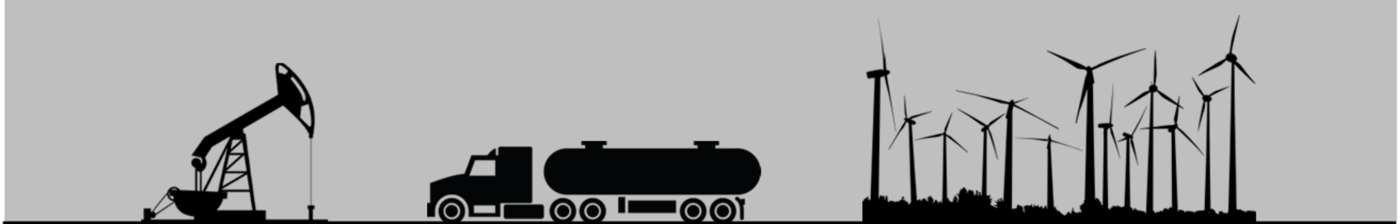
Truck Axle Weight Distributions

Implementation Report IR-16-02



Prepared for Texas Department of Transportation
Maintenance Division

Prepared by
Texas A&M Transportation Institute

Cesar Quiroga
Senior Research Fellow

Jing Li
Assistant Research Engineer

Jerry Le
Software Applications Developer

TxDOT Contract No. 47-4PV1A007

TTI Contract No. 409186

July, 2016

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

INTRODUCTION

Energy developments that rely on horizontal drilling and hydraulic fracturing (also called fracking) technologies generate enormous amounts of truck traffic on state, county, and local roads. Quantifying the number of truck trips and resulting 18-kip equivalent single axle loads (ESALs) associated with the development and operation of oil and gas wells is a critical requirement for designing and maintaining pavement structures on energy sector roads.

This report describes a methodology to characterize axle weight distributions for estimating ESALs based on data obtained from the network of permanent weigh-in-motion (WIM) stations that TxDOT operates. Deploying portable WIM systems in the immediate vicinity of a well under development was not technically or financially feasible. For this reason, an indirect approach was implemented, which relied on WIM readings from the network of permanent WIM stations along major TxDOT corridors and concurrent video data collection at the WIM station locations. The analysis involved using more than 50,000 sample trucks that were captured via video screenshots and their corresponding WIM readings to develop aggregated axle weight distributions at 1,000-lb intervals. For additional information on how to use axle weight distribution data, refer to Implementation Report IR-16-03 and Energy Sector Brief ESB-16-08.

VIDEO DATA COLLECTION AND WIM DATA MATCHING

TxDOT collects data from approximately 1,148 permanent stations in Texas for a number of data collection programs that collect vehicle volume, vehicle classification, and vehicle weight data. Of these, 41 permanent stations collect WIM data, either using bending plate or piezo sensors. These sensors are deployed at 20 TxDOT districts.

Texas A&M Transportation Institute (TTI) researchers analyzed data from four WIM stations (PZ-502, W-531, W-533, and W-535), which are located in areas of active energy development activity (Figure 1). To further understand what types of trucks normally drive in energy development areas, and how these trucks are different from the overall truck population, TTI also collected video data at these four WIM stations and then matched samples of trucks to existing WIM data records. The analysis involved using more than 50,000 sample trucks that were captured via video screenshots and their corresponding WIM readings. The focus of the analysis was the following truck types that are commonly used in the energy sector: dump trucks, drilling rig trucks, flatbed trucks, equipment trucks, water trucks, sand trucks, crude oil trucks, gasoline trucks, and liquefied natural gas trucks.

To assist in the video/WIM data matching and analysis, TTI developed a standalone program in C# to play back video files, identify trucks of interest and generate snapshots, select WIM records from a Microsoft Access database, and generate a record to document the match between snapshots and WIM records. Figure 2 provides a view of the graphical user interface.

