# GEORGE DAVIS CREEK
# FISH PASSAGE PROJECT

## HYDRAULIC REPORT
## PRELIMINARY

Prepared for:

**City of Sammamish**
Sammamish, WA

On behalf of:

**PBS Engineering and Environmental Inc.**
Issaquah, WA

Prepared by:


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# 1 INTRODUCTION

## 1.1 Background and Overview

The City of Sammamish (City) plans to improve fish passage, stream function, and geomorphic continuity along George Davis Creek by replacing two existing culvert crossings at East Lake Sammamish Parkway and downstream at East Lake Sammamish Shore Lane (Figure 1). In addition, the City also plans to remove a small historic diversion dam located on George Davis Creek approximately 1,000 feet upstream of Lake Sammamish.

An intermediate culvert crossing is located between the two City culverts at East Lake Sammamish Trail. This crossing is owned by King County (County) and is planned for replacement as part of the County's separate East Lake Sammamish Trail Project (Parametrix, 2016). It is anticipated that the City and County culvert replacements would occur concurrently.

The City retained PBS Engineering and Environmental Inc. (PBS) to develop designs and provide civil engineering services for the project. Northwest Hydraulic Consultants Inc. (NHC) was retained by PBS as a subconsultant to provide specialized hydrologic, hydraulic, and geomorphic services, as well as assist in developing conceptual culvert and stream designs following Washington Department of Fish and Wildlife's (WDFW's) stream simulation guidelines (Barnard et al, 2013). This report documents findings of NHC's hydrologic, hydraulic, and geomorphic analyses and presents recommendations for culvert and stream designs on George Davis Creek.

## 1.2 Previous Work

An alternatives assessment was conducted by the City and PBS design team in 2018-2019 as part of the initial phase of this project. Four conceptual alternatives were considered to restore fish passage on George Davis Creek (PBS, 2019). The preferred alternative consisted of daylighting George Davis Creek from Lake Sammamish to Shore Lane, and replacing Shore Lane, the Trail, and East Lake Sammamish Parkway culvert crossings with WDFW stream simulation culverts (Figure 1). This alternative would require acquisition of private property to daylight the creek and also include decommissioning of an existing high flow bypass upstream of East Lake Sammamish Parkway.

Subsequently, the City has successfully negotiated the buy-out of a lakefront parcel (0777100040) to accommodate daylighting the creek and has been in negotiation with the County regarding coordination with the East Lake Sammamish Trail Project.

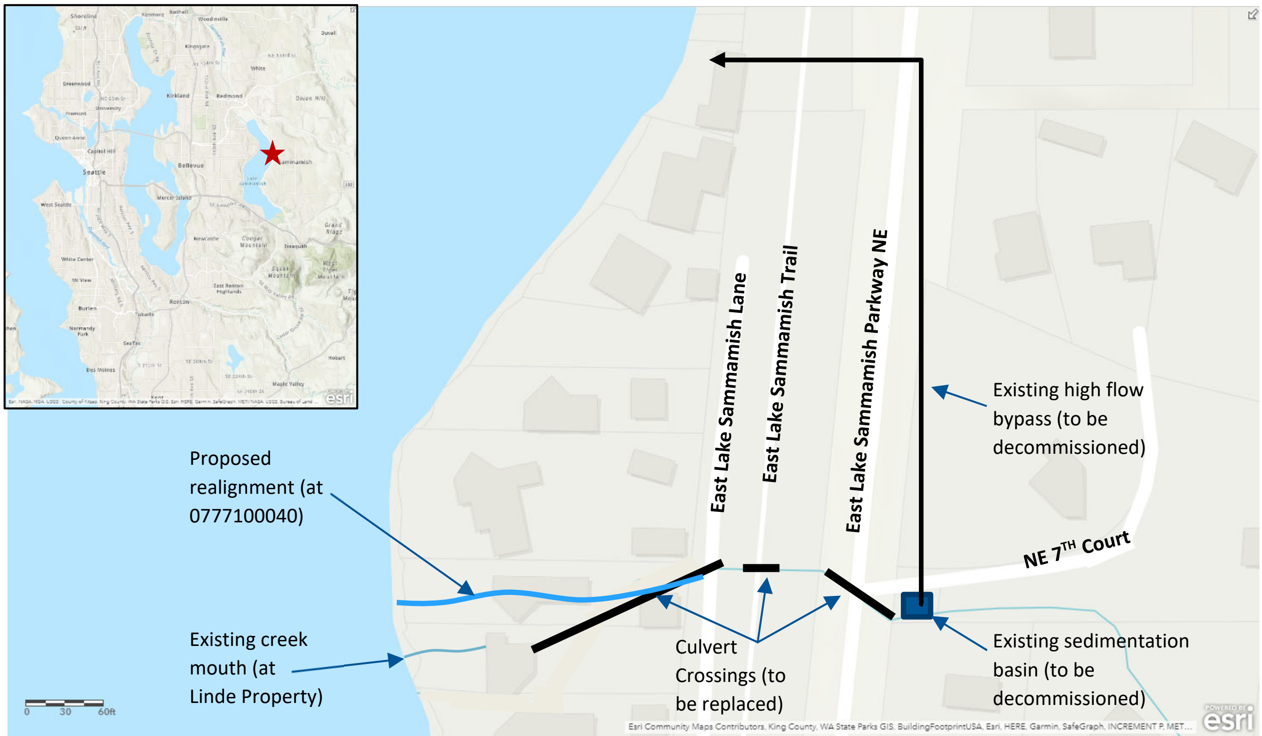


**Figure 1. Project vicinity map (WSDOT Online Map Center)**

# 2 EXISTING CONDITIONS

## 2.1 Project Site Description

The project site is located on the eastern shore of Lake Sammamish approximately 1.5 miles west of the City of Sammamish in King County, WA (Section 32, Township 25N, Range 6E). Three culvert crossings are located in the project area: 1) East Lake Sammamish Parkway (ELSP), 2) the East Lake Sammamish Trail (Trail), and 3) East Lake Sammamish Shore Lane (Shore Lane) (Figure 1). Immediately upstream, George Davis Creek emerges from a steep forested ravine draining from the upper Sammamish plateau and enters the project area near the intersection of ELSP and NE 7$^{th}$ Court.

Upstream of ELSP, where George Davis Creek exits the ravine, the stream is channelized through a private property[1] (Photo 1), then confined between NE 7$^{th}$ Court and additional private residences to the south. A sharp bend with high outside bank occurs where the creek turns westward. Downstream, the

[1] During the site assessment, the resident here reported to NHC that the highest stream level they had observed had reached just below the back deck (Photo 1).

**Photo 1. Creek channel at exit of ravine**

**Photo 2. Sedimentation basin upstream of ELSP**

stream corridor is narrow, approximately 35 feet wide, with near vertical banks, 2 to 6 feet high. Evidence of moderate bank erosion was observed along the entirety of this reach. Stream grade upstream of ELSP is controlled by boulder and log steps installed as part of a sedimentation basin (Photo 2) constructed by the County in 1994-95, after the previous undersized crossing experienced severe flooding during a high flow event in January 1990 (Parametrix, 2011). The sedimentation basin measures approximately 30 feet long, 25 feet wide, and is four to five feet deep, and has a storage volume of approximately 60 cubic yards. City staff report that the basin typically requires maintenance once or twice a year to remove trapped sediment (Pers. Comm. October 20, 2018). In addition to trapping sediment, the basin also functions as a high flow bypass. The bypass consists of two elevated manhole overflows fitted with birdcages located on the right (north) side of the pond (Photo 2). Overflow into these structures diverts George Davis Creek flood waters through a bypass culvert that follows ELSP northward and ultimately discharges to Lake Sammamish approximately 550 feet north of the existing creek mouth (Figure 1 and Photo 3)[2].

Flow down the mainstem George Davis Creek is controlled by an 18-inch diameter inlet pipe that drains to a manhole then finally into the 68-foot long, 60-inch diameter concrete culvert with seven percent slope passing under ELSP (King County, 1995). A perforated standpipe and weir at the rim of the manhole allow for additional overflow into the ELSP culvert during highwater events or if the inlet becomes plugged with sediment. Flow through the manhole can be regulated with a shear gate. An approximately two-foot drop occurs at the ELSP culvert outlet.

**Photo 3. Bypass activated during high flow event (12/20/19)**

Downstream of the ELSP, George Davis Creek enters King County jurisdiction at the East Lake Sammamish Trail. The trail is a converted railroad alignment that historically connected the cities of Issaquah to the south and Redmond to the north. The creek flows under the trail through a 36-inch corrugated metal pipe (CMP) and an 18-inch concrete culvert structure. The County plans to replace these structures with a 14-foot wide by 7-foot high box culvert (Parametrix, 2016).

**Photo 4. Creek corridor through Linde residence, facing upstream**

Downstream of the trail, George Davis Creek enters an approximately 150-foot long, 24-inch diameter clay pipe that crosses under East Lake Sammamish Lane and two lake front properties. The estimated elevation drop through the culvert is 10 feet, with a slope of approximately seven percent. The culvert discharges at the eastern foundation of the Linde residence (Figure 1), then flows through a 40-foot enclosed corridor underneath the home (Photo 4) followed by



[2] The sedimentation basin and high flow bypass was recently activated during a storm event in December 2019. NHC visited the site and observed that the inlet to mainstem George Davis Creek became plugged with sediment further reducing downstream flow through the control structure. The majority of flow was observed to be entering the bypass. City maintenance staff were monitoring the site during the event to make sure it was functioning properly.

approximately 60 feet of open channel to Lake Sammamish. This lower segment was restored circa 2009 to provide fish habitat (Parametrix, 2017). The homeowner has observed Kokanee in this lower 60-foot reach, but the series of upstream culverts effectively function as barriers preventing passage further upstream. It should be noted the lower segment of George Davis Creek, downstream of the trail, currently relies on the high flow bypass at ELSP to prevent potential flood damage, especially within the Linde property reach.

**Photo 5. Diversion dam 500 feet upstream of ELSP**

In addition to the Shore Lane and ELSP culverts, the City project includes removal of a diversion dam located in the George Davis ravine, approximately 500 feet upstream of ELSP (Photo 5). The dam consists of an approximately 20-foot wide channel spanning concrete weir with a 3.5 -foot drop. It is estimated that 125 to 200 cubic yards of sediment are captured behind the dam. These deposits extend approximately 150 feet upstream.

## 2.2 Reach Characterization

A reach assessment of lower George Davis Creek was conducted to evaluate stream condition and to identify a reference reach from which stream simulation designs could be developed for the project area (Barnard et al, 2013). The lower mile of George Davis Creek extends from Lake Sammamish upstream to NE 6$^{th}$ Street and is steep and generally confined within a ravine. Upstream of NE 6$^{th}$ Street, George Davis Creek takes on a distinctly different character as the gradient reduces significantly and much of the creek is either channelized through residential and commercial properties or contained in wetland areas on the relatively flat Sammamish Plateau. The lower mile of George Davis Creek was determined to be the most relevant in terms of geomorphic processes and as a design analog to the project reach.

Reach characteristics on George Davis Creek were evaluated using a combination of field-based observations and analyses using available remote sensing and mapping data. NHC and 48 North Solutions conducted a reach assessment of George Davis Creek extending from Lake Sammamish to the NE 6th Street crossing on August 14, 2018. Based on observations made during the first visit, NHC identified an appropriate reference reach (Barnard et al, 2013) and conducted a site-specific assessment on September 27, 2019. The following sections describe the findings of the field and desktop-based reach assessments.

### 2.2.1 Basin Geology

Figure 2 presents geologic mapping of the George Davis Creek drainage basin from Booth et al (2012). The upper basin, on the Sammamish Plateau, is underlain by a combination of glacial till (Qvt) and recessional outwash ($Qvr_4$), ice-contact ($Qvi_2$), and wetland deposits ($Q_w$). The more permeable recessional deposits ($Qvr_4$) are dominant in low-lying areas of the plateau and are likely responsible for considerable infiltration to groundwater aquifers.

Recessional outwash ($Qvr_4$) continues to dominate along much of lower George Davis Creek. These deposits, consisting of stratified sand and gravels, are a remnant of one of several channels draining westward from glacial Lake Snoqualmie to glacial Lake Sammamish following the Vashon strade of the Fraser glaciation (Booth et al, 2012). The George Davis Creek ravine was formed through channel incision into these highly erodible recessional outwash materials, which likely contribute to the current high sediment load observed on the system. Mapping shows that downcutting just downstream of NE 6$^{th}$ Street has exposed a deposit of more resistant till (Qvt) material. Further downstream near the ravine outlet, George Davis Creek is mapped as underlain by older (pre-glacial) fine grained materials ($Qpf_f$) that are well compacted, have some cohesive properties, and are more resistant to erosion (Booth et al, 2012). Immediately downstream, the remainder of George Davis Creek, including the project reach, is mapped as a fan deposit (Qf).

The varying underlying geology likely influences the current longitudinal profile of lower George Davis Creek, as discussed in the following section. It also has implications for potential channel instability in the project reach.



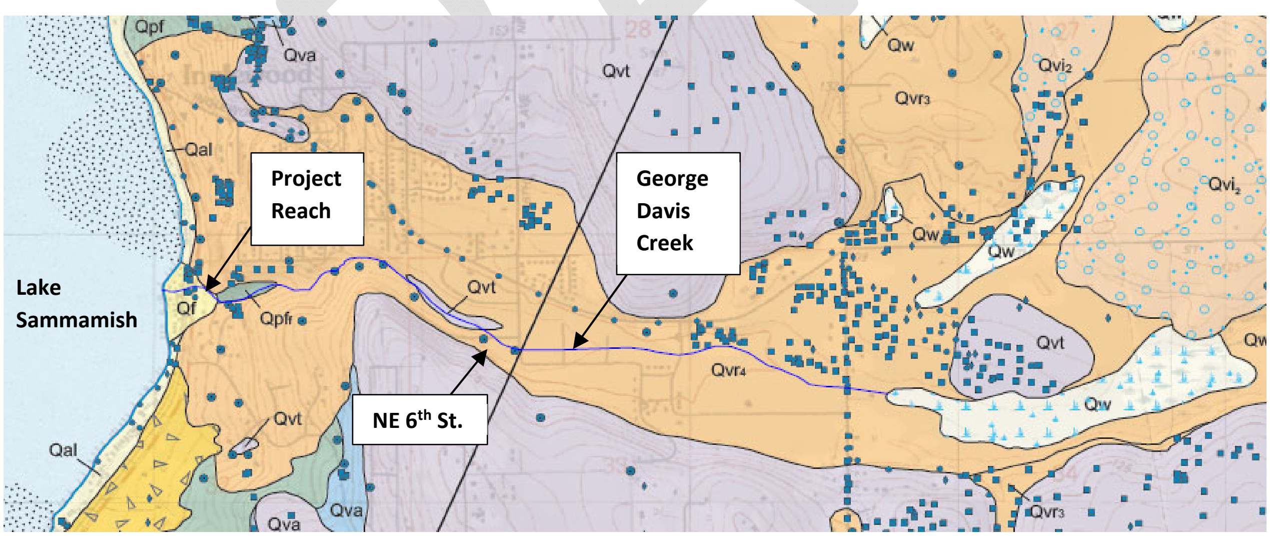


**Figure 2. Geologic mapping of George Davis Creek basin, from Booth et al. (2012), creek alignment added by NHC**

## 2.2.2 Longitudinal Profile

Figure 3 shows the longitudinal profile of lower George Davis Creek extracted from 2016 King County LiDAR topographic data. The reach is subdivided into four segments at distinct grade breaks in the longitudinal profile. Segment 1 is located from Lake Sammamish to just upstream of ELSP. Coinciding with the project reach, this is the steepest segment on lower George Davis Creek, with slopes varying

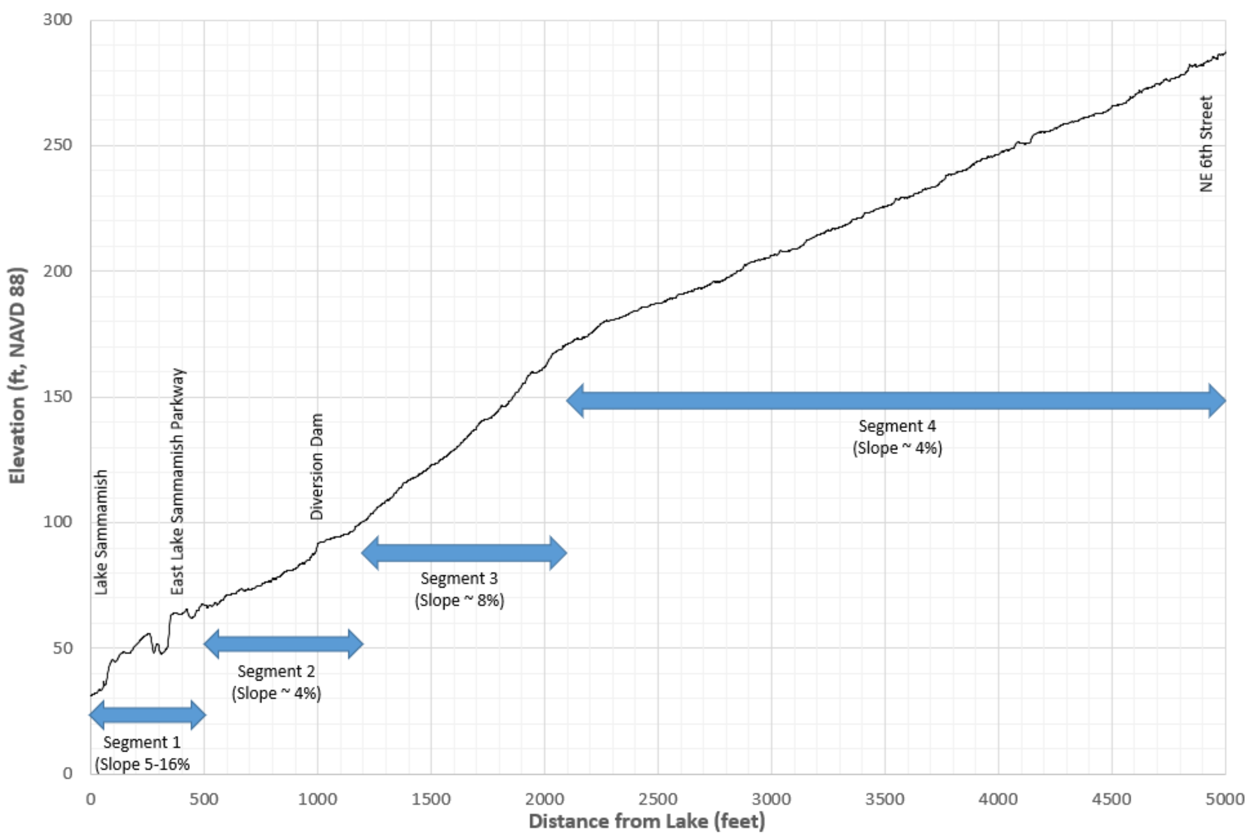


**Figure 3. Longitudinal profile of lower George Davis Creek based on 2016 King County LiDAR topography**

from five to 16 percent. The steep slopes along this 500-foot long reach can be attributed to extensive manipulation through channelization, regrading, and grade control provided by existing stream crossings.

Segment 2 extends upstream of ELSP approximately 700 feet to just upstream of the existing diversion dam. The reach-averaged slope is fairly uniform at four percent. The relatively low slope could be attributed to grade controls in the vicinity of ELSP but may also reflect some controls from underlying geology. Segment 2 coincides with the transition between alluvial fan and compacted pre-glacial deposits. Although not conclusive, the lower gradient observed in this reach may be associated with refusal to further channel incision as the stream has encountered a more stable underlying geology. The existing diversion dam is located toward the upper extent of Segment 2. As previously noted, the LiDAR data indicates a sediment impoundment extending approximately 150 feet upstream of the dam.

Segment 3 of George Davis Creek extends upstream 800 feet and steepens to approximately eight percent. An abrupt grade break occurs upstream in the transition between Segment 3 and 4. The abrupt change in channel gradient is likely attributed to hillslope processes, as indicated in LiDAR data. Figure 4 shows a hill shade of King County LiDAR data overlain by the geologic mapping of Booth et al (2012) and stream segments. The LiDAR data indicates a significant landslide scarp, several hundred feet wide, along the south (left) edge of the ravine between stream station 2,000 and 2,500. It is believed that the grade break in this vicinity is the direct result of a landslide that blocked the channel. The age of this landslide is unknown.

