Channel Capacity and Flood Risk Communication on The Lower White River in Washington State

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Introduction

A recent effort in 2021 sponsored by the USACE (U.S. Army Corps of Engineers) SJ (Silver Jackets) program, a group of local officials and flood engineers for the area, came together to collaborate and develop better flood risk communication for the Lower White River in Washington State. From this effort, a framework of deliverables was created that can be applied each flood season as the ongoing effort is made to estimate channel capacity, flood extents, and to predict sedimentation through use of HEC RAS 1d and 2d modeling. Each flood season, hydraulic modeling is updated with new topo-bathy LiDAR, USGS (U.S. Geological Survey) gage data, and high-water marks to inform deployment of spotters, emergency management efforts, and reservoir regulation (USACE, 2021). From this effort, flood maps and flood warnings are updated annually for the Northwest River Forecast Center. Sediment modeling was developed, in-parallel to hydraulic modeling, to predict future conditions through the 2021-2026 period (Corum et al., 2023). Predictions were used to inform implementation of future flood protection measures for the Lower White River. This paper is a companion to the Corum et. al. 2023 paper which focuses on development of sediment modeling.

The White River drains the northern slopes of Mount Rainier, with its near infinite supply of sediment, in Washington state. The lower reaches of the river are highly dynamic, with rapidly changing sedimentation through developed areas that heavily influences channel capacity and the extent of flood risks. Cessation of dredging practices in the 1990's has left the local communities with the prospect of containing flood flows with temporary measures and new levees. In January 2009, significant rainfall on top of a melting snowpack caused high flows in the White River in Western Washington, which spilled over its banks and inundated homes, businesses, and streets in the City of Pacific. A location map is shown in figure 1. The magnitude of this 2009 event, which was regulated by the upstream MMD (Mud Mountain Dam), previously was seen to occur in 2006 without any local flooding. A photo taken during the 2009 flood event is shown in figure 2. Loss of channel capacity continues to present times, causing significant uncertainty in the appropriateness of the FEMA (Federal Emergency Management Agency) FIRMs (Flood Insurance Rate Maps), NWS (National Weather Service) forecasted flood stages, and general risk communication. Sedimentation, local levee projects, climate change, flood warnings, and MMD regulation all play into a system that can change from flood season to flood season and that has, in the past, lacked a clear picture of flood risk.

