ALASKA HIGHWAY ACTIVE TRANSPORTATION UNDERPASS FEASIBILITY REVIEW

FINAL REPORT

January 31, 2024

URBAN SYSTEMS

CYCLING ASSOCIATION OF YUKON

Cougar Creek Underpass, City of Canmore *(Mountain View Today, 2022)*

PREPARED FOR:

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1.0 INTRODUCTION

The City of Whitehorse is the vibrant and rapidly growing capital city of the Yukon Territory. The City currently has a population of over 30,000 residents, and this is expected to increase to more than 40,000 residents over the next 20 years, which will add increasing pressures to the City's transportation system.

The City is committed to promoting active transportation such as walking and cycling as a healthy, safe, comfortable, and convenient transportation option for people of all ages and abilities and for all seasons. The City already has a well-established active transportation culture and relatively high levels of walking and, with approximately, with nearly 10% of all Whitehorse residents walking or cycling as their primary means of transportation to work or school based on the 2021 Census (including 6.8% who walk and 2.7% who cycle).

In 2018, the City developed a Bicycle Network Plan to establish a long-term vision for cycling, increase transportation choices in the city and ultimately increase the percentage of residents using a bicycle for transportation year-round. The Bicycle Network Plan identified future cycling routes with a focus on providing facilities that are comfortable for people of all ages and abilities.

The Bicycle Network Plan identifies a long-range bicycle network along with short-term priorities. The City has made progress building out its cycling network since the Bicycle Network Plan was developed, and has implemented a number of new and improved cycling facilities since the Plan was developed. However, there are still significant gaps in the bicycle network and many cycling facilities are not comfortable for people of all ages and abilities, resulting in safety concerns and challenges increasing bicycle use. Some of the most significant gaps in the bicycle network are at major barriers, such as highways and other major roadways, railways, and water courses. The Bicycle Network Plan identifies several potential active transportation crossings to address these barriers. Active transportation crossings are proposed at locations within the city that cross major roadways, including the Alaska Highway. Some of these crossings can potentially take advantage of topography to provide grade separation.

This study was initiated as a grass-roots, citizen-led initiative by the residents of Takhini North with support from the Hillcrest Community Association and the cycling community. The Cycling Association of Yukon (CAY) offered to provide institutional capacity to support this study by applying for federal funding from the National Active Transportation Fund and helping to administer the study. In 2022, the CAY applied for federal funding from the National Active Transportation Fund to conduct a feasibility study for two high-quality active transportation underpasses under the Alaska Highway, including one located at the north end of the Takhini North neighbourhood, and one at the north end of the airport.

1.1 STUDY PURPOSE

The purpose of this study is to assess the feasibility of high-quality active transportation underpass connections across a portion of the Alaska Highway at two locations in the City of Whitehorse. The Alaska Highway currently bisects the City and poses a significant barrier to active transportation users wanting to cross the highway from a number of neighbourhoods. Two locations were identified by the Cycling Association of Yukon as candidate locations for this feasibility review, including a connection to and from the Takhini North neighbourhood (Takhini North Connection) and a connection north of the Erik Nielsen Whitehorse International Airport (Airport Connection), as shown in **Figure 1.** These two locations are coincident with active transportation crossing locations identified in the City of Whitehorse's Bicycle Network Plan.

The study presents the case for why these are critical connections in the City's transportation network from a range of perspectives, including safety, social equity, network connectivity, and reducing car dependency, among other benefits. A key focus of the study is to demonstrate what is possible to provide a high-quality experience with the design of these underpasses by considering a state-of-the-art approach for user comfort, accessibility, and social safety while also ensuring it is safe and comfortable for people of all ages and abilities, and in all seasons based on a case study review and international best practices.

The study also outlines the technical feasibility and order-of-magnitude cost estimates for active transportation underpasses at these two locations, including identifying options that are technically feasible for optimal design and orientation at each proposed location. Each design option has been informed by a comprehensive best practice review of comparable jurisdictions, ensuring what is proposed is both innovative and practical.

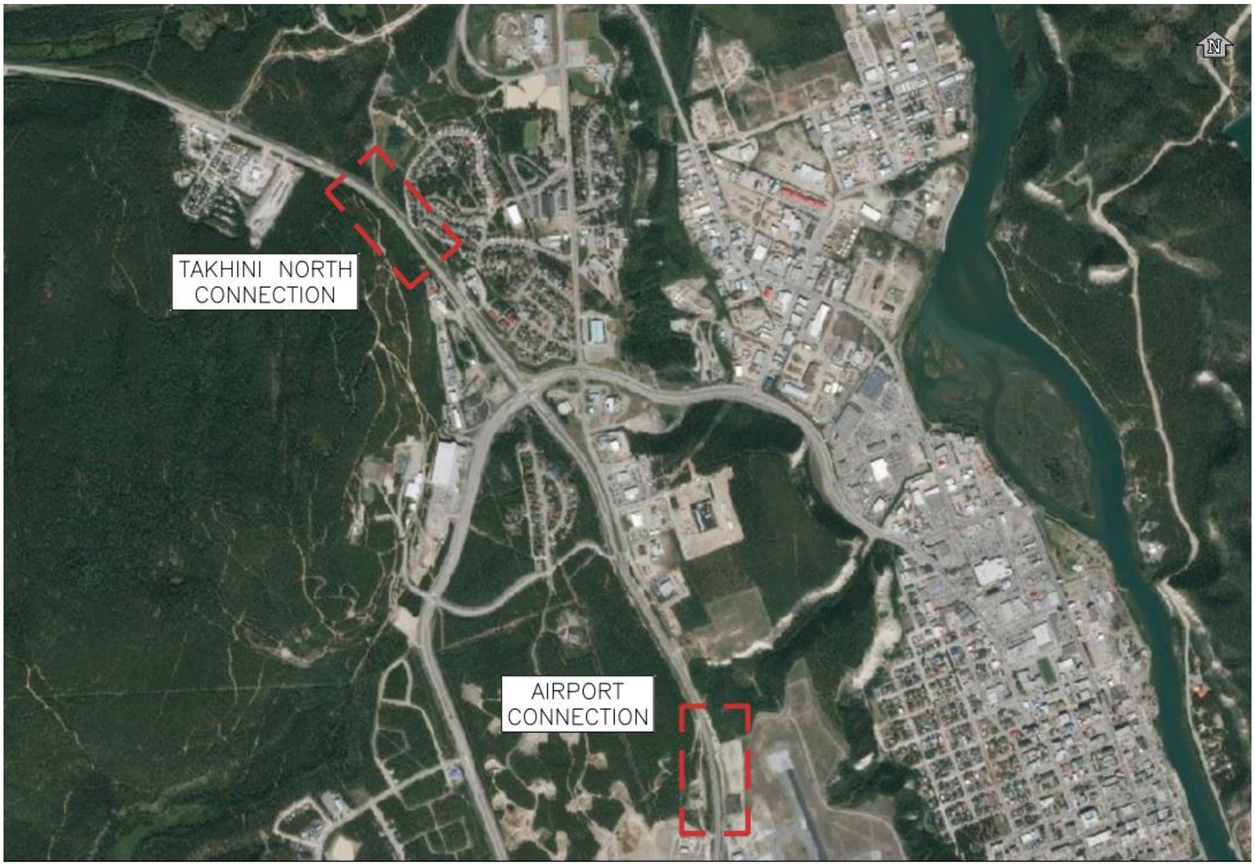


Figure 1: Feasibility Study Area

1.2 STUDY BACKGROUND AND CONTEXT

The City of Whitehorse is committed to promoting active transportation as a healthy, safe, comfortable, and convenient transportation option for people of all ages and abilities during all seasons. The City's population has grown 21% since 2011 and is projected to grow a further 44% by 2040, to a total projected population of 40,600, according to the City's Official Community Plan.

To properly plan for such a significant increase the City acknowledges it is important that active transportation routes are direct, safe, and provide connections to key destinations within community.

In 2018, the City adopted its Bicycle Network Plan which established the long-term vision for cycling in the City. The Plan's overarching goal is to increase transportation options and ultimately increase the percentage of residents using a bicycle for transportation year-round. The Bicycle Network Plan proposed several locations along the highway that would be ideal for future connections, including the proposed underpass locations in this study, as shown in **Figure 2**.

The portion of the Alaska Highway that bisects the City has been identified by the public and stakeholders as being a prominent location for close calls between drivers and those crossing the highway by walking, cycling, and cross-country skiing. Recent near misses have sparked community concern on the lack of safe active transportation connections across the highway. At a larger scale, the Yukon Territory[1] has the second highest rate of injuries and fatalities across all provinces and territories. Annually, approximately 11 people are killed and 643 are injured per 100,000 across the Yukon. This study and many recent initiatives undertaken by the City and the Territory are focused are improving the safety, traffic flow, and experience of the Alaska Highway as it bisects the City.

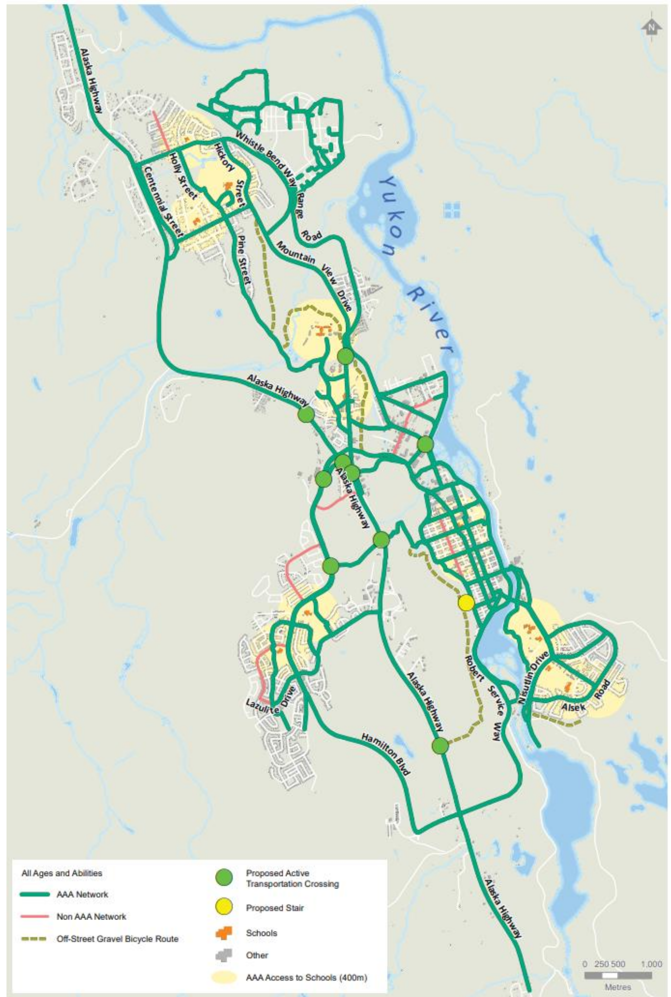


Figure 2: Proposed Bicycle Network (Source: Whitehorse Bicycle Network Plan)

1.3 RELATED INITIATIVES

This feasibility study furthers the City's and the Yukon Government's recent initiatives to enhance the portion of the Alaska Highway that passes through the City of Whitehorse. According to the Yukon Government, Yukoners have raised a number of safety concerns regarding the Alaska Highway through Whitehorse[2]. Both jurisdictions have recent and ongoing projects along this portion of the highway with the goal to enhance traffic flow and increase safety for all modes of transportation.

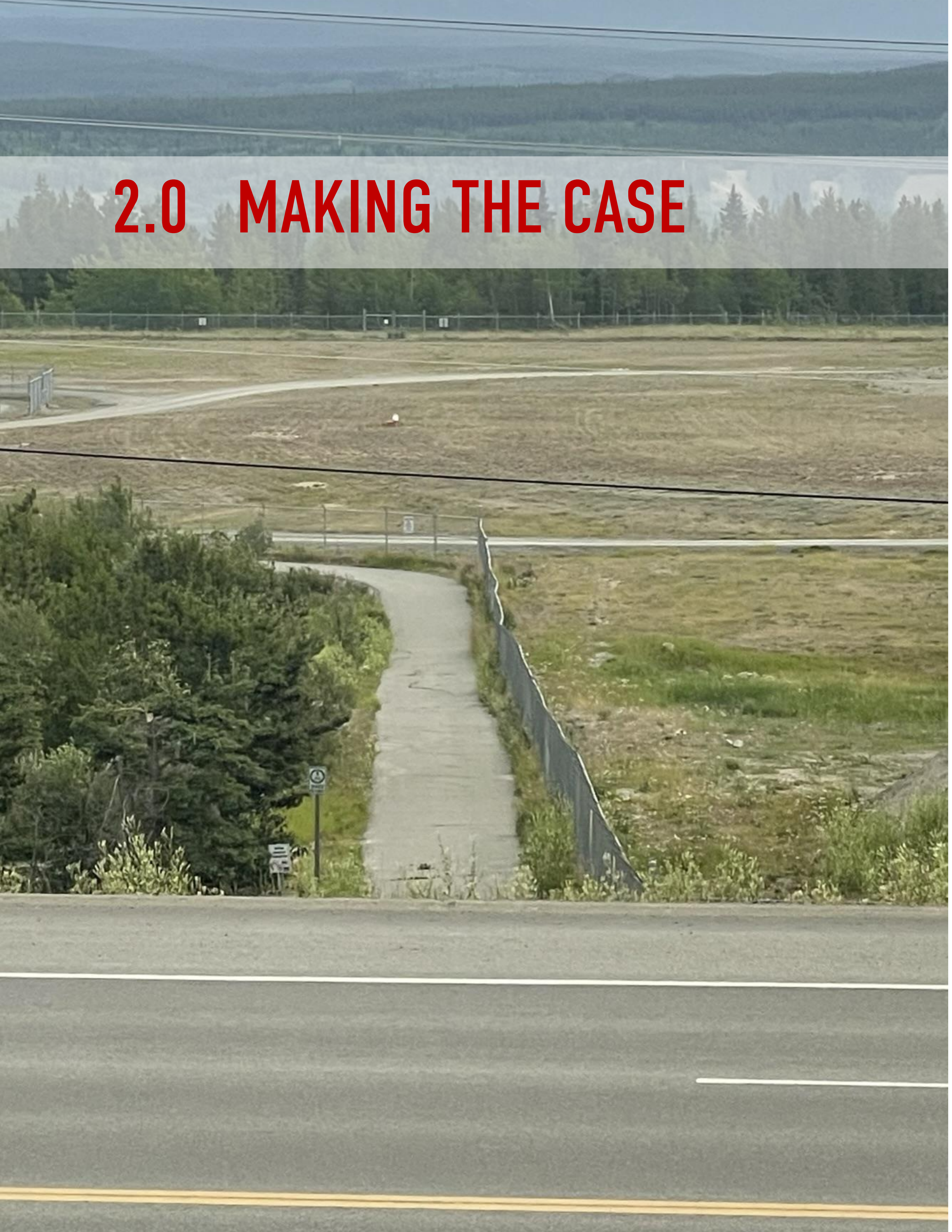
[1] *Motor Vehicles in Yukon: A public Health Perspective* (2020),

[2] Alaska Highway safety improvements through Whitehorse. (Yukon Government, 2023)

The Alaska Highway is a territorially designated highway, meaning the right-of-way is maintained and managed by the Yukon Government. Subsequently, the Yukon Government has recently completed several projects along the Alaska Highway through the City. The projects claimed to be about improving safety and connectivity at several intersections and enhancing traffic flow between intersections. Intersection improvements have included the implementation of traffic signals, street lights, pedestrian activated crossings, paved multi-use pathways, and the construction of frontage roads. Other recently completed projects include the construction of new general purpose vehicle lanes, pavement markings, turning lanes, and new pathways adjacent to the highway. The recent intersection improvement projects along the highway have been located at Range Road, North Klondike, Wann Road, and Carcross Cut Off.

The Yukon Government has several ongoing projects along this stretch of the Alaska Highway, including projects at the following locations: Hillcrest and Burns Road, Robert Service Way, and Porter Creek and Crestview. Improvements at these locations include new paved multi-use pathways, safer highway accesses and exits, new turn lanes, improved pedestrian pavement markings, and pedestrian-controlled traffic signals, among other enhancements. The Yukon Government and the City of Whitehorse are also collaborating on the **H**amilton Boulevard, **A**laska Highway, **R**ange Road and **T**wo Mile Hill (HART) Combined Intersection Upgrades Project, which focuses on implementing Intersection improvements at Hamilton Boulevard and Alaska Highway / Two Mile Hill Road and the Range Road & Two-Mile Hill Road intersections. The HART project focuses on developing improvements to make walking, biking, transit, and driving through these intersections easier, safer, and more enjoyable. It is intended that this underpass study will integrate with and inform the HART project.

2.0 MAKING THE CASE



As noted previously, the Alaska Highway divides the City of Whitehorse, creating a significant safety barrier for those outside of a motor vehicle. Within the City's Urban Growth Boundary, there are limited opportunities to cross the Alaska Highway with only six existing signalized crossing locations over approximately 15 kilometres. Within the study area, the Takhini North Connection is located nearly 1 km north of the Hamilton Boulevard / Two Mile Hill signalized intersection, and the Airport Connection location would fill a gap of approximately 1 km between existing signalized crossings at Range Road and Burns Road. The existing gaps between these crossing locations equates to potential ten-minute detours on foot. As made evident through recent near misses, the distance between these crossing locations is encouraging pedestrians and cyclists to cross at the most convenient and often uncontrolled locations rather than losing time detouring to designated crossing locations.

It is evident that from site observations and a review of cycling data that both proposed locations are currently being used as uncontrolled crossing points for pedestrians and cyclists. At both proposed locations, clear desire lines can be seen crossing the highway, as shown in **Figure 3**. **Figure 4** also illustrates user ride data reported by Strava which shows that the Takhini North location in particular sees significant use as an east-west cycling connection. At current population and cycling mode share rates, the case for implementing high-quality active transportation underpasses at these locations is not necessarily based on a typical warrant process based on factors such as traffic volumes, but rather based on improving safety, addressing social inequity, improving connectivity, and enabling current and would-be users to reduce their automobile dependency. This section reviews the key benefits of implementing underpasses at the proposed locations.

