Floodplains Technical Memorandum

PREPARED FOR: CDOT Region 1

COPY TO: FHWA CO Division

PREPARED BY: EA Team, Kyle Winslow, Ph.D., P.E., Lead Hydraulic Engineer (Jacobs)

DATE: March 2022

1.0 Introduction

Colorado Department of Transportation (CDOT) and the Federal Highway Administration (FHWA), in conjunction with local partners Adams County and Commerce City, are proposing improvements to 6 miles of Interstate 270 (I-270) in Adams County, Commerce City, and the City and County of Denver, Colorado, between Interstate 25 (I-25) and Interstate 70 (I-70). This technical memorandum presents the technical analysis, findings, and any applicable mitigation measures related to floodplain resources. Sections 1 and 2 of the EA, and EA Appendix A, contain the project setting and a detailed description of alternatives.

2.0 Regulatory Context

Floodplains are mapped and regulated by the Federal Emergency Management Agency (FEMA) through the National Flood Insurance Program (NFIP). NFIP regulations (44 Code of Federal Regulations [CFR] Sections 59, 60, 65, and 70) include limitations on project activities within floodplains and floodways and define processes to re-map flood hazard areas if a project does result in a change in base flood elevations that exceeds the pertinent flood hazard area thresholds. The relevant thresholds to the project are discussed in depth in Section 4.0, Existing Conditions, of this memorandum. Communities that participate in the NFIP must follow the federal regulations but also have the authority to enact local floodplain ordinances that may be more stringent than the NFIP regulations. Applicable legislation and regulations pertaining to flood hazards and floodplain management within the study area include the following:

- National Flood Insurance Act of 1968, as amended
- Flood Disaster Protection Act of 1973, as amended
- Executive Order (EO) 11988, Floodplain Management, 1977
- U.S. Department of Transportation (DOT) Order 2650.2, 1979
- FHWA Procedures for Coordinating Highway Encroachments of Floodplains with FEMA, 1982
- Rules and Regulations for Regulatory Floodplains in Colorado, Colorado Water Conservation Board: 2 Colorado Code of Regulations (CCR) 408-1

FEMA identifies floodplain boundaries on Flood Insurance Rate Maps (FIRM) and provides the supporting narratives and hydraulic analysis in Flood Insurance Studies. FIRM maps, and any subsequent FIRM revisions, are adopted by the local jurisdiction(s). Because the effective FIRM are adopted through local jurisdiction processes, they are considered the best available data for the purposes of evaluating a project’s potential impacts to the floodplain. Where discrepancies exist between the effective FIRM floodplain and updated hydraulic analysis, the Letter of Map Revision (LOMR) process is undertaken to update the effective FIRM maps for the relevant area.

2.1 Federal Regulations

Floodplains are defined by FEMA as "*Any land area susceptible to being inundated by flood waters from any source*" (44 CFR 59.1). The NFIP was established pursuant to the National Flood Insurance Act of 1968, as amended (42 U.S. Code [U.S.C.] 4001) and the Flood Disaster Protection Act of 1973, as amended (42 U.S.C. 4001), to encourage sound floodplain management programs at the state and local levels. To provide a national standard without regional discrimination, the 100-year flood has been adopted by FEMA as the "*flood having a one percent chance of being equaled or exceeded in any given year*" (44 CFR 59.1).

EO 11988, Floodplain Management (1977) requires agencies to avoid adverse impacts on floodplains, to the extent possible, and to avoid situations that would support floodplain development if a practicable alternative exists. In addition, the U.S. DOT Order 5650.2 describes policies and procedures for "*ensuring that proper consideration is given to avoidance and mitigation of adverse floodplain impacts in agency actions, planning programs and budget requests.*" The FEMA Regulations contain the basic policies and procedures of FEMA in regulating floodplain management and analyzing, identifying, and mapping floodplains.

2.2 State and Local Regulations

In Colorado, the Colorado Water Conservation Board coordinates the NFIP in cooperation at the county and municipal levels. Statewide floodplain regulations are identified in 2 CCR 408-1, Rules and Regulations for Regulatory Floodplains in Colorado. The project intersects three jurisdictions: unincorporated Adams County, the City of Commerce City, and the City and County of Denver. All three of these jurisdictions participate in the NFIP. Each NFIP participating community has a designated floodplain administrator whose main responsibility is overseeing the management of and development within the community's floodplains. The Mile High Flood District (MHFD) and local floodplain administrators oversee floodplain regulation for Adams County, City of Commerce City, and City and County of Denver. As detailed in Section 8 of this memorandum, coordination with MHFD occurred during scoping and will remain ongoing through the design and permitting phases of the project.

3.0 Methods

3.1 Data Gathering

The following information was gathered from FEMA's Map Service Center:

- FIRM panel numbers and PDFs of the applicable FIRM maps
- The Flood Insurance Study (FIS) for the study area, which contains the narrative that accompanies the FIRM maps
- GIS data (shapefiles) of the regulatory floodplain, floodway, and LOMR boundaries within the project vicinity
- U.S. Geological Survey 12-minute triangle maps to identify any levees that cross the study area

Maps based on GIS data have been developed to help visually synthesize floodplain boundaries that may intersect the proposed project facilities (Figure 1). Topographic data required for the hydraulic analysis have been obtained.

3.2 Analysis Approach

A floodplain comprises two major parts: the regulatory floodway and the area between the floodway and the limit of the floodplain. The floodway is the main channel of a watercourse that must be kept free of encroachment in order to discharge flood waters. Development within the floodway is prohibited by FEMA unless it can be shown that the development does not increase the height of flooding during a

100-year equivalent event. Development outside the floodway, but still within the floodplain, is permitted provided the development meets NFIP and local floodplain regulations.

Therefore, the analysis of potential floodplain impacts focuses on how the alternatives:

- Impact the base flood elevation. This analysis requires hydraulic modeling and coordination with hydraulic design staff.
- Ensure consistency with local floodplain ordinances, which may be more restrictive than FEMA floodplain regulations.
- Require additional coordination with FEMA to revise the floodplain if the project is not able to meet NFIP and local floodplain requirements.

3.3 Floodplains Study Area

The study area for floodplains consists of the temporary and permanent disturbance areas resulting from construction and operation of the Proposed Action. This area includes temporary impacts from equipment and raw material staging and needed work areas to construct the Proposed Action.

4.0 Existing Conditions

A flood zone is a geographic area that FEMA defines according to varying levels of flood risk. Several different flood zone types exist within the study area. An area designated as floodplain Zone AE, which is defined as an area with a 1 percent annual chance of flooding (referred to as the 100-year floodplain), is considered at high risk of flooding by FEMA. Zone AO designations represent areas of sheet flow and shallow flooding with depths ranging from 1 to 3 feet. A Zone A floodplain is an area likely to be inundated by a 100-year flooding event, but for which a detailed analysis has not been performed to identify the depth of flooding. A floodway is the channel of a river or other watercourse and the adjacent land areas that must be reserved to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height (FEMA 2018).

There are three major water features in the study area including the South Platte River, Sand Creek, and Clear Creek. The two flooding characteristics of the South Platte River and its tributaries, including Sand Creek and Clear Creek, are snow melt and strong summer weather fronts producing intense precipitation events. Major recorded floods have occurred on the South Platte River and its tributaries since 1844 in the Adams County area. During that period, more than ten of these major flood events have occurred on the South Platte River and three on Clear Creek (FEMA 2018). The South Platte River, Sand Creek, and Clear Creek all have mapped floodways and floodplains that parallel or intersect the study area (Figure 1).

4.1 Effective Floodplain Data

The current effective FIRM and FIS data for the study area extends across unincorporated Adams County, the City of Commerce City, and the City and County of Denver. Table 1 shows the current effective floodplain information within the study area.

Table 1. Effective FEMA Floodplain Data

Jurisdiction	FIS Number	FIRM Panel(s)	Panel Effective Date
Unincorporated Adams County	80881CV001D	08001C0604H	3/5/2007
City of Commerce City	80881CV001D	08001C0604H 08001C0612H 08001C0616H	3/5/2007
City and County of Denver	080046V001E	0800460092H	11/20/2013

Source: FEMA Map Service Center

Two LOMRs have been completed for Sand Creek and the South Platte River that removed most of the Suncor oil refinery from the floodplain (LOMR Case Numbers 10-08-1048P and 12-08-0512P). The LOMRs are reflected in the FEMA data shown on Figure 1. Early in the project's scoping phase, during preliminary examination of the effective FIRM maps, concerns with the extents of the floodways and floodplains of Sand Creek, Clear Creek, and the South Platte River were identified. The effective FIRM maps show I-270 being inundated by the 100-year flood at the I-76 interchange and where the South Platte River crosses I-270. In addition, the regulatory floodway is shown to inundate Sandcreek Drive for nearly its entire length and an approximate 300-foot stretch of the eastbound I-270 lanes near Commerce City's Wetland Park (Figure 1). Despite these FIRM boundaries and designations, CDOT's current maintenance staff anecdotally have not observed overtopping of I-270 or Sandcreek Drive during heavy precipitation events (Smith, pers. comm. 2021). Furthermore, no overtopping of I-270 is noted in the descriptions of major flood events along Sand Creek in the FIS.

Because of the suspected inaccuracies of the effective FIRM, and in accordance with CDOT's *Drainage Design Manual* (CDOT 2019), CDOT remodeled the existing floodplains for Sand Creek and the South Platte River in the study area using a more accurate SRH-2D hydraulic modeling process with supplemental topographic channel surveys. The hydraulic modeling completed for this project indicates that neither I-270 nor Sandcreek Drive would be inundated by the 100-year event because flood flows are contained by the gabion wall on the northern side of the floodway. Hydraulic modeling completed for the South Platte River shows one overtopping location of I-270, west of the South Platte River, during the 100-year flood event; however, this condition is predicated on simultaneous 100-year flows on both the South Platte River and Sand Creek. The peak flow analysis and low overtopping probability (less than 1 in 10,000) indicate a combined 100-year event is not likely. Floodplain levels are below the I-270 pavement elevation for scenarios where the 100-year- flow is assigned to one river and the 50-year- flow is assigned to the other. The complete hydraulic analysis performed for the project is included in the Hydraulic Analysis Addendum to the Floodplains Technical Memorandum, provided as Attachment 1 to this technical memorandum.

Although the hydraulic modeling performed for this project indicates the Sand Creek floodplain and floodway shown on the effective FIRM panels is inaccurate, FHWA procedures dictate "Where NFIP maps are available, their use is mandatory in determining whether a highway location alternative will include an encroachment on the base floodplain" (FHWA 1982). As a result, the effective FEMA floodplain data was used in the analysis for the purposes of determining potential floodplain impacts resulting from the Proposed Action. As detailed in Section 6 of this memorandum, a Conditional Letter of Map Revision (CLOMR)/LOMR will be initiated by CDOT in cooperation with the project partners to revise the effective FIRMs and remove I-270 from the floodplain. During stakeholder outreach conducted in January 2021, the project team met with MHFD and verified the preliminary hydraulic analysis findings that I-270 is not inundated by the 100-year event. These findings will be finalized through the CLOMR/LOMR process.

The effective floodplain relates to the project in the following areas.

Clear Creek: A Zone AE floodplain and floodway crosses I-270 just north of the I-76/I-270 interchange at milepost (MP) 0.9 of I-270. At this crossing, the floodway measures 500 feet wide and occupies the entire open space corridor that contains Clear Creek and the Clear Creek Trail. The floodplain extends beyond the floodway an additional 120 feet to the north. To the south, the floodway encroaches onto the westbound I-270 to westbound I-76 ramp. The floodplain extends an additional 400 feet beyond the floodway, encroaching on the westbound I-76 to eastbound I-270 ramp and portions of the westbound I-270 to westbound I-76 ramp.

Both the eastbound and westbound bridges that carry I-270 over Clear Creek are wide enough to accommodate the proposed roadway template and would remain in place. Similarly, the I-76 ramps where the floodway and floodplain encroach onto the roadway would not be impacted by the project. Because Clear Creek would be unimpacted by the project, it was not modeled as part of this analysis. The ramp encroachments of the Clear Creek floodway and floodplain are likely due to terrain elevation inaccuracies that were observed for Sand Creek and the South Platte River, which were modeled as part of this analysis. The floodplain boundary also fails to consider the existing detention pond in the infield area of the I-76 eastbound to I-270 eastbound ramp, which would likely eliminate the overtopping of I-270 in this area. Given the known inaccuracies in the adjacent Sand Creek and South Platte River FEMA floodplains and floodways, and the lack of consideration of flood detention features, there is low risk for the 100-year flow to overtop I-270 as shown in the effective FIRM map. Anecdotally, the current CDOT maintenance staff did not report any overtopping of I-270 anywhere along the corridor due to flooding.

