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City of Concordia, Kansas Technical Assistance
21st Street Dam and Storm Sewer XPSWMM

Kansas Department of Agriculture,
Division of Water Resources

March 2022

Prepared for:

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1. Introduction

The City of Concordia submitted a request for Technical Assistance to conduct an enhanced Zone A study of the Unnamed Tributary flowing parallel to Lincoln Street and into the Republican River north of town. Flood risk from the Unnamed Tributary is assumed to be reduced by two dams on the south side of town at 21st Street and Plum Road, and the storm sewer system through town, but this is not reflected in the current FEMA flood maps from 2014 or in the Draft 2021 BLE results. The City requested KDA to provide a SWMM Model that accounts for the dams and storm sewer capacity, draft flood hazard mapping outputs, and the number of buildings that could potentially be removed from the SFHA with an enhanced study. This data is to be used by the City in preparing a Benefit Cost Analysis for city council to decide whether to fund a new detailed analysis for use in submitting a Letter of Map Revision to FEMA.

The BLE HEC-RAS 2D Zone A is a product of 'rain-on-grid' hydraulic surface routing representing fluvial and pluvial flood hazard risk on existing Quality Level 3 (QL3) LiDAR. The BLE does not include hydraulic structures or closed storm sewer systems such as those referenced herein. Using survey data and existing model data from the 2D BLE analysis, AECOM developed a 1D/2D XPSWMM model to model the hydraulic structures and storm sewer system, to evaluate the flood risk more accurately along the Unnamed Tributary parallel to Lincoln Street.

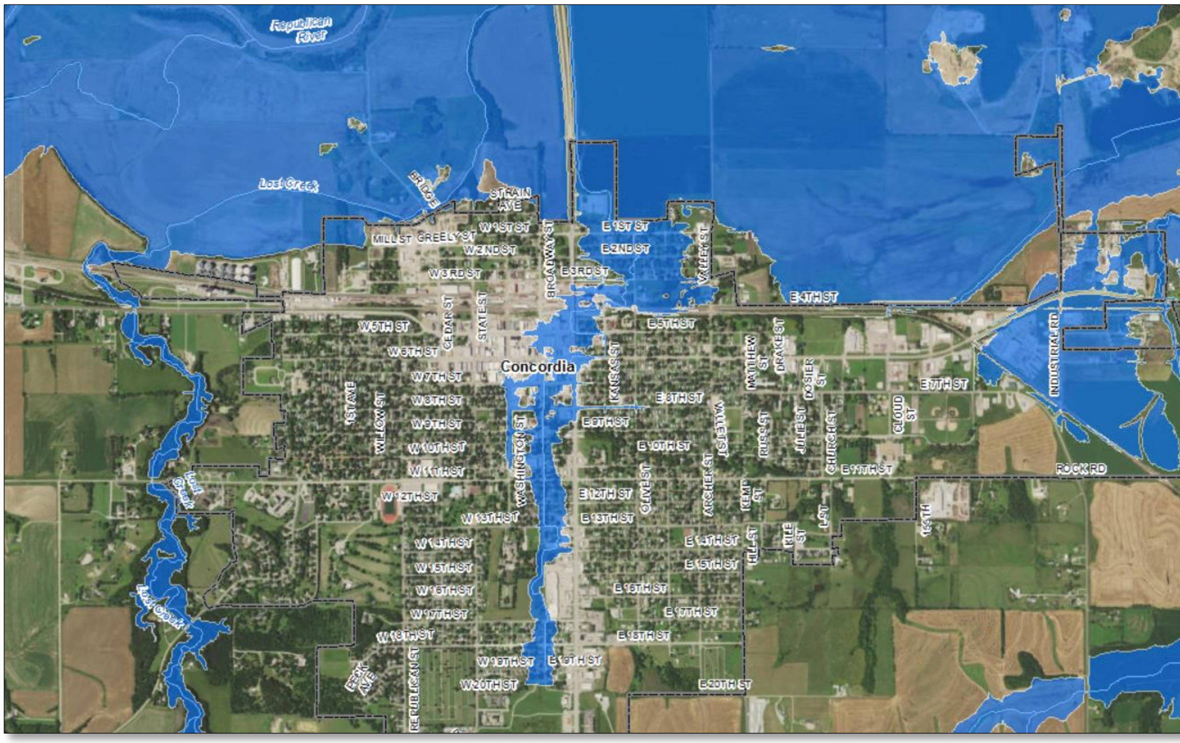

Figure 1: Effective Zone A

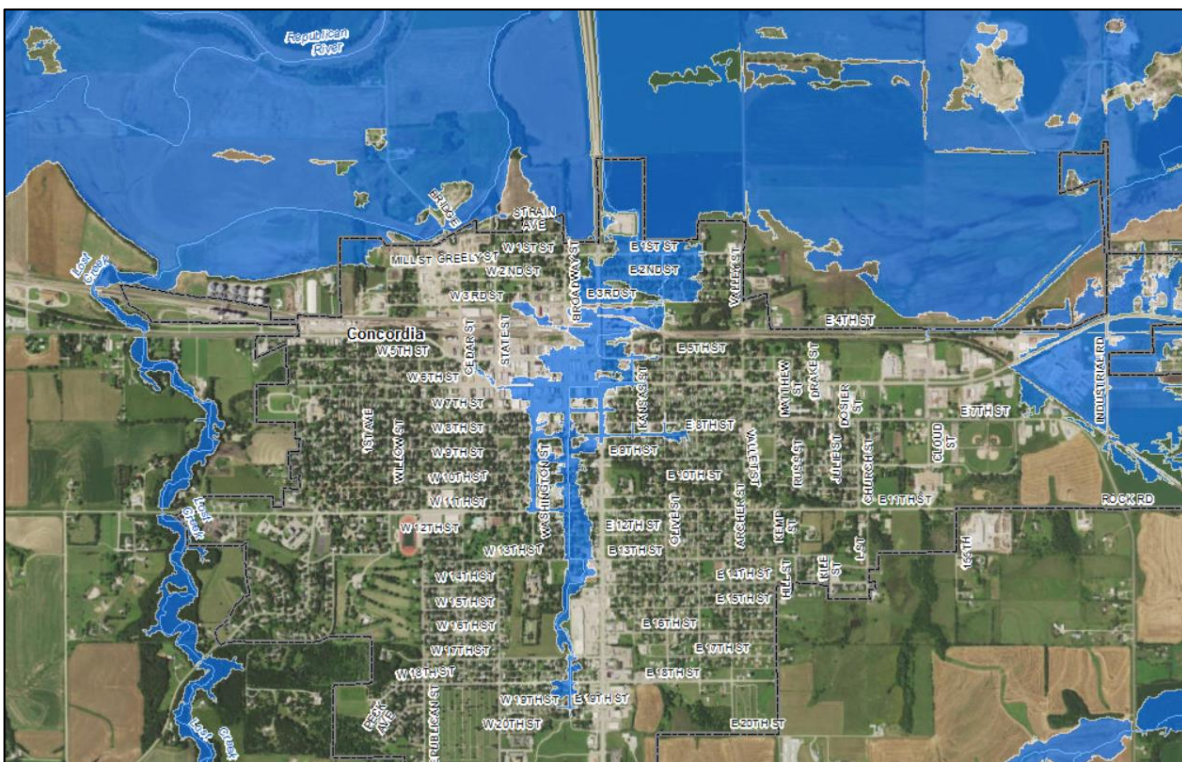

Figure 2: BLE Zone A

2. Engineering Methods

Data Collection

Data for use in the model was obtained from multiple sources, including storm sewer infrastructure data provided by the City of Concordia and data from the BLE study rain-on-grid analysis. The latest LiDAR terrain data obtained from the State of Kansas GIS Data Access & Support Center (DASC) for the Lower Republican Watershed 2D BLE project, which was collected in 2017, was used and clipped to the City of Concordia study area to minimize dataset size.

AECOM leveraged survey information for storm sewers, culverts, and dam as-built drawings provided by the City of Concordia. The spatial data provided with the survey data allowed for the storm sewer and culverts to be applied in the correct location in the XPSWMM model. Additionally, the City of Concordia provided field verification drawings for unavailable or questionable storm sewer sizes. The survey data and schematic drawings can be found in Appendix A. Finally, floodplains developed during the BLE study as well as the effective Zone A delineations were also used as a reference.

Leveraging 2D BLE Data

To maintain consistency with the 2D BLE study, the same hydrology inputs were used for the Concordia model. Excess rainfall hyetographs were pulled from the Lower Republican (LR-1) 2D BLE study HEC-HMS model for each of the storm events (10, 4, 2, 1, 0.2%). Surface roughness information from the BLE model were used as the surface roughness for the XPSWMM model. A single modification to the surface roughness from the BLE model was done in the XPSWMM model to represent the surface roughness more accurately along East 4th Street and the adjacent railroad.

