Lower Nooksack River
Geomorphic Assessment

APPENDIX A
Geologic and Geomorphic History

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Appendix A: Geologic and Geomorphic History

Executive Summary
A late Holocene avulsion of the Nooksack River abandoned the connection between the Nooksack and Fraser Rivers and established a new course down a former glacial outwash channel. The avulsion was a significant disturbance and the residual effects from this event are apparent in today’s geomorphic conditions. The avulsion has influenced modern-day channel morphology, floodplain morphology, and sediment transport processes. As the river continues to evolve post-avulsion, geologic context should be considered in the development of river management strategies so that continued evolutionary trends are incorporated as natural processes uniquely present on the Nooksack River.

Geologic Background
The North Cascade Range creates the geologic backdrop of the Nooksack River watershed. The watershed covers over 800 square miles, with more than half the drainage area in the steep Cascade Mountains and foothills. The Nooksack River is a gravel bed river throughout most of its total length. Three primary forks of the Nooksack River exit the Cascades Mountains and converge near the western edge of the Cascade foothills near Deming. The North and Middle Fork Nooksack drainages are fed by the glaciers of the west and north flanks of Mount Baker and adjacent peaks. The South Fork Nooksack drains the foothills of the Twin Sisters Mountains and the southwest foothills of Mount Baker.

Downstream of the confluence, the lower Mainstem Nooksack River encounters a variety of landforms and unconsolidated glacial deposits throughout its course, which contribute a range of hydrologic and sedimentary inputs. The Mainstem Nooksack River valley is a net-aggradational sedimentary basin that formed during the Holocene that is eroded into relict glacial landforms. It is a product of complex paraglacial earth processes, which reworked the landscape following the late Pleistocene Fraser glaciation (Collins and Montgomery, 2010). Within the alluvial plain of the study reach, the sedimentary glacial substrate has either been eroded laterally along the valley margins by Nooksack channel migration processes or has been buried to variable depths by Holocene alluvial deposits. The processes identified as influencing the modern geomorphic conditions of the study reach occurred within the general geologic timeline presented in Table 1:

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Sub-epoch</th>
<th>Approx. Age (before present)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene</td>
<td>Holocene (early)</td>
<td>11,700 to ~5,000</td>
</tr>
<tr>
<td></td>
<td>Holocene (late)</td>
<td>~5,000 to present</td>
</tr>
<tr>
<td></td>
<td>Modern or Anthropocene</td>
<td>~150 years to present</td>
</tr>
</tbody>
</table>

Table 1. Geologic timeframes relevant to Nooksack River evolution.
Influence of Pleistocene Geologic Conditions and Processes on Fluvial Morphology

The most recent glaciation in the Puget Lowland, known as the Fraser Glaciation, occurred during the Pleistocene epoch and included several alternating periods of glacial advance and retreat, referred to respectively as stades and interstades. Glaciomarine drift sediment from the Everson Interstade and localized glacial outwash deposits from the Sumas Stade are mapped in and around the Mainstem Nooksack River study area. The Everson Interstade glaciomarine drift was deposited between 13,500 and 11,300 years ago, during a recessional period when marine waters inundated the study area and the primary sediment input was from floating glacial ice (Lapen, 2000). As the glaciers calved and ablated, melting glacial ice released predominantly fine-grained sediment entrained in the ice into the marine waters, where it settled and was deposited as glaciomarine diamicton. Following glacial recession during the Everson Interstade, glacial advance during the Sumas Stade around 10,000 years ago resulted in the localized incision of the underlying glacial sequence by meltwater channels and the deposition of glacial outwash on top of Everson glaciomarine sediment. Today, underfit streams and wetlands often occupy these relict outwash channels, and a significant proportion of the lithic bedload in the Nooksack River is exotic gravel, cobble, and boulder clasts contributed by the erodible glacial stratigraphy; locally derived rock, including Mount Baker andesite and metamorphic and sedimentary colluvium from the surrounding foothills makes up the remainder of the bedload material.

Influence of Holocene Geologic Conditions and Processes on Fluvial Morphology

The signature of Holocene fluvial processes contrasts with those developed by Pleistocene glacio-fluvial systems; however, the Holocene Nooksack River floodplain is primarily situated within these relict Pleistocene glacial troughs and outwash valleys. The mainstem floodplain splits near Everson and meets the southern Georgia Strait at two locations – Vancouver (via the Sumas/Fraser River Valleys) and Lummi/Bellingham Bay (via the Lower Nooksack Valley). The modern Nooksack River flows to Bellingham Bay by following the Lower Nooksack Valley west from Everson; however, the Nooksack River occasionally overflows into the Fraser River via the Sumas Valley during overbank flooding between Lawrence and Everson. Geomorphic evidence supports the theory that the Nooksack was a tributary to the Fraser River for a majority of the Holocene and only recently avulsed into the Lower Nooksack Valley near Everson (Maudlin and Pittman, 2003).

