APPENDIX EE
LEVEL 1 & 2 DESIGN EXCEPTIONS

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LEVEL ONE DESIGN EXCEPTION REQUEST
For Tier 2, Section 5 (Bloomington to Martinsville)
of the I-69 Evansville to Indianapolis Project

A Level One Design Exception is being requested for the following elements:

- ***Shoulder Widths***
  - From South End of Project Limits to SR 46 (approximately Sta. 1541+00 -1614+45, Sta. 1776+00 – 1796+00, Sta. 1823+46 – 1841+00)
    - **Required Left Shoulder Width = 12-foot** (From IDM Fig. 53-1 – footnote (5)b *–where there are 3 or more lanes in one direction and the volume of trucks exceed 250 DHV, a 12-foot width should be used*)
    - **Proposed Left Should Width = 11'-9"** (DHV ranges from 4,586 to 7,745 in this area)

  - At Indiana Railroad Overpass (approximately Sta. 1725+40)
    - **Required Left Shoulder Width = 12-foot** (From IDM Fig. 53-1 – footnote (5)b *–where there are 3 or more lanes in one direction and the volume of trucks exceed 250 DHV, a 12-foot width should be used*)
    - **Proposed Left Should Width = 10-foot** (DHV ranges from 4,586 to 7,745 in this area)

- ***Maximum Grade***
  - From Kinser Pike to Griffy Creek (approximately Sta. 1971+00 to 1997+25)
    - **Required Maximum Grade = 4%** (From IDM Fig. 53-1 for 70 mph in a rolling terrain for both urban and rural situations)
    - **Proposed Maximum Grade = 5%**

  - Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00)
    - **Required Maximum Grade = 4%** (From IDM Fig. 53-1 for 70 mph in a rolling terrain for both urban and rural situations)
    - **Proposed Maximum Grade = 5%**

Detailed information about each element and location of the request is included in this request.

Project Description

Section 5 of the I-69 Evansville to Indianapolis project begins just north of the intersection with SR37 and Victor Pike, south of Bloomington, and continues northward on the existing alignment of SR 37 to just south of the interchange of SR 37 and SR 39 in Martinsville. This section of the I-69 project is approximately 23 miles in length and extends through Monroe and Morgan Counties, Indiana, following the existing alignment of SR 37, a multi-lane divided principal arterial highway with partial access control. This project would reconstruct the corridor to meet freeway standards with full access control.

From the southern terminus of the project to Sample Road, the project is designed with an urban typical section. From Sample Road to the north end of the project, a rural typical section will be used. The terrain throughout the project area is rolling. Areas with long, upward grades exist necessitating the existing truck climbing lanes in several different locations within the project limits. The current posted speed limit ranges from 55 mph in the urban section to 60 mph in the rural section. The proposed design speed is 70 mph. The proposed posted speed limit is 55 mph through the urban limits of the city of Bloomington and 70 mph in the rural areas.

Existing SR 37 in the urban section generally consists of two lanes each direction. An auxiliary lane is present between the two most closely spaced urban interchanges (SR 45 and SR 48) with additional auxiliary lanes at the intersections and interchanges with approximately 4-foot inside shoulders and 8-9 foot outside shoulders. The existing typical cross section includes an open grass median throughout the corridor. The proposed alternative will utilize three 12-foot lanes in each direction for the urban area with an auxiliary lane between the SR 45 and SR 48 interchanges. Auxiliary lanes will also be included at the interchange ramp terminals. Twelve-foot inside shoulders with minor exceptions and twelve-foot outside shoulders will be provided in the urban typical sections with the introduction of a concrete median barrier to separate opposing directions of traffic. For the typical section, the limits of the urban/rural section are based on forecasted traffic and continuing development in the area. The project will have an urban section from its south end up to the Sample Road interchange. North of Sample Road it will have a rural typical section.

In the rural section of this project, existing SR 37 is two lanes in each direction with auxiliary lanes at the intersections. The existing typical section includes inside shoulders of approximately 4-foot width and 8-9-foot outside shoulders. It has a typical 60-foot wide open grassy median. The proposed typical section will have two 12-foot lanes in each direction with a 4-foot inside and 12-foot outside shoulders and an open grassy median which typically is 60-foot wide.

The primary objective in the development of the minimal impact alternatives was to avoid impacts where practical and to minimize associated project costs. This is being achieved by following the existing horizontal and vertical alignment of SR 37 wherever feasible and maintaining many of the existing bridge structures. However, with the increase from the existing posted speed (55-60 mph) to the design speed (70 mph) and to comply with current design standards, there are existing features that will be substandard and require either upgrading or a design exception to maintain the existing feature.

The proposed project will be designed in accordance with both the American Association of Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets and the Indiana Design Manual (IDM). Specifically, the mainline highway utilizes IDM, Chapter 53, Geometric Design Criteria for Freeways, New Construction or Complete Reconstruction. As proposed, the following design features do not meet the level one design criteria for the design speed of 70 mph at the specific locations listed below within the project limits:

***Shoulder Widths* – From South End of Project Limits to SR 46 (approximately Sta. 1541+00 -1614+45, Sta. 1776+00 – 1796+00, Sta. 1823+46 – 1841+00) – Urban Typical Section**

- **Design Feature**
  Throughout much of the urban section, there are two existing through lanes in each direction, with adjacent auxiliary lanes between the existing SR 45 and SR 48 interchanges. The existing paved shoulders are 4-foot (inside) and 8-foot (outside). The proposed I-69 cross section will use the existing two through lanes; the existing horizontal alignment and vertical profile in this area

will be maintained. Based on forecasted traffic levels, a third through lane is required in the urban limits of the project.

The existing median width from the south end of the project up to SR 46 is 50-foot. This width will accommodate the additional travel lane in each direction; median shoulders for the two travel directions are separated by a concrete median barrier. The required travel lane width is 12-foot, the required inside shoulder width is 12-foot, and the typical INDOT concrete median barrier is 2'-6" in width. As part of the minimal impact design initiative and to utilize as much of the existing facility as possible, an effort was made to keep the travel lanes in the same location as the existing travel lanes. This will minimize costs by overlaying the pavement structure instead of having to completely reconstruct the entire thickness. It will also provide a better quality end product by eliminating the need for pavement joints through a travel lane if widening were necessary. So, in order to stay on the existing through lane lines and expand to the median side, the median width is 6 inches less than is required to provide a full 12-foot shoulder in each direction.

Based on IDM Figure 53-1, Geometric Design Criteria for Freeway (New Construction or Complete Reconstruction) for a urban situation, a 10-foot inside paved shoulder width is required; however, footnote (5)b states that a shoulder width of 12-foot is required due to forecasted truck volumes.

In some portions of this section of the project, existing pavement must be reconstructed due to either an alignment shift, or building wider outside median shoulders on a horizontal curve (to provide adequate stopping sight distance). However, where there is an existing 50-foot wide median and no additional widening or reconstruction is required, a Level One Design Exception will be necessary. This Level One Design Exception would allow an inside shoulder of 11'-9", which is 3 inches less than required 12-foot wide shoulder.

Other barrier types (which are only 2-foot wide) were considered; however, these barriers would likely result in a higher cost due to the additional reinforcing requirements and a possible difficulty during construction as the 2-foot wide barrier differs from the INDOT standard median barrier.

Another option would be to gain the 3 inches required by slightly shifting the alignment to provide widening on one side of the section. However, this would require reconstruction of portions of the pavement structure.

Therefore, it is proposed to provide the third travel lane, inside shoulders and median barrier within the existing median, maintaining the existing lane lines and pavement structure. This provides an 11'-9" inside shoulder as compared to the required 12-foot width.

- **Construction Costs**
  To provide the required shoulder width through the existing urban section of Bloomington would require that either a non-standard median barrier (less than standard 2'-6" in width) be used or the alignment be shifted with full depth pavement widening occurring on one side. The cost for the full depth pavement reconstruction for portions of these areas is estimated at $3,172,000 more than the option to build the inside shoulders to a width of 11'-9".

- **Project Design**
  From the southern terminus of the project to Kinser Pike (urban section of the project):

2035 AADT	63,800 - 90,260	Commercial Vehicles
2035 DHV	4,856 - 7,745	15.6 - 22.4% AADT
2035 DHV	7.0 – 9.3%	6.9 – 7.6% DHV

Existing Posted Speed:	55 mph
Design Speed	70 mph
Proposed Posted Speed:	55 mph (location of posted speed limit change from 55 mph to 70 mph will be at Kinser Pike – urban boundary for the City of Bloomington – differs from typical section change)
Access Control:	Full

- **Crash Analysis** (Crash Data Maps are provided in Appendix "A")
  - ***Sta. 1541+00 -1614+45*** **-** During the 5-year period, in this area, there were a total of 88 crashes. Within this area are the existing at-grade intersections of Rockport Road and Fullerton Pike. The majority of these crashes occurred at the intersections[1]. Roadway departure crashes are the type of crashes which could be attributed to insufficient shoulder widths. There were only 6 run-off crashes within the 5-year period.

Median Shoulders - Sta. 1541+00 - 1614+45				
Projected Traffic Data in 2035 **AADT 75,580 vpd** **Cars = 82.3%** **Trucks = 17.7%**				
2007 - 2011				
Crash Type	**PDO**	**Injury**	**Fatality**	**Total**
Head-On	9	4	0	13
Run Off	4	2	0	6
Rear End	6	4	0	10
Right Angle	25	13	0	38
Sideswipe	6	1	0	7
Other	8	6	0	14
Total	58	30	0	88

  - ***Sta. 1776+00 – 1796+00*** **-** During the 5-year period, in this area, there were a total of 55 crashes. This area is just south of the intersection with Vernal Pike. The majority of these crashes occurred at the intersection. Roadway departure crashes are the type of crashes which could be attributed to insufficient shoulder widths. There were only 4 run off crashes within the 5-year period.

[1] Right-angle and head-on crashes (51 of the 88 reported) would be expected no longer to occur once the project is completed in this section.

Median Shoulders - Sta. 1776+00 - 1796+00				
Projected Traffic Data in 2035 **AADT 87,430 vpd** **Cars = 83.6%** **Trucks = 16.4%**				
2007 - 2011				
Crash Type	**PDO**	**Injury**	**Fatality**	**Total**
Head-On	2	1	0	3
Run Off	4	0	0	4
Rear End	29	16	0	45
Right Angle	0	0	0	0
Sideswipe	2	0	0	2
Other	1	0	0	1
Total	38	17	0	55

- ***Sta. 1823+46 – 1841+00*** **-** During the 5-year period, in this area, there were a total of 4 crashes. This area is just north of the intersection with Vernal Pike. Roadway departure crashes are the type of crashes which could be attributed to insufficient shoulder widths. There were only 2 run off crashes within the 5-year period.

Median Shoulders - Sta. 1823+46 – 1841+00				
Projected Traffic Data in 2035 **AADT 87,430 vpd** **Cars = 83.6%** **Trucks = 16.4%**				
2007 - 2011				
Crash Type	**PDO**	**Injury**	**Fatality**	**Total**
Head-On	0	0	0	0
Run Off	1	1	0	2
Rear End	0	0	0	0
Right Angle	0	0	0	0
Sideswipe	2	0	0	2
Other	0	0	0	0
Total	3	1	0	4

- **Cost-Effective Analysis**
  Providing a 12-foot median shoulder width throughout the urban section would require the use of a special non-standard INDOT median barrier to correct the substandard design feature, if

existing lane lines are to be maintained. Based on the cost of the special median barrier and the small number of crashes in this areas that are attributable to this design feature, it would not be cost-effective to correct these design features as part of this project.

A benefit/cost analysis was performed to justify the design exception requests. The calculations are in the Appendix "B".

- **Ancillary Impacts**
  Throughout the urban section of Bloomington, the substandard shoulder widths will not have any adverse effects on any other design elements within the project.

- **Remedial Actions**
  There are no remedial actions necessary for these areas.

***Shoulder Widths* – At Indiana Railroad Overpass (approximately Sta. 1725+40) – Urban Typical Section**

- **Design Feature**
  The Indiana Railroad Overpass falls in between the SR 45 and SR 48 interchanges were there are existing auxiliary lanes in each direction for the entrance and exit ramps. The horizontal alignment is in a tangent section at the overpass and the vertical alignment includes a sag vertical curve. The existing paved shoulders are 4-foot (inside) and 8-foot (outside). The proposed I-69 cross section uses the existing two through lanes; the existing horizontal alignment and vertical profile in this area will be maintained. Based on forecasted traffic levels, a third through lane is required in the urban limits of the project. It is proposed that the Indiana Railroad overpass remain in place. The existing structure was built in 1972 and from the most current INDOT Bridge Inspection Report (dated 6/7/11), the structure has a remaining life of 22 years. Keeping the current overpass means that the inclusion of the third through lane results in a 10-foot inside shoulder width and maintains the existing 8-foot outside shoulder width, adjacent to the auxiliary lane.

  The primary objective for maintaining the existing Indiana Railroad overpass is to minimize impacts and construction costs by retaining the existing lane lines and crown location. The resulting substandard shoulder width condition (10-foot inside shoulder as opposed to 12-foot) will exist for only the short distance under the railroad structure and will be transitioned from full shoulder widths (12-foot) on either side as appropriate using the appropriate taper rates from the Indiana Design Manual. Per IDM Fig. 76-2B, and upstream shoulder taper should be 1/3L with L equal to the taper rate (70:1) times the width.

  It is proposed that when the railroad structure warrants replacement, the new structure be long enough for I-69 to meet all current design standards and provide the appropriate mainline shoulder widths.

  INDOT design criteria permits the use of 6-foot shoulders adjacent to auxiliary lanes on reconstruction projects. In this situation, there are auxiliary lanes/ramps (entrance SB from 3rd Street/SR48 and exit NB to 3rd Street/SR 48) adjacent to the existing outside lanes.

  Guardrail is recommended for both the inside and outside structures (adjacent to the bridge) to protect the existing structure and to mitigate the substandard shoulder width.

- **Construction Costs**
  In order to provide the required shoulder widths, the bridge carrying the Indiana Railroad over SR 37 would need to be reconstructed. The cost associated with this are estimated at $3,850,000. Replacing the bridge will also cause disruption to the railroad service. The bridge is currently in good condition and has an estimated remaining service life of approximately 22 years. It is recommended that the existing structure remain in place until the structural condition warrants replacement.

- **Project Design**
  At Indiana Railroad Crossing:

2035 AADT	63,800 - 90,260	Commercial Vehicles
2035 DHV	4,856 - 7,745	15.6 - 22.4% AADT
2035 DHV	7.0 – 9.3%	6.9 – 7.6% DHV

Existing Posted Speed:	55 mph
Design Speed	70 mph
Proposed Posted Speed:	55 mph (location of posted speed limit change from 55 mph to 70 mph will be at Kinser Pike – urban boundary for the City of Bloomington – differs from typical section change)
Access Control:	Full

- **Crash Analysis** (Crash Data Maps are provided in Appendix "A")
  During the 5-year period, in this area, there were a total of 5 crashes. Of these, none occurred at the overpass or involved injury or fatality. There have not been any crashes to which the current substandard shoulder width was a contributing factor.

Indiana Railroad Overpass*

Projected Traffic Data in 2035
AADT 90,260 vpd
Cars = 84.4%
Trucks = 15.6%

2007 - 2011

Crash Type	PDO	Injury	Fatality	Total
Head-On	1	0	0	1
Run Off	1	0	0	1
Rear End	0	0	0	0
Right Angle	1	0	0	1
Sideswipe	1	0	0	1
Other	1	0	0	1
Total	5	0	0	5

* 500-foot each direction of the overpass

- **Cost-Effective Analysis**
  The shoulder width at the Indiana Railroad Bridge would require the replacement of the overhead structure to correct the substandard design feature. Based on the cost of the replacement structures and the lack of crashes in this areas that are attributable to this design feature, it would not be cost-effective to correct these design features as part of this project.

  A benefit/cost analysis was performed to justify the design exception request. The calculations are in Appendix "C".

- **Ancillary Impacts**
  At the Indiana Railroad overpass, the substandard shoulder widths will not have any adverse effects on any other design elements within the project.

- **Remedial Actions**
  Guardrail will be placed in advance of the structure (in each direction) to protect the bents. It is recommended that additional signage be placed in this area regarding the shoulder widths.

***Maximum Grade* – From Kinser Pike to Griffy Creek (approximately Sta. 1971+00 to 1997+25) – Urban Typical Section**

- **Design Feature**
  The existing vertical grade in both the northbound and southbound directions between Kinser Pike and Griffy Creek is 5%. The maximum vertical grade for new construction/reconstruction of freeways according to both INDOT and AASHTO design criteria is 4%. It is proposed that the existing grade in this area be maintained. This will minimize project construction costs.

  As part of the preliminary design, an alternative was developed which would correct the grade to meet the 4% maximum requirement. Plan and profile views for this alternative were developed and are included in Appendix "D". The plan view illustrates the extent of the sideslope impacts for this scenario and also shows where the earthwork changes from cut to fill. The alternative would require a maximum cut of approximately 6-foot and fill of up to approximately 12-foot to achieve the 4% maximum grade. Both alternatives can be built within the existing right-of-way; therefore, there are no environmental resources impacted.

  Estimated construction costs, length of reconstruction required, and the associated speed reduction for both the 4% grade correction and maintaining the existing 5% grade are compared in the table below. The benefits gained by correcting the profile grade to 4% are a gain of 3 mph in speed reduction[2]. The additional costs of reconstruction and the extensive impacts to upgrade the facility to meet the maximum grade requirements do not provide meaningful benefits or improvements in the total speed reduction (compared to the existing 5% grade).

[2] "Speed reduction" refers to the decrease in velocity for trucks, given a certain percent grade and length of grade, compared to the velocity of autos on the same section of road.

Condition	Total Speed Reduction	Reconstruction Length	Total Cost
Existing 5% Grade	27 MPH	0'	$2,498,000*
Corrected 4% Grade	24 MPH	4,230'	$12,480,000

* Pavement Overlay assumed for this construction cost

A Level Two Design Exception is being documented for critical length of grade within this area. Note that the Level Two Design Exception will be required whether the existing 5% profile grade is maintained or if it is improved to the standard 4% grade. The proposed typical section in this area is 3 lanes in each direction. LOS calculations were performed and the 3 lane section provides a LOS of "B" in the design year for the projected traffic. An additional (fourth) lane is not considered for a truck climbing lane in this 3-lane section.

- **Construction Costs**
  See cost comparisons provided above for different alternatives to improve the grade to meet the 4% maximum grade.

- **Project Design**
  From Kinser Pike to Griffy Creek:

2035 AADT	63,800 - 90,260	Commercial Vehicles
2035 DHV	4,856 - 7,745	15.6 - 22.4% AADT
2035 DHV	7.0 – 9.3%	6.9 – 7.6% DHV

Existing Posted Speed:	60 mph
Design Speed	70 mph
Proposed Posted Speed:	70 mph (location of posted speed limit change from 55 mph to 70 mph will be at Kinser Pike – urban boundary for the City of Bloomington – differs from typical section change)
Access Control:	Full

- **Crash Analysis** (Crash Data Maps are provided in Appendix "A")
  During the 5-year period, in this area, there were only two crashes.

Kinser Pike to Griffy Creek - Southbound				
Projected Traffic Data in 2035 **AADT 68,670 vpd** **Cars = 79.9%** **Trucks = 20.1%**				
2007 - 2011				
Crash Type	**PDO**	**Injury**	**Fatality**	**Total**
Head-On	0	0	0	0
Run Off	1	0	0	1
Rear End	0	0	0	0
Right Angle	0	0	0	0
Sideswipe	1	0	0	1
Other	0	0	0	0
Total	2	0	0	2

- **Cost-Effective Analysis**
  A benefit-cost analysis was performed for this design element. The documentation is included in Appendix "E". The approach for determining the crash reduction factors for this project has been complicated. With the conversion of the facility from a partial access highway to a limited access interstate, many assumptions have been made. In general, a safer facility will be provided when the facility is upgraded from an arterial road to a fully-grade separated freeway; this would lead to a reduction in crashes. Traffic forecasts in the design year are more than double existing traffic counts. A benefit/cost analysis is attached as Appendix "E".

  Operational-level Level of Service (LOS) calculations were also performed for the existing 5% grade and the 4% grade that would be necessary to correct this design element. There was no change in the LOS between the 4% and 5% grades. In the northbound direction (downgrade), a LOS "B" is predicted in the design year. In the southbound direction (upgrade), a LOS "C" is anticipated. Again, there was no increase in the LOS when the grade was corrected to 4%. Improving the grade, results in a gain of only 3 mph in the truck speed reduction (compared to the existing 5% grade).

  Regarding the 5% maximum grade from Kinser Pike to Griffy Creek, due to:

  - the additional costs of reconstruction,
  - the extensive impacts to upgrade the facility to meet the maximum grade requirements,
  - the lack of a significant number of rear-end crashes,
  - the minimal improvement in the total speed reduction, and
  - the favorable benefit-cost analysis,

  It would not be beneficial to improve this feature. In addition, even with correction of the grade, the critical length of grade would still be exceeded within this area.

- **Ancillary Impacts**
  In this area with the vertical grade exceeding the maximum grade, the steeper grade also affects the critical length of grade and the associated speed reduction.

- **Remedial Actions**

There are no remedial actions necessary for these areas.

***Maximum Grade* – Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00) – Rural Typical Section**

- **Design Feature**

  The existing vertical grade through southern-most portion of the existing southbound SR 37 bifurcation in northern Monroe County is 5%. The maximum vertical grade for new construction/reconstruction of freeways according to both INDOT and AASHTO design criteria is 4%. It is proposed that the existing grade in this area be maintained to minimize project construction costs.

  As part of the preliminary design, an alternative was developed which would correct the grade to meet the 4% maximum requirement. Plan and profile views for this alternative were developed and are included in Appendix "F". The plan view illustrates the extent of the side-slope impacts for this scenario and also shows where the earthwork changes from cut to fill. This option would require a maximum cut of approximately 6.5-foot and fill of up to approximately 7-foot. There are a few small areas where the footprint required for this option extends beyond the existing right-of-way limits. It only results in an impact of 0.26 acres of forest. Other than the forest impacts, there are no additional environmental resources impacted; however, there would be 2.66 acres of additional tree clearing necessary within the existing right-of-way.

  Estimated construction costs, length of reconstruction required, and the associated speed reduction for both the 4% grade correction and maintaining the existing 5% grade are compared in the table below. The benefits gained by correcting the profile grade to 4% are a gain of 2 mph in speed reduction. The additional costs of reconstruction and extensive impacts to upgrade the facility to meet the maximum grade requirements do not provide meaningful benefits or improvements in the total speed reduction (compared to the existing 5% grade).

Condition	Total Speed Reduction	Reconstruction Length	Total Cost
Existing	33 MPH	0'	$ 2,221,000*
Balanced Alternative	31 MPH	3,650	$3,737,000

* Pavement Overlay assumed for this construction cost

  A Level Two Design Exception is being documented for critical length of grade within this area. Note that the Level Two Design Exception will be required for the southbound direction only whether the existing 5% profile grade is maintained or if it is improved to the standard 4% grade. It is proposed that a truck climbing lane will be added in the southbound direction to mitigate the effects of both the maximum grade and the critical length of grade being exceeded. The truck climbing lane is necessary for both the 4% grade correction and maintaining the 5% existing grade. The costs shown above include the addition of the truck climbing lane for both the 4% and 5% grades.

- **Construction Costs**

See cost comparisons provided above for different alternatives to improve the grade to meet the 4% maximum grade.

- **Project Design**
  From Sample Road to the northern terminus of the project (rural section of the project):

2035 AADT	66,520 - 68,660	Commercial Vehicles
2035 DHV	5,040 – 6,290	21.0 - 21.7% AADT
2035 DHV	7.3 – 9.2%	3.6 – 7.1% DHV

Existing Posted Speed:	60 mph
Design Speed	70 mph
Proposed Posted Speed:	70 mph
Access Control:	Full

- **Crash Analysis** (Crash Data Maps are provided in Appendix "A")
  During the 5-year period, in this area, there were only 2 crashes in the southbound lanes. With this low number, there does not appear to be an issue with the existing 5% grade contributing to higher crashes numbers.

Through Bifurcation - Southbound				
Projected Traffic Data in 2035 **AADT 66,520 vpd** **Cars = 78.4%** **Trucks = 21.6%**				
2007 - 2011				
Crash Type	**PDO**	**Injury**	**Fatality**	**Total**
Head-On	0	0	0	0
Run Off	0	0	0	0
Rear End	0	0	0	0
Right Angle	0	0	0	0
Sideswipe	0	0	0	0
Other	2	0	0	2
Total	2	0	0	2

- **Cost-Effective Analysis**
  A benefit-cost analysis was performed for this design element. The documentation is include in Appendix "G". The approach for determining the crash reduction factors for this project has been complicated. With the conversion of the facility from a partial access highway to a limited access interstate, many assumptions have been made. In general, a safer facility will be provided when the facility is upgraded from an arterial road to a fully-grade separated freeway; this would lead to a reduction in crashes. Traffic forecasts in the design year are more than double existing traffic counts. A benefit/cost analysis is attached in Appendix "G".

  Operational-level Level of Service (LOS) calculations were also performed for the existing 5% grade and the 4% grade that would be necessary to correct this design element. There was an

improvement in the LOS when comparing the two scenarios. Maintaining the 5% grade resulted in a LOS of "C" in the design year. Correcting the grade to 4%, the LOS predicted is "B". Improving the grade, results in a gain of only 2 mph for the truck speed reduction as compared to the existing 5% grade. This comparison reflects that a truck climbing lane would be added in both scenarios.

Regarding the 5% maximum grade through the southbound bifurcation, due to:

- the additional costs of reconstruction,
- the extensive impacts to upgrade the facility to meet the maximum grade requirements,
- the lack of a significant number of rear-end crashes,
- the minimal improvement in the total speed reduction, and
- the favorable benefit-cost analysis,

It would not be beneficial to improve this feature. In addition, even with correction of the grade, the critical length of grade would still be exceeded within this area.

- **Ancillary Impacts**
  In this area with the vertical grade exceeding the maximum grade, the steeper grade also affects the critical length of grade and the associated speed reduction.

- **Remedial Actions**
  In the area of the bifurcation, it is proposed that a truck climbing lane be added in the southbound direction to mitigate the violation of critical length of grade. It is recommended that additional signage be placed in this area regarding the grade.

