# Commerce City Oil & Gas Roadway Impact Study

**DRAFT June 18, 2019**

Commerce CITY

FELSBURG HOLT & ULLEVIG

# Oil & Gas Roadway Impact Study

# DRAFT

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## Background and Purpose

Due to Commerce City's location in the Denver-Julesburg Basin, energy companies have shown an increased interest in exploration and drilling in the City. 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. Commerce City has commissioned this study to understand the potential impacts of oil and gas development and production on the City's road system and to design a roadway impact fee to offset increased costs of transportation impacts associated with heavy truck traffic 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 Commerce City'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 City associated with road deterioration and other related impacts. Commerce City has authority derived from state statutes to regulate public roads over which it has jurisdiction. The oil and gas 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 on a single pad in the study area will generate an estimated 3,138 trips during its two- to three-week development period, largely related to water and fracking sand 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-pad, one-well format to the more common multi-well pad configuration. For example, a 10-well pad configuration will generate nearly 22,300 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 8,000 to 23,000 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 Commerce City's road network within the study area defined as the incorporated City land north of 88th Avenue, as well as the part of the City southeast of 88th Avenue and Buckley Road. Only City land outside of defined floodways and with adequate surface space to drill was considered for development within this study.

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 "Very Poor" condition, when more cost effective
- Increased maintenance requirements on unpaved roads

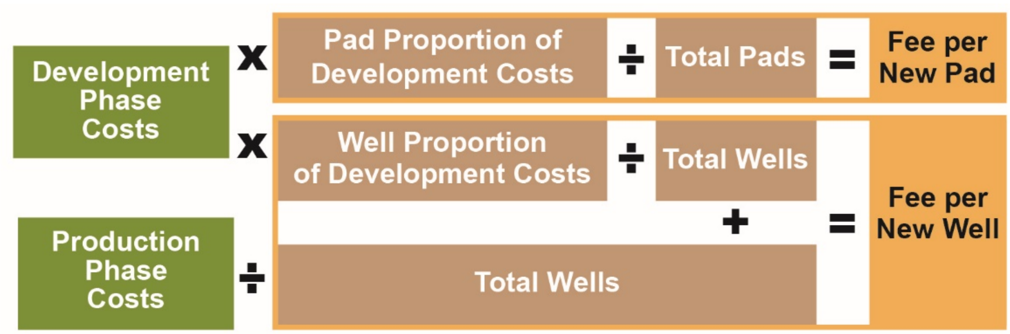
Roadway widening needs for vehicle-carrying capacity and safety are also considered; however, these improvements are more trip-based in nature rather than being load based. Safety costs are associated with shoulder widening to maintain safe multimodal roads with the increased truck traffic associated 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.

## *Oil & Gas Roadway Impact Fee Methodology*

Two fee methods are used in this study: one to calculate fees for recovering road deterioration (load-based) costs and one to calculate fees to account for roadway widening including the need to improve shoulders for multimodal safety reasons.

The figure below illustrates the methodology used to calculate the oil and gas road deterioration 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. Only a small percentage of the ESAL generation and roadway costs is attributable to pad construction; a large majority of costs are attributed to the well development with multi-well development. All production costs are associated with the well fee.

### Road Deterioration Fee Calculation Methodology




The oil and gas roadway deterioration fees are calculated by estimating the total roadway deterioration impact costs associated with oil and gas development and production, and then dividing the total cost by the total number of pads and wells.

An additional well characteristic was then factored into the fee calculations: 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.

Fees associated with widening, including improving shoulders for multimodal safety, were calculated using the City's existing road impact fee structure. This was done because these improvements are more trip-based than load-based, and the existing road impact fee program was designed for these types of improvements. This process uses average oil and gas activity daily traffic volumes to apply the current road impact fee cost of $250 / daily trip in creating oil and gas specific fees per pad and per well.

The two fees are then added together per pad and per well to arrive at a final fee schedule, as described on the next page.

## Stakeholder Engagement

The City provided opportunities for the oil and gas industry and general public to hear about the transportation impact study process, ask questions, and comment on the proposed methodology and assumptions.

An industry stakeholder meeting held on May 10, 2019 was attended by representatives from the Colorado Oil & Gas Association, Colorado Petroleum Council, and oil & gas companies active in the City. A public open house held on May 23, 2019 was attended by approximately 20 individuals. Verbal and written comments received have been considered in developing the draft study for presentation to the Planning Commission and City Council.

The proposed impact fee was also advertised to the community via social media and newsletter communications.

## Oil & Gas Roadway Impact Fee Schedule

The following table provides the combined maximum oil and gas impact fee schedule that can be adopted corresponding to the estimated impact cost for each new pad and well by pipeline scenario.

### Combined Maximum Oil and Gas Roadway Impact Fee Schedule (2019$)

| Pipeline Scenario | | | Study Area |
|---|---|---|---|
| Fresh Water Pipeline | Produced Water Pipeline | Product Pipeline | |
| | | | *Per Pad Fees* |
| n/a | n/a | n/a | $996 |
| | | | *Per Well Fees* |
| - | - | - | $21,172 |
| ✓ | - | - | $20,260 |
| - | - | ✓ | $13,853 |
| - | ✓ | - | $13,217 |
| ✓ | - | ✓ | $12,703 |
| ✓ | ✓ | - | $12,067 |
| - | ✓ | ✓ | $3,295 |
| ✓ | ✓ | ✓ | $2,145 |

# 1 INTRODUCTION

Colorado is one of the nation's leading energy producing states. According to the United States Energy Information Administration (EIA), Colorado was the $7^{th}$ highest state in total energy production in 2016. Oil and gas energy production is the primary source of the state's large output of energy, with Colorado ranking $7^{th}$ in crude oil production in 2017 and $5^{th}$ in natural gas production in 2016. These rankings are largely due to the presence of the Niobrara shale formation, which encompasses Commerce City. According to the Colorado Oil and Gas Conservation Commission (COGCC), Commerce City ranks as the $5^{th}$ highest oil producing City in the state, while also ranking $14^{th}$ in natural gas production. The City continues to see an increase in development interest.

Oil and gas drilling and production can impact local road systems, as well as other public infrastructure and services. Given the increase in development interest in recent years, Commerce City has commissioned this study 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

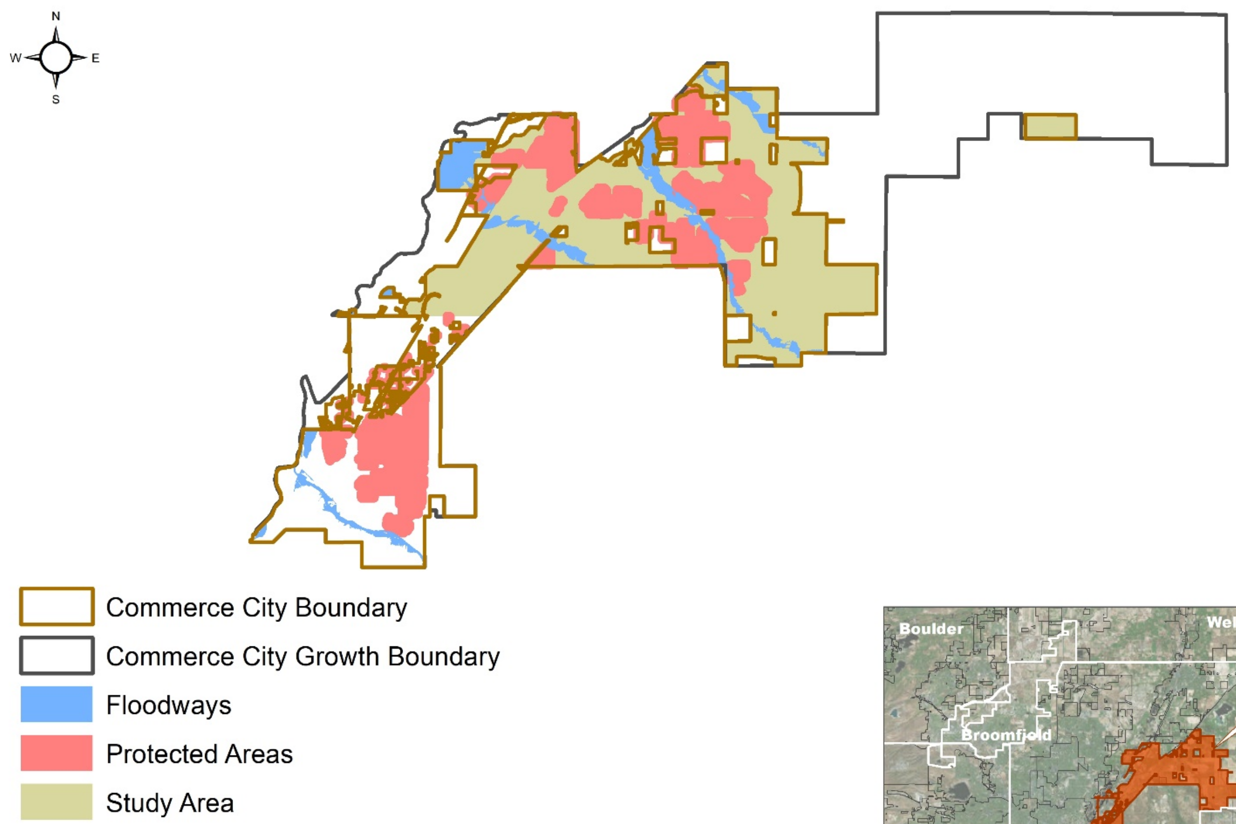
This study seeks to understand and quantify the potential impacts of oil and gas development to the City transportation system. This study is not intended to predict oil and gas development location or intensity, but rather to provide City officials with information about the potential impacts to the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

