COLORADO
Department of Transportation

Applied Research and Innovation Branch

OIL AND GAS IMPACTS ON TRANSPORTATION

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Report No. CDOT-2015-09
November 2015

Technical Report Documentation Page

1. Report No. CDOT-2015-09	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle OIL AND GAS IMPACTS ON TRANSPORTATION		5. Report Date November 2015 6. Performing Organization Code
7. Author(s) Felsburg Holt & Ullevig and BBC Research & Consulting		8. Performing Organization Report No. CDOT-2015-09
9. Performing Organization Name and Address Felsburg Holt & Ullevig 6330 S. Syracuse Way Suite. 600 Centennial, CO 80111		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 312.01
12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes Prepared in cooperation with the US Department of Transportation, Federal Highway Administration		

16. Abstract

Colorado's oil and gas industry is continually evolving, and there have been considerable changes in drilling techniques and geographic focus since the 2010 CDOT research study on Energy Development and the Transportation System. This research study builds upon the 2010 study and aims to answer the following questions:

- What are other states with similar levels of oil and gas activity doing to recoup the costs of the industry's impacts to roads?
- How do the trip generation characteristics of oil and gas development differ based on variables such as: well organization (i.e., number of wells per pad), drilling technology (i.e., horizontal vs. vertical), fracking activity, pipeline infrastructure, and development phase (i.e., construction, drilling, completion, production)?
- What are the truck typologies and duration for various phases of development and what are the corresponding impacts (ESAL)?
- What are the industry's impacts (in terms of reduction of drivability life and costs to offset the impacts) on a per-mile basis?
- What variables affect the level of industry impacts (e.g., current drivability life, seasonality of activity, freeze/thaw cycle, duration of activity compounded with environmental impacts, etc.)
- How do the bridges on the State Highway system with weight and/or height restrictions affect the industry (e.g., rerouting requirements, bridge replacements for improved access)?
- What areas of the state are currently most affected by the oil and gas industry and what might future scenarios of oil and gas activity in Colorado look like?
- What is the magnitude of the oil and gas industry's impacts on the State Highway System? (How much truck activity on the state highway system is related to the industry? What portion of the loads on the state highway system is related to the industry? What are the estimated costs to offset the industry impacts?)
- What State Highways are generally most susceptible to industry impacts, given the current road conditions, current oil and gas activity and future development scenarios?

17. Keywords	18. Distribution Statement
Oil and gas, energy impacts, hydraulic fracturing, fracking, road deterioration, bridge deterioration, energy development, drivability life	This document is available on CDOT's website http://www.coloradodot.info/programs/research/pdfs

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	88	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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LIST OF ACRONYMS

AADT	Average Annual Daily Traffic
AASHTO	Association of State Highway and Transportation Officials
ADTT	Average Daily Truck Traffic
BLM	Bureau of Land Management
BTU	British thermal unit
CDL	commercial driver's license
CDOT	Colorado Department of Transportation
COGCC	Colorado Oil and Gas Conservation Commission
DES	Division of Engineering Support
D-J	Denver-Julesburg Basin
DNR	Colorado Department of Natural Resources
DOLA	Department of Local Affairs
DTD	Division of Transportation Development
EIS	Environmental Impact Statement
ESAL	equivalent single axle load
GPS	global positioning system
HMA	Hot Mix Asphalt
HUTF	Highway User Tax Fund
IRI	International Roughness Index
MCF	thousand cubic feet of natural gas
MDOT	Montana Department of Transportation
MP	milepost
NDDOT	North Dakota Department of Transportation
NDSU	North Dakota State University
NPS	National Park Service
OTIS	Online Transportation Information System
PCCP	Pavement and Concrete Pavement
PennDOT	Pennsylvania Department of Transportation
RUMA	Road Use Maintenance Agreement

SH	State Highway
SN	Structure Number
TIF	tax increment financing
TxDOT	Texas Department of Transportation
UDOT	Utah Department of Transportation
USDOT	United States Department of Transportation
VMT	vehicles miles of travel
WYDOT	Wyoming Department of Transportation

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

1.1 Background and Purpose

Colorado's oil and gas industry is continually evolving, and there have been considerable changes in drilling techniques and geographic focus since the 2010 Colorado Department of Transportation (CDOT) research study on *Energy Development and the Transportation System*. As of December 2014, Colorado has about 53,000 active wells. Although the number of annual well permits peaked in 2008, over the past five years, Colorado's active well count has increased by approximately 26 percent. Drilling activity in Colorado remains active and a source of considerable media and policy discussion throughout the state. Virtually all active drilling and exploration companies in Colorado employ extended lateral horizontal drilling and fracking techniques, which generate considerably different truck activity than traditional vertical drilling. When the previous CDOT research study was initiated, Colorado was in the midst of the West Slope gas boom; today the industry focus is predominately the Front Range Niobrara Shale oil play. These changes in conditions were the impetus for CDOT to commission this research study to refine and expand the analysis techniques of the previous study.

1.2 Study Objectives

The scope of work for this research study covered a range of topics to provide CDOT with a better understanding of the oil and gas impacts on State Highways and the corresponding cost implications, and the funding practices used by other states with significant oil and gas activity to handle the transportation costs of resource development. The primary study objectives were to answer each of the following nine questions:

- What are other states with similar levels of oil and gas activity doing to recoup the costs of the industry's impacts to roads?
- How do the trip generation characteristics of oil and gas development differ based on variables such as: well organization (i.e., number of wells per pad), drilling technology (i.e., horizontal vs. vertical), fracking activity, and development phase (i.e., construction, drilling, completion, production)?
- What are the truck typologies and duration for various phases of development and what are the corresponding impacts (ESAL)?
- What are the industry's impacts (in terms of reduction of drivability life and costs to offset the impacts) on a per-mile basis?
- What variables could affect the level of industry impacts (e.g., current drivability life, seasonality of activity, freeze/thaw cycle, pipeline infrastructure, duration of activity compounded with environmental impacts, etc.)?
- How do the bridges on the State Highway system with weight and/or height restrictions affect the industry (e.g., rerouting, bridge replacements for improved access)?
- What areas of the state are currently most affected by the oil and gas industry and what might future scenarios of oil and gas activity in Colorado look like?

- What is the magnitude of the oil and gas industry's impacts on the State Highway System? (How much truck activity on the state highway system is related to the industry? What portion of the loads on the state highway system is related to the industry? What are the estimated costs to offset the industry impacts?)
- What State Highways are generally most susceptible to industry impacts, given the current road conditions, current oil and gas activity and future development scenarios?

2.0 EXISTING AND FUTURE OIL & GAS ACTIVITY IN COLORADO

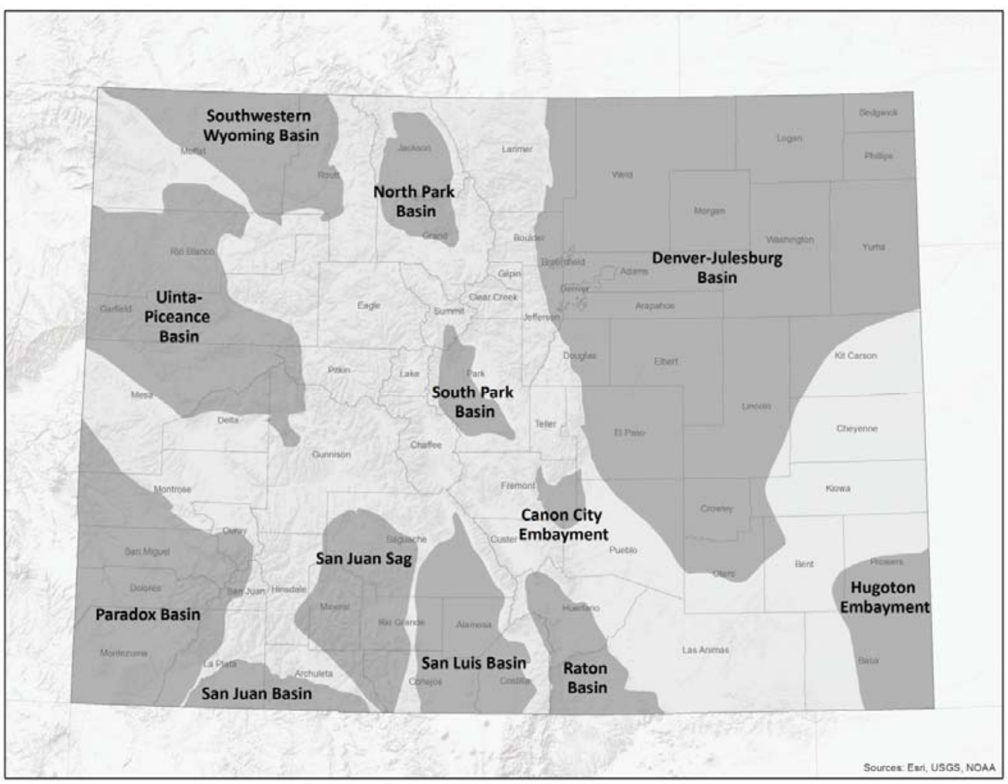
Chapter 2.0 provides potential future oil and gas development scenarios in Colorado based on a blended methodology using historic drilling rig counts, current drilling patterns, and future industry investment assumptions. The study team examined historic well development in active basins in Colorado to provide a check on the future development scenarios.

The study team developed a set of three future development scenarios. The following exercise is not an attempt to predict the future, but rather an effort to develop an informed set of development scenarios based on the best available data and does not attempt to quantify the likelihood of any particular scenario.

2.1 Recent Oil & Gas Development

The following provides a discussion of recent oil and gas development in active counties across the state to provide context for the drilling scenarios. The location of basins in Colorado is shown in **Figure 2-1**.

Figure 2-1 Oil and Gas Basins in Colorado



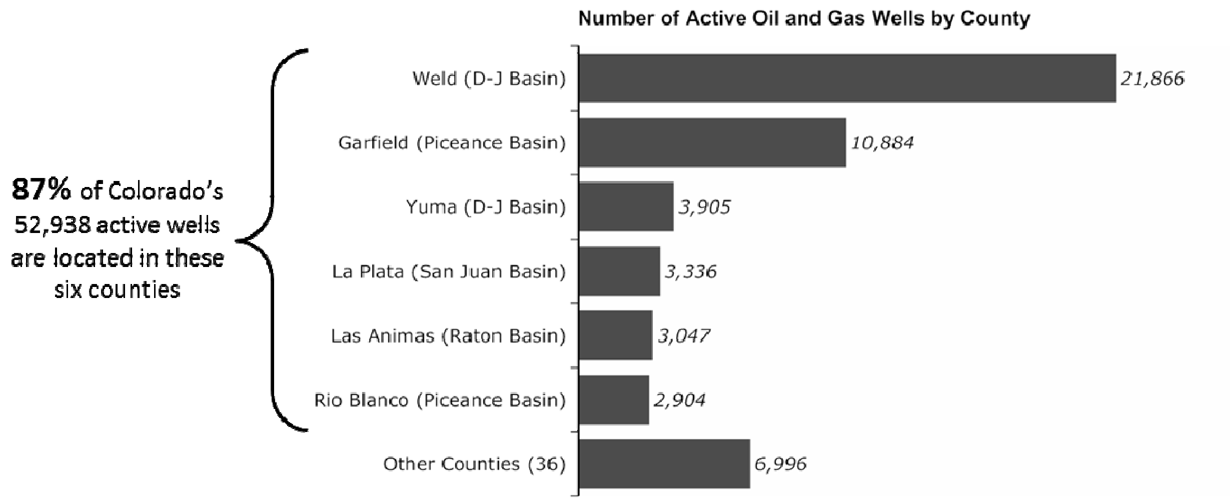
SOURCES: Bureau of Land Management, 2008

Historically, the majority of oil and gas development has occurred within the Denver-Julesburg (D-J), Piceance, and San Juan Basins. The D-J Basin is currently the most active play in the state.

EXISTING OIL & GAS WELLS

As of December 2014, Colorado has about 53,000 active wells. Over the past five years, Colorado's active well count has increased by approximately 26 percent. Oil and gas activity is heavily concentrated in Weld County, which has nearly 21,900 active wells or roughly 40 percent of all active wells within the state. **Figure 2-2** shows data from the Colorado Oil and Gas Conservation Commission (COGCC) on active oil and gas wells by county.

Figure 2-2 Active Oil and Gas Wells in Colorado, December 2014



SOURCE: Colorado Oil & Gas Conservation Commission, 2014

Figure 2-2 shows most production occurs in Weld County, Garfield County, and Yuma County. The six highest producing counties have 87 percent of the state's active wells. Most other counties currently have about 500 active oil and gas wells or fewer. Historically, production has been concentrated in the Front Range and on the western slope. Due to recently low natural gas prices, activity in the Piceance Basin has declined and the industry is currently most active along the Front Range.

WELL DEVELOPMENT

The study team obtained data on active wells by county from the COGCC for each of the last six years. **Table 2-1** shows number of active wells in Colorado as a whole and the four most active resource-producing counties.

Table 2-1 Active Wells in Colorado, 2009–2014

County	2009	2010	2011	2012	2013	2014
Weld	15,272	16,558	17,982	19,296	20,881	21,886
Garfield	6,471	7,513	8,850	9,879	10,558	10,884
Yuma	3,218	3,549	3,738	3,871	3,885	3,905
La Plata	3,015	3,162	3,282	3,346	3,339	3,336
Colorado Total	**41,993**	**43,600**	**46,600**	**50,500**	**51,692**	**52,938**

SOURCES: Colorado Oil & Gas Conservation Commission

Between 2009 and 2014, active wells have increased by nearly 11,000. Weld County had the largest increase in active wells—an annual average increase of about 1,300. Garfield County had an annual average increase of almost 950 wells over the same period. In Yuma County, about 150 new wells have been drilled in the past six years. Active wells in La Plata County increased by an average of 70 per year over the same period; however, in the last two years the number of active wells in the county has declined slightly. These growth trends are used to establish context for the development scenarios and ensures that the projections are in range of actual development trends.

2.2 Future Oil & Gas Development

To assist CDOT in determining where future oil and gas development is most likely to occur, the study team developed future oil and gas development scenarios through the year 2040. This information, paired with existing oil and gas activity and traffic data, helps provide CDOT with a range of potential future impacts to inform capital planning efforts.

Scenario Development Methodology

As part of the background research effort, the study team reviewed information from multiple sources, including local news outlets, energy company investor literature, and the COGCC. This research process provides up-to-date information on trends in this rapidly changing industry. Current and historic trend data was then used to develop the future drilling scenarios, which estimate the number of wells drilled annually based on the number of active rigs in each basin.

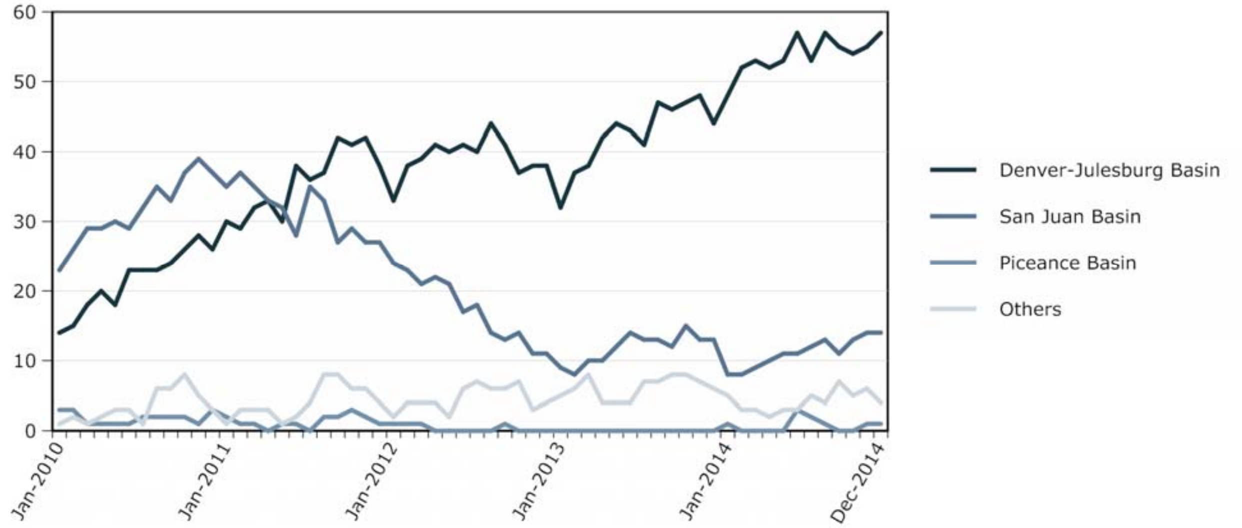
The geological conditions of resource deposits vary greatly across the basins. For example the Piceance Basin has more natural gas and oil shale while the D-J Basin has more shale oil formations[1]. In addition to different resource concentrations, the producing layers in each basin are located at varying depths. These differences in the basin formations require unique drilling approaches in order to most efficiently recover the resources. This study does not address the individual drilling techniques used in each basin. Instead, the scenarios are based on trends and statewide averages.

Rig Utilization

Drilling rigs are large capital investments and the associated purchase or rental costs represent a significant barrier to entry into the industry. Information regarding rig activity is tracked and reported by oil field service companies. Anderson Reports, a local company, provided the Colorado specific data. There were 1,917 drilling rigs operating in the U.S. on November 26, 2014, of which 76 were operating in Colorado. **Figure 2-3** shows the number of drilling rigs in operation in Colorado by month from 2010 to the present.

[1] **Oil shale** is sedimentary rock that must be heated and condensed in order to produce hydrocarbons. **Shale oil** is non-porous rock that contains pockets of trapped liquid hydrocarbons. Shale oil plays are considered unconventional and are typically unlocked using hydraulic fracturing.

Figure 2-3 Drilling Rigs in Colorado, January 2010 to December 2014



SOURCES: Colorado Oil & Gas Conservation Commission

Figure 2-3 shows that operating drilling rigs patterns vary by basin. When natural gas prices were high (natural gas price hit $5.83 per million BTU in 2010[2]), the Piceance Basin had more drilling activity. However, the rig counts have declined along with natural gas prices in recent years (early 2015 natural gas prices were $2.87 per million BTU[2]). Drilling in the D-J Basin has been steadily increasing over the past 5 years. Drilling activity in the San Juan and other basins has been comparatively lower and has not trended in any particular direction.

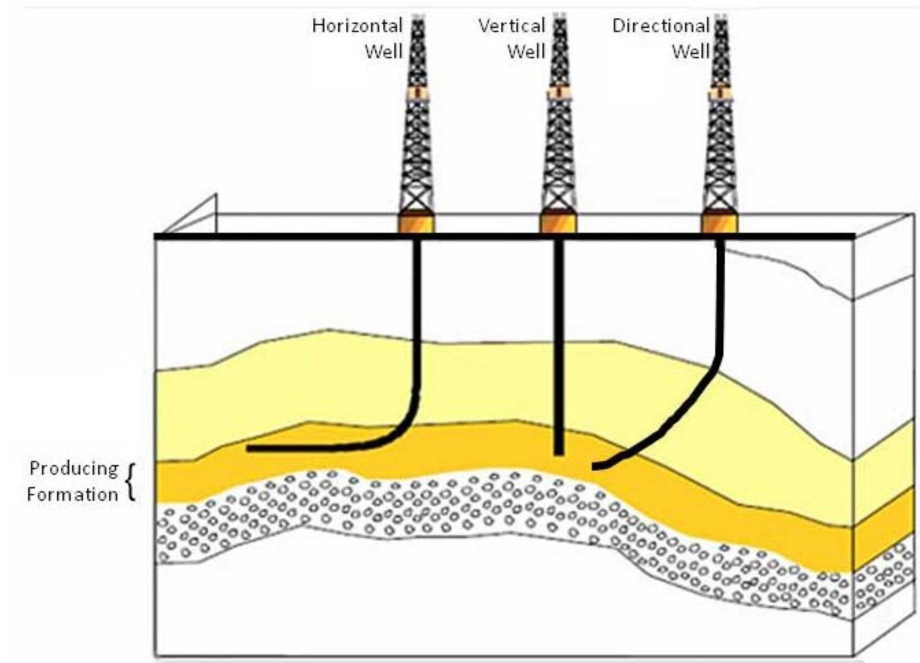
As of the first week of December 2014, 57 rigs are operating in the D-J Basin, 14 rigs in the Piceance Basin and 1 rig in the San Juan Basin. There are 14 other rigs spread among other basins in the state. Total rig allocation in Colorado peaked at 80 rigs in 2011; however current activity is near the 5 year high with 76 active rigs.

Oil and gas companies have a finite amount of capital resources and operating a drilling rig is expensive and requires a significant capital commitment. Oil and gas operators will allocate drilling rigs to areas that show the most promise in developing a productive well. Depending on their land holdings and market conditions, oil and gas companies will consider other counties along the Front Range, Western Slope and across the nation, when deciding where to drill.

There has been oil and gas drilling in Colorado since the late 1800s and over time, Colorado has seen a variety of drilling techniques to reach the resource rich formations. Past well development techniques in the area include directional and vertical wells to reach targeted resource deposits. **Figure 2-4** illustrates the types of drilling techniques most commonly used in Colorado.

[2] Henry Hub Natural Gas Spot Price, EIA.gov

Figure 2-4 Drilling Techniques



SOURCES: Energy Information Administration, Office of Oil and Gas

Over time, energy companies have refined their drilling methods to most effectively extract the hydrocarbons from shale formations. Rather than drilling traditional vertical wells, it is now most common to drill horizontal wells and use hydraulic fracturing to release hydrocarbons from the rock formation.

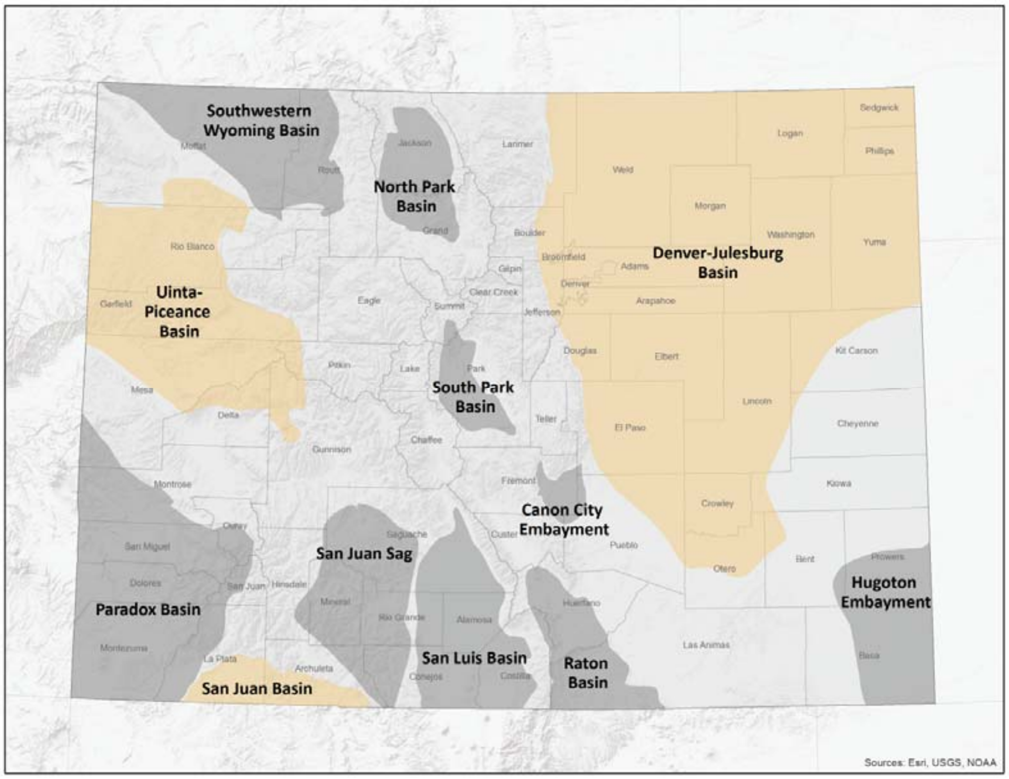
The study team met with COGCC staff to discuss current trends and possible future well development scenarios in Colorado. As drilling techniques have changed, rules regulating well spacing have also been modified. Historically, well spacing was determined by a maximum number of allowable wells per square mile section. Current drilling practices, however, require a different approach to regulation. Over the past few years, technological advancements have enabled more wells to be placed on a single pad. Wells lateral lengths are also increasing, with some extending over two miles. These advancements enable more resources to be recovered from a smaller area of surface disturbance. Therefore, spacing regulations have been modified to address subsurface geological conditions rather than surface area. This means that the number of square miles available for drilling is no longer a major determinant in the numbers of wells.

The study team contacted COGCC staff to discuss methods to project drilling development. COGCC staff described a favored methodology, where drilling rigs and the well drilling period are used to calculate the total amount of annual wells drilled per year. The well drilling period consists of two major stages. The first stage is referred to as “spud to release.” This describes the number of days that it takes to physically drill the well. The next stage is “release to spud” and refers to the number of days required to move the rig from one well to the next. In the last few years, drilling has become significantly more efficient and the industry has seen a rapid decrease in the time required to complete both stages of rig activity.

STATEWIDE DEVELOPMENT SCENARIOS

The study team used the historic drilling rig activity to derive three hypothetical future well development scenarios. **Figure 2-5** shows the location of proven oil and gas reserves in Colorado. The map highlights the three most active plays, the D-J, Piceance, and San Juan Basins, which drive the majority of oil and gas development in the identified scenarios.

Figure 2-5 Three Primary Oil and Gas Basins in Colorado



SOURCES: Bureau of Land Management, 2008

The three basins highlighted in the map above have historically been the most prevalent areas for oil and gas development in Colorado and this is projected to continue through 2040. The scenarios specifically account for drilling activity in these basins. Since the activity in the remaining basins is minimal and sporadic, they have been evaluated as a group.

As drilling technology improves, the drilling capacity in a given area increases. **Table 2-2** presents the baseline drilling assumptions. These assumptions are then used in conjunction with the rig count data by basin to produce the various development scenarios.

Table 2-2 Baseline Drilling Assumptions

Drilling Assumptions	Value
Spud to Release (days)	12.5
Release to Spud (days)	3
Total Average Drill Time (days)	**15.5**
Wells per Rig per Year	**24**

NOTE: Numbers are rounded

While this number can vary from basin to basin and even well to well, there is an average of 15.5 days between when drilling starts on one well before it starts on the next. Since drilling activity tends to occur on nearly every day of the year, this means that a single rig can drill an estimated 24 wells per year.

Table 2-3 shows the hypothetical development scenarios during a 25-year development period. The total cumulative wells in Colorado include the 53,000 existing wells at the end of 2014. Based on annual well and permitting data, it is assumed that approximately 1 percent of all wells will be retired each year. This includes both shut-in and plugged wells. The number of wells that become inactive will inevitably vary across the years and basins, but given the relatively young age of the majority of wells, there is not expected to be a major decline.

The high development scenario shown below assumes that drilling activity occurs at historic highs in every basin for the next 25 years (about 80 rigs statewide). Under this scenario, approximately 2,520 new wells would be drilled per year. By 2040, this means there would be approximately 98,700 wells in Colorado.

The medium development scenario assumes that drilling is 50 percent of the high scenario. Under this scenario there would be approximately 1,260 new wells drilled ever year. By 2040 there would be about 69,700 wells in Colorado.

The low development scenario projects there will be 20 percent of the number of active rigs shown in the high scenario. This suggests approximately 378 new wells annually and 49,500 total wells by 2040.

Table 2-3 Development Scenarios

	Number of Annual Wells per Scenario		
Basin	**High**	**Medium**	**Low**
D-J Basin	1,342	671	201
Piceance	918	459	138
San Juan Basin	71	35	11
Others	188	94	28
Total	**2,520**	**1,260**	**378**
Cumulative in Colorado Wells in 2040	**98,700**	**69,700**	**49,500**

OTHER CONSIDERATIONS

These development projections show potential ranges for drilling activity in Colorado over the next 25 years. However, this complex industry is impacted by various domestic and international conditions, making it difficult to determine the scale of future drilling activity.

One of the most important variables that will determine drilling activity in Colorado is the price of oil and natural gas. For instance, the price of natural gas has fallen low enough to notably decrease drilling activity in the gas intensive Piceance Basin. The price of oil has also been decreasing, though not yet to the point where it has discouraged production in the D-J Basin. However, the major operators have indicated plans to slow drilling activity in 2015 in response to the lower prices. These recent trends, however, are not necessarily indicative of consistent conditions over the next 25 years. If prices become low enough, production throughout Colorado could become unprofitable. Should prices rise, it could encourage increased production in the three primary basins and open currently unprofitable fields to future production. The price of both resources can be highly volatile and will greatly impact the future of Colorado's oil and gas industry.

Future drilling activity will also be influenced by local, state, and federal regulations. Due to the rapid changes in the industry, laws and regulations continually alter the drilling landscape. More permissive actions would enable and encourage increased development while tougher regulations could diminish future oil and gas development in the state. Colorado's future legislative and regulatory decisions could be a significant determining factor in drilling activity.

Lastly, the oil and gas industry is sensitive to dramatic technological advancements. It is difficult to foresee how rapidly the technology might change and what impacts that will have on future drilling conditions in Colorado. These scenarios are based on current drilling practices and do not make any assumptions about future increases in drilling efficiencies.

3.0 COST IMPLICATIONS OF OIL & GAS VEHICLES

One of the primary objectives of this study is to quantify the level of impact that oil and gas activities can inflict on CDOT's highways and bridges on a per-mile and per-bridge basis. Impacts are a result of repeated heavy loads associated with oil and gas activity, which cause accelerated damage to roadways and bridges. To illustrate these impacts, it is most practical to convert damage caused by oil and gas truck trips into incurred costs. The study team developed a process to calculate this cost by analyzing oil and gas truck trip generation, types, and impacts. This analysis estimates the amount of deterioration that can be attributed to oil and gas activity, and uses CDOT standard values to identify the cost to offset industry impacts. The following sections describe the impact analysis methodology and application of a calculation tool developed as part of this research study.

3.1 Truck Trips & Impacts

The number of oil and gas truck trips, the types of trucks, and their level of impact must be determined in order to assess the magnitude of industry impacts. The study team conducted literature reviews of numerous studies and reports, along with interviews of industry stakeholders such as local government officials and regulatory bodies, to derive baseline trip generation and impact assumptions to be used in assessing impacts.

TRIP GENERATION

Oil and gas development requires the transport of heavy equipment to the well site to build access roads, construct a well pad and transport a drilling rig. Heavy trucks are also required to bring fresh water to the well site and often to transport produced water and extracted resources off site. The following section presents trip generation information on horizontal and vertical well drilling and production as well as the recompletion of existing vertical wells.

Horizontal Well Trip Generation

Several independent studies inform the truck trip generation model for horizontal drilling in Colorado. These studies were conducted by the National Park Service (NPS), NTC Consultants, Utah Department of Transportation (UDOT), North Dakota State University (NDSU), and Economic Advisors Inc. Multiple studies focused in the Marcellus Shale formation in Pennsylvania, New York and Ohio refer to the truck trip data of the National Park Service study. In addition, other Marcellus Shale development studies use NTC truck trip data. The UDOT study quantifies potential truck trips of oil and gas development in the Utah's Uintah Basin. The NDSU study focuses on development in the Bakken Shale Formation in North Dakota. As part of the *Arapahoe County Oil & Gas Impact Study*, Arapahoe County obtained additional trip generation data directly from Renegade Oil and Gas Company, LLC (Renegade), which is currently active in developing wells in Arapahoe County. Additional trip generation data was received from Economic Advisors Inc. as part of a response to Boulder County's analyses of oil and gas activity, including the *Boulder County Oil and Gas Roadway Impact Study*.

The study team also interviewed knowledgeable persons that are connected to oil and gas activity in the Niobrara Basin; including discussions with well permitting staff at the COGCC. **Table 3-1** shows data extracted from the multiple studies and industry outreach examining trip generation by well development and production periods. Trips from each study are averaged across each development phase and then summed to calculate average trip generation figures.

