Columbia Water Use Plan

Monitoring Program Terms of Reference

CLBMON-8 Kinbasket Reservoir Monitoring of the Valemount Peatland

Addendum 1
January 31, 2019

A1.0 Addendum to CLBMON-8 Kinbasket Reservoir Monitoring of the Valemount Peatland

A1.1 Monitoring Program Rationale

During the Columbia River System Water Use Planning (WUP) process, the Water Use Plan Consultative Committee (WUP CC) recognized that riparian wetlands provide a variety of physical, biological, cultural and aesthetic benefits (BC Hydro 2005). Given the rarity of the remaining riparian habitats, the WUP CC further stated the importance of protecting and even enhancing these habitats through a series of physical works and monitoring programs to evaluate the potential impacts from dam and reservoir operations. In particular, the WUP CC expressed concern that water level fluctuations in the reservoir were causing significant erosion of the remaining Valemount wetland, threatening its long-term viability. First Nations committee members expressed additional concern that any erosion could potentially disturb archaeological sites existing within the drawdown zone.

Prior to the WUP, a study was undertaken to evaluate the potential for vegetation enhancement in Kinbasket Reservoir (Moody and Carr 2003), and a remnant wetland was identified. In 2006, the wetland was revisited and bands of disrupted peat deposits in the north and central portions of the fen indicated that this area may be eroding. The extent and rate of loss of the deposits were not quantified nor were investigations into potential mechanisms of erosion conducted.

The CLBMON-8 monitoring program was subsequently implemented under the WUP to assess the rate of peatland erosion due to wave action when Kinbasket Reservoir is at mid-pool elevations (739 m to 749 m) and to determine the extent to which on-going reservoir operations influence the erosion processes which affect long-term viability of the wetland.

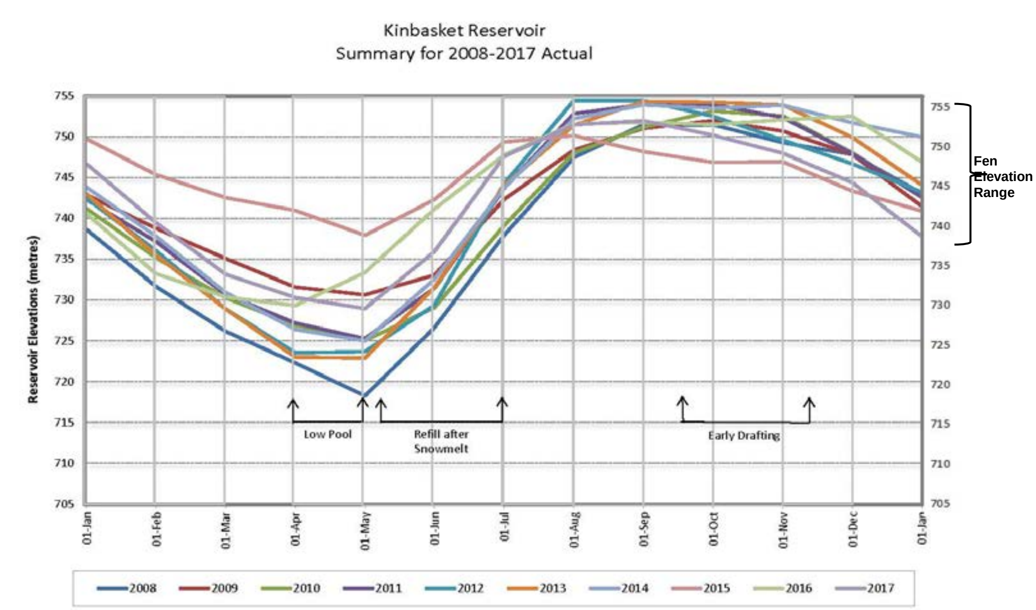
The Valemount Peatland is impacted by a wide variety of erosional processes. Vertical denudation caused by lateral erosion by the Canoe River and denudation of the entire peatland surface by runoff and wave action appear to be the main factors limiting vegetation growth on the peatland. Wind erosion and ATV use were also identified as localized sources of erosion (Ham and Menezes 2008). The archaeology assessment for the Canoe Reach reported that reservoir processes, especially wave erosion, had significantly reworked the post glacial fine sediment cap (where archaeology remains are expected to occur), with a large proportion of most vegetation polygons covered with wave-reworked and reservoir-deposited sediment (BC Hydro 2008).