AECOM initially considered extracting stage hydrographs for selected cells from the LR-1 2D BLE model to implement as downstream boundary conditions for the multiple points of outfall in the area of interest. The initial model design included several stage vs time hydrographs at different locations along the boundary where flow enters the Lower Republican River floodplain. After reviewing the results, slope of the watershed, model stability, and timing of the hydrograph from the Lower Republican vs the local storm event, the boundary conditions were moved to fall within the Lower Republican floodplain and set to normal depth. Since the LR-1 BLE model only includes results for 100-year and 500-year, this assumption prevented AECOM from running the HEC-RAS BLE model for the missing storm events or requesting the City of Concordia for further information. During mapping, the higher of the two WSEs in the area immediately adjacent to the XPSWMM downstream boundary will be used, with the XPSWMM results taking precedence farther uphill. Figure 3 shows the stage vs time hydrograph for the Lower Republican at the stream centerline at the upstream edge of the 2D boundary as well as the flow entering the Lower Republican from the XPSWMM model at around the same location, demonstrating that the two can be treated independently.

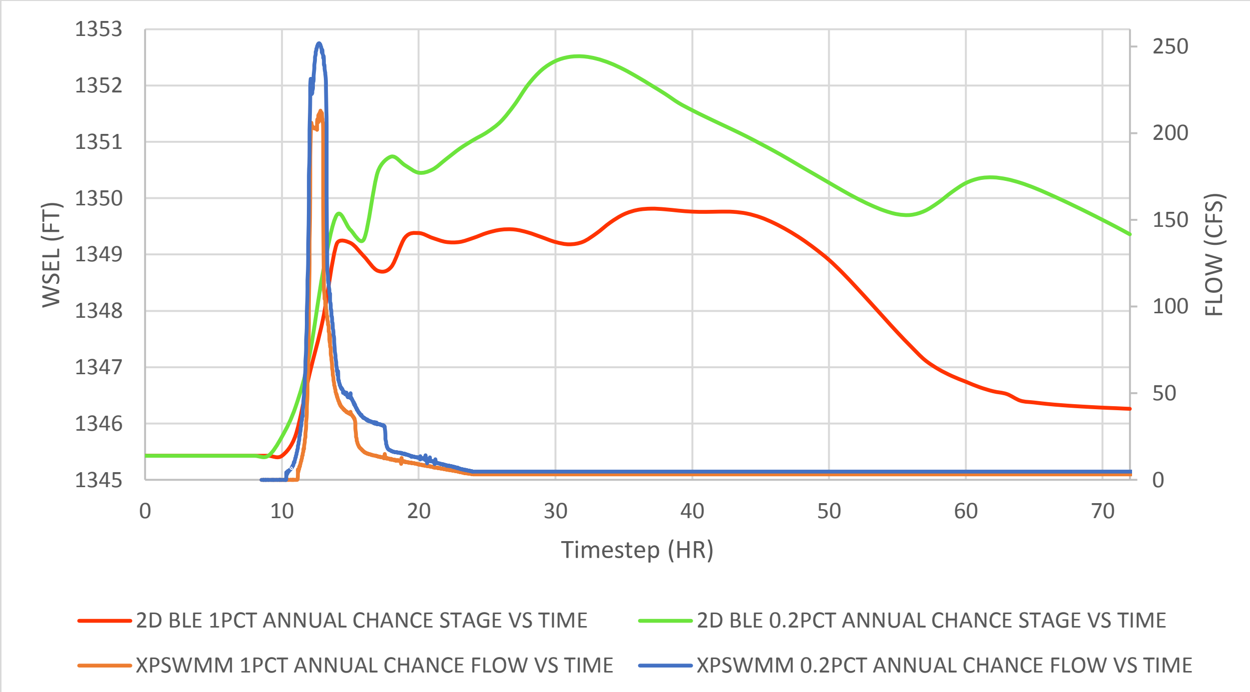

Figure 3: 2D BLE Stage vs. Time Hydrographs & XPSWMM 1D/2D Flow vs. Time Hydrographs

Model Assumptions

AECOM included major storm trunk lines, generally 24 inch or greater in size, as the 1D domain for the model. Smaller lateral pipes were included as needed to connect low points and obtain more accurate results. 1D/2D connections were applied, mostly at locations of inlets and localized low spots in the terrain, to allow water that would otherwise be stranded to flow into the storm sewer system.

With the available survey data and storm drain information provided by the City of Concordia, some general assumptions and approximations had to be made where storm sewer data seemed to be questionable or not available. Generally, for the drainage systems north of East 11th Street, in between 1st Avenue. and Matthew Street, assumptions on storm sewer invert elevations and slopes were made to ensure positive slopes and reasonable ground cover. Storm sewer gradual slopes of 0.5% to 1% were assumed for model stability, with higher slopes where terrain was steeper. A minimum of 1.5 feet depth below grade to top of pipe was assumed where terrain and storm sewer slopes were low, with a desired 3 feet depth of cover where terrain elevations were suitable. Spatial data with storm sewer assumptions are documented in Deliverable 3.

The City of Concordia provided as-built drawings for 21st Street Dam and Plum Road Dam. After comparing storage volume curves specified in the as-built drawings against LiDAR, it was determined that storage curve obtained from the LiDAR is generally representative of the as-built drawings. For both dams, the vertical datum used for construction and in the as-built drawings is NGVD29, which differs from that of the LiDAR, which is NAVD88. The National Geodetic Survey datum conversion tool was used to calculate the datum adjustment, which was NAVD88 = NGVD29 + 0.49 feet. The Plum Road Dam plan set indicates that the main dam structure was built higher than the intended final elevation, with the understanding that future settling would happen. The LiDAR shows that the centerline of the dam is about 1.5 feet (after the datum adjustment) above the ‘top of dam’ in the plans. At the 21st Street Dam, the LiDAR shows a dam top elevation that is also higher than the datum-adjusted ‘after-settling’ elevation of 1426.2 + 0.49.

After a review of the LiDAR and aerial photos, it is clear that some additional excavation has occurred inside the 21st Street Dam, resulting in a larger storage volume, and a sidewalk was added along the top of the dam. Plans for these updates were not provided, however, there is no indication that there are changes that would affect the modeled storm events aside from the storage volume changes, which are captured by the LiDAR.

For both dams, the WSE inside the dam for largest modeled event (500-year) is well below the emergency spillway and the top of dam. For both dams, all infrastructure such as weirs and outflow pipes were adjusted for the SWMM model by adding 0.49 foot to the elevations.

Model Parameters/Setup

The overall study area was delineated based on the terrain conditions and the general contributing drainage area for the system in question. The limits of the XPSWMM model in relation to the Area LR-1 2D BLE model are shown in Figure 4 below. By examining the level of detail required and the size of the area of interest, AECOM selected a cell size of 10 feet to carry out the analysis. Rain-on-grid rainfall was applied as a time series to a polygon spanning the entire 2D model domain, with uniform excess rainfall taken from the BLE model. See Section 2.5 from the BLE report for excess rainfall details.

