City of Concordia, KS
Technical Assistance Report

PREPARED FOR:

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Division of Water Resources

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February 2024

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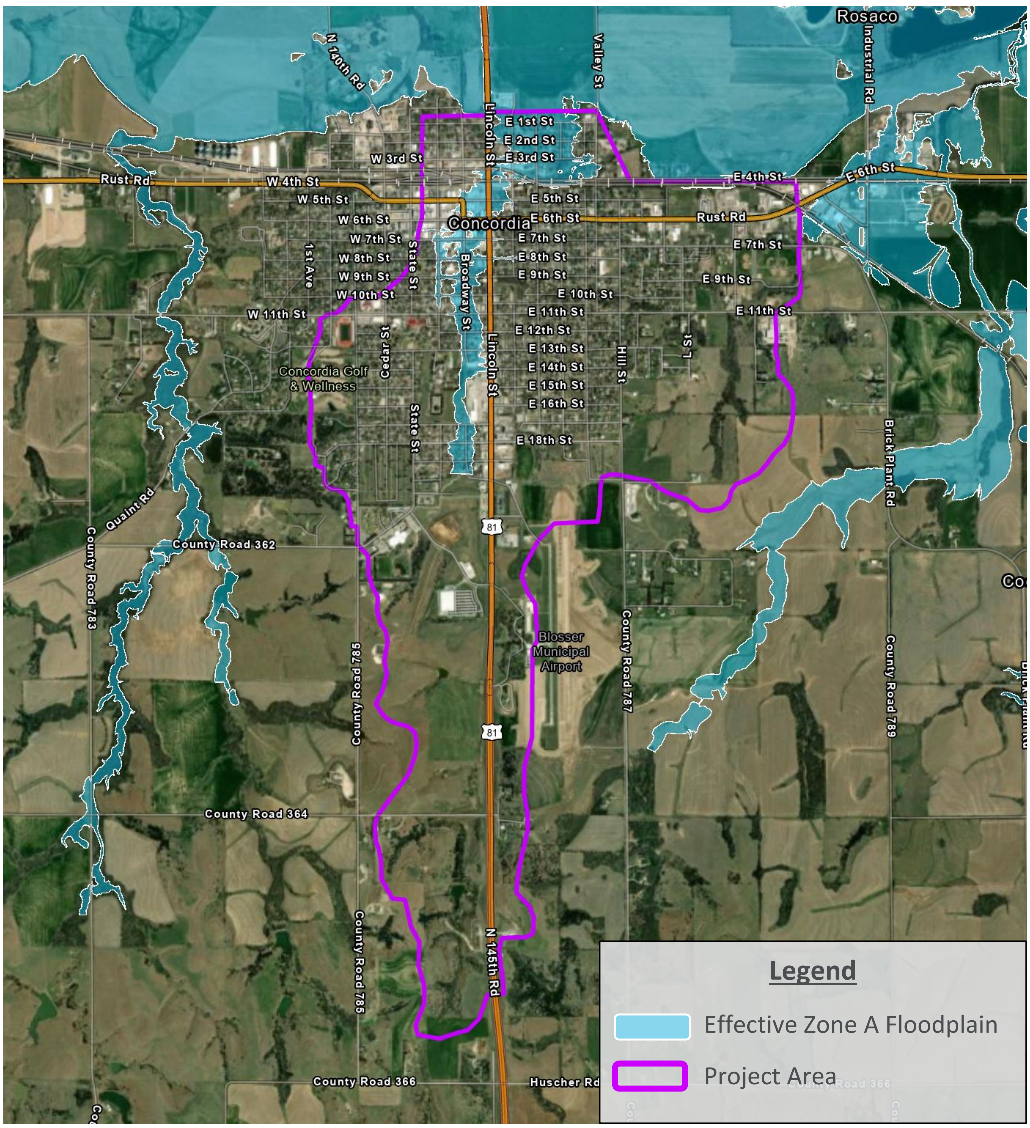
1 INTRODUCTION

The Kansas Department of Agriculture- Division of Water Resources (KDA-DWR) received funding from FEMA to complete a technical assistance project for the City of Concordia to provide the City with accurate flood risk data that can be utilized for stormwater management purposes, along with a future Letter of Map Revision (LOMR). The City of Concordia is located within the Lower Republican Watershed, which was part of a base level engineering (BLE) study. Additional modeling was performed for the City of Concordia but did not result in modeling or mapping that was suitable for a LOMR submittal. The purpose of this technical assistance project is to provide the City of Concordia with a PC-SWMM model that accurately represents the flood risk throughout town, adequately capturing the underground storm sewer system and above ground storage areas and is of the quality considered to be acceptable to FEMA for LOMR approval. The project also includes the development of draft floodplains that are specifically associated with the FEMA designated flooding sources, which includes the tributary to the Republican River that is included on the effective maps and associated overflow areas.

FIGURE 1- PROJECT AREA



The Cloud County Flood Insurance Study (FIS) Report and effective Flood Insurance Rate Maps (FIRMs) are dated July 2014. The effective mapping includes Zone A special flood hazard areas for a tributary to the Republican River and backwater from the Republican River. The overall goal of the project is to evaluate the existing flooding conditions for the primary watershed extending through Concordia.

An XP-SWMM model was previously developed as part of a separate technical assistance project. The XP-SWMM model used 2-Dimensional modeling methodology and excess rainfall application. The XP-SWMM model captured the critical features of the underground storm sewer network, using survey data and storm drain information provided by the city, with some general assumptions where data was missing or questionable. Unfortunately, the XP-SWMM model had inaccuracies in the hydrologic data, along with several errors and instabilities that were considered to be well outside of an acceptable tolerance; both impacting the associated water surface elevations. The intent of this technical assistance project was to provide Concordia with a PC-SWMM model that has more accurate hydrologic information, minimal instabilities and flow losses, and is of the quality believed to be acceptable to FEMA. The PC-SWMM software will provide more opportunities for future uses, thus being more beneficial to the City of Concordia. The model excludes the Republican River; however, backwater from the Republican River has been accounted for in the floodplain plotting portion of the project.

2 MODELING METHODS

2.1 Modeling Software

The detailed model for this flood study was generated using PC-SWMM. The PC-SWMM software is a modeling interface with various tools to develop files that are still compatible with the EPA-SWMM engine, which is a free software. PC-SWMM modeling is widely accepted in the industry and licensing is considered reasonable to purchase. For this project PC-SWMM version 7.5 was used in conjunction with EPA-SWMM engine version 5.2.3. The PC-SWMM hydrologic and hydraulic model accurately represents surface flow, subsurface flow through the pipe network, and interconnecting flow between the two. The project area was modeled using a 2-Dimensional (2D) approach to incorporate surface flow and subsurface flow to the appropriate degree of detail.