Segment 4 begins near stream station 2,100 and extends upstream to the top of the ravine following a relatively low, uniform slope of approximately four percent. During the August 2018 reach assessment, surface stream flow discontinued near stream station 2,800. This location coincides with the apparent upstream limit of perennial flow in lower George Davis Creek.

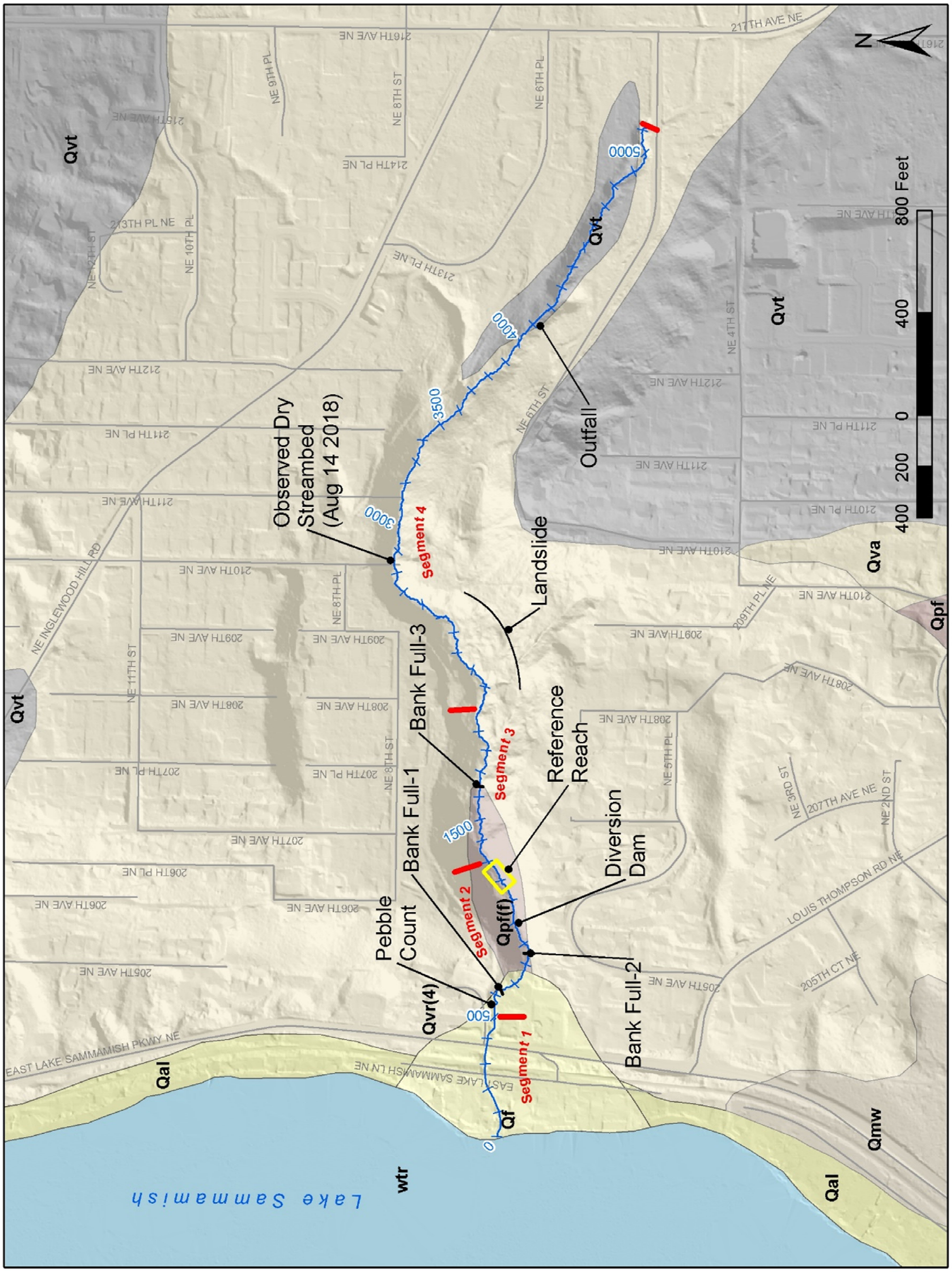


Figure 4. Topographic and reach map of lower George Davis Creek

### 2.2.3 Channel Morphology

Natural processes and channel morphology have been suppressed in Segment 1 of George Davis Creek (i.e. the project reach) due to residential development, culvert construction, and stormwater controls. Mapped as an alluvial fan (Figure 2), this reach was historically a depositional environment where the channel was allowed to migrate laterally, distributing sediments in a fan-like pattern. Currently, the creek corridor is confined laterally with grade controls providing vertical stability.

A more natural stream morphology begins in Segment 2 where George Davis Creek enters the relatively undisturbed upland ravine; however, some anthropogenic influence is found in the ravine. In addition to the previously described diversion dam, a 12-inch stormwater tight-line discharges stormwater from the north in Segment 2 (Parametrix, 2011). Furthermore, installations of man-made log jams begin in Segment 2. In tandem construction of the high flow bypass and sedimentation basin, King County also undertook a ravine stabilization project with the placement of approximately 70 large woody debris (LWD) structures primarily in Segments 3 and 4 of lower George Davis Creek (King County, 1994). Naturally occurring LWD deposits were also observed along the entirety of the ravine. Channel morphology in the lower gradient portion of Segment 2 is not well defined, likely owing to a combination of active sedimentation, vegetative controls, and influence of LWD. Alternating cascade, pool-riffle, and step-pool morphologies were observed and bank widths fluctuated widely. Bed composition varied from cobbles and small boulders to small to medium gravels. Well defined pools were generally not observed in Segment 2 (Photo 6).

**Photo 6. Channel in Segment 2**

Segment 3 begins approximately 200 feet upstream of the former diversion dam and the channel gradient noticeably steepens as suggested by the presence of boulder-sized material (> 256 mm) armoring a narrowed channel (Photo 7). Boulder-sized materials are likely lag deposits originating from previously overlying glacial till or outwash. Channel morphology varied from step-pool to cascade in Segment 3, but again, well-formed pools were generally not observed. Near stream station 1,900 the channel reaches maximum confinement between a narrow 50-foot wide section of the ravine. Channel incision here has exposed underlying densely consolidated (likely) pre-glacial material from which seepage was observed. Narrow conditions continue upstream for another 200 feet with nearly vertical banks and evidence of the previously described landslide along the south bank of the ravine.

**Photo 7. Channel in Segment 3**

Segment 4 begins at approximately stream station 2,100 where the gradient and surface flow both noticeably decrease. The channel bed widens in Segment 4 and the streambed material consists of uniform, medium sized gravel (Photo 8). As previously noted, surface stream flow discontinued near stream station 2,800. Significant amounts of gravel-sized material were observed along the entirety of Segment 4, but it is unclear how frequently it is exposed to mobilizing flows. Infrequent wetting was supported by observations of increasing amounts of duff material and moss-covered sediment further up in the ravine. At stream station 4,100, a stormwater tight-line and energy dissipater were observed entering the creek from the south side of the ravine.

**Photo 8. Channel in Segment 4**

## 2.3 Sediment Loading

Excessive sediment loading on George Davis Creek has been recognized since at least the early 1990s when damages sustained during a high flow event resulted in the construction of the existing high flow bypass and sedimentation basin immediately upstream of ELSP (Parametrix, 2011; King County, 1994). As noted above, the County installed approximately 70 LWD structures primarily in Segments 3 and 4 of lower George Davis Creek (King County, 1994). Based on observation, these LWD structures have provided some limited reduction in downstream sediment loading, but ongoing excessive sediment supply has now likely exceeded available storage. Larson et al. (2001) came to a similar conclusion when they evaluated a number of small urbanized streams in the Puget Sound lowlands. They reported that most streams with increased LWD frequency were successful at retaining increased amounts of sediment; however, the LWD projects did not generally meet expectations with regard to reductions in downstream sedimentation. Furthermore, outflanking of several installed County LWD structures was observed. At these locations, downstream transport continued with recruitment of new sediment from bank erosion. Despite installation of the LWD structures, sediment loading on George Davis Creek is still considered high.

A first-order estimate of annual sediment load on George Davis Creek was computed using anecdotal information provided by the City, whose maintenance crews report that the sedimentation basin typically requires clearing one to two times per year (Pers. Comm. October 20, 2018). The estimated volume of the basin is approximately 60 cubic yards. This volume and frequency of maintenance roughly translates to an annual sediment load on the order to 60 to 120 cubic yards per year. Although uncertain, it generally aligns with unit load estimates from other basins in the Sammamish Drainage (Table 1).

**Table 1. Sediment load estimates in the Sammamish Basin**

| Stream | Basin Area* (sq. mi.) | Est. Annual Load (cu. yd.) | Est. Unit Load (cu. yd./sq. mi.) |
|---|---|---|---|
| George Davis Creek | 0.7 | 60 - 120 | 90 – 170 |
| Derby Creek[1] | 1.0 | 120 - 260 | 120 – 260 |
| Tosh Creek[2] | 0.2 | 12 - 40 | 70 – 220 |
| 90th Street Drainage (Redmond)[3] | 0.2 | 50 - 90 | 230 – 410 |

*Effective basin area contributing surface flow to stream; [1]NHC (2019); [2]NHC (2013); [3]NHC (2018)

## 2.4 Risk Assessment

### 2.4.1 Profile Adjustment

George Davis Creek is a steep system with high stream power and sediment load. Currently, the project reach stream profile, spanning from Lake Sammamish to upstream of ELSP, is stabilized through a combination of man-made grade controls, non-fish passage compliant culverts, and the sedimentation basin. With removal of these structures and replacement with stream simulation culverts (Barnard et al, 2013), the primary risk will be the potential for rapid vertical profile adjustment through incision, or downcutting, into the surrounding geology.

As previously noted, the lower portion of George Davis Creek (Segment 1) is located on a mapped alluvial fan feature (Figure 2 and Figure 4). NHC reviewed geotechnical explorations conducted by Aspect Consulting for this project. Boring logs from four test explorations indicate that approximately 10-foot thick deposits of alluvium (loose silt, sand, gravel, and cobble material) underlie the project reach with bottom elevations ranging from 38 to 45 feet, NAVD 88. Below the alluvial deposits, silty sands with varying degrees of density extend down an additional 10 to 15 feet. Were a newly daylighted and realigned George Davis Creek to contact these native deposits, the available stream power would be adequate to begin a process of vertical channel adjustment. This would involve rapid incision through alluvial deposits of five to 10 feet in the vicinity of ELSP and upwards of 20 feet upstream near the ravine outlet and possible formation of headcuts. Vertical adjustment could continue further downward if adequate natural armoring is unavailable. Although incision is a natural process, it poses significant risks in the steep and developed environment around the project site. Left to incise unchecked, lower George Davis Creek could be destabilized, risking damage not only to the proposed stream crossings, but also to adjacent landowners. Destabilization of the creek system could also risk fish passage itself for the foreseeable future.

Similarly, but to a lesser extent, removal of the upstream diversion dam will likely result in channel adjustment through upstream channel incision. However, since there is no development in the immediate vicinity and the stream corridor is less disturbed, adjustment here would not be considered as severe. It would likely result in increased sediment loading downstream, but this could be seen as a benefit since it could reintroduce spawning gravels to the restored lower segment of George Davis Creek.

### 2.4.2 Bank Instability

Bank instability is a major concern because of the confinement of lower George Davis Creek. The stream corridor downstream of ELSP is approximately 50 wide feet and narrows to 35 to 40 feet wide upstream. Bank instability can arise from either active bank erosion from direct hydraulic forces or side slope destabilization following channel incision. Bank erosion is a concern primarily at channel bends, like those found upstream of ELSP, but can also occur locally where debris creates hydraulic obstructions directing flow towards the bank. Channel incision can lead to over-steepened banks that create geotechnical instabilities. Assuming 2H:1V stable side slopes, channel incision of 5 to 10 feet could result in channel corridor widening of 20 to 40 feet. Widening of this magnitude would pose substantial risks to nearby private residences and public infrastructure.

### 2.4.3 Large Woody Debris Loading

The risk of LWD loading on George Davis Creek is considered low, primarily because the stream is too small to transport materials sizable enough to significantly affect channel stability or culvert conveyance. Regardless, the threat of natural tree fall into the creek could pose risks to stream and bank stability. The occurrence of this is difficult to predict; thus, it is recommended that the stream corridor be monitored.

### 2.4.4 Sedimentation and Delta Formation

The steep gradient (six to eight percent) through the project reach precludes the potential for significant sediment deposition in the George Davis Creek channel, as it will function as a transport reach. Rather, the majority of sediment transported into the reach will be directed to Lake Sammamish where deposition and delta formation are to be expected. Patterns and rate of delta growth are difficult to predict given uncertainty with upstream sediment loading, lake bathymetry, and longshore transport of sediments. A first-order estimate of delta planform growth, assuming sediment loads in the range of 60 to 120 cubic yards per year (see Section 2.3), predicts a delta lobe could extend 35 to 55 feet into Lake Sammamish within 10 years of project construction. Given the relatively wide buffer, sediment deposition and delta formation are not expected to adversely affect access to neighboring docks or the overall quality of the waterfront in the vicinity (Figure 5).

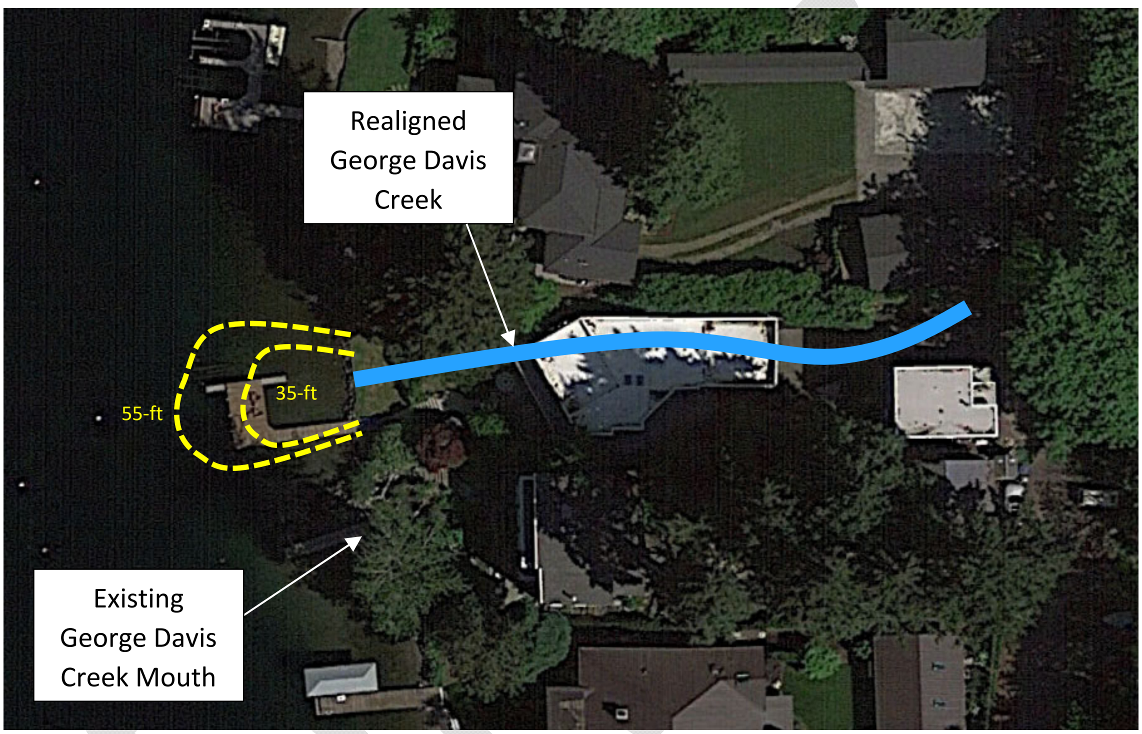


**Figure 5. Aerial photo of estimated delta growth in 10 years**

# 3 HYDROLOGY

## 3.1 Previous Analysis

Hydrologic analysis for George Davis Creek was initially anticipated to be conducted using an existing HSPF model encompassing the east Lake Sammamish tributary streams (i.e. tributaries entering the lake from the Sammamish Plateau between Issaquah Creek and Evans Creek). This East Lake Sammamish (or "regional") model was originally developed, and subsequently modified, by King County and was most recently updated by NHC as part of an ongoing project for the County. The George Davis Creek basin is represented in the regional model, but basin-specific flow routing is not accounted for. Based on frequency analysis over a long-term simulation with the regional model, estimates of frequency flows at the mouth of George Davis Creek range from 108 cfs for a 2-year peak (Q2) to 365 cfs for a 100-year event (Q100).

NHC also reviewed the hydrologic modeling of the basin performed by MGS (MGS, 2009 included in Parametrix, 2011). A significant difference between this basin-specific modeling and the regional model is the assumption that all surface runoff is re-infiltrated into a shallow outwash aquifer, which results in extremely muted peak flows for a basin of this size (Q2 18 cfs, Q100 47 cfs). This assumption would be consistent with field observations upstream of the ravine, where the channel is poorly defined and appears to receive only intermittent flow. The MGS model assumes that drainage local to the ravine has the same groundwater buffer. Given the stormwater tight-lines observed coming into the ravine and the steeper terrain, it is less clear that surface runoff from these local drainage areas would be attenuated to the same level.

NHC used the regional model to estimate peak flows from just the areas directly tributary to the ravine, as a simplified representation of minimal upland flow contribution and increasing runoff into the ravine. Flow frequency quantiles for this scenario are tabulated below in Table 2 and were used for preliminary hydraulic analyses in the initial phase of this project.

**Table 2. Preliminary flow frequency estimates for George Davis Creek**

| Preliminary Flow Frequency Discharges (cfs) | | | | |
|---|---|---|---|---|
| 2-year | 10-year | 25-year | 50-year | 100-year |
| 38 | 74 | 99 | 121 | 148 |

Both NHC and the MGS modeling study recommended stream flow gaging to better understand storm flow patterns and the range of flows the site experiences. The City authorized NHC to install a stream gage and monitor flows in the ravine. This work began in December 2018 and continued through the winter of 2019/2020.

## 3.2 Monitoring Data

NHC installed a stream gage on December 13, 2018 (Photo 9) approximately 120 feet upstream of the ELSP sedimentation basin. The gage setup consists of PVC piping with a perforated bottom to allow water inside the column and a Solinist level logger inside, sitting in the water, taking measurements at five-minute increments. A tape measure is attached to the gage housing to act as a staff gage. Flow measurements in the channel were collected approximately 50 feet downstream (Photo 10). A total of six flow measurements were taken during the fall and winter of 2019/2020 (Table 3). Staff gage readings and data from the level logger and barometric pressure logger were also downloaded during these site visits.

