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Technical Report

Tijuana River Border Barrier Flood Hazard Analysis

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Introduction

Customs and Border Protection (CBP) intends to install a 900’ border security barrier across the Tijuana river channel, immediately downstream of the US-Mexico border. The planned barrier is composed of a steel structure, anchored to the Tijuana River channel by four 72” columns. The steel structure will house approximately fifty three individually hoistable gates, designed to be lowered during low river flow and raised during high flow. The bottom 5’ of each gate is impermeable and the remaining 25’ are approximately 40% permeable. In the case the gates remain in the lowered position during high flow, they would allow conveyance of approximately one-third of channel flow, assuming no further blockage from debris.

The purpose of this effort is to model flood hazard from the proposed river barrier bridge and gates to address concerns that flooding could impact US government funded wastewater infrastructure projects including the South Bay International Treatment Plant and Tijuana-side wastewater pumps and collectors. The infrastructure project locations are shown in Figure 1, as well as across all results graphics, to highlight their exposure to various flood scenarios. This modeling is in alignment with the Federal Flood Risk Management Standard, which requires agencies to prepare for and protect federally funded projects from flood risks. This standard recommends modeling for a 500-year storm event. This will help understand, plan for, and mitigate potential flood risk from the barrier, under various flow events and operational scenarios.

This project investigates the effect of the planned barrier structure on flood hazard in three ways: 1) by simulating the blockage effect of the support columns on river flow during a range of large flow events, 2) by simulating scenarios of possible malfunction of the gates whereby some or all of the gates would remain lowered during extreme flow, and 3) by simulating a sudden breakaway of the barrier, resulting in a sudden release of the blocked flow.

It is important to note that this analysis only considers flooding from levee overtopping due to the barrier’s blockage to flow. Not considered are the impacts on urban drainage during rainfall events, which will be influenced by higher channel flows when gates are left in the lowered position.

Methods

Hydrodynamic modeling of extreme flows is carried out for this project using the widely adopted HEC-RAS (Hydrologic Engineering Center – River Analysis System) software, version 6.3.1, supported by the U.S. Army Corps of Engineers (Brunner, 2016). Version 6.3.1 allows for two-dimensional (2D) hydrodynamic simulation of stream flow when given as input a digital terrain model of stream and floodplain geometry, a representation of landcover flow resistance, and a set of flow boundary conditions. In addition, culverts and bridge structures can be modeled based on their engineering design properties, as well as breachable or breakaway gates.

Digital Terrain Model (DTM):

Topographic data from two lidar surveys was merged to generate a digital terrain model (DTM) of the project site. For the orange portion of the model domain, shown in Figure 1, a 2014 USGS lidar survey was obtained from NOAA's Coastal elevation data portal (OCM Partners, 2023). The digital terrain model has a 1 meter horizontal resolution and is projected to NAD 1983 UTM Zone 11N horizontal reference system, and NAVD88 vertical system using metric units. Vertical errors are reported to be 11.6 cm (RMSE) on open terrain. For the blue portion of the model domain a 2007 lidar survey was extracted from USGS's National Elevation Data at 3 meter resolution. The 2007 lidar data was also projected to NAD 1983 UTM Zone 11N horizontal reference system and NAVD88 vertical system using metric units. The 2014 and 2007 DTMs were merged in ArcGIS software (Esri, Redlands, CA) using 1 m resolution. This DTM is referenced throughout the report as the 2014 lidar DTM due to it representing the 2014 channel bottom conditions, including deposition of sediments at the energy dissipator (see Figure 2A), where the Tijuana River Channel widens downstream of the proposed barrier structure to reduce flow velocity and downstream erosion (black box in Figure 1).

A second DTM was generated by replacing the elevations at the energy dissipator with a smooth sloping bottom representing design conditions (i.e., the channel bottom as originally designed, without any accumulated sediment). (see Figure 2B). This DTM is referenced throughout the report as the design DTM.

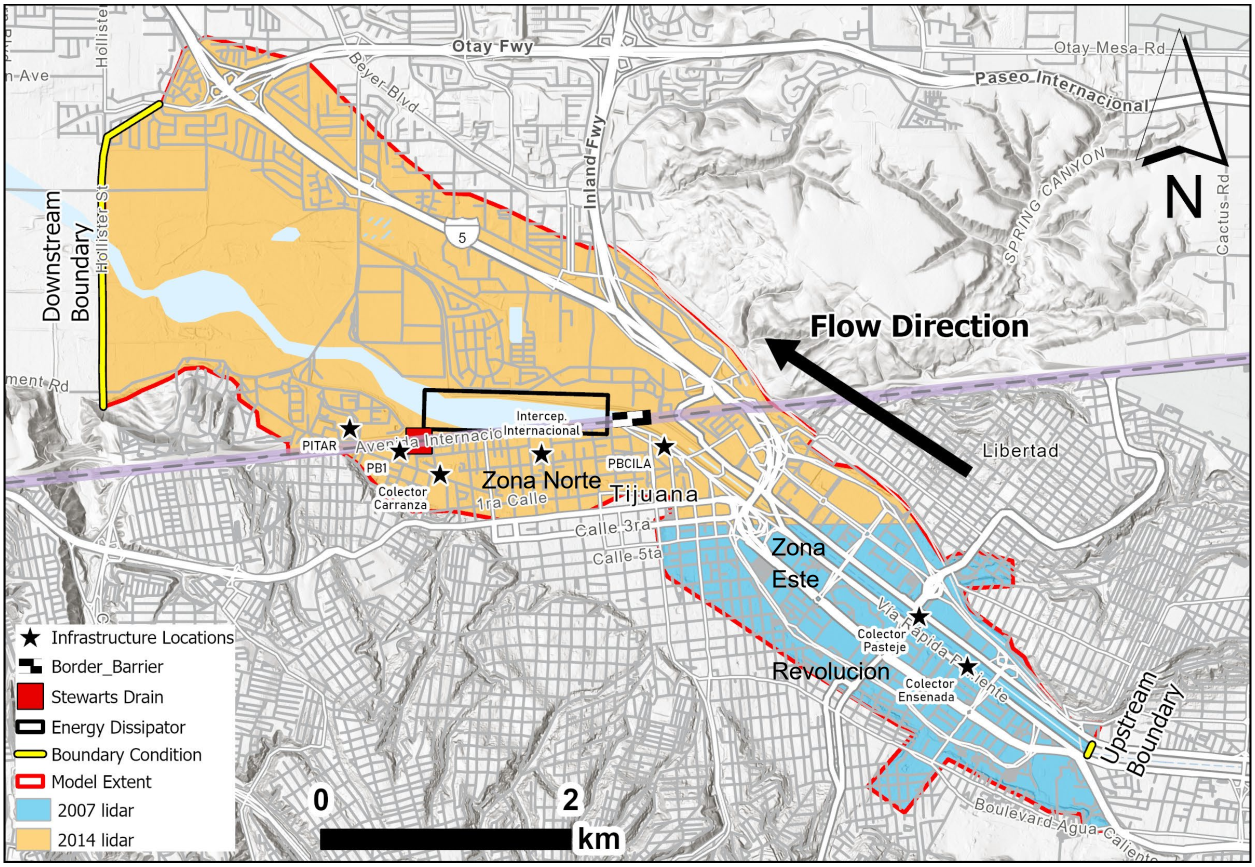

Figure 1. Study site with model extent, barrier location, and sources of terrain/channel data.

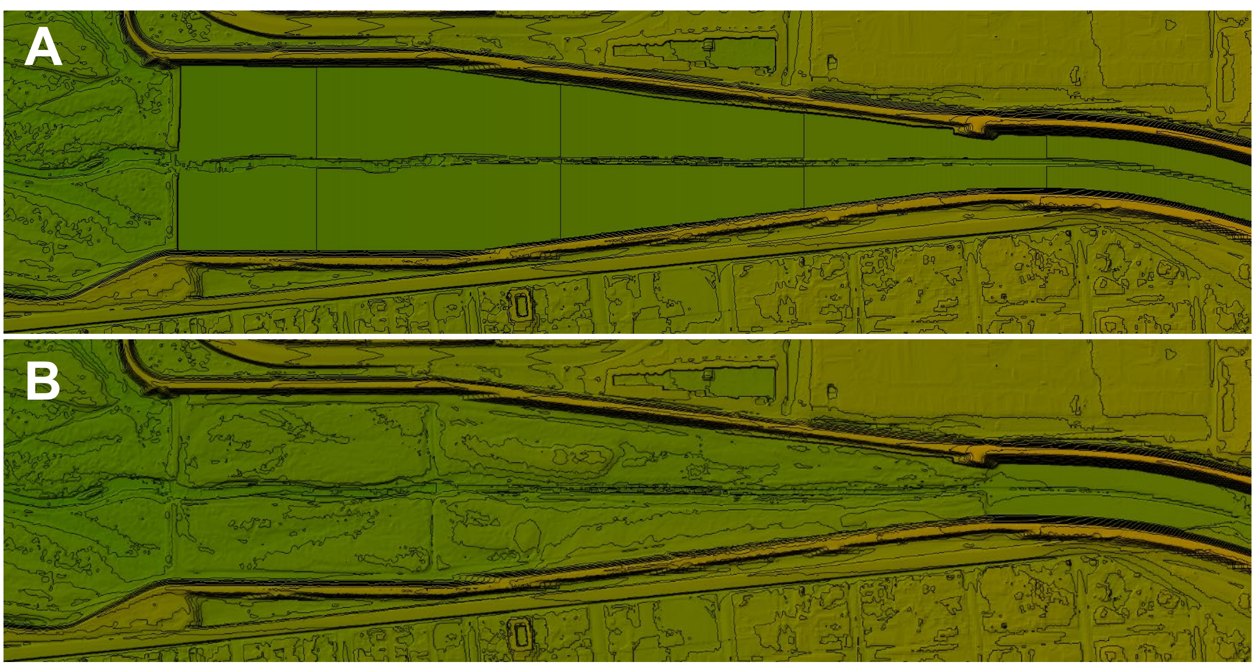

Figure 2. Energy dissipator (see Figure 1 for location) under *A)* design bottom conditions, and *B)* sedimentation as measured by a 2014 lidar survey. Contour lines represent 0.5 m intervals.

Flow Resistance Parameters:

Landcover/use data was acquired from two sources to generate a map of spatially distributed Manning parameters for this study. On the U.S. side of the border, 2019 National Land Cover Database (NLCD, 2019) landcover was obtained at 30 m resolution. On the Mexico side of the border, landcover/use information was obtained from Open Street Map (OSM Contributors, 2023). Spatially distributed Manning resistance parameters were attributed to each landcover class based on a combination of tabulated values from various sources: 1) a hydrology and floodplain report prepared by USACE for the Tijuana River valley, (USACE, 2018), 2) values used for urban flood hazard modeling in peer reviewed literature (Schubert et al., 2022), and 3) empirical values from Chow, 1959. The range of landcover types and associated Manning N parameter values can be seen in Figure 3.