2.2 Modeled Area

The modeled area is shown in Figure 1 as the project area. The topography for this project was obtained from the State of Kansas Data Access and Support Center. One-meter resolution LiDAR from 2018 was utilized for the elevation data. This model does not rely on model sub catchments for rainfall application; rather the model utilizes excess rainfall on mesh hydrology.

2.3 Rainfall

The modeling includes the 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), and 0.2% (500-year) annual chance exceedance storm events. Rainfall depths were developed by taking the average values of the partial-duration gridded rainfall data developed by the National Oceanic and Atmospheric Administration (NOAA) as part of Atlas 14, Volume 8: Precipitation-Frequency Atlas of the United States (National Oceanic and Atmospheric Administration (NOAA), 2013). The rainfall depths are shown in Table 1. The rainfall distribution for this area is the Natural Resource Conservative Service (NRCS) Midwest and Southeast (MSE) Region Type 3. Note that no areal reduction ratio was applied to rainfall depths due to the watershed's relatively small size.

TABLE 1- RAINFALL DEPTHS

Storm Event	Rainfall Depth (in)
10% AC (10-yr)	4.4
4% AC (25-yr)	5.4
2% AC (50-yr)	6.3
1% AC (100-yr)	7.2
0.2% AC (500-yr)	9.6

2.4 Landuse

The landuse data from the previous study (XP-SWMM model) was used and then manually updated for this PC-SWMM model to ensure accurate surface flow. The landuse data includes refined impervious areas. The landuse dataset was used during the generation of the 2D-mesh, which applies Manning's roughness values to the surface flow paths. Table 2 describes the Manning's roughness value for each landuse type.

TABLE 2- MANNING'S VEGETATIVE ROUGHNESS FOR UPDATED LANDUSE

Landuse Description	Manning's Roughness
Channel	0.045
Cultivated Crops	0.05
Mixed Trees	0.12
Developed, Low Intensity	0.05
Developed, Medium Intensity	0.05
Developed, High Intensity	0.05
Developed, Open Space	0.05
Grassland-Herbaceous	0.05
Impervious	0.015
Open Water	0.03
Pasture-Hay	0.05
Shrub-Scrub	0.08

2.5 Infiltration

Infiltration losses were computed using USDA's Soil Conservation Service (SCS) Curve Number Method, detailed in the National Engineering Handbook Part 630, Chapter 10. The curve number is a function of both hydrologic soil group and land use. To determine the curve number utilized by the model, the NLCD landuse layer was used. Soils data was obtained from the United Stated Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey, which includes an aggregate hydrologic soil group for individual soil series. Assuming an antecedent runoff condition (ARC) of II, a curve number value was defined for each category of the landuse and soil layers. The following table summarizes these curve number values. A watershed average curve number value of 78 was computed for the model area.

TABLE 3- CURVE NUMBER VALUES FOR SPATIALLY VARYING INFILTRATION

Landuse Description	Curve Number by Hydrologic Soil Group			
	A	B	C	D
Developed Open Space	49	69	79	84
Barren/Bare	77	86	91	94
Deciduous/Evergreen/Mixed Forest	30	55	70	77
Shrub/Scrub	43	65	76	82
Herbaceous	43	65	76	82
Hay/Pasture	49	69	79	84
Cultivated Crops	65	75	82	86
Woody Wetlands	36	60	73	79
Emergent Herbaceous Wetlands	36	60	73	79
Impervious Surfaces	98	98	98	98
Open Water	98	98	98	98

This model does not contain subbasins; therefore, the curve number was used in the excess rainfall calculations and applied directly to the 2D mesh cells. Consistent with accepted engineering practices, the initial abstraction was calculated as 0.2S, where S is the maximum potential retention. Similarly, the continuous abstraction, or actual retention after runoff begins, F_a, was calculated using methods from the National Engineering Handbook Part 630, Chapter 10.

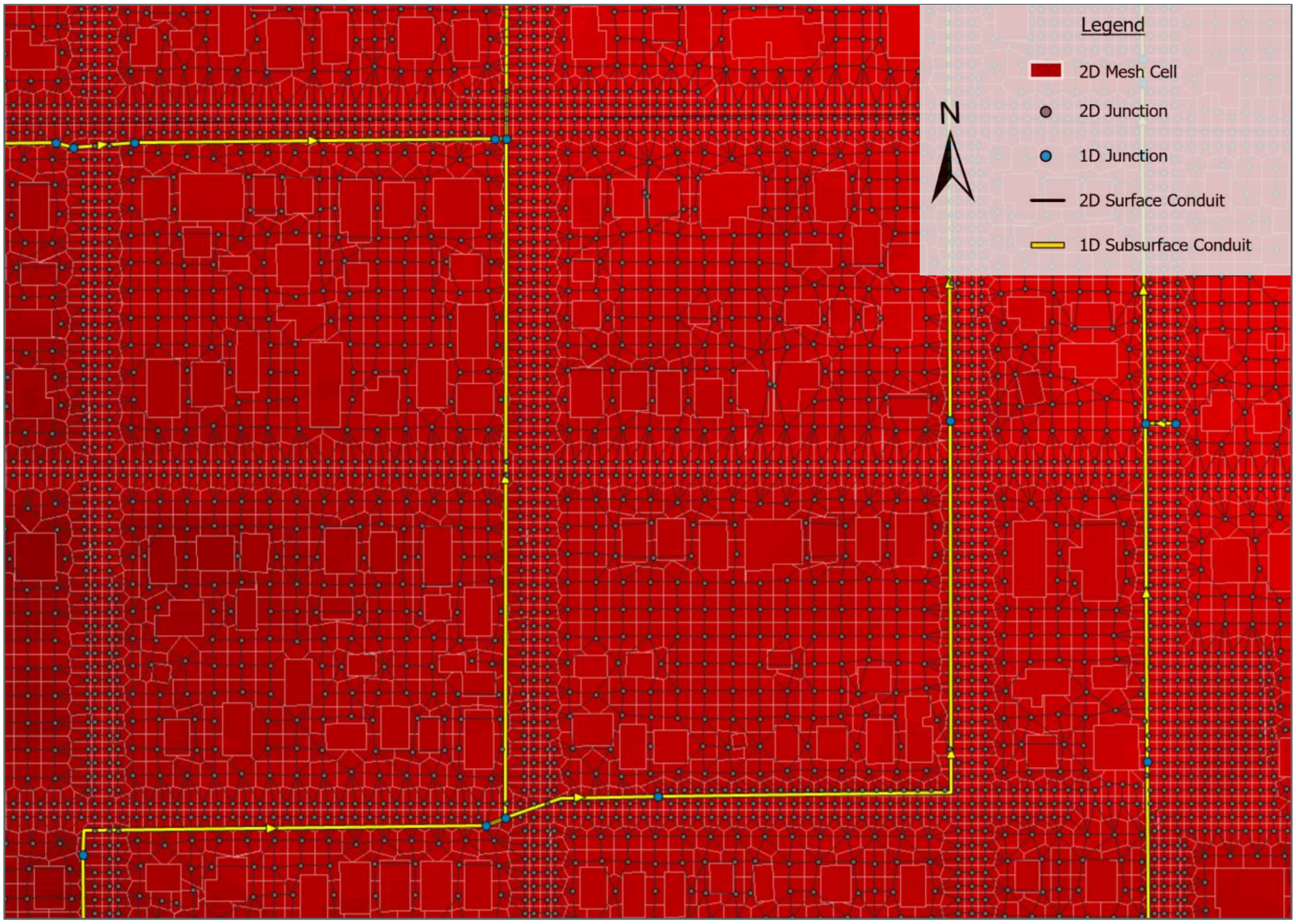
After rainfall losses were computed, the excess rainfall hyetograph was applied directly to each 2D junction and weighted based on the area of the associated cell.

