RED RIVER DIVERSION

FARGO-MOORHEAD METRO FLOOD
RISK MANAGEMENT PROJECT

FEASIBILITY STUDY - PHASE 4

Volume 1

General Report

Report for the US Army Corps of Engineers and the cities of Fargo, ND and Moorhead, MN

Prepared by:
Moore Engineering, Inc.; Houston Engineering, Inc.; Barr Engineering Company; and HDR Engineering, Inc.

April 2011

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FINAL – Version April 19, 2011

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1.0 Background

The Red River of the North and its tributaries have posed a repeated flood threat to the Cities of Fargo, North Dakota and Moorhead, Minnesota as well as to the surrounding communities. Although people and organizations (including support from the U.S. Army Corps of Engineers (USACE)) have demonstrated significant skill in defending themselves against floods, the efforts can be massive and highly disruptive to the cities and the surrounding communities. In addition, there is considerable concern over the prospect of larger floods than those that have recently occurred and that could be defended against. As a reference, the flood of record occurred during the spring of 2009, and 11 out of the 20 largest flood events in the 108 years of record happened in the past 18 years. Various plans have been formulated to varying degrees that address portions of the flood risk. However, no previous plan has offered an integrated and more permanent solution to deal with such flood risk.

This study, following several previous levels of feasibility completed over the past two years, looks at the Locally Preferred Plan (LPP) diversion alternative with upstream staging to provide flood damage reduction up to the 0.2-percent chance flood event in the Red River of the North (i.e., the 500-yr event in the Red River of the North is the design flood) for nearly 200,000 people and 80 square miles of infrastructure. For this report the LPP diversion alternative is designated as the plan comparable to the North Dakota East alignment with a maximum diversion discharge of 35,000 cfs and no upstream staging. The Federally Comparable Plan (FCP) is the Minnesota Short Diversion alignment with a maximum diversion discharge of 35,000 cfs and no upstream staging.

The primary reason for the switch in the project design concept of the LPP from the previous Phase 3 (diversion only) to the current Phase 4 (diversion and storage) of the feasibility study is as follows. To provide flood damage reduction, any proposed action not only has to deal with the peak flow of the design flood hydrograph, but also with the associated flood hydrograph volume. Without some staging or off-channel engineered storage immediately upstream of the diversion works, the proposed diversion would result in increased flood levels that could extend to the Canadian border and beyond, with approximately 4,500 structures impacted. Staging and storing water immediately upstream of the diversion works would be limited to a well defined area, as required by the National Environmental Policy Act (NEPA), with approximately 800 structures impacted.

2.0 Study Approach and Report Organization

The work carried out by the Consultant from Phase 1 through Phase 3 of this study was based on a project design concept that relied on diversion only, and it included the feasibility evaluation of four diversion alignments and eight values for the maximum diversion discharge. This feasibility analysis together with that performed by the USACE (which looked at other options) led to the determination of the National Economic Development (NED) plan and to the selection of the LPP and FCP (see Figure 1). The previous Phase 3 of this study developed the feasibility design and cost estimates for two alternative alignments of the proposed diversion, one through Minnesota (the FCP) and one through North Dakota (the LPP), in both cases considering diversion works capable of diverting 35,000 cfs from the Red River of the North and Wild Rice River (ND) during a 0.2-percent chance flood event in the Red River of the North. The feasibility analysis in Phase 3 of this study was based on the Phase 3.1 hydrology produced by the USACE (see Appendix A), which was completed using up to date data and considerations for a wet/dry cycle in the basin. Because the project design concept relied on a diversion only, the work conducted in Phase 3 was done using a one-dimensional (1D) HEC-RAS steady flow model for project feasibility design. However, a 1D HEC-RAS unsteady flow model had to be used for evaluation of impacts on flood levels downstream of the diversion outlet, as such impacts could depend on the timing of the flows and volumes of water being diverted, not only on the peak flows used for project feasibility design.

The current Phase 4 of this study develops the feasibility design and cost estimates for the LPP that includes diversion (maximum discharge of approximately 20,000 cfs) combined with staging and storage immediately upstream of the diversion works. Some minor modifications to the alignment of the LPP diversion channel with respect to Phase 3, mostly on the north end (near Harwood, North Dakota), have been incorporated too. Because the project design concept now relies on diversion and storage, the work conducted in Phase 4 has been done using a revised, expanded (in its spatial domain) and improved HEC-RAS unsteady flow model (see Figure 2) for both project feasibility design and evaluation of impacts on flood levels upstream and downstream of the proposed diversion. This hydraulic model has been developed, calibrated, validated and used for cases of peak flows on the Red River of the North paired with coincidental events on the MN and ND tributaries (including the Wild Rice River, Sheyenne River, Maple River, Lower Rush River, Rush River, and some local drains and ditches). The model runs completed in Phase 4 include the analysis of Existing Conditions and With-Project for the four more recent larger flood events in Fargo-Moorhead (1997, 2006, 2009 and 2010) as well as for four hypothetical design floods along 325 river miles of the Red River of the North (10-percent, 2-percent, 1-percent and 0.2-percent chance synthetic hydrograph events). In addition, a separate HEC-RAS unsteady flow model has been developed and used for cases of peak flows on the ND tributaries and coincidental events on the Red River of the North to perform the feasibility design of the hydraulic structures required in the ND tributaries.

Following input from the USACE Project Delivery Team (PDT), the feasibility design and cost estimates developed for the FCP in Phase 3 have been maintained in Phase 4.

It is worthwhile highlighting that the feasibility design presented in this Phase 4 of the study has benefited significantly from the input received before and after submittal of the Phase 3 report (Consultant, 2010) and the Draft Environmental Impact Statement (EIS) published last year (USACE, 2010), including several comments and suggestions from:

- the USACE-PDT;
- the USACE Agency Technical Review (ATR);
- the USACE Independent External Peer Review (IEPR);
- the Fargo-Moorhead Metropolitan Technical Committee (FMMTC), with representatives from the City of Fargo, North Dakota; the City of Moorhead, Minnesota; Cass County, North Dakota; and Clay County, Minnesota;
- State and Federal Agencies, with representatives from the Minnesota Department of Natural Resources (MnDNR); the North Dakota Fish and Game Department (NDFGD); the North Dakota Department of Health – Division of Water Quality (NDDH-DWQ); the U.S. Fish and Wildlife Service (USFWS); the U.S. Federal Emergency Management Agency (FEMA); the U.S. Environmental Protection Agency (EPA); and the U.S. Geological Survey (USGS); and
- the general public.

The project concept designs presented here have been carried out to a feasibility level using general hydrologic, hydraulic, environmental, geotechnical, structural and civil design considerations. Given the constraints imposed by the amount and quality of the information available and the timeframe to complete the different phases of the feasibility study, the feasibility designs presented in this Phase 4 report are deemed sufficient to develop Class 3 cost estimates (see Appendix G) for congressional budgetary appropriation per USACE Engineer Regulation ER 1110-2-1302. However, it is acknowledged that additional investigations on aquatic ecosystems, fish passage, ice engineering, sediment transport and geomorphology (some of these investigations are already underway); future revisions and updates of the HEC-RAS unsteady flow models; physical modeling, and potentially additional 2D numerical modeling, of the more critical hydraulic structures (more critical for the overall functioning of the project); additional site specific information (e.g., soil borings, soil mechanics laboratory tests, field-scale pile driving tests) that become available in support of detailed geotechnical and structural engineering designs may result in changes to the proposed configuration, functioning and cost of some of the project features. These changes are not anticipated to result in an overall project cost increase beyond the cost contingency recommended in this feasibility study, unless there is a change in the scope or design criteria of the project.

The Phase 4 report has been organized in three tiers. The first one corresponds to this General Report, which is intended for a general audience, and it provides a description of the project design concept (i.e., the "big picture"), benefits and impacts, and cost estimates. This General Report also presents some specifics about the considerations used for determining the configuration, sizing and functioning of the main project features. The second tier corresponds to the main sections of Appendices A through G, which is intended for a more technical audience (including the different State and Federal Agencies), and it provides more specifics about the considerations used for the hydrologic, hydraulic, environmental, geotechnical, structural and civil design aspects and feasibility analysis of the proposed diversion works. The last tier corresponds to the Exhibits within some of the Appendices referred to above, which is intended for the specialists interested in learning all the details (including computational sheets) behind the feasibility design and cost estimates. The hard copies of the Phase 4 report are accompanied by DVD's with all the relevant electronic files, including those related to the HEC-RAS unsteady flow models for hydrology/hydraulics analysis and the MII files for cost estimates.

3.0 Summary of Project Alternatives and Features

3.1 General Design Considerations

As indicated above, the project proposed is intended to provide flood damage reduction up to the 0.2-percent chance flood event in the Red River of the North; that is, the 500-yr event in the Red River of the North is the design flood. Flood damage reduction has been defined in terms of target stages (or water surface elevations) in the Red River of the North at the USGS gage in Fargo. For reference, a stage of 30 feet corresponds to the start of major flooding in the City of Fargo, and the flood of record in the early spring of 2009 (about a 2-percent chance or 50-yr flood event) resulted in a stage near 41 feet. The target stages were set in Phase 3 and have served as the main reference for the Phase 4 feasibility design.

More specifically, the following main criteria have been used for feasibility design and evaluation of impacts on flood levels in Phase 4 of the study:

- to match the model Phase 3 With-Project stage in the Red River of the North at the USGS gage in Fargo within ±0.15 feet, such that the difference in project benefits between the Phase 4 and Phase 3 feasibility designs is less than 5 percent (email communication from USACE-PDT dated February 12, 2011);
- to eliminate adverse impacts on floods levels downstream of the diversion channel outlet at a point that is located upstream of the Canadian border, such that the area to be impacted is well defined and NEPA requirements are met. The elimination of impacts is considered as a difference in water surface elevations between model With-Project and Existing Conditions that is within ±0.04 feet. Because the tolerance used in HEC-RAS is 0.1 feet for water surface elevations in storage cells (i.e., model representation of floodplain), the precision of the model results is not greater than 0.1 feet. Therefore, the impacts on water surface elevations are rounded to the nearest 0.1 feet for flood management purposes, even though the model results are reported to the nearest 0.01 feet for transparency (email communication from USACE-PDT dated January 25, 2011); and
- to limit the amount of staging upstream of the diversion works (in order to accomplish the two criteria above) without the need for an engineered storage area that encroaches too close into the most populated centers within the protected area. It is an implicit goal to limit the extent of the area impacted, such that the number of structures affected with this Phase 4 feasibility design is less than that with the previous Phase 3 feasibility design (see general discussion in Section 1 above).

The project feasibility design has also considered measures for an effective routing of the Standard Project Flood (with a peak flow that is approximately 70 percent larger than that of the design flood) that does not compromise the integrity of the flood protection infrastructure, hence to avoid a catastrophic failure of the diversion system that could result in loss of life in the protected area. In addition, the design of the hydraulic structures in the ND tributaries have been based on the peak flows associated with the

0.2-percent chance flood event in the ND tributaries, which can be larger than the ones associated with the coincidental event to peaks in the Red River of the North.

Although it is not the goal of this General Report to present a comprehensive list of all the design criteria that have guided the feasibility design presented in the Phase 4 report (see Appendices C-F for details), some of the other key general design considerations follow below:

- passive over active (e.g., gated) flood control operational systems is preferred, except in the main line of flood protection at the south end of the diversion works, and possibly also at locations where backwater effects or interior flood control could require active systems;
- limiting the footprint of the diversion infrastructure is desired, to minimize direct and potential indirect environmental impacts;
- maintaining ice and debris flows in the rivers rather than in the diversion channel is preferred. In some cases, heating provisions may be needed to reduce the risk of freezing at critical diversion locations;
- avoiding operation of the diversion system during smaller floods is desired, to minimize impacts on the aquatic ecosystems and fisheries as well as on sediment transport and geomorphology of the affected riverine systems. In some cases, fishways may be desired to allow for fish migration during larger floods;
- designing infrastructure that meets geotechnical and structural engineering standards (from the USACE and industry) is required, to secure the physical integrity of the diversion works during the life of the project, given appropriate operation and maintenance practices; and
- developing flood protection infrastructure that is cost effective, to provide the level of flood damage reduction that is needed within the protected area.

3.2 HEC-RAS Unsteady Flow Model

The Existing Conditions HEC-RAS unsteady flow model was developed with sufficient detail to be used as a baseline for project feasibility design as well as benefit and impact analysis. It was calibrated based on the 2009 spring flood and the calibration was verified using the 2006, 1997, and 2010 historic spring flood events. The 10-percent, 2-percent, 1-percent, and 0.2-percent annual chance synthetic flood events were developed as the primary means to evaluate Existing Conditions, to assist with project feasibility design, and to analyze potential impacts from flood mitigation alternatives (LPP and FCP) being considered as part of this project.

The hydraulic analysis spans approximately 325 miles of the Red River of the North from near Abercrombie, North Dakota through Fargo, North Dakota and Moorhead, Minnesota to the downstream end at Drayton, North Dakota. The communities of Fargo and Moorhead are located approximately 453 river miles above the mouth of the Red River of the North at Lake Winnipeg, Manitoba. The river model geometry is highlighted in Figure 2. It includes the Red River of the North main stem and several tributaries. The Phase 2 study area originally extended north only to River Mile 375 at Halstad, MN. When it was found that downstream impacts could not be fully defined (zero impact location) within the original study extents, the model was first extended to River Mile 316 near Thompson, North Dakota (Phase 3), and then to River Mile 198 at Drayton (Phase 4). It has also been extended upstream on the Red River of the North to near Abercrombie, North Dakota at approximately River Mile 524. The model was also extended farther upstream on the Sheyenne and Maple Rivers to better define the breakouts and flow distribution on the western side of the project.

The HEC-RAS unsteady flow model geometry was developed by combining geometry from existing unsteady and steady state models with new geometry developed for this project. The combined geometry includes approximately 880 storage areas and 2935 cross sections. The cross sections were created using a hybrid of LiDAR elevation data and surveyed channel bathymetry. They were extended upstream on the Red River of the North and upstream on most of the tributaries to locations with input data from USGS stream gages. The storage areas and storage area connections were developed using LiDAR elevation data and field survey. Hydraulic structures (bridges and culverts) were created with survey data or were estimated depending on their location. The source and quality of data must be considered when using the model for analysis and when reviewing results. Appendix B provides additional documentation on the geometry sources and quality.

The HEC-RAS unsteady flow model was calibrated to the 2009 spring flood event using high water mark and gage data obtained from city, county, and federal agencies. This flood event was chosen for the calibration event because it was the flood of record and was well documented by high water marks and stream gage data. The model was generally calibrated to a tolerance of within one-half foot of the 2009 spring flood high water marks, which matches FEMA's criteria for hydraulic model calibration. The model was verified using the spring floods of 2006 (fifth highest), 1997 (second highest), and 2010 (sixth highest). Temporary flood protection measures (levees) specific to each flood event were added to the respective model geometry. The temporary flood protection measures were removed for the synthetic design events. Calibration included adjusting model geometry parameters such as Manning's "n" values, ineffective flow limits, overbank reach lengths, evaluating different model representations of flow through the floodplain, and verifying the quality of observed inflow data.

Model inflows for the HEC-RAS unsteady flow model consist of nearly 80 inflow hydrographs. Some originate at USGS gage locations, others are un-gaged local inflows. The hydrograph development procedures used for historic events and synthetic events are similar. An inflow hydrograph was inserted at the upper boundary condition of each river reach and intermediate hydrographs were added as local inflow to help match the target hydrographs on the Red River of the North. USGS stream gage hydrographs (daily data) were inserted at the upstream boundary condition of each stream for historic events. Synthetic design events used a balanced hydrograph at the upstream end of the Red River of the North and the 2006 USGS stream gage hydrograph with a specified multiplier on each of the upstream ends of the tributaries. The typical multipliers vary depending on flood event, with some additional variation by watershed. The 10-percent chance multiplier is 0.65, the 2-percent chance multiplier is 1.40, the 1-percent chance multiplier is 1.80, and the 0.2-percent chance multiplier is 2.30.

Local inflow hydrographs were estimated to supplement the modeled hydrographs between calibration locations in the Red River of the North. The model was executed with known upstream boundary condition hydrographs (historic or synthetic). The flood hydrographs were then routed downstream to the next match-to location in the HEC-RAS unsteady flow model. These are stream gages for historic events and balanced hydrograph locations for synthetic events. The difference between the routed hydrograph and the observed (gage or balanced hydrograph) is the required local inflow hydrograph. This hydrograph is adjusted for routing and is spatially distributed amongst the local un-gaged drainage areas. Therefore, the model runs for historic events and synthetic events includes upstream end hydrographs and local inflow hydrographs. Less detail was placed on the model geometry and inflows downstream of Thompson. The tributaries in this model reach were not modeled and all synthetic inflow hydrographs were created by spatially distributing all local inflows across the contributing drainage area.

The With-Project HEC-RAS unsteady flow model was developed based on the Existing Conditions HEC-RAS unsteady flow model described above, and it included the modification of the storage cells and lateral structures (i.e., model representation of the floodplain) along the diversion alignment to allow for the diversion channel and hydraulic structures geometry to be merged with the Existing Conditions model. Utilizing GIS and HEC-RAS capabilities, a corridor of sufficient width to accommodate the diversion channel and spoil banks was cut through the storage areas included in the model. Some storage areas were split into two smaller areas and some resulted in one smaller storage area. After this was completed, the storage area connections were adjusted to reflect the changes. In addition, the upstream staging and storage areas identified for this project feasibility design were incorporated into the model along with the associated connections.

Due to the amount of time required for the unsteady state simulations to be completed, utilizing the initial HEC-RAS unsteady flow models for optimizing the diversion channel design would not have been efficient, especially considering the timeline for completion of this phase of the feasibility study. As the unsteady state baseline models were being modified, a steady state model was created to generate an initial diversion design that could be inserted into the unsteady state model for further refinement. However, the feasibility design as well as the evaluation of impacts on flood levels upstream and downstream of the project that is presented in this Phase 4 report reflects the hydrologic and hydraulic modeling using the With-Project HEC-RAS unsteady flow model. This modeling incorporates the proposed configuration of the diversion channel (see Appendix D) and primary hydraulic structures (see Appendix F).

3.3 Locally Preferred Plan (LPP)

3.3.1 Summary of Project Features

The main features consist of the LPP diversion channel, Storage Area 1 and tie-back levees, the primary inlet structure, the control and diversion structures at the Red River of the North and ND tributaries, and the outlet structure (see Figure 1). Additionally, the LPP includes 19 highway bridges and 4 railroad bridges that cross the diversion channel.

The LPP diversion channel starts approximately 9 river miles south of the confluence of the Red River of the North and Wild Rice River, leads west toward the existing Horace to West Fargo diversion, then north around the Cities of Fargo and West Fargo, and ultimately re-enters the Red River of the North 8 river miles north of its confluence with the Sheyenne River. The alignment is approximately 36 miles long. The diversion channel geometry was determined based on required conveyance capacity, which increases in the downstream direction to accommodate diversion from the ND tributaries and numerous legal drains (see Figures 5-8), and then modified based on geotechnical slope stability analysis at various reaches along the diversion. Two other goals considered were first to result in a 100-yr (1-percent chance) water surface elevation in the LPP diversion channel that is mostly below existing ground for the reach between the inlet structure and the Maple River crossing, and second to reduce (compared to Phase 3) the volume of excavation of Brenna clays (see Figure 3). For the main reach downstream of the primary inlet structure, the LPP diversion channel would have an earth excavated trapezoidal cross section (except at the location of hydraulic structures), bottom width of 250 feet, and sideslopes of 7H:1V above and below benches of varying width. A low flow pilot channel would run along the bottom of this reach, and erosion protection at the toe of the main channel sideslopes would be provided. Upstream of the primary inlet structure, the diversion channel would have a smaller cross section and a longitudinal slope that follows natural topography, as it is mostly intended for local drainage and hydraulic conveyance during smaller flood events, not for controlling flows diverted downstream during the larger flood events.