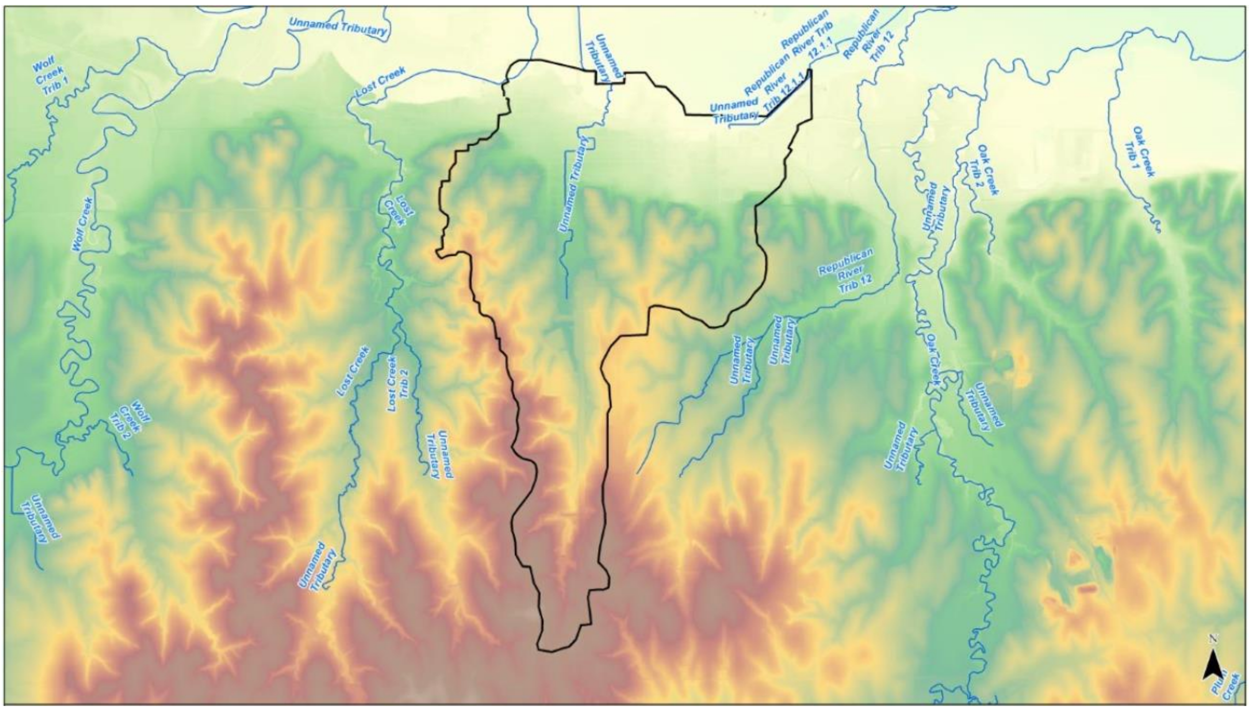

Figure 4: XPSWMM Model Limits

The flood risk analysis consists of a 1D/2D XPSWMM model, with the City of Concordia storm sewer network as its main 1D attribute. The model contains the main trunk lines and multiple laterals. Various driveway culverts, roadway cross-culverts, and dam primary spillway pipes are also included as part of the 1D network. A schematic of the XPSWMM 1D setup is shown in Figure 5.

The model includes 1D/2D connection lines that connect low spots within the 2D terrain to an associated manhole to the 1D system. This is done in lieu of adding all leads, laterals, and inlets to the model. In areas where AECOM found the terrain not being representative, particularly where the terrain elevation was higher compared to surveyed invert elevations, gullies were added to smooth out the 2D terrain. These gullies were primarily used for roadside ditches and near the dam invert/outfalls.

The storm sewers do not all continue directly down Lincoln Street toward the Lower Republican River. One in particular (See Figure 5) turns 90 degrees to the east and carries water from this area across what would otherwise be a watershed divide, entering the system at the intersection of Lincoln Street and East 8th Street (off to the east). The presence of this system required that the XPSWMM model be larger than originally anticipated and allowed AECOM to also assess the floodplain north of the intersection of 6th Street and Cloud Street and along 4th Street south of the railroad tracks, which was not originally in the area of interest described by the City of Concordia.

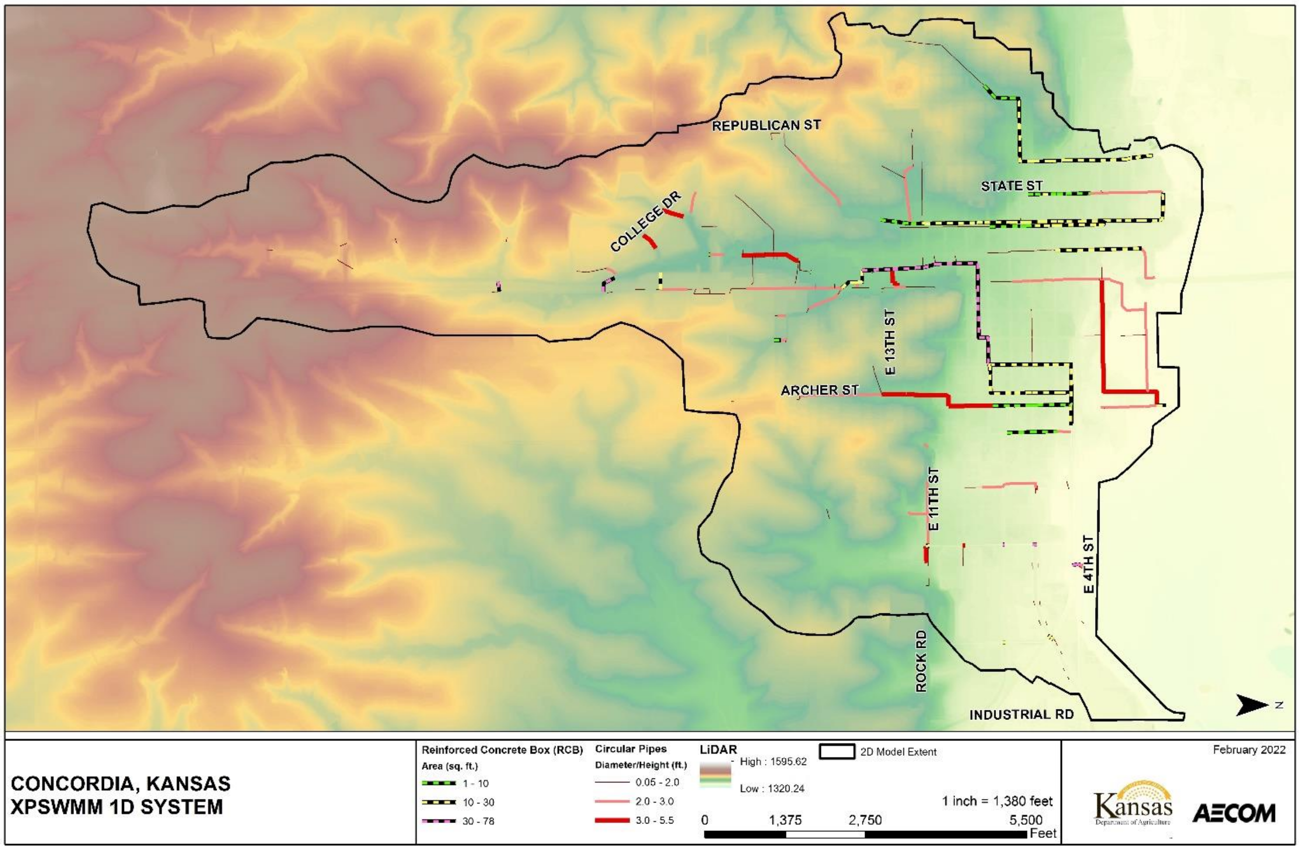

Figure 5: XPSWMM 1D System

3. Results

The results from the XPSWMM 1D/2D model indicate that the consideration of the City of Concordia sub-surface storm sewer system and 21st Street and Plum Road Dams results in lower water surface elevations compared to the 2D BLE study. Profile plots along the Unnamed Tributary parallel to Lincoln Street, comparing these results are shown in Exhibits 6 through 10 for the 100-yr and 500-yr events, respectively. This result is expected, as underground storm sewers are not accounted for in large scale 2D BLE rain-on-mesh modeling and storage from 21st Street and Plum Road Dams are more accurately represented in the XPSWMM 1D/2D model. Incorporating the major storm sewer lines and the two dams into the model is a more realistic representation of overall flood risk for the study area, especially along the Unnamed Tributary parallel to Lincoln Street. Exhibits 1 and 2 show the 2D BLE Flooding and the XPSWMM 1D/2D results respectively.

The XPSWMM 1D/2D results shown in Exhibit 2 include all flood depths greater than 0.5 ft. This is the standard for most FEMA flood mapping. An average flood depth greater than 1 foot can be applied to the mapping results and shown as a flood zone of X, 1 PCT DEPTHS LESS THAN 1 FOOT. This option has been included in the deliverable and shown on Exhibits 3 and 5. The calculation was performed on the initial results from the model that were mapped as 100-yr flood boundaries. Using Zonal Statistics tools in ArcGIS, with the depth raster and mapped flood boundaries as the inputs, an average depth was calculated for each 100-year flood boundary. Exhibit 3 shows the XPSWMM 1D/2D results with the average depths less than 1 foot applied to the mapping and designated as X, 1 PCT DEPTHS LESS THAN 1 FOOT. The 100-yr flood areas that were calculated to have an average depth of greater than 1 ft. remained as Zone A.

Exhibit 4 shows both the BLE model results and the XPSWMM 1D/2D (without average depths calculated) compared to the effective floodplain. Exhibit 5 shows the same comparison against the effective floodplain except with the average depths less than 1 foot calculated and shown in the XPSWMM 1D/2D results. Flooding for the 100-yr and 500-yr storm events is more contained within the Lincoln Street storm sewer system apart from localized low-lying areas. Exhibits 1 through 5 show larger floodplain profile graphs along the BLE Unnamed Tributary profile line and along 4 additional profile lines within the City of Concordia.