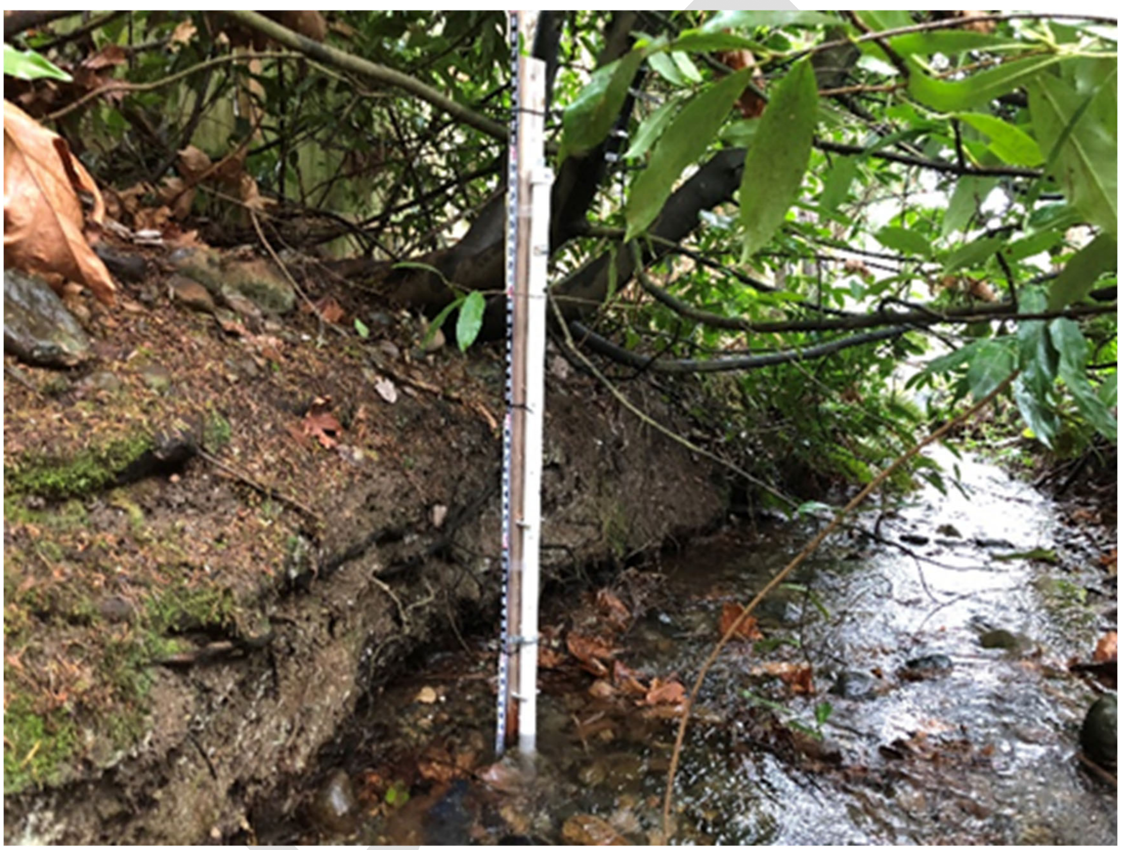

**Photo 9. Stream gage installation on George Davis Creek**

**Table 3. Stream flow measurements on George Davis Creek**

| Date | Time | Flow (cfs) |
|---|---|---|
| 12/13/18 | 12:30 | 0.5 |
| 12/19/18 | 12:30 | 0.7 |
| 10/22/19 | 9:00 | 0.9 |
| 12/20/19 | 13:15 | 14.8 |
| 1/23/2020 | 16:20 | 2.0 |
| 1/28/2020 | 10:50 | 3.8 |
| 2/5/2020 | 13:45 | 11.8 |


**Photo 10. Flow measurements on George Davis Creek**

The recorded monitoring data were compiled, but NHC was not able to develop a consistent rating curve due to the changing conditions at the gage site. Two data gaps occurred because of the level logger running out of memory in May-June and late November-December 2019 (Figure 3). As a result, there was a significant event at the end of December that was not captured by the installed gage. NHC staff were able to visit the site and gather a flow measurement as well as observe conditions in the upper basin in December. From that visit, it was concluded that the upper basin was not contributing any sizeable flow to the ravine. During the following February 2020 event, it was confirmed that NHC's flow measurement did not occur during the peak based on data from nearby stream gages and the level logger stage hydrograph on George Davis Creek. Since the peak flows were not captured by the flow measurements, data from a nearby streamflow gage, King County's Laughing Jacobs Creek, was obtained for flow frequency analysis.

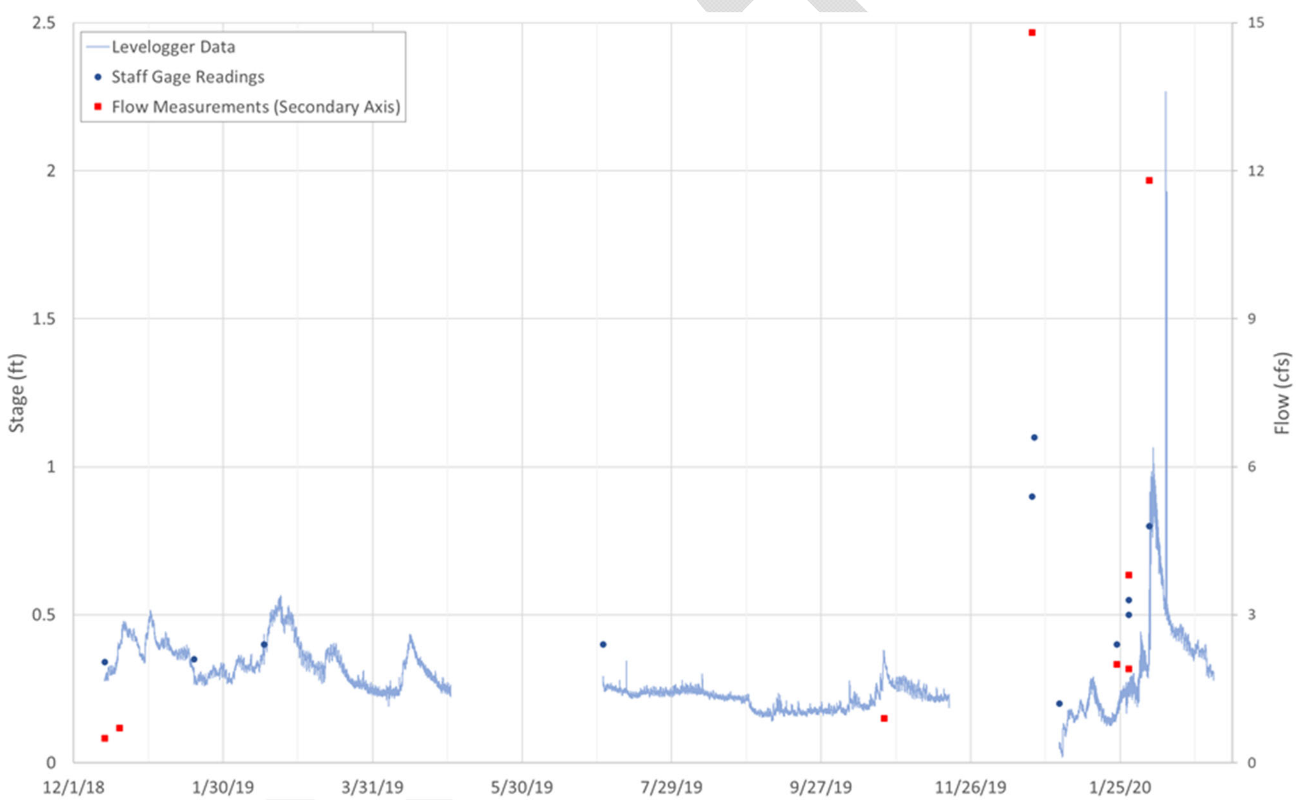


**Figure 6. Recorded monitoring data on George Davis Creek**

## 3.3 Flow Frequency Analysis

The Laughing Jacobs record extends from 1991 to present, and the basin has similar physiography to George Davis Creek, originating in wetlands on the Sammamish plateau and transitioning down to Lake Sammamish through a steep ravine. The Laughing Jacobs basin covers four square miles, approximately 30 percent larger than the 2.7-square mile George Davis Creek watershed. By USGS standards, an ungaged site with a drainage area between 0.5 and 1.5 times the drainage area of the long-term stream gage is acceptable for comparison (Mastin, et al, 2016). To estimate peak flows for George Davis Creek, the results from the Laughing Jacobs Creek analysis were scaled by basin area per USGS methodology (Mastin, et al, 2016). The peak flow results for both Laughing Jacobs Creek and George Davis Creek are provided in Table 4.

**Table 4. Peak flow estimates based on flow frequency analysis**

| Recurrence Interval (year) | Laughing Jacobs Ck Flood Frequency Flow (cfs) | George Davis Creek Flood Frequency Flow (cfs) |
|---|---|---|
| 1.01 | 16 | 11 |
| 2 | 56 | 39 |
| 5 | 87 | 61 |
| 10 | 109 | 76 |
| 25 | 138 | 96 |
| 50 | 160 | 112 |
| 100 | 183 | 128 |
| 500 | 240 | 168 |

The Laughing Jacobs flow frequency analysis would put the December 2019 event between a 2- and 5-year return period and the February 2020 event as a 10-year return period. Flows in Laughing Jacobs Creek at the same date and time that George Davis flow measurements were collected show that the peak flows in the December and February events for Laughing Jacobs Creek were two and five times greater than at the time of the George Davis flow measurements, respectively. Similar checks of the flow record on Ebright Creek provided very similar peak flow ratios (Figure 7). Applying the Laughing Jacobs peak multipliers for these events to the measured George Davis flows produces estimated peaks of 32 cfs for December 2019 and 56 cfs for February 2020. These correspond to 2-year and 5-year frequency events per the results in Table 4, fairly consistent with the Laughing Jacobs flow frequencies.

Based on the flow frequency analysis, the MGS flows are very low and the HSPF regional model estimates are too large. There is not enough evidence from the monitoring data or nearby flow gage comparison to support use of the low MGS flows. Utilization of the peak flow estimates from the flow frequency analysis are suggested for design since they are based on observed data as opposed to the two previously suggested uncalibrated models (Table 4).

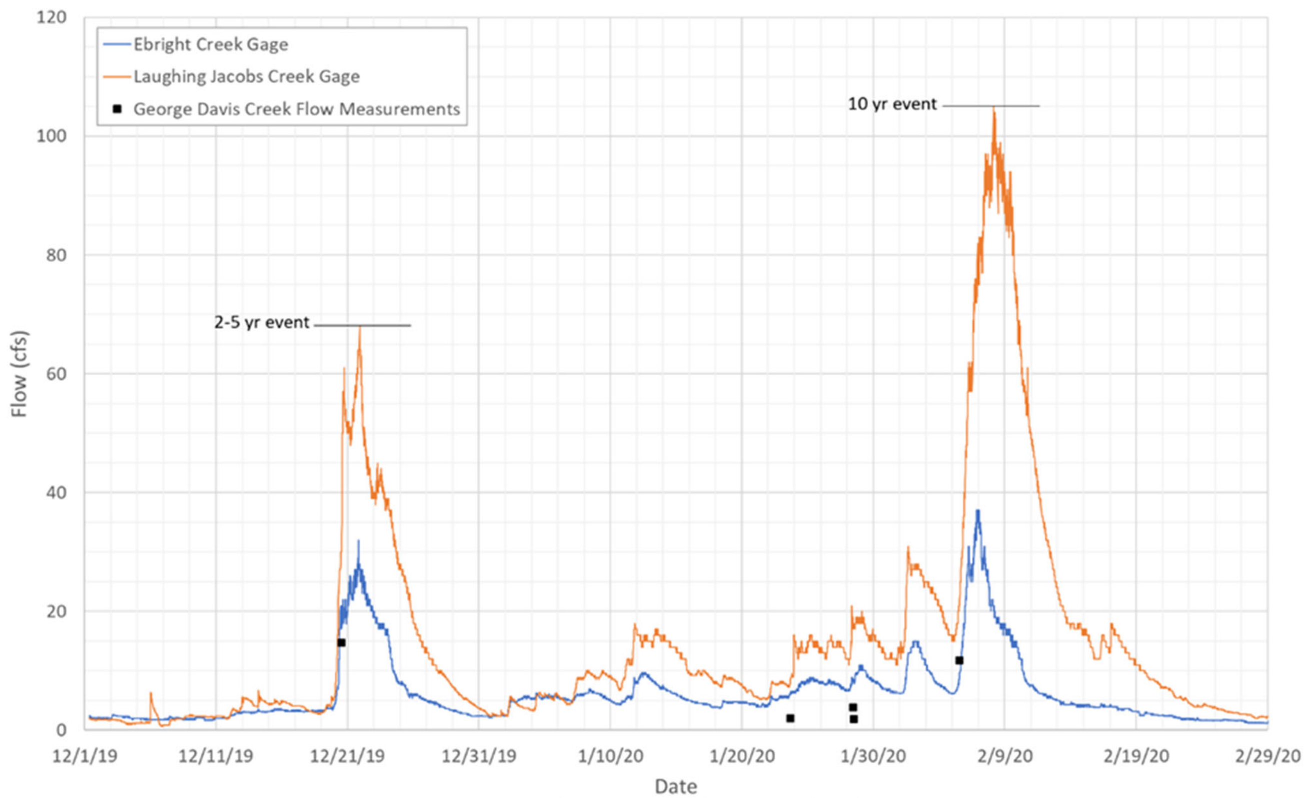


**Figure 7. Flow hydrographs on Ebright and Laughing Jacobs Creek compared to flow measurements on George Davis Creek**

# 4 HYDRAULICS

## 4.1 Model Description

Hydraulic analysis of George Davis Creek was conducted using the U.S. Army Corps of Engineers HEC-RAS modeling software (v5.0.7). Steady-state, one-dimensional (1D) models were constructed for existing and proposed conditions. The existing condition model includes the lower 1,300 feet of George Davis Creek using ground survey, County as-built drawings, and LiDAR topographic data to construct model geometry. The downstream boundary condition assumed an average January lake level of approximately 31.14 feet, NAVD 88, measured at the USGS Gage (122122000 Sammamish Lake Near Redmond, WA). Lake Sammamish levels fluctuate monthly and peak in January. Minimum lake levels are typically observed in September with a monthly average level of 29.54 feet, NAVD 88, as reported by the USGS. Preliminary FEMA floodplain mapping shows the 100-year lake level substantially higher with a base flood elevation of 36 feet, NAVD 88 (FEMA, 2013). In general, model results were not sensitive to lake level fluctuations owing to the steep gradient on George Davis Creek; however, an abrupt hydraulic transition can be expected to occur at the creek mouth. This is discussed further below. Flows presented in Table 4 for George Davis Creek were simulated for proposed conditions.

## 4.2 Existing Conditions

An existing condition model was developed to evaluate current hydraulic controls at the sedimentation and flood diversion facility upstream of ELSP. The flood diversion components to this facility are complex as they limit the amount of flow allowed to move down the mainstem of George Davis Creek, through a series of culverts and under the private residence at the lakefront. Flow down the mainstem of the creek is regulated by an 18-inch diameter culvert connected to the inlet of the 60-inch diameter culvert under ELSP. The constriction created by the 18-inch inlet culvert causes flood waters to back up in the pond facility and divert overflow to a bypass through two elevated drop structures (Rim El. 63.6 feet, NAVD 88). The flood bypass consists of a culvert that parallels ELSP and ultimately discharges into Lake Sammamish approximately 500 feet north of the creek mouth. During extreme events, or if the pond were filled with sediment, a third overflow structure (Rim El. 65.1 ft, NAVD 88) located adjacent to the ELSP will route flow down the mainstem of George Davis Creek. The original design calculations for this structure are unavailable, so precise operation of the flow split is uncertain. To estimate facility operation, the HEC-RAS model was used to compute a stage-discharge rating curve for the 18-inch inlet culvert, from which lateral weir calculations could be used to compute overflow into the bypass. This computation is simplified by neglecting the influence of several components in the facility (e.g. several gates, a perforated standpipe, and an additional 18-inch lateral culvert) as well as the influence of sedimentation on hydraulic performance, the complexity of which is beyond the capabilities of HEC-RAS. Despite these simplifying assumptions, the methodology is considered reasonable for assessment of existing conditions.

Results indicate that the maximum capacity of the 18-inch culvert directing flow down the mainstem is approximately 10 cfs. Between streamflows of 12 to 14 cfs, water surface elevations in the pond rise and activate the two lower elevation drop structures. These results are consistent with observations made in the winter of 2019/2020 (see Photo 3 and Section 3.3). When the pond reaches the elevation of the third higher drop structure, the flow capacity of the system is 142 cfs, well in excess of the estimated 100-year discharge reported in Table 4. Were streamflow to exceed this threshold, overtopping of ELSP could be expected.

## 4.3 Proposed Conditions

NHC developed a proposed condition 1D HEC-RAS model using a grading surface provided by PBS on May 1, 2020. The model surface extends along the lower 700 feet of George Davis Creek, to approximately the ravine outlet (Figure 8). Model grading assumed an active channel width of approximately 12 feet and side slopes graded at 2H:1V. The channel gradient from ELSP to Lake Sammamish averages approximately 6.5 percent and increases to 7 percent through ELSP upstream 300 feet to where it ties into natural grade at the ravine outlet. A high Manning roughness coefficient (n) was selected for the channel in anticipation of roughness elements to be included as part of design. The U.S. Forest Service's (USFS) Stream Channel Flow Resistance Coefficient Computation Tool (version 1.1, 2-2018) was utilized to estimate n-values (Yochum, 2018). Of the several relations provided, only those of Yochum et al (2012) and Aberle and Smart (2003) are considered applicable for steep channels with wood. These relations yield roughness coefficients of 0.192 and 0.209, respectively. These values are consistent with photographic data provided in Yochum et al (2014). An average value of 0.20 was selected for modeling proposed conditions on lower George Davis Creek.

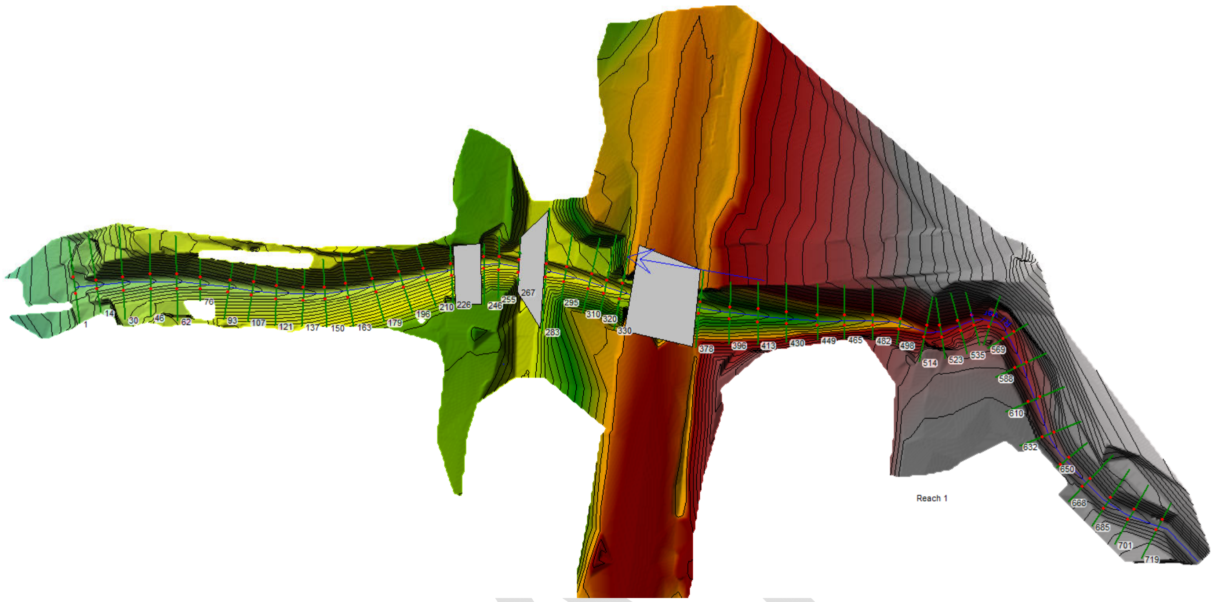


**Figure 8. Proposed condition model domain and surface**

The proposed condition model includes three stream crossing structures, all of which were modeled as bridges in HEC-RAS to account for bed grading within the culvert barrels. The ELSP and Shore Lane crossings within the City project limit as well as the intermediate County Trail crossing were modeled as 17-foot wide box culverts. The latter was agreed to in negotiations between the City and County.

## 4.4 Proposed Condition Results

Figure 9 shows computed flood profiles for the 1.01-, 2-, 10-, and 100-year events under proposed conditions along George Davis Creek. Maximum flow depths during a 100-year event (128 cfs) are approximately 3.5 feet and are contained to the channel. Freeboard, i.e. the distance between the low chord of the stream crossing and water surface elevation, ranges from approximately 1.5 to 1.9 feet during the 100-year event. Computed maximum flow velocities are low, ranging from 3.5 to 5 feet per second (fps), reflecting the high roughness coefficient selected. Use of a high roughness coefficient does translate into higher energy gradients as more friction is computed between cross-sections. Energy gradients are seen to range from approximately 0.065 to 0.08, generally correlating with channel gradient. As will be discussed in the following section, energy gradient and unit discharge (q) are more useful parameters for evaluating stability in high gradient channels. It should be noted that Figure 9 shows an abrupt water surface drop at the mouth of George Davis Creek. In this vicinity, rapid flow expansion into a level pool (i.e. the lake) is expected to result in significant energy dissipation and erosion potential.