Figure 3: Existing Desire paths at Both Crossing Locations (South: Left & North: Right)

Figure 4: Bicycle User Data at Both Crossing Locations (South: Left & North: Right) (Source: Strava)

2.1 SAFETY

Underpasses across the Alaska Highway would significantly improve safety for people walking, cycling, and cross-country skiing as well as for people driving. When compared with at-grade intersections, underpasses have several key safety benefits, including reduced modal interaction, a more comfortable environment, and protection from the weather. Active transportation underpasses lessen the need for cyclists and drivers to slow down for each other, eliminating the opportunity for cross-modal accidents and increasing overall trip efficiency, including reduced delays for motorists resulting from pedestrian and cyclists use of intersection signals to cross the highway. Through the City of Whitehorse, the Alaska highway has a posted speed limit of 60km/h, faster than is often comfortable for most cyclists and which poses a significant safety risk for people crossing at uncontrolled locations, particularly with horizontal and/or vertical curves in the roadway and under some weather conditions.

Increasing safety and enabling more people to walk and ride can also have crucial health benefits. According to the City's Bicycle Network Plan, cycling and walking for transportation and recreation effectively support mental and physical health and build a healthier and happier community. The World Health Organization has identified physical inactivity as one of the main risk factors for global mortality and as an underlying factor for many chronic diseases. Therefore, by encouraging people to walk and cycle, transportation safety and broader community health can be increased.

2.2 SOCIAL EQUITY

One of the aims of this feasibility study is to create an active transportation network that serves all areas of the City and provides equitable access for all residents. This means being inclusive of – and prioritizing – people of all ages, abilities, backgrounds, and identities. It is essential to focus on centering equity and supporting equity-deserving populations. Equity-deserving populations face unique and intersecting challenges when navigating the transportation system. They may be uncomfortable walking, rolling, and cycling due to personal safety concerns and lack of lighting. They may also need infrastructure treatments, including sidewalks, curb ramps, audible pedestrian signals, and tactile warning indicators to safely navigate the transportation network. These populations – especially seniors and the BIPOC community – also tend to be overrepresented in traffic fatalities and serious injuries.

To inform the selection of the proposed underpass locations, a GIS-based equity analysis was used to identify neighbourhoods with higher concentrations of equity-priority groups. The analysis included the following indicators based on the following 2021 Statistics Canada data:

- Indigenous identity;
- Youth;
- Visible minorities;
- Single-parent households;
- Seniors;
- Shelter costs;
- Recent immigrants;
- Low Income Households; and
- Limited English Knowledge.

Figure 5 illustrates eight (8) of the nine (9) indicators used in the equity analysis. The analysis is limited by census parcel dissemination; therefore, the scale of analysis is limited to the pre-determined census tracts.

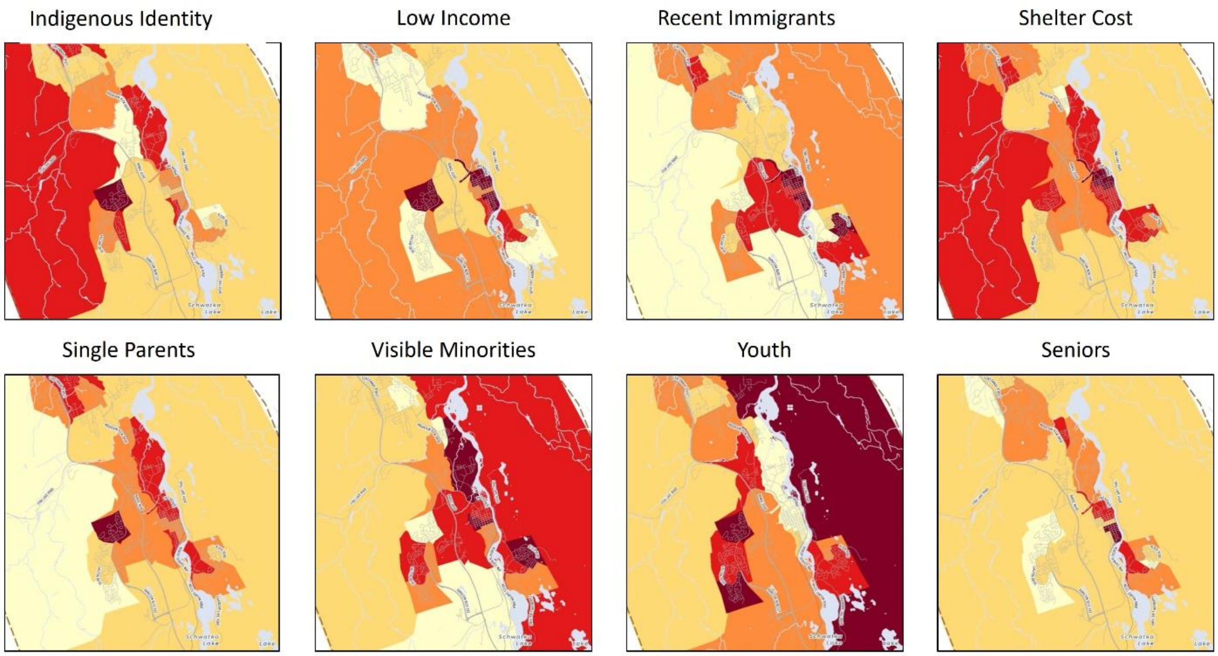


Figure 5: Equity Inputs

Figure 6 combines the different equity indicators to provide an overall equity score for the City. Two neighbourhoods in particular are of note from the individual equity indicators and the overall equity score: the McIntyre and Kopper King neighbourhoods, as summarized below. The McIntyre neighbourhood received a moderate-high overall equity need score. Compared to the City-wide average, the McIntyre neighbourhood was found to have a higher equity need than most neighbourhoods, except for the Downtown and its immediately adjacent neighbourhoods. This neighbourhood had a moderate-high equity need score as it includes a high Indigenous population, high proportion of low-income households, and high proportion of single-family households, among other factors.

The Kopper King neighbourhood received a lower overall equity score. However, this small neighbourhood in the north portion of the study area is included in a larger Census Tract thus, it may not fully capture the neighbourhood's accurate equity picture. This neighbourhood also includes a relatively high Indigenous population, has a high proportion of low-income households, and has a high proportion of single family households, among other factors.

In addition to both neighbourhoods having a high equity need, both neighbourhoods are relatively isolated and very little to no existing active transportation infrastructure, resulting in their residents not having safe ways to walk or cycle to the rest of Whitehorse. By specifically increasing the connectivity and safety of the active transportation network to these neighbourhoods, those struggling with finances may reduce their car dependency and adopt less financially burdensome forms of transportation such as walking and cycling.

MCINTYRE NEIGHBOURHOOD

1. ≥31% identify as Indigenous
2. 17% to 27% of households spend ≥30% of their income on shelter.
3. ≥50% single-parent households
4. ≥13% low-income households
5. ≥20% youth population
6. ≤10% seniors population

KOPPER KING NEIGHBOURHOOD

1. 18% to 27% of households spend ≥30% or more of their income on shelter.
2. 5% to 10% of households are low-income
3. 19% to 31% identify as Indigenous
4. 3% to 10% of visible minorities
5. 11% to 16% youth population
6. ≤10% to 14% seniors population

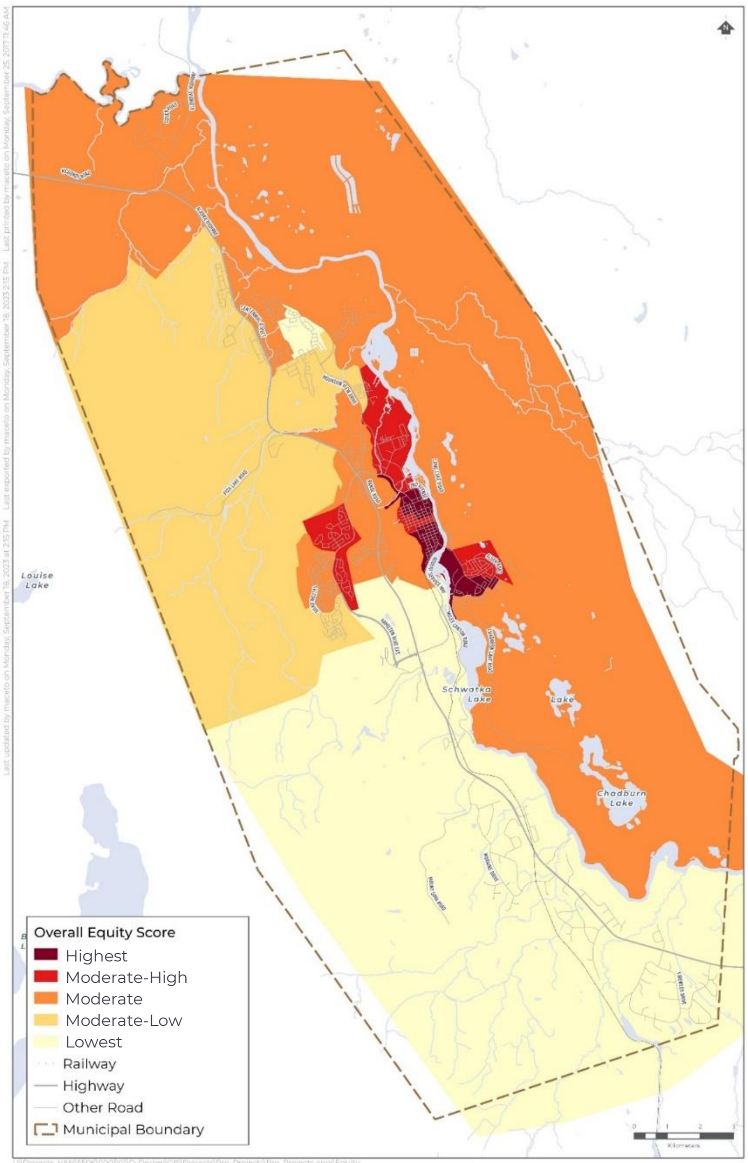


Figure 6: Overall Equity Score

2.3 REDUCING AUTOMOBILE DEPENDENCE

Allowing more people to safely, efficiently, and comfortably walk and cycle for commuting and recreational purposes can reduce the City's automobile dependence. Automobile dependency has been shown to increase social isolation, cost-of-living, and discrimination; negatively affect public health; and contribute to the decline of small businesses[3]. Some research suggests that health care cost savings resulting from increased active travel exceed the cost of infrastructure, resulting in a net cost saving to society. Transportation is the most significant contributor to greenhouse gas (GHG) emissions in the Yukon, with motor vehicles being the main culprit. Encouraging more trips by active transportation is an integral part of climate change resilience strategies and aligns with other territorial and federal climate change initiatives. As noted in Section 1.2, Yukon has the second-highest rate of road-related injuries and fatalities compared to other Provinces and Territories. Thus, by increasing the number of people walking and cycling and reducing car dependency, the City can reduce its impact on the environment, improve public health and safety, and strengthen the economy.

2.4 NETWORK ENABLING

Connecting key neighbourhoods and destinations is essential to an efficient, active transportation network. The Alaska Highway poses a significant barrier to a well-connected network, and grade-separated solutions, such as underpasses, represent the safest way to improve connectivity. For individuals to actively choose to walk or cycle instead of driving, routes must be safe, efficient, and provide direct connections between critical locations of employment, recreation, and residential areas.

Both underpass locations enable safe, seamless, and direct active transportation connections to many important destinations, as shown in **Figure 7.** For example the Takhini North Connection provides a direct connection between the Canada Games Centre and Yukon University that avoids the at-grade crossing of the Alaska Highway / Hamilton Boulevard / Two Mile Hill intersection, while also enabling connections to Takhini School. Similarly the Airport Connection enables a direct connection from between the Downtown core and several neighbourhoods, including Hillcrest, Valleyview South, McIntyre, including connection to several schools.

Additionally, for those living and working within the study area, particularly for users of the Kopper King neighbourhood, direct and safe walking and cycling routes are severely limited.

The Kopper King neighbourhood is located approximately 400 metres north of the proposed Takhini North location. This neighbourhood includes a small shopping centre and a residential neighbourhood, primarily composed of mobile homes. The neighbourhood currently does not have an existing active transportation crossing point across the highway. For those travelling to and from the Kopper King neighbourhood, pedestrians and cyclists must travel approximately 1.5-kilometers via the highway shoulders or trails south to the Hamilton Boulevard / Two Mile Hill Road intersection to safely cross the highway. There is also no safe walking or cycling route for students to reach the neighbourhood's elementary school in Takhini. By implementing an underpass at the proposed northern location, residents of the Kopper King neighbourhood have access to a safer and more direct route to the eastern side of the City, including Yukon University and the services and amenities offered by the downtown core.

[3] *The Negative Consequences of Car Dependency*. (Strong Towns, 2015)

The Copper Ridge and McIntyre neighbourhoods are located further south closer to the proposed Airport Connection underpass location on the western side of the Alaska Highway, on a slope overlooking the downtown core and the airport. The McIntyre neighbourhood includes residential, educational, and institutional land primarily on Kwanlin Dün First Nation settlement land parcels and has a high Indigenous population. The Copper Ridge neighbourhood is primarily composed of single detached homes and also includes several amenities, including two elementary schools, recreational fields and courts, one small retail area, and trailheads leading to mountain bike and cross-country ski routes. To the north of the two neighbourhoods are the Canada Games Centre, Cross Country Ski Club, and further recreation opportunities. As shown in **Figure 5**, the Copper Ridge and McIntyre neighbourhoods includes a higher-than-average proportion of youth; however, all three of the City's secondary schools are located east of the highway. By implementing an underpass at the proposed southern location, not only would it connect the users of the Copper Ridge and McIntyre eighbourhoods to the downtown core, but it would also connect people east of the highway to the schools and recreational opportunities located in the Copper Ridge and McIntyre neighbourhoods.

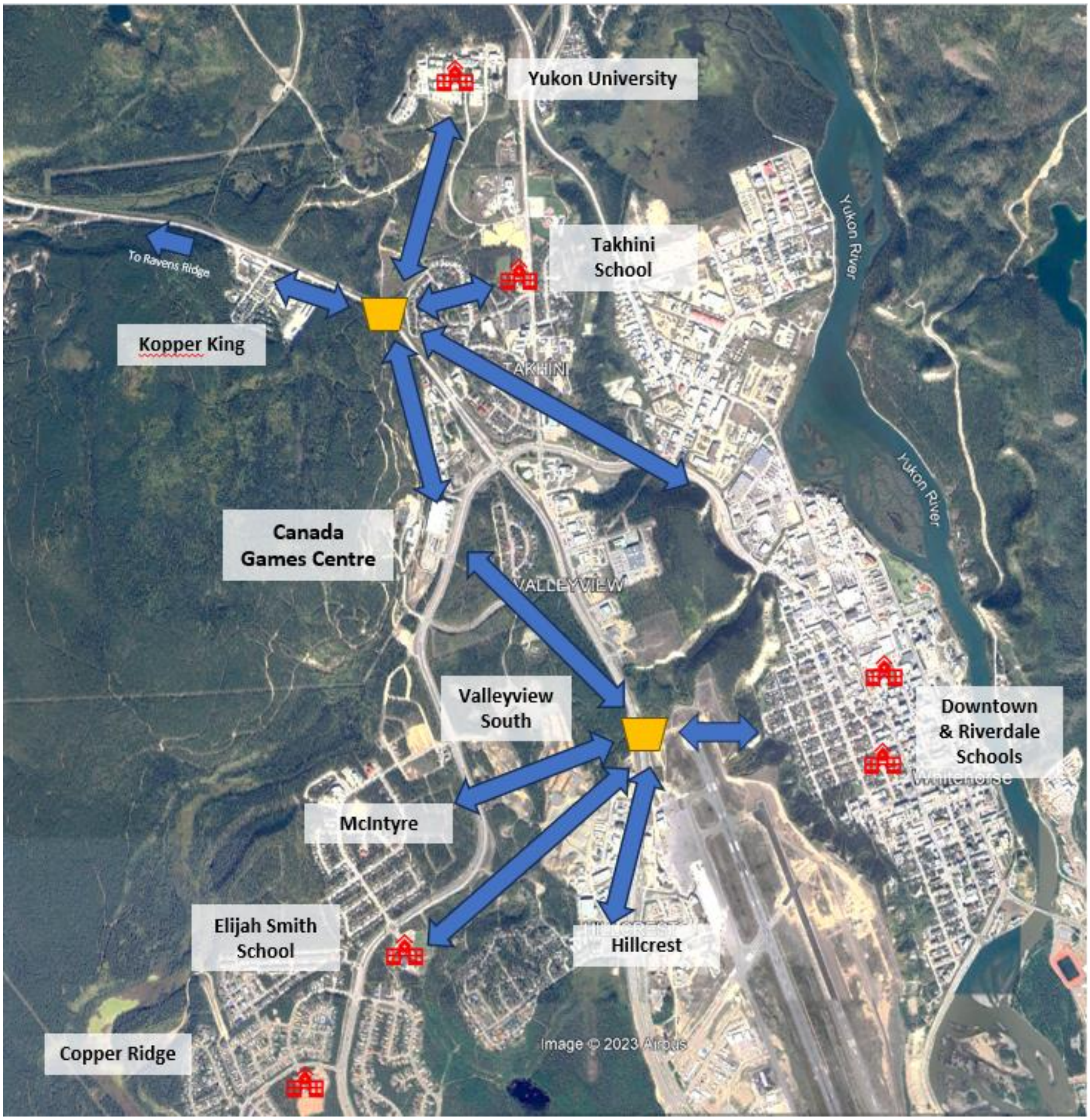


Figure 7: Active Transportation Connections Enabled by Proposed Underpasses

3.0 BEST PRACTICES

City of Oulu, Finland *(Source: Timo Perälä)*

This section provides an overview of the implementation of national and international best practices for active transportation underpasses. **Section 3.1** includes four case studies outlining how different innovative jurisdictions are implementing active transportation underpasses for people all ages and abilities, and in all seasons while ensuring a high-quality user experience. These case studies provide the feasibility study with a comprehensive understanding of the best practices in underpass design, common design shortcomings, and potential resulting social benefits. **Section 3.2** outlines how Crime Prevention Through Environmental Design (CPTED) principles can be applied to underpass design, and **Section 3.3** provides additional considerations for underpass and network design that are specific to winter cities.

3.1 CASE STUDIES

This section summarizes the findings from four case studies of innovative places implementing world-class active transportation underpasses outlines the best practices for underpass design, as shown in **Figure 8.** The case studies focus on the following four locations: the City of Oulu, Finland; the Netherlands; Boulder, Colorado; and Canmore Alberta. These locations were selected due to their similar climate to Whitehorse and the fact that each showcase high-quality underpass designs that increase social equity through enabling people to walk, roll, and cycle efficiently and comfortably and with a high-quality experience. The case studies were developed through local expert interviews and targeted desktop review. The research highlights how each jurisdiction has implemented underpasses to increase social equity, overcome specific barriers, and how infrastructure maintainability is planned for.

Figure 8: High-Quality Active Transportation Underpasses.

