April 2018

Approved Study

ADAMS COUNTY OIL & GAS TRAFFIC IMPACT STUDY

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EXECUTIVE SUMMARY

Background and Purpose

Due to Adams County's location to the Wattenberg Field, energy companies have shown an increased interest in exploration and drilling in the County. Many national and international factors will shape future levels of drilling activity, including oil and gas prices, national economic growth prospects, and the merit of the Niobrara Shale relative to other production areas.

Oil and gas drilling and production can impact local road systems, as well as other public infrastructure and services. Adams County has commissioned this study to understand the potential impacts of oil and gas development and production on the County's road system and to design a roadway impact fee to offset increased transportation maintenance, rehabilitation, and safety costs associated with heavy truck traffic and road damage from oil and gas activity.

The purpose of designing oil and gas roadway impact fees is to recover the incremental costs associated with the oil and gas industry's impact on Adams County's road network. Because of the nature of oil and gas development, the most intense impact occurs during the first month of a well's life. After the development phase, the well enters the less trip-intensive, though ongoing, production phase. The capital required to recover the costs of the development phase is ideally recovered before development begins or during the permitting process. The fees are designed to recoup the cost to the County associated with road deterioration and safety. Adams County has authority derived from state statutes to regulate public roads over which it has jurisdiction. The oil and gas roadway deterioration and safety impact fees are designed and structured within these parameters.

Constructed well pad with drilling rig in the Niobrara Shale.
Source: Carrizo Oil & Gas Inc.

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 to transport produced water and extracted resources off site. Based on literature reviews and recent oil and gas studies completed along the Front Range, a typical horizontally-drilled and fracked well in the study area will generate an estimated 2,932 trips during its two- to three-week development period, largely related to water delivery and removal. Once a well is in the production phase, it generates about two trips per day for the remainder of its productive life. This trip generation estimate can be converted from a one-rig, one-well format to the more common multi-well pad configuration. For example, a 12-well pad configuration will generate nearly 24,500 truck trips during the development phase.

Loads for each truck – the weight and how it is distributed across a truck's axles – are the main determinants of impacts to roadway surfaces. Equivalent single-axle loads (ESALs) for each trip are used to calculate heavy vehicle trips' impacts on a road's surface condition. A variety of the vehicle types used for oil and gas activities are specialized and/or of significant weight, resulting in ESAL factors greater than many typical vehicles. The load impact of oil and gas trucks can be as much as 15,000 to 46,000 times that of a passenger car.

An oil derrick being hauled.
Source: Colorado Motor Carriers Association

Mitigation Costs

This roadway impact study utilizes a travel demand model that focuses exclusively on oil and gas trips and loads using Adams County's road network within the study area (unincorporated County land excluding areas south of E 112th Avenue and west of Tower Road), which was divided into a West district and East district along Schumaker Road. The model calculates the industry trips and loads associated with a single 12-well pad within each 1-mile section of the West district (268) and within 24 square-mile blocks of sections in the East district (32, for a total of 300 pads). The costs to offset the impacts on Adams County's roads are calculated and divided by the number of pads and wells to calculate a per-pad and per-well fee that is representative of the average impacts of oil and gas development in the County.

The roadway deterioration costs account for:

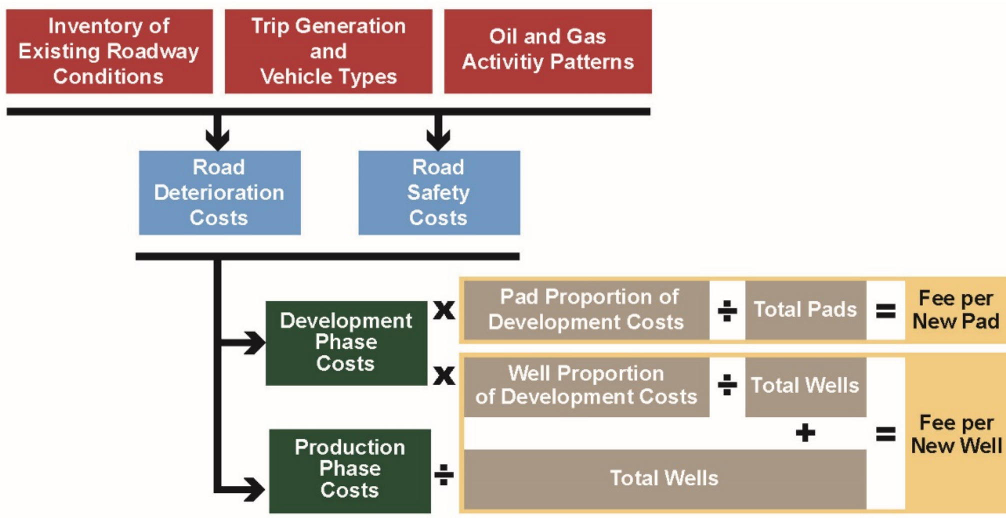
- The incremental depth of pavement required to recover the damage on asphalt roads
- Reconstruction of asphalt roads that are in poor condition
- The incremental reduction in service life and expedited reconstruction of concrete roads
- Increased maintenance requirements on unpaved roads
- Paving of unpaved roads that exceed daily traffic volume thresholds

The safety costs are based on shoulder widening to maintain safe multimodal roads designated as bike routes with the increased truck traffic associated with the oil and gas development. Wider shoulders provide space for bicyclists separate from the travel lanes. Shoulders also provide safety benefits for all roadway users: they serve as a countermeasure to run-off-road crashes and provide a stopping area for breakdowns or other emergencies.

Oil & Gas Roadway Impact Fee Methodology

The figure below illustrates the methodology used to calculate the oil and gas transportation impact fees. To allow for variations in the number of wells per pad, the fee calculation is based on two components: a pad construction fee and a well development and production fee. One percent of all costs associated with developing a 12-well pad is attributable to pad construction based on that activity's ESAL generation, and the remaining costs are attributed to the well development. All production costs are associated with the well fee.

Fee Calculation Methodology



The oil and gas roadway impact fees are calculated by estimating the total roadway deterioration and safety impact costs associated with oil and gas development and production, and then dividing the total cost by the total number of pads and wells. Two additional well characteristics were then factored into the fee calculations:

- Due to longer trip lengths and a less developed roadway network in the East district, costs associated with oil and gas are greater, so fees were calculated separately for the two districts.
- Fresh water, produced water, and product pipelines reduce truck trips and therefore reduce roadway impacts, so reductions in fees are included for all pipeline combinations.

Oil & Gas Roadway Impact Fee Schedule

A draft Adams County Oil & Gas Traffic Impact Study was prepared in December 2017 and posted on the County's website for sixty days to allow public review and comment. Comments were received from resident groups, the Colorado Oil and Gas Association with assistance from the Arcadis Consulting Group, and the Colorado Petroleum Council. The resident groups expressed support for the study and fees. Comments provided by the oil and gas industry expressed certain concerns. Based on this feedback, several edits were made to the revised Oil & Gas Traffic Impact Study and two methodology changes were made that result in reduced fee levels:

- The traffic volume threshold for paving unpaved roads was increased from 400 vehicles per day to 500.
- Requirement to add shoulders on designated bike routes was removed for roads used during the oil and gas development phase and only applied for roads used during the longer production phase.

The following table provides the recommended oil and gas impact fee schedule corresponding to the estimated impact cost for each new pad and well by pipeline scenario for the West and East districts, incorporating the changes listed above.

Recommended Oil and Gas Roadway Impact Fee Schedule (2017$)

Pipeline Scenario				
Fresh Water Pipeline	Produced Water Pipeline	Product Pipeline	West	East
Per Pad Fees				
n/a	n/a	n/a	$753	$1,767
Per Well Fees				
-	-	-	$36,523	$61,827
✓	-	-	$35,034	$61,122
-	-	✓	$21,112	$37,781
-	✓	-	$20,227	$38,019
✓	-	✓	$19,623	$37,076
✓	✓	-	$18,738	$37,313
-	✓	✓	$4,816	$13,973
✓	✓	✓	$3,327	$13,268

1.0 INTRODUCTION

Colorado is one of the nation's leading energy producing states. According to the United States Energy Information Administration (EIA), Colorado was the 7th highest state in total energy production in 2015. Oil and gas energy production is the primary source of the state's large output of energy, with Colorado ranking 7th in crude oil production in 2017 and 5th in natural gas production in 2016. The state's largest oil and gas producing area includes the Wattenberg Field and the Niobrara shale formation, which lies beneath parts of Adams County. Because of the County's proximity to these plays, Adams County ranks in the top ten producing counties in Colorado for both oil and natural gas production according to the Colorado Oil and Gas Conservation Commission (COGCC), and continues to see additional development.

Oil and gas drilling and production can impact local road systems, as well as other public infrastructure and services. Adams County has commissioned this study to understand the potential impacts of oil and gas development and production on the County's road system and to design a fee system to offset increased roadway rehabilitation, maintenance, and safety costs associated with heavy truck traffic from oil and gas activity.

Study Purpose

This study seeks to understand and quantify the potential impacts of oil and gas development to the County transportation system. This study is not intended to predict oil and gas development location or intensity, but rather to provide County officials with information about the potential impacts to the County's transportation system and associated costs using an informed set of assumptions based on the best available data.

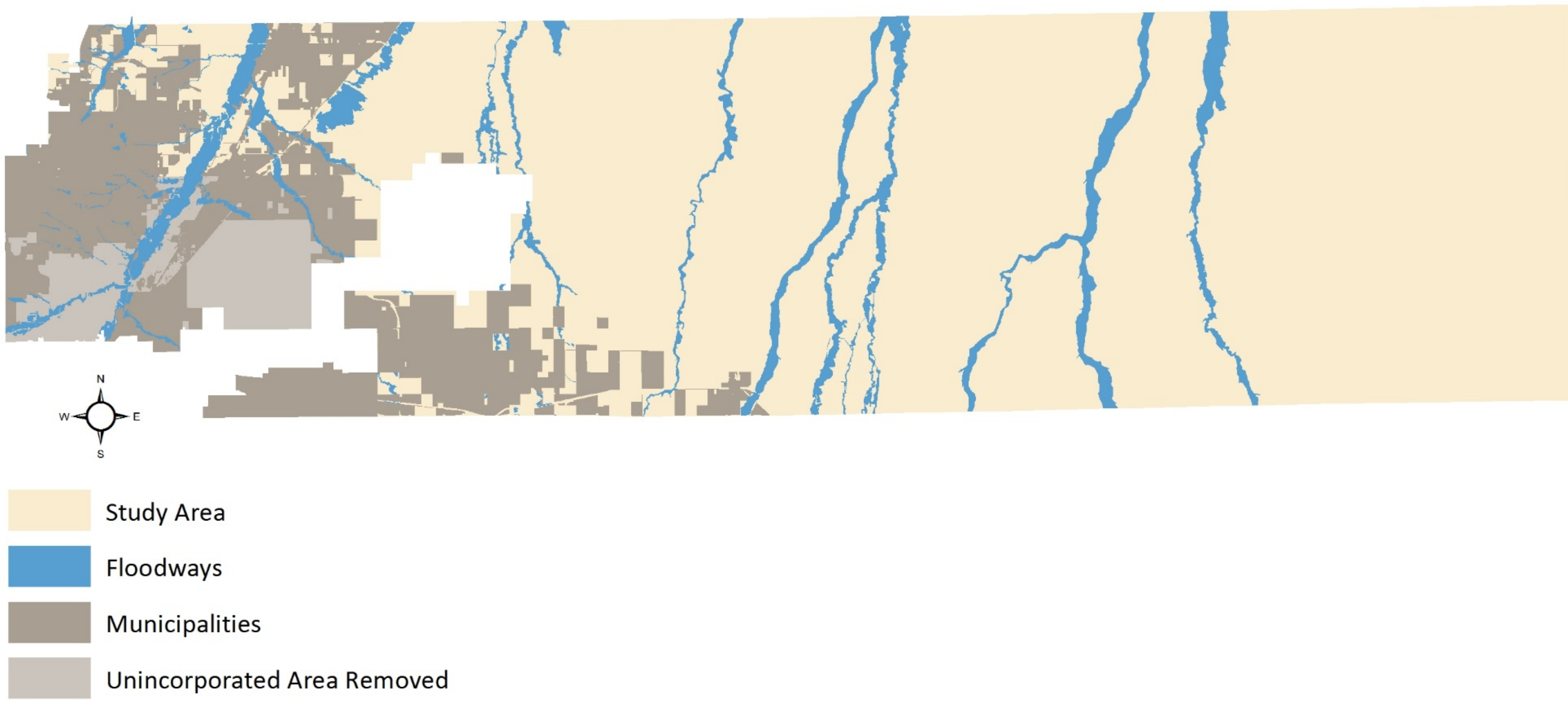
The transportation impacts estimated within this study are used to design and calculate impact fees that will offset the transportation-related impacts of oil and gas development. Adams County has authority derived from state statutes to regulate public roads over which it has jurisdiction. The oil and gas transportation impact fees are designed and structured within these parameters.

Study Area

The study area is defined as the unincorporated County land north of E 112th Avenue and east of Tower Road that is not within a defined floodway. Historically, activity has occurred in the northwestern portion of this area, as it contains the Wattenberg Field and Niobrara formation, but the eastern portion of the County was also included due to some recent exploration activity occurring and the presence of other known fields despite those fields lacking a history of horizontal well development. Only unincorporated County land outside of defined floodways and with adequate surface space to drill was considered for development within this study. The southwestern portion of the County was excluded from the study because it contains less unincorporated land, is more densely built, and lacks the presence of known fields and historical development.

Figure 1 shows the study area as described above, with incorporated land and land within floodways removed. Additional information as to how the study area was divided and assessed for oil and gas impacts is provided in **Chapter 2**.

