STREAM MORPHOLOGY AND SEDIMENT TRANSPORT
NORTH FORK AND MAIN STEM CACHE LA Poudre RIVER
PROJECT EFFECTS REPORT
VOLUME I

for the

Halligan Water Supply Project Environmental Impact Statement

Prepared for

U.S. Army Corps of Engineers

Omaha District

Prepared by:

Anderson Consulting Engineers, Inc.

375 E. Horsetooth Road, Bldg. 5
Fort Collins, CO 80525

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1 Introduction

A third-party technical consulting team (Anderson Consulting Engineers, Inc) prepared this stream morphology and sediment transport effects technical report for the Halligan Water Supply Project (Halligan Project). This report presents descriptions of potential environmental effects to stream morphology and sediment transport associated with the City of Fort Collins’ (Fort Collins) Proposed Action, three alternatives to Fort Collins’ Proposed Action, and the No-Action Alternative. Project effects will be evaluated along the North Fork and Main Stem of the Cache la Poudre River. The Halligan Project Environmental Impact Statement (EIS) will summarize the information in this technical report.

In February 2009, the Corps decided that a common technical platform (CTP) would be developed for several key resources within the Cache la Poudre River Basin potentially affected by the Northern Integrated Supply Project (NISP), Halligan Project, and the Milton Seaman Water Supply Project (Seaman Project). As part of the CTP, various baseline reports were prepared for the North Fork and Main Stem of the Cache la Poudre River. This report presents results and interpretations using the same analyses that were described in the Cache la Poudre River Morphology and Sediment Transport Baseline Report (Anderson Consulting Engineers Inc. 2013), hereafter referred to as the Main Stem Baseline Report; the Assessment of Flushing Flows on the Cache la Poudre River (Anderson Consulting Engineers, Inc. 2017), hereafter referred to as the Main Stem Flushing Flow Report; and the North Fork River Morphology and Sediment Transport Baseline Report (Anderson Consulting Engineers Inc. 2017), hereafter referred to as the North Fork Baseline Report. To be consistent with the CTP reports, throughout this report the North Fork of the Cache la Poudre River will be referred to as the North Fork while the main stem of the Cache la Poudre River will be referred to as the Main Stem or Poudre River.

We have presented this project effects report in three volumes to facilitate the review of information. Volume I of this report describes the results and interpretation of all project alternative analyses. All analytical results discussed and referenced in Volume I are presented in graphical and tabular form in Volumes II and III.

1.1 Description of Alternatives

The Corps conducted a screening process to identify alternatives to Fort Collins’ Proposed Action that met the future water demands for Fort Collins as stated in the Purpose and Need Report (WEST et al. 2015). The Alternatives Screening Report (DiNatale Water Consultants and CDM Smith 2015) presents the screening process and the three alternatives identified along with the No-Action Alternative. As part of the screening process, Fort Collins provided details regarding the construction, water conveyance, technical aspects and assumptions for Fort Collins’ Proposed Action, three alternatives and the No-Action Alternative that are discussed in the Final Alternatives Description Report (MWH 2015). The hydrologic models and associated
outputs are described in the Hydrologic Modeling Technical Report (CDM Smith and DiNatale Water Consultants 2016). For this report, we present a brief overview of Fort Collins’ Proposed Action, three alternatives, and the No-Action Alternative for a general understanding.

All of the alternatives include the storage of water with the exception of the No-Action Alternative. Under Fort Collins’ Proposed Action and each alternative, Fort Collins proposed to store the same existing water rights including: converted Southside Ditch rights, reusable Water Supply and Storage Company rights, the conditional Grey Mountain right, and the conditional water right associated with the enlarged Halligan Reservoir with a priority date of December 10, 2013.

1.1.1 Fort Collins’ Proposed Action

Fort Collins’ Proposed Action is to enlarge the Halligan Reservoir, which is on the North Fork about 25 miles northwest of Fort Collins. Currently, the North Poudre Irrigation Company (NPIC) owns the entire water storage capacity of 6,400 acre-feet at the Halligan Reservoir. Fort Collins would increase the capacity by 8,125 acre-feet for a total water storage capacity of 14,525 acre-feet. The current maximum surface area of the Halligan Reservoir is 253 acres, while the maximum surface area of the enlarged reservoir would be approximately 386 acres. Fort Collins has a conditional water right for the storage of water in the enlarged Halligan Reservoir with a priority date of December 13, 2013. To enlarge the existing reservoir, Fort Collins would raise the existing dam an estimated 25 feet. In general, Fort Collins would enlarge the reservoir by expanding the foundation on the downstream face of the dam approximately 8 to 12 feet and make the dam thicker and taller while maintaining a geometry similar to the existing dam. Preparation for the foundation would require rock excavation along the abutments and valley bottom outside of the existing footprint. During construction, the North Fork would bypass the construction activity via a temporary cofferdam and outlet pipes.

Fort Collins could not directly divert water released from Halligan Reservoir into their existing intake facilities that convey water to the Fort Collins water treatment facility. Under its Proposed Action, Fort Collins would release water from Halligan Reservoir into the North Fork and allow that water to flow down into and through Milton Seaman Reservoir (Seaman Reservoir) and into the Poudre River. Fort Collins would divert a similar amount of water at their intakes located on the Poudre River above the confluence with the North Fork. This process is referred to as an exchange and must be authorized by a court issued exchange decree. Fort Collins has two separate intakes on the Poudre River: 1) the existing City of Fort Collins Pipeline via its diversion structure located at Gateway Park, and 2) the Pleasant Valley Pipeline via the existing Munroe Canal (a.k.a. North Poudre Supply Canal or Munroe Gravity Ditch) diversion structure.

Fort Collins would develop the following infrastructure and construction areas in association with this alternative (Figure 1-1): the raised Halligan dam, new outlet works, a cofferdam and temporary outlet pipes, a temporary bridge below the existing dam to access both sides of the North Fork during construction, staging areas, a batch plant, burrow pits, and access roads.
Figure 1-1. Fort Collins’ Proposed Action.
1.1.2  Gravel Pits Alternative

The Gravel Pits Alternative would involve using for water storage a complex of gravel pits on the north side of the Poudre River near Taft Hill Road. The eight interconnected cells at the gravel pit complex would provide approximately 3,875 acre-feet of combined water storage. After the gravel pits were completed, Fort Collins would excavate additional storage within the area of the permitted gravel pit, if needed, to achieve the desired water storage. Two of the existing pits outside the floodplain would likely require above-grade storage achieved by the construction of 20-foot tall berms around the perimeter of the pit. Twenty-foot high berms are classified as jurisdictional dams under the Colorado Division of Safety of Dam criteria (Colorado Division of Water Resources, [http://water.state.co.us/SurfaceWater/DamSafety/DesignConstruction/Pages/default.aspx](http://water.state.co.us/SurfaceWater/DamSafety/DesignConstruction/Pages/default.aspx)) and would require specific design standards provided by the Colorado State Engineer. The final design would require the approval of the Colorado State Engineer prior to construction.

Generally, Fort Collins would convey water from the Poudre River to the gravel pits and then release the water from the gravel pits back to the Poudre River for exchange or into the existing Fort Collins raw water pipelines. To move water to the gravel pits, Fort Collins would divert water from the Larimer County No. 2 Canal diversion structure on the south side of the Poudre River. Fort Collins would install a 42-inch pipeline beneath the riverbed to carry the water north to the gravel pits. Water would enter the gravel pit complex at the Stenger pit or Home Office pit, and would flow to other pits by gravity, or in some cases, by pumping into the North Shores No. 1 pit, depending on the difference in water levels between the Stenger and North Shore pits.

For an exchange, Fort Collins would release water from the gravel pits into new pipelines and then into the Poudre River at a turnout located on the north bank in exchange for water diverted into their intakes higher up on the Poudre River. The other option would be for Fort Collins to pump water to a pretreatment facility. The pretreatment facility would improve the water quality to levels similar to the water diverted at Fort Collins’ intakes, and would deliver this pretreated water directly into the Fort Collins raw water supply lines.

As part of this alternative, Fort Collins would store more water over the winter at Joe Wright Reservoir by authorizing fewer single use water trades with the NPIC. No physical changes would be required for this operational change.

Fort Collins would develop the following infrastructure in association with this alternative (Figure 1-2): new pipelines, three pump stations, a pretreatment facility, diversion structure, staging areas, and access roads.
Figure 1-2. Gravel Pits Alternative.
1.1.3 Agricultural Reservoirs Alternative

For the Agricultural Reservoirs Alternative, Fort Collins would achieve additional water storage by procuring dedicated space in two existing reservoirs: NPIC Reservoir No. 5 and Reservoir No. 6. These reservoirs are interconnected and can be operated as a single element. The reservoirs are located approximately nine miles northeast of the Fort Collins water treatment facility. The feasibility of this alternative depends on Fort Collins and NPIC being able to manage their storage capacity independently. The combined reservoirs have a capacity of 17,830 acre-feet, so Fort Collins would need to acquire 6,475 acre-feet that would constitute approximately 36 percent of the available combined capacity of the two reservoirs. Fort Collins would acquire the storage in the reservoirs through a purchase and operating agreement with NPIC. Fort Collins would need to independently own, operate, and otherwise control the water storage for it to count towards their safety factor. If an acquisition were to be possible, Fort Collins would need to compensate NPIC for loss of water capacity, loss of water rights, and any detrimental consequences inflicted to NPIC’s system or shareholders.

Fort Collins would divert water from the Poudre River at the Munroe Canal diversion structure and convey the water by gravity into the Pleasant Valley Pipeline and through a new bi-directional 48-inch diameter pipe ending at the control valve by the Reservoir No. 6 outlet. From Reservoir No. 6, a new dedicated pipeline would convey the water to Reservoir No. 5 using a pressurized conveyance system eliminating the need for a pump.

Similar to the Gravel Pits Alternative, Fort Collins would have two options for water released from Reservoirs Nos. 5 and 6: either to use the water in an exchange or direct the water into Fort Collins existing raw water supply lines. For an exchange, Fort Collins would release water from the reservoirs into the bi-directional pipeline and then into the Poudre River at a turnout located on the north bank in exchange for water diverted into their intakes on the Poudre River above the confluence with the North Fork. The other option would be for Fort Collins to pump water to a pretreatment facility and then into the Fort Collins’ raw water supply lines. The pretreatment facility would improve the water quality to levels similar to the water diverted at Fort Collins’ raw water intakes. Fort Collins would release water for exchanges when possible to reduce the amount of pumping required.

Fort Collins would develop the following infrastructure in association with this alternative (Figure 1-3): new pipelines, a value house, a pump station, a pretreatment facility, diversion structure, staging areas, and access roads.
Figure 1-3. Agricultural Reservoirs Alternative.
1.1.4 Expanded Glade Alternative

The Expanded Glade Alternative would provide Fort Collins with 6,075 acre-feet of water storage through the expansion of the proposed Glade Reservoir. The Expanded Glade Alternative is contingent on the Corps permitting the Glade Reservoir. Glade Reservoir would be a 170,000 acre-feet reservoir that is part of Northern Colorado Water Conservancy District’s (Northern Water) proposed action analyzed in the Northern Integrated Supply Project Supplemental Draft EIS (NISP SDEIS 2015). The Corps expects to issue the Final NISP EIS and Record of Decision sometime in 2018. Under this alternative Fort Collins would operate its storage in the enlarged Glade Reservoir independently, enlarging and using several components of the proposed Glade Reservoir infrastructure to store and release water from the reservoir. Fort Collins would require some additional infrastructure. The expansion would require raising the dam approximately four feet higher than the NISP design. The maximum surface area of the expanded Glade Reservoir is expected to be approximately 1,693 acres which is 57 acres more than the maximum surface area of the Glade Reservoir proposed by NISP.

Fort Collins would deliver water through the Poudre Valley Canal to the NISP proposed diversion point into Glade Reservoir. This diversion point and the Poudre Valley Canal would need to be enlarged to accommodate both NISP and Fort Collins water inflows simultaneously. Fort Collins would temporarily retain the diverted water in the Glade Forebay and then pump it into the reservoir. Fort Collins would release water through the Glade Dam infrastructure and either route the water to the Poudre River for use in an exchange or send it directly into Fort Collins existing raw water supply lines. Fort Collins would construct a new pipeline that would connect the Glade Reservoir outlet pipeline to Fort Collins’ existing pipelines and the Pleasant Valley Pipeline. Fort Collins could release water into Fort Collins’ new pipeline and then into the Poudre River at a river turnout in exchange for water diverted by Fort Collins upstream of the confluence with the North Fork. Alternatively, Fort Collins could direct water to a new pretreatment facility co-located with the Glade Pump Station at the foot of the dam and then convey the water through their new pipeline to their existing raw water supply lines.

Fort Collins would develop the following infrastructure in association with this alternative (Figure 1-4): the raised Glade dam, increased depth to the NISP proposed forebay, larger or additional pumps located at the NISP pump station, a pretreatment facility, a pipeline from the pretreatment facility to the raw water supply lines, and a river turnout on the new pipeline.
Figure 1-4. Expanded Glade Alternative.
1.1.5 **No-Action Alternative**

The No-Action Alternative, unlike the above alternatives, would not involve structural changes to existing infrastructure or development of new structures associated with the Fort Collins water supply system. The No-Action Alternative is an administrative approach developed by Fort Collins to try to meet as much of the city’s purpose and need as possible with the three following measures.

- Fort Collins would change its operational procedures at their existing Joe Wright reservoir to store more water over the winter.
- Fort Collins would acquire additional NPIC shares either through direct purchase of shares or by requiring residential and commercial development to provide dedicated shares.
- Fort Collins would implement mandatory water use restrictions during drought periods and system failures.

All components of the No-Action Alternative would be non-structural and require no ground disturbance of any type.

Under the first measure of their No-Action Alternative, Fort Collins would conduct fewer single-use water transactions with NPIC to maintain a higher water level at the Joe Wright Reservoir over the winter, similar to the Gravel Pits Alternative. Fort Collins would set the winter carryover capacity for Joe Wright Reservoir at 3,200 acre-feet. To sustain this level, Fort Collins would need to cut the amount of late summer and fall distribution of single-use water for subsequent exchange with NPIC. NPIC has previously accepted these single use exchanges of Joe Wright Reservoir water for NPIC’s water from the Colorado-Big Thompson Project (C-BT) stored in Horsetooth Reservoir, which has been mutually beneficial for Fort Collins and NPIC. Fort Collins benefitted from the water exchanges by reducing the amount of single use water stored in Joe Wright Reservoir allowing storage space for more reusable use water collected in the spring from Michigan Ditch. For NPIC, the exchanges allowed water diversion at Munroe Canal during times when the exchange potential for moving C-BT water upstream to the Munroe Canal was low. This reoperation option would require no new infrastructure and would provide no new storage capacity for Fort Collins.

Under the second measure of their No-Action Alternative, Fort Collins would either directly purchase NPIC shares or would require future developers to dedicate NPIC shares to Fort Collins as a condition of future development. NPIC shares would specifically need to have a C-BT storage component. Acquiring NPIC shares provides Fort Collins additional C-BT water and its associated storage. Northern Water has imposed limitations on the amount of additional C-BT shares Fort Collins can directly purchase. However, it would be permissible for Fort Collins to acquire C-BT units by purchasing NPIC shares or through dedication from developers. Fort Collins has deliberately focused on developing its Poudre River sources to diversify its system as it already owns a large amount of C-BT shares.
The third measure Fort Collins would enact as part of the No-Action Alternative is to impose more frequent and severe mandatory water restrictions. Fort Collins has already implemented a Water Supply Shortage Response Plan (2003; revised in 2013) to address drought and emergency water supply situations. The Plan provides four response levels to address various levels of supply shortage severity. Since their inception in 2003, Fort Collins has imposed mandatory water restrictions (Response Level 1) twice: in 2003 to respond to the early 2000s drought, and in 2013 in response to a drought and water quality effects of the High Park Fire. Under the No-Action Alternative, water supply shortages would likely be more frequent and severe and water restrictions would be implemented more frequently, would be more severe, and would last longer. Mandatory water use restrictions would not create additional firm water yield or storage capacity, but the approach would extend available supplies during a drought or interruption in water supply. However, modeling suggests that during the design drought, even with restrictions, Fort Collins would not be able to maintain a reserve of water equal to 15 percent of Fort Collins’ average annual demand as a buffer in case of storage or delivery system failure, forest fire, adverse unexpected water court rulings, or other unanticipated stressors on the water delivery system. This would make Fort Collins vulnerable to water shortages and the possibility of water shutoffs if an unforeseen event disrupted the water supply system.

For further details on this alternative or the other proposed alternatives, please see the Final Alternatives Description Report (MWH 2015).

1.2 Study Area

The study area includes the North Fork and Main Stem. We have evaluated each water course separately. A description of the North Fork and Main Stem study areas is provided below.

1.2.1 North Fork Study Area

The North Fork study area includes approximately 28 miles of river extending from the confluence with the Main Stem upstream to Dale Creek (Figure 1-5). Halligan Reservoir is located near the upstream end of the study area and Seaman Reservoir near the downstream end. In between the two reservoirs, the river flows through two canyons (referred to as the upper and lower canyons) that are separated by a 7.5-mile unconfined reach where the river flows over an area of alluvial valley fill. The upper and lower canyons laterally confine the river channel with little to no overbank or floodplain areas. The upper canyon is also referred to as Phantom Canyon. A notable transition in river condition would occur within Phantom Canyon at the diversion to the North Poudre Canal. Immediately downstream of this diversion the river channel becomes indistinct, often runs dry, is filled with bed material, and is heavily encroached by vegetation. Once the river emerges from Phantom Canyon it meanders through an alluvial valley where the channel is unconfined and larger flows can spill into overbank areas. Three tributaries have their confluence with the North Fork within the unconfined valley reach. The river then enters the lower canyon where the channel again becomes laterally confined until it reaches Seaman Reservoir.
The following terms are used to describe locations within the North Fork study area where analyses were performed (Figure 1-6):

- **Study Reaches.** These segments represent river reaches with similar geomorphic and sediment transport characteristics such that within each reach, response to change is expected to be similar. Table 1-1 provides a listing of North Fork study reaches and corresponding reach extents described by physical location and station in feet above the confluence with the Main Stem.

- **Cross Sections.** These represent the channel configuration at several locations within the North Fork study area and are utilized as input to hydraulic modeling with the results utilized in subsequent geomorphic and sediment transport analyses. The hydraulic model includes a total of 412 cross sections. Hydraulic conditions at 349 of the 412 cross sections were utilized in the North Fork study area for analysis. The 63 model cross sections not utilized in the analyses were filtered out due to the close proximity to hydraulic structures (e.g., bridges, diversion structures, etc.) and location within reservoir backwater areas.

- **Hydrologic Nodes.** These locations represent points along the North Fork where daily flow series estimates were provided by CDM Smith to support the hydrologic, hydraulic, geomorphic, and sediment transport analyses (CDM Smith and DiNatale Water Consultants 2016).

More information regarding the study area and areas of analytical interest can be found in the North Fork Baseline Report.

### Table 1-1. North Fork study reaches and hydrologic nodes.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Upstream Location of Study Reach</th>
<th>Upstream Station (ft)*</th>
<th>Reach Length in feet (miles)</th>
<th>Hydrologic Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF 1</td>
<td>Dale Creek</td>
<td>149,600</td>
<td>8,600 (1.63 mi)</td>
<td>Above Halligan</td>
</tr>
<tr>
<td>Halligan</td>
<td>Halligan Reservoir Inundation Zone</td>
<td>141,000</td>
<td>10,844 (2.05 mi)</td>
<td></td>
</tr>
<tr>
<td>NF 2</td>
<td>Halligan Reservoir Dam</td>
<td>130,156</td>
<td>32,099 (6.08 mi)</td>
<td>Below Halligan</td>
</tr>
<tr>
<td>NF 3</td>
<td>North Poudre Canal Diversion</td>
<td>98,057</td>
<td>6,557 (1.24 mi)</td>
<td>Below NPC</td>
</tr>
<tr>
<td>NF 4</td>
<td>Downstream End of Phantom Canyon</td>
<td>91,500</td>
<td>15,195 (2.88 mi)</td>
<td>Below NPC</td>
</tr>
<tr>
<td>NF 5</td>
<td>Rabbit Creek</td>
<td>76,305</td>
<td>24,705 (4.68 mi)</td>
<td>Livermore Gage</td>
</tr>
<tr>
<td>NF 6</td>
<td>Upstream End of Lower Canyon</td>
<td>51,600</td>
<td>33,600 (6.36 mi)</td>
<td>Livermore Gage</td>
</tr>
<tr>
<td>Seaman</td>
<td>Seaman Reservoir Inundation Zone</td>
<td>18,000</td>
<td>11,760 (2.23 mi)</td>
<td></td>
</tr>
<tr>
<td>NF 7</td>
<td>Seaman Reservoir Dam</td>
<td>6,240</td>
<td>6,240 (1.18 mi)</td>
<td>Below Seaman</td>
</tr>
</tbody>
</table>

* River distance upstream of confluence with Main Stem based on 2009 aerial photography.
Figure 1-5. North Fork Study Area.
Figure 1-6. Schematic of North Fork study reaches as they relate to reservoirs, tributaries, gages, crossings, and hydrologic nodes.
1.2.2 Main Stem Study Area

The Main Stem study area includes approximately 60 miles of the Poudre River between the Munroe Canal Diversion and its confluence with the South Platte River (Figure 1-7). This reach of the Poudre River is referred to as the Main Stem in this report. Within the Main Stem study area, the river transitions from a steep, fast flowing, cobble and boulder bed stream occupying most of the width of the canyon floor, to a narrow, slow flowing, sand and silt bed, lowland stream, flowing within a wide floodplain and dominated by vigorous in-channel and channel margin vegetation. Within these broad distinctions, there are anomalous sub-reaches, often associated with bridge or diversion structures or with channelization, channel straightening, floodplain encroachment or flood protection works.

The following terms are used to describe locations within the Main Stem study area where analyses were performed (Figure 1-8):

- **Study Reaches.** These segments represent river reaches with similar geomorphic and sediment transport characteristics such that within each reach, response to change is expected to be similar. Table 1-4 provides a listing of study reaches and corresponding reach extents described by physical location and station in feet above the confluence with the South Platte River.

- **Fort Collins Sub-Reaches.** The Fort Collins Study Reach was further subdivided into six sub-reaches to allow impacts to be discriminated at a finer level of detail due to: (a) the presence of several significant water diversions; and (b) the transition in this study reach from the steep canyon reaches upstream and the flatter plains reaches downstream.

- **SIAM Reaches.** These are reaches that are defined for sediment transport analyses. Includes a total of 20 reaches defined by the extent of study reaches and changes in hydrology defined by hydrologic nodes.

- **Cross Sections.** These represent the channel configuration at several locations within the study reach and are utilized as input to the channel hydraulic modeling with the results utilized in subsequent geomorphic and sediment transport analyses. The hydraulic model includes a total of 428 cross sections, 222 located upstream of Interstate-25 and 206 located downstream of Interstate-25. Hydraulic conditions at 407 of the 428 cross sections were utilized in the study area for analysis, with 206 located upstream of Interstate-25 and 201 located downstream of Interstate-25. The 21 model cross sections not utilized in the analyses were filtered out due to the close proximity to hydraulic structures (e.g., bridges, diversion structures, etc.)

- **Hydrologic Nodes.** These locations represent points along the Main Stem between the Munroe Canal diversion and the confluence with the South Platte River where daily flow series estimates were provided to support the hydrologic, hydraulic, geomorphic, and sediment transport analyses.

More information regarding the study area and areas of analytical interest can be found in the Main Stem Baseline Report.
Figure 1-7. Main Stem Study Area.
### Hydrologic Nodes

<table>
<thead>
<tr>
<th>Hydrologic Nodes</th>
<th>Laporte</th>
<th>Fort Collins</th>
<th>Collins</th>
<th>Timnath</th>
<th>Windsor</th>
<th>Greeley Upstream</th>
<th>Greeley Channelized</th>
<th>Greeley D/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>32</td>
<td>34</td>
<td>35</td>
</tr>
</tbody>
</table>

### SIAM Reaches

<table>
<thead>
<tr>
<th>Siam Reaches</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
</table>

---

Figure 1-8. Schematic of Main Stem study reaches as they relate to major crossings, diversions, inflows, and hydrologic nodes.
Table 1-2. Main Stem study reaches and hydrologic nodes.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Upstream Location</th>
<th>Upstream Station (ft)*</th>
<th>Hydrologic Node**</th>
<th>Data Delivery Mile (DDM)***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laporte</td>
<td>Munroe Canal</td>
<td>322,944</td>
<td>1</td>
<td>1.59</td>
</tr>
<tr>
<td>Laporte</td>
<td>North Fork Confluence</td>
<td>315,220</td>
<td>2</td>
<td>1.69</td>
</tr>
<tr>
<td>Laporte</td>
<td>Poudre Valley Canal</td>
<td>295,484</td>
<td>4</td>
<td>5.63</td>
</tr>
<tr>
<td>Laporte</td>
<td>Hansen Supply Canal</td>
<td>287,670</td>
<td>7</td>
<td>6.93</td>
</tr>
<tr>
<td>Laporte</td>
<td>Larimer County Canal</td>
<td>279,990</td>
<td>8</td>
<td>8.02</td>
</tr>
<tr>
<td>Laporte</td>
<td>Little Cache La Poudre Ditch (Little Cache Ditch)/New Mercer Ditch/LCC No 2</td>
<td>262,406</td>
<td>12</td>
<td>13.63</td>
</tr>
<tr>
<td>Fort Collins</td>
<td>Larimer &amp; Weld Irrigation Canal</td>
<td>246,435</td>
<td>17</td>
<td>14.92</td>
</tr>
<tr>
<td>Fort Collins</td>
<td>Lake Canal</td>
<td>236,129</td>
<td>20</td>
<td>16.84</td>
</tr>
<tr>
<td>Fort Collins</td>
<td>Cache la Poudre (CLP) Reservoir Inlet Canal</td>
<td>221,670</td>
<td>23</td>
<td>21.09</td>
</tr>
<tr>
<td>Timnath</td>
<td>Fossil Creek Reservoir Inlet</td>
<td>208,582</td>
<td>32</td>
<td>23.14</td>
</tr>
<tr>
<td>Timnath</td>
<td>New Cache la Poudre Co. Ditch (New Cache Ditch)</td>
<td>169,865</td>
<td>34</td>
<td>27.86</td>
</tr>
<tr>
<td>Windsor/ Greeley US</td>
<td>Whitney Irrigation Ditch</td>
<td>150,867</td>
<td>35</td>
<td>31.66</td>
</tr>
<tr>
<td>Greeley US/ Greeley Chan</td>
<td>Greeley No. 3</td>
<td>84,620</td>
<td>41</td>
<td>44.38</td>
</tr>
<tr>
<td>Greeley Channelized</td>
<td>Greeley Waste Water Treatment Plant</td>
<td>28,126</td>
<td>43</td>
<td>55.14</td>
</tr>
<tr>
<td>Greeley Downstream</td>
<td>Greeley Gage</td>
<td>15,120</td>
<td>47</td>
<td>57.43</td>
</tr>
</tbody>
</table>

* Station in feet upstream of confluence with the South Platte River utilized in hydraulic and sediment transport modeling.
** Hydrology data provided by CDM Smith at hydrologic nodes applied to hydraulic modeling between stations identified.
*** Data Delivery Mile is a reference used by CDM Smith and is representative of river distance downstream of Munroe Canal.
1.3 Summary of Baseline Conditions

For reference, we have provided an overview of baseline conditions on the North Fork and Main Stem that project alternatives will be compared against. Under the CTP, baseline conditions were developed for both “Current Conditions” hydrology and “Future Conditions hydrology.”

The Current Conditions baseline used 1950 to 2005 monthly naturalized streamflows with 2010 demands, infrastructure, and operations to estimate 56 years of future streamflows without the proposed NISP, Halligan Project, Seaman Project, or reasonably foreseeable future actions (RFFAs) that are independent of NISP, the Halligan Project, or the Seaman Project, or any other future condition.

The Future Condition baseline used 1950 to 2005 naturalized streamflows with projected 2050 demands, infrastructure, and operations (including RFFAs that are independent of the proposed NISP, Halligan Project, and Seaman Project) to estimate 56 years of future streamflows without the proposed NISP, Halligan Project, and Seaman Project.

Evaluations provided in this report rely heavily upon daily stream flows disaggregated from monthly flow volumes. On the North Fork a 19-year daily flow time series (November 1, 1986 through October 31, 2005; irrigation years 1987-2005) was developed for evaluations. Estimated daily streamflows for a 26-year time series (November 1, 1979 through October 31, 2005; irrigation years 1980 – 2005) were produced by the hydrologic modeling (CDM Smith and DiNatale Water Consultants 2016) on the Main Stem.

1.3.1 North Fork Baseline Conditions

Current and Future Conditions baselines were developed for comparison to Fort Collins’ Proposed Action, all alternatives, and the No-Action alternative on the North Fork.

1.3.1.1 Current Conditions

Detailed evaluation and description of the North Fork under Current Conditions is documented in the North Fork Baseline Report. Overall conclusions from the North Fork Baseline Report are summarized below. For detailed discussion of Current Conditions conclusions on a reach by reach basis see Section 8.2 of the North Fork Baseline Report.

The morphology of the North Fork between Halligan and Seaman Reservoirs has largely been influenced by the canyon geology and change in hydrology associated with the construction and operation of Halligan Reservoir and the North Poudre Canal Diversion.

Assessments indicate that impacts of historic changes are greatest downstream of the North Poudre Canal Diversion at least as far as the Rabbit Creek confluence, where river morphology is substantially changed from its natural characteristics and the environmental functions that depend on morphology are already degraded. The dominant change in these zones is deposition of silts, and sands on channel margins associated with vegetation encroachment leading to
channel contraction. Elsewhere, the magnitude of hydrologic change and the apparent morphologic consequences are less evident.

While recognizing the reality of non-linear response and associated geomorphic thresholds, observation and assessment of current processes provides the most reliable guide to predicting trajectories under a continuation of Current Conditions.

The prognosis, or predicted trajectory, for the river channel between the North Poudre Canal Diversion and the Rabbit Creek confluence under Current Conditions hydrology is a continuation of the process of channel diminution (channel contraction) by vegetation encroachment and associated deposition of fine material on channel margins. This trajectory will be punctuated from time to time when a large flood is able to reset channel morphology by scouring of vegetation and deposited sediments, but the overall trajectory of channel diminution will prevail.

Upstream of the North Poudre Canal Diversion, there will be a minor tendency toward a similar trajectory, but morphologic change is expected to be small. If fine material is flushed from Halligan Reservoir during drawdown, it will temporarily impact channel morphology and associated environmental values until it is largely remobilized and passed downstream.

Downstream of Rabbit Creek, the inflowing tributaries redress much of the hydrologic change from upstream and no consistent trajectory of morphologic change is expected.

### 1.3.1.2 Future Conditions

A comparative assessment of Current and Future Conditions on the North Fork is provided in Chapter 3 of this report. Detailed results of all Future Conditions analyses on the North Fork are provided in Volume II Appendix B. Comparative evaluations of Future versus Current Conditions is provided in Volume II Appendix C. Results of the comparative assessment indicate a slight increase in North Fork flows from Current to Future Conditions, generally downstream of the North Poudre Canal Diversion.

In overview, the trajectory of the North Fork River condition is expected to continue under both Current and Future Conditions hydrology. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the North Fork Baseline Report for Current Conditions are expected to continue under Future Conditions with negligible change.

Fort Collins’ Proposed Action, the No-Action Alternative, and Cumulative Effects will be compared to the Future Conditions baseline.

### 1.3.2 Main Stem Baseline Conditions

Current and Future Conditions baselines were developed for comparison to project alternatives on the Main Stem. Fort Collins’ Proposed Action and all project alternatives will be compared against Current and Future Conditions with the exception of the Expanded Glade Alternative.
River condition predicted under NISP’s Proposed Action (Glade Reservoir) will be used as a baseline to determine effects of the Expanded Glade Alternative. Baseline conditions are summarized below.

### 1.3.2.1 Current Conditions

Evaluation of Current Conditions on the Main Stem is documented in the Main Stem Baseline Report. Below is a summary of overall conclusions from the Main Stem Baseline Report.

Since settlement, the morphology of the Poudre River within the study reach has been heavily influenced by the following combination of factors:

- **Direct changes** to the channel associated with gravel mining, flood control and urban and agricultural development;
- **Changes to riparian and instream vegetation and land use** including invasion of reed canary grass; and
- **Hydrologic change** associated with interbasin diversions and diversions from the river.

An evaluation of these factors suggest that the river is substantially changed from its natural morphological condition and the environmental functions, and social and economic values that depend on morphology are already reduced and are likely to be further reduced throughout the study area.

**Direct changes** to the channel have been substantial throughout but concentrated in the vicinity of the urban areas. Most changes for gravel mining and flood control have straightened and leveed the river channel. In particular, around Fort Collins, Windsor, and Greeley, long lengths of the Poudre River now flow in artificial channels where natural channel morphology is lost. Other direct influences on river morphology include erosion control works and the many diversion weirs which pool water, trap sediment and cause downstream scour pools.

**Loss of vegetation** from the banks has reduced the resistance to erosion although large-scale bank erosion is isolated in time and in space. Elsewhere, particularly downstream of Interstate-25, a bio geomorphic feedback is apparent where vegetation encroaches on deposited material and stabilizes it, encouraging further deposition.

The observed **hydrologic change** is a net decrease in flows. This has led generally to an increased tendency toward channel aggradation. In turn, aggradation leads to:

- **Channel Contraction.** Deposition of silts, sands, or gravels on channel bars and margins or on mid-channel islands leading to reduced channel width and/or depth;
- **Fining of Surficial Material.** Reduced magnitude, frequency, or duration of flows leading to a fining of surficial material and possible blanketing of the bed with interstices filled with fine material; and
- **Loss of Hydraulic and Morphologic Complexity.** Channel contraction and fining of surficial material together with increased wavelength and decreased amplitude of
meanders and possible loss of pool riffle sequencing leading to loss of hydraulic and morphologic complexity and reduced spatial frequency or variability of biotypes.

Hydrologic change has been greatest in the vicinity of Fort Collins however the morphologic consequences of the hydrologic change have, to date, been greater downstream of Interstate-25.

Downstream of Interstate-25 the river channel has contracted to as little as 15 feet wide at some riffles. Vegetation (predominantly reed canary grass) colonizes deposited material and ensures the longevity of mid channel bars, bank attached side bars, islands, and lee side deposits. This section of the Poudre River exhibits strong trends in aggradation and is characterized as “transport limited” which is defined as conditions in which sediment supply greatly exceeds sediment transport potential. Transport limited systems are sensitive to hydrologic change.

Upstream of Interstate-25 the river channel is generally armored, larger, and steeper with a strong aggradational tendency as a result of reduced flows and various diversion structures that control in-channel hydraulics. However, consistent and contiguous aggradation is constrained by a lack of available sediment compared to the overall sediment transporting capacity of the channel. The armor layer is comprised of cobbles and generally devoid of fine gravels and sands. This is an indication that sediment transport potential greatly exceeds supply of fine gravels and sands. This reach of the Poudre River is generally characterized as “supply limited” which is defined as having sediment transport potential that greatly exceeds available sediment supply. Supply limited systems are less sensitive to hydrologic change.

The difference between supply limited and transport limited reaches was described in testimony to the Colorado Water Division 1 trial (Gordon, 1995) quoted below. Note that the term hydraulically-controlled is used here to mean the same as transport limited.

“The consequences of flow reduction would therefore be different in hydraulically-controlled (transport limited) and supply limited streams. In a hydraulically-controlled (transport limited) stream, there was normally a balance between the sediment supply and the amount carried by the stream. If flows were reduced, aggradation would be expected because the sediment supply wouldn’t change. However, in a supply limited stream, the capacity to carry sediment was much higher than the amount being delivered to the stream; therefore, the flows could be substantially reduced, and they would still be able to transport the delivered material without aggradation. The opposition believed that flows could be reduced substantially in the WD1 streams without causing aggradation. Walch made the point that the supply limitation also depended on the sizes of materials being provided to the stream, and the WD1 streams had an abundance of gravels and cobbles to be moved but a shortage of finer materials.”

While recognizing the reality of non-linear response and associated geomorphic thresholds, this observation of the result of current processes provides the most reliable guide to the future under Current Conditions hydrology.
**Trajectory Upstream of Interstate-25**

Broadly, for the reasons discussed above, channel change in the existing river condition is as much a consequence of direct interference in the river (gravel extraction, floodplain encroachment, realignment, channel modification, structures, etc.) as it is a consequence of hydrologic change. The prognosis for the channel upstream of Interstate-25 under Current Conditions is a continuation of spatially discrete episodes of alignment and longitudinal profile instability during short periods of flood flow with prolonged periods (measured in years) of relative stability at other times. Particular areas, such as upstream of Mulberry Street, are vulnerable to change.

Despite the relative stability of the existing condition, the Poudre River still has a propensity to aggrade, constrained in the Current Conditions by the limited availability of incoming sediment relative to the ability of the channel to transport it. Deposition and vegetation encroachment will continue in discrete areas – probably at a rate similar to the current unless some unpredicted intrinsic threshold is reached, or some other change occurs such as an invasion of reed canary grass or a substantial increase in sediment supply from upstream sources. Localized areas of bank erosion will continue, mainly associated with episodes of gravel movement during larger flow events.

**Trajectory Downstream of Interstate-25**

Prognosis for the Poudre River differs downstream of Interstate-25 for two main reasons:

- Under baseline conditions, sediment transport in the upstream section is supply limited whereas sediment transport in the downstream section tends toward transport limited behavior. A transport limited system is more sensitive to changes in hydrology because its behavior is controlled by the hydraulics of the system rather than by sediment supply.

- Under baseline conditions, downstream of Interstate-25, vegetation (reed canary grass in particular) is playing a dominant role in channel contraction processes. Even temporary deposition of material at or near the water surface allows rapid establishment of vegetation which then encourages further deposition and so on.

Interestingly, these reasons fall outside the scope of the available analytical tools; so definitive, quantitative predictions of their influence is not possible.

The broad prognosis for the channel downstream of Interstate-25 is a continuation of the current aggradational trend. Deposition of sands and fine gravels will continue in preferential zones causing ripples to narrow, bars and islands to form, and the toe of banks to gradually accrete. In many places this will result in a narrow secondary channel, probably 10 to 20 feet wide, formed by slow terracing within the larger historic channel. Progress would be gradual, limited by constraints in sediment supply. The river is not truly transport limited for all size fractions, otherwise pools would fill with sediment and channel change would be rapid. The process is heavily influenced by vegetation which stabilizes recently deposited material near water level.
and then provides the hydraulic conditions to encourage further deposition. Vegetation is probably encouraged by long periods of constant water levels from return flows.

Floods and high flows will occasionally disrupt the trend of channel contraction, stripping vegetation and mobilizing bed material. Evidence from comparable systems, e.g., the Central Platte River (Pollen-Bankhead, Thomas, & Simon, 2011) suggests that wholesale removal of vegetation is unlikely during these events and if the time between scouring flows is sufficient for the vegetation to re-establish, it will resist removal and continue to stabilize deposits. This behavior is supported by observation in the Main Stem below Interstate-25.

A trend of ongoing channel contraction and loss of channel complexity in the Poudre River downstream of Interstate-25 characterizes the baseline condition of the river and is already impacting riverine functions. The trend represents the response of the river to various changes in the watershed over the last two centuries. In particular, river morphology continues to respond to changes in hydrology associated with water resources development and direct interference with the river channel through channel modification associated with gravel extraction, urban development, and structures. The trend of channel contraction and loss of channel complexity is projected to continue under a continuation of Current Conditions hydrology.

Fort Collins’ Proposed Action, and the Gravel Pits and Agricultural Reservoirs alternatives will be compared with Current Conditions baseline.

1.3.2.2 Current Conditions with NISP’s Glade Alternative

The Expanded Glade Alternative involves water storage in NISP’s proposed Glade Reservoir. River condition with NISP’s Glade Reservoir Alternative will be used as a baseline to determine effects of the project’s Expanded Glade Alternative. Detailed evaluations of the Main Stem with NISP’s Glade Alternative under Current Conditions can be found in Chapter 3 and Chapter 11 of the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, Inc. 2014).

In summary, the trajectory of the Poudre River with NISP’s Glade Alternative (referred to as Alternative 2 in the NISP Project Effects Report) is expected to be a continuation of Current Conditions. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report (Anderson Consulting Engineers, Inc. 2013) are expected to continue and be more severe downstream of Interstate-25 than upstream of Interstate-25. Assessments of the effects of NISP’s Glade Alternative compared to the Current Conditions confirm and further amplify this trajectory of the river condition reflected in continuing channel contraction, fining of surficial material, and loss of channel complexity. NISP’s Glade Alternative could result in a detectable change on geomorphology and sediment transport that is considered to be minor (defined as detectable change, but the change would be slight) in the reaches upstream of Interstate-25 and a clear detectable change considered to be moderate (defined as clearly detectable change with measurable effects) downstream of Interstate-25.
1.3.2.3 Future Conditions

Detailed evaluations of Future Conditions on the Main Stem are documented in Chapter 2 and Chapter 6 of the NISP Project Effects Report (Anderson Consulting Engineers, Inc. 2014). All Future Condition analyses are provided in Volume III Appendix K of this report. Comparative analyses of future versus Current Conditions is provided in Volume III Appendix L of this report.

In overview, the current trajectory of the river condition is also expected to continue under Future Conditions hydrology. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report (Anderson Consulting Engineers, Inc. 2013) are expected to continue and be more severe downstream of Interstate-25 than upstream of Interstate-25 because:

- Sediment supply in the size fractions relevant for deposition is more limited upstream of Interstate-25 than downstream; and
- Bio-geomorphic processes involving vegetation establishment on benches and bars prevail more downstream of Interstate-25 compared to upstream.

The comparative assessment of Current Conditions to Future Conditions generally reflects a reduction in the flows within the river system which provides a future condition that demonstrates a reduction in the flushing of fines, bed material movement, stream power, and sediment transport potential.

Fort Collins’ Proposed Action, the Gravel Pits Alternative, the Agricultural Reservoirs Alternative, and the No-Action Alternative will be evaluated relative to the Future Conditions baseline. All cumulative effects hydrology will also be compared against the Future Conditions baseline.

1.3.2.4 Future Conditions with NISP’s Glade Alternative

Detailed evaluations of the Main Stem with NISP’s Glade Alternative under Future Conditions can be found in Chapter 7 and Chapter 11 of the NISP Project Effects Report (Anderson Consulting Engineers, Inc. 2014).

In summary, the trajectory of the river condition is expected to continue under Future Conditions with NISP’s Glade Reservoir Alternative. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report (Anderson Consulting Engineers, Inc. 2013) are expected to continue and be more severe downstream of Interstate-25 than upstream of Interstate-25. Assessments of the effects of the NISP Glade Reservoir Alternative compared to the Future Conditions further confirm and amplify trajectory of the river condition reflected in continuing channel contraction, fining of surficial material, and loss of channel complexity. NISP’s Glade Reservoir Alternative could result in a detectable effect on geomorphology and sediment transport that is considered to be
in the reaches upstream of Interstate-25 and a clear detectable change considered to be downstream of Interstate-25.

The Future Conditions with NISP’s Glade Alternative will be the baseline against which the Expanded Glade Alternative will be compared.

### 1.4 Basis of Assessment

Fort Collins and the third-party contractor team from CDM Smith and DiNatale Water Consultants developed and ran a series of hydrologic models simulating the operations of Fort Collins’ Proposed Action and all alternatives. The daily streamflow time series calculated in these hydrologic models were the basis for this stream morphology and sediment transport analysis. Fort Collins simulated Fort Collins’ Proposed Action and three action alternatives under both Current Conditions, Future Conditions, and Cumulative Effects scenarios. A No-Action Alternative under Future Conditions was also simulated. The Hydrologic Modeling Technical Report (CDM Smith and DiNatale Water Consultants 2016) described the hydrologic modeling in greater detail. Similarly, the Operations Plan Report (City of Fort Collins 2016) described model output for reservoir operations and key diversions.

Hydrologic modeling of Fort Collins’ Proposed Action, all action alternatives, and the No-Action Alternative (CDM Smith and DiNatale Water Consultants 2016) was developed to evaluate effects. On the North Fork a 19-year daily flow time series (November 1, 1986 through October 31, 2005; irrigation years 1987-2005) was developed for evaluations. Estimated daily streamflows for a 26-year time series (November 1, 1979 through October 31, 2005; irrigation years 1980 – 2005) were produced by the hydrologic modeling (CDM Smith and DiNatale Water Consultants 2016) on the Main Stem.

Hydrologic model runs are identified below by alternative and condition. ‘Run 3’ indicates Current Conditions, ‘Run 4’ Future Conditions, and ‘Run 5’ Cumulative Effects. For convenience, we developed the following abbreviated nomenclature for the with-project hydrologic model runs:

- PA3: Fort Collins’ Proposed Action Run 3 (Current Conditions),
- PA4: Fort Collins’ Proposed Action Run 4 (Future Conditions),
- PA5: Cumulative Effects with Fort Collins’ Proposed Action Run 5 (Future Conditions),
- GP3: Gravel Pits Alternative Run 3 (Current Conditions),
- GP4: Gravel Pits Alternative Run 4 (Future Conditions),
- GP5: Cumulative Effects with Gravel Pits Alternative Run 5 (Future Conditions),
- AR3: Agricultural Reservoirs Alternative Run 3 (Current Conditions),
- AR4: Agricultural Reservoirs Alternative Run 4 (Future Conditions),
- AR5: Cumulative Effects with Agricultural Reservoirs Alternative Run 5 (Future Conditions),
- EG3: Expanded Glade Alternative Run 3 (Current Conditions),
- EG4: Expanded Glade Alternative Run 4 (Future Conditions),
- EG5: Cumulative Effects with Expanded Glade Alternative Run 5 (Future Conditions), and
- NA4: No-Action Alternative Run 4 (Future Conditions).

The baseline runs are as follows:

- Run 1: Current Conditions, no projects,
- Run 2: Future Conditions, no projects,
- NISP Run 3a: Current Conditions with NISP’s Glade Reservoir Alternative, and
- NISP Run 4a: Future Conditions with NISP’s Glade Reservoir Alternative.

Each with-projects model run was the same as the associated baseline run, with the following changes:

- Inclusion of expanded Halligan or the proposed storage for each action alternative, and any associated conveyance;
- Inclusion of water rights used to fill the expanded Halligan or alternative storage or used under the No-Action Alternative;
- Other operational changes under the No-Action Alternative; and
- Increased municipal demand by Fort Collins.

The differences in demand and water rights portfolio were necessary to achieve realistic modeled operations of each alternative. These changes also ensured realistic operation of Ft. Collins’ water supply system as a whole under both baseline and with-projects conditions. However, comparing model runs in which demands and water right portfolios are different indicates streamflow impacts that are in fact wholly unrelated to the operation of each alternative.

Streamflow effects therefore fell into several categories, including both direct and indirect effects, as follows:

- Direct effects
  - Streamflows dropping when Ft Collins diverts water into storage;
  - Streamflows increasing when Ft Collins releases water from storage; and
  - For the No-Action Alternative, streamflows changing due to revised diversions and releases at Joe Wright Reservoir.

- Indirect effects
Increased reliance on other water rights within the Ft Collins water supply system to meet increased demand, including increased diversions at the Ft Collins intake pipeline on the Upper Poudre and increased reliance on transbasin supplies from Horsetooth Reservoir; and

Increased return flows at the two wastewater treatment plants due to increased demand.

Therefore, some streamflow effects could be attributed to changes in demand and water rights portfolios distinct from the alternatives themselves. However, the changes in demands and water rights were necessary to model the alternative operations and effects accurately, and these indirect effects reflect the fact that the alternatives would meet an increased future need and be integrated into the larger Fort Collins water supply system. Indirect effects are not attributable to the alternatives; therefore, mitigation will be necessary only for the direct effects. Indirect effects were more significant in the current-conditions model run comparisons due to the larger changes in demand and water rights required to simulate realistic operations of a future project using a current-conditions baseline. The Water Resources Technical Report (CDM Smith 2016) discussed direct and indirect effects in greater detail and provides a quantitative comparison of direct and indirect effects for the Propose Action at a few key river segments.

To determine the potential effects of each alternative, we compared each with-project model run to the appropriate baseline run. For all alternatives except the Expanded Glade Alternative, we compared Run 3s to Run 1, Run 4s to Run 2, and Run 5s to Run 2. For the Expanded Glade Alternative, we compared EG3 to NISP Run 3a, EG4 to NISP Run 4a, and EG5 to Run 2. This allows for isolation of effects related to the expanded storage in Glade Reservoir only. We considered differences in streamflows for each comparison to be the streamflow effects of each alternative. The Water Resources Technical Report (CDM Smith 2016) discussed streamflow effects in more detail.

1.5 Methods

The methods used to provide results for each alternative scenario have been described in detail in the North Fork Baseline Report (Anderson Consulting Engineers, Inc. 2017), Main Stem Baseline Report (Anderson Consulting Engineers, Inc. 2013), and the Main Stem Flushing Flow Report (Anderson Consulting Engineers, Inc. 2017). The reader should be familiar with the methods and assessments described in these reports before considering the results presented in this document. The analyses documented in this report repeat the analyses described in the North Fork and Main Stem Baseline Reports and Main Stem Flushing Flow Report for each of the modeled daily flow data sets described above. The results of these analyses are used to generate comparisons relative to baseline conditions for channel hydraulics, geomorphology (initiation of motion of bed material, magnitude and duration of stream power) and sediment transport.

