SEH

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TO: Mark Lobermeier, PE
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FROM: Brad Woznak, PE, PH, CFM
Tim Diedrich, PE

DATE: July 27, 2017

RE: Kinni Corridor Plan - Hydrologic & Hydraulic Analysis Summary
SEH No. RIVER 138553 14.00

This draft memorandum has been prepared to summarize the hydrologic and hydraulic analyses conducted as part of the Kinnickinnic Corridor Plan being prepared for the City of River Falls.

SUMMARY OF BACKGROUND INFORMATION REVIEWED

April 1999: Kinnickinnic River Priority Watershed Project (The Wisconsin Nonpoint Source Water Pollution Abatement Program; Wisconsin DNR). This report was prepared under the Wisconsin Nonpoint Source (NPS) Water Pollution Abatement Program. It includes a description of the Kinnickinnic River watershed, sources of nonpoint pollution along with management goals and objectives. While the report is somewhat dated, it provides a myriad of information that is useful and applicable to the Kinnickinnic Corridor Study area. The report also includes a historical account of key activities within the Kinnickinnic River watershed dating back prior to the 1850's.

October 2003: Kinnickinnic River at River Falls, Wisconsin Thermal study (USACE). This study was completed to develop a thermal model to aid in evaluating the effectiveness of various storm water management plans on the cold water fishery downstream of River Falls. A CE-QUAL-W2 model was developed as part of the study to aid in evaluating how storm water may alter the temperature and flow regimes of the Kinnickinnic River.

March 2009: Flood Insurance Study for St Croix Co, WI and Incorporated Areas (FIS No. 55109CV000A, FEMA). FEMA Flood Insurance Studies (FIS) for St Croix County which establishes regulatory floodplain zones for the Kinnickinnic River primarily upstream of the City of River Falls and the corridor study area. The study also describes engineering methods including the hydrologic and hydraulic analyses that were completed to support the development of the FIS and floodplain mapping.

February 2011: Coldwater Fish and Fisheries Working Group Report (Wisconsin Initiative on Climate Change Impacts). While not specific to the Kinnickinnic River, this study discusses how the distribution of some cold water fish in Wisconsin may be altered with climate change. A discussion of adaptation strategies is also discussed to lessen the impacts of climate change on cold water fisheries.

November 2011: Flood Insurance Study for Pierce Co, WI and Incorporated Areas (FIS No. 55093CV000A, FEMA). FEMA Flood Insurance Studies (FIS) for Pierce County which establish regulatory floodplain zones for the Kinnickinnic River through the City of River Falls and the corridor study area. The study also describes engineering methods including the hydrologic and hydraulic analyses that were completed to support the development of the FIS and floodplain mapping.

March 2016: Lake George and Lake Louise, Sediment Assessment Report (Inter-Fluve). This study was completed for the City by Inter-Fluve to evaluate existing sediment conditions in the upper and lower impoundments, Lakes George and Louise, respectively. The main focus of the work was to assess the quantity and quality of impounded sediment behind both dams, and to determine the potential volume of sediment that may be evacuated or need to be excavated in the event of dam removal.

January 2017: Restoration of the Kinnickinnic River through Dam Removal Feasibility Report (Inter-Fluve). The aforementioned report was completed for the Friends of the Kinni (FOTK) by Inter-Fluve to evaluate the feasibility of removal of the Junction Falls and Powell Falls Dams. The study evaluated construction methods, water and sediment management and river restoration outcomes for removing the two dams while considering the project goals of the improvement of water quality, fish habitat, public safety, aesthetics, protection of infrastructure, and recreational values.

HYDROLOGY

The Kinnickinnic River watershed area near the upper end of the Kinni Corridor Study Area, at the crossing of State Route 35, is approximately 77 square miles and near the downstream end of the Study Area, below the confluence of the Rocky Branch is approximately 128 square miles per Table 4 of the 2011 Pierce County FIS.

The Kinnickinnic River flooding in the City of River Falls occurs primarily as a result of spring rainfall events during snowmelt runoff or more recently during high intensity rainstorms occurring in the summer or early fall months.

