

September 8, 2021

Government of Yukon
Box 2703
Whitehorse, Yukon Y1A 2C6

Attention: Mr. Luc Bibeau
Incident Commander
Southern Lakes Flood Incident Comment

Re: Yukon Emergency Flood Protection Works – Status Update

Dear Mr. Bibeau:

The Government of Yukon has requested a formal updating of the status of Yukon emergency flood protection works near Marsh Lake, Yukon. The letter is prepared in response to emails received by KGS Group staff on August 18, 2021 and August 25, 2021, sent by Cal Read requesting recommendations moving forward. A preliminary email update was provided by KGS Group's Dr. Rob Kenyon, P.Eng., FEIC on August 24, 2021.

1.0 CURRENT STATUS

Since late June 2021, Yukon has been facing historic flood levels in the southern lakes region, requiring emergency flood engineering and flood response assistance. Affected areas include Marsh Lake, specifically the Army Beach, South M'clintock and Bayview areas. Assistance was also provided to the communities at Carcross, Tagish and Lake Laberge. Those areas are not addressed specifically in this report but most of the discussions and recommendations at Marsh Lake would generally be applicable in those communities as well.

As of August 27, 2021, lake levels were at approximately 2007 peak flood elevations (email by Anthony Bier, August 27, 2021) with lake levels projected to be 1 m below August 27 levels by freeze-up.

1.1 Existing Infrastructure

In the Marsh Lake area, emergency flood protection was constructed by a combination of private owners, volunteers, Canadian Armed Forces (CAF) and by Yukon. The dike systems are variable from property to property, but consisted of one of:

Early earth dikes of sand and gravel were first pushed into place in late June, as a first response, and prior to KGS Group's arrival, as per Photo 1 below. The dikes were intended as this first response to secure sites until more resources were available (sand bags and superbags were limited initially) and awaiting arrival of the engineering emergency response team of KGS Group, Manitoba Infrastructure, and Canadian Armed Forces (CAF).



Photo 1. Early Earth Dike of Sand and Gravel.

Many of the early earth dikes were wrapped with poly wrap as per Photo 2 below.



Photo 2. Typical Sand and Gravel Dike, Wrapped in Poly.

Sandbag dikes were used frequently, constructed both by homeowners and later by the army. Photo 3 is typical of a dike in early July. That dike was later raised another 1 metre and all of the deck was removed. Photo 4 is another example of an early sandbag dike. Note in that photo the murky, sandy coloured water, indicative of ongoing shoreline erosion. Shoreline erosion and undermining was a common threat in numerous areas.



Photo 3. Typical Sandbag dike

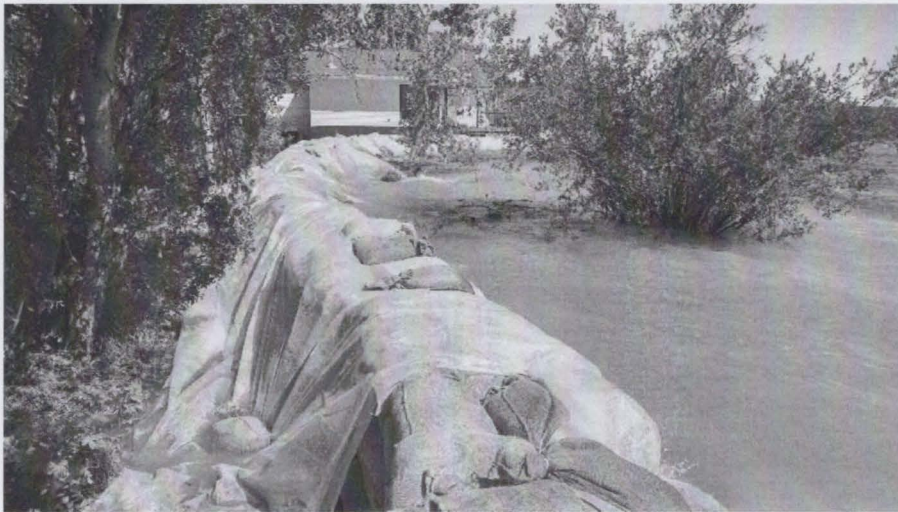


Photo 4. Typical Sandbag Dike



Photo 5. Superbag Dikes along South M'clintock Road.

