Memorandum

Subject	**DRAFT SH 82 S-curve Technical Memo**
Project Name	Entrance to Aspen/Castle Creek Bridge
Attention	City of Aspen
From	Jacobs Engineering
Date	February 2024
Copies to	Project File

1. Introduction

This memorandum summarizes a concept analysis and safety evaluation performed by Jacobs Engineering Group, Inc. (Jacobs) regarding the S-curve alignment along State Highway 82 (SH82) in Aspen, Colorado. The City of Aspen (City) has requested Jacobs investigate design options and impacts of increasing the curve radii (curve softening) at two 90-degree (S-curve) turn locations entering the City.

Figure 1. S-curve Alignment Study Area

2. History and Crash Data

As a resort town and year-round destination for many travelers, traffic and congestion has continued to grow and challenge the existing infrastructure. Since the Entrance to Aspen Final Environmental Impact Statement (CDOT, 1997) and Record of Decision (ROD) (FHWA, 1998), many transportation and traffic studies have occurred over the years to evaluate SH82 improvements through the City. Exhibit A presents the transportation studies and implemented improvements specific to addressing issues on the S-curves and Castle Creek Bridge over the last 20 years. Not all studies were conclusive, resulting in non-implemented improvements.

The safety and driver expectations of commuters in Aspen and along SH82 is a key consideration when evaluating corridor modifications. According to the latest 5-year crash data (2018 to 2022), the majority of incidents were rear-end collisions occurring at the Castle Creek Bridge, on North 6th Street, and near or between the S-curve locations. Rear-end collisions are a symptom of congestion and speed differentials between vehicles.

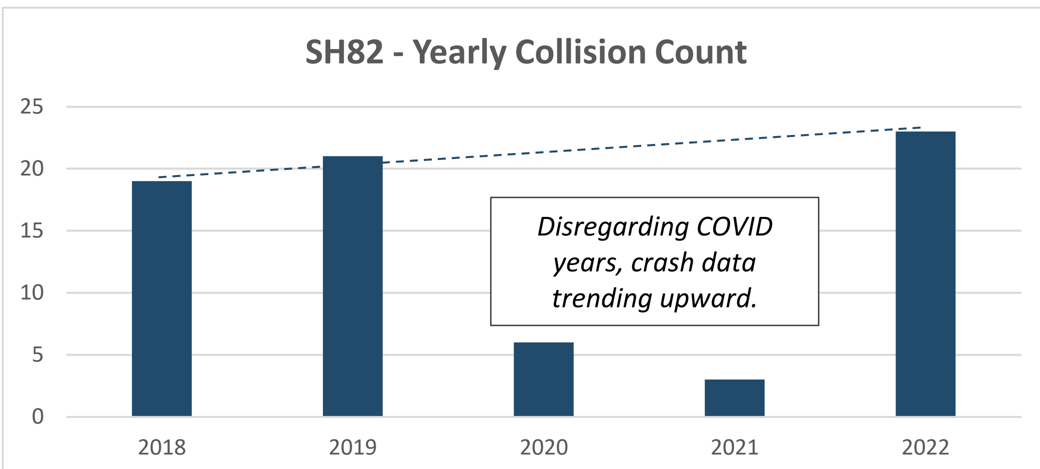
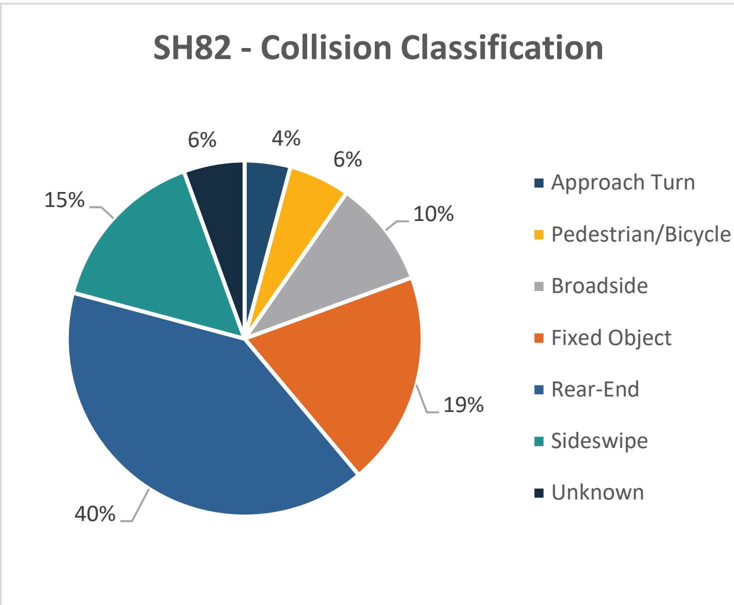


Figure 2. Yearly Collision Count – SH82

As shown on Figure 2, crashes dipped during the COVID-19 pandemic; however, post-COVID-19, crash statistics drastically increased and began to highlight an upward trend from 2018 (ignoring COVID-19 data).

Several locations that experience higher numbers of crashes, shown on Figure 4, have pinch points that contribute to these crashes. To address some of these crash problems and types (Figure 3), mitigation options could include minimizing conflict points by extending designated transit lanes, removing access at select intersecting streets, and reconfiguring the outbound zipper lane on West Main Street. The options discussed in the following section feature these enhancements to reduce conflict points while improving traffic flow.



