
FEASIBILITY STUDY

**US 421 FROM US 221 IN WATAUGA COUNTY
TO SR 1301 IN WILKES COUNTY
TRUCK ESCAPE RAMPS AND IMPROVEMENTS**

**Watauga and Wilkes Counties
Division 11
FS-0711A**

Prepared For:

North Carolina Department of Transportation



A handwritten signature in black ink, appearing to read "R. Abadilla", written over a horizontal line.

**Rasay Abadilla, P.E.
Feasibility Studies Unit
Program Development Branch
NCDOT**

11/18/09
Date

Prepared By AECOM

A handwritten signature in blue ink, appearing to read "Eddie B. McFalls", written over a horizontal line.

**Eddie McFalls, P.E.
Project Manager
AECOM**

A handwritten signature in black ink, appearing to read "Derrick W. Lewis", written over a horizontal line.

**Derrick Lewis, P.E.
Feasibility Studies Unit
Program Development Branch
NCDOT**

11/7/09
Date

I. General Description

This feasibility study addresses upgrading truck escape ramps and associated improvements along US 421 between US 221 in Watauga County and SR 1301 in Wilkes County. A project vicinity map is included as *Figure 1*. Improvements studied include upgrading two existing truck escape ramps to gravel arrester beds, providing an additional truck escape ramp, providing a truck stop and information station, flattening some horizontal curves along the route, upgrading signing, and providing ITS features. Typical sections are shown in *Figure 2* and the improvements are shown in *Figure 3*.

This study is the initial step in the planning and design process for this project and is not the product of exhaustive environmental or design investigations. The purpose of this study is to describe the proposed project, including costs, and to identify potential problems that may require consideration in the planning and design phases.

II. Background Information

The purpose of the proposed project is to reduce the frequency and severity of truck crashes along southbound (downhill) US 421 between US 221 in Watauga County and SR 1301 in Wilkes County.

The feasibility study was initiated by the Department in January, 2008. Since that time, the Department has received letters expressing support for the proposed project from the Deep Gap Volunteer Fire Department in Watauga County, the Champion Volunteer Fire Department in Wilkes County, and the Wilkes County Fire Marshall's Office. Specifically, the fire departments requested a truck stop / information station be located at the top of the mountain, the existing truck pull-out be expanded, and the curve at the bottom of the mountain be flattened. The areas's State Representative expressed support for the fire departments' proposal.

Since the initiation of the feasibility study, the Regional Traffic Engineering office has coordinated with Division staff to develop some short term improvements that include: additional signage to provide enhanced truck specific information regarding the grade and the location of the escape ramps, ITS devices that will detect when a truck enters an escape ramp and immediately notify EMS, and a CB blaster that will broadcast information to truck drivers over their CB radios.

US 421 is a rural, four-lane highway and is classified as a principal arterial and is designated as a Strategic Highway Corridor. US 421 is designated as a "Major Thoroughfare" in both the Boone Thoroughfare Plan and the North Wilkesboro / Wilkesboro Thoroughfare Plan. The route is statutorily available for use by truck transports with 53-foot long trailers and serves as a primary route for the transfer of freight into northwest North Carolina. Additionally, the route is vital for travel / tourism and is used by college students and families traveling back and forth to Appalachian State University in Boone. The existing cross-section consists of four 12-foot lanes. Shoulder widths vary along the route; however, the route generally has 8-foot wide outside shoulders (with 4-foot paved shoulders). From US 221 to just east of the Blue Ridge Parkway, US 421 has a 46-foot wide median. From just east of the Blue Ridge Parkway to just east of SR 1361 (Orchard Road), US 421 has a center two-way left turn lane. From just east of SR 1361 (Orchard Road) to just east of the second existing truck escape ramp, US 421 has no median. East of the second existing truck escape ramp, US 421 has a 46-foot wide median. Grades along US 421 vary from 4 to 9 percent. The steep downgrades occur along southbound US 421.

The majority of the route is posted at 55 mph, however, the downgrade is posted 30 mph for trucks and 55 mph for all other vehicles.

Two existing truck escape ramps are located along US 421. The first ramp is located near US 421's intersection with SR 1377 (Old US 421). The second ramp is located approximately 0.7 mile downhill (east) of the first ramp. These existing ramps are sand piles, approximately 350 feet long.

The project area is rural. Low density residential development is scattered throughout the project area.

At the western end of the project study area, US 221 intersects US 421. Transportation Improvement Project (TIP) R-2915 will widen US 221 to four lanes and will provide a new interchange at US 421. In the 2009-2015 Transportation Improve Program, the initial section of TIP R-2915 is scheduled for right of way acquisition in 2012 and construction in 2013. This potential interchange influences this feasibility study in two ways. First, the interchange location limits the location of a proposed truck stop and information station. It is not anticipated that there will be enough room between the proposed interchange and the Blue Ridge Parkway to provide a truck stop / information station. Locations east of the Blue Ridge Parkway will have to be studied for this improvement. Second, some interchange concepts under consideration will provide free-flow movements and will not use traffic signals at US 221. As a result of the potential elimination of the existing signal at US 221 / US 421, trucks will no longer stop and may be traveling at higher speeds by the time they reach the downgrade just east of the Blue Ridge Parkway.

III. Traffic and Safety

Existing and projected traffic data on US 421 was obtained from a traffic forecast prepared in 2008. According to the forecast, the base year average daily traffic volume (2008 volumes) on US 421, east of US 221 is 8700 vehicles per day (vpd). In 2035, the average daily traffic volume on US 421, east of US 221 is anticipated to increase to 19,300 vpd. The percentage of truck traffic is 10 % (5 % Duals, 5 % TTST's).

A Crash Strip Analysis Report for a ten year time period (July 1, 1997 to June 30, 2007) was obtained and reviewed to identify the location and types of truck crashes occurring along the subject length of US 421. Sections of US 421 were widened to four lanes during the ten-year time period, with the last portion being completed in 2004. Approximate locations of these crashes are shown in **Figure 3**. Two hundred and thirty-nine crashes occurred during this time period, resulting in a crash rate of 174.43 crashes per 100 million vehicle miles. Fifty-one of these crashes (21 %) involved trucks. Assuming a truck volume percentage of 10%, the calculated truck crash rate for US 421 is 372.21 truck crashes per 100 million vehicle miles. Seven crashes along the route resulted in fatalities, resulting in a fatal crash rate of 5.11 fatal crashes per 100 million, three of which involved trucks (43%). Because portions of the studied segment were widened during the ten year time period, a comparison to statewide accident rates for four-lane US routes is not applicable.

Accident reports were reviewed to better determine the location of truck accidents along the route. Of the fifty-one crashes involving trucks, forty-two occurred along southbound US 421. Of those forty-two crashes, seven occurred in the first (westernmost) existing truck ramp, 28 occurred in the second (easternmost) existing truck ramp. Two of the crashes in the second ramp resulted in fatalities. In both fatal crashes, the trucks' loads shifted. Reported truck escape ramp entry speeds varied from 25 mph to 75 mph. The average reported ramp entry speed approaches 50 mph.

IV. Description of Studied Alternatives

The alternative improvements studied include the provision of a truck stop / information station, upgrading two existing sandpile truck escape ramps to gravel arrester beds, the provision of an additional truck escape ramp, and the flattening of some horizontal curves along the alignment. Design criteria used for truck escape ramps and a truck stop / information station were developed by compiling information found in the AASHTO Greenbook, *NCHRP Synthesis 178 Truck Escape Ramps: A Synthesis of Highway Practice*, NCDOT's Design Manual, a meeting with Jim Speer, P.E. of Roadway Design, and excerpts from design plans for truck emergency escape ramps constructed as a part of the construction of US 23 (Future I-26) from US 19 to the Tennessee State Line (TIP Project A-0010CA).

These alternative improvements are shown in **Figures 3** and **4**, and are described below.

A. Truck Stop / Information Station

A truck stop / information station is located just east of the Blue Ridge Parkway and Winebarger Road. The potential location for the truck stop / information station is located just east of the ridge, near the top of the southbound US 421 downgrade. The truck stop / information station must be located near the top of the downgrade so information about the presence of steep grades and location of truck escape ramps can be communicated to drivers. The truck stop / information station also will provide an opportunity for truck drivers to cool their brakes before traveling down the mountain. During the project development process, legislative research will be needed to determine whether or not the use of the truck stop / information stop can be made mandatory. By statute, the route is available for use by trucks with 53-foot trailers. US 421 is a primary route used to transfer freight into and out of northwest North Carolina. The route also serves as a primary route used by students and families traveling to Appalachian State University.

The truck stop / information station concept is based on the station designed as a part of improvements to US 23 (future I-26). It will provide two 400-foot long, 12-foot wide lanes for truck storage, information signs and a dynamic message sign to update trucks on travel conditions. A dynamic message sign will also be located in advance of the truck stop / information station. Lighting will be provided at the truck stop / information station. Glare screening will The truck stop / information station lanes will be separated from the mainline by a 30-foot wide, depressed median and a 12-foot outside shoulder will be provided. A typical section for the truck stop / information station is shown in **Figure 2**. The truck stop / information station is shown in plan view as Location A on **Figure 3C**.

Winebarger Road currently ties into existing US 421 where the taper for the truck stop / information station begins. Winebarger Road is a low volume road that serves approximately three homes. Relocating Winebarger Road's intersection with US 421 may be difficult, due to the terrain and the location of Blue Ridge Parkway property. If access to Winebarger Road cannot be maintained, three residential relocations would result. The proposed right of way for the truck stop / information station varies to encompass the anticipated sideslopes. Right of way and construction costs for the truck stop / information station are presented below.

Construction	\$ 3,550,000
Utilities	\$ 92,209
Right of Way	<u>\$ 446,500</u>
Total	\$ 4,088,709

Locating the truck stop / information station west of the Blue Ridge Parkway was initially considered. However, this would place the truck stop between and in close proximity to US 421's proposed interchange with US 221 (TIP Project R-2915) and the Blue Ridge Parkway property. Therefore, locating the truck stop / information station west of the Blue Ridge Parkway was not investigated further as a part of this study.

B. Truck Escape Ramps

1. Criteria

After a review of the AASHTO Greenbook, *NCHRP Synthesis 178 Truck Escape Ramps: A Synthesis of Highway Practice*, and NCDOT's Design Manual, the following basic criteria were established for upgrading the existing truck escape ramps and preparing functional designs for new truck escape ramp locations:

Type: Arrester Beds that use rolling resistance to stop vehicles are preferred over transverse mounds because they reduce the speeds of trucks more gradually.

Design Speed for Entry: The AASHTO Green Book notes that truck escape ramps should be designed for a minimum speed of 80 mph and a desirable speed of 90 mph. Two of the proposed ramp locations may require a design exception. Providing the length needed for an 80 mph entry speed results in a large increase in borrow. It should be noted that based on accident reports at the existing ramps, the average entry speed is approximately 50 mph. The highest reported entry speed into the existing ramps was 75 mph. In cases where the 80 mph criteria cannot be met, the AASHTO Green Book notes either mounds of aggregate, barrels, or crash cushions should be provided as a measure of last resort.

Departure Angles: The AASHTO Green Book states the departure angle should be small, usually 5 degrees or less. The maximum departure angle used by NCDOT on A-10 is 4 degrees and 7 minutes.

Ramp Width / Access Road: The NCHRP report and AASHTO Green Book establish a 26-foot minimum width for pea gravel beds. It is recommended that wider beds be used where possible (to allow for a second truck to enter). Project A-10 used 38 feet to 42 feet on its ramps. The NCHRP notes the need to provide a paved 12-14 foot service road along the highway side of the arrester bed for tow trucks to access vehicles in the bed. The A-10 plans include a service road, but it is located on the far side of the bed.

Arrester Bed Length: Arrester bed lengths can be calculated using the following formula: $L=V^2/(30(R\pm G))$ where L is the distance to stop (feet), V is entering velocity (mph), G is percent grade divided by 100, and R is rolling resistance. Pea gravel, with a rolling resistance of 0.25, was used to calculate lengths.

Tow-anchors: Tow anchors should be provided at 150-foot intervals along the service road and should also be provided on the approach to the bed approximately 150 feet in front of it.

Bed Material Depth: The AASHTO Green Book and NCHRP note a minimum depth of 36 inches. Within the first 100 feet of the gravel bed, the depth of the gravel starts at 3 inches and transitions to the full 36-inch depth.

Base Material / Drainage: A 12 inch layer of large aggregate (at least 3 inches in diameter) should be considered to help drain the bed. The subgrade should have cross-slope leading to a

perforated CSP (A-10 uses a 12-15 inch perforated CSP). The large aggregate should be confined to the layer by either forming gabions or fabric. Hazardous spill catch basins should be designed to catch any water draining from the beds.

Maintenance Issues: The provision of the subgrade aggregate and base material described above is essential to promote positive drainage of the truck beds so that water or ice does not degrade their performance. According to NCHRP Synthesis 178 – *Truck Escape Ramps: A Synthesis of Highway Practice*, effective performance of the truck beds can be maintained by reshaping and loosening the beds after they have been used and preventing fine materials from contaminating the bed material. For the most part, contamination by fine materials can be prevented or minimized by stopping surface runoff and infiltrating subsurface water from entering the beds. Regular inspections and periodic loosening of the bed material should also be conducted even if the bed has not been used.

2. Truck Escape Ramp Alternatives

Truck escape ramps were considered at four locations. These locations are based on accident experience and the need for ramps, rather than optimization for earthwork. These truck escape ramp alternatives are described below and are shown in **Figures 3** and **4**. Typical sections for the truck escape ramps are shown in **Figure 2**.