A1.2 Background

The Valemount Peatland is in the northern end of the 216 km long Kinbasket Reservoir which is impounded behind the Mica Dam and retains up to 12 million acre feet (MAF) of Treaty and Non-treaty storage. The mean annual elevation of Kinbasket Reservoir varies from 724 m to 750 m (license range 710 m to 754.4 m; Figure 1).

The 37,500 ha peatland occupies the mid to upper drawdown zone elevations from 738 m to 755 m. The lowest extent of the peatland is slightly above the active Canoe River floodplain. Prior to reservoir inundation in the mid-1970's, the peatland was a large unforested wetland with imperfect drainage formed through the slow growth of fen peat over a long period of time and bounded by coniferous and deciduous forest and treed swamps and a river levee with mature conifers (Ham, 2010). The pre-reservoir peatland was comprised of two main vegetation types: 1) a fen with low scrub birch, bog willow with sedge understory covering approximately 30,000 hectares, and 2) a swamp with peatland mosses covering approximately 7,500 hectares.

Figure 1 Seasonal pattern of water level drawdown and refill for Kinbasket Reservoir (from BC Hydro 2018)



A1.3 Rationale for Addendum

The main objectives of CLBMON-8 are to measure the type and rate of erosion occurring at the Valemount Peatland, to assess the relative contribution and importance of reservoir operations to that erosion, and to examine how vegetation and wildlife species respond to erosion. Evaluation of erosion processes and vegetation was to occur in Years 1 (2008) and 2 (2009) of the program, with most field work completed during Year 1 (BC Hydro 2007). It was further expected that a desktop analysis to be conducted in Year 10 would provide enough information to determine which processes caused most of the observed erosion, based on aerial imagery collected in the meantime through the Kinbasket revegetation monitoring program CLBMON-10.

In the first year of the program eleven erosion pins were installed in the peatland to collect baseline information on the rate of surface denudation; however, data from these pins were of limited value in determining the overall rate of erosion throughout the peatland (Ham, 2010).

The intent in the initial years of CLBMON-8 was for the aerial imagery flown for vegetation monitoring under CLBMON-10 to also be used for CLBMON-8 (Charlene

Menzies pers. com). However the ability to measure changes in the areal extent of the peatland using this aerial imagery captured between 2008 and 2017 was not possible as it was flown in late-June to coincide with maximum vegetation vigor in the upper drawdown zone. The reservoir is inundating the lower one-third of the peatland at this time so year to year changes in overall peatland extent could not be measured.

Peatland inundation was also not consistent among years and in most years the peatland was not completely visible (above water) thus it was not possible to compare the erosion year to year for the full extent of the peatland (Charlene Menzies pers. com.). Detection of erosion at a fine scale from existing orthophotography resources has proven difficult. At a medium scale (1:20,000) of the imagery, clear changes in peatland extent are visible only in a few locations where the peat is completely removed from the underlying gravel material.

A key remaining uncertainty is thus whether the erosion of the peatland is an ongoing phenomenon caused by current operations of Kinbasket Reservoir or if it is more likely to be caused by the initial reservoir in the mid-1970's inundation leading to peatland mortality soon after the reservoir was filled.

This Addendum's main objective is therefore to address the management questions related to erosion rate and processes (cf. Section A1.4).

A1.4 Management Questions

The status of the CLBMON-8 Management Questions (MQ) to date (Ham and Menezes 2008, Ham 2010) are:

1) MQ 1. What are the processes and associated rates leading to the observed erosion of the wetland? Are erosion rates increasing or decreasing?