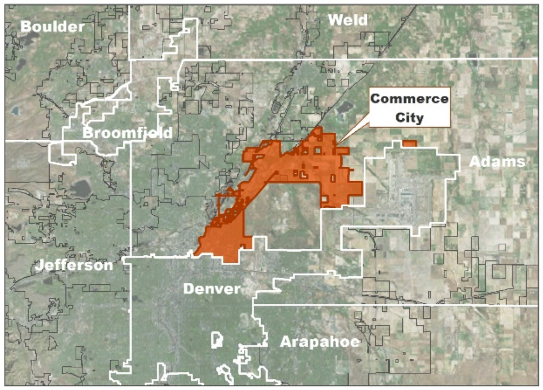
The transportation impacts estimated within this study are used to design and calculate impact fees that will offset the transportation-related impacts of oil and gas development. Commerce City has authority derived from state statutes to regulate public roads over which it has jurisdiction. The oil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

## Study Area

This roadway impact study utilizes a travel demand model that focuses exclusively on oil and gas trips and loads using Commerce City's road network within the study area defined as the incorporated City land north of $88^{th}$ Avenue or east of Buckley Road. Only City land outside of defined floodways and with adequate surface space to drill was considered for development within this study. **Figure 1** shows the study area as described above.

**Figure 1. Study Area**



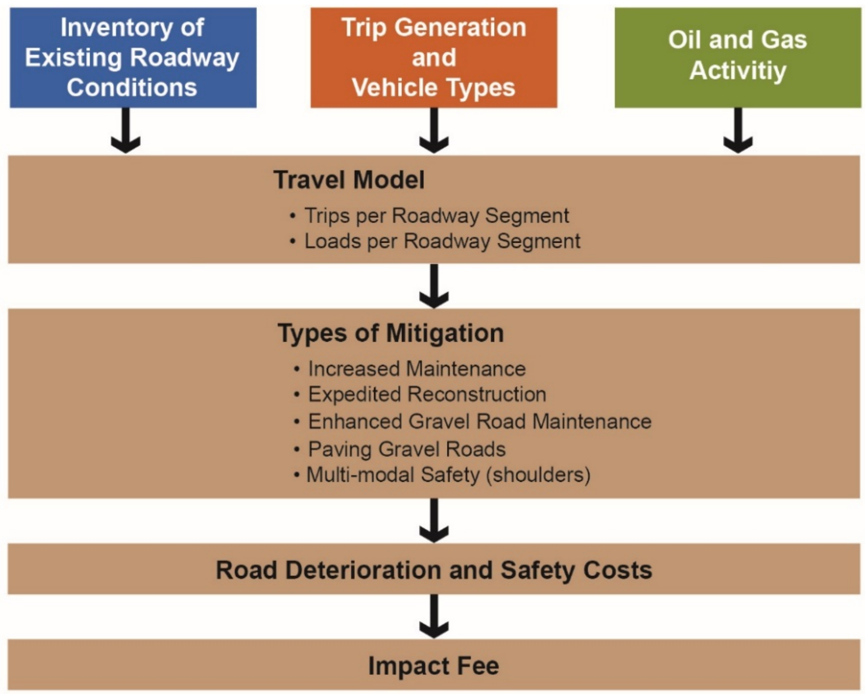




*Sources: CDOT, 2018; FEMA, 2017; Commerce City, 2019; BLM, 2017*

## *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 City roadway network. Finally, the oil and gas activity provides information about development and production patterns applicable to Commerce City.

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 and rehabilitation that result in roadway deterioration costs attributed to oil and gas activity. After the proportional costs of road deterioration are calculated, the analysis is combined with a trip-based methodology for calculating the costs of mitigation activities that utilizes the Commerce City road impact fee process for road widening improvements. The result is a fee 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 Commerce City. 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 Commerce City staff were conducted to better understand current development trends and how oil and gas trucks could potentially impact City 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 ASSUMPTIONS FOR COMMERCE CITY

## *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 five-plus acres in area, depending on the number of wells. 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

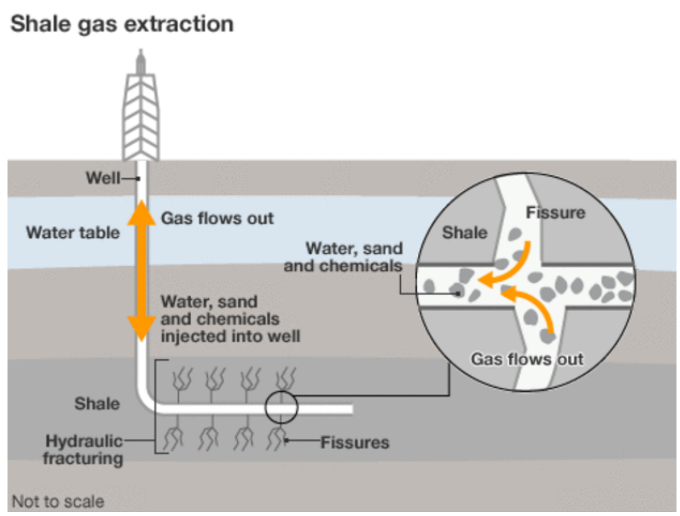
Once drilling is complete, wells must be completed using hydraulic fracturing – known as fracking. The drilling rig is replaced with a multitude of hydraulic fracturing equipment including blender trucks, pump trucks, water tanks, produced water trucks, and fracture sand. Most of the completion equipment 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 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.

An ever more popular 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 study area is defined as the incorporated City land north of 88th Avenue or east of Buckley Road. Pad location and well density assumptions were made to create a development scenario that would allow for development of a reasonable average roadway mitigation cost per pad and per well for the study area.