The main hydraulic structures controlling the flows passing into the protected area during the larger flood events are the control structures proposed on the Red River of the North and Wild Rice River, with effective flow widths of 150 feet and 60 feet, respectively. These gated structures would be operated only when the forecasted peak flow of the incoming hydrograph in the Red River of the North at the USGS gage in Fargo is greater than 9600 cfs, which has a frequency of approximately 2 days per year on the average (note: it does not happen every year for 2 days). Otherwise, the structure resembles a bridge (with fully open gates). Secondary by-pass channels for fish passage have been included at both of these structures. The main line of flood protection at the south end of the project would be completed with Storage Area 1 and the primary diversion inlet structure. Storage Area 1 is a 4360-acre area on the north side of the LPP diversion channel between the Wild Rice River and the Sheyenne River, which will be formed by nearly 12 miles of embankments. Storage Area 1, combined with staging in the floodplain (see Figure 4), will eliminate impacts on flood levels downstream of the diversion channel outlet. The diversion inlet structure is a passive weir (no gates or other regulation controls), with an effective flow width of 90 feet. Although the maximum diversion flows at this location are smaller in Phase 4 than in Phase 3, the increased headwater and greater vertical drop have warranted a change to an Ogee-type concrete spillway.

The other main hydraulic structures include three types at different locations along the LPP diversion channel. The first type is located at the Sheyenne River and Maple River. It would include a combination of a transition to a reinforced concrete rectangular cross section in the LPP diversion channel, with a total width of 250 feet; a reinforced concrete aqueduct crossing of the LPP diversion channel transition, with approximate dimensions 50 feet wide and 20 feet high, which would include roughness elements to provide flow complexity patterns and a low flow channel to avoid freezing during winter; and a sheetpile-rockfill protected spillway (similar concept to that used at the inlet structure of the West Fargo diversion in the Sheyenne River), which would be approximately 300 feet wide. The crest elevation of the spillway would be set at the 2-yr water surface elevation associated with the peak flow in the tributary (it will be the sum of the 2-yr peak flows in the Maple River, Lower Rush River and Rush River at the Maple River), such that up to this event the entire tributary flow would be passed through the aqueduct into the protected area, but for larger events most of the tributary flow would be diverted into LPP diversion channel. The second type is located at the Lower Rush River and Rush River. It would include a combination of a vertical drop (this is also proposed for Drain 14), with a total width of 60 feet and 100 feet at the Lower Rush River and Rush River, respectively; and a fishway consisting of 40 feet wide riffle-pool sequences, that would extend from the tributary channel down to the low flow pilot channel of the LPP diversion channel. The entire tributary would be diverted into the LPP diversion channel during all flow conditions, and to compensate for the loss of approximately 5.5 miles of existing tributary channels (the channel was built by the USACE several decades ago to convey the natural overland flow pattern in this area), the lower 11 miles of the low flow pilot channel in the LPP diversion channel would be allowed to meander. The last type is the outlet structure, which would be an Ogee-type concrete spillway, with an effective flow width of 250 feet. Although the maximum diversion flows at this location are smaller in Phase 4 than in Phase 3, the significantly greater vertical drop have warranted the change in the concept feasibility design at this location.

3.3.2 Upstream Staging/Storage and Downstream Impacts – Historic Events

As indicated above in Section 2, work completed in Phase 4 includes the modeling of Existing Conditions and With-Project (see Figures 3-14) for the four more recent larger flood events in Fargo-Moorhead (1997, 2006, 2009 and 2010). Although these model runs are not intended for project feasibility design or for flood damage reduction evaluation, they provide two very tangible benefits. First, they offer the possibility to better communicate the project impacts to all stakeholders and the general public because they can relate to how the project would change the conditions that were experienced during the recent larger flood events. It is more reasonable to anticipate that this information could be conveyed in a clear way, as there is no need to explain concepts that are not familiar to a layperson, like the meaning of balanced hydrographs or return periods. However, the caveat to highlight is that the model Existing Conditions for historic and synthetic event comparisons do not include the emergency protection measures that were in place during these historic events. The second benefit of having conducted these model runs is that they allow estimation of project upstream staging/storage and downstream impacts without having to assume that the magnitude and timing of tributary flows affect the magnitude and timing of flooding downstream; this is better captured with looking at four historic events versus the synthetic event analysis.

In general, the comparison of model Existing Conditions and model With-Project for these four historic flood events sheds lights on the magnitude of upstream staging/storage that is required to eliminate impacts on flood levels downstream of the diversion outlet; for more details on the model results, see Table 1. Maps that show the Existing Conditions and With-Project floodplain are included in Appendix C.

The review of the model Existing Conditions shows that the peak stage in the Red River of the North at Fargo was near 40 feet during the historic 1997 and 2009 flood events, whereas the peak stage at this location was near 37 feet during the historic 2006 and 2010 flood events. For additional reference, the first two larger flood events were close to a 2-percent chance event in Fargo, whereas the other two were close to a 5-percent chance event in Fargo. For the two larger historic flood events, if the water levels upstream of the diversion works are staged from model Existing Conditions 912-914 feet to model With-Project 922 feet, then downstream impacts could be eliminated before reaching the downstream end of the model at Drayton. For the 2006 and 2010 events, staging would be from model Existing Conditions 910-911 feet to model With-Project 919 feet in order to eliminate downstream impacts. Although the relative staging (difference in water surface elevations for model With-Project and Existing Conditions immediately upstream of the diversion works) is similar for the four events, it appears that the ultimate water surface elevation upstream of the diversion works is the one dictating the downstream impacts. In other words, the additional volume of approximately 75,000 acre-feet that can be staged and stored between 919 feet (approximately 125,000 acre-feet) and 922 feet (approximately 200,000 acre-feet) explains the elimination of downstream impacts for the two larger historic flood events. And this occurs even when the With-Project stage at the Red River of the North in Fargo is very similar for the four historic flood events (within a range of 1.5 feet). All of this suggests that in order to eliminate downstream impacts, upstream staging and storage to water surface elevations around 922 feet (which includes over 50,000 acre-feet in Storage Area 1) would be required, and more importantly, that the diversion works need to be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular those during the rising limb of the hydrograph.

3.3.3 Upstream Staging/Storage and Downstream Impacts – Design Floods

Work completed in Phase 4 also includes the modeling of Existing Conditions and With-Project for four synthetic events (0.2-percent, 1-percent, 2-percent, and 10-percent chance design floods), which have been used for project feasibility design, flood damage reduction evaluation and impacts assessment on flood levels upstream and downstream of the proposed diversion. It is important to clarify here that the models referred to above and the discussion in this section of the General Report correspond to peak flows on the

Red River of the North paired with coincidental events on the ND tributaries. For project feasibility design, separate models have been created for cases of peak flows on the ND tributaries paired with coincidental events on the Red River of the North in order to appropriately size the hydraulic structures in the ND tributaries for extreme events in these rivers.

The summary results of model Existing Conditions (which do not include emergency protection measures that were in place during the larger historic events, as indicated above) and model With-Project at gaged locations along the Red River of the North are presented in Table 2. Maps that show the Existing Conditions and With-Project floodplain are included in Appendix C, and a condensed version of areas of inundation upstream and downstream of the project is provided in Figures 15-22.

The review of the model Existing Conditions shows that the flows immediately upstream of the diversion works in the Red River of the North main conveyance channel vary between approximately 10,300 and 28,600 cfs from the 10-percent to the 0.2-percent chance design flood. Accordingly, the model Existing Conditions flows and stage in the Red River of the North at the Fargo gage (which include the contribution of the Wild Rice River) vary between approximately 17,000 and 61,700 cfs and between approximately 34.6 and 43.1 feet, respectively, from the 10-percent to the 0.2-percent chance design flood. For the two larger synthetic events (i.e., the 0.2-percent and 1-percent chance design floods), if the water levels upstream of the diversion works are staged from model Existing Conditions 915-916 feet to model With-Project 922-923 feet, then downstream impacts could be eliminated before reaching the downstream end of the model at Drayton and the model With-Project stage in the Red River of the North at the Fargo gage is within ±0.15 feet of the Phase 3 values. This range of staged water surface elevation upstream of the diversion works (which translates into over 50,000 acre-feet in Storage Area 1, and a total volume staged/stored of approximately 200,000 acre-feet), is similar to that obtained for the two larger historic flood events in the Red River of the North at Fargo (i.e., 2009 and 1997), and it reinforces the suggestion that in order to eliminate downstream impacts for extreme floods, upstream staging and storage to water surface elevations near 922 feet would be required.

When looking at the magnitude of the relative staging upstream required to eliminate downstream impacts for the smallest synthetic event analyzed (i.e., the 10-percent chance design flood), from water surface elevation for model Existing Conditions 908 feet to water surface elevation for model With-Project 916 feet, it becomes clear that the diversion works need to be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular during the rising limb of the hydrograph. That is, the overall performance of the diversion works (to meet the three main design criteria listed above) depends on the trade between storage (through upstream staging or Storage Area 1) and release (through the diversion channel or the control structure on the Red River of the North) of the incoming flood flows and volumes during the rising limb of the hydrograph. This in turn may imply that, as found during several trial runs of the HEC-RAS unsteady flow model for With-Project, allowing more water to pass into the protected area through the control structure on the Red River of the North does not necessarily help to eliminate impacts downstream if the timing of this release is similar to the timing of the peak flows and flood volumes being conveyed through the diversion channel. Indeed, it was found that the best operational scheme of the gates in the control structure on the Red River of the North (the best to eliminate downstream impacts without increasing the upstream staging) was the one that decouple the peak flows and flood volumes conveyed through the diversion channel from those passing into the protected side. Thus, for all synthetic events, the operational scheme of these gates proposed at this feasibility level is to progressively close them during the rising limb until approaching (but before) the peak of the incoming hydrograph, keep them at their lowest position until the peak flows and flood volumes in the diversion channel have exited the diversion, and then progressively open the gates to reach the Phase 3 stage in the Red River of the North at the Fargo gage.

3.4 Federally Comparable Plan (FCP)

3.4.1 Summary of Project Features

The FCP diversion alternative for the Phase 4 feasibility study is the same as the one presented in the Phase 3 report. The main features consist of a control structure on the Red River of the North, the diversion channel, and the outlet structure for the diversion channel. The FCP diversion channel starts approximately one mile north of the confluence of the Red River of the North and Wild Rice River, extends north around the Cities of Moorhead and Dilworth and ultimately re-enters the Red River of the North near its confluence with the Sheyenne River. The alignment is approximately 25 miles long. In addition to the main diversion channel, this alignment requires additional channels upstream of the Red River control structure to prevent stage increases upstream of the project along the Red River of the North and Wild Rice River. A supplementary extension channel parallels the Red River of the North upstream of the entrance to the diversion channel to allow for additional capacity to offset blockage of the breakouts to Cass County Drains 27 and 53. This secondary FCP extension channel is approximately 3 miles long and has a 215 foot bottom width. A second, shorter channel, the Wild Rice Breakout Channel, was added near the intersection of I-29 and Cass County Highway 16. This channel, which is less than one mile long and crosses under I-29, will convey water across I-29 that would have naturally broken out to Cass County Drain 27 and has a 50 foot bottom width. Additionally, the FCP includes 20 roadway bridges and 4 railroad bridges that cross the diversion channel.

The diversion channel consists of an inlet weir, which consists of a passive (i.e., no gates or movable parts) compound weir with a crest elevation approximately one half foot above the water surface elevation for the 3.6-yr event (9,600 cfs) from the steady state hydrology. The diversion channel geometry was determined based on hydraulic capacity and then modified based on geotechnical analysis at various reaches along the diversion. The feasibility design sections for the FCP diversion channel include a 10H:1V slope near the bottom below a bench of varying width. Above the bench, the sideslope is 7H:1V up to existing ground and the spoil piles are offset 50 feet from the top of the slope. The bottom width of the FCP diversion channel varies from 225 feet at the downstream end to 400 feet beginning near Clay County Highway 22. A low flow pilot channel runs along the bottom of the diversion channel.

For the FCP, the control structure located on the Red River of the North is similar to the one proposed for the LPP. However, in this case the design goal for this structure is to avoid increasing water surface elevations upstream in the Red River of the North, while minimizing (not necessarily eliminating) impacts on flood levels downstream of the diversion. The outlet of the FCP diversion channel into the Red River of the North consists of riprap covering approximately 300 feet of the downstream end of the diversion channel.

3.4.2 Downstream Impacts – Historic Events

Similar to the LPP, Phase 4 includes the modeling of Existing Conditions and With-Project (FCP) for the historic 1997, 2006, 2009, and 2010 spring floods to determine the downstream impacts. These impacts are related to the loss of floodplain storage and changes to timing as a result of the flows conveyed through the diversion channel. For the FCP downstream impact analysis, the emergency protection measures that were in place during these historic event calibrations/verifications were not included. The FCP diversion channel from the Phase 3 design was incorporated into the Phase 4 HEC-RAS unsteady flow model. The With-Project water surface profiles were then compared to the Existing Conditions water surface profile to quantify the project impacts. The downstream impact tables for the FCP for the historic 1997, 2006, 2009, and 2010 spring flood events are presented in Appendix C, and a summary is provided in Table 3.

In summary, the downstream impacts begin just downstream from the diversion channel outlet and gradually attenuate downstream. Two factors that contribute to localized increases in downstream impacts are the floodplain width as well as timing of tributaries that enter the Red River of the North downstream from the diversion channel outlet. Maps that show the existing conditions and with-project floodplain are included in Appendix C. For the historic 1997 flood event, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (0.63 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.03 feet). For the historic 2006 flood event, the maximum downstream impacts occur between Fargo, ND and Halstad, MN (0.37 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.01 feet). For the historic 2009 flood event, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (1.12 feet) while the minimum impact occurs between Oslo, MN and Drayton, ND (0.08 feet). For the historic 2010 flood event, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (0.37 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.02 feet).

3.4.3 Downstream Impacts – Design Floods

Phase 4 also includes the modeling of Existing Conditions and With-Project (FCP) for four synthetic events (0.2-, 1-, 2-, and 10-percent chance design floods) to determine the downstream impacts. These impacts are related to the loss of floodplain storage and changes to timing as a result of the diversion channel. The FCP diversion channel from the Phase 3 design was incorporated into the Phase 4 HEC-RAS unsteady flow model. The With-Project water surface profiles were then compared to the Existing Conditions water surface profile to quantify the project impacts. The downstream impact tables for the FCP for the 0.2-, 1-, 2-, and 10-percent chance design flood events are presented in Appendix C, and a summary is provided in Table 4.

In summary, the downstream impacts begin just downstream from the diversion channel outlet and gradually attenuate downstream. Two factors that contribute to localized increases in downstream impacts are the floodplain width as well as timing of tributaries that enter the Red River of the North downstream from the diversion channel outlet. Maps that show the Existing Conditions and With-Project floodplain are included in Appendix C. For the 0.2-percent chance design flood, the maximum downstream impacts occur between Thompson, ND and Grand Forks, ND (0.45 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.06 feet). For the 1-percent chance design flood, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (1.23 feet) while the minimum impact occurs between Oslo, MN and Drayton, ND (0.05 feet). For the 2-percent chance design flood, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (1.01 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.02 feet). For the 10-percent chance design flood, the maximum downstream impacts occur between Fargo, ND and Halstad, MN (0.45 feet) while the minimum impact occurs between Oslo, MN and Drayton, ND (0.03 feet).

4.0 Project Costs

Phase 4 feasibility costs for the LPP have been completed. These cost estimates have been developed to the same Class 3 level of estimate as in Phase 3. All estimates are completed using the MII cost estimating program, USACE manual guidance and coordination with the USACE-PDT. Cost estimates, documentation and discussion included in this Phase 4 report are intended to provide background information for feasibility cost risk assessment and analysis purposes by the USACE, and to be finalized and used by the USACE for congressional budgetary appropriation of the selected diversion alternative.

Selected project features incorporated in the cost estimates presented by the Consultant in this Phase 4 report include (numbering shown refers to categories presented in the USACE total project cost summary):

- 02 Relocations (Roadway Bridges and Road Raises only);
- 08 Roads, Railroads and Bridges (costs to reconstruct railway facilities in the vicinity of the project);
- 09 Channels and Canals (costs to construct the diversion channel facilities, hydraulic structures and associated site work); and
- 11 Levees and Floodwalls (costs to construct tie-back levees, storage area(s) and floodwalls).

Items are intentionally excluded from the cost estimates presented in this Phase 4 report, as coordinated with the USACE-PDT, but they are required for a complete feasibility estimate of the Total Project Cost Summary. These items will be estimated by the USACE-PDT, or others. These items include:

- 01 Lands and Damages
- 02 Relocations (except for Roadway Bridges and Roadway Raises)
- 06 Fish and Wildlife Facilities (except for fishways on Red River of the North, Wild Rice River, Lower Rush River and Rush River, which are included in 09 Channels and Canals)
- 14 Recreation Facilities
- 30 Planning, Engineering and Design (PED)
- 31 Construction Management (CM)
- Other additions as determined by the USACE, including temporal escalation factors, HTRW, final contingency assignment upon cost risk analysis, environmental mitigation, cultural resources work, etc.

The methodology and summary tables of the cost estimates for the LPP and FCP that are presented in Table 5 and Table 6, respectively, correspond to the February 28, 2011 submittal of the Consultant's Report. Revisions to the cost estimates following USACE-ATR dated April 15, 2011 have been fully addressed in Appendix L of the Feasibility Report by the USACE-PDT. For completeness, the revised summary cost estimates for the LPP and FCP are presented in Table 7 and Table 8, respectively of this April 19, 2011 submittal of the Consultant's Report. It is important to note that a contingency has been intentionally omitted from the cost estimates in Tables 7 and 8, as the contingency will be determined by the USACE-PDT after the Cost Schedule Risk Analysis (CSRA) currently underway is completed. Tables 5 and 6 present the contingencies recommended by the Consultant.

The discussion below is based on contract costs (i.e., without including a contingency) and the cost estimates presented in Tables 7 and 8 (i.e., after incorporating the changes recommended by the USACE-ATR dated April 15, 2011).

In the previous Phase 3 of this feasibility study (including revisions to the FCP cost estimates dated August 18, 2010), the construction costs (not including contingencies) developed by the Consultant for selected project features (within the categories listed above) of the LPP and FCP were $752 Million and $650 Million, respectively. In the current Phase 4 of this feasibility study, the construction costs (not including contingencies) for selected project features (within the categories listed above) of the LPP and FCP are $870 Million and $690 Million, respectively. All of these costs correspond to 2010 US Dollars and do not include temporal escalation factors (these costs were later added by USACE in Phase 3, and will be again added by USACE in Phase 4). Summary tables of the feasibility cost estimates for the selected project features referred to above of the LPP and FCP are presented in Tables 7 and 8, respectively. These feasibility cost estimates for the two diversion alternatives are submitted to the USACE-PDT in the form of two (2) digital MII files, and a detailed description of the assumptions used to develop quantities and cost estimates (including work analysis, contractor assumptions, unit prices, contingencies and breakdown of labor, equipment and materials) are provided in Appendix G.

