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From:
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Date:
April 8, 2009

ARCADIS Project No.:
B0039158.0000.00005

Subject:
Superior, Wisconsin Site

On May 7, 2008, a meeting was held among Beazer, ARCADIS and Sevenson Environmental Services (SES) to discuss potential remedial alternatives involving the relocation of a portion of Crawford Creek as part of corrective action activities for the Koppers Inc. Superior, Wisconsin Facility (the Site). As a result of that meeting, and at the request of Beazer, ARCADIS has performed several tasks in order to provide additional information needed for a more thorough evaluation of the identified potential remedial alternatives.

On October 27, 2008, ARCADIS provided Beazer with a memorandum summarizing the hydrologic analysis ARCADIS had performed to determine peak stream flows (i.e., peak discharges) for Crawford Creek for the 2-, 10-, 25-, and 100-year storm events, for later use in evaluating the potential hydraulic impacts (e.g., changes in flow conditions, flooding potential) that could result from realigning the stream. ARCADIS also directed the compilation of a Site survey and topographic mapping for various portions of the Site that would be impacted by the potential remedial activities.

Under Task 5 of our September 15, 2008 scope of work, ARCADIS proposed the development of a HEC-RAS model to assess flooding conditions on Crawford Creek, to evaluate potential upstream and/or downstream impacts that could result from channel relocation activities, and to identify potential constructability issues (e.g., flood levels, potential for sediment migration during remediation, appropriate best management practices [BMPs]) that could influence the implementation of the work. However, upon review of the topographic mapping of the Site and further consideration of historically observed flooding conditions along Crawford Creek and the Nemadji River, ARCADIS determined that, due to the significant influence of the Nemadji River on flood levels in Crawford Creek, a more simplified approach, focusing primarily on flood levels in the Nemadji River, would be better suited and a more cost-effective approach to providing the information necessary to assess the Site’s hydraulic conditions. This memorandum summarizes the results of this simplified hydraulic analysis.

INTRODUCTION

The Project Area includes the portion of Crawford Creek and its floodplain bounded by East Hammond Avenue to the south (upstream) and the SOO Railroad Line to the north (downstream), and is located approximately 2,000 feet upstream from Crawford Creek’s confluence with the Nemadji River. Based on a review of various data sources (i.e., Federal Emergency Management Agency [FEMA] flood mapping for the city of Superior, Wisconsin; USGS 7.5-minute quadrangle maps; 2008 field survey; field-observed flooding conditions; and photographs of flooding conditions within Crawford Creek), ARCADIS has determined that flood elevations within the Project Area will be directly influenced by (i.e., will be the same as) flood elevations in the Nemadji River during all flood events equaling or exceeding the 2-year design flood. Although the same conditions may also occur during more frequent flood events, the 2-year design flood is the smallest flood event that has been evaluated. Due to this condition, ARCADIS believes that a HEC-RAS model of Crawford Creek will not provide any greater detail than what can be determined from an evaluation of flood elevations within the Nemadji River and a few basic hydraulic calculations, as described herein.

OBJECTIVE 1: DETERMINE WATER SURFACE ELEVATIONS WITHIN THE PROJECT AREA

Since water surface elevations (WSEs) and velocities within the Project Area are directly influenced by flood elevations on the Nemadji River, the flood elevations on the Nemadji River, at the mouth of Crawford Creek, (hereinafter simply referred to as “the Nemadji River”) were first determined using the following three steps:

1. Determine the relationship between flood flows and WSEs on the Nemadji River (this is typically referred to as a Stage-Discharge relationship).

2. Determine design flood flows for the Nemadji River for the desired flood events (i.e., the 2-, 10-, 25-, and 100-year flood events).

3. Determine the anticipated flood elevations on the Nemadji River, during each flood event, based on the Stage-Discharge relationship determined in Step 1 and the design flood flows determined in Step 2.

Step 1 – Determine Stage-Discharge Relationship for Nemadji River

Flood flows and WSEs used to develop the Stage-Discharge relationship for the Nemadji River were obtained from the following source:

- Department of Housing and Development Federal Insurance Administration (FIA). June 1977. *Flood Insurance Study* (FIS) – *City of Superior, Wisconsin – Douglas County.*

Design flood flows within the Nemadji River, according to the above-referenced document (hereinafter referred to as the "FIS Report"), are summarized below in Table 1.