Figure 1. Study Area

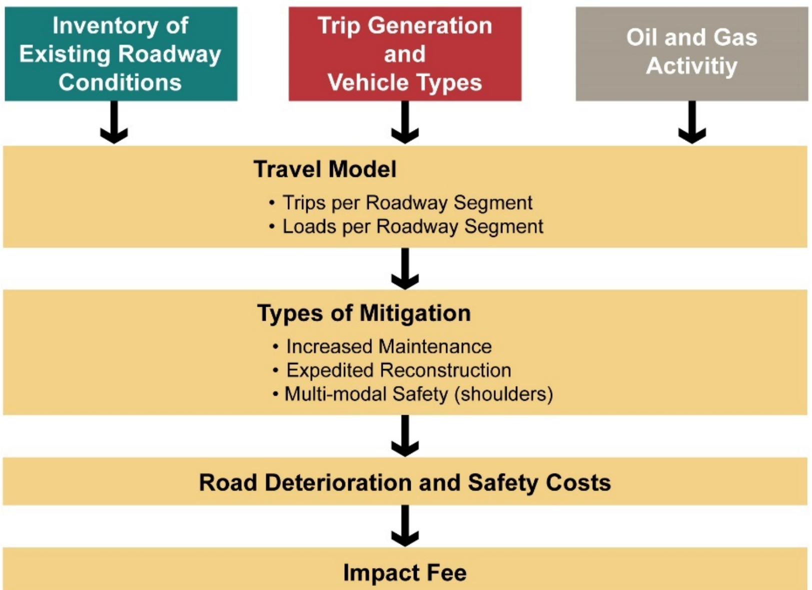


Sources: CDOT, 2017; FEMA, 2017; Adams County, 2017; BLM, 2017

Process

A process consisting of a series of analytical techniques has been developed and used to achieve the study purpose of assessing the potential impacts to the transportation system, quantifying transportation system needs (maintenance, rehabilitation, and safety), and calculating an appropriate roadway impact fee. **Figure 2** provides a flowchart summarizing this process and its inputs.

Figure 2. Study Process Diagram



The inventory of existing roadway conditions provides a baseline for identifying investment needs that might result from oil and gas truck impacts. The trip generation and vehicle types provide the foundation for assigning trips and vehicle loads to the County roadway network. Finally, the oil and gas activity provides information about development and production patterns applicable to Adams County.

All three primary inputs have been used in the development of a travel model, which assigns both oil and gas trips and loads to individual road segments in the study area. Using the results of the travel model, mitigation strategies can be identified based on roadway maintenance needs, rehabilitation, and safety improvements that result in roadway deterioration and safety costs resulting from oil and gas activity. After the proportional costs of road deterioration and road safety costs are calculated, a fee is designed to recover these costs during the oil and gas land use application process.

Each box in **Figure 2** represents a set of calculations, many of which require assumptions because of the uncertainties of oil and gas development in general (e.g., the intensity of development), as well as the development potential in Adams County. Previous studies on the transportation impacts of oil and gas development from across the country were referenced in the creation of these assumptions. Likewise, a series of interviews with key Adams County staff were conducted to better understand current development trends and how oil and gas trucks could potentially impact County roads. A list of references is provided in **Appendix A**. A more in-depth description of the assumptions and analytical processes used is provided in **Chapter 3**.

2. OIL & GAS ACTIVITY ASSUMPTIONS FOR ADAMS COUNTY

Oil & Gas Development Process Overview

There are five stages in the development and operation of an oil or gas well:

- **Leasing and exploration** – Obtaining mineral rights and developing a well drilling program.
- **Pad construction** – Preparing the site, including building the access road and the pad upon which wells will be drilled.
- **Drilling** – The process of drilling the well to the desired depth and completing the requisite number of horizontal bores.
- **Completion** – Converting the well system to a producing well, typically by fracturing the shale and completing the production well requirements, and removing produced water from the site.
- **Production** – Extracting, storing, and distributing the resource.

For the purposes of this study, impacts have been estimated for all stages above except the leasing and exploration stage. More detail about these stages is provided below.

Pad Construction

The first stage of development is pad construction. In this stage, crews build a road to the drilling site and construct a well pad. This process requires building a gravel road and grading a pad site generally three to five acres in area. The number of wells per pad may range significantly; however, the road and the pad require roughly the same amount of construction equipment, materials, and truck trips regardless of the number of wells.

Drilling

The next stage of development is the drilling stage. This stage requires one drilling rig to drill the well bore into the earth and continue horizontally in the direction of the intended extraction locations. In the Niobrara Shale, typical wells reach depths of between 6,000 to 8,000 feet and can extend two or more miles horizontally into the shale formation. If the site is a multi-well pad, the same single rig generally drills all wells on the pad. While the drilling rig transport is sensitive to the number of pads constructed, transportation of other materials including drilling fluid and materials, drilling equipment, casing, and drill pipe are all "well sensitive," meaning each well will require additional materials. Thus, the number of trips required to transport the drilling materials will increase with each well on the pad.

Active drilling rig near Greeley, Colorado.
Source: Julie Dermansky for Earthworks, 2014

Completion

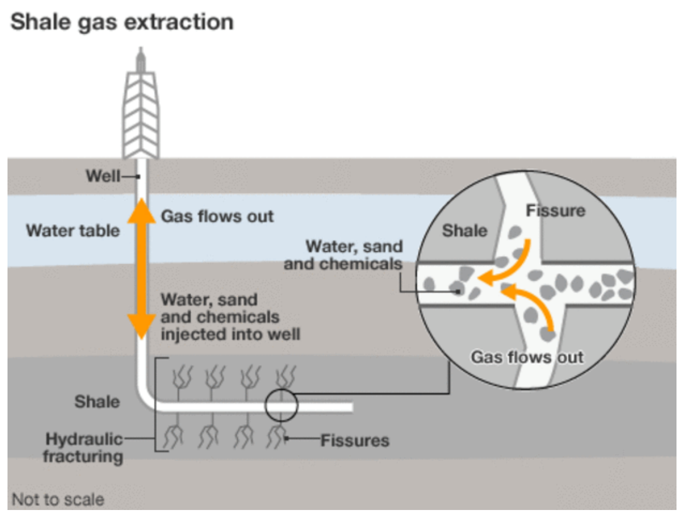
Once drilling is complete, wells must be completed using hydraulic fracturing – known as fracking. The drilling rig is replaced with a multitude of hydraulic fracturing equipment including blender trucks, pump trucks, water tanks, produced water trucks, and fracture sand. Most of the completion equipment is well-sensitive, meaning the number of trips will increase depending on the number of wells on a pad.


Completion rig and trucks on a well pad in Weld County, September 2014.
Source: Sangosti/The Denver Post, 2015

The majority of all development truck trips are used for transporting fresh frack water to the site, and produced flowback wastewater from the site. Well completion typically requires millions of gallons of water as an input. Once a well is fracked, it also produces large quantities of wastewater. Since typical water trucks have capacities between 5,000 and 6,000 gallons, a large number of trips are required to transport fresh water and produced water.

A newer alternative to tanker trucks for transporting water to and from the site is the use of surface water pipelines. A pad site will have significantly fewer truck trips if they are able to utilize pipelines for water transportation.

To complete a well, the workers first use a fracking gun to penetrate through the well casing and fracture the shale at the furthest depths of the well. Once the well has been penetrated by the fracking gun in the appropriate areas, a highly pressurized mixture of water and chemicals is pumped into the fractures starting at the deepest end of the well. The fracking fluid flows through the fractures and begins to crack the shale along natural weaknesses in the rock. Proppant, usually a sand mixture, is introduced into the fractures to keep the cracks open and help oil and gas escape into the well. The workers use a series of plugs to maintain the pressure of a fracked segment and continue to frack the shale along the horizontal well. During this stage, millions of gallons of water are pumped at high pressures into the shale and then subsequently retrieved. Under COGCC guidelines, all water used in this process is either recycled or properly disposed of under Commission regulations, primarily through injection wells. Once each of the arms of a well is sufficiently fractured, the plugs are removed and the well is ready for oil or gas production.



Drilling and completion stage technology: horizontal gas well with hydraulic fracking.
Source: BBC News, 2015

Production

Once the well is complete, the well pad transitions to the production phase, pumping oil or gas and produced water from the well for storage, disposal, or distribution. As oil and gas is pumped from the well, the contents are sent to machines that separate the oil, gas, water, and other gases. The produced water is most commonly injected into underground injection wells, which often requires transport by pipeline or truck. The well must maintain optimal pressure to continue the production of energy resources, and is monitored constantly. If any abnormality is indicated, the off-site well maintenance crew is automatically notified. Production trips continue throughout the life of the well, possibly up to 25 years. In areas of highly clustered energy development, pipelines may be constructed to transport resources and produced water away from the site to common holding or distribution facilities.

Location and Density

As noted in the definition of the study area in **Chapter 1**, the area south of E 112th Avenue and west of Tower Road was removed from the analysis because it was deemed to be unlikely for future development given it is predominately incorporated, is more densely built, and historically has not been developed. The large open lands in this area are primarily located in the Rocky Mountain Arsenal National Wildlife Range, within which drilling is currently restricted from being conducted (Zaffos, 2013).

Dividing into West and East

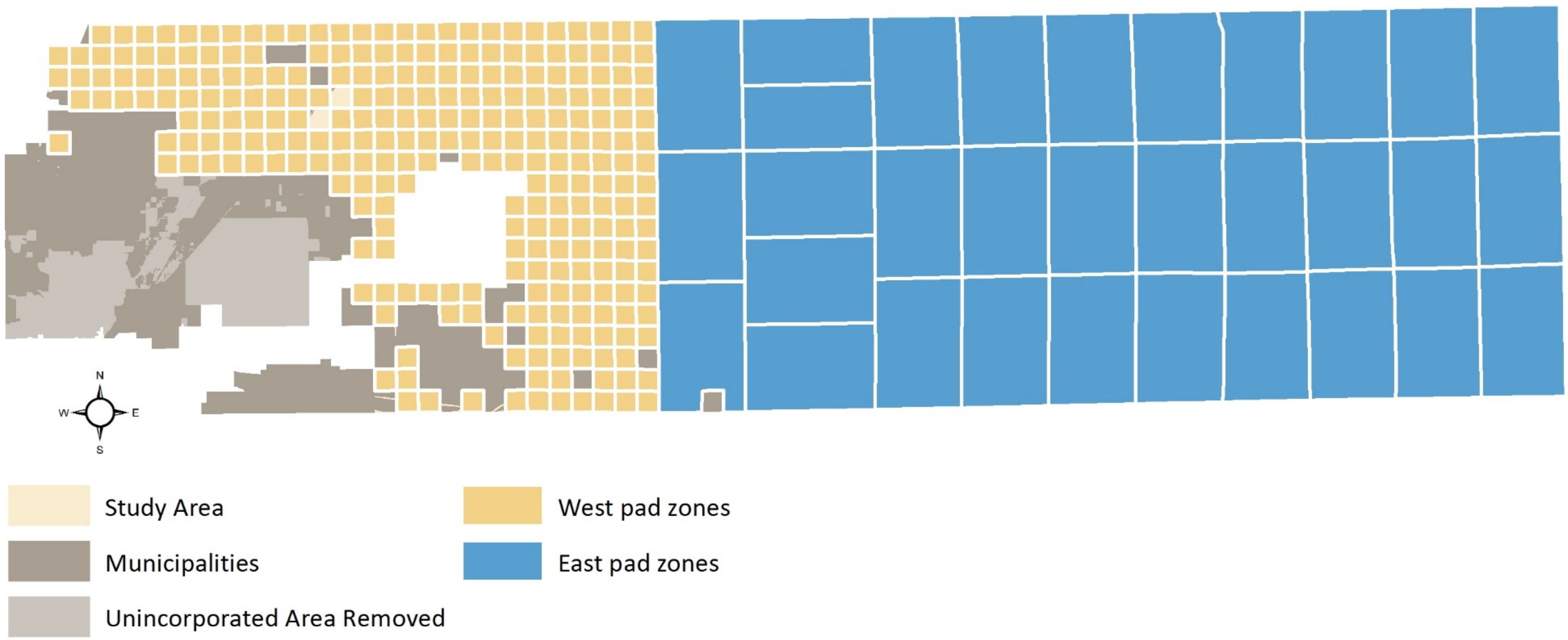
Little development has historically occurred in the eastern portion of the County. It is also further away from existing oil and gas facilities and has a less developed roadway network that could potentially need significant upgrades to handle oil and gas traffic. To track the potential difference in cost per pad and well, the unincorporated land making up the study area was divided into a West district and an East district, with Schumaker Road serving as the dividing line.

Pad Density & Zones

Given the uncertainty of where oil and gas pads might be developed, one-mile sections that intersect unincorporated Adams County land within the study area served as the mechanism to distribute pads. A density of one pad per square-mile section was used in the West, while a density of one pad per 24 square-mile area was used in the East. The lower density in the East was used out of concern that a higher density like that used in the West could overstate the transportation needs in an area that has seen little development and has numerous roads that would require significant improvements to handle heavy oil and gas traffic. The density was derived based on that of existing pads in neighboring Arapahoe County, in an area south of I-70 and east of the City of Aurora. This area is the most similar to eastern Adams County that has existing development, as little development exists in similar locations of other nearby counties such as Morgan County or Washington County, and Weld County's rural areas were determined to have too high of a density given a better proximity to existing fields and formations.

After removing sections covered by municipalities and floodways/bodies of water from the study area, as well as sections completely developed, a total of 268 square-mile sections cover the remaining unincorporated land eligible for oil and gas development in the West, while 32 grouped sections each 24 square miles cover the East. **Figure 3** shows the study area divided into these 300 pad zones. For this study, each pad zone contains one oil and gas pad. Additional information as to how these pad zones were used and how pads were placed in each zone are provided in **Chapter 3**.

Figure 3. Pad Zones



Sources: CDOT, 2017; Adams County, 2017; BLM, 2017

Well Density

Another important factor in estimating the impacts of oil and gas activity is the number of wells per pad. Since the *City of Thornton Oil & Gas Traffic Impact Fee Study* was completed in 2016, and its study area includes some of the most active locations of unincorporated Adams County, this study uses the same wells per pad configuration that was assumed in that study – 12 wells per pad. Like that study, this study assumes all wells will be horizontal wells.

Other Oil & Gas Assumptions

Phase & Stage Duration

Also important is the duration it takes to develop a pad and its wells. Since the Thornton study was completed, the 2017 update of the *Boulder County Oil and Gas Roadway Impact Study* found that the duration to develop a pad and its wells has decreased. The estimated typical durations for the three development stages from that study are listed below, which are used in this study.

