Benefit Cost Analysis Memorandum

Fixing LOw Water Bridges for Emergency, Transportation, Technology, Equity, and Resilience (FLOW BETTER)

2021 RAISE Grant Application

Prepared for NCDOT by AECOM

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Executive Summary

A benefit-cost analysis (BCA) was conducted for the Fixing LOw Water Bridges for Emergency, Transportation, Technology, Equity, and Resilience (FLOW BETTER) Project to support the grant application of the North Carolina Department of Transportation for the USDOT 2021 Rebuilding America's Infrastructure with Sustainability and Equity (RAISE) program. There are 28 bridges comprising the project as a whole, and because each bridge has independent utility, individual BCAs were estimated for each. This analysis was conducted in accordance with the 2021 Benefit-Cost Analysis Guidance for Discretionary Grant Programs (Guidance).[1] Capital outlays are scheduled to begin in 2023 for the first bridges and some bridges are scheduled to begin operations starting in 2024. The last bridge is scheduled for completion in 2027. All values are in 2019 dollars discounted to 2021 and cover a 20-year operations period, consistent with Guidance.

Exhibit 1 presents the Impact Matrix, which describes the baseline, the Project as a whole, and the estimated results.

[1] USDOT Benefit Cost Analysis Guidance 2021, https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

Exhibit 1 – Impact Matrix

Current Status/Baseline & Problem to be Addressed	Change to Baseline or Alternatives	Types of Impacts	Affected Population	Present Values, $2019 M) Discounted at 7%	Page Reference in BCA
Twenty-six (26) of the 28 Project bridges are structurally deficient or functionally obsolete, and are scheduled for replacement within the next STIP cycle. Twenty-four (24) of the bridges are posted due to weight restrictions with the result that the large or heavy vehicles typically used in agriculture and shipping cannot use the route. The restrictions result in detours or partial loading; both practices raise production costs and decrease farm incomes, in an area heavily reliant on Christmas Tree farming for economic vitality. Detours also occur due to frequent flooding of the bridges and cut off populations and delay critical emergency services.	The Project would replace 28 rural bridges, bringing them up to a state of good repair and allowing for all vehicles to use them, reducing VMT and travel times in the region. In addition, adjacent farms will save some operating expenses from improved efficiencies in the transportation network, and the bridges will be safer and allow for more reliable emergency access. Bringing the bridges up to a greater level of service reduces the frequency and duration of flooding that results in detours. The reduced VMT results in travel cost savings for autos, operating cost savings for trucks, emissions savings, safety improvements and crash reductions, and residual value.	Safety			
		Reduced Roadway Fatalities and Crashes	Drivers and passengers who reduce VMT after Project opening	$3.7	10
		Safety Improvements at Bridges	Drivers, passengers, and property owners near the Project bridges	$7.5	12
		Emergency Access Benefit	Populations relying on bridges that have reduced access when flooded	$0.5	12
		State of Good Repair			
		Roadway Maintenance Savings	NCDOT, Taxpayers	$0.0	13
		Bridge Repair Costs Avoided	NCDOT, Taxpayers	$5.1	13
		Bridge Current Maintenance Costs Avoided	NCDOT, Taxpayers	$0.1	13
		Economic Competitiveness			
		Travel Time Savings Detours	Drivers and passengers who reduce VMT after Project opening	$2.7	13
		Travel Time Savings Bridge Lanes	Drivers and passengers who use the bridges	$0.3	13
		Auto Travel Cost Savings	Drivers and passengers who reduce VMT after Project opening	$2.3	14
		Residual Savings	NCDOT, Taxpayers	$4.4	14
		Truck Operating Savings	Freight operators, Shippers, Customers	$4.0	14
		Trip Not Taken	Populations located on dead-ends that rely on bridges	$23.6	14
		Environmental Sustainability			
		Emissions Savings	General public	$0.2	14
		Quality of Life			
		Agricultural Access Improvement	Farms in the vicinity of Project bridges and tourists accessing the farms	$33.2	15

Exhibit 2 summarizes long term outcomes of the Project. Taken in total, the Project provides $89.1 million in benefits—reduced roadway fatalities and crashes, safety improvements at the bridges, emergency access benefits, roadway maintenance savings, bridge repair costs avoided, bridge maintenance costs avoided, travel time savings, auto travel cost savings, residual savings, truck operating savings, the value of a trip not taken, emissions savings, and agricultural access improvements—over the analysis period, using a 7 percent discount rate. Compared to a similarly discounted cost estimate, the Benefit-Cost Ratio for the Project is 2.35, a solid return on this critical investment for the region. The net benefits of the Project are $51.2 million using a 7 percent discount rate.

Exhibit 2 – Costs and Benefits Delivered by Long Term Outcomes

Costs (2019 $M)	
Capital Cost	$38.0
Total Costs	*$38.0*
Benefits (2019 $M)	
Safety Benefits	
Reduced Roadway Fatalities and Crashes	$3.7
Safety Improvements at Bridges	$7.5
Emergency Access Benefit	$0.5
Sub-Total	$11.7
State of Good Repair Benefits	
Roadway Maintenance Savings	$0.003
Bridge Repair Costs Avoided	$5.1
Bridge Current Maintenance Costs Avoided	$0.1
Sub-Total	$5.2
Economic Competitiveness Benefits	
Travel Time Savings Detours	$2.7
Travel Time Savings Bridge Lanes	$0.3
Auto Travel Cost Savings	$2.3
Residual Savings	$4.4
Truck Operating Savings	$4.0
Trip Not Taken	$23.6
Sub-Total	*$37.2*
Environmental Sustainability	
Emissions Savings	$0.2
Sub-Total	$0.2
Quality of Life	
Agricultural Access Improvement	$33.2
Sub-Total	$33.2
Net Operating & Maintenance Costs	$1.6
Total Benefits	*$89.1*
Outcome	
Net Benefits (2019 $M)	$51.2
Benefit-Cost Ratio	**2.35**

