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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

CHARACTERISTICS OF MOTOR CARRIER TRANSPORTATION OF HAZARDOUS MATERIALS IN OKLAHOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PUBLIC HEALTH

BY

F. LEE MELLISH, JR.

Oklahoma City, Oklahoma

1973

CHARACTERISTICS OF MOTOR CARRIER TRANSPORTATION

OF HAZARDOUS MATERIALS IN OKLAHOMA

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CHARACTERISTICS OF MOTOR CARRIER TRANSPORTATION OF HAZARDOUS MATERIALS IN OKLAHOMA

By F. Lee Mellish, Jr.

Major Professor: Carl A. Nau, M.D.

Motor carriers transporting hazardous materials were surveyed over a 3-year period at 14 highway scale houses in Oklahoma, and it was determined that a wide variety of these materials exist. The data suggest that hazardous material shipments in Oklahoma may occur up to 2.5 times over the national average. It was also noted that local and state control regarding movement, handling, and storage of hazardous materials is inadequate in Oklahoma, and planning for accident response and cleanup is nonexistent.

Hazardous material shipments concentrate toward metropolitan areas and create an inordinant risk to citizens of Oklahoma. Ammunition, explosives, and bombs move predominantly westward through Oklahoma City, suggesting the need for additional preparedness and training for emergency accident response personnel. The study indicates a need for communities in Oklahoma to inventory characteristics of intracity movement of hazardous materials and provide the necessary land use controls for accident control. Communities must also provide the mechanism to remove debris from hazardous material incidents and properly decontaminate and dispose of the material.

THE GRADUATE COLLEGE OF THE UNIVERSITY OF OKLAHOMA

ANNOUNCES THE FINAL EXAMINATION OF

F. LEE MELLISH, JR.

B.S., Oregon State University, Corvallis, Oregon, 1964
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FOR THE DEGREE OF DOCTOR OF PUBLIC HEALTH

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CHARACTERISTICS OF MOTOR CARRIER TRANSPORTATION OF HAZARDOUS MATERIALS IN OKLAHOMA

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

The American technological and economic expansion, the unprecedented population growth, and the shifting of industrial establishments from urban centers have been responsible for growing concern associated with the movement of hazardous materials. The continued movement of increasing volumes of hazardous materials is evident and essential to the economy and general welfare of the nation's communities and people; however, potential threats to people and property exist when transportation systems move through heavily populated areas. The states and municipalities have only recently emphasized the need for broad, realistic controls for movement of these materials.

The American city has been vulnerable to the resulting destruction from hazardous material incidents. Regulations, when adopted, have been directed toward a narrow spectrum of hazardous materials or aimed at a broad range of chemicals too vaguely defined for adequate enforcement. Additional evidence has indicated that many cities do not have manpower, facilities, expertise, or resources to properly respond to hazardous material incidents.

Virtually no state, including Oklahoma and its cities, has the basic knowledge of what species and amounts of hazardous material move through its respective jurisdictions. Only one state, California, has a hazardous materials reporting system for listing commodities on all trucks involved in highway accidents. Reporting of accidents involving the other modes of transportation is nonexistent except at the federal level.

Numerous hazardous material incidents have occurred in Oklahoma, and probably several hundred such accidents have occurred daily throughout the United States. Fortunately, only a small number of these incidents resulted in release of the transported commodity to cause death, property damage, or environmental damage. Because of various safety factors, standards, and other conditions of the accident, all incidents have not resulted in major disasters. Accident experience suggests, however, that when release of the hazardous material has occurred, catastrophic consequences can occur to an unsuspecting populace.

The National Safety Council has reported transportation accidents as the leading cause of accidental death in the United States (1). In 1971, some 54,700 people were killed in vehicle accidents including 10,000 pedestrians. In addition, there were 1,472 recreational boating deaths, 1,322 general aviation fatalities, 203 commercial air losses, 850 bicycle, 2,410 motorcycle, 600 railroad, 1,500 railroad crossing, 400 marine disasters, and four deaths from pipeline explosions. While there has been a trend toward a reduction of total automobile accidents, deaths tend to be increasing in other categories such as recreational vehicles and hazardous material transportation.

The Torrey Canyon oil tanker which broke up off the coast of England in 1967 directed new attention to the need for better control of hazardous material transportation. The Water Quality Improvement Act of 1970 (2) contained a specific section entitled "Control of Hazardous Material". This section required the promulgation of regulations designating hazardous material. This Act gave the Environmental Protection Agency authority to undertake research and development aimed at giving those people faced with control of hazardous material spills better tools with which to do the job.

The Department of Transportation (DOT) under Title 49 of the Code of Federal Regulations has primary responsibility for transportation of hazardous materials (3). Within the framework of the DOT is the Hazardous Materials Regulations Board, Federal Railroad Administration, Federal Highway Administration, Coast Guard, Federal Aviation Administration, National Highway Traffic Safety Administration, Urban Mass Transportation Administration, and Interstate Commerce Commission. With the creation of the DOT in 1965, the Interstate Commerce Commission was stripped of its transportation safety regulations and left with the powers to regulate interstate commerce. The Bureau of Motor Carrier Safety, Bureau of Railroad Safety, Bureau of Pipeline Safety, and the Coast Guard have been delegated the enforcement agencies for the transportation of hazardous materials for each mode. The Hazardous Materials Regulation Board has been given the responsibility to promulgate the rules and regulations governing transportation of hazardous materials.

The Oklahoma Bureau of Motor Carrier Safety (BMCS) has authority over all motor carriers engaged in interstate commerce in Oklahoma.

Caldwell (4) has stated that only one BMCS inspector is available for the majority of Oklahoma, and that actual surveillance and inspection of motor carriers on the highway occurs about 8 hours per week.

The Oklahoma Bureau of Railroad Safety (BRS) has authority to regulate rail shipments of hazardous materials. One inspector has been assigned to inspect and enforce the DOT regulations for railroads in the State of Oklahoma. Moore (5) commented that the BRS investigated rail accidents if $50,000 property damage occurred, if death or serious injury resulted, or if conditions existed which warranted special investigation. Few of these kinds of accidents have occurred in Oklahoma during the past 2 years.

The Coast Guard has regulatory authority for all inland water traffic in addition to coastline movement by ship or barge. The Coast Guard regulations govern construction and safety requirements of ships, tankers, and barges including port facilities. The Coast Guard investigates all waterway accidents and assists in recovery and cleanup operations (6).

The Environmental Protection Agency (EPA), under the Department of Health, Education, and Welfare, has also been involved in hazardous material transportation. The EPA has lead responsibility for in-plant spills and spills threatening a water course. Hazardous material incidents not involving a water course are generally not investigated by the EPA.

The Council for Environmental Quality has been directed under the Federal Water Quality Improvement Act of 1970 to establish a National Oil and Hazardous Substance Contingency Plan (7). This plan estab-

lished an organization for handling spills beyond the capabilities of regional or local authorities. The primary agencies involved in the plan have been the Environmental Protection Agency, Council on Environmental Quality, Department of Commerce, Department of Health, Education, and Welfare, Department of Defense, Department of Interior, Department of Transportation, Department of Justice, Office of Emergency Preparedness, and the Department of State.

Hess (8) reported that only California, Florida, Maine, Maryland, and Washington have developed a spill contingency plan. Hanson (9) stated that the Oklahoma Pollution Control Department has completed a contingency plan for Oklahoma to compliment the EPA's Oil and Hazardous Substance Contingency Plan for Region VI.