3.1.1 OULU, FINLAND

Figure 9: Oulu Underpass Example, 2021 (Source: Timo Perälä)

The City of Oulu, Finland, is a world leader in winter cycling as well as with the design and implementation of active transportation underpasses, with over 300 grade-separated active transportation crossings. The City of approximately 200,000 people is located at a latitude 5 degrees further north than Whitehorse and significantly invests in active transportation infrastructure. The result is that Oulu is renowned as one of the world's leading winter cycling cities. Oulu has a summer cycling mode of 32%, which only decreases to 12% during the winter season. The land use structure of Oulu is similar to many North American cities in that the neighbourhoods surrounding the urban core are composed of low-density single-family residential homes. Subsequently, many of Oulu's high-quality underpasses are in suburban and rural areas.

In the early 1970's, with an already high cycling mode share, Oulu began substantially investing in active transportation infrastructure as a means to provide safe and efficient routes for cyclists and to reduce vehicle dependency further. The movement focused on prioritizing and normalizing cycling as a primary mode of transportation, rapidly expanding its active transportation network. The network, which now includes approximately 930km, provides fast and direct connections to key employment, education, commercial, and recreational destinations and is largely distinct from the vehicle network. Oulu's cycling network often does not parallel vehicle routes but is designed to provide the most efficient route, and vehicle routes are forced to detour, including in the urban core. These key network choices ensure that bicycle travel is more efficient and convenient for many daily trips. Oulu's approximately 300 underpasses play a significant role in this system; by eliminating the need for intersections, both drivers and active transportation users have more efficient and safe journeys, with limited modal interaction.

The City's first active transportation underpasses were designed and built in the 1970's. The initial design of many of the underpasses is shown in **Figure 10**. Although this early iteration increased network connectivity, it lacked many key design features to create a high-quality experience which is why, apart from a few state-owned examples, they have been largely phased out over time. The early examples did not adequately plan for drainage, leading to pooling water in the warmer seasons and ice build-up in the winter. The early underpasses designs were challenging to maintain as not all maintenance vehicles could be accommodated due to height and width constraints and lacked intentional snow storage areas. The early designs also lacked key safety features, such as low-grade and direct entrances and exits. Poor visibility and the lack of adequate lighting made these designs prone to vandalism and lack of perceived and real safety.

The modern design of Oulu's underpasses, through key design innovations, expands the scope of intention beyond connectivity and focuses more broadly on enhancing the experience of walking and cycling. **Figure 9** and **Figure 11** showcase how more modern examples have included key design strategies that enhance safety, maintainability, and social security. A key innovation in Oulu's modern designs is using outward angled walls, made possible by using concrete pillars. This design feature opens up the underpass's interior space, increasing visibility for those near, within, and entering the underpass.

By increasing visibility, the underpasses are less likely to attract vandalism and undesirable behaviors while still providing an important refuge from inclement weather. The extra space also provides for dedicated drainage and snow storage areas, reducing water pooling and ice build-up depending on the season. Furthering maintainability, **Figure 11** showcases a significant snow-casting barrier on the roadway above, reducing snow dumping and debris landing on the active transportation corridor.

Oulu's modern designs prioritize modal separation between pedestrians and cyclists, reducing potential speed conflict. To control and moderate speed near underpasses, modern designs strive to use grades below 3-5% and reduce the angle on entry leading up to the underpass. The City has also been incorporating its approximately 300km cross-country skiing network into its underpass designs. **Figure 11** shows an example of a multi-use pathways for pedestrians and cyclists on the left and a cross-country skiing and skating route in the winter.

Figure 10: Oulu, Early 1970s Underpass Design (Source: Timo Perälä)

Figure 11: Oulu Underpass example, 2016 (Source: Timo Perälä)

3.1.2 THE NETHERLANDS

Figure 12: Underpass Integrated with Rapid Transit Station, Bilthoven (Source: Bicycle Dutch, 2020)

The Netherlands is famous for its cycling culture, extensive active transportation networks, and human-scaled urbanism. Dutch cities such as Amsterdam, Utrecht, and the Rotterdam-The Hague region have walking and cycling transportation mode shares of 70%[4], 61%[5], and 44%[5], respectively. Dutch transportation systems prioritize social equity by ensuring that the most affordable modes of transportation, such as walking and cycling, are also the most efficient and pleasant. Dutch cities, such as Amsterdam, Utrecht, and the Rotterdam-The Hague region, significantly invest in building well-connected, efficient, and comfortable active transportation networks, so walking, rolling, and cycling are often more desirable than driving or transit. Dutch cycling routes are often distinct from vehicle routes, using the most direct routes to and from key destinations, while vehicle routes are forced to take detours. These high-capacity commuter-focused routes are often called cycle super-highways, which provide seamless cycling routes across large geographic areas. Notably, the Dutch see these types of routes as an effective method to combat traffic congestion and enhance the driving experience.

Dutch cycle super-highways and networks of lower-capacity routes ensure people can safely and efficiently travel from their homes to key destinations, such as places of employment, retail, services, and recreation. Underpasses are seen as a key piece to ensuring seamless connectivity. In some instances, the Dutch even construct underpasses for vehicle roadways to avoid impacting active transportation routes and to conserve green space. In the Netherlands, and in general, people may not be able to drive a vehicle due to the high cost of vehicle ownership, safety concerns, accessibility reasons, being too old or too young, or preferring other modes. The well-connected pedestrian and cycling networks increase social equity by enabling those who do not drive the ability to fully participate in public life. In many cases, active transportation routes are designed to provide the most efficient and direct connections. In contrast, high-capacity vehicle routes are designed to detour, further increasing overall attractiveness of

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[4] Cycling increased again in Utrecht. (Bicycle Dutch, 2019)
[5] Deloitte City Mobility Index

walking, rolling, and cycling. Investing in these cycle-super-highways, is seen as an effective method to combat traffic congestion and enhance the driving experience by removing signalized crossings.

The primary physical barriers for Dutch active transportation networks are waterways, highways, and railways. In the 1950's, the Dutch built high-capacity highways in rural areas connecting different cities; however, with urban expansion these highways are now situated in urban and suburban contexts, creating dangerous barriers for cyclists and pedestrians. The Dutch prioritize the use of underpasses rather than overpasses due to the required climb for cyclists, which limit the efficiency of high-capacity routes such as cycling super-highways. Underpasses, especially along cycle super-highways, significantly reduce the number of multi-modal crossings, allowing cyclists to maintain speed, reducing overall energy expenditure, commute times, and increasing safety.

A key feature of Dutch underpasses is that a significant effort is put towards beautification. **Figure 12**, **Figure 13**, and **Figure 14**, showcase examples of how the Dutch use public art, and high-quality landscaping and design to create interesting and attractive underpasses. The beautification of the Dutch underpasses is intended to create three key benefits:

1. Enhance overall trip experience
2. Reduce vandalism / increase civic pride
3. Create interesting and beautiful places

Figure 13: Underpass Bypassing an Arterial Roadway, Utrecht (Bicycle Dutch, 2022)

Good visibility is a key aspect of what makes Dutch underpasses attractive and comfortable during all four seasons and all hours of the day. Like in Finland, early Dutch underpasses were narrow, straight-walled, poorly lit, and included sharp turns directly before exits. Modern Dutch underpasses are designed to ensure users can see what is inside and beyond upcoming underpasses, limiting potential surprises and enhancing comfort. This achieved by including high-quality lighting, reducing the turn radii of connections, and flaring out walls, as shown in **Figure 13**.

Figure 14: Underpass Integrated with Amsterdam Central Station, Amsterdam (Bicycle Dutch, 2015)

One-third of the Netherlands is below sea-level, which introduces significant drainage and water table issues. Controlling stormwater is a key focus in modern underpass designs. Snow, however, is not a significant concern in much of the country. Modern Dutch underpasses are designed to incorporate a slope inward from both sides as to create a shallow U-shape. This design allows for a single pump to be located at the lowest point.

3.1.3 BOULDER, COLORADO

Figure 15: University of Colorado Underpass, Boulder (Source: Google Streetview, 2011)

The City of Boulder, Colorado is a winter city with a population of approximately 108,000 people located at the foothills of the Rocky Mountains. Boulder is consistently rated as one of the best places to bicycle in America, with over 480 km of bikeways. The City includes a well-connected network of multi-use pathways separated from vehicle traffic, and approximately 85 active transportation underpasses that make it possible for almost completely uninterrupted travel, regardless of a trip's origin and destination. As of 2018, the City has a combined walking and cycling mode share of 37%.

In the early 1990's, the City of Boulder began prioritizing the shift away from a car-dominated transportation system by significantly investing in active transportation. The University of Boulder, which hosts approximately 36,000 students and 10,000 faculty and staff, was a key driver in the development of Boulder's active transportation network. The City sought to increase social equity in its transportation system by ensuring users can access the university safely and efficiently regardless of mode of transportation. For all active transportation routes that intersect a roadway, where the posted speed limit is at least 40 miles per hour (64 km/h), the City has decided that grade separation is necessary.

Boulder's initial car-oriented transportation systems created significant barriers to developing a well-connected, and comfortable active transportation network. The main barriers include five major highways, several high-traffic arterial roadway, railways, and 15 major waterways that each require a bridge. Boulder's 85 active transportation underpasses have been implemented to reduce the fragmentation impact of such barriers. The City prioritizes the implementation of underpasses instead of overpasses, as underpasses require less area and are less visually distracting to drivers and the overall view shed.

In 2023, the City completed construction on its largest active transportation underpass to-date. The 30th Street underpass increases traffic safety and flow at one of the City's busiest intersections (see **Figure 16**). The intersection previously fragmented a high-traffic active transportation route connecting to the university. The design features two distinct underpasses, creating an L-Shape connecting three of the intersection's corners and providing a seamless experience for active transportation users.

Figure 16: 30th Street and Colorado Ave Underpass, Boulder (Source: City of Boulder, 2023)

The 30th Street underpass cost approximately $15 million to construct, but the City saw this as a fair cost for increasing social equity by enhancing the experience of those who walk, roll, or cycle to and from the university. By enabling staff, students, and community members to access educational and employment opportunities via the most affordable and safe modes of transportation, a more diverse demographic can meaningfully participate in public life and the economy. Safety for active transportation users was also a key motivator for the project, as the intersection was a high crash location, with 20% of collisions involving cyclists. Construction involved raising the intersection and using pre-cast concrete structures.

The City, over its three-decade history of constructing underpasses, has established a set of key design features, as shown in **Figure 17** and **Figure 18**. Several of these features include soft techniques to enhance social security and safety, including high-quality lighting and good visibility. The City has uniquely designed its underpass lighting to reduce the contrast between sunlight and the underpass. This has been done to reduce the time it takes for the human eye to adjust to different light levels, which can be particularly difficult for older individuals. The City's modern underpasses prioritize minimum turn angles of connecting pathways, minimal grades, and highly visible structures with outward slanting walls, which reduce ice build-up at entryways by reducing a shadowing effect. Public art is seen as a key design feature to enhance the experience of walking, rolling, and cycling and has been found to reduce vandalism. The underpass shown in **Figure 15**, which is located near the university, and sees 1,200-2,500 users per peak hour, showcases how high-quality lighting and public art can transform an otherwise dark tunnel into a beautiful, well-used, and safe connection, even at night.

Figure 17: 30th Street Underpass Lighting (Source: City of Boulder, 2023)

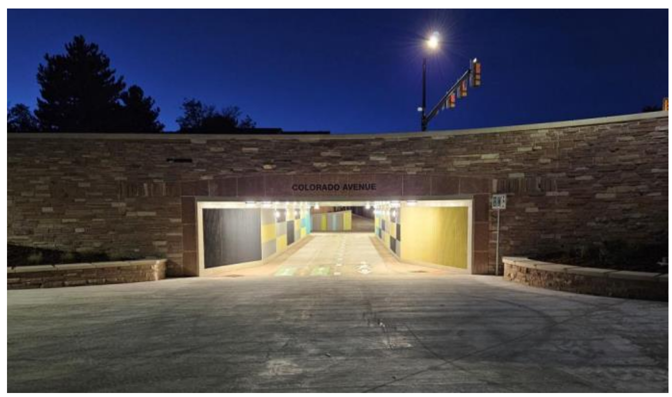


Figure 18: 30th Street Underpass Interior Lighting (Source: City of Boulder, 2023)

Drainage is a key concern for Boulder's underpasses. The City receives a significant amount of annual precipitation, much of which is in the form of snow. The City often designs its underpasses to have a central pumping system located in the middle of the facility. Boulder's modern underpasses are typically a minimum of 16-18 feet wide, inclusive of a 2-3-foot-wide paved buffer for drainage and snow storage. The buffers are designed to have different paving textures or colours to signify its specific use. A minimum height of 8 feet is used to ensure all necessary maintenance vehicles, often light-duty trucks, can access each underpass.

3.1.4 CANMORE, ALBERTA

Figure 19: Cougar Creek Underpass, Canmore (Mountain View Today, 2022).

The Town of Canmore, Alberta, is located within the Rocky Mountains, approximately 80 kilometres west of the City of Calgary. The City is home to approximately 16,000 residents. According to the most recent Census data, Canmore has a combined walking and cycling mode share of approximately 20%, which is significant for the town because of its population base, climate, and sparse urban structure. Like the City of Whitehorse and many other smaller Canadian communities, Canmore is fragmented by a major highway, in this case the Trans Canada Highway. The highway creates a significant barrier for active transportation users to safely travel between residential and employment areas on the east side of the highway and the town centre on the west side. Canmore's active transportation routes are also fragmented by rail rights-of-way, several creeks, and the Bow River and its associated bridge crossings.

As of 2023, Canmore has implemented four active transportation underpasses to enhance connectivity and safety for those walking, rolling, and cycling. Canmore's underpasses include one recently constructed high-quality underpass, the Cougar Creek underpass (see **Figure 19**), one underpass which passes under a bridge crossing the Bow River, and two older tunnel-like underpasses. The Town is also currently planning a fifth underpass which emulates the design of the Cougar Creek Underpass.

The Cougar Creek underpass, constructed in the early 2010s, showcases several high-quality design features that enhance safety, maintenance, and experience. Through a significant focus on the beautification of the underpass, the Town created a place where people want to go and use, which otherwise may have been an unwelcoming tunnel under a major highway. The landscaping, brickwork, and stonework create a sense of place and complement the aesthetic of the surrounding natural landscape and views. The underpass features a high level of visibility via central overhead lighting and stepped-back structural walls, which allow for wider sightlines, in addition to the split bridge design, which provides ample natural light.

The Cougar Creek Underpass was designed with maintainability at the forefront to ensure the facility can be used year-round, which is essential for a winter city. The underpass pathway includes generous shoulders that ensure stormwater drains effectively and provide an area for snow storage during Canmore's long snow season. The underpass is also designed to a height for several types of maintenance and emergency vehicles.

3.1.5 KEY LESSONS LEARNED

The four case studies above showcase design characteristics and considerations for high-quality active transportation underpasses that can be applied in broadly. Underpasses in each of the selected jurisdictions have been implemented to overcome similar barriers, such as highways, arterial roads, waterways, and railways. Overall, the intent of implementing underpasses across the four jurisdictions was identified to increase social equity by enhancing the safety, efficiency, connectivity, and experience of active transportation networks. The four jurisdictions accomplish the primary goal of increasing social equity by designing for the following considerations: visibility and lighting, grades and approach angles and beautification.

Visibility and Lighting

Incorporating high-quality lighting and visibility increases social security and safety. By ensuring users, upon approach, can clearly see what is inside and just beyond an underpass, user anxiety and surprise can be reduced. By designing underpasses to be open with angled and/or stepped wells with ample widths, visibility is increased, the facilities feel larger, and natural lighting can provide ample daytime lighting (as shown in **Figure 9** and **Figure 11**). The incorporation of high-quality lighting (as shown in **Figure 14**, **Figure 18,** and **Figure 19**) also ensures the attractiveness of underpasses at any time of day. Lighting can also be used to reduce the strain on people's eyes as they transition between varying levels of light. While underpasses provide vital protection from the elements, especially in winter cities, good visibility and lighting makes users more comfortable and willing to use the facility, which in turn leads to greater social safety.

Beautification

Investing in aesthetically attractive underpasses enhances the experience for those walking, rolling, and cycling. Beautification is important because it invites users to continue using and enjoying the underpass and route. By incorporating high-quality paving materials, locally appropriate cladding, welcoming landscaping, and public art into underpass design, the experience of using one will be better. Creating places people enjoy in conjunction with being highly visible can also reduce vandalism and undesirable behaviour.

Grades and Approach Angles

Minimal grades and gradual approach angles increase safety and route efficiency. Through orientation, landscaping, and location selection, grades should be minimized to approximately 3° with a maximum of 5°. By reducing inclines and the need for sharp turns, pedestrians and cyclists can maintain speed and increase trip efficiency, while also ensuring the underpass is accessible for people of all ages and abilities. Approaches with minimal grades and angles can also improve safety through increasing visibility into the underpass and ensuring bicycles can maintain a speed at which they can balance. Grades are particularly important for winter cities as snow and ice build-up can occur.

Maintainability and Drainage

Embedding maintainability, reliable drainage systems, and snow clearage and storage into underpass design reduces capital expenditure and ensures facilities can be used year-round. Winter cities such as Whitehorse, Canmore, Oulu, and Boulder require special consideration when it comes to underpasses. Drainage is a key concern as pooling water in warmer seasons and ice in colder seasons presents a significant barrier to those walking and cycling. The case study research offers several design solutions for drainage, including specific shoulder areas dedicated to drainage or a central pump located in the middle of the underpass's length. The City of Boulder recommends designing redundancy into the system to ensure that if repairs are needed, the corridor can facilitate movement as usual.

3.2 CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN (CPTED)

Underpasses are inherently confined spaces and require specific design considerations to ensure social safety. This section outlines best practices for incorporating CPTED principles into underpass design. The implementation of CPTED relies on two generations of strategies. First-generation principles, developed in the 1970s, focus on decreasing crime by reducing opportunity and anonymity and increasing a sense of ownership. Second-generation strategies, focus on addressing the social environment.

3.2.1 FIRST-GENERATION CPTED STRATEGIES

Natural surveillance is a strategy that ensures users can see potential activity in and beyond a space while approaching, using, and exiting said space. The strategy is based on the idea that individuals will be less likely to act nefariously if their actions are clearly visible. Natural surveillance can be integrated into underpass design by minimizing approach angles, increasing overall width, implementing high-quality lighting, daylighting, and using outwardly leaning walls. In instances where a sharp turn in an underpass is required, angled mirrors should be used to improve sightlines. These techniques increase visibility at a broader range of approach angles.