Table 3-1 Trip Generation – Horizontal Drilling (1 Pad / 1 Well)

Development Period: Stage	Development Period: Phase	NPS Study[1], 2008	NTC Study[2], 2011 Update	NTC Study, 2009	UDOT Study, 2006	NDSU Study, 2010	Bakken Study, 2013	Renegade Input[3], 2012	Noble Energy[4], 2013	Average
Construction	Pad and Road Construction	55	87	56	55	160	180	10	90	87
Drilling	Drilling Rig	60	61	60	60	100	65	30	102	67
	Drilling Fluid and Materials	75	90	75	30	100	100	68	91	79
	Drilling Equipment (casing, drill pipe, etc)	75	75	75	-	50	80	75	24	65
Completion	Completion Rig	30	-	30	65	-	65	2	8	33
	Completion Fluid and Materials	30	40	30	70	8	-	43	6	32
	Completion Equipment (pipe, wellhead, etc)	10	10	10	-	-	30	10	5	13
	Fracturing Equipment (pump trucks, tanks, etc)	250	350	350	-	244	230	317	9	250
	Fracture Water	1,052	1,000	1,000	1,100	800	900	840	691	923
	Fracture Sand	48	46	45	52	160	200	48	71	84
	Flowback Water Disposal	-	200	500	-	400	450	277	21	308
Total Trips – 1 Pad / 1 Well		**1,685**	**1,959**	**2,231**	**1,432**	**2,022**	**2,300**	**1,720**	**1,118**	**1,941**
Production Period (annual, 20 year average)										**560**

[1] NPS study grouped water and sand trips. So for the summary table, the number of sand trips is the average of the three other studies (48) and the water trips reflects the deduction (1,052)

[2] NTC 2011 study had conspicuously high Pad construction, drilling rig and drilling equipment trips. These figures were adjusted downward to the average of the other sources

[3] Renegade did not provide input for drilling fluid/materials, drilling equipment, completion fluid/materials, completion equipment, fracturing equipment. These figures use the averages of the other sources

[4] Noble provided data per 4 well pad. Per well numbers are interpolated

SOURCES: National Park Service, 2008; NTC Consultants, 2009 and 2011 Update; Kuhn, 2006; (Upper Great Plains Transportation Institute, 2010; Tolliver, 2014; Renegade Oil & Gas Company, LLC, 2012; Orlando, 2013

All trip estimates in **Table 3-1** include both inbound and outbound trips (Example: the 2008 NPS study identified 60 trips associated with the drilling rig or 30 inbound and 30 outbound trips). The average trips per well data are for a specified development period of roughly one month[3], while the production related trips are expressed as annual trips and will continue for the duration of the well's production life.

The reported trips in **Table 3-1** represent averages and can vary, sometimes widely, based on formation geology and other factors. Technological advances in drilling, completion and stimulation techniques continue and the trip profiles in **Table 3-1** are a reflection of well development characteristics at the time each study was published. Certain outlier trips were adjusted using the average of the other sources. These data suggest that a typical well will generate about 1,941 trips during its month-long development period or an average of 65 trips per day, largely related to fracture water delivery and removal.

There are a number of factors that determine trip generation during the production period including the nature of the field, success of wells, and storage capacity for produced water and resource at the well pad. Based on a number of studies, an annual trip count of 560 can be expected, which averages to about 1.5 trips per day per well pad. This production period trip profile is primarily made up of maintenance and water/resource extraction trips, but also includes the occasional need to "re-frack" a well. However, the frequency and extent of re-fracking is uncertain and is a minimal portion of the daily average trip generation.

As horizontal drilling and fracturing techniques evolve, the standard practice has become to drill multiple wells on a single pad, resulting in additional trips. **Table 3-2** on the following page shows the trip sensitivity for each development phase from the 2009 NTC study. The project team used the underlying relationships in the study to determine which trip types must adapt to additional wells developed on a pad. The process involves increasing well-sensitive trips, such as fracturing water and drilling fluid hauling, while holding constant pad-sensitive trips, such as pad construction trips and drilling rig transport. The production period is pad-sensitive.

To adapt the trip generation average for one well on one pad to multiple wells per pad, the averages are adjusted according to pad and well sensitive trips, with pad-sensitive trips remaining constant and well-sensitive trips multiplied by the number of wells on the pad. **Table 3-3** on the following page shows trip generation for up to eight wells per pad, using the average derived in **Table 3-1** for a single well on a pad.

The trip profiles in **Table 3-1** (and subsequent multi-well pad calculations in **Table 3-3**) do not account for the presence of any pipeline system for development or production periods. In areas where well densities warrant water pipelines or development activity is located in an area where temporary water pipelines are permitted, both fresh and produced water trips are eliminated in all phases/stages/periods. The presence of pipelines reduces overall well development trips by about 80 percent for an eight well pad, or nearly 65 percent for a single well pad. Pipelines are generally present in the most dense fields. In Colorado, the study team could find evidence of pipeline use in the D-J Basin, most prevalently in Weld County. While there is no public registry for pipeline information, Weld County staff indicated that as many as 60 percent of new wells use pipeline systems to transport water during well development and production periods.

[3] Typical amount of time, actual length can vary depending on basin and other geological considerations

Table 3-2 Trip Generation Sensitivity by Development Phase

Stage	Phase	Trip Sensitivity
Construction	Pad and Road Construction	Pad-sensitive
	Drilling Rig	Pad-sensitive
Drilling	Drilling Fluid and Materials	Well-sensitive
	Drilling Equipment (casing, drill pipe, etc)	Well-sensitive
	Completion Rig	Pad-sensitive
	Completion Fluid and Materials	Well-sensitive
	Completion Equipment (pipe, wellhead, etc)	Pad-sensitive
Completion	Fracturing Equipment (pump trucks, tanks, etc)	Pad-sensitive
	Fracture Water	Well-sensitive
	Fracture Sand	Well-sensitive
	Flowback Water Disposal	Well-sensitive

Table 3-3 Trip Generation – Horizontal Drilling (1 Pad / Multiple Wells)

Development Period		Pad Sensitive Trips Only	Average	Average	Average	Average	Average	Average	Average	Average
Stage	Phase		1 pad 1 well	1 pad 2 wells	1 pad 3 wells	1 pad 4 wells	1 pad 5 wells	1 pad 6 wells	1 pad 7 wells	1 pad 8 wells
Construction	Pad and Road Construction	87	87	87	87	87	87	87	87	87
	Drilling Rig	67	67	67	67	67	67	67	67	67
Drilling	Drilling Fluid and Materials		79	158	237	316	395	474	553	632
	Drilling Equipment (casing, drill pipe, etc)		65	130	195	260	325	390	455	520
	Completion Rig	33	33	33	33	33	33	33	33	33
	Completion Fluid and Materials		32	64	96	128	160	192	224	256
	Completion Equipment (pipe, wellhead, etc)	13	13	13	13	13	13	13	13	13
Completion	Fracturing Equipment (pump trucks, tanks, etc)	250	250	250	250	250	250	250	250	250
	Fracture Water		923	1,846	2,769	3,692	4,615	5,538	6,461	7,384
	Fracture Sand		84	168	252	336	420	504	588	672
	Flowback Water Disposal		308	616	924	1,232	1,540	1,848	2,156	2,464
Total Trips		**450**	**1,941**	**3,432**	**4,923**	**6,414**	**7,905**	**9,396**	**10,887**	**12,378**

Vertical Well Development and Recompletion Trip Generation

The study team developed trip generation profiles for vertical well development and recompletion by compiling regional and national studies and by directly contacting industry representatives active in Colorado. For vertical well drilling, two Environmental Impact Statement (EIS) studies were obtained—one at the Jonah Field in western Wyoming and another in the Marcellus Shale region of New York. These sources are supplemented with industry feedback from Renegade and K.P. Kauffman Company, Inc., which are active in Arapahoe County. Trips are averaged across the sources by phase and then summed to calculate total well development trips. The study team expects production trips to be similar to horizontally drilled wells. **Table 3-4** below shows average trips per vertical well.

Table 3-4 Trip Generation – Vertical Drilling

Development Period Stage	Phase	Jonah Field	NY DEC SGEIS	KP Kauffman	Renegade	Average
Construction	Pad and Road Construction	87	132	22	10	63
Drilling	Drilling Rig	93	100	42	30	66
	Drilling Fluid and Materials	42	30	66	42	45
	Drilling Equipment (casing, drill pipe, etc)	70	80	14	70	59
Completion	Completion Rig	42	-	-	2	22
	Completion Fluid and Materials	26	20	-	26	24
	Completion Equipment (pipe, wellhead, etc)	10	10	2	10	8
	Fracturing Equipment (pump trucks, tanks, etc)	317	150	70	50	147
	Fracture Water	645	180	140	19	246
	Fracture Sand	30	10	6	15	15
	Flowback Water Disposal	218	84	-	6	103
Total Trips		**1,580**	**796**	**362**	**280**	**798**

SOURCES: Bureau of Land Management, 2006; New York State Department of Environmental Conservation, 2011; Renegade Oil & Gas Company, LLC, 2012; KP Kauffman Company, LLC, 2012

For existing vertical well recompletions, the study team included just the completion stage of the studies shown in **Table 3-4**. A recompletion of a vertical involves the same activities as its initial completion, including hydraulic fracturing stimulation techniques. **Table 3-5** below presents a recompletion trip generation profile.

Table 3-5 Trip Generation – Vertical Well Recompletion

Development Period Stage	Phase	Jonah Field	NY DEC SGEIS	KP Kauffman	Renegade	Average
Completion	Completion Rig	42	-	-	2	22
	Completion Fluid and Materials	26	20	-	26	24
	Completion Equipment (pipe, wellhead, etc)	10	10	2	10	8
	Fracturing Equipment (pump trucks, tanks, etc)	317	150	70	50	147
	Fracture Water	645	180	140	19	246
	Fracture Sand	30	10	6	15	15
	Flowback Water Disposal	218	84	-	6	103
Total Trips		**1,288**	**454**	**218**	**128**	**565**

SOURCES: Bureau of Land Management, 2006; New York State Department of Environmental Conservation, 2011; Renegade Oil & Gas Company, LLC, 2012; KP Kauffman Company, LLC, 2012

Truck Types & Impacts

The number of truck trips is the main indicator of impacts to bridges, but weight and how it is distributed across a truck is what impacts roadway surfaces. To analyze impacts on a roadway, an equivalent single axle load (ESAL) factor is derived for each vehicle. Roadways are designed according to an estimated number of ESALs it will experience within a given timeframe.

A variety of vehicle types are used for oil and gas activities, many of which are specialized and/or of significant weight, resulting in ESAL factors greater than many typical truck types. Trucks often differ between manufacturers and evolve as drilling techniques quickly advance. In order to determine how oil and gas trucks impact roadways, it's important to understand as much as possible the different types of trucks used, their weights and configurations, and volumes within each development phase.

Truck Types

Although many studies and reports document truck trip generation for oil and gas activities, many do not provide significant detail on the types of trucks used or how their weight is distributed across each axle – an important detail in calculating a truck's impact on roadway surfaces. Some of the resources consulted provided both axle and weight characteristics, but most provided only one or partial information, and required estimations based on other similar configurations. A combination of resources from the United States Department of Transportation (USDOT), Rio Blanco and Arapahoe counties, NDSU, the North Dakota Department of Transportation (NDDOT), and equipment manufacturers such as Putzmeister were consulted to determine truck types and their assumed weight configuration (total empty and full, per axle).

Table 3-6 provides a complete list of trucks estimated to be used for oil and gas activity. Some of the trucks listed are specific truck types by unique names, while others are generic to help standardize otherwise variable names and types used, and to allow for similar vehicles to be grouped together and applied to multiple development stages and phases. In total, nearly forty unique truck types were identified through this research effort.

Table 3-6 Types of Trucks Used for Oil and Gas Activity

Acid Pump	Derrick	Mud Boat	Shaker Skid
Acid Tanker	Draw Works	Mud Pump	Shaker Tank/Pit
Cement Pump	Frac Tank	Mud Tank	Substructure, etc.
Cement Truck	Fuel Tanker	Oil Tanker	Suction Tank
Chemical Tanker	Generator House	Pickup	Tool Room / Junk Box
Choke Manifold	Gravel Haul Truck	Pipe Haul Truck	VFD House
Construction Equipment Haul Truck	Hydraulic Unit	Pump Truck	Water Tanker
Control Van	Light Plant	Sand Haul Truck	Wireline
Crown Section	MCC House	Screen House	Workover Rig

SOURCES: North Dakota Department of Transportation, 2006; RPI Consulting, LLC, 2008; La Plata County, 2002; Renegade Oil & Gas Company, LLC, 2012; Bureau of Land Management, 2008; Upper Great Plains Transportation Institute, 2012; Upper Great Plains Transportation Institute, 2013

Truck Impacts

All of the truck trips presented earlier in this chapter can have varying levels of impact. The load impact of oil and gas trucks can be as much as 15,000 to 46,000 times that of a passenger car depending on truck configurations described above and the surface type of the roadway. To account for the load impacts, ESALs for each truck type listed in **Table 3-6** have been estimated for flexible (asphalt) and rigid (concrete) surfaces, and as fully loaded and/or empty depending on the truck's purpose, based on the assumed axle and weight configurations.

These ESAL factors were estimated based on the Pavement Interactive's ESAL equations for flexible and rigid surfaces, which produce ESAL factors consistent with the American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures* that defines ESALs for different truck configurations. The axle and weight configuration of a truck is important when determining a truck's total impact. The equations used to calculate ESALs apply to a single axle setup (single, tandem, etc.), which is applied to each axle of a truck and aggregated to arrive at the total ESAL factor. **Table 3-7** provides an example of how ESAL factors are derived for each axle and aggregated for the entire vehicle. It also illustrates how different axle and weight configurations for the same total weight can result in different ESAL factors. The equations used to calculate ESAL factors are displayed in **Figure 3-1** (flexible surfaces) and **Figure 3-2** (rigid surfaces).

Table 3-7 Example of Determining a Truck's ESAL Factor for a Flexible Surface

% of Weight/Axle	30,000 lbs.	80,000 lbs.
$30^1 / 35^2 / 35^2$	0.056 + 0.008 + 0.008 = 0.073	3.032 + 0.495 + 0.495 = 4.022
$15^1 / 40^2 / 45^2$	0.003 + 0.014 + 0.023 = 0.041	0.189 + 0.857 + 1.376 = 2.422
$15^1 / 40^2 / 45^3$	0.003 + 0.014 + 0.005 = 0.023	0.189 + 0.857 + 0.313 = 1.359

NOTE: Scenarios are examples only, and assume a Serviceability Index of 2.5, Structural Number of 5, and Slab Depth of 12 inches
^{1} = single axle, ^{2} = tandem axle, ^{3} = triple axle

Figure 3-1 Flexible Pavement ESAL Equation

$$\frac{W_x}{W_{18}} = \left[\frac{L_{18}+L_{2s}}{L_x+L_{2x}}\right]^{4.79}\left[\frac{10^{G/\beta_x}}{10^{G/\beta_{18}}}\right]\left[L_{2x}\right]^{4.33}$$

W = axle applications inverse of equivalency factors (where W_{18} = number of 18,000 lb (80 kN) single axle loads)

L_x = axle load being evaluated (kips)

L_{18} = 18 (standard axle load in kips)

L_2 = code for axle configuration (# = # of axles, x = axle load equivalency factor being evaluated, s = standard axle [single axle])

p_t = "terminal" serviceability index (point at which the pavement is considered to be at the end of its useful life)

G = $\log\left(\frac{4.2-p_t}{4.2-1.5}\right)$, a function of the ratio of loss in serviceability at time $_t$ to the potential loss taken at a point where p_t = 1.5

SN = structural number

b = $0.4+\left(\frac{0.081(L_x+L_{2x})^{3.23}}{(SN+1)^{5.19}{L_{2x}}^{3.23}}\right)$, a function determining the relationship between serviceability and axle load applications

SOURCE: Pavement Interactive, 2009

Figure 3-2 Rigid Pavement ESAL Equation

$$\frac{W_x}{W_{18}} = \left[\frac{L_{18} + L_{2s}}{L_x + L_{2x}}\right]^{4.62} \left[\frac{10^{G/\beta_x}}{10^{G/\beta_{18}}}\right] [L_{2x}]^{3.28}$$

W = axle applications inverse of equivalency factors (where W_{18} = number of 18,000 lb (80 kN) single axle loads)

L_x = axle load being evaluated (kips)

L_{18} = 18 (standard axle load in kips)

L_2 = code for axle configuration (# = # of axles, x = axle load equivalency factor being evaluated, s = standard axle [single axle])

p_t = "terminal" serviceability index (point at which the pavement is considered to be at the end of its useful life)

G = $\log\left(\frac{4.5 - p_t}{4.5 - 1.5}\right)$, a function of the ratio of loss in serviceability at time $_t$ to the potential loss taken at a point where p_t = 1.5

SN = structural number

b = $1.00 + \left(\frac{3.63(L_x + L_{2x})^{5.20}}{(D+1)^{8.46} {L_{2x}}^{3.52}}\right)$, a function determining the relationship between serviceability and axle load applications

D = slab depth in inches

SOURCE: Pavement Interactive, 2009

Because these equations take roadway characteristics into account that were not obtained during this study (such as the serviceability index, structural number, and slab depth), values were generalized with input from CDOT staff and standard use of these values found in other reports referenced for this study.

Other factors not incorporated into this study can also play a role in how much deterioration a truck might cause to a roadway. Roadway sub-grade strengths can be at their weakest during thaw periods, meaning more damage can occur. Transportation Research Board Special Report 225 *Truck Weight Limits: Issues and Options* suggests that tire pressure, tire width, and single versus dual tires are also variables that affect deterioration levels.

TRUCK TRIPS BY PHASE

Some truck types are used in multiple stages and phases, while others are used only once. And for those trucks operating within more than one phase, their number of trips varies by phase. This variation requires each phase to have a vehicle classification profile where truck types, trip shares, and impacts are linked.

The truck configuration profiles were linked with their respective phase using available information from the resources used for determining truck trip generation and types along with additional input from a report produced by the Montana Department of Transportation (MDOT) and EIS studies from La Plata County in Colorado and the United States Department of the Interior's Bureau of Land Management (BLM) in Utah.

Because descriptions were not always available as to exactly which trucks are used for each phase, the reports and studies consulted were used to produce a best estimate as to how trucks are used. These resources were also referenced to estimate the average share of a phase's trips that each truck configuration would account for, and if the truck is loaded for inbound, outbound, or both trip directions.

Table 3-8 summarizes the types of trucks used by development stage and phase. Not shown in the table are truck types for the production period, which is primarily made up of pickup or similar trucks for maintenance and 5-axle haul trucks to handle resources and flowback water.

Table 3-8 Typical Truck Types by Development Phase

Stage	Phase	Truck Types
Construction	Pad and Road Construction	Pickup, 5-axle haul
	Drilling Rig	Pickup, Specialty (6+ axles)
Drilling	Drilling Fluid and Materials	3-axle haul, 5-axle haul
	Drilling Equipment (casing, drill pipe, etc)	3-axle haul, 5-axle haul
	Completion Rig	Pickup, Workover Rig
	Completion Fluid and Materials	3-axle haul, 5-axle haul
	Completion Equipment (pipe, wellhead, etc)	3-axle haul, 5-axle haul
Completion	Fracturing Equipment (pump trucks, tanks, etc)	3-axle haul, 5-axle haul
	Fracture Water	5-axle haul
	Fracture Sand	5-axle haul
	Flowback Water Disposal	5-axle haul

SOURCE: RPI Consulting, LLC, 2008; New York State Department of Environmental Conservation, 2011; Bureau of Land Management, 2008; La Plata County, 2002; North Dakota Department of Transportation, 2006; Upper Great Plains Transportation Institute, 2012; Upper Great Plains Transportation Institute, 2013; Bureau of Land Management, 2006; Upper Great Plains Transportation Institute, 2010; Bureau of Land Management, 2011; STE, 2012

3.2 Pavement Deterioration Calculation Methodology

The improvements and associated costs presented in this section represent the additional costs attributable to oil and gas traffic. They do not include baseline maintenance and/or improvement costs incurred by CDOT prior to substantial growth of oil and gas traffic.

Two factors are critical in analyzing the capabilities of paved roads to accommodate additional truck traffic: the current condition of the pavement and the structural rating, which is measured through the structural number (SN). The structural number is a function of the thickness of the surface and base layers and the materials of these layers. Pavement condition is measured by Drivability Life, which "is a measure, in years, of how long a highway will have acceptable driving conditions" and "is a function of smoothness, pavement distress, and safety based on [the International Roughness Index (IRI)], cracking, and rut depth data collected annually." CDOT classifies Drivability Life into three categories: high (>10 years), medium (3-10 years), and low (≤ 2 years).

Since oil and gas impacts can be seen statewide, other location and configuration inputs are required to aid in defining the impacts and aspects of the roadways being analyzed, such as:

- Which CDOT Engineering Region is the roadway located in? (R1, R2, R3, R4 or R5)
- What is the functional classification of the roadway? (interstate, arterial, collector, local)
- Is the roadway located in an urban environment or a rural environment?
- Is the roadway located in the Rocky Mountains or the Colorado plains?
- What is the roadway configuration? (paved width, # of through lanes, segment length) These factors are utilized to determine the associated cost.

Surface treatments were not included in the improvement cost because these treatments do not have an impact on the structural ability of the pavement. However, it is noted that surface treatments aid in the prevention of oxidation of the pavement, which in turn, prolongs the life of the pavement. The following sections describe the methodology that was utilized for Hot Mix Asphalt (HMA) Pavement and Concrete Pavement (PCCP).

HOT MIX ASPHALT

The approach to determine the associative impacts of oil and gas traffic on hot mix asphalt pavement roads requires the determination of the pavement structural number for existing traffic as well as existing traffic plus oil and gas traffic. In order to determine the existing structural number, the existing serviceability, initial serviceability, terminal serviceability, background ESALs, reliability level and standard deviation have to be defined. These values are then utilized to solve for the structural number within the 1993 AASHTO Guide equation for flexible pavement in **Figure 3-3**. The existing serviceability is based on the Drivability Life, as provided by CDOT, for each roadway. The existing serviceability is selected based on the Drivability Life and values shown in **Figure 3-4**. The remaining values shown in **Table 3-9** and **Table 3-10** are based on industry standards and calculations for the different roadway functional classifications.

After the structural number is calculated for the existing conditions, the structural number is calculated for the existing traffic plus the oil and gas traffic. The structural number deficiency is then calculated ($SN_{COMBINED}$ - $SN_{EXISTING}$). The required pavement overlay for the oil and gas traffic is then calculated by dividing the structural number deficiency by the standard deviation. A cost for the required overlay can then be calculated for each respective section of hot mix asphalt road. An example of this process follows.

Figure 3-3 AASHTO Guide Equation for Flexible Pavement

$$\log W_{18} = Z_R \times S_0 + 9.36 \log(SN+1) - 0.20 + \frac{\log\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \log(M_R) - 8.07$$

W_{18} = predicted number of 18,000 lbs. (ESALs)

Z_R = standard normal deviate

S_0 = standard deviation

SN = structural number

ΔPSI = existing serviceability – terminal serviceability

M_R = subgrade resilient modulus (in psi)

SOURCE: American Association of State Highway and Transportation Officials, 1993

Figure 3-4 Pavement Condition Rating

Pavement Condition	Drivability Life	Existing Serviceability	All Roads 4.5 ↓↓↓
GOOD	10 ↓↓↓ 9	4 Interstates, Arterials Major Collectors ↓↓↓	4 Minor Collectors Locals ↓↓↓
FAIR	8 ↓↓↓ 3	3.3 ↓↓↓	3.5 ↓↓↓
POOR	2 ↓↓↓ < 1	2.7 ↓↓↓ 2.0	3 ↓↓↓ 2.5

Table 3-9 Assumptions for Existing Pavement Sections

Functional Classification	Reliability (%)	Standard Normal Deviate (Z_R)	Initial Serviceability	Terminal Serviceability	Standard Deviation	(New) Structural Number (SN)
Interstate	95	-1.645	4.5	2.0	0.44	See **Table 3-10**
Principal Arterials – Other Freeways and Expressways	95	-1.645	4.5	2.0	0.44	
Principal Arterials – Other	95	-1.645	4.5	2.0	0.44	
Minor Arterial	95	-1.645	4.5	2.0	0.44	
Major Collectors	90	-1.282	4.5	2.0	0.44	
Minor Collectors	90	-1.282	4.5	2.5	0.44	
Local	80	-0.841	4.5	2.5	0.44	

SOURCE: Colorado Department of Transportation, 2014

Table 3-10 Assumptions for Design ESALs, Structural Numbers, and PCCP Thickness by CDOT Region

Functional Classification	CDOT Region 1			
	20-Year Design 18k ESALs		Structural Number[1] (SN) (New)	PCCP Thickness[2] (Inches)
	HMA	PCCP		
Urban Interstate (Plains)	41,225,509	69,162,414	5.93	13.25
Urban Interstate (Mountains)	-	-	-	-
Rural Interstate (Plains)	21,123,880	33,343,202	5.43	11.75
Rural Interstate (Mountains)	16,037,300	24,669,917	3.70	11.00
Urban Principal Arterial (Plains)	14,904,245	23,204,955	5.18	11.00
Urban Principal Arterial (Mountains)	-	-	-	-
Rural Principal Arterial (Plains)	13,119,668	-	5.09	-
Rural Principal Arterial (Mountains)	-	-	-	-
Urban Principal Arterial – Others (Plains)	5,137,529	8,403,350	4.47	9.50
Urban Principal Arterial – Others (Mountains)	-	-	-	-
Rural Principal Arterial – Others (Plains)	3,556,295	7,157,386	4.24	9.25
Rural Principal Arterial – Others (Mountains)	3,307,053	8,878,968	2.77	9.25
Urban Minor Arterial (Plains)	3,231,454	5,419,471	4.18	8.75
Urban Minor Arterial (Mountains)	1,550,946	829,801	2.46	6.00
Rural Minor Arterial (Plains)	2,060,232	-	3.91	-
Rural Minor Arterial (Mountains)	1,406,336	4,640,339	2.42	8.25
Urban Major Collector (Plains)	740,773	-	3.16	-
Urban Major Collector (Mountains)	-	-	-	-
Rural Major Collector (Plains)	1,679,945	-	3.59	-
Rural Major Collector (Mountains)	374,168	-	1.83	-
Urban Minor Collector (Plains)	-	-	-	-
Urban Minor Collector (Mountains)	-	-	-	-
Rural Minor Collector (Plains)	543,105	-	2.93	-
Rural Minor Collector (Mountains)	287,895	-	1.74	-
Urban Local (Plains)	-	-	-	-
Urban Local (Mountains)	-	-	-	-
Rural Local (Plains)	69,170	-	1.99	-
Rural Local (Mountains)	-	-	-	-

[1] The overall standard deviation (S) for HMA is 0.44

[2] The overall standard deviation (S) for PCCP is 0.34, a modulus of rupture of 650 psi, a modulus of elasticity of 3,400,000 psi, and J-factor of 2.8

* CDOT minimum thickness

- No value provided due to facility not within the CDOT region

SOURCE: Colorado Department of Transportation, 2014

Table 3-10 Assumptions for Design ESALs, Structural Numbers, and PCCP Thickness by CDOT Region (continued)

Functional Classification	CDOT Region 2			
	20-Year Design 18k ESALs		Structural Number[1] (SN) (New)	PCCP Thickness[2] (Inches)
	HMA	PCCP		
Urban Interstate (Plains)	24,794,357	48,464,346	5.55	12.25
Urban Interstate (Mountains)	-	-	-	-
Rural Interstate (Plains)	12,529,325	-	5.06	-
Rural Interstate (Mountains)	-	-	-	-
Urban Principal Arterial (Plains)	8,124,995	12,628,288	4.77	10.00
Urban Principal Arterial (Mountains)	7,137,711	-	3.13	-
Rural Principal Arterial (Plains)	-	-	-	-
Rural Principal Arterial (Mountains)	-	-	-	-
Urban Principal Arterial – Others (Plains)	3,826,673	2,126,101	4.28	7.50
Urban Principal Arterial – Others (Mountains)	4,460,576	-	2.91	-
Rural Principal Arterial – Others (Plains)	3,658,427	17,093,999	4.26	10.50
Rural Principal Arterial – Others (Mountains)	3,006,166	-	2.73	-
Urban Minor Arterial (Plains)	944,942	-	3.48	-
Urban Minor Arterial (Mountains)	1,267,536	-	2.38	-
Rural Minor Arterial (Plains)	1,090,433	-	3.55	-
Rural Minor Arterial (Mountains)	721,772	-	2.17	-
Urban Major Collector (Plains)	531,930	-	3.00	-
Urban Major Collector (Mountains)	-	-	-	-
Rural Major Collector (Plains)	454,704	300,395	2.93	5.00*
Rural Major Collector (Mountains)	639,983	-	2.00	-
Urban Minor Collector (Plains)	-	-	-	-
Urban Minor Collector (Mountains)	-	-	-	-
Rural Minor Collector (Plains)	138,380	-	2.39	-
Rural Minor Collector (Mountains)	212,074	-	1.65	-
Urban Local (Plains)	-	-	-	-
Urban Local (Mountains)	-	-	-	-
Rural Local (Plains)	-	-	-	-
Rural Local (Mountains)	-	-	-	-

[1] The overall standard deviation (S) for HMA is 0.44

[2] The overall standard deviation (S) for PCCP is 0.34, a modulus of rupture of 650 psi, a modulus of elasticity of 3,400,000 psi, and J-factor of 2.8

* CDOT minimum thickness

- No value provided due to facility not within the CDOT region

SOURCE: Colorado Department of Transportation, 2014

Table 3-10 Assumptions for Design ESALs, Structural Numbers, and PCCP Thickness by CDOT Region (continued)

Functional Classification	CDOT Region 3			
	20-Year Design 18k ESALs		Structural Number[1] (SN) (New)	PCCP Thickness[2] (Inches)
	HMA	PCCP		
Urban Interstate (Plains)	14,303,879	-	4.96	-
Urban Interstate (Mountains)	14,999,192	19,649,108	3.51	10.50
Rural Interstate (Plains)	13,729,143	23,429,680	4.93	11.00
Rural Interstate (Mountains)	13,566,981	19,224,499	3.45	10.50
Urban Principal Arterial (Plains)	-	-	-	-
Urban Principal Arterial (Mountains)	3,498,380	-	2.80	-
Rural Principal Arterial (Plains)	-	-	-	-
Rural Principal Arterial (Mountains)	-	-	-	-
Urban Principal Arterial – Others (Plains)	4,159,109	6,119,289	4.16	9.00
Urban Principal Arterial – Others (Mountains)	2,943,068	6,350,062	2.72	8.75
Rural Principal Arterial – Others (Plains)	2,572,820	-	3.88	-
Rural Principal Arterial – Others (Mountains)	2,431,663	-	2.64	-
Urban Minor Arterial (Plains)	1,816,911	-	3.68	-
Urban Minor Arterial (Mountains)	-	-	-	-
Rural Minor Arterial (Plains)	-	-	-	-
Rural Minor Arterial (Mountains)	760,115	-	2.19	-
Urban Major Collector (Plains)	2,070,074	-	3.41	-
Urban Major Collector (Mountains)	1,226,296	-	2.23	-
Rural Major Collector (Plains)	778,553	-	2.97	-
Rural Major Collector (Mountains)	701,247	965,522	2.03	5.75
Urban Minor Collector (Plains)	-	-	-	-
Urban Minor Collector (Mountains)	-	-	-	-
Rural Minor Collector (Plains)	-	-	-	-
Rural Minor Collector (Mountains)	144,499	-	1.54	-
Urban Local (Plains)	-	-	-	-
Urban Local (Mountains)	-	-	-	-
Rural Local (Plains)	-	-	-	-
Rural Local (Mountains)	-	-	-	-

[1] The overall standard deviation (S) for HMA is 0.44

[2] The overall standard deviation (S) for PCCP is 0.34, a modulus of rupture of 650 psi, a modulus of elasticity of 3,400,000 psi, and J-factor of 2.8

