Slope Stability Study Using LiDAR Imagery
City of Quesnel and Surrounding Fringe Area

Prepared for:

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July 1, 2022
File No. 021-069

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Attached: *Appendix A, Interpretation and Use of Study and Report and Limitations*
Figure 1: Overall Extent of the Study Area
Figure 2: The Study Area Extent for the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets
Figure's 6 through 16 showing the change detection analysis results for specific areas within the study area
Figures 18 and 19 show the likely extent of the slopes where the stability maybe questionable within the study area overlain on an ortho-image and LiDAR Bare Earth image

1 Introduction and Scope

As requested by the Cariboo Regional District (CRD), Westrek Geotechnical Services Ltd. (Westrek) has completed a limited study of the stability of the slopes within the City of Quesnel (the City) limits and parts of the surrounding fringe area within the CRD boundary. The approximate extent of the overall study area is shown on the Figure 1.

The scope of this limited study is to:

- Conduct a change detection analysis using the 2019 and 2021 LiDAR imagery, to identify areas that experienced detectable slope movement during this time period. In areas where small slope movement may have occurred, i.e., less than 10 cm horizontally and/or vertically, the change detection was unlikely to record the movement
- Identify slopes from the LiDAR imagery where the City and CRD should consider requesting an assessment of the overall stability[1] when considering development or redevelopment applications. This work was primarily based on identifying the typical landform characteristics where the stability of the slopes, from the imagery, may be uncertain; for discussion purposes in this report only, we refer to these slopes as the "slopes where the stability maybe questionable". It is important to note that where the ground surface has been modified by urban development, the slope stability characteristics may not be evident; this scenario exists specifically on parts of the West Quesnel slide. Limited ground truthing was undertaken in some areas, as part of other work done for either the City or CRD.

This work was requested by the CRD, in conjunction with the City, following recent slope movement on several of the large-scale, slow moving landslides within the City limits and surrounding fringe area during the springs of 2020 and 2021. A similar study is being completed for the City of Williams Lake and surrounding fringe area; this is presented under a separate cover.

This study may be referenced by governmental bodies when forming their approach to managing development (both existing and proposed) on or adjacent to slopes where the stability may be questionable, within their boundaries. It is expected that this study may form part of a continuum of work that governmental bodies and private property owners complete over time.

The services provided by Westrek are subject to the terms and conditions set out in the *Interpretation and Use of Report and Limitations,* which is attached in Appendix A and incorporated herein by reference.

[1] As a minimum, this work should be done in accordance with Engineers Geoscientists BC's 2010 *Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC*.

2 Background Information

The following background information was reviewed to aid in this study:

- *Figure 1: Summary Plan of Ground Movement (GPS Hubs and Slope Inclinometers)* as part of the *West Quesnel Land Stability Program Quesnel, BC* prepared by Amec Foster Wheeler Environment & Infrastructure (AMEC) and dated February 2017.
- *Figure 29: 2016 Pumping Well & Horizontal Drain Productivity* as part of the *West Quesnel Land Stability Program Quesnel, BC* prepared by AMEC and dated March 2017.
- A copy of the *West Quesnel Land Stability Area Map* prepared by the City's Development Services Department and dated February 12, 2020.
- *Figure 7; Areas of Unstable Terrain – High Risk* as part of the *Quesnel Fringe OCP Terrain Hazard Study* prepared by AMEC and dated January 28, 2009.
- A copy of the *Geotechnical Hazard Mapping Quesnel Fringe Area Cariboo Regional District British Columbia* report prepared by AMEC and dated November 2009.
- *Figure 8: Sloping Terrain and Other Features with Moderate Risk* as part of the *Quesnel Fringe OCP Terrain Hazard Study* prepared by AMEC and dated February 5, 2009.
- A copy of *The Landslide Problem in the Quesnel Area: Its Implications for Sub-division Approval* report prepared by Evans and Crook in September 1973.
- A copy of *The Development of Big Slide, near Quesnel, British Columbia, between 1953 and 1982* report prepared by Evans and dated July 15, 9182.

3 LiDAR Imagery

The study area for the change detection analysis in Quesnel and the surrounding fringe areas is approximately 59 km^2 (Figure 2) while the overall unstable/potentially unstable slopes identification study area is 278 km^2 (Figure 1). Two LiDAR datasets were used for this analysis; the 2019 imagery referred to as the baseline dataset, and the 2021 imagery, referred to as the active dataset. The data for both sets was provided as LAS point clouds.

3.1 2019 Imagery

The 2019 data was obtained from LidarBC's Open Lidar Data Portal[2], under BC's Open Government Licence. It was flown on behalf of the BC Ministry of Forests, Lands, and Natural Resource Operations and Rural Development between July 21 and October 11, 2019. Additional tiles (part of the same project but not available through the portal) were supplied by the CRD.

The specifications for this imagery are as follows:

- The Lidar point density averaged 12 points per m^2.

[2] https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=d06b37979b0c4709b7fcf2a1ed458e03.

- Ground points were pre-classified in the LAS files.
- The coordinate system was NAD83 (CSRS) 2002, UTM 10-N[3].

3.2 2021 Imagery

The 2021 data was collected by Aeroquest Mapcon/Airborne Imaging (Aeroquest), on behalf of the CRD. The Quesnel area LiDAR; it was flown on June 22, 2021.

The specifications for this imagery are as follows:

- The Lidar point density averaged 20 points per m^2.
- Ground points were pre-classified in the LAS files.
- The coordinate system used was NAD83 (CSRS) 2002, UTM 10-N, i.e., to match the 2019 dataset.

4 Change Detection Analysis

The purpose of this analysis is to delineate where significant ground movement (primarily on slow-moving landslides) took place between 2019 and 2021. The results show the spatial extent and approximate magnitudes of the movement (horizontally and vertically), and using the principles of landslide movement, it allows the direction of the movement to be determined.

The results are presented as colour-contoured images, illustrating the shortest distance change calculated between the baseline and active datasets. Positive model differences can be interpreted as material accumulation or bulging, and negative model differences can be interpreted as a loss of material (material removal, erosion or slumping). Zones of negative model difference are coloured yellow to red; zones of positive model difference are coloured light blue to purple.

There are several limitations with point cloud change detection:

- The inability to detect translational movement where the ground and slip surfaces are parallel; in this instance, the ground surface appears unchanged between the two datasets.
- Because the point cloud data represents the surface topography at the date of each flight, the analysis reflects surface changes only and cannot necessarily be extrapolated to interpret slide movements at depth.
- Positive or negative changes represent the amount of change that occurred along the shortest distance vector between the two datasets, and not necessarily the maximum magnitude of the deformation. This limits the ability to accurately measure landslide displacement where the movements are parallel to the slope.

[3] Specifications for LiDAR for the Province of BC, v4.0.

Change detection results are also limited by the temporal and spatial resolution of the three-dimensional (3D) datasets and the relative accuracy of the points between each dataset (also referred to as data precision, or local accuracy). Slope deformations that occurred outside these time windows are not detected or shown in the analysis.

4.1 Methodology

4.1.1 Point Cloud Alignment

The process of assessing 3D surface change with point cloud data involves four main steps:

1. Align the active dataset to the baseline dataset. This is conducted by adjusting the spatial position of the active dataset to minimize the difference relative to the baseline dataset. During the alignment, areas of known or suspected changes are ignored to improve the accuracy of the alignment and improve the limit of detectable change. The initial step of realigning the point cloud data reduces georeferencing errors resulting from poor GPS or ground control at the time of data collection. This process maximizes the ability to detect real change between datasets.
2. Calculate the limit of detectable change (LOD 95%); this is defined as the 2.5% and 97.5% cumulative alignment interval of the model differences between the non-changing regions of the active and baseline point cloud models. The alignment error between datasets is a function of the alignment, data precision, resolution, and the presence of non-changing sections of the datasets to control the alignment. Model differences within the LOD 95% may represent noise, error, or real change, if changes are too small to identify. Because of the variability in the 2019 dataset and large spatial extent of the study area, it was not feasible to formally calculate the LOD; instead it was estimated visually. Generally, model outputs outside of the LOD may represent noise, error, or real change.
3. Conduct a 3D shortest distance change analysis using the complete active and baseline datasets.
4. Interpret the results of the change detection as real change, spurious change, or error.

To minimise error between the data sets, the active dataset was aligned by Aeroquest to the same datum as the baseline dataset. A preliminary comparison of open areas with high ground point densities, such as road surfaces, confirmed that the horizontal error between the two sets was nominal, i.e., the differences would not significantly alter the results of the analysis.

Differences in the data quality between the 2019 tiles were also noted, i.e., primarily the density of ground-classified points. Some tiles had denser ground-point coverage, but were “noisier”, i.e., there was higher variability in the interpolated ground surface. This suggests that the classification parameters used were not consistent across the entire 2019 dataset.

In areas of with dense vegetation, the ground classified points in both datasets were sparser, but particularly in the 2019 data set. This resulted in relatively more error between the interpolated ground surfaces.

4.1.2 Change Detection

We used two methods of change detection for the analysis:

1. The DEM[4] of Difference (DOD); and
2. The Multiscale Model to Model Cloud Comparison (M3C2).

4.1.2.1 The DOD Method

This is a common method used in the earth sciences when the large-scale geometry of a study area is roughly planar. The two point clouds are gridded to generate DEMs, which are then differentiated on a pixel-by-pixel basis, which amounts to measuring a vertical distance, i.e., displacement along a vertical surface normal.

The DEMs were created from the LiDAR data at a 1 m pixel resolution.

4.1.2.2 M3C2 Method

This method operates directly on point clouds without the need for a gridded DEM, and it computes the local distance between two point clouds along a local normal surface direction, which tracks 3D variations in surface orientation. The advantages of this approach are:

- The change detection is improved over the DOD method on steeper slopes, such as landslide headwalls/headscarps; and
- It computes a confidence interval depending on point cloud roughness and registration error.

This method was used for the Quesnel area even though it is computationally more intense than the DOD method. To speed up the computation, the analysis area was trimmed to include only slopes where significant movement was detected during the initial analysis and similar adjacent slopes.

The model output, a point cloud, was then gridded at a 1 m resolution for visualisation; the same as the DOD output.

4.2 Model Outputs

The model results were classified into 10 cm increments between -2 m and 2 m, and in 1 m increments beyond this range. Figure 3 depicts an output sample using both methods, and as noted:

- The yellow to red colours represent areas where the elevation change was negative, i.e., the elevation dropped between 2019 and 2021; and
- The light blue to purple colours represent areas where the elevation change was positive, i.e., the elevation increased between 2019 and 2021.

[4] Digital elevation model.

To classify an area where a difference in elevation was detected as movement on a slide or slide complex in the study area, a decrease in elevation needed a corresponding increase in elevation to be in close proximity, i.e., based on the mechanics of slope movement. The slope morphology (or signature) on the LiDAR bare earth image was also used to correlate the change detection results as landslide or slope movement.