A flood analysis was performed on the buildings and other structures along the Unnamed Tributary parallel to Lincoln Street. The goal of this analysis is to obtain an estimate of the number of buildings impacted by the 1% annual chance BLE Zone A floodplain, compared to an estimate of the number of buildings impacted by the 1% annual chance XPSWMM model results. A building footprint GIS shapefile, extracted from the Portal in ArcGIS Pro and created by Microsoft in 2018, was intersected with the flooding extents of the 2D BLE and XPSWMM 1D/2D model results. Table 1 shows the number of flooded building footprints during 100-year storm event from the 2D BLE and from XPSWMM. As expected, taking into consideration of major storm sewer lines and 21st Street and Plum Road Dams greatly reduces the estimated number of flooded structures.

Table 1. Buildings Inside the 100-yr Floodplain (Special Flood Hazard Area)

Model Scenario	Structures in SFHA	Map Exhibit
2D BLE Zone A	248	1
XPSWMM 1D/2D (Depths Greater than 0.5 ft)	35	2 and 4
XPSWMM 1D/2D (Depths Greater than 1 ft)	22	3 and 5

The steps taken to create Zone A and Zone X floodplain boundaries from the XPSWMM model results were consistent with the standard methodology used for the 2D BLE studies. Further description of this methodology can be found in Section 4 of the 2D BLE report.

4. Recommendations

Further refinement and possible extension of the model to the east may be warranted if the City of Concordia decides to pursue modeling that would result in FEMA regulatory map revisions. The interaction of the BLE-mapped floodplains with the XPSWMM-mapped floodplains in this area is not clearly defined. Exhibit 6 shows the model extent on the east, which ends within an area mapped by the BLE. The extent of the XPSWMM model was selected based on a review of the surface terrain. It appears that the BLE floodplain extent crosses a ridge in the terrain.

This XPSWMM study included enhancements to the BLE hydrology and hydraulics, through the incorporation of local GIS storm sewer system inventory data, local as-built drawings and field verification of pipe inlet and outlet sizes. As such, the study may meet the FEMA standards for an enhanced analysis, and thus could be depicted on the Flood Insurance Rate Map with Base Flood Elevations (BFE) in the form of Zone AE and/or Zone AH. Flood zones with BFE's can be easier to regulate development. However, if the City prefers to maintain it's current level of Zone A (without BFE) mapping on the FIRM, this XPSWMM study can be leveraged for that as well.

There are multiple options for updating the FEMA regulatory floodplain and flood insurance rate maps. It is recommended that the City coordinate with the Kansas Department of Agriculture (KDA) and FEMA with regard to the best option. For example, the City could pursue a Letter of Map Revision (LOMR). The LOMR would be the most efficient route to update the FEMA mapping. This would require the City to submit a LOMR application to FEMA, including all of supporting engineering models, flood hazard mapping changes, as well as proposed updates to the Flood Insurance Study Report and Flood Insurance Rate Map. The applicant would be required to show engineering justification for any revisions to the effective Special Flood Hazard Areas (SFHA). The City would have the option to also map other areas of disconnected flood hazard identified by the XPSWMM model in low-lying areas in other parts of the model area. At a minimum, flood hazard areas identified with depths greater than 1 foot are recommended to be mapped as SFHA.

Another option to update the FEMA mapping would be to request that KDA scope this area as a need for a future Physical Map Revision (PMR) project. This type of project would be funded by FEMA grant money at no cost to the City. However PMR projects can take 3-5 years to be completed. It is recommended that the City coordinate with the Kansas Department of Agriculture (KDA) and FEMA with regard to the best option.

5. References

AECOM, 2021. *Lower Republican Custom Watershed 2D BLE project: 2D Base Level Engineering and Mapping*.