   Status: Not fully addressed. Some erosion features may be the result of a combination of reservoir operations and other causes such as wind and runoff erosion. It is not yet clear if erosion rates are increasing or decreasing.

2) MQ 2. Are current reservoir operations creating or contributing to conditions that are leading to the observed erosion processes?

   Status: Not fully addressed. Although some erosion features in the peatland have been attributed to reservoir operations (Ham 2010) the extent to which reservoir operations contribute to peatland erosion is unclear.

3) MQ 3. Are the erosion processes, which are caused or being contributed to by an on-going reservoir operations, affecting long-term viability of the wetland and associated riparian vegetation and wildlife species? If so, how can these impacts be mitigated?

   Status: Mostly addressed. Riparian and wildlife species in the upper peatland (i.e., above 748 m elevation) were monitored in 2008 and 2009 under CLBMON-8 and between 2008 and 2017 under CLBMON-9, 10, 11a and 58. Reservoir operations periodically refloat or entrain new wood debris which is redeposited on vegetation communities and wildlife habitat in the upper elevations (Hawkes and Miller 2016; Hawkes and Peatt 2017; Hawkes and Tuttle 2016). The effect of reservoir operations on the lower elevations is not fully known, as vegetation cover is largely absent from these areas.

4) MQ 4. Erosion in the lower peatland may be due to reservoir operations or to other causes such as runoff from higher elevations into the unvegetated peat, however this is still unknown.

5) MQ 5. What are the riparian vegetation species that have been successfully surviving long-term inundation? What are the wildlife species that utilize the habitat provided by the Valemount Peatland?

   Status: Mostly addressed. The lowest peatland elevation is 738 m (Ham and Menezes 2008), and peatland riparian vegetation species communities were mapped to approximately 740 m (average reservoir elevation in mid-June when orthophotos were flown) through CLBMON-10 (Hawkes and Gibeau 2017). Detailed vegetation species lists exist for those community types (Hawkes and Miller 2016).

   Wildlife species using the Valemount Peatland have been well documented for elevations >748 m under CLBMON-11a and CLBMON-58 (Hawkes and Tuttle 2016) but are less known for peatland elevations <748 m.

A1.5 Key Water Use Decision Affected

Results from this monitoring program will be used to better understand the potential impacts of the reservoir operations on the Valemount Peatland and the associated plant and wildlife species that it supports. Operational changes to Kinbasket Reservoir are not contemplated at this time.

A2.0 Monitoring Program Proposal

A2.1 Objective and Scope

The objective of Addendum 1 focuses on addressing Management Questions 1 and 2. Data from other monitoring programs of wildlife and vegetation under Management Plans 2 and 6 will be used to address the remaining uncertainties from Management Questions 3 and 4.

A2.2 Approach

MQs 1 and 2 will be addressed through a combination of aerial imagery and ground truthing:

Aerial photography will document the state of the Valemount peatland and will be calibrated with Light incidence Direction and Ranging (LiDAR), as this technique has a finer vertical resolution than Digital Elevation Models (DEMs) used previously in CLBMON-8. Field work will occur at the same time to document, assess and categorize the erosion processes.

Aerial photography and field work data will be collected five (5) years later at the same sites. Aerial photography may also be collected during intervening years. LiDAR may be also be used if it is deemed that aerial photographs need to be recalibrated.

The viability of peatland vegetation and the role of reservoir operations in this process may be investigated through tracking the location of the boundary between the upper portion of the peatland, with high vegetation cover (sedges and grasses), and the lower peatland with little or no vegetation cover. This vegetation boundary is visible in existing orthophotos flown for CLBMON-10 and other orthophotos from 2002 and 2017.

Changes in this vegetation boundary may be used in understanding wildlife use of the peatland as monitored under CLBMON-11a (Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir) and amphibian and reptile use under CLBMON-37 (Kinbasket and Arrow Lakes Reservoir Amphibian and Reptile Life History and Habitat Use Assessment) .

