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**GOVERNMENT OF YUKON ENERGY, MINES AND RESOURCES -  
ASSESSMENT AND ABANDONED MINES**

# **Clinton Creek Engineering Review and Assessment**

## **Part 1**

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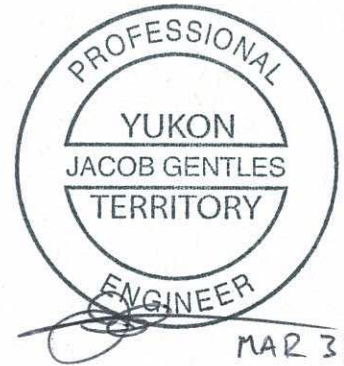
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**GOVERNMENT OF YUKON ENERGY, MINES AND RESOURCES - ASSESSMENT AND ABANDONED MINES  
CLINTON CREEK ENGINEERING REVIEW AND ASSESSMENT  
PART 1**

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**PROJECT 307071-00997 - CLINTON CREEK ENGINEERING REVIEW AND ASSESSMENT**

REV	DESCRIPTION	ORIG	REVIEW	WORLEYPARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Issued for Client Review	<u>J. Gentles</u>	<u>A. Timmis</u>	<u>L. Martin</u>	02-Oct-14	_____	
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## ABBREVIATIONS

Abbreviation	Description
AAM	Assessment and Abandoned Mines
AANDC	Aboriginal Affairs and Northern Development Canada
DS4	Drop Structure No. 4
EC	Environment Canada
m	metres
m <sup>3</sup>	cubic metres



## DEFINITIONS

Definition	Description
Almost Certain	Event happens often - once every five years.
Cascading Failure	Failure of Clinton Creek channel, originating at DS4 and propagating upstream to the Hudgeon Lake outlet, which results in the rapid drawdown of Hudgeon Lake.
Extreme Flow	An unusually large flow generated by freshet or precipitation flows with a return period greater than 1.
Freshet	The flow generated as a result of snow and ice melt.
Gabion	A metal cage filled with rock installed to provide erosion protection in a channel.
Likely	Event could easily happen - once every 15 years.
Major Blockage	Blockage of the Hudgeon Lake outlet during which the water level in Hudgeon Lake reaches approximately 414.0 m.
Minor Blockage	Blockage of the Hudgeon Lake outlet during which the water level in Hudgeon Lake reaches approximately 412.5 m.
Moderate Blockage	Blockage of the Hudgeon Lake outlet during which the water level in Hudgeon Lake reaches approximately 413.0 m.
Possible	Could happen and has happened elsewhere - once every 40 years.
Risk Rating	A rating assigned based on likelihood / consequence classifications and the AANDC risk table.
Trigger	A qualitative value assigned to a specific attribute of a site component that, when exceeded, should prompt a pre-defined response to address the stability of the component.
Unlikely	Has not happened yet, but could - once every 200 years.
Very Unlikely	Conceivable, but only in extreme circumstances - once every 1,000 years.

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## **1. INTRODUCTION**

WorleyParsons Canada Services Ltd. (WorleyParsons) completed a site visit at the Clinton Creek mine site on August 25, 2014 as part of the Clinton Creek Engineering Review and Assessment project (the Project), on behalf of Yukon Energy, Mines and Resources, Assessment and Abandoned Mines (AAM). This visit included the visual inspection of various infrastructure and geotechnical features located throughout the site, including components of the Clinton Creek channel.

The content and structure of this report is based on AAM's scope of work document dated July 21, 2014 and WorleyParsons' Proposal No. 307076-06967-0002 dated August 13, 2014.

### **1.1 Site Background**

The Clinton Creek site (the site) is a former asbestos mine which was in operation between 1968 and 1978. The site is located 80 km northwest of Dawson City, Yukon (YT), near the confluence of Fortymile River and the Yukon River. During operation, waste rock was placed along the south valley wall of Clinton Creek while tailings from the milling operation were placed along the west valley wall of Wolverine Creek. Subsequent movement of the waste rock and tailings have since blocked Clinton Creek and Wolverine Creek, respectively.

The blockage of Clinton Creek resulted in impoundment of approximately 10 million m<sup>3</sup> (UMA 2002) of runoff from the surrounding natural portion of the watershed and the formation of Hudgeon Lake.

Discharge from Hudgeon Lake is conveyed southeast by Clinton Creek to Fortymile River. Four rock gabion drop structures (DS1, DS2, DS3, and DS4) were constructed across the upper portion of Clinton Creek between 2002 and 2004 to stabilize the waste rock pile to the south; however, Drop Structure No. 4 (DS4) was destabilized in 2010, and the channel immediately downstream continues to degrade due to down-cutting.

### **1.2 Report Components**

This report includes the following:

- Summary of observations made during the site visit related to components of the Clinton Creek channel (Section 2);
- The methodology used to complete the risk assessments (Section 3);
- Presentation and discussion of a risk assessment completed for the failure of DS4 in isolation (Section 4);
- Presentation and discussion of a risk assessment completed for a cascading failure of the Clinton Creek channel resulting in a rapid draw-down of Hudgeon Lake (Section 0);
- Recommended short-term mitigation works for DS4 and the Clinton Creek channel; and
- Review of existing triggers to determine if they have been exceeded and recommendations to assess their validity (Section 6).



## 2. SITE INSPECTION

The August 25, 2014 site visit was conducted by the following WorleyParsons staff:

- Lee Martin;
- Margaret McBride; and
- Jake Gentles.

Transportation to and from the site was achieved by helicopter (Trans North Helicopters in Dawson City). Site reconnaissance was generally conducted on foot supplemented by helicopter flyovers of inaccessible areas and areas where an elevated vantage point was advantageous. The observations made during the site visit are summarized in Table A. Site visit photographs can be found in Appendix 1.

**Table A Summary of Site Visit Observations**

Location	Access Method	Observations
Site Access Roads: Forty Mile Bridge to First Ford	Flyover	Road is accessible. Site access gate at Wolverine Creek confluence damaged and unlocked (note that the gate cannot be secured without repairs).
Site Access Roads: First Ford	On foot	Although the ford was not used during the site visit, it appeared to be geotechnically stable and passable by 4WD vehicles.
Site Access Roads: First Ford to Hudgeon Lake	Primarily on foot	Road is accessible with some minor rill erosion damage located periodically along route. Some of these rills may become impassible to vehicle traffic from ongoing erosion if not filled in.
Site Access Roads: Hudgeon Lake to Mill Site	Flyover	Road appears accessible.
Hudgeon Lake Outlet <sup>1</sup>	On foot	Outlet is in good condition; however, ford may be impassable due to high water depth. Although the boom abutments have been installed and appeared to be stable, the boom itself was not in place at the time of the visit. Though the beaver lodge located along the lakeshore (approximately 150 m west of the outlet) was not identified during the site visit, it can be seen in the background of photographs taken at the lake outlet (Appendix 1).
Hudgeon Lake Surrounding Slopes	Flyover	No visible signs of recent slope movement or failures in the area surrounding Hudgeon Lake.
Gabion DS1	On foot	Large woody debris constricting flow at upstream side of DS1. Damage to gabion basket on north side of second drop structure tier. One basket displaced horizontally in channel. Tension cracks located along the south top of bank between DS1 and DS2.
Gabion DS2	On foot	Large woody debris located above water line. Baskets are in good condition. Tension cracks (4 m in length) located along south top of bank.
Gabion DS3	On foot	Large woody debris located primarily above water line. Baskets are in generally good condition. One basket installed downstream of drop structure along channel bottom displaced vertically.

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<b>Location</b>	<b>Access Method</b>	<b>Observations</b>
Gabion DS4	On foot	Woody debris located in channel. In channel baskets significantly damaged beginning 3 m to 4 m above plunge pool. Baskets below this height have failed, including baskets on north and south banks. Failed basket material observed approximately 15 m downstream. Tension cracks (5 m to 6 m in length) located along south top of bank.  WorleyParsons completed a site visit in 2013 (attended by Lee Martin and Alex Timmis) to review the condition of DS4 and to inform the development of a repair strategy. The condition of DS4 does not appear to be significantly different than last year, based on a comparison of photos taken during the 2013 and 2014 site visit.
Clinton Creek Channel and Site Access Road	On foot and flyover	Slope failures along north and south banks. Significant tension cracks (6 m to 7 m in length) located along south top of bank. Undercutting of bedrock along toe of north bank.
Clinton Creek Waste Rock Pile	On foot and flyover	Some rill erosion damage on south slope. Note that the rill damage was not located near the unstable section of the Clinton Creek embankment, adjacent to the closed portion of the access road.
Wolverine Creek Tailings Pile	Flyover	Tension cracks located at the following locations: <ul style="list-style-type: none"> <li>• Upper slope of the south lobe</li> <li>• Lower slope of the south lobe (concentrated at southeast corner)</li> <li>• Upper slope of the north lobe (concentrated at north face of the slope)</li> <li>• Mid slope of the north lobe (located at the north side of the east face of the slope)</li> </ul>
Wolverine Creek Tailings Pile Ponds	Flyover	Although there is woody debris located at the outlets of both the north and south ponds, it does not appear that the debris is constricting discharge from the ponds. It should be noted that a beaver dam has been observed upstream of the north lobe pond by AAM staff but was not observed during the site visit. The channel connecting the north and south ponds does not appear to be obstructed by debris or tailings material.
Wolverine Creek Rock Lined Channel	On foot	Rock weirs and rock protection are in good condition. No significant erosion sites identified. Wolverine culvert is unobstructed and headwall is in good condition.
Porcupine Pit	On foot and flyover	Tension cracks located along top of north pit wall. No observed indication of recent slope failures.
Snowshoe Pit	Flyover	No observed indication of recent slope failures.

<sup>1</sup>Note: Based on discussions with AAM, it is understood that while the boom was originally constructed in the summer of 2013, it was not installed in 2014. The boom is intended to be installed post-freshet each year and removed in the fall. In 2014, AAM completed regular debris removal manually from the drop structures through the open water season where it was safe to do so.

Following the site visit, Underhill Geomatics Ltd. (Underhill) completed a topographic and monitoring survey of the features listed above as part of the 2014 Clinton Creek Long-Term Monitoring Program (LTMP). The results of this survey will be presented and discussed in a forthcoming report prepared by WorleyParsons.