* CDOT minimum thickness

- No value provided due to facility not within the CDOT region

SOURCE: Colorado Department of Transportation, 2014

Table 3-10 Assumptions for Design ESALs, Structural Numbers, and PCCP Thickness by CDOT Region (continued)

Functional Classification	CDOT Region 4			
	20-Year Design 18k ESALs		Structural Number[1] (SN) (New)	PCCP Thickness[2] (Inches)
	HMA	PCCP		
Urban Interstate (Plains)	18,579,164	46,753,640	5.34	12.25
Urban Interstate (Mountains)	-	-	-	-
Rural Interstate (Plains)	14,879,876	24,623,861	5.18	11.25
Rural Interstate (Mountains)	-	-	-	-
Urban Principal Arterial (Plains)	8,844,609	7,969,472	4.83	9.25
Urban Principal Arterial (Mountains)	7,502,156	11,361,775	3.15	9.75
Rural Principal Arterial (Plains)	8,193,530	3,582,431	4.77	8.25
Rural Principal Arterial (Mountains)	-	-	-	-
Urban Principal Arterial – Others (Plains)	-	-	-	-
Urban Principal Arterial – Others (Mountains)	3,133,894	7,854,895	2.75	9.00
Rural Principal Arterial – Others (Plains)	3,467,029	13,238,864	4.22	10.00
Rural Principal Arterial – Others (Mountains)	3,276,806	8,757,033	2.77	9.25
Urban Minor Arterial (Plains)	-	-	-	-
Urban Minor Arterial (Mountains)	1,191,455	2,158,674	2.35	7.25
Rural Minor Arterial (Plains)	-	-	-	-
Rural Minor Arterial (Mountains)	634,776	-	2.13	-
Urban Major Collector (Plains)	1,596,290	-	3.56	-
Urban Major Collector (Mountains)	2,498,928	-	2.50	-
Rural Major Collector (Plains)	918,758	-	3.27	-
Rural Major Collector (Mountains)	1,849,445	-	2.38	-
Urban Minor Collector (Plains)	-	-	-	-
Urban Minor Collector (Mountains)	-	-	-	-
Rural Minor Collector (Plains)	461,165	-	2.86	-
Rural Minor Collector (Mountains)	62,178	-	1.32	-
Urban Local (Plains)	-	-	-	-
Urban Local (Mountains)	-	-	-	-
Rural Local (Plains)	604,981	-	2.79	-
Rural Local (Mountains)	-	-	-	-

[1] The overall standard deviation (S) for HMA is 0.44

[2] The overall standard deviation (S) for PCCP is 0.34, a modulus of rupture of 650 psi, a modulus of elasticity of 3,400,000 psi, and J-factor of 2.8

* CDOT minimum thickness

- No value provided due to facility not within the CDOT region

SOURCE: Colorado Department of Transportation, 2014

Table 3-10 Assumptions for Design ESALs, Structural Numbers, and PCCP Thickness by CDOT Region (continued)

Functional Classification	CDOT Region 5			
	20-Year Design 18k ESALs		Structural Number[1] (SN) (New)	PCCP Thickness[2] (Inches)
	HMA	PCCP		
Urban Interstate (Plains)	-	-	-	-
Urban Interstate (Mountains)	-	-	-	-
Rural Interstate (Plains)	-	-	-	-
Rural Interstate (Mountains)	-	-	-	-
Urban Principal Arterial (Plains)	3,259,733	4,157,271	4.02	8.50
Urban Principal Arterial (Mountains)	3,922,137	6,226,763	2.85	8.75
Rural Principal Arterial (Plains)	2,567,408	-	3.88	-
Rural Principal Arterial (Mountains)	2,621,244	4,935,178	2.67	8.50
Urban Principal Arterial – Others (Plains)	-	-	-	-
Urban Principal Arterial – Others (Mountains)	-	-	-	-
Rural Principal Arterial – Others (Plains)	-	-	-	-
Rural Principal Arterial – Others (Mountains)	-	-	-	-
Urban Minor Arterial (Plains)	-	-	-	-
Urban Minor Arterial (Mountains)	862,074	-	2.23	-
Rural Minor Arterial (Plains)	682,183	-	3.16	-
Rural Minor Arterial (Mountains)	719,941	665,433	2.17	5.75
Urban Major Collector (Plains)	-	-	-	-
Urban Major Collector (Mountains)	-	-	-	-
Rural Major Collector (Plains)	285,405	-	2.60	-
Rural Major Collector (Mountains)	669,877	-	1.75	-
Urban Minor Collector (Plains)	-	-	-	-
Urban Minor Collector (Mountains)	-	-	-	-
Rural Minor Collector (Plains)	271,011	-	2.53	-
Rural Minor Collector (Mountains)	231,348	-	1.68	-
Urban Local (Plains)	-	-	-	-
Urban Local (Mountains)	-	-	-	-
Rural Local (Plains)	-	-	-	-
Rural Local (Mountains)	-	-	-	-

[1] The overall standard deviation (S) for HMA is 0.44

[2] The overall standard deviation (S) for PCCP is 0.34, a modulus of rupture of 650 psi, a modulus of elasticity of 3,400,000 psi, and J-factor of 2.8

* CDOT minimum thickness

- No value provided due to facility not within the CDOT region

SOURCE: Colorado Department of Transportation, 2014

Hot Mix Asphalt Pavement Example – State Highway 63A (Anton to Akron)

Start Mile Post: 0

End Mile Post: 28.315

CDOT Engineering Region: R4

Functional Classification: Major Collector

Urban or Rural? Rural

Mountain or Plains? Plains

Paved Width: Varies from 35 feet to 65 feet (Use 37 feet)

Drivability Life: 4

Pavement Condition = Fair

Design ESAL = 918,758 (from **Table 3-10**)

Design ESAL (per year) = 918,758/20 (20-year design life) = 45,938

Existing Serviceability = 3.5 (from **Figure 3-4**)

Terminal Serviceability = 2.0 (from **Table 3-9**)

Reliability Level = 90% (from **Table 3-9**)

Standard Normal Deviate (Z_R) = -1.282 (from **Table 3-9**)

Existing SN = Solving AASHTO Equation = 2.05

Oil & Gas ESAL (per year) = 12,625

Combined ESAL = 45,938 + 12,625 = 58,563

Combined SN = Solving AASHTO Equation = 2.14

SN Deficiency = $SN_{COMBINED}$ - $SN_{EXISTING}$ = 2.14 – 2.05 = 0.09

Required Overlay to achieve the Same Remaining Life = SN Deficiency/Standard Deviation = 0.09/0.44 = 0.20”

Associated Costs = Inches of HMA x Length of Road x Roadway Width x HMA Overlay Costs ($155/Ton)

Associated Costs = 0.20” x (0.055 Tons/SY/1” Thickness) x 28.315 Miles x (5280 Feet/Mile) x 37 Feet x (1 Sq Yard/9 Sq Feet) x $155/Ton = $1,047,934.38 (Rounded to $1,048,500)

CONCRETE

The approach to determine the associative impacts of oil and gas traffic on concrete pavement roads requires the determination of the pavement service life. Standard design for pavement service life is a span of 20 years. The associated ESAL for the 20-year pavement service life are shown in **Table 3-10**.

Oil and gas traffic will decrease the overall pavement service life for concrete roads. The amount of this decrease is calculated as a percentage and based on the calculated ESAL amount for oil and gas traffic divided by the overall design ESAL. This percentage is then multiplied by the improvement costs per mile to reconstruct a concrete pavement road in its entirety. In the analysis, a reconstruction cost of $572,725 per lane per mile is utilized for reconstruction. This cost was derived from the CDOT *Transportation Facts for 2011* publication. An example of this process follows.

Concrete Pavement Example – State Highway 121A (Wadsworth Boulevard)
(West Chatfield Avenue to West Ken Caryl Avenue)

Start Mile Post: 1.204

End Mile Post: 2.276

CDOT Engineering Region: R1

Functional Classification – Principal Arterial – Freeways and Expressways

Urban or Rural? Urban

Mountain or Plains? Plains

Paved Width: Varies from 70 feet to 100 feet (Use 70 feet)

# of Through Lanes: 4

Drivability Life: 11

Pavement Condition = Good

Design ESAL = 23,204,955 (from **Table 3-10**)

Oil & Gas ESAL = 21,564

Pavement Service Life Impact = Oil & Gas ESAL/Design ESAL = 21,564/23,204,955 = 0.000929 or 0.093%

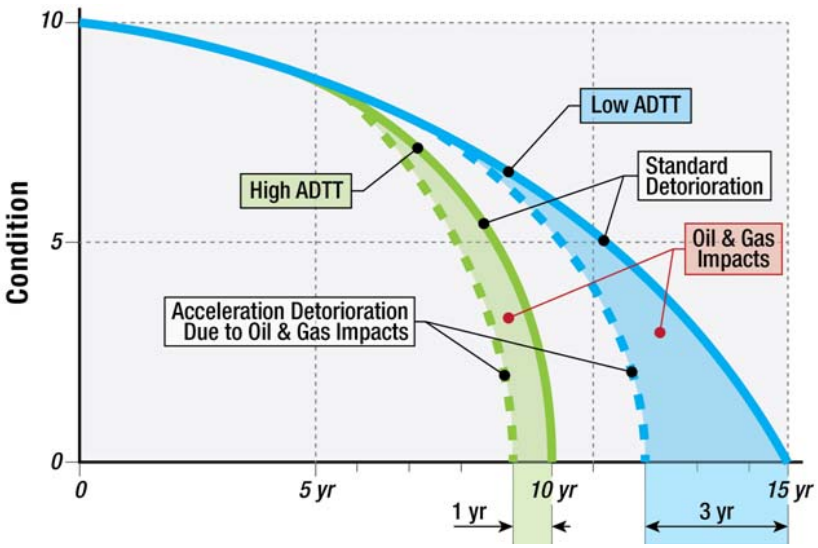
Associated Costs = Impact x Length of Road x Lanes x Reconstruction Cost

Associated Costs = 0.093% x 1.072 Miles x 4 Lanes x $572,725/Lane/Mile = $2,282 (Rounded to $2,300)

3.3 Bridge Deterioration Calculation Methodology

The impacts to the CDOT bridge network from oil and gas activities have been estimated using average life cycle deterioration rates and current year replacement costs. Our approach has attributed a “fair share” approach to oil and gas by comparing existing Average Daily Truck Traffic (ADTT) to the increased ADTT’s when oil and gas operations are introduced. Facilities with existing high ADTTs, such as interstate highways, are less impacted by the oil and gas industry. Facilities with low ADTT, such as some rural 2-lane highways, are much more impacted when oil and gas is introduced to the facility. **Figure 3-5** illustrates this concept.

Figure 3-5 Bridge Deterioration



This approach does not depend on the current condition of the bridge and its various elements. If a bridge is in dire need of major rehabilitation, the oil and gas industry is not responsible for the cost of the full rehabilitation prior to beginning its production, as it did not cause the disrepair. Nor is the oil and gas industry void of any financial responsibility if it uses a brand new bridge, as it still is participating in a shortened lifespan of the various elements over time. This approach relies on a comparison of truck traffic and the basic elements of the bridge, simplifying user input and eliminating the need for constant tracking of existing bridge condition.

Specific bridge elements which are considered in the evaluation are those most often addressed during rehabilitation of the state’s bridges: deck overlay, deck replacement, expansion joints, and bearings. Replacement costs for rehabilitation elements are inflated to account for the premium of rehabilitation when compared to new construction. In addition, the replacement cost of the bridge is calculated so that the overall impact to the bridge lifespan can be estimated, and a fair share of impact can be attributed to the increase in truck traffic due to oil and gas. Replacement cost is estimated using average bridge costs for new construction.

Our methodology in estimating the impacts due to oil and gas activity reflects only the direct impact of the truck traffic on the bridge, and does not identify additional environmental induced deterioration trends from heavy truck usage. If bridge repair and rehabilitation activities are not accelerated in proportion to the impacts of oil and gas activity, bridge lifespan will be further reduced by the affects of environmental factors such as freeze-thaw on deck concrete, water intrusion in leaking joints, and associated deterioration of bearings to name a few.

3.4 Cost Estimation Tool

The CDOT Oil & Gas Impacts Calculator is an Excel-based tool that estimates the costs associated with oil and gas development and production truck traffic on user-specified CDOT roadway segments and bridges. The tool is designed to provide spot analysis for a particular site, giving local and regional staff the ability to estimate impacts on specific facilities according to localized transportation and industry parameters.

Process and Capabilities

The tool consists of inputs that the user provides, data constants as a result of this study (trip generation, truck types, road and bridge costs, etc.) and from CDOT (design ESALs, roadway coefficients, costs, etc.), calculations to determine impacts on roadways and bridges as described earlier in this study, and outputs summarizing the calculated impacts. Only the inputs and outputs are visible to the user.

Inputs

The tool allows the user to analyze the impacts of oil and gas truck traffic on multiple road segments, bridges, or both. The tool also uses parameters that incorporate the level of oil and gas activity, which can be modified by the user. **Table 3-11** outlines the inputs that must or can be entered to obtain impacts from the tool.

Table 3-11 CDOT Oil & Gas Impacts Calculator Inputs

Roadway Inputs	Bridge Inputs	Oil & Gas Activity Inputs
• Name • Starting and ending mileposts • CDOT Region • Functional class • Location (urban or rural) • Topography (mountains or plains) • Length and paved width • Surface type (asphalt or concrete) • Number of through lanes • Drivability life (years remaining)	• Structure number • Facility carried • Feature intersected • Baseline Average Daily Truck Traffic (ADTT) • Width and length • Deck overlay type • Joints (type, number, and skew) • Bearings (type and number) • Bridge replacement method (percent increase in area or defined width/length)	• Type of development (horizontal, vertical, or recompletion) • Fresh water pipeline • Number of pads and wells to be developed • Anticipated number of years of production • Length of development • Number of existing producing pads and wells • Estimated number of years of production remaining for existing pads/wells • Percent of trip types using the facilities

Analysis

The tool takes the inputs and applies them to formulas designed to determine impacts. For asphalt roadway segments, the tool uses inputs to estimate the amount of overlay necessary to offset the impacts of the oil and gas trucks, while the tool estimates the portion of concrete reconstruction attributed to oil and gas based on the facility’s design ESAL life. Bridge analysis operates similar to the concrete roadway analysis by estimating the portion of bridge repair and replacement attributed to oil and gas based on designed truck volumes. These calculations utilize CDOT standards relative to the design life of these facilities.

Outputs

Once impacts have been calculated, the tool applies CDOT-provided standard costs to arrive at costs attributed to the oil and gas industry. Costs are broken out four ways: development phase costs, annual production phase costs, total production phase costs over the defined well lifespan, and a grand total of all costs.

Application and Limitations

The tool is specifically designed for a micro-level analysis rather than a macro-level analysis, such as the entire CDOT highway network or bridge inventory. The following provides a list of applications and limitations of the tool.

Applications

- Used to understand the level of impacts to a specific localized facility and/or corridor
- Assists in route optimization to reduce transportation system impacts by comparing multiple available routes, with the optimal route possibly not being the shortest path
- Provide context of oil and gas activity impacts compared to overall costs

Limitations

- Used for specific roadway segments/corridors and/or bridges, not the entire CDOT highway network or bridge inventory
- Analysis for multiple time periods would require setting up the tool for a year, copying it, and editing the copy to reflect the oil and gas activity in the new year of analysis
- Requires the manual input of the variables defined
- Constants used by the tool are currently locked to prevent modifications, but can be unlocked to update the tool in the future.

Example Applications

To help illustrate how the tool can be used and what outputs it generates, three examples complete with screenshots have been developed for this document. Please refer to **Appendix A** for a more in-depth description on how to operate the tool.

Example #1: Eastern Plains

The first example is a relatively simple scenario that takes place on SH 63 south of Akron, demonstrating a relatively short route with a medium Drivability Life. The example assumes trips are traveling to/from I-70 to the north, after which trips are no longer being analyzed in this particular scenario. **Figure 3-6** is a screenshot of the input requirements for the first of three segments of SH 63 that are being analyzed, all of which are actual data from CDOT at the time of this study.

Figure 3-6 Tool Example #1: Screenshot of Roadway Segment Inputs

SEGMENT: 1			
Q1.	Name of the roadway:	SH 63	
Q2.	Start Mile Post:	21.150	
Q3.	End Mile Post:	27.000	
Q4.	CDOT Region:	R4	
Q5.	Functional Class:	Major Collector	
Q6.	Urban or Rural?:	Rural	
Q7.	Mountains or Plains?:	Plains	
Q8.	Segment Length (miles):	5.850	mi
Q9.	Surface Type:	Asphalt	
Q10.	Paved Width (feet, total of both directions):	37	ft
Q11.	# of Through Lanes (total of both directions):	2	
Q12.	Driveability Life (years remaining):	4	years

This example also has a bridge located along the analysis route. **Figure 3-7** is a screenshot of the input requirements for this bridge being analyzed, of which most are actual data from CDOT at the time of this study.

Figure 3-7 Tool Example #1: Screenshot of Bridge Inputs

BRIDGE: 1			
Q1.	Structure #:	D-24-M	
Q2.	Facility Carried:	SH 63	
Q3.	Feature Intersected:	draw	
Q4.	Baseline Average Daily Truck Traffic (ADTT):	80	trucks/day
Q5.	Bridge Width (feet):	99	ft
Q6.	Bridge Length (feet):	35	ft
Deck -			
Q7.	Deck Overlay Type:	HMA/Membrane	
Joints -			
Q8.	Bridge Joint Type:	0-4 inch	
Q8a.	# of Joints along Bridge:	1	
Q8b.	Joint Skew (no skew = 0 deg):	30	deg
Bearings -			
Q9.	Bridge Bearing Type:	No Bearings	
Replacement Bridge -			
Q10.	Replacement Estimate Method:	% Increase	
Q10a.	% Increase in Replacement Bridge Area:	0	% (100% of the existing area will automatically be added)

The final inputs in this example pertain to oil and gas activity. This example assumes a small amount of new activity based on the assumed current industry standard of eight wells on a pad. This example also analyzes an existing pad with four wells that are producing oil. **Figure 3-8** shows all of the oil and gas related inputs assumed in this example, including that all trips involved are assumed to use SH 63 and bridge D-24-M.

Figure 3-8 Tool Example #1: Screenshot of Oil and Gas Activity Inputs

Activity Settings

Q1.	**What is the type of development?**	Horizontal	
Q2.	**Is a pipeline providing fresh water?**	No	
Q3.	**# of DEVELOPING Pads and Wells to Analyze:**	*Pad(s)*	*Well(s)*
	(wells are the total # across all pads)	2	16
Q3a.	**Anticipated # of years of production:**	20 years	
	(Leave at 20 if unsure)		
Q3b.	**Anticipated length of development (days):**	30 days	
	(Leave at 30 if unsure)		
Q4.	**# of EXISTING Pads and Wells to Analyze:**	*Pad(s)*	*Well(s)*
	(wells are the total # across all pads)	1	4
Q4a.	**Estimated # of years of production remaining:**	12 years	
Q5.	**What % of trip types will be using the facility?**		
	(Leave at 100% if unsure)	*%*	

Workers:	100 %
Construction equipment:	100 %
Drilling Rig & Support:	100 %
Pipe:	100 %
Gravel:	100 %
Cement:	100 %
Fuel:	100 %
Drilling Chemicals:	100 %
Sand:	100 %
Fresh Water:	100 %
Flowback Water Disposal:	100 %
Produced Oil:	100 %

With all inputs entered and the analysis executed, the tool provides a summary of costs attributed to the entered oil and gas activity on the analyzed roadway segments and bridge. It also provides a summary of the number of one-way oil and gas trips. **Figure 3-9** is a screenshot of these impact outputs for this example.

Figure 3-9 Tool Example #1: Screenshot of Impacts Report

Roadway Impacts

ID	Name	Start MP	End MP	Length	Surface	Development Costs ($2014)	Future Pad(s) Production Costs ($2014) / Year	Existing Pad(s) Production Costs ($2014) / Year
1	SH 63	21.150	27.000	5.850	Asphalt	$ 408,700.00	$ 25,500.00	$ 12,900.00
2	SH 63	27.000	28.884	1.884	Asphalt	$ 145,900.00	$ 9,100.00	$ 4,600.00
3	SH 63	28.884	29.006	0.122	Asphalt	$ 6,500.00	$ 400.00	$ 200.00
TOTAL:				7.856		$ 561,100.00	$ 35,000.00	$ 17,700.00
					Total over years of production:		$ 700,000.00	$ 212,400.00

Total additional roadway costs over life of pad(s): $ 1,473,500.00 ($2014)

Bridge Impacts

ID	Structure #	Facility Carried	Feature Intersected	Development Costs ($2014)	Future Pad(s) Production Costs ($2014) / Year	Existing Pad(s) Production Costs ($2014) / Year
1	D-24-M	SH 63	draw	$ 13,900.00	$ 600.00	$ 300.00
TOTAL:				$ 13,900.00	$ 600.00	$ 300.00
			Total over years of production:		$ 12,000.00	$ 3,600.00

Total additional bridge costs over life of pad(s): $ 29,500.00 ($2014)

Total Impacts

	Total Development Costs ($2014)	Total Future Pad(s) Production Costs ($2014) / Year	Total Existing Pad(s) Production Costs ($2014) / Year
	$ 575,000.00	$ 35,600.00	$ 18,000.00
Total over years of production:		$ 712,000.00	$ 216,000.00

Total additional transportation costs over life of pad(s): $ 1,503,000.00 ($2014)

Activity Settings & Totals

Type of Activity: Horizontal

Pad(s):	*Future*	*Existing*
Total Pad(s):	2	1
Total Well(s):	16	4
Years of Production:	20	12
Total One-Way Development Trips:	24,740 *	
One-Way Production Trips (Annual):	1,120	560 *
Total One-Way Production Trips:	22,400	6,720 *

* *Trips may have been reduced (through user settings) based on estimated % of trip types using the facilities. See the "Inputs" tab for settings used.*

Example #2: Weld County

The second example is also along one roadway, but for a longer stretch and with more oil and gas activity being assumed. It is intended to show a scenario where a greater amount of impact is anticipated given the longer route and additional oil and gas activity compared to Example #1.

Example #2 is for about twenty miles of SH 14 in Weld County, starting in Ault and going east. The example assumes trips are traveling to/from US 85 in Ault, after which trips are no longer being analyzed in this particular scenario. **Figure 3-10** is a screenshot of the input requirements for the first two segments of SH 14 that are being analyzed, of which most of the data is actual roadway data from CDOT at the time of this study. The Drivability Life was modified for the first segment to demonstrate results of a low Drivability Life segment.

Figure 3-10 Tool Example #2: Screenshot of Roadway Segment Inputs

SEGMENT: 1

Q1.	Name of the roadway:	SH 14	
Q2.	Start Mile Post:	153.286	
Q3.	End Mile Post:	153.427	
Q4.	CDOT Region:	R4	
Q5.	Functional Class:	Principal Arterial - Others	
Q6.	Urban or Rural?:	Urban	
Q7.	Mountains or Plains?:	Plains	
Q8.	Segment Length (miles):	0.141	mi
Q9.	Surface Type:	Asphalt	
Q10.	Paved Width (feet, total of both directions):	50	ft
Q11.	# of Through Lanes (total of both directions):	2	
Q12.	Driveability Life (years remaining):	0	years

SEGMENT: 2

Q1.	Name of the roadway:	SH 14	
Q2.	Start Mile Post:	153.427	
Q3.	End Mile Post:	153.622	
Q4.	CDOT Region:	R4	
Q5.	Functional Class:	Principal Arterial - Others	
Q6.	Urban or Rural?:	Rural	
Q7.	Mountains or Plains?:	Plains	
Q8.	Segment Length (miles):	0.195	mi
Q9.	Surface Type:	Asphalt	
Q10.	Paved Width (feet, total of both directions):	44	ft
Q11.	# of Through Lanes (total of both directions):	2	
Q12.	Driveability Life (years remaining):	6	years

As mentioned, this example has an elevated level of oil and gas activity compared to Example #1, with ten pads each with eight wells (for a total of eighty wells) analyzed. No existing producing wells were analyzed. All trip types were assumed to be using the defined route. **Figure 3-11** shows all of the oil and gas related inputs assumed in this example.

Figure 3-11 Tool Example #2: Screenshot of Oil and Gas Activity Inputs

Activity Settings

Q1.	**What is the type of development?**	Horizontal	
Q2.	**Is a pipeline providing fresh water?**	No	
Q3.	**# of DEVELOPING Pads and Wells to Analyze:**	*Pad(s)*	*Well(s)*
	(wells are the total # across all pads)	10	80
Q3a.	**Anticipated # of years of production:**	20 years	
	(Leave at 20 if unsure)		
Q3b.	**Anticipated length of development (days):**	30 days	
	(Leave at 30 if unsure)		
Q4.	**# of EXISTING Pads and Wells to Analyze:**	*Pad(s)*	*Well(s)*
	(wells are the total # across all pads)		
Q4a.	**Estimated # of years of production remaining:**	years	
Q5.	**What % of trip types will be using the facility?**		
	(Leave at 100% if unsure)	*%*	
	Workers:	100 %	
	Construction equipment:	100 %	
	Drilling Rig & Support:	100 %	
	Pipe:	100 %	
	Gravel:	100 %	
	Cement:	100 %	
	Fuel:	100 %	
	Drilling Chemicals:	100 %	
	Sand:	100 %	
	Fresh Water:	100 %	
	Flowback Water Disposal:	100 %	
	Produced Oil:	100 %	

With all inputs entered and the analysis executed, the tool provides a summary of costs attributed to the entered oil and gas activity on the analyzed roadway segments and bridge. It also provides a summary of the number of one-way oil and gas trips. **Figure 3-12** is a screenshot of these impact outputs for this example. Note there are no bridge impacts, as no bridge was analyzed along the route.

Figure 3-12 Tool Example #2: Screenshot of Impacts Report

Roadway Impacts

ID	Name	Start MP	End MP	Length	Surface	Development Costs ($2014)	Future Pad(s) Production Costs ($2014) / Year	Existing Pad(s) Production Costs ($2014) / Year
1	A(n) Urban Principal Arterial - Others in the Plains for R4 is not in the CDOT database. Please select a different combination for this segment.							
2	SH 14	153.427	153.622	0.195	Asphalt	$ 28,600.00	$ 1,900.00	$ -
3	SH 14	153.622	157.350	3.728	Asphalt	$ 496,300.00	$ 32,400.00	$ -
4	SH 14	157.350	158.430	1.080	Asphalt	$ 115,100.00	$ 7,600.00	$ -
5	SH 14	158.430	159.000	0.570	Asphalt	$ 68,300.00	$ 4,500.00	$ -
6	SH 14	159.000	162.000	3.000	Asphalt	$ 279,600.00	$ 18,300.00	$ -
7	SH 14	162.000	164.000	2.000	Asphalt	$ 213,100.00	$ 13,900.00	$ -
8	SH 14	164.000	176.000	12.000	Asphalt	$ 985,800.00	$ 65,500.00	$ -
TOTAL:				22.573		$ 2,186,800.00	$ 144,100.00	$ -
					Total over years of production:		$ 2,882,000.00	$ -

Total additional roadway costs over life of pad(s): $ 5,068,800.00 ($2014)

Bridge Impacts

ID	Structure #	Facility Carried	Feature Intersected	Development Costs ($2014)	Future Pad(s) Production Costs ($2014) / Year	Existing Pad(s) Production Costs ($2014) / Year
TOTAL:				$ -	$ -	$ -
			Total over years of production:		$ -	$ -

Total additional bridge costs over life of pad(s): $ - ($2014)

Total Impacts

	Total Development Costs ($2014)	Total Future Pad(s) Production Costs ($2014) / Year	Total Existing Pad(s) Production Costs ($2014) / Year
	$ 2,186,800.00	$ 144,100.00	$ -
Total over years of production:		$ 2,882,000.00	$ -

Total additional transportation costs over life of pad(s): $ 5,068,800.00 ($2014)

Activity Settings & Totals

Type of Activity: Horizontal

Pad(s):	*Future*	*Existing*
Total Pad(s):	10	0
Total Well(s):	80	0
Years of Production:	20	0
Total One-Way Development Trips:	123,700 *	
One-Way Production Trips (Annual):	5,600	0 *
Total One-Way Production Trips:	112,000	0 *

* *Trips may have been reduced (through user settings) based on estimated % of trip types using the facilities. See the "Inputs" tab for settings used.*

Example #3: Multiple Routes Comparison

The last example consists of two analyses: one for a route using SH 7 to reach I-25, and another to analyze the same level of oil and gas activity (displayed in **Figure 3-13**) using another viable route consisting of E-470 and I-25 to reach the same point a truck is trying to reach by using SH 7. The purpose of this example is to show how the tool can be used to compare two routes and see if an alternative route that is deemed to be a reasonable substitute to the initially preferred route might result in lower financial impacts due to the difference in the type of facilities and their condition.

The SH 7 portion of Example #3 is from Colorado Boulevard north of E-470 to I-25, after which trips are no longer analyzed in this particular scenario. The alternative to SH 7 is to take Colorado Boulevard to E-470 and then use I-25. For simplicity, this example does not account for the fact that E-470 is a tolled facility.

Figure 3-13 Tool Example #3: Screenshot of Oil and Gas Activity Inputs

Activity Settings

Q1.	**What is the type of development?**	Horizontal	
Q2.	**Is a pipeline providing fresh water?**	No	
Q3.	**# of DEVELOPING Pads and Wells to Analyze:**	*Pad(s)*	*Well(s)*
	(wells are the total # across all pads)	2	16
Q3a.	**Anticipated # of years of production:**	20 years	
	(Leave at 20 if unsure)		
Q3b.	**Anticipated length of development (days):**	30 days	
	(Leave at 30 if unsure)		
Q4.	**# of EXISTING Pads and Wells to Analyze:**	*Pad(s)*	*Well(s)*
	(wells are the total # across all pads)	1	5
Q4a.	**Estimated # of years of production remaining:**	15 years	
Q5.	**What % of trip types will be using the facility?**		
	(Leave at 100% if unsure)	*%*	
	Workers:	100 %	
	Construction equipment:	100 %	
	Drilling Rig & Support:	100 %	
	Pipe:	100 %	
	Gravel:	100 %	
	Cement:	100 %	
	Fuel:	100 %	
	Drilling Chemicals:	100 %	
	Sand:	100 %	
	Fresh Water:	100 %	
	Flowback Water Disposal:	100 %	
	Produced Oil:	100 %	

Screenshots for roadway and bridge inputs are not included for this example since they are similar to the first two examples. Important differences between the two routes are shown in **Table 3-12**. All values used for roadway segments are actual values from CDOT for the facilities, current at the time of this study. The bridge located on SH 7 is mostly represented by real data, though some unknown inputs were picked to allow for an example.

Table 3-12 Tool Example #3: Comparing Inputs for Two Routes

Input	SH 7 Route	E-470 / I-25 Route
Length (miles):	2.650 miles	3.943 miles
Drivability Life:	6 years	9 years
Average Pavement Width (feet):	116 feet	66 feet
Bridges:	1	0

Table 3-13 compares the output of impacts for each route in 2014 dollars. These costs are for the life of the pad, which includes both development and production periods, of which production is estimated to be twenty years.

Table 3-13 Tool Example #3: Comparing Outputs for Two Routes

Outputs	SH 7 Route	E-470 / I-25 Route
Roadway Costs:	$281,000	$126,700
Bridge Costs:	$27,400	$0
Total Costs:	$308,400	$126,700

Despite the SH 7 route being 1.3 miles less than the E-470 / I-25 route, its cost impact is estimated to be more than double the E-470 / I-25 alternative. Even if the bridge on SH 7 is removed from the calculation, the SH 7 route is still double the cost. This is because of the design differences between the two routes. Both E-470 and I-25 are designed to handle more ESALs than SH 7. This comparison shows that the tool can be useful in trying to find a less impactful route if multiple routes exist.