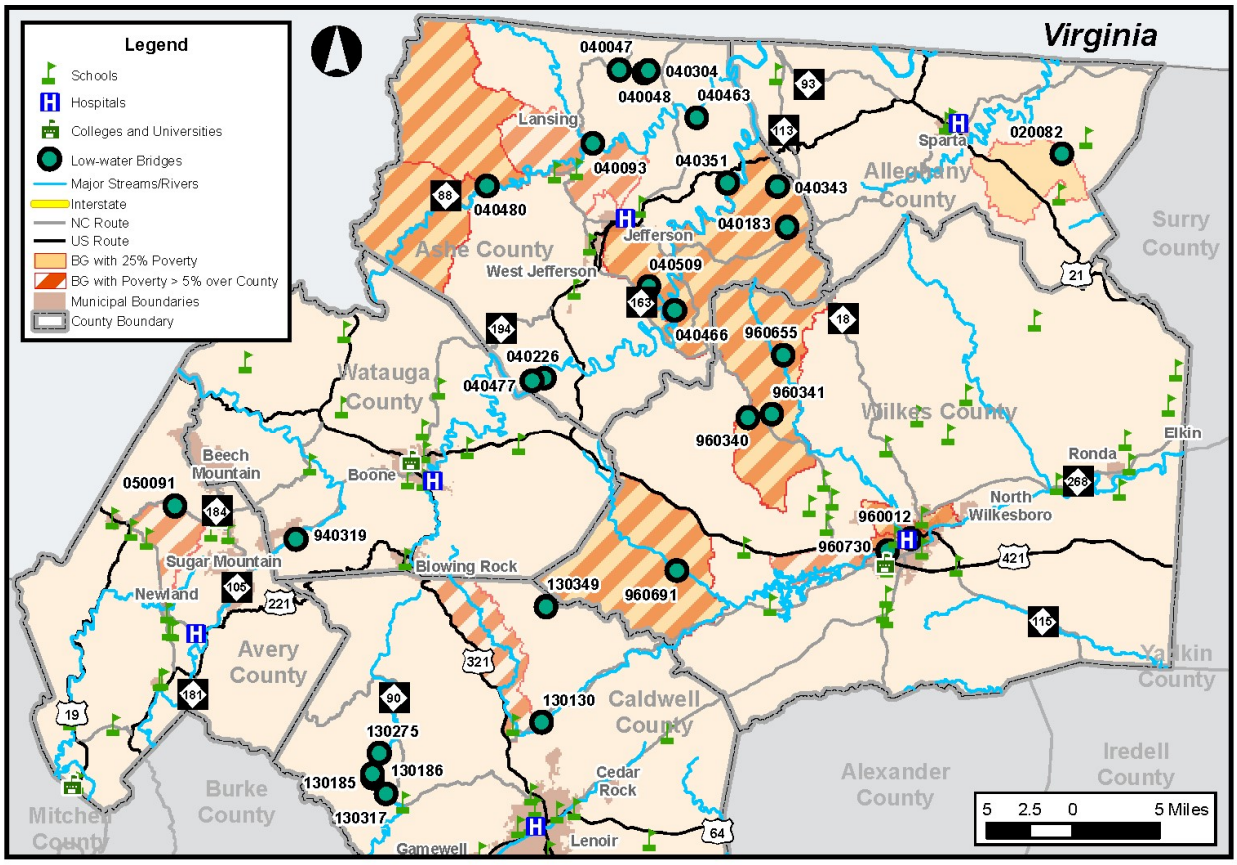
1. Introduction

FLOW BETTER (or "Project" hereafter) was developed through North Carolina's Department of Transportation ("NCDOT" hereafter). The Project will replace 28 rural bridges located in 6 of the most rural and economically depressed counties across the state.

The following North Carolina counties contain one or more of the FLOW BETTER Bridges as identified in parenthesis. Figure 3 illustrates the location of each Project bridge.

1. Alleghany (1)
2. Ashe (13)
3. Avery (1)
4. Caldwell (6)
5. Watauga (1)
6. Wilkes (6)

Exhibit 3 – Location of the Bridges in Western North Carolina



The FLOW BETTER Project addresses multiple criteria in the RAISE Grant program. These include: Safety, Economic Competitiveness, Quality of Life, State of Good Repair, and Environmental Sustainability. In some cases, the expected FLOW BETTER Project outcomes apply to more than one of the benefit categories identified above.

- ***Safety***: The Project improves safety in several ways.
  - First, in instances where the existing bridge was built decades ago, the new bridge and approach will be designed for modern standards and vehicles, reducing the potential for fatalities, injuries, and crashes.
  - Second, once the bridge is replaced and able to accommodate all types of vehicles, detours will be eliminated, reducing vehicle miles traveled (VMT) and the chance of a crash.

  - Third, each of the replacement bridges will be built higher and with guardrails, reducing the likelihood of being flooded, damaged by debris and unavailable for use. The BCA estimates the value of the safer bridge design and the reduction in VMT. In order to value the improved reliability of the bridges, the Level of Service (LOS) between the No Build and Build condition was used to evaluate the change in the number and duration of flooding events.[2]
  - Finally, the improved bridges reduce the risk of delays in the event of an emergency, particularly for populations stranded by a dead-end and a washed-out bridge. An emergency access benefit is estimated for bridges based on the number of flooding events and durations avoided.

