# APPENDIX 15-P
# TEIGEN CREEK INSTREAM FLOW THRESHOLD ASSESSMENT

# Memorandum

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| **DATE:** | January 11, 2013 |
| **TO:** | Chris Burns |
| **FROM:** | Ali Naghibi and David Luzi |
| **SUBJECT:** | KSM Project: Instream Flow Threshold for Teigen Creek |

Refer to File No.: N:\868 Seabridge\868-016 KSM 2012 EA\868-016-26 Fish and Aquatics\Word Processing\Appendix 15-P\0.6 Teigen Creek Instream FlowThreshold.docx

## 1. Introduction

The results from the completed flow threshold analysis for Teigen Creek in relation to the proposed Tailings Management Facility (TMF) are presented in this report. The analysis appends the accompanying memo report (KSM Project: Instream Flow Threshold for Proposed Tailings Management Facility).

## 2. Methodology

The 2008 to 2010 daily discharge records from the Teigen Creek (TGN-H1) hydrometric station were used as the baseline period for the analysis. In order to generate synthetic long-term discharge records, and estimate instream flow thresholds, this analysis follows the British Columbia Instream Flow Threshold Guidelines (Hatfield *et al.* 2003. That is, long-term (i.e., 1968-2010) daily discharge records at Water Survey of Canada (WSC) hydrometric stations at Kispiox River Near Hazelton (08EB004), Iskut River below Johnson River (08CG001), Nass River Above Shumal Creek (08DB001), and Surprise Creek Near the Mouth (08DA005) were used as reference data sets.

## 3. Results and Observations

As shown in Figures 3-1 to 3-4, the comparison of unit runoff hydrographs shows a relatively good correlation between the reference WSC stations and Teigen Creek. Differences are notable during the spring freshet and the summer periods when Surprise Creek has higher unit runoff values compared with TGN-H1. During these periods, unit runoff values of Kispiox River are lower than those of TGN-H1. Unit runoff values of Iskut River and Nass River show a mix of higher and lower values compared with TGN-H1.

### 3.1 Regression Analysis

Monthly regression analysis using the ranked monthly daily flow data for Teigen Creek and the reference WSC stations was carried out. The accompanying memo report (KSM Project: Instream Flow Threshold for Proposed Tailings Management Facility) shows that unranked regression results were not as reliable as those of ranked regression. Therefore, unranked regression was not conducted in this study. Monthly regression equations were developed that were used to produce the best fit curves. Figures 3-5 and 3-6 show two examples. For the month of October, two regression equations between TGN-H1 and Surprise Creek best defined the relationship, as opposed to the month of June where one equation between TGN-H1 and Nass River was sufficient. The resulting monthly regression equations (Table 3-1) were applied to the reference WSC stations data to calculate the long-term synthetic flows for Teigen Creek.

**Table 3-1. Selected Regression Equations to Estimate Daily Synthetic Flows at TGN-H1**

| Month | Equation |
|---|---|
| Jan | $Q = 0.5469\ln(K) + 0.0550$ |
| Feb | $Q = 0.6898\ln(K) - 0.172$ |
| Mar | $Q = 1.2229\ln(S) + 0.9723$ if $S < 2.0$ <br> $Q = 0.1878\ln(S) + 1.6838$ if $S \geq 2.0$ |
| Apr | $Q = 2.399(S) - 1.6587$ if $S < 1.5$ <br> $Q = 0.3764(S) + 1.1236$ if $S \geq 1.5$ |
| May | $Q = 0.0087(I)^{1.2166}$ if $I < 930$ <br> $Q = 0.0852(I) - 43.785$ if $I \geq 930$ |
| Jun | $Q = 0.0233(N) - 14.695$ |
| Jul | $Q = 0.0006(N)^{1.3442}$ |
| Aug | $Q = 2.288e^{0.0008(N)}$ if $N < 1660$ <br> $Q = 0.0287(N) - 37.666$ if $N \geq 1660$ |
| Sep | $Q = 0.0005(I)^{1.5369}$ if $I < 1840$ <br> $Q = 10.75\ln(I) - 28.741$ if $I \geq 1840$ |
| Oct | $Q = 6.5577\ln(S) - 6.996$ if $S < 22.5$ <br> $Q = 1.0427(S) - 10.484$ if $S \geq 22.5$ |
| Nov | $Q = 0.4301(S) + 1.4268$ if $S < 4.35$ <br> $Q = 2.4789(S) - 7.1606$ if $4.35 \leq S < 5.11$ <br> $Q = 4.1246\ln(S) - 1.2414$ if $S \geq 5.11$ |
| Dec | $Q = 0.6154(S) + 0.5873$ |