4.0 MAGNITUDE OF STATEWIDE IMPACTS AND KEY ENERGY CORRIDORS

4.1 Inventory of Roadways and Bridges

An inventory of roadways and bridges that may impede oil and gas activity or be susceptible to increased deterioration from oil and gas activity were identified. These facilities are then mapped along corridors where oil and gas activity is anticipated to have the greatest impact.

Roadways with a low Drivability Life (≤ 2 years) may be susceptible to an increased level of impact from heavy loads, requiring reconstruction. **Figure 4-1** maps the Drivability Life of the entire state highway system throughout Colorado.

Bridges have a number of factors that can be of concern when it comes to large vehicles crossing over and/or under them. Based on available data from the National Bridge Inventory, height and weight restrictions were used to identify bridges of possible concern with trucks used for oil and gas activity. **Figure 4-2** maps these bridges on the state highway system in Colorado. Depending on specifics of the restricted bridges and trucking needs of the industry, these structures could require rerouting to accommodate specialized vehicles used in oil and gas development.

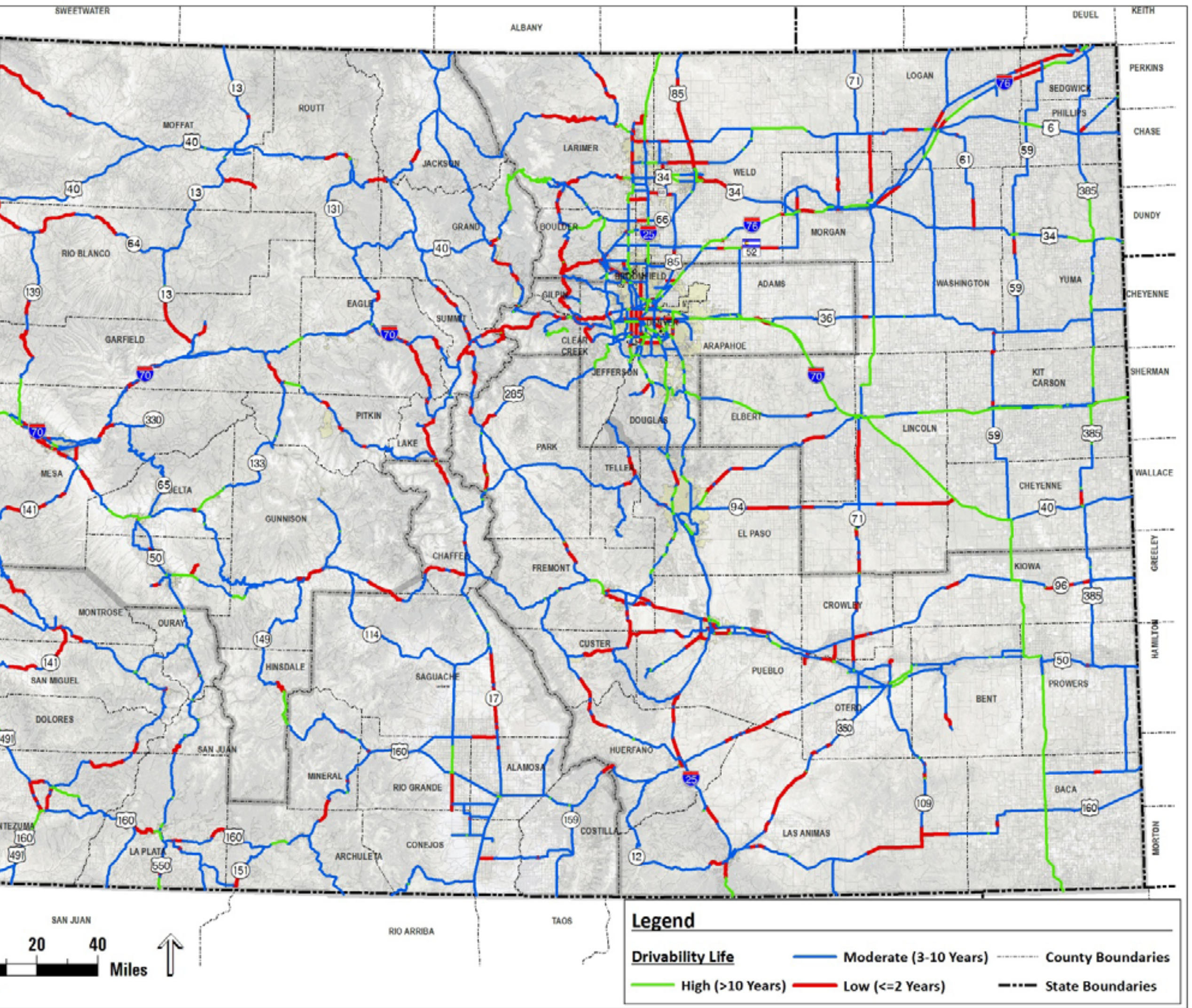
4.2 Overview of Truck Trip Generation and Loads

Oil and gas development requires the transport of heavy equipment to the well site to build access roads, construct a well pad, and transport a drilling rig. Heavy trucks are also required to bring fresh water to the well site and often to transport produced water and extracted resources off site. Oil and gas drilling practices have evolved to cluster multiple wells on one pad and employ horizontal drilling and hydraulic fracturing (fracking) techniques. Average trip generation for a horizontal 6-well pad is 9,393 trips during the development phase and 560 annual trips during the production phase. The development trips typically occur over a four-month timeframe. Most of the trips are associated with the large amounts of water required in fracking operations. In areas where well density allows, some oil and gas operators are using pipelines to transport water to the well sites for fracking and to transport flowback water to disposal sites. If pipelines are used (as they reportedly are on approximately 60 percent of new pads in Weld County), about 80 percent of trips could be reduced.

Oil and gas development results in more traffic on the system, but even more impactful are the increased loads on state highways. A loaded water truck (the highest frequency trucking activity for the oil and gas industry) can result in 3,500 to 14,000 times the load impact of a passenger car. **Figure 4-3** shows the average number of truck trips per day and the typical duration of that activity for a 6-well pad.

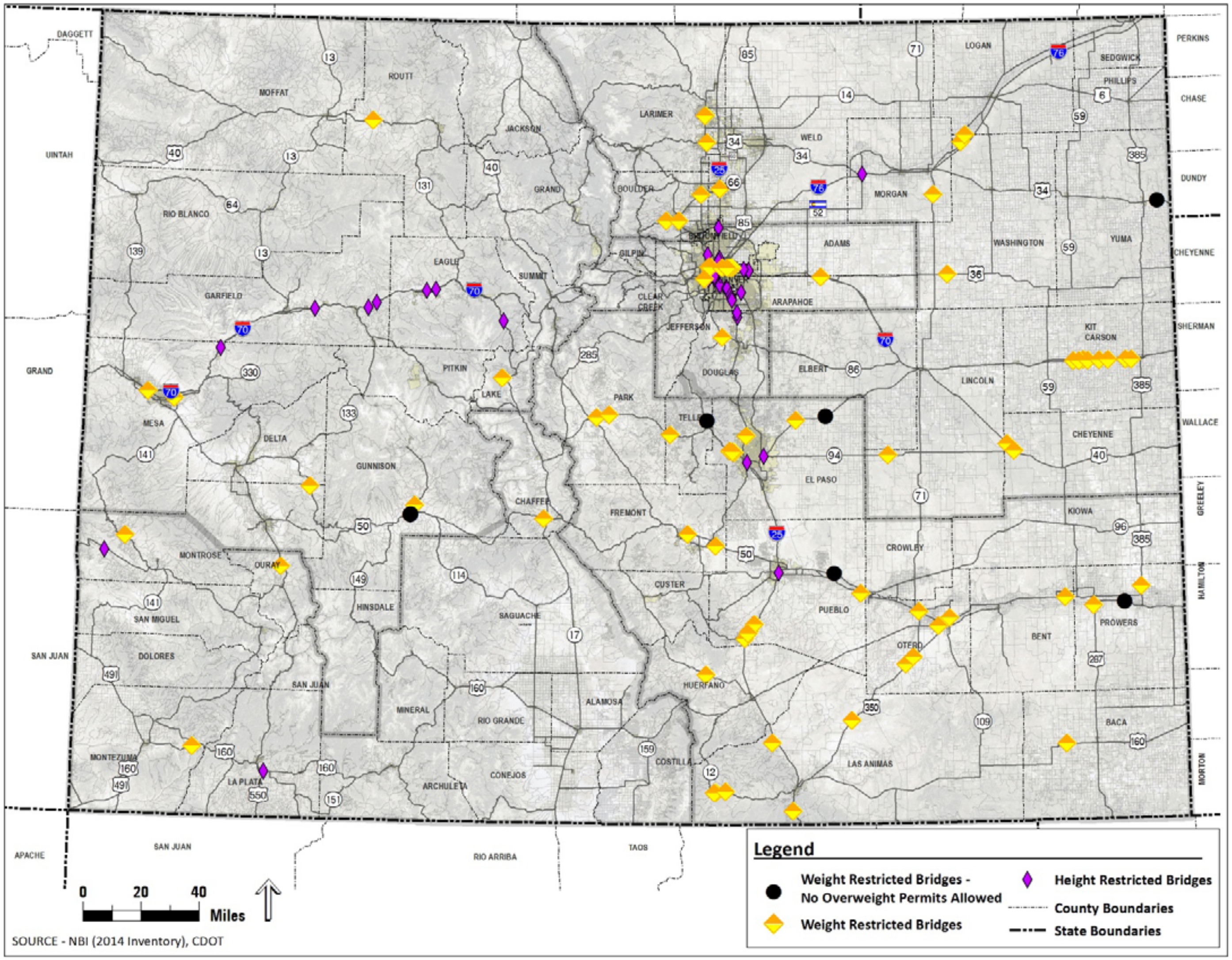
To provide context to the loads generated by the oil and gas industry, the research team compared the truck loads (Equivalent Single Axle Loads - ESALs) generated by development of a single pad (with six wells) to the truck loads generated during construction of a typical big box retail store. A big box retail store construction generates approximately 1.75 times the load of a single pad development. In 2013, an estimated 300 oil and gas pads were developed; which would be equivalent (in terms of truck loads) to the construction of 170 big box retail stores.

ility Life of State Highways



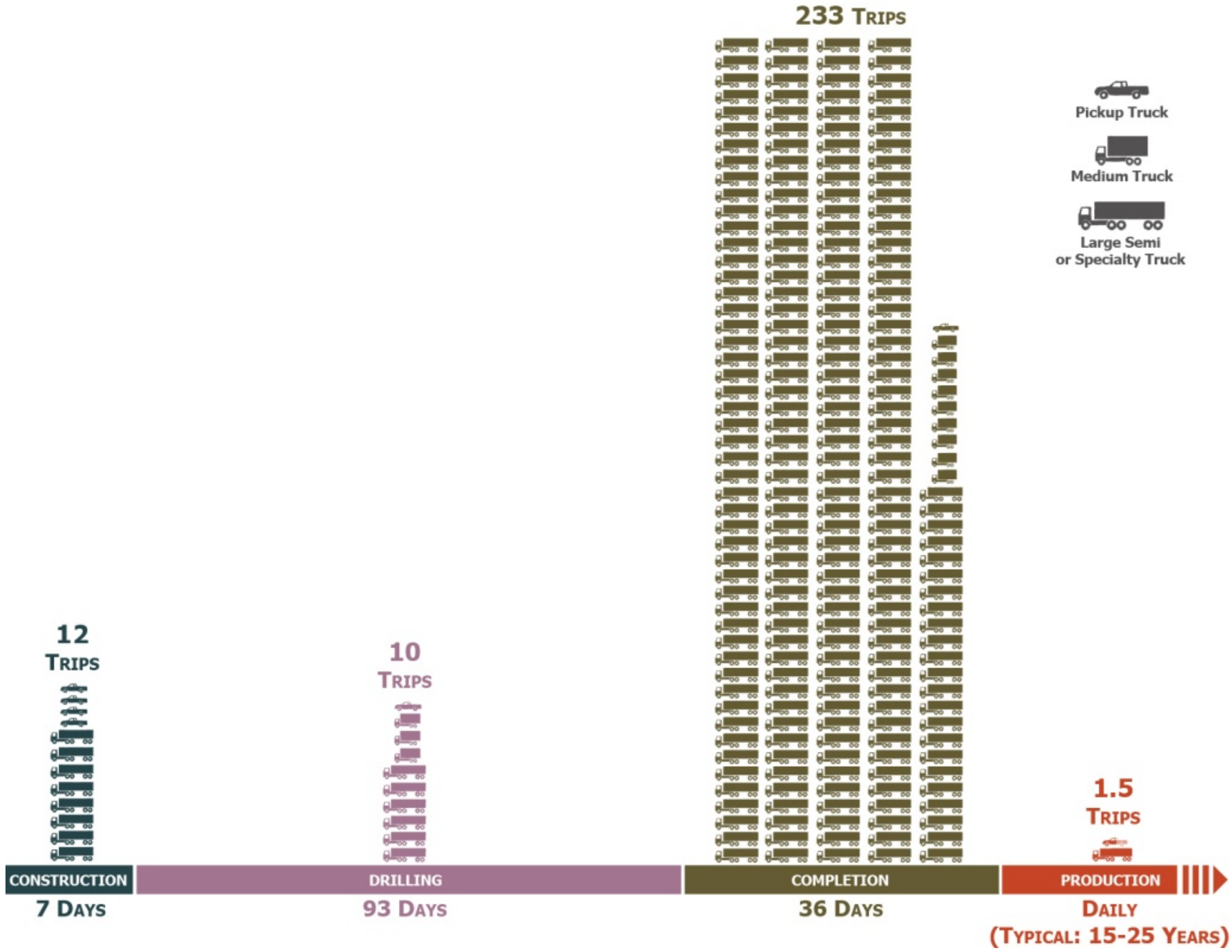
SOURCE: Colorado Department of Transportation, 2014

Figure 4-2 Bridges with Height and/or Weight Restrictions on State Highways



SOURCE: Colorado Department of Transportation, 2014; United States Department of Transportation Federal Highway Administration, 2014

Figure 4-3 Average Daily Truck Trips by Phase (6-well pad)



4.3 Statewide Impacts

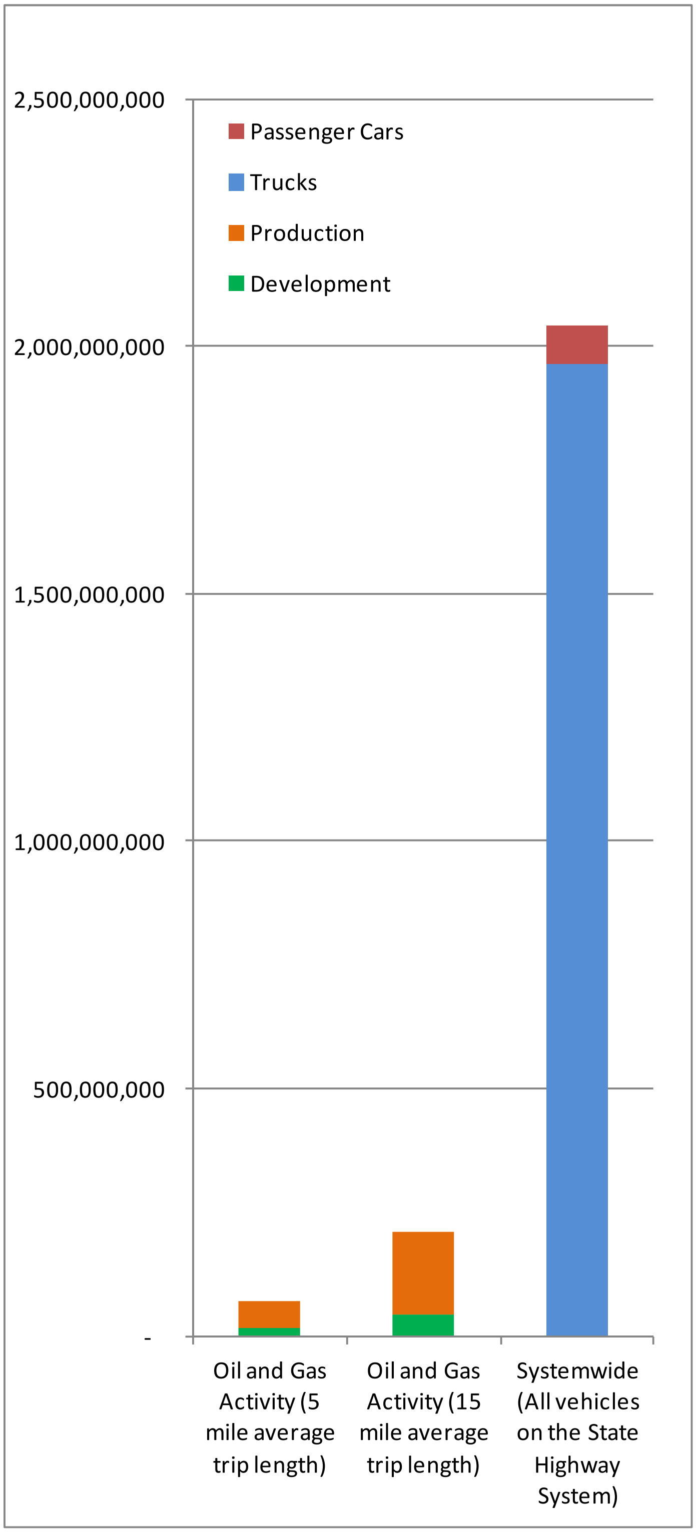
This research study helps to address four questions to provide a better understanding of the magnitude of oil and gas impacts on the state highway system:

- How much truck activity on the state highway system is related to the industry?
- What portion of the loads on the state highway system is related to the industry?
- What are the estimated costs to offset the industry impacts?

The research team based the analysis on actual well activity in 2013, as provided by COGCC. In 2013, 1,839 wells were drilled in Colorado, and there were 49,878 producing wells.

The oil and gas industry can contribute to a variety of impacts to our roads and bridges, including pavement deterioration, increased safety concerns, capacity problems in areas of intense activity, and bridge deterioration. The methodology used to estimate the statewide impacts focuses solely on pavement deterioration. The research team developed an approach to isolate the road surface damage caused by the industry and to calculate the cost to offset those incremental impacts.

Figure 4-4 2013 Annual ESAL-miles



To estimate the statewide impacts, the cost estimation tool (as described in Chapter 3.0) was applied using generalized parameters. The research team made assumptions about trip length, which can be widely variable; two average trip lengths (5 and 15 miles) were used to provide a range of possible impacts. Estimating the magnitude of statewide impacts required other generalizations, including the use of average roadway characteristics to estimate the cost implications, and the conservative assumption that all water is transported by truck.

In 2013, the state highway system carried approximately 2.4 billion truck vehicle miles of travel (VMT). Using the estimated trip lengths of 5 and 15 miles, the research team estimated that the oil and gas industry trips (development and production activities) may have been 60 to 180 million VMT, accounting for 2.5 to 7.5 percent of the system wide truck VMT.

The portion of loads on the state highway system that came from the oil and gas industry in 2013 was also estimated. Similar to the concept of VMT, ESAL-miles were used, which is the load times the trip length. In this case, all vehicles on the state highway system were accounted for, not just trucks. As shown on **Figure 4-4**, trucks account for the vast majority of system wide ESAL-miles. Using the estimated trip lengths of 5 and 15 miles, the research team estimated that the oil and gas industry (development and production activity) may have accounted for 3 to 10 percent of the system wide ESAL-miles in 2013.

By calculating the pavement overlay depth required to compensate for the estimated 2013 industry loads, the study team estimated the magnitude cost to offset the impacts to be in the range of $10 to $30 million. For comparison, CDOT's FY16 budget for surface treatment is $236 million. Mitigating oil and gas impacts could take 4 to 13 percent of CDOT's annual surface treatment budget.

KEY CONCLUSIONS

Following is a summary of the key conclusions that can be made based on the estimation of statewide impacts; assuming 2013 levels of oil and gas activity:

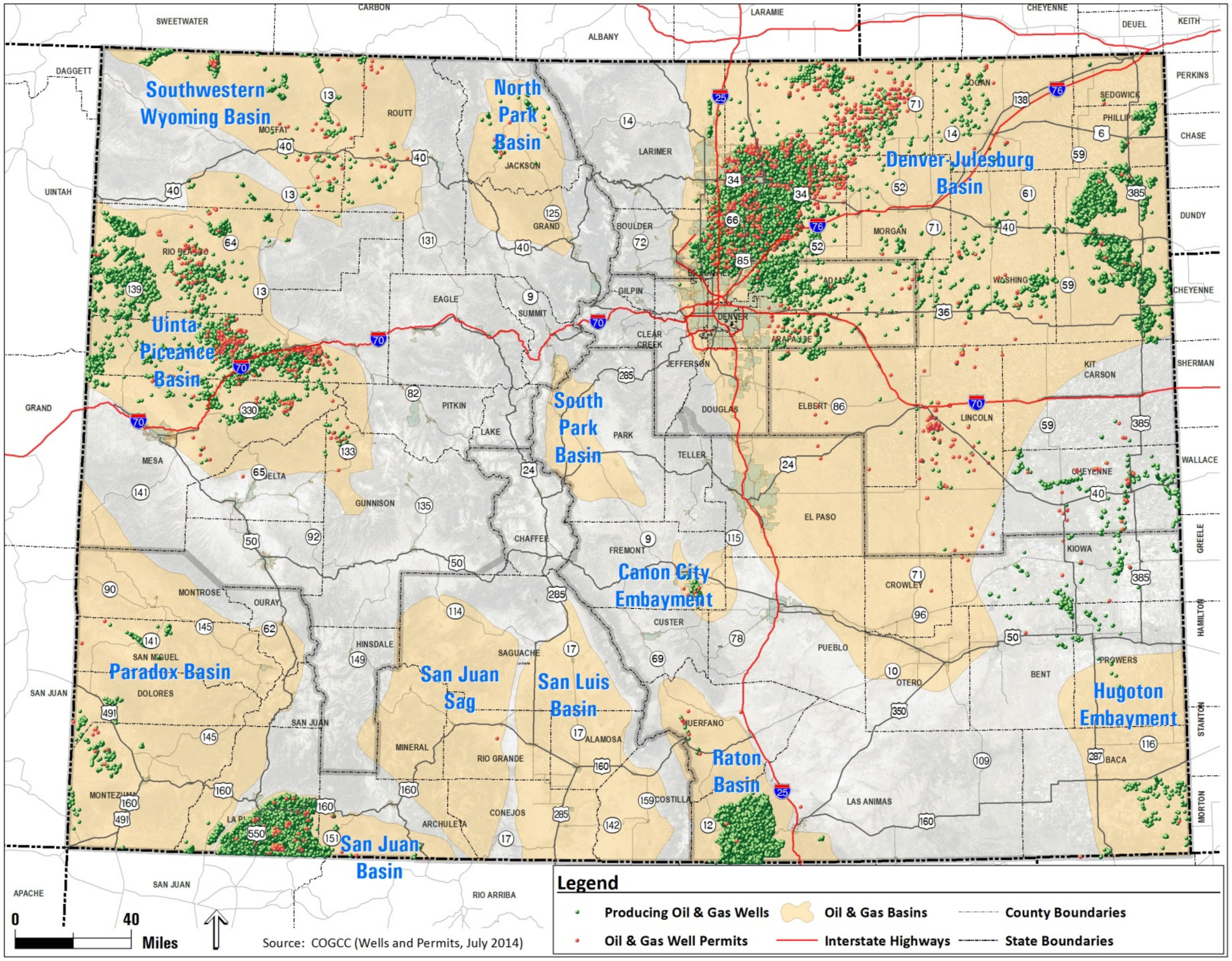
- Oil and gas loads (development and production) are estimated to be 3 to 10 percent of the total loads on the state highway system.
- Costs to offset the impacts of oil and gas pad development could account for 4 to 13 percent of CDOT's annual surface treatment budget.
- Oil and gas activity is geographically focused in several key areas of the state; therefore, transportation impacts are concentrated specifically in those areas. The use of pipelines to transport water to the site and for flowback water greatly affects the number of trips associated with site development.
- The research team recognizes that there are other transportation impacts of the oil and gas industry that are not accounted for in this approximation, including increased safety concerns, capacity problems in areas of intense activity, and bridge deterioration.

4.4 Oil & Gas Activity Impact Areas and Key Energy Corridors

Using the "Key Energy Development Corridors – Oil & Gas" map from the previous CDOT *Energy Development and the Transportation System* research study as a starting point, the study team updated the key energy corridors specifically for oil and gas activity by looking at the location of current and potential future oil and gas production in Colorado, which are shown in **Figure 4-5**. **Figure 4-6** shows the corridors identified as being key to oil and gas activity. These Key Energy Corridors identify, at a very cursory level, those state highways that are likely most susceptible to the impacts of the oil and gas industry based on the future development scenarios.

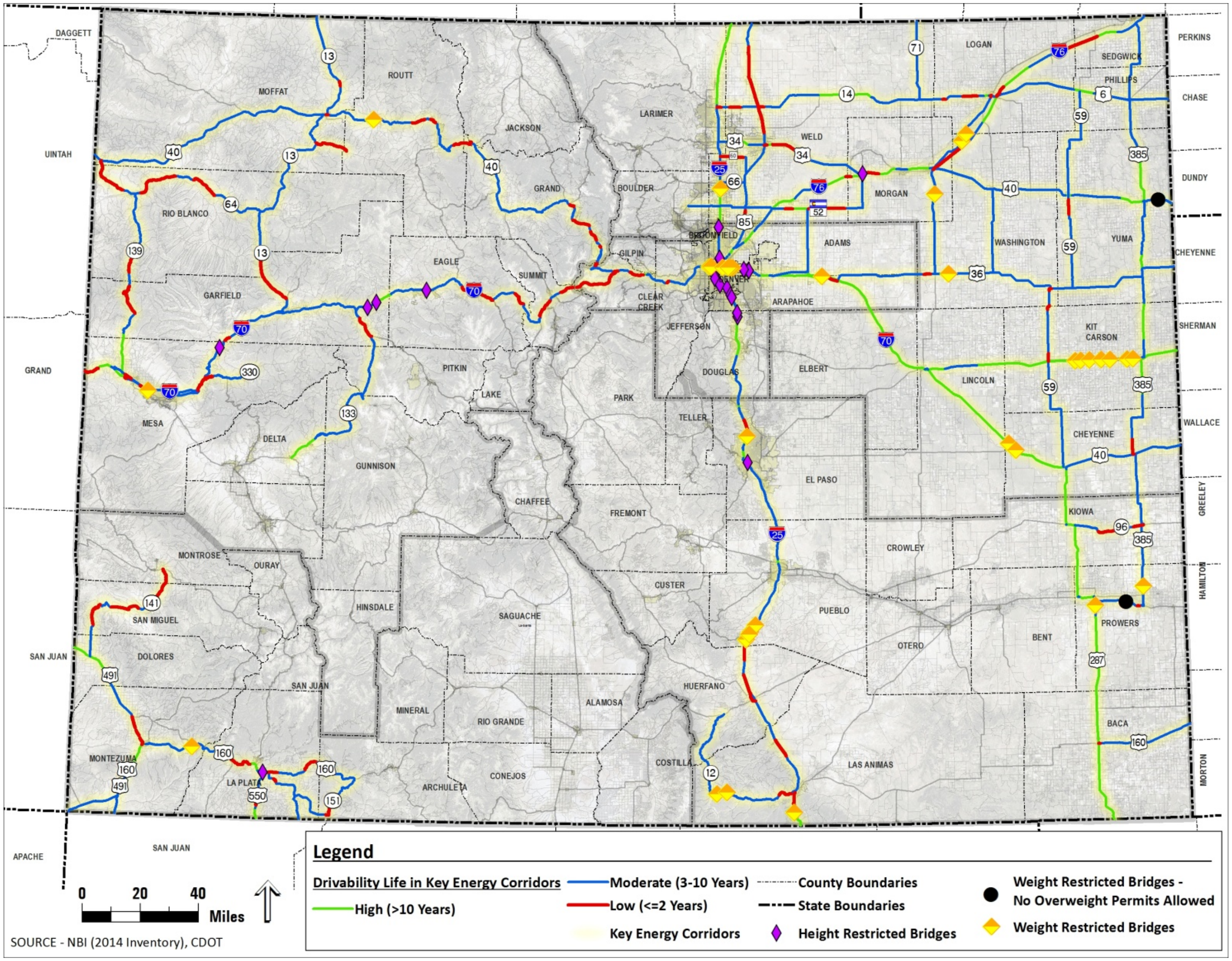
This map is also overlaid with the Drivability Life for each state highway from **Figure 4-1** identified as a Key Energy Corridor and bridges with height and/or weight restrictions from **Figure 4-2** that are on those corridors. This overlay analysis was done to identify highway segments likely to experience oil and gas truck traffic that have a low Drivability Life and/or have bridges that may impede oil and gas traffic or experience greater deterioration as a result of an increase in truck traffic from oil and gas activity. Segments of the Key Energy Corridors with a low Drivability Life may be considered most critical for pavement overlays lest the industry impacts are so great as to require full pavement reconstruction. Of the 3,415 miles of state highways considered a key corridor, 490 miles have a low Drivability Life, or about 14 percent.

Figure 4-5 Producing Oil & Gas Wells and Oil & Gas Well Permits as of July 2014



SOURCE: Colorado Oil & Gas Conservation Commission, 2014

Figure 4-6 Key Corridors for Oil and Gas Activity



Colorado Department of Transportation, 2014; United States Department of Transportation Federal Highway Administration, 2014

5.0 CDOT REGION 4 KEY ENERGY CORRIDOR PAVEMENT AND SAFETY IMPACTS

Chapter 5.0 provides specific CDOT Region 4 examples of oil and gas impacts in the areas of pavement and safety. CDOT Region 4's related analysis of pavement design life and crash history helps to provide impacts context for the area of the state that has recently seen the greatest impact from the oil and gas industry. The data collection and analysis documented in this chapter was conducted by CDOT Region 4 as a part of a separate effort; the Research Team was not involved in this effort.

5.1 Region 4 Pavement Analysis

SUMMARY

Northern and Eastern Colorado has experienced a dramatic increase in traffic possibly due to the oil and gas industry's development and production of the area. Below are the findings from three segments of roadway that are assumed to be heavily used by the industry. This analysis attempted to establish a relationship between traffic increases occurring between roughly 2008 and 2015 and the loss of roadway design life. Please be aware that the conclusions below need to be placed in context with the assumptions stated under the Analysis portion of this discussion. At no time are the thicknesses or treatments used in the comparisons below to be used as a design as important distress thresholds are not accounted for. The two traffic scenarios referenced below refer to the Low Traffic (Circa 2008-2011) scenario which would occur pre-oil industry exploration and the current anticipated High Traffic (2015) scenario.

Highway 85C: Between Fort Lupton and Platteville;

- From 2011 to 2015 truck traffic increased by 781 trucks per day from 1,330 trucks to 2,111. This is an increase of 58.72 percent from the 2011 traffic.
- Assuming a new 2” overlay was placed in both traffic scenarios, the road would approximately get 4 fewer years than the forecasted 11 years at the lower traffic scenario. This is a loss of approximately 36 percent of design life between the two traffic scenarios.
- Ignoring select distresses like reflective cracking thresholds, we expect at least a 50 percent increase in surface thickness cost to meet a 10-year design in 2015 as opposed to 2011 traffic.

Highway 392B: Between Lucerne and Barnseville

- From 2008 to 2015 truck traffic increased by 341 trucks per day from 440 trucks to 781. This is an increase of 77.71 percent from the 2008 traffic.
- Assuming a new 2” overlay was placed in both traffic scenarios, the road would approximately get 4 fewer years than the forecasted 11 years at the lower traffic scenario. This is a loss of approximately 36 percent of design life between the two traffic scenarios.
- Ignoring select distresses like reflective cracking thresholds, we expect at least a 33 percent increase in surface thickness cost to meet a 10-year design in 2015 as opposed to 2008 traffic.