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## 3. RISK ASSESSMENT OVERVIEW

This report discusses risks associated with and influenced by the failure of DS4 (summarized in Appendix 2). A risk assessment for the remaining infrastructure located at the Clinton Creek mine site is underway, based on field observations from WorleyParsons' site visit and survey data provided by Underhill, and will be submitted as Clinton Creek Engineering Assessment and Review - Part 2 (Part 2).

### 3.1 Failure Modes

Two failure modes were considered for this risk assessment:

1. DS4 Failure in Isolation (Section 4) - the complete failure of gabion drop structure materials resulting in the erosion of the underlying waste rock; and
2. Clinton Creek Channel Infrastructure Cascading Failure (Section 5) - the complete failure of the drop structures and Hudgeon Lake outlet (propagating upstream from DS4) resulting in the rapid draw down of Hudgeon Lake and the discharge of a large flood flow through the Clinton Creek channel.

### 3.2 Methodology

Risk assessments for DS4 and the Clinton Creek channel cascading failure were completed using the Aboriginal Affairs and Northern Development Canada (AANDC) risk assessment format (using reference documents provided by AAM). Each risk assessment includes the following:

- Qualitative classification of four consequence categories based on Table B (note that although Special Considerations and Community / Media / Reputation categories are important components of a risk assessment, WorleyParsons' understanding of the issues related to these categories is not sufficient to assign a classification to them);
- Description of the potential consequence scenario associated with each classification, summarized as distinct risk event statements;
- Estimated likelihood of occurrence of each scenario (based on professional judgement) in the short-term (i.e., two to five years) and medium-term (i.e., 10 years), based on Table C; and
- An overall qualitative risk rating, based on the AANDC risk table presented as Table D.

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**Table B Consequence-Severity Matrix**

Consequence Categories	Severity Descriptors				
	Very Low	Minor	Moderate	Major	Critical
1. Environmental Impact	No impact.	Minor localized or short-term impacts.	Significant impact on valued ecosystem component.	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.	Serious long-term impairment on ecosystem function.
2. Special Considerations	Some disturbance but no impact to traditional land use.	Minor or perceived impact to traditional land use.	Some mitigable impact to traditional land use.	Significant temporary impact to traditional land use.	Significant permanent impact on traditional land use.
3. Legal Obligations	Informal advice from a regulatory agency.	Technical / administrative non-compliance with permit, approval, or regulatory requirement. Warning letter issued.	Breach of regulations, permits, or approvals (e.g., one-day violation of discharge limits). Order or direction issued.	Substantive breach of regulations, permits, or approvals (e.g., multi-day violation of discharge limits). Prosecution.	Major breach of regulation - willful violation. Court order issued.
4. Consequence Costs	<\$100,000	\$100,000 to \$500,000	\$500,000 to \$2.5 million	\$2.5 million to \$10 million	>\$10 million
5. Community / Media / Reputation	Local concerns, but no local complaints or adverse press coverage.	Public concern restricted to local complaints or local adverse press coverage.	Heightened concern by local community, criticism by non-governmental organizations (NGOs) or adverse local / regional media attention.	Significant adverse national public, NGO, or media attention.	Serious public outcry / demonstrations or adverse international NGO attention or media coverage.
6. Human Health and Safety	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability / impairment and/or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Single fatality and/or severe irreversible disability or impairment to one or more people.	Multiple fatalities.

**Table C Likelihood Terminology**

Likelihood	Descriptor 2	Frequency Descriptor	Probability of Occurrence Over 20 Years	Probability of Occurrence in Any One Year
Almost Certain	Happens often.	High frequency (more than once every five years).	98%	17.8%
Likely	Could easily happen.	Event does occur, has a history, once every 15 years.	75%	6.7%
Possible	Could happen and has happened elsewhere.	Occurs once every 40 years.	40%	2.5%
Unlikely	Has not happened yet but could.	Occurs once every 200 years.	10%	0.5%
Very Unlikely	Conceivable, but only in extreme circumstances.	Occurs once every 1,000 years.	2%	0.1%



**Table D AANDC Risk Table**

Impact	Critical	Moderately High	Moderately High	High	Very High	Very High
	Major	Moderate	Moderately High	High	High	Very High
	Moderate	Low	Moderate	Moderately High	Moderately High	High
	Minor	Low	Low	Moderate	Moderate	Moderately High
	Low	Low	Low	Low	Low	Low
		Very Unlikely	Unlikely	Possible	Likely	Almost Certain
		Likelihood				

### 3.3 Timeframes

Three timeframes were examined for the purposes of this risk assessment:

- Short-term: Years 1 to 2;
- Medium-term: Years 1 to 5; and
- Long-term: Years 1 to 10.

### 3.4 Failure Mechanisms

The following failure mechanisms were examined for the purposes of this risk assessment and are discussed further in Sections 4.5 and 5.2.

- Extreme flow generated by freshet or precipitation and conveyed through the Clinton Creek channel resulting in severe shear stress acting against the channel and drop structures.
- Blockage of Hudgeon Lake caused by the collection of debris at the outlet of Hudgeon Lake that increases the water level in Hudgeon Lake and, when dislodged, results in the release of impounded water in a flood flow and severe shear stress acting against the channel and drop structures. The following blockage severities were defined for this risk assessment:
  - **Minor:** similar to the blockage of Hudgeon Lake in August 2010 which resulted in the destabilization of DS4. Evidence indicates that the water level in Hudgeon Lake reached 412.5 m as a result of the blockage (R100 AECOM 2010). The likelihood of occurrence of a minor blockage was assumed to be ‘Likely’ (i.e., could easily happen - with a frequency of once every 15 years).

- **Moderate:** a blockage during which the water level in Hudgeon Lake reaches an elevation of 413.5 m (higher than the elevation of the boom structure). The likelihood of a major blockage occurring was assumed to be ‘Possible’ (i.e., could happen and has happened elsewhere - with a frequency of once every 40 years).
- **Major:** a blockage during which the water level in Hudgeon Lake reaches an elevation of 414.0 m. The likelihood of a major blockage occurring was assumed to be ‘Unlikely’ (i.e., has not happened yet, but could - with a frequency of once every 200 years).
- Structural failure of DS4 due to ongoing erosion and metal fatigue of gabion baskets, independent of extreme flows.

It should be noted that the extreme flow events and blockage related water levels used for this assessment were based on our professional judgement and are indicative in nature; these estimates are intended for comparative purposes only.

### 3.4.1 Flow Rates

The estimated peak instantaneous flow rates in Clinton Creek at the outlet of Hudgeon Lake used in the risk assessment are presented in Table E. Note that although these flow rates were estimated using data collected prior to 2003, have not been updated as they are indicative in nature and used for comparison purposes only.

**Table E Estimated Peak Instantaneous Flow Rates in Clinton Creek at Hudgeon Lake**

Return Period (Years)	Flow Rate (m <sup>3</sup> /s)	Source
5	21	Interpolated <sup>1</sup>
15	26	Interpolated
25	29	Document R48 <sup>2</sup>
40	32	Interpolated
50	34	Document R48
100	39	Document R48
200	45	Document R48
1,000	55	Interpolated

Notes:

<sup>1</sup> Values were interpolated by plotting the previously reported flow rates using a log-log scale to generate a flow versus return period curve.

<sup>2</sup> UMA 2003.

### 3.5 Likelihood and Consequence Classifications

Likelihood and consequence classifications were based on the professional judgement and understanding of site conditions of WorleyParsons’ staff.



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## 4. DS4 FAILURE IN ISOLATION

### 4.1 DS4 Failure

The complete failure of DS4, including the total loss of structural integrity, is a result of the following elements (either separately or in conjunction):

- Loss of connection between the majority of the gabion baskets such that they no longer perform as a single mat;
- Loss of integrity of the gabion basket mesh (due to deformation or damage) resulting in the displacement of gabion rocks; and
- Displacement of the gabion baskets from the top of the drop structure to downstream.

If DS4 should fail as described above, it is likely that the underlying waste rock will be exposed to creek flows and the associated shear stress resulting in erosion. Potentially, this erosion could propagate upstream to DS3, particularly if the DS4 failure is not immediately repaired; however, it is unlikely that the triggers associated with the failure of DS4 in isolation (discussed in Section 4.5) would also cause the complete and immediate failure of DS3.

A cascading failure of the Clinton Creek channel, including DS1 to DS4 and the Hudgeon Lake outlet, is discussed in Section 5.

### 4.2 DS4 Current Stability

A large precipitation event in August 2010, in addition to the possible blockage of the Hudgeon Lake outlet, resulted in the conveyance of a large flow through the Clinton Creek channel (R100 AECOM 2010). This high flow event resulted in the destabilization of DS4 due to undercutting and the development of a plunge pool at the base of the drop structure (R94 AECOM 2011).

While DS4 is still in place, it has become destabilized due to the August 2010 flow event and the ongoing erosion of underlying granular material. This erosion has already resulted in the failure of some of the lower courses of gabion baskets. Due to the high energy of flow at the base of the drop structure, it is likely that erosion will continue during periods of low to moderate flows and that erosion will increase during periods of high and extreme flows. As additional courses of gabion baskets fail, the surface area exposed to high shear stresses will increase, further threatening other surrounding gabion baskets.

Furthermore, some gabion baskets at DS4 have shifted but have not failed as they are still held together by the metal comprising their cage. It is likely that at some point this metal will fail due to fatigue, further weakening the drop structure integrity.

It should be noted that gabion baskets are not typically intended to be used as a long-term solution (>25 years) and often require maintenance following seven to 10 years of service. As DS4 has been in service for more than 10 years and has partially failed, ongoing stability issues will likely continue to impact the structural integrity of the gabion baskets and eventually resulting in the complete failure of DS4.

### 4.3 DS4 Survey Results

DS4 is monitored as part of the Clinton Creek LTMP, including the periodic completion of topographic surveys (every one or two years) to determine the movement of monitoring points and changes to the channel cross-section at DS4; however, the downstream section of DS4 was not surveyed in 2014 as it could not be safely accessed due to the instability of DS4.