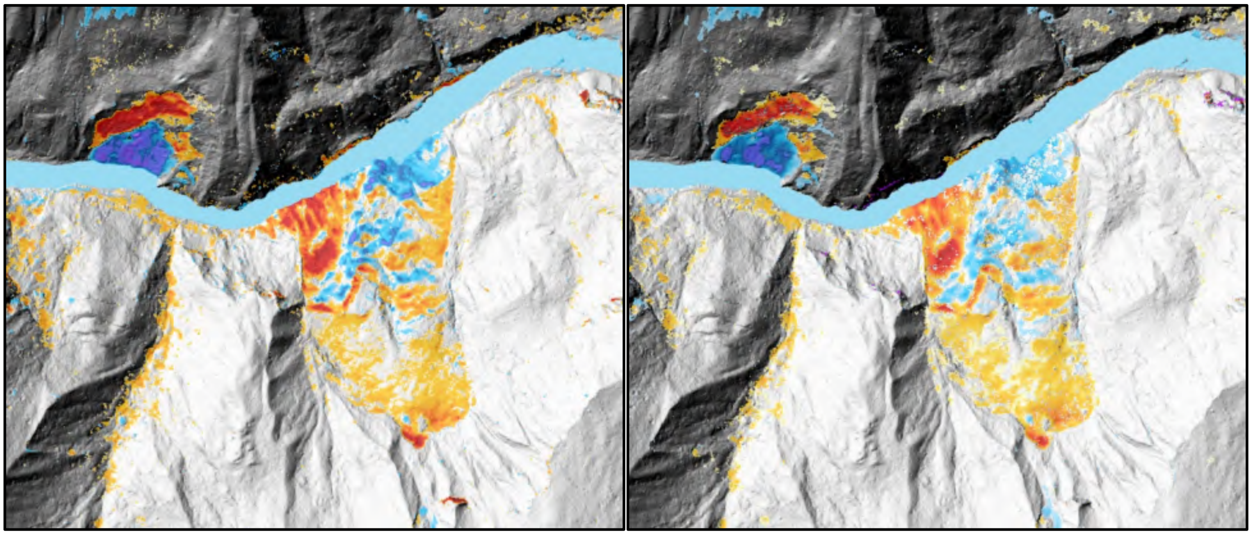


Figure 3: *An excerpt from the output using the DOD (on the left) and M3C2 methods (on the right).*

Some of the landslide/slope movements observed on the change detection output contained transverse ridges and troughs (Figure 4). A translational shift perpendicular to the ridges (i.e., generally down the fall-line) appears as alternating bands of negative and positive vertical change. The leading edge of the ridge will appear to have gained elevation, while the trailing edge will appear to have lost elevation.

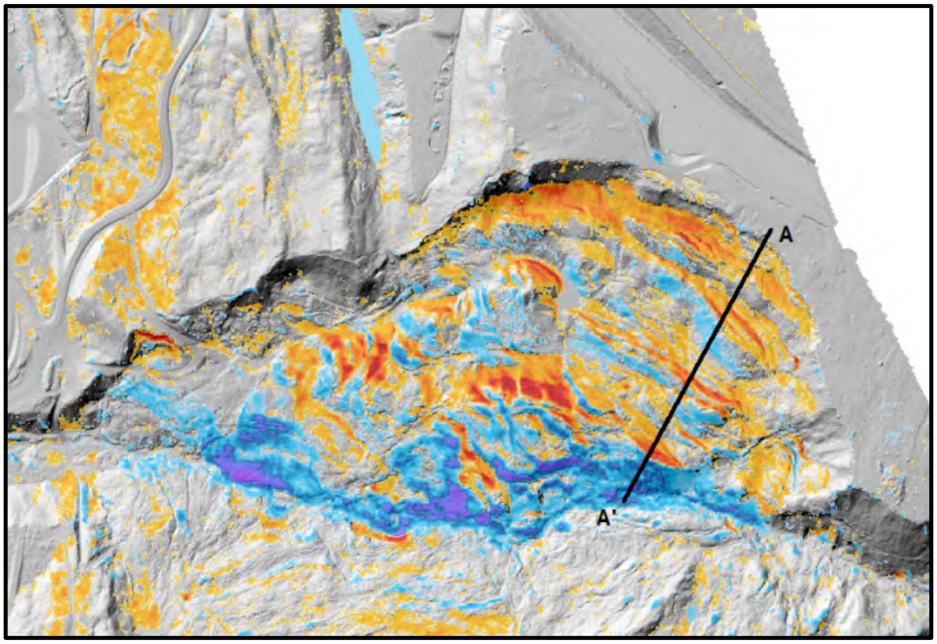


Figure 4: *Part of the recent slope movement next to Dragon Creek, showing the transverse ridges and troughs from the change detection analysis, which delineate the slope movement from 2019 to 2021.*

The slope profile (Figure 5) generated along line A-A′ (Figure 4) illustrates this by showing the relative elevation changes in red (negative) and blue (positive). The black arrows depict the probable overall displacement direction, i.e., the slope movement was from A to A′.

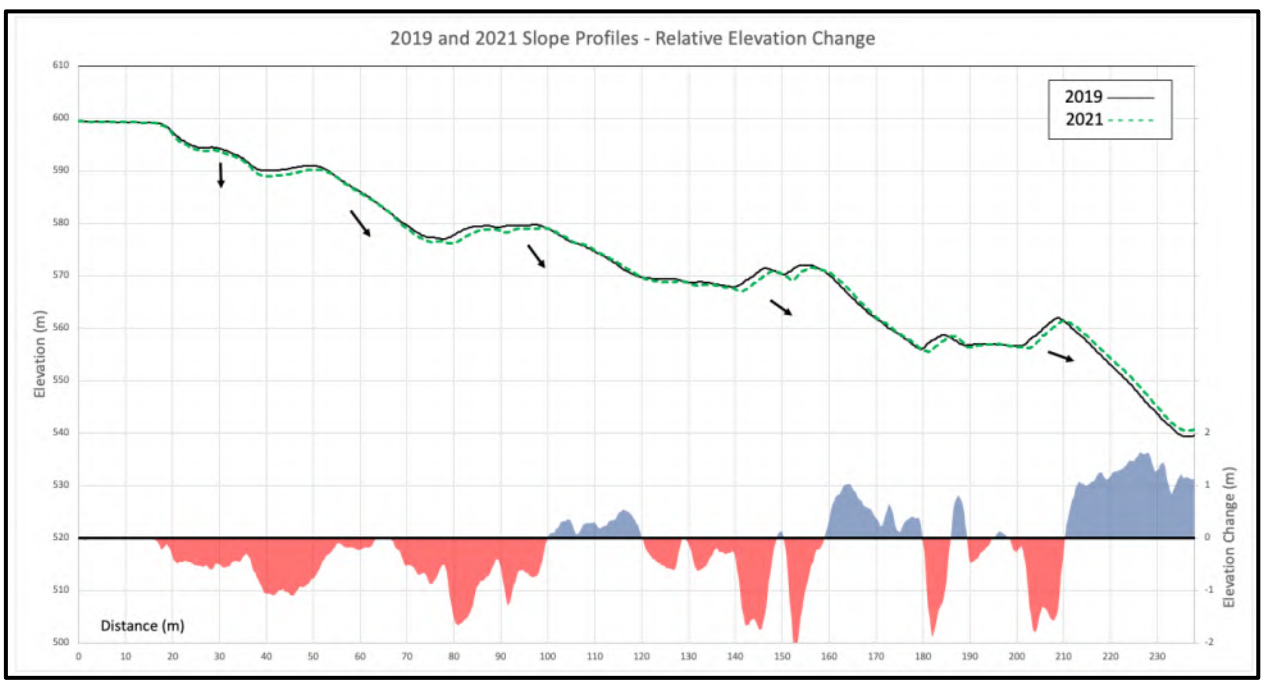


Figure 5: *The slope profile along the slope traverse from A to A′ showing the slope movement from 2019 to 2021, both horizontally and vertically.*

4.3 Summary

For the DOD method, the limit for negative change was estimated at about - 40 cm, and the positive change at about + 20 cm (i.e., the vertical change).

The M3C2 model was somewhat less noisy, and the limit for negative change was estimated at about - 30 cm, and the positive change at about + 10 cm (i.e., in the local surface-normal direction).

For both models, however, more noise/error was detected in the negative direction, i.e., the 2021 DEM was lower in elevation than the 2019 DEM. This was observed primarily in heavily vegetated areas, and could be the result of the lower density of LiDAR ground-returns in the 2019 dataset.

For the analysis, the LOD limits were sufficiently precise to detect landslide/slope movement[5].

Overall, the results for both methods were similar, and as result, the DOD method was sufficient for an overview level change detection analysis.

4.4 Results

The majority of the slope movement detected between 2019 and 2021 was confined to five (5) main areas, which included[6]:

- The slopes around Baker Creek, and on the Baker Creek slide, the Baker Creek Pinnacles Road slide and the South Baker Creek slides.
- The Red Bluff and Plywood Hill slides.
- The Quesnel Hill slide complex and the Dragan Hill Road slide.
- The Garbage Dump slide.
- The Plateau/Abbot Drive slides, the Ruric Springs Subdivision slide and the Marsh Road Hill slide.

Some detectable movement was also noted on the Westply slide.

The change detection results in these areas and for the overall area are shown on Figure's 6 through 16 (attached).

The analysis, however, did not highlight any substantial movement on the West Quesnel Landslide Area; this was a likely due to the movement being below the detectable limits of LiDAR over the short time period reviewed. Based on the monitoring currently be undertaken by the Wood Group for the City, movement on this slide did occur between 2019 and 2021.

The above landslides/slide complexes are generally large scale features likely occurring in very thick sequences of glaciolacustrine and/or glaciofluvial sediments.

Movement on these features:

[5] For areas where more detail or more precise measurements are required, a formal calculation of the LOD for subsets of the data should be undertaken.

[6] Where possible, we have used the landslide names shown on Figure 7 from AMEC's 2009 report to identify these areas.

1. Is usually associated with (i) longer term changes in the regional groundwater regimes, affected by climatic trends, and (ii) loss of toe support due to erosional scour created by rivers, creeks and streams.
2. Can be complex and differential, i.e. different parts of the slide can move at different rates. Certain zones of the slide may activate and continue to move, while others can be seemingly stable for decades.
3. Is difficult to determine without a detailed subsurface investigation, slope monitoring and analysis. The results of the current change detection analysis provides a "snap shot in time" for the movement between 2019 and 2021.

5 Slopes Where the Stability Maybe Questionable

5.1 AMEC 2009 Report

In 2009, AMEC conducted a study for the CRD to delineate landslide complexes and unstable slopes within the Quesnel Fringe Area[7]. To do this, AMEC utilized the following methodology:

- Conducted a review of the available historic engineering/technical reports for landslides and other natural hazards.
- Reviewed historic stereo air photo coverage (1969 to 1997) of the study area to delineate other terrain features subject to natural hazards, not covered in the historic reports.
- Ground truthed select areas to confirm preliminary findings from the air photo review.
- Overlaid information gathered from the background review and fieldwork on the TRIM map base.
- Used GIS modelling of terrain attributes to identify (i) areas of similar slope gradients, (ii) slopes with bedrock exposures, and (iii) infer terrain features associated with landslides and ground instabilities.

The limitations identified by AMEC using this methodology included:

- The identification of natural hazards was qualitative and approximate, rather than quantitative.
- The study was an overview level assessment.
- The list of hazards identified is representative at a regional scale, although at the property scale it may not be fully comprehensive.