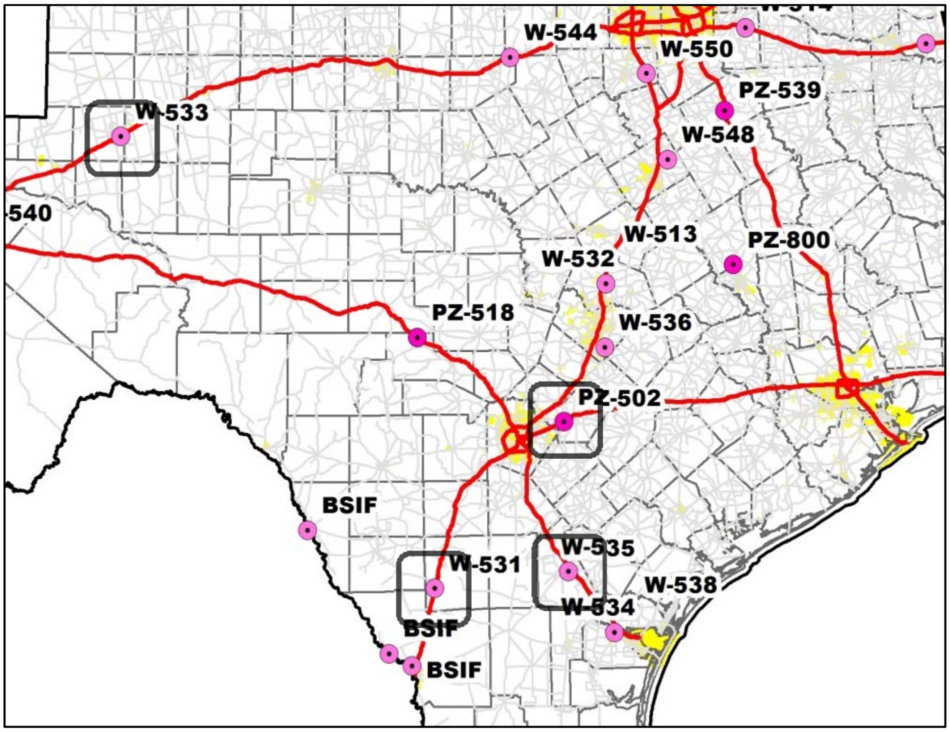


Figure 1. Locations of 4 WIM Stations for Video Data Collection.