Conclusion

It is requested that the proposed project receive design exceptions for the following design elements at the locations listed:

- Shoulder Widths – From South End of Project Limits to SR 46
- Shoulder Widths – At Indiana Railroad Overpass (approximately Sta. 1725+40)
- Maximum Grade – From Kinser Pike to Griffy Creek (approximately Sta. 1971+00 to 1997+25)
- Maximum Grade – Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00)

This request is based upon perpetuating or improving existing conditions along with minimizing construction cost. The favorable benefit-cost analysis for each location demonstrates that safety is not compromised with the proposed design exceptions. This will also allow impacts to be minimized.

Level One Design Exception

Appendix "A" – Crash Data Maps

Appendix "B" – Benefit-Cost Analysis for Shoulder Widths

From South End of Project Limits to SR 46 (approximately Sta. 1541+00 - 1614+45, Sta. 1776+00 – 1796+00, Sta. 1823+46 – 1841+00) – Urban Typical Section

Appendix "C" – Benefit-Cost Analysis for Shoulder Widths

Shoulder Widths – At Indiana Railroad Overpass (approximately Sta. 1725+40) – Urban Typical Section

Appendix "D" – Plan and Profile for Alternatives

Maximum Grade – From Kinser Pike to Griffy Creek (approximately Sta. 1971+00 to 1997+25) – Urban Typical Section

Appendix "E" – Benefit-Cost Analysis for Vertical Grade

Maximum Grade – From Kinser Pike to Griffy Creek (approximately Sta. 1971+00 to 1997+25) – Urban Typical Section

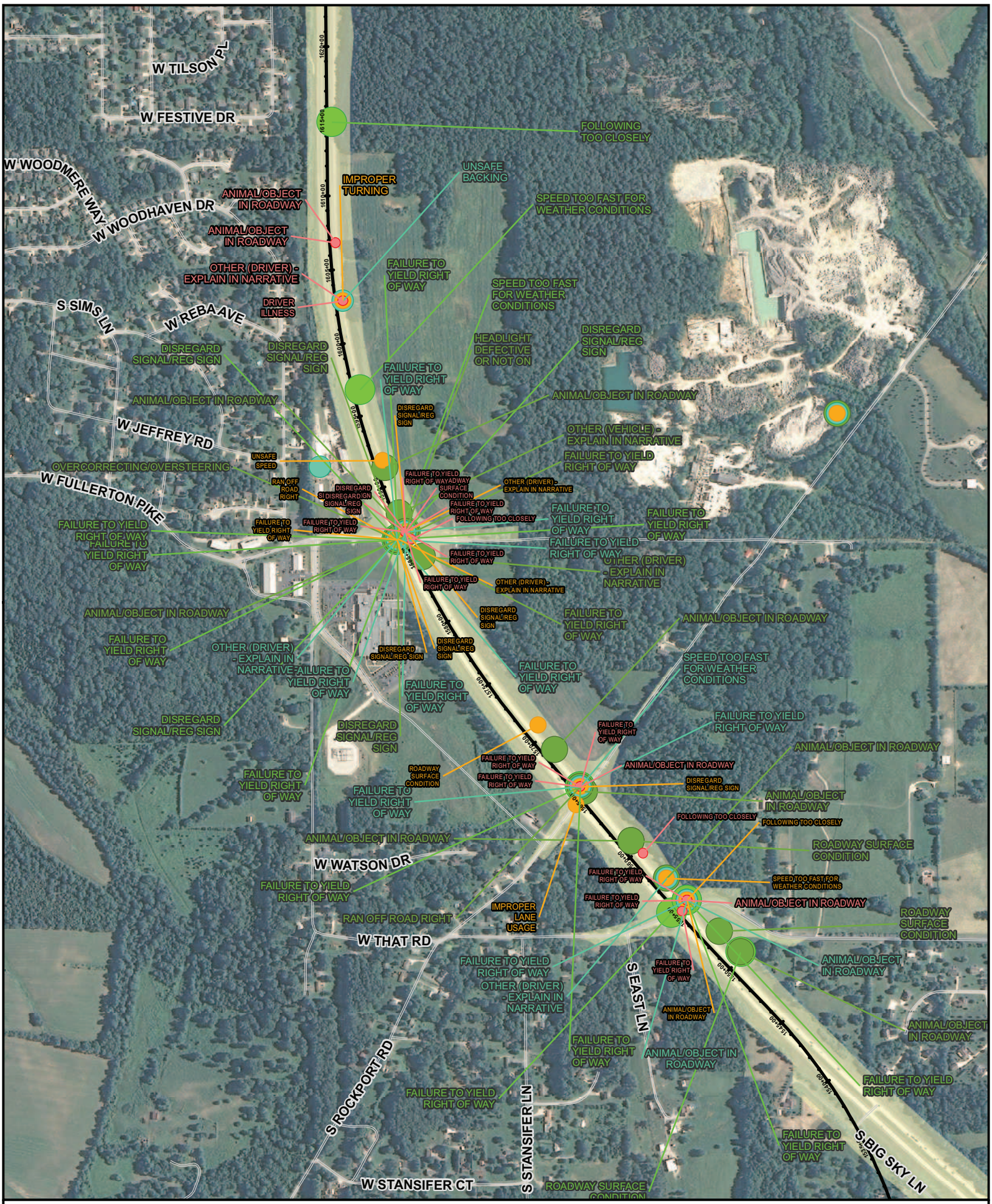
Appendix "F" – Plan and Profile for Alternatives

Maximum Grade – Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00) – Rural Typical Section

Appendix "G" – Benefit-Cost Analysis for Vertical Grade

Maximum Grade – Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00) – Rural Typical Section

Appendix "A"
Crash Data Maps



2007
2008
2009
2010
2011
SR 37 Existing ROW

I-69 Crash Data 2007-2011

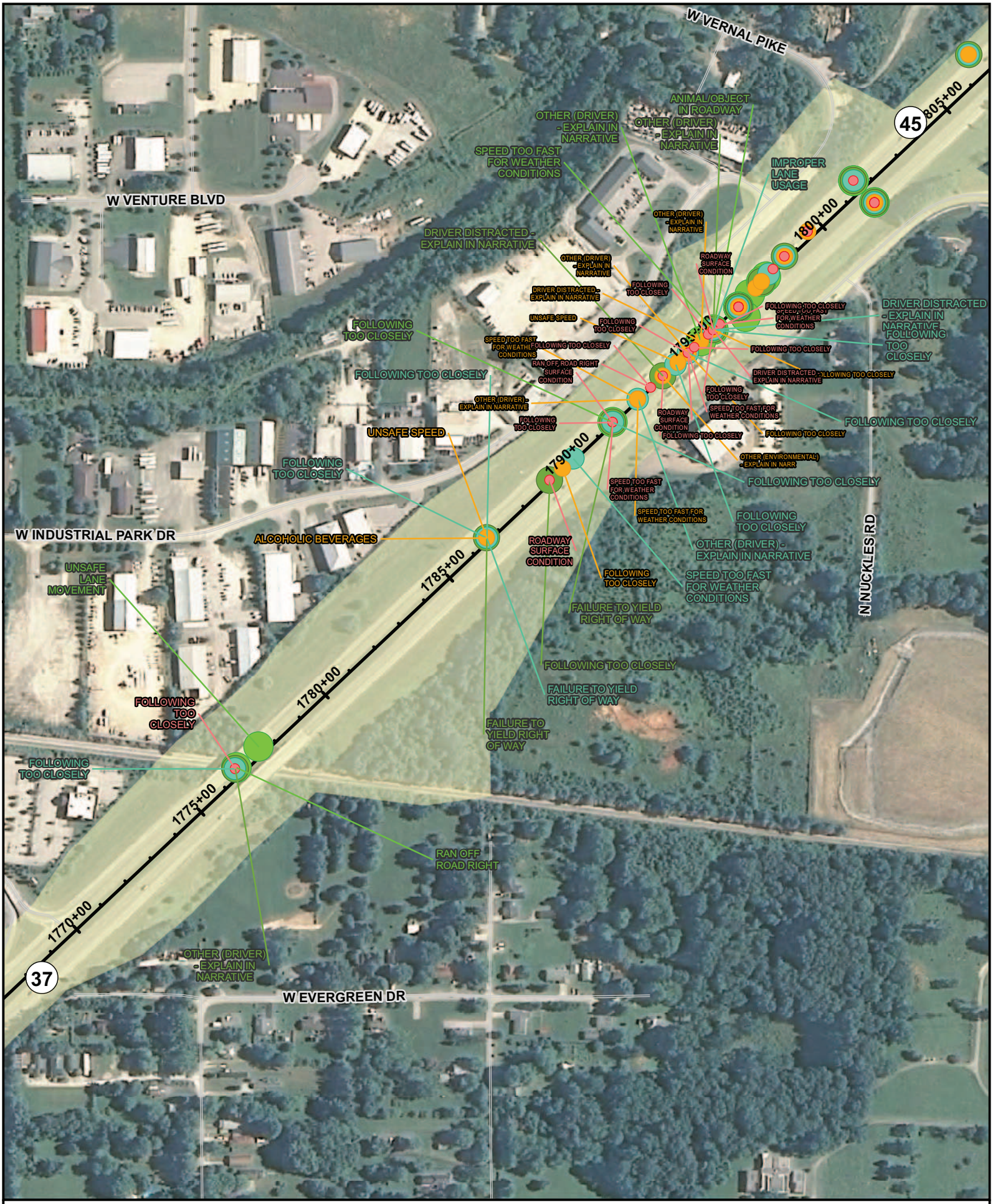
Design Exception 1

0 800 1,600 Feet

N

APPENDIX "A-1"

August, 2012



I-69 Crash Data 2007-2011

Design Exception 2

APPENDIX "A-2"

August, 2012

2007
2008
2009
2010
2011
SR 37 Existing ROW

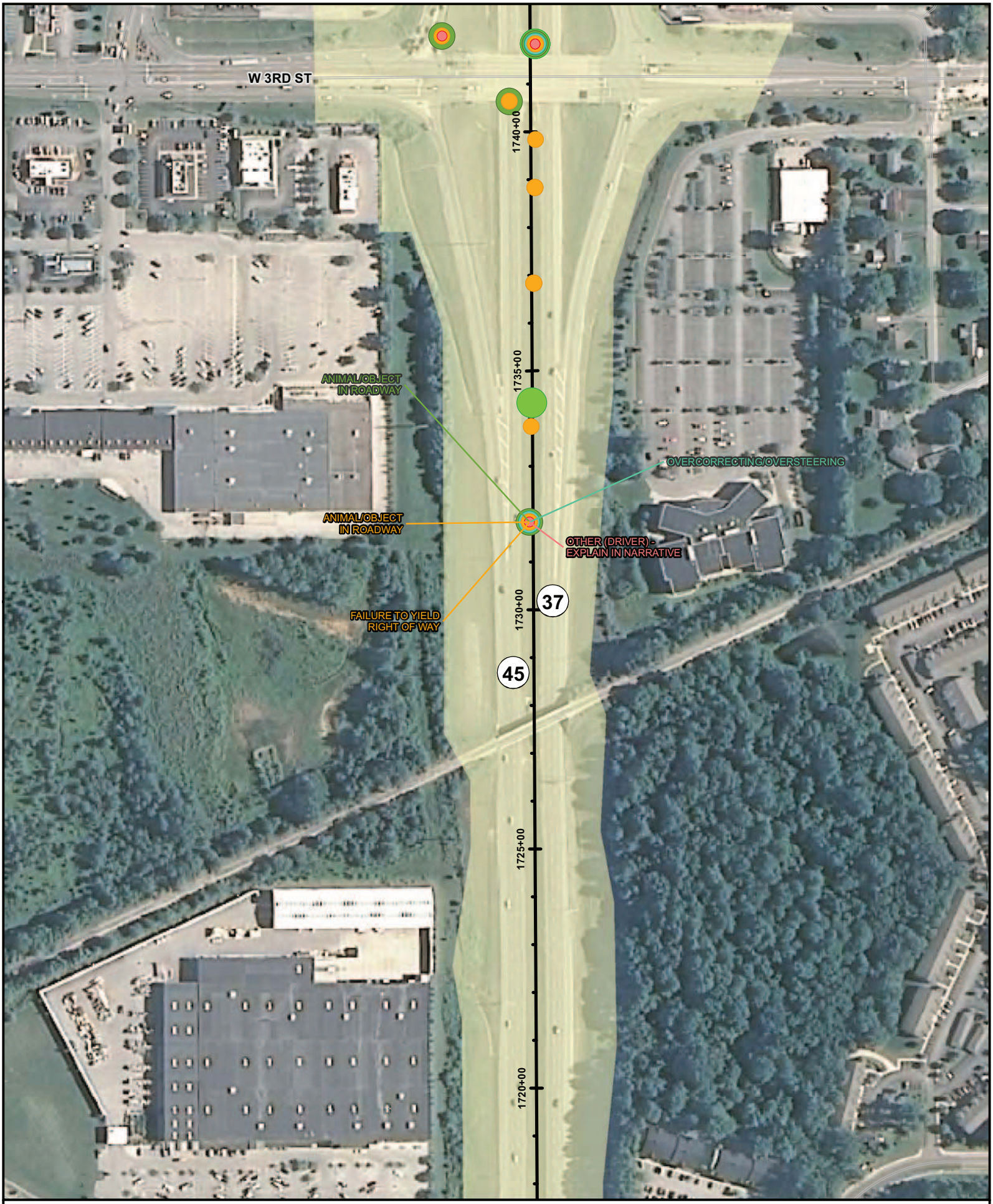
I-69 Crash Data 2007-2011
Design Exception 3

0 300 600 Feet

N

APPENDIX "A-3"

August, 2012



I-69 Crash Data 2007-2011

Indiana Railroad Overpass

APPENDIX "A-4"

August, 2012

I-69 Crash Data 2007-2011

Kinser Pike

APPENDIX "A-5"

August, 2012

I-69 Crash Data 2007-2011

Bifurcation (SB)

APPENDIX "A-6"

August, 2012

Appendix "B"
Benefit-Cost Analysis for Shoulder Widths

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	1	of	2
CALCULATED BY	JAT	DATE	8/20/2012
CHECKED BY	SJS	DATE	8/20/2012

Benefit/Cost Analysis - Shoulder Widths ***From South End of Project Limits to SR 46 (approximately Sta. 1541+00 -1614+45, Sta. 1776+00 – 1796+00, Sta. 1823+46 – 1841+00)***

Extensive research and discussions have occurred relating to the best, defensible methodology for determining crash predictions, crash modification factors (CMF) and crash reduction factors (CRF) for the benefit/cost analysis given the change in facility type with the proposed project. This represents a rather unique tranisition and one that 'typical' approaches of utilizing existing crash data are not applicable. Much of the data that was found in crash predictions was not applicable to interstate situations. Upon consultation with many experts in the traffic field, the HERS manual provides equations based on AADT numbers and lane widths to predict the number of crashes that may occur along a segment of roadway.

The other issue besides crash prediction was determining a reasonable and more refined crash modification factor based on the project specific elements. While the CMF Clearinghouse provides many different scenarios of studies, it didn't provide much that was a direct correlation to the I-69, Section 5 Project. Further research yielded discovery of the "Roadway Safety Design Synthesis" which represents the state of the practice more definitively. Equations are available for many different scenarios that yield CMFs applicable to specific situations on freeways. This provides values based on calculations/equations obtained from studies with a high level of credibility instead of generalized conditions that are not project specific.

References:

Indiana Design Manual, 2011, Part 5 Road Design, Chapter 50 Economic Analysis
Highway Economic Requirements System - State Version (HERS Manual), Techncial Report, USDOT, FHWA, August, 2005
ROADWAY SAFETY DESIGN SYNTHESIS, J. Bonneson, K. Zimmerman and K. Fitzpatrick, FHWA, 2005

From South End of Project Limits to SR 46 (approximately Sta. 1541+00 -1614+45, Sta. 1776+00 – 1796+00, Sta. 1823+46 – 1841+00)

Determine the cost effectiveness of reconstruction of this segment of I-69 to provide 12'-0" shoulders versus using 11'-9" shoulders to match the existing median width. Urban Freeway crash prediction method.

1. Crash Modification Factor

The Crash Modification Factors were calculated using equations from the following FHWA-sponsored report:

Report No. FHWA/TX-05/0-4703-P1
"ROADWAY SAFETY DESIGN SYNTHESIS" by J. Bonneson, K. Zimmerman and K. Fitzpatrick, 2005
http://tti.tamu.edu/documents/0-4703-P1.pdf

Equation with 11'-9" inside shoulder

Eqn. 2-19 -> $\mathbf{AMF_{swi} = (e^{-0.021\,(W_{is} - W_{sb})} - 1.0)\,P_i/0.15 + 1.0}$

W_{is} = inside shoulder width, ft = 11'-9" = 11.75'
W_{sb} = base inside shoulder width = 10.0' for six or more lanes
P_i = 0.13 from Table 2-7 for Urban area with 6 through lanes

CMF = AMF_{swi} = 0.969 (1) CRF = 3.10%

Equation with 12'-0" inside shoulder

W_{is} = inside shoulder width, ft = 12'-0" = 12.00'

CMF = AMF_{swi} = 0.964 (1) CRF = 3.60%

Resulting increase in crashes with 11'-9" inside shoulder

CMF = AMF_{swi} = 1.005 CRF = -0.50%

(1) A CMF less than 1.00 represents a reduction in crashes. This occurs because the analysis conducted identifies 10' shoulder as the base width for shoulders with less than 10' width increasing crashes and greater than 10' width reducing crashes.

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	2	of	2
CALCULATED BY	JAT	DATE	8/20/2012
CHECKED BY	SJS	DATE	8/20/2012

2. Accident Data

DESIGN SERVICE YEAR	AADT (1)	CRASH RATE (2)	PREDICTED CRASHES PER YEAR WITH 12' SHLDR WIDTH (3)	CRASH MODIFICATION FACTOR FOR SHLDR WIDTH (5)	PREDICTED CRASHES PER YEAR WITH 11'-9" SHLDR WIDTH	ADDED CRASHES PER YEAR WITH 11'-9" SHLDR	PREDICTED F/I CRASHES WITH 11'-9" SHLDR(4)	PREDICTEDPDO CRASHES WITH 11'-9" SHLDR (4)
1	46913	170	58.93	1.005	59.22	0.29	29.61	29.61
2	48461	170	60.87	1.005	61.18	0.30	30.59	30.59
3	50060	170	62.88	1.005	63.20	0.31	31.60	31.60
4	51712	170	64.96	1.005	65.28	0.32	32.64	32.64
5	53419	170	67.10	1.005	67.44	0.34	33.72	33.72
6	55182	170	69.32	1.005	69.66	0.35	34.83	34.83
7	57003	170	71.60	1.005	71.96	0.36	35.98	35.98
8	58884	170	73.97	1.005	74.34	0.37	37.17	37.17
9	60827	170	76.41	1.005	76.79	0.38	38.39	38.39
10	62834	170	78.93	1.005	79.32	0.39	39.66	39.66
11	64908	170	81.53	1.005	81.94	0.41	40.97	40.97
12	67050	170	84.22	1.005	84.65	0.42	42.32	42.32
13	69263	170	87.00	1.005	87.44	0.44	43.72	43.72
14	71549	170	89.88	1.005	90.32	0.45	45.16	45.16
15	73910	170	92.84	1.005	93.31	0.46	46.65	46.65
16	76349	170	95.91	1.005	96.38	0.48	48.19	48.19
17	78869	170	99.07	1.005	99.57	0.50	49.78	49.78
18	81472	170	102.34	1.005	102.85	0.51	51.43	51.43
19	84161	170	105.72	1.005	106.25	0.53	53.12	53.12
20	86938	170	109.21	1.005	109.75	0.55	54.88	54.88
		TOTAL ADDITIONAL CRASHES OVER LIFE OF PROJECT				8		
			ADDITONAL CRASHES PER YEAR (AVERAGE)			0.41		

(1) AADT for Design Service Year 20 from BLA Mainline Volumes Summary, April 21 Alt 7. A 3.3% per year growth rate was assumed for design service years 1-19

(2) HERS Technical Report, Chapter 5, Equation 5-34 CRASH=154.0*$e^{(0.0082*12)}$; lane width = 12 (assume 10' inside shoulder)

(3) [Crash rate * 365 * 1 yr * ADT *segment length (2.10 mi) / 100,000,000] * 0.964, where 0.964 is the 12' shoulder adjustement

(4) HERS Techicnal Report Table 5-12; 1.4 fatalities per 100 crashes/45.5 injuries per 100 crashes. Assume 50% of predicted crashes are F/I and 50% are PDO

(5) The assumption is that the HERS equations used to predict the number of crashes predicts crashes for a facility that is in compliance with AASHTO standards. Based on the proposed configuration with the 11'-9" shoulders (which exceeds minimum AASHTO), it is assumed that the number of crashes will be impacted. However, research on crashes related to inside shoulder width identifies 10' as the critical width, with less than 10' increasing crashes and more than 10' reducing crashes. The applied CMF is the difference between the 12'-0" CMF and the 11'-9" CMF and results in a 0.5% crash increase.

3. Service Life for Shoulder Widening or Improvement

20 years (Figure 50-2B)

4. Costs

Increase in Construction Cost to Meet Design Criteria **$ 3,172,000.00**

(Associated with additional full depth pavement replacement on one side and re-alignment)

5. Benefit Cost Analysis

See attached Benefit Cost Analysis

Benefit/Cost Analysis

I-69 Tier 1 - Section 5 - Construction of Median Shoulder Width at 11'-9"

From South End of Project Limits to SR 46 (approximately Sta. 1541+00 -1614+45, Sta. 1776+00 – 1796+00, Sta. 1823+46 – 1841+00)

20-Aug-12

							Accident Reduction			Adjusted Benefits						Benefit/Cost Calculations									
Service Year	Annual PDO Acc.	Annual F/I Acc.)	ARF (PDO)	ARF (F/I)	ARF*Annual (PDO)	ARF*Annual (F/I)	APF	PDO	F/I	PDO*$8735	F/I*$100,795	Total Unadj. Benefits	PWF	Total Adj. Benefits	Cum. Yr. Benefits	CRF	EUAB	Initial Cost	AMC	PWF-EQ	Salvage	PWF-SP	EUAC	B/C	NAB
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	29.46	29.46	0.005	0.005	0.15	0.15	1.00	0.15	0.15	$ 1,286.87	$ 14,849.45	$ 16,136.32	0.9615	$ 15,515.07	$ 15,515.07	1.0400	$ 16,135.67	$ 3,172,000.00	$ -	0.9615	$ -	0.9615	$ 3,298,880.00	0.0049	$ (3,282,744.33)
2	30.44	30.44	0.005	0.005	0.15	0.15	1.00	0.15	0.15	$ 1,329.33	$ 15,339.44	$ 16,668.77	0.9246	$ 15,411.95	$ 30,927.01	0.5302	$ 16,397.50	$ 3,172,000.00	$ -	1.8861	$ -	0.9246	$ 1,681,794.40	0.0098	$ (1,665,396.90)
3	31.44	31.44	0.005	0.005	0.16	0.16	1.00	0.16	0.16	$ 1,373.19	$ 15,845.57	$ 17,218.77	0.8890	$ 15,307.48	$ 46,234.50	0.3603	$ 16,658.29	$ 3,172,000.00	$ -	2.7751	$ -	0.8890	$ 1,142,871.60	0.0146	$ (1,126,213.31)
4	32.48	32.48	0.005	0.005	0.16	0.16	1.00	0.16	0.16	$ 1,418.51	$ 16,368.48	$ 17,786.99	0.8548	$ 15,204.32	$ 61,438.82	0.2755	$ 16,926.40	$ 3,172,000.00	$ -	3.6299	$ -	0.8548	$ 873,886.00	0.0194	$ (856,959.60)
5	33.55	33.55	0.005	0.005	0.17	0.17	1.00	0.17	0.17	$ 1,465.33	$ 16,908.80	$ 18,374.14	0.8219	$ 15,101.70	$ 76,540.52	0.2246	$ 17,191.00	$ 3,172,000.00	$ -	4.4518	$ -	0.8219	$ 712,431.20	0.0241	$ (695,240.20)
6	34.66	34.66	0.005	0.005	0.17	0.17	1.00	0.17	0.17	$ 1,513.70	$ 17,466.85	$ 18,980.54	0.7903	$ 15,000.32	$ 91,540.85	0.1908	$ 17,465.99	$ 3,172,000.00	$ -	5.2412	$ -	0.7903	$ 605,217.60	0.0289	$ (587,751.61)
7	35.80	35.80	0.005	0.005	0.18	0.18	1.00	0.18	0.18	$ 1,563.65	$ 18,043.25	$ 19,606.90	0.7599	$ 14,899.28	$ 106,440.13	0.1666	$ 17,732.93	$ 3,172,000.00	$ -	6.0021	$ -	0.7599	$ 528,455.20	0.0336	$ (510,722.27)
8	36.98	36.98	0.005	0.005	0.18	0.18	1.00	0.18	0.18	$ 1,615.24	$ 18,638.65	$ 20,253.89	0.7307	$ 14,799.52	$ 121,239.65	0.1485	$ 18,004.09	$ 3,172,000.00	$ -	6.7327	$ -	0.7307	$ 471,042.00	0.0382	$ (453,037.91)
9	38.20	38.20	0.005	0.005	0.19	0.19	1.00	0.19	0.19	$ 1,668.54	$ 19,253.67	$ 20,922.21	0.7206	$ 15,076.55	$ 136,316.20	0.1345	$ 18,334.53	$ 3,172,000.00	$ -	7.4353	$ -	0.7206	$ 426,634.00	0.0430	$ (408,299.47)
10	39.46	39.46	0.005	0.005	0.20	0.20	1.00	0.20	0.20	$ 1,723.60	$ 19,888.95	$ 21,612.55	0.6576	$ 14,212.41	$ 150,528.61	0.1233	$ 18,560.18	$ 3,172,000.00	$ -	8.1109	$ -	0.6576	$ 391,107.60	0.0475	$ (372,547.42)
11	40.77	40.77	0.005	0.005	0.20	0.20	1.00	0.20	0.20	$ 1,780.49	$ 20,545.43	$ 22,325.92	0.6496	$ 14,502.92	$ 165,031.53	0.1141	$ 18,830.10	$ 3,172,000.00	$ -	8.7605	$ -	0.6496	$ 361,925.20	0.0520	$ (343,095.10)
12	42.11	42.11	0.005	0.005	0.21	0.21	1.00	0.21	0.21	$ 1,839.25	$ 21,223.45	$ 23,062.69	0.6246	$ 14,404.96	$ 179,436.48	0.1066	$ 19,127.93	$ 3,172,000.00	$ -	9.3185	$ -	0.6246	$ 338,135.20	0.0566	$ (319,007.27)
13	43.50	43.50	0.005	0.005	0.22	0.22	1.00	0.22	0.22	$ 1,899.95	$ 21,923.93	$ 23,823.88	0.6006	$ 14,308.62	$ 193,745.11	0.1001	$ 19,393.89	$ 3,172,000.00	$ -	9.9856	$ -	0.6006	$ 317,517.20	0.0611	$ (298,123.31)
14	44.94	44.94	0.005	0.005	0.22	0.22	1.00	0.22	0.22	$ 1,962.66	$ 22,647.52	$ 24,610.18	0.5775	$ 14,212.38	$ 207,957.49	0.0947	$ 19,693.57	$ 3,172,000.00	$ -	10.5631	$ -	0.5775	$ 300,388.40	0.0656	$ (280,694.83)
15	46.42	46.42	0.005	0.005	0.23	0.23	1.00	0.23	0.23	$ 2,027.42	$ 23,394.85	$ 25,422.28	0.5553	$ 14,116.99	$ 222,074.47	0.0899	$ 19,964.50	$ 3,172,000.00	$ -	11.1184	$ -	0.5553	$ 285,162.80	0.0700	$ (265,198.30)
16	47.95	47.95	0.005	0.005	0.24	0.24	1.00	0.24	0.24	$ 2,094.33	$ 24,166.87	$ 26,261.20	0.5339	$ 14,020.85	$ 236,095.33	0.0858	$ 20,256.98	$ 3,172,000.00	$ -	11.6523	$ -	0.5339	$ 272,157.60	0.0744	$ (251,900.62)
17	49.54	49.54	0.005	0.005	0.25	0.25	1.00	0.25	0.25	$ 2,163.45	$ 24,964.53	$ 27,127.99	0.5134	$ 13,927.51	$ 250,022.84	0.0822	$ 20,551.88	$ 3,172,000.00	$ -	12.1657	$ -	0.5134	$ 260,738.40	0.0788	$ (240,186.52)
18	51.17	51.17	0.005	0.005	0.26	0.26	1.00	0.26	0.26	$ 2,234.86	$ 25,788.46	$ 28,023.32	0.4936	$ 13,832.31	$ 263,855.15	0.0790	$ 20,844.56	$ 3,172,000.00	$ -	12.6593	$ -	0.4936	$ 250,588.00	0.0832	$ (229,743.44)
19	52.86	52.86	0.005	0.005	0.26	0.26	1.00	0.26	0.26	$ 2,308.62	$ 26,639.62	$ 28,948.24	0.4746	$ 13,738.83	$ 277,593.98	0.0761	$ 21,124.90	$ 3,172,000.00	$ -	13.1339	$ -	0.4746	$ 241,389.20	0.0875	$ (220,264.30)
20	54.60	54.60	0.005	0.005	0.27	0.27	1.00	0.27	0.27	$ 2,384.79	$ 27,518.63	$ 29,903.42	0.4564	$ 13,647.92	$ 291,241.90	0.0736	$ 21,435.40	$ 3,172,000.00	$ -	13.5903	$ -	0.4564	$ 233,459.20	0.0918	$ (212,023.80)