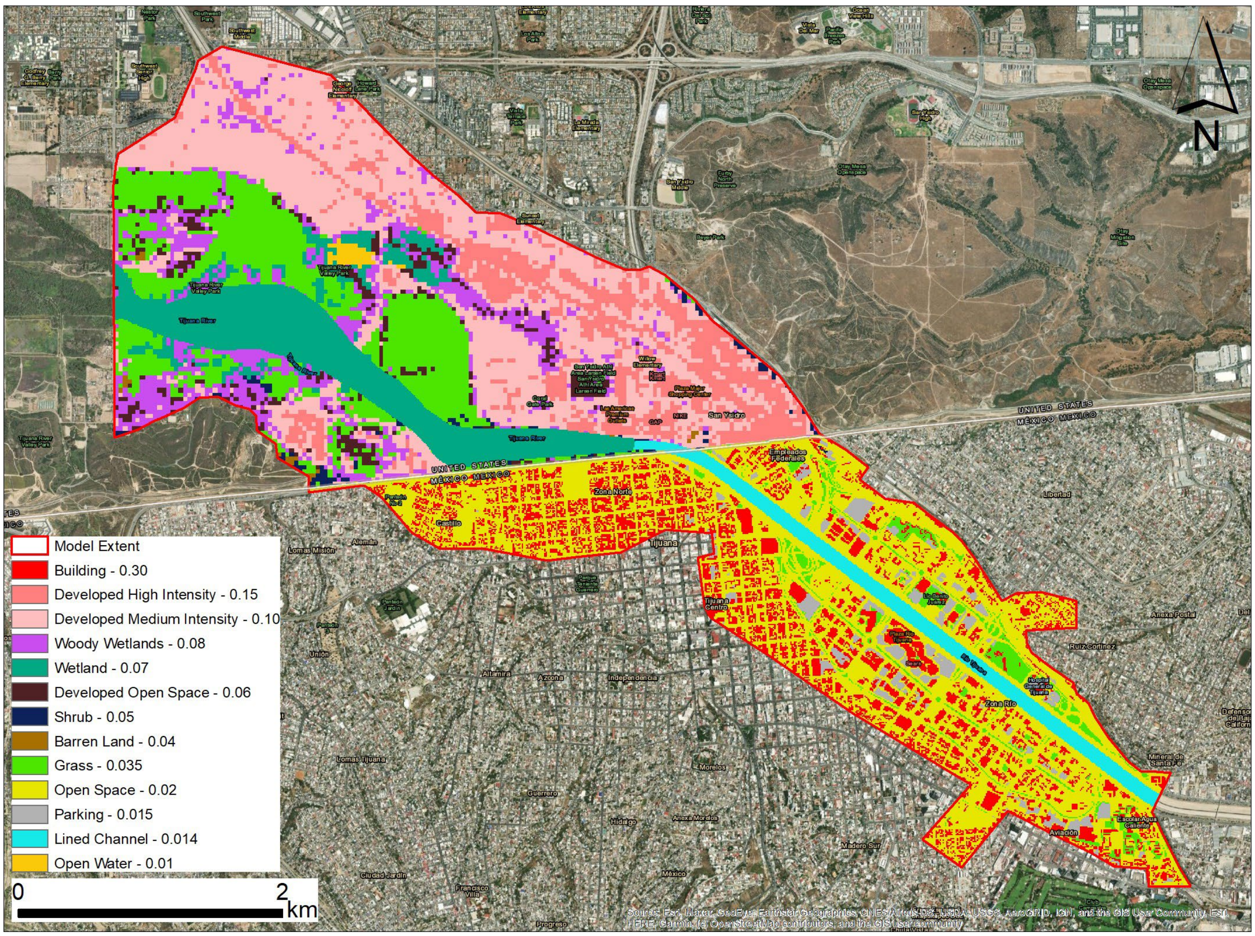

Figure 3. Map of spatially distributed Manning resistance parameter values adopted for this study.

Flow Hydrographs:

USACE (2018) reports that while there is no typical storm hydrograph for the Tijuana River near the international border, a pattern hydrograph for the Average Flood Hydrograph was determined for San Diego County, and published in the State of California, Department of Water Resources (DWR), Bulletin #182, *Upper San Diego River Flood Control Investigation*, February 1976 (State of California, 1976). This hydrograph shows that the flood has relatively short duration with discharge rising and falling rapidly, a typical characteristic of semi-arid areas. Like in USACE (2018), this pattern hydrograph was adopted for this study at the model's upstream boundary condition, and the shape and peak flow for the various return periods can be seen in Figure 4 and Table 1.

Return Period (years)	Tijuana River @ IBWC Streamgage (m^3/s)
50	1,164
100	1,900
200	2,973
500	5,182

Table 1. Peak discharge estimates for return periods used in this study.

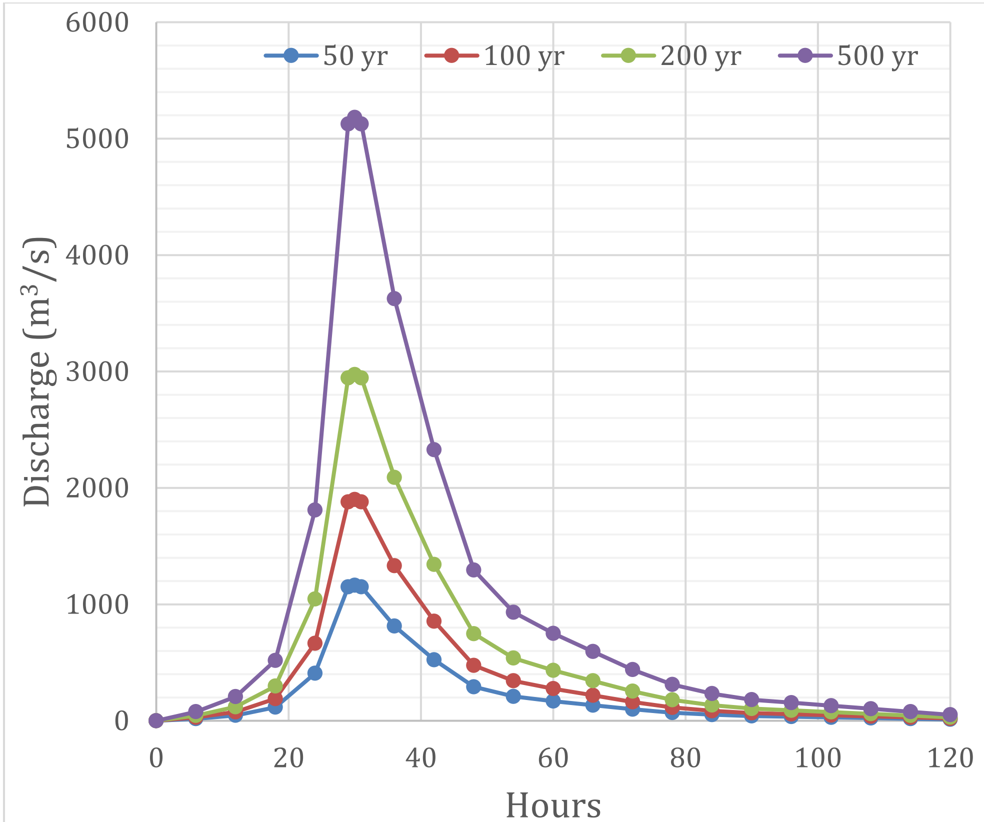

Figure 4. Typical storm hydrographs for San Diego County used for this study.

HEC-RAS Model setup:

Figure 1 shows the extent of the developed hydrodynamic model (red outline), extending between the railway bridge across the Tijuana River at the upstream end of the model, and Hollister St. at the downstream end. Flow in the model is forced at the upstream boundary location using the flow hydrographs shown in Figure 4. The downstream boundary condition is approximated using the normal depth option in HEC-RAS, whereby the location of the downstream domain boundary was calibrated using convergence analysis. Several model runs were executed, each shifting the downstream boundary location further from the proposed border barrier location. The final location of the downstream domain boundary was determined by the most upstream location where water levels at the proposed barrier structure were not further influenced by the location of the downstream boundary condition. The initial model condition is a dry channel as is typical for the Tijuana River.

The site topography is discretized using a computational mesh with 30 m cell size across the floodplain and 10 m cell size along levees, while flow is propagated using a model timestep of 3 seconds. Optimal timestep and cell size were determined through convergence analysis accounting for simulation runtime and model stability. The utilized 30 m computational mesh resolution is equivalent to a factor of 30 upscaling from the original 1 meter resolution terrain data. Upscaling is a technique available in HEC-RAS 6.3.1 by applying a sub-grid bathymetry approach. During model pre-processing, hydraulic radius, volume, and cross-sectional data for each 30 meter mesh cell are collected based on the original 1 meter resolution data, and are stored in property tables (Brunner 2016). This allows for detailed simulations of surface flows using timesaving coarse meshes. In the case of this project, model runtimes between 1-10 hours are reported with mass-balance errors under 0.05%.

Two flow structures of particular importance to this study were included in the HEC-RAS model: the Stewart's Drain and the proposed barrier structure (see Figure 1 for locations).
Stewart's Drain allows urban runoff from Tijuana to drain across the US-Mexico border into the Tijuana River Valley. In the case of levee overtopping, it also routes flows from the Zona Norte of Tijuana into the Tijuana River valley. The Stewarts Drain is modeled as a five barrel culvert in HEC-RAS, and its dimension was provided by the United States Section, International Boundary & Water Commission (IBWC).

The river barrier is modeled in HEC-RAS as a 2D flow area internal bridge, consistent with the proposed design drawing provided to EPA by CBP. Figure 5 top panel shows the cross section of the modeled barrier bridge with four 1.83 m (72") support columns.

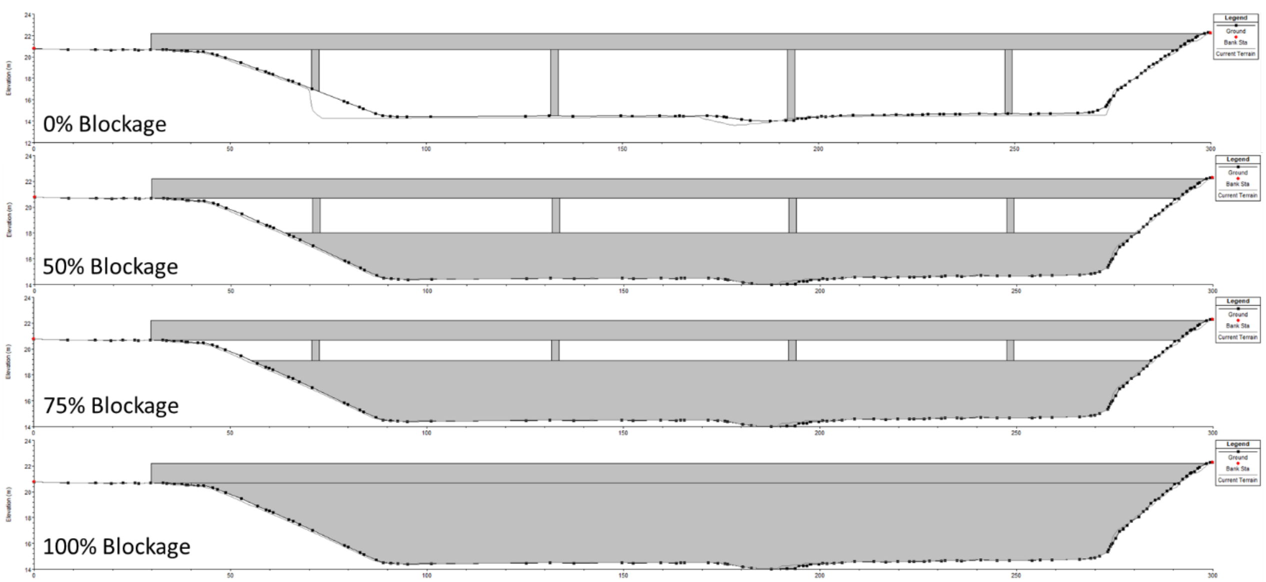

Figure 5. Modeled bridge structure and various level of gate blockage.

