# Monitoring Report 2018-2019

West Quesnel Land Stability Program
Quesnel, BC
Project # KX0439755

## Prepared for:

City of Quesnel
410 Kinchant Street Quesnel, BC V2J 7J5

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## 7/21/2020

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# 1.0 Introduction

Wood Environment & Infrastructure Solutions (Wood), a Division of Wood Canada Limited (formerly Amec Foster Wheeler) has carried out instrumentation monitoring in West Quesnel as part of the ongoing West Quesnel Land Stability Program. The purpose of the instrumentation monitoring is to track landslide related ground movement, groundwater conditions and precipitation. The monitoring is also used to assess the effectiveness of dewatering programs that have been implemented by the City of Quesnel in 2012 (Phase I) and 2016 (Phase II).

Several sets of Global Positioning System (GPS) ground surface movement hubs have been established in the field and surveyed between 1998 and 2019. Between 2000 and 2007, Amec Foster Wheeler installed geotechnical instrumentation including slope inclinometers and piezometers. Additional instrumentation, including slope inclinometers, piezometers, flow meters and precipitation measurement equipment was installed in 2012 and 2016 in conjunction with the construction of the various phases of pumping wells, horizontal drains and storm drainage.

For detailed background information including geology and project history, the reader is referred to previous Amec Foster Wheeler reports, including our previous annual monitoring reports, the "2012 Subsurface Dewatering System" report dated 21 November 2014, the "Trial Dewatering" report dated May 2008, and the "West Quesnel Land Stability Study" report dated May 2007.

During 2016 a program involving storm drainage, horizontal drain and pumping well construction along with reconfiguration and addition to some of the geotechnical instrumentation was carried out in the West Quesnel area. Some of those works involved temporary disruption or changes to pre-existing instrumentation, and in some cases may have influenced data collection as the new Phase II drainage measures (and related instrumentation) were only gradually brought into service during the latter half of 2016 and early 2017.

During 2018, several of the instrumentation data collection stations experienced communications issues which resulted in data gaps that occurred generally between late spring and mid summer of 2018. In 2018, a program of decommissioning previously sheared slope inclinometer casing and an abandoned pumping well PW10 was completed. Pumping well PW25 was also cleaned.

In 2019, slope inclinometer SI17 was decommissioned and replaced by SI17a. Pumping wells PW5 and PW24 were also cleaned, however not reactivated.

This report summarizes monitoring data collected during 2018 and 2019 and provides an update on observed trends or interpretations that have developed or changed since our 2017 Annual Monitoring Report, dated 09 August 2018.

# 2.0 GPS Movement Hubs

Beginning in September 1998, FortisBC (formerly Terasen Gas and BC Gas) installed and monitored a series of GPS surface movement hubs. Subsequently, in 2001, 2006 and 2008, the GPS hub network was expanded and modified such that a current total of up to 47 hubs have been monitored. The monitoring consisted of comparing changes in the specific positions of the defined survey reference points over time as measured periodically by survey contractors (most recently McElhanney Consultants Limited), retained by both FortisBC and Wood on behalf of the City of Quesnel. Surveys are typically conducted on a quarterly basis with the results forwarded to us for inclusion in the monitoring program. In 2011 Fortis arranged for installation of some additional closely spaced GPS hubs in a small part of West Quesnel that are monitored annually in conjunction with UBC for a research project. These hubs are not generally monitored as part of the West Quesnel Land Stability Program and are not reported on herein.

During 2018 and 2019, semi-annual GPS monitoring was carried out in June and December for the GPS hubs established in 1998, 2001, 2006, and 2008 and for one replacement location (GPS Hub 13-02) established in 2013.

A summary table and detailed individual plots of movements for all GPS hubs are provided in Appendix A. Please note that while both horizontal and vertical movement data is recorded, typically vertical GPS survey data has at least one order of magnitude lower accuracy than the horizontal data. Accordingly, while there are some general trends that can be observed regarding vertical and/or the resultant of both horizontal and vertical movement, the following discussion refers primarily to horizontal movement information.

The locations of the various GPS hubs monitored for the West Quesnel Land Stability Program are depicted on Figure 1. Figure 1 also provides a simplified vector movement plot for GPS hubs monitored in the West Quesnel area. The GPS vector plots in Figure 1 show relative magnitude and azimuth of the latest total horizontal movement vectors. Intermediate movements are approximated. Details for individual GPS movement hubs and intermediate movement vectors are provided in Appendix A.

The GPS movement hubs can be separated into four general categories based upon their location and displacement. The first category represents benchmark hubs, which are used to provide reference control for the survey. These benchmarks are theoretically located outside the landslide area on stable ground and have recorded little, if any, movement since installation. The exceptions to this are survey tolerance variations that may suggest no or minor movement (typically less than 15 mm of total horizontal movement over the length of time the surveying has been conducted with no discernible consistent directional trend). While there have been as many as eight benchmark hubs installed, typically only three (Water Tank, GPS 01-38, and GPS 98-23) have been utilized to gauge the accuracy of the obtained survey data. Note that due to construction and replacement of the water tank a control point (Water Tank 3) was added in 2017.

The second category consists of twelve hubs that are at or near the eastern extremity of the study area and are used to define the approximate toe area or likely eastern boundary of active landslide movement. Generally, cumulative total horizontal displacement less than 20 to 25 mm is interpreted to mean that the location is beyond the active movement toe area. This is especially true if there is no long term consistent directional trend observed in successive measurements. Higher values suggest that the hub is on or very near the toe of the slide, more so if there is a consistently observed easterly trend in successive measurements.

The third category consists of two hubs that are located at or near the upper west portion of the study area, which were placed to assist in defining the western extent or crest of landsliding. Similar to the toe area, where total horizontal displacement less than 20-25 mm and a lack of consistent directional movement of the hubs has occurred, they have been considered as being outside the area of active landslide movement.

The fourth category comprises 30 GPS hubs that are interpreted to be within the main body of the landslide. These hubs have shown continuing cumulative displacement and consistent directionality of movement (easterly or north-easterly) over the course of the 21 years that the 15 oldest hubs have been monitored. The total horizontal movement measured between September 1998 and December 2019 for the 15 oldest hubs, ranged from 296 to 721 mm, depending on location.

Table 1 below, presents cumulative, annual, and peak rate horizontal movement data for GPS Hub 98-17 since 1998. GPS Hub 98-17 is considered as being a representative but essentially 'worst-case' monitoring location near the middle of the study area. Figure A1 (duplicated from Appendix A) graphically shows the pattern of cumulative annual horizontal movement data presented in Table 1. Prior to 2013, the long-term average horizontal movement detected was in the order of 44 mm per year. Movements in excess of average were detected in eight of the 14 years of monitoring prior to 2013, while there were six years of significantly less than average movements (e.g. less than 25 mm/year). The lower movement years have generally been attributed to three periods of unusually low precipitation extending over successive years, while the higher movement years have been generally correlated with periods of above average precipitation. In 2018 and 2019, only 9 and 7mm, respectively, of horizontal displacement was measured at Hub 98-17. These movements were greater than the 6 mm recorded in 2017, however less than the 14 mm recorded in 2016. Measured movements at GPS Hub 98-17 have now been less than 25 mm per year for the seven successive years since 2012, the year during which the Phase I subsurface dewatering works were installed, and less than 10 mm per year since 2016, corresponding with the Phase II subsurface dewatering and surface dewatering works.

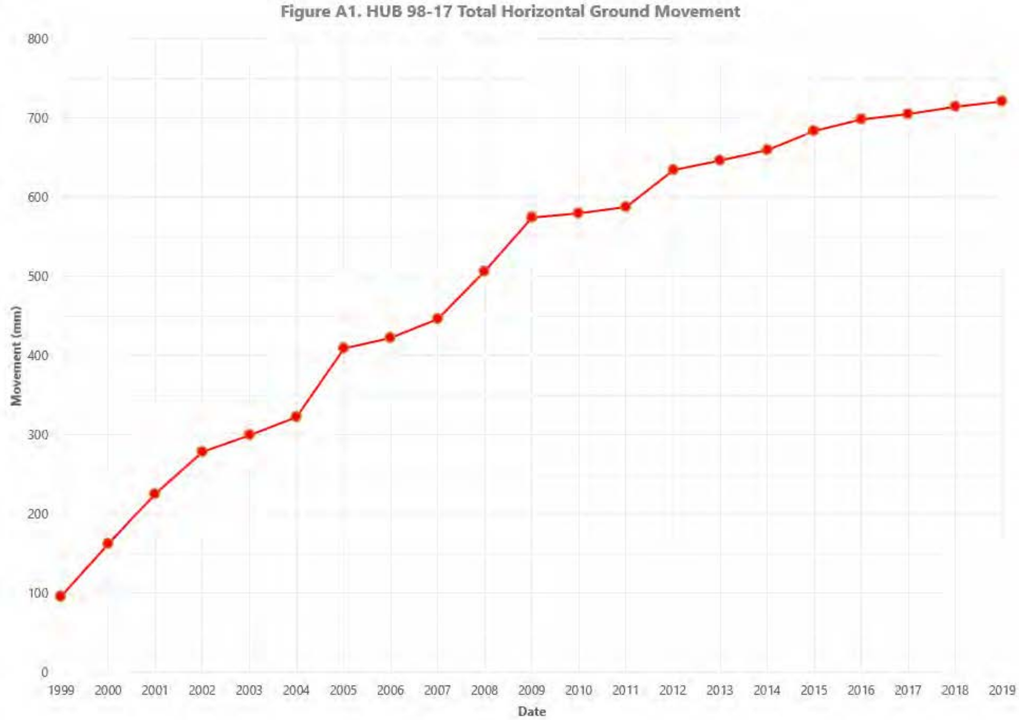
Table 1. Typical Horizontal Movement (from GPS Hub 98-17) from 1998 to 2019

| Year | Cumulative Movement (mm) | Annual Movement Rate (mm/yr) | Peak Movement Rate (mm/yr)[1] |
|---|---|---|---|
| 1998 | 16[2] | n/a[2] | 66 |
| 1999 | 96 | 80 | 115 |
| 2000 | 163 | 67 | 110 |
| 2001 | 225 | 62 | 75 |
| 2002 | 279 | 54 | 83 |
| 2003 | 300 | 21 | 23 |
| 2004 | 322 | 22 | 22 |
| 2005 | 409 | 87 | 75 |
| 2006 | 423 | 14 | 75 |
| 2007 | 447 | 24 | 43 |
| 2008 | 506 | 59 | 160 |
| 2009 | 574 | 68 | 216 |
| 2010 | 580 | 6 | 56 |
| 2011 | 588 | 8 | 107 |
| 2012 | 635 | 47 | 93 |
| 2013 | 647 | 12 | 38 |
| 2014 | 660 | 13 | 39 |
| 2015 | 684 | 24 | 53 |
| 2016 | 699 | 14 | 92 |
| 2017 | 705 | 6 | 20 |
| 2018 | 714 | 9 | N/A |
| 2019 | 721 | 7 | N/A |

Note(s)

1. Peak movement rate typically observed during the spring, as the frequency of GPS hub monitoring changed in 2018 it is not representative to report the short term peak movement rate
2. GPS Hub initialized in September 1998.

Figure A1. HUB 98-17 Total Horizontal Ground Movement






wood.

Figures 2 through 32 show contour plots of total and annual GPS hub movement data selected over different time periods (which also means that only hubs active during the entire time period are included in the contour plotting) and for different components (i.e. horizontal movement, vertical movement and resultant total three-dimensional (3D) movement). Historical ground movement contours (Figures 7 through 20) were drawn using triangulation in AutoCAD Civil 3D (2013); while the relative 2014 through 2019 ground movement contours (Figures 2 through 6, and 21 to 32) were triangulated in ArcGIS (version 10.2 for Desktop). Please note that these are simplified contour plots, and that not all the cumulative movements are necessarily in the same vector direction.

Figure 2 shows total horizontal movement between September 1998 and December 2019, for the GPS hubs installed in September 1998. Significant movement has been observed at the GPS hubs within the slide mass since 1998. A total horizontal movement of 721 mm has been detected at GPS Hub 98-17 (corner of Bettcher St. and Lark Ave.) since the inception of GPS monitoring.

Figure 3 shows total horizontal movement between December 2001 and December 2019, for the GPS hubs installed in September 1998 and December 2001.

Figure 4 shows total horizontal movement between November 2006 and December 2019, for the GPS hubs installed in September 1998, December 2001 and November 2006. Figures 2, 3, and 4 show that the greatest horizontal movement observed since 1998 has generally occurred in the middle of the slide area.

Figure 5 shows total vertical movement between November 2006 and December 2019. This contour plot shows generally downwards movement along the upper, north and west edges of the slide (typically near the scarp area, although it should be noted that there are very few hubs in this area to properly define the scarp area separately from the main body of the slide). There were also some observed upwards movement trends (thrusting/bulging) near the toe of the slide. A significant bulge related to toe thrust movements of the slide has been detected on Lewis Drive, just east of Healy Street.

Figure 6 shows total 3D movement between November 2006 and December 2019. As in Figure 4, the largest movements have generally been observed in the middle of the slide area.

Figures 7 through 32 show annual horizontal movement and annual 3D movement respectively for the years 2007 through 2019 (two figures per year). For 2018 a general pattern of less than 10 mm of horizontal movement (Figure 29) and predominantly less than 20mm 3D movement (Figure 30) was recorded. For 2019 a general pattern of less than 20 mm of horizontal movement (Figure 31) and predominantly less than 30mm 3D movement (Figure 32) was recorded.

The differences in annual movements between the relatively low activity years of 2007, 2010, and 2011 as compared to higher movement years of 2008, 2009, and 2012 are judged to be mainly attributable to differences in annual precipitation that influenced the groundwater pressures within the landslide area. However, in addition to the precipitation effects, beginning in the second half of 2012 the effects of the subsurface dewatering have been a significant contributing factor to the reduced movements relative to precipitation observed for 2013 through 2019 (see Section 7.0 for more details on precipitation data and Section 8.0 for a discussion on the relationships between precipitation, groundwater pressures and ground movement).

# 3.0 Slope Inclinometers

A total of 15 slope inclinometer (SI) casings were installed by Wood in West Quesnel, between November 2000 and August 2006, to monitor depths and rates of subsurface lateral ground movements. Installation details and the results of previous SI monitoring on the original fifteen SI's are described in previous Amec Foster Wheeler reports. In mid-2009, it was noted that all of these slope inclinometers except SI8 and SI11had been sheared off as a result of the continued ground movement.

In November 2018, to accommodate the revised BC Groundwater Protection Regulation 152/2016 a decommissioning program was completed by Westech Drilling Corp., monitored by a Wood representative. All previously sheared SI installations installed between November 2000 and August 2006 were decommissioned.

To decommission the SI's, a 30% grout mixture achieved by mixing 45.4 kg (100lbs) Enviroplug bentonite grout with 136.4 litres (30 gallons) of water was pumped into the SI casing from the maximum allowable tremie pipe advancement depth. After the grout was set, the infilled SI casings were cut approximately 1.1 m below surface, and a 1.0 m bentonite seal, consisting of hydrated and hand packed bentonite pellets was placed. At surface, a thin layer (approximately 100 mm thick) of locally available soil material was used to restore the ground surface. Table 2 below provides SI decommissioning details. Although at some locations the tremie pipe was not able to be advanced to the desired minimum depths (shear surface) the decommissioned SI's are considered to be decommissioned and pose no groundwater transmission/ infiltration risk. The locations of the decommissioned SI's are shown on Figure 37.

Table 2. 2018 SI Decommissioning Program Details

| ID | Original SI Installation Depth (m) | Shear Surface Depth (m) | Tremie Pipe Advancement Depth (m) |
|---|---|---|---|
| SI 1 | 43.6 | 40 | 40 |
| SI 2 | 74.6 | 41 | 46 |
| SI 3 | 102.4 | 39 | 39 |
| SI 4 | 158 | 51 | 51 |
| SI 5 | 144.8 | 35 | 49 |
| SI 6[1] | 154.5 | 78 | 30 |
| SI 7 | 125.6 | 68 | 46 |
| SI 9 | 79 | 65 | 64 |
| SI 10 | 80 | 21 | 12 |
| SI 12 | 73 | 63 | 62 |
| SI 13 | 40 | 13 | 12 |
| SI 14 | 100.3 | 20 | 19 |
| SI 15 | 100 | 18 | 18 |
| Unnamed (near SI 15)[2] | 91[3] | N/A | 50 |
| SI17 (IPI)[4] | 74.8 | 65 | 74.8 |

Note(s)
1. Grout mixture settled after placement. Upper 3.0 m backfilled with hydrated bentonite chips
2. HQ rod encountered 0.4 m below surface. Removed down to 1.1 m below surface with SI pipe.
3. Pre-decommissioning measurement, initial installation was proposed to be 100 m, however the SI installation resulted in HQ rods being cemented/grouted in place.
4. Decommissioned and replaced in late 2019

In 2012, as part of the monitoring package for the Phase I dewatering program, two real time in-place slope inclinometer (IPI) strings were installed across the approximate depths of previously detected sub-surface landslide failure surfaces. These in-place inclinometers allow determination of subsurface lateral displacement in real time. The real time data allows for the most accurate correlation between movement, water infiltration and the dewatering activities. Real time data collection for these instruments, SI16 and SI17, commenced 20 September 2012 and 16 October 2012 respectively. Prior to installing the IPI's, manual baseline SI survey measurements were also performed. In mid-2016 a third real time IPI (SI18) was installed as part of Phase II of the West Quesnel dewatering works. Real time data collection of SI18 commenced in mid-2017. The locations of the installed IPI's and their associated displacement magnitude and direction are shown on Figure 1.

In early fall 2018, it was noted that SI17 was displaying very irregular readings across most of the sensors, and in late 2019 it was decommissioned, using the same decommissioning procedure described above. SI17 was replaced by SI17a in an immediately adjacent location.

The collected IPI sensor displacement data is presented in Appendix B. The data associated with the plots depicting the IPI displacement presented in Appendix B has been automatically collected utilizing Wood's web-based data management system, custom developed for the West Quesnel Land Stability Program. Although the IPI's provide continuous real time movement detection, only the average daily horizontal ground displacement at specific depths along each IPI sensor string is presented on the Appendix B plots.

Between the 2012 installation and the beginning of 2014, the SI16 and SI17 IPI sensors detected similar small movement events, with SI16 showing an additional event prior to SI17 being initialized (20-22 September 2012). The four events occurred on 17-18 October 2012, 3-7 January 2013, 29 April – 7 May 2013, and 19-22 December 2013. SI16 moved a total of 12 mm over this time frame with individual event movements of approximately 1.5 mm, 1.5 mm, 3 mm, 5 mm, and 1 mm respectively. SI17 moved a total of 15 mm with individual event movements of approximately 2 mm, 4 mm, 6 mm and 3 mm respectively. Typically, the movements were observed to be relatively short events; however, creep like movements were also observed at SI17 between the two major movement events (7 January through 29 April 2013).

In 2014, a total of 7 mm and 8 mm of movement was observed for SI16 and SI17, respectively. The movement occurred in two distinct movement events: 20-25 April, and 26 May – 11 June. The April event had an approximate relative movement of 3 mm for both SI16 and SI17, while the May-June event had an approximate relative movement of 4 mm and 5 mm for SI16 and SI17, respectively.

The total 2015 movement for SI16 was on the order of 25 mm. SI17 recorded a total movement of approximately 14 mm before its failure in April. A larger than average movement event was noted at SI16 between 10 March and 15 May, with a total of 18 mm of movement. The beginning of this movement event was also noted at SI17 before the instrument began to malfunction. Additional smaller movements of 2 mm and 1 mm were noted on 7-23 February and 31 July – 22 August respectively, at SI16. In addition, 4 mm of creep movement occurred between approximately 14 September and the end of 2015 at SI16.

During 2016, total movements on the order of 8 mm and 10 mm were observed at SI16 and SI17, respectively. The movements occurred in five distinct movement events at SI16: 7-10 March, 22-27 April, 22-28 July, 27-30 November, and 13-20 December. Individual event movements in SI16 were small (from 0.5 to 1.5 mm each) however there was also about 2 mm of creep movement throughout the year not associated with any specific event. The SI17 sensor string had not been reinstalled until after the first 2016 movement event was detected in SI16, but it did record the three distinct movement events on 22-27 April, 22-28 July, and 27-30 November of 2016. Movements recorded for each event were slightly greater at SI17, being approximately 4 mm, 3 mm and 2 mm respectively.

In 2017, only three small movements in the order of approximately 1 mm each were detected between late March and mid-May at SI16 and SI17. SI17 and SI18 indicated a movement event on the order of 1 mm in October 2017, and a 0.5 mm movement event at SI18 in late December.

In 2018, SI16 showed a net 5 mm inverse movement or relaxation over the course of the year, however two positive slide type movement events were noted. A 0.5 mm movement was observed between May 25 and 31, and a 1.4 mm creep movement was observed between December 7 and 31. Total movements on the order of approximately 8 mm were observed at SI17 (prior to failure on August 31) and at SI18. Three distinct movement events were observed at SI17 consisting of: a 2 mm movement event between March 16 and 18, a 0.5 mm movement event between May 23 and 31, and an approximately 1.5 mm event that started on August 28. In addition to the distinct movement events, a 4 mm creep movement was observed, between July 01 and August 28. Three distinct movement events were also observed at SI18 consisting of: 1.5 mm between March 16 and 20, 2 mm between April 3 and 13, and 2.5 mm between November 14 and 25. Between April 25 and October 29th there was a communication error with the data logger for this station that resulted in data loss. Based on SI16 and SI17 movement events, it is likely that another 2 mm of movement occurred at SI18 in early to mid-May.

In 2019, total movements on the order of 8.5 mm and 4.5 mm were observed at SI16 and SI18, respectively. SI17 failed in 2018 and was not replaced by SI17a until late 2019. SI17a did not detect any movement in 2019. The majority of the movement observed at SI16 occurred between March 17 and May 8. During this period four distinct movement events and four creep movements were observed totalling 8 mm of movement. A distinct movement event of 0.5 mm was also observed between November 19 and 23. In addition to the distinct and major movement events creep like movement (positive and inverse) were also observed throughout the year with no overall change. On November 25, the SI16A and SI16B sensors recorded a significant inverse movement. This movement is not consistent with other sensors and is an indication that this sensor may no longer be reliable. At SI18, movement events observed in 2019 consisted of two distinct and two creep like movement events. A 0.5 mm movement was observed between January 7 and 10, and a 2 mm movement event was observed between March 30 and April 6. Creep like movement (positive and inverse) with no net change was observed between February 2 and March 30, and a 2 mm creep like movement was observed between April 6 and December 31.

In general, there is a strong correlation between the ground movement data collected through surface GPS hub monitoring and the subsurface IPI sensors, however like GPS hub movements, subsurface IPI movements vary between locations. Figure 1 also depicts ground movement observations from the IPI sensor measurements.

# 4.0 Piezometers

Two general types of piezometers (with three different installation configurations) have been utilized in West Quesnel to monitor groundwater pressures in the vicinity of the landslide area. The predominant type of piezometer used in West Quesnel is a vibrating wire piezometer (VWP), which is an electronic water pressure sensing device that is installed directly in the ground via grouting in a borehole, to continually and remotely detect and obtain a record of groundwater pressure over time. A vibrating wire piezometer measures water pressure acting at the specific depth of its tip and can provide a rapid response to a change in ambient pressure. A number of retrofit installations have also been created where vibrating wire piezometer sensors were suspended inside open pipes (standpipes or well casings) for automated electronic detection of water pressures. Figure 27 depicts the locations for the various groundwater instruments and their related data logger stations.

The second type of installed piezometer at the site is a standpipe, which generally consists of a vertical pipe (plastic or steel) with openings (slots or screens) at depth that admit groundwater from the surrounding horizon where the screen is placed. The slotted screen sections of the standpipe piezometers are typically surrounded by a sand pack and have a bentonite seal both below and above the sand pack. Water pressures were historically measured manually using a water level dip tape, but these readings were discontinued at the end of 2012 as this information was more readily available with the addition of the automated VWPs installed during the 2012 full scale subsurface dewatering program.

Four standpipes have since been retrofitted with vibrating wire piezometer transducers installed inside the standpipes (VWP 3A/B and VWP 4A/B). A total of 48 vibrating wire piezometers were grouted directly in the ground to various depths at 21 different locations during the trial dewatering program prior to 2008. An additional 32 vibrating wire piezometers were grouted in at 14 new locations during the 2012 Phase I dewatering program. An additional nine vibrating wire piezometers were installed at six new locations during the Phase II dewatering program in 2016, bringing the installed total to 93 vibrating wire piezometer instruments. However, some of these instruments have been damaged or become dysfunctional (or dry) over time. The total number of active vibrating wire piezometers monitored during 2017 was 87. The locations of the boreholes in which the various piezometers are installed is shown on Figure 33.

All of the vibrating wire piezometer sensors are connected to Campbell Scientific data loggers (stations). These data loggers are used to automatically record sensor water pressures at set intervals and can store large quantities of data. Studies have shown that barometric pressure changes impact VWP readings[1]. Thus, all collected VWP readings have been corrected using readings from a barometer installed in data logger Station 2. The Campbell Scientific data loggers are connected to cellular modems, such that near real time data can be collected and accessed remotely by Wood staff.

A summary table listing the various piezometers, along with their groundwater pressures (phreatic surface elevation plots) can be found in Appendix C. Depending on the location of the piezometers, they depict various short and long-term groundwater pressure conditions within the West Quesnel area. Some near surface installations are more sensitive to seasonal precipitation trends, short-term weather events and potential water service line breaks, particularly if they are installed in shallow sands or gravels. Deeper installations tend to show longer term background trends with subdued seasonal response indicative of larger scale, more regional groundwater conditions. Some of the piezometers show the effects of nearby dewatering installations (pumping wells and horizontal drains).

1 Contreras, I.A., Grosser, A.T., Ver-Strate, R.H; 2012,"Update of the Fully-grouted Method for Piezometer Installations". Geotechnical News, Volume 30, No. 2., June 2012, www.geotechnicalnews.com/instrumentation_news.php

Table C1 (Background Piezometers), in Appendix C, presents the individual trends and observations from 2018 and 2019 for piezometer locations that were judged to be unlikely to have been affected by the dewatering efforts, and are more reflective of general background subsurface groundwater patterns in the West Quesnel study area. During 2018 and 2019 these instruments generally demonstrated patterns similar to previous years, that of steady state with temporary increases in response to seasonal precipitation and freshet. However, starting in 2016 and continuing through 2019 a few of these instruments that were previously unaffected, began to show slight decreases in groundwater pressures. Whether or not this is indicative of a normal response to weather patterns or due to a gradual influence of the dewatering programs remains to be seen. An exception to those observations was noted at VWP39. A spike in groundwater level of approximately 4 m was observed in May 2018 and, a 3.5 m spike to an elevation of 570 m was observed in the spring of 2019. The groundwater level generally remained at that higher elevation for the remainder of 2019.