2.6 Hydraulic Routing

The dynamic wave routing method was used so that the model can properly estimate reverse flow in pipes, backwater effects, and divided flow. In the SWMM modeling environment, links are used to represent conveyance through open channels, pipe networks, gutters, streets, pumps, weirs, and orifices. Pipe lengths, diameter, roughness coefficients, and entrance and exit loss coefficients were established. Surface dimensions for channels, gutters, streets, and overflows were estimated based on LIDAR elevation data while roughness coefficients were estimated from imagery and landuse data. Flow between subsurface pipes and surface elements was shared using direct connections of the respective elements at stormwater inlets, manholes, and outfalls. In the SWMM modeling environment, nodes are used to represent manholes, pipe junctions, inlet locations, storage areas, and outfalls. Junction inverts and maximum depth elevations were established. Outfalls were placed at all model outflow locations.

The 2D mesh was developed using PC-SWMM mesh generation tools. Elevation data for the mesh was taken from the LIDAR elevation data. Mesh resolution and alignment was set to accurately represent surface flow paths through channels and streets, as well as embankments and other features critical to hydraulic computations. Building footprints were represented as obstructions in the mesh. Vegetative roughness coefficients were estimated from imagery and landuse data. Ties to subsurface pipes were implemented using direct connections. An example of the 2D mesh is shown in Figure 2.

FIGURE 2- ILLUSTRATION OF 2D MESH



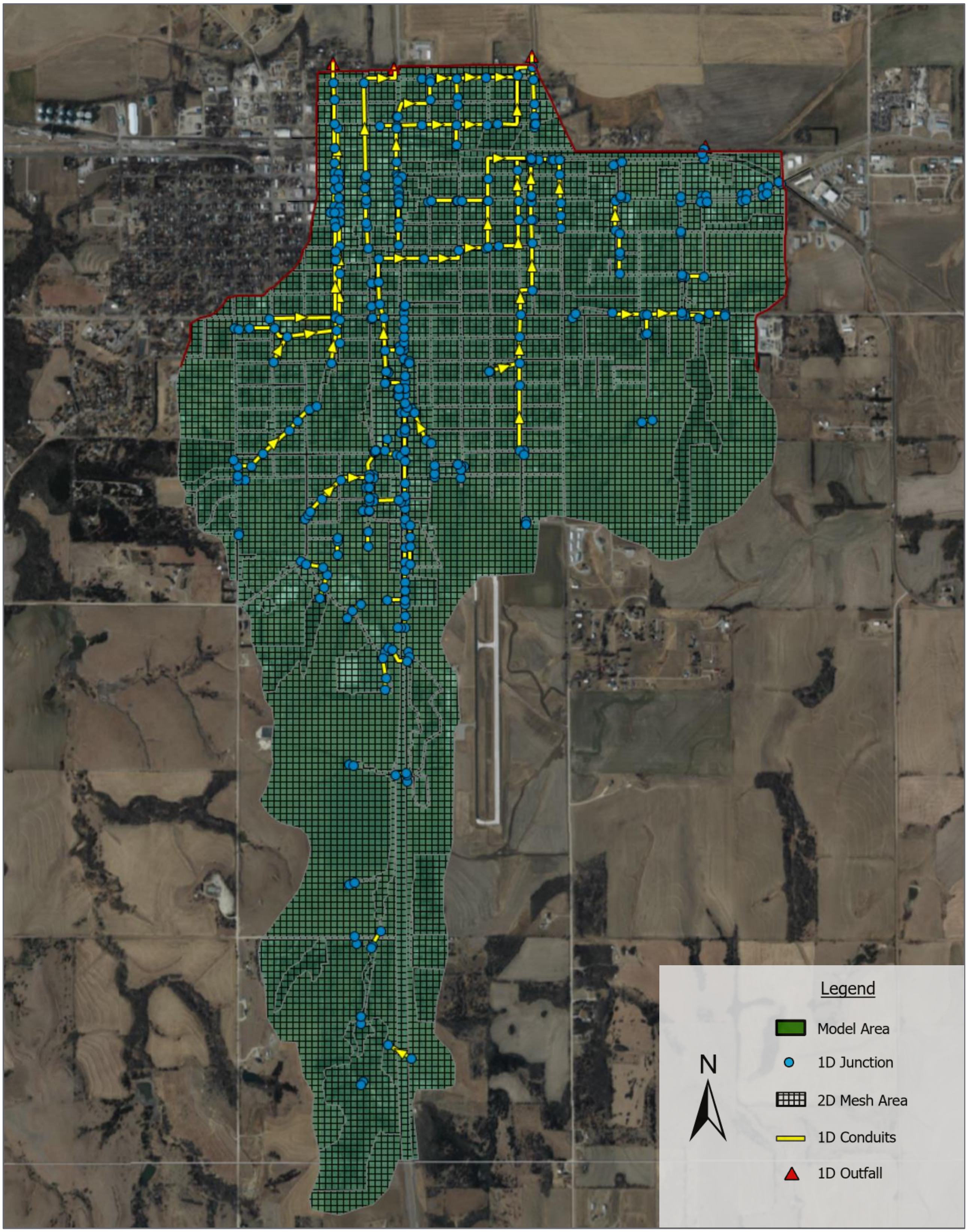
2.7 Infrastructure Incorporation

Conduit shapefiles were developed for the previous study (XP-SWMM model) and used for this study, with some adjustments based on aerial imagery and engineering judgement. The modeled pipe network includes storm pipes that are 2-ft or greater in diameter and those critical to the mapped areas of interest, such as overflow pipes and connections. Details that were incorporated into the model included pipe placement, dimensions, material type, elevations, and the number of barrels.