Highway 14C: Near New Raymer

- From 2009 to 2015 truck traffic increased by 348 trucks per day from 430 trucks to 778. This is an increase of 80.93 percent from the 2009 traffic.
- Assuming a new 2” overlay was placed in both traffic scenarios, the road would approximately get 4 fewer years than the forecasted 9 years at the lower traffic scenario. This is a loss of approximately 44 percent of design life between the two traffic scenarios.
- Ignoring select distresses like reflective cracking thresholds, we expect at least a 44 percent increase in surface thickness cost to meet a 10-year design in 2015 as opposed to 2009 traffic.

Considering that the loss of design life occurs at an exponential rate, it could be assumed that increasing the required design life would generate a larger difference in expected design life years between the two traffic scenarios as evidenced in the graphs provided in the analysis section.

Considering that each road in Region 4 is unique, it is very difficult to make a blanket statement of loss of design life across the region. Above are a few select examples, which may give insight into a few of our more prominent roads that may provide service to the oil and gas industry.

Additional data collection and study need to be performed to verify any actual impacts from the oil and gas industry.

Background

Region 4 has experienced significant truck traffic growth in regards to the oil and gas exploration in Northern and Eastern Colorado. This increased truck traffic is believed to be responsible for accelerated degradation of some of our roadways. We typically see a significant increase in truck traffic beginning to occur between the years of 2008 and 2011 roughly correlating with local exploration activities. Through the use of the Pavement ME software and CDOT’s historical traffic, three roadways that are assumed to be heavily used by the oil and gas industry have been analyzed for potential loss of design life due to increased truck traffic loading. Several representative segments of roadways were modeled utilizing extrapolated and assumed soils and pavement data and were subsequently analyzed for pre-oil exploration traffic and current traffic. These two traffic situations are referred to as Low Traffic, which occurs pre-exploration, and High Traffic which refers to current 2015 traffic levels. When modeling a representative design life, consideration needs to be paid to the fact that several Pavement ME distress thresholds are still under review by Division of Engineering Support (DES) notably, Reflective Cracking and Rut Thresholds. The simplified analysis presented below should not be taken as a roadway design as it does not encompass all of the required design parameters and thresholds but can provide a reasonable approximation of loss of design life due to truck traffic increases.

The Pavement ME design software uses truck traffic counts to approximate the amount of damage that will occur on a roadway. When attempting to achieve the required design life of a roadway, acceptability thresholds of distresses are established by DES. Several distresses of this system are not currently represented in the analysis below as they are either currently under review or are not applicable for this type of analysis. Using the above noted Low Traffic (2008-2011) and High Traffic (2015) truck counts, a comparison was made in achieved design lives of a pavement if a new overlay was applied to each section.

The three analyzed roadway segments consist of the following;

- Highway 85C: Between Fort Lupton and Platteville (MP 244.204 to 246.214)
- Highway 392B: Between Lucerne and Barnesville (MP 116.6)
- Highway 14C: Near New Raymer (MP 197.75)

Each segment exhibits easily recognizable truck traffic increases and is assumed to be heavily used by the oil and gas industry.

Please note that the analysis below does not constitute a roadway design as several failure criteria are not met. The analysis below is a simplified design life comparison only.

ANALYSIS

Several techniques and assumptions were made in the analysis of these three segments of roadway. What follows below are the assumptions that were made on each roadway, the techniques that had to be used to make comparisons to design life, and the individual analysis of each roadway segment.

The three segments of roadway were selected due to their assumed significant use in the oil and gas industry's explorations. Each segment was also selected on a basis of easily identifiable traffic increases, which can be determined from a traffic analysis over several years.

Assumptions:

- Soil profiles for two of the three projects were assumed from previous borings nearby. The pavement sections were also built using historical data of the segment.
- Selection of the Low Traffic year was based visually off of traffic analysis graphs as presented below.
- Growth rates for each analyzed segment were derived from CDOT's OTIS (Online Transportation Information System) and are segment specific. Historical traffic counts through year 2013 were received from Division of Transportation Development (DTD) and predicted future truck traffic counts were compiled from OTIS's traffic projections from 2014 onward.
- Required distress thresholds are unique to each segment and are in conformance with CDOT roadway Functional Classification requirements
- Distress data in some cases was approximated within Pavement ME as the surface conditions do not accurately model the current distresses/conditions existing within the pavement structure.
- To perform a comparative analysis of loss of design life, an existing pavement must have a minimum of a 2" overlay modeled within the program under both the Low Traffic and High Traffic scenarios. From the Design Life achieved from each traffic scenario, a design life loss is calculated.
- Please note that some pavement distress threshold requirements were ignored for this comparison. If these distresses were not removed from the analysis a treatment deviating from the HMA overlay would be required. Deviation from this overlay would not allow a simple comparison in loss of design life from two similar treatments.

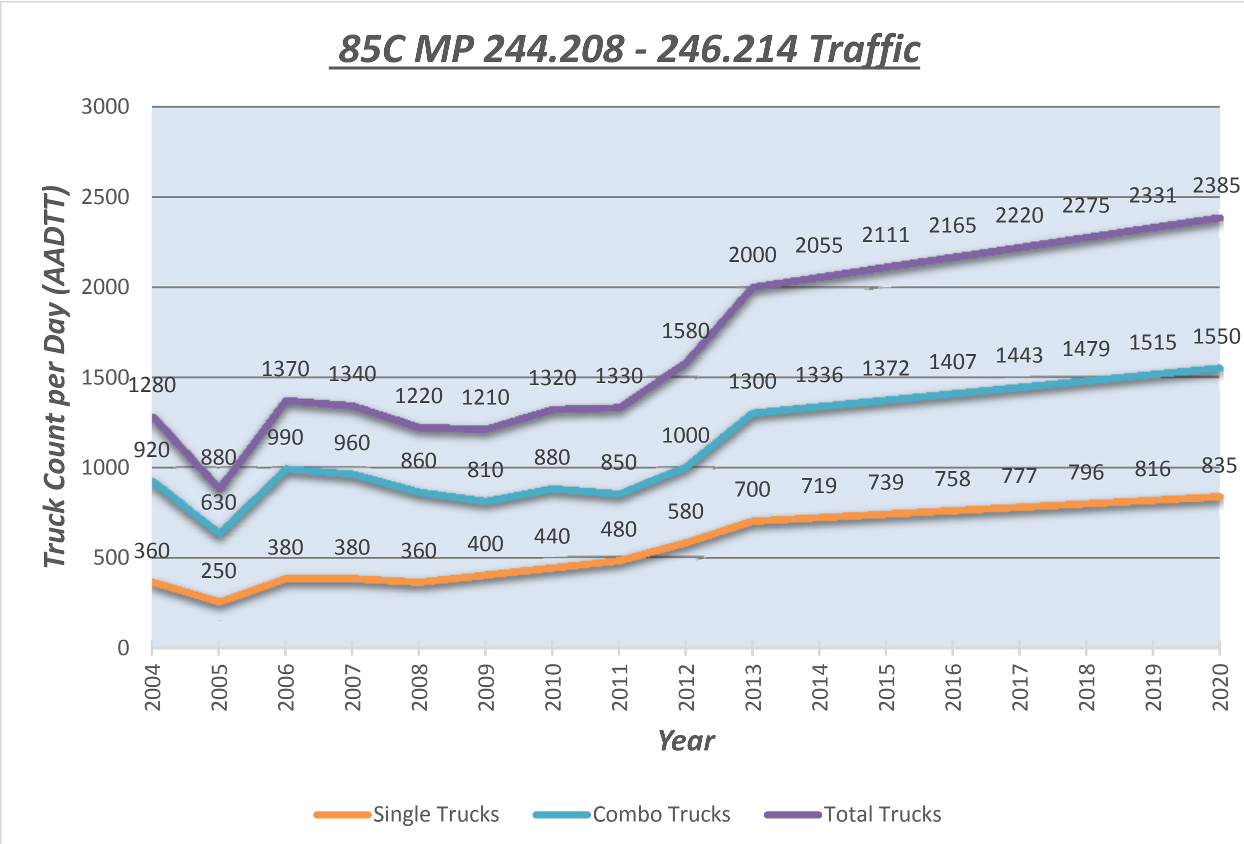
- Only select sections of each roadway's project MP were analyzed. The selected areas were based on a section which we would typically design for and exhibited an easily identifiable traffic increase. Prior to a full design, multiple sections need to be analyzed to provide an acceptable treatment. This further reiterates the understanding that the below analysis is only a comparison in design life years in relation to truck traffic increases.

Comparisons:

Highway 85C: Between Fort Lupton and Platteville

The analyzed segment of roadway occurs between Fort Lupton and Platteville on Highway 85C with the selected traffic segment occurring between MP 244.204 and MP 246.214. This segment has seen a significant jump in truck traffic between the years of 2011 (Low Traffic) and 2015 (High Traffic) as exhibited by the graph below. The graph below presents several items for review. The orange line represents the surveyed single trucks, the blue line represents the surveyed combination trucks and the purple line represents the total trucks when adding the single and combination trucks together. It is assumed that the oil and gas industry may be utilizing Highway 85C for conveyance of materials. Single and combination trucks are typically responsible for a significant amount of the damage which is occurring on our roadways. As shown below, the total truck count between the years of 2011 and 2015 roughly increases by 781 trucks per day. This gain in 781 trucks per day equates to a 58.72 percent increase from the original 2011 traffic count.

Figure 5-1 Truck Counts on 85C

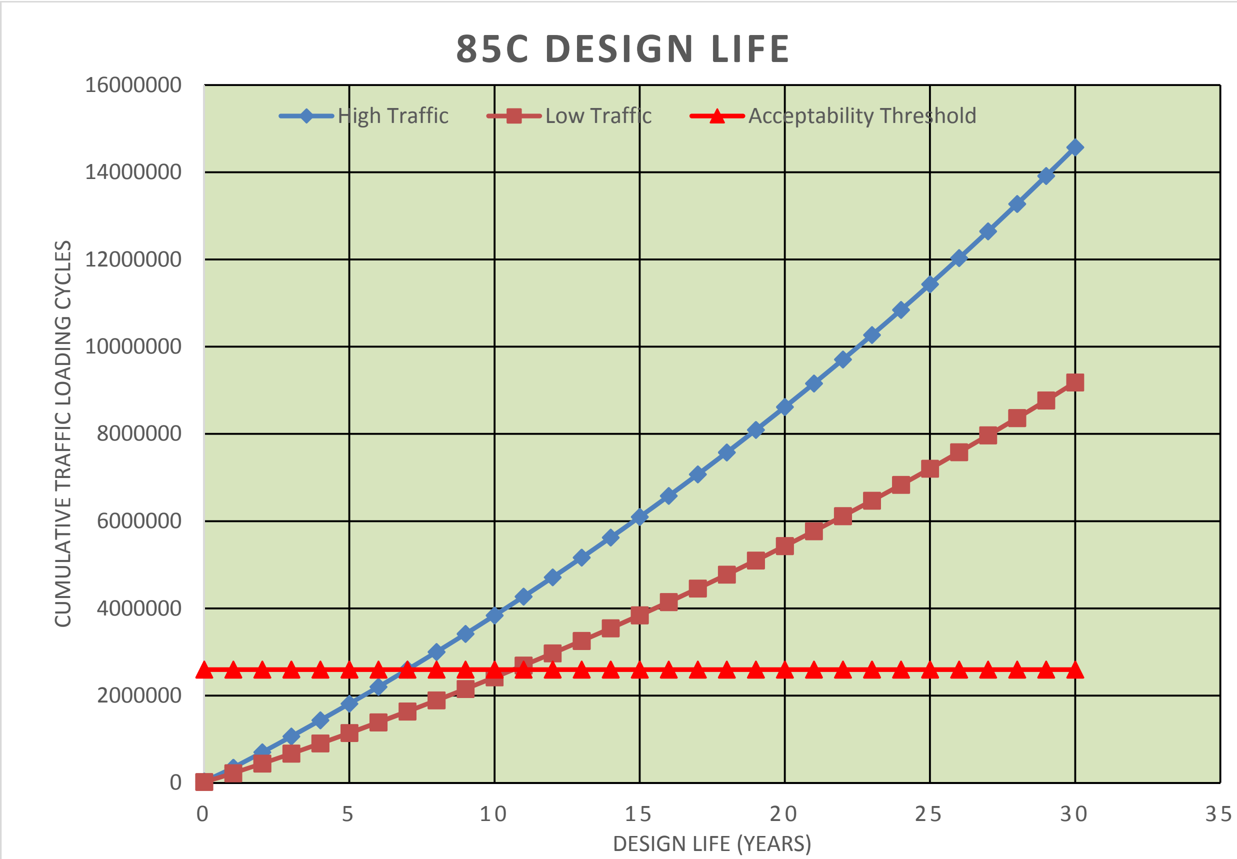


Using the traffic counts from 2011 and 2015 as a basis for design life evaluation, when comparing the expected design life difference of a 2" overlay you receive the following graph. On the left hand side of the graph the number of cycles of axles from the differing truck classifications is shown. The Pavement ME software takes the expected initial truck count and converts the count to how many cycles/axles the pavement will experience within the selected time frame. The lower axis of the graph is the expected Design Years of the 2" overlay.

The blue line represents the expected design life of the High Traffic scenario we are currently experiencing and the dark red line represents the Low Traffic scenario experienced in 2011. The red line represents when these two loadings exceed the allowable distress thresholds set by DES. In this instance, on highway 85C we see that a 2" overlay exceeds its acceptable threshold at year 7 for the 2015 loading and at year 11 roughly for the 2011 loading. This translates to a loss of 4 years of life between the two situations. This equates to roughly a 36 percent loss of design life due to the increased traffic.

Please note that reflective cracking is not analyzed in this comparison and a 2" overlay is not a suitable solution.

Figure 5-2 85C Design Life

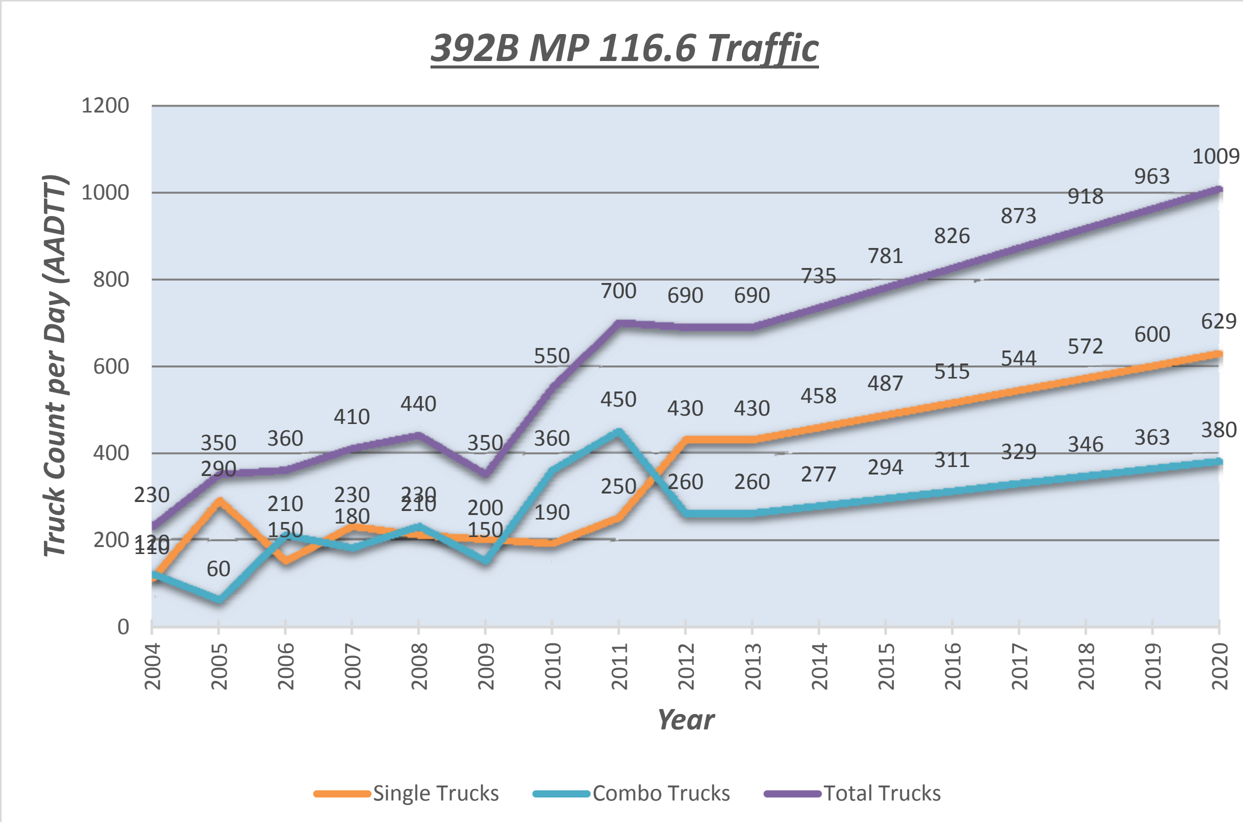


When analyzing the High Traffic (2015) scenario for a 10 year design, and ignoring reflective cracking, a minimum of 4” of HMA is required. Even if 4” of HMA is applied reflective cracking failure is anticipated to occur within 5 years. With this being the case a different pavement treatment will be required for construction. Comparing to the Lower Traffic scenario, in which case a 2” overlay would have been sufficient for 10 years, 2” of additional HMA is required to meet current traffic demands. This would yield an increased cost of at least 50 percent in HMA alone, if not greater, when ancillary requirements like additional shouldering are needed. Please keep in mind that this 4” overlay still will not appropriately address reflective cracking failure and that a different treatment is actually required to meet all design parameters.

Highway 392B: Between Lucerne and Barnesville

The analyzed segment of roadway occurs between Lucerne and Barnesville on Highway 392B with the selected traffic segment occurring at MP 116.6. This segment has seen a significant jump in truck traffic between the years of 2008 (Low Traffic) and 2015 (High Traffic) as exhibited by the graph below. The graph below presents several items for review. The orange line represents the surveyed single trucks, the blue line represents the surveyed combination trucks and the purple line represents the total trucks when adding the single and combination trucks together. The oil and gas industry is assumed to be utilizing a significant amount of single and combination trucks in their operations in the area. Single and combination trucks are typically responsible for a significant amount of the damage which is occurring on our roadways. As shown below, the total truck count between the years of 2008 and 2015 roughly increases by 341 trucks per day. This gain in 341 trucks per day equates to a 77.71 percent increase from the original 2008 traffic count.

Figure 5-3 Truck Counts on 392B

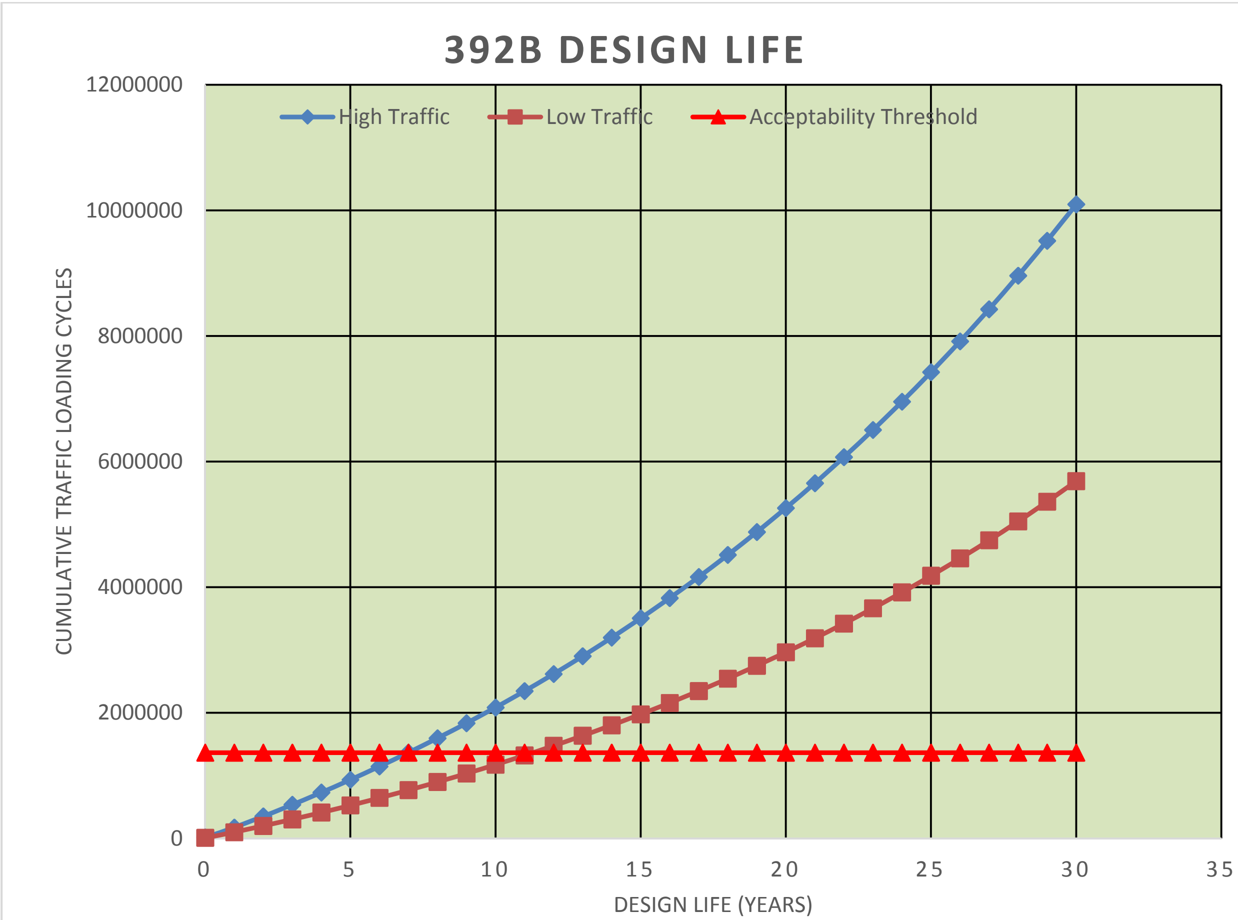


Utilizing the traffic counts from 2008 and 2015 as a basis for design life evaluation, when comparing the expected design life difference of a 2” overlay you receive the following graph. On the left hand side of the graph the number of cycles of axles from the differing truck classifications is shown. The Pavement ME software takes the expected initial truck count and converts the count to how many cycles/axles the pavement will experience within the selected time frame. The lower axis of the graph is the expected Design Years of the 2” overlay.

The blue line represents the expected design life of the High Traffic scenario we are currently experiencing and the dark red line represents the Low Traffic scenario experienced in 2008. The red line represents when these two loadings exceed the allowable distress thresholds set by DES. In this instance on Highway 392B we see that a 2” overlay exceeds its acceptable threshold at year 7 for the 2015 loading and at year 11 roughly for the 2008 loading. This translates to a loss of 4 years of life between the two situations. This equates to roughly a 36 percent loss of design life due to the increased traffic.

Please note that reflective cracking is not analyzed in this comparison and a 2” overlay is not a suitable solution.

Figure 5-4 392B Design Life

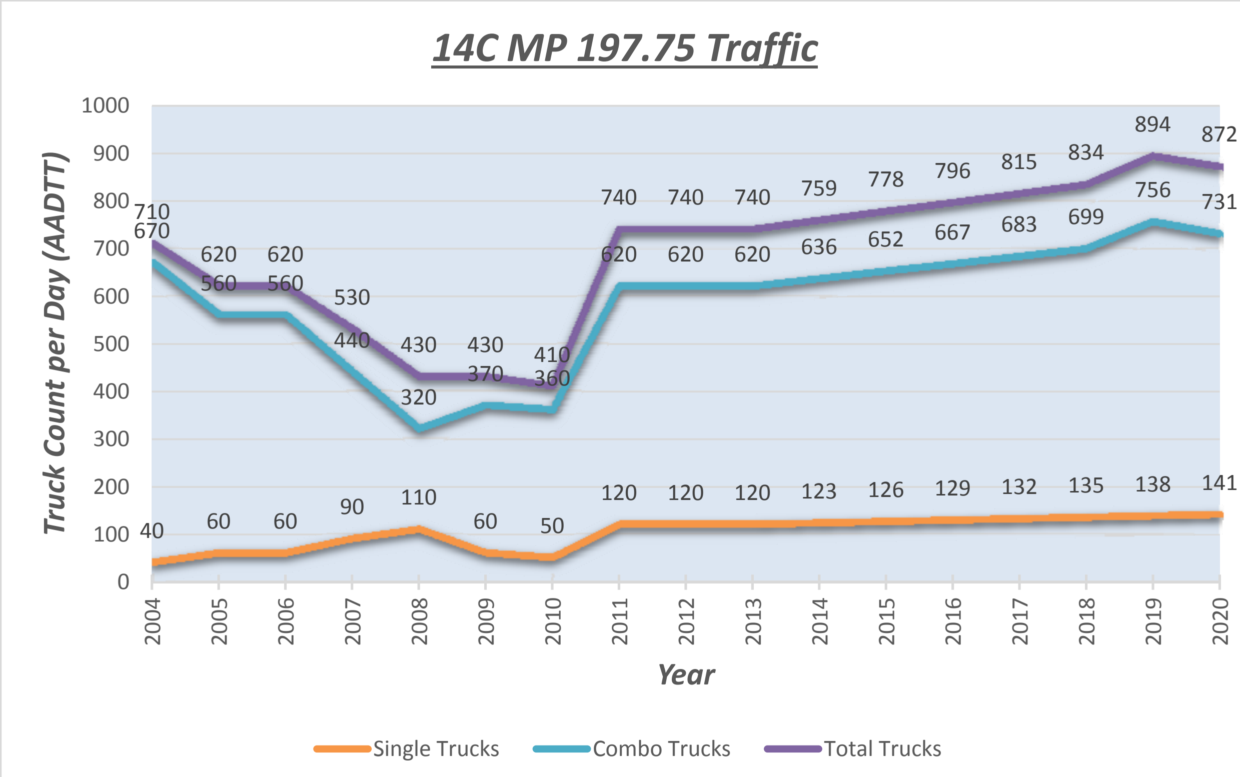


When analyzing the High Traffic (2015) scenario for a 10 year design, and ignoring reflective cracking, a minimum of 3” of HMA is required. Even if 3” of HMA is applied this roadway still fails in reflective cracking within 1.2 years. This necessitates a treatment greater than a simple overlay. Comparing to the Lower Traffic scenario, in which case a 2” overlay would have been sufficient for 10 years, 1” of additional HMA is required to meet current traffic demands. This would yield an increased cost of at least 33 percent in HMA alone, if not greater, when ancillary requirements like additional shouldering are needed. Please keep in mind that this 3” overlay still will not appropriately address reflective cracking failure and that a different treatment is actually required to meet all design parameters.

Highway 14C: Near New Raymer

The analyzed segment of roadway occurs near the town of New Raymer on Highway 14C with the selected traffic segment occurring at MP 197.75. This segment has seen a significant jump in truck traffic between the years of 2009 (Low Traffic) and 2015 (High Traffic) as exhibited by the graph below. The graph below presents several items for review. The orange line represents the surveyed single trucks, the blue line represents the surveyed combination trucks and the purple line represents the total trucks when adding the single and combination trucks together. The oil and gas industry is assumed to be utilizing a significant number of single and combination trucks in their operations in the area. Single and combination trucks are typically responsible for a significant amount of the damage which is occurring on our roadways. Highway 14C near New Raymer is currently one of the most active drilling spots in Northern Colorado. As shown below, the total truck count between the years of 2009 and 2015 roughly increases by 348 trucks per day. This gain in 348 trucks per day equates to an 80.93 percent increase from the original 2009 traffic count.

Figure 5-5 Truck Counts on 14C

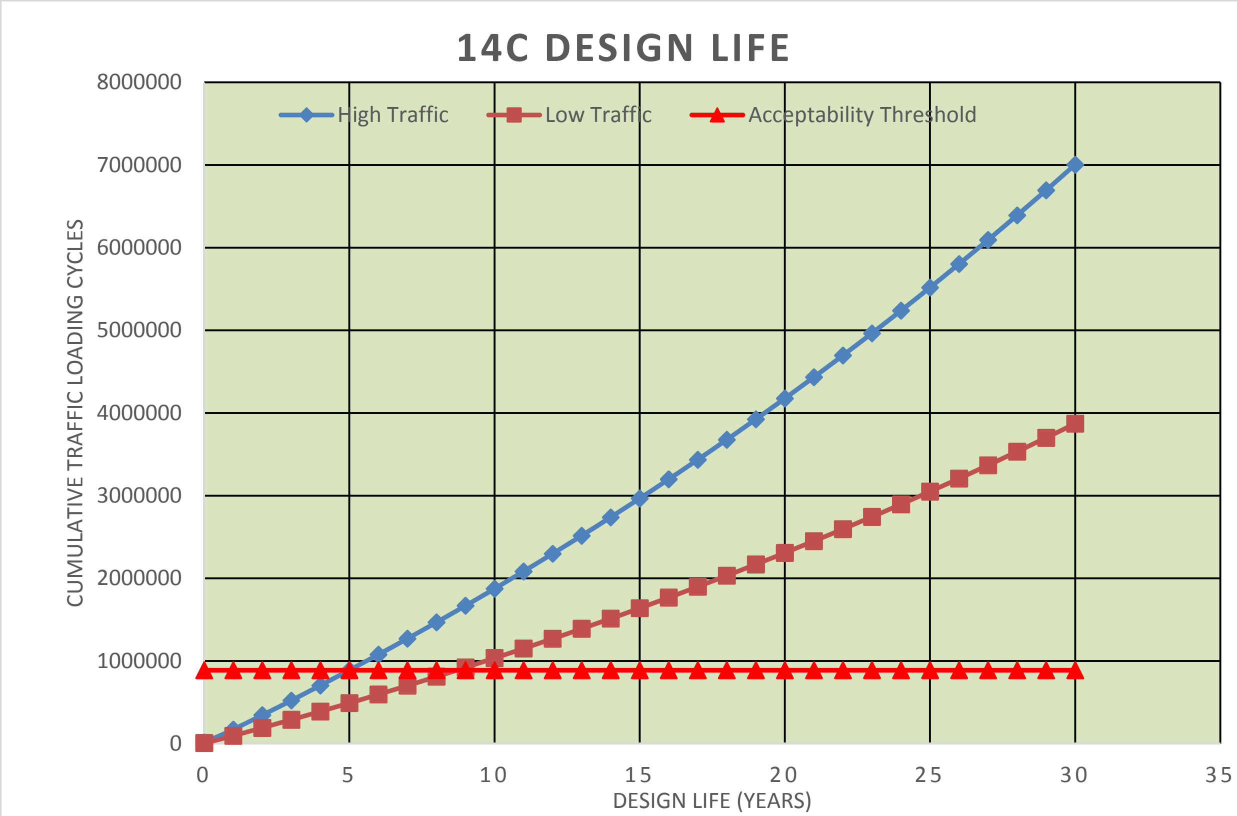


Utilizing the traffic counts from 2009 and 2015 as a basis for design life evaluation, when comparing the expected design life difference of a 2" overlay you receive the following graph. On the left hand side of the graph the number of cycles of axles from the differing truck classifications is shown. The Pavement ME software takes the expected initial truck count and converts the count to how many cycles/axles the pavement will experience within the selected time frame. The lower axis of the graph is the expected Design Years of the 2" overlay.

The blue line represents the expected design life of the High Traffic scenario we are currently experiencing and the dark red line represents the Low Traffic scenario experienced in 2009. The red line represents when these two loadings exceed the allowable distress thresholds set by DES. In this instance on highway 14C we see that a 2" overlay exceeds its acceptable threshold at year 5 for the 2015 loading and at year 9 roughly for the 2009 loading. This translates to a loss of 4 years of life between the two situations. This equates to roughly a 44 percent loss of design life due to the increased traffic.

Please note that reflective cracking is not analyzed in this comparison and a 2" overlay is not a suitable solution.