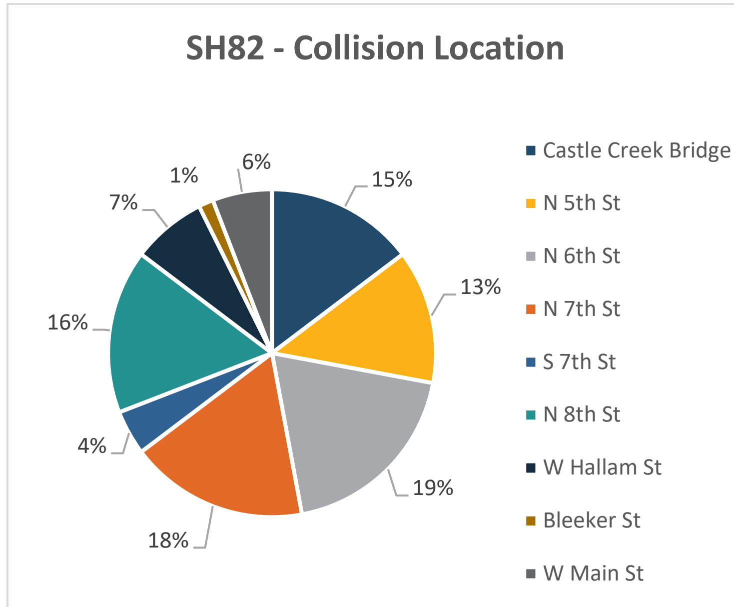


Figure 3. Collision Classification – SH82 (2018 to 2022)

Figure 4. Collision Location – SH82 (2018 to 2022)

3. Options Developed

Two options were developed to smooth the S-curves while improving safety and outbound traffic flow, prioritizing buses, and maintaining bicycle and pedestrian connections. Traffic flow was not modeled, but access points were selectively eliminated to reduce conflict points and ease traffic congestion. Further traffic impact analysis (that is, traffic modeling) would be required to make quantitative assessments (such as travel time or speeds) regarding the options' travel benefits.

The options were laid out to qualitatively assess the impacts of softening the curves, widening the corridor to four lanes, and eliminating access. Softening the curves was strategic because layouts were based on accommodating buses in the outside lanes, heavy trucks (WB-67 design vehicle), and a future fixed rail transit system. For the transit system, an assumption of a light rail transit (LRT) vehicle was selected to set a minimum radius for the curves (refer to Section 6. Transit Options). To accommodate the larger vehicles through the curves, lane width widening is needed in the S-curve corners.

Each option includes bike and pedestrian accommodations to help safely facilitate connectivity and pedestrian travel throughout the corridor. As alignment changes may impact pedestrian facilities, sidewalk modifications and connections are proposed to propagate hike and bike travel from Castle Creek Bridge to North 6th St.

Option 1 is designed to work with the existing two-lane bridge, while Option 2 is designed to match a three-lane bridge over Castle Creek. [1] Option 2 would extend the outbound bus lane to Cemetery Lane, where a bus queue jump could be designed to prioritize transit. Table 1 lists and compares critical design elements of Option 1 and Option 2. Drawings depicting each option are provided in Exhibit B.

These proposed improvements would have impacts, including right-of-way (ROW) and temporary construction easement (TCE) acquisition, removal of existing trees, and minor impacts to a historic property. The design options and associated impacts are noted in Table 1 for each option.

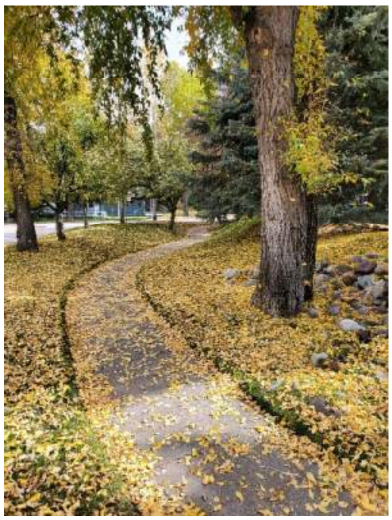
Table 1. Options 1 and 2: Design Elements and Impacts

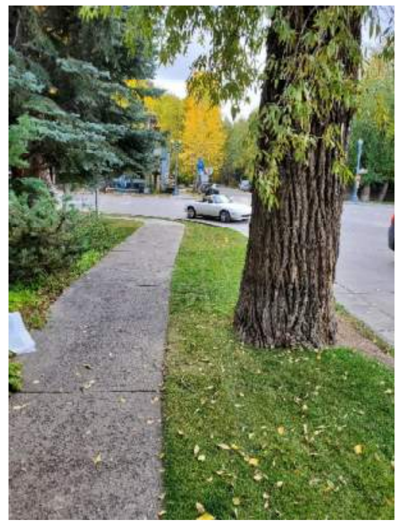
Design Elements and Impacts	Option 1	Option 2
Two lanes of travel in each direction. Outer lanes designated bus/transit lanes	☑	☑
Matches three-lane bridge section. Outer outbound lane designated bus/transit lane		☑
Matches two-lane bridge section	☑	
Ingress/Egress to North 8th Street. removed	☑	☑
Ingress/Egress to North 7th Street removed	☑	☑
Access from outbound SH82 to North 7th Street		☑
Increase radii at S-curves (accommodates large vehicles and future transit system)	☑	☑
Ingress/Egress to South 7th Street and West Main Street removed		☑
ROW/TCE acquisition (square feet)	**2,000/1,800**	**2,200/5,000**
Mature trees impacted by option	**7**	**15**
Historic property impacts (Not Adverse) – 7th/Main Street	☑	☑
Queue jump at Cemetery Lane to facilitate merge of outbound buses with general traffic		☑
Main Street zipper lane removed and converted to merge lane	☑	☑
Better facilitates outbound flow of traffic		☑

[1] As part of a separate task, Jacobs is evaluating rehabilitating or replacing the existing SH82/Castle Creek Bridge to accommodate two or three lanes.

The Christian Science Society building at 734 West Main Street is the one historic property that is impacted by both options. Two large, 36-inch diameter trees are removed for each option. Right-of-way and temporary construction easements are needed for softening the curve (encroachment on the property) and reconstructing the sidewalk on this property. Even with these impacts the affect is expected to be non-adverse for this historic property.

Figures 5 and 6 provide examples of impacted trees with both options.





Figures 5 and 6. Mature Trees Impacted by Both Options

Some design elements from one option can be picked and implemented (à la carte) on the other option as desired. For instance, Option 2 features removing ingress and egress to South 7th Street; this could be done on Option 1 as well.

4. Operational Benefits

The following sections summarize qualitative assessments of operations based on engineering judgment.