Super bag dikes, as per Photo 5 and Photo 6, were used in areas where equipment access was readily available, both to protect critical access roads (Photo 5) as well as homes (Photo 6).



Photo 6. Super bag dike (background along lake shore) being constructed to replace exposed sand and gravel dike (right side, middle of photo).

Many of the early dikes were particularly susceptible to undermining of foundations and internal erosion of the dike (sand and gravel). A plume of silt along the shoreline meant, for example, that the fines were being washed out of the sand and gravel dikes. If left unchecked, dike failure would be the consequence.

This concern resulted in a second line of dikes being constructed in numerous locations along Army Beach, South M'clintock, and Bayview Road, now set back further from the shoreline, once the Canadian Armed Forces had arrived. Photo 7 shows such a typical reconstruction. The concern was that if any one dike failed then an entire community might be inundated.



Photo 7. Second Line of Sandbag Dikes Constructed Behind Original Dike Line

Dikes were typically founded on highly permeable beach sand deposits, and as such, the dikes were particularly susceptible to foundation seepage and potential foundation blowout under higher flood levels and/or wave action.

Beach and shoreline erosion protection was variable along the flooded areas, with some shoreline properties being natural unguarded shoreline, and others being protected by various systems including rockfill riprap, concrete lock-blocks and gabion baskets. Shoreline protection, such as a riprap blanket, not only reduces the potential for shoreline erosion, but it also acts as an energy dissipator to reduce wave uprush energy and height during high wind events.

The existing dikes were constructed as emergency flood works and were not intended to be long-lasting flood protection systems. The dikes are intended to last a single flood event but may remain stable for up to one year.

Properties with super bag dike structures or sandbag dike structures, constructed by CAF, have been the most stable and secure flood protection works to date. Sand and gravel dikes or poly-wrapped sand dikes were particularly susceptible to shoreline washout during wave action and wind. Almost all of them were replaced with the more secure diking systems once the CAF support became available in July.

In all situations properties with erosion protection are much less susceptible to erosion.

1.2 System Threats

Dike and foundation seepage were and are ongoing technical issues in all areas where the temporary dikes have been constructed. To date, there has been no observed foundation soil migration below the flood protection structures, causing piping or foundation blowouts. Depending on the lake levels during freeze-up, ground icing behind the dikes may become a concern throughout the winter as saturated soils freeze and as groundwater seepage continues.

As long as monitoring of the current diking infrastructure continues daily, KGS Group is confident that these structures can be maintained in their current condition until at least freeze-up of 2021 or until lake levels subside to the point where wave action is no longer a threat.

High winds were and are the greatest threat to the dike system at current lake levels. Winds will continue to be the biggest unknown until freeze-up.

A secondary unknown remains the projection of the drawdown rate on the lake. If water levels are drawn down below flood levels, flood risk decreases significantly. Current projections are that lake levels will drop a further one metre before freeze-up. Current lake levels are approximately 0.4 m below the peak elevations of early July, 2021.