Kinnickinnic River Design Discharge

The discharge frequency values from the 2011 FIS model were utilized for the hydraulic analyses associated with this study. The following table summarizes the peak discharge rates for the Kinnickinnic River in the study area. In addition to the design discharges listed in Table 1, a base flow alternative was analyzed with a constant flow rate of 100 cfs, to predict normal depths and typical daily water surface profiles in a dam removal scenario.

Table 1. Discharge Frequency Values for Kinnickinnic River at River Falls

Return Frequency (Exceedance Probability)	Upstream of State Route 35 Discharge (cfs)	Upstream of Junction Falls Dam Discharge (cfs)	Upstream of Powell Falls Dam Discharge (cfs)
10-year (10-percent)	3,050	3,350	6,800
50-year (2-percent)	6,450	7,050	11,000
100-year (1-percent)	8,000	8,700	12,800
500-year (0.2-percent)	11,900	13,000	16,900

Previous reports have cited large potential discrepancies between published FIS design discharge rates when compared with design discharge rates obtained from more recently generated USGS regression analyses (Walter & Krug, 2003). SEH has further analyzed the merit of this claim by first conducting a statistical analysis of available flow discharge data utilizing HEC-SSP, and secondly, by conducting an independent computation of design discharge rates utilizing the USGS regression methodology both from print edition and from the USGS online StreamStats application.

Available USGS stream discharge data was obtained for the period of record and analyzed in HEC-SSP. According to Bulletin 17B, Guidelines for Determining Flood Flow Frequency (USGS 1982) there is a sufficient period of record of discharge data to warrant a statistical flood frequency analysis. As seen in Table 2, results of the flood frequency analysis correlate well to the discharge rates published in the Pierce County FIS. It is important to note that the flood frequency analysis conducted utilizes average daily discharge data instead of instantaneous discharge data, and therefore, instantaneous peak discharge rates could be expected to be significantly higher than those seen in Table 2.

Table 2. HEC-SSP Discharge Frequency Results

Return Interval	Flood Magnitude (cfs)
10-year	3,810
50-year	6,580
100-year	7,930
500-year	11,460

Computations following the methodologies outlined by the USGS published Flood Frequency Characteristics of Wisconsin Streams were conducted and compared to published FIS discharge rates. Variables utilized for the regression analyses reflect those just upstream of Junction Falls and are as follows: drainage area (A) in square miles = 90, main channel slope (S) in feet per mile = 10.7, soil permeability (SP) in inches per hour = 0.8. Results following the regression methodology can be seen in Table 3. An important note relating to the regression variables is that the USGS Flood Frequency Characteristics document states that the soil permeability (SP) utilized for the analysis is based on the least permeable soil horizon in the soil column. Referencing the print version of Plate 2, Soil Permeability in Wisconsin, developed by the USGS in association with the Flood Frequency Characteristics document, an acceptable value to utilize is 0.8 in/hr. By inspection, a limiting infiltration rate of 0.8 in/hr is reasonable, given knowledge of governing soil horizons in the western Wisconsin regional area. Results of the analysis can be seen in Table 3. However, when utilizing the StreamStats program developed by the USGS in conjunction with the Flood Frequency Characteristics document, an average soil permeability value of 16 in/hr is reported as a basin characteristic, which is an unrealistic limiting soil parameter given knowledge of soils in west central Wisconsin and when further compared to Plate 2. The regression analyses were not developed for the 500-year return interval flood magnitudes, and are therefore not included in Table 3.

Table 3. Flood magnitude results utilizing USGS Regression Analyses

Return Interval	Flood Magnitude (cfs)
10-year	4,130
50-year	6,260
100-year	7,170

When results depicted in Table 3 are compared with those published in the Pierce County FIS as shown in Table 1, there is a general agreement with discharge magnitude providing further confidence in the FIS published discharge rates. It is important to note that the regression equations developed by the USGS are highly sensitive to the soil permeability variable, which is also the most difficult and subjective parameter to quantify without appropriate field data.

Available discharge data for USGS gage ID 05342000 can be seen in Figure 1.