Figure 5-6 14C Design Life



When analyzing the High Traffic (2015) scenario for a 10 year design, and ignoring reflective cracking, a minimum of 4.5" of HMA is required. Even if 4.5" of HMA is applied, this roadway still fails in reflective cracking within 5.5 years. This necessitates a treatment greater than a simple overlay. Comparing to the Lower Traffic scenario, in which case a 2.5" overlay would have been sufficient for 10 years, 2" of additional HMA is required to meet current traffic demands. This would yield an increased cost of at least 44.44 percent in HMA alone, if not greater, when ancillary requirements like additional shouldering are needed. Please keep in mind that this 4.5" overlay still will not appropriately address reflective cracking failure and that a different treatment is actually required to meet all design parameters.

Results

After analyzing the above three segments of roadway the following summarized conclusions can be drawn.

Highway 85C: Between Fort Lupton and Platteville;

- From 2011 to 2015 truck traffic increased by 781 trucks per day from 1,330 trucks to 2,111. This is an increase of 58.72 percent from the 2011 traffic.
- Assuming a new 2" overlay was placed in both traffic scenarios, the road would approximately get 4 fewer years than the forecasted 11 years at the lower traffic scenario. This is a loss of approximately 36 percent of design life between the two traffic scenarios.

- Ignoring select distresses like reflective cracking thresholds, we expect at least a 50 percent increase in surface thickness cost to meet a 10 year design in 2015 as opposed to 2011 traffic.

Highway 392B: Between Lucerne and Barnseville

- From 2008 to 2015 truck traffic increased by 341 trucks per day from 440 trucks to 781. This is an increase of 77.71 percent from the 2008 traffic.
- Assuming a new 2" overlay was placed in both traffic scenarios, the road would approximately get 4 fewer years than the forecasted 11 years at the lower traffic scenario. This is a loss of approximately 36 percent of design life between the two traffic scenarios.
- Ignoring select distresses like reflective cracking thresholds, we expect at least a 33 percent increase in surface thickness cost to meet a 10 year design in 2015 as opposed to 2008 traffic.

Highway 14C: Near New Raymer

- From 2009 to 2015 truck traffic increased by 348 trucks per day from 430 trucks to 778. This is an increase of 80.93 percent from the 2009 traffic.
- Assuming a new 2" overlay was placed in both traffic scenarios, the road would get approximately 4 fewer years than the forecasted 9 years at the lower traffic scenario. This is a loss of approximately 44 percent of design life between the two traffic scenarios.
- Ignoring select distresses like reflective cracking thresholds, we expect at least a 44 percent increase in surface thickness cost to meet a 10 year design in 2015 as opposed to 2009 traffic.

Considering that the loss of design life occurs at an exponential rate it could be assumed that increasing the required design life would generate a larger difference in expected design life years between the two traffic scenarios.

Considering that each road in Region 4 is unique it is very difficult to make a blanket statement of loss of design life across the region. Above are a few select examples which may give insight into a few of our more prominent roads that provide service to the oil and gas industry.

Additional data collection and study need to be performed to verify any actual impacts from the oil industry.

All calculations and Pavement ME soil sections and files are available upon request for further review.

5.2 Region 4 Safety Analysis

We were asked to document and comment on the crash history of four Region 4 corridors that carry traffic generated by the oil and gas industry. Here are the results and analysis.

Summary

The cycle of activities involved in locating and extracting oil and gas from the Niobrara Shale layer beneath part of Colorado's Front Range has created many jobs in CDOT Region 4. As a consequence this area is also experiencing a growth in traffic volumes and a portion of that traffic is composed of large trucks. Many of these trucks are traveling to and from pads where wells are being drilled and completed. The development phase of a typical well site generates over 9,300 one-way trips in a period of about approximately two-four months.

The Colorado county most impacted by this Niobrara oil and gas activity is Weld in which 41 percent of the active wells in Colorado are located. At one point during 2014 Weld County was producing 85 percent of Colorado's monthly oil output. Between 2009 and 2015 the number of active wells in Weld County increased by 43 percent.

This study focused on the traffic volumes and crash histories of 4 corridors that carry traffic associated with the oil and gas industry: State Highway 14 between I-25 and New Raymer, US 85 between Brighton and Greeley, US 85 between Greeley and Nunn, and State Highway 392 between Windsor and Briggsdale.

Between 2000 and 2014 the traffic volumes on all four corridors grew with SH 392 seeing the greatest increase of 20 percent. The number of crashes involving large trucks increased slightly to moderately on SH 14 and both US 85 corridors but SH 392 experienced a 163 percent increase in large truck crashes. The number of fatal crashes decreased on SH 14 and both US 85 corridors but increased 64 percent on SH 392. During the past five years 82 percent of the fatal crashes on SH 392 involved at least one large truck.

As you will see in this report the increased oil and gas traffic has impacted Region 4's crash totals and the driving public's safety.

Background

The town of Hereford in Weld County is situated two miles south the Colorado – Wyoming state line. Four miles west of Hereford on August 14, 2009 EOG Resources Inc. began drilling a wildcat well they named JAKE #2-01H. This well reaches a depth of 7,500 ft. and includes a horizontal line that extends 4,500 ft. within the Niobrara shale formation. A typical new well in the D-J Basin might produce 100 to 150 barrels of crude oil a day. Jake averaged 556 barrels per day for its first 90 days.[4] This is often cited as the well that initiated the Niobrara Play, responsible for the sudden growth in exploration and drilling that brought many jobs to the Front Range along with the heavy equipment and support vehicles associated with the industry.

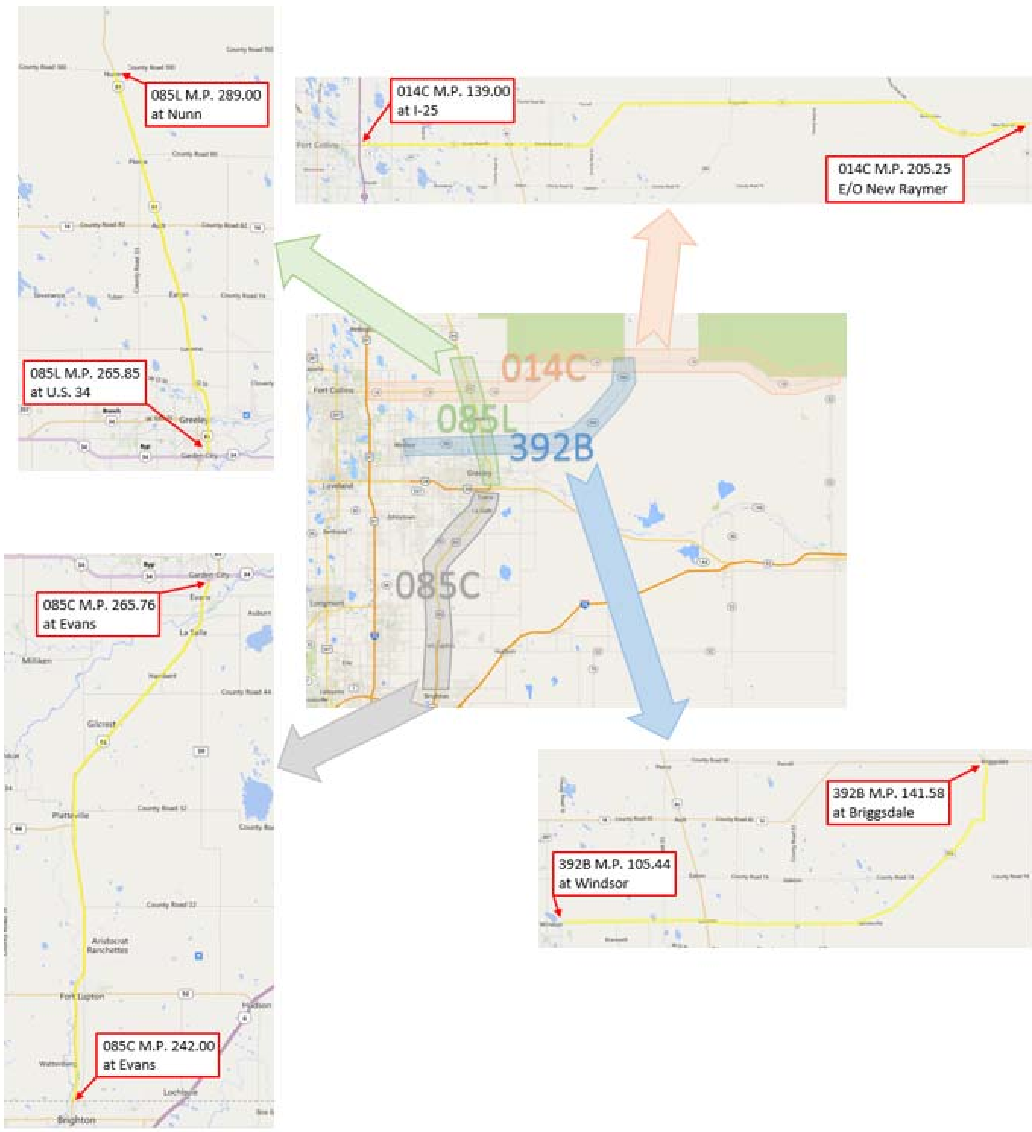
The estimated number of one-way trips generated during the oil and gas extraction process for a single pad location with six drilled horizontal lines, as documented in Chapter 3.0, was used for this analysis.

[4] http://www.bizjournals.com/denver/stories/2010/04/05/daily51.html?page=all

The Colorado county most impacted by this Niobrara oil and gas activity is Weld. In Weld County in October 2014 there were 21,597 active wells, constituting 41 percent of the 52,556 active wells in the state.[5] In May 2014 Weld County was responsible for 85 percent of Colorado's oil production.[6] By the end of 2014 there were 21,886 active wells in Weld County. Between 2009 and 2015 the number of active wells in Weld County increased by 43 percent.

This study looks at traffic volumes and crash histories on four corridors that include traffic associated with the oil and gas industry: State Highway 14 between I-25 and New Raymer, US 85 between Brighton and Greeley, US 85 between Greeley and Nunn, and SH 392 between Windsor and Briggsdale (see **Figure 5-7**).

Figure 5-7 Corridors for which Traffic Volume and Crash Data are Analyzed



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[5] http://www.greeleytribune.com/news/business/12854193-113/colorado-production-2014-gas
[6] http://www.greeleytribune.com/news/13493110-113/oil-production-weld-bedard

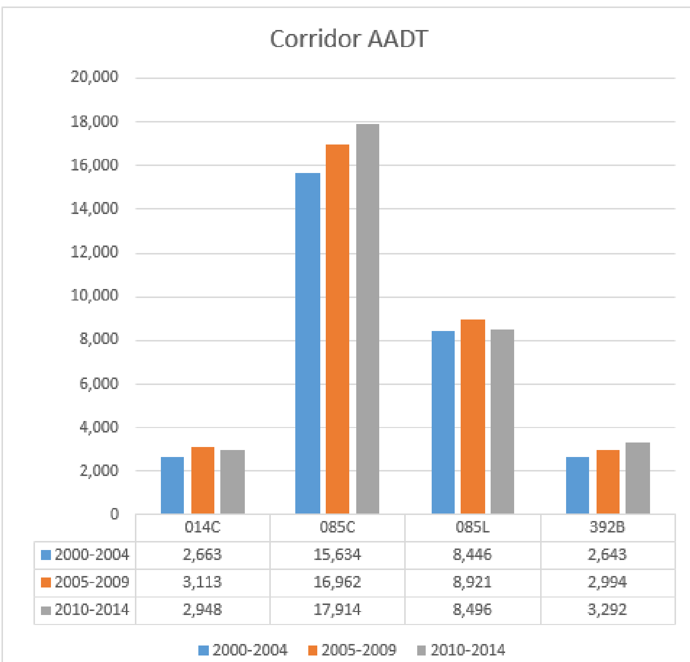
The crash history is divided into 3 periods of 5 years: 7/1/1999 to 6/30/2004, 7/1/2004 to 6/30/2009, and 7/1/2009 to 6/30/2014 (the most recent available data is 6/30/2014). To simplify data labeling the periods are treated as CDOT fiscal years i.e., 2000-2004, 2005-2009, and 2010-2014.

During this time we would expect impacts to traffic volumes and crashes due to increased oil and gas traffic on these corridors to be reflected in the final period, 2010-2014.

ANALYSIS

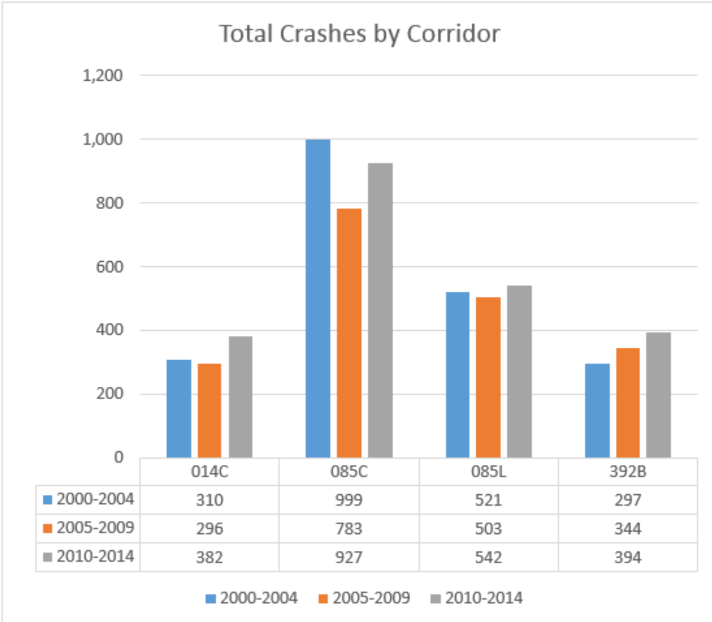
Volumes on US 85C and SH 392B increased over each of the periods. While there was increase from the first to the last periods both SH 14C and US 85L experienced maximum AADT during the middle period (**Figure 5-8**).

Figure 5-8 Corridor Average Annual Daily Traffic (AADT)



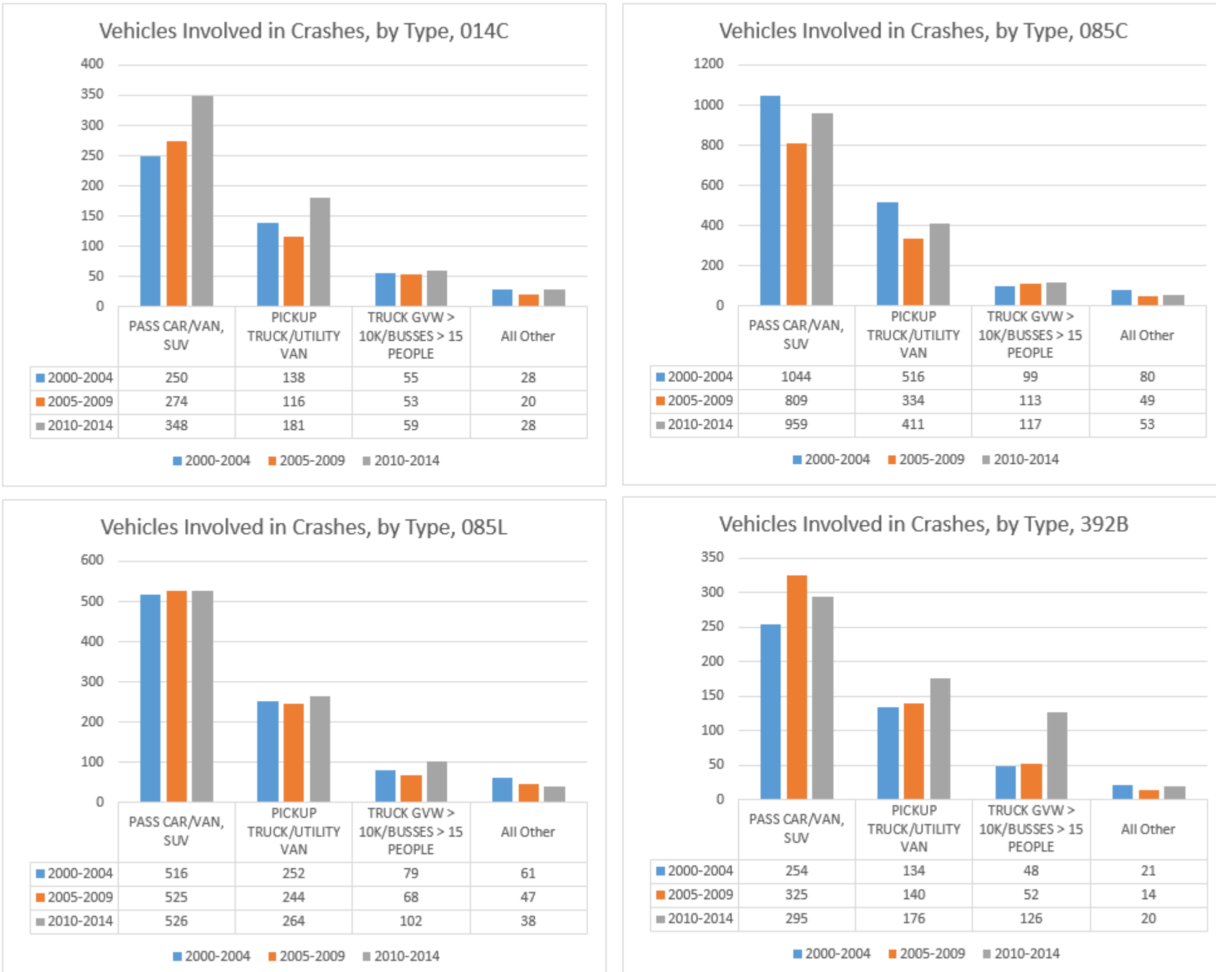
The total number of crashes rose each period on SH 392B. Both SH 14C and US 85L had increasing crashes over the total period with a minimum number during the middle period. For US 85C the maximum number of crashes was recorded during the first period and the minimum was seen in the second period (**Figure 5-9**).

Figure 5-9 Corridor Crashes



The number of vehicles by vehicle type involved in crashes for each corridor is presented in **Figure 5-10**. Maximums are seen in the last period for both the Pickup Truck / Utility Van and the Large Truck / Bus vehicle types. Note that on SH 392B the number of large trucks involved in crashes more than doubled during the last period.

Figure 5-10 Crashes by Vehicle Type



Vehicles Involved in Crashes, by Type, 014C

	PASS CAR/VAN, SUV	PICKUP TRUCK/UTILITY VAN	TRUCK GVW > 10K/BUSSES > 15 PEOPLE	All Other
2000-2004	250	138	55	28
2005-2009	274	116	53	20
2010-2014	348	181	59	28

Vehicles Involved in Crashes, by Type, 085C

	PASS CAR/VAN, SUV	PICKUP TRUCK/UTILITY VAN	TRUCK GVW > 10K/BUSSES > 15 PEOPLE	All Other
2000-2004	1044	516	99	80
2005-2009	809	334	113	49
2010-2014	959	411	117	53

Vehicles Involved in Crashes, by Type, 085L

	PASS CAR/VAN, SUV	PICKUP TRUCK/UTILITY VAN	TRUCK GVW > 10K/BUSSES > 15 PEOPLE	All Other
2000-2004	516	252	79	61
2005-2009	525	244	68	47
2010-2014	526	264	102	38

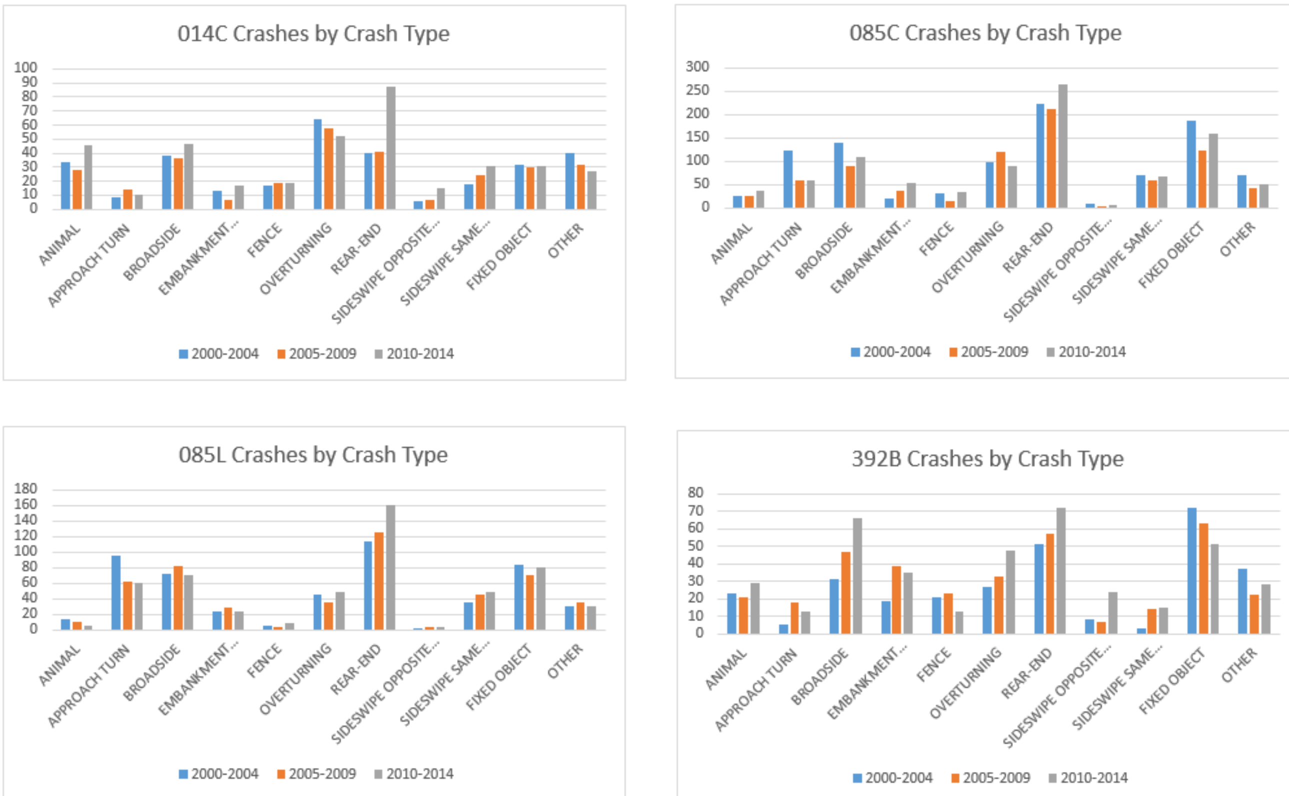
Vehicles Involved in Crashes, by Type, 392B

	PASS CAR/VAN, SUV	PICKUP TRUCK/UTILITY VAN	TRUCK GVW > 10K/BUSSES > 15 PEOPLE	All Other
2000-2004	254	134	48	21
2005-2009	325	140	52	14
2010-2014	295	176	126	20

Crashes grouped by crash type are shown in **Figure 5-11**. On all corridors rear end crashes increased with the difference between the first and last periods ranging from +19 percent on 085C to +118 percent on 014C. For rear end crashes during the most recent period large trucks were involved in 10 percent of the SH 014C crashes, in 13 percent of the US 085C crashes, 23 percent of the US 085L crashes, and in 38 percent of the SH 392B crashes.

The rear end crashes are consistent with slow moving or turning large trucks. In addition a majority of the rear end crashes occur at intersections.

Figure 5-11 Crashes by Crash Type



See **Figure 5-12** for stacked column graphs showing the period proportions of crashes by severity for each corridor. All corridors except SH 392B have fewer fatal crashes in the last period which roughly reflects the general trend of decreasing fatal crashes in Colorado (see **Figure 5-13**).

Figure 5-12 Crashes by Severity

014C Crashes by Severity

	PDO	INJ	FAT
2010-2014	273	103	6
2005-2009	195	90	11
2000-2004	168	133	9

085C Crashes by Severity

	PDO	INJ	FAT
2010-2014	648	273	6
2005-2009	486	286	11
2000-2004	655	332	12

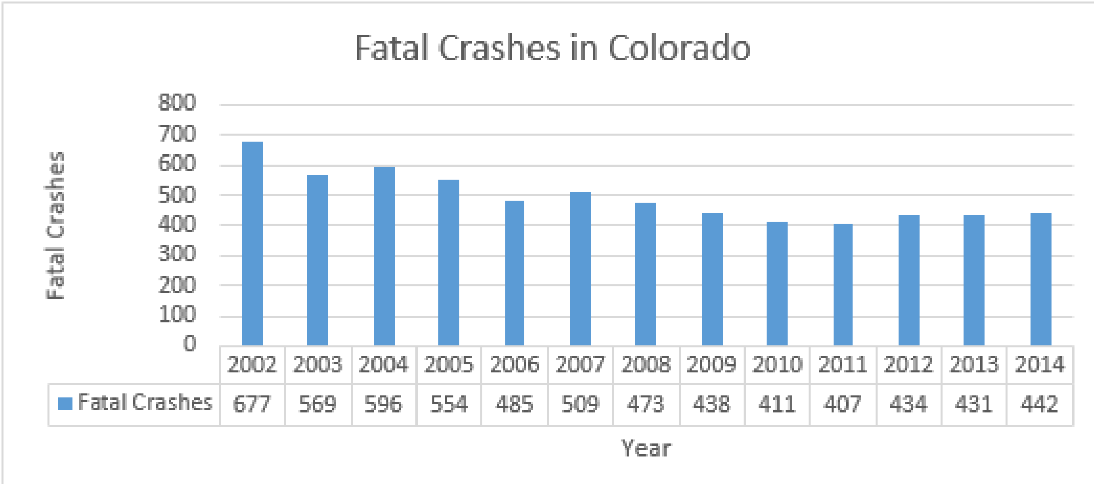
085L Crashes by Severity

	PDO	INJ	FAT
2010-2014	380	157	5
2005-2009	346	149	8
2000-2004	332	183	6

392B Crashes by Severity

	PDO	INJ	FAT
2010-2014	267	116	11
2005-2009	229	106	9
2000-2004	187	106	4

Figure 5-13 Annual Fatal Crashes in Colorado

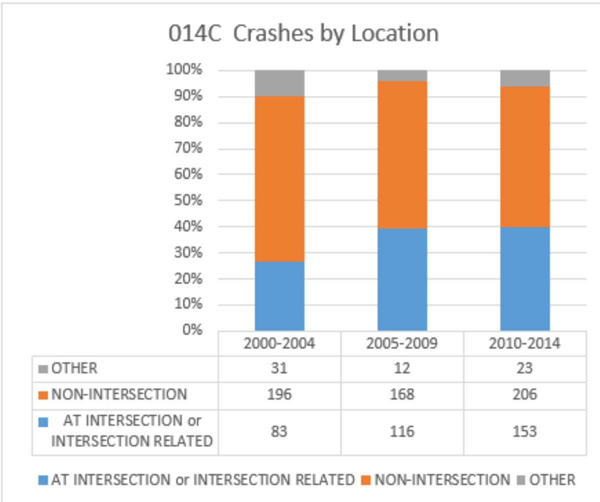


	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fatal Crashes	677	569	596	554	485	509	473	438	411	407	434	431	442

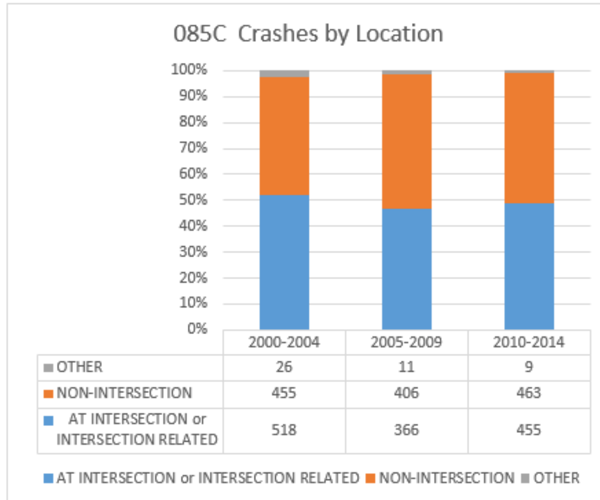
The crash data for the four corridors is broken down to reflect the proportion of crashes associated with intersections in **Figure 5-14** [7] (the “Other” category includes driveways, alleys, parking lots, ramps, and “unknown”).

[7] https://www.codot.gov/library/traffic/traffic-manuals-guidelines/safety-crash-data/fatal-crash-data-city-county/historical_fatals.pdf/view

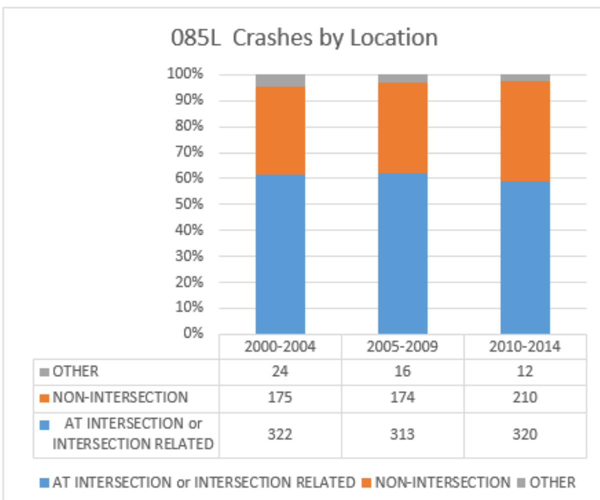
Figure 5-14 Crashes by Location



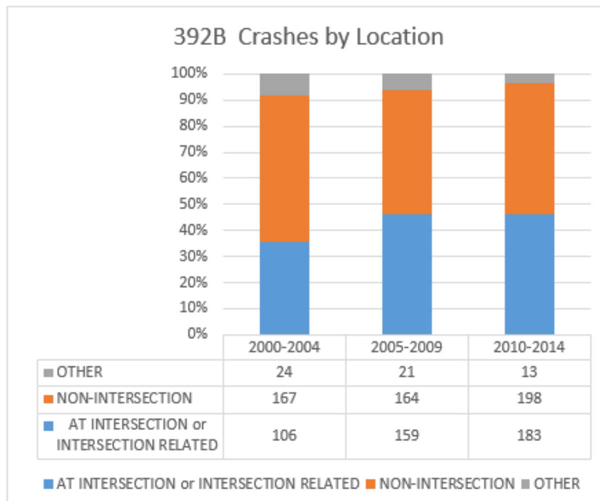
	2000-2004	2005-2009	2010-2014
OTHER	31	12	23
NON-INTERSECTION	196	168	206
AT INTERSECTION or INTERSECTION RELATED	83	116	153



	2000-2004	2005-2009	2010-2014
OTHER	26	11	9
NON-INTERSECTION	455	406	463
AT INTERSECTION or INTERSECTION RELATED	518	366	455



	2000-2004	2005-2009	2010-2014
OTHER	24	16	12
NON-INTERSECTION	175	174	210
AT INTERSECTION or INTERSECTION RELATED	322	313	320



	2000-2004	2005-2009	2010-2014
OTHER	24	21	13
NON-INTERSECTION	167	164	198
AT INTERSECTION or INTERSECTION RELATED	106	159	183

CONCLUSIONS:

- SH 14 east of I-25, US 85 North and South of Greeley and SH 392 east of Windsor experienced increases in AADT between 2000 and 2014. The growth ranged from 1 percent on US 85 north of Greeley to 20 percent on SH 392.
- Over the same period crash totals increased on three of the four corridors. Only US 85 south of Greeley saw fewer crashes with a decrease of 8 percent while the greatest growth of 25 percent was seen on SH 392.
- SH 392 experienced appreciable growth (62 percent) in the number of crashes that involved the large truck / bus vehicle type between 2000 and 2014.
- SH 392 saw an increase (64 percent) in fatal crashes between 2000 and 2014. Between 2010 and 2014 at least one large truck was involved in 9 of the 11 fatal crashes on SH 392.