- **Pad construction** – 5 to 7 days
- **Drilling** – 3 to 7 days per well
- **Completion** – 2 to 5 days per well

Multi-well pads have an extended development schedule, depending on the number of wells to be drilled. **Figure 4** illustrates the estimated timeline for developing the 12-well pad assumed in this study.

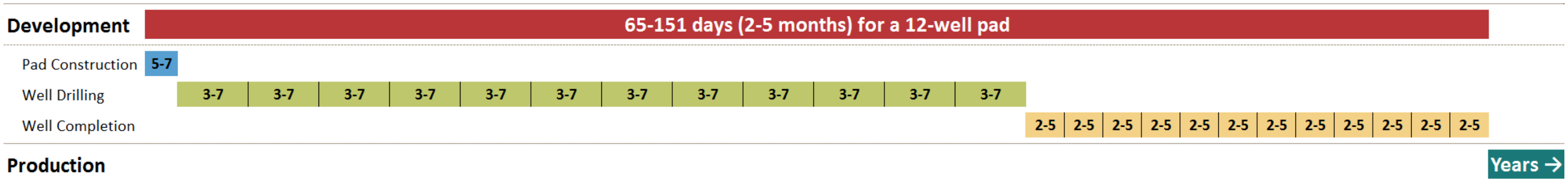
Once wells are producing, they can be active for up to 25 years or more. However, according to the 2017 Boulder County study, production significantly tapers off after 10 years, after which trips generated are marginal. This study uses this 10-year timeframe for analyzing traffic impacts of the production phase.

Pipelines

County staff reported an increase in interest by oil and gas developers to utilize pipelines to move fresh water, produced water, and produced product. Fresh water pipelines are the most commonly used pipeline for oil and gas development, as developers typically use temporary pipe that can be laid on top of the ground surface, often in ditches. These pipelines can easily be installed and removed after development is complete.

Surface frack water pipeline in Weld County
Source: Colorado Public Radio, photo courtesy of Anadarko Petroleum Corporation, 2014

Figure 4. Estimated Phase & Stage Duration for a 12-Well Pad in 2017



Note: Stage durations are in days. There may be large variances in these timelines depending on the operator, equipment, techniques used, and local geography.
Source: FHU & BBC, 2017

During and after the fracking process, a significant amount of water rises to the surface as flowback/produced water. According to the COGCC Environmental Unit's exploration and production waste management description, the COGCC requires oil and gas operators to "properly store, handle, transport, treat, and recycle or dispose of" waste from development. In the past, developers would use evaporation pits to dispose of produced water, but they are no longer approved by COGCC in the Front Range. In areas around Adams County, produced water is now most commonly disposed of via underground injection control (UIC) wells. Produced water may also be recycled or processed at a commercial facility. To transport this flowback produced during well completion to an approved facility, developers may utilize underground pipelines in place of tanker trucks.

Underground wastewater pipelines are most commonly used by large developers with significant land holdings. Developers with smaller land holdings are less likely to use wastewater disposal pipelines since they wouldn't necessarily be able to take advantage of the major infrastructure investment for multiple contiguous development sites. However, some developers have been known to enter into agreements to use each other's facilities and infrastructure, including pipelines and UIC wells.

Trench for sub-surface produced water pipeline in Weld County
Source: Colorado Public Radio, photo by Lesley McClurg, 2014

Pipelines to transport product during the production phase are similar in their requirements as produced water pipelines, but require even greater infrastructure investments, thus they usually require a higher density of pads and wells to make them economically viable. However, such pipelines may be viable for Adams County given its proximity to Weld County's facilities and if high levels of development are seen.

As discussed in the following chapter, the availability of pipelines can have significant implications for truck traffic to/from pad sites, and thus their overall roadway impacts and costs. This study considers the impacts on Adams County's transportation system of no pipelines versus the addition of fresh water, produced water, and/or product pipelines being used.

3. MODELING TRAVEL DEMAND OF OIL & GAS ACTIVITY

Travel Demand Model Methodology

A travel model has been developed using VISUM software to estimate the impacts to the Adams County roadway system from oil and gas activity. VISUM is a GIS-based computer program that utilizes collected data to assign traffic to a network based on trip generation, trip distribution, and roadway network characteristics. Although the travel model includes roadways outside the jurisdiction of Adams County (US and State Highways, and municipal roads) to allow trips to connect to their external origins/destinations, the transportation impacts (and associated improvement needs and costs) have been assessed only on roads under the responsibility of Adams County – referred to as the study area roadways or Adams County responsible roads.

Oil and gas development will result in increased traffic on the roadway network (vehicle-trips), as well as increased loads on the County's roads from the many heavy vehicle trips associated with the industry. For this reason, the VISUM model has been used to assign not only vehicle trips, but also loads as measured in equivalent single-axle loads (ESALs). The impact of heavy vehicles is dependent on a roadway's surface type: flexible pavement (asphalt) versus rigid pavement (concrete) versus unpaved. To properly calculate the ESAL impacts on Adams County's roads, two ESAL model iterations are required; one for flexible pavement and one for rigid pavement. Impacts for unpaved roads are dependent on vehicle volumes instead of loads.

The trip generation characteristics for the oil and gas development phase are substantially different from the trip generation characteristics during the on-going well production phase. Therefore, the travel model has been run separately for the two phases.

A summary of assumptions used to develop the travel model is provided in **Appendix C**. The model was also used to test the impact of using pipelines for fresh and produced water, as well as for transport of produced product, the results of which are explored in the fee calculation chapter – **Chapter 6**.

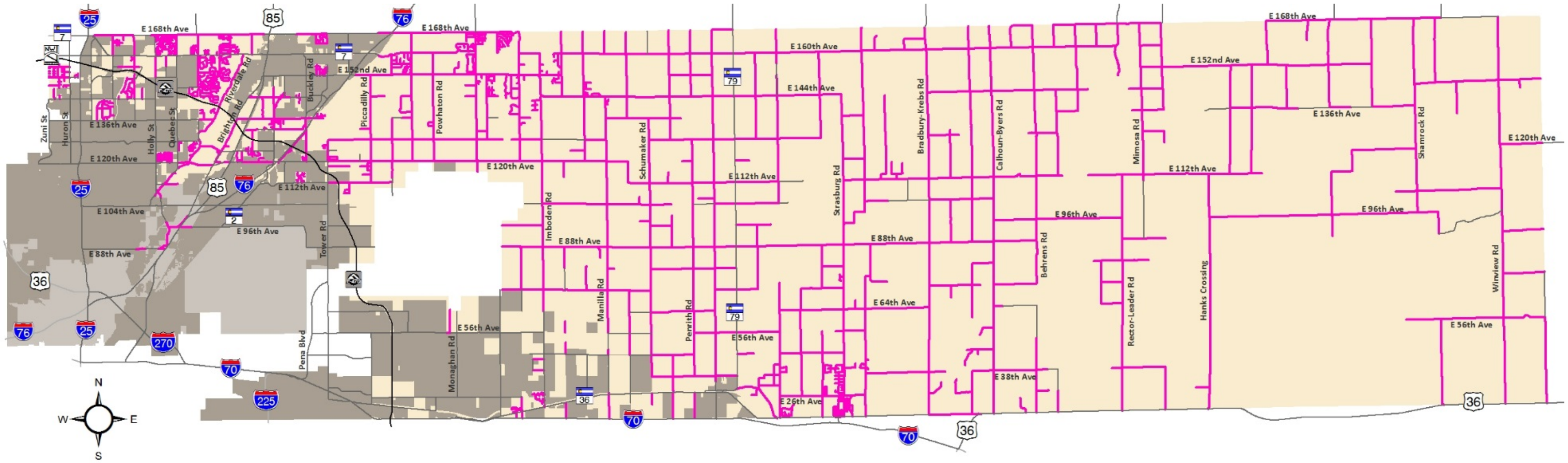
Inventory of Study Area Roadways

The first step in modeling oil and gas travel in Adams County was to understand the existing conditions of the study area roadways. The Adams County responsible roads, shown on **Figure 5**, total 989 centerline miles. The following sections describe data that were collected on this roadway system.

Surface Conditions

Of the study area roadways, approximately 70.4 percent (by centerline mileage) are unpaved, 29.5 percent are asphalt, and 0.1 percent are concrete. **Figure 6** shows the surface type for each of the study area roadways. The surface condition, including the surface type and the remaining service life, significantly affect how well a particular roadway segment can accommodate heavy truck traffic. The addition of numerous heavy trucks will, over time, cause a roadway to age at a greater rate than was originally anticipated. To estimate the degree to which the need for improvements on these roads would be accelerated, and to provide the cost of these improvements, the pavement condition index (PCI) of each paved road segment was obtained. The PCI of each road segment was used to apply a rating of either "Excellent", "Very Good", "Good", "Fair", or "Poor" condition. **Figure 7** displays ratings for each paved study area roadway.

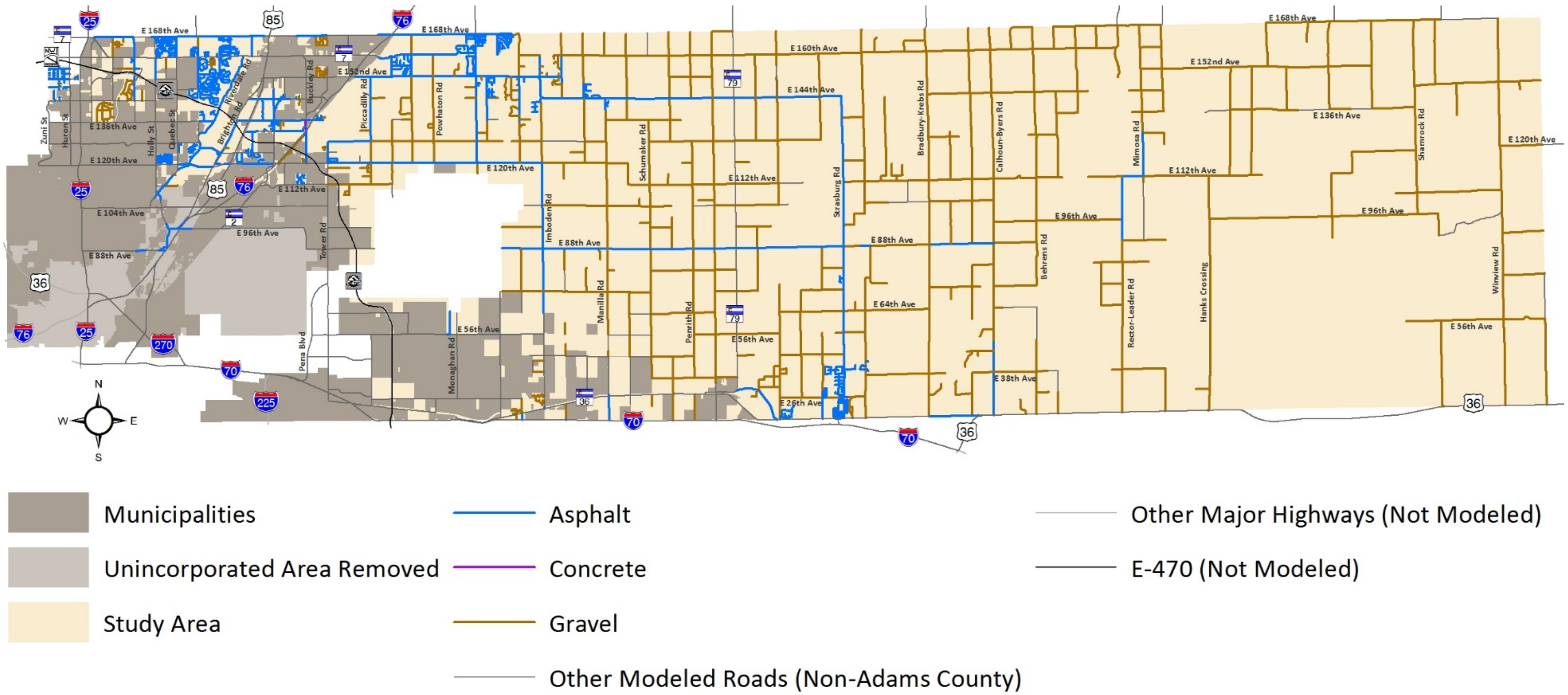
Figure 5. Study Area Road Network



Municipalities	Adams County Responsible Roads
Unincorporated Area Removed	Other Modeled Roads (Non-Adams County)
Study Area	
Other Major Highways (Not Modeled)	E-470 (Not Modeled)

Sources: CDOT, 2017; Adams County, 2017;

Figure 6. Surface Types



Sources: CDOT, 2017; Adams County, 2017;

Figure 7. Existing Pavement Conditions

Sources: CDOT, 2017; Adams County, 2017; Adams County Transportation Department, 2017

Shoulders

Varying geometric configurations affect how well a roadway could accommodate the heavy truck traffic associated with the oil and gas industry in conjunction with other roadway users. Wider shoulders provide space for bicyclists separate from the travel lanes. Shoulders also provide safety benefits for all roadway users: they serve as a countermeasure to run-off-road crashes and provide a stopping area for breakdowns or other emergencies.

Pavement and lane width data from Adams County and CDOT databases were used to inventory shoulder widths. **Table 1** lists the shoulder requirements for each road classification. **Figure 8** displays the roadway segments that require a shoulder and whether the existing shoulder meets Adams County's standards. The map also highlights which study area roadway segments are listed as a bike route in the County's transportation plan, as these are the only segments analyzed for shoulder needs as described in **Chapter 5**. Only four percent of the study area roadway segments on the bike network have sufficient shoulders.