- ***Economic Competitiveness***: Six types of economic competitiveness benefits are estimated as part of the BCA. With the elimination of detours, (1) travelers save time and (2) avoid the cost associated with VMT from the detour and, (3) Trucks will save operating cost as well. As these bridges have a long useful life that exceeds the 20-year analysis period applied in the BCA, (4) a residual value is estimated. Many bridges are one lane and will be upgraded to two when they are rebuilt; (5) the travel time savings for vehicles that must wait while other vehicles cross under current conditions is included as a benefit. Finally, for bridges that lead to dead-end roads, the loss of the bridge during flooding events means those populations are cut off from all trips including employment, education, health care, and any other trips. Avoiding this loss to those populations is valued as (6) a trip not taken.
- ***Quality of Life***: The Project benefits Quality of Life in two primary ways. First, the low posted weight limit of the bridge causes a daily inconvenience to travelers, including school buses. Second, the ability to move large farm equipment among fields allows agricultural producers to conduct their work more efficiently. The AADT for the bridges likely omit counts of tractors and other farm machinery that must divert and find another route when moving from field to field during planting or harvest season, as well as delivery vehicles between farms and retail locations. This analysis provides a conservative estimate of the value of improved agricultural access improvements in the vicinity of the bridges. The improved efficiency allows farmers to reduce farm expenses, supporting rural incomes.
- ***State of Good Repair***: Once the posted bridges are replaced and able to accommodate all types and weights of typical vehicles in use, the need to detour around the bridge will be eliminated, reducing truck and auto VMT and roadway wear and tear. Avoided damages and repairs to bridges after flooding events will also keep the bridges in a state of good repair.
- ***Environmental Protection***: Once the posted bridges are replaced and able to accommodate all types and weights of typical vehicles in use, and the higher bridges flood less frequently and for shorter durations, the need to detour around the bridge will be eliminated, reducing VMT and associated emissions.

Supplementary Materials can be found on the website (https://connect.ncdot.gov/resources/RAISE-LowWater/Pages/default.aspx).

2. Benefit Analysis Framework

The parameters of the benefits analysis follow the protocols set by the Office of Management and Budget (OMB) Circular A-94 as well as the recommended benefit quantification methods by the USDOT and the Federal Emergency Management Agency (FEMA). Generally, standard factors and values accepted by Federal agencies were used for the benefits calculation except in cases where more Project-specific values or prices were available. In all such cases, modifications are noted and references are provided for data sources. The analysis follows a conservative estimation of the benefits. By adhering to a strict standard of what could be included in the benefits analysis, actual total benefits may be greater than depicted in the results.

The baseline assumes that the Project would not be built and current conditions and operations would continue in the project area. Under the baseline, the purpose of and need for the Project would not be met

[2] See Analysis Assumptions for more information on how the LOS impacts the benefits

and would generally be limited to the operation and maintenance of existing infrastructure. The Project was compared to the baseline to identify benefits and costs.

A custom model was developed to estimate the future benefits for the Project. Benefits were estimated over a 20-year period of analysis beginning when construction ends and concluding after 20 full years of operations. Each project schedule varies, but for the group of 28 projects, the construction period is from 2023 through 2027, and operations begin in 2024 with partial years included as needed.

The benefits are expressed in constant 2019 dollars, which avoids forecasting future inflation and escalating future values for benefits and costs accordingly. The gross domestic product chained price index from the OMB was used to adjust past cost estimates or price values into 2019 dollar terms (OMB, 2018).

The use of constant dollar values requires the use of a real discount rate for discounting to the present value. Projects expecting to use federal funding are required to use a 7 percent discount rate.

3. Analysis Assumptions

A list of assumptions for the Project is provided in the BCA workbook (see Inputs tab in the file BCA.xlsx) as well as in Exhibit 4.

Exhibit 4 – BCA Calculation Inputs

Input	Value	Source
General		
Discount Rate	7%	2021 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Discount Rate - CO2 Emissions	3%	2021 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
Deflator	See "Deflator" Sheet	https://www.whitehouse.gov/wp-content/uploads/2019/03/hist10z1-fy2020.xlsx
Dollar year	2019	
Discount year	2021	
Annualization factor	365	
Vehicle occupancy - All Travel	1.67	2021 BCA Guidance for Discretionary Grant Programs
AADT annual growth	1%	NCDOT
Population annual growth	1%	Assumed
Truck share	4.0%	Assumed
Water gage installation per bridge (2019$)	$35,000	NCDOT
O&M for flood gage (2021$)	$2,500	NCDOT
O&M for flood gage (2019$)	$2,428	NCDOT
State of Good Repair		
Roadway Maintenance Cost, Rural Interstate (2000$/mi) - Auto	$0.000	Source: FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13
Roadway Maintenance Cost per Mile, Rural Interstate (2019$) - Auto	$0.000	Adjusted by GDP Deflator
Roadway Maintenance Cost, Rural Interstate (2000$/mi) - 40 kip truck	$0.010	Source: FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13
Roadway Maintenance Cost per Mile, Rural Interstate (2019$) - 40 kip truck	$0.014	Adjusted by GDP Deflator
Share of Construction costs that are for bridge structure	75%	Engineering judgement
Economic Competitiveness		