Sand Creek: Flowing parallel to the eastbound I-270 lanes from the eastern limit of the project until it converges with the South Platte River and crosses I-270 at MP 0.9 of I-270, the mapped FEMA Sand Creek Zone AE floodway and floodplain encroaches on the study area nearly continuously from the I-270/Quebec Street interchange at MP 4.5 to its confluence with the South Platte River and subsequent crossing beneath I-270. Before it converges with the South Platte River, Sand Creek crosses over the Burlington Ditch. Like the South Platte River discussed in this section, a levee borders the western edge of the Burlington Ditch. The flood mapping in this area clearly shows that during the 100-year flood event, Sand Creek flows impact the Burlington Ditch (also referred to as the O'Brien Canal) and the levee creates a backwater flooding effect extending approximately 1,700 feet that encroaches into the CDOT right-of-way but does not encroach onto the lanes of I-270.

Immediately south of the I-270/Vasquez Boulevard interchange, Sandcreek Drive serves as a frontage road from East 56^{th} Avenue until it ends at Quebec Street. The mapped FEMA Sand Creek floodplain is shown as overtopping the Sandcreek Drive from its origin near the I-270/Vasquez Boulevard interchange extending approximately 1.4 miles to the southeast. The mapped FEMA Sand Creek floodway is shown to overtop the frontage road and extend into the I-270 eastbound travel lanes at MP 3.1.

A separate two-dimensional hydraulic analysis was performed as part of this project using SRH-2D. The results of the model show no floodplain impacts on the eastbound travel lanes of I-270.

South Platte River: Crossing the study area perpendicularly at MP 0.9 of I-270, the South Platte River exhibits a well-defined floodway contained by a levee on the west side of the river. Although it is shown to contain the floodway, a Zone AO (that is, sheet flow area) is identified behind the levees immediately adjacent to both travel directions of I-270. Floods along this portion of the South Platte River in 1965 and 1973 showed these levees to be ineffective against 1-percent-annual-chance floods (FEMA 2018). Because the stability of the levees is unknown, they are not certified U.S. Army Corps of Engineers levees. The Zone AE floodplain beneath I-270 where it crosses the South Platte River is shown to encroach on all four existing travel lanes on the western side of the bridges. Subsequent hydraulic modeling (see Attachment 1, Hydraulic Analysis Addendum to the Floodplains Technical Memorandum) shows inundation of the pavement has a rare chance of occurrence.

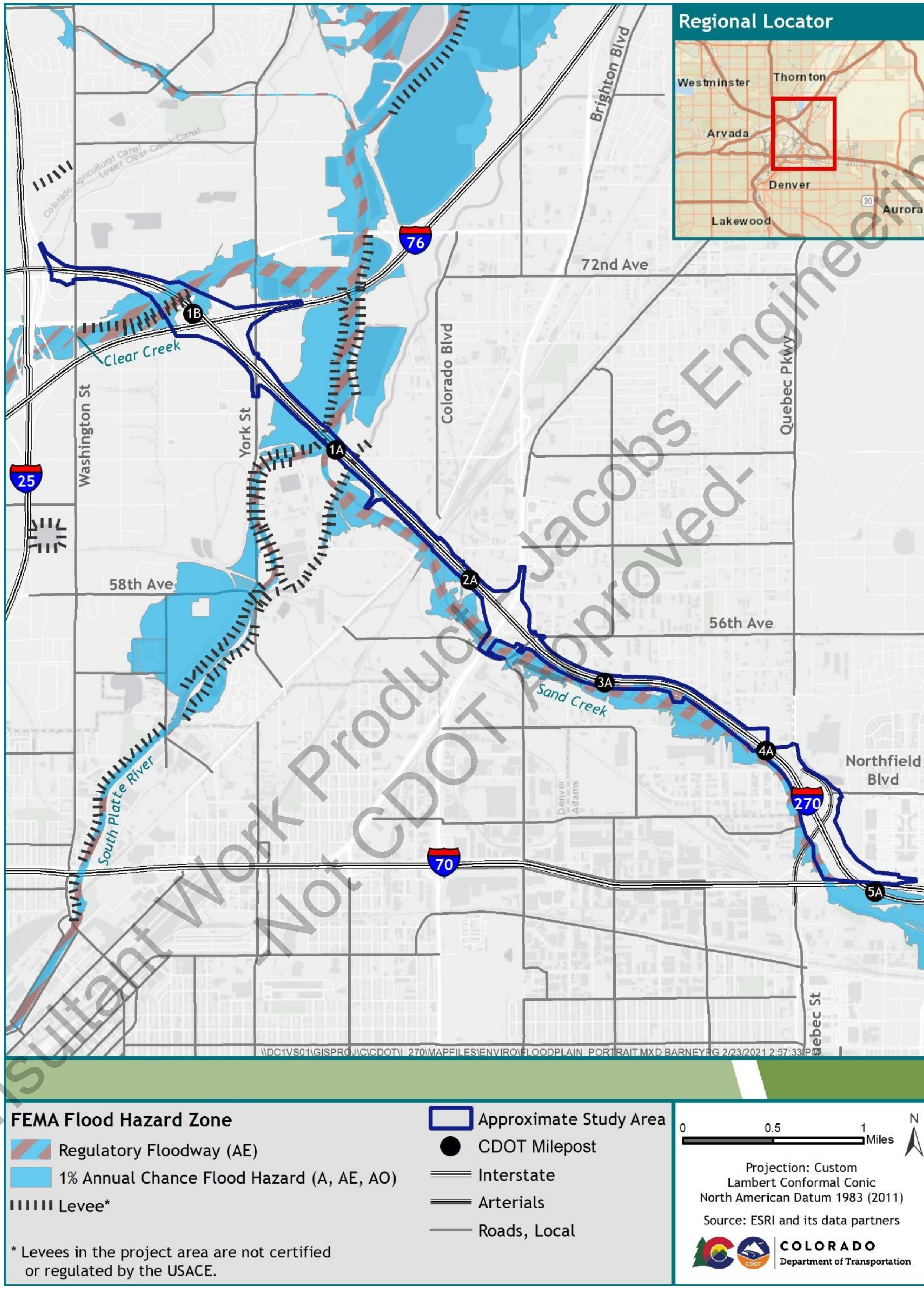

Figure 1. Existing Floodplains and Floodways

5.0 Impacts Assessment

CDOT's National Environmental Policy Act (NEPA) Manual (2020) identifies levels of significance for floodplain encroachments when determining impacts as part of the NEPA process. The following levels of significance are used when describing the impacts and related mitigation of the alternatives considered.

Significant Encroachment – May result in a high probability of loss of human life, will likely cause future damage that could be substantial in cost or extent (including interruption of service or loss of vital transportation facilities), or will cause a notable adverse impact on natural and beneficial floodplain services.

Minimal Encroachment – There is floodplain involvement, but the impacts on human life, transportation facilities, and natural and beneficial floodplain services are not significant and can be resolved with minimal efforts.

No Encroachment – There are floodplains near the proposed alternatives, but there is no floodplain encroachment.

No Involvement – There are no floodplains near the proposed alternatives.

5.1 No Action Alternative:

No measurable changes to floodplain resources in the study area are anticipated to occur under the No Action Alternative. If any or all of the projects included in the No Action Alternative were found to encroach on the floodway or floodplain, they would be subject to the same NFIP requirements that apply to the Proposed Action and which limit those floodplain impacts to minimal encroachments. Discrepancies in outdated FIRM mapping would need to be updated through the CLOMR/LOMR processes. Without updating the effective FIRM panels and FIS, the effective FIRM data will continue to reflect inaccurate floodway and floodplain boundaries.

5.2 Proposed Action:

According to the effective FEMA floodplain data, the Proposed Action would encroach on existing floodways and floodplains in the areas noted in Table 2.

Table 2. Proposed Action Impacts to Floodways and Floodplains

Flood Source	Flood Zone	Floodway (Y/N)	Area (acre)	I-270 Milepost[a]
Clear Creek	AE	N	7.1	0.8B
	AE	Y	1.5	0.8B
South Platte River	AE	N	1.2	1A
	AE	Y	0.7	1A
	AO	N	1.9	0.7A
Sand Creek	AE	N	6.8	3.2A
	AE	Y	14.5	2.7A-3.6A

Source: Jacobs

[a]Because I-270 was built in two major segments at different times, it has milepost subsets A and B. Subset A extends 1.3 miles from the I-25/US-36/I-270 interchange to the I-270/I-76 interchange, where it turns into milepost 0 of Subset B.

Most of the encroachment into the floodway and floodplain would occur from the widening of I-270 where it runs parallel to Sand Creek and along the west bank of the South Platte River where I-270 is widened before spanning across the river. After revising the floodplain through the CLOMR/LOMR process, the floodway and floodplain boundaries are anticipated to be contained within the channel banks during the 100-year event. Therefore, after mitigation, the Proposed Action would have minimal encroachment or no encroachment to any of the floodways or floodplains associated with Clear Creek, the South Platte River, and Sand Creek.

6.0 Mitigation Measures

Temporary and permanent impacts to floodplains could occur as a result of the Proposed Action. The recommended mitigation measures that will be implemented for the Proposed Action are summarized in Table 3.

Table 3. **Mitigation Measures**

Activity Triggering Mitigation	Location of Activity	Impact	Mitigation Commitment	Responsible Branch	Timing/Phase that Mitigation will be Implemented
Construction activities within the regulatory floodplain and floodway	Along Sand Creek and at the South Platte River Crossing of I-270	Temporary reduction in flood conveyance	Construction materials will not be stored in the floodplain, and construction activities (including trail detours) will be limited within the floodplain as feasible to reduce the potential impacts to the floodplain. A construction stormwater and a floodplain permit will be obtained from the City and County of Denver, Adams County, and Commerce City, if determined necessary.	CDOT Engineering and Contractor	Construction
Placement of fills within the regulatory floodplain and floodway	Along Sand Creek and at the South Platte River Crossing of I-270	Changes to the 100-year base flood elevation	CDOT will initiate with FEMA a CLOMR along Sand Creek and the South Platte River to conditionally update the effective FIS and FIRM panel data, followed by a LOMR to formalize the changes.	CDOT Engineering and Contractor	CLOMR/LOMR process will be concurrent with final design and construction

7.0 Required Permits

The following permits related to floodplains may be required as part of the proposed project.

- Floodplain development permit(s)
- CLOMR
- LOMR

CDOT will submit the CLOMR/LOMR and coordinate with Adams County, the City of Commerce City, the City and County of Denver to acquire any needed floodplain development permits.

8.0 Agency Coordination

Coordination with Adams County, the City of Commerce City, the City and County of Denver, MHFD, and FEMA began occurring early in the project's development during the scoping and stakeholder engagement beginning in summer 2020. In January 2021, CDOT met with MHFD to communicate preliminary hydraulic modeling findings and the project's approach to the CLOMR/LOMR process. MHFD, FEMA, and the floodplain administrators will continue engaging through the complete project lifecycle, including close coordination throughout the CLOMR/LOMR process as it continues in parallel with the NEPA process and final design.

9.0 References

Colorado Department of Transportation (CDOT). 2019. *Drainage Design Manual*. https://www.codot.gov/business/hydraulics/drainage-design-manual.

Colorado Department of Transportation (CDOT). 2020. *CDOT NEPA Manual.* Version 6. https://www.codot.gov/programs/environmental/nepa-program/nepa-manual.

Federal Emergency Management Agency (FEMA). 2018. *Flood Insurance Study: Adams County Colorado*.

Federal Highway Administration (FHWA). 1982. Procedures for Coordinating Highway Encroachments of Floodplains with FEMA. https://www.fhwa.dot.gov/engineering/hydraulics/policymemo/820625.pdf.

Smith, Shawn. Superintendent, Region 1, Section 5, Colorado Department of Transportation. 2021. Personal communication (email) with George Woolley, Jacobs. March 2.

Attachment 1
Hydraulic Analysis Addendum to the Floodplains Technical Memorandum

Hydraulic Analysis Addendum to the Floodplains Technical Memorandum

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1.0 Two-Dimensional Floodplain Analysis for Sand Creek

1.1 Description of SRH-2D and its Running Platform

The U.S. Bureau of Reclamation's SRH-2D hydraulic model was used to analyze the hydraulic conditions of Sand Creek along the Interstate 270 (I-270) Corridor and to determine the extents of the 100-year floodplain. Additionally, the model was run to confirm that the 100-year floodplain does not currently encroach onto the I-270 travel lanes. SRH-2D is a nonproprietary, two-dimensional (2D) model, allowing for discretization of the study reach laterally across the river channel and floodplain, as well as longitudinally down the river channel. SRH-2D is run through a custom interface within Surface-water Modeling System, which offers a way to set model parameters and a graphical user interface to run the model and visualize the results.