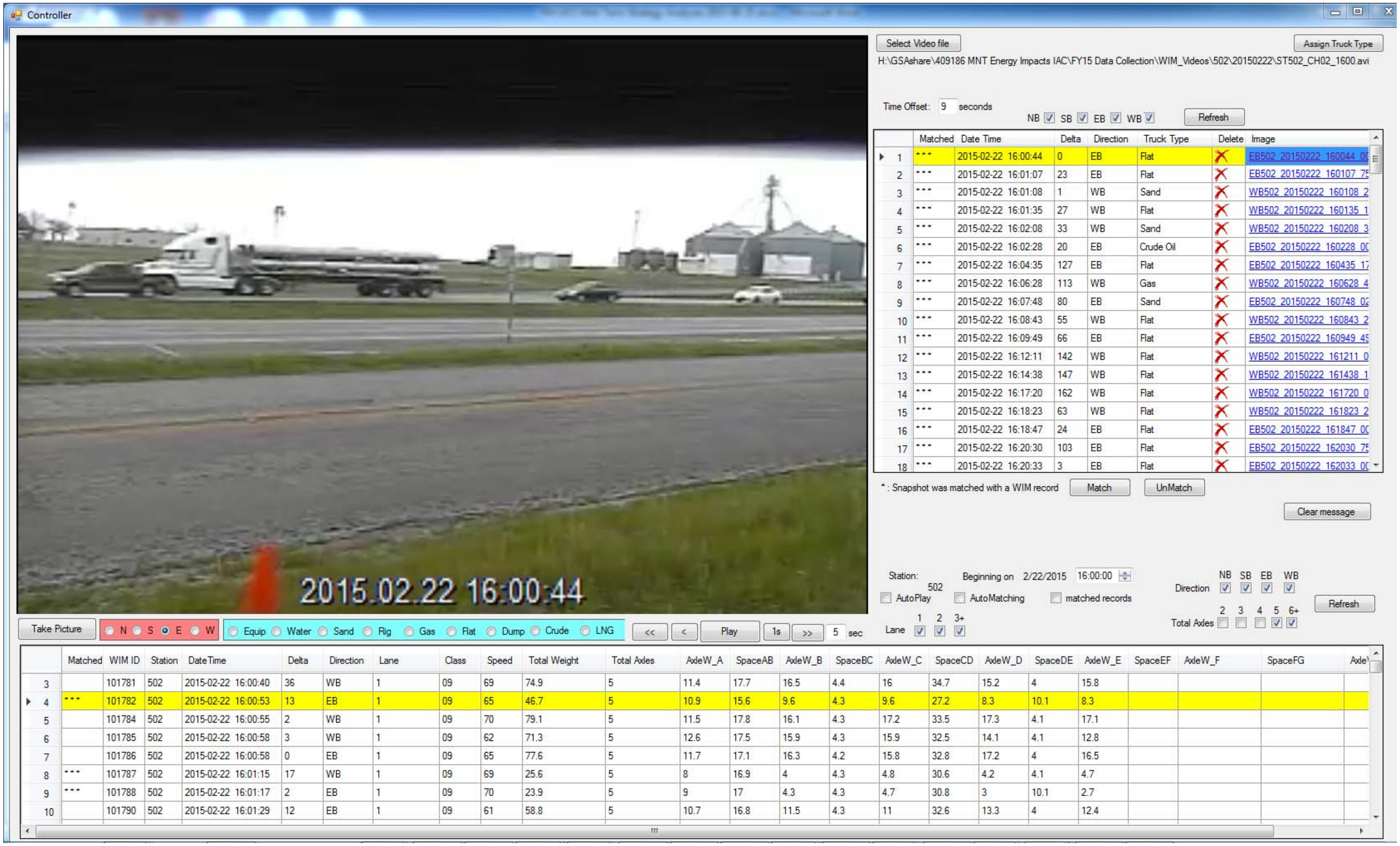


Figure 2. User Interface of WIM Data Processing Application.

TRUCK WEIGHT DISTRIBUTIONS

TTI researchers processed 54,249 WIM records, as summarized in Table 1. In general, although the video cameras collected video data continuously while the cameras were deployed in the field (roughly two weeks per location), the cameras did not have night vision capabilities. In effect, only video data collected during daylight hours were usable. Overall, the focus was trucks with five axles or more fitting the truck types listed in Table 1. Regular tractor-trailer five-axle trucks (i.e., regular "eighteen wheelers") were not analyzed. Trucks were fewer than five axles were also not analyzed.

Table 1. Overview of WIM Data Processing.

Truck Type	Number of Records Process at WIM Stations				
	502	**531**	**533**	**535**	**Total**
5-axle dump truck	946	799	2,342	214	**4,301**
5-axle rig truck	2	7	56	13	**78**
5-axle flatbed truck	5,397	4,673	9,803	684	**20,557**
5-axle equipment truck	489	130	833	82	**1,534**
5-axle water truck	617	703	2,865	326	**4,511**
5-axle sand truck	2,088	1,319	8,021	304	**11,732**
5-axle crude oil truck	222	298	2,297	89	**2,906**
5-axle gasoline truck	1,849	443	1,597	294	**4,183**
5-axle LNG truck	87	29	291	34	**441**
6+ axle trucks (all types)	705	295	2,591	415	**4,006**
Total	**12,402**	**8,696**	**30,696**	**2,455**	**54,249**

For each truck type, the data collected enabled the production of charts documenting the distribution of gross vehicle weights and axle group weights. As an illustration, Figure 3 shows the gross vehicle weight distribution for all 54,249 trucks collected in the sample. Research Report RR-15-01 includes similar charts for each truck type listed in Table 1. With this information, TTI researchers conducted a high-level analysis of weight distribution trends, including an evaluation of the percentage of 5-axle trucks weighing more than 80,000 lb (legal limit for 5-axle trucks) or more than 84,000 lb, i.e., maximum allowable weight assuming an annual oversize/overweight (OS/OW) permit is in place. Table 2 summarizes the percentage of 5-axle trucks for each truck type that exceed each of these categories.