Storage curves for reservoirs and storage areas within the modeled area were based on the LiDAR data.

An overview of the PC-SWMM model is shown in Figure 3.

FIGURE 3- OVERVIEW OF THE PC-SWMM MODEL



2.8 Model Results

The PC-SWMM model was refined as needed to limit model instabilities. As a result, the model has very limited routing errors and flow losses. To provide an example of the model stability, the routing results table for the 1% annual chance (100yr) storm event is shown in Figure 4. For this plan, the routing continuity error for this storm event is only 0.064% in the model. The other storm events have similar stability results. The errors for continuity, flow instabilities, and convergence reported within the results are well within an acceptable tolerance level for FEMA acceptance.

FIGURE 4- ROUTING RESULTS TABLE FOR 100YR EVENT

Flow Routing Continuity	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	740.219	241.211
External Outflow	612.583	199.619
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.188	0.061
Final Stored Volume	127.351	41.499
Continuity Error (%)	0.064	

Surcharging | Routing: 0.1% | Results up-to-date

3 FLOODPLAIN PLOTTING

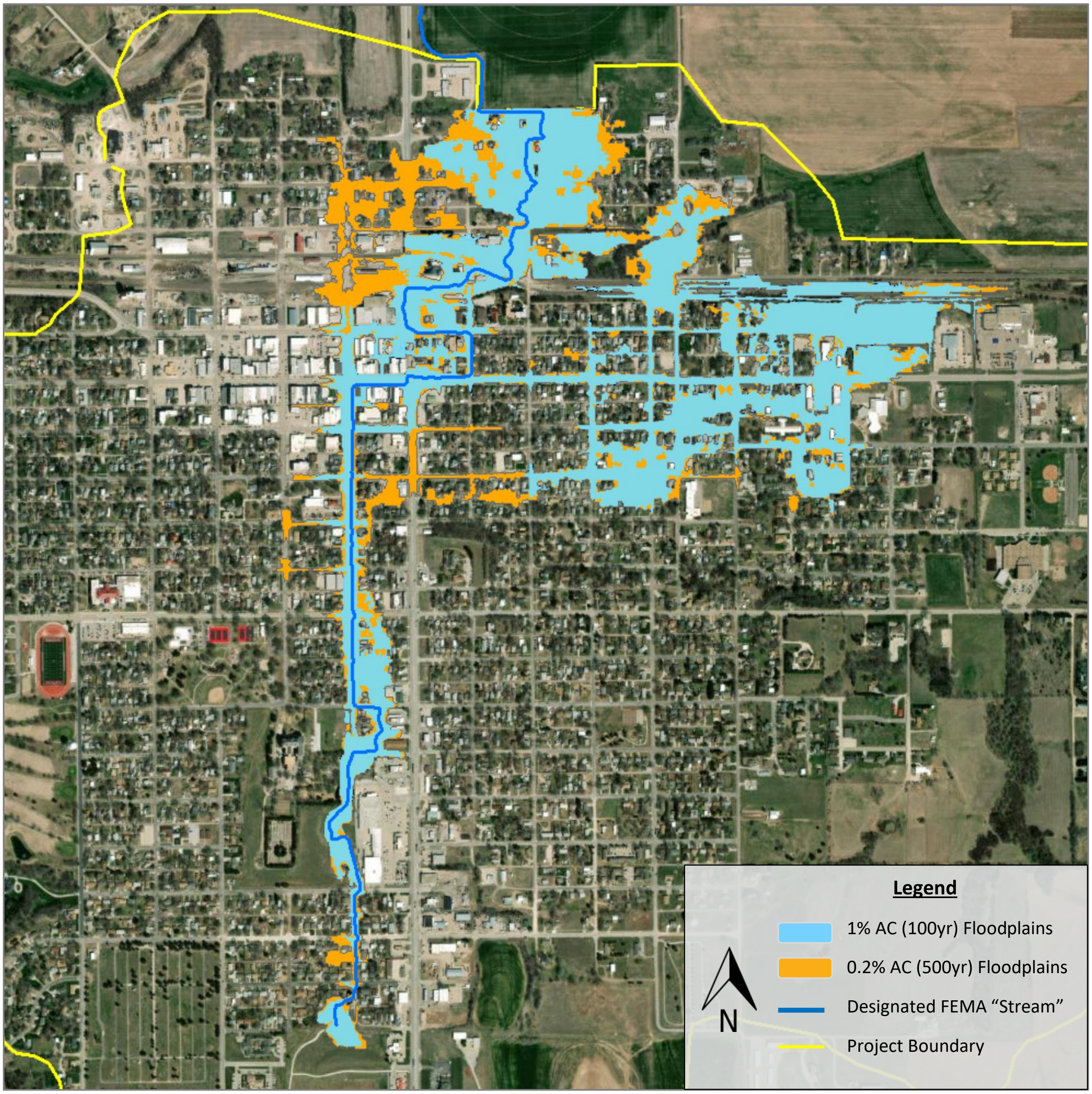
Draft floodplains have been prepared for the designated FEMA flooding sources and associated overflow areas, based on the PC-SWMM modeling results. The floodplains include all flooding depths associated with the FEMA flooding sources, with backwater impacts from the Republican River applied, to adequately represent the associated flood risk.

Due to the use of excess rainfall on mesh hydrology and the application of precipitation to every cell in the 2D mesh, almost every mesh cell has a flooding depth associated with it, most of which are very small depths. Therefore, the flooding that is generated from the PC-SWMM model results far exceeds what would be considered a FEMA designated flooding area. Therefore, customized plotting processes are required to achieve floodplains that are specific to the designated FEMA flooding sources and associated overflow areas.