Table 1. Required Shoulder by Classification

Classification	Feet of Shoulder Required
Principal Arterial	6
Minor Arterial	6
Rural Arterial	6
Collector	8
Section Line Arterial	8
Local	2-6*

* An average of 4 feet was used in the study's analysis
Source: Adams County Transportation Department, 2017

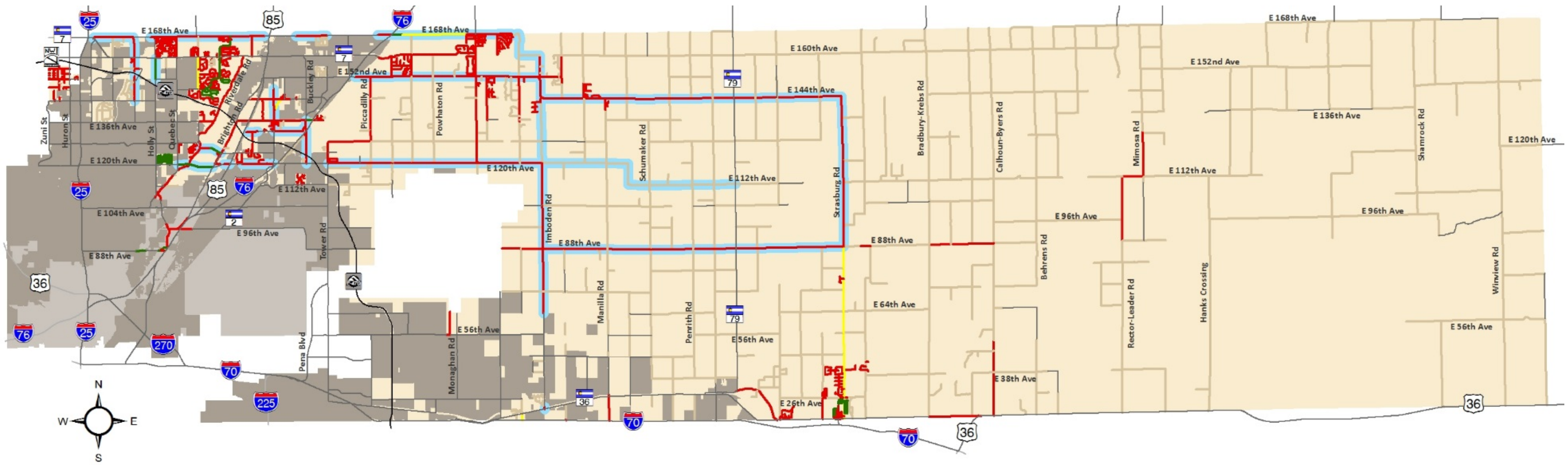
Traffic Counts

Increased maintenance of unpaved roads as a result of oil and gas activity is primarily triggered by daily traffic volumes rather than the level of loads experienced. Existing daily traffic counts on unpaved roads were gathered where available from Adams County's database, as well as from CDOT, ranging from 2014 to 2017. An additional twelve counts were conducted during the fall of 2017 by the County. The vehicles per day (vpd) of any study area unpaved road used by the travel model without an available count were estimated based on their location and level of connectivity, which was reviewed by County staff for reasonableness. **Figure 9** illustrates count data and count estimates for all unpaved roads that were identified as routes for oil and gas traffic. Counts are used as the "background traffic" to determine the appropriate level of maintenance or possible paving.

Other Roadway Characteristics

Other important roadway characteristics for modeling oil and gas traffic include road segment length and speed limits. These factors play into the model's shortest path routing decisions for oil and gas trips. The number of lanes and paved widths of roadways were also collected and used to calculate the cost of maintenance required as a result of oil and gas impacts.

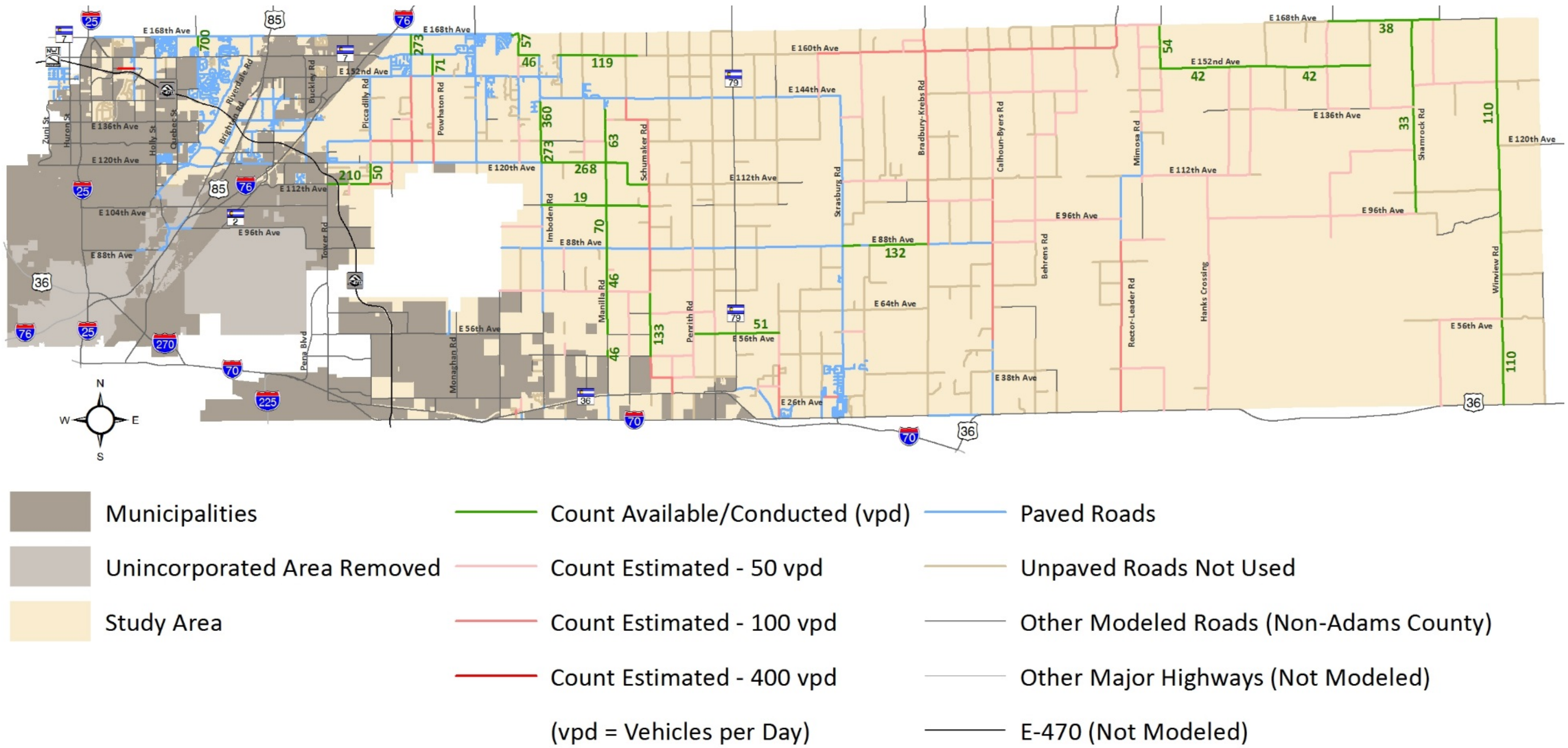
Figure 8. Shoulder Sufficiency



Municipalities	Needs Shoulder, None Existing	Other Major Highways (Not Modeled)
Unincorporated Area Removed	Has Shoulder, Needs Additional Width	E-470 (Not Modeled)
Study Area	Has Shoulder with Sufficient Width	
	Unpaved	
	Other Modeled Roads (Non-Adams County)	
	Bike Route on Adams County Responsible Road	

Sources: CDOT, 2017; Adams County, 2017; FHU, 2012

Figure 9. Vehicles per Day on Unpaved Study Area Roads Receiving Oil & Gas Traffic



Sources: CDOT, 2017; Adams County, 2017; Adams County Transportation Department, 2016-2017

Trip Origins/Destinations

Trip origins and destinations were identified by determining where oil and gas trips will likely be traveling to and from. For all trips, the pad site serves as either the point of origin or the destination. Trips will either involve a truck delivering items to the site, removing elements to an off-site location, in transit (empty) to pick up a load or return from delivery, or transporting workers and machinery to and from the pad. All wells were assumed to be located within the study area, while locations of the other end of oil and gas trips were estimated by researching their trip purposes. There are four primary trip purposes for oil and gas development, which each uniquely impact where oil and gas trucks travel: fresh water delivery, produced water removal, equipment transport, and transport of other materials. The following sections provide further detail on pad placement and assumptions regarding the origin/destination by trip type.

Oil and Gas Pads

As noted in **Chapter 2**, the study models a total of 300 pads to estimate impacts, translating into 3,600 wells using the twelve wells per pad assumption adopted for this study. The pad in each pad zone of the model was located in the most open, least developed, and unincorporated location outside of the floodway and nearest to a road for access. Furthermore, with so much open land available in the East district, pads in those zones were located to try and consolidate accesses onto major gravel roads rather than a spattering of numerous gravel roads in order to take advantage of paving one road rather than numerous minor gravel roads if volumes warranted paving. The most current satellite imagery in Google Earth was analyzed to conduct this placement process. The purpose of placing one pad per zone is not to predict the level or location of development; rather, it is intended to derive the average potential impacts of an oil and gas pad regardless of location within the study area. Further explanation of how this assumption goes into the calculation of impact fees is found in **Chapter 6**.

Fresh Water

Water is a key resource in the well drilling process and during the high-pressure fracturing stage, where water is mixed with sand and chemicals. For development in Adams County, fresh water could be purchased from local water providers willing to provide water for oil and gas development, the nearest ditch company, or private land owners. Conversations with the larger water providers in the County yielded no provider that could confirm they provide water for oil and gas development, though many stated they do not. Summaries of responses from water providers are included in **Appendix B**. Most of the West district is well covered by ditches, so the study assumed most West zones would access water via the nearest ditch. No ditches exist In the East district and the eastern portion of the West district, so their local water access was assumed to be the nearest of either Bijou Creek or Kiowa Creek, which were identified by Adams County oil and gas staff as being the best water sources for the area. To establish locations to/from which the model could send/receive fresh water trips, 34 locations were established for access to ditches, while an additional 7 locations were established for access to the two creeks. To place these water sources, pad zones were individually assessed to determine where the nearest and/or most convenient access might be to these two types of water sources, with access points consolidated where appropriate.

Depending on pricing and transport costs, it is conceivable that fresh water could be purchased from further outside of Adams County; however, water conservation rules often restrict where water can be transported to. Given the uncertainty of these factors, it was assumed that oil and gas developers in the West district would acquire the majority of their water from the nearest local resource (90 percent) and transport the remaining water from areas outside of the County (10 percent). Due to the scarcity of water sources in the East district, it was assumed that less water would be sourced locally, evenly splitting fresh water 50/50 between local sources versus from outside of the County. **Figure 10** illustrates the water source assumptions, including source locations.

Produced Water

Water is also a major byproduct of both the development and production phases. Produced water from the fracking process and from the extraction of oil and gas is generated and must be appropriately treated. Because COGCC regulations restrict the use of evaporation ponds, a large majority of produced water is disposed via underground injection control (UIC) wells. Colorado has roughly 800 UIC wells, with some in eastern Adams County, but most in the area located in Weld County. County staff noted that the UIC wells in Adams County are used sparingly, which was confirmed with production data from the COGCC for the past two years. Using this data, four of the top receiving UIC wells over the past two years for the region surrounding Adams County were identified to include in the model. **Figure 11** shows the location of these four UIC wells and which pad zones were linked to each disposal site.

Equipment

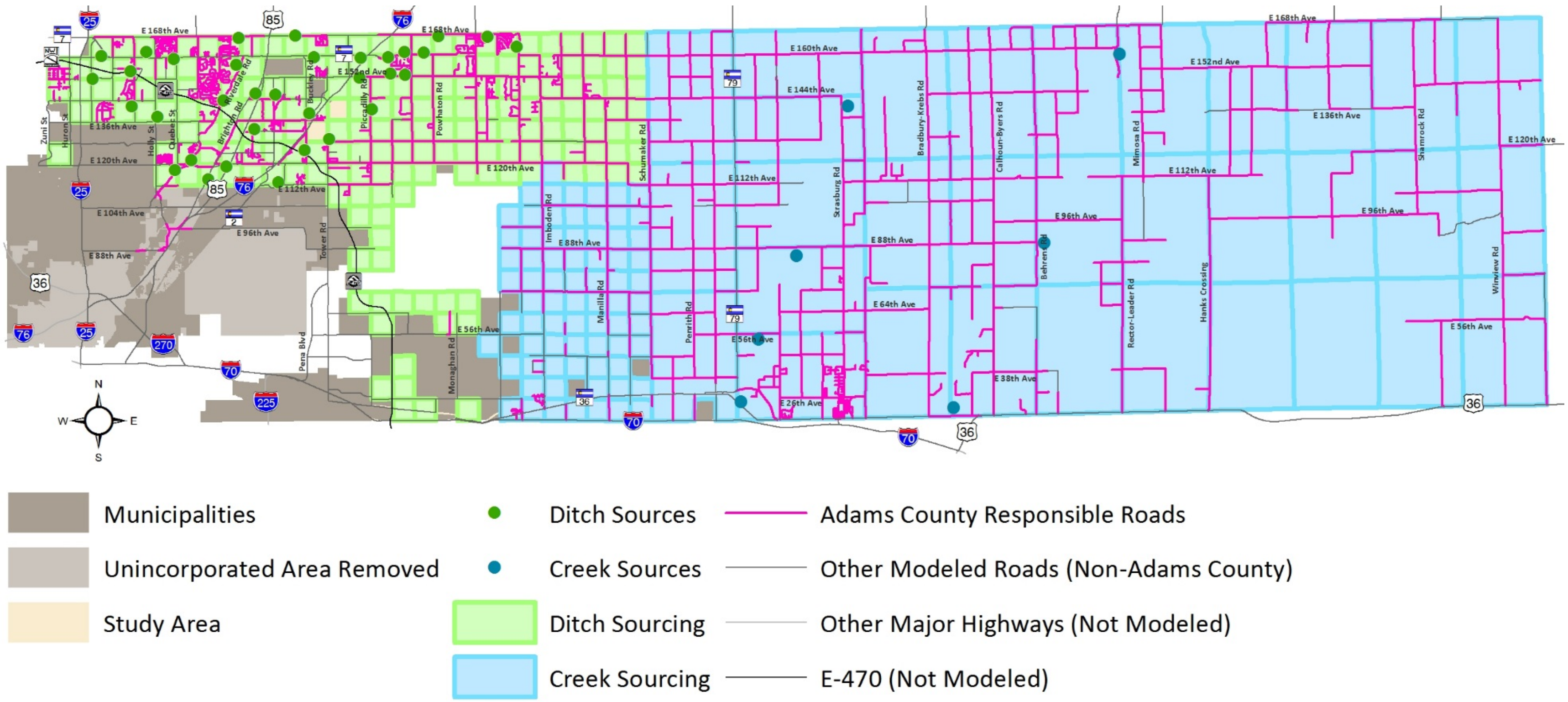
The equipment required for oil and gas development – including the drilling rig, the well structure, pumps, well casings, fracking tanks, and construction equipment – could come from any location where oil and gas companies have operations, or where contractors providing such services are located. Equipment used by oil and gas development in the region surrounding Adams County was identified to exist primarily in Weld County along the US 85 corridor. However, some equipment, particularly equipment not unique to oil and gas, could come from the Denver area given the density of these providers in a large urban area.