Figure 20: Oulu, Finland. (Google Maps, 2023)

Natural access control focuses on decreasing crime opportunity. It is based on the premise that a person confronted with a clearly defined and/or strategically developed boundary will typically show it some deference by respecting the way it guides and influences their movement as they transition from public through private space. For underpass design, natural access control is applied by eliminating any recessed surfaces and areas that could be used to hide.

Figure 21: Nijmegen, Netherlands. (Cycling Embassy of Great Britian, 2019)

Territorial Reinforcement realizes that physical design can create or extend a sphere of influence so that users develop a sense of ownership of space. If implemented correctly, territorial reinforcement encourages the use of a space as intended, while if implemented incorrectly, it can result in people becoming territorial over a public space. In underpass design, territorial reinforcement ensures each area has a clearly defined, and ideally active, purpose. This is often achieved through differing paving textures between areas for travel, drainage, snow storage, and rest.

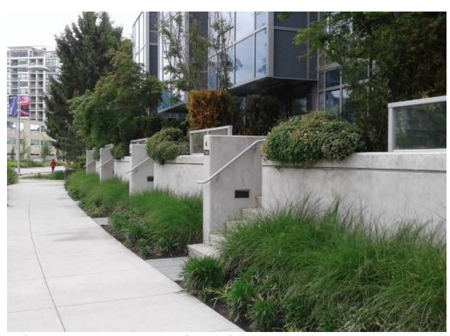


Figure 22: Territorial Reinforcement. (CPTED Canada, 2023)

3.2.2 SECOND GENERATION CPTED STRATEGIES

Figure 23: Whistler, BC (Hamilton Kent, 2020)

Community Culture focuses on creating a sense of place, shared history, and commemorating a significant neighbourhood event or people. In underpass design, the principle of community culture is often associated with the integration of public art. Locally contextualized public art fosters a sense of civic pride among users and can reduce the likelihood of potential vandalism and associated maintenance costs.

Figure 24: Gelderland, Netherlands. (European Cyclists Federation, 2017)

Social Cohesion describes the ability of public spaces to bring a community together to build relationships and increase trust. By considering how people might use and experience a space, it can be designed to provide for social interaction. In underpass design, social cohesion can be implemented by incorporating rest areas via public seating, water fountains, and weather protection.

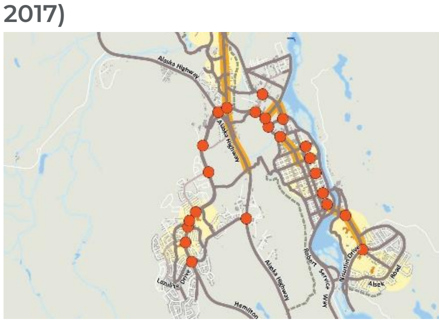


Figure 25: Bicycle Network Plan, (Whitehorse, 2018)

Connectivity describes the intentional integration of different neighbourhoods and demographics to create relationships and strengthen social resilience and cohesion. The location of an underpass must be selected to maximize connectivity between different neighbourhoods, ideally connecting people of all ages and abilities to each other and key destinations.

3.3 WINTER CITY CONSIDERATIONS

Cycling in winter cities, including places with climates with significant snowfall, ice, and freezing temperatures for much of year, require special infrastructure considerations. Planning in cold climates must factor in seasonal variations to ensure that facilities are safe and comfortable year-round. Cycling mode share during the winter season is bound to decrease, as only the dedicated and confident remain, primarily only for utilitarian purposes. However, many comparable winter cities have shown that networks intentionally designed to work well in winter climates can still be well used. **Table 1** highlights comparable cities that have invested in winter-ready bicycle networks typically retain approximately 25%-30% of their peak cycling mode share. Whitehorse's local climate is colder than most urban places worldwide and thus will require even more intention when designing a winter active transportation network.

This section builds upon Sections 3.1 and 3.2 and provides further considerations specific to winter cities. The key specific winter city considerations include maintenance, network planning and prioritization, and lighting.

Table 1: Peer City Comparison Profile, 2014 (Adapted from *Plan Canada: Cycling Through Winter*, 2014)

	POPULATION	AVERAGE JANUARY HIGH (°C)	AVERAGE JANUARY LOW (°C)	AVERAGE SNOW FALL (CM)	SUMMER BICYCLE MODE SHARE	WINTER BICYCLE MODE SHARE
WHITEHORSE, YUKON	**29,201**	**-9°**	**-16°**	**145**	**3%**	**No Record**
OULU, FINLAND	190,000	-5°	-7°	91	33%	9%
MONTREAL, QUEBEC	1.6 million	-5°	-12°	200	3%	1%
CALGARY, ALBERTA	1.1 million	-1°	-13°	126	3%	1%
MINNEAPOLIS, MINNESOTA	380,000	-4°	13°	123	4%	1%
COPENHAGEN, DENMARK	570,000	2°	-2°	N/A	36%	9%
BOULDER, COLORADO	98,000	7°	-5°	200	9%	2%

3.3.1 NETWORK PLANNING AND PRIORITIZATION

During the winter season, it is likely that many cyclists and pedestrians will reduce their number of recreational trips and will instead primarily use active transportation networks for commuting and daily needs. For this reason, it is essential that active transportation networks are direct, efficient and connect to key destinations and neighbourhoods. Like road networks for motor vehicles, bicycle and pedestrian networks must be prioritized accordingly to ensure users have predictable and reliable routes. To this point, many winter cities with high active transportation mode shares adopt bylaws that highlight the timing and prioritization of snow clearing routes after snowfalls[6].

3.3.2 WINTER CITY - MAINTENANCE

As a winter city, a key component of encouraging active transportation is ensuring that it is a safe, comfortable, and accessible mode of transportation at all times of day and all times of year. As such, it is important to ensure that facilities are regularly maintained, which is made easier and more cost-efficient if facilities are designed to be easily maintainable at the outset. Key components of winter city maintenance include snow clearing and storage as well as adequate drainage to ensure rain and melting snow do not pool and create ice along paths.

A heavy snowfall will typically require the initial removal of snow to restore functionality. Both proactive approaches, such as salting and sanding, and reactive approaches, such as snow clearing, are important to ensure useability. For the efficient clearing of snow in and near underpasses, the design must include intentional snow storage areas. Incorporating a casting barrier to block overspill from snow clearage on above roads is also a well-used technique.

Ensuring facilities adequately drain in winter cities is crucial for retaining safe and comfortable routes year-round. The thoroughfare areas of an underpass should be graded to reduce potential pooling and to ensure ice build-up does not occur near pumping systems. Snow storage areas should be graded to direct run-off away from travel areas.

It is also important to design facilities to be accessible by a jurisdiction's available maintenance vehicles and to ensure snow storage areas are proposed position for applicable vehicles. For underpass design, it is important to both provide the height, width, and approach and exit angles can accommodate appropriate maintenance vehicles.

[6] *Winter Bike Lane Maintenance - A Review of National and International Best Practices*. Alta Planning and Design, 2014

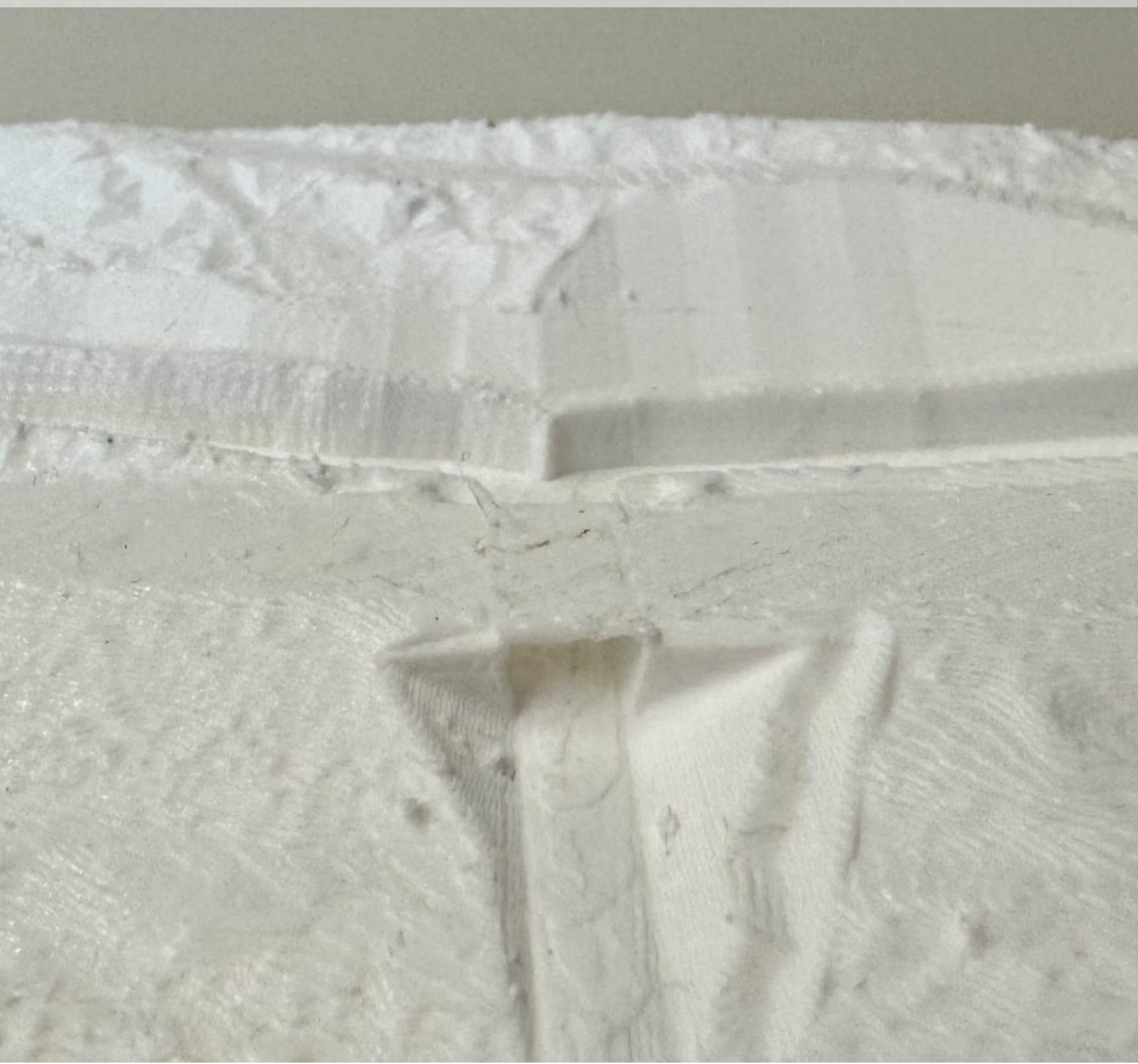
Figure 26: Underpass in Winter, Oulu Finland (Source: Timo Perälä)

3.3.3 WINTER CITY - LIGHTING

Whitehorse can receive as little as six hours of daylight during winter months. For this reason, lighting in Whitehorse and many other comparable winter cities is an important consideration for active transportation networks. In many instances, people commuting to work via walking or cycling will do so in the dark in both directions. Ensuring facilities are adequately lit can improve real and user-perceived levels of safety. As noted in Sections 3.1 and 3.2, lighting can serve a crucial function in increasing visibility near an underpass. Lighting can ensure all relevant signage is still visible, such as caution signs, speed recommendations, and modal separation. During the winter, active transportation routes can often have a layer of snow covering any pavement marking present. **Figure 27** shows an innovative example of how lighting can be used to replace pavement markings during the winter, both enhancing safety and comfortability as well as creating more interesting places.

Figure 27: Innovative Light Signs, Oulu Finland (Government of Oulu, 2023)

4.0 OPTIONS DEVELOPMENT AND PREFERRED CONCEPT



This section identifies recommended concepts for the two proposed underpass locations across the Alaska Highway based on a high-level feasibility review, considering several design criteria such as design speed, overhead clearance, optimal grade, turn radii and maintenance vehicles. It should be noted that this study was only developed to a feasibility level of detail based on limited data and information. This study did not involve any conceptual or detailed design work and did not involve any topographic survey or geotechnical information. As such, this report is a starting point to assess whether these options may feasible, subject to further topographic, geotechnical, and engineering studies to further advance high-level concepts to subsequent design studies.

4.1 DESIGN CRITERIA

Table 2 summarizes the key design criteria used for the feasibility review. The design criteria are informed by the best practice review and key lessons learned outlined in section 3.1.5, as well as the BC Active Transportation Design Guide (BCATDG) and the TAC Geometric Design Guide for Canadian Roads (2017).

Table 2: Design Criteria

Design Criteria	Value	Intent	Source
Max Slope (Cut and Fill)	• 2:1 (Sand) • 0.25 (Rock)	Technical Feasibility	Client recommendation
Underpass grade under structure	• <5%	Technical Feasibility	BCATDG
Lateral Clearance	• 0.6m unpaved shoulders	Maintenance	BCATDG
Sag Curve, K	• 1.5	Maintenance	TAC Geometric Design Guide, Section 5.5.4.3
Design Vehicle	• PistenBully 100	Maintenance	Client recommendation*
Control Vehicle	• Ford F-250	Maintenance	Client recommendation
Underpass overhead clearance	• 3.5m (Takhini North Connection) • 3.0m (Airport Connection)	Maintenance AAA Design	Dictated by PistenBully 100 dimensions (height of 2.6m) while allowing for snowpack and maximizing social comfort
Design Speed	• 25 km/hr (Approach) • <20 km/hr (Switchbacks/sharp turns)	AAA Design	TAC Geometric Design Guide, Section 5.5.1
Approach grade:	• Maximum 8% • No low points should exist within the underpass.	AAA Design	TAC Geometric Design Guide, Section 5.5.4.1
Horizontal Radius	• 15m (Approach) • 8.0m (Switchbacks/sharp turns)	AAA Design	TAC Geometric Design Guide, Section 5.5.3.1
Pavement Width	• 1.8m travel lanes • 3.6m combined path width	AAA Design	BCATDG

** This vehicle has been assumed to accommodate future flexibility of the infrastructure. The PistenBully100 is of similar size to City of Whitehorse maintenance equipment.*

4.2 OPTIONS DEVELOPED

Based on existing desire lines from site observations, a review of Strava data, as well as input from the Cycling Association of Yukon and stakeholders, the existing network, concepts for underpasses at two locations were developed:

- **Takhini North Connection:** An underpass connecting to the neighbourhood of Takhini with the south/west side of the highway; and
- **Airport Connection:** An underpass connecting the trail network surrounding the airport with the west side of the highway.

Figure 28: Study area

4.3 TAKHINI NORTH CONNECTION

4.3.1 INITIAL ALIGNMENT OPTIONS EVALUATION AND SCREENING

The proposed Takhini North underpass would connect the Takhini neighbourhood east of the Alaska Highway to the trail network and the Kopper King Neighborhood on the west side of the Alaska Highway. The connection is intended to match the existing desire lines visible in both satellite imagery and site photos and supported by Strava usage data (as shown in **Figure 3**, **Figure 4** and **Figure 29**).

Figure 29: Strava Usage (All Modes) for Takhini North

As the nearest signalized crossing is 860 metres to the south at Two Mile Hill Road (approximately a 10-minute walk away), a significant number of people are known to cross the Alaska Highway where the trail network on the west side of the highway approaches the neighbourhood of Takhini North. This has resulted in significant demonstrated safety issues at this location with people walking, cycling, and cross-country skiing crossing a highway with high vehicle speeds and volumes, including anecdotal stories of near misses involving pedestrians at this location. This is exacerbated by the radius of the highway, adjacent slope, and limited horizontal visibility for drivers at this location.

Figure 30 shows a base plan of this proposed crossing location, including showing existing informal trails and desire lines. Existing multi-use trails run parallel to the highway close to the crossing desire line, as well as a connection to Takhini North, to the multi-use trail network to the south, and a connection leading northwards to Yukon University.

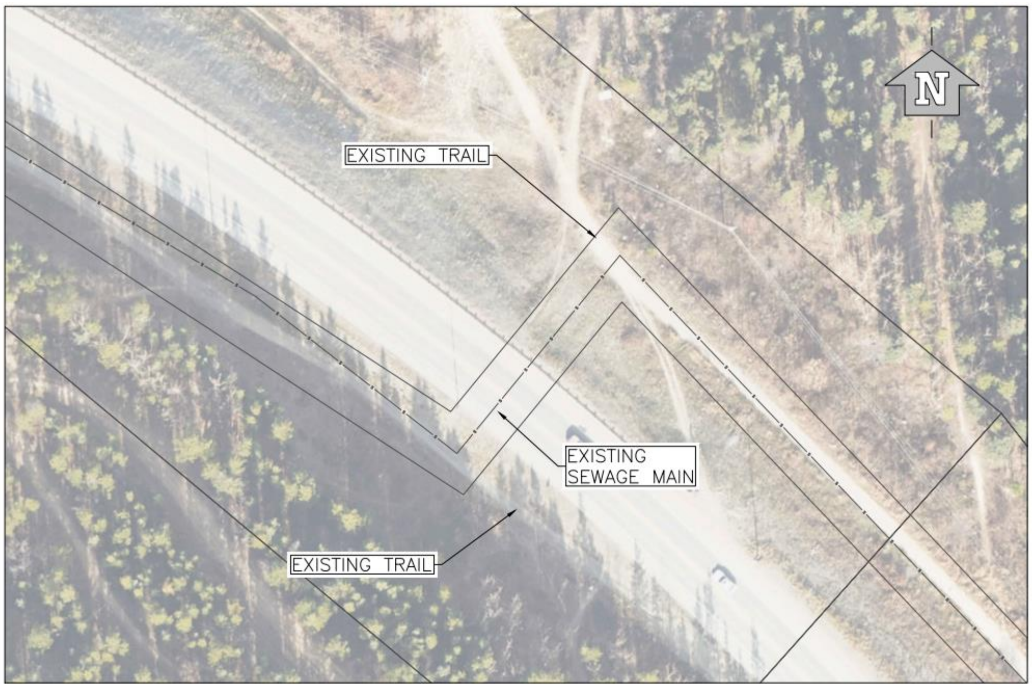


Figure 30: Takhini North Local Trail Connections and Utilities

The primary challenges associated with this location are:

- The steep slope running perpendicular to the highway.
- The highway grade of 3.5% running westwards; while this facilitates an approach ramp to the east, any underpass approach to the west will be quite long.
- The sewage connection in this location. To avoid costly utility relocation, the preferred alignment should maintain a suitable distance from the existing sewage main.

Based on this analysis, five alignment options for potential grade-separated crossings in this general area were developed, as shown in **Figure 31.** Alignments A through D are candidate locations for underpasses, while Alignment E is a candidate location for an overpass, taking advantage of the small hills on each side of the highway further to the north.