Exhibits

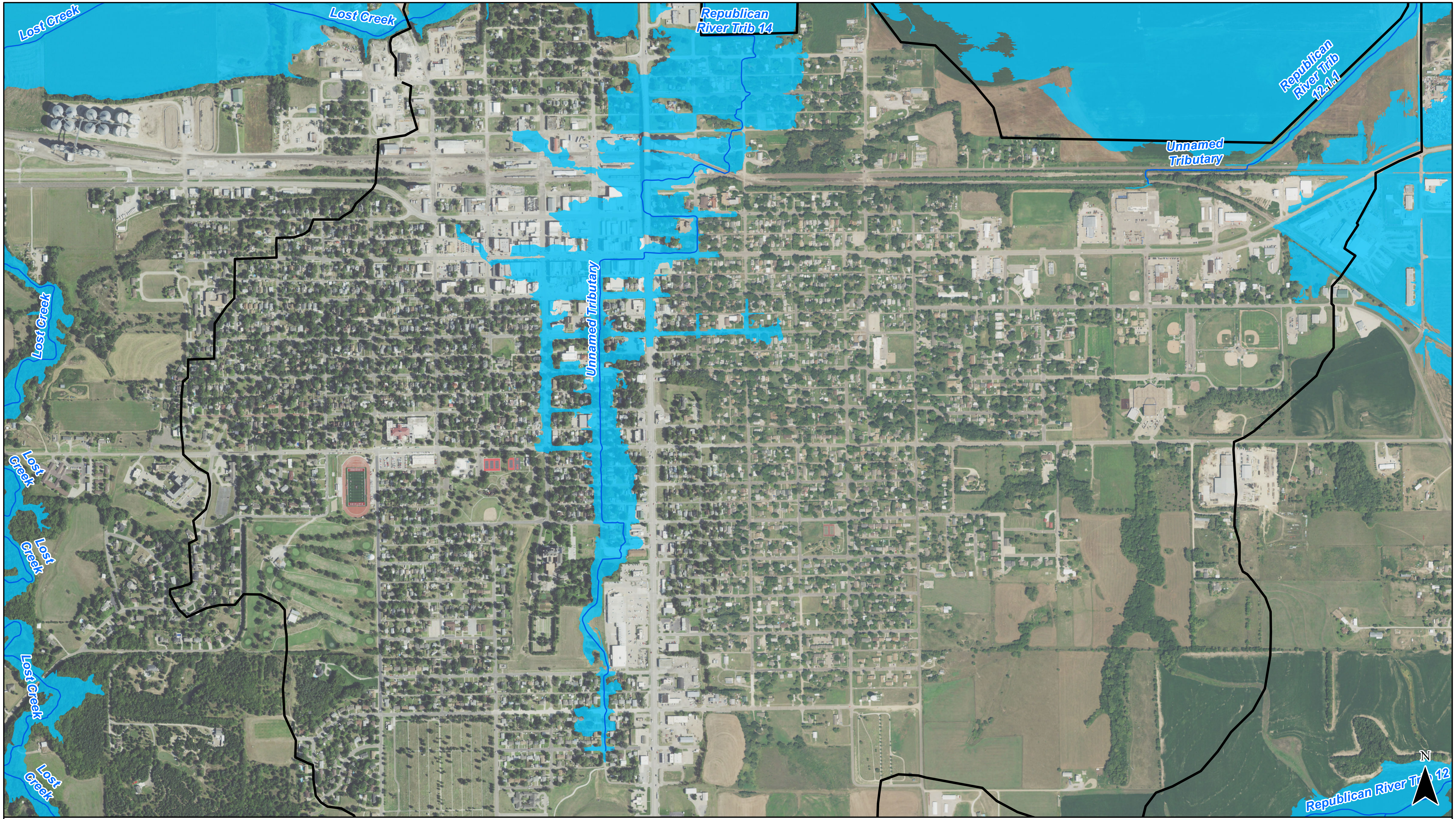

EXHIBIT 1:
BLE RESULTS
CONCORDIA, KANSAS

BLE Streams
BLE Zone A
2D Model Extent

0 | 875 | 1,750 | 3,500 Feet

1 inch = 875 feet

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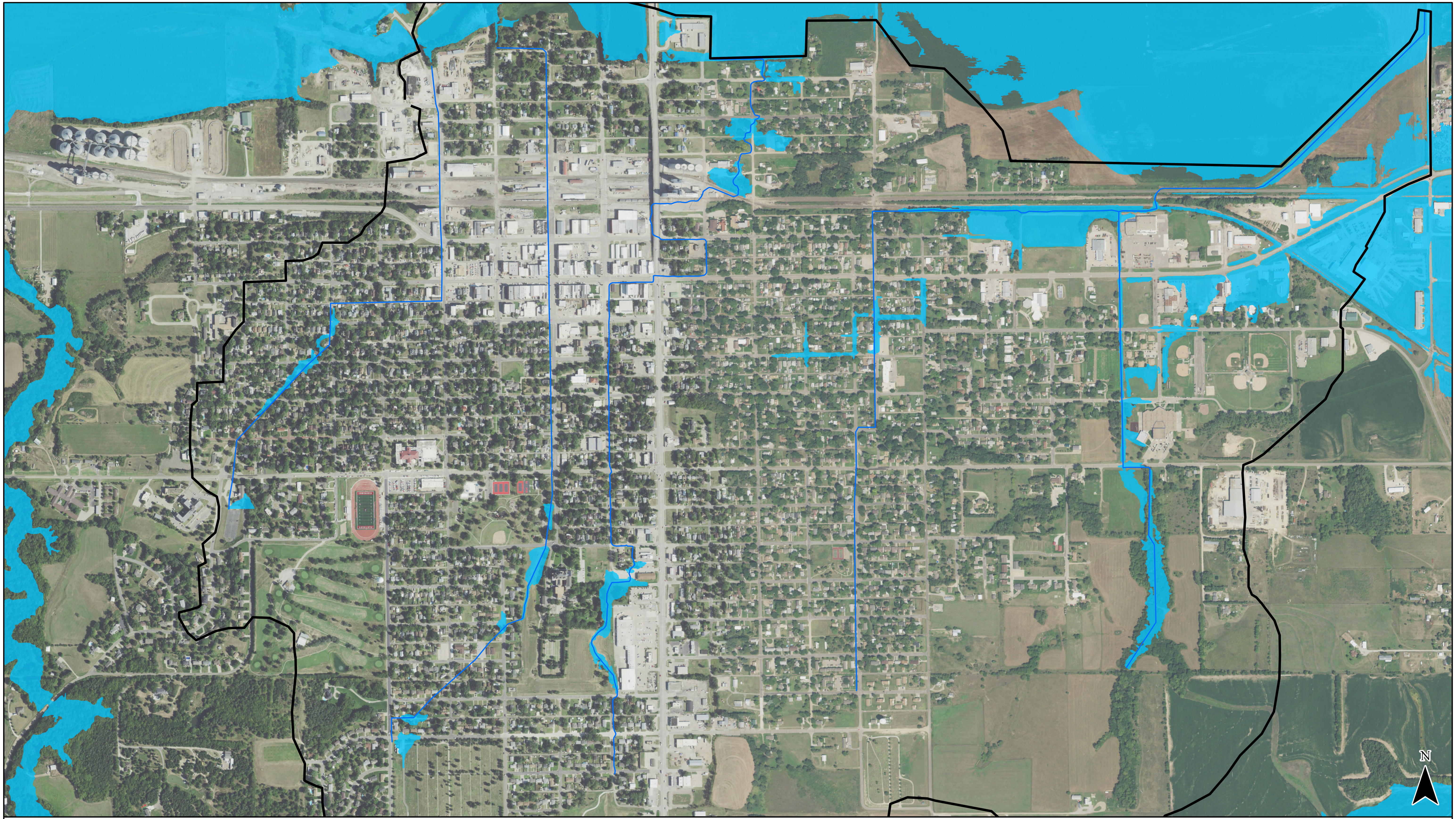

EXHIBIT 2:
XPSWMM MODEL RESULTS
CONCORDIA, KANSAS

Profile Lines
XPSWMM Zone A - Depths > 1 ft
2D Model Extent

0 875 1,750 3,500
Feet
1 inch = 875 feet

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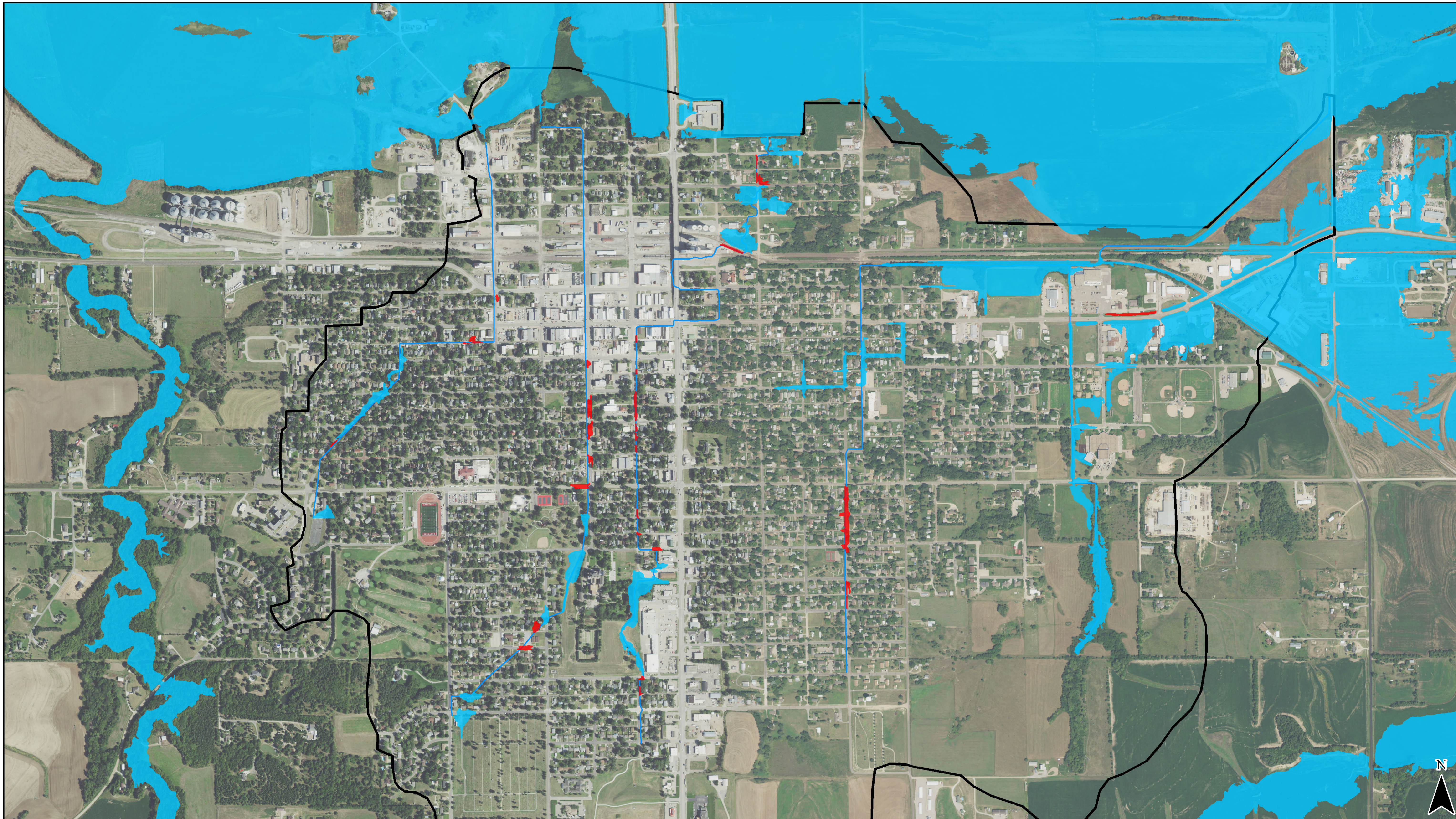