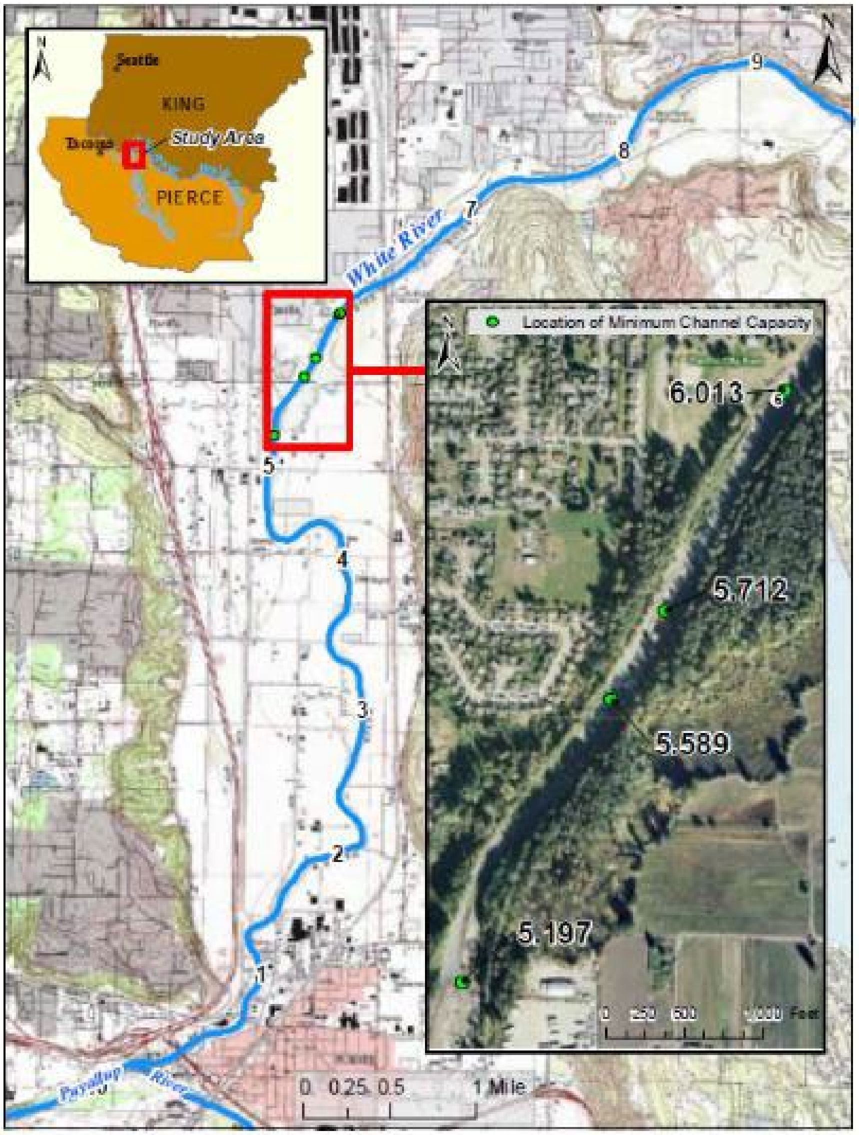

Figure 1. Study Area Near the City of Pacific, WA. Shown is 2009; Highlighting Area of Channel Capacity Concerns

Figure 2. City of Pacific Adjacent to the Lower White River in January 2009

The Washington SJ team identified several priorities for assessing flood risk and focused on the following themes:

1. Compile relevant assessments of flood risk on the lower White River completed over the last 10 years
2. Better understand the effects of climate change, MMD operations, and sediment dynamics as they relate to channel capacity
3. Reconstruct and suggest improvements in the flood risk communication strategy in the near and long term (including flood warning levels and flood map products)
4. Combine local project efforts (and proposed projects) from stakeholders into a platform that clearly articulates changes in the basin, and that is accessible to everyone
5. Improve public engagement

Floodplain and Flooding Characteristics

The heaviest rainfall and, consequently, the highest runoff into the White River generally occur during the winter storm season from November through March. Frequent sharp peaks of short duration characterize runoff during this period. However, peaks may be separated by periods of relatively low flow when temperatures drop with the intrusion of a cold air mass and there is no precipitation or, if there is any, it falls mostly as snow. Intense winter rainstorms with warm winds and accompanying snowmelt cause the river to swell from relatively low flow to flood levels within 24 to 36 hours (WCM, 2004).

The MMD project is located at RM (River Mile) 29.6 of the White River and is a single-purpose project providing flood control for the Lower White and Puyallup River valleys. The Seattle District Water Management Section has primary responsibility for regulation of the MMD project. The project is operated as a run-of-river dam most of the year, typically providing flood control only during high-flow events in winter months (WCM, 2004). Mud Mountain Dam is operated exclusively for flood risk management and was originally designed with a single control point (50,000 cfs at Puyallup River at Puyallup gage). The MMD project is presently operating on a deviation request to reduce outflows, during flood events, to 6,000 cfs from the 12,000 cfs upper limit authorized in the Water Control Plan. The original authorization for the project was an upper limit of 17,600 cfs. The deviation is in place due to construction of the barrier dam and fish trap at RM 24.2 (also operated by the USACE) and the decreasing channel capacity of the Lower White River. A release more than 6,000 cfs may result in some downstream impacts, perhaps even significant. This is considered an unavoidable consequence of needing to balance the desire to minimize downstream flood damage at relatively modest flows with a desire to minimize overall risk to the project and to the Lower Puyallup River valley (MMD, 2018). Typically, during flood events spotters are used on local levees to inform regulation of MMD.