5.2 The Current Study

To better delineate the extent of the "slopes where the stability maybe questionable" in the study area, and improve on the earlier work completed by AMEC (2009), the LiDAR bare earth image

[7] This study did not include the landslides or unstable slopes within the City.

created from the 2019 DEM combined with the results from the change detection analysis, were used. The 2019 dataset was chosen because it covers a much larger area then the 2021 dataset.

This image allowed us to review the ground surface morphology with the vegetative cover removed. This effectively depicts what has happened to the ground surface within the study area since deglaciation, which occurred around 10,000 years ago. Numerous landslides have occurred during this period and in some cases, historic slope movement can also generally be seen, although the imagery does not allow either an estimate as to when a landslide or slope movement(s) occurred or sometimes how frequently they may have occurred.

Using this approach, the extent of "slopes where the stability maybe questionable" within the City limits and adjacent fringe area can be better identified (Figure's 18 and 19).

The surface morphology "signature" for active or recent slope movement on a bare earth image is generally clearer and can be more distinct, allowing for more reliable identification. It is important to note that while actively unstable slopes can be easier to identify using this imagery, urban development can mask the ground morphology and give the impression that the ground could be stable on large-scale landslides and slide complexes.

Older slope movement (i.e., ancient) and potentially unstable slopes, where the slope movement either may not be as clear, may have either been smoothed over, or have some characteristics of slope movement (Figure 17), may not be as clear to identify.

For this study, we have grouped all of these slope conditions together. The rationale for this is to convey the extent of the potential problems facing development and re-development, both existing and proposed, within the study area. These slopes could be further delineated in a more detailed study.

With this approach, the City and CRD should be aware that:

- Slopes where the stability maybe questionable can become more unstable over time, especially in the context of climate change.
- Movement on active landslides or unstable slopes can change (i.e., increase or decrease) over time.
- The stability of a slope can change over short distances.

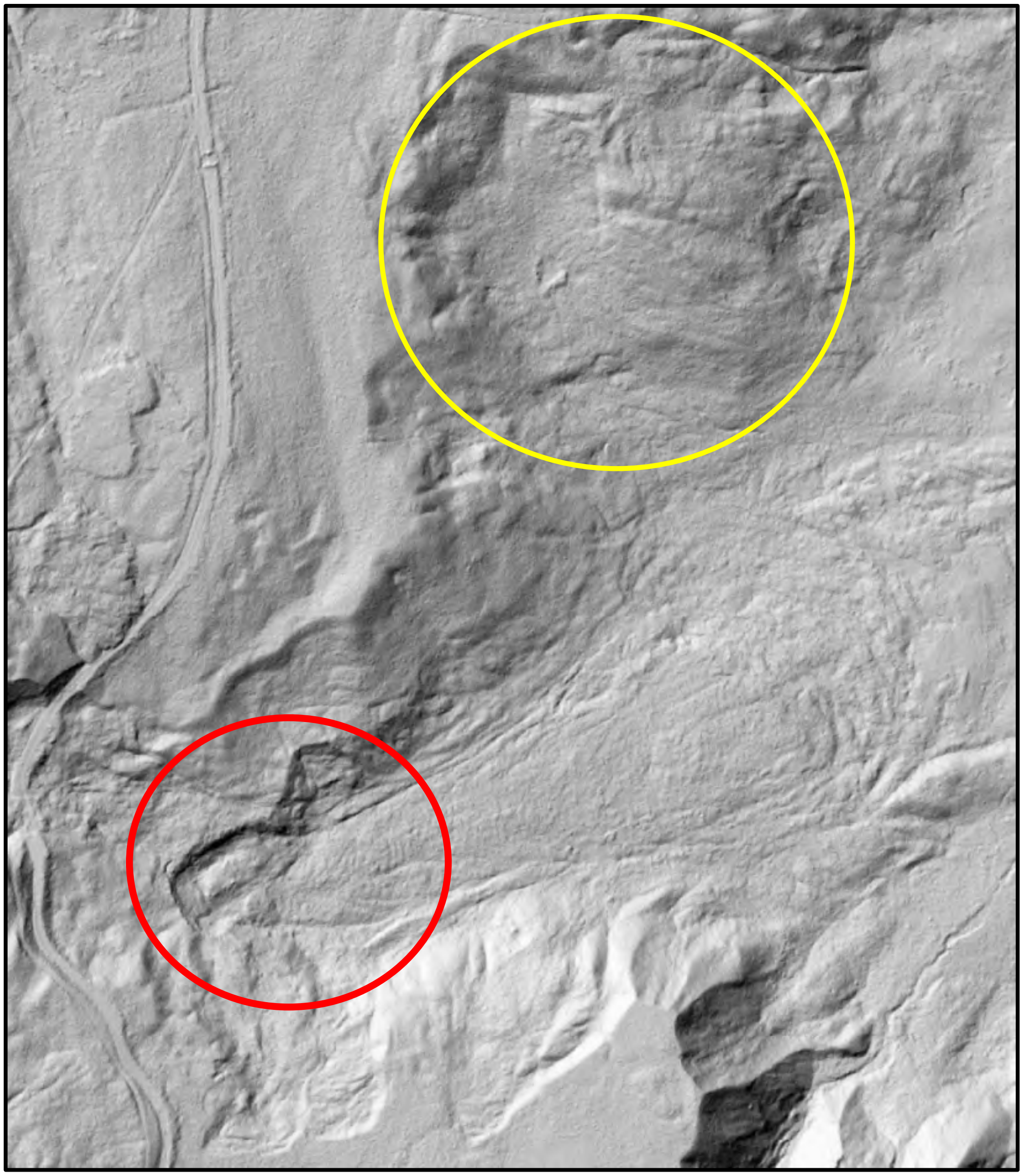


Figure 17: *An excerpt from the 2019 LiDAR bare earth image showing the distinct slope morphology from an example of actively unstable slopes (the red circle) and the more subdued morphology from an example of potentially unstable slopes (the yellow circle).*

It is possible that:

- Not all slopes where the stability maybe questionable have been identified in this study.
- Some areas where the stability maybe questionable, may not be.

Additional and more detailed investigation is required to better understand these limitations.

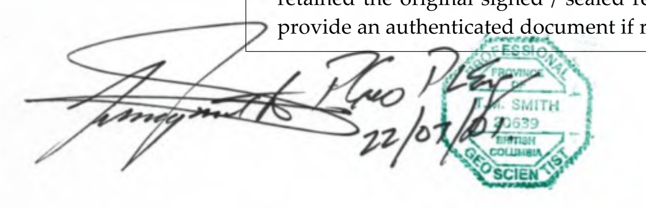
6 Closure

We trust that this report is complete for your present requirements. Please contact the undersigned if you have any questions.

Yours truly,

Westrek Geotechnical Services Ltd.

This is an electronic replica of the original signed and sealed report and has been provided for convenience. Westrek has retained the original signed / sealed report on file and can provide an authenticated document if required.



Timothy Smith PGeo, PLEng
Principal and Senior Engineering Geologist

APPENDIX A
INTERPRETATION AND USE OF STUDY AND REPORT AND LIMITATIONS

1. STANDARD OF CARE.

This study and Report have been prepared in accordance with generally accepted engineering and geoscience practices. No other warranty, express or implied, is made. Geological and geotechnical studies and reports do not include environmental consulting unless specifically stated in the report.

2. COMPLETE REPORT.

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT.

The Report has been prepared for the specific site, development, design objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT.

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report or any portion thereof, available to any party without our written permission. Any uses, which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. Westrek accepts no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT.

(i) Nature and Exactness of Soil and Description: Classification and identification of soils, rocks, geological units, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilising the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

(ii) Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations or fraudulent acts of any persons providing representations, information and instructions.

(iii) To avoid misunderstandings, Westrek should be retained to work with the other design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to engineering issues. Further, Westrek should be retained to provide field reviews during the construction, consistent with generally accepted practices.

6. LIMITATIONS OF LIABILITY.

Westrek's liability will be limited as follows:

(a) In recognition of the relative risks and benefits of the Services to be provided to the Client by Westrek, the risks have been allocated such that the Client agrees, to the fullest extent permitted by law, to limit the liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for any and all claims, losses, costs, damages of any nature whatsoever or claims expenses from any cause or causes, whether arising in contract or tort including negligence, including legal fees and costs and disbursements (the "Claim"), so that the total aggregate liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals:

   i. if the Claim is satisfied by the re-performance of the Services proven to be in error, shall not exceed and shall be limited to the cost to Westrek in re-performing such Services; or

   ii. if the Claim cannot be satisfied by the re-performance of the Services and:

      1. if Westrek's professional liability insurance does not apply to the Claim, shall not exceed and shall be limited to Westrek's total fee for services rendered for this matter, whichever is the lesser amount. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such amount; or

      2. if Westrek's professional liability insurance applies to the Claim, shall be limited to the coverage amount available under Westrek's professional liability insurance at the time of the Claim. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such coverage amount. Westrek shall maintain professional liability insurance in the amount of $2,000,000 per occurrence, $2,000,000 in the aggregate, for a period of two (2) years from the date of substantial performance of the Services or earlier termination of this Agreement. If the Client wishes to increase the amount of such insurance coverage or duration of such policy or obtain other special or increased insurance coverage, Westrek will cooperate with the Client to obtain such coverage at the Client's expense.

      It is intended that this limitation will apply to any and all liability or cause of action however alleged or arising, including negligence, unless otherwise prohibited by law. Notwithstanding the foregoing, it is expressly agreed that there shall be no claim whatsoever against Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for loss of income, profit or other consequential damages howsoever arising, including negligence, liability being limited to direct damages.

(b) Westrek is not responsible for any errors, omissions, mistakes or inaccuracies contained in information provided by the Client, including but not limited to the location of underground or buried services, and with respect to such information, Westrek may rely on it without having to verify or test that information. Further, Westrek is not responsible for any errors or omissions committed by persons, consultants or specialists retained directly by the Client and with respect to any information, documents or opinions provided by such persons, consultants or specialists, Westrek may rely on such information, documents or opinions without having to verify or test the same.