Table C2 (Piezometers Near Pumping Wells), in Appendix C, presents overall trends and observations for piezometers that are situated near the pumping wells and may have been influenced by them. The piezometers nearest the pumping wells and closer to surface have experienced the greatest influence (decrease in groundwater pressure) since pumping started and many have reached a new steady-state pressure, depending on how productive and what the radius of influence of the well has been. Piezometers that have groundwater pressures remaining at steady state (with or without seasonal influences) are likely out of the radius of influence of the well or are too deep to be influenced. Some of the piezometers influenced by the pumping wells are also still reactive to seasonal precipitation. Generally, for this set of piezometers, in 2018 and 2019 there were no significant changes noted from previous years, with very gradual groundwater pressure drawdowns continuing where previously influenced by pumping wells. In late 2019, there was a temporary localized groundwater pressure increase noted in VWP9B and VWP09C that corresponded with the drill installation for SI17a. Some instrument locations still indicated slight influences from seasonal or storm events. Of note, a few locations previously apparently unaffected also started to show slight declines in groundwater pressures (e.g. VWP 14A, 27A and 31B). As above, whether or not this is indicative of a normal response to weather patterns or due to a gradual influence of the pumping wells remains to be seen.

Table C3 (Piezometers Near Horizontal Drains), in Appendix C, presents the overall trends and observations from 2018 and 2019 for piezometers situated above or near the horizontal drain (HD) installations. These piezometers have generally been at a steady state since initial drawdowns in 2012 when the majority of the horizontal drains were installed. Several of the instruments also exhibit regular variation patterns in reaction to seasonal weather and precipitation conditions.

The plots depicting the groundwater elevations found in Appendix C have been generated, utilizing Woods's data management system, custom developed for the West Quesnel Land Stability Program. The average daily groundwater elevation (phreatic surface) is presented in the plots. However, in order to allow practical plotting of the instrument data, digital filters were utilized to remove some erroneous data points, and to smooth or bridge data gaps.

In general, historic groundwater pressures within the West Quesnel area have been generally quite high relative to the ground surface, and thus detrimental to slope stability. The overall background trend in the groundwater pressure regime observed in 2018 and 2019 was relatively consistent with previous years with some short-term seasonal groundwater increases. However, from 2016 through 2019 it was noted that the seasonal spring freshet induced groundwater peaks measured at many of the locations were more subdued or muted than observed in previous years. Groundwater pressures adjacent to and previously drawn down by the trial pumping wells and trial horizontal drains continued to remain at or near their steady state lowered pressures. The instruments near the 2012 installations initially showed significant response and lowering water pressures due to the horizontal drain and pumping well installations and have since reached a steady state or continued with a slight downward trend. Figure 34 is a simplified graphic showing the estimated groundwater drawdown at the end of 2019 relative to what was inferred to be natural background elevations just prior to the implementation of the Phase I subsurface dewatering in 2012.

# 5.0 Pumping Wells

Prior to 2012, there were four pumping wells (PW) installed in West Quesnel. PW1 and PW2 were installed in 2003 and PW4 and PW5 were installed in 2007 as part of previous trial groundwater dewatering assessment studies. As part of the 2012 Phase I subsurface dewatering program, 14 new potential pumping well locations (PW6 through PW19) were drilled and pumps were installed at 13 of the locations (potential well PW10 was dry upon completion so no pump was installed). Though the pumps were installed and tested during the latter part of 2012, they were not fully activated until April 2013. As part of the Phase II dewatering works, six new wells (PW20 through PW25) were drilled and pumps installed during 2016, bringing the total number of installed and instrumented pumping well sites in West Quesnel to 23. Figure 33 shows the locations of the pumping wells.

In November 2015 the wires controlling the pump at PW6 were severed and the pump was left off. The pump was not reactivated until April 2016 when the wires were repaired. PW6 was also turned off briefly in July 2016.

From January to early February 2016, PW18 stopped pumping temporarily. PW18 stopped pumping again for three days in December 2016. This was likely due to the outlet freezing.

Several new pumping wells were drilled as part of the Phase II dewatering program in 2016. PW20 through PW23 were not put into service until late September of 2016. The pump in PW24 required adjustment after installation and full operation was deferred until January 2017. PW25 was only operated for a short time in December 2016, with adjustments also requiring a deferment of full operation until January 2017. Accordingly, only partial data is available from the new pumping well sites for reference in 2016 monitoring.

A summary table of the well installation details, along with charts of well water elevations and production rates since installation are presented in Appendix D.

The plots depicting the pumping well levels and production rates presented in Appendix D have been generated, utilizing Wood's data management system, custom developed for the West Quesnel Land Stability Program. The pumping well flow measurements were collected on an hourly basis and summed to establish a daily flow rate. Water well elevations presented are average daily values with digital filtering to remove erroneous readings.

During 2018, an estimated total of approximately 57.3 million litres of water was removed by the pumping wells. This estimated quantity however includes some interpolated data for missing or lost data due to communication and instrumentation outages in 2018. The increase in volume experienced in 2018 as compared to previous years was mainly due to the PW 24 operation for the majority of 2018. PW 24 accounted for 32.7 million litres of water was removed in 2018. PW 25 accounted for 9.9 million litres of water removal in less than 3 months (October through December) of full operation. The remaining pumping wells extracted approximately 14.7 million litres of the overall 2018 total.

In 2018, PW 10 was also decommissioned as it had been non-productive (dry) since installation. The well casing along with the slotted PVC screen that was installed within the well casing was removed with the aid of a pipe-jacking device. The open hole measuring 250 mm in diameter to a depth of 16.4 m was backfilled with grout (as described in Section 3.0 of this report for decommissioned SI's) up to 1.1 m below surface. A 1.0 m deep hydrated bentonite plug was placed near surface and a 100 mm thick locally available soil was used at surface to complete the decommissioning process.

During 2019, a total of approximately 87 million litres of water was removed by the pumping wells. Over 50% (45.6 million litres) of which was removed by PW25.

Table 3 presents a summary of calculated total annual flows from pumping wells for 2018 and 2019, based on a combination of automatic flow metering and interpolated data during data outages, where possible. An overall summary is presented in Appendix D, Figure D1.

Table 3. Pumping Wells - Total Annual Flows
(Results reported in Litres)

| ID | Pre 2018 | 2018 | 2019 | Total |
|---|---|---|---|---|
| PW1 | 276,114 | 22,785 | 21,705 | 320,603 |
| PW2 | 30,072 | 4,485 | 10,743 | 45,300 |
| PW4 | 41,222,018 | 1,908,692 | 2,298,874 | 45,429,583 |
| PW5 | 15,396 | - | 107 | 15,503 |
| PW6 | 7,987,565 | 614,248 | 721,468 | 9,323,281 |
| PW7 | 276,153 | 27,616 | 38,668 | 342,436 |
| PW8 | 3,183,878 | 584,691 | 961,057 | 4,729,626 |
| PW9 | 12,102,313 | 3,211,611 | 4,177,945 | 19,491,869 |
| PW11 | 411,621 | 61,482 | 50,628 | 523,732 |
| PW12 | 2,508,092 | 414,317 | 425,780 | 3,348,189 |
| PW13 | 34,166,772 | 4,353,351 | 5,509,769 | 44,029,892 |
| PW14 | 639,836 | 98,451 | 88,305 | 826,592 |
| PW15 | 1,013,025 | 132,920 | 145,631 | 1,291,576 |
| PW16 | 83,189 | 12,338 | 14,269 | 109,796 |
| PW17 | 552,828 | 547,879 | 481,471 | 1,582,178 |
| PW18 | 2,003,589 | 367,855 | 311,844 | 2,683,288 |
| PW19 | 701,922 | 184,312 | 195,108 | 1,081,342 |
| PW20 | 373,681 | 130,179 | 315,581 | 819,441 |
| PW21 | 1,109,532 | 797,209 | 1,087,563 | 2,994,304 |
| PW22 | 2,334 | 795 | 1,009 | 4,138 |
| PW23 | 1,674,694 | 1,246,714 | 1,293,156 | 4,214,564 |
| PW24 | 12,970,502 | 32,715,210 | 23,178,285 | 68,863,997 |
| PW25 | 24,637,600 | 9,901,211 | 45,648,535 | 80,187,346 |
| **Total** | **147,942,726** | **57,338,351** | **86,977,501** | **292,258,578** |

Overall, a total of just over 292 million litres of water has been removed by all wells since installation. Figures 35 and Figure 36 depict a simplified diagrammatic comparison of average daily pumping well production rates at various well locations for 2018 and 2019 respectively.

# 6.0 Horizontal Drains

During the fall of 2007, four trial horizontal (gravity) drains (HD) were installed at two different locations (HD1, HD4) into the slope underlying the West Quesnel study area. In mid-2012, as part of the Phase I subsurface dewatering program, 64 additional horizontal drains were installed at ten other sites (HD5 through HD14, see Figure 29). A total of 21 of the drains were observed to be dry (at the discharge end) shortly after installation. This included all the drains at sites HD1, HD5, HD6, HD7 and HD14 as well as three drains at HD9 and one drain at HD11. Although there was no initial water flowing from any of the drains at HD14, one drain did begin to produce water during the 2013 spring melt, and the flow rate was manually measured periodically until it stopped flowing in mid-2013. In mid-2016, 14 new horizontal drains were installed at three different sites (HD15, HD16, and HD18) as part of the Phase II dewatering program. Six of these drains were noted to be dry (at the discharge end) shortly after installation (five at HD16 and one at HD18). A summary table of the drain installations can be found in Appendix E.

Table 44 presents a summary of calculated total annual flows from the horizontal drain sites for 2018 and 2019, based on a combination of automatic flow metering some manual measurement and interpolations. An overall summary is presented in Appendix E, Figure E1. To date, almost 714 million litres of water has been removed through the horizontal drains.

Table 4. Horizontal Drains – Total Annual Flows
(Results reported in Litres)

| ID | Pre 2018 | 2018 | 2019 | Total |
|---|---|---|---|---|
| HD4 | 5,914,616 | 551,058 | 492,924 | 6,455,636 |
| HD8 | 513,607,157 | 49,874,455 | 42,580,903 | 552,568,951 |
| HD9 | 26,064,880 | 4,671,093 | 5,034,212 | 31,391,789 |
| HD10 | 46,109,186 | 2,980,364 | 122 | 45,235,215 |
| HD11 | 16,300,841 | 769,510 | 641,023 | 16,263,385 |
| HD12 | 25,603,322 | 5,575,363 | 860,601 | 28,300,588 |
| HD13 | 16,441,298 | 26 | 3,380,525 | 16,418,547 |
| HD15 | 1,290,292 | 90,628 | 0 | 1,380,920 |
| HD16 | 1,914,700 | 1,839,726 | 8,150,457 | 11,904,882 |
| HD18 | 3,246,623 | 392,591 | 118,579 | 3,757,793 |
| **Total** | **585,673,543** | **66,744,816** | **61,259,347** | **713,677,706** |

Appendix E contains individual production charts for each of the horizontal drain installations. Figures 35 and 36 depict a simplified diagrammatic comparison of average daily horizontal drain production rates between various drain installation locations for 2018 and 2019, respectively.

The plots presented in Appendix E depicting the flow rate measurements for the horizontal drain sites have been generated, utilizing Wood's data management system, custom developed for the West Quesnel Land Stability Program. The flow measurements were collected on an hourly basis and summed to establish daily flow rates. Where flow data gaps exist, or an incomplete daily data set was collected, false drops in flow rates were recorded. These are temporary data aberrations and can generally be disregarded, as the horizontal drains flow regardless of the flow meters being functional or not.

Total flow for all drains observed in 2018 and 2019 was approximately 66.7 and 61.3 million litres, respectively. Generally, a trend of decreasing production from the drains has been noted. This trend is mainly due to production decreases for HD8, the flow from which dominates the magnitude of flow from other sites. A general overall production decrease was anticipated and is considered typical of a system that is gradually dewatering an area, particularly when one considers the effect of HD8 and the drainage of the Lewis Pond area. HD8 also exhibited a reduced spring freshet peak in 2018 and 2019. The installation and activation of PW25 also appears to have resulted in curtailment of production from HD10, as PW25 has effectively drained HD10's recharge source.

# 7.0 Precipitation Data

Precipitation has a significant influence on groundwater patterns and hence ground stability in West Quesnel. The primary source of precipitation information has been data from Environment Canada[2] for the Quesnel Airport weather station variously known as Quesnel AWOS (prior to June 2010), Quesnel (from June 2010 to the end of 2012) and Quesnel Airport Auto (from 2013 to present), located approximately 6 km northeast of West Quesnel. Monthly and daily precipitation records, including current and previous historic 30-year climate normals, were obtained from the Environment Canada stations. Table 5, below, presents a comparison between published climate normals[3] data and computed 30-year average with associated observed trends.

Table 5. Monthly Precipitation Historical Data Trends

| | Quesnel Climate Normals[3] | | | 30 yr Average[2] |
|---|---|---|---|---|
| | 1961-1990 | 1971-2000 | 1981-2010 | 1990-2019 |
| Jan | 50.5 | 48.5 | 47.8 | 43.3 |
| Feb | 28.7 | 24.4 | 22.7 | 22.8 |
| Mar | 28.2 | 28.9 | 24.9 | 23.3 |
| Apr | 22.6 | 21.9 | 24.5 | 28.1 |
| May | 42.5 | 40.7 | 42.6 | 40.7 |
| Jun | 56.7 | 68.6 | 66.4 | 58.9 |
| Jul | 59.0 | 61.6 | 65.6 | 59.9 |
| Aug | 56.3 | 50.0 | 46.2 | 40.3 |
| Sep | 49.3 | 44.8 | 50.2 | 44.2 |
| Oct | 49.6 | 51.4 | 52.6 | 51.2 |
| Nov | 46.0 | 49.8 | 51.3 | 46.8 |
| Dec | 49.3 | 49.7 | 41.6 | 40.6 |
| **Year** | **538.7** | **540.3** | **536.4** | **500.1** |

The annual total precipitation recorded by Environment Canada at the Quesnel Airport for 2018 and 2019 was 488.3 mm and 499.8 mm, respectively, which are lower than the 1981-2010 climate normal of 536.4 mm and slightly lower that than the 30yr average of 500.1 mm.

In August 2015, an optical precipitation sensor (Optical Scientific Inc. ORS-815-DS) was installed within West Quesnel (Station 31) on Dixon Street north of Lewis Drive. This sensor (WS1) allows near real-time measurement of local precipitation (rain and snow events) intensity and duration within the West Quesnel Land Stability Program area. Figure F1B, in Appendix F, presents monthly total precipitation since August 2015 for WS1. The optical sensor collects data by measuring the amount of obstructions, typically rain and snow, but unfortunately it also appears to measure suspended particulates, such as dust and ash from wildfires. Thus, this instrument can be expected to record precipitation generally higher than actual precipitation depending on air quality at the time. This certainly appears to have been the case during recent wildfire seasons.

2 Environment Canada, 2020. Historical Data https://climate.weather.gc.ca/historical_data/search_historic_data_e.html Last visited July 13, 2020.

3 Environment Canada, 2020. Canadian Climate Normals https://climate.weather.gc.ca/climate_normals/index_e.html Last visited July 13, 2020.

Table 6, below, presents the annual total precipitation (rainfall and snow water equivalent) for the respective weather data station sources from 1996 to 2019. It also presents the antecedent total precipitation (i.e. precipitation in the months leading up to spring freshet from the previous November through to April) compared to a historic normal of 205 mm for those same months.

Table 6. Annual and Antecedent Total Precipitation from 1996 to 2019

| Year | Data Source | Annual | | Antecedent | |
|---|---|---|---|---|---|
| | | Total Precipitation (mm) | Difference from Historic Normal (1981 to 2010) (mm) | Nov-Apr Precipitation (mm) | Difference from Historic Normal (1981 to 2010) (mm) |
| 1996 | Quesnel AWOS | 657 | +121 | 231 | 26 |
| 1997 | Quesnel AWOS | 579 | +43 | 287 | 82 |
| 1998 | Quesnel AWOS | 488 | -48 | 181 | -24 |
| 1999 | Quesnel AWOS | 628 | +92 | 275 | 70 |
| 2000 | Quesnel AWOS | 554 | +18 | 189 | -16 |
| 2001 | Quesnel AWOS | 554 | +18 | 172 | -33 |
| 2002 | Quesnel AWOS | 471 | -65 | 213 | 8 |
| 2003 | Quesnel AWOS | 478 | -58 | 140 | -65 |
| 2004 | Quesnel AWOS | 692 | +156 | 226 | 21 |
| 2005 | Quesnel AWOS | 524 | -12 | 249 | 44 |
| 2006 | Quesnel AWOS | 465 | -71 | 142 | -63 |
| 2007 | Quesnel AWOS | 541 | +5 | 273 | 68 |
| 2008 | Quesnel AWOS | 530 | -6 | 206 | 1 |
| 2009 | Quesnel AWOS | 423 | -113 | 238 | 33 |
| 2010 | Quesnel AWOS/Quesnel | 315 | -221 | 135 | -70 |
| 2011 | Quesnel | 450 | -86 | 104 | -101 |
| 2012 | Quesnel | 427 | -109 | 163 | -42 |
| 2013 | Quesnel Airport Auto | 404 | -132 | 161 | -44 |
| 2014 | Quesnel Airport Auto | 416 | -120 | 168 | -37 |
| 2015 | Quesnel Airport Auto | 428 | -108 | 233 | 28 |
| 2016 | Quesnel Airport Auto | 495 | -41 | 169 | -36 |
| | West Quesnel WS1 | 761 | N/A | 215 | N/A |
| 2017 | Quesnel Airport Auto | 301 | -235 | 128 | -77 |
| | West Quesnel WS1 | 488 | N/A | 224 | N/A |
| 2018 | Quesnel Airport Auto | 448 | -88 | 177 | -28 |
| | West Quesnel WS1 | 728 | N/A | 243 | N/A |
| 2019 | Quesnel Airport Auto | 500 | -36 | 237 | 59 |
| | West Quesnel WS1 | 638 | N/A | 264 | N/A |

Figures F1A and F1B, present the 2018 and 2019 monthly precipitation collected from Quesnel Airport and WS1 compared to Canadian Climate Normals, 10 year and 30 year moving averages. An overall drying trend since 2010 is evident in Figure F2, a chart which presents the cumulative difference of total monthly precipitation relative to the 30-year monthly average. However, in 2019, there appears to have been a return towards historical average precipitation.

Figures F3A and F3B present the cumulative daily precipitation for 2018 and 2019 for both Quesnel Airport and WS1 along with the average temperature recorded for that day by the Quesnel Airport.

Figures F4A and F4B present precipitation storm events that occurred in 2018 and 2019 that had a greater than 10 mm accumulation relative to associated durations.

In 2018, 15 storm events were recorded by WS1. Prior to March 13, the last day the average daily temperature typically stayed below 0 °C, five storm events on January 29th, February 4th, 5th, 8th and March 9th, were recorded and were likely snow events as opposed to rainfall. Unfortunately, due to connection issues with WS1 precipitation data between April 25 and July 22 was lost. Thus, the next known storm event that occurred in 2018 was in August. Four events were recorded in August, on the 14th, 24th, and two events on the 29th. There was one event recorded on September 2nd, and four events in November (2nd, 4th, 6th, and 15th). Post December 1, the day after which the average daily temperature typically stayed below 0 °C, one event (likely a snow event) was recorded, on December 29th.

In 2019, six storm events were recorded by WS1. Prior to March 11, the last day that the average daily temperature typically stayed below 0 °C, two storm events were recorded, one on January 3rd and one on February 1st. The next storm event recorded in 2019 occurred on August 2nd. There was one event recorded on September 26th, and another on November 15th. Post November 21, the day after which the average daily temperature typically stayed below 0 °C, one event on December 7th was recorded.

# 8.0 Trends & Correlations

Selected typical data from different types of instrumentation was plotted to determine if any general trends or correlations were apparent. Although the availability of relatively comprehensive data sets across the study area was only phased in between 2007 and 2012, several trends can be identified, and are discussed below. Charts illustrating the data comparisons are presented in Appendix G.

## 8.1 Precipitation Effect on Groundwater

Figure G1, depicts total monthly precipitation compared to general groundwater pressures (elevations) at selected VWP sensors. Upon reviewing the collected data it is apparent that a significant natural seasonal rise in groundwater elevations occurs just after the winter season (during the freshet) each year. In some rarer instances, post-freshet secondary rises in groundwater levels can also be seen, generally corresponding with individual storm events or general late fall (pre-freezing) increases in precipitation. These seasonal rise patterns are more obvious on some instruments than others and can be artificially influenced by drainage systems and/or utility leaks. In general, the natural groundwater increases are observed to occur either gradually (e.g. as depicted by VWP 14A) or relatively rapidly (e.g. VWP 15A and VWP 39B). Examples of more subdued seasonal responses (VWP 9A and VWP 10C) and little or no apparent spring freshet response (VWP 4) are also depicted on Figure G1. The freshet response at a particular location is highly dependent on local ground permeability and precipitation accumulated over the preceding winter months. Shortly after the freshet increase, a gradual decrease in groundwater pressures can typically be observed. The rate of decrease is also dependent on ground permeability and dissipation capacity within the overall regional groundwater system but can also be influenced by the connectivity to the natural hydro-geologic environment and/or artificial dewatering systems.

An example of the apparent influence of the 2012 subsurface dewatering system is shown in the data plot for VWP 10C. Prior to activation of PW14, a natural but muted seasonal variation in groundwater pressure at VWP 10C can be seen in the winter of 2011 and 2012. In the spring of 2013, the natural groundwater fluctuation pattern observed for VWP 10C was interrupted by a sharp drop in groundwater pressure followed by a gradual stabilization and resumption of an even more subdued seasonal variation pattern approximately 5 m below the previous elevation. The interruption of the previous natural pattern coincided with the activation of nearby pumping well PW14, and the gradual decrease since then is considered attributable to the ongoing dewatering effects of this well. Similarly, a sharp upward spike in the groundwater pressure at VWP 10C observed in November of 2017 coincided with the same period when the pump in PW14 was off.

There is also likely an over-riding time-lag effect of infiltration of previous rainfall or snow melt (during frozen/non-frozen and dry/saturated ground conditions) which likely influences groundwater pressures. There may also be additional factors operating such as infiltration variability depending on surface moisture conditions and near surface groundwater conditions, lawn watering, variable losses from sewers and water systems and other unknown factors. In addition, in some landslide masses, the degree of infiltration has been found to vary with ongoing ground movement over time, as internal flow paths, tension cracks and shear zones change as movement occurs.

For 2018 and 2019 the observed natural seasonal spring increase in background groundwater pressures for instruments unlikely to have been affected by dewatering systems appeared to be generally similar to or even slightly higher than that observed in previous years. In addition, the post freshet dissipation in groundwater levels has not been as much as observed in previous years. Significant seasonal spring freshet increases of approximately 4 m in 2018 and 3 m in 2019 at VWP39B were observed with little to no following dissipation, resulting in a 7m groundwater pressure increase over two years. This does appear to be a localized condition as there are no other instruments showing same trend, but it does demonstrate that there are still potentially significant areas within the landslide area with high groundwater pressures driven by natural phenomena or local ground disturbance that are not mitigated by the current drainage infrastructure.

## 8.2 Precipitation Effect on Ground Movement

Previous Wood reports describe a general and expected correlation between periods of higher precipitation and subsequently increased ground movements as measured by quarterly or annual GPS surveys, with the majority of movement observed within any one year generally correlating with spring freshet. As noted in previous annual reports, there also appears to be a time-lag between increased precipitation and resulting magnitude of annual total ground movement, likely due to the delayed effect on groundwater pressures from the location, timing, type and amount of precipitation as noted above. Figure G2 illustrates this time-lag effect between the magnitude of total movement in any given year and the total amount of antecedent precipitation (i.e. that occurring in the previous November to April) prior to the movement. Although still a fairly general and simplistic correlation made with limited available data, it is clear that up until 2012 there was a relatively good correlation between the antecedent precipitation and the magnitude of movement, i.e. whenever the total antecedent precipitation was higher than about 150 mm for one or two years then the annual ground movement was typically in excess of 50 mm (averaging 54 mm per year). However, from 2013 onwards, whenever the antecedent precipitation has been above 150 mm the observed annual ground movement has been averaging 13 mm per year. This change in the historic correlation pattern is attributed to the early effects of components of the subsurface dewatering system coming online in 2012- 2013 and again in 2016. In 2017 the antecedent precipitation fell to below 150 mm, and at the same time the annual movement was the lowest recorded (6 mm). In 2018 and 2019, the departure from the historically higher movement pattern observed prior to 2013 continued, with movements of only 9 mm and 7 mm per year against antecedent precipitation of 177 mm and 237 m in 2018 and 2019, respectively. It is difficult to discern how much of the reduced movement was due to the observed background trend of gradually drying precipitation but the change to the movement-precipitation correlation after 2012 indicates that the cumulative drainage effects of the dewatering system are having a significant positive effect on reducing movements.

Beginning in the fall of 2012, more detailed (daily) ground movement data from the IPI instruments (as opposed to intermittent GPS surveys) became available. Also starting in August 2015, higher detailed local precipitation data became available from WS1, and although the precipitation data recorded via this optical sensor appears to be over-stated due to air quality issues, a preliminary correlation between significant precipitation storm events and ground movement can be seen. Figure G3 depicts detailed plots of cumulative ground movements against daily precipitation and temperature for the last 5 years.

## 8.3 Groundwater Correlation with Ground Movement

While precipitation patterns can be shown to have a general influence on ground movement, typically it is actually the resulting groundwater pressures that more directly influence landslide movements. Previous Wood reports have described how increased groundwater pressures acting on a landslide failure surface reduce overall stability and potentially cause subsequent increases in ground movement. Figure G3 depicts daily precipitation, ground movement (as determined by horizontal GPS surveys and daily IPI data) and daily groundwater elevation from a typical background groundwater instrument (VWP 14A) since September 2012. Even though ground movements for 2013 through 2019 are significantly reduced from previous years, a clear correlation still exists between the most significant movement events that do occur, and the corresponding spring freshet groundwater pressure rises. Some non-freshet movement events also occur; however those were noted to correspond with reports of significant water main and sewer utility leaks, and storm events. The detected leak events demonstrate the importance of the City of Quesnel's annual leak detection and repair program.