An oil derrick being hauled.
Source: Colorado Motor Carriers Association

To implement the above equipment assumptions into the model, 90 percent of equipment trips were sent to/from the north to Weld County, while 10 percent were sent to/from Denver. An exception was made for completion stage equipment, as a site within Adams County at US 85 and East 104th Avenue was identified by County oil and gas staff as a primary source in the area for such equipment. An even 50/50 split was agreed upon for completion stage equipment, with half sent to/from this specific site and the remaining half sent to/from Weld County.

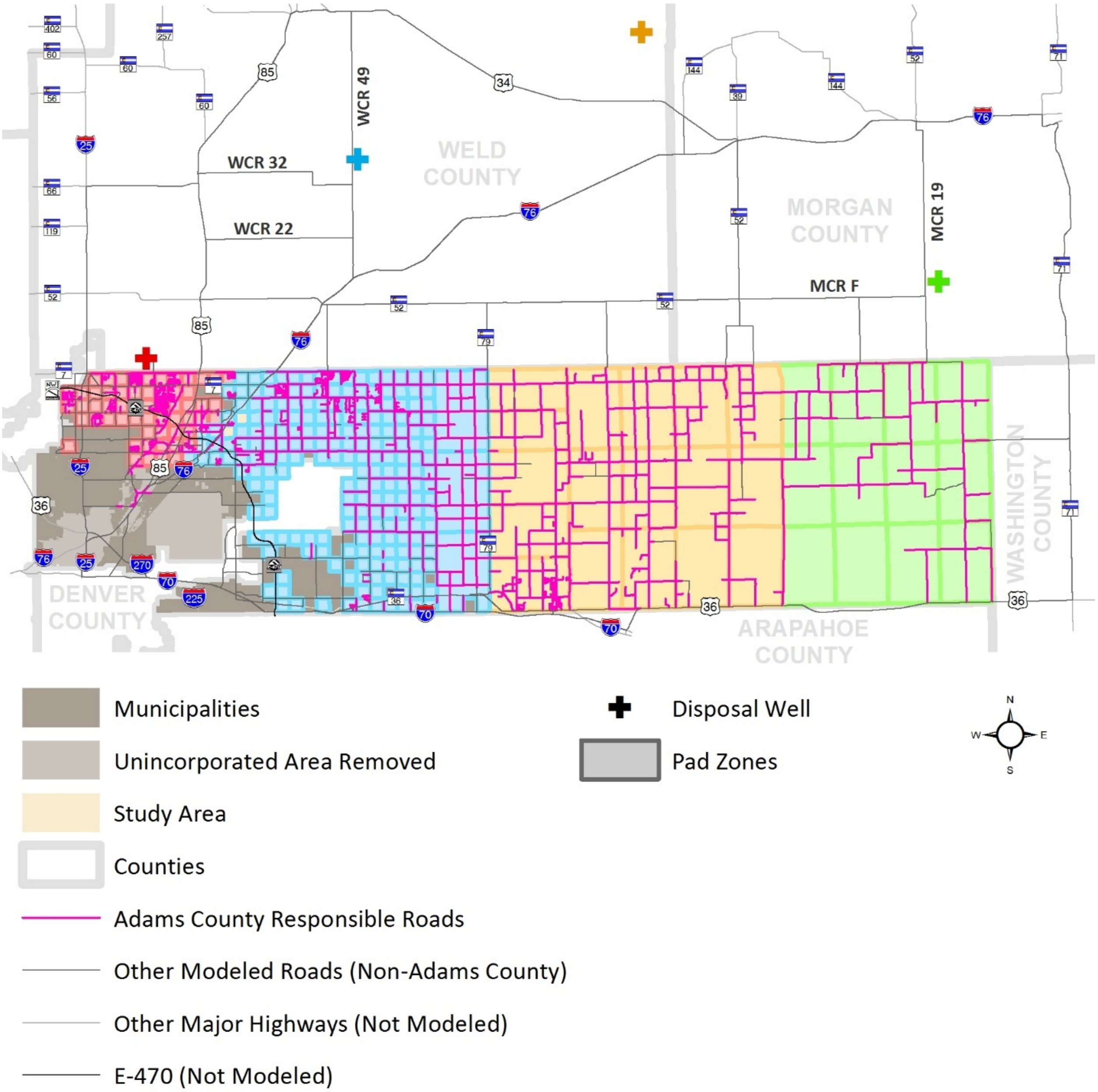
Transport of well equipment.
Source: Colorado Motor Carriers Association

Figure 10. Fresh Water Sources



Sources: CDOT, 2017; Adams County, 2017

Figure 11. Produced Water Disposal Assumptions



Sources: CDOT, 2017; Adams County, 2017; COGCC, 2017

Materials

Oil and gas development requires a variety of other materials in addition to water. Gravel, sand, piping, cement, chemicals, and other construction materials must be trucked to the site at different stages of the development phase. These resources would likely come from where supply is the greatest, trucking distance is shortest, and prices are the lowest. Because these factors create a great deal of uncertainty as to where a resource may arrive from, it has been assumed that materials would arrive in a similar fashion as oil and gas equipment since material providers would locate around active oil and gas areas to better provide their services. Thus, 90 percent of materials were assumed to be sent to/from Weld County, while the remaining 10 percent were sent to/from Denver.

Production

The production phase primarily consists of maintenance trips and trips for transporting product and produced water. Maintenance trips were assumed to be similar to equipment, materials, and worker trips. Thus, 90 percent of those trips were assumed to be sent to/from Weld County, while the remaining 10 percent were sent to/from Denver. The same assumption was made for transporting product, since oil and gas handling facilities are likely aligned with the other oil and gas services. Produced water trips were handled in the same fashion as described earlier for the development phase.

Trip Generation

As described in **Chapter 2**, oil and gas development involves three stages: pad construction, drilling, and completion. Each stage involves different volumes and types of trucks. Once operating, a pad enters the production phase, which generates less demand on the road network than the development phase, but continues to generate impacts for as long as wells are active. The following sections document the trip generation assumptions developed for this study.

Development 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 transport produced water and extracted resources off-site.

The 2017 update of the *Boulder County Oil and Gas Roadway Impact Study* developed a per-pad and per-well trip generation profile from studies conducted around the country, which was used for trip generation in this study. **Table 2** provides the estimates from multiple national and regional studies examining vehicle trip generation by well development stage. The trips of each study are averaged across each stage of development and then summed to calculate trip generation figures in the far-right column. These development trips occur intensively within the average stage lengths previously outlined in **Figure 4**. Production related trips, on the other hand, will continue for the duration of the well's productive life.

These data suggest that the development of a typical pad and single well will generate 2,932 trips during the development period, largely related to water delivery and removal. For sites that have access to fresh and/or produced water pipelines, the total number of development trips will decrease accordingly. **Table 3** illustrates how the availability of water pipelines will affect the total estimated truck trips during the development phase.

Table 2. National Data on Trip Generation During Pad and Well Development

Stage	Activity	Machemehl et al. 2016	NDSU 2014	RESI 2014	UDOT 2013	NYSDEC 2011	Average 1 pad, 1 well
Construction	Pad and Road Construction	80	160	230	1,300	230	400
Drilling	Drilling Rig and Crew	-	-	404	306	404	371
	Drilling Fluid and Materials	-	150	45	340	45	145
	Drilling Equipment (casing, drill pipe, etc)	50	130	45	34	45	61
Completion	Completion Rig and Crew	-	6	21	8	21	14
	Completion Equipment (pipe, wellhead, etc)	25	30	5	24	5	18
	Fracturing Equipment (pump trucks, tanks, etc)	125	260	175	166	175	180
	Fracture Water	1,486	900	1,346	828	846	1,081
	Fracture Sand and Chemicals	200	200	23	166	23	122
	Produced Water Disposal	594	450	300	828	100	454
Miscellaneous		-	-	85	-	85	85
Total Development Trips							**2,932**

Source: FHU & BBC, 2017

Original Sources: Mechemal, P.E., et al., 2016; North Dakota State University (NDSU) Upper Great Plains Transportation Institute, 2014; Regional Economic Studies Institute, 2014; Utah Department of Transportation, 2013; New York Department of Environmental Conservation, 2011

Table 3. Impact of Water Pipelines on Average Development Trip Generation (1 pad, 1 well)

Stage	Activity	No Water Pipelines	Fresh Water Pipelines	Produced Water Pipelines	Fresh & Produced Water Pipelines
Construction	Pad and Road Construction	400	400	400	400
Drilling	Drilling Rig and Crew	371	371	371	371
	Drilling Fluid and Materials	145	145	145	145
	Drilling Equipment (casing, drill pipe, etc)	61	61	61	61
Completion	Completion Rig and Crew	14	14	14	14
	Completion Equipment (pipe, wellhead, etc)	18	18	18	18
	Fracturing Equipment (pump trucks, tanks, etc)	180	180	180	180
	Fracture Water	1,081	0	1,081	0
	Fracture Sand and Chemicals	122	122	122	122
	Produced Water Disposal	454	454	0	0
Miscellaneous		85	85	85	85
Total Development Trips		**2,932**	**1,851**	**2,478**	**1,396**

Source: FHU & BBC, 2017

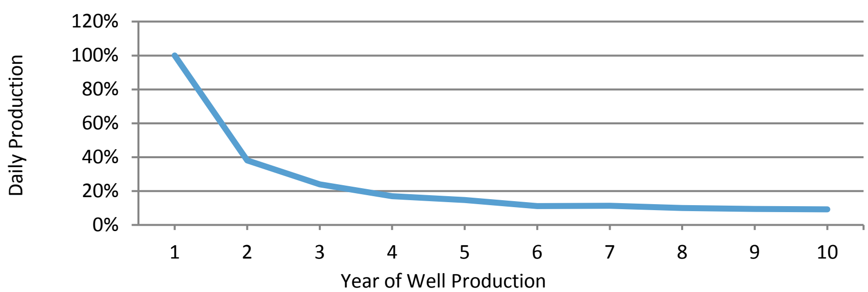
It is important to note that each truck trip reflects a one-way trip, so that all trips to and from the development site are included. This distinction is crucial in subsequent stages of the analysis when, for example, the roadway impacts are examined for a truck that arrives to the development site with a full load of water, but leaves empty.

Production Trip Generation

There are a number of factors that determine trip generation during the production stage such as the nature of the field, success of wells, and storage capacity for produced water and resource at the pad. The trips primarily consist of maintenance trips to check on the wells and tanker trucks to haul produced water and product to off-site facilities.

The 2017 update of the *Boulder County Oil and Gas Roadway Impact Study* found that produced water and product production is at its peak in the first year of a well's production life, declining quickly over a 10-year period, after which production and truck trips are marginal. Applying the declining production to the initial truck trips estimated at the start of production yields an average of about two trips per day per well during the 10-year production horizon, or 730 trips annually per well, which aligns closely with findings from a report for the Texas Department of Transportation on the Barnett Shale. **Figure 12** presents the production decline from the Boulder County study.

Figure 12. Production Decline in Niobrara Wells



Source: FHU & BBC, 2017
Original Source: The Niobrara News, 2014; Peters, 2017

Multi-Well Pad Site Trip Generation

Data from the studies used in **Table 2** were used to adapt trip generation estimates from the one-pad, one-well format to the one-pad, 12-well configuration assumed for this study. This configuration will affect traffic generation and the traffic profile associated with drilling activity by increasing well-sensitive trips, such as fracking water and drilling fluid hauling, while pad-sensitive trips for construction and drilling rig transport remain constant. The 12-well configuration was used because it closely represents the average pad configuration in the area in the past few years, as noted in the 2016 Thornton study, and helps show the potential magnitude of the associated costs. However, the total costs are divided to determine the necessary fee to offset the costs per pad and per well, so a similar result would occur with other well densities. **Table 4** presents the trip sensitivity by oil and gas activity.

Table 4. Trip Sensitivity by Activity

Stage	Activity	Trip Sensitivity
Construction	Pad and Road Construction	Pad-Sensitive
Drilling	Drilling Rig and Crew	Pad-Sensitive
	Drilling Fluid and Materials	Well-Sensitive
	Drilling Equipment (casing, drill pipe, etc)	Well-Sensitive
Completion	Completion Rig and Crew	Pad-Sensitive
	Completion Equipment (pipe, wellhead, etc)	Pad-Sensitive
	Fracturing Equipment (pump trucks, tanks, etc)	Pad-Sensitive
	Fracture Water	Well-Sensitive
	Fracture Sand and Chemicals	Well-Sensitive
	Produced Water Disposal	Well-Sensitive
Miscellaneous		Well-Sensitive
Total Development Trips		**Varies**
Total Production Trips		**Well-Sensitive**

Source: FHU & BBC, 2017

By segregating truck trips by development stage and activity, the total truck trips for various configurations of pads and wells were estimated, as well as estimates for a typical 12-well pad based on the availability of pipelines. An average 12-well pad will generate an estimated 24,359 truck trips during the development phase and 8,760 annual trips during the production phase if no pipelines are used. The activity-based number of trips for the 12-well pad configuration is displayed in **Table 5** for a pad with no pipelines, as well as trips for a pad under the pipeline scenarios made up of different combinations using fresh water, produced water, and product pipelines. These configurations serve as the basis for the trip generation used by the travel demand model when determining how many trips, and their associated loads, should be distributed and assigned to Adams County's road network.