4.1 Designated Bus Lanes

A critical design element in the proposed options is the extension of designated bus lanes through the S-curves. It is generally understood incorporating designated bus lanes will help alleviate congestion and improve safety by removing zippering of bus and general traffic on SH82. Currently, existing outbound buses merge with general traffic near North 6th Street and Main Street. The reintroduction of bus traffic to general traffic creates a bottleneck, causing friction between buses and general traffic. Therefore, both options considered repositioning or removing this merge. In Option 1, the outbound bus lane is extended to the bus stop near 8th Street on SH82. Option 2 would carry the outbound bus over a widened three-lane bridge and feature a queue jump for the transit lane at the Cemetery Lane signal, improving safety, reducing congestion, and prioritizing transit. Additionally, signal timing optimization at Cemetery Lane can be evaluated to improve traffic operations for all traffic.

4.2 S-curve Accesses

To help with evening peak period traffic flow, the City commissioned a project that removed access to SH82 from West Hallam Street. Additionally, the City manually suspends access to SH82 from North 7th Street during evening peak hours by placing a barricade to keep west end traffic from entering SH82. Removing access points along SH82 will improve traffic flow and reduce conflict points and potentially traffic collisions. Option 1 and Option 2 each propose eliminating ingress/egress at the 8th Street access to SH82. Option 1 also eliminates access at Curve-1 (North 7th Street) by wrapping West Hallam Street into North 7th Street (Figure 7). Option 2 proposes maintaining egress from SH82 to North 7th Street at Curve-1. Pedestrian connectivity and safety are critical elements of each option. Sidewalks and crosswalks are planned for each option, and the existing inbound and outbound bus stops will remain in both options.

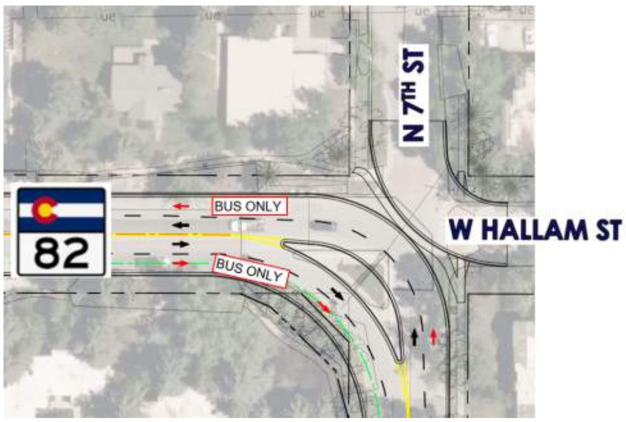


Figure 7. Curve-1 Option 1

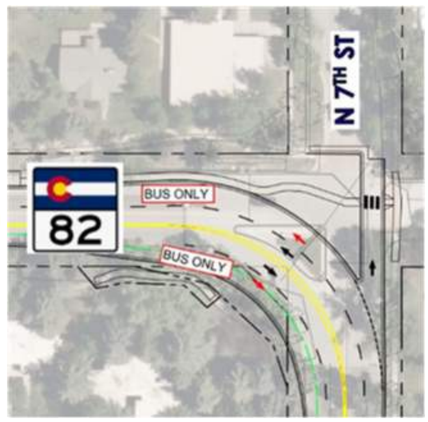


Figure 8. Curve-1 Option 2

Option 1 proposes a raised median at Curve-1, which splits opposing traffic on the curve but is not intended to be used as a pedestrian refuge (Figure 7). Option 2 proposes a painted median at Curve-1, providing a smaller separation of opposing traffic (Figure 8). Option 2 could be designed with a raised median similar to Option 1.

At Curve-2, Option 1 provides the current daily movements for users to continue onto West Main Street to access the Aspen Villas or make a left onto South 7th Street. Because of the curve softening at this location, the stop bar for the left turn is set back about 40 feet from its current position, providing longer time needed to cross the road with oncoming traffic (Figure 9). Option 2 proposes to eliminate ingress/egress access to SH82 at Curve-2, cutting access from South 7th Street and West Main Street by connecting them (Figure 10). Eliminating access at this curve will reduce vehicle conflicts on SH82 and improve traffic flow through the curve.

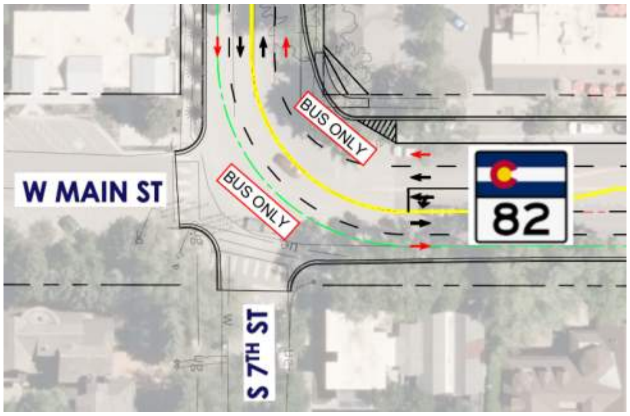


Figure 9. Curve-2 Option 1

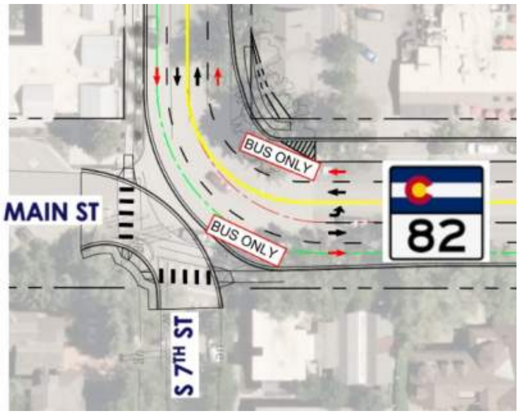


Figure 10. Curve-2 Option 2

4.3 Widening at Castle Creek Bridge

Approaches to narrow bridges tend to slow and congest traffic because the traveler feels compressed by both oncoming traffic and the bridge elements along the driving lane. Creating additional capacity and shoulder widths by widening the bridge at Castle Creek would improve safety and facilitate traffic flow.