The FEMA designated streams, used in developing the mapped floodplains, include the length of the streams currently designed by FEMA, plus the conveyances with defined channels and drainage paths with drainage areas equal to or greater than 1-square mile of drainage area. Detailed adjustment of the streamline relative to aerial photography and LiDAR elevation data was completed to ensure proper streamline alignment and extent.

The only FEMA designated stream within the project area is the tributary to the Republican River that extends south to north through the center of town, along with its associated overflow paths.

FIGURE 5- DRAFT FLOODPLAINS FOR PROJECT AREA



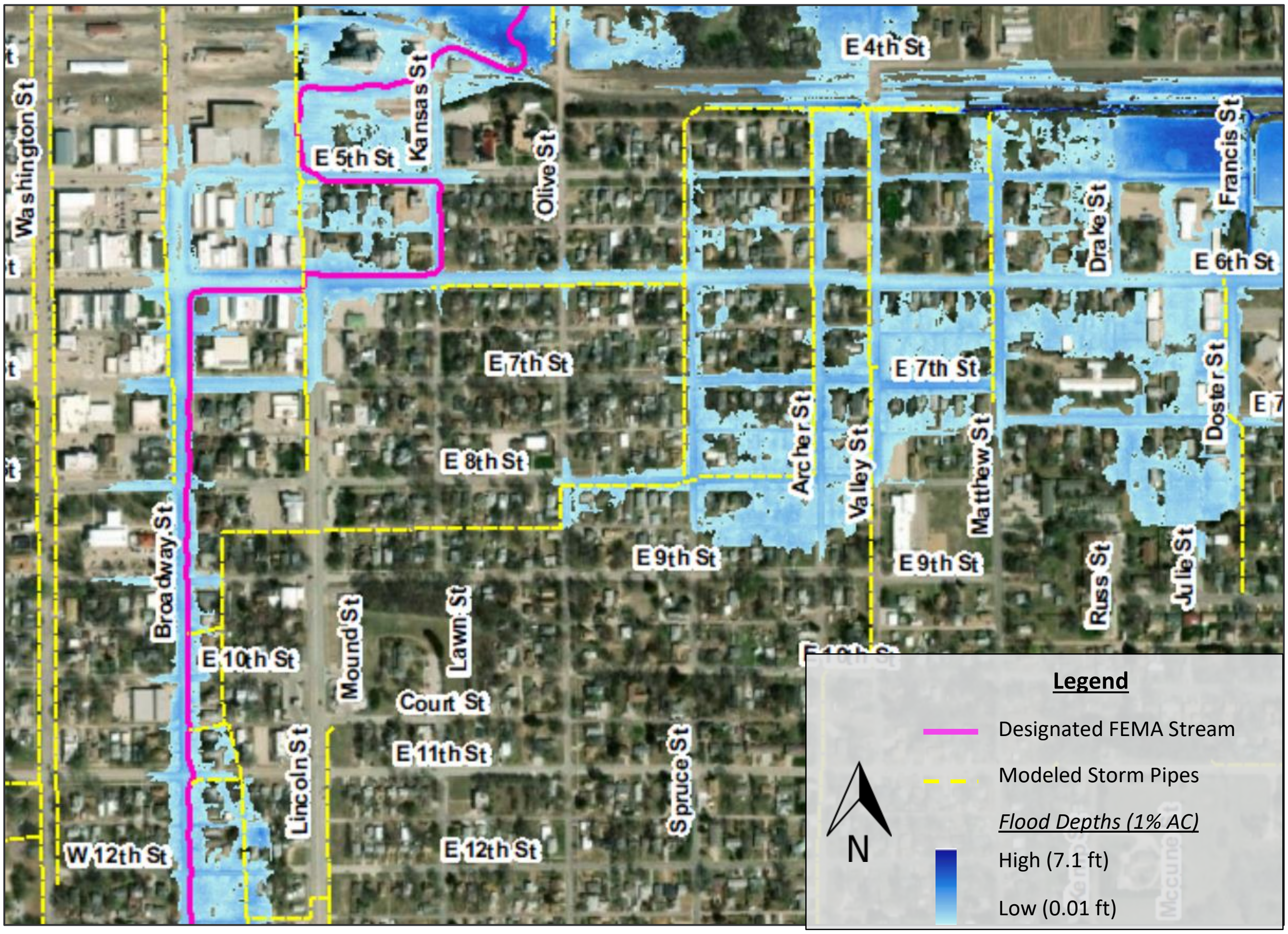
The plotting process includes the creation of multiple shapefiles that include points for the flooding origins of the designated FEMA flooding sources, i.e. the starting point at the upstream limit of the mapped streamline. These shapefiles establish the starting water surface elevations, taken directly from the model results. Water surface elevations are then obtained from the model as the flooding extends downstream, taken at the center point of each associated mesh cell, including overflow areas from the FEMA flooding source. The 2D cell points from the model mesh serve as the basis for following water surface elevations downstream. Water surface elevations associated with these flooding sources are then extended outward until the water surface intersects the natural ground surface. Backwater is determined by following flow through 2D cell walls, comparing the water surface elevations with ground elevations at cell walls. The terrain used for the plotting is the bare-earth terrain that does not include building footprints. The plotting process results in water surface elevation grids, depth grids, and floodplain polygons that represent the flooding associated with the designated FEMA flooding sources. The draft 1% annual chance (100yr) and 0.2% annual chance (500yr) floodplains for the project area are shown in Figure 5.

3.1 Average Flood Depths

The majority of the flooding associated with the 1% annual chance (100yr) draft floodplains is very shallow in nature. Typically, FEMA defines a Zone A special flood hazard area as a flood hazard zone that corresponds to the 1% annual chance floodplains. A Zone A flood hazard area is considered a regulatory floodplain. However, in the case of shallow flooding areas, FEMA defines 1% annual chance flooding where average depths are less than 1.0 foot as a Zone X (shaded) moderate flood hazard. A Zone X (shaded) flood hazard area is considered an advisory floodplain. Most of this area, including the current effective Zone A flood zone, has an underground stormwater network. In general, there is not a continuous riverine channel with defined bed and banks, even for the blue line shown in Figure 5 as the designated FEMA stream, which represents the drainage path with greater than one square mile of drainage.