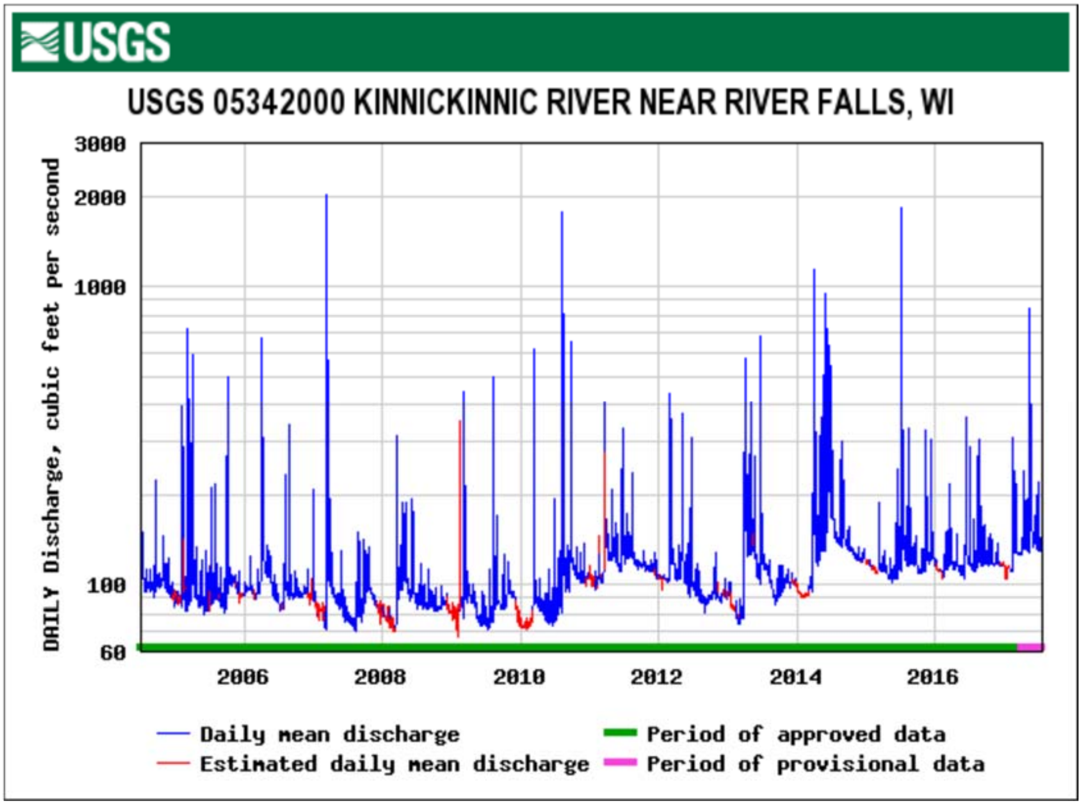

Figure 1. USGS Available Discharge Data for Gage ID 05342000

After a cursory review of the discharge data on record, one can assume that within the 13 years of record shown, statistically speaking, few if any 10-year events, have occurred. Other reports have cited that the FIS published discharge rates may be overestimating design discharges by more than an order of magnitude. However, the former statement would imply that a 100-year discharge rate would be roughly equivalent to 800 cfs, which has been met or exceeded numerous times within the 13 year period shown in Figure 1. Restating that the discharge rates depicted in Figure 1 are average daily discharge rates, implies that if instantaneous rates were plotted, the alleged 100-year event would have been met or exceeded many more times than shown. Lastly, due to the size of the watershed, lack of available storage and prevailing soil and watershed characteristics, a 100-year return interval discharge rate of 800 cfs from a 90+ square mile watershed is unreasonably low, and therefore we have conducted our analyses utilizing the published FIS discharge rates.

Atlas 14 Rainfall Data

The existing HEC-2 hydraulic model and published FIS discharge rates were developed utilizing a SCS TR-55 based computer model and US Weather Bureau's TP-40 rainfall depths. NOAA Atlas 14 rainfall data includes approximately 50 additional years of relevant rainfall data and is considered the current industry standard data set utilized for hydrologic and hydraulic design and analysis. The complexity and level of effort involved in updating a hydrologic model of the entire Kinnickinnic River watershed based on updated rainfall data and distributions, and consequent updates to the FIS hydraulic model is well beyond the scope of this analysis. Comparison values of rainfall depths are shown in Table 4. Assuming all other variables are held constant, if the hydraulic and hydrologic models are updated with Atlas 14 rainfall depths and distributions, an increase in floodplain stage can be expected given the additional depth and associated volume of runoff.