1 Service Year - Time improvement can reasonably be expected to impact accident experience
2 Annual Property Damage Only Accidents (PDO)
3 Annual Fatality or Injury Accidents (F/I)
4 Accident Reduction Factor for PDO Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
5 Accident Reduction Factor for F/I Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
6 Accident Reduction for PDO Accidents Col (2) * Col (4)
7 Accident Reduction for F/I Accidents Col (3) * Col (5)
8 Accident Projection Factor (APF) - Growth Rate is accounted for in Crash Prediction (2% increase per year not applied)
9 Accident Reduction for PDO Accidents Col (6) * Col (8)
10 Accident Reduction for F/I Accidents Col (7) * Col (8)
11 PDO Accidents * $6500 plus 3% inflation for 10 years (IDM Figure 50-2A) Col (9) * $8735
12 F/I Accidents * $75000 + 3% inflation for 10 years (IDM Figure 50-2A) Col (10)*$100,795 [rural cost used to better represent
13 Total Unadjusted Benefits Col (11) + Col (12)
14 Present Worth Factor (PWF) - Factor to determine Present Worth of economic benefit during service life (IDM Figure 50-2C)
15 Adjusted Benefits - Unadjusted Benefits times the PWF Col (13) * Col (14)
16 Ajusted Cumulative Year Benefits
17 Capital Recovery Factor (CRF) (IDM Figure 50-2C)
18 Equivalent Uniform Annual Benefit (EUAB) - CRF multiplied by Adjusted Cumulative Year Benefit Col (16) * Col (17)
19 Initial Cost of the Recommended Improvement (increse in Cost to meet design criteria)
20 Annual Maintenance Cost (AMC)
21 Present Worth Factor for an Equal Payment Serices (PWF-EQ) (IDM Figure 50-2C)
22 Salvage Value of the Improvement at the End of the Service Life
23 Present Worth Factor for a Single Payment (PWF-SP) (IDM Figure 50-2C)
24 Equivalent Uniform Annual Cost (EUAC) - CRF * [Initial Cost + (AMC*PWP-EQ)-(Salvage Value *PWP-SP)
25 Benefit to Cost Ratio (B/C) - EUAB divided by EUAC Col (18)/ Col (24)
26 Net Annual Benefit (NAB) - Difference between EUAB and EUAC Col (18)- Col (24)

Appendix "C"
Benefit-Cost Analysis for Shoulder Widths

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	1	of	2
CALCULATED BY	JAT	DATE	7/6/2012
CHECKED BY	SJS	DATE	7/6/2012

Benefit/Cost Analysis - Shoulder Widths ***At Indiana Railroad Overpass (approximately Sta. 1725+40)***

Extensive research and discussions have occurred relating to the best, defensible methodology for determining crash predictions, crash modification factors (CMF) and crash reduction factors (CRF) for the benefit/cost analysis given the change in facility type with the proposed project. This represents a rather unique tranisition and one that 'typical' approaches of utilizing existing crash data are not applicable. Much of the data that was found in crash predictions was not applicable to interstate situations. Upon consultation with many experts in the traffic field, the HERS manual provides equations based on AADT numbers and lane widths to predict the number of crashes that may occur along a segment of roadway.

The other issue besides crash prediction was determining a reasonable and more refined crash modification factor based on the project specific elements. While the CMF Clearinghouse provides many different scenarios of studies, it didn't provide much that was a direct correlation to the I-69, Section 5 Project. Further research yielded discovery of the "Roadway Safety Design Synthesis" which represents the state of the practice more definitively. Equations are available for many different scenarios that yield CMFs applicable to specific situations on freeways. This provides values based on calculations/equations obtained from studies with a high level of credibility instead of generalized conditions that are not project specific.

References:

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ROADWAY SAFETY DESIGN SYNTHESIS, J. Bonneson, K. Zimmerman and K. Fitzpatrick, FHWA, 2005

At Railroad overpass over SR 46 at approximately Sta. 1725+40

Determine the cost effectiveness of reconstruction of the railroad structure over I-69 to provide 12'-0" shoulders versus using 10'-0" shoulders to match the available horizontal clerance under the structure. Urban Freeway crash prediction method.

1. Crash Modification Factor

The Crash Modification Factors were calculated using equations from the following FHWA-sponsored report:

Report No. FHWA/TX-05/0-4703-P1
"ROADWAY SAFETY DESIGN SYNTHESIS" by J. Bonneson, K. Zimmerman and K. Fitzpatrick, 2005
http://tti.tamu.edu/documents/0-4703-P1.pdf

Equation with 10'-0" inside shoulder

Eqn. 2-19 -> $\mathbf{AMF_{swi} = (e^{-0.021\,(W_{is} - W_{sb})} - 1.0)\,P_i/0.15 + 1.0}$

W_{is} = inside shoulder width, ft = 10.0'
W_{sb} = base inside shoulder width = 10.0' for six or more lanes
P_i = 0.13 from Table 2-7 for Urban area with 6 through lanes

CMF = AMF$_{swi}$ = 1.000 (1) CRF = 0.00%

Equation with 12'-0" inside shoulder

W_{is} = inside shoulder width, ft = 12'-0" = 12.00'

CMF = AMF$_{swi}$ = 0.964 (1) CRF = 3.60%

Resulting increase in crashes with 10'-0" inside shoulder

CMF = AMF$_{swi}$ = 1.036 CRF = -3.60%

(1) A CMF equal to 1.00 represents no change in crashes. This occurs because the analysis conducted identifies 10' shoulder as the base width for shoulders with less than 10' width increasing crashes and greater than 10' width reducing crashes.

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	1	of	2
CALCULATED BY	JAT	DATE	7/6/2012
CHECKED BY	SJS	DATE	7/6/2012

At Indiana Railroad Overpass (approximately Sta. 1725+40)

Determine the cost effectiveness of reconstruction of the Indiana Railroad Bridge on I-69 to build the full 12' width shoulder instead of utilizing the existing width of 10' instead of 12'. Urban Freeway crash prediction method.

2. Accident Data

DESIGN SERVICE YEAR	AADT (1)	CRASH RATE (2)	PREDICTED CRASHES PER YEAR WITH 12' SHLDR WIDTH (3)	CRASH MODIFICATION FACTOR FOR SHLDR WIDTH (5)	PREDICTED CRASHES PER YEAR WITH 10' SHLDR WIDTH	ADDED CRASHES PER YEAR WITH 10' SHLDR WIDTH	PREDICTED F/I CRASHES WITH 10' SHLDR(4)	PREDICTEDP DO CRASHES WITH 10' SHLDR (4)
1	46913	170	3.09	1.036	3.20	0.11	1.54	1.54
2	48461	170	3.19	1.036	3.30	0.11	1.59	1.59
3	50060	170	3.29	1.036	3.41	0.12	1.65	1.65
4	51712	170	3.40	1.036	3.53	0.12	1.70	1.70
5	53419	170	3.51	1.036	3.64	0.13	1.76	1.76
6	55182	170	3.63	1.036	3.76	0.13	1.82	1.82
7	57003	170	3.75	1.036	3.89	0.14	1.88	1.88
8	58884	170	3.87	1.036	4.01	0.14	1.94	1.94
9	60827	170	4.00	1.036	4.15	0.14	2.00	2.00
10	62834	170	4.13	1.036	4.28	0.15	2.07	2.07
11	64908	170	4.27	1.036	4.42	0.15	2.14	2.14
12	67050	170	4.41	1.036	4.57	0.16	2.21	2.21
13	69263	170	4.56	1.036	4.72	0.16	2.28	2.28
14	71549	170	4.71	1.036	4.88	0.17	2.35	2.35
15	73910	170	4.86	1.036	5.04	0.18	2.43	2.43
16	76349	170	5.02	1.036	5.20	0.18	2.51	2.51
17	78869	170	5.19	1.036	5.38	0.19	2.59	2.59
18	81472	170	5.36	1.036	5.55	0.19	2.68	2.68
19	84161	170	5.54	1.036	5.74	0.20	2.77	2.77
20	86938	170	5.72	1.036	5.93	0.21	2.86	2.86
		TOTAL ADDITIONAL CRASHES OVER LIFE OF PROJECT				3		
			ADDITONAL CRASHES PER YEAR (AVERAGE)			0.15		

(1) AADT for Design Service Year 20 from BLA Mainline Volumes Summary, April 21 Alt 7. A 3.3% per year growth rate was assumed for design service years 1-19

(2) HERS Technical Report, Chapter 5, Equation 5-34 CRASH=154.0*$e^{(0.0082*12)}$; lane width = 12 (assume 10' inside shoulder)

(3) [Crash rate * 365 * 1 yr * ADT *segment length (0.10 mi) / 100,000,000] * 0.964, where 0.964 is the 12' shoulder adjustement

(4) HERS Techicnal Report Table 5-12; 1.4 fatalities per 100 crashes/45.5 injuries per 100 crashes. Assume 50% of predicted crashes are F/I and 50% are PDO

(5) The assumption is that the HERS equations used to predict the number of crashes predicts crashes for a facility that is in compliance with AASHTO standards. Based on the proposed configuration with the 10'-0" shoulders (which is minimum AASHTO), it is assumed that the number of crashes will be impacted compared. to a 12'-0" shoulder. However, research on crashes related to inside shoulder width identifies 10' as the critical width, with less than 10' increasing crashes and more than 10' reducing crashes. The applied CMF is the difference between the 12'-0" CMF and the 10'-0" CMF and results in a 3.6% crash increase.

3. Service Life for Shoulder Widening or Improvement

20 years (Figure 50-2B)

4. Costs

Increase in Construction Cost to Meet Design Criteria **$ 3,850,000.00**

(Associated with the cost of a structure replacement of the bridge over proposed I-69)

5. Benefit Cost Analysis

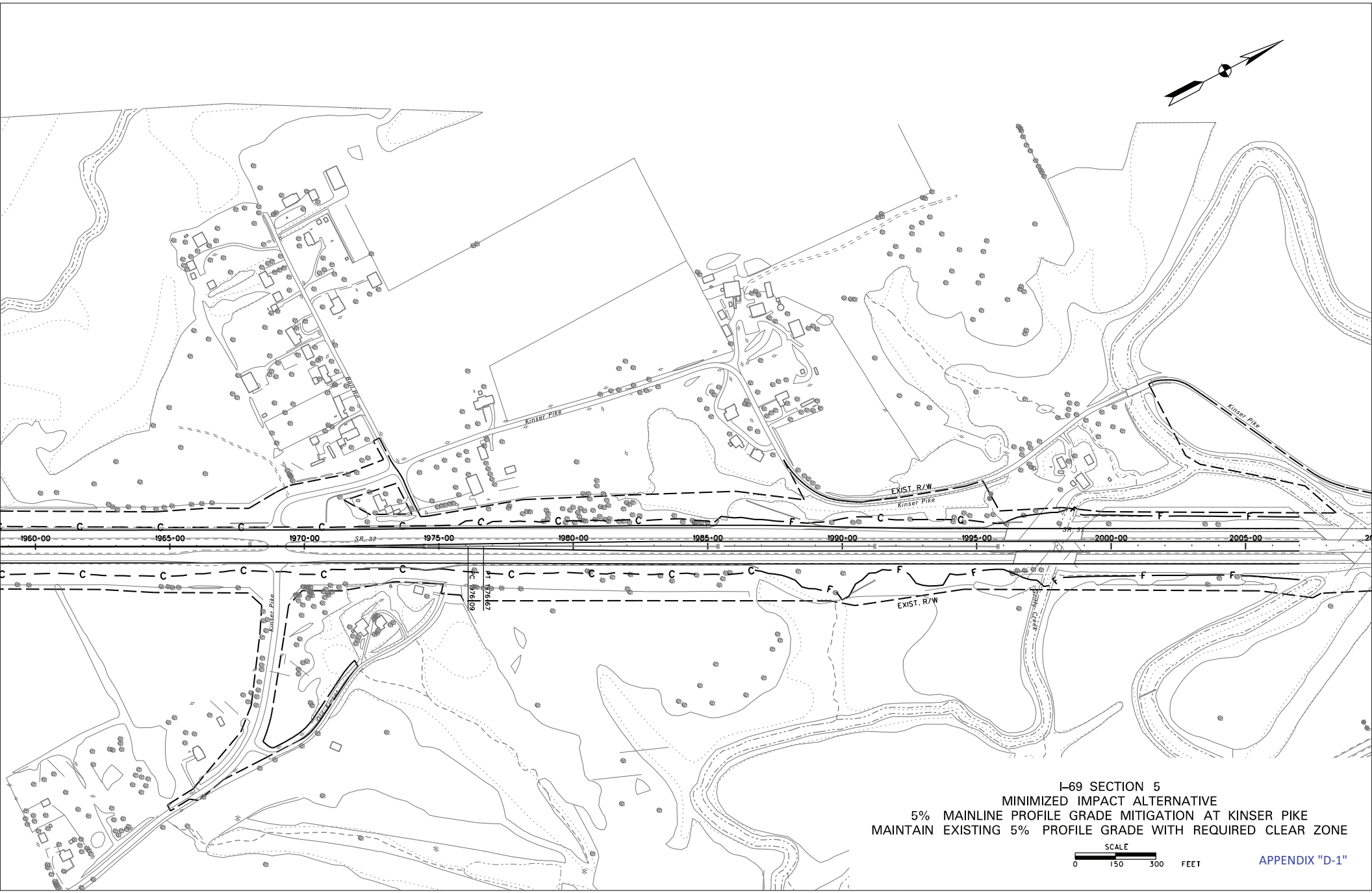
See attached Benefit Cost Analysis

Benefit/Cost Analysis
I-69 Tier 1 - Section 5 - Construction Median Shoulder Width at 10'
At Indiana Railroad Overpass (approximately Sta. 1725+40)
20-Aug-12

							Accident Reduction			Adjusted Benefits						Benefit/Cost Calculations									
Service Year	Annual PDO Acc.	Annual F/I Acc.)	ARF (PDO)	ARF (F/I)	ARF*Annual (PDO)	ARF*Annual (F/I)	APF	PDO	F/I	PDO*$8735	F/I*$100,795	Total Unadj. Benefits	PWF	Total Adj. Benefits	Cum. Yr. Benefits	CRF	EUAB	Initial Cost	AMC	PWF-EQ	Salvage	PWF-SP	EUAC	B/C	NAB
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.54	1.54	0.036	0.036	0.06	0.06	1.00	0.06	0.06	$ 485.33	$ 5,600.36	$ 6,085.70	0.9615	$ 5,851.40	$ 5,851.40	1.0400	$ 6,085.45	$ 3,850,000.00	$ -	0.9615	$ -	0.9615	$ 4,004,000.00	0.0015	$ (3,997,914.55)
2	1.59	1.59	0.036	0.036	0.06	0.06	1.00	0.06	0.06	$ 501.35	$ 5,785.16	$ 6,286.51	0.9246	$ 5,812.51	$ 11,663.90	0.5302	$ 6,184.20	$ 3,850,000.00	$ -	1.8861	$ -	0.9246	$ 2,041,270.00	0.0030	$ (2,035,085.80)
3	1.65	1.65	0.036	0.036	0.06	0.06	1.00	0.06	0.06	$ 517.89	$ 5,976.04	$ 6,493.94	0.8890	$ 5,773.11	$ 17,437.01	0.3603	$ 6,282.56	$ 3,850,000.00	$ -	2.7751	$ -	0.8890	$ 1,387,155.00	0.0045	$ (1,380,872.44)
4	1.70	1.70	0.036	0.036	0.06	0.06	1.00	0.06	0.06	$ 534.98	$ 6,173.26	$ 6,708.24	0.8548	$ 5,734.20	$ 23,171.21	0.2755	$ 6,383.67	$ 3,850,000.00	$ -	3.6299	$ -	0.8548	$ 1,060,675.00	0.0060	$ (1,054,291.33)
5	1.76	1.76	0.036	0.036	0.06	0.06	1.00	0.06	0.06	$ 552.64	$ 6,377.03	$ 6,929.67	0.8219	$ 5,695.50	$ 28,866.71	0.2246	$ 6,483.46	$ 3,850,000.00	$ -	4.4518	$ -	0.8219	$ 864,710.00	0.0075	$ (858,226.54)
6	1.82	1.82	0.036	0.036	0.07	0.07	1.00	0.07	0.07	$ 570.88	$ 6,587.50	$ 7,158.38	0.7903	$ 5,657.26	$ 34,523.98	0.1908	$ 6,587.17	$ 3,850,000.00	$ -	5.2412	$ -	0.7903	$ 734,580.00	0.0090	$ (727,992.83)
7	1.88	1.88	0.036	0.036	0.07	0.07	1.00	0.07	0.07	$ 589.72	$ 6,804.88	$ 7,394.60	0.7599	$ 5,619.16	$ 40,143.14	0.1666	$ 6,687.85	$ 3,850,000.00	$ -	6.0021	$ -	0.7599	$ 641,410.00	0.0104	$ (634,722.15)
8	1.94	1.94	0.036	0.036	0.07	0.07	1.00	0.07	0.07	$ 609.18	$ 7,029.43	$ 7,638.61	0.7307	$ 5,581.53	$ 45,724.67	0.1485	$ 6,790.11	$ 3,850,000.00	$ -	6.7327	$ -	0.7307	$ 571,725.00	0.0119	$ (564,934.89)
9	2.00	2.00	0.036	0.036	0.07	0.07	1.00	0.07	0.07	$ 629.28	$ 7,261.38	$ 7,890.66	0.7206	$ 5,686.01	$ 51,410.68	0.1345	$ 6,914.74	$ 3,850,000.00	$ -	7.4353	$ -	0.7206	$ 517,825.00	0.0134	$ (510,910.26)
10	2.07	2.07	0.036	0.036	0.07	0.07	1.00	0.07	0.07	$ 650.04	$ 7,500.97	$ 8,151.02	0.6576	$ 5,360.11	$ 56,770.79	0.1233	$ 6,999.84	$ 3,850,000.00	$ -	8.1109	$ -	0.6576	$ 474,705.00	0.0147	$ (467,705.16)
11	2.14	2.14	0.036	0.036	0.08	0.08	1.00	0.08	0.08	$ 671.50	$ 7,748.56	$ 8,420.06	0.6496	$ 5,469.67	$ 62,240.46	0.1141	$ 7,101.64	$ 3,850,000.00	$ -	8.7605	$ -	0.6496	$ 439,285.00	0.0162	$ (432,183.36)
12	2.21	2.21	0.036	0.036	0.08	0.08	1.00	0.08	0.08	$ 693.66	$ 8,004.27	$ 8,697.93	0.6246	$ 5,432.73	$ 67,673.19	0.1066	$ 7,213.96	$ 3,850,000.00	$ -	9.3185	$ -	0.6246	$ 410,410.00	0.0176	$ (403,196.04)
13	2.28	2.28	0.036	0.036	0.08	0.08	1.00	0.08	0.08	$ 716.55	$ 8,268.45	$ 8,985.01	0.6006	$ 5,396.39	$ 73,069.58	0.1001	$ 7,314.27	$ 3,850,000.00	$ -	9.9856	$ -	0.6006	$ 385,385.00	0.0190	$ (378,070.73)
14	2.35	2.35	0.036	0.036	0.08	0.08	1.00	0.08	0.08	$ 740.20	$ 8,541.35	$ 9,281.55	0.5775	$ 5,360.10	$ 78,429.68	0.0947	$ 7,427.29	$ 3,850,000.00	$ -	10.5631	$ -	0.5775	$ 364,595.00	0.0204	$ (357,167.71)
15	2.43	2.43	0.036	0.036	0.09	0.09	1.00	0.09	0.09	$ 764.63	$ 8,823.20	$ 9,587.83	0.5553	$ 5,324.12	$ 83,753.80	0.0899	$ 7,529.47	$ 3,850,000.00	$ -	11.1184	$ -	0.5553	$ 346,115.00	0.0218	$ (338,585.53)
16	2.51	2.51	0.036	0.036	0.09	0.09	1.00	0.09	0.09	$ 789.86	$ 9,114.36	$ 9,904.22	0.5339	$ 5,287.87	$ 89,041.67	0.0858	$ 7,639.78	$ 3,850,000.00	$ -	11.6523	$ -	0.5339	$ 330,330.00	0.0231	$ (322,690.22)
17	2.59	2.59	0.036	0.036	0.09	0.09	1.00	0.09	0.09	$ 815.93	$ 9,415.20	$ 10,231.13	0.5134	$ 5,252.66	$ 94,294.33	0.0822	$ 7,750.99	$ 3,850,000.00	$ -	12.1657	$ -	0.5134	$ 316,470.00	0.0245	$ (308,719.01)
18	2.68	2.68	0.036	0.036	0.10	0.10	1.00	0.10	0.10	$ 842.86	$ 9,725.94	$ 10,568.80	0.4936	$ 5,216.76	$ 99,511.08	0.0790	$ 7,861.38	$ 3,850,000.00	$ -	12.6593	$ -	0.4936	$ 304,150.00	0.0258	$ (296,288.62)
19	2.77	2.77	0.036	0.036	0.10	0.10	1.00	0.10	0.10	$ 870.68	$ 10,046.94	$ 10,917.62	0.4746	$ 5,181.50	$ 104,692.59	0.0761	$ 7,967.11	$ 3,850,000.00	$ -	13.1339	$ -	0.4746	$ 292,985.00	0.0272	$ (285,017.89)
20	2.86	2.86	0.036	0.036	0.10	0.10	1.00	0.10	0.10	$ 899.41	$ 10,378.45	$ 11,277.86	0.4564	$ 5,147.22	$ 109,839.80	0.0736	$ 8,084.21	$ 3,850,000.00	$ -	13.5903	$ -	0.4564	$ 283,360.00	0.0285	$ (275,275.79)

1 Service Year - Time improvement can reasonably be expected to impact accident experience
2 Annual Property Damage Only Accidents (PDO)
3 Annual Fatality or Injury Accidents (F/I)
4 Accident Reduction Factor for PDO Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
5 Accident Reduction Factor for F/I Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
6 Accident Reduction for PDO Accidents Col (2) * Col (4)
7 Accident Reduction for F/I Accidents Col (3) * Col (5)
8 Accident Projection Factor (APF) - Growth Rate is accounted for in Crash Prediction (2% increase per year not applied)
9 Accident Reduction for PDO Accidents Col (6) * Col (8)
10 Accident Reduction for F/I Accidents Col (7) * Col (8)
11 PDO Accidents * $6500 plus 3% inflation for 10 years (IDM Figure 50-2A) Col (9) * $8735
12 F/I Accidents * $75000 + 3% inflation for 10 years (IDM Figure 50-2A) Col (10)*$100,795 [rural cost used to better represent
13 Total Unadjusted Benefits Col (11) + Col (12)
14 Present Worth Factor (PWF) - Factor to determine Present Worth of economic benefit during service life (IDM Figure 50-2C)
15 Adjusted Benefits - Unadjusted Benefits times the PWF Col (13) * Col (14)
16 Ajusted Cumulative Year Benefits
17 Capital Recovery Factor (CRF) (IDM Figure 50-2C)
18 Equivalent Uniform Annual Benefit (EUAB) - CRF multiplied by Adjusted Cumulative Year Benefit Col (16) * Col (17)
19 Initial Cost of the Recommended Improvement (increse in Cost to meet design criteria)
20 Annual Maintenance Cost (AMC)
21 Present Worth Factor for an Equal Payment Serices (PWF-EQ) (IDM Figure 50-2C)
22 Salvage Value of the Improvement at the End of the Service Life
23 Present Worth Factor for a Single Payment (PWF-SP) (IDM Figure 50-2C)
24 Equivalent Uniform Annual Cost (EUAC) - CRF * [Initial Cost + (AMC*PWP-EQ)-(Salvage Value *PWP-SP)
25 Benefit to Cost Ratio (B/C) - EUAB divided by EUAC Col (18)/ Col (24)
26 Net Annual Benefit (NAB) - Difference between EUAB and EUAC Col (18)- Col (24)