The storage, manufacturing, distribution, and selling of explosive material comes under the auspices of the Alcohol, Tobacco, and Firearms (ATF) Division of the United States Treasury Department. The Oklahoma ATF division has responsibility in licensing dealers to sell, and manufacturers to make and sell explosive commodities (10). Explosions that have occurred with intent to commit a crime are investigated by the ATF. A recent explosion of a truck transporting explosives near Joplin, Missouri, in 1971, killing the driver and a passing motorist, was investigated by the ATF division from the Tulsa regional office (11).

The Occupational Safety and Health Act (OSHA) of 1970 (12) was designed primarily to insure a safe and healthful working environment for all working men and women. Hazardous materials used within the work environment are specifically regulated to protect the health and safety

of the workers. There have been overlapping areas of authority between the Department of Labor regulations under OSHA and the Department of Transportation regulations for the BMCS. It has not been specifically determined if a motor carrier involved in an accident reports to the DOT or to OSHA. Caldwell (4) has suggested that motor carriers involved in accidents report to both agencies.

Several Oklahoma State agencies have regulations regarding the transportation of hazardous materials. The Corporation Commission has regulations requiring transporters of passengers or property for hire to obtain a Corporation Commission permit. Rule 16 (a) of the Motor Carrier regulations states that:

> ". . . no motor carrier shall transport deleterious liquids or substances harmful to livestock, soil, or crops, including, but not limited, to salt water, tank bottoms, and similar substances transported for disposal or otherwise in any quantity above twenty gallons, without having first secured a Deleterious Substance License" (13).

The rule further states that dumping or disposal of any deleterious substance must be approved by the Corporation Commission.

According to the minutes of the Pollution Control Coordinating Board Task Force meeting of August 28, 1972, the disposal and movement of hazardous substances in Oklahoma should be regulated by a single agency (14). Three state agencies have authority to license disposal of waste substances, the Corporation Commission for salt water disposal, Oklahoma Department of Pollution Control for deep well disposal of industrial waste and the Oklahoma State Health Department for septic tank pumpings. The adoption of a single regulation governing all hazardous material disposal within the framework of one agency was referred to a future meeting.

The Department of Public Safety (DPS) has not been directly responsible for transportation of hazardous materials in Oklahoma but is more concerned with the equipment and safety requirements of vehicles, gross weights, and measurements. In the event of an accident involving hazardous materials, the highway troopers have traditionally been the first on the scene. The trooper has the responsibility to determine the hazard involved, contact the proper authorities, and establish roadblocks if necessary. The explosives truck that crashed and exploded near Okemah on November 17, 1972, was an example of quick response by the trooper. On the assumption that the truck contained a bomb, the trooper rerouted traffic many miles around the scene until the true danger was assessed (15).

Installation and storage of liquified petroleum gas (LPG) in Oklahoma is regulated by the Oklahoma Liquified Petroleum Gas Commission. The LPG Commission licenses installers of LPG appliances, licenses storage facilities, and license vehicles transporting LPG in Oklahoma. The LPG Commission is also prepared to train local fire departments in Oklahoma on the methods of fighting LPG fires and assist in recovery of LPG involved in an accident (16).

The authority to regulate any condition considered hazardous to public health, including the movement of certain hazardous materials in Oklahoma, comes under the authority of the Oklahoma State Health Department (OSHD). Specifically, the OSHD regulates the use, storage, transportation, and disposal of radioisotopes; however, the OSHD Environmental Health Division has been studying disposal locations for hazardous materials.

Besides the federal explosives regulations, the Oklahoma State Fire Marshal's (OSFM) office has adopted, as of July 1, 1971, the State of Oklahoma Explosives Control Law (17). The Fire Marshal has been given power to regulate anyone manufacturing, selling, transporting for hire, or storing explosives and blasting agents in the state of Oklahoma. A permit system has been adopted by OSFM for anyone handling explosive items in Oklahoma.

The OSFM explosive control regulations have, in addition, adopted the DOT requirements for transporting explosive agents via roads, railroads, and waterways. The regulation does not, however, regulate other than explosive agents or certain chemicals stored in conjunction with blasting agents.

The City of Oklahoma City, in March, 1972, adopted the American Insurance Association Fire Prevention Code (18). This ordinance has regulated tank storage of hazardous materials, container, and portable tank storage of hazardous materials, container and portable tank storage, tank vehicles, and liquified petroleum gas. Article 20, Section 20 has a specific section for hazardous material and chemicals as follows:

> A permit shall be required for the storage or handling of more than 55 gallons of corrosive liquids, or more than 50 pounds of oxidizing materials, or more than 10 pounds of organic peroxides; or more than 500 pounds of nitromethane; or 1000 pounds or more of Ammonium Nitrate, Ammonium Nitrate fertilizers and fertilizer mixtures defined in Section 20.10 (a) or any amount of highly toxic material or poisonous gas.

The ordinance has further required that anyone transporting hazardous materials within the city limits of Oklahoma City first obtain a permit from the City Fire Marshal's Office. According to Koch (19), no permit has been issued for movement of hazardous materials within Oklahoma City

since the adoption of the ordinance.

The Oklahoma State Civil Defense (OSCD) agency has authority under the Oklahoma Civil Defense and Emergency Resources Management Act of 1967 (20) to declare an emergency in the event of a serious accident with hazardous materials. In 1970, a tank car derailment near Wetumka, Oklahoma, threatened the community with release of toxic gases. The OSCD mobilized the police, fire, and National Guard units to evacuate the town until the hazard could be eliminated (21).

The Civil Defense agencies throughout the state maintain a constant surveillance of police broadcasting networks. According to Mitchell (22), the Oklahoma City Civil Defense agency has the only 24-hour monitoring of police and emergency broadcasting systems in central Oklahoma.

The Oklahoma Safety Council (OSC) has been the central clearinghouse for information regarding many areas of public safety. Accident statistics are assimilated for Oklahoma and the United States and are made available to interested agencies. The OSC also works with public agencies in organization of safety programs such as storage, handling, and use of hazardous materials (23).

Hazardous Materials

The Code of Federal Regulations on hazardous materials (3) separates hazardous materials into six categories for identification: explosives, flammable liquids, flammable solids and oxidizing materials, acids and corrosives, compressed gasses, and poisonous and radiological materials. The regulations list over 1,200 specific hazardous materials and specify packing and shipping requirements, labeling necessary and maximum quantity that can be shipped for each item.

Sonnenburg (24) explained that the degree of hazard with each material is different according to the kind and amount involved. He went on to say that accidents have occurred releasing only small amounts of liquid parathion causing serious hazards, and accidents with other chemicals may require several hundred gallons before hazards exist.

According to Attaway (25), the following chemicals are released into the United States environment annually:

a) 1.7 million pounds of sulfuric acid

b) 3.2 million pounds industrial alcohols

c) 3.4 million pounds fertilizer solution

d) 44,000 thousand pounds of phenol

e) 2-3 million gallons industrial waste

f) 360,000 pounds acetone

g) 600,000 pounds various monomers

h) 3 million pounds organic chemicals

i) 19,000 pounds especially toxic chemicals (pesticides)

j) 2 billion gallons mining wastes

The above figures have included estimates on both inplant spills and transportation losses.