EXHIBIT 3:
XPSWMM MODEL RESULTS
CONCORDIA, KANSAS

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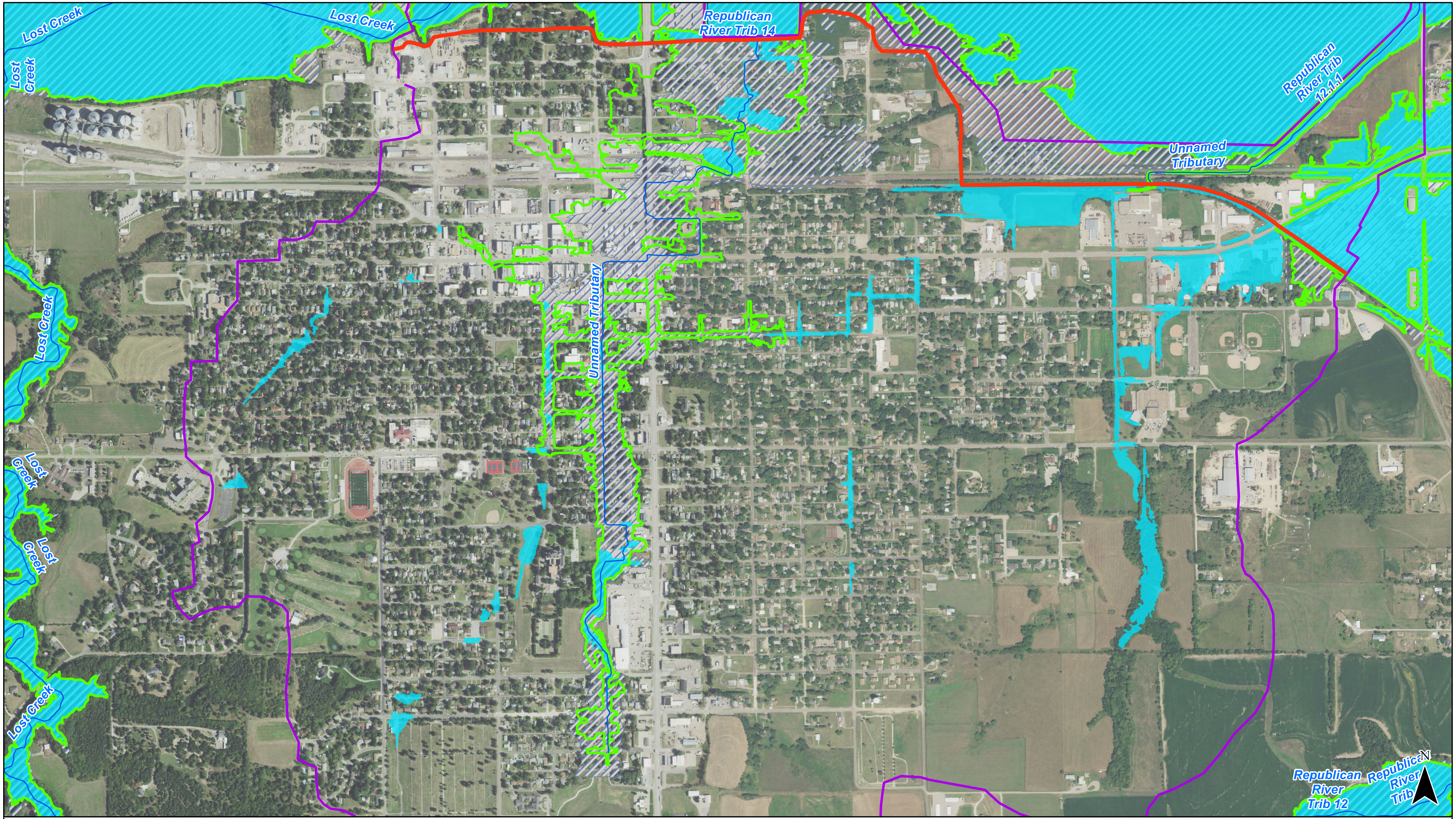

EXHIBIT 4: FLOOD SCENARIO RESULTS CONCORDIA, KANSAS

BLE Streams
2D Model Extent
XPSWMM Zone A
BLE Zone A
Effective Zone A
XPSWMM-BLE Boundary

0 875 1,750 3,500 Feet

1 inch = 875 feet

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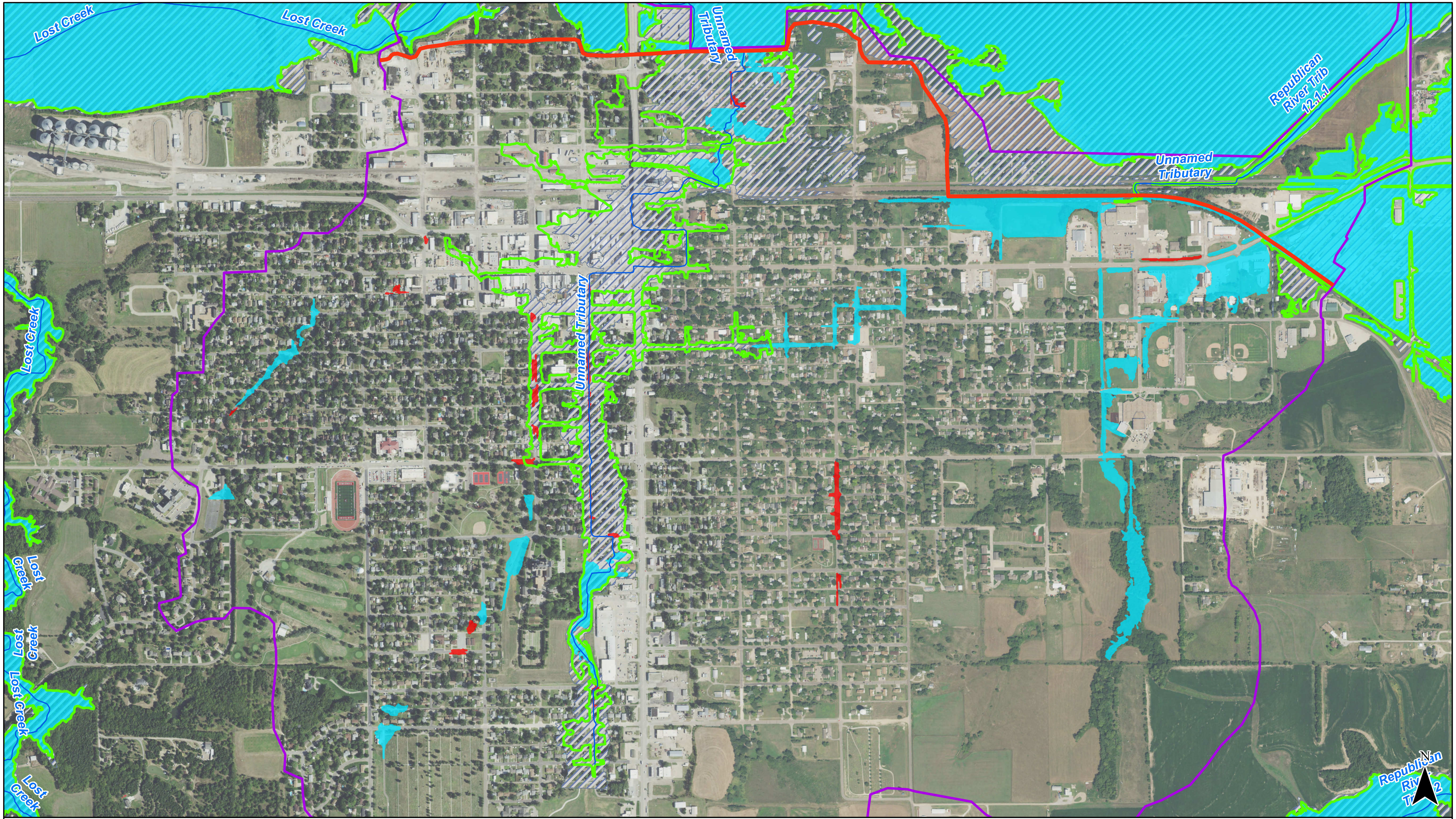

EXHIBIT 5: FLOOD SCENARIO RESULTS CONCORDIA, KANSAS

2D Model Extent
BLE Zone A
Effective Zone A
XPSWMM Zone A
XPSWMM - 1% Average Depths < 1 Ft.

0 875 1,750 3,500 Feet

1 inch = 875 feet

BLE Streams
XPSWMM-BLE Boundary

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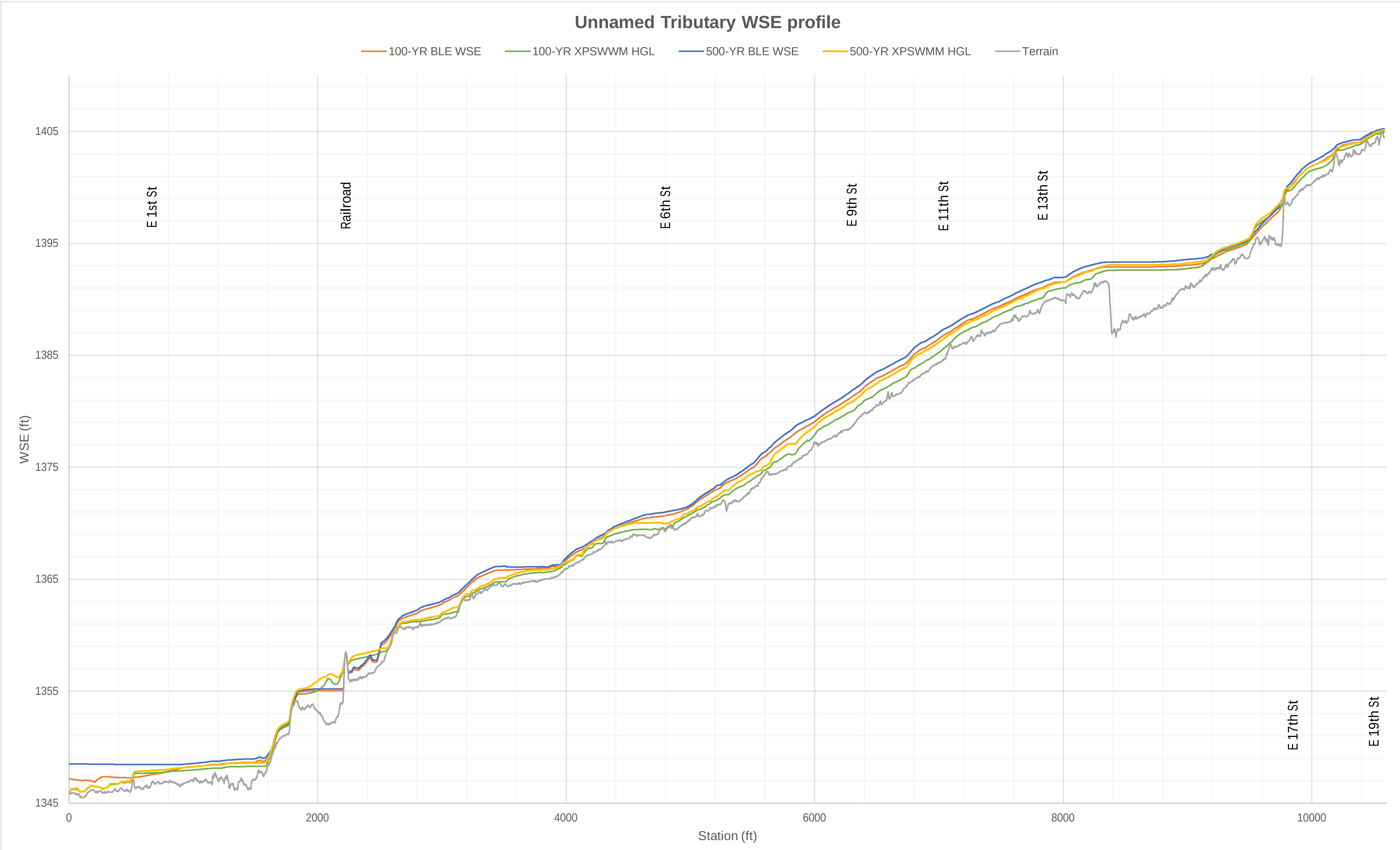