*Q = Daily flow at TGN-H1 ($m^3/s$)*
*K = Daily flow in Kispiox River ($m^3/s$)*
*S = Daily flow in Surprise Creek ($m^3/s$)*
*I = Daily flow in Iskut River ($m^3/s$)*
*N = Daily flow in Nass River ($m^3/s$)*

A comparison between the synthetic and observed hydrographs of Teigen Creek for 2008, 2009 and 2010 is presented in Figure 3-7. Visually the actual and synthetic daily discharges match well with respect to time and magnitude, although some of the peaks were overestimated by the synthetic results. Using regression to establish the fit between the synthetic and observed datasets at TGN-H1, the $r^2$ values were estimated and summarized in Table 3-3. As an additional metric to evaluate the goodness of fit between observed and synthetic hydrologic data, the Nash-Sutcliffe model efficiency (NSE) value was applied (Nash and Sutcliffe 1970). The resulting NSE values for TGN-H1 data in 2008, 2009 and 2010 are provided in Table 3-3. The results from both metrics are comparable, and thus indicate that the synthetic flows are sufficiently calibrated and match reasonably well with the observed data for the three year period.

**Table 3-3. Goodness of Fit Measures for Modelled Daily Discharges at TGN-H1 during 2008, 2009, and 2010**

| Goodness of Fit Measure | 2008 | 2009 | 2010 |
|---|---|---|---|
| $R^2$ | 0.89 | 0.90 | 0.88 |
| NSE | 0.84 | 0.87 | 0.68 |

For validation purpose, the synthetic and observed hydrographs of Teigen Creek for 2011 were compared (Figure 3-8). These hydrographs follow the same pattern with respect to time and magnitude but show some differences throughout the year. Quantitative comparison of the synthetic and observed hydrographs with the linear regression analysis and Nash-Sutcliffe model results in $r^2$ and NSE values of 0.85 and 0.77, respectively.

## 3.2 B.C. Instream Flow Thresholds Guidelines

The British Columbia Instream Flow Threshold Guidelines (Hatfield *et al.* 2003) were applied to the synthetic flow discharge data for Station TGN-H1. The summary statistics are presented in Table 3-4. Based on the synthetic flow data, the mean annual discharge at TGN-H1 is 8.77 $m^3/s$. This equates to a mean annual unit runoffs of 54.1 $l/s/km^2$. A regional analysis, completed in 2012 (Appendix 13-A), calculated mean annual unit runoff for the Station TGN-H1 to be 50.2 $l/s/km^2$. These values are considered to be of fairly good agreement.

As per the guideline for fish-bearing streams, the maximum diversion rate is set at the $80^{th}$ percentile and is based on the entire period of record (POR). For Station TGN-H1, the $80^{th}$ percentile was determined to be 9.68 $m^3/s$, as noted in Table 3-4. This discharge value represents the estimated maximum flow discharges that can be diverted at any time from Teigen Creek.

**Table 3-4. Summary Statistics for Synthetic Flow Discharges for Teigen Creek (Station TGN-H1) by Month for the Period of Record (POR). Flows are expressed as $m^3/s$.**

| | Monthly Flow Discharge Parameters | | | | Monthly Flow Discharge Percentiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Mean | Median | Min | Max | $10^{th}$ | $20^{th}$ | $30^{th}$ | $40^{th}$ | $50^{th}$ | $60^{th}$ | $70^{th}$ | $80^{th}$ | $90^{th}$ |
| Jan | 1.16 | 1.15 | 1.04 | 1.34 | 0.90 | 0.98 | 1.03 | 1.07 | 1.15 | 1.21 | 1.25 | 1.31 | 1.48 |
| Feb | 1.16 | 1.15 | 1.04 | 1.31 | 0.74 | 0.88 | 0.99 | 1.09 | 1.15 | 1.20 | 1.30 | 1.44 | 1.58 |
| Mar | 1.06 | 1.04 | 0.78 | 1.42 | 0.42 | 0.72 | 0.80 | 0.90 | 1.04 | 1.15 | 1.28 | 1.54 | 1.78 |
| Apr | 2.77 | 2.73 | 1.23 | 6.00 | 1.54 | 1.89 | 2.21 | 2.39 | 2.73 | 3.02 | 3.18 | 3.63 | 4.11 |
| May | 18.47 | 16.98 | 6.96 | 44.21 | 10.11 | 11.30 | 13.26 | 15.95 | 16.98 | 18.47 | 20.95 | 24.99 | 27.90 |
| Jun | 33.78 | 32.44 | 17.36 | 58.22 | 24.13 | 26.56 | 28.78 | 30.97 | 32.44 | 33.32 | 37.57 | 41.32 | 46.06 |
| Jul | 12.75 | 12.45 | 8.02 | 20.46 | 8.18 | 10.00 | 10.52 | 11.46 | 12.45 | 12.83 | 14.05 | 15.76 | 17.76 |
| Aug | 6.31 | 5.78 | 4.23 | 13.07 | 4.73 | 4.92 | 5.29 | 5.54 | 5.78 | 5.96 | 6.53 | 7.30 | 8.68 |
| Sep | 11.83 | 11.20 | 3.88 | 34.11 | 6.91 | 8.30 | 9.45 | 10.13 | 11.20 | 12.28 | 13.38 | 14.95 | 17.88 |
| Oct | 9.86 | 8.71 | 3.45 | 39.63 | 5.25 | 6.10 | 6.77 | 7.68 | 8.71 | 9.43 | 10.47 | 11.85 | 17.40 |
| Nov | 4.14 | 3.57 | 2.57 | 7.95 | 2.48 | 2.89 | 3.26 | 3.42 | 3.57 | 4.36 | 4.69 | 5.23 | 6.69 |
| Dec | 1.85 | 1.75 | 1.48 | 2.60 | 1.37 | 1.45 | 1.51 | 1.59 | 1.75 | 1.80 | 1.93 | 2.15 | 2.44 |
| Average* | 8.77 | 8.74 | 0.78 | 58.22 | 7.23 | 7.80 | 8.17 | 8.62 | 8.74 | 9.03 | 9.36 | 9.68 | 10.07 |