As part of the FIS Report flood study, design flows were modeled using the US Army Corps of Engineers (USACE) "HEC-2" hydraulic modeling software to determine predicted flood elevations along the Nemadji River. The input file for the FIS Report's hydraulic model is available online, at the Wisconsin Department of Natural Resources' (WDNR's) "Surface Water Viewer" website (FIS Report also available through this link):

- http://dnrmaps.wisconsin.gov/imf/imf.jsp?site=SurfaceWaterViewer.floodplain

The resulting flood profiles for the Nemadji River are illustrated in Figures 02P through 06P of the FIS Report. The mouth of Crawford Creek is located at approximately River Mile 7.24 on Figure 04P of the FIS Report (attached). Flood elevations at the mouth of Crawford Creek have been determined graphically from these water surface profiles, and are summarized in Table 1, below.

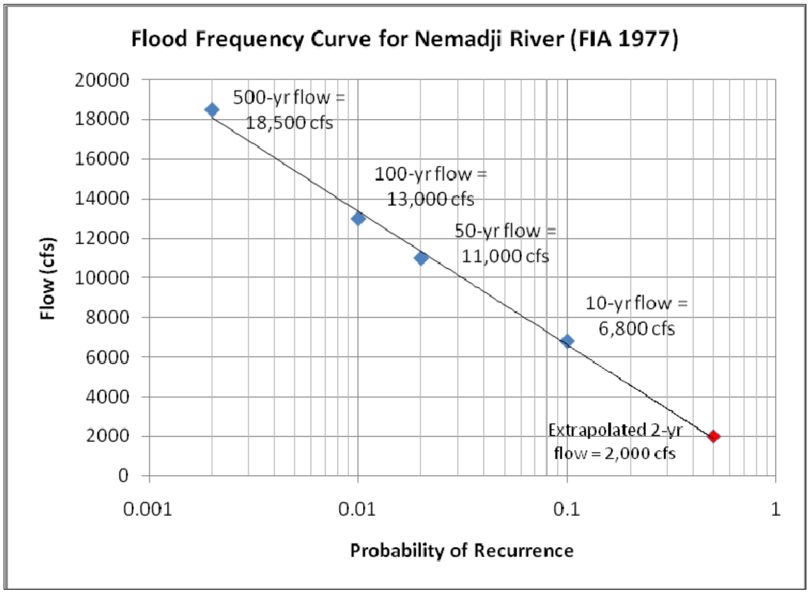
Table 1 - Nemadji River Design Flows and WSEs (FIA 1977)

Flood Event	Flow (cfs)	WSE (FMSL[1] – NGVD 29[2])
10-yr	6,800	615.8
50-yr	11,000	618.2
100-yr	13,000	619.2
500-yr	18,500	621.9

1. FMSL = Feet above Mean Sea Level
2. NGVD 29 = National Geodetic Vertical Datum of 1929

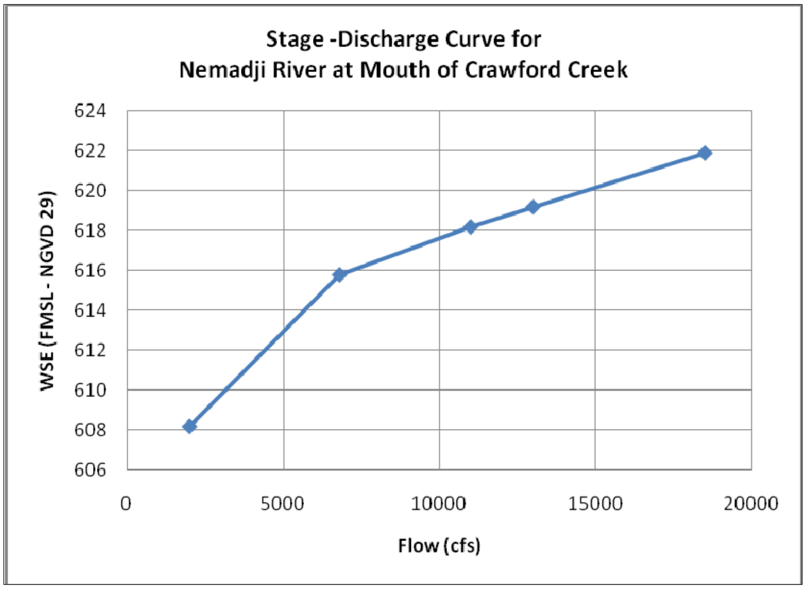
To supplement the 10-, 50-, 100- and 500-year design flows provided in the FIS Report, ARCADIS plotted the flows against the probabilities of recurrence for each flood event (i.e., the reciprocal of the return period [e.g., 1/100 = 0.01]), on a logarithmic scale, and then extrapolated to estimate a 2-year design flow for the Nemadji River, as shown in Figure 1 below.