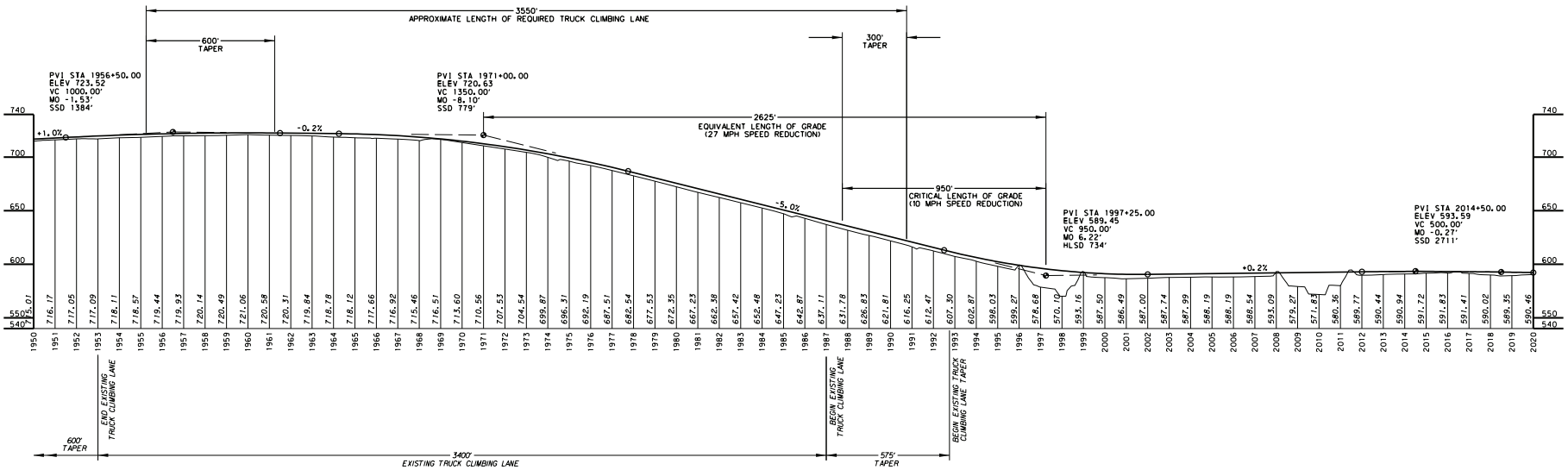
Appendix "D"
Plan and Profile for Alternatives



I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT KINSER PIKE
MAINTAIN EXISTING 5% PROFILE GRADE WITH REQUIRED CLEAR ZONE

SCALE
0 150 300 FEET

APPENDIX "D-1"



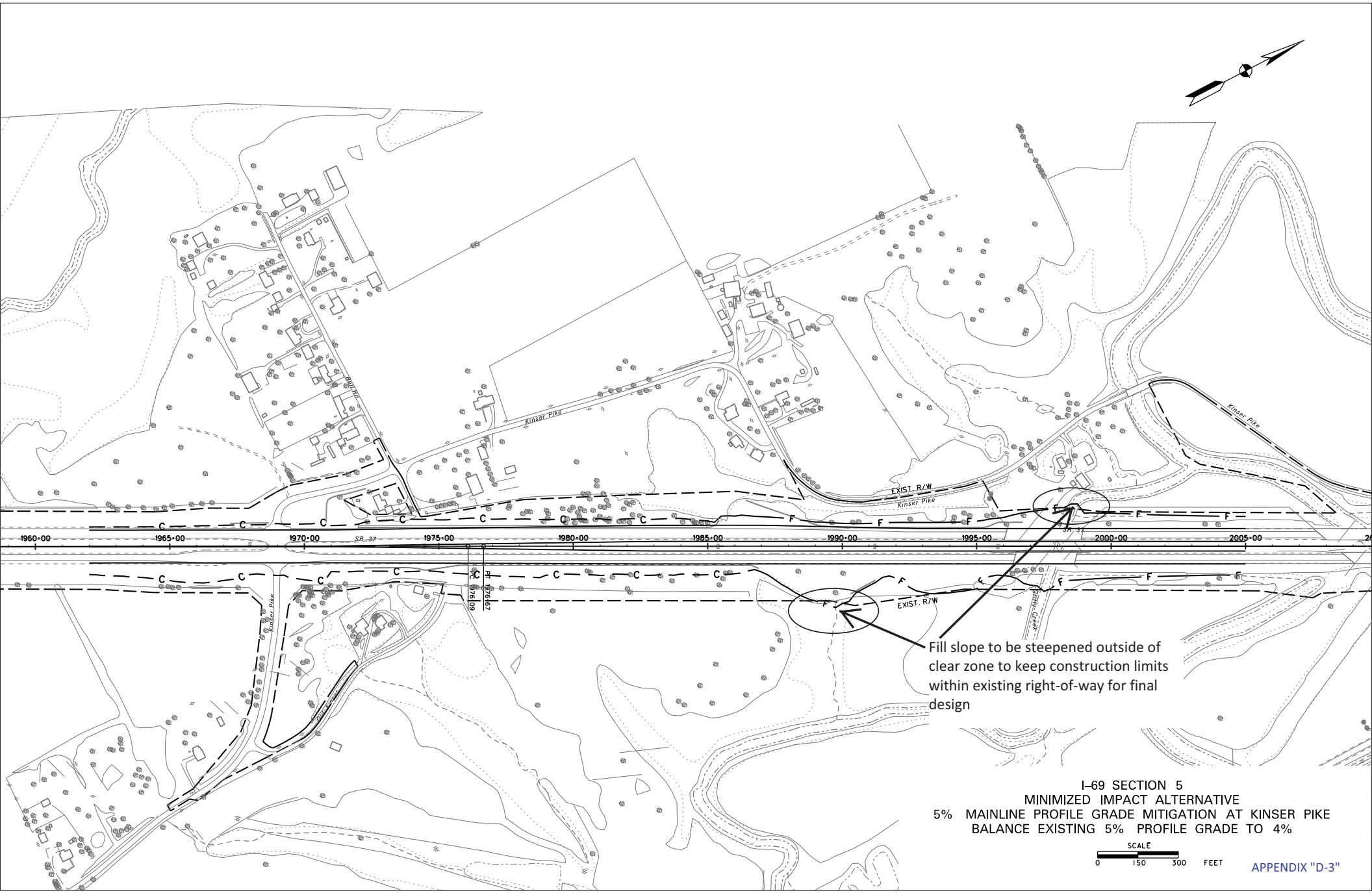
PROFILE – MAINLINE

I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT KINSER PIKE
MAINTAIN EXISTING 5% PROFILE GRADE WITH REQUIRED CLEAR ZONE

VERTICAL SCALE
0 50 100 FEET

HORIZONTAL SCALE
0 250 500 FEET

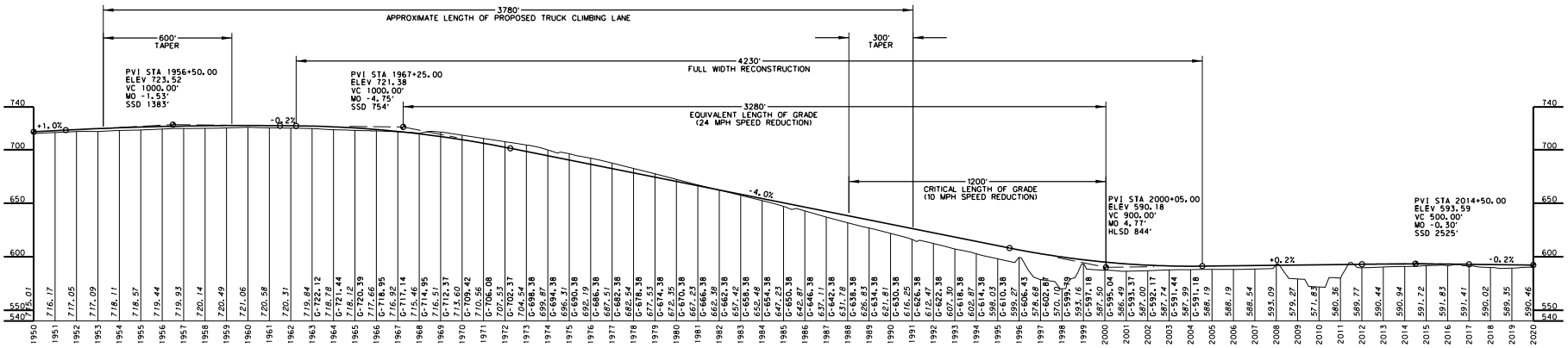
APPENDIX "D-2"



I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT KINSER PIKE
BALANCE EXISTING 5% PROFILE GRADE TO 4%

SCALE
0 150 300 FEET

APPENDIX "D-3"



PROFILE – MAINLINE

I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT KINSER PIKE
BALANCE EXISTING 5% PROFILE GRADE TO 4%

VERTICAL SCALE
0 50 100 FEET

HORIZONTAL SCALE
0 250 500 FEET

APPENDIX "D-4"

Appendix "E"
Benefit-Cost Analysis for Vertical Grade

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	1	of	2
CALCULATED BY	JAT	DATE	8/20/2012
CHECKED BY	SJS	DATE	8/20/2012

Benefit/Cost Analysis - Vertical Grade **Kinser Pike to Griffey Creek (approx. Sta. 1971+00 to Sta. 1997+25)**

Extensive research and discussions have occurred relating to the best, defensible methodology for determining crash predictions, crash modification factors (CMF) and crash reduction factors (CRF) for the benefit/cost analysis given the change in facility type with the proposed project. This represents a rather unique tranisition and one that 'typical' approaches of utilizing existing crash data are not applicable. Much of the data that was found in crash predictions was not applicable to interstate situations. Upon consultation with many experts in the traffic field, the HERS manual provides equations based on AADT numbers and lane widths to predict the number of crashes that may occur along a segment of roadway.

The other issue besides crash prediction was determining a reasonable and more refined crash modification factor based on the project specific elements. While the CMF Clearinghouse provides many different scenarios of studies, it didn't provide much that was a direct correlation to the I-69, Section 5 Project. Further research yielded discovery of the "Roadway Safety Design Synthesis" which represents the state of the practice more definitively. Equations are available for many different scenarios that yield CMFs applicable to specific situations on freeways. This provides values based on calculations/equations obtained from studies with a high level of credibility instead of generalized conditions that are not project specific.

References:

Indiana Design Manual, 2011, Part 5 Road Design, Chapter 50 Economic Analysis
Highway Economic Requirements System - State Version (HERS Manual), Techncial Report, USDOT, FHWA, August, 2005
ROADWAY SAFETY DESIGN SYNTHESIS, J. Bonneson, K. Zimmerman and K. Fitzpatrick, FHWA, 2005

Kinser Pike to Griffey Creek (approx. Sta. 1971+00 to Sta. 1997+25)

Determine the cost effectiveness of reconstruction of this segment of I-69 to improve the vertical grade from 5% to meet the design criteria of 4% maximum. Urban Freeway crash prediction method.

1. Crash Modification Factor

The Crash Modification Factors were calculated using equations from the following FHWA-sponsored report:

Report No. FHWA/TX-05/0-4703-P1
"ROADWAY SAFETY DESIGN SYNTHESIS" by J. Bonneson, K. Zimmerman and K. Fitzpatrick, 2005
http://tti.tamu.edu/documents/0-4703-P1.pdf

Eqn. 2-13 -> $AMF_g = (e^{b P_g} - 1.0) P_s + 1.0$

b = 0.019 from Table 2-4 for Urban arterial
Pg = percent grade (absolute value), % = 1%
P_s = 1.0 from Table 2-4 for Urban arterial

CMF = AMF_{swi} = 1.019 -> Use 1.02 **CRF = -2.0%**

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	2	of	2
CALCULATED BY	JAT	DATE	8/20/2012
CHECKED BY	SJS	DATE	8/20/2012

2. Accident Data

DESIGN SERVICE YEAR	AADT (1)	CRASH RATE (2)	PREDICTED CRASHES PER YEAR WITH 4% GRADE (3)	CRASH MODIFICATION FACTOR FOR GRADE CHANGE (5)	PREDICTED CRASHES PER YEAR WITH 5% GRADE	ADDED CRASHES PER YEAR WITH 5% GRADE	PREDICTED F/I CRASHES WITH 5% GRADE (4)	PREDICTED PDO CRASHES WITH 5% GRADE (4)
1	34432	170	10.68	1.02	10.90	0.21	5.45	5.45
2	35568	170	11.03	1.02	11.26	0.22	5.63	5.63
3	36742	170	11.40	1.02	11.63	0.23	5.81	5.81
4	37954	170	11.78	1.02	12.01	0.24	6.01	6.01
5	39206	170	12.16	1.02	12.41	0.24	6.20	6.20
6	40500	170	12.57	1.02	12.82	0.25	6.41	6.41
7	41836	170	12.98	1.02	13.24	0.26	6.62	6.62
8	43217	170	13.41	1.02	13.68	0.27	6.84	6.84
9	44643	170	13.85	1.02	14.13	0.28	7.06	7.06
10	46116	170	14.31	1.02	14.59	0.29	7.30	7.30
11	47638	170	14.78	1.02	15.08	0.30	7.54	7.54
12	49210	170	15.27	1.02	15.57	0.31	7.79	7.79
13	50834	170	15.77	1.02	16.09	0.32	8.04	8.04
14	52512	170	16.29	1.02	16.62	0.33	8.31	8.31
15	54245	170	16.83	1.02	17.17	0.34	8.58	8.58
16	56035	170	17.38	1.02	17.73	0.35	8.87	8.87
17	57884	170	17.96	1.02	18.32	0.36	9.16	9.16
18	59794	170	18.55	1.02	18.92	0.37	9.46	9.46
19	61767	170	19.16	1.02	19.55	0.38	9.77	9.77
20	63805	170	19.80	1.02	20.19	0.40	10.10	10.10
		TOTAL ADDITIONAL CRASHES OVER LIFE OF PROJECT				6		
			ADDITONAL CRASHES PER YEAR (AVERAGE)			0.30		

(1) AADT for Design Service Year 20 from BLA Mainline Volumes Summary, April 21 Alt 7. A 3.3% per year growth rate was assumed for design service years 1-19

(2) HERS Technical Report Equation 5-34 CRASH=154.0*$e^{(0.0082*12)}$; lane width = 12

(3) Crash rate * 365 * 1 yr * ADT *segment length (.50 mi) / 100,000,000

(4) HERS Techicnal Report Table 5-12; 1.4 fatalities per 100 crashes/45.5 injuries per 100 crashes. Assume 50% of predicted crashes are F/I and 50% are PDO

(5) The assumption is that the HERS equations used to predict the number of crashes assumes the facility is in compliance with AASHTO standards. Based on the proposed condition with a 5% grade (which is not in compliance), it is assumed that the crash rate will be affected. A 2% increase in crashes is anticiapted based on available research of the affect of grade on interstate crashes.

2. Service Life for Vertical Alignment Improvement

20 years (Figure 50-2B)

4. Costs

Construction Cost 4% Vertical Grade (Balanced)	$ 12,480,000.00
Construction Cost 5% Minimum Impact Vertical Grade	$ 2,498,000.00
Increase in Construction Cost to Meet Design Criteria	**$ 9,982,000.00**

(Associated with full depth pavement reconstruction and earthwork to correct grade for length of approximately 4230')

5. Benefit Cost Analysis

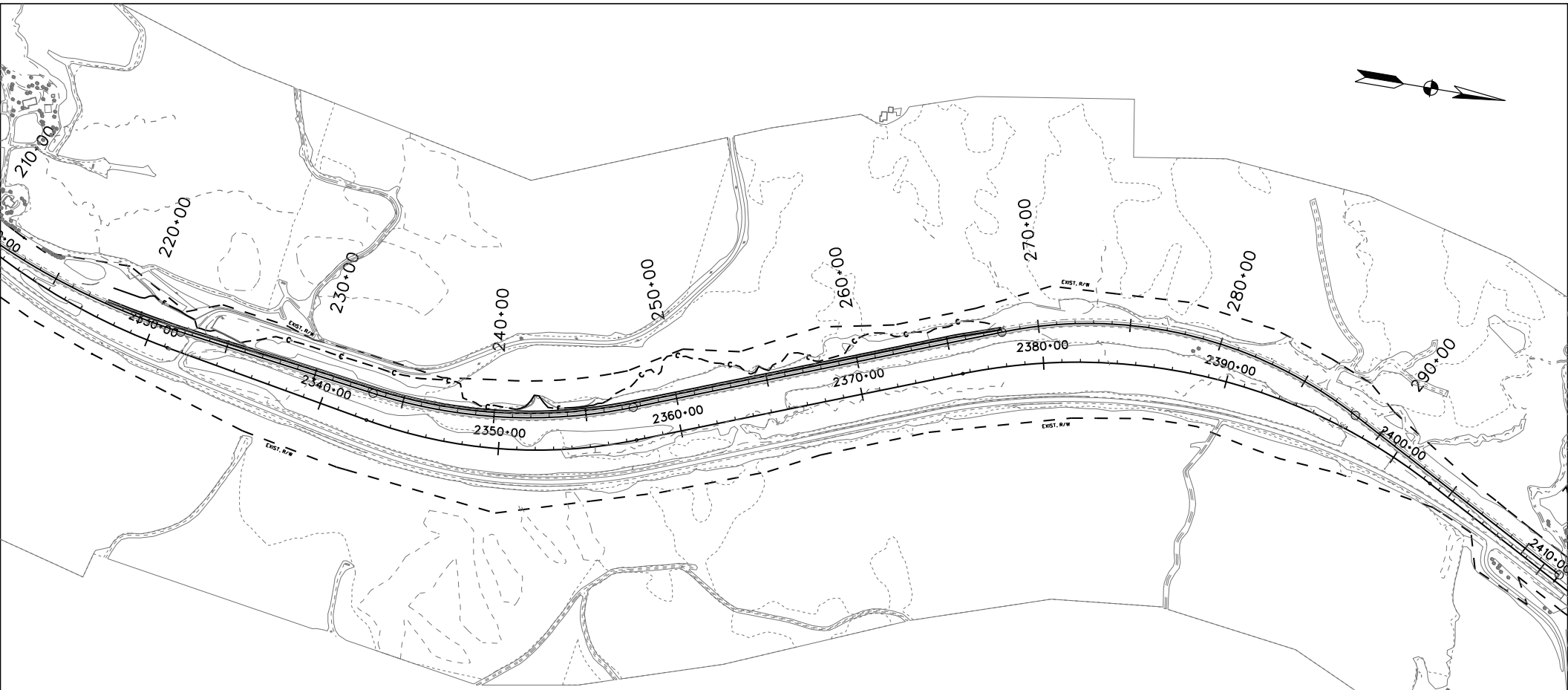
See attached Benefit Cost Analysis

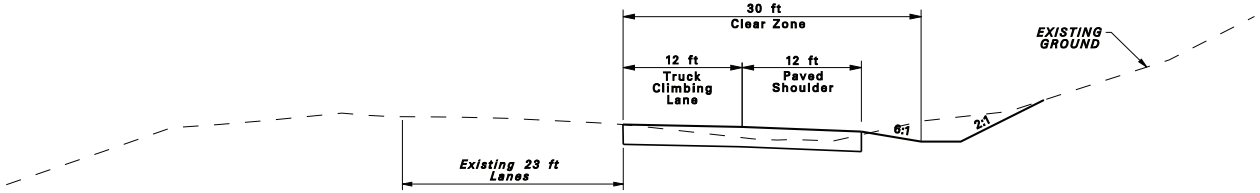
Benefit/Cost Analysis
I-69 Tier 1 - Section 5 - Construction of Profile at Max. 4% Grade
Kinser Pike to Griffey Creek (approx. Sta. 1971+00 to Sta. 1997+25)
20-Aug-12

							Accident Reduction			Adjusted Benefits						Benefit/Cost Calculations									
Service Year	Annual PDO Acc.	Annual F/I Acc.)	ARF (PDO)	ARF (F/I)	ARF*Annual (PDO)	ARF*Annual (F/I)	APF	PDO	F/I	PDO*$8735	F/I*$100,795	Total Unadj. Benefits	PWF	Total Adj. Benefits	Cum. Yr. Benefits	CRF	EUAB	Initial Cost	AMC	PWF-EQ	Salvage	PWF-SP	EUAC	B/C	NAB
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	5.45	5.45	0.02	0.02	0.11	0.11	1.00	0.11	0.11	$ 951.78	$ 10,982.80	$ 11,934.58	0.9615	$ 11,475.10	$ 11,475.10	1.0400	$ 11,934.11	$ 9,982,000.00	$ -	0.9615	$ -	0.9615	$ 10,381,280.00	0.0011	$ (10,369,345.89)
2	5.63	5.63	0.02	0.02	0.11	0.11	1.00	0.11	0.11	$ 983.18	$ 11,345.15	$ 12,328.34	0.9246	$ 11,398.78	$ 22,873.88	0.5302	$ 12,127.73	$ 9,982,000.00	$ -	1.8861	$ -	0.9246	$ 5,292,456.40	0.0023	$ (5,280,328.67)
3	5.81	5.81	0.02	0.02	0.12	0.12	1.00	0.12	0.12	$ 1,015.64	$ 11,719.63	$ 12,735.26	0.8890	$ 11,321.65	$ 34,195.53	0.3603	$ 12,320.65	$ 9,982,000.00	$ -	2.7751	$ -	0.8890	$ 3,596,514.60	0.0034	$ (3,584,193.95)
4	6.01	6.01	0.02	0.02	0.12	0.12	1.00	0.12	0.12	$ 1,049.14	$ 12,106.22	$ 13,155.36	0.8548	$ 11,245.20	$ 45,440.73	0.2755	$ 12,518.92	$ 9,982,000.00	$ -	3.6299	$ -	0.8548	$ 2,750,041.00	0.0046	$ (2,737,522.08)
5	6.20	6.20	0.02	0.02	0.12	0.12	1.00	0.12	0.12	$ 1,083.75	$ 12,505.57	$ 13,589.32	0.8219	$ 11,169.06	$ 56,609.79	0.2246	$ 12,714.56	$ 9,982,000.00	$ -	4.4518	$ -	0.8219	$ 2,241,957.20	0.0057	$ (2,229,242.64)
6	6.41	6.41	0.02	0.02	0.13	0.13	1.00	0.13	0.13	$ 1,119.51	$ 12,918.32	$ 14,037.83	0.7903	$ 11,094.10	$ 67,703.89	0.1908	$ 12,917.90	$ 9,982,000.00	$ -	5.2412	$ -	0.7903	$ 1,904,565.60	0.0068	$ (1,891,647.70)
7	6.62	6.62	0.02	0.02	0.13	0.13	1.00	0.13	0.13	$ 1,156.45	$ 13,344.46	$ 14,500.91	0.7599	$ 11,019.24	$ 78,723.13	0.1666	$ 13,115.27	$ 9,982,000.00	$ -	6.0021	$ -	0.7599	$ 1,663,001.20	0.0079	$ (1,649,885.93)
8	6.84	6.84	0.02	0.02	0.14	0.14	1.00	0.14	0.14	$ 1,194.62	$ 13,784.96	$ 14,979.58	0.7307	$ 10,945.58	$ 89,668.71	0.1485	$ 13,315.80	$ 9,982,000.00	$ -	6.7327	$ -	0.7307	$ 1,482,327.00	0.0090	$ (1,469,011.20)
9	7.06	7.06	0.02	0.02	0.14	0.14	1.00	0.14	0.14	$ 1,234.04	$ 14,239.81	$ 15,473.85	0.7206	$ 11,150.46	$ 100,819.16	0.1345	$ 13,560.18	$ 9,982,000.00	$ -	7.4353	$ -	0.7206	$ 1,342,579.00	0.0101	$ (1,329,018.82)
10	7.30	7.30	0.02	0.02	0.15	0.15	1.00	0.15	0.15	$ 1,274.75	$ 14,709.66	$ 15,984.41	0.6576	$ 10,511.35	$ 111,330.51	0.1233	$ 13,727.05	$ 9,982,000.00	$ -	8.1109	$ -	0.6576	$ 1,230,780.60	0.0112	$ (1,217,053.55)
11	7.54	7.54	0.02	0.02	0.15	0.15	1.00	0.15	0.15	$ 1,316.83	$ 15,195.13	$ 16,511.96	0.6496	$ 10,726.17	$ 122,056.68	0.1141	$ 13,926.67	$ 9,982,000.00	$ -	8.7605	$ -	0.6496	$ 1,138,946.20	0.0122	$ (1,125,019.53)
12	7.79	7.79	0.02	0.02	0.16	0.16	1.00	0.16	0.16	$ 1,360.28	$ 15,696.55	$ 17,056.83	0.6246	$ 10,653.70	$ 132,710.38	0.1066	$ 14,146.93	$ 9,982,000.00	$ -	9.3185	$ -	0.6246	$ 1,064,081.20	0.0133	$ (1,049,934.27)
13	8.04	8.04	0.02	0.02	0.16	0.16	1.00	0.16	0.16	$ 1,405.17	$ 16,214.56	$ 17,619.73	0.6006	$ 10,582.41	$ 143,292.79	0.1001	$ 14,343.61	$ 9,982,000.00	$ -	9.9856	$ -	0.6006	$ 999,198.20	0.0144	$ (984,854.59)
14	8.31	8.31	0.02	0.02	0.17	0.17	1.00	0.17	0.17	$ 1,451.55	$ 16,749.80	$ 18,201.35	0.5775	$ 10,511.28	$ 153,804.07	0.0947	$ 14,565.25	$ 9,982,000.00	$ -	10.5631	$ -	0.5775	$ 945,295.40	0.0154	$ (930,730.15)
15	8.58	8.58	0.02	0.02	0.17	0.17	1.00	0.17	0.17	$ 1,499.46	$ 17,302.57	$ 18,802.03	0.5553	$ 10,440.77	$ 164,244.84	0.0899	$ 14,765.61	$ 9,982,000.00	$ -	11.1184	$ -	0.5553	$ 897,381.80	0.0165	$ (882,616.19)
16	8.87	8.87	0.02	0.02	0.18	0.18	1.00	0.18	0.18	$ 1,548.94	$ 17,873.53	$ 19,422.47	0.5339	$ 10,369.66	$ 174,614.49	0.0858	$ 14,981.92	$ 9,982,000.00	$ -	11.6523	$ -	0.5339	$ 856,455.60	0.0175	$ (841,473.68)
17	9.16	9.16	0.02	0.02	0.18	0.18	1.00	0.18	0.18	$ 1,600.05	$ 18,463.31	$ 20,063.36	0.5134	$ 10,300.53	$ 184,915.02	0.0822	$ 15,200.01	$ 9,982,000.00	$ -	12.1657	$ -	0.5134	$ 820,520.40	0.0185	$ (805,320.39)
18	9.46	9.46	0.02	0.02	0.19	0.19	1.00	0.19	0.19	$ 1,652.85	$ 19,072.54	$ 20,725.39	0.4936	$ 10,230.05	$ 195,145.07	0.0790	$ 15,416.46	$ 9,982,000.00	$ -	12.6593	$ -	0.4936	$ 788,578.00	0.0195	$ (773,161.54)
19	9.77	9.77	0.02	0.02	0.20	0.20	1.00	0.20	0.20	$ 1,707.38	$ 19,701.87	$ 21,409.26	0.4746	$ 10,160.83	$ 205,305.91	0.0761	$ 15,623.78	$ 9,982,000.00	$ -	13.1339	$ -	0.4746	$ 759,630.20	0.0206	$ (744,006.42)
20	10.10	10.10	0.02	0.02	0.20	0.20	1.00	0.20	0.20	$ 1,763.72	$ 20,351.93	$ 22,115.65	0.4564	$ 10,093.58	$ 215,399.49	0.0736	$ 15,853.40	$ 9,982,000.00	$ -	13.5903	$ -	0.4564	$ 734,675.20	0.0216	$ (718,821.80)