Model Simulations:
Table 3 provides a summary of scenario simulations executed to capture the impacts of the border barrier itself, as well as various levels of its blockage on flow conditions in the Tijuana River. Scenarios without Barrier (1-5) represent flood hazard under baseline conditions, before

construction of the barrier bridge. Scenarios 6-9 address the effects on flood hazard from the bridge structure and its support columns. Scenarios 10-20 address the influence of gate blockage on flood hazard. Here we assume that some or all of the gates may fail to be raised during high flow conditions, and various levels of debris accumulation may occur against the barrier gates. Finally, scenarios 21 and 22 explore a potential breakaway of the barrier structure. As parameterized in the model, the sudden release of dammed water occurs when the water level in the river channel reaches the levee crest at the location of the barrier, and the blockage capacity of the structure is instantly removed.

Scenario ID	Return Period (yrs)	Energy Dissipator Conditions	Barrier	Gate Blockage (%)
1	100	Design	No	NA
2	100	2014 lidar	No	NA
3	200	Design	No	NA
4	200	2014 lidar	No	NA
5	500	Design	No	NA
6	100	Design	Yes	0
7	100	2014 lidar	Yes	0
8	200	Design	Yes	0
9	200	2014 lidar	Yes	0
10	500	Design	Yes	0
11	50	2014 lidar	Yes	50
12	100	Design	Yes	50
13	100	2014 lidar	Yes	50
14	200	Design	Yes	50
15	200	2014 lidar	Yes	50
16	100	Design	Yes	75
17	100	2014 lidar	Yes	75
18	50	2014 lidar	Yes	100
19	100	Design	Yes	100
20	100	2014 lidar	Yes	100
21	200	2014 lidar	Yes	100
22	100	2014 lidar	Yes/Breakaway	100
23	200	2014 lidar	Yes/Breakaway	100

Table 3. Summary of simulations.

Results

Baseline Flood Hazard:

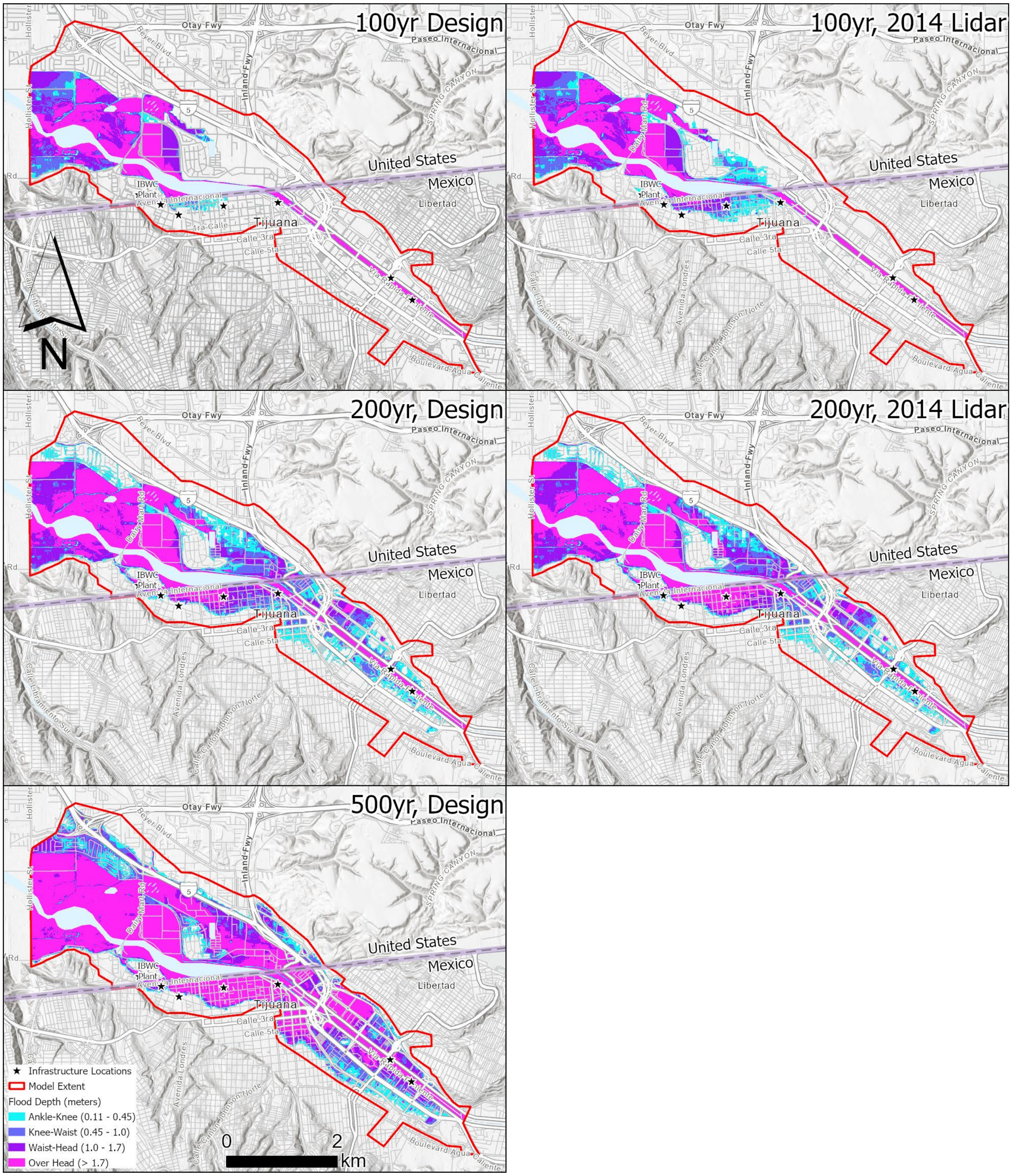

Figure 6. Baseline (no barrier) flood hazard extents for various return period flow events and under design as well as 2014 sedimentation conditions.

Figure 6 shows the flood extents from the 100yr, 200yr, and 500yr return period flows and two types of channel bottom conditions at the energy dissipator (see Figure 1): design conditions (Scenarios 1,3, and 5 respectively), and levels of sedimentation as observed by the 2014 lidar survey (Scenarios 2 and 4). The scenarios displayed in Figure 6 do not consider the proposed border barrier, and therefore represent the baseline conditions of flood hazard. Simulation results show that in the case of the 100yr flow and channel bottom design conditions at the energy dissipator, flood hazard is minimal with some flow crossing the US-Mexico border at the Stewarts Drain, inundating portions of Tijuana's Zone Norte (top left panel). 2014 sedimentation conditions at the energy dissipator result in an increased flood hazard extent across the Zona Norte of Tijuana, whereby overtopping of the south levee of the Tijuana River is predicted at the US-Mexico border (top right panel). Under 200yr flow conditions Tijuana River levees throughout the city of Tijuana are predicted to be overtopped, irrespective of channel bottom conditions at the energy dissipator. Flooding throughout the city is widespread, and a substantial increase inf flood depths is predicted across Tijuana's Zone Norte and in portions of San Ysidro (middle panels). Finally, the 500yr flow scenario is not contained by the Tijuana River levees and widespread flooding is predicted across the modeling domain (bottom panel).

Implication of Barrier Bridge structure:

Figure 7 provides a visual assessment of the implications to flood extent from the installation of the proposed bridge structure (see Figure 5 top panel). Note that for these scenarios the barrier gates are assumed to be completely raised, or absent, and pose no blockage to flow. The panels in the left column represent scenarios without proposed barrier bridge, while panels in the right column represent the equivalent scenario including the bridge structure. Visually for the 100yr and 200yr flow under channel bottom design and 2014 sedimentation conditions (Scenarios 6, 7, and 8) no or minimal differences can be observed in flood extents and depths. Predicted flow depth differences between scenarios are calculated through arithmetic calculation considering the barrier scenarios and those without (difference plots not provided in this report). In the case of the 100yr flow scenario under design channel bottom conditions (Figure 7 first row), implications of the bridge structure on flood depth are less than ±6 cm across the entire flooded area. For the 100yr and 200yr flow scenarios under 2014 energy dissipator sedimentation conditions (Figure 7 second and third row respectively), the placement of the bridge structure results in water depth difference in the channel of between ±5 cm. For the 500yr flow scenario under design bottom conditions (Figure 7 fourth row, scenarios 5 and 10), differences in flood extent and depth are visible across Tijuana's Zona Este and Revolución areas (neighborhood locations shown in Figure 1) whereby depths transition from ankle-waist deep to waist-overhead as a result of the bridge structure. Arithmetic difference calculation indicates that flow depths are increased in the Tijuana River upstream of the barrier by up to 60 cm, while the barrier causes a decrease of flow depth downstream of the structure by the equivalent amount.