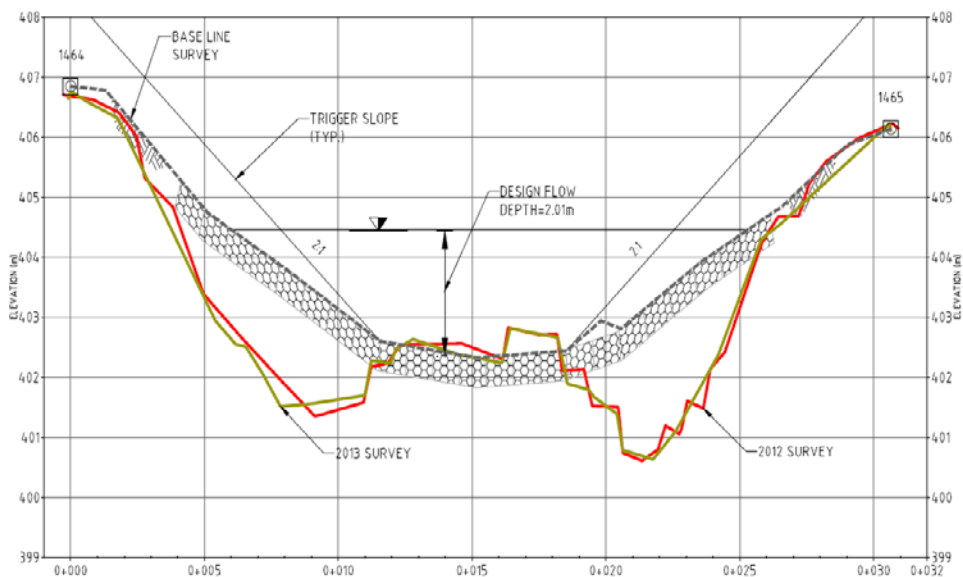
DS4 survey results from 2013 as well as 2012 (R104 AE 2013) and baseline and trigger values (R22 UMA 2006) are presented in Table F. Data provided is for the downstream cross-section, between Monitoring Point Nos. 1464 and 1465.

**Table F DS4 (Downstream) End Survey Results**

Feature	Trigger Value	Baseline Value (2006)	2012 Value	2013 Value
North Side Slope	<2H:1V	3.4H:1V	1.3H:1V	1.4H:1V
South Side Slope	<2H:1V	3H:1V	2.1H:1V	1.4H:1V
Channel Invert at End Sill Centreline	N/A	402.3	402.5	402.3
Channel Invert Downstream of DS4 (metres above sea level [masl]) <sup>1</sup>	N/A	402.0	397.8	397.9

Note: Based on nearest downstream channel centerline survey point.

A DS4 cross-section, based on survey results from previous survey programs, is presented as Figure A. Stationing increases from south to north (i.e., the north slope is located on the right hand side of the figure).



**Figure A DS4 Cross-Section**



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Between 2006 and 2013, the DS4 side slopes became approximately 18 deg. (130%) steeper, with side slope trigger levels exceeded for both slopes by 2013. Over the same timeframe the channel invert at the downstream cross-section remained at approximately the same elevation. Between 2012 and 2013, the DS4 side slopes were altered between 2 deg. to 10 deg. (7% to 50%) while the channel invert at the downstream cross-section shifted downward 0.2 m.

Based on the 2012 and 2013 survey results, the channel invert immediately downstream of DS4 has shifted downward approximately 4.1 m compared to the 2006. As the invert elevation has not significantly changed between 2012 and 2013, it appears that the invert has stabilized. This indicates that the waste rock below DS4 has been mobilized and contact with the bedrock has been made (i.e., the channel invert at this location has not significantly changed) and will remain at roughly the same elevation from year to year.

Based on the results of the 2012 and 2013 surveys as well as the observations made during the 2013 and 2014 site visits, it does not appear that the destabilization of DS4 is accelerating.

#### **4.4 Proposed DS4 Repair**

A repair plan for DS4 was designed by WorleyParsons in 2014 consisting of the construction of a chute (integrated into the remaining gabion baskets) downstream of DS4 using articulated revetment mats and re-grading of the waste rock pile located south of DS4. During its development, it was assumed that site-wide remediation works to address slope instability and channel protection infrastructure would be underway within five years, including a permanent repair option for DS4. Consequently, the proposed repair plan was developed as a short-term protection measure.

The chute was designed to convey 25-year extreme flow (selected due to the anticipated 5- to 10-year service life of the proposed infrastructure). The 25-year peak flow condition should be considered as the minimum flow rate at which damage would occur to a repaired DS4.

It was assumed, based on professional judgement, that the repaired DS4 would be capable of conveying the 100-year peak flow without resulting in its complete failure (i.e., the mobilization of the majority or all of the chute infrastructure and existing gabion baskets such that the majority of the channel is exposed to erosion).

Based on the current condition of DS4, the estimated cost to complete the repair is approximately \$700,000 (WorleyParsons 2014). This estimated cost was based on the following key assumptions:

- Repairs will be completed during the 2014 summer construction window - it is anticipated that implementation costs will escalate beyond this period;
- Deterioration of existing gabion baskets since 2012 survey will be limited;
- Repairs to Fortymile Bridge will not be required; and
- No off-site disposal or on-site containment required for excavated material.

## **4.5 Mechanisms and Likelihood Classifications**

The failure of DS4 could be triggered by the three failure mechanisms discussed in the following sections.

### **4.5.1 Ongoing Structural Failure**

Due to the nature of the ongoing structural failure of DS4 through continued erosion (discussed in Sections 4.1 and 4.2), the stability of DS4 is expected to worsen with time. The following likelihood classifications for the complete failure of DS4 were assigned for the three timeframes:

- Years 1 to 2: 'Possible' (i.e., could happen and has happened elsewhere);
- Years 3 to 5: 'Likely' (i.e., could easily happen); and
- Years 6 to 10: 'Almost Certain' (i.e., happens often).

Following the completion of the proposed repairs to DS4, the ongoing structural failure would be mitigated and the likelihood classification for all three timeframes would be reduced to 'Unlikely' (i.e., has not happened yet, but could).

### **4.5.2 Extreme Flood Flow**

Due to its high flow depth and velocity, the conveyance of an extreme flood flow (i.e., an unusually large flow generated by precipitation or freshet) would generate large shear stresses acting against the channel cross-section (i.e., the bottom and sides of the channel), which could result in the failure of DS4.

Due to the ongoing destabilization of DS4, it was assumed that, without being repaired, the magnitude of the extreme flow event that could potentially trigger a complete failure would decrease over time. The triggers that could instigate the failure of DS4 are as follows:

- Years 1 to 2: 'Possible', corresponding to the 40-year peak instantaneous flow;
- Years 3 to 5: 'Likely', corresponding to the 15-year peak instantaneous flow; and
- Years 6 to 10: 'Almost Certain', corresponding to the 5-year peak instantaneous flow.

Following the completion of the proposed repairs, it is anticipated that the magnitude of the extreme flow required to trigger the complete failure of DS4 would increase to the 100-year peak instantaneous flow for all timeframes, corresponding to a likelihood classification of 'Unlikely'.

It should be noted that the flow events used for this assessment were based on our professional judgement and are indicative in nature; these estimates are intended for comparative purposes only. The exact determination of flow rates that would result in the failure of DS4 would require further investigation and analysis, and is beyond the scope of this assessment.



### 4.5.3 Blockage of Hudgeon Lake

A minor blockage of the Hudgeon Lake outlet, similar to the August 2010 blockage, would most likely be the result of accumulation of debris at the outlet. It was assumed that the most likely source of the debris would be a landslide in the area surrounding Hudgeon Lake, during freshet; however, it is possible that an extreme precipitation event outside of freshet could also trigger a landslide. The blockage would result in the restriction of discharge from the lake and a corresponding elevated water level (estimated to be 412.5 masl).

The rising water level behind the blockage would cause an increase in the hydrostatic pressure acting against the blockage. This increased pressure could dislodge the blockage resulting in the sudden release of a large volume of impounded water in the lake. This water would travel down the channel at a high flow velocity and depth, generating large shear stresses acting against the channel cross-section, which could result in the complete failure of DS4. It was assumed that this event would be independent of high rates of inflow to Hudgeon Lake generated by an extreme hydrologic event (i.e., normal inflow patterns could raise the water level over a long period between site inspections).

It should be noted that the installation of the planned boom structure at the Hudgeon Lake outlet may reduce the likelihood of a dislodgement of a minor blockage at the lake outlet; however, as it is unproven and is not in place year-round, the likelihood classification for all three times frames, with or without installation of the boom, was estimated to be 'Likely'.

It was assumed that following repairs, DS4 would be capable of withstanding a larger flow, corresponding to a moderate blockage of Hudgeon Lake (with an estimated water level of 413.5 masl). As such, the likelihood classification following repairs was reduced to 'Possible'.

### 4.5.4 Estimated Likelihood Classifications

Likelihood classifications associated with the 2-year, 5-year, and 10-year timeframes that could result in the complete failure of DS4 are summarized in Table G and Table H.

**Table G Likelihood Classification of DS4 Failure in Isolation Due to Ongoing Structural Failure or Extreme Flow**

Timeframe	Without Repair	With Repair
Years 1 to 2	Possible	Unlikely
Years 1 to 5	Likely	Unlikely
Years 1 to 10	Almost Certain	Unlikely

**Table H Likelihood Classification of DS4 Failure in Isolation Due to Hudgeon Lake Blockage**

Timeframe	Without Repair (Minor Blockage)	With Repair (Moderate Blockage)
Years 1 to 10	Likely	Possible

## 4.6 Consequence Scenarios

The consequence scenarios presented and discussed in the following sections were developed based on the AANDC methodology and using WorleyParsons' understanding of the site condition and professional judgement. The scenarios are summarized in Appendix 2 and in Table I.

**Table I Consequence Classifications - DS4 Failure in Isolation**

Category	Classifications	Descriptor
Environmental Impact	Minor	Acute degradation of local aquatic habitat.
Legal Obligations	Minor	Warning letter issued by Environment Canada (EC) for release of deleterious material causing degradation of aquatic habitat.
Consequence Costs	Moderate	Additional repair costs (up \$2 million) to account for increased repair footprint and access restoration.
Human Health and Safety - Person Near DS4	Major	Single fatality or severe, irreversible disability / impairment and/or injuries requiring hospitalization.
Human Health and Safety - Person Downstream	Minor	Objective but reversible disability / impairment and/or medical treatment injuries requiring hospitalization.