Trip not taken (hours per trip)	12	FEMA
Travel time savings - share of vehicles per bridge that wait	5%	Assumed
Travel time savings per vehicle (minutes)	1	Assumed
Percent of farms affected by county	5.0%	Assumed
Percent of farm expenses saved by county	3.5%	Assumed
Vehicle Maintenance Cost per Mile, Auto (2019$)	$0.43	2021 BCA Guidance for Discretionary Grant Programs
Vehicle Operating Costs per Mile, Truck (2019$)	$0.93	
Value of Time (2019$), private vehicle travel time per person hour, all purposes	$17.90	
Value of Time (2019$), truck driver per hour	$30.80	
Times bridges flood in No Build, on average per year	6	Per EMS, most bridges flood 3-6 times per year
Reduction in time of bridge closure in Build due to flooding	50%	Assumed
Safety		
PDO Crash Modification Factor	18%	NCDOT, https://connect.ncdot.gov/resources/safety/TrafficSafetyResources/NCDOT%20CRF%20Update.pdf
Injury Modification Factor	32%	
PDO - Property Damage Only Crashes (2019$)	$4,500	2021 Benefit-Cost Analysis Guidance for Discretionary Grant Programs
C - Possible Injury (2019$)	$72,500	
B - Non-incapacitating (2019$)	$142,000	
A - Incapacitating (2019$)	$521,300	
K - Killed (2019$)	$10,900,000	
U - Injured (Severity Unknown) (2019$)	$197,600	
# Accidents Reported (Unknown if Injured) (2019$)	$150,200	
Emergency Response Time without flooding (minutes)	10	Assumed
Emergency Response Time with flooding (minutes)	40	Assumed
Emergency Response Population Impacted	100	Assumed
Environmental Sustainability		
Cost of CO2, NOx, and PM2.5 per metric ton (2019$)	See “Std. Inputs” sheet	2021 Benefit-Cost Analysis Guidance for Discretionary Grant Programs

Flood Frequency and Duration

The low water bridges in the Project are designed to overtop, but the rebuilt structures will include guardrail that will reduce debris and damages and the duration of bridge closure from flood events. The analysis of the impacts from detours that result from flooding of the low water bridges is based on both the frequency of floods (per year) and the duration of bridge closure from a flood (days). The frequency of the flood is estimated at 6 floods per year in the No Build. The duration of bridge closure from each flood

is based off of NCDOT TIMS data which is a record of flooding events that have caused the bridges to flood and close; it is bridge-specific and provided by NCDOT. The bridge's LOS relates to the frequency with which the bridges are designed to flood. For example, some of the bridges have a LOS of 0.5 in the No Build, indicating that they are designed to flood twice per year. In the Build, bridges will be improved up to at least a LOS of 2, or once every two years. Bridges will be improved to a greater degree, as allowable by geometry and other localized considerations. The degree to which the LOS improves in the Build compared to the No Build, as well as a reduction in bridge flood closure duration of 50 percent, is used to estimate the days of detoured bridge traffic that would be saved in the Build.

4. Benefits Methodology

The methodology used to estimate the benefits of the Project are described in the following sections.

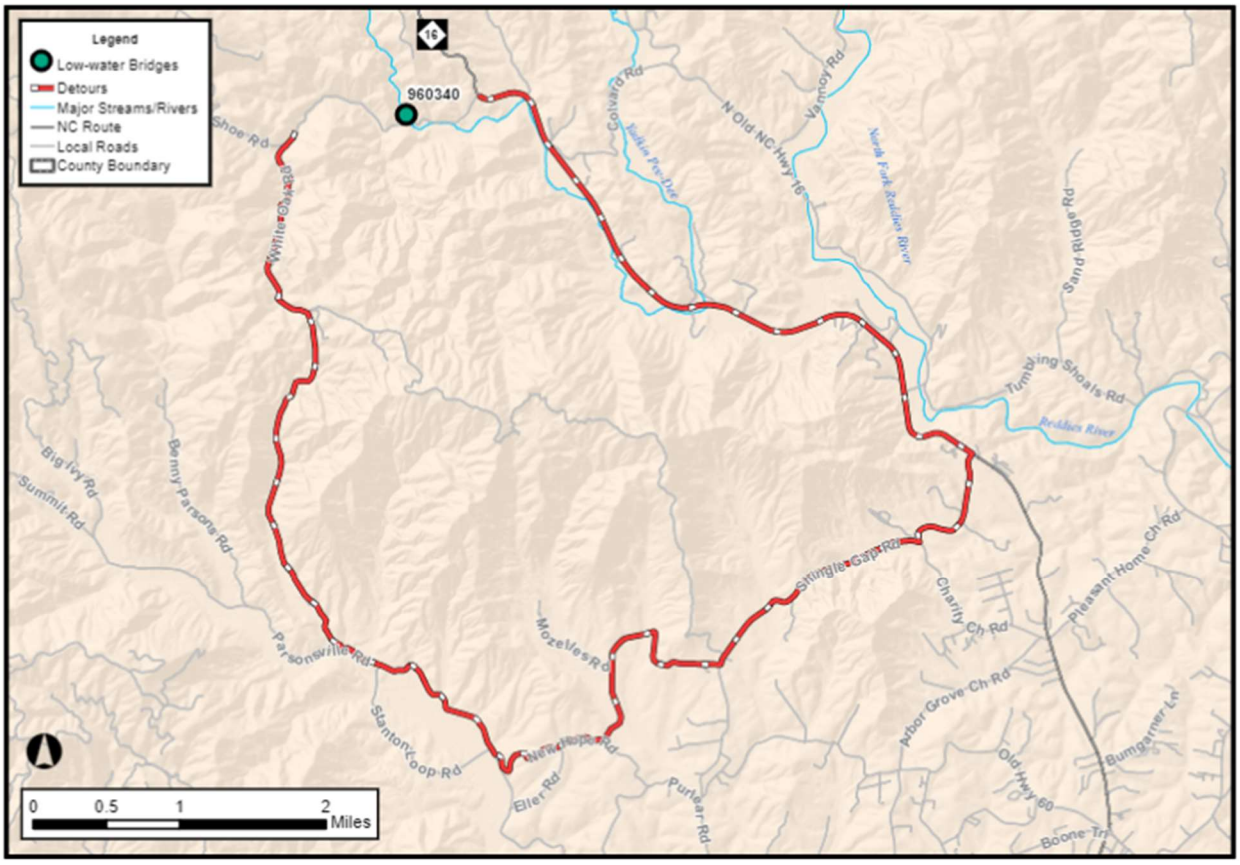
Safety

The Project would result in safety benefits by removing VMT from the region's roads and bringing the bridges up to current design standards.