Figure G4 presents a longer-term plot of horizontal ground movement (GPS 98-17, IPI 16 C, SI17 B, and SI18 B) versus typical background groundwater pressure (VWP 14A). From 2008 to 2012 a clear pattern of increased ground movement and corresponding annual spring freshet groundwater pressure increases is evident. During 2010 and 2011 there was a very subdued spring groundwater pressure rise (likely due to an extended period of significantly lower than normal antecedent precipitation), which also corresponded with a period of lesser ground movement. However, starting in 2013 there has been appreciably less ground movement despite background seasonal groundwater pressures at or above elevations that would have been expected to trigger greater movements in previous years. This change in the historic pattern is deemed to be due to the incremental effects of the Phase I subsurface dewatering works installed and initiated between mid-2012 and the spring of 2013. The timing of the installation of the dewatering works as well as the output from select horizontal drains are overlain on Figure G4 to illustrate this effect. The even further reduced movement observed in 2017 through 2019 is contrasted against still significantly high natural seasonal groundwater peaks is judged to be further evidence of the cumulative positive stabilizing effect of the storm drainage, additional pumping wells and horizontal drains being brought on line during the last half of 2016.

## 9.0 Closure

This report presents the results of the annual monitoring carried out by Wood for the 2018 and 2019 calendar years. This report has been prepared for the exclusive use of the City of Quesnel and their representatives for specific application to West Quesnel Land Stability Program. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. Wood accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report was prepared in accordance with generally accepted geotechnical engineering principles and practice. No other warranty, expressed or implied, is made. This report and associated data are subject to the attached limitations (Appendix H).

Please do not hesitate to contact the undersigned at (250) 564-3243 should you have any questions or require further information.

Respectfully submitted,

**Wood Environment & Infrastructure Solutions,**
**a Division of Wood Canada Limited**

PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA, D. OSTRITCHENKO # 40470
July 21, 2020

Dmitri Ostritchenko, P.Eng.
Geotechnical Engineer

Reviewed by:

Nick Polysou, P.Eng.
Principal, Geotechnical Engineer

# Figures


Notes:
1. GPS Hub Data provided by McElhanney January 2020.
2. Cadastral provided by City of Quesnel.

**GPS Monitoring Dates**

Inital September 1998

| | | | |
|---|---|---|---|
| #1 December 1998 | #17 December 2007 | #33 November 2011 | #49 December 2015 |
| #2 April 1999 | #18 March 2008 | #34 April 2012 | #50 April 2016 |
| #3 December 1999 | #19 June 2008 | #35 July 2012 | #51 July 2016 |
| #4 February 2000 | #20 August 2008 | #36 September 2012 | #52 October 2016 |
| #5 May 2000 | #21 November 2008 | #37 December 2012 | #53 December 2016 |
| #6 December 2000 | #22 March 2009 | #38 April 2013 | #54 April 2017 |
| #7 May 2001 | #23 June 2009 | #39 July 2013 | #55 August 2017 |
| #8 December 2001 | #24 September 2009 | #40 October 2013 | #56 October 2017 |
| #9 May 2002 | #25 November 2009 | #41 November 2013 | #57 December 2017 |
| #10 October 2002 | #26 March 2010 | #42 April 2014 | #58 June 2018 |
| #11 November 2003 | #27 July 2010 | #43 July 2014 | #59 December 2018 |
| #12 January 2005 | #28 September 2010 | #44 October 2014 | #60 June 2019 |
| #13 March 2006 | #29 November 2010 | #45 November 2014 | #61 December 2019 |
| #14 November 2006 | #30 April 2011 | #46 April 2015 | |
| #15 April 2007 | #31 June 2011 | #47 July 2015 | |
| #16 August 2007 | #32 October 2011 | #48 October 2015 | |

**Legend**

**GPS Hubs Installed**
- September 1998
- December 2001
- November 2006
- June 2008
- November 2013

**GPS Hub Vector**

GPS98-02
(**617mm**, -86mm)

September 1998 to December 2001 · December 2001 to November 2006 · November 2006 to July 2008 · July 2008 to December 2019

Total vertical movement in mm at surface
Positive (+) elevation shows a rise in elevation
Negative (-) elevation shows a drop in elevation
Total horizontal movement in mm at surface

Slide Extent
Slide Extent (Approximate)

**In-place Inclinometer Initialized**

| | | |
|---|---|---|
| SI16 (**60.2mm**, 51.0m) | (September 20, 2012) |
| SI17 (**71.4mm**, 65.0m) | (March 19, 2016) * |
| SI17A (**0mm**, TBD) | (November 26, 2019) |
| SI18 (**13.9mm**, 78.0m) | (June 1, 2016) |

* Decommissioned 2019

**In-place Inclinometer Vector**

Total Horizontal Movement

SI16
(**60.2mm**, 47.5m)

Movement depth below surface in m
Total horizontal movement in mm

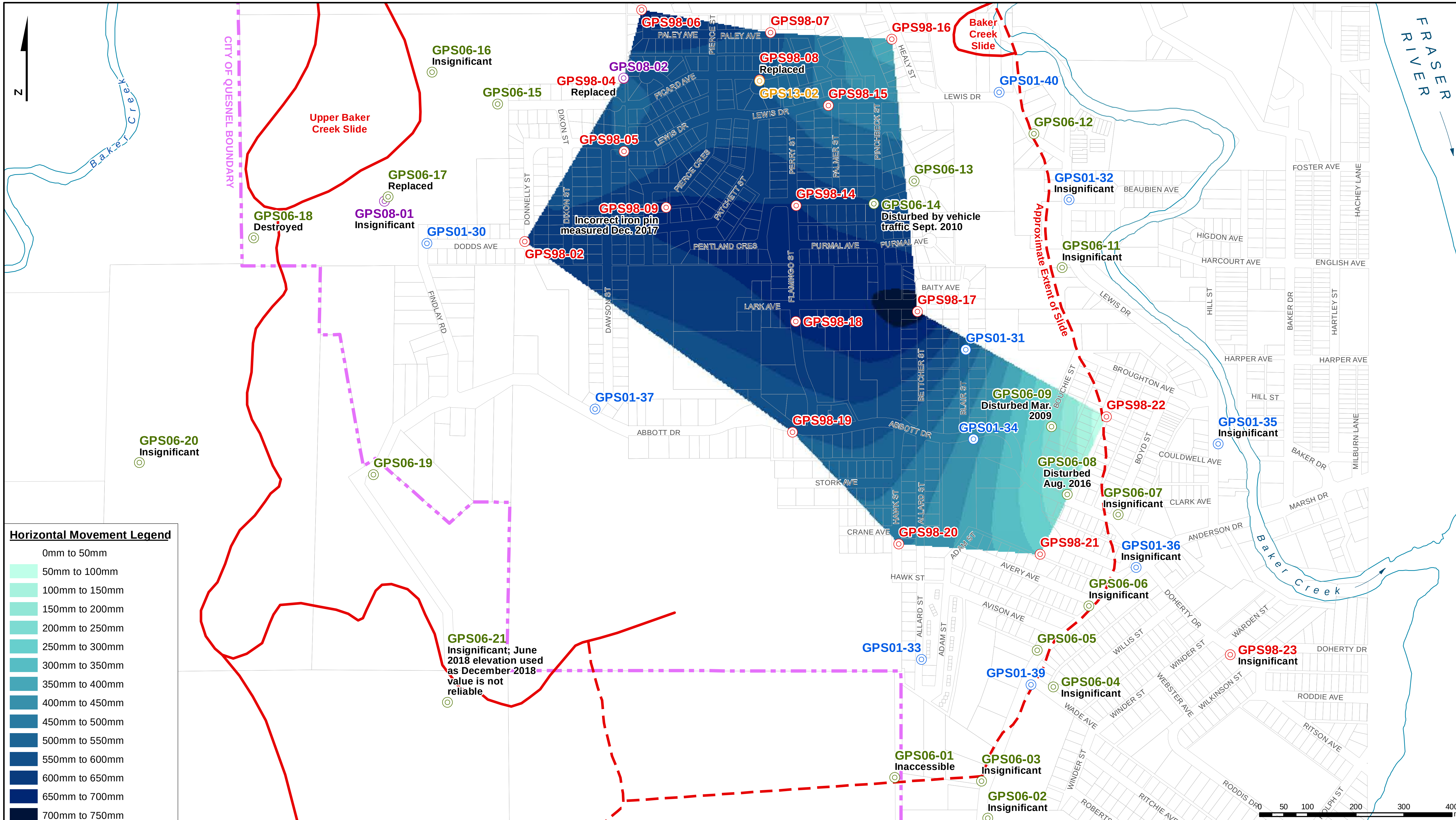
In-place Inclinometer Vector

West Quesnel Land Stability Program

| | | | |
|---|---|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: SUMMARY PLAN OF GROUND MOVEMENT (GPS HUBS AND SLOPE INCLINOMETERS) | DATE: JUNE 2020 |
| | CHK'D BY: DO | | PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions, 3456 Opie Crescent, Prince George, BC, CANADA V2N 2P9 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV NO.: A |
| wood. | PROJECTION: UTM Zone 10 | | |
| | SCALE: 1:5,000 | | FIGURE 1 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig01-SummaryPlanOfGroundMovement-Dec2019.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

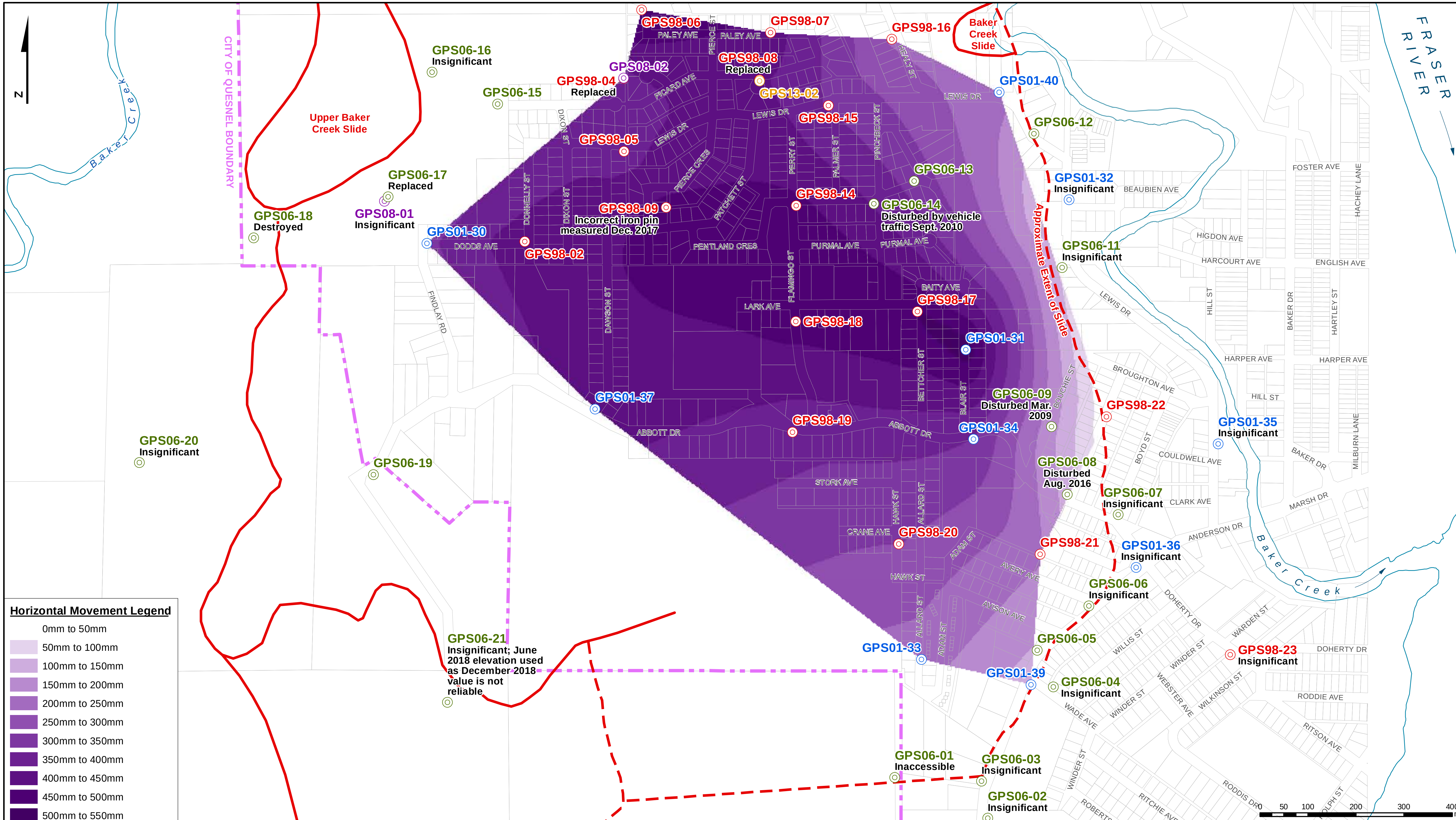
West Quesnel Land Stability Program

wood.

| | | | |
|---|---|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: TOTAL HORIZONTAL MOVEMENT SEPTEMBER 1998 TO DECEMBER 2019 FOR THE 1998 GPS HUBS | DATE: JUNE 2020 |
| | CHK'D BY: DO | | PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV NO.: A |
| | PROJECTION: UTM Zone 10 | | |
| | SCALE: 1:7,500 | | FIGURE 2 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig02-HMove-Sept98-Dec19-98Hubs.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

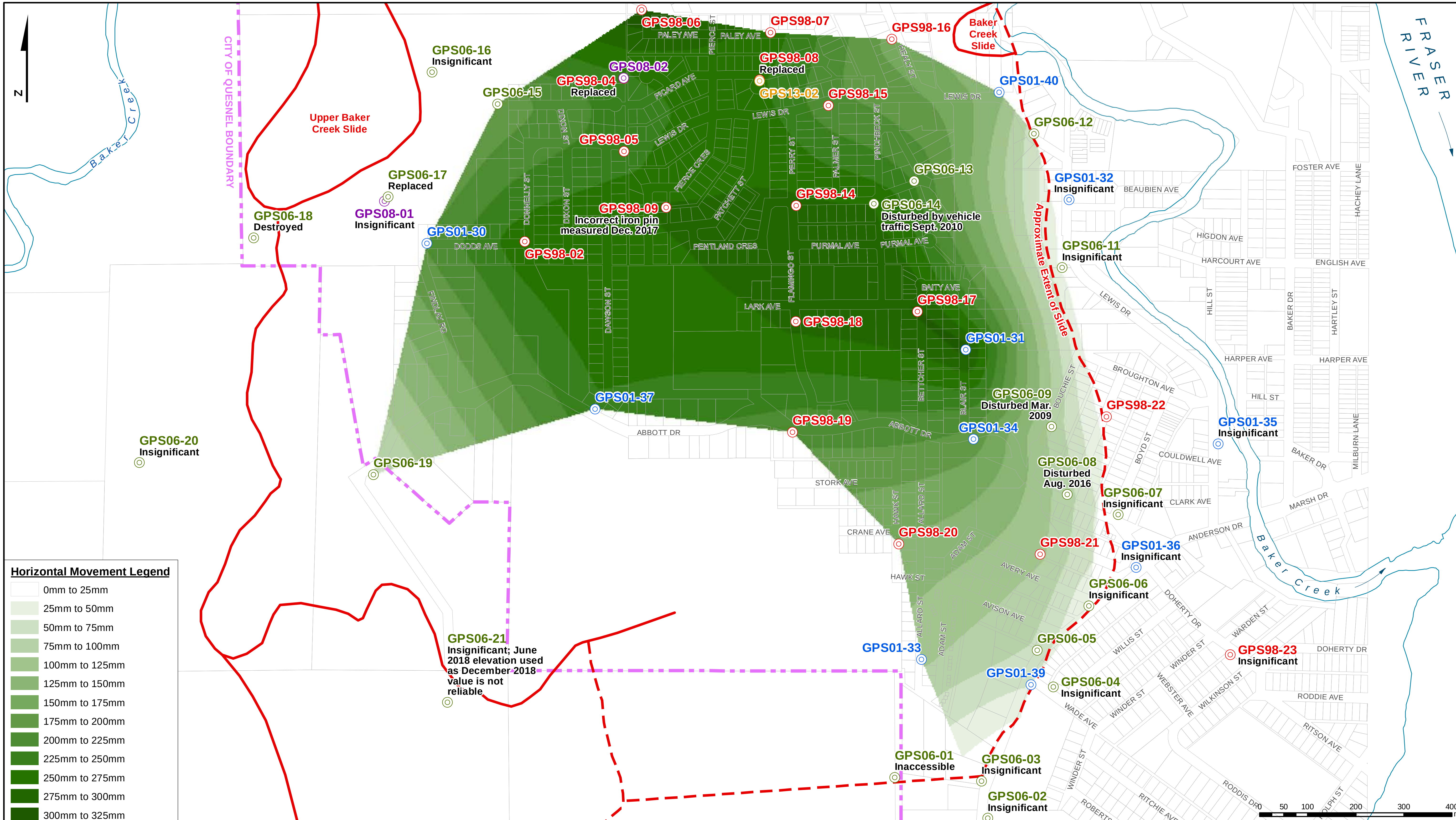
West Quesnel Land Stability Program

wood.

| | | | |
|---|---|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB<br>CHK'D BY: DO | TITLE: TOTAL HORIZONTAL MOVEMENT DECEMBER 2001 TO DECEMBER 2019 FOR THE 1998 AND 2001 GPS HUBS | DATE: JUNE 2020<br>PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83<br>PROJECTION: UTM Zone 10<br>SCALE: 1:7,500 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV NO.: A<br>FIGURE 3 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig03-HMove-Dec01-Dec19-98-01Hubs.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
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| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: TOTAL HORIZONTAL MOVEMENT NOVEMBER 2006 TO DECEMBER 2019 FOR THE 1998, 2001 AND 2006 GPS HUBS

PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC

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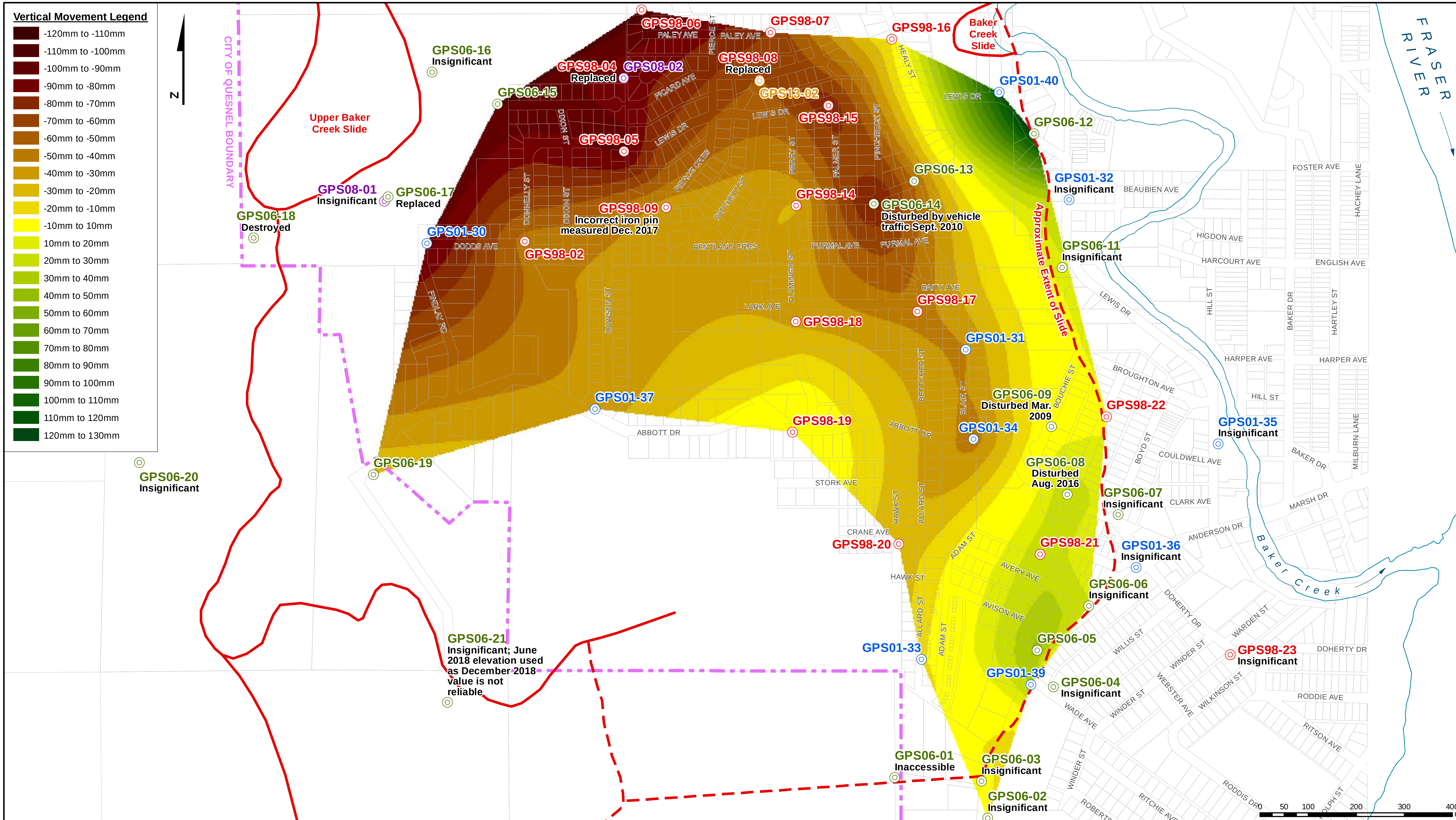
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 4

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig04-HMove-Nov06-Dec19-AllHubs.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: TOTAL VERTICAL MOVEMENT NOVEMBER 2006 TO DECEMBER 2019 FOR THE 1998, 2001 AND 2006 GPS HUBS

PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC

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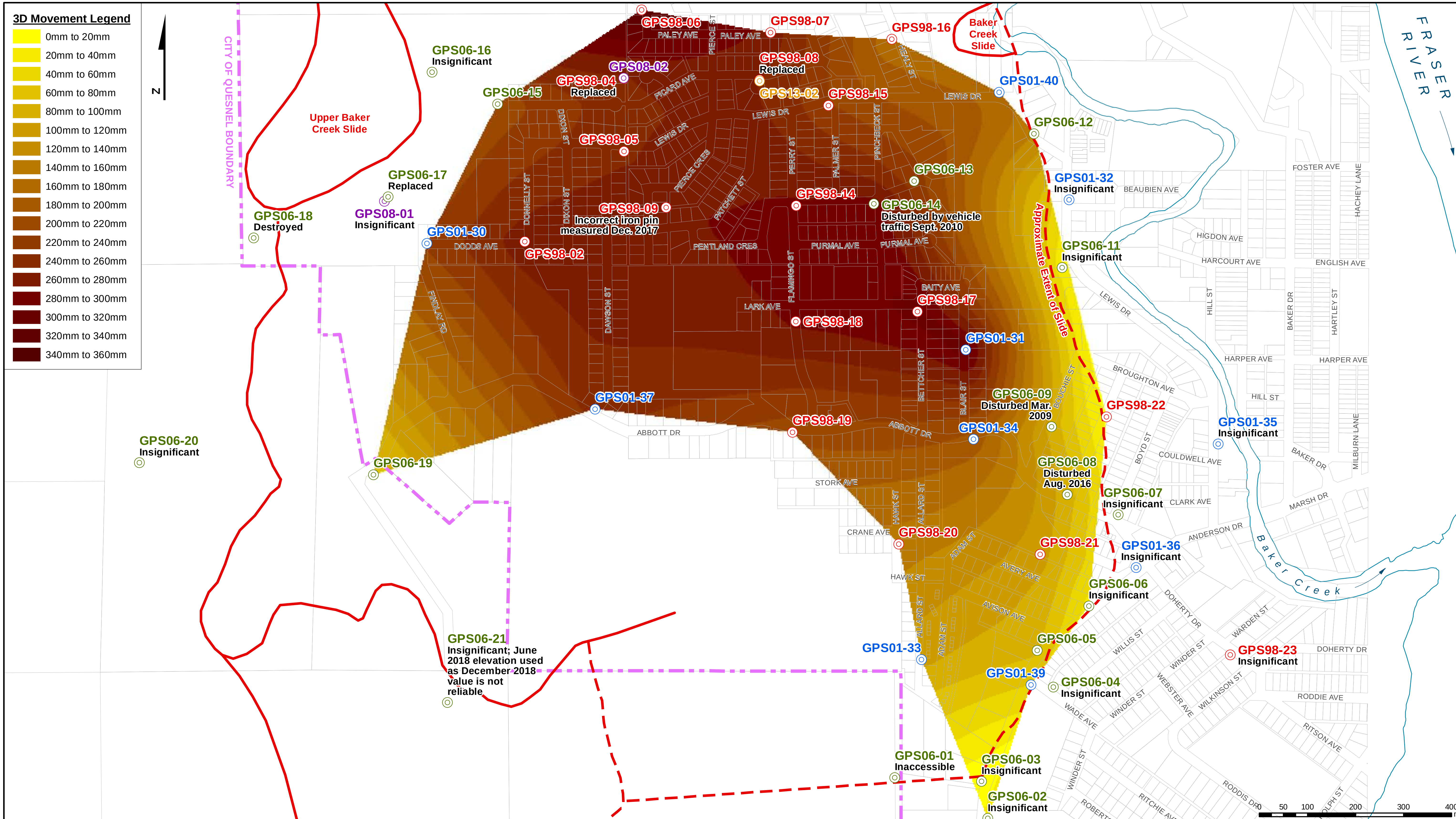
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 5

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig05-VMove-Nov06-Dec19-AllHubs.mxd

This drawing was originally produced in colour.