Increasing capacity at the bridge is also critical when considering emergency egress. Per the City's evacuation models, it will take more than 12 hours to completely evacuate the City, even using both lanes of the existing bridge for outbound. Considering all S-curve improvements, the existing two-lane bridge will remain a bottleneck and result in significant congestion during an evacuation event and daily peak periods.

Construction of a widened three-lane Castle Creek Bridge would be beneficial for traffic flow, safety, and emergency evacuation; however, the widening option has numerous challenges and impacts. Details are captured in the SH82 Castle Creek Bridge Feasibility Study (Jacobs 2024).

5. SH82 Pinch Point Analysis

Pinch points can be defined as a place where a road or path becomes narrow or a place where there is often a lot of traffic convergence, causing the traffic to slow down or stop. SH82 has several pinch points that inhibit the flow of traffic, resulting in congestion or increase accident potential. S-curve modifications may alleviate some conflict points; however, congestion and queueing will remain if the pinch points are not properly addressed. The West End Neighborhood Traffic Study SH82 (Fox Tuttle, 2022) peak hour volume data indicates the S-curves, the Maroon Creek roundabout, and other traffic constrictions (pinch points) reduce capacity on SH82 in the Castle Creek Bridge area to between 1,000 to 1,400 vehicles per hour.

Figure 11 presents pinch point locations along the corridor. The six pinch points are as follows:

1. Maroon Creek Roundabout
2. Existing Castle Creek Bridge
3. 90-degree S-curve (7th/Hallam Street)—(Curve-1)
4. 90-degree S-curve (7th/Main Street)—(Curve-2)
5. Outbound Bus Merge

6. Zipper Lane

Both options soften the S-curves and remove access at conflicting streets, providing substantive improvements to pinch points 3 and 4. Additionally, pinch point 5 will be relocated but not resolved because buses will have to merge with general traffic at some other westerly point (depending on the option). Pinch point 6 is also being addressed to serve as an outside merge for outbound traffic rather than an atypical inside zipper lane, which will be a safer merge but will still cause traffic friction and congestion.

Figure 11. SH82 Pinch Point Exhibit (See attached Exhibit D for enlarged view)

Although each option proposes improvements for the pinch points described, these are not solutions that solve the bottleneck issues entirely. The Maroon Creek roundabout remains in each scenario, and Castle Creek Bridge will remain a point of restriction as a narrow two-lane bridge for Option 1.

6. Transit Options

One of the considerations in adding designated bus lanes and softening the curves along the route now is that these bus lanes can be repurposed later for future transit options. Advancements in transit technology could provide more options than when the Entrance to Aspen ROD (FHWA, 1998) was completed. These advancements include improvements to vehicle, route, and station designs with an emphasis on efficiency and performance and an eye toward sustainability and reducing greenhouse gas emissions.

Transit technology options include LRT, trolleybus, battery electric and fuel cell electric buses, and hybrid in-motion charging trolley buses. Technology selection will naturally be influenced by the subject corridor, including considerations of capacity, trip frequency, and snow. Given the common inclement weather in the project corridor, issues such as snow removal and maintenance of facilities, management of mixed traffic, and other issues can all be assessed through a technology comparison. Track systems and overhead lines can be adversely affected by snow and ice, and even high winds can disrupt the bus/electric line connections.

The proposed curve softening improvements will accommodate a variety of transit options and will not preclude a future fixed rail LRT system when ridership and funding can support such an investment. There are numerous options regarding bus technology, with each providing its own pros and cons as it relates to performance, infrastructure impacts, and operational and maintenance costs. If ridership warrants the consideration of longer articulated buses, these buses have a better turning radii than a typical bus, so the proposed improvements would be more than adequate to support these longer buses as well. Exhibit E documents some transit options for the corridor.

7. Impact Costs of Options

Table 2 presents estimated costs of impacts from the curve softening based on engineering judgment. Impact costs would likely change if options advance and are refined for the better or worse.

Each proposed option will result in property impacts, necessary for ROW acquisition, TCEs, and tree removals. ROW acquisition costs are based on recent acquisition data from City staff.

	Quantity		Unit	Approx. Unit Cost	Estimated Cost	
	Opt 1	Opt 2			Opt 1	Opt 2
ROW Acquisition	2,000	2,200	Square foot	$ 8,000	$ 16,000,000	$ 17,600,000
Temporary Construction Easement	1,800	5,000	Square foot	$ 1,500	$ 2,700,000	$ 7,500,000
Tree Removals	7	15	Each	$ 10,000	$ 70,000	$ 150,000
Impact Costs					$18,770,000	$25,250,000

Table 2. SH82 Option Impact Cost Comparison

8. Conclusions

The two options discussed in this memorandum may improve traffic mobility and safety within the S-curves but would not address larger congestion and travel time problems. Implementation of these options would not adequately address the other nearby corridor pinch points and do not improve emergency egress out of Aspen. Overall project costs for design, construction and impact costs are quite high for these improvements. Considering Option 1 is less impactful and able to implement with the existing bridge, construction and design is estimated at $4M. When including ROW acquisition and TCE (impact costs), the total cost is approximated to be nearly $23M. Though these estimates provide perspective of estimated cost and impacts against benefits to safety and mobility, further detailed design and construction cost estimates are needed to assess total cost more adequately for each option.

Exhibit A – History of studies and implemented improvements relative to S-Curves

Transportation Studies Timeline: *Castle Creek Bridge and S Curves*

***1994-1998:** During the EIS process, improving the existing bridge and S Curves were evaluated and eliminated at the comparative screening level based on community acceptability and safety issues. The EIS analysis found that, compared to other alignments, the safety of State Highway (SH) 82 would not significantly improve because of the S curves, even with curve improvements. The existing alignment also does not address the need for an alternative emergency access route in and out of Aspen.*

Since then, because of continued interest in improving existing SH 82, other studies have been conducted, as shown below.