Figure 1 - Extrapolated Flood Flows for Nemadji River



The 2-year design flow (i.e., approximately 2,000 cfs) was then routed through the FIS Report hydraulic model that was obtained from the WDNR website to determine an approximate 2-year flood elevation at the mouth of Crawford Creek. To simplify the process, the HEC-2 input file was first converted to a HEC-RAS file (i.e., a more recent, Windows®-based hydraulic modeling package, developed by the USACE) and run using the HEC-RAS software (Version 4.0). The resulting 2-year flood elevation was determined to be approximately 608.2 FMSL. The final Stage-Discharge relationship for the Nemadji River is shown in Figure 2, below.

Figure 2 - Stage-Discharge Relationship for Nemadji River



Step 2 – Determine Design Flows for Nemadji River

Rather than utilizing the design flows provided in the FIS Report, design flows for the Nemadji River were obtained from the following, more recent document:

- United States Geologic Survey (USGS), Reston, Virginia. 2003. *Flood-Frequency Characteristics of Wisconsin Streams (Water-Resources Investigations Report 03-4250).*

The design flows contained in the above-referenced document (hereinafter referred to as the "USGS WRI Report"), were based on a longer period of flow record and appear to be significantly more conservative (i.e., greater) than the flood flows presented in the FIS Report. It should be noted, however, that these design flows represent flows occurring on the Nemadji River at a point located approximately 2 miles upstream of the mouth of Crawford Creek (i.e., at the location of USGS Gauging Station 04024430 – Nemadji River near South Superior, WI). To determine the design flows in the Nemadji River at the mouth of Crawford Creek, the estimated design flows for Crawford Creek (i.e., the peak flows calculated as part of the hydrologic analysis summarized in the ARCADIS memo dated October 27, 2008) were added to the design flows provided in the USGS WRI Report. It should be noted that this methodology disregards the watershed area that contributes flow to the 2-mile stretch of the Nemadji River between the USGS Gauging Station and the mouth of Crawford Creek. However, it has been estimated that this watershed area represents less than 1% of the total watershed area for the Nemadji River and can therefore be considered negligible. The final estimated design flows for the Nemadji River are summarized in Table 2 below.

Table 2 - Design Flood Flows for Nemadji River at Mouth of Crawford Creek

Flood Event	Flow in Nemadji River at USGS Gauging Station (USGS 2003) (cfs)	Flow in Crawford Creek (cfs)	Flow in Nemadji River at Mouth of Crawford Creek (cfs)
2-yr	5,250	388	**5,638**
10-yr	9,020	888	**9,908**
25-yr	10,900	1,155	**12,055**
100-yr	13,800	1,547	**15,347**

Step 3 – Determine Flood Elevations for Nemadji River

Design flood elevations for the Nemadji River were determined by interpolation using the Stage-Discharge relationship developed in Step 1 (Figure 2) and the design flood flows determined in Step 2 (Table 2). The resulting flood elevations are illustrated in Figure 3 and are summarized in Table 3 below.

Figure 3 - Calculation of Flood Elevations for the Nemadji RIver at the Mouth of Crawford Creek