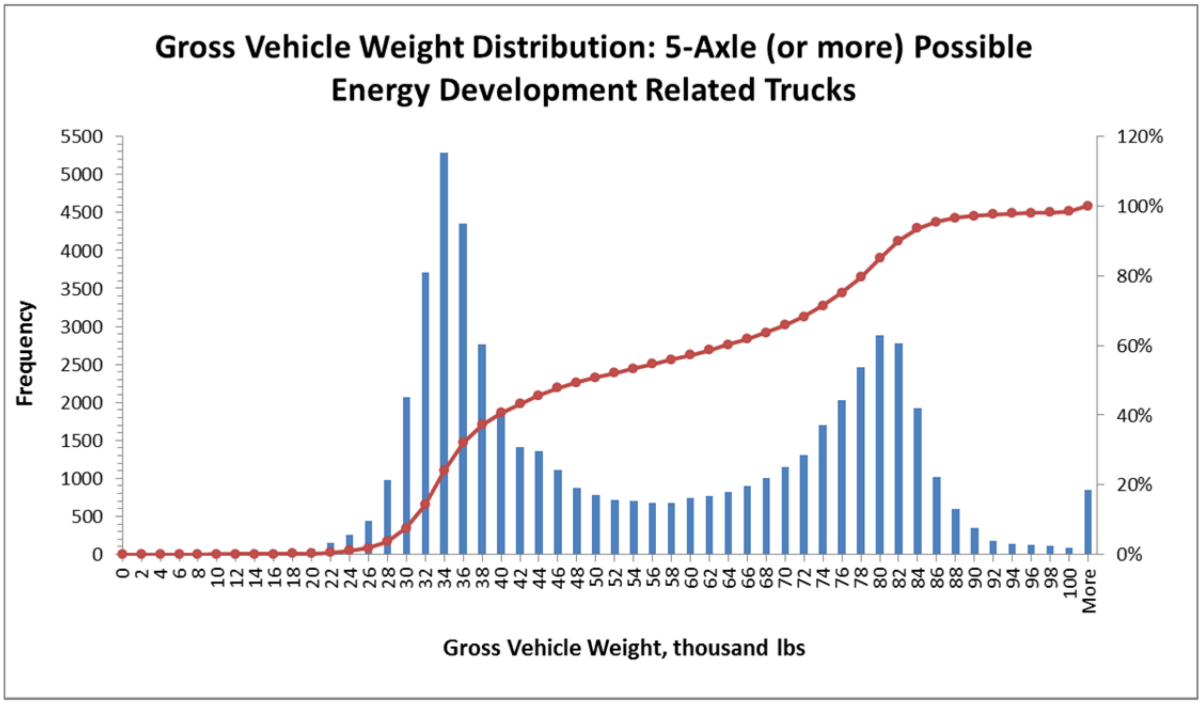


Figure 3. Distribution of Gross Vehicle Weights for All Truck Types.

Table 2. Percentage of Trucks Heavier than 80,000 lb and 84,000 lb.

Truck Type	No. of Records in Sample	Trucks with Gross Vehicle Weight >80,000 lb	Trucks with Gross Vehicle Weight >84,000 lb
5-axle dump truck	3,496	17%	5%
5-axle rig truck	59	67%	64%
5-axle flatbed truck	17,391	8%	2%
5-axle equipment truck	1,293	31%	17%
5-axle water truck	3,771	12%	5%
5-axle sand truck	9,447	14%	3%
5-axle crude oil truck	2,102	17%	8%
5-axle gasoline truck	3,692	21%	6%
5-axle LNG truck	369	17%	6%

There were similarities across truck type categories, but also differences. In general, there was clear differentiation between unloaded trucks and loaded trucks, as depicted by the bimodal weight distribution in Figure 3. The exceptions were rig trucks (the sample size was too small) and equipment trucks (the weight distribution was relatively uniform across weight bins). In most cases, 12-17 percent of trucks were heavier than 80,000 lb. Flatbed trucks showed the lowest percentage of trucks heavier than 80,000 lb (eight percent), while equipment trucks had the highest percentage of trucks heavier than 80,000 lb (31 percent). (Note: the percentage of trucks heavier than 80,000 lb was higher for rig trucks, but the sample size was very small.) The trends were similar for the percentage of trucks heavier than 84,000 lb.

AXLE WEIGHT DISTRIBUTIONS

TTI researchers also conducted an axle load analysis on all 54,249 WIM data records. Based on the processed axle group weights, TTI produced axle load distribution charts using relative frequencies of axle group weights for single, tandem, tridem, and quadrem axles. As an illustration, Figure 4 to Figure 7 show the distribution of axle group weights in 1,000-lb intervals for single, tandem, tridem, and quadrem axles for all WIM data records in the sample. Figure 8 and Figure 9 show the distribution of single-axle and tandem-axle weights for water trucks. Research Report RR-15-01 includes similar charts for each truck type listed in Table 1.

Table 3 shows the percentage of loads that exceed thresholds that are normally used to identify overweight loads, i.e., 20,000 lb for single axle loads, 34,000 to 38,000 lb for tandem axle loads, 45,000 lb for tridem axle loads, and 51,667 lb for quadrem axle loads. For tandem axles, the maximum legal weight varies from 34,000 lb to 38,000 lb based on the axle configuration. For completeness, Table 3 also shows the corresponding percentages for all the trucks that were weighed at each of the four WIM stations in 2013.

Overall, Table 3 shows that the percentage of loads heavier than the maximum legal weight increased as the number of axles in an axle group increased from single to tandem, tridem, and quadrem. Table 3 also shows that, with one exception, all the percentages of loads heavier than the maximum legal weight for the sample of 54,249 trucks represented in Table 1 (i.e., typical trucks used for energy developments) were significantly higher than the corresponding percentages for the entire population of trucks weighed at the four WIM stations.

HOW TO USE THE RESULTS

An Excel spreadsheet template enables users to calculate the following for each oil or gas well:

- Total number of trucks needed by phase activity and analysis period.
- Total amount of ESALs for trips to the well by phase activity and analysis period.
- Total amount of ESALs for trips leaving the well by phase activity and analysis period.