Legend
- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

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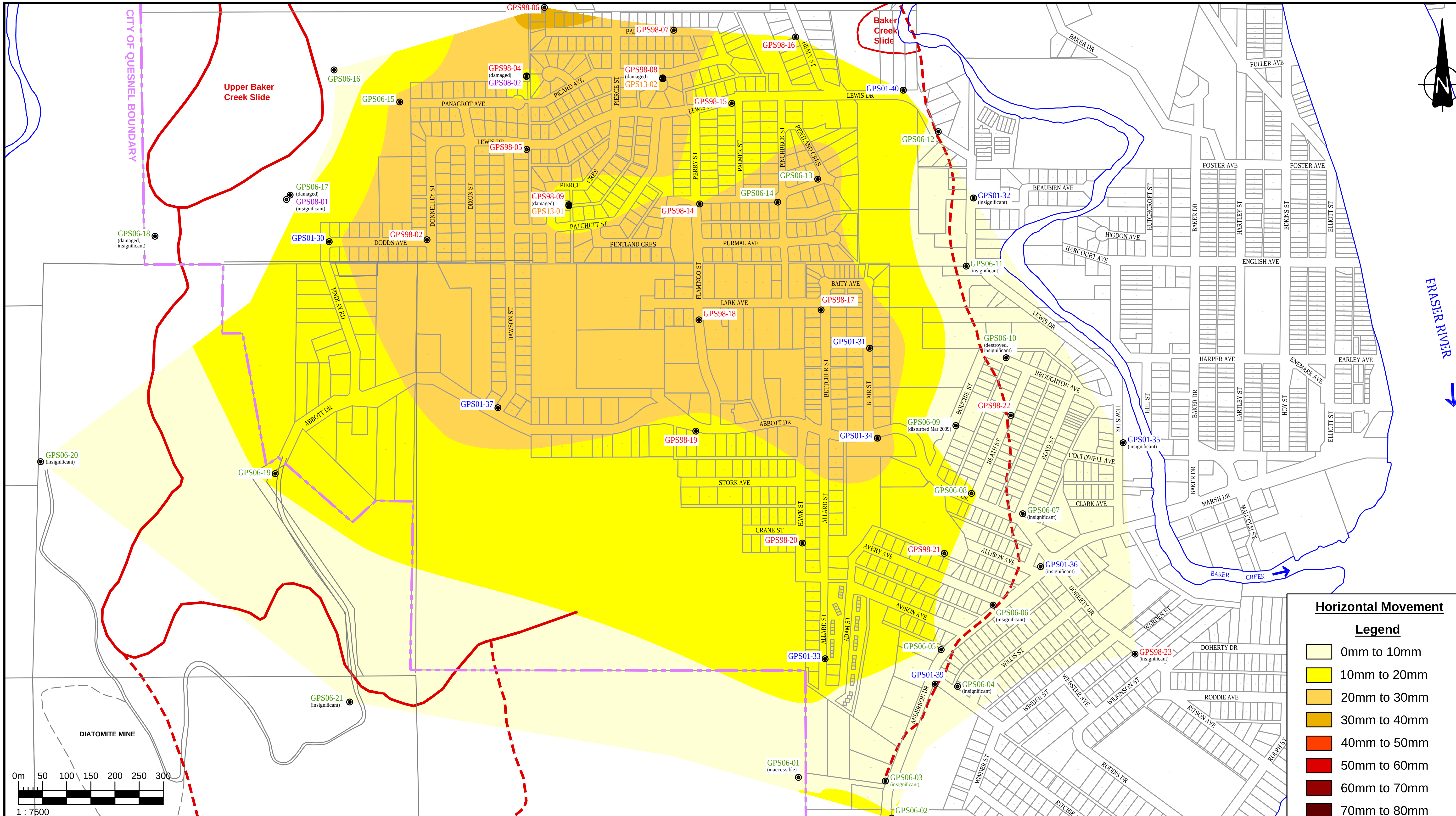
|---|---|---|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: TOTAL 3D MOVEMENT NOVEMBER 2006 TO DECEMBER 2019 FOR THE 1998, 2001 AND 2006 GPS HUBS | | DATE: JUNE 2020 |
| | CHK'D BY: DO | | | PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | | REV NO.: A |
| | PROJECTION: UTM Zone 10 | | | |
| | SCALE: 1:7,500 | | | FIGURE 6 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig06-3DMove-Nov06-Dec19-AllHubs.mxd

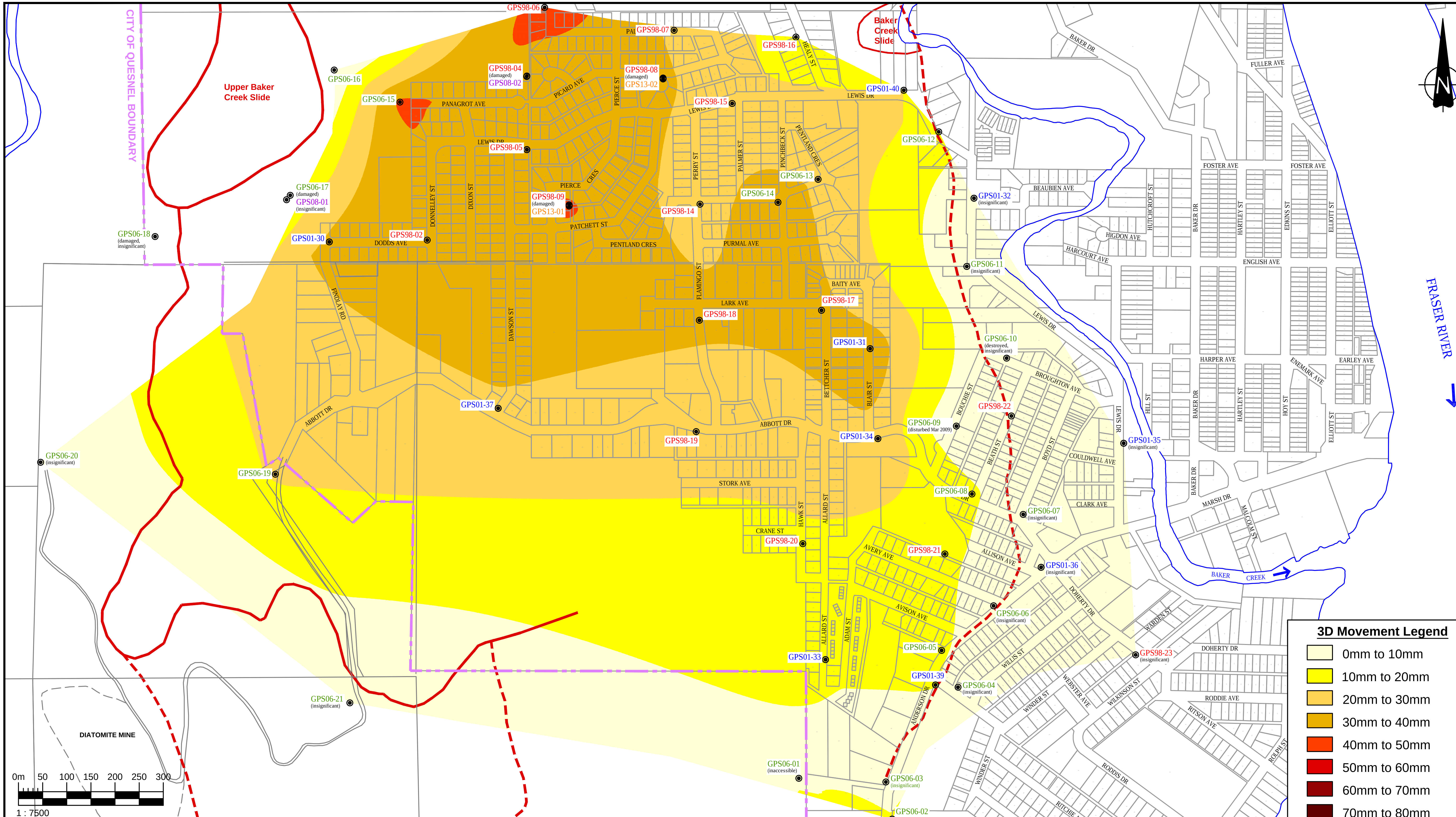
This drawing was originally produced in colour.




| Legend | | CLIENT: CITY OF QUESNEL | DWN BY: SR/BB | TITLE: ANNUAL HORIZONTAL MOVEMENT - 2007 NOVEMBER 2006 TO DECEMBER 2007 FOR THE 1998, 2001 AND 2006 GPS HUBS | DATE: JUNE 2020 |
|---|---|---|---|---|---|
| Slide Extent | West Quesnel Land Stability Program | | CHK'D BY: DO | | PROJECT NO.: KX0439755 |
| Slide Extent (Approximate) | wood. | Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV. NO.: A |
| | | | PROJECTION: UTM Zone 10 | | |
| | | | SCALE: 1:7 500 | | FIGURE 7 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig07-HMove-Nov06-Dec07-AllHubs.dwg - Figure7 - Jun. 30, 2020 1:13pm

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions

a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

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|---|---|
| DWN BY: | SR/BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE:

ANNUAL 3D MOVEMENT - 2007
NOVEMBER 2006 TO DECEMBER 2007
FOR THE 1998, 2001 AND 2006 GPS HUBS

PROJECT:

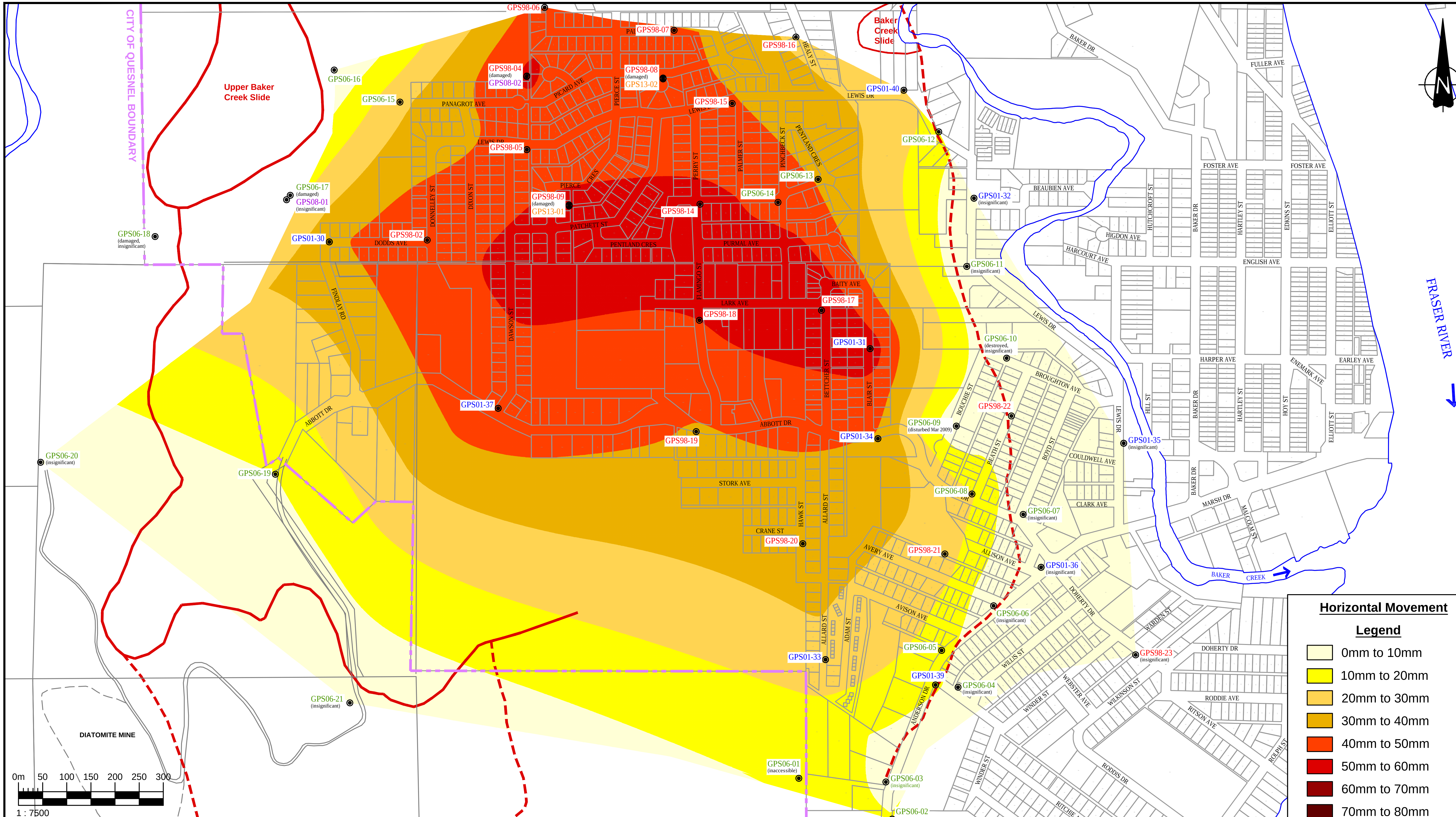
WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |

FIGURE 8

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig08-3DMove-Nov06-Dec07-AllHubs.dwg - Figure8 - Jun. 30, 2020 1:13pm

This drawing was originally produced in colour.




**Legend**

Slide Extent

Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | SR/BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE:
ANNUAL HORIZONTAL MOVEMENT - 2008
DECEMBER 2007 TO NOVEMBER 2008
FOR THE 1998, 2001 AND 2006 GPS HUBS

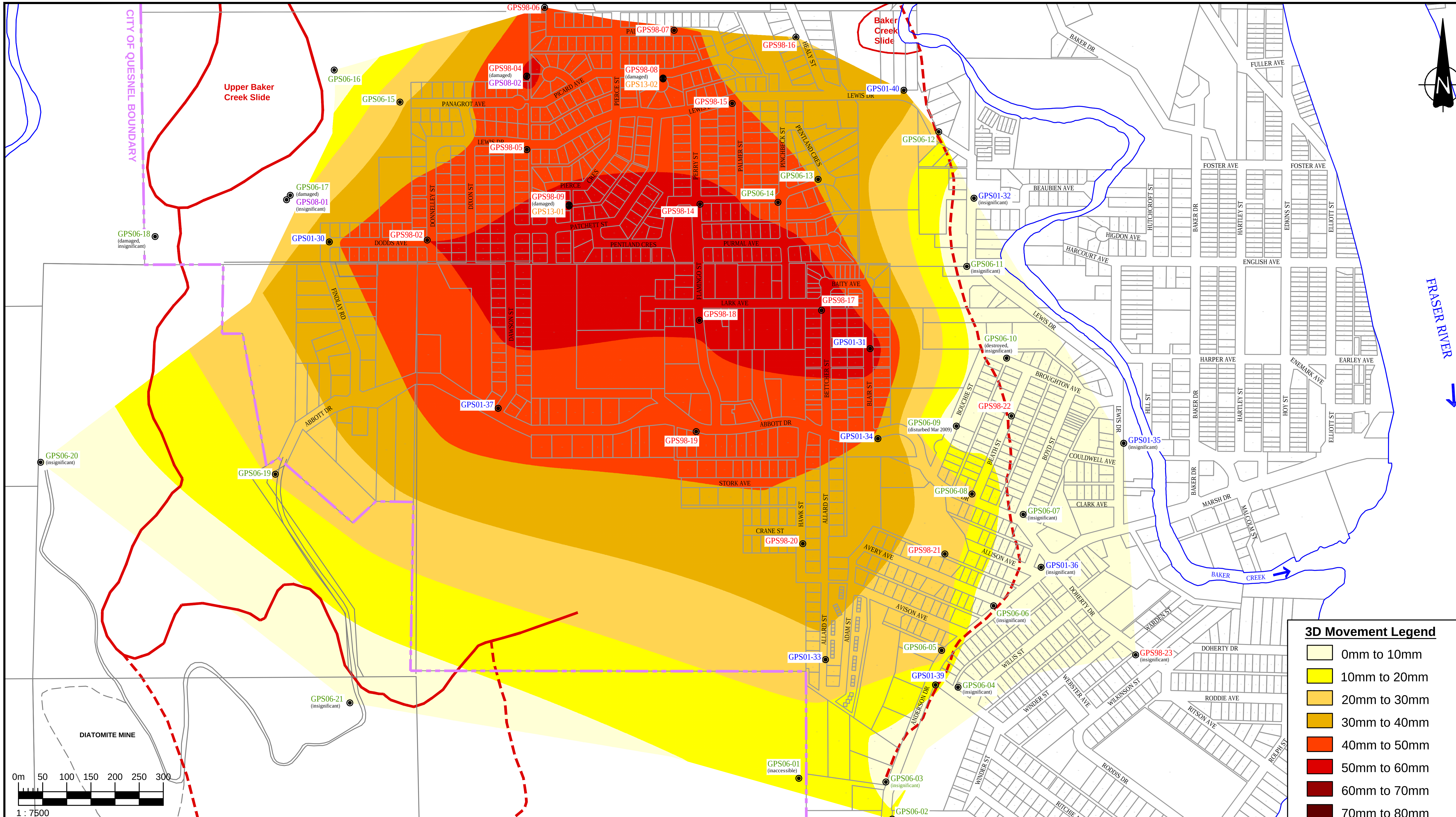
PROJECT:
WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |

FIGURE 9

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig09-HMove-Dec07-Nov08-AllHubs.dwg - Figure9 - Jun. 30, 2020 1:14pm

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

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|---|---|
| DWN BY: | SR/BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE: ANNUAL 3D MOVEMENT - 2008
DECEMBER 2007 TO NOVEMBER 2008
FOR THE 1998, 2001 AND 2006 GPS HUBS

PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

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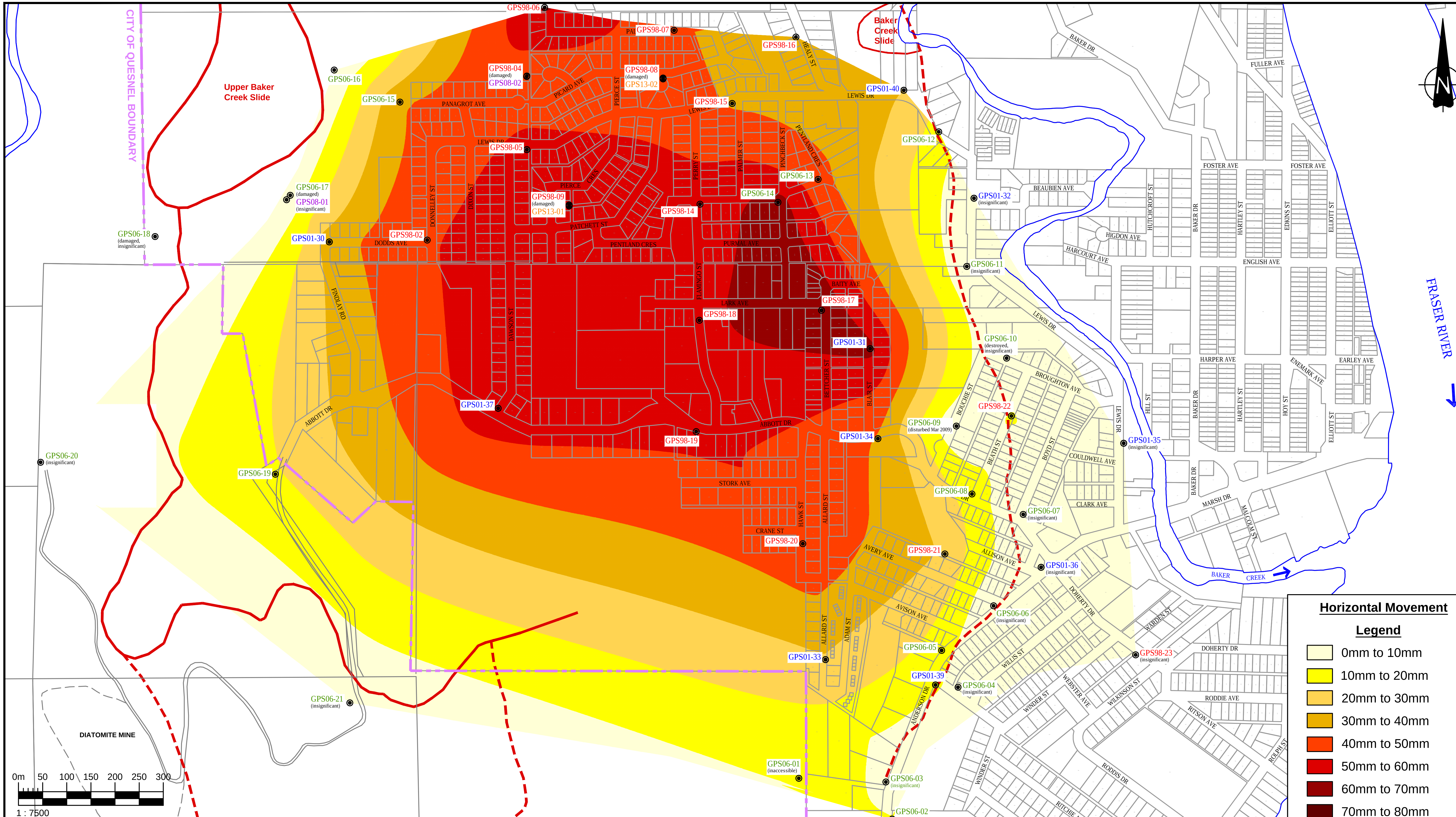
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 10 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig10-3DMove-Dec07-Nov08-AllHubs.dwg - Figure10 - Jun. 30, 2020 1:14pm

This drawing was originally produced in colour.




Legend

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | SR/BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE:

ANNUAL HORIZONTAL MOVEMENT - 2009
NOVEMBER 2008 TO NOVEMBER 2009
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT:

WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

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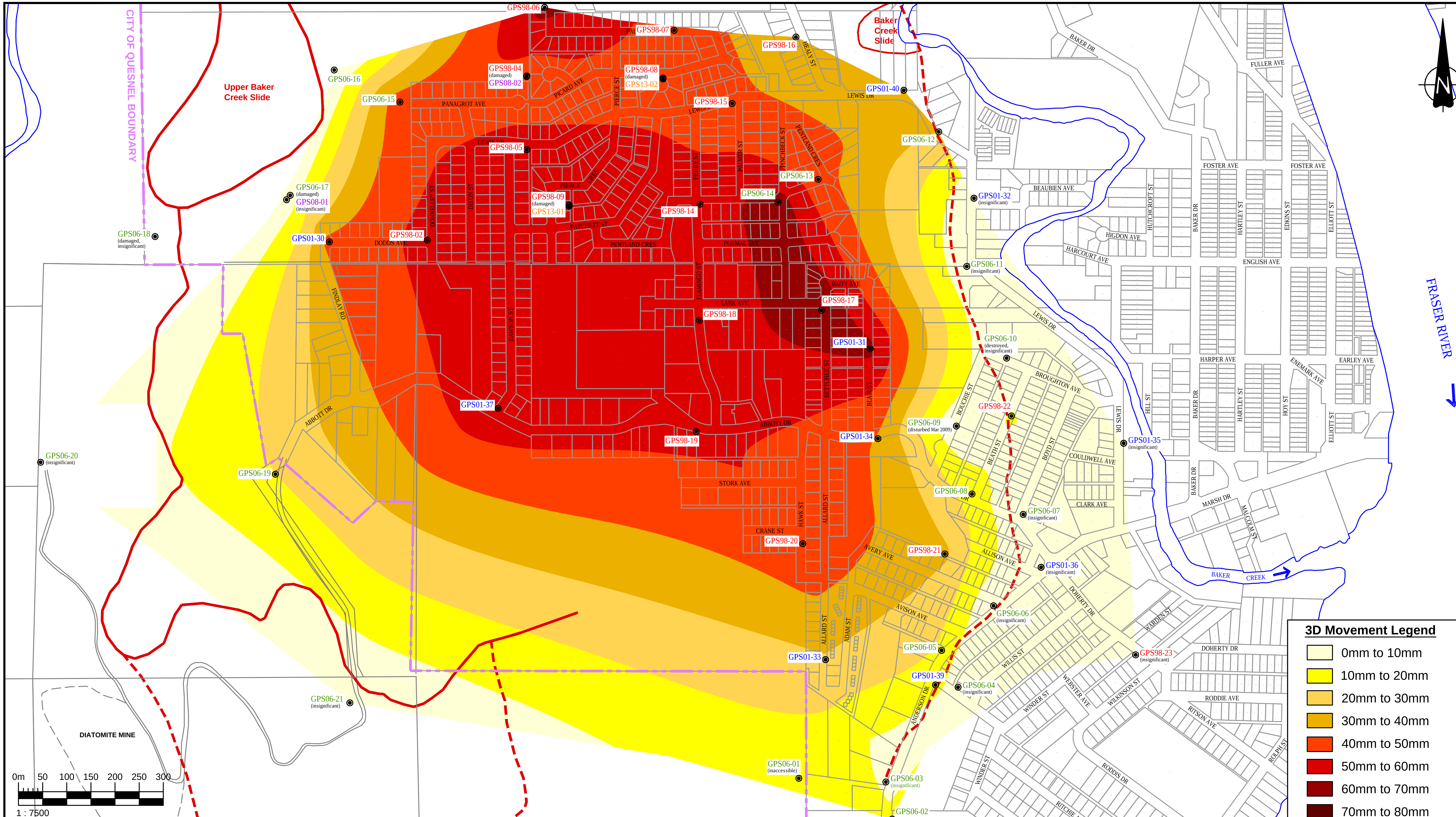
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 11 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig11-HMove-Nov08-Nov09-AllHubs.dwg - Figure11 - Jun. 30, 2020 1:14pm

This drawing was originally produced in colour.