Results presented in this technical memorandum reflect initial modeling to investigate the validity of Federal Emergency Management Agency (FEMA) maps showing encroachment of the 100-year floodplain onto I-270. The initial model is bounded by Vasquez Boulevard on the west and Quebec Street on the east (upstream). Supplemental modeling analyses include an enlarged model domain for Sand Creek to the confluence with the South Platte River and portions of the South Platte River and are described in Section 2. Details will be added where necessary to support the potential redesign of several bridges in the project reach, including the bridges over the South Platte River and Vasquez Boulevard.

A simulation was conducted for the 100-year flood event with a peak flow of 30,000 cubic feet per second (cfs) based on the 1977 Sand Creek Flood Hazard Area Delineation report prepared by the Urban Drainage and Flood Control District. Model friction was set at a Manning's n value of 0.05 in the channel. The average slope of the channel was 0.0012 foot per foot (ft/ft) between Vasquez Boulevard and the lower drop structure, and 0.0023 ft/ft between the two large concrete drop structures included in the initial model domain (Figure 1). The bed elevation drops 60 feet from 5,220 to 5,260 over the 12,000-foot model reach, for an average slope of 0.005 ft/ft.

Model results are presented in Table 1 and as plan view contour maps of key model parameters throughout the model domain, including water velocity, bed shear, and flow depth.

1.2 Extents of Study

The initial existing conditions model simulations were conducted with a model grid extending approximately 12,000 feet from Vasquez Boulevard to Quebec Street to focus on validation of the FEMA flood maps that show the floodplain encroaching over Sandcreek Drive and onto the eastbound lanes of

I-270. Overpasses in the initial model domain include bridges at Vasquez Boulevard, East 56th Avenue, East 49th Avenue, East 47th Avenue, and Quebec Street (State Highway 35).

There are two large concrete drop structures between East 56th Street and East 49th Street. The downstream structure is approximately 4,000 feet upstream (east) of Vasquez Boulevard, and the upstream structure is approximately 1,500 feet east of the downstream structure. The model geometry accounts for the elevations of these structures, based on the digital elevation model (DEM) and supplemental ground surveys obtained and used to specify local ground elevations. Ground elevations were extracted from the DEM at sections shown on Figure 1 to demonstrate the size of the drops. Elevation transects on Figure 2 show that the downstream drop structure drops approx. 12.3 feet while the upstream structure drops approximately 7.2 feet.

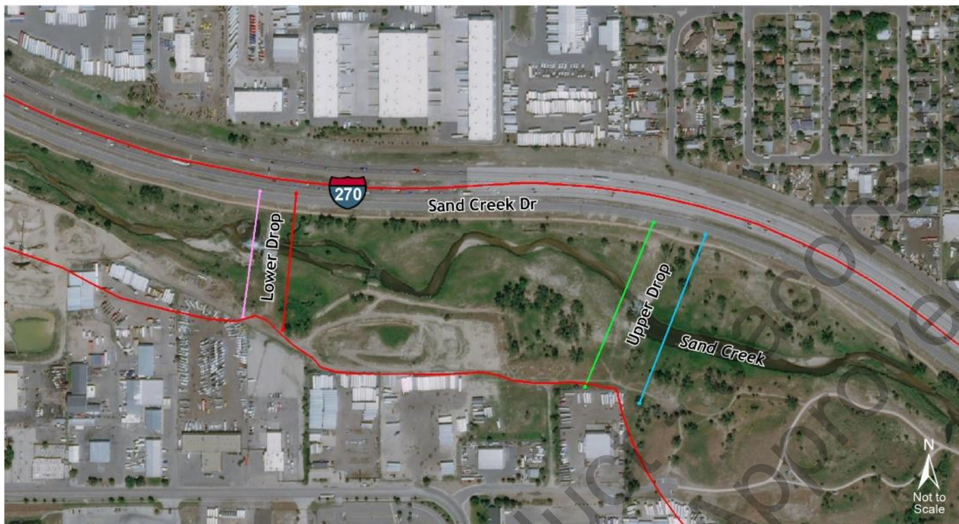

Figure 1. Location of Transects near Concrete Drop Structures on Sand Creek
Source: Jacobs

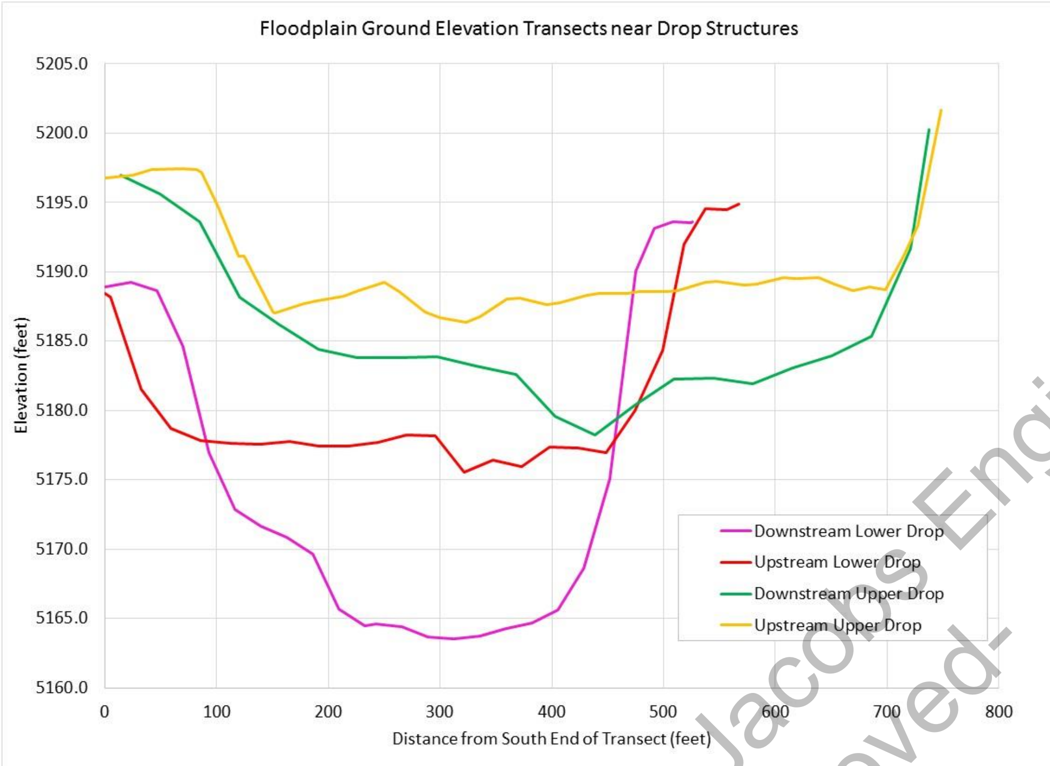

Figure 2. Ground Elevation Transects above and below Two Concrete Drop Structures
Source: Jacobs

There is a small pedestrian bridge (Colorado Front Range Trail) that crosses over the low flow channel of Sand Creek upstream of the upper drop structure. This bridge is inundated during the 100-year simulation and was not included in the model. Figure 3 shows the model elevations and grid extent for the initial floodplain model.

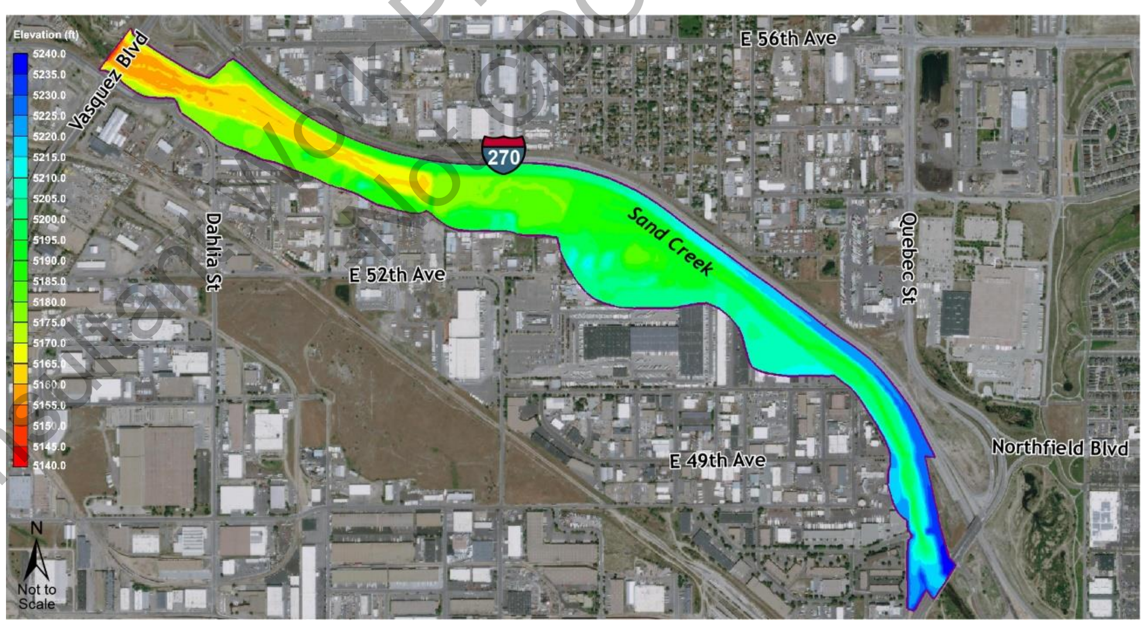

Figure 3. Sand Creek Model Elevations in Feet
Source: Jacobs

1.3 Surveyed Features

Based on the initial focus area in the reach between Vasquez Boulevard and East 49th Street, it was decided not to include bridge pier structures in the initial model. The downstream drop structure 4,000 feet above Vasquez Boulevard, with an elevation drop of over 12 feet, acts as a local downstream stage control during the 100-year flow event, and thus bridge structures at Vasquez and East 56th Street would have no impact on water surface elevations upstream of the lower drop structure. Bridge structures (piers, walls) in their ultimate configuration will be added to subsequent versions of the hydraulic model.

1.4 Assumptions Made

Several simplifying assumptions were made in the initial model because of the focus on the lateral extent of the predicted floodplain relative to the FEMA maps that show encroachment onto I-270. These assumptions include no bridge piers and a uniform conservative friction coefficient of 0.05. Sensitivity studies were run with smaller friction coefficients and the use of 0.05 instead of 0.03 raises the water surface by an average of 2.0 feet over the 12,000-foot-long model reach. The higher friction value was retained to add a level of conservatism to the model predictions.

1.5 Results

Model results with the 100-year flow of 30,000 cfs at Quebec Street show no inundation of Sandcreek Drive or I-270. In the current model, flood flows are contained by the gabion wall on the north side of the floodway. The FEMA model predates construction of the gabion wall. Figure 4 shows local water depths for the 100-year flow simulation. The light purple outline shows the extent of the model grid.