Each underpass option was developed with a maximum grade of 8%. Shallower grades, particularly for the westbound approach ramps, would require unacceptably long ramps.

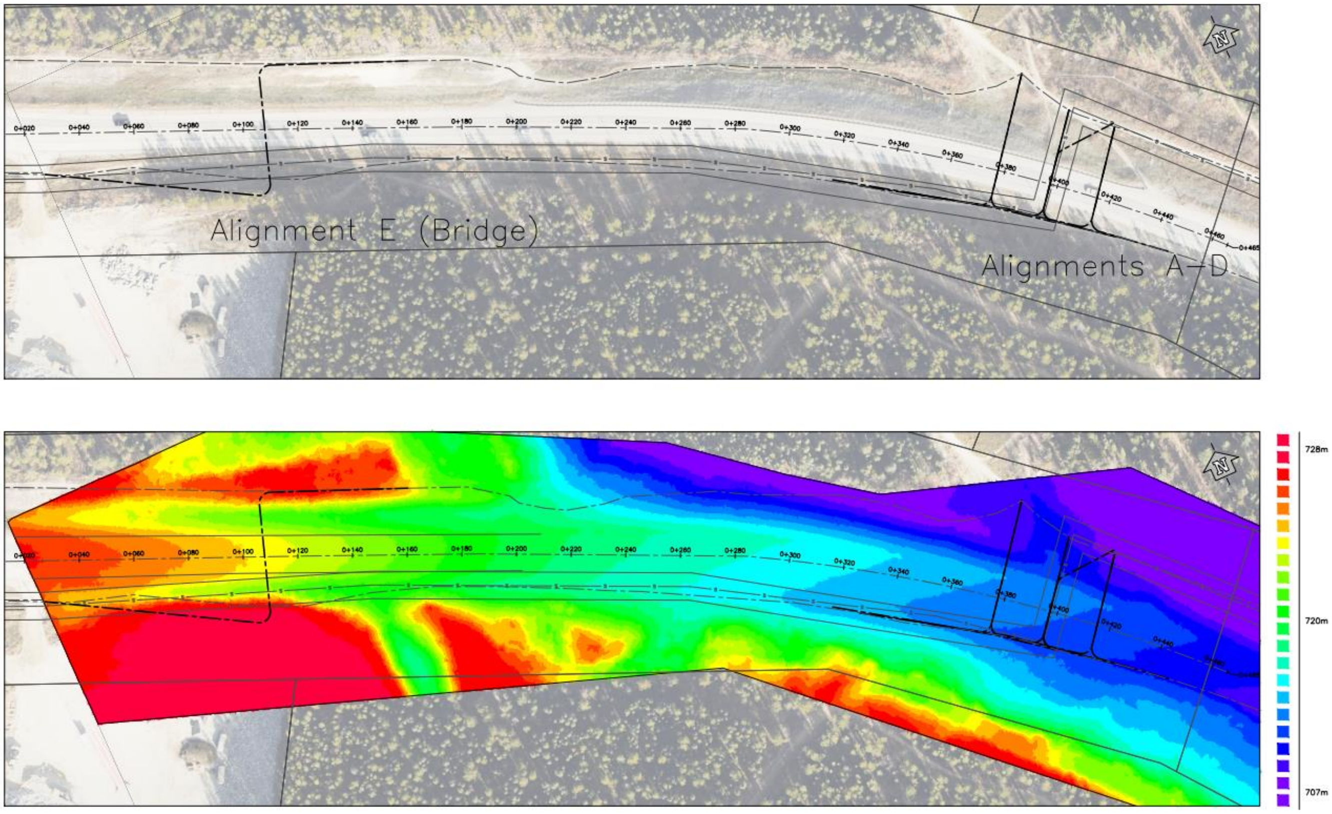


Figure 31: Takhini North Connection Alignment Options

Based on an initial screening of these alignment options, several conclusions were apparent:

- An overpass connection at the more northern location is not desirable as it does not coincide with existing desire lines and does not connect to the existing trail, and likely would not help address the concerns of people crossing at the existing location at-grade.
- All of the underpass locations had similar lengths of the approach ramps with little variability.
- For all of the underpass locations, the north approach ramp, regardless of the location, would be quite short, as the highway is already several metres higher in elevation than the north pathways.
- The preferred underpass alignment is the easternmost option to avoid conflicts with the sewer main and to best align the crossing with the existing desire lines.

4.3.2 PREFERRED ALIGNMENT OPTION

Based on this evaluation, a preferred design option was developed, shown in **Figure 32** and **Figure 33**. This design features two approach ramps on the south side of the highway; one running west and one running east. The grading of the approach ramps is optimized for winter drainage, with the slope running away from the tunnel where possible.

A full conceptual drawing package is included in **Appendix A**.

Figure 32: Takhini North Connection Preferred Concept Rendering

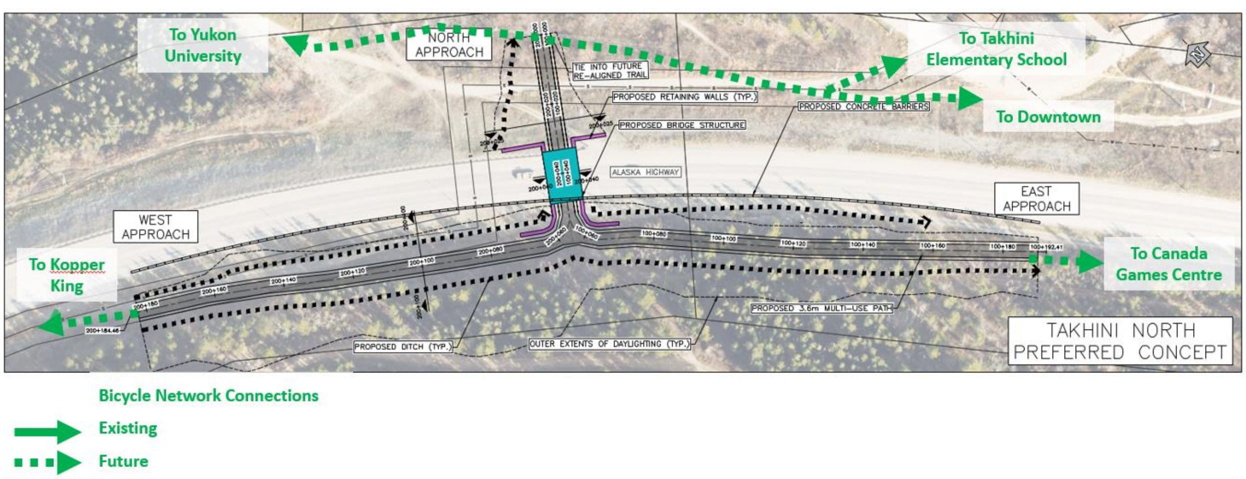


Figure 33: Takhini North Connection Preferred Concept

Where possible, the walls of the approach ramps are daylit to minimize costs and improve social comfort. North of the highway, the approach ramp is daylit at a 2:1 slope. While a geotechnical assessment was not within the scope of this project, based on observations on-site, the slope south of the highway is primarily bedrock. For the approach ramps on the south side of the highway, the preferred concept was modelled based on the following assumptions:

- 2:1 sand cut for 1.5m of depth.
- 0.25:1 rock cut for the remaining depth.

Figure 34 shows a sample cross section for the north approach ramp.

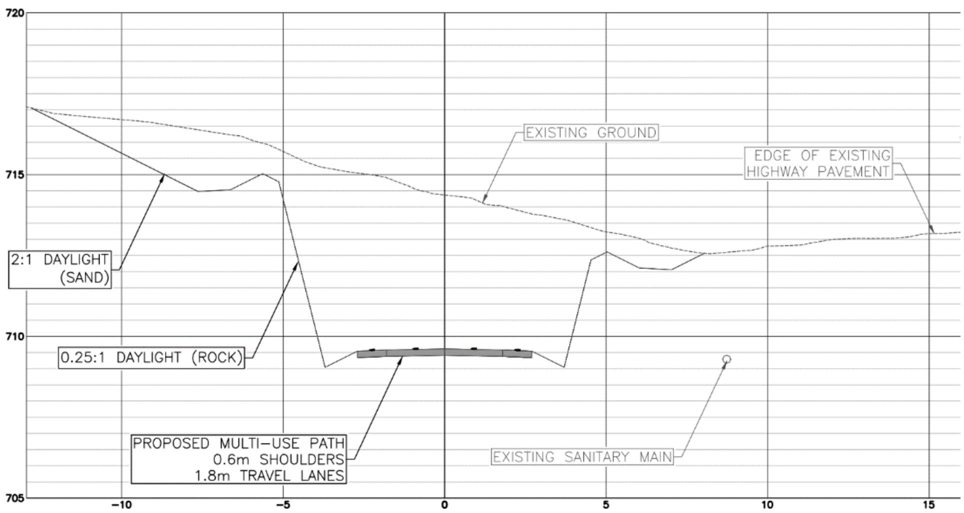


Figure 34: Takhini North Connection, Cross-Section of West Approach Path

Drainage Considerations

A hydrological study was not within the scope of this preliminary feasibility study and should be considered in subsequent phases of design. However, the preliminary design has incorporated significant considerations for drainage:

- No low points exist within the underpass structure. Water collected along the path is expected to drain through the north and east approach ramps.
- Ditches are provided at the top of the rock cuts on either side of the west/east approach ramp to catch incoming water from the highway and the slope adjacent to the path. A hydrological study would be required to confirm the necessary capacity of these ditches. The ditch along the north approach does slope towards the proposed underpass structure and a drainage solution such as a culvert under the highway would likely be required.

Utility Considerations

The west approach ramp is south of the existing sanitary main and would likely not require reducing the ground cover of the main, mitigating the need for additional utility insulation or relocation. However, on the north approach ramp, reducing the soil cover to approximately 1 metre was required; this is lower than the 2.8 metres required for uninsulated sewage mains required by the City of Whitehorse. Insulation of the sewage main could be warranted.

Other Challenges

Other challenges include:

- Some tree removal would be required on the south side of the highway (however; tree removal is a common part of highway infrastructure projects elsewhere in Whitehorse).
- Existing trails on the north and south side of the highway would need to be minorly re-aligned to tie into the proposed underpass.
- Electrical utility relocation may be required.
- Highway clear zone and barriers: an underpass adjacent to the Alaska Highway may be within the clear zone and require barriers (e.g., concrete barriers or guardrails). Further design work would confirm the necessary clear zone of the Alaska Highway in the vicinity of the proposed underpasses. If the proposed underpass approach ramps are within this clear zone, then barriers would be required as shown in the concept drawings.
- It is assumed that rock cut would be required for a portion of the western approaches.

Other Considerations

Residents have raised concerns that will need to be considered in future work, including:

- Impact to runoff and spring range to homes along Arnhem Road, which already experience drainage issues.
- Increased local traffic if non-residents use the underpass to access the Mt. McIntyre trail network.
- Increased wildlife access to the subdivision. Conversely, the underpass could provide a safer route for wildlife. For example, there was a yearling bear hit on the Alaska Highway at this location, and there is potential that this wildlife death could have been avoided had there been safe passage.

4.4 AIRPORT CONNECTION

4.4.1 INITIAL ALIGNMENT OPTIONS EVALUATION AND SCREENING

Only one alignment option was considered at this location. The primary challenges associated with this connection include:

- Any connection must be north of the Airport to produce active transportation network connection benefits.
- Steep hills exist to the west of the Alaska Highway, limiting the potential footprint of the underpass.
- Existing water mains run east of the highway.

4.4.2 PREFERRED ALIGNMENT OPTION

Figure 35 shows a concept for a potential underpass that ties into the existing trail that runs north of the airport, and ties into the trails that run west of the highway. A connection that directly ties into the existing trail north of the airport presents relatively favorable grades for an underpass; the ground east of the highway is approximately 8 metres below the elevation of the highway. On the other side, the ground is above the elevation of the highway; however, it is possible to route approach ramps that tie into where there is an existing gravel shoulder along the highway.

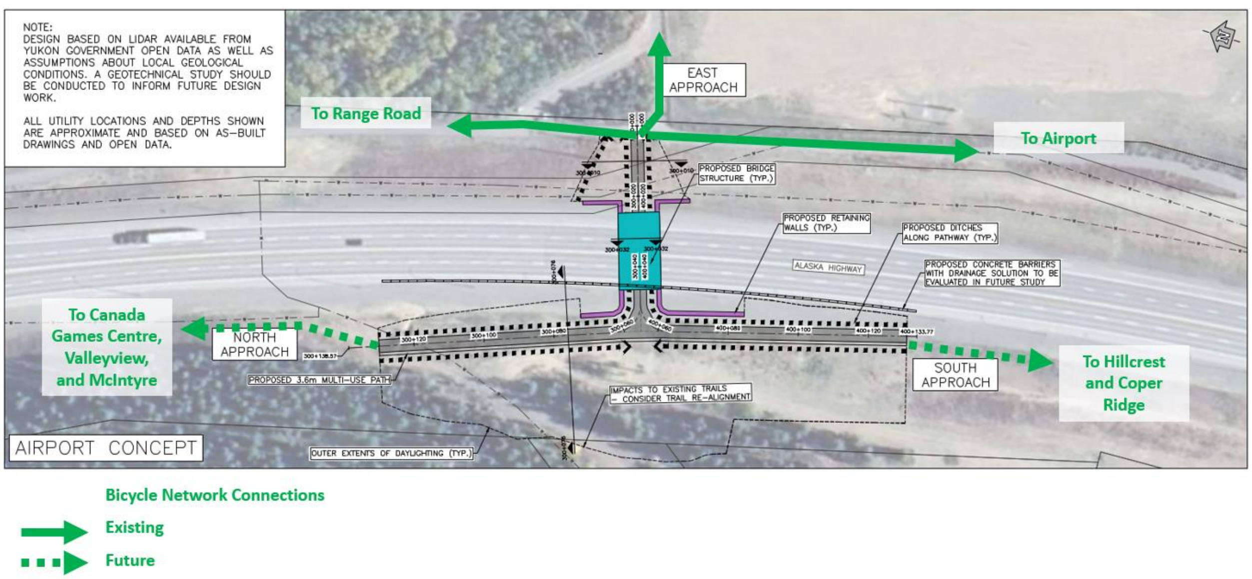


Figure 35: Airport Connection Preferred Concept

Within the east approach, the path can be built at a 2% grade. On the west side of the highway, the north ramp is a maximum of 8% and is approximately 77 metres from the entrance to the tunnel, and the south ramp is a maximum of 4.8% and runs 68 metres from the entrance of the tunnel.

Drainage Considerations

This concept for this connection features ramps that slope towards the underpass on the north and south sides of the tunnel, and an approach ramp that slopes away from the tunnel on the east side. It is not possible to construct approach ramps slope away from the tunnel on the west side.

To avoid creating a low point within the tunnel structure, reducing the structure clearance to 3.0 metres is required. However, this would still allow a PistenBully 100 (height of 2.6m) to travel under the highway.

Based on observations on-site and client feedback, the ground in this region is primarily sand; accordingly, the design features 2:1 cut slope long all approach ramps. Additionally, ditches are proposed on either side of the path to collect water incoming from the highway and adjacent slopes. This includes a ditch along the south side of the north and south approach ramps; a culvert would be required to transport water collected by this ditch to the other side of the highway. A hydrological study would be required to confirm the required capacity for any ditches.

Based on the analysis, a design solution that features 2:1 cut slope on either side of the pathway would likely leave insufficient room for a new ditch adjacent to the highway, particularly along the south approach. If this is the case, then drainage improvements (e.g., a new enclosed storm sewer and catch basins) would be required along the highway to collect any runoff accumulated along the concrete barriers. **Figure 36** shows a cross-section of the north approach ramp.

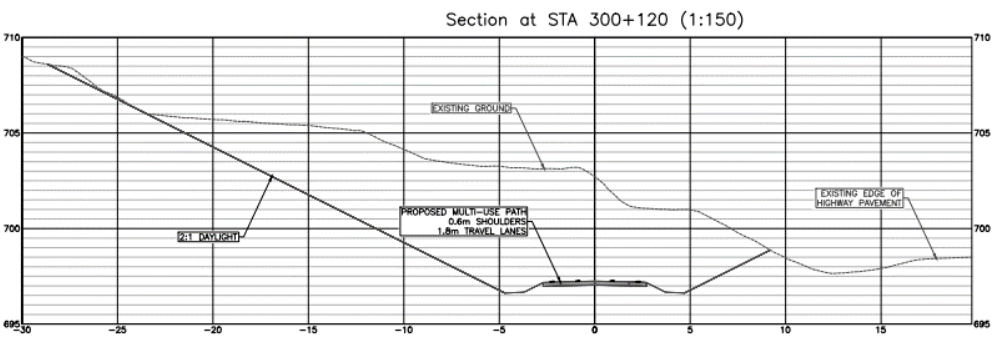


Figure 36: Airport Connection Cross-section, North Approach

Utility Considerations

The design would require reducing the ground cover over the existing watermains to approximately 1.1 metres. This is lower than the 3.0 metres required by the City of Whitehorse; utility insulation or relocation would be required.

Other Challenges

Other challenges include:

- The trails on the west side would need to be re-aligned with the new underpass, and a new trail along the highway would need to be created to tie into the proposed south approach.
- Electrical utility relocation may be required.
- Highway clear zone and barriers: an underpass adjacent to the Alaska Highway may be within the clear zone and require barriers (e.g., concrete barriers or guardrails). Further design work would confirm the necessary clear zone of the Alaska Highway in the vicinity of the proposed underpasses. If the proposed underpass approach ramps are within this clear zone, then barriers would be required as shown in the concept drawings.

4.5 COST ESTIMATES

Preliminary, high-level order-of-magnitude cost estimates for each option are shown in **Table 3** and **Table 4**. Note that these cost estimates assume that water and sewage main relocation is **not** required, as well as other assumptions outlined in this report. It should be emphasized that these are high-level, order-of-magnitude costs for preliminary purposes, and have not been based on actual conceptual or detailed design work. Based on this, it is estimated that the cost of the underpasses at each location would be between $4 and 10 million.

While it is recognized that these are not trivial investments, they are consistent with the annual level of spend the Yukon Government makes on the Alaska Highway. For context, the Government of Yukon has spent almost $40 million on the Alaska Highway within Whitehorse city limits over the past 8 years. Thus, a project costing on the order of $5 million is of similar scale to a single year of Government of Yukon expenditure on the Highway in Whitehorse. However, these underpasses would provide significant health and safety improvements for Yukoners. Furthermore, these are key network enabling investments that will unlock active transportation opportunities for people west of the Alaska Highway. In addition, there are anticipated to be significant external funding opportunities available for this type of infrastructure, including federal funding opportunities, and the Yukon Government routinely accesses external funding for projects of this scale.

