

## **MEMORANDUM**

**Subject:** Betasso Preserve Connection Trail Feasibility Study  
**To:** Matt Wempe, Boulder County Transportation  
**CC:** Al Hardy, Boulder County Parks and Open Space  
**From:** Karen Fuhr, Muller Engineering  
**Date:** August 16, 2016

---

The purpose of this study is to evaluate the engineering feasibility of potential trail connections to the Betasso Open Space Preserve identified by Boulder County Parks and Open Space staff. Three locations were identified for study, denoted as Options A, B, and C in this memo and the attached appendices. A fourth option, Option D, includes extending the Boulder Canyon Trail to the Betasso Link Trail and was studied in the 2011 Boulder Canyon Trail Feasibility Study. This study examines the feasibility of extending an access trail from the Boulder Canyon Trail to the property line of the Betasso Open Space Preserve. A mountain bike trail would be constructed by Boulder County Parks and Open Space beginning at the terminus of the selected option, to connect to the existing trail system within the park. The options will be vetted through the Betasso Preserve Management Plan amendment process and include opportunities for public input.

This memorandum includes a decision matrix (Figure 3) with discussion of the relative merits of each option considered, a summary of the staircase design, geotechnical investigation, and renderings, as well as a comparative cost estimate (Figure 2). The paragraphs below discuss each of the options in detail. The attached appendices include renderings, schematic drawings of the proposed improvements, and supplemental information used in the development of the comparative costs. The detailed borehole logs of the geotechnical investigation by Yeh and Associates, Inc. are also attached.

## **PROJECT LOCATION**

The map on the following page shows the general project location as well as the locations evaluated under each of the options studied.

THIS PAGE INTENTIONALLY LEFT BLANK –  
INSERT MAP FROM PARKS AND OPEN SPACE HERE

## **OPTION A**

Option A creates a new bicycle and pedestrian trail starting at the intersection of SH 119 / Boulder Canyon Drive and Fourmile Canyon Drive, extending up Fourmile Canyon, passing through the Boulder Adventure Lodge, to the beginning of the mountain bike trail into Betasso Preserve. The new trail switchbacks downhill from the intersection on the south side of SH 119 and passes under a 16' wide by 10' tall concrete box culvert underpass beneath SH 119 between Fourmile Creek and Fourmile Canyon Drive. From there the trail heads north paralleling the east side of Fourmile Creek, with an uphill soil nail cut-wall separating the trail from Fourmile Canyon Drive.

Near the Adventure Lodge there are two possible trail alignment options, denoted Option A1 and Option A2 in the plan sheets:

- Option A1 turns west just south of the Adventure Lodge Property line, traveling along the northern portion of the 38899 Boulder Canyon Drive parcel, and crosses Fourmile Creek on a bridge. The mountain bike trail into Betasso Preserve would begin where the bridge ends at the base of the hillside.
- Option A2 travels further north onto the Adventure Lodge property before turning west towards the base of the mountain bike trail.

Option A1 and A2 both require easements on the 38899 Boulder Canyon Drive parcel. The alignment of Option A1 is located on this parcel from approximately station 15+50 to station 20+00, while the alignment of Option A2 is located on this parcel from station 15+50 to station 18+50. The future mountain bike trail requires an additional easement on the west side of this parcel to access Betasso Preserve. Functionally, these trail easements occupy more than half of the property.

## **OPTION B**

Option B creates a new access into Betasso Preserve via a 48-step staircase on the north side of SH 119 at the existing private driveway into 38899 Boulder Canyon Drive. Starting from the existing Boulder Canyon Trail, a pedestrian bridge crosses Boulder Creek immediately downstream of the confluence with Fourmile Creek. The trail then goes down into a 16' wide by 10' tall concrete box culvert underpass beneath SH 119, switchbacks up to grade on the existing highway pulloff at the northeast corner of SH 119 and Fourmile Canyon Drive, before crossing Fourmile Canyon Drive at the existing at-grade intersection. From there, the trail parallels the north side of SH 119 for approximately 250 feet to the base of the staircase.

The future mountain bike trail begins at the top of the staircase and switchback up the mountain. As with Option A, the mountain bike trail alignment requires a trail easement on the western portion of 38899 Boulder Canyon Drive that effectively takes up more than half of the parcel. Option B also has potential impacts to the front of 38899 Boulder Canyon Drive. Although the 250-foot long portion of trail in front of the parcel can be constructed in existing CDOT right-of-way, a temporary construction easement in the private parcel will likely be required. A number of trees along SH 119 that currently serve as a buffer between the highway and the private residence on this parcel will also be removed for wall and trail construction.

The highway pulloff at the northeast corner of SH 119 and Fourmile Canyon Drive is currently used as an informal parking area by a variety of recreational users. Although this pulloff is entirely within CDOT right-of-way and no acquisition will be needed to construct the switchback and underpass in this location, the parking would be eliminated, which is an impact to users of the canyon's recreation facilities.

Further discussion of the design of the staircase structure is provided below.

Construction can be split into two phases denoted Option B1 and B2 in the plan sheets based on available funding:

- Option B1 improves the existing SH119 at-grade crossing on the west side of the Fourmile Canyon Drive/SH119 intersection. New trail on the north side of SH119 would extend to the west and connect to the 48-step staircase.
- Option B2 includes the Boulder Creek bridge and SH119 bike and pedestrian underpass on the east side of Fourmile Canyon Drive before turning west towards the staircase.

### **OPTION C**

Option C creates a 251-step staircase structure from the base of the planned Boulder Canyon Trail Extension, near an existing stone headwall and 48" drainage culvert, on the north side of SH 119. The Boulder Canyon Trail Extension project would construct an underpass beneath SH 119, providing safe and direct access to the staircase from the parking area at the existing highway pulloff at the current terminus of the Boulder Canyon trail. The staircase includes multiple landings and at least three observation decks / resting platforms at various intervals along the stairs. The future mountain bike trail into Betasso preserve begins immediately at the top of the staircase, on Open Space property. A permanent easement for the staircase is required on the northern portion of the Alps Boulder Canyon Inn property.

Further discussion of the design of the staircase structure is provided below.

### **OPTION D**

Option D would extend the Boulder Canyon Trail from its planned terminus at Chapman Drive to the Betasso Link Trail/Tunnel #1 along SH119. This option was not included in this study, but was outlined in the 2011 Boulder Canyon Trail Feasibility Study. The preferred alignment continues along the south side of SH119 west to the existing picnic area. An underpass connects the trail to the Betasso Link Trail on the north side of SH119.

### **STAIR STRUCTURES**

As described above, a 48-step staircase is required in Option B and a 251-step staircase is required in Option C to ascend from trail grade to the start of the mountain bike trail into Betasso Preserve. The height of the stair profile above the ground surface would be kept to a minimum to reduce the amount

of substructure required to support the stairs and landings. The treads rise approximately seven inches for every twelve inches of length. This closely matches the slope of the hill side at both location alternatives. For the longer runs of stairs required in Option C, landings are spaced down the hillside. Straight runs on Option C were also minimized to the extent practical to create a more aesthetically pleasing appearance and prevent runaway bicycles or a catastrophic tumble. Small observation platforms are located at some of the landing platforms on Option C where space is available. These platforms can likely be made large enough to accommodate bench seating.

The stairs are made out of steel. The steel construction will be relatively light compared to other materials and better facilitate construction on the hill side. The stairs are anticipated to be eight feet wide. This is approximately the upper limit of the feasible span length for the treads. Additional width would necessitate the use of three stringers to support the treads, instead of just two in the proposed design. This would entail a much more complicated structure and higher cost. A steel handrail is located on both sides of the stairs. A wheeling ramp would be installed on the treads along each side of the stairs to facilitate rolling bikes up or down the stairs. The ramp consists of a three-inch-wide channel placed approximately eight inches from the side of the stairs. The space between the stairs railing and the channel provide clearance for the pedals of the bike. Treads and landings would be made out of grating that minimizes the occurrence of water and ice building up on the structure. Snow is likely to remain on the stairs until it melts naturally. Option B stairs have eastern exposure and Option C stairs have a southern exposure.

For cost estimating purposes at this conceptual level, the treads, landings, and wheeling ramps were assumed to consist of galvanized steel. Galvanization is generally more durable than paint, and provides long-term protection against corrosion. The galvanized coating could be left exposed or painted as desired. In lieu of galvanization, the steel members could be powder coated for protection against corrosion.

The steel structure would be supported on cast-in-place concrete footings. Where rock is shallow, a rock anchor would be drilled into the side of the hill and a plate at the top of the anchor cast into the footing. This helps the structure resist overturning due to wind loads and sliding due to snow and live loads. Near the top of the proposed stair structure, where rock is deeper, each footing is slightly oversized in regards to bearing capacity requirements. The extra width of the footing allows the overburden soil on top of the footing to resist uplift and sliding forces. A layer of rock would be placed above the overburden soil to prevent erosion.

## **GENERAL GEOLOGIC SITE CONDITIONS**

A geotechnical investigation and geohazard evaluation were conducted as part of the feasibility study. One boring was advanced at each connection option. Figure 1 provides a summary of these borings and whether bedrock was encountered. Detailed information about each borehole is provided in Appendix E and borehole locations are shown on the plan sheets in Appendix B.