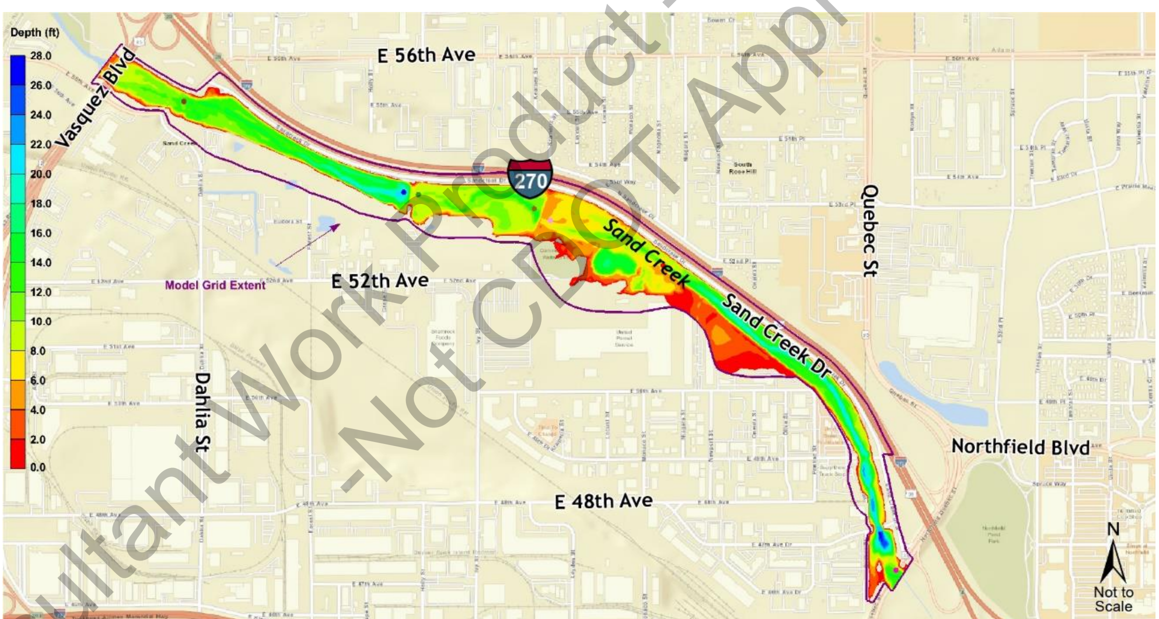

Figure 4. Flow Depths and Floodplain Extents for 100-year Flow Simulation with n = 0.05
(Initial model bounded by Vasquez Boulevard and Quebec Street)
Source: Jacobs

Figure 5 and Figure 6 present an overlay of the FEMA flood zone boundaries and the model results with a conservatively high friction coefficient of 0.05. Note that the color contours showing the modeled flood extent do not spread as far laterally as the FEMA flood zone boundaries shown in blue and blue/pink stripes. The light-blue polygon is the FEMA 100-year floodplain, and the blue/pink hatched polygon is the regulatory floodway. Figure 6 focuses on the area where the FEMA flood zones encroach onto I-270. This is upstream of the lower drop structure. The northern extent of the modeled floodplain generally coincides with the rock gabion wall just north of the paved multi-use trail.

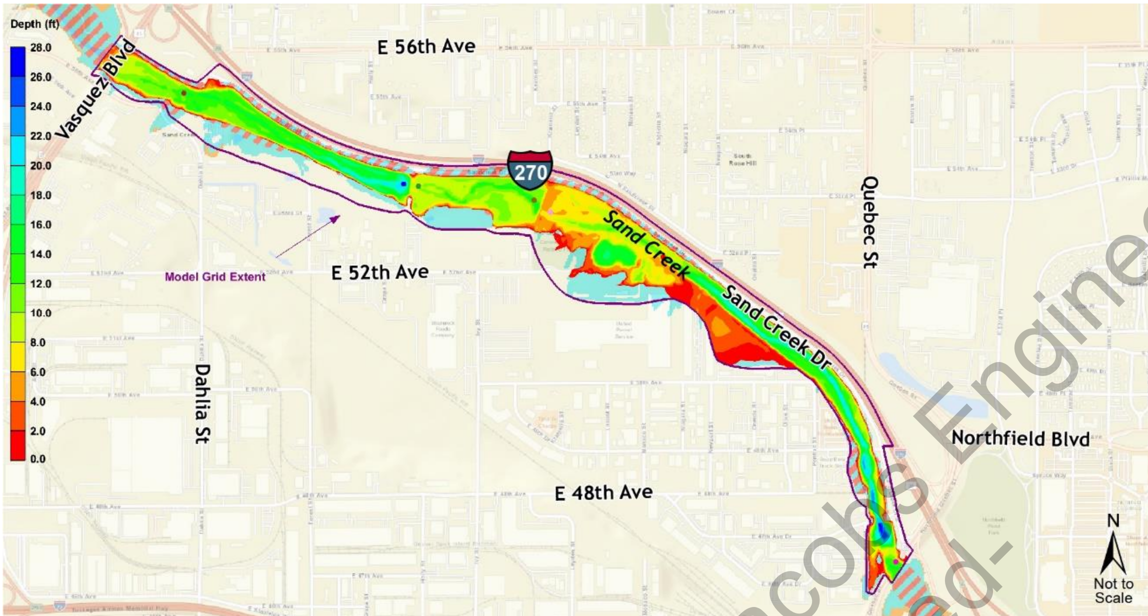

Figure 5. Overlay of Model Flow Depths with FEMA Flood Zones
Source: Jacobs

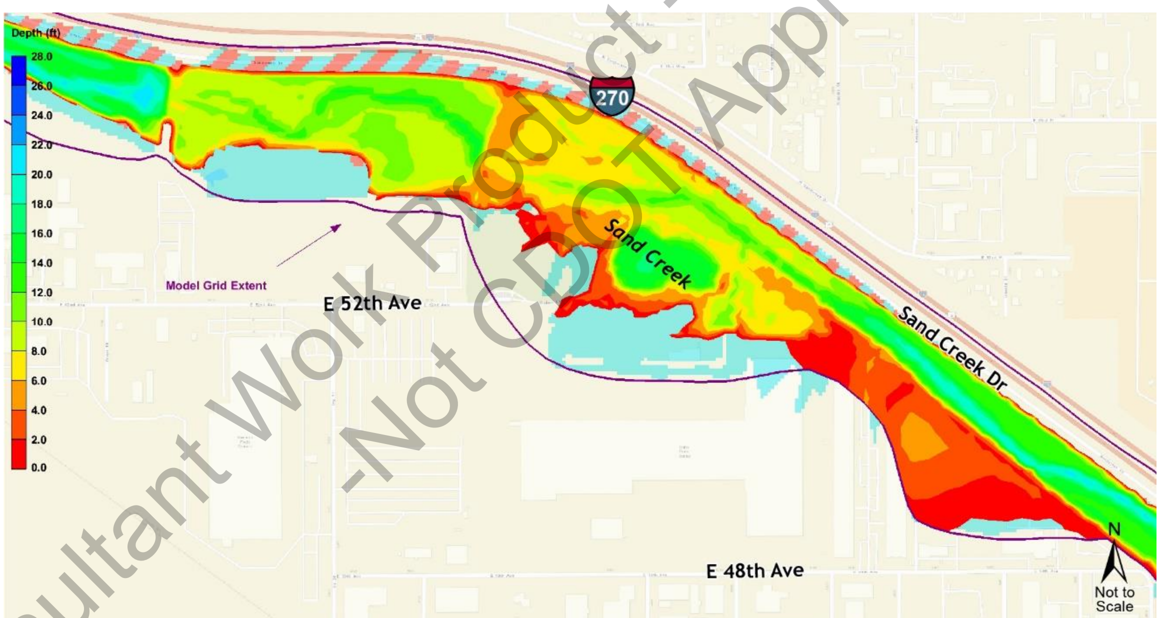

Figure 6. FEMA Flood Zones encroaching into Sandcreek Drive South and I-270
Source: Jacobs

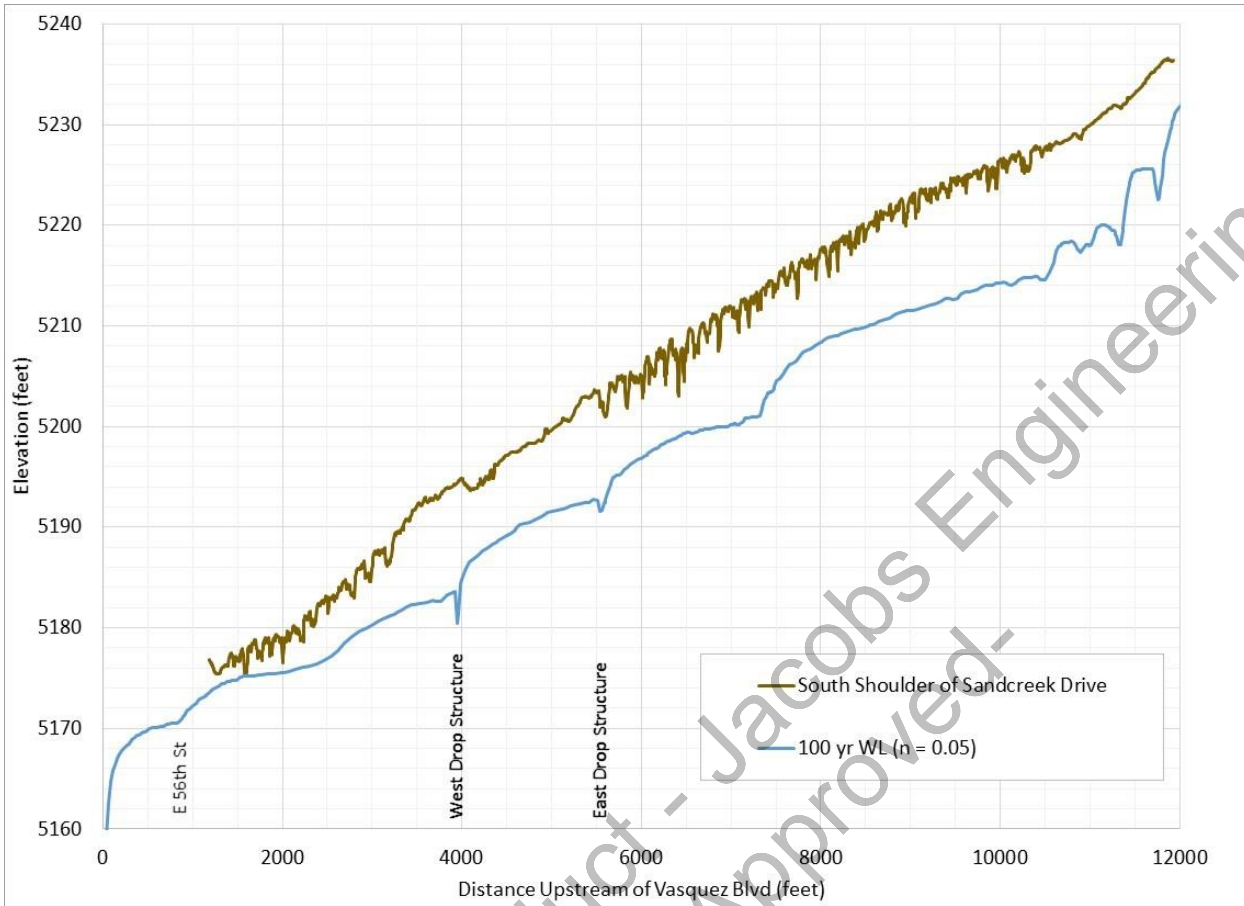

Figure 7. Longitudinal Profiles of Water Surface Elevation and Local Ground Elevations along Northern Border of Floodplain

Source: Jacobs

Figure 7 shows water surface elevations for the 100-year flow simulation relative to the ground elevation along the south shoulder of Sandcreek Drive South indicating that the predicted floodplain does not extend on to Sandcreek Drive South or I-270, which is just north and at a higher elevation. The resolution of the DEM is responsible for the noise in the elevation transect of Sandcreek Drive South. The average vertical clearance between the projected local maximum water level and the south shoulder of Sandcreek Drive South is 8 to 10 feet through the region (between 4,000 and 5,500 feet upstream of Vasquez Boulevard) where the FEMA maps indicate encroachment of the floodplain onto Sandcreek Drive South and I-270. The only location where the projected maximum water surface elevation approaches the south shoulder of Sandcreek Drive South is near the Dahlia trailhead at the intersection of East 56th Street and Sandcreek Drive South.

1.6 Bed Shear and Velocity

Figure 8 shows the predicted bed shear in the initial model domain for the 100-year flow simulation. Bed shear along the channel centerline averages under 4 pounds per square foot (lb/sq ft) with spikes above 6 lb/sq ft over the drop structures. The median bed shear is approximately 3 lb/sq ft.