Reduced Roadway Fatalities and Crashes

The construction of the bridges results in temporary closure of the bridge and therefore forces all traffic to detour on a longer route. This longer route results in increased VMT for the duration of the bridge closure. The temporary increase in VMT for construction is offset with the reduction in VMT once the bridges open. Under the baseline condition, trucks that are overweight of the posted bridge weight limit must divert around the bridge and all traffic must divert when the bridge is flooded. The diversion mileage was estimated for each bridge using GIS for the shortest alternate route. The diversion is conservative, as a vehicle that originates or is destined closer to the bridge location would take a longer detour than the average through traffic. See Exhibit 5 – Example Detour Route for an example of the routes estimated for each bridge. The green dot is the bridge, and the dark gray route (NC Route) is the through-route that a vehicle intends to travel, but because the bridge is posted or flooded, the vehicle must take the longer red route (Detours). The difference in mileage between the red and dark gray route is the net detour used in the analysis.

Exhibit 5 – Example Detour Route



Source: AECOM GIS

The annual average daily traffic (AADT) for each bridge was provided by NCDOT and the number of trucks that divert due to posted weight limits were estimated using existing AADT, truck percentages, and growth rates. Multiplying the number of trucks diverted daily by 365 to get annual traffic and by the net diversion results in the annual VMT saved under the project.

In addition, VMT is saved during flood events. Emergency services providers in Ashe County note that the bridges flood 6 times per year for a duration of time based on NCDOT TIMS data by bridge; therefore, the detours due to flooding for all vehicles are factored by the LOS change from the No Build to the Build. The duration of flooding and bridge closure are assumed to decrease by 50 percent in the Build compared to the No Build, which is based on TIMS data. The product of the AADT and mileage of net detours is the VMT avoided by the Project.

Multiplying the AADT by the bridge closure time for construction (up to 7 days per bridge) provided by NCDOT and the net diversion mileage results in the additional VMT incurred during the construction period.

Net VMT is found by offsetting the additional VMT incurred during construction against the VMT avoided from reduced flooding. The rates of crashes that result in fatalities, injuries, and property damage are applied to the net annual VMT to derive the estimated crashes from the change in VMT. The crash rates for fatalities, injuries, and property damage are County-specific rates from NCDOT data.[3]

These crash rates multiplied by the VMT avoided were then converted to KABCO ratings, which refers to the letters used to designate five levels of crash severity used by police at a crash scene. Estimating the distribution of expected injury types is important because the economic cost of the injury increases as injury severity increases. Values for K - fatality, U - injured (severity unknown), and Property Damage Only (PDO)

[3] See Appendix A at the end of this document

were used, based on USDOT guidance. Exhibit 4 provides the estimated cost of different types of crashes. ***The total reduction in highway fatalities, injuries, and PDO results in $3.7 million in benefits, discounted at 7 percent.***

Safety Improvements at Bridges

In addition to the safety benefit from changes to VMT, the replacement of the bridges results in safety benefits from bringing the bridges up to current design standards. The bridges are out of date and lacking the safety features and designs of today's bridges. Three improvements will be made to the new bridges: first, guard rail will be added and replaced up to AASHTO standard; second, the bridges will be widened; and third, horizontal alignments will be altered to the degree possible.

NCDOT estimated that a 32% reduction in fatal and injury crashes and an 18% reduction in PDO crashes would occur at the bridges once replaced.[4] NCDOT provided crash data within 500 feet of the bridges over a five-year period. Data were provided for fatalities and injuries of type A, B, and C, and PDO and unknown crashes. The reduced fatalities, injuries, and property damage were valued based on USDOT guidance and are listed in Exhibit 4. Only four bridges experienced crashes since 2013, including Structure 960730 where two pedestrians were struck and killed in June 2021.[5] The existing bridge does not have sidewalks, but the replacement structure will. ***The total safety improvements at bridges result in $7.5 million in benefits when discounted at 7 percent.***

In addition, the project bridges will be replaced at higher elevations where possible, reducing the likelihood of wash-out and improving hydraulic conveyance. They are likely to reduce upstream flooding, possibly affecting open farmland and forest areas. These benefits were not quantified for this BCA.

Emergency Access Benefit

Emergency services provide vital services to communities, such as fire response and emergency medical care. The ability for emergency services to respond quickly is essential to reducing damages and decreasing injuries and fatalities. Currently, emergency response is delayed due to the flooding of the bridges.

The FEMA method for estimating the loss of emergency services was used to estimate the benefits of the Project.[6] Due to the flooding, the analysis assumes that emergency response is delayed by 30 minutes for a population of 100, based on conversations with Ashe County Emergency Medical Services (EMS). The value of emergency access was factored by the frequency of floods based on each bridge's improvement in LOS from the No Build to Build and change in flooding duration per incident. The duration of flooding is based on a conservative 50 percent reduction to the TIMS data per bridge. Population growth is expected to growth at 1 percent annually for the duration of the analysis period.

With the bridges reconstructed, the net results are positive safety benefits for the Project due to the faster response time. ***The emergency access benefit totals $0.5 million discounted at 7 percent.***

State of Good Repair

The Project would result in state of good repair benefits by removing auto trips from the region's roads.