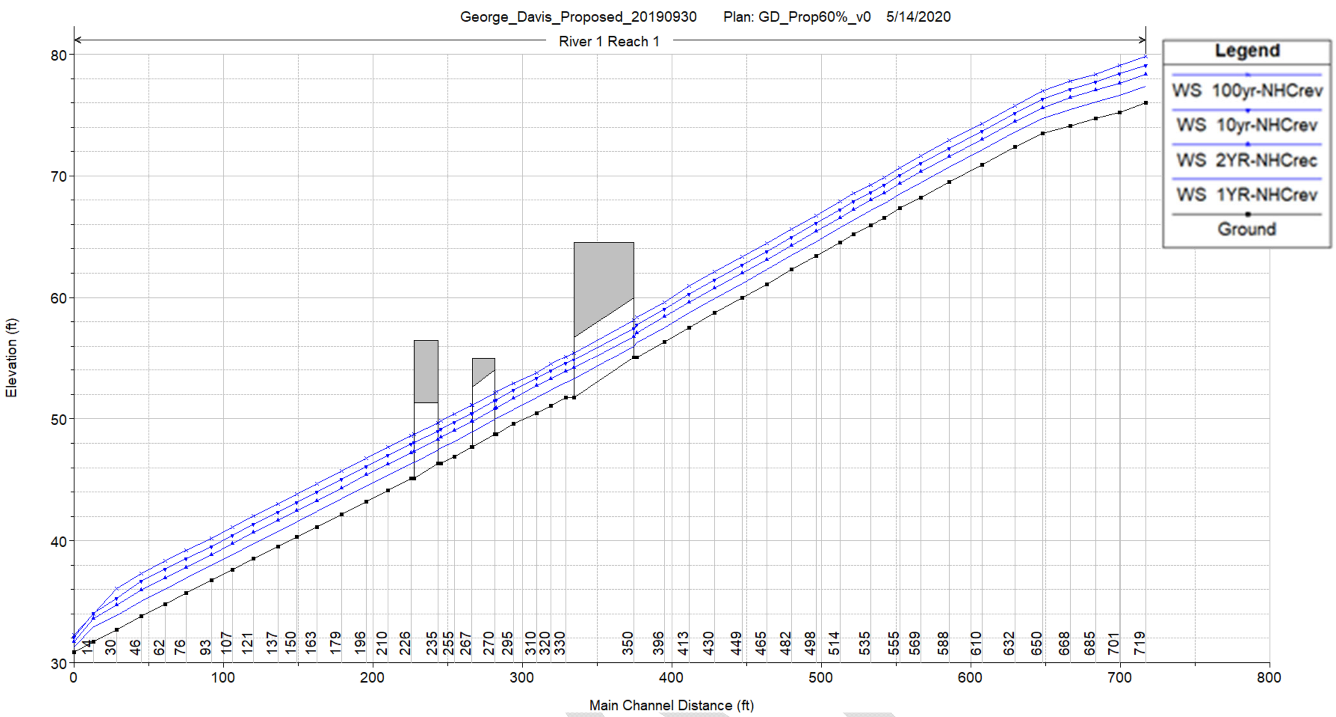


**Figure 9. Computed flood profiles on George Davis Creek for proposed conditions**

It should be noted that both existing and proposed condition modeling predicts overtopping of the left bank at the private residence upstream of ELSP at the outlet of the George Davis ravine. As previously mentioned, this resident told NHC that the highest they had ever witnessed the creek was to the deck elevation. Model results predict that overtopping could occur at flow frequencies between a 2- and 10-year event.

# 5 STREAM SIMULATION CULVERT DESIGN

## 5.1 Reference Reach

NHC identified a suitable stream simulation reference reach (Barnard et al, 2013) approximately 250 feet upstream of the existing diversion dam, in the transition between Segments 2 and 3 (see Figure 4 and Photo 11). This reach was selected because it represents a relatively undisturbed natural condition of George Davis Creek and has a similar channel gradient (seven to eight percent) to that anticipated for the project reach. Although well-confined in the ravine, a low floodplain bench and small side has formed along the left (south) bank. The channel follows a cascade morphology, without either distinct steps or pools, and is dominated by irregularly spaced boulder clusters. Naturally fallen wood debris was observed spanning above and adjacent to the channel but appeared to have limited influence on channel morphology at the site. A channel spanning log jam placed by the County (King County, 1994) was identified toward the upper edge of the reference reach.


**Photo 11. Reference reach on George Davis Creek (inset: reach location)**

### 5.1.1 Bankfull Width

A bankfull width of approximately eight feet was measured in the reference reach. Additional measurements were taken elsewhere along lower George Davis Creek (Figure 4); however, finding suitable sites was difficult due to the rapidly varying channel conditions observed along upstream segments. In many locations, the channel banks were shallow and poorly defined, while in others the channel was constricted by either large woody debris (man-made or natural) and dense vegetation. Bankfull width measurements outside the reference reach ranged from nine to 12 feet. Table 5 summarizes bankfull width measurements and respective stream stationing on George Davis Creek.

**Table 5. Bankfull Width Measurements**

| Field Measurement | Stream Station (ft) | Bankfull Width (ft) |
|---|---|---|
| BF-1 | 630 | 9 |
| BF-2 | 780 | 11 |
| Reference Reach | 1,250 | 8 |
| BF-3 | 1,650 | 12 |

An average bankfull width of 10 feet was computed and selected for design of the ELSP and Shore Lane crossings. This value is consistent with that (10 feet) selected by Parametrix (2016) for design of the County Trail crossing.

### 5.1.2 Sediment Composition

Classification of natural streambed material on lower George Davis Creek is challenging because of the rapidly varying and dynamic morphologic conditions observed along the reach. In particular, the influence of either boulder deposits or woody debris functioning as grade control were observed to strongly influence localized streambed composition. Streambed texture was seen to vary from localized deposits of very uniform fine gravels to boulder dominated clusters within relatively short distances. Streambed conditions within the reference reach generally aligned with the latter (Photo 11).

To quantify surface streambed composition on lower George Davis Creek, random-walk pebble counts following the methodology of Wolman (1954) were collected at two locations. The first pebble count sample was taken within the central portion of the reference reach and the second approximately 150 feet upstream of ELSP in the transition between Segment 1 and 2 (Figure 4). Sample 2 was collected approximately 50 feet upstream of grade control features associated with the sedimentation basin at ELSP. As such, Sample 2 is not considered representative of natural self-formed conditions, but rather, reflects armoring upstream of grade control. Grain size distributions and characteristic particle sizes of each sample are given in Figure 10 and Table 6, respectively.

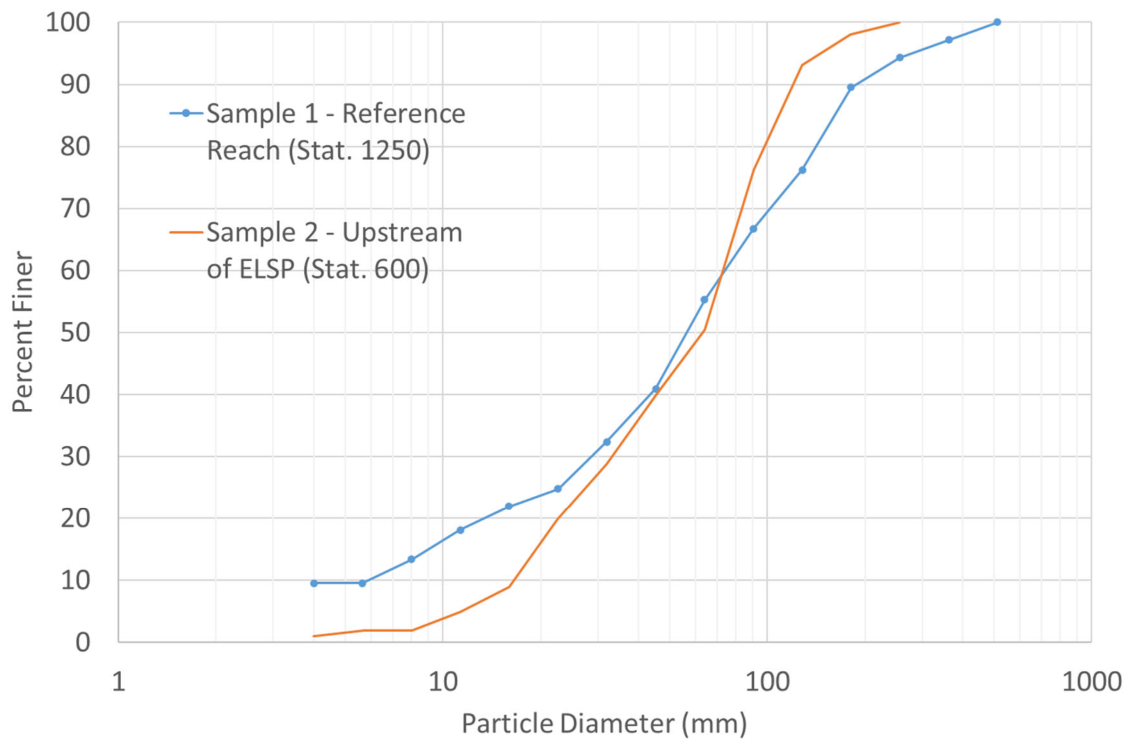


**Figure 10. Grain size distributions of surface streambed material on George Davis Creek**

**Table 6. Characteristic particle sizes on George Davis Creek**

| Characteristic Particle Size (mm) | Sample 1 (Reference Reach) | Sample 2 (Upstream of ELSP) |
|---|---|---|
| $D_{90}$ | 180 | 120 |
| $D_{50}$ | 54 | 62 |
| $D_{10}$ | 6 | 16 |

The central portions of the Sample 1 and 2 grain size distributions are similar; both are composed of gravel to fine cobbles (45 mm to 72 mm). Sample 1, however, has a broader, well-graded mixture that includes significant fractions of coarse cobbles and small boulders. Approximately 25 percent of the sample falls within the cobble classification (64 mm to 256 mm) and five percent within the boulder classification (> 256 mm). This coarse fraction forms the framework that maintains stability along the steeper gradient observed in the reference reach. In addition to collecting a pebble count sample in the reference reach, NHC also sketched surface bed material and morphologic conditions within the reference reach (Figure 11). The sketch includes features such as natural (and man-made) woody debris, bank and floodplain conditions, and layout of boulder clusters with measurements of intermediate (b-axis) diameters, in inches. Key boulders in the reach included sizes ranging from 12 to 36 inches, which aligns with WSDOT one- and two-man boulders.

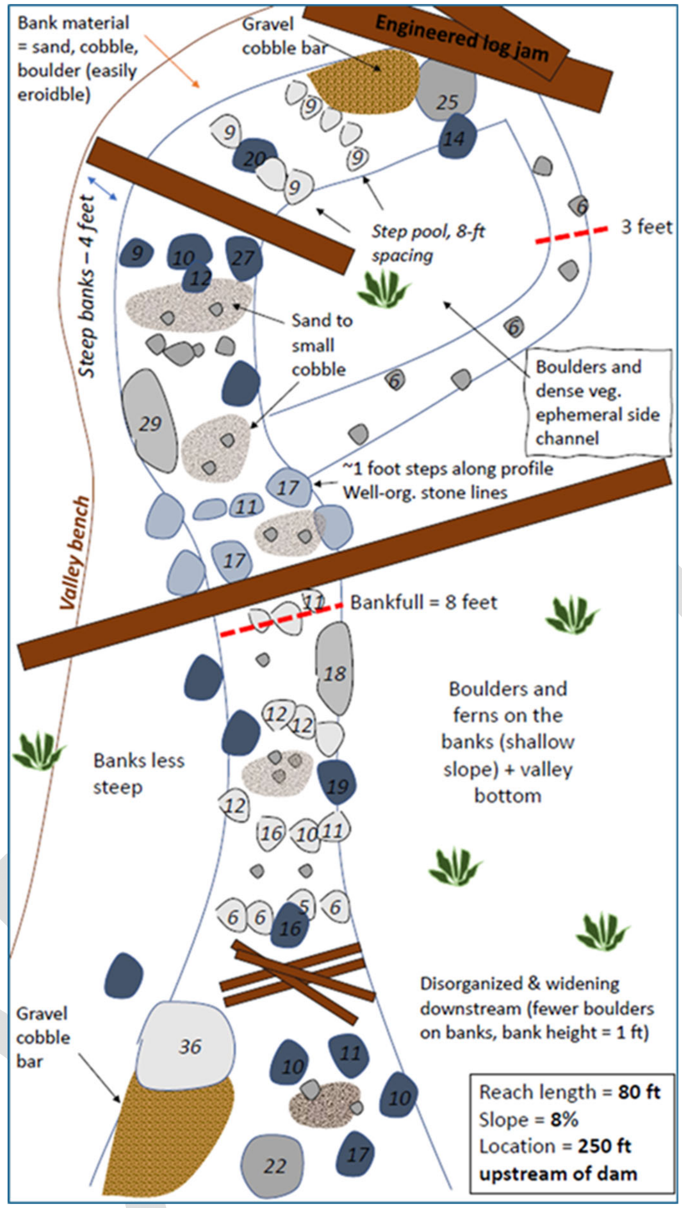


**Figure 11. Sketch of reference reach conditions**

## 5.2 Design Analysis and Recommendations

### 5.2.1 Alignment and Grading

Alignment of George Davis Creek, upstream of ELSP, is relatively fixed as it is confined between a steep hillslope to the east, private residences to the southwest, and NE 7th Court to the north. Between ELSP and Shore Lane, the alignment is fairly linear. The primary alignment change being proposed involves shifting the mainstem of George Davis Creek from its current course under the Linde property (Parcel No. 0777100045) to the north through the Sigmar property (Parcel No. 0777100040). As previously noted, the City has arranged for a buyout of the Sigmar property to accommodate daylighting of lower George Davis Creek. The Sigmar property is a narrow parcel, approximately 50 feet wide, with existing residential structures located to the immediate north and south. The proposed alignment through the Sigmar property is relatively linear to be consistent with typical steep gradient channel planform. Maintaining a linear planform also meets spatial constraints and reduces risks to adjacent structures from bank erosion and instability.

A uniform average channel slope of approximately 6.5 to 7 percent is being proposed from Lake Sammamish to ELSP. This slope meets grading limits required for the County Trail crossing. From ELSP upstream, the channel slope transitions from 7 to approximately 5.5 percent to meet upstream tie-in requirements and property constraints. Relatively uniform average channel slopes are being proposed to simplify construction; however, grading of localized pool areas are anticipated and will result in short steeper gradients. Spacing of proposed LWD structures is intended to augment local steeper gradients and encourage maintenance of chute and pool sections (see Section 5.2.3).

Channel side slopes will be graded to 2H:1V through the Sigmar property up to ELSP. Upstream of ELSP, the narrow stream corridor (35 to 40 feet) will likely require a combination of concrete headwalls, rockeries, or log-toe structures to maintain steep side slopes, particularly along the south (left) bank adjacent to private properties. These features will need to be designed to withstand anticipated scour, bank erosion, and allowable vertical channel adjustment. It is recommended that banks be stabilized to a minimum height of four feet above and two feet below the proposed channel grade.

### 5.2.2 Culvert Structures

The average bankfull width along George Davis Creek is 10 feet (Section 5.1.1). Following the stream simulation guidelines presented in Barnard et al (2013), a structure width of 14 feet is computed. Given that bankfull widths were observed to be somewhat variable and larger in places, culvert widths of 17 feet for ELSP and Shore Lane are proposed. A minimum burial of four feet is recommended for each structure to provide for allowable vertical channel adjustment.

### 5.2.3 Large Woody Debris

Currently, lower George Davis (Segment 1) is effectively free of any substantial wood material in the channel. Upstream, in the ravine (Segments 2-4), substantially more wood is found, although a significant portion can be attributed to pieces placed by King County in the mid-90s (King County, 1994). Because of its small size, George Davis Creek has very limited capacity to carry sizable woody debris any significant distance; rather, it is more dependent on localized tree-fall for wood recruitment. Owing to the developed nature, and that much of the creek is currently piped along the project reach, natural wood recruitment is suppressed. This condition is likely to persist well into the future, even after channel realignment and fish passage restoration has occurred.

### LWD Loading

In early consultation, the Muckleshoot Indian Tribe (MIT) and WDFW recommended that LWD be an integral component in the restoration design of lower George Davis Creek. Fox and Bolton (2007) was used to provide a benchmark for wood quantity and volumes. In small degraded streams, such as George Davis Creek, Fox and Bolton (2007) recommend targeting the 75$^{th}$ percentile of wood loading. This translates to a recommended loading of more than 38 individual LWD pieces with cumulative volume greater than 99 cubic meters per 100 m of stream length. Of the 38 individual pieces, 11 should be key pieces with an individual volume of approximately one cubic meter (Fox and Bolton, 2007). Based on this metric, a 12-foot long, 24-inch diameter log, with or without rootwad, would function as a key piece. Fox and Bolton (2007) also specify a minimum LWD size has a diameter of 10 cm (four inches) and length of one meter (seven feet).

The project reach is approximately 700 feet (215 m) long, so a minimum of 24 key pieces (24"dia x 12'L) and an additional 58 individual pieces would be required from the 75$^{th}$ percentile recommended in Fox and Bolton (2007). Achieving the cumulative volume metric (99 $m^3$ per 100 m) however, may be difficult as preliminary calculations indicate significant amounts (100s to 1000s of pieces) would be required. It is recommended that minimum key and individual piece metrics be included in the design and total volume requirements be discussed further with MIT and WDFW.

### LWD Placement and Anchoring

It is envisioned that key pieces and larger individual LWD pieces (10 inch min. dia.) will be used to provide grade breaks and energy dissipation between chutes and pools throughout the restored reach. Although not intended to function as distinct step-pools, spacing recommendations are taken from the step-pool literature. Knighton (1998) specifies step-pool spacing of two to three channel widths and Chin (1989) reports similar spacing at 0.43 to 2.5 channel widths. Given an average bankfull width of 10 feet on George Davie Creek, it is recommended that spacing between 'pool' forming structures vary from approximately 20 to 30 feet. It is also recommended that each structure consist of two to three pieces placed on alternate sides of the channel spaced one to three feet apart. Each piece should span a minimum of half the low flow channel width (six-eight feet) with tips in the channel buried a minimum of 18 inches. It is recommended that each piece be oriented with the tip pointing diagonally in the upstream direction to encourage flow toward the center of channel during higher stages. The landward segment of each piece should be either keyed into the bank a minimum of one half its length, anchored with boulder ballast, or secured with piles driven below anticipated scour depth. Anchoring should allow for vertical adjustment of wood pieces but maintain horizontal stability to prevent shifting. Lateral movements of LSD could result in fish barrier creation or bank instability. Preferred wood species include Douglas Fir, Red Cedar, or Sitka Spruce; Western Hemlock is not recommended.

### LWD Bank Armoring

Flanking and bank disturbance were observed at several sites where the County installed LWD in the George Davis ravine (Segments 2 and 3). Outflanking on lower George Davis Creek could pose significant risks to adjacent landowners, infrastructure, and overall reach stability. To prevent outflanking, it is recommended that a two-foot thick blanket of WSDOT 12-inch cobbles (9-03.11(2)) be installed in the banks adjacent to and upstream of each log structure. This blanket should extend a minimum of four feet above the average adjacent channel grade and 12 feet (one channel width) upstream of each structure. The blanket can be top-coated with soil and planted with appropriate vegetation to encourage riparian development.