The spreadsheet calculates these values based on inputs the user provides in various places of the spreadsheet. Input data include the number of trucks used for various oil or gas well development, operation, and maintenance activities. Once all the input data are populated, the spreadsheet calculates the number of trucks and ESALs per well for the selected analysis period, both for trips to the well and trips leaving the well. For each type of truck listed, the spreadsheet uses the truck axle weight distributions described in the previous section. Separate tabs in the spreadsheet document the calculations for each truck type. Implementation Report IR-16-03 provides additional information and instructions on how to use the Excel template.

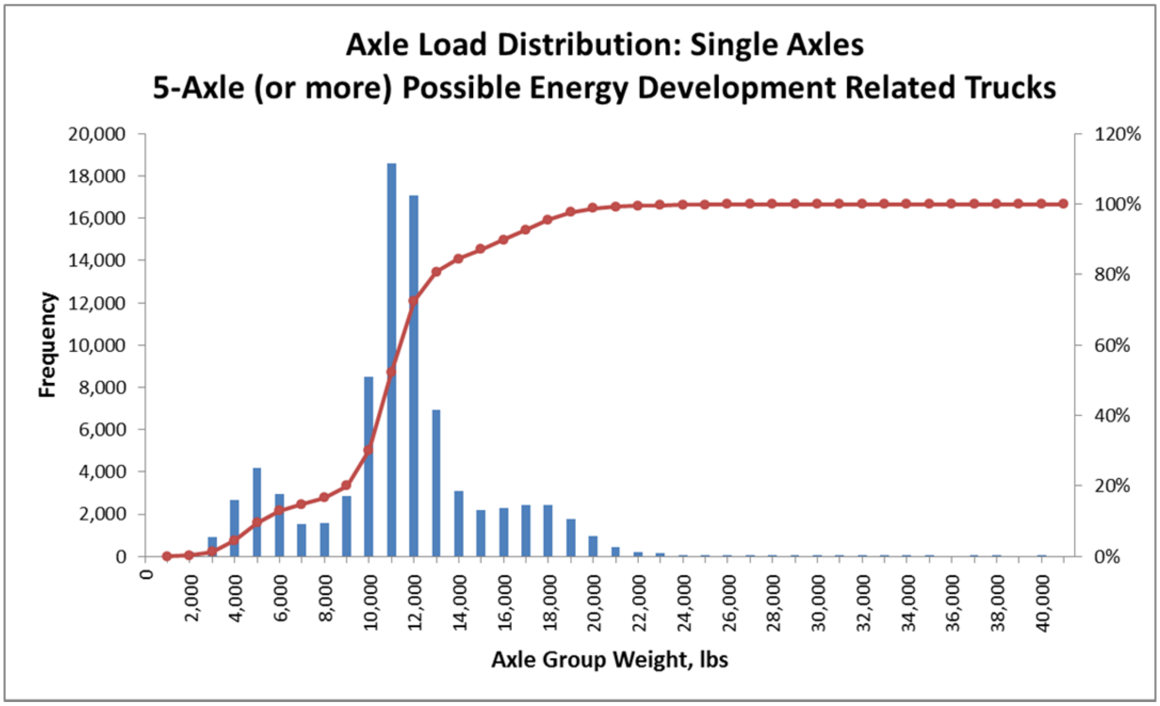


Figure 4. Distribution of Single Axle Loads for All Trucks in the Sample.