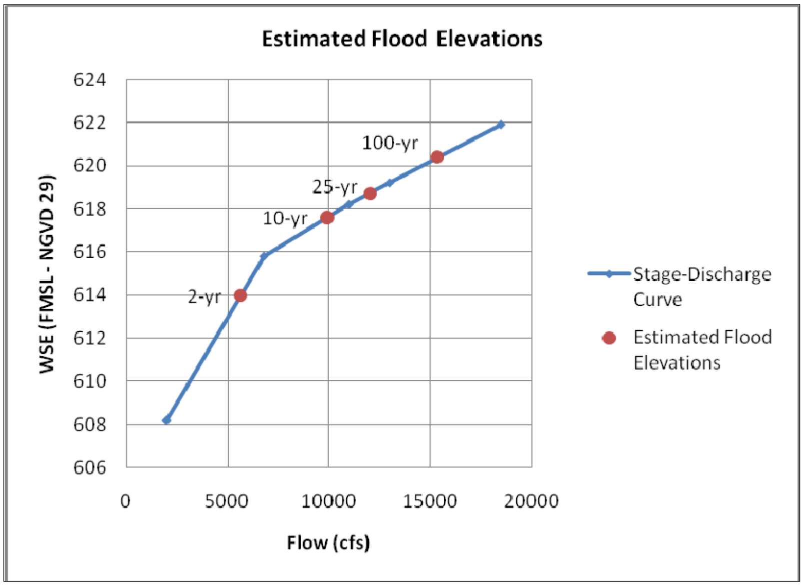


Table 3 - Flood Elevations for Nemadji River at Mouth of Crawford Creek

Flood Event	Flood Elevation (FMSL – NGVD 29)
2-yr	**614.0**
10-yr	**617.6**
25-yr	**618.7**
100-yr	**620.4**

Due to the extrapolation technique used in Step 1 to determine the 2-year stage-discharge relationship for the Nemadji River, the 2-year flood elevation presented in Table 3, above, is potentially subject to the greatest margin for error. However, aerial survey information indicates an approximate top-of-bank elevation of 614 FMSL along the Nemadji River, near the mouth of Crawford Creek. Given that "bank-full" flow conditions typically occur during a 1-1/2 to 2-year flow event on most natural streams and rivers, this top-of-bank elevation supports the 2-year flood elevation estimated above.

OBJECTIVE 2: DETERMINE FLOW VELOCITIES WITHIN THE PROJECT AREA

In consideration of the variations in floodplain elevations and valley geometry along the length of the Project Area, separate flow velocities have been estimated for the upstream and downstream ends of the Project Area. Table 4, below, summarizes the anticipated flood depths and estimated flow velocities that are expected to occur in the upstream and downstream portions of the Project Area during each flood event, based on predicted flood elevations (from Table 3), existing topographic conditions (as surveyed in 2008), and the peak design flows that were calculated for Crawford Creek as part of the hydrologic analysis summarized in ARCADIS' October 27, 2008 memorandum. For conservatism, the flood elevations used for this portion of the analysis are based on the higher values determined using the more recent USGS Report (i.e., presented in Table 3), rather than the lower values determined using the older FIS Report (i.e., presented in Table 1 and Figure 2).

Table 4 - Anticipated Flood Depths and Estimated Flow Velocities within the Project Area during Peak Flood Stage of the Nemadji River

Flood Event	Flood Elevation (FMSL – NGVD 29)	Peak Flow (cfs)	Upstream Portion of the Project Area			Downstream Portion of the Project Area		
			Average Flood Depth[1,2]	Flow Area[2] (sf)	Average Velocity[3] (fps)	Average Flood Depth[1,2]	Flow Area[2] (sf)	Average Velocity[2] (fps)
2-yr	614.0	388	**5 ft**	1,689	**0.23**	**9 ft**	3,763	**0.10**
10-yr	617.6	888	**9 ft**	3,038	**0.29**	**13 ft**	5,693	**0.16**
25-yr	618.7	1,155	**10 ft**	3,509	**0.33**	**14 ft**	6,339	**0.18**
100-yr	620.4	1,547	**12 ft**	4,347	**0.36**	**16 ft**	7,376	**0.21**

1. Average flood depth represents average depths of flooding expected to occur within the floodplain areas (i.e., outside of the main channel).
2. Average flood depths and flow areas were calculated based on topographic field survey information obtained between October and December 2008.
3. Average velocity was calculated using the following formula: V = Q/A, where V = average velocity, Q = peak flow, A = flow area.

As a direct result of the significant flooding depths and backwater effects caused by the Nemadji River, the resulting flow velocities within the Project Area are expected to be relatively minor under these flooding conditions and are not expected to create a significant potential for sediment scour during the evaluated flood events. However, it should be noted that the estimated velocities presented in Table 4 represent flow conditions after the Nemadji River has achieved its peak flood stage. Due to the vast size of the Nemadji River watershed (i.e., more than 420 square miles), it may take the river a couple of days to achieve peak flood stage after a storm event. Whereas, the much smaller Crawford Creek watershed (i.e., approximately 8.3 square miles) would likely peak within a few hours of a storm event. Depending on the relative timing of peak flows in Crawford Creek and rising flood levels in the Nemadji River, maximum velocities experienced throughout the project area, during/following a storm event, could be greater than those shown in Table 4. Therefore, flow velocities in the upstream and downstream portions of the Project Area have also been calculated excluding the backwater effects from the Nemadji River (i.e., prior to achieving peak flood stage on the Nemadji River).