The Lower White River is characterized by relatively flat slopes and significant overbank storage, meaning that when floods occur, they will spread out extensively through floodplain areas. Since construction of the Countyline levee setback in 2017 on the left bank, the primary flooding source has become the right bank of the White River between approximately RM 4.2 and 6.7. The Countyline Levee setback has essentially split flow, with sediment continuing to deposit in the old channel. Except for the Butte Ave levee, which is a locally owned and maintained levee, there are no permanent flood control works along this bank. Several features considered temporary flood protection measures known as “Hesco” barriers (essentially a sand filled wire-framed floodwall), sandbag walls, pumps, and supersacks, have been built since 2009.

Project Description, Goals, and Objectives

Description

The SJ team built its project around the following criteria in selecting deliverables:

- This project will help protect life safety and reduce flood risk by updating our current understanding of flood risk, which is not being accurately reflected in some of our classic communication tools (flood maps, flow warnings, etc.). Jurisdictions are generally using their own analysis and monitoring of present flood risk. Which can lead to disparity in communicating that risk. In addition, climate change will exacerbate these risk as melting snowpack and heavier rain events combine to lead to bigger floods. The outcome of this project will also aid NOAA/NWS in setting more accurate flood warning levels.
- This project will promote shared responsibility in support of flood risk reduction and communication. Efforts need to be synthesized to clearly articulate recent changes in flood risk on the lower White, what is being done about it, and what more in needed to manage risks to lives, property, and the environment.
- This project will synthesize efforts from local stakeholders in developing priority in their flood hazard mitigation plans.

Goals

- Expand the depth and distribution of knowledge and resources about changing flood risk to help stakeholders maintain resilience to that change with their flood risk management (FRM) efforts and policies.
- Raise awareness that opportunities for funding future studies may exist within the state and federal governments. FEMA may be willing to assist in funding annual updates to the channel capacity model.

- Work in a collaborative manner that utilizes expertise of the Silver Jackets team in building tools, resources, and relationships to support local planning efforts.

Objectives

- Gather present information on recent assessments, studies, research, and proposed projects.
- Update and re-calibrate the USACE channel capacity hydraulic modeling with new 2021 LiDAR data to improve accuracy for the next flood season.
- Synthesize information, data, and modeling to help build a better picture of flood risk, which can be used as a baseline to communicate risk, guide stakeholder FRM, and inform the need for future products.

Team Members

The Team consisted of the relevant partners from the Washington SJ Team, plus local stakeholders. The SJ Team is comprised of roughly 10 state, federal, and regional organizations. The SJ Team developed and submitted the proposal for this interagency project. Current project PDT agencies include (in order of federal, state, and local):

- US Army Corps of Engineers (USACE)
- Federal Emergency Management Agency (FEMA)
- US Geologic Survey (USGS)
- National Weather Service (NWS)
- WA Emergency Management Division (EMD)
- WA Department of Ecology (ECY)
- University of Washington (UW) Climate Group
- Pierce County (PC)
- King County (KC)
- City of Sumner
- City of Pacific
- City of Puyallup
- City of Auburn

Project Deliverables

A series of workshops with a focus of flood risk management, communication in the basin, and development of deliverables, were hosted by the USACE for the Washington SJ team. Several deliverables were completed as explained below. It was determined early on that a platform for exchanging documents, floodmaps, data, and correspondence was needed. The USACE manages a SharePoint designed for internal and external access. The USACE Partners SharePoint website (https://partners.usace.army.mil) was selected to initially serve this purpose. The web interface is shown in figures 3 and 4 below. The SharePoint is located at: https://partners.usace.army.mil/sites/NWS/WRFR/default.aspx.