1 Service Year - Time improvement can reasonably be expected to impact accident experience
2 Annual Property Damage Only Accidents (PDO)
3 Annual Fatality or Injury Accidents (F/I)
4 Accident Reduction Factor for PDO Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
5 Accident Reduction Factor for F/I Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
6 Accident Reduction for PDO Accidents Col (2) * Col (4)
7 Accident Reduction for F/I Accidents Col (3) * Col (5)
8 Accident Projection Factor (APF) - Growth Rate is accounted for in Crash Prediction (2% increase per year not applied)
9 Accident Reduction for PDO Accidents Col (6) * Col (8)
10 Accident Reduction for F/I Accidents Col (7) * Col (8)
11 PDO Accidents * $6500 plus 3% inflation for 10 years (IDM Figure 50-2A) Col (9) * $8735
12 F/I Accidents * $75000 + 3% inflation for 10 years (IDM Figure 50-2A) Col (10)*$100,795 [rural cost used to better represe
13 Total Unadjusted Benefits Col (11) + Col (12)
14 Present Worth Factor (PWF) - Factor to determine Present Worth of economic benefit during service life (IDM Figure 50-2C)
15 Adjusted Benefits - Unadjusted Benefits times the PWF Col (13) * Col (14)
16 Ajusted Cumulative Year Benefits
17 Capital Recovery Factor (CRF) (IDM Figure 50-2C)
18 Equivalent Uniform Annual Benefit (EUAB) - CRF multiplied by Adjusted Cumulative Year Benefit Col (16) * Col (17)
19 Initial Cost of the Recommended Improvement (increse in Cost to meet design criteria)
20 Annual Maintenance Cost (AMC)
21 Present Worth Factor for an Equal Payment Serices (PWF-EQ) (IDM Figure 50-2C)
22 Salvage Value of the Improvement at the End of the Service Life
23 Present Worth Factor for a Single Payment (PWF-SP) (IDM Figure 50-2C)
24 Equivalent Uniform Annual Cost (EUAC) - CRF * [Initial Cost + (AMC*PWP-EQ)-(Salvage Value *PWP-SP)
25 Benefit to Cost Ratio (B/C) - EUAB divided by EUAC Col (18)/ Col (24)
26 Net Annual Benefit (NAB) - Difference between EUAB and EUAC Col (18)- Col (24)

Appendix "F"
Plan and Profile for Alternatives



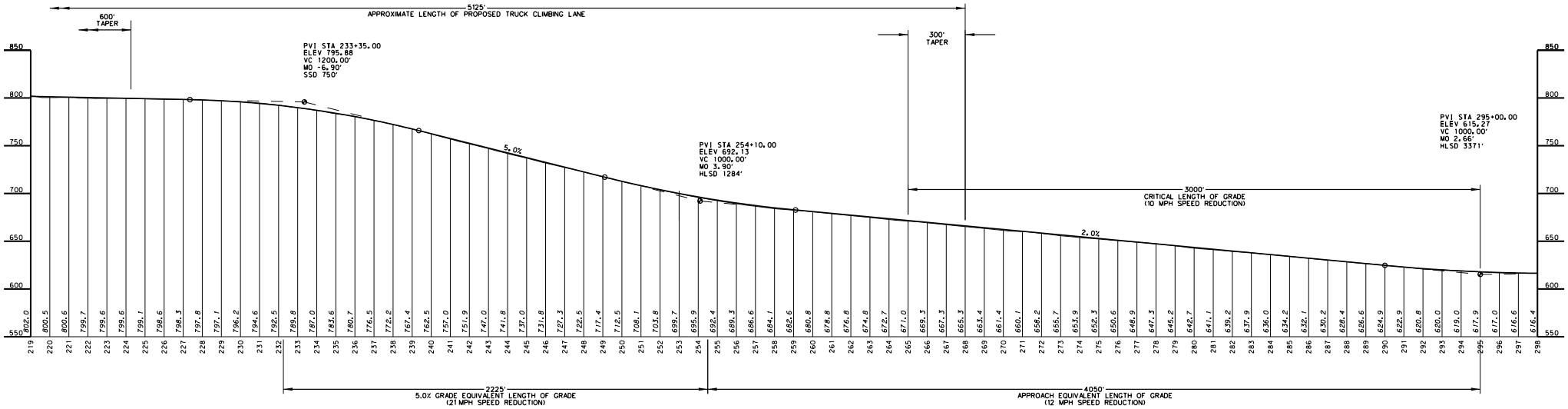


TYPICAL SECTION

I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT BIFURCATION
MAINTAIN EXISTING 5% GRADE

SCALE
0 250 500 FEET

APPENDIX "F-1"



TANGENT	GRADE	LENGTH	SPEED REDUCTION*
APPROACH	2.0%	4,050'	12 MPH
GRADE	5.0%	2,225'	21 MPH
COMBINED		6,275'	33 MPH

*OBTAINED FROM FIGURE 3-24, 2011 AASHTO GREEN BOOK

I-69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT BIFURCATION
MAINTAIN EXISTING 5% GRADE

VERTICAL SCALE
0 50 100 FEET

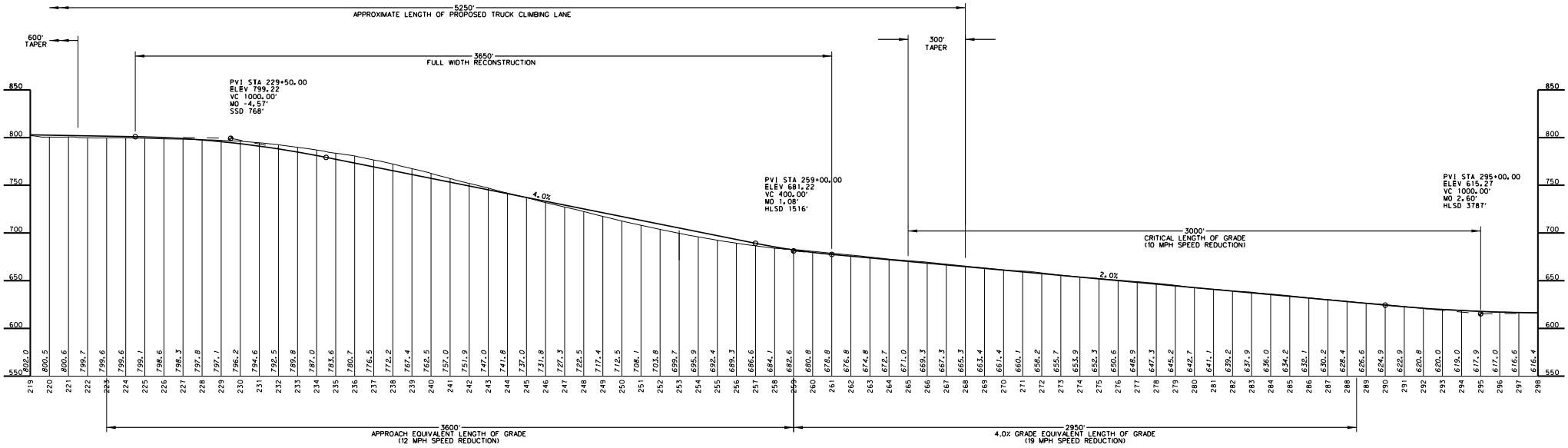
HORIZONTAL SCALE
0 250 500 FEET

APPENDIX "F-2"

I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT BIFURCATION
BALANCE EXISTING 5% PROFILE GRADE TO 4%

SCALE
0 250 500 FEET

APPENDIX "F-3"



TANGENT	GRADE	LENGTH	SPEED REDUCTION*
APPROACH	2.0%	3,600'	12 MPH
GRADE	4.0%	2,950'	19 MPH
COMBINED		6,550'	31 MPH

*OBTAINED FROM FIGURE 3-24, 2011 AASHTO GREEN BOOK

I-69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT BIFURCATION
BALANCE EXISTING 5% PROFILE GRADE TO 4%

VERTICAL SCALE
0 50 100 FEET

HORIZONTAL SCALE
0 250 500 FEET

APPENDIX "F-4"

Appendix "G"
Benefit-Cost Analysis for Vertical Grade

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	1 of 2		
CALCULATED BY	JAT	DATE	8/20/2012
CHECKED BY	SJS	DATE	8/20/2012

Benefit/Cost Analysis - Vertical Grade **Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00)**

Extensive research and discussions have occurred relating to the best, defensible methodology for determining crash predictions, crash modification factors (CMF) and crash reduction factors (CRF) for the benefit/cost analysis given the change in facility type with the proposed project. This represents a rather unique tranisition and one that 'typical' approaches of utilizing existing crash data are not applicable. Much of the data that was found in crash predictions was not applicable to interstate situations. Upon consultation with many experts in the traffic field, the HERS manual provides equations based on AADT numbers and lane widths to predict the number of crashes that may occur along a segment of roadway.

The other issue besides crash prediction was determining a reasonable and more refined crash modification factor based on the project specific elements. While the CMF Clearinghouse provides many different scenarios of studies, it didn't provide much that was a direct correlation to the I-69, Section 5 Project. Further research yielded discovery of the "Roadway Safety Design Synthesis" which represents the state of the practice more definitively. Equations are available for many different scenarios that yield CMFs applicable to specific situations on freeways. This provides values based on calculations/equations obtained from studies with a high level of credibility instead of generalized conditions that are not project specific.

References:

Indiana Design Manual, 2011, Part 5 Road Design, Chapter 50 Economic Analysis
Highway Economic Requirements System - State Version (HERS Manual), Techncial Report, USDOT, FHWA, August, 2005
ROADWAY SAFETY DESIGN SYNTHESIS, J. Bonneson, K. Zimmerman and K. Fitzpatrick, FHWA, 2005

Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00)

Determine the cost effectiveness of reconstruction of this segment of I-69 to improve the vertical grade from 5% to meet the design criteria of 4% maximum. Rural Freeway crash prediction method.

1. Crash Modification Factor

The Crash Modification Factors were calculated using equations from the following FHWA-sponsored report:

Report No. FHWA/TX-05/0-4703-P1
"ROADWAY SAFETY DESIGN SYNTHESIS" by J. Bonneson, K. Zimmerman and K. Fitzpatrick, 2005
http://tti.tamu.edu/documents/0-4703-P1.pdf

Eqn. 2-13 -> $AMF_g = (e^{b P_g} - 1.0)\, P_s + 1.0$

b = 0.016 from Table 2-4 for Rural arterial
Pg = percent grade (absolute value), % = 1%
P_s = 1.0 from Table 2-4 for Rural arterial

CMF = **AMF_{swi} =** **1.016 -> Use 1.02** **CRF = -2.0%**

Baker
8888 Keystone Crossing, Suite 1300
Indianapolis, IN 46240
(317)581-8590

JOB	I-69, Section 5 - Tier 2		
SHEET NO.	1	of	2
CALCULATED BY	JAT	DATE	8/20/2012
CHECKED BY	SJS	DATE	8/20/2012

2. Accident Data*

DESIGN SERVICE YEAR	AADT (1)	CRASH RATE (2)	PREDICTED CRASHES PER YEAR WITH 4% GRADE (3)	CRASH MODIFICATION FACTOR FOR GRADE CHANGE (5)	PREDICTED CRASHES PER YEAR WITH 5% GRADE	ADDED CRASHES PER YEAR WITH 5% GRADE	PREDICTED F/I CRASHES WITH 5% GRADE (4)	PREDICTED PDO CRASHES WITH 5% GRADE (4)
1	35897	98.92	5.70	1.02	5.82	0.11	2.91	2.91
2	37082	99.42	5.92	1.02	6.04	0.12	3.02	3.02
3	38306	99.92	6.15	1.02	6.27	0.12	3.13	3.13
4	39570	100.42	6.38	1.02	6.51	0.13	3.25	3.25
5	40876	100.93	6.63	1.02	6.76	0.13	3.38	3.38
6	42225	101.44	6.88	1.02	7.02	0.14	3.51	3.51
7	43618	101.95	7.14	1.02	7.28	0.14	3.64	3.64
8	45057	102.46	7.41	1.02	7.56	0.15	3.78	3.78
9	46544	102.98	7.70	1.02	7.85	0.15	3.93	3.93
10	48080	103.50	7.99	1.02	8.15	0.16	4.08	4.08
11	49667	104.02	8.30	1.02	8.46	0.17	4.23	4.23
12	51306	104.55	8.61	1.02	8.79	0.17	4.39	4.39
13	52999	105.07	8.94	1.02	9.12	0.18	4.56	4.56
14	54748	105.60	9.29	1.02	9.47	0.19	4.74	4.74
15	56555	106.14	9.64	1.02	9.83	0.19	4.92	4.92
16	58421	106.67	10.01	1.02	10.21	0.20	5.10	5.10
17	60349	107.21	10.39	1.02	10.60	0.21	5.30	5.30
18	62341	107.75	10.79	1.02	11.00	0.22	5.50	5.50
19	64398	108.29	11.20	1.02	11.42	0.22	5.71	5.71
20	66523	108.84	11.63	1.02	11.86	0.23	5.93	5.93
		TOTAL ADDITIONAL CRASHES OVER LIFE OF PROJECT				3		
		ADDITONAL CRASHES PER YEAR (AVERAGE)				0.17		

(1) AADT for Design Service Year 20 from BLA Mainline Volumes Summary, April 21 Alt 7. A 3.3% per year growth rate was assumed for design service years 1-19

(2) HERS Technical Report Equation 5-34 $CRASH=17.64*AADT^{0.155}*e^{(0.0082*12)}$; lane width = 12

(3) Crash rate * 365 * 1 yr * ADT *segment length (.44 mi) / 100,000,000

(4) HERS Techicnal Report Table 5-12; 1.4 fatalities per 100 crashes/45.5 injuries per 100 crashes. Assume 50% of predicted crashes are F/I and 50% are PDO

(5) The assumption is that the HERS equations used to predict the number of crashes assumes the facility is in compliance with AASHTO standards. Based on the proposed condition with a 5% grade (which is not in compliance), it is assumed that the crash rate will be affected. A 2% increase in crashes is anticiapted based on available research of the affect of grade on interstate crashes.

3. Service Life for Vertical Alignment Improvement

20 years (Figure 50-2B)

4. Costs

Construction Cost 4% Vertical Grade (Balanced)	$ 3,737,000.00
Construction Cost 5% Minimum Impact Vertical Grade	$ 2,221,000.00
Increase in Construction Cost to Meet Design Criteria	**$ 1,516,000.00**

(Associated with full depth pavement reconstruction and earthwork to correct grade for length of approximately 3650')

5. Benefit Cost Analysis

See attached Benefit Cost Analysis

Benefit/Cost Analysis
I-69 Tier 1 - Section 5 - Construction of Profile at Max. 4% Grade
Through Bifurcation – Southbound Lanes (approximately Sta. 2342+00 to 2365+00)
20-Aug-12

							Accident Reduction			Adjusted Benefits						Benefit/Cost Calculations									
Service Year	Annual PDO Acc.	Annual F/I Acc.)	ARF (PDO)	ARF (F/I)	ARF*Annual (PDO)	ARF*Annual (F/I)	APF	PDO	F/I	PDO*$8735	F/I*$100,795	Total Unadj. Benefits	PWF	Total Adj. Benefits	Cum. Yr. Benefits	CRF	EUAB	Initial Cost	AMC	PWF-EQ	Salvage	PWF-SP	EUAC	B/C	NAB
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	2.91	2.91	0.02	0.02	0.06	0.06	1.00	0.06	0.06	$ 508.08	$ 5,862.87	$ 6,370.95	0.9615	$ 6,125.67	$ 6,125.67	1.0400	$ 6,370.69	$ 1,516,000.00	$ -	0.9615	$ -	0.9615	$ 1,576,640.00	0.0040	$ (1,570,269.31)
2	3.02	3.02	0.02	0.02	0.06	0.06	1.00	0.06	0.06	$ 527.50	$ 6,086.97	$ 6,614.48	0.9246	$ 6,115.74	$ 12,241.41	0.5302	$ 6,490.40	$ 1,516,000.00	$ -	1.8861	$ -	0.9246	$ 803,783.20	0.0081	$ (797,292.80)
3	3.13	3.13	0.02	0.02	0.06	0.06	1.00	0.06	0.06	$ 547.66	$ 6,319.62	$ 6,867.29	0.8890	$ 6,105.02	$ 18,346.43	0.3603	$ 6,610.22	$ 1,516,000.00	$ -	2.7751	$ -	0.8890	$ 546,214.80	0.0121	$ (539,604.58)
4	3.25	3.25	0.02	0.02	0.07	0.07	1.00	0.07	0.07	$ 568.59	$ 6,561.08	$ 7,129.68	0.8548	$ 6,094.45	$ 24,440.87	0.2755	$ 6,733.46	$ 1,516,000.00	$ -	3.6299	$ -	0.8548	$ 417,658.00	0.0161	$ (410,924.54)
5	3.38	3.38	0.02	0.02	0.07	0.07	1.00	0.07	0.07	$ 590.32	$ 6,811.83	$ 7,402.15	0.8219	$ 6,083.83	$ 30,524.70	0.2246	$ 6,855.85	$ 1,516,000.00	$ -	4.4518	$ -	0.8219	$ 340,493.60	0.0201	$ (333,637.75)
6	3.51	3.51	0.02	0.02	0.07	0.07	1.00	0.07	0.07	$ 612.88	$ 7,072.14	$ 7,685.02	0.7903	$ 6,073.47	$ 36,598.17	0.1908	$ 6,982.93	$ 1,516,000.00	$ -	5.2412	$ -	0.7903	$ 289,252.80	0.0241	$ (282,269.87)
7	3.64	3.64	0.02	0.02	0.07	0.07	1.00	0.07	0.07	$ 636.29	$ 7,342.29	$ 7,978.59	0.7599	$ 6,062.93	$ 42,661.10	0.1666	$ 7,107.34	$ 1,516,000.00	$ -	6.0021	$ -	0.7599	$ 252,565.60	0.0281	$ (245,458.26)
8	3.78	3.78	0.02	0.02	0.08	0.08	1.00	0.08	0.08	$ 660.60	$ 7,622.78	$ 8,283.38	0.7307	$ 6,052.66	$ 48,713.76	0.1485	$ 7,233.99	$ 1,516,000.00	$ -	6.7327	$ -	0.7307	$ 225,126.00	0.0321	$ (217,892.01)
9	3.93	3.93	0.02	0.02	0.08	0.08	1.00	0.08	0.08	$ 685.84	$ 7,914.08	$ 8,599.92	0.7206	$ 6,197.10	$ 54,910.87	0.1345	$ 7,385.51	$ 1,516,000.00	$ -	7.4353	$ -	0.7206	$ 203,902.00	0.0362	$ (196,516.49)
10	4.08	4.08	0.02	0.02	0.08	0.08	1.00	0.08	0.08	$ 712.05	$ 8,216.50	$ 8,928.55	0.6576	$ 5,871.41	$ 60,782.28	0.1233	$ 7,494.46	$ 1,516,000.00	$ -	8.1109	$ -	0.6576	$ 186,922.80	0.0401	$ (179,428.34)
11	4.23	4.23	0.02	0.02	0.08	0.08	1.00	0.08	0.08	$ 739.27	$ 8,530.54	$ 9,269.80	0.6496	$ 6,021.66	$ 66,803.94	0.1141	$ 7,622.33	$ 1,516,000.00	$ -	8.7605	$ -	0.6496	$ 172,975.60	0.0441	$ (165,353.27)
12	4.39	4.39	0.02	0.02	0.09	0.09	1.00	0.09	0.09	$ 767.51	$ 8,856.50	$ 9,624.01	0.6246	$ 6,011.16	$ 72,815.10	0.1066	$ 7,762.09	$ 1,516,000.00	$ -	9.3185	$ -	0.6246	$ 161,605.60	0.0480	$ (153,843.51)
13	4.56	4.56	0.02	0.02	0.09	0.09	1.00	0.09	0.09	$ 796.84	$ 9,194.90	$ 9,991.74	0.6006	$ 6,001.04	$ 78,816.14	0.1001	$ 7,889.50	$ 1,516,000.00	$ -	9.9856	$ -	0.6006	$ 151,751.60	0.0520	$ (143,862.10)
14	4.74	4.74	0.02	0.02	0.09	0.09	1.00	0.09	0.09	$ 827.29	$ 9,546.26	$ 10,373.55	0.5775	$ 5,990.72	$ 84,806.86	0.0947	$ 8,031.21	$ 1,516,000.00	$ -	10.5631	$ -	0.5775	$ 143,565.20	0.0559	$ (135,533.99)
15	4.92	4.92	0.02	0.02	0.10	0.10	1.00	0.10	0.10	$ 858.91	$ 9,911.10	$ 10,770.01	0.5553	$ 5,980.58	$ 90,787.45	0.0899	$ 8,161.79	$ 1,516,000.00	$ -	11.1184	$ -	0.5553	$ 136,288.40	0.0599	$ (128,126.61)
16	5.10	5.10	0.02	0.02	0.10	0.10	1.00	0.10	0.10	$ 891.72	$ 10,289.76	$ 11,181.48	0.5339	$ 5,969.79	$ 96,757.24	0.0858	$ 8,301.77	$ 1,516,000.00	$ -	11.6523	$ -	0.5339	$ 130,072.80	0.0638	$ (121,771.03)
17	5.30	5.30	0.02	0.02	0.11	0.11	1.00	0.11	0.11	$ 925.80	$ 10,682.96	$ 11,608.76	0.5134	$ 5,959.94	$ 102,717.18	0.0822	$ 8,443.35	$ 1,516,000.00	$ -	12.1657	$ -	0.5134	$ 124,615.20	0.0678	$ (116,171.85)
18	5.50	5.50	0.02	0.02	0.11	0.11	1.00	0.11	0.11	$ 961.18	$ 11,091.28	$ 12,052.46	0.4936	$ 5,949.09	$ 108,666.27	0.0790	$ 8,584.64	$ 1,516,000.00	$ -	12.6593	$ -	0.4936	$ 119,764.00	0.0717	$ (111,179.36)
19	5.71	5.71	0.02	0.02	0.11	0.11	1.00	0.11	0.11	$ 997.91	$ 11,515.04	$ 12,512.95	0.4746	$ 5,938.64	$ 114,604.92	0.0761	$ 8,721.43	$ 1,516,000.00	$ -	13.1339	$ -	0.4746	$ 115,367.60	0.0756	$ (106,646.17)
20	5.93	5.93	0.02	0.02	0.12	0.12	1.00	0.12	0.12	$ 1,036.03	$ 11,955.02	$ 12,991.05	0.4564	$ 5,929.12	$ 120,534.03	0.0736	$ 8,871.30	$ 1,516,000.00	$ -	13.5903	$ -	0.4564	$ 111,577.60	0.0795	$ (102,706.30)

1 Service Year - Time improvement can reasonably be expected to impact accident experience
2 Annual Property Damage Only Accidents (PDO)
3 Annual Fatality or Injury Accidents (F/I)
4 Accident Reduction Factor for PDO Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
5 Accident Reduction Factor for F/I Accidents (calculated fromROADWAY SAFETY DESIGN SYNTHESIS)
6 Accident Reduction for PDO Accidents Col (2) * Col (4)
7 Accident Reduction for F/I Accidents Col (3) * Col (5)
8 Accident Projection Factor (APF) - Growth Rate is accounted for in Crash Prediction (2% increase per year not applied)
9 Accident Reduction for PDO Accidents Col (6) * Col (8)
10 Accident Reduction for F/I Accidents Col (7) * Col (8)
11 PDO Accidents * $6500 plus 3% inflation for 10 years (IDM Figure 50-2A) Col (9) * $8735
12 F/I Accidents * $75000 plus 3% inflation for 10 years (IDM Figure 50-2A) Col (10)*$100,795
13 Total Unadjusted Benefits Col (11) + Col (12)
14 Present Worth Factor (PWF) - Factor to determine Present Worth of economic benefit during service life (IDM Figure 50-2C)
15 Adjusted Benefits - Unadjusted Benefits times the PWF Col (13) * Col (14)
16 Ajusted Cumulative Year Benefits
17 Capital Recovery Factor (CRF) (IDM Figure 50-2C)
18 Equivalent Uniform Annual Benefit (EUAB) - CRF multiplied by Adjusted Cumulative Year Benefit Col (16) * Col (17)
19 Initial Cost of the Recommended Improvement (increse in Cost to meet design criteria)
20 Annual Maintenance Cost (AMC)
21 Present Worth Factor for an Equal Payment Serices (PWF-EQ) (IDM Figure 50-2C)
22 Salvage Value of the Improvement at the End of the Service Life
23 Present Worth Factor for a Single Payment (PWF-SP) (IDM Figure 50-2C)
24 Equivalent Uniform Annual Cost (EUAC) - CRF * [Initial Cost + (AMC*PWP-EQ)-(Salvage Value *PWP-SP)
25 Benefit to Cost Ratio (B/C) - EUAB divided by EUAC Col (18)/ Col (24)
26 Net Annual Benefit (NAB) - Difference between EUAB and EUAC Col (18)- Col (24)

OFFICE MEMORANDUM

Date: September 26, 2012
To: I-69 Tier 2 PMC
From: Julie Thurman, PE – I-69 Section 5, Deputy Project Manager
Subject: Level Two Design Exception Documentation

After careful consideration of impacts to safety, mobility and project costs, Level Two Design Exceptions are being documented for I-69, Section 5 for critical length of grade and barrier offset in the median. Please see the following as documentation of the decision to request the Level Two Design Exception.