1.6 Presentation of Results

Discussion and interpretation of all analytical results are provided in Volume I of this report. Graphical and tabular results are provided in Volumes II and II. Comparative results are
presented as an absolute difference and where appropriate as a relative difference (or percent difference). Care is needed in reviewing relative changes. A change to a small absolute value can appear as large relative change, overstating its importance.

As discussed in both Baseline Reports (Anderson Consulting Engineers, Inc. 2013 and 2017), there isn’t a deterministic analysis that can provide an unequivocal description of future river morphology and sediment transport under each of the alternatives. Instead, based on the range of analyses listed below, the estimated difference in river response is interpreted, leading to a discussion of the predicted effects (difference in the trajectory of river conditions) for each alternative relative to its baseline.

The comparisons for which results are presented on the North Fork are listed below.

- **Hydrology**
  - General Statistics (Annual, Monthly, Seasonal),
  - Flow Duration Curves and Histograms,
  - Exceedance Discharges (1, 2, 5, 10, 25, 50, 75, 95 and 100%),
  - Annual Maximum Flood Discharge (2-, 5-, and 10-year),
  - Spells Analysis for Effective Discharge,
  - Spells Analysis for Flushing Flows, and
  - Spells for Channel Maintenance Flows.

- **Hydraulics**
  - Duration of Channel Maintenance Flows,
  - Duration of Movement of Coarse Bed Material,
  - Total Work on Channel Boundary, and
  - Total Work on Channel Boundary above Incipient Motion.

- **Sediment Transport**
  - Annual Sediment Transport Potential (using SIAM) and
  - Transport Potential by Size Fraction over Flow Range (using SIAM)

The comparisons for which results are presented on the Main Stem are listed below.

- **Hydrology**
  - General Statistics (Annual, Monthly, Seasonal),
  - Flow Duration Curves and Histograms,
  - Exceedance Discharges (1, 2, 5, 10, 25, 50, 75, 95 and 100%),
  - Annual Maximum Flood Discharge (2-, 10-, and 25-year),
  - Spells Analysis for Flushing Flows,
  - Spells Analysis for Channel Maintenance Flows, and
  - Spells Analysis for Movement of Coarse Bed Material.

- **Hydraulics**
  - Duration of Channel Maintenance Flows,
• Duration of Movement of Coarse Bed Material,
• Total Work on Channel Boundary, and
• Total Work on Channel Boundary above Incipient Motion.

- Sediment Transport
  - Annual Sediment Transport Potential (using SIAM),
  - Transport Potential by Size Fraction over Flow Range (using SIAM).

In the interpretations provided we have tried to avoid value judgments and qualitative relative descriptors (like ‘large’ or ‘small’, ‘significant’ or ‘insignificant’, etc.) as much as possible. Instead we have referred to the absolute change in a result or the relative change from baseline conditions to alternatives or between alternatives. Where necessary to achieve consistency with other resource specialists, we have used the following determination of effects defined below.

- Negligible: The effect would be at the lowest levels of detection, barely measurable, with no perceptible consequences.
- Minor: The action might result in a detectable change, but the change would be slight.
- Moderate: The action could result in a clearly detectable change with measurable effects.
- Major: The action could result in readily apparent effects with substantial consequences.

1.7 Guide to Evaluation of Halligan Project Alternatives

Volumes II and III of this report present an exhaustive presentation of the results of analyzing each of the thirteen daily flow data sets according to the CTP methods developed in the Baseline Reports (Anderson Consulting Engineers, Inc. 2013 and 2017). In each case, information provided in Volumes II and III also present a summary of the change between the result of each analysis and the corresponding result from the appropriate baseline condition. Interpretations of the results are given in Volume 1.

Table 1-3 provides a complete listing and location of the comparisons conducted on the North Fork. Table 1-4 provides a complete listing and location of the Main Stem comparisons.

Evaluation of alternatives on the North Fork are limited to Fort Collins’ Proposed Action and the No-Action Alternative. Operation of the project alternatives (Gravel Pits, Agricultural Reservoirs, and Expanded Glade Alternatives) do not include diversions from the North Fork. Operations on the North Fork under the Current Conditions baseline includes winter flow releases of 3 cfs from the existing Halligan Reservoir. Operation of project alternatives under Current Conditions would relocate the 3 cfs winter flow release from Halligan Reservoir to the storage facility associated with the corresponding alternative. A qualitative assessment of the project alternative hydrology compared with Current Conditions was conducted. Differences in daily flows critical to stream morphology and sediment transport did not warrant a detailed analysis. Changes associated with project alternatives under Current Conditions may be evaluated by other resources specialists. Under Future Conditions there is no difference in the operations of the North Fork for with and without the project alternatives, and therefore a detailed analysis was not conducted.
### Table 1-3. North Fork alternative evaluation guide.

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Note: The Gravel Pits, Agricultural Reservoirs, and Expanded Glade Alternatives do not divert water directly from the North Fork, and therefore were not evaluated.
Table 1-4. Main Stem alternative evaluation guide.

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** Refer to the NISP Stream Morphology and Sediment Transport Project Effects Report, Chapter 6 (Anderson Consulting Engineers, Inc. 2014).
2 North Fork - Effects of Fort Collins’ Proposed Action versus Current Conditions

This Chapter presents a detailed discussion of the effects of Fort Collins’ Proposed Action relative to Current Conditions on the North Fork. Hydrology for Fort Collins’ Proposed Action (PA3) is compared against Current Conditions (Run 1) and used in a range of various analyses. We have provided analytical results, in graphical and tabular form, associated with the comparison of Fort Collins’ Proposed Action versus Current Conditions on the North Fork in Volume II, Appendix A of this report. A listing of all comparison figures and tables in Volume II that corresponds to each analysis is provided at the top of each analysis section. The location within the North Fork Baseline Report (Anderson Consulting Engineers, Inc. 2017) where corresponding baseline condition analysis can be found is also listed at the top of each section.

2.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figure A-1 (Appendix A, Volume II)  
North Fork Baseline Report Section 4.2 (Anderson Consulting Engineers, Inc. 2017)

The box and whisker plot of monthly flows at the Livermore Gage (Appendix Figure A-1) is based on the entire modeled monthly data set which covers the 56-year period from 1950 to 2005. The plot provides an overview of the predicted changes in overall flow volumes in the North Fork as a result of Fort Collins’ Proposed Action over a longer time than the 19-year period of record for the daily data set. The plots include the minimum, maximum, 25th and 75th percentiles, median, and average monthly flow volumes.

Average monthly flows would increase under Fort Collins’ Proposed Action for all months except May and June (Figure 2-1). Increases are attributed to timed flow releases from Halligan Reservoir simulated as operational exchanges in the hydrologic modeling of Fort Collins’ Proposed Action. Under Fort Collins’ Proposed Action releases from Halligan Reservoir would be conveyed through the North Fork to the Main Stem, increasing flows during certain times of the year. A reduction in diversions at the North Poudre Canal would also contribute to increases.

Increases in average monthly flows during the late fall and winter (October through February) would be between 12 percent and 28 percent. Smaller increases of less than 10 percent would be observed in March and April. Water storage in Halligan Reservoir results in a reduction in average monthly flows of up to 6% during May and June. July and August flows reflect a slight reduction (less than 3 percent). Note that due to data limitation at other gages this comparison is provided at one location within the study area.
Figure 2-1. Percent change in average monthly flow at the Livermore Gage – Fort Collins’ Proposed Action versus Current Conditions.

*Interpretation*

A comparison at the Livermore Gage shows an increase in monthly flows for most of the year with a minor decrease in May and June. No significant implications for sediment transport or geomorphology are indicated by this change in monthly flow. Possible benefits related to other river functions are more suitably addressed by water quality, vegetation, and aquatic resource specialists.

### 2.2 Daily Flow Frequency and Duration

Refer to Appendix Figures A-2 and A-3, Appendix Tables A-1 through A-15 (Appendix A, Volume II)


The seasonality of changes in daily flow statistics (minimum, 10th percentile, Average, 90th percentile, and maximum) are tabulated in Appendix Tables A-1 through A-12. During low flow winter months (October through February), average daily flows would increase between 19 and 60 percent below Halligan Reservoir (Appendix Table A-3). It should be noted that these large percent increases would be occurring for small average flows (generally less than 20 cfs). Slight increases of up to 5 percent are noted in average daily flows during early spring (March through April 15th) (Appendix Table A-6).

During the high flow runoff months (April 16th through July 15th), critical to morphology and sediment transport, the average and 90th percentile flows would be reduced by up to 9 and 13 percent, respectively (Appendix Table A-9) throughout the study area. More specifically, daily...
average flows would be reduced by 5 percent in Study Reach NF2 between Halligan Reservoir and the North Poudre Canal Diversion, by 9 percent in study reaches NF3 and NF4 between the North Poudre Canal and Rabbit Creek, and by up to 6 percent in study reaches NF5, NF6, and NF7 located below Rabbit Creek. Between July 16th and September 30th average monthly flows would be also reduced between 5 and 9 percent (Appendix Table A-12).

A key observation from the plotted frequency distributions of daily flows (Appendix Figure A-2) is the reduction in flows at or above approximately 100 cfs and an increase in flows at or below approximately 100 cfs throughout the study area.

Another way of expressing change in flow frequency distributions is to evaluate change in the flow of a particular duration. The flow frequency tables (Appendix Tables A-13, A-14, and A-15) indicate reduction in flows that would be equaled or exceeded 1 to 10 percent of the time. These flows represent the high flow range that is critical to sediment transport and morphology. The 1 percent exceedance flows would be reduced up to 3 percent. Reduction in the 2 percent exceedance flows would be 6 percent between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2), 9 percent between the North Poudre Canal Diversion and Rabbit Creek (study reaches NF3 and NF4), and 8 percent below Rabbit Creek (study reaches NF5, NF6, and NF7) (Figure 2-2). Reductions of up to 10 percent are noted in the 5 percent, and 10 percent exceedance flow range.

Lower flows (flow equaled or exceeded 25 to 95 percent of the time) would increase as a result of flow releases from Halligan Reservoir under Fort Collins’ Proposed Action.

Under Current Conditions, there is a significant amount of time when the North Fork study reaches NF3 and NF4, located between the North Poudre Canal Diversion and Rabbit Creek, have minimal or no flow. During the 19-year modeled period, there is zero flow in the river 34 percent of the time (2,356 out of 6,940 days). Flow releases from Halligan Reservoir under Fort Collins’ Proposed Action would reduce the number of zero flow days to 496. While this would not have a direct impact on morphology it would likely provide benefits to other resources (water quality, aquatics, vegetation, etc.). Similarly, the number of zero flow days between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2) would be reduced from 283 days to 31 days. In study reaches NF5 and NF6, between Rabbit Creek and Seaman Reservoir, zero flow days would be reduced from 212 days to 60 days. Below Seaman Reservoir (Study Reach NF7) 123 days of zero flow would be eliminated.
Figure 2-2. Percent change in 2 percent exceedance discharge – Fort Collins’ Proposed Action versus Current Conditions.
Interpretation

There would be minor changes in flow frequency below Halligan Reservoir as a result of Fort Collins’ Proposed Action. Seasonal reduction in flows related to impoundment of water would be greatest during the high flow period (April 15th through July 15th) and in the reaches between the North Poudre Canal Diversion and Rabbit Creek (study reaches NF3 and NF4). Effects would be slightly lessened in study reaches NF5 and NF6 where tributary flows enter the system. In general, the occurrence of flows at or above roughly 100 cfs would be reduced. Taken over the whole year, the 2, 5, and 10 percent exceedance flows would be reduced by up to 10 percent. Lower flows (25 to 95 percent exceedance) would increase as a result of flow releases from Halligan Reservoir under Fort Collins’ Proposed Action.

Reduction in the occurrence of high flows could have an impact on channel forming discharges and channel morphology. Implications for the likelihood and magnitude of possible channel contraction, fining of surficial material and loss of hydraulic and morphologic complexity, are further explored in the comparisons presented below. Increases in low flows associated with release of water from Halligan Reservoir under Fort Collins’ Proposed Action and changes to North Poudre Canal Diversions would provide some benefits related to other river functions that are more suitably addressed by water quality, vegetation, and aquatic resource specialists.

2.3 Flood Frequency

Refer to Appendix Figure A-4 and Appendix Tables A-16 and A-17 (Appendix A, Volume II) North Fork Baseline Report Section 4.5 (Anderson Consulting Engineers, Inc. 2017)

Flood frequency was evaluated using the 19-year period of modeled daily flows. The analysis should not be compared with other flood frequency analyses for the river which are undertaken for a different purpose and based on much longer periods of record covering a wider range of flood peaks. It should also be noted that the limited period of modeling means that confidence intervals for the less frequent floods in this analysis are wide.

The flood frequency analysis differs from the flow duration analysis reported in the previous section in that a flood frequency analysis only considers the likelihood that a flood peak will occur or be exceeded in any year. It takes no account of flow duration.

Under Fort Collins’ Proposed Action, the 2-year flood discharge would be reduced by 5 percent in Study Reach NF2, 13 percent in study reach NF3, and 10 percent in study reaches NF4, NF5, NF6, and NF7 (Figure 2-3). Reduction in the 5- and 10-year floods would range from 2 to 7 percent. The largest reduction in flood magnitudes is noted in study reaches NF3 and NF4 between the North Poudre Canal Diversion and Rabbit Creek. The impact of Fort Collins’ Proposed Action on floods larger than these (e.g., the 25- to 100-year flood) cannot be reliably estimated with the 19-year modeled data set.
Figure 2-3. Percent change in 2-year flood discharge – Fort Collins’ Proposed Action versus Current Conditions.
Interpretation

The reduction in flood frequency correlates with reductions in daily flows and reflects increased storage of water in Halligan Reservoir. A reduction in the frequency of occurrence of high flows would have the potential to cause morphologic change through reduced sediment mobility. These implications are explored further in analyses presented below.

2.4 Bankfull Flows

Refer to Appendix Figures A-5 and A-6, Appendix Tables A-18 and A-19 (Appendix A, Volume II)
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

Bankfull discharge can be an important hydraulic and morphologic parameter. A comparison of the occurrence and duration of bankfull flows in the unconfined study reaches NF 4 and NF5 indicates no change under Fort Collins’ Proposed Action (Appendix Table A-18 and A-19).

Interpretation

Although no change would be observed in frequency and duration of bankfull flows, other evaluations provided below are likely better indicators of morphologic change (e.g., effective discharge) given the low frequency of bankfull flows under both Current Conditions and project hydrology.

2.5 Flushing Flows

Refer to Appendix Figures A-7 through A-11, Appendix Tables A-20 and A-21 (Appendix A, Volume II)
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

Flushing flows are defined as flows that flush or move sediments (gravels sized and smaller) resting on top of the coarse bed material matrix (or armor layer) in riffles. Flushing flows allow for surface cleaning of riffles necessary to support ecological functions of the river channel. A key function of flushing flows is to maintain spawning habitat for fish. Baseline flushing flows identified for comparative assessments (ranging from 327 cfs up to 436 cfs) were defined as flows having a magnitude approximately equal to the 2-year flood relative to Current Conditions hydrology (Anderson Consulting Engineers, Inc. 2017). Baseline flushing flows range from 327 cfs up to 436 cfs.

Fort Collins’ Proposed Action would not change the number of years of occurrence in Study Reach NF2 between Halligan Reservoir and the North Poudre Canal Diversion, and the average annual recurrence interval would be 1.9 years. The number of years of occurrence would be reduced from 11 years to 9 years in study reaches NF3 and NF4, between the North Poudre Canal Diversion and Rabbit Creek. This corresponds to an increase in the average annual recurrence interval from 1.7 years to 2.1 years. In study reaches NF5 and NF6, between Rabbit...
Creek and Seaman Reservoir the number of years of occurrence remains the same with a slight reduction in the average duration. The number of years of occurrence would be reduced in Study Reach NF7, below Seaman Reservoir, from 12 years to 10 years, corresponding to an increase in the average annual recurrence interval from 1.6 years to 1.9 years. The absolute difference in the total number of years of occurrence and duration of flushing flow spells is provided in Appendix Table A-21. A graphical comparison at each hydrologic node is provided in Appendix Figures A-7 to A-11.

Interpretation

There would be a minor impact to flushing flows that maintain riffles and support aquatic habitat below the North Poudre Canal Diversion. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

2.6 Channel Maintenance Flows

Channel maintenance flows are defined as the flow required to remove sediments trapped in between coarser material that comprises the bed material matrix (armor layer). For the CTP, a critical dimensionless shear stress was adopted to represent conditions when bed material moves sufficiently to just allow finer material to be released from the interstices of coarser surface layers of the bed. The geomorphic process related to channel maintenance flows is of ecological significance. Ecological criteria would consider not only the total duration of channel maintenance flows in the 19-year period but also the number of occurrences and the time between occurrences. The analysis reported in this section provides no information on specific ecologic criteria, but the spells analysis (Section 2.6.2) presents information on the frequency and duration of channel maintenance flows.

2.6.1 Analysis at all Cross Sections

Refer to Appendix Figure A-12 (Appendix A, Volume II)
North Fork Baseline Report Section 6.2.3 (Anderson Consulting Engineers, Inc. 2017)

We compared the duration for which channel maintenance flows would be expected to occur under Current Conditions and Fort Collins’ Proposed Action at 349 cross sections throughout the study area (Figure 2-4). The comparison shows a strong signal of reduction in duration in most reaches, with the exception of NF3 and NF5. Channel maintenance flows required in NF3 are quite large (greater than the maximum value in the 19-year period of record) in order to overcome energy losses associated with vegetation encroachment. Increases in duration shown in NF5 are a function of lower threshold flows. Reduction in duration of channel maintenance flows would be as much as 10 to 20 percent in study reaches NF2, NF4, NF6, and NF7, with some outliers noted.

It is important to put this finding in the context that the changes shown in Figure 2-4 only represent a subset of all cross sections on the river. As described below, there are many other
cross sections that the analysis predicts would not be impacted by a change in channel maintenance flow duration.

In addition to the cross sections where a change in the duration of channel maintenance flow is shown, there are many cross sections where channel maintenance flows would not occur in the 19-year modeled period for either Current Conditions or Fort Collins’ Proposed Action; and others where no change in channel maintenance flow duration is predicted. Out of a total of 349 cross sections analyzed, 224 (64 percent) show no occurrence of channel maintenance flows during the modeled period. Conversely, channel maintenance flows occur at 125 cross sections (or 36 percent of cross sections) in the study area under Current Conditions. Of those sections, 58 out of 125 show no change in duration under Fort Collins’ Proposed Action. Consequently, 67 cross sections out of 125 show a change in duration with Fort Collins’ Proposed Action. Change in duration across the 67 cross sections indicate an average reduction in duration of roughly 10 percent. On a study reach basis an average reduction in duration of 8 percent is noted in Study Reach NF2 (based on 30 cross sections), 13 percent in study reaches NF3 and NF4 (based on 9 cross sections), and 11 percent in study reaches NF5, NF6, and NF7 (based on 28 cross sections).

Small absolute changes in the duration of channel maintenance flows can appear as large percentage changes (greater than 20 percent) in Figure 2-4. However, sensitivity analysis indicates that these changes do not skew the spread of the results.

**Interpretation**

The analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of Fort Collins’ Proposed Action. The information presented suggests a reduction in channel maintenance flow duration by as much as 20 percent at a limited number of cross sections with an overall average reduction in duration of approximately 10 percent. Where these impacts occur, the reduction in channel maintenance flows could lead to fining of surficial material at those locations. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.
Figure 2-4. Percent change in the duration of channel maintenance flows – Fort Collins’ Proposed Action versus Current Conditions.
2.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure A-13, Appendix Tables A-22 and A-23 (Appendix A, Volume II) North Fork Baseline Report Section 6.2.4 (Anderson Consulting Engineers, Inc. 2017)

Reduction in channel maintenance flows is further examined at specific cross sections selected as representative in each reach. We computed the occurrence of periods where channel maintenance shear stress criterion would be exceeded for Current Conditions and Fort Collins’ Proposed Action. These periods are illustrated graphically in Appendix Figure A-13 and in tabular form in Appendix Tables A-22 and A-23 for both Current Conditions and Fort Collins’ Proposed Action.

Channel maintenance flows were not achieved in study reaches NF1 through NF5 at selected cross sections for either Current Conditions or Fort Collins’ Proposed Action. Limited episodes of channel maintenance flows occur above and below Seaman Reservoir in reaches NF6 and NF7 under both hydrologic conditions. The occurrence below Seaman Reservoir in Study Reach NF7 would be reduced by half. Above Seaman Reservoir there would be no change.

*Interpretation*

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes is best described by the analysis already reported in Section 2.6.1.

2.7 Flows that Move Coarse Bed Material

Refer to Appendix Figure A-14 (Appendix A, Volume II) North Fork Baseline Report Section 6.2.7 (Anderson Consulting Engineers, Inc. 2017)

The point at which coarse material in the bed of the river starts to move is considered a geomorphic threshold. The occurrence of bed material motion and the duration of flows above this threshold influence the size, shape, and dynamics of the river channel. For the CTP evaluation, initiation of motion was related to a critical shear stress which varies along the river according to the size of material present in the river bed. Initiation of motion is particularly important because it represents the flow at which the armor layer is broken, and underlying sediment is released.

A comparison of the duration for which bed material movement would be expected to occur under Current Conditions and Fort Collins’ Proposed Action was evaluated at 349 cross sections (Figure 2-5). Movement of coarse bed material would not occur during the Current Conditions 19-year model period at 90 percent of modeled cross sections. Under Current Conditions, movement of bed material would occur at 34 out of 349 cross sections (10 percent). Fort Collins’ Proposed Action would reduce the duration of bed material movement at 16 of the 34 cross-sections.
sections. The average reduction in duration, based on the 16 cross sections, would be 14 percent. On a study reach basis an average reduction in duration of 13 percent is noted in Study Reach NF2 (based on 10 cross sections), less than 1 percent in study reaches NF3 and NF4 (based on 1 cross section), and 17 percent in study reaches NF5, NF6, and NF7 (based on 6 cross sections).

**Interpretation**

Reduced duration of flows that generate motion of bed material implies that the river bed would be adjusted less frequently and move less sediment through the system. A signal of change in the occurrence and duration of flows that move coarse bed material was noted but was not found to be spatially prevalent.

Supply of material that makes up the bed is limited, and reduced movement of bed material could lead to lower rates of change of in-channel bars, islands, benches, and channel form. Erosion is predicted to still occur at some locations and on some occasions particularly as a consequence of floods. Bed material would only move at approximately 10 percent of cross sections so spatial variability in hydraulic conditions is predicted to be maintained with existing channel features. Increased stability would have benefits but could lead to reduced temporal variability of biotopes.
Figure 2-5. Percent change in duration of bed material movement – Fort Collins’ Proposed Action versus Current Conditions.
2.8 Stream Power

Refer to Appendix Figures A-15 through A-18 (Appendix A, Volume II)  
North Fork Baseline Report Section 6.3 (Anderson Consulting Engineers, Inc. 2017)

Stream power can be calculated at each cross section over the range of flows included in the modeled data sets. Summed over the 19-year modeled period (with appropriate units), stream power represents the ability of the flow to “do work” on the channel boundaries. Also of interest is the stream power in excess of the power that is required to initiate bed material motion. This can give an indication of the amount of “work” that can move the channel bed.

The difference in total work along the length of the North Fork was evaluated (Figure 2-6). Between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2), change in total work would be plus or minus 5 percent. In reaches NF3 and NF4, between the North Poudre Canal Diversion and Rabbit Creek, a reduction would be more clearly prevalent and estimated to be less than 5 percent. An increase in total work is noted in reaches NF5 and NF6. Increases in energy are attributed to increased duration of lower flows associated with Halligan Reservoir releases and reduced diversions at the North Poudre Canal.

Differences in the total work described above generally disappear when looking at work in excess of the stream power required to move bed material (Figure 2-7). Under both Current Conditions and with project hydrology, work in excess of bed movement would occur at approximately 10 percent of the locations evaluated, which is consistent with the evaluation of bed material movement discussed in Section 2.7. At these locations, sporadic change in the “work” that the flow can do in moving the channel bed is noted (Figure 2-7). Reductions are shown in reaches NF2, NF4, and NF6. Large percent changes coincide with locations where the total work in excess of stream power would be extremely small and likely inconsequential to movement of the bed.

Interpretation

Changes noted in total work are spatially limited with some small reductions noted. Increase in total work are attributed to an increase in the duration of low flows as a result of releases from Halligan Reservoir and changes to North Poudre Canal diversions under Fort Collins’ Proposed Action. This increase is predicted to have limited adverse morphologic consequence because it would occur at low stream power where there is no channel adjustment. Most increases disappear in the comparison of work in excess of the threshold of motion.

The comparison in Figure 2-7 shows minimal instances of a decrease in energy in excess of bed material movement. Changes shown are not likely to manifest into adverse effects.
Figure 2-6. Percent change in total work – Fort Collins’ Proposed Action versus Current Conditions.

Figure 2-7. Percent change in total work in excess of incipient motion – Fort Collins’ Proposed Action versus Current Conditions.
2.9 Sediment Transport Potential

Refer to Appendix Figure A-19, Appendix Tables A-24 and A-25 (Appendix A, Volume II)
North Fork Baseline Report Section 7.1.2 (Anderson Consulting Engineers, Inc. 2017)

The change in reach averaged sediment transport potential between Current Conditions and Fort Collins’ Proposed Action was evaluated (Figure 2-8). Sediment transport potential is the capacity of the river to move sediment over the 19-years of modeled flows if sediment were available to be moved. The results are presented separately for total bed material load, sand, gravel, and cobble sized material. Size gradations used in the sediment transport calculations reflect a composite of surface and sub-surface bed material samples. Note that transport potential of cobbles is zero under both Current Conditions and Fort Collins’ Proposed Action hydrology.

Small percent changes are noted in the total amount of material that could be moved in Study Reach NF2 (less than 1 percent). In the remainder of the reaches, the total amount of transport potential would be slightly increased by 4 to 5 percent. Change in the transport of sands would be greater than for gravels. Release of water from Halligan Reservoir under Fort Collins’ Proposed Action would slightly increase the transport of sands through the system. Impacts to the amount of gravel that can be transported would be minimal.

Note that increases in total transport potential is a function of increased duration of frequently occurring low flows (less than 100 cfs). These low flows would not be capable of moving some gravels and cobbles. Evaluation of impacts to transport across the flow range will be addressed in Section 2.10.

Interpretation

These results of the change in sediment transport potential cannot be directly interpreted to provide an estimate of the actual magnitude of sediment transport response due to lack of availability of sediment entering the river system below Halligan Reservoir. However, given the findings of the North Fork Baseline Report, some conclusions about sediment response can be drawn as follows.

NF2 – Halligan Reservoir to North Poudre Canal Diversion

Evaluation of Current Conditions provided in the North Fork Baseline Report and Chapter 1 indicate that while sands and silts can be readily mobilized through this reach, there is evidence that there would be deposition on margins and mid-channel bars during low flow periods that would support vegetation. The current trajectory of the North Fork includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. This trajectory would be expected to be interrupted from time to time with the occurrence of large floods that are unaffected by Halligan Reservoir. Fort Collins’ Proposed Action would not impact the total sediment transport potential (less than 1 percent change). Therefore, minor to negligible changes in morphology associated with the Current Conditions trajectory are not predicted to change under Fort Collins’ Proposed Action.
Figure 2-8. Percent change in average annual sediment transport potential – Fort Collins’ Proposed Action versus Current Conditions.
Fine material released from Halligan Reservoir would temporarily impact the well-defined pool-riffle morphology in the reach until it would be remobilized and flushed downstream. Under Current Conditions, low flows (less than 100 cfs) are capable of transporting sands and silts. Under Fort Collins’ Proposed Action, the duration of flows less than 100 cfs would increase. However, the ability of the river to flush fine sediments that would be released from Halligan Reservoir would see negligible change.

**NF3 and NF4 - North Poudre Canal Diversion to Rabbit Creek**

This reach has historically experienced the largest hydrologic and morphological change within the study area. The trajectory of the North Fork in this section would be a continuation of observed diminution by heavy vegetation encroachment and associated deposition of fine material on channel margins.

Within Phantom Canyon below the North Poudre Canal Diversion (Study Reach NF3), pool margins and riffle areas have been invaded by vegetation (mainly willows). It is expected that the channel in this reach would continue to lose definition in the long term under Current Conditions. Steeper slopes within Phantom Canyon could allow for scour during large floods not influenced by Halligan Reservoir or Current Conditions hydrology. Changes in sediment transport potential under Fort Collins’ Proposed Action would provide little benefit and would likely not have an impact on the current rate of change given energy losses associated with a heavily vegetated channel.

As the North Fork emerges from the Phantom Canyon into Study Reach NF4 above Rabbit Creek, hydrologic conditions would be the same as Study Reach NF3, for both with and without project hydrology. Active encroachment of vegetation would be noted here, and a trajectory of channel narrowing is predicted under Current Conditions. Increases noted in sediment transport potential attributed to increased low flows would not be likely to provide benefit or manifest as an adverse impact.

**NF5, NF6, and NF7 - Rabbit Creek to Confluence**

Current tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustment and encroachment would occur over time. Slight increases in sediment transport potential under Fort Collins’ Proposed Action would not be likely to have an impact on the trend or rate of the current trajectory.

**2.10 Distribution of Sediment Transport Potential with Flow**

Refer to Appendix Figures A-20 and A-21 (Appendix A, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)
The difference in sediment transport potential magnitude-duration curves between Current Conditions and Fort Collins’ Proposed Action was evaluated (Figure 2-9). The curves demonstrate how sediment transport potential would be distributed across the flow range. The peak of the magnitude-duration curves indicates what discharge would be most effective at transporting sediments in each study reach (referred to as effective discharge).

A comparative assessment of the magnitude-duration curves between Current Conditions and Fort Collins’ Proposed Action was conducted to determine if hydrologic changes under Fort Collins’ Proposed Action would be likely to affect channel morphology. The following are types of indicators of change.

- A change in the location of the peak of the magnitude-duration curve between Fort Collins’ Proposed Action and Current Conditions gives an indication of a change in effective discharge.
- A change in the magnitude and shape of the peak gives an indication of the change in the strength of the effective discharge signal.
- A change in the area under the curve gives an indication of the change in average annual sediment transport potential (allowing for the log scale).
- The area between the curves demonstrates the change in annual sediment transport potential (allowing for the log scale).
- Changes in the distribution of sediment transport potential across the flow range (see the histograms) show the flow intervals where sediment transport potential would be most affected by the change in hydrology.

Under Fort Collins’ Proposed Action, change in the location of the peak of the curve was not noted between Halligan Reservoir and the North Poudre Canal Diversion. The peak of the curves in all reaches below the North Poudre Canal Diversion becomes less defined and shifts towards lower flow values. This would indicate more movement of finer material and less movement of coarse material. Movement of the peak of the curves towards lower flows can indicate a tendency towards channel contraction. However, manifestation of that change would only occur if upstream sediment supply was limitless and the system was transport limited (defined as conditions in which sediment supply greatly exceeds sediment transport potential). Given that there is limited sediment supply, differences noted in the curves would not be likely to manifest in overall changes to morphology. However, there is evidence in support of a continuation of the current trajectory of vegetation encroachment and minor channel contraction over time.

Annual sediment transport rates would increase between 10 and 20 percent for flows less than 100 cfs, as indicated by the histograms shown on the bottom line of Appendix Figures A-20 and A-21. Overall, for flows greater than 100 cfs there would be a decrease in transport rates of roughly 10 percent.
Figure 2-9. Distribution of sediment transport potential with flow – Fort Collins’ Proposed Action versus Current Conditions.
Interpretation

Increases in transport rates across the low flow range under Fort Collins’ Proposed Action would not be likely to manifest in morphologic change. Reductions in transport rates in the high flow ranges would slightly reduce the movement of gravels and coarse bed material. This reduction would have more impact on the North Fork between North Poudre Canal Diversion and Rabbit Creek (reaches NF3 and NF4) than elsewhere in the study area.

2.11 Effective Discharge Spells

Refer to Appendix Figures A-22 through A-28, Appendix Tables A-26 and A-27 (Appendix A, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

Effective discharge is defined as the flow most responsible for moving the largest volume of sediment over time, if that sediment is available for transport. The frequency and duration of effective discharge occurrences are considered of morphological significance and in this system more meaningful than bankfull flows. Effective discharge ranges from 120 cfs up to 350 cfs in the study area. Changes in the occurrence and duration of effective discharge associated with Fort Collins’ Proposed Action are presented in Appendix Tables A-26 and A-27 and Appendix Figures A-22 through A-28.

The number of years in which effective discharge would occur during the 19-year model period would not change in reaches NF1 and NF4 through NF7. The years of occurrence would be reduced by 1 year in NF2 and NF3, both located in Phantom Canyon, under Fort Collins’ Proposed Action. Changes in the average duration of effective discharge are noted in reaches NF3 through NF7, even if the number of years of occurrence was the same.

Interpretation

Changes in the occurrence and duration of effective discharge coincide with a reduction in flows above 100 cfs. Reductions could increase tendencies towards channel contraction and surficial fining. However, the magnitude of these reductions suggests that the impact would be minimal.

2.12 Overview of Effects of Fort Collins’ Proposed Action on Sediment Transport and River Morphology

This section presents an overview of predicted conditions associated with implementation of Fort Collins’ Proposed Action compared to Current Conditions. A summary of results and possible impacts are summarized in Table 2-1.

Results of the individual analyses described above are collectively considered to determine effects of Fort Collins’ Proposed Action on the current trajectory of river condition. Impacts associated with a reduction in flows can lead to the following impacts listed below.
• **Fining of Surficial Material.** Reduced magnitude, frequency or duration of flows leads to a fining of surficial material and possible blanketing of the bed and filling of interstices with fine sediments.

• **Channel Contraction.** Deposition of silts, sands or gravels on channel bars and margins or on mid-channel islands leading to reduced channel width and/or depth.

• **Loss of Hydraulic and Morphologic Complexity.** Channel contraction and fining of surficial material can lead to loss of hydraulic and morphologic complexity and reduced spatial frequency or variability of biotypes.

Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the North Fork Baseline Report would be expected to continue with negligible effects due to Fort Collins’ Proposed Action.
The duration of bed material movement at these locations would reduce by an average of 13 percent under Fort Collins’ Proposed Action. Below Seaman Reservoir, a total of 123 zero flows that would reduce the duration of bed material movement from 1.7 years to 2.1 years. This change would have a minor to negligible effect on flushing.

The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer below Seaman Reservoir would be reduced by an average of 8 percent. This would have minor to negligible impact on the ability of the river to remove sediments from the interstices of the coarse armor layer.

The occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer would be unchanged by Fort Collins’ Proposed Action. However, there would be a slight reduction in the average duration of flushing flows in this reach. In other terms, the average annual recurrence interval of flushing flows, also unchanged, would be 1.9 years. These changes would have a negligible effect on flushing flows.

Fort Collins’ Proposed Action would reduce the duration of channel maintenance flows at 28 (out of 167) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be reduced by an average of 8 percent. This would have minor to negligible impact on the ability of the river to remove sediments from the interstices of the coarse armor layer.

Fort Collins’ Proposed Action would reduce the duration of channel maintenance flows at 9 (out of 37) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be reduced by an average of 13 percent. This would have minor to negligible impact on the ability of the river to remove sediments from the interstices of the coarse armor layer.
<table>
<thead>
<tr>
<th>Analysis</th>
<th>Study Reach NF2: Halligan Reservoir to North Poudre Canal Diversion</th>
<th>Study Reaches NF3 and NF4: North Poudre Canal Diversion to Rabbit Creek</th>
<th>Study Reaches NF5, NF6, and NF7: Rabbit Creek to Confluence</th>
<th>Impact Indicator</th>
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<tr>
<td>Effective Discharge</td>
<td>Collins’ Proposed Action. These reductions were not found to be spatially prevalent. Overall, there would be a negligible impact on changes to morphologic complexity and channel structure.</td>
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<td>Proposed Action. These reductions were not found to be spatially prevalent. Overall, there would be a negligible impact to channel structure or morphologic complexity.</td>
<td>Channel Contraction</td>
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<tr>
<td>Sediment Transport</td>
<td>There would be a slight reduction in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This would have a negligible impact.</td>
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<td>Channel Contraction</td>
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<td></td>
<td>Average annual sediment transport potential above the North Poudre Canal Diversion shows less than 1 percent change. Evaluation of transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse materials of approximately 10 percent. For flows less than 100 cfs, transport rates would increase which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Average annual sediment transport increases by approximately 4 percent under Fort Collins’ Proposed Action. Evaluation of transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse materials of approximately 10 percent. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Average annual sediment transport increases by approximately 5 percent under Fort Collins’ Proposed Action. Evaluation of transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse materials of approximately 10 percent. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Channel Contraction</td>
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Anderson Consulting Engineers, Inc.
### Analysis

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<th>Impact Indicator</th>
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<tbody>
<tr>
<td>Sediment Transport</td>
<td>Evaluation of Current Conditions provided in the North Fork Baseline Report and Chapter 1 indicates that while sands and silts can be readily mobilized through this reach there is evidence of deposition on margins and mid-channel bars during low flow periods that support vegetation. The current trajectory of the North Fork includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. This trajectory is expected to be interrupted from time to time with the occurrence of large floods that would be unaffected by Halligan Reservoir. Fort Collins’ Proposed Action would not impact the total sediment transport potential (less than 1 percent change). Therefore, minor changes in morphology under Current Conditions are not predicted to change under Fort Collins’ Proposed Action.</td>
<td>This reach has historically experienced the largest hydrologic and morphological change within the study area. The trajectory of the North Fork in this section would be a continuation of observed diminution by vegetation encroachment and associated deposition of fine material on channel margins. Within Phantom Canyon below the North Poudre Canal Diversion (Study Reach NF3), pool margins and riffle areas have been invaded upon by vegetation (mainly willows). It is expected that the channel in this reach would continue to lose definition in the long term under Current Conditions. Steeper slopes within the canyon could allow for scour during large floods not influenced by Halligan Reservoir or Current Conditions hydrology. Changes in sediment transport potential under Fort Collins’ Proposed Action would provide little benefit and would likely not have an impact on the current rate of change. As the river emerges from Phantom Canyon into Study Reach NF4 above Rabbit Creek, hydrologic conditions would be the same as Study Reach NF3, with and without the project. Active encroachment of vegetation is also noted in this reach and a trajectory of channel narrowing would be predicted under Current Conditions. Increases noted in sediment transport potential attributed to increased low flows associated with Fort Collins’ Proposed Action would not be likely to provide benefit or manifest as an adverse impact. Therefore, Fort Collins’ Proposed Action will have minor impacts on the current rate of change.</td>
<td>Current tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Slight increases in sediment transport potential under Fort Collins’ Proposed Action would not be likely to change the trend or rate of the current trajectory.</td>
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Fine material released from Halligan Reservoir would temporarily impact the well-defined pool-riffle morphology in the reach until it was remobilized and flushed downstream. Under Current Conditions, low flows (less than 100 cfs) are capable of transporting sands and silts. Under Fort Collins’ Proposed Action, the duration of flows less than 100 cfs would increase. However, the ability of the river to flush fine sediments that are released from Halligan Reservoir would likely not change.
3 North Fork - Future versus Current Conditions

The North Fork Baseline Report (Anderson Consulting Engineers, Inc. 2017) presented a detailed interpretation of the results under Current Conditions hydrology. This Chapter presents a comparison of Current Conditions (Run 1) with Future Conditions (Run 2). The comparison of Current Conditions with Future Conditions shows the changes that are predicted to occur in the future (2050) without the construction and operation of the Halligan Project or NISP but with Reasonably Foreseeable Future Actions (RFFAs). The RFFAs predicted to affect future hydrology are presented in the CTP Hydrologic Modeling Report (CDM Smith and DiNatale Water Consultants 2013). RFFAs have the potential to change water operations in the Poudre River Basin including the North Fork. Changes in water operations in the Poudre River Basin associated with Future Conditions RFFAs that have a direct effect on North Fork flows include:

- Tri-Districts have converted some of the North Poudre Irrigation Company (NPIC) shares to municipal use. They take delivery of this water at the Munroe Canal by letting water bypass the North Poudre Canal Diversion (below Halligan Reservoir) and run downstream on the North Fork, then exchange up to the Munroe Canal headgate on the Main Stem. This results in more water flowing in the North Fork between the North Poudre Canal Diversion and the Main Stem.

- Greeley's Bellvue Pipeline will increase the city's delivery capability and may reduce exchange potential in certain reaches of the Poudre River. In addition, this potential to divert water impacts the timing and releases of North Fork supplies.

- Fort Collins, Greeley, and the Tri-Districts will use the Overland Trail Gravel Pits for municipal water supply storage. Fort Collins will also utilize the South Gravel Pit, and Greeley will have additional gravel pit storage in the lower Poudre Basin. This allows for movement of water down the river to the Overland Trails Gravel Pits which also impacts timing of North Fork supplies.

- Future agricultural water demands will be reduced due to agricultural-to-municipal water transfers. Municipal water demands will be increased to reflect the addition of these supplies to the water providers' portfolios. This would reduce flows on the North Fork during the summer when agricultural demands are higher and increases flows in the winter to meet municipal demands.

Detailed results of the Future Conditions analysis are provided in Volume II, Appendix B. Full results associated with the comparison of Current and Future Conditions in graphical and tabular form, are provided in Volume II, Appendix C. This Chapter reports differences in Future and Current Conditions analyses. Analytical results inform development of changes to the current trajectory of the river under Future Conditions hydrology.
3.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figure C-1 (Appendix C, Volume II)
North Fork Baseline Report Section 4.2 (Anderson Consulting Engineers, Inc. 2017)

For this comparison, monthly flows at the Livermore Gage were evaluated based on the full modeled monthly data set which covers the 56-year period from 1950 to 2005. The box and whisker plot provides a good overview of the changes in overall flow volumes in the river associated with RFFAs, (i.e., what is predicted to occur in the future without the Halligan Project). Appendix Figure C-1 illustrates the average monthly flows in the comparative assessment of the future versus Current Conditions. Average monthly flows are increased for Future Conditions for all months except in June. In the month of June there is roughly a 2 percent decrease in average monthly flow (Figure 3-1).

**Interpretation**

A comparison at the Livermore Gage gives an indication of an overall increase in monthly flow volumes, except for June. It should be noted that increases in monthly flows do not necessarily indicate an increase throughout the range of daily flows. Changes to daily flows that have consequential impacts on sediment mobility and channel morphology are evaluated in the following comparisons.

![Box and Whisker Plot of Monthly Flows](image)

**Figure 3-1. Percent change in average monthly flow at Livermore Gage – Future versus Current Conditions.**
3.2 Daily Flow Frequency and Duration

Refer to Appendix Figures C-2 and C-3, Appendix Tables C-1 through C-15 (Appendix C, Volume II)

The comparisons of seasonal statistics indicate overall increases in flows, mostly noted during the low flow seasons (Appendix Tables C-1 through C-12). During low flow winter months (October through February) average daily flows are increased between 6 and 46 percent below Halligan Reservoir (Appendix Table C-3). It should be noted that these large percent increases are occurring for very small average flows (generally less than 20 cfs). Slight increases ranging from 5 to 18 percent are noted in average daily flows in the spring (March through April 15th) (Appendix Table C-6).

During the high flow runoff months (April 16th through July 15th) that are critical to morphology and sediment transport, average daily flows are slightly increased by up to 4 percent upstream of Seaman Reservoir and slightly decreased by 3 percent downstream (Appendix Table C-9). More specifically, daily average flows are increased by 4 percent in Study Reach NF2 between Halligan Reservoir and the North Poudre Canal Diversion, and by 2 percent in study reaches NF3, NF4, NF5, and NF6. Between July 16th and September 30th, average monthly flows are increased between 6 and 57 percent as a result of more water in the river.

A comparison of flow frequency distributions also indicates overall increases in flows. However, a consistent and very small decrease in the 2 percent exceedance flow (flow equaled or exceeded 2 percent of the time and generally ranging from 300 to 400 cfs) is noted below the North Poudre Canal Diversion (Figure 3-2). Under Current Conditions there is a significant amount of time when the North Fork study reaches NF3 and NF4, located between the North Poudre Canal Diversion and Rabbit Creek, have minimal or no flow. During the 19-year modeled period, there is zero flow in the river 34 percent of the time (2,356 out of 6,940 days). Future conditions hydrology would reduce the number of zero flow days to 1,014. While this would not have a direct impact on morphology, it will likely provide benefits to other resources (water quality, aquatics, vegetation, etc.). Similarly, the number of zero flow days between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2) is reduced from 283 days to 130 days.

In study reaches NF5 and NF6, between Rabbit Creek and Seaman Reservoir, zero flow days are eliminated. Below Seaman Reservoir (Study Reach NF7) 123 days of zero flow is reduced to 30.

**Interpretation**

The magnitude of changes in flow duration under Future Conditions is not expected to be consequential to sediment mobility and channel morphology relative to Current Conditions.
Figure 3-2. Percent change in 2 percent exceedance discharge – Future versus Current Conditions.
3.3 Flood Frequency

Refer to Appendix Figure C-4 and Appendix Tables C-16 and C-17 (Appendix C, Volume II) North Fork Baseline Report Section 4.5 (Anderson Consulting Engineers, Inc. 2017)

Changes in the magnitude of the 2-, 5-, and 10-year floods are minimal. Under Future Conditions the 2-year flood discharge is increased by 3 percent in Study Reach NF2, 6 percent in study reaches NF3 and NF4, 4 percent in study reaches NF5 and NF6, and decreased by 3 percent in Study Reach NF7 (Figure 3-3). The larger 5- and 10-year floods generally show change less than plus or minus 2 percent (Appendix Table C-17 and Appendix Figure C-4).

Interpretation

Changes in flood discharge under Future Conditions are negligible.

3.4 Bankfull Flows

Refer to Appendix Figures C-5 and C-6, Appendix Tables C-18 and C-19 (Appendix C, Volume II) North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

The frequency and occurrence of bankfull flows in the unconfined study reaches NF4 and NF5 are identical for Current and Future Conditions.

3.5 Flushing Flows

Refer to Appendix Figures C-7 and C-11, Appendix Tables C-20 and C-21 (Appendix C, Volume II) North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

The number of years of occurrence of flushing flows is increased by 1 year under Future Conditions between the North Poudre Canal Diversion and Seaman Reservoir. The number of years of occurrence is decreased by 2 years below Seaman Reservoir.

Interpretation

There is a slight reduction in the occurrence of flushing flows that maintain riffles and support aquatic habitat below Seaman Reservoir under Future Conditions. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.
Figure 3-3. Percent change in 2-year flood discharge – Future versus Current Conditions.
3.6 Channel Maintenance Flows

Channel maintenance flows are defined as the flow required to remove sediments trapped within the coarser material that comprises the bed material matrix (armor layer).

3.6.1 Analysis at all Cross Sections

Refer to Appendix Figure C-12 (Appendix C, Volume II) North Fork Baseline Report Section 6.2.3 (Anderson Consulting Engineers, Inc. 2017)

The duration of channel maintenance flows under Current and Future Conditions were compared (Figure 3-4). At the majority of cross sections where channel maintenance flows occur the duration remains the same for Future Conditions. However, there are several cross sections where duration is increased by 5 to 10 percent.

It is important to put this finding in the context that the changes shown in Figure 3-4 only represent a subset of all cross sections on the river. As described below, there are many other cross sections that the analysis predicts will not be impacted by a change in channel maintenance flow duration.

In addition to the cross sections where a change in the duration of channel maintenance flow is shown, there are many cross sections where channel maintenance flows do not occur in the 19-year modeled period for either current or Future Conditions; and others where no change in channel maintenance flow duration is predicted. Out of a total of 349 cross sections analyzed, 224 (64 percent) show no occurrence of channel maintenance flows during the modeled period. Conversely, channel maintenance flows occur at 125 cross section (or 36 percent of cross sections) in the study area under Future Conditions. Of those cross sections, 59 out of 125 show no change in duration under Future Conditions. Consequently, 66 cross sections out of 125 show a change in duration. Change in duration across the 66 cross sections indicate an average increase in duration of roughly 2 percent. On a study reach basis an average increase in duration of 5 percent is noted in Study Reach NF2 (based on 28 cross sections), an increase of 6 percent in study reaches NF3 and NF4 (based on 7 cross sections), and an average of 0 percent change in study reaches NF5, NF6, and NF7 (based on 31 cross sections).

Interpretation

Results of the comparison indicate a slight increase in the duration of channel maintenance flows with Future Conditions. The magnitude of change is negligible.
Figure 3-4. Percent change in duration of channel maintenance flows – Future versus Current Conditions.
3.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure C-13, Appendix Tables C-22 and C-23 (Appendix C, Volume II)
North Fork Baseline Report Section 6.2.4 (Anderson Consulting Engineers, Inc. 2017)

Reduction in channel maintenance flows is further examined at specific cross sections selected as representative in each reach. No change in occurrence or duration of channel maintenance flows was observed between Current and Future Conditions at these cross sections.

**Interpretation**

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes is best described by the analysis already reported in Section 3.6.1.

3.7 Flows that Move Coarse Bed Material

Refer to Appendix Figure C-14 (Appendix C, Volume II)
North Fork Baseline Report Section 6.2.7 (Anderson Consulting Engineers, Inc. 2017)

The point at which coarse material in the bed of the river starts to move is a geomorphic threshold. The occurrence of bed material motion and the duration of flows above this threshold influence the size, shape, and dynamics of the river channel. For the CTP evaluation, initiation of motion was related to a critical shear stress which varies along the river according to the size of material present in the river bed. Initiation of motion is particularly important because it represents the flow at which the armor layer is broken, and underlying sediment is released.