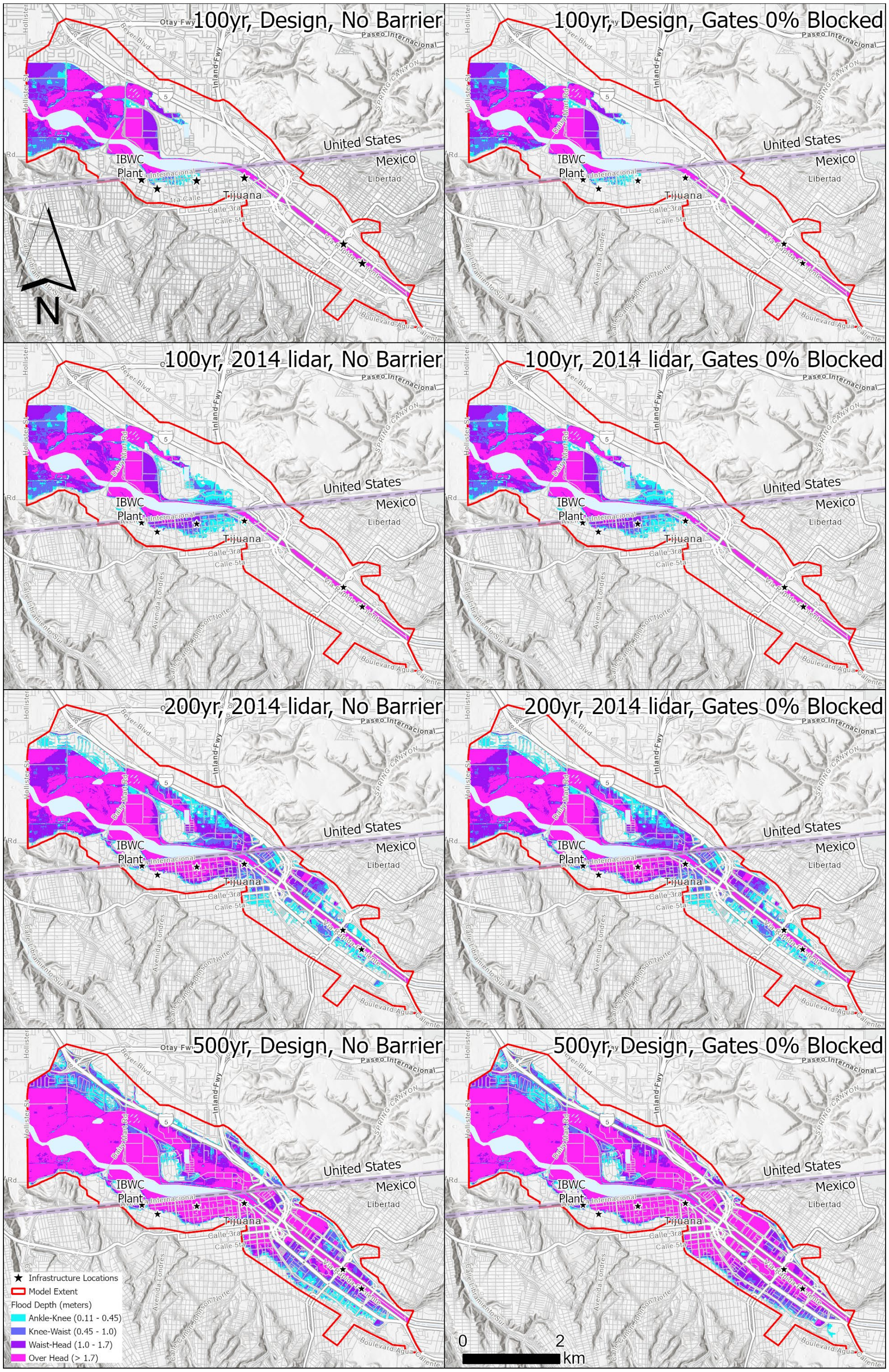

Figure 7. Flood hazard extents and depths for various return period flow scenarios and channel bottoms with and without proposed barrier bridge structure.

Implication of Gate blockage:

Figures 8, 9, 10 and 11 visualize the implications of barrier gate blockage to flood hazard. Figure 8 left panel shows the 50yr flow event under 2014 sedimentation conditions at the energy dissipator and 50% barrier blockage (Scenario 11). Ankle to knee deep flooding on streets near the Stewart's Drain is caused by high water level in the river valley backing up through the drain, while the proposed border barrier does not contribute to flooding. Under 100% barrier blockage (Figure 8 right panel, Scenario 18), the 50yr flow overtops the south-bank levee causing over-head flooding across Tijuana's Zona Norte, and waist to head deep flooding in the Zona Este.

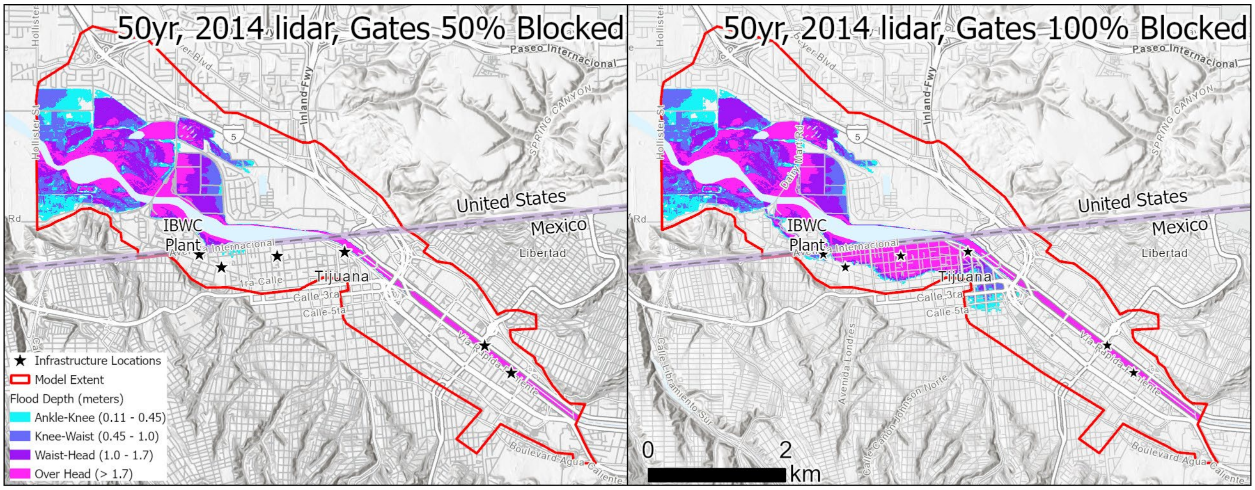

Figure 8. Flood hazard extents and depths for 50yr flow under 2014 channel sedimentation conditions with barrier gates blockage 50% (left panel) and 100% (right panel).

100yr flow scenarios are shown in Figure 9. Panels in the left column represent scenarios with design channel bottom conditions at the energy dissipator (see Figure 1 for location) and various barrier gates blockage levels. Right panels show the same scenarios with 2014 channel bottom sedimentation conditions at the energy dissipator. Under 50% gate blockage conditions for both left and right panels (Scenarios 12 and 13), large portions of Tijuana's Zone Norte are predicted flooded, whereby flood depths are compounded closer to the Stewart's Drain by flows backing up the drain as well as through street runoff from levee overtopping. Under design channel bottom conditions a majority of the flood zone is predicted to be ankle- to knee-deep flooded, while sedimentation of the channel at the energy dissipator increases flood depths to overhead near the Stewart's Drain and to waist-deep closer to the Tijuana River channel. At 75% and 100% blockage levels (Scenarios 16, 17, 19, and 20), model predictions show little sensitivity to channel bottom conditions at the energy dissipator. For the 75% blockage scenarios, large parts of Tijuana's Zone Norte are predicted to flood at head- or over-head levels. For the 100% blockage scenarios, most of the Zona Norte is predicted over-head flooded, parts of the Zona Este are predicted to flood to waist- and head-level, and large parts of San Ysidro on the U.S. side of the border are also predicted to flood to between ankle- and waist-level.

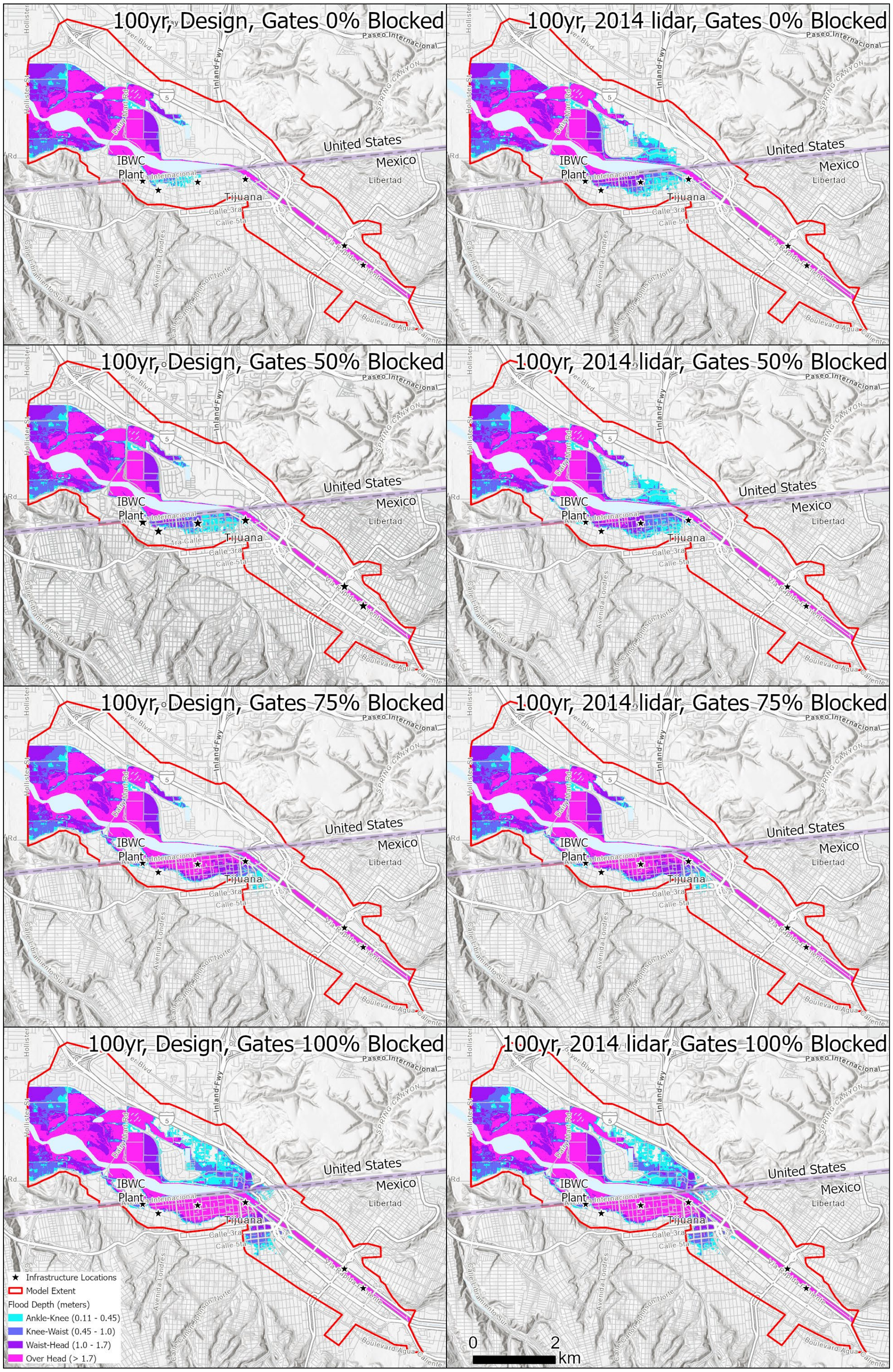

Figure 9. Flood hazard extents and depths for 100yr flow conditions under design channel bottom (left panels) and 2014 bottom sedimentation conditions (right panels) with barrier gates blockage from 0%-100%.