Truck Escape Ramp 1 (Location B): Truck Escape Ramp 1 is shown on **Figure 3G** and is located near the base of the first long downgrade on US 421. Two truck accidents have occurred in the horizontal curves past the ramp location. Just beyond the truck escape ramp and following horizontal curves, the grade of US 421 is less severe. The ramp would protect this relatively level area where there are several homes and businesses.

The proposed gravel arrester bed is 42 feet wide and has a 1.5% grade. The full-depth length of the gravel bed is 1019 feet, which provides for a 90 mph entry speed. The truck escape ramp would require two residential relocations. The proposed right of way for the truck escape ramp varies, but is generally 260 feet wide. Right of way and construction costs for this truck escape ramp are presented below.

Construction	\$ 3,650,000
Utilities	\$ 0
Right of Way	\$ 430,000
Total	\$ 4,080,000

Truck Escape Ramp 2 – Alternative 2 (Location H): Truck Escape Ramp 2 – Alternative 2 is shown on **Figure 3I** and is located at the first existing sandpile ramp. Seven truck accidents have occurred in the existing ramp. This location is just beyond a horizontal curve and sight distance to the ramp is poor. To enhance sight distance and assist trucks in navigating into the ramp from the inside of the horizontal curve, the curve in advance of the ramp will be flattened. A radius of 2670 feet is shown for the revised horizontal curve.

The proposed gravel arrester bed is 26 feet wide and has a -8.5% grade. The grade of the truck escape ramp was set to match the grade of the mainline. Using a flatter grade with departure angles of less than five percent would require a retaining wall be constructed between the ramp and mainline. If during preliminary and final design it is determined that sharper departure angles can be used, the grade of this ramp could be improved and the ramp could be shortened. The full-depth length of the gravel bed is 990 feet, which provides for a

70 mph entry speed. The lower design speed was used to reduce the length of the bed and associated earth work (80 mph would require a full-depth length of 1293 feet). A design exception would be required, and beyond the bed, crash cushions or barrels would be needed.

The truck escape ramp would not require any relocations. The proposed right of way for the truck escape ramp and flattened curve varies and is shown on **Figure 3I**. Right of way and construction costs for this truck escape ramp and curve flattening are presented below.

Construction	\$ 7,300,000
Utilities	\$ 0
Right of Way	<u>\$ 106,500</u>
Total	\$ 7,406,500

Truck Escape Ramp 3 (Location E): Truck Escape Ramp 3 is shown on **Figure 3K** and is located at the second existing sandpile ramp. Twenty-eight truck accidents have occurred in the existing ramp and additional accidents have occurred in the horizontal curve just beyond the ramp, including a fatal accident that occurred since the accident summary report was obtained.

The proposed gravel arrester bed is 42 feet wide and has a -3.5% grade. The full-depth length of the gravel bed is 760 feet, which provides for a 70 mph entry speed. The lower design speed was used to reduce the length of the bed and associated earth work (80 mph would require a full-depth length of 992 feet) and stream impacts. As designed, the truck escape ramp will require a 540-foot long, double 8X8 culvert to carry South Prong Lewis Fork. A longer escape ramp (higher design speed) would substantially increase longitudinal stream impacts. A design exception would be required, and beyond the bed, crash cushions or barrels would be needed.

The truck escape ramp would not require any relocations. The proposed right of way for the truck escape ramp varies and is shown on **Figure 3K**. Right of way and construction costs for this truck escape ramp are presented below.

Construction	\$ 9,500,000
Utilities	\$ 0
Right of Way	<u>\$ 500,500</u>
Total	\$10,000,500

Truck Escape Ramp 2 – Alternative 1 (Location D): Truck Escape Ramp 2 – Alternative 1 is shown in **Figure 4**. This alternative was developed to address sight distance and location issues associated with Truck Escape Ramp 2 – Alternative 2 (Location H). Rather than flattening the curve leading to the ramp, the alternative was developed to exit the mainline prior to the horizontal curve. However, due to the flat departure angles recommended and the alignment of US 421, the ramp had to be moved approximately 2400 feet west of the initial ramp location. At this location, the ramp would be just east of the relatively level portion of US 421. No accidents were reported in the immediate vicinity of this revised location.

The proposed gravel arrester bed is 26 feet wide and has a -8 % grade. The full-depth length of the gravel bed is 961 feet, which provides for a 70 mph entry speed. The lower design speed was used to reduce the length of the bed and associated earth work (80 mph would require a full-depth length of 1255 feet). A design exception would be required, and beyond the bed, crash cushions or barrels would be needed. If during preliminary and final design it is

determined that sharper departure angles can be used, the grade of this ramp could be improved and the ramp could be shortened.

The truck escape ramp would require two residential relocations. The proposed right of way for the truck escape ramp varies and is shown on **Figure 4**. Right of way and construction costs for this truck escape ramp are presented below.

Construction	\$ 5,000,000
Utilities	\$ 0
Right of Way	<u>\$ 604,000</u>
Total	\$ 5,604,000

All of the truck escape ramp alternatives described include intelligent transportation system (ITS) elements. ITS elements include a dynamic message sign in advance of the ramp, a microwave vehicle presence detector, a closed circuit video camera, and associated communication equipment. Lighting will be provided along each ramp as well. Each ramp includes a paved service road along the side of the gravel arrester bed to enhance access for emergency vehicles and access for tow trucks and equipment. Additionally, deadman anchors are included along the ramp to assist with truck removal.

C. Curve Improvements and Rumble Strips

The flattening of three horizontal curves along the southbound US 421 downgrade were investigated as a part of this study. These locations are described below.

Location C: Flattening the horizontal curve at Location C (beginning at STA 255) would improve access and sight distance to the existing truck stop on US 421 (see **Figure 3G**). Additionally, two truck accidents have occurred in this general vicinity within the last ten years. The existing radius is 725 feet. A 1200-foot radius is proposed to flatten the southbound (downhill) lanes. Flattening this curve would relocate one home. Right of way and construction costs for this improvement are listed below.

Construction	\$ 2,800,000
Utilities	\$ 0
Right of Way	<u>\$ 403,000</u>
Total	\$ 3,203,000

Location G: Flattening the next horizontal curve (Location G, beginning at STA 271) was investigated (see **Figure 3H**). The existing radius is 725 feet. A 1200-foot radius is proposed to flatten the curve for both directions of travel. No truck accidents have occurred within this curve in the last ten years. Flattening this curve would relocate three homes that are now located along the north side of US 421. Right of way and construction costs for this improvement are listed below.

Construction	\$ 2,650,000
Utilities	\$ 0
Right of Way	<u>\$ 321,000</u>
Total	\$ 2,971,000

Location F: Location F, shown on **Figure 3K**, is located at the bottom of the steep US 421 grade. If trucks navigate this curve, they reach a long, relatively level tangent section of

highway. Twenty-eight truck crashes have occurred in the truck escape ramp located just prior to this curve. Additional truck crashes have occurred within the horizontal curve, including a fatal accident where a truck crossed the median and hit an oncoming car. An 1810-foot radius is proposed to flatten the southbound (downhill) lanes and a median barrier is proposed. The median barrier should include glare screening from opposing traffic. Flattening this curve would not require any relocations. If both the curve improvement and the truck escape ramp (TER 3, Location F) are constructed, the culvert included in the truck escape ramp estimate would have to be extended an additional 90 feet. A larger radius (2670 feet) was considered; but, it would have resulted in longitudinal impacts to South Prong Lewis Fork. Right of way and construction costs for this improvement are listed below.

Construction	\$ 2,850,000
Utilities	\$ 0
Right of Way	\$ 319,000
Total	\$ 3,169,000

Rumble Strips: Rumble strips will be placed along the southbound shoulder of the subject section of US 421. The estimated construction cost of the rumble strips is \$12,000.

V. Environmental Concerns

A detailed environmental study was not conducted for this feasibility study. However, an environmental screening was conducted to identify potential issues which will require further investigation during the project development process.

A. Human Environment

Primary impacts to the human environment will be the residential relocations required. Table 1 summarizes the relocations for each alternative improvement.

Table 1. Relocations

Location	Description	Number of Relocations	
		Homes	Businesses
A	Truck Stop / Information Station	0*	0
B	Truck Escape Ramp 1	2	0
C	Curve At Existing Truck Stop	1	0
D	Truck Escape Ramp 2 – Alternative 1 (not recommended)	2	0
E	Truck Escape Ramp 3	0	0
F	Curve at Base of Grade	0	0
G	Curve at STA 271 (Figure 3H)	3	0
H	Truck Escape Ramp 2 – Alternative 2 (recommended)	0	0
Total (Excluding Location D)		8*	0

* As discussed on page 4, Winebarger Road ties into US 421 just west of the proposed truck stop / information station. If access to Winebarger Road cannot be maintained, three additional residential relocations will be required.

In addition to the potential truck stop / information station is located in close proximity to the Blue Ridge Parkway. The truck stop / information station should be designed to avoid impacts to this resource, which would be protected under Section 4(f) of the U.S. Department of Transportation Act of 1966.

B. Natural Environment

National Wetland Inventory mapping indicates that this project will not impact any identified wetlands. Additionally, a review of Natural Heritage Program data showed no known populations of federally threatened and endangered species along the route. However, threatened and endangered species surveys will be required during subsequent phases of project development

Some of the proposed improvements will impact streams. Streams in the project area are all classified by the Division of Water Quality as Class C Tr (trout) waters. The truck stop / information station (Location A) and Truck Escape Ramp 2 – Alt. 2 (Location H) will require the installation and extension of pipes carrying tributaries to Stony Fork and South Prong Lewis Fork. The construction of Truck Escape Ramp 3 (Location E) and the curve flattening at Location F will require the construction of a culvert to carry South Prong Lewis Fork and will likely require some channel relocation.

VI. Recommendations

The alternative improvements presented in Section IV of this report are presented individually so the Department can isolate specific improvements to implement, based on need and funding constraints. The recommended improvements are subdivided into two categories: near-term improvements, and long-range improvements.

A. Near-Term Recommendations

Near-term improvements are considered top priorities needed to reduce the frequency and severity of truck crashes along this section of US 421. These improvements include the following:

Table 2. Near-Term Recommendations

Location	Description	Costs		
		Construction	R/W & Utilities	Total
A	Truck Stop / Information Station	\$ 3,550,000	\$ 538,709	\$ 4,088,709
E	Truck Escape Ramp 3	\$ 9,500,000	\$ 500,500	\$ 10,000,500
F	Curve at Base of Grade	\$ 2,850,000	\$ 319,000	\$ 3,169,000
H	Truck Escape Ramp 2 – Alternative 2	\$ 7,300,000	\$ 106,500	\$ 7,406,500
Entire Length	Rumble Strips	\$ 12,000	\$ 0	\$ 12,000
Total Near-Term Improvements		\$ 23,212,000	\$ 1,464,709	\$ 24,678,709

The Truck Stop / Information Station is essential to inform truck drivers of the upcoming steep grades and the location of the truck escape ramps. It will also give drivers a chance to inspect their brakes prior to traveling down the mountain. The Truck Stop / Information Station and constructing Truck Escape Ramp 3 are the two top priorities. Twenty-eight truck crashes have occurred at the existing truck escape ramp. As described in Section IV., the truck stop / information station and truck escape ramps include ITS improvements. The information station includes a dynamic message sign to update trucks on travel conditions and a dynamic message sign located in advance of the truck stop / information station. ITS elements at each truck escape ramp include a dynamic message sign in advance of the ramp, a microwave vehicle presence detector, a closed circuit video camera, and associated communication equipment. Lighting will be provided at the information station and along each ramp as well.

Although only seven crashes have occurred at the first existing truck escape ramp (the location of Truck Escape Ramp 2), the recommended improvements to Truck Escape Ramp 2 –Alternative 2 and

associated horizontal curve flattening will enhance the visibility of Truck Escape Ramp 2. This may encourage more trucks to use this ramp.

Improving the curve at the base of the mountain may help truckers avoid crashes and the use of truck escape ramps. Additionally, the median developed and median barrier may help reduce the number and severity of trucks crashing into oncoming traffic.

B. Long Range Recommendations

In addition to the near-term improvements listed above, additional recommendations include the following:

Table 3. Additional Long Range Recommendations

Location	Description	Costs		
		Construction	R/W & Utilities	Total
B	Truck Escape Ramp 1 (new ramp)	\$ 3,650,000	\$ 430,000	\$ 4,080,000
C	Curve Flattening in Advance of Existing Truck Stop	\$ 2,800,000	\$ 403,000	\$ 3,203,000
G	Curve Flattening	\$ 2,650,000	\$ 321,000	\$ 2,971,000
Total Additional Improvements		\$ 9,100,000	\$ 1,154,000	\$ 10,254,000
Near Term Improvements from Table 2		\$ 23,212,000	\$ 1,464,709	\$ 24,678,709
Total for All Recommendations		\$ 32,312,000	\$ 2,618,709	\$ 34,930,709

Truck Escape Ramp 1 would be placed just prior to two sharp curves that lead to a more developed, relatively level section of US 421. However, this location may be too close to the top of the hill to catch a high number of runaway trucks. The curve flattening in advance of the existing truck stop would enhance sight distance and encourage its use.

If constructed with the near-term improvements, Truck Escape Ramp 1 and the flattening of the curve in advance of the truck stop could both serve as a source of borrow material (as could the strip of land between the two improvements).