Production of hazardous materials has had significant increases annually. The Department of Transportation, U. S. Coast Guard, indicated over 500 new chemicals developed yearly (26). DOT (27) (Table 1) has compiled production figures for ten classifications of hazardous materials produced in 1968-69. This figure shows that well over 2 billion tons of these materials were produced in 1968-69. A 73 per cent

TABLE 1

HAZARDOUS MATERIAL PRODUCTION

Classification	Tons (ooo) Produced and Handled 1968-69	1979-80	Percentage Increase 1968-69	1979-80	Percentage Increase Per Year
Flammable Material	1,620,000	2,420,000	50		3.8
Compressed Gas	508,000	1,067,000	110		7.0
Explosives	20,000	40,000	100		6.5
Corrosive Material	45,100	95,900	112		7.1
Oxidizing Agents	7,800	19,400	149		8.6
Poisons	1,200	2,600	117		7.3
Etiologic Material	7,800	-	-		-
Cryogenic Material	36,000	92,000	156		8.9
Radioactive Material	170	163	860		22.8
Molten Material	13,000	41,000	215		15.0
Total	2,258,900	3,778,100	67		

increase to nearly 4 billion tons is expected by 1979-80.

The National Transportation Safety Board (27) revealed that between 1958-1968 the yearly increase for all classifications, except flammable materials, has been greater than the annual growth rate of the real Gross National Product (4.4 per cent). A 10-year projected growth rate of hazardous materials production was approximately 1.5 times greater than the Gross National Product growth rate.

McConnaughey et al. (28) have provided in Figure 1 a comparison of chemical production to population growth between 1958 and 1968. Organic chemical production more than doubled, inorganic about doubled, petroleum increased 40 per cent while the population increased only 15 per cent.

Fallwell (29) pointed out that total chemical production registered only a small percentage increase in 1971. Table 2 lists the top 50 chemicals produced in 1971 with an overall increase over 1970 of about 1 per cent.

The combined production of all synthetic organic chemicals, tars, tar crudes, and crude products from petroleum and natural gas in 1970 was 233,110 million pounds, an increase of 4.2 per cent over the input in 1969 as shown in Table 3 (30). The total marketed production of crude oil and natural gas in Oklahoma and certain other states for selected years are reviewed in Table 4 and Table 5. Production has increased for the selected years both in Oklahoma and the United States (31, 32).

The American Petroleum Institute has reported that the domestic demand for petroleum products in 1971 amounted to 5,535 billion barrels,

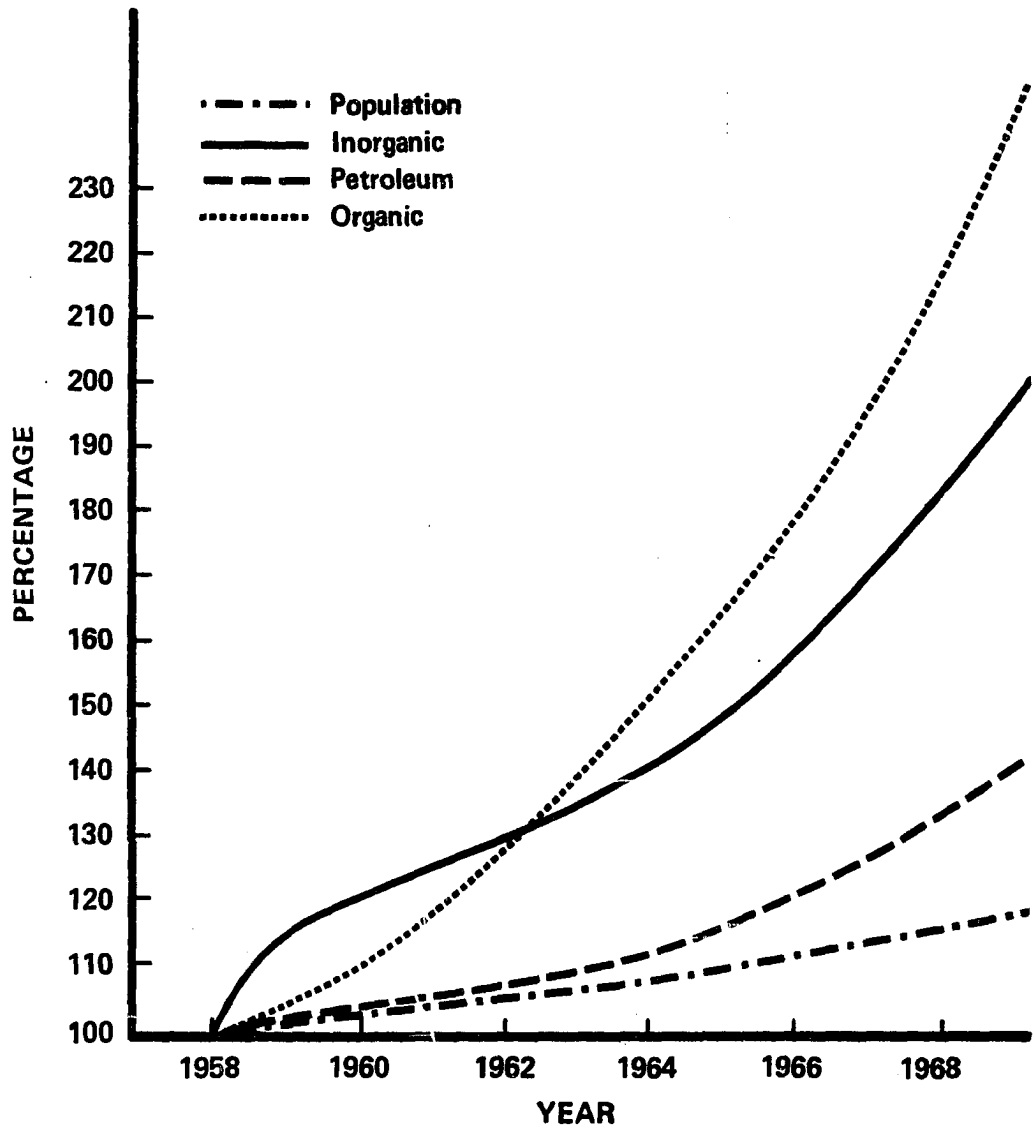

Figure 1.--Growth in Population and Chemical Production, 1958-68.