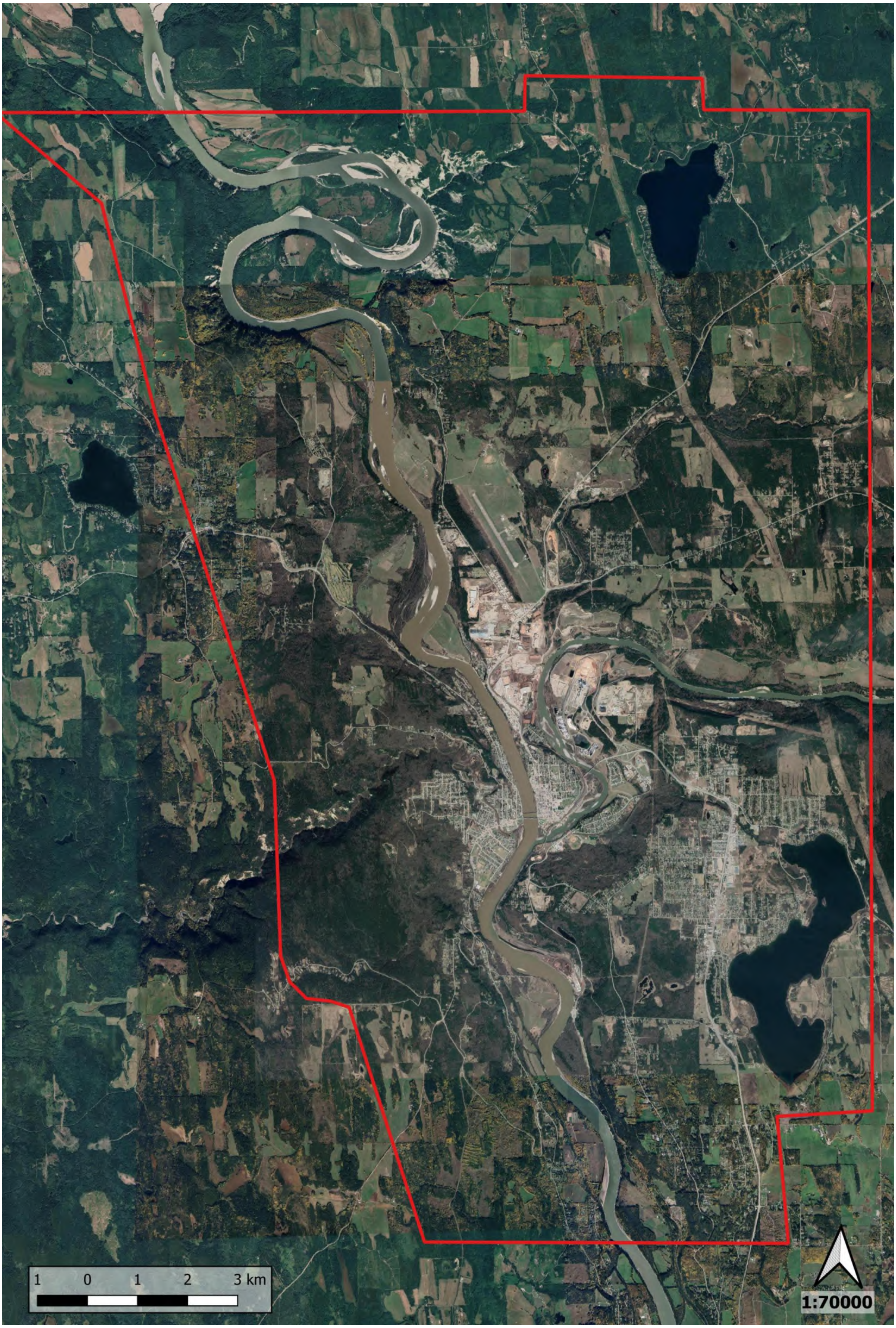
(c) Notwithstanding the provisions of the Limitation Act, R.S.B.C. 2012 c. 13, amendments thereto, or new legislation enacted in its place, Westrek's liability for any and all claims, including a Claim as defined herein, of the Client or any third party shall absolutely cease to exist after a period of two (2) years following the date of:

   i. Substantial performance of the Services,

   ii. Suspension or abandonment of the Services provided under this agreement, or

   iii. Termination of Westrek's Services under the agreement,

   whichever shall occur first, and following such period, the Client shall have no claim, including a Claim as defined herein, whatsoever against Westrek.



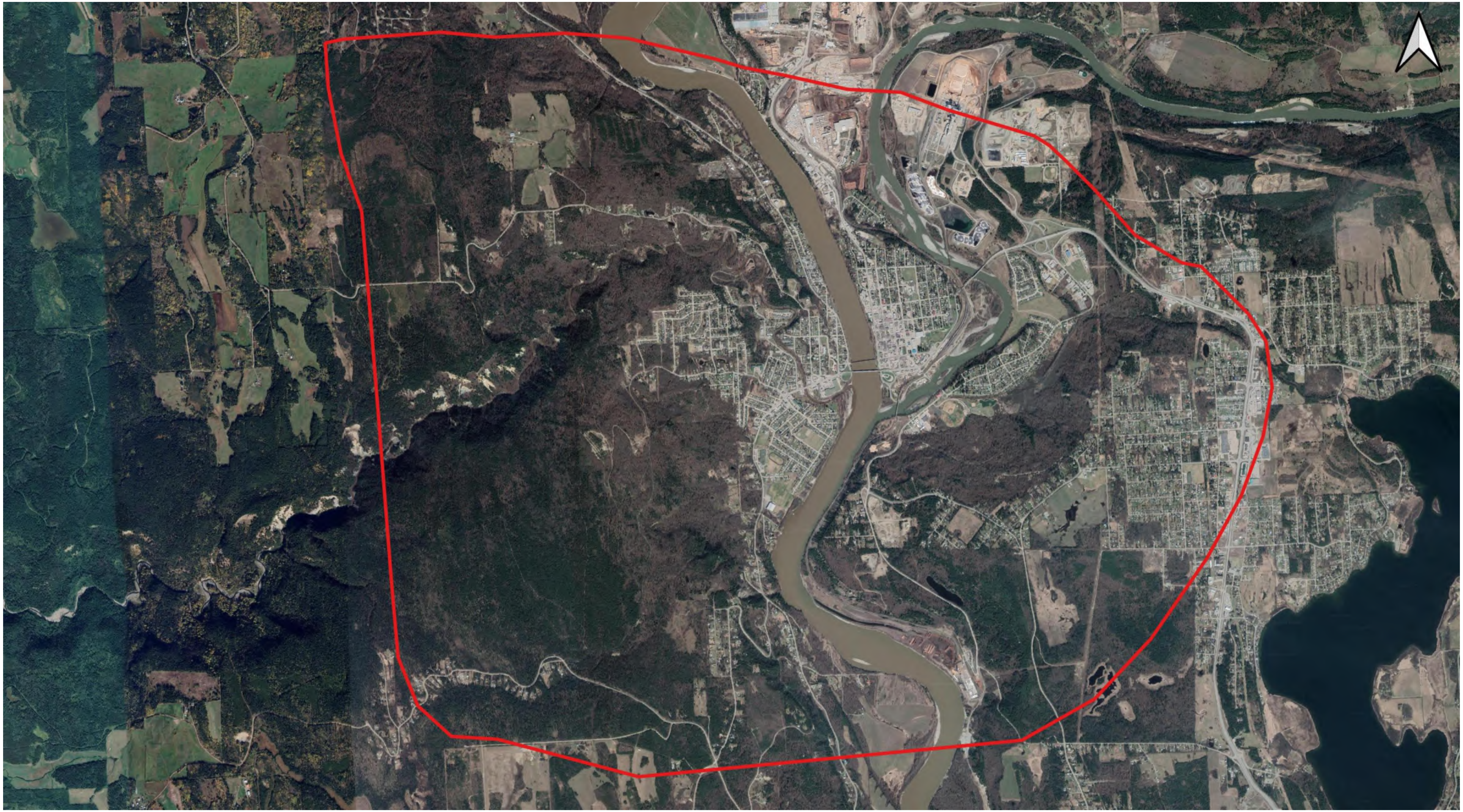
westrek geotechnical services ltd.

Overall Extent of Study Area

Figure 1

Source: Oct 7, 2021, Satellite Imagery provided by Google Earth Engine

Project No. 021-069



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100 -1383 McGill Road, Kamloops, BC V2C 6K7

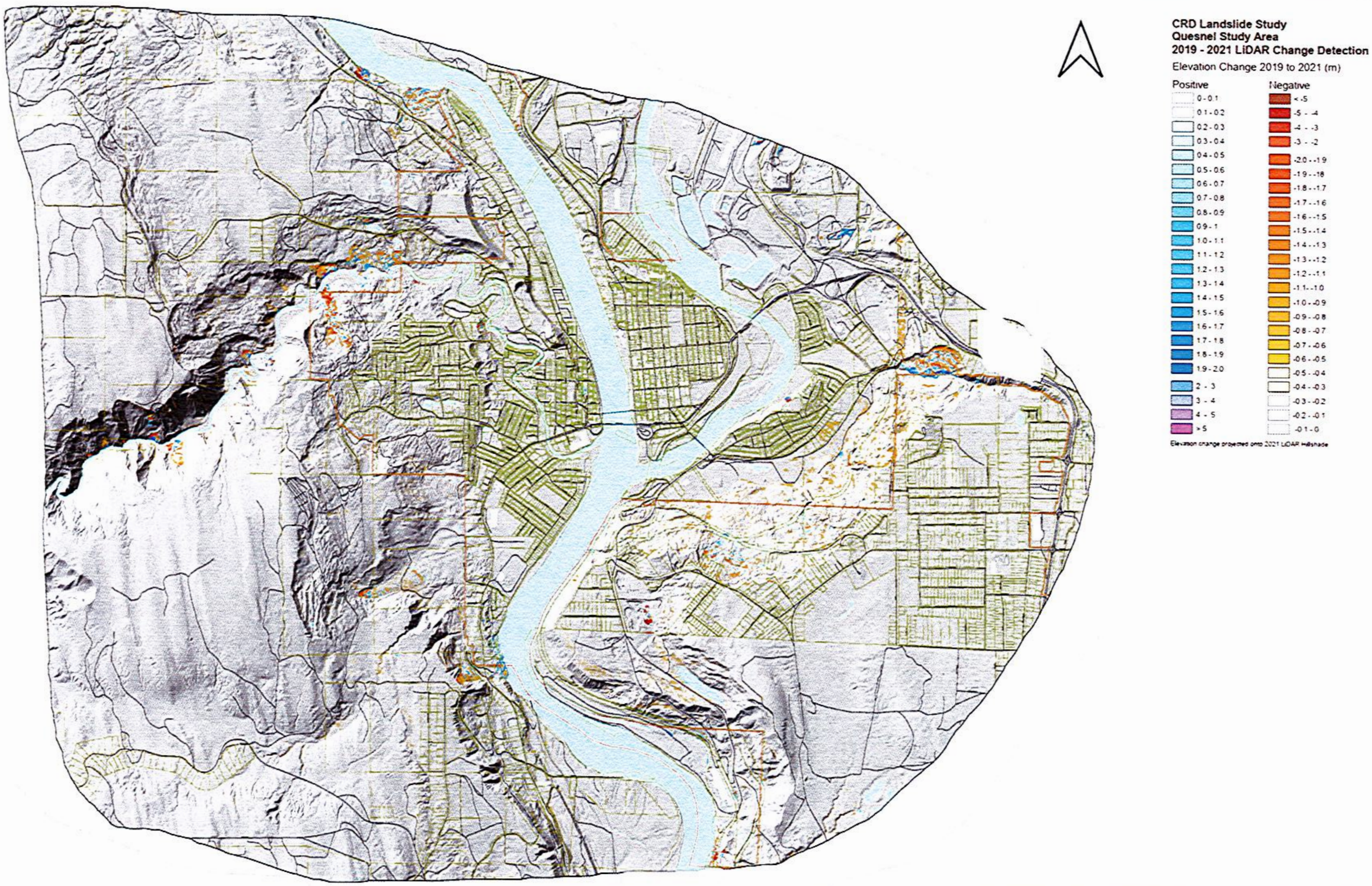
SCALE: 1:35,000

Imagery Date is Oct 07, 2021

Project: 021-069

The Study Area Extent for the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets.