Table 4. Rainfall depths as a function of duration and data set

Rainfall Depth (inches)						
	NRCS type II	NOAA Atlas 14	NRCS type II	NOAA Atlas 14	NRCS type II	NOAA Atlas 14
Duration	10-year	10-year	50-year	50-year	100-year	100-year
5 min	0.26	0.64	0.34	0.89	0.37	1.00
15 min	0.78	1.14	1.02	1.58	1.12	1.79
1 hour	1.86	2.15	2.44	3.12	2.67	3.59
2 Hours	2.21	2.67	2.9	3.97	3.17	4.62
3 Hours	2.45	2.98	3.21	4.55	3.51	5.36
6 Hours	2.91	3.46	3.81	5.37	4.17	6.38
12 Hours	3.46	3.91	4.53	5.90	4.96	6.92
24 hours	4.12	4.20	5.39	6.23	5.90	7.29

KINNICKINNIC RIVER FLOODPLAIN AND HYDRAULIC INFORMATION

Kinnickinnic River Hydraulics – Existing Conditions

The HEC-2 model developed for the FIS was imported and utilized as the basis for the Existing conditions model and extended downstream through Lake Louise and Powell Falls.

Additional cross sections were added to the Existing conditions model from downstream of Powell Falls upstream through Lake George. The additional cross section elevations were primarily predicated on survey and bathymetry data acquired by Inter-Fluve, for the aforementioned 2016 sediment study. For areas not covered by the 2016 sediment study, best available data was utilized for topography and bathymetry which included LiDAR data and as-built drawings. As-built data and information obtained from the Restoration of the Kinnickinnic River through Dam Removal Feasibility Report (Inter-Fluve, 2017) were utilized as the basis for importing the Powell Falls and Junction Falls dams in the existing conditions HEC-RAS model. The extended existing conditions model was created for a baseline to compare velocity results and water surface profiles relative to a dam removal scenario. Cross sections taken through Lake George and Lake Louise utilized ineffective flow areas to limit conveyance to an approximate 300-foot wide channel and overbank, thus excluding the majority of the ponded lake areas. Boundary conditions for the extended existing model were altered to account for energy loss through the additional river corridor. As previously mentioned, one additional water surface profile was generated for a base flow condition, based on historical USGS average daily flow rates.

Existing floodway extents can be seen in the previously referenced FEMA flood insurance studies within the project limits. The average cross sectional velocity results of the existing conditions model are reported in Table 5 for each return interval discharge.

Table 5. Existing Conditions - Average Cross Sectional Velocities (fps)

Return Frequency	River Station								
	51060	52038	53219	53389	53495	53978	54260	54912	55167
Base flow	0.1	0.3	0.4	8.7	7.0	0.1	0.1	0.5	0.3
10-year	3.1	1.9	4.5	9.2	7.1	2.6	1.6	2.7	3.1
50-year	4.2	2.1	5.6	12.2	9.4	4.1	2.3	3.1	4.5
100-year	4.6	2.3	6.0	13.2	10.1	4.6	2.6	3.3	5.0
500-year	5.6	2.6	6.9	15.2	11.7	5.8	3.1	3.7	5.2

Kinnickinnic River Hydraulics – Proposed Conditions

In a dam removal scenario, the Kinnickinnic river channel bottom would be expected to migrate back toward bedrock depths as river velocities and shear stresses increase. As a result of the previous assumption, cross sections were modified from the existing condition hydraulic model to emulate the bedrock depths and slopes in the added cross sections downstream through Powell Falls. The bedrock elevations were based on Inter-Fluve's survey and bathymetry data collection efforts from the 2016 sediment analysis. Areas that were not surveyed for the 2016 sediment analysis utilized best available data for interpreting what river transects would look like in a removal scenario.

It is very important to note that the water surface profiles developed in the proposed conditions HEC-RAS model should be interpreted with caution in the vicinity of both Powell Falls and Junction Falls, in addition to any areas where the river gradient exceeds a 1:10 vertical to horizontal ratio because HEC-RAS results are not valid at these slopes. In addition, it is imperative to note that due to a lack of survey data in the areas surrounding the dams and the falls, river cross sections were generally approximated as rectangular with a width corresponding to best available LiDAR or as-built data. For an accurate representation of the water surface profiles through each of the respective falls in a dam removal scenario, much more detailed survey and bathymetry data would need to be acquired.