TABLE 2

TOP FIFTY CHEMICAL PRODUCTS IN 1971

Rank 1971		1971 Production Billions of Pounds	Billions of Pounds 1970	1969	1961
1	Sulfuric acid, total	58.57	59.15	59.07	35.70
2	Ammonia, synthetic anhydrous	27.44	26.20	25.84	10.41
3	Oxygen, high and low purity	25.94	27.30	26.91	9.52
4	Sodium hydroxide, 100% liquid	19.37	20.15	19.83	9.83
5	Chlorine, gas	18.68	19.51	18.83	9.20
6	Ethylene	18.30	18.50	16.44	5.66
7	Sodium carbonate, synthetic and natural	14.28	14.03	14.07	10.60
8	Nitric acid, total	13.34	12.92	12.89	6.76
9	Ammonium nitrate, original solution	13.17	12.37	11.78	8.47
10	Phosphoric acid, total	12.07	10.93	10.75	4.51
11	Nitrogen, high and low purity	11.91	10.96	9.62	1.94
12	Benzene	7.56	8.31	8.69	3.91
13	Ethylene dichloride	7.15	7.46	8.04	1.37
14	Polyethylene, high and low density	8.40	5.81	5.49	1.61
15	Toluene	6.21	6.01	5.50	1.86
16	Urea, primary solution	6.14	6.50	5.95	1.83
17	Propylene	5.56	6.99	7.24	2.67
18	Methanol, synthetic	5.01	4.93	4.21	2.04
19	Ethylbenzene	4.83	4.83	4.91	1.94
20	Ammonium sulfate	4.65	4.99	5.13	3.09
21	Styrene	4.41	4.34	4.65	1.76
22	Formaldehyde	4.37	4.43	4.40	1.75
23	Xylene, total	4.35	3.88	2.75	1.85
24	Vinyl chloride	4.19	4.04	3.74	1.04
25	Hydrochloric acid, total	4.05	3.84	3.82	1.82

TABLE 2--Continued

Rank 1971		1971 Production Billions of Pounds	Production Billions of Pounds 1970	1969	1961
26	Ethylene oxide	3.61	3.86	3.41	1.36
27	Polyvinyl chloride and copolymers	3.44	3.12	3.03	0.98
28	Butadiene (1.3-), rubber grade	3.06	3.11	3.12	1.91
29	Carbon black	3.03	2.93	2.96	1.98
29	Ethylene glycol	3.03	3.04	2.57	1.18
31	Sodium sulfate, high and low purity	2.70	2.72	2.95	2.34
32	Carbon dioxide, all forms	2.52	2.23	2.33	1.82
33	Polystyrene, straight and rubber-mofified	2.44	2.37	2.21	0.74
34	Calcium chloride, solid and liquid	2.37	2.42	2.35	1.69
35	Aluminum sulfate, commercial	2.26	2.35	2.49	1.78
36	Cumene	2.10	1.98	1.69	0.29
37	Sodium tripolyphosphate	2.08	2.38	2.48	1.51
38	Acetic acid	2.05	1.93	1.77	0.76
39	Ethanol, synthetic	1.96	1.96	2.36	1.68
40	Isopropanol	1.82	1.92	2.03	1.19
41	Phenol, total	1.74	1.76	1.69	0.78
42	Cyclohexane	1.73	1.84	2.23	0.70
43	Acetone	1.64	1.62	1.52	0.75
44	Acetaldehyde	1.61	1.61	1.65	na
45	Acetic anhydride	1.55	1.59	1.68	1.26
46	Dimethyl terephthalate	1.50	1.45	1.54	na
47	Terephihalic acid	1.50	1.33	1.05	na
48	Titanium dioxide	1.30	1.31	1.32	1.01
49	Polypropylene	1.26	1.03	1.09	0.10
50	Adipic acid	1.25	1.08	1.22	na

TABLE 3

SYNTHETIC ORGANIC CHEMICALS AND THEIR RAW MATERIALS
UNITED STATES PRODUCTION - 1969 AND 1970

Chemical	Millions of Pounds 1969	1970	Percentage Increase or Decrease
Grand Total	223,684	233,110	4.2
Tar	7,688	7,609	- 1.0
Tar Crudes	9,996	9,300	- 7.0
Crude Prod. from Petroleum and Natural Gas	71,315	77,879	9.2
Synthetic Organic Chemicals	134,685	138,322	2.7
Cyclics	28,571	28,257	- 1.1
Dyes	240	235	- 2.4
Organic Pigmont	61	57	- 7.4
Medicines	200	214	7.2
Flavors and Perfumes	120	100	-16.7
Plastic and Resins Material	18,557	19,210	3.5
Rubber Processing Chemicals	303	298	- 1.7
Elastomers	4,524	4,438	- 1.9
Plasticizers	1,382	1,336	- 3.3
Surface-Active Agents	3,901	3,886	- .4
Pesticides and Related	1,104	1,034	- 6.4
Miscellaneous Chemicals	76,720	79,257	4.7

TABLE 4

UNITED STATES CRUDE OIL PRODUCTION

State	Thousands 42-Gallon Barrels 1966	1967	1968	1969
Alabama	8,030	7,348	7,635	7,701
Alaska	14,358	29,126	66,204	73,953
Arizona	132	2,924	3,370	2,433
Arkansas	23,824	21,075	19,464	18,049
California	345,295	359,219	375,496	375,291
Colorado	33,492	33,905	31,937	28,294
Florida	1,799	1,568	1,474	1,731
Illinois	61,661	59,142	56,391	50,391
Indiana	10,617	10,081	8,692	7,841
Kansas	103,738	99,200	94,505	88,716
Kentucky	18,066	15,535	14,036	12,924
Louisiana	674,318	774,527	817,426	844,603
Michigan	14,273	13,664	12,974	12,213
Mississippi	55,227	57,147	58,708	64,283
Missouri	97	75	65	67
Montana	35,380	34,959	48,460	45,954
Nebraska	13,850	13,373	13,183	12,106
Nevada	307	279	271	223
New Mexico	124,154	126,144	128,550	129,227
New York	1,735	1,972	1,532	1,256
North Dakota	27,126	25,315	25,040	22,703
Ohio	10,899	9,924	11,204	10,972
Oklahoma	224,839	230,749	223,623	224,729
Pennsylvania	4,337	4,387	4,160	4,448
South Dakota	239	211	187	158
Tennessee	7	7	6	32
Texas	1,057,706	1,119,962	1,133,380	1,151,775
Utah	24,112	24,048	23,504	23,295
Virginia	1	3	3	1
Washington	0	0	0	0
West Virginia	3,675	3,561	3,312	3,104
Wyoming	134,470	136,312	144,250	154,945
Other States	0	0	0	0
Total United States	3,027,763	3,215,742	3,329,042	3,371,751

TABLE 5

MARKETED PRODUCTION NATURAL GAS

State	Millions Cubic Feet 1965	1966	1967	1968
Alaska	7,255	11,267	14,438	17,343
Arkansas	82,831	105,174	116,522	156,627
California	660,384	689,607	687,080	714,893
Colorado	126,381	136,667	116,857	121,424
Illinois	7,396	7,230	5,144	4,380
Indiana	239	215	198	234
Kansas	793,379	847,495	871,971	835,555
Kentucy	78,976	76,536	89,168	89,024
Louisiana	4,466,786	5,081,435	5,716,857	6,416,015
Maryland	408	696	621	864
Michigan	34,558	34,120	33,589	40,480
Mississippi	166,825	156,652	139,497	135,051
Montana	28,105	30,685	25,966	19,313
Nebraska	10,720	10,196	8,453	8,129
New Mexico	937,205	998,076	1,067,510	1,164,182
New York	3,340	2,699	8,837	4,632
North Dakota	35,652	46,585	40,462	41,023
Ohio	35,684	43,133	41,315	42,673
Oklahoma	1,320,995	1,351,225	1,412,952	1,390,884
Pennsylvania	84,461	90,914	89,966	87,987
Texas	6,636,555	6,953,790	7,188,900	7,495,414
Utah	46,151	48,965	69,366	71,616
Virginia	3,152	4,249	3,818	3,389
West Virginia	207,416	211,610	211,460	236,971
Wyoming	235,849	243,381	240,070	248,481
Other States	3,585	3,625	1,068	1,281
Total United States	16,042,753	17,206,628	18,171,325	19,322,400

an increase of 3.2 per cent over 1970. The total United States production of crude oil during 1971 was 3,329,600,000 barrels, a drop of 0.6 per cent as compared to 1970. The significant factor was the 25.8 per cent increase in crude oil imports to make up the difference in supply and demand (33). Table 6, taken from the American Petroleum report of supply and demand of crude oil products, has suggested an increased role for the transportation industry.