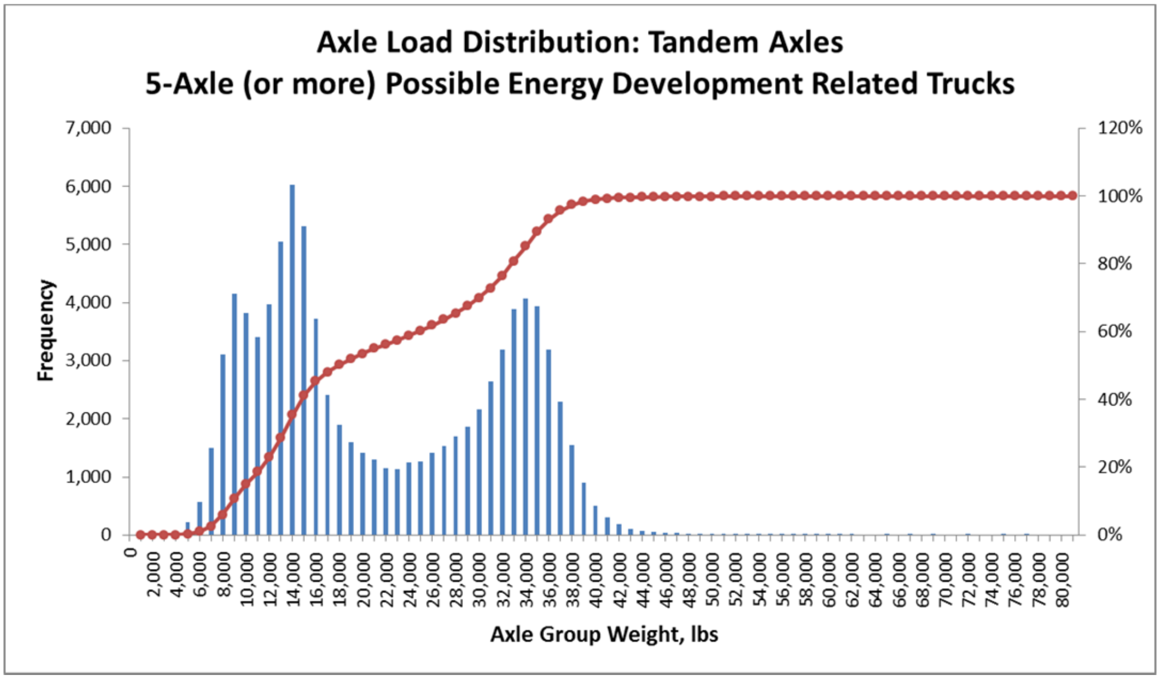


Figure 5. Distribution of Tandem Axle Loads for All Trucks in the Sample.

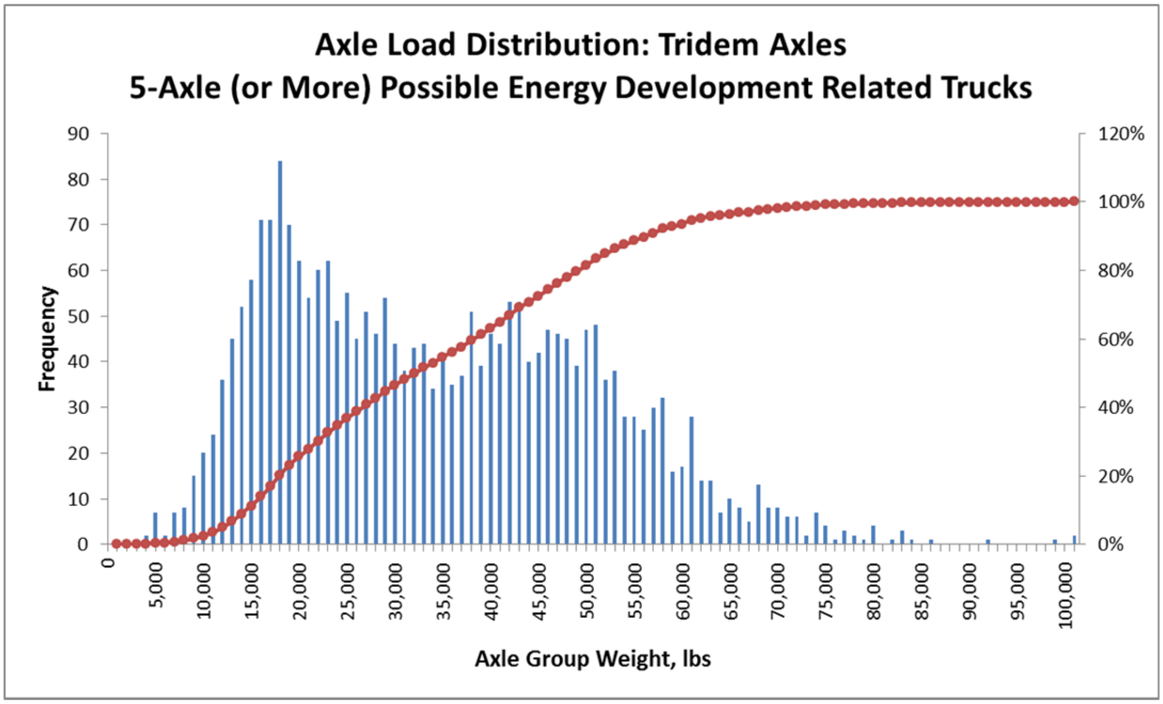


Figure 6. Distribution of Tridem Axle Loads for All Trucks in the Sample.

