TECHNICAL MEMO

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To:	Teri Camery (CBJ)	**Date:**	April 27, 2022
c:	Scott Ciambor (CBJ)	**Memo No.:**	3
From:	Rita Kors-Olthof, Vladislav Roujanski, Shirley McCuaig	**File:**	704-ENG.EARC03168-01 / 704-ENG.EARC0168-02A
Subject:	Mapping Overview at Starr Hill Subdivision and Additional Information Downtown Juneau Landslide and Avalanche Hazard Assessment		

1.0 INTRODUCTION

This technical memo addresses some of the comments and questions that arose from Tetra Tech Canada Inc.'s (Tetra Tech) Issued-for-Review (3rd Draft) Report, Downtown Juneau Landslide and Avalanche Assessment, dated May 28, 2021 (Tetra Tech 2021), and the Landslide and Avalanche Hazard Public Meeting that took place on July 21, 2021.

The City and Borough of Juneau (CBJ) has requested a response for each of three key points, as described in CBJ's email dated July 27, 2021. Two of these items were addressed in Technical Memos #1 and #2, which have since been updated (in Appendix C of the main report; Tetra Tech 2022a, 2022b). This Technical Memo #3 responds to commentary and requests for additional information about hazards surrounding the Starr Hill subdivision. It includes the information provided in the Issued-for-Review memo dated September 16, 2021, as well as the supplementary information for Question #5 provided by email on September 17, 2021, as well as some additional mapping information compiled since April 1, 2022. A few additional remarks have also been provided for Question #14.

2.0 LANDSLIDE HAZARD DESIGNATIONS AND BOUNDARIES

2.1 Mapping Overview at Starr Hill Subdivision

2.1.1 Comparing Adopted (1987) and Proposed (2021) Mapping

The residents of the Starr Hill Subdivision have been concerned to discover that landslide hazards designated *High* and *Severe* have been identified on the slopes around the subdivision. These hazards had not been identified in the 1987 adopted hazard mapping, in which only *Moderate* hazards had been shown at existing structures along most of the adjacent portion of Basin Road, 6th Street, Nelson Street, and several houses on 5th Street and in a zone upslope of 5th Street beyond the built roads of Kennedy and East Streets, as shown in Figure 1A below. Only a few structures further upslope of Kennedy, East, and Harris Streets were already mapped within a *Severe* zone in 1987, although continuing south and then southeast onto the main slope of Mt. Roberts, many more structures were mapped within *Severe*.

As seen in Figure 1 below, the main difference between the 1987 adopted hazard mapping and the new 2021 proposed hazard mapping is that many of the former *Moderate* areas surrounding Starr Hill (colored in pale lavender on Figure 1A) are now designated *High* or *Severe* (colored in dark pink on Figure 1B).

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The 1987 adopted hazard mapping is understood to have been based on Swanston (1972). However, the 1987 mapping follows property lines, resulting in numerous right-angle corners in the hazard boundaries. The 2021 mapping does *not* follow property lines. It follows hazard designations based on terrain features, such as surficial geology, geomorphology (evidence of past and more recent slope movement types accentuated by vegetation patterns), and activity levels for slope instabilities as seen from the air photos and confirmed by field observations. For instance, along 6th Street, between East Street and Nelson Street, the lower boundary of the new 2021 proposed hazard zone does *not* arbitrarily stop at the upslope property lines of the affected properties as it does in the 1987 mapping. The same is true upslope of Nelson Street, and upslope of 5th Street, where the lower boundary of the 2021 proposed hazard mapping does *not* arbitrarily stop at the upslope property lines of the affected properties.

Figure 1: Excerpts from CBJ's 1987 adopted hazard mapping (Figure 1A) and comparison of 1987 adopted hazard mapping and 2021 proposed hazard mapping (Figure 1B) at the Starr Hill subdivision.

Since Tetra Tech has identified some important differences in the mapping methodology seen in the 1987 adopted mapping and Tetra Tech's 2021 mapping, it is useful to show the origins of that 1987 mapping, as discussed further in Section 2.1.2.

2.1.2 Comparing Swanston (1972) and Tetra Tech's (2021) Mapping

This section has some general comments comparing the mapping from Swanston (1972) and Tetra Tech (2021), followed by a few comments for specific slope sections above Starr Hill.

Swanston (1972) did not create arbitrary transitions in hazard designation based on property lines. Despite the poor scan quality of this old report, it is clear that Swanston based his 1972 hazard designations on geology and landslide features, *not* on property lines, as seen below in Figure 2.

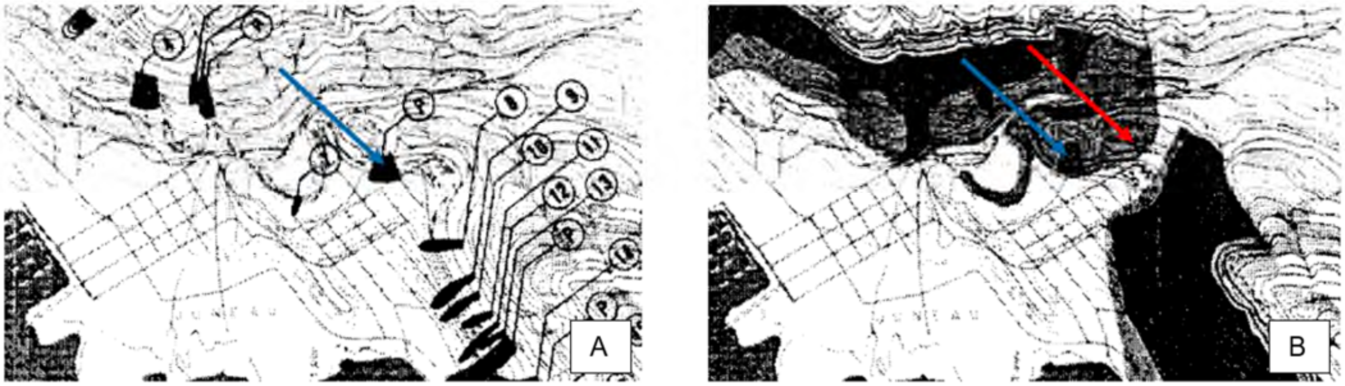

Figure 2: Excerpts from Swanston (1972) – Figure 5 – Historic Landslide Deposits (Figure 2A) and Figure 6 – Mass Wasting Hazard Areas (Figure 2B).

In Swanston's Figure 5, "P" means "Prehistoric" (before 1880). A prehistoric slide area was noted on the south side of Mt. Maria (blue arrow in Figure 2A). In Swanston's Figure 6 (Figure 2B), hazards for mass wasting (landslide) hazard areas are shown, with *Potential* Hazards marked in gray, and *High* Hazards marked in black. The prehistoric slide is shown as a *High* Hazard area (blue arrow in Figure 2B). A small cliff with a talus deposit above the corner of 6th and Nelson Streets was also designated as being in a *High* Hazard area (red arrow in Figure 2B).

Comparing Swanston's hazard mapping (Figure 2B) with the 1987 adopted mapping (Figure 1A), CBJ renamed Swanston's "*Potential* Hazard" as *Moderate* Hazard and renamed Swanston's "*High* Hazard" as *Severe* Hazard.

A summary of Tetra Tech's mapping of the Starr Hill area and the adjacent portion of Basin Road is shown below in Figure 3, with surficial geology in Figure 3A and landslide hazard designation mapping in Figure 3B. There is a clear correlation between the shapes of the surficial geology units and the associated landslide hazard designations.

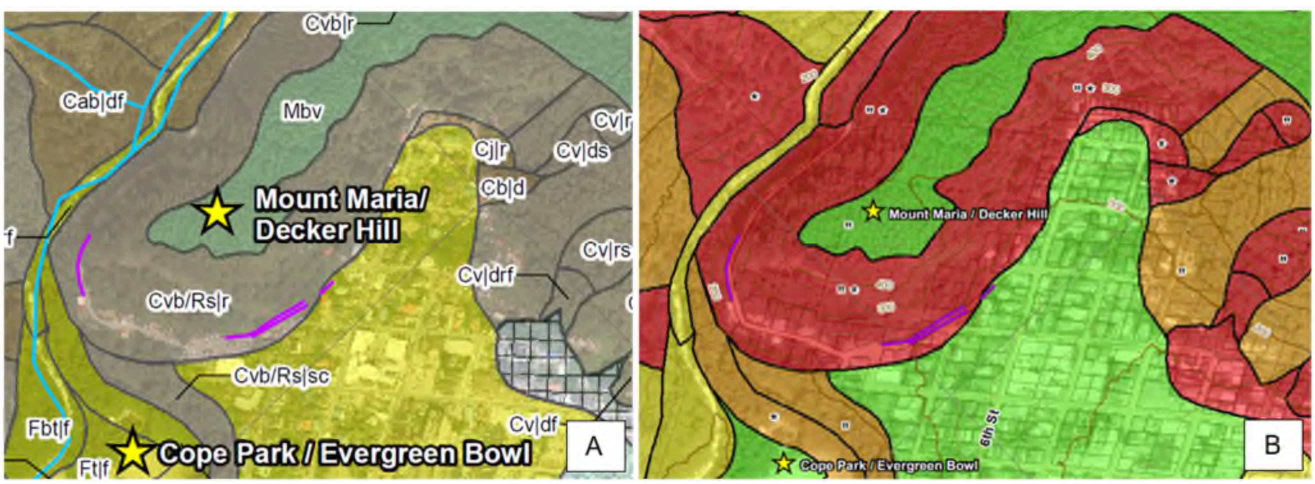

Figure 3: Excerpts from Tetra Tech Figure 1.3b Surficial Geology (Figure 3A), and Figures 1.6c and 1.6h Landslide Hazard Designation Mapping (Figure 3B).