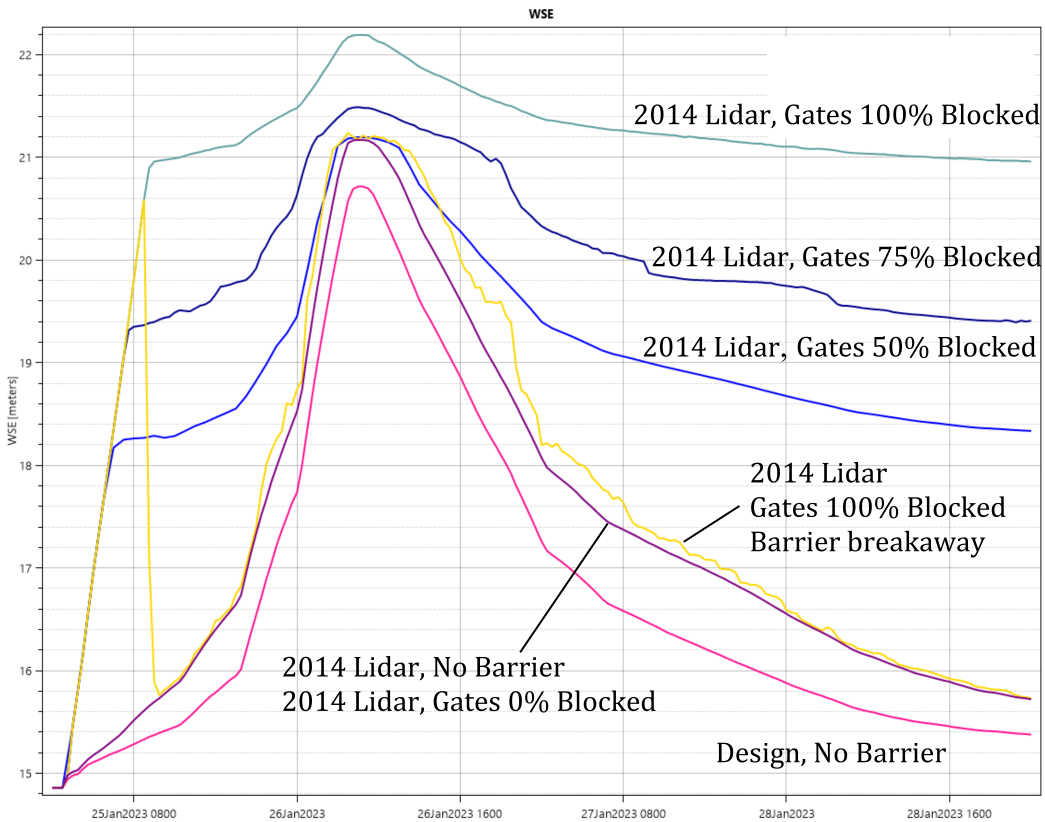

Figure 10. Water surface elevation 100 meter upstream of proposed border barrier under 100yr flow scenarios.

Figure 10 shows the evolution of water surface elevations approximately 100 meters upstream of the proposed barrier structure for the 100yr flow scenarios. The purple line shows flow elevations for the scenario without border barrier under 2014 sedimentation conditions at the energy dissipator (Scenario 2). The same flow elevation profile is also predicted for the scenario including the proposed border barrier with gates completely raised and posing no blockage to flow (Scenario 7). Light blue, dark blue, and green lines show water elevation profiles under increasing barrier gates blockage levels (50% - Scenario 13, 75% - Scenario 17, and 100% - Scenario 20 respectively). The 50% blockage scenario predicts the same peak water surface elevation as the 0% blockage scenario (purple line), however the 75% and 100% blockage scenario increase water surface elevations in the channel by 25 cm and 100 cm respectively.

The yellow line shows the water surface elevation profile of the 100% gate blockage scenario whereby the gate structure is modeled to break away as channel water levels approach bankfull elevation (Scenario 22). This is characterized by water levels dropping quickly after the initial steep increase, and with the barrier removed the remainder of the flow profile approximates that of the purple line.

The influence on water surface elevations from channel sedimentation at the energy dissipator is represented by the pink line, characterizing the scenario with design conditions at the energy dissipator and no border barrier (Scenario 1). Compared to the no-barrier scenario with 2014 sedimentation conditions, a difference in water surface elevations of 45 cm is predicted.

200yr flow scenarios under 2014 sedimentation conditions at the energy dissipator are shown in Figure 11 (Scenarios 8, 15, and 21). Flooding is widespread along the river channel in Tijuana as well as across the San Ysidro area for all gate blockage levels, as both north and south levees are predicted to overtop. The transition from 0% blockage to 50% blockage shows to marginally reduce flood depths in San Ysidro, while across the Zona Norte of Tijuana they are shown to increase. For the 100% blockage scenario, overhead flooding can be observed across the Zona Norte and Este in Tijuana, as well as across San Ysidro.

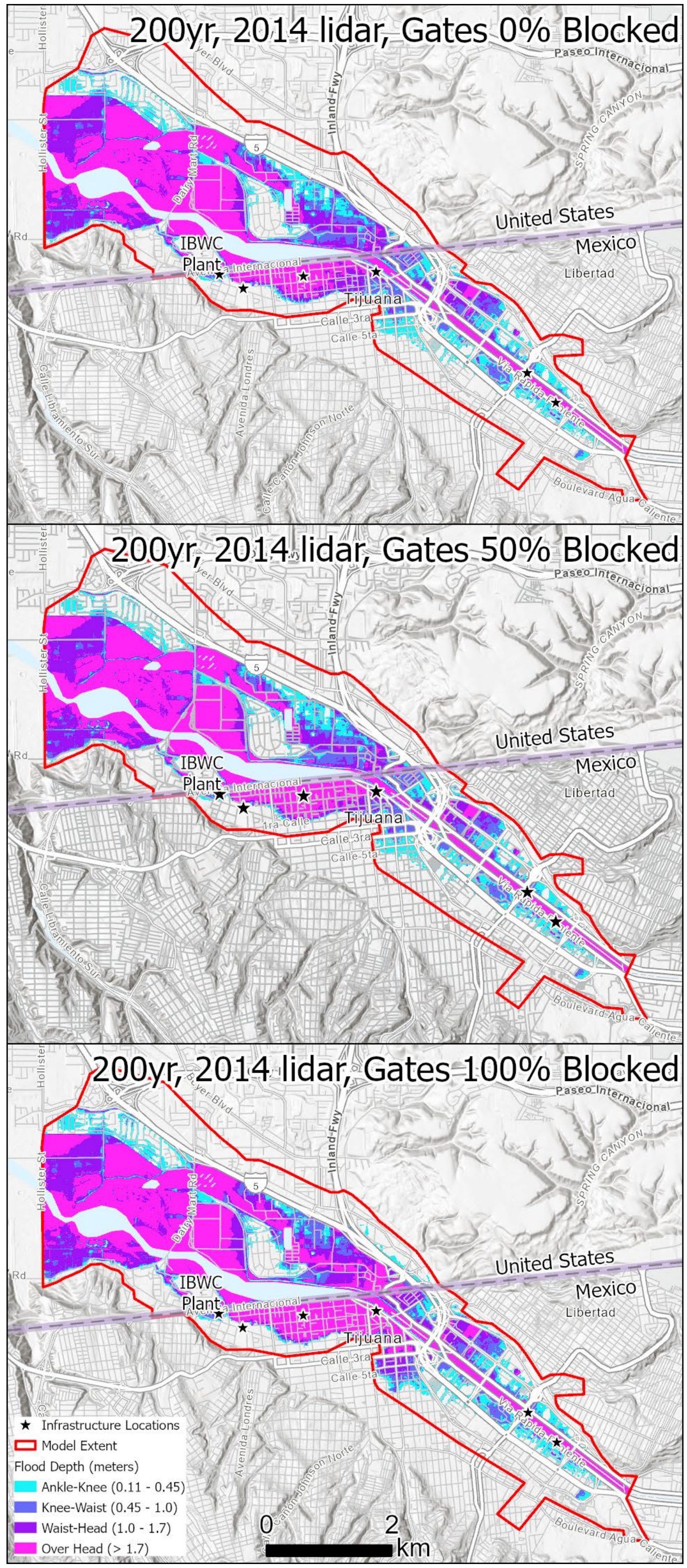

Figure 11. Flood hazard extents and depths for 200yr flow conditions under 2014 channel sedimentation conditions with barrier gates blockage from 0%-100%.

Implication of Barrier Breakaway:

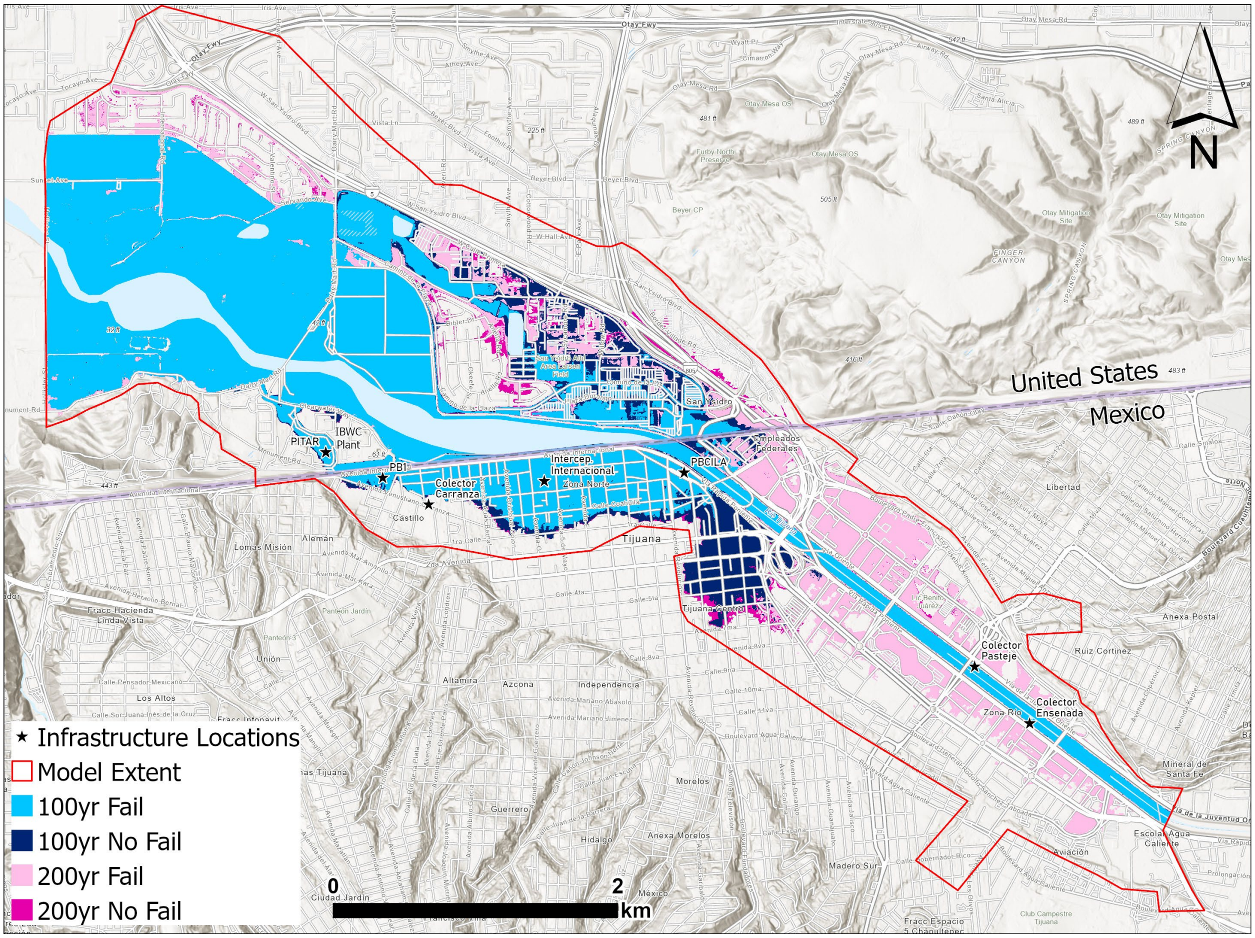

Figure 12. Flood hazard extents for 100yr and 200yr flow scenarios with and without barrier breakaway.