**Figure 1: Summary of Geotechnical Borings**

Boring Number	Approximate Location	Total Depth (ft)	Depth to Bedrock (ft)
Betasso-1	Option C, bottom of stairs	2.5	2.5*
Betasso-2	Option B, bottom of stairs	9.8	Not encountered
Betasso-3	Option A2, east abutment	22	11

\*Hand-operated auger, refusal at 2.5 feet

Samples from these borings were tested for soil gradation and other engineering characteristics, and are predominantly composed of low-plasticity silty sand with some gravels, and granite bedrock. Shallow foundations are geotechnically feasible at all three locations. Where bedrock is very shallow, a grouted rock anchor is recommended to provide sliding and overturning resistance for shallow foundations of the stair structures. Deep foundations, including driven piles, are also feasible for the bridge at Option A.

Subsurface conditions for the underpasses and walls which would be required if Betasso Option A or B were chosen were not investigated at this time.

No significant geohazards which would preclude construction or require mitigation features, such as landslides or a major rockfall hazard, are present at any of the Betasso trail connection options.

## **COMPARATIVE COST ESTIMATE**

A comparative cost estimate for each alternative was prepared, and is summarized in Figure 2 below. See Appendix D for a detailed breakdown of these costs by Option.

**Figure 2: Comparative Cost Estimate**

	<b><u>Options A1 and A2</u></b>	<b><u>Option B</u></b>		<b><u>Option C</u></b>
		<b><u>Option B1</u></b>	<b><u>Option B2</u></b>	
<b>Trail / Roadway</b>	\$ 279,500	\$ 111,700	\$ 131,500	\$ 2,520
<b>Walls</b>	\$ 329,200	\$ 91,200	\$ 465,500	\$ -
<b>Concrete Box Culvert</b>	\$ 361,800	\$ -	\$ 220,500	\$ -
<b>Pedestrian Bridge</b>	\$ 220,900	\$ -	\$ 375,200	\$ 32,900
<b>Stairs</b>	\$ -	\$ 50,500	\$ -	\$ 556,500
<b>Connecting Trail – Option Terminus to Betasso *</b>	\$ 150,500	\$ 150,500	\$ -	\$ 134,700
<b>50% Contingency / Miscellaneous Items</b>	\$ 670,900	\$ 202,000	\$ 596,400	\$ 363,400
<b>TOTAL</b>	<b>\$ 2,013,000</b>	<b>\$ 606,000</b>	<b>\$ 1,790,000</b>	<b>\$ 1,090,000</b>

*Total cost is an estimate of the relative difference in construction costs between alternatives. Cost is for comparative purposes only and does not include many items (traffic control, erosion control, etc.) necessary to construct the project. Cost is for major construction items only and does not include engineering design, environmental clearance permits, construction engineering, or indirect costs.*

*Estimates are based on 2016 unit costs and it is recommended that costs should be inflated by approximately 3% per year to account for inflation.*

*\*cost estimate provided by Boulder County Parks and Open Space*

## **DECISION MATRIX**

Figure 3 shows a qualitative comparison between Options A, B, and C, highlighting the major issues of concern. Appendix A has a more extensive qualitative comparison between the options.

**Figure 3: Qualitative Comparison**

Option A	Option B	Option C
<ul style="list-style-type: none"> <li>+ <b>Good User Experience:</b> grade separated SH119 crossing; no stairs</li> <li>- Property Acquisition: high uncertainty about obtaining multiple private property easements</li> <li>+ <b>Route Options:</b> connects to both potential new alignments on Betasso Preserve</li> <li>o Middle Cost Option: \$2.0 million</li> <li>o Requires 1.9 miles of new trail from end of BCTE, wall structure and bike/ped bridge; est. \$150,500</li> <li>o Combination of Options A and B possible, plus rock cut and realignment of Fourmile Canyon Drive, if unable to obtain south private property easement</li> </ul>	<ul style="list-style-type: none"> <li>o Average User Experience: grade separated SH119 crossing; minimal stairs; indirect route if parking along SH119</li> <li>o Property Acquisition: uncertainty about obtaining private property easement</li> <li>o Route Options: connects only to south potential new alignment on Betasso Preserve</li> <li>- High Cost Option: \$2.4 million</li> <li>o Requires 1.9 miles of new trail from end of BCTE, wall structure and 48-step staircase; est. \$150,500</li> <li>o Phased construction possible: build SH119 underpass and trail up to Fourmile Canyon Drive; extend when Betasso funding is identified</li> </ul>	<ul style="list-style-type: none"> <li>- Poor User Experience: 251-step staircase; challenging even with landings; cannot ride bike up/down</li> <li>o Property Acquisition: uncertainty about obtaining private property easement; owner is attempting to sell property</li> <li>o Route Options: connects only to south potential new alignment on Betasso Preserve</li> <li>+ <b>Low Cost Option:</b> \$1.0 million</li> <li>o Requires 1.7 miles of new trail from end of BCTE, 251-step staircase and potential rock fall mitigation measures est. \$134,700</li> </ul>

## **SUMMARY**

Each of the three options studied is feasible from an engineering and constructability point of view. While the relative cost varies between Options, each option provides a unique user experience and are all viable ways to connect the Boulder Canyon Trail to the Betasso Open Space Preserve for bicyclists and pedestrians. The County should consider the ultimate user experience that they desire to achieve, along with all other impacts and opportunities described in this memo, to decide which Option to proceed with.

## **APPENDIX A: DECISION MATRIX**

## **APPENDIX B: PLAN SHEETS – OPTIONS A, B, AND C**

## **APPENDIX C: RENDERINGS**

## **APPENDIX D: COST ESTIMATE**

## **APPENDIX E: GEOTECHNICAL REPORT**



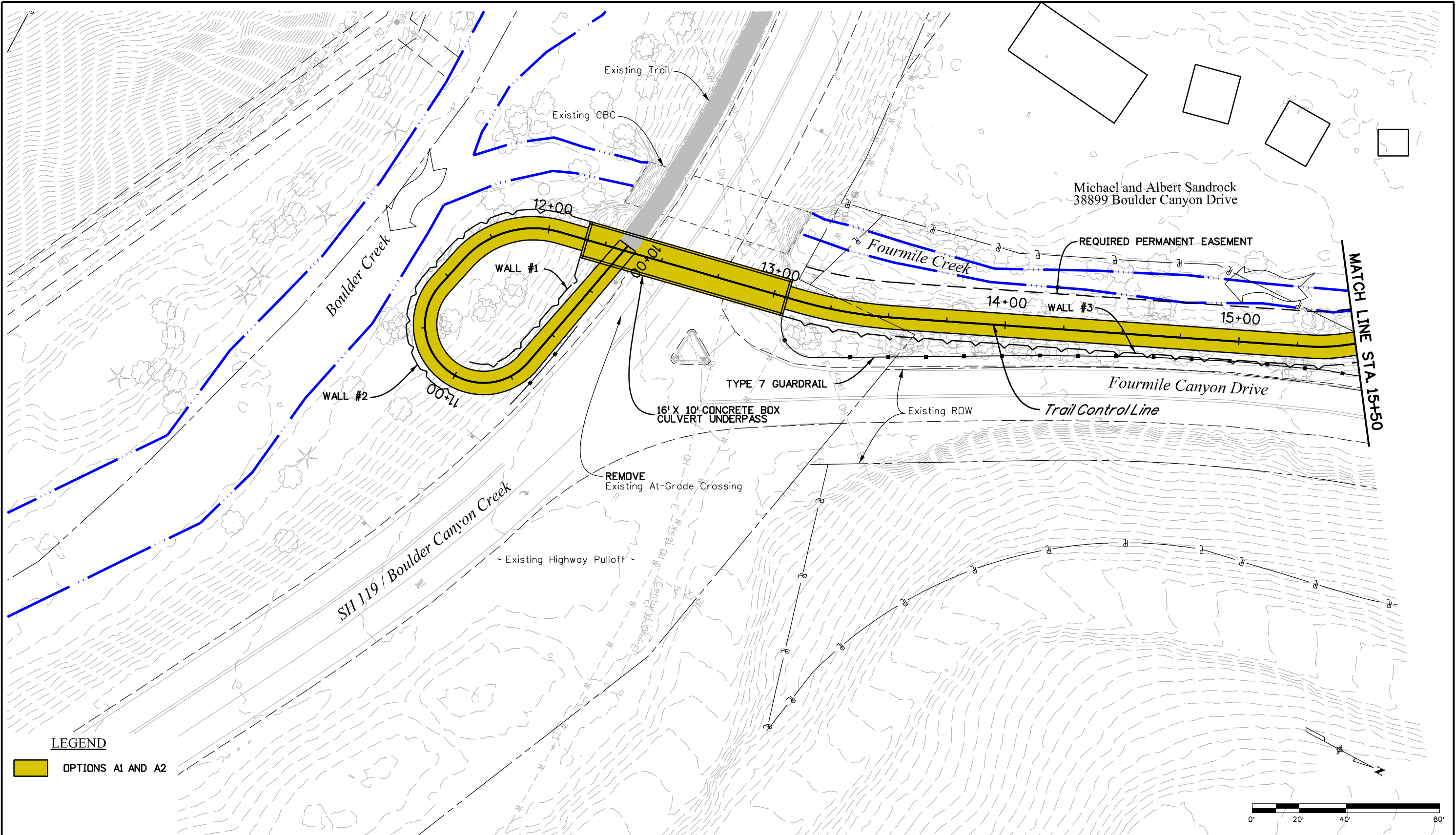
**APPENDIX A: DECISION MATRIX – OPTIONS A, B, AND C**