Geologic and archaeological evidence suggests that as recently as several hundred years ago, the Nooksack River flowed through the Sumas Valley and into the Fraser River (Figure 1; Maudlin and Stark, 2007; Cameron, 1983).

A major avulsion event is interpreted to have occurred near Everson during the late Holocene, rerouting the lower Nooksack River from the Sumas Valley and Fraser River watershed into a relict glacial outwash channel (Figure 2; Pittman and Maudlin, 2003).
Figure 1. Nooksack River map showing drainage network prior to avulsion (left) and post-avulsion (right); avulsion site is circled.
Figure 2. Nooksack River drainage divide and avulsion nodes shown with relative elevation model (top) and on air photo (bottom).
The numerous abandoned channel forms and valley margin erosion features demonstrate that the pre-
avulsion channel morphology was a complex anastomosing system, likely dominated by large woody
debris (LWD) jams and rapid bedload sedimentation. This relict Nooksack channel signature extends up
the Sumas Valley and across the modern Nooksack alluvial plain in Lower Reach 4.

The Nooksack River system still interacts with the Fraser River during relatively frequent flooding events
(5 to 10-year recurrence events). Flooding along the right bank that accesses the pre-avulsion alluvial
plain conveys water northeast via the Sumas Valley into the Fraser Valley in British Columbia (Figure 3).
As a result of this inter-basin and international flooding issue, there has been a focused effort on flood
management within the reach. This includes levees at the avulsion nodes near Everson and Hopewell
Road and on-going bank armoring to prevent a retreat of the drainage divide topography along the right
bank. While an avulsion of the Nooksack River back in to the Sumas River is theoretically possible,
modern management efforts and existing channel conditions render this scenario highly unlikely.
However, because of the potentially significant consequences associated with such an event, protecting
the drainage divide is often considered a rationale for managing channel migration in this reach.

![Figure 3. Flood image showing former Sumas Lake, now referred to as Sumas Prairie.](image)

The Mainstem Nooksack River may have also been influenced by a variety of other large scale natural
geologic and ecological processes, including crustal tectonic deformation and regional uplift and/or
subsidence, volcanic activity, landslides, sedimentation, climate, vegetative succession, and biological
activity. The extent to which these potential influences have acted on the system is difficult to quantify.
However, the deposition of a major lahar (volcanic mudflow) approximately 6,000 years ago almost
certainly created a significant disturbance in the Nooksack River watershed, including the study reach, where several feet of lahar deposits and wood were observed in the stratigraphy at Nugent’s Corner (Dragovich et al. 1997) and reached as far as Sumas Valley (Cameron, 1983). Field evidence collected in August 2017 suggest that the lahar did not extend down the Nooksack valley westward of Everson. The role of large woody debris and log jams in affecting fluvial processes is supported by reports of extensive snagging and debris removal in support of navigation. The presence of tall, large diameter trees within the channel migration zone undoubtedly influenced channel processes and supported the creation of numerous and extensive wood jams which may have contributed to the aggradation rates of the valley.

Latest Holocene and Anthropocene Setting
A new epoch called the “Anthropocene” has been proposed for the latest period of the Holocene; a time when human’s influence on the landscape, climate, and ecosystems has been substantial enough to create a change in the geologic record (Borenstein, 2014; Simon et al, 2015; Waters, et al, 2016; Zalasiewicz, 2008). The study reach has been impacted by river management and land use practices since European settlement in the area roughly 200 years ago. Anthropogenic impacts include, but are not limited to, log jam clearing, levee construction and bank armoring, log drives, dredging, gravel extraction, channel straightening for navigation or flood management, forest and floodplain clearing, transportation networks and urbanization. In terms of the present channel and floodplain conditions of the study area, these anthropogenic changes were undeniable drivers influencing present geomorphic processes. The cumulative impacts of both historic and contemporary river and watershed management will continue to exert a powerful influence on the geomorphic conditions and will undoubtedly leave a lasting signature on the landscape. Although recovering conditions present in the early mapping of the 1880s is unlikely, it may be possible to recover some functions that were supported by those conditions. Looking ahead, we anticipate that past and contemporary management actions will continue to influence physical processes, as well as the broader effects of changing local and regional geologic, climatic, and environmental conditions.