EXHIBIT 6: UNNAMED TRIBUTARY WSE PROFILE

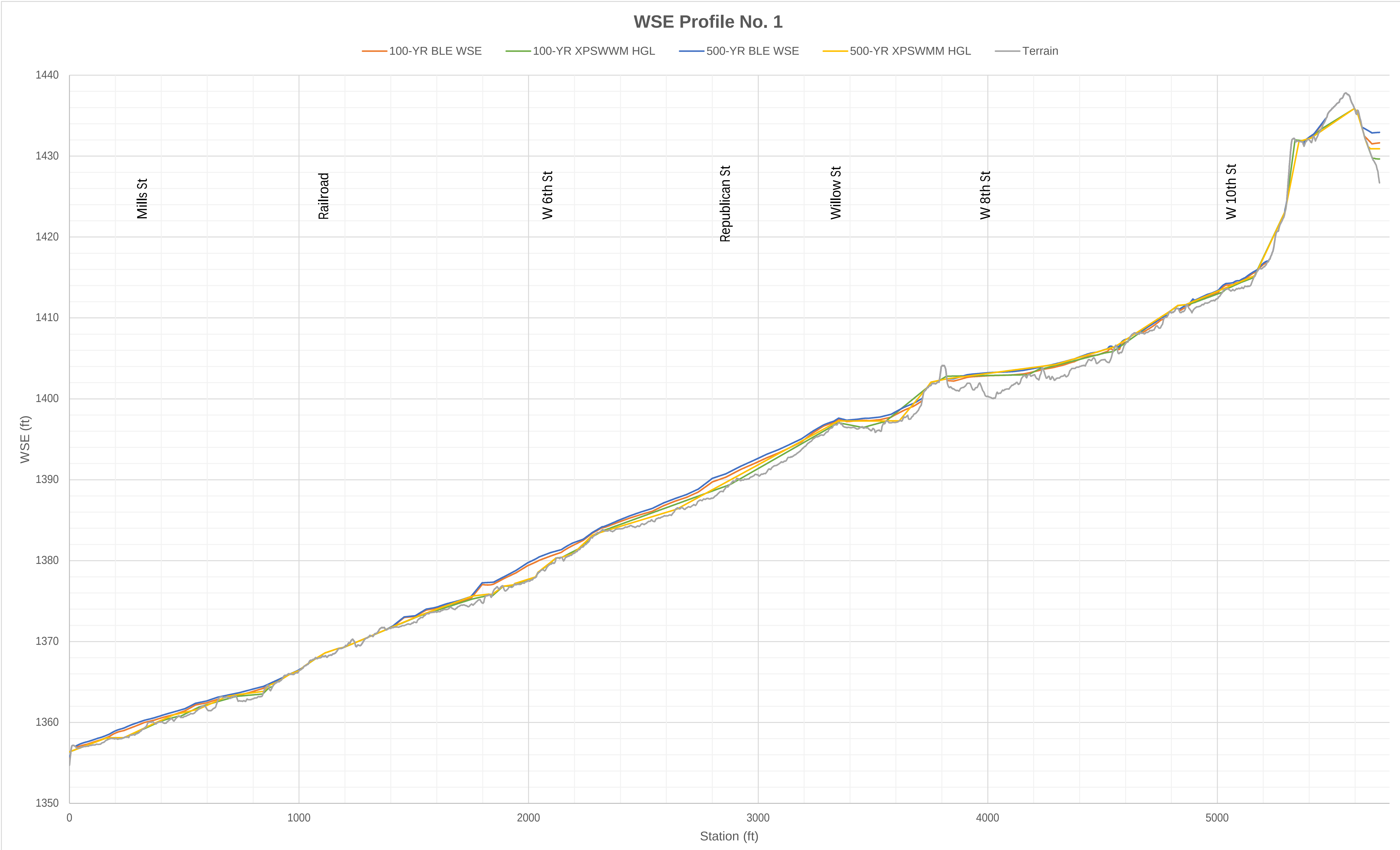

EXHIBIT 7: WSE PROFILE No. 1

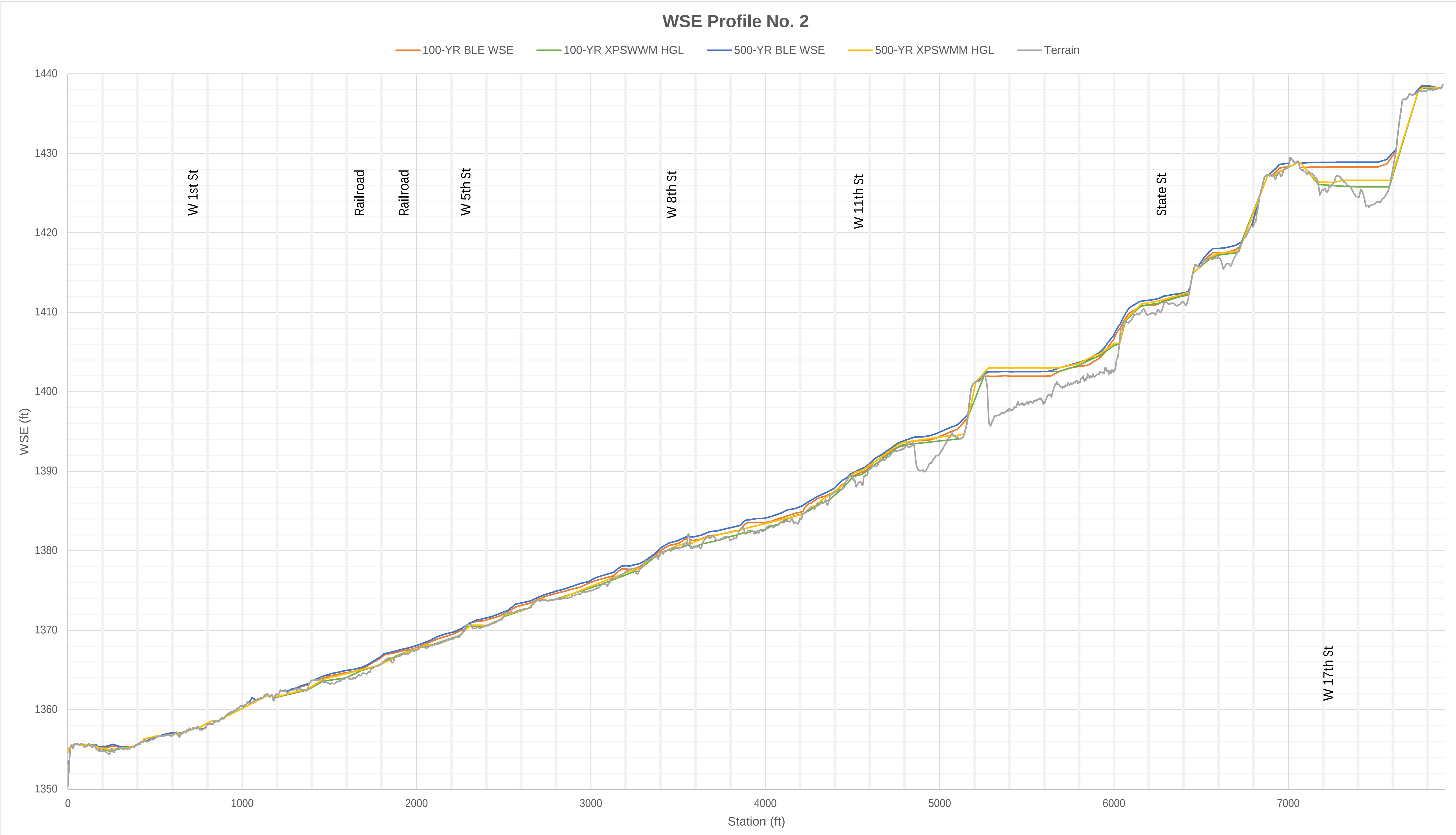

EXHIBIT 8: WSE PROFILE No. 2