Boundary conditions were updated in the proposed conditions model to a normal depth friction slope comparable to the river bed/bedrock profile. Assumed channel geometry for the cross sections running through what is now Lakes Louise and George were estimated based upon conveyance needs and a desired 200-foot to 300-foot floodplain width. Average cross sectional velocities resulting from the dam removal scenario are included in Table 6.

Table 6. Proposed Conditions - Average Cross Sectional Velocities (fps)

Return Frequency	River Station								
	51060	52038	53219	53389	53495	53978	54260	54912	55167
Base flow	3.3	3.2	3.8	7.4	7.1	3.4	2.3	1.3	0.7
10-year	12.9	10.5	10.1	10.0	7.4	9.7	6.9	5.2	5.0
50-year	14.9	11.2	11.3	13.6	9.7	12.1	8.4	7.3	7.5
100-year	15.5	10.9	11.8	14.5	10.5	12.9	8.8	8.0	8.4
500-year	14.2	11.0	12.7	16.3	12.1	14.4	9.3	9.3	10.2

Additional modifications to the proposed cross sections and channel optimization may be beneficial in lowering velocities to the maximum extent practicable. However, with the transition to a natural falls and slope of the existing bedrock in the vicinity of the falls, it is highly likely that the flow regime would transition to supercritical. A more comprehensive and detailed analysis would be required to design the falls in a sustainable way such to minimize undesirable hydraulic conditions in a dam removal scenario. Approximate changes to the floodway extents can be seen in Figure 2.

Kinnickinnic River Floodplain Information

The Kinnickinnic River and its floodplain, through the Study Area, are designated as a FEMA Zone AE detailed floodplain with a defined Floodway. Any projects or modifications which fall within the designated floodplain must be compliant with the requirements set by the FEMA National Flood Insurance Program and the more restrictive State of Wisconsin floodplain management statutes as defined in NR 116, along with any City of River Falls floodplain zoning regulations.

Removal of the dams will result in a general lowering of the flood profiles through the Lake George and Lake Louise impoundment areas. The flow conditions and water surface profiles have been estimated by continuing the effective hydraulic model downstream through the Lake Louise impoundment, as referenced in the previous section.

The current regulatory floodway through both Lake Louise and Lake George encompass the entire normal pool of each impoundment. It is anticipated that the regulatory floodway could be reduced to the limits of the effective flow of the restored river and floodplain section. It is likely that the regulatory floodway width could be reduced to approximately 200-300 feet wide through each impoundment area based on the existing floodway widths upstream and downstream of the impoundments and hydraulic modeling performed, see Figure 1. A Conditional Letter of Map Revision from FEMA would likely be required prior to any proposed dam removal and river restoration activities. A follow-up Letter of Map Revision would be required from FEMA to officially revise the floodplain and floodway boundaries subsequent to dam removal and river restoration activities.