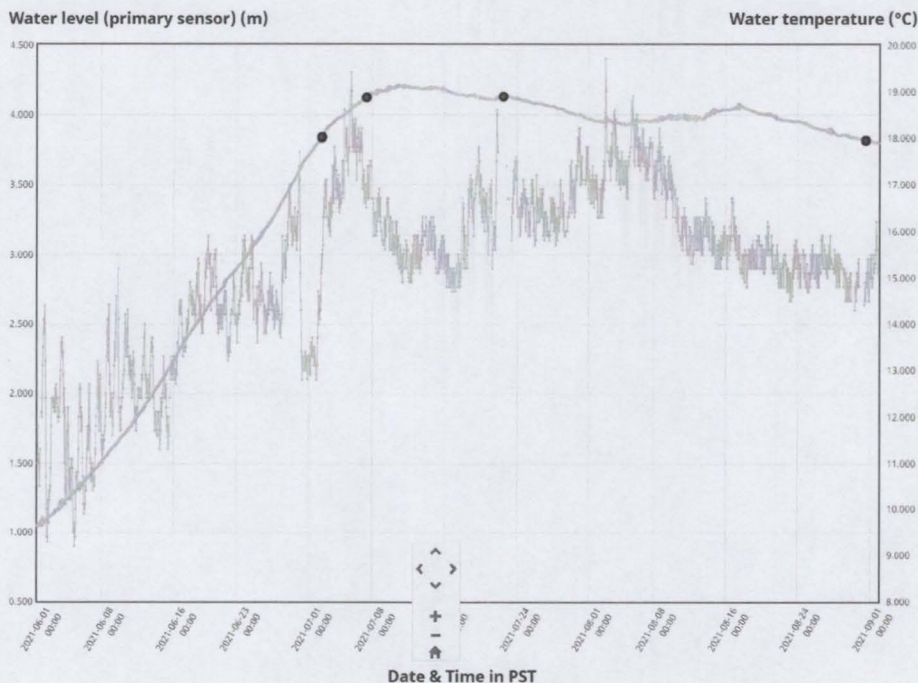
Moving forwards into winter months, ice action could become a risk, where ice thrusting with wind setup can push ice pans up the slope to the dikes. Temporary dikes were not designed to withstand any sort of ice thrusting, which therefore could result in further issues if levels were to remain high throughout winter.

2.0 NEAR-TERM RECOMMENDATIONS

Figure 1 shows the Marsh Lake Gauging Station hydrograph from the beginning of the flood event to September 1, 2021. On September 1, 2021, Marsh Lake gauging station was reading 3.81 m, local datum, which in Canadian Geodetic Vertical Datum 2013 is Elevation 657.48 m. All surveying during this event has been to the 2013 reference datum. Confusion can occur because prior to 2013, including the LiDAR survey, all levels were referenced to a Canadian Geodetic Survey of Canada Datum which is listed as 0.315 m lower than the later 2013 datum.

Regardless of the datum, lake levels had dropped approximately 0.4 m by September 1 versus the early July peak. Latest lake level projections, as provided by email (Anthony Bier to cffc@yukon.ca and Holly Goulding, August 27, 2021) are that "YEC has high confidence that freeze-up will occur below Full Supply Level of 656.23 (>1 m below current levels)". We understand that to mean that lake levels are anticipated to drop a further metre from current levels before freeze-up. That prediction would be consistent with the lake drawdown rate shown in the last two weeks on Figure 1. If so, that places the lake level at approximately 1.4 m lower than its early July peak.

FIGURE 1. GOVERNMENT OF CANADA HYDROMETRIC GAUGING DATA, MARSH LAKE GAUGE



KGS Group understands that Yukon is facing pressure from residents to remove dikes in areas where water levels appear to have receded below the base of the berm. On the other hand, there is significant concern by Yukon

that a repeat flood event could occur in 2022. Following are comments and suggestions provided to guide that decision making process.

KGS Group recommends that a working group of emergency engineering staff and Yukon planning and operational staff and decision makers meet, mid-September, to develop a formal plan and schedule for takedown of the dikes. KGS Group has been part of such working groups in other jurisdictions. The first task is to establish what criteria must be met before the dikes can be taken down. In making those decisions it is important to realize that most individual property dikes form a part of a larger community ring dike. In many areas that means that if one dike comes down, then the rest of the dikes within that community are no longer providing protection to the property because of potential "end run". As a starting point, it might be considered that once lake levels are 0.9 m below the base of the community diking system, then the dikes should be removed. We offer the suggestion of 0.9 m, as a discussion point for now, because at that stage the shorelines will provide protection against most moderate wind action in terms of wind set up and wave action. A final decision should also include an analysis of the probability of various wave heights that may occur between mid-September and freeze-up. KGS Group could provide that analysis, if requested. A hydraulic review of historic winter / spring ice thrust due to wind shear should also be completed.