CITY OF ASPEN

S Curves - Citizen Task Force Project Development
AUG 2004

Final report for Citizen task force work to improve traffic flow and increase pedestrian safety. (April 2002- August 2004)

S Curve Project - Next Steps
NOV 2004

Staff presentation to Council requesting approval to move forward with the Citizen Task Force recommendations for a main street transit lane and access point closures to improve conditions in advance of the PA

S Curve Safety Improvements / Main Street Transit Lane Signing and Striping
MAR 2006

Restripe the S Curves and Main Street for better transit performance. Add crosswalk striping for pedestrians.

Feasibility Study Update - SH 82 Maroon Creek Roundabout to Main Street Reversible Lane
MAY 2008

Reversible lanes are feasible but largest impediment is cost of the bridge improvements. Widening of bridge to the north would reduce construction impacts but problematic. Bridge replacement consistent with PA is most cost effective.

SH 82 Entrance to Aspen Split Shot Alternative Additional Studies
JUN 2008

The PA travel times were 20% lower than the Split Shot. The PA also had lower open space impacts.

Aspen Area Community Plan
FEB 2012

Maintain SH 82 as a two-lane facility with any extra capacity going to transit. Avoid a net loss of open space.

Entrance to Aspen Analysis and Cost Analysis
JUN 2012

Travel times were lower through the PA as compared to all other alternatives. Costs for the PA are greater than all of the other alternatives.

Bicycle and Pedestrian Plan
JAN 2015

Build a pathway from Buttermilk to the Inn at Aspen

Castle Creek Bridge Connectivity - Conceptual Design Review
FEB 2015

Add sidewalk and barrier to the north side of Castle Creek Bridge. Add new path connections to bridge sidewalk.

Upper Valley Mobility Study
JUN 2017

The PA is the best solution for optimizing transit. Build the PA including the new bridge and dedicated bus lanes.

Upper Valley Mobility Report
SEP 2017

Extend HOV lanes into Aspen to reduce congestion. Add HOV lane enforcement. Pursue LRT because of transit driver shortage.

Near Term Transit Improvements
JUL 2021

Extend HOV lanes into Aspen to improve transit ridership

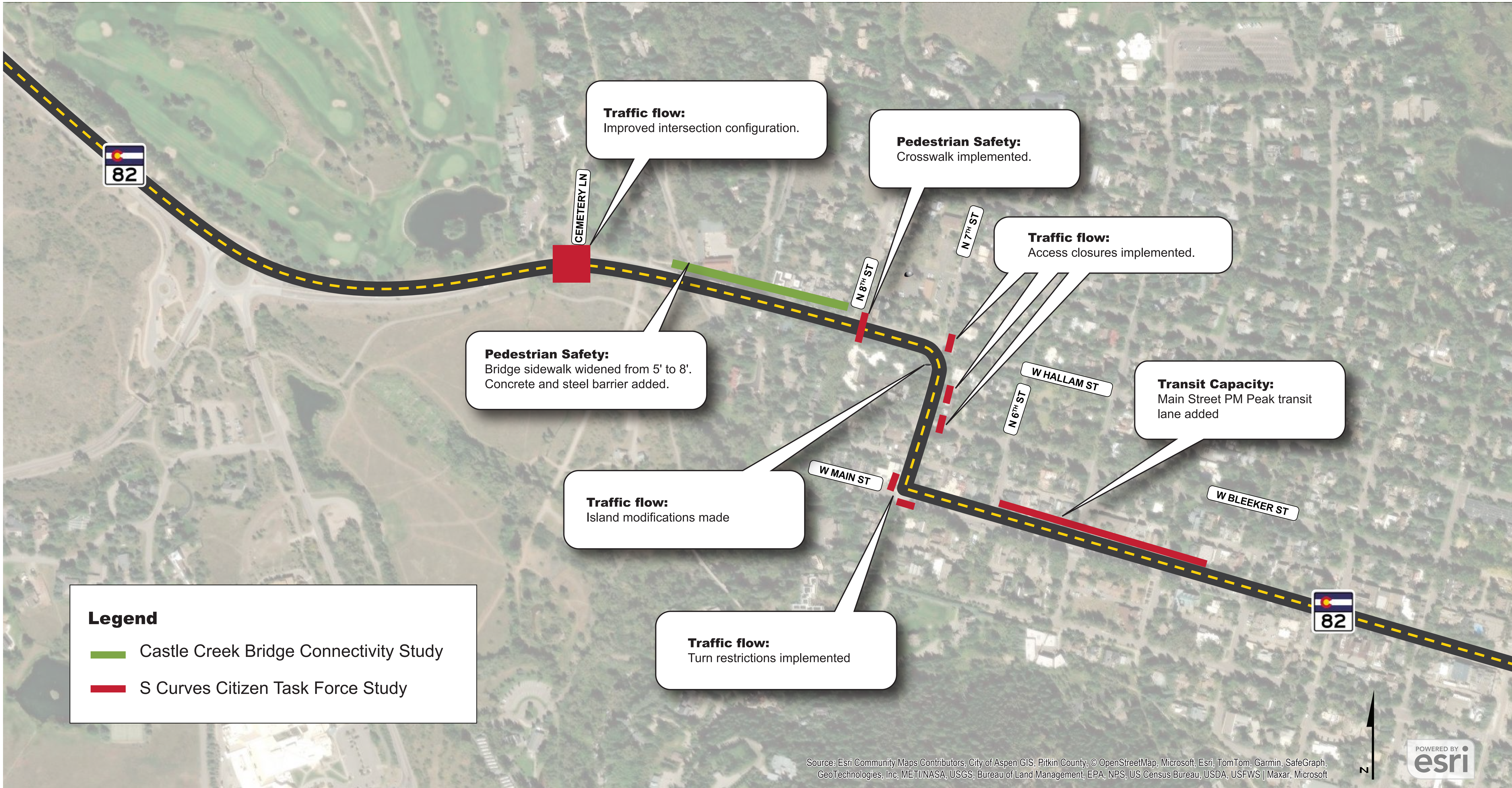
West End Traffic Calming and Traffic Evaluation
AUG 2022

S curves only can accommodate 38% of current westbound volume in the PM peak. 35% of overall traffic diverts to the neighborhoods in the PM peak. Traffic calming was not recommended