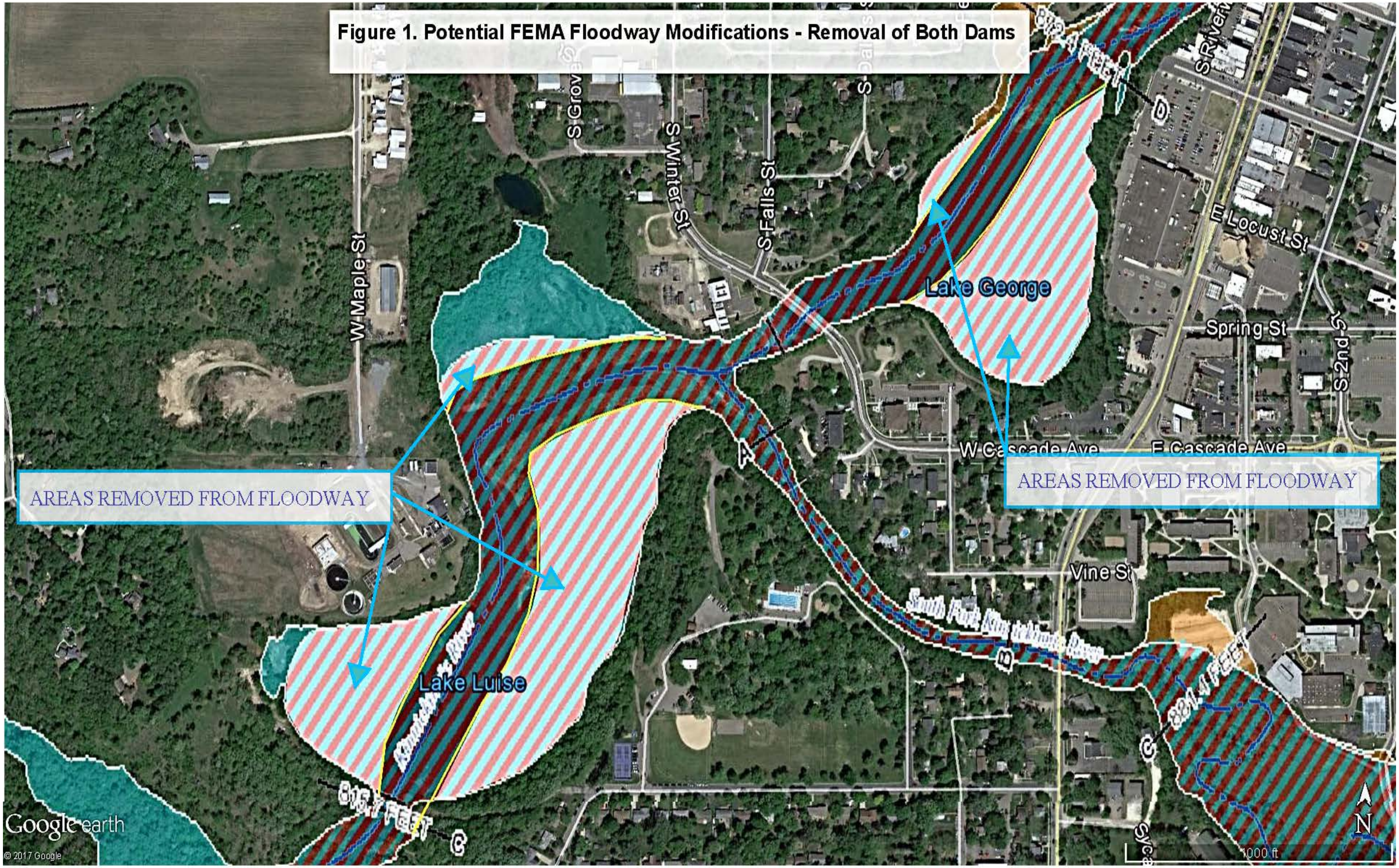

Figure 1. Potential FEMA Floodway Modifications - Removal of Both Dams
AREAS REMOVED FROM FLOODWAY
AREAS REMOVED FROM FLOODWAY
Lake George
Lake Luise
W Maple St
S Grove St
S Winter St
S Falls St
W Cascade Ave
E Cascade Ave
E Locust St
Spring St
S 2nd St
Vine St
S Riverview
South Fork Kinnickinnic River
Kinnickinnic River
A
B
C
D
N
1000 ft
Google earth
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Scour Discussion

The primary structure impacted by a potential dam removal scenario within the study area is the Winter Street Bridge, due to its proximity to the Junction Falls dam and methods of construction. Other structures would be impacted by a dam removal scenario and would warrant further analysis, such as the pedestrian bridge and Maple Street Bridge, but to a far lesser degree due to their respective proximities to the Junction Falls dam. Removal of the Junction Falls dam will undoubtedly increase velocities and shear stresses in the river corridor which in turn increases scour potential at piers, columns and abutments. Review of the as-built/construction drawings of the Winter Street Bridge resulted in concern over the structural viability of the existing bridge after a potential removal of the Junction Falls dam.

As-built drawings indicate that the Winter Street Bridge is founded directly on an approximate 11-foot thick non-reinforced concrete seal, bearing on bedrock at an approximate elevation of 841.5. The elevations and boring results referenced in the Winter Street as-built drawings correlate well to recent survey conducted in the project area, providing confidence that the vertical datum are consistent. The concrete seal does not appear to be keyed or doweled into the bedrock, nor do the column footings appear to be doweled into the seal. The aforementioned items pose challenges due to a potential lowering of the water surface profile and associated changes to the loading of the structure.