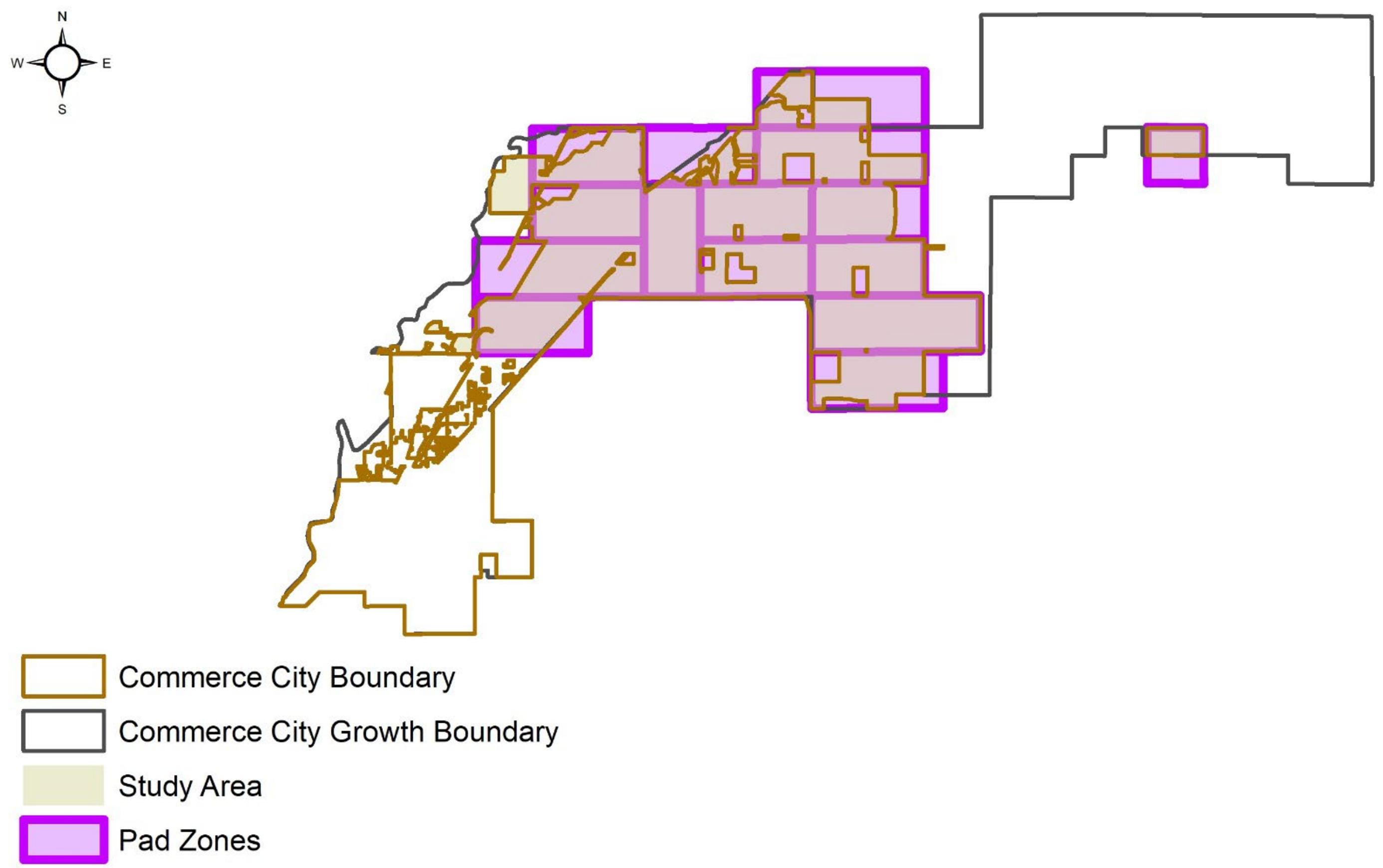
## Pad Density & Zones

The City and consultant study team worked to develop pad and well density assumptions, including pad zones and theoretical pad locations based on spacing applications received by the City. Overall, 15 pads zones with 18 pads were modeled in the study area, as shown on **Figure 3**. Pad zones vary between one-, two-, and three-square mile-sections. Additional information as to how these pad zones were used and how pads were placed in each zone are provided in **Chapter 3**.

## Well Density

Another important factor in estimating the impacts of oil and gas activity is the number of wells per pad. Based again on spacing applications and Form 2a's that have been submitted to the state, along with the overall geography of the study area, an average of 23 wells per pad was derived for the 18 pads, resulting in a total of 410 wells being modeled for the purpose of developing average trip generation and roadway improvement costs per pad and per well.

**Figure 3. Pad Zones**




*Sources: CDOT, 2018; Commerce City, 2019; BLM, 2017*

## Other Oil & Gas Assumptions

### Phase & Stage Duration

Also important is the duration it takes to develop a pad and its wells. 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.

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

City 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*

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 along the Front Range, 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 Commerce City should oil and gas activity continue to increase in the City and neighboring Adams County.

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 Commerce City's transportation system of no pipelines versus reduced truck impacts with 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 Commerce City 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 Commerce City (US and State Highways, and County 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 Commerce City – referred to as the study area roadways or Commerce City responsible roads.

Oil and gas development will result in increased traffic on the roadway network (vehicle-trips), as well as increased loads on the City'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) and rigid pavement (concrete) versus unpaved. Impacts for pavements are generally dependent on loads and their distribution on a truck, while 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 list of other assumptions used to develop the travel model is provided in **Appendix B**. 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**.

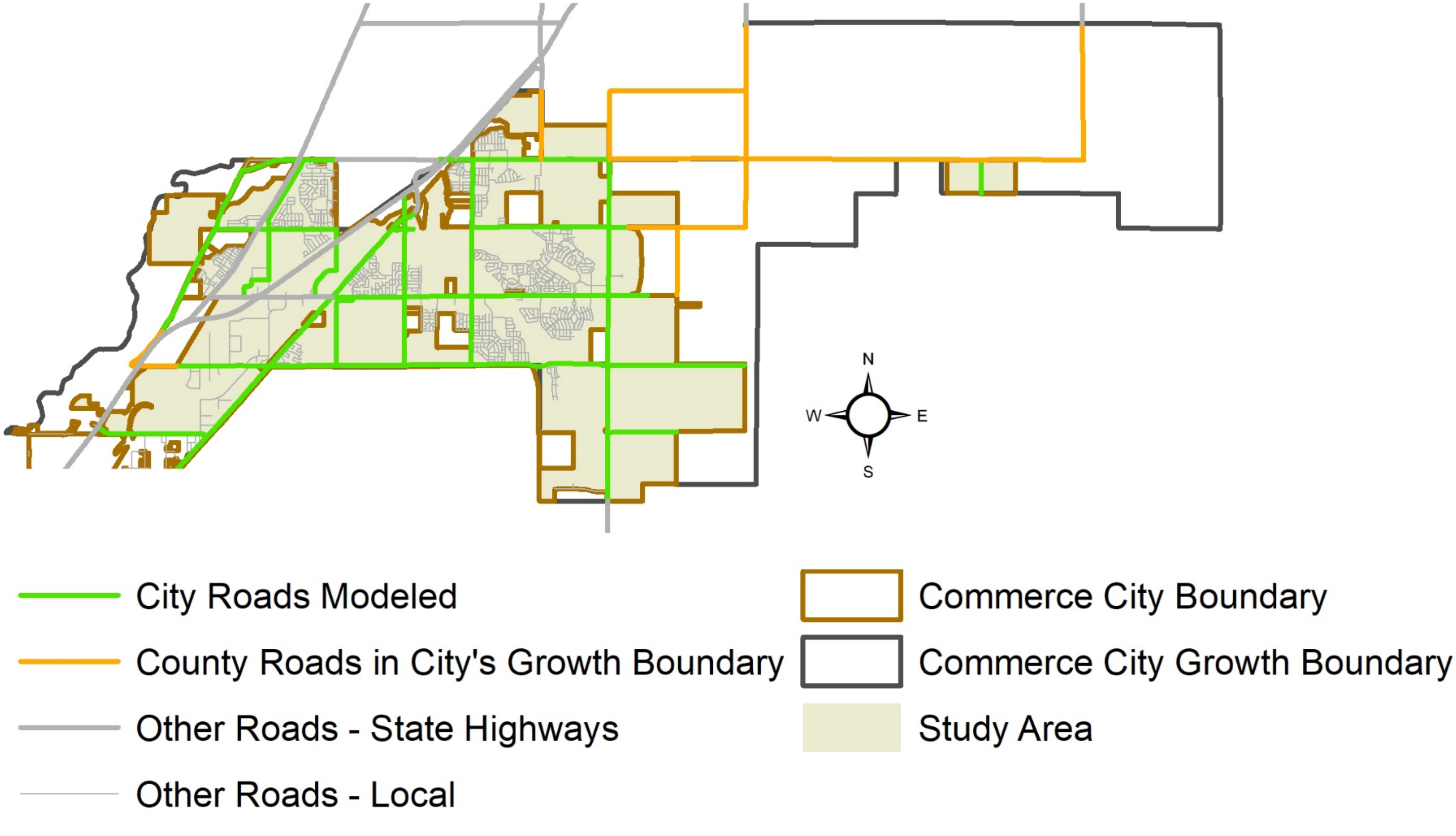
## *Inventory of Study Area Roadways*

The first step in modeling oil and gas travel in Commerce City was to understand the existing conditions of the study area roadways. The Commerce City responsible roads, shown on **Figure 4**, total 52 centerline miles for the study area. The following sections describe data that were collected on this roadway system.