***:** *Based on average annual flow values*

The minimum required monthly instream flows were calculated as described in the British Columbia Instream Flow Threshold Guidelines (Hatfield *et al.* 2003), and presented in Table 3-5. The instream flow thresholds are shown in Figure 3-9. The guideline permits the monthly diversion of flows that leave instream flows greater than those specified with the thresholds.

**Table 3-5. Monthly Flow Discharge Thresholds for TGN-H1 as determined using the guidelines in Hatfield *et al*. (2003). Flows expressed as $m^3/s$.**

| Month | Mean Baseline Flow ($m^3/s$) | Instream Flow Threshold ($m^3/s$) | Ratio of Instream Flow Threshold to Mean Monthly Baseline Flow |
|---|---|---|---|
| Jan | 1.16 | 1.48 | 127.0% |
| Feb | 1.16 | 1.58 | 136.0% |
| March | 1.06 | 1.58 | 149.0% |
| April | 2.77 | 3.75 | 135.5% |
| May | 18.47 | 17.40 | 94.2% |
| June | 33.78 | 26.56 | 78.6% |
| July | 12.75 | 13.13 | 102.9% |
| Aug | 6.31 | 7.24 | 114.7% |
| Sept | 11.83 | 13.05 | 110.3% |
| Oct | 9.86 | 10.78 | 109.3% |
| Nov | 4.14 | 5.73 | 138.5% |
| Dec | 1.85 | 2.35 | 127.5% |

**: Based on hydrometric monitoring during 2008 to 2011*

Station TGN-H1 is located upstream of the confluence with South Teigen Creek, and hence, is not directly affected by the Project. The ratio of instream flow threshold to average monthly discharge values at TGN-H1 (Table 3-5) are assumed to be transferrable to TEC2 which is located downstream of the confluence with South Teigen. Such an assumption is justifiable because the two stations are close enough to have similar monthly flow distributions and yearly variations.

Suggested ratios of instream flow threshold to mean monthly flow (Table 3-5) are more than 100% for most of the months. That is, for drier than normal years, no reduction to the baseline flows are allowed. Nevertheless, proposed operational flows (Appendix 13-B) in Table 3-6 show flow reduction in all months of year during the first 45 years of the Project. That is further investigation is required to determine whether the proposed operational flows will lead to HADD.

**Table 3-6. Comparison of Baseline and Proposed Operational Flows for Teigen Creek (TGN-H1)**

| | Baseline Flow ($m^3/s$) | Years 0-45 | | Years 45-56 | | Years 57+ | |
|---|---|---|---|---|---|---|---|
| | | Flow (m3/s) | Change from baseline (%) | Flow ($m^3/s$) | Change from baseline (%) | Flow ($m^3/s$) | Change from baseline (%) |
| Jan | 1.80 | 1.72 | -4.1% | 1.82 | 1.1% | 1.81 | 0.8% |
| Feb | 1.86 | 1.76 | -5.3% | 1.84 | -0.8% | 1.84 | -1.3% |
| Mar | 1.98 | 1.90 | -4.1% | 1.99 | 0.7% | 1.98 | 0.0% |