Based on the proposed hydraulic model, indications that the 100-year return interval water surface profile could decrease by upwards of 10-feet in the vicinity of the existing Junction Falls dam. The river bed profile in a dam removal scenario would very likely migrate back toward bedrock elevation, which in the vicinity of Junction Falls is relatively steep. Based on a potential steep river gradient, high velocities and transitions to a critical/supercritical flow regime could be expected in a removal scenario presenting concerns with high shear stresses near the Winter Street bridge seal. Lastly with removal of the dam, floodplain debris and hydrodynamic forces would need to be accounted for when analyzing the viability of the existing structure.

btw

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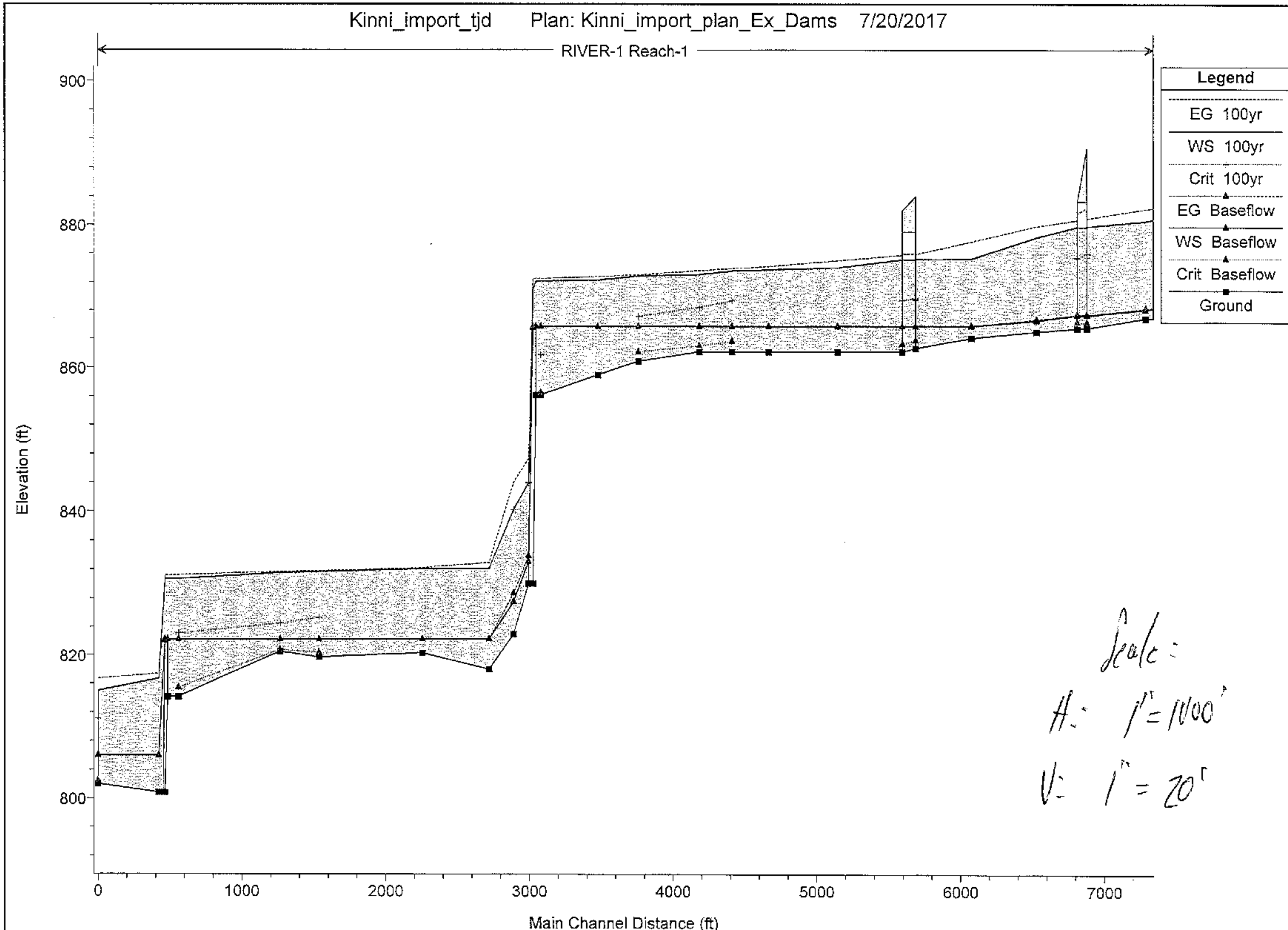