Other technical considerations in any decision matrix include the main floor elevations of the houses or seasonal cabins, along with the actual topographic profile between the lake level and the dwelling. KGS Group understands that Stantec has completed surveys along the base of the dikes, the top of the dikes, the main house floor elevations, as well as typical topographic sections from lake level to the individual houses at each property. That data, and the resulting plans and profiles, along with the projected lake elevations, are necessary to make informed assessments and technical recommendations about where and when dikes come down.

Planning, operational and administration considerations will include who takes down the dikes and where is that material to be disposed of. Other jurisdictions have, at times, either relied upon the residents to take down their own dikes or contracts have been let to complete the work of removal and disposal. More recently, agencies have chosen to let contracts to remove dikes. In order to make informed decisions in this regard it is important to complete an inventory of dike constructions (sand and gravel, sandbag quantities, super bag quantities) on a property-by-property basis, particularly if the decision is to tender and let contracts for dike removal. Disposal sites must be identified and either developed or provided. Typically an environmental inspection of dike materials is completed to ensure that they dike materials have not been contaminated by flood waters. This may be more applicable to other jurisdictions where flood waters may also contain increased chemical contamination, fuel oils, pesticides, etc. as a product of the flooding but it should be completed here in terms of due diligence.

Consideration is required as to what to do with the bags, either sandbags or the super bags. Typically poly-bags degrade rapidly when exposed to sunshine and typically the bags are not re-used after a full season of exposure. Suppliers, however, should be consulted with respect to the projected design life of the fabric of the particular type of bag. Our experience elsewhere is that the sandbags are not re-used. They are frequently made available for re-use by the owners or for pickup by others, once it is determined that there is no environmental liability.

3.0 ADDITIONAL INFORMATION TO GUIDE NEAR-TERM RESPONSE AND RECOVERY EFFORTS.

From a technical perspective there are several surveys and data that is necessary to guide both short term takedown and long term planning.

A new LiDAR based photogrammetrical survey should be completed in each of the affected areas. At Marsh Lake, for example, existing LiDAR was completed after the 2007 flood but pre-dates much of the flood upgrading works constructed subsequently by the owners. Recent works included raising of lots and homes and seasonal cabins in many areas, none of which is captured by the current LiDAR survey.

We understand that the topographic surveys are currently being performed by Stantec. That data is necessary to assist informed decisions in the near-term regarding property elevations versus lake levels, and to prioritize and schedule dike takedown.

In addition to the topographic surveys, it is necessary, as discussed earlier, to complete a quantity survey of sandbag quantities, super bag quantities, and sand and gravel dike quantities, both for a record of what was constructed, but also to enable contracts to be tendered on a competitive basis, if that is the decision by Yukon in terms of take-down.

KGS Group considers it prudent to conduct an environmental inspection, representative sampling and assessment of the dikes to ensure that the dikes have not suffered contamination of any kind (lagoons flooded, septic fields, chemicals etc), such that material disposal options are not affected by environmental constraints (landfill disposal not required).

4.0 OPTIONS FOR MANAGING THE DIKES

Earlier discussions and emails (Bruno Arpin, July 24, 2021 email to Luc Bebeau, Rob Kenyon August 24, 2021 email to Luc Bibeau) considered the options of:

- Leave in place
- Remove
- Rebuild, converting to permanent flood protection

Current lake level projections show that lake levels are currently dropping and are projected to continue dropping until freeze-up, at the current drawdown rate. Given these projections, it is KGS Group's opinion, based upon the information available, that:

- Leave in place remains an option but is no longer necessary for this event.
- Removal is a viable option with low risk of flooding occurring again in this year flood event.
- Rebuilding or converting the present system into a permanent flood protection system is neither practical nor viable.

- Timing of dike removal, this fall versus next spring, depends upon projected lake levels next summer under both ordinary snowfall events as well as a repeat of the 2020 / 2021 snowfall scenario. Ultimately the decision as to when to remove the dikes is based on risk assessment of possible flooding in 2022.

All works constructed to date are temporary and emergency in nature, including sand dikes, sandbag dikes, and super bag dikes. All internal drainage considerations have been handled on an “as required” basis using portable pumps, i.e. there is no formal mechanism for permanent internal drainage, a necessary component of all permanent diking systems.