[4] NCDOT, Crash Reduction Factor (CRF) Information, Traffic Safety Unit, July 21, 2020, https://connect.ncdot.gov/resources/safety/TrafficSafetyResources/NCDOT%20CRF%20Update.pdf
[5] McKenith, DaVonte, WXII 12, "Wilkesboro Police arrest woman in deadly hit & run case," June 10, 2021, https://www.wxii12.com/article/2-dead-hit-and-run-suspect-wanted-bodies-found-under-wilkesboro-bridge/36642386
[6] Presented in the USDOT's Benefit-Cost Analysis Guidance for Discretionary Grant Programs (December 2018) and described in FEMA's Benefit-Cost Analysis Re-Engineering (BCAR), Development of Standard Economic Values Version 6.0, December 2011

Roadway Maintenance Savings

An increase in auto VMT during construction incurs additional roadway maintenance costs, such as painting and paving. The roadway maintenance cost savings is negligible per auto VMT on rural highways, as obtained from the FHWA Highway Cost Allocation Study. Like autos, trucks incur more VMT during construction but save VMT once the bridges are open. The FHWA Highway Cost Allocation Study values roadway maintenance cost per mile at $0.014 for a 40-kip truck. Multiplying the auto and truck VMT by the maintenance costs per VMT results in roadway maintenance savings. ***Roadway maintenance savings amount to $3,000, discounted at 7 percent.***

Bridge Repair Costs Avoided

When the low water bridges flood, the bridges incur damages. NCDOT provided estimates of the costs for debris removal, inspection, and repairs per flooding event in the No Build and Build. For each flooding event, NCDOT would save $1,500 in repair costs, while debris removal and inspections would remain the same. Based on TIMS data on flood durations, the improvement in LOS in the Build compared to the No Build, and the costs of repairs for the floods, the ***bridge repair costs avoided amount to $5.1 million discounted at 7 percent.***

Bridge Current Maintenance Costs Avoided

The bridges are in need of maintenance investments in order to bring them into a state of good repair. NCDOT estimated the costs of these necessary repairs that would be made in the next six months. As such, the analysis assumes these costs are incurred in 2021. If the bridges are reconstructed, these costs would be avoided. ***Bridge current maintenance costs avoided amount to $0.1 million, discounted at 7 percent.***

Economic Competitiveness

The Project would produce economic benefits by allowing vehicles to take a more direct route, resulting in travel time savings, auto travel cost savings and truck operating cost savings. The remaining value of the Project is captured by the residual value. Vehicles would avoid waiting at single-lane bridges because the bridges would be upgraded to two lanes if they are not already. Finally, populations stranded on a dead-end road will not be able to make any trips during flooding events; these trips are valued as a trip not taken and will be incurred less frequently when the Project bridges are reconstructed.

Travel Time Savings Detours

Because autos must travel longer routes during the construction period, they incur travel time delays. Assuming a 55 mile per hour travel speed on both the through-route and the detour route, the average travel time loss was estimated for the annual traffic volumes. Multiplying the annual hours lost by the average vehicle occupancy (1.67) and the personal value of time ($17.90 in 2019 dollars), as found in Exhibit 4,[7] as well as the change in frequency and duration of flooding events, yields the total travel time savings. ***The total travel time savings for the Project amounts to $2.7 million discounted at 7 percent.***

Travel Time Savings Bridge Lanes

Travel time is saved for vehicles that utilize the one-lane bridges.[8] Assuming one minute of delay for five percent of the AADT per bridge, ***the travel time savings for bridge lanes totals $0.3 million discounted at 7 percent.*** Note that no benefit accrues for bridges 960012 and 960730 because they each already have two lanes.

[7] USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 17, 2021, https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

[8] Bridges greater than or equal to 20 feet in width can accommodate two lanes. 21 bridges are one-lane.

Auto Travel Cost Savings

The longer auto trips during construction also result in negative travel cost savings, while reduced detours due to flooding events saves auto VMT in the Build. Travel cost savings was estimated using a cost savings of $0.43 per reduced auto VMT as recommended by Guidance.[9] ***Auto travel cost savings amount to $2.3 million discounted at 7 percent.***

Residual Value

Construction of the new bridges results in residual value after the end of the 20-year analysis period because the useful life of the bridge is 75 years.[10] The full value of the right of way acquired for the Project was also included in the residual analysis. It was assumed that 75 percent of the capital costs for construction are for bridge infrastructure. The remaining value of the bridge and right of way acquired was summed and discounted from the last year of the 20-year analysis period. ***The value of the remaining useful life for the Project discounted at 7 percent is $4.4 million.***

Truck Operating Savings

Based on the additional truck VMT incurred during construction and the long-term truck VMT savings from avoiding detours when the bridges' posted weights increase and when the bridges flood, the net truck operating savings is calculated. The savings per mile of $0.93 in 2019 dollars as recommended by Guidance. ***The total truck operating savings for the Project amounts to $4.0 million discounted at 7 percent.***

Trip Not Taken

There is value in trip-making; otherwise, trips would not be made. Likewise, there is a value for trips that are not taken, and the cost is primarily in productivity and economic activity. The value of a trip not taken is estimated using FEMA guidance, which assumes a 12-hour penalty for each one-way trip lost.[11] The analysis estimates the value of the loss in productivity and spending for each trip that is not made. The avoidance of this loss is a benefit for the region.

When a trip is not made, the productivity and spending impacts associated with that trip are lost to the region. It is assumed that no trips can be made when the bridges flood because there is no detour for the populations stranded by a dead-end. ***The value of trips not taken avoided during flooding closures totals $23.6 million discounted at 7 percent.***

Environmental Protection

The Project would result in net environmental protection benefits by temporarily increasing auto and truck VMT during construction but reducing VMT in the long-term by avoiding detours during flooding events and detours due to posted bridges.