The main differences between the Phase 3 and Phase 4 feasibility cost estimates (not including contingencies) for the LPP are as follow:

- there is an increase of approximately $39 Million in the cost of the Roadway Bridges, Road Raises & Local Road Construction from Phase 3 to Phase 4, which is mainly driven by road raises in the area subject to staging immediately south of the diversion works;
- there is a reduction of approximately $80 Million in the cost of the Diversion Channel from Phase 3 to Phase 4, which is mainly driven by a smaller cross section of the diversion channel, and also the fact that approximately 3.5 miles of diversion channel have been associated with the cost of the hydraulic structures in Phase 4 (we did this to allow for appropriate grading from the hydraulic structures to the main section of the diversion channel);
- there is an increase of approximately $6.3 Million in the cost of the Control Structure in the Red River of the North from Phase 3 to Phase 4, which is mainly driven by the requirement of a taller structure due to staging immediately south of the diversion works;
- there is an increase of approximately $0.9 Million in the combined cost of the Control Structure in the Wild Rice River, East Weir and the primary Diversion Inlet Structure from Phase 3 to Phase 4, which results from the trade between a taller structure in the Wild Rice River due to staging immediately south of the diversion works, a more robust and expensive Inlet Structure, a significantly

reduced scope and cost of the Phase 3 East Weir, and the elimination of the Phase 3 West Weir;

- there is an increase of approximately $11 Million in the combined cost of the Hydraulic Structures at the Sheyenne River and Maple River from Phase 3 to Phase 4, which is mainly driven by the inclusion of longer reaches (in Phase 4) of the main diversion channel that are associated with the cost of these structures, and longer spillways due to lower water surface elevations in these tributaries (after revisions with the unsteady flow model);
- there is an increase of approximately $7.9 Million in the combined cost of the Hydraulic Structure at Drain 14 and the Large Drain Structure from Phase 3 to Phase 4, which is mainly driven by the need for a very large concrete drop structure at Drain 14 in order to minimize impacts to the floodplain to the west of the diversion channel (after revisions with the unsteady flow model). However, one possibility is to construct a less expensive drop structure to convey low to average flows into the diversion channel at the current Drain 14 crossing location combined with a flood flow channel at a higher elevation to convey high flows north to the proposed hydraulic structures at the Maple River;
- there is an increase of approximately $1.8 Million in the combined cost of the Hydraulic Structures at the Lower Rush River and Rush River from Phase 3 to Phase 4. However, at both locations there is a real opportunity for further evaluating the design of the fishway to operate during all flow conditions, therefore eliminating the need for the very large concrete drop structures that account for a very significant fraction of the total cost (of approximately $35 Million) for the structures at these two sites. Alternatively, the structure at the Lower Rush River could be completely eliminated by routing the flows of this tributary at existing grade along the west side of the diversion channel all the way north to the Rush River, where a single combined drop structure and fish passage could be constructed;
- there is an increase of approximately $20 Million in the cost of the Outlet Structure from Phase 3 to Phase 4, which is mainly driven by the change in feasibility design from the Phase 3 rip rap protection of the downstream 300 feet of the diversion channel to a Phase 4 Ogee-type concrete spillway due to the significant increase in drop between the diversion channel invert at the outlet and the Red River thalweg elevation at that location. However, additional detailed studies could demonstrate that when high flows (driven by either peaks in the Red River of the North or peaks in the ND tributaries) are discharging through this structure, the flows and related water surface elevations in the Red River of the North are also high, so a smaller drop or shorter stilling basin could be justified, in both cases reducing the cost; and
- there is an increase of approximately $108 Million in the cost of the Levees and Floodwalls from Phase 3 to Phase 4, which is mainly driven by the requirement of taller and longer levees (including Storage Area 1 embankments, inlet and outlet structures) due to staging immediately south of the diversion works, and the new explicit requirement in Phase 4 to deal with routing of the Standard Project Flood.

Tables

TABLE 1: Summary HEC-RAS Unsteady Flow Model Results for Historic Floods - Locally Preferred Plan

North Dakota Diversion (LPP) - 1997 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.95	123,404	801.94	123,251	-0.01	-153
Oslo Gage	1416287	813.29	124,661	813.30	124,735	0.01	74
Minimum Impact Location	1555329	833.59	119,246	833.60	119,281	0.01	35
Grand Forks Gage	1558518	834.04	119,103	834.05	119,142	0.01	39
Thompson Gage	1667877	847.29	78,351	847.43	79,439	0.14	1,088
Maximum Impact Location (Nielsville)	1829877	860.86	71,728	861.11	72,925	0.25	1,197
Halstad Gage	1981580	868.65	64,821	868.78	66,780	0.13	1,959
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.42 (39.68*)	27,574	893.11 (30.37*)	9,968	-9.31	-17,606
US Diversion**	2531315	911.89	13,686	921.60	9,530	9.71	-4,156
Hickson Gage**	2563754	913.85	13,729	921.63	13,235	7.78	-494
Abercrombie**	2764835	931.08	13,995	931.36	13,995	0.28	0

North Dakota Diversion (LPP) - 2006 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.44	78,252	799.46	78,666	0.02	414
Oslo Gage	1416287	811.58	74,550	811.61	75,093	0.03	543
Minimum Impact Location	1443147	813.86	75,635	813.88	76,312	0.02	677
Grand Forks Gage	1558518	828.63	72,782	828.72	73,387	0.09	605
Thompson Gage	1667877	840.63	52,499	840.84	53,273	0.21	775
Maximum Impact Location	1749702	848.33	52,262	848.59	53,030	0.26	768
Halstad Gage	1981580	866.64	43,060	866.70	43,552	0.06	492
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.57 (36.83*)	21,028	891.96 (29.22*)	10,109	-7.61	-10,919
US Diversion**	2531315	910.60	14,053	918.72	9,530	8.12	-4,523
Hickson Gage**	2563754	913.11	14,313	918.90	14,362	5.79	49
Abercrombie**	2764835	931.58	15,027	931.74	15,027	0.16	0

North Dakota Diversion (LPP) - 2009 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.85	85,308	799.84	85,166	-0.01	-143
Minimum Impact Location	1345544	805.87	91,028	805.88	90,929	0.01	-99
Oslo Gage	1416287	812.02	85,672	812.04	84,367	0.02	-1,304
Grand Forks Gage	1558518	829.33	77,165	829.39	77,550	0.06	385
Maximum Impact Location	1561353	830.20	63,468	830.28	63,506	0.08	38
Thompson Gage	1667877	843.05	61,510	843.07	61,577	0.02	67
Halstad Gage	1981580	867.60	55,176	867.56	54,910	-0.04	-266
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.66 (39.92*)	29,234	893.46 (30.72*)	11,561	-9.20	-17,674
US Diversion**	2531315	914.24	23,639	921.62	10,897	7.38	-12,742
Hickson Gage**	2563754	917.76	24,393	921.64	24,562	3.88	170
Abercrombie**	2764835	937.51	28,176	937.59	28,176	0.08	0

North Dakota Diversion (LPP) - 2010 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.71	65,928	798.72	66,106	0.01	177
Minimum Impact Location	1327581	803.80	66,011	803.81	65,808	0.01	-203
Oslo Gage	1416287	811.09	67,101	811.07	66,850	-0.02	-251
Grand Forks Gage	1558518	827.23	63,406	827.19	63,172	-0.04	-235
Thompson Gage	1667877	840.28	52,023	840.44	52,694	0.16	672
Halstad Gage	1981580	866.55	42,389	866.70	43,585	0.15	1,196
Maximum Impact Location (Hendrum)	2038409	870.62	38,264	870.86	39,350	0.24	1,085
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.77 (37.03*)	21,481	892.38 (29.64*)	10,291	-7.39	-11,190
US Diversion**	2531315	910.17	12,352	918.90	8,623	8.73	-3,729
Hickson Gage**	2563754	912.23	12,677	918.98	12,686	6.75	8
Abercrombie**	2764835	930.57	13,236	930.74	13,236	0.17	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

** Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

TABLE 2: Summary HEC-RAS Unsteady Flow Model Results for Design Floods - Locally Preferred Plan

North Dakota Diversion (LPP) - 0.2% Chance Event (No Protection)

Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	804.12	168,364	804.23	171,002	0.11	2,638
Minimum Impact Location	1410241	812.15	152,872	812.19	156,165	0.04	3,294
Oslo Gage	1416287	813.88	152,851	813.93	156,084	0.05	3,232
Grand Forks Gage	1558518	836.36	146,225	836.58	149,112	0.22	2,887
Maximum Impact Location	1561353	838.53	102,444	838.80	102,054	0.27	-390
Thompson Gage	1667877	850.69	112,422	850.64	111,394	-0.05	-1,027
Halstad Gage	1981580	871.54	101,754	871.32	92,746	-0.22	-9,007
Fargo Gage (13th Ave S, 12th Ave S)	2388223	905.8 (43.06*)	61,717	902.77 (40.03*)	29,865	-3.03	-31,852
US Diversion**	2531315	915.94	28,577	922.44	27,846	6.50	-731
Hickson Gage**	2563754	919.69	35,636	922.54	32,491	2.85	-3,145
Abercrombie**	2764835	940.90	44,308	940.91	44,308	0.01	0

North Dakota Diversion (LPP) - 1% Chance Event (No Protection)

Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.73	119,255	801.81	120,751	0.08	1,496
Minimum Impact Location	1410241	811.47	113,625	811.51	115,682	0.04	2,057
Oslo Gage	1416287	813.01	113,556	813.07	115,628	0.06	2,071
Grand Forks Gage	1558518	832.97	107,980	833.21	110,497	0.24	2,517
Maximum Impact Location	1573768	835.27	80,735	835.56	80,686	0.29	-49
Thompson Gage	1667877	847.35	82,926	847.39	82,608	0.04	-317
Halstad Gage	1981580	869.09	71,581	869.03	70,992	-0.06	-589
Fargo Gage (13th Ave S, 12th Ave S)	2388223	903.86 (41.12*)	34,875	893.54 (30.8*)	11,718	-10.32	-23,157
US Diversion**	2531315	914.65	21,458	922.88	11,024	8.23	-10,434
Hickson Gage**	2563754	917.52	21,730	922.90	18,655	5.38	-3,075
Abercrombie**	2764835	935.62	23,000	935.73	23,000	0.11	0

North Dakota Diversion (LPP) - 2% Chance Event (No Protection)

Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	800.72	100,869	800.80	102,165	0.08	1,296
Minimum Impact Location	1410241	811.12	97,700	811.15	98,889	0.03	1,189
Oslo Gage	1416287	812.53	97,643	812.57	98,857	0.04	1,215
Grand Forks Gage	1558518	831.13	91,118	831.31	92,619	0.18	1,501
Maximum Impact Location	1602184	836.27	69,861	836.65	70,584	0.38	723
Thompson Gage	1667877	844.83	69,367	845.07	70,104	0.24	737
Halstad Gage	1981580	867.99	59,416	867.99	59,542	0.00	126
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.6 (39.86*)	29,167	892.72 (29.98*)	10,603	-9.88	-18,565
US Diversion**	2531315	913.76	18,435	920.86	10,477	7.10	-7,959
Hickson Gage**	2563754	916.34	18,898	920.92	18,428	4.58	-470
Abercrombie**	2764835	934.48	20,726	934.62	20,726	0.14	0

North Dakota Diversion (LPP) - 10% Chance Event (No Protection)

Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.53	62,917	798.54	63,042	0.01	125
Minimum Impact Location	1327581	803.44	57,657	803.45	58,094	0.01	437
Oslo Gage	1416287	810.51	59,092	810.55	59,629	0.04	537
Grand Forks Gage	1558518	825.98	56,662	826.09	57,169	0.11	507
Maximum Impact Location	1561283	826.49	43,551	826.61	43,504	0.12	-47
Thompson Gage	1667877	837.58	42,815	837.62	42,843	0.04	28
Halstad Gage	1981580	864.55	34,653	864.43	34,160	-0.12	-493
Fargo Gage (13th Ave S, 12th Ave S)	2388223	897.33 (34.59*)	17,024	891.86 (29.12*)	10,156	-5.47	-6,868
US Diversion**	2531315	908.06	10,333	916.29	8,861	8.23	-1,472
Hickson Gage**	2563754	910.21	10,428	916.80	10,077	6.59	-351
Abercrombie**	2764835	929.05	11,278	929.16	11,278	0.11	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

** Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

TABLE 3: Summary HEC-RAS Unsteady Flow Model Results for Historic Floods - Federally Comparable Plan

Minnesota Diversion (FCP) - 1997 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.95	123,404	802.05	125,375	0.10	1,971
Oslo Gage	1416287	813.29	124,661	813.34	126,501	0.05	1,840
Minimum Impact Location	1425253	814.37	107,206	814.40	108,227	0.03	1,021
Grand Forks Gage	1558518	834.04	119,103	834.21	120,893	0.17	1,790
Thompson Gage	1667877	847.29	78,351	847.66	81,143	0.37	2,792
Maximum Impact Location	1813905	859.97	71,913	860.6	74,743	0.63	2,830
Halstad Gage	1981580	868.65	64,821	868.92	68,476	0.27	3,655
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.42 (39.68*)	27,574	894.1 (31.36*)	9,978	-8.32	-17,596
US Diversion**	2470898	908.85	23,779	908.94	25,235	0.09	1456
Hickson Gage**	2563754	913.85	13,729	914.00	13,738	0.15	10
Abercrombie**	2764835	931.08	13,995	931.08	13,995	0.00	0

Minnesota Diversion (FCP) - 2006 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.44	78,252	799.47	78,770	0.03	518
Oslo Gage	1416287	811.58	74,550	811.60	74,929	0.02	379
Minimum Impact Location	1448026	814.15	67,113	814.16	67,444	0.01	331
Grand Forks Gage	1558518	828.63	72,782	828.69	73,160	0.06	378
Thompson Gage	1667877	840.63	52,499	840.84	53,450	0.21	951
Halstad Gage	1981580	866.64	43,060	866.86	44,955	0.22	1,895
Maximum Impact Location	2058853	871.99	36,500	872.36	38,554	0.37	2,054
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.57 (36.83*)	21,028	893.15 (30.41*)	10,078	-6.42	-10,950
US Diversion**	2470898	906.81	20,782	906.53	20,782	-0.28	0.00
Hickson Gage**	2563754	913.11	14,313	913.15	14,352	0.04	39
Abercrombie**	2764835	931.58	15,027	931.58	15,027	0.00	0

Minnesota Diversion (FCP) - 2009 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.85	85,308	799.98	87,702	0.13	2,393
Minimum Impact Location	1410241	810.81	83,759	810.89	87,295	0.08	3,536
Oslo Gage	1416287	812.02	85,672	812.16	87,316	0.14	1,645
Grand Forks Gage	1558518	829.33	77,165	829.83	80,831	0.50	3,666
Thompson Gage	1667877	843.05	61,510	843.97	65,379	0.92	3,869
Maximum Impact Location	1789494	853.76	58,180	854.88	62,266	1.12	4,086
Halstad Gage	1981580	867.6	55,176	868.02	60,798	0.42	5,622
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.66 (39.92*)	29,234	894.03 (31.29*)	11,964	-8.63	-17,270
US Diversion**	2470898	909.61	28,395	909.47	27,912	-0.14	-483
Hickson Gage**	2563754	917.76	24,393	917.75	24,407	-0.01	14
Abercrombie**	2764835	937.51	28,176	937.51	28,176	0.00	0

Minnesota Diversion (FCP) - 2010 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.71	65,928	798.76	66,687	0.05	759
Oslo Gage	1416287	811.09	67,101	811.11	67,463	0.02	363
Minimum Impact Location	1467237	815.28	66,433	815.30	66,870	0.02	437
Grand Forks Gage	1558518	827.23	63,406	827.29	63,783	0.06	377
Thompson Gage	1667877	840.28	52,023	840.55	53,139	0.27	1,116
Maximum Impact Location	1829650	853.73	49,914	854.1	51,122	0.37	1,208
Halstad Gage	1981580	866.55	42,389	866.76	43,888	0.21	1,499
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.77 (37.03*)	21,481	893.37 (30.63*)	10,231	-6.40	-11,250
US Diversion**	2470898	906.89	20,427	906.8	21,469	-0.09	1043
Hickson Gage**	2563754	912.23	12,677	912.42	12,697	0.19	20
Abercrombie**	2764835	930.57	13,236	930.57	13,236	0.00	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

**Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

TABLE 4: Summary HEC-RAS Unsteady Flow Model Results for Design Floods - Federally Comparable Plan

Minnesota Diversion (FCP) - 0.2% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	804.12	168,364	804.27	170,409	0.15	2,045
Oslo Gage	1416287	813.88	152,851	813.95	157,374	0.07	4,523
Minimum Impact Location	1416400	814.23	152,852	814.29	157,375	0.06	4,522
Grand Forks Gage	1558518	836.36	146,225	836.72	150,748	0.36	4,523
Maximum Impact Location	1580152	839.75	102,174	840.20	104,725	0.45	2,551
Thompson Gage	1667877	850.69	112,422	850.93	115,330	0.24	2,908
Halstad Gage	1981580	871.54	101,754	871.72	104,334	0.18	2,580
Fargo Gage (13th Ave S, 12th Ave S)	2388223	905.8 (43.06*)	61,717	902.83 (40.09*)	30,044	-2.97	-31,673
US Diversion**	2470898	910.99	32,153	910.81	34,471	-0.18	2,319
Hickson Gage**	2563754	919.69	35,636	919.67	35,565	-0.02	-71
Abercrombie**	2764835	940.90	44,308	940.90	44,308	0.00	0

Minnesota Diversion (FCP) - 1% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.73	119,255	801.92	122,945	0.19	3,690
Minimum Impact Location	1408098	811.34	113,281	811.39	116,227	0.05	2,946
Oslo Gage	1416287	813.01	113,556	813.09	116,500	0.08	2,944
Grand Forks Gage	1558518	832.97	107,980	833.35	112,047	0.38	4,067
Thompson Gage	1667877	847.35	82,926	848.11	88,519	0.76	5,593
Maximum Impact Location	1813905	860.78	75,611	862.01	81,907	1.23	6,296
Halstad Gage	1981580	869.09	71,581	869.68	80,624	0.59	9,043
Fargo Gage (13th Ave S, 12th Ave S)	2388223	903.86 (41.12*)	34,875	894.91 (32.17*)	11,756	-8.95	-23,119
US Diversion**	2470898	910.13	29,330	910.71	22,794	0.58	-6,536
Hickson Gage**	2563754	917.52	21,730	917.51	21,734	-0.01	3
Abercrombie**	2764835	935.62	23,000	935.62	23,000	0.00	0

Minnesota Diversion (FCP) - 2% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	800.72	100,869	800.83	102,845	0.11	1,976
Oslo Gage	1416287	812.53	97,643	812.56	98,491	0.03	848
Minimum Impact Location	1448026	814.89	84,147	814.91	85,013	0.02	867
Grand Forks Gage	1558518	831.13	91,118	831.26	92,141	0.13	1,023
Thompson Gage	1667877	844.83	69,367	845.61	73,330	0.78	3,963
Maximum Impact Location	1829650	858.51	63,541	859.52	67,966	1.01	4,425
Halstad Gage	1981580	867.99	59,416	868.47	65,150	0.48	5,735
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.6 (39.86*)	29,167	894.02 (31.28*)	10,878	-8.58	-18,289
US Diversion**	2470898	909.54	27,658	909.4	27,987	-0.14	329
Hickson Gage**	2563754	916.34	18,898	916.37	18,925	0.03	27
Abercrombie**	2764835	934.48	20,726	934.49	20,726	0.01	0

Minnesota Diversion (FCP) - 10% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.53	62,917	798.57	63,651	0.04	734
Minimum Impact Location	1410241	809.75	58,880	809.78	59,596	0.03	717
Oslo Gage	1416287	810.51	59,092	810.56	59,699	0.05	607
Grand Forks Gage	1558518	825.98	56,662	826.10	57,258	0.12	596
Thompson Gage	1667877	837.58	42,815	837.82	43,590	0.24	775
Halstad Gage	1981580	864.55	34,653	864.88	35,715	0.33	1,063
Maximum Impact Location	2236491	883.37	29,991	883.82	32,040	0.45	2,048
Fargo Gage (13th Ave S, 12th Ave S)	2388223	897.33 (34.59*)	17,024	892.66 (29.92*)	9,933	-4.67	-7,091
US Diversion**	2470898	904.54	16,759	904.71	17,329	0.17	570
Hickson Gage**	2563754	910.21	10,428	910.27	10,459	0.06	31
Abercrombie**	2764835	929.05	11,278	929.05	11,278	0.00	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

** Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

Fargo-Moorhead Metro Flood Risk Management Project

Table 5
LPP North Dakota Diversion - MII Cost Estimate Summary
Phase 4 - MII Estimate 2-28-2011

North Dakota Diversion

Description	Contract Cost	(1) Contingency	Project Cost	Percent of Total
RELOCATIONS				
Roadway Bridges, Road Raises & Local Road Construction	103,611,762	14,740,166	118,351,928	11.74%
Railroad Bridges	46,497,415	13,614,538	60,111,954	5.96%
CHANNELS AND CANALS				
Diversion Channel	318,633,134	63,726,627	382,359,760	37.91%
Control Structure on Red River	47,355,147	9,471,029	56,826,177	5.63%
Hydraulic Structure at Wolverton Creek	4,290,478	858,096	5,148,573	0.51%
Hydraulic Structure at Wild Rice River	29,348,084	5,869,617	35,217,701	3.49%
Hydraulic Structure - East Weir (at Connecting Channel)	219,666	43,933	263,599	0.03%
Hydraulic Structure - Inlet Weir to Diversion	9,786,068	1,957,214	11,743,281	1.16%
Hydraulic Structures at Sheyenne River	49,677,739	9,935,548	59,613,286	5.91%
Hydraulic Structure - Drain 14 - Large Drain Structure	8,236,281	1,647,256	9,883,537	0.98%
Hydraulic Structures at Maple River	45,108,856	9,021,771	54,130,627	5.37%
Hydraulic Structures at Lower Rush River	17,256,300	3,451,260	20,707,560	2.05%
Hydraulic Structures at Rush River	17,215,143	3,443,029	20,658,171	2.05%
Small Drain Structures (2)	252,369	126,185	378,554	0.04%
Large Drain Structure (1)	448,922	224,461	673,383	0.07%
Side Channel Inlets 1x72" (19)	8,343,417	4,171,708	12,515,125	1.24%
Side Channel Inlets 2x72" (7)	5,616,955	2,808,477	8,425,432	0.84%
Outlet to Red River	22,007,824	4,401,565	26,409,389	2.62%
LEVEES AND FLOODWALLS				
Tie-Back Levee - TBL East 2B (Constructed in MN)	18,573,020	3,714,604	22,287,624	2.21%
Tie-Back Levee - TBL Cass 17 (Constructed in ND)	6,320,611	1,264,122	7,584,733	0.75%
Levee - Connecting Channel - Reach 2018 (ND-23, 26)	1,683,581	336,716	2,020,297	0.20%
Levee - Connecting Channel - Reach 2019 (ND-25)	6,971,436	1,394,287	8,365,723	0.83%
Storage Area 1 Embankment and Inlet	57,965,277	14,481,249	72,446,526	7.18%
Storage Area 1 Closure/Drainage Structure (North)	5,169,828	1,033,966	6,203,794	0.62%
Storage Area 1 Closure/Drainage Structure (East)	5,169,828	1,033,966	6,203,794	0.62%
Subtotal	**$835,759,138**	**$172,771,389**	**$1,008,530,528**	**100.0%**

(1) Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction.