- (green flag) = Improvements Implemented
- (orange flag) = More Study/Recommendations Inconclusive
- (blue flag) = Improvements Not Implemented

ACRONYMS

HOV - High Occupancy Vehicle
VPH - Vehicles per Hour
LRT - Light Rail Transit
BRT - Bus Rapid Transit
ROW - Right of Way
PA - Preferred Alternative



S Curve and CCB Improvements

for traffic flow and pedestrian safety (2002-2024)

City of Aspen

Jacobs

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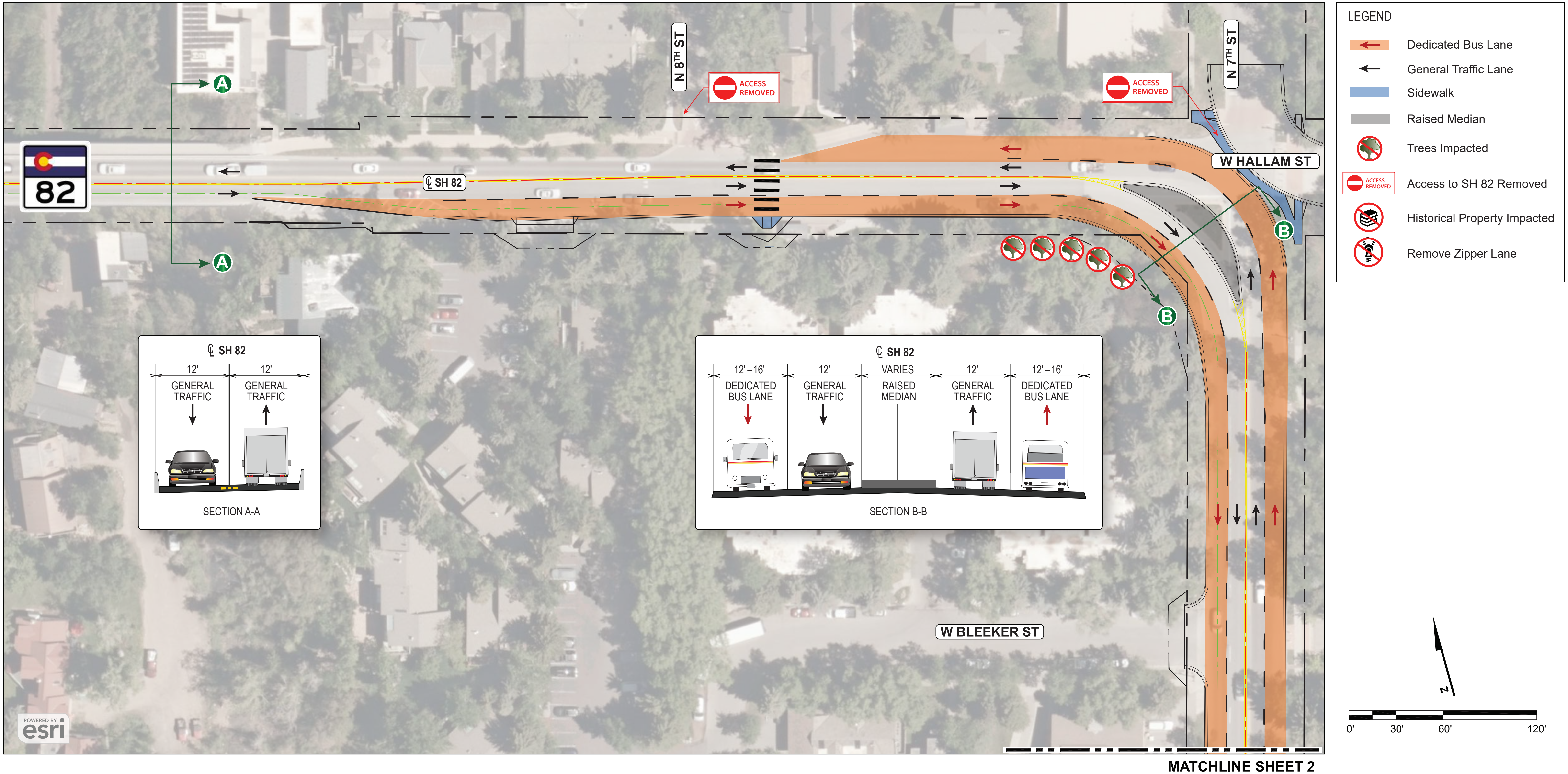
Exhibit B – S-Curves Option 1