A2.3 **Methods**

The following tasks are required for successful implementation of the project:

A2.3.1 Task 1 Project Management and Coordination

Project coordination involves the general administration and technical oversight of the monitoring program. This will include, but not be limited to budget management, study team personnel, project coordination, technical oversight and analyses.

A safety management plan must be developed and submitted to BC Hydro contact for all aspects of the study involving field work, in accordance with BC Hydro procedures and guidelines. Specific safety training may be required.

A2.3.2 Task 2 Study Design

The proposed study design must allow for quantitative assessment of changes in the spatial extent of the peatland through data collected from both remote sensing (i.e., LiDAR and multispectral aerial photography) and field observations. The study must quantify any changes in erosion mechanisms over the five year time frame in living and dead peat areas and ascribe them to specific erosional processes.

The sampling design must be sensitive enough to assess whether any detected erosion affects peatland plant species (i.e., occurrence presence or absence).

A2.3.3 Task 3 Aerial Imagery

Aerial photography will be carried out according to BC Hydro Specifications for Aerial Photography (Appendix 1). However, methods for change detection through analysis of multi-spectral imagery (e.g., near-infrared) may also be considered.

It is recognized the acquisition of remote sensing data is an evolving technology, and that improvements in resolution and cost effectiveness may occur. However, to quantify changes in peatland substrate mass and extent and associated vegetation cover, it is essential that the methods and resolution remain consistent for the duration of the program. Minimization of spatial referencing error is particularly important between years and various sources of remote data such as LiDAR, aerial photography, UAV etc.

Aerial photography and/or LiDAR will be acquired in 2019 and in 2024 (five year interval) to document any changes in the extent and distribution of peatland and other substrate types within the Valemount Peatland area. It will be conducted at low water levels when the entire peatland is exposed during the early part of the growing season after snow cover has melted (usually in April) and before the reservoir level reaches 734 m (the lowest elevation of the peatland). These conditions occur between May 1 and June 7 in most years. The mean reservoir level on May 1 is approximately 726 m rising to 735 m by June 7 (Figure 1).

The key criteria for aerial photograph/LiDAR acquisition of the drawdown zone are:

- Kinbasket reservoir levels are at or below 734 m a.s.l.; and
- Snow and ice cover is absent.

Aerial photography acquisition should occur after vegetation “green-up” has occurred (i.e. when it is not dormant). The aerial photography acquired should include near-infrared, light wavelengths as these capture vegetation vigor.

- The vegetation has “greened-up” (i.e. is not dormant).

Key constraints for aerial photography within the day(s) chosen for acquisition are:

- Clear weather with no smoke or haze;
- No cloud or cloud shadow; and
- Acquisition from 10 am and 2 pm local time to align with highest sun angle for this time of year (May-June).

To effectively determine the best timing for aerial photography, consideration will be given to reservoir water level data (as provided by BC Hydro) and field observations of site conditions provided through coordination with other Water Use Plan programs.

Aerial photography will be required at equivalent of 1:5,000 normal colour scale, however, methods for change detection between 2019 and 2024 through analysis of multi-spectral imagery (e.g., near-infrared) may also be considered. Historical imagery is available from BC Hydro’s aerial imagery library (Appendix 1). This aerial imagery dates from 1966 (prior to reservoir inundation in 1976) to 2008 and varies in the features resolvable from the scanned analogue photography.

LiDAR will be captured from fixed wing aircraft along with the aerial photography for the entire peatland. Consideration should be given to the number of LiDAR points to be collected per m^2 as this determines vertical accuracy. Erosional features are low relief except for a river cutbank. The peatland is a very flat environment, so a relatively dense number of points have a higher chance of capturing erosional features.

Rigorous aerial triangulation process will be applied to images to enable stereo/ photogrammetric collection of features such as vegetation polygons, terrain (break lines, mass points) and planimetric (roads, rivers) features. Subsequent LiDAR flights might not be necessary with controlled aerial photography, as terrain data can be collected photogrammetrically.