The durations for which bed material movement is expected to occur under Current and Future Conditions were compared at 349 cross sections (Figure 3-5). Movement of coarse bed material would not occur during the Current Conditions 19-year model period at 90 percent of modeled cross sections. Under Current Conditions, movement of bed material would occur at 34 out of 349 cross section (10 percent). The duration of bed material movement is changed under Future Conditions at 15 of the 34 cross sections. There is an average increase of 8 percent in duration under Future Conditions, based on the 15 cross sections. On a study reach basis, an average increase in duration of 16 percent is noted in Study Reach NF2 (based on 7 cross sections), no change in study reaches NF3 and NF4, and no change in study reaches NF5, NF6, and NF7 (based on 8 cross sections).
Figure 3-5. Percent change in duration of bed material movement – Future versus Current Conditions.
Interpretation

Increased duration of flows that generate motion of bed material implies that the river bed would be adjusted more frequently and move more sediment through the system. However, the signal of change in the occurrence and duration of flows that move coarse bed material is weak and not found to be spatially prevalent. This indicates that there will be negligible change in the movement of coarse bed material under Future Conditions, relative to Current Conditions.

3.8 Stream Power

Refer to Appendix Figures C-15 through C-18 (Appendix C, Volume II)
North Fork Baseline Report Section 6.3 (Anderson Consulting Engineers, Inc. 2017)

Stream power can be calculated at each cross section over the range of flows included in the modeled data sets. Summed over the 19-year modeled period (with appropriate units), stream power represents the ability of the flow to “do work” on the channel boundaries. Also of interest is the stream power in excess of the power that is required to initiate bed material motion. This can give an indication of the amount of “work” that can move the channel bed.

Appendix Figures C-15 and C-16 illustrate the difference, between Current and Future Conditions hydrology, in total work along the length of the North Fork. Between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2) total work is increased by approximately 5 percent. In reaches NF3 and NF4, between the North Poudre Canal Diversion and Rabbit Creek, the increase is slightly more than 5 percent. An increase in total work by as much as 10 to 15 percent is noted in study reaches NF5, NF6, and NF7. Increases in energy are attributed to increased duration of lower flows associated with changes in flow operations associated with RFFAs.

Appendix Figures C-17 and C-18 illustrate that differences in the total work described above generally disappear when looking at work in excess of the stream power required to move bed material. Under both Current and Future Conditions hydrology, work in excess of bed movement only would occur at approximately 10 percent of the locations evaluated, which is consistent with the evaluation of bed material movement discussed in Section 3.7. At these locations, sporadic change in the work that the flow can do in moving the channel bed is noted (Appendix Figure C-18). Reductions are shown in reaches NF2, NF6, and NF7. Large percent changes coincide with locations where the total work in excess of stream power is extremely small and likely inconsequential to movement of the bed.

Interpretation

Changes noted in total work are spatially limited with some small reductions noted. Increases in total work are attributed to increased flows associated with RFFAs. This increase is predicted to have a negligible impact on morphology because it would largely occur at lower or moderate stream powers where there is no channel adjustment. Most increases disappear in the comparison of work in excess of the threshold of motion.
The comparison in Appendix Figures C-17 and C-18 shows few instances of a decrease in energy in excess of bed material movement. Changes shown are not likely to manifest into effects.

### 3.9 Sediment Transport Potential

Refer to Appendix Figure C-19, Appendix Tables C-24 and C-25 (Appendix C, Volume II) North Fork Baseline Report Section 7.1.2 (Anderson Consulting Engineers, Inc. 2017)

Change in reach averaged sediment transport potential between Current and Future Conditions was evaluated (Figure 3-6). Sediment transport potential is the capacity of the river to move sediment over the 19-years of modeled flows if sediment were available to be moved. Size gradations used in the sediment transport calculations reflect a composite of surface and sub-surface bed material samples. The results are presented separately for total bed material load, sand, gravel, and cobble sized material.

Throughout the study area, the total average annual sediment transport potential is increased between 3 and 10 percent. Increase in the transport of sands is greater than for gravels. Increased transport rates are associated with additional flow in the river related to RFFAs.

**Interpretation**

These results of the change in sediment transport potential cannot be directly interpreted to provide an estimate of the actual magnitude of sediment transport response due to lack of availability of sediment entering the river system below Halligan Reservoir. However, given the findings of the North Fork Baseline Report, some conclusions about sediment response can be drawn as follows.

**NF2 – Halligan Reservoir to North Poudre Canal Diversion**

Evaluation of Current Conditions provided in the North Fork Baseline Report and Chapter 1 indicates that while sands and silts can be readily mobilized through this reach, there is evidence of deposition on margins and mid-channel bars during low flow periods that will support vegetation. The current trajectory of the river includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. This trajectory is expected to be interrupted from time to time with the occurrence of large floods that are unaffected by Halligan Reservoir. Future conditions show a slight increase in total sediment transport potential of approximately 3 percent. This magnitude of change will have negligible effects on morphology or the transport of sediments relative to Current Conditions.
Figure 3-6. Percent change in average annual sediment transport potential – Future versus Current Conditions.
Fine material released from Halligan Reservoir will temporarily impact the well-defined pool-riffle morphology in the reach until it is remobilized and flushed downstream. Under Current Conditions, low flows (less than 100 cfs) are capable of transporting sands and silts. Under Future Conditions, the duration of flows less than 100 cfs will be increased. However, the ability of the river to flush fine sediments that are released from Halligan Reservoir will see negligible change.

**NF3 and NF4 - North Poudre Canal Diversion to Rabbit Creek**

This reach has historically experienced the largest hydrologic and morphological change within the study area. The trajectory of the North Fork in this section is a continuation of observed diminution by heavy vegetation encroachment and associated deposition of fine material on channel margins.

Within Phantom Canyon below the North Poudre Canal Diversion (Study Reach NF3), pool margins and riffle areas have been invaded by vegetation (mainly willows). It is expected that the channel in this reach will continue to lose definition in the long term under Current Conditions. This trend is expected to continue under Future Conditions even though overall sediment transport potential is increased by 8 percent. Steeper slopes within Phantom Canyon could allow for scour during large floods not influenced by Halligan Reservoir, Current Conditions, or Future Conditions hydrology. Changes in sediment transport potential under Future Conditions will provide minimal benefit and will likely not have an impact on the current rate of change given energy losses associated with a heavily vegetated channel.

As the river emerges from the Phantom Canyon into Study Reach NF4 above Rabbit Creek, hydrologic conditions are the same as Study Reach NF3. Active encroachment of vegetation is also noted here, and a trajectory of channel narrowing is predicted under Current Conditions. Under Future Conditions, increases noted in sediment transport potential attributed to increased flows are not likely to provide benefit or manifest as an adverse impact.

**NF5, NF6, and NF7 - Rabbit Creek to Confluence**

Current tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Increases in sediment transport potential under Future Conditions are not likely to have an impact on the trend or rate of the current trajectory.

**3.10 Distribution of Sediment Transport Potential with Flow**

Refer to Appendix Figures C-20 and C-21 (Appendix C, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

Figure 3-7 and Appendix Figures C-20 to C-21 compare magnitude-duration analyses for Current and Future Conditions. The curves demonstrate how sediment transport potential is
distributed across the flow range under Current and Future Conditions. The peaks of the magnitude-duration curves indicate what discharge is most effective at transporting sediments in each study reach.

The magnitude-duration curves for Current and Future Conditions were compared to determine if hydrologic changes under Future Conditions are likely to affect channel morphology. The following are types of indicators of change.

- A change in the location of the peak of the magnitude-duration curve between future and Current Conditions gives an indication of a change in effective discharge.
- A change in the magnitude and shape of the peak gives an indication of the change in the strength of the effective discharge signal.
- A change in the area under the curve gives an indication of the change in average annual sediment transport potential (allowing for the log scale).
- The area between the curves demonstrates the change in annual sediment transport potential (allowing for the log scale).
- Changes in the distribution of sediment transport potential across the flow range (see the histograms) show the flow intervals where sediment transport potential is most affected by the change in hydrology.

Under Future Conditions, a more consistently defined curve with slight change in the location of the peak of the curve was noted between Halligan Reservoir and the North Poudre Canal Diversion. The shape of future condition curves between North Poudre Canal Diversion and Seaman Reservoir (study reaches NF3, NF4, NF5, and NF6) are generally the same when compared with Current Conditions but with a higher magnitude in sediment transport for flow ranging from 5 cfs to 400 cfs. These changes are not likely to manifest in overall changes to morphology, but the current trajectory of vegetation encroachment and minor channel contraction will continue under Future Conditions.

In Study Reach NF7 (below Seaman Reservoir) the future condition curve exhibits a well-defined double peak that would slightly amplify the current trajectory of vegetation encroachment and channel contraction over time.

**Interpretation**

Increases in transport rates across the low flow range under Future Conditions are not likely to manifest in morphologic change relative to Current Conditions trajectories upstream of Seaman Reservoir. Changes in the magnitude-duration curves downstream of Seaman Reservoir would also have the same trajectory with a slight acceleration in temporal change.
Figure 3-7. Distribution of sediment transport potential with flow – Future versus Current Conditions.
3.11 Effective Discharge Spells

Refer to Appendix Figures C-22 to C-28, Appendix Tables C-26 and C-27 (Appendix C, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

Effective discharge is defined as the flow most responsible for moving the largest volume of sediment over time, if that sediment is available for transport. The frequency and duration of effective discharge occurrences are considered of morphological significance and in this system more meaningful than bankfull flows. Effective discharge ranges from 120 cfs up to 350 cfs in the study area. The occurrence and duration of effective discharge associated with Current and Future Conditions is presented in Appendix Tables C-26 and C-27 and Appendix Figures C-22 through C-28.

Under Future Conditions the number of years in which effective discharge would occur during the 19-year model period remains the same in study reaches NF2 and NF5. The number of years of occurrence is increased by 1 year in study reaches NF3, NF4, NF6 and NF7. Change in the average duration is negligible throughout the study area.

Interpretation

Changes in the occurrence of effective discharge coincide with increased flows associated with RFFAs. Increased occurrence will not likely result in change in the trajectory of the river relative to Current Conditions.

3.12 Overview of Effects of Future Conditions

Refer to Table 3-1

This section presents an overview of the predicted river trajectory associated with Future Conditions. Results of the comparison of Current and Future Conditions and possible impacts are summarized in Table 3-1.

The comparative assessment of Current and Future Conditions generally reflects slight increases in North Fork flows, generally downstream of the North Poudre Canal Diversion. In overview, the trajectory of the North Fork River condition is expected to continue under both Current and Future Conditions hydrology. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the North Fork Baseline Report (Anderson Consulting Engineers, Inc. 2017) are expected to continue throughout the study area under Future Conditions with a negligible impact on the rate of change.
<table>
<thead>
<tr>
<th>Analysis</th>
<th>Study Reach NF2: Halligan Reservoir to North Poudre Canal Diversion</th>
<th>Study Reaches NF3 and NF4: North Poudre Canal Diversion to Rabbit Creek</th>
<th>Study Reaches NF5, NF6, and NF7: Rabbit Creek to Confluence</th>
<th>Impact Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seasonal Average Daily Discharge</strong></td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows are <strong>increased by 4 percent</strong>. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) are increased. Note that increased low flows will have a <strong>negligible</strong> impact on morphology and sediment transport.</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows are increased by <strong>2 percent</strong>. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) are increased. Note that increased low flows will have a <strong>negligible</strong> impact on morphology and sediment transport.</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows are <strong>increased by up to 2 percent</strong>. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) are increased. Note that increased low flows will have a <strong>negligible</strong> impact on morphology and sediment transport.</td>
<td><strong>Change in Flow Regime</strong></td>
</tr>
<tr>
<td><strong>2 Percent Exceedance Discharge</strong></td>
<td>There is <strong>no change</strong> in the 2 percent exceedance discharge.</td>
<td>The 2 percent exceedance discharge is <strong>reduced by 2 percent</strong>. This reduction is considered <strong>negligible</strong>.</td>
<td>The 2 percent exceedance discharge is <strong>reduced by up to 3 percent</strong>. This reduction is considered <strong>negligible</strong>.</td>
<td></td>
</tr>
<tr>
<td><strong>Zero Flow Days</strong></td>
<td>The Current Conditions hydrology indicates a total of 283 days where flow in the river is zero. The number of zero flow days is reduced to 130 zero days under Future Conditions. This is likely a benefit to other resources but would have a <strong>negligible</strong> impact relative to morphology and sediment transport.</td>
<td>The Current Conditions hydrology indicates a total of 2,356 days where flow in the river is zero. The number of zero flow days is reduced to 1,014 days under Future Conditions. This will likely provide benefit to other resources but would have a <strong>negligible</strong> impact relative to morphology and sediment transport.</td>
<td>The Current Conditions hydrology indicates a total of 212 days where flow in the river is zero above Seaman Reservoir. This number is reduced to 0 days under Future Conditions. Below Seaman Reservoir a total of 123 zero flow days are reduced to 30 days. This will likely provide benefit to other resources but would have a <strong>negligible</strong> impact relative to morphology and sediment transport.</td>
<td></td>
</tr>
<tr>
<td><strong>2-Year Flood Discharge</strong></td>
<td>The 2-year flood discharge is <strong>increased by 3 percent</strong>. This increase is considered <strong>negligible</strong>.</td>
<td>The 2-year flood discharge is <strong>increased by 6 percent</strong>. This increase is considered <strong>minor to negligible</strong>.</td>
<td>The 2-year flood discharge is <strong>increased by 4 percent</strong> upstream of Seaman Reservoir and <strong>decreased 3 percent</strong> downstream. These changes are considered <strong>negligible</strong>.</td>
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</tr>
<tr>
<td><strong>Flushing Flows</strong></td>
<td>The occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer is <strong>unchanged</strong> from Current to Future Conditions.</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer is <strong>increased from 11 to 12 years</strong> under Future Conditions.</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer above Seaman Reservoir is <strong>increased from 10 to 11 years</strong>. Below Seaman Reservoir is <strong>reduced from 12 to 10 years</strong> under Future Conditions.</td>
<td><strong>Fining of Surficial Material</strong></td>
</tr>
<tr>
<td><strong>Channel Maintenance Flows</strong></td>
<td>Future conditions increase the duration of channel maintenance flows at 28 (out of 108) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows is <strong>increased by an average of 5 percent</strong>. This will have <strong>negligible</strong> impacts on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
<td>Future conditions increase the duration of channel maintenance flows at 7 (out of 37) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows is <strong>increased by an average of 6 percent</strong>. This will have <strong>negligible</strong> benefit on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
<td>Future conditions do <strong>not change</strong> the average duration of channel maintenance flows based on occurrence at 31 (out of 167) cross sections under Current Conditions.</td>
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</tr>
<tr>
<td><strong>Movement of Bed Material</strong></td>
<td>Future conditions increase the duration of bed material movement at 7 (out of 108) cross sections in this reach. The duration of bed material movement at these locations is <strong>increased by an average of 16 percent</strong>. Overall, this increase will have a <strong>negligible</strong> impact on morphologic complexity and channel structure.</td>
<td>There is <strong>no change</strong> in the duration of bed material movement under Future Conditions. Overall there is a <strong>negligible</strong> impact to channel structure or morphologic complexity.</td>
<td>There are negligible changes in the duration of bed material movement under Future Conditions. However, the average duration, based on 8 (out of 167) cross sections is 0 percent. Overall there is a <strong>negligible</strong> impact to channel structure or morphologic complexity.</td>
<td><strong>Loss of Morphologic Complexity</strong></td>
</tr>
<tr>
<td>Analysis</td>
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<tr>
<td>Effective Discharge</td>
<td>There is no change in the occurrence or duration of effective discharge under Future Conditions.</td>
<td>There is a slight increase in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This will have a negligible impact.</td>
<td>There is a slight increase in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This will have a negligible impact.</td>
<td>Channel Contraction</td>
</tr>
<tr>
<td>Sediment Transport</td>
<td>Average annual sediment transport potential above the North Poudre Canal Diversion is increased by 3 percent under Future Conditions.</td>
<td>Average annual sediment transport potential is increased by up to 8 percent under Future Conditions. Evaluation of transport rates over a range of flows indicates that there will be slight reduction in transport for flows greater than 400 cfs. Overall, there will be an increase in the transport of sands and silts but a slight decrease in the ability of the river to transport coarse bed material.</td>
<td>Average annual sediment transport potential is increased by 7 to 10 percent under Future Conditions. Evaluation of transport rates over a range of flows indicates that there will be slight reduction in transport for flows greater than 400 cfs. Overall, there will be an increase in the transport of sands and silts but a slight decrease in the ability of the river to transport coarse bed material.</td>
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<tr>
<td>Sediment Transport</td>
<td>Evaluation of Current Conditions provided in the North Fork Baseline Report and Chapter 1 indicate that while sands and silts can be readily mobilized through this reach there is evidence of deposition on margins and mid-channel bars during low flow periods that will support vegetation. The current trajectory of the river includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. This trajectory is expected to be interrupted from time to time with the occurrence of large floods that are unaffected by Halligan Reservoir. Changes in sediment transport potential under Future Conditions are minor. Morphology under Current Conditions are not predicted to change under Future Conditions. Fine material released from Halligan Reservoir will temporarily impact the well-defined pool-riffle morphology in the reach until it is remobilized and flushed downstream. Under Current Conditions, low flows (less than 100 cfs) are capable of transporting sands and silts. This is also true under Future Conditions.</td>
<td>This reach has historically experienced the largest hydrologic and morphological change within the study area. The trajectory of the river in this section is a continuation of observed diminution by vegetation encroachment and associated deposition of fine material on channel margins. Within Phantom Canyon below the North Poudre Canal Diversion (Study Reach NF3) pool margins and riffle areas have been invaded upon by vegetation (mainly willows). It is expected that the channel in this reach will continue to lose definition in the long term under Current Conditions. This will continue under Future Conditions, even though there are increases in flows. Steeper slopes within the canyon could allow for scour during large floods not influenced by Halligan Reservoir or Future Conditions hydrology. Changes in sediment transport potential under Future Conditions will provide little benefit and will likely not have an impact on the current rate of change.</td>
<td>Current tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Increases in sediment transport potential under Future Conditions are not likely to change the trend or rate of the current trajectory.</td>
<td>Channel Contraction</td>
</tr>
<tr>
<td></td>
<td>Overall, the Future Conditions river trajectory in this reach is predicted to be the same as Current Conditions.</td>
<td></td>
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</tbody>
</table>

Anderson Consulting Engineers, Inc. 3.19
4 North Fork - Effects of Fort Collins’ Proposed Action versus Future Conditions

This Chapter presents a detailed discussion of the effects of Fort Collins’ Proposed Action relative to Future Conditions on the North Fork. Hydrology for Fort Collins’ Proposed Action (PA4) is compared against Future Conditions (Run 2) and used in a range of various analyses. We have provided analytical results associated with the comparison of Fort Collins’ Proposed Action versus Future Conditions on the North Fork, in graphical and tabular form in Volume II, Appendix D of this report. A listing of all comparison figures and tables in Volume II that corresponds to each analysis is provided at the top of each analysis section. The location within the North Fork Baseline Report where corresponding baseline condition analysis can be found is also listed at the top of each analysis section.

4.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figure D-1 (Appendix D, Volume II)
North Fork Baseline Report Section 4.2 (Anderson Consulting Engineers, Inc. 2017)

The box and whisker plot of monthly flows at the Livermore Gage (Appendix Figure D-1) is based on the entire modeled monthly data set which covers the 56-year period from 1950 to 2005. The plot provides an overview of the predicted changes in overall flow volumes in the river as a result of Fort Collins’ Proposed Action over a longer time period than the daily flow 19-year period of record. The plots include the minimum, maximum, 25th and 75th percentiles, median, and average monthly flow volumes.

Average monthly flows would decrease under Fort Collins’ Proposed Action in the months of May through August (Figure 4-1). Average monthly flows would increase for all other months. Increases are attributed to timed flow releases from Halligan Reservoir simulated as operational exchanges in the hydrologic modeling of Fort Collins’ Proposed Action. Under Fort Collins’ Proposed Action releases from Halligan Reservoir would be conveyed through the North Fork to the Main Stem, increasing flows during certain times of the year. A reduction in diversions at the North Poudre Canal also contributes to increases. Increases in average monthly flows during the fall and winter (September through February) would be between 2 and 20 percent. Smaller increases of less than 11 percent would be observed in March and April. Water storage in Halligan Reservoir results in a reduction in average monthly flows of up to 7 percent during the month of May. June, July, and August show slight changes (less than 3 percent) in average monthly flow. Note that due to data limitation this comparison is provided at one location within the study area.
Figure 4-1. Percent change in average monthly flow at Livermore Gage – Fort Collins’ Proposed Action versus Future Conditions.

Interpretation

A comparison at the Livermore Gage shows an increase in monthly flows for most of the year with a minor decrease in May. No significant implications for sediment transport or geomorphology are indicated by this change in monthly flow. Other possible benefits relate to other functions that are more suitably addressed by water quality, vegetation, and aquatic resource specialists.

4.2 Daily Flow Frequency and Duration


The seasonality of changes in daily flow statistics (minimum, 10th percentile, Average, 90th percentile, and maximum) are tabulated in Appendix Tables D-1 through D-12. During low flow winter months (October through February) average daily flows would increase between 12 and 43 percent below Halligan Reservoir (Appendix Table D-3). It should be noted that these large percent increases correspond to small average flows (generally less than 20 cfs). Increases are also noted in average daily flows during early spring (March through April 15th) (Appendix Table D-6).

During the high flow runoff months (April 16th through July 15th), critical to morphology and sediment transport, the average and 90th percentile daily flows would be reduced by up to 8 and
11 percent, respectively (Appendix Table D-9) throughout the study area. More specifically, daily average flows would be reduced by 6 percent in Study Reach NF2 between Halligan Reservoir and the North Poudre Canal Diversion, by 8 percent in study reaches NF3 and NF4 between the North Poudre Canal and Rabbit Creek, and by up to 5 percent in study reaches NF5, NF6, and NF7 located below Rabbit Creek. Between July 16th and September 30th, changes in average monthly flows would be negligible (Appendix Table D-12).

A key observation from the plotted frequency distributions of daily flows (Appendix Figure D-2) is the reduction in flows at or above approximately 100 cfs and an increase in flows at or below approximately 100 cfs throughout the study area.

Another way of expressing the change in the flow frequency distribution is to look at change in flow of a particular duration. The flow frequency tables (Appendix Tables D-13, D-14, and D-15) indicate reduction in flows that would be equaled or exceeded 1 to 10 percent of the time. These flows represent the high flow range that is critical to sediment transport and morphology. The 1 percent exceedance flows would be reduced by up to 5 percent. Reduction in the 2 percent exceedance flows would be 6 percent between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2), 9 percent between the North Poudre Canal Diversion and Rabbit Creek (study reaches NF3 and NF4), and 7 percent below Rabbit Creek (study reaches NF5, NF6, and NF7) (Figure 4-2). Reductions of up to 7 percent are noted in the 5 and 10 percent exceedance flow range.

Lower flows (flow equaled or exceeded 25 to 95 percent of the time) would increase as a result of flow releases from Halligan Reservoir under Fort Collins’ Proposed Action.

Under Future Conditions, there would be a significant amount of time when the North Fork study reaches NF3 and NF4, located between the North Poudre Canal Diversion and Rabbit Creek, would have minimal or no flow. During the 19-year modeled period, there would be zero flow in the river 15 percent of the time (1,014 out of 6,940 days). Flow releases from Halligan Reservoir under Fort Collins’ Proposed Action would reduce the number of zero flow days to 471. While this would not have a direct impact on morphology it would likely provide benefits to other resources (water quality, aquatics, vegetation, etc.). Similarly, the number of zero flow days between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2) would be reduced from 130 days to 11 days. In study reaches NF5 and NF6, between Rabbit Creek and Seaman Reservoir, there would be no zero flow days for Future Conditions or Fort Collins’ Proposed Action. Below Seaman Reservoir (Study Reach NF7) a total of 30 zero flow days would occur under both conditions.
Figure 4-2. Percent change in 2 percent exceedance discharge – Fort Collins’ Proposed Action versus Future Conditions.
**Interpretation**

There would be minor changes in flow frequency below Halligan Reservoir as a result of Fort Collins’ Proposed Action. Seasonally, reduction in flows related to impoundment of water would be greatest during the high flow period (April 15th through July 15th) and in the reaches between the North Poudre Canal Diversion and Rabbit Creek (study reaches NF3 and NF4). Effects would be slightly lessened in study reaches NF5 and NF6 where tributary flows enter the system. In general, the occurrence of flows at or above roughly 100 cfs would be reduced. Throughout the year, the 2, 5, and 10 percent exceedance flows would be affected by a reduction of up to 9 percent. Lower flows (25 to 95 percent exceedance) would increase as a result of flow releases from Halligan Reservoir under Fort Collins’ Proposed Action.

Reduction in the occurrence of high flows could have an impact on channel forming discharges and channel morphology. Implications for the likelihood and magnitude of possible channel contraction, fining of surficial material, and loss of hydraulic and morphologic complexity are further explored in the comparisons presented below. Increases in low flows associated with release of water from Halligan Reservoir under Fort Collins’ Proposed Action and changes to North Poudre Canal Diversions would provide some benefits related to other functions that are more suitably addressed by water quality, vegetation, and aquatic resource specialists.

**4.3 Flood Frequency**

Refer to Appendix Figure D-4 and Appendix Tables D-16 and D-17 (Appendix D, Volume II) North Fork Baseline Report Section 4.5 (Anderson Consulting Engineers, Inc. 2017)

Flood frequency was evaluated using the 19-year period of modeled daily flows. The analysis should not be compared with other flood frequency analyses for the river which are undertaken for a different purpose and based on much longer periods of record covering a wider range of flood peaks. It should also be noted that the limited period of modeling means that confidence intervals for the less frequent floods in this analysis are wide.

The flood frequency analysis differs from the flow duration analysis reported in the previous section in that a flood frequency analysis only considers the likelihood that a flood peak would occur or be exceeded in any year. It takes no account of flow duration.

Under Fort Collins’ Proposed Action the 2-year flood discharge would be reduced by 6 percent in Study Reach NF2, 12 percent in study reaches NF3 and NF4, 11 percent in study reaches NF5 and NF6, and by 9 percent in Study Reach NF7 (Figure 4-3). Reduction in the 5- and 10-year floods would range from 3 to 9 percent. The largest reduction in flood magnitudes is noted in study reaches NF3 and NF4 between the North Poudre Canal Diversion and Rabbit Creek. The impact of Fort Collins’ Proposed Action on floods larger than these (e.g., the 25- to 100-year flood) cannot be reliably estimated with the 19-year modeled data set.
Figure 4-3. Percent change in 2-year flood discharge – Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

The reduction in flood frequency correlates with reductions in daily flows and reflects increased storage of water in Halligan Reservoir. Reductions in the frequency of occurrence of high flows have the potential to cause morphologic change through reduced sediment mobility. These implications are explored further in analyses presented below.

4.4 Bankfull Flows

Refer to Appendix Figures D-5 and D-6, Appendix Tables D-18 and D-19 (Appendix D, Volume II)
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

Bankfull discharge can be an important hydraulic and morphologic parameter. A comparison of the occurrence and duration of bankfull flows in the unconfined study reaches NF 4 and NF5 indicates no change under Fort Collins’ Proposed Action (Appendix Table D-18 and D-19).

Interpretation

Although no change is observed in bankfull flow spells, other evaluations provided below are likely better indicators of morphologic change (e.g. effective discharge spells) given the low frequency of bankfull flows under both Future Conditions and project hydrology.

4.5 Flushing Flows

Refer to Appendix Figures D-7 and D-11, Appendix Tables D-20 and D-21 (Appendix D, Volume II)
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

Flushing flows are defined as flows that flush or move sediments (gravels sized and smaller) resting on top of the coarse bed material matrix (or armor layer) in riffles. Flushing flows allow for surface cleaning of riffles necessary to support ecological function of the river channel. A key function of flushing flows is to maintain spawning habitat for fish. Baseline flushing flows identified for comparative assessments were defined as flows having a magnitude approximately equal to the 2-year flood relative to Current Conditions hydrology (Anderson Consulting Engineers, Inc. 2017).

The absolute difference in the total number of years of occurrence and duration of flushing flow spells is provided in Appendix Table D-21. A graphical comparison at each hydrologic node is provided in Appendix Figures D-7 to D-11. Fort Collins’ Proposed Action would not change the number of years of occurrence in Study Reach NF2, and the average annual recurrence interval would be 1.9 years. The number of years of occurrence would be reduced from 12 years to 9 years in study reaches NF3 and NF4. This corresponds to an increase in the average annual recurrence interval from 1.6 years to 2.1 years. In study reaches NF5 and NF6, the number of years of occurrence would be reduced from 11 years to 9 years, corresponding to an increase in
the average annual recurrence interval from 1.7 years to 2.1 years. The number of years of occurrence would be reduced in Study Reach NF7 from 10 years to 9 years, corresponding to an increase in the average annual recurrence interval from 1.9 years to 2.1 years.

**Interpretation**

There would be a minor impact to flushing flows that maintain riffles and support aquatic habitat below the North Poudre Canal Diversion. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

### 4.6 Channel Maintenance Flows

Channel maintenance flows are defined as the flow required to remove sediments trapped in between coarser material that comprises the bed material matrix (armor layer). For the CTP, a critical dimensionless shear stress was adopted to represent conditions when bed material moves sufficiently to just allow finer material to be released from the interstices of coarser surface layers of the bed. The geomorphic process related to channel maintenance flows is of ecological significance. Ecological criteria would consider not only the total duration of channel maintenance flows in the 19-year period but also the number of occurrences and the time between occurrences. The analysis reported in this section provides no information on specific ecologic criteria, but the spells analysis (Section 4.6.2) presents information on the frequency and duration of channel maintenance flows.

#### 4.6.1 Analysis at all Cross Sections

Refer to Appendix Figure D-12 (Appendix D, Volume II)
North Fork Baseline Report Section 6.2.3 (Anderson Consulting Engineers, Inc. 2017)

We compared the duration for which channel maintenance flows would be expected to occur under Future Conditions and Fort Collins’ Proposed Action at 349 cross sections throughout the study area (Figure 4-4). The comparison shows a strong signal of reduction in duration in most reaches, with the exception of NF3 and NF5. Channel maintenance flows required in NF3 would be quite large (greater than the maximum value in the 19-year period of record) in order to overcome energy losses associated with vegetation encroachment. Increases in duration shown in Study Reach NF5 are a function of lower threshold flows. Reduction in duration of channel maintenance flows would be as much as 20 to 30 percent in study reaches NF2, NF4, NF6, and NF7, with some outliers noted.

It is important to put this finding in the context that the changes shown in Figure 4-4 only represent a subset of all cross sections on the river. As described below, there are many other cross sections that the analysis predicts would not be impacted by a change in channel maintenance flow duration.

In addition to the cross sections where a change in the duration of channel maintenance flow is shown, there are many cross sections where channel maintenance flows would not occur in the
19-year modeled period for either Future Conditions or Fort Collins’ Proposed Action; and others where no change in channel maintenance flow duration is predicted. Out of a total of 349 cross sections analyzed, 217 (62 percent) show no occurrence of channel maintenance flows during the Future Conditions modeled period. Conversely, channel maintenance flows occur at 132 cross section (or 38 percent of cross sections) in the study area. Of those sections, 61 out of 132 show no change in duration under Fort Collins’ Proposed Action. Consequently, 71 cross sections out of 132 show a change in duration with Fort Collins’ Proposed Action. Change in duration across the 71 cross sections indicates an average reduction in duration of roughly 9 percent. On a study reach basis an average reduction in duration of 9 percent is noted in Study Reach NF2 (based on 37 cross sections), 15 percent in study reaches NF3 and NF4 (based on 9 cross section), and 8 percent in study reaches NF5, NF6, and NF7 (based on 25 cross sections).

Some very small absolute changes in the duration of channel maintenance flows can appear as large percentage changes (greater than 30 percent) in the comparison (Figure 4-4). However, sensitivity analyses indicate that these changes do not skew the spread of results.

**Interpretation**

Analysis of channel maintenance flows address one process by which fining of surficial material could be an impact of Fort Collins’ Proposed Action. The information presented suggests a reduction in channel maintenance flow duration by as much as 20 to 30 percent at specific cross sections with an overall average reduction of approximately 8 percent throughout the study area. This reduction could lead to fining of surficial material. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

### 4.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure D-13, Appendix Tables D-22 and D-23 (Appendix D, Volume II)
North Fork Baseline Report Section 6.2.4 (Anderson Consulting Engineers, Inc. 2017)

Reduction in channel maintenance flows is further examined at specific cross sections selected as representative in each reach. We computed the occurrence of periods where channel maintenance shear stress criterion would be exceeded for Future Conditions and Fort Collins’ Proposed Action. These periods are illustrated graphically in Appendix Figure D-13 and in tabular form in Appendix Tables D-22 and D-23 for both Future Conditions and Fort Collins’ Proposed Action.
Figure 4-4. Percent change in duration of channel maintenance flows – Fort Collins’ Proposed Action versus Future Conditions.
Channel maintenance flows were not achieved in study reaches NF1 through NF5 at selected cross sections for either Future Conditions or Fort Collins’ Proposed Action. Limited episodes of channel maintenance flows occur above and below Seaman Reservoir in reaches NF6 and NF7 under both hydrologic conditions. There would be no change in occurrence and a negligible change in the average duration in these study reaches.

**Interpretation**

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 4.6.1.

### 4.7 Flows that Move Coarse Bed Material

Refer to Appendix Figure D-14 (Appendix D, Volume II)
North Fork Baseline Report Section 6.2.7 (Anderson Consulting Engineers, Inc. 2017)

The point at which coarse material in the bed of the river starts to move is a geomorphic threshold. The occurrence of bed material motion and the duration of flows above this threshold influence the size, shape, and dynamics of the river channel. For the CTP evaluation, initiation of motion was related to a critical shear stress which varies along the river according to the size of material present in the river bed. Initiation of motion is particularly important because it represents the flow at which the armor layer is broken, and underlying sediment is released.

The duration for which bed material movement would be expected to occur under Future Conditions and Fort Collins’ Proposed Action was evaluated at 349 cross sections (Figure 4-5). Note that the vertical lines represent all cross sections where initiation of motion calculations were undertaken. Movement of coarse bed material would not occur during the Future Conditions 19-year model period at 89 percent of modeled cross sections. Under Future Conditions, movement of bed material would occur at 38 out of 349 cross section (11 percent). Fort Collins’ Proposed Action would reduce the duration of bed material movement at 20 of the 38 cross sections. The average reduction in duration, based on the 20 cross sections, would be 20 percent. On a study reach basis, an average reduction in duration of 19 percent is noted in Study Reach NF2 (based on 10 cross sections), 50 percent in study reaches NF3 and NF4 (based on 1 cross section), and 17 percent in study reaches NF5, NF6, and NF7 (based on 9 cross sections).

**Interpretation**

Reduced duration of flows that generate motion of bed material implies that the river bed would be adjusted less frequently and move less sediment through the system. A signal of change in the occurrence and duration of flows that move coarse bed material was noted but was not found to be spatially prevalent.
Supply of material that makes up the bed is limited, and reduced movement of bed material could lead to lower rates of change of in-channel bars, islands, benches, and channel form. Erosion is predicted to still occur at some locations and on some occasions particularly as a consequence of floods. Bed material would only move at approximately 11 percent of cross sections, so spatial variability in hydraulic conditions is predicted to be maintained with existing channel features. Increased stability would have benefits but could lead to reduced temporal variability of biotopes.

4.8 Stream Power

Refer to Appendix Figures D-15 through D-18 (Appendix D, Volume II)
North Fork Baseline Report Section 6.3 (Anderson Consulting Engineers, Inc. 2017)

Stream power can be calculated at each cross section over the range of flows included in the modeled data sets. Summed over the 19-year modeled period (with appropriate units), stream power represents the ability of the flow to “do work” on the channel boundaries. Also of interest is the stream power in excess of the power that is required to initiate bed material motion. This can give an indication of the amount of “work” that can move the channel bed.

Appendix Figures D-15 and D-16 illustrate the change in total work along the length of the North Fork. Between Halligan Reservoir and the North Poudre Canal Diversion (Study Reach NF2), change in total work would be plus or minus 5 percent. In reaches NF3 and NF4, between the North Poudre Canal Diversion and Rabbit Creek, change in total work would be plus or minus 10 percent. A consistent increase in total work (as much as 20 percent) is noted throughout study reaches NF5, NF6, and NF7. Increases in energy are attributed to increased duration of lower flows associated with Halligan Reservoir releases and reduced diversions at the North Poudre Canal.

Appendix Figures D-17 and D-18 illustrate that differences in the total work described above generally disappear when looking at work in excess of the stream power required to move bed material. Under both Future Conditions and with project hydrology, work in excess of bed movement would only occur at approximately 10 percent of the location evaluated, which is consistent with the evaluation of bed material movement discussed in Section 4.7. At these locations, sporadic change in the “work” that the flow can do in moving the channel bed is noted (Appendix Figure D-18). Reductions are shown in reaches NF2, NF4, NF5, and NF6. Large percent changes coincide with locations where the total work in excess of stream power would be extremely small and likely inconsequential to movement of the bed.
Figure 4-5. Percent change in the duration of bed material movement – Fort Collins’ Proposed Action versus Future Conditions.
**Interpretation**

Changes noted in total work would be spatially limited with some small reductions noted. Increase in total work are attributed to an increased in the duration of low flows as a result of releases from Halligan Reservoir and changes to North Poudre Canal Diversions under Fort Collins’ Proposed Action. This increase is predicted to have limited adverse morphologic consequence because it would occur at low stream powers where there is no channel adjustment. Most increases disappear in the comparison of work in excess of the threshold of motion.

The comparison in Appendix Figures D-17 and D-18 shows few instances of a decrease in energy in excess of bed material movement. Changes shown would not be likely to manifest into adverse effects.

### 4.9 Sediment Transport Potential

Refer to Appendix Figure D-19, Appendix Tables D-24 and D-25 (Appendix D, Volume II)
North Fork Baseline Report Section 7.1.2 (Anderson Consulting Engineers, Inc. 2017)

The change in reach averaged sediment transport potential between Future Conditions and Fort Collins’ Proposed Action was evaluated (Figure 4-6). Sediment transport potential is the capacity of the river to move sediment over the 19-years of modeled flows if sediment was available to be moved. The results are presented separately for total bed material load, sand, gravel, and cobble sized material. Size gradations used in the sediment transport calculations reflect a composite of surface and sub-surface bed material samples.

Slight changes are noted in the total amount of material that could be moved in Study Reach NF2 (less than 1.5 percent reduction). The total amount of transport potential would be slightly increased by 2 to 6 percent between the North Poudre Canal Diversion and Rabbit Creek (study reaches NF3 and NF4), and by 2 to 8 percent downstream of Rabbit Creek (Figure 4-6). Change in the transport of sands would be greater than for gravels. Release of water from Halligan Reservoir under Fort Collins’ Proposed Action would slightly increase the transport of sands through the system. Impacts to the amount of gravel that could be transported would be minimal.

Note that increases in total transport potential is a function of increased duration of frequently occurring low flows (less than 100 cfs). These low flows would not be capable of moving some gravels and cobbles. Evaluation of impacts to transport across the flow range will be addressed in Section 4.10.
Figure 4-6. Percent change in average annual sediment transport potential – Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

These results of the change in sediment transport potential cannot be directly interpreted to provide an estimate of the actual magnitude of sediment transport response due to lack of availability of sediment entering the river system below Halligan Reservoir. However, given the findings of the North Fork Baseline Report, some conclusions about sediment response can be drawn as follows.

**NF2 – Halligan Reservoir to North Poudre Canal Diversion**

Evaluation of Future Conditions provided in Chapter 3 indicate a continuation of Current Conditions identified in the North Fork Baseline Report. While sands and silts could be readily mobilized through this reach there is evidence of deposition on margins and mid-channel bars during low flow periods that would support vegetation. The trajectory of the river under Future Conditions includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. This trajectory would be expected to be interrupted from time to time with the occurrence of large floods that are unaffected by Halligan Reservoir. Fort Collins’ Proposed Action would not impact the total sediment transport potential (less than 1.5 percent change). Therefore, a minor to negligible change in morphology associated with the predicted river trajectory under Future Conditions would be expected with Fort Collins’ Proposed Action.

Fine material released from Halligan Reservoir would temporarily impact the well-defined pool-riffle morphology in this reach until it was remobilized and flushed downstream. Under Future Conditions, low flows (less than 100 cfs) are capable of transporting sands and silts. Under Fort Collins’ Proposed Action the duration of flows less than 100 cfs would increase. However, the ability of the river to flush fine sediments released from Halligan Reservoir would see negligible change.

**NF3 and NF4 - North Poudre Canal Diversion to Rabbit Creek**

This reach has historically experienced the largest hydrologic and morphological change within the study area. The trajectory of the river in this section would be a continuation of observed diminution by heavy vegetation encroachment and associated deposition of fine material on channel margins.

Within Phantom Canyon below the North Poudre Canal Diversion (Study Reach NF3), pool margins and riffle areas have been invaded by vegetation (mainly willows). It is expected that the channel in this reach would continue to lose definition in the long term under Future Conditions. Steeper slopes within Phantom Canyon could allow for scour during large floods not influenced by Halligan Reservoir or Future Conditions hydrology. Changes in sediment transport potential under Fort Collins’ Proposed Action would provide little benefit and is not likely to have an impact on the rate of change given energy losses associated with a heavily vegetated channel.

As the river emerges from the Phantom Canyon into Study Reach NF4 above Rabbit Creek, hydrologic conditions would be the same as Study Reach NF3, for both with and without project
hydrology. Active encroachment of vegetation is also noted here, and a trajectory of channel narrowing is predicted under Future Conditions. Under Fort Collins’ Proposed Action, increases noted in sediment transport potential attributed to increased low flows would not be likely to provide benefit or manifest as an adverse impact on morphology.

**NF5, NF6, and NF7 - Rabbit Creek to Confluence**

Tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Slight increases in sediment transport potential under Fort Collins’ Proposed Action would not be likely to have an impact on the trend or rate of the trajectory.

### 4.10 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figures D-20 and D-21 (Appendix D, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

Figure 4-7 and Appendix Figures D-20 to D-21 compare magnitude-duration analyses for Future Conditions and Fort Collins’ Proposed Action. The curves demonstrate how sediment transport potential would be distributed across the flow range for Future Conditions and Fort Collins’ Proposed Action hydrology. The peak of the magnitude-duration curves indicate what discharge would be most effective at transporting sediments in each study reach.

A comparison of the magnitude-duration curves between Future Conditions and Fort Collins’ Proposed Action was provided to determine if hydrologic changes under Fort Collins’ Proposed Action would impact channel morphology. The following are types of indicators of change.

- A change in the location of the peak of the magnitude-duration curve between Fort Collins’ Proposed Action and Future Conditions gives an indication of a change in effective discharge. A change in the magnitude and shape of the peak gives an indication of the change in the strength of the effective discharge signal.
- A change in the area under the curve gives an indication of the change in average annual sediment transport potential (allowing for the log scale).
- The area between the curves demonstrates the change in annual sediment transport potential (allowing for the log scale).
- Changes in the distribution of sediment transport potential across the flow range (see the histograms) show the flow intervals where sediment transport potential would be most affected by the change in hydrology.

Under Fort Collins’ Proposed Action, a slight change in the location of the peak of the curve is noted between Halligan Reservoir and the North Poudre Canal Diversion. The peak of the curves in all reaches below the North Poudre Canal Diversion becomes less defined and a more defined
peak towards lower flow values is emerging. This would indicate more movement of finer material and less movement of coarse material. Movement of the peak of the curves towards lower flows can indicate a tendency towards channel contraction. However, manifestation of that change would only eventuate if upstream sediment supply was limitless and the system was transport limited (defined as conditions in which sediment supply greatly exceeds sediment transport potential). Given that there would be limited sediment supply, differences noted in the curves would not be likely to manifest in overall changes to morphology. But there is support of continuation of the future trajectory of vegetation encroachment and minor channel contraction over time.

Annual sediment transport rates would increase 10 to 30 percent for flows less than 100 cfs, as indicated by the histograms shown on the bottom line of Appendix Figures D-20 and D-21. Overall, for flows greater than 100 cfs there would be a decrease in transport rates of roughly 10 percent.

**Interpretation**

Increases in transport rates across the low flow range under Fort Collins’ Proposed Action would not be likely to manifest in morphologic change. Reductions in transport rates in the high flow ranges would slightly reduce the movement of gravels and coarse bed material. This reduction would have more impact on the river between North Poudre Canal Diversion and Rabbit Creek (reaches NF3 and NF4) than elsewhere in the study area.
Figure 4-7. Distribution of sediment transport potential with flow – Fort Collins' Proposed Action versus Future Conditions.
### 4.11 Effective Discharge Spells

Refer to Appendix Figures D-22 through D-28, Appendix Tables D-26 and D-27 (Appendix D, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

Effective discharge is defined as the flow most responsible for moving the largest volume of sediment over time, if that sediment is available for transport. The frequency and duration of effective discharge occurrences are considered of morphological significance and in this system more meaningful than bankfull flows. Effective discharge ranges from 120 cfs up to 350 cfs in the study area. Changes in the occurrence and duration of effective discharge associated with Fort Collins’ Proposed Action is presented in Appendix Tables D-26 and D-27 and Appendix Figures D-22 through D-28.

The number of years in which effective discharge would occur during the 19-year model period would be the same for Future Conditions and Fort Collins’ Proposed Action, with the exception of Study Reach NF7. The number of years of occurrence would be reduced by 1 year in NF7. Changes in the average duration of effective discharge would be noted throughout the study, even if the number of years of occurrence would be unchanged. The average duration of effective discharge would be reduced by less than 10 percent.

**Interpretation**

Changes in the occurrence and duration of effective discharge coincide with a reduction in flows above 100 cfs. Reductions could increase tendencies towards channel contraction and surficial fining. However, the magnitude of these reductions suggests that the impact would be minimal.

### 4.12 Overview of Effects of Fort Collins’ Proposed Action on Sediment Transport and River Morphology

This section presents an overview of predicted conditions associated with implementation of Fort Collins’ Proposed Action compared to Future Conditions. A summary of results and possible impacts are summarized in Table 2-1.

Results of the individual analyses described above are collectively considered to determine effects of Fort Collins’ Proposed Action on the future trajectory of river condition. Impacts associated with a reduction in flows can lead to the following impacts listed below.

- **Fining of Surficial Material.** Reduced magnitude, frequency or duration of flows leads to a fining of surficial material and possible blanketing of the bed and filling of interstices with fine sediments.
- **Channel Contraction.** Deposition of silts, sands or gravels on channel bars and margins or on mid-channel islands leads to reduced channel width and/or depth.
- **Loss of Hydraulic and Morphologic Complexity.** Channel contraction and fining of
surficial material can lead to loss of hydraulic and morphologic complexity and reduced spatial frequency or variability of biotypes.