Tables 5 and 6, below, present the anticipated maximum average flow depths and velocities that could occur within the Project Area prior to achieving peak flood stage on the Nemadji River. The estimated flow depths and velocities presented below are based on: average valley slope (in the direction of flow); an estimated valley roughness coefficient, assuming Class B vegetation (i.e., 12- to 24-inch height); generalized trapezoidal valley cross sections, based on 2008 topographic survey information; and normal flow conditions (i.e., assuming no backwater effects from the Nemadji River).

Table 5 - Estimated Flow Depths and Velocities in the Upstream Portion of the Project Area, Prior to Achieving Peak Flood Stage on the Nemadji River

Flood Event	Peak Flow (cfs)	Manning's n	Valley Slope (ft/ft)	Average Flow Depth[1] (ft)	Flow Area[2] (sf)	Wetted Perimeter[2] (ft)	Velocity[3] (fps)
2-yr	388	0.124	0.0016	**2.0**	538	293	**0.7**
10-yr	888	0.077	0.0016	**2.4**	672	300	**1.3**
25-yr	1,155	0.068	0.0016	**2.6**	735	304	**1.6**
100-yr	1,547	0.061	0.0016	**2.9**	821	309	**1.9**

1. Average flow depth represents average depth of flow in the floodplain, across the width of the valley.
2. Flow area and wetted perimeter are based on an assumed trapezoidal valley geometry, with a base width of approximately 260 feet and approximately 6.7H:1V and 10H:1V side slopes.
3. Average velocity was calcaulated using the following formula: V = (1.486/n)*(A/P)^(2/3)*(S)^(1/2), where V = average velocity, n = Manning's roughness coefficient for Class B vegetation, A = flow area, P = wetted perimeter, and S = average valley slope.

Table 6 - Estimated Flow Depths and Velocities in the Downstream Portion of the Project Area, Prior to Achieving Peak Flood Stage on the Nemadji River

Flood Event	Peak Flow (cfs)	Manning's n	Valley Slope (ft/ft)	Average Flow Depth[1] (ft)	Flow Area[2] (sf)	Wetted Perimeter[2] (ft)	Velocity[3] (fps)
2-yr	388	0.142	0.0016	**1.9**	633	358	**0.6**
10-yr	888	0.086	0.0016	**2.3**	774	365	**1.2**
25-yr	1,155	0.075	0.0016	**2.4**	840	369	**1.4**
100-yr	1,547	0.066	0.0016	**2.7**	930	374	**1.7**

1. Average flow depth represents average depth of flow in the floodplain, across the width of the valley.
2. Flow area and wetted perimeter are based on an assumed trapezoidal valley geometry, with a base width of approximately 320 feet and approximately 10H:1V side slopes.
3. Average velocity was calcaulated using the following formula: V = (1.486/n)*(A/P)^(2/3)*(S)^(1/2), where V = average velocity, n = Manning's roughness coefficient for Class B vegetation, A = flow area, P = wetted perimeter, and S = average valley slope.

It should be noted that the estimated flow depths and velocities presented in Tables 5 and 6, above, represent average conditions across the full width of the Project Area and do not account for the uneven distribution of flow between the main channel and the floodplain. Due to the reduced roughness of the main channel (i.e., relative to the floodplain), a larger portion of the flow would likely be carried by the main channel under actual flooding conditions, resulting in a slightly reduced average flooding depth overall, with slightly lower velocities in the floodplain areas and higher velocities in the main channel. The end result would be a relatively low potential for sediment migration within the floodplain and a higher potential for sediment migration within and immediately adjacent to the main channel.

SUMMARY

Tables 3 and 4 present estimated peak flood elevations and corresponding flow velocities within the Project Area during peak flood stage of the Nemadji River. These results illustrate that peak flood elevations within the Project Area are more directly influenced by flood elevations on the Nemadji River than by the channel geometry of Crawford Creek and would therefore be largely unaffected by changes in that geometry (i.e., as a result of channel relocation). Additionally, these results show us that although inundation of active excavation areas would likely be inevitable under the flood conditions evaluated, flow velocities associated with those high flood stages are not expected to create a significant potential for sediment migration. A detailed HEC-RAS model would not provide any greater detail than what this simplified analysis can tell us for this peak flood stage scenario.