Some parallels can be seen in the locations of the mapping boundaries of Swanston (1972) and Tetra Tech (2021), in that they appear to follow the terrain (in contrast to the 1987 mapping which defers to nearby property lines). However, there are some significant differences in the details, due to better quality data, i.e., higher resolution imagery and new LiDAR data available to Tetra Tech, and more advanced mapping techniques used in the current study (Figure 4).

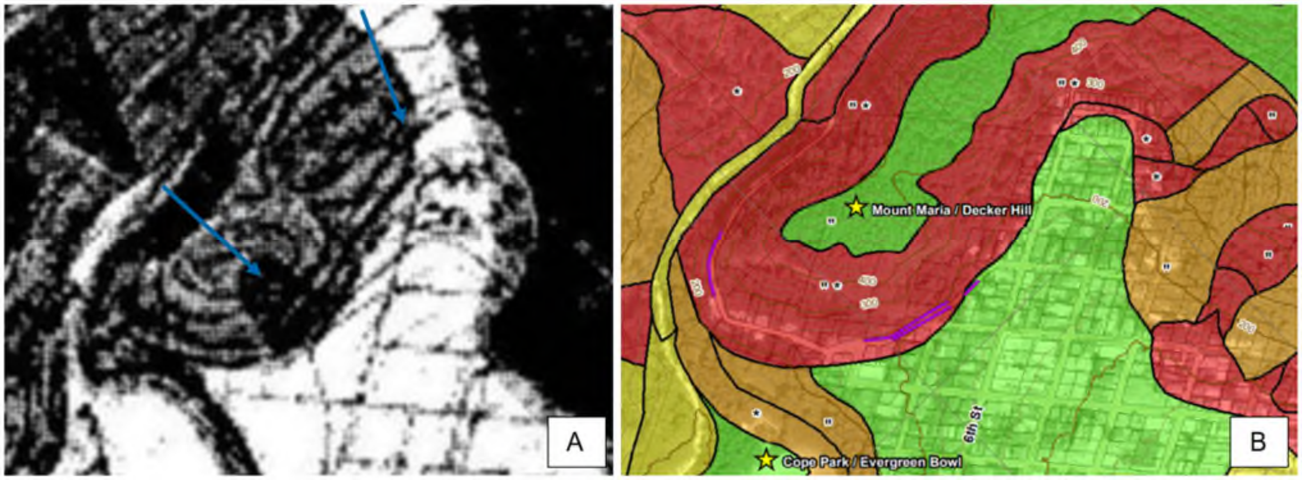

Figure 4: Comparison of Swanston's Figure 6 (Figure 4A) and Tetra Tech's Figures 1.6c and 1.6h Landslide Hazard Designation Mapping (Figure 4B). Swanston (1972) uses *Potential* Hazard (gray) and *High* Hazard (black), designated in the 1987 adopted mapping as *Moderate* and *Severe* hazards. Tetra Tech uses *Low* (green), *Moderate* (yellow), *High* (orange), and *Severe* (red) hazard designations.

As shown in Figure 4A, Swanston mapped most of Mt. Maria on the Starr Hill side as having a *Potential* Hazard (gray area), except at the prehistoric slide area and a small cliff above the corner of 6th and Nelson Streets, which were designated as being in *High* Hazard areas (blue arrows). These two areas are also shown with blue arrows in Figure 5. Heading northeast along 6th Street from Basin Road towards Nelson Street, the lower boundary of Swanston's *Potential* Hazard area was mapped progressively closer to 6th Street.

Along the entire southeast edge of Starr Hill, including a portion of the mapped lots, Swanston (1972) marked an area of *Potential* Hazard, with *High* Hazard marked further upslope on Mt. Roberts. The lower boundary of Swanston's *Potential* Hazard area begins at about Harris and 4th Streets, becoming progressively closer to 5th Street heading northeast. The northeast corner of Swanston's mapped landslide hazard area curves to the north to encompass the terrain southeast and northeast, upslope of the corner of Nelson and 5th Streets. Swanston did not designate hazards along or above the northwest part of Nelson Street. CBJ's 1987 adopted map called that area *Moderate* (Figure 1A).

The sections that follow provide some additional details about the slope sections for which hazard designation changes have been proposed.

Nelson Street (between 5th and 6th Streets)

Swanston's mapped rockslide hazard appears to continue around the corner to Nelson Street (more red arrows in Figure 5), although that is less clear due to the poor scan quality of Swanston's mapping. The presence of rockfall/ rockslide hazard areas along Nelson Street did not appear to be reflected in Swanston's hazard mapping (Figure 4A).

The findings in Swanston (1972) are generally consistent with Tetra Tech's findings on the northwest and northeast sides of the Starr Hill Subdivision, except for the gap in Swanston's hazard mapping along Nelson Street.

Corner of Nelson Street and 5th Street to Harris Street

Tetra Tech identified some additional debris slide and debris flow features on the southeast side of the Starr Hill Subdivision that were not specifically identified by Swanston, but which do appear to account for Swanston's overall hazard designations for that slope (Figure 2B; Figure 4A).

Debris Flows above 5th Street between Park and Kennedy Streets and Kennedy and East Streets

On the southeast side of the subdivision, Swanston (1972) also found a record of a "slump" that occurred on November 27, 1935, at "5th Street above Kennedy" Street that did not cause damage. Swanston did not map that feature; however, nor did he detail the active slope processes at that location. The debris flow feature identified by Tetra Tech between Kennedy and Park Streets and upslope (southeast) of 5th Street, might be related to the "slump" mentioned by Swanston (located at approximately the orange arrow on Figure 5). That significant debris flow gully (called G000 Park in the new avalanche mapping) appears to be a different debris flow than the feature identified by Miller (1975), which is located slightly to the southwest, between East and Kennedy Streets (green arrow on Figure 5).

At that location, Miller (1975) showed a debris flow about 85 yards long that he reported as a 1972 event. Due to this location being located at the edge of one of the air photos, and possibly due to regrowth of vegetation since 1972, Tetra Tech's review of the 1977 air photos was inconclusive. However, Google Street View (July 2011 imagery), near the southeast end of the paved part of East Street, clearly shows the aftermath of a recent debris flow and/or erosion type event from upslope of the road at 415 East Street. The 2013 imagery also suggests disturbed ground between the house closest to the road and the next house located almost due east at 622 4th Street.

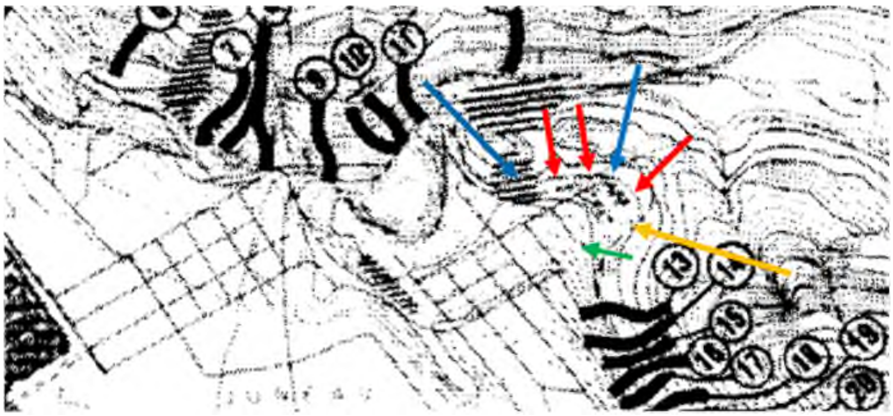

Figure 5: Excerpt from Swanston (1972) Figure 7 – "Mass Wasting Channels and Rock Slide Areas." Striped map areas are rockslide hazard areas; heavy numbered lines are mass movement channels.

2.1.3 Reasons to Update the Landslide Hazard Designations around Starr Hill

Swanston (1972) *specifically* identified many of the rockfall/rockslide hazards on the Basin Road and 6th Street boundaries of Mt. Maria, and along Nelson Street, and *generally* identified landslide hazards between Nelson Street and Harris Street above 5th Street, near the northwest end of the Mt. Roberts ridge.

However, Swanston's hazard designation system was slightly less conservative than Tetra Tech's designation system. This difference is partly due to Tetra Tech's modern mapping capabilities identifying more features than might have been detected in 1972, particularly on the southeast side of the subdivision, and partly due to the Four-Tier Landslide Hazard Designation System developed by Tetra Tech.

The other main difference in hazard designation mapping is that Swanston's hazard mapping between Nelson Street and Harris Street on the southeast side of Starr Hill shows a lower level of hazard activity along the toe of slope than upslope. Swanston's mapping transition; however, does *not* entirely reflect the actual landslide hazards in the area. For example, landslide hazard is associated with the *deposition zone* of landslide debris just as much as it is with the initiation zone or the path of the debris. If the residences are located within the natural deposition zone, then, logically, damage *could* occur if a landslide does happen. Therefore, the *Severe* hazard designations *should* extend into the deposition zones along Basin Road, 6th Street, Nelson Street, and around the corner along and above 5th Street. Similarly, the debris flow deposition zone between Park and Kennedy Streets widens towards the toe of slope, due to the way that debris flow cones or fans are formed (as explained in Technical Memo #2). The deposition zone of the debris flow gully (the lower cone/fan-shaped area) *should* also be designated as a *Severe* hazard.

Tetra Tech has mapped the slope in the vicinity of 415 East Street and 622 4th Street as being within a *High* landslide hazard designation zone. However, given the findings of an apparent debris flow feature at that location, the judgement of whether to upgrade the landslide hazard designation to *Severe* should be made after a site-specific investigation in that area. It does appear possible that the debris flow might be related to a cutline upslope (apparently a former powerline alignment), and the problem might be solved by remediating the surface water drainage at the cutline. However, if the feature is not related to water drainage problems originating at the cutline, this area should be mapped as *Severe*.