Based largely on an observational model of response to Future Conditions hydrology, the river trajectory with Fort Collins’ Proposed Action would be expected to continue with negligible effects.
**Table 4-1 Overview of the effects of Fort Collins’ Proposed Action versus Future Conditions.**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Study Reach NF2: Halligan Reservoir to North Poudre Canal Diversion</th>
<th>Study Reaches NF3 and NF4: North Poudre Canal Diversion to Rabbit Creek</th>
<th>Study Reaches NF5, NF6, and NF7: Rabbit Creek to Confluence</th>
<th>Impact Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal Average Daily Discharge</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows would be <strong>reduced by 6 percent</strong>. This reduction would be <strong>minor to negligible</strong>. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. Note that increased low flows would have a <strong>negligible impact</strong> on morphology and sediment transport.</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows would be <strong>reduced by 8 percent</strong>. This reduction would be <strong>minor</strong>. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. Note that increased low flows would have a <strong>negligible impact</strong> on morphology and sediment transport.</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows would be <strong>reduced by up to 5 percent</strong>. This reduction would be <strong>minor to negligible</strong>. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. Note that increased low flows would have a <strong>negligible impact</strong> on morphology and sediment transport.</td>
<td>Change in Flow Regime</td>
</tr>
<tr>
<td>2 Percent Exceedance Discharge</td>
<td>The 2 percent exceedance discharge would be <strong>reduced by 6 percent</strong>. This reduction would be <strong>minor</strong>.</td>
<td>The 2 percent exceedance discharge would be <strong>reduced by 9 percent</strong>. This reduction would be <strong>minor</strong>.</td>
<td>The 2 percent exceedance discharge would be <strong>reduced by up to 7 percent</strong>. This reduction would be <strong>minor</strong>.</td>
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</tr>
<tr>
<td>Zero Flow Days</td>
<td>The future condition hydology indicates a total of 130 days where flow in the river is zero. The number of zero flow days would be reduced to 11 zero flow days under Fort Collins’ Proposed Action. This would likely be a benefit to other resources but would have a negligible impact relative to morphology and sediment transport.</td>
<td>The future condition hydology indicates a total of 1,014 days where flow in the river is zero. The number of zero flow days would be significantly reduced to 471 days under Fort Collins’ Proposed Action. This would likely provide benefit to other resources but would have a negligible impact relative to morphology and sediment transport.</td>
<td>There would be <strong>no change</strong> in the number of zero flow days between Future Conditions and Fort Collins’ Proposed Action.</td>
<td></td>
</tr>
<tr>
<td>2-Year Flood Discharge</td>
<td>The 2-year flood discharge would be <strong>reduced by 6 percent</strong>. This reduction would be <strong>minor</strong>.</td>
<td>The 2-year flood discharge would be <strong>reduced by 12 percent</strong>. This reduction would be <strong>minor</strong>.</td>
<td>The 2-year flood discharge would be <strong>reduced by up to 11 percent</strong>. This reduction would be <strong>minor</strong>.</td>
<td></td>
</tr>
<tr>
<td>Flushing Flows</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer would show <strong>no change</strong> under Fort Collins’ Proposed Action. The average annual recurrence interval of flushing flows, <strong>also unchanged</strong>, would be 1.9 years.</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer would be <strong>reduced from 12 to 9 years</strong> by Fort Collins’ Proposed Action. In other terms, the average annual recurrence interval would increase from 1.6 years to 2.1 years. This change would have <strong>minor to negligible</strong> effect on flushing.</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer would be <strong>reduced from 11 years to 9 years</strong> by Fort Collins’ Proposed Action. The average annual recurrence interval of flushing flows would increase from 1.7 years to 2.1 years. Below Seaman Reservoir the number of years of occurrence would be reduced from 10 years to 9 years, with a corresponding increase in average annual recurrence interval of 1.9 years to 2.1 years. These changes would have a <strong>minor to negligible</strong> effect on flushing.</td>
<td>Fining of Surficial Material</td>
</tr>
<tr>
<td>Channel Maintenance Flows</td>
<td>Fort Collins’ Proposed Action would reduce the duration of channel maintenance flows at 37 (out of 108) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be <strong>reduced by an average of 9 percent</strong>. This would have a <strong>minor to negligible</strong> impact on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
<td>Fort Collins’ Proposed Action would reduce the duration of channel maintenance flows at 9 (out of 37) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be <strong>reduced by an average of 15 percent</strong>. This would have a <strong>minor to negligible</strong> impact on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
<td>Fort Collins’ Proposed Action would reduce the duration of channel maintenance flows at 25 (out of 167) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be <strong>reduced by an average of 8 percent</strong>. This would have a <strong>minor to negligible</strong> impact on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
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<tr>
<td>Movement of Bed Material</td>
<td>Fort Collins’ Proposed Action would reduce the duration of bed material movement at 10 (out of 108) cross sections in this reach. The duration of bed material movement at these locations would be <strong>reduced by an average of 19 percent</strong> under Fort Collins’ Proposed Action.</td>
<td>Fort Collins’ Proposed Action would reduce the duration of bed material movement at 1 (out of 37) cross section in this reach.</td>
<td>Fort Collins’ Proposed Action would reduce the duration of bed material movement at 9 (out of 167) cross sections in this reach. The duration of bed material movement at these locations would be <strong>reduced by an average of 17 percent</strong> under Fort Collins’ Proposed Action.</td>
<td>Loss of Morphologic Complexity</td>
</tr>
<tr>
<td>Analysis</td>
<td>Study Reach NF2: Halligan Reservoir to North Poudre Canal Diversion</td>
<td>Study Reaches NF3 and NF4: North Poudre Canal Diversion to Rabbit Creek</td>
<td>Study Reaches NF5, NF6, and NF7: Rabbit Creek to Confluence</td>
<td>Impact Indicator</td>
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<td>Collins’ Proposed Action. These reductions were not found to be</td>
<td>Overall there would be a negligible impact to channel structure</td>
<td>Proposed Action. These reductions were not found to be</td>
<td>Channel Contraction</td>
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<td></td>
<td>spatially prevalent. Overall, this reduction would have a negligible</td>
<td>or morphologic complexity in this reach.</td>
<td>spatially prevalent. Overall there would be a negligible</td>
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<tr>
<td></td>
<td>impact on changes to morphologic complexity and channel structure.</td>
<td></td>
<td>impact to channel structure or morphologic complexity.</td>
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<tr>
<td>Effective Discharge</td>
<td>There would be no change in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This would have a negligible impact.</td>
<td>There would be no change in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This would have a negligible impact.</td>
<td>There would be a no change in the number of years in which effective discharge would occur upstream of Seaman Reservoir, and a loss of 1 year below. There would be a slight decrease in the duration of effective discharge. This would have a minor to negligible impact.</td>
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<tr>
<td>Sediment Transport</td>
<td>Average annual sediment transport potential above the North Poudre Canal Diversion shows less than 1.5 percent change. Evaluation of transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse materials of approximately 10 percent. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Average annual sediment transport increases by approximately 2 to 6 percent under Fort Collins’ Proposed Action. Evaluation of transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse materials of approximately 10 percent. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Average annual sediment transport increases by approximately 2 to 8 percent under Fort Collins’ Proposed Action. Evaluation of transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse materials of approximately 10 percent. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Channel Contraction</td>
</tr>
<tr>
<td>Analysis</td>
<td>Study Reach NF2: Halligan Reservoir to North Poudre Canal Diversion</td>
<td>Study Reaches NF3 and NF4: North Poudre Canal Diversion to Rabbit Creek</td>
<td>Study Reaches NF5, NF6, and NF7: Rabbit Creek to Confluence</td>
<td>Impact Indicator</td>
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<td>----------------------------------------------</td>
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<tr>
<td><strong>Sediment Transport</strong></td>
<td>Evaluation of Future Conditions indicate that, while sands and silts could be readily mobilized through this reach, there would be evidence of deposition on margins and mid-channel bars during low flow periods that would support vegetation. The trajectory of the river includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. This trajectory would be expected to be interrupted from time to time with the occurrence of large floods that are unaffected by Halligan Reservoir. Fort Collins’ Proposed Action would not impact the total sediment transport potential (less than 1.5 percent change). Therefore, <em>minor to negligible</em> changes in morphology would be expected with Fort Collins’ Proposed Action. Fine material released from Halligan Reservoir would temporarily impact the well-defined pool-riffle morphology in the reach until it was remobilized and flushed downstream. Under Future Conditions, low flows (less than 100 cfs) would be capable of transporting sands and silts. Under Fort Collins’ Proposed Action the duration of flows less than 100 cfs would increase. However, the ability of the river to flush fine sediments that would be released from Halligan Reservoir would likely not change.</td>
<td>This reach has historically experienced the largest hydrologic and morphological change within the study area. The trajectory of the river in this section would be a continuation of observed diminution by vegetation encroachment and associated deposition of fine material on channel margins. Within Phantom Canyon below the North Poudre Canal Diversion (Study Reach NF3) pool margins and riffle areas have been invaded upon by vegetation (mainly willows). It is expected that the channel in this reach would continue to lose definition in the long term under Future Conditions. Steeper slopes within the canyon could allow for scour during large floods not influenced by Halligan Reservoir or Future Conditions hydrology. Increases in sediment transport potential under Fort Collins’ Proposed Action would provide little benefit and would likely not have an impact on the rate of change. As the river emerges from Phantom Canyon into Study Reach NF4 above Rabbit Creek hydrologic conditions would be the same as Study Reach NF3, with and without the project. Active encroachment of vegetation is also noted in this reach and a trajectory of channel narrowing is predicted under Future Conditions. Increases noted in sediment transport potential attributed to increased low flows associated with Fort Collins’ Proposed Action would not be likely to provide benefit or manifest as an adverse impact to morphology. Therefore, Fort Collins’ Proposed Action would have minor to negligible impacts on the rate of change.</td>
<td>Tendencies toward sediment accumulation and vegetation encroachment on channel margins was noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Slight increases in sediment transport potential under Fort Collins’ Proposed Action would not be likely to change the trend or rate of change.</td>
<td></td>
</tr>
</tbody>
</table>
5 North Fork - Effects of No-Action Alternative versus Future Conditions

This Chapter presents a brief discussion of the effects of the No-Action Alternative relative to Future Conditions on the North Fork. Hydrology for the No-Action Alternative (NA4) is compared against Future Conditions (Run 2) and used in a range of various analyses. We have provided all analytical results, in graphical and tabular form, associated with the comparison of the No-Action Alternative versus Future Conditions on the North Fork in Volume II, Appendix E of this report. A listing of all comparison figures and tables in Volume II that corresponds to each analysis is provided at the top of each section.

5.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figure E-1 (Appendix E, Volume II)
North Fork Baseline Report Section 4.2 (Anderson Consulting Engineers, Inc. 2017)

Changes in monthly flows associated with the No-Action Alternative would be negligible (less than 1 percent).

5.2 Daily Flow Frequency and Duration

Refer to Appendix Figures E-2 and E-3, Appendix Tables E-1 through E-15 (Appendix E, Volume II)

A comparison of seasonal daily flow statistics and flow frequency indicates that there would be negligible change between Future Conditions and the No-Action Alternative.

5.3 Flood Frequency

Refer to Appendix Figure E-4 and Appendix Table E-16 and E-17 (Appendix E, Volume II)
North Fork Baseline Report Section 4.5 (Anderson Consulting Engineers, Inc. 2017)

There would be no change in flood frequency between Future Conditions and the No-Action Alternative.
## 5.4 Bankfull Flows

Refer to Appendix Figures E-5 and E-6, Appendix Tables E-18 and E-19 (Appendix E, Volume II)
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

A comparison of the occurrence and duration of bankfull flows in the unconfined study reaches NF4 and NF5 indicates no change with the No-Action Alternative.

## 5.5 Flushing Flows

Refer to Appendix Figures E-7 and E-11, Appendix Tables E-20 and E-21 (Appendix E, Volume II)
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

There would be no change in the occurrence and duration of flushing flows under the No-Action Alternative.

## 5.6 Channel Maintenance Flows

### 5.6.1 Analysis at all Cross Sections

Refer to Appendix Figure E-12 (Appendix E, Volume II)
North Fork Baseline Report Section 6.2.3 (Anderson Consulting Engineers, Inc. 2017)

We compared the duration for which channel maintenance flows would be expected to occur under Future Conditions and the No-Action Alternative at 349 cross sections throughout the study area (Appendix Figure E-12). The comparison shows no change, except for a few outlying points where percent changes are a function of slight changes at an extremely small flow magnitude.

### 5.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure E-13, Appendix Tables E-22 and E-23 (Appendix E, Volume II)
North Fork Baseline Report Section 6.2.4 (Anderson Consulting Engineers, Inc. 2017)

The occurrence and duration of channel maintenance flows at representative cross sections are identical between Future Conditions and the No-Action Alternative, indicating no change.
5.7 Flows that Move Coarse Bed Material

Refer to Appendix Figure E-14 (Appendix E, Volume II)
North Fork Baseline Report Section 6.2.7 (Anderson Consulting Engineers, Inc. 2017)

Appendix Figure E-14 compares the duration for which bed material movement would be expected to occur under Future Conditions and the No-Action Alternative. Results indicate no change in the duration.

5.8 Stream Power

Refer to Appendix Figures E-15 through E-18 (Appendix E, Volume II)
North Fork Baseline Report Section 6.3 (Anderson Consulting Engineers, Inc. 2017)

Total work and work in excess of the stream power required to move bed material would not change under the No-Action Alternative.

5.9 Sediment Transport Potential

Refer to Appendix Figure E-19, Appendix Tables E-24 and E-25 (Appendix E, Volume II)
North Fork Baseline Report Section 7.1.2 (Anderson Consulting Engineers, Inc. 2017)

There would be negligible change (less than 1 percent) in sediment transport potential under the No-Action Alternative.

5.10 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figure E-20 and E-21 (Appendix E, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

The distribution of sediment transport potential over a range of flows would also be unaffected by the No-Action Alternative.

5.11 Effective Discharge Spells

Refer to Appendix Figures E-22 to E-28, Appendix Tables E-26 and E-27 (Appendix E, Volume II)
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

There would be no change in the occurrence and negligible change in the duration of effective discharge with the No-Action Alternative.
5.12 Overview of Effects of No-Action Alternative on Sediment Transport and River Morphology

Based largely on an observational model of response to Future Conditions hydrology, there would be no impact on the river trajectory under the No-Action Alternative.
6 North Fork – Cumulative Effects with Fort Collins’ Proposed Action versus Future Conditions

This Chapter presents a discussion of Cumulative Effects with Fort Collins’ Proposed Action relative to Future Conditions on the North Fork. Hydrology for Cumulative Effects with Fort Collins’ Proposed Action (PA5) is compared against Future Conditions (Run 2) and used in a range of various analyses. Cumulative Effects hydrology (PA5) combines Fort Collins’ Proposed Action, NISP’s Proposed Action, the Seaman Project’s Proposed Action, and RFFAs.

The discussion provided in this chapter relies heavily on the detailed assessment presented in Chapter 4 which compared Fort Collins’ Proposed Action versus Future Conditions. This Chapter does not repeat the detailed descriptions of Chapter 4 for the cumulative effects comparison. Instead, it reports by exception – identifying areas where differences between the Fort Collins’ Proposed Action comparison from Chapter 4 and Cumulative Effects with Fort Collins’ Proposed Action comparison could be important and, where feasible, presenting a “comparison of the comparisons”.

Full documentation, including figures and tables, associated with the comparison of Cumulative Effects with Fort Collins’ Proposed Action versus Future Conditions can be found in Volume II, Appendix F of this report. A listing of all comparison figures and tables in Volume II that corresponds to each analysis is provided at the top of each section. The location within the North Fork Baseline Report where corresponding baseline condition analysis can be found is also listed at the top of each analysis section. Discussions provided in the sections below refer to Cumulative Effects with Fort Collins’ Proposed Action as ‘Cumulative Effects’.

6.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figure F-1 (Appendix F, Volume II)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.1
North Fork Baseline Report Section 4.2 (Anderson Consulting Engineers, Inc. 2017)

At the Livermore Gage, changes in average monthly flow for Cumulative Effects shows results comparable to those of Fort Collins’ Proposed Action alone (Figure 6-1). Average monthly flows would decrease in the high flow months of May through August; however, monthly flow volumes appear to decrease just slightly more in June and August with Cumulative Effects. Average monthly flows would increase for all other months. Some differences in the percent change are noted for Cumulative Effects, however these changes are minimal when considering the absolute magnitude of change.
Figure 6-1. Change in average monthly flow for Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
6.2 Daily Flow Frequency and Duration

Refer to Appendix Figures F-2 and F-3, Appendix Tables F-1 through F-15 (Appendix F, Volume II)  
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.2  

Changes in seasonal daily flow statistics for Cumulative Effects indicate results similar to those of Fort Collins’ Proposed Action. During the low flow season, increases in average daily flows relative to Future Conditions would be similar in magnitude. During the high flow runoff months (April 16th through July 15th), the percent change in average daily flows would generally be the same (within 1 percent), with reduction in flow being slightly more for Cumulative Effects downstream of Seaman Reservoir (Study Reach NF7).

A key observation from the plotted frequency distributions of daily flows (Appendix Figure F-2) is the reduction in flows at or above approximately 100 cfs and an increase in flows at or below approximately 100 cfs throughout the study area. For flows greater than 1,000 cfs, there would be a slightly larger reduction in duration noted downstream of Seaman Reservoir.

Compared to Fort Collins’ Proposed Action, Cumulative Effects would have a similar impact on flows equaled or exceeded 2 percent of the time. These flows are critical to morphology and sediment transport. Figure 6-2 compares the reduction in 2 percent exceedance flows with and without Cumulative Effects. Results indicate that reduction in flows for Fort Collins’ Proposed Action Cumulative Effects would be slightly less but within a margin of 1 to 2 percent. Cumulative effects would have the same impact on morphology and sediment transport as described in Chapter 4 for Fort Collins’ Proposed Action.

The number of zero flow days for Fort Collins’ Proposed Action Cumulative Effects would be reduced with generally the same magnitude as Fort Collins’ Proposed Action. Benefits associated with a reduction in the number of zero flow days with and without Cumulative Effects would be the same.
Figure 6-2. Percent change in 2 percent exceedance discharge Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
6.3 Flood Frequency

Refer to Appendix Figure F-4 and Appendix Tables F-16 and F-17 (Appendix F, Volume II)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.3
North Fork Baseline Report Section 4.5 (Anderson Consulting Engineers, Inc. 2017)

In general, the 2-, 5-, and 10-year flood discharges would be reduced by Fort Collins’ Proposed Action and Cumulative Effects to a similar degree. Reductions in flood discharge would be slightly less for Cumulative Effects. A comparison of change in the 2-year flood discharge is shown graphically in Figure 6-3. Under Cumulative Effects, reduction in the 2-year discharge would be the same through Phantom Canyon (Study Reaches NF2 and NF3) but slightly less for the remainder of the reach.

6.4 Bankfull Flows

Refer to Appendix Figures F-5 and F-6, Appendix Tables F-18 and F-19
(Appendix F, Volume II)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.4
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

Bankfull discharge can be an important hydraulic and morphologic parameter. A comparison of the occurrence and duration of bankfull flows in the unconfined study reaches NF 4 and NF5 indicates no change for Fort Collins’ Proposed Action or Cumulative Effects.

6.5 Flushing Flows

Refer to Appendix Figures F-7 and F-11, Appendix Tables F-20 and F-21
(Appendix F, Volume II)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.5
North Fork Baseline Report Section 5.2 (Anderson Consulting Engineers, Inc. 2017)

Change in the occurrence and duration of flushing flows for Cumulative Effects would be slightly less than Fort Collins’ Proposed Action. Changes would be identical in Study Reach NF2, between Halligan Reservoir and the North Poudre Canal Diversion. Reduction in the number of years of occurrence for Cumulative Effects downstream of the North Poudre Canal would be one year less relative to Fort Collins’ Proposed Action (Figure 6-4). Changes in the duration of flushing flows would be similar.
Figure 6-3. Percent change in 2-year flood discharge Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
Figure 6-4. Change in number of years of occurrence of flushing flows Fort Collins’ Proposed Action and Cumulative Effects vs Future Conditions.
6.6 Channel Maintenance Flows

Refer to Appendix Figure F-12 (Appendix F, Volume II)  
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.6.1  
North Fork Baseline Report Section 6.2.3 (Anderson Consulting Engineers, Inc. 2017)

Change in the duration of channel maintenance flows, evaluated at 349 cross sections throughout the study reach, for Cumulative Effects would be generally the same when compared with Fort Collins’ Proposed Action (Figure 6-5). Slight differences are noted at some individual cross sections; however, the overall trends across the study area would be the same.

6.7 Flows that Move Coarse Bed Material

Refer to Appendix Figure F-14 (Appendix F, Volume II)  
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.7  
North Fork Baseline Report Section 6.2.7 (Anderson Consulting Engineers, Inc. 2017)

Change in the duration of flows that move coarse bed material, evaluated at 349 cross sections throughout the study reach, would generally be the same for Cumulative Effects as for Fort Collins’ Proposed Action (Figure 6-6). Slight differences are noted at some individual cross sections between Cumulative Effects and Fort Collins’ Proposed Action; however, the overall trends across the study area would be the same.

6.8 Stream Power

Refer to Appendix Figures F-15 through F-18 (Appendix F, Volume II)  
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.8  
North Fork Baseline Report Section 6.3 (Anderson Consulting Engineers, Inc. 2017)

Both the total stream power and the stream power above incipient motion show a similar pattern. The stream power would be reduced by up to about 50 percent compared to Future Conditions, generally about 5 percent more with the Cumulative Effects than for NISP Alternative 2 (Run 4a). Work above incipient motion shows a greater impact with a decrease up to 60 percent. Fort Collins’ Proposed Action would account for 5 to 15 percent of this change.

Figure 6-7 illustrates the percent change from Future Conditions in total work for Fort Collins’ Proposed Action and Cumulative Effects. Similar trends in the resulting changes are noted. Similarly, Figure 6-8 shows a comparison of change in total work above the threshold of motion for Fort Collins’ Proposed Action and Cumulative Effects. The graphical results indicate little to no change in movement of bed material.
Figure 6-5. Percent change in the duration of channel maintenance flows Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
Figure 6-6. Percent change in duration of bed material movement Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
Figure 6-7. Percent change in total work Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
Figure 6-8. Percent change in total work in excess of stream power Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
6.9 Sediment Transport Potential

Refer to Appendix Figure F-19, Appendix Tables F-24 and F-25 (Appendix F, Volume II)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.9
North Fork Baseline Report Section 7.1.2 (Anderson Consulting Engineers, Inc. 2017)

Change in average annual sediment transport potential for Fort Collins’ Proposed Action and Cumulative Effects, relative to Future Conditions, is shown in Figure 6-9. In Study Reach NF2, upstream of the North Poudre Canal Diversion, change would be the same. Between the North Poudre Canal Diversion and Seaman Reservoir, Fort Collins’ Proposed Action would increase the average annual sediment transport slightly more than Cumulative Effects. Downstream of Seaman Reservoir, the opposite trend is noted.

6.10 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figure F-20 and F-21 (Appendix F, Volume II)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.10
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

Results of the magnitude-duration analysis demonstrating how sediment transport potential is distributed across the flow range for Future Conditions, Fort Collins’ Proposed Action, and Cumulative Effects are shown in Figure 6-10. The peak of the magnitude-duration curves indicate what discharge would be most effective at transport sediments. Changes in the shape of the curve can give insight into how channel morphology could be changing. The shape of the curves for Fort Collins’ Proposed Action and Cumulative Effects are generally the same.

6.11 Effective Discharge Spells

Refer to Appendix Figures F-22 to F-28, Appendix Tables F-26 and F-27
(Appendix F, Volume II)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 4, Section 4.11
North Fork Baseline Report Section 7.1.3 (Anderson Consulting Engineers, Inc. 2017)

The occurrence of effective discharge would be the same for Fort Collins’ Proposed Action and Cumulative Effects throughout the study area, with the exception of Study Reach NF7. Cumulative Effects shows one additional year of occurrence in Study Reach NF7. Reduction in the average duration of effective discharge, relative to Future Conditions, would be slightly less for Cumulative Effects. However, the difference between Fort Collins’ Proposed Action and Cumulative Effects would be small and not likely to manifest in differing results.
Figure 6-9. Percent change in average annual sediment transport Fort Collins’ Proposed Action and Cumulative Effects versus Future Conditions.
Figure 6-10. Distribution of sediment transport potential with flow Future Conditions, Fort Collins’ Proposed Action, and Cumulative Effects.
6.12 Overview of Cumulative Effects with Fort Collins’ Proposed Action on Sediment Transport and River Morphology

An overview of the comparative assessment of Cumulative Effects with Fort Collins’ Proposed Action versus Future Conditions is provided in Table 6-1.

Results of the individual analyses for Cumulative Effects, discussed above relative to Fort Collins’ Proposed Action, do not indicate a strong signal of difference. The Cumulative Effects on the future trajectory of river conditions would be the same as those predicted with Fort Collins’ Proposed Action alone (Chapter 4).
### Table 6-1: Overview of the Cumulative Effects with Fort Collins’ Proposed Action versus Future Conditions.

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<thead>
<tr>
<th>Analysis</th>
<th>Study Reach NF2: Halligan Reservoir to North Poudre Canal Diversion</th>
<th>Study Reaches NF3 and NF4: North Poudre Canal Diversion to Rabbit Creek</th>
<th>Study Reaches NF5, NF6, and NF7: Rabbit Creek to Confluence</th>
<th>Impact Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal Average Daily Discharge</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows would be reduced by 6 percent. This reduction is considered minor to negligible. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. Note that increased low flows would have a negligible impact on morphology and sediment transport.</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows would be reduced by 8 percent. This reduction is considered minor. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. Note that increased low flows would have a negligible impact on morphology and sediment transport.</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows would be reduced by up to 6 percent. This reduction is minor to negligible. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. Note that increased low flows would have a negligible impact on morphology and sediment transport.</td>
<td>Change in Flow Regime</td>
</tr>
<tr>
<td>2 Percent Exceedance Discharge</td>
<td>The 2 percent exceedance discharge would be reduced by 6 percent. This reduction is minor.</td>
<td>The 2 percent exceedance discharge would be reduced by 7 percent. This reduction is minor.</td>
<td>The 2 percent exceedance discharge would be reduced by up to 8 percent. This reduction is considered minor.</td>
<td></td>
</tr>
<tr>
<td>Zero Flow Days</td>
<td>The Future Condition hydrology indicates a total of 130 days where flow in the river is zero. The number of zero flow days would be reduced to 11 under Cumulative Effects. This would likely benefit other resources but would have a negligible impact relative to morphology and sediment transport.</td>
<td>Future Condition hydrology indicates a total of 1,014 days where flow in the river is zero. The number of zero flow days would be significantly reduced to 388 days under Cumulative Effects. This would likely benefit other resources but would have a negligible impact relative to morphology and sediment transport.</td>
<td>There would be no change in the number of zero flow days between Future Conditions and Cumulative Effects.</td>
<td></td>
</tr>
<tr>
<td>2-Year Flood Discharge</td>
<td>The 2-year flood discharge would be reduced by 6 percent. This reduction is considered minor.</td>
<td>The 2-year flood discharge would be reduced by 12 percent. This reduction is minor.</td>
<td>The 2-year flood discharge would be reduced by up to 9 percent. This reduction is minor.</td>
<td></td>
</tr>
<tr>
<td>Flushing Flows</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer shows no change under Cumulative Effects. The average annual recurrence interval of flushing flows, also unchanged, would be 1.9 years.</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer would be reduced from 12 to 10 years by Cumulative Effects. In other terms, the average annual recurrence interval would increase from 1.6 years to 1.9 years. This change would have a minor to negligible effect on flushing.</td>
<td>The total number of years of occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer upstream of Seaman Reservoir (study reaches NF5 and NF6) would be reduced from 11 years to 10 years by Cumulative Effects. The average annual recurrence interval of flushing flows would increase from 1.7 years to 1.9 years. Below Seaman Reservoir the number of years of flushing occurrence would be the same, with a corresponding increase in average annual recurrence interval of 1.9 years. These changes would have a minor to negligible effect on flushing.</td>
<td>Fining of Surficial Material</td>
</tr>
<tr>
<td>Channel Maintenance Flows</td>
<td>Cumulative Effects would reduce the duration of channel maintenance flows at 37 (out of 108) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be reduced by an average of 8 percent. This would have minor to negligible impacts on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
<td>Cumulative Effects would reduce the duration of channel maintenance flows at 9 (out of 37) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be reduced by an average of 12 percent. This would have minor to negligible impacts on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
<td>Cumulative Effects would reduce the duration of channel maintenance flows at 25 (out of 167) cross sections. The overall duration (over the 19-year model period) of channel maintenance flows would be reduced by an average of 9 percent. This would have minor to negligible impacts on the ability of the river to remove sediments from the interstices of the coarse armor layer.</td>
<td></td>
</tr>
<tr>
<td>Movement of Bed Material</td>
<td>Cumulative Effects would reduce the duration of bed material movement at 10 (out of 108) cross sections in this reach. The duration of bed material movement at these locations would be reduced by an average of 19 percent under Cumulative Effects. These reductions were not found to be spatially</td>
<td>Cumulative Effects would reduce the duration of bed material movement at 1 (out of 37) cross sections in this reach. Overall there would be a negligible impact to channel structure or morphologic complexity in this reach.</td>
<td>Cumulative Effects would reduce the duration of bed material movement at 9 (out of 167) cross sections in this reach. The duration of bed material movement at these locations would be reduced by an average of 16 percent under Cumulative Effects. These reductions were not found to be spatially</td>
<td>Loss of Morphologic Complexity</td>
</tr>
</tbody>
</table>
**Anderson Consulting Engineers, Inc.**

**HALLIGAN WATER SUPPLY PROJECT**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Study Reach NF2: Halligan Reservoir to North Poudre Canal Diversion</th>
<th>Study Reaches NF3 and NF4: North Poudre Canal Diversion to Rabbit Creek</th>
<th>Study Reaches NF5, NF6, and NF7: Rabbit Creek to Confluence</th>
<th>Impact Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Discharge</td>
<td>There would be no change in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This would have a negligible impact.</td>
<td>There would be no change in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This would have a negligible impact.</td>
<td>There would be no change in the number of years in which effective discharge would occur and little to no change in the duration of effective discharge. This would have a negligible impact.</td>
<td>Channel Contraction</td>
</tr>
<tr>
<td>Sediment Transport</td>
<td>Average annual sediment transport potential above the North Poudre Canal Diversion shows less than 2 percent change. Evaluation of transport rates over a range of flows indicates that there would be a reduction of approximately 10 percent in transport during high flow periods that move coarse materials. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Average annual sediment transport increases by approximately 3 percent under Cumulative Effects. Evaluation of transport rates over a range of flows indicates that there would be a reduction of approximately 10 percent in transport during high flow periods that move coarse materials. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Average annual sediment transport increases by approximately 5 to 7 percent under Cumulative Effects. Evaluation of transport rates over a range of flows indicates that there would be a reduction of approximately 10 percent in transport during high flow periods that move coarse materials. For flows less than 100 cfs, transport rates would increase, which would not impact movement of the coarse armor layer material. This would result in minor to negligible effects to morphology.</td>
<td>Channel Contraction</td>
</tr>
<tr>
<td>Sediment Transport</td>
<td>Evaluation of Future Conditions indicate that while sands and silts could be readily mobilized through this reach there is evidence of deposition on margins and mid-channel bars during low flow periods that could support vegetation. The trajectory of the river includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. This trajectory would be expected to be interrupted from time to time with the occurrence of large floods that are unaffected by Halligan Reservoir. Cumulative Effects do not impact the total sediment transport potential (less than 2 percent change). Therefore, minor to negligible changes in morphology would be expected with Cumulative Effects.</td>
<td>This reach has historically experienced the largest hydrologic and morphologic change within the study area. The trajectory of the river in this section would be a continuation of observed diminution by vegetation encroachment and associated deposition of fine material on channel margins. Within Phantom Canyon below the North Poudre Canal Diversion (Study Reach NF3), pool margins and riffle areas have been invaded upon by vegetation (mainly willows). It is expected that the channel in this reach would continue to lose definition in the long term under Future Conditions. Steeper slopes within the canyon could allow for scour during large floods not influenced by Halligan Reservoir or Future Conditions hydrology. Increases in sediment transport potential under Cumulative Effects would provide little benefit and would likely not have an impact on the rate of change.</td>
<td>Tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Slight increases in sediment transport potential under Cumulative Effects would not be likely to change the trend or rate of river trajectory.</td>
<td>Channel Contraction</td>
</tr>
</tbody>
</table>

Fine material released from Halligan Reservoir would temporarily impact the well-defined pool-riffle morphology in the reach until it was remobilized and flushed downstream. Under Future Conditions, low flows (less than 100 cfs) would be capable of transporting sands and silts. Under Cumulative Effects the duration of flows less than 100 cfs would increase. However, the ability of the river to flush fine sediments released from Halligan Reservoir would likely not change.

As the river emerges from Phantom Canyon into Study Reach NF4 above Rabbit Creek, hydrologic conditions would be the same as Study Reach NF3, with and without the project. Active encroachment of vegetation is also noted in this reach and a trajectory of channel narrowing is predicted under Future Conditions. Increases noted in sediment transport potential attributed to increased low flows associated Fort Collins’ Proposed Action Cumulative Effects would not be likely to provide benefit or manifest as an adverse impact to morphology. Therefore, Cumulative Effects would have minor to negligible impacts on the rate of change.
7 North Fork – Summary of Effects

7.1 Summary of Effects under Current Conditions

As indicated in Chapter 1, the trajectory of river condition predicted in the North Fork Baseline Report under a continuation of Current Conditions includes channel contraction, fining of surficial material, and loss of channel complexity.

Sediment transport and morphologic analyses have endeavored to quantify or at least provide some relative scale to the predicted effects of Fort Collins’ Proposed Action relative to Current Conditions. The results of the analyses are summarized in Table 7-1. Interpretations of the results in previous chapters have avoided using value judgments and qualitative relative descriptors (like ‘large’ or ‘small’, ‘significant’ or ‘insignificant’, etc.) as much as possible. To achieve consistency with other resource specialists, the following determination of overall effects have been applied to results presented in Table 7-1:

- Negligible: The effect would be at the lowest levels of detection, barely measurable, with no perceptible consequences.
- Minor: The action might result in a detectable change, but the change would be slight.
- Moderate: The action could result in a clearly detectable change, with measurable effects.
- Major: The action could result in readily apparent effects with substantial consequences.

Based on the information presented in this report and summarized in Table 7-1, the following conclusions about the effects of Fort Collins’ Proposed Action under Current Conditions are as follows.

- Assessments of the river condition between the North Poudre Canal Diversion and Rabbit Creek indicate that the process of channel contraction by vegetation encroachment and deposition of fine material on channel margins would continue under Current Conditions and Fort Collins’ Proposed Action. Changes in sediment transport potential under Fort Collins’ Proposed Action would not likely provide benefit or manifest as an adverse impact.

- Between Halligan Reservoir and the North Poudre Canal Diversion, the current trajectory of the river includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. Changes to the current trajectory are not predicted under Fort Collins’ Proposed Action. The ability of the river to flush fine sediments that are released from Halligan Reservoir would also see negligible change under Fort Collins’ Proposed Action.

- Current tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree
than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Slight increases in sediment transport potential under Fort Collins’ Proposed Action would not be likely to have an impact on the trend or rate of the current trajectory.

In summary, the trajectory of the river condition would be expected to continue under a continuation of Current Conditions and Fort Collins’ Proposed Action hydrology. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the North Fork Baseline Report would be expected to continue with negligible effect on morphology and sediment transport on the North Fork.
Table 7-1. Halligan Project Alternative effects under Current Conditions on the North Fork.

<table>
<thead>
<tr>
<th>Possible Impact</th>
<th>Fort Collins’ Proposed Action versus Current Conditions (PA3 versus Run 1)</th>
<th>Gravel Pits Alternative versus Current Conditions (GP3 versus Run 1)</th>
<th>Expanded Glade Alternative versus Current Conditions (EG3 versus Run 1)</th>
<th>Agricultural Reservoirs Alternative versus Current Conditions (AR3 versus Run 1)</th>
<th>Future Conditions versus Current Conditions (Run 2 versus Run 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Flow Regime</td>
<td>During high flow months (April 16 to July 15) that are critical to morphology, daily average flows would be reduced by 5 to 8 percent. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. The 2 percent exceedance discharge would be reduced by 7 to 9 percent. The 2-year flood discharge would be reduced by 6 to 12 percent, with the most reductions noted downstream of the North Poudre Canal Diversion.</td>
<td>Not applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Flows would be generally increased under Future Conditions hydrology. During high flow months (April 16 to July 15), daily average flows would increase up to 4 percent. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. The 2 percent exceedance discharge would be reduced by less than 3 percent. The 2-year flood discharge would increase by as much as 4 percent.</td>
</tr>
<tr>
<td>Fining of Surficial Material</td>
<td>The occurrence of flushing flows would be reduced downstream of the North Poudre Canal Diversion by 2 to 3 years. This could result in a minor impact to flushing flows that maintain riffles and support aquatic habitat. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists. The duration of channel maintenance flows would be reduced at 67 out of 349 cross sections by an average of 10 percent under Fort Collins’ Proposed Action. Reductions at individual cross sections would be largest between the North Poudre Canal Diversion and Rabbit Creek. This reduction could lead to fining of surficial material. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>The occurrence of flushing flows would increase by 1 year between the North Poudre Canal Diversion and Seaman Reservoir. Occurrence would decrease by 2 years downstream. There would be negligible change in duration of flushing flows throughout. The duration of channel maintenance flows would increase at 66 out of 349 cross sections by an average of 2 percent under Future Conditions. This change would be negligible.</td>
</tr>
<tr>
<td>Loss of Morphologic Complexity</td>
<td>Movement of bed material under Current Conditions hydrology would be spatially limited to 34 out of 349 cross sections. Under Fort Collins’ Proposed Action the duration of bed material movement would be reduced at 16 of the 34 cross sections by an average of 14 percent. A signal of change in the duration of flows that move coarse bed material was noted but was not found to be spatially prevalent.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Movement of bed material under Current Conditions hydrology is spatially limited to 34 out of 349 cross sections. Under Future Conditions the duration of bed material movement would increase at 15 of the 34 cross sections by an average of 8 percent. A slight signal of change in the duration of flows that move coarse bed material was noted but was not found to be spatially prevalent.</td>
</tr>
<tr>
<td>Channel Contraction</td>
<td>Average annual sediment transport potential shows negligible change upstream of the North Poudre Canal Diversion, and the current trajectory would not be predicted to change with Fort Collins’ Proposed Action. Downstream of the North Poudre Canal Diversion there would be an increase of up to 8 percent in average annual sediment transport potential. Transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse material (coarse sands and gravels) of approximately 10 percent. For flows less than 100 cfs, the transport of finer sands would increase. Given that there would be limited sediment supply, changes in sediment transport potential under Fort Collins’ Proposed Action would provide little benefit and would not be likely to have an impact on the trend or rate of the current trajectory.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Average annual sediment transport potential would increase by 3 percent upstream of the North Poudre Canal Diversion. Downstream of the North Poudre Canal Diversion there would be an increase of up to 8 percent in average annual sediment transport potential. Transport rates over a range of flows indicates that there would be a slight reduction in transport during high flow periods that move coarse material (coarse sands and gravels). For flows less than 400 cfs, the transport of finer sands would increase. Given that there would be limited sediment supply, changes in sediment transport potential under Future Conditions would not be likely provide benefit or adversely impact the trend or rate of current trajectory.</td>
</tr>
<tr>
<td>Determination of Effects</td>
<td>Effects of Fort Collins’ Proposed Action on geomorphology and sediment transport on the North Fork would be negligible.</td>
<td>The Gravel Pits Alternative would have no effect on the North Fork.</td>
<td>The Expanded Glade Alternative would have no effect on the North Fork.</td>
<td>The Agricultural Reservoirs Alternative would have no effect on the North Fork.</td>
<td>Effects of Future Conditions hydrology on geomorphology and sediment transport would be negligible throughout the system.</td>
</tr>
</tbody>
</table>
7.2 Summary of Effects under Future Conditions

A detailed description of the effects of Fort Collins’ Proposed Action and the No-Action Alternative under Future Conditions was reported in Chapter 4 and Chapter 5, respectively. This Chapter presents an overview of these comparisons.

It is important to note that evaluations of alternative effects are presented relative to Future Conditions hydrology. The evaluations therefore represent the difference between likely Future Conditions with the Halligan Project alternatives, and likely Future Conditions without the Halligan Project alternatives. Future conditions are described in Chapter 3 of this report. It is different from the Current Conditions described in the North Fork Baseline Report (ACE, 2017) which was a description based on the trajectory of Current Conditions without RFFAs. The difference between Current and Future Conditions was also presented in Chapter 3 and summarized in Table 7-1.

Based on the information presented in this report and summarized in Table 7-2, the following conclusions about the effects of Fort Collins’ Proposed Action under Future Conditions are as follows.

- Assessments of the river condition between the North Poudre Canal Diversion and Rabbit Creek indicates that the process of channel contraction by vegetation encroachment and deposition of fine material on channel margins would continue under Future Conditions and Fort Collins’ Proposed Action. Changes in sediment transport potential under Fort Collins’ Proposed Action would not likely provide benefit or manifest as an adverse impact.

- Between Halligan Reservoir and the North Poudre Canal Diversion, the future trajectory of the river includes a minor tendency towards marginal and mid-channel bar deposition and vegetation encroachment. Changes to the future trajectory are not predicted to occur under Fort Collins’ Proposed Action. The ability of the river to flush fine sediments that would be released from Halligan Reservoir would also see negligible change under Fort Collins’ Proposed Action.

- Current tendencies toward sediment accumulation and vegetation encroachment on channel margins were noted in the reaches below Rabbit Creek, but to a smaller degree than upstream. Tributary flows from Rabbit, Stonewall, and Pine creeks reduce the rate at which channel adjustments and encroachment occur over time. Slight increases in sediment transport potential under Fort Collins’ Proposed Action would not be likely to have an impact on the trend or rate of the river trajectory under Future Conditions.

In summary, the trajectory of the river condition would be expected to continue under Future Conditions and Fort Collins’ Proposed Action hydrology. Based largely on an observational model of response to Future Conditions hydrology, the river trajectory would be expected to have **negligible effect** on morphology and sediment transport on the North Fork.
### Table 7-2. Effects on the North Fork from Halligan Project alternatives under Future Conditions.

<table>
<thead>
<tr>
<th>Possible Impact</th>
<th>Fort Collins’ Proposed Action versus Future Conditions (PA4 versus Run 2)</th>
<th>Gravel Pits Alternative versus Future Conditions (GP4 versus Run 2)</th>
<th>Expanded Glade Alternative versus Future Conditions (EG4 versus Run 2)</th>
<th>Agricultural Reservoirs Alternative versus Future Conditions (AR4 versus Run 2)</th>
<th>No-Action Alternative versus Future Conditions (NA4 versus Run 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Flow Regime</td>
<td>During high flow months (April 16th – July 15th) that are critical to morphology, daily average flows would be reduced by 6 to 8 percent. Average daily flows in the fall (July 16 to September 30), winter (October to February), and spring (March to April 15) would increase. The 2 percent exceedance discharge would be reduced by 6 to 9 percent. The 2-year flood discharge would be reduced by 6 to 12 percent, with the most reductions occurring downstream of the North Poudre Canal Diversion.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>No change.</td>
</tr>
<tr>
<td>Fining of Surficial Material</td>
<td>The occurrence of flushing flows would be reduced downstream of the North Poudre Canal Diversion by 1 to 3 years. This could result in a minor impact to flushing flows that maintain riffles and support aquatic habitat. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists. The duration of channel maintenance flows would be reduced at 67 out of 349 cross sections by an average of 10 percent under Fort Collins’ Proposed Action. Reductions at individual cross sections would be largest between the North Poudre Canal Diversion and Rabbit Creek. This reduction could lead to fining of surficial material. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>No change.</td>
</tr>
<tr>
<td>Loss of Morphologic Complexity</td>
<td>Movement of bed material under Future Conditions hydrology would be spatially limited to 34 out of 349 cross sections. Under Fort Collins’ Proposed Action the duration of bed material movement would be reduced at 16 of the 34 cross sections by an average of 14 percent. A signal of change in the duration of flows that move coarse bed material was noted but was not found to be spatially prevalent.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>No change.</td>
</tr>
<tr>
<td>Channel Contraction</td>
<td>Average annual sediment transport potential shows negligible change upstream of the North Poudre Canal Diversion, and the future trajectory would not be predicted to change with Fort Collins’ Proposed Action. Downstream of the North Poudre Canal Diversion there would be an increase of up to 8 percent in average annual sediment transport potential. Transport rates over a range of flows indicates that there would be a reduction in transport during high flow periods that move coarse material (coarse sands and gravels) of approximately 10 percent. For flows less than 100 cfs the transport of finer sands would increase. Given that there would be limited sediment supply, changes in sediment transport potential under Fort Collins’ Proposed Action would provide little benefit and would likely not have an impact on the trend or rate of the future trajectory.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>Not Applicable.</td>
<td>No change.</td>
</tr>
<tr>
<td>Determination of Effects</td>
<td>Effects of Fort Collins’ Proposed Action on geomorphology and sediment transport on the North Fork would be <strong>negligible.</strong></td>
<td>The Gravel Pits Alternative would <strong>have no effect</strong> on the North Fork.</td>
<td>The Expanded Glade Alternative would <strong>have no effect</strong> on the North Fork.</td>
<td>The Agricultural Reservoirs Alternative would <strong>have no effect</strong> on the North Fork.</td>
<td>The No-Action Alternative would <strong>have no effect</strong> on the North Fork.</td>
</tr>
</tbody>
</table>
8 Main Stem - Effects of Fort Collins’ Proposed Action versus Current Conditions

This Chapter presents a detailed discussion of the effects of Fort Collins’ Proposed Action relative to Current Conditions on the Main Stem. Hydrology for Fort Collins’ Proposed Action (PA3) is compared against Current Conditions (Run 1) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of Fort Collins’ Proposed Action versus Current Conditions can be found in Volume II, Appendix G of this report.

8.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures G-1 and G-2 (Appendix G, Volume II)
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

The box and whisker plot of monthly flows is based on the full modeled monthly data set which covers the 56-year period from 1950 to 2005. The box and whisker plots (Figures G-1 and G-2) provide an overview of the predicted changes in overall flow volumes in the river because of Fort Collins’ Proposed Action over a longer time period than the 26-year period of daily data. The plots include the minimum, maximum, 25th and 75th percentiles, median, and average monthly flow volumes. Note that the average monthly value sometimes falls outside of the 25th to 75th percentile range. This indicates a non-normal distribution of flow that is associated with diversion patterns.

Subtle differences between Current Conditions and Fort Collins’ Proposed Action are noted at both the Canyon Gage and Lincoln Gage. Fort Collins’ Proposed Action would decrease average monthly flows by less than 5 percent in all months of the year at the Canyon Gage (Figure 8-1). Changes in average monthly flows at the Lincoln Gage during high flow months (May through July) would be negligible (less than plus or minus 1 percent), with reductions of up to 7 percent during low flow months (Figure 8-2).

Interpretation

Changes in monthly flow statistics under Fort Collins’ Proposed Action would be generally small. Reduction in average monthly flow would be less than 5 percent during high flow months that are critical to morphology and sediment transport at the Canyon Gage and less than plus or minus 1 percent at the Lincoln Gage.
Figure 8-1. Percent change in average monthly flow at the Canyon Gage – Fort Collins’ Proposed Action versus Current Conditions.

Figure 8-2. Percent change in average monthly flow at the Lincoln Gage – Fort Collins’ Proposed Action versus Current Conditions.
8.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures G-3 through G-10, Appendix Tables G-1 through G-3 (Appendix G, Volume II) Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

Changes in flow frequency along the Main Stem associated with Fort Collins’ Proposed Action would be slight. The amount of time the river flows at or above about 1,000 cfs would be reduced by less than 3 percent through the Laporte Reach above the Little Cache and New Mercer ditches. Below the Little Cache and New Mercer ditches, changes in the frequency of flows at or above 1,000 cfs would be plus or minus 1 percent. An increase in the duration of low flows, defined roughly between 50 to 150 cfs, of 3 to 10 percent is noted between the New Cache Ditch and the Greeley Gage.

Another way of expressing the change in the flow frequency distribution is to look at change in the discharge of a particular duration. The flow frequency tables (Appendix Tables G-1, G-2, and G-3) indicate that change in the 1, 2, and 5 percent exceedance discharges (flows exceeded 1, 2, and 5 percent of the time) would be negligible (plus or minus 3 percent). The 2 percent exceedance discharge would be slightly reduced by 1 to 2 percent (Figure 8-3).

The seasonality of changes in mean daily and maximum daily flow is illustrated in Appendix Figures G-7 to G-10. During the low flow winter months (October through February), mean daily flows would be slightly reduced above the New Cache Ditch and generally increased 5 to 10 percent below the ditch (Appendix Figure G-7). The same trend is noted during the spring months of March through April 15th (Appendix Figure G-8). During the high flow summer months, mean and maximum daily flows show negligible change (plus or minus 2 percent) (Appendix Figure G-9). Mean daily flows would be generally reduced throughout the length of the river by up to 4 percent during the fall months of July 15th through September (Appendix Figure G-10).

Interpretation

The magnitude of changes in flow frequency throughout the system are considered negligible. Similarly, seasonal change in daily flow statistics would also be negligible.
Figure 8-3. Percent change in 2 percent exceedance discharge – Fort Collins’ Proposed Action versus Current Conditions.
8.3 Flood Frequency Analysis

Refer to Appendix Figure G-11 and Appendix Tables G-4 and G-5 (Appendix G, Volume II) Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

It is important to note that this flood frequency analysis has been undertaken on the 26-year period of modeled daily flows. The analysis should not be compared with other flood frequency analyses for the river which are undertaken for a different purpose and based on much longer periods of record covering a wider range of flood peaks. Changes in the magnitude of the 2-year (Figure 8-4), 10-year, and 25-year floods would be plus or minus 3 percent (Appendix Table G-5).

**Interpretation**

Changes in the magnitude of floods associated with Fort Collins’ Proposed Action hydrology would be negligible.

8.4 Flushing Flows


(Note that flushing flow information is not provided in the Main Stem Baseline Report)

Flushing flows are defined as flows that flush or move sediments (sands and gravels) resting on top of the coarse bed material matrix (or armor layer) in riffles. Flushing flows allow for surface cleaning of riffles necessary to support ecological function of the river channel. Flushing flows are necessary to maintain spawning habitat for fish. Baseline flushing flows identified for comparative assessments were defined as flows having a recurrence interval of approximately 2-years relative to Current Conditions hydrology (Anderson Consulting Engineers, Inc. 2017).

The absolute difference in the number and duration of flushing flow spells is provided in Appendix Table G-7. A graphical comparison at each hydrologic node is provided in Appendix Figures G-12 to G-20. The annual maximum discharge for Fort Collins’ Proposed Action and Current Conditions are graphically compared with the flushing flow threshold at each flow node, see Appendix Figures G-21 to G-29.

The occurrence of flushing flows would be reduced by 2 years (from 15 years to 13 years) in the Laporte reach at hydrologic node 4, located between the Poudre Valley and Hansen Supply canals. However, the recurrence interval of flushing flows under Fort Collins’ Proposed Action at this location would remain on the order of 2-years. At hydrologic node 8, located between the Larimer County Canal and the Little Cache/New Mercer Ditch, the number of years of occurrence would be reduced by 1 year (from 13 years to 12 years). There was no change in the
Figure 8-4. Percent change in 2-year flood discharge – Fort Collins’ Proposed Action versus Current Conditions.
number of years of occurrence at all other locations. There would be slight reductions in the average duration of flushing flows throughout, however they are considered negligible. Comparison of the average annual recurrence interval of flushing flows is provided in Table 8-1. Fort Collins’ Proposed Action would increase the average annual recurrence interval from approximately 2.0 years to 2.2 in the Laporte Reaches, with no change in the Fort Collins and Timnath reaches.

**Interpretation**

Changes in the occurrence and duration of flushing flows would be negligible.