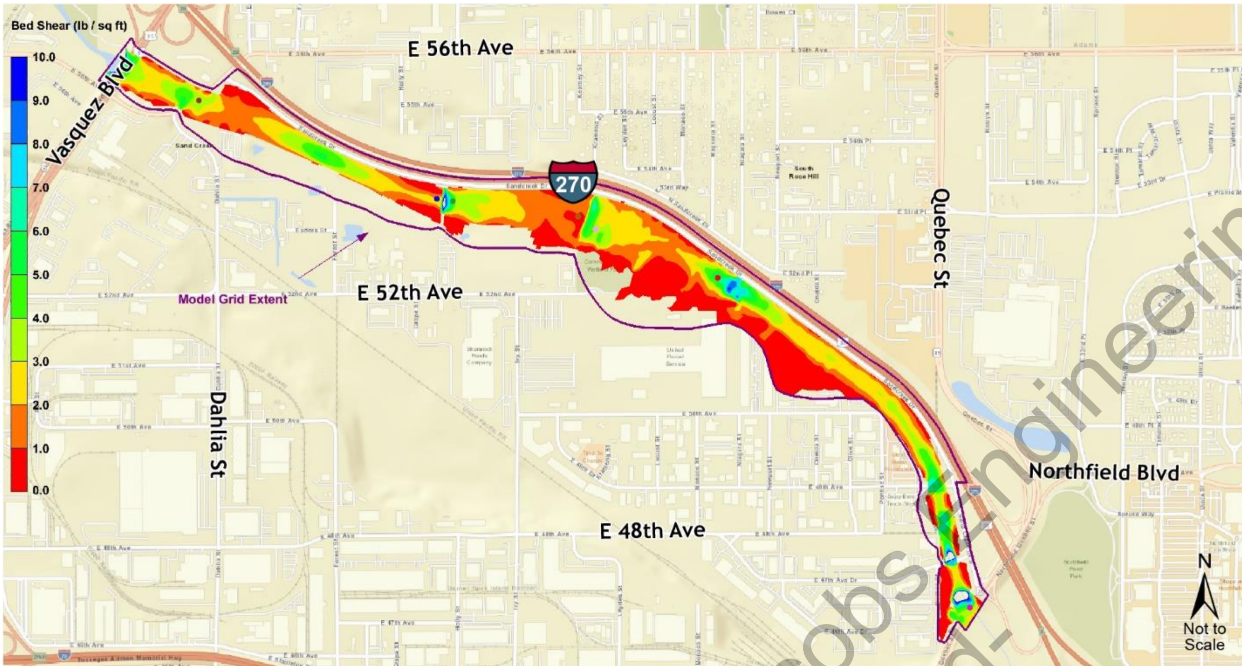

Figure 8. Bed Shear Stress for 100-year Flow of 30,000 cfs
Source: Jacobs

Figure 9 shows the modeled velocity at a steady flow of 30,000 cfs. Peak velocities near the drop structures range from 10 to over 25 feet per second (ft/sec). Average floodplain velocities are 11 ft/sec taken over a longitudinal transect down the channel centerline. In the downstream third of the model domain, velocities are higher than average because of the reduced floodplain width.

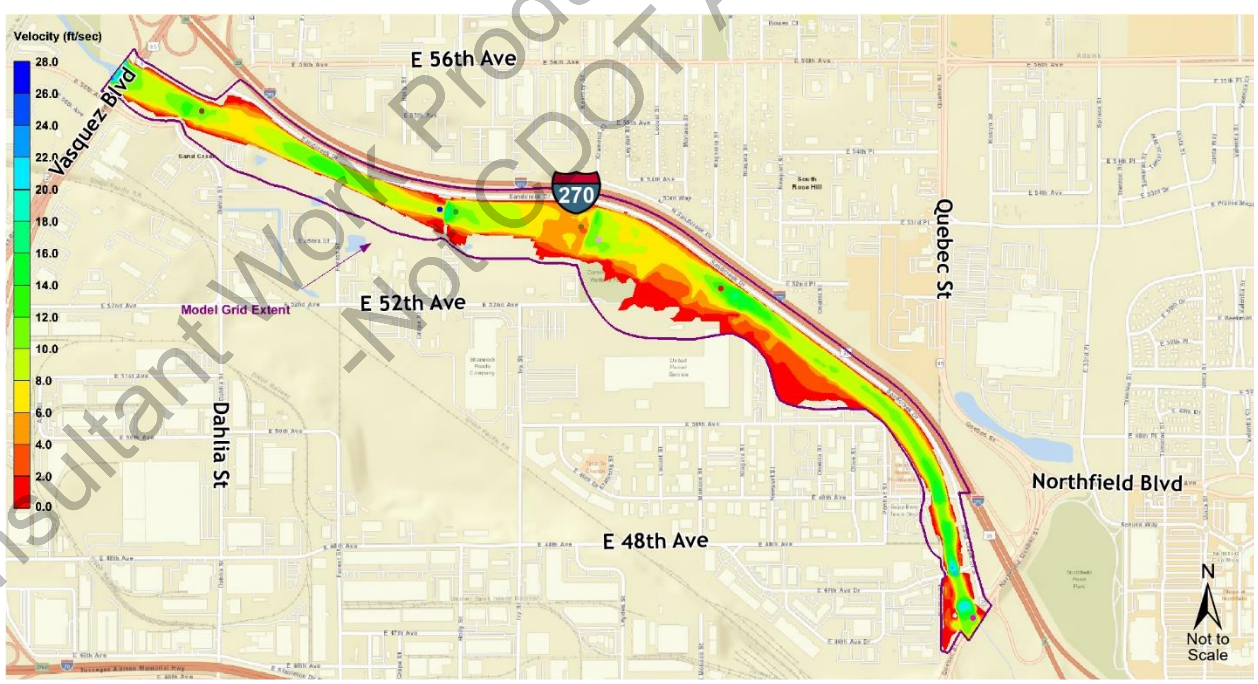

Figure 9. Velocity for 100-year Flow of 30,000 cfs
Source: Jacobs

Table 1 summarizes model predictions for average water surface elevations and average velocities at 10 key bridges and structures in the model domain. Results are presented for the baseline case with a conservative upper bound Manning's friction coefficient of 0.05 to maximize stage as well as a lower bound on the friction coefficient (0.03) to maximize velocity. Data reflect point results at the given sections along the channel centerline.

Table 1. Summary of Model Predictions for Average Water Surface Elevation and Average Velocities at Key Locations in Model Domain

Location	n = 0.05 WS Elevation (ft)	n = 0.05 Velocity ft/sec	n = 0.03 WS Elevation (ft)	n = 0.03 Velocity ft/sec
Vasquez Boulevard	5,166.1	13.6	5,165.4	15.0
East 56th Street	5,172.5	10.9	5,170.7	13.0
DS 1st Drop	5,183.4	9.0	5,180.3	11.8
US 1st Drop	5,186.0	12.3	5,184.9	14.4
DS 2nd Drop	5,192.6	4.5	5,190.7	4.2
US 2nd Drop	5,194.1	9.9	5,193.0	12.0
Pedestrian Bridge	5,200.7	13.2	5,198.8	18.8
East 49th Street	5,215.4	15.8	5,212.4	19.8
East 47th Street	5,222.9	16.1	5,222.2	16.9
Quebec Street	5,230.7	11.9	5,229.9	12.6

Source: Jacobs

DS = downstream
US = upstream
WS = water surface

2.0 Two-Dimensional Floodplain Analysis for Lower Sand Creek and South Platter River Confluence Area

2.1 Extension of Downstream Model Boundary for South Platte Analysis

The SRH-2D hydraulic model was extended from the initial downstream location at Vasquez Boulevard to I-76 in order to compare the predicted 100-year floodplain extents near the Sand Creek/South Platte confluence to those in the FEMA Flood Insurance Study (FIS), as well as investigate the influence of various combinations of boundary inflows on predicted overtopping of I-270 west of the South Platte River.

2.2 Extended Model Details

The new model boundary is at I-76. The model grid was developed in a consistent fashion with the upstream portion of the Sand Creek model presented above. The elevations interpolated to the model grid were from a combination of project-specific site surveys, including in-channel surveys, and publicly available terrain data obtained directly from the modeling software (level 15 resolution). Figure 10 presents the ground elevations used in the model grid downstream of Vasquez Boulevard. The narrow, shallow, low flow channel is well represented in the model geometry.

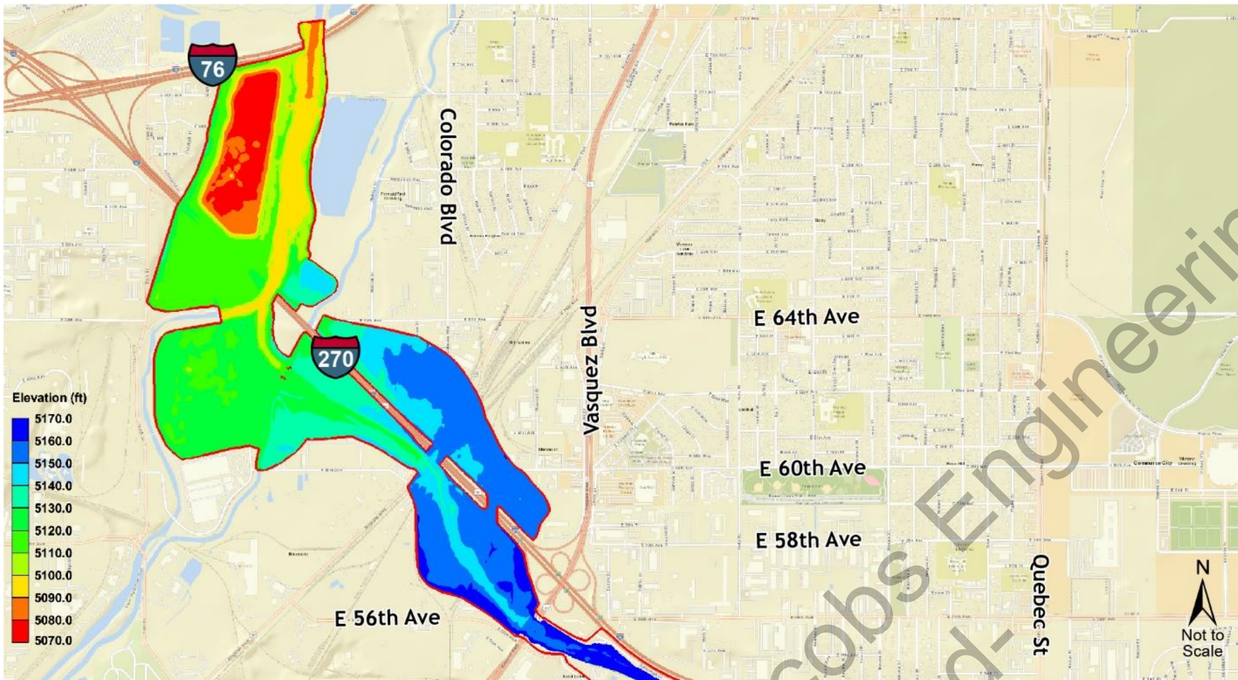

Figure 10. Model Ground Elevations in feet
Source: Jacobs

2.3 Model Structures

There are several engineered structures on Sand Creek downstream of Vasquez Boulevard, including multiple bridges and drop structures. From upstream to downstream, these features include the following:

- Four railroad bridges between Vasquez Boulevard and Brighton Boulevard
- Brighton Boulevard
- Sheet pile drop structure west of Brighton Boulevard
- Four riprap drop structures between Brighton Boulevard and Burlington Ditch
- Large weir/drop structure at Burlington Ditch
- Two riprap drop structures between Burlington Ditch and confluence with South Platte River
- Bike Path bridge over the South Platte River (parallel to I-270)
- I-270 Bridges over the South Platte River
- I-76 Bridges over the South Platte River

Individual flow obstructions are not currently included in the 2D model. The conservative channel friction specification is considered an adequate approach for this simple comparison between the FEMA floodplain and that produced by the more detailed 2D model.

2.4 Assumptions Made

The simplifying assumptions presented in Section 1.4 for the initial model upstream of Vasquez Boulevard were generally retained for the extended model. The bridge piers are not explicitly included in the model geometry. A relatively high friction coefficient was used (n=0.05) to account for additional losses at structures and provide a conservative estimate of peak water surface elevations.

In the initial model, the downstream boundary was placed just downstream of Vasquez Boulevard. The extended model had a downstream stage boundary conditions at I-76. No rating curve information was available at this location, so the stage was set at 5100 feet elevation for all flood simulations. The channel slope is steep in this reach and the model results are not very sensitive to the downstream stage specification for the range of flows investigated.

2.5 Results

Model results are presented in a series of figures in this section reflecting the 100-year flow on Sand Creek of 30,000 cfs at Quebec Street and the 100-year flow on the South Platte River of 22,300 cfs. This is a conservative assumption, having both rivers at the 100-year flow level. Additional simulations with other combinations of return interval events are discussed in this section.

Figure 11 shows the local water depths for the 100-year flow simulation. The red outline shows the extent of the model grid.