The airplane minimum speed and terrain will need to take into consideration BC Hydro Aircraft Operations safety standards (BC Hydro 2018).

LiDAR acquisition in 2024 may not be necessary if the photogrammetry is found to be as accurate as the LiDAR-derived Digital Terrain Model from 2019.

A2.3.4 Task 5 Field Work

a) Ground Control of Aerial Photography and LiDAR

To verify spatial accuracy of remote sensing 5 to 6 ground control points are required. The ground control points can be used for both aerial photography (multispectral imagery) and LiDAR. These ground control points can be used for all subsequent imagery and LiDAR acquisitions of the Valemount Peatland as they are set up as permanent reference survey sites. Please refer to Remote Sensing specifications documents in Appendix 2.

b) Erosion effects on Peatland Vegetation and Wildlife Habitat

Vegetation and wildlife habitat of the peatland can be compared using historical baseline aerial photography information collected prior to the start of the program (Appendix 1) and new aerial photography to be acquired in 2019 and 2024. This may include, but is not limited to tracking the boundary between upper peatland and lower peatland vegetation cover, and reference to wildlife studies (CLBMON-11a and CLBMON-58).

Field surveys should occur in the May-June period, consistent with high activity periods for amphibians, nesting birds and ease of detection of most vascular and non-vascular plants. BC Hydro will develop a scope of services document to ensure that rationale, standards, and timing of surveys are articulated.

In the event rare plants (e.g., federally or provincially list species) are found during ground sampling, the data will be provided to the Conservation Data Centre (CDC) by the contractor, using appropriate forms. Similarly, noxious weed species, if encountered, should be identified and weed sites should be entered into the Ministry of Forests and Range Invasive Alien Plan Program Application.

A2.3.5 Task 6 Data Analysis and Mapping

A standardized method for identifying polygons, based on specific criteria for classification/delineation of different communities, is recommended. The methodology proposed needs to identify attributes that are quantifiable, objective and reproducible and it is important that these attributes be directly related to the variables of interest (i.e., those likely to be changing).

a) Data Analysis

Study design and associated analytical approaches to quantify the observed changes in peatland spatial extent and the elevation of substrate/ terrain types comprising the peatland should be clearly described (including peatland water conditions), as should the field and remote sensing data used to understand the relationships between documented attributes (e.g. vegetation community boundaries, erosion features) and the reservoir operating regime (i.e., inundation frequencies, duration and depth).

b) Surficial Material (Substrate/Terrain) Mapping

Two options in the development of a terrain model are:

1. Rigorous aerial triangulation process may be applied to aerial imagery collected in 2019 and 2024 which should enable stereo/photogrammetric collection of features using softcopy overlapping aerial photos to create an accurate three-dimensional model. Surficial material types (break lines, mass points), vegetation, and planimetric features (rivers and ponds) can be modelled with a high degree of spatial accuracy.
2. The LiDAR acquired in 2019 could be used as a test of spatial accuracy of aerial imagery for developing a Digital Terrain Model through reference points on the aerial photography tied to the LiDAR. This could be used to make high resolution orthophotography (either multispectral red, green and blue wavelengths) or near-infrared (NIR) longer wavelength. The GSD should be at least 0.5 m.

Digital Terrain Model (DTM)

The terrain model developed from aerial photography stereopairs will be the basis of mapping surficial material and substrate types of the peatland and assigning an erosion status value. A standardized method for identifying polygons, based on specific criteria for classification/delineation of different communities, is recommended.

The topography of the Valemount Peatland is subdued, with most surface features being <0.2 metres deep into the peatland which itself has a very gentle incline. To derive the 0.5 m contour intervals, either a triangulated irregular network (TIN) model (a vector-based DEM data collection set) or through interpolating elevation points of LiDAR terrain dataset surface is required to represent any changes in the surface due to erosion between 2019 and 2024. This may be done retrospectively if the previous datasets (Appendix 1, Table 1) can be resampled to the required level of accuracy to measure any changes in surface elevation from early reservoir inundation years (i.e. from 1976) to the 2019 and 2024 spatial data as these are raster datasets comprised of pixels.