**FIGURE 1**  
**DECISION MATRIX**

	Option A Adjacent to Boulder Adventure Lodge	Option B Southern portion of 38899 Boulder Canyon Drive, near driveway	Option C Northern end of Alps Inn Property
User Experience	+ No stairs required. Users can bike on Fourmile Canyon Trail directly to beginning of mountain bike trail. + New Trail along Fourmile Creek would be scenic and provides users access to new areas. + View of trail from Fourmile Canyon Drive is mostly obscured. Visual impacts will be minimal from the roadway - Option A2 only: Visual impacts to Adventure Lodge property are significant. Trail bisects the property, passes directly adjacent to the south building. - Option A2 only: Trail displaces a portion of the Adventure Lodge recreation area, and patrons will have to cross the trail to access the recreation area from the main building.	- Fewer steps (48) than Option C.	+ Betasso Connection is directly adjacent to Boulder Canyon Trail Extension. + Observation platforms at staircase landings provide scenic overlook views. - Long staircase with 251 steps needed to gain elevation on steep mountainside.
Access to Boulder Canyon Trail	+ All existing highway pull offs that are used as parking areas for the Boulder Canyon Trail remain undisturbed. o Requires 1.9 miles of additional trial to connect to Betasso trail system with an estimated cost of \$150,500.	- Parking at the existing highway pull off at the corner of SH 119 and Fourmile Canyon Drive would be eliminated for construction of switchback to SH 119 underpass. o Requires 1.9 miles of additional trial to connect to Betasso trail system with an estimated cost of \$150,500.	+ All existing highway pull offs that are used as parking areas for the Boulder Canyon Trail remain undisturbed. o Requires 1.7 miles of additional trial to connect to Betasso trail system with an estimated cost of \$134,700.
Access to Betasso Preserve	+ Close Proximity to existing parking at the highway pull off at the current terminus of the Boulder Canyon Trail, and direct safe access is provided to the Betasso Trail via the proposed underpass beneath SH 119 at Fourmile Canyon Drive. - No direct connection from the existing highway pull off at the corner of SH 119 and Fourmile Canyon Drive to the trail to Betasso Preserve without crossing SH 119 at grade, and then using the trail switchback to go back under SH 119 in the box culvert underpass.	+ Staircase to Betasso Preserve trail is located at an RTD bus stop. - The safe route from the existing highway pull off at the current terminus of the Boulder Canyon Trail into Betasso is circuitous. One would have to travel from the highway pull off down the Boulder Canyon Trail, across the bridge over Boulder Creek, through the SH 119 underpass, up the switchback, across the at-grade crossing of Fourmile Canyon Drive, then along the trail on the north side of SH 119, to the foot of the staircase. - View of stairs is prominent from SH 119 westbound, which may encourage drives to turn into the private driveway at 38899 Boulder Canyon Drive hoping to access the trail.	+ Close Proximity to existing parking at the highway pull off at the current terminus of the Boulder Canyon Trail, and direct safe access is provided via the planned Boulder Canyon Trail Extension underpass beneath SH 119. - No direct connection from the existing highway pull off at the corner of SH 119 and Fourmile Canyon Drive to the Betasso Trail without crossing SH 119 at grade, and then using the Boulder Canyon Trail Extension to access the staircase.
Safety	+ Safe access if users ride up Boulder Canyon Trail or if they park at existing highway pull off at current trail terminus. - If users park at the existing informal lot at the corner of Fourmile and SH 119, they still have an at-grade crossing of SH 119 to get to the trail.	- At-grade crossing at Fourmile Canyon Drive. - Switchback to SH 119 underpass will have minimal sight distance / low design speed due to constrained site. - Due to proximity of staircase directly across from existing trailhead parking, users may cross SH 119 at grade in spite of an underpass provided for them at Fourmile. o Bike ramp on staircase will need to be designed to discourage bicyclists / skateboarders from riding down staircase.	+ Safe and direct access to Betasso Connection Trail from Boulder Canyon Trail Extension and existing parking o Bike ramp on staircase will need to be designed to discourage bicyclists / skateboarders from riding down staircase. - If users park at the existing informal lot at the corner of Fourmile and SH 119, they still have an at-grade crossing of SH 119 to get to the trail.
Floodplain Issues	+ The SH 119 underpass CBC may be able to be designed to convey water in the large events (> 10 year storm). SH 119 currently overtops in the 100-year event. o Potential Floodplain impacts for bridge over Fourmile Creek need to be studied further. - Will require a wall along Boulder Creek in the Boulder Creek floodplain to construct switchback down to underpass beneath SH 119. - Improvements in floodplain will require a CLOMR for Boulder Creek and Fourmile Creek	- Trail construction in the Boulder Creek floodplain will be necessary between the bridge and the underpass. - Foundation of Wall 4 will need to be constructed in the Fourmile Creek floodplain. - Improvements in floodplain will require a CLOMR for Boulder Creek and Fourmile Creek	+ No floodplain impacts + No CLOMR required
Required Structures	- Bridge across Fourmile Creek - Underpass beneath SH 119 - Soil nail or other cut-type wall walls between Fourmile Canyon Drive and the trail. - Retaining walls on switchback south of SH 119 at Boulder Creek / Fourmile Creek confluence	- Bridge across Boulder Creek - Underpass beneath SH 119 - Large retaining walls north and south of SH 119 to allow for underpass - Retaining wall behind portion of trail on north side of SH 119 between Fourmile Canyon Drive and the staircase. - 48-step staircase from driveway area to Betasso Connection trail.	- Requires 251-step staircase to gain elevation from BCTE to start of Betasso Connection Trail
Right of Way / Property Issues	+ Boulder Adventure Lodge owner has expressed interest in having the facility connect to the property. - Adventure Lodge property is constrained, so the trail and bridge will either have to go on 38899 Boulder Canyon Drive property just south of the property line with the Adventure Lodge (Option A1), or the trail will bisect the Adventure Lodge property (Option A2). Trail easement will be needed for either option. - Additional easement will also be required from 38899 Boulder Canyon Drive for future mountain bike trail alignment that takes up more than half of the property.	- Requires a permanent easement for the future mountain bike trail and staircase that effectively takes up more than half of the 38899 Boulder Canyon Drive property.	+ This is the only option that will not require an easement on private property for future construction of the mountain bike trail connecting into Betasso Preserve. - A permanent easement will be required for the staircase on the northern portion of the Alps Inn property. The bottom of the staircase is on Alps Inn property, but the top of the staircase is on Open Space property.
Utility Issues	- The trail parallel to Fourmile Canyon Drive will impact an Xcel power pole that would need to be relocated. - Possible impact to Adventure Lodge's septic tank manhole for Option A2.	o Switchback on north side of SH 119 can be designed to avoid City of Boulder Water line. - Possible impact to Century Link Fiber.	+ No utility conflicts
Maintenance	+ No stairs - entire trail approach to Betasso Connection Trail can be plowed. - Some portion of trail near SH 119 will not get much natural light / snowmelt. - Long-term maintenance of underpass and bridge. - Need agreement for maintenance on private property	+ Staircase has eastern exposure -- natural snow melt will be normal - Staircase cannot be plowed - Switchback on north side of SH 119 will be in a large cut with 10-ft tall cut walls, which will minimize natural sunlight exposure and snowmelt. - This option has the most long-term structural maintenance - bridge, underpass, walls, staircase.	+ Staircase has southern exposure -- natural snowmelt will be fast - Staircase cannot be plowed.
Geotechnical Issues	+ H-piles are a viable foundation option for bridge across Fourmile Creek. - A fill wall along Fourmile Canyon Drive is not recommended. A soil nail wall, with soil nails under Fourmile Canyon Drive, will be needed instead. - Additional Borings will be required to make geotech recommendations for additional structures if this option is chosen.	+ Shallow foundations for the stair structure are feasible. - Larger footings for stair structure may be required due to somewhat deeper bedrock. - Additional borings will be required to make geotech recommendations for additional structures if this option is chosen.	+ No additional borings required. - Excavation on hillside for shallow foundations. - Shallow foundations for stair structure would require grouted rock anchors to resist sliding and overturning.
Constructability	- Requires lane closure on SH 119 for construction of CBC underpass - Requires possible lane closure on Fourmile Canyon Drive for construction of wall - Construction schedule requires close coordination with owner of Adventure Lodge - Construction requires removal of many trees along creek. View shown in renderings will take time to establish	- Requires lane closure on SH 119 for construction of CBC underpass and possible lane closure for all four walls	+ Can be constructed without lane closures or impacts to SH 119 traffic
Comparative Cost	o Intermediate Cost Option - \$2,013,000	- Highest Cost Option - \$2,396,000 (B1 - \$606,000, B2 - \$1,790,000)	+ Lowest Cost Option - \$1,090,000