### 4.6.1 Environmental Impact

The failure of DS4 would result in the exposure of waste rock and granular materials in the channel due to erosion. The deposition of these materials could cause an acute degradation of downstream aquatic habitat due to infilling of runs and pools impacting fish passage as well the loss of gravels and cobbles available for spawning and shelter along the creek channel. It is anticipated that the extent of the degradation would be localized and that the habitat would recover following the repair of DS4.

This scenario was assigned a 'Minor' consequence classification.

### 4.6.2 Legal Obligations

The failure of DS4 could result in degradation of downstream aquatic habitat as described above due to deposition of waste rock and granular materials. These substances would be considered "deleterious substances" per the Canadian Fisheries Act (the Act). Section 36 of the Act states, "*No person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish.*" Due to the limited scale of the deposition and anticipated impact on aquatic habitat, it is likely that EC, the body responsible for enforcing the Act, may issue a warning letter rather than an order or direction.

This scenario was assigned a 'Minor' consequence classification.



### 4.6.3 Consequence Costs

Given the steep side slopes downstream and adjacent to DS4, its failure could further limit accessibility. To facilitate the repairs, additional site works, over and above the proposed repair, would then be necessary to restore access to DS4. These works could involve the use of specialized equipment, stabilization of surrounding waste rock, significant earthworks, and/or the restoration of the channel between DS4 and DS3. These additional site works could increase the cost to repair by up to \$2 million, not including the cost to implement the proposed DS4 repairs.

This scenario was assigned a 'Moderate' consequence classification.

### 4.6.4 Human Health and Safety

Two human health and safety scenarios were examined for the risk assessment.

#### Person in Vicinity of DS4

A single fatality or severe, irreversible disability / impairment and/or injuries requiring hospitalization could occur as a result of the failure of DS4 if an unauthorized recreational user or worker were in the vicinity (i.e., within approximately 50 m) of the structure at the time of failure. If located in the channel downstream of the structure, the person could be struck by the gabion basket materials or buried beneath waste rock material. If the person was located on the banks of the channel, the mobilized material could cause a loss of footing, resulting in them falling down the embankment.

This scenario was assigned a 'Major' consequence classification. The likelihood of this scenario was considered to be 'Unlikely' for all timeframes.

#### Person Downstream of DS4

Objective but reversible disability / impairment and/or injuries requiring hospitalization could occur as a result of the failure of DS4 if an unauthorized recreational user or worker were located in the channel, downstream of the structure at the time of failure. Injuries sustained could be the result of being struck by mobilized cobbles, ingesting sediment laden water, or a loss of stable footing.

This scenario was assigned a 'Minor' consequence classification. The likelihood of this scenario was considered to be 'Possible' for all timeframes.

## 4.7 Preventative Measures

The following preventative measures are in place to reduce the likelihood and severity of the failure of DS4 in isolation:

- Annual inspection and topographic survey of DS4 (by consultant);
- Monthly inspection during the summer (by AAM staff);
- Security measures that limit access to the site (e.g., locked security gate at site entrance, warning signs) to discourage access by unauthorized recreational users; and
- Safety measures to prohibit workers and staff from accessing DS4 or working downstream during periods of high flow without a detailed safety plan approved by AAM.

The following preventative measures should be implemented to reduce the likelihood and consequence classifications associated with the failure of DS4 in isolation:

- Implement proposed DS4 repair plan (WorleyParsons 2014) summarized in Section 4.4 to increase the stability of DS4 and the magnitude of extreme event it can safely convey;
- Complete the installation of the boom at the outlet structure at Hudgeon Lake to collect debris and reduce the likelihood of a dislodgement of a potential blockage of the outlet (i.e., withstand hydrostatic forces that could dislodge the blockage);
- Install and remotely monitor a water level gauge at the Hudgeon Lake outlet to notify AAM of high water levels that may indicate a blockage; and
- Develop a protocol to define water depths in Hudgeon Lake above which AAM staff are sent to site to investigate and determine if the channel is blocked and, if so, the urgency with which the blockage should be removed based on its severity.

## 4.8 Risk Event Statement

The DS4 in isolation failure is summarized in the following risk event statement:

*“Ongoing stability issues (i.e., erosion and metal fatigue) and/or the conveyance of an extreme flow (generated by a blockage of Hudgeon Lake or hydrologic processes) causes the complete failure of Gabion DS4, which could result in the minor degradation of local aquatic habitat, issuance of a warning letter by the EC, escalation of repair costs, and/or serious injuries or a fatality.”*



## 4.9 Overall Risk Rating

The consequence and likelihood classifications presented in the preceding sections were used to assign the qualitative risk ratings summarized in Table J. A complete list of these ratings can be found in Appendix 2.

**Table J Risk Ratings of DS4 Failure - Years 1 to 10**

Consequence Category	Extreme Flow	Extreme Flow Following Repair	Blockage of Hudgeon Lake Outlet	Blockage of Hudgeon Lake Following Repair
Environmental	Moderately High	Low	Moderate	Moderate
Legal Obligations	Moderately High	Low	Moderate	Moderate
Consequence Costs	High	Moderate	Moderately High	Moderately High
Human Health and Safety - Person Near DS4	Moderately High	Moderate	Moderately High	Moderate
Human Health and Safety - Person Downstream	Moderate	Low	Moderate	Low

Note that although the repair of DS4 does not reduce all risk ratings assigned to the blockage of Hudgeon Lake failure mechanism, it would reduce the overall likelihood that DS4 would fail and would reduce the risk rating assigned to the extreme flow failure mechanism from 'High' to 'Moderate'.

## 5. CLINTON CREEK CHANNEL INFRASTRUCTURE CASCADING FAILURE

### 5.1 Clinton Creek Channel Failure

The complete failure of the Clinton Creek channel would take the form of a cascading failure, originating at DS4 due to its partially failed state and propagating upstream through the other three drop structures and the Hudgeon Lake outlet. Once the Hudgeon Lake outlet fails, all or a significant portion of the water impounded in the lake would be rapidly drawn down, discharging a large flood flow through what remains of the Clinton Creek channel. The conveyance of this flood flow would result in severe erosion and mobilization of waste rock and granular materials. Water impounded in Hudgeon Lake contains concentrations of cadmium, iron, sulphate, and copper at levels that exceed Canadian Council of Ministers of the Environment (CCME) guidelines (R05 UMA 2004).

Other failure mechanisms related to the Clinton Creek channel, including short circuiting of the Hudgeon Lake outlet, failure in isolation of DS1; DS2; or DS3, and down-cutting downstream of DS4 will be presented and assessed in the Part 2 report.

### 5.2 Failure Mechanisms and Likelihood Classifications

The cascading failure could be triggered by the failure mechanisms discussed in the following sections.

#### 5.2.1 Extreme Flood Flow

The conveyance of an extreme flood flow could trigger the cascading failure of Clinton Creek, similar to the failure of DS4 (discussed in Section 4.5.2).

Due to the ongoing destabilization of DS4, it was assumed that, without being repaired, the magnitude of the extreme flow event that could potentially trigger the cascading failure would decrease over time.

The triggers that could instigate the cascading failure are as follows:

- Years 1 to 2: 'Very Unlikely', corresponding to the 1,000-year peak instantaneous flow;
- Years 3 to 5: 'Unlikely', corresponding to the 200-year peak instantaneous flow; and
- Years 6 to 10: 'Possible', corresponding to the 40-year peak instantaneous flow.

Following the completion of the proposed repairs, it is anticipated that the magnitude of the flow required to trigger the cascading failure would be greater than the 1,000-year peak instantaneous flow for all timeframes, corresponding to a likelihood classification of 'Very Unlikely'.



### 5.2.2 Blockage of Hudgeon Lake Outlet

Similar to the blockages discussed in Section 4.5.3, a moderate blockage of the Hudgeon Lake outlet (with an estimated water level of 413.5 masl) could trigger the cascading failure, independent of an extreme flood flow generated by hydrologic processes. It is anticipated that the boom structure at the outlet would not prevent the dislodgement of a moderate blockage. The likelihood classification associated with a moderate blockage for all three time frames is 'Possible'. This classification is based on the similar dam failures presented in Table K<sup>1</sup>.

**Table K Reported Dam Failures**

Location	Date	Description of Failure
San Marcelino, Zambales, Philippines	August 27, 2002	An increase in impounded water levels caused erosion of spillways resulting in the release of mine wastes.
Jinduicheng, Shaanxi Province, China	April 30, 1988	Spillway blockage resulted in an increase to the impounded water level causing a breach of the dam wall.
Sgorigrad, Bulgaria	May 1, 1966	Failure of diversion channel resulted in an increase to the impounded water level causing a dam failure.

It was assumed that following repairs to DS4, a major blockage of the Hudgeon Lake outlet (with an estimated water level of 414.0 masl) would be required to trigger the cascading failure. The likelihood classification associated with a major blockage for all three time frames is 'Unlikely'.

### 5.2.3 Estimated Likelihood Classifications

Likelihood classifications associated with the 2-year, 5-year, and 10-year timeframes that could result in the cascading failure of the Clinton Creek channel are summarized in Table L and Table M.

**Table L Likelihood Classification of Clinton Creek Cascading Failure Due to Extreme Flow**

Timeframe	Without Repair	With Repair
Years 1 to 2	Very Unlikely	Very Unlikely
Years 1 to 5	Unlikely	Very Unlikely
Years 1 to 10	Possible	Very Unlikely

**Table M Likelihood Classification of Clinton Creek Cascading Failure Due to Hudgeon Lake Blockage**

Timeframe	Without Repair (Moderate Blockage)	With Repair (Major Blockage)
Years 1 to 10	Possible	Unlikely

<sup>1</sup> Compiled by the WISE Uranium project ([www-wise-uranium.org/mdaf.html](http://www-wise-uranium.org/mdaf.html)).

### 5.3 Consequence Scenarios

The scenarios are summarized in Appendix 2 and in Table N.