### Surface Conditions

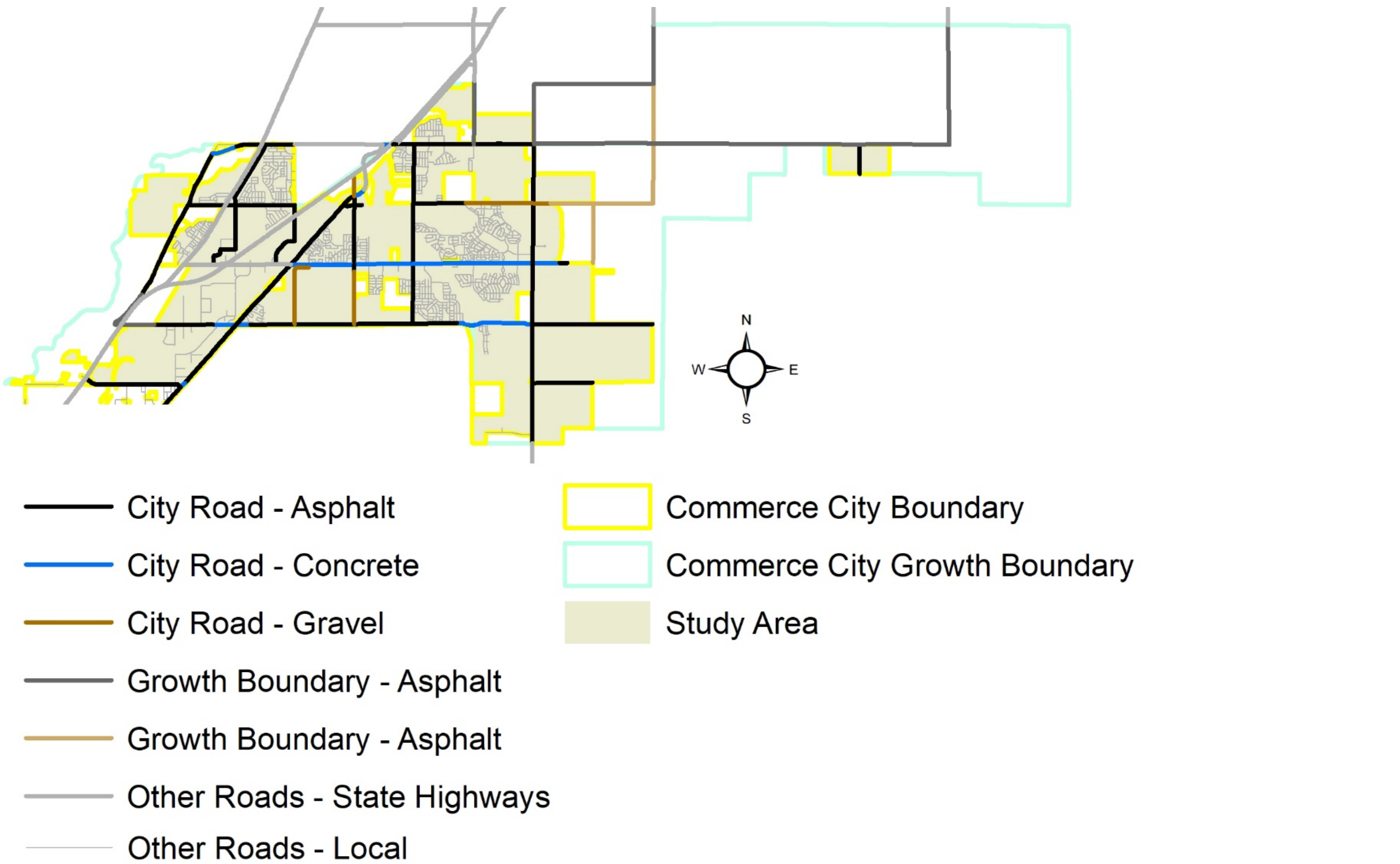
Of the study area roadways, approximately 78.9 percent (by centerline mileage) are asphalt, 13.9 percent are concrete and 7.2 percent are unpaved. **Figure 5** shows the surface type for each of the study area roadways. The surface condition, including the surface type and the remaining service life, 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 "Good", "Satisfactory", "Fair", "Poor", or "Very Poor/Serious/Failed". **Figure 6** displays ratings for each paved study area roadway.

**Figure 4. Study Area Road Network**



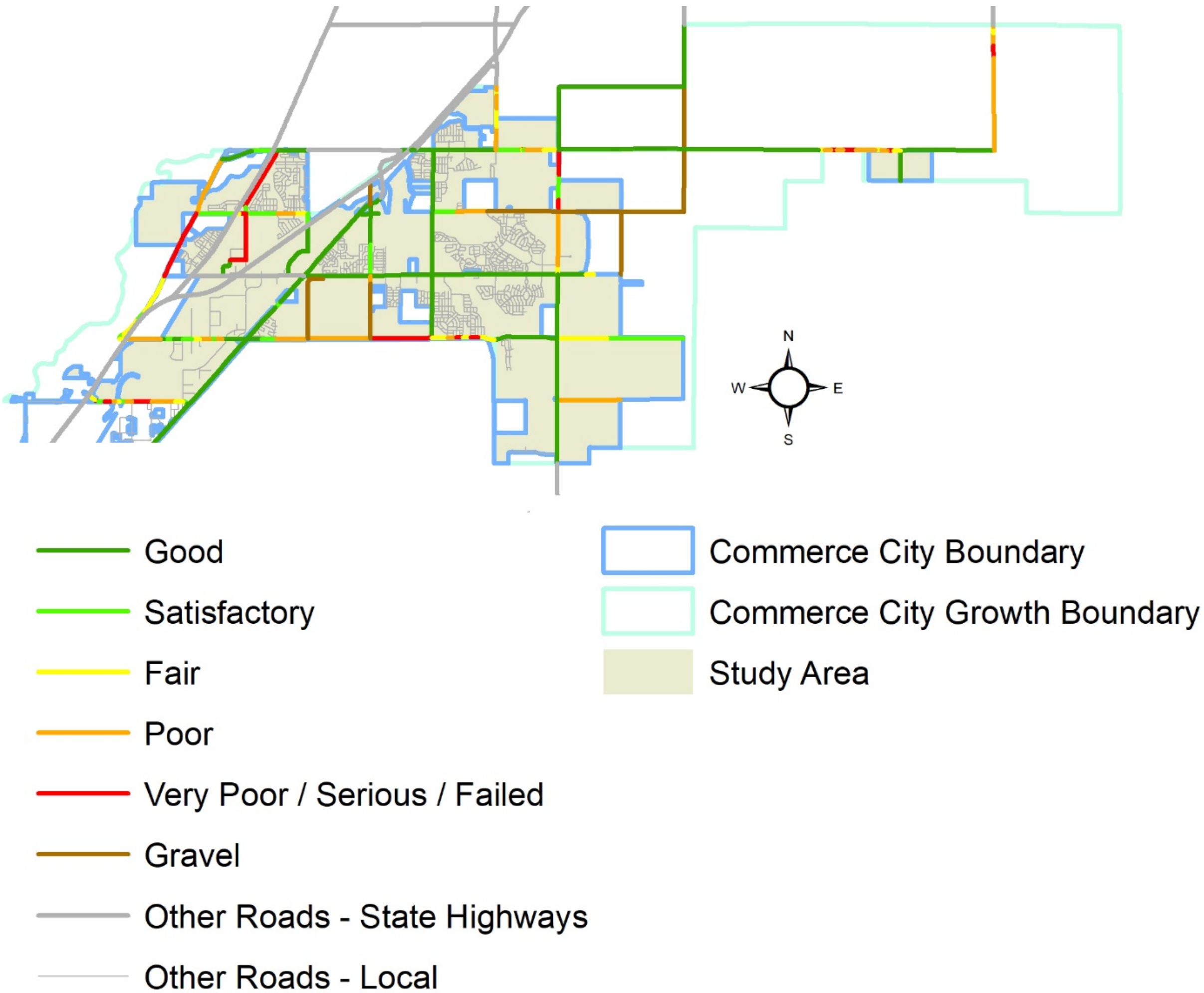

*Sources: CDOT, 2018; Commerce City, 2019*

**Figure 5. Surface Types**




*Sources: CDOT, 2018; Commerce City, 2019*

**Figure 6. Existing Pavement Conditions**




*Sources: CDOT, 2018; Commerce City, 2019*

### Widening

Roadways may need to be widened to accommodate additional traffic. Widening may include additional lanes or wider shoulders provide space for bicyclists separate from the travel lanes. Shoulders also provide safety benefits to all roadway users: they serve as a countermeasure to run-off-road crashes and provide a stopping area for breakdowns or other emergencies.

Because road widening is included in the City's established road impact fee program, this improvement type is part of the trip-based fee element that is being added as part of this study. Thus, road widening was not included as part of the modeling and cost calculation process described at the beginning of this chapter.

### 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. This kind of mitigation is not part of the City's existing road impact fee program, thus it was retained as part of the modeling process.

Existing daily traffic counts on unpaved roads were gathered where available from Commerce City's database, as well as from CDOT, including primarily 2017 and 2018 counts. 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 City staff for reasonableness. **Figure 7** 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 need for enhanced maintenance or the possibility of paving with oil and gas traffic added.