**APPENDIX B: PLAN SHEETS – OPTIONS A, B, AND C**

Leah 9/13/16 AM 03:15:36 Projects\15-025.02 Betasso Feasibility Study - Boulder County\15025\Design Drawings\15025DES-Option\_A\_Plan01.dgn  
8/16/2016 CDT-DefaultPrinter-V8i.plt C1g 15025.02\_BCT Options.tbl

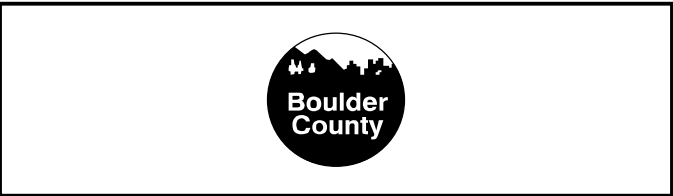


Print Date: 8/16/2016

Drawing File Name: 15025DES-Option\_A\_Plan01.dgn

Horiz. Scale: 1:40      Vert. Scale: As Noted

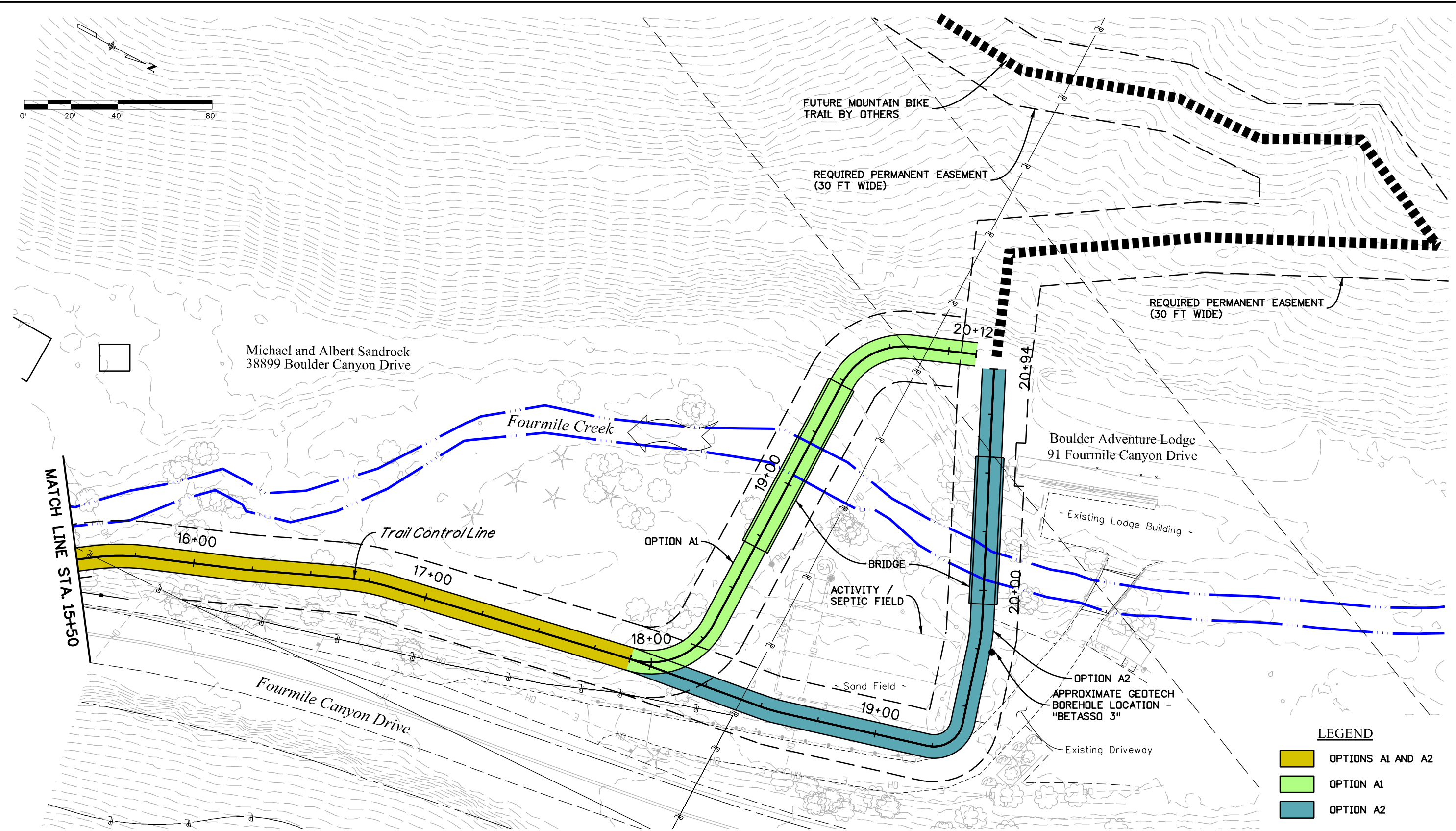
Sheet Revisions		
Date:	Comments	Init.



As Constructed		CANYON TRAIL EXTENSION: BETASSO PRESERVE CONNECTION - OPTIONS A1 AND A2			
No Revisions:		Designer: SDB	Structure Numbers	Sheet Number	
Revised:		Detailer: ZDA			
Void:		Sheet Subset: CONCEPT	Subset Sheets: 1 of 2		



Leah 8/07/08 AM 01/2015 Projects\15-025.02 Betasso Feasibility Study - Boulder County\15025\Design\Drawings\15025DES\_Option\_A\_Plan02.dgn  
8/16/2016 CDDT-DefaultPrinter-V8i.plt c1g 15025.02\_BCT Options.tbl



Print Date: 8/16/2016  
Drawing File Name: 15025DES\_Option\_A\_Plan02.dgn  
Horiz. Scale: 1:40 Vert. Scale: As Noted



0000

**Sheet Revisions**

Date:	Comments	Init.



**As Constructed**

No Revisions:

Revised:

Void:

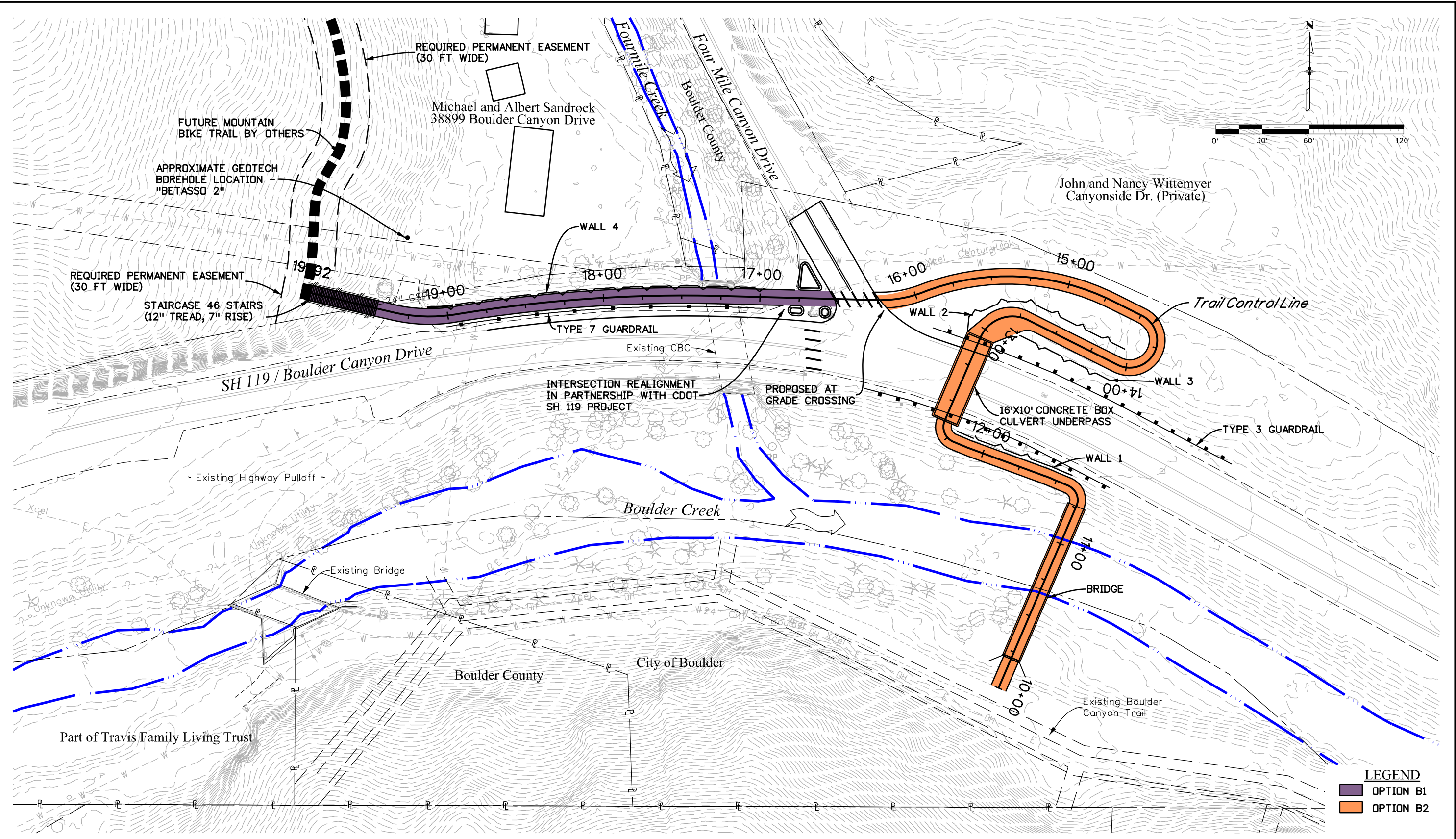
**BOULDER CANYON TRAIL EXTENSION:  
BETASSO PRESERVE CONNECTION -  
OPTIONS A1 AND A2**