Waterway Transportation

In 1967, an estimated 414 million tons of hazardous materials were shipped via water carriers according to reports by the National Transportation Safety Board (27). This constituted approximately 23 per cent of the total quantity of hazardous materials shipped in the United States. This figure is expected to be 470 million tons by 1980, a 13.5 per cent increase. Approximately 17 per cent of all crude petroleum products were shipped via water carriers in 1971. Petroleum products constituted 84 per cent of all hazardous materials shipped.

U. S. News and World Report (34) reported that in 1971, there were 20,000 barges on the 26,000 miles of inland and coastal waterways of the United States. The U. S. Maritime Administration figures in Table 7 indicate a 23.8 per cent decrease in U. S. merchant vessels from 1968 to 1970 (35). However, the world merchant vessel population has increased 3.1 per cent during the same period.

In 1970, there were over 300 billion ton miles of freight along United States waterways, an increase of 58 per cent over 1960. A 50 per cent increase in water traffic has been projected for the next 10 years (34). In Table 8, the total ton-miles of freight on the five waterway

TABLE 6

UNITED STATES PETROLEUM SUPPLY AND DEMAND

	Thousands of Barrels				
	1970	Daily Average	1971	Daily Average	Percentage Change
Total Stock (January 1)	980,123		1,017,861		
New Supply:					
Total United States Production	4,129,604	11,314	4,118,800	11,284	- 0.3
Total Import	1,248,062	3,419	1,405,200	3,850	12.6
Total New Supply	5,377,666	14,733	5,524,000	15,134	2.7
Domestic Demand:					
Motor Gasoline	2,111,349	5,785	2,187,100	5,992	3.6
Aviation Gasoline	19,903	55	17,900	49	-10.9
Jet Fuel - Naph. Type	90,927	249	90,500	248	- 0.4
Jet Fuel - Kero. Type	262,051	718	273,100	748	4.2
Special Naph.	31,390	86	30,400	83	- 3.5
Kerosine	95,974	263	91,200	250	- 4.9
Distillate Fuel Oil	927,211	2,540	982,300	2,691	5.9
Residual Fuel Oil	804,288	2,203	827,200	2,266	2.9
Others	1,021,380	2,798	1,035,300	2,837	1.4
Total Domestic Demand	5,364,473	14,697	5,535,000	15,164	3.2

TABLE 6--Continued

	Thousands of Barrels				
	1970	Daily Average	1971	Daily Average	Percentage Change
Exports: Total	94,458	259	81,400	223	13.9
Total Demand	5,458,931	14,956	5,616,400	15,387	2.9
Unaccounted for Crude	-7,721	-21	-6,100	-17	-19.0
Crude Oil Losses	4,328	12	4,461	12	
Net Processing Gain	131,052	359	142,100	389	8.9
Total Change in Stock	37,738	103	39,139	107	
Total Stock December 31	1,017,861		1,057,000		

TABLE 7

UNITED STATES MERCHANT VESSELS - 1968 AND 1970

	Passenger Cargo		Freighters		Bulk Carriers		Tankers		Total	
	No.	Avg. Age	No.	Avg. Age	No.	Avg. Age	No.	Avg. Age	No.	Avg. Age
United States	195	23	1511	22	53	23	312	19	2071	22
Foreign	794	20	10357	14	2556	8	3583	10	17290	12
1968 World Total	989	20	11868	15	2609	9	3895	11	19351	13
United States	171	25	1076	23	38	25	294	19	1579	22
Foreign	724	20	10823	13	2916	8	3938	10	18401	12
1970 World Total	895	21	11899	13	2954	8	4232	11	19980	13

TABLE 8

FREIGHT CARRIED ON INLAND WATERWAYS BY SYSTEM
1950 - 1970

System	Millions of ton miles						
	1950	1955	1960	1965	1968	1969	1970
Atlantic Coast Rivers	6,497	27,042	28,583	27,781	25,938	26,603	28,572
Gulf Coast Rivers	1,229	13,860	16,932	21,808	25,757	27,808	28,582
Pacific Coast Rivers	1,686	4,736	6,001	6,630	7,303	8,061	8,397
Mississippi River System	33,598	52,019	69,257	96,593	120,339	125,195	138,534
Great Lakes System	120,334	118,850	99,480	109,609	112,073	115,235	114,475
Total	163,344	216,508	220,253	262,421	291,409	302,901	318,560

systems of the United States increased dramatically. The Mississippi River system, including the Arkansas River of Oklahoma, showed a 11.6 per cent increase in traffic from 1969 to 1970 (36).

The water carrier industry has met the challenge of the increasing chemical production by constructing gigantic oil and chemical tankers with capacity over 2.5 million gallons and weighing up to 400,000 tons (37). These carriers have plied the waters of the world carrying potential catastrophic accidents. Water carrier accident experience with projection to 1980 by Booz-Allen has been included in Table 9 (27). These figures have suggested that by 1980, 77 per cent of all water carrier accidents will involve hazardous materials.

Notable accidents involving death and property damage have occurred in the transportation of hazardous materials via water carriers. The most devastating was the Texas City explosion on April 16, 1947. According to the acounts of the Daily Oklahoman (38), a French freighter, Grandcamp, was loading ammonium nitrate at the Monsanto Chemical Corporation docks. Late in the afternoon of the 16th the ship caught fire, attracting numerous onlookers. At 9:13 P.M., the ship exploded and completely vanished. The crew, firemen, and onlookers were all killed. The force of the blast was felt 150 miles away. A second nitrate-loaded barge moored in the harbor also caught fire, consequently exploding at 1:08 A.M., April 17th, killing many more rescuers and firemen.

The Monsanto Company was completely destroyed in addition to two nearby oil refineries. The death toll stood at 468 dead, 302 missing and presumed dead, and 2,000 injured. Property damage was in excess

TABLE 9

DOMESTIC WATER CARRIER ACCIDENT EXPERIENCE 1957 - 1968

Year	Domestic Waterborne Traffic Ton Miles (billions)	Total Number of Accidents	Total Hazardous Materials Accidents	Percentage Accident Rate	Percentage Hazardous Materials Accident Rate
1957	480	-	-	-	-
1958	429	-	-	-	-
1959	461	-	-	-	-
1960	476	-	-	-	-
1961	463	-	-	-	-
1962	474	-	-	-	-
1963	478	-	-	-	-
1964	487	1,625	237	3.3	0.5
1965	489	1,685	384	3.5	0.8
1966	505	1,569	387	3.1	0.8
1967	505	1,783	433	3.5	0.9
1968	506	1,803	515	3.6	1.0

of $50,000,000.

With the advent of large oil tanker ships, an increasing number of tanker accidents have occurred during the last decade. The loss of wildlife and property damage are the main results of oil spills. Moffitt and Orr (39) reported 6,600 seabirds killed off the California coast in 1937 when an oil tanker broke up. Hawkes (40) estimated that in 1961, 250,000 breeding colonies of seabirds were lost off Newfoundland by oil spills. Beer (41) stated that the 1967 Torrey Canyon incident resulted in 30,000 bird deaths.