**Table N Consequence Classifications - DS4 Failure in Isolation**

Category	Classifications	Descriptor
Environmental Impact	Major	Acute degradation of aquatic and terrestrial habitat over an extended area.
Legal Obligations	Major	Order or direction issued or prosecution taken by Environment Canada for the release of a deleterious material causing degradation of an aquatic habitat (salmon bearing). Order or direction issued or prosecution taken by Compliance, Monitoring and Inspection (Energy, Mines and Resources) Yukon for the release of TSS laden water to an aquatic habitat without a license.
Consequence Costs	Critical	Costs for environmental mitigation, waste rock stabilization, and access restoration greater than \$10 million.
Human Health and Safety - People in Clinton Creek Floodplain	Critical	Multiple fatalities.
Human Health and Safety - People in Clinton Creek Valley	Moderate	Moderate irreversible disability or impairment to one or more people.

#### 5.3.1 Environmental Impact

The cascading failure of the Clinton Creek channel would result in geomorphological changes to the channel within the boundaries of the site as well as erosion and deposition similar to that described in Section 4.6.1. It is anticipated that aquatic and terrestrial habitat over an extended area, possibly as far downstream as the Forty Mile River, would be impacted and that the mitigation works would be required for the habitat to recover.

This scenario was assigned a 'Major' consequence classification.

#### 5.3.2 Legal Obligations

Due to the degradation of aquatic and terrestrial habitat described above, it is likely that the EC would issue an order or direction requiring the mitigation of the degraded habitat. It is also likely that Compliance, Monitoring and Inspection (EMR) Yukon would become involved due to the release of water containing constituents (e.g., metals and total suspended solids [TSS]) at levels in excess of the CCME guidelines which would ultimately enter the Yukon River. It is also possible that either or both regulatory agencies could choose to prosecute.

This scenario was assigned a 'Major' consequence classification.



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### 5.3.3 Consequence Costs

Given the proximity of the Clinton Creek access road to the channel, it is likely that the cascading failure of Clinton Creek would destroy portions of the access road, limiting access to the site. This, in addition to the costs associated with the extensive environmental mitigation and waste rock stabilization, could result in overall consequence costs greater than \$10 million.

This scenario was assigned a Critical consequence classification.

### 5.3.4 Human Health and Safety

#### People Located in Clinton Creek Floodplain

Multiple fatalities could occur as a result of the cascading failure of Clinton Creek if unauthorized recreational users or workers were within the channel at the time of failure. Fatalities could be a result of being struck by mobilized boulders or debris, drowning, or burial under debris torrent.

This scenario was assigned a 'Critical' consequence classification. The likelihood of this scenario was considered to be 'Very Unlikely' for all timeframes.

#### Person Located in Clinton Creek Valley

Moderate irreversible disability or impairment to one or more people could occur as a result of the cascading failure of Clinton Creek if workers or recreational users are located within the Clinton Creek valley at the time of the rapid drawdown of Hudgeon Lake. Injuries sustained could be the result of being struck by mobilized cobbles or debris, ingesting sediment laden water, loss of stable footing, or being swept downstream.

This scenario was assigned a 'Moderate' consequence classification. The likelihood of this scenario was considered to be 'Unlikely' for all timeframes.

## 5.4 Preventative Treatments

The preventative treatments listed in Section 4.7 could be implemented to reduce the likelihood and consequence classifications associated with the cascading failure of Clinton Creek.

## 5.5 Risk Event Statement

The Clinton Creek cascading failure is summarized in the following risk event statement:

*"The conveyance of an extreme flow (generated by the dislodgement of a blockage at Hudgeon Lake or hydrologic processes) causes the failure of the four gabion drop structures and Hudgeon Lake outlet which could result in a significant impact of aquatic and terrestrial habitat, issuance of an order/direction or prosecution by EC or EMR Yukon, critical mitigation costs, and/or multiple injuries or fatalities."*

## 5.6 Overall Risk Rating

The consequence and likelihood classifications presented in the preceding sections were used to assign the qualitative risk ratings over the Years 1 to 10 timeframe, summarized in Table O. A complete list of these ratings can be found in Appendix 2.

**Table O Risk Ratings of Clinton Creek Cascading Failure Years 1 to 10**

<b>Consequence Category</b>	<b>Extreme Flow</b>	<b>Hudgeon Lake Blockage</b>	<b>With Repair (Both Failure Mechanisms)</b>
Environmental	Moderately High	High	Moderate
Legal Obligations	Moderately High	High	Moderate
Consequence Costs	Moderately High	High	Moderately High
Human Health and Safety - Person Near DS4	Moderately High	Moderately High	Moderately High
Human Health and Safety - Person Downstream	Moderate	Moderate	Low



## 6. PREVIOUSLY REPORTED TRIGGERS AND RECOMMENDATIONS

The triggers related to the failure of DS4 and the cascading failure of the Clinton Creek channel provided in the 2005 Long-Term Performance Monitoring Program report (R22 UMA 2006) are presented in Table P. Recommendations provided in previous reports and relating to the failure of DS4, damage to the drop structures, and the cascading failure of the Clinton Creek channel are presented in Table Q. The triggers and recommendations remain valid; specifically that the inspection and survey of the Clinton Creek channel and gabion drop structures should be completed on an annual basis. AAM should also consider adding the Hudgeon Lake outlet to the annual survey program rather than the biennial survey program.

Triggers and recommendations relating to other Clinton Creek infrastructure (e.g., tailings pile, waste rock) will be compiled and presented in the Part 2 report.

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**Table P Previously Reported Triggers**

No.	Trigger Description	Value	Response	Status	Discussion
1	Changes to drop structures geometry.	<ul style="list-style-type: none"> <li>• Side slopes at 2H:1V.</li> <li>• Width of DS drawdown reduction weir 0.5 m less than baseline.</li> <li>• Width of DS end sill 0.5 m less than baselines.</li> <li>• Top width of DS 0.5 m less than baseline.</li> </ul>	Plan remedial works of the drop structures and execute within one year.	DS4 side slope trigger exceeded based on 2012 survey. Response not implemented.	Although DS4 has not undergone significant deterioration between the 2013 and 2014 site visits, the trigger itself is still valid and the response should be implemented as soon as possible.
2	Down cutting of Clinton Creek channel immediately downstream of DS4.	<ul style="list-style-type: none"> <li>• 0.5 m immediately downstream of DS4,</li> </ul>	Line channel with cobble and bolder revetments.	Down cutting at 5 m based on 2012 survey. Response not implemented.	Same as above.
3	Down cutting of Clinton Creek channel approximately 50 m downstream of DS4.	<ul style="list-style-type: none"> <li>• 1.5 m approximately 50 m downstream of DS4.</li> </ul>	Channel stabilization and waste rock stabilization. Urgency of repair based on length of channel affected and rate of down cutting.	Trigger level reached or exceeded along 200 m length downstream of DS4 in 2010. Response not implemented.	Same as above.
4	Water flowing below the gabion baskets or undermining / piping between DS1 and DS4.	<ul style="list-style-type: none"> <li>• Visual evidence.</li> </ul>	Immediate repair.	DS4 gabions undermined at downstream end based on 2014 inspection. Response not implemented.	The damaged DS4 baskets will be removed as part of the proposed DS4 repair.
5	Damage to gabion mesh.	<ul style="list-style-type: none"> <li>• Visual evidence.</li> </ul>	Repair prior to end of the construction season.	Visual evidence of significant damage to DS4 gabions and minor damage to DS1 and DS3 gabions based on 2014 inspection. Response not implemented.	Same as above. The damaged gabion baskets at DS1 and DS3 should be repaired as soon as possible.



**Table Q Previously Reported Recommendations**

No.	Recommendation	Source Document	Status
1	Make repairs to the drop structures and Clinton Creek channel to address the damage caused by the August 2010 precipitation events.	R51 AECOM 2011	Apron downstream of DS3 extended, DS4 left as is (R94 AECOM 2011).
2	Monitoring of DS4 continue on an annual basis and that a stabilization plan, such as drawing down the Hudgeon Lake water level and removing the gabion structures, be investigated and implemented in order to provide long-term stability to the site.	R104 Associated Engineering 2013	Repair strategy developed in 2014 by WorleyParsons.
3	Inspection and survey of the Clinton Creek channel should be completed on an annual basis.	R104 Associated Engineering 2013	Inspection and survey completed in 2014 by WorleyParsons and Underhill.
4	Inspection and survey of the gabion drop structures should be completed on an annual basis. This specifically would include monitoring for increased movements in comparison with the waste rock piles to determine any trends.	R104 Associated Engineering 2013	Inspection and survey completed in 2014 by WorleyParsons and Underhill.
5	Inspection and survey of the tension cracks along the Clinton Creek access road should be completed on an annual basis.	R104 Associated Engineering 2013	Inspection and survey completed in 2014 by WorleyParsons and Underhill.
6	Visual inspection of the Hudgeon Lake outlet and pond at the Wolverine tailings pile should be completed on an annual basis to check for debris accumulation or blockage at these outlets.	R104 Associated Engineering 2013	Inspection completed in 2014 by WorleyParsons.
7	Trigger level for waste rock monitors should be further investigated and implemented. This would also include the installation of additional monitoring pins adjacent to where Clinton Creek has relocated closer to the waste rock area.	R104 Associated Engineering 2013	Monitoring pins installed in 2014 by Underhill.
8	Additional geotechnical investigation and evaluation should be undertaken to provide a more in-depth discussion on possible causes for differing movement rates between the gabion monitors and waste rock dump monitors.	R104 Associated Engineering 2013	Not yet completed.
9	Consider installation of an automated remote water level monitor to notify AAM when lake water level rises indicating possible blockage of the Hudgeon Lake outlet.	R104 Associated Engineering 2013	Not yet completed.

## **7. RISK ASSESSMENT SUMMARY**

### **7.1 Complete Failure of DS4**

Ongoing stability issues will continue to deteriorate the condition of DS4, most likely resulting in its complete failure in the next 10 years, independent of extreme flow events. The following four consequence scenarios were assessed and assigned risk ratings over the 10-year timeframe:

- Environmental Impact: degradation of local aquatic habitat due to deposition of granular material and waste rock – ‘Moderately High’;
- Legal Obligations: degradation of local aquatic habitat results in issuance of warning letter from DFO due to non-compliance with The Act – ‘Moderately High’;
- Consequence Costs: costs associated with this failure could be as much as \$2.0 million (not including the cost to implement the repair of DS4), nearly three times the estimated cost of the currently proposed repair strategy alone – ‘High’; and
- Human Health and Safety: low potential for a fatality if a person is in the vicinity of DS4 at the time of failure – ‘Moderately High’.