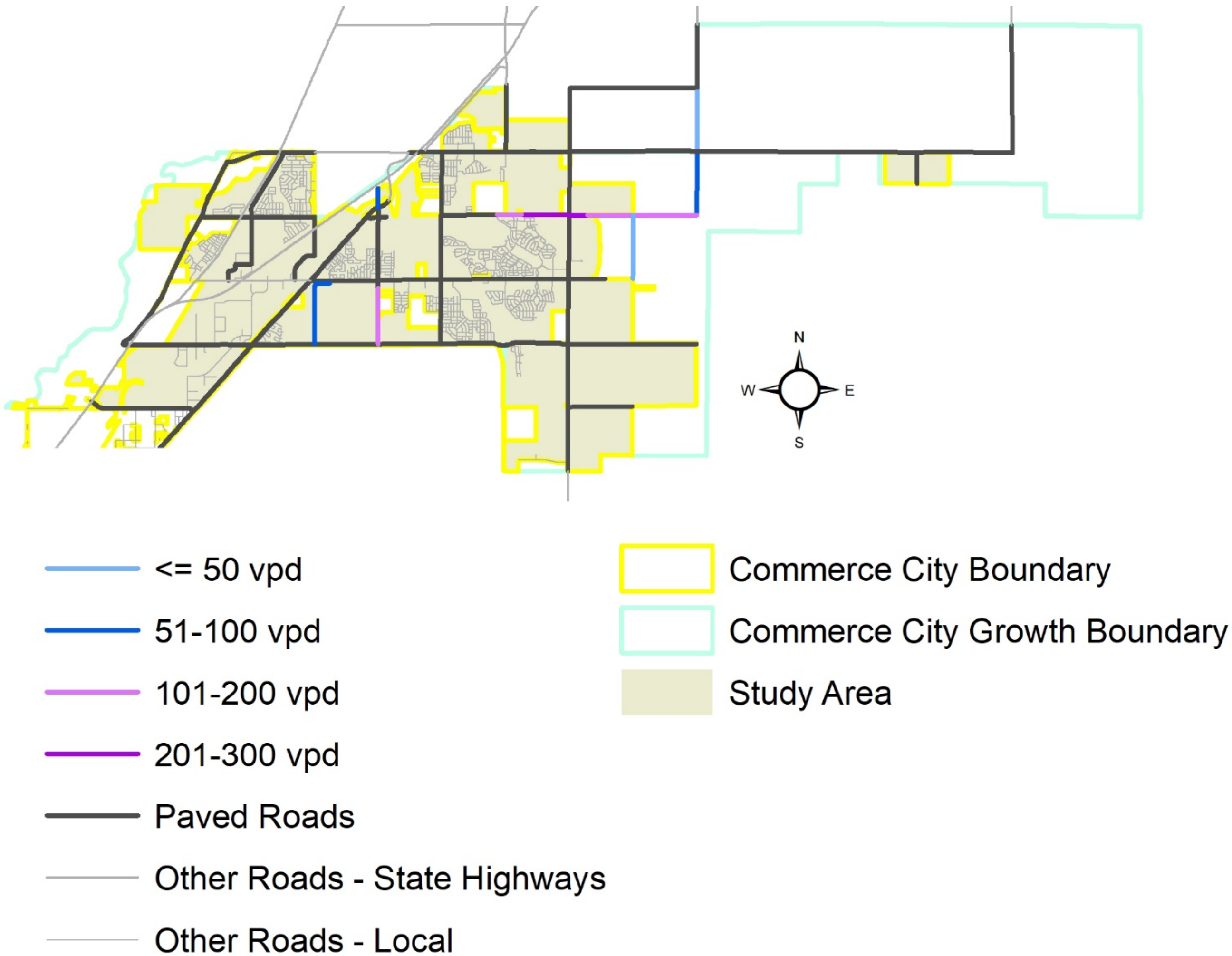
### Other Roadway Characteristics

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.

## *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.

**Figure 7. Vehicles per Day on Unpaved Study Area Roads Receiving Oil & Gas Traffic**




*Sources: CDOT, 2018; Commerce City, 2019*

## Oil and Gas Pads

As noted in **Chapter 2**, the study models a total of 18 pads to estimate impacts, translating into 410 wells. The pad in each pad zone of the model was located in the most open and least developed location outside of the floodway and nearest to a road for access.

## 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. After researching potential water providers and discussions with oil and gas industry representatives, it was determined that the most likely sources for fresh water are South Adams County Water & Sanitation District hydrants and local irrigation ditches. Water for each well was assumed to come from the closest available access to these two sources.

## 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 most located in Weld County, thus 100% of produced water trips were distributed to the north toward Weld County.

## Equipment and Materials

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. Oil and gas development also requires a variety of other materials in addition to water, including gravel, sand, piping, cement, chemicals, and other construction materials. 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.


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

Assumptions were developed based on information summarized above and discussions with oil and gas industry representatives. During the drilling phase, it was assumed that 100% of equipment and materials would come from the north in Weld County. During the completion phase it was assumed that 50% of equipment and material would come from the US 85/104th Avenue vicinity and 50% would come from Weld County.

## Workers

It was assumed that 90% of workers would come from the north and 10% would come from the south.

## 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, predominantly to the north in Weld County. All trips for transporting product were routed to Weld County, since oil and gas handling facilities are likely aligned with the other oil and gas services. Produced water trips during the production phase 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. This Commerce City study added two additional sources from the Texas A&M Transportation Institute (TTI) and input from the Colorado Oil and Gas Association (COGA) to further update trip generation assumptions. **Table 1** provides the estimates from these sources 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. 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 3,138 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 2** illustrates how the availability of water pipelines will affect the total estimated truck trips during the development phase. Note that “Miscellaneous” trips have been folded into the “Completion Rig and Crew” trip type as crew trips based on interpretation of data received from COGA.

### Table 1. National Data on Trip Generation During Pad and Well Development

| Stage | Activity | Machemehl et al. 2016 | NDSU 2014 | RESI 2014 | UDOT 2013 | TTI 2015 | TTI 2016 | COGA 2019 | Average 1 pad, 1 well |
|---|---|---|---|---|---|---|---|---|---|
| Construction | Pad and Road Construction | 80 | 160 | 230 | 1,300 | 260 | 70 | 1,190 | 470 |
| Drilling | Drilling Rig and Crew | - | - | 404 | 306 | 564 | - | 546 | 455 |
| | Drilling Fluid and Materials | - | 150 | 45 | 340 | 26 | 59 | 70 | 115 |
| | Drilling Equipment | 50 | 130 | 45 | 34 | 20 | 54 | 70 | 58 |
| Completion | Completion Rig | - | 6 | 21 | 8 | 10 | - | - | 11 |
| | Completion Equipment | 25 | 30 | 5 | 24 | 26 | - | 290 | 67 |
| | Fracturing Equipment | 125 | 260 | 175 | 166 | 94 | 74 | 86 | 140 |
| | Fracture Water | 1,486 | 900 | 1,346 | 828 | - | 694 | - | 1,051 |
| | Fracture Sand and Chemicals | 200 | 200 | 23 | 166 | 504 | 90 | 263 | 207 |
| | Produced Water Disposal | 594 | 450 | 300 | 828 | 676 | 173 | 122 | 449 |
| Miscellaneous | | - | - | 85 | - | - | - | 144 | 115 |
| **Total Development Trips** | | | | | | | | | **3,138** |

*Sources: Machemal, 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; Texas A&M Transportation Institute, 2015 & 2016, Colorado Oil and Gas Association, 2019*

### Table 2. 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 | 470 | 470 | 470 | 470 |
| Drilling | Drilling Rig and Crew | 456 | 455 | 455 | 455 |
| | Drilling Fluid and Materials | 114 | 115 | 115 | 115 |
| | Drilling Equipment | 58 | 58 | 58 | 58 |
| Completion | Completion Rig and Crew | 126 | 126 | 126 | 126 |
| | Completion Equipment | 67 | 67 | 67 | 67 |
| | Fracturing Equipment | 140 | 140 | 140 | 140 |
| | Fracture Water | 1,051 | - | 1,051 | - |
| | Fracture Sand and Chemicals | 207 | 207 | 207 | 207 |
| | Produced Water Disposal | 449 | 449 | - | - |
| **Total Development Trips** | | **3.138** | **2,087** | **2,689** | **1,638** |

*Source: FHU & BBC, 2017*

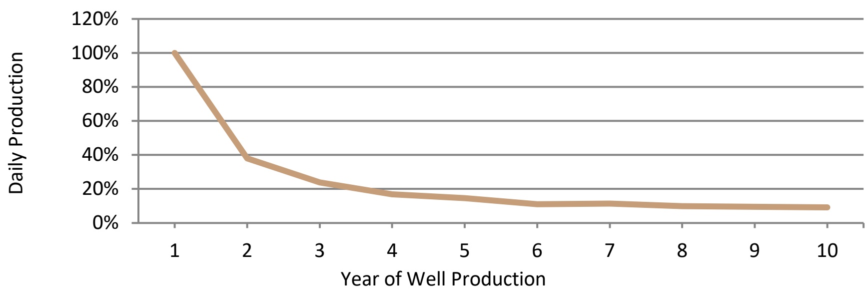
It is important to note that each truck trip reflects a one-way trip, so that all trips to and from the development site are included. This distinction is crucial in subsequent stages of the analysis when, for example, the roadway impacts are examined for a truck that arrives to the development site with a full load of water, but leaves empty. Because of this, trips in **Table 2** and in all tables going forward are rounded to an even number.

## 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 for the oil or gas 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 8** presents the production decline from the Boulder County study.

### Figure 8. 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 1** were used to adapt trip generation estimates from the one-pad, one-well format to the one-pad, 23-well configuration assumed for this study. This scaling 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. It is worth noting that 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 3** presents the trip sensitivity by oil and gas activity.