Based on Tetra Tech's mapping of surficial geology, slope movement activity, gully erosion features, and field observations, as well as some recent landslide events documented in the past 10 to 12 years, it appears that much of the *Moderate* hazard terrain in this area should be reclassified to *High* or *Severe* hazard, as was done in the 2021 hazard designation mapping. *Furthermore, arbitrary hazard boundaries along property lines should be removed as not reflecting the true threat to the public safety, i.e., hazard designations based on property lines do **not** adequately describe the hazards.*

Severe hazard designations are assigned to the areas subject to rockfall, debris slides, and debris flows, as shown on the surficial geology map in Figure 3A. Areas with a *High* hazard rating were assigned based on the results of the semi-quantitative analysis. These areas are expected to experience rockfall that damages but does not always knock out trees, and as such are a less severe hazard than a debris flow or debris slide that removes everything in its path. Evidence of this type of rockfall activity was identified during the field investigation.

2.2 Requests for Additional Information for Starr Hill Subdivision

Numerous comments and questions were received from residents about the Starr Hill mapping area. These comments and questions have been excerpted and documented below in a question-and-answer format. In cases where questions were similar or related, these have been combined for the response. Tetra Tech has also incorporated and greatly appreciates several anecdotal observations and photos from Starr Hill residents that provide additional context for the slopes around the subdivision.

1. **Question/Comment:** I've seen the rockfall above Basin Road, and I can see why that slope is in a *Severe* hazard zone, but what about the slope above 6th Street? Why is that *Severe*?

   Answer: Let's start with the work done by Swanston (1972) to understand why that is. Along the south side of Mt. Maria, Swanston (1972) identified rockfall/rockslide hazards primarily at the prehistoric rockslide and at the corner of 6th and Nelson Streets where a talus deposit was observed (blue arrows in Figure 5). Swanston also reported small deposits of angular rock fragments and talus above 6th Street from Basin Road to Nelson Street, which apparently correspond to the rockfall/rockslide hazard mapped above 6th Street (red arrows point to the hazard in Figure 5). These observations were confirmed by Tetra Tech's fieldwork, during which numerous unstable rock cliffs and bluffs were also observed above 6th Street (Figures 6 and 7). Swanston (1972) further noted that, although the bedrock dips into Last Chance Basin (on the north side of Mt. Maria), freeze-thaw action in the fractures and joints of the exposed bedrock, and water acting as a lubricant in the cracks, result in instabilities. The elevated level of slope movement activity on this slope, including several well-established slide paths below prominent bedrock bluffs and cliffs, requires the slopes below the cliffs to be designated as *Severe* hazard. These are the kinds of processes that have been ongoing since long before Swanston's observations and are expected to continue.

The prehistoric slide area (Figure 5, blue arrow on left side) appears to be in the same place where a rockfall/ rockslide was reported on October 18, 1913 (Swanston 1972, Figure 6), and where a distinct landslide scar is still present despite reforestation of the slope (Figure 13). Swanston reported that several houses had been destroyed, and that a deposit of angular rock fragments had been created above Basin Road between 6th and 7th Streets.

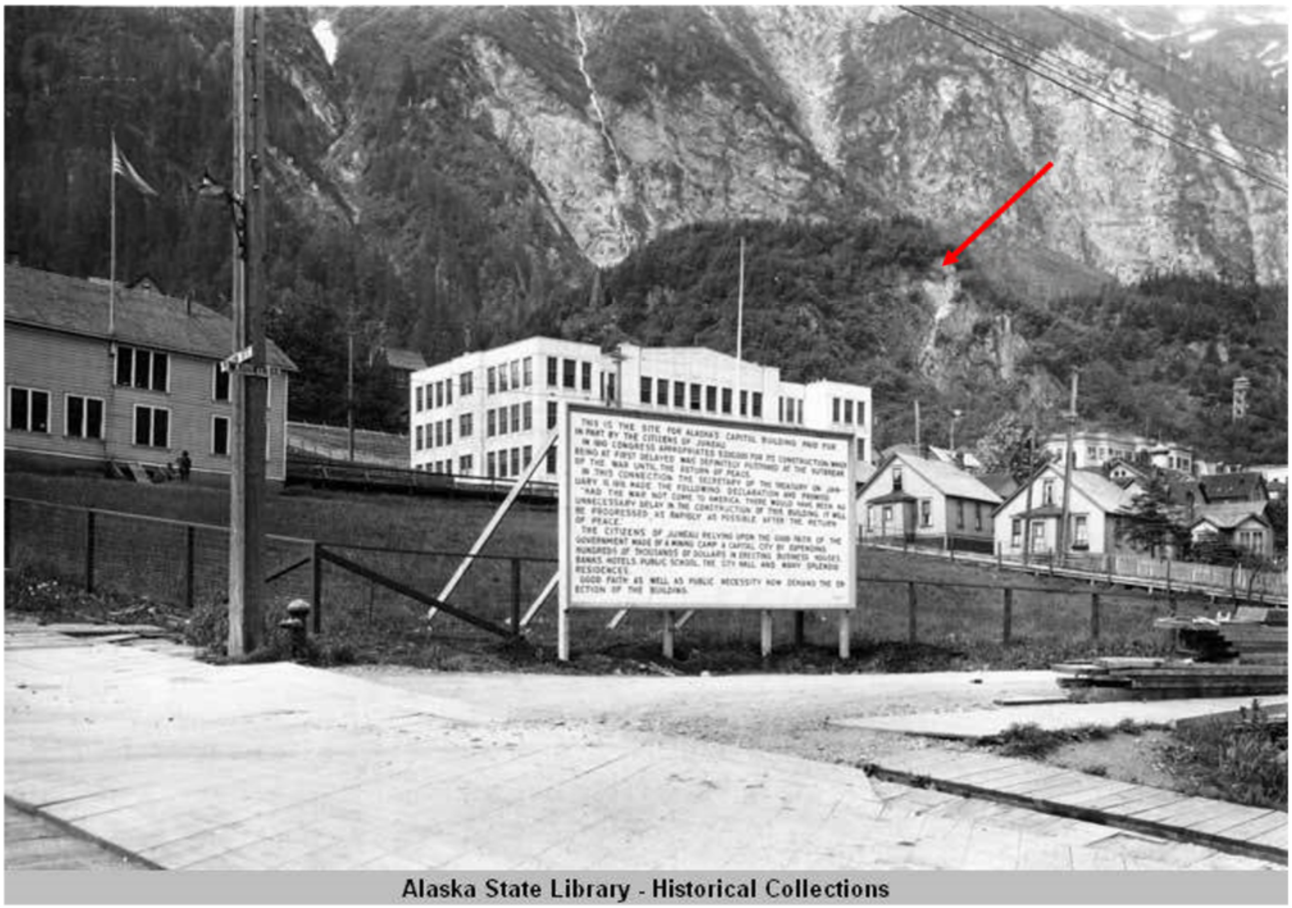

Figure 6: Looking north towards the Juneau Public School. Rockfall/rockslide scar on Decker Hill/Mt. Maria in the background was the likely origin of the October 18, 1913 landslide event (red arrow). The rock slope immediately to the right of the red arrow appeared more active (less reforestation) than the slope to the left in 1918, and some of the debris might also have originated from there. See Figure 13 for present-day view of Mt. Maria. (Photo credit: Alaska State Library – Historical Collections, ASL-Juneau-Capitol-Building-1, Alaska State Library Place File. Photographs. ASL, ca. 1918.)

A news story about the 1913 event reported two large rocks, each several tons in weight, falling from the cliff on the side of Decker Hill facing town and above Basin Road (Figure 6). One of these rocks impacted a huge boulder below, which had lain there for many years and, although the falling rock lifted the existing boulder up on edge, it was prevented from travelling further downslope. That existing boulder was reported to be located at the edge of the road, opposite the Nelson home, protecting it. The other large rock that fell was deflected and crossed the road to crush a woodshed below Basin Road, at the Price home. The power poles along Basin Road were also snapped, resulting in a short circuit (The Alaska Daily Empire October 20, 1913). The Nelson home is likely Structure C-8 Nelson House II, located downslope of Basin Road at the northeast corner of Harris Street and 6th Street, as shown by the purple arrow on Figure 12 (CBJ 1986). The Price home was not listed in the inventory, so its exact location is not known.

To summarize the results of Tetra Tech's mapping and fieldwork upslope of 6th Street and Nelson Street and continuing along Basin Road on the slopes of Mt. Maria/Decker Hill, there are unstable bedrock bluffs that are considered a *Severe* hazard due to observed features and potential rockfall activity that comes close to or into residential areas (Figures 7 and 8). There is also a talus deposit at the corner of 6th and Nelson Streets (Figure 8D). Exposed talus means that there is still rockfall coming down from above. If the rockfall activity had ceased, there would be much more regrowth of vegetation than is apparent now, nearly 50 years after Swanston first described the talus deposit. Above the houses in the rockfall area, trees show damage from being hit by large angular boulders, many of which are so large they could easily injure or kill a person who happened to be in their paths (Figure 7). Along the houses on 6th Street, the *Severe* zone affects the backyard, but might or might not affect the house. Figure 8 shows examples of rock bluffs, slide tracks, and talus. The housing itself obscures the effects of the rockfall activity – if a boulder rolls into a yard or onto the road, it is typically removed, so the evidence is no longer available for mapping. The boundary of the *Severe* hazard area for Mt. Maria is thus very conservative and may well extend further southeast than that shown.