A Level Two Design Exception is being requested for the following elements:

- ***Critical Length of Grade***
  - Between Vernal Pike and SR 46 - SB Lanes (approx. Sta. 1810+50 to 1830+00) – Urban Section
  - From Kinser Pike to Griffy Creek – SB Lanes (approx. Sta. 1971+00 to 1997+25) – Urban Section
  - Ellis Road to N. Wayport Rd. - NB Lanes (approx. Sta. 2054+00 to 2104+75)– Urban Section
  - Through Bifurcation – SB Lanes (approx. Sta. 2328+50 to 2378+50) – Rural Section
  - South of Paragon Road - NB Lanes (approx. Sta. 2465+00 to 2483+75) – Rural Section
  - North of Paragon Road - SB Lanes (approx. Sta. 2492+75 to 2537+00) – Rural Section
- ***Roadside Safety Design Element – Barrier Offset***
  - From South End of Project to approx. SR 46
  - Through Bifurcation – Northbound Lanes (approximately Sta. 2325+00 to 2405+00)

Project Description

Section 5 of the I-69 Evansville to Indianapolis project begins just north of the intersection with SR37 and Victor Pike, south of Bloomington, and continues northward on the existing alignment of SR 37 to just south of the interchange of SR 37 and SR 39 in Martinsville. This section of the I-69 project is approximately 23 miles in length and extends through Monroe and Morgan Counties, Indiana, following the existing alignment of SR 37, a multi-lane divided principal arterial highway with partial access control. This project would reconstruct the corridor to meet freeway standards with full access control. From the southern terminus of the project to Sample Road, the project is designed with an urban typical section. These limits have been extended further north than initially anticipated due to forecasted traffic levels and continuing development in the area. From Sample Road to the north end of the project, a rural

typical section will be used. The terrain throughout the project area is rolling. Areas with long, upward grades exist necessitating the existing truck climbing lanes in several different locations within the project limits. The current posted speed limit ranges from 55 mph in the urban section to 60 mph in the rural section. The proposed design speed is 70 mph. The proposed posted speed limit is 55 mph through the urban limits of the city of Bloomington and 70 mph in the rural areas.

Existing SR 37 in the urban section generally consists of two lanes each direction. An auxiliary lane is present between the two most closely spaced urban interchanges (SR 45 and SR 48) with additional auxiliary lanes at the intersections and interchanges with approximately 4-feet inside shoulders and 8-9 feet outside shoulders. The existing typical cross section includes an open grass median throughout the corridor. The proposed alternative will utilize three 12-foot lanes in each direction for the urban area with an auxiliary lane between the SR 45 and SR 48 interchanges. Auxiliary lanes will also be included at the interchange terminals. Twelve-foot inside and outside shoulders will be provided in the urban typical sections with the introduction of a concrete median barrier to separate opposing directions of traffic. There are a few locations where a Level One Design Exception is being requested for the inside shoulders widths. The minimum inside should width with a design exception is 10-foot. For the typical section, the limits of the urban/rural section are based on forecasted traffic and continuing development in the area. The project will have an urban section from its south end up to the Sample Road interchange. North of Sample Road it will have a rural typical section.

In the rural section of this project, existing SR 37 is two lanes in each direction with auxiliary lanes at the intersections. The existing typical section includes inside shoulders of approximately 4-foot width and 8-9 foot outside shoulders. It has a typical 60-foot wide open grassy median. The proposed typical section will have two 12-foot lanes in each direction with 4-foot inside and 12-foot outside shoulders and an open grassy median which typically is 60' wide.

The primary objective in the development of alternatives was to avoid impacts where practical and to minimize associated project costs. This is being achieved by following the existing horizontal and vertical alignment of SR 37 wherever feasible and maintaining many of the existing bridge structures. However, with the increase from the existing posted speed (55-60 mph) to the design speed (70 mph) and to comply with current design standards, there are existing features that will be substandard and require either upgrading or a Level One or Level Two Design Exception to maintain the existing feature.

Level 2 Design Feature - Critical Length of Grade

Critical Length of Grade is defined as the maximum length of a specific upgrade on which a loaded truck can operate without an unreasonable reduction in speed. A common basis for determining critical length of grade is based on a reduction in speed of trucks below the average running speed of traffic. The American Association of State Highway and Transportation Officials – Geometric Design of Highways and Streets (AASHTO) and the Indiana Design Manual (IDM) recommend a 10 mph speed reduction be used as a general guide for determining critical lengths of grade on major routes such as freeways, arterials, or on the extra-heavy-duty-highway system.

AASHTO states that the suggested design criteria for determining critical length of grade is not intended as a strict control but as a guideline and recognizes that in some instances, the terrain or other physical characteristics may preclude meeting these guidelines. In regard to the application of these criteria, IDM 44-1.04 states, "If the critical length of grade is exceeded, the grade should be flattened, if practical, or the need for a truck-climbing lane should be evaluated." Due to the terrain that exists within the I-69 Tier 2, Section 5 project limits, the 10 mph critical length of grade is exceeded in several locations resulting in the need to evaluate the addition of truck climbing lanes as mitigation.

Analysis was done to evaluate flattening the grade to eliminate the areas where the critical length of grade is exceeded. The rolling terrain, excessive impacts, length of total reconstruction and costs make this option impractical. As an example, in the area of Kinser Pike, a 1.5% grade was designed. This resulted in approximately 1.75 miles of reconstruction with cuts and fills in excess of 40 feet through areas of a floodplain. Additionally, all bridges within the limits would have needed replacement. This would have significant impacts to right-of-way, streams, wetlands and forests. This exercise was quickly discarded with the most feasible option being the addition of truck climbing lanes to mitigate the critical length of grade.

Level of Service (LOS) analysis was performed for each location. In the rural sections (2-lanes each direction), a truck climbing lane is proposed at all locations of concern. LOS calculations for the typical two lane section were compared to that of adding the third lane/truck climbing lane to justify the need for that added lane. In the urban sections (3-lanes each direction), the LOS in the incline areas satisfied applicable design criteria with an acceptable LOS (LOS C or better). In addition, when there are more than two lanes in each direction, truck climbing lanes are typically not considered.

The following is a list of locations where the critical length of grade is exceeded:

- ***Between Vernal Pike and SR 46 - SB Lanes (approx. Sta. 1810+50 to 1830+00) – Urban Section***
  The total truck speed reduction for this area is **12 mph**. It is proposed that the existing length of grade of 1,950' be maintained although the critical length of grade per AASHTO for an approximate 3% grade is 1,750'. The proposed typical section in this area is 3 lanes in each direction. An additional lane is not considered in this situation due to the critical length of grade issues; however, there is an existing auxiliary lane in this area. It is proposed that the existing auxiliary lane be maintained to provide for acceleration and merging traffic due to the entrance ramp from the SR 46 interchange. The LOS in this area with 3 lanes in each direction is "C" in the proposed design year; therefore 3 lanes in each direction provides the capacity needed for the projected thru traffic. See Appendix "A" for a profile sheet showing the critical length of grade.

- ***From Kinser Pike to Griffy Creek – SB Lanes (approx. Sta. 1971+00 to 1997+25) – Urban Section***
  The total truck speed reduction for this area is **27 mph**. It is proposed that the existing length of grade of 2,625' be maintained although the critical length of grade per AASHTO for an approximate 5% grade is 950'. The proposed typical section in this area is 3 lanes in each direction. LOS calculations were performed and the 3 lane section provides a LOS of "B" in the design year for the projected traffic. An additional truck climbing lane is not necessary in addition to the 3-lane section already provided.

  A Level One Design Exception will be necessary in this area for exceeding the maximum grade. For a design speed of 70 mph in accordance with IDM Fig. 53.1, the maximum grade is 4%. The existing grade through this area is 5%. Several options to correct the grade to meet the 4% maximum requirement were evaluated. The total truck speed reduction for the 4% option was 24 mph as compared to 27 mph for the 5% grade. Cost comparisons were also prepared and are available for review in the Level One Design Exception Request. Note that even if the grade is reduced to the maximum 4%, critical length of grade would still be exceeded for this location. See Appendix "B" for a profile sheet showing the critical length of grade.

- ***Ellis Road to N. Wayport Rd. - NB Lanes (approx. Sta. 2054+00 to 2104+75)– Urban Section***
  The total truck speed reduction for this area is **28 mph**. It is proposed that the existing length of grade of 5,075' be maintained although the critical length of grade per AASHTO for a 2% approach grade is 2,300'. The existing grade consists of a 2% grade for 1860-foot then a 4% grade for 3215-foot. The proposed typical section in this area is 3 lanes in each direction. The LOS in this area with 3 lanes in each direction is "C" in the proposed design year; therefore 3 lanes in each direction provide the capacity needed for the projected traffic. An additional truck climbing lane is not required in addition to the 3-lane section already provided. See Appendix "C" for a profile sheet showing the critical length of grade.

- ***Through Bifurcation – SB Lanes (approx. Sta. 2328+50 to 2378+50) – Rural Section***
  The total truck speed reduction for this area is **33 mph**. It is proposed that the existing length of grade of 6,275' be maintained although the critical length of grade per AASHTO for a 2% approach grade is 3,000'. The existing grade consists of a 2% grade for 4050-foot then a 5% grade for 2225-foot. It is proposed that a truck climbing lane be added in the southbound direction. A Level One Design Exception will be necessary in this area for exceeding the maximum grade. For a design speed of 70 mph in accordance with IDM Fig. 53-1, the maximum grade is 4%. The existing grade through this area is 5%. An option to correct the grade to meet the 4% maximum requirement was evaluated. The total truck speed reduction for the 4% option was 30 mph as compared to 33 mph for the 5% grade. Cost comparisons were also prepared and are available for review in the Level One Design Exception Request. Note that even if the grade is reduced to the maximum 4%, a truck climbing lane would still be required for this location.

  LOS calculations were performed in this area. LOS on the upgrade in the southbound direction is forecasted at LOS D if only two lanes are provided; it improves to LOS C if a truck climbing lane is provided on the upgrade. Forecasts show LOS C on the level approach section. Per IDM Section 44-2.01(02), a climbing lane may be warranted if there is a reduction of one or more LOS when moving from the approach segment to the upgrade. See Appendix "D" for a profile sheet showing the critical length of grade.

- ***South of Paragon Road - NB Lanes (approx. Sta. 2465+00 to 2483+75) – Rural Section***
  The total truck speed reduction for this area is **13 mph**. It is proposed that the existing length of grade of 1,875' be maintained although the critical length of grade per AASHTO for an approximate 3.5% grade is 1,500'. It is proposed that the existing truck climbing lane be maintained and extended in the northbound direction.

  LOS calculations were performed in this area. With only two lanes in the northbound direction, a LOS of "C" is provided on the upgrade. When in the level area approaching the upgrade, a LOS of "C" is also provided. By adding the third lane in this area as a truck climbing lane, a LOS of "B" was achieved on the upgrade. Even though the LOS doesn't vary between the level approach and the upgrade, there is an existing truck climbing lane in this area and it is recommended to be maintained. See Appendix "E" for a profile sheet showing the critical length of grade.

- ***North of Paragon Road - SB Lanes (approx. Sta. 2492+75 to 2537+00) – Rural Section***
  The total truck speed reduction for this area is **20 mph**. It is proposed that the existing length of grade of 4,440' be maintained although the critical length of grade per AASHTO for a 1.5% approach grade is 3,000'. The existing grade consists of a 1.5% grade for 2350-foot then a 4%

grade for 2090-foot. It is proposed that a new truck climbing lane be constructed in the southbound direction, as no such feature currently exists.

LOS calculations were performed in this area. With only two lanes in the northbound direction, a LOS of "C" is provided on the upgrade. When in the level area approaching the upgrade, a LOS of "C" is also provided. By adding the third lane in this area as a truck climbing lane, a LOS of "B" was achieved on the upgrade. Even though the LOS doesn't vary between the level approach and the upgrade, due to there being a greater reduction in speed in this section as compared to that in the northbound direction and the fact that the northbound direction already contains a truck climbing lane, it is recommended that one be constructed in this location. See Appendix "F" for a profile sheet showing the critical length of grade.

Appendix "G" provides the charts used to determine the speed reductions at each locations based on the charts from the AASHTO "A Policy on Geometric Design of Highways and Streets."

Overall Justification – Critical Length of Grade Design Exceptions

The existing terrain does not allow critical length of grade criteria to be fully satisfied without extensive impacts to the surrounding area, as well as significantly-increased costs. The proposed alternatives were chosen to avoid these environmental impacts and to minimize costs.

- ***Experience with Differing Truck Speeds***
  Indiana and several other states have truck speed limits set lower than other vehicle traffic on rural interstates. Typically, the posted speed limit for trucks is 5 to 15 mph slower than the maximum speed limit for other vehicles traveling the same routes. Therefore, the drivers in Indiana are conditioned to expect trucks to be traveling at a slower speed.

- ***Truck Climbing Lanes***
  In all of the areas where the critical length of grade is exceeded, truck climbing, auxiliary lanes, or a three lane section will be provided. This allows trucks to travel up the incline without an inordinate speed reduction in the adjacent through lanes of traffic. In locations where new truck climbing lanes are proposed, it will be an improvement over existing conditions. There will be an additional travel lane for trucks to climb the incline without slowing down other vehicular traffic. In many locations where it is proposed that the existing truck climbing lane be maintained, the length of the truck climbing lane is extended.

Level 2 Design Feature – Roadside Safety Design Element – Barrier Offset

The desirable offset to a barrier from the effective usable-shoulder width is 2 feet with a minimum of 1 foot for new construction. For reconstruction projects, the desirable barrier offset is 2 feet with the minimum being 0 feet.

- ***From South End of Project to approx. SR 46***

  In the urban section, it is proposed to add the third lane to the inside of the existing travel lanes in order to utilize the existing infrastructure. The 12 feet median shoulder is necessary due to the number of lanes in each direction and the projected truck traffic. Throughout much of the urban section, the existing median from inside edge of pavement to inside edge of pavement is approximately 50'. This will allow adequate space to provide an additional 12 feet travel lane,

however, with a 2'-6" median barrier, this only allows for an 11'-9" median shoulder. A Level One Design Exception is being requested for the median shoulder width. Therefore, it is proposed that the median shoulder be constructed at a minimum width of 11'-9" adjacent to the median barrier without providing the additional width for the barrier offset.

- ***Through Bifurcation – Northbound Lanes (approximately Sta. 2325+00 to 2405+00)***

  There are currently two existing through lanes in each direction. The existing paved shoulders vary between 4-9' (inside) and 8-10' (outside). It is proposed that the median shoulders be reconstructed to required 4' width with the 2' additional barrier offset where adjacent to guardrail. The required outside shoulder width is 12'; most of this area will require gurardrail placement adjacent to the outside shoulder. However, any widening would involve significant impacts to natural resources. The 12' width should provide adequate width for emergency stops. It is not proposed to provide an additional 2' barrier offset along the outside shoulder. The primary objective for this is to minimize impacts to the adjacent Morgan-Monroe State Forest, and minimize construction costs.

  The barrier offset is the only substandard design element within these limits. However, many of the design elements in this area are at the upper limits of their acceptable ranges. Existing conditions will be improved by the widening of the outside shoulder and addition of guardrail; however, there currently are a high number of accidents in this area. This may be related to having multiple design elements within a rather short area which are near their upper boundaries. Also, this area is heavily wooded on both sides of the roadway, such that much of its length is shaded most of the time. This appears to be a contributing factor to the number of accidents, because approximately 50% occur under wet or icy conditions. Many accidents involve a collision with an animal. There are also superelevated reverse curves, along with a vertical downgrade at 4.0% (the maximum for interstates in rolling terrain). These factors stem from the surrounding natural environment. Further discussion of these issues will be provided in the Engineer's Report.

Crash Histories

The information below summarizes the crash data and traffic data in each of the locations. Crash data were obtained for a 5-year period from 2007 – 2011. Crash rates for each segment were also calculated and compared to those from a 2010 Corridor Model for SR 37 South of I-465[1]to assess the existing rates.

For critical length of grade, the primary factor relating to the crash data that would be a major indicator of a problem would be rear end collisions, specifically following too closely. There is no significant history of rear-end type accidents in the specific locations where the truck climbing lanes are being proposed or added.

- ***Critical Length of Grade - Between Vernal Pike and SR 46 - SB Lanes (approx. Sta. 1810+50 to 1830+00)***

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[1] **Crash Data Source:** Indiana Crash Facts 2010. Indiana Criminal Justice Institute. <Retrieved from http://www.in.gov/cji/files/FactBook_2010.pdf> in July 2012.
VMT Data Source: 2010 Indiana Historic Traffic Data by County and System. INDOT. Retrieved from http://www.in.gov/indot/2469.htm
I69 Corridor Model for Section 5 developed by BLA, Inc.2011-2012

During the 5-year period, in this area, there were a total of 52 accidents. Of those, 40 were rear end collisions and of the 40 rear end collisions, 20 were attributed to following too closely. From the attached map that shows the locations and types of accidents, it is noted that the majority of the accidents were clustered at the intersection of SR 37 and Vernal Pike and most were associated with the intersection itself and probably not related to the grade.

The crash rate for this area over the five year period was 398.6 accidents per 100 million vehicle miles traveled. Compared to the annual crash rate for "Other Urban Freeways" of 115.9, this would indicate a relative high number of crashes in this area. The proposed improvements of the elimination of the at-grade signalized intersection at Vernal Pike and the addition of the median barrier will improve the safety in this area and reduce the number of crashes.

Vernal Pike to SR 46 - Southbound		
Year	**Total No. of Accidents**	**Rear End / Following Too Closely**
2007	12	7 / 3
2008	8	7 / 5
2009	9	8 / 4
2010	16	12 / 5
2011	7	6 / 3
Crash Rates Average Yearly Accidents = 10.4 2010 AADT = 19,341 Segment Distance = 1950 ft Annual VMT = 2,608,907		
Roadway Segment Annual Accident Rate (per 100 million VMT)		398.6
Annual Accident Rate for Other Urban Freeway (per 100 million VMT)		115.9

- ***Critical Length of Grade - From Kinser Pike to Griffy Creek – SB Lanes (approx. Sta. 1971+00 to 1997+25)***

During the 5-year period, in this area, there were only two accidents in this area and neither of them were rear end collisions.

The crash rate for this area over the five year period 23.3 accidents per 100 million vehicle miles traveled. Compared to the annual crash rate for "Rural Principal Arterials" of 86.7, this would indicate that the numbers of accidents that occur in this area are very low.

Kinser Pike to Griffy Creek - Southbound		
Year	**Total No. of Accidents**	**Rear End / Following Too Closely**
2007	1	0 / 0
2008	0	0 / 0
2009	0	0 / 0
2010	0	0 / 0
2011	1	0/ 0
Crash Rates Average Yearly Accidents = 0.4 2010 AADT = 9,471 Segment Distance = 2625 ft Annual VMT = 1,719,753		
Roadway Segment Annual Accident Rate (per 100 million VMT)	23.3	
Annual Accident Rate for Rural Principal Arterials (per 100 million VMT)	86.7	

- ***Critical Length of Grade - Ellis Road to N. Wayport Rd. - NB Lanes (approx. Sta. 2054+00 to 2104+75)***

  During the 5-year period, in this area, there were a total of 14 accidents. Of those, 5 were rear end collisions and were attributed to following too closely. From the attached map that shows the locations and types of accidents, it is noted that the majority of the accidents were clustered at the intersection of SR 37 and the access point for Showers Road/Wylie Road and most were associated with the intersection itself and probably not related to the grade.

  The crash rate for this area over the five year period was 63.0 accidents per 100 million vehicle miles traveled. Compared to the annual crash rate for "Rural Principal Arterials" of 86.7, this would indicate that the numbers of accidents that occur in this area are low compared to the average for the corridor.

Ellis Road to N. Wayport Road - Northbound		
Year	**Total No. of Accidents**	**Rear End / Following Too Closely**
2007	2	1 / 1
2008	7	4 / 3
2009	1	0 / 0
2010	4	0 / 0
2011	0	0 / 0
Crash Rates Average Yearly Accidents = 2.8 2010 AADT = 12,669 Segment Distance = 5075 ft Annual VMT = 4,447,692		
Roadway Segment Annual Accident Rate (per 100 million VMT)	63.0	
Annual Accident Rate for Rural Principal Arterials (per 100 million VMT)	86.7	

- ***Critical Length of Grade - Through Bifurcation – SB Lanes (approx. Sta. 2328+50 to 2378+50)***

During the 5-year period, in this area, there were a total of 13 accidents. Of those, 2 were rear end collisions and only 1 was attributed to following too closely.

The crash rate for this area over the five year period was 65.1 accidents per 100 million vehicle miles traveled. Compared to the annual crash rate for "Rural Principal Arterials" of 86.7, this would indicate that the numbers of accidents that occur in this area are low compared to the average for the corridor.

Through Bifurcation - Southbound		
Year	**Total No. of Accidents**	**Rear End / Following Too Closely**
2007	2	1 / 1
2008	4	0 / 0
2009	2	0 / 0
2010	2	0 / 0
2011	3	1 / 0

Crash Rates Average Yearly Accidents = 2.6 2010 AADT = 11,552 Segment Distance = 5000 ft Annual VMT = 3,995,691	
Roadway Segment Annual Accident Rate (per 100 million VMT)	65.1
Annual Accident Rate for Rural Principal Arterials (per 100 million VMT)	86.7

- ***Critical Length of Grade - South of Paragon Road - NB Lanes (approx. Sta. 2465+00 to 2483+75)***

  During the 5-year period, in this area, there were a total of 5 accidents. Of those, none were rear end type collisions.

  The crash rate for this area over the five year period was 68.3 accidents per 100 million vehicle miles traveled. Compared to the annual crash rate for "Rural Principal Arterials" of 86.7, this would indicate that the numbers of accidents that occur in this are low compared to the average for the corridor.

South of Paragon Rd - Northbound		
Year	**Total No. of Accidents**	**Rear End / Following Too Closely**
2007	1	0 / 0
2008	1	0 / 0
2009	0	0 / 0
2010	1	0 / 0
2011	2	0 / 0
Crash Rates Average Yearly Accidents = 1.0 2010 AADT = 11,281 Segment Distance = 1875 ft Annual VMT = 1,463,168		
Roadway Segment Annual Accident Rate (per 100 million VMT)		68.3
Annual Accident Rate for Rural Principal Arterials (per 100 million VMT)		86.7

- ***Critical Length of Grade - North of Paragon Road - SB Lanes (approx. Sta. 2492+75 to 2537+00)***

  During the 5-year period, in this area, there were a total of 5 accidents. Of those, none were rear end type collisions.

  The crash rate for this area over the five year period was 52.9 accidents per 100 million vehicle miles traveled. Compared to the annual crash rate for "Rural Principal Arterials" of 86.7, this would indicate that the numbers of accidents that occur in this area are low compared to the average for the corridor.

North of Paragon Rd - Southbound		
Year	**Total No. of Accidents**	**Rear End / Following Too Closely**
2007	1	0 / 0
2008	1	0 / 0
2009	2	0 / 0
2010	5	0 / 0
2011	0	0 / 0
Crash Rates Average Yearly Accidents = 1.8 2010 AADT = 11,106 Segment Distance = 4425 ft Annual VMT = 3,399,477		
Roadway Segment Annual Accident Rate (per 100 million VMT)	52.9	
Annual Accident Rate for Rural Principal Arterials (per 100 million VMT)	86.7	

- ***Barrier Offset – Through Bifurcation – Northbound Lanes (approximately Sta. 2325+00 to 2405+00)***

  During the 5-year period, in this area, there were a total of 36 accidents. Of these, 19 were a result of a vehicle that ran off the road. Ten of these occurred when weather conditions were snow/sleet/freezing rain and the vehicle was traveling too fast for the weather conditions. Four were the result of the vehicle running off the road to the right side and the remaining five were attributed to either the driver falling asleep or an animal in the roadway. While the vehicles running off the road to the right could possibly be associated with a substandard shoulder width, the number of this type of accident is considered very low (one or less per year).

  The crash rate for this area over the five year period was 114.1 accidents per 100 million vehicle miles traveled. Compared to the annual crash rate for "Rural Principal Arterials" of 86.7, this would

indicate a relative high number of crashes in this area. The proposed improvements of the providing wider outside shoulders will improve the safety in this area.

Through Bifurcation - Northbound				
2007 - 2011				
Crash Type	**PDO**	**Injury**	**Fatality**	**Total**
Head-On	6	1	0	7
Run Off	16	3	0	19
Rear End	3	0	0	3
Right Angle	0	3	0	3
Sideswipe	1	0	0	1
Other	3	0	0	3
Total	29	7	0	36
Crash Rates Average Yearly Accidents = 7.2 2010 AADT = 11,404 Segment Distance = 8000 ft Annual VMT = 6,311,354				
Roadway Segment Annual Accident Rate (per 100 million VMT)	114.1			
Annual Accident Rate for Rural Principal Arterials (per 100 million VMT)	86.7			

Overall Recommendations

This analysis of recommended design exceptions supports consideration of the DEIS Preferred Alternative 8. They accommodate the truck speed reductions stated above (between 12 and 33 mph), by providing at least three lanes of travel or providing a truck climbing lane. The Indiana Design Manual (see IDM Section 44-2.0) provides that these are appropriate mitigation measures for such truck speed reductions.