**Table 8-1. Comparison of flushing flow annual recurrence interval, Fort Collins’ Proposed Action and Current Conditions**

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Current Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laporte</td>
<td>2</td>
<td>2,406</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Laporte</td>
<td>4</td>
<td>2,337</td>
<td>1.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Laporte</td>
<td>7</td>
<td>2,250</td>
<td>1.9</td>
<td>1.9</td>
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<tr>
<td>Laporte</td>
<td>8</td>
<td>1,999</td>
<td>2.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Laporte</td>
<td>12</td>
<td>1,797</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Ft Collins</td>
<td>17</td>
<td>1,381</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Ft Collins</td>
<td>20</td>
<td>1,300</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Ft Collins</td>
<td>23</td>
<td>1,355</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Timnath</td>
<td>32</td>
<td>972</td>
<td>2.2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**8.5 Channel Maintenance Flows**

Channel maintenance flows are defined as the flow required to remove sediment trapped in between coarser material that comprises the bed material matrix (armor layer). For the CTP, a critical dimensionless shear stress was adopted to represent conditions when bed material moves sufficiently to just allow finer material to be released from the interstices of coarser surface layers of the bed. The geomorphic process related to channel maintenance flows is of ecological significance. Ecological criteria would consider not only the total duration of channel maintenance flows in the 26-year period but also the number of occurrences and the time between occurrences. The analysis reported in this section provides no information on specific
ecologic criteria, but the spells analysis (Section 8.5.2) presents information on the frequency and duration of channel maintenance flows.

This process and the applicability of this criterion are considered to be most important within reaches of the Main Stem located upstream of Interstate-25 where there is a gravel and cobble substrate that has been observed to be smothered by fine material between channel maintenance flow events. Channel maintenance flows also have some ecological relevance in the portion of the study area downstream of Interstate-25 where sands and silts can be flushed from bars and islands in high flows to reveal underlying gravels. The process downstream of Interstate-25 is considered to be controlled by criteria for general bed material movement rather than criteria for channel maintenance flows and is further discussed in Section 8.6.

### 8.5.1 Analysis at all Cross Sections

Refer to Appendix Figure G-30 (Appendix G, Volume II)
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

The duration for which channel maintenance flows would be expected to occur under Current Conditions and Fort Collins’ Proposed Action was compared at 407 cross sections. The results are shown for the whole river system, but the process is most important in the gravel and cobble bed reaches upstream of Interstate-25 (36 miles above South Platte confluence). The comparison demonstrates that the duration of channel maintenance flows would be consistently decreased in the Laporte Reach by up to 6 percent (Figure 8-5). Reductions in Fort Collins and Timnath range from 1 to 3 percent. In the remaining reaches located in Windsor and Greeley, duration would be both slightly increased and decreased generally by plus or minus 2 percent. Increases are noted at cross sections where channel maintenance flows would be between 50 and 150 cfs. Computations were conducted at all cross sections to capture the highly variable nature of hydraulic conditions along the river.

It is important to put this finding in the context that changes do not occur at all cross sections on the river. As described below, there are many other cross sections that the analysis predicts would not be impacted by a change in channel maintenance flow duration.

- In addition to the cross sections where a change in the duration of channel maintenance flow is shown, there are many cross sections where channel maintenance flows do not occur in the 26-year modeled period for either Current Conditions or Fort Collins’ Proposed Action; and others where no change in channel maintenance flow duration is predicted. Out of a total of 407 cross sections analyzed, 170 (42 percent) show no occurrence of channel maintenance flows during the modeled period. There are 237 cross sections (58 percent) where channel maintenance flows would occur. A total of 76 cross sections (out of 237) show no change in the duration of channel maintenance flows from Current Conditions to Fort Collins’ Proposed Action. Consequently, 161 cross sections (out to 237) show a change in duration with Fort Collins’ Proposed Action. The average reduction in duration computed at the 161 cross sections would be less than 1 percent.
Upstream of Interstate-25, out of 206 cross sections analyzed, 103 show an occurrence of channel maintenance flows during the modeled period and of those cross sections, 41 cross sections show no change in channel maintenance flow duration. At the remaining 62 cross sections the average reduction in duration would be 1 percent.

**Interpretation**

Analysis of channel maintenance flows address one process by which fining of surficial material could be an impact of Fort Collins’ Proposed Action. For the reaches upstream of Interstate-25, the information presented suggests a reduction in channel maintenance flow duration by as much as 6 percent at specific cross sections in the Laporte Reach. However, the average change in duration upstream of Interstate-25 would be less than 1 percent overall, which would be a negligible change. Similarly, the average change in duration downstream of Interstate-25 would be also less than 1 percent. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists. Further information to assist interpretation of ecological implications is provided in the following spells analysis (Section 8.5.2).
Figure 8-5. Percent change in the duration of channel maintenance flows – Fort Collins’ Proposed Action versus Current Conditions.
8.5.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures G-32 through G-39 and Appendix Tables G-8 to G-9 (Appendix G, Volume II)
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections by evaluating the occurrence of periods where channel maintenance shear stress criterion would be exceeded. These periods are illustrated graphically in Appendix Figures G-32 to G-39, and in tabular form in Appendix Tables G-8 and G-9 for both Current Conditions and Fort Collins’ Proposed Action. For the reach above Interstate-25, a change in channel maintenance flow occurrence is only noted at Cross Section 300786 in the Laporte Reach. At this section, there would be a loss of 2 channel maintenance events (6 events for Current Conditions and 4 under Fort Collins’ Proposed Action). The number of events at all other locations above Interstate-25 show no change.

**Interpretation**

In summary, upstream of Interstate-25, the spells analysis predicts a negligible reduction in number of events of channel maintenance flows in the Laporte Reach. Change at all other locations above Interstate-25 would be negligible.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes is best described by the analysis already reported in Section 8.5.1.

Taken together, this and the preceding analysis indicate a reduction in the number of channel maintenance events would be isolated to the Laporte Reach. The Laporte reach also shows a consistent reduction in the duration of channel maintenance flow of up to 6 percent. Reductions in duration in Fort Collins and Timnath reaches above Interstate-25 would be less. Overall, the duration of channel maintenance flows was found to be reduced by an average of approximately 1 percent based upon evaluation at all cross section upstream of Interstate-25. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

8.6 Flows that Move Coarse Bed Material

The point at which bed material in the bed of the river starts to move is a geomorphic threshold. The occurrence of bed material motion and the duration of flows above this threshold influence the size, shape, and dynamics of the river channel. For the CTP evaluation, initiation of motion was related to a critical shear stress which varies along the river according to the size of material present in the river bed. Upstream of Interstate-25, where the bed is generally armored, initiation of motion is particularly important because it represents the flow at which the armor layer is
broken, and underlying sediment is released. Downstream of Interstate-25, the frequency and duration of bed material motion provides an indication of the frequency and magnitude of sediment transport.

8.6.1 Analysis at all Cross Sections

Refer to Appendix Figure G-31 (Appendix G, Volume II)
Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

The duration of coarse bed material movement under Current Conditions and Fort Collins’ Proposed Action was compared at 407 cross sections. Throughout the river, durations of bed material movement under Fort Collins’ Proposed Action would generally differ from Current Conditions. Reduction in duration would be most notably consistent in the Laporte Reach where it would be no greater than 5 percent (Figure 8-6). In the reaches downstream of Laporte change in duration would be plus or minus 2.5 percent.

Upstream of Interstate-25, under Current Conditions, bed material movement would occur at 57 out of 206 cross sections (28 percent). Under Fort Collins’ Proposed Action, motion still would occur at these cross sections but with a change, both positive and negative, in duration noted at 29 of the cross sections. The average change in duration would be a reduction of less than 1 percent.

Downstream of Interstate-25, under Current Conditions bed material motion would occur at 122 out of 201 cross sections (59 percent). Under Fort Collins’ Proposed Action motion still would occur at these cross sections but for a reduced duration at 61 of the cross sections. For these 61 cross sections, the average change in the duration of motion would be less than 1 percent increase.

*Interpretation*

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. A signal of change in the duration of flows that move coarse bed material was not indicated in results of the analysis.
Figure 8-6. Percent change in duration of coarse bed material movement – Fort Collins’ Proposed Action versus Current Conditions.
8.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures G-32 through G-39 and Appendix Tables G-10 and G-11 (Appendix G, Volume II)
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

The reduction in bed material motion is further examined at selected representative cross sections by computing the occurrence of periods for which the shear stress criterion for initiation of motion would be exceeded. These periods are illustrated graphically in Appendix Figures G-32 to G-39 and in tabular form in Appendix Tables G-10 and G-11 9 for both Current Conditions and Fort Collins’ Proposed Action.

Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated. In the reaches below Interstate-25, there would be slight differences in the occurrence and average duration of episodes that move bed material, however they would be negligible.

*Interpretation*

Changes in the occurrence and duration of bed material motion under Fort Collins’ Proposed Action would be negligible.

8.7 Stream Power

Refer to Appendix Figures G-40 to G-43 (Appendix G, Volume II)
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Stream power can be calculated at each cross section for each flow in the modeled data sets. Summed over the 26-year modeled period (with appropriate units), stream power represents the ability of the flow to “do work” on the channel boundaries. Also of interest is the stream power in excess of the power that is required to initiate bed material motion. This can give an indication of the amount of “work” that can move the channel bed.

Upstream of Interstate-25, total flow energy would generally be unchanged with some slight reductions noted in the Laporte Reach (Figure 8-7). Downstream of Interstate-25 there would be increases in flow energy that would be generally limited to less than 5 percent, likely due to an increase in the occurrence of low flow between 50 and 150 cfs.

Differences generally disappear when looking at work in excess of the stream power required to move bed material. There would be generally a plus or minus 2 percent change in the “work” that the flow can do in moving the channel bed (Figure 8-8). These changes are considered negligible.
Figure 8-7. Percent change in total work – Fort Collins’ Proposed Action versus Current Conditions.

Figure 8-8. Percent change in total work above incipient motion – Fort Collins’ Proposed Action versus Current Conditions.
**Interpretation**

Changes noted in total work above Interstate-25 would be negligible. The increase in total work in the reaches below Interstate-25 reflects an increase in low flows between 50 and 150 cfs associated with Fort Collins’ Proposed Action hydrology. This increase is predicted to have limited morphologic consequence because it would occur at low stream powers where there is no channel adjustment. Most increases disappear in the comparison of work above the threshold of motion.

The comparisons show few instances of a decrease in energy available to move the bed. Increases shown would not be likely to manifest into adverse impacts.

### 8.8 Sediment Transport Potential

Refer to Appendix Figure G-44 and Appendix Tables G-12 and G-13 (Appendix G, Volume II)

Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Sediment transport potential is the capacity of the river to move sediment over the 26 years of modeled flows if that sediment were available to be moved. The results are presented separately for total bed material load, sand, gravel, and cobble sized material. Size gradations used in the sediment transport calculations reflect current gradations in the river bed. Note that transport potential of cobbles is zero under both Current Conditions and Fort Collins’ Proposed Action hydrology.

Upstream of Interstate-25, the total amount of material that could be moved would be slightly reduced by up to 3 percent (Figure 8-9). Transport potential for sand only would be reduced by up to 3 percent, and for gravels up to 3.4 percent. Downstream of Interstate-25 the total amount of material that could be moved would be slightly increased by up to 2.4 percent, or considering sand only, the increase would be as much as 3 percent. Transport potential for gravels downstream of Interstate-25 would increase a maximum of 1.7 percent.

**Interpretation**

Results of the change in sediment transport potential, both decreases and increases, are of such a small magnitude that effects are considered negligible.
Figure 8-9. Percent change in total average annual sediment transport potential – Fort Collins’ Proposed Action versus Current Conditions.
8.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figures G-45 through G-48 (Appendix G, Volume II)
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Figure 8-10 through Figure 8-12 compare magnitude-duration analyses for Current Conditions and Fort Collins’ Proposed Action. The curves demonstrate how sediment transport potential would be distributed across the flow range for Current Conditions and Fort Collins’ Proposed Action. The peak of the magnitude-frequency curve gives an indication of the effective discharge for the channel based on the sediment transport potential of the current bed material distribution for each reach in the SIAM model.

Note that the curves presented here differ from the curves shown in the Main Stem Baseline Report in two respects.

1. The Main Stem Baseline Report illustrated magnitude-frequency analyses for each of the standard particle size intervals in each reach as if each particle size interval were the only size in transport. To simplify the comparison between scenarios, the presentation herein shows a single curve that is based on accumulating the sediment transport potential for each size interval in proportion to the size distribution of the bed material.

2. The Main Stem Baseline Report presented the magnitude-frequency analysis based on 15 logarithmically distributed discharge intervals. For the comparisons reported here, the range of discharges has been increased to include the first discharge interval with zero occurrences and the size of the discharge interval has been increased so that the number of discharge intervals is reduced.

A comparison of the magnitude-frequency curves between Current Conditions and Fort Collins’ Proposed Action was provided to determine if hydrologic changes under Fort Collins’ Proposed Action would be likely to affect channel morphology. The following are types of indicators of change.

- A change in the location of the peak of the magnitude-frequency curve gives an indication of a change in effective discharge.
- A change in the magnitude and shape of the peak gives an indication of the change in the strength of the effective discharge signal.
- A change in the area under the curve gives an indication of the change in average annual sediment transport potential (allowing for the log scale).
- The area between the curves demonstrates the change in annual sediment transport
potential (allowing for the log scale).

- Changes in the distribution of sediment transport potential across the flow range (see the histograms) show the flow intervals where sediment transport potential would be most affected by the change in hydrology.

Negligible change was noted in comparison of the curves for Fort Collins’ Proposed Action and Current Conditions.

**Interpretation**

Effect of Fort Collins’ Proposed Action on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 8-10. Distribution of sediment transport potential with flow in Laporte reaches – Fort Collins’ Proposed Action versus Current Conditions.
Figure 8-11. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches—Fort Collins' Proposed Action versus Current Conditions.
Figure 8-12. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches –Fort Collins’ Proposed Action versus Current Conditions.
8.10 Overview of Effects of Fort Collins’ Proposed Action on Sediment Transport and River Morphology

In overview, the trajectory of the river condition would be expected to continue under both Current Conditions and Fort Collins’ Proposed Action hydrology with negligible impacts.

Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue both downstream of Interstate-25 than upstream of Interstate-25 with negligible effects due to Fort Collins’ Proposed Action.
9 Main Stem - Effects of the Gravel Pits Alternative versus Current Conditions

This Chapter presents a discussion of the effects of the Gravel Pits Alternative relative to Current Conditions on the Main Stem. Hydrology for the Gravel Pits Alternative (GP3) is compared against Current Conditions (Run 1) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of the Gravel Pits Alternative with Current Conditions can be found in Volume II, Appendix H of this report.

Discussion below relies heavily on the detailed assessment presented in Chapter 8 which compared Fort Collins’ Proposed Action versus Current Conditions. This Chapter does not repeat the detailed descriptions of Chapter 8 for the Gravel Pits Alternative. Instead, it reports by exception – identifying areas where differences between the Fort Collins’ Proposed Action versus Current Conditions comparison and the Gravel Pits Alternative versus Current Conditions comparison could be important and, where feasible, presenting a “comparison of the comparisons”.

9.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures H-1 and H-2 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.1
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

During high flow months critical to morphology and sediment transport (May, June, and July), reduction in average monthly flow at the Canyon Gage would be less for the Gravel Pits Alternative than Fort Collins’ Proposed Action (Figure 9-1). This reflects the effect of diverting water upstream of the North Fork confluence associated with Fort Collins’ Proposed Action. However, reductions in average monthly flow volumes for both alternatives would still be less than 5 percent, which would be considered small. During most of the low flow months the Gravel Pits Alternative would reduce average monthly flows more than Fort Collins’ Proposed Action.

At the Lincoln Gage, the same trends of change are noted for the Gravel Pits Alternative and Fort Collins’ Proposed Action. During high flow months (May, June, and July) critical to geomorphology and sediment transport, there would be negligible change shown for both comparisons (Figure 9-2). Reduction in the average monthly flow volumes during low flow months would be slightly more under the Gravel Pits Alternative.

Interpretation

Changes in monthly flow statistics under the Gravel Pits Alternative would generally be small. Reduction in average monthly flow would be less than 4 percent during high flow months that...
are critical to morphology and sediment transport at the Canyon Gage and less than plus or minus 1 percent at the Lincoln Gage.

Figure 9-1. Percent change in average monthly flow volumes at Canyon Gage – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.

Figure 9-2. Percent change in average monthly flow volumes at Lincoln Gage – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
9.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures H-3 through H-10, Appendix Tables H-1 through H-3 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.2
Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

Changes in flow frequency associated with the Gravel Pits Alternative would generally be similar in magnitude to changes associated with Fort Collins’ Proposed Action. A comparison of change in flows for both alternatives indicates subtle differences that would be spatially driven by varying operations. The 2 percent exceedance discharge (flow equaled or exceeded 2 percent of the time) is critical to geomorphology and sediment transport. Change in the 2 percent exceedance discharge with the Gravel Pits Alternative would be generally less than plus or minus 1 percent (Figure 9-3). This would be slightly less change but within less than 1 percent of change associated with Fort Collins’ Proposed Action.

**Interpretation**

The magnitude of changes in flow frequency throughout the system would be considered negligible. Similarly, seasonal change in daily flow statistics would also be negligible.

9.3 Flood Frequency Analysis

Refer to Appendix Figures H-11 and Appendix Tables H-4 and H-5 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.3
Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

Changes in the magnitude of the 2-year, 10-year, and 25-year floods would be plus or minus 2 percent under the Gravel Pits Alternative. Changes would be slightly less than Fort Collins’ Proposed Action (Figure 9-4), but both would be negligible relative to Current Conditions.

**Interpretation**

Changes in the magnitude of floods associated with Gravel Pits Alternative would be negligible.
Figure 9-3. Percent change in 2 percent exceedance discharge – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Figure 9-4. Percent change in 2-year flood discharge – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
9.4 Flushing Flows

Refer to Appendix Figures H-12 to H-29 and Appendix Tables H-6 and H-7 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.4
(Note that flushing flow information is not provided in the Main Stem Baseline Report)

Results of the comparative assessment of the occurrence and duration of flushing flows for the Gravel Pits Alternative are nearly the same when compared with Fort Collins’ Proposed Action. Reduction in the number of years of occurrence would be between 1 and 2 years, and spatially limited to the Laporte Reach for both alternatives (Figure 9-5). Reductions would be slightly less for the Gravel Pits Alternative.

Comparison of the average annual recurrence interval of flushing flows is provided in Table 9-1. Changes in the average annual recurrence interval would be negligible.

*Interpretation*

Changes in the occurrence and duration of flushing flows would be negligible under the Gravel Pits Alternative.

![Figure 9-5. Change in number of years of occurrence of flushing flows—Gravel Pits Alternative versus Fort Collins’ Proposed Action.](image-url)
Table 9-1. Comparison of flushing flow annual recurrence interval – Gravel Pits Alternative, Fort Collins’ Proposed Action, and Current Conditions

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Current Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
<th>Gravel Pits Alternative Annual Recurrence Interval (years)</th>
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</thead>
<tbody>
<tr>
<td>Laporte</td>
<td>2</td>
<td>2,406</td>
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<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Laporte</td>
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<tr>
<td>Laporte</td>
<td>7</td>
<td>2,250</td>
<td>1.9</td>
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</tr>
<tr>
<td>Laporte</td>
<td>8</td>
<td>1,999</td>
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<td>Laporte</td>
<td>12</td>
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<td>Timnath</td>
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<td>972</td>
<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

9.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

9.5.1 Analysis at all Cross Sections

Refer to Appendix Figure H-30 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.5.1
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Under the Gravel Pits Alternative, 155 cross sections (out of 407) would show a change in duration of channel maintenance flows. The duration of channel maintenance flows would be consistently decreased in the Laporte Reach by up to 6 percent (Figure 9-6). Reductions in Fort Collins and Timnath range from 1 to 3 percent. In the Windsor and Greeley reaches change in duration would be plus or minus 2 percent. The same general observations would be noted for both the Gravel Pits Alternative and Fort Collins’ Proposed Action (Figure 9-6), with slightly less change under the Gravel Pits Alternative.
Interpretation

The analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of the Gravel Pits Alternative. For the reaches upstream of Interstate-25, the information presented suggests a reduction in channel maintenance flow duration by as much as 6 percent at specific cross sections in the Laporte Reach. However, the average change in duration upstream of Interstate-25 would be less than 1 percent overall, which would be a negligible change. Similarly, the average change in duration downstream of Interstate-25 would be also less than 1 percent. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

9.5.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures H-32 to H-39 and Appendix Tables H-8 to H-9 (Appendix H, Volume II)

Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.5.2 Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections. Upstream of Interstate-25, there would not be a reduction in the number of channel maintenance flow events under the Gravel Pits Alternative. Downstream of Interstate-25 there would be some increases in the number of events. Changes would be similar for the Gravel Pits Alternative and Fort Collins’ Proposed Action (Figure 9-7).
Figure 9-6. Percent change in the duration of channel maintenance flows – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Interpretation

In summary, upstream of Interstate-25, the spells analysis does not predict a reduction in number of events of channel maintenance flows in the Laporte Reach. Change at all other locations above Interstate-25 would be negligible.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 9.5.1.

Taken together, this and the preceding analysis indicate a reduction in the number of channel maintenance events generally isolated to the Laporte and Fort Collins reaches. The duration of channel maintenance was found to also be slightly reduced (no more than 6 percent) based upon evaluation at all cross section upstream of Interstate-25. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

![Graph showing change in number of channel maintenance flow events for various sections.](image)

Figure 9-7. Change in number of channel maintenance flow events – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.

### 9.6 Flows that Move Coarse Bed Material

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as reach representative cross sections.
9.6.1 Analysis at all Cross Sections

Refer to Appendix Figure H-31 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.6.1
Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

Throughout the river, durations of bed material movement under the Gravel Pits Alternative and Fort Collins’ Proposed Action generally differ from Current Conditions by plus or minus 2.5 percent. Reduction in duration would be most notably consistent in the Laporte Reach where it would be as much as 5 percent. Reductions would be slightly less under the Gravel Pits Alternative (Figure 9-8).

Upstream of Interstate-25, under Current Conditions, bed material movement would occur at 57 out of 206 cross sections (28 percent). Under the Gravel Pits Alternative motion still would occur at these cross sections but with a change, both positive and negative, in duration noted at 26 of the cross sections. The average change in duration would be a reduction of less than 1 percent.

Downstream of Interstate-25, under Current Conditions bed material motion would occur at 122 out of 201 cross sections (59 percent). Under Fort Collins’ Proposed Action motion still would occur at these cross sections but for a reduced duration at 57 of the cross sections. For these 57 cross sections, the average change in the duration of motion would be less than 1 percent (increase).

Interpretation

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. A signal of change in the duration of flows that move coarse bed material was not indicated in results of the analysis.
Figure 9-8. Percent change in duration of coarse bed material movement – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
9.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure H-32 to H-39 and Appendix Tables H-10 and H-11 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.6.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

The reduction in bed material motion is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated for the Gravel Pits Alternative or Fort Collins’ Proposed Action (Figure 9-9). In the reaches below Interstate-25, there would be slight differences in the occurrence and average duration of episodes that move bed material, however they would be minimal.

*Interpretation*

Changes in the occurrence and duration of bed material motion under the Gravel Pits Alternative would be negligible.

9.7 Stream Power

Refer to Appendix Figures H-40 to H-43 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.7
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Under the Gravel Pits Alternative, total flow energy upstream of Interstate-25 would be generally unchanged with some slight reductions noted in the Laporte Reach. Downstream of Interstate-25, there would be slight increases in flow energy that would be generally limited to less than 5 percent, likely due to an increase in the occurrence of low flow between 50 and 150 cfs. These changes would be similar to Fort Collins’ Proposed Action (Figure 9-10), with the Gravel Pits Alternative showing slightly less change.

Change in total work in excess of stream power required to move bed material show a similar trend for both the Gravel Pits Alternative and Fort Collins’ Proposed Action (Figure 9-11).

*Interpretation*

Changes in total work above Interstate-25 would be negligible. The increase in total work in the reaches below Interstate-25 reflects an increase in low flows between 50 and 150 cfs associated with the Gravel Pits Alternative. This increase is predicted to have limited morphologic consequence because it would occur at low stream powers where there is no channel adjustment. Most increases disappear in the comparison of work above the threshold of motion.

Reductions in the total work in excess of stream power required to move bed material would be negligible. Increases shown would not be likely to manifest into adverse effect.
Figure 9-9. Change in number of events of coarse bed material movement – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Figure 9-10. Percent change in total work – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.

Figure 9-11. Percent change in total work above incipient motion – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
9.8 Sediment Transport Potential

Refer to Appendix Figure H-44 and Appendix Tables H-12 and H-13 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.8
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Change in average annual sediment transport potential for the Gravel Pits Alternative and Fort Collins’ Proposed Action relative to Current Conditions would generally be the same (Figure 9-12).

Upstream of Interstate-25 the total amount of material that could be moved would be slightly reduced by up to 3 percent under the Gravel Pits Alternative. Transport potential for sand would only be reduced by up to 2.5 percent, and for gravels up to 2.6 percent. Downstream of Interstate-25, the total amount of material that could be moved would be slightly increased by up to 2.4 percent, or considering sand only, the increase would be as much as 3 percent. Transport potential for gravels downstream of Interstate-25 would increase a maximum of 1.6 percent.

Interpretation

Results of the change in sediment transport potential, both decreases and increases, would be of such a small magnitude that effects would be considered negligible.
Figure 9.12. Percent change in average annual sediment transport potential – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Current Conditions.
9.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figures H-45 to H-48 (Appendix H, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.9
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

A comparison of the magnitude-frequency curves for the Gravel Pits Alternative, Fort Collins’ Proposed Action, and Current Conditions indicates little to no change (Figure 9-13, Figure 9-14, and Figure 9-15). Subtle change noted between curves are not likely to manifest as an adverse impact.

Interpretation

Effect of the Gravel Pits Alternative on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 9-13. Distribution of sediment transport potential with flow in Laporte reaches – Gravel Pits Alternative, Fort Collins’ Proposed Action, and Current Conditions.
Figure 9-14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Gravel Pits Alternative, Fort Collins’ Proposed Action, and Current Conditions.
Figure 9-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches – Gravel Pits Alternative, Fort Collins’ Proposed Action, and Current Conditions.
9.10 Overview of Effects of Gravel Pits Alternative on Sediment Transport and River Morphology

In overview, the trajectory of the river condition would be expected to continue under both Current Conditions and the Gravel Pits Alternative hydrology with negligible impacts.

Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue with negligible effects due to the Gravel Pits Alternative.

The effects of the Gravel Pits Alternative were found to be the same as Fort Collins’ Proposed Action. Evaluations indicated that the Gravel Pits Alternative would have just slightly less impact, but the difference would be unmeasurable.
10 Main Stem – Effects of the Agricultural Reservoirs Alternative versus Current Conditions

This Chapter presents a discussion of the effects of the Agricultural Reservoirs Alternative relative to Current Conditions on the Main Stem. Hydrology for the Agricultural Reservoirs Alternative (AR3) is compared against Current Conditions (Run 1) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of the Agricultural Reservoirs Alternative with Current Conditions can be found in Volume II, Appendix I of this report.

Discussion below relies heavily on the detailed assessment presented in Chapter 8 which compared Fort Collins’ Proposed Action versus Current Conditions. This Chapter does not repeat the detailed descriptions of Chapter 8 for the Agricultural Reservoirs Alternative. Instead, it reports by exception – identifying areas where differences between the Fort Collins’ Proposed Action versus Current Conditions comparison and the Agricultural Reservoirs Alternative versus Current Conditions comparison could be important and, where feasible, presenting a “comparison of the comparisons”.

10.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures I-1 and I-2 (Appendix I, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.1
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

During high flow months critical to morphology and sediment transport (May, June, and July), the reduction in average monthly flow at the Canyon Gage would be just slightly larger for the Agricultural Reservoirs Alternative when compared with Fort Collins’ Proposed Action (Figure 10-1). However, reductions in average monthly flow volumes for both alternatives would still be less than 5 percent, which would be considered small. During most of the low flow months the Agricultural Reservoir Alternative would reduce average monthly flows more than Fort Collins’ Proposed Action.

At the Lincoln Gage the same general trends of change are noted for the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action. During high flow months (May, June, and July) critical to geomorphology and sediment transport, there would be negligible change shown for both comparisons (Figure 10-2).
Figure 10-1. Percent change in average monthly flow volumes at Canyon Gage – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.

Figure 10-2. Percent change in average monthly flow volumes at Lincoln Gage – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.


Interpretation

Changes in monthly flow statistics under the Agricultural Reservoirs Alternative would be generally small. Reduction in average monthly flow would be less than 4 percent during high flow months that are critical to morphology and sediment transport at the Canyon Gage and less than plus or minus 1 percent at the Lincoln Gage.

10.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures I-3 through I-10, Appendix Tables I-1 through I-3 (Appendix I, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.2
Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

Changes in flow frequency associated with the Agricultural Reservoirs Alternative would generally be similar in magnitude to changes associated with Fort Collins’ Proposed Action. The 2 percent exceedance discharge (flow equaled or exceeded 2 percent of the time) is critical to geomorphology and sediment transport. Change in the 2 percent exceedance discharge with the Agricultural Reservoirs Alternative would be nearly the same as Fort Collins’ Proposed Action (Figure 10-3).

Interpretation

The magnitude of changes in high flow frequency throughout the system would be considered negligible. Similarly, seasonal change in daily flow statistics would also be negligible.

10.3 Flood Frequency Analysis

Refer to Appendix Figures I-11 and Appendix Tables I-4 and I-5 (Appendix I, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.3
Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

Changes in the magnitude of the 2-year, 10-year, and 25-year floods would be plus or minus 2 percent under the Agricultural Reservoirs Alternative. Reductions under the Agricultural Reservoirs Alternative would be slightly less than Fort Collins’ Proposed Action (Figure 10-4), however both show negligible change relative to Current Conditions.

Interpretation

Changes in the magnitude of floods associated with Fort Collins’ Proposed Action hydrology would be negligible.
Figure 10-3. Percent change in 2 percent exceedance discharge – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Figure 10-4. Percent change in 2-year flood discharge – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
10.4 Flushing Flows

Refer to Appendix Figures I-12 to I-29 and Appendix Tables I-6 and I-7 (Appendix I, Volume II) Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.4 Assessment of Flushing Flows on the Cache la Poudre River Section 3.1 (Anderson Consulting Engineers, Inc. 2017)

(Note that flushing flow information is not provided in the Main Stem Baseline Report)

Results of the comparative assessment of the occurrence and duration of flushing flows for the Agricultural Reservoirs Alternative are the same when compared with Fort Collins’ Proposed Action. Reduction in the number of years of occurrence would be between 1 and 2 years, and spatially limited to the Laporte Reach for both alternatives (Figure 10-5). Comparison of the average annual recurrence interval of flushing flows is provided in Table 10-1. Changes in the average annual recurrence interval would be negligible for the Agricultural Reservoirs Alternative.

**Interpretation**

Changes in the occurrence and duration of flushing flows would be negligible under the Agricultural Reservoirs Alternative.

![Diagram](image)

**Figure 10-5. Change in number of years of occurrence of flushing flows—Agricultural Reservoirs Alternative versus Fort Collins’ Proposed Action.**
Table 10-1. Comparison of flushing annual recurrence interval – Agricultural Reservoirs, Fort Collins’ Proposed Action, and Current Conditions.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Current Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
<th>Agricultural Reservoirs Alternative Annual Recurrence Interval (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laporte</td>
<td>2</td>
<td>2,406</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Laporte</td>
<td>4</td>
<td>2,337</td>
<td>1.7</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Laporte</td>
<td>7</td>
<td>2,250</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Laporte</td>
<td>8</td>
<td>1,999</td>
<td>2.0</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Laporte</td>
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<td>1,797</td>
<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Ft Collins</td>
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<td>2.0</td>
</tr>
<tr>
<td>Timnath</td>
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<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

10.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

10.5.1 Analysis at all Cross Sections

Refer to Appendix Figure I-30 (Appendix I, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.5.1
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Under the Agricultural Reservoirs Alternative, 150 cross sections (out of 407) show a change in duration of channel maintenance flows. The duration of channel maintenance flows would be consistently decreased in the Laporte Reach by up to 6 percent (Figure 10-6). Reductions in Fort Collins and Timnath range from 1 to 3 percent, with two outliers that show a reduction of upwards of 12 percent. In the Windsor and Greeley reaches, change in duration would be plus or minus 2 percent. The same general observations are noted for both the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action (Figure 10-6), with slightly less change under the Agricultural Reservoirs Alternative.
Figure 10-6. Percent change in the duration of channel maintenance flows – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
**Interpretation**

The analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of the Agricultural Reservoirs Alternative. For the reaches upstream of Interstate-25, the information presented suggests a reduction in channel maintenance flow duration by as much as 6 percent at specific cross sections in the Laporte Reach. However, the average change in duration upstream of Interstate-25 would be less than 1.2 percent overall, which would be a negligible change. Similarly, the average change in duration downstream of Interstate-25 would be also less than 1 percent. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

**10.5.2 Spells Analysis at Representative Cross Sections**

Refer to Appendix Figures I-32 to I-39 and Appendix Tables I-8 to I-9 (Appendix I, Volume II) Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.5.2 Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections. Upstream of Interstate-25, reduction in channel maintenance flow events under the Agricultural Reservoirs Alternative would be isolated to the Laporte Reach. Downstream of Interstate-25 there would be some increases in the number of events. Changes would be similar for the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action (Figure 10-7).

**Interpretation**

In summary, upstream of Interstate-25, the spells analysis predicts a slight reduction in number of events of channel maintenance flows in the Laporte Reach. Change at all other locations above Interstate-25 would be negligible.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 10.5.1.

Taken together, this and the preceding analysis indicate a reduction in the number of channel maintenance events generally isolated to the Laporte and Fort Collins reaches. The duration of channel maintenance was found to also be slightly reduced (generally no more than 6 percent) based upon evaluation at all cross section upstream of Interstate-25. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.


10.6 Flows that Move Coarse Bed Material

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as reach representative sections.

### 10.6.1 Analysis at all Cross Sections

Refer to Appendix Figure I-31 (Appendix I, Volume II)

Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.6.1

Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

Throughout the Poudre River, durations of bed material movement under the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action generally differ from Current Conditions by plus or minus 2.5 percent. Reduction in duration would be most notably consistent in the Laporte Reach where it would be as much as 5 percent. Reductions under the Agricultural Reservoirs Alternative would be similar to Fort Collins’ Proposed Action (Figure 10-8).

Upstream of Interstate-25, bed material movement would occur at 57 out of 206 cross sections (28 percent) under Current Conditions. Under the Agricultural Reservoirs Alternative, bed material would still move at these cross sections but with a change, both positive and negative, in duration noted at 25 of the cross sections. The average change in duration would be a reduction of less than 1 percent.

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**Figure 10-7.** Change in number of channel maintenance flow events – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Figure 10-8. Percent change in duration of coarse bed material movement – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Downstream of I-25 Interstate-25, bed material would move at 122 out of 201 cross sections (59 percent) under Current Conditions. Under Fort Collins’ Proposed Action, bed material would still move at these cross sections but for a reduced duration at 61 of the cross sections. For these 61 cross sections, the average change in the duration of motion would be an increase of less than 1 percent.

Interpretation

Reduced duration of flows that move bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. A signal of change in the duration of flows that move coarse bed material was not indicated in results of the analysis.

10.6.2 Spells Analysis at Representative Cross Sections

The reduction in bed material motion is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated for the Agricultural Reservoirs Alternative or Fort Collins’ Proposed Action (Figure 10-9). In the reaches below Interstate-25, changes would be the same for the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action, both being minimal.

Interpretation

Changes in the occurrence and duration of bed material motion under the Agricultural Reservoirs Alternative would be negligible.
### Figure 10-9. Change in number of events of coarse bed material movement – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.

#### 10.7 Stream Power

Refer to Appendix Figure I-40 to I-43 (Appendix I, Volume II)  
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.7  
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Under the Agricultural Reservoirs Alternative, total flow energy upstream of Interstate-25 would be generally unchanged with some slight reductions noted in the Laporte Reach. Downstream of Interstate-25, there would be slight increases in flow energy that would generally be limited to less than 5 percent, likely due to an increase in the occurrence of low flow between 50 and 150 cfs. These changes would be similar to Fort Collin’s Proposed Action Figure 10-10) with the Agricultural Reservoirs Alternative showing slightly more reductions in the Laporte Reach.

Change in total work in excess of stream power required to move bed material show a similar trend for both the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action (Figure 10-11).
Figure 10-10. Percent change in total work – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Figure 10-11. Percent change in total work above incipient motion – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
Interpretation

Changes noted in total work above Interstate-25 would be negligible. The increase in total work in the reaches below Interstate-25 reflects an increase in low flows between 50 and 150 cfs associated with the Agricultural Reservoirs Alternative. This increase is predicted to have limited morphologic consequence because it would occur at low stream powers where there is no channel adjustment. Most increases disappear in the comparison of work above the threshold of motion. Reductions in the total work in excess of stream power required to move bed material would be negligible. Increases shown would not be likely to manifest into adverse impacts.

10.8 Sediment Transport Potential

Refer to Appendix Figure I-44 and Appendix Tables I-12 and I-13 (Appendix I, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.8
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Change in average annual sediment transport potential for the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action relative to Current Conditions would be generally the same (Figure 10-12). There would be just slightly more reduction in transport potential in the Laporte and Fort Collins reaches under the Agricultural Reservoirs Alternative.

Upstream of Interstate-25, the total amount of material that could be moved would be slightly reduced by up to 3.4 percent under the Agricultural Reservoirs Alternative. Transport potential for sand only would be reduced by up to 3.3 percent, and for gravels up to 3.9 percent. Downstream of Interstate-25, the total amount of material that could be moved would be slightly increased by up to 2.2 percent, or considering sand only, the increase would be no greater than 2.3 percent. Transport potential for gravels downstream of Interstate-25 would increase a maximum of 1.5 percent.

Interpretation

Results of the change in sediment transport potential, both decreases and increases, would be of such a small magnitude that effects would be considered negligible.
Figure 10-12. Percent change in average annual sediment transport potential – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Current Conditions.
10.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figure I-45 to I-48 (Appendix I, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.9
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

A comparison of the magnitude-frequency curves for the Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Current Conditions indicates little to no change (Figure 10-13, Figure 10-14, and Figure 10-15). Subtle changes noted between curves would not be likely to manifest as an adverse impact.

Interpretation

Effect of the Agricultural Reservoirs Alternative on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 10-13. Distribution of sediment transport potential with flow in Laporte reaches – Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Current Conditions.
Figure 10-14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Current Conditions.
Figure 10-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches—Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Current Conditions.
10.10 Overview of Effects of Agricultural Reservoir Alternative on Sediment Transport and River Morphology

In overview, the trajectory of the river condition is expected to continue under both Current Conditions and the Agricultural Reservoirs Alternative hydrology with negligible impacts.

Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue with negligible effects due to the Agricultural Reservoirs Alternative.

Assessment of the effects of the Agricultural Reservoirs Alternative was found to be the same as Fort Collins’ Proposed Action. The Agricultural Reservoirs Alternative would have slightly more impact in the Laporte and Fort Collins reaches, but the difference would be negligible.
11 Main Stem – Effects of the Expanded Glade Alternative versus NISP Current Conditions

This Chapter presents a discussion of the effects of the Expanded Glade Alternative relative to NISP Current Conditions on the Main Stem. NISP Current Conditions hydrology (Run 3a) is representative of NISP’s Proposed Action with Glade Reservoir and serves as the baseline condition against which effects of the Expanded Glade Alternative are evaluated. Detailed information and discussion about condition of the Poudre River under NISP Current Conditions (Alternative 2) can be found in the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, Inc. 2014). Hydrology for the Expanded Glade Alternative (EG3) is compared against NISP Current Conditions (Run 3a) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of the Expanded Glade Alternative with NISP Current Conditions can be found in Volume II, Appendix J of this report.

Discussion below reports results of the Expanded Glade Alternative versus NISP Current Conditions comparison. We also report the differences between the Fort Collins’ Proposed Action versus Current Conditions comparison and the Expanded Glade Alternative versus NISP Current Conditions comparison that could be important and, where feasible, presenting a “comparison of the comparisons”. While comparison of the impact of the Expanded Glade Alternative and Fort Collins’ Proposed Action is informative the reader should keep in mind that baseline conditions are different. A comparison of percent change should be reviewed with care given that there are large differences in baseline conditions.

11.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures J-1 and J-2 (Appendix J, Volume II)

Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.1

NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.2 (Anderson Consulting Engineers, Inc. 2014)

During high flow months critical to morphology and sediment transport (May, June, and July), reduction in average monthly flow at the Canyon Gage would be reduced between 3 percent and 5 percent for the Expanded Glade Alternative (Figure 11-1). This would be similar to Fort Collins’ Proposed Action. During the low flow months of October through March, reductions would be up to 11 percent. During most of the low flow months the Expanded Glade Alternative would reduce average monthly flows more than Fort Collins’ Proposed Action.

At the Lincoln Gage, the Expanded Glade Alternative changes in average monthly flows during high flow months would be plus or minus 5 percent, which would be similar to Fort Collins’ Proposed Action (Figure 11-2). Larger reductions in average monthly flow, between 10 and 36 percent, are noted during low flow months of the year under the Expanded Glade Alternative.
Small changes in the magnitude of flow volumes during the low flow months appear as larger percent changes. A comparison of percent change during low flow months between the Expanded Glade Alternative and Fort Collins’ Proposed Action is difficult given difference in baseline conditions.

**Interpretation**

Changes in average monthly flow statistics under the Expanded Glade Alternative would be generally less than 5 percent during the high flow months critical to morphology and sediment transport. The percent reduction of average monthly under the Expanded Glade Alternative would be more pronounced relative to change shown for Fort Collins’ Proposed Action. This would be largely due to the difference in baseline conditions at small flow values.

Figure 11-1. Percent change in average monthly flow volumes at Canyon Gage – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.
Figure 11-2. Percent change in average monthly flow volumes at Lincoln Gage – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.

11.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures J-3 through J-10, Appendix Tables J-1 through J-3 (Appendix J, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.2
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.3 (Anderson Consulting Engineers, Inc. 2014)

Changes in flow frequency associated with the Expanded Glade Alternative would generally be similar in magnitude to changes associated with Fort Collins’ Proposed Action. The 2 percent exceedance discharge (flow equaled or exceeded 2 percent of the time) is critical to geomorphology and sediment transport. Change in the 2 percent exceedance discharge with the Expanded Glade Alternative would be generally plus or minus 2 percent throughout the river and similar in magnitude to Fort Collins’ Proposed Action (Figure 11-3).

Interpretation

The magnitude of changes in high flow frequency throughout the system under the Expanded Glade Alternative would be negligible relative to NISP Current Conditions.
Figure 11-3. Percent change in 2 percent exceedance discharge – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.
11.3 Flood Frequency Analysis

Refer to Appendix Figures J-11 and Appendix Tables J-4 and J-5 (Appendix J, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.3
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.4 (Anderson Consulting Engineers, Inc. 2014)

The magnitude of the 2-year flood discharge would be reduced by up to 4 percent in the Laporte Reach and increased by up to 8 percent downstream under the Expanded Glade Alternative (Figure 11-4). The 10-year and 25-year flood discharge would be just slightly reduced by no more than 3 percent upstream of Interstate-25 and increased by no more than 3 percent downstream. Increases in flood magnitudes under the Expanded Glade Alternative would not be likely to provide benefit relative to NISP Current Conditions.

Interpretation

Reduction in flood magnitudes would be negligible. Increases noted in the 2-year flood discharge would not be likely to provide benefit relative to NISP Current Conditions.
Figure 11-4. Percent change in 2-year flood discharge – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.
11.4 Flushing Flows

Refer to Appendix Figures J-12 to J-29 and Appendix Tables J-6 and J-7 (Appendix J, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.4
NISP Future Conditions Refer to Assessment of Flushing Flows on the Cache la Poudre River
Section 4.2 (Anderson Consulting Engineers, Inc. 2017)
(Note that flushing flow information is not provided in the NISP Stream Morphology and Sediment Transport Project Effects Report)

The number of years of occurrence of flushing flows is unchanged by the Expanded Glade Alternative relative to NISP Current Conditions, with the exception of one additional year in the Timnath Reach (Figure 11-5). Spells analyses also indicate that there would be negligible reduction in the average duration of flushing flows under the Expanded Glade Alternative. Comparison of the average annual recurrence interval of flushing flows is provided in Table 11-1. The Expanded Glade Alternative does not increase the flushing flow annual recurrence interval relative to NISP Current Conditions.

Interpretation

Changes in the occurrence and duration of flushing flows would be negligible under the Expanded Glade Alternative relative to NISP Current Conditions.

Figure 11-5. Change in number of years of occurrence of flushing flows—Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Current Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
<th>NISP Current Conditions Annual Recurrence Interval (years)</th>
<th>Expanded Glade Alternative Annual Recurrence Interval (years)</th>
</tr>
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<tr>
<td>Laporte</td>
<td>2</td>
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<td>Laporte</td>
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<td>2,250</td>
<td>1.9</td>
<td>1.9</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Laporte</td>
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<td>1,999</td>
<td>2.0</td>
<td>2.2</td>
<td>2.9</td>
<td>2.9</td>
</tr>
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<td>2.2</td>
<td>2.4</td>
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</tr>
</tbody>
</table>

11.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

11.5.1 Analysis at all Cross Sections

Refer to Appendix Figure J-30 (Appendix J, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.5.1
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.5.1 (Anderson Consulting Engineers, Inc. 2014)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the NISP Stream Morphology and Sediment Transport Project Effects Report)

Under the Expanded Glade Alternative, 188 cross sections (out of 407) show a change in duration of channel maintenance flows relative to NISP Current Conditions. Duration would be consistently decreased in most of the Laporte Reach by up to 6 percent (Figure 11-6). Reductions in Fort Collins and Timnath vary and range up to 13 percent. In the reaches below Interstate-25 change would range generally from a reduction of 5 percent up to an increase of 10 percent. Larger percent changes would be associated with small magnitudes in duration for both NISP Current Conditions and the Expanded Glade Alternative. Change in the duration of channel maintenance flows would be larger, both increases and decreases, and more variable when compared with Fort Collins Proposed Action.
Figure 11-6. Percent change in the duration of channel maintenance flows – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.
**Interpretation**

The analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of the Expanded Glade Alternative. For the reaches upstream of Interstate-25, the information presented suggests a reduction in channel maintenance flow duration by as much as 13 percent at specific cross sections with an average reduction of less than 3 percent. Downstream of Interstate-25, a signal of overall increase in duration is noted. Increases would be unlikely to provide benefit to NISP Current Conditions. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

**11.5.2 Spells Analysis at Representative Cross Sections**

Reduction in channel maintenance flows is further examined at selected representative cross sections. Throughout the river, change in spells under the Expanded Glade Alternative would be negligible relative to NISP Current Conditions. Increases in the number of events noted, mostly downstream of Interstate-25, would not be likely to provide benefit (Figure 11-7).

**Interpretation**

In summary, spells analyses do not predict a reduction in the number of channel maintenance events upstream of Interstate-25 under the Expanded Glade Alternative. Changes below Interstate-25 would be considered negligible.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 11.5.1.

Taken together, this and the preceding analysis indicate that although there would not be a reduction in the number channel maintenance events upstream of Interstate-25, there is an indication of reduction in the duration. However, percent change in duration would be large due to the small magnitudes of duration associated with NISP Current Conditions. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.
11.6 Flows that Move Coarse Bed Material

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as reach representative cross sections.

11.6.1 Analysis at all Cross Sections

Refer to Appendix Figure J-31 (Appendix J, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.6.1
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.6.1 (Anderson Consulting Engineers, Inc. 2014)

Reduction in duration of coarse bed material movement under the Expanded Glade Alternative would be more variable when compared with Fort Collins’ Proposed Action (Figure 11-8). However, similar to Fort Collins’ Proposed Action, reduction in duration would be consistent in the Laporte Reach where it would be no more than 7 percent. Throughout the remainder of the river, changes associated with the Expanded Glade Alternative would generally be plus or minus 10 percent.

Upstream of Interstate-25, bed material movement would occur at 57 out of 206 cross sections (28 percent) under NISP Current Conditions. Under the Expanded Glade Alternative, motion still would occur at these cross sections but with a change in duration, mostly reductions, noted at 29 of the cross sections. The average change in duration would be a reduction of less than 2 percent.
Figure 11-8. Percent change in duration of coarse bed material movement – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.
Downstream of Interstate-25, bed material motion would occur at 122 out of 201 cross sections (59 percent) under Current Conditions. Under Fort Collins’ Proposed Action motion still would occur at these cross sections but for a reduced duration at 93 of the cross sections. For these 93 cross sections, the average change in the duration of motion would be an increase of approximately 3 percent.

**Interpretation**

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. The Expanded Glade Alternative generally would reduce duration of bed material movement upstream of Interstate-25, but reductions would be small and not spatially prevalent. An indication of increased duration in bed material movement is noted downstream of Interstate-25; however, the magnitude of change would not be likely to provide benefit relative to NISP Current Conditions.

### 11.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure J-32 to J-39 and Appendix Tables J-10 and J-11 (Appendix J, Volume II)

Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.6.2

NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.6.2 (Anderson Consulting Engineers, Inc. 2014)

The reduction in bed material motion is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated for the Expanded Glade Alternative or Fort Collins’ Proposed Action (Figure 11-9). In the reaches below Interstate-25, changes for the Expanded Glade Alternative and Fort Collins’ Proposed Action would both be negligible.

**Interpretation**

Changes in the occurrence and duration of bed material motion under the Expanded Glade Alternative would be negligible.
Under the Expanded Glade Alternative, total flow energy upstream of Interstate-25 would be generally reduced by 5 percent with some larger reductions of up to 15 percent in Laporte and Fort Collins. Downstream of Interstate-25, there would be increases in flow energy that would generally be between 5 and 10 percent. These changes would be similar to Fort Collin’s Proposed Action (Figure 11-10) with the Expanded Glade Alternative showing larger reductions in the Laporte Reach.