FIGURE 2



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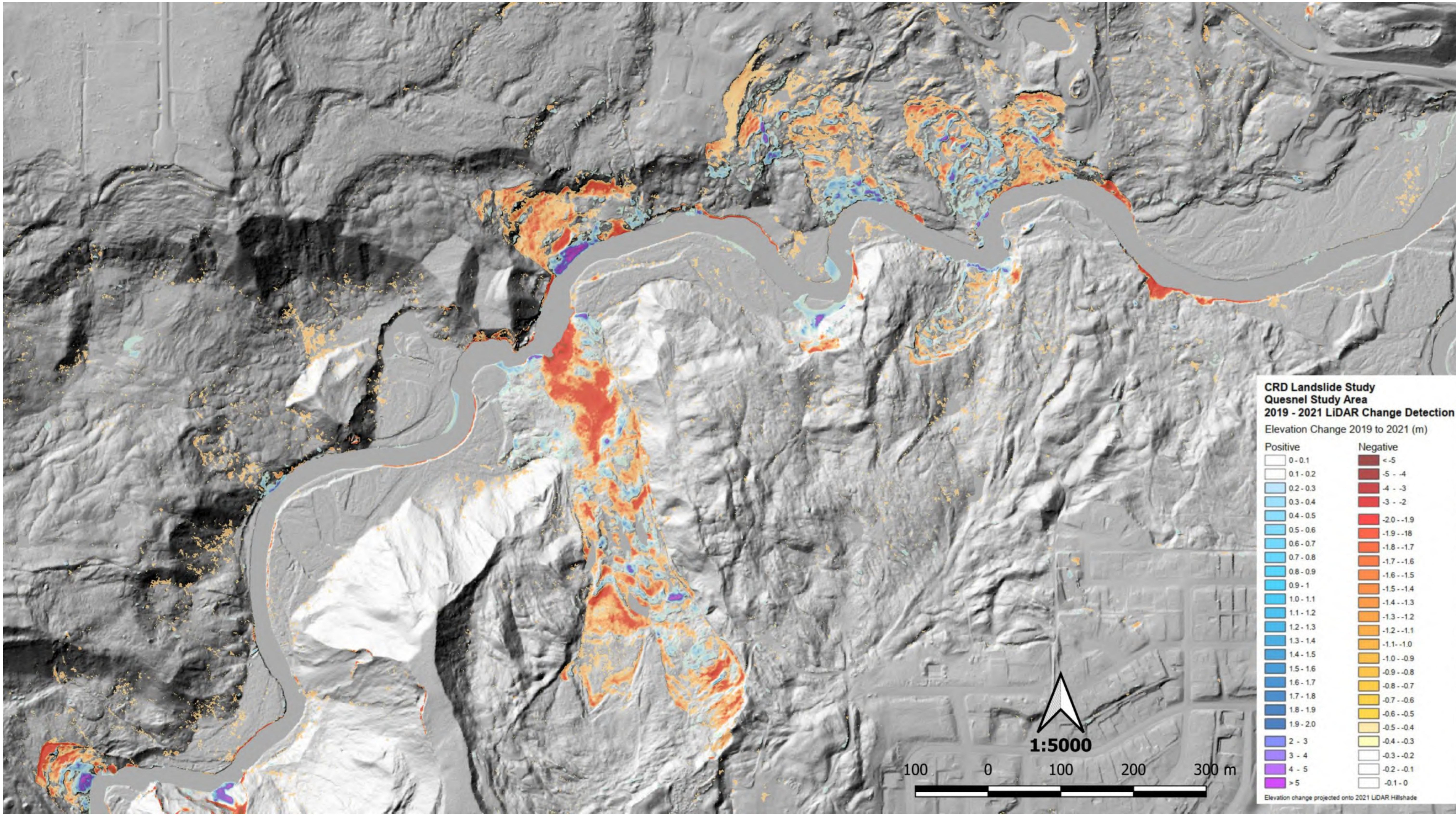
SCALE: 1:35,000

Imagery Date is July 30, 2021

Project: 021-069

The Study Area Extent for the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets.

FIGURE 6



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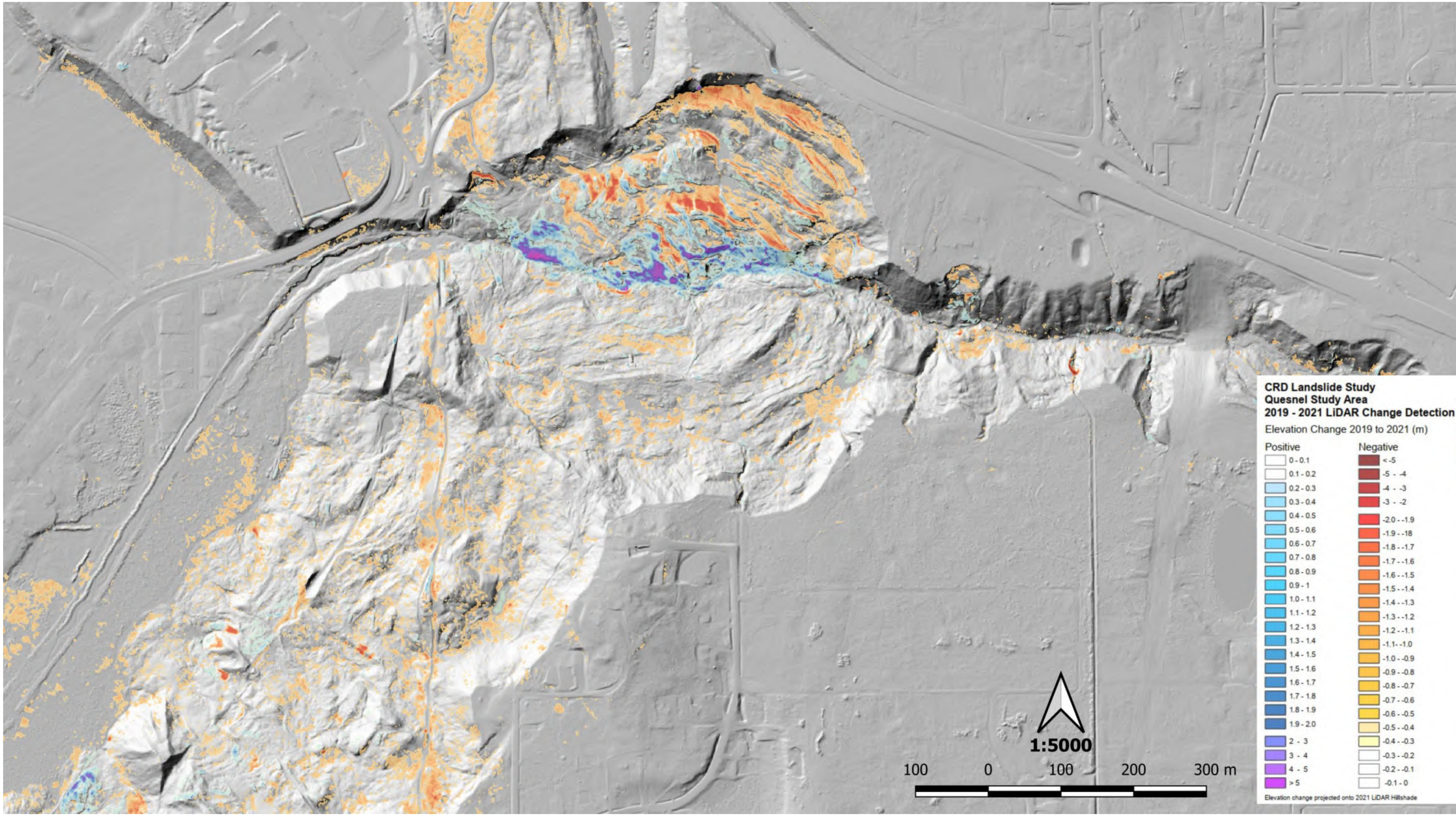
Imagery Date is July 30, 2021	
Project: 021-069	

The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes around Eastern Reaches of Baker Creek and Baker Creek Pinnacles Road Slides

FIGURE 7



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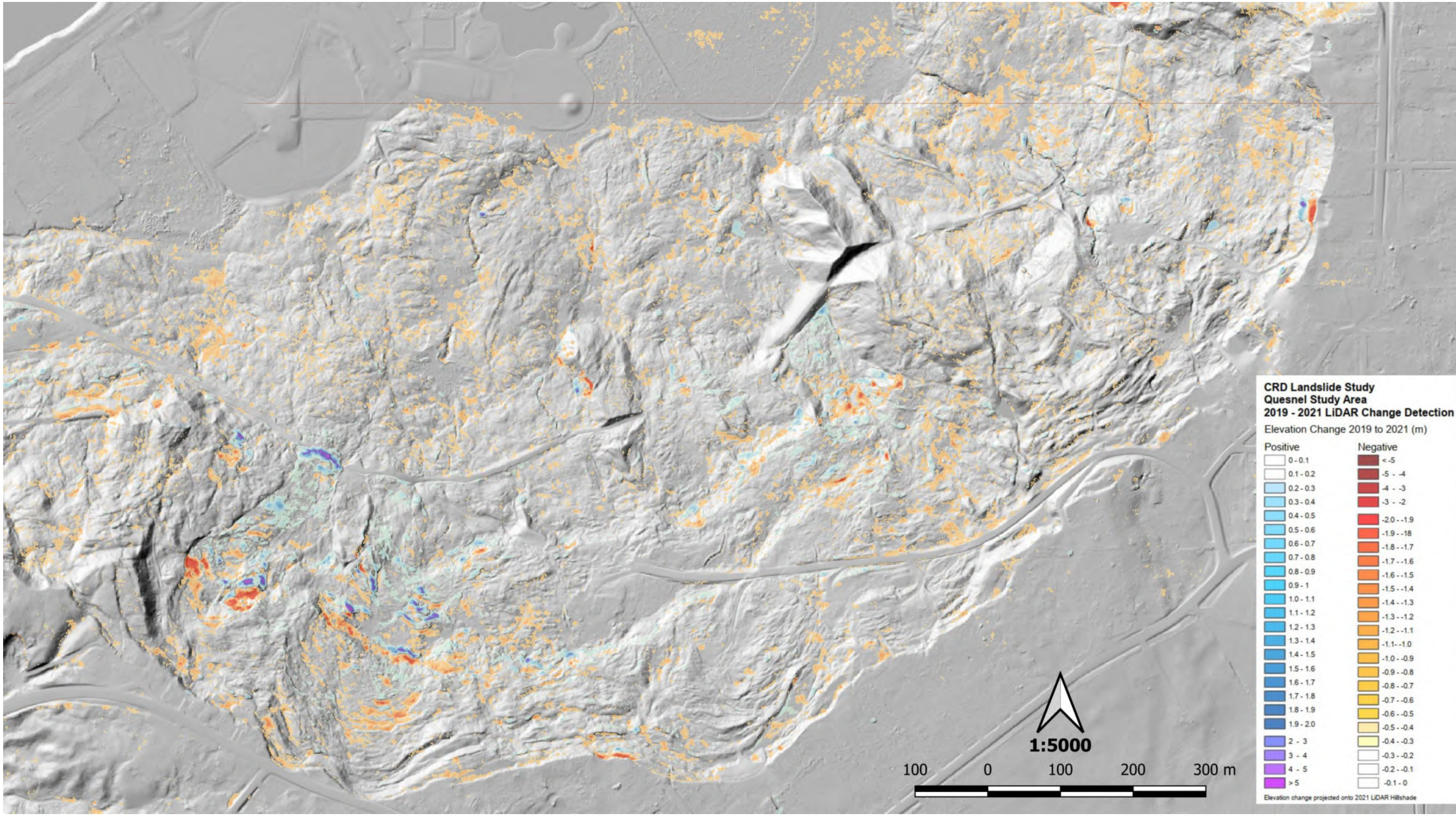
SCALE: AS SHOWN	
Imagery Date is July 30, 2021	**The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes Around the Quesnel Hill Slide Complex and the Dragon Hill Road Slide**
Project: 021-069	**FIGURE 8**