### Table 3. Trip Sensitivity by Activity

| Stage | Activity | Trip Sensitivity |
|---|---|---|
| Construction | Pad and Road Construction | Pad-Sensitive |
| Drilling | Drilling Rig and Crew | Pad & Well-Sensitive |
| | Drilling Fluid and Materials | Well-Sensitive |
| | Drilling Equipment | Well-Sensitive |
| Completion | Completion Rig and Crew | Pad & Well-Sensitive |
| | Completion Equipment | Pad-Sensitive |
| | Fracturing Equipment | Pad-Sensitive |
| | Fracture Water | Well-Sensitive |
| | Fracture Sand and Chemicals | Well-Sensitive |
| | Produced Water Disposal | Well-Sensitive |
| **Total Development Trips (one-time)** | | **Varies** |
| **Total Production Trips (annual)** | | **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 pad based on the availability of pipelines. The activity-based number of trips for the 23-well pad configurations are displayed in **Table 4** for pads with no pipelines, as well as trips for pads 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 Commerce City's road network. Development phase trips for a 23-well pad range from as high as 49,998 with no pipelines to 16,096 with all three pipeline types. Production phase trips range from as high as 16,790 annually with no pipelines to 8,396 with all three pipelines.

### Table 4. Trip Generation Estimates for 23-Well Pad with Various Pipeline Scenarios

| Activity | Trips | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No Pipelines | Fresh Water Pipelines | Produced Water Pipelines | Fresh & Produced Water Pipelines | Product Pipelines | Fresh Water & Product Pipelines | Produced Water & Product Pipelines | Fresh Water, Produced Water, & Product Pipelines |
| Construction Stage | | | | | | | | |
| Pad and Road Construction | 470 | 470 | 470 | 470 | 470 | 470 | 470 | 470 |
| Drilling Stage | | | | | | | | |
| Drilling Rig and Crew | 3,448 | 3,448 | 3,448 | 3,448 | 3,448 | 3,448 | 3,448 | 3,448 |
| Drilling Fluid and Materials | 2,622 | 2,622 | 2,622 | 2,622 | 2,622 | 2,622 | 2,622 | 2,622 |
| Drilling Equipment | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 |
| Completion Stage | | | | | | | | |
| Completion Rig and Crew | 2,634 | 2,634 | 2,634 | 2,634 | 2,634 | 2,634 | 2,634 | 2,634 |
| Completion Equipment | 66 | 66 | 66 | 66 | 66 | 66 | 66 | 66 |
| Fracturing Equipment | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 |
| Fracture Water | 23,552 | 0 | 23,552 | 0 | 23,552 | 0 | 23,552 | 0 |
| Fracture Sand and Chemicals | 5,382 | 5,382 | 5,382 | 5,382 | 5,382 | 5,382 | 5,382 | 5,382 |
| Produced Water Disposal | 10,350 | 10,350 | 0 | 0 | 10,350 | 10,350 | 0 | 0 |
| **Total Development Trips (one-time)** | **49,998** | **26,446** | **39,648** | **16,096** | **49,998** | **26,446** | **39,648** | **16,096** |
| **Total Production Trips (annual)** | **16,790** | **16,790** | **13,180** | **13,180** | **12,006** | **12,006** | **8,396** | **8,396** |

## 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 5** 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 5. 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 8,000 (typical water tanker) to 23,000 (specialized vehicle) times that of a passenger car on an asphalt road depending on truck configurations. To account for the load impacts, ESALs for each truck type listed in **Table 5** 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 6** 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 9** (flexible surfaces) and **Figure 10** (rigid surfaces).

### Table 6. 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 9. Flexible Pavement ESAL Equation

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

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

$L_x$ = axle load being evaluated (kips)

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

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

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

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

SN = structural number

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

*Source: Pavement Interactive, 2009*

## Figure 10. 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, EIS studies from La Plata County in Colorado and the United States Department of the Interior's Bureau of Land Management (BLM) in Utah, and data provided by COGA. 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 7** 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 7. 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 |

*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; Colorado Oil and Gas Association, 2019*

## *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 earlier in this chapter. Trips to/from the north were primarily routed to US 85 to travel north to Weld County. The decision as to which road to use was determined by the model during trip assignment, which is described below. No trips were assigned to E-470 based on industry representative comments that the tollway is generally not a preferred route for industry trips.

### 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 Commerce City to account for real-world connectivity needed to facilitate the distribution of origins and destinations, some of which exist outside of Commerce City. As noted above, E-470 was excluded from the modeling process.

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.

## *Model Results*

Results from each model (trips and ESALs, development and production phases) were exported into a spreadsheet to be assessed for impacts, namely overlay and reconstruction needs. 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. STAKEHOLDER ENGAGEMENT

The City provided opportunities for the oil and gas industry and general public to hear about the transportation impact study process, ask questions, and comment on the proposed methodology and assumptions.

An industry stakeholder meeting held on May 10, 2019 was attended by representatives from the Colorado Oil & Gas Association, Colorado Petroleum Council, and oil & gas companies active in the City. A public open house held on May 23, 2019 was attended by approximately 20 individuals. Verbal and written comments received have been considered in developing the draft study for presentation to the Planning Commission and City Council.

The proposed impact fee was also advertised to the community via social media and newsletter communications.

# 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 City 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 City 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 City provided the pavement rating (PCI) for all paved City-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).

### 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 ESALs (non-oil and gas 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 City, for each study area asphalt roadway. The existing serviceability is interpolated based on the PCI and values shown in **Figure 11**. The values shown in **Table 8** are based on industry standards and input from the City 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 12**.

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 C**.

## Figure 11. Pavement Condition Assumptions

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

*Source: Commerce City, 2019*

## Table 8. 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 | 2,190,000 | 90 | -1.645 | 3,500 psi | 4.5 | 2.5 | 0.44 | 0.35 |
| Minor Arterial | 1,642,500 | 90 | -1.282 | 3,500 psi | 4.5 | 2.5 | 0.44 | 0.35 |
| Major Collector | 949,000 | 85 | -1.037 | 3,500 psi | 4.5 | 2.5 | 0.44 | 0.35 |
| Local Industrial | 730,000 | 85 | -1.037 | 3,500 psi | 4.5 | 2.0 | 0.44 | 0.35 |

*Source: Commerce City, 2019*

## Figure 12. 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*

### Failing Asphalt Methodology

When heavy truck traffic (like that associated with oil and gas activity) uses an asphalt road with a PCI rating below 40 ("Very Poor"), it can expedite or even immediately warrant the need to reconstruct it. To capture this potentially immediate high cost, the study analyzed any "Very Poor" condition asphalt road used by oil and gas traffic in the model to determine if reconstruction was more cost effective than overlay when looking at the cumulative costs of the development phase and 10 years of production.

If reconstruction was determined to be more cost effective, 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. A summary of mitigation unit costs used in this study is available in **Appendix C**. This special analysis of "Very 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.

In many cases, reconstruction is less expensive than additional overlays that would be needed for the oil and gas industry use of roads in "Very Poor" condition. However, there were scenarios where added overlay remained more cost effective. City staff noted that this blended approach to recovering costs associated with potential use of "Very Poor" roads is also more representative of real-world considerations for maintaining these kinds of roads in the City.

The blended "Very Poor" road mitigation approach is noted in subsequent cost and fee tables to highlight which scenarios used reconstruction of "Very Poor" roads versus calculating the offsetting overlay when developing the associated fee.

### 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 8**.

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 C**.

## *Unpaved Road Analysis*

The increase in maintenance and rehabilitation costs is 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 18 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 18 pads and their wells evenly over the 10-year study period would not account for annual fluctuations that could result in substantially more pads being developed, consequently underestimating needs that could occur during peaks in development. Furthermore, development is unlikely to occur evenly throughout the study area, 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 multiplied by the number of estimated development periods it would take to develop all 18 pad sites and their wells at a pace greater than an evenly spaced average but lower than all at once. A pace equivalent to developing all pads and their wells in any given area over a 4-year period was selected, as this pace represents a peak condition observed for areas in Weld County in the past five years. This selected pace 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 9** 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 C**. 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 9. 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<br>$3,619.60 per mile for subsequent years |
| **≥ 300** | New Gravel | 1/12 years | $100,000 per mile |

*Source: Commerce City, 2019*

### 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 of the triggering phase – a similar concept to reconstructing very 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.

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 that would be analyzed for overlay needs. This assumption of paving does not commit the City to pave the unpaved road, but does allow it 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.  A summary of mitigation unit costs used in this study is provided in **Appendix C**.

# 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 Commerce City'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 City can be as proactive as possible in offsetting impacts. This is accomplished through oil and gas roadway impact fees.