Implementing the proposed DS4 repair plan, as well as other preventative treatments listed in Section 4.7, would reduce these risk ratings to ‘Moderate’ (Environmental Impact, Consequence Costs, and Human Health and Safety) or ‘Moderately High’ (Legal Obligations) over the 10-year timeframe.

### **7.2 Cascading Failure of Clinton Creek Channel**

The most likely trigger for the Clinton Creek cascading failure would be the dislodgement of a moderate blockage of the Hudgeon Lake outlet, causing in the complete failure of DS4 propagating upstream causing the failure of DS3 to DS1 and the outlet, resulting in the rapid draw down of Hudgeon Lake and the release of a flood flow through the channel. The following four consequence scenarios were assessed and assigned risk ratings over the Years 1 to 10 timeframe:

- Environmental Impact: degradation of downstream aquatic and terrestrial habitat due to deposition of granular material and waste rock as well as geomorphological changes to the Clinton Creek channel - ‘High’;
- Legal Obligations: degradation of aquatic and terrestrial habitat results in issuance of an order or direction from DFO due non-compliance with The Act or Environment Yukon due to exceedance of CCME guidelines - ‘High’;
- Consequence Costs: environmental clean, waste rock stabilization, and access restoration costs could result in consequence costs greater than \$10 million - ‘High’; and
- Human Health and Safety: low potential for a multiple fatalities if people are in the vicinity of DS4 at the time of failure – ‘Moderately High’.

Implementation of the preventative treatments, would reduce these risk ratings to ‘Moderate’ (Environmental Impact and Legal Obligations) or ‘Moderately High’ (Consequence Costs and Human Health and Safety) over the Years 1 to 10 timeframe.



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## 8. CONCLUSIONS AND RECOMMENDATIONS

### 8.1 Conclusions

#### 8.1.1 DS4 Failure

The overall risk ratings associated with the complete failure of DS4 were estimated using the AANDC risk assessment format. The ratings were based on the assignment of likelihood and consequence classifications for various failure mechanisms, timeframes, consequence scenarios, and whether preventative measures are implemented.

The following ratings represent the highest ratings estimated for each time frame, if DS4 is not repaired, as well as the applicable consequence scenarios:

- Years 1 to 2: 'Moderately High' (Consequence Costs and Human Health and Safety);
- Years 1 to 5: 'Moderately High' (Consequence Costs and Human Health and Safety); and
- Years 1 to 10: 'High' (Consequence Costs).

For all time frames the highest rating estimated, if preventative measures (including the repair of DS4) are implemented, was 'Moderately High'. This rating applied to the Consequence Costs consequence scenario based on the blockage of Hudgeon Lake failure mechanism.

Based on the observations made at the site and the results of this assessment, the triggers provided in the 2005 Long-Term Performance Monitoring Program report (R22 UMA 2006) remain valid.

The responses associated with the trigger levels that have been reached should be implemented as soon as possible.

#### 8.1.2 Clinton Creek Cascading Failure

For all time frames the highest rating estimated for the cascading failure of Clinton Creek, if DS4 is not repaired, was 'High'. This rating applied to the Environmental Impact, Legal Obligations, and Consequence Costs consequence scenarios.

For all time frames the highest rating estimated for the cascading failure of Clinton Creek, if preventative measures are implemented, was 'Moderately High'. This rating applied to the Consequence Costs and Human Health and Safety consequence scenarios based on both the extreme flow and blockage of Hudgeon Lake failure mechanisms.

### 8.2 Recommendations

Based on the results of the risk assessment, AAM should consider the following recommendations, discussed in the following sections:

- Repair DS4 as soon as possible;
- Remove woody debris from Clinton Creek channel prior as soon as possible;

- Install and remotely monitor a water level gauge at the Hudgeon Lake outlet; and
- Survey the Hudgeon Lake outlet on an annual basis.

### **8.2.1 Repair DS4**

As a 'High' risk rating was estimated for the complete failure of DS4 and the cascading failure of Clinton Creek, and that the costs of repairing DS4 are anticipated to increase with time due to ongoing destabilization. It is recommended that the proposed plan for the completion of repairs to DS4 developed by WorleyParsons (2014) is implemented as soon as possible.

Repairing DS4 as soon as possible will provide the following benefits:

- Limits cost escalation to complete the repair plan;
- Reduces the likelihood of the complete failure of DS4 due to the release of a blockage of Hudgeon Lake in Year 1 from 'Likely' to 'Possible'; and
- Reduces the likelihood of cascading failure due to the release of a blockage of Hudgeon Lake in Year 1 from 'Possible' to 'Very Unlikely'.

### **8.2.2 Removal of Woody Debris**

It is recommended that the large woody debris that has collected in the channel and along the gabion baskets is removed as soon as possible. Due to its instability, it is not recommended that large woody debris is removed from DS4.

It is anticipated that the installation of the log boom will reduce the accumulation of debris in the channel; however, the channel should still be inspected on a regular basis for debris.

### **8.2.3 Water Level Gauge**

It is recommended that an automated, remote water level gauge is installed at the Hudgeon Lake outlet and regularly monitored by AAM staff for rising water levels which may indicate a blockage at the outlet. Furthermore, a protocol should be developed to define the following:

- The water level above which AAM staff will be mobilized to site to inspect the outlet;
- How to conduct the inspection in a safe manner; and
- The severity of blockage that requires removal as well as the timeframe in which it should be removed.

### **8.2.4 Hudgeon Lake Outlet Survey**

It is recommended that the Hudgeon Lake outlet is inspected and surveyed on an annual basis.

The survey would include the following components:

- Hudgeon Lake outlet cross-sections;
- Boom structure abutments; and
- Riprap around boom structure abutments.



## 9. REFERENCES

R22 UMA Engineering (2006): Former Clinton Creek Asbestos Mine Long-Term Performance Monitoring Program - 2005.

R48 Government of Yukon Energy, Mines and Resources Abandoned Mines Project Office and INAC Yukon Region, Waste Management Program (2003): Stage 2 (2003) Clinton Creek Channel Stabilization.

R51 AECOM (2011): Former Clinton Creek Asbestos Mine Long-Term Performance Monitoring Program - 2010.

R94 AECOM (2011): Former Clinton Creek Mine Emergency Drop Structure Repairs Construction Activity Report - 2011.

R100 AECOM (2010): September 7, 2010 Letter to Brett Hartshorne (Project Manager with AAM) Re: Former Clinton Creek Asbestos Mine - Site Inspection on August 23, 2010.

R104 Associated Engineering (2013): Former Clinton Creek Asbestos Mine Long-Term Performance Monitoring, 2012.

Canadian Minister of Justice (2013): *Fisheries Act*.

WorleyParsons (2014): Clinton Creek Drop Structure No. 4 Repair - Design Summary.

## Appendix 1 Site Visit Photographs





**Photo 1: Access Road north of Porcupine Pit looking east.**



**Photo 2: Access Road north of Porcupine Pit looking south.**



**Photo 3: Access Road east of DS4 looking north.**



**Photo 4: Access Road east of DS4 looking east.**



**Photo 5: Access road north of Snowshoe Pit looking northwest.**



**Photo 6: Access road north of Snowshoe Pit looking west.**



**Photo 7: Access road north of Snowshoe Pit looking west.**



**Photo 8: Decommissioned access road and Clinton Creek east of DS4 looking west.**



**Photo 9: Decommissioned access road east of DS4 looking southwest.**



**Photo 10: Decommissioned access road east of DS4 looking southwest.**



**Photo 11: Decommissioned access road and Clinton Creek east of DS4 looking west.**



**Photo 12: Decommissioned access road and Clinton Creek east of DS4 looking west.**



**Photo 13: Decommissioned access road east of DS4 looking north.**



**Photo 14: Decommissioned access road east of DS4 looking east.**



**Photo 15: Mill access road north of Hudgeon Lake looking east.**



**Photo 16: Mill access road north of Hudgeon Lake looking east.**



**Photo 17: Mill access road north of Clinton Creek looking northeast.**



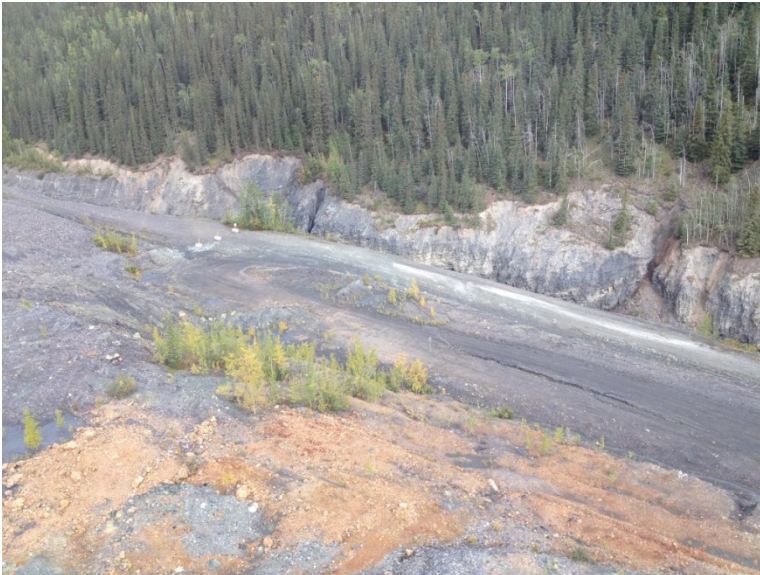
**Photo 18: Access Road at Primary Ford Crossing looking south.**