Table 3: Takhini North Underpass Cost Estimate

Item	Quantity	Unit	Unit Rate	Cost
Rock Cut	9600	Cubic Meter	$65	$624,000
Sand Cut	7500	Cubic Meter	$35	$262,500
Retaining Walls	300	Square Meter	$2,000	$600,000
Span Area	150	Square Meter	$6,000	$900,000
MUP Area	1150	Square Meter	$200	$230,000
Concrete Barriers	260	Lineal Meter	$200	$52,000
Sewage Main Insulation		Lump Sum		$100,000
Electrical Relocation		Lump Sum		$100,000
Culvert		Lump Sum		$100,000
Lighting		Lump Sum		$100,000
Subtotal				$3,068,500
Contingency			50%	$1,534,250
Design Costs			15%	$690,413
General Requirements (Traffic Management, Mobilization, etc.)			10%	$460,275
Total				$5,753,438
			Rounded	**$5,800,000**
			Expected Maximum (+50%)	**$8,700,000**
			Expected Minimum (-30%)	**$4,060,000**

Table 4: Airport North Underpass Cost Estimate

Item	Quantity	Unit	Unit Rate	Cost
Net Cut - Sand	22000	Cubic Meter	$35	$770,000
Retaining Walls	400	Square Meter	$ 2,000	$800,000
Span Area	260	Square Meter	$ 6,000	$ 1,560,000
MUP Area	840	Square Meter	$200	$168,000
Concrete Barriers	150	Lineal Meter	$200	$ 30,000
Water Main Insulation		Lump Sum		$200,000
Lighting		Lump Sum		$100,000
Highway Drainage		Lump Sum		$200,000
Electrical Relocation		Lump Sum		$100,000
Culvert		Lump Sum		$100,000
Subtotal				$ 3,628,000
Contingency			50%	$ 1,814,000
Design Costs			15%	$816,300
General Requirements (Traffic Management, Mobilization, etc.)			10%	$544,200
Total				$ 6,802,500
			Rounded	**$6,900,000**
			Expected Maximum (+50%)	**$10,350,000**
			Expected Minimum (-30%)	**$4,830,000**

5.0 SUMMARY AND NEXT STEPS

As noted previously, the scope of this study was to conduct a high-level feasibility review to determine whether underpasses at these locations could be feasible. This study demonstrates that the proposed underpasses are feasible and have a compelling case based on social equity principles, climate action, health and safety, and the active mobility network that would be enabled.

This study was based on limited data and information, and did not include topographic survey, geotechnical engineering, or conceptual or detailed design. This study has concluded that it appears that underpasses at both locations are feasible, but that further technical work would be required through future studies. Other design considerations not in the scope of this study that should be considered as part of further design work includes the following:

- **Geotechnical study**: A geotechnical study was not in the scope of this study, and the assumptions used for concept design are based on observations at site and feedback from the client. A geotechnical study should be conducted to confirm the feasibility of the cut slopes shown.
- **Hydrology study**: As the proposed underpasses feature approach ramps located between a highway and adjacent slope, redirecting incoming precipitation is a critical design concern to mitigate the risk of flooding. The concepts in this study either feature ditches above the rock cuts/retaining walls (Takhini North Connection, see **Figure 34**), or ditches adjacent to the multi-use path (Airport Connection, see **Figure 36**). However, a hydrology study and further design work is required to quantify runoff from the slopes and highways and confirm overall project feasibility.
- **Alterations to the existing profile of the highway:** This study assumes the existing vertical profile of the Alaska Highway would be maintained, and the length and depth of the proposed underpasses are designed accordingly. However, raising the profile of the highway would reduce the necessary depth of an underpass. It is our understanding that Yukon plans to widen the highway in the general area of the Takhini North connection; when this occurs, adjusting the profile of the highway could be explored alongside the creation of an underpass near Takhini North.
- **Highway clear zone and barriers:** An underpass adjacent to the Alaska Highway may be within the clear zone and require barriers (e.g., concrete barriers or guardrails). Further design work would confirm the necessary clear zone of the Alaska Highway in the vicinity of the proposed underpasses. If the proposed underpass approach ramps are within this clear zone, then barriers would be required as shown in the concept drawings.

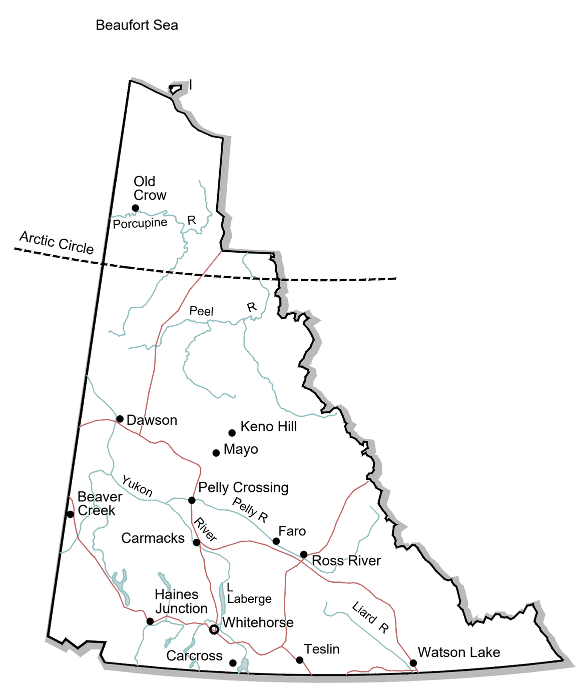
Further to the findings of this study, it is suggested that the Cycling Association of Yukon work with partners, including the City of Whitehorse and Yukon Government, to identify funding to conduct a more detailed engineering review of the proposed concepts identified in this study. This study should investigate each of the issues noted above as part of advancing the concepts in this study to preliminary and detailed design.

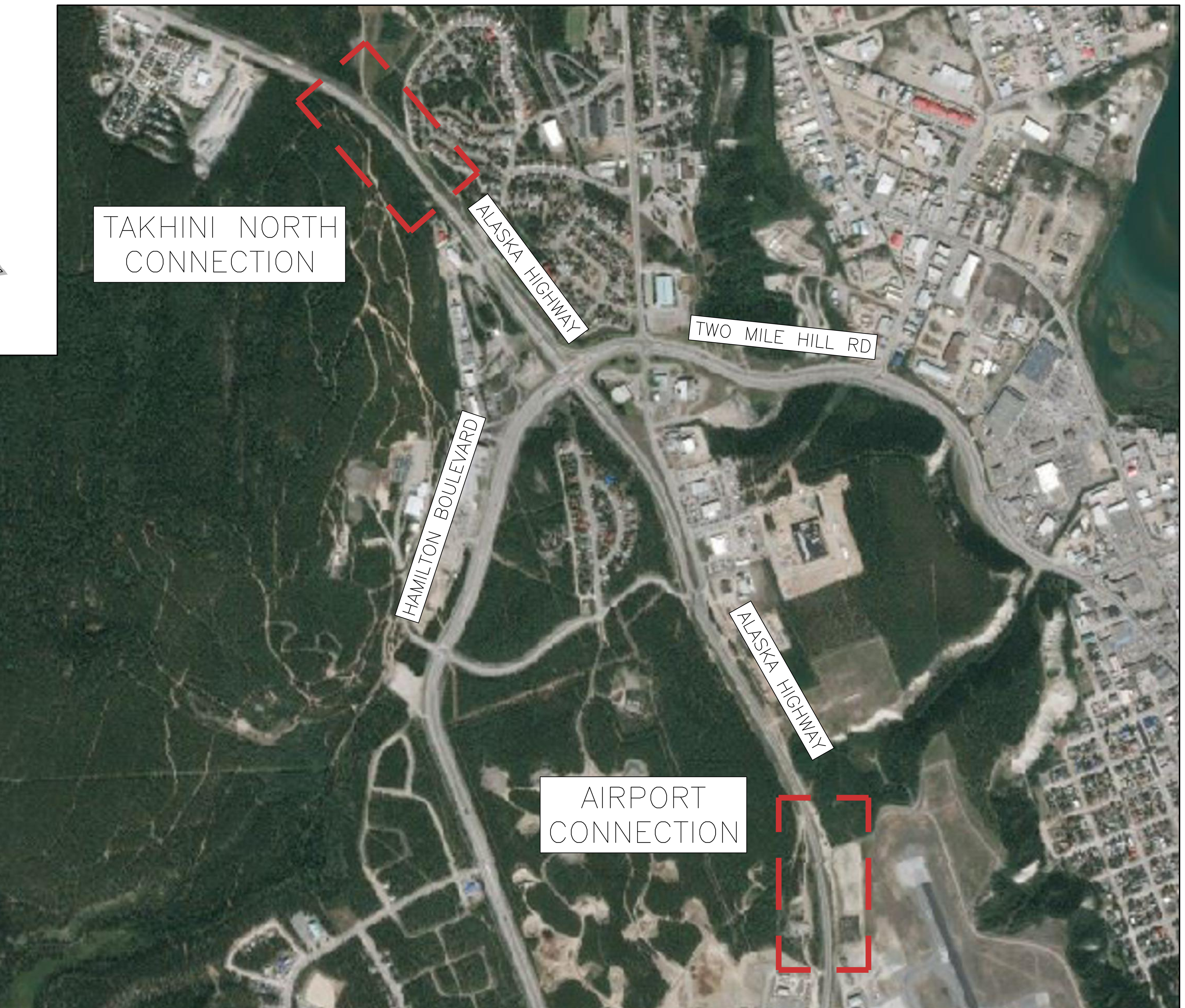
The two projects represent a significant investment in the City of Whitehorse, with the individual cost estimated between approximately $4 to 10 million depending on site specific conditions. Leveraging any cost-saving opportunities should be explored, such the timing of implementation with the other schedule major highway alternations such as right-of-way widening. The City and Territory should continue to actively pursue any available grant opportunities and continue to monitor available opportunities.

APPENDIX A:
CONCEPTUAL PLANS

ALASKA HIGHWAY UNDERPASS FEASIBILITY STUDY

CYCLING ASSOCIATION OF YUKON





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Sheet List Table	
Sheet Number	Sheet Title
C00	COVER
C01	TAKHINI NORTH CONNECTION
C02	TAKHINI NORTH CONNECTION
C03	TAKHINI NORTH CONNECTION
C04	AIRPORT CONNECTION
C05	AIRPORT CONNECTION

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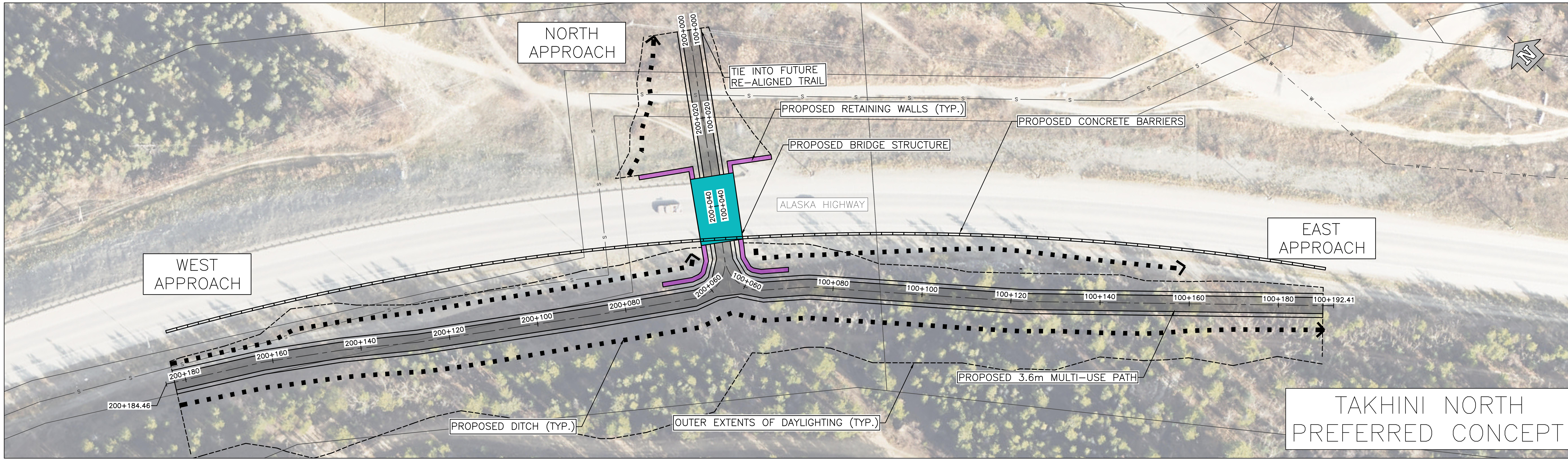
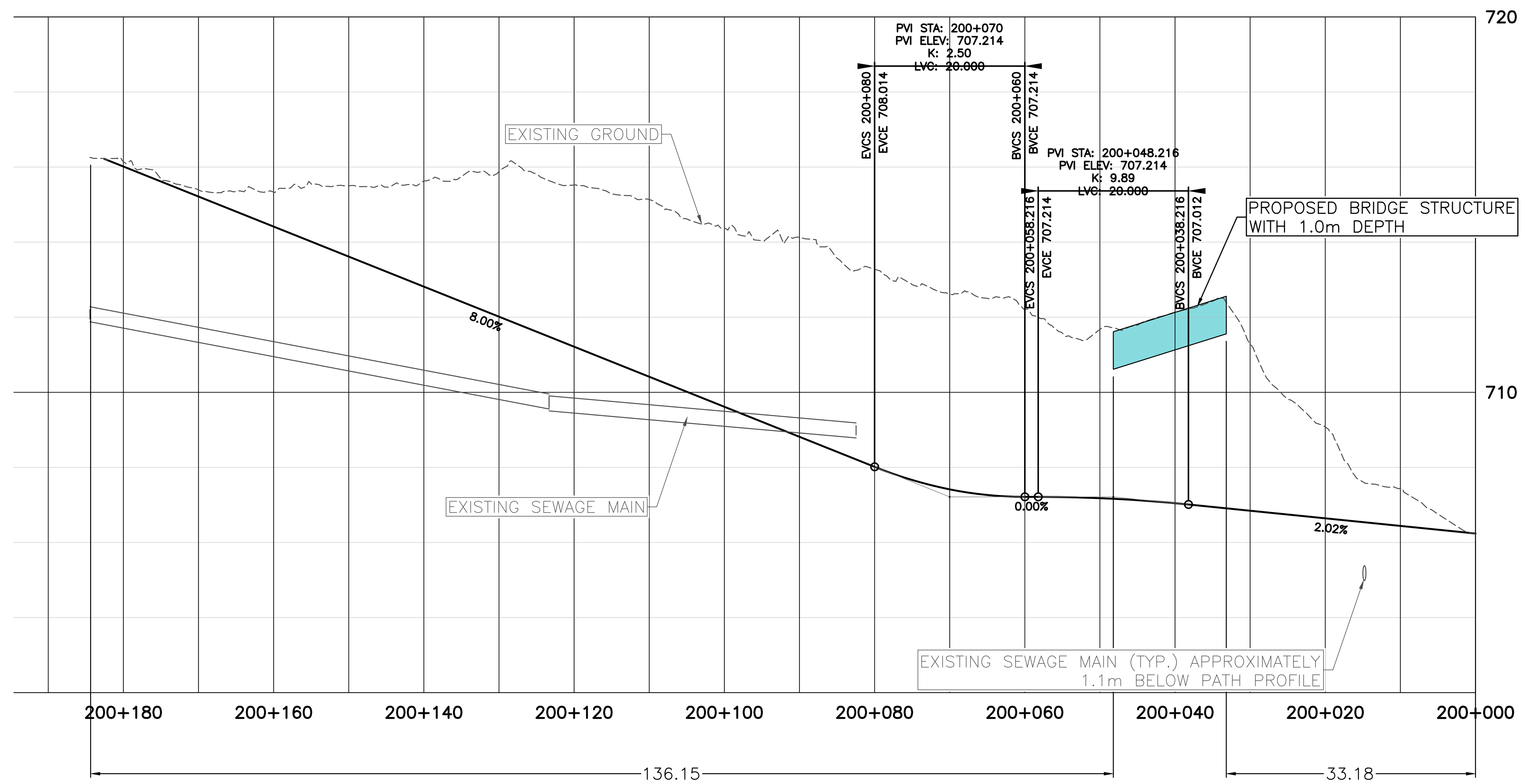


Takhini North Vertical Profile - West and North Approaches (L200)



NOTE:
DESIGN BASED ON LIDAR AVAILABLE FROM YUKON GOVERNMENT OPEN DATA AS WELL AS ASSUMPTIONS ABOUT LOCAL GEOLOGICAL CONDITIONS. A GEOTECHNICAL STUDY SHOULD BE CONDUCTED TO INFORM FUTURE DESIGN WORK.

ALL UTILITY LOCATIONS AND DEPTHS SHOWN ARE APPROXIMATE AND BASED ON AS-BUILT DRAWINGS AND OPEN DATA.