Figure 3. Secure Access Through the I-Pass System

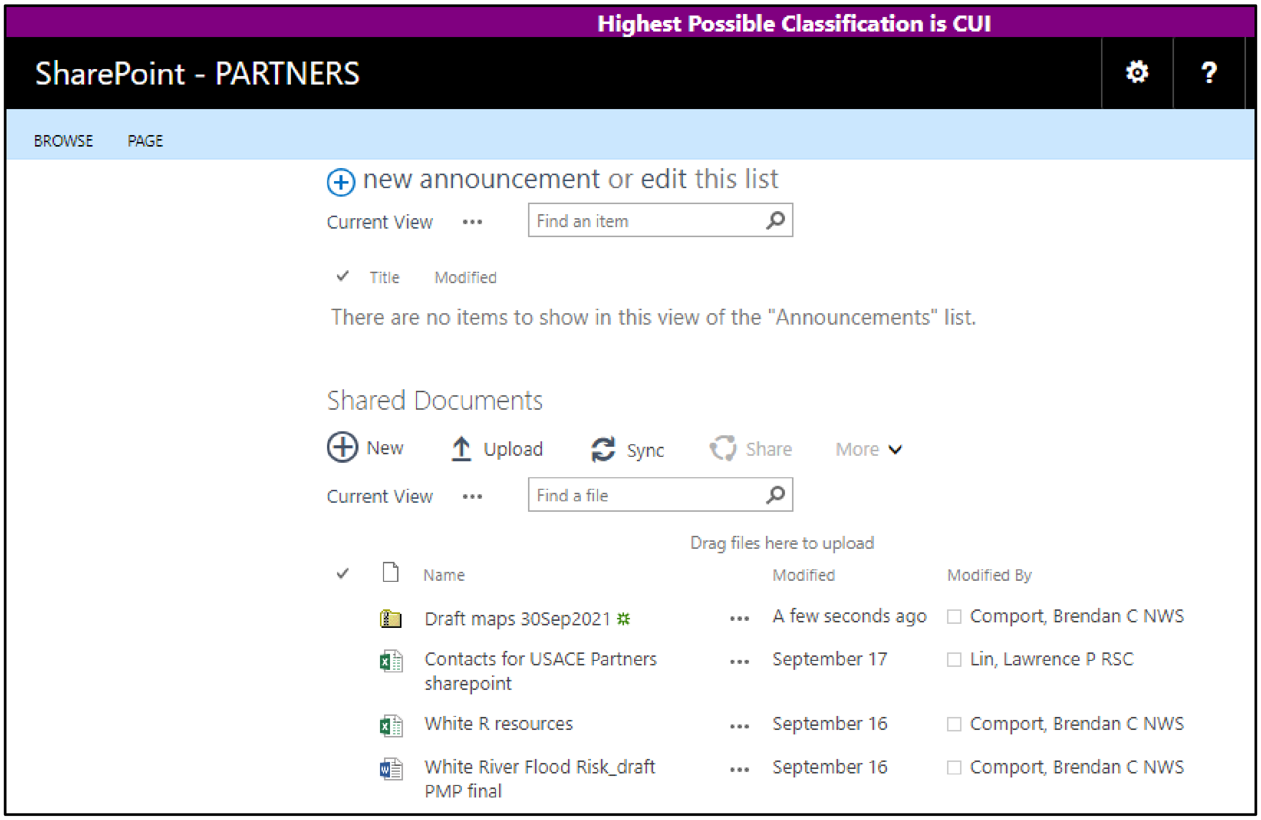

Figure 4. USACE Partners SharePoint

Database

An inventory of present and proposed projects, available data, resources, studies, and a synopsis of tools to inform flood risk was compiled by the team. The format is a simple spreadsheet titled "White River Resources" with hyperlinks to the agency with more information about each item. If this is to serve the goal of "Expanding the depth and distribution of knowledge and resources about changing flood risk…", and the objective of "Gathering present information on recent assessments, studies, research, and proposed projects", it will need to be updated continually. Columns in the spreadsheet are category, agency, name, hyperlink, POC, and summary. A sample of the spreadsheet is shown in table 1 below.