*(continued)*

**Table 3-6. Comparison of Baseline and Proposed Operational Flows for Teigen Creek (TGN-H1) (completed)**

| | Baseline Flow ($m^3/s$) | Years 0-45 | | Years 45-56 | | Years 57+ | |
|---|---|---|---|---|---|---|---|
| | | Flow (m3/s) | Change from baseline (%) | Flow ($m^3/s$) | Change from baseline (%) | Flow ($m^3/s$) | Change from baseline (%) |
| May | 22.88 | 21.86 | -4.4% | 22.78 | -0.4% | 22.31 | -2.5% |
| Jun | 31.48 | 29.96 | -4.8% | 31.34 | -0.4% | 30.85 | -2.0% |
| Jul | 18.12 | 17.37 | -4.1% | 18.23 | 0.6% | 18.16 | 0.3% |
| Aug | 9.98 | 9.57 | -4.1% | 10.00 | 0.2% | 9.96 | -0.2% |
| Sep | 13.34 | 12.73 | -4.5% | 13.27 | -0.5% | 13.15 | -1.4% |
| Oct | 9.71 | 9.30 | -4.1% | 9.80 | 1.0% | 9.77 | 0.6% |
| Nov | 4.26 | 4.06 | -4.5% | 4.31 | 1.4% | 4.33 | 1.7% |
| Dec | 2.43 | 2.33 | -4.1% | 2.46 | 1.4% | 2.46 | 1.3% |
| MAD* | 10.20 | 9.75 | -4.5% | 10.21 | 0.0% | 10.10 | -1.0% |

***:** *Mean Annual Discharge*

# 4. Conclusions and Recommendations

The British Columbia Instream Flow Threshold Guidelines (Hatfield *et al*. 2003) are conservative measures to identify whether further instream flow assessment is required. Since the instream flow thresholds of these guidelines are not met in Teigen Creek, further investigation must be conducted to determine whether exceeding the minimum flow threshold will lead to a HADD.

## References

Hatfield, T., A. Lewis, D. Ohlson, M. Bradford. 2003. *Development of Instream Flow Thresholds as Guidelines for Reviewing Proposed Water Uses*. Prepared for: B.C. Ministry of Sustainable Resources Management and B.C. Ministry of Water, Land and Air Protection.

Lewis, A., T. Hatfield, B. Chilibeck and C. Roberts. 2004. *Assessment methods for aquatic habitat and instream flow characteristics in support of applications to dam, divert, or extract water from streams in British Columbia*. Prepared for the BC Ministry of Water, Land & Air Protection and the BC Ministry of Sustainable Resource Management, Victoria, BC.

Nash, J.E. and J.V. Sutcliffe. 1970. River flow forecasting through conceptual models, Part I – A discussion of principles. *Journal of Hydrology*, 10**:** 282 – 290**.**