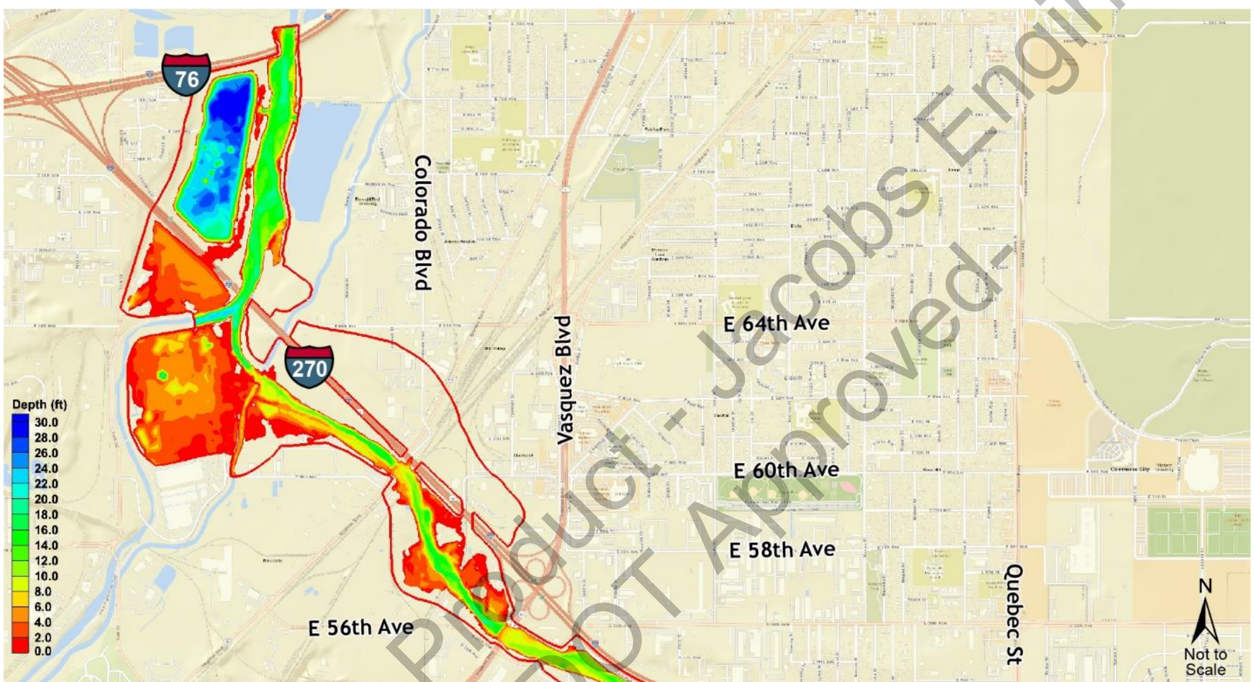

Figure 11. Flow Depths and Floodplain Extents for 100-year Flow Simulation with n = 0.05
Source: Jacobs

Figure 12 presents an overlay of the FEMA flood zone boundaries and the model predicted inundation boundary for the conservative 100-year flow applied at both inflow boundaries. The light blue polygon is the FEMA 100-year floodplain and the blue/pink hatched polygon is the regulatory floodway. The orange polygon is the FEMA 500-year floodplain. Figure 13 through Figure 15 provide detailed comparisons between model predicted inundation extents and the FEMA floodplain designations.

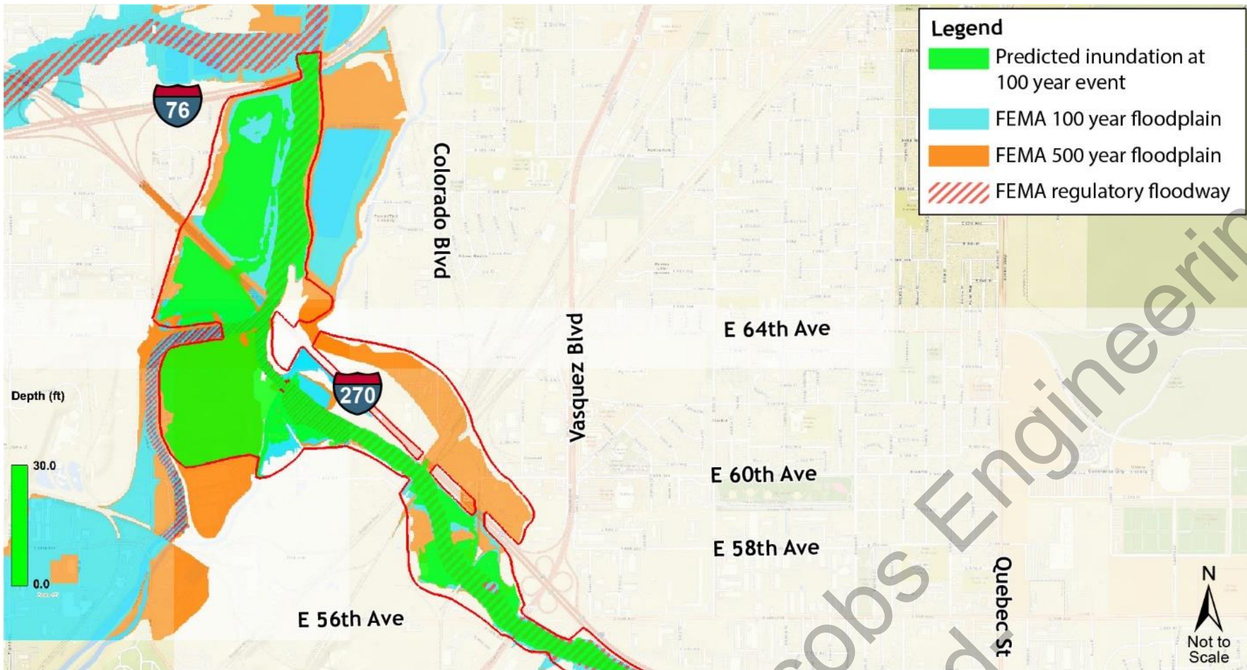

Figure 12. Overlay of Model Inundation Extents with FEMA Flood Zones
Source: Jacobs

Figure 13 presents an overlay of the FEMA flood zone boundaries and the model predicted inundation between Vasquez Boulevard and Brighton Boulevard. In general, the FEMA 100-year floodplain is slightly larger than that predicted by the model, but agreement is generally good between the two.

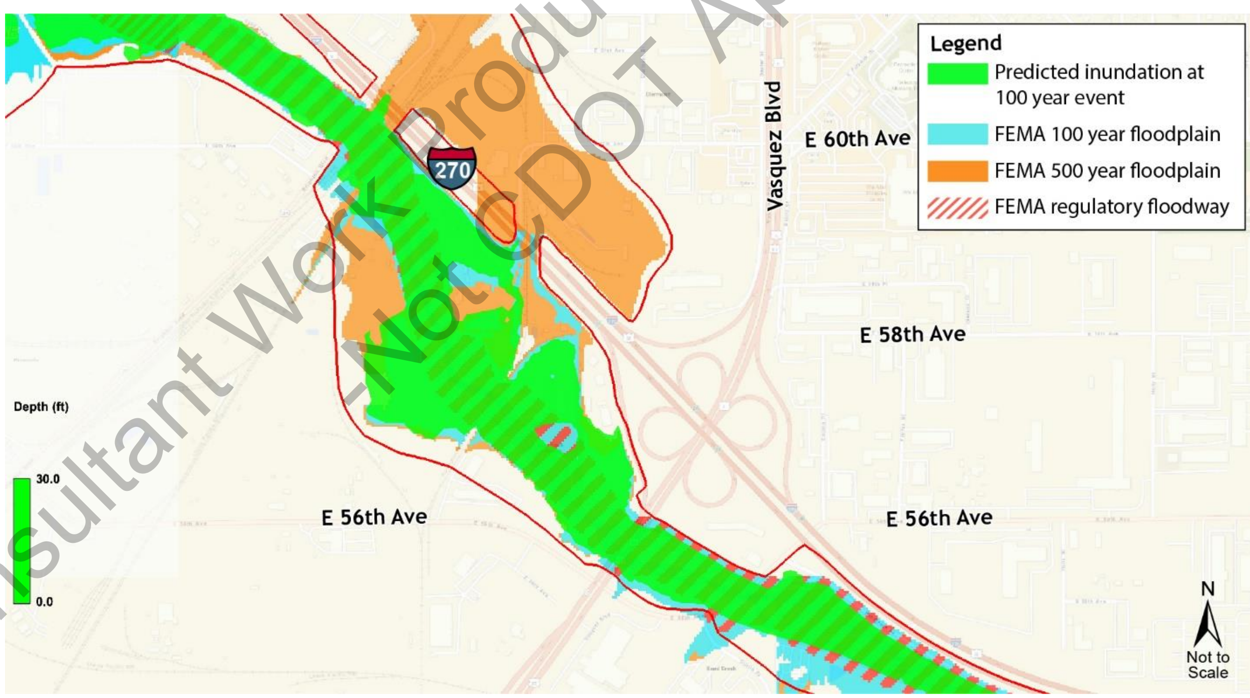

Figure 13. Overlay of Model Inundation Extents between Vasquez Boulevard and Brighton Boulevard with FEMA Flood Zones
Source: Jacobs

There are four railroad bridges between Vasquez Boulevard and Brighton Boulevard, which could explain the SRH-2D model predicting a smaller floodplain, as the rough model does not explicitly include the railroad trestle structures and their impacts on flow. Neither the SRH-2D model nor the FEMA FIS predicts encroachment of the 100-year floodplain onto I-270 in this reach.

Figure 14 presents an overlay of the FEMA flood zone boundaries and the model predicted inundation between Brighton Boulevard and the confluence with the South Platte River. There are four riprap drop structures downstream of Brighton Boulevard and upstream of the weir over the Burlington Ditch inverted siphon. Model results show good agreement with the FEMA 100-year floodplain between Brighton Boulevard and the Burlington Ditch. The FEMA 100-year floodplain is slightly larger just upstream of the Burlington Ditch.

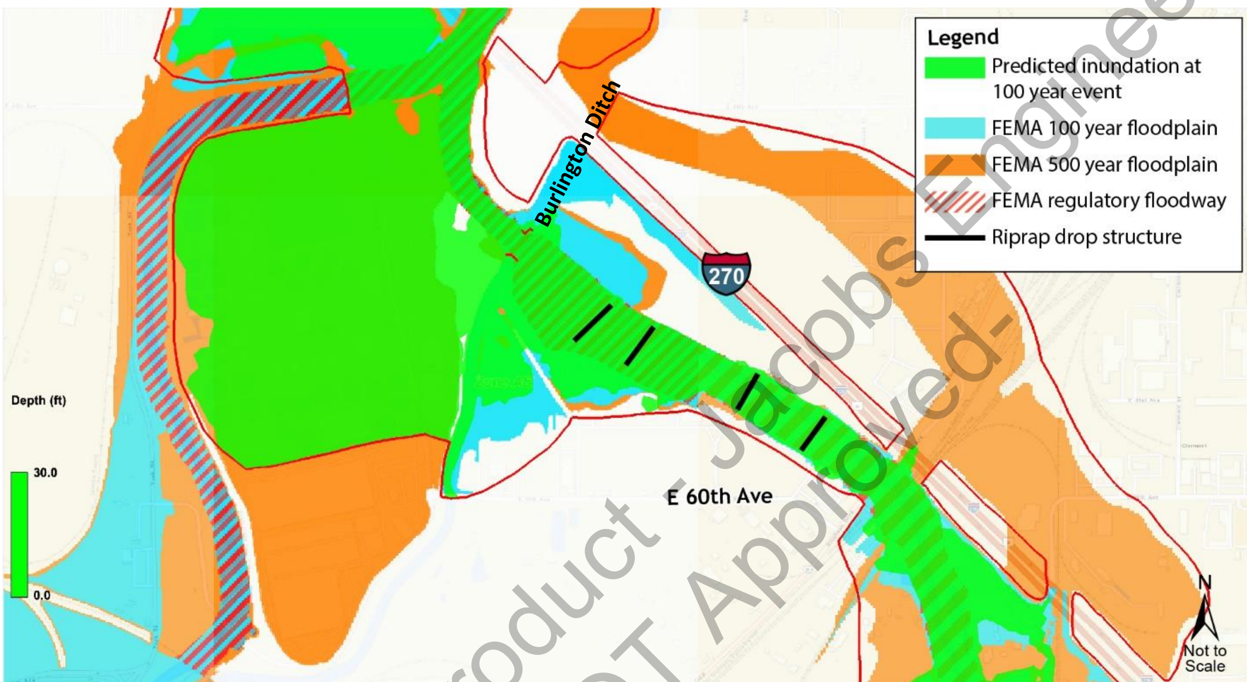

Figure 14. Overlay of Model Inundation Extents between Brighton Boulevard and South Platte River Confluence with FEMA Flood Zones
Source: Jacobs

Downstream of the Burlington Ditch and upstream of the South Platte River, the FEMA 100-year floodplain is confined to the main channel. The large area on the left bank of Sand Creek between the confluence and the Burlington Ditch is only inundated in the 500-year event according to the FEMA FIS. The SRH-2D model, however, shows inundation of this area during the 100-year event. This discrepancy is likely associated with the terrain detail on the left bank of the Burlington Ditch. The LiDAR (light detection and ranging) data used to set the ground elevations may not adequately represent the berm on the left bank of the Burlington Ditch that would prevent overtopping and spillage into the area shown as inundated by the model. The light rail line obstructs the left bank in this area, and the overall resolution likely leads to an underestimation of the bank crest elevation. Additional ground surveys will be needed in the future to refine the limits of the floodplain for this reach.