Tables 5 and 6 present the approximate maximum average flow velocities that *could* occur (i.e., depending on the relative timing of peak flows in Crawford Creek and rising flood levels on the Nemadji River) within the Project Area prior to achieving peak flood stage on the Nemadji River. Although these results show us that there is a higher potential for sediment migration prior to achieving peak flood stage on the Nemadji River, the flooding depths associated with these conditions are much more manageable. As noted above, once peak flood stage is achieved on the Nemadji River, the entire Crawford Creek valley would be inundated by a substantial depth of flooding (i.e., 5 to 9 feet deep under the 2-year flood event, alone), coupled with a notable drop in velocities.

At this time, ARCADIS does not believe that a detailed hydraulic model (i.e., a HEC-RAS model) would provide any more useful information for evaluating potential remedial alternatives and possible construction approaches than what has already been determined. However, if the need for such a model arises (e.g., due to regulatory agency requirements, or to facilitate detailed design of construction measures once a specific remedy has been selected), the information needed to develop that model (i.e., peak discharges, detailed Site topography) is now available and ARCADIS would coordinate with Beazer at that time to determine the appropriate scope and purpose of the model.

Based on the findings of this hydraulic evaluation, ARCADIS recommends a conference call with Beazer and Sevenson to discuss the information gathered since our last meeting, to further refine the remedial alternatives previously established, and to establish a team-based approach for the next steps of the remedial design.

Please feel free to contact me at 518.452.7826, ext. 11 or Jeff Holden at 860.645.1084 if you have any questions. Thank you.

Attachments:

- FIS Report (Select Pages)

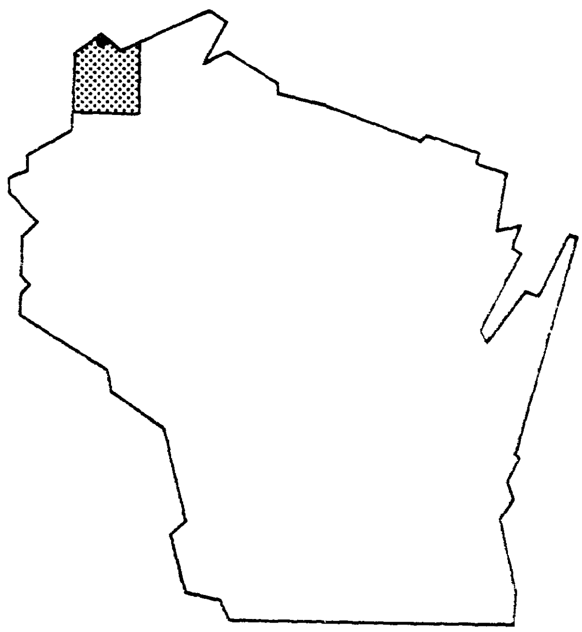
- USGS WRI Report – Appendix A (Select Pages)

ARCADIS

FIS Report
(Select Pages)