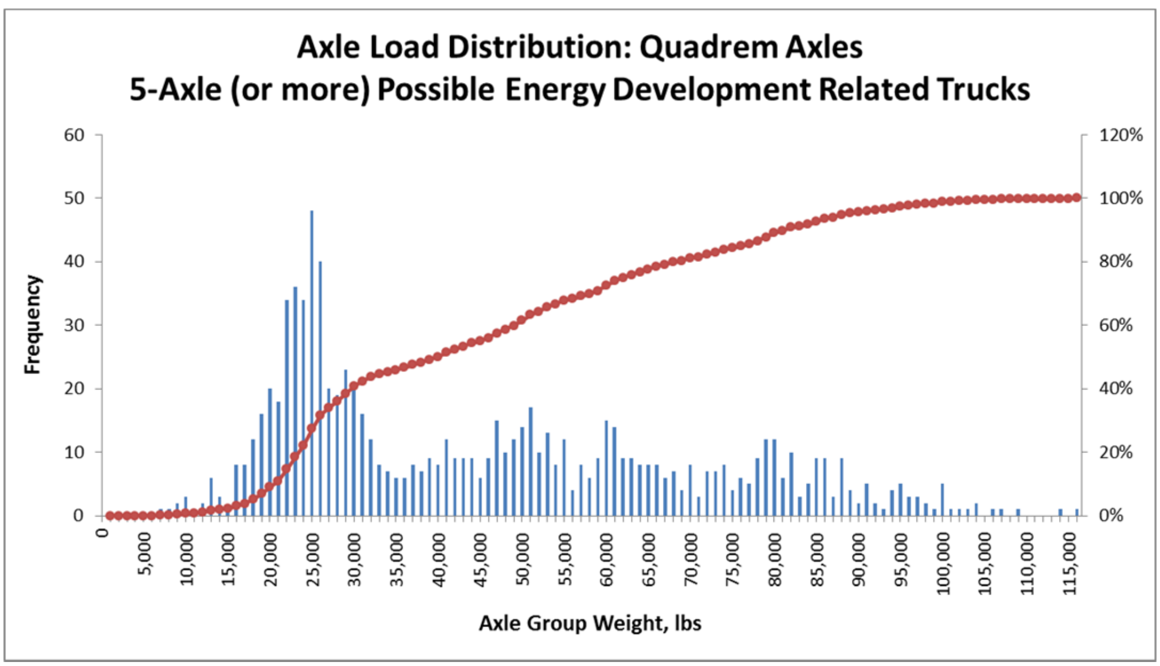


Figure 7. Distribution of Quadrem Axle Loads for All Trucks in the Sample.

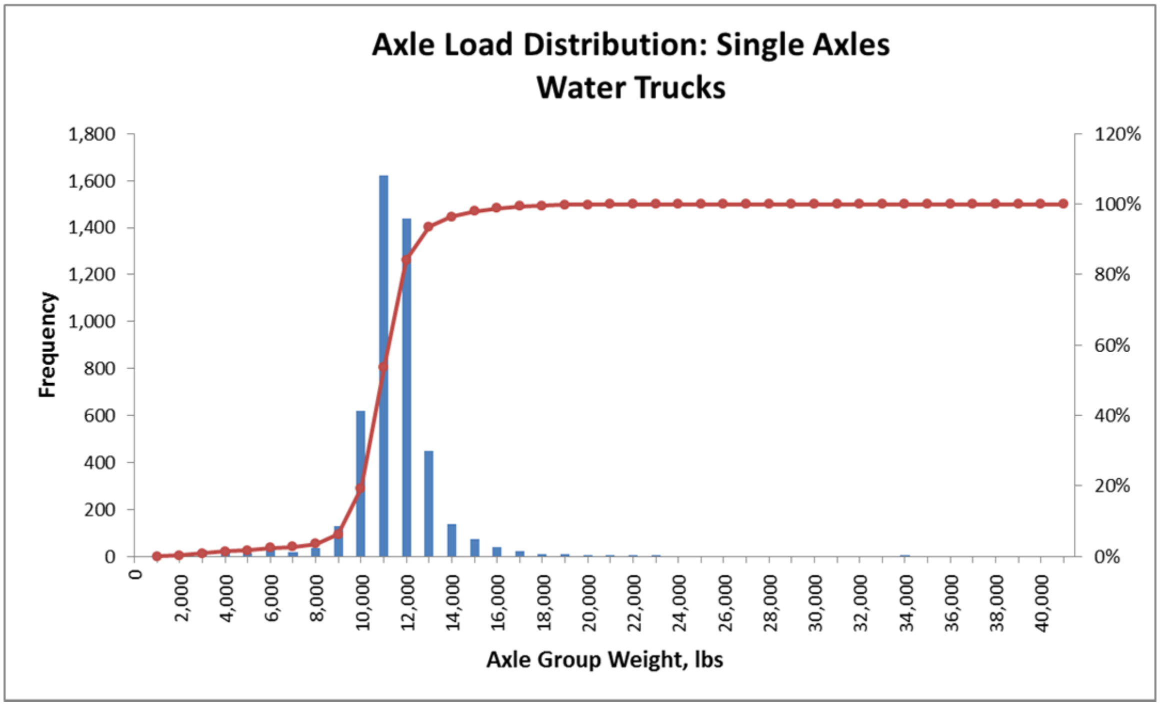


Figure 8. Distribution of Single Axle Loads for Water Trucks.