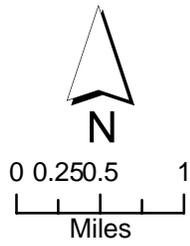
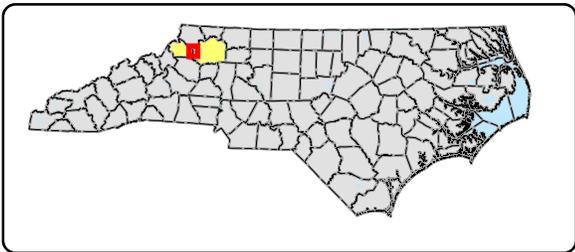
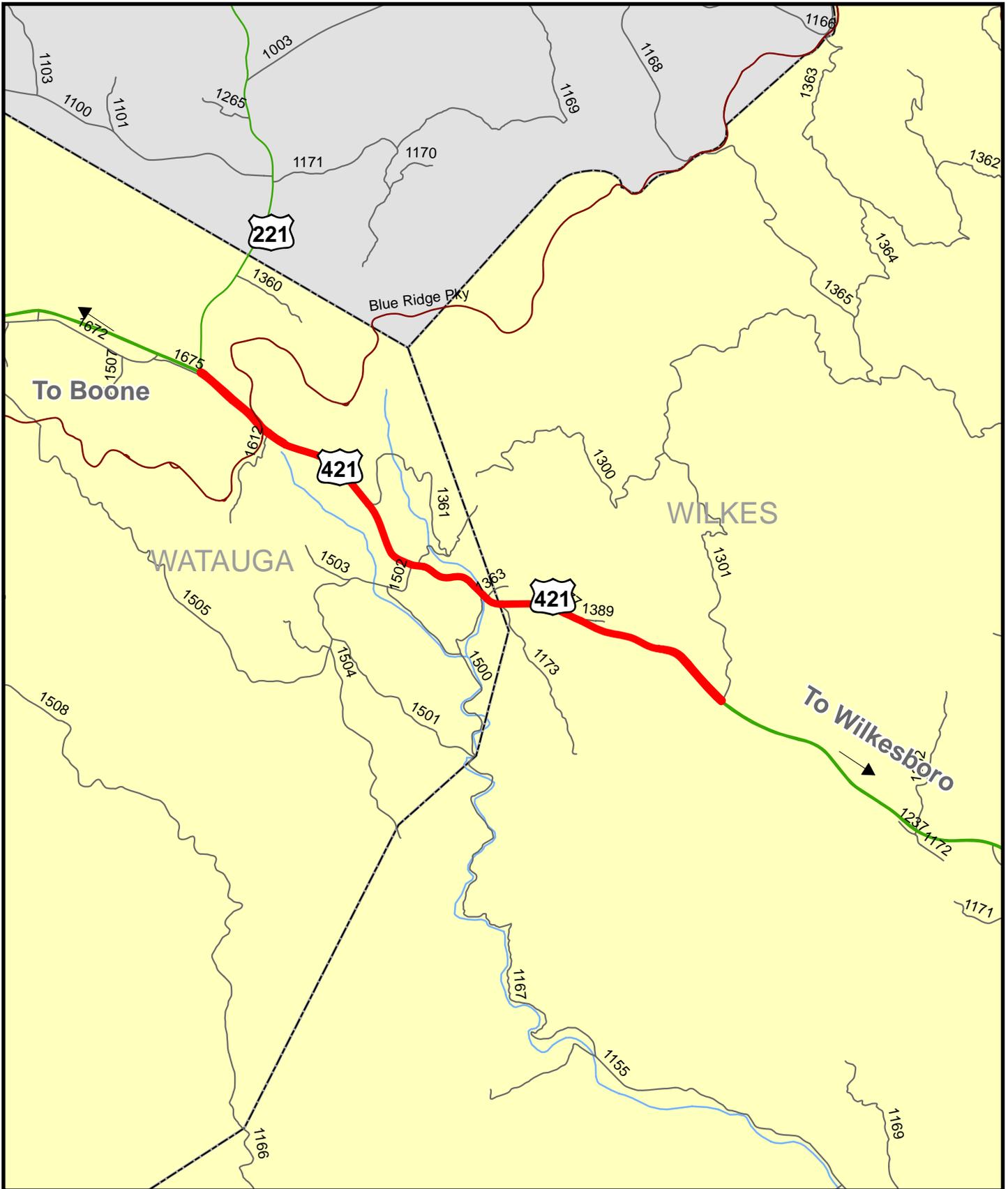
VII. Additional Comments / Issues

As the project moves through the project development process, the following design and constructability issues should be considered:

- Due to the sinuosity of US 421's alignment, the use of flat departure angles limits the location and grades of the truck escape ramps. The flat departure angles do not allow for much separation between the truck escape ramp and the mainline. Therefore, downgrades and grades that closely approximate the grade of US 421 have been used. If more separation can be achieved, flatter grades can be used, which will reduce the length of the beds, borrow material needed, and impacts. Additionally, a greater departure angle at Truck Escape Ramp 3 would allow for a more perpendicular crossing of South Prong Lewis Fork and would help reduce the amount of borrow needed.
- The improvements to the existing truck escape ramps should be phased, so that at least one ramp is open at all times. Additionally, as designs and mapping progress, refining

the alignment of Truck Escape Ramp 3 should be considered so it can be constructed while the existing, frequently-used sandpile remains open.

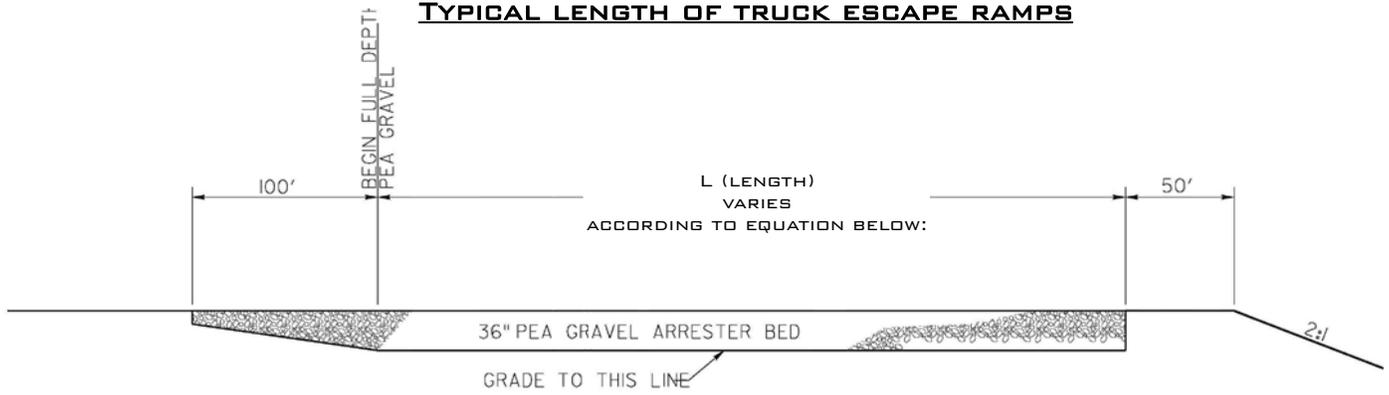
- Borrow material will be needed for these improvements. Truck Escape Ramp 3 will require the largest amount of borrow material, approximately 370,000 cubic yards. If a source of borrow material cannot be identified nearby, hauling this material in on US 421 could become a constructability and safety issue.
- Foliage along the route must be trimmed and maintained to ensure the visibility of critical signs, arrester beds, and pull-out areas.
- A public outreach and education program should be designed to inform the general public and trucking industry of the presence and purpose of the truck information station. Advisories should be published with the trucking industry. Additionally, coordination with representatives of the State Highway Patrol and judicial system should be initiated to stress the importance of enforcement issues along the US 421 downgrade.



Vicinity Map
 Truck Emergency Escape Ramps
 US 421 between US 221 in Watauga County
 & SR 1301 in Wilkes County
 FS-0711A, WBS 34263.1.1

June 2009	Watauga/Wilkes County, North Carolina		Figure 1
Earth Tech Project No. 102725	AECOM		

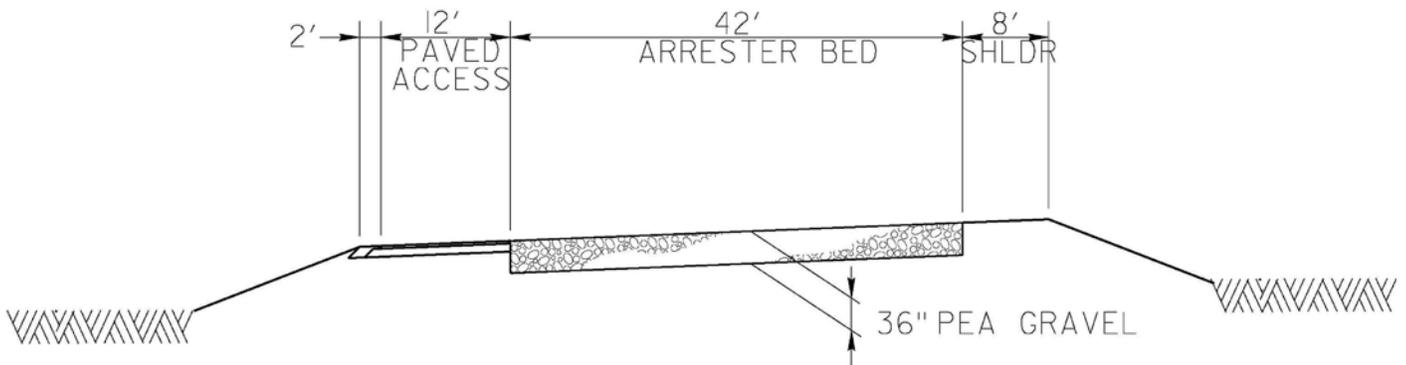
TYPICAL LENGTH OF TRUCK ESCAPE RAMPS



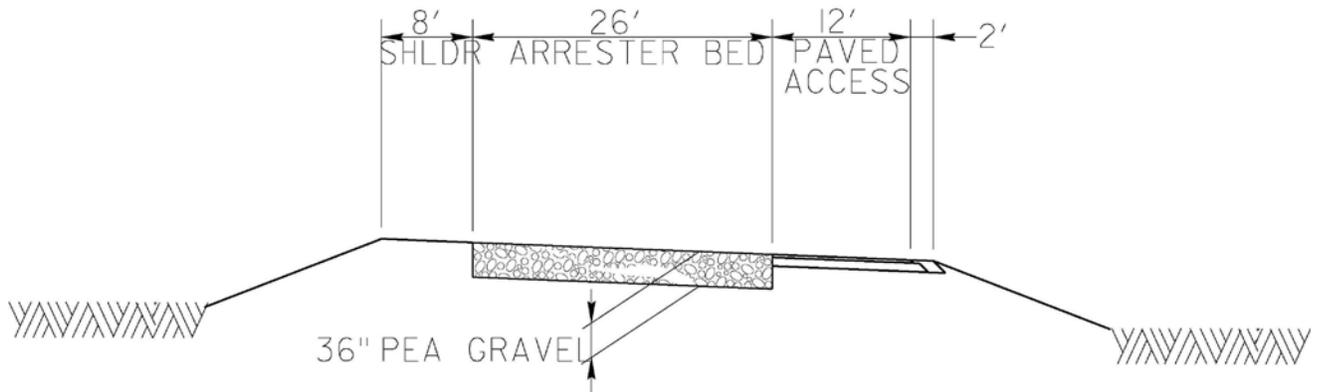
$$L = \frac{v^2}{30(R \pm G)}$$

WHERE: L = LENGTH OF FULL DEPTH BED (FT)
 V = ENTERING VELOCITY (MPH)
 R = ROLLING RESISTANCE OF BED MATERIAL
 (0.25 FOR PEA GRAVEL)
 G = GRADE (%/100)

ARRESTER BED TYPICAL FOR TER 1 (LOCATION B), TER 3 (LOCATION H)