FLOOD INSURANCE STUDY

CITY OF SUPERIOR, WISCONSIN
DOUGLAS COUNTY

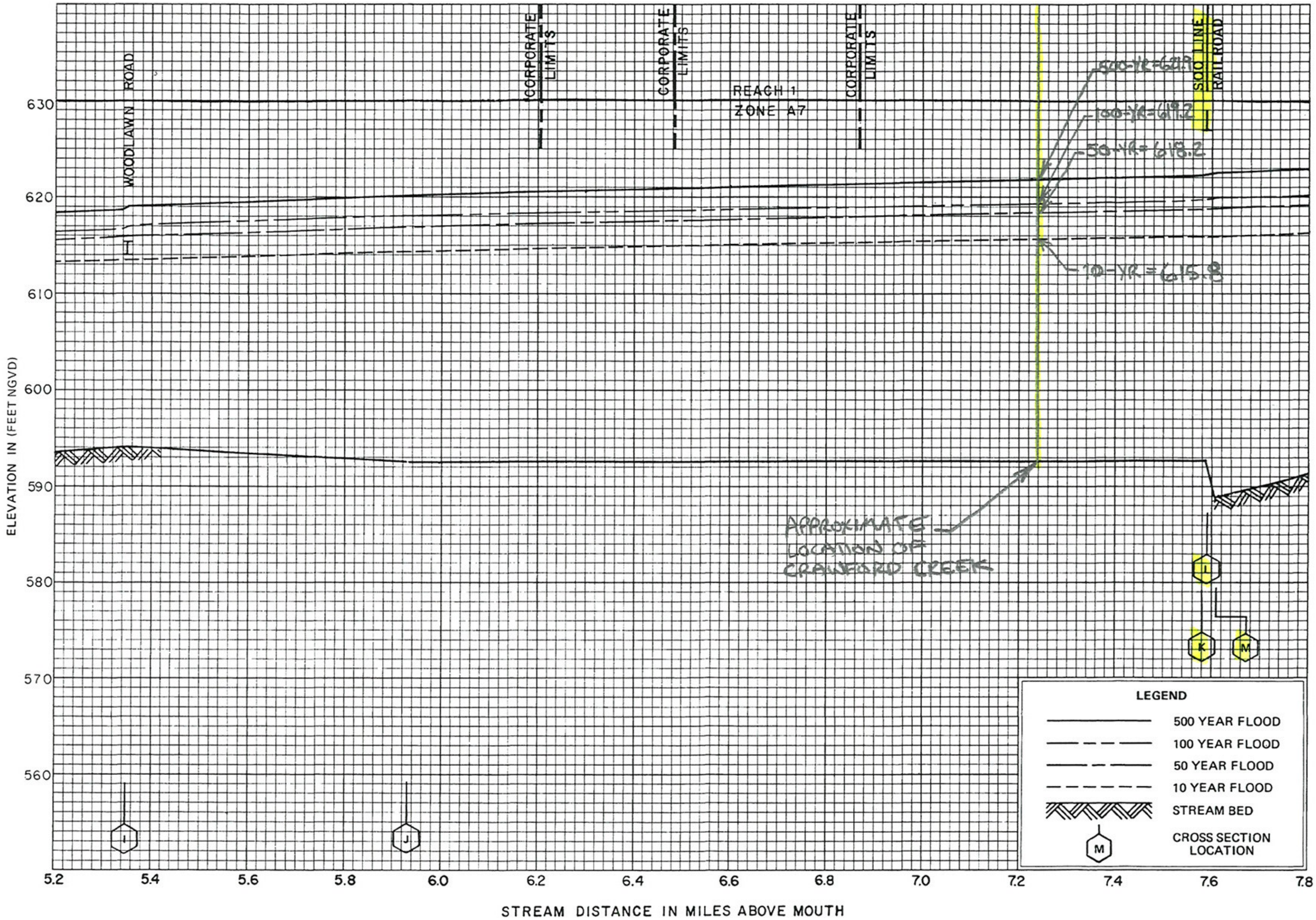


JUNE 1977

U.S. DEPARTMENT of HOUSING & URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION

Table 1. Summary Of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
Pokegama River					
Downstream Limit of Study-Section 5 and 6 Boundary	29.2	950	1,650	2,000	3,000
Wisconsin Highway 105	26.1	850	1,500	1,850	2,750
Unnamed Tributary					
Downstream Limit of Study-Storm Sewer in Central Park	4.2	305	590	720	1,150
28th Street	1.9	290	440	520	690
Wisconsin Highway 35 (Tower Avenue)	0.4	80	120	140	190
Nemadji River					
Mouth	438.0	6,800	11,000	13,000	18,500
Douglas County Trunk Highway C	422.0	6,650	10,700	12,700	18,000
Bluff Creek					
Mouth	19.6	1,200	1,900	2,200	3,000
Confluence With an Unnamed Tributary Near Mouth	18.2	1,150	1,800	2,100	2,900
Bear Creek					
Mouth	6.9	680	1,050	1,200	1,650
Corporate Limits	6.0	600	920	1,100	1,500



FLOOD PROFILES

NEMADJI RIVER

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

CITY OF SUPERIOR WI
(DOUGLAS CO.)