Option 1 | Sheet 1

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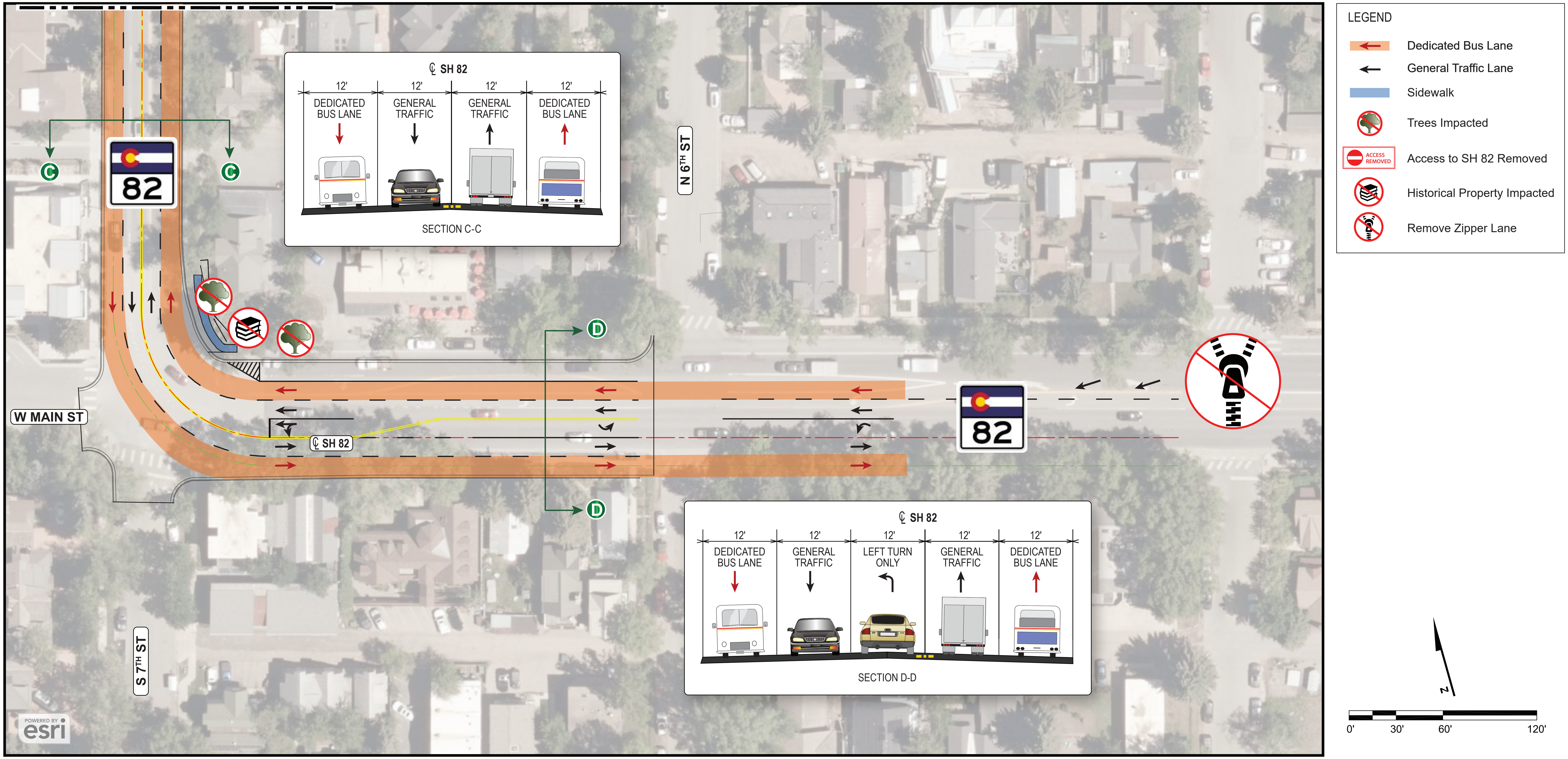
MATCHLINE SHEET 1



Option 1 | Sheet 2
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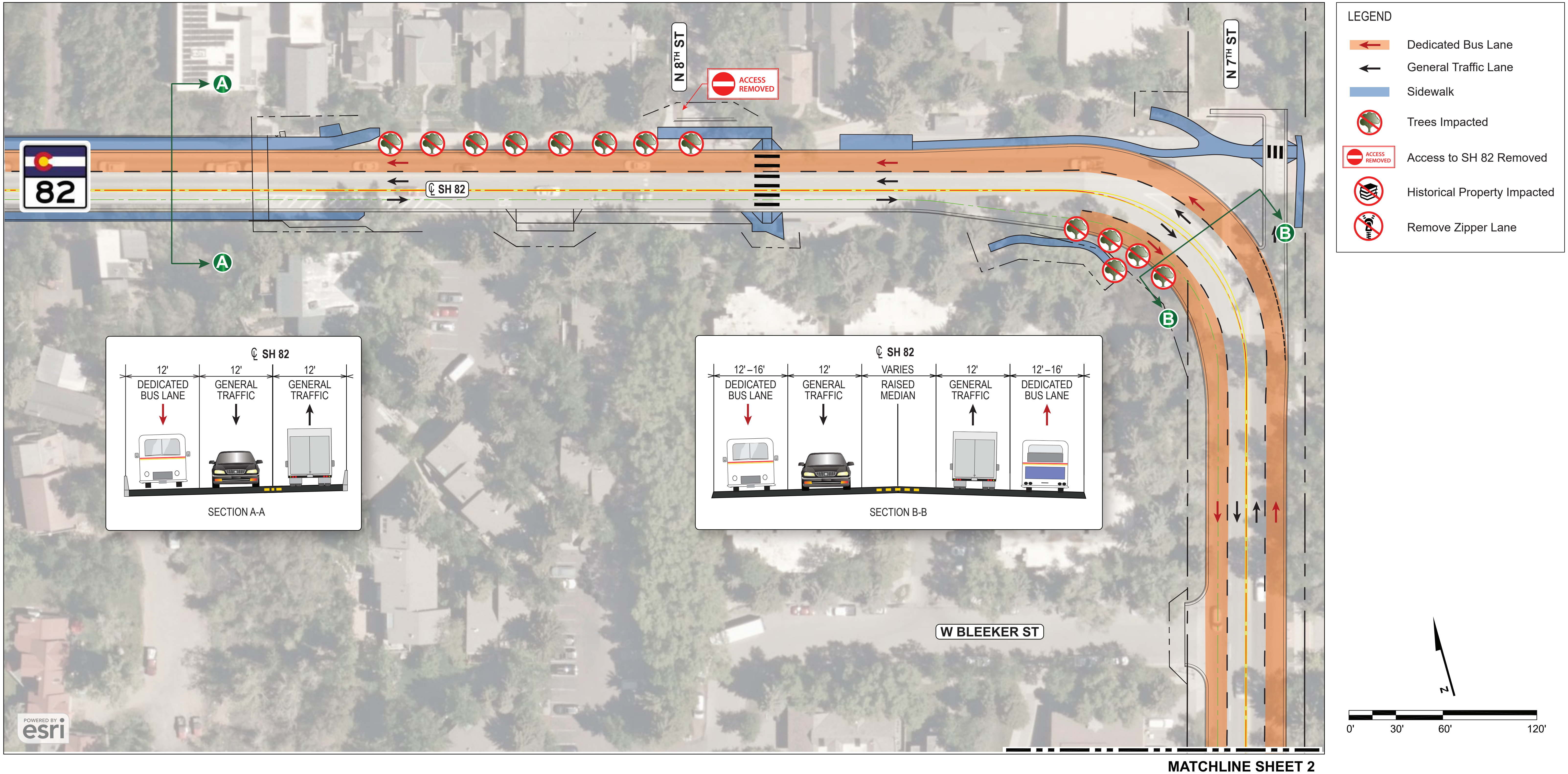
Exhibit C – S-Curves Option 2