At this time, lake level projections are available to freeze-up with a high level of confidence; projected levels which will be low enough to permit removal of the dikes with a low to minimal risk of additional flooding in the near future. At the same time, residents and owners are anxious to remove the dikes. Some owners also, therefore, have concluded that the need for these temporary works this calendar year is now minimal. KGS Group concludes therefore that it is no longer necessary to leave the dikes in place over winter for this flood event and that removal is now a viable option. However a formal decision regarding the removal schedule (this fall versus next spring) should include a risk assessment of possible 2022 flooding. If the dikes remain in place over winter, then convenient cutouts should be implemented to allow winter access onto the lake.

Rebuilding or converting the present system into permanent flood protection is considered impractical at this point in time. In other jurisdictions KGS Group has had excellent success converting emergency dikes into permanent diking systems but only where the emergency dikes were constructed of low permeability clays and constructed on low permeability clay foundations. In other words, it is most sensible to convert temporary dikes into permanent dikes when the emergency dikes are originally constructed of excellent soils on excellent foundations.

We are aware of one attempt to convert sandbag dikes into permanent dikes by covering the sandbags with earth and topsoil and grass, but those dikes proved problematic in the next flood event. Ultimately, they were ripped out during the next flood and replaced with a properly designed earthen dike. In the southern lakes, the diking systems, consist of adhoc combinations of poly-wrapped sand and gravel, sandbags, and super bags. Geometric configurations are therefore quite varied, depending on whether the dikes were construction by volunteers versus CAF constructed dikes. There is no practical way to convert these dikes, in-place, into permanent flood protection works.

KGS recommends that Yukon move forward with plans to remove the emergency dikes, either this fall or next spring.

5.0 LONG-TERM SOLUTIONS

The southern lakes region of Yukon has now experienced two floods of historic levels in the past 14 years. In both events, large temporary flood protection works were constructed and then removed. The cost of temporary works is significant and the disruption to daily lives is to be considered. Given that emergency

management of the flood response has largely been the responsibility of Yukon Wildland Fire Management staff, the response becomes problematic in a summer with a high incidence of forest fires.

The implementations of permanent flood protection works typically follows a path of preliminary and planning studies, environmental approvals, community approvals, funding, followed by detailed design and construction.

Studies typically begin with a Benefit-Cost analysis of temporary flood measures versus permanent flood protection works. KGS Group has completed numerous such studies in the past, including the historic Red River basin flooding in 1997, the City of Winnipeg flooding in 1997, the Assiniboine Basin historic flood of record in 2011, as well as numerous smaller events in southern Ontario and elsewhere. The purpose of this study is to evaluate the economic, environmental, and social benefits of permanent flood protection systems versus ad hoc responses on an as-required basis. These studies also become important in procuring funding for any permanent measures.

Preliminary designs are required to support application for environmental and regulatory approvals for the project and to provide updated cost estimates. All designs must include appropriate geotechnical investigations, environmental and heritage mapping and investigations, hydrologic analysis, mapping and surveys, selection of an appropriate flood protection level, followed by dike design, shoreline protection, and interior drainage design. Here dikes must be designed to accommodate through-dike seepage, foundation seepage, and wave action.

The permanent flood protection study would allow the Yukon to evaluate different alternatives, examining their advantages and disadvantages. This option would have the engineering proponent complete a hydraulic, hydrologic and geotechnical study of the project area, developing a number of permanent flood solutions to present to the Yukon, and complete an evaluation matrix of each option. Construction and design cost estimates would also be developed for each proposed solution.

At the time of writing this letter report, options could include, but are not limited to a naturalized, flattened dune-type structures, acting as a water protection barrier on which temporary flood protection works can be constructed if flood levels reach threshold elevations. The benefits of raising houses and other structures above the design FPL is part of that consideration. Other options would include conventional diking, such as provided in the 2008 EBA study, but with updated flood levels and designs.

Public engagement would be of great importance to any permanent flood protection system, and KGS Group suggests that “lessons learned” and “what we heard” sessions be held with locals and stakeholders, sharing past experiences and knowledge.