See also Question #3 below for more information on what the rockfall/rockslide paths look like on this slope.

Figure 7: Photos from Tetra Tech's main report, at the southwest end of Mt. Maria above Basin Road at Harris and 7th Street. Photo P24 (Figure 7A) shows a tree damaged by rockfall. Photo P25 (Figure 7B) shows the typical size of some of the fallen rocks.

Figure 8: Rockslide track and cliff above rockfall at left-hand blue arrow on Figure 5 (Figure 8A); typical rock bluff above 6th Street at red arrows on Figure 5 (Figure 8B); rock cliff with detached blocks above corner of 6th Street and Nelson Street at right-hand blue arrow on Figure 5 (Figure 8C); and talus deposit below rock cliff, 6th Street visible below (Figure 8D).

2. **Question/Comment:** Could you please explain the slope hazards above Nelson Street? I've noticed several fallen trees and continued evidence of mudslides in this area.

   Answer: Upslope of Nelson Street, there are debris slides and rockfall (Figures 12 and 15). Due to additional information about landslides above Nelson Street and around the corner above 5th Street that was received during the public review process, the hazard in this area is now mapped as *Severe* (Figure 3B). Figure 9 shows some examples of active debris slide paths and rock bluffs above Nelson Street. See Question #3 for information on the effects of historical forestry activities on this slope and to see where the most prominent landslide paths are located. See Questions #5 and #6 for information on the slopes above the corner of Nelson and 5th Streets. See Question #12 for information on the possible effects of the old Mt. Roberts Trailhead.

Figure 9: Active debris slide paths above Nelson Street are shown in Figures 9A and 9B; rock bluffs and broken or damaged trees above Nelson Street are shown in Figures 9C and 9D.

3. **Question/Comment:** Starr Hill/Mt. Maria were clearcut early on, and the area is gradually becoming reforested. These historical conditions would have exaggerated the landslide risks and frequencies during that time, while reforested conditions should reduce the risks, even with climate change-driven precipitation events. There was no discussion about that in the report.

   Answer: Residents provided two historical photos from 1901 and 1940 with perspectives close enough to the slopes for good comparisons to be made with more recent imagery. Tetra Tech has added another photo from 1902 showing Mt. Maria, two recent Google Earth oblique views to compare how the slopes appear now, and the 2013 LiDAR that clearly shows the bedrock outcrops on Mt. Maria.

   It is important to recognize that the slopes around Starr Hill were not uniformly treed prior to clearcutting (Figures 10 through 14). Tetra Tech agrees that increased interception from reforestation would help to reduce the infiltration of surface water onto slopes that are sensitive to the input of additional water, particularly slopes with thin colluvium over bedrock. Equally important is the reduction of water that would otherwise flow from the reforested slopes – as surface water drainage or subsurface water drainage – into the swales and gullies that are (and always were) sparsely treed or lacking tree cover altogether. Reforestation would be expected to have some benefit to slope stability.

   The evaluation of climate change effects was not in the project scope, so the effects of climate change on precipitation in Juneau are not known in any detail. If (as suspected) the likelihood of extreme precipitation and/or wind events is increasing due to climate change, reforestation is likely not enough to reduce slope instability hazards, especially on slopes with shallow bedrock. Comparing Tetra Tech's observations from 2019 to the observations from residents in 2021, landslide activity above Starr Hill is clearly ongoing.

Figure 10: Looking east-northeast toward Starr Hill from top of Chicken Ridge, 7th and Franklin Streets, July 1901. Slopes appear to have been recently clearcut (within the previous few years) with numerous stumps visible. There are some swales and slope sections with few or no stumps, indicating that this slope was not uniformly forested prior to clearcutting (red arrows). At least two recent soil debris slides are visible above what appears to have been Park Street in 1901. (Photo credit: Alaska State Library – Historical Collections, ASL-P1-506, Vincent Soboleff Photograph Collection, ca. July 1901.)

Landmarks shown in Figure 10 include the Distin-Dawes-Pelto House at 529 East Street (blue arrow), St. Ann's Hospital staff residence (green arrow) at the south corner of 6th and Harris Streets, apparent precursors to the Lund Houses I and II at 504 and 510 Kennedy Street (yellow arrow), and the Mitchell House at 715 – 6th Street (aqua arrow), based on the Inventory of Historic Sites and Structures (1986) and various historical photos from the Alaska State Library. Some of the dates and descriptions are uncertain in the inventory, and it is possible that changes or additions have been made to some of the structures that still exist. As well, some of the structures present in this photo no longer exist, or were replaced with other structures. Park Street appears to have been the approximate upper end of the developed area in 1901, since the earliest houses above Nelson Street were built in 1928.

Figure 11: Looking east-northeast, this view of Starr Hill in 1940 is from a little further southwest of the view in Figure 10, and somewhat foreshortened. After more than 40 years of tree growth after clearcutting, the swales and gullies where no coniferous trees grow are especially clear in this photo. Selected swales and gullies are shown with red arrows; several other swales and gullies are also visible between the red arrows. (Photo credit unknown.)

Landmarks shown in Figure 11 include the Distin-Dawes-Pelto House at 529 East Street (partly obscured, blue arrow); St. Ann's Hospital (green arrow) at the south corner of 6th and Harris Streets, with the newer concrete section northeast of the green arrow (replacing the former staff residence), and the older wooden section to the southwest; the Lund Houses I and II at 504 and 510 Kennedy Street (yellow arrow); and the Mitchell House at 715 – 6th Street (aqua arrow), based on the Inventory of Historic Sites and Structures (1986) and various historical photos from the Alaska State Library. Some of the dates and descriptions of structures are uncertain in the inventory, and it is possible that changes or additions have been made to some of the structures that still exist. As well, some of the structures present in this photo may no longer exist, or were replaced with other structures. Nelson Street was the upper end of the developed area in 1940, with most of the houses above Nelson Street built by then.

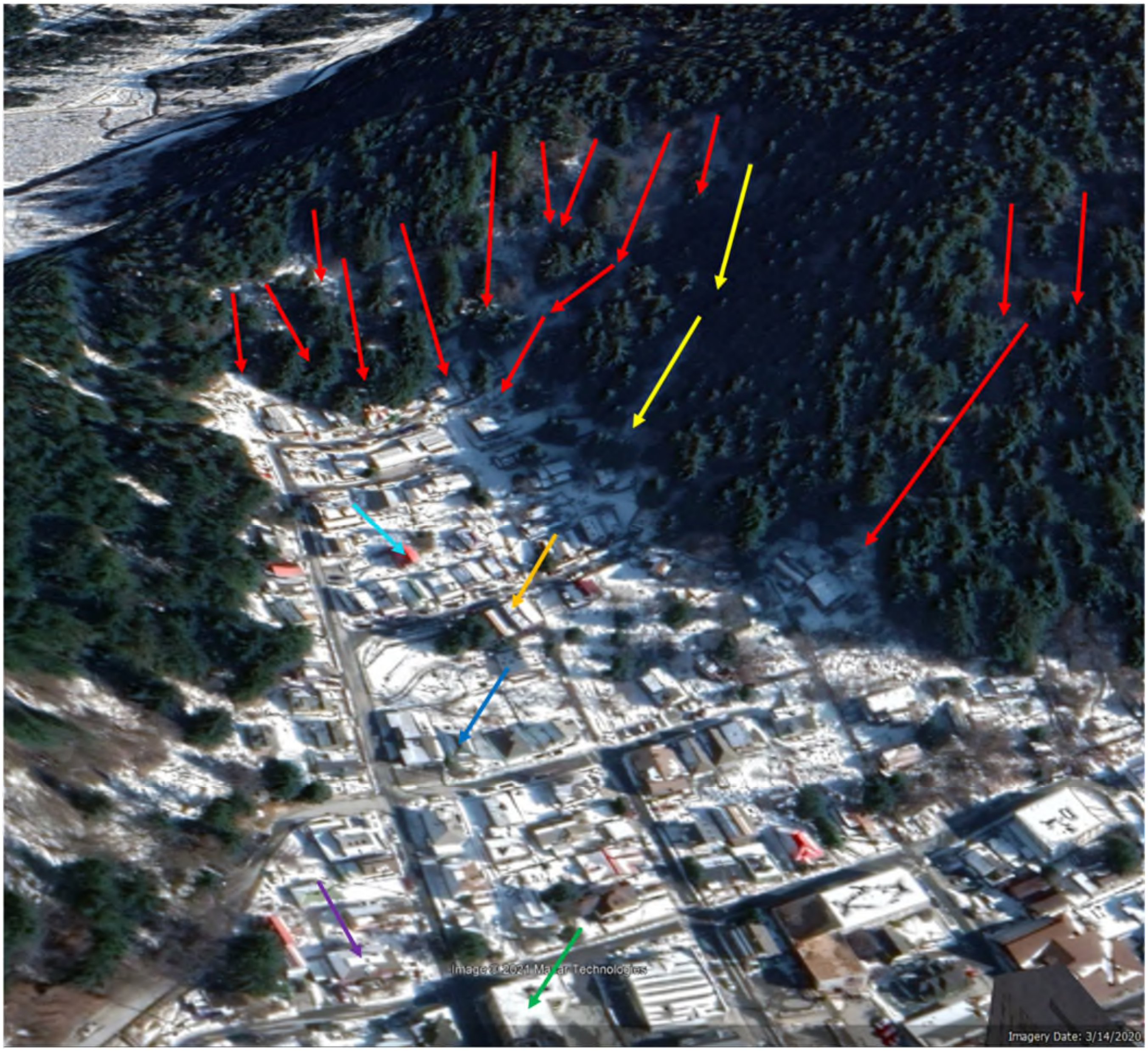

Figure 12: Looking east-northeast, this Google Earth view is from an eye elevation of about 1,100 feet and at a snowy time of year (March 2020), so that the areas without coniferous trees can be seen more easily. The same swales and gullies that lack tree cover that were seen in the 1940 photo (Figure 11) are still visible in 2020, along with a few more. The landmarks are the same as in Figure 11, although St. Ann's Hospital is now called St. Ann's Center, and a new landmark at Nelson House II has been added below Basin Road (purple arrow). (Image credit: Google Earth 2022.)