Aldrich (42) listed tanker groundings causing 17 spills and 238 tanker collisions from June, 1964 through April, 1967, in navigable waters off England. The U. S. Coast Guard (43) reported 690 tanker and tank barge collisions in navigable waters of the United States during the fiscal year 1971.

The Arkansas Waterway has created a new dimension in transportation for Oklahoma. Numerous accidents involving hazardous materials have occurred on the Mississippi River system, indicating potential problems for cities and people living along the Arkansas. The WYCHEM 112 Chlorine barge which sank near Natchez, Mississippi in 1961, could have endangered the lives and property of people living many miles from the scene, if the deadly chlorine gas had been released (44).

The petroleum transportation industry has designed huge 24,000 cubic meter liquified natural gas (LNG) tankers to meet the growing energy needs of the United States. The Coast Guard theorize that instant vaporization of that amount of LNG in New York Harbor could have an explosive range greater than New York City (45).

Railroad Transportation

A second important mode of transportation of hazardous materials has been the railroads. The rail transport systems have unique qualities from other modes of transportation because of the fixed nature of the system. Slight variations in the system, particularly in the track, has caused serious derailments.

O'Driscoll (46) reported over 2 million carloads of chemicals and petroleum products handled by rail in 1970. This represented over 40 per cent of all hazardous materials produced. He has indicated four problems encountered by the rail transportation of hazardous materials. First, the amounts of materials spilled vary from a tea cup quantity to tank losses of 8,000 to 48,000 gallons. Secondly, spills can involve any of thousands of hazardous materials carried by rail. A single material or a variety of materials have been involved in a single incident. Third, accidents within the rail systems frequently have occurred in remote, inaccessable locations. This type of situation has made cleanup and removal difficult. Fourth, incidents involving a small leak in one tank car have lead to catastrophic chain reactions.

The Federal Railroad Administration (FRA) investigated 91 railroad accidents in 1971. Hazardous materials were involved in 21 of the wrecks which represents 23 per cent of the total accidents. A summary of 1969-1971 accident data has been accumulated in Table 10 (47). In a separate report by the FRA, it has been shown that 20.6 per cent of all crossing accidents in the United States in 1970 involved a truck (48). In Oklahoma, trucks were involved in 16.1 per cent of all crossing accidents (see Table 11).

TABLE 10

FEDERAL RAILROAD ADMINISTRATION INVESTIGATED RAILROAD ACCIDENT EXPERIENCE - 1969 AND 1970

Collisions		82
Derailments		97
Rail - Highway crossings		23
Other		6
	Total	208
Total Killed		152
Total Injured		986
Total Property Damage		$35,404,925
Percentage by Cause:		
Track Condition		15
Car Condition		14
Human Factors		40
Crossing Accident		11
Shifted Loads		2
Malicious Tampering		2
Miscellaneous and Others		16

TABLE 11

UNITED STATES AND OKLAHOMA CASUALTIES IN ACCIDENTS AT PUBLIC RAIL - HIGHWAY GRADE CROSSINGS - MOTOR CARRIERS 1970

	Number of Accidents	Killed	Injured
United States:			
Truck struck by train	572	222	409
Truck into side of train	162	46	143
Total truck - train	734	268	552
Total all crossings accidents	3,559	1,440	3,336
Oklahoma:			
Total truck - train	17	3	17
Total all crossings accidents	69	20	65

Several rail accidents have occurred exemplifying the potential problems of hazardous material transportation. On January 25, 1969, a Southern Railroad train derailed at Laurel, Mississippi. Derailed were 14 loaded liquified petroleum gas tank cars (49). The tank cars were damaged and violent explosions and fires occurred 40 minutes after the incident. Pieces of tank cars were hurled 1,600 feet from the wreck, igniting dwellings and commercial buildings. Extensive property damage occurred to other nearby structures from the concussion of the blast. A tank car of hydrocyanic acid was not damaged, but if it had ruptured, widespread death from toxic gas could have resulted. A total of 55 residences were destroyed and 1,350 residences sustained damage. Damage was also reported by six schools and five churches. Two fatalities resulted from the fires and 33 persons were hospitalized. Total damage was estimated at $3,000,000.

A second train derailment occurred at Dunreith, Indiana, January 1, 1968, at 9:30 P.M. (50). Derailed were five tanks cars containing 20,000 gallons each of the following: two cars of acetone cyanohydrin and one each of vinyl chloride, ethylene oxide, and methyl methacrylate. An explosion and fire resulted with evolution of toxic gases. The tank car of cyanohydrin contaminated the adjacent stream causing death of farm animals and fish. The cyanide compound also leached into the aquifer contaminating the towns drinking water supply. Forty-five minutes after the derailment the ethylene oxide tank exploded and carried the entire 1,600 pound tank car 800 feet into a residential area. Damage to 94 homes and businesses amounted to over $1,000,000. No deaths occurred and only minor injuries were reported by firemen.

The Dunrieth cannery was located adjacent to the accident site. The cannery was completely destroyed, but the potential consequences were minimized by the fact that the accident occurred on New Year's Day, a holiday.

A third example of rail accidents involving hazardous materials occurred in Houston, Texas, October 19, 1971, as reported by the Tulsa Daily World (51). A Missouri Pacific freight train derailed piling up 16 cars. Among the 16 cars were six 48,000-gallon tank cars of vinyl chloride, three of fuel oil, one acetone, one butadiene, and one formaldahyde. One of the vinyl chloride tank cars was punctured and ignited. The Houston Fire Department responded to the scene within a few minutes and attempted to contain the blaze. Forty-five minutes after the derailment, a second vinyl chloride car exploded killing one fireman and seriously burning 37 other people. Large sections of the tank car were found 400 feet from the accident site.

Greer (52) stated that the facts of the Houston derailment have not been released pending litigation in the courts. The results, however, have suggested that even the most sophisticated fire departments can not adequately handle hazardous material incidents.

Still another type of incident involving hazardous material on railroads occurred at Crete, Nebraska, February 18, 1969, at 6:30 A.M. (53). A Chicago Burlington and Quincy train derailed, fracturing three anhydrous ammonia tank cars and releasing some 29,300 gallons of the chemical. At normal atmospheric pressure, the anhydrous ammonia vaporized to ammonia gas and blanketed the entire area. The ammonia cloud drifted into the town of Crete killing seven persons on the streets and

seriously injuring 53 others.

Air Transportation

The National Transportation Safety Board (54) reported a total of 355 accidents involving aerial application of agricultural chemicals for 1969. A total of 35 pilots were killed and 52 seriously injured. Extremely toxic chemicals were involved in 42 per cent of the accidents. In 40 per cent of the accidents, the aircraft was carrying "nontoxic" chemicals and 10 per cent were carrying unknown chemicals. Pilot error caused 80 per cent of all aerial applicator accidents. From the available statistics it could not be determined how much of the material was lost due to the accident and how cleanup operations were handled. Nearly all aerial applicator accidents occurred in rural, sparsely populated areas. Agricultural activities were responsible for 90 per cent of the applicator accidents.

Ferrarase (55) remarked that "there have been no accidents in air transportation of hazardous materials; therefore, we have no data or statistics on accidents involving these materials." However, the Daily Oklahoman (56) reported a Delta Airline passenger flight from Houston to Atlanta on January 12, 1972, was contaminated with radioactive material. The contamination occurred when a container of radioactive material leaked in the baggage compartment of the aircraft. A total of 917 passengers were potentially exposed before the leak was detected. No injuries from the incident were reported.