Producing accurate orthorectified raster datasets of this older imagery, where distortions are geometrically removed such that every location has consistent scales across all parts of the image and it matches the spatial accuracy (x,y) and elevation (z) values is key to accurately measuring any changes in peatland elevation over time (ESRI 2018).

Surficial Material Mapping

The relationship between the remote sensing and ground samples will be used to delineate boundaries between substrate types. The historic, current, and future spatial and field data will be available for creating a series of thematic maps to identify changes in the boundaries and area of surficial material (e.g., living or dead peat material, river deposited sediment substrate and terrain types between years.

To minimize variability and error in these estimates, methods to maintain consistence in the photo interpretation from year to year will need to be established through ground control points for new photography and registration of existing imagery to base layers

Historical aerial photography is available between 1966 and 2008 (Table 1) to help quantify changes in the rate and extent of erosion of the peatland. Although the resolution and spatial accuracy are not up to present standards this imagery may be informative for qualitative analysis to complement the quantitative analysis in the surficial mapping in 2019 and 2024.

A2.3.6 Task 7 Reporting

A brief technical report will be prepared following the 2019 field season to summarize the methods employed during the program, preliminary data analyses and study findings. At the end of the program, a final comprehensive report will be submitted that summarizes study findings and provides a recommendation of ways to limit further erosion to the Valemount Peatland and associated vegetation communities and wildlife habitats due to reservoir operations.

A comprehensive report will be prepared after 2024 at the conclusion of the study which will include:

- an executive summary;
- a description of the methods employed;
- a data summary;
- analysis results and comparison of 2019 and 2024; and
- a detailed summary of the findings as they relate to the management questions.

Reports will follow the standard format that is being developed for WUP monitoring programs. All reports will be provided in soft-copy and as Microsoft Word and Adobe Acrobat (*.pdf) format (unsecured), and all maps and figures will be provided as embedded objects in the Word file or as separate files.

A2.4 **Interpretation of Monitoring Program Results**

The data will be used to identify linkages between the current reservoir operating regime and changes in spatial extent, surface elevation, viability of vegetation and wildlife in the peatland. Analysis of these relationships should provide a better understanding of the interactions between water levels, inundation frequency and duration with associated erosional action and viability of vegetation and for wildlife using that habitat.

Data collected during the monitoring program will be used to assess whether the peatland is eroding and if so, the extent to which this is due to reservoir operations.

A2.5 **Schedule**

A two-year extension of the CLBMON-8 program in 2019 and 2024 is proposed to collect additional years of data to address MQs 1 and 2.

The monitoring program will be extended from the current end date of the October 24, 2007 approved TOR to mid-2025. The schedule for Addendum 1 is presented in Table 1.

Table 1: Schedule of tasks for the Kinbasket Reservoir Monitoring of the Valemount Peatland

Task/Year	2019	2024
Collection of Aerial Photography and LiDAR from helicopter	X	X
Evaluation of peatland erosion sites (Vegetation and Wildlife)	X	X
Data Analysis	X	X
Reporting	X	X

A2.6 **Budget**

Total revised program cost: $455,491.

A3.0 References

BC Hydro, 2005. Columbia River Project Water Use Plan: Consultative Committee Report and Draft Water Use submitted to the Comptroller of Water Rights, August 2002.

BC Hydro, 2007. Columbia River Project Water Use Plan: Monitoring Program Terms of Reference. Kinbasket Reservoir Fish and Wildlife Information Plan. October 2007

BC Hydro, 2008. Archeological Overview Assessment. Monitoring Program No. CLBMON-51 Kinbasket and Revelstoke Reservoirs. Final Report. Report prepared by Wayne Choquette, Archeologist. January 24, 2008. BC Hydro Contract Report.Esri 2016: ArcGIS 10.4.1 Help. Fundamentals of orthorectifying a raster dataset.