**Photo 19: Access road west of confluence of Clinton Creek and Wolverine Creek looking northeast.**



**Photo 20: Access road north of Snowshoe Pit looking north.**



**Photo 21: Access road north of Snowshoe Pit looking northwest.**



**Photo 22: Access road at confluence of Clinton Creek and Wolverine Creek looking southwest.**



**Photo 23: Access road at primary ford crossing looking south.**



**Photo 24: DS1 looking north.**



**Photo 25: DS1 looking north.**



**Photo 26: Tension cracks located along south bank of DS1 looking east (downstream).**



**Photo 27: DS2 looking northwest.**



**Photo 28: DS3 looking north.**



**Photo 29: Vertically displaced gabion basket at DS3 looking northeast.**



**Photo 30: DS3 looking northwest.**



**Photo 31: DS3 looking northwest.**



**Photo 32: Vertically displaced gabion basket at DS3 looking north.**



**Photo 33: DS4 looking north.**



**Photo 34: DS4 looking north.**



**Photo 35: Failed gabion basket downstream (east) of DS4.**



**Photo 36: Tension cracks along south bank of DS4 looking west (upstream).**



**Photo 37: DS4 looking northwest.**



**Photo 38: DS4 looking north.**



**Photo 39: DS4 looking northwest.**



**Photo 40: DS4 looking northwest.**



**Photo 41: DS4 in 2013 looking north.**



**Photo 42: DS4 in 2013 looking north.**



**Photo 43: Drop structures looking northwest.**



**Photo 44: Drop structures looking east.**



**Photo 45: Drop structures looking north.**



**Photo 46: Drop structures looking north.**



**Photo 47: Waste dump looking northwest.**



**Photo 48: Waste dump looking southeast.**



**Photo 49: Hudgeon Lake outlet looking northwest.**



**Photo 50: Hudgeon Lake water level gauge looking west.**



**Photo 51: Hudgeon Lake water level gauge looking west.**



**Photo 52: Porcupine Pit looking southwest.**



**Photo 53: Porcupine Pit looking northeast.**



**Photo 54: Snowshoe Pit looking south.**



**Photo 55: Tailings slope looking north.**



**Photo 56: Tailings slope looking west.**



**Photo 57: Tailings slope looking southeast.**



**Photo 58: Tailings slope and Wolverine Creek looking southeast.**



**Photo 59: Tailings slope looking northwest.**



**Photo 60: Tailings slope looking northwest.**



**Photo 61: Tailings slope looking west.**



**Photo 62: Tailings slope looking southwest.**



**Photo 63: Tailings slope and tailings pond looking west.**



**Photo 64: Tailings slope and tailings pond looking west.**



**Photo 65: Tailings slope and tailings pond looking south.**



**Photo 66: Tailings slope looking southwest.**



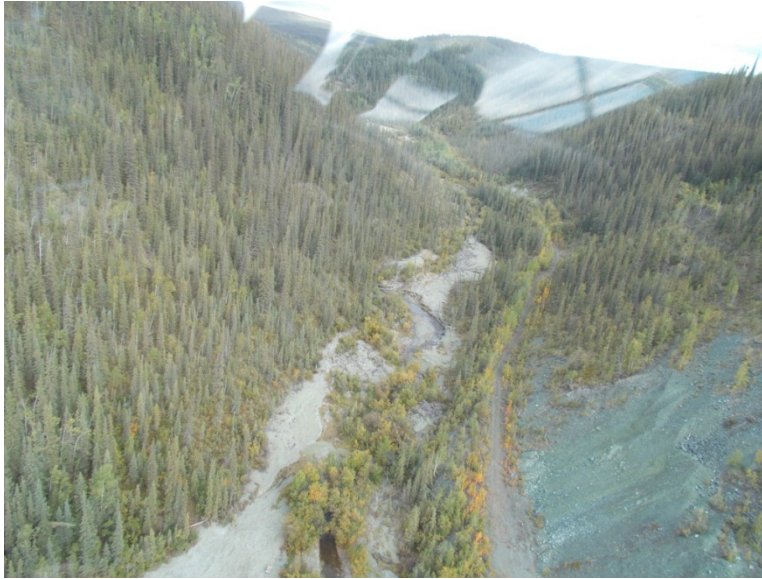
**Photo 67: Mill site looking south.**



**Photo 68: Wolverine Creek looking southeast.**



**Photo 69: Wolverine Creek at confluence with Clinton Creek looking east.**



**Photo 70: Wolverine Creek looking southeast.**



**Photo 71: Wolverine Creek at confluence with Clinton Creek looking southeast.**



**Photo 72: Wolverine Creek near confluence with Clinton Creek looking south (downstream toward access road).**



**Photo 73: Wolverine Creek north of confluence with Clinton Creek looking north.**



**Photo 74: Wolverine Creek north of confluence with Clinton Creek looking northeast (upstream).**



**Photo 75: Wolverine Creek north of confluence with Clinton Creek looking north (upstream).**



**Photo 76: Wolverine Creek north of  
confluence with Clinton Creek  
looking east.**



**Photo 77: Wolverine Creek north of confluence with Clinton Creek looking east.**



**Photo 78: Wolverine Creek north of confluence with Clinton Creek looking east.**



**Photo 79: Wolverine Creek north of confluence with Clinton Creek looking east.**



**Photo 80: Wolverine Creek north of confluence with Clinton Creek looking northeast.**



**Photo 81: Wolverine Creek tailings ponds looking southeast.**

## Appendix 2 Risk Assessment Summary



Number	Event	Existing Preventative Measures	Timeframe	Assumed Failure Trigger	Likelihood of Failure	Consequence Type and Description	Risk Severity Before Treatment			Recommended Preventative Measures	Risk Severity After Treatment																							
							Likelihood	Consequence	Risk Rating Before Treatment		Likelihood	Consequence	Risk Rating After Treatment																					
1	Conveyance of an extreme flood event causes the complete failure of DS4 (i.e., collapse of the gabion baskets exposing underlying granular materials to erosion and destabilization of the channel embankment)	Annual inspection, including topographic survey, of DS4 by consultant and monthly inspections by AAM staff during the summer.  Security measures to limit access by unauthorized users.  Safety measures to prohibit workers and staff from accessing DS4 or working downstream during periods of high flow without a detailed safety plan approved by AAM.	Year 1 to Year 2	Ongoing structural failure or extreme flow: 40-year peak instantaneous flow (32 m <sup>3</sup> /s)	<i>Possible</i>	Environmental Impact - downstream deposition of granular materials as a direct result of the failure of DS4 (i.e., release of subgrade material and waste rock below and behind DS4) and increased erosion of Clinton Creek channel and embankment material resulting in minor or short-term impacts to the local ecosystem	Possible	Minor	Moderate	Repair DS4 using concrete revetments to withstand up to 100-year peak instantaneous flow (39 m <sup>3</sup> /s)	Unlikely	Minor	Low																					
Possible							Minor	Moderate	Unlikely		Minor	Low																						
Possible							Moderate	Moderately High	Unlikely		Moderate	Moderate																						
Unlikely							Major	Moderately high	Very Unlikely		Major	Moderate																						
Possible							Minor	Moderate	Unlikely		Minor	Low																						
2			Year 1 to Year 5	Ongoing structural failure or extreme flow: 1) 40-year peak instantaneous flow (32 m <sup>3</sup> /s) from Year 1 to Year 2; 2) 15-year peak instantaneous flow (26 m <sup>3</sup> /s) from Year 3 to Year 5	<i>Likely</i>	Environmental Impact - downstream deposition of granular materials as a direct result of the failure of DS4 (i.e., release of subgrade material and waste rock below and behind DS4) and increased erosion of Clinton Creek channel and embankment material resulting in minor or short-term impacts to the local ecosystem	Likely	Minor	Moderate		Unlikely	Minor	Low																					
Likely							Minor	Moderate	Unlikely		Minor	Low																						
Likely							Moderate	Moderately High	Unlikely		Moderate	Moderate																						
Unlikely							Major	Moderately high	Very Unlikely		Major	Moderate																						
Possible							Minor	Moderate	Unlikely		Minor	Low																						
3							Year 1 to Year 10	Ongoing structural failure or extreme flow: 1) 40-year peak instantaneous flow (32 m <sup>3</sup> /s) from Year 1 to Year 2; 2) 15-year peak instantaneous flow (26 m <sup>3</sup> /s) from Year 3 to Year 5; 3) 5-year peak instantaneous flow (21 m <sup>3</sup> /s) from Year 5 to Year 10	<i>Almost Certain</i>		Environmental Impact - downstream deposition of granular materials as a direct result of the failure of DS4 (i.e., release of subgrade material and waste rock below and behind DS4) and increased erosion of Clinton Creek channel and embankment material resulting in minor or short-term impacts to the local ecosystem	Almost Certain	Minor	Moderately High	Unlikely	Minor	Low																	
Almost Certain												Minor	Moderately High	Unlikely	Minor	Low																		
Almost Certain												Moderate	High	Unlikely	Moderate	Moderate																		
Unlikely												Major	Moderately High	Very Unlikely	Major	Moderate																		
Possible												Minor	Moderate	Unlikely	Minor	Low																		
4	All timeframes	Minor blockage of the Hudgeon Lake outlet due to the accumulation of debris causes restriction of outflow from the lake and elevated water levels at the outlet. The release of the blockage would result in the discharge of an extreme flow	<i>Likely</i>	Environmental Impact - downstream deposition of granular materials as a direct result of the failure of DS4 (i.e., release of subgrade material and waste rock below and behind DS4) and increased erosion of Clinton Creek channel and embankment material resulting in minor or short-term impacts to the local ecosystem	Likely	Minor	Moderate	Repair DS4 using concrete revetments.  Ensure that the PVC boom is in place at the start of every summer.  Install and remotely monitor a water level gauge at the Hudgeon Lake outlet to notify AAM of high water levels that may indicate a blockage. Develop a protocol to determine water depths above which AAM staff are sent to site to investigate and determine if the channel is blocked.	Possible	Minor	Moderate																							
Likely					Minor	Moderate	Possible		Minor	Moderate																								
Likely					Moderate	Moderately High	Possible		Moderate	Moderately High																								
Unlikely					Major	Moderately High	Very Unlikely		Major	Moderate																								
Possible					Minor	Moderate	Unlikely		Minor	Low																								
5	Human Health and Safety a) Major - single fatality or severe, irreversible disability / impairment if a worker or recreational user is in the vicinity of DS4 at time of failure. Given that persons are rarely in the vicinity of DS4 due to its high instability, the likelihood of this scenario was considered to be <i>Unlikely</i> based on a reduced probability that a person would be present at the exact time of failure	Human Health and Safety b) Minor - objective but reversible disability / impairment and / or injuries requiring hospitalization if a worker or recreational user is located downstream of DS4 at time of failure	<i>Possible</i>	Human Health and Safety a) Major - single fatality or severe, irreversible disability / impairment if a worker or recreational user is in the vicinity of DS4 at time of failure. Given that persons are rarely in the vicinity of DS4 due to its high instability, the likelihood of this scenario was considered to be <i>Unlikely</i> based on a reduced probability that a person would be present at the exact time of failure	Human Health and Safety b) Minor - objective but reversible disability / impairment and / or injuries requiring hospitalization if a worker or recreational user is located downstream of DS4 at time of failure	Possible	Minor	Moderate	Unlikely	Minor	Low																							
Human Health and Safety a) Major - single fatality or severe, irreversible disability / impairment if a worker or recreational user is in the vicinity of DS4 at time of failure. Given that people are rarely in the vicinity of DS4 due to its high instability, the likelihood of this scenario was considered to be <i>Unlikely</i> based on a reduced probability that a person would be present at the exact time of failure												Human Health and Safety b) Minor - objective but reversible disability / impairment and / or injuries requiring hospitalization if a worker or recreational user is located downstream of DS4 at time of failure	Possible	Minor	Moderate	Unlikely	Minor	Low																
																			Human Health and Safety a) Major - single fatality or severe, irreversible disability / impairment if a worker or recreational user is in the vicinity of DS4 at time of failure. Given that people are rarely in the vicinity of DS4 due to its high instability, the likelihood of this scenario was considered to be <i>Unlikely</i> based on a reduced probability that a person would be present at the exact time of failure	Human Health and Safety b) Minor - objective but reversible disability / impairment and / or injuries requiring hospitalization if a worker or recreational user is located downstream of DS4 at time of failure	Possible	Minor	Moderate	Unlikely	Minor	Low								
																											Human Health and Safety a) Major - single fatality or severe, irreversible disability / impairment if a worker or recreational user is in the vicinity of DS4 at time of failure. Given that people are rarely in the vicinity of DS4 due to its high instability, the likelihood of this scenario was considered to be <i>Unlikely</i> based on a reduced probability that a person would be present at the exact time of failure	Human Health and Safety b) Minor - objective but reversible disability / impairment and / or injuries requiring hospitalization if a worker or recreational user is located downstream of DS4 at time of failure	Possible	Minor	Moderate	Unlikely	Minor	Low