#### LWD at Creek Mouth

As noted in Section 4.4, significant energy dissipation is anticipated at the mouth of George Davis Creek during moderate to high flows. Energy dissipation would likely be in the form of a hydraulic jump, the formation of which could result in upstream incision and potential channel destabilization through headcutting. Conversely, sediment deposition would likely occur downstream of a hydraulic jump and could result in lateral channel migration. Downstream deposition will result in delta formation into the lake (Section 2.4.4). To address headcut instability, it is recommended that LWD be more densely spaced within the lower 40 feet of George Davis Creek. This stream length is intended to account for varying lake levels including the FEMA 100-year base flood elevation of 36 feet NAVD 88. Placement could mimic that alternate bank pattern, spacing, and burial depths described above, but pieces would be placed continuously for the entire 40-foot length. To address lateral migration, it is recommended that additional wood be placed along the shoreline in a streamwise widening pattern. Pieces should be anchored to prevent recruitment into the lake and placed shoreward (e.g. above ordinary high water) to reduce habitat potential for predatory fish species.

#### LWD as Bank Slope Protection

Additional pieces of wood can be used to provide slope toe and bank protection in areas subject to high hydraulic forces. These areas include the left bank at the residence just downstream of the ravine exit, along the sharp left bend near NE 7$^{th}$ Court, and along the left bank upstream of ELSP. In these areas, logs buried and placed parallel to flow can act as toe protection. It is recommended that logs be buried to a minimum of 18 inches or the computed scour depth, whichever is greater. It is further recommended that these logs be anchored mechanically, with boulders, or overburden, if possible. Bank protection should extend to a minimum height of four feet above the constructed channel level.

### 5.2.4 Bed Material Gradation

Given the extremely high potential for channel incision on the steepened portion of lower George Davis Creek, a surface and subgrade mix are recommended. The surface gradation would be generally stable up to a 2-year event but allowed to shift at higher discharges. It is assumed that the LWD described in the previous section would function as the primary energy dissipaters in the restored reach. Regardless, the subgrade material would be sized to be stable up to the 100-year event to prevent excessive channel incision.

#### Subgrade Mix

Several methods were used to evaluate channel stability of the subgrade mix. In general, standard incipient motion relations (i.e. Shields) are not well suited for evaluating bed mobility in steep channels. Instead, results from several accepted methods for sizing stone in steep channels were compared:

- Bathurst (1987), as presented in Barnard (2013)
- USACE (1991) steep slope riprap design
- Abt and Johnson (1991), as presented in USBR (2007)
- Ullmann (2000), as presented in USBR (2007)

The four relations above are similar as they all compute stable stone size as a function of unit discharge (q) and slope (S). Design unit discharge was assumed to be the 100-year discharge (Q, 128 cfs) divided by the active channel width (12 feet), yielding a value of approximately 11 cfs per foot. Slope was assumed to be eight percent, which coincides with the approximate maximum energy gradient computed along the reach. The relations of Abt and Johnson (1991) and Ullmann (2007) yielded similar $D_{50}$ stone sizes ranging from 16 to 17 inches. USACE (1991) computes the $D_{30}$ stone size and assumes angular riprap. The $D_{50}$ size was computed using the coefficient of uniformity conversion provided in USACE (1991), assuming a $D_{85}/D_{15}$ ratio less than two, and 46 percent size increase to account for rounded rock (Ullmann, 2000). From this, USACE (1991) yielded a $D_{50}$ of 17 to 18 inches. Bathurst (1987) computes the $D_{84}$ particle diameter, which yields a value of 11 inches, well lower than the $D_{50}$ values computed by the other relations. Given these results, it is recommended that the subgrade be composed of 50-50 mix of WSDOT one-man and two-man habitat boulders (9-03.11(3)), with diameters ranging from 12-28 inches. This will result in a fairly uniform gradation; however, this is generally preferred to withstand higher discharges (USBR, 2007). It is further recommended that filter layer be placed under the subgrade, and WSDOT streambed sediment mix (9-03.11(1)) washed into the boulder matrix to seal interstices, prevent piping, and avoid subsurface flow. A minimum subgrade thickness of 24 inches or $1.5D_{50}$ is recommended (USBR, 2007). This subgrade mix is intended to be stable up to the 100-year discharge, if exposed, and provide assurance that unchecked channel incision does not occur.

#### Surface Mix

The surface mix was sized using the relation of Bathurst (1987), discussed above, and the recommended ratios for natural grain size distributions presented in Barnard et al (2013). A target flow threshold for motion was set to the 2-year event (39 cfs). Results yield a recommended mixture of 40 percent WSDOT streambed sediment mix (9-03.11(1)) and 60 percent WSDOT 12-inch cobbles ((9-03.11(2)). Figure 12 compares the recommended average WSDOT mixture with that computed using Bathurst (1987) and bed gradation (Sample 1) measured in the reference reach (Section 5.1.2). Dashed lines indicate uncertainty within the WSDOT specifications.

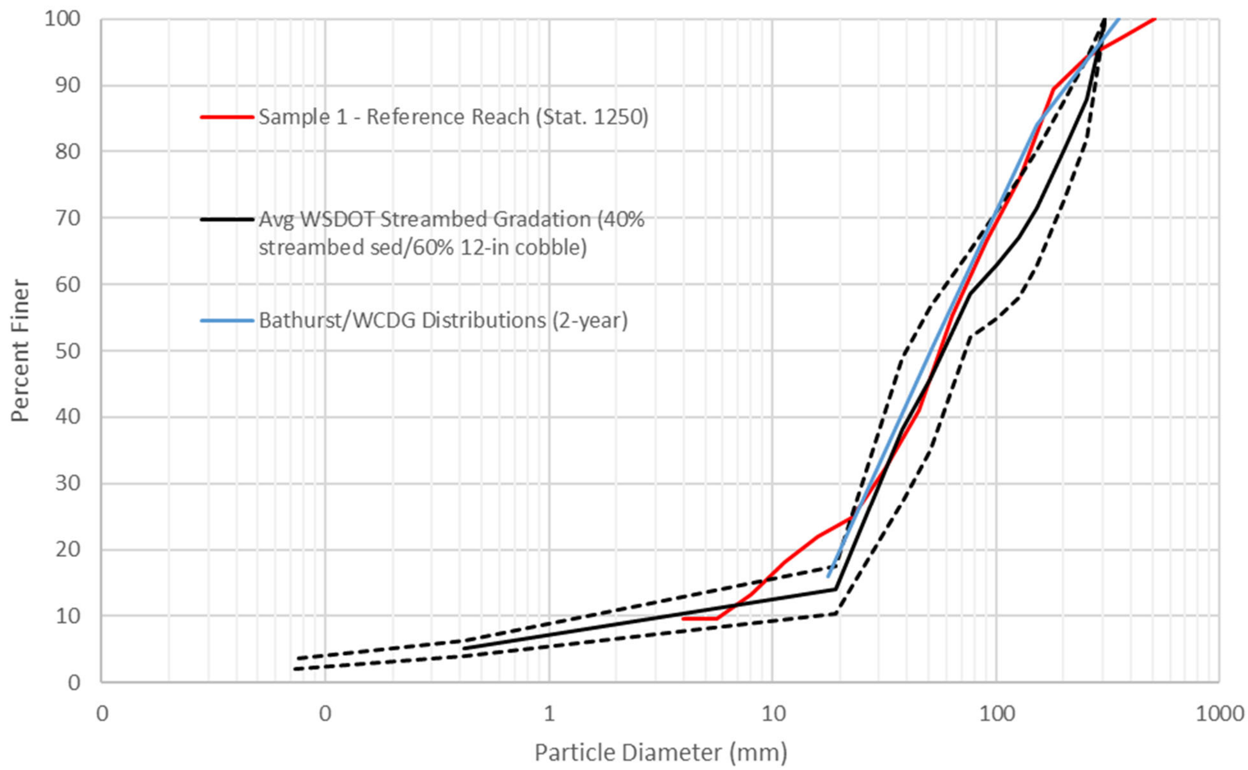


**Figure 12. Recommended surface mix grain size distribution compared to Bathurst (1987) and surface grain size distribution measured in reference reach**

Figure 12 shows the proposed surface mix closely follows the gradation of the reference reach and Bathurst (1987) for $D_{50}$ and finer fractions but tends to be coarser at the higher end of the distribution. This is considered ideal in that it provides sufficient fines (< $D_{50}$) to seal the bed and allow for minor channel adjustment, but also provides a reasonable coarser matrix to give some stability. Given the high sediment loads on George Davis Creek, it would be expected that finer materials eroded during a competent event would be replaced by incoming materials. As previously noted, the surface mix is intended to be somewhat dynamic, allowing for sediment exchange and formation of pools and bars. The recommended thickness for the surface mix is 24 inches.

# 6 ANTICIPATED GEOMORPHIC RESPONSE

## 6.1 Profile Adjustment

The proposed LWD and streambed design is intended to allow for some adjustment of the streambed profile, approximately two feet maximum, while also providing protection against severe incision and channel destabilization. Anchored LWD features will form the primary matrix material to dissipate energy and provide passage routes for migrating fish at a variety of flow levels. Streambed material is anticipated to adjust but maintain overall stability with the aid of LWD features. Furthermore, it is anticipated that sediment transport continuity will be fully restored on George Davis Creek, providing sufficient materials from upstream to replenish and renew the streambed after high flows. This design is intended to integrate the use of wood and substrate in a constrained but dynamic system, without the use of static step-pool structures, to ensure channel stability, geomorphic resilience, and restored fish passage and habitat.

### 6.1.1 Delta Formation

As discussed in Section 2.4.4, a delta is expect to grow at the mouth of George Davis Creek and extend into Lake Sammamish. Rapid growth can be expected within 10 years of project construction; however, with the property buyout and added buffer between adjacent properties, adverse impacts to neighboring properties is not expected. Although the delta could extend 35 to 55 feet into the lake; beyond this limit growth will decay as sediments deposit into deeper water or are eroded by wave action.

Delta growth will result in minor adjustment to the lower George Davis Creek profile as sediment deposition extends the creek length. This deposition is considered beneficial, not only because it will create dynamic nearshore habitat, but also because, once formed, it will effectively smooth the transition between the lake and steep upstream creek segment. Sediment and debris deposits at the mouth will function as a geomorphic buffer that will help dissipate hydraulic energy and prevent upstream channel degradation.

### 6.1.2 Dam Removal

Removal of the existing diversion dam (Photo 5) 500 feet upstream of ELSP will likely result in degradation (headcutting) of the approximately 125 to 200 cubic yards of sediment currently stored behind the structure. This is approximately one to two times the volume of the current sediment load on George Davis Creek (Section 2.3). Channel incision of up to three feet could extend upstream 150 feet upstream and eroded materials would be transported downstream. The precise fate of this eroded material is uncertain, given that the bulk composition of the deposit is unknown. Based on observations elsewhere, however, it is likely most of the deposit consists for medium to fine gravels and sand materials. Material of this size would be expected to be transported to Lake Sammamish, with some fraction depositing in the intervening creek within five years of dam removal.

Channel adjustment in the vicinity of the dam, once removed, may result in dynamic conditions that could adversely affect fish passage by creating barriers. To meter the process, naturally occurring LWD found in the reach could be repositioned to help encourage sediment deposition downstream and control the incision rate upstream. The position and extent of these placements would need to be negotiated during permitting and likely field fit during construction.

## 6.2 Freeboard

Preliminary hydraulic modeling shows the proposed 17-foot wide box culverts at Shore Lane, Trail, and ELSP provide approximately 1.5 to 2.5 feet of clearance (freeboard) between the computed 100-year water surface elevation and culvert crowns. This is less than the two feet recommended for debris clearance in streams with bankfull widths ranging from 8 to 15 feet (Barnard et al, 2013); however, site conditions suggest an allowance for a lower clearance would be acceptable at these crossings.

George Davis Creek is relatively small and entrenched with computed 100-year flow depths less than four feet. These conditions suggest George Davis Creek does not have the capacity to transport debris sizable enough (e.g. logs with rootwads) to present racking issues. Forested conditions located further upstream present potential woody debris sources, but the stream's limited transport capacity indicates low debris loading and racking risk at the project crossings. As such, a freeboard clearance of 1.5 to 2.5 feet at the 100-year event is considered sufficient.

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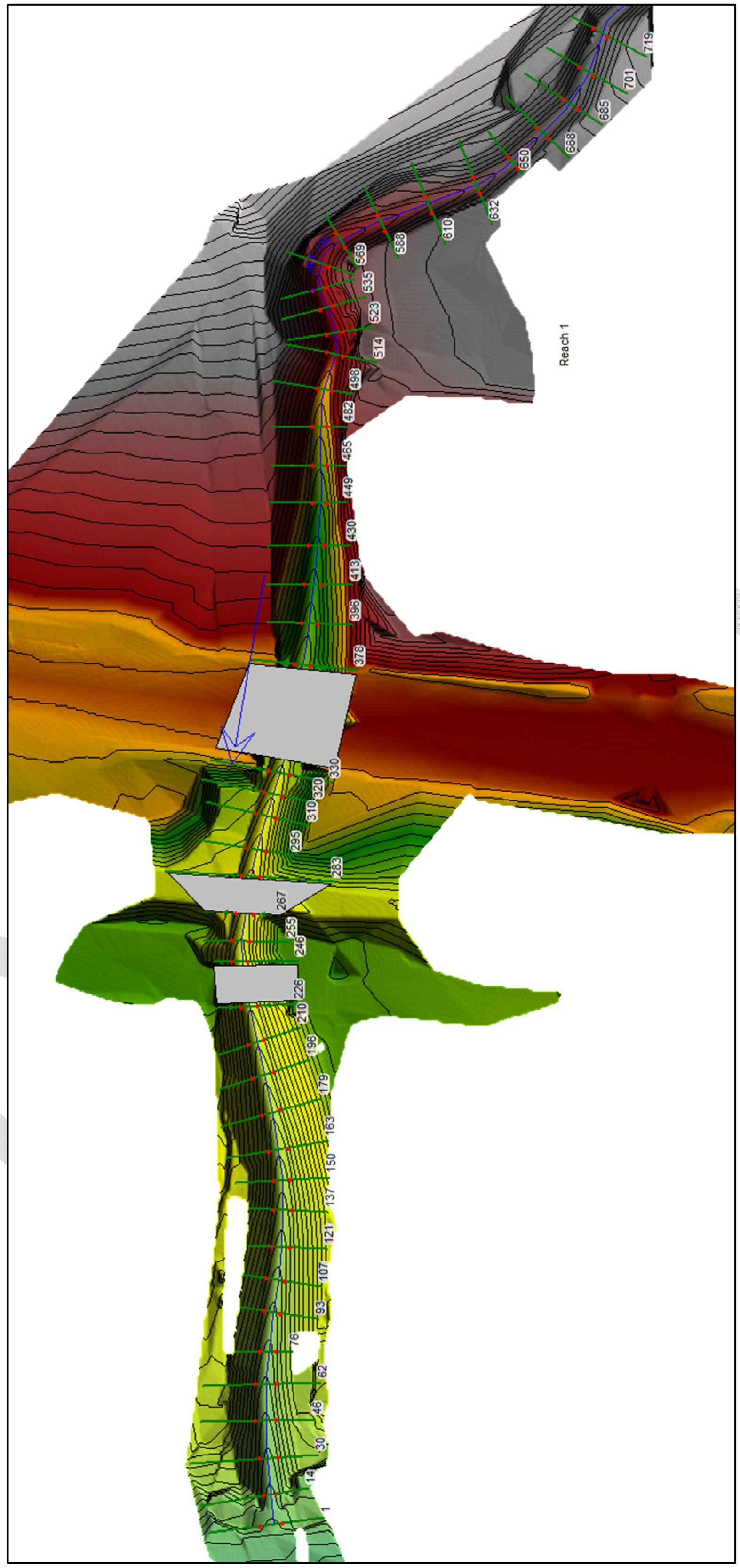
# APPENDIX A

Preliminary Hydraulic Results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46
30
14
1
Reach 1