GIS Wiki – The GIS Encyclopedia.

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Ham, D. and C. Menezes, 2008. Kinbasket Reservoir Monitoring of the Valemount Peatland. Northwest Hydraulic Consultants (NHC) report for BC Hydro Columbia Water Use Plan. December 2008

Ham, D. 2010. Kinbasket Reservoir Monitoring of the Valemount Peatland. Northwest Hydraulic Consultants (NHC) report for BC Hydro Columbia Water Use Plan. January 2010.

Hawkes, V.C. and M.T. Miller 2016. Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Prepared for BC Hydro June 2014

Hawkes, V. C. and P.G. Gibeau 2017. Kinbasket Inventory of Vegetation Resources. Prepared for BC Hydro March 2017.

Hawkes, V.C and A. Peatt 2017. Wildlife Effectiveness Monitoring of Revegetation Efforts and Physical Works Trials in Kinbasket Reservoir. Prepared for BC Hydro May 2017.

Hawkes, V.C and K.N Tuttle 2016 Monitoring the Effects of Mica Units 5 and 6 on Amphibians and Reptiles in Kinbasket Reservoir. Prepared for BC Hydro. May 2016.

Moody, A.I and W Carr, 2003. Mica – Revelstoke – Keenleyside Water Use Plan: Potential Areas for Vegetation Establishment in Kinbasket Reservoir. BC Hydro Contract Report

Appendix 1 Available Aerial Photography

Table 1 Historic Aerial photography at BC Hydro for Kinbasket Reservoir

Can #	Roll	Project	Scale	Date
111	W1101	Mica Project/Columbia River.Kinbasket		July 1, 1966
111	W1103	Mica Project/Columbia River.Kinbasket		July 1, 1966
223	W1479	Kinbasket Reservoir – pre inundation	1:32,000	April 24, 1974
246	W1559	Kinbasket Reservoir	1:31,680	June 28, 1976
254	W1581	Kinbasket Reservoir	1:31,680	October 18, 1976
288	W1520	Kinbasket Reservoir – pre inundation	1:31,680	Sept 03, 1974
624	SRS4994	Kinbasket Reservoir	1:10,000	May 4, 1993
625	SRS4995	Kinbasket Reservoir	1:10,000	May 6, 1993
627	SRS5007	Kinbasket Reservoir	1:25,000	May 11, 1993
782	SRS6565	Kinbasket Reservoir – low water (724.5 m)	1:10,000	May 15, 2002
783	SRS6564	Kinbasket Reservoir – low water	1:10,000	May 15, 2002
874	SRS7726	Kinbasket Reservoir	1:10,000	May 30, 2007
895	FF08035	Kinbasket Reservoir	1:5,000	July 25, 2008

The sensitivity of aerial Imagery will be to plan for Ground Smallest Dimension (GSD) of less than 5 cm. In other words, the smallest feature that can be discerned in the aerial photo is less than 5 cm by 5 cm in size.

Appendix 2 BC Hydro Remote Sensing Specifications Documents

ES 41A 3.4 R0_Lidar

Appendix 3.4.1 BC Hydro LiDAR data Guideline for Deliverables specification.

ES41A R0 (air photo).pdf

ES41A 3.3 R0 (AT).pdf (ground control)

Definitions

LiDAR is a remote sensing method used to examine the surface of the Earth and create three-dimensional information about the shape and surface characteristics. In this method, the distance to an object is measured by illuminating the target with pulsed light from a near-infrared wavelength laser and then measures the reflected pulses with a sensor. The return time of the reflected pulses can be used to make digital three-dimensional representations of the objects of interest. LiDAR provides high levels of locational accuracy. It also has the ability to quantify structure of three-dimensional features such as forest vegetation (GIS Wiki). Airplanes and helicopters are the most commonly used platforms for acquiring LiDAR data over broad areas. The two types of LiDAR are topographic and bathymetric.