Change in total work in excess of stream power required to move bed material for the Expanded Glade Alternative would be similar to Fort Collins’ Proposed Action (Figure 11-11) upstream of Interstate-25. Changes would be slightly more pronounced under the Expanded Glade Alternative downstream of Interstate-25.
Figure 11-10. Percent change in total work – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.

Figure 11-11. Percent change in total work above incipient motion – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.
**Interpretation**

Changes noted in total work above Interstate-25 would be mostly negligible, except for reductions shown in Laporte and Fort Collins. The increase in total work predicted downstream of Interstate-25 would have limited morphologic consequence because it would occur at low stream powers where no channel adjustment would occur. Most increases disappear in the comparison of work above the threshold of motion.

Reductions in the total work in excess of stream power required to move bed material would be generally less than 5 percent. Increases shown would not be likely to manifest into adverse impacts.

**11.8 Sediment Transport Potential**

Refer to Appendix Figure J-44 and Appendix Tables J-12 and J-13 (Appendix J, Volume II)

Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.8

NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.8 (Anderson Consulting Engineers, Inc. 2014)

Change in average annual sediment transport potential for the Expanded Glade Alternative and Fort Collins’ Proposed Action shows similar trends upstream and downstream of Interstate-25 (Figure 11-12). There would be slightly more reduction in transport potential in the Laporte and Fort Collins reaches under the Expanded Glade Alternative.

Upstream of Interstate-25, the total amount of material that could be moved would be reduced by up to 6 percent under the Expanded Glade Alternative. Transport potential for sand only would be reduced by up to 7 percent, and for gravels up to 6 percent. Downstream of Interstate-25, the total amount of material that could be moved would be slightly increased by up to 4 percent, or considering sand only, the increase would be as much as 5 percent. Transport potential for gravels downstream of Interstate-25 would increase a maximum of 2.6 percent.

**Interpretation**

Results of the change in sediment transport potential, both decreases and increases, would be negligible relative to NISP Current Conditions.
Figure 11-12. Percent change in average annual sediment transport potential – Expanded Glade Alternative versus NISP Current Conditions and Fort Collins’ Proposed Action versus Current Conditions.
11.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figure J-45 to J-48 (Appendix J, Volume II)
Fort Collins’ Proposed Action versus Current Conditions Refer to Chapter 8, Section 8.9
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 3.9 (Anderson Consulting Engineers, Inc. 2014)

A comparison of the magnitude-frequency curves for the Expanded Glade Alternative and NISP Current Conditions shows subtle changes mostly in the low flow ranges (Figure 11-13, Figure 11-14, and Figure 11-15). Changes in the curves at flows less than 100cfs would not likely manifest as an adverse impact. Differences between the curves do not indicate a signal of change relative to NISP Current Conditions.

Interpretation

Effect of the Expanded Glade Alternative on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 11-13. Distribution of sediment transport potential with flow in Laporte reaches – Expanded Glade Alternative versus NISP Current Conditions.
Figure 11-14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Expanded Glade Alternative versus NISP Current Conditions.
Figure 11-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches – Expanded Glade Alternative versus NISP Current Conditions.
11.10 Overview of Effects of Expanded Glade Alternative on Sediment Transport and River Morphology

In overview, the Expanded Glade Alternative would be expected to have a negligible impact on the trajectory of the river under NISP Current Conditions with Glade Reservoir, briefly described in Section 1.3.2.2.

Based largely on an observational model of response to NISP Current Conditions hydrology, a negligible impact on the trends that were identified in the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, 2014) is expected.

Results of the assessment of the effects of the Expanded Glade Alternative was found to be similar to Fort Collins’ Proposed Action, but relative to their respective baseline conditions. The Expanded Glade Alternative would have slightly more impact in the Laporte and Fort Collins reaches.
12 Main Stem - Effects of Fort Collins’ Proposed Action versus Future Conditions

This Chapter presents a detailed discussion of the effects of Fort Collins’ Proposed Action relative to Future Conditions on the Main Stem. Hydrology for Fort Collins’ Proposed Action (PA4) is compared against Future Conditions (Run 2) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of Fort Collins’ Proposed Action versus Future Conditions can be found in Volume III, Appendix M of this report.

12.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures M-1 and M-2 (Appendix M, Volume III)
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

The box and whisker plot of monthly flows is based on the full modeled monthly data set which covers the 56-year period from 1950 to 2005. The box and whisker plots provide an overview of the predicted changes in overall flow volumes in the river because of Fort Collins’ Proposed Action over a longer time period than the 26-year period of daily data. The plots include the minimum, maximum, 25th and 75th percentiles, median, and average monthly flow volumes. Note that the average monthly value sometimes falls outside of the 25th to 75th percentile range. This indicates a non-normal distribution of flow that is associated with diversion patterns.

Subtle differences between Future Conditions and Fort Collins’ Proposed Action are noted at both the Canyon Gage (Figure 12-1) and Lincoln Gage (Figure 12-2). Average monthly flows would decrease under Fort Collins’ Proposed Action by less than 3 percent in the months of March through October at the Canyon Gage. Changes in average monthly flows at the Lincoln Gage during high flow months (May through July) would be less than 4 percent, with reductions of up to 4 percent during some low flow months. Increases in monthly flows are noted at the Lincoln Gage for the months of August, and January through March of up to 7 percent.

Interpretation

Changes in monthly flow statistics under Fort Collins’ Proposed Action would generally be small. Reduction in average monthly flow would be less than 3 percent during high flow months that are critical to morphology and sediment transport at the Canyon Gage and less than 4 percent at the Lincoln Gage.
Figure 12-1. Percent change in average monthly flow at the Canyon Gage – Fort Collins’ Proposed Action versus Future Conditions.

Figure 12-2. Percent change in average monthly flow at the Lincoln Gage – Fort Collins’ Proposed Action versus Future Conditions.
12.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures M-3 through M-10, Appendix Tables M-1 through M-3 (Appendix M, Volume III) Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

Changes in flow frequency associated with Fort Collins’ Proposed Action along the Main Stem would be slight. The amount of time the river flows at or above about 1,000 cfs would be reduced by less than 2 percent throughout.

Another way of expressing the change in the flow frequency distribution is to look at the change in the flow of a particular duration. The flow frequency tables (Appendix Tables M-1, M-2, and M-3) indicate a slight reduction less than 2 percent in the 1, 2 (Figure 12-3), and 5 percent exceedance flows (flows exceeded 1, 2, and 5 percent of the time) with the exception of the Timnath Reach upstream of Interstate-25 where reductions would be nearly 5 percent. Overall, changes would be negligible.

The seasonality of changes in mean daily and maximum daily flow is illustrated in Appendix Figures M-7 to M-10. During the low flow winter months (October through February) mean daily flows would be slightly reduced above the Larimer No. 2 Canal and generally increased up to 3 percent below (Appendix Figure M-7). Increases in mean daily discharge of up to 5 percent throughout are noted during the spring months of March through April 15th (Appendix Figure M-8). During the high flow summer months, mean daily flows show a consistent reduction of up to 2 percent (Appendix Figure M-9). Change in mean daily flows would generally be plus or minus 2 percent throughout the length of the river during the fall months of July 15th through September (Appendix Figure M-10).

Interpretation

The magnitude of changes in flow frequency throughout the system would be negligible. Similarly, seasonal change in daily flow statistics would be also negligible.
Figure 12-3. Percent change in 2 percent exceedance discharge – Fort Collins’ Proposed Action versus Future Conditions.
12.3 Flood Frequency Analysis

Refer to Appendix Figures M-11 and Appendix Tables M-4 and M-5 (Appendix M, Volume III) Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

It is important to note that this flood frequency analysis has been undertaken on the 26-year period of modeled daily flows. The analysis should not be compared with other flood frequency analyses for the river which are undertaken for a different purpose and based on much longer periods of record covering a wider range of flood peaks. There would be generally a consistent reduction in the 2-year flood discharge between 1 and 3 percent (Figure 12-4). Reduction in the magnitude of the 10-year and 25-year floods would be no more than 2 percent (Table M-5).

Interpretation

Changes in the magnitude of floods associated with Fort Collins’ Proposed Action hydrology would be negligible.

12.4 Flushing Flows

Refer to Appendix Figures M-12 to M-29 and Appendix Tables M-6 and M-7 (Appendix M, Volume III) Assessment of Flushing Flows on the Cache la Poudre River Section 3.1 (Anderson Consulting Engineers, Inc. 2017)

(Note that flushing flow information is not provided in the Main Stem Baseline Report)

Flushing flows are defined as flows that flush or move sediments (sands and gravels) resting on top of the coarse bed material matrix (or armor layer) in riffles. Flushing flows allow for surface cleaning of riffles necessary to support ecological function of the river channel. A positive effect of flushing flows is that they maintain spawning habitat for fish. Baseline flushing flows identified for comparative assessments were defined as flows having a recurrence interval of 2-years relative to Future Conditions hydrology (Anderson Consulting Engineers, Inc. 2017).

The absolute difference in the number and duration of flushing flow spells is provided in Table M-7. A graphical comparison at each hydrologic node is provided in Appendix Figures M-12 to M-20. A comparison of the annual maximum discharge for Fort Collins’ Proposed Action and Future Conditions is graphically compared with the flushing flow threshold at each flow node, see Appendix Figures M-21 to M-29.
Figure 12-4. Percent change in 2-year flood discharge – Fort Collins’ Proposed Action versus Future Conditions.
The occurrence of flushing flows would be reduced by 1 year (from 13 years to 12 years) in the Laporte reach at hydrologic node 4, located between the Poudre Valley and Hansen Supply canals. However, the recurrence interval of flushing flows under Fort Collins’ Proposed Action at this location would remain on the order of 2-years. At hydrologic node 12, located between the Little Cache Ditch/New Mercer Ditch and Larimer and Weld Canal, the number of years of occurrence would be reduced by 1 year (from 11 years to 10 years). There was no change in the number of years of occurrence at all other locations. There would be slight reductions in the average duration of flushing flows throughout, however they would be negligible.

Comparison of the average annual recurrence interval of flushing flows is provided in Table 12-1. Fort Collins’ Proposed Action would just slightly increase the average annual recurrence interval in the Laporte Reaches, with no change in the Fort Collins and Timnath reaches.

Table 12-1. Comparison of flushing flow annual recurrence interval – Fort Collins’ Proposed Action and Future Conditions.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Future Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laporte</td>
<td>2</td>
<td>2,406</td>
<td>2.4</td>
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</tr>
<tr>
<td>Laporte</td>
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<tr>
<td>Laporte</td>
<td>7</td>
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<tr>
<td>Timnath</td>
<td>32</td>
<td>972</td>
<td>2.2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Interpretation**

Changes in the occurrence and duration of flushing flows would be negligible.

**12.5 Channel Maintenance Flows**

Channel maintenance flows are defined as the flow required to remove sediment trapped in between coarser material that comprises the bed material matrix (armor layer). For the CTP, a critical dimensionless shear stress was adopted to represent conditions when bed material moves...
sufficiently to just allow finer material to be released from the interstices of coarser surface layers of the bed. The geomorphic process related to channel maintenance flows is of ecological significance. Ecological criteria would consider not only the total duration of channel maintenance flows in the 26-year period but also the number of occurrences and the time between occurrences. The analysis reported in this section provides no information on specific ecologic criteria, but the spells analysis (Section 12.5.2) presents information on the frequency and duration of channel maintenance flows.

This process and the applicability of this criterion are considered to be most important within reaches of the Main Stem located upstream of Interstate-25 where there is a gravel and cobble substrate that has been observed to be smothered by fine material between channel maintenance flow events. Channel maintenance flows also have some ecological relevance in the portion of the study area downstream of Interstate-25 where sands and silts can be flushed from bars and islands in high flows to reveal underlying gravels. The process downstream of Interstate-25 is considered to be controlled by criteria for general bed material movement rather than criteria for channel maintenance flows and is further discussed in Section 12.6.

12.5.1 Analysis at all Cross Sections

Refer to Appendix Figure M-30 (Appendix M, Volume III)
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

The duration for which channel maintenance flows would be expected to occur under Future Conditions and Fort Collins’ Proposed Action were evaluated at 407 cross sections. The results are shown for the whole river, but the process would be most important in the gravel and cobble bed reaches upstream of Interstate-25 (36 miles above South Platte confluence). The comparison demonstrates that the duration of channel maintenance flows would be consistently decreased by no more than 5 percent throughout the entire length of the river (Figure 12-5). Computations were conducted at all cross sections in order to capture the highly variable nature of hydraulic conditions along the river.

It is important to put this finding in the context that changes do not occur at all cross sections on the river. As described below, there are many other cross sections that the analysis predicts would not be impacted by a change in channel maintenance flow duration.

- In addition to the cross sections where a change in the duration of channel maintenance flow is shown, there are many cross sections where channel maintenance flows do not occur in the 26-year modeled period for either Future Conditions or Fort Collins’ Proposed Action; and others where no change in channel maintenance flow duration is predicted. Out of a total of 407 cross sections analyzed, 170 (42 percent) show no occurrence of channel maintenance flows during the modeled period. There are 237 cross sections (58 percent) where channel maintenance flows would occur. A total of 70 cross sections (out of 237) show no change in the duration of channel maintenance flows from Future Conditions to Fort Collins’ Proposed Action. Consequently, 167 cross sections
(out of 237) show a change in duration with Fort Collins’ Proposed Action. The average change in duration computed at the 167 cross sections would be a reduction of less than 2 percent.

- Upstream of Interstate-25, out of 206 cross sections analyzed, 103 show an occurrence of channel maintenance flows during the modeled period and of those cross sections, 41 cross sections show no change in channel maintenance flow duration. At the remaining 62 cross sections the average reduction in duration would be 2 percent.

**Interpretation**

Analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of Fort Collins’ Proposed Action. For the reaches upstream of Interstate-25, the information presented suggests there would be a reduction in channel maintenance flow duration by as much as 5 percent at specific cross sections. However, the average reduction in duration upstream of Interstate-25 would be less than 2 percent overall, which overall would be a negligible change. Similarly, the average reduction in duration downstream of Interstate-25 would be 2 percent. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists. Further information to assist interpretation of ecological implications is provided in the following spells analysis (Section 12.5.2).
Figure 12-5. Percent change in the duration of channel maintenance flows – Fort Collins’ Proposed Action versus Future Conditions.
12.5.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures M-32 to M-39 and Appendix Tables M-8 to M-9 (Appendix M, Volume III)
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections by evaluating the occurrence of periods where channel maintenance shear stress criterion would be exceeded. These periods are illustrated graphically in Appendix Figures M-32 to M-39, and in tabular form in Appendix Tables M-8 and M-9 for both Future Conditions and Fort Collins’ Proposed Action. For the reach above Interstate-25, a reduction of 1 event (from 12 events to 11 events) is noted at Cross Section 257663 in the Laporte Reach. A reduction of 2 events (from 22 events to 20 events) is noted at Cross Section 231351 in the Fort Collins reach. All other section above Interstate-25 would show no change in the number of channel maintenance events.

Interpretation

In summary, upstream of Interstate-25, the spells analysis predicts a minimal reduction in number of events of channel maintenance flows in the Laporte and Fort Collins reaches. Change at all other locations above Interstate-25 would be negligible.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 12.5.1.

Taken together, this and the preceding analysis indicate a limited reduction in the number of channel maintenance flow events upstream of Interstate-25. The duration of channel maintenance was found to be consistently reduced by an average of 2 percent based upon evaluation at all cross section upstream of Interstate-25 (and generally no more than 5 percent at specific cross sections). The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

12.6 Flows that Move Coarse Bed Material

The point at which bed material in the bed of the river starts to move is a geomorphic threshold. The occurrence of bed material motion and the duration of flows above this threshold influence the size, shape, and dynamics of the river channel. For the CTP evaluation, initiation of motion was related to a critical shear stress which varies along the river according to the size of material present in the river bed. Upstream of Interstate-25, where the bed is generally armored, initiation of motion is particularly important because it represents the flow at which the armor layer would be broken and underlying sediment would be released. Downstream of Interstate-25, the
frequency and duration of bed material motion provides an indication of the frequency and magnitude of sediment transport.

12.6.1 Analysis at all Cross Sections

Refer to Appendix Figure M-31 (Appendix M, Volume III) Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

The duration for which bed material movement would be expected to occur under Future Conditions and Fort Collins’ Proposed Action was compared at 407 cross sections (Figure 12-6). Throughout the river, durations of bed material movement under Fort Collins’ Proposed Action would be consistently reduced no more than 5 percent throughout the river.

Under Future Conditions, bed material movement would occur at 57 out of 206 cross sections (28 percent) upstream of Interstate-25. Under Fort Collins’ Proposed Action, motion still would occur at these cross sections but with an average reduction of 2.8 percent in the duration at 27 of the cross sections.

Downstream of Interstate-25, bed material motion would occur at 122 out of 201 cross sections (59 percent) under Future Conditions. Under Fort Collins’ Proposed Action, motion still would occur at these cross sections but for a reduced duration at 76 of the cross sections. For these 76 cross sections, the average reduction in duration would be approximately 2 percent.

Interpretation

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. Although a consistent signal of reduction in duration is noted, the magnitude of reduction (2 to 3 percent) would be negligible.
Figure 12-6. Percent change in the duration of coarse bed material movement – Fort Collins’ Proposed Action versus Future Conditions.
12.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure M-32 to M-39 and Appendix Tables M-10 and M-11 (Appendix M, Volume III)
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

The reduction in bed material motion is further examined at selected representative cross sections by computing the occurrence of periods for which the shear stress criterion for initiation of motion would be exceeded. These periods are illustrated graphically in Appendix Figures M-32 to M-39 and in tabular form in Appendix Tables M-10 and M-11 for both Future Conditions and Fort Collins’ Proposed Action.

Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated. In the reaches below Interstate-25, there would be slight differences in the occurrence and average duration of episodes that move bed material, however they are negligible.

Interpretation

Overall, changes in the occurrence and duration of bed material motion under Fort Collins’ Proposed Action would be negligible.

12.7 Stream Power

Refer to Appendix Figures M-40 to M-43 (Appendix M, Volume III)
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Stream power can be calculated at each cross section for each flow in the modeled data sets. Summed over the 26-year modeled period (with appropriate units), stream power represents the ability of the flow to “do work” on the channel boundaries. Also of interest is the stream power in excess of the power that is required to initiate bed material motion. This can give an indication of the amount of “work” that can move the channel bed.

Figure 12-7 illustrate a difference between the change in flow energy upstream and downstream of Interstate-25. Upstream of Interstate-25, total flow energy would be slightly reduced by up to 3 percent. Downstream of Interstate-25, changes would generally be within plus or minus 1 percent.

Changes in the total work in excess of stream power required to move bed material reveals a more consistent signal of reduction generally ranging from 2 to 3 percent but no more than 5 percent throughout the river (Figure 12-8). The magnitude of change would be considered negligible.
Figure 12-7. Percent change in total work – Fort Collins’ Proposed Action versus Future Conditions.

Figure 12-8. Percent change in total work above incipient motion – Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

Reductions in the total work in excess of stream power indicates a signal of reduction, but it would be negligible in magnitude.

12.8 Sediment Transport Potential

Refer to Appendix Figure M-44 and Appendix Tables M-12 and M-13 (Appendix M, Volume III) Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Sediment transport potential is the capacity of the river to move sediment over the 26 years of modeled flows if that sediment were available to be moved. The results are presented separately for total bed material load, sand, gravel, and cobble sized material. Size gradations used in the sediment transport calculations reflect current gradations in the river bed.

Upstream of Interstate-25, the total amount of material that could be moved would be slightly reduced by approximately 1 to 3 percent (Figure 12-9). Transport potential for sand only would be reduced by up to 3 percent, and for gravels up to 3.6 percent. Downstream of Interstate-25 the total amount of material that could be moved would be slightly reduced by nearly 2 percent, or considering sand only, the reduction would be no more than 1 percent. Transport potential for gravels downstream of Interstate-25 would be reduced by a maximum of 3.4 percent.

Interpretation

The change in sediment transport potential would be of such a small magnitude that effects would be negligible.
Figure 12-9. Percent change in total average annual sediment transport potential – Fort Collins’ Proposed Action versus Future Conditions.
12.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figures M-45 to M-48 (Appendix M, Volume III)
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Figure 12-10 through Figure 12-12 compare magnitude-duration analyses for Future Conditions and Fort Collins’ Proposed Action. The curves demonstrate how sediment transport potential would be distributed across the flow range for Future Conditions and Fort Collins’ Proposed Action. The peak of the magnitude-frequency curve gives an indication of the effective discharge for the channel based on the sediment transport potential of the current bed material distribution for each reach in the SIAM model.

Note that the curves presented here differ from the curves shown in the Main Stem Baseline Report in two respects.

3. The Main Stem Baseline Report illustrated magnitude-frequency analyses for each of the standard particle size intervals in each reach as if each particle size interval were the only size in transport. To simplify the comparison between scenarios, the presentation herein shows a single curve that is based on accumulating the sediment transport potential for each size interval in proportion to the size distribution of the bed material.

4. The Main Stem Baseline Report presented the magnitude-frequency analysis based on 15 logarithmically distributed discharge intervals. For the comparisons reported here, the range of discharges has been increased to include the first discharge interval with zero occurrences and the size of the discharge interval has been increased so that the number of discharge intervals is reduced.

   o Increasing the range has the effect of driving all magnitude-frequency curves to zero at the maximum discharge. This is realistic since no flow and hence no sediment transport has occurred in that interval over the modeled period.
   o Increasing the size of the discharge interval reduces oscillations in the magnitude-frequency curve and facilitates comparisons between scenarios.

A comparison of the magnitude-frequency curves between Future Conditions and Fort Collins’ Proposed Action was provided to determine if hydrologic changes under Fort Collins’ Proposed Action would be likely to affect channel morphology. The following are types of indicators of change.

- A change in the location of the peak of the magnitude-frequency curve gives an indication of a change in effective discharge.
- A change in the magnitude and shape of the peak gives an indication of the change in the strength of the effective discharge signal.
- A change in the area under the curve gives an indication of the change in average annual sediment transport potential (allowing for the log scale).
- The area between the curves demonstrates the change in annual sediment transport.
potential (allowing for the log scale).

- Changes in the distribution of sediment transport potential across the flow range (see the histograms) show the flow intervals where sediment transport potential would be most affected by the change in hydrology.

Little to no change was noted in comparison of the curves for Fort Collins’ Proposed Action and Future Conditions.

**Interpretation**

Effect of Fort Collins’ Proposed Action on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 12-10. Distribution of sediment transport potential with flow in Laporte reaches—Fort Collins’ Proposed Action versus Future Conditions.
Figure 12-11. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Fort Collins’ Proposed Action versus Future Conditions.
Figure 12-12. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches –Fort Collins’ Proposed Action versus Future Conditions.
12.10 Overview of Effects of Fort Collins’ Proposed Action on Sediment Transport and River Morphology

In overview, the trajectory of the river condition would be expected to continue under both Future Conditions and Fort Collins’ Proposed Action hydrology with negligible impacts.

Based largely on an observational model of response to Future Conditions hydrology, the trends that were identified in the future condition assessment would be expected to continue with negligible effects due to Fort Collins’ Proposed Action.
13 Main Stem – Effects of the Gravel Pits Alternative versus Future Conditions

This Chapter presents a discussion of the effects of the Gravel Pits Alternative relative to Future Conditions on the Main Stem. Hydrology for the Gravel Pits Alternative (GP4) is compared against Future Conditions (Run 2) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of the Gravel Pits Alternative with Future Conditions can be found in Volume III, Appendix N of this report.

Discussion below relies heavily on the detailed assessment presented in Chapter 12 which compared Fort Collins’ Proposed Action versus Future Conditions. This Chapter does not repeat the detailed descriptions of Chapter 12 for the Gravel Pits Alternative. Instead, it reports by exception – identifying areas where differences between the Fort Collins’ Proposed Action versus Future Conditions comparison and the Gravel Pits Alternative versus Future Conditions comparison could be important and, where feasible, presenting a “comparison of the comparisons”.

13.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures N-1 and N-2 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.1
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

During high flow months critical to morphology and sediment transport (May, June, and July), reduction in average monthly flow at the Canyon Gage would be less for the Gravel Pits Alternative than for Fort Collins’ Proposed Action (Figure 13-1). This reflects the effect of diverting water upstream of the North Fork confluence associated with Fort Collins’ Proposed Action. However, reductions in average monthly flow volumes for both alternatives would still be very small (1 to 3 percent) and considered negligible. During most of the low flow months the Grave Pits Alternative would reduce average monthly flows more than Fort Collins’ Proposed Action.

At the Lincoln Gage, the same general trends of change are noted for the Gravel Pits Alternative and Fort Collins’ Proposed Action. During high flow months (May, June, and July) critical to geomorphology and sediment transport, there would be negligible change shown for both comparisons (Figure 13-2).
Figure 13-1. Percent change in average monthly flow volumes at Canyon Gage – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.

Figure 13-2. Percent change in average monthly flow volumes at Lincoln Gage – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

Changes in monthly flow statistics under the Gravel Pits Alternative would generally be small. Reduction in average monthly flow would be less than 3 percent during high flow months that are critical to morphology and sediment transport at the Canyon Gage and less than 4 percent at the Lincoln Gage.

13.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures N-3 through N-10, Appendix Tables N-1 through N-3 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.2
Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

Spatial changes in flow frequency associated with the Gravel Pits Alternative would generally be similar to Fort Collins’ Proposed Action, with slightly smaller reductions noted under the Gravel Pits Alternative. The 2 percent exceedance discharge (flow equaled or exceeded 2 percent of the time) is critical to geomorphology and sediment transport. Reduction in the 2 percent exceedance discharge with the Gravel Pits Alternative would be generally less than 1 percent except for the Timnath Reach upstream of Interstate-25 where flow would be reduced by a little more than 2 percent (Figure 13-3).

Interpretation

The magnitude of changes in flow frequency throughout the system would be negligible. Similarly, seasonal change in daily flow statistics would also be negligible.

13.3 Flood Frequency Analysis

Refer to Appendix Figure N-11 and Appendix Tables N-4 and N-5 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.3
Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

Reduction in the 2-year, 10-year, and 25-year floods would be 1 percent or less under the Gravel Pits Alternative. Reductions would be slightly less under the Gravel Pits Alternative when compared with Fort Collins’ Proposed Action (Figure 13-4), but both would be negligible relative to Future Conditions.

Interpretation

Changes in the magnitude of floods associated with Gravel Pits Alternative would be negligible.
Figure 13-3. Percent change in 2 percent exceedance discharge – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Figure 13-4. Percent change in 2-year flood discharge – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
13.4 Flushing Flows

Refer to Appendix Figures N-12 to N-29 and Appendix Tables N-6 and N-7 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.4 Assessment of Flushing Flows on the Cache la Poudre River Section 3.1 (Anderson Consulting Engineers, Inc. 2017)
(Note that flushing flow information is not provided in the Main Stem Baseline Report)

The occurrence and duration of flushing flows for the Gravel Pits Alternative would be nearly the same when compared with Fort Collins’ Proposed Action. Reduction in the number of years of occurrence would be between 1 and 2 years, and spatially limited to the Laporte Reach for both alternatives (Figure 13-5). Reductions would be slightly less for the Gravel Pits Alternative. Comparison of the average annual recurrence interval of flushing flows is provided in Table 13-1. Changes in the average annual recurrence interval would be negligible.

**Interpretation**

Changes in the occurrence and duration of flushing flows would be negligible under the Gravel Pits Alternative.

![Figure 13-5. Change in number of years of occurrence of flushing flows– Gravel Pits Alternative versus Fort Collins’ Proposed Action.](image-url)
Table 13-1. Comparison of flushing flow annual recurrence interval – Gravel Pits Alternative, Fort Collins’ Proposed Action and Future Conditions.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Future Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
<th>Gravel Pits Alternative Annual Recurrence Interval (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laporte</td>
<td>2</td>
<td>2,406</td>
<td>2.4</td>
<td>2.4</td>
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</tr>
<tr>
<td>Laporte</td>
<td>4</td>
<td>2,337</td>
<td>2.0</td>
<td>2.2</td>
<td>2.0</td>
</tr>
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<td>Laporte</td>
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<td>2,250</td>
<td>2.6</td>
<td>2.6</td>
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</tr>
<tr>
<td>Laporte</td>
<td>8</td>
<td>1,999</td>
<td>2.6</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Laporte</td>
<td>12</td>
<td>1,797</td>
<td>2.4</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Ft Collins</td>
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<td>2.0</td>
<td>2.0</td>
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</tr>
<tr>
<td>Ft Collins</td>
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<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
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<td>1,355</td>
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<td>2.0</td>
</tr>
<tr>
<td>Timnath</td>
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<td>972</td>
<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

13.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

13.5.1 Analysis at all Cross Sections

Refer to Appendix Figure N-30 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.1
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Under the Gravel Pits Alternative, 155 cross sections (out of 407) show a change in duration of channel maintenance flows. The duration of channel maintenance flows would be consistently decreased by no more than 5 percent throughout the length of the river (Figure 13-6). The same general observations are noted for both the Gravel Pits Alternative and Fort Collins’ Proposed Action (Figure 13-6), with slightly less change under the Gravel Pits Alternative.
Figure 13-6. Percent change in the duration of channel maintenance flows – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

Analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of the Gravel Pits Alternative. For the reaches upstream of Interstate-25, the information presented suggests a reduction in channel maintenance flow duration by as much as 5 percent at specific cross sections. However, the average change in duration upstream of Interstate-25 would be less than 2 percent overall, which is a negligible change. Similarly, the average change in duration downstream of Interstate-25 would be also less than 1 percent. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

13.5.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures N-32 to N-39 and Appendix Tables N-8 to N-9
(Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections. There would be no change in the number of channel maintenance flow events under the Gravel Pits Alternative upstream of Interstate-25, where Fort Collins’ Proposed Action shows two locations of a reduction (Figure 13-7). Downstream of Interstate-25, there would be some increases in the number of events under the Gravel Pits Alternative.

![Graph showing channel maintenance flows](image)

Figure 13-7. Change in number of channel maintenance flow events – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.

Anderson Consulting Engineers, Inc.
**Interpretation**

In summary, the spells analysis does not predict a reduction in number of events of channel maintenance flows upstream of Interstate-25.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 13.5.1.

The duration of channel maintenance flows was found to be slightly reduced (no more than 5 percent) based upon evaluation at all cross sections upstream of Interstate-25. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

**13.6 Flows that Move Coarse Bed Material**

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as at reach representative cross sections.

**13.6.1 Analysis at all Cross Sections**

Refer to Appendix Figure N-31 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.1
Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

Throughout the river, durations of bed material movement under the Gravel Pits Alternative and Fort Collins’ Proposed Action would be generally reduced between 2 and 5 percent. Reductions in duration would be slightly less under the Gravel Pits Alternative (Figure 13-8).

Upstream of Interstate-25, bed material movement would occur at 57 out of 206 cross sections (28 percent) under Future Conditions. Under the Gravel Pits Alternative, motion still would occur at these cross sections but with a reduced duration noted at 26 of the cross sections. The average reduction in duration would be roughly 2 percent.

Downstream of Interstate-25, bed material motion would occur at 122 out of 201 cross sections (59 percent) under Future Conditions. Under Fort Collins’ Proposed Action, motion still would occur at these cross sections but for a reduced duration at 65 of the cross sections. For these 65 cross sections, the average reduction in duration would be 2 percent.
Figure 13-8. Percent change in duration of coarse bed material movement – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. A signal of change in the duration of flows that move coarse bed material was not indicated in results of the analysis due to small percent changes (generally less than 2 percent).

13.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure N-32 to N-39 and Appendix Tables N-10 and N-11 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

The reduction in bed material motion is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated for the Gravel Pits Alternative or Fort Collins’ Proposed Action (Figure 13-9). In the reaches below Interstate-25, there would be slight differences in the occurrence and average duration of episodes that move bed material; however, they would be minimal.

![Graph showing movement of coarse bed material](image)

Figure 13-9. Change in number of events of coarse bed material movement – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
**Interpretation**

Changes in the occurrence and duration of bed material motion under the Gravel Pits Alternative would be negligible.

### 13.7 Stream Power

Refer to Appendix Figure N-40 to N-43 (Appendix N, Volume III) Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.7 Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Under the Gravel Pits Alternative total flow energy upstream of Interstate-25 would be reduced by up to 3 percent. Downstream of Interstate-25, change would be limited to plus or minus 1 percent. These changes would be similar to Fort Collin’s Proposed Action (Figure 13-10) with the Gravel Pits Alternative showing slightly less change.

Changes in the total work in excess of stream power required to move bed material reveals a more consistent signal of reduction generally ranging from 2 to 3 percent but no more than 5 percent throughout the river (Figure 13-11). Reductions under the Gravel Pits Alternative would be just slightly less than Fort Collins’ Proposed Action.

**Interpretation**

Changes noted in total work above Interstate-25 would be negligible. Reductions in the total work in excess of stream power required to move bed material would be negligible. Increases shown would not be likely to manifest into adverse effect.
Figure 13-10. Percent change in total work – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.

Figure 13-11. Percent change in total work above incipient motion – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
13.8 Sediment Transport Potential

Refer to Appendix Figure N-44 and Appendix Tables N-12 and N-13 (Appendix N, Volume III) Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.8 Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

The pattern of change in average annual sediment transport potential for the Gravel Pits Alternative would be the same as for Fort Collins’ Proposed Action, with the Gravel Pits Alternative showing a slightly smaller magnitude of change (Figure 13-12).

Upstream of Interstate-25, the total amount of material that could be moved would be slightly reduced by no more than 2 percent under the Gravel Pits Alternative. Downstream of Interstate-25, the total amount of material that could be moved would be within plus or minus 0.5 percent of Future Conditions.

**Interpretation**

The changes in sediment transport potential, both decreases and increases, would be negligible.
Figure 13-12. Percent change in average annual sediment transport potential – Gravel Pits Alternative and Fort Collins’ Proposed Action versus Future Conditions.
13.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figures N-45 to N-48 (Appendix N, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.9
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

A comparison of the magnitude-frequency curves for the Gravel Pits Alternative, Fort Collins’ Proposed Action, and Future Conditions indicates little to no change (Figure 13-13, Figure 13-14, and Figure 13-15). Subtle change noted between curves would not be likely to manifest as an adverse impact.

Interpretation

Effect of the Gravel Pits Alternative on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 13.13. Distribution of sediment transport potential with flow in Laporte reaches – Gravel Pits Alternative, Fort Collins’ Proposed Action, and Future Conditions.
Figure 13-14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Gravel Pits Alternative, Fort Collins’ Proposed Action, and Future Conditions.
Figure 13-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches – Gravel Pits Alternative, Fort Collins’ Proposed Action, and Future Conditions.
13.10 Overview of Effects of Gravel Pits Alternative on Sediment Transport and River Morphology

In overview, the trajectory of the river condition would be expected to continue under both Future Conditions and the Gravel Pits Alternative hydrology with negligible impacts.

Based largely on an observational model of response to Future Conditions hydrology, the trends that were identified in the future condition assessment would be expected to continue throughout the river (both upstream and downstream of Interstate-25) with negligible effects due to the Gravel Pits Alternative.

Assessment of the effects of the Gravel Pits Alternative was found to be the same as Fort Collins’ Proposed Action. The Gravel Pits Alternative would have slightly less impact, but the difference would be negligible.
14 Main Stem – Effects of the Agricultural Reservoirs Alternative versus Future Conditions

This Chapter presents a discussion of the effects of the Agricultural Reservoirs Alternative relative to Future Conditions on the Main Stem. Hydrology for the Agricultural Reservoirs Alternative (AR4) is compared against Future Conditions (Run 2) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of the Agricultural Reservoirs Alternative with Future Conditions can be found in Volume III, Appendix O of this report.

Discussion below relies heavily on the detailed assessment presented in Chapter 12 which compared Fort Collins’ Proposed Action versus Future Conditions. This Chapter does not repeat the detailed descriptions of Chapter 12 for the Agricultural Reservoirs Alternative. Instead, it reports by exception – identifying areas where differences between the Fort Collins’ Proposed Action versus Future Conditions comparison and the Agricultural Reservoirs Alternative versus Future Conditions comparison could be important and, where feasible, presenting a “comparison of the comparisons”.

14.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures O-1 and O-2 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.1
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

During high flow months critical to morphology and sediment transport (May, June, and July), reduction in average monthly flow at the Canyon Gage would be just slightly larger for the Agricultural Reservoirs Alternative than for Fort Collins’ Proposed Action (Figure 14-1). However, reductions in average monthly flow volumes for both alternatives would still be less than 1 percent. During most of the low flow months, the Agricultural Reservoir Alternative would reduce average monthly flows more than Fort Collins’ Proposed Action.

At the Lincoln Gage the same general trends of change are noted for the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action. During high flow months (May, June, and July) critical to geomorphology and sediment transport, there would be negligible change shown for both comparisons (Figure 14-2).

Interpretation

Changes in monthly flow statistics under the Agricultural Reservoirs Alternative would generally be small. Reduction in average monthly flow would be less than 3 percent during high flow months that are critical to morphology and sediment transport at the Canyon Gage and less than 4 percent at the Lincoln Gage.
Figure 14-1. Percent change in average monthly flow volumes at Canyon Gage – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.

Figure 14-2. Percent change in average monthly flow volumes at Lincoln Gage – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
14.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures O-3 through O-10, Appendix Tables O-1 through O-3 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.2
Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

Reduction in flow frequency associated with the Agricultural Reservoirs Alternative would generally be similar in magnitude to changes associated with Fort Collins’ Proposed Action. The 2 percent exceedance discharge (flow equaled or exceeded 2 percent of the time) is critical to geomorphology and sediment transport. Under the Agricultural Reservoirs Alternative, the 2 percent exceedance discharge would be generally reduced between 1 and 3 percent (Figure 14-3).

*Interpretation*

The changes in high flow frequency throughout the system would be negligible. Similarly, seasonal change in daily flow statistics would also be negligible.

14.3 Flood Frequency Analysis

Refer to Appendix Figures O-11 and Appendix Tables O-4 and O-5 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.3
Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

Reduction in the 2-year, 10-year, and 25-year floods would be 1 percent or less under the Agricultural Reservoirs Alternative. Reductions would be slightly less under the Agricultural Reservoirs Alternative when compared with Fort Collins’ Proposed Action (Figure 14-4), however both show negligible change relative to Future Conditions.

*Interpretation*

Changes in the magnitude of floods associated with the Agricultural Reservoirs Alternative would be negligible.
Figure 14-3. Percent change in 2 percent exceedance discharge – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Figure 14-4. Percent change in 2-year flood discharge – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
14.4 Flushing Flows

Refer to Appendix Figures O-12 to O-29 and Appendix Tables O-6 and O-7 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.4 Assessment of Flushing Flows on the Cache la Poudre River Section 3.1 (Anderson Consulting Engineers, Inc. 2017)
(Note that flushing flow information is not provided in the Main Stem Baseline Report)

Results of the comparative assessment of the occurrence and duration of flushing flows for the Agricultural Reservoirs Alternative are the same when compared with Fort Collins’ Proposed Action. Reduction in the number of years of occurrence would be between 1 and 2 years, and spatially limited to the Laporte Reach for both alternatives (Figure 14-5). Comparison of the average annual recurrence interval of flushing flows is provided in Table 14-1. Changes in the average annual recurrence interval would be negligible for the Agricultural Reservoirs Alternative.

**Interpretation**

Changes in the occurrence and duration of flushing flows would be negligible under the Agricultural Reservoirs Alternative.

![Figure 14-5. Change in number of years of occurrence of flushing flows—Agricultural Reservoirs Alternative versus Fort Collins’ Proposed Action.](image-url)

Anderson Consulting Engineers, Inc. 14-6
Table 14-1. Comparison of flushing flow annual recurrence interval – Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Future Conditions.

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<th>Study Reach</th>
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<th>Future Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
<th>Agricultural Reservoirs Alternative Annual Recurrence Interval (years)</th>
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14.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

14.5.1 Analysis at all Cross Sections

Refer to Appendix Figure O-30 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.1 Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Under the Agricultural Reservoirs Alternative, 150 cross sections (out of 407) show a change in duration of channel maintenance flows. The duration of channel maintenance flows would be consistently decreased by up to 5 percent throughout (Figure 14-6). The same general observations are noted for both the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action (Figure 14-6), with slightly less change under the Agricultural Reservoirs Alternative.
Figure 14-6. Percent change in the duration of channel maintenance flows – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
**Interpretation**

Analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of the Agricultural Reservoirs Alternative. For the reaches upstream of Interstate-25, the information presented suggests a reduction in channel maintenance flow duration by as much as 5 percent at specific cross sections. However, the average change in duration upstream of Interstate-25 would be less than 2 percent overall, which is a negligible change. Similarly, the average change in duration downstream of Interstate-25 would also be less than 2 percent. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

### 14.5.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures O-32 to O-39 and Appendix Tables O-8 to O-9 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.2 Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no reduction in the number of channel maintenance flow events under the Agricultural Reservoirs Alternative (Figure 14-7). Downstream of Interstate-25, there would be some increases in the number of events.

![Figure 14-7. Change in number of channel maintenance flow events – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.](image)
**Interpretation**

In summary, upstream of Interstate-25, the spells analysis does not predict a reduction in number of channel maintenance events. This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 14.5.1.

The duration of channel maintenance flows was found to also be slightly reduced (generally no more than 5 percent) based upon evaluation at all cross section upstream of Interstate-25. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

**14.6 Flows that Move Coarse Bed Material**

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as reach representative cross sections.

**14.6.1 Analysis at all Cross Sections**

Refer to Appendix Figure O-31 (Appendix O, Volume III)  
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.1  
Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

Throughout the river, durations of bed material movement under the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action would be reduced between 2 and 5 percent. Reductions under the Agricultural Reservoirs Alternative would be similar to those for Fort Collins’ Proposed Action (Figure 14-8).

Upstream of Interstate-25, bed material movement would occur at 57 out of 206 cross sections (28 percent) under Future Conditions. Under the Agricultural Reservoirs Alternative, motion still would occur at these cross sections but with a change, both positive and negative, in duration noted at 25 of the cross sections. The average change in duration would be a reduction of less than 1 percent.

Downstream of Interstate-25, bed material motion would occur at 122 out of 201 cross sections (59 percent) under Future Conditions. Under Fort Collins’ Proposed Action, motion still would occur at these cross sections but for a reduced duration at 61 of the cross sections. For these 61 cross sections, the average change in the duration of motion would be an increase of less than 1 percent.
Figure 14-8. Percent change in duration of coarse bed material movement – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. A signal of change in the duration of flows that move coarse bed material was not indicated in results of the analysis.

14.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure O-32 to O-39 and Appendix Tables O-10 and O-11 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

The reduction in bed material motion is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated for the Agricultural Reservoirs Alternative or Fort Collins’ Proposed Action (Figure 14-9). In the reaches below Interstate-25, changes would be the same for the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action, with both being minimal.

![Graph showing movement of coarse bed material](image)

Figure 14-9. Change in number of events of coarse bed material movement – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

Changes in the occurrence and duration of bed material motion under the Agricultural Reservoirs Alternative would be negligible.

14.7 Stream Power

Refer to Appendix Figures O-40 to O-43 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.7
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Under the Agricultural Reservoirs Alternative, total flow energy upstream of Interstate-25 would be generally unchanged with some slight reductions of up to 3 percent. Downstream of Interstate-25, change would be plus or minus 1 percent. These changes would be similar to Fort Collin’s Proposed Action (Figure 14-10).

Change in total work in excess of stream power required to move bed material indicates a reduction generally ranging from 2 to 3 percent but no greater than 5 percent for both the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action (Figure 14-11).

Interpretation

Reductions in the total work in excess of stream power indicates a signal of reduction, but it would be negligible in magnitude.
Figure 14-10. Percent change in total work – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.

Figure 14-11. Percent change in total work above incipient motion – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
14.8 Sediment Transport Potential

Refer to Appendix Figure O-44 and Appendix Tables O-12 and O-13 (Appendix O, Volume III) Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.8 Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Change in average annual sediment transport potential for the Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action relative to Future Conditions would be generally the same (Figure 14-12).

Upstream of Interstate-25, the total amount of material that could be moved would be slightly reduced by up to 2.5 percent under the Agricultural Reservoirs Alternative. Transport potential for sand only would be reduced by up to 2.5 percent, and for gravels up to 2.7 percent. Downstream of Interstate-25, change in sediment transport potential would be plus or minus 1 percent. Compared with Fort Collins’ Proposed Action, the Agricultural Reservoirs Alternative would have just slightly less impact on transport potential (Figure 14-12).

**Interpretation**

Results of the change in sediment transport potential, both decreases and increases, would be negligible.
Figure 14-12. Percent change in average annual sediment transport potential – Agricultural Reservoirs Alternative and Fort Collins’ Proposed Action versus Future Conditions.
14.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figures O-45 to O-48 (Appendix O, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.9
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

A comparison of the magnitude-frequency curves for the Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Future Conditions indicates little to no change (Figure 14-13, Figure 14-14, and Figure 14-15). Subtle changes that are noted between curves would not be likely to manifest as an adverse impact.

**Interpretation**

Effect of the Agricultural Reservoirs Alternative on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 14-13. Distribution of sediment transport potential with flow in Laporte reaches – Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Future Conditions.
Figure 14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Future Conditions.
Figure 14-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches – Agricultural Reservoirs Alternative, Fort Collins’ Proposed Action, and Future Conditions.
14.10 Overview of Effects of Agricultural Reservoirs Alternative on Sediment Transport and River Morphology

In overview, the trajectory of the river condition would be expected to continue under both Future Conditions and the Agricultural Reservoirs Alternative hydrology with negligible effects.

Based largely on an observational model of response to Future Conditions hydrology, the trends that were identified in the Future Conditions assessment are expected to continue throughout the river with negligible impacts under the Agricultural Reservoirs Alternative.

The effects of the Agricultural Reservoirs Alternative were found to be the same as Fort Collins’ Proposed Action. The Agricultural Reservoirs Alternative would have just slightly less impact, but the difference is insignificant.
15 Main Stem - Effects of the Expanded Glade Alternative versus NISP Future Conditions

This Chapter presents a discussion of the effects of the Expanded Glade Alternative relative to NISP Future Conditions on the Main Stem. NISP Future Conditions hydrology (Run 4a) is representative of NISP’s Proposed Action with Glade Reservoir and serves as the baseline condition against which effects of the Expanded Glade Alternative are evaluated. Detailed information and discussion about condition of the river under NISP Future Conditions (Alternative 2) can be found in the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, Inc. 2014). Hydrology for the Expanded Glade Alternative (EG4) is compared against NISP Future Conditions (Run 4a) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of the Expanded Glade Alternative with NISP Future Conditions can be found in Volume III, Appendix P of this report.

Discussion below reports results of the Expanded Glade Alternative versus NISP Future Conditions comparison. We also report the differences between the Fort Collins’ Proposed Action versus Future Conditions comparison and the Expanded Glade Alternative versus NISP Future Conditions comparison that could be important and, where feasible, presenting a “comparison of the comparisons”. While comparison of the impact of the Expanded Glade Alternative and Fort Collins’ Proposed Action is informative, the reader should keep in mind that baseline conditions are different. A comparison of percent change should be reviewed with care given that there are differences in baseline conditions.

15.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures P-1 and P-2 (Appendix P, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.1
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.2 (Anderson Consulting Engineers, Inc. 2014)

During high flow months critical to morphology and sediment transport (May, June, and July) reduction in average monthly flow at the Canyon Gage would be negligible (less than 3 percent) for both the Expanded Glade Alternative and Fort Collins’ Proposed Action (Figure 15-1).
During the low flow months of October through May, the Expanded Glade Alternative would reduce average monthly flows between 3 and 6 percent.

At the Lincoln Gage, the Expanded Glade Alternative changes in average monthly flows during high flow months would be plus or minus 5 percent, which is similar to Fort Collins’ Proposed Action (Figure 15-2). Larger reductions in average monthly flow, between 10 and 36 percent, are noted during low flow months of the year under the Expanded Glade Alternative. Larger percent changes are attributed to differing baseline conditions at small flow magnitudes.
Figure 15-1. Percent change in average monthly flow volumes at Canyon Gage – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.

Figure 15-2. Percent change in average monthly flow volumes at Lincoln Gage – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

Changes in average monthly flow statistics under the Expanded Glade Alternative would generally be less than 5 percent during the high flow months critical to morphology and sediment transport. The percent reduction of average monthly flow under the Expanded Glade Alternative would be more pronounced relative to changes shown for Fort Collins’ Proposed Action. This is largely due to the difference in baseline conditions at small flow values.

15.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures P-3 through P-10, Appendix Tables P-1 through P-3 (Appendix P, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.2
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report Section 7.3 (Anderson Consulting Engineers, Inc. 2014)

Changes in flow frequency associated with the Expanded Glade Alternative would generally be similar in magnitude to changes associated with Fort Collins’ Proposed Action. The 2 percent exceedance discharge (flow equaled or exceeded 2 percent of the time) is critical to geomorphology and sediment transport. Reduction in the 2 percent exceedance discharge with the Expanded Glade Alternative would be generally 2 percent through Laporte and Fort Collins. In the remaining reaches, reductions would consistently be 4 percent and less. Downstream of Interstate-25, the Expanded Glade Alternative would have slightly more impact on the 2 percent exceedance discharge than would Fort Collins’ Proposed Action (Figure 15-3).