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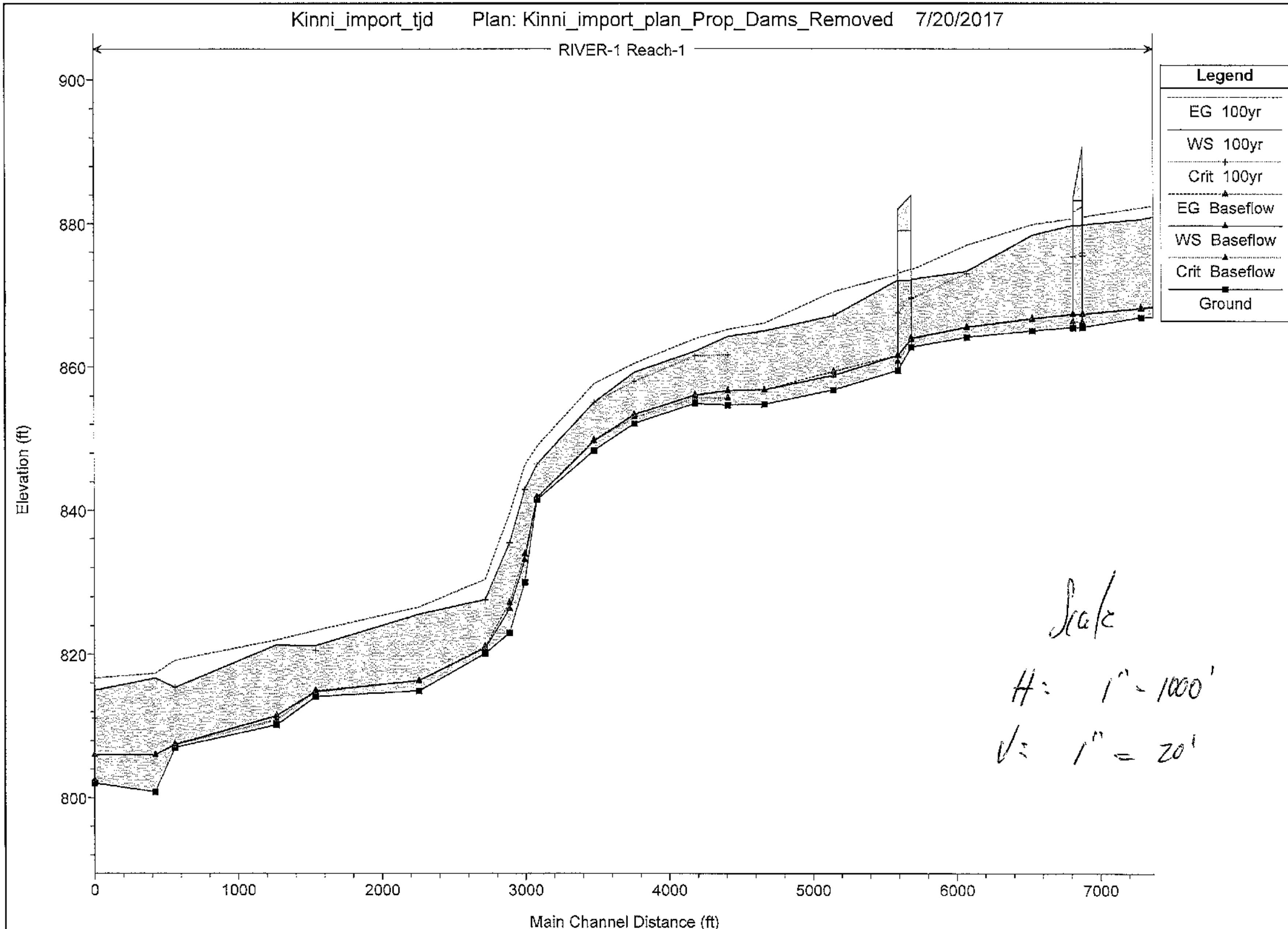

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