Fargo-Moorhead Metro Flood Risk Management Project

Table 6
FCP Minnesota Diversion - MII Cost Estimate Summary
Phase 4 - MII Estimate Revised 2-28-2011

Minnesota Diversion

Description	Contract Cost	(1) Contingency	Project Cost	Percent of total
RELOCATIONS				
Roadway bridges	79,730,554	9,309,137	89,039,691	11.3%
Railroad bridges	132,712,322	39,662,974	172,375,295	21.8%
CHANNELS AND CANALS				
Diversion channel	353,339,582	70,667,916	424,007,499	53.6%
Control structure on Red River	59,545,729	11,909,146	71,454,875	9.0%
Small drain structure (3)	752,396	376,198	1,128,593	0.1%
Side channel inlet 1x72" (7)	3,128,818	1,564,409	4,693,227	0.6%
Side channel inlet 2x72" (11)	8,986,446	4,493,223	13,479,669	1.7%
Channel Drop Structure	2,123,007	424,601	2,547,609	0.3%
Outlet to Red River	1,595,053	319,011	1,914,064	0.2%
LEVEES AND FLOODWALLS				
Levees and floodwalls	8,246,709	1,954,203	10,200,912	1.3%
Subtotal	**$650,160,615**	**$140,680,818**	**$790,841,433**	**100.0%**

(1) Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction.

Fargo-Moorhead Metro Flood Risk Management Project

Table 7
LPP North Dakota Diversion - MII Cost Estimate Summary
Phase 4 - MII Estimate Revised 4-18-2011 following USACE Agency Technical Review (ATR)

North Dakota Diversion				
Description	**Contract Cost**	(1) **Contingency**	**Project Cost**	**Percent of Total**
RELOCATIONS				
Roadway Bridges, Road Raises & Local Road Construction	103,611,762	0	103,611,762	11.91%
RAILROAD BRIDGES				
Railroad Bridges	46,497,415	0	46,497,415	5.35%
CHANNELS AND CANALS				
Diversion Channel	338,217,173	0	338,217,173	38.88%
Control Structure on Red River	48,276,228	0	48,276,228	5.55%
Hydraulic Structure at Wolverton Creek	4,366,235	0	4,366,235	0.50%
Hydraulic Structure at Wild Rice River	29,630,288	0	29,630,288	3.41%
Hydraulic Structure - East Weir (at Connecting Channel)	215,712	0	215,712	0.02%
Hydraulic Structure - Inlet Weir to Diversion	9,942,054	0	9,942,054	1.14%
Hydraulic Structures at Sheyenne River	50,805,769	0	50,805,769	5.84%
Hydraulic Structure - Drain 14 - Large Drain Structure	8,378,185	0	8,378,185	0.96%
Hydraulic Structures at Maple River	45,799,454	0	45,799,454	5.26%
Hydraulic Structures at Lower Rush River	17,743,527	0	17,743,527	2.04%
Hydraulic Structures at Rush River	17,709,812	0	17,709,812	2.04%
Small Drain Structures (2)	254,374	0	254,374	0.03%
Large Drain Structure (1)	447,425	0	447,425	0.05%
Side Channel Inlets 1x72" (19)	8,454,002	0	8,454,002	0.97%
Side Channel Inlets 2x72" (7)	5,662,176	0	5,662,176	0.65%
Outlet to Red River	22,704,305	0	22,704,305	2.61%
LEVEES AND FLOODWALLS				
Tie-Back Levee - TBL East 2B (Constructed in MN)	19,829,863	0	19,829,863	2.28%
Tie-Back Levee - TBL Cass 17 (Constructed in ND)	6,801,067	0	6,801,067	0.78%
Levee - Connecting Channel - Reach 2018 (ND-23, 26)	1,830,998	0	1,830,998	0.21%
Levee - Connecting Channel - Reach 2019 (ND-25)	7,570,035	0	7,570,035	0.87%
Storage Area 1 Embankment and Inlet	62,505,446	0	62,505,446	7.19%
Storage Area 1 Closure/Drainage Structure (North)	5,332,286	0	5,332,286	0.61%
Storage Area 1 Closure/Drainage Structure (East)	5,332,286	0	5,332,286	0.61%
Road Raise for LPP SA1 Levees ND	1,987,535	0	1,987,535	0.23%
Subtotal	**$869,905,414**	**$0**	**$869,905,414**	**100.0%**

(1) Contingency must be added to complete this estimate. Contingency to be determined by USACE with Cost Schedule Risk Analysis (CSRA). Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction. A/E recommended contingencies were presented in the 2-28-2011 deliverable to USACE (See Table 5).

Fargo-Moorhead Metro Flood Risk Management Project

Table 8
FCP Minnesota Diversion - MII Cost Estimate Summary
Phase 4 - MII Estimate Revised 4-18-2011 following USACE Agency Technical Review (ATR)

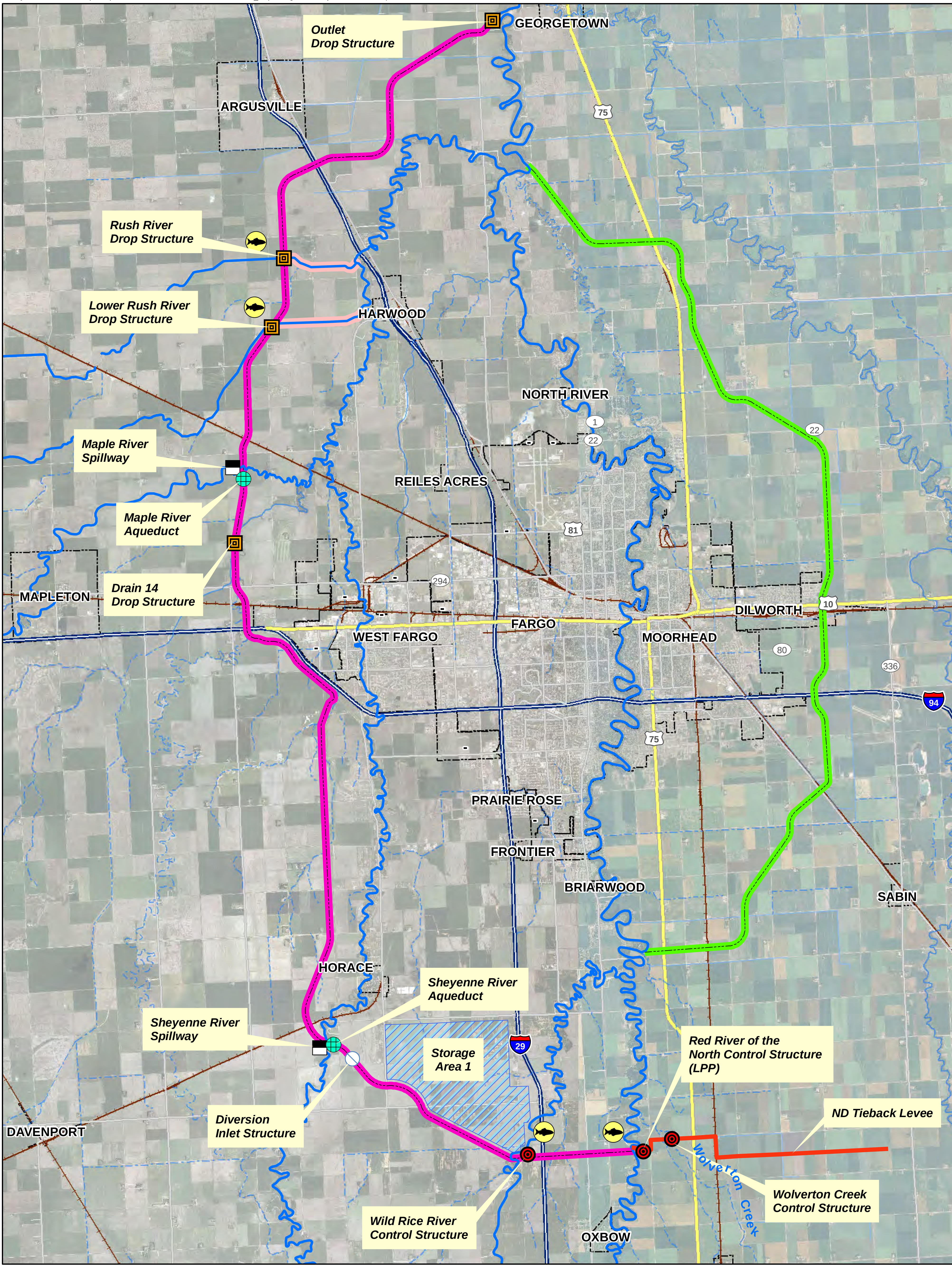
Minnesota Diversion

Description	Contract Cost	(1) Contingency	Project Cost	Percent of total
RELOCATIONS				
Roadway bridges	79,730,554	0	79,730,554	11.6%
RAILROAD BRIDGES				
Railroad bridges	127,294,440	0	127,294,440	18.4%
CHANNELS AND CANALS				
Diversion channel	385,841,384	0	385,841,384	55.9%
Control structure on Red River	64,323,225	0	64,323,225	9.3%
Small drain structure (3)	785,494	0	785,494	0.1%
Side channel inlet 1x72" (7)	3,180,752	0	3,180,752	0.5%
Side channel inlet 2x72" (11)	9,076,396	0	9,076,396	1.3%
Channel Drop Structure	4,312,324	0	4,312,324	0.6%
Outlet to Red River	1,617,839	0	1,617,839	0.2%
LEVEES AND FLOODWALLS				
Levees and floodwalls	14,144,391	0	14,144,391	2.0%
Subtotal	**$690,306,798**	**$0**	**$690,306,798**	**100.0%**

(1) Contingency must be added to complete this estimate. Contingency to be determined by USACE with Cost Schedule Risk Analysis (CSRA). Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction. A/E recommended contingencies were presented in the 2-28-2011 deliverable to USACE (See Table 6).

Figures

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure1 - Project Overview Map.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- ND Tieback Levee
- North Dakota Diversion Locally Preferred Plan (LPP)
- Minnesota Diversion Federally Comparable Plan (FCP)
- Channel Reclamation Reaches
- Storage Area 1

Figure 1

PROJECT OVERVIEW

Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

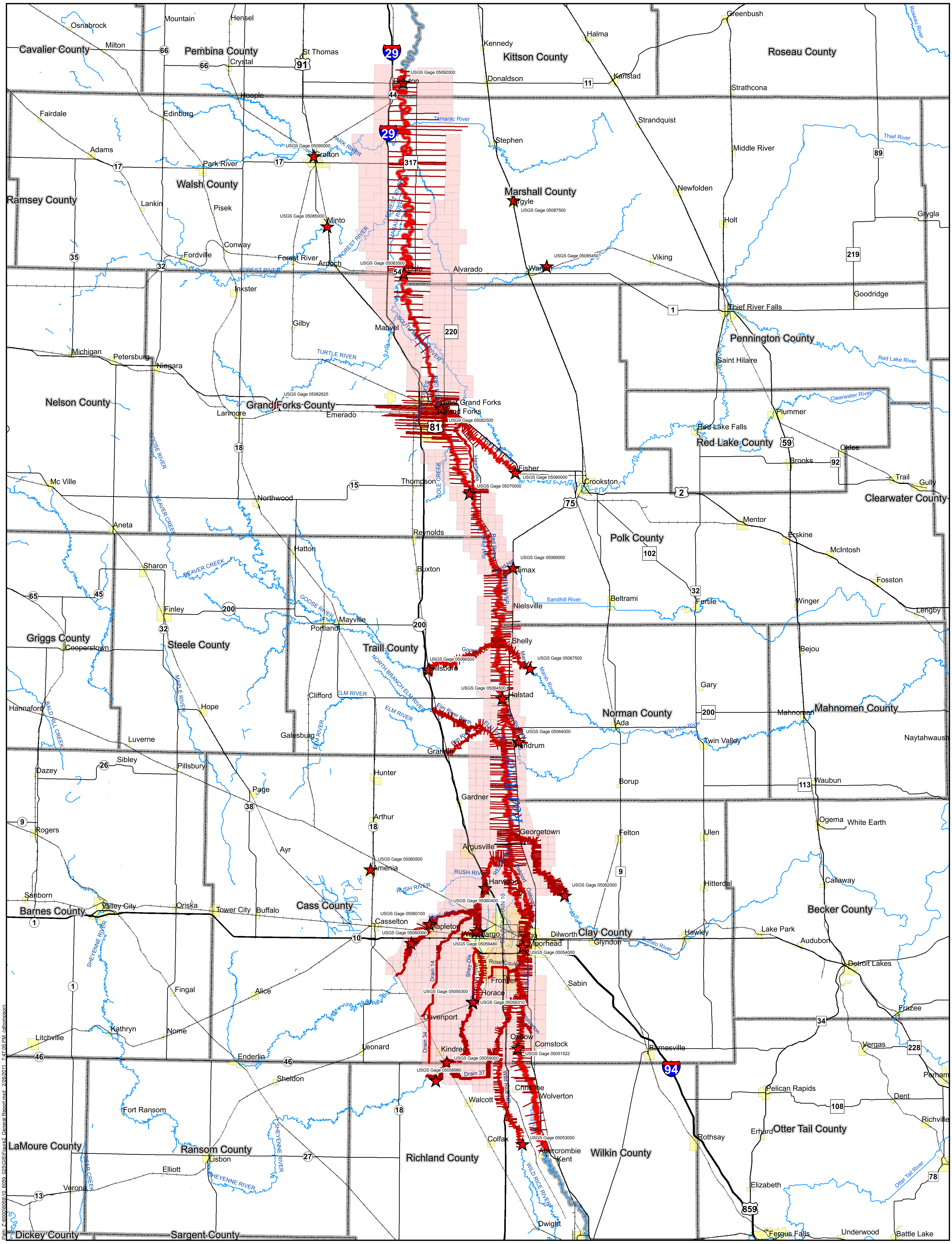


Figure 2

Unsteady HEC-RAS Modeling Study Area Map

- USGS Gages
- Existing Conditions Model Cross Sections
- Existing Conditions Model Reaches
- Existing Conditions Model Storage Areas
- Model Cross Sections
- City Boundaries
- Counties