Interpretation

The magnitude of changes in high flow frequency throughout the system under the Expanded Glade Alternative would be small relative to NISP Future Conditions.
Figure 15-3. Percent change in 2 percent exceedance discharge – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.
15.3 Flood Frequency Analysis

Refer to Appendix Figures P-11 and Appendix Tables P-4 and P-5 (Appendix P, Volume III) Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.3 NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.4 (Anderson Consulting Engineers, Inc. 2014)

Reduction in the 2-year flood discharge under the Expanded Glade Alternative would be similar to Fort Collins’ Proposed Action (Figure 15-4). Reductions in 2-year flood discharge would be generally less than 2 percent, except for a 4 percent decrease in Fort Collins.

The 10-year and 25-year flood discharge would be reduced by no more than 3 percent upstream of Interstate-25 and no more than 4 percent downstream under the Expanded Glade Alternative.

Interpretation

Reduction in flood magnitudes would be negligible.
Figure 15-4. Percent change in 2-year flood discharge – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.
15.4 Flushing Flows

Refer to Appendix Figures P-12 to P-29 and Appendix Tables P-6 and P-7 (Appendix P, Volume III)

Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.4
NISP Future Conditions Refer to Assessment of Flushing Flows on the Cache la Poudre River Section 4.7 (Anderson Consulting Engineers, Inc. 2017)

(Note that flushing flow information is not provided in the NISP Stream Morphology and Sediment Transport Project Effects Report)

The Expanded Glade Alternative would reduce the number of years of occurrence of flushing flows by 1 year relative to NISP Future Conditions (Figure 15-5). Spells analyses also indicate that there would be a negligible reduction in the average duration of flushing flows under the Expanded Glade Alternative. Comparison of the average annual recurrence interval of flushing flows is provided in Table 15-1. The Expanded Glade Alternative does not increase the flushing flow annual recurrence interval relative to NISP Future Conditions except at one location in the Fort Collins Reach.

Interpretation

Changes in the occurrence and duration of flushing flows would be negligible under the Expanded Glade Alternative relative to NISP Future Conditions.

Figure 15-5. Change in number of years of occurrence of flushing flows—Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Future Conditions Annual Recurrence Interval (years)</th>
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<th>NISP Future Conditions Annual Recurrence Interval (years)</th>
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15.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

15.5.1 Analysis at all Cross Sections

Refer to Appendix Figure P-30 (Appendix P, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.1
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.5.1 (Anderson Consulting Engineers, Inc. 2014)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the NISP Stream Morphology and Sediment Transport Project Effects Report)

Under the Expanded Glade Alternative, 168 cross sections (out of 407) show a change in duration of channel maintenance flows relative to NISP Future Conditions. The average reduction in duration, computed using the 168 cross sections, would be less than 2 percent. However, larger reductions between 5 and 10 percent are noted at individual cross sections in the Laporte and Fort Collins reaches. When compared with Fort Collins’ Propose Action, reductions would be larger for the Expanded Glade Alternative (Figure 15-6).
Figure 15-6. Percent change in the duration of channel maintenance flows – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.
**Interpretation**

The analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of the Expanded Glade Alternative. For the reaches upstream of Interstate-25, the information presented suggests that a reduction in channel maintenance flow duration on average would be less than 2 percent and much as 10 percent at specific cross sections in Laporte and Fort Collins reaches. Reductions of up to 5 percent are noted in the reaches below Interstate-25. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.

**15.5.2 Spells Analysis at Representative Cross Sections**

Refer to Appendix Figures P-32 to P-39 and Appendix Tables P-8 to P-9 (Appendix P, Volume III)
Fort Collins' Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.2
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.5.2 (Anderson Consulting Engineers, Inc. 2014) (Note that Channel Maintenance flows are referred to and labeled as flushing flows in the NISP Stream Morphology and Sediment Transport Project Effects Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections. Reduction in the number of channel maintenance events under the Expanded Glade Alternative would be the same as Fort Collins’ Proposed Action upstream of Interstate-25 (Figure 15-7). Changes noted downstream of Interstate-25 would be negligible.

**Interpretation**

In summary, spells analyses predict a slight reduction in the number of channel maintenance events upstream of Interstate-25 under the Expanded Glade Alternative. Changes below Interstate-25 would be negligible.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 15.5.1.

Taken together, this and the preceding analysis indicate a limited reduction in the number of channel maintenance flow events upstream of Interstate-25. The duration of channel maintenance flows was found to be consistently reduced by an average of 2 percent based upon evaluation at all cross section upstream of Interstate-25 (and up to 10 percent at specific cross sections). The ecological and other implications of this finding will be analyzed and reported by other resource specialists.
15.6 Flows that Move Coarse Bed Material

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as reach representative cross sections.

15.6.1 Analysis at all Cross Sections

Refer to Appendix Figure P-31 (Appendix P, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.1
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.6.1 (Anderson Consulting Engineers, Inc. 2014)

Throughout the Poudre River, durations of bed material movement under the Expanded Glade Alternative and Fort Collins’ Proposed Action would be reduced between 2 and 5 percent. Reductions under the Expanded Glade Alternative would be similar to Fort Collins’ Proposed Action (Figure 15-8) upstream of Interstate-25, but slightly larger downstream.

Upstream of Interstate-25, bed material movement would occur at 57 out of 206 cross sections (28 percent) under NISP Future Conditions. Under the Expanded Glade Alternative, motion still would occur at these cross sections but with a change in duration, mostly reductions, noted at 23 of the cross sections. The average change in duration would be a reduction of 2 percent.
Downstream of Interstate-25, bed material motion would occur at 122 out of 201 cross sections (59 percent) under Future Conditions. Under Fort Collins’ Proposed Action, motion still would occur at these cross sections but for a reduced duration at 77 of the cross sections. For these 77 cross sections, the average reduction in duration would be 3 percent.

**Interpretation**

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it would imply that the river would move less sediment through the system. The Expanded Glade Alternative generally would reduce duration of bed material movement upstream of Interstate-25, but reductions would be small and not spatially prevalent. A stronger signal of reduction is noted downstream of Interstate-25, however the magnitude of change would be small.
Figure 15-8. Percent change in duration of coarse bed material movement – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.
15.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figure P-32 to P-39 and Appendix Tables P-10 and P-11 (Appendix P, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.2
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.6.2 (Anderson Consulting Engineers, Inc. 2014)

The reduction in bed material motion is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated for the Expanded Glade Alternative or Fort Collins’ Proposed Action (Figure 15-9). In the reaches below, Interstate-25 changes for the Expanded Glade Alternative and Fort Collins’ Proposed Action would both be negligible.

**Interpretation**

Changes in the occurrence and duration of bed material motion under the Expanded Glade Alternative would be negligible.

![Graph](image-url)

**Figure 15-9. Change in number of events of coarse bed material movement – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.**
15.7 Stream Power

Refer to Appendix Figure P-40 to P-43 (Appendix P, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.7
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.7 (Anderson Consulting Engineers, Inc. 2014)

Under the Expanded Glade Alternative, total flow energy upstream of Interstate-25 would be similar to Fort Collins’ Prossed Action except for the Laporte and Fort Collins reaches where reductions would be noticeably larger (Figure 15-10). The larger percent reductions in total work, ranging from 15 to nearly 20 percent, would be likely to have limited morphologic consequence because changes occur at low stream powers where there is no channel adjustment.

The larger percent changes in total work in Laporte and Fort Collins disappear above the threshold of motion. Reduction in total work in excess of stream power required to move bed material would be generally less than 5 percent for the Expanded Glade Alternative and would be similar to Fort Collins’ Proposed Action (Figure 15-11). Reductions would be slightly larger under the Expanded Glade Alternative downstream of Interstate-25 when compared with Fort Collins’ Proposed Action.

Interpretation

Changes noted in total work above Interstate-25 would generally be small (less than 5 percent), except for reductions shown in Laporte and Fort Collins. However, these changes would have limited morphologic consequence because it would occur at low stream powers where there is no channel adjustment. Most of the larger reductions disappear in the comparison of work above the threshold of motion.

Reductions in the total work in excess of stream power required to move bed material would be generally less than 5 percent under the Expanded Glade Alternative and would have negligible impact.
Figure 15-10. Percent change in total work – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.

Figure 15-11. Percent change in total work above incipient motion – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.
15.8 Sediment Transport Potential

Refer to Appendix Figure P-44 and Appendix Tables P-12 and P-13 (Appendix P, Volume III) Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.8 NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.8 (Anderson Consulting Engineers, Inc. 2014)

Reduction in average annual sediment transport potential under the Expanded Glade Alternative would be slightly larger upstream of Interstate-25 when compared with Fort Collins’ Proposed Action (Figure 15-12). The most notable difference would be in the Fort Collins reach where reductions under the Expanded Glade Alternative would be nearly 8 percent. Downstream of Interstate-25, reductions would be similar and generally less than 2 percent.

Upstream of Interstate-25, the total amount of material that could be moved would be reduced by up to 4 percent under the Expanded Glade Alternative with the exception of the Fort Collins reach where reductions would be up to 8 percent. Downstream of Interstate-25, the total amount of material that could be moved would be slightly reduced by less than 2 percent.

Interpretation

Results of the change in sediment transport potential would be negligible relative to NISP Future Conditions.
Figure 15-12. Percent change in average annual sediment transport potential – Expanded Glade Alternative versus NISP Future Conditions and Fort Collins’ Proposed Action versus Future Conditions.
15.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figure P-45 to P-48 (Appendix P, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.9
NISP Future Conditions Refer to NISP Stream Morphology and Sediment Transport Project Effects Report, Section 7.9 (Anderson Consulting Engineers, Inc. 2014)

A comparison of the magnitude-frequency curves for the Expanded Glade Alternative and NISP Future Conditions shows subtle changes mostly in the low flow ranges (Figure 15-13, Figure 15-14, and Figure 15-15). Changes in the curves at flows less than 100cfs would not likely manifest as an adverse impact. Differences between the curves do not indicate a signal of change relative to NISP Future Conditions.

**Interpretation**

Effect of the Expanded Glade Alternative on the distribution of sediment transport potential with flow was determined to be negligible.
Figure 15-13. Distribution of sediment transport potential with flow in Laporte reaches – Expanded Glade Alternative versus NISP Future Conditions.
Figure 15-14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Expanded Glade Alternative versus NISP Future Conditions.
Figure 15-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches – Expanded Glade Alternative versus NISP Future Conditions.
15.10 Overview of Effects of the Expanded Glade Alternative on Sediment Transport and River Morphology

In overview, the Expanded Glade Alternative would be expected to have a negligible impact on the trajectory of the Poudre River under NISP Future Conditions with Glade Reservoir, briefly described in Section 1.3.2.4.

Based largely on an observational model of response to NISP Future Conditions hydrology, a negligible impact on the trends that were identified in the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, 2014) would be expected.

The effects of the Expanded Glade Alternative were found to be similar to Fort Collins’ Proposed Action, but relative to their respective baseline conditions. The Expanded Glade Alternative would have slightly more impact in the Laporte and Fort Collins reaches.
16 Main Stem – Effects of the No-Action Alternative versus Future Conditions

This Chapter presents a discussion of the effects of the No-Action Alternative relative to Future Conditions on the Main Stem. Hydrology for the No-Action Alternative (NA4) is compared against Future Conditions (Run 2) and used in a range of various analyses. Full documentation, including figures and tables, associated with the comparison of the No-Action Alternative with Future Conditions can be found in Volume III, Appendix Q of this report.

The discussion below relies heavily on the detailed assessment presented in Chapter 12 which compared Fort Collins’ Proposed Action versus Future Conditions. This Chapter does not repeat the detailed descriptions of Chapter 12 for the No-Action Alternative. Instead, it reports by exception – identifying areas where differences between the Fort Collins’ Proposed Action versus Future Conditions comparison and the No-Action Alternative versus Future Conditions comparison could be important and, where feasible, presenting a “comparison of the comparisons”.

16.1 Box and Whisker Plot of Monthly Flows

Refer to Appendix Figures Q-1 and Q-2 (Appendix Q, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.1
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

During high flow months critical to morphology and sediment transport (May, June, and July), change in average monthly flow at the Canyon Gage would be negligible (plus or minus 0.5 percent) for the No-Action Alternative (Figure 16-1).

At the Lincoln Gage, changes under the No-Action Alternative and less than Fort Collins’ Proposed Action (Figure 16-2).

Interpretation

Changes in monthly flow statistics under the No-Action Alternative would be negligible.
Figure 16-1. Percent change in average monthly flow volumes at Canyon Gage – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.

Figure 16-2. Percent change in average monthly flow volumes at Lincoln Gage – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.
16.2 Flow Frequency and Duration Analysis

Refer to Appendix Figures Q-3 through Q-10, Appendix Tables Q-1 through Q-3 (Appendix Q, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.2
Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

Reduction in frequency of high flows (1 to 5 percent exceedance flows) associated with the No-Action Alternative would be nearly zero. Under the No-Action Alternative, the 2 percent exceedance discharge (flow equaled or exceeded 2 percent of the time) critical to geomorphology and sediment transport would be nearly the same as Future Conditions (Figure 16-3).

Interpretation

There would be no changes in high flow frequency throughout the system under the No-Action Alternative. Similarly, seasonal change in daily flow statistics would be negligible.

16.3 Flood Frequency Analysis

Refer to Appendix Figures Q-11 and Appendix Tables Q-4 and Q-5 (Appendix Q, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.3
Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

The No-Action Alternative only would reduce the 2-year flood discharge in the Laporte Reach between the Little Cache/New Mercer Ditch and the Larimer and Weld Canal by no more than 2 percent (Figure 16-4).

Interpretation

Overall, there would be negligible change in the magnitude of floods associated with the No-Action Alternative.
Figure 16-3 Percent change in 2 percent exceedance discharge – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Figure 16-4. Percent change in 2-year flood discharge – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.
## 16.4 Flushing Flows

Refer to Appendix Figures Q-12 to Q-29 and Appendix Tables Q-6 and Q-7 (Appendix Q, Volume III)

Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.4 Assessment of Flushing Flows on the Cache la Poudre River Section 3.1 (Anderson Consulting Engineers, Inc. 2017)

(Note that flushing flow information is not provided in the Main Stem Baseline Report)

The No-Action Alternative only would have impact at one location within the Laporte Reach with a loss of one year of flushing flows (Figure 16-5). Flushing flow spells at all other locations would be the same as Future Conditions. Comparison of the average annual recurrence interval of flushing flows is provided in Table 16-1. Changes in the average annual recurrence interval would be negligible for the No-Action Alternative.

### Interpretation

Changes in the occurrence and duration of flushing flows would be negligible under the No-Action Alternative.

![Figure 16-5. Change in number of years of occurrence of flushing flows—No-Action Alternative versus Fort Collins’ Proposed Action.](image)

Anderson Consulting Engineers, Inc.
Table 16-1. Comparison of flushing flow annual recurrence interval – No-Action Alternative, Fort Collins’ Proposed Action, and Future Conditions.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Future Conditions Annual Recurrence Interval (years)</th>
<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
<th>No-Action Alternative Annual Recurrence Interval (years)</th>
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</tr>
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</table>

16.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

16.5.1 Analysis at all Cross Sections

Refer to Appendix Figure Q-30 (Appendix Q, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.1
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Under the No-Action Alternative, 150 cross sections (out of 407) show a change in duration of channel maintenance flows. The duration of channel maintenance flows would be subtly decreased by an average of less than 1 percent (Figure 16-6). Relative to Fort Collins’ Proposed Action there would be less change with the No-Action Alternative throughout the river.

Interpretation

Negligible reduction (less than 1 percent) in the duration of channel maintenance flows is noted under the No-Action Alternative throughout the river. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists.
Figure 16-6. Percent change in the duration of channel maintenance flows – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.
16.5.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures Q-32 to Q-39 and Appendix Tables Q-8 to Q-9
(Appendix Q, Volume III)

Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.5.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no reduction in the number of channel maintenance flow events under the No-Action Alternative (Figure 16-7). Downstream of Interstate-25, there would be some increase in the number of events, but impacts would be negligible.

![Figure 16-7. Change in number of channel maintenance flow events – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.](image)

**Interpretation**

In summary, upstream of Interstate-25, the spells analysis does not predict a reduction in number of events of channel maintenance flows. This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 16.5.1.
The duration of channel maintenance flows was found to also be subtly reduced by an average of 1 percent. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

### 16.6 Flows that Move Coarse Bed Material

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as reach representative cross sections.

#### 16.6.1 Analysis at all Cross Sections

Refer to Appendix Figure Q-31 (Appendix Q, Volume III)

Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.1

Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

Throughout the Poudre River, durations of bed material movement under the No-Action Alternative would be generally reduced by no more than 2 percent and would be smaller than Fort Collins’ Proposed Action (Figure 16-8).

Upstream of Interstate-25, bed material movement would occur at 57 out of 206 cross sections (28 percent) under Future Conditions. Under the No-Action Alternative, motion still would occur at these cross sections but with a change, both positive and negative, in duration noted at 20 of the cross sections. The average change in duration would be a reduction of less than 1.4 percent.

Downstream of Interstate-25, bed material motion would occur at 122 out of 201 cross sections (59 percent) under Future Conditions. Under Fort Collins’ Proposed Action, motion still would occur at these cross sections but for a reduced duration at 42 of the cross sections (21 cross sections less than for Fort Collins’ Proposed Action). For these 42 cross sections, the average reduction in duration would be 1.4 percent.

**Interpretation**

A signal of change in the duration of flows that move coarse bed material was not indicated in results of the analysis under the No-Action Alternative.
Figure 16-8. Percent change in duration of coarse bed material movement – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.
16.6.2 Spells Analysis at Representative Cross Sections

Refer to Appendix Figures Q-32 to Q-39 and Appendix Tables Q-10 and Q-11 (Appendix Q, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.6.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

The reduction in bed material motion is further examined at selected representative cross sections. Upstream of Interstate-25, there would be no change in spells at any of the representative cross sections evaluated for the No-Action Alternative or Fort Collins’ Proposed Action (Figure 16-9). In the reaches below Interstate-25, changes would be the same for the No-Action Alternative and Fort Collins’ Proposed Action, with both being minimal.

**Interpretation**

Changes in the occurrence and duration of bed material motion under the No-Action Alternative would be negligible.

![Graph](image.png)

**Figure 16-9. Change in number of events of coarse bed material movement – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.**

16.7 Stream Power

Refer to Appendix Figures Q-40 to Q-43 (Appendix Q, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.7
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)
Under the No-Action Alternative there would be negligible changes in total flow energy (change would be less than plus or minus 1 percent) (Figure 16-10).

Change in total work in excess of stream power required to move bed material indicates a reduction generally no greater than 2 percent for both the No-Action Alternative, which would be consistently less change than for Fort Collins’ Proposed Action (Figure 16-11).

*Interpretation*

Reductions in the total work in excess of stream power required to move bed material would be generally less than 2 percent under the No-Action Alternative and would have negligible impact.

### 16.8 Sediment Transport Potential

Refer to Appendix Figure Q-44 and Appendix Tables Q-12 and Q-13 (Appendix Q, Volume III)

Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.8

Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Change in average annual sediment transport potential for the No-Action Alternative would be less than 0.5 percent throughout the river (Figure 16-12).

*Interpretation*

Change in sediment transport potential would be negligible.
Figure 16-10. Percent change in total work – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.

Figure 16-11. Percent change in total work above incipient motion – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.
Figure 16-12. Percent change in average annual sediment transport potential – No-Action Alternative and Fort Collins’ Proposed Action versus Future Conditions.
16.9 Distribution of Sediment Transport Potential with Flow

Refer to Appendix Figures Q-45 to Q-48 (Appendix Q, Volume III)
Fort Collins’ Proposed Action versus Future Conditions Refer to Chapter 12, Section 12.9
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

A comparison of the magnitude-frequency curves for the No-Action Alternative, Fort Collins’
Proposed Action, and Future Conditions indicates little to no change (Figure 16-13, Figure
16-14, and Figure 16-15). Subtle changes that are noted between curves would not be likely to
manifest as an adverse impact.

**Interpretation**

Effect of the No-Action Alternative on the distribution of sediment transport potential with flow
was determined to be negligible.
Figure 16.13. Distribution of sediment transport potential with flow in Laporte reaches – No-Action Alternative, Fort Collins’ Proposed Action, and Future Conditions.
Figure 16-14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – No-Action Alternative, Fort Collins’ Proposed Action, and Future Conditions.
Figure 16-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches – No-Action Alternative, Fort Collins’ Proposed Action, and Future Conditions.
16.10 Overview of Effects of the No-Action Alternative on Sediment Transport and River Morphology

In overview, the trajectory of the river condition would be expected to continue under both Future Conditions and the No-Action Alternative with negligible change.

Based largely on an observational model of response to Future Conditions hydrology, the trends that were identified in the Future Conditions assessment would be expected to continue throughout the river with negligible impacts under the No-Action Alternative.

The No-Action Alternative would have less impact than Fort Collins’ Proposed Action.
17 Main Stem – Cumulative Effects with Fort Collins’ Proposed Action versus Future Conditions

This Chapter presents a detailed discussion of Cumulative Effects with Fort Collins’ Proposed Action relative to Future Conditions on the Main Stem. Cumulative Effects with Fort Collins’ Proposed Action hydrology (PA5) is compared against Future Conditions (Run 2) and used in a range of various analyses. In this Chapter Cumulative Effects with Fort Collins’ Proposed Action is referred to as ‘Cumulative Effects’. Cumulative Effects hydrology combines Fort Collins’ Proposed Action, NISP’s Proposed Action (Alternative 2), the Seaman Project Proposed Action, and RFFAs.

Discussion of Cumulative Effects provided below is also presented with comparisons of Fort Collins’ Proposed Action versus Future Conditions, previously presented in Chapter 12. This allows the reader to identify what portion of Cumulative Effects would be attributed to Fort Collins’ Proposed Action.

Full documentation, including figures and tables, associated with the comparison of Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions can be found in Volume III, Appendix R of this report.

17.1 Box and Whisker Plot of Monthly Flows

Refer to Figures R-1 and R-2 (Appendix R, Volume III)
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

The box and whisker plot of monthly flows is based on the full modeled monthly data set which covers the 56-year period from 1950 to 2005. The box and whisker plots provide an overview of the predicted changes in overall flow volumes in the river because of Cumulative Effects over a longer time period than the 26-year period of daily data. The plots include the minimum, maximum, 25th and 75th percentiles, median, and average monthly flow volumes. Note that the average monthly value sometimes falls outside of the 25th to 75th percentile range. This indicates a non-normal distribution of flow that is associated with diversion patterns.

Cumulative Effects would reduce average monthly flow volumes at the Canyon Gage during the months of April through October, with the largest reduction occurring in the high flow month of May (Figure 17-1). Average monthly flows would be reduced between 15 and 30 percent during the high flow months (May, June, and July) that are critical to morphology and sediment transport.

At the Lincoln Gage, average monthly flows would be reduced in all months except October and November. Average monthly flows would be reduced 25 to 44 percent during the high flow months (May, June, and July) (Figure 17-2).
Figure 17-1. Percent change in average monthly flow at the Canyon Gage – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.

Figure 17-2. Percent change in average monthly flow at the Lincoln Gage – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
**Interpretation**

Comparisons at the Canyon Gage and Lincoln Gage show relatively large reductions in flows associated with Cumulative Effects. Although there would be further complex changes to flow diversions and returns downstream of the Canyon and Lincoln Gages, the comparison results provide an indication of the gross impact of all three projects on flows downstream through the river. The reduction in flow volumes during high flow months would tend to reduce hydrologic variability in the system. Consequential impacts on sediment mobility and channel morphology including channel contraction, fining of surficial material, or loss of morphologic complexity are discussed in the following analyses. Most of these reductions would be associated with NISP’s Proposed Action (Alternative 2) and the Seaman Project Proposed Action.

**17.2 Flow Frequency and Duration Analysis**

Refer to Figures R-3 through R-10, Tables R-1 through R-3 (Appendix R, Volume III) Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

A key observation from the plotted frequency distributions of daily flows (Figure R-3 and Figure R-4) is that at almost all hydrologic nodes downstream of the Poudre Valley Canal there would be a reduction of 40 to 50 percent in the amount of time the river flows at or above about 1,000 cfs.

Another way of expressing the change in the flow frequency distribution is to look at the change in the flow of a particular duration. The flow frequency tables (Table R-2, Table R-3, and Table R-4) indicate that reductions would be greatest for the 1, 2, and 5 percent exceedance flows (flows that would be equaled or exceeded 1, 2, and 5 percent of the time). These flows represent the high flow range critical to morphology and sediment transport and would be reduced by 25 to 45 percent upstream of Interstate-25. Cumulative Effects would reduce the 2 percent exceedance discharge between 19 and 43 percent throughout the length of the river (Figure 17-3).

The seasonality of changes in mean daily and maximum daily flow was also evaluated (Figures R-7 to R-10). During the low flow winter months (October through February), mean daily flows would be slightly reduced above the Larimer No. 2 Canal by up to 10 percent and generally increased by up to 10 percent below and through Fort Collins (Figure R-7). Reductions of up to 30 percent in mean daily flows are noted during the spring months of March through April 15th upstream of Interstate-25 (Figure R-8). During the high flow summer months mean daily flows show a consistent reduction of up to 35 percent (Figure R-9). During the fall (July 15th through September), mean daily flows would be reduced by as much as 25 percent upstream of Interstate-25, with negligible change noted downstream of Interstate-25 (Figure R-10).
Figure 17-3. Percent change in 2 percent exceedance discharge – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
Interpretation

There would be large changes in flow frequency throughout the system as a result of Cumulative Effects hydrology. Changes would vary, reflecting the complex interactions of diversions, transfers, and returns at various locations. Throughout the study area, changes to flows would be greatest during the high flow period – late spring to early summer. Taken over the whole year, the 1, 2, and 5 percent flows would be affected by a reduction of 25 to 45 percent in duration and magnitude at different places in the system.

Widespread 25 to 45 percent reductions in the 1 to 5 percent exceedance flows could have an impact on channel forming discharges and channel morphology. Implications for the likelihood and magnitude of possible channel contraction, fining of surficial material, and loss of hydraulic and morphologic complexity are further explored in the comparisons presented below.

17.3 Flood Frequency Analysis

Refer to Figures R-11 and Tables R-4 and R-5 (Appendix R, Volume III)
Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

It is important to note that this flood frequency analysis has been undertaken on the 26-year period of modeled daily flows. The analysis should not be compared with other flood frequency analyses for the river which are undertaken for a different purpose and based on much longer periods of record covering a wider range of flood peaks.

A 20 to nearly 50 percent reduction in the magnitude of the 2-year flood would be shown upstream of Interstate-25, with a more consistent reduction of roughly 20 percent downstream (Figure 17-4). The impact on the 10-year flood would be more consistent across the length of the river and would range from roughly 20 to 35 percent (Figure 17-5). The impact of Cumulative Effects on floods larger than these (e.g., the 100-year flood) cannot be reliably estimated with the 26-year existing modeled data set.

Interpretation

The reductions in flood magnitudes correlate with reductions in flow durations and reflect increased diversions from the river. Reductions in the frequency of occurrence of high flows have the potential to cause morphologic change through reduced sediment mobility. These implications are explored below.
Figure 17-4. Percent change in 2-year flood discharge – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
Figure 17-5. Percent change in 10-year flood discharge – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
17.4 Flushing Flows

Refer to Figures R-12 to R-29 and Tables R-6 and R-7 (Appendix R, Volume III)
(Note that flushing flow information is not provided in the Main Stem Baseline Report)

Flushing flows are defined as flows that flush or move sediments (sands and gravels) resting on top of the coarse bed material matrix (or armor layer) in riffles. Flushing flows allow for surface cleaning of riffles necessary to support ecological function of the river channel. A positive effect of flushing flows is that they maintain spawning habitat for fish. Baseline flushing flows identified for comparative assessments were defined as flows having a recurrence interval of 2 years relative to Future Conditions hydrology (Anderson Consulting Engineers, Inc. 2017).

In the Laporte Reaches, between the Poudre Valley Canal and the Larimer and Weld Canal, the number of years of occurrence of flushing flows would be reduced by Cumulative Effects a total of 5 to 7 years (a 50 to 64 percent reduction in occurrence) in the 26-year period (Figure 17-6 and Appendix Table R-7). This translates to change in the annual recurrence interval of flushing flows from 2 to 2.6 years under Future Conditions and 4.3 to 6.5 years under Cumulative Effects. The average annual duration of flushing flows would be reduced by up to 1 day per year. The median duration would be reduced by up to 5 days per year (Appendix Table R-7).

Through Fort Collins, flushing flows occur in 13 out of 26 years under Future Conditions and 6 to 7 years out of 26 under Cumulative Effects hydrology. This would be a reduction in the number of years of occurrence of 6 to 7 years (Figure 17-6). The annual recurrence interval would be approximately 3.7 to 4.3 years with Cumulative Effects. The large reduction in occurrences results in an increase in the average and median duration of flushing flows (Appendix Table R-7).

The occurrence of flushing flow in the Timnath reach would be reduced under Cumulative Effects from 12 years to 9 years, a 3-year reduction (Appendix Table R-7). The average duration would be reduced by 7.4 days per year and the median duration by 16 days per year.

Comparison of the average annual recurrence interval of flushing flows for Future Conditions, Fort Collins’ Proposed Action, and Cumulative Effects is provided in Table 17-1. Cumulative effects would increase the average annual recurrence interval to as much as 6.5 years in the Laporte Reaches, as much as 4.3 years in Fort Collins, and to 2.9 years in Timnath.
Figure 17-6. Change in the number of years of occurrence of flushing flows – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.

Table 17-1. Comparison of flushing flow annual recurrence interval – Fort Collins’ Proposed Action, Cumulative Effects, and Future Conditions.

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<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
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<th>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</th>
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<td>2.0</td>
<td>2.0</td>
<td>4.3</td>
</tr>
<tr>
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<td>2.0</td>
<td>2.0</td>
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</tr>
<tr>
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<td>2.0</td>
<td>2.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Timnath</td>
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<td>972</td>
<td>2.2</td>
<td>2.2</td>
<td>2.9</td>
</tr>
</tbody>
</table>
Interpretation

The analysis of flushing flows addresses one process by which fining of surficial material could be an impact of Cumulative Effects. The annual occurrence of flushing flows would be reduced by half under Cumulative Effects. This also means that the average annual recurrence intervals (time between flushing) would be doubled in some reaches. The Laporte and Fort Collins reaches would be most impacted. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

17.5 Channel Maintenance Flows

Channel maintenance flows are defined as the flow required to remove sediment trapped in between coarser material that comprises the bed material matrix (armor layer). For the CTP, a critical dimensionless shear stress was adopted to represent conditions when bed material moves sufficiently to just allow finer material to be released from the interstices of coarser surface layers of the bed. The geomorphic process related to channel maintenance flows is of ecological significance. Ecological criteria would consider not only the total duration of channel maintenance flows in the 26-year period but also the number of occurrences and the time between occurrences. The analysis reported in this section provides no information on specific ecologic criteria, but the spells analysis (Section 17.5.2) presents information on the frequency and duration of channel maintenance flows.

This process and the applicability of this criterion are considered to be most important within reaches of the Main Stem located upstream of Interstate-25 where there is a gravel and cobble substrate that has been observed to be smothered by fine material between channel maintenance flow events. Channel maintenance flows also have some ecological relevance in the portion of the study area downstream of Interstate-25 where sands and silts can be flushed from bars and islands in high flows to reveal underlying gravels. The process downstream of Interstate-25 is considered to be controlled by criteria for general bed material movement rather than criteria for channel maintenance flows and is further discussed in Section 17.6.

17.5.1 Analysis at all Cross Sections

Refer to Figure R-30 (Appendix R, Volume III)
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

The duration for which channel maintenance flows would be expected to occur under Future Conditions and Cumulative Effects were evaluated at 407 cross sections. The results are shown for the whole river, but the process is most important in the gravel and cobble bed reaches upstream of Interstate-25 (36 miles above South Platte confluence). The comparison demonstrates that the duration of channel maintenance flows would be consistently decreased by up to 55 percent throughout the entire length of the river (Figure 17-5). Computations were
conducted at all cross sections in order to capture the highly variable nature of hydraulic conditions along the river.

It is important to put this finding in the context that changes do not occur at all cross sections on the river. As described below, there are many other cross sections that the analysis predicts would not be impacted by a change in channel maintenance flow duration.

- In addition to the cross sections where a change in the duration of channel maintenance flow is shown, there are many cross sections where channel maintenance flows would not occur in the 26-year modeled period for either Future Conditions or Cumulative Effects; and others where no change in channel maintenance flow duration is predicted. Out of a total of 407 cross sections analyzed, 170 (42 percent) show no occurrence of channel maintenance flows during the modeled period. There are 237 cross sections (58 percent) where channel maintenance flows would occur. A total of 14 cross sections (out of 237) show no change in the duration of channel maintenance flows from Future Conditions to Cumulative Effects. Consequently, 223 cross sections (out to 237) show a change in duration with Cumulative Effects. The average change in duration computed at the 223 cross sections would be a reduction of 29 percent.

- Upstream of Interstate-25, out of 206 cross sections analyzed, 103 show an occurrence of channel maintenance flows during the modeled period and of those cross sections, 11 cross sections show no change in channel maintenance flow duration. At the remaining 92 cross sections, the average reduction in duration would be 28 percent.
Figure 17-7. Percent change in the duration of channel maintenance flows – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
**Interpretation**

The analysis of channel maintenance flows addresses one process by which fining of surficial material could be an impact of Cumulative Effects. For the reaches upstream of Interstate-25, the information presented suggests a reduction in the duration of channel maintenance flows by an average of 29 percent and as much as 55 percent at certain cross sections. The ecological impact of such change depends on the ecological criteria that are applied and will be further reported by other resource specialists. Further information to assist interpretation of ecological implications is provided in the following spells analysis (Section 17.5.2).

**17.5.2 Spells Analysis at Representative Cross Sections**

Refer to Figures R-32 to R-39 and Tables R-8 to R-9 (Appendix R, Volume III)  
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)  
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections by evaluating the occurrence of periods where channel maintenance shear stress criterion would be exceeded. For the reach upstream of Interstate-25, change in the occurrence and duration of channel maintenance flows is well illustrated at Cross Section 257663 in the Laporte reach and Cross Section 231351 in the Fort Collins reach, although it should be noted that little or no change is demonstrated at the remaining cross sections presented evaluated (Figure 17-8).

In the Laporte Reach (Section 257663), 12 channel maintenance events under Future Conditions hydrology lasting for 121 days in total become 5 events under Cumulative Effects lasting for 54 days in total (see Appendix Table R-8).

In the Fort Collins Reach (Section 231351), 22 channel maintenance events with Future Conditions hydrology lasting for 301 days in total become 14 events under Cumulative Effects lasting for 157 days in total, (see Appendix Table R-8).
Interpretation

In summary, the spells analysis predicts a reduced duration of channel maintenance events at individual cross sections upstream of Interstate-25. The number of events would be also reduced.

This analysis provides detail of the temporal distribution of channel maintenance flows but is limited by being spatially discrete and relying on a selection of individual cross sections. Quantitative extrapolation from an individual cross section to a reach requires caution, but the overall spatial distribution of the changes can be inferred from the analysis already reported in Section 17.5.1.

Taken together, this and the preceding analysis indicate a reduction in the duration of flows that remove sediments from the interstices of coarse material within the armor layer of the river bed upstream of Interstate-25. The ecological and other implications of this finding will be analyzed and reported by other resource specialists.

17.6 Flows that Move Coarse Bed Material

The point at which material in the bed of the river starts to move is a geomorphic threshold. The occurrence of bed material motion and the duration of flows above this threshold influence the size, shape, and dynamics of the river channel. For the CTP evaluation, initiation of motion was related to a critical shear stress which varies along the river according to the size of material
present in the river bed. Upstream of Interstate-25, where the bed is generally armored, initiation of motion is particularly important because it represents the flow at which the armor layer is broken, and underlying sediment is released. Downstream of Interstate-25, the frequency and duration of bed material motion provides an indication of the frequency and magnitude of sediment transport.

17.6.1 Analysis at all Cross Sections

Refer to Figure R-31 (Appendix R, Volume III)  
Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

The duration for which bed material movement would be expected to occur under Future Conditions and Cumulative Effects was compared at 407 cross sections (Figure 17-6). Throughout the river, durations of bed material movement under Cumulative Effects would consistently be reduced by up to 60 percent throughout the river.

Under Future Conditions, bed material movement would occur at 57 out of 206 cross sections (28 percent) upstream of Interstate-25. Under Cumulative Effects, motion still would occur at these cross sections but with an average reduction of 25 percent in the duration at 48 of the cross sections.

Downstream of Interstate-25 bed material motion would occur at 122 out of 201 cross sections (59 percent) under Future Conditions. Under Cumulative Effects, motion would still occur at these cross sections but for a reduced duration at 117 of the cross sections. For these 117 cross sections, the average reduction in duration would be approximately 32 percent.

Interpretation

Reduced duration of flows that generate motion of bed material would have implications both upstream and downstream of Interstate-25. In both cases, it implies that the river is predicted to move less sediment through the system under Cumulative Effects than under Future Conditions hydrology.

As a second order effect, the truncated periods of bed material motion are predicted to decrease the opportunity for scouring of in-channel vegetation from bars, islands, and channel margins. Observations following the flood in September 2013 indicated little scouring of vegetation so this reduction of in-channel vegetation attributable to scour could be limited. This is a duration dependent process, and the reduced duration of scouring flows would be expected to increase the persistence of in-channel vegetation. Where vegetation endures, it could then continue to grow and strengthen and act to reduce future motion of bed material (a bio-geomorphic feedback threshold). The likelihood that vegetation would colonize and stabilize bars and islands is also dependent on the time between the flow events that initiate motion. This is further investigated by a spells analysis in Section 17.6.2.
Where the supply of material that makes up the bed is limited, such as in the Fort Collins and Laporte Reaches, reduced movement of bed material under Cumulative Effects would be likely to lead to lower rates of change of in-channel bars, islands, benches, and channel form. This trend has already been reported for Future Conditions hydrology in the Main Stem Baseline Report (Anderson Consulting Engineers, Inc. 2013). Erosion would be predicted to still occur at some locations and on some occasions particularly as a consequence of floods, but the frequency and magnitude of channel change would be likely to decrease with Cumulative Effects. Bed material only moves at approximately 30 percent of cross sections so spatial variability in hydraulic conditions would be predicted to be maintained with the existing array of channel features and in-channel structures. Increased stability would have benefits, particularly in an urban environment such as Fort Collins, but increased stability would be predicted to also lead to reduced temporal variability of biotopes.

As well as the decrease in temporal variability, decreased durations of bed material movement would also be likely to reduce spatial variability downstream of Interstate-25 where bed material is smaller and more mobile.
Figure 17-9. Percent change in the duration of coarse bed material movement – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
17.6.2 Spells Analysis at Representative Cross Sections

The reduction in bed material motion is further examined at selected representative cross sections by computing the occurrence of periods for which the shear stress criterion for initiation of motion would be exceeded. Upstream of Interstate-25, there is one cross section that indicates a reduction of events (Figure 17-10). Downstream of Interstate-25, there would be consistent reductions in Windsor and Greeley.

![Figure 17-10](image)

**Figure 17-10.** Change in number of events of bed material movement – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.

*Interpretation*

The occurrences of bed material movement would not be consistently reduced upstream of Interstate-25. The spells analysis suggests further that the time between occurrences of bed material motion would not be generally increased under Cumulative Effects, so to the extent that colonization of vegetation is dependent on the existence of a stable substrate, negligible change in the rate or extent of new colonization would be expected.
17.7 Stream Power

Refer to Figure R-40 to R-43 (Appendix R, Volume III)
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Stream power can be calculated at each cross section for each flow in the modeled data sets. Summed over the 26-year modeled period (with appropriate units), stream power represents the ability of the flow to “do work” on the channel boundaries. Also of interest is the stream power in excess of the power that would be required to initiate bed material motion. This can give an indication of the amount of “work” that can move the channel bed.

Upstream of Interstate-25, total flow energy would be reduced by up to 40 percent (Figure 17-7). Downstream of Interstate-25, the reduction in flow energy attributable to Cumulative Effects would be generally limited to less than 25 percent.

Cumulative Effects would reduce the “work” that flow can do in moving the channel bed by up to 55 percent (Figure 17-8). However, it should be noted that the reduction would occur at about 13 percent of cross sections upstream of Interstate-25 (27 of the 206) and about 40 percent of cross sections downstream of Interstate-25 (80 of the 201).

Interpretation

The results serve to underscore the former interpretations and reinforce the finding that the ability of the river to move its bed and banks would be predicted to decrease under Cumulative Effects.

The comparison also predicts that the decrease in energy available to move the bed would be more pervasive downstream of Interstate-25 than upstream of Interstate-25. A reduction in available energy above the threshold that can move bed material would be more than twice as common spatially downstream of Interstate-25 than upstream of Interstate-25. This is a direct consequence of the armored bed in the upstream reaches.
Figure 17-11. Percent change in total work – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.

Figure 17-12. Percent change in total work above incipient motion – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
17.8 Sediment Transport Potential

Refer to Figure R-44 and Tables R-12 and R-13 (Appendix R, Volume III)
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

Sediment transport potential is the capacity of the river to move sediment over the 26 years of modeled flows, if that sediment were available to be moved. The results are presented separately for total bed material load, sand, gravel, and cobble sized material. Size gradations used in the sediment transport calculations reflect current gradations in the river bed.

Upstream of Interstate-25, the total amount of material that could be moved would be reduced by approximately 17 to 44 percent (Figure 17-9) below the Poudre Valley Canal. Transport potential for sand only would be reduced between 15 and 43 percent, and for gravels by 20 to 47 percent, (Table R-12 and R-13). Downstream of Interstate-25, the total amount of material that could be moved would be reduced by 10 to 25 percent (Figure 17-9), or considering sand only, the reduction would be 9 to 19 percent. Transport potential for gravels downstream of Interstate-25 would be reduced by 25 to 42 percent.

Interpretation

These results of the change in sediment transport potential cannot be directly interpreted to provide an estimate of the actual magnitude of sediment transport response due to lack of information on the availability of sediment entering the river system from upstream. However, given the findings of the Main Stem Baseline Report, some conclusions about sediment response can be drawn as follows.

Downstream of Interstate-25

Starting at around Interstate-25 and continuing downstream to Greeley, the contemporary state of the river channel is evidence that there is net deposition of sands and fine gravels as defined in the Main Stem Baseline Report. For any of the available bed material size fractions, a further reduction in sediment transport potential around the predicted 10 to 25 percent range predicted for Cumulative Effects would be anticipated to further reduce the duration of periods when transport exceeds or balances supply. The reduction in transport potential for gravels only would be between about 25 and 42 percent, indicating more impact to the transport of gravels than sands. The result would be expected to reinforce the future net depositional trend. It is predicted that there would continue to be occasions when some of the material that enters a reach from upstream would not be transported and would deposit in the lee of obstructions, downstream of bars and islands, and on channel margins. The frequency and duration of these occasions are predicted to increase under Cumulative Effects.
Figure 17-13. Percent change in total average annual sediment transport potential – Cumulative Effects and Fort Collins’ Proposed Action versus Future Conditions.
Observation over the course of this study also makes it clear that deposition would be episodic. Within the net depositional trend, there are periods when sand and fine gravels would build up in the channel and other periods when, at least at some cross sections, sediment would be removed again. Even with the reduced sediment transport potential, the model that derives from the observed response indicates that the processes would not be continuous or even uni-directional. Change would be predicted to be episodic in response to variations in water flow and sediment flux and changes in the rate of colonizion and the persistence of in-channel vegetation. It is predicted that there would be periods when the channel would be essentially static, periods when deposition would be the dominant process, and other periods when transport exceeds supply and previously deposited material would be removed. Nor would deposition be uniform in space. The loci of maximum deposition is predicted to move within the reach in response to variability in flow and sediment supply. Despite the episodic nature of the process, the net effect of a further reduction in sediment transport potential is predicted to reinforce the future process of channel contraction in this reach.

**Upstream of Interstate-25**

Upstream of Interstate-25, all the same forces are at play, but the model based on contemporary observations predicts that the response would be less, given the limited supply of sediment in this reach. Under Future Conditions hydrology, the contemporary armor layer and the general absence of available sands and fine gravels in the river bed attest that the majority of this finer material that enters the reach is soon transported through without long-term deposition. Furthermore, there is little evidence of progressive accumulation of medium or coarse gravels or cobbles in the reach despite the historical reductions in the flow regime and the depositional environments that exist upstream of the numerous diversion structures. These contemporary observations led to the conclusion in the Main Stem Baseline Report that the reach was supply limited — flows would generally be able to transport all incoming material (sands and gravels) through the reach without deposition. Under these conditions, a reduction in sediment transport potential would negligible unless a threshold was reached whereby upstream (or in-channel) sediment supply exceeded sediment transport potential, or vegetation effects started to dominate. Instances of excess sediment supply could occur locally during flow events that capture adjacent gravel pits, remove a diversion structure, result in channel relocation or mass failure of channel banks, or supply fine sediment following a fire and subsequent hillslope erosion in the upstream watershed.

It should also be pointed out that adopting a fixed descriptive boundary such as Interstate-25 is more of a convenience than a reality. The episodic nature of erosion and deposition processes demands a transition zone between the two types of river response and the boundary demarcating observable deposition is predicted to move upstream and downstream depending on recent history of flows and the particle size, quantity, and rate of sediment supply. Based on observations, Interstate-25 approximately marks this transition.
17.9 Distribution of Sediment Transport Potential with Flow

Refer to Figure R-45 to R-48 (Appendix R, Volume III)
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

A comparison of magnitude-duration analyses was conducted to demonstrate how sediment transport potential would be distributed across the flow range for Future Conditions and Cumulative Effects. The peak of the magnitude-frequency curve gives an indication of the effective discharge for the channel based on the sediment transport potential of the current bed material distribution for each reach in the SIAM model.

Note that the curves presented here differ from the curves shown in the Main Stem Baseline Report in two respects.

- The Main Stem Baseline Report illustrated magnitude-frequency analyses for each of the standard particle size intervals in each reach as if each particle size interval were the only size in transport. To simplify the comparison between scenarios, the presentation herein shows a single curve that is based on accumulating the sediment transport potential for each size interval in proportion to the size distribution of the bed material.

- The Main Stem Baseline Report presented the magnitude-frequency analysis based on 15 logarithmically distributed discharge intervals. For the comparisons reported here, the range of discharges has been increased to include the first discharge interval with zero occurrences and the size of the discharge interval has been increased so that the number of discharge intervals is reduced.
  - Increasing the range has the effect of driving all magnitude-frequency curves to zero at the maximum discharge. This is realistic since no flow and hence no sediment transport has occurred in that interval over the modeled period.
  - Increasing the size of the discharge interval reduces oscillations in the magnitude-frequency curve and facilitates comparisons between scenarios.

A comparison of the magnitude-frequency curves for Future Conditions and Cumulative Effects was provided to determine if hydrologic changes under Cumulative Effects would be likely to affect channel morphology. The following are types of indicators of change.

- A change in the location of the peak of the magnitude-frequency curve gives an indication of a change in effective discharge.
- A change in the magnitude and shape of the peak gives an indication of the change in the strength of the effective discharge signal.
- A change in the area under the curve gives an indication of the change in average annual sediment transport potential (allowing for the log scale).
- The area between the curves demonstrates the change in annual sediment transport potential (allowing for the log scale).
- Changes in the distribution of sediment transport potential across the flow range (see the histograms) show the flow intervals where sediment transport potential would be most
affected by the change in hydrology.

The curves representing the distribution of sediment transport potential with flow can be grouped into three regions showing trends as follows.

- **Laporte Reaches** (Figure 17-14 and Appendix Figure R-45). Loss of high flows under Cumulative Effects would reduce the contribution of high flows to sediment transport potential. This change in hydrology drives a reduction in sediment transport potential of up to 45 percent for flows in the range of 1,000 to 6,600 cfs, accounting for most of the overall reduction in annual average sediment transport potential (Appendix Figure R-45). Effective discharge is indicated to decrease slightly (100-200 cfs) as smaller flows provide an increasing proportion of the sediment transport potential.

- **Fort Collins Reaches** (Figure 17-15, Appendix Figure R-46 and Appendix Figure R-47). The hydrologic changes in these reaches lead to a reduction in sediment transport potential of around 40 to 50 percent across a broader flow range than for the upstream reach. The consequence of this change would be that under Cumulative Effects, flows around 2,000 cfs become less important at transporting sediment because they would be less frequent, but the peak associated with this effective discharge remains. Under Future Conditions hydrology, an effective discharge is clearly identified at 2,000 cfs for all sub-reaches. This is repeated under Cumulative Effects for Fort Collins reaches; however, for Fort Collins Study Reaches 3 and 4 (from Coy Ditch to downstream of Lemay Avenue) a second peak at very low flows would emerge under Cumulative Effects. It appears that the hydraulics in these sub-reaches dictate a higher sediment transport potential at low flows than in other reaches.

- **Timnath, Windsor, Greeley** (Figure 17-16, Appendix Figure R-47 and Appendix Figure R-48). Under Future Conditions, there would be a peak in the distribution of sediment transport potential at around 2,000 cfs, as well as another at around 40 to 110 cfs. The 2,000 cfs peak would be generally dominant under Future Conditions hydrology but this would be also where the biggest absolute change in sediment transport potential would occur, and so the two peaks would be of similar magnitude in some reaches under Cumulative Effects.
Figure 17.14. Distribution of sediment transport potential with flow in Laporte reaches—Fort Collins' Proposed Action, Cumulative Effects, and Future Conditions.
Figure 17-15. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Fort Collins’ Proposed Action, Cumulative Effects, and Future Conditions.
Figure 17-16. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches –Fort Collins' Proposed Action, Cumulative Effects, and Future Conditions.
Interpretation

Laporte Reach

For the Laporte Reach, the predicted reduction in sediment transport potential at high flows suggests an ongoing tendency toward channel contraction by deposition in response to Cumulative Effects. Likewise, the slight shift in the peak of the distribution suggests a lower effective discharge for Cumulative Effects compared to Future Conditions hydrology which implies a trend toward a smaller channel.