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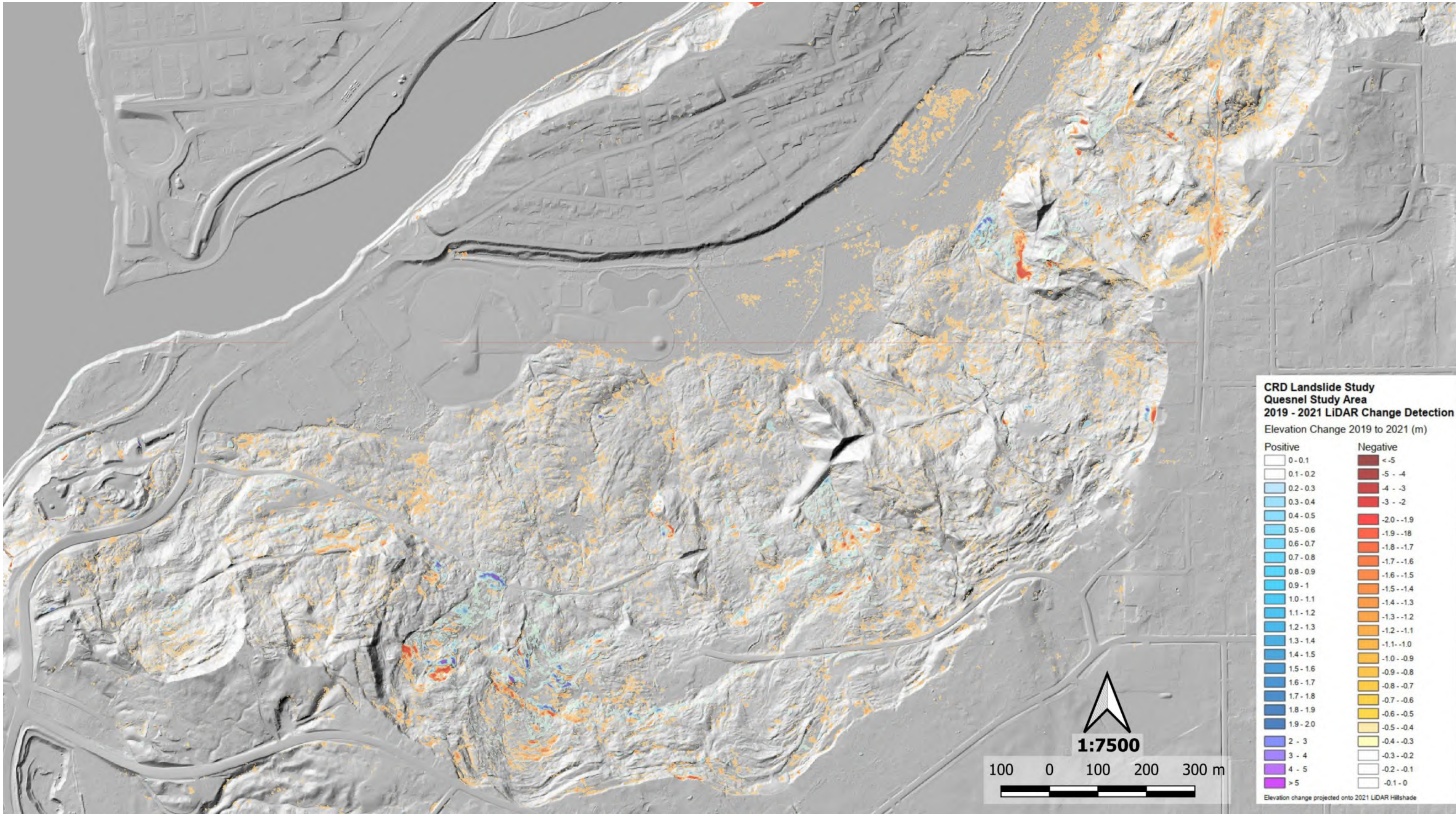
Imagery Date is July 30, 2021

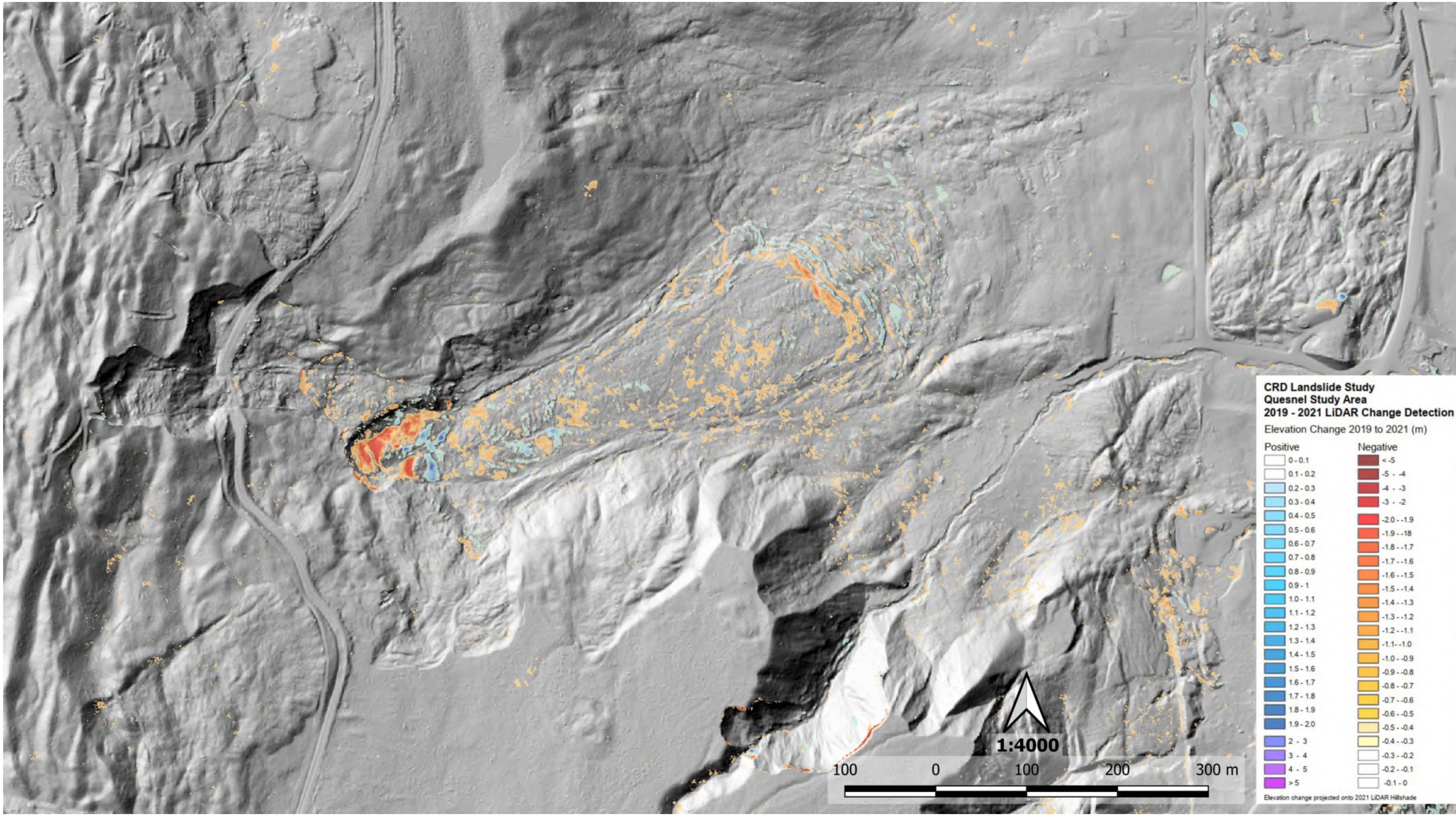
Project: 021-069

The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes on the East Side of the Red Bluff Slide