Figure 12 summarizes the effect of a barrier breakaway in case of 100% gate blockage during 100yr and 200yr flow events (Scenarios 22 and 23). Blue flood extents represent the 100yr flow scenarios. Among those, the light blue flood extent, representing the scenario with barrier breakaway, shows a much-reduced extent compared to the dark blue extent, which represents the scenario where the barrier remains intact during the same flow event.

Pink flood extents represent the 200yr flow scenarios. The light pink flood extent represents the scenario accounting for barrier breakaway, which again shows a reduced flood extent compared to the scenario without breakaway (dark pink). However at this larger flow, the relative reduction of flood extent, compared to the 100yr scenario, is less pronounced.

Summary

This study assesses the contribution to flood hazard from the proposed Tijuana River border barrier, through a set of hydrodynamic modeling scenarios executed using the two-dimensional HEC-RAS numerical flow model. The modeled scenarios provide information about baseline flood hazard conditions, implications of the barrier bridge to flood hazard, implications of barrier gates blockage to flood hazard, and implications of a barrier breakaway. Major study findings include the following:

- Sedimentation of the Tijuana River energy dissipator at 2014 levels or greater contributes to levee overtopping under 100yr flow conditions, with and without planned border barrier.
- The planned 72" barrier bridge columns have negligible impact on river flow conditions and flooding for flow events up to the 200yr return period. For the least frequent 500yr event, the barrier contributes to deeper flooding across Tijuana and San Ysidro.
- Under channel sedimentation at 2014 levels or greater, any blockage of the barrier gates during 100yr flow conditions would increase the risk of levee overtopping in Tijuana.
- If the lowered/blocked gates break open prior to levee overtopping, impacts on both sides of border are significantly reduced.
- Both sedimentation and blockage scenarios significantly increase river depth (see figure 10), which may further exacerbate flooding by preventing the drainage of urban stormwater runoff.
- The existing facilities at IBWC's South Bay International Wastewater Treatment Plant (ITP) are not predicted to be inundated under the modeled scenarios, provided the surrounding levees do not fail.
- Certain facilities contemplated in the proposed ITP expansion could be flooded under various scenarios without additional flood protection.
- Previous and currently planned EPA-funded wastewater infrastructure projects in Tijuana, especially those adjacent to the border, could be impacted by flooding under numerous scenarios.

Recommendations

The following scenarios are recommended to further extend the analysis of border barrier flood hazard implications:

1. Update HEC-RAS model with latest channel conditions to account for further sedimentation since 2014.
2. Determine the effect of the proposed barrier structure on the Tijuana stormwater drainage system. Any blockage at barrier gates will likely cause river levels in Tijuana to remain higher for longer periods, exacerbating flooding in two ways: 1) stormwater backflow from channel onto city streets, and 2) preventing urban runoff during rainfall to drain into river.

3. Consider flooding impacts due to upstream dam releases (Barret's Dam, Rodriguez Dam, etc.) during lowered gates conditions.
4. Assess whether lowered barrier gates could result in increased sediment deposition inside lined channel through Tijuana.
5. Consider strategies to manage potential flood hazard. Examples include:
   - Targeted sediment removal at the energy dissipator.
   - Inclusion of check valves at drainage infrastructure.
   - Deployment of sandbags and flood barriers.

Data

All HEC-RAS simulation results in raster format can be obtained at: **bit.ly/tjrbarrier**

References:

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Update October 2023

Additional model runs with 2019 sedimentation conditions at energy dissipator.

Introduction

A 2019 lidar survey carried out by Stantec (July, 2020) captures higher sediment levels in the energy dissipator, downstream of the border barrier, compared to 2014 sedimentation levels. Prior flood hazard scenarios executed using 2014 lidar data have shown that the sedimentation of the energy dissipator is cause for levee overtopping and significant flood hazard in Tijuana as well as portions of San Ysidro (see Figure 9). The purpose of this update is to assess the impact of the additional sedimentation in the energy dissipator on flood hazard and US funded wastewater infrastructure projects along the Tijuana river, between the railway bridge across the Tijuana River at the upstream end of the model, and Hollister St. at the downstream end (see Figure 1).

2019 DEM

The 2019 DEM was surveyed by Stantec using airborne lidar. The data uses the North American Datum of 1983 California State Plane VI with units in meters for the horizontal datum, and the North American Vertical Datum of 1988 (NAVD88) with units of meters. More details about the 2019 lidar DEM can be found in Appendix C of the "Hydrology, Hydraulics and Sediment Transport Report" by Stantec (2020). Figure 13 shows the difference between the 2019 and 2014 sediment elevations at the energy dissipator. White colors indicate an increase or decrease in elevation of less than 10 cm. Green colors indicate progressively increasing levels of sedimentation, while red colors indicate progressively decreasing levels of sedimentation. The majority of elevation decrease in the energy dissipator is shown along the center of the channel reach and along the sides of the levees. While the reduction in elevation in the channel center may be attributable to erosion from streamflow and potentially from sediment removal, along the banks of the reach the elevation change may be a result of vegetation cleaning. The major increase in sediment deposition is foremost visible on the upstream end of the energy dissipator immediately after the channel widens.

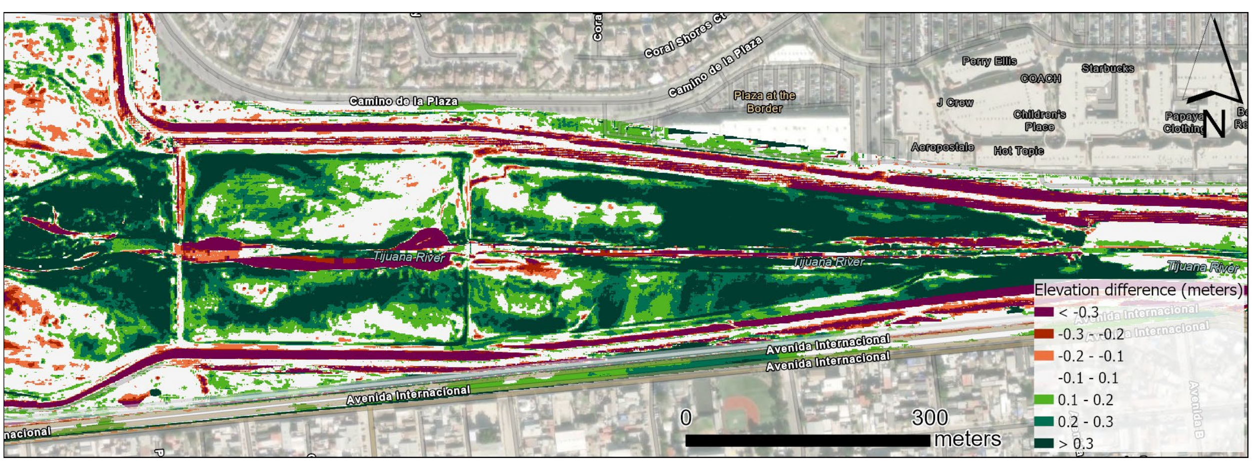

Figure 13. Difference between 2019 and 2014 sediment elevations inside the energy dissipator.

Between 1979-2019 (40 years), 272,724 m^3 of sediment have accumulated at the energy dissipator, 57% of those between 2015-2019 (Stantec, 2020). Since 1979, 55,430 m^3 of sediment were removed from the energy dissipator, of which only 17% since 2015 (Stantec, 2020). Hence, while sediment accumulation has rapidly increased since 2015, removal of said sediment has not kept pace, reducing the flow conveyance capability of the Tijuana River at the energy dissipator.

Model Simulations

A new set of scenarios was developed using the 2019 lidar topography data as shown in Table 4.

Scenario ID	Return Period (yrs)	Energy Dissipator Conditions	Barrier	Gate Blockage (%)
24	100	2019 lidar	Yes	0
25	100	2019 lidar	Yes	50
26	100	2019 lidar	Yes	75
27	100	2019 lidar	Yes	100
28	200	2019 lidar	Yes	0
29	500	2014 lidar	Yes	0
30	500	2019 lidar	Yes	0

Table 4. Additional scenario runs considering 2019 lidar data and various levels of Barrier Gate blockage.