In Figure 12, one of the main gullies (shown with two bright yellow arrows, ending between Park and Kennedy Streets) is the G000 Park debris flow gully. See Figure 15 for more information about this gully.

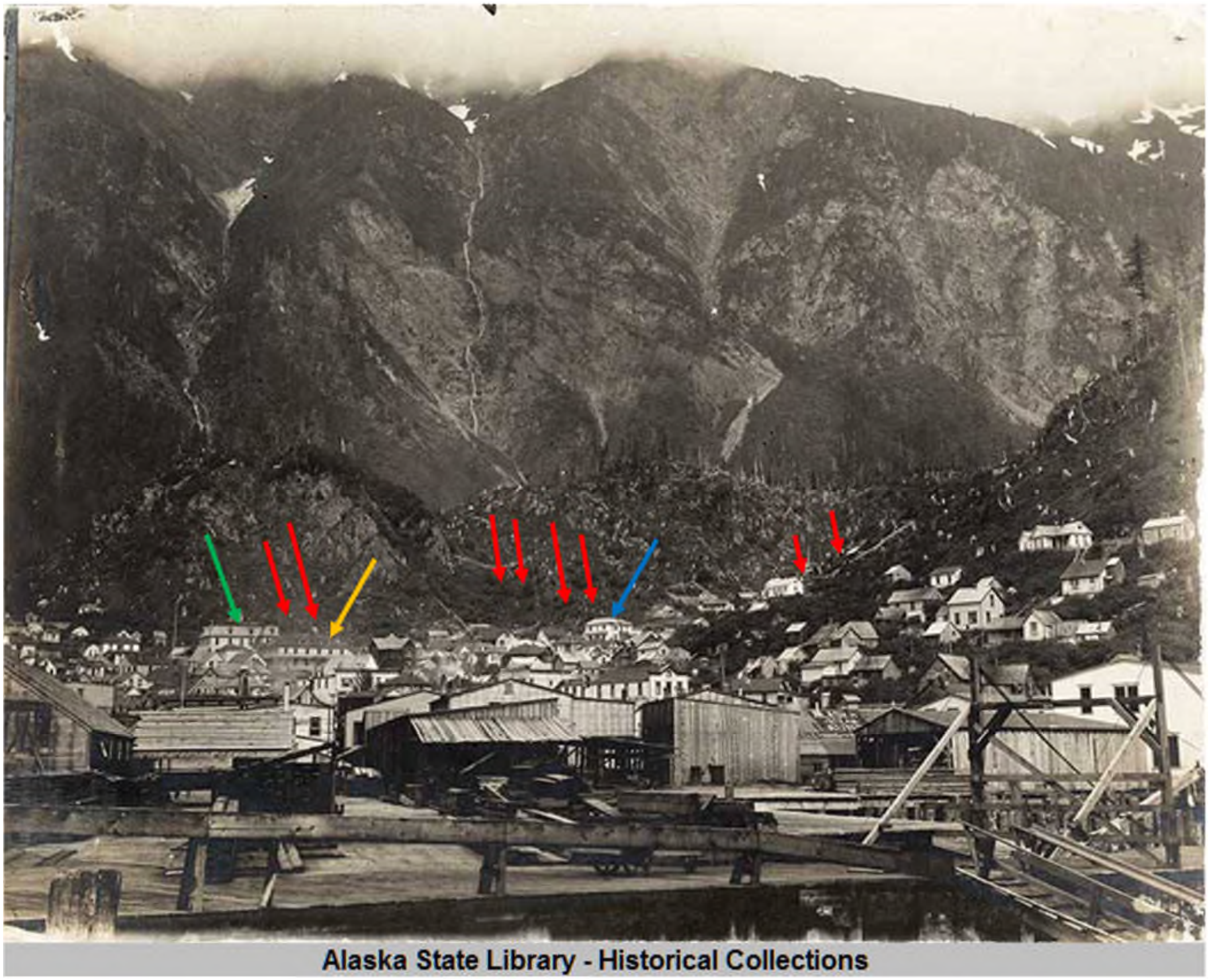

Figure 13: Looking north toward Starr Hill from the waterfront. Mt. Juneau is in the background. Slopes appear to have been recently clear-cut with numerous stumps visible above the buildings. The exposed rock slope on the west end of Mt. Maria (Decker Hill) is the location of the pre-historic rockslide, where in 1913 another major rockfall event would occur. (Photo credit: Alaska State Library – Historical Collections, ASL-P334-16, Ark A. Tower Photograph Collection, June 8, 1902.)

The perspective of the 1902 photo (Figure 13) makes it more difficult than the 1901 photo (Figure 10) to see the slope details, and apparent logging debris remaining above the upper end of 6th Street also obscures the slope. However, there are some swales and slope sections with few or no stumps visible, indicating that the Mt. Maria slope was not uniformly forested prior to clearcutting (red arrows). Above 6th Street, areas lacking forest cover appear to be associated with the rock bluffs visible upslope. Landmarks include 529 East Street at the blue arrow, St. Ann's Hospital staff residence (green arrow). Just to the southeast along 5th Street (in the foreground of the staff residence) were the Church of the Nativity, the chancellery, and St. Ann's Hospital (later the school, and now the Parish Hall, orange arrow), based on the Inventory of Historic Sites and Structures (1986) and various historical photos from the Alaska State Library.

Figure 14: Looking north-northwest, this Google Earth view is from an eye elevation of about 1,100 feet in early spring (April 2020), so that the slopes currently lacking coniferous trees can be seen more easily. Several of the swales and slope sections lacking tree cover that were seen in the 1902 photo (Figure 13) are still visible in 2020, along with a few more slide paths (red arrows). The apparent alignment of the paths lacking trees is slightly different in Figures 13 and 14, due to the different perspectives of the images. The landmarks in Figure 14 are the same as those in Figure 12. (Image credit: Google Earth 2022.)

At the top ends of all the paths are rock bluffs or cliffs (Figure 14), which are the source of the rockfalls and rockslides that periodically scour out lower-growing vegetation along the paths, or damage mature trees alongside the paths if the debris is large enough. A couple of the paths seen in 1902 between Kennedy and Park Streets are obscured by trees in 2020 but are likely still present under the tree canopy. Some of the swales that seem to end mid-slope in this image likely continue further downslope under the tree canopy. In some areas of the slope, there are still some trees below rock bluffs, but they tend to be smaller than the trees on slopes not regularly affected by rockfall or rockslide debris (Figure 7). On the far left, the path shown crossing Basin Road represents the rock debris that impacted 712 Basin Road about 12 years ago (CBJ 2020).

Three cutlines are visible in Figure 14: on the left, the powerline above Basin Road; in the middle, where an old cutline crosses over to the north side of Mt. Maria; and, on the right, parallel to 6th Street, another old cutline crosses above the corner of 6th and Nelson Streets into Last Chance Basin. The latter two cutlines may be related to old mining infrastructure, and/or powerlines.