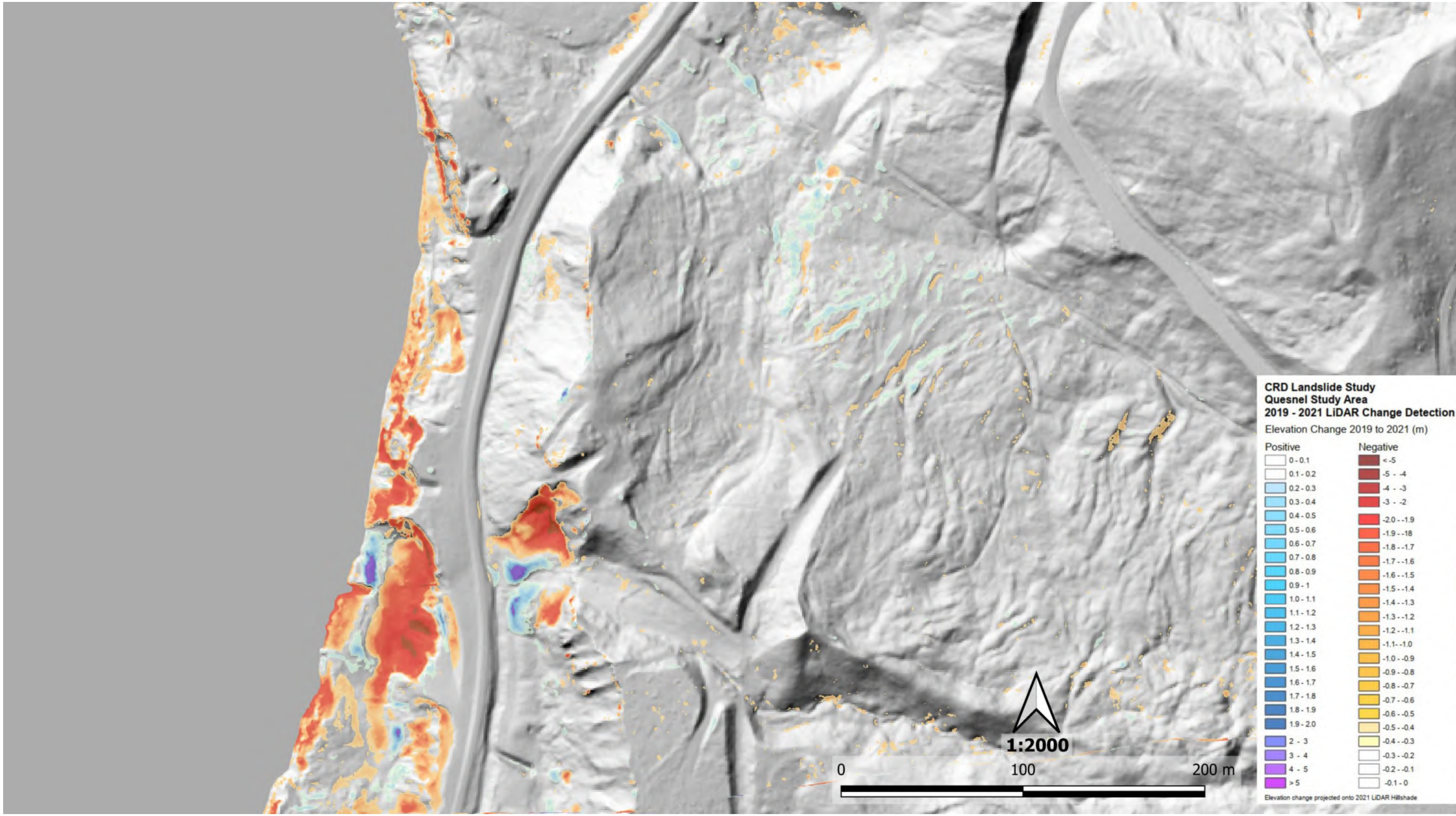
FIGURE 9



westrek geotechnical services ltd. 100 -1383 McGill Road, Kamloops, BC V2C 6K7	SCALE: AS SHOWN	**The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes on the West Side of the Red Bluff Slide**	**FIGURE 10**
	Imagery Date is July 30, 2021		
	Project: 021-069		



westrek geotechnical services ltd.	SCALE: AS SHOWN	The the Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes around the Plateau/Abbot Drive Slides	FIGURE 11
	Imagery Date is July 30, 2021		
100 -1383 McGill Road, Kamloops, BC V2C 6K7	Project: 021-069		



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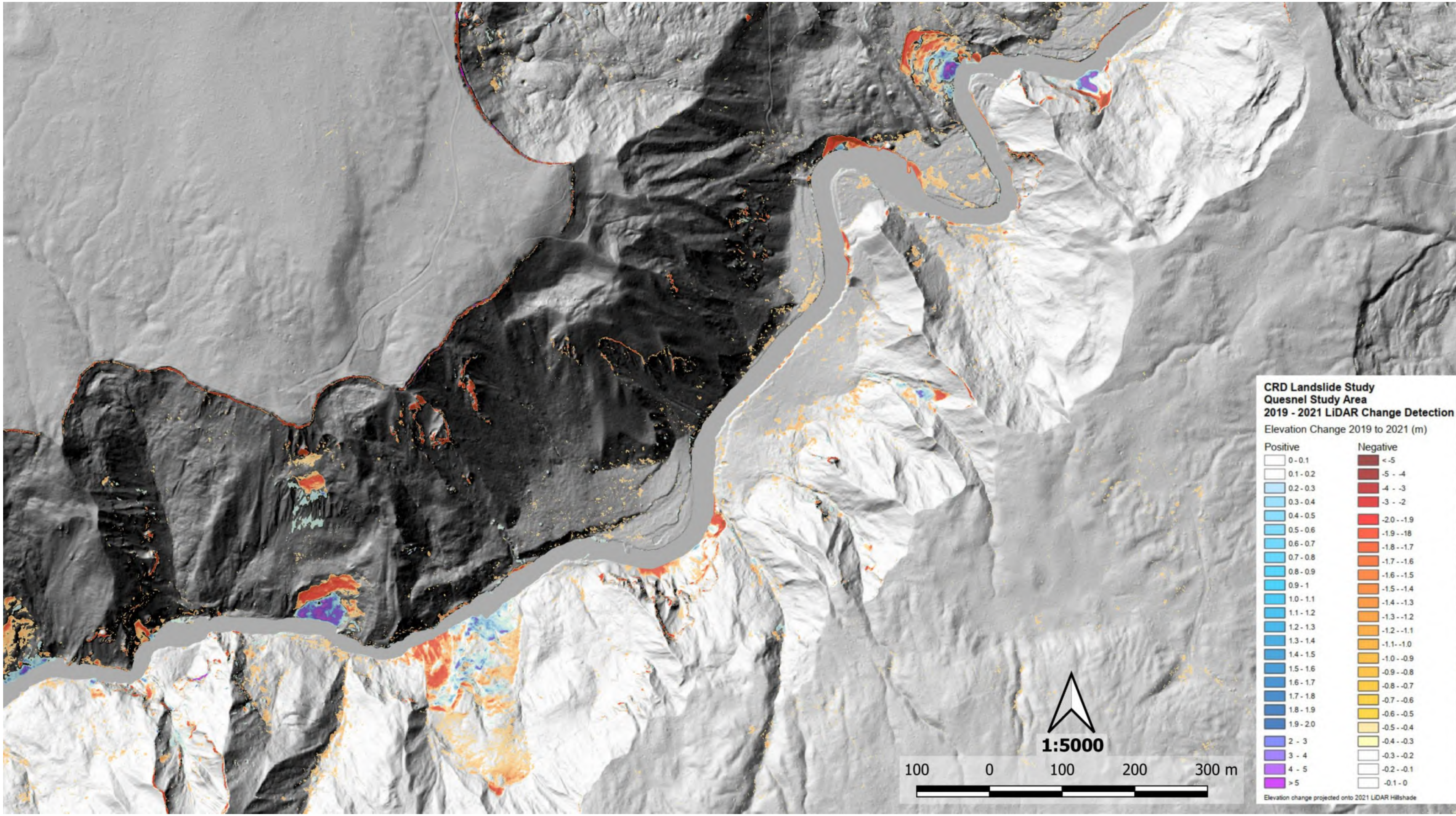
SCALE: AS SHOWN	**The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes around The West Ply Slide**
Imagery Date is July 30, 2021	
Project: 021-069	

FIGURE 12



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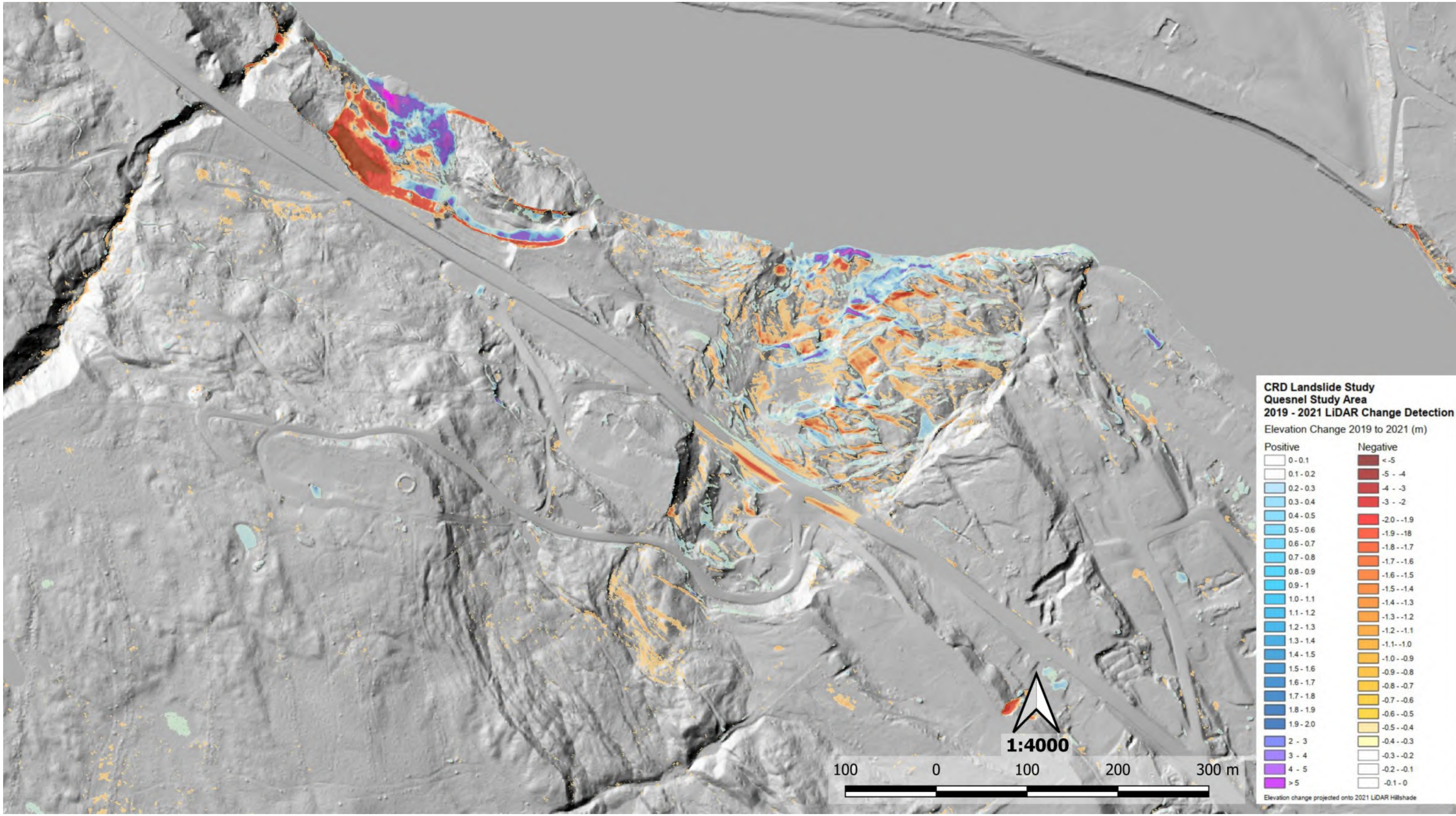
SCALE: AS SHOWN

Imagery Date is July 30, 2021

Project: 021-069

The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes Along the Western Reaches of Baker Creek