It is also recommended that appropriate vertical grade warning signage be added to segments in which a truck speed reduction of greater than 10 mph is expected. Special warning signs may also be considered in the final design indicating “Slow Moving Trucks Next __ Miles” per the MUTCD manual.

Level Two Design Exception

Appendix "A" – Profile for Critical Length of Grade

Between Vernal Pike and SR 46 - SB Lanes (approx. Sta. 1810+50 to 1830+00) – Urban Section

Appendix "B" – Profile for Critical Length of Grade

From Kinser Pike to Griffy Creek – SB Lanes (approx. Sta. 1971+00 to 1997+25) – Urban Section

Appendix "C" – Profile for Critical Length of Grade

Ellis Road to N. Wayport Rd. - NB Lanes (approx. Sta. 2054+00 to 2104+75)– Urban Section

Appendix "D" – Profile for Critical Length of Grade

Through Bifurcation – SB Lanes (approx. Sta. 2328+50 to 2378+50) – Rural Section

Appendix "E" – Profile for Critical Length of Grade

South of Paragon Road - NB Lanes (approx. Sta. 2465+00 to 2483+75) – Rural Section

Appendix "F" – Profile for Critical Length of Grade

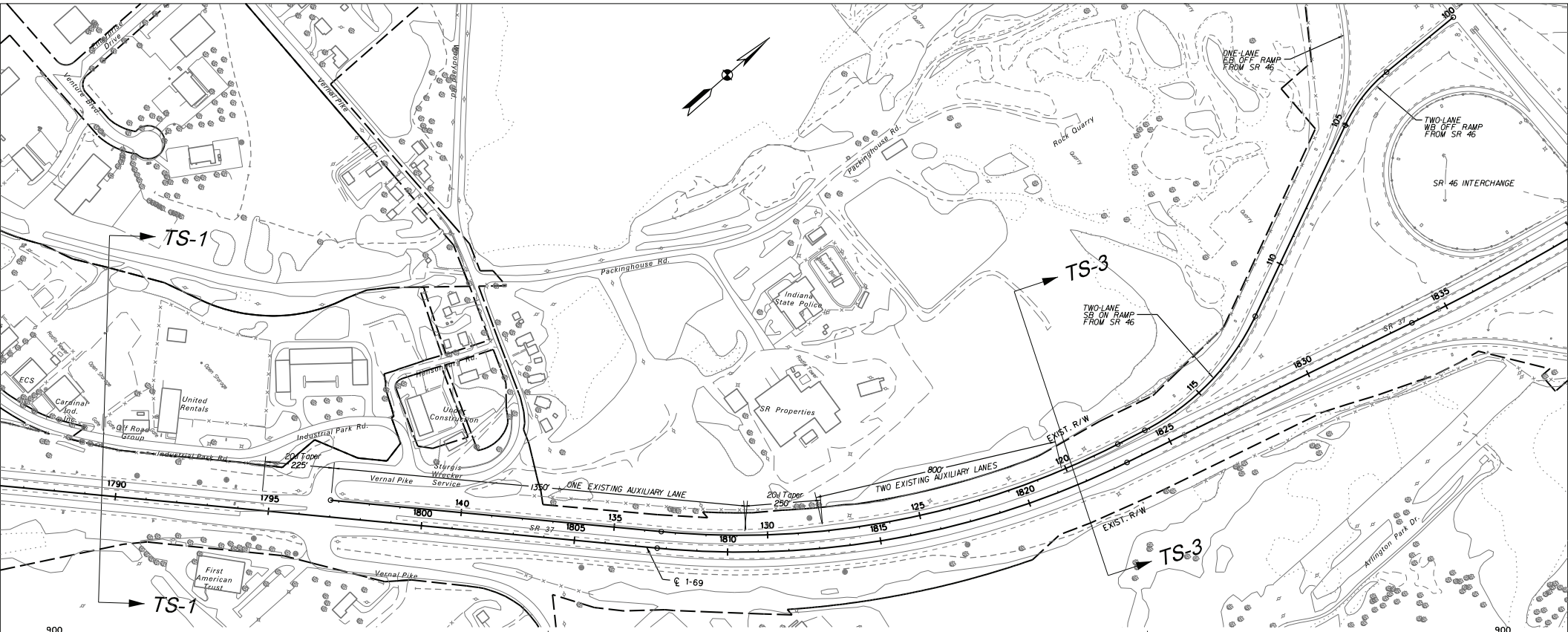
North of Paragon Road - SB Lanes (approx. Sta. 2492+75 to 2537+00) – Rural Section

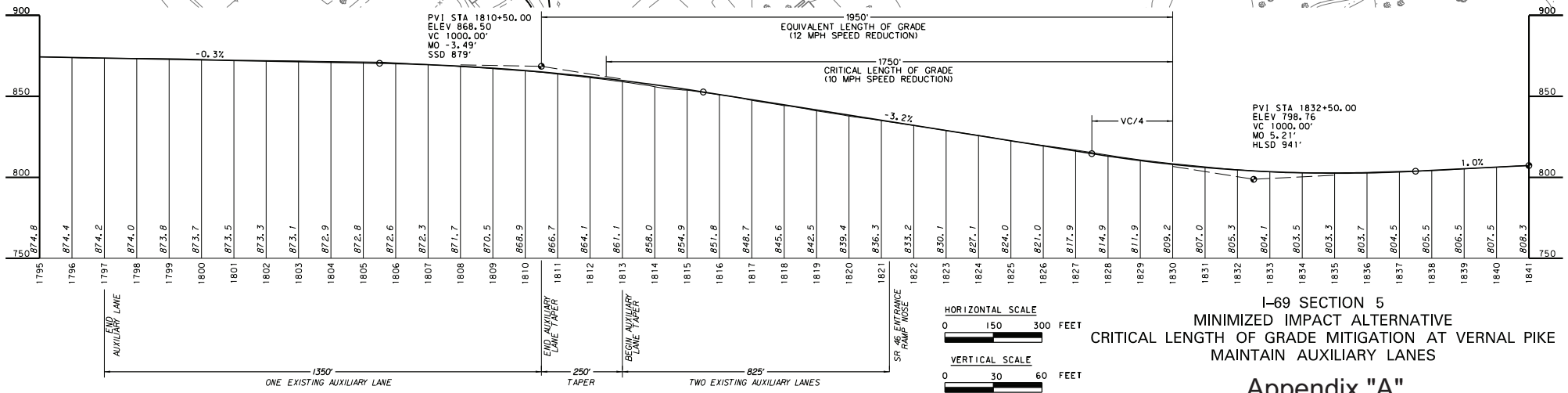
Appendix "G" – Speed Reduction for Critical Length of Grade

Appendix "A"

Profile for Critical Length of Grade

Between Vernal Pike and SR 46 - SB Lanes
(approx. Sta. 1810+50 to 1830+00) – Urban Section





HORIZONTAL SCALE
0 150 300 FEET

VERTICAL SCALE
0 30 60 FEET

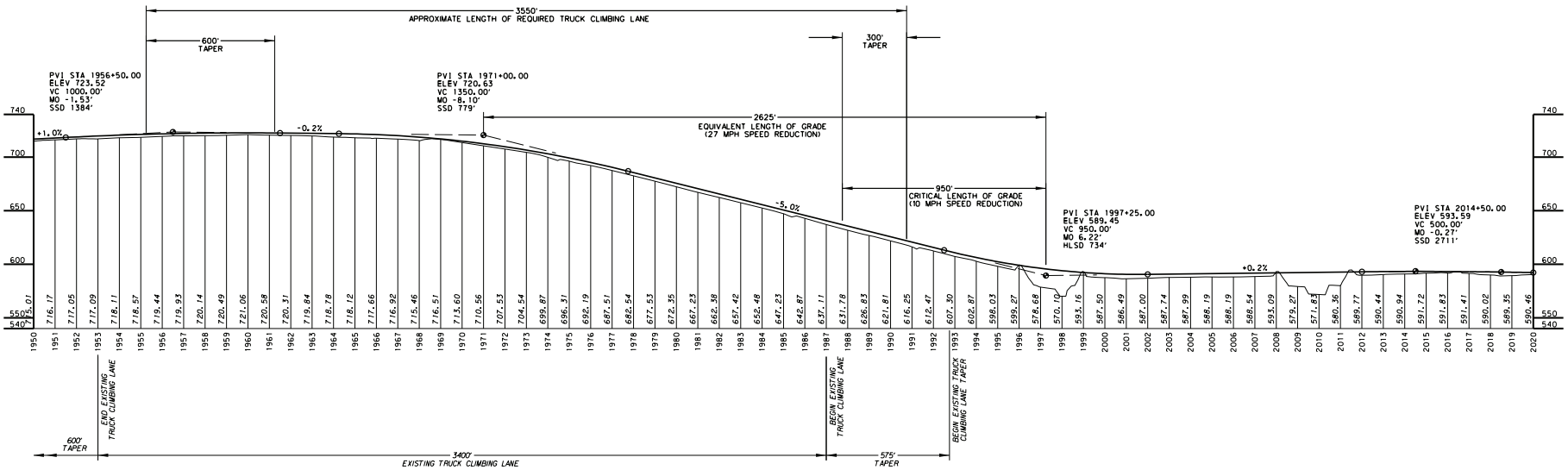
I-69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
CRITICAL LENGTH OF GRADE MITIGATION AT VERNAL PIKE
MAINTAIN AUXILIARY LANES

Appendix "A"

Appendix "B"

Profile for Critical Length of Grade

From Kinser Pike to Griffey Creek – SB Lanes
(approx. Sta. 1971+00 to 1997+25) – Urban Section



PROFILE – MAINLINE

I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT KINSER PIKE
MAINTAIN EXISTING 5% PROFILE GRADE WITH REQUIRED CLEAR ZONE

VERTICAL SCALE
0 50 100 FEET

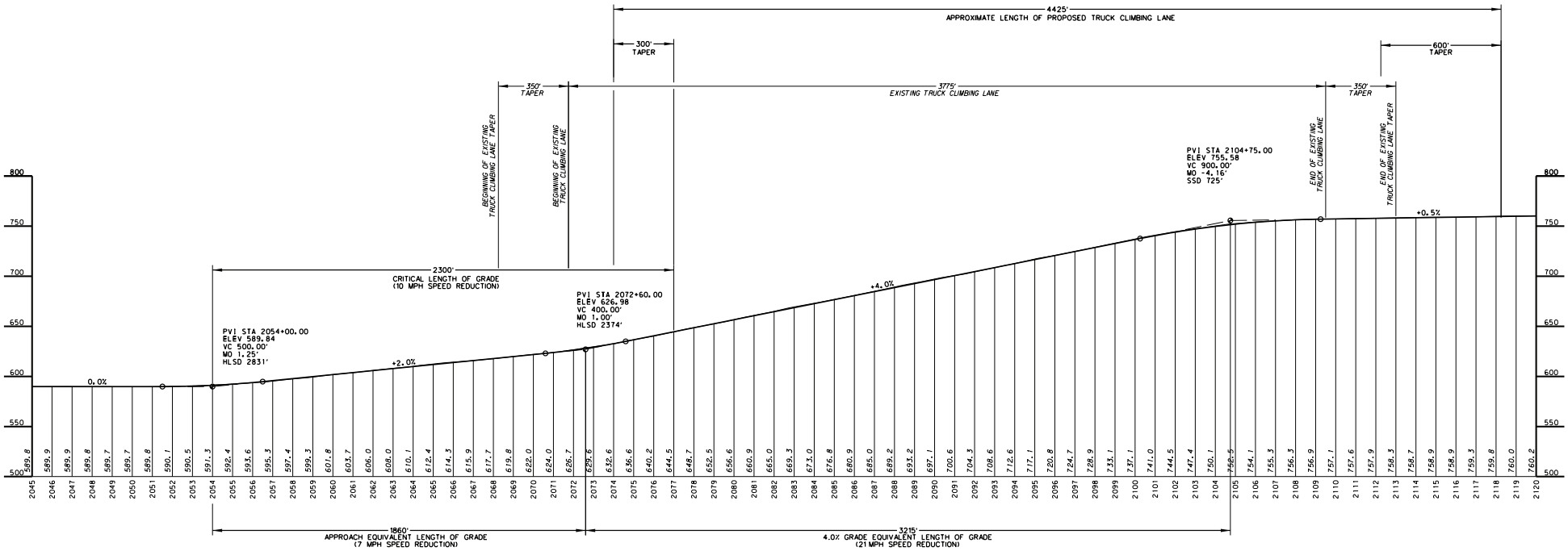
HORIZONTAL SCALE
0 250 500 FEET

Appendix "B"

Appendix "C"

Profile for Critical Length of Grade

Ellis Road to N. Wayport Rd. - NB Lanes
(approx. Sta. 2054+00 to 2104+75)– Urban Section



TANGENT	GRADE	LENGTH	SPEED REDUCTION*
APPROACH	2.0%	1,860'	7 MPH
GRADE	4.0%	3,215'	21 MPH
COMBINED		5,075'	28 MPH

*OBTAINED FROM FIGURE 3-24, 2011 AASHTO GREEN BOOK

I-69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
CRITICAL LENGTH OF GRADE MITIGATION BETWEEN ELLIS RD AND WAYPORT RD
MAINTAIN EXISTING NORTHBOUND TRUCK CLIMBING LANE

VERTICAL SCALE
0 50 100 FEET

HORIZONTAL SCALE
0 250 500 FEET

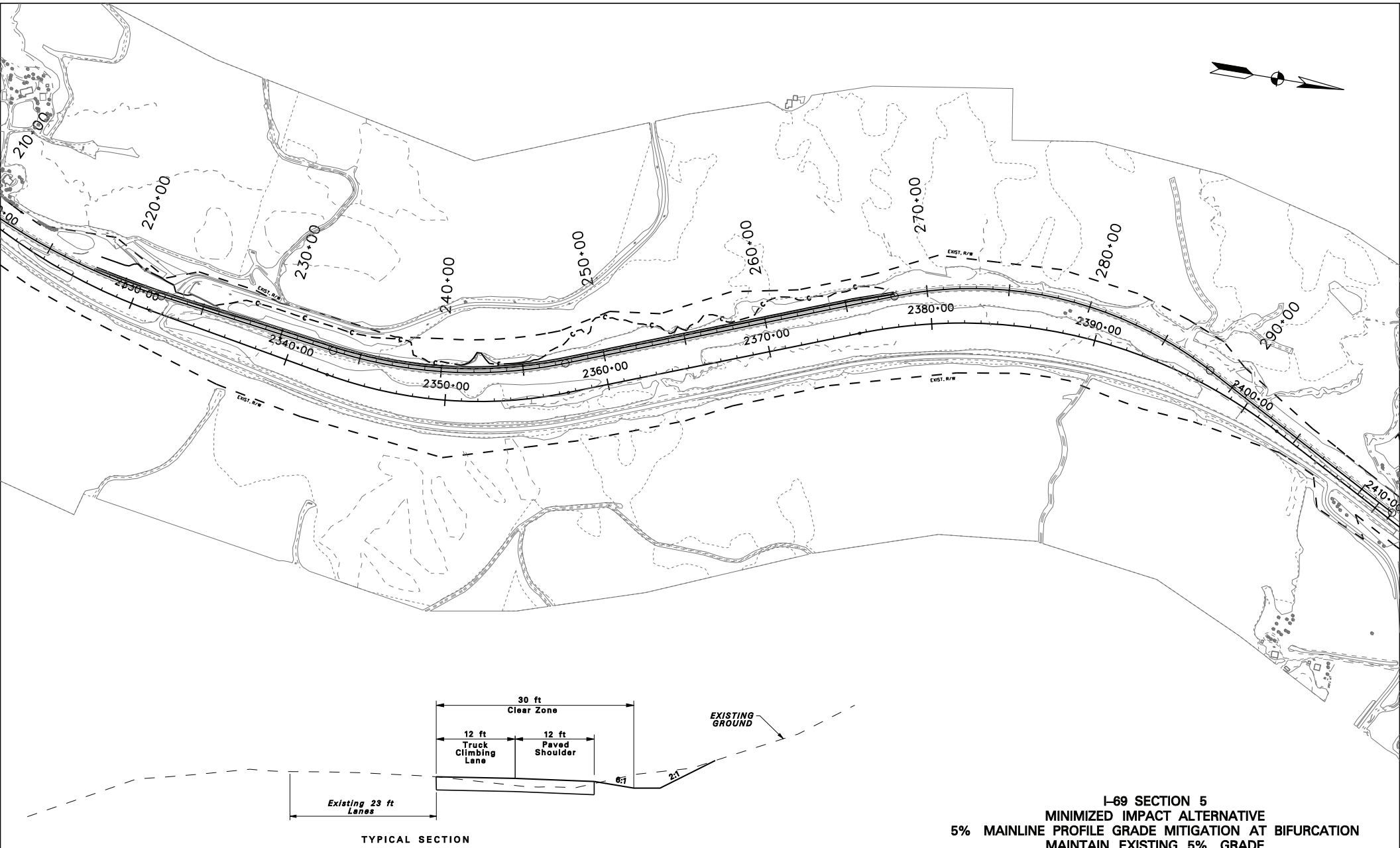
Appendix "C"

Appendix "D"

Profile for Critical Length of Grade

Through Bifurcation – SB Lanes

(approx. Sta. 2328+50 to 2378+50) – Rural Section

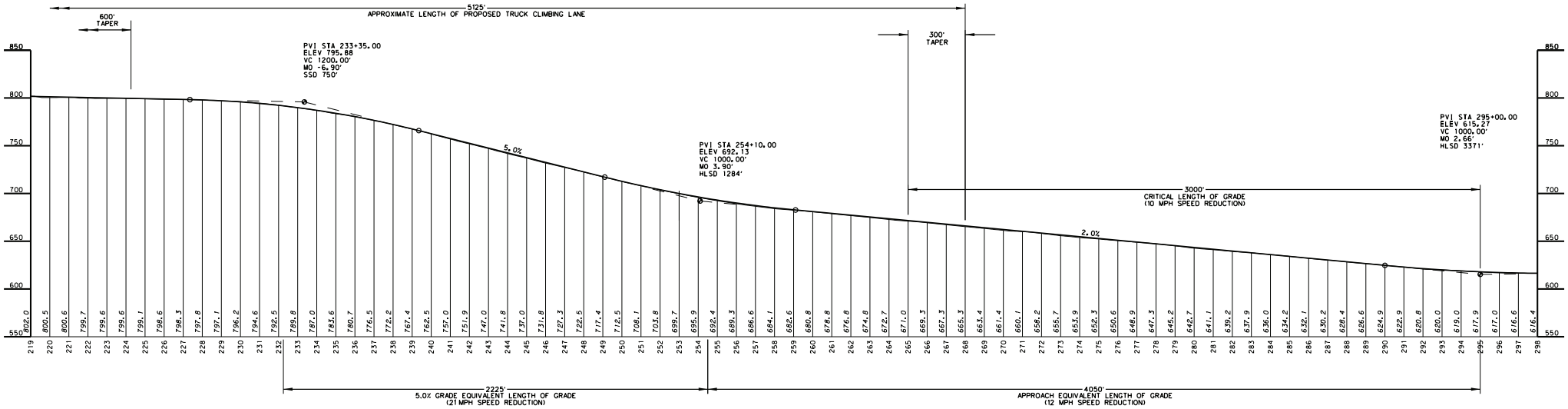


TYPICAL SECTION

I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT BIFURCATION
MAINTAIN EXISTING 5% GRADE

SCALE
0 250 500 FEET

Appendix "D"



TANGENT	GRADE	LENGTH	SPEED REDUCTION*
APPROACH	2.0%	4,050'	12 MPH
GRADE	5.0%	2,225'	21 MPH
COMBINED		6,275'	33 MPH

*OBTAINED FROM FIGURE 3-24, 2011 AASHTO GREEN BOOK

I-69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
5% MAINLINE PROFILE GRADE MITIGATION AT BIFURCATION
MAINTAIN EXISTING 5% GRADE

VERTICAL SCALE
0 50 100 FEET

HORIZONTAL SCALE
0 250 500 FEET

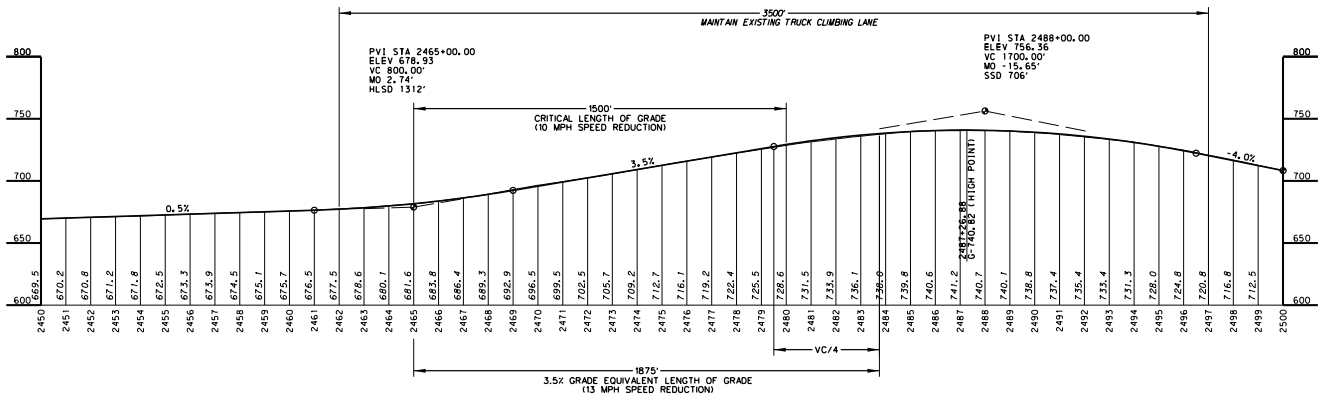
Appendix "D"

Appendix "E"

Profile for Critical Length of Grade

South of Paragon Road - NB Lanes

(approx. Sta. 2465+00 to 2483+75) – Rural Section



I–69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
CRITICAL LENGTH OF GRADE MITIGATION AT PARAGON
MAINTAIN NORTHBOUND TRUCK CLIMBING LANE

VERTICAL SCALE
0 50 100 FEET

HORIZONTAL SCALE
0 250 500 FEET

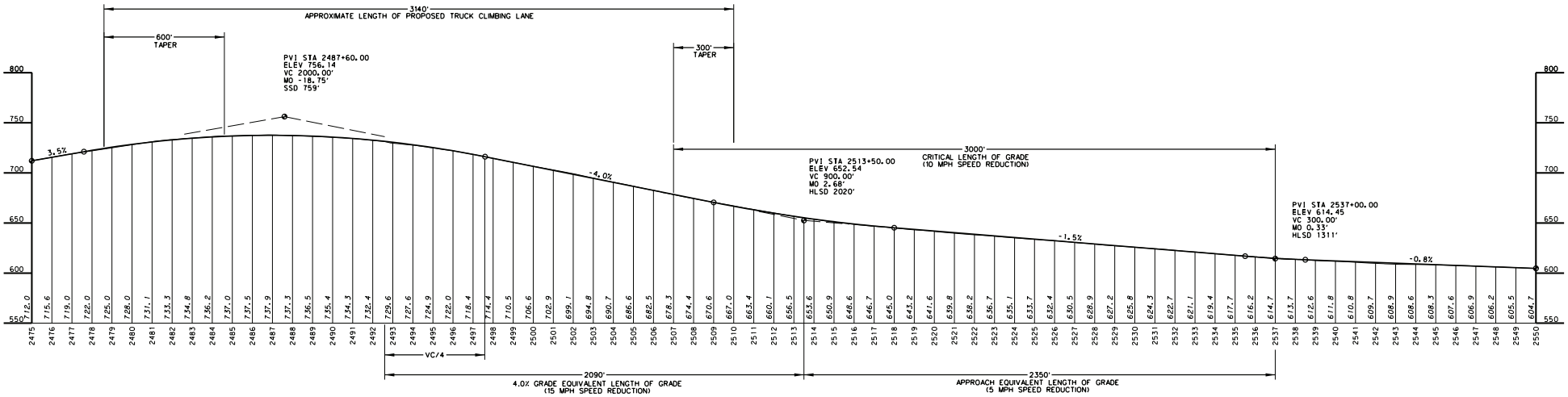
Appendix "E"

Appendix "F"

Profile for Critical Length of Grade

North of Paragon Road - SB Lanes

(approx. Sta. 2492+75 to 2537+00) – Rural Section



TANGENT	GRADE	LENGTH	SPEED REDUCTION*
APPROACH	1.5%	2,350'	5 MPH
GRADE	4.0%	2.090'	15 MPH
COMBINED		4,440'	20 MPH

*OBTAINED FROM FIGURE 3-24, 2011 AASHTO GREEN BOOK

I-69 SECTION 5
MINIMIZED IMPACT ALTERNATIVE
CRITICAL LENGTH OF GRADE MITIGATION AT PARAGON
ADD SOUTHBOUND TRUCK CLIMBING LANE

VERTICAL SCALE
0 50 100 FEET

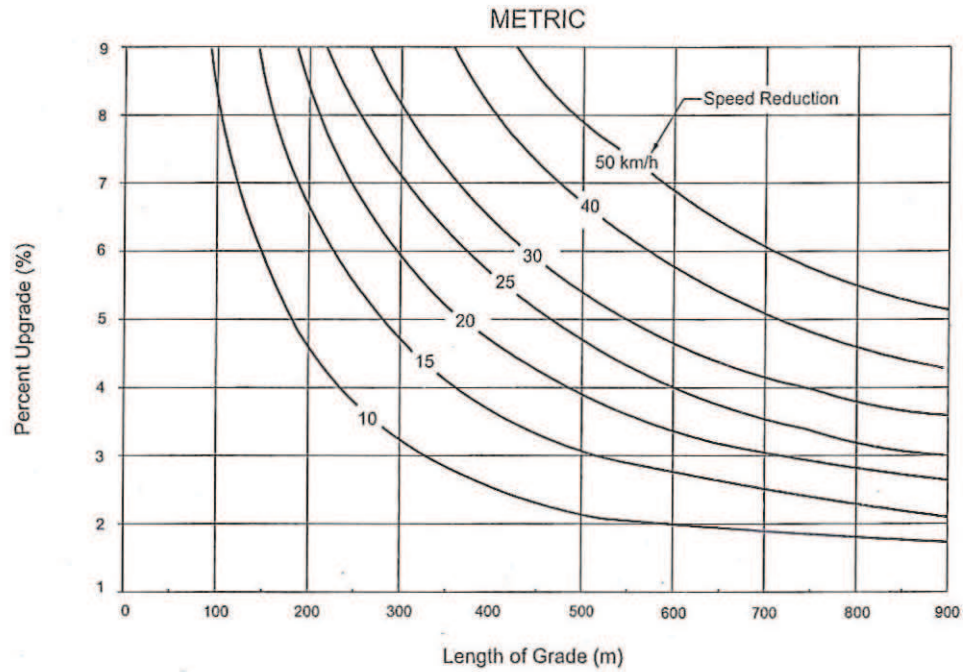
HORIZONTAL SCALE
0 250 500 FEET

Appendix "F"