Figure 3 Longitudinal Profile of LPP Diversion Channel

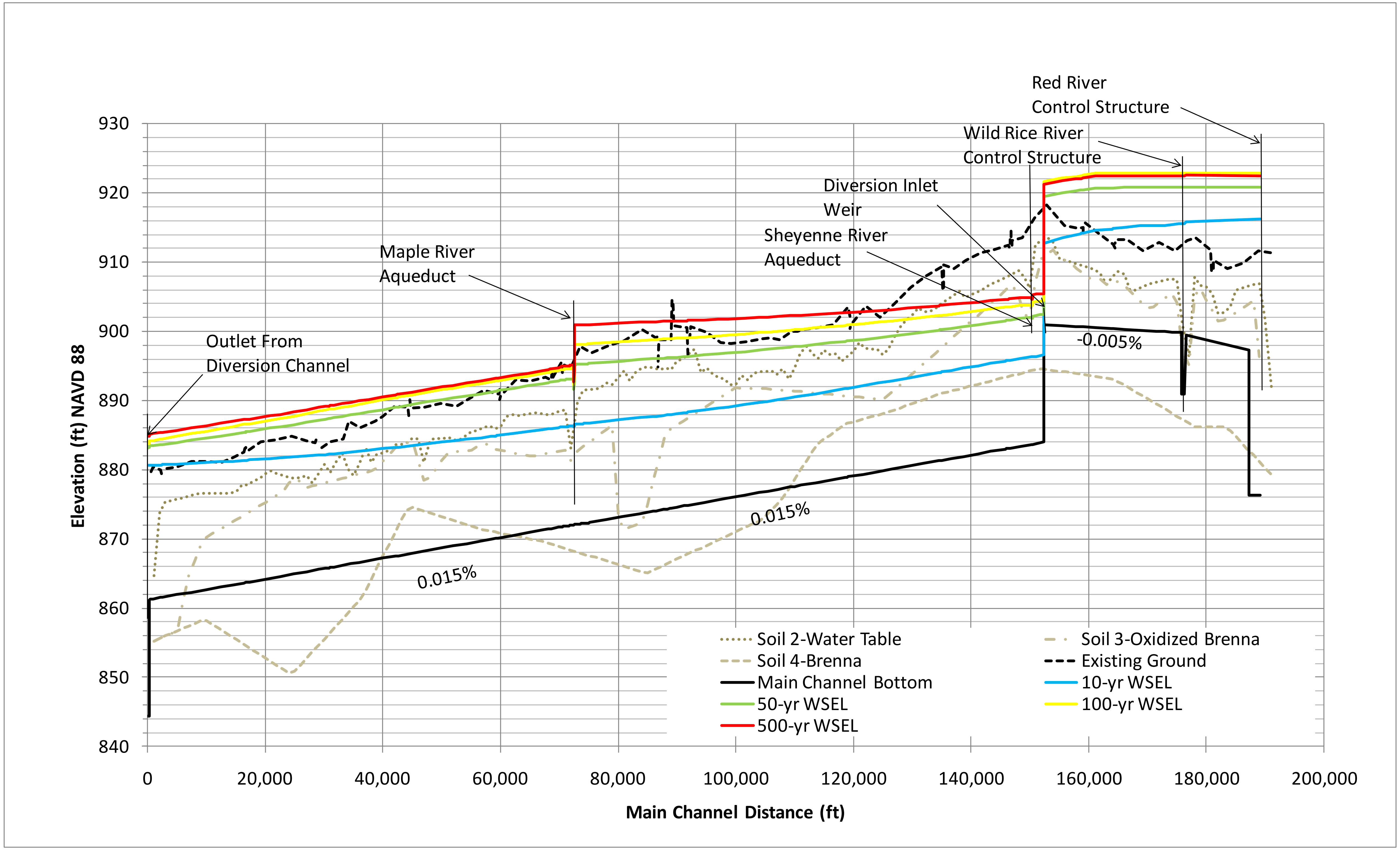
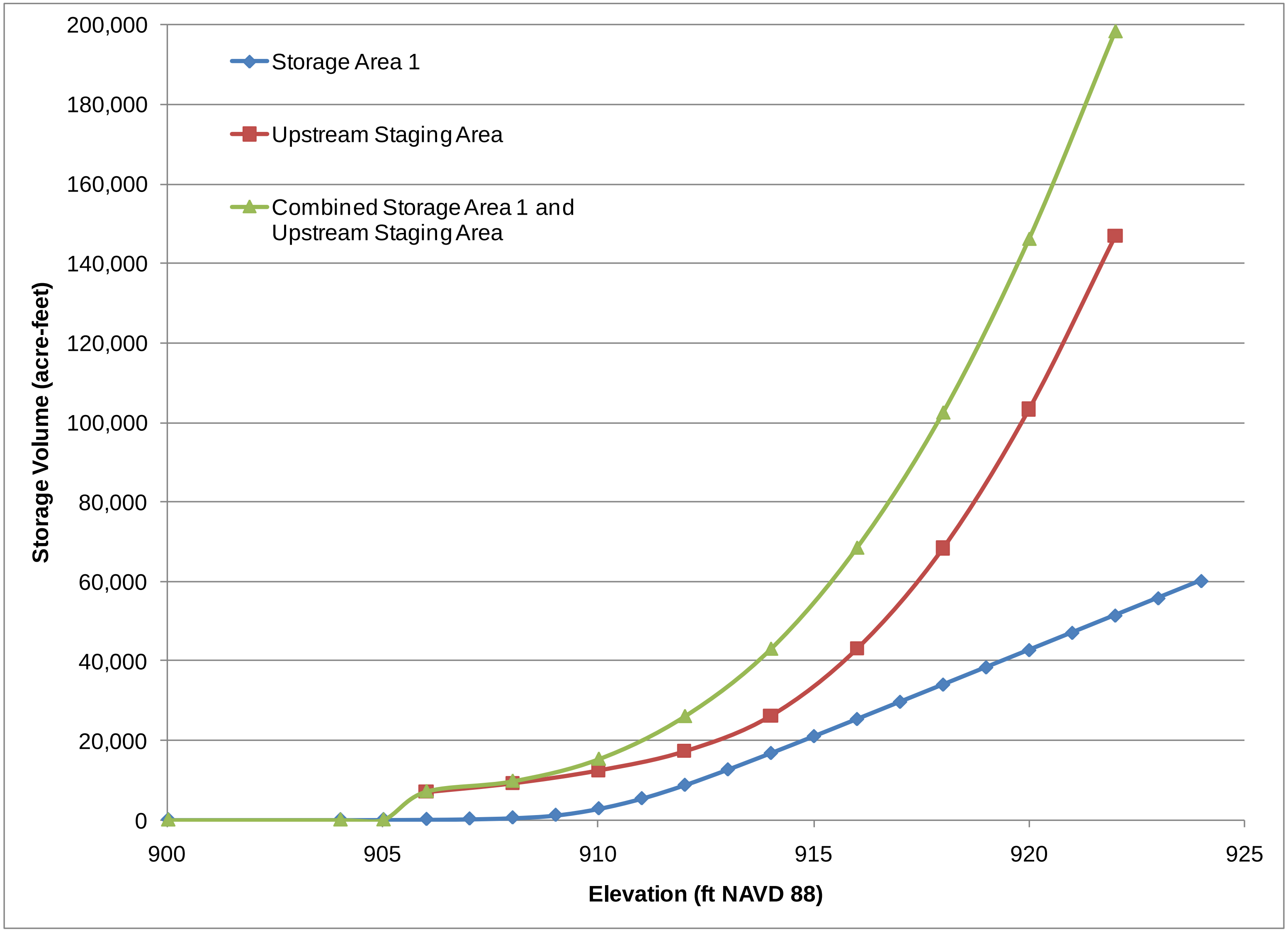
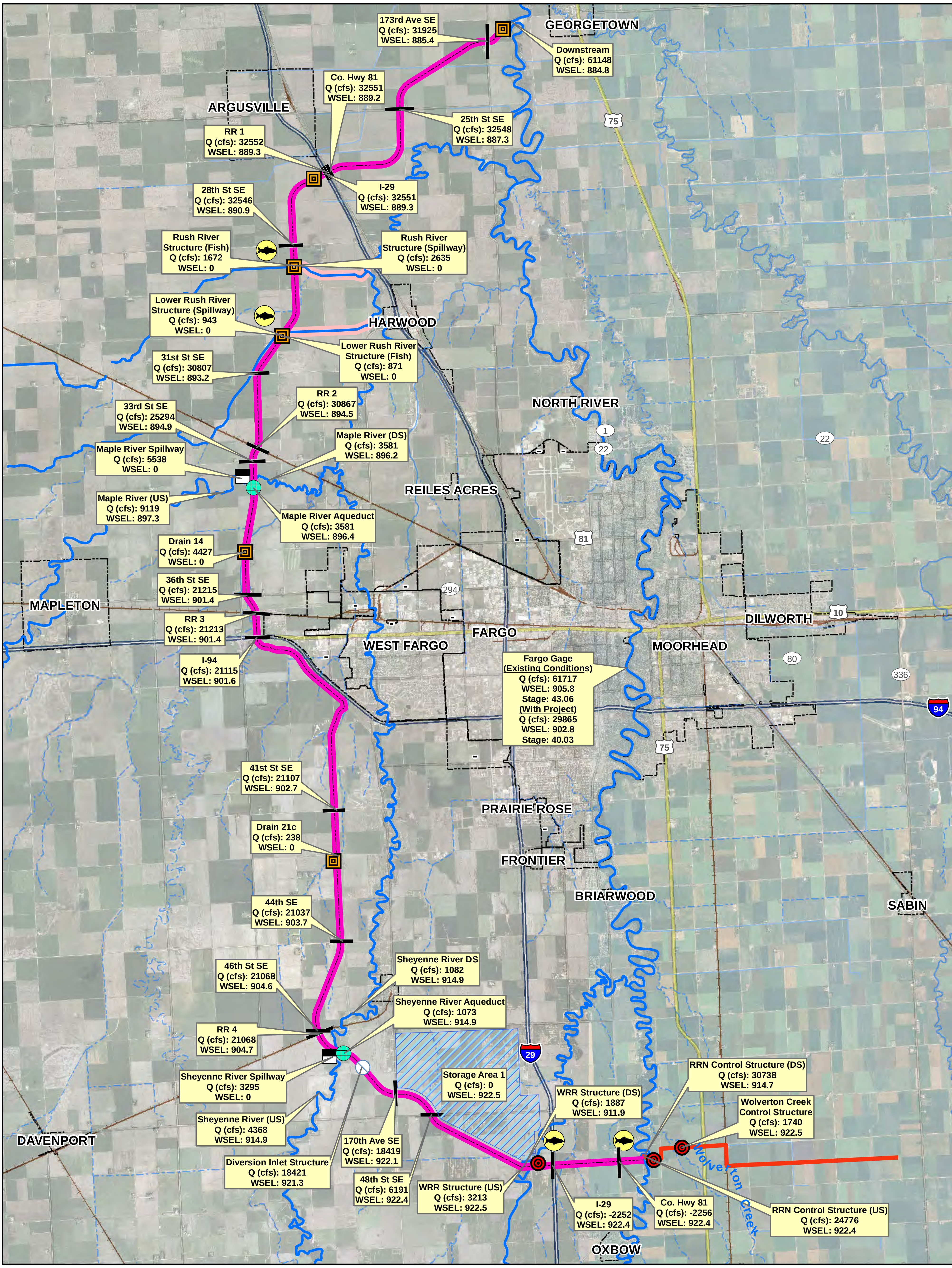


Figure 4 Storage Elevation Curves for Upstream Staging Area and Storage Area 1



I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 5 -Flow and Water Elevation - 500 Year Event On Red.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

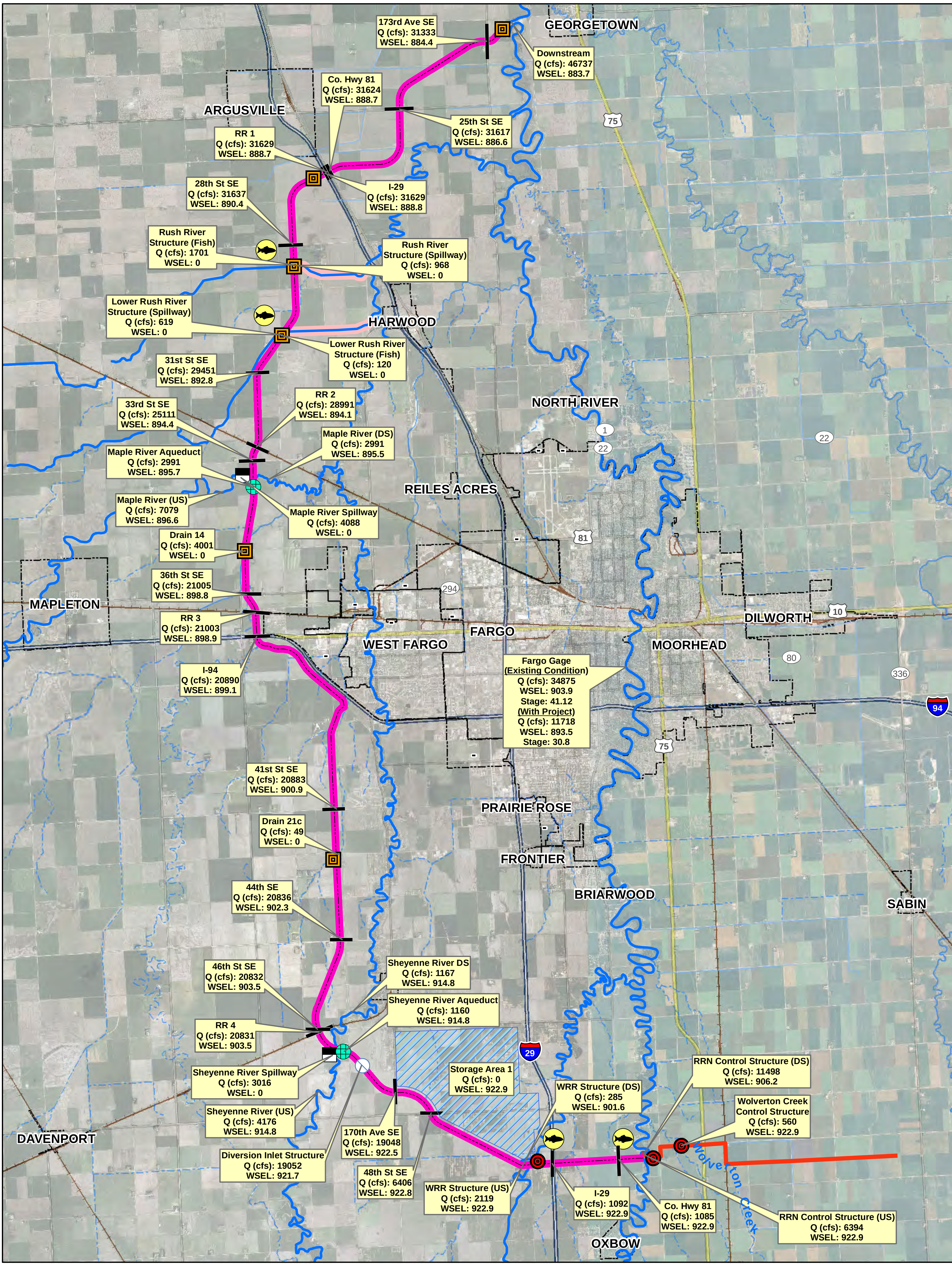
Figure 5

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 0.2-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 6 -Flow and Water Elevation - 100 Year Event On Red.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

Note: Flows in rivers (US) are in main channel only.
Flows in overbanks/floodplain are not reported.

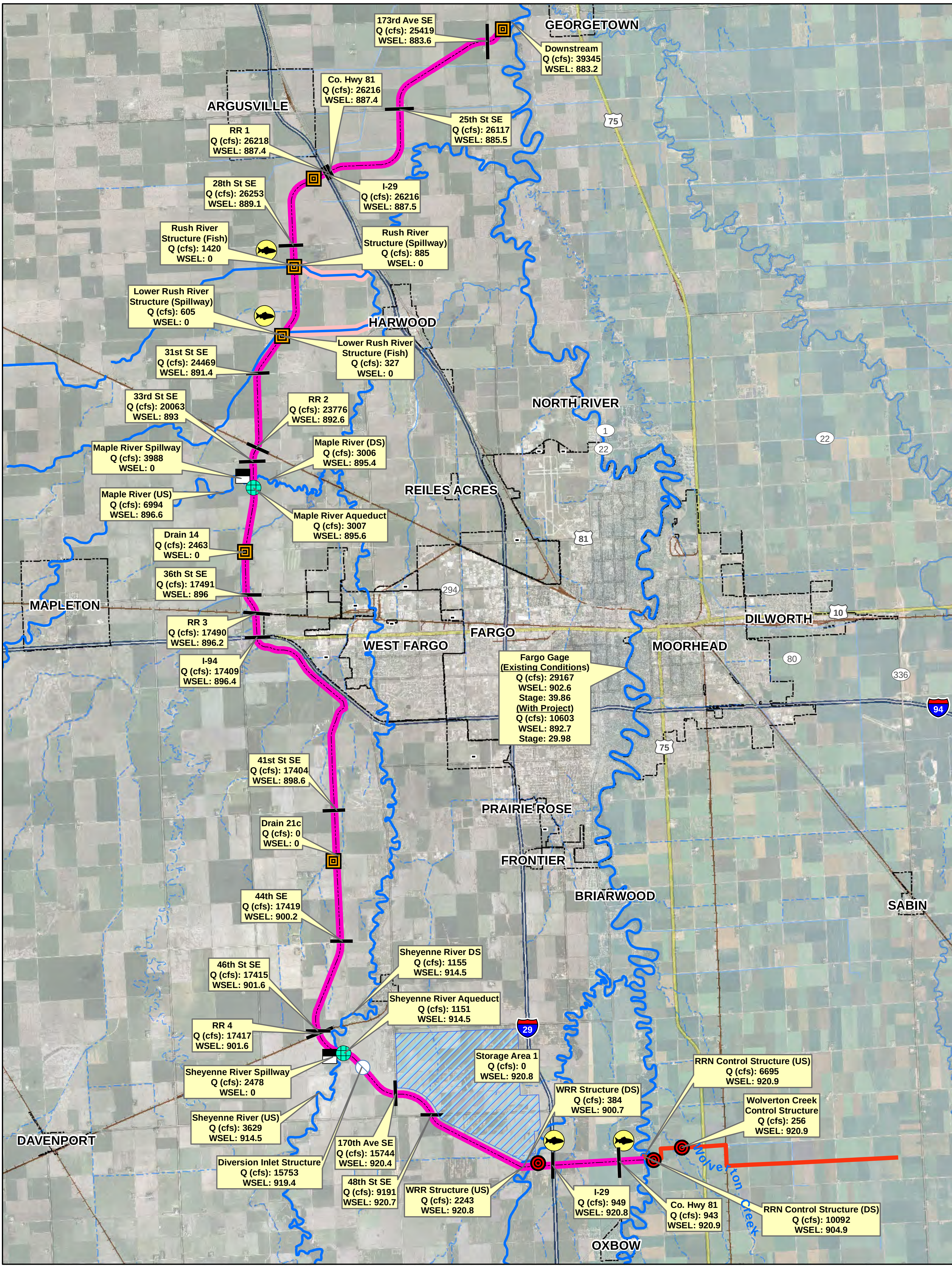
Figure 6

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 1-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 7 -Flow and Water Elevation - 50 Year Event On Red.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

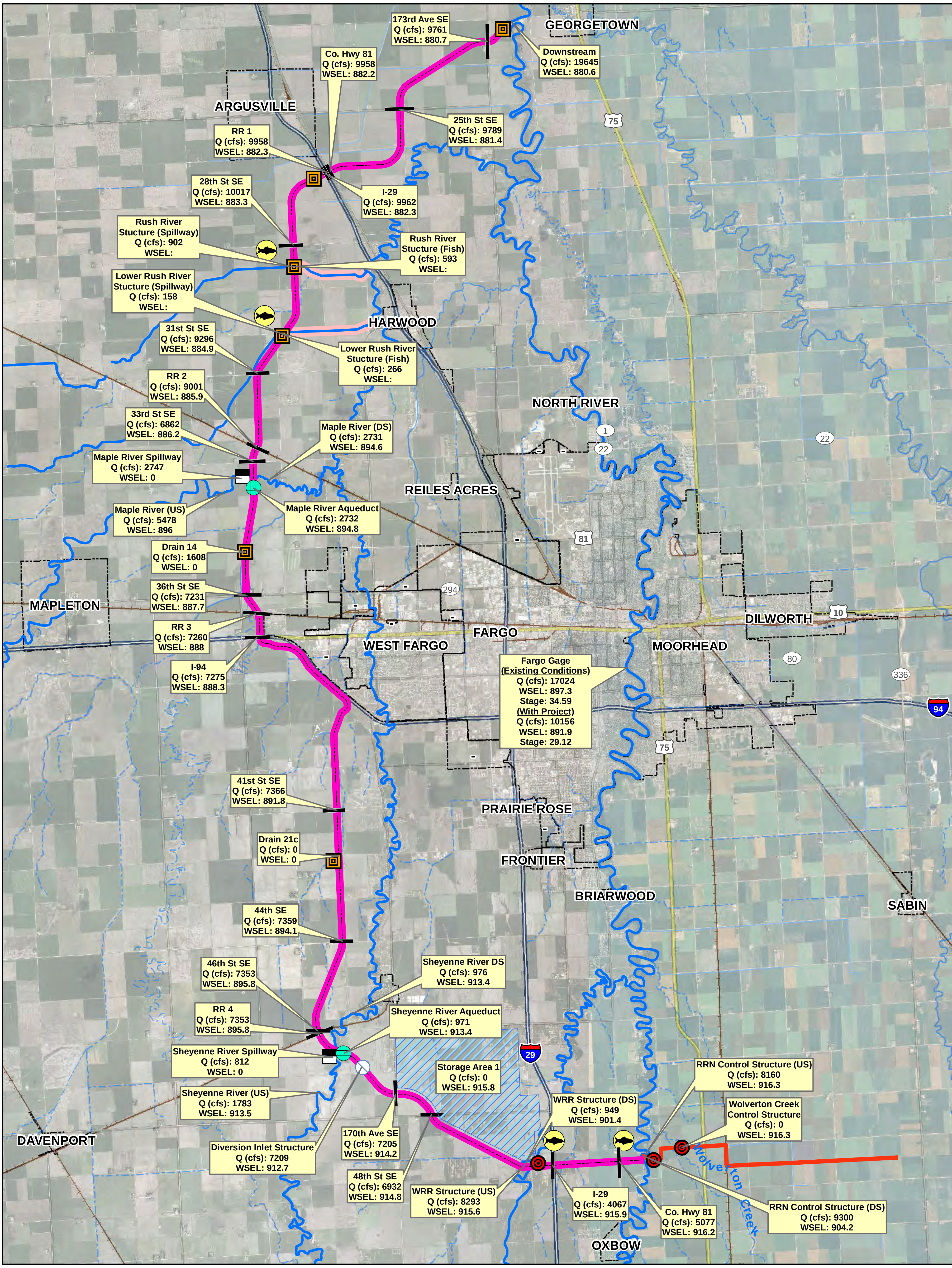
Figure 7

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 2-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 8 -Flow and Water Elevation - 10 Year Event On Red.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