04P

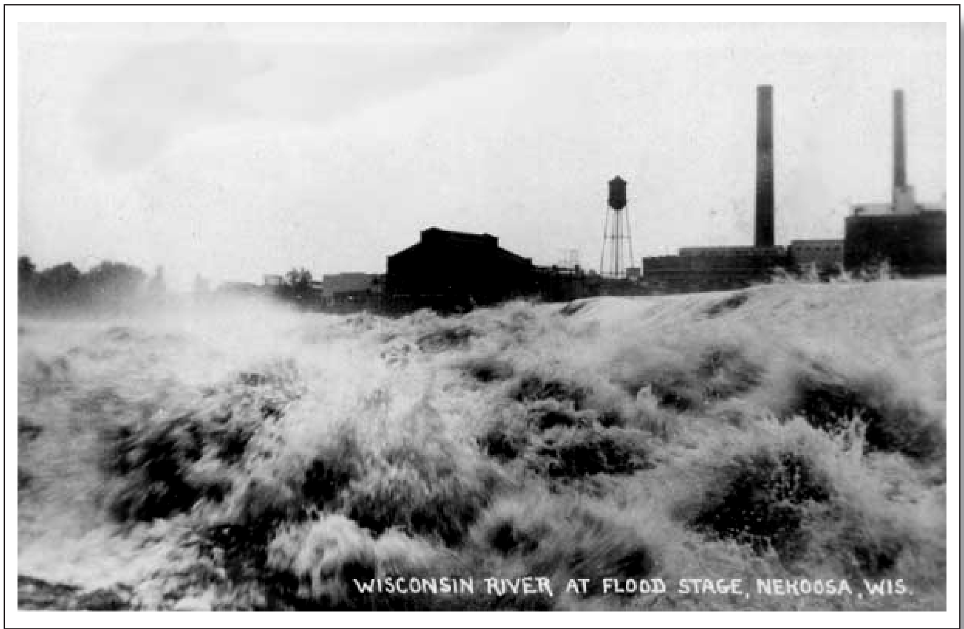
ARCADIS

USGS WRI Report – Appendix A (Select Pages)

science for a changing world

In cooperation with the Wisconsin Department of Transportation

Flood-Frequency Characteristics of Wisconsin Streams



Water-Resources Investigations Report 03-4250

U.S. Department of the Interior
U.S. Geological Survey

Table A-1. Flood discharges at selected recurrence intervals and WRC skew for streamflow-gaging stations in the Wisconsin flood-frequency network

[WRC skew, skewness as defined in Bulletin 17B (Interagency Advisory Committee on Water Data, 1981); recurrence intervals in years; discharge in cubic feet per second; SE100, standard error of 100-year discharge, in log units; C, crest-stage gage; G, continuous-record gage]

Stationnumber	Station name	WRC skew	Discharge for indicated recurrence interval							Type	Period of record
			2	5	10	25	50	100	SE100		
Unregulated Stations											
04024400	Stoney Brook near Superior, Wis.	-0.457	182	312	402	516	599	681	0.07219	C	1959–2000
04024430	Nemadji River near South Superior, Wis.	-.093	5,250	7,510	9,020	10,900	12,400	13,800	.06607	G	1974–2000
04025200	Pearson Creek near Maple, Wis.	.415	350	609	834	1,190	1,510	1,890	.10020	C	1957–2000
04025500	Bois Brule River at Brule, Wis.	.071	607	864	1,040	1,280	1,460	1,640	.04830	G	1943–2000
04026200	Sand River tributary near Red Cliff, Wis.	.384	112	198	273	391	498	624	.10347	C	1959–2000
04026300	Sioux River near Washburn, Wis.	.477	467	780	1,050	1,470	1,840	2,280	.09817	C	1959–2000
04026400	Spillerberg Creek near Cayuga, Wis.	-.002	77	110	133	163	186	209	.07335	C	1958–1958
04026450	Bad River near Mellen, Wis.	.091	915	1,340	1,650	2,050	2,370	2,700	.07463	C	1971–2000
04026700	Trout Brook tributary near Marengo, Wis.	-.186	124	203	260	336	394	455	.09759	C	1960–1981
04027000	Bad River near Odanah, Wis.	.317	7390	10,800	13,300	16,800	19,700	22,700	.05616	G	1915–2000
04027200	Pearl Creek at Grandview, Wis.	.596	179	295	395	555	701	874	.10298	C	1960–2000
04027500	White River near Ashland, Wis.	-.113	2,640	3,970	4,890	6,090	7,000	7,920	.05505	G	1949–2000
04028000	Montreal River at Ironwood, Mich.	.239	1,080	1,650	2,090	2,700	3,200	3,750	.13014	G	1918–1962
04029000	West Branch Montreal River at Gile, Wis.	-.684	924	1,200	1,350	1,500	1,600	1,690	.06013	G	1918–1947
04029700	Boomer Creek near Saxon, Wis.	-.260	131	213	272	348	405	464	.09667	C	1958–1981
04029990	Montreal River at Saxon Falls near Saxon, Wis.	-.172	3,200	4,720	5,740	7,040	8,000	8,960	.05343	G	1939–2000
	Allen Creek										1960–