Appendix "G"

Speed Reduction for Critical Length of Grade

VERNAL/SR 46 (3%)



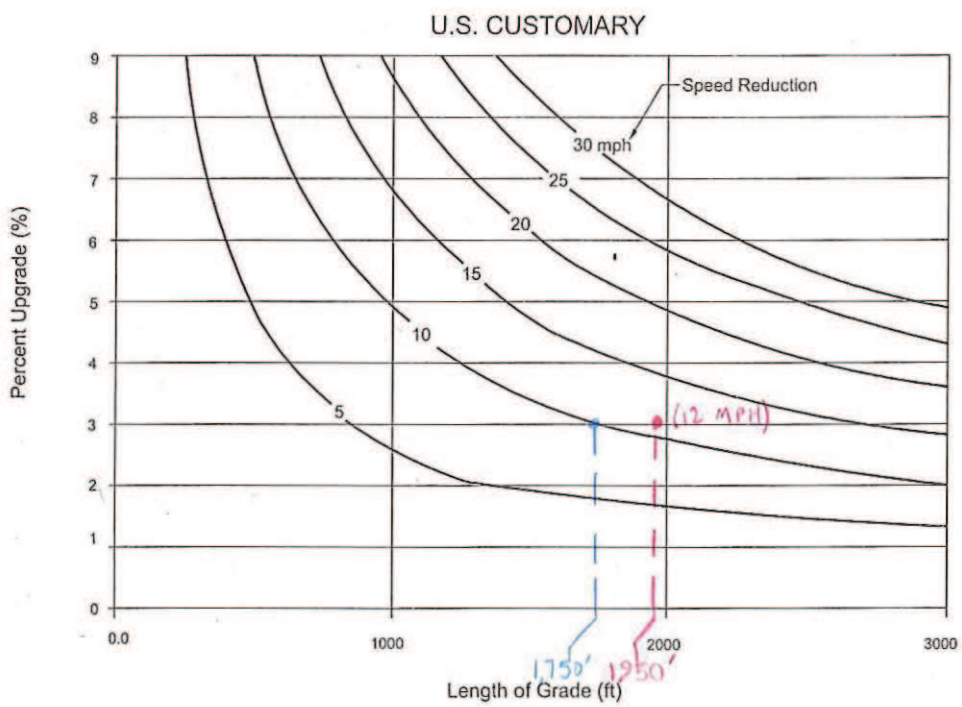


Figure 3-28. Critical Lengths of Grade for Design, Assumed Typical Heavy Truck of 120 kg/kW [200 lb/hp], Entering Speed = 110 km/h [70 mph]

LEGEND:

Equivalent Length of grade

Critical Length of grade

Appendix "G-1"

KINSER PIKE
5% EXISTING

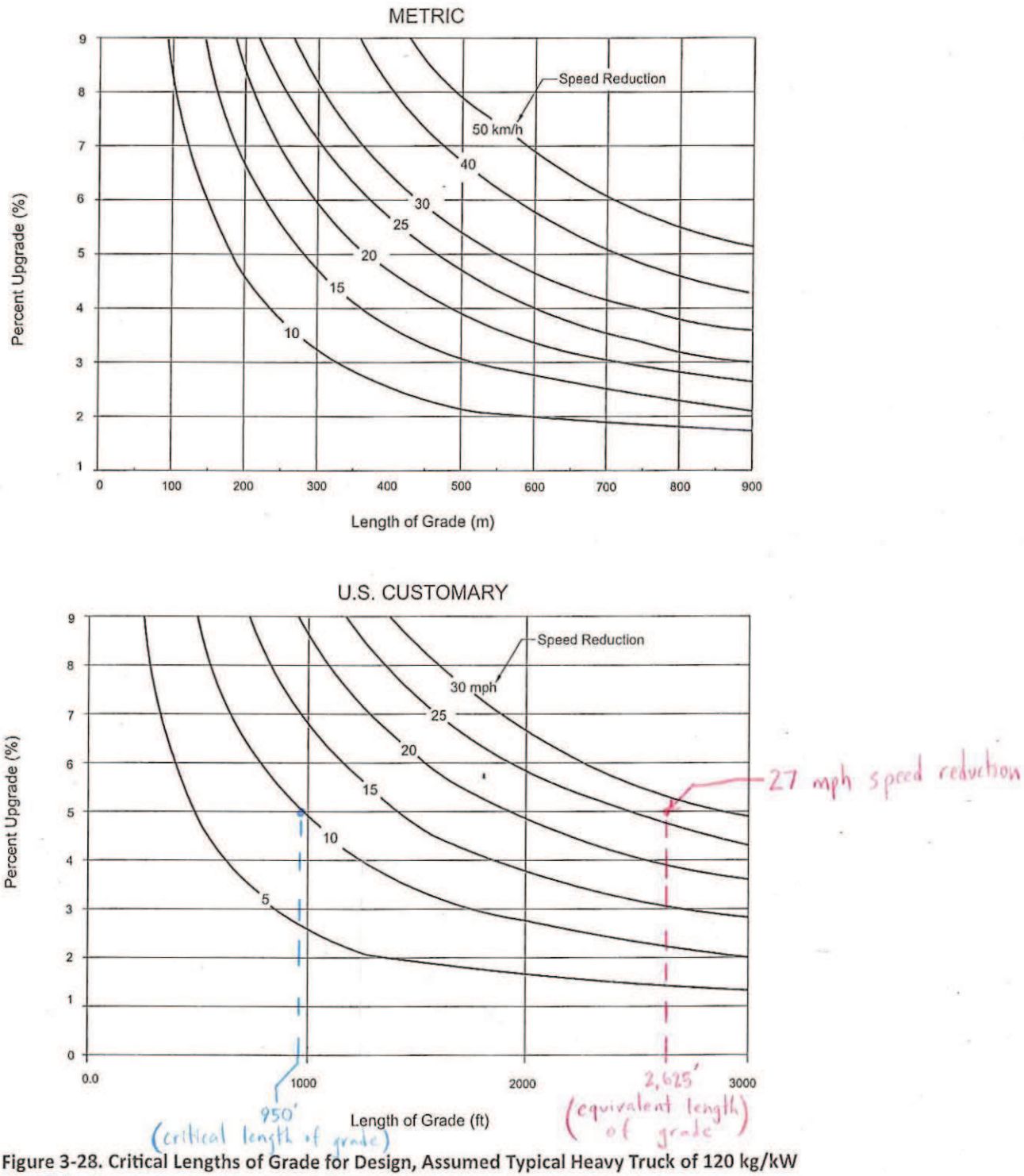


Figure 3-28. Critical Lengths of Grade for Design, Assumed Typical Heavy Truck of 120 kg/kW [200 lb/hp], Entering Speed = 110 km/h [70 mph]

Appendix "G-2"

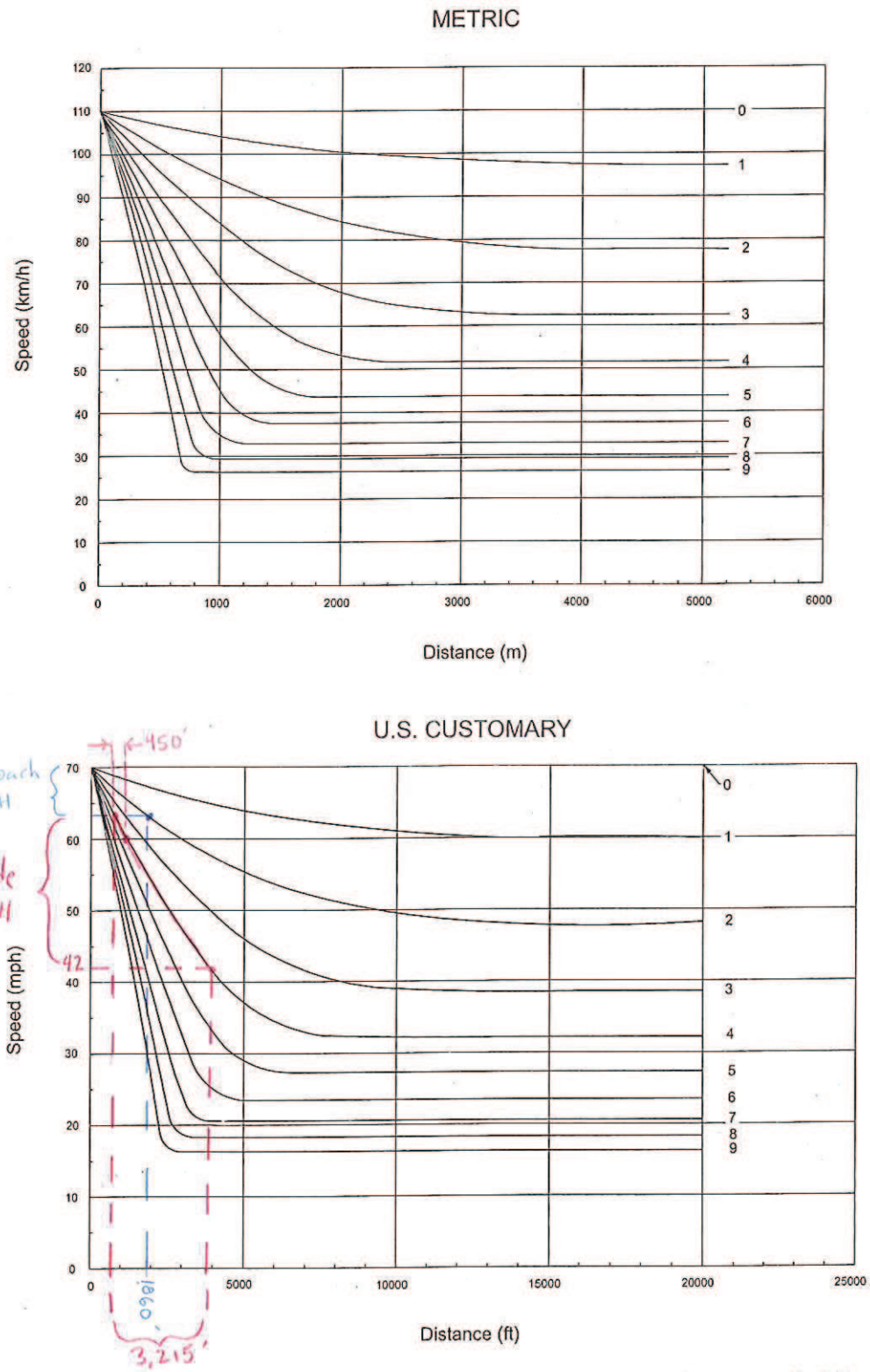


Figure 3-24. Speed-Distance Curves for a Typical Heavy Truck of 120 kg/kW [200 lb/hp] for Deceleration on Upgrades

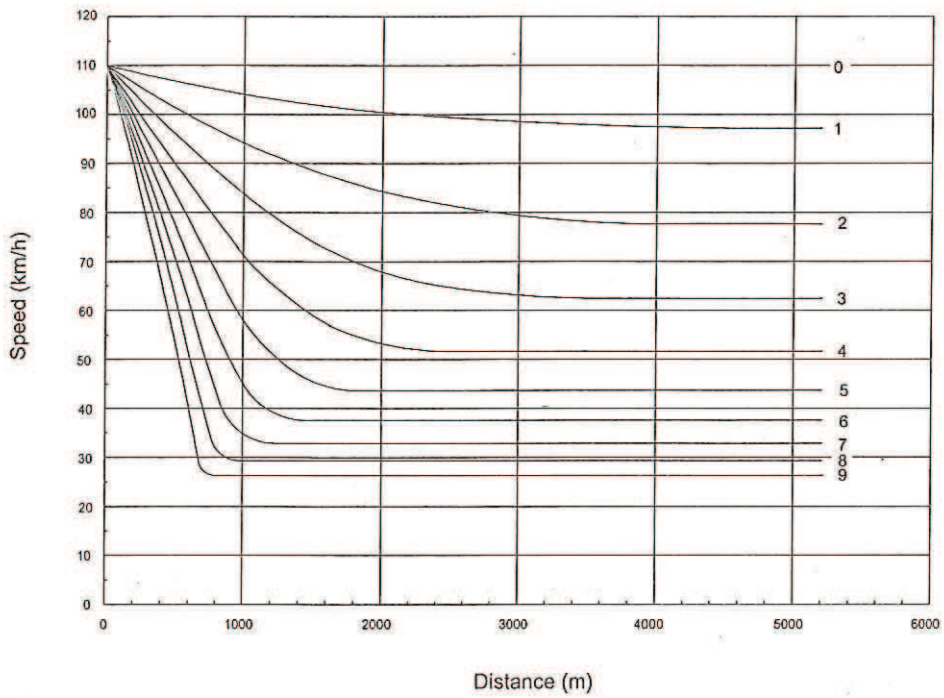
Critical length of grade = Length of Approach + distance along 4% to reach 10 mph reduction

= 1860' + 450' ≅ 2,300'

Appendix "G-3"

5% (EXISTING)

METRIC



U.S. CUSTOMARY

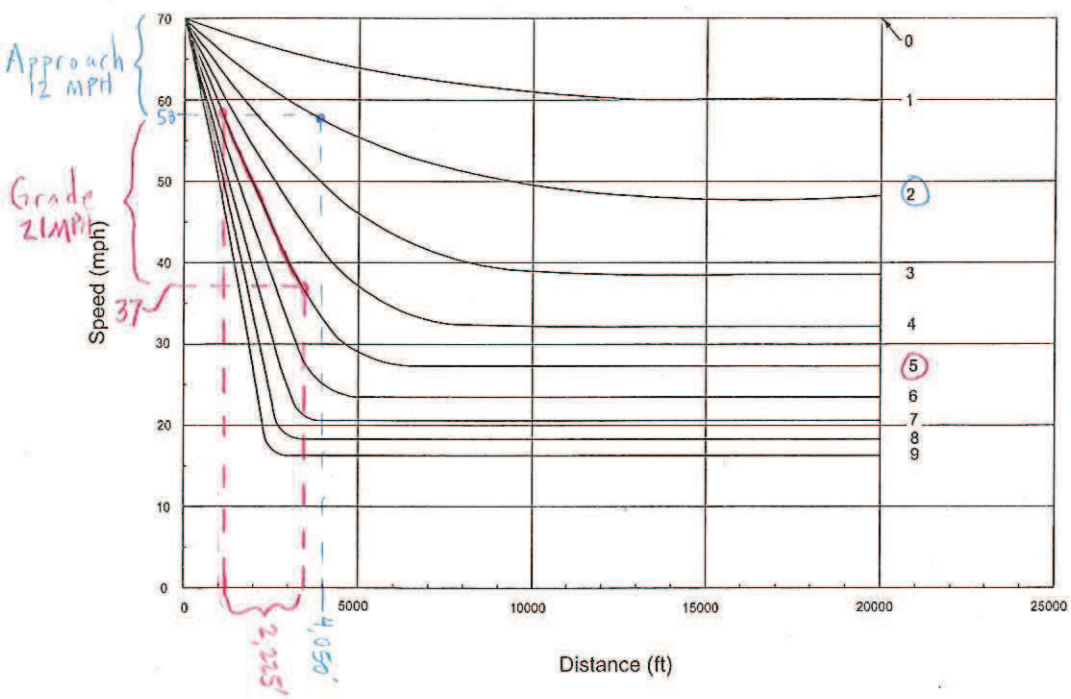
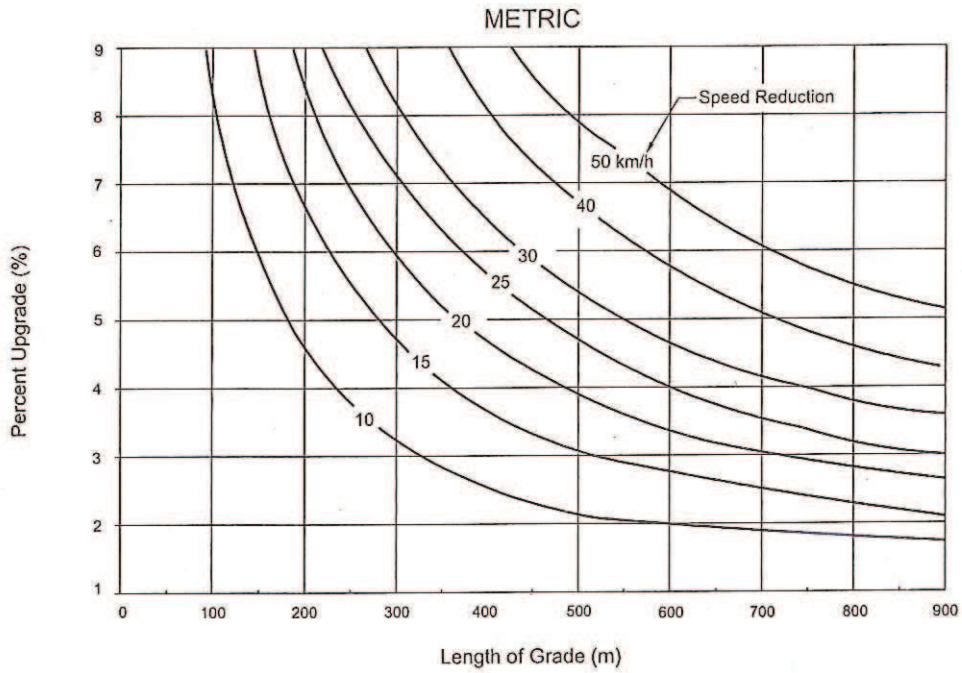


Figure 3-24. Speed-Distance Curves for a Typical Heavy Truck of 120 kg/kW [200 lb/hp] for Deceleration on Upgrades

Appendix "G-4"

Paragon NB (3.5%)



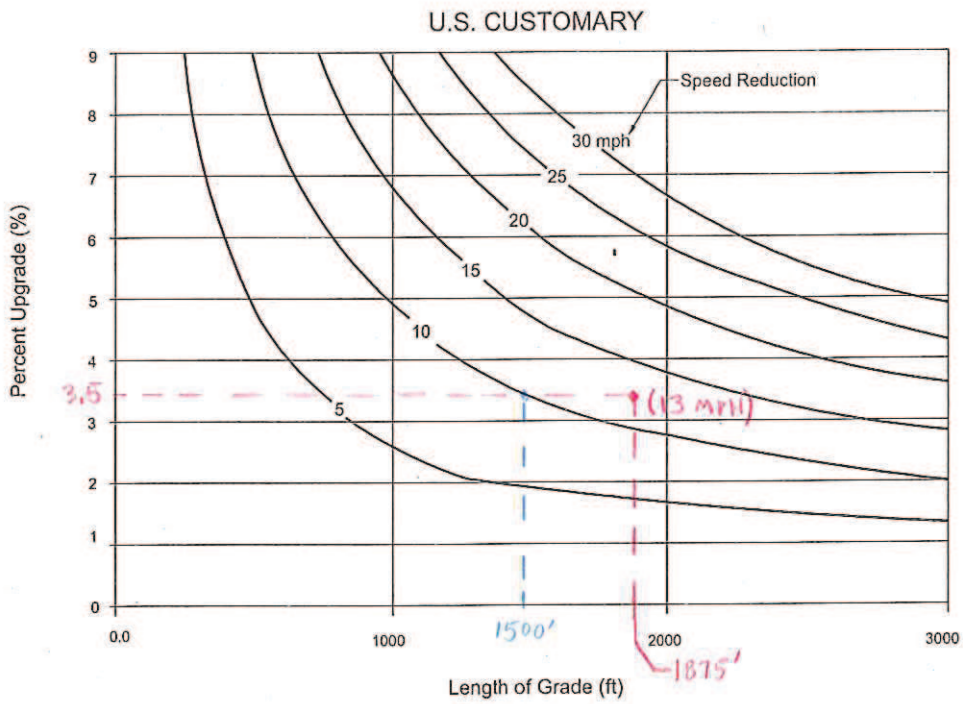


Figure 3-28. Critical Lengths of Grade for Design, Assumed Typical Heavy Truck of 120 kg/kW [200 lb/hp], Entering Speed = 110 km/h [70 mph]

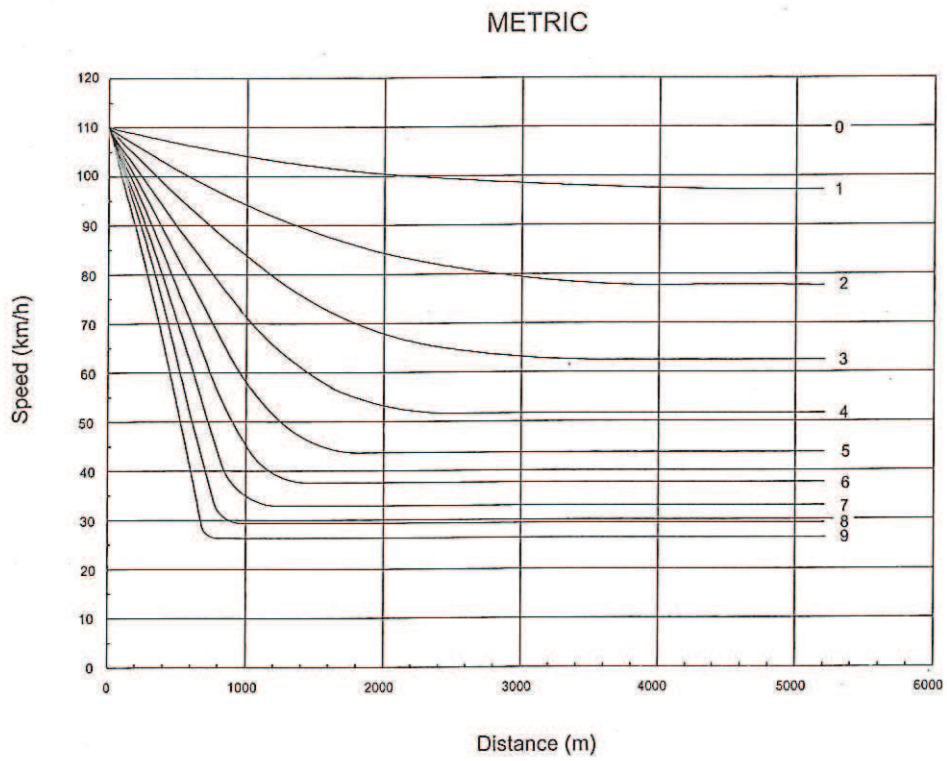
LEGEND:

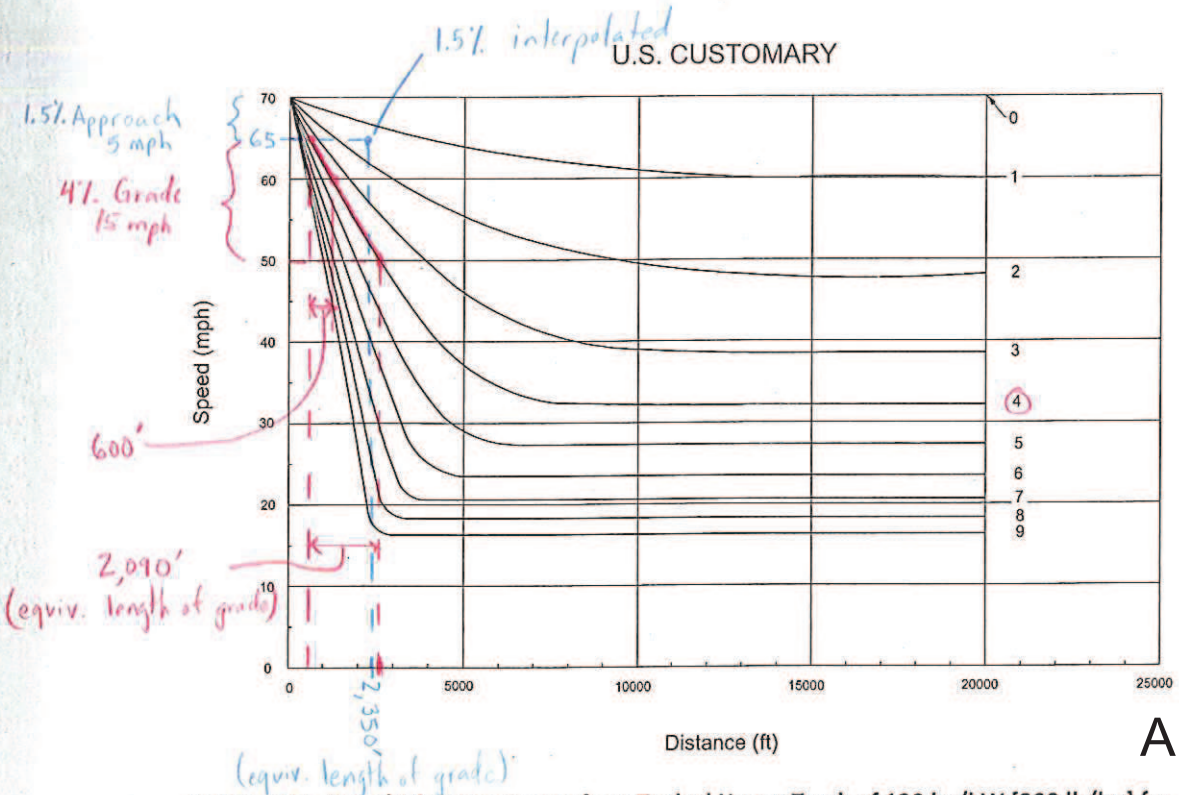
Critical length of Grade

Equivalent length of Grade

Appendix "G-5"

Paragon SB (4%)





Appendix "G-6"

Figure 3-24. Speed-Distance Curves for a Typical Heavy Truck of 120 kg/kW [200 lb/hp] for Deceleration on Upgrades

Critical length of grade = Approach equiv. length of grade + distance along 4% grade to reach 10 mph reduction

= 2,350 + 600' = 2,950 → say 3,000'