Figure 15 presents an overlay of the FEMA flood zone boundaries and the model predicted inundation between the confluence with the South Platte River and I-76. There is generally good agreement between the predicted 100-year inundation extent and the FEMA floodplain in this region. The model predicts limited, shallow overtopping of I-270 for the conservative 100-year flood simulation when the 100-year flows are applied to both Sand Creek and the South Platte River. The FEMA FIS shows a small area of ponded inundation (red circle), but this result is confusing as the area marked is elevated on the approach to the bridge over the South Platte River. Elevations in the region FEMA indicates as inundated are approximately 5 feet higher than the low point on I-270 500 feet to the northwest (Figure 16).

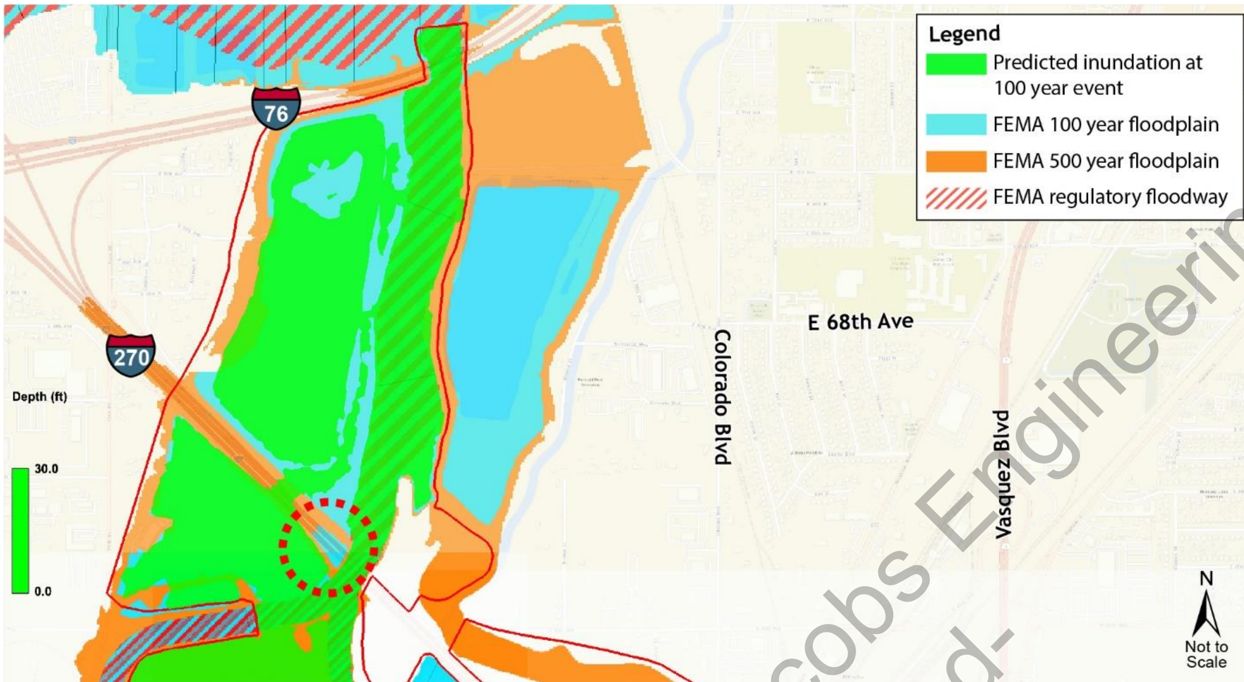

Figure 15. Overlay of Model Inundation Extents between South Platte River Confluence and I-76 with FEMA Flood Zones
Source: Jacobs

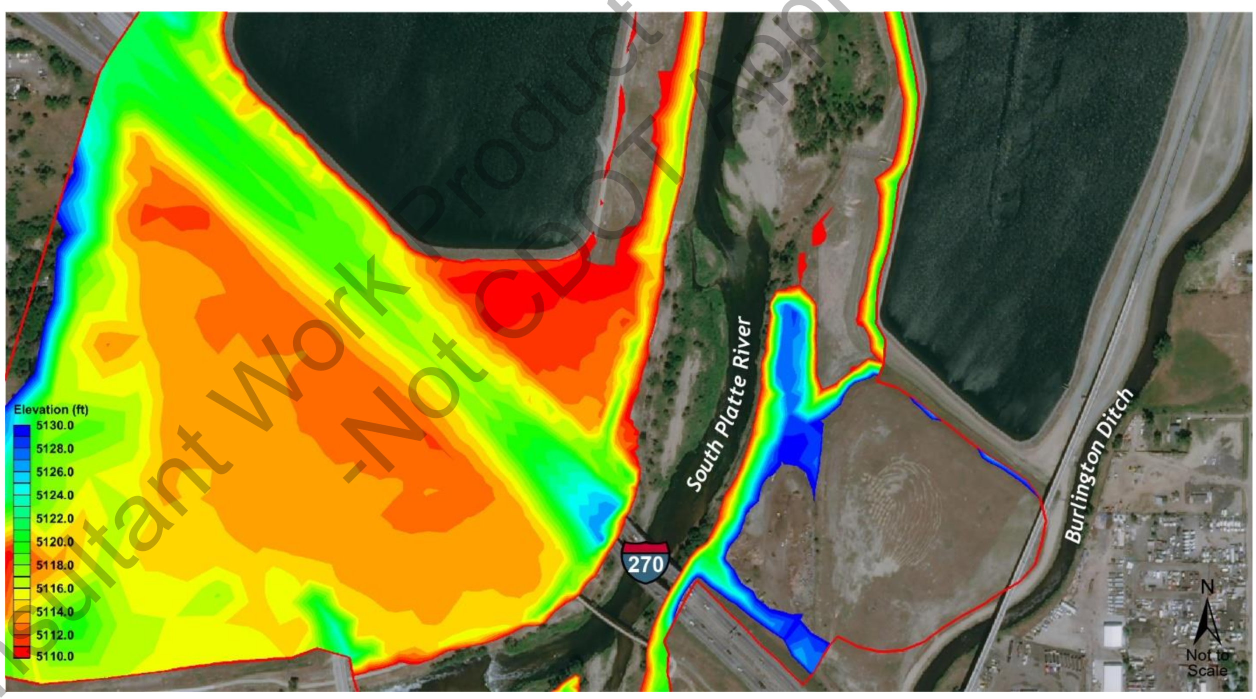

Figure 16. Ground Elevation Detail for I-270 West of South Platte River
Source: Jacobs

Figure 17 shows the predicted depths of the flows overtopping I-270 during the conservative 100-year flow simulation. Maximum depths in the travel lanes are approximately 0.5 to 0.75 foot. Depths are truncated in the legend to show only depths less than 2 feet to improve resolution in the overflow region. Figure 18 shows a cross section through the area of overtopping with water levels for three simulations and the local ground elevation. The simulations have different combinations of return interval events on Sand Creek and the South Platte River (see Table 2).

To assess the likelihood of a combined 100-year event, peak annual flow events were obtained from USGS online resources for stations at the mouth of Sand Creek and the South Platte River at 64th Avenue. The period of overlap covers 28 years between 1993 and 2020. The date of occurrence of the peak annual event was compared between the two river systems to show the correlation between peak annual flow events. The average difference in the dates of peak annual flows was 21 days, indicating low correlation. Taking the five largest events on Sand Creek, the average difference between peaks was 4 days, but three of the five events had a peak on the South Platte the same day. For the South Platte, the five largest events in the 28-year record occurred an average of 9 days apart from the corresponding peak on Sand Creek, but two of the five largest events on the South Platte occurred on the same day as the peak event that year on Sand Creek.

The spread in days was largest for the largest event on each river. The largest event in the 28-year overlapping record on the South Platte at 64th Avenue was July 25, 1998, with a peak daily flow of 11,800 cfs. The peak on Sand Creek in 1998 occurred on August 19, a difference of 25 days. The largest event on Sand Creek in the 28-year overlapping record occurred on September 12, 2013. The corresponding annual peak in 2013 on the South Platte River occurred on the same day. For these large events, the relative magnitude of the flows on both rivers does not show a high correlation. The 1998 peak flow event on the South Platte of 11,800 cfs is between a 10- and 25-year storm event, while the peak flow that year on Sand Creek was just 1,390 cfs, which is approximately a one-year event (USGS 2021)

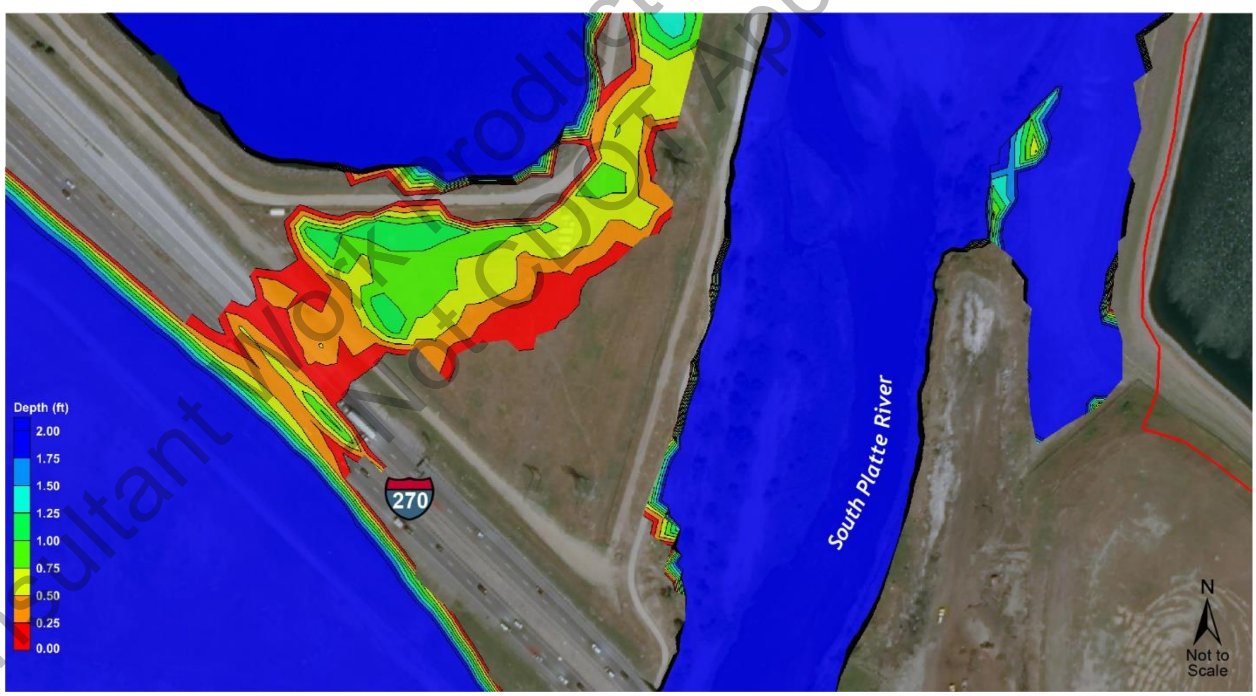

Figure 17. Flow Depths Overtopping I-270 during 100-year Simulation (West of South Platte River)
Source: Jacobs