Number	Event	Existing Preventative Measures	Time Frame	Assumed Failure Trigger	Likelihood of Failure	Consequence Type and Description	Risk Severity Before Treatment			Recommended Preventative Measures	Risk Severity After Treatment						
							Likelihood	Consequence	Risk Rating Before Treatment		Likelihood	Consequence	Risk Rating After Treatment				
21	Conveyance of an extreme flood event results in the cascading failure of the Clinton Creek channel	Annual inspection, including topographic survey, of DS4 by consultant and monthly inspections by AAM staff during the summer.  Security measures to limit access by unauthorized users.  Safety measures to prohibit workers and staff from accessing DS4 or working downstream during periods of high flow without a detailed safety plan approved by AAM.	Year 1 to Year 2	Extreme flow: 1,000-year peak instantaneous flow (55 m <sup>3</sup> /s)	Very Unlikely	Environmental Impact - downstream deposition of granular materials and geomorphological alteration of downstream portions of the Clinton Creek channel resulting in significant impact on valued ecosystem component and medium-term impairment of ecosystem function  Legal Obligations - The cascading failure could result in a breach of regulations including the Fisheries Act and the issuance of an order / direction or prosecution taken by EC or Compliance, Monitoring and Inspection (EMR) Yukon  Consequence Costs - significant clean up and remediation costs, potentially greater than \$10 million  Human Health and Safety a) Critical - multiple fatalities if workers or recreational users were within the Clinton Creek floodplain at the time of the rapid drawdown of Hudgeon Lake  Human Health and Safety b) Moderate - moderate irreversible disability or impairment to one or more people if workers or recreational users were located in the Clinton Creek valley at the time of the rapid drawdown of Hudgeon Lake	Very Unlikely	Major	Moderate	Repair DS4 using concrete revetments so that Clinton Creek channel can withstand a peak instantaneous flow with a return period greater than 1,000 years (i.e., > 55 m <sup>3</sup> /s).	Very Unlikely	Major	Moderate				
22							Very Unlikely	Major	Moderate		Very Unlikely	Major	Moderate				
23							Very Unlikely	Critical	Moderately High		Very Unlikely	Critical	Moderately High				
24							Very Unlikely	Critical	Moderately High		Very Unlikely	Critical	Moderately High				
25							Unlikely	Moderate	Moderate		Very Unlikely	Moderate	Low				
26			Year 1 to Year 5	Extreme flow: 1) 1,000-year peak instantaneous flow (55 m <sup>3</sup> /s) from Year 1 to Year 2; 2) 200-year peak instantaneous flow (45 m <sup>3</sup> /s) from Year 3 to Year 5.	Unlikely	Environmental Impact - downstream deposition of granular materials and geomorphological alteration of downstream portions of the Clinton Creek channel resulting in significant impact on valued ecosystem component and medium-term impairment of ecosystem function  Legal Obligations - The cascading failure could result in a breach of regulations including the Fisheries Act and the issuance of an order / direction or prosecution taken by EC or Compliance, Monitoring and Inspection (EMR) Yukon  Consequence Costs - significant clean up and remediation costs, potentially greater than \$10 million  Human Health and Safety a) Critical - multiple fatalities if workers or recreational users were within the Clinton Creek floodplain at the time of the rapid drawdown of Hudgeon Lake. Given that human activity at the site is infrequent, the likelihood of this scenarios was considered to be Very Unlikely based on a reduced probability that a person would be in the vicinity of the channel at the exact time of failure  Human Health and Safety b) Moderate - moderate irreversible disability or impairment to one or more people if workers or recreational users were located in the Clinton Creek valley at the time of the rapid drawdown of Hudgeon Lake	Unlikely	Major	Moderately High		Very Unlikely	Major	Moderate				
27							Unlikely	Major	Moderately High		Very Unlikely	Major	Moderate				
28							Unlikely	Critical	Moderately High		Very Unlikely	Critical	Moderately High				
29							Very Unlikely	Critical	Moderately High		Very Unlikely	Critical	Moderately High				
30							Unlikely	Moderate	Moderate		Very Unlikely	Moderate	Low				
31							Year 1 to Year 10	Extreme flow: 1) 1,000-year peak instantaneous flow (55 m <sup>3</sup> /s) from Year 1 to Year 2; 2) 200-year peak instantaneous flow (45 m <sup>3</sup> /s) from Year 3 to Year 5; 3) 40-year peak instantaneous flow (32 m <sup>3</sup> /s) from Year 5 to Year 10	Possible		Environmental Impact - downstream deposition of granular materials and geomorphological alteration of downstream portions of the Clinton Creek channel resulting in significant impact on valued ecosystem component and medium-term impairment of ecosystem function  Legal Obligations - The cascading failure could result in a breach of regulations including the Fisheries Act and the issuance of an order / direction or prosecution taken by EC or Compliance, Monitoring and Inspection (EMR) Yukon  Consequence Costs - significant clean up and remediation costs, potentially greater than \$10 million  Human Health and Safety a) Critical - multiple fatalities if workers or recreational users were within the Clinton Creek floodplain at the time of the rapid drawdown of Hudgeon Lake. Given that human activity at the site is infrequent, the likelihood of this scenarios was considered to be Very Unlikely based on a reduced probability that a person would be in the vicinity of the channel at the exact time of failure  Human Health and Safety b) Moderate - moderate irreversible disability or impairment to one or more people if workers or recreational users were located in the Clinton Creek valley at the time of the rapid drawdown of Hudgeon Lake	Unlikely	Major	Moderately High	Very Unlikely	Major	Moderate
32												Unlikely	Major	Moderately High	Very Unlikely	Major	Moderate
33												Unlikely	Critical	Moderately High	Very Unlikely	Critical	Moderately High
34												Very Unlikely	Critical	Moderately High	Very Unlikely	Critical	Moderately High
35												Unlikely	Moderate	Moderate	Very Unlikely	Moderate	Low
36		The release of a major blockage of Hudgeon Lake causes the cascading failure of the Clinton Creek channel (including all drop structures and the Hudgeon Lake outlet structure) and the rapid drawdown of Hudgeon Lake	Inspect DS4 and maintain security / safety measures (as above).  PVC boom at the outlet structure to collect debris and withstand hydrostatic forces acting against the blockage until the blockage can be cleared.	All timeframes	Major blockage of the Hudgeon Lake outlet due to the accumulation of debris causes restriction of outflow from the lake and elevated water levels at the outlet. The release of the blockage would result in the discharge of an extreme flow	Possible	Environmental Impact - downstream deposition of granular materials and geomorphological alteration of downstream portions of the Clinton Creek channel resulting in significant impact on valued ecosystem component and medium-term impairment of ecosystem function  Legal Obligations - The cascading failure could result in a breach of regulations including the Fisheries Act and the issuance of an order / direction or prosecution taken by EC or Compliance, Monitoring and Inspection (EMR) Yukon  Consequence Costs - significant clean up and remediation costs, potentially greater than \$10 million  Human Health and Safety a) Critical - multiple fatalities if workers or recreational users were within the Clinton Creek floodplain at the time of the rapid drawdown of Hudgeon Lake. Given that human activity at the site is infrequent, the likelihood of this scenarios was considered to be Very Unlikely based on a reduced probability that a person would be in the vicinity of the channel at the exact time of failure  Human Health and Safety b) Moderate - moderate irreversible disability or impairment to one or more people if workers or recreational users were located in the Clinton Creek valley at the time of the rapid drawdown of Hudgeon Lake	Possible	Major	High	Repair DS4 using concrete revetments.  Ensure that the PVC boom is in place at the start of every summer.  Install and remotely monitor a water level gauge at the Hudgeon Lake outlet to notify AAM of high water levels that may indicate a blockage. Develop a protocol to determine water depths above which AAM staff are sent to site to investigate and determine if the channel is blocked.	Very Unlikely	Major	Moderate			
37								Possible	Major	High		Very Unlikely	Major	Moderate			
38								Possible	Critical	High		Very Unlikely	Critical	Moderately High			
39								Very Unlikely	Critical	Moderately High		Very Unlikely	Critical	Moderately High			
40								Unlikely	Moderate	Moderate		Very Unlikely	Moderate	Low			