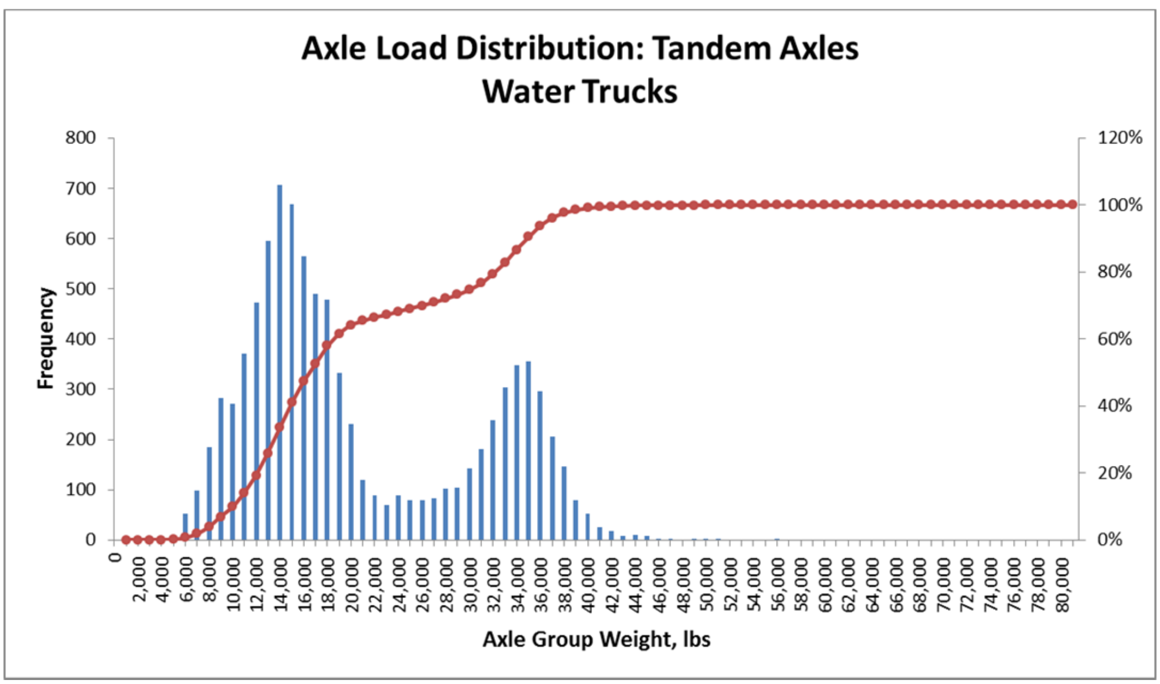


Figure 9. Distribution of Tandem Axle Loads for Water Trucks.

Table 3. Axle Group Weight Comparison at Four WIM Stations: Trucks in Table 1 versus All Trucks Detected at the WIM Stations.

WIM Data Group	Percentage of Overweight Axle Groups				
	Single Axles (>20,000 lb)	**Tandem Axles (>Weight Limit[*])**		**Tridem Axles (>45,000 lb)**	**Quadrem Axles (>51,667 lb)**
Trucks in Table 1	1.20%	13.76%		27.46%	35.47%
All Trucks Detected at Stations 502, 531, 533, and 535					
	Single Axles	**Tandem Axles**		**Tridem Axles**	**Quadrem Axles**
	(>20,000 lb)	**(>34,000 lb)**	**(>38,000 lb)**	**(>45,000 lb)**	**(>51,667 lb)**
Station 502 (2013)	0.75%	10.09%	1.51%	20.49%	37.35%
Station 531 (2013)	0.60%	6.35%	0.63%	16.42%	19.31%
Station 533 (2013)	0.48%	9.78%	1.11%	25.2%	28.59%
Station 535 (2013)	0.51%	16.19%	2.77%	23.17%	29.9%

[*] Weight Limit was determined based on the specific axle configuration of each tandem axle group.