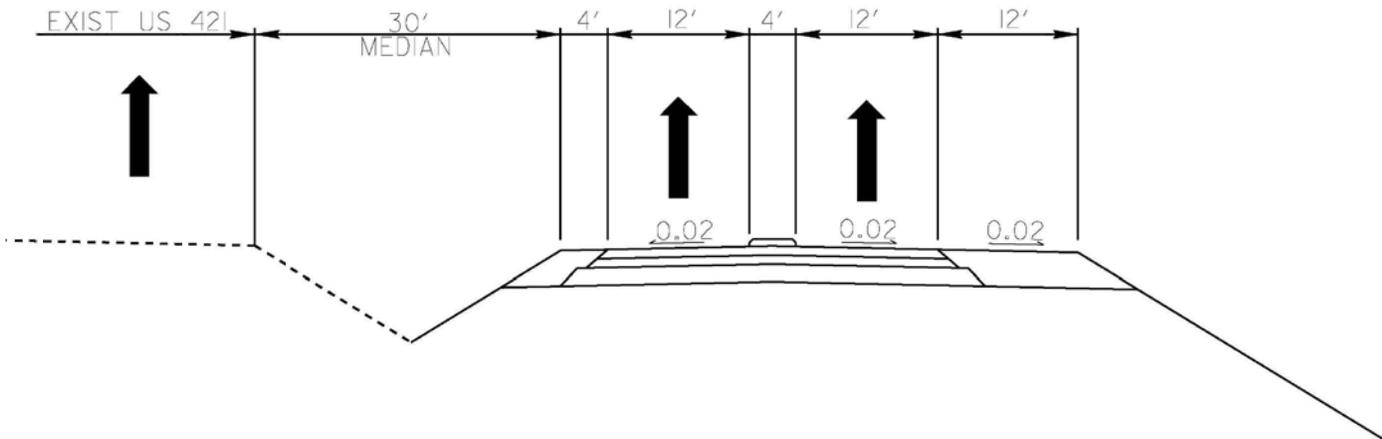


**ARRESTER BED TYPICAL FOR TER 2-ALT 1 (LOCATION D),
 TER 2-ALT 2 (LOCATION E)**

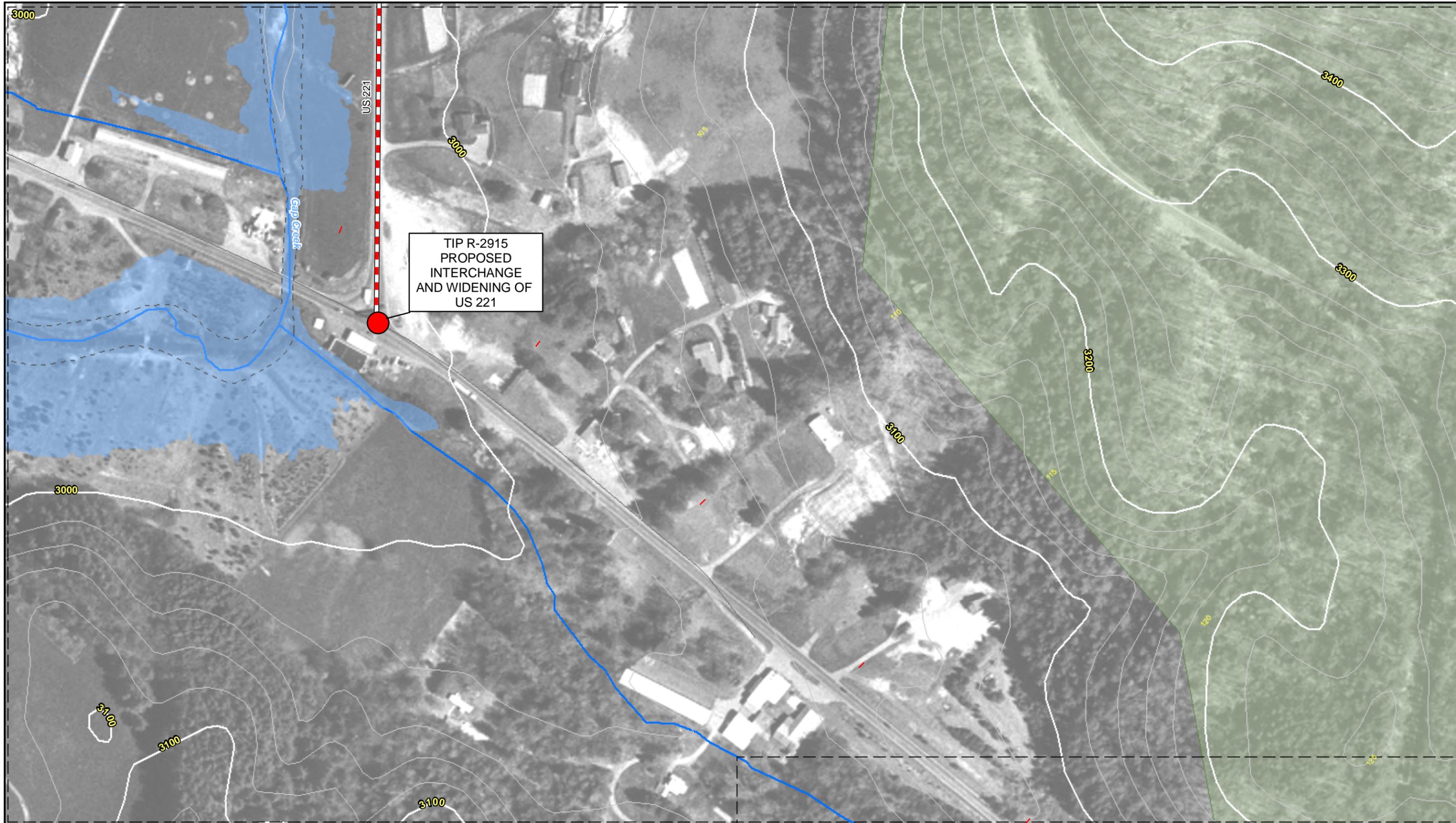


Typical Sections		
Truck Emergency Escape Ramps US 421 between US 221 in Watauga County & SR 1301 in Wilkes County FS-0711A, WBS 34263.1.1		
June 2009	Watauga/Wilkes County, North Carolina	Figure 2A
AECOM Project No. 102725	AECOM	

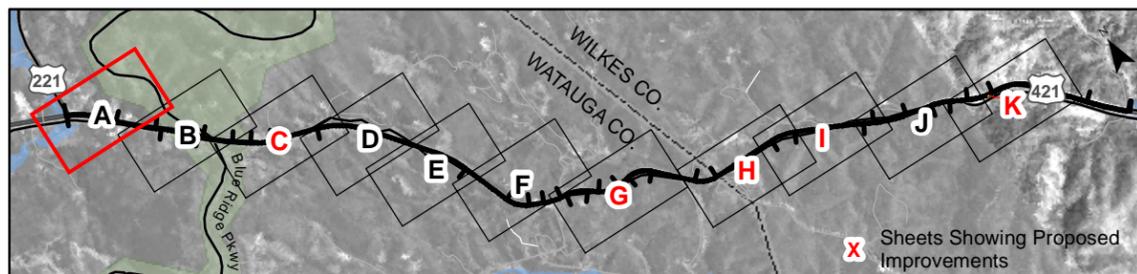
TRUCK STOP/INFORMATION STATION



<p>Typical Sections Truck Emergency Escape Ramps US 421 between US 221 in Watauga County & SR 1301 in Wilkes County FS-0711A, WBS 34263.1.1</p>		
June 2009	Watauga/Wilkes County, North Carolina	<p>Figure 2B</p>
AECOM Project No. 102725	<p>AECOM</p>	



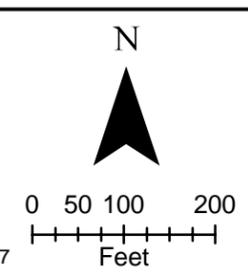
TIP R-2915
 PROPOSED
 INTERCHANGE
 AND WIDENING OF
 US 221



X Sheets Showing Proposed Improvements

LEGEND

Grass	Stream	Right of Way
Monolithic Island	NWI Wetland	Slopestake
Pavement	100 Year Floodplain	Blue Ridge Parkway
Pea Gravel	Floodway	Truck Crashes July 1997 to June 2007



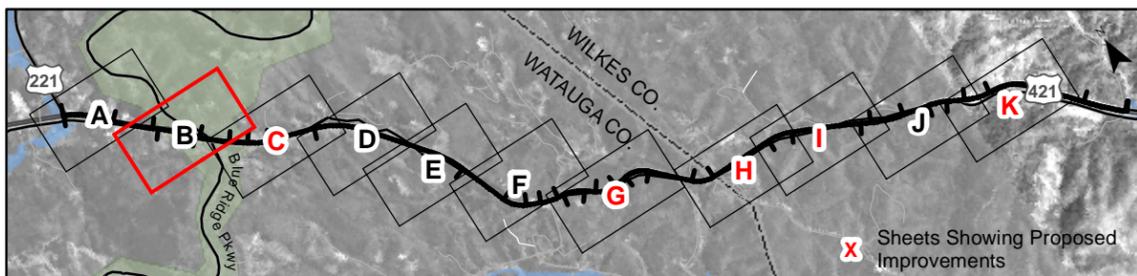
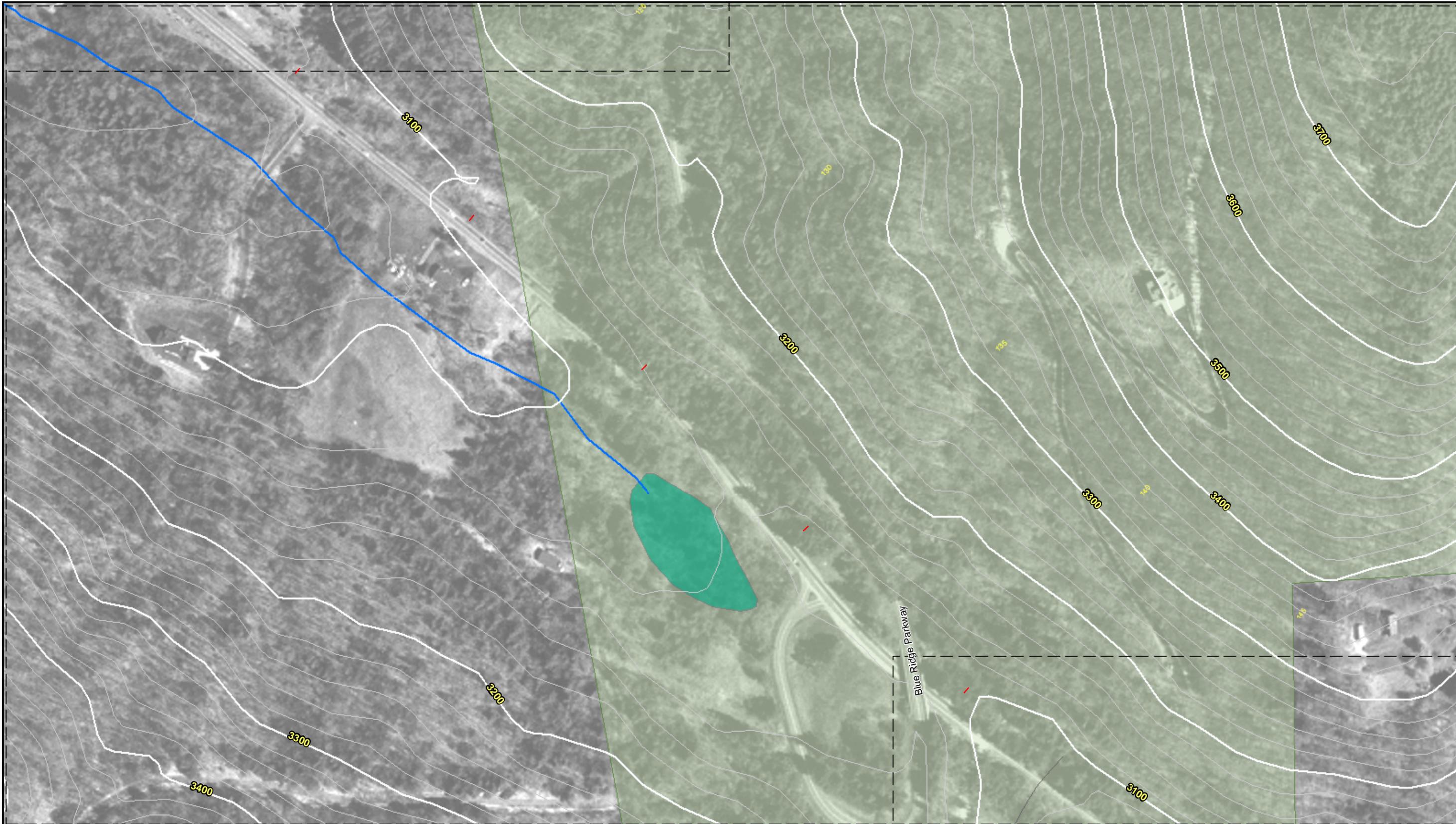
Feasibility Study
 Truck Emergency Escape Ramps
 US 421 between US 221 in Watauga County
 & SR 1301 in Wilkes County
 FS-0711A, WBS 34263.1.1