Designer:	SDB	Structure Numbers	
Detailer:	ZDA		
Sheet Subset:	CONCEPT	Subset Sheets:	2 of 2

Sheet Number



Leah 8/16/2016 8:07:14 AM C:\2015 Projects\15-025\02 Betasso Feasibility Study - Boulder County\15025DES\_Design Drawings\15025DES\_Option\_B\_Plan01.dgn  
CDOT-DefaultPrinter-V8i.plt C:\2015 Projects\15-025\02 Betasso Feasibility Study - Boulder County\15025DES\_Option\_B\_Plan01.dgn



**LEGEND**

OPTION B1

OPTION B2

Print Date: 8/16/2016

Drawing File Name: 15025DES\_Option\_B\_Plan01.dgn

Horiz. Scale: 1:60      Vert. Scale: As Noted

**MULLER**  
ENGINEERING COMPANY

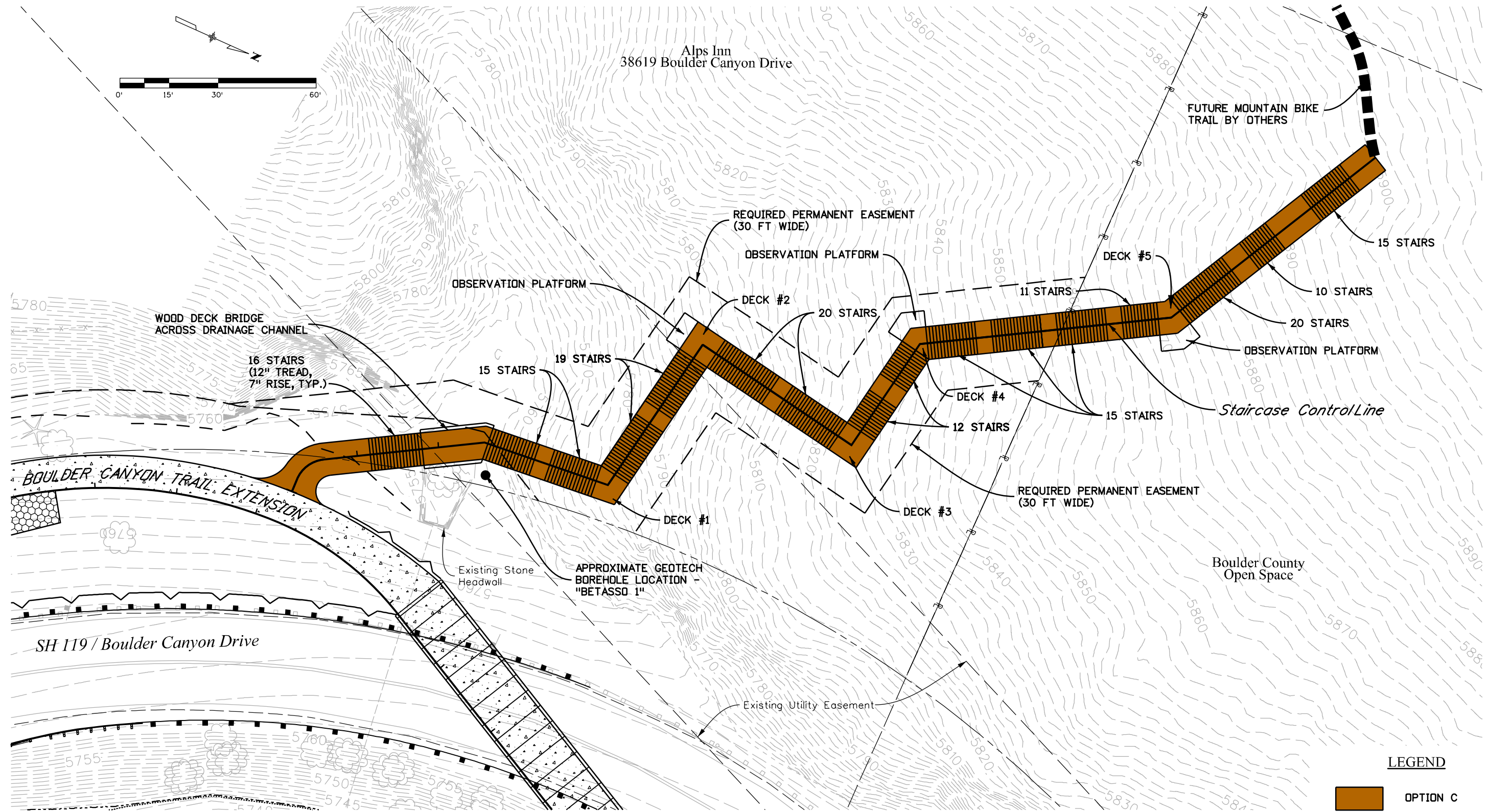
Sheet Revisions		
Date:	Comments	Init.

**Boulder County**

As Constructed		BOULDER CANYON TRAIL EXTENSION: BETASSO PRESERVE CONNECTION - OPTIONS B1 AND B2			
No Revisions:		Designer: SDB	Structure Numbers		Sheet Number
Revised:		Detailer: LJJ			
Void:		Sheet Subset: ROADWAY	Subset Sheets:	1 of 1	



Leah 8/16/2016 AM 01:2015 Projects\15-025.02 Betasso Feasibility Study - Boulder County\15025DES\_Option\_C\_Plan01.dgn  
8/16/2016 CDT-DefaultPrinter-V8i.plt 15025.02\_BCT Options.tbl



LEGEND

 OPTION C

Print Date: 8/16/2016  
Drawing File Name: 15025DES\_Option\_C\_Plan01.dgn  
Horiz. Scale: 1:30 Vert. Scale: As Noted



0000

Sheet Revisions

Date:	Comments	Init.



As Constructed

No Revisions:

Revised:

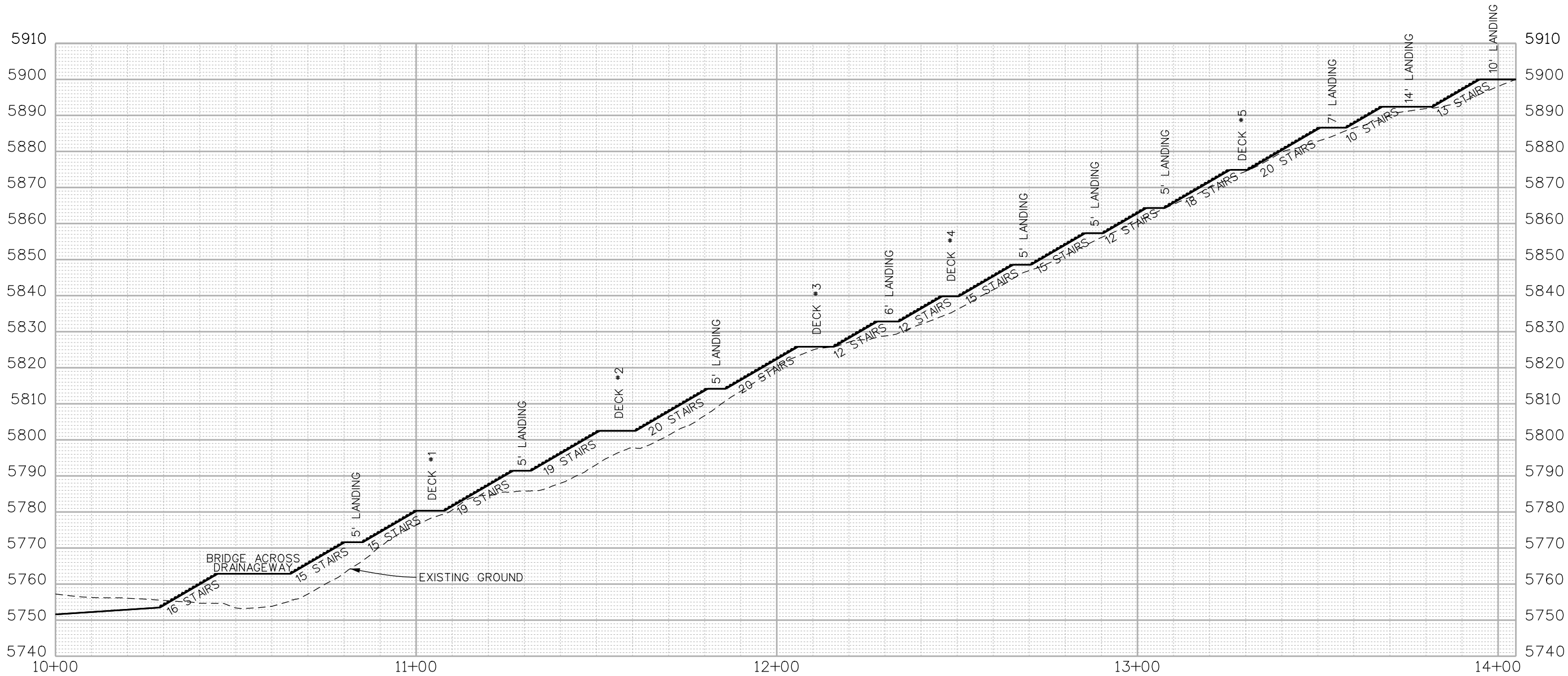
Void:

BOULDER CANYON TRAIL EXTENSION:  
BETASSO PRESERVE CONNECTION -  
OPTION C

Designer:	SDB	Structure	
Detailer:	ZDA	Numbers	
Sheet Subset:	CONCEPT	Subset Sheets:	1 of 2

Sheet Number

StevenB 8/09/53 AM C:\2015 Projects\15-025.02\_Betasso\_Feasibility Study - Boulder County\15025\Design\Drawings\Reference Files\15025DES\_Profile\_Option\_C.dgn  
7/19/2016 C:\2015 Projects\15-025.02\_Betasso\_Feasibility Study - Boulder County\15025\Design\Drawings\Reference Files\15025DES\_Profile\_Option\_C.dgn  
7/19/2016 C:\2015 Projects\15-025.02\_Betasso\_Feasibility Study - Boulder County\15025\Design\Drawings\Reference Files\15025DES\_Profile\_Option\_C.dgn



Print Date: 7/19/2016

Drawing File Name: 15025DES\_Profile\_Option\_C.dgn

Horiz. Scale: 1:30

Vert. Scale: As Noted



0000

Sheet Revisions

Date:	Comments	Init.



As Constructed

No Revisions:

Revised:

Void:

OPTION C  
PROFILE

Designer:

SDB

Detailer:

ZDA

Sheet Subset:

CONCEPT

Structure  
Numbers

Sheet Number

Subset Sheets:

2 of 2



## **APPENDIX C: RENDERINGS**



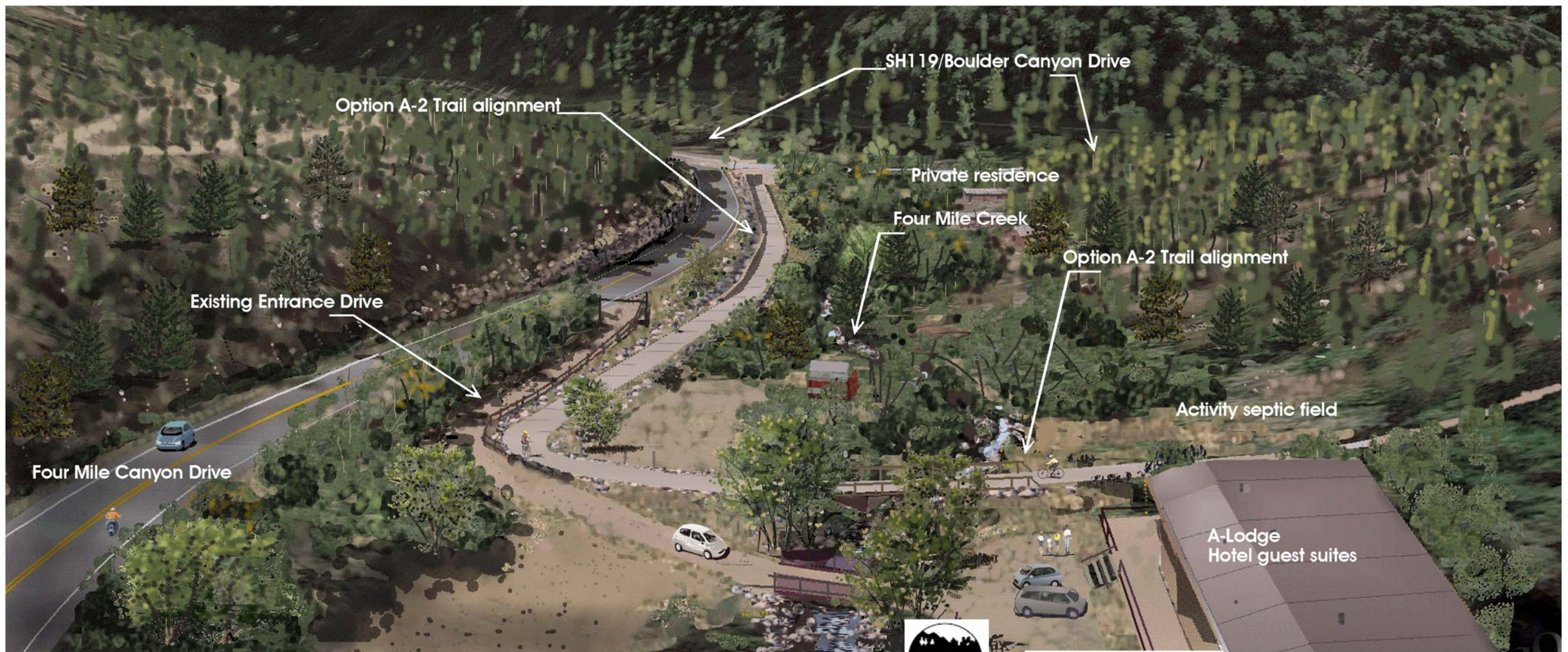


## Option A-2

With this option the proposed trail crosses SH 119 /Boulder Canyon Drive as an underpass and is routed roughly parallel to Four Mile Canyon Drive where a large number of riparian trees will need to be removed . It then crosses the Four Mile Creek near the A-Lodge. From there the trail climbs up the side of the hill . Some tree cover has been omitted in this sketch for clarity purposes.

This image was adapted from a Google Earth view.

Option A-2, Bird's eye view to the south near the existing driveway on Four Mile Canyon Drive







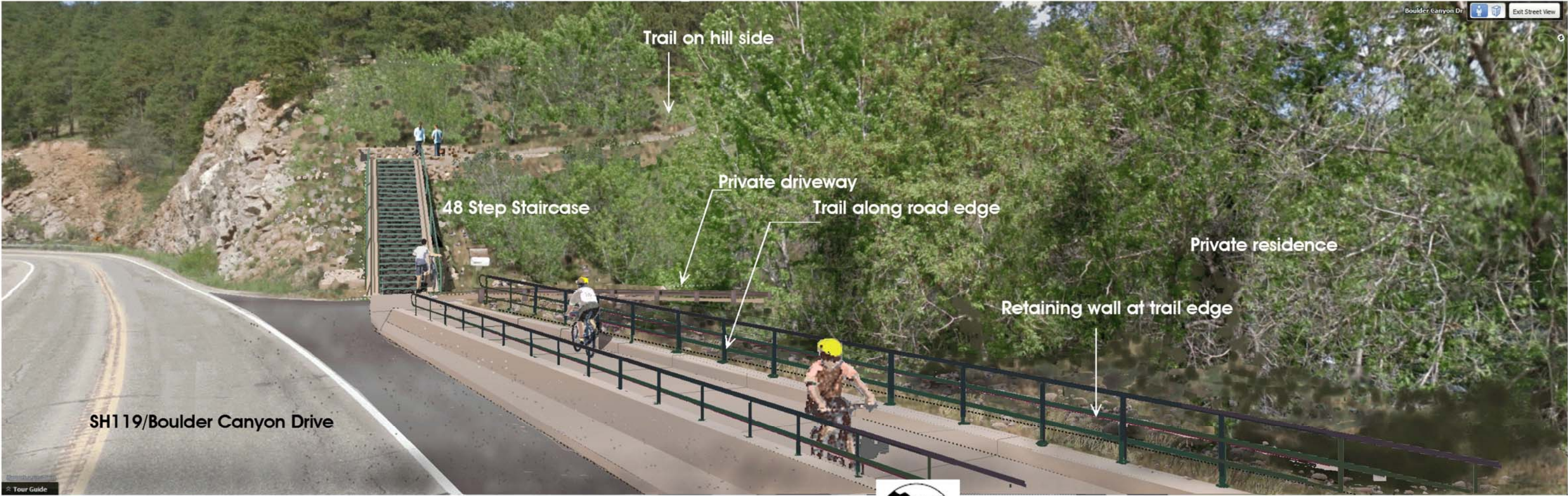
**Option B**

With this option the proposed trail crosses under SH119/ Canyon Drive and heads west paralleling the highway. At an existing driveway the trail utilizes steps to get up the steep hill side grade. From there the trail switch-backs up to the Betasso Preserve.

Along the roadway the trail is separated from SH119/ Boulder Canyon Drive with a concrete barrier. A retaining wall is just beyond the outside railing.