While this would be the channel response inferred from the analyses, channel contraction would be predicted to only occur if there would be sufficient material in transport that would be available to be deposited. Initiation of motion and sediment transport analyses show that medium gravel would be the size of bed material that would be near the point of motion in this reach at around the effective discharge for Cumulative Effects. It is therefore concluded that while there would be a tendency towards channel contraction in this reach, it is predicted to only occur at a rate that would be dictated by the availability of material in transport of medium gravel or larger sized material.

Given the history of hydrologic change in the river, the Main Stem Baseline Report documented Future Conditions and future bed material gradations that give an indication that the rate of adjustment would be slow. The Main Stem Baseline Report also presented the finding that the channel in this reach is already subject to contraction as the result of historical changes in flow regime. It showed that the effective discharge for Future Conditions indicated an expected channel capacity of around 1,000 cfs under Future Conditions hydrology but channel capacity was generally much higher. It was concluded that the trend toward channel contraction was constrained by a lack of material (of around medium gravel size) available to deposit in the reach. The same constraint would apply to any trend of channel contraction that would be attributable to Cumulative Effects. The Future Conditions analyses have suggested that the channel has barely responded to the historic changes in flow regime over the last two centuries. Any change attributable to Cumulative Effects is predicted to be similarly constrained by lack of sediment supply.

Fort Collins Reach

The Main Stem Baseline Report suggested that there is also a depositional trend in this reach, but lack of available sediment constrains the depositional response. The Main Stem Baseline Report presented analyses that proposed an effective discharge in this reach of about 2,000 cfs. This compares with estimates of channel capacity in the reach averaging about 6,000 cfs.

Throughout most of this reach, the effects analyses predict an effective discharge of 2,000 cfs for Cumulative Effects – unchanged from the Future Conditions hydrology. Unless the quantity or size distribution of available sediment changes, channel capacity would be similar under Cumulative Effects. That does not mean there would be no change from the present. The future channel would continue undergoing slow adjustment in response to historical changes in the flow
regime. Any change attributable to the Cumulative Effects would be incremental to that existing response.

Under Cumulative Effects, it is possible that the reduced incidence of flows around the future 1-year and 2-year flood level would increase the likelihood that colonizing vegetation can become established before it would be scoured out by subsequent high flows. Channel contraction can then be driven by vegetation in the absence of abundant sediment. An example of a threshold mechanism that could accelerate channel response would be the establishment of vegetation on bars and channel margins, possibly triggered by an influx of sediment. This was observed to occur in Fort Collins following the 2012 wildfires. Small but frequent in-channel deposits of fine sediment provided locations for vegetation to colonize. In this case, most of the new vegetation was scoured from the channel during floods in 2013, but if a series of dry years had allowed the vegetation to establish, it could have become a permanent feature and contributed to channel contraction.

There is a special case that applies to Fort Collins Study Reaches 3 and 4, between Coy Ditch and Lemay. In this reach, hydraulic conditions allow sediment to be moved at low flows and provide a secondary peak in the sediment potential distribution curve at around 25 cfs. Lack of available sediment precludes a systematic response to this secondary peak and it is predicted that the peak at 2,000 cfs would prevail, although channel contraction could occur from time to time in response to pulses of sediment or dry periods and there could be a tendency for the river to develop a smaller benched channel within the larger cross section.  

**Timmath, Windsor, Greeley upstream, Greeley Channelized and Greeley Reaches**

The Main Stem Baseline Report described strong depositional trends at many locations throughout this section of the Poudre River and attributed them to reduced sediment transport potential resulting from historic changes to the flow regime. Vegetation has also been implicated in the persistence of sediment deposits.

Under Cumulative Effects, the minor peak in the distribution of sediment transport potential at 40 to 110 cfs becomes more dominant and it would be likely that renewed channel contraction would occur at some locations for extended periods, as the channel adjusts toward that low flow. Channel contraction in response to the Cumulative Effects would occur as an extension of the processes already underway by deposition on bars, islands, riffles, and channel margins.

The second peak in the curve (at about 2,000 cfs) suggests the possibility of a two-stage channel (one where a benched low flow channel establishes within a larger cross section), or a channel that oscillates between the larger and smaller channel in response to the most recent history of flows. It is important to note however that the sediment transport potential analysis takes no account of the effect of in-channel vegetation. Recent history suggests that as sediment accumulates in the channel in this reach, vegetation would colonize and stabilize the deposits such that channel contraction that might otherwise be temporary, becomes an enduring characteristic. At many locations, channel capacity is already at or below 2,000 cfs. Further contraction would be likely at these cross sections in response to Cumulative Effects, and a
compound channel with capacities as low as 40 to 110 cfs could form by deposition of benches within the larger channel.

Based on the modeled flow record for this reach, the 2-year flood is estimated at roughly 650 to 1,120 cfs under Future Conditions hydrology and 470 to 910 cfs under Cumulative Effects. The effect of the trend of channel contraction on flooding would be balanced to some extent by the decreased frequency of flooding at this recurrence interval. However, larger floods (greater than the 25-year flood) would be less affected by Cumulative Effects, and channel contraction would be predicted to continue to have adverse consequences for flooding from these events.

The complexity of in-channel morphologic features is already low in this reach as the result of sand deposition smothering the bed and reducing the magnitude and frequency of pool and riffle sequences. Further channel contraction under Cumulative Effects would be predicted to exacerbate this condition. Although channel contraction would be predicted to lead to floodplain engagement at lower flows and this could have ecological benefits, the frequency of flows around the future 2-year to 5-year flood would be also reduced.

While the rate of change in channel morphology cannot be directly predicted by these analyses, guidance can be assumed from the history of channel change through the reach. Investigations for the Main Stem Baseline Report concluded that the river downstream of Interstate-25 had crossed a bio-geomorphic threshold and is on a trajectory leading to a shallower and narrower channel. The comparisons show that the impact of Cumulative Effects would be to exaggerate and extend these contemporary changes in channel morphology. Nevertheless, the rate of change would probably be dominated by the rate of sediment supply. The rate of sediment supply from upstream of Interstate-25 and from local catchments would not be sensitive to the hydrologic changes under Cumulative Effects so it is likely that the rate of change downstream Interstate-25 would not be sensitive to the changes either. The best guide to the rate of change under Cumulative Effects would be a continuation of future rates.

Even without this second peak, channel contraction would not be a continual progressive process. While the net response over several years would be expected to reveal a trend toward a shallower and narrower channel, the response at any time depends on the relative location and the recent hydrologic history. For example, observations following the 2013 flood suggest that some previously deposited sand in the Timnath and Windsor reaches was mobilized only to be deposited further downstream in the Windsor and Greeley Reaches.

### 17.10 Overview of Cumulative Effects with Fort Collins’ Proposed Action on Sediment Transport and River Morphology

This section presents an overview of predicted conditions associated with implementation of Cumulative Effects compared to Future Conditions hydrology. The results of the analyses are summarized in Table 17-2.
In overview, the trajectory of the river condition would be expected to continue under both Future Conditions and Cumulative Effects hydrology.

Based largely on an observational model of response to Future Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue and be more severe downstream of Interstate-25 than upstream of Interstate-25 because:

- sediment supply in the size fractions relevant for deposition would be more limited upstream of Interstate-25 than downstream; and
- bio-geomorphic processes involving vegetation establishment on benches and bars prevail more downstream of Interstate-25 compared to upstream.

The trajectory of the river condition with RFFAs ratifies and amplifies the trends that were already identified in the Main Stem Baseline Report for a continuation of Current Conditions. Assessments of the effects of the Cumulative Effects compared to the Future Conditions hydrology further confirm and amplify this trajectory of the river condition reflected in continuing channel contraction, fining of surficial material, and loss of channel complexity.

The contribution of Fort Collins’ Proposed Action to the total impact on the river from Cumulative Effects would be small (on the order of one-tenth) relative to changes attributed to NISP’s Proposed Action (Alternative 2), the Seaman Project Proposed Action, and RFFAs combined. Impacts on the river related to Fort Collins’ Proposed Action alone would be negligible as reflected in the comparative assessment of the Fort Collins’ Proposed Action versus Future Conditions (Chapter 12).
### Table 17-2 Overview of the Main stem effects of Cumulative Effects versus Future Conditions.

<table>
<thead>
<tr>
<th>Possible Impact</th>
<th>Laporte Reach</th>
<th>Fort Collins Reach (plus Timnath Reach upstream of Interstate-25)</th>
<th>Timnath, Windsor and Greeley Reaches downstream of Interstate-25</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Change in flow regime</strong></td>
<td>There would be large changes to flow frequency throughout the system. Changes to flows would be greatest during the high flow period – late spring to early summer. Mean flow would be reduced up to 35 percent from mid-April to mid-July. The duration of flows at or above 1,000 cfs would be reduced by 40 to 50 percent throughout.</td>
<td>Impact would be greatest on 5 to 10 percent exceedance flows which would be reduced by 35 to 55 percent. The 2 percent exceedance flow would be reduced up to 45 percent. A 40 to 49 percent reduction in the magnitude of the 2-year flood would be indicated for the Fort Collins and Timnath reaches; the 25-year flood would be reduced by 20 percent.</td>
<td>Impact would be greatest on 2 percent exceedance flows which would be reduced by 34 to 40 percent. The impact on floods up to the 25-year flood would be reasonably uniform, with the 2-year, 10-year, and 25-year flood peaks all reducing between 16 and 28 percent.</td>
</tr>
<tr>
<td><strong>Fining of surficial material</strong></td>
<td>Fine material accumulating on top of the armored gravel bed could have ecological significance. The occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer would be reduced by 50 to 67 percent in the Laporte Reaches. This can also be viewed in terms of average annual recurrence. Flushing flows have an average annual recurrence of 2.0 to 2.6 years under Future Conditions and 4.3 to 6.5 years under Cumulative Effects.</td>
<td>Fine material accumulating on the armored gravel bed could have ecological significance. The occurrence of flushing flows that remove sediments (gravel sized and finer) resting on top of the coarse armor layer would be reduced by 46 to 53 percent. This can also be viewed in terms of average annual recurrence. Flushing flows have an average annual recurrence of 2.0 to 2.2 years under Future Conditions and 3.7 to 4.3 years under Cumulative Effects.</td>
<td>Reduction in flushing flows would be much less in the Timnath Reach. The occurrence of flushing flows in the Timnath reach would be reduced under Cumulative Effects from 12 years to 9 years. Cumulative Effects decreases the average duration by 7.4 days per year and the median duration by 16 days per year.</td>
</tr>
<tr>
<td><strong>Channel maintenance flows</strong></td>
<td>At 58 percent of the cross sections evaluated for the main stem, the duration of channel maintenance flows (flows that release sediment from the interstices of the coarse armor layer matrix) would be reduced by as much as 55 percent. For the remaining 42 percent of cross sections, there would be either no occurrence of channel maintenance flows under Future Conditions or no change attributable to Cumulative Effects in the duration of channel maintenance events.</td>
<td>Channel maintenance flows (flows that release sediment from the interstices of the coarse armor layer matrix) occur less often under Cumulative Effects compared to Future Conditions hydrology. At 44 percent of the cross sections, the duration of channel maintenance flows would be reduced by up to 50 percent with an average of 28 percent. For the remaining 56 percent of the cross sections, there would be either no occurrence or no change in the duration of channel maintenance flows.</td>
<td>The adopted channel maintenance criteria (dimensionless shear stress greater than 0.02) would be likely to be less ecologically meaningful in this reach because there would be more sand and silt in the bed anyway.</td>
</tr>
<tr>
<td><strong>Loss of morphologic complexity</strong></td>
<td>Bed material moves at about 28 percent of the cross sections under both Future Conditions and Cumulative Effects. Average duration of bed material movement would be reduced by 25 percent for Cumulative Effects hydrology. Spatial variability of biotopes would be provided by existing bed forms and the proliferation of diversion structures. Spatial variability would be predicted to be maintained under Cumulative Effects, but temporal variability would be predicted to be reduced because of reduced flow variability.</td>
<td>Bed material moves at 59 percent of the cross sections under both Future Conditions and Cumulative Effects hydrology. Average duration of bed material movement would be predicted to be reduced by 32 percent. Reduced bed material movement and ongoing deposition of sands mean that bed features would tend to become more uniform through time. Spatial and temporal variability of biotopes would be predicted to be reduced.</td>
<td></td>
</tr>
</tbody>
</table>
Possible Impact | Laporte Reach | Fort Collins Reach (plus Timnath Reach upstream of Interstate-25) | Timnath, Windsor and Greeley Reaches downstream of Interstate-25
---|---|---|---
Channel contraction | Sediment transport potential would be predicted to be reduced throughout the river under Cumulative Effects. | Under Cumulative Effects, total transport potential would be reduced by 17 to 44 percent. Transport potential to move sand and gravel would be reduced by 15 to 43 percent and 20 to 47 percent, respectively, under Cumulative Effects. | The total sediment transport potential would be reduced by 10 to 25 percent. Transport potential for sand would be reduced by 9 to 19 percent and for gravels by 25 to 42 percent.

Together with the reduced sediment transport capacity, a slight reduction in effective discharge suggests an ongoing tendency toward channel contraction in this reach as the result of Cumulative Effects. But the response would be predicted to be constrained by the limited supply of material available for deposition. A model based on observed historic response predicts that the reach would be supply limited and that processes of channel contraction would be insensitive to the changes in sediment transport potential that would be attributable to Cumulative Effects. The persistence of in-channel vegetation would be expected to increase, and this could encourage channel contraction even without abundant sediment. However, the average time between scouring events would not be greatly altered so the rate of growth of vegetated areas should not be greatly affected. The spells analysis suggests that the time between occurrences of bed material motion would generally be the same under Cumulative Effects, so to the extent that colonization of vegetation would be dependent on the existence of a stable substrate, negligible change in the rate or extent of new colonization would be expected.

Sediment transport potential would be reduced by around 45 percent across a broad range of flows, but the effective discharge remains unchanged at about 2,000 cfs. The effective discharge suggests an ongoing trend of channel contraction, but this would be the same for Future Conditions hydrology and Cumulative Effects and channel contraction would be predicted to continue to be constrained by the limited supply of material available for deposition. The reduced duration of high flows suggests an increase in vegetation persistence. Vegetation could cause channel contraction by colonizing bars and channel margins but there would be little change in the average time between high (scouring) flows between Future Conditions and Cumulative Effects so no rapid expansion in vegetated area would be expected. The spells analysis suggests that the time between occurrences of bed material motion would generally be the same under Cumulative Effects, so to the extent that colonization of vegetation would be dependent on the existence of a stable substrate, negligible change in the rate or extent of new colonization would be expected. In the reach between Coy Ditch and Lernay Avenue, channel contraction would be more likely to be temporary in response to pulses of sediment or dry periods. There would be a tendency in this reach for the river to develop a temporary smaller channel within the larger cross section.

The Main Stem Baseline Report concluded that channel contraction would be already occurring in this reach because of sediment deposition on bars, islands, and channel margins. Vegetation would be predicted to colonize and stabilize the deposits such that channel contraction, that might otherwise be temporary, becomes an enduring characteristic. This process would be predicted to continue strongly under Cumulative Effects, but the rate of channel contraction would be largely limited by sediment supply. The effective discharge analysis suggests further contraction would be likely at some cross sections in response Cumulative Effects, and a low flow channel with capacities as low as 40 to 110 cfs could form by deposition of benches within the larger channel. An increase in overbank flooding would be a likely consequence.
18 Main Stem – Cumulative Effects with Alternatives versus Future Conditions

This Chapter presents a discussion of the Cumulative Effects with the Gravel Pits, Agricultural Reservoirs, and Expanded Glade alternatives relative to Future Conditions on the Main Stem. Cumulative Effects hydrology combines a given project alternative (Gravel Pits, Agricultural Reservoir, or Expanded Glade), NISP’s Proposed Action (Alternative 2), the Seaman Project Proposed Action, and RFFAs.

Discussion below relies heavily on the detailed assessment presented in Chapter 17 which compared Cumulative Effects (with Fort Collins’ Proposed Action, NISP’s Proposed Action, the Seaman Project Proposed Action, and RFFAs) versus Future Conditions. This chapter does not repeat the detailed descriptions and interpretations of Chapter 17 for the alternatives. Instead, it reports by exception – identifying areas where differences between the Cumulative Effects with varying alternatives versus Future Conditions could be important and, where feasible, presenting a “comparison of the comparisons”.

Full documentation of the comparative assessment of Cumulative Effects with Gravel Pits Alternative (GP5) versus Future Conditions (Run 2) is provided in Volume III, Appendix S. Cumulative Effects with Agricultural Reservoirs Alternative (AR5) versus Future Conditions (Run 2) is provided in Volume III, Appendix T, and Cumulative Effects with Expanded Glade Alternative (EG5) versus Future Conditions (Run 2) is provided in Volume III, Appendix U.

18.1 Box and Whisker Plot of Monthly Flows

Gravel Pits Alternative Refer to Appendix Figures S-1 and S-2 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figures T-1 and T-2 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figures U-1 and U-2 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.1
Main Stem Baseline Report Section 4.2.3 (Anderson Consulting Engineers, Inc. 2013)

Change in monthly flow volumes for Cumulative Effects with all project alternatives would be similar in magnitude to Cumulative Effects with Fort Collins’ Proposed Action. Reduction in average monthly flows at the Canyon Gage in the months of April through October for all alternatives would be within plus or minus 2.5 percent of change associated with Cumulative Effects with Fort Collins’ Proposed Action (Figure 18-1). Reduction in average monthly flow for Cumulative Effects with all alternatives and Fort Collins Proposed Action would be almost indistinguishable at the Lincoln Gage (Figure 18-2).
Figure 18-1. Percent change in average monthly flow volumes at Canyon Gage – Cumulative Effects with Alternatives versus Future Conditions.

Figure 18-2. Percent change in average monthly flow volumes at Lincoln Gage – Cumulative Effects with Alternatives versus Future Conditions.
18.2 Flow Frequency and Duration Analysis

Gravel Pits Alternative Refer to Appendix Figures S-3 through S-10, Appendix Table S-1 through S-3 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figures T-3 through T-10, Appendix Table T-1 through T-3 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figures U-3 through U-10, Appendix Table U-1 through U-3 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.2
Main Stem Baseline Report Section 5.3 (Anderson Consulting Engineers, Inc. 2013)

The impact on daily flow frequency for Cumulative Effects with alternative were found to follow the same spatial patterns as Cumulative Effects with Fort Collins’ Proposed Action with subtle differences in magnitude. For example, there would be slightly less change in the 2 percent exceedance discharge between alternatives when compared with Fort Collins’ Proposed Action (Figure 18-3). The Expanded Glade and Gravel Pits alternatives shows the least amount of change. Fort Collins’ Proposed Action would have the largest impact. However, the difference in change between the Expanded Glade Alternative and Fort Collins’ Proposed Action would be no greater than 3 percent.
Figure 18-3. Percent change in 2 percent exceedance discharge – Cumulative Effects with Alternatives versus Future Conditions.
18.3 Flood Frequency Analysis

Gravel Pits Alternative Refer to Appendix Figure S-11 and Appendix Tables S-4 and S-5 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figure T-11 and Appendix Tables T-4 and T-5 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figure U-11 and Appendix Tables U-4 and U-5 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.3
Main Stem Baseline Report Section 5.4.1 (Anderson Consulting Engineers, Inc. 2013)

The trends and magnitude of reduction in the 2-year, 10-year, and 25-year floods would be similar for Cumulative Effects with each alternative when compared to Cumulative Effects with Fort Collins’ Proposed Action. All alternatives show less impact on flood magnitude than Fort Collins Proposed Action with the Expanded Glade Alternative showing the least (Figure 18-4). Differences in change between the Expanded Glade Alternative and Fort Collins’ Proposed Action would be approximately 5 percent upstream of Interstate-25. Differences between alternatives and Fort Collins’ Proposed Action would be much less (less than 2 percent) downstream.
Figure 18-4. Percent change in 2-year flood discharge – Cumulative Effects with Alternatives versus Future Conditions.
18.4 Flushing Flows

Gravel Pits Alternative Refer to Appendix Figures S-12 to S-29 and Appendix Table S-6 and S-7 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figures T-12 to T-29 and Appendix Table T-6 and T-7 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figures U-12 to U-29 and Appendix Table U-6 and U-7 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.4
(Note that flushing flow information is not provided in the Main Stem Baseline Report)

Overall, the number of years of flushing flows would be reduced most by Cumulative Effects with Fort Collins’ Proposed Action and the Agricultural Reservoirs Alternative (Figure 18-5). Reductions would be the least for Cumulative Effects with the Expanded Glade Alternative. There would generally be an additional 2 years of occurrence of flushing flows for Cumulative Effects with the Expanded Glade Alternative relative to Fort Collins’ Proposed Action.

Comparison of the average annual recurrence interval of flushing flows for Cumulative Effects with Fort Collins’ Proposed Action and all alternatives is provided in Table 18-1.

![Graph](image-url)
Table 18.1. Comparison of flushing flow annual recurrence interval – Cumulative Effects with Alternatives.

<table>
<thead>
<tr>
<th>Study Reach</th>
<th>Flow Node</th>
<th>Flushing Flow (cfs)</th>
<th>Cumulative Effects</th>
<th>Cumulative Effects</th>
<th>Cumulative Effects</th>
<th>Cumulative Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fort Collins’ Proposed Action Annual Recurrence Interval (years)</td>
<td>Gravel Pits Alternative Annual Recurrence Interval (years)</td>
<td>Agricultural Reservoirs Alternative Annual Recurrence Interval (years)</td>
<td>Expanded Glade Alternative Annual Recurrence Interval (years)</td>
</tr>
<tr>
<td>Laporte</td>
<td>2</td>
<td>2,406</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Laporte</td>
<td>4</td>
<td>2,337</td>
<td>4.3</td>
<td>3.7</td>
<td>4.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Laporte</td>
<td>7</td>
<td>2,250</td>
<td>5.2</td>
<td>5.2</td>
<td>5.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Laporte</td>
<td>8</td>
<td>1,999</td>
<td>5.2</td>
<td>3.7</td>
<td>4.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Laporte</td>
<td>12</td>
<td>1,797</td>
<td>6.5</td>
<td>4.3</td>
<td>5.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Ft Collins</td>
<td>17</td>
<td>1,381</td>
<td>4.3</td>
<td>3.3</td>
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<td>3.3</td>
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<tr>
<td>Ft Collins</td>
<td>20</td>
<td>1,300</td>
<td>4.3</td>
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<td>2.9</td>
</tr>
<tr>
<td>Ft Collins</td>
<td>23</td>
<td>1,355</td>
<td>3.7</td>
<td>3.3</td>
<td>4.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Timnath</td>
<td>32</td>
<td>972</td>
<td>2.9</td>
<td>2.4</td>
<td>3.3</td>
<td>2.6</td>
</tr>
</tbody>
</table>

18.5 Channel Maintenance Flows

The occurrence and duration of channel maintenance flows were evaluated on a cross section by cross section basis and at reach representative cross sections.

18.5.1 Analysis at all Cross Sections

Gravel Pits Alternative Refer to Appendix Figure S-30 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figure T-30 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figure U-30 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.5.1
Main Stem Baseline Report Section 5.5.1 and 7.2 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Evaluation of channel maintenance flows at all cross sections, for Cumulative Effects with each alternative, shows nearly the same result as for Cumulative Effects with Fort Collins’ Proposed Action. Change in duration of channel maintenance flows under Cumulative Effects would be indistinguishable between alternatives and Fort Collins’ Proposed Action (Figure 18-6).
Figure 18-6. Percent change in the duration of channel maintenance flows – Cumulative Effects with Alternatives versus Future Conditions.
18.5.2 Spells Analysis at Representative Cross Sections

Gravel Pits Alternative Refer to Appendix Figures S-32 to S-39 and Appendix Table S-8 to S-9 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figures T-32 to T-39 and Appendix Table G-8 to G-9 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figures U-32 to U-39 and Appendix Table U-8 to U-9 (Appendix U, Volume III)

Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.5.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)
(Note that Channel Maintenance flows are referred to and labeled as flushing flows in the Main Stem Baseline Report)

Reduction in channel maintenance flows is further examined at selected representative cross sections. There would be slightly less impact at representative cross sections for Cumulative Effects with alternatives when compared with Cumulative Effects with Fort Collins’ Proposed Action (Figure 18-7).

![Graph showing change in number of channel maintenance flow events - Cumulative Effects with Alternatives versus Future Conditions.](image-url)

Figure 18-7. Change in number of channel maintenance flow events – Cumulative Effects with Alternatives versus Future Conditions.
18.6 Flows that Move Coarse Bed Material

The occurrence and duration of movement of coarse bed material was also evaluated at all cross sections as well as reach representative cross sections.

18.6.1 Analysis at all Cross Sections

Gravel Pits Alternative Refer to Appendix Figure S-31 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figure T-31 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figure U-31 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.6.1
Main Stem Baseline Report Section 7.1.5 (Anderson Consulting Engineers, Inc. 2013)

The changes in duration of bed material movement at all cross sections, for Cumulative Effects with each alternative, are nearly the same as for Cumulative Effects with Fort Collins’ Proposed Action. Change in duration of bed material movement would be indistinguishable for Cumulative Effects with alternatives and Fort Collins’ Proposed Action (Figure 18-8).
Figure 18-8. Percent change in duration of coarse bed material movement – Cumulative Effects with Alternatives versus Future Conditions.
18.6.2 Spells Analysis at Representative Cross Sections

Gravel Pits Alternative Refer to Appendix Figure S-32 to S-39 and Appendix Table S-10 and S-11 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figure T-32 to T-39 and Appendix Table T-10 and T-11 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figure U-32 to U-39 and Appendix Table U-10 and U-11 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.6.2
Main Stem Baseline Report Section 5.5.1 (Anderson Consulting Engineers, Inc. 2013)

Results of the spells analysis at representative cross sections show that bed material motion for Cumulative Effects with all alternatives would be similar to Cumulative Effects with Fort Collins’ Proposed Action (Figure 18-9).

Figure 18-9. Change in number of events of coarse bed material movement – Cumulative Effects with Alternatives versus Future Conditions.
18.7 Stream Power

Gravel Pits Alternative Refer to Appendix Figure S-40 to S-43 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figure T-40 to T-43 (Appendix T,
Volume III)
Expanded Glade Alternative Refer to Appendix Figure U-40 to U-43 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17,
Section 17.7
Main Stem Baseline Report Section 7.3 (Anderson Consulting Engineers, Inc. 2013)

Changes in total work and work in excess of stream power would be similar for Cumulative
Effects with each alternatives and Fort Collins’ Proposed Action (Figure 18-10 and Figure
18-11).
Figure 18-10. Percent change in total work – Cumulative Effects Alternatives versus Future Conditions.

Figure 18-11. Percent change in total work above incipient motion – Cumulative Effects with Alternatives versus Future Conditions.
18.8 Sediment Transport Potential

Gravel Pits Alternative Refer to Appendix Figure S-44 and Appendix Table S-12 and S-13 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figure T-44 and Appendix Table T-12 and T-13 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figure U-44 and Appendix Table U-12 and U-13 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.8
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

The pattern of change in average annual sediment transport potential for Cumulative Effects with each alternative would be the same as Cumulative Effects with Fort Collins’ Proposed Action. Reduction in reach average annual sediment transport potential would be similar in magnitude but with Cumulative Effects with Fort Collins’ Proposed Action showing the most change (Figure 18-12). Cumulative Effects with the Expanded Glade Alternative shows the least amount of change; however, it would be within 2 percent of Cumulative Effects with Fort Collins’ Proposed Action.
Figure 18-12. Percent change in average annual sediment transport potential – Cumulative Effects with Alternatives versus Future Conditions.
18.9 Distribution of Sediment Transport Potential with Flow

Gravel Pits Alternative Refer to Appendix Figures S-45 to S-48 (Appendix S, Volume III)
Agricultural Reservoirs Alternative Refer to Appendix Figures T-45 to T-48 (Appendix T, Volume III)
Expanded Glade Alternative Refer to Appendix Figures U-45 to U-48 (Appendix U, Volume III)
Fort Collins’ Proposed Action Cumulative Effects versus Future Conditions Refer to Chapter 17, Section 17.9
Main Stem Baseline Report Section 8.1 (Anderson Consulting Engineers, Inc. 2013)

A comparison of the magnitude-frequency curves for Cumulative Effects with each alternative and Fort Collins’ Proposed Action shows similar trends in change (Figure 18-13, Figure 18-14, and Figure 18-15). Subtle differences noted between curves for Cumulative Effects with each alternative and Fort Collins’ Proposed Action would not be likely to have differing impacts.
Figure 18-13. Distribution of sediment transport potential with flow in Laporte reaches – Cumulative Effects with Alternatives and Future Conditions.
Figure 18-14. Distribution of sediment transport potential with flow in Fort Collins and Timnath reaches – Cumulative Effects with Alternatives and Future Conditions.
Figure 18-15. Distribution of sediment transport potential with flow in Timnath, Windsor, and Greeley reaches – Cumulative Effects with Alternatives and Future Conditions.
18.10 Overview of Cumulative Effects of Alternatives on Sediment Transport and River Morphology

Overall, cumulative effects on morphology and sediment transport on the Main Stem would be the same for Cumulative Effects with Fort Collins’ Proposed Action and Cumulative Effects with each project alternatives. Differences are noted in the percent change between Cumulative Effects with alternatives and Cumulative Effects with Fort Collins’ Proposed Action, however these differences would be negligible and the effect on sediment transport and river morphology would be similar.

The contribution of each of Fort Collins’ project alternatives to the total impact on the river associated with Cumulative Effects would be small (on the order of one-tenth) relative to changes attributed to NISP’s Proposed Action, the Seaman Project, and RFFAs combined. Impacts on the river related to each of Fort Collins’ project alternatives alone would be negligible as reflected in the comparative assessment of each of Fort Collins’ project alternatives versus Future Conditions (Chapters 13, 14, and 15).
19 Main Stem – Summary of Effects

19.1 Summary of Effects under Current Conditions

As indicated in Chapter 1, the trajectory of the Poudre River condition predicted in the Main Stem Baseline Report (Anderson Consulting Engineers, Inc. 2013) under a continuance of Current Conditions includes channel contraction, fining of surficial material, and loss of channel complexity. These trends are predicted to be more severe downstream of Interstate-25 than upstream of Interstate-25.

Descriptions of the effects of Fort Collins’ Proposed Action, the Gravel Pits Alternative, and Agricultural Reservoirs Alternative compared to Current Conditions are reported in Chapters 8, 9, and 10, respectively. A description of the effects of the Expanded Glade Alternative compared to NISP Current Conditions is reported in Chapter 11. This section presents an overview of these comparisons. As indicated in Chapter 1, the No-Action Alternative includes RFFAs and consequently is only compared against Future Conditions.

Sediment transport and morphologic analyses have endeavored to quantify or at least provide some relative scale to the predicted effects of Fort Collins’ Proposed Action and project alternatives relative to Current Conditions. The results of the analyses are summarized in Table 19-1. Interpretations of the results in previous chapters have avoided using value judgments and qualitative relative descriptors (like ‘large’ or ‘small’, ‘significant’ or ‘insignificant’, etc.) as much as possible. To achieve consistency with other resource specialists, the following determination of overall effects have been applied to results presented in Table 19-1:

- **Negligible**: The effect would be at the lowest levels of detection, barely measurable, with no perceptible consequences.
- **Minor**: The action might result in a detectable change, but the change would be slight.
- **Moderate**: The action could result in a clearly detectable change, with measurable effects.
- **Major**: The action could result in readily apparent effects with substantial consequences.

These results as a whole reflect a relative rating of the action alternatives compared to Current Conditions. Based on the information presented in this report and summarized in Table 7-1, the following conclusions are provided.

- **The trajectory of the river, as described under Current Conditions, would be expected to continue with Fort Collins’ Proposed Action. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue with negligible impact. Effects of Fort Collins’ Proposed Action on geomorphology and sediment transport are expected to result in the lowest level of detectable change that would be considered to be negligible throughout the river.**
- The trajectory of the river, as described under Current Conditions, would be expected to continue with the Gravel Pits Alternative. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue with negligible impact. Effects of the Gravel Pits Alternative on geomorphology and sediment transport are expected to result in the lowest level of detectable change that would be considered to be negligible throughout the river.

- The trajectory of the river, as described under Current Conditions, would be expected to continue with the Agricultural Reservoirs Alternative. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue with negligible impact. Effects of the Agricultural Reservoirs Alternative on geomorphology and sediment transport are expected to result in the lowest level of detectable change that would be considered to be negligible throughout the river.

- The trajectory of the river, as described, NISP’s Proposed Action (Alternative 2) under Current Conditions, would be expected to see negligible change with the Expanded Glade Alternative. Based largely on an observational model of response to NISP Current Conditions hydrology, the impacts described in the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, Inc. 2014) for NISP’s Proposed Action would be expected to continue with negligible impact. Effects of the Expanded Glade Alternative on geomorphology and sediment transport conditions under NISP’s Proposed Action are expected to result in the lowest level of detectable change that would be considered to be negligible throughout the river.

In summary, the trajectory of the river would be expected to continue under Fort Collins’ Proposed Action or any project alternative. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue with negligible effect on morphology and sediment transport on the Main Stem.
<table>
<thead>
<tr>
<th>Possible Impact</th>
<th>Fort Collins’ Proposed Action (PA3) versus Current Conditions (Run 1)</th>
<th>Gravel Pits Alternative (GPS) versus Current Conditions (Run 1)</th>
<th>Agricultural Reservoirs Alternative (AR3) versus Current Conditions (Run 3a)</th>
<th>Expanded Glade Alternative (EG3) versus NISP Current Conditions (Run 3a)</th>
<th>Future Conditions versus Current Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Flow Regime</td>
<td>Under Fort Collins’ Proposed Action, there would be minimal changes to flow frequency throughout the system.</td>
<td>Under the Gravel Pits Alternative, there would be minimal changes to flow frequency throughout the system.</td>
<td>Under the Agricultural Reservoirs Alternative, there would be minimal changes to flow frequency throughout the system.</td>
<td>Under the Expanded Glade Alternative, there would be minimal changes to flow frequency throughout the system relative to NISP Current Conditions.</td>
<td>Under Future Conditions, there would be predicted to be a general increase in the duration of moderate flows and a reduction of up to 20 percent in the duration of flows in the higher flow intervals.</td>
</tr>
<tr>
<td></td>
<td>The 2 percent exceedance flow would be reduced by 1 to 2 percent.</td>
<td>The 2 percent exceedance flow would be reduced by less than 1 percent.</td>
<td>The 2 percent exceedance flow would be reduced by 1 to 2 percent.</td>
<td>The 2 percent exceedance flow would be reduced by 2 to 3 percent.</td>
<td>The 2 percent exceedance flow would be reduced by 5 to 11 percent.</td>
</tr>
<tr>
<td></td>
<td>The 2-year flood would be reduced by 1 to 3 percent and the 10-year flood peak generally less than 2 percent.</td>
<td>The 2-year and 10-year flood would be reduced by less than 1 percent.</td>
<td>The 2-year flood would be reduced by less than 2 percent. The 10-year flood peak would be reduced by less than 1 percent.</td>
<td>The 2-year and 10-year floods would be reduced by 3 percent in the Laporte Reach and increased in the remaining reaches. Increases in flood discharge would not be likely to provide benefit to morphology or sediment transport.</td>
<td>The 2-year would be reduced by 7 to 12 percent, and the 10-year 5 to 18 percent.</td>
</tr>
</tbody>
</table>

| Fining of Surficial Material                       | Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 to 2 years in the Laporte Reach. | Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 year at one location in the Laporte Reach. | Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 to 2 years in the Laporte Reach. | Upstream of Interstate-25, there would be no reduction in the number of years of occurrence of flushing flows. | Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 to 4 years in the Laporte Reach. |
|                                                     | At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 1 percent and as much as 6 percent under Fort Collins’ Proposed Action. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows. | At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 1 percent and as much as 6 percent at individual cross sections under the Gravel Pits Alternative. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows. | At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 1 percent and as much as 6 percent under the Agricultural Reservoirs Alternative. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows. | At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 3 percent and as much as 12 percent under the Expanded Glade Alternative. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows. | At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by up to 20 percent throughout the river system. |
|                                                     | Loss of morphologic complexity                                       | Loss of morpologic complexity                                     | Loss of morphologic complexity                                            | Loss of morphologic complexity                                          | Loss of morphologic complexity |
|                                                     | At 28 percent of section upstream of Interstate-25, there would be an average reduction in duration of bed material movement of less than 1 percent, with reductions at individual cross sections of as much as 5 percent. Downstream of Interstate-25, there would be an average of 1 percent increase in duration. | At 28 percent of cross section upstream of Interstate-25, there would be an average reduction in duration of bed material movement of less than 1 percent, with reductions at individual cross sections of as much as 5 percent. Downstream of Interstate-25, there would be an average of 1 percent increase in duration. | At 28 percent of cross section upstream of Interstate-25, there would be an average reduction in duration of bed material movement of less than 1 percent, with reductions at individual cross sections of as much as 5 percent. Downstream of Interstate-25, there would be an average of 1 percent increase in duration. | At 28 percent of cross section upstream of Interstate-25, there would be an average reduction in duration of bed material movement of less than 2 percent, with reductions at individual cross sections of as much as 7 percent. Downstream of Interstate-25, there would be an average of 3 percent increase in duration. | The duration of bed material movement would be predicted to be reduced by an average of 10 percent and up to 20 percent in some locations under Future Conditions compared to Current Conditions. |
| Channel Contraction                                 | Under Fort Collins’ Proposed Action, annual sediment transport potential would be reduced by less than 3 percent upstream of Interstate-25 and just slightly increased by up to 2.4 percent downstream. Increased transport potential of a small percentage would not be likely to provide benefit or manifest as an adverse impact. | Under the Gravel Pits Alternative, average annual sediment transport potential would be reduced by less than 2.5 percent upstream of Interstate-25 and just slightly increased by up to 2.4 percent downstream. Increased transport potential of a small percentage would not be likely to provide benefit or manifest as an adverse impact. | Under the Agricultural Reservoirs Alternative, average annual sediment transport potential would be reduced by less than 3.4 percent upstream of Interstate-25 and just slightly increased by up to 2.2 percent downstream. Increased transport potential of a small percentage would not be likely to provide benefit or manifest as an adverse impact. | Under the Expanded Glade Alternative, average annual sediment transport potential would be reduced by less than 6 percent upstream of Interstate-25 and just slightly increased by up to 4 percent downstream. Increased transport potential would not be likely to provide benefit or manifest as an adverse impact. | Under Future Conditions, the sediment transport potential would be predicted to be reduced throughout the length of the river. Upstream of Interstate-25, the amount of material that could be moved would be reduced by between about 4 and 16 percent. Downstream of Interstate-25, the reduction would be 7 to 9 percent. |

Determinant of Effects
Effects of Fort Collins’ Proposed Action on geomorphology and sediment transport would be negligible.

Effects of the Gravel Pits Alternative on geomorphology and sediment transport would be negligible.

Effects of the Agricultural Reservoirs Alternative on geomorphology and sediment transport would be negligible.

Effects of the Expanded Glade Alternative on geomorphology and sediment transport would be negligible.
19.2 Summary of Effects under Future Conditions

Detailed descriptions of the effects of Fort Collins’ Proposed Action, the Gravel Pits Alternative, the Agricultural Reservoirs Alternative, and the No-Action Alternative versus Future Conditions are reported in Chapters 12, 13, 14, and 16, respectively. A detailed description of the effects of the Expanded Glade Alternative relative to NISP Future Conditions is provided in Chapter 15. This section presents an overview of these comparisons.

It is important to note that evaluations of alternative effects are presented relative to Future Conditions hydrology. The evaluations therefore represent the difference between likely Future Conditions with the Halligan Project alternatives, and likely Future Conditions without the Halligan Project alternatives. Future Conditions are described in Chapter 3 of the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, Inc. 2014) and are different from the Current Conditions described in the Main Stem Baseline Report which was a description based on the trajectory of Current Conditions without RFFAs. The difference between Current and Future Conditions was presented in Chapter 6 of the NISP Stream Morphology and Sediment Transport Project Effects Report (Anderson Consulting Engineers, Inc. 2014).

Sediment transport and morphologic analyses have endeavored to quantify or at least provide some relative scale to the predicted effects of Fort Collins’ Proposed Action and project alternatives relative to Future Conditions. The results of the analyses are summarized in Table 19-2. These results reflect a relative rating of the alternatives compared to Future Conditions. Based on the information presented in this report and summarized in Table 19-2, the following conclusions are provided:

- The trajectory of the river, as described by Current Conditions, would be expected to continue under Future Conditions with Fort Collins’ Proposed Action. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue and be more severe downstream of Interstate-25 than upstream of Interstate-25. The trajectory of river condition under Future Conditions ratifies and amplifies the trends that were already identified in the Main Stem Baseline Report for a continuation of Current Conditions. Effects of Fort Collins’ Proposed Action on geomorphology and sediment transport under Future Conditions would be considered to be negligible throughout the river.

- The trajectory of the river, as described by Current Conditions, would be expected to continue under Future Conditions and under the Gravel Pits Alternative. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue and be more severe downstream of Interstate-25 than upstream of Interstate-25. The trajectory of river condition under Future Conditions ratifies and amplifies the trends that were already identified in the Main Stem Baseline Report for a continuation of Current Conditions. Effects of Gravel Pits Alternative on geomorphology and sediment transport under Future Conditions would be considered to be negligible throughout the river.

- The trajectory of the river, as described by Current Conditions, would be expected to...
continue under Future Conditions and the Agricultural Reservoirs Alternative. Based largely on an observational model of response to Current Conditions hydrology, the trends that were identified in the Main Stem Baseline Report would be expected to continue and be more severe downstream of Interstate-25 than upstream of Interstate-25. The trajectory of river condition under Future Conditions ratifies and amplifies the trends that were already identified in the Main Stem Baseline Report for a continuation of Current Conditions. Effects of Agricultural Reservoirs Alternative on geomorphology and sediment transport under Future Conditions would be considered to be negligible throughout the river.

- The trajectory of the river, as described for NISP’s Proposed Action under Future Conditions, would be expected to see negligible change with the Expanded Glade Alternative. Based largely on an observational model of response to NISP Future Conditions hydrology, the impacts described in the NISP Stream Morphology and Sediment Transport Project Effects Report for NISP’s Proposed Action under Future Conditions would be expected to be similar. Effects of the Expanded Glade Alternative on geomorphology and sediment transport conditions with NISP’s Glade Reservoir would be considered to be negligible throughout the river.

The Main Stem Baseline Report describes the projected trajectory for river conditions. This trajectory is expected to continue under Future Conditions hydrology as the result of on-going channel contraction, fining of surficial material, and loss of channel complexity. These predicted changes in river condition would be a fluvial response to historic and contemporary physical and hydrologic changes to the river, floodplain, and watershed. Based largely on an observational model of response to date, these changes in river condition would be expected to be more severe downstream of Interstate-25 than upstream of Interstate-25 because:

- sediment supply in the size fractions relevant for deposition is more limited upstream of Interstate-25 than downstream; and

- biogeomorphic processes involving vegetation establishment on benches and bars prevail more downstream of Interstate-25 compared to upstream.

The difference between future and Current Conditions represents the effects of the RFFAs. The trajectory of river condition with RFFAs ratifies and amplifies the trends that were already identified in the Main Stem Baseline Report for a continuation of Current Conditions. Assessments of the effects of the Fort Collins’ Proposed Action or project alternatives compared to Future Conditions are expected to have a negligible effect on this trajectory of continuing channel contraction, fining of surficial material, and loss of channel complexity.
<table>
<thead>
<tr>
<th>Possible Impact</th>
<th>Fort Collins' Proposed Action (PA4) versus Future Conditions (Run 2)</th>
<th>Gravel Pits Alternative (GP4) versus Future Conditions (Run 2)</th>
<th>Agricultural Reservoirs Alternative (AR4) versus Future Conditions (Run 2)</th>
<th>Expanded Glade Alternative (EG4) versus NISP Future Conditions (Run 4a)</th>
<th>No-Action Alternative (NA4) versus Future Conditions (Run 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Flow Regime</td>
<td>Under Fort Collins' Proposed Action, there would be minimal changes to flow frequency throughout the system.</td>
<td>Under the Gravel Pits Alternative, there would be minimal changes to flow frequency throughout the system.</td>
<td>Under the Agricultural Reservoirs Alternative, there would be minimal changes to flow frequency throughout the system.</td>
<td>Under the Expanded Glade Alternative, there would be minimal changes to flow frequency throughout the system relative to NISP Future Conditions.</td>
<td>Under the No-Action Alternative, there would be negligible changes to flow frequency throughout the system.</td>
</tr>
<tr>
<td></td>
<td>The 2 percent exceedance flow would be reduced by up to 5 percent.</td>
<td>The 2 percent exceedance flow would be reduced by 1 to 2 percent.</td>
<td>The 2 percent exceedance flow would be reduced by 1 to 3 percent.</td>
<td>The 2 percent exceedance flow would be reduced by less than 4 percent.</td>
<td>The 2 percent exceedance flow would be reduced by less than 1 percent.</td>
</tr>
<tr>
<td></td>
<td>The 2-year flood would be reduced by 1 to 3 percent and the 10-year flood peak generally less than 2 percent.</td>
<td>The 2-year and 10-year flood would be reduced by less than 1 percent.</td>
<td>The 2-year and 10-year flood would be reduced by less than 1 percent.</td>
<td>The 2-year flood would be reduced between 2 and 4 percent. The 10-year flood would be reduced by less than 4 percent.</td>
<td>The 2-year and 10-year flood would be reduced by 1 to 2 percent.</td>
</tr>
<tr>
<td>Fining of Surficial Material</td>
<td>Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 to 2 years in the Laporte Reach.</td>
<td>Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 year at one location in the Laporte Reach.</td>
<td>Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 year at one location in the Laporte Reach.</td>
<td>Upstream of Interstate-25, the number of years of occurrence of flushing flows would be reduced by 1 year.</td>
<td>Upstream of Interstate-25, flushing flow occurrence would be reduced by 1 year at one location in the Laporte Reach.</td>
</tr>
<tr>
<td></td>
<td>At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 2 percent and as much as 5 percent under Fort Collins' Proposed Action. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows.</td>
<td>At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 2 percent and as much as 5 percent at individual cross sections under the Gravel Pits Alternative. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows.</td>
<td>At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 2 percent and as much as 5 percent under the Agricultural Reservoirs Alternative. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows.</td>
<td>At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by an average of 2 percent and as much as 10 percent under the Expanded Glade Alternative. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows.</td>
<td>At 58 percent of the cross sections, the duration of channel maintenance flows would be predicted to be reduced by less than 1 percent under the No-Action Alternative. For the remaining 45 percent of the cross sections, there would be either no flushing or no change in the duration of flushing flows.</td>
</tr>
<tr>
<td>Loss of Morphologic Complexity</td>
<td>At 28 percent of the cross sections upstream of Interstate-25, there would be an average reduction in duration of bed material movement of 2.8 percent, with reductions at individual cross sections of as much as 5 percent. Downstream of Interstate-25, there would be an average reduction in duration of 2 percent.</td>
<td>At 28 percent of the cross sections upstream of Interstate-25, there would be an average reduction in duration of bed material movement of less than 2 percent, with reductions at individual cross sections of as much as 5 percent. Downstream of Interstate-25, there would be an average reduction in duration of 2 percent.</td>
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<td>At 28 percent of the cross sections upstream of Interstate-25, there would be an average reduction in duration of bed material movement of 1.4 percent. Downstream of Interstate-25, there would be an average reduction in duration of 1.4 percent.</td>
</tr>
<tr>
<td>Channel Contraction</td>
<td>Under Fort Collins' Proposed Action, average annual sediment transport potential would be reduced by less than 3 percent upstream of Interstate-25 and by less than 2 percent downstream.</td>
<td>Under the Gravel Pits Alternative, average annual sediment transport potential would be reduced by less than 2 percent upstream of Interstate-25 and less than 0.5 percent downstream.</td>
<td>Under the Agricultural Reservoirs Alternative, average annual sediment transport potential would be reduced by less than 2.5 percent upstream of Interstate-25. Downstream of Interstate-25, change would be less than plus or minus 1 percent.</td>
<td>Under the Expanded Glade Alternative, average annual sediment transport potential would be reduced by 4 to 8 percent upstream of Interstate-25 and less than 2 percent downstream.</td>
<td>Under the No-Action Alternative, average annual sediment transport potential would be changed by less than 0.5 percent.</td>
</tr>
<tr>
<td>Determination of Effects</td>
<td>Effects of Fort Collins' Proposed Action on geomorphology and sediment transport would be negligible.</td>
<td>Effects of the Gravel Pits Alternative on geomorphology and sediment transport would be negligible.</td>
<td>Effects of the Agricultural Reservoirs Alternative on geomorphology and sediment transport would be negligible.</td>
<td>Effects of the Expanded Glade Alternative on geomorphology and sediment transport, relative to NISP Future Conditions, would be negligible.</td>
<td>Effects of the No-Action Alternative on geomorphology and sediment transport would be negligible.</td>
</tr>
</tbody>
</table>
20 Literature Cited


Colorado Department of Natural Resources. 2016. Design Review and Construction Inspection. Colorado Division of Water Resources, Department of Natural Resources. Information Available at: http://water.state.co.us/SurfaceWater/DamSafety/DesignConstruction/Pages/default.aspx


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