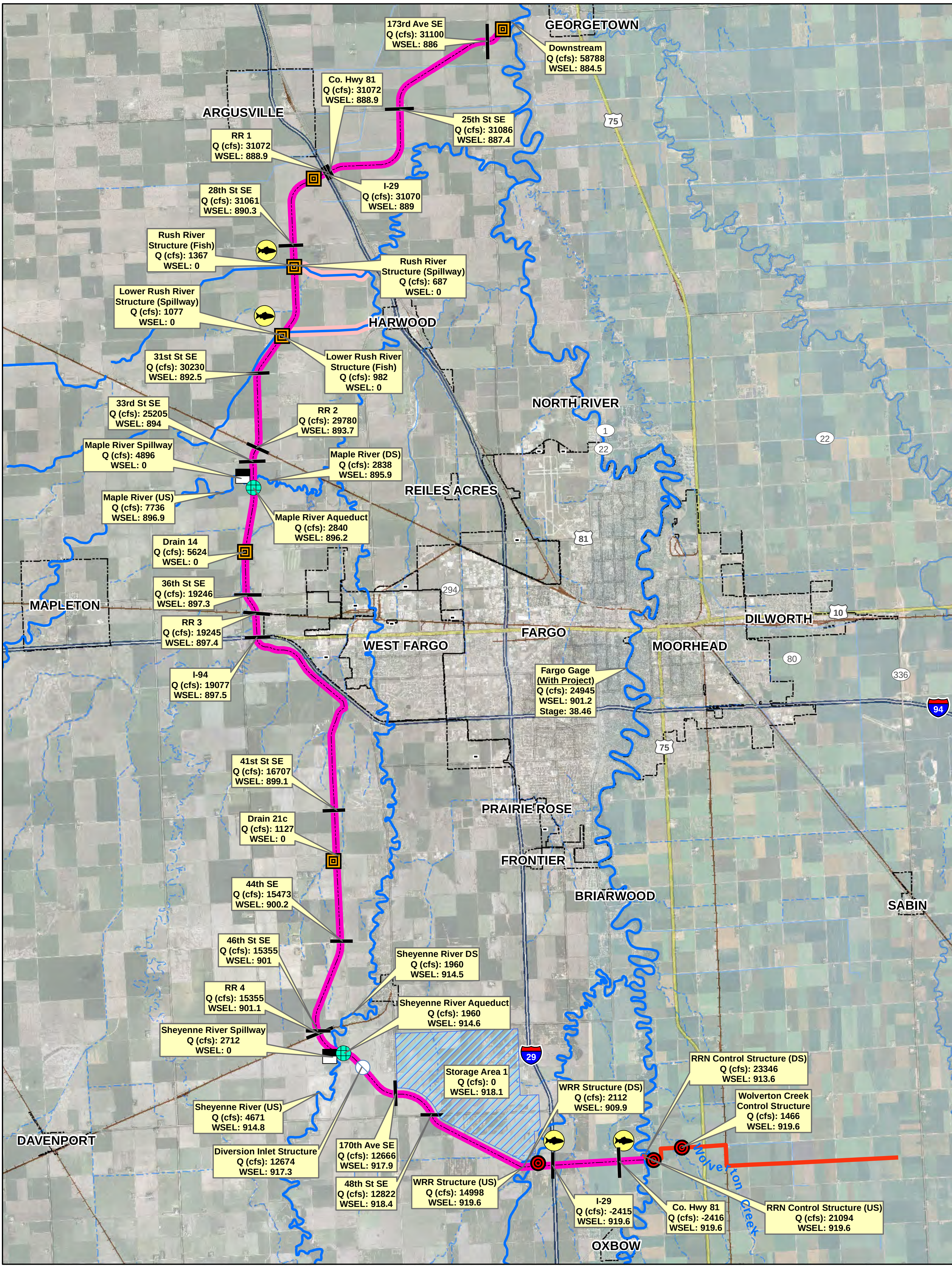
Figure 8

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 10-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 9 -Flow and Water Elevation - 500 Year Event On Tribs.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

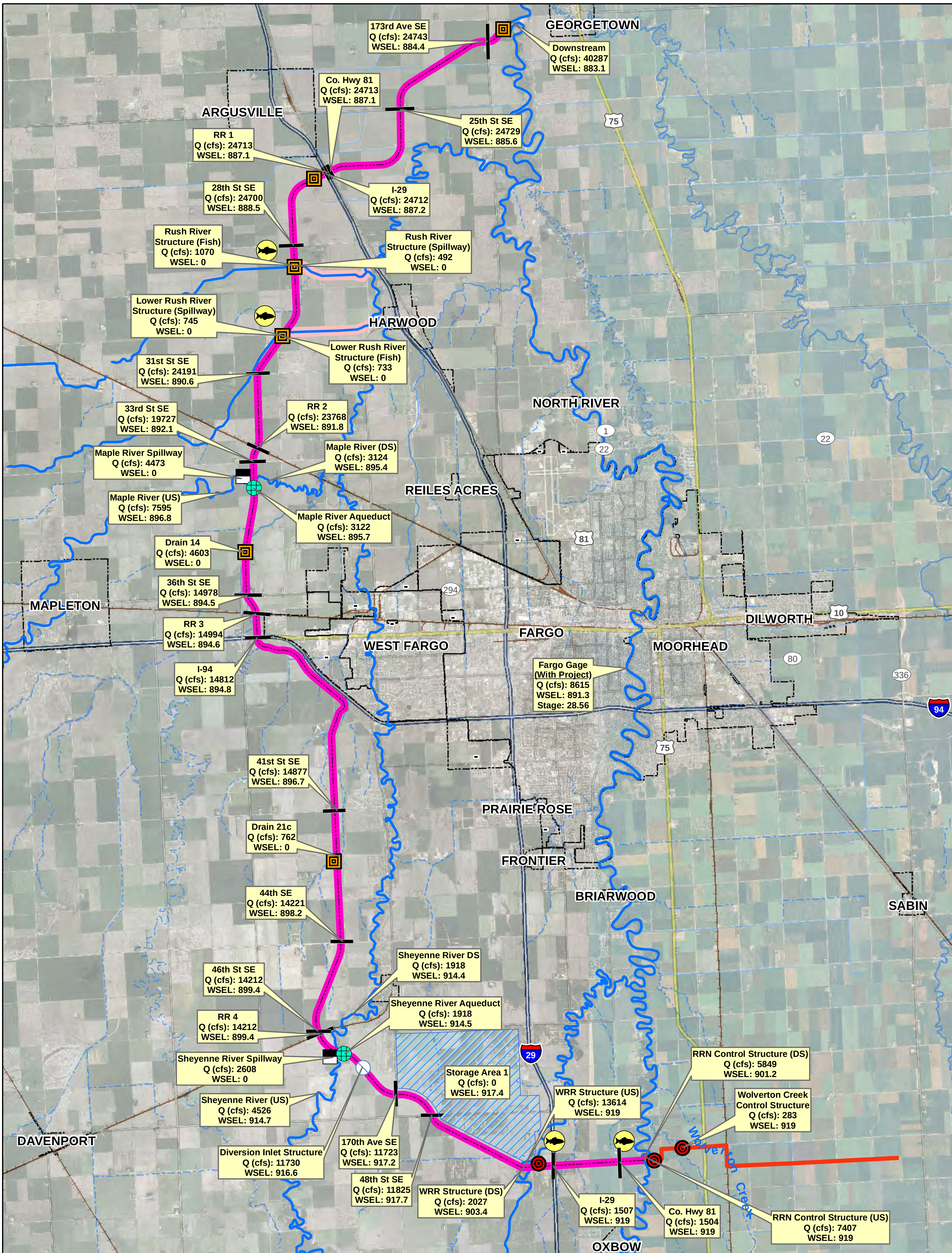
Figure 9

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 0.2-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 10 -Flow and Water Elevation - 100 Year Event On Tribs.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

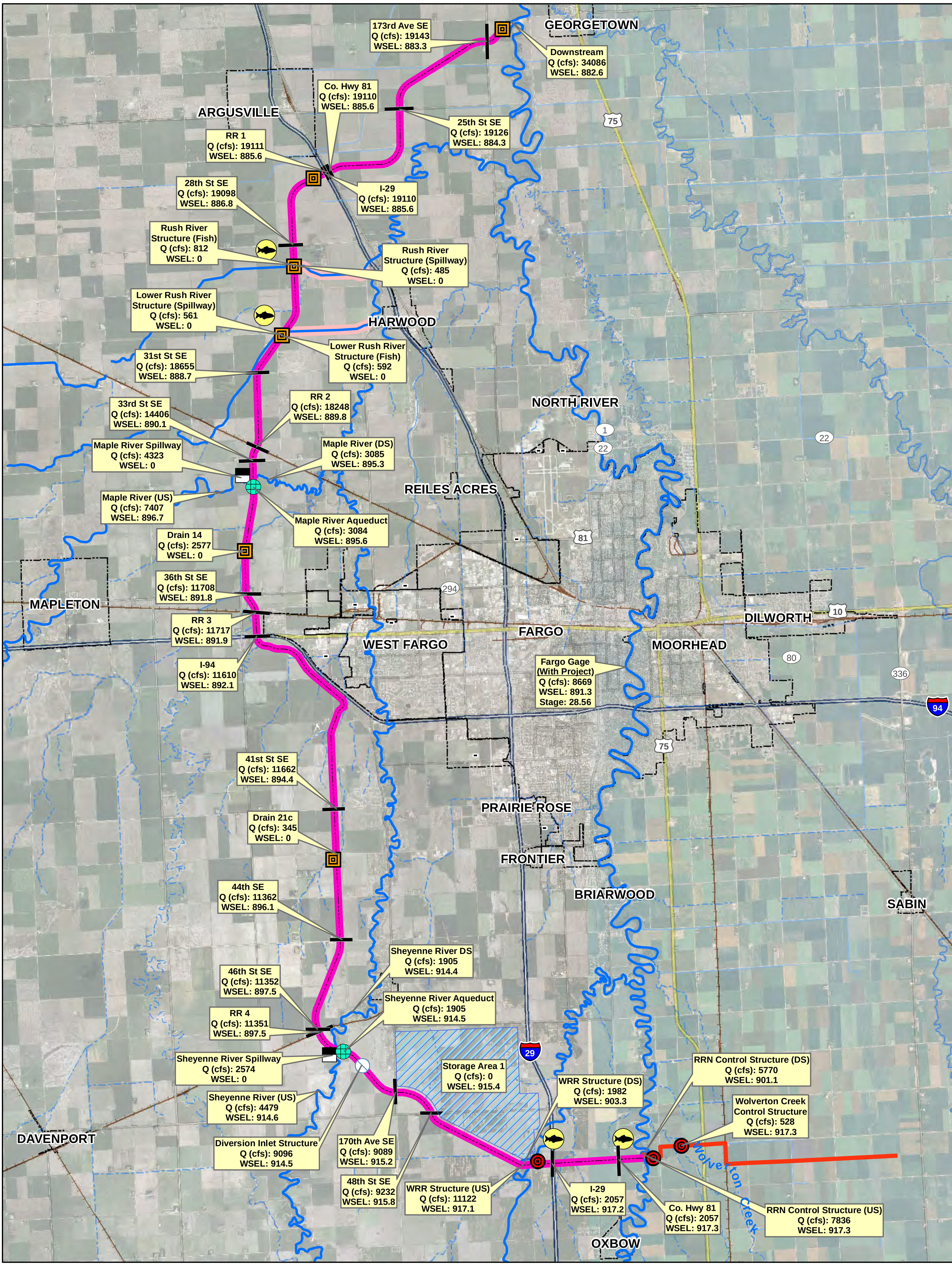
Figure 10

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 1-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 11 -Flow and Water Elevation - 50 Year Event On Tribs.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

North Dakota Diversion Locally Preferred Plan (LPP)

ND Tieback Levee

Channel Reclamation Reaches

Bridge Reconstruction

Storage Area 1

Note: Flows in rivers (US) are in main channel only.
Flows in overbanks/floodplain are not reported.

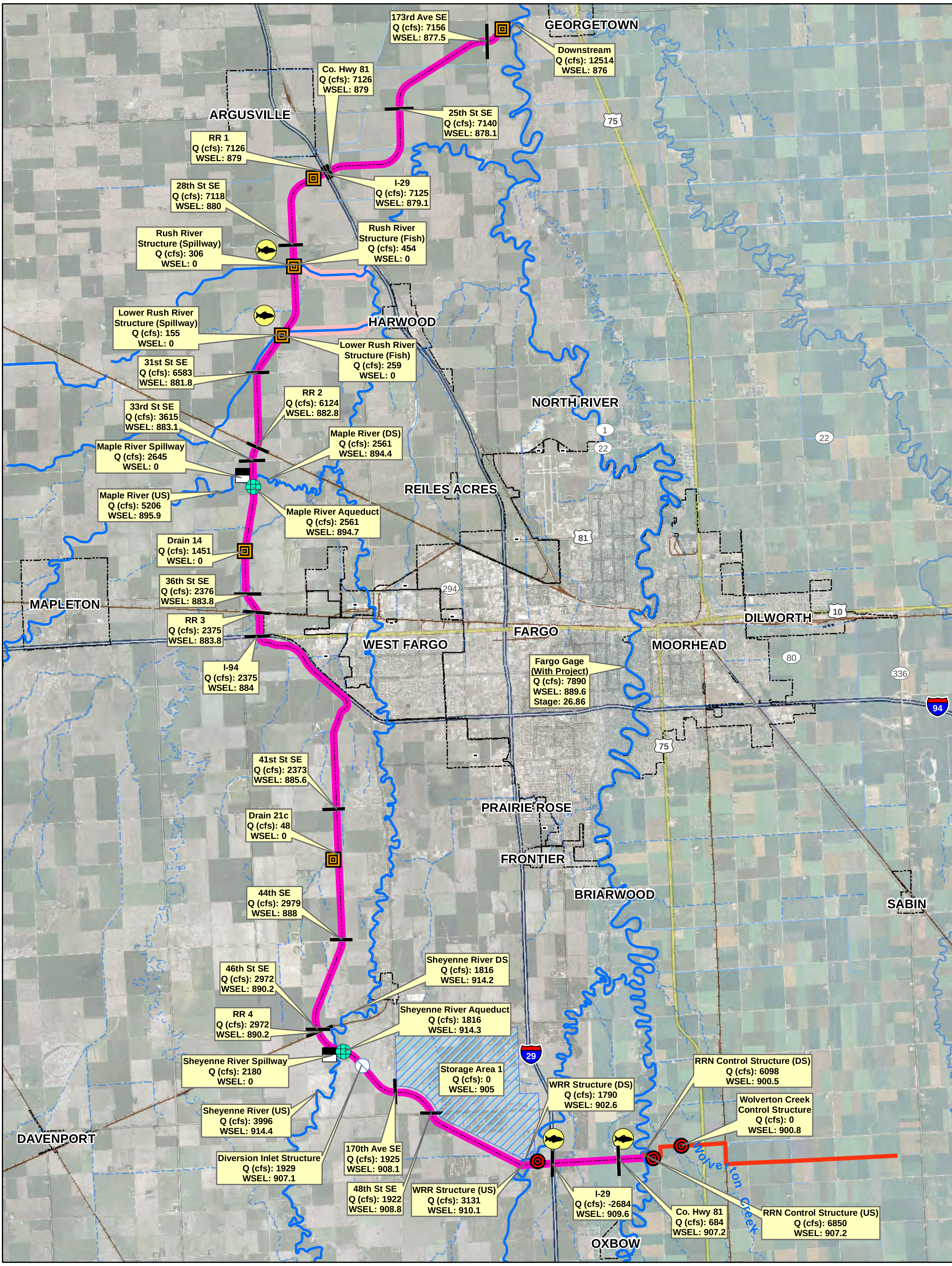
Figure 11

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 2-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

I:\Projects\34\09\1004\Maps\Reports\PhaseIV Event Flow and WSEL\Main_Report\Figure 12 -Flow and Water Elevation - 10 Year Event On Tribs.mxd



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

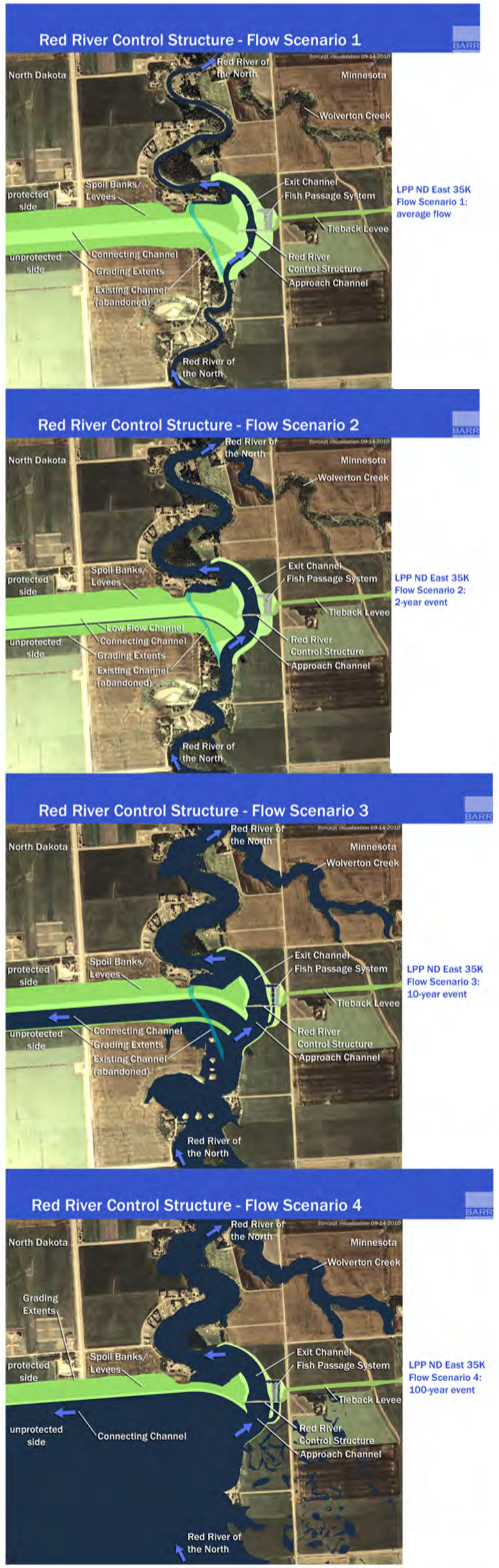
Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

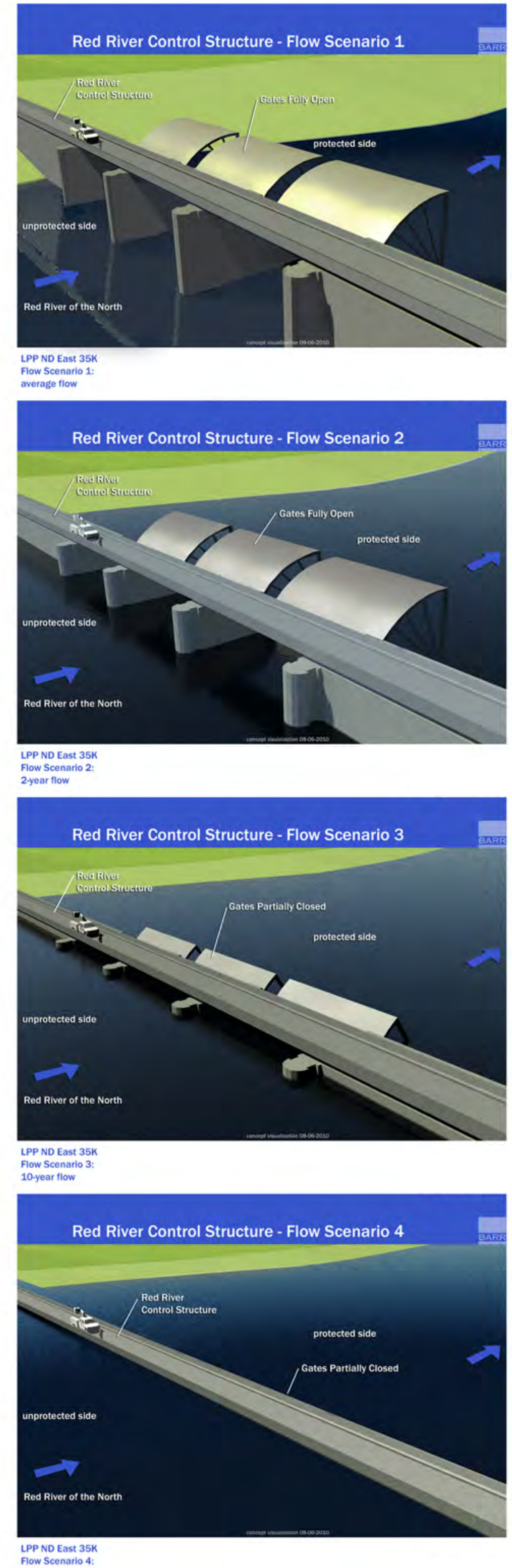
Figure 12

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 10-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles





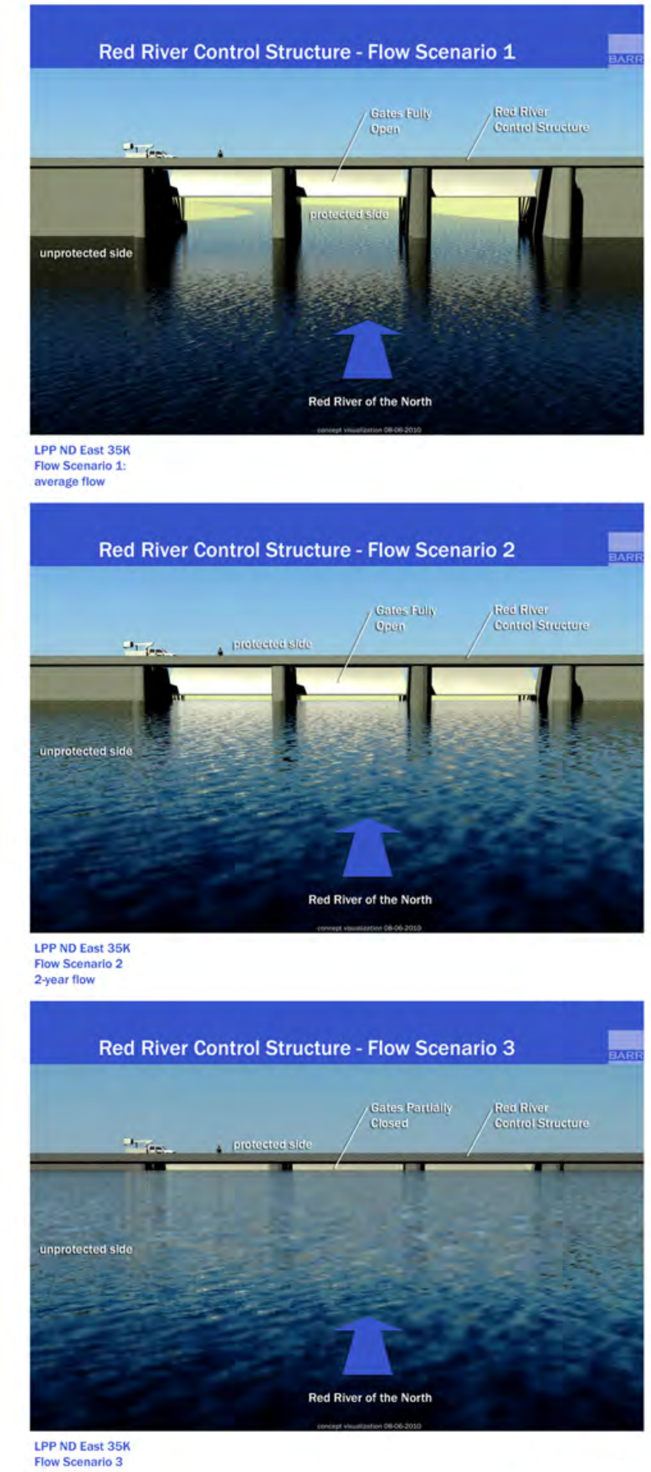


Figure 13

MOSAIC OF RENDERINGS OF

RED RIVER LPP CONTROL STRUCTURE

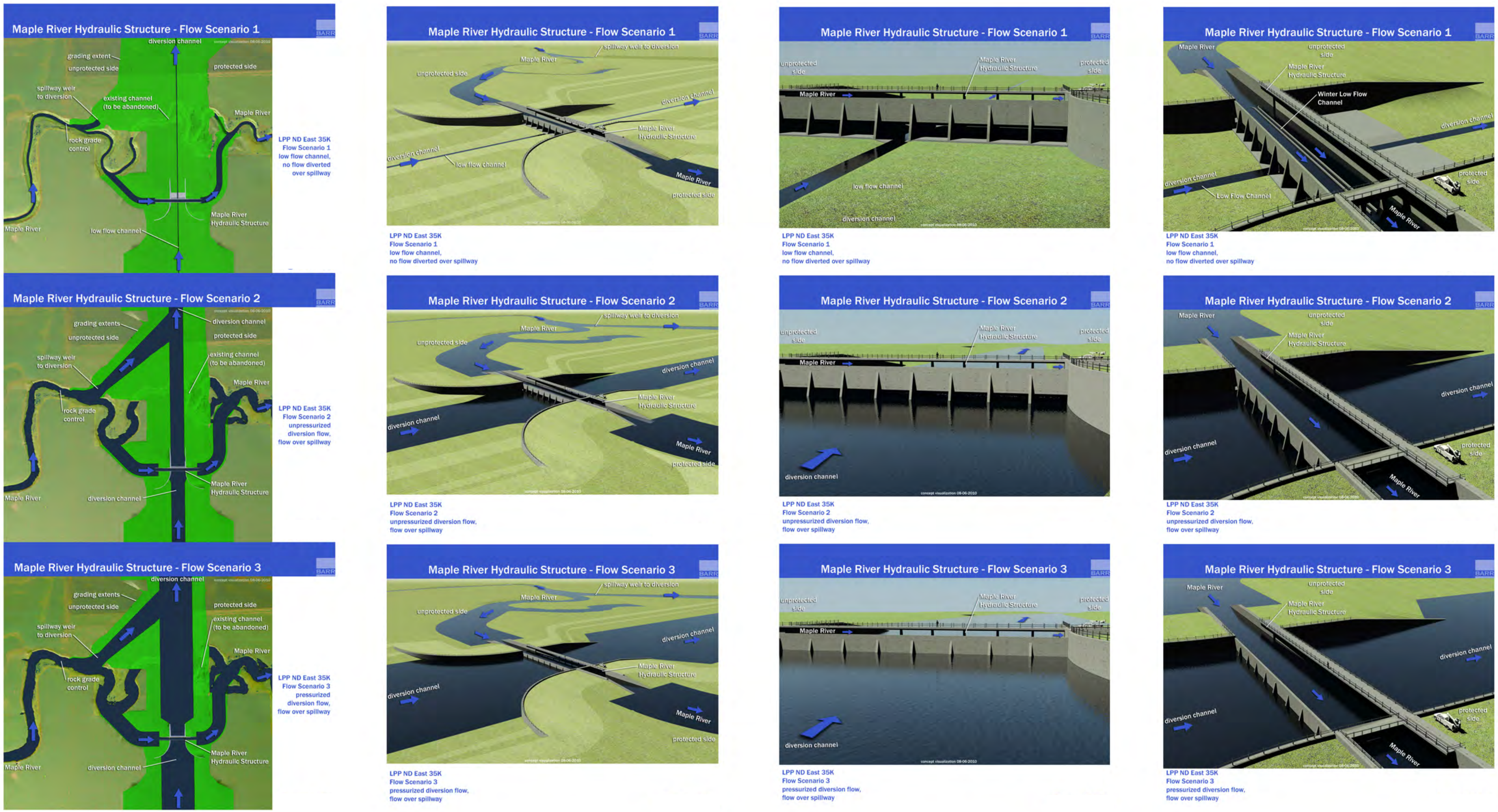
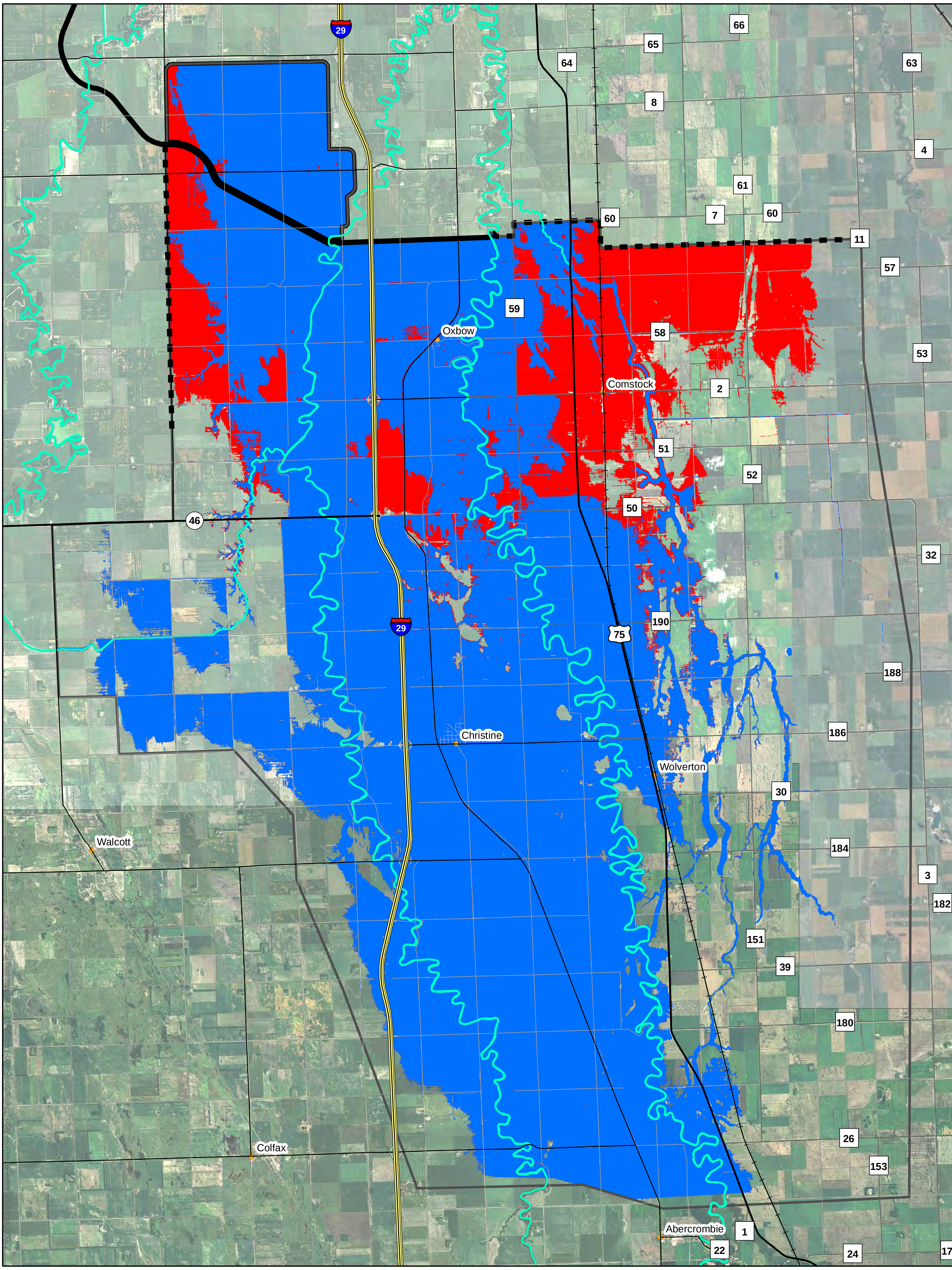


Figure 14
MOSAIC OF RENDERINGS OF
MAPLE RIVER HYDRAULIC STRUCTURES



0.2% Existing (66,566 Acres)

LPP 0.2% (78,876 Acres)

Mapping Extent

Storage Area 1

LPP Diversion

LPP Tieback

Cities

Figure 15

Inundation Map for the Model Existing Conditions and With Project for 0.2-percent Chance Event in the Red River of the North - South of Diversion Works - LPP

0 0.3750.75 1.5 2.25

Miles

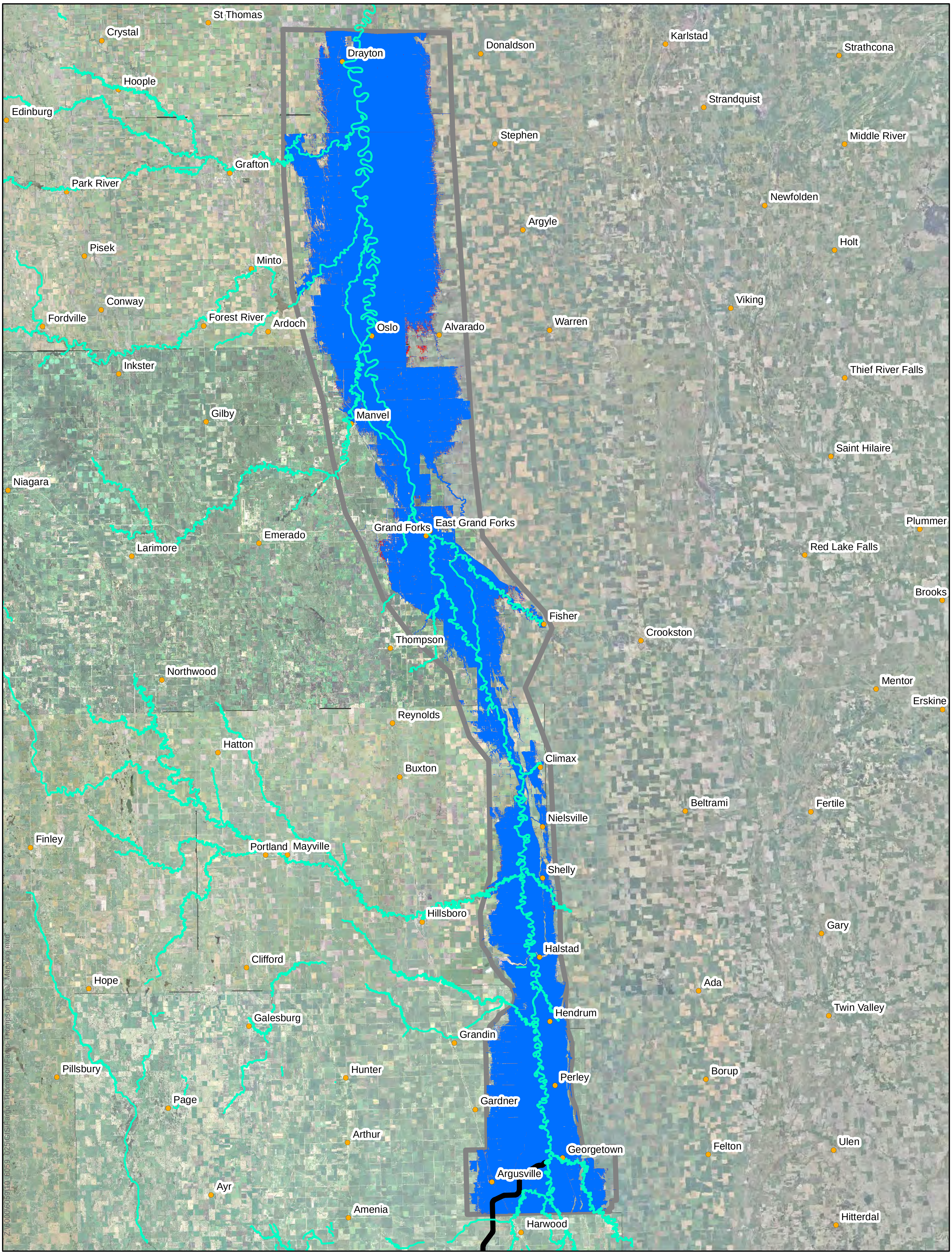


Figure 16

Inundation Map for the Model Existing Conditions and With Project for 0.2-percent Chance Event in the Red River of the North - North of Diversion Works - LPP

0.2% Existing (521,944 Acres)
LPP 0.2% (521,738 Acres)
Mapping Extent
Storage Area 1
LPP Diversion
LPP Tieback
Cities

0 2 4 8 12
Miles

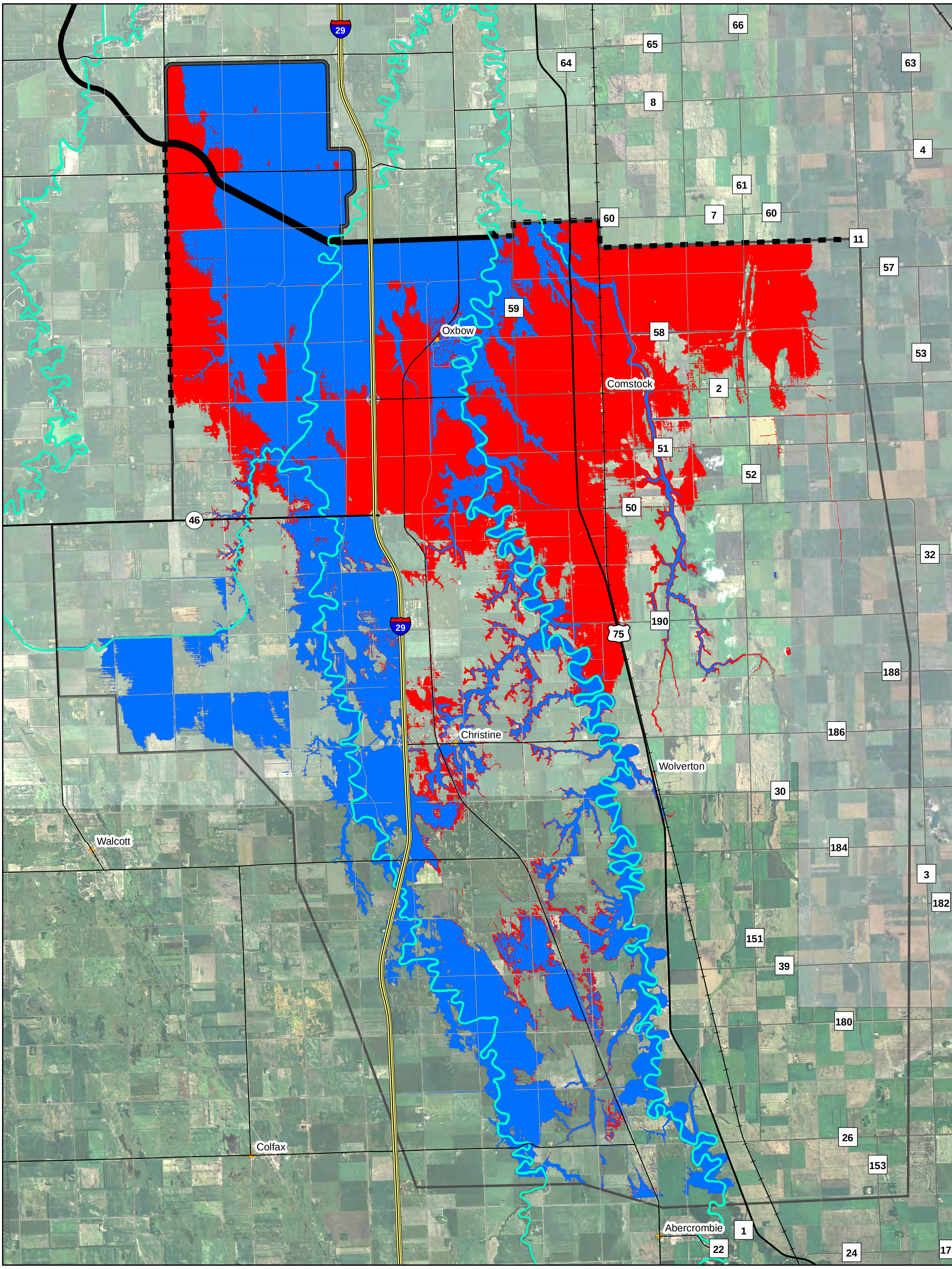


Figure 17

Inundation Map for the Model Existing Conditions and With Project for 1-percent Chance Event in the Red River of the North - South of Diversion Works - LPP

1% Existing (31,546 Acres)

LPP 1%(54,721 Acres)