2-year Event

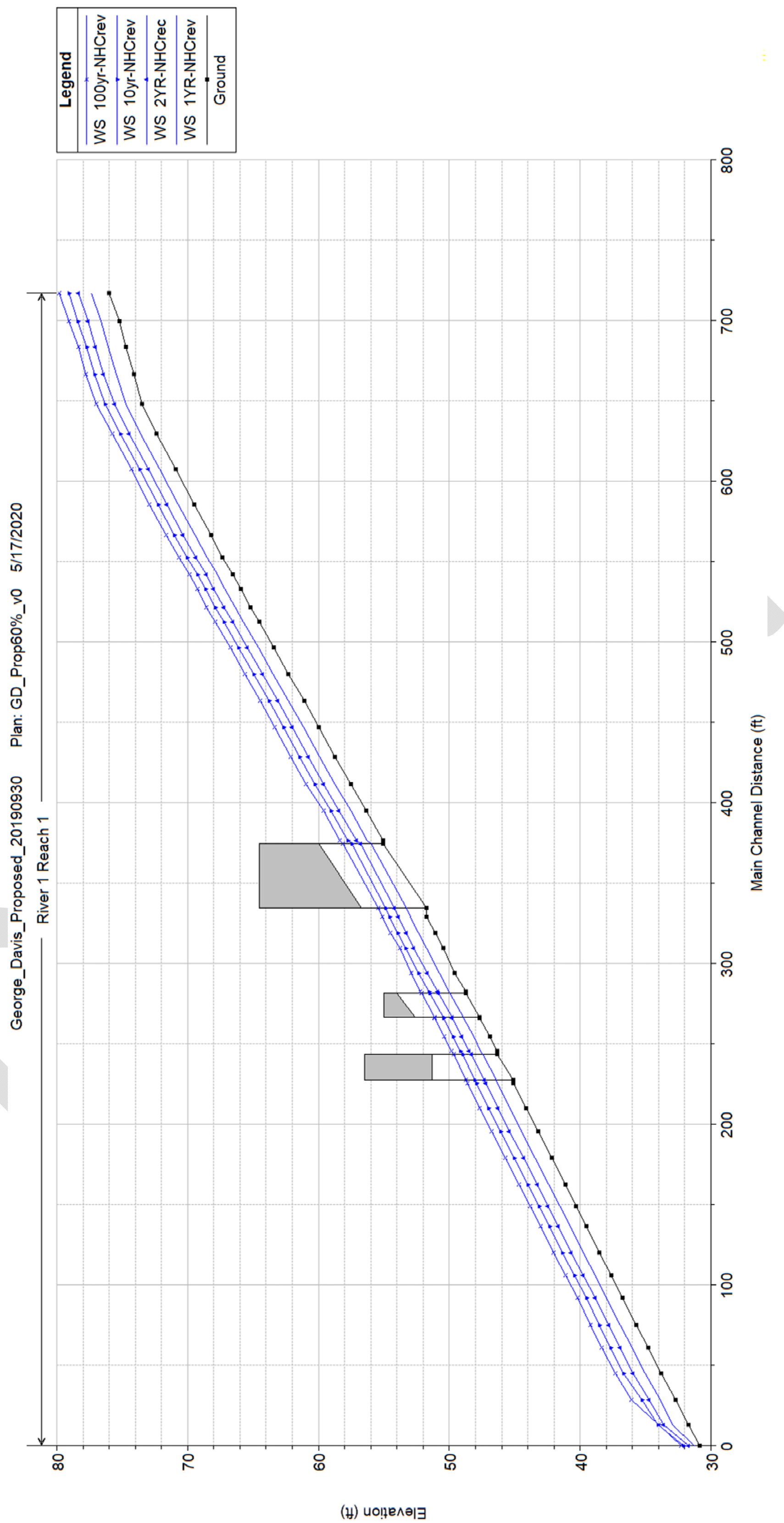
| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Hydr Depth C | Froude # Chl | Shear Chan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (cfs) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | (ft) | | (lb/sq ft) |
| Reach 1 | 1 | 2YR-NHCrec | 39.00 | 30.84 | 31.74 | 32.03 | 0.493916 | 4.35 | 8.98 | 28.12 | 0.76 | 0.88 | 23.44 |
| Reach 1 | 14 | 2YR-NHCrec | 39.00 | 31.70 | 33.64 | 33.74 | 0.059523 | 2.62 | 15.37 | 19.90 | 1.78 | 0.35 | 6.47 |
| Reach 1 | 30 | 2YR-NHCrec | 39.00 | 32.72 | 34.73 | 34.85 | 0.084217 | 2.85 | 13.91 | 10.44 | 1.61 | 0.40 | 7.98 |
| Reach 1 | 46 | 2YR-NHCrec | 39.00 | 33.78 | 35.96 | 36.05 | 0.063611 | 2.52 | 15.70 | 10.96 | 1.67 | 0.34 | 6.20 |
| Reach 1 | 62 | 2YR-NHCrec | 39.00 | 34.79 | 36.96 | 37.06 | 0.064739 | 2.54 | 15.60 | 10.87 | 1.66 | 0.35 | 6.29 |
| Reach 1 | 76 | 2YR-NHCrec | 39.00 | 35.70 | 37.82 | 37.92 | 0.057420 | 2.59 | 15.27 | 10.82 | 1.83 | 0.34 | 6.28 |
| Reach 1 | 93 | 2YR-NHCrec | 39.00 | 36.75 | 38.84 | 38.95 | 0.064261 | 2.68 | 14.77 | 10.69 | 1.77 | 0.36 | 6.81 |
| Reach 1 | 107 | 2YR-NHCrec | 39.00 | 37.63 | 39.76 | 39.86 | 0.066012 | 2.63 | 15.09 | 10.89 | 1.71 | 0.35 | 6.67 |
| Reach 1 | 121 | 2YR-NHCrec | 39.00 | 38.51 | 40.67 | 40.77 | 0.060316 | 2.56 | 15.53 | 10.99 | 1.76 | 0.34 | 6.27 |
| Reach 1 | 137 | 2YR-NHCrec | 39.00 | 39.51 | 41.66 | 41.76 | 0.063563 | 2.61 | 15.25 | 10.85 | 1.73 | 0.35 | 6.51 |
| Reach 1 | 150 | 2YR-NHCrec | 39.00 | 40.34 | 42.44 | 42.55 | 0.059046 | 2.60 | 15.18 | 10.82 | 1.81 | 0.34 | 6.39 |
| Reach 1 | 163 | 2YR-NHCrec | 39.00 | 41.13 | 43.27 | 43.38 | 0.066098 | 2.63 | 15.15 | 10.91 | 1.70 | 0.35 | 6.65 |
| Reach 1 | 179 | 2YR-NHCrec | 39.00 | 42.17 | 44.33 | 44.43 | 0.062341 | 2.57 | 15.48 | 10.96 | 1.73 | 0.34 | 6.35 |
| Reach 1 | 196 | 2YR-NHCrec | 39.00 | 43.23 | 45.41 | 45.50 | 0.065584 | 2.50 | 15.77 | 10.95 | 1.62 | 0.35 | 6.17 |
| Reach 1 | 210 | 2YR-NHCrec | 39.00 | 44.14 | 46.29 | 46.39 | 0.057341 | 2.56 | 15.48 | 10.90 | 1.81 | 0.34 | 6.18 |
| Reach 1 | 226 | 2YR-NHCrec | 39.00 | 45.13 | 47.21 | 47.31 | 0.060951 | 2.63 | 15.04 | 10.88 | 1.78 | 0.35 | 6.52 |
| Reach 1 | 235 | | Bridge | | | | | | | | | | |
| Reach 1 | 246 | 2YR-NHCrec | 39.00 | 46.35 | 48.48 | 48.58 | 0.056980 | 2.57 | 15.31 | 10.93 | 1.82 | 0.34 | 6.21 |
| Reach 1 | 255 | 2YR-NHCrec | 39.00 | 46.90 | 49.02 | 49.13 | 0.066609 | 2.65 | 15.05 | 11.01 | 1.71 | 0.36 | 6.75 |
| Reach 1 | 267 | 2YR-NHCrec | 39.00 | 47.72 | 49.79 | 49.90 | 0.063361 | 2.67 | 14.85 | 10.83 | 1.77 | 0.35 | 6.74 |
| Reach 1 | 270 | | Bridge | | | | | | | | | | |
| Reach 1 | 283 | 2YR-NHCrec | 39.00 | 48.76 | 50.91 | 51.01 | 0.062512 | 2.59 | 15.39 | 11.32 | 1.74 | 0.35 | 6.44 |
| Reach 1 | 295 | 2YR-NHCrec | 39.00 | 49.57 | 51.70 | 51.80 | 0.070207 | 2.59 | 15.27 | 10.94 | 1.62 | 0.36 | 6.62 |
| Reach 1 | 310 | 2YR-NHCrec | 39.00 | 50.48 | 52.70 | 52.79 | 0.060147 | 2.46 | 16.12 | 11.30 | 1.68 | 0.33 | 5.87 |
| Reach 1 | 320 | 2YR-NHCrec | 39.00 | 51.07 | 53.27 | 53.36 | 0.055556 | 2.48 | 16.04 | 11.15 | 1.78 | 0.33 | 5.85 |
| Reach 1 | 330 | 2YR-NHCrec | 39.00 | 51.75 | 53.88 | 53.99 | 0.072476 | 2.59 | 15.24 | 11.17 | 1.58 | 0.36 | 6.68 |
| Reach 1 | 350 | | Bridge | | | | | | | | | | |
| Reach 1 | 378 | 2YR-NHCrec | 39.00 | 55.08 | 57.11 | 57.23 | 0.074841 | 2.82 | 14.10 | 10.55 | 1.70 | 0.38 | 7.62 |
| Reach 1 | 396 | 2YR-NHCrec | 39.00 | 56.37 | 58.42 | 58.53 | 0.068352 | 2.74 | 14.42 | 10.57 | 1.75 | 0.37 | 7.17 |
| Reach 1 | 413 | 2YR-NHCrec | 39.00 | 57.51 | 59.60 | 59.71 | 0.071962 | 2.72 | 14.65 | 10.74 | 1.68 | 0.37 | 7.14 |
| Reach 1 | 430 | 2YR-NHCrec | 39.00 | 58.73 | 60.78 | 60.89 | 0.066993 | 2.73 | 14.52 | 10.63 | 1.76 | 0.36 | 7.06 |
| Reach 1 | 449 | 2YR-NHCrec | 39.00 | 60.00 | 62.02 | 62.14 | 0.067257 | 2.78 | 14.00 | 10.49 | 1.79 | 0.37 | 7.29 |
| Reach 1 | 465 | 2YR-NHCrec | 39.00 | 61.11 | 63.12 | 63.25 | 0.069288 | 2.81 | 13.86 | 10.45 | 1.78 | 0.37 | 7.46 |
| Reach 1 | 482 | 2YR-NHCrec | 39.00 | 62.28 | 64.29 | 64.42 | 0.070133 | 2.82 | 13.81 | 10.47 | 1.78 | 0.37 | 7.53 |
| Reach 1 | 498 | 2YR-NHCrec | 39.00 | 63.41 | 65.43 | 65.56 | 0.068932 | 2.80 | 13.93 | 10.47 | 1.78 | 0.37 | 7.40 |
| Reach 1 | 514 | 2YR-NHCrec | 39.00 | 64.52 | 66.57 | 66.69 | 0.073324 | 2.79 | 14.17 | 10.42 | 1.71 | 0.38 | 7.49 |
| Reach 1 | 523 | 2YR-NHCrec | 39.00 | 65.17 | 67.24 | 67.35 | 0.068372 | 2.74 | 14.48 | 11.19 | 1.74 | 0.37 | 7.15 |
| Reach 1 | 535 | 2YR-NHCrec | 39.00 | 65.96 | 68.01 | 68.13 | 0.065701 | 2.75 | 14.21 | 10.52 | 1.80 | 0.36 | 7.13 |
| Reach 1 | 544 | 2YR-NHCrec | 39.00 | 66.56 | 68.59 | 68.71 | 0.069291 | 2.78 | 14.08 | 10.58 | 1.76 | 0.37 | 7.34 |
| Reach 1 | 555 | 2YR-NHCrec | 39.00 | 67.32 | 69.37 | 69.48 | 0.073343 | 2.78 | 14.28 | 10.58 | 1.70 | 0.38 | 7.43 |
| Reach 1 | 569 | 2YR-NHCrec | 39.00 | 68.20 | 70.33 | 70.43 | 0.065209 | 2.63 | 15.13 | 10.78 | 1.73 | 0.35 | 6.64 |
| Reach 1 | 588 | 2YR-NHCrec | 39.00 | 69.47 | 71.58 | 71.68 | 0.065752 | 2.66 | 14.95 | 10.83 | 1.73 | 0.36 | 6.76 |
| Reach 1 | 610 | 2YR-NHCrec | 39.00 | 70.89 | 73.01 | 73.12 | 0.065114 | 2.65 | 14.96 | 10.86 | 1.73 | 0.35 | 6.72 |
| Reach 1 | 632 | 2YR-NHCrec | 39.00 | 72.39 | 74.47 | 74.58 | 0.065887 | 2.68 | 14.87 | 10.93 | 1.74 | 0.36 | 6.83 |
| Reach 1 | 650 | 2YR-NHCrec | 39.00 | 73.47 | 75.60 | 75.70 | 0.056365 | 2.59 | 15.14 | 10.98 | 1.85 | 0.34 | 6.28 |
| Reach 1 | 668 | 2YR-NHCrec | 39.00 | 74.10 | 76.44 | 76.52 | 0.036457 | 2.25 | 17.80 | 12.85 | 2.08 | 0.28 | 4.55 |
| Reach 1 | 685 | 2YR-NHCrec | 39.00 | 74.69 | 77.08 | 77.15 | 0.036612 | 2.18 | 18.28 | 11.77 | 2.00 | 0.27 | 4.34 |
| Reach 1 | 701 | 2YR-NHCrec | 39.00 | 75.22 | 77.63 | 77.70 | 0.032654 | 2.13 | 18.51 | 11.79 | 2.09 | 0.26 | 4.07 |
| Reach 1 | 719 | 2YR-NHCrec | 39.00 | 76.03 | 78.33 | 78.42 | 0.050023 | 2.39 | 16.37 | 11.67 | 1.88 | 0.31 | 5.39 |

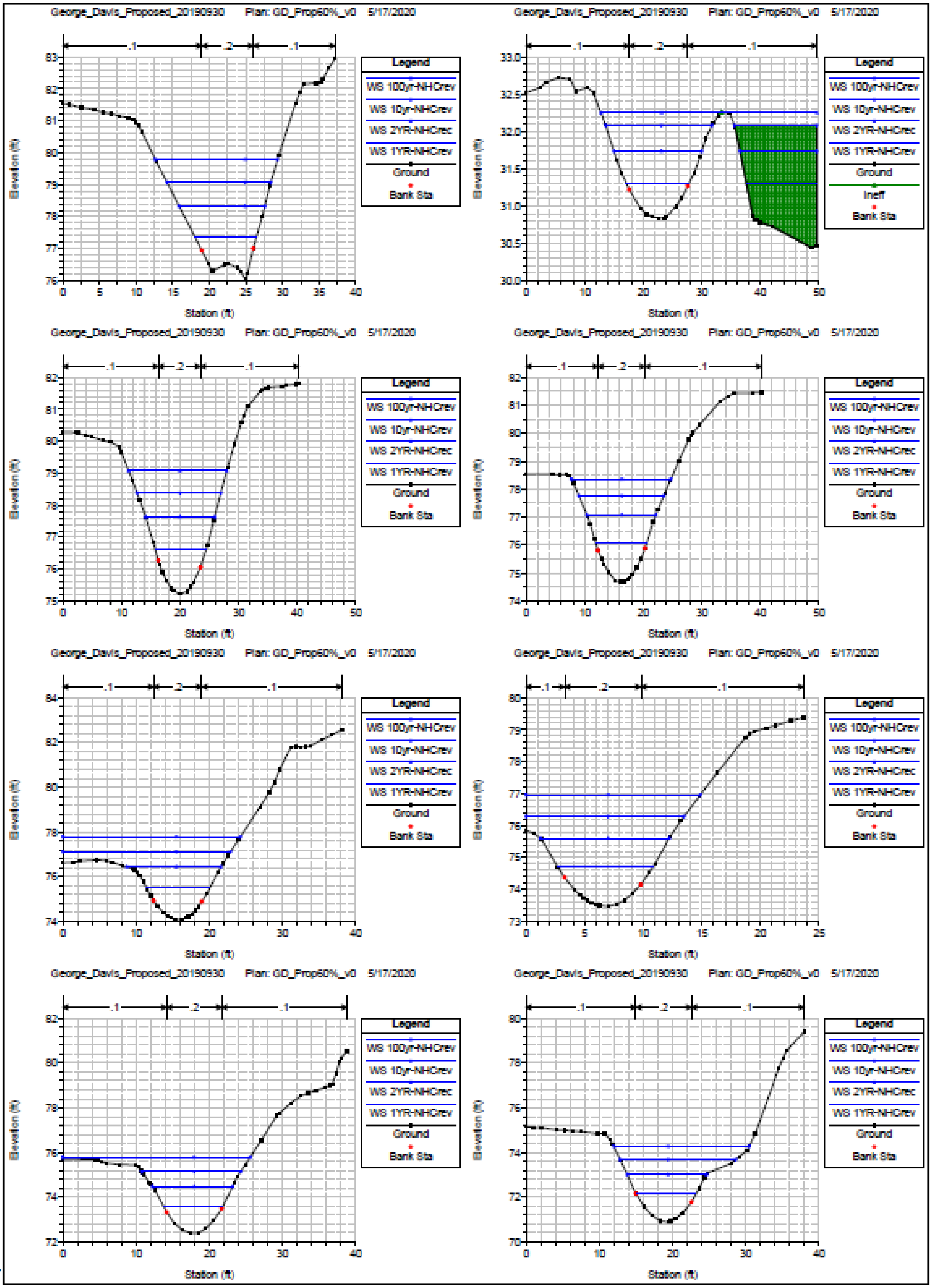
## 10-year Event

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Hydr Depth C | Froude # Chl | Shear Chan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (cfs) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | (ft) | | (lb/sq ft) |
| Reach 1 | 1 | 10yr-NHCrev | 76.00 | 30.84 | 32.08 | 32.50 | 0.411241 | 5.09 | 14.68 | 32.18 | 1.11 | 0.85 | 28.34 |
| Reach 1 | 14 | 10yr-NHCrev | 76.00 | 31.70 | 34.07 | 34.20 | 0.062369 | 3.10 | 26.90 | 31.49 | 2.21 | 0.37 | 8.40 |
| Reach 1 | 30 | 10yr-NHCrev | 76.00 | 32.72 | 35.26 | 35.49 | 0.108083 | 3.90 | 19.88 | 12.25 | 2.13 | 0.47 | 13.62 |
| Reach 1 | 46 | 10yr-NHCrev | 76.00 | 33.78 | 36.68 | 36.83 | 0.062973 | 3.19 | 24.43 | 13.36 | 2.39 | 0.36 | 8.78 |
| Reach 1 | 62 | 10yr-NHCrev | 76.00 | 34.79 | 37.67 | 37.83 | 0.064588 | 3.22 | 24.23 | 13.31 | 2.38 | 0.37 | 8.96 |
| Reach 1 | 76 | 10yr-NHCrev | 76.00 | 35.70 | 38.53 | 38.69 | 0.056797 | 3.21 | 23.96 | 13.56 | 2.54 | 0.35 | 8.64 |
| Reach 1 | 93 | 10yr-NHCrev | 76.00 | 36.75 | 39.54 | 39.71 | 0.063587 | 3.33 | 23.12 | 13.28 | 2.47 | 0.37 | 9.41 |
| Reach 1 | 107 | 10yr-NHCrev | 76.00 | 37.63 | 40.45 | 40.62 | 0.065908 | 3.30 | 23.51 | 13.47 | 2.41 | 0.37 | 9.35 |
| Reach 1 | 121 | 10yr-NHCrev | 76.00 | 38.51 | 41.37 | 41.52 | 0.061079 | 3.23 | 24.08 | 13.52 | 2.46 | 0.36 | 8.89 |
| Reach 1 | 137 | 10yr-NHCrev | 76.00 | 39.51 | 42.37 | 42.53 | 0.063140 | 3.26 | 23.74 | 13.15 | 2.44 | 0.37 | 9.11 |
| Reach 1 | 150 | 10yr-NHCrev | 76.00 | 40.34 | 43.15 | 43.31 | 0.058906 | 3.24 | 23.64 | 13.16 | 2.51 | 0.36 | 8.87 |
| Reach 1 | 163 | 10yr-NHCrev | 76.00 | 41.13 | 43.98 | 44.14 | 0.065237 | 3.29 | 23.66 | 13.36 | 2.41 | 0.37 | 9.29 |
| Reach 1 | 179 | 10yr-NHCrev | 76.00 | 42.17 | 45.03 | 45.19 | 0.062964 | 3.24 | 24.03 | 13.53 | 2.43 | 0.37 | 9.01 |
| Reach 1 | 196 | 10yr-NHCrev | 76.00 | 43.23 | 46.11 | 46.27 | 0.066292 | 3.20 | 24.32 | 13.39 | 2.32 | 0.37 | 8.96 |
| Reach 1 | 210 | 10yr-NHCrev | 76.00 | 44.14 | 47.00 | 47.16 | 0.057202 | 3.20 | 24.10 | 13.28 | 2.52 | 0.35 | 8.61 |
| Reach 1 | 226 | 10yr-NHCrev | 76.00 | 45.13 | 47.92 | 48.08 | 0.059846 | 3.25 | 23.54 | 13.26 | 2.49 | 0.36 | 8.94 |
| Reach 1 | 235 | | Bridge | | | | | | | | | | |
| Reach 1 | 246 | 10yr-NHCrev | 76.00 | 46.35 | 49.17 | 49.33 | 0.057865 | 3.22 | 23.70 | 13.24 | 2.51 | 0.36 | 8.73 |
| Reach 1 | 255 | 10yr-NHCrev | 76.00 | 46.90 | 49.72 | 49.88 | 0.065611 | 3.30 | 23.48 | 13.21 | 2.41 | 0.37 | 9.35 |
| Reach 1 | 267 | 10yr-NHCrev | 76.00 | 47.72 | 50.47 | 50.62 | 0.057615 | 3.16 | 24.61 | 20.80 | 2.45 | 0.36 | 8.47 |
| Reach 1 | 270 | | Bridge | | | | | | | | | | |
| Reach 1 | 283 | 10yr-NHCrev | 76.00 | 48.76 | 51.58 | 51.73 | 0.058844 | 3.13 | 24.66 | 22.09 | 2.41 | 0.36 | 8.40 |
| Reach 1 | 295 | 10yr-NHCrev | 76.00 | 49.57 | 52.33 | 52.48 | 0.067789 | 3.18 | 26.03 | 24.20 | 2.25 | 0.37 | 8.90 |
| Reach 1 | 310 | 10yr-NHCrev | 76.00 | 50.48 | 53.33 | 53.48 | 0.063813 | 3.13 | 25.57 | 18.61 | 2.31 | 0.36 | 8.58 |
| Reach 1 | 320 | 10yr-NHCrev | 76.00 | 51.07 | 53.93 | 54.08 | 0.059822 | 3.19 | 24.79 | 16.63 | 2.45 | 0.36 | 8.67 |
| Reach 1 | 330 | 10yr-NHCrev | 76.00 | 51.75 | 54.55 | 54.68 | 0.062250 | 3.04 | 25.89 | 17.42 | 2.25 | 0.36 | 8.15 |
| Reach 1 | 350 | | Bridge | | | | | | | | | | |
| Reach 1 | 378 | 10yr-NHCrev | 76.00 | 55.08 | 57.79 | 57.94 | 0.065194 | 3.28 | 23.96 | 17.32 | 2.38 | 0.38 | 9.27 |
| Reach 1 | 396 | 10yr-NHCrev | 76.00 | 56.37 | 59.05 | 59.24 | 0.075653 | 3.54 | 21.73 | 12.83 | 2.38 | 0.40 | 10.78 |
| Reach 1 | 413 | 10yr-NHCrev | 76.00 | 57.51 | 60.29 | 60.47 | 0.070765 | 3.39 | 22.92 | 13.17 | 2.38 | 0.39 | 9.94 |
| Reach 1 | 430 | 10yr-NHCrev | 76.00 | 58.73 | 61.46 | 61.64 | 0.067122 | 3.40 | 22.64 | 13.17 | 2.44 | 0.38 | 9.83 |
| Reach 1 | 449 | 10yr-NHCrev | 76.00 | 60.00 | 62.70 | 62.89 | 0.066812 | 3.44 | 21.81 | 12.55 | 2.47 | 0.39 | 9.99 |
| Reach 1 | 465 | 10yr-NHCrev | 76.00 | 61.11 | 63.80 | 63.99 | 0.069339 | 3.48 | 21.52 | 12.44 | 2.45 | 0.39 | 10.29 |
| Reach 1 | 482 | 10yr-NHCrev | 76.00 | 62.28 | 64.96 | 65.16 | 0.069799 | 3.49 | 21.57 | 12.74 | 2.45 | 0.39 | 10.33 |
| Reach 1 | 498 | 10yr-NHCrev | 76.00 | 63.41 | 66.11 | 66.30 | 0.069238 | 3.47 | 21.71 | 12.82 | 2.45 | 0.39 | 10.24 |
| Reach 1 | 514 | 10yr-NHCrev | 76.00 | 64.52 | 67.25 | 67.43 | 0.073801 | 3.50 | 21.93 | 12.37 | 2.39 | 0.40 | 10.53 |
| Reach 1 | 523 | 10yr-NHCrev | 76.00 | 65.17 | 67.90 | 68.06 | 0.061278 | 3.22 | 24.28 | 16.13 | 2.41 | 0.37 | 8.86 |
| Reach 1 | 535 | 10yr-NHCrev | 76.00 | 65.96 | 68.65 | 68.83 | 0.070093 | 3.48 | 22.19 | 14.50 | 2.43 | 0.39 | 10.29 |
| Reach 1 | 544 | 10yr-NHCrev | 76.00 | 66.56 | 69.25 | 69.44 | 0.070943 | 3.48 | 21.86 | 13.15 | 2.42 | 0.39 | 10.33 |
| Reach 1 | 555 | 10yr-NHCrev | 76.00 | 67.32 | 70.05 | 70.22 | 0.072965 | 3.47 | 22.64 | 14.60 | 2.38 | 0.40 | 10.35 |
| Reach 1 | 569 | 10yr-NHCrev | 76.00 | 68.20 | 71.01 | 71.18 | 0.067236 | 3.34 | 23.26 | 13.05 | 2.41 | 0.38 | 9.57 |
| Reach 1 | 588 | 10yr-NHCrev | 76.00 | 69.47 | 72.27 | 72.43 | 0.063013 | 3.26 | 24.11 | 15.14 | 2.43 | 0.37 | 9.07 |
| Reach 1 | 610 | 10yr-NHCrev | 76.00 | 70.89 | 73.68 | 73.84 | 0.065831 | 3.31 | 23.88 | 15.80 | 2.40 | 0.38 | 9.40 |
| Reach 1 | 632 | 10yr-NHCrev | 76.00 | 72.39 | 75.15 | 75.32 | 0.066503 | 3.35 | 23.13 | 13.50 | 2.42 | 0.38 | 9.58 |
| Reach 1 | 650 | 10yr-NHCrev | 76.00 | 73.47 | 76.29 | 76.45 | 0.056041 | 3.19 | 23.77 | 13.48 | 2.54 | 0.35 | 8.55 |
| Reach 1 | 668 | 10yr-NHCrev | 76.00 | 74.10 | 77.12 | 77.22 | 0.033496 | 2.61 | 31.04 | 22.91 | 2.76 | 0.28 | 5.55 |
| Reach 1 | 685 | 10yr-NHCrev | 76.00 | 74.69 | 77.76 | 77.88 | 0.042921 | 2.87 | 27.13 | 14.46 | 2.68 | 0.31 | 6.81 |
| Reach 1 | 701 | 10yr-NHCrev | 76.00 | 75.22 | 78.38 | 78.49 | 0.034822 | 2.70 | 28.27 | 14.31 | 2.83 | 0.28 | 5.90 |
| Reach 1 | 719 | 10yr-NHCrev | 76.00 | 76.03 | 79.07 | 79.21 | 0.046421 | 2.88 | 26.03 | 14.18 | 2.63 | 0.31 | 6.99 |