**Figure 3-1. Comparison of Daily Unit Runoff between Teigen Creek and Kispiox River**

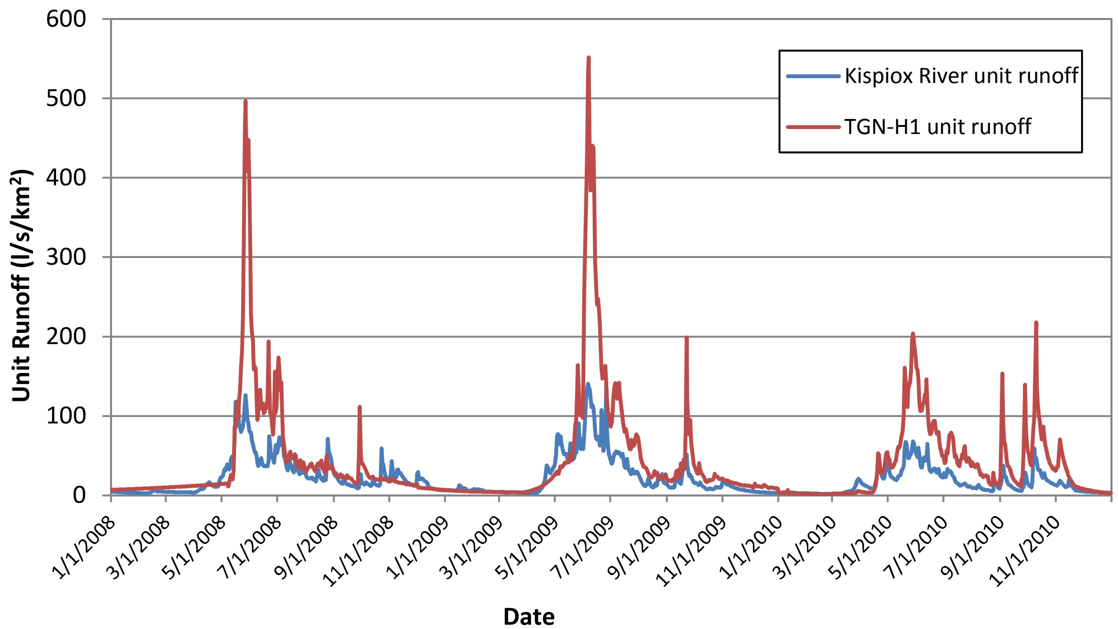



**Figure 3-2. Comparison of Daily Unit Runoff between Teigen Creek and Iskut River**

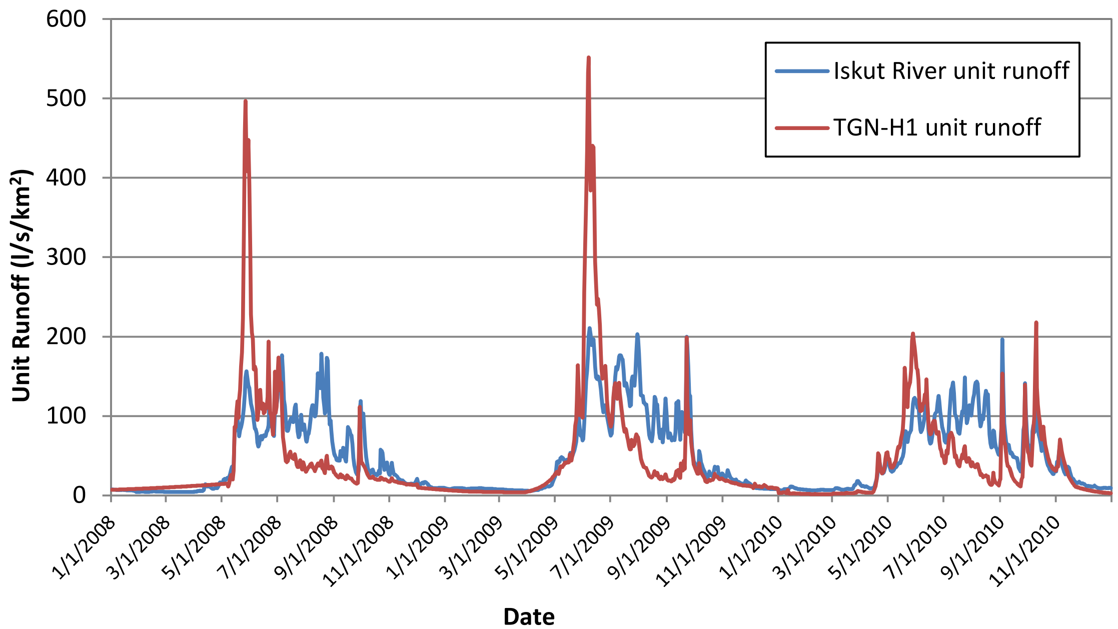