Mapping Extent

Storage Area 1

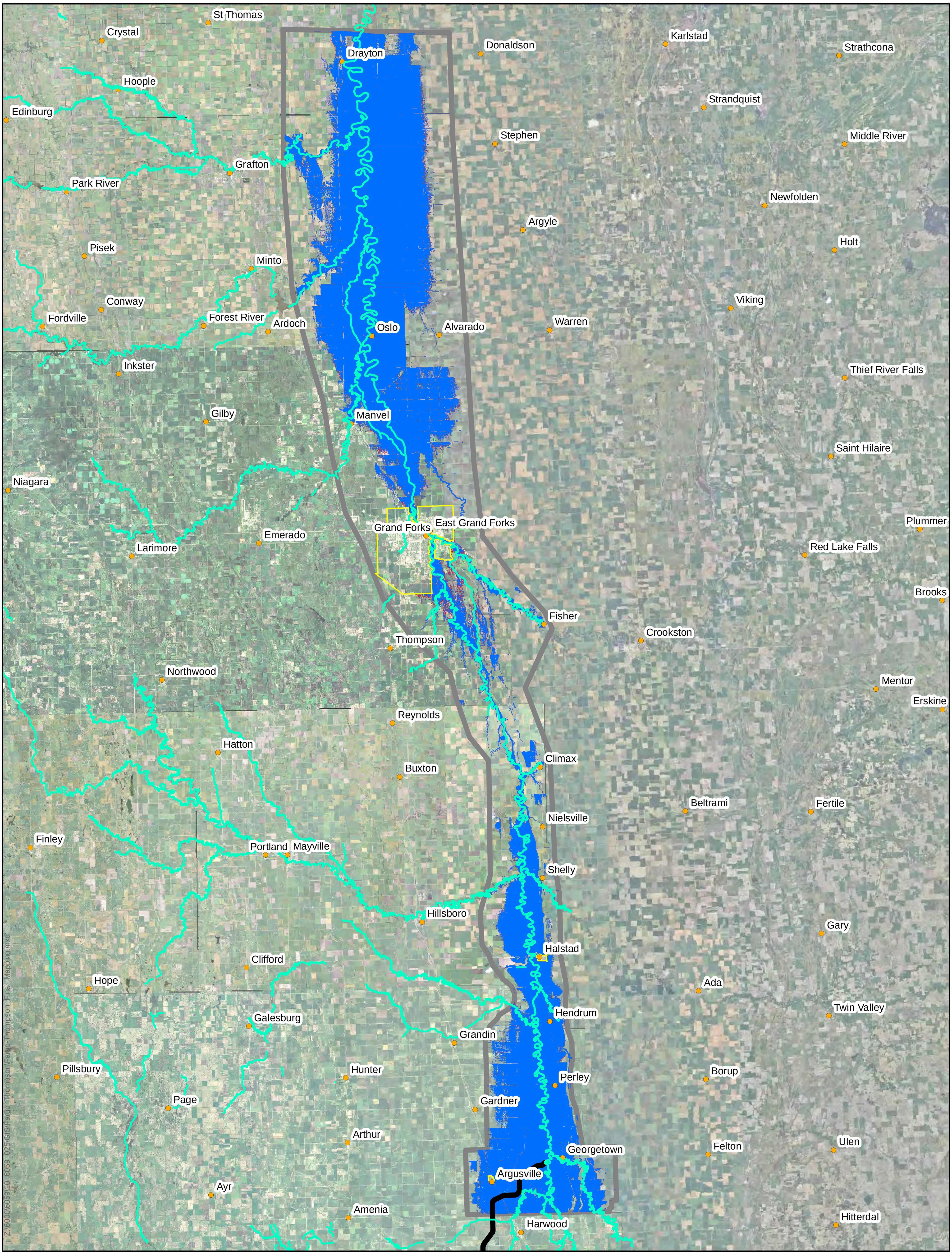
LPP Diversion

LPP Tieback

Cities

0 0.3750.75 1.5 2.25

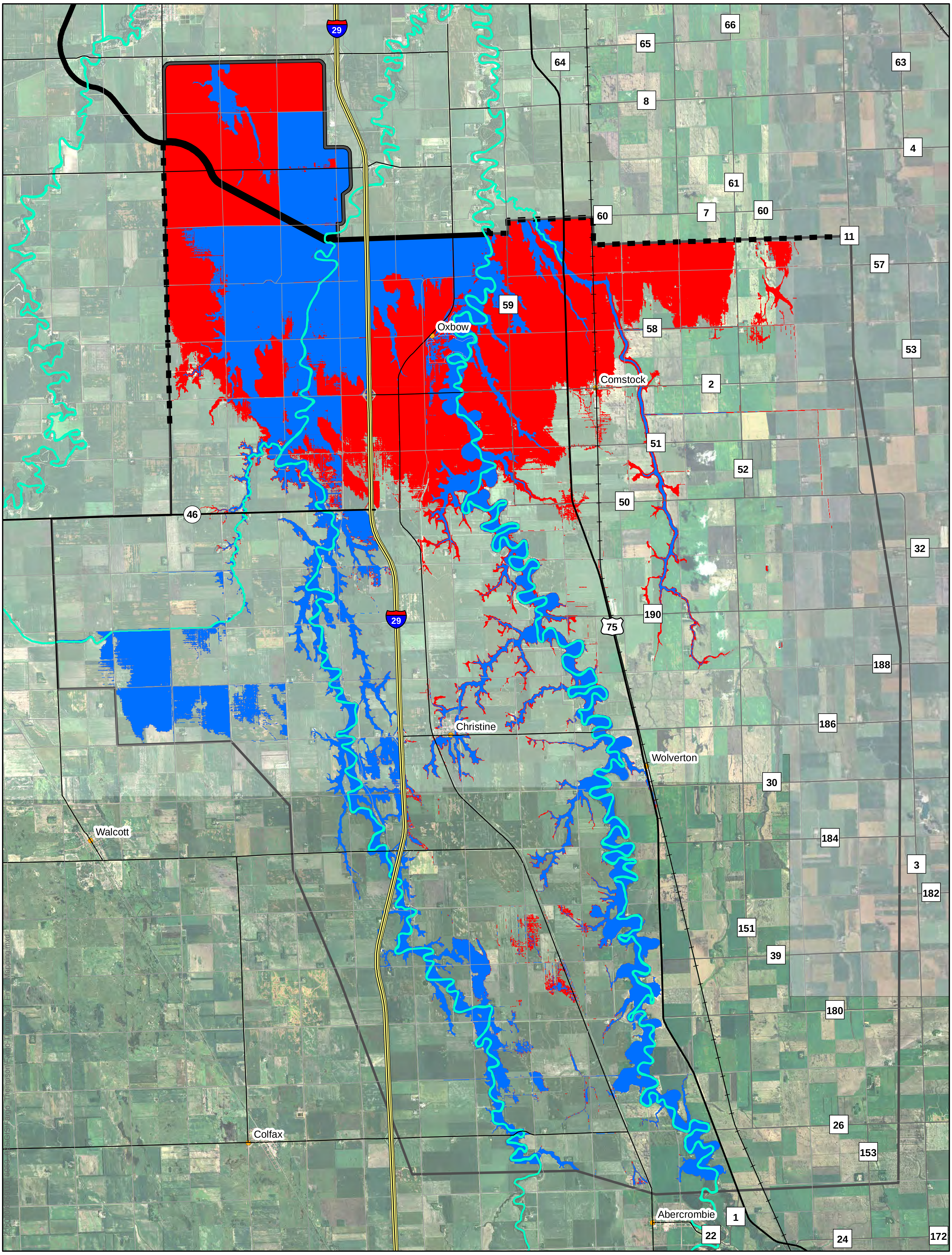
Miles



1% Existing (390,866 Acres)
LPP 1% (390,557 Acres)
Mapping Extent
Protection
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 18

Inundation Map for the Model Existing Conditions and With Project for 1-percent Chance Event in the Red River of the North - North of Diversion Works - LPP



2% Existing (20,363 Acres)

LPP 2% (38,000 Acres)

Mapping Extent

Storage Area 1

LPP Diversion

LPP Tieback

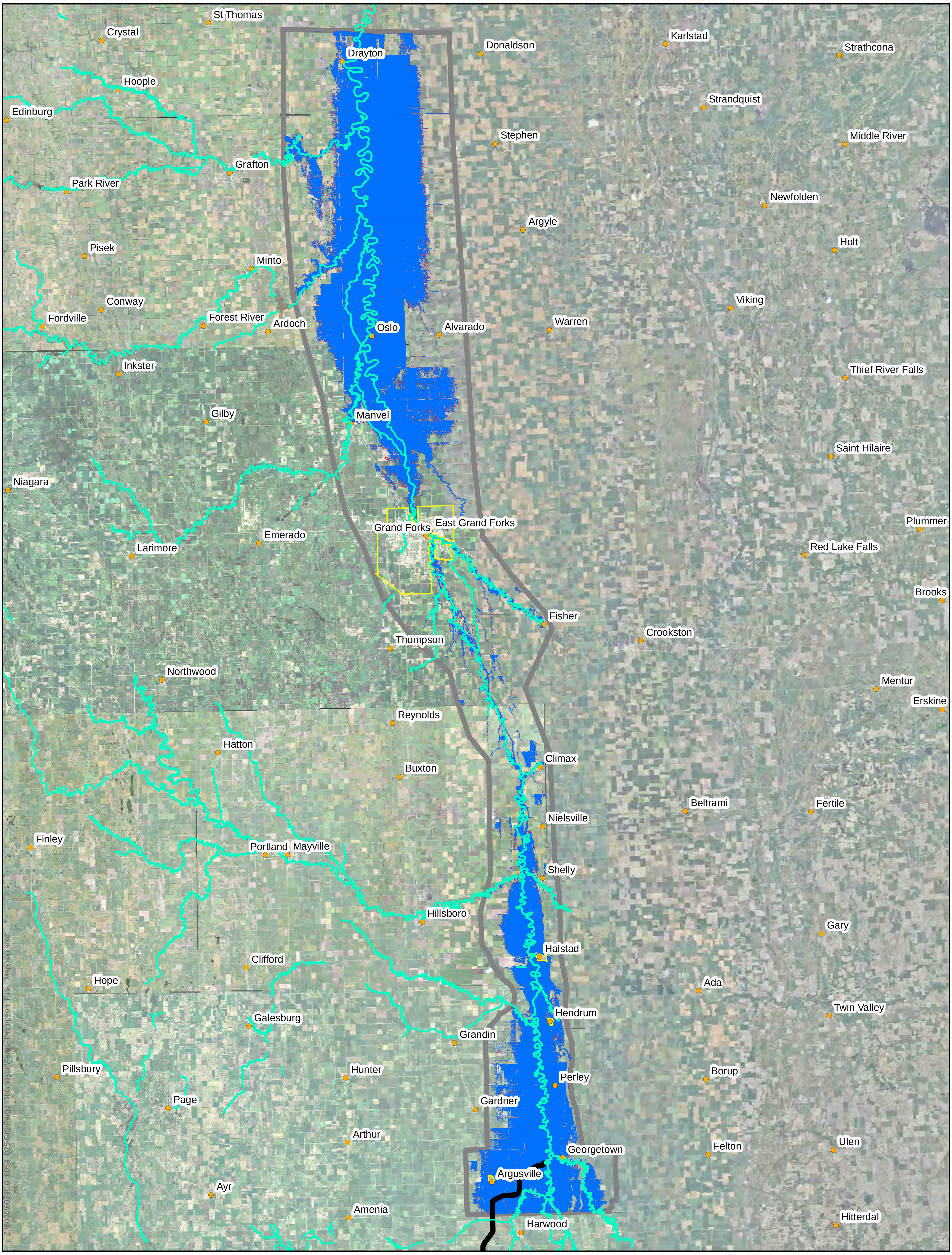
Cities

Figure 19

Inundation Map for the Model Existing Conditions and With Project for 2-percent Chance Event in the Red River of the North - South of Diversion Works - LPP

0 0.3750.75 1.5 2.25

Miles



2% Existing (347,158 Acres)

LPP 2% (346,696 Acres)

Mapping Extent

Protection

Storage Area 1

LPP Diversion

LPP Tieback

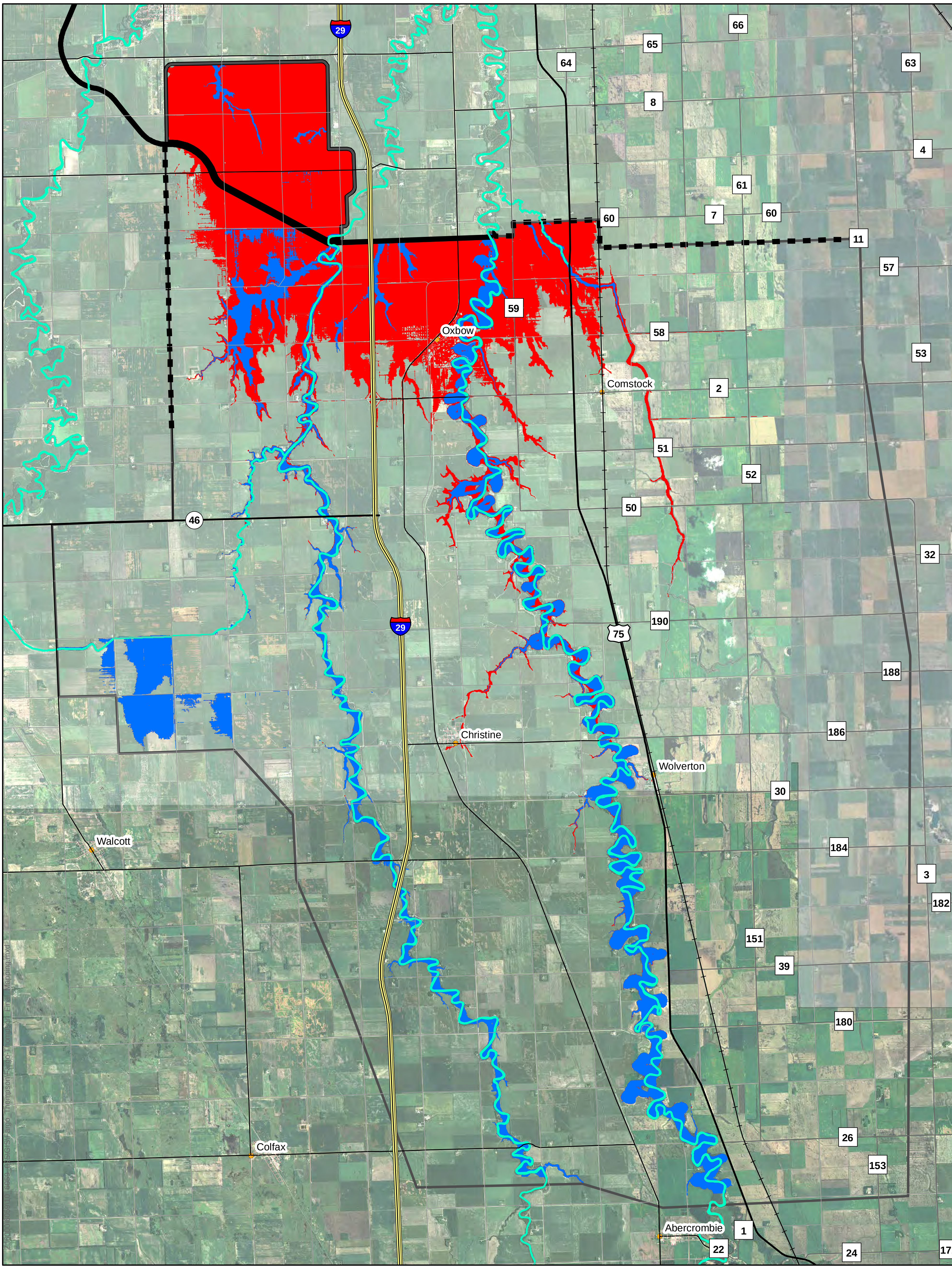
Cities

Figure 20

Inundation Map for the Model Existing Conditions and With Project for 2-percent Chance Event in the Red River of the North - North of Diversion Works - LPP

0 2 4 8 12

Miles

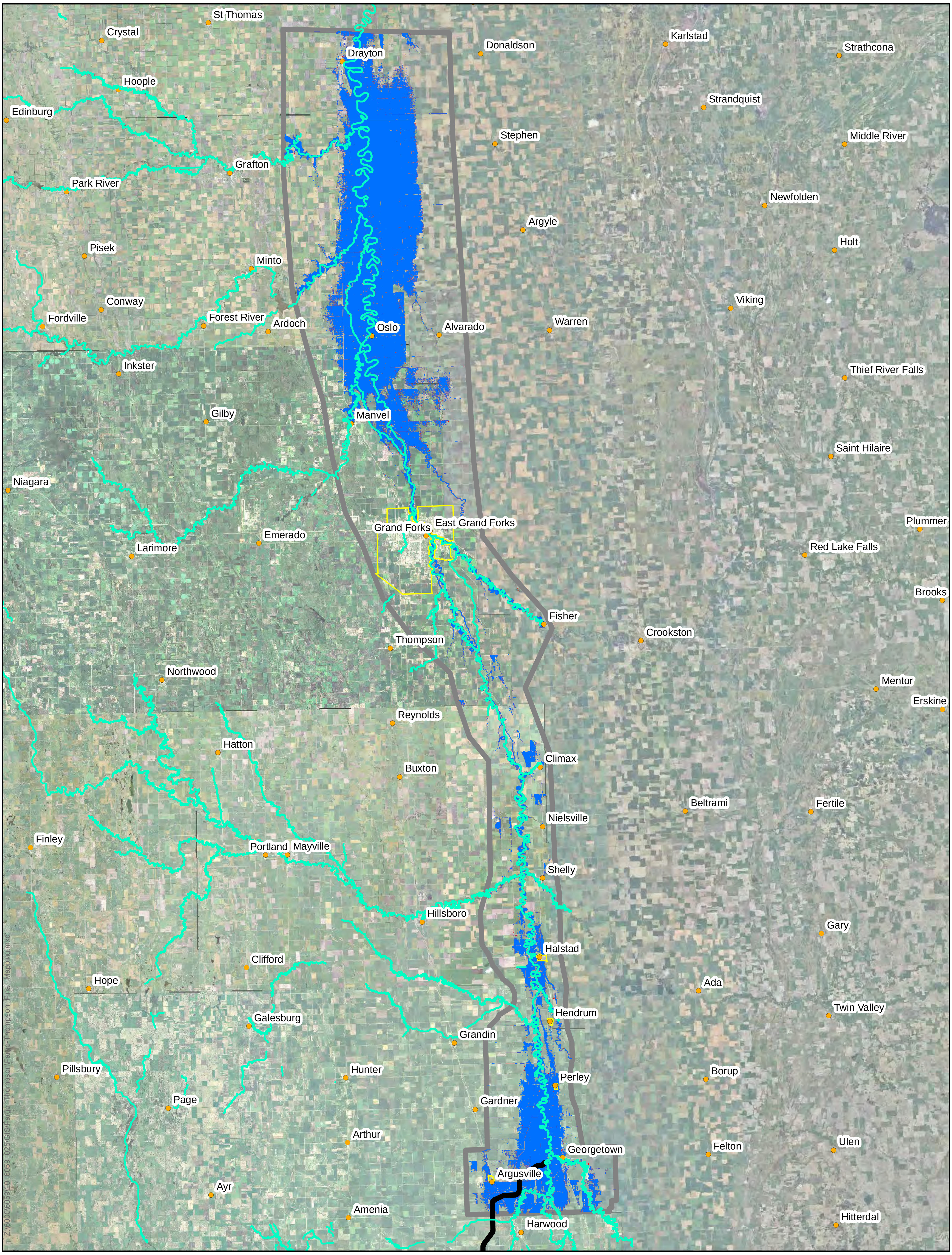


10% Existing (7,858 Acres)
LPP 10% (20,841 Acres)
Mapping Extent
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 21

Inundation Map for the Model Existing Conditions and With Project for 10-percent Chance Event in the Red River of the North - South of Diversion Works - LPP

0 0.375 0.75 1.5 2.25
Miles



10% Existing (224,166 Acres)
LPP 10% (221,176 Acres)
Mapping Extent
Protection
Storage Area 1
LPP Diversion
LPP Tieback
Cities

0 2 4 8 12
Miles

Figure 22

Inundation Map for the Model Existing Conditions and With Project for 10-percent Chance Event in the Red River of the North - North of Diversion Works - LPP