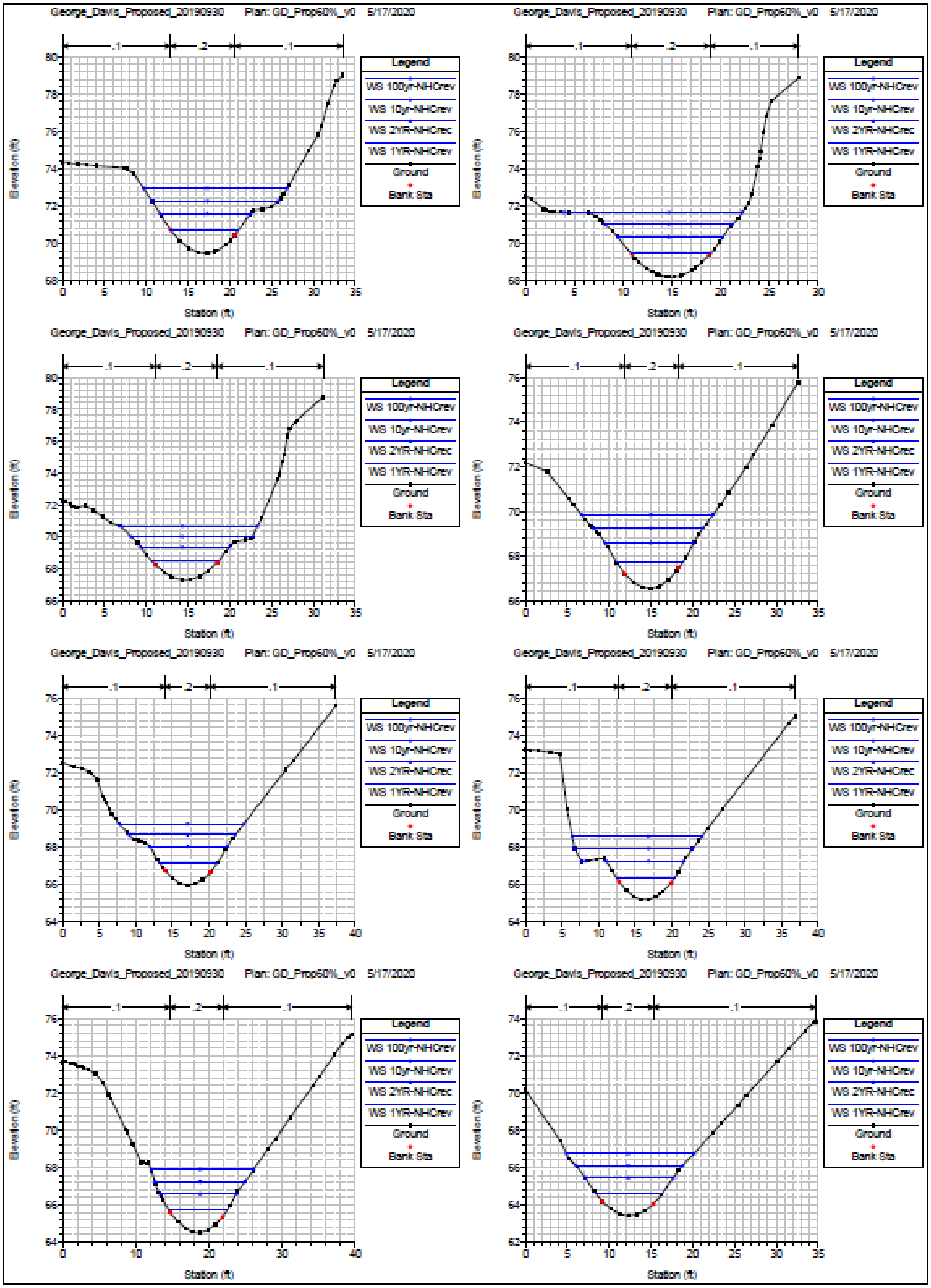
## 100-year Event

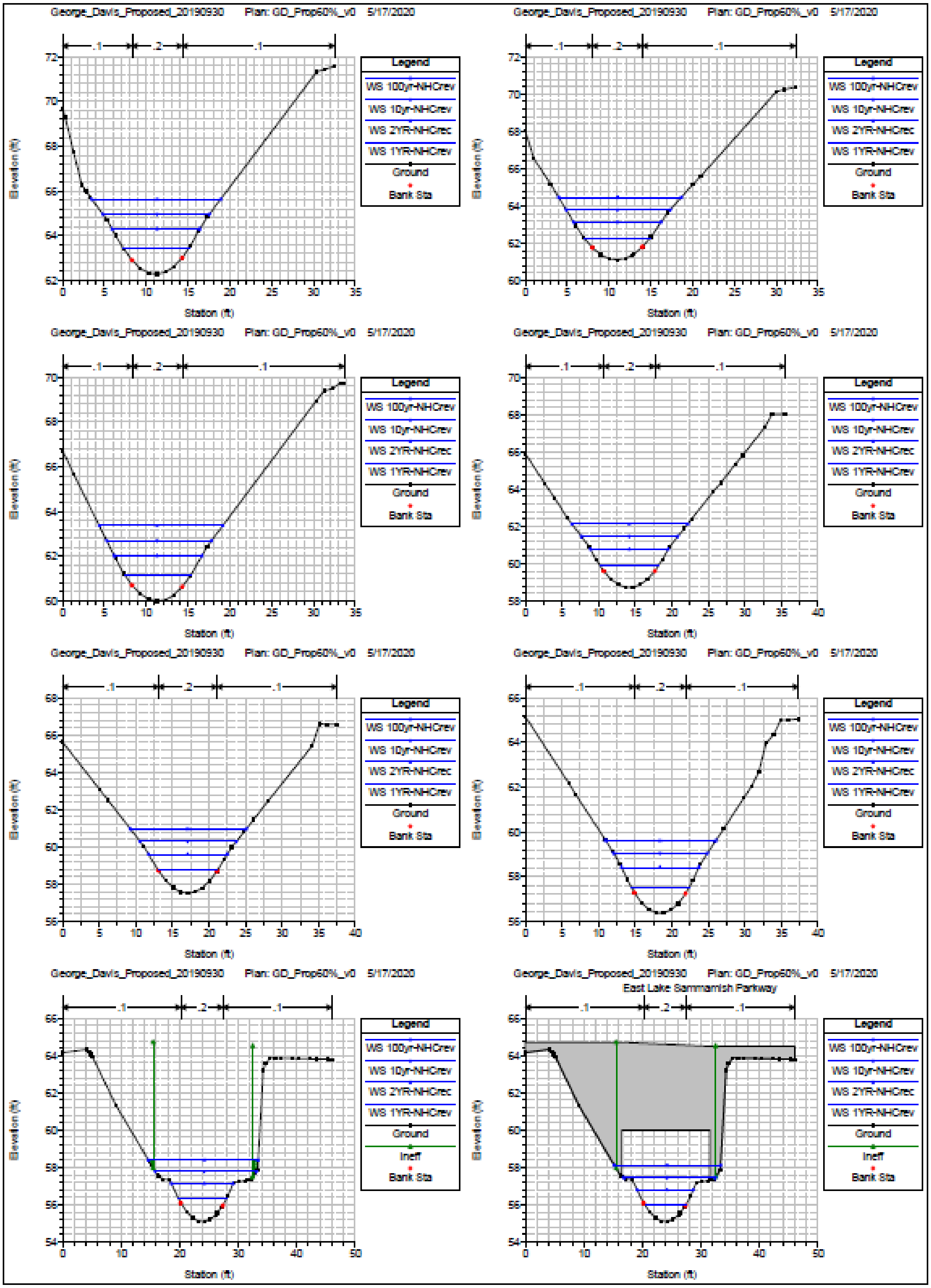
| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Hydr Depth C | Froude # Chl | Shear Chan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (cfs) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | (ft) | | (lb/sq ft) |
| Reach 1 | 1 | 100yr-NHCrev | 128.00 | 30.84 | 32.25 | 32.45 | 0.077738 | 2.43 | 38.02 | 36.82 | 1.28 | 0.38 | 6.17 |
| Reach 1 | 14 | 100yr-NHCrev | 128.00 | 31.70 | 34.00 | 34.43 | 0.217308 | 5.66 | 24.77 | 30.10 | 2.14 | 0.68 | 28.35 |
| Reach 1 | 30 | 100yr-NHCrev | 128.00 | 32.72 | 36.10 | 36.35 | 0.077627 | 4.13 | 31.57 | 15.57 | 2.97 | 0.42 | 13.64 |
| Reach 1 | 46 | 100yr-NHCrev | 128.00 | 33.78 | 37.33 | 37.55 | 0.067426 | 3.87 | 33.85 | 15.68 | 3.04 | 0.39 | 11.96 |
| Reach 1 | 62 | 100yr-NHCrev | 128.00 | 34.79 | 38.37 | 38.59 | 0.064485 | 3.81 | 34.36 | 15.76 | 3.08 | 0.38 | 11.57 |
| Reach 1 | 76 | 100yr-NHCrev | 128.00 | 35.70 | 39.22 | 39.44 | 0.056381 | 3.75 | 34.28 | 16.44 | 3.23 | 0.37 | 10.90 |
| Reach 1 | 93 | 100yr-NHCrev | 128.00 | 36.75 | 40.22 | 40.46 | 0.062878 | 3.89 | 33.05 | 15.98 | 3.15 | 0.39 | 11.86 |
| Reach 1 | 107 | 100yr-NHCrev | 128.00 | 37.63 | 41.13 | 41.35 | 0.065402 | 3.87 | 33.49 | 16.13 | 3.08 | 0.39 | 11.88 |
| Reach 1 | 121 | 100yr-NHCrev | 128.00 | 38.51 | 42.04 | 42.26 | 0.061705 | 3.81 | 34.13 | 16.22 | 3.14 | 0.38 | 11.45 |
| Reach 1 | 137 | 100yr-NHCrev | 128.00 | 39.51 | 43.05 | 43.28 | 0.063997 | 3.87 | 33.53 | 15.56 | 3.12 | 0.39 | 11.81 |
| Reach 1 | 150 | 100yr-NHCrev | 128.00 | 40.34 | 43.84 | 44.07 | 0.059290 | 3.82 | 33.47 | 15.49 | 3.20 | 0.38 | 11.37 |
| Reach 1 | 163 | 100yr-NHCrev | 128.00 | 41.13 | 44.67 | 44.89 | 0.064060 | 3.85 | 33.83 | 16.06 | 3.10 | 0.39 | 11.74 |
| Reach 1 | 179 | 100yr-NHCrev | 128.00 | 42.17 | 45.72 | 45.94 | 0.062534 | 3.81 | 34.26 | 16.28 | 3.11 | 0.38 | 11.48 |
| Reach 1 | 196 | 100yr-NHCrev | 128.00 | 43.23 | 46.80 | 47.02 | 0.067071 | 3.83 | 34.31 | 15.77 | 3.01 | 0.39 | 11.74 |
| Reach 1 | 210 | 100yr-NHCrev | 128.00 | 44.14 | 47.69 | 47.91 | 0.057775 | 3.77 | 34.10 | 15.70 | 3.21 | 0.37 | 11.08 |
| Reach 1 | 226 | 100yr-NHCrev | 128.00 | 45.13 | 48.61 | 48.83 | 0.059166 | 3.81 | 33.56 | 15.72 | 3.18 | 0.38 | 11.29 |
| Reach 1 | 235 | | Bridge | | | | | | | | | | |
| Reach 1 | 246 | 100yr-NHCrev | 128.00 | 46.35 | 49.86 | 50.09 | 0.058044 | 3.79 | 33.63 | 15.66 | 3.20 | 0.37 | 11.15 |
| Reach 1 | 255 | 100yr-NHCrev | 128.00 | 46.90 | 50.40 | 50.64 | 0.065088 | 3.88 | 33.15 | 14.98 | 3.09 | 0.39 | 11.92 |
| Reach 1 | 267 | 100yr-NHCrev | 128.00 | 47.72 | 51.11 | 51.32 | 0.050900 | 3.46 | 34.80 | 25.02 | 3.09 | 0.35 | 9.42 |
| Reach 1 | 270 | | Bridge | | | | | | | | | | |
| Reach 1 | 283 | 100yr-NHCrev | 128.00 | 48.76 | 52.25 | 52.46 | 0.053108 | 3.50 | 35.25 | 48.23 | 3.09 | 0.35 | 9.70 |
| Reach 1 | 295 | 100yr-NHCrev | 128.00 | 49.57 | 52.94 | 53.08 | 0.047638 | 3.12 | 43.30 | 30.93 | 2.86 | 0.33 | 7.94 |
| Reach 1 | 310 | 100yr-NHCrev | 128.00 | 50.48 | 53.79 | 54.00 | 0.075585 | 3.84 | 35.44 | 24.29 | 2.77 | 0.41 | 12.18 |
| Reach 1 | 320 | 100yr-NHCrev | 128.00 | 51.07 | 54.48 | 54.69 | 0.065509 | 3.82 | 35.82 | 22.74 | 3.00 | 0.39 | 11.63 |
| Reach 1 | 330 | 100yr-NHCrev | 128.00 | 51.75 | 55.12 | 55.31 | 0.061708 | 3.51 | 36.09 | 18.41 | 2.82 | 0.37 | 10.12 |
| Reach 1 | 350 | | Bridge | | | | | | | | | | |
| Reach 1 | 378 | 100yr-NHCrev | 128.00 | 55.08 | 58.39 | 58.61 | 0.057079 | 3.58 | 34.25 | 18.75 | 2.98 | 0.37 | 10.19 |
| Reach 1 | 396 | 100yr-NHCrev | 128.00 | 56.37 | 59.62 | 59.90 | 0.085481 | 4.34 | 29.66 | 15.03 | 2.95 | 0.45 | 15.09 |
| Reach 1 | 413 | 100yr-NHCrev | 128.00 | 57.51 | 60.97 | 61.21 | 0.070096 | 3.99 | 32.70 | 15.88 | 3.05 | 0.40 | 12.63 |
| Reach 1 | 430 | 100yr-NHCrev | 128.00 | 58.73 | 62.13 | 62.37 | 0.066943 | 3.98 | 32.27 | 15.83 | 3.11 | 0.40 | 12.47 |
| Reach 1 | 449 | 100yr-NHCrev | 128.00 | 60.00 | 63.36 | 63.63 | 0.067671 | 4.05 | 30.88 | 14.77 | 3.14 | 0.40 | 12.84 |
| Reach 1 | 465 | 100yr-NHCrev | 128.00 | 61.11 | 64.46 | 64.74 | 0.069512 | 4.10 | 30.58 | 14.68 | 3.12 | 0.41 | 13.12 |
| Reach 1 | 482 | 100yr-NHCrev | 128.00 | 62.28 | 65.63 | 65.90 | 0.068757 | 4.07 | 30.97 | 15.42 | 3.12 | 0.41 | 12.95 |
| Reach 1 | 498 | 100yr-NHCrev | 128.00 | 63.41 | 66.75 | 67.02 | 0.069664 | 4.08 | 30.88 | 15.27 | 3.10 | 0.41 | 13.03 |
| Reach 1 | 514 | 100yr-NHCrev | 128.00 | 64.52 | 67.90 | 68.18 | 0.076248 | 4.19 | 30.62 | 14.05 | 3.05 | 0.42 | 13.88 |
| Reach 1 | 523 | 100yr-NHCrev | 128.00 | 65.17 | 68.57 | 68.77 | 0.053555 | 3.54 | 35.57 | 17.75 | 3.08 | 0.36 | 9.88 |
| Reach 1 | 535 | 100yr-NHCrev | 128.00 | 65.96 | 69.24 | 69.50 | 0.070238 | 4.03 | 31.62 | 17.13 | 3.03 | 0.41 | 12.84 |
| Reach 1 | 544 | 100yr-NHCrev | 128.00 | 66.56 | 69.85 | 70.13 | 0.075253 | 4.16 | 30.59 | 15.75 | 3.03 | 0.42 | 13.69 |
| Reach 1 | 555 | 100yr-NHCrev | 128.00 | 67.32 | 70.68 | 70.92 | 0.069857 | 3.97 | 32.49 | 16.48 | 3.01 | 0.40 | 12.56 |
| Reach 1 | 569 | 100yr-NHCrev | 128.00 | 68.20 | 71.66 | 71.91 | 0.075208 | 4.13 | 32.56 | 18.24 | 3.06 | 0.42 | 13.57 |
| Reach 1 | 588 | 100yr-NHCrev | 128.00 | 69.47 | 72.95 | 73.16 | 0.056884 | 3.65 | 35.13 | 17.22 | 3.11 | 0.36 | 10.48 |
| Reach 1 | 610 | 100yr-NHCrev | 128.00 | 70.89 | 74.27 | 74.49 | 0.064985 | 3.81 | 34.10 | 18.47 | 2.99 | 0.39 | 11.56 |
| Reach 1 | 632 | 100yr-NHCrev | 128.00 | 72.39 | 75.79 | 76.02 | 0.071838 | 4.06 | 34.64 | 25.59 | 3.06 | 0.41 | 13.08 |
| Reach 1 | 650 | 100yr-NHCrev | 128.00 | 73.47 | 76.96 | 77.19 | 0.056809 | 3.76 | 33.38 | 14.87 | 3.22 | 0.37 | 10.99 |
| Reach 1 | 668 | 100yr-NHCrev | 128.00 | 74.10 | 77.78 | 77.90 | 0.027325 | 2.71 | 46.57 | 24.24 | 3.42 | 0.26 | 5.61 |
| Reach 1 | 685 | 100yr-NHCrev | 128.00 | 74.69 | 78.36 | 78.55 | 0.050575 | 3.56 | 36.59 | 17.03 | 3.28 | 0.35 | 9.83 |
| Reach 1 | 701 | 100yr-NHCrev | 128.00 | 75.22 | 79.08 | 79.24 | 0.037889 | 3.26 | 39.07 | 16.73 | 3.53 | 0.31 | 8.00 |
| Reach 1 | 719 | 100yr-NHCrev | 128.00 | 76.03 | 79.79 | 79.98 | 0.045405 | 3.35 | 37.14 | 16.70 | 3.35 | 0.32 | 8.71 |