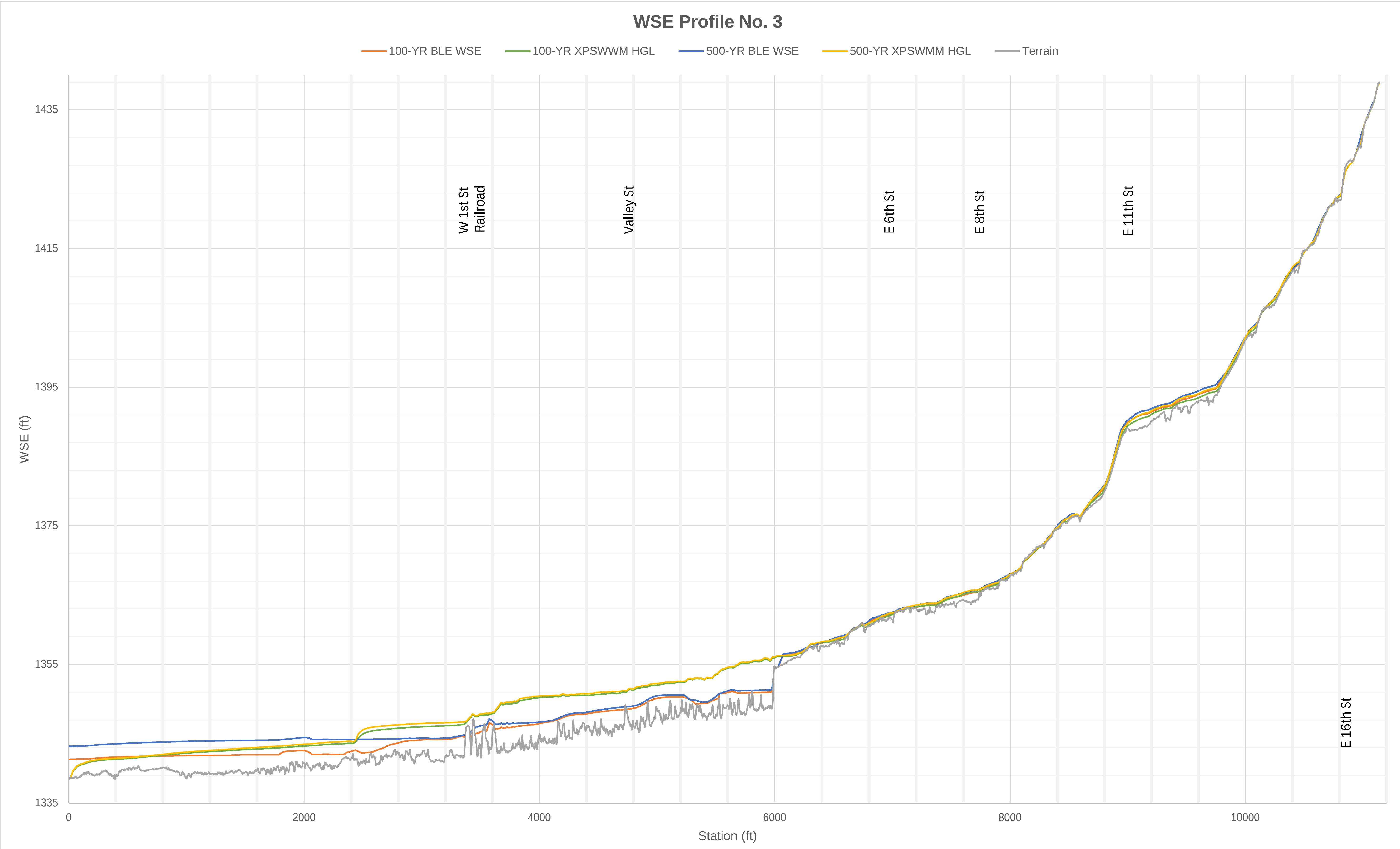

EXHIBIT 9: WSE PROFILE No. 3

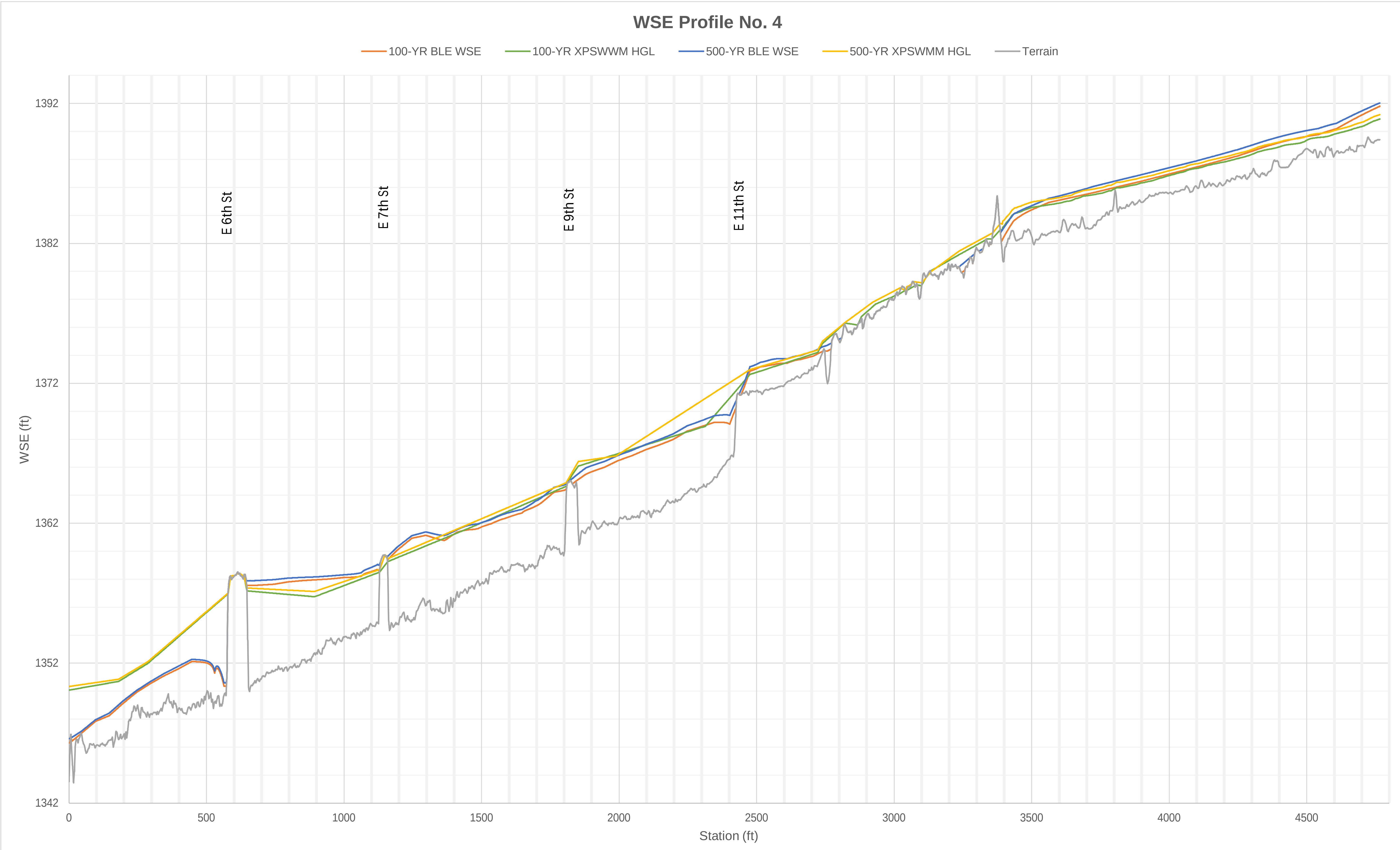

EXHIBIT 10: WSE PROFILE No. 4

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