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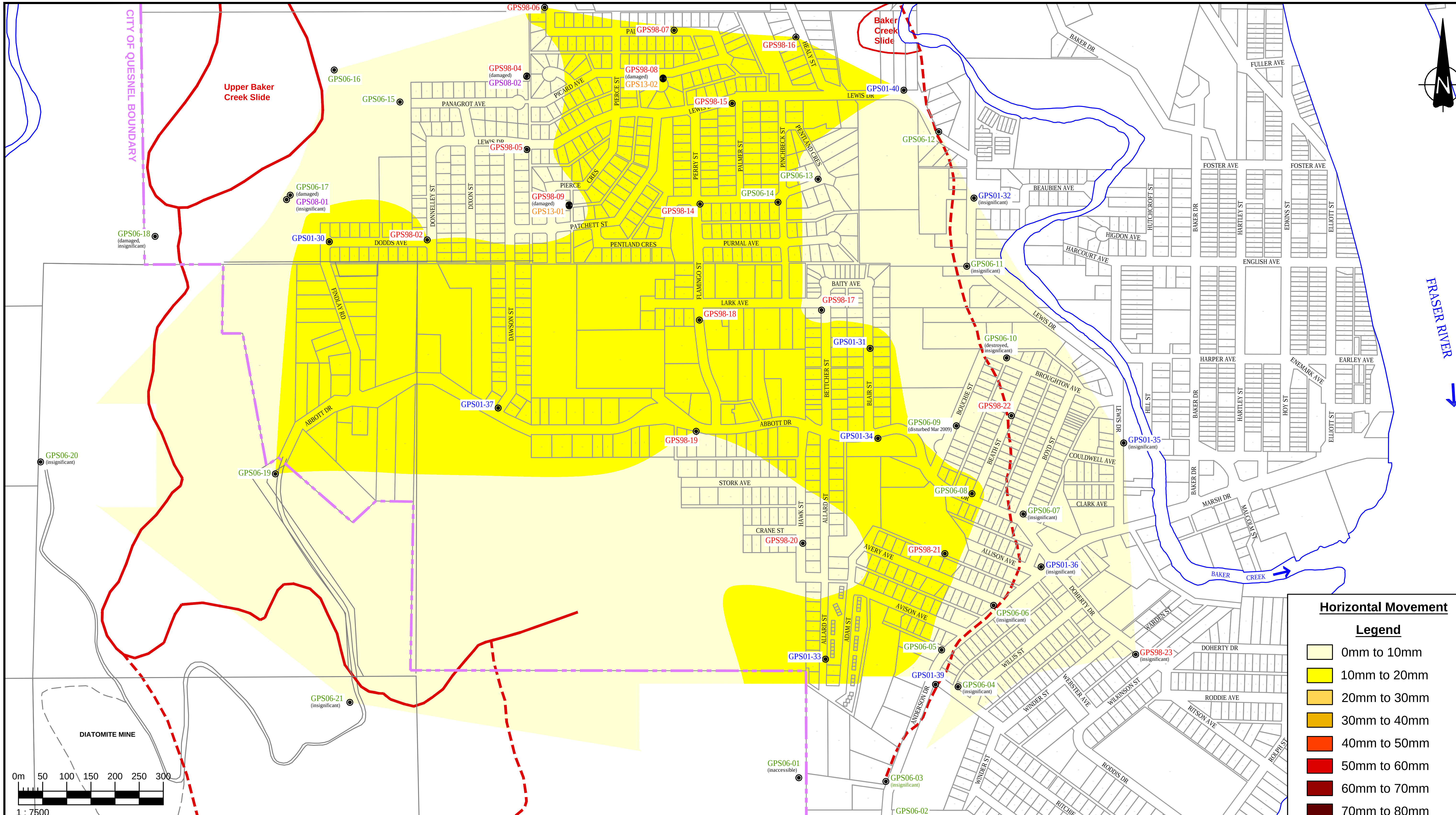
|---|---|---|---|---|---|
| **Legend**<br>Slide Extent<br>Slide Extent (Approximate) | West Quesnel Land Stability Program | wood. | CLIENT:<br>CITY OF QUESNEL<br><br>Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DWN BY: SR/BB<br>CHK'D BY: DO<br>DATUM: NAD83<br>PROJECTION: UTM Zone 10<br>SCALE: 1:7 500 | TITLE:<br>ANNUAL 3D MOVEMENT - 2009<br>NOVEMBER 2008 TO NOVEMBER 2009<br>FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS<br><br>PROJECT:<br>WEST QUESNEL LAND STABILITY PROGRAM<br>QUESNEL, BC<br><br>DATE: JUNE 2020<br>PROJECT NO.: KX0439755<br>REV. NO.: A<br>FIGURE 12 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig12-3DMove-Nov08-Nov09-AllHubs.dwg - Figure12 - Jun. 30, 2020 1:15pm

This drawing was originally produced in colour.




**Legend**

Slide Extent

Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

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|---|---|
| DWN BY: | SR/BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

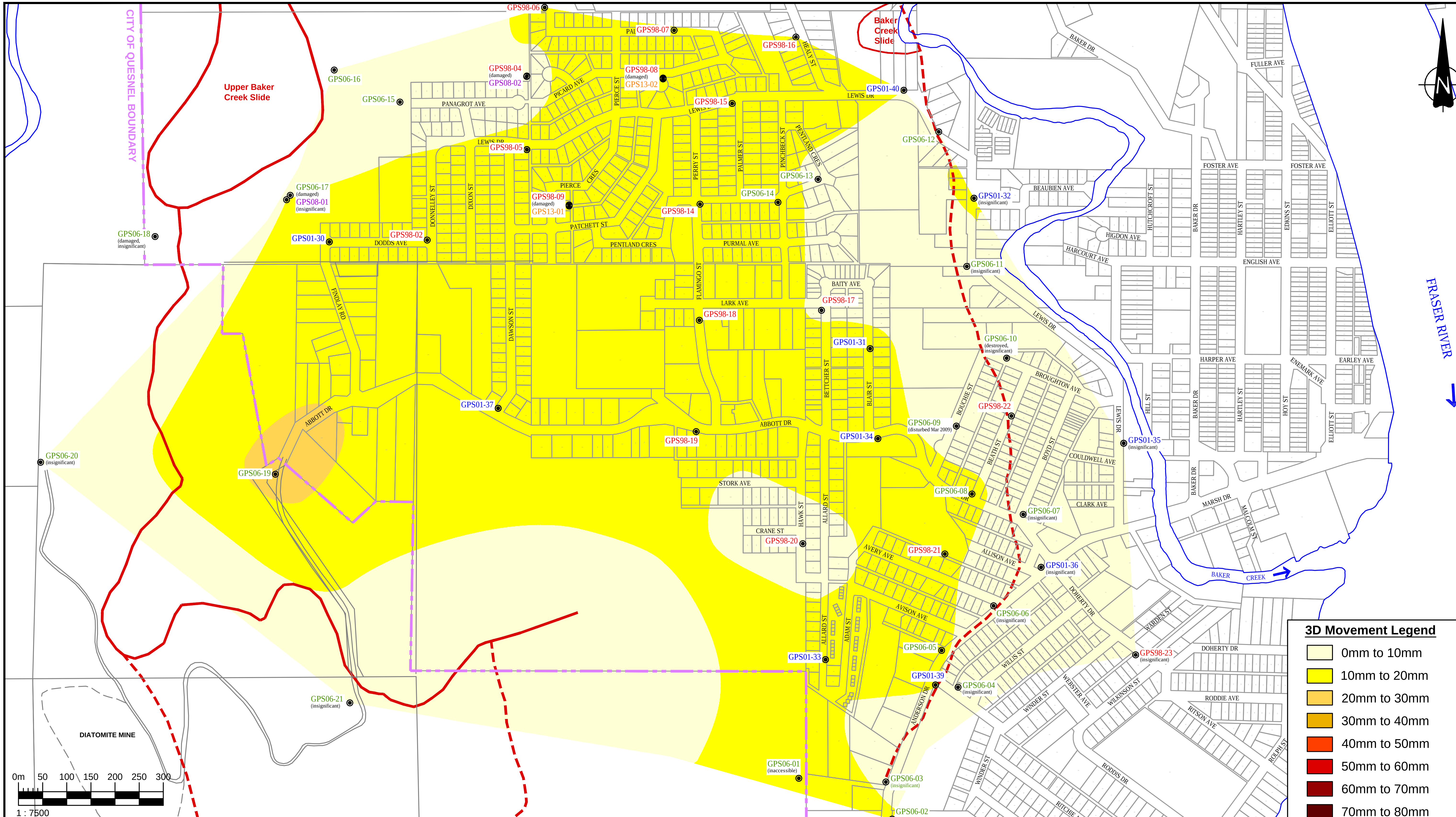
TITLE: ANNUAL HORIZONTAL MOVEMENT - 2010
NOVEMBER 2009 TO NOVEMBER 2010
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 13 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig13-HMove-Nov09-Nov10-AllHubs.dwg - Figure13 - Jun. 30, 2020 1:15pm

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

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| DWN BY: | SR/BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE:

ANNUAL 3D MOVEMENT - 2010
NOVEMBER 2009 TO NOVEMBER 2010
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

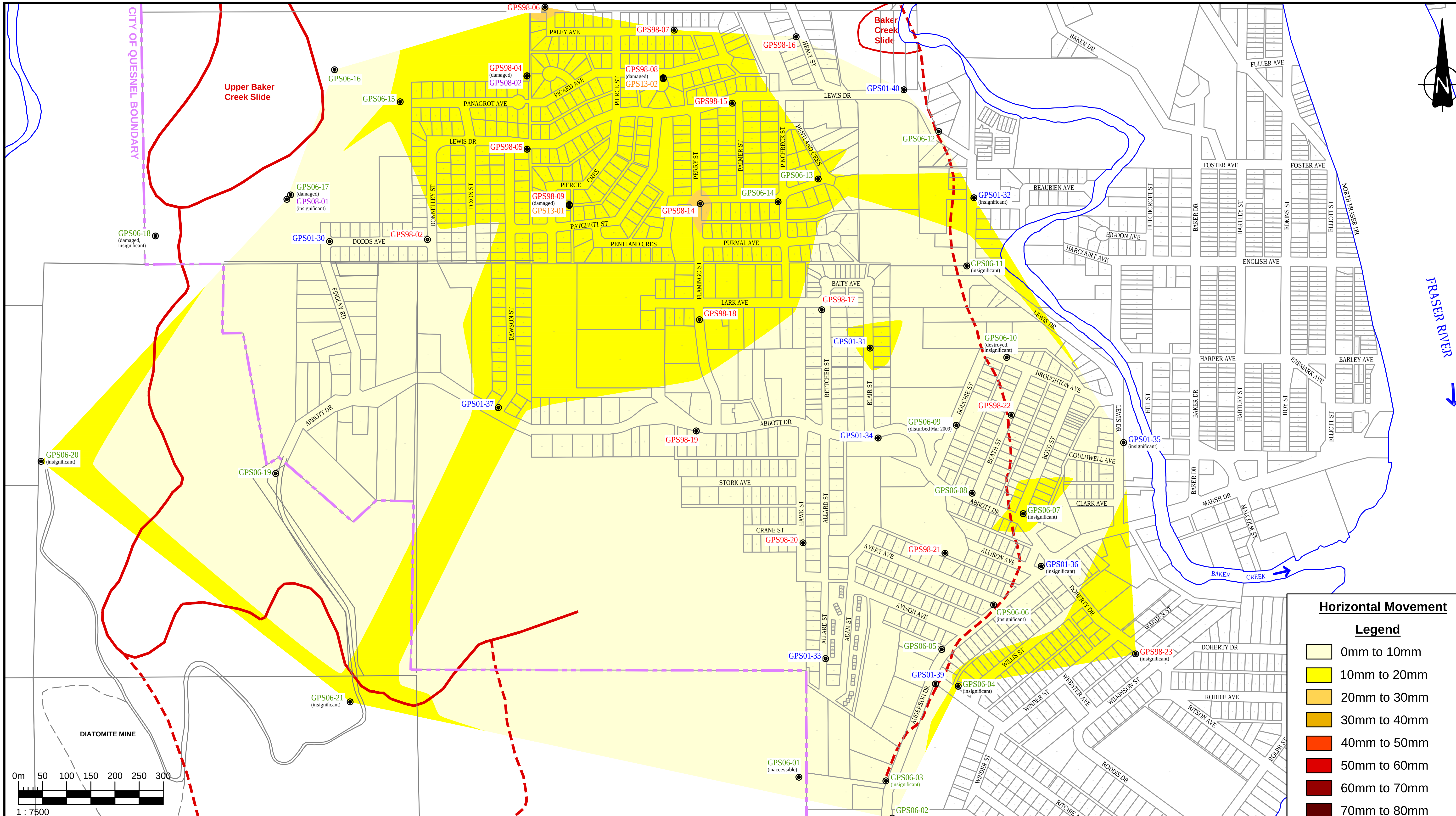
PROJECT:

WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 14 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig14-3DMove-Nov09-Nov10-AllHubs.dwg - Figure14 - Jun. 30, 2020 1:15pm

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

| | |
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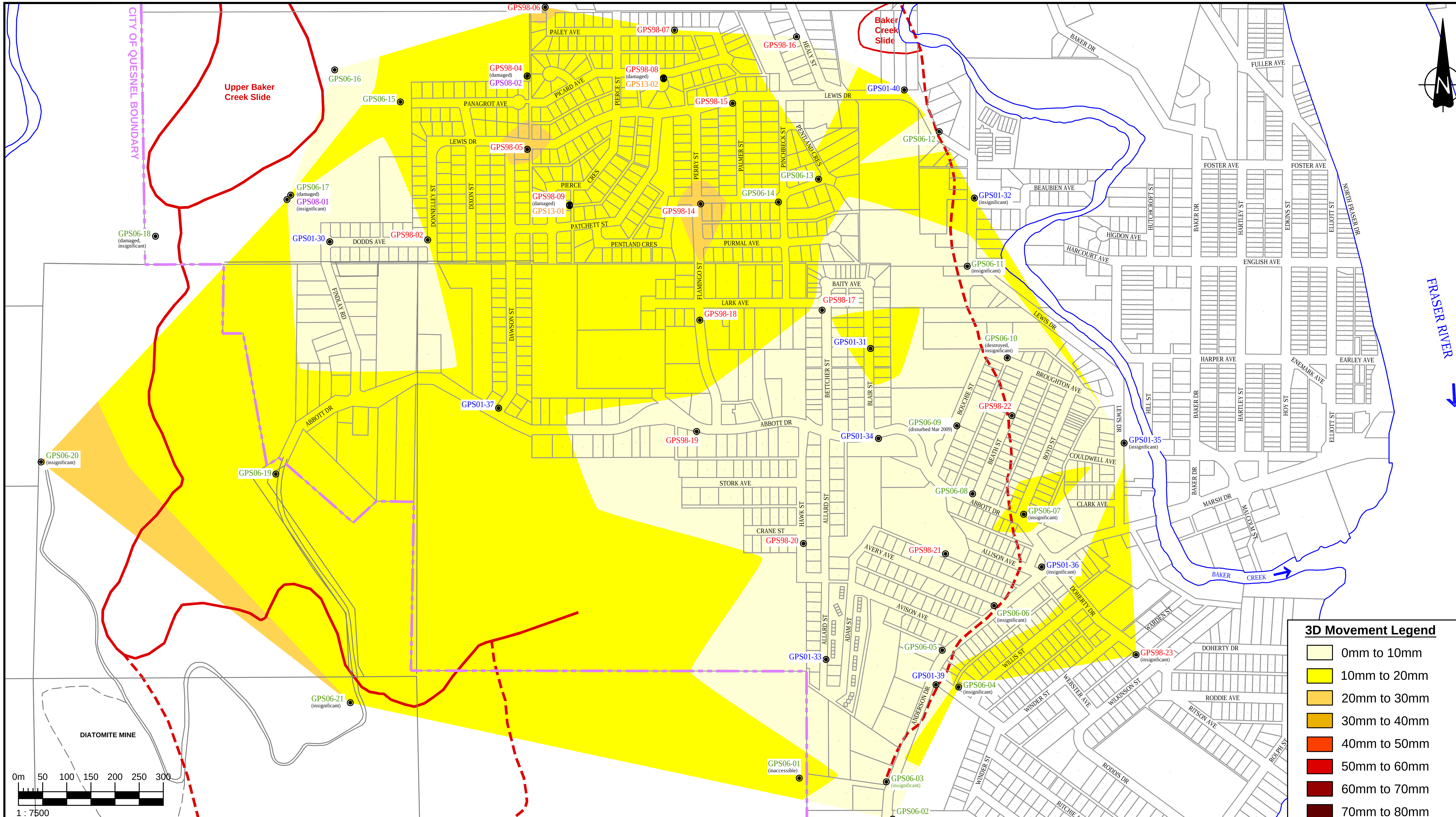
| CLIENT: | CITY OF QUESNEL |
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |
| TITLE: | ANNUAL HORIZONTAL MOVEMENT - 2011 NOVEMBER 2010 TO NOVEMBER 2011 FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS |
| PROJECT: | WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC |
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 15 |

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig15-HMove-Nov10-Nov11-AllHubs.dwg - Figure15 - Jun. 30, 2020 1:15pm

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel
Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

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|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

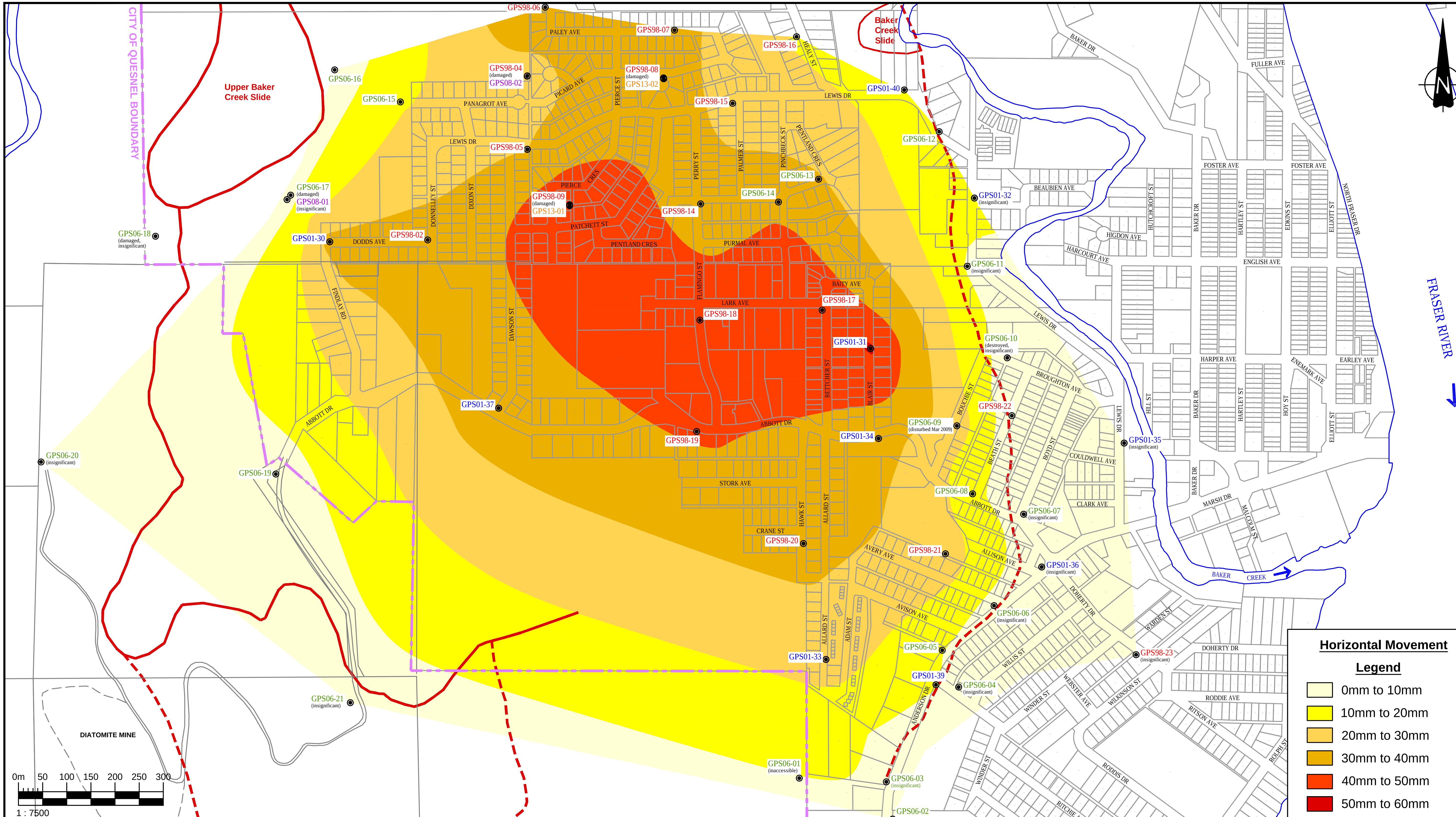
TITLE:
ANNUAL 3D MOVEMENT - 2011
NOVEMBER 2010 TO NOVEMBER 2011
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT:
WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 16 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig16-3DMove-Nov10-Nov11-AllHubs.dwg - Figure16 - Jun. 30, 2020 1:15pm

This drawing was originally produced in colour.




**Legend**

Slide Extent

Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL


Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045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|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE:

ANNUAL HORIZONTAL MOVEMENT - 2012
NOVEMBER 2011 TO DECEMBER 2012
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT:

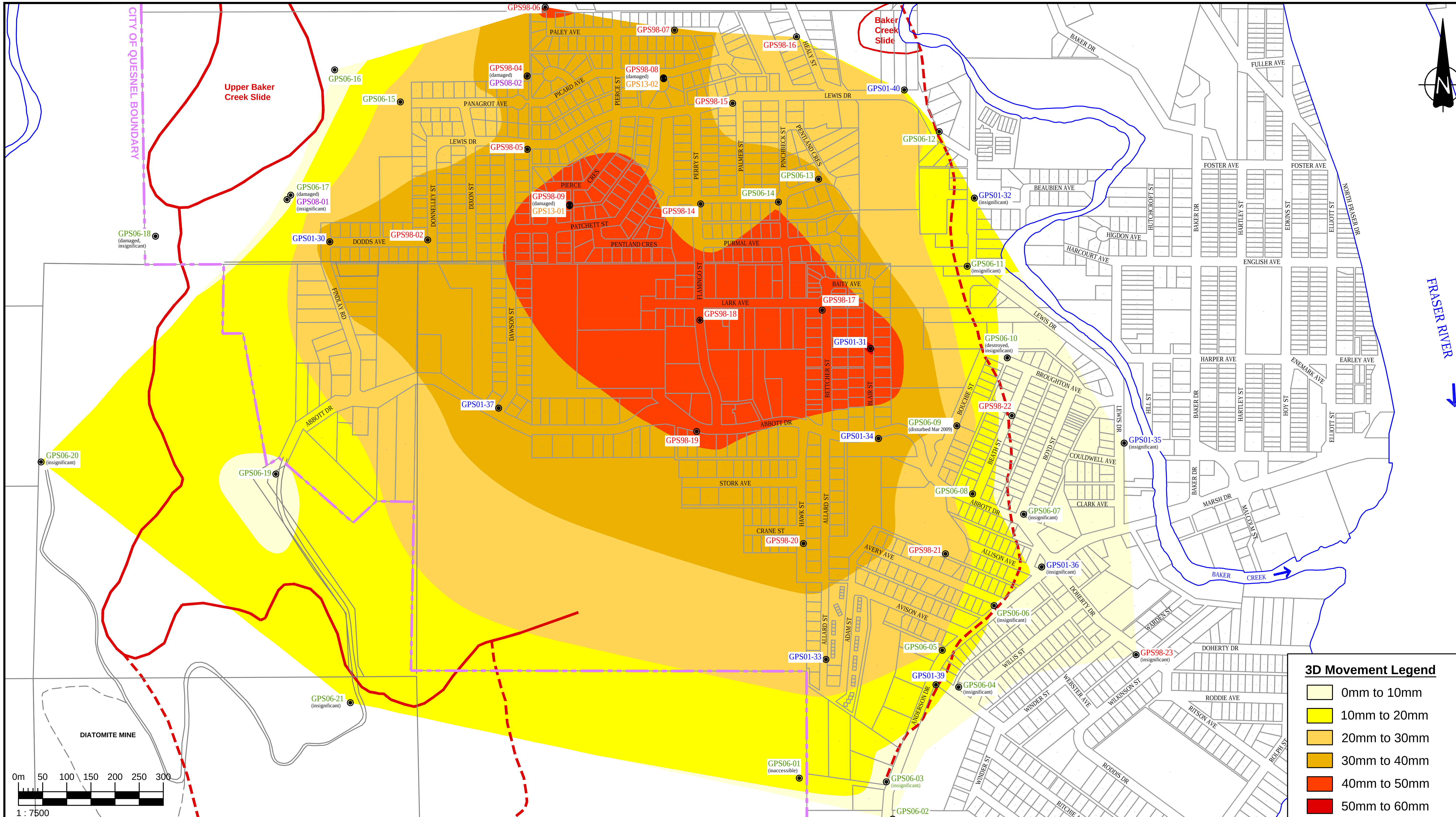
WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |

FIGURE 17

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig17-HMove-Nov11-Dec12-AllHubs.dwg - Figure17 - Jun. 30, 2020 1:16pm

This drawing was originally produced in colour.