June 2009 Watauga/Wilkes County, North Carolina

AECOM Project No. 102725

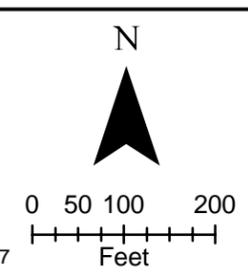
AECOM

Figure 3 A

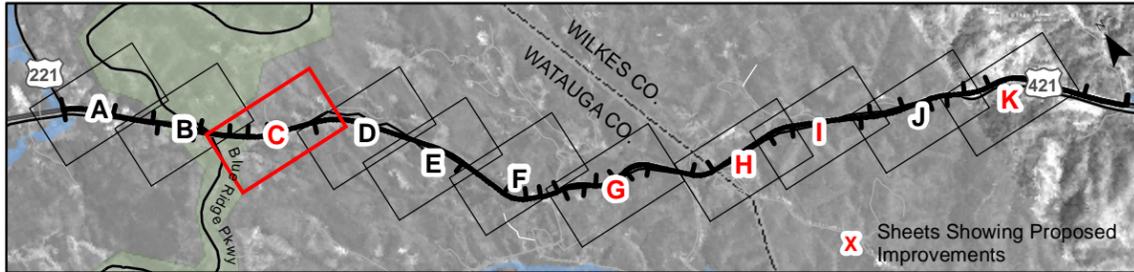
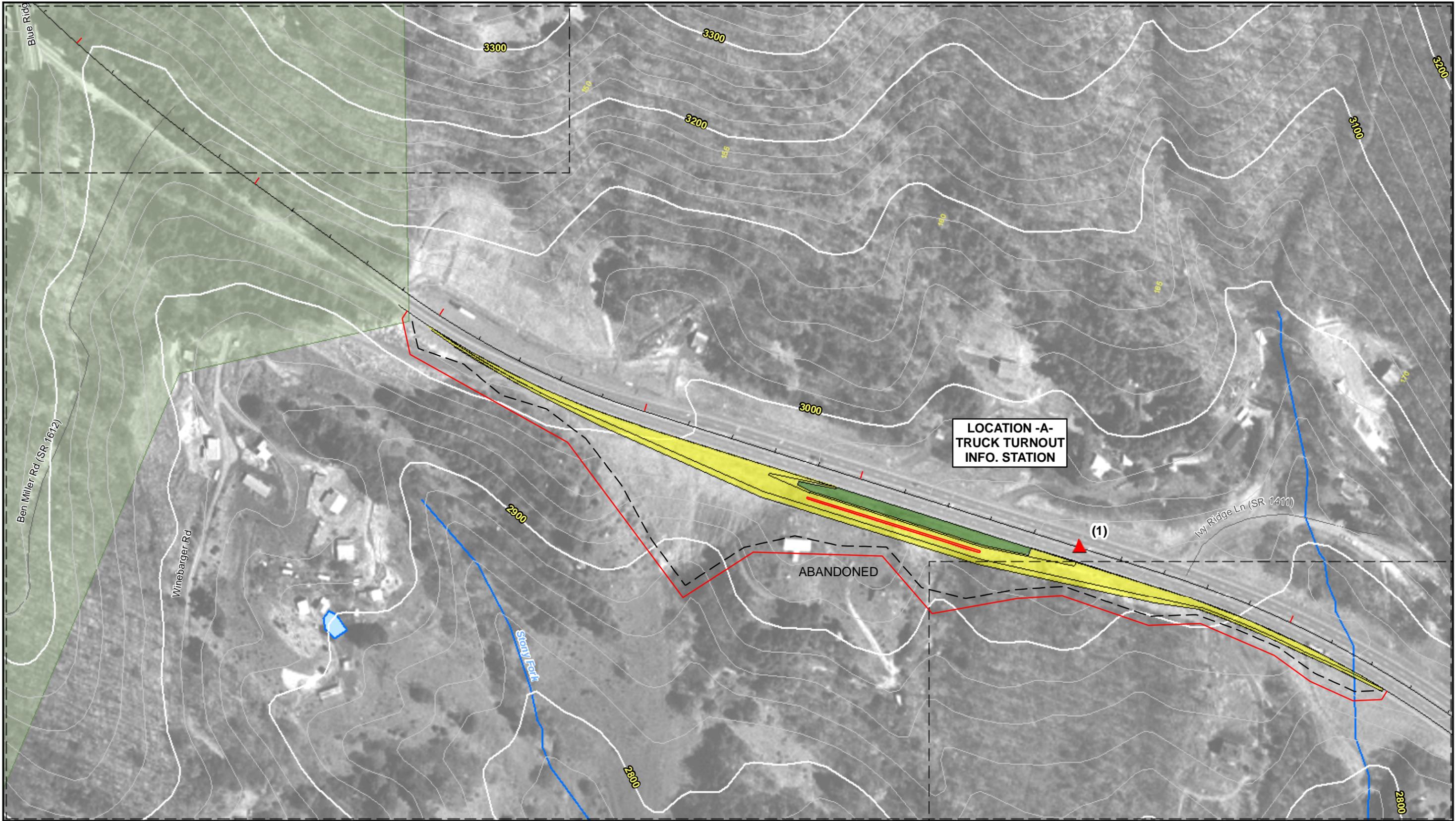


LEGEND

Grass	Stream	Right of Way
Monolithic Island	NWI Wetland	Slopestake
Pavement	100 Year Floodplain	Blue Ridge Parkway
Pea Gravel	Floodway	Truck Crashes July 1997 to June 2007

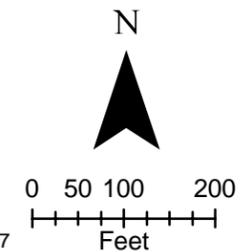


Feasibility Study Truck Emergency Escape Ramps US 421 between US 221 in Watauga County & SR 1301 in Wilkes County FS-0711A, WBS 34263.1.1	
June 2009	Watauga/Wilkes County, North Carolina
AECOM Project No. 102725	AECOM
	Figure 3 B



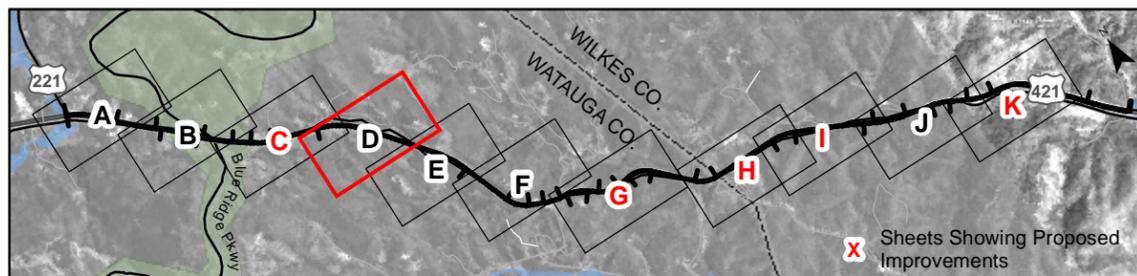
LEGEND

Grass	Stream	Right of Way
Monolithic Island	NWI Wetland	Slopestake
Pavement	100 Year Floodplain	Blue Ridge Parkway
Pea Gravel	Floodway	Truck Crashes July 1997 to June 2007



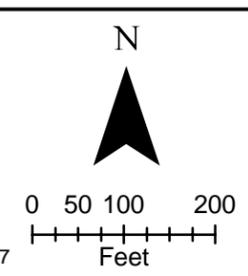
Feasibility Study
 Truck Emergency Escape Ramps
 US 421 between US 221 in Watauga County
 & SR 1301 in Wilkes County
 FS-0711A, WBS 34263.1.1

June 2009	Watauga/Wilkes County, North Carolina	
AECOM Project No. 102725	AECOM	Figure 3 C



LEGEND

Grass	Stream	Right of Way
Monolithic Island	NWI Wetland	Slopestake
Pavement	100 Year Floodplain	Blue Ridge Parkway
Pea Gravel	Floodway	Truck Crashes July 1997 to June 2007



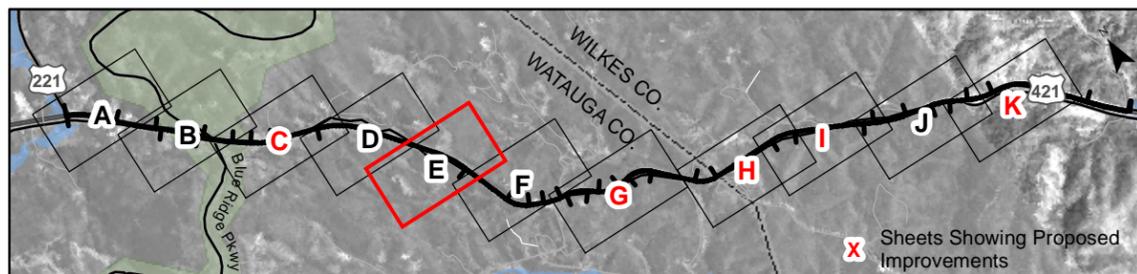
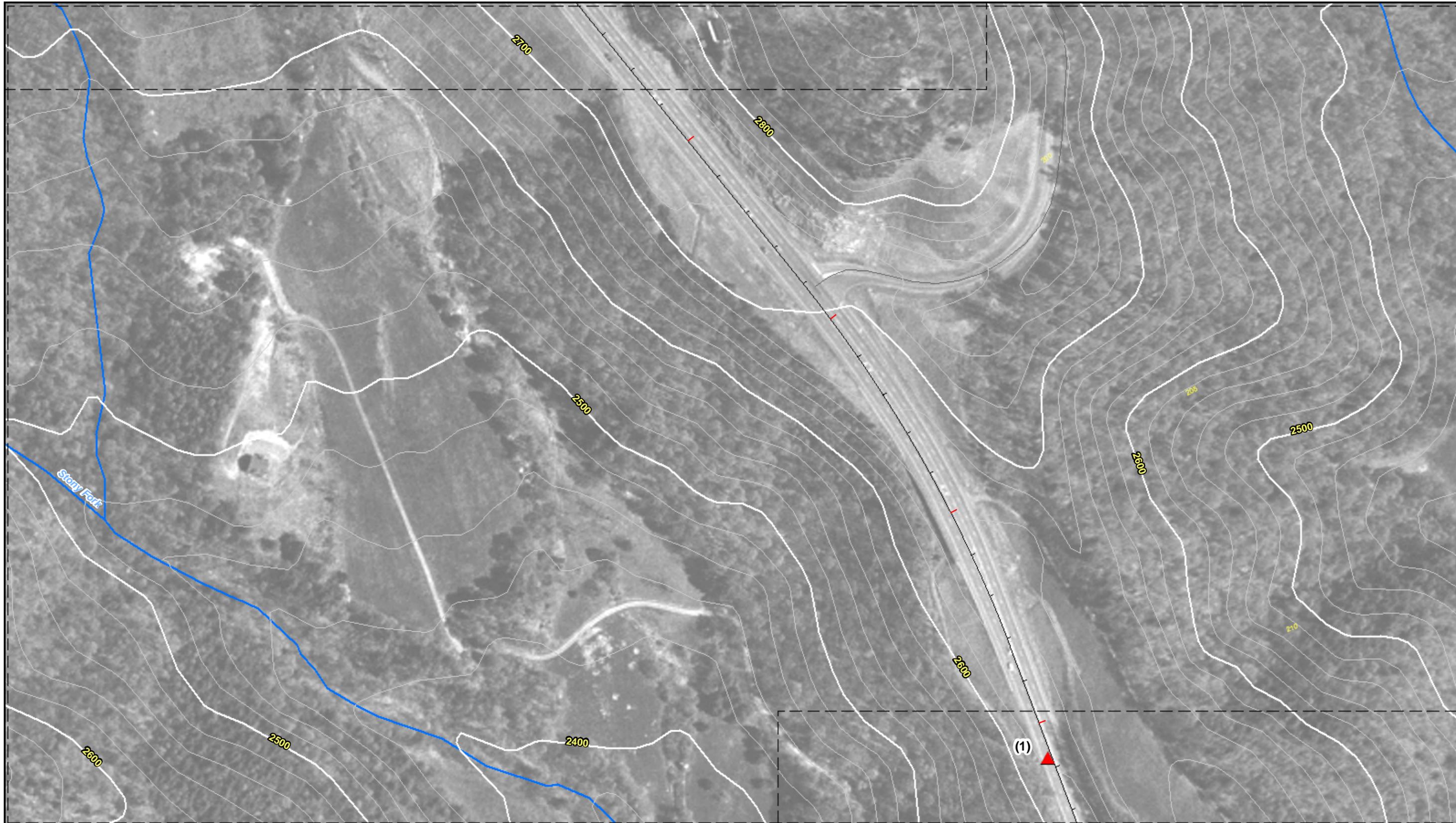
Feasibility Study
 Truck Emergency Escape Ramps
 US 421 between US 221 in Watauga County
 & SR 1301 in Wilkes County
 FS-0711A, WBS 34263.1.1

June 2009 Watauga/Wilkes County, North Carolina

AECOM Project No. 102725

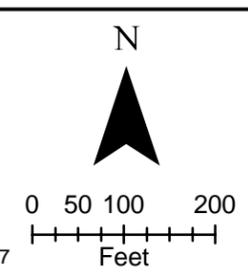
AECOM

Figure 3 D



LEGEND

Grass	Stream	Right of Way
Monolithic Island	NWI Wetland	Slopestake
Pavement	100 Year Floodplain	Blue Ridge Parkway
Pea Gravel	Floodway	Truck Crashes July 1997 to June 2007