A pedestrian bridge crossing Boulder Creek and an underpass under SH119/Boulder Canyon Drive near Four Mile Canyon are additional elements of this option

**Option B View to the west, just west of Four Mile Canyon Drive.**







## Option C

About one fourth mile west of Four Mile Canyon this proposed trail option connects to the Boulder Creek Path where it crosses under Boulder Canyon Drive. From that point this option has a zig zag stair case climbing the steep hill side to access the Betasso Preserve. The staircase connects to a dirt surface trail beyond this view.

Some trees have been omitted for clarity.





## **APPENDIX D: COST ESTIMATE**



Title	Betasso Connection Trail Feasibility Study	Date	8/16/2016	Job No.	15-025.02
Subject	Conceptual Cost Estimate - Options A, B and C	By	JDM/ASP/SDB		

**FIGURE 1**  
**Options A1 & A2**

Item No	Description	Unit	Quantity	Unit Cost	Total Cost
<b>Trail / Roadway</b>					
203	Unclassified Excavation	CY	900	\$ 18.00	\$ 16,200
304	Aggregate Base Course	TON	370	\$ 54.00	\$ 19,980
514	Hand and Bikeway Railing	LF	660	\$ 220.00	\$ 145,200
606	Guardrail Type 7	LF	325	\$ 47.00	\$ 15,275
606	Guardrail End Anchorage	EA	2	\$ 4,500.00	\$ 9,000
608	Concrete Bikeway (6 inch)	SY	1230	\$ 60.00	\$ 73,800
	<i>Subtotal - Trail / Roadway</i>			\$	279,455
<b>Walls</b>					
504	Wall 1 (MSE)	SF	420	\$ 60.00	\$ 25,200
504	Wall 2 (MSE)	SF	1440	\$ 60.00	\$ 86,400
504	Wall 3 (Soil Nail)	SF	1080	\$ 175.00	\$ 189,000
506	Riprap (18 Inch) (Scour Protection for Wall 2)	CY	260	\$ 110.00	\$ 28,600
	<i>Subtotal - Walls</i>			\$	329,200
<b>Box Culvert (16' x 10')</b>					
206	Structure Excavation	CY	930	\$ 30.00	\$ 27,900
206	Structure Backfill (Class 1)	CY	200	\$ 50.00	\$ 10,000
206	Filter Material (Class B)	CY	35	\$ 100.00	\$ 3,500
514	Pedestrian Railing (Steel)	LF	40	\$ 150.00	\$ 6,000
515	Waterproofing (Membrane)	SY	210	\$ 60.00	\$ 12,600
601	Concrete (Class D) (Includes Precast Elements)	CY	230	\$ 800.00	\$ 184,000
602	Reinforcing Steel	LB	64200	\$ 1.00	\$ 64,200
605	4 Inch Perforated Pipe Underdrain	LF	100	\$ 500.00	\$ 50,000
606	Bridge Rail (Type 10H)	LF	18	\$ 200.00	\$ 3,600
	<i>Subtotal - Box Culvert (16' x 10')</i>			\$	361,800
<b>Pedestrian Bridge (85' Span)</b>					
206	Structure Excavation	CY	30	\$ 30.00	\$ 900
206	Structure Backfill (Class 1)	CY	50	\$ 50.00	\$ 2,505
502	Pile Tip	EA	8	\$ 150.00	\$ 1,200
502	Steel Piling (HP 12X54)	LF	160	\$ 100.00	\$ 16,000
506	Riprap (12 Inch)	CY	80	\$ 130.00	\$ 10,400
514	Pedestrian Railing (Steel)	LF	160	\$ 150.00	\$ 24,000
601	Concrete (Class D) (Bridge)	CY	50	\$ 800.00	\$ 40,000
602	Reinforcing Steel	LB	9500	\$ 1.00	\$ 9,500
605	Geocomposite Drain	SY	410	\$ 35.00	\$ 14,350
628	Pedestrian Bridge (Superstructure)	LS	1	\$ 102,000	\$ 102,000
	<i>Subtotal - Pedestrian Bridge (85' Span)</i>			\$	220,855
	<i>Subtotal - Options A1 &amp; A2</i>			\$	1,191,400
	<i>Miscellaneous Items (Not Quantified)</i>	50%		\$	595,700
<b>TOTAL - Options A1 &amp; A2</b>				<b>\$</b>	<b>1,788,000</b>

Total cost is an estimate of the relative difference in construction costs between alternatives. Cost is for comparative purposes only and does not include many items (right of way acquisition, traffic control, etc.) necessary to construct the project. Estimates are based on 2016 unit costs and it is recommended that costs should be inflated by approximately 3% per year to account for inflation.



Title	Betasso Connection Trail Feasibility Study	Date	8/16/2016	Job No.	15-025.02
Subject	Conceptual Cost Estimate - Options A, B and C	By	JDM/ASP/SDB		

**FIGURE 2**  
**Option B1**

**Trail / Roadway**

203	Unclassified Excavation	CY	250	\$	18.00	\$	4,500
304	Aggregate Base Course	TON	100	\$	54.00	\$	5,400
514	Hand and Bikeway Railing	LF	230	\$	220.00	\$	50,600
606	Guardrail Type 3	LF		\$	20.00	\$	-
606	Guardrail Type 7	LF	200	\$	47.00	\$	9,400
606	Guardrail End Anchorage	EA	2	\$	4,500.00	\$	9,000
608	Concrete Bikeway (6 inch)	SY	380	\$	60.00	\$	22,800
	Intersection Improvements	LS	1	\$	10,000.00	\$	10,000
	<i>Subtotal - Trail / Roadway</i>					\$	111,700

**Walls**

504	Wall 1 (Soil Nail)	SF	0	\$	175.00	\$	-
504	Wall 2 (Soil Nail)	SF	0	\$	175.00	\$	-
504	Wall 3 (Soil Nail)	SF	0	\$	175.00	\$	-
504	Wall 4 (MSE)	SF	1520	\$	60.00	\$	91,200
	<i>Subtotal - Walls</i>					\$	91,200

**Stairs**

509	Steel Stairs with Railing	LF	50	\$	1,010.00	\$	50,500
	<i>Subtotal - Option B1</i>					\$	253,400
	<i>Miscellaneous Items (Not Quantified)</i>		50%			\$	126,700

<b>TOTAL - Option B1</b>						<b>\$</b>	<b>381,000</b>
--------------------------	--	--	--	--	--	-----------	----------------

Total cost is an estimate of the relative difference in construction costs between alternatives. Cost is for comparative purposes only and does not include many items (right of way acquisition, traffic control, etc.) necessary to construct the project. Estimates are based on 2016 unit costs and it is recommended that costs should be inflated by approximately 3% per year to account for inflation.



Title	Betasso Connection Trail Feasibility Study	Date	8/16/2016	Job No.	15-025.02
Subject	Conceptual Cost Estimate - Options A, B and C	By	JDM/ASP/SDB		

**FIGURE 3**  
**Option B2**

**Trail / Roadway**

203	Unclassified Excavation	CY	2000	\$	18.00	\$	36,000
304	Aggregate Base Course	TON	200	\$	54.00	\$	10,800
514	Hand and Bikeway Railing	LF	100	\$	220.00	\$	22,000
606	Guardrail Type 3	LF	375	\$	20.00	\$	7,500
606	Guardrail Type 7	LF		\$	47.00	\$	-
606	Guardrail End Anchorage	EA	4	\$	4,500.00	\$	18,000
608	Concrete Bikeway (6 inch)	SY	620	\$	60.00	\$	37,200
	<i>Subtotal - Trail / Roadway</i>					\$	131,500

**Walls**

504	Wall 1 (Soil Nail)	SF	490	\$	175.00	\$	85,750
504	Wall 2 (Soil Nail)	SF	1460	\$	175.00	\$	255,500
504	Wall 3 (Soil Nail)	SF	710	\$	175.00	\$	124,250
504	Wall 4 (MSE)	SF	0	\$	60.00	\$	-
	<i>Subtotal - Walls</i>					\$	465,500

**Box Culvert (16' x 10')**

206	Structure Excavation	CY	600	\$	30.00	\$	18,000
206	Structure Backfill (Class 1)	CY	130	\$	50.00	\$	6,500
206	Filter Material (Class B)	CY	30	\$	100.00	\$	3,000
515	Waterproofing (Membrane)	SY	140	\$	60.00	\$	8,400
605	4 Inch Perforated Pipe Underdrain	LF	70	\$	40.00	\$	2,800
601	Concrete (Class D) (Includes Precast Elements)	CY	150	\$	800.00	\$	120,000
602	Reinforcing Steel	LB	41800	\$	1.00	\$	41,800
606	Bridge Rail (Type 10H)	LF	40	\$	500.00	\$	20,000
	<i>Subtotal - Box Culvert (16' x 10')</i>					\$	220,500

**Pedestrian Bridge (100' Span)**

206	Structure Excavation	CY	30	\$	30.00	\$	900
206	Structure Backfill (Class 1)	CY	55	\$	50.00	\$	2,750
503	Drilled Caissons (36 Inch)	LF	320	\$	500.00	\$	160,000
509	Riprap (18 Inch)	CY	130	\$	110.00	\$	14,300
514	Pedestrian Railing (Steel)	LF	60	\$	150.00	\$	9,000
601	Concrete (Class D) (Bridge)	CY	55	\$	800.00	\$	44,000
602	Reinforcing Steel	LB	9900	\$	1.00	\$	9,900
605	Geocomposite Drain	SY	410	\$	35.00	\$	14,350
628	Pedestrian Bridge (Superstructure)	LS	1	\$	120,000	\$	120,000
	<i>Subtotal - Pedestrian Bridge (100' Span)</i>					\$	375,200

*Subtotal - Option B2*

\$ 1,192,700

*Miscellaneous Items (Not Quantified)*

50%

\$ 596,400

**TOTAL - Option B2**

\$ 1,790,000

Total cost is an estimate of the relative difference in construction costs between alternatives. Cost is for comparative purposes only and does not include many items (right of way acquisition, traffic control, etc.) necessary to construct the project. Estimates are based on 2016 unit costs and it is recommended that costs should be inflated by approximately 3% per year to account for inflation.