**Legend**

Slide Extent

Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions

a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE:

ANNUAL 3D MOVEMENT - 2012
NOVEMBER 2011 TO DECEMBER 2012
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

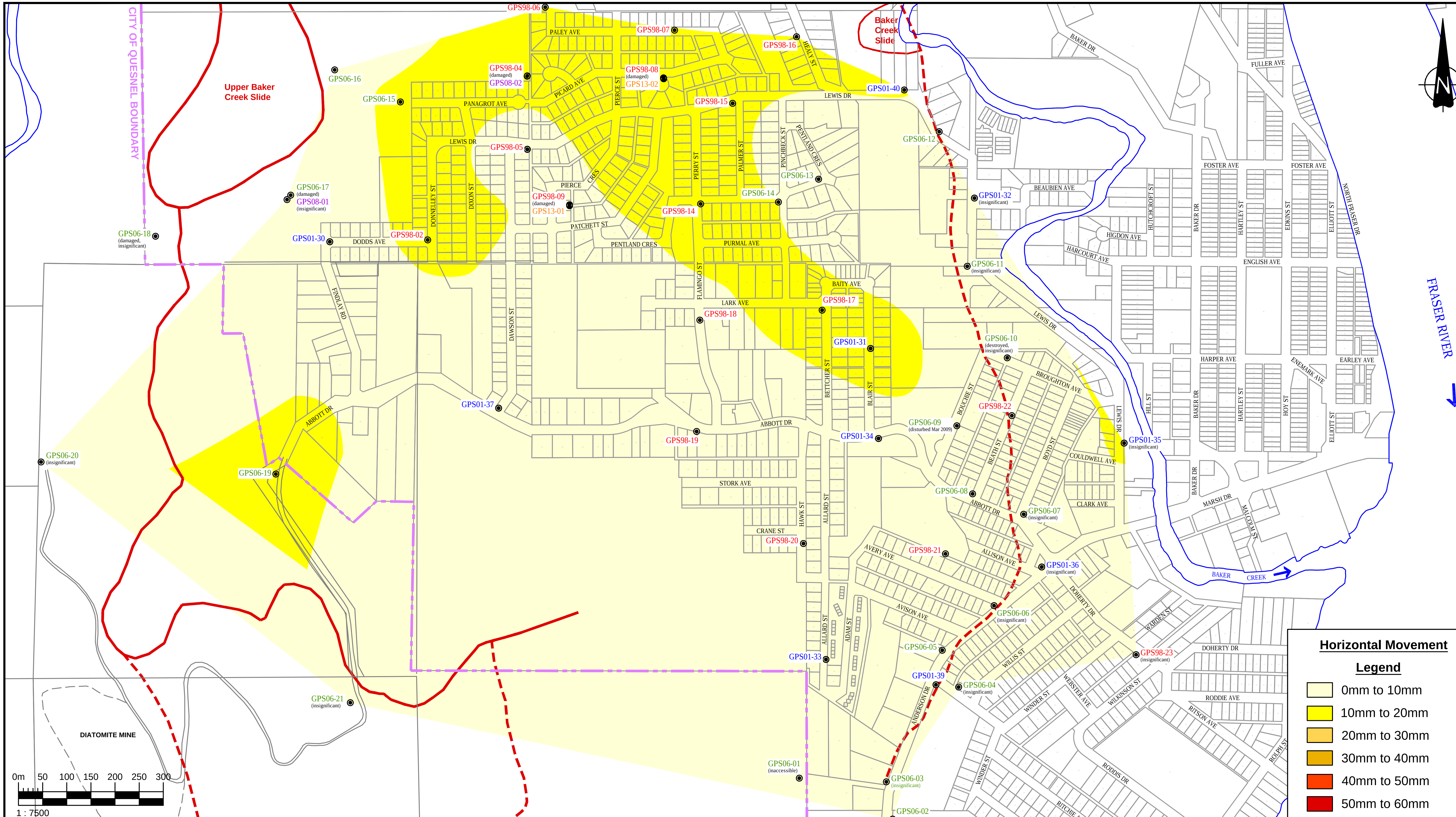
PROJECT:

WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 18 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig18-3DMove-Nov11-Dec12-AllHubs.dwg - Figure18 - Jun. 30, 2020 1:16pm

This drawing was originally produced in colour.




**Legend**

Slide Extent

Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions

a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE:

ANNUAL HORIZONTAL MOVEMENT - 2013
NOVEMBER 2012 TO NOVEMBER 2013
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT:

WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
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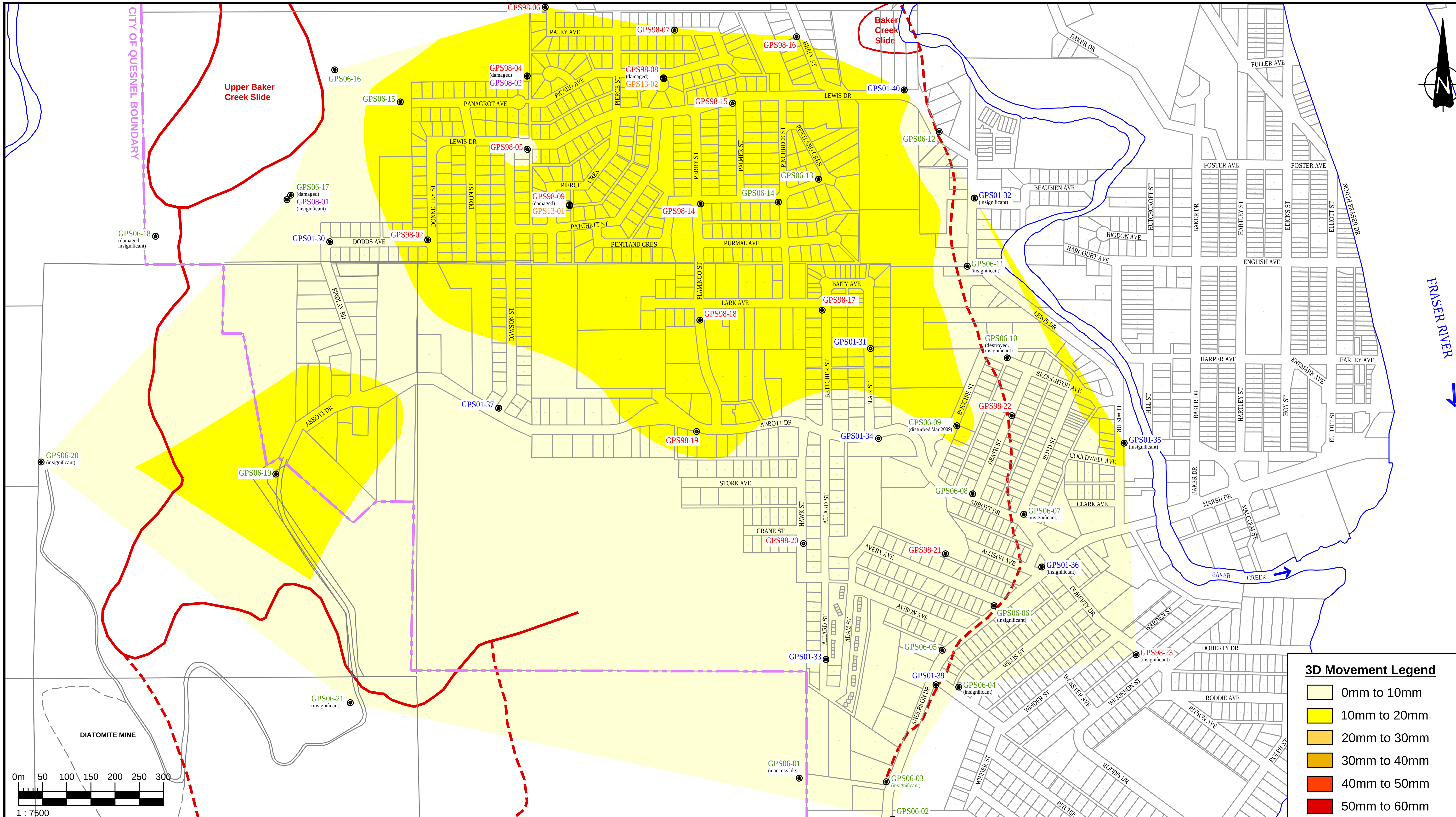
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 19 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig19-HMove-Dec12-Nov13-AllHubs.dwg - Figure19 - Jun. 30, 2020 1:16pm

This drawing was originally produced in colour.




| Legend | |
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| Slide Extent (Approximate) | |

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7 500 |

TITLE: ANNUAL 3D MOVEMENT - 2013
NOVEMBER 2012 TO NOVEMBER 2013
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

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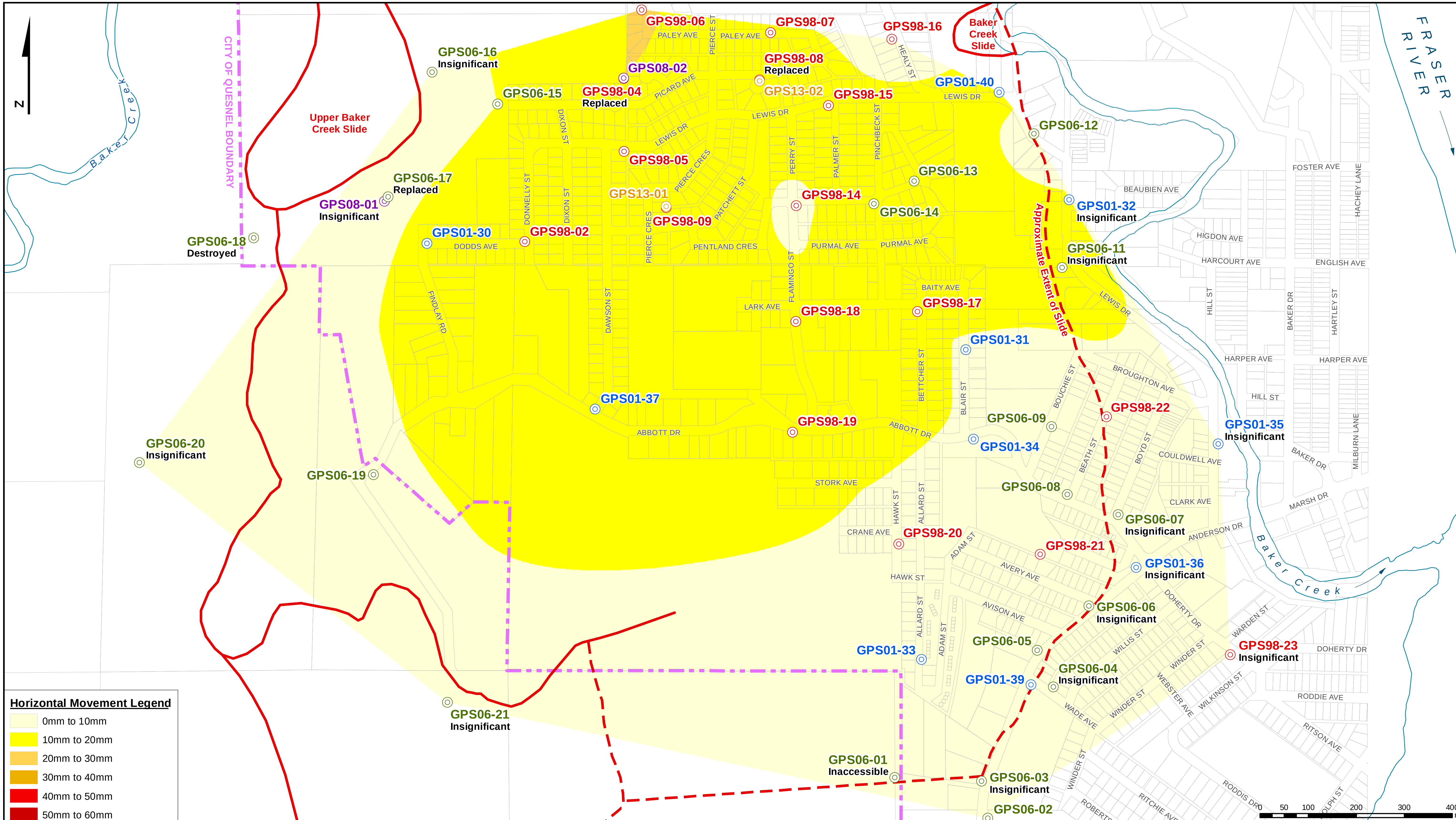
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV. NO.: | A |
| | FIGURE 20 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig20-3DMove-Dec12-Nov13-AllHubs.dwg - Figure20 - Jun. 30, 2020 1:16pm

This drawing was originally produced in colour.




Legend
Slide Extent
Slide Extent (Approximate)

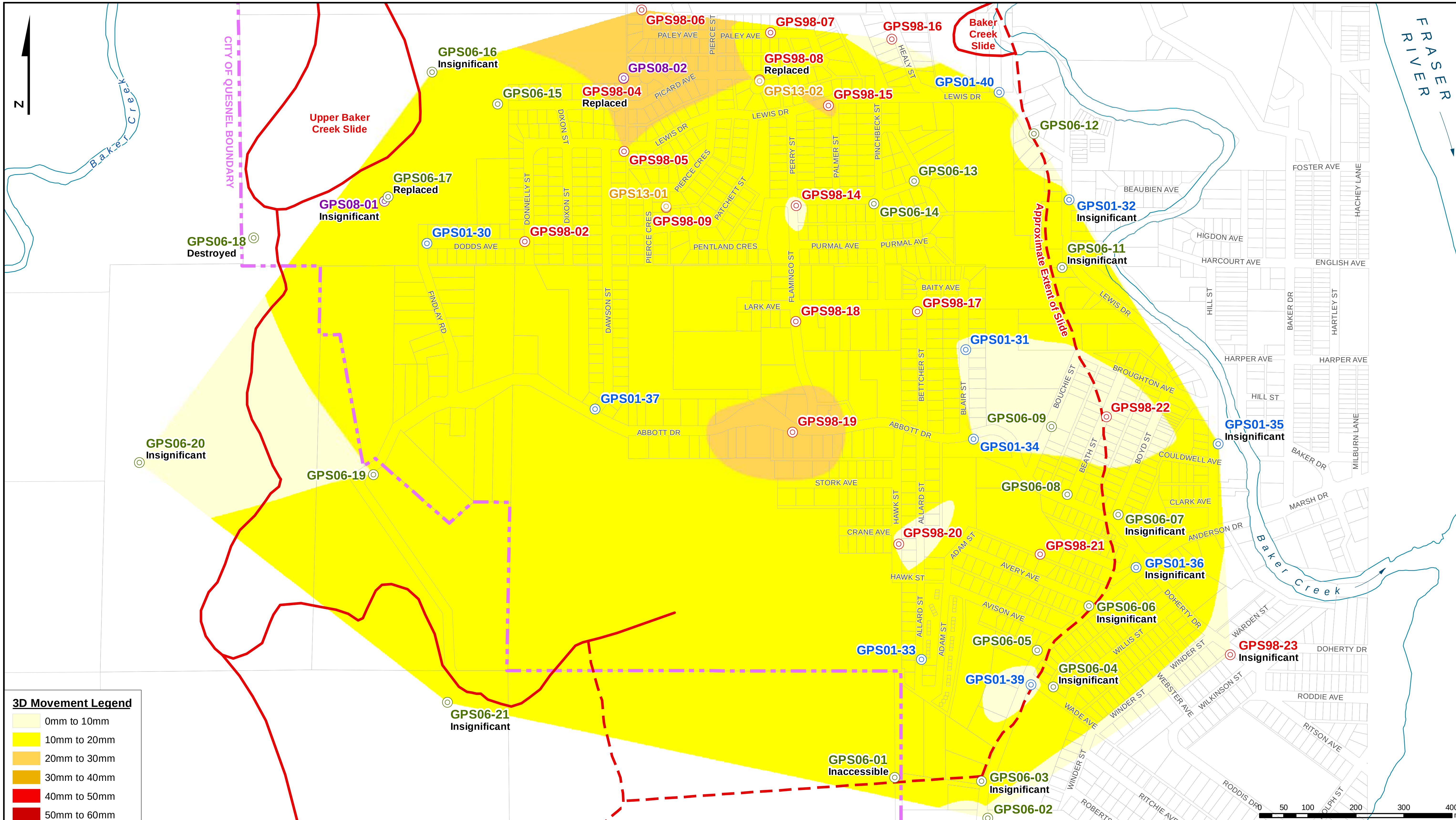
West Quesnel Land Stability Program

wood.

| | | | |
|---|---|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: ANNUAL HORIZONTAL MOVEMENT - 2014 NOVEMBER 2013 TO NOVEMBER 2014 FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS | DATE: JUNE 2020 |
| | CHK'D BY: DO | | PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV NO.: A |
| | PROJECTION: UTM Zone 10 | | FIGURE 21 |
| | SCALE: 1:7,500 | | |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig21-HMove-Nov13-Nov14-AllHubs.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: ANNUAL 3D MOVEMENT - 2014
NOVEMBER 2013 TO NOVEMBER 2014
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

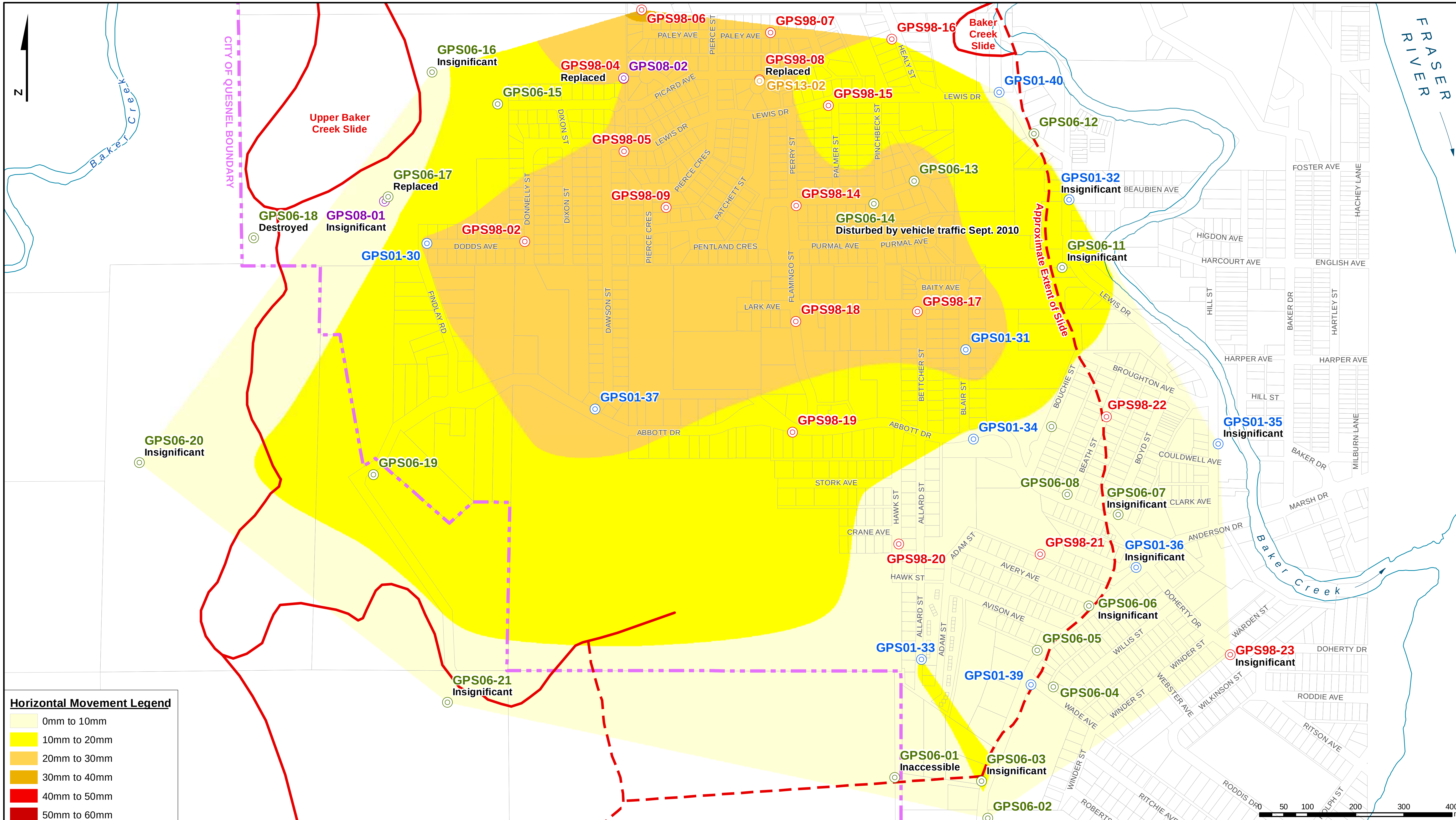
PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 22

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig22-3DMove-Nov13-Nov14-AllHubs.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: ANNUAL HORIZONTAL MOVEMENT - 2015
NOVEMBER 2014 TO DECEMBER 2015
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 23

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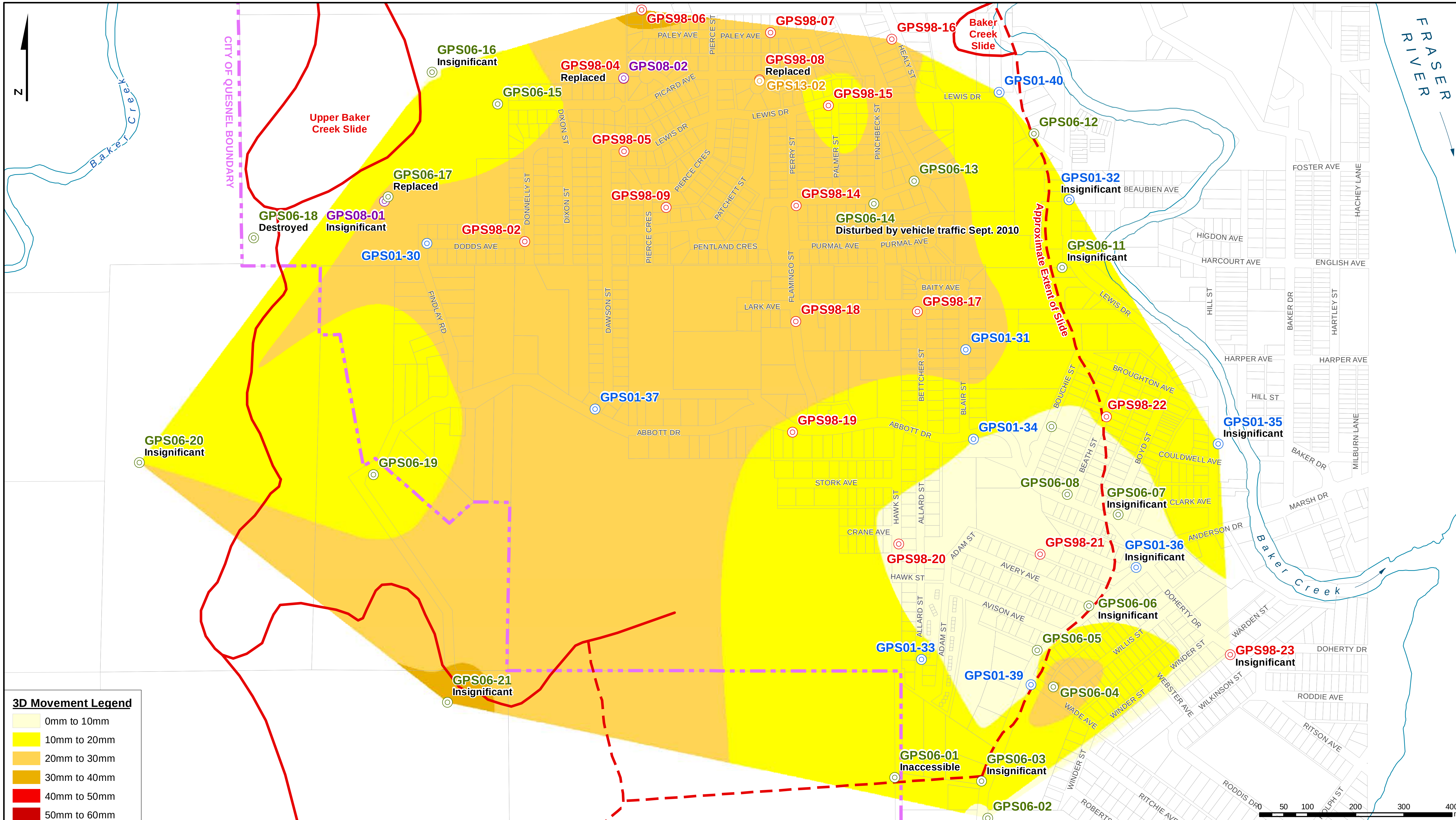
This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE:
ANNUAL 3D MOVEMENT - 2015
NOVEMBER 2014 TO DECEMBER 2015
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

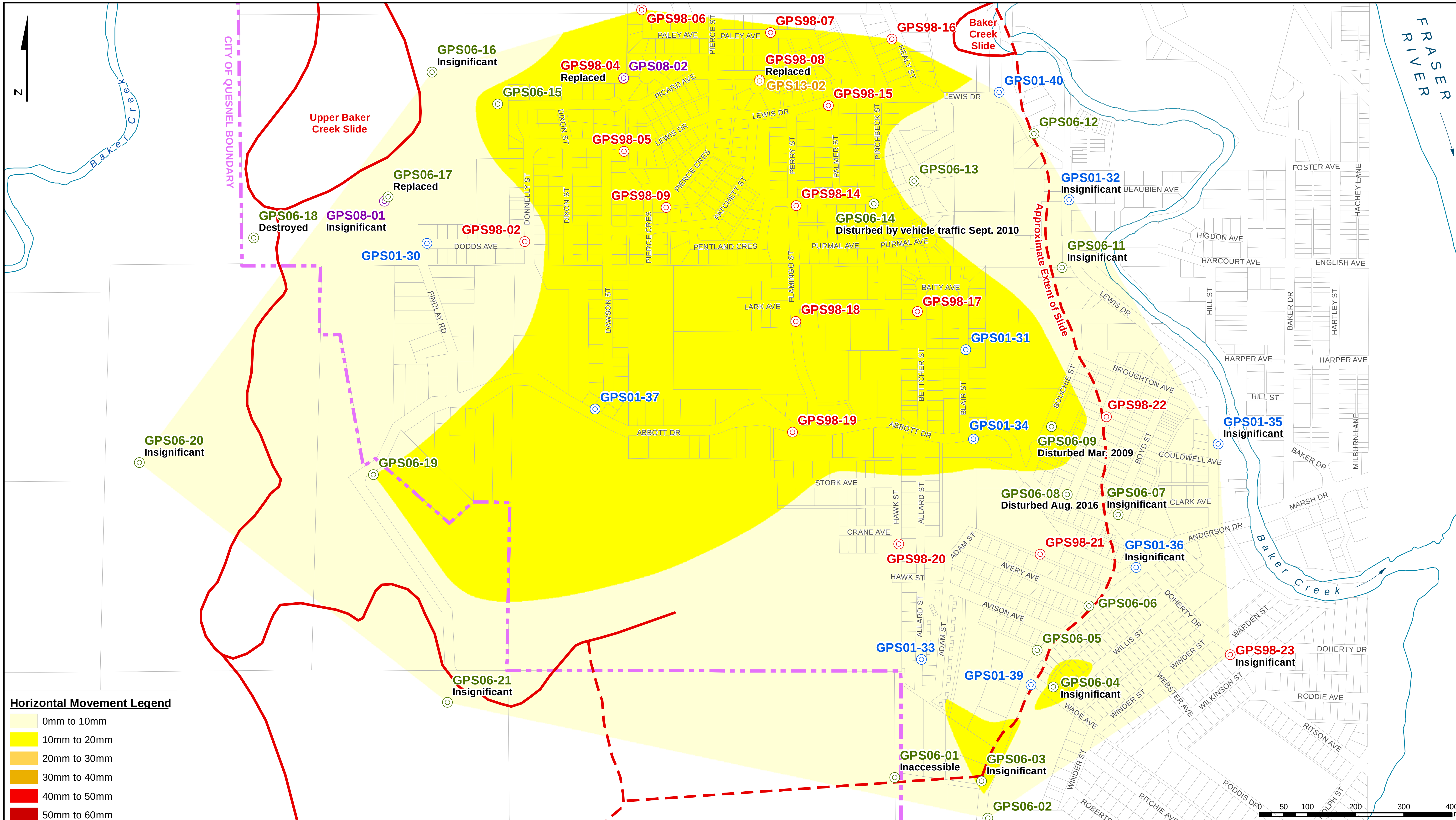
PROJECT:
WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 24

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig24-3DMove-Nov14-Dec15-AllHubs.mxd

This drawing was originally produced in colour.