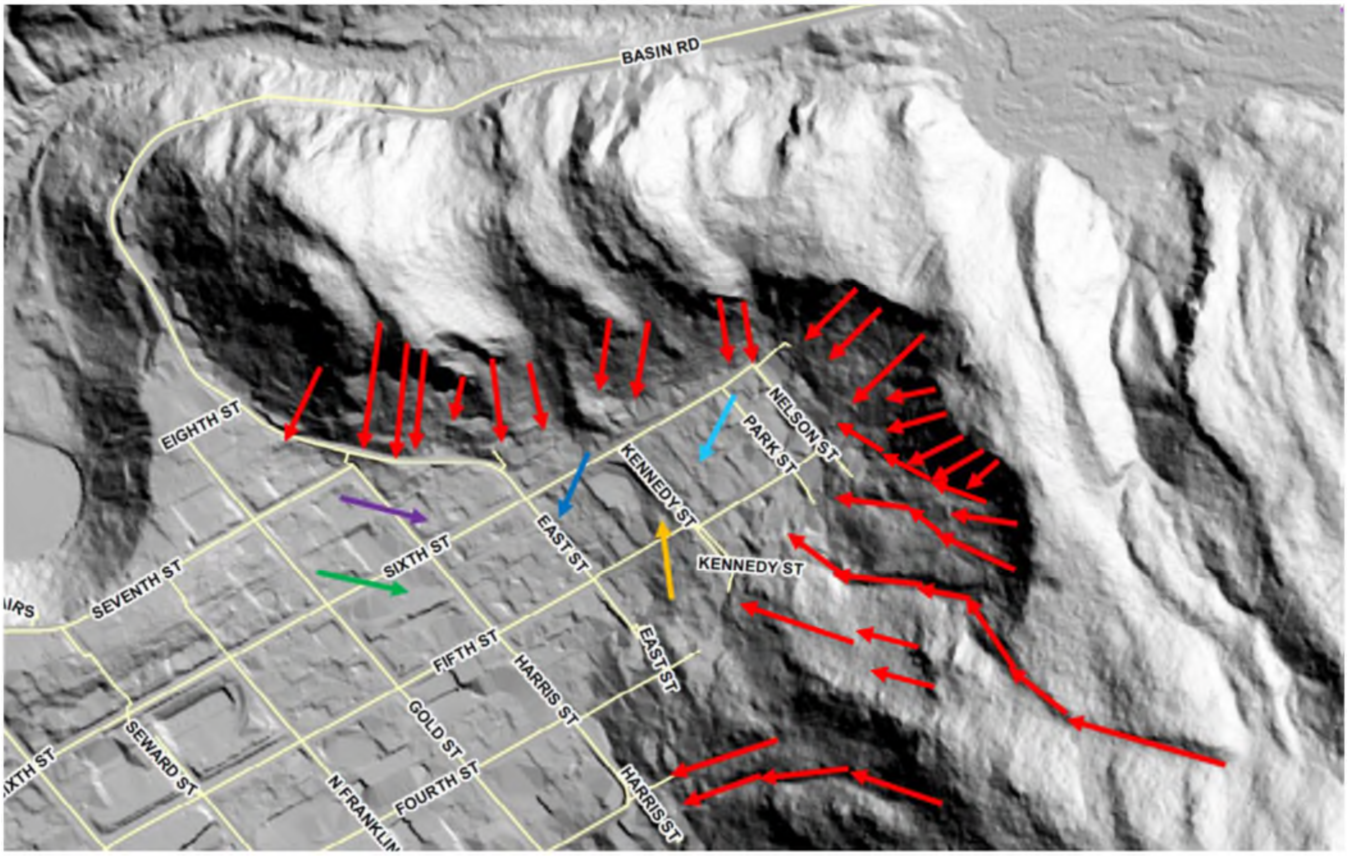

Figure 15: This excerpt from the 2013 LiDAR image shows several bedrock cliffs and bluffs above Basin Road, 6th Street, Nelson Street, and the north end of 5th Street. Fieldwork identified numerous active rockfalls/rockslides as well as some debris slide areas that confirm the observations from the LiDAR and the air photo mapping (Figures 6, 7, and 8). Apparent landslide locations shown are based on poorly-vegetated slopes, swales and gullies seen on Google Earth that are also visible on LiDAR hillshade models (red arrows). Landmarks are as for Figure 14. (Image credit: CBJ 2013.)

The longest red arrow in Figure 15 shows the location of the debris flow gully within the G000 Park avalanche path. This gully appears to receive water and debris not only from the local slopes immediately above 5th Street, but also from surface drainage swale or gully that originates further upslope along the Mt. Roberts crest.

4. **Question/Comment:** We agree that there is landslide activity in the [G000] Park gully, but properties have largely been protected by maintenance and instream mitigation structures and drains. The structures were installed by homeowners… with materials that were supplied by the City and Borough of Juneau. Some of these structures need to be repaired or replaced in order to continue proper drainage of this creek through the city-installed culvert that runs under the 725 5th Street home.

   The area designated as *Severe* (red) has resulted in two debris flow events in the last 35 years… A debris flow incident occurred in the late 1980s, as a result of the drain above 725 5th Street becoming plugged because the home was vacant and there was no one to monitor/maintain the drain. In 2019, the gully creek undercut a bank, causing a flowerpot to fall and temporarily block the flow.

   Answer: The review of the slopes in Question #3 provides some useful background in the overall slope processes that are happening in this area of Starr Hill. Specifically, between Park Street and Kennedy Street, there is a debris flow gully that was not identified in any of the previous studies, except possibly as the “slump” reported in Swanston (1972), as discussed in Section 2.1.2.

Although the residents have reported only two debris flow events in the past 35 years, this does not mean that the hazard is not significant. Based on the field observations, this debris flow gully has a high potential to affect downslope residences. Clearly, residents were concerned enough about the debris flow hazard to build structures to control debris flows, but these structures are not by any means engineered structures (Figure 16). Routing a debris-flow creek under a house also seems fraught, considering that the drain upslope has become plugged in the past, and that the slightest misstep upslope can create further havoc. (Case in point, the creek undercutting the stream bank and a fallen flowerpot blocking the flow in 2019.) Furthermore, as shown in Figure 15, it appears that this debris flow gully could potentially receive significantly more debris and water than just from the local slopes. As it stands, due to these multiple sources of hazard, Tetra Tech considers that this debris flow gully has been correctly designated as *Severe*.

Figure 16: Photos from the fieldwork in September 2019 showing one of the existing debris-flow mitigation structures that were built by homeowners living below the G000 Park debris flow path above Starr Hill. This structure has captured debris material from one or more mass-wasting events and measured about 8 feet wide by 7 feet long by 2 feet deep.

Depending on the size of the next debris flow, the structure shown in Figure 16 could retain a little more debris or, instead, it could collapse, be overrun by debris, or even be completely scoured out by a larger debris flow that could originate from further up the gully. The same applies to the other structures documented by residents. Debris can incorporate both large and small woody debris, as seen in these photos and the photos supplied by residents of the mid and upper reaches of the gully. The upslope portion of this debris flow feature is bowl-shaped, indicating the potential for small debris slides from the side slopes to fail and entrain debris in the gully, of which there is a significant amount. The particle size of the material that can be moved by a debris flow is also important – some cobble- and boulder-sized material is also visible in the residents' photos. Despite the mitigation attempts, debris slides/flows could result in enough volume to impact the houses below.

5. **Question/Comment:** We question the high risk [orange] designation adjacent to the gully, as the topography is relatively dry, stable, and does not seem to foster conditions for any landslide, debris flow, or erosion.

   Answer: The answer to this question can be applied to both areas mapped as *High* hazard terrain (orange) beside the G000 Park gully: the open slopes located to the southwest and northeast of the debris flow gully. The bowl-shaped terrain located upslope of the corner of Nelson and 5th Streets is now mapped as *Severe*, so this discussion no longer applies to that terrain (see Question #2). The surficial geology is the same in both areas. The review of the slopes in Question #3 provides some useful background in the slope processes that are happening in this area of Starr Hill. Figure 15 shows clearly the very rough and disturbed terrain that has resulted from highly active slope processes, particularly on the northeast side of the G000 Park gully. Figures 10, 11, and 12 show the paths along which the most frequent landslides (debris slides/flows) tend to occur northeast of the gully, and Figure 12 also shows the paths southwest of the gully.

   On the right-hand side of Figure 12, for the area southwest of the G000 Park gully, there are two red arrows high on the slope and a longer red arrow on the lower slope. The two upper red arrows on Figure 12 show the main areas of slope instability activity higher on the slope and, as seen on Figure 15, this instability is related to the rock bluffs/cliffs upslope, resulting in rockfall/rockslides. The geology mapping shows that debris slides can occur in this terrain too. The lower longer arrow indicates a transition zone where most of the rockslide or debris slide material continues downslope. Due to the open-slope environment, this slope is not as hazardous as the debris flow gullies on either side. However, the prominent toe of slope at the edge of the residential area clearly shows the edge of this terrain unit, and the considerable proportion of ground with sparse or no tree cover upslope is indicative of ongoing slope instabilities. This is why this slope section has a *High* hazard designation.

Figure 17: Compare Tetra Tech's photo from September 10, 2019 (Figure 17A) with residents' photo from August 1, 2021 (Figure 17B) at the same location. Slope instabilities appear to be ongoing in the historical slide path locations.

Note that local material volumes incorporated in debris slides can often be relatively small, but they are cumulative, and just as for debris flows, debris slides can include large and small woody debris. Eventually, there will be enough new or built-up debris combined with enough precipitation to bring the debris downslope to an elevation where it can cause damage. One recent example is the landslide that occurred on these slopes in November 2020 that was reported by a nearby resident in the online comments of the July 21, 2021, Neighborhood Meeting.

The primary distinction in hazards between slopes with debris slides and slopes with debris flow gullies is the mobility of the debris material. Debris flows are generally much more mobile than debris slides, and would be expected to run out further downslope, potentially affecting a much larger area, and thus warranting a *Severe* rating. However, every report from residents about landslides that have impacted their properties is important and will be taken into account when finalizing the landslide hazard designations in the Issued-for-Use report.

6. **Question/Comment:** The boundaries between the *Low*, *Moderate*, *High*, and *Severe* landslide hazard zones do not seem to match the land.