Results

Implication of sedimentation at energy dissipator:

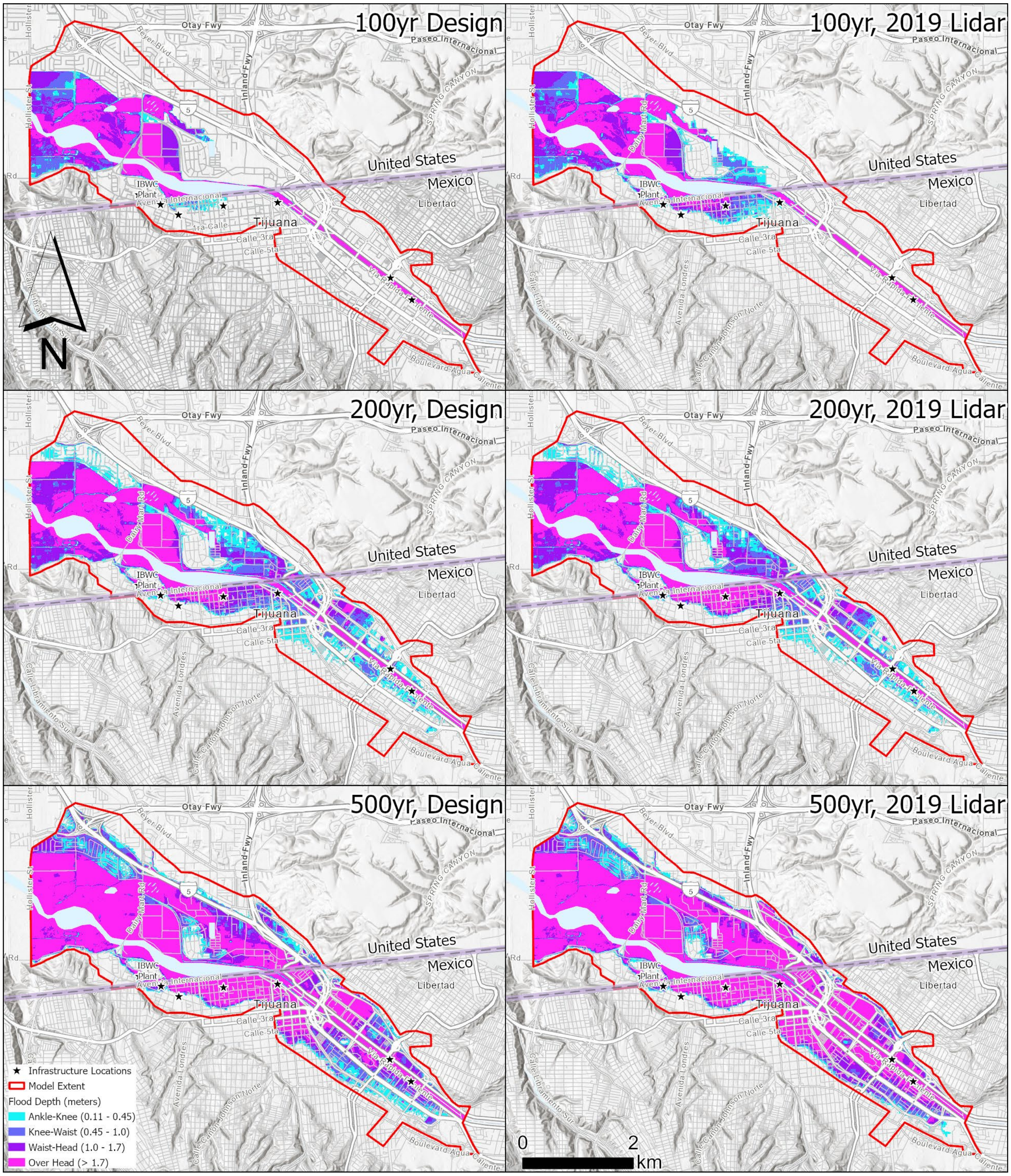

Figure 14. Flood hazard depths and extents for various return period flows and under design as well as 2019 sedimentation conditions. The scenarios consider the border barrier with fully open gates.

Figure 14 shows the flood extents from the 100yr, 200yr, and 500yr return period flows and two types of channel bottom conditions at the energy dissipator (see Figure 1): design conditions (Scenarios 6,8, and 10 respectively), and levels of sedimentation as observed by the 2019 lidar survey (Scenarios 24, 28 and 30). The scenarios displayed in Figure 14 consider the proposed border barrier with its gates fully open. Simulation results show that in the case of the 100yr flow and channel bottom design conditions at the energy dissipator, flood hazard is minimal with some flow crossing the US-Mexico border at the Stewarts Drain, inundating portions of Tijuana's Zone Norte (top left panel). 2019 sedimentation conditions at the energy dissipator result in considerably increased flood hazard extent across the Zona Norte of Tijuana, whereby overtopping of the south levee of the Tijuana River is predicted at the US-Mexico border (top right panel). Under 200yr flow conditions Tijuana River levees throughout the city of Tijuana are predicted to be overtopped, irrespective of channel bottom conditions at the energy dissipator. Flooding throughout the city is widespread, and a substantial increase inf flood depths is predicted across Tijuana's Zone Norte and in portions of San Ysidro (middle panels). Finally, the 500yr flow scenarios are not contained by the Tijuana River levees and widespread flooding is predicted across the modeling domain irrespective of sedimentation conditions at the energy dissipator (bottom panels). 2019 sedimentation appears to marginally increase flood hazards in portions of San Ysidro. Wastewater infrastructure projects across the Zona Norte are all impacted by flooding under a current 100 yr flood with the exception of Colector Carranza, unless sedimentation is not reduced in the energy dissipator.

Figure 15 shows the implication on flood depth and extent caused by the additional deposition of sediment at the energy dissipator between 2014 (Scenarios 7, 9, and 29) and 2019 (Scenarios 24, 28 and 30). The scenarios displayed in Figure 15 consider the proposed border barrier with its gates fully open. Under 100yr flow conditions (top panels), flood extent in Tijuana's Zona Norte is marginally increased by the additional sedimentation in the energy dissipator, while flood depth is increased substantially from head deep to over-head deep along the border, and from up to knee to up to waist deep further south of the border. Under this scenario mainly the PB1 and Interceptor Internacional wastewater project will experience flooding, with flood depths transitioning from up to 1 m under 2014 energy dissipator sedimentation conditions to up to 1.7 m under 2019 sedimentation conditions. The PB1 and PBCILA projects would experience up to 45 cm of flood depth. Portions of San Ysidro, north of the levee along the energy dissipator are also predicted to experience deeper flooding. For the 200yr and 500yr scenarios differences in flood extent and depth caused by the additional sedimentation are less marked, with flooding already very widespread across Tijuana and San Ysidro. Most wastewater projects will be impacted by flooding, under the 200yr and 500yr scenarios, with only Colector Carranza predicted to remain dry.

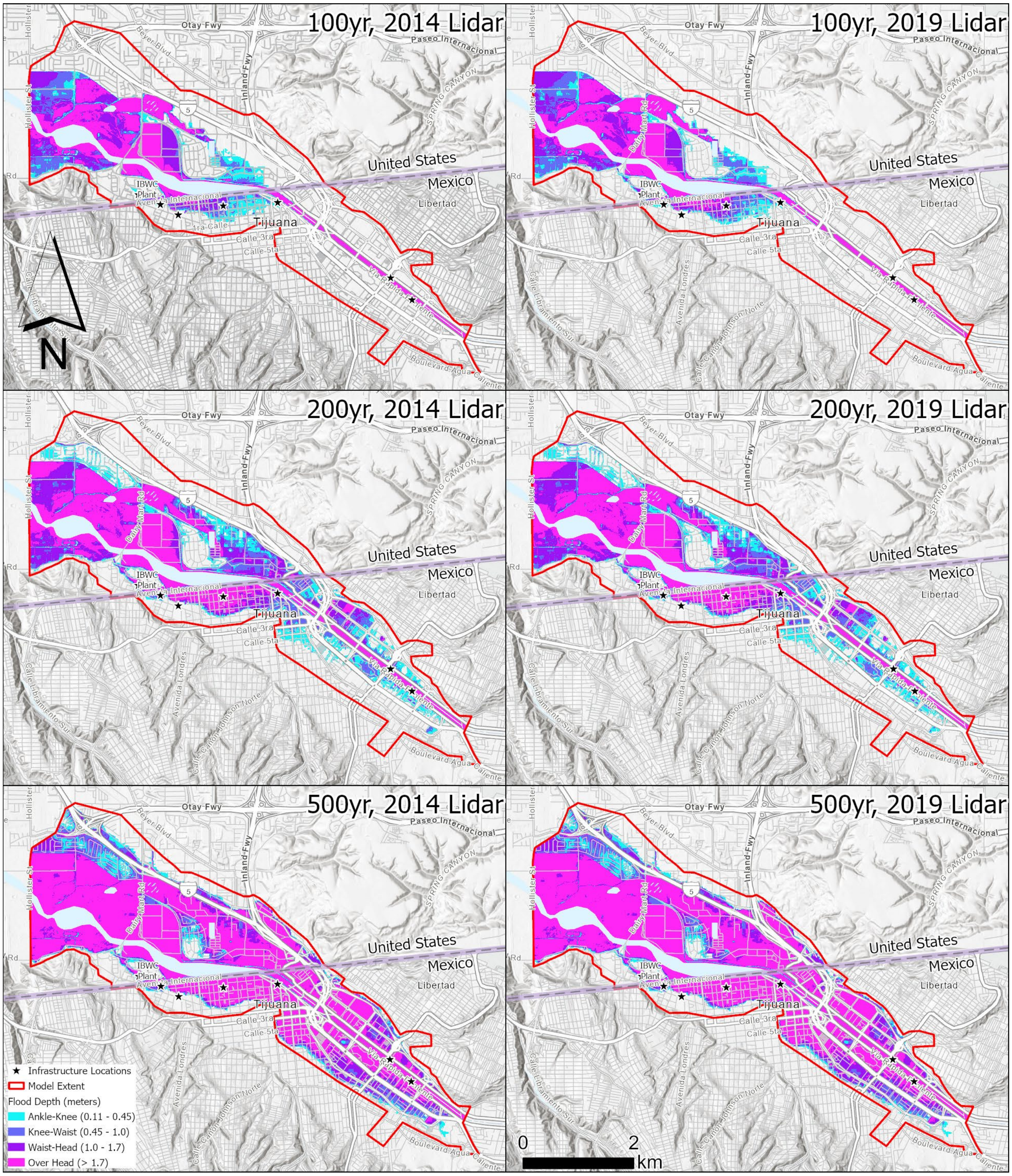

Figure 15. Flood hazard depths and extents for various return period flows and under 2014 as well as 2019 sedimentation conditions. The scenarios consider the border barrier with fully open gates.

Implication of Gate blockage:

Figure 16 visualizes the implications on the 100yr flood hazard caused by different levels of border barrier blockage as well as the additional deposition of sediment at the energy dissipator between 2014 (Scenarios 7, 13, 17, and 20) and 2019 (Scenarios 24-27).

First we focus on the effects of border gate blockage under 2019 sedimentation conditions (right panels only, viewed top to bottom). In terms of flood extent little difference is noticed between the 0% and 50% gate blockage conditions (Scenarios 24 & 25), whereby large portions of Tijuana's Zone Norte are predicted flooded. When considering flood depths, a larger proportion of the flooded extent is predicted to reach depths up to waist deep, although flood depths are slightly reduced across San Ysidro for the scenario with border barrier gates at 50% blockage. At 75% gate blockage (Scenario 26), large parts of Tijuana's Zone Norte are predicted to flood at head- or over-head levels, while San Ysidro remains largely spared from flooding through the overtopping of the southern Tijuana river levee near the US-Mexico border, and subsequent flood water diversion into Tijuana's Zona Norte. For the 100% blockage scenario (Scenario 27), most of the Zona Norte is predicted over-head flooded, parts of the Zona Este are predicted to flood to waist- and head-level, and large parts of San Ysidro on the U.S. side of the border are also predicted to flood to between ankle- and waist-level.