Legend
- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | PO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: ANNUAL HORIZONTAL MOVEMENT - 2016
DECEMBER 2015 TO DECEMBER 2016
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

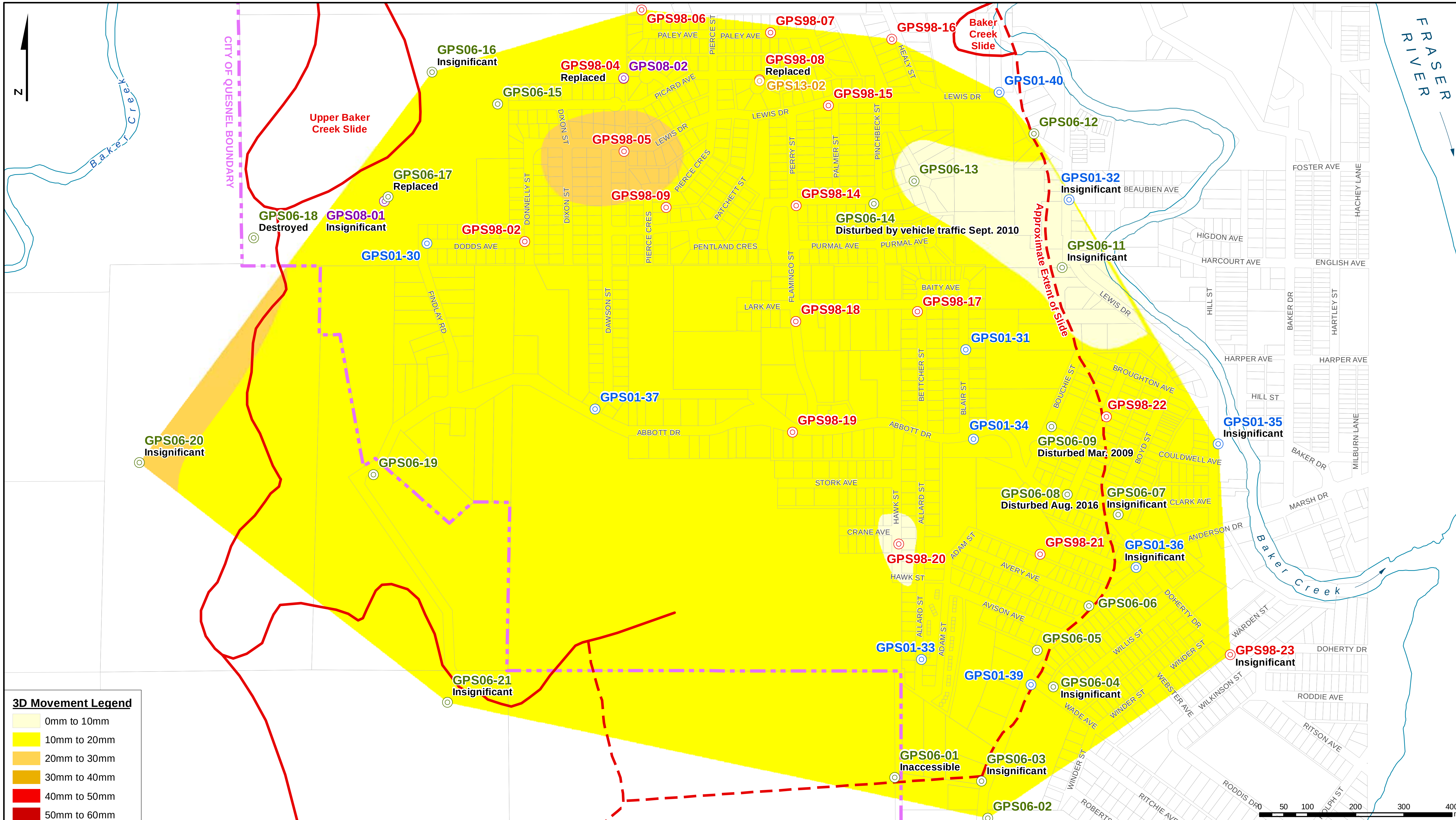
PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 25

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig25-HMove-Nov15-Dec16-AllHubs.mxd

This drawing was originally produced in colour.

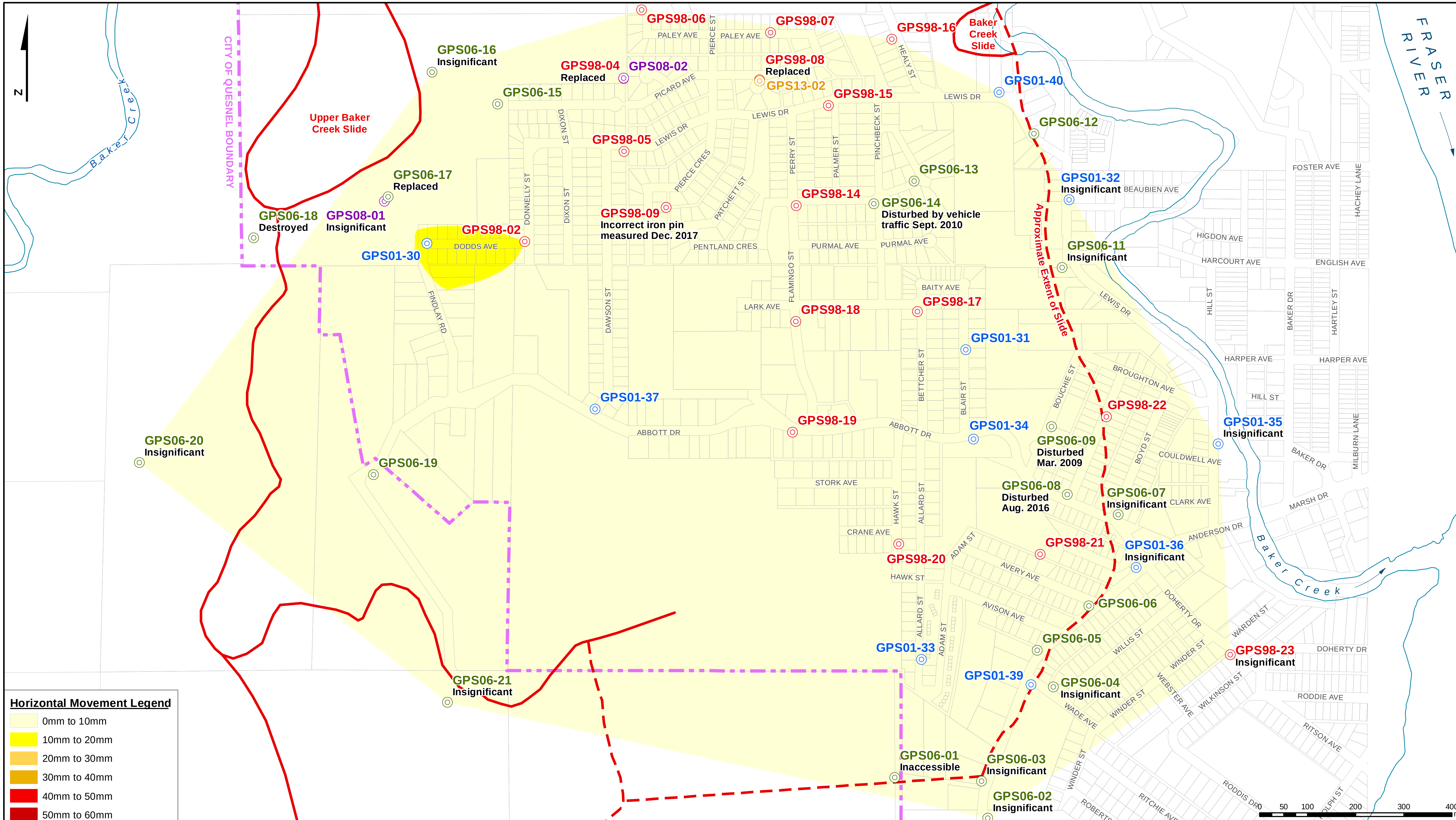



| | | | | |
|---|---|---|---|---|
| **Legend**<br>Slide Extent<br>Slide Extent (Approximate) | West Quesnel Land Stability Program | wood. | CLIENT: CITY OF QUESNEL | DWN BY: BB<br>CHK'D BY: PO |
| | | | Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83<br>PROJECTION: UTM Zone 10<br>SCALE: 1:7,500 |

| | |
|---|---|
| TITLE: ANNUAL 3D MOVEMENT - 2016<br>NOVEMBER 2015 TO DECEMBER 2016<br>FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS | DATE: JUNE 2020<br>PROJECT NO.: KX0439755 |
| PROJECT: WEST QUESNEL LAND STABILITY PROGRAM<br>QUESNEL, BC | REV NO.: A<br>FIGURE 26 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig26-3DMove-Nov15-Dec16-AllHubs.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

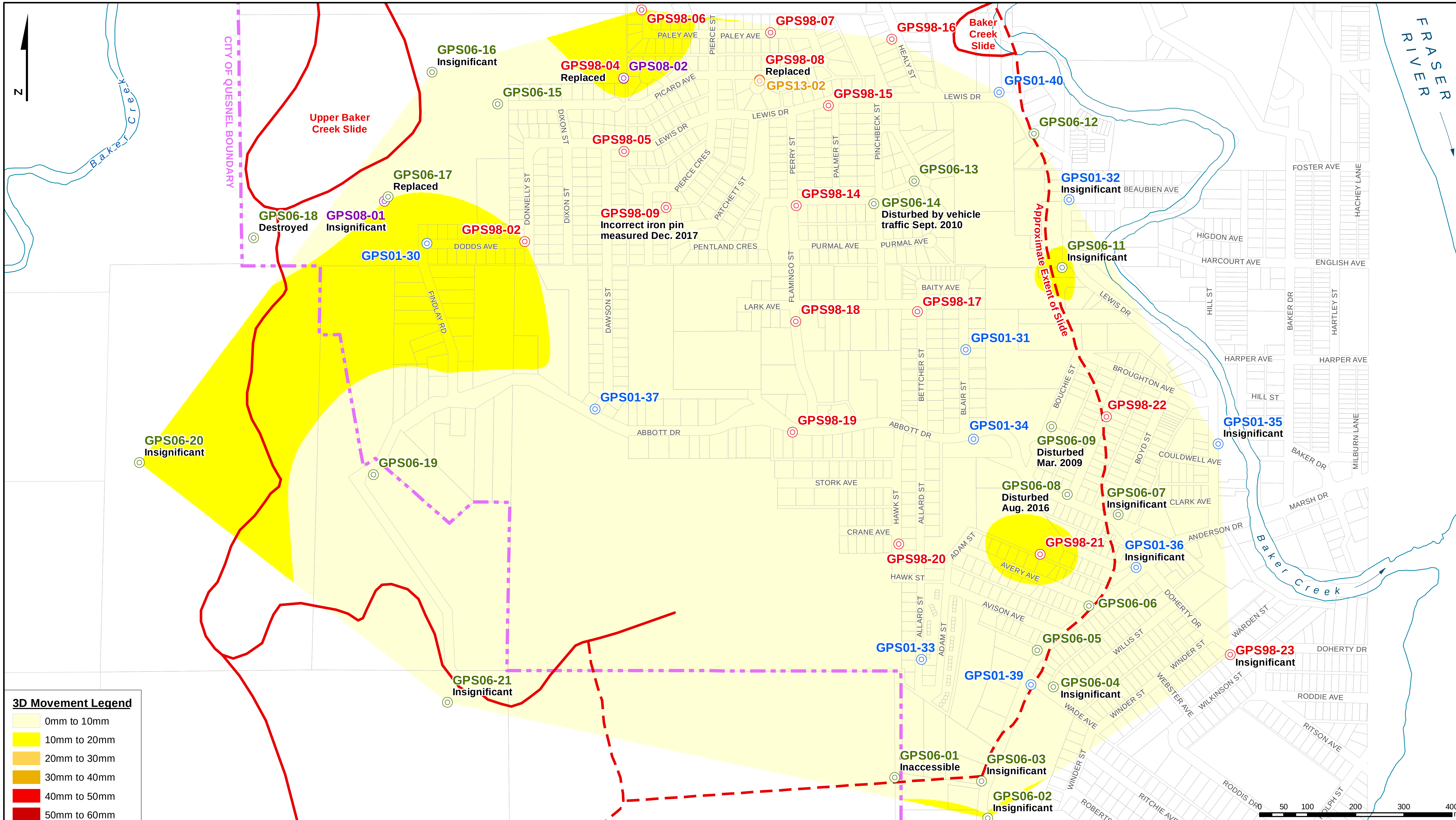
West Quesnel Land Stability Program

wood.

| | | | |
|---|---|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: ANNUAL HORIZONTAL MOVEMENT - 2017 DECEMBER 2016 TO DECEMBER 2017 FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS | DATE: JUNE 2020 |
| | CHK'D BY: DO | | PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV NO.: A |
| | PROJECTION: UTM Zone 10 | | |
| | SCALE: 1:7,500 | | FIGURE 27 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig27-HMove-Dec16-Dec17-AllHubs.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

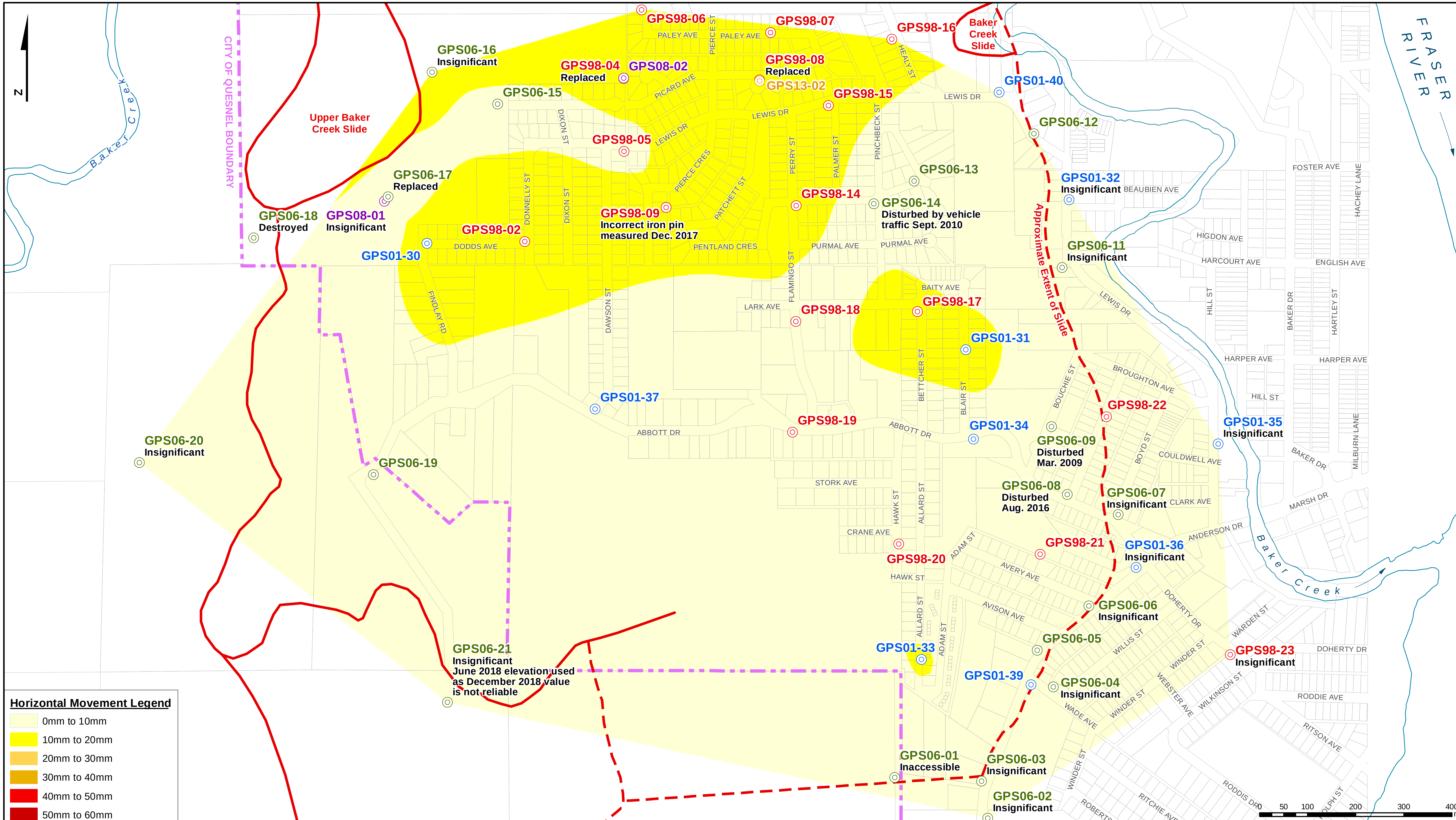
wood.

| | |
|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB |
| | CHK'D BY: DO |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 |
| | PROJECTION: UTM Zone 10 |
| | SCALE: 1:7,500 |

| | |
|---|---|
| TITLE: ANNUAL 3D MOVEMENT - 2017<br>DECEMBER 2016 TO DECEMBER 2017<br>FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS | DATE: JUNE 2020 |
| | PROJECT NO.: KX0439755 |
| PROJECT: WEST QUESNEL LAND STABILITY PROGRAM<br>QUESNEL, BC | REV NO.: A |
| | FIGURE 28 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig28-3DMove-Dec16-Dec17-AllHubs.mxd

This drawing was originally produced in colour.




Legend

Slide Extent

Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: ANNUAL HORIZONTAL MOVEMENT - 2018
DECEMBER 2017 TO DECEMBER 2018
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |
| | FIGURE 29 |

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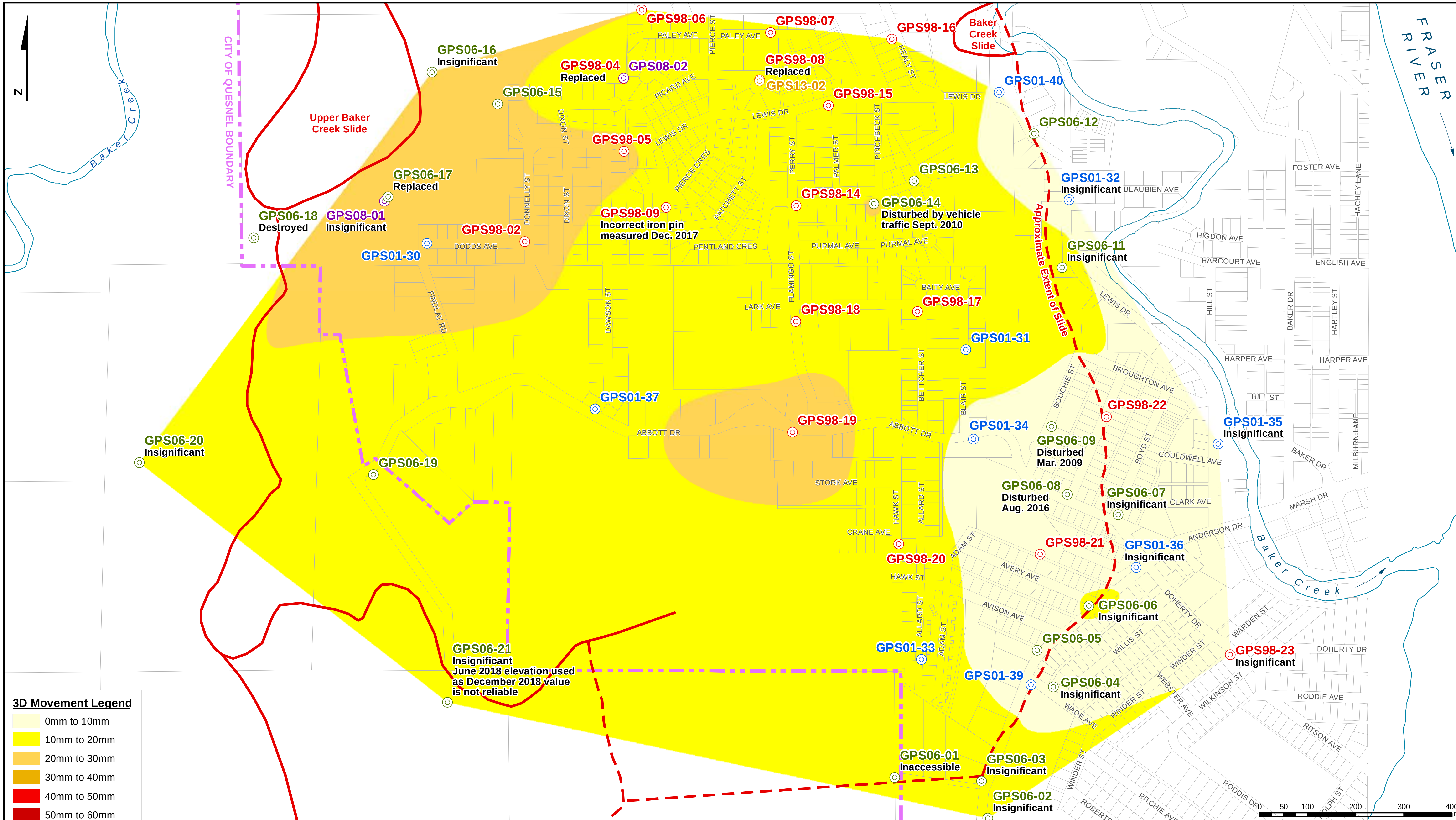
This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

| | | | |
|---|---|---|---|
| CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: ANNUAL 3D MOVEMENT - 2018 DECEMBER 2017 TO DECEMBER 2018 FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS | DATE: JUNE 2020 |
| | CHK'D BY: DO | | PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV NO.: A |
| | PROJECTION: UTM Zone 10 | | FIGURE 30 |
| | SCALE: 1:7,500 | | |

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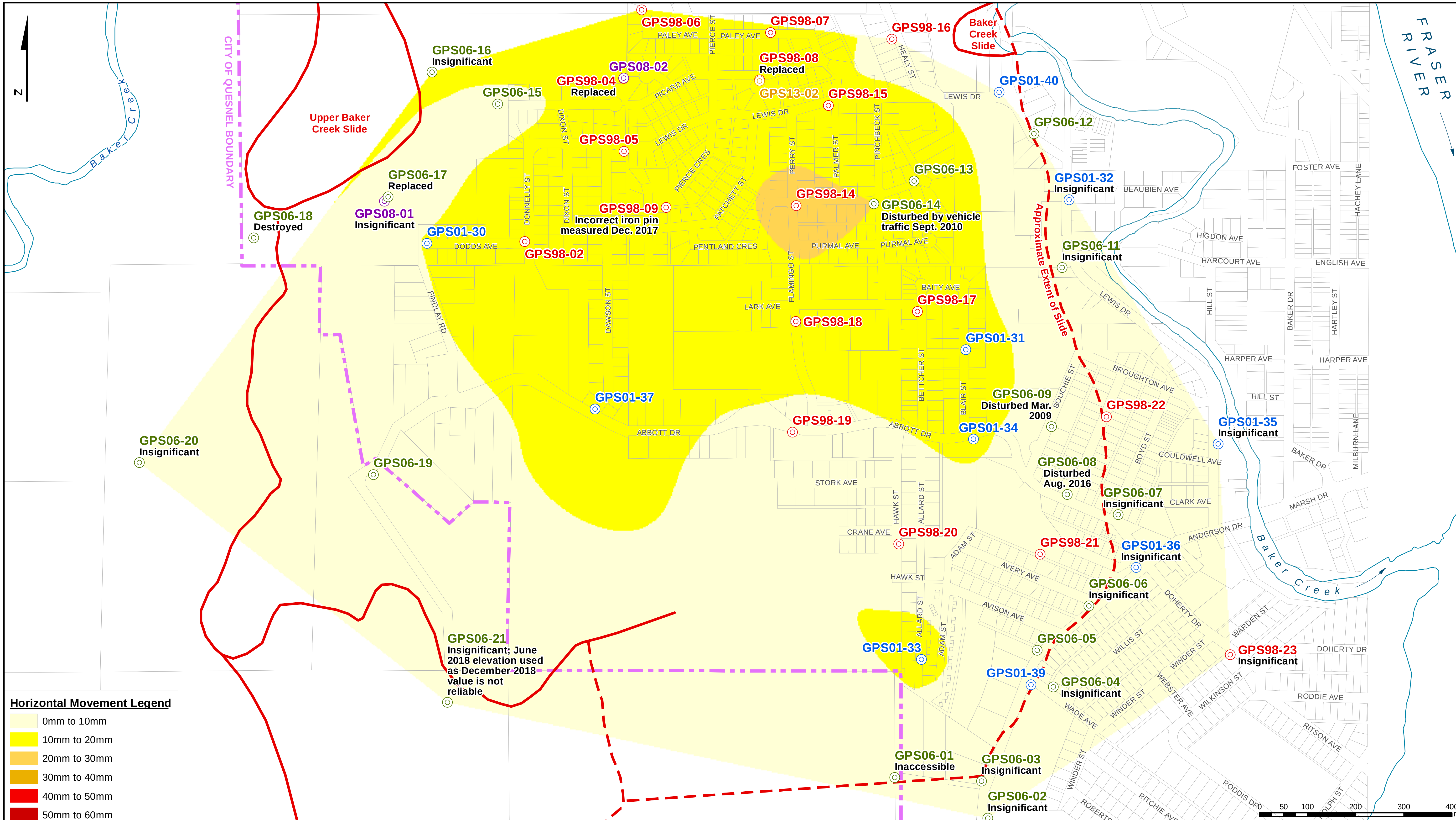
This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE:

ANNUAL HORIZONTAL MOVEMENT - 2019
DECEMBER 2018 TO DECEMBER 2019
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

PROJECT:

WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 31

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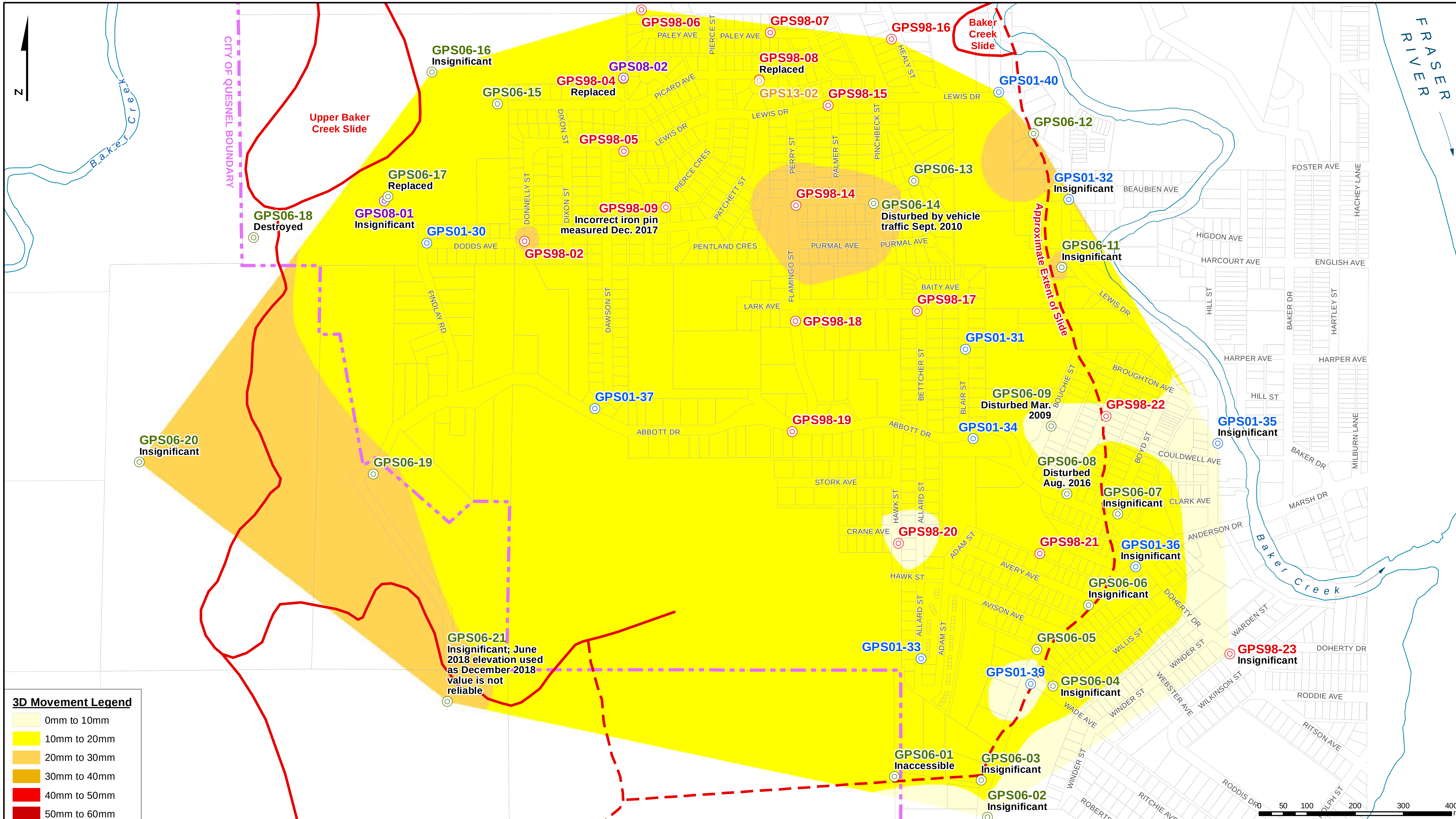
This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: ANNUAL 3D MOVEMENT - 2019
DECEMBER 2018 TO DECEMBER 2019
FOR THE 1998, 2001, 2006 AND 2008 GPS HUBS

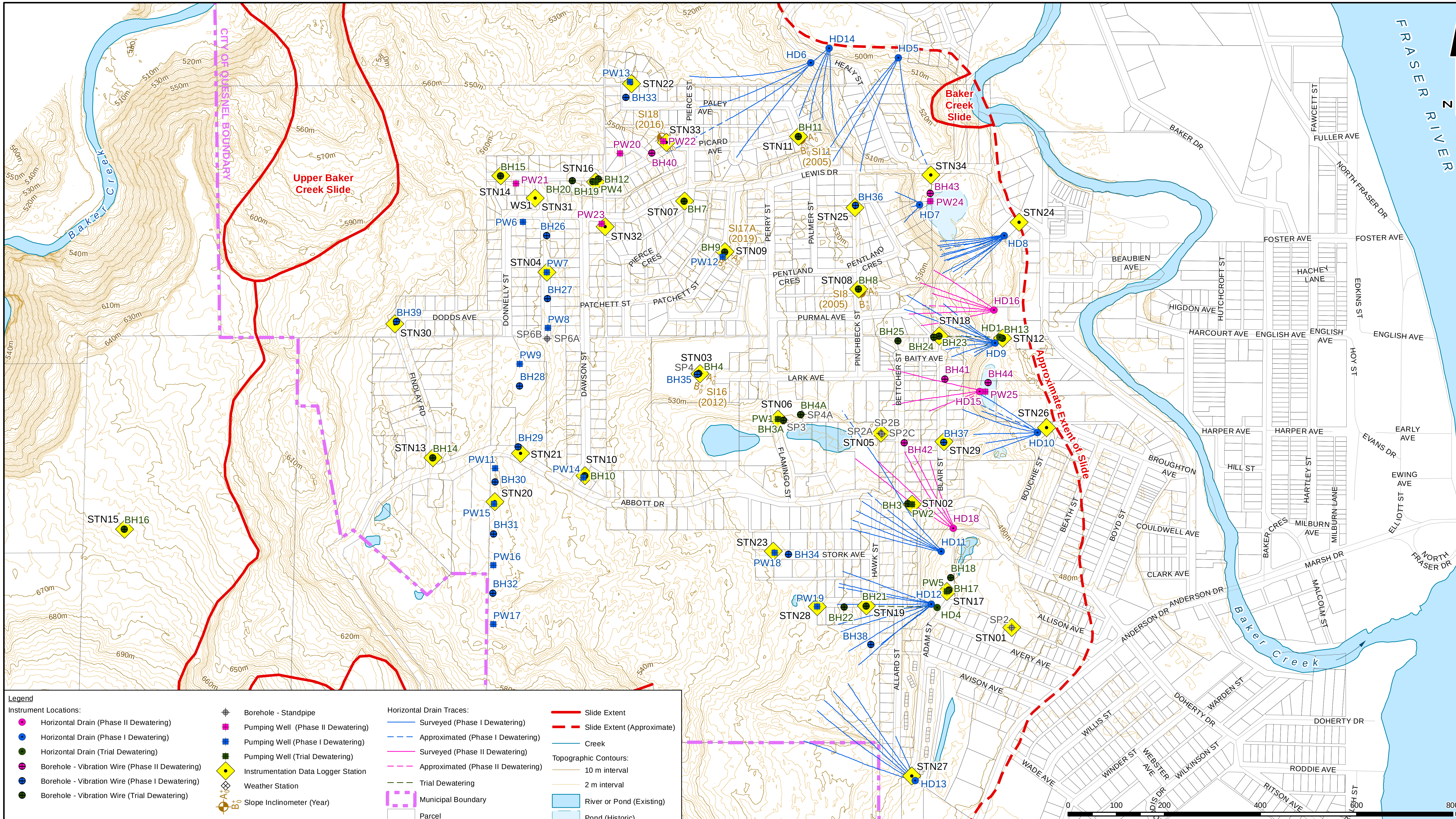
PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 32

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig32-3DMove-Dec18-Dec19-AllHubs.mxd

This drawing was originally produced in colour.



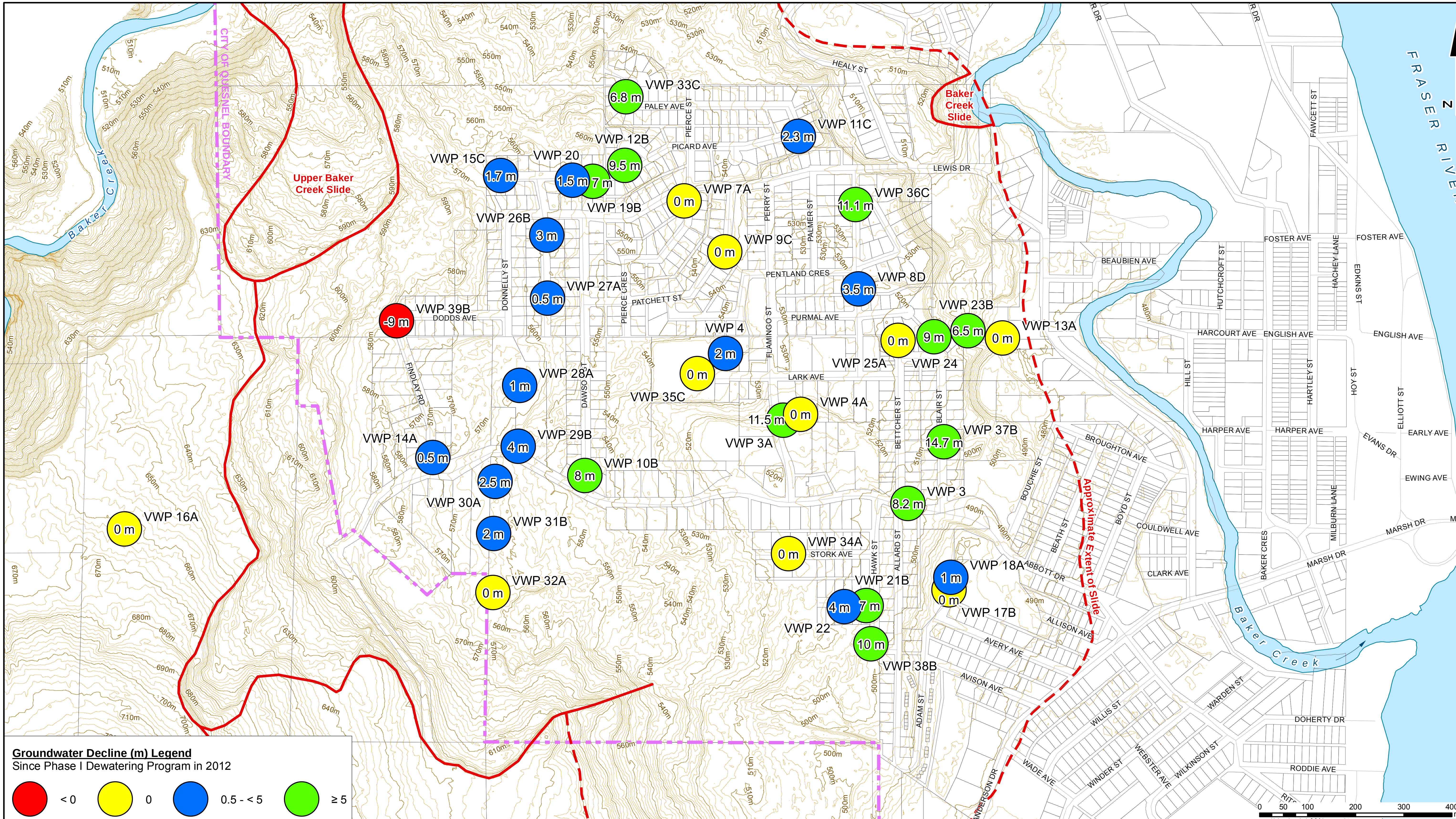

| CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: OVERALL INSTRUMENTATION SITE PLAN | DATE: JUNE 2020 |
|---|---|---|---|
| | CHK'D BY: DO | | PROJECT NO.: KX0439755 |
| Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC | REV NO.: A |
| | PROJECTION: UTM Zone 10 | | FIGURE 33 |
| | SCALE: 1:7,500 | | |

West Quesnel Land Stability Program

wood.

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig33-OverallInstrumentationSitePlan.mxd

This drawing was originally produced in colour.




Legend
Slide Extent
Slide Extent (Approximate)

Note: Groundwater elevation of VWP 39B has increased by 2.5 m.

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

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a Division of Wood Canada Limited (Wood)
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Tel. (250) 564-3243 Fax (250) 562-7045

DWN BY: BB
CHK'D BY: DO
DATUM: NAD 83
PROJECTION: UTM Zone 10
SCALE: 1:7,500

TITLE: GROUNDWATER DRAWDOWN

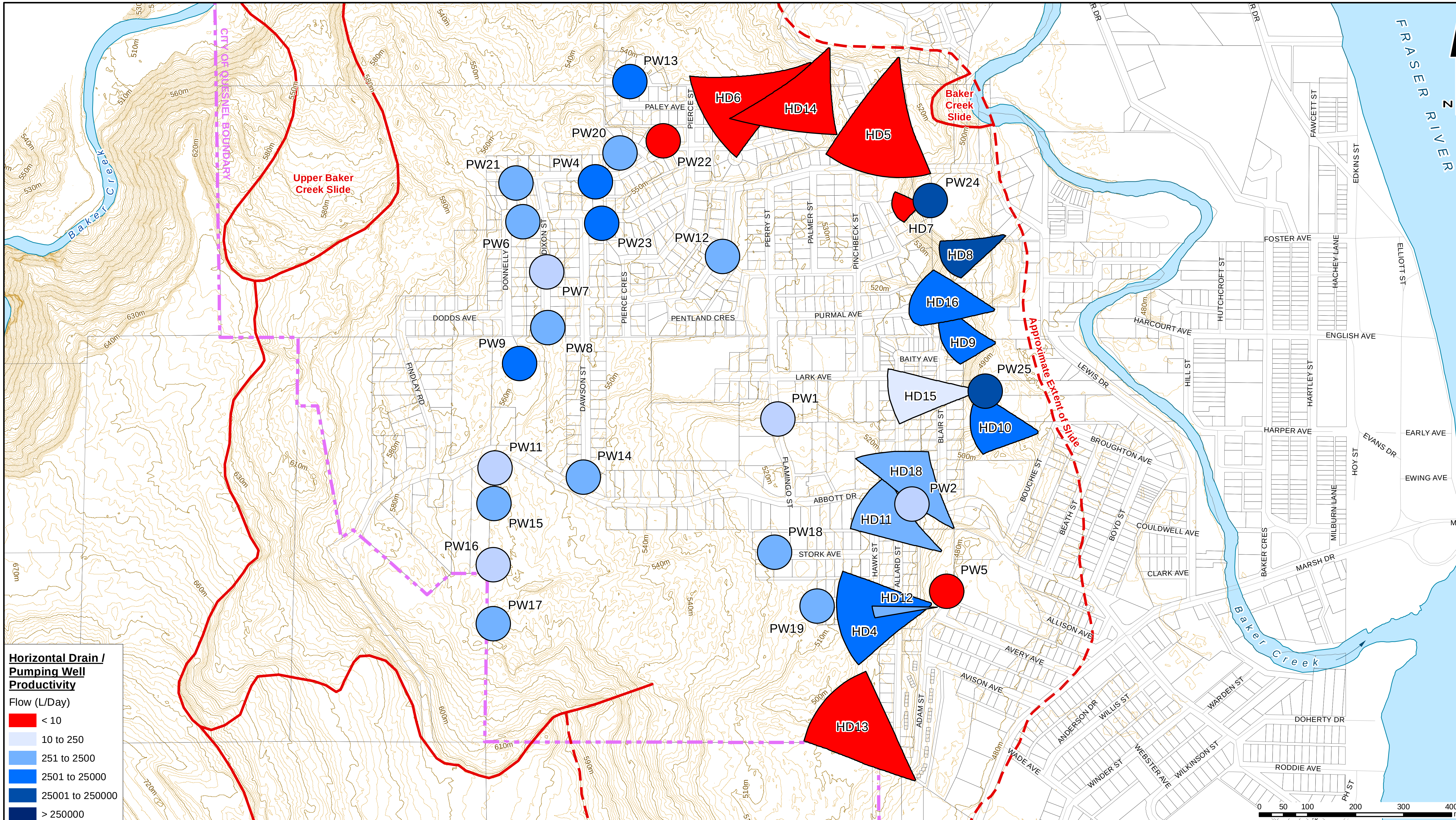
PROJECT: WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

DATE: JUNE 2020
PROJECT NO.: KX0439755
REV NO.: A

FIGURE 34

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig34-GroundwaterDrawdown.mxd

This drawing was originally produced in colour.




**Legend**

Slide Extent

Slide Extent (Approximate)

Note: Productivity flow (L/day) calculated by averaging total flows over number of days in service.

West Quesnel Land Stability Program

wood.

CLIENT:

CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE:

2018 PUMPING WELL &
HORIZONTAL DRAIN PRODUCTIVITY

PROJECT:

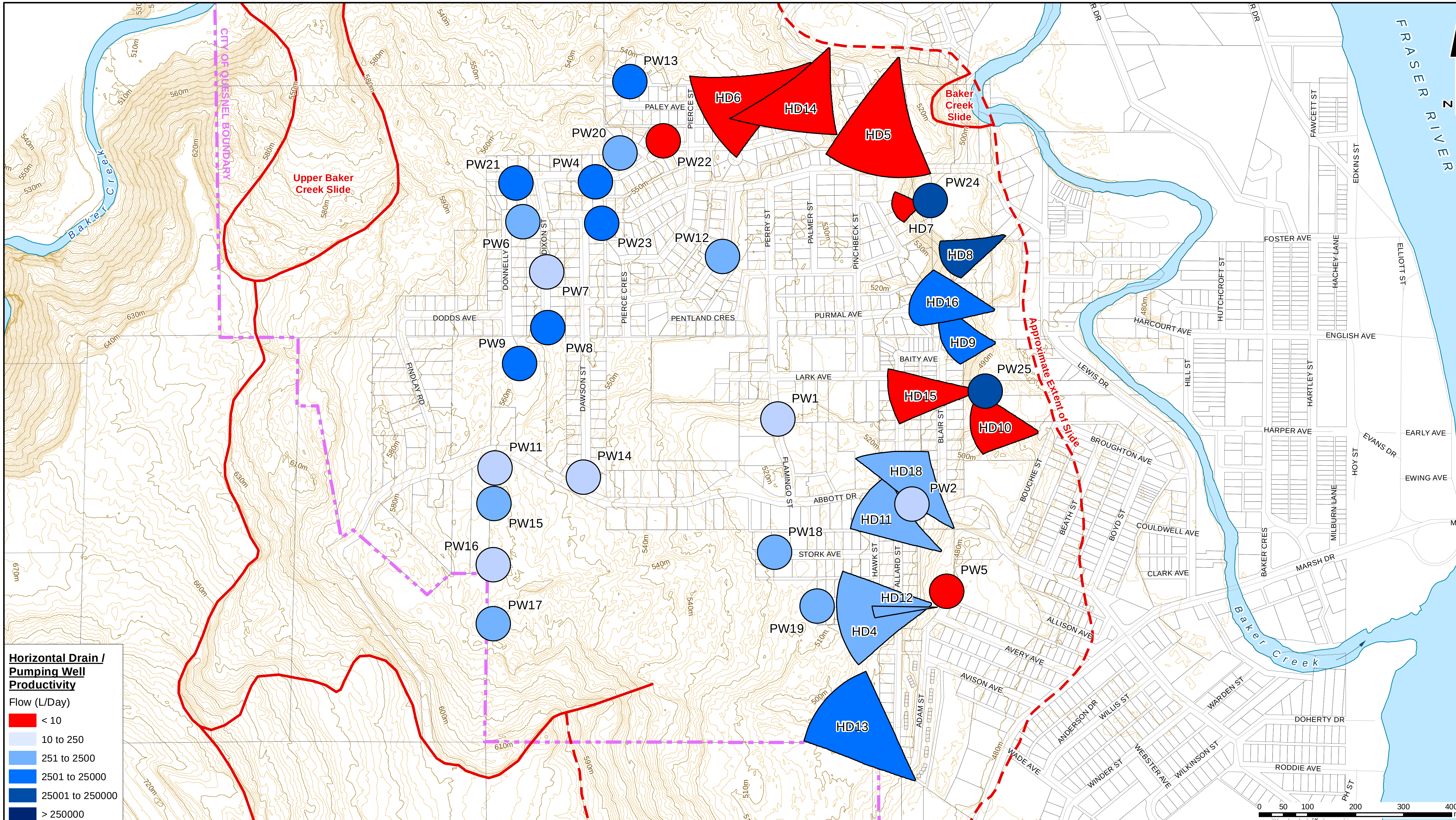
WEST QUESNEL LAND STABILITY PROGRAM
QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 35

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig35-2018PW&HDProductivity.mxd

This drawing was originally produced in colour.




**Legend**

- Slide Extent
- Slide Extent (Approximate)

Note: Productivity flow (L/day) calculated by averaging total flows over number of days in service.

West Quesnel Land Stability Program

wood.

CLIENT: CITY OF QUESNEL

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited (Wood)
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Prince George, BC, CANADA V2N 2P9
Tel. (250) 564-3243 Fax (250) 562-7045

| | |
|---|---|
| DWN BY: | BB |
| CHK'D BY: | DO |
| DATUM: | NAD 83 |
| PROJECTION: | UTM Zone 10 |
| SCALE: | 1:7,500 |

TITLE: 2019 PUMPING WELL & HORIZONTAL DRAIN PRODUCTIVITY

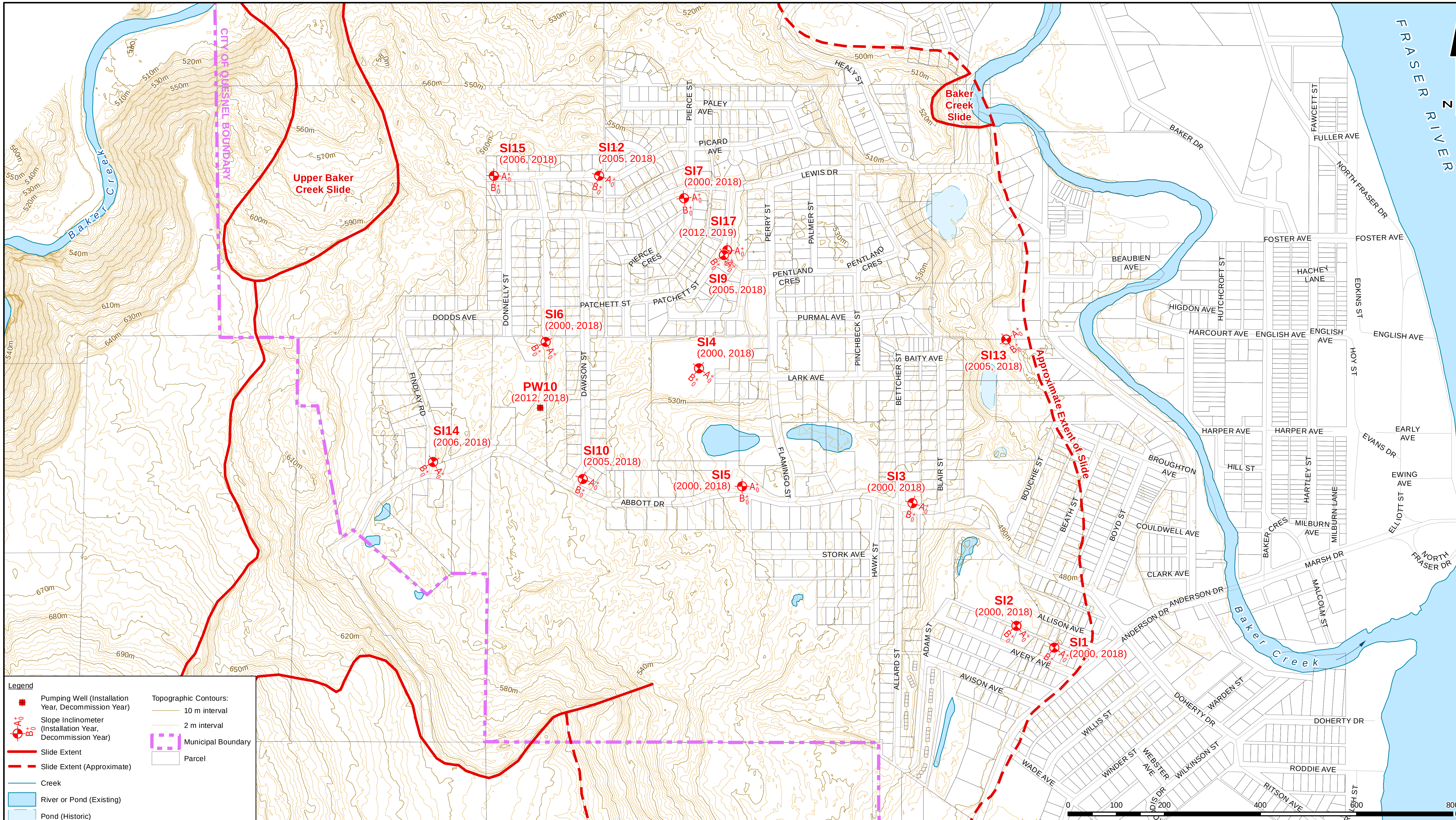
PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC

| | |
|---|---|
| DATE: | JUNE 2020 |
| PROJECT NO.: | KX0439755 |
| REV NO.: | A |

FIGURE 36

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig36-2019PW&HDProductivity.mxd

This drawing was originally produced in colour.




| | | | | |
|---|---|---|---|---|
| West Quesnel Land Stability Program | wood. | CLIENT: CITY OF QUESNEL | DWN BY: BB | TITLE: 2018 AND 2019 DECOMMISSIONING SITE PLAN |
| | | | CHK'D BY: DO | DATE: JUNE 2020 |
| | | | | PROJECT NO.: KX0439755 |
| | | Wood Environment & Infrastructure Solutions<br>a Division of Wood Canada Limited (Wood)<br>3456 Opie Crescent<br>Prince George, BC, CANADA V2N 2P9<br>Tel. (250) 564-3243 Fax (250) 562-7045 | DATUM: NAD 83 | PROJECT: WEST QUESNEL LAND STABILITY PROGRAM QUESNEL, BC |
| | | | PROJECTION: UTM Zone 10 | REV NO.: A |
| | | | SCALE: 1:7,500 | FIGURE 37 |

S:\Internal\KX04397-WQLS-GIS\KX0439755.5-2019AnnualMonitoringReport\KX0439755-Fig37-2018&2019DecomSitePlan.mxd

This drawing was originally produced in colour.