Figure 3-3. Comparison of Daily Unit Runoff between Teigen Creek and Nass River

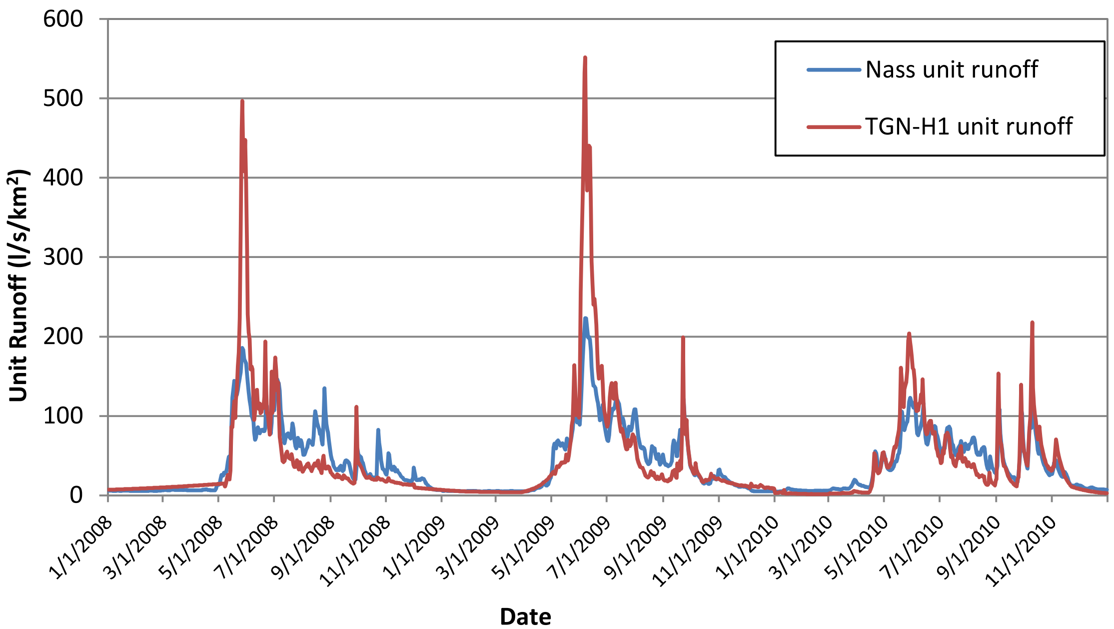



Figure 3-4. Comparison of Daily Unit Runoff between Teigen Creek and Surprise Creek