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Coordinate System: -
Compilation Date: -

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Scale 1:500H 0 10 20m
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Designed by ME
Drawn by ME

ALASKA HIGHWAY UNDERPASS STUDY
TAKHINI NORTH CONNECTION PLAN AND PROFILE

Sheet Number 1 of 5
Project Number 5506.0001.01
Drawing Number C01
Revision ----

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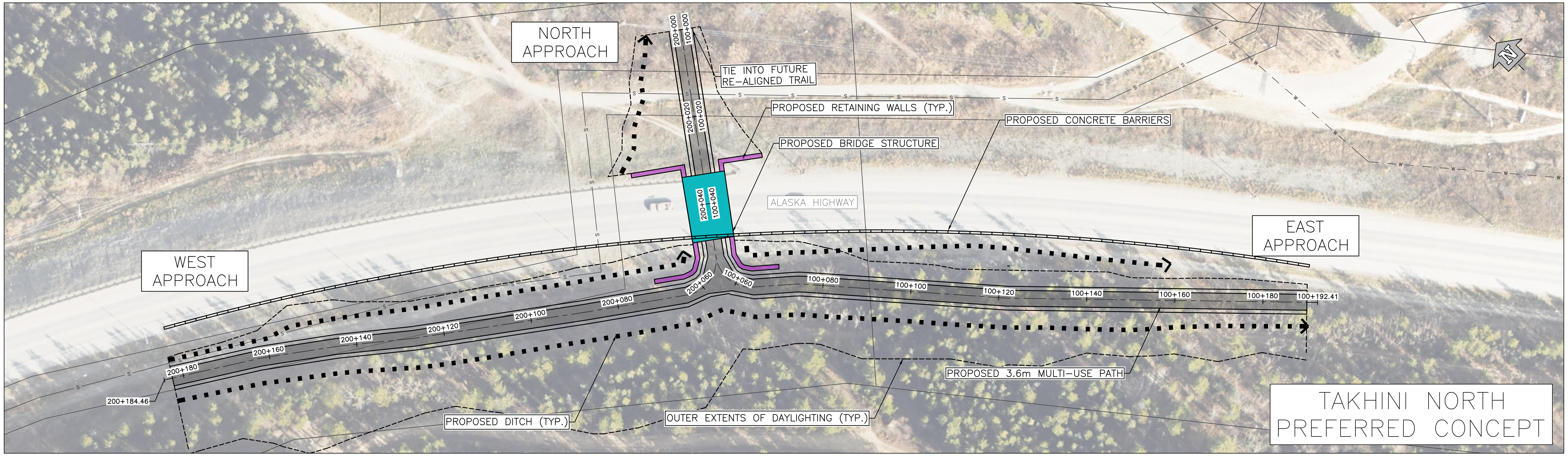
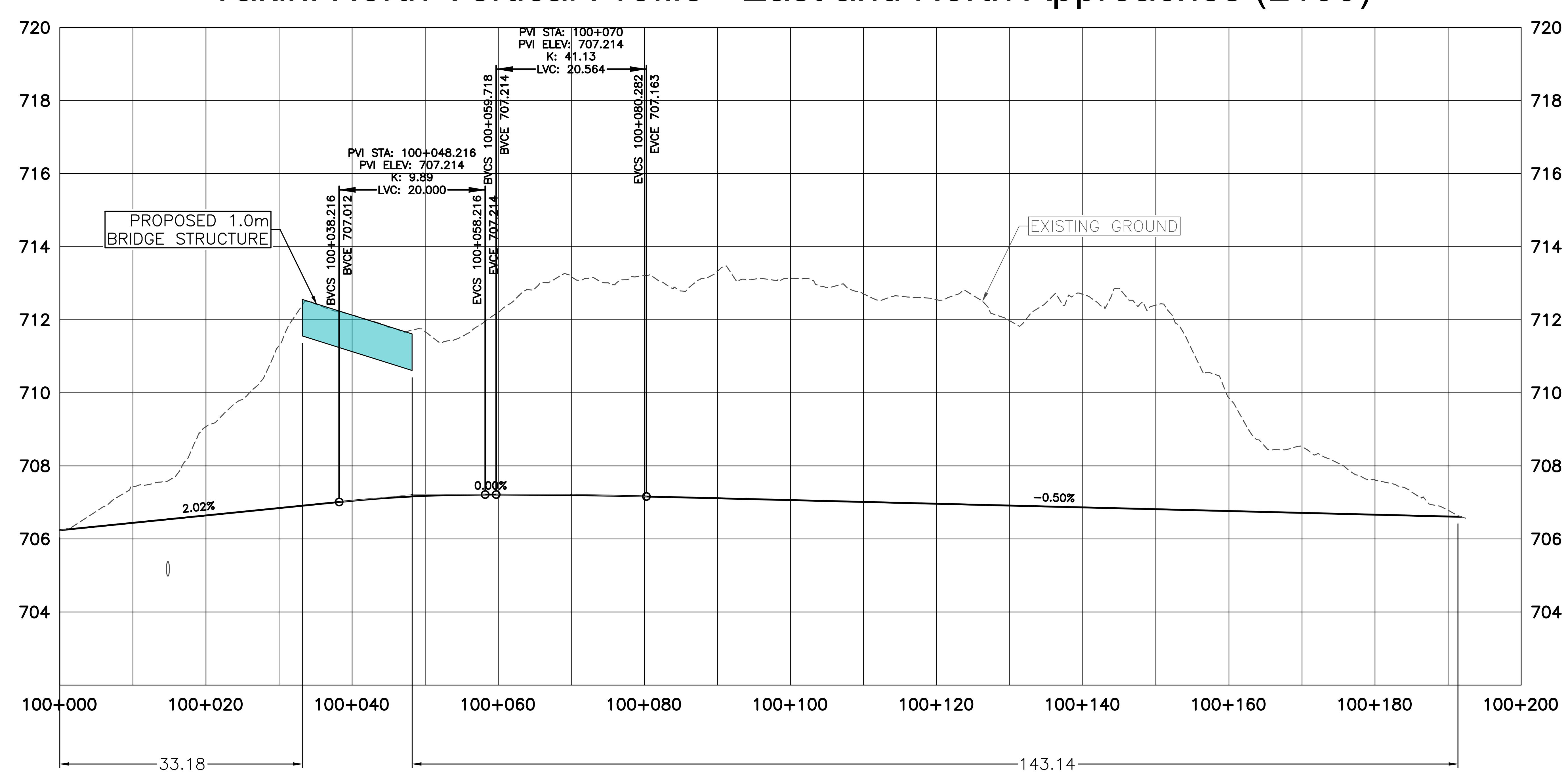


Takini North Vertical Profile - East and North Approaches (L100)



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TAKHINI NORTH CONNECTION PLAN AND PROFILE

Sheet Number 2 of 5
Project Number 5506.0001.01
Drawing Number C02
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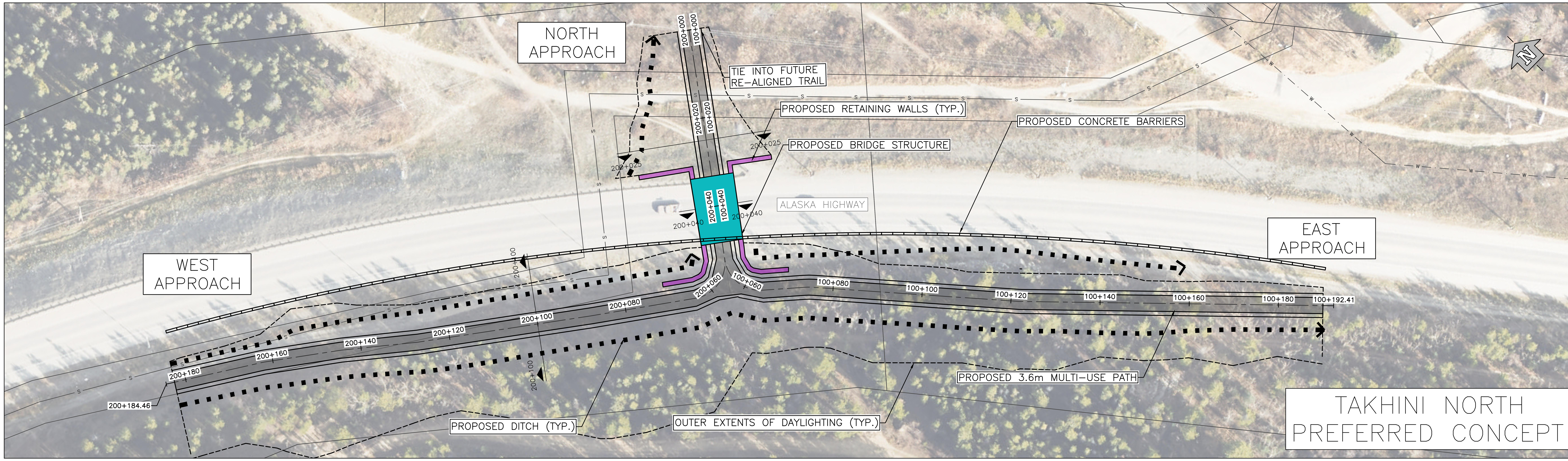

TAKHINI NORTH PREFERRED CONCEPT

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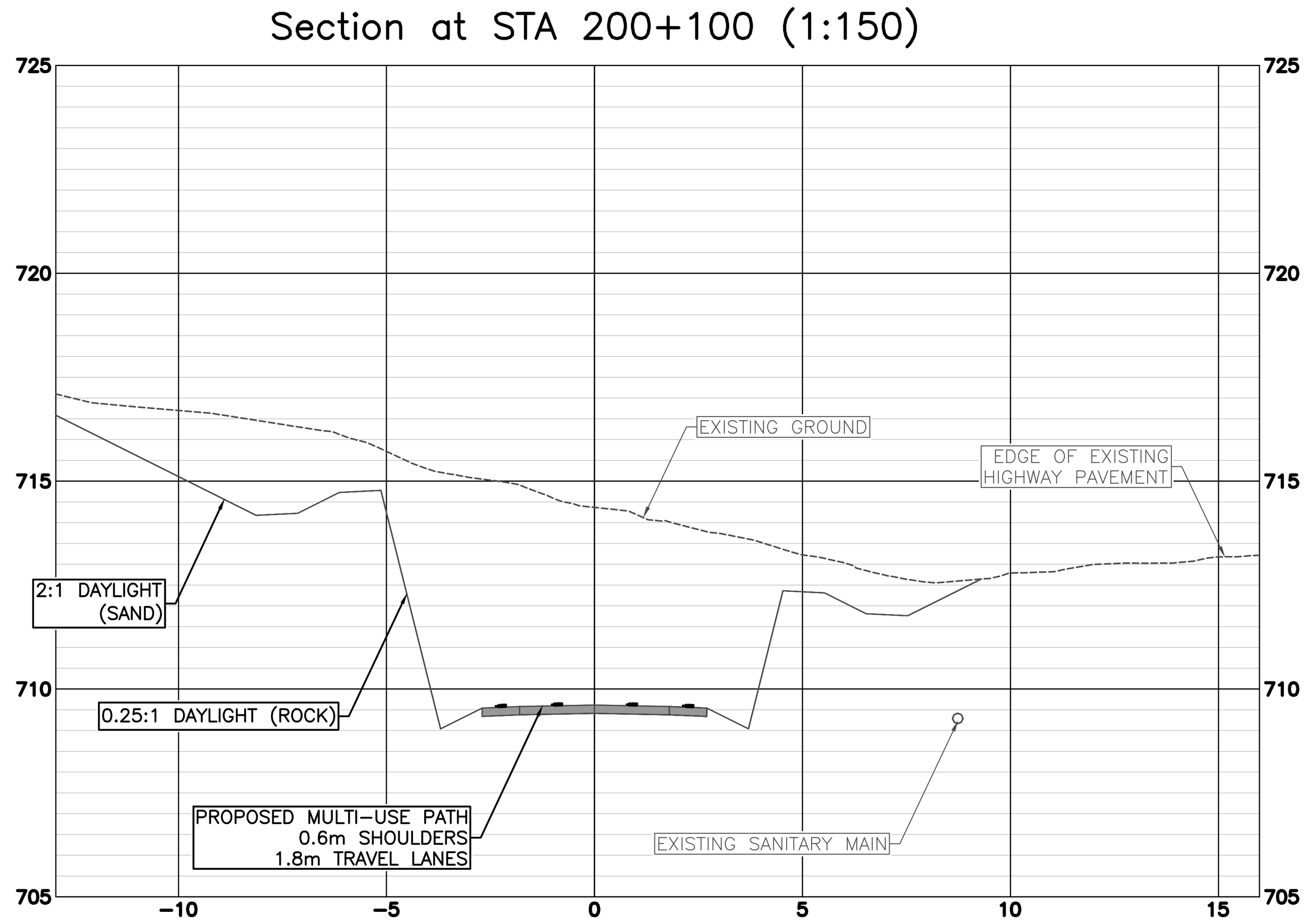

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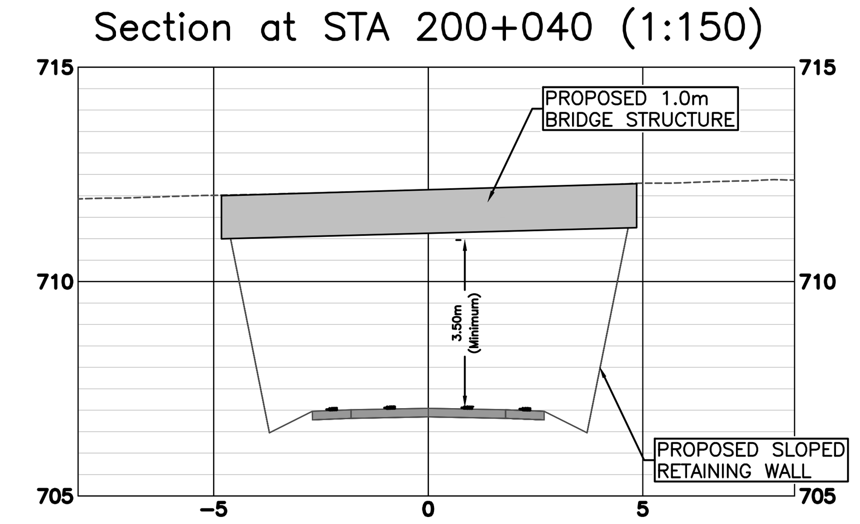

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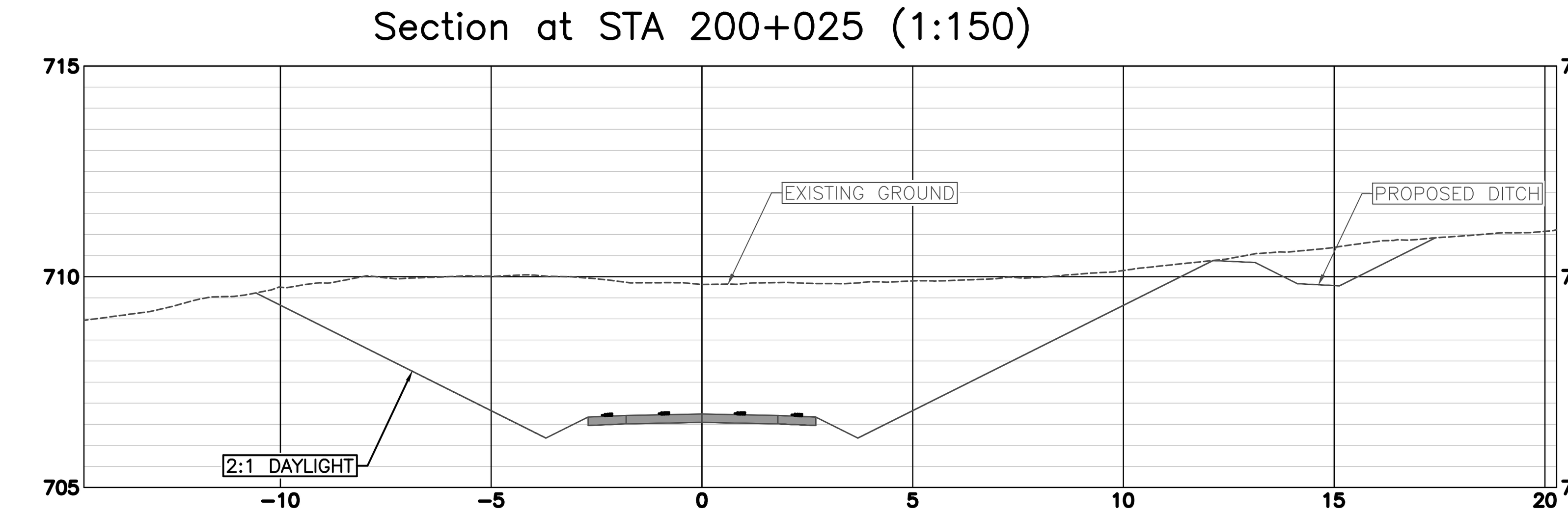

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ALL UTILITY LOCATIONS AND DEPTHS SHOWN ARE APPROXIMATE AND BASED ON AS-BUILT DRAWINGS AND OPEN DATA.

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ALASKA HIGHWAY UNDERPASS STUDY
TAKHINI NORTH CONNECTION CROSS SECTIONS