Table 1. Sample of Spreadsheet "White River Resources"

Category	Agency	Name	Hyperlink
Mapping	FEMA	Map Service Center; FIS 53033C1263G	https://msc.fema.gov/portal/search?AddressQuery=Pacific%2C%20WA#searchresultsanchor
Study	USGS	Channel-Conveyance Capacity, Channel Change, and Sediment Transport in the Lower Puyallup, White, and Carbon Rivers, Western Washington	https://pubs.usgs.gov/sir/2010/5240/
Project	King County	Lower White River Countyline Levee Setback Project	https://kingcounty.gov/depts/dnrp/wlr/sections-programs/river-floodplain-section/capital-projects/lower-white-river-countyline-a-street.aspx
Data	USACE Water Management	Public website for the Seattle District Reservoir Control Center	https://www.nwd-wc.usace.army.mil/nws/hh/www/index.html#
Study	ERDC	Modeled Sedimentation in the Lower White River Countyline Levee Setback, Washington State	https://erdc-library.erdc.dren.mil/jspui/handle/11681/27787
Forecast	NWS	National weather Service forecast for White River at R St.	https://water.weather.gov/ahps2/hydrograph.php?wfo=SEW&gage=WRAW1&view=1,0,1,0,0,0,1,0
Website	King County	Flood Hazard Management Plan	https://kingcounty.gov/depts/dnrp/wlr/sections-programs/river-floodplain-section/documents/flood-hazard-management-plan-update.aspx

Channel Capacity Modeling

A significant objective to "Synthesize information, data, and modeling to help build a better picture of flood risk, which can be used as a baseline to communicate risk, guide stakeholder FRM, and inform the need for future products" was defined previously. The channel capacity HEC RAS model consists of a 1-D channel with 2-D floodplain, begun in 2016, and has been a primary communication tool for several years to inform stakeholders with a best available estimate of flood risk. The channel capacity model was updated to HEC RAS version 6.3.1 for this effort with available data for terrain, cross sections, closures, levees, flood barriers, bridges, and culverts as of September 2021. The model was calibrated to six USGS gages located throughout the reach. This model represents the most current available product to depict estimated flood extents at various flows at the R Street USGS gage.

Overall, the channel capacity model has shown decrease in capacity, from last year, through the Auburn section just upstream of the A Street Bridge, and the Sumner section at the bend directly downstream of the Stewart St bridge. Through 8,000 cfs water is generally contained within the channel. At 9,000 cfs channel capacity is essentially reached at several locations. At 10,000 cfs developed areas of the floodplain are affected. By 12,000 cfs a significant increase in flooding occurs. A sample map of the 12,000 cfs scenario is included as figure 5. The reader is referred to the channel capacity study memorandum for further maps and details (USACE, 2021).

Stakeholders in this group expressed the desire to have a more current and flexible tool, than what exists presently in the FIRM panels from FEMA, to establish baseline flood risk in their communities. The maps developed for this effort essentially provide flood extents similar to what is found in the FIRM panels for the region. However, development of these maps is considerably more flexible and has thus far been done annually as new data is available. The exception being that these maps were developed at specific flow intervals in contrast to how FEMA typically provides estimations of the 1% and 0.2% AEP (annual Exceedance Probability) events for determination of flood insurance requirements. The USACE does not normally participate in the development or administration of the NFIP (National Flood Insurance Program). The Department of Ecology is the state administrator of the NFIP in coordination with FEMA and local jurisdictions. Coordination at that level for use of these maps is entirely up to local elected officials and flood plain administrators.

Updated Floodmaps and Warnings

As part of the channel capacity model update, the USACE worked with NWS to update Flood warnings at the website:
https://water.weather.gov/ahps2/hydrograph.php?wfo=sew&gage=wraw1

Also updated were the flood maps hosted on the website:
https://www.wrh.noaa.gov/media/sew/hydro/white_river_webpage2.htm
The model was run for several flows from 8,000 to 20,000 cfs. A sample downloadable map for the 12,000 cfs scenario is shown in figure 5.