Table 5. Trip Generation Estimates by Pipeline Scenario for a 12-Well Pad

Stage	Activity	No Pipelines	Fresh Water Pipelines	Produced Water Pipelines	Fresh & Produced Water Pipelines
Construction	Pad and Road Construction	400	400	400	400
Drilling	Drilling Rig and Crew	371	371	371	371
	Drilling Fluid and Materials	1,740	1,740	1,740	1,740
	Drilling Equipment (casing, drill pipe, etc)	732	732	732	732
Completion	Completion Rig and Crew	14	14	14	14
	Completion Equipment (pipe, wellhead, etc)	18	18	18	18
	Fracturing Equipment (pump trucks, tanks, etc)	180	180	180	180
	Fracture Water	12,972	0	12,972	0
	Fracture Sand and Chemicals	1,464	1,464	1,464	1,464
	Produced Water Disposal	5,448	5,448	0	0
Miscellaneous		1,020	1,020	1,020	1,020
Total Development Trips		**24,359**	**11,387**	**18,911**	**5,939**
Total Production Trips		**8,760**	**8,760**	**6,876**	**6,876**

Stage	Activity	Product Pipelines	Fresh Water & Product Pipelines	Produced Water & Product Pipelines	Fresh Water, Produced Water, & Product Pipelines
Construction	Pad and Road Construction	400	400	400	400
Drilling	Drilling Rig and Crew	371	371	371	371
	Drilling Fluid and Materials	1,740	1,740	1,740	1,740
	Drilling Equipment (casing, drill pipe, etc)	732	732	732	732
Completion	Completion Rig and Crew	14	14	14	14
	Completion Equipment (pipe, wellhead, etc)	18	18	18	18
	Fracturing Equipment (pump trucks, tanks, etc)	180	180	180	180
	Fracture Water	12,972	0	12,972	0
	Fracture Sand and Chemicals	1,464	1,464	1,464	1,464
	Produced Water Disposal	5,448	5,448	0	0
Miscellaneous		1,020	1,020	1,020	1,020
Total Development Trips		**24,359**	**11,387**	**18,911**	**5,939**
Total Production Trips		**6,264**	**6,264**	**4,380**	**4,380**

Truck Typology

The number of truck trips might be what is most visible to the public when it comes to oil and gas development, but the weight and how it is distributed across a truck is what impacts paved roadway surfaces the most. To analyze impacts on a roadway, an 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 activity.

Truck Types

There are numerous vehicle types used in oil and gas development and operations. 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 provide both axle and weight characteristics, but most provided only 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, North Dakota State University (NDSU), the North Dakota Department of Transportation (NDDOT), and equipment manufacturers such as Putzmeister were consulted to determine truck types and the following characteristics: axle configurations, weight configurations (total empty and full, and per axle), and level of impact expressed as ESAL factors.

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

Table 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 and the surface type of the roadway. To account for the load impacts, ESALs for each truck type listed in **Table 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 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 generic 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 group of a truck and aggregated to arrive at the total ESAL factor. **Table 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 13** (flexible surfaces) and **Figure 14** (rigid surfaces).

Table 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

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 13. Flexible Pavement ESAL Equation

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

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 14. 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

Merging Trip Generation and Vehicle Classifications

Some truck types are used in multiple stages and activities, while others are used only once. And for trucks used in more than one stage, their trip generation varies by activity. This variation requires each activity to have a vehicle classification profile where types, trip shares, and impacts are linked. Truck types and configurations were linked with their respective activity using available information from trip generation and type sources previously listed, along with additional input from a report produced by the Montana Department of Transportation (MDOT), a Texas A&M Transportation Institute (TTI) study, 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 activity, the sources 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 an activity's trips that each truck configuration would account for, and if the truck is loaded for inbound, outbound, or both trip directions.

Table 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 produced water.

Table 8. Typical Truck Classifications by Development Phase

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

Sources: 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

Trip Distribution and Assignment

With trips per pad and their vehicular makeup established, the development and production phases could be modeled. To model where trips would go and the impacts they would generate, trips and ESALs were loaded (separately) into the VISUM model. This process consists of two primary steps: distributing the trips and ESALs, and assigning them to the modeled road network.

Trip Distribution

Once the trips and ESALs per pad were calculated, they were entered into the VISUM travel model at each pad, distributing trips and ESALs to origins and destinations based on activities as described in this chapter. **Table 9** summarizes how trips were allocated to/from each pad site.

Table 9. Trip Distribution Assumptions

Trip Profile	Trip Origin/Destination	
	West District	East District
Equipment (excluding completion)	90% to Weld County, 10% to Denver	90% to Weld County, 10% to Denver
Completion Equipment	50% to US 85/E. 104th Ave, 50% to Weld County	50% to US 85/E. 104th Ave, 50% to Weld County
Materials	90% to Weld County, 10% to Denver	90% to Weld County, 10% to Denver
Workers / Maintenance	90% to Weld County, 10% to Denver	90% to Weld County, 10% to Denver
Fresh Water	90% local source, 10% to Weld County	50% local source, 50% to Weld County
Produced Water	100% north to Weld or Morgan County	100% north to Weld or Morgan County
Product	90% to Weld County, 10% to Denver	90% to Weld County, 10% to Denver

Trips to/from the north could use I-25, I-76, US 85, SH 71, SH 79, or Hayesmount Road to leave Adams County, while trips to/from the south use I-25 or I-70 to head into/from Denver. The decision as to which road to use was determined by the model during trip assignment, which is described below.

Trip Assignment

With trips and ESALs distributed and linked, the VISUM travel model was used to assign the trips and ESALs to the model road network based on which path would provide the shortest travel time – a function of route length and speed limit. As noted at the beginning of this chapter, the model network includes roads outside of the jurisdictional responsibility of Adams County to account for real-world connectivity needed to facilitate the distribution of origins and destinations, some of which exist outside of Adams County. E-470 and Northwest Parkway tollways were an exception, as they were excluded from the model network due to their costs and exclusion of hazardous materials being transported.

Because oil and gas trips take place at all hours of the day and every day of the week, background traffic and congestion were not factored into the modeling process to impact assignment. The assignment process was conducted for a combination of each phase (development and production), for both trips and ESALs, which were assigned for both pavement surface types (flexible and rigid).

Model Results

Results from each model (trips and ESALs, development and production phases, flexible and rigid pavements) were exported into a spreadsheet to be assessed for impacts – overlay needs, reconstruction needs, shoulder widening, etc. Impact results (ESALs) of the two surface-type models were merged to assign the appropriate number of ESALs to each segment based on its surface type. Daily trips were recorded for unpaved roads, which were paired with existing counts to fully assess their unique needs. This process was also conducted when comparing the impacts of having no pipelines (the base modeling scenario) versus using pipelines for all fresh water, produced water, and product transport. **Chapter 5** describes how mitigation needs and associated costs were calculated from the impacts exported from the travel model.

4. PUBLIC & STAKEHOLDER ENGAGEMENT

Public Meetings

Once the process for assessing oil and gas impacts on Adams County's road network was defined, it was presented to the public and stakeholders from the oil and gas industry to receive feedback. A total of three meetings were held at the Eagle View Adult Center during August 2017.

- 8/9/2017 for the General Public
- 8/16/2017 for Oil & Gas Industry Stakeholders
- 8/21/2017 for the General Public and Stakeholders

The following topics were presented during these meetings:

- What an impact fee is
- Background and trends of oil and gas development in Adams County
- Study objectives
- Characteristics of oil and gas development and how it differs from other land uses in terms of transportation impacts
- Study process of how impacts would be calculated
- Model assumptions regarding how oil and gas operates in Adams County
(for reaction from stakeholders)
- Mitigation activities
- Impact fee calculation methodology
- Next steps

Overall, participants expressed their support for this study. Most questions centered on better understanding the process taken to conduct the study, particularly to clarify what was and was not included in the study. Following are brief summaries of some of the additional questions and responses:

- Will a Hazardous Material Fee be included?
Response: Not part of the scope of this study.
- Will traffic congestion on major roads be addressed?
Response: This is addressed in traffic impact studies submitted by applicants.
- Can the County restrict use of certain roads by some oil and gas vehicles to avoid using bike routes and/or roads in poor condition?
Response: This is addressed in traffic impact studies submitted by applicants.
- Will bridges be part of the analysis?
Response: Not part of the scope of this study.
- Would a County fee push development into incorporated areas?
Response: Many factors go into oil and gas siting decisions; this study focused on roads under Adams County's jurisdiction.
- Will air quality impacts be considered?
Response: Not part of the scope of this study.

Draft Report Comments

A draft Adams County Oil & Gas Traffic Impact Study was prepared in December 2017 and posted on the County's website for sixty days to allow public review and comment. Comments were received from resident groups, the Colorado Oil and Gas Association with assistance from the Arcadis Consulting Group, and the Colorado Petroleum Council. The resident groups expressed support for the study and fees. Comments provided by the oil and gas industry expressed certain concerns. Based on this feedback, several edits were made to the revised Oil & Gas Traffic Impact Study and two methodology changes were made that result in reduced fee levels:

- Rather than using the 400 vpd gravel road paving threshold initially proposed, County staff recommended a 500 vpd threshold to require paving of an unpaved road to create consistency with the general adopted policy of using 500 vpd in other County processes. Revision from this change has resulted in reduction of a certain section of the initial fees provided in the report.
- The revised fee requires safety (i.e. addition of shoulders) improvements on roads designated as bike routes that are used by the industry during the production phase. The requirement has been excluded for roads projected to be used during the development phase when the impact would be short-term. This adjustment has resulted in substantial reduction in the initial fees, with the most substantial changes occurring with those activities that utilize pipelines to transport fresh water, produced water, and associated products.

In addition to incorporating the two changes described above, and minor editorial and formatting changes, two notable edits were made to the revised report:

- The previous draft report mistakenly listed the annual production phase costs while listing them as the total 10-year costs in **Tables 12** and **13**. A revision was made to correctly calculate the total 10-year costs by multiplying the annual production phase costs by 10. With this correction, the average cost per 12-well pad aligns with the calculated fees.
- **Tables 12** and **13** were also updated to provide additional detail regarding the estimated costs by listing the calculated costs by mitigation category.

5. OIL & GAS IMPACT MITIGATION NEEDS

The mitigation measures and associated costs presented herein represent the additional costs or funding needs attributable to oil and gas traffic based on the assumptions and calculations described in the previous chapters. They do not include baseline maintenance or improvement costs that would be incurred by the County without the addition of oil and gas traffic, and do not involve any changes in roadway classifications. It should further be noted that the mitigation measures and costs represent typical treatments used by the County for cost estimation purposes; this is not meant to prescribe exact treatments that would be applied to each road segment since each road is unique. These mitigation methods and associated costs are described below.

Paved Road Analysis

Two factors are critical in analyzing the capabilities of paved roads to accommodate additional truck traffic: the current pavement condition (PCI) and structural rating expressed as the structural number (SN). The SN is a function of the thickness of the surface and base layers, and the layer materials.

The County provided the pavement rating (PCI) for all paved County-responsible roads within the study area. Surface treatments (such as crack sealing, fog coats, cold mix pot hole fixes, etc.) were not included as a cost because these treatments do not impact the structural ability of pavement and a cost proportioning method of these activities to the industry was not identifiable. 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 utilized to quantify the rehabilitation needs attributable to the oil and gas industry for hot mix asphalt (HMA) and concrete pavements.

Hot Mix Asphalt Pavement Methodology

The approach to determine the rehabilitation needs to offset the impacts of oil and gas traffic on asphalt pavement roads requires the determination of the pavement structural number (SN) for existing traffic as well as existing traffic plus oil and gas traffic.

The existing serviceability, initial serviceability, terminal serviceability, background ESAL (one year's portion of the design ESALs), reliability level, and standard deviation must be defined in order to determine the existing SN. The existing serviceability is based on the PCI, as provided by the County, for each study area asphalt roadway. The existing serviceability is interpolated based on the PCI and values shown in **Figure 15**. The values shown in **Table 10** are based on industry standards and input from the County for the different roadway classifications. These values are then used to solve for SN within the 1993 AASHTO Guide equation for flexible pavement, which is provided in **Figure 16**.

After the SN is calculated for the existing conditions ($SN_{EXISTING}$), the SN is calculated for the existing conditions plus the oil and gas traffic ($SN_{COMBINED}$). The SN Deficiency is then calculated ($SN_{COMBINED}$ - $SN_{EXISTING}$). The required pavement overlay for the oil and gas traffic is then calculated by dividing the SN Deficiency by the Standard Deviation. The cost for the required overlay was then calculated for each respective section of asphalt road using a price of $85/ton. A summary of mitigation unit costs used in this study is available in **Appendix D**.

Figure 15. Pavement Condition Assumptions

Pavement Condition	PCI	Existing Serviceability *arterials, collector*	Existing Serviceability *local*
EXCELLENT	100 ↓	4.5 ↓	4.5 ↓
VERY GOOD	85 ↓	4.0 ↓	4.0 ↓
GOOD	70 ↓	3.5 ↓	3.3 ↓
FAIR	55 ↓	3.0 ↓	2.6 ↓
POOR	40 ↓	2.5 ↓	2.0 ↓
	0.0	Terminal Serviceability	

Source: Adams County Transportation Department

Table 10. Assumptions for Existing Pavement Sections

Classification	Design ESAL	Reliability (%)	Standard Normal Deviate (Z_R)	Resilient Modulus (M_R)	Initial Serviceability	Terminal Serviceability	Standard Deviation	
							Asphalt	Concrete
Principal Arterial	1,825,000	95	-1.645	3,500 psi	4.5	2.5	0.44	0.35
Minor Arterial	1,460,000	90	-1.282	3,500 psi	4.5	2.5	0.44	0.35
Rural Arterial	1,460,000	90	-1.282	3,500 psi	4.5	2.5	0.44	0.35
Collector	730,000	85	-1.037	3,500 psi	4.5	2.5	0.44	0.35
Section Line Arterial	730,000	85	-1.037	3,500 psi	4.5	2.5	0.44	0.35
Local	73,000	80	-0.841	3,500 psi	4.5	2.0	0.44	0.35

Source: Adams County Transportation Department

Figure 16. AASHTO Equation for Flexible Pavements

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

Source: AASHTO, 1993

Poor Condition Asphalt Methodology

When heavy truck traffic (like that associated with oil and gas activity) uses an asphalt road with a “Poor” pavement condition, it expedites or even immediately warrants the need to reconstruct it. To capture this potentially immediate high cost, any “Poor” condition asphalt road was assumed to be reconstructed if oil and gas traffic used the road. The full cost of reconstruction was attributed to the oil and gas activity using a price of $30,000/mile per foot of roadway width, which includes the cost of removing the existing pavement. In many cases, reconstruction is less expensive than additional overlays that would be needed for the oil and gas industry use of roads in “Poor” condition. A summary of mitigation unit costs used in this study is available in **Appendix D**.