In designing oil and gas roadway impact fees, it is critical to isolate the oil and gas damage on the City's roads. Because the City already has an impact fee to address road widening two fee methodologies were used in this study. Road deterioration related fees are designed to recoup the cost to the City associated with ESAL-based and gravel maintenance related impacts as estimated in this study, and are expressed as per pad and per well fees. Other trip-based related fees covered by the City's existing road impact fee are designed using the current road impact fee costs per daily trip applied to oil and gas activity. **Table 10** outlines which mitigation activities are covered by each fee methodology.

### Table 10. Oil & Gas Impact Fee Methods by Mitigation Activity

| Mitigation Activity | Fee Calculation Method |
|---|---|
| Asphalt Overlay | ESAL-Based Average Cost per Pad & per Well (**Figure 14** illustrates this calculation) |
| Gravel Maintenance and Paving Gravel Roads | Trip-Based Average Cost per Pad & Well |
| Roadway Widening | Existing Road Impact Fee Cost per Trip applied to Oil & Gas activity |

Both fees are combined to form one fee schedule, which is explained later in this chapter. The following subsections further describe the two methodologies and the calculations conducted for each.

## *Road Deterioration Based Fee*

### Road Deterioration Component Costs

The roadway deterioration impact costs were calculated by applying the cost assumptions described in **Chapter 5** with the modeling of impacts for the development of 410 wells on 18 pads and aggregated for the whole study area. The average per-pad and per-well costs were calculated by dividing these roadway costs by the number of pads (18) and number of wells (410) modeled.

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.

**Table 11** provides the total roadway deterioration impact costs associated with development of the 18 pads, 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, and documents the analysis using both the reconstruction of "Very Poor" condition roads method versus the overlay method for these roads.

**Table 11. Impact Costs for Oil and Gas Development and Production without Pipelines (2019$)**

| | Study Area |
|---|---|
| Total Pads | 18 |
| Wells per Pad | 23 |
| ***Reconstruction Method for "Very Poor" Condition Roads*** | |
| *Development Phase* | |
| Asphalt Overlay | $732,300 |
| Concrete Reconstruction | $36,300 |
| Gravel Maintenance | $76,400 |
| Paving Gravel Roads | $263,000 |
| Very Poor Road Reconstruction | $2,201,900 |
| *Production Phase (10-years)* | |
| Asphalt Overlay | $4,927,000 |
| Concrete Reconstruction | $161,000 |
| Gravel Maintenance | $0 |
| Paving Gravel Roads | $0 |
| Very Poor Road Reconstruction | $0 |
| Total Costs | $8,397,900 |
| Cost per Modeled 23-Well Pad | $466,550 |
| ***Overlay Method for "Very Poor" Condition Roads*** | |
| *Development Phase* | |
| Asphalt Overlay | $1,228,300 |
| Concrete Reconstruction | $36,300 |
| Gravel Maintenance | $76,400 |
| Paving Gravel Roads | $263,000 |
| Very Poor Road Reconstruction | $0 |
| *Production Phase (10-years)* | |
| Asphalt Overlay | $7,693,000 |
| Concrete Reconstruction | $161,000 |
| Gravel Maintenance | $0 |
| Paving Gravel Roads | $0 |
| Very Poor Road Reconstruction | $0 |
| Total Costs | $9,458,000 |
| Cost per Modeled 23-Well Pad | $525,444 |

When looking at the development and production phases combined, the breakdowns show that Asphalt Overlay and Very Poor Road Reconstruction account for a large majority of the total costs. Concrete Reconstruction, Gravel Maintenance, and Paving Gravel Roads account for relatively small proportions of the total fee. When the reconstruction method is used for roads in very poor condition (as in the top portion of the table), that category generates more than $2 million in costs, but with the overlay method (bottom portion of the table) increases in Asphalt Overlay costs cause the total cost to increase. Therefore, the reconstruction method is used for this no-pipeline scenario as the lower cost method

The same costs associated with implementing pipelines for all fresh and produced water, as well as product, are similarly displayed in **Table 12**. This table shows that the overlay method for very poor condition roads is the lower cost method for this scenario.

**Table 12. Impact Costs for Oil and Gas Development and Production with Fresh Water, Produced Water, and Product Pipelines (2019$)**

| | Study Area |
|---|---|
| Total Pads | 18 |
| Wells per Pad | 23 |
| ***Reconstruction Method for "Very Poor" Condition Roads*** | |
| *Development Phase* | |
| Asphalt Overlay | $419,600 |
| Concrete Reconstruction | $16,500 |
| Gravel Maintenance | $28,600 |
| Paving Gravel Roads | $0 |
| Very Poor Road Reconstruction | $2,201,900 |
| *Production Phase (10-years)* | |
| Asphalt Overlay | $7,000 |
| Concrete Reconstruction | $1,000 |
| Gravel Maintenance | $0 |
| Paving Gravel Roads | $0 |
| Very Poor Road Reconstruction | $0 |
| Total Costs | $2,674,600 |
| Cost per Modeled 23-Well Pad | $148,589 |
| ***Overlay Method for "Very Poor" Condition Roads*** | |
| *Development Phase* | |
| Asphalt Overlay | $719,000 |
| Concrete Reconstruction | $16,500 |
| Gravel Maintenance | $28,600 |
| Paving Gravel Roads | $0 |
| Very Poor Road Reconstruction | $0 |
| *Production Phase (10-years)* | |
| Asphalt Overlay | $11,000 |
| Concrete Reconstruction | $1,000 |
| Gravel Maintenance | $0 |
| Paving Gravel Roads | $0 |
| Very Poor Road Reconstruction | $0 |
| Total Costs | $776,100 |
| Cost per Modeled 23-Well Pad | $43,117 |

## Calculating the Road Deterioration Fee Component

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. A relatively small percentage of all costs associated with developing a multi-well pad is attributable to pad construction based on that activity's ESAL generation, and the majority of costs are attributed to the well development. All production costs are associated with the well fee. **Figure 13** illustrates this process.

## Figure 13. Road Deterioration Based Fee Calculation Methodology

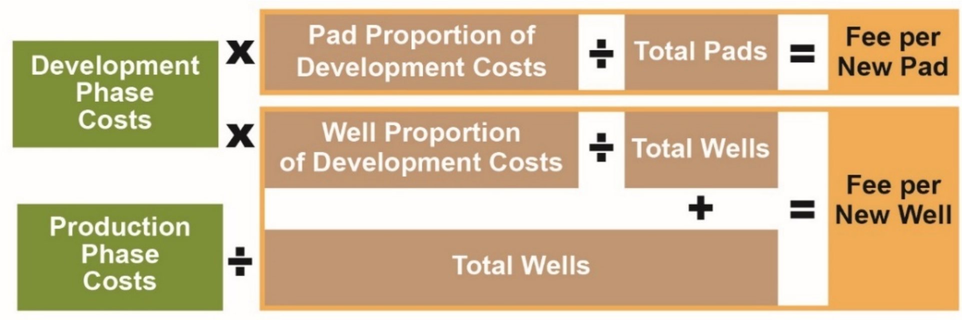



**Table 13** presents the calculated impact fees, which are the average impact costs associated with pad construction and well development, and the 10-year cumulative impact costs of well production. The table splits the impact fees between phases (development versus ten years of production), boundary (full study area versus the three districts), pipeline scenario, and per-pad versus per-well fee. Fees in red use the overlay method rather than the reconstruction method for impacts to "Very Poor" roads.

## Table 13. Full Oil and Gas Road Deterioration Impact Fee Schedule Options (2019$)

| Pipeline Scenario | | | Fee Type | Study Area |
|---|---|---|---|---|
| Fresh Water Pipeline | Produced Water Pipeline | Product Pipeline | | Roadway Deterioration Impact Fees |
| | | | | *Per Pad Fees* |
| n/a | n/a | n/a | **Pad Fee (D)** | **$891** |
| | | | | *Per Well Fees* |
| - | - | - | Well Fee (D) | $7,915 |
| | | | Well Fee (P) | $12,290 |
| | | | **Total Well Fee** | **$20,205** |
| ✓ | - | - | Well Fee (D) | $7,138 |
| | | | Well Fee (P) | $12,290 |
| | | | **Total Well Fee** | **$19,428** |
| - | - | ✓ | Well Fee (D) | $3,836 |
| | | | Well Fee (P) | $9,311 |
| | | | **Total Well Fee** | **$13,147** |
| - | ✓ | - | Well Fee (D) | $2,822 |
| | | | Well Fee (P) | $9,689 |
| | | | **Total Well Fee** | **$12,511** |
| ✓ | - | ✓ | Well Fee (D) | $2,822 |
| | | | Well Fee (P) | $9,311 |
| | | | **Total Well Fee** | **$12,132** |
| ✓ | ✓ | - | Well Fee (D) | $1,807 |
| | | | Well Fee (P) | $9,689 |
| | | | **Total Well Fee** | **$11,496** |
| - | ✓ | ✓ | Well Fee (D) | $2,822 |
| | | | Well Fee (P) | $29 |
| | | | **Total Well Fee** | **$2,850** |
| ✓ | ✓ | ✓ | Well Fee (D) | $1,807 |
| | | | Well Fee (P) | $29 |
| | | | **Total Well Fee** | **$1,836** |

(D) = Development Phase
(P) = Production Phase
$xx,xxx = Uses overlay method rather than reconstruction method for "Very Poor" condition roads because it is more cost effective

**Table 14** summarizes the resulting maximum defensible road deterioration fee structure – total fees by pipeline scenario.