Still another incident involved an Eastern Airlines passenger aircraft at Louisville, Kentucky (57). Material described on the waybill as "ten metal shipping drums of precious metal solution," leaked

onto the cargo bin flooring of the aircraft. Holes up to 8 inches in diameter were burned into the flooring. It was later described as hydrochloric acid solutions. The drums contained four times the maximum allowable corrosive liquid for cargo aircraft and 40 times maximum permitted for passenger aircraft. This accident has suggested that the wording on the bill of lading may be deceiving and not representing the actual cargo being shipped.

Pipeline Transportation

The annual report of the Association of Oil Pipe Lines (58) indicated that 46.8 per cent of all crude petroleum and petroleum products were carried by pipelines, 23.25 per cent by water carriers, 28.22 per cent by motor carriers, and 1.62 per cent by railroad (see Table 12). Pipelines also handled 17 per cent of all chlorine transported which equaled 4.25 million tons in 1971 (59). Chlorine distribution by transportation mode is indicated in Table 13.

Pipeline accidents have decreased 30 per cent from 1968 to 1970 (60). Liquid pipeline operators reported 499 accidents in 1968, 403 in 1969, and 347 in 1970. Property damage amounted to $899,228 in 1970 compared to $1,347,509 in 1968.

The Office of Pipeline Safety figures revealed Oklahoma as second only to Texas in number of pipeline accidents (61). Oklahoma had 39 accidents in 1969 and 38 in 1970. Texas ranked first both years with 139 and 121, respectively. Table 14 summarizes pipeline accidents showing few deaths having occurred in 1970.

Thayer (62) announced that on December 9, 1970, in Franklin County, Missouri, a propane pipeline ruptured. After leaking for 1

TABLE 12

TOTAL CRUDE PETROLEUM AND PETROLEUM PRODUCTS
CARRIED IN DOMESTIC TRANSPORTATION

(Million Tons)

Year	Pipelines		Water Carriers		Motor Carriers		Rail		Total Products Carried
	Tons	Percentage	Tons	Percentage	Tons	Percentage	Tons	Percentage	Tons
1938	139	39.28	138	38.86	21	5.8	57	16.06	354
1943	196	41.46	116	24.49	76	16.14	85	17.91	474
1948	262	38.24	238	34.61	121	17.62	65	9.53	686
1953	359	41.63	273	31.70	185	21.40	45	5.27	863
1958	433	42.57	300	29.36	252	24.78	33	3.29	1017
1959	464	43.22	310	28.86	267	24.82	33	3.10	1074
1960	468	43.01	318	29.22	270	24.83	32	2.94	1089
1961	484	43.60	323	29.06	274	24.64	30	2.70	1110
1962	502	43.36	330	28.46	298	25.69	29	2.49	1159
1963	521	43.57	336	28.06	313	26.14	27	2.23	1196
1964	559	44.54	322	25.63	347	27.65	27	2.18	1256
1965	588	44.43	323	24.47	385	29.14	26	1.96	1323
1966	630	44.81	333	23.68	417	29.67	26	1.84	1405
1967	679	45.64	350	23.50	434	29.13	26	1.73	1488
1968	726	46.47	361	23.09	450	28.16	26	1.68	1563
1969	760	46.81	379	23.35	458	28.22	26	1.62	1623

TABLE 13

CHLORINE GAS SHIPMENTS - 1971

Mode	Tonnage	Percentage
Rail	2,805,000	66
Pipeline	723,000	17
Barge	553,000	13
Ton Containers and Cylinders	127,000	3
Tank Trucks	42,000	1
Total	4,250,000	100

TABLE 14

LIQUID PIPELINE ACCIDENT SUMMARY JANUARY 1, 1970 - DECEMBER 31, 1970

Cause	Number	Per-centage	Deaths	Injuries	Property Damage ($)	Loss of Commodity (Barrels)
Corrosion - Ext.	149	42.8	-	5	68,421	45,232
Equipment Rupturing Line	70	20.2	1	3	119,900	80,121
Defect Pipe Stem	29	8.4	-	-	12,500	40,174
Corrosion - Int.	30	8.7	-	10	345,380	15,616
Carrier Personnel	13	3.8	2	-	16,336	26,804
Previous Damaged Pipe	5	1.4	-	-	18,200	1,410
Valve	3	0.9	-	-	682	3,470
Relief Equipment	3	0.9	1	3	135,000	12,803
Defective Metal	3	0.9	-	-	800	995
Gasket	11	3.2	-	-	2,754	3,112
Defective Weld	3	0.9	-	-	400	984
Flood	1	0.3	-	-	160	2,500
Surge	7	2.0	-	-	1,956	5,737
Miscellaneous	20	5.6	-	-	176,739	282,891
Totals	347	100.0	4	21	899,228	521,849

hour, an explosion resulted destroying all buildings in the immediate vicinity. Thirteen other homes were damaged within a 2-mile radius of the explosion. On the 10th of December a second explosion occurred from the escaped propane lying in low valleys around the rupture site. The force of the second blast equaled 100,000 pounds of TNT or about 750 barrels of propane. No deaths resulted but ten people were injured. A seismograph 50 miles away recorded the shock.

A second pipeline accident as reviewed by Thayer (62), occurred September 2, 1970, at Jacksonville, Maryland. A 30-inch petroleum pipeline from Houston to New Jersey sprang a leak and contaminated the local water supply. An explosion occurred, injuring five people before the leak was discovered and repaired.

Motor Carrier Transportation

The Automobile Manufacturing Association (63) listed Oklahoma as 13th in the United States for total number of truck registrations. Table 15 lists the top 13 states in truck registrations. These statistics have included all trucks, including pick-ups. There was a total of 18,747,781 trucks registered in the United States in the year 1970.

Caldwell (4) reported that 1,747 for-hire motor carrier companies have been registered as Oklahoma based motor carriers by the Oklahoma Bureau of Motor Carrier Safety. The registered company could include a single truck or several hundred trucks in a fleet. The Oklahoma registered carriers have as a base of operation an Oklahoma location, such as Transcon Trucking, reportedly the world's largest trucking firm. Companies based in other states, such as Time D C, operate a number of carriers in Oklahoma but are not included in the Oklahoma registration

TABLE 15

TOTAL MOTOR TRUCK REGISTRATIONS BY STATES

Rank	State	Total Registered		Percentage United States Total	
		1967	1970	1967	1970
1	California	1,740,729	1,996,334	10.7	10.6
2	Texas	1,283,686	1,544,104	7.9	8.2
3	Pennsylvania	653,443	743,865	4.0	3.9
4	New York	623,924	687,721	3.9	3.7
5	Illinois	596,458	660,450	3.7	3.5
6	Ohio	559,018	650,256	3.5	3.5
7	Michigan	533,564	637,655	3.3	3.4
8	North Carolina	482,197	578,302	3.0	3.1
9	Florida	425,408	556,210	2.6	3.0
10	Georgia	410,899	510,886	2.5	2.7
11	Missouri	448,578	510,465	2.8	2.7
12	Indiana	495,685	505,274	3.1	2.7
13	Oklahoma	424,321	490,815	2.6	2.6
	United States Total	16,178,849	18,747,781		

figures.