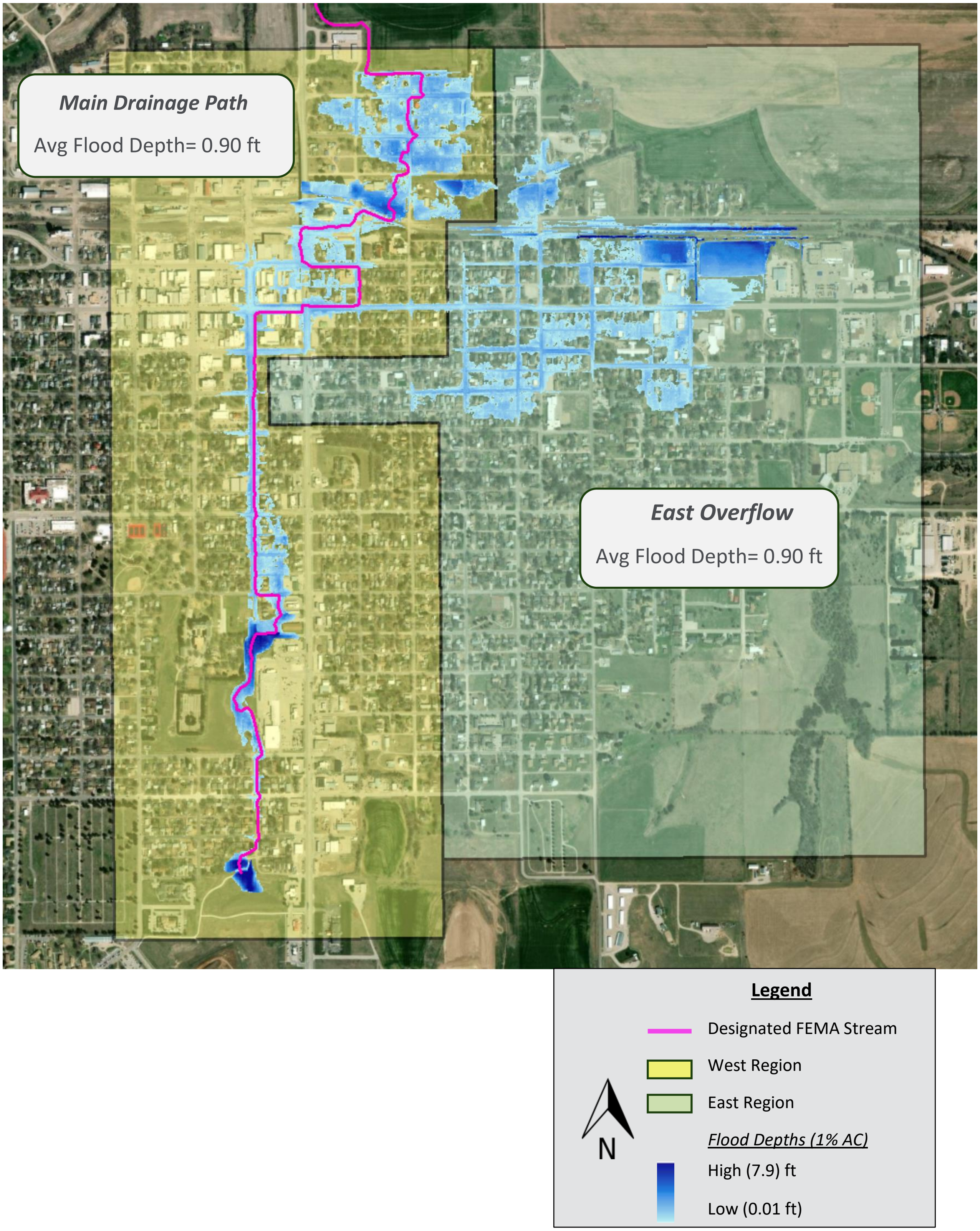
Due to the shallow flood depths associated with the draft floodplains that were developed from the PC-SWMM modeling, average flood depths were evaluated for the draft 1% annual chance (100yr) floodplains. For the purpose of the evaluation, two different regions were analyzed. The west region is for the main drainage path that extends south to north through the center of town. The east region is for the east overflow area that is predominately connected to the main drainage path via an underground storm pipe located between E 8th Street and E 9th Street and minor street flooding on E 6th Street. Figure 6 shows the flooding and storm pipe network near the location of the connection/overflow from the main drainage path to the east.

FIGURE 6- FLOOD DEPTHS AND STORM PIPE NETWORK AT OVERFLOW



Zonal Statistics were utilized to determine the average flood depths associated with the 1% annual chance (100yr) draft floodplains for each region. The west region, or main drainage path region, has an average flood depth of 0.90 ft (0.899 ft). The east region, or east overflow region, has an average flood depth of 0.90 ft (0.904 ft). Therefore, based on FEMA definitions, it appears that both regions would qualify for the Zone X (shaded) designation for average flood depths of less than 1.0 foot, which would be considered a moderate flood hazard or advisory flood data.