Emissions Savings

The increase in auto and truck VMT will result in a temporary increase in emissions during the construction period, but the reduction in VMT after the bridges open results in overall emissions savings for the long-term. The two are netted in this analysis.

[9] USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 17, 2021, https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf
[10] Source: USDOT Bridge Preservation guide, Maintaining a State of Good Repair Using Cost Effective Investment Strategies, August 2011, page 2, http://docplayer.net/11349542-Bridge-preservation-guide-maintaining-a-state-of-good-repair-using-cost-effective-investment-strategies.html
[11] Federal Transit Administration, How to Use the FTA HMCE Tool, 2014, http://www.fta.dot.gov/documents/FTA-User_Guide-final.pdf

The avoided VMT decreases the amount of annual nitrogen oxides (NOx), particulate matter ($PM_{2.5}$), and carbon dioxide (CO2) in the atmosphere. Auto and truck emissions rates (g/mile) are estimated based on the California Air Resources Board (CARB) Onroad Emissions Rates model, which was run in order to estimate the long-term change in emissions rates. CARB projected annual emission rates were used to estimate emission rates for 2020-2047.

The tons of reduced emissions were monetized using the recommended values as shown in Exhibit 4. ***In total, the Project results in emissions savings of $0.2 million, discounted at 7 percent.*** The value of CO2 avoided was discounted at 3 percent.

Quality of Life

The ability to easily move large farm equipment and trucks among fields and roadways allows agricultural producers to conduct their work more efficiently. The improved efficiency allows farmers to reduce transportation costs and be more profitable, supporting rural incomes.

Agricultural Access

The Project benefits the farms that are nearby by allowing trucks to take more direct routes to and from markets and also allowing farm equipment and products to move around more efficiently within and between farms. The improved access during flooding also means tourists destined for the local Christmas Tree Farms, for example, can travel more easily and further support the region's agricultural interests. The agricultural access benefit quantifies the increase in farm efficiency that can be realized with an improved transportation network. Western North Carolina is well-known as a destination for tourists seeking to cut their own Christmas trees, and the state produces over 20 percent of the nation's Christmas trees. Most of the trees grown in the region are Fraser Fir and they are shipped to every state in the U.S. as well as internationally.[12] The trees are transported from farms by a variety of trucks ranging from dry van trucks, refrigerated trailers, open trailers, and flatbeds. One of the ways for producers to keep shipping costs down is to get drivers in and out quickly and by reducing stops and handling as much as possible. [13] Therefore, an efficient transportation network through reliable routes that can accommodate heavy trucks reduces the burden on growers.

Based on 2017 county average total farm production expenses,[14] converted to 2019 dollars, it was assumed that a 3.5 percent reduction in expenses is attributable to the Project. Assuming each bridge replacement affects 5 percent of the farms in the county, multiplying the average expense savings by the number of farms results in the total annual agriculture access benefits. The annual reduction in expenses was held constant throughout the analysis period by county. This improved efficiency allows farmers to be more profitable, supporting rural incomes. ***In total, the Project results in agricultural access benefits of $33.2 million when discounted at 7 percent.***

5. Costs

The Project has two cost components: the initial capital costs and ongoing operating and maintenance (O&M) costs.

[12] North Carolina Christmas Tree Association, North Carolina Christmas Tree Facts, https://ncchristmastrees.com/tree-facts/
[13] ZMODAL, "Logistics of Christmas Tree Shipping," December 15, 2020, https://zmodal.com/2020/12/15/logistics-of-christmas-tree-shipping/
[14] USDA County Summary, Crop and Livestock Cash Receipts by County, https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/AgStat/Section06.pdf

Capital Costs

The capital costs for the Project include the costs for right of way, utilities, design, and construction. Six bridges receive conduit for future fiber installation[15] and six bridges receive flood gages.[16] [17] The capital costs are applied over the individual project construction periods, beginning in summer 2023 and ending in summer 2027. Capital costs were estimated in 2021 dollars and converted to 2019 dollars using the GDP deflator, resulting in a total cost of $48.9 million. The individual project costs are expended equally over the construction periods and the bridges range in cost between $778,000 and $11.7 million. ***The total capital costs for the Project discounted at 7 percent are $38.0 million.***

Annual Operating and Maintenance Costs

The Project requires annual and periodic O&M expenditures to maintain the new bridges, but the replacement bridges would result in O&M savings from the baseline. In the baseline, the cost to maintain the bridges was provided by NCDOT for each bridge. In addition, O&M costs for bridge gages is $2,400 (2019$) per year for the six bridges where they will be installed. ***The net O&M savings over the analysis period and discounting at 7 percent is $1.6 million.***

6. BCA Results

The analysis results in a total Project Benefit Cost Ratio (BCR) of 2.35 when discounted at a rate of 7 percent.

Exhibit 6 displays a summary of the BCA results for the total Project.

Because each rural bridge has independent utility, a separate BCA was developed for each bridge. The individual results go up to 11.9 at a 7 percent discount rate. While three of the 28 bridges do not cross a 1.0 BCR threshold at 7 percent, they all reflect a BCR over 0.81 —a high bar for rural low-volume bridges. Importantly, the bridges surpass the 1.0 threshold as a group, indicating the project benefits justify the cost. The reason a few bridges do not result in BCRs over 1.0 is primarily due to the high cost of the bridge replacement and the low AADT in these rural areas (40-80 vehicles per day), resulting in lower net benefits than would be the case if there were more traffic on the bridges. Exhibit 7 shows the BCR for each bridge individually.