Second we can focus on the implications of the additional sedimentation at the energy dissipator between 2014 and 2019 (all panels, viewed left to right). Under 0% gate blockage (top panels), flood extent in Tijuana's Zona Norte is marginally increased due to additional sedimentation, while flood depth is increased noticeably (see also Figure 15). For the 50% gate blockage scenarios the same trend is visible, with progressively increasing flood depths and marginally larger flood extents compared to the 0% blockage scenarios. Much of the Zona Norte is predicted to experience at least waist deep flooding. Under the 75% and 100% gate blockage scenarios the additional sedimentation in the energy dissipator doesn't appear to contribute to large changes in flood extent and depth.

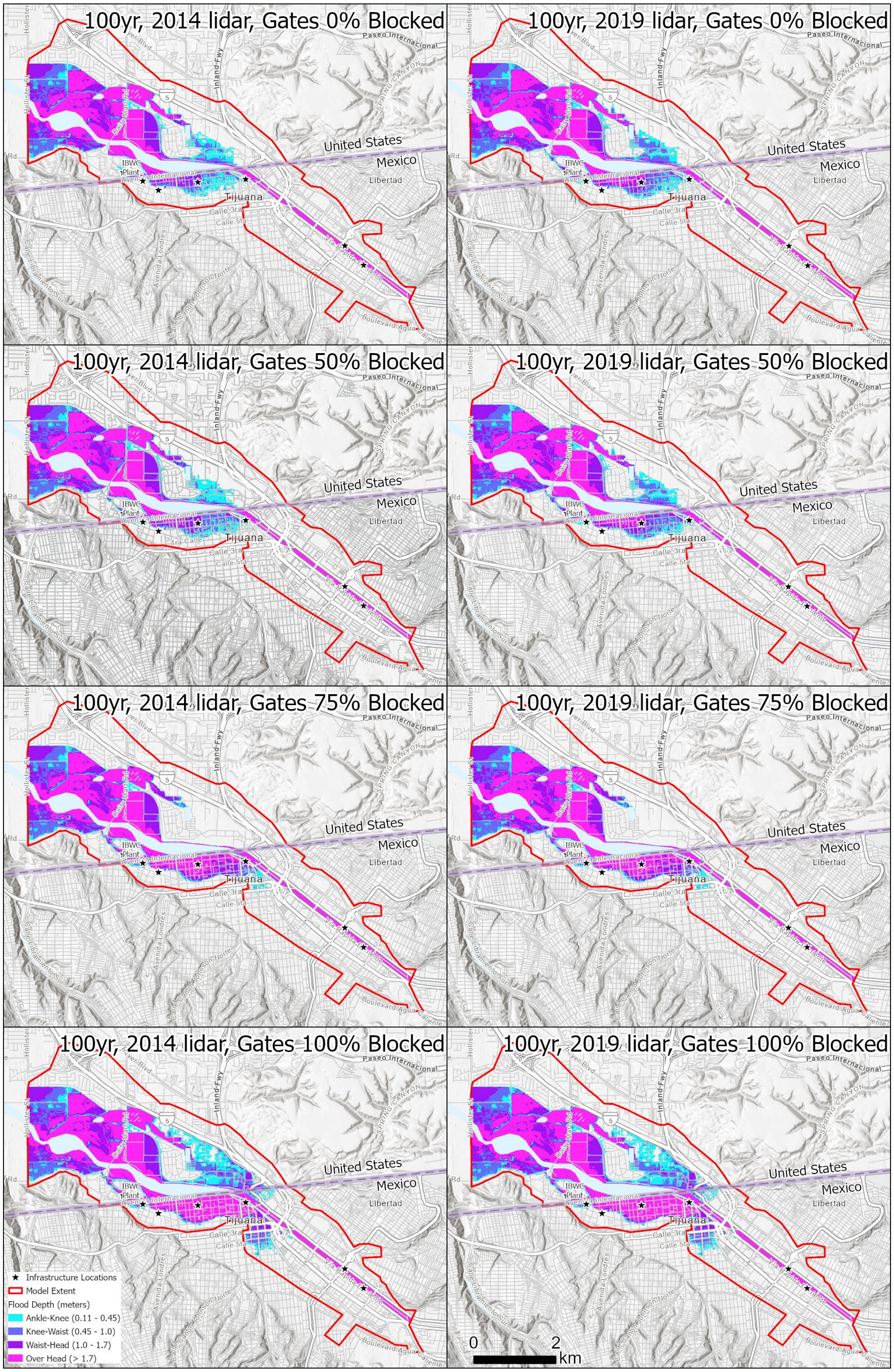

Figure 16. Flood hazard depths and extents for the 100yr scenario with various barrier gate blockage levels and 2014 sedimentation conditions compared to 2019 sedimentation conditions at the energy dissipator.

Figure 17 provides a close-up look at flood depths at the International Water Treatment Plant for the same scenarios as shown in Figure 16. Across the scenarios the treatment plant remains relatively dry, with only the 75% and 100% barrier blockage scenarios producing up to 50 cm and 90 cm respectively of flood depth along its northern levee. The flooding originates from the overtopping of the channel bank where Dairy Mart Rd. intersects Clearwater Wy, and travels east along Clearwater Wy. Also shown on Figure 17, for wastewater infrastructure projects PITAR and PB1, are maximum flood depths (demarcated by the letter “D”), relative to local ground elevation, and water surface elevations (demarcated by the letter “E”), relative to the vertical datum NAVD88.

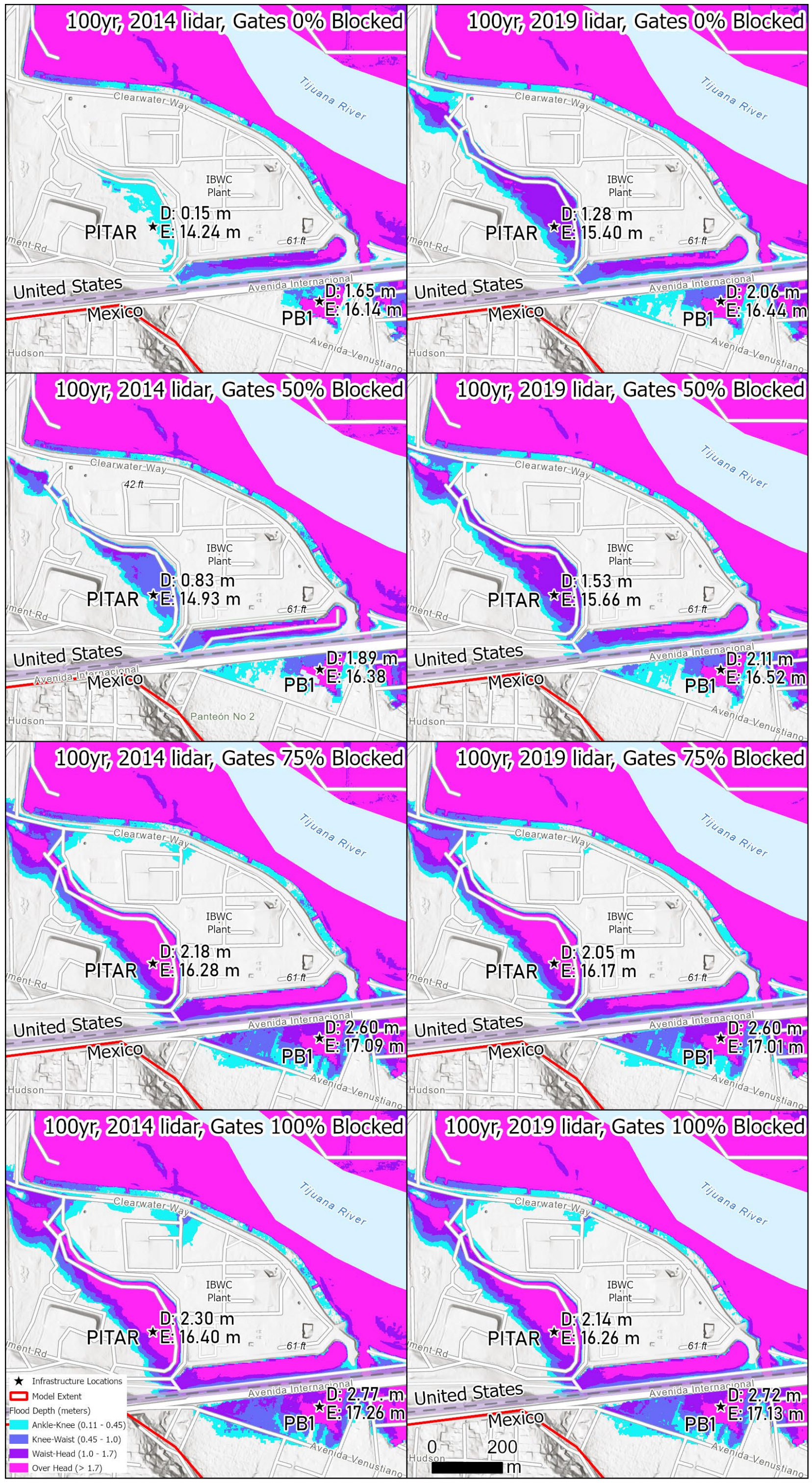

Figure 17. Close up of flood depths at IBWC Plant for 100yr flow under 2014 and 2019 channel sedimentation conditions with barrier gates blockage from 0%-100%. Shown for two wastewater infrastructure projects, PITAR and PB1, are maximum flood depths (D), expressed relative to local ground level, and water surface elevation (E), expressed relative to the NAVD88 vertical datum.

For PB1, the additional sedimentation at the energy dissipator between 2014-2019 results in a water depth increase of 40 cm and 20 cm for the 0% gate blockage and 50% blockage scenarios respectively, while blockage levels above 75% do not contribute to deeper flooding at that location. At PITAR, the additional sedimentation results in marked increase in flood depths for the 0% and 50% gate blockage levels, 1.13 m and 70 cm respectively, and a slight decrease in water depths for the 75% and 100% gate blockage scenarios (-13 cm , and -16 cm respectively).

Conclusions:

- Differences in sedimentation at the energy dissipator primarily increase flood hazard for the 100yr scenarios, and especially when barrier gate blockage is at 50% or less. For 200yr and 500yr scenarios, and border barrier blockage above 50% the additional sedimentation does not show to have a marked impact on flood extent or depth.
- The International Water Treatment Plant is predicted to stay mostly protected by flooding from the 100yr flow event, under 2019 sedimentation conditions, and various levels of border barrier gate blockage.
- Wastewater infrastructure projects across the Zona Norte are all impacted by flooding under a current 100 yr flood, with the exception of Colector Carranza, unless sedimentation is not reduced in the energy dissipator.
- Under 200yr and 500yr scenarios all wastewater infrastructure projects across Tijuana are impacted, with the exception of Colector Carranza.

Recommendation:

To assist with the removal of accumulated sediment in the energy dissipator, we recommend using hydrodynamic modeling to exploring and identify configurations of sediment removal that would be cost effective and have the greatest impact at reducing flood hazard across Tijuana, San Ysidro, and the installed wastewater treatment projects.