Title	Betasso Connection Trail Feasibility Study	Date	8/16/2016	Job No.	15-025.02
Subject	Conceptual Cost Estimate - Options A, B and C	By	JDM/ASP/SDB		

**FIGURE 4****Option C**

Item No	Description	Unit	Quantity	Unit Cost	Total Cost
<b>Trail</b>					
304	Aggregate Base Course	TON	10	\$ 54.00	\$ 540
608	Concrete Bikeway (6 inch)	SY	33	\$ 60.00	\$ 1,980
	<i>Subtotal - Trail</i>			\$	2,520
<b>Stairs and Landings</b>					
509	Steel Stairs with Railing	LF	250	\$ 1,010.00	\$ 252,500
509	Small Landing with Foundation	EA	10	\$ 14,800	\$ 148,000
509	Large Landing with Foundation	EA	5	\$ 24,400	\$ 122,000
509	Observation (Platforms)	SF	170	\$ 200.00	\$ 34,000
	<i>Subtotal - Stairs and Landings</i>			\$	556,500
<b>Pedestrian Bridge (20' Span)</b>					
601	Concrete (Class D) (Wall)	CY	15	\$ 800.00	\$ 12,000
602	Reinforcing Steel	LB	600	\$ 1.20	\$ 720
628	Pedestrian Bridge (Superstructure)	LS	1	\$ 20,200	\$ 20,200
	<i>Subtotal - Pedestrian Bridge (20' Span)</i>			\$	32,920
	<i>Subtotal - Option C</i>			\$	592,000
	<i>Miscellaneous Items (Not Quantified)</i>	50%		\$	296,000
<b>TOTAL - Option C</b>				\$	<b>888,000</b>

Total cost is an estimate of the relative difference in construction costs between alternatives. Cost is for comparative purposes only and does not include many items (right of way acquisition, traffic control, etc.) necessary to construct the project. Estimates are based on 2016 unit costs and it is recommended that costs should be inflated by approximately 3% per year to account for inflation.

**APPENDIX E: GEOTECHNICAL REPORT**



**Boring Began: 6/9/2016**

**Total Depth: 2.5 ft**

Weather Notes: Sunny, warm

**Boring Completed: 6/9/2016**

Ground Elevation:

Inclination from Horiz.: Vertical

Drilling Method(s): Hand Auger

Coordinates: N: E:

Driller: Yeh & Associates, Inc.

Location: Adjacent to historic culvert wall

Night Work: ☐

Drill Rig: N/A

Hammer Type:

Logged By: K. Asay

Final By: S. Hansen

**Groundwater Levels:**

Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/ Advancement Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifi- cations	Field Notes and Other Lab Tests
			Blows per 6 in	Penetration Resistance						Liquid Limit	Plasticity Index		
						0.0 - 2.5 ft. <b>SAND</b> well to poorly graded with silt, brown-dark brown with rust, no plasticity, moist, loose.							
							3.9		8	NV	NP	A-1-b (0) SW-SM	
							3.1		6	NV	NP	A-1-a (0) SP-SM	2.5 ft - Auger refusal, likely bedrock (next to outcrop)
Bottom of Hole at 2.5 ft.													



**Boring Began: 6/9/2016**

**Total Depth: 9.8 ft**

Weather Notes: Sunny, warm

**Boring Completed: 6/9/2016**

Ground Elevation:

Inclination from Horiz.: Vertical

Drilling Method(s): Solid-Stem Auger (4" OD)

Coordinates: N: E:

Driller: Dakota Drilling

Location: Sandrock Residence Driveway

Night Work: ☐

Drill Rig: CME 55

Hammer Type: Cathead and rope

Logged By: K. Asay

Final By: S. Hansen

**Groundwater Levels:**

Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/ Advancement Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifi- cations	Field Notes and Other Lab Tests
			Blows per 6 in	Penetration Resistance						Liquid Limit	Plasticity Index		
						<b>0.0 - 9.8 ft. silty SAND</b> with clay lenses in upper 3 feet, brown-dark brown with rust, no to low plasticity, moist, medium dense to dense.							
	5		7-11-14	25		Some gravel present, no clay.	4.6		15	21	6	A-1-b (0) SM-SC	
			25-50:3"	50:3"		Becoming gravelly, dense, brown and light gray.	5.5		24	NV	NP	A-2-4 (0) SM-SC	
Bottom of Hole at 9.8 ft.													



**Boring Began: 6/10/2016**

**Total Depth: 22.0 ft**

Weather Notes: Sunny, warm

**Boring Completed: 6/10/2016**

Ground Elevation:

Inclination from Horiz.: Vertical

Drilling Method(s): ODEX

Coordinates: N: E:

Driller: Dakota Drilling

Location: A Lodge Property

Night Work: ☐

Drill Rig: CME 55

Hammer Type: Cathead and rope

Logged By: K. Asay

Final By: S. Hansen

Groundwater Levels:

Symbol	Depth	Date		
	5.5 ft	6/10/16	-	-

Elevation (feet)	Depth (feet)	Sample Type/ Advancement Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifi- cations	Field Notes and Other Lab Tests
			Blows per 6 in	Penetration Resistance						Liquid Limit	Plasticity Index		
						0.0 - 5.5 ft. <b>silty SAND</b> with gravel, brown-dark brown with rust, no plasticity, moist, medium dense, probable flood deposits.							
	5		6-9-9	18			18.7		15	NV	NP	A-1-b (0) SM	
						5.5 - 11.0 ft. <b>silty SAND</b> with some gravel, well graded, brown-dark brown with rust, no to low plasticity, wet, medium dense to very dense.				NV	NP		
	10		50:4"	50:4"			10.7		7	23	7	A-1-a (0) SW-SM	pH=8.2 S=0.002% Re=8382ohm·cm
						11.0 - 22.0 ft. <b>GRANITE</b> , gray with white - pink, fresh, very hard.							
	15		50:25"	50:25"									
	20		50:0"	50:0"									17.0 ft - No obvious sand cuttings out of hole to indicate boulder pH=8.8 S=0.004% Re=6154ohm·cm

Bottom of Hole at 22.0 ft.



## Legend for Symbols Used on Borehole Logs

### Sample Types



Bulk Sample of  
auger/odex cuttings



ODEX/Downhole  
Hammer



Standard Penetration  
Test  
(ASTM D1586)

### Lithology Symbols (see Boring Logs for complete descriptions)



Asphalt



Fill with Sand as  
major soil



USCS Poorly-graded  
Gravel



USCS Clayey Sand



USCS Silty Sand



USCS Poorly-graded  
Sand



USCS Well-graded  
Sand with Silt



GRANITE

### Lab Test Standards

Moisture Content	ASTM D2216
Dry Density	ASTM D7263
Sand/Fines Content	ASTM D421, ASTM C136, ASTM D1140
Atterberg Limits	ASTM D4318
AASHTO Class.	AASHTO M145, ASTM D3282
USCS Class.	ASTM D2487
(Fines = % Passing #200 Sieve	
Sand = % Passing #4 Sieve, but not passing	
#200 Sieve)	

### Other Lab Test Abbreviations

pH	Soil pH (AASHTO T289-91)
S	Water-Soluble Sulfate Content (AASHTO T290-91, ASTM D4327)
Chl	Water-Soluble Chloride Content (AASHTO T291-91, ASTM D4327)
S/C	Swell/Consolidation (ASTM D4546)
UCCS	Unconfined Compressive Strength (ASTM D2166)
R-Value	Resistance R-Value (ASTM D2844)
DS (C)	Direct Shear cohesion (ASTM D3080)
DS (phi)	Direct Shear friction angle (ASTM D3080)
Re	Electrical Resistivity (AASHTO T288-91)
PtL	Point Load Strength Index (ASTM D5731)

### Notes

1. "Penetration Resistance" on the Boring Logs refers to the N value for SPT samples only, as per ASTM D1586. For samples obtained with a Modified California sampler, drive depth was 12 inches, and "Penetration Resistance" refers to the sum of all blows. For all sample types, where blow counts were more than 50 for the last increment, the blows and length for the last increment are reported under "Penetration Resistance."

2. The Modified California sampler used to obtain samples is a 2.5-inch OD, 2.0-inch ID (1.95-inch ID with liners), split-barrel sampler with internal liners, as per ASTM D3550. Sampler is driven with a 140-pound hammer, dropped 30 inches per blow.