This special analysis of "Poor" condition roads only occurred in the development phase model, after which any reconstructed road was analyzed as an "Excellent" pavement condition (PCI = 95) in the production phase model since any road used in the production phase would have been triggered for reconstruction in the development phase.

Concrete Pavement Methodology

The approach to determine the rehabilitation needs to offset the 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 by roadway classification are shown in **Table 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 by dividing the calculated ESALs generated from oil and gas traffic by the overall Design ESAL. This percentage is then multiplied by the cost per lane mile ($580,000/lane/mile, 12-inch depth) to reconstruct a concrete road. A summary of mitigation unit costs used in this study is available in **Appendix D**.

Safety Mitigation

In addition to the mitigation measures needed to offset road deterioration, this study also considered mitigation for safety concerns associated with oil and gas traffic. The safety mitigation is based on the need for shoulder widening to maintain safe multimodal roads with the increased truck traffic associated with the oil and gas development. Wider shoulders provide space for bicyclists separate from the travel lanes. Shoulders also provide safety benefits for all roadway users: they serve as a countermeasure to run-off-road crashes and provide a stopping area for breakdowns or other emergencies.

As a result of comments received on the draft report, the previous methodology was modified so that these safety improvements are only accounted for if oil and gas traffic triggers the need in the production phase of a well's life when the safety concerns associated with industry traffic are more long-term than the shorter development phase. If oil and gas trucks were assigned to roadways identified as having a shoulder deficiency (as described in **Chapter 3**) and that road is designated as a bike route in the County's transportation plan, a shoulder widening was programmed to meet the width required by the design standard for the roadway's classification (see **Table 1**) to improve multimodal safety.

This process consists of removing a foot of width from the existing pavement to allow for proper leveling, and then repaving that removed foot of width along with adding the needed width of pavement.

For example, a minor arterial requires six feet of shoulder. If a minor arterial with no shoulder received oil and gas production traffic, one foot of width would be removed from the travel lane, and seven feet of pavement would be added (1 foot of travel lane, 6 feet of required new shoulder). Likewise, if the minor arterial had three feet of shoulder (a deficiency of three feet), one foot of width would be removed from it, and four feet of pavement would be added (1 foot to recover the removed shoulder, 3 feet of required new shoulder).

A price of $23,00/mile per foot of pavement width was used for the additional shoulder pavement, and the price of $3,000/mile per foot of pavement width was used for the removal. A summary of mitigation unit costs used in this study is available in **Appendix D**.

Unpaved Road Analysis

The increase in maintenance and rehabilitation costs are a key element in determining the improvement cost for unpaved roads. Unlike paved roads, impacts for unpaved roads are realized as daily traffic volumes increase rather than the number of ESALs experienced. As the number of vehicles per day increases, activities such as grading and gravel applications must be implemented to preserve the surface quality, while dust suppression must also be implemented to address environmental concerns.

Existing daily traffic volumes were collected/estimated for each unpaved road that experienced oil and gas traffic in the model to establish an existing baseline of maintenance occurring. Oil and gas daily traffic was then applied to determine if any additional maintenance was necessary. Costs were only calculated for the additional maintenance or paving required due to oil and gas traffic. The following sections describe how daily oil and gas traffic was estimated and the parameters for increased maintenance or paving.

Estimating Daily Oil & Gas Traffic Volumes

For modeling purposes, oil and gas trips for the development phase are expressed as the total number of trips for the entirety of the development phase. Furthermore, the model assigns trips for all pads and wells in one model run since paved maintenance is reliant on loads, not time-based traffic volumes, allowing for an average impact of a pad and well developed anywhere at any time.

Conversely, increased maintenance or paving of unpaved roads is based on daily traffic volume thresholds, so estimates were needed about the distribution of oil and gas traffic over time. Making this estimate using trips generated by all 300 pads and their wells being developed at one time would overestimate daily traffic attributed to oil and gas, triggering maintenance or paving that realistically would not be necessary. Alternatively, spacing development of the 300 pads and their wells evenly over the 10-year study period (30 pads per year) would not account for annual fluctuations that could result in substantially more pads being developed, subsequently underestimating needs that could occur during peaks in development. Furthermore, development is unlikely to occur evenly throughout the County, and instead be focused in clusters, further bolstering the fact that an average pace would not account for peak demands on unpaved roads.

To devise an estimate in between the two extremes described above, modeled oil and gas volumes were divided by a factor consisting of the average number of days in development (102 days) multiplied by the number of estimated development periods it would take to develop all 300 pad sites and their wells at a pace greater than an evenly spaced average (30) but lower than all at once (300). A pace equivalent to developing all 300 pads and their wells in any given area over a 4-year period was selected, as this pace represents a peak condition observed for the Wattenburg field in the past five years. This selected pace is based on historical data from the same formation that intersects Adams County, and represents a data-driven estimate that attempts to neither over nor under estimate needs as described above, yet account for spikes in development that could trigger increased maintenance or paving need.

Modeling for the production phase also assigned all trips in one model run, but post-processing of the results for daily traffic-based thresholds recognized that pads would incrementally come online over the ten years, resulting in the full modeled volume at Year 10. For example, if an unpaved road is estimated to have 100 vpd at "full buildout" of all pads, Year 1 was estimated to have 10 vpd, Year 2 to have 20 vpd, and so on. The maintenance or paving needs and costs were assessed for each year, the total 10-year costs aggregated, and the aggregated costs divided by ten to establish an average annual cost. Although it is unlikely pads would be developed at a steady pace over the 10-year horizon, this method accounts for incrementally increased maintenance needs as more and more pads are developed and begin to produce over time, while recognizing the uncertainty of development timing and intensity.

Maintenance and Rehabilitation Schedule and Costs

Table 11 outlines the maintenance thresholds for unpaved roads and the County's average costs associated with each maintenance activity. A summary of mitigation unit costs used in this study is available in **Appendix D**. Because all unpaved roads were assumed to have some level of existing traffic, no grading costs were attributed to the oil and gas industry since the threshold was met prior to oil and gas traffic. As stated earlier, only additional maintenance or paving as a result of adding oil and gas traffic was attributed to the industry.

Table 11. Unpaved Road Maintenance Schedule and Costs

VPD Thresholds	Activity	Frequency	Cost
> 0	Grading	1/week	$445.50 per mile per week
>= 100	Chemical Treatment for Dust	Annually	$7,239.20 per mile for Year 1 $3,619.60 per mile for subsequent years
>= 300	New Gravel	1/12 years	$100,000 per mile

Source: Adams County Transportation Department

Paving of Unpaved Roads

Any unpaved road with over 500 vpd was assumed to have the potential to be paved and the cost was attributed to oil and gas activity for the triggering phase – a similar concept to reconstructing "Poor" condition roads. While the high proportion of truck traffic on unpaved roads used by the industry may actually warrant consideration of paving at a lower volume threshold, the 500 vpd threshold has been used to be conservative and to maintain consistency with previous County transportation planning.

Once paved, this same roadway was then assumed to be paved for the remainder of the production phase and analyzed as an "Excellent" condition road (PCI = 95) that would be analyzed for overlay needs. This assumption of paving does not commit the County to pave the unpaved road, but does allow them to recover the cost to pave if needed. Paving assumed the removal and reuse of the unpaved road for base material and the addition of a shoulder depending on the road's classification requirements, all at a price of $23,00/mile per foot of pavement width. A summary of mitigation unit costs used in this study is available in **Appendix D**.

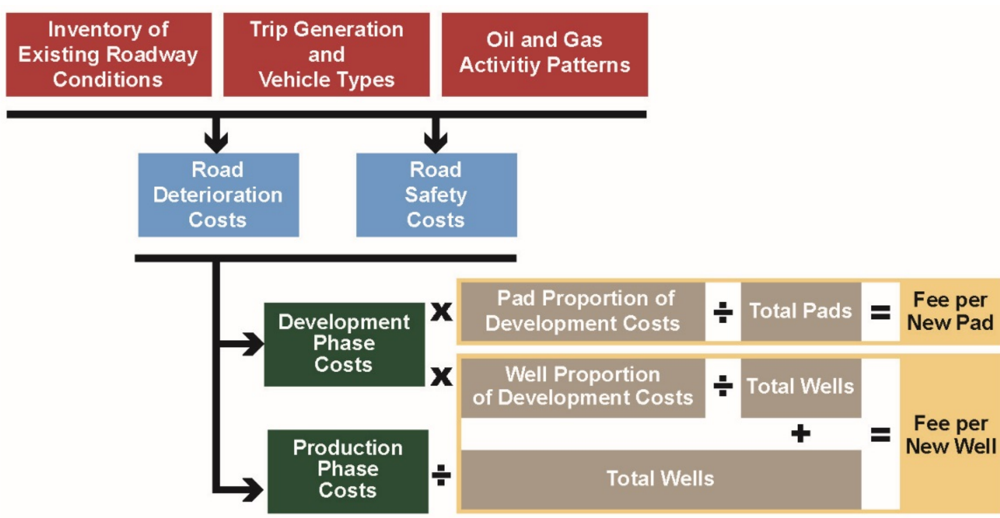
6. OIL & GAS ROADWAY IMPACT FEES

The purpose of designing oil and gas roadway impact fees is to recover the incremental costs associated with the industry's impact on Adams County's roads. Because of the nature of oil and gas development, the most intense impact occurs during development, prior to when wells generate tax revenue that could be used to offset impacts upfront. After the development phase, the well enters the less traffic-intensive production phase, but this activity continues over the life of the well. The capital required to recover costs of both phases is ideally recovered during the permitting process so the County can be as proactive as possible in offsetting impacts. This is accomplished through oil and gas roadway impact fees.

Fee Calculation Methodology

In designing oil and gas roadway impact fees, it is critical to isolate the oil and gas damage on the County's roads. The fees are designed to recoup the cost to the County associated with road deterioration and safety, as estimated in this study. **Figure 17** illustrates the methodology used to calculate the oil and gas roadway impact fees.

Figure 17. Fee Calculation Methodology



The roadway deterioration and safety impact costs were calculated by applying the cost assumptions described in **Chapter 5** with the modeling of impacts for the development of 3,600 wells on 300 pads placed throughout the study area (one pad with 12 wells per developable pad zone), aggregated for the whole study area and individually for the West and East districts, as explained in **Chapters 2** and **3**. The average per-pad and per-well costs were calculated by dividing these roadway costs by the number of pads (300) and number of wells (3,600).

Two separate scenarios were modeled and analyzed: one assuming that all wells utilize trucks for all water (fresh and produced) and product transport, and another assuming that all wells utilize pipelines for all transport of these materials. This approach allowed for the capture of the overall effect of pipelines on total impact costs and for the calculation of fees based on whether pad sites will have access to any combination of fresh water, produced water, and product pipelines.

Calculated Costs

Table 12 provides the total roadway and safety impact costs associated with the development of 300 pads with twelve wells each, as well as the impact costs associated with the production trips of those same pads over a 10-year period, using the process and unit costs outlined in **Chapter 5**. Costs are shown for each of the mitigation cost categories. The breakdown shows that Asphalt Overlay represents the largest cost component in both the development and production phases. Poor Road Reconstruction and Adding Shoulders are the other major cost components. Costs associated with Concrete Reconstruction, Gravel Maintenance, and Paving Gravel Roads are relatively small components of the total costs.

This set of results is shown for the study area as a whole, as well as individually for the West and East districts. It includes all truck trips for the transportation of fresh and produced water, as well as product produced, and is considered the base scenario. The same costs associated with implementing pipelines for all fresh and produced water, as well as product, are similarly displayed in **Table 13**. Both tables also show the average cost to offset the roadway impacts of a single pad with twelve wells (total costs divided over 300 pads), accounting for ten years of production.

Table 12. Impact Costs for Oil and Gas Development and Production without Pipelines (2017$)

	Full Study Area	West District	East District
Development Phase			
Roadway Deterioration Costs			
Asphalt Overlay	$15,225,200	$13,619,000	$1,606,300
Concrete Reconstruction	$221,200	$221,200	$0
Gravel Maintenance	$744,300	$726,600	$17,800
Paving Gravel Roads	$411,000	$411,000	$0
Poor Road Reconstruction	$9,241,600	$5,211,700	$4,030,000
Safety Impact Costs			
Adding Shoulders	$0	$0	$0
Production Phase (10-years)			
Roadway Deterioration Costs			
Asphalt Overlay	$85,776,000	$77,061,000	$8,715,000
Concrete Reconstruction	$876,000	$876,000	$0
Gravel Maintenance	$311,000	$250,000	$61,000
Paving Gravel Roads	$0	$0	$0
Poor Road Reconstruction	$0	$0	$0
Safety Impact Costs			
Adding Shoulders	$28,651,000	$19,283,000	$9,368,000
Total Costs	$141,457,300	$117,659,500	$23,798,100
Cost per 12-well Pad	$471,524	$439,028	$743,691

Table 13. Impact Costs for Oil and Gas Development and Production with Fresh Water, Produced Water, and Product Pipelines (2017$)

	Full Study Area	West District	East District
	Development Phase		
	Roadway Deterioration Costs		
Asphalt Overlay	$6,455,100	$5,916,200	$539,000
Concrete Reconstruction	$26,600	$26,600	$0
Gravel Maintenance	$0	$0	$0
Paving Gravel Roads	$0	$0	$0
Poor Road Reconstruction	$9,241,600	$4,668,300	$4,573,400
	Safety Impact Costs		
Adding Shoulders	$0	$0	$0
	Production Phase (10-years)		
	Roadway Deterioration Costs		
Asphalt Overlay	$173,000	$160,000	$14,000
Concrete Reconstruction	$1,000	$1,000	$0
Gravel Maintenance	$153,000	$129,000	$25,000
Paving Gravel Roads	$0	$0	$0
Poor Road Reconstruction	$0	$0	$0
	Safety Impact Costs		
Adding Shoulders	$0	$0	$0
Total Costs	$16,050,300	$10,901,100	$5,151,400
Cost per 12-well Pad	$53,501	$40,676	$160,981

Fee Calculation

To allow for variations in the number of wells per pad, the fee calculation is based on two components: a pad construction fee and a well development and production fee. One percent of all costs associated with developing a 12-well pad is attributable to pad construction based on that activity's ESAL generation, and the remaining costs are attributed to the well development. All production costs are associated with the well fee.