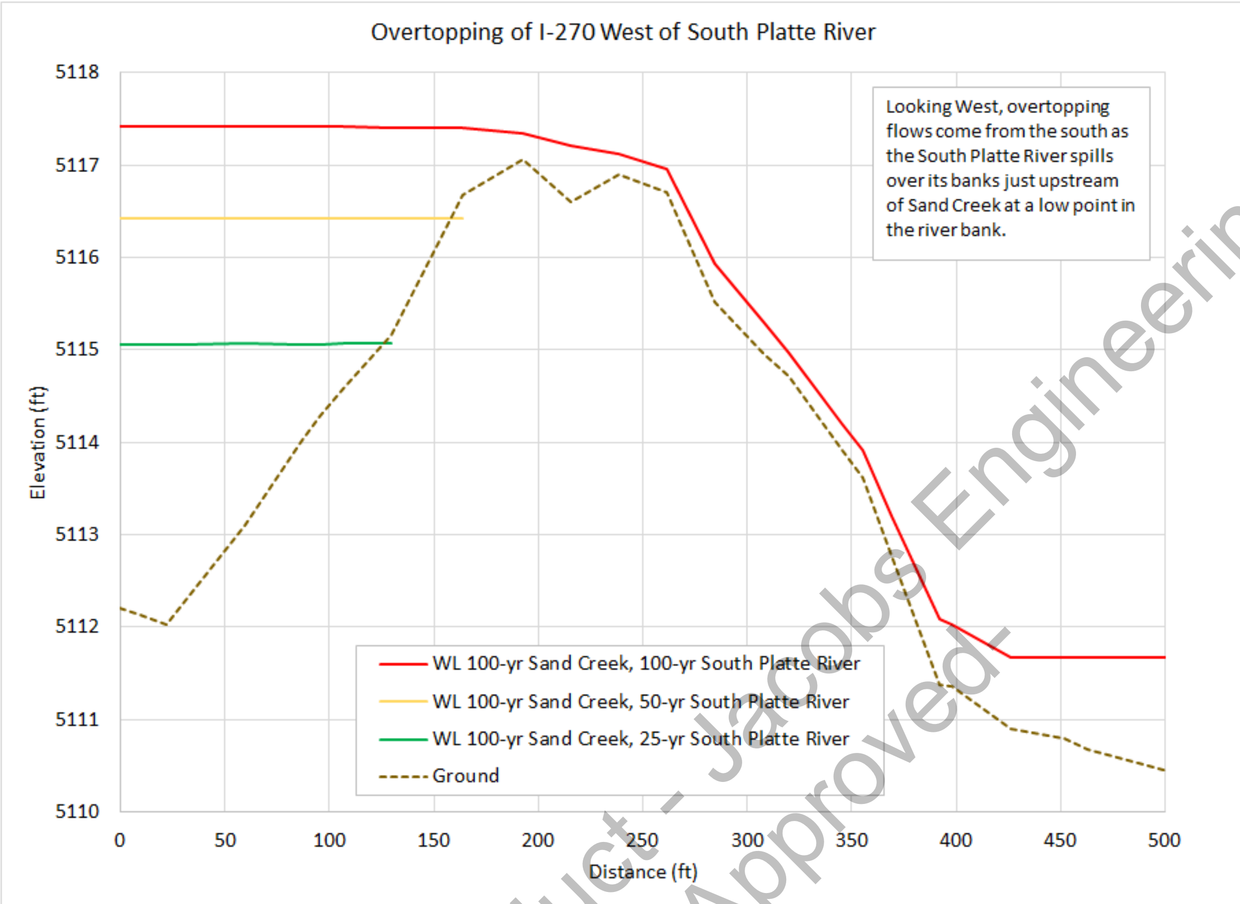

Figure 18. Ground Elevation Detail for I-270 West of South Platte River
Source: Jacobs

The 100-year flow on Sand Creek exceeds the 100-year flow on the South Platte River.. The only modeling scenario that is shown to overtop I-270 is when the 100-year event flows on both rivers occur simultaneously. There is no overtopping of I-270 when using Sand Creek's 100-year flow for one inflow and the 50-year or lower for the South Platte River. --

Table 2. Summary of Boundary Inflow Combinations Used in Analysis

Location	Sand Creek	Return Interval	South Platte	Return Interval
Grid 6 V01	30,000 cfs	100-year	22,300 cfs	100-year
Grid 6 V02	30,000 cfs	100-year	17,600 cfs	50-year
Grid 6 V03	30,000 cfs	100-year	9,700 cfs	10-year
Grid 6 V04	30,000 cfs	100-year	13,900 cfs[1]	25-year
Grid 6 V05	22,400 cfs	50-year	22,300 cfs	100-year
Grid 6 V06	16,000 cfs	25-year	22,300 cfs	100-year
Grid 6 V07	10,000 cfs	10-year	22,300 cfs	100-year

Source: Jacobs

[1] 25-year return interval flow estimated for South Platte River

Figure 19 shows the predicted bed shear in the model domain downstream of Vasquez Boulevard for the 100-year flow simulation. Bed shear along the channel centerline averages under 4 lb/sq ft with spikes above 10 lb/sq ft over the drop structures at Brighton Boulevard and downstream of the Burlington Ditch. The median bed shear is approximately 3 lb/sq ft.

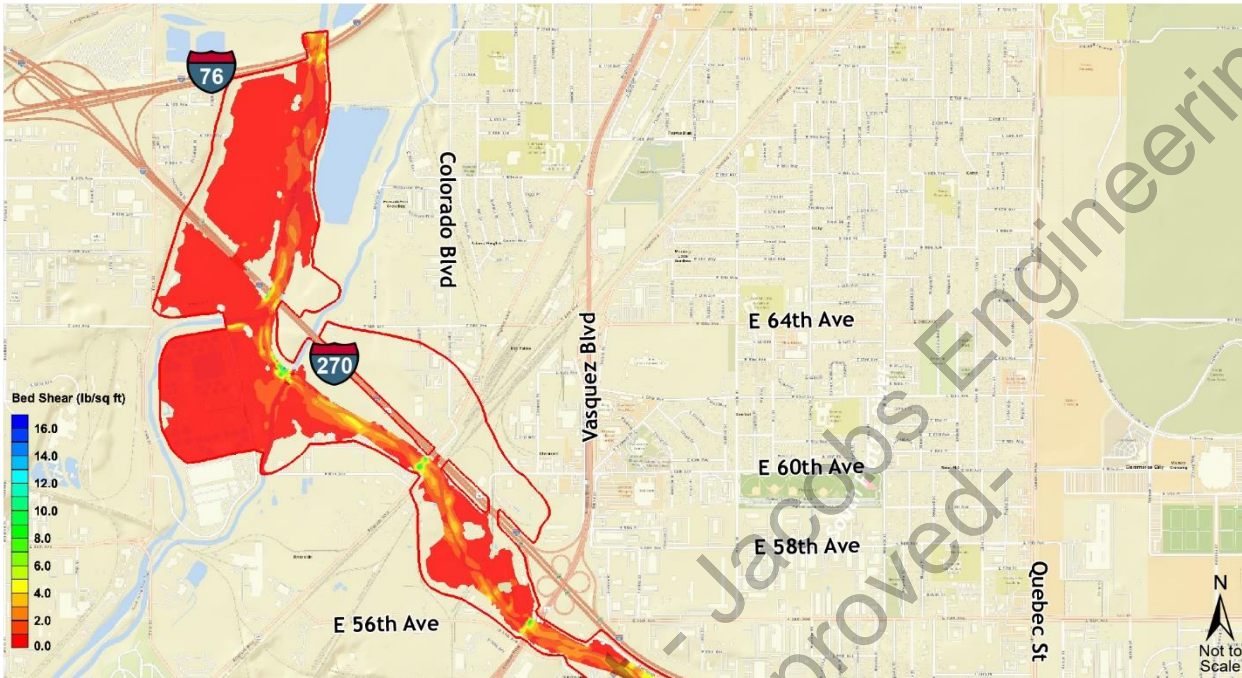

Figure 19. Bed Shear Stress for 100-year Flow of 30,000 cfs
Source: Jacobs

Figure 20 shows the modeled velocity downstream of Vasquez Boulevard for the combined 100-year flow simulation. Peak velocities at the drop structures exceed 25 ft/sec. Average floodplain velocities are 11 ft/sec taken over a longitudinal transect down the channel centerline. Velocities are related to the floodplain width and relative channel gradient. The channel steepens downstream of Brighton Boulevard and again downstream of the Burlington Ditch.

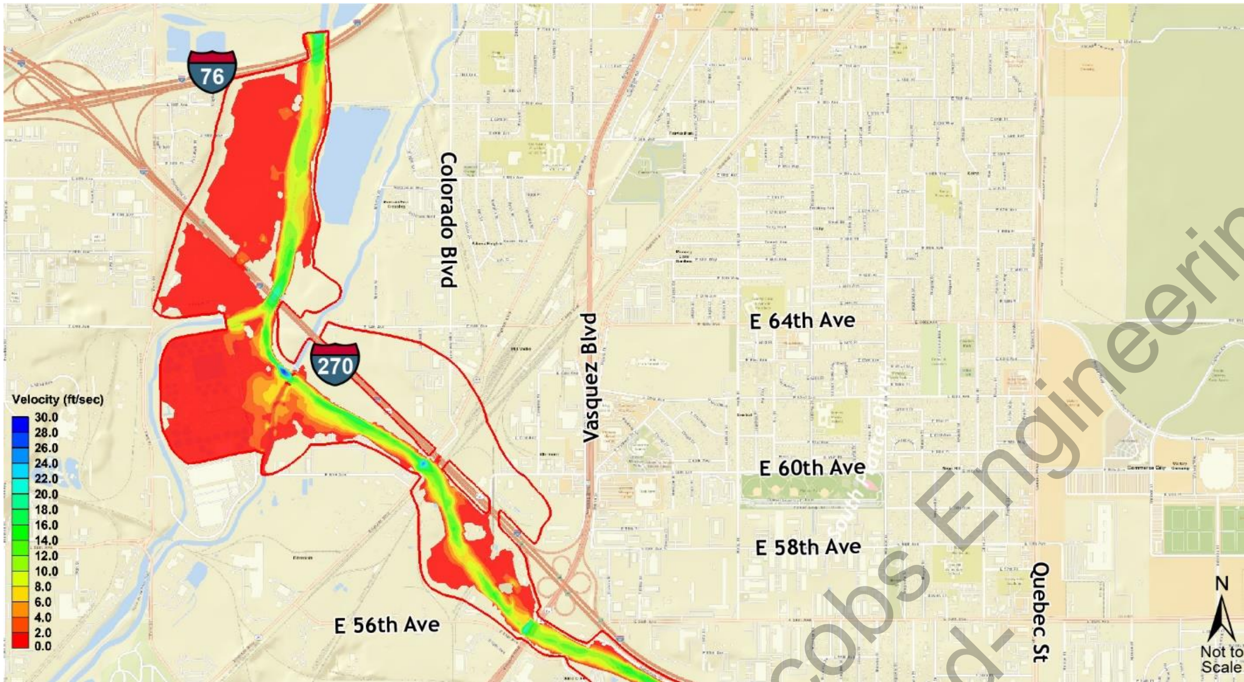

Figure 20. Velocity for 100-year Flow of 30,000 cfs
Source: Jacobs

3.0 Conclusions and Future Work

The hydraulic modeling analysis with the U.S. Bureau of Reclamation's SRH-2D model generally reproduces the floodplain provided by FEMA in their FIS. The 2D model has more resolution in the depiction of local ground elevations, and thus some differences are expected when comparing results to the FEMA study that was done with a 1D model. There are two considerable areas of difference between the two models as it concerns the I-270 project. First, the 2D model does not predict encroachment of the floodplain on Sand Creek Drive South and I-270 upstream of Vasquez Boulevard. This is likely because of the improved local ground elevation representation in the 2D model. Second, the 2D model does predict overtopping of I-270 west of the South Platte River for the 100-year simulation using a conservative representation of inflows where both Sand Creek and the South Platte River were assigned the 100-year flow condition; however, the peak flow analysis and low overtopping probability (less than 1 in 10,000) indicate a combined 100-year event is not likely. Floodplain levels are below the I-270 pavement elevation for scenarios where the 100-year flow is assigned to one river and the 50-year flow is assigned to the other.

The 2D model will be used going forward to investigate local bridge hydraulics to support scour analysis at select bridges and any modeling needed for analyzing new roadway embankments and the impacts on the floodway. This analysis will involve modification of the local model grid on a case-by-case basis to include bridge structures affecting local hydraulics and incorporation of any new ground surveys where needed. A Conditional Letter of Map Revision (CLOMR)/LOMR will be initiated by CDOT in cooperation with the project partners to revise the effective FIRMs and remove I-270 from the floodplain. These findings will be finalized through the LOMR/CLOMR process.

4.0 References

Urban Drainage and Flood Control District. 1977. Flood Hazard Area Delineation: Sand Creek.

United States Geological Survey. 2021. USGS Surface Water for Colorado: Peak Streamflow. https://nwis.waterdata.usgs.gov/co/nwis/peak/?site_no=394839104570300&agency_cd=USGS