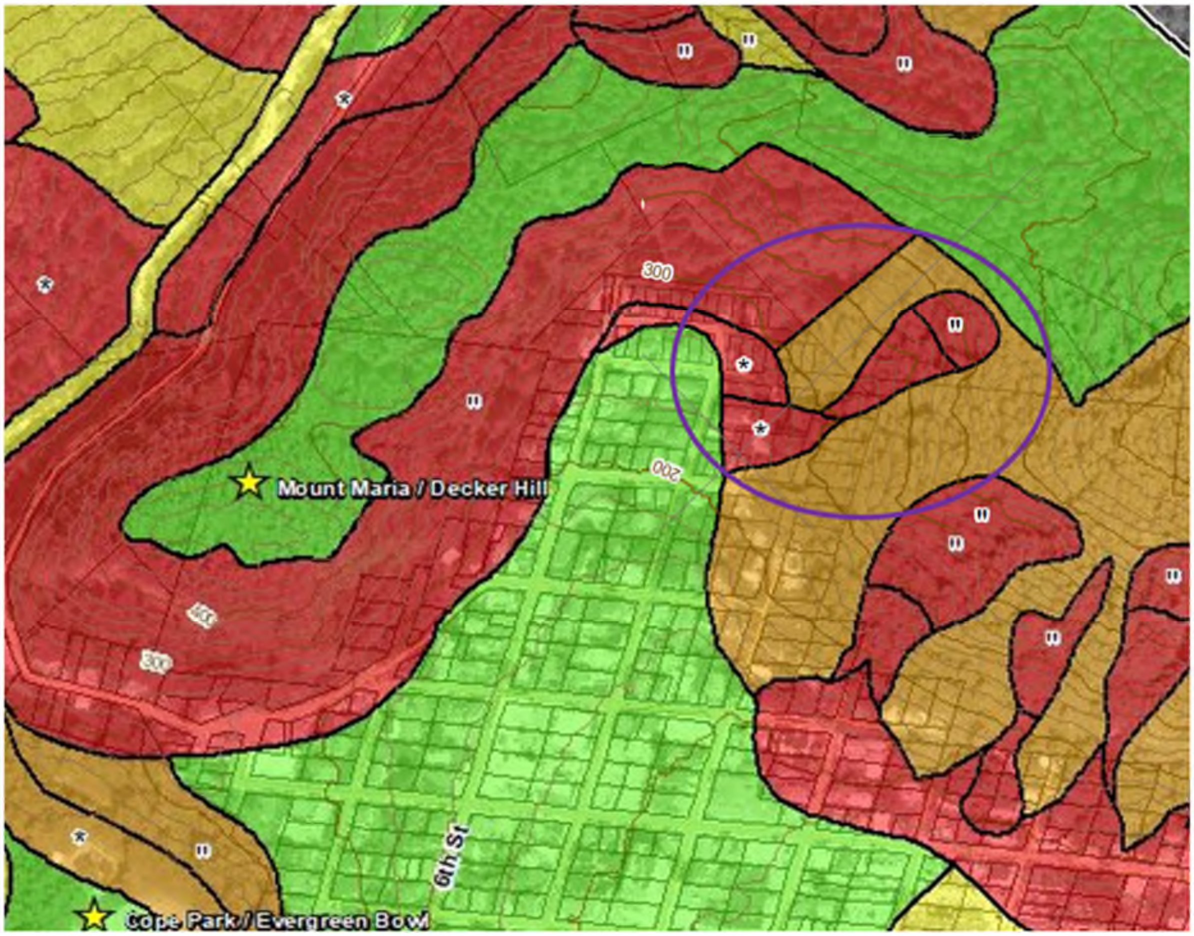

Figure 18: Excerpt from the landslide hazard designation mapping. The purple outline shows an area where residents requested more information to understand the shapes of the mapping units and the reasons supporting the hazard designations.

Answer: The boundaries between the different landslide hazard designation zones are closely related to the surficial geology mapping terrain unit boundaries (Figure 3A). The reason for this relationship is that the different soil and rock features have a large influence on how the slopes behave. For shapes that do not seem to make sense, it is helpful to look at the features beside that odd shape. Usually, it will be a terrain feature whose characteristics will govern the shape of the boundary between the two units, like a bedrock outcrop, or a terrain unit that overlaps a previous unit. Sometimes, the odd-looking boundary is only because there is a corner or curve in the slope, so that debris from one side falls down in one direction, and material from the other side falls down in a different direction. These two debris areas might then meet at the bottom of the slope, like the southeast corner of Starr Hill, where debris can fall or slide from above Nelson Street, and it can also fall or slide or flow from above 5th Street. Since this part of the subdivision is essentially the shape of a bowl, the mapping of the unit boundaries can also reflect slope contours and fall-lines, as well as the surficial geology unit boundaries. See also Technical Memo #2, Question #3, for more explanation on how apparently odd-shaped boundaries are determined.

Specific to this area of Starr Hill, it is now known that a resident has identified a recent landslide event in a *High* hazard zone (see Question #6 above), which also happened to be within one of the apparently odd-shaped hazard units (Figure 18, purple outline). This area has now been updated, resulted in a shifting of the hazard boundary above the corner of Nelson Street and 5th Street. Note that the *Severe* hazard zone mapped at the toe of slope is due to this area being a deposition zone for slide debris.

If other property owners have experienced landslide events – rockfalls, rockslides, debris slides, debris flows, and so on – at their properties, not just in Starr Hill, but anywhere in the downtown Juneau study area, this is the time to report those landslides, to help finetune the mapping. When reporting landslides, please report if there was damage and, if so, what was damaged and to what extent, for example, structures or landscaping. If quantities of debris removed or cleaned up are known, please report approximate quantities also.

7. **Question/Comment:** The maps raise significant questions as to how areas were given certain designations. Houses that have had tree slides damaging the structure have been included in lower hazard zones than those below with no tree slide history. How are some areas adjacent to severe hazard zones rated as low hazard zones without a transition area? What site specific analysis was done in each area, such as Starr Hill?

   Answer: As noted above in the answers to Questions #3, #4, and #6, information about landslide events is important to improve the accuracy of the mapping, especially where these events may not be visible on the air photos or the LiDAR, or events that are not part of the historical record. Where such information has been provided, it is used to confirm or update the mapping, as applicable.

   Landslide hazards are generally not downgraded in a downslope direction. If there is a history of slide activity, or if it is a runout zone (i.e., a deposition zone), an area is considered to pose a severe hazard. Note that not all landslide events begin at the top of the mapped feature, nor do they necessarily extend to the bottom of the feature, which can be seen clearly in the historical air photo record and LiDAR data analysis, in both the slope movement features (Figures 1.4a to 1.4c) and the gully erosion features (Figures 1.5a to 1.5c). See also Technical Memo #2, Question #2.

   For general information on how the landslide designations are determined, Technical Memo #2 provides a good summary. In general, the landslide hazard mapping shapes follow the shapes of the types of ground that they represent, and this is true for Starr Hill also. Using the air photos and other imagery, Tetra Tech targeted the areas that specifically needed to be visited in the field. A foot traverse was done around the slopes of the Starr Hill subdivision to confirm, correct, or add to the information collected from the imagery. A greater concentration of field observations were made on slopes above residential areas.

8. **Question/Comment:** How are severe hazard zones with a 300 foot run from the ridge above a residence compare to those with 3,000 foot runs? Are these actually comparable situations?

   Answer: When comparing debris slides, the length of the mountain slope does not necessarily determine the length of the debris slide. For example, comparing the sizes of debris slides mapped above Nelson and 5th Streets to the sizes of debris slides further southeast on the main slope of Mt. Roberts, most of them are very similar. Where the debris slides do tend to be larger (or longer) on the larger slopes, they are usually associated with gullies that have steeper sideslopes, or with large open avalanche slopes (more typically on Mt. Juneau, but also south of Snowslide Creek), and usually on high-elevation terrain – see Figures 1.4a, 1.4b, and 1.4c in Tetra Tech's report. This can be important where high-elevation debris slides end up in long gullies where debris flows are active, and the size of the initiation zones reflect that.

   When comparing gullies, long gullies do not always mean that a debris flow event will extend along the entire length of the gully every time it flows – notice all the shorter arrows of different colours on Figures 1.5a, 1.5b, and 1.5c in Tetra Tech's report. However, there are some major gullies which do experience debris flows, at least some of the time over a significant proportion, if not all, of the gully length. The degree of the hazard is shown not only by the hazard designation – always *Severe* for debris flows, but also by the size of the cone/fan that receives debris from the gully – the runout or deposition zone. For example, compare the size of the cone/fan at Bathe Creek to the size of the cone/fan below 3rd and Harris Streets, or between Kennedy and Park Streets above 5th Street. The size of the receiving area for debris at the toe of slope correlates roughly to the upslope terrain providing debris to the gullies, within or along the gullies.

In general, an area is given a hazard designation of *Severe* if:

- A cone or fan of colluvium is present at the base of a slope, no matter how old it is, because the hazard still exists (Howes and Kenk 1997); and/or
- Evidence of slope instability (exhibited on air photos as a lack of vegetation in a formerly vegetated area with an obvious downslope movement component; incident reports; and/or field observations) is identified within the same feature in more than one air photo/LiDAR year and/or field investigation year.

These criteria are met for numerous landslide features around the Starr Hill subdivision. Technical Memo #2 provides more information on how landslides are evaluated.

9. **Question/Comment:** I don't understand why my property is now in a *Low* hazard zone. My property never used to be in any zone at all, and now I don't know if my property is at risk for landslides. I would also like to know more about the geology and hazards that are present directly above my property.

   Answer: In the current adopted hazard mapping system, two hazard zone designations were specifically mapped: *Moderate* Hazard Zone (or Special Engineering Zone in some of the references) and *Severe* Hazard Zone (or *High* Hazard Zone in some of the references). Anything outside those two mapped zones was not specifically considered in the old mapping. Including the new hazard designation of *Low* for both avalanche and landslide hazards will make the mapping system consistent with numerous internationally accepted hazard mapping systems. In the case of avalanche hazards, everything not mapped as *Moderate* or *Severe* is considered *Low*. In the case of landslide hazards, everything not mapped as *Moderate*, *High*, or *Severe* is considered *Low*.

   This does not mean that the hazard has changed for properties that are now designated as being in a *Low* hazard zone. It just means that it has been given a name that recognizes that a hazard is never "zero," but the hazard is low enough that owners of properties within the *Low* hazard zone should not have to do anything extra to protect their properties from avalanches or landslides, except for being attentive, i.e., observing and recording anything unusual at or around their properties, such as ground settlement, cracking etc. See the definitions for Avalanche Hazard Designation and Landslide Hazard Designation in the glossary of the Tetra Tech report. Note that the estimated event probabilities for landslide hazard designations have been updated to a format similar to the return periods reported in the avalanche study. See also the discussions in Technical Memo #2, Question #1, and Technical Memo #4 (both in Appendix C of the main report; Tetra Tech 2022b, 2022d).

   The only caveat to this answer is that if there was a landslide (like a rockfall, rockslide, debris slide, or debris flow) that resulted in debris ending up at, beside, or very close to, your property; or a house upslope of your property was damaged due to a landslide and now that house is gone, the boundary between hazard zones might need to be adjusted. For debris that is cleaned up after a landslide happens, or for former houses that did not appear on any of the air photos, the mapping cannot always detect where landslides might have occurred. That means the mapping also needs to be supported by good historical records, including property owner reporting, if applicable and available.