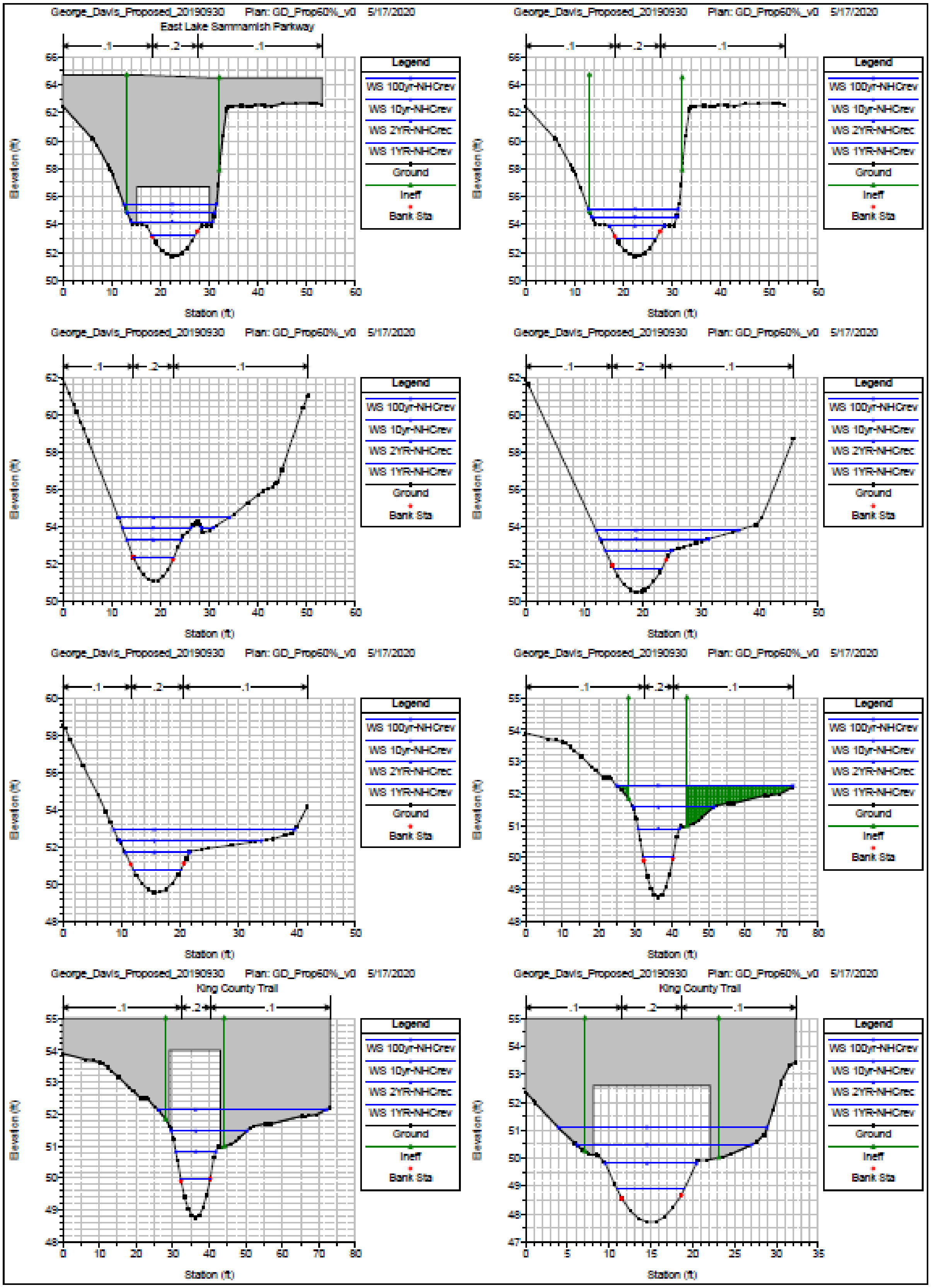

George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
River 1 Reach 1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Elevation (ft)
Main Channel Distance (ft)

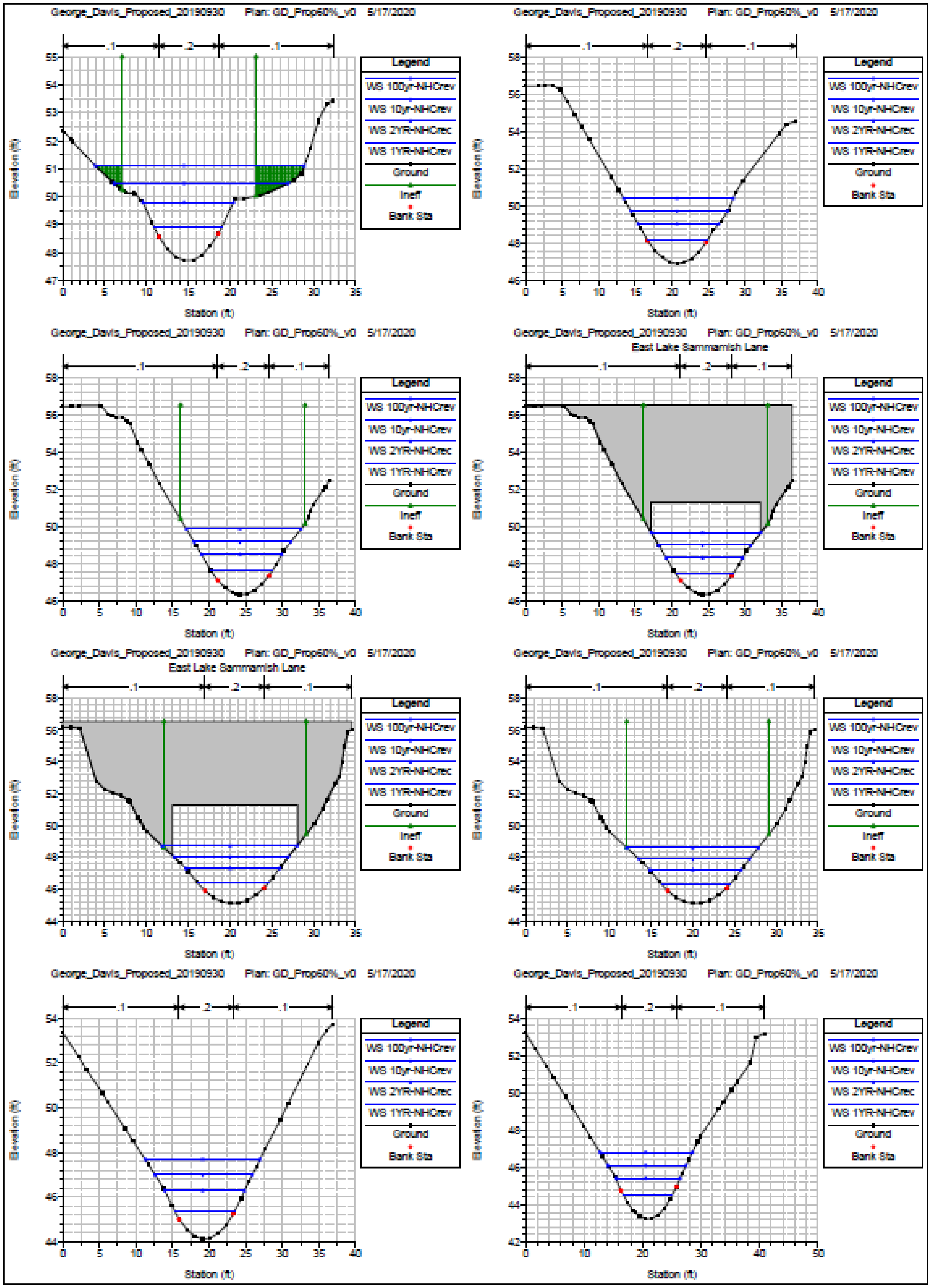


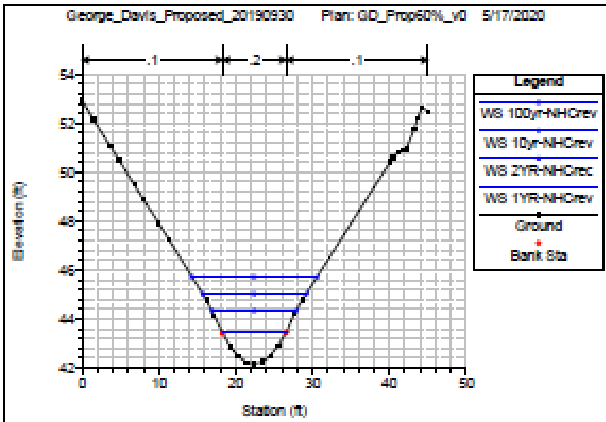
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Station (ft)
Elevation (ft)

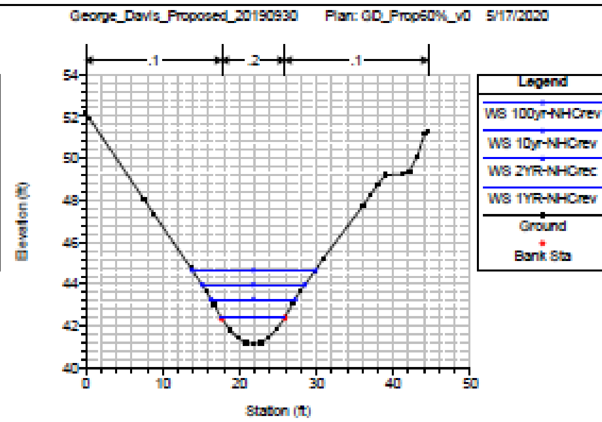

George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)

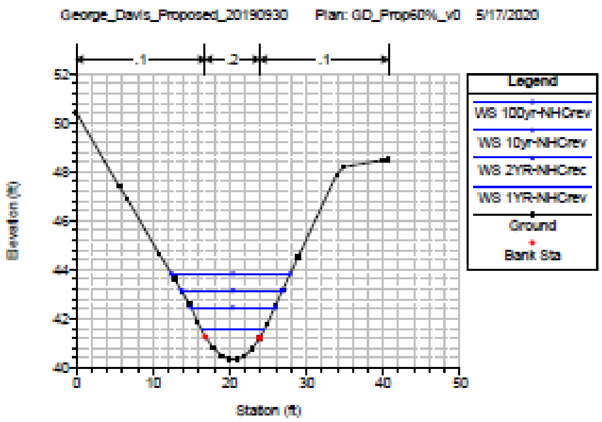

George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
East Lake Sammamish Parkway
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
East Lake Sammamish Parkway
King County Trail
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
East Lake Sammamish Lane
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
East Lake Sammamish Lane
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)
George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)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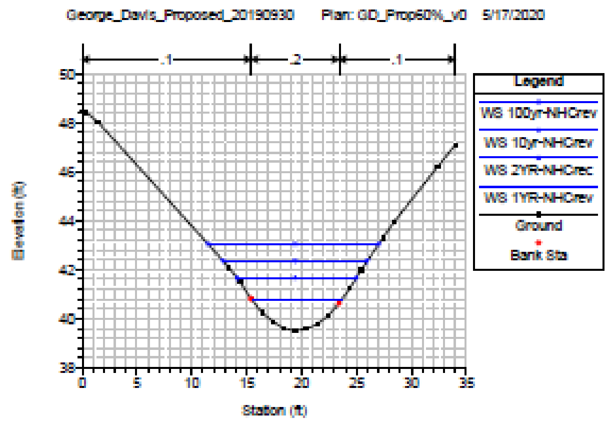
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)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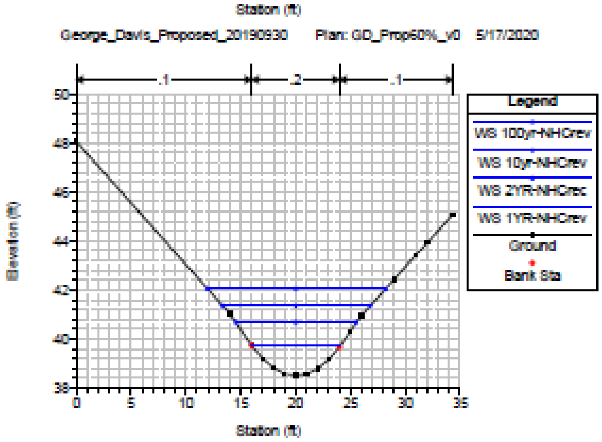
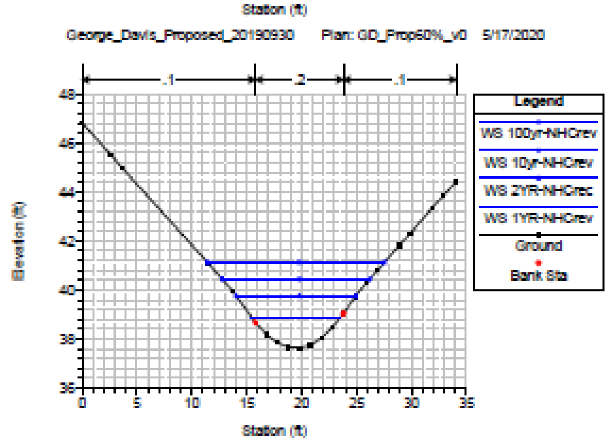
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)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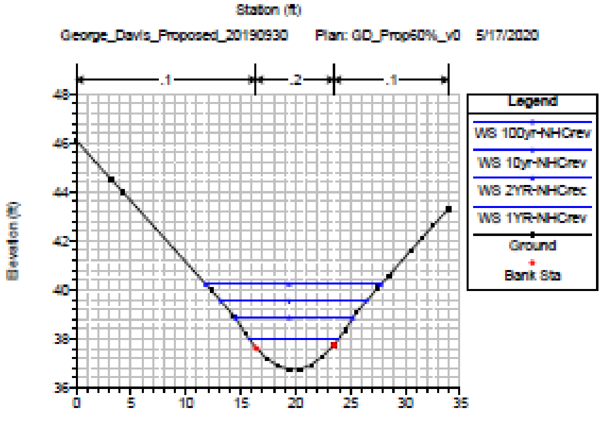
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)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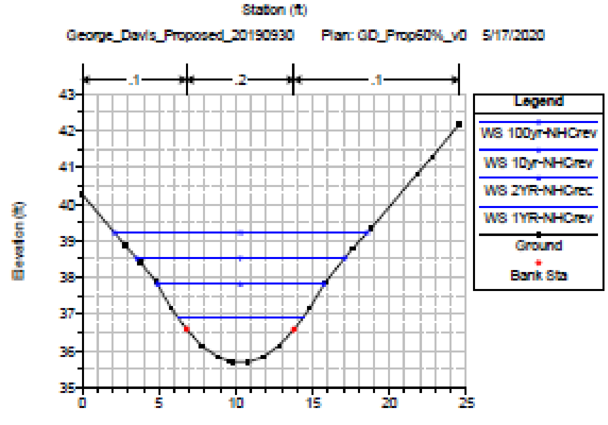
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)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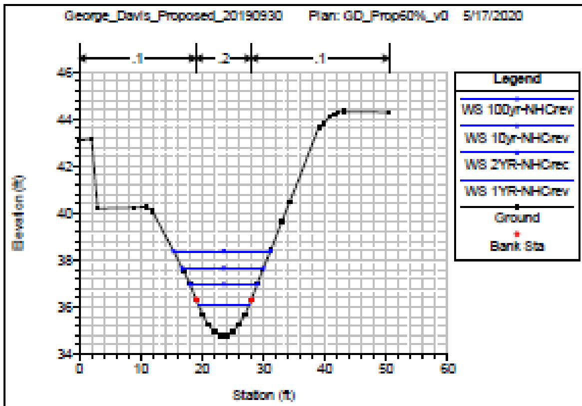
.1 .2 .1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1
.2
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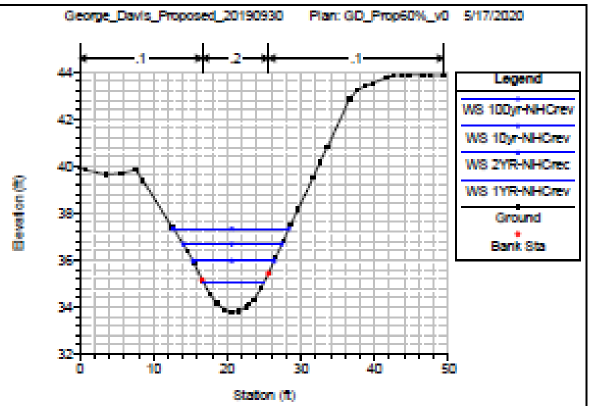
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1
.2
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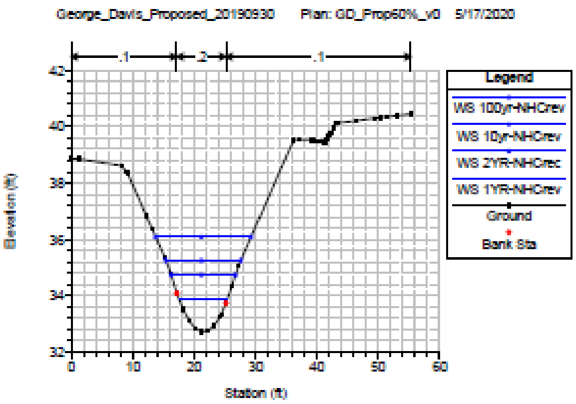
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)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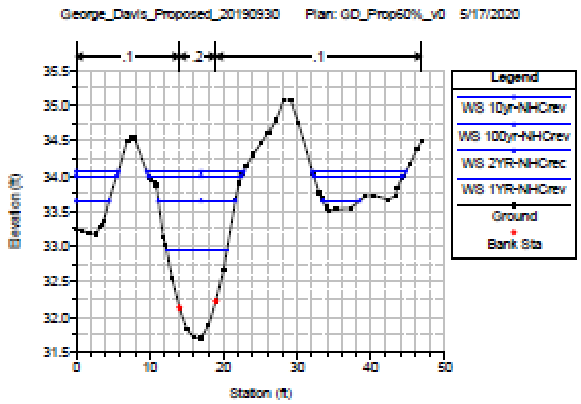
.1
.2
.1
Legend
WS 100yr-NHCrev
WS 10yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)


George_Davis_Proposed_20190930 Plan: GD_Prop60%_v0 5/17/2020
.1
.2
.1
Legend
WS 10yr-NHCrev
WS 100yr-NHCrev
WS 2YR-NHCrec
WS 1YR-NHCrev
Ground
Bank Sta
Elevation (ft)
Station (ft)