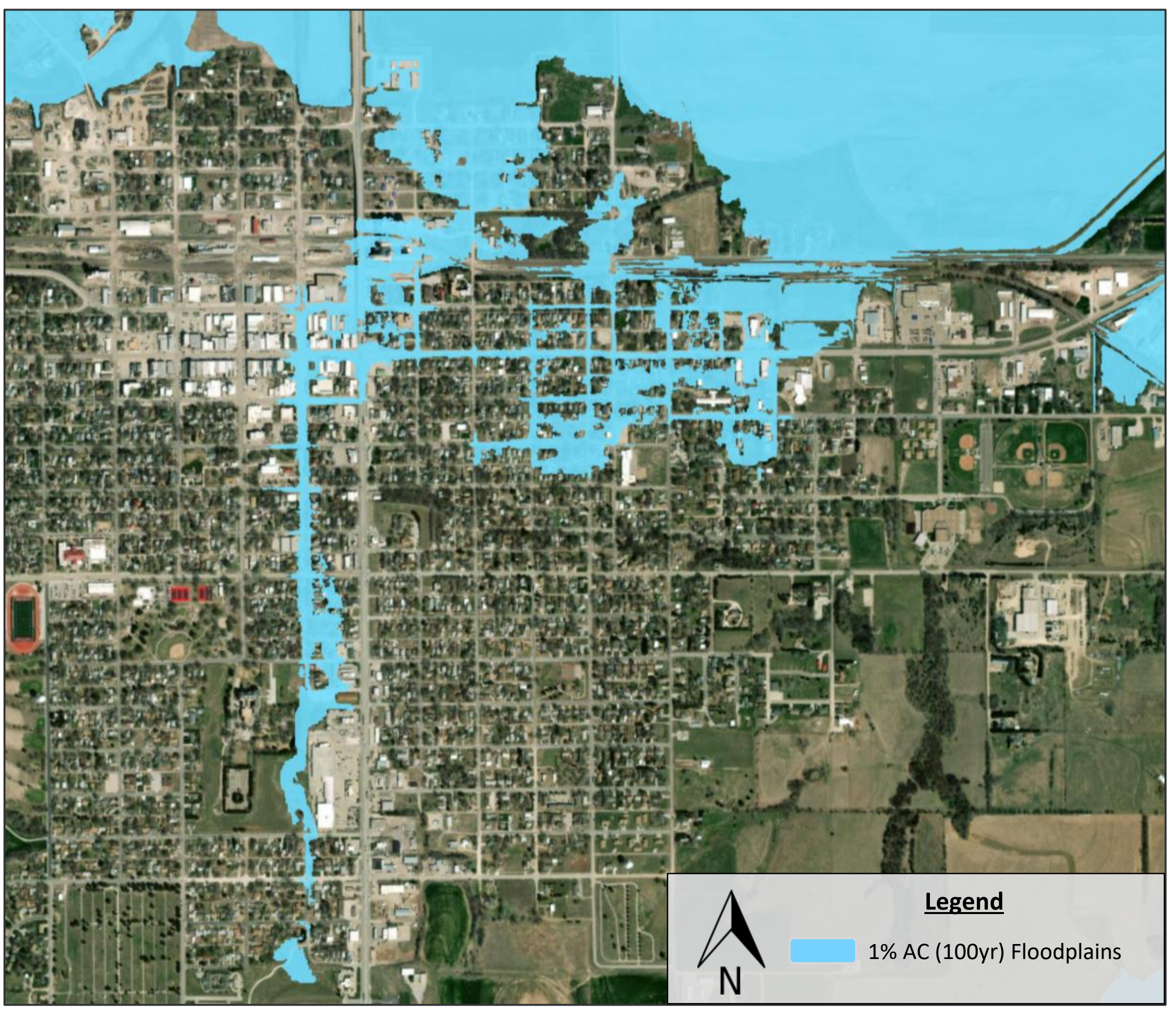
FIGURE 7- AVERAGE FLOOD DEPTHS FOR EACH REGION



3.2 Republican River Backwater

The Republican River is located north of Concordia. Backwater from the Republican River extends into Concordia, and into this project area. Therefore, flooding associated with the backwater conditions of the Republican River were captured in the draft floodplains to provide accurate flood risk data and avoid discontinuities in the floodplains. The Kansas Department of Agriculture provided base flood elevation information from the effective FEMA model for the Republican River. The elevations were obtained from cross sections in the model. The backwater elevation at the location of the Republican River tributary in Concordia was interpolated between the nearest two cross sections. The water surface elevations for the Republican River were plotted on the most current LiDAR dataset to generate draft floodplains that tie-in with the draft floodplains associated with the PC-SWMM Modeling, accurately representing the 1% annual chance (100yr) flood risk for Concordia and seamlessly tying-in with the effective floodplains for the Republican River. Cross-sections were extended to fully capture flooding in the backwater area, but no other modifications to geometry and values were made. Figure 8 shows the draft 1% annual chance (100yr) floodplains for Concordia. It should be noted that there are no effective 0.2% annual chance (500yr) floodplains for the Republican River in Cloud County.

FIGURE 8- DRAFT FLOODPLAINS WITH BACKWATER APPLIED



4 RECOMMENDATIONS

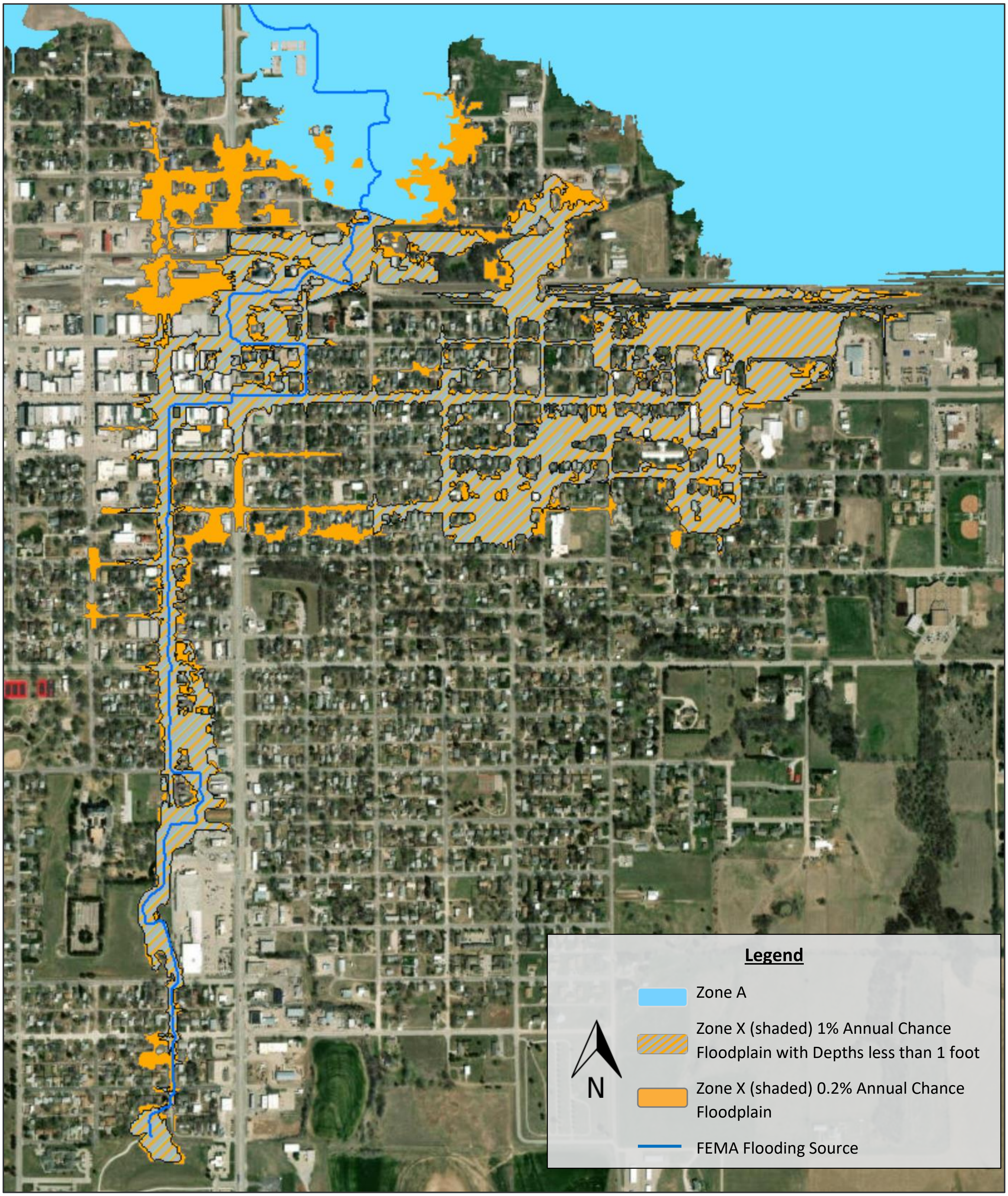
The City of Concordia intends to pursue a LOMR based on the information presented in this technical assistance report. Benesch recommends that the draft 1% annual chance floodplains associated with the PC-SWMM modeling, including both the main drainage path region and the east overflow region, be mapped as shaded Zone X flood hazard areas with average depths less than 1 foot. The tributary to the Republican River is the drainage path through the center of town that has greater than 1 square mile of drainage and is thus considered a FEMA flooding source. This tributary is not a continuous riverine channel with defined bed and banks but is rather a mixture of channels, ditches and underground storm pipes. There are no areas beyond the flooding source previously mentioned that have a drainage area of 1 square mile or greater. The flooding associated with the tributary to the Republican River, both the main drainage path and the overflows to the east, all have average flood depths of less than 1 foot. This is highlighted by the fact that a large portion of the flooded area is contained within streets. The shallow nature of the flooding falls in line with the moderate flood risk classification and is more suitable as an advisory floodplain, as opposed to a regulatory floodplain.