[15] 040047, 040093, 040480, 130130, 960012, and 960730
[16] 040047, 040226, 040509, 130275, 940319, and 960012
[17] The narrative and this memo use the U.S. Geological Survey (USGS) spelling of “gage” per the agency’s use in its standard discharge records.

Exhibit 6 – BCA Results for Total Project

Costs (2019 $M)	
Capital Cost	$38.0
Total Costs	*$38.0*
Benefits (2019 $M)	
Safety Benefits	
Reduced Roadway Fatalities and Crashes	$3.7
Safety Improvements at Bridges	$7.5
Emergency Access Benefit	$0.5
Sub-Total	$11.7
State of Good Repair Benefits	
Roadway Maintenance Savings	$0.003
Bridge Repair Costs Avoided	$5.1
Bridge Current Maintenance Costs Avoided	$0.1
Sub-Total	$5.2
Economic Competitiveness Benefits	
Travel Time Savings Detours	$2.7
Travel Time Savings Bridge Lanes	$0.3
Auto Travel Cost Savings	$2.3
Residual Savings	$4.4
Truck Operating Savings	$4.0
Trip Not Taken	$23.6
Sub-Total	*$37.2*
Environmental Sustainability	
Emissions Savings	$0.2
Sub-Total	$0.2
Quality of Life	
Agricultural Access Improvement	$33.2
Sub-Total	$33.2
Net Operating & Maintenance Costs	$1.6
Total Benefits	*$89.1*
Outcome	
Net Benefits (2019 $M)	$51.2
Benefit-Cost Ratio	**2.35**

Exhibit 7 – BCA Results for Each Project

Bridge ID	BCR at 7% Discount Rate
040351	0.86
960340	5.64
960341	4.86
040048	1.54
040093	1.88
040463	0.81
020082	0.97
940319	11.91
040477	1.52
130130	1.31
050091	2.26
040343	1.51
040183	1.43
130317	3.03
130185	3.37
130186	3.84
130275	3.35
040304	2.99
040466	1.91
040509	1.15
040226	1.39
040480	1.91
960655	10.72
040047	2.62
960691	6.79
130349	6.48
960012	1.07
960730	2.10

Appendix A List of Supporting Documents

AECOM, “BCA.xls” excel workbook

BEA Rate of Depreciation, Service Lives, Declining-Balance Rates, and Hulten-Wykoff Categories, https://apps.bea.gov/scb/account_articles/national/0797fr/table3.htm

FHWA Highway Cost Allocation Study, 2000 Addendum, Table 13, https://www.fhwa.dot.gov/policy/hcas/addendum.cfm

McKenith, DaVonte, WXII 12, “Wilkesboro Police arrest woman in deadly hit & run case,” June 10, 2021, https://www.wxii12.com/article/2-dead-hit-and-run-suspect-wanted-bodies-found-under-wilkesboro-bridge/36642386

NCDOT, Crash Reduction Factor (CRF) Information, Traffic Safety Unit, July 21, 2020, https://connect.ncdot.gov/resources/safety/TrafficSafetyResources/NCDOT%20CRF%20Update.pdf

North Carolina Christmas Tree Association, North Carolina Christmas Tree Facts, https://ncchristmastrees.com/tree-facts/

USDA County Summary, Crop and Livestock Cash Receipts by County, https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/AgStat/Section06.pdf

USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, February 17, 2021, https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

USDOT Bridge Preservation guide, Maintaining a State of Good Repair Using Cost Effective Investment Strategies, August 2011, page 2, http://docplayer.net/11349542-Bridge-preservation-guide-maintaining-a-state-of-good-repair-using-cost-effective-investment-strategies.html

White House Office of Management and Budget. Historical Tables, Table 10.1 – Gross Domestic Product and Deflators Used in the Historical Tables 1940-2026. https://www.whitehouse.gov/wp-content/uploads/2021/05/hist10z1_fy22.xlsx

ZMODAL, “Logistics of Christmas Tree Shipping,” December 15, 2020, https://zmodal.com/2020/12/15/logistics-of-christmas-tree-shipping/

Crash Data by County:

NCDOT, Allegany County 2019 County Profiles (Revised November 2020): https://connect.ncdot.gov/resources/safety/Crash%20Data%20and%20TEAAS%20System/Crash%20Data%20and%20Information/2019%20Alleghany%20County%20Crash%20Profile.pdf

NCDOT, Ashe County 2019 County Profiles (Revised November 2020): https://connect.ncdot.gov/resources/safety/Crash%20Data%20and%20TEAAS%20System/Crash%20Data%20and%20Information/2019%20Ashe%20County%20Crash%20Profile.pdf

NCDOT, Avery County 2019 County Profiles (Revised November 2020): https://connect.ncdot.gov/resources/safety/Crash%20Data%20and%20TEAAS%20System/Crash%20Data%20and%20Information/2019%20Avery%20County%20Crash%20Profile.pdf

NCDOT, Caldwell County 2019 County Profiles (Revised November 2020): https://connect.ncdot.gov/resources/safety/Crash%20Data%20and%20TEAAS%20System/Crash%20Data%20and%20Information/2019%20Caldwell%20County%20Crash%20Profile.pdf

NCDOT, Watauga County 2019 County Profiles (Revised November 2020):

https://connect.ncdot.gov/resources/safety/Crash%20Data%20and%20TEAAS%20System/Crash%20Data%20and%20Information/2019%20Watauga%20County%20Crash%20Profile.pdf

NCDOT, Wilkes County 2019 County Profiles (Revised November 2020): https://connect.ncdot.gov/resources/safety/Crash%20Data%20and%20TEAAS%20System/Crash%20Data%20and%20Information/2019%20Wilkes%20County%20Crash%20Profile.pdf