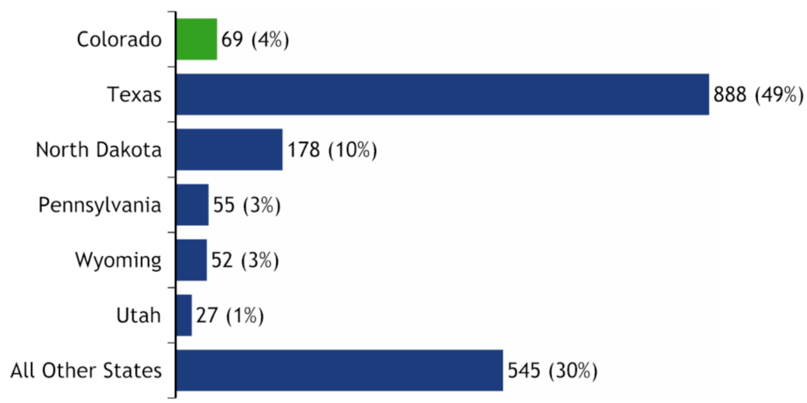
6.0 REGULATORY RESEARCH

As resource development continues throughout the state, CDOT is faced with increasing infrastructure demands and corresponding higher costs. Although conditions in Colorado's basins are unique, other states face similar funding issues relating to oil and gas development. The study team conducted a comparison of funding practices used to address increasing transportation costs due to resource development in Colorado, Texas, North Dakota, Pennsylvania, Wyoming and Utah.

6.1 Colorado in Context

Due to technological advancements and favorable economic conditions, onshore oil and gas development has significantly increased across the country over the past five years and Colorado is one of several states to experience dramatic increases in industry activity. From the Marcellus Shale in Pennsylvania to the Eagle Ford Basin in Texas, the oil and gas industry is booming. Nearly half of all domestic onshore oil and gas activity is occurring in Texas, according to rig count data published by Baker-Hughes. Comparatively, Colorado has only 4 percent of the country's onshore rigs. **Figure 6-1** shows rig counts by state in July 2014.

Figure 6-1 Oil & Gas Rigs by State, July 2014



NOTE: National Total = 1,814 onshore rigs

SOURCE: Baker Hughes, 2014

Each state has a different approach to generating and distributing revenues from oil and gas development. The most common form of revenue collection from oil and gas development is a form of production or severance tax—a tax paid on the amount of the resource extracted or "severed" from the ground. Pennsylvania is the only large producer of oil and gas that currently does not have a severance tax. Instead, Pennsylvania levies an impact fee on each well. The differences between states' approaches to resource taxation are discussed in more detail later in this chapter.

In addition to severance taxes, the industry also pays other applicable taxes, such as property taxes, corporate income taxes, and sales tax. Combined, these taxes contribute to the overall effective industry tax rate. The effective tax rate is the level of taxation that is actually applied to the industry, including all nominal tax rates and any applicable exemptions. Of oil and gas producing states in the west, Wyoming and North Dakota have the highest effective tax rate, both over 11 percent. In contrast, Colorado and Texas have much lower effective tax rates, indicating oil and gas production generates less revenue by volume for Colorado and Texas compared to other states with higher effective tax rates. **Table 6-1** shows a comparison of effective tax rates in the west.

Table 6-1 Effective Tax Rate, by State

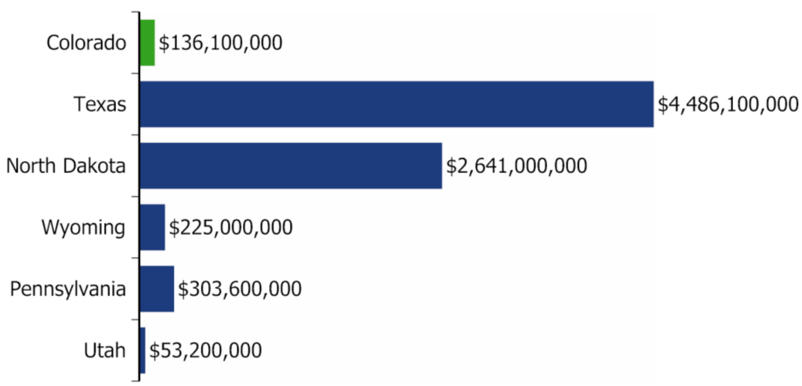
State	Total Effective Oil & Gas Tax
Wyoming	11.7%
North Dakota	11.2%
Utah	9.9%
Pennsylvania*	-
Colorado	6.8%
Texas	6.8%

*: No current Pennsylvania studies with comparable methodology

SOURCE: Headwater Economics, 2014

Taxation rates on oil and gas can be contentious, in part because of how tax competition affects the industry. Oil and gas production is determined by a complex series of factors, including the location of geological formations as well as imposed regulatory conditions, which makes it difficult to determine the impacts of taxation rates on resource extraction activity. Despite the ambiguous impacts of tax rates on production, effective tax rates have a direct impact on public revenues. **Figure 6-2** shows the state level tax revenues for significant oil and gas producing states.

Figure 6-2 2013 State-Level Oil & Gas Tax Revenues



NOTE: Only includes severance tax revenues; impact fee revenues for Pennsylvania

SOURCES: Colorado Department of Revenue; North Dakota Office of State Tax Commissioner; Pennsylvania Department of Revenue; Texas Comptroller of Public Accounts; Utah State Tax Commission; Wyoming Department of Revenue

The effects of North Dakota's higher tax rate on oil and gas production are evident in **Figure 6-2**, when compared to **Figure 6-1**. Despite having approximately 20 percent of the rigs that are in Texas, North Dakota collects nearly 60 percent of the revenues collected in Texas. Colorado collects less revenue from oil and gas production than either Pennsylvania or Wyoming, even though Colorado has a comparable amount of industry activity.

6.2 State-Level Oil & Gas Cost-Recovery Instruments

States have different methods of funding the department of transportation. In general, motor vehicle taxes, user fees, general fund appropriations, and federal funds are the largest sources of transportation revenues. However, tracing revenue sources across states is a difficult process as every state has unique funding strategies. Therefore, the case studies below do not show the same funding categories for every state. Instead it lists the level of detail readily available in the respective state budgets.

Only three states included in this study have specific transportation funding sources directly related to oil and gas extraction. Texas and Wyoming both directly allocate severance tax revenues to the DOT while PennDOT receives revenues from an oil and gas impact fee, which functions similar to a severance tax. However, even though these states all have dedicated oil and gas funding source, it is a relatively small portion of the total revenues. The severance tax (and impact fee) revenues are shared with many departments and therefore only a small amount is transferred to the DOTs.

It should be noted that this level of analysis does not comment on whether or not the amount of severance taxes transferred to the DOT adequately covers oil and gas related transportation expenditures.

In general, state governments raise money through production taxes and fees related to oil and gas development. The following provides a description of each cost recovery instrument.

Production Taxes

As oil and gas are "severed" from the earth, states may assess a production or a severance tax. Typically, states collect the tax and then apportion the revenue between state funds and local governments. The redistribution methods vary greatly depending on state policy.

Fees and Charges

Fees and charges are sometimes used to offset the cost of public capital and service provision to the oil and gas industry. Fees are often applied as a user fee (e.g., overweight/oversize truck permits) or impact fees.

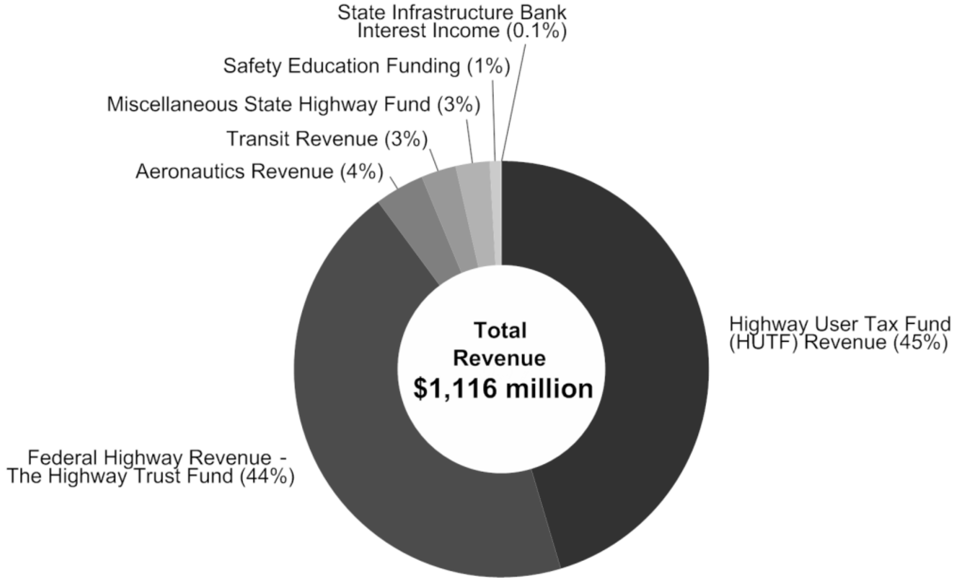
6.3 Case Studies

Each state uses different methods to generate revenue. The following provides a state specific description of state-level oil and gas taxation methods.

COLORADO

Figure 6-3 shows the various sources of transportation funding for CDOT.

Figure 6-3 Colorado Department of Transportation Funding Sources

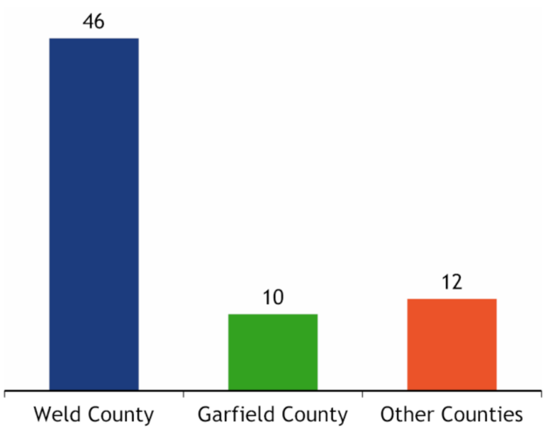


SOURCE: Colorado Department of Transportation, 2015

Oil and Gas in Colorado

Recent oil and gas activity in Colorado has been primarily concentrated in the D-J and Piceance Basins. The D-J Basin is generally located beneath the Weld, Broomfield, Adams, and Denver Counties, although the vast majority of the formation underlies Weld County. The Piceance Basin lies on the western edge of the state, primarily in Garfield County. **Figure 6-4** shows the current distribution of drilling rigs in Colorado, which is heavily concentrated in Weld County and Garfield County.

Figure 6-4 Drilling Rigs in Colorado, July 2014



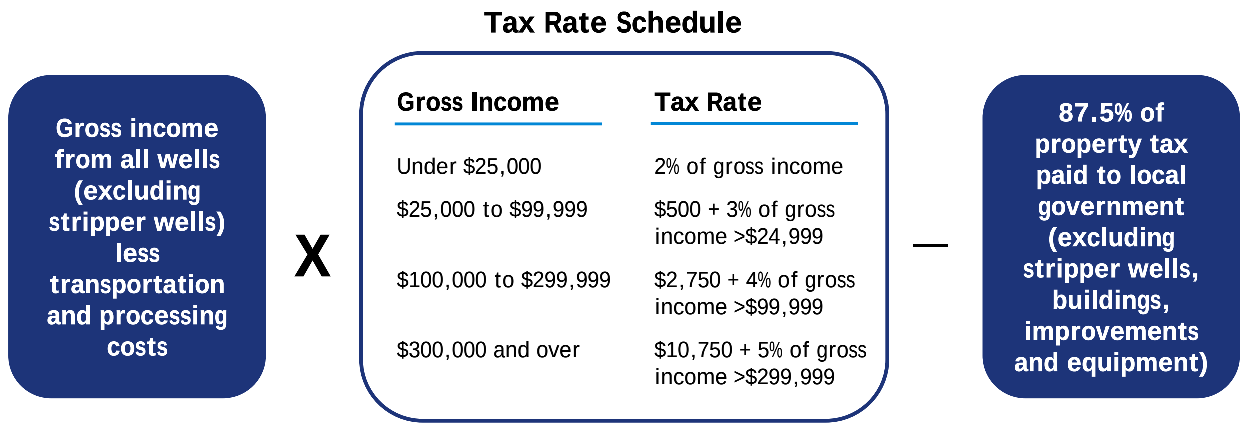
SOURCE: Baker Hughes, 2014

Severance Tax

Colorado imposes a severance tax on oil and gas production. As shown in **Figure 6-2** previously, Colorado collected approximately $136 million in state severance tax revenue in 2013. The amount of severance tax collected is calculated based on the taxable income from each well. In Colorado, the taxable income is the gross income from all wells, minus transportation and processing costs. Colorado does not collect severance tax on income from stripper wells (oil or gas wells that are nearing the end of their life cycle and produce small amounts of resources – generally less than ten barrels per day or less for any twelve-month period.[8] The gross taxable income from oil and gas wells is then taxed according to a progressive tax rate for specific income brackets, shown in **Figure 6-5**.

One of the primary factors that contribute to Colorado's comparatively low effective tax rates on oil and gas is that, unlike other states, Colorado allows local taxes to be deducted from severance tax. Companies are allowed to deduct 87.5 percent of property taxes to local governments from the total amount of severance tax owed. Since the local property tax assessment ratio on oil and gas is 87.5 percent of market value, this deduction allowance amounts to a significant reduction in state collected revenues.

Figure 6-5 Colorado Severance Tax Collection Formula



SOURCE: Colorado Department of Revenue, 2014

Figure 6-5 shows the calculation for severance tax collection in Colorado, which has averaged nearly $150 million over the past five years, as shown in **Table 6-2**. It is also important to note the variability of severance tax revenue, which is based on the price and quantity of oil and gas extracted.

Table 6-2 Total Severance Tax Collected in Colorado

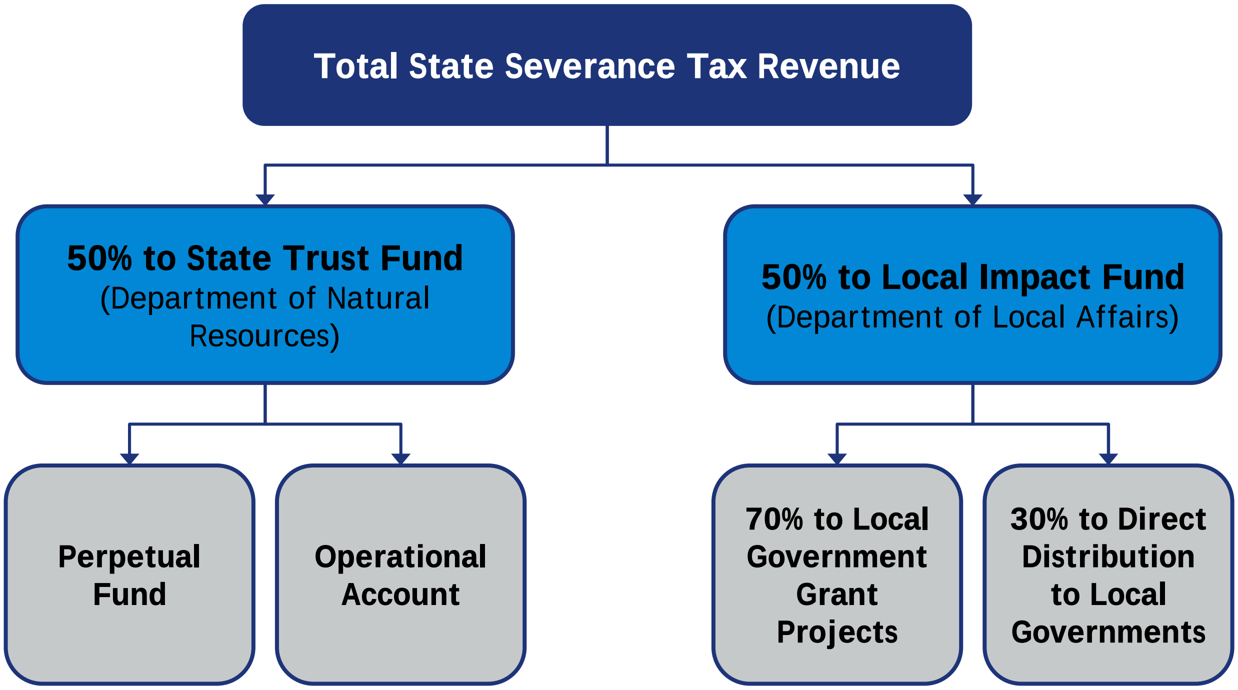
Year:	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Dollars (Millions):	$126.45	$139.55	$272.65	$63.71	$130.70	$163.05

SOURCE: Lewandowski & Wobbekind, 2013

Once collected, severance taxes are distributed through the process depicted in **Figure 6-6**. Severance tax funds are not directly dedicated to fund state highway projects.

[8] https://en.wikipedia.org/widi/Stripper_well

Figure 6-6 Colorado Severance Tax Distribution



Severance tax revenues are divided evenly between the State Trust Fund and the Local Impact Fund. The Colorado Department of Natural Resources (DNR) administers the State Trust Fund and divides the allocated revenues between the Perpetual Base Account and the Operational Account Grant Program. The Perpetual Fund is used to provide funding for state water projects and is overseen by the Colorado Water Conservation Board. The Operational Account provides funding for various other programs administered by DNR.

The Local Impact Fund is administered by the Department of Local Affairs (DOLA) and is used to distribute funds to local governments. Of the money distributed through DOLA, 70 percent is awarded to local governments through grants for specific applicable projects. Local governments occasionally spend funds on local road projects. State highways generally are not funded through these grant funds. The remaining 30 percent of funds are directly distributed to local governments based on their relative level of industry impact.

The direct distribution to local governments has two steps. The first step is a county allocation, where monies are allocated among Colorado counties based on local resource production, energy employee residence and drilling/mining permits. Each county's proportion of the state total for each of these factors is weighed to determine payout of severance tax direct distribution receipts. The current allocation for each factor is 40 percent to energy employee residence, 30 percent to mining and well permits, and 30 percent to mineral production.

The second step is a sub-county allocation, where the severance tax funds allocated to each county are divided among the county and its municipalities based on road mileage, population and energy worker residence. Each factor is weighed roughly evenly in the sub-county allocation process. Counties accrue severance tax funds based on the proportion of road mileage, population and energy worker population residing in the unincorporated county.

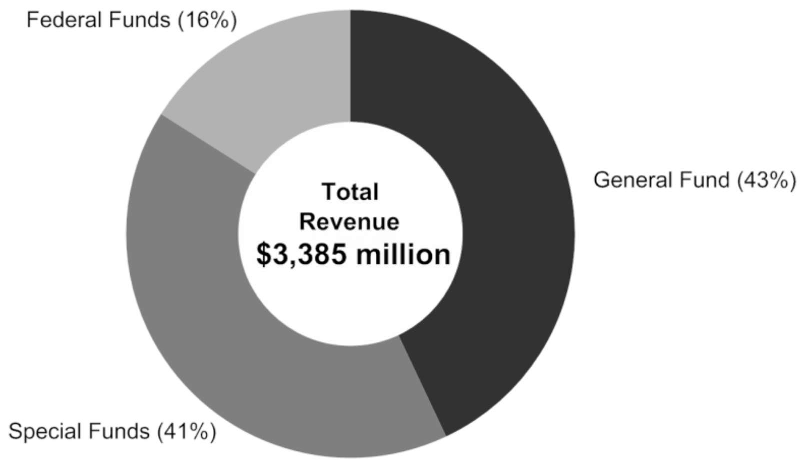
Ballot Initiatives

In 2008, two failed ballot initiatives attempted to modify severance tax collection and distribution in Colorado. One initiative proposed increasing the severance tax rate and one proposed eliminating the local property tax deductions. In 2014, there were four ballot initiatives (two industry-supported initiatives and two industry-opposed) that targeted various aspects of oil and gas regulation. While none of the initiatives directly focused on transportation, they did target environmental aspects, tax distribution practices and local government regulation authority over oil and gas drilling. These initiatives were withdrawn as part of a statewide agreement to discuss conflicts between the industry, citizens, local governments, and the state through a gubernatorial task force. This task force is intended to reduce conflict between competing parties and conflicting ideologies related to oil and gas development in Colorado. Recommendation #37 from the task force final report is related to reducing truck traffic on public streets, roads, and highways for oil and gas activities.

North Dakota

Figure 6-7 shows the various sources of transportation funding for NDDOT.

Figure 6-7 North Dakota Department of Transportation Funding Sources

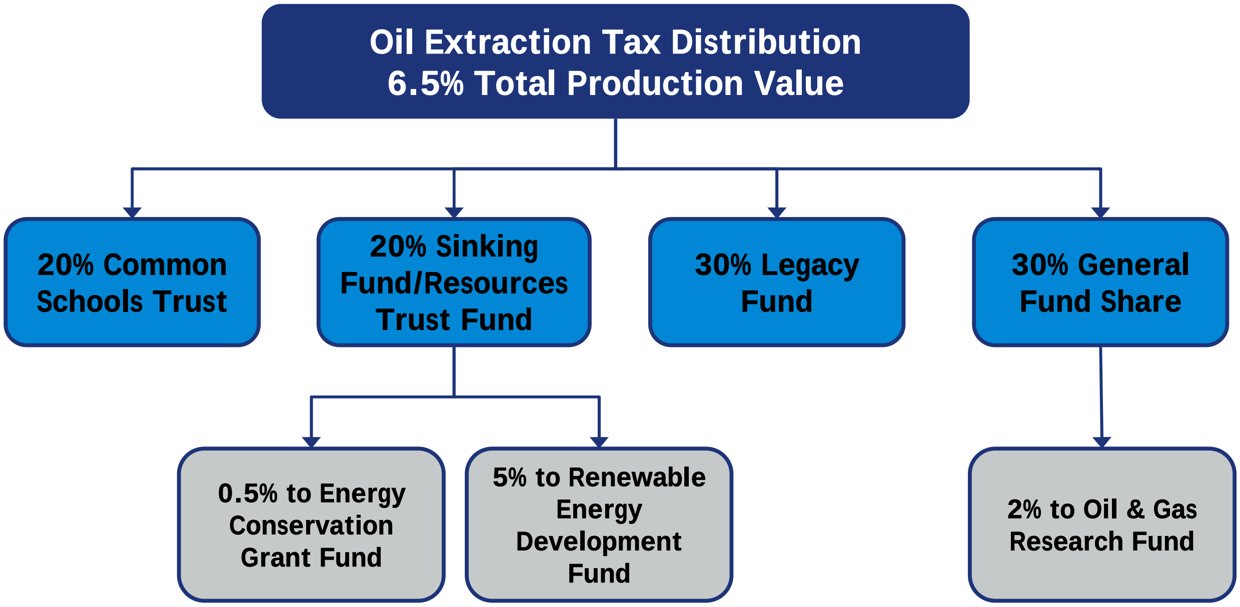


SOURCE: North Dakota Department of Transportation, 2015.

Production Tax

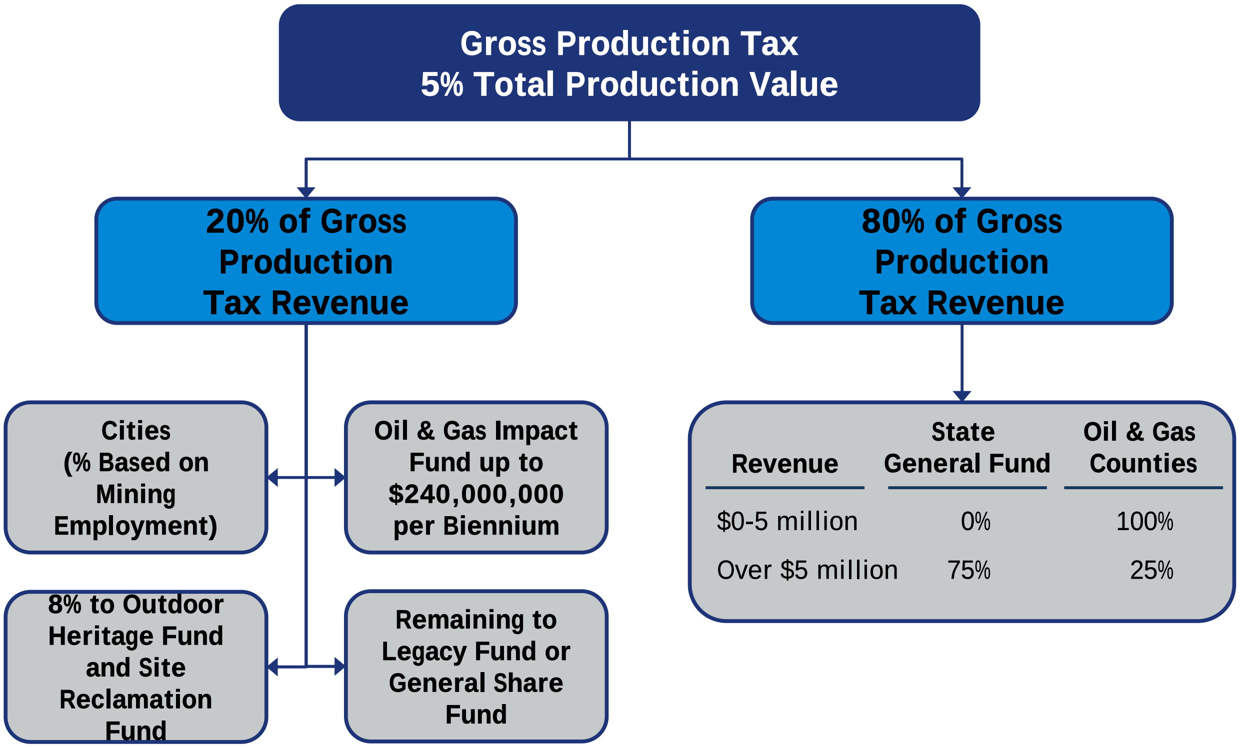
North Dakota applies a 6.5 percent Oil Extraction Tax and a 5 percent Gross Production Tax. The Oil Extraction Tax is collected by the state and distributed between the State General Fund, Water Resources Fund, Common School Fund and Resources Trust Fund, as shown in **Figure 6-8**. All revenue from this tax remains with the State.

Figure 6-8 Oil Extraction Tax Distribution



The 5 percent Gross Production Tax is distributed according to two formulas. Twenty percent of revenue is distributed between cities and various state funds. Eighty percent of the funds are divided between the State General Fund and the oil and gas counties depending on the value of the production tax revenue. **Figure 6-9** shows how these funds are distributed.

Figure 6-9 Gross Production Tax Distribution



The 80 percent of gross production tax revenue allocated to the State General Fund and oil and gas producing counties is distributed on a sliding scale. One-hundred percent of the first $5 million in revenue is allocated to the oil and gas counties. Revenue over $5 million is split with 25 percent going to oil and gas counties and 75 percent going to the State General Fund.

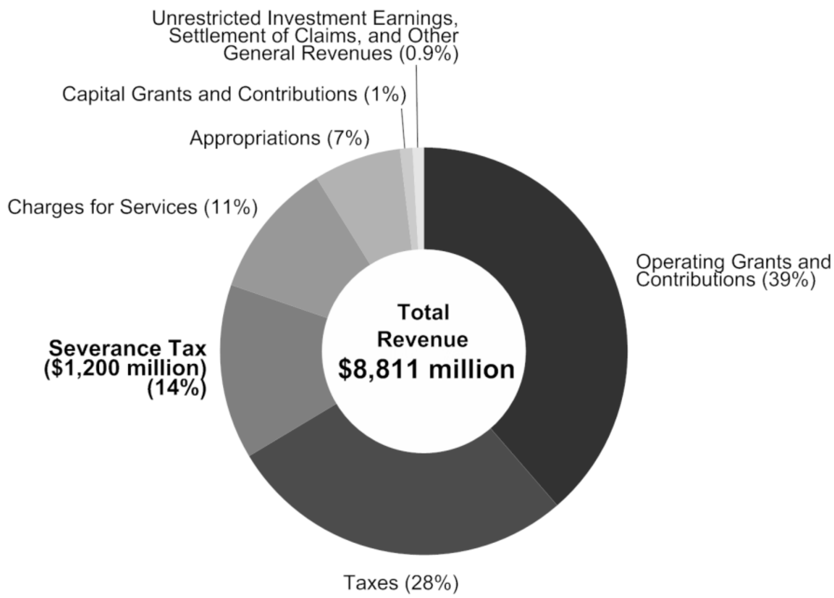
Highway Funding

Oil and gas related truck traffic has caused significant damage to North Dakota's highways. Like many other states, including Colorado, North Dakota does not have a dedicated distribution of oil and gas revenues to NDDOT for associated road repairs. However, because North Dakota is currently collecting significant tax revenues, the state has unallocated general funds that it is able to use for ad hoc appropriations to address public need. In the past biennium, approximately $230 million was appropriated for pressing NDDOT projects. An additional $142 million has been appropriated for road repairs at the county and township level.

TEXAS

Texas will likely have a larger share of total funding (approximately 14 percent) derived from severance taxes than other states in the study. However, since this was a ballot issue in November 2014, the amount shown in **Figure 6-10** is just a projection.

Figure 6-10 Texas Department of Transportation Funding Sources



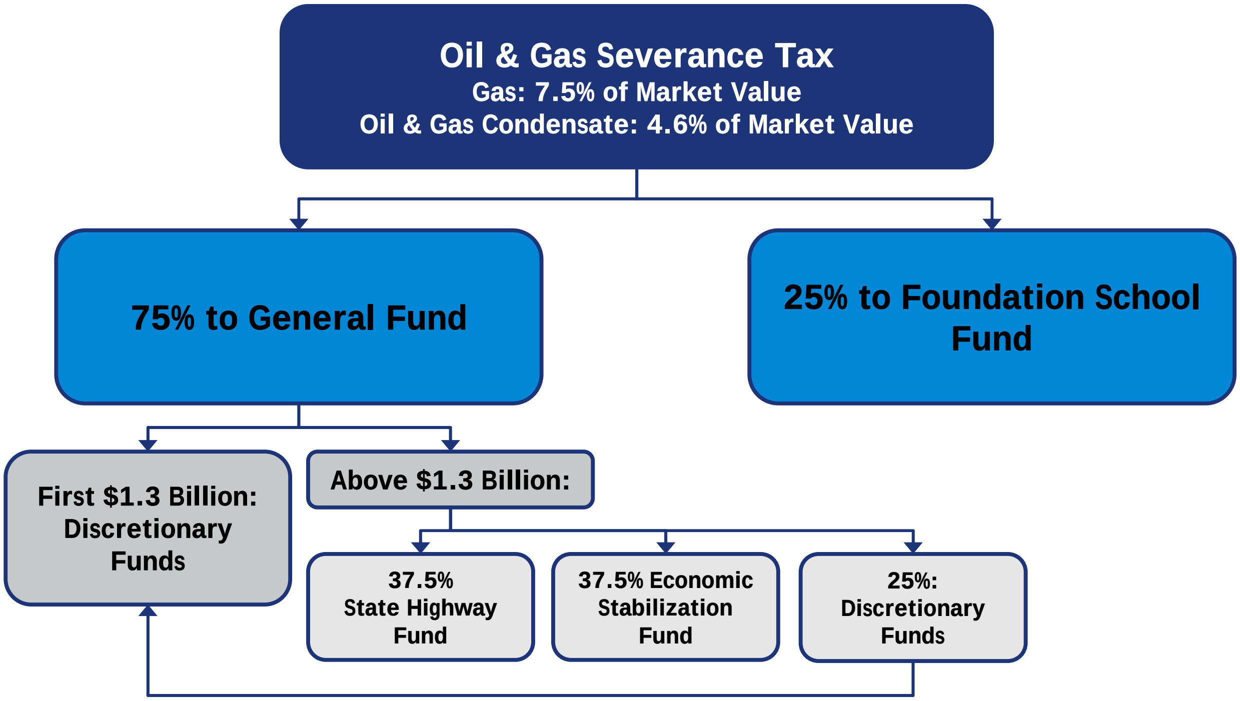
SOURCE: TxDOT, 2015

Texas is the nation's largest oil and gas producer and the state collects severance tax at a rate of 7.5 percent[9] for natural gas and 4.6 percent for oil.