The KDA-DWR, which is the Cooperating Technical Partner (CTP) for FEMA in the State of Kansas, and the City of Concordia have discussed the floodplain results and the impacts to the community. Both parties agree that the preferred flood zone designation for the 1% annual chance floodplain that is associated with the tributary to the Republican River is the shaded Zone X flood zone designation for average flood depths less than 1 foot. The KDA-DWR, as the Kansas CTP, also discussed this independently with FEMA Region 7 staff during a discussion held on November 29, 2023. FEMA Region 7 staff expressed initial support of the subject area being designated as a shaded Zone X flood zone for average flood depths less than 1 foot on the FEMA maps, so long as the required correspondence is made, including documentation that the proposed mapping change meets the appropriate SID requirements. FEMA Region 7 staff indicated they would evaluate and make a final assessment of the proposed mapping, including zone designations, upon completion of the Technical Assistance project and submittal of the supporting documentation.

FEMA Standard Identification Number (SID) 645 states, in part, that removal of an effective base level (Zone A) special flood hazard area (SFHA) may be considered by FEMA if the impacted community and FEMA Regional Project Monitor both concur about the removal on the same correspondence, such as email or letter form. If the engineering analysis shows there is still flood hazard, but the depth is less than 1 foot, the SFHA may be considered for change to a shaded Zone X, with concurrence by the two parties.

Therefore, the project team strongly recommends that the City of Concordia proceed with a LOMR submittal package that presents the flood hazard areas in this way. First, the City of Concordia will need to provide the FEMA Regional Project Monitor an email or letter stating their desire to move forward with the removal of the Zone A SFHA and including a shaded Zone X for average depths less than 1 foot, providing this technical report as the supporting documentation along with the supporting SID criteria. The FEMA Regional Project Monitor will need to concur on the same correspondence. Once the final concurrence is achieved, the LOMR submittal package can then be prepared and submitted. Figure 9 provides an image of the recommended flood zones for the LOMR submittal. It should be noted that the zone break between the shaded Zone X floodplain for average flood depths less than 1 foot and the Zone A floodplain for the Republican River was placed at the location where the Republican River no longer impacts, or drives, the 1% annual chance flooding.

FIGURE 9- RECOMMENDED FLOOD ZONES FOR LOMR SUBMITTAL



5 CONCLUSION

The purpose of this technical assistance project was to ultimately provide the City of Concordia with a PC-SWMM model and associated draft floodplains that accurately represent the flood risk in Concordia and can be utilized to pursue a FEMA Letter of Map Revision (LOMR). A PC-SWMM model was developed that accurately captures flows in the underground storm system in addition to surface flows, while having minimal instabilities and flow losses. Draft floodplains have been developed for the designated FEMA flooding sources and associated overflow areas, based on the PC-SWMM modeling. The floodplains include all flooding depths associated with the FEMA flooding sources, with backwater impacts from the Republican River applied, to adequately represent the associated flood risk. The resulting model and draft floodplains meet FEMA standards for an enhanced analysis. The project team met with a FEMA LOMR reviewer in October to discuss the modeling methodology for the project and to gain initial feedback. The intent of the conversation was to ensure that our modeling approach was consistent with the approach expected from the LOMR reviewers. Therefore, it is our belief that the resulting flood data is suitable for a LOMR submittal package.

An analysis has been completed to determine the average flood depths for two distinct flood regions. Both regions have a calculated average flood depth of less than 1.0 foot for the 1% annual chance (100yr) storm event. Based on the shallow nature of the flooding, the lack of a continuous channel through town, the community's needs and interests, and initial discussions that have been had with KDA-DWR staff, it is recommended that the City seek to obtain concurrence with FEMA Region 7 staff, in the form of email or letter correspondence that documents both parties' concurrence of the Zone A removal, to change the Zone A special flood hazard area to a shaded Zone X flood hazard with average depths less than 1 foot. This report should be provided to FEMA Region 7 staff as the supporting documentation needed for their approval. Once written concurrence is obtained, it is recommended that the City pursue a LOMR that would include shaded Zone X flood hazard designations for the entire floodplain that is associated with the FEMA designated flooding source through town, described as the tributary to the Republican River. The shaded Zone X designation would result in advisory floodplains of the 1% annual chance (100yr) floodplains with depths less than 1 foot, with the 0.2% annual chance (500yr) floodplains also shown as shaded Zone X on the LOMR mapping.

Finally, the PC-SWMM model can serve as a valuable tool for the City of Concordia in their floodplain management efforts. PC-SWMM is compatible with EPA-SWMM, which is a free software, and is widely accepted in the industry. Thus, the model could have many uses to the community into the future.

6 REFERENCES

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7 APPENDIX ITEMS - ELECTRONIC DELIVERABLES

PC-SWMM Model

Digital Supporting Data

- SWMM Shapefiles
- Resulting Draft Floodplains
- Resulting Water Surface Elevation and Depth Grids