6.0 MOVING FORWARD- LESSONS LEARNED

6.1 Construction Report

A construction report outlining all works completed throughout the emergency flood response will be developed by KGS Group. This report will contain details about all completed emergency flood protection works, lessons learned, updated maps of affected areas.

The construction report would be accompanied by a photo log of the project as well as estimated volumes and resources used in the construction of temporary works.

This construction report serves as a technical record of the flood and flood fighting activities, and will serve as a valuable document when considering future alternatives by the Yukon.

6.2 Lessons Learned Session

It has been KGS Group's experience that a "Lessons Learned" symposium or seminar is an important post-flood follow-up activity. The seminar would include input from all senior members of the flood response team and examine topics such as flood forecasting, flood planning, response to the flooding, and lessons learned. Such an event would be appropriate in the early winter of 2022, after dike removal but before forecasting starts to look at potential flood conditions in the summer of 2022.

7.0 CONCLUSIONS AND RECOMMENDATIONS

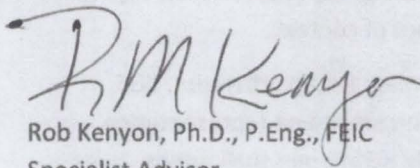
KGS Group's conclusions and recommendations for the project, both near-term and long-term, are provided below:

- Continued monitoring is required by a geotechnical engineer experienced in flood protection as long as flooding remains a threat. KGS Group recommends that all sites be inspected once a day.
- Maintain a rapid response team consisting of the following:
 - Supply of super bags (minimum of 100 at Marsh Lake)
 - Supply of sandbags
 - Stockpiled sand and gravel (5,000 m³)
 - Rapid access to contractors and equipment and labour (skid steers, tandems, small loaders)
- Implement planning and execution of emergency dike removal in mid-September, pending confirmation that lake levels are continuing to drop at current rates and an updated lake level forecast through the winter of 2022 by YEC.
- Institute a "lessons learned" seminar in early 2022 to review all aspects of the 2021 flood from initial forecasting to final dike removal.

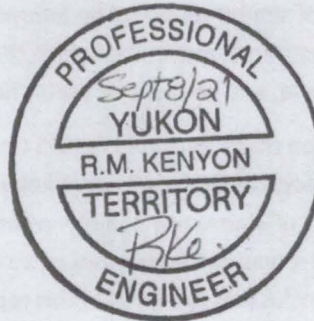
- Initiate a preliminary or feasibility study to examine the benefits of permanent flood protection works versus ongoing emergency response.

KGS Group appreciates the opportunity to have been involved in this emergency response and looks forward to working alongside the Yukon to develop a scope of work for such studies required in developing a long-term flood protection solution, along with cost estimates for discussion and review by Yukon.

Yours truly,


Rob Kenyon, Ph.D., P.Eng., FEIC
Specialist Advisor

RK/BPA/



STATEMENT OF LIMITATIONS AND CONDITIONS

Limitations

This report has been prepared for (Yukon) in accordance with the agreement between KGS Group and (Yukon) (the "Agreement"). This report represents KGS Group's professional judgment and exercising due care consistent with the preparation of similar reports. The information, data, recommendations and conclusions in this report are subject to the constraints and limitations in the Agreement and the qualifications in this report. This report must be read as a whole, and sections or parts should not be read out of context.

This report is based on information made available to KGS Group by (Yukon). Unless stated otherwise, KGS Group has not verified the accuracy, completeness or validity of such information, makes no representation regarding its accuracy and hereby disclaims any liability in connection therewith. KGS Group shall not be responsible for conditions/issues it was not authorized or able to investigate or which were beyond the scope of its work. The information and conclusions provided in this report apply only as they existed at the time of KGS Group's work.

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Any use a third party makes of this report or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

Geotechnical Investigation Statement of Limitations

The geotechnical investigation findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practice. The findings and recommendations are based on the results of field and laboratory investigations, combined with an interpolation of soil and groundwater conditions found at and within the depth of the test holes drilled by KGS Group at the site at the time of drilling. If conditions encountered during construction appear to be different from those shown by the test holes drilled by KGS Group or if the assumptions stated herein are not in keeping with the design, KGS Group should be notified in order that the recommendations can be reviewed and modified if necessary.