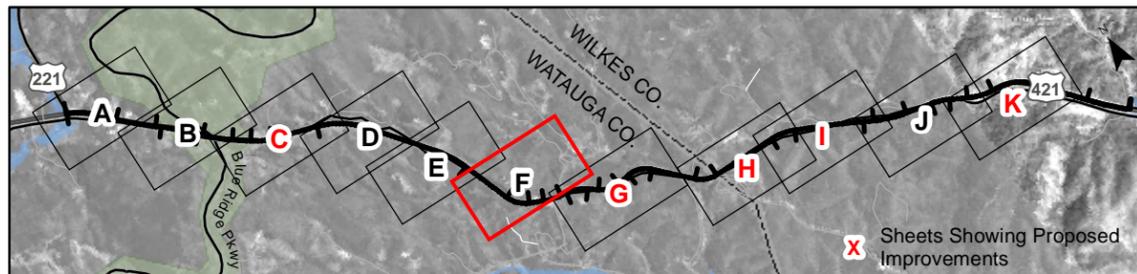
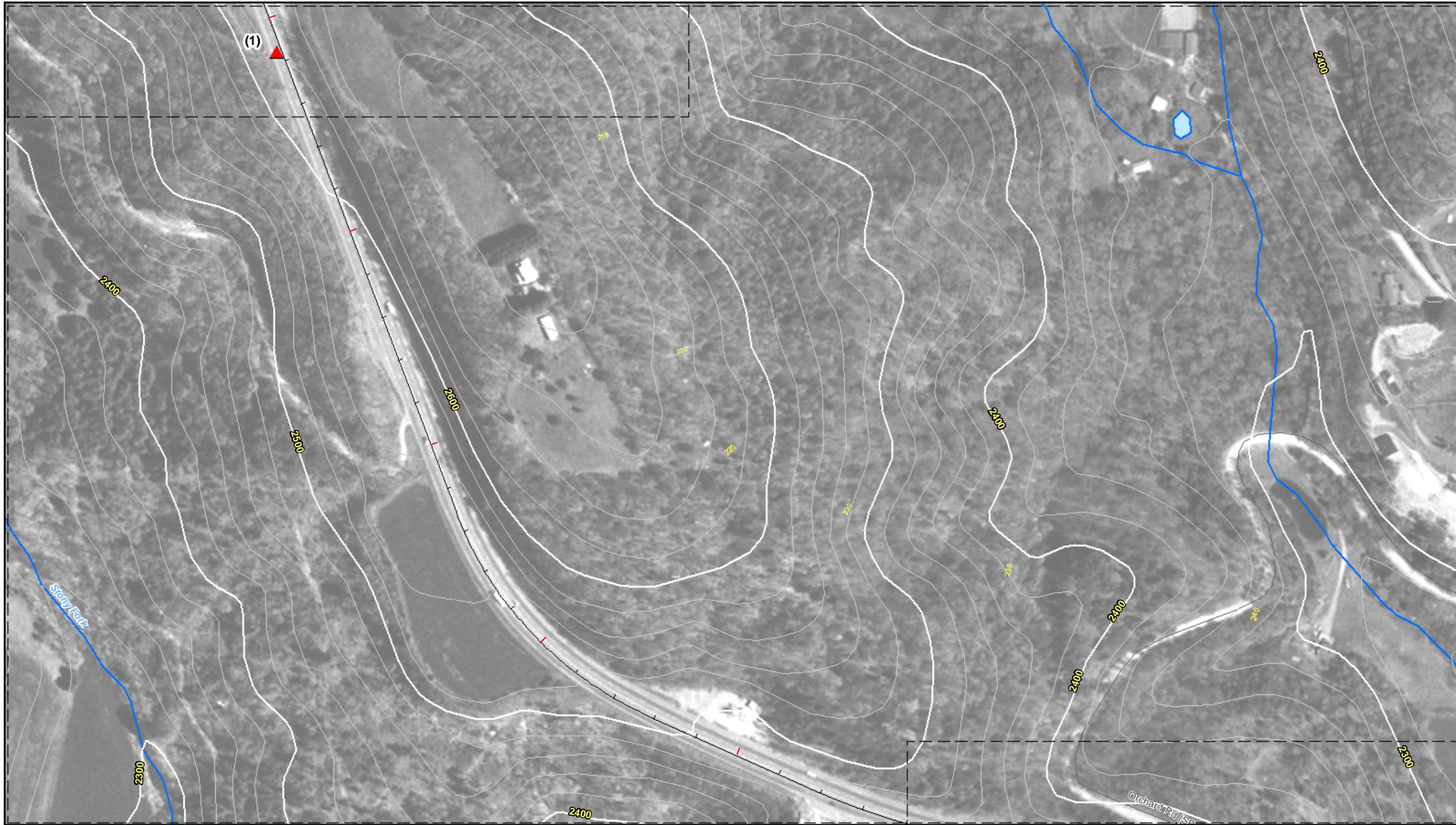
Feasibility Study
 Truck Emergency Escape Ramps
 US 421 between US 221 in Watauga County
 & SR 1301 in Wilkes County
 FS-0711A, WBS 34263.1.1

June 2009 Watauga/Wilkes County, North Carolina

AECOM Project No. 102725

AECOM

Figure 3 E



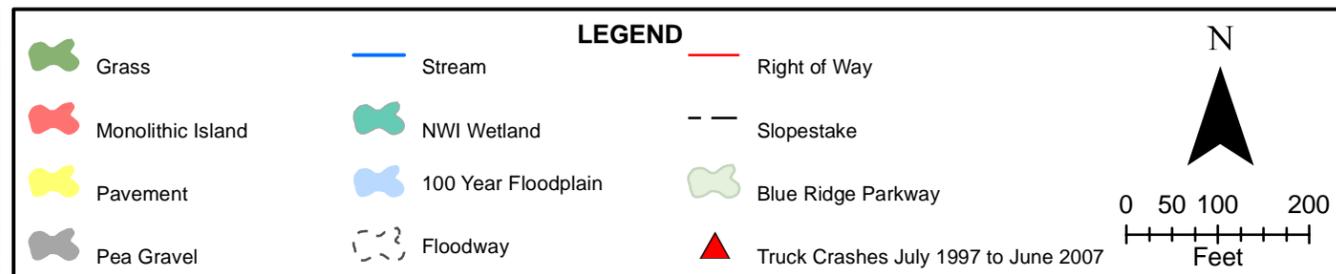
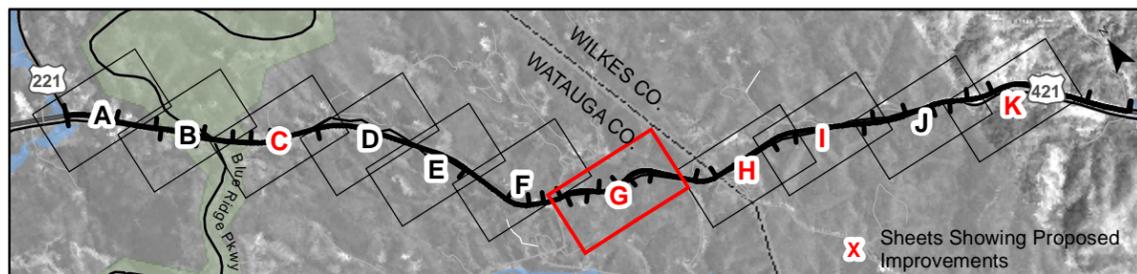
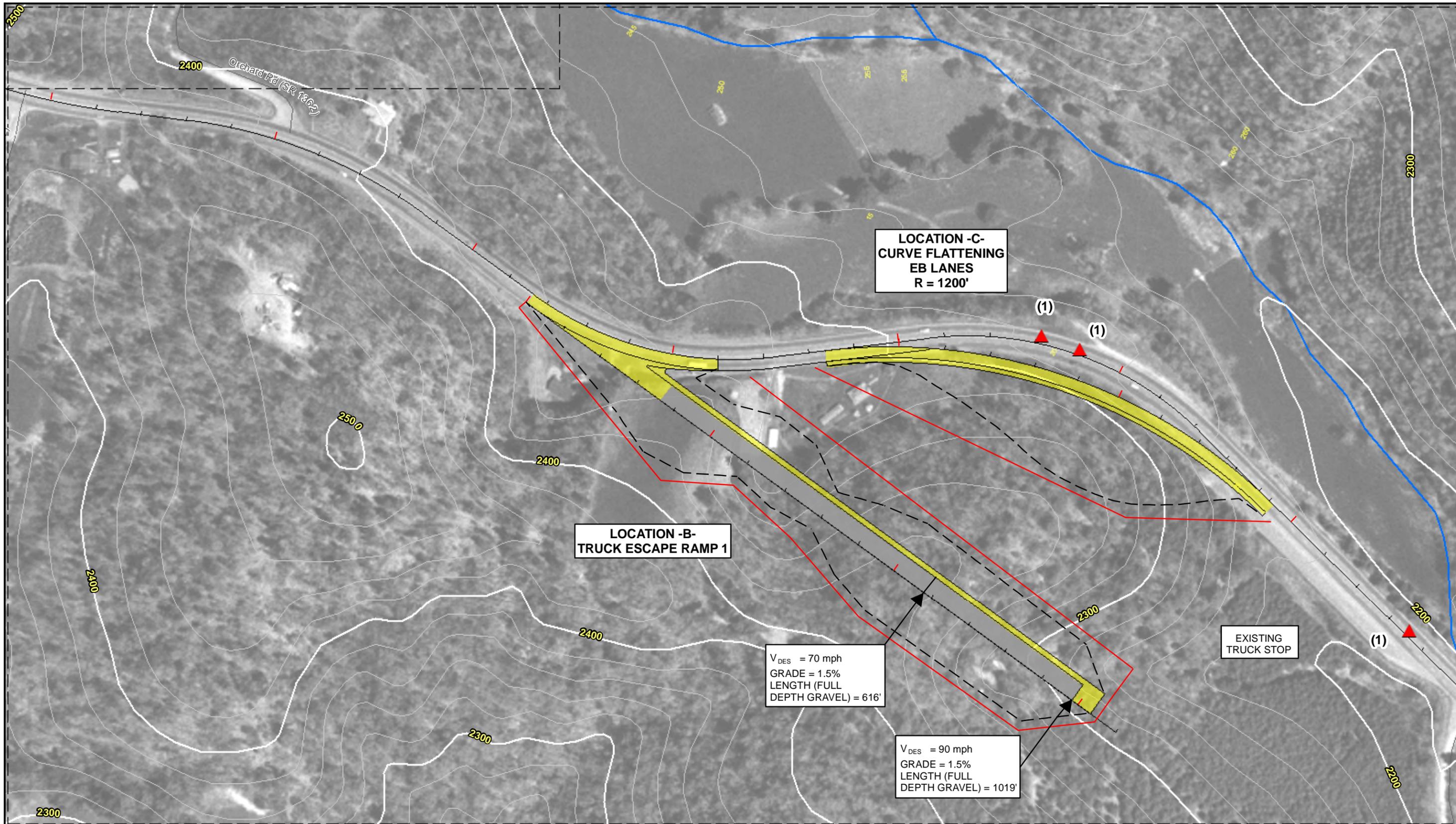
LEGEND

Grass	Stream	Right of Way
Monolithic Island	NWI Wetland	Slopestake
Pavement	100 Year Floodplain	Blue Ridge Parkway
Pea Gravel	Floodway	Truck Crashes July 1997 to June 2007

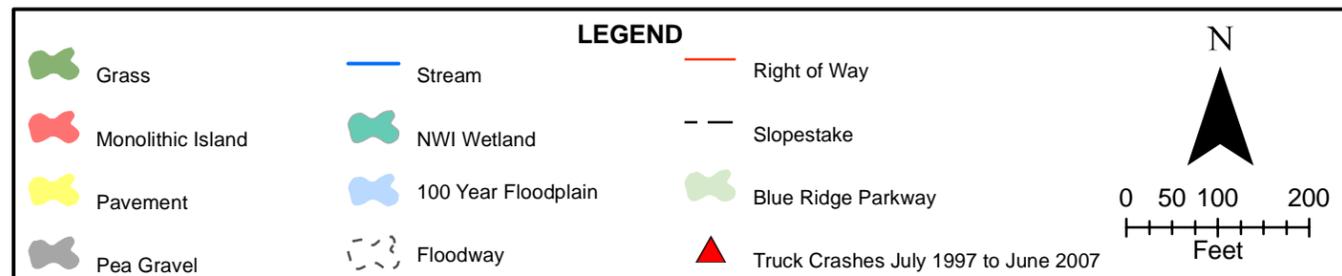
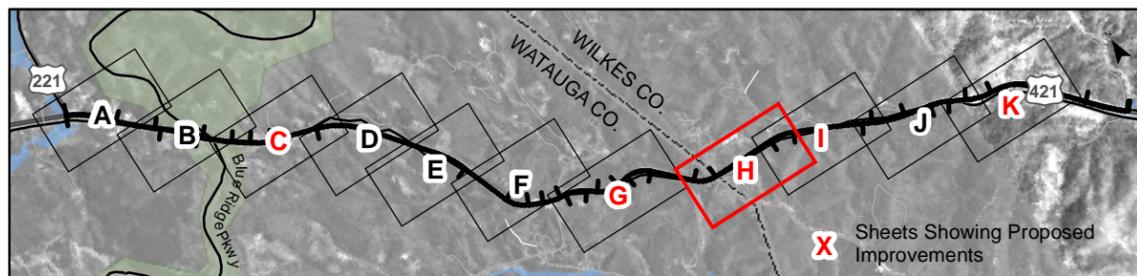
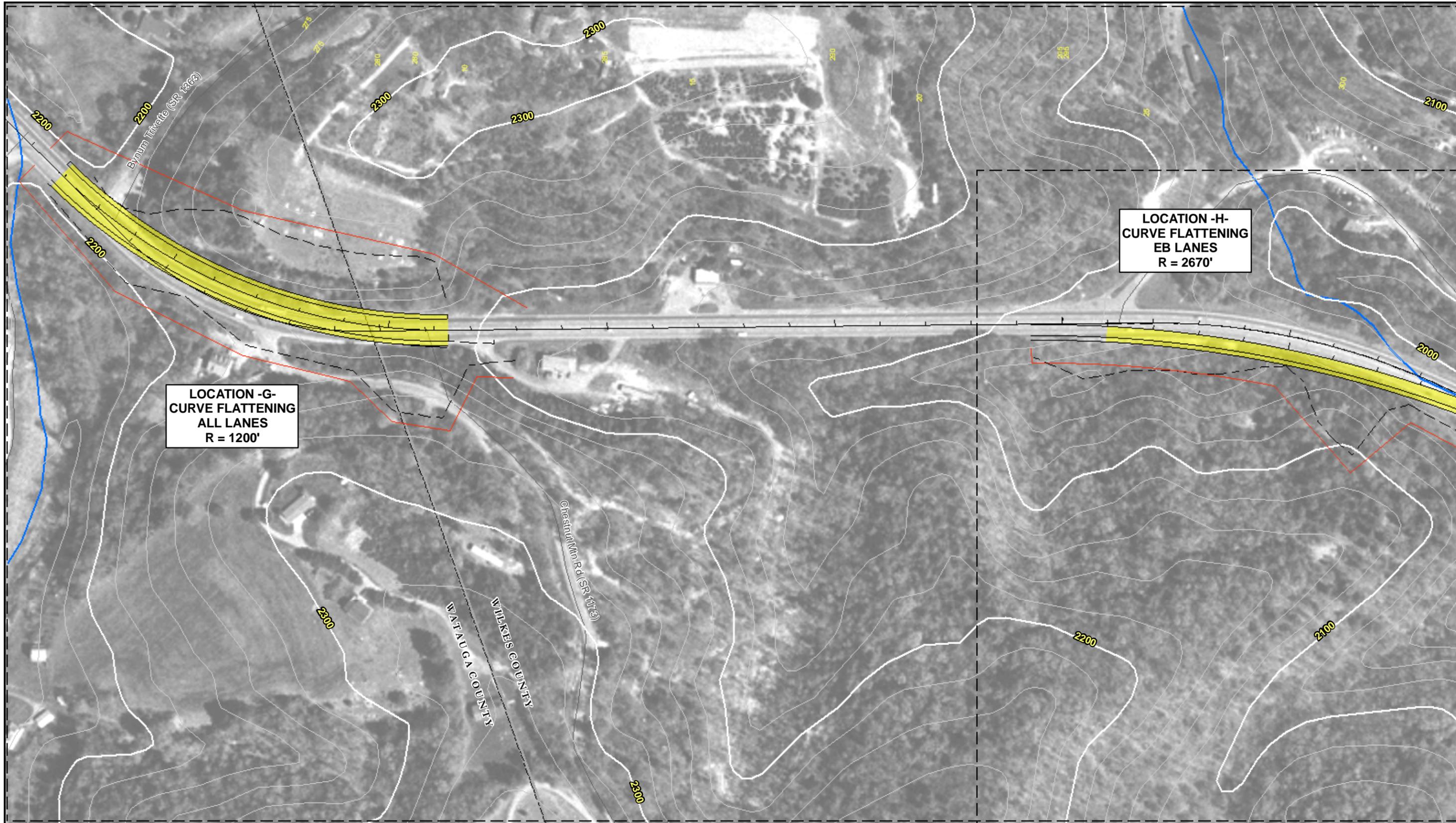
N
 0 50 100 200
 Feet