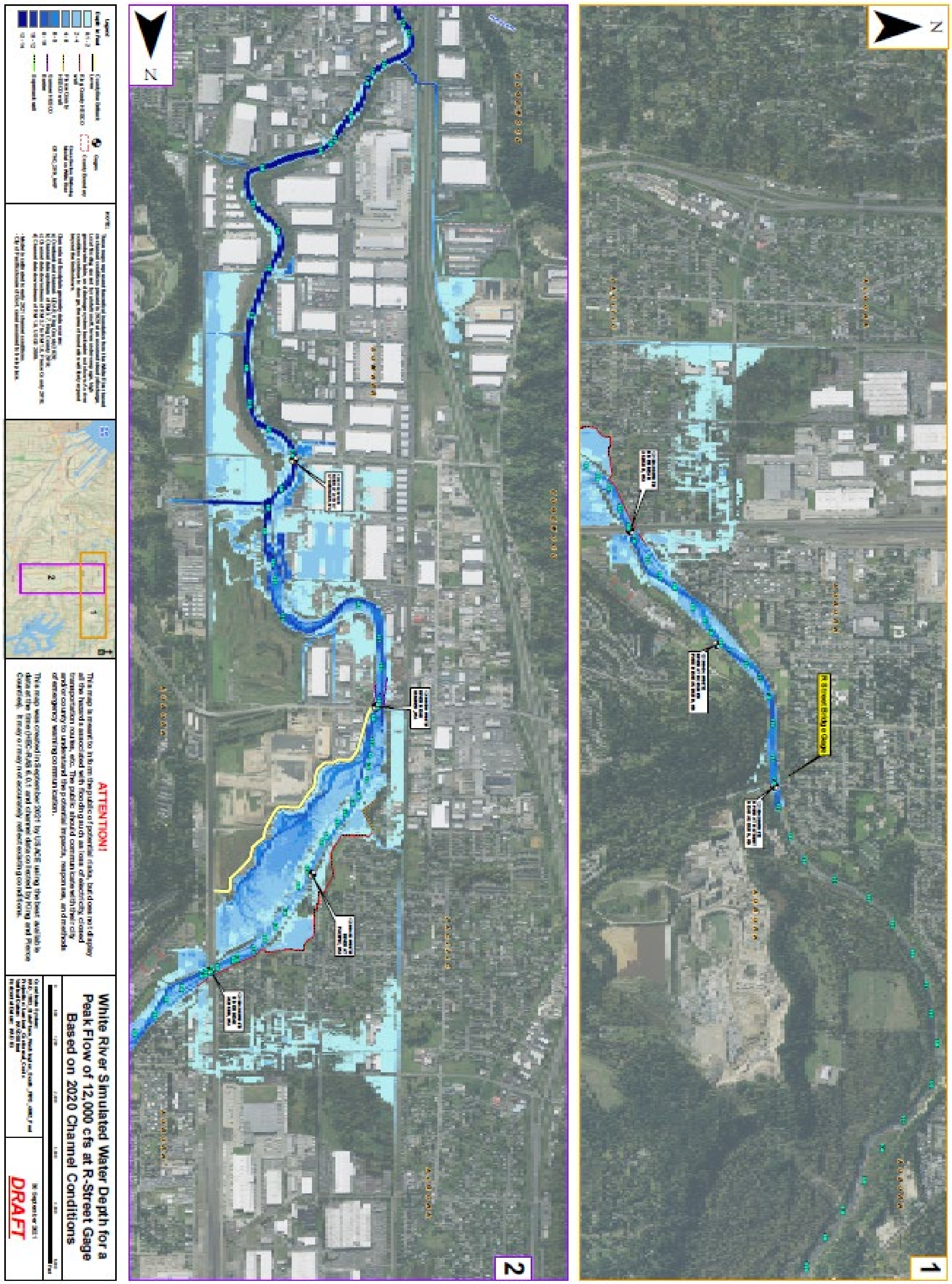

Figure 5. Sample Flood Map at 12,000 cfs for 2021 Channel Conditions

Predicted Channel Capacity

An additional task, completed after the Silver Jacket's effort, was development of Sediment modeling to predict channel capacity in the future. The calibrated hydraulic modelling was used as the starting point for sediment models. HEC RAS version 6.3.1 was used, running 1d sediment and Laursen-Copeland total load transport (Corum et al, 2023). The sediment model was calibrated to 2017-2021 channel bed changes (the period following setback of the County Line Levee), and then run to predict future channel bed change for 2021-2026. This 5-year simulated period repeated historic flows and was essentially a continuation of present regulation practices (restricting flows to 6,000 cfs). The sediment transport model's end state cross sections were exported to a new geometry, which was then converted to bathymetric DEM, which then allowed for rapid update of the 1D/2D hydraulic model cross sections and lateral structures affected by sedimentation. This fixed bed hydraulic model was then run with the aggraded channel for a range of potential floods to establish changes in channel capacity. The modeling indicates that risks in this reach are greater than the current fixed bed model suggests, and that channel capacity will likely continue to decrease in the near future despite the 2017 setback levee. Channel capacity is predicted to decrease from the 2021 estimate of 9,000 cfs to nearly 4,000 cfs by 2026. Several locations of concern were identified, and most concerning is the location immediately upstream of the A-Street Bridge on the right bank. Flow leaving at this location can inundate residential and commercial areas, before returning to the river farther downstream. Shown in figure 6 is a prediction of flood extents at 8,000 cfs in 2026 compared with 12,000 cfs in 2021. Differences in inundation between the present and future scenarios is alarming. Near pacific, the inundation extents are nearly identical between the two scenarios. Channel capacity reduction of nearly 4,000 cfs is predicted over that period. As a result of modeling efforts, the local sponsor is now pursuing deployment of additional Hesco barriers at several locations, while more permanent measures are planned. The sediment modeling thus provided and early warning system to give emergency managers greater response time and specific locations to focus attention.