Table 14 presents the calculated impact fees, which are the average impact costs associated with pad construction and well development, and the 10-year cumulative impact costs of well production. The table splits the impact fees between phases (development versus ten years of production), boundary (full study area versus West/East districts), mitigation type (roadway deterioration versus safety), pipeline scenario, and per-pad versus per-well fee.

Table 14. Full Oil and Gas Roadway Impact Fee Schedule Options (2017$)

Pipeline Scenario			Fee Type	Full Study Area			West District			East District		
Fresh Water Pipeline	Produced Water Pipeline	Product Pipeline		Roadway Deterioration Impact Fees	Safety Impact Fees	Total Impact Fees	Roadway Deterioration Impact Fees	Safety Impact Fees	Total Impact Fees	Roadway Deterioration Impact Fees	Safety Impact Fees	Total Impact Fees
Per Pad Fees												
n/a	n/a	n/a	**Pad Fee (D)**	**$861**	**$0**	**$861**	**$753**	**$0**	**$753**	**$1,767**	**$0**	**$1,767**
Per Well Fees												
			Well Fee (D)	$7,107	$0	**$7,107**	$6,215	$0	**$6,215**	$14,577	$0	**$14,577**
-	-	-	Well Fee (P)	$24,156	$7,959	**$32,115**	$24,312	$5,996	**$30,308**	$22,854	$24,396	**$47,250**
			Total Well Fee	**$31,263**	**$7,959**	**$39,222**	**$30,527**	**$5,996**	**$36,523**	**$37,431**	**$24,396**	**$61,827**
			Well Fee (D)	$5,702	$0	**$5,702**	$4,726	$0	**$4,726**	$13,872	$0	**$13,872**
✓	-	-	Well Fee (P)	$24,156	$7,959	**$32,115**	$24,312	$5,996	**$30,308**	$22,854	$24,396	**$47,250**
			Total Well Fee	**$29,858**	**$7,959**	**$37,817**	**$29,038**	**$5,996**	**$35,034**	**$36,726**	**$24,396**	**$61,122**
			Well Fee (D)	$7,107	$0	**$7,107**	$6,215	$0	**$6,215**	$14,577	$0	**$14,577**
-	-	✓	Well Fee (P)	$11,883	$3,900	**$15,783**	$11,959	$2,938	**$14,897**	$11,250	$11,954	**$23,204**
			Total Well Fee	**$18,990**	**$3,900**	**$22,890**	**$18,174**	**$2,938**	**$21,112**	**$25,827**	**$11,954**	**$37,781**
			Well Fee (D)	$5,702	$0	**$5,702**	$4,726	$0	**$4,726**	$13,872	$0	**$13,872**
-	✓	-	Well Fee (P)	$12,364	$4,059	**$16,423**	$12,443	$3,058	**$15,501**	$11,705	$12,442	**$24,147**
			Total Well Fee	**$18,066**	**$4,059**	**$22,125**	**$17,169**	**$3,058**	**$20,227**	**$25,577**	**$12,442**	**$38,019**
			Well Fee (D)	$5,702	$0	**$5,702**	$4,726	$0	**$4,726**	$13,872	$0	**$13,872**
✓	-	✓	Well Fee (P)	$11,883	$3,900	**$15,783**	$11,959	$2,938	**$14,897**	$11,250	$11,954	**$23,204**
			Total Well Fee	$17,584	$3,900	**$21,484**	$16,685	$2,938	**$19,623**	$25,122	$11,954	**$37,076**
			Well Fee (D)	$4,296	$0	**$4,296**	$3,237	$0	**$3,237**	$13,166	$0	**$13,166**
✓	✓	-	Well Fee (P)	$12,364	$4,059	**$16,423**	$12,443	$3,058	**$15,501**	$11,705	$12,442	**$24,147**
			Total Well Fee	**$16,660**	**$4,059**	**$20,719**	**$15,680**	**$3,058**	**$18,738**	**$24,871**	**$12,442**	**$37,313**
			Well Fee (D)	$5,702	$0	**$5,702**	$4,726	$0	**$4,726**	$13,872	$0	**$13,872**
-	✓	✓	Well Fee (P)	$91	$0	**$91**	$90	$0	**$90**	$102	$0	**$102**
			Total Well Fee	**$5,792**	**$0**	**$5,792**	**$4,816**	**$0**	**$4,816**	**$13,973**	**$0**	**$13,973**
			Well Fee (D)	$4,296	$0	**$4,296**	$3,237	$0	**$3,237**	$13,166	$0	**$13,166**
✓	✓	✓	Well Fee (P)	$91	$0	**$91**	$90	$0	**$90**	$102	$0	**$102**
			Total Well Fee	**$4,387**	**$0**	**$4,387**	**$3,327**	**$0**	**$3,327**	**$13,268**	**$0**	**$13,268**

(D) = Development Phase

(P) = Production Phase

The study team presented these impact fee calculations along with three policy choices in fee implementation to the Adams County Board of County Commissioners (BOCC) at a study session on November 14th, 2017. BOCC direction on these policy choices included:

- **Account for all fee elements presented**: All calculated road impact elements associated with both the development and production phases.
- **Allow for fee reductions based on pipelines used**: Reduce fees to account for pipelines that would reduce truck trips.
- **Assess different fees for pads/wells by district (West versus East)**: The fee structure should account for the longer truck trips and less developed roadway network in the eastern part of the County.

The BOCC also directed the study team to post a copy of this study on the County's website for public review and comment. As described in **Chapter 4**, two major modifications to the fee calculation methodology were applied based on comments received and a subsequent re-review of the study.

Table 15 summarizes the resulting recommended fee structure – total fees by pipeline scenario for the West and East districts.

Table 15. Recommended Oil and Gas Roadway Impact Fee Schedule (2017$)

Pipeline Scenario			West	East
Fresh Water Pipeline	Produced Water Pipeline	Product Pipeline		
		Per Pad Fees		
n/a	n/a	n/a	$753	$1,767
		Per Well Fees		
-	-	-	$36,523	$61,827
✓	-	-	$35,034	$61,122
-	-	✓	$21,112	$37,781
-	✓	-	$20,227	$38,019
✓	-	✓	$19,623	$37,076
✓	✓	-	$18,738	$37,313
-	✓	✓	$4,816	$13,973
✓	✓	✓	$3,327	$13,268

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APPENDIX B. WATER PROVIDER INTERVIEW SUMMARIES

City of Brighton Utilities Department

The City of Brighton does provide water for oil and gas development, but restricts its water use to only developments whose well terminus is within the city limits. To ensure this policy is followed, water must be transported via pipeline and cannot be trucked.

With all pad sites assumed to be in unincorporated Adams County, no water can be used from the City of Brighton for these developments.

South Adams County Water & Sanitation District

The District has never had an application for use by oil and gas, and noted their water usage is heavily regulated. If such use was permitted, it would be done via water hydrant.

Because of a lack of history supplying to oil and gas, and because their service area primarily lies where ditches exist or in the southwest area removed from the study, no water was assumed to be sourced from the District.

Strasburg Sanitation & Water District

The District stated they do not issue access for oil and gas development.

Todd Creek Village Metro District

Anecdotal evidence from County oil and gas staff suggested that the District might supply water for oil and gas development, but the study team was not able to connect with the District to verify. With numerous ditches covering the same service area, it was assumed that estimated access points to these ditches used in the study would closely represent any access to District water in the event water was provided.

Other Water Districts

Adams County has numerous other water districts throughout the County, including some in the east-central portion that has limited water supplies. However, the remaining districts are very small in size (often built to supply a small housing development) or are in urbanized areas in the southwest portion of the County. Thus, they were deemed to not be suitable for oil and gas companies to use since the other more viable providers above do not or have severe limitations.

APPENDIX C. TRAVEL MODEL ASSUMPTIONS

Assumption	Reasoning / Notes
Some Adams County roads in the excluded southwest area were included	Their connectivity was deemed to potentially serve trip paths to/from the study area's network
Roads from adjacent counties were included in the model but not assessed for impacts	Origins/destinations outside of Adams County, specifically to the North, were programmed at actual locations of where facilities are located
Most roads used a standardized speed limit based on functional classifications and location, with some acquired from agency databases and Google StreetView	State highways acquired from CDOT, some major roads from Adams County GIS Major paved roads were validated/acquired via Google StreetView Finding speeds for each road segment, specifically minor local roads, would have had a low benefit/cost ratio Gravel roads typically do not have a posted speed limit
Shoulder widths were estimated using total pavement widths and lane widths, with unusual widths verified via Google Earth	No reliable shoulder width data were available Such a large road network cannot be fully reviewed manually for shoulder widths Resulting widths were generally reasonable and were spot checked via Google Earth
All highway ramps entered into the model as a one-lane roadway	Congestion was not factored within the model, and all ramps in the travel shed are the responsibility of CDOT, thus do not factor into calculated impacts
Intersection controls were not defined	Programming signal timing would have had a low benefit/cost ratio Delay from intersection controls would be low in comparison to the total trip time
Actual turn lane configurations were not included within the network	Programming turn lanes into the model would have had a low benefit/cost ratio Delay reduction from turn lanes would be low in comparison to the total trip time
12 wells per pad	Used from 2016 Thornton study to be consistent since study areas overlap
1 pad per 24 square-miles in the East district	Used density found in similar Arapahoe County area south of Watkins
No pad-to-pad travel	Data on pad-to-pad travel patterns and volumes were unavailable, and such travel patterns are complex and highly uncertain case-by-case occurrences to predict
The pad in each pad zone of the model was located in the most open, least developed, and unincorporated location outside of the floodway and nearest to a road for access	Pads typically locate away from housing and other buildings to avoid conflict with local residents The analysis for this study was only concerned with pads developing in unincorporated portions of the County Floodways mainly influenced the placement of a pad within a zone, with only a few potential pad zones eliminated due to being fully covered by a floodway
Paths connecting pad centroids were connected to the nearest major road in a geographically logical manner	Development would be unlikely to construct a bridge to cross water unless absolutely necessary Major roads would be most suitable for travel Connecting to the nearest road reduces access road costs and travel time
No trips were assigned to travel via the E-470 tollway	Hazardous materials are prevented from traveling on E-470 Multiple free comparable travel paths are available and transporters are toll-averse
Trips to/from the North were allowed to exit Adams County via I-25, I-76, US 85, SH 71, SH 79, or Hayesmount Road	These highways provide faster and easier exit from the area to Weld County Because origins/destinations to the North were programmed at actual locations of where facilities are located, the travel model determined which route was used
Trips to/from the Southwest were allowed to exit Adams County via I-25 and I-70	These highways provide faster and easier exit from the area to the Denver area Adding other routes would not have changed travel patterns on Adams County roads
West district pads obtained 90% of water locally from ditches, 10% from the North	Nearest local source estimated based on access to nearest ditch 10% was obtained externally to account for possibly unforeseen issues and needs
East district pads obtained 50% of water locally from creeks, 50% from the North	Used 50/50 split due to lack of established local water sources Local creek sourcing of water (Bijou and Kiowa) provided by County oil and gas staff
Produced water trips to/from nearest of top 4 disposal wells to the North	Most other disposal wells in/near Adams County had lower historical use Other high-use disposal wells were generally in the same area as selected wells
Other equipment/materials/worker trips split 90% to the North and 10% to the South	Recognizes that the vast majority of oil and gas operators/contractors are in Weld County, but some general construction and worker trips would be to/from Denver
All pads were modeled to generate trips in one model run per phase	The approach defined to the left and in the report results in a true average potential cost to the County's road network regardless of where and when a pad develops Not conducted was the creation of pace-of-development scenarios that utilize a random location selection process of active pads (because the location of future pads is unknown) because this can lead to situations where if the randomization process selected pad locations that must use more County roads, the cost per pad/well is higher; or if the randomization process selected pad locations that primarily accessed state highways or municipal roads, the cost per pad/well is lower
50% of completion equipment trips to/from facility at US 85 and E 104th Avenue	County oil and gas staff identified this contractor as the main provider for completion equipment services for the area
Trip generation from 2017 Boulder study	Used most current trip generation data developed just prior to this study

APPENDIX D. MITIGATION UNIT COSTS SUMMARY

The following unit costs were developed in coordination with Adams County staff using County data in conjunction with CDOT costs. These are generalized planning-level costs that incorporate standard values used by the County for all occurrences of these activates, not just for the purposes of this study. These costs do not include any changes in roadway classification or acquisition of right-of-way.

Maintenance Activity	2017 Cost	Unit	Assumptions
Asphalt overlay	$85	Per ton	n/a
Asphalt reconstruction	$30,000	Per foot of width, per mile	Includes removal cost
Concrete reconstruction	$580,000	Per lane, per mile	12-foot lane width, 12-inch depth
Shoulder removal	$3,000	Per foot of width, per mile	Done to 1-foot past existing pavement edge
Shoulder addition	$23,000	Per foot of width, per mile	Includes portion removed (1-foot) and additional width
Grading	$445.50	Per mile	Weekly
Gravel	$100,000	Per mile	Applied every 12 years
Chemical treatment	$7,239.20 $3,619.60	Per mile	For 1st year's application and reapplication after 5 years For each subsequent year after first/reapplication
Paving of gravel road	$23,000	Per foot of width, per mile	Includes removing existing gravel and reusing as base

Source: Adams County Transportation Department

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