Feasibility Study
 Truck Emergency Escape Ramps
 US 421 between US 221 in Watauga County
 & SR 1301 in Wilkes County
 FS-0711A, WBS 34263.1.1

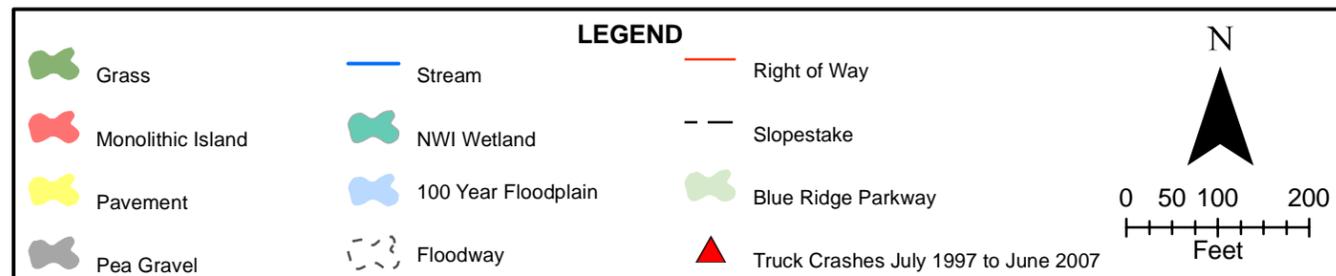
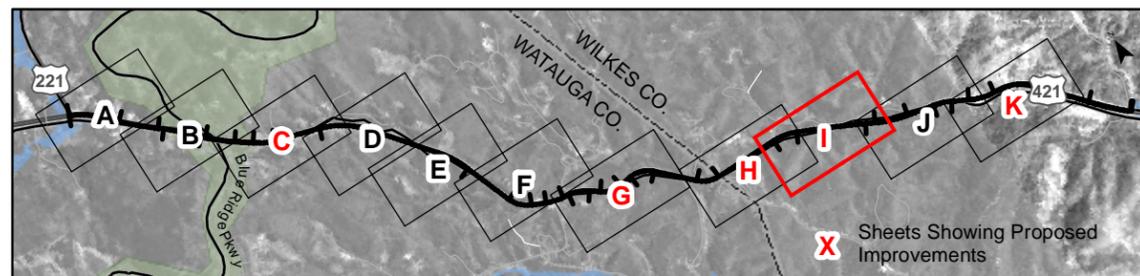
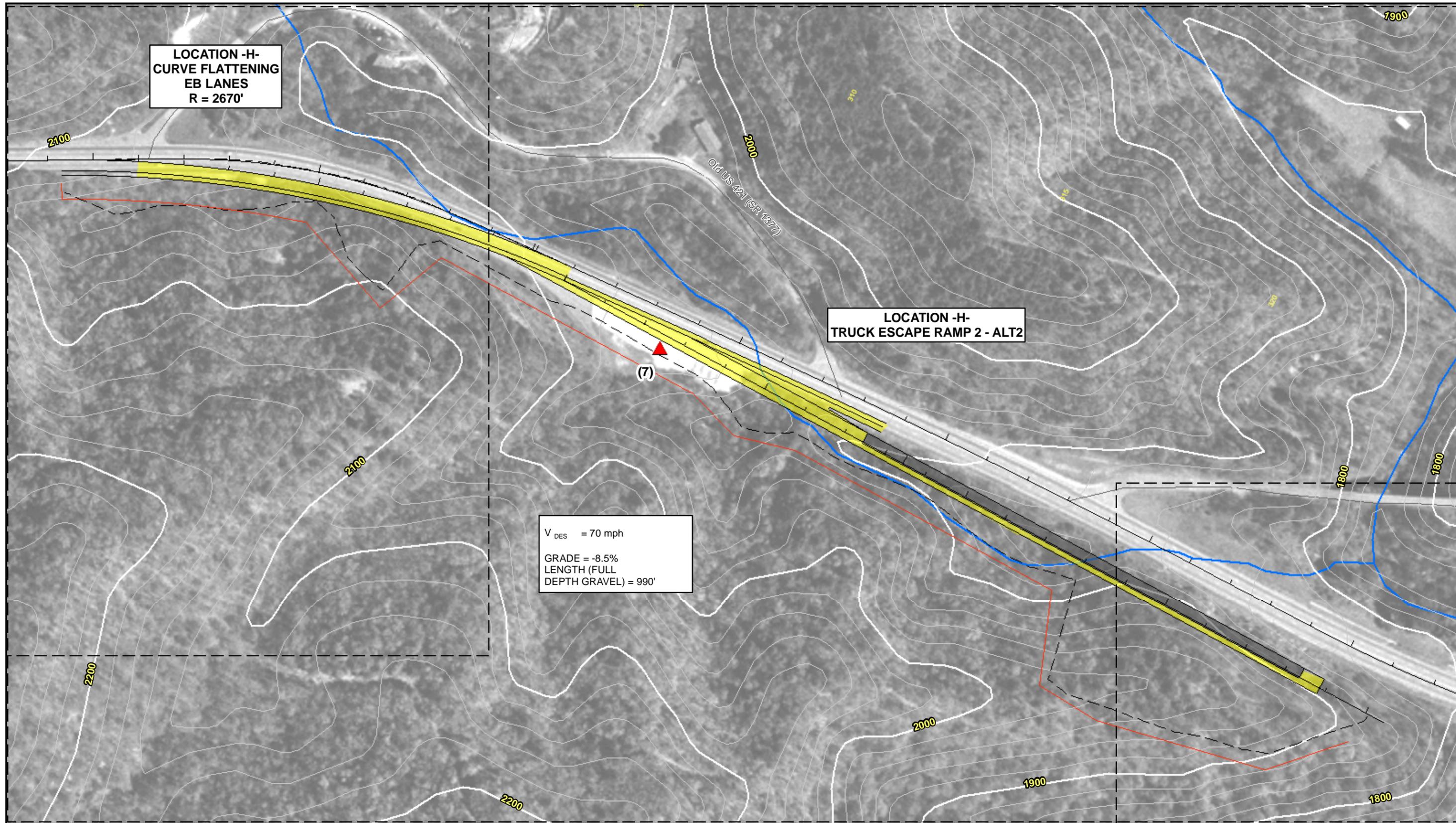
June 2009	Watauga/Wilkes County, North Carolina
AECOM Project No. 102725	AECOM
	Figure 3 F



Feasibility Study Truck Emergency Escape Ramps US 421 between US 221 in Watauga County & SR 1301 in Wilkes County FS-0711A, WBS 34263.1.1	
June 2009	Watauga/Wilkes County, North Carolina
AECOM Project No. 102725	AECOM
	Figure 3 G



Feasibility Study	
Truck Emergency Escape Ramps US 421 between US 221 in Watauga County & SR 1301 in Wilkes County FS-0711A, WBS 34263.1.1	
June 2009	Watauga/Wilkes County, North Carolina
AECOM Project No. 102725	AECOM
	Figure 3 H



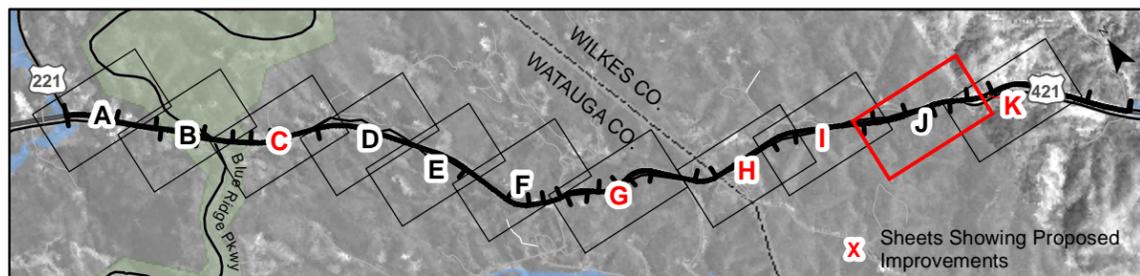
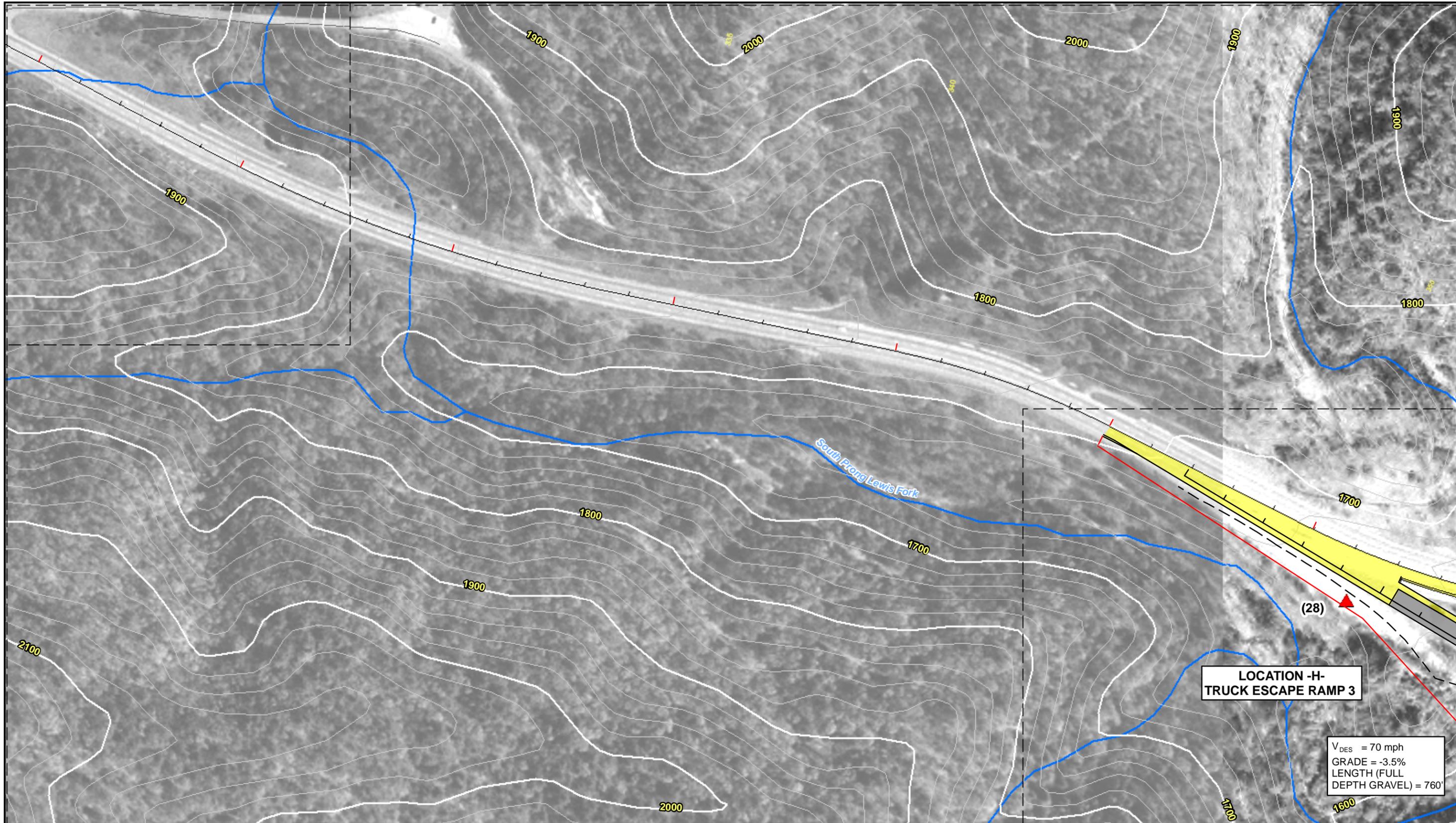
Feasibility Study
Truck Emergency Escape Ramps
US 421 between US 221 in Watauga County
& SR 1301 in Wilkes County
FS-0711A, WBS 34263.1.1