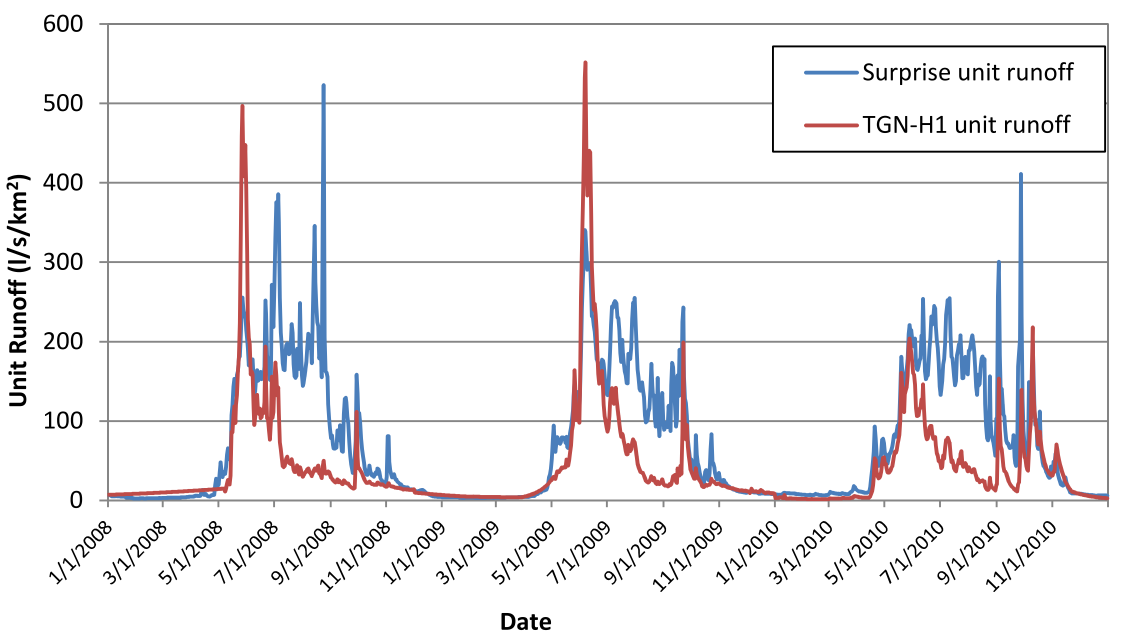


Figure 3-5. Regional Ranked Regression Analysis for TGN-H1 - October

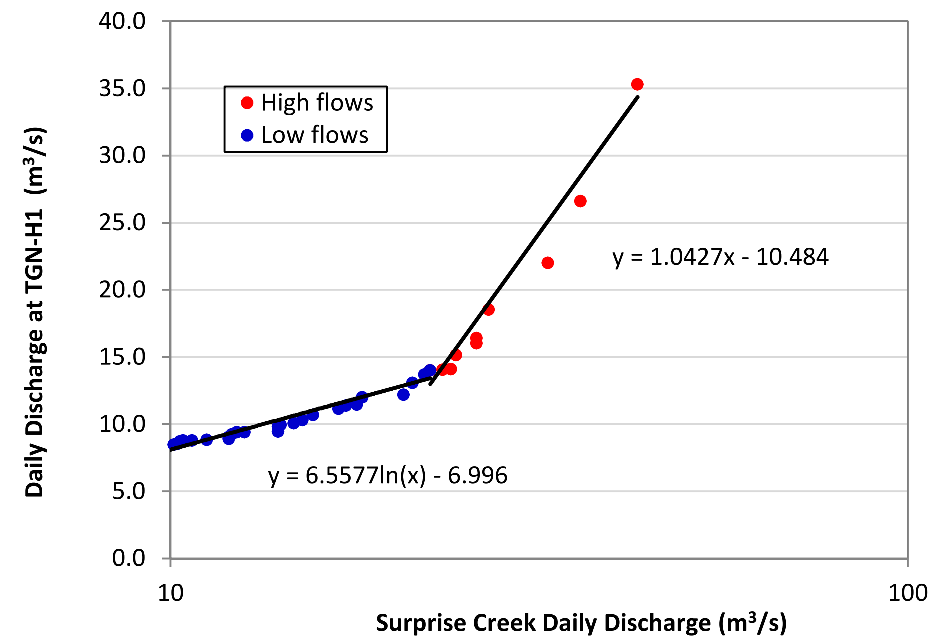
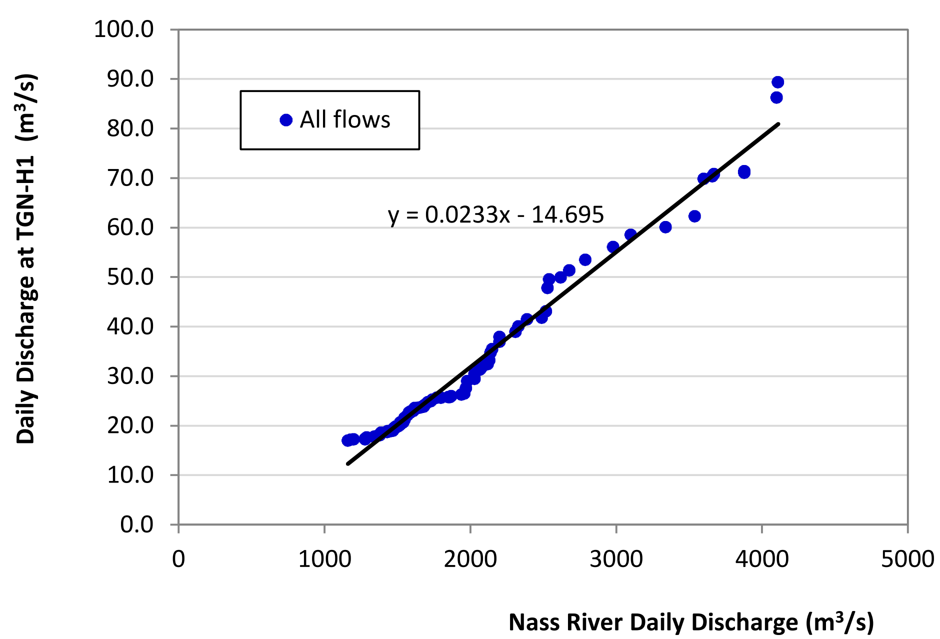