Sheet Number 3 of 5
Project Number 5506.0001.01
Drawing Number C03
Revision ----

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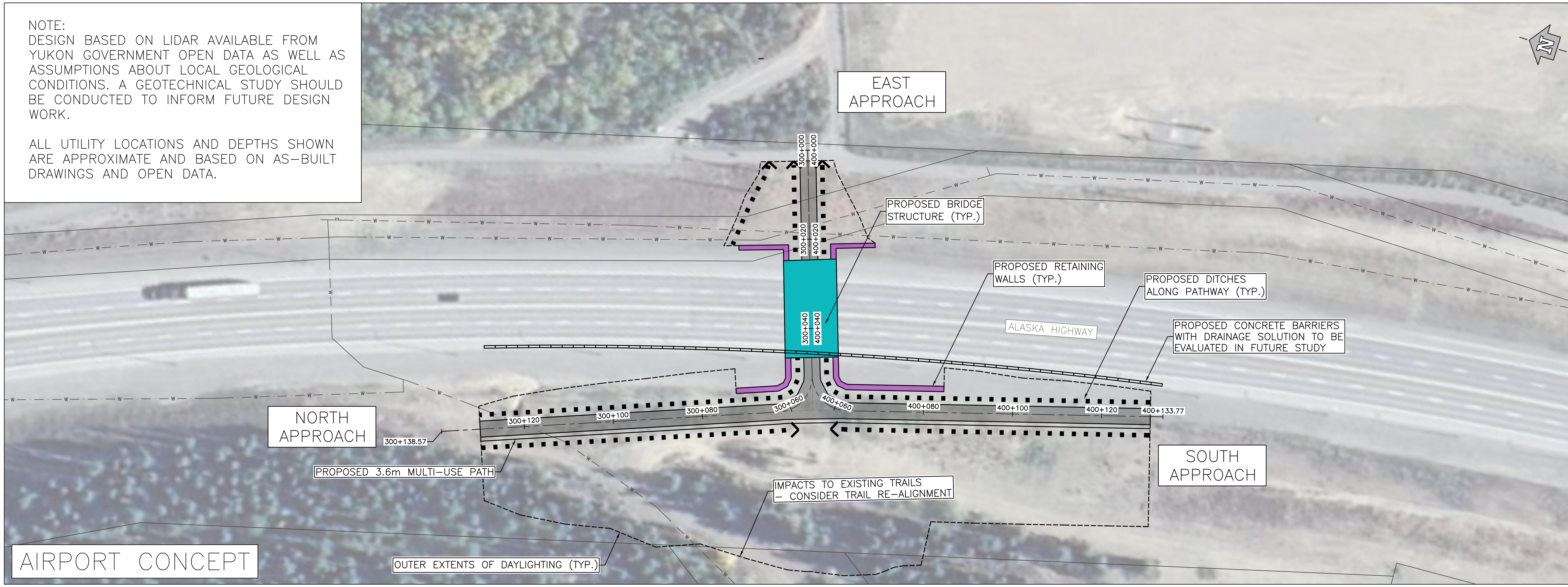
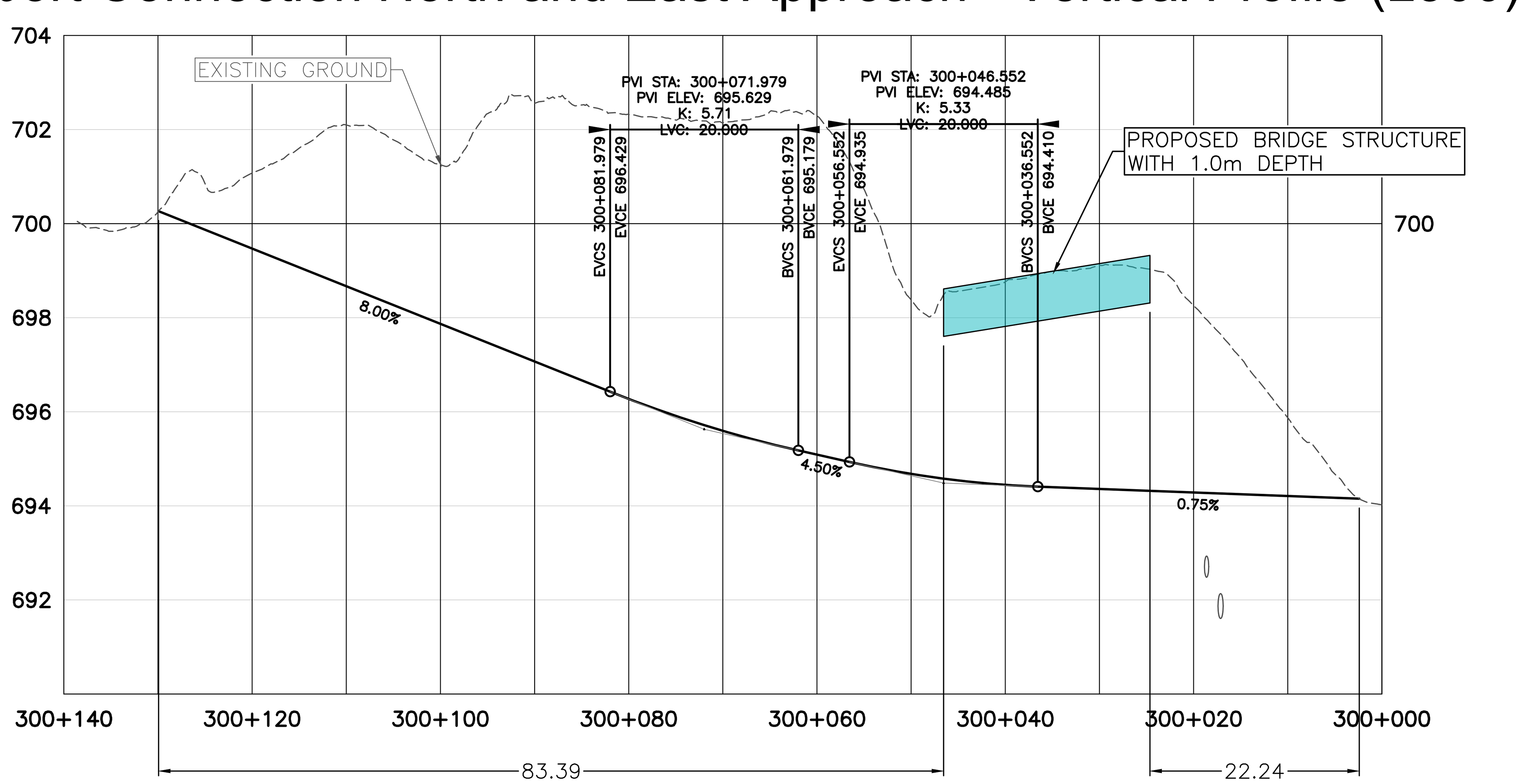
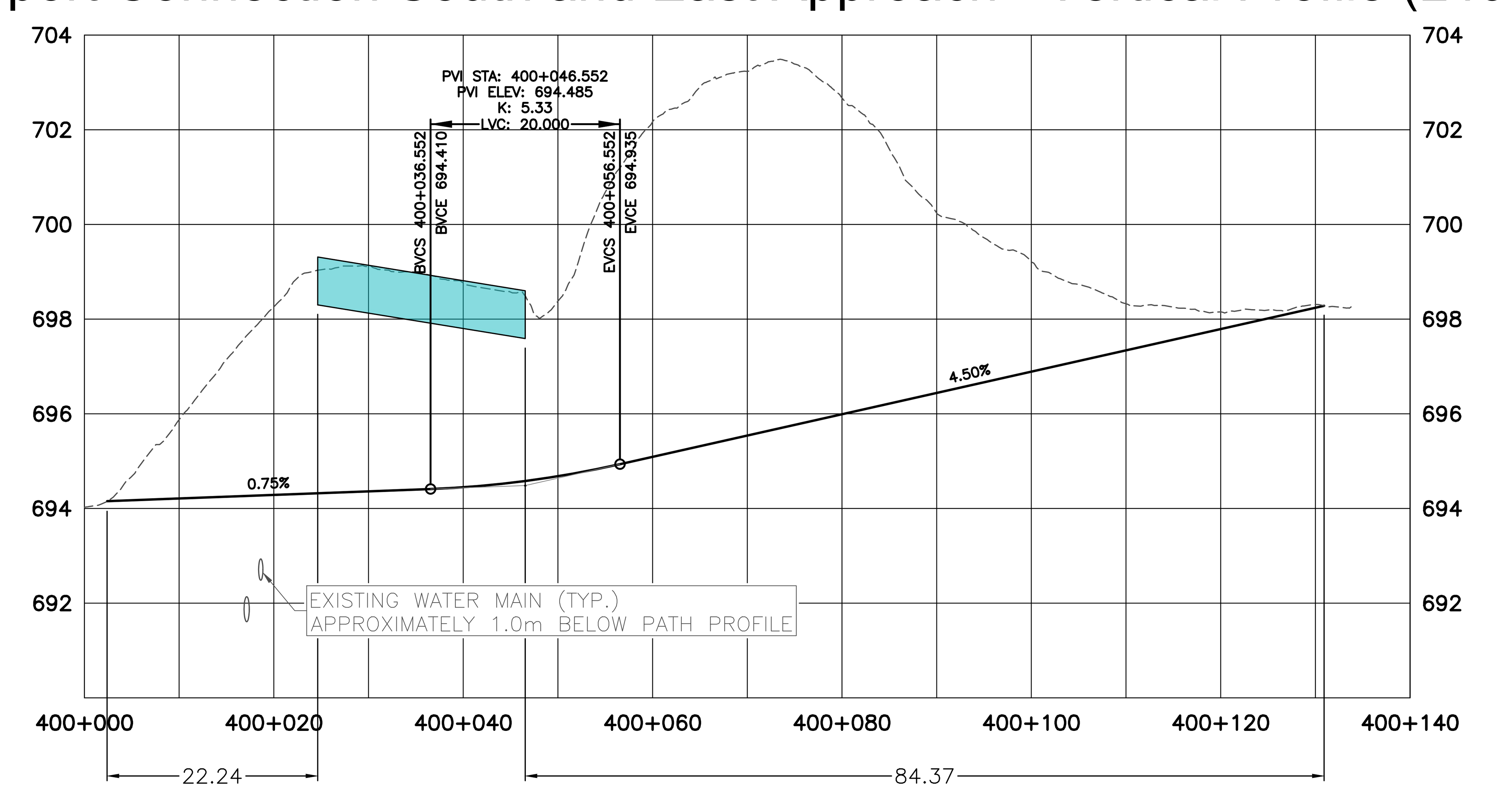


AIRPORT CONCEPT

Airport Connection North and East Approach - Vertical Profile (L300)



Airport Connection South and East Approach - Vertical Profile (L400)



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ALASKA HIGHWAY UNDERPASS STUDY
AIRPORT CONNECTION PLAN AND PROFILE

Sheet Number 4 of 5
Project Number 5506.0001.01
Drawing Number C04
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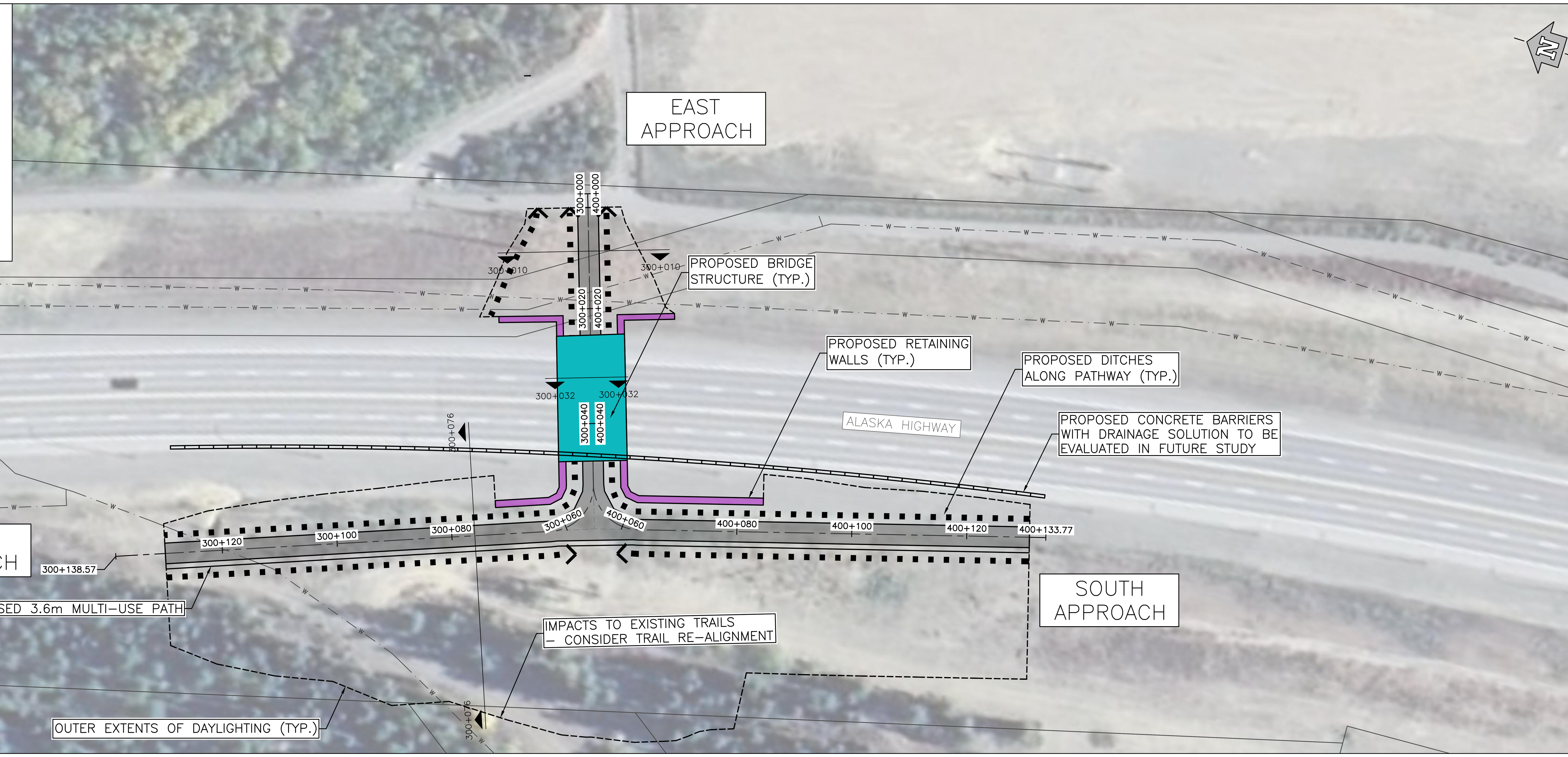

AIRPORT CONCEPT

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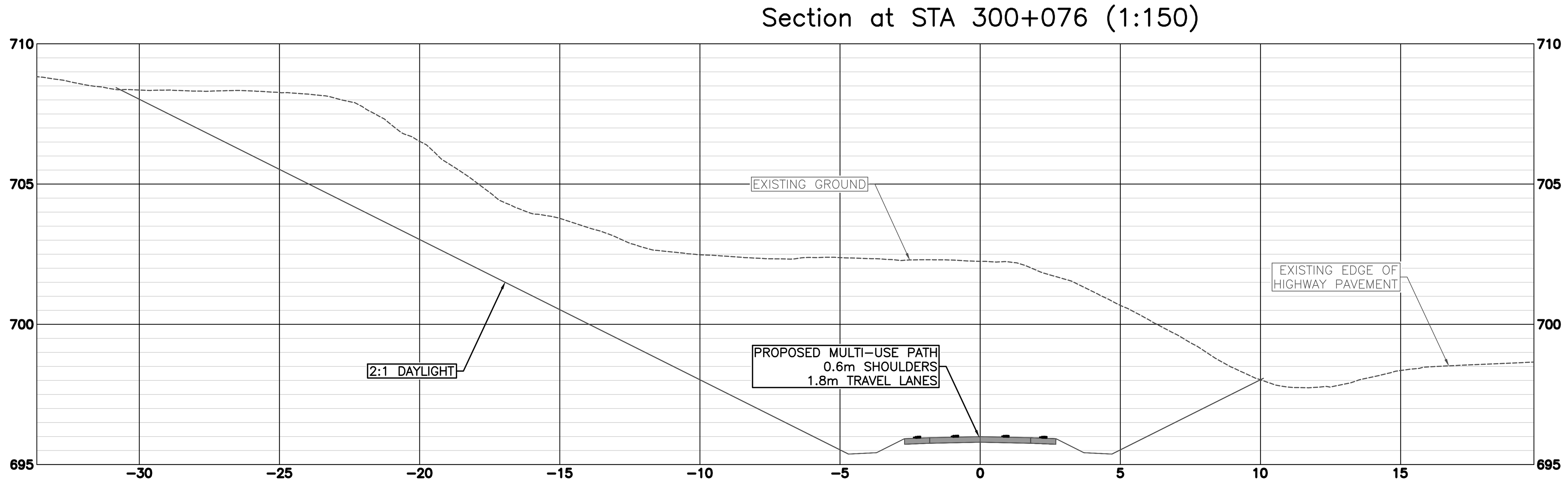

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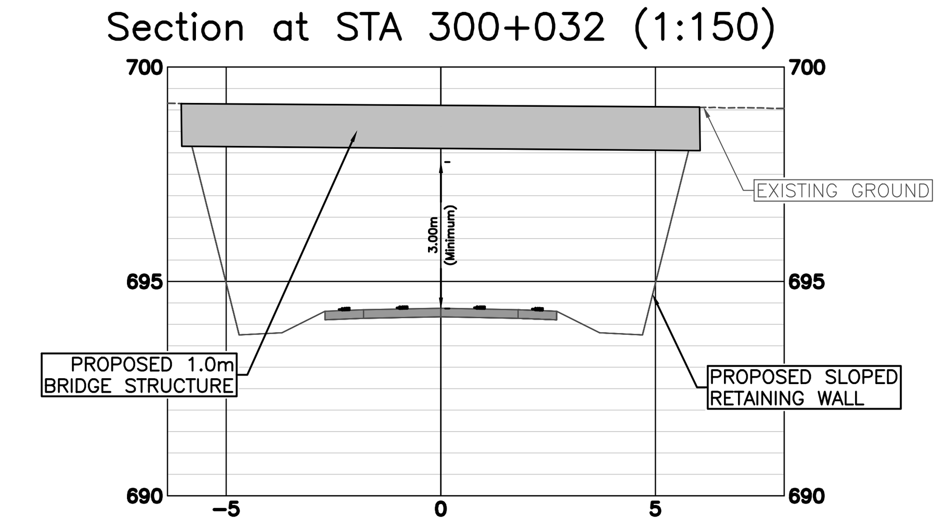

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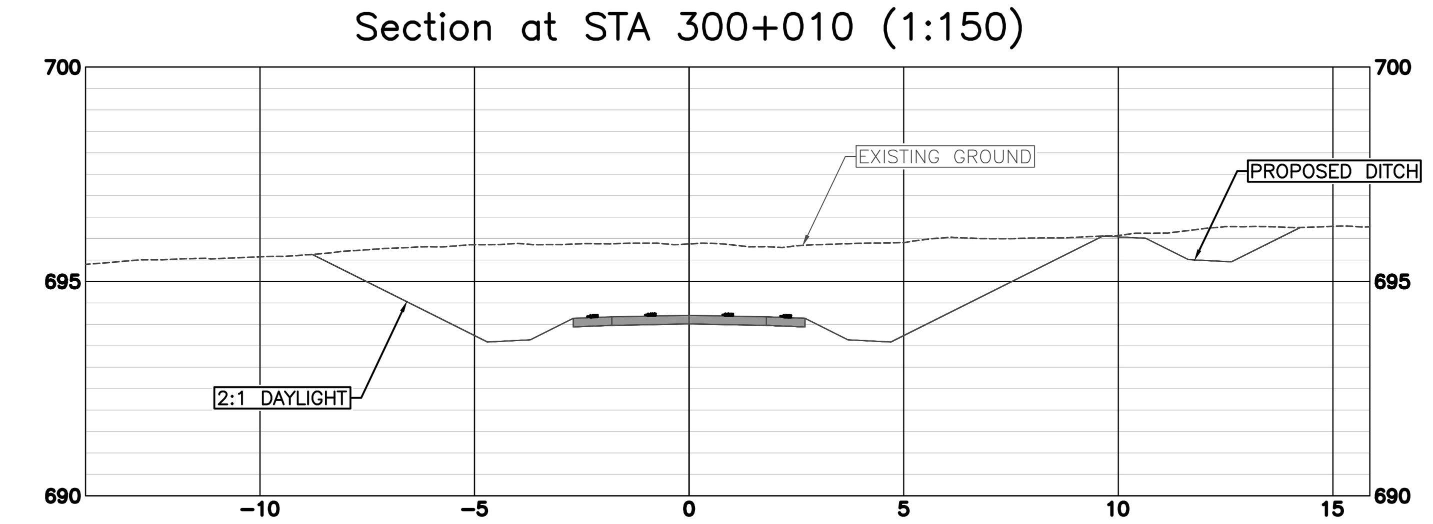

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ALASKA HIGHWAY
UNDERPASS STUDY
AIRPORT CONNECTION
CROSS SECTIONS

Sheet Number 5 of 5
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Drawing Number C05
Revision ----

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