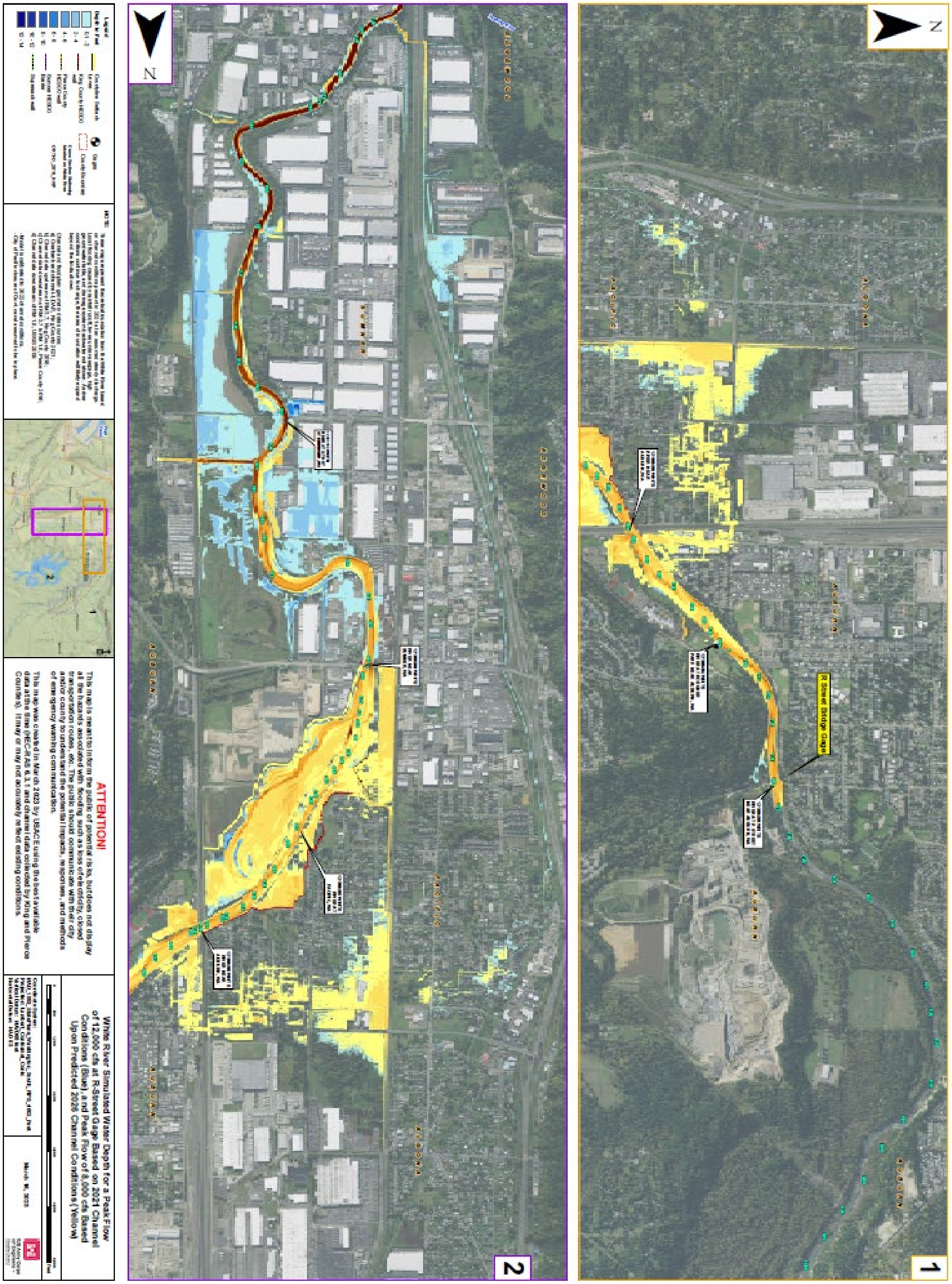

Figure 6. Sample Flood Map at 12,000 cfs for 2021 Conditions (shown in Blue) and at 8,000 cfs for 2026 Predicted Conditions (Shown in Yellow)

Recommendations for Future Work

- A product is needed that gives estimated flood extents as a graphical web-based tool that can be updated and disseminated in a timelier manner than maps can be produced. The USACE MMC (Modeling Mapping Consequence Center) is developing the static mapping web-based tool RIM (Rapid Inundation Mapping) with sliders to set different flood levels. This may be an ideal platform to use once the basin can be incorporated.
- Continued annual updates to channel capacity model as new survey and/or LiDAR data becomes available, as well as sediment modeling updates.
- Integrate probabilistic forecast methods into flood warnings to improve flood risk communication strategy.
- FEMA update to the FIS and FIRM maps for the area (likely several years out).
- Development of climate change flow estimates (likely by the University of Washington Climate Group) to run in the MMD reservoir model. This would give outflow hydrographs from the dam incorporating climate change estimates, which would then be run in the sediment model.
- Incorporate hydrographs reflecting predicted climate change flows, and predicted cross sections from sediment modeling, into the channel capacity hydraulic model to give more complete future flood predictions.

Conclusions

Through this project, much was done to develop a clear picture of present and future flood risk through development of maps, and to share knowledge and resources to assess that risk through development of the SharePoint site and spreadsheet resources. Through several meetings, the Washington SJ team was able to promote shared responsibility and to collaborate on deliverables. A framework of deliverables was developed that can be applied each flood season, illustrating how data, computational modeling, flood mapping, collaboration, and communication come together to give a complete picture of flood risk. Hydraulic modeling was updated to the latest data and calibrated. Sediment modeling was accomplished to predict future 2026 conditions and inform deployment of flood risk reduction measures. Although this project was successful in meeting many of the goals and objectives laid out earlier, there is much to be done to reduce flood risk. It is hoped that in subsequent years, climate change modeling for MMD will be available to support this effort with predicted flows. Coupling that with sediment and hydraulic modeling will provide a more comprehensive picture of future risk.

References

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