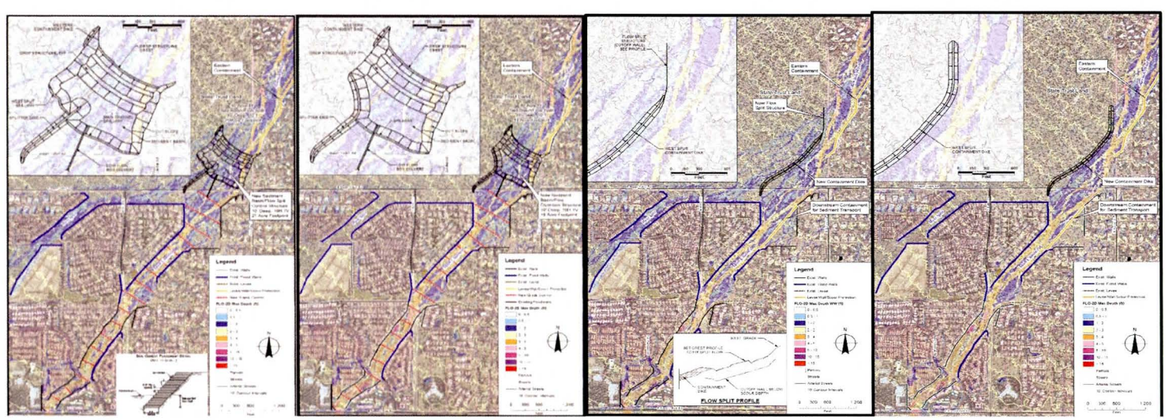
The PPW ADMS model results can assist in the evaluation of future roadway drainage crossing improvements and the potential downstream impacts. Evaluation of access outside the study area boundary may be needed to fully assess the transportation improvement network needs for the area.

MCDOT Safety Plan

It is understood that MCDOT currently has a safety plan methodology to assess when and where County transportation elements need to be upgraded or improved. It is further understood that drainage does not play a large role in the project rating system used to evaluate safety improvements. Therefore, it is suggested that the PPW ADMS risk assessment results be consulted and potentially incorporated into the County safety plan methodology to evaluate safety improvements in the PPW study area. Similar analyses could be performed for other study areas as well. The GIS data from the PPW or other similar analyses could be consolidated with other County GIS systems to facilitate the understanding of issues, ownership, O&M, and future need for transportation improvements.

Alternatives to Reduce Flood Risk – Rawhide Wash Executive Summary

PINNACLE PEAK WEST AREA DRAINAGE MASTER STUDY
RAWHIDE WASH ALTERNATIVES SUMMARY

Alternative ID	BUILD				NO BUILD	NO ACTION
	A	B	C	D		
Description	**Happy Valley In-Line Sediment Basin/Flow Splitter**	**Happy Valley In-Line Sediment Basin, Main Channel Only**	**Happy Valley Flow Splitter, Main Channel Sediment Conveyance**	**Main Channel Only with Sediment Conveyance**	**Re-delineate Effective Zone AO Floodplain**	**Regulate to Effective Zone AO Floodplain**
Components	Sediment Basin Eastern Containment Floodwall/Levee Western Containment Dike Splitter Dike Downstream Grade Control Los Portones Drive Improvements Floodwall/Levee Investigation Floodwall/Levee Retrofit North Scottsdale Channel CLOMR/LOMR	Sediment Basin Eastern Containment Floodwall/Levee Western Containment Dike West Split Containment Dike Downstream Grade Control Los Portones Drive Improvements Floodwall/Levee Investigation Floodwall/Levee Retrofit CLOMR/LOMR	Eastern Containment Floodwall/Levee Flow Split Cutoff Wall West Split Containment Dike Sediment Transport Analysis Downstream Sediment Containment Los Portones Drive Improvements Floodwall/Levee Investigation Floodwall/Levee Retrofit North Scottsdale Channel CLOMR/LOMR	Eastern Containment Floodwall/Levee West Split Containment Dike Sediment Transport Analysis Downstream Sediment Containment Los Portones Drive Improvements Floodwall/Levee Investigation Floodwall/Levee Retrofit CLOMR/LOMR	LOMR Fill Required for New Development El Cert.s for New Development Existing Flood Insurance Premiums Future Flood Insurance Premiums Flood Damage Exposure	Fill Required for New Development El Cert.s for New Development Existing Flood Insurance Premiums Future Flood Insurance Premiums Flood Damage Exposure
Advantages	Removes Flow Path Uncertainty Reduce FEMA Floodplain Extents	Removes Flow Path Uncertainty Reduce FEMA Floodplain Extents No need for North Scottsdale Channel	Removes Flow Path Uncertainty Reduce FEMA Floodplain Extents	Removes Flow Path Uncertainty Reduce FEMA Floodplain Extents No need for North Scottsdale Channel	Reduce FEMA Floodplain Extents	
Disadvantages	Requirement for grade control	Requirement for grade control Likely disruptive Floodwall Retrofit		Likely disruptive Floodwall Retrofit	Flood hazard left un-mitigated Flood Insurance Burden	Flood hazard left un-mitigated Flood Insurance Burden
Implementation	DCR, Floodwall/Levee Investigation, Design, CLOMR, Construction, Wall Certification, LOMR	DCR, Floodwall/Levee Investigation, Design, CLOMR, Construction, Wall Certification, LOMR	DCR, Sediment Transport Analysis, Floodwall/Levee Investigation, Design, CLOMR, Construction, Wall Certification, LOMR	DCR, Sediment Transport Analysis, Floodwall/Levee Investigation, Design, CLOMR, Construction, Wall Certification, LOMR	LOMR, regulate to new floodplain, majority of existing and future development would still need flood insurance	Regulate to effective floodplain Existing and future development still need flood insurance
50-Year Cost	**$46,100,000**	**$27,400,000**	**$32,700,000**	**$16,000,000**	**$164,000,000**	**$224,000,000**
Implementation Costs	**$46,100,000**	**$27,400,000**	**$32,700,000**	**$16,000,000**	**$300,000[3]**	**$0**
Property Owner Costs	**$0**	**$0**	**$0**	**$0**	**$68,000,000**	**$115,000,000**
Future Development Costs	**$21,000,000[1]**	**$9,000,000[2]**	**$21,000,000**	**$9,000,000**	**$96,000,000**	**$109,000,000**
Existing Structures Removed from Floodplain	**3400**	**3400**	**3400**	**3400**	**3200**	**0**
Existing Developed Acres Removed from Floodplain	**2036**	**2246**	**2036**	**2246**	**1498**	**0**
Future Developable Acres Removed from Floodplain	**620**	**1651**	**620**	**1651**	**409**	**0**

Notes: [1]Estimated Paradise Ridge drainage infrastructure costs. [2]Paradise Ridge drainage infrastructure costs minus N. Scottsdale channel. [3]LOMR cost.