Severance tax revenues are distributed between the Foundation School Fund, the General fund, the Economic Stabilization Fund, and the State Highway Fund, as shown in **Figure 6-11.** Twenty-five percent of revenues are allocated to the school fund. The remaining 75 percent is allocated based on the level of revenue collected. The first $1.3 billion is deposited into the General fund. Above $1.3 billion, 37.5 percent of revenues are allocated to the Economic Stabilization Fund, 37.5 percent to the State Highway Fund, and 25 percent remains in the General Fund as discretionary revenue.

[9] Many wells qualify for an exemption based on the well's drilling and completion costs. High-cost wells are taxed at a reduced rate of 0 percent to 7.4 percent.

Figure 6-11 Texas Severance Tax Distribution



Historically, Texas did not have a dedicated allocation of oil and gas revenues for the Texas Department of Transportation (TxDOT). Instead, the Texas Legislature appropriated $225 million from the General Fund to TxDOT over a two-year period. However, because the oil and gas boom is causing severe road damage, Texas modified its approach to funding repairs. In 2014, Texas voters passed a Constitutional amendment to divert a portion of the severance tax revenues previously going to the Economic Stabilization Fund to the State Highway Fund for road repairs. This will provide approximately $1.2 billion per year for TxDOT.

Roadway Funding Study

In 2012, TxDOT sponsored a task force on Texas' energy sector roadway needs. This task force looked at various ways in which the state and impacted counties could legally fund the increasing demand for roadway infrastructure. The task force published a report discussing potential funding strategies, summarized below[10]:

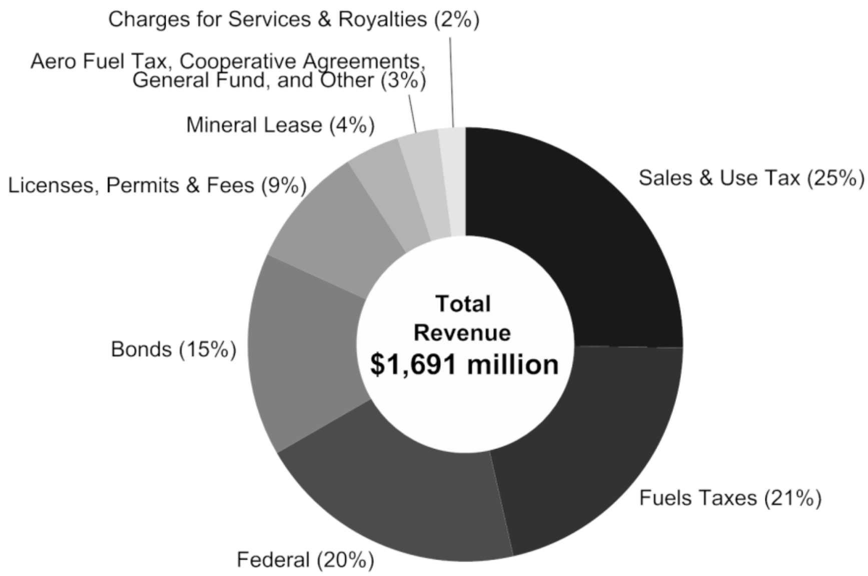
- Road use maintenance agreement (RUMA): Agreement between the state and the company drilling the well. Survey the road condition before and after the drilling and the company is responsible to restoring to original condition. Shared between companies if shared road.
- Property tax code alteration: Eliminates "TABOR"-like provisions in county property tax code as applied to oil and gas wells.
- Commercial driver's license fee: Increase CDL fees.
- Oversize/Overweight violations: Increase fines on violators.
- Truck fee: Establish a weight and utilization truck fee that is proportional to truck weight.
- Severance tax bonding: Bonds backed by future severance tax revenue.
- Severance tax dedication: Dedicate severance taxes to counties of origin. Dedicating tax revenues would increase money available to counties, but not the state as a whole.
- Increase severance taxes: Dedicate a severance tax rate increase to roadway improvements.
- Public private partnership: Private entity would collect user fees from commercial traffic. Roadway usage could be measured by GPS or electronic tag.
- County road districts: New property tax exclusively for roads. These districts could exclude current residents and only levy tax on commercial and new residents' properties.
- Tire tax: Creation of an excise tax on oversized tires. Similar to the federal tax. This method would impose a tax on vehicles with a disproportionately higher impact on the road system.
- Tax increment financing: Use a TIF district for bonding by counties with revenue dedicated to road expansion, repair and maintenance.
- Redirect mineral rights: Redirecting royalty proceeds from the Texas General Land Office to TxDOT or counties for producing formations under state or county right-of-way.

[10] http://ftp.dot.state.tx.us/pub/txdot-info/energy/final_report.pdf

UTAH

Figure 6-12 shows the various sources of transportation funding for UDOT.

Figure 6-12 Utah Department of Transportation Funding Sources

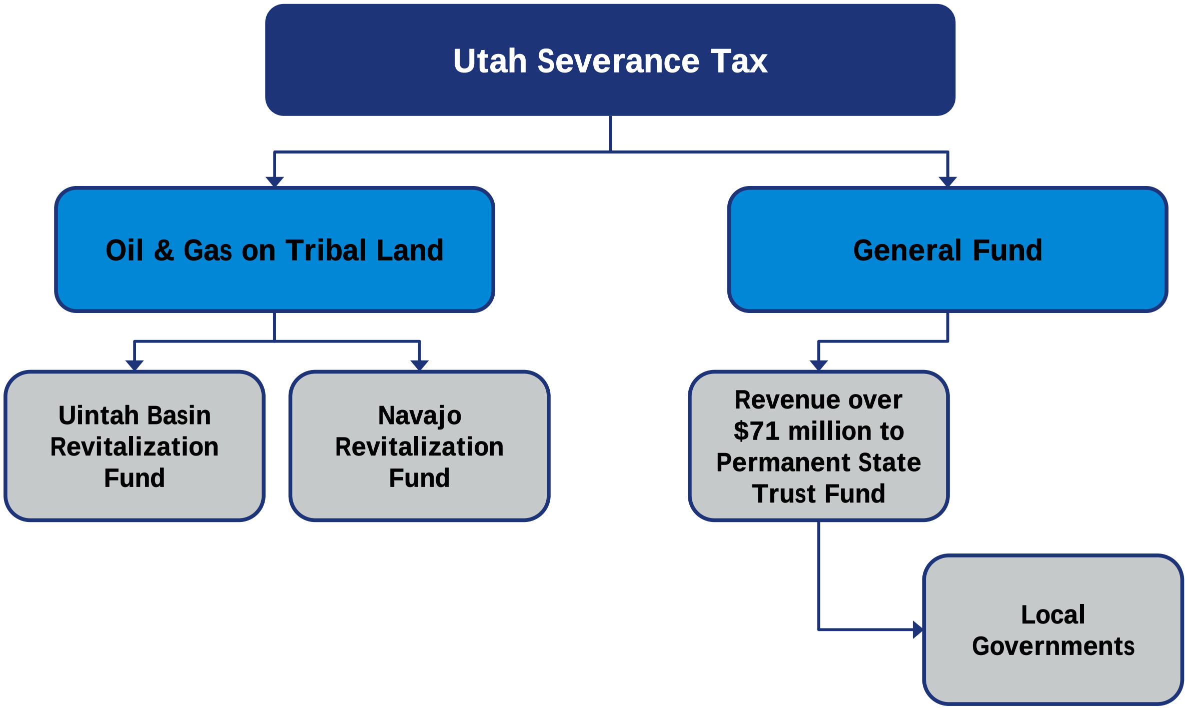


SOURCE: UDOT, 2015

In Utah, oil and gas drilling is concentrated in the Uintah Basin, in the eastern part of the state. A conservation fee and severance tax is collected on oil and gas that is produced, saved, sold, or transported from the field in which it is produced. The conservation fee is .002 percent of the value of oil or gas. The severance tax rate depends on the value of the product. The first $13 per barrel of oil is taxed at 3 percent, and anything above $13/barrel is taxed at 5 percent. The tax rate for natural gas is 3 percent for the first $1.50 per thousand cubic feet of natural gas (MCF) and 5 percent for the value above $1.50/MCF. No severance tax is imposed on stripper wells, resources stockpiled for over two years, the first 12 months of a production for a well outside of a proven play (wildcat well), or the first six months of production for development wells. Enhanced recovery projects are taxed at 50 percent.

The distribution of severance tax depends on the location of the well. Severance tax collected on production from wells on tribal lands is redistributed to tribal revitalization funds, as well as the Uintah Basin Revitalization Fund. Severance tax revenues in excess of $71 million are dedicated to a Permanent State Trust Fund. Funds not otherwise dedicated are then distributed between the state general fund and local governments. Utah's severance tax distribution method is shown in **Figure 6-13**.

Figure 6-13 Utah Severance Tax Distribution

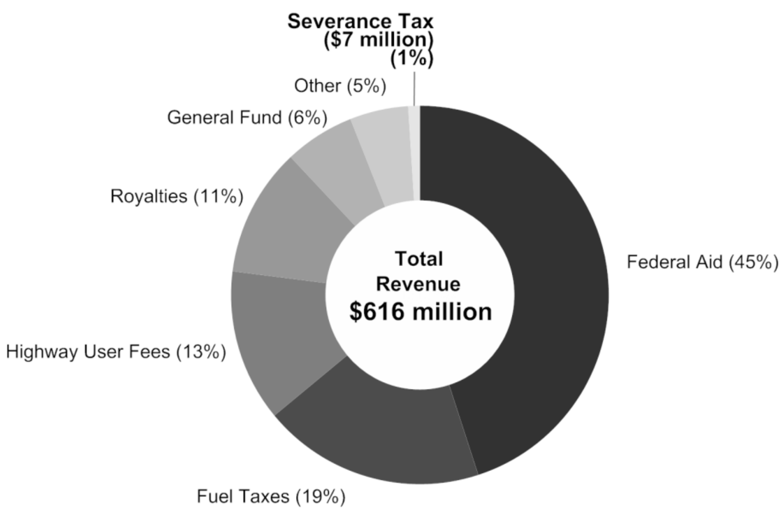


Utah does not have a regular severance tax allocation to UDOT; however UDOT receives some oil and gas revenues from other sources. Each year, approximately 7 percent of UDOT's total revenue comes from Federal mineral lease payments.

Wyoming

Figure 6-14 shows the various sources of transportation funding for WYDOT.

Figure 6-14 Wyoming Department of Transportation Funding Sources

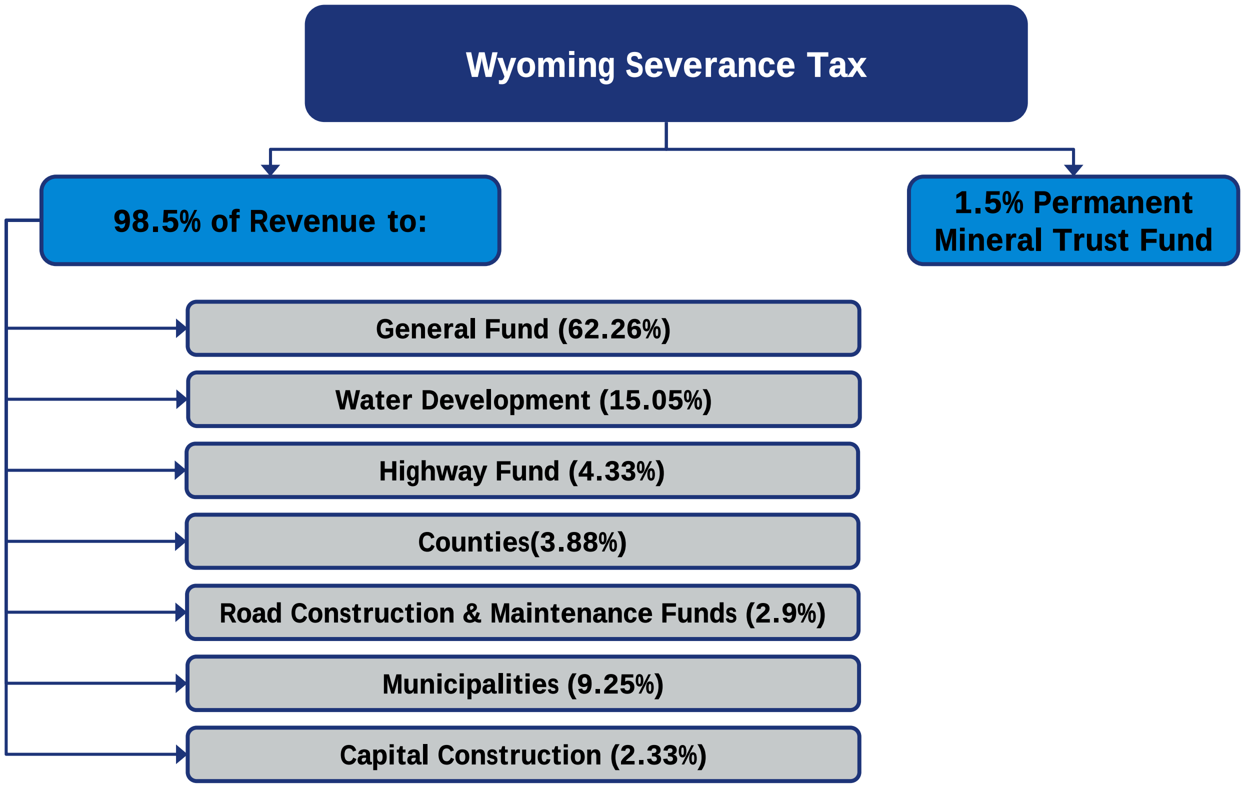


SOURCE: WYDOT, 2015

Like Utah, Wyoming levies a conservation fee and assesses a severance tax on oil and gas production. All revenues from the 8/10 mill conservation fee applied to the market value of production go to the Wyoming oil and gas conservation commission.

Compared to other states, Wyoming has a simplified severance tax structure where six percent tax is applied to the market value of the production. Production from stripper wells is taxed at only 4 percent. Wyoming severance tax is distributed according to the formula shown in **Figure 6-15**.

Figure 6-15 Wyoming Severance Tax Distribution



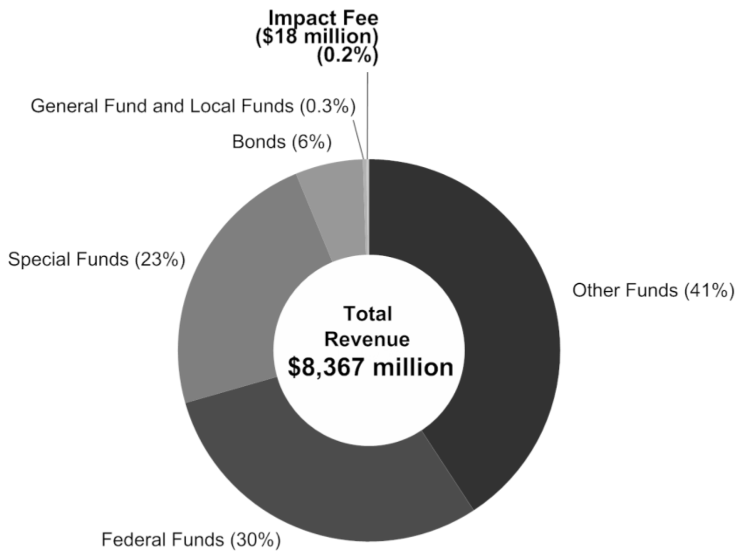
A portion of severance tax revenues in Wyoming is automatically distributed to the state highway fund and to county road construction and maintenance funds. These distributions help offset the oil and gas related impacts on state and local roadway infrastructure. In 2014, about $7 million in severance tax revenues were allocated to WYDOT.

In addition to the direct allocation of severance tax revenues, Wyoming also diverts about 30 percent of federal mineral royalties to WYDOT. In 2014 this amounted to nearly $66.5 million.

PENNSYLVANIA

Figure 6-16 shows the various sources of transportation funding for PennDOT.

Figure 6-16 Pennsylvania Department of Transportation Funding Sources



SOURCE: PennDOT, 2015

A statewide gas well impact fee is the sole cost recovery instrument used by Pennsylvania state and local governments. On February 7, 2012, Pennsylvania's legislature passed Act 13, the Gas Well Impact Fee Act, making Pennsylvania the first state to pass a statewide natural gas impact fee.

According to the fee schedule, the impact fee per well each year is based on the year of production and price of natural gas. Depending on these factors, fees can range between $25,000 and $60,000 in the first three years, between $10,000 and $20,000 annually from year 4 to year 10 and between $5,000 and $10,000 annually for years 11 to 15. There is no annual fee charged after 15 years. According to state estimates, the impact fee could generate between $110,000 and $195,000 annually per well in the first 15 years. **Table 6-3** shows the Pennsylvania gas well impact fee schedule, given the current price of natural gas.

Table 6-3 Pennsylvania Impact Fee Schedule

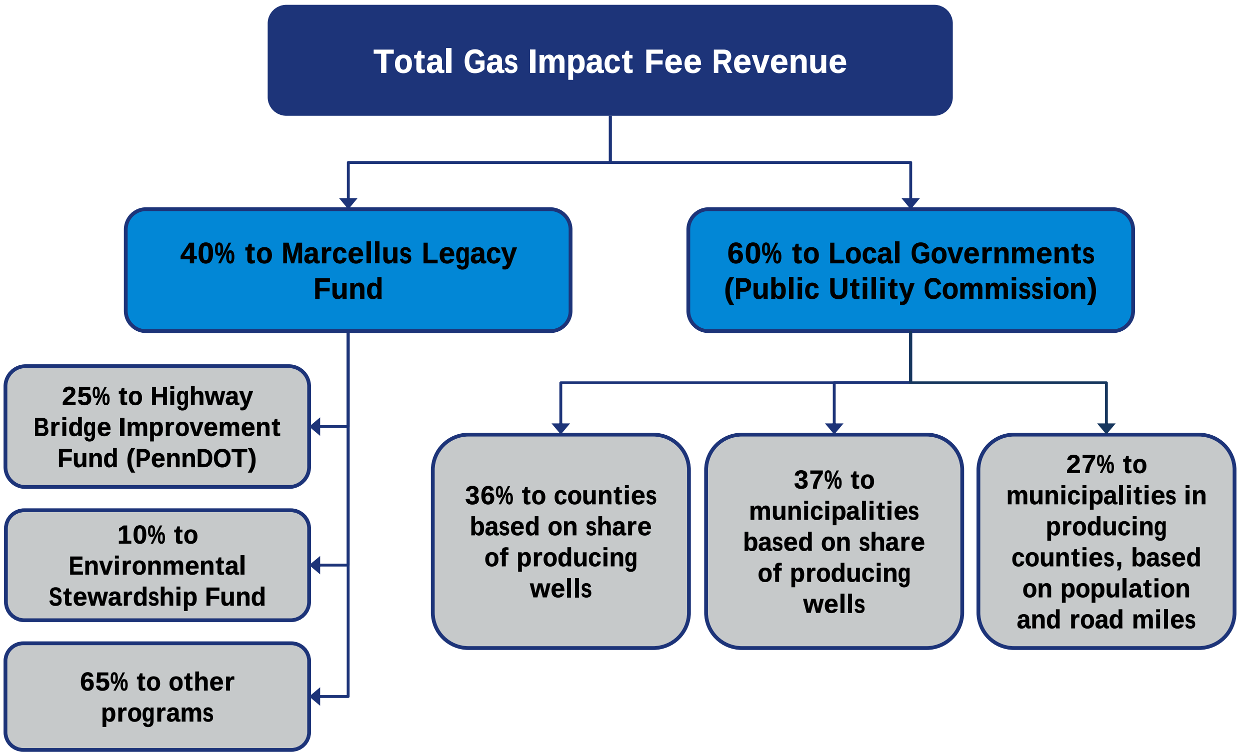
Year	Price of Natural Gas* $3.00-$4.99/MCF
1	$50,000
2	$40,000
3	$30,000
4-10	$20,000
11-15	$10,000

*: As of the week of July 25, 2014

SOURCE: Sacavage, 2013

The state collects the funds and then distributes them to the local governments. The state will take about $25 million for state agencies to offset the statewide impact of drilling. The remainder is divided 60 percent to counties/municipalities and 40 percent for statewide initiatives with potential local impact and value. The Pennsylvania Public Utility Commission administers the distribution of impact fee money, as shown in **Figure 6-17**.

Figure 6-17 Pennsylvania Impact Fee Distribution



Notably, Pennsylvania has a direct appropriation of oil and gas impact fee revenues to PennDOT. Of the 40 percent allocated to the Marcellus Legacy Fund, 25 percent goes directly to PennDOT's Highway Bridge Improvement Fund.

6.4 Summary

Every state has a different method for collecting revenues related to oil and gas development. The majority of states researched apply a severance tax on the value of the extracted resource. Pennsylvania is the only state with a notable oil and gas industry that does not have a severance tax, and instead levies an annual impact fee on each well. However, the method of revenue collection is not the only significant difference between states' approach to oil and gas funding.

Distribution of collected funds also varies greatly across these states. Many states redistribute some of the collected revenues back to the oil and gas impacted cities and counties through grants or direct appropriations. In other states, such as Texas, all collected production tax funds remain at the state level. Additionally, some states have much more clearly defined distribution formulas, while others leave more funds available for discretionary uses.

Wyoming, Texas, and Pennsylvania are the only states of those researched that have a dedicated appropriation of oil and gas production revenues to state transportation departments. Without an automatic diversion of funds, other states, including Colorado, are left to make ad hoc allocations in order to address increasing highway funding needs.

The lack of a dedicated revenue source impacts CDOT to a greater degree than NDDOT, and previously TxDOT, because Colorado's general fund is not flush with excess oil and gas revenues due to the low effective tax rate and gratuitous property tax exemption. Colorado is the only state of the six that does not dedicate some production revenue into the general fund. The lack of a dedicated revenue source combined with Colorado's large severance tax exemption and low effective tax rate leads to significantly less oil and gas revenue available for state services, including state highway repair and maintenance.

7.0 IMPLEMENTATION

The completion of the Oil & Gas Study is the result of a collaborative effort between various parts of CDOT. The information contained in the Study will help to inform the Department's future discussions on Oil & Gas impacts to the transportation system and influence informed decision making. One the most useful deliverables from the Oil and Gas study is the cost estimation tool. This tool is useful for determining the level of impacts to pavement specifically in areas of the state where there is a high level of oil and gas development. The oil and gas cost estimation tool will provide CDOT engineers the ability to help determine oil and gas truck loads on specific state highway segments and can help CDOT engineers establish baseline costs to offset the impacts of oil and gas pad development.

CDOT staff will share the cost estimation tool with program and project engineers and other areas within CDOT. Additionally, staff will look at online training options, whereby training can be self-paced and delivered on-demand.

APPENDIX A

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APPENDIX B

Cost Estimation Tool User Guide

CDOT Oil & Gas Impacts Calculator Tool User Guide

v1.0
1/21/2015

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Introduction

The CDOT Oil & Gas Impacts Calculator is an Excel-based tool that estimates the costs associated with oil and gas development and production truck traffic on user-specified CDOT roadway segments and bridges. The tool is designed to provide spot analysis for a particular site by taking inputs from the user and applying them to formulas designed to determine impacts.

This guide provides technical details on how to use the Excel-based CDOT Oil & Gas Impacts Calculator Tool and how it functions. The tool is built for distribution to multiple users and allows for limited and controlled data changes by the user.

Setup

In order to use the tool, Microsoft Excel must be installed and macros enabled. To enable macros, complete the following steps:

1. Click the Office icon in the top left.
2. Click the “Excel Options” button.
3. Select the “Trust Center” tab.
4. Click the “Trust Center Settings…” button.
5. Select the “Macro Settings” tab.
6. Select the “Enable all macros” option.
7. Click “OK” until back to Excel.
    a. If the tool was open before macros were enabled, close Excel and reopen the tool.

Using the Tool

Two tabs are available within the tool: *Inputs* and *Impacts*. The *Impacts* tab is hidden upon opening the tool (or if anything on the *Inputs* page is changed) and is only made visible once the “Run Analysis” button at the bottom of the *Inputs* tab is pushed.

Inputs Tab

The *Inputs* tab is split into three sections where all user-required data for calculating impacts is entered. The “Roadway Information” section allows for input of necessary data to analyze roadway segments. Users can add segments should roadway characteristics vary along the corridor being analyzed. Clicking the “Add Segment” button copies all data from the segment above it. Note that a segment requires a name and bridge requires a structure number to be recognized by the tool when reporting impacts.

The “Bridge Information” section operates in a similar fashion to the “Roadway Information” section. Users can enter as many bridges to analyze as desired.

The “Activity Settings” section contains settings related to oil and gas activity that the user can change. These settings are pre-set with typical assumptions should a user not know details about the activity to analyze. Once all data has been entered, the user must push the “Run Analysis” button to obtain impacts.

The following subsections describe each of these sections of the tool in greater detail.

Roadway Information

Only black-lined boxes can be changed within this section. Some boxes allow direct input, while others require a choice from a dropdown box. Some boxes are pre-populated with either the most likely answer or the first available item. Each box is programmed to validate the entry to avoid inputs that are not valid for analysis.

Roadway segments can be added by clicking the “Add Segment” button. Similarly, segments can be deleted by clicking the “Delete Segment” button, which only appears if there is more than one segment. Clicking this button opens a message box requiring a segment number to delete. A segment’s number is located above the first input question. This is the number to input if a user wants to delete a segment.

The following are descriptions of the inputs necessary for each roadway segment:

Name of the roadway:	Name of roadway segment, required to be analyzed
Start Mile Post:	Starting mile post number of segment
End Mile Post:	Ending mile post number of segment
CDOT Region:	Dropdown select (Region 1-5), used to select appropriate AASHTO equation variables, including designed ESAL life
Functional Class:	Dropdown select (CDOT functional classes), used to select appropriate AASHTO equation variables, including designed ESAL life
Urban or Rural:	Dropdown select (Urban or Rural), used to select appropriate AASHTO equation variables, including designed ESAL life
Mountains or Plains:	Dropdown select (Mountains or Plains), used to select appropriate AASHTO equation variables, including designed ESAL life
Segment Length (miles):	Automatically calculated from the mile post numbers, can change manually
Surface Type:	Dropdown select (Asphalt or Concrete), used to select appropriate AASHTO equation variables, including designed ESAL life; different impact analysis approaches are used for asphalt and concrete
Paved Width (feet):	Edge-to-edge total paved width
# of Through Lanes:	Total of both directions
Drivability Life:	CDOT calculated value of years of roadway life remaining

Bridge Information

Only black-lined boxes can be changed within this section. Some boxes allow direct input, while others require a choice from a dropdown box. Some boxes are pre-populated with either the most likely answer or the first available item. Each box is programmed to validate the entry to avoid inputs that are not valid for analysis. Certain dropdown box selections reveal additional inputs required for that choice.

Bridges can be added by clicking the "Add Bridge" button. Similarly, bridges can be deleted by clicking the "Delete Bridge" button, which only appears if there is more than one bridge. Clicking this button opens a message box requiring a bridge number to delete. A bridge's number is located above the first input question. This is the number to input if a user wants to delete a bridge.

The following are descriptions of the inputs necessary for each bridge:

<u>General Inputs</u>

Structure #:	Structure number of the bridge, required to be analyzed
Facility Carried:	Name of the facility carried by the bridge
Feature Intersected:	Feature that the bridge passes over
Baseline Average Daily Truck Traffic (ADTT):	ADTT value (if only truck percentage and ADT available, multiply ADT by truck percentage)
Bridge Width (feet):	Width of structure
Bridge Length (feet):	Length of structure

<u>Deck Inputs</u>

Deck Overlay Type:	Dropdown select (HMA/Membrane, Polyester, or No Overlay)

<u>Joints Inputs</u>

Bridge Joint Type:	Dropdown select; choices other than "No Joints" reveals next two inputs
# of Joints along Bridge:	*(only if a joint type is selected)* Number of joints along the bridge
Joint Skew:	*(only if a joint type is selected)* Degrees of skew (no skew = 0 degrees)

<u>Bearings Inputs</u>

Bridge Bearing Type: Dropdown select; choices other than "No Bearings" reveals next input

# of Bearings: *(only if a bearing type is selected)*
Number of bearings

<u>Replacement Bridge Inputs</u>

Replacement Estimate Method: Method as to how to calculate the size of a replacement bridge:

"% Increase" allows for a simple percent of additional bridge area

"Width/Length" allows for entry of new width and length

% Increase in Replacement Bridge Area: *(only if "% Increase" is selected)*
The percentage of additional area to be added to the existing bridge's area (100% of the existing area will automatically be included)

Replacement Width: *(only if "Width/Length" is selected)*
New bridge width in feet, auto populated with the existing bridge width

Replacement Length: *(only if "Width/Length" is selected)*
New bridge length in feet, auto populated with the existing bridge length

Activity Settings

Only black-lined boxes can be changed within this section. Some boxes allow direct input, while others require a choice from a dropdown box. All boxes are pre-populated with either the most likely answer or the first available item. Each box is programmed to validate the entry to avoid inputs that are not valid for analysis. Pre-populated inputs are typically-observed values that should only be changed if better information is available from the industry or other relevant source for the specific analysis location.

The following are descriptions of the inputs used to alter oil and gas activity:

What is the type of development?	Choices are: • "Horizontal" • "Vertical" • "Recompletion" – Re-stimulating a previously drilled well that has slowed in production
Is a pipeline providing fresh water?	Only "Yes" if a freshwater pipeline directly serves the pad site; eliminates all freshwater truck trips from analysis
# of DEVELOPING Pads and Wells to Analyze:	Total number of future pads and total number of wells across those pads that the user wants to analyze on the facilities entered; current typical wells per pad are pre-populated into the tool as a start
Anticipated # of years of production:	Estimated number of years the wells to be drilled are anticipated to produce; current typical length (20 years) is pre-populated into the tool as a start
Anticipated length of development (days):	Number of days it will take to prepare the pad site and drill the wells; current typical length (30 days) is pre-populated into the tool as a start
# of EXISTING Pads and Wells to Analyze:	Total number of existing pads and total number of wells across those pads that the user wants to analyze as in the production period on the facilities entered
Estimated # of years of production remaining:	*(only necessary if existing pads/wells entered)* Estimated number of years the existing wells have left to produce
What % of trip types will be using the facility?	Percentages of trip types that are anticipated to use the facilities to be analyzed; to be edited if knowledge of routing warrants reducing some trip types

IMPACTS TAB

The *Impacts* tab summarizes the impacts calculated by the tool based on the inputs the user provided. The tab only becomes visible when the user pushes the "Run Analysis" button. It disappears if the user changes any input variable after the analysis has been executed. Information on this tab is read-only.

The *Impacts* tab displays impacts in four different sections:

- Roadway Impacts
- Bridge Impacts
- Total Impacts
- Activity Settings & Totals

Roadway Impacts

Each segment from the *Inputs* tab is listed within this section, along with some of the identification information provided. Cost impacts (in 2014 dollars) associated with each segment are also listed. The first is "Development Costs" – costs attributed to developing the pad site and drilling the wells. The second is the annual cost attributed to the production of oil/gas from the site – the "Future Pad(s) Production" cost. Lastly, the "Existing Pad(s) Production" cost is the annual cost attributed to production trips of pads that already existed before.

The cost impact associated with each segment is totaled for each cost category, representing a one-time cost for the development period and annual cost for each production period. Below this summation is the cumulative cost for each type of production period, which takes the annual cost and multiplies it by the number of years of production defined by the user on the *Inputs* tab.

The development period cost and total lifespan cost of production are totaled and displayed within the black-lined box to provide a total cost associated with oil and gas activity on the roadway segments provided by the user.

Bridge Impacts

Bridge impacts are displayed in the same manner as the roadway impacts – identification information and costs per bridge, with totals at the end.

Total Impacts

This section combines the aggregated totals from the "Roadway Impacts" and "Bridge Impacts" sections to provide an overall impact from oil and gas activity on analyzed facilities.

Activity Settings and Totals

This section provides a summary of important oil and gas activity settings made by the user on the *Inputs* tab, along with the number of one-way trips the tool generated based on those settings. These are reported for two different categories: future one-way trips based on future pads/wells to be developed and then produce, and existing pads that are generating production trips.

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