FIGURE 13



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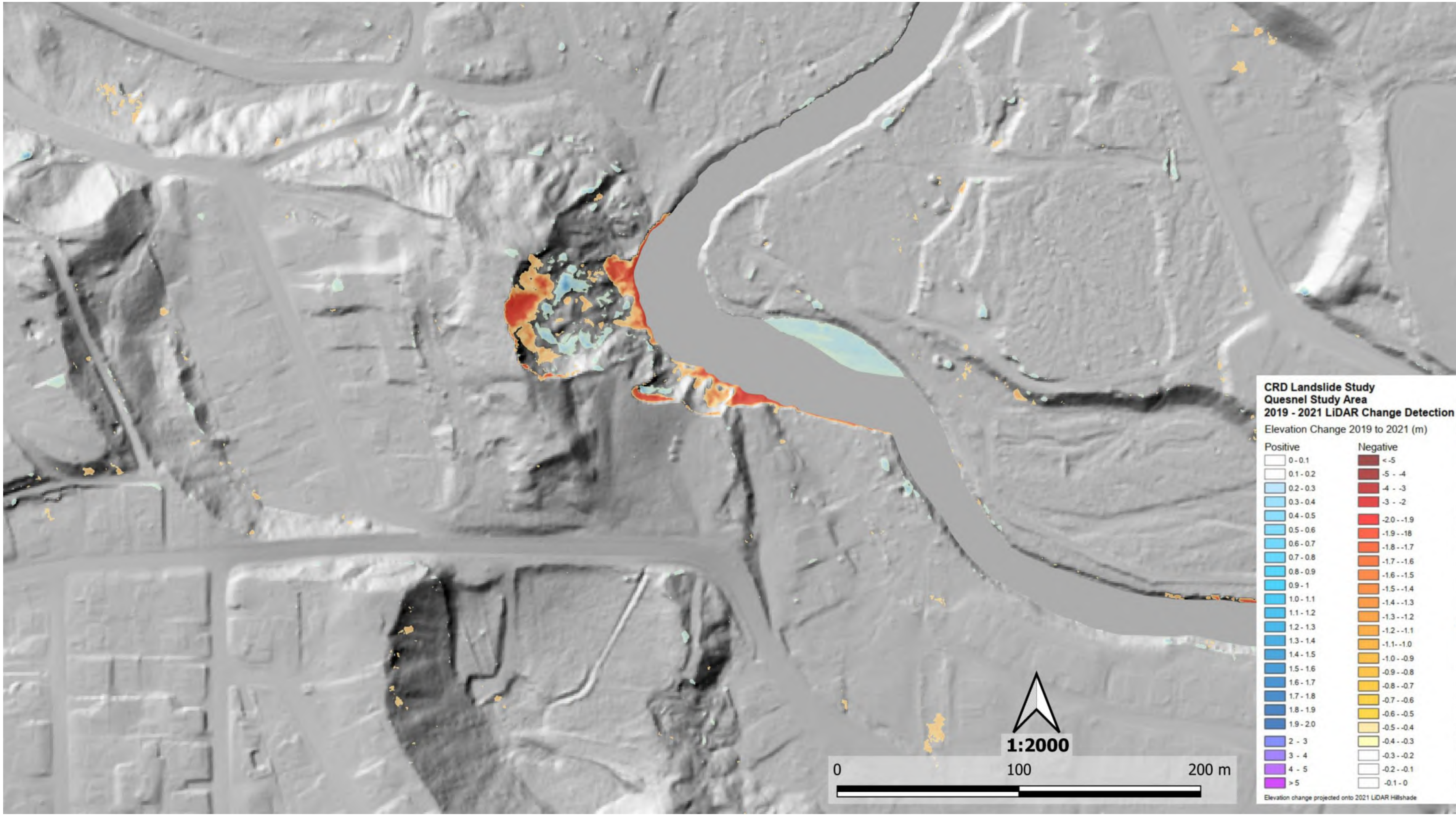
Imagery Date is July 30, 2021

Project: 021-069

The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes on and Around the Garbage Dump Slide

FIGURE 14



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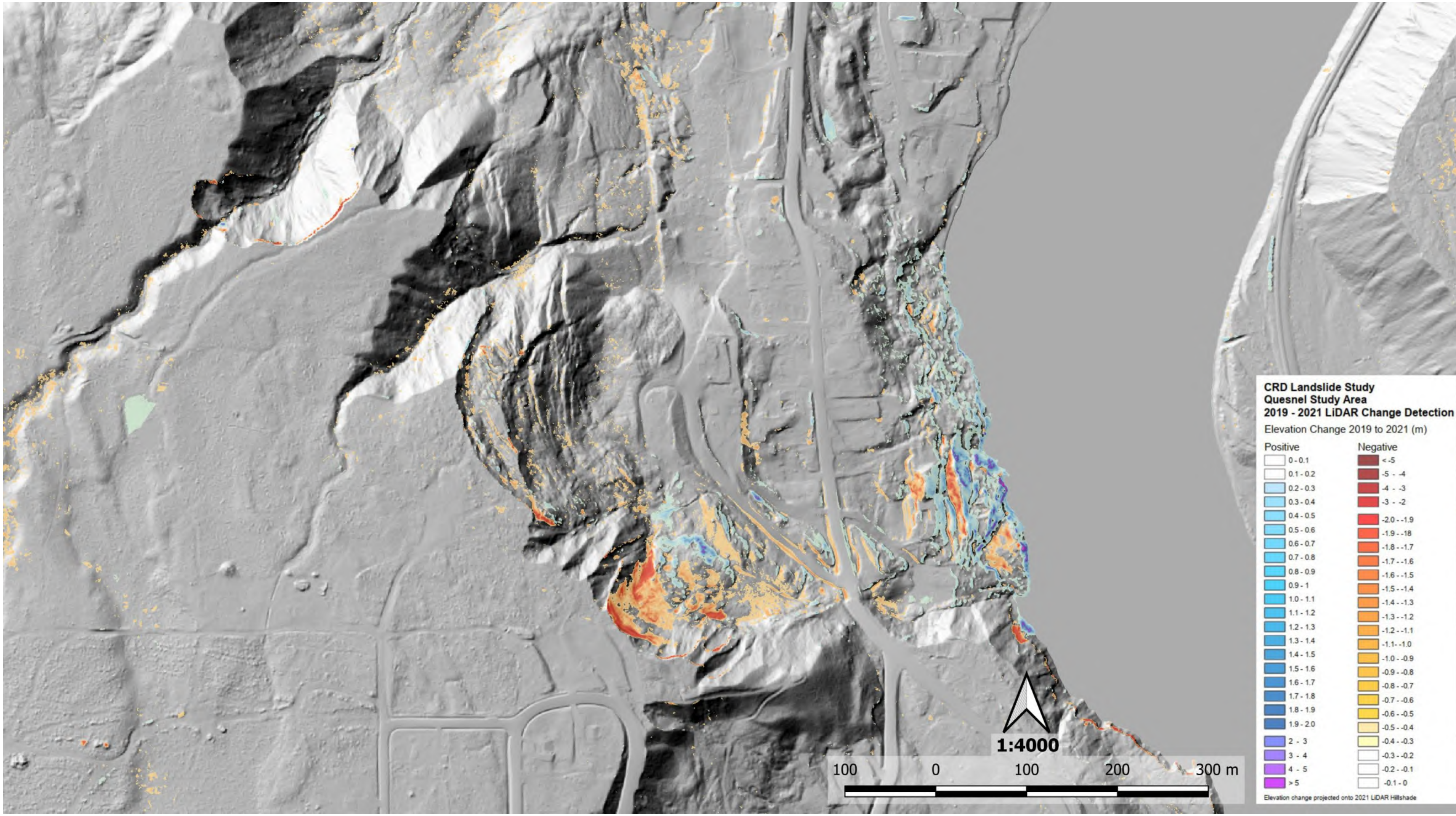
Imagery Date is July 30, 2021

Project: 021-069

The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes at the Toe of the West Quesnel Slide

FIGURE 15



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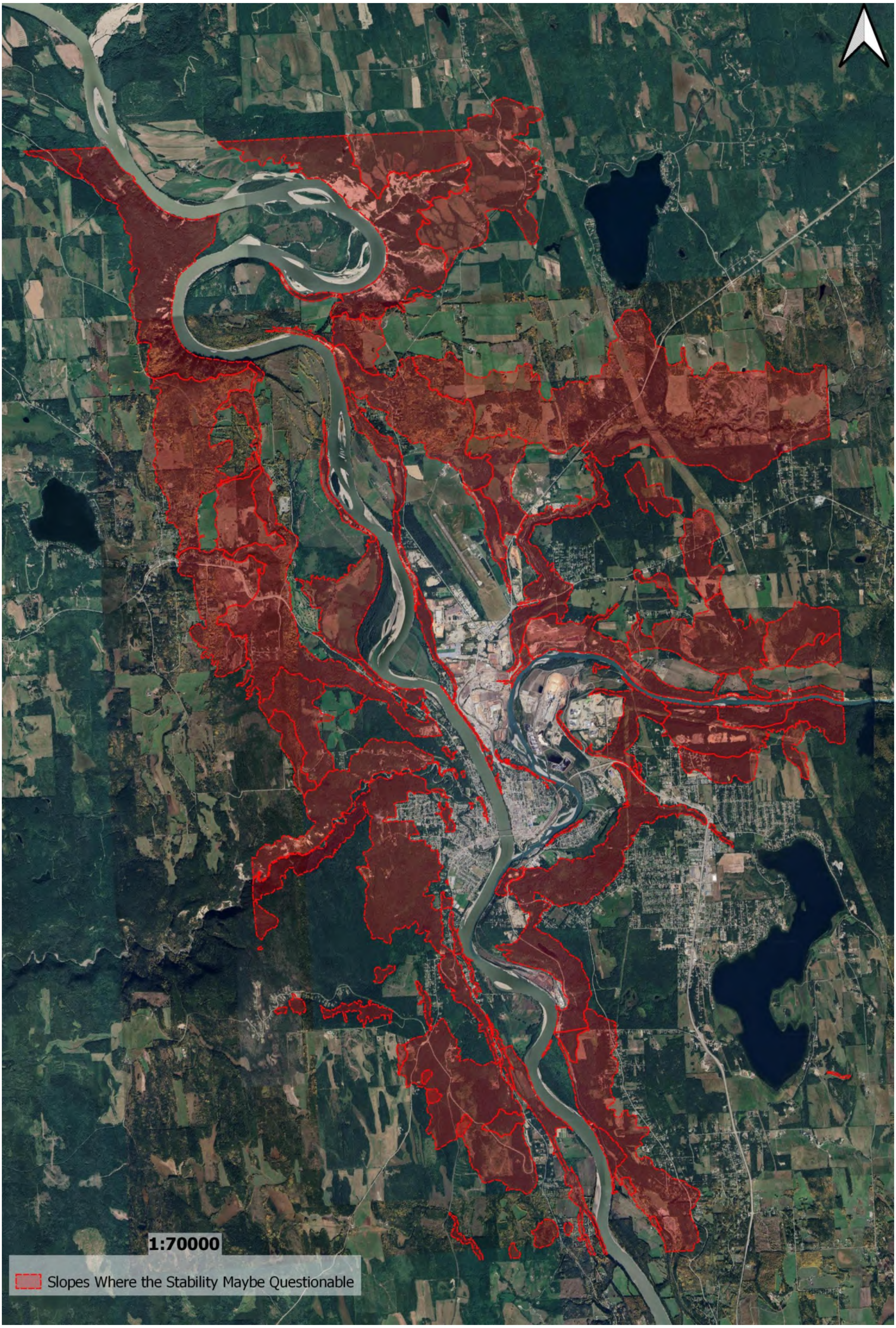
SCALE: AS SHOWN	**The Results of the Change Detection Analysis using the 2019 and 2021 LiDAR Datasets for the Slopes around the Ruric Springs Subdivision Slide and the Marsh Road Hill Slide**	**FIGURE 16**
Imagery Date is July 30, 2021		
Project: 021-069		



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Overall Extent of Study Area Overlain with the Slopes Where the Stability Maybe Questionable

Figure 18

Source: Oct 7, 2021, Satellite Imagery provided by Google Earth Engine

Project No. 021-069

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Hillshade of Study Area Extent Overlain with the Slopes Where the Stability Maybe Questionable

Figure 19

Source: 2019 / 2021 LiDAR Imagery provided by CRD

Project No. 021-069