Option 2 | Sheet 1

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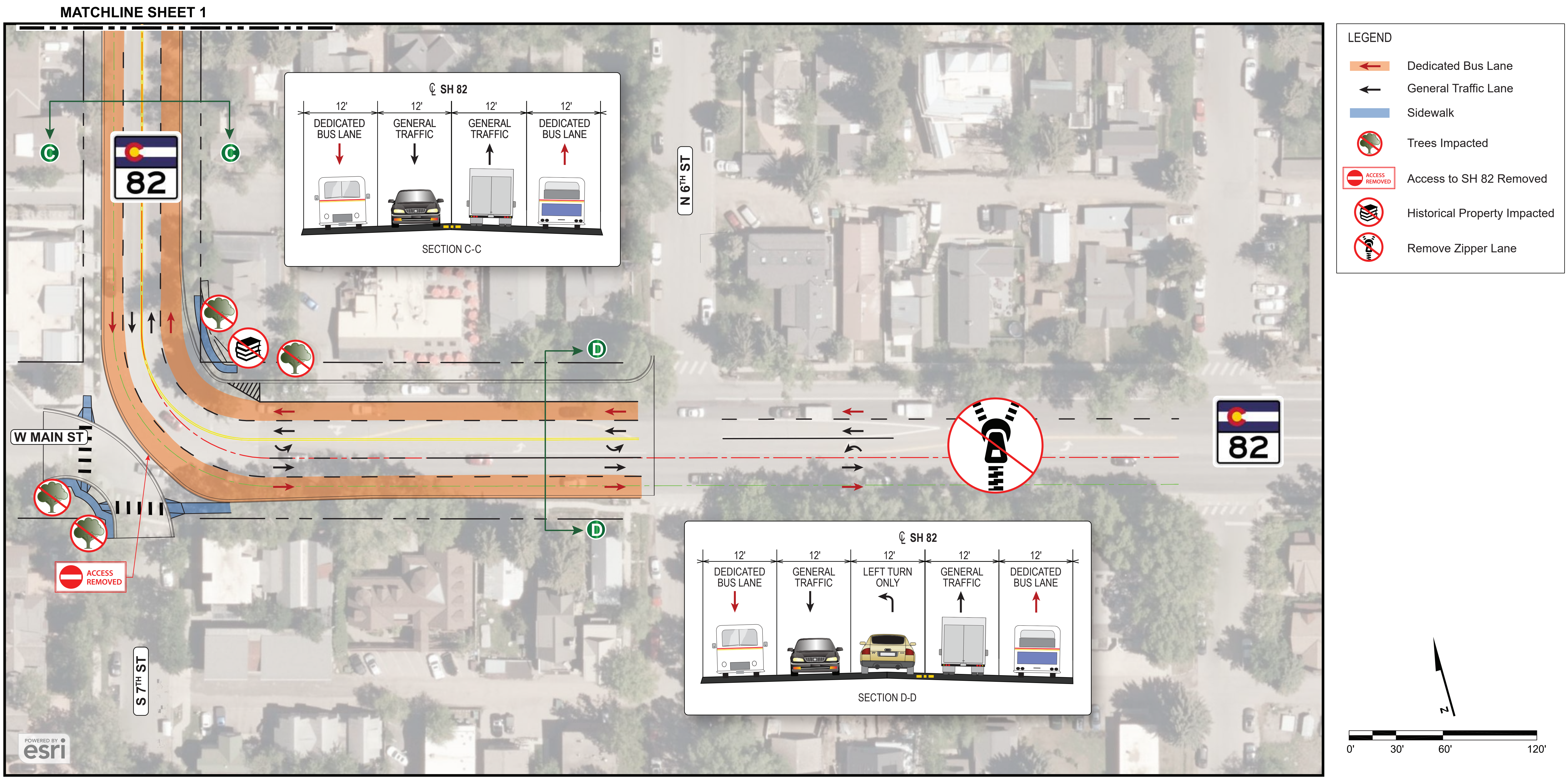

Option 2 | Sheet 2

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Exhibit D – Pinch Point Diagram

SH 82 Pinch Point Exhibit

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Exhibit E – Transit Options

Jacobs Challenging today. Reinventing tomorrow.

Public Transit Options

Aspen, CO

Light Rail

- Reduces air pollution and greenhouse gas emissions by providing alternative to private vehicles
- Higher passenger capacity per lane per hour
- Lower operating cost per passenger
- Can be accommodated through S-Curve alignment
- High construction costs
- No intermingling of transit and general traffic
- Overhead electric can be affected by high winds and snow

Trolleybus

- Draws power from overhead wires and requires poles
- Differs from a traditional trolley system in that two wires and two poles are necessary to complete the electrical circuit
- Bus has greater flexibility to maneuver along the roadway
- Trackless design that provides more opportunities to mix traffic and maximize use of ROW
- Track systems and overhead lines can be adversely affected by snow and ice
- High winds can disrupt the bus/electric line connection

Battery Electric Bus

- Battery electric buses and fuel cell electric buses eliminate the need and impacts from electrification lines
- Accommodates sensitive built environments and constrained ROW
- Battery life and recharge time can pose a challenge
- Recharged, stationary, in 5–20-minute sessions

Overhead In-Motion Charging Trolleybus

- In-motion charging allows operations to continue smoothly without interruption
- In-motion charging trolleybuses use overhead catenary wires, covering about 20-40% of the route, otherwise battery powered
- Reduces overall impacts caused by catenary wires
- Reduces challenges associated with recharging systems
- Ideal in rural/urban corridors

Trackless Tram

- A hybrid technology utilizing rubber wheels and powered by rechargeable batteries
- Sustainable public transit with net zero emission vehicle
- Guided by digital rail with sensors in road, no catenary wires required
- Optical guidance may not be ideal in heavy snow conditions
- Vehicle weight requires substantial roadway surfaces