### Table 14. Maximum Oil and Gas Road Deterioration Impact Fee Schedule (2019$)

| Pipeline Scenario | | | Study Area |
|---|---|---|---|
| Fresh Water Pipeline | Produced Water Pipeline | Product Pipeline | |
| | | | *Per Pad Fees* |
| n/a | n/a | n/a | $891 |
| | | | *Per Well Fees* |
| - | - | - | $20,205 |
| ✓ | - | - | $19,428 |
| - | - | ✓ | $13,147 |
| - | ✓ | - | $12,511 |
| ✓ | - | ✓ | $12,132 |
| ✓ | ✓ | - | $11,496 |
| - | ✓ | ✓ | $2,850 |
| ✓ | ✓ | ✓ | $1,836 |

## *Vehicle-Mile-Based Fee*

Two road improvement needs generated by oil and gas traffic are tied more to traffic volumes than to road damage caused by vehicle loads:

- Adding shoulders to paved roads with no or substandard shoulders as a multi-modal safety measure for roads with increased truck traffic due to oil and gas activity.
- Widening of paved roads to increase traffic carrying capacity.

In contrast to asphalt and concrete repaving and enhanced gravel maintenance costs that make up a majority of the oil and gas impact fee calculations, these shoulder and road widening improvements are also included in the types of improvements that are the focus of the Road Impact Fees that Commerce City currently assesses on all new development.

Based on these characteristics, Commerce City is adopting a method to account for these improvements in the oil and gas impact fees that uses the City's current Road Impact Fee rate and applies oil and gas vehicle miles of travel (VMT) to that rate. This method is used to calculate the oil and gas fee component to address shoulder improvements and road widening. This fee component is added to the ESAL-based fees being developed for overlays, road reconstruction and gravel road maintenance.

### Calculating the Vehicle-Mile-Based Fee Component

This section documents calculations to use the existing road impact fee methodology for developing the trip-based fee component for road widening including shoulder improvements.

## Daily Trips

The first step is to calculate the average daily trips generated per pad and per well. **Table 15** shows these calculations based on trip generation rates provided in **Chapter 3**. Trips that occur during the early development phase for a well or pad are spread over a 10-year period to derive average daily trips.

### Table 15. Average Daily Trips Per Well and Per Pad

| | Total Trips | Days in 10-Year Time Frame | Average Daily Trips |
|---|---|---|---|
| ***Per Pad*** | | | |
| Development Phase | 1,008 | 3,650 | 0.28 |
| Production Phase | n/a | n/a | 0 |
| Total | | | 0.28 |
| ***Per Well*** | | | |
| Development Phase | 2,130 | 3,650 | 0.58 |
| Production Phase | n/a | n/a | 2.0 |
| Total | | | 2.58 |

## Passenger Car Equivalents

Due to their size, each heavy truck has an elevated impact on the need for shoulder improvements or paving of gravel roads. The *Highway Capacity Manual (HCM)*, published by the Transportation Research Board, provides a national standard for the analysis of operations on roadway. The HCM defines a concept of Passenger Car Equivalents (PCE) and trucks are assigned a 1.9 PCE on level terrain for two-lane roads. Oil and gas trip generation analysis shows that approximately 57% of trips generated are trucks. With 57% of vehicles at a PCE of 1.9 the average PCE for all oil and gas trips is approximately 1.5.

## Primary Trips

Defining "primary" daily trips is a concept used in developing Commerce City's and many road impact fees. Trips generated by some land uses start or end at another Commerce City impact fee-generating use, so the trip generation by those uses is reduced to avoid double charging for the same trip at both ends. For a large majority of trips generated by oil and gas wells, the other end of the trip is not at a fee-generating Commerce City land use, so 100% of oil and gas trips are considered as primary trips.

## Fee Calculation

The City's current road impact fee charged for residential, commercial, office and industrial development equates to $250 per primary daily trip. Using this cost/trip and the values noted in **Table 15**, **Table 16** provides the calculated fees per pad and per well for this fee component.

### Table 16. Trip-Based Fee Component Calculation

| | Factor | Value |
|---|---|---|
| ***Per Pad*** | | |
| Daily Trips | | 0.28 trips |
| Passenger Car Equivalent | 1.5 PCE | 0.42 trips |
| Fee | $250 / Trip | $105 fee |
| ***Per Well*** | | |
| Daily Trips | | 2.58 trips |
| Passenger Car Equivalent | 1.5 PCE | 3.87 trips |
| Fee | $250 / Trip | $967 fee |

These fees apply to wells with no pipelines. **Table 17** shows the trip base fees accounting for reduced trip levels with different pipelines.

### Table 17. Trip-Based Fee Component Fee Schedule (2019$)

| Pipeline Scenario | | | |
|---|---|---|---|
| Fresh Water Pipeline | Produced Water Pipeline | Product Pipeline | Study Area |
| | | | *Per Pad Fees* |
| n/a | n/a | n/a | $105 |
| | | | *Per Well Fees* |
| - | - | - | $967 |
| ✓ | - | - | $832 |
| - | - | ✓ | $706 |
| - | ✓ | - | $706 |
| ✓ | - | ✓ | $571 |
| ✓ | ✓ | - | $571 |
| - | ✓ | ✓ | $445 |
| ✓ | ✓ | ✓ | $309 |

## *Combined Fee*

To make applying the two fees simpler, they have been combined in **Table 18** by adding the VMT-based fee per pad and per well from **Table 16** with the fee schedule laid out in **Table 14**.

### Table 18. Combined Maximum Oil and Gas Roadway Impact Fee Schedule (2019$)

| Pipeline Scenario | | | |
|---|---|---|---|
| Fresh Water Pipeline | Produced Water Pipeline | Product Pipeline | Study Area |
| | | | *Per Pad Fees* |
| n/a | n/a | n/a | $996 |
| | | | *Per Well Fees* |
| - | - | - | $21,172 |
| ✓ | - | - | $20,260 |
| - | - | ✓ | $13,853 |
| - | ✓ | - | $13,217 |
| ✓ | - | ✓ | $12,703 |
| ✓ | ✓ | - | $12,067 |
| - | ✓ | ✓ | $3,295 |
| ✓ | ✓ | ✓ | $2,145 |

### *Per-ESAL Fee for Independent Fee Studies*

It is anticipated that the enabling ordinance for the oil and gas impact fee will allow development applicants to conduct an independent fee study if they meet specific criteria. In doing so, they may be required to use an average per-ESAL fee derived from this study's methodology. A $2.71 average fee per ESAL was calculated by taking the road deterioration fees shown in **Table 14** divided by the ESALs generated by a pad and well. The trip-based fees in **Table 16** are to be applied separately.

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# APPENDIX B. OTHER TRAVEL MODEL ASSUMPTIONS

| Assumption | Reasoning / Notes |
|---|---|
| Roads from adjacent areas were included in the model but not assessed for impacts | ▸ Origins/destinations outside of Commerce City were programmed at actual locations of where facilities are located |
| Speed limits were acquired from a Commerce City GIS shapefile and using Google StreetView | ▸ Road segments received nearest signed speed<br>▸ Major paved roads were validated/acquired via Google StreetView<br>▸ Finding speeds for each road segment, specifically minor local roads, would have had a low benefit/cost ratio<br>▸ Gravel roads do not have a posted speed limit; generalized speeds were used |
| 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<br>▸ 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<br>▸ Delay reduction from turn lanes would be low in comparison to the total trip time |
| 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<br>▸ The analysis for this study was only concerned with pads developing in incorporated portions of the City<br>▸ 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<br>▸ Major roads would be most suitable for travel<br>▸ 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<br>▸ Multiple free comparable travel paths are available<br>▸ Transporters are toll-averse and way to estimate the percentage of trips that would be will to use is not feasible |
| 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 City's road network regardless of where and when a pad develops<br>▸ 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 City 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 |

# APPENDIX C. MITIGATION UNIT COSTS SUMMARY

The following unit costs were developed in coordination with Commerce City staff using available data in conjunction with CDOT costs. These are generalized planning-level costs that incorporate standard values used by the City 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 |
| **Paving gravel roads** | $30,000 | Per lane, per mile | Assumes using existing gravel as base |
| **Grading** | $350 | Per mile | 1 every 2 months |
| **Gravel** | $45,000 | Per mile | Applied every 7 years |
| **Dust Suppressant** | $9,000 | Per mile | 1 per year |

*Source: Commerce City, 2019*

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