Figure 3-6. Regional Ranked Regression Analysis for TGN-H1 - June



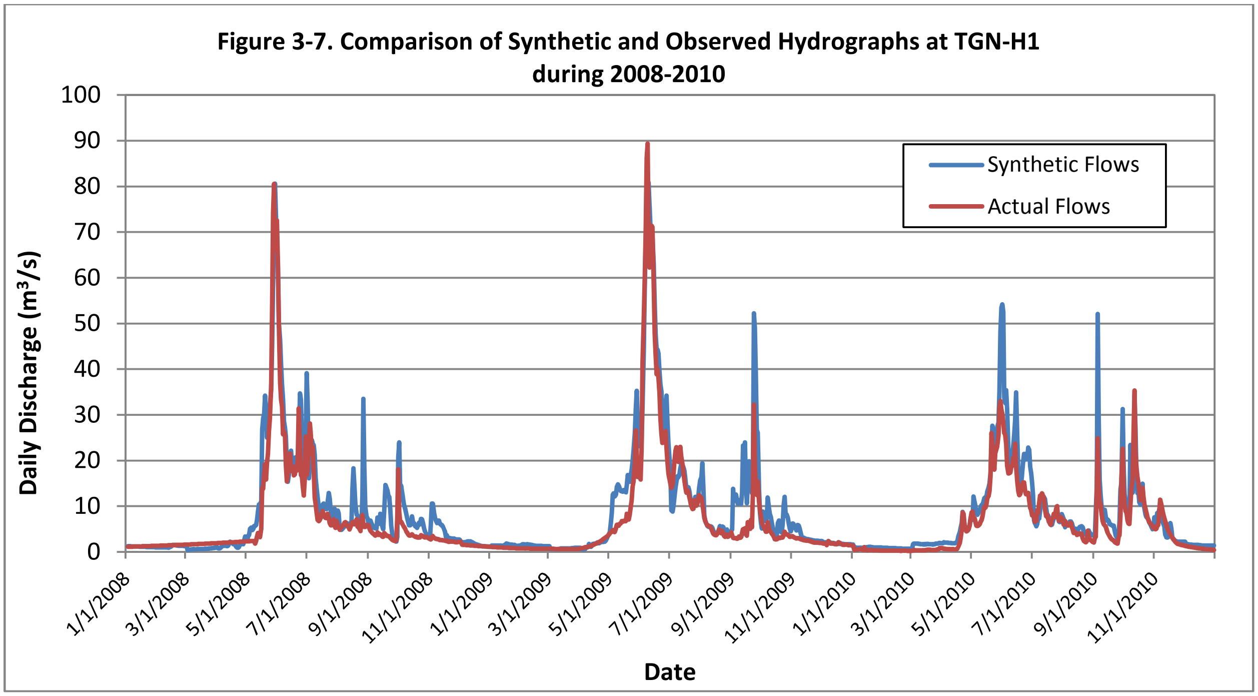


Figure 3-7. Comparison of Synthetic and Observed Hydrographs at TGN-H1 during 2008-2010
Daily Discharge (m³/s)
0
10
20
30
40
50
60
70
80
90
100
Synthetic Flows
Actual Flows
1/1/2008
3/1/2008
5/1/2008
7/1/2008
9/1/2008
11/1/2008
1/1/2009
3/1/2009
5/1/2009
7/1/2009
9/1/2009
11/1/2009
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3/1/2010
5/1/2010
7/1/2010
9/1/2010
11/1/2010
Date

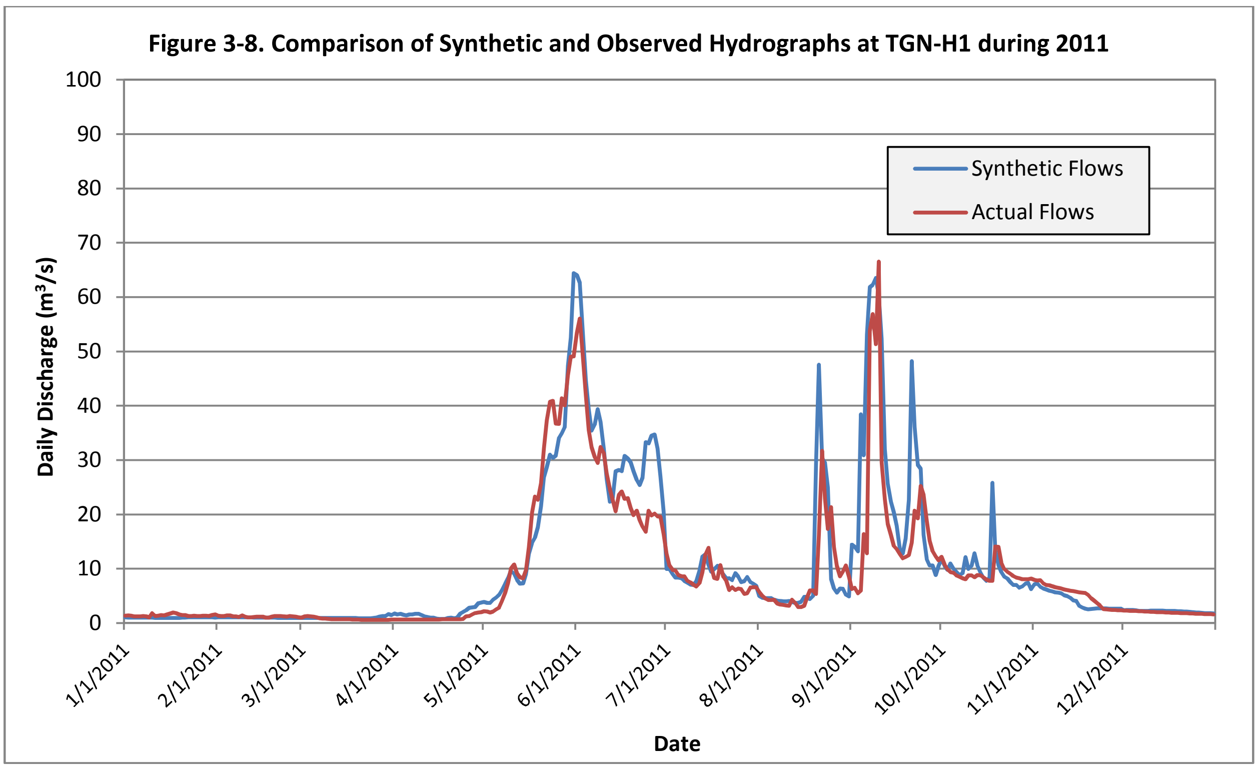
Figure 3-8. Comparison of Synthetic and Observed Hydrographs at TGN-H1 during 2011
Daily Discharge (m³/s)
0
10
20
30
40
50
60
70
80
90
100
Synthetic Flows
Actual Flows
1/1/2011
2/1/2011
3/1/2011
4/1/2011
5/1/2011
6/1/2011
7/1/2011
8/1/2011
9/1/2011
10/1/2011
11/1/2011
12/1/2011
Date

**Figure 3-9. Instream flow threshold for Teigen Creek (TGN-H1) as determined from the proposed guidelines for fish-ebearing streams (Hatfield *et al.* 2003)**