10. **Question/Comment:** My house is over 90 (or 100) years old and still standing. How can I be in a *Severe* hazard zone? I don't recall anything happening to my house in the 25 (or 50) years I've lived here, and the neighbours don't remember anything either.

    Answer: See the bottom part of the answer to Question #6 above, about how an area is designated as being in a *Severe* hazard zone. Sometimes the hazard is not related to what is happening right around your house, but what is happening higher on the slope or around your neighbour's house. That is especially true for hazards related to debris flows, because where the debris will end up is not always predictable. See also Technical Memo #2, Question #8 for more information. Also, residents might not always know what happened to their lot or house before they moved there.

11. **Question/Comment:** I feel the historical timeline and perspective on how the mapped risk areas have changed is not given enough consideration. How can we get more information on how changing conditions, geology, and climate affect slope stability? Some of the changes are due to human-altered landscapes, like clearcut logging or rock cuts. Has the city reached out to geotechnical experts on rock type behavior, slope angles, vegetation, and historical and future angle of repose? Often those questions can only be answered by drilling and core analysis.

    Answer: Tetra Tech's project team of engineers and geoscientists provided expertise for this project. Tetra Tech's report provides a full description of the procedures used to evaluate the slopes, such as mapping of surficial geology and confirmation of surface materials during the fieldwork, including areas mapped as anthropogenic (human-modified) terrain. Information on changing vegetation (for example, as a result of landslides), slope angles, and surficial geology can all be obtained by means of desktop study terrain analysis (which included air photo and LiDAR data analysis), mapping, and confirmatory fieldwork. Rock types and characteristics were recorded by Tetra Tech's highly qualified and experienced engineering geologist/ geotechnical engineer where bedrock was exposed at ground surface. The evaluation of engineered rock cuts or other engineered slope mitigations like retaining walls was not in the project scope. Geotechnical drilling was also not in the project scope, nor was an evaluation of climate change. See Tetra Tech's report, as well as Technical Memos #1 and #2 for additional information on the methods of evaluation, as well as the limitations of the work. Question #1 above addresses clearcutting.

12. **Question/Comment:** Although the old Mt. Roberts trailhead at the top of 6th Street was supposedly abandoned years ago, it continues to receive regular, year-round (and likely daily) use by locals and visitors alike. This use by hikers and runners is likely destabilizing the hillside above the Nelson Street homes and worsening the landslide conditions, especially because the trail is no longer maintained, and hikers have made their own shortcuts. The current signage and availability of stair access does more to invite users than it does to discourage them. The CBJ should consider removing the stairs and placing signage that strongly discourages users by explaining that foot traffic is causing erosion, destabilizing the hillside, and threatening the homes below. Other strategies could include educational outreach to local hiking clubs and local guides, and updating local trail maps.

    Answer: Figures 9 and 17 show some typical slope sections above Nelson Street. Eliminating access to sensitive slopes that also pose a safety hazard to trail users is an important strategy used in many jurisdictions. Even after the stairs have been removed, physically blocking access with sections of fencing might also be necessary to deter ambitious hikers. Interpretive signage can also help, especially if there are other elements of value that would be preserved by deterring foot traffic.

    The trail should not be simply abandoned and ignored. Control of surface water drainage may be very important on the deactivated trail section, especially where there are switchbacks with no intermediate water management provisions along the trail. This is because trails (especially in-sloped ones) tend to concentrate surface water drainage over long sections of trail, until accumulated water from numerous small streams and swales all run downslope at the end of a switchback. Shortcutting is particularly common on trails with switchbacks and, in addition to erosion resulting from foot traffic, shortcuts can result in additional slope sections with concentrated surface water drainage. At best, concentrated water can result in soil erosion; at worst, it can result in slope failures. Therefore, when deactivating the trail, the original drainage paths across the trail should be restored. These same considerations apply to active trail sections – good control of surface water drainage will improve slope stability.

13. **Question/Comment:** The study (or at least the new regulations) should address how structures factor into landslide hazards. The new zones were drawn agnostic of human-made structures, like buildings, above us. But realistically the structures exist and will mitigate landslides. That means many, if not hundreds of homes not actually at risk of a landslide will be classified as if they were, which benefits no one.

    Answer: The premise of this comment is that upslope structures will always protect the structures downslope. However, this is not always true. Sometimes the upslope structures are simply incorporated into the debris, adding more mass to damage or destroy the downslope structures. A classic example of this kind of event is the January 2, 1920 landslide that occurred between Decker Way and Bulger Way, destroying 16 buildings from Gastineau Avenue to Front Street (now South Franklin Street). That landslide resulted in numerous buildings sliding downslope with the debris, overrunning other structures and destroying them too. See Question #14 and Technical Memos #5 and #7 (in Appendix C of the main report; Tetra Tech 2022e, 2022g)for more information about the landslide.

14. **Question/Comment:** Why are past landslides used as indicative, without accounting for the fact that some were on deforested slopes undergoing blasting and water discharge from mining?

    Answer: A detailed review of mining practices including blasting and water discharges was not within the project scope. However, terrain where the ground surface was drastically modified by human activities such as mining, cutting into slopes or placing fill, where visible on the air photos, was mapped as “anthropogenic” terrain. These modifications of geological material have been mapped along a significant length of the map area along the toe of Mt. Roberts, as seen in the cross-hatched areas shown on Figures 1.3b and 1.3c in the Tetra Tech report. The closest anthropogenic terrain to the Starr Hill subdivision is located southeast of 4th Street and northeast of Gold Street, just around the corner onto the main slope of Mt. Roberts, where a cone/fan-shaped area is the runout zone for debris from the upslope debris flow gully. Most of the modifications of this terrain appear to be related to residential development.

    It is understood that the Alaska Juneau Gold Mining Company (AJGMC) had its mill on the slope of Mt. Roberts near the southeast end of the historical downtown area. The AJGMC mill began operating in 1917, with the mine operating 24 hours per day and 363 days per year by 1930. The mine was closed in 1944.

    Drilling and blasting would have been part of the operations associated with the Alaska-Juneau mine, along with the Ebner and Perseverance workings, accessed from Last Chance Basin along Gold Creek or from the Sheep Creek Tunnel. There was also a tunnel upslope of the former office above Gastineau Avenue, with the first portal completed in 1913 near the north end of the tramway, and the second portal completed in 1916 about 500 feet further to the southeast, between the north portal and the AJGMC Mill. Blasting would not have taken place at the mill, although crushing of the ore might well have resulted in some vibrations during operations. The Starr Hill subdivision was about 0.5 miles and 0.7 miles west of the entrances of the Ebner and AJGMC adits, respectively, roughly 2.0 miles to 2.5 miles west of the top ends of all the adits at Silverbow Basin, 0.3 miles to 0.5 miles northwest of the AJGMC tunnel, and about 0.7 miles northwest of the AJGMC Mill, based on the 1914 topographic map of Juneau. No blasting-related or vibration-related slope instabilities were mentioned in any news reports so far reviewed for the landslides at Mt. Roberts specifically, nor for Juneau in general.

The AJGMC flume was reported to have overflowed at the time of the January 2, 1920 landslide. Since there was also melting snow and nearly 2 inches of heavy rain in 24 hours (Swanston 1972), the overflow of the flume might have contributed to that debris slide but was likely not the only cause. In a photo from the Gastineau Channel, at least two streams of concentrated water were running downslope, one within the landslide area and one to the north (Alaska State Library, Photo ASL-P87-1223).

Surficial geology mapping by Miller (1975) shows that another landslide occurred on October 1, 1952 at the same location as the 1920 landslide, again after nearly 2 inches of rain in 24 hours. Since the mine had closed eight years prior, water from the flume should not have been a factor in the 1952 landslide, and no mine-related complaints have been found thus far in relation to the 1952 slope failure. That landslide resulted in the closure of South Franklin Street by the old Columbia Lumber Co. kiln. The exact location of the kiln is not known, but it could have been either between Decker Way and Bulger Way, or in the vicinity of 475 South Franklin Street, and likely belonged to the new plywood plant of its subsidiary Columbia Plywood Co. Two structures were also destroyed in 1952, due to landslides at 261 Gastineau Avenue and 475 South Franklin Street, located further southeast along Mt. Roberts (Swanston 1972). Notably, a small house was built at 261 Gastineau Avenue sometime after 1920 – at the same location where two houses had been destroyed in the 1920 landslide. The 475 South Franklin Street landslide would have been located within, or very close to, the path of the major landslides that occurred on November 22, 1936.

In the November 22, 1936, landslide, a tension crack was noted at a slope failure below the flume, and this location also appears to have been the approximate initiation zone for that event, based on the appearance of the vegetation on the 1971 map of Juneau. Water from the flume was not directly implicated in that event, however. If there was a leak, it might or might not have been significant compared to the nearly 4 inches of rain that fell in 24 hours (Swanston 1972). In any case, the initiation zone for the overall debris flow feature is nearly at the top of the ridge, indicating that no leaky flume would be necessary to trigger another landslide. No reports so far reviewed have implicated flume leakage in any of the landslide areas on the slopes above Starr Hill.

Upslope of almost all this human-modified terrain, there are debris flow gullies, originating in natural terrain. Those natural debris flow gullies are the source of the material that runs out onto the cones/fans along the toe of slope. Even after the removal of all mining-related structures and activities, those upslope debris flow gullies remain as the most significant sources of landslide hazards on this slope.

3.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of City and Borough of Juneau and its agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than City and Borough of Juneau and its agents, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on Use of this Document attached or Contractual Terms and Conditions executed by both parties.

4.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
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