June 2009 Watauga/Wilkes County, North Carolina

AECOM Project No. 102725

AECOM

Figure 31



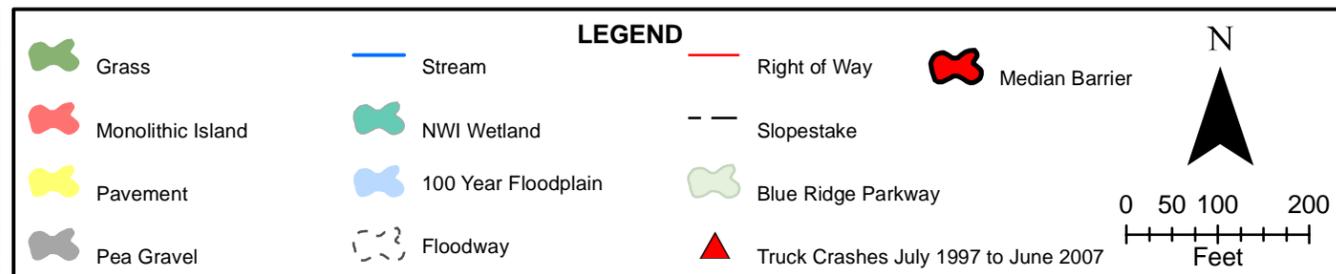
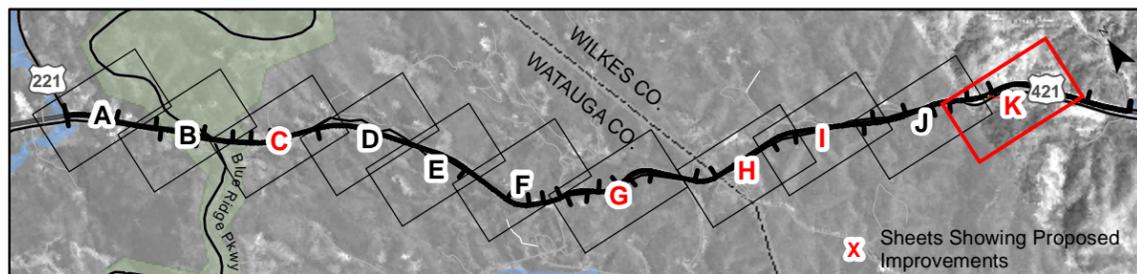
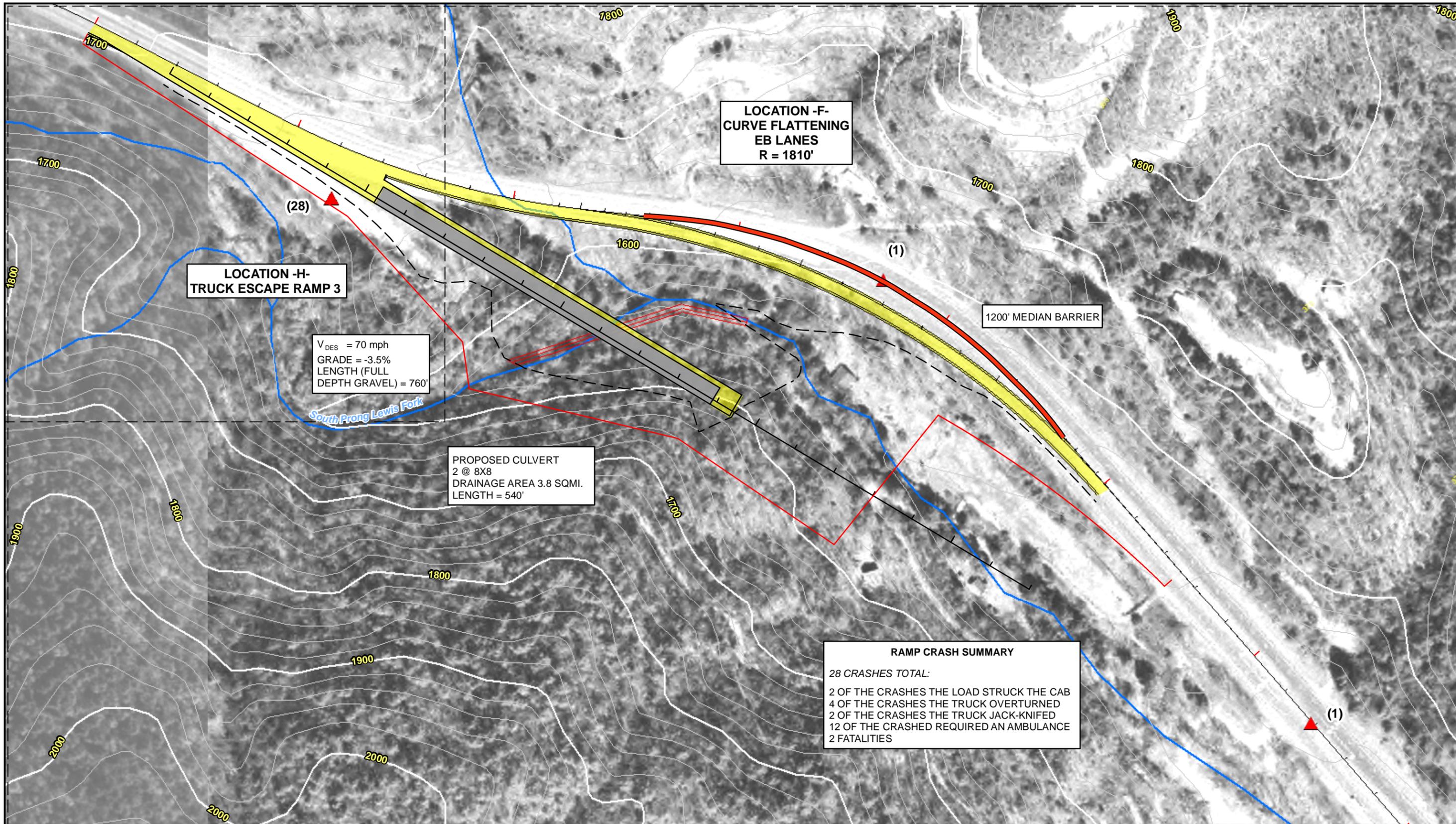
LEGEND

Grass	Stream	Right of Way
Monolithic Island	NWI Wetland	Slopestake
Pavement	100 Year Floodplain	Blue Ridge Parkway
Pea Gravel	Floodway	Truck Crashes July 1997 to June 2007

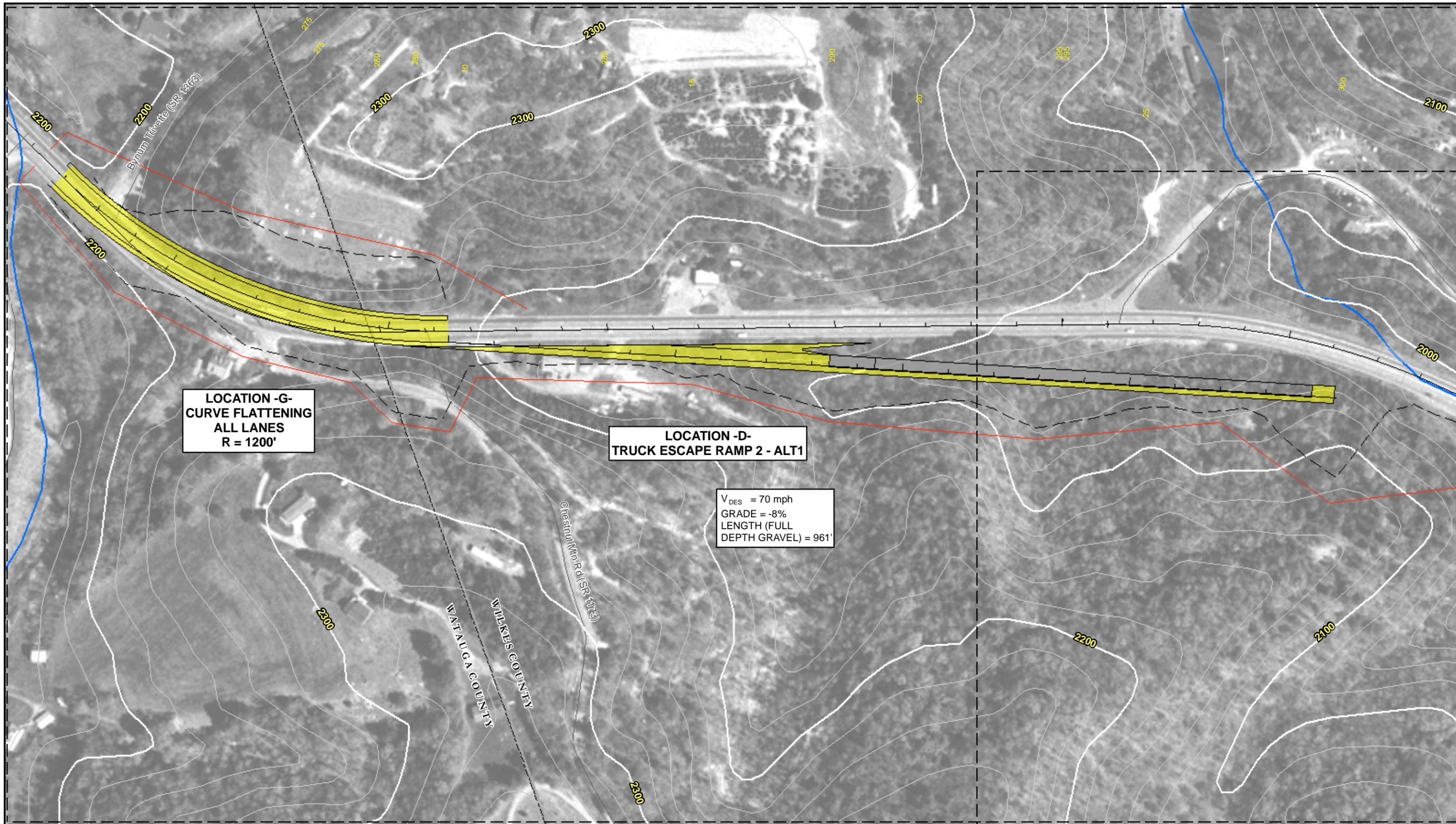
0 50 100 200
 Feet

Feasibility Study
 Truck Emergency Escape Ramps
 US 421 between US 221 in Watauga County
 & SR 1301 in Wilkes County
 FS-0711A, WBS 34263.1.1

June 2009	Watauga/Wilkes County, North Carolina	
AECOM Project No. 102725	AECOM	Figure 3 J



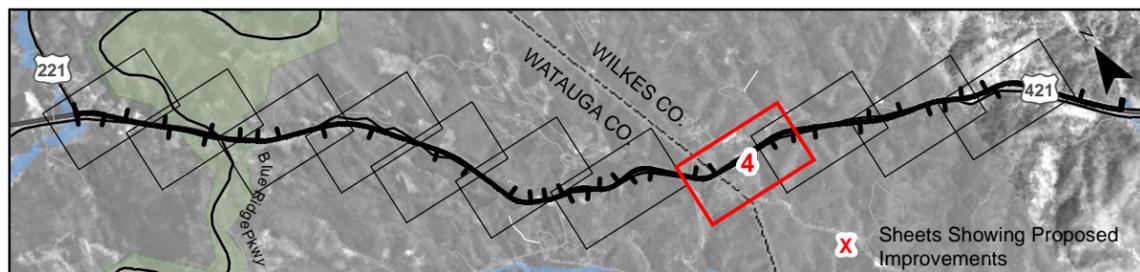
Feasibility Study Truck Emergency Escape Ramps US 421 between US 221 in Watauga County & SR 1301 in Wilkes County FS-0711A, WBS 34263.1.1	
June 2009	Watauga/Wilkes County, North Carolina
AECOM Project No. 102725	AECOM Figure 3 K



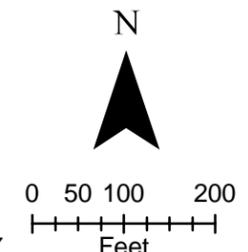
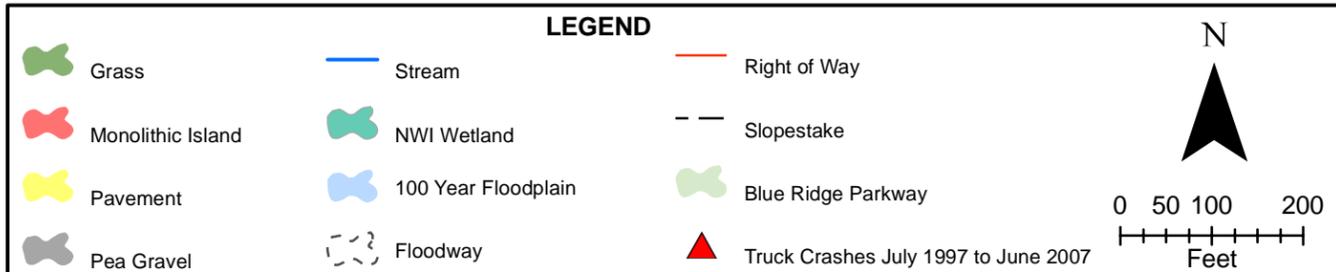
**LOCATION -G-
CURVE FLATTENING
ALL LANES
R = 1200'**

**LOCATION -D-
TRUCK ESCAPE RAMP 2 - ALT1**

V_{DES} = 70 mph
GRADE = -8%
LENGTH (FULL)
DEPTH GRAVEL = 961'



X Sheets Showing Proposed Improvements



Feasibility Study	
Truck Emergency Escape Ramps US 421 between US 221 in Watauga County & SR 1301 in Wilkes County FS-0711A, WBS 34263.1.1	
June 2009	Watauga/Wilkes County, North Carolina
AECOM Project No. 102725	AECOM
	Figure 4