Sonnenberg (64) was quoted to say that the ICC has approximately 20,877 for-hire carriers registered in the United States. It cannot be determined from the Oklahoma Bureau of Motor Carrier Safety files how many of the 1,747 Oklahoma based carriers are also licensed by the ICC as interstate carriers. However, it has been assumed that nearly all carriers that come under BMCS regulations are also licensed by the ICC because it is very difficult to transport commodities that would not have some element constructed or produced in another state. It is considered an interstate shipment under ICC regulations if any portion of the commodity has been produced in one state and transported into another.

The Office of Hazardous Materials reported 2,255 accidents involving hazardous materials in 1971 from motor carriers (65). These accidents involved 233 carriers of a possible 10,000 handling hazardous materials (see Table 16). It has been estimated that only one out of twenty accidents are ever reported. This low reporting incidence may be a result of carriers inability to estimate damage other than physical damage to the truck.

Gasoline delivery trucks were involved in 311 accidents in 1971. This would appear to be a very low figure compared to the total number of service stations and deliveries. Petroleum products represented the lowest distance shipped of any type of cargo by motor carrier (see Table 17).

The 1967 U. S. Truck Inventory (66) figures showed that for the West South Central region of the United States, trucks engaged in

TABLE 16

DEPARTMENT OF TRANSPORTATION INCIDENT
REPORTS FILED DURING 1971

Mode	Number of Carriers	Number of Reports Submitted
Air Carriers	3	5
For Hire Highway Carriers	233	1,633
Private Highway Carriers	54	258
Rail Carriers	28	346
Water Carriers	10	13
Total	338	2,255

TABLE 17

AVERAGE DISTANCE SHIPPED BY MODE OF TRANSPORT

Group	(In Miles) Rail	Motor Carrier	Private Truck	Total
Meat and Dairy	611	468	166	402
Canned Food	532	335	135	405
Candy and Beverages	690	319	141	368
Textile and Leather	789	457	233	432
Apparel	695	543	238	527
Paper Products	680	277	137	488
Chemicals, Plastics, Synthetics & Rubber	548	283	142	447
Drugs and Paint	447	272	131	312
Petroleum and Coal	379	112	95	692
Rubber and Plastics	714	474	315	528
Lumber and Wood Products	1098	311	178	754
Furniture	903	528	299	569
Stone, Clay & Glass	285	136	107	196
Iron and Steel	367	204	208	314
Non Ferrous Metal	822	415	215	589
Fabricated Metal	556	402	161	366
Metal Cans	543	298	185	334
Industrial Machines	965	536	468	618
Machinery	497	497	313	577
Communication Products	912	547	242	627
Electrical Products	800	498	354	595
Motor Vehicles	539	232	139	409
Transportation Equipment	465	391	443	435
Instruments, Photo & Watches	1123	523	179	593
Average Total Miles	550	270	152	490

agriculture are the most numerous. The second most important group in the four-state region was the wholesale and retail trade trucks. This group, shown in Table 18, represented nearly 225,000 trucks surveyed, including over 40,000 truck-hauling chemicals and petroleum products.

Krasner (67) concluded in his study that 69 per cent of the hazardous material trucking accidents reported to DOT in 1966 involved flammable liquids. Tankers were involved in 72 per cent of the reported hazardous material trucking accidents. There was no indication that flammable liquids or that tankers as a vehicle type represented disproportionate hazards. The high percentage of accidents was more likely due to the equally high percentage of tanker trucks. Table 19 is a review of accidents reported to DOT from July, 1966, to December, 1968.

The Bureau of Motor Safety has compiled figures on motor carrier accidents with hazardous materials in local and intercity transportation in 1969 (68). Petroleum products represented 1.24 per cent of all accidents and 24.2 per cent of hazardous material accidents. Accident experience of major commodity groups is listed in Table 20.

The Oklahoma Department of Public Safety compiled annual statistics on traffic collisions. The 1970 annual report as revised in Table 21 indicates total number of vehicle accidents by vehicle type (69). A total of 123,213 vehicles were involved in accidents of which 4.86 per cent were trucks not classified as pickups.

Motor carrier accidents involving hazardous materials can be classified into three types. First, the intermodal accident between the motor carrier and another vehicle. Secondly, are the single vehicle accidents involving a single motor carrier. A third type of motor

TABLE 18

1967 UNITED STATES TRUCK INVENTORY AND USE SURVEY TRUCKS:
DISTRIBUTION OF PRINCIPLE PRODUCTS CARRIED IN THE
ARKANSAS, TEXAS, OKLAHOMA, AND
LOUISIANA AREA

	(Percentage)						
	Agri-culture	For-estry	Mining	Con-struction	Manufac-turing	Wholesale & Retail Trade	For Hire
Farm Products	81.7	4.4	0.1	-	3.1	9.9	9.9
Processed Foods	0.5	-	-	-	8.0	20.5	1.2
Primary Metals	-	0.2	3.8	6.3	15.0	2.1	1.6
Machinery	0.7	0.6	10.5	6.3	6.3	5.2	3.7
Transportation Equipment	0.2	0.5	0.3	0.8	3.3	5.4	1.9
Building Materials	-	33.8	1.8	42.0	14.7	8.0	2.9
Furniture	-	-	-	-	3.9	11.5	10.8
Chemicals	0.1	-	0.6	2.0	3.4	4.5	1.4
Petroleum	0.1	-	5.4	1.6	0.9	10.8	6.9
Scrap and Garbage	0.3	0.2	-	0.6	2.4	1.0	0.9
Mixed Cargoes	5.5	0.3	3.4	9.7	9.2	10.3	44.5
No Products	4.7	3.3	41.0	20.7	17.4	2.4	2.5
Other	1.5	45.6	14.4	5.7	4.7	5.9	9.6
Unknown	4.7	11.1	18.7	4.3	7.7	2.5	2.2

TABLE 19

MOTOR CARRIER ACCIDENTS INVOLVING FIRE BY COMMODITY
JULY, 1966 - DECEMBER, 1968

Type of Commodity	Accidents No.	Accidents Percent of Total	Deaths No.	Deaths Percent of Total	Injuries No.	Injuries Percent of Total
Gasoline	65	58.56	32	66.67	42	43.75
Other Petroleum	24	21.62	7	14.58	12	12.50
Other Combustible Liquids	3	2.70	4	8.33	20	20.83
Flammable Liquids	5	4.50	0	0.00	10	10.42
Explosives	3	2.70	1	2.08	5	5.21
Non-Combustible Compressed Gas	2	1.80	1	2.08	1	1.04
Corrosive Liquids	5	4.50	2	4.17	2	2.08
Total	111	100.00	48	100.00	96	100.00

TABLE 20

LOCAL AND INTERCITY MOTOR CARRIER ACCIDENTS
BY TYPE OF CARGO TRANSPORTED - 1969

Type of Cargo	Vehicle Total	1969 Percentage
Hazardous Materials		
Other Unclassified Combustibles	592	1.51
Flammable Solids	2	0.01
Gasoline	327	0.83
Other Petroleum Products	489	1.24
Combustible Compressed Gases	56	0.14
Other Combustible Liquids	166	0.42
Explosives	86	0.22
Oxydizing Agents	8	0.02
Dry Acid	1	0.00
Other Flammable Liquid	52	0.13
Non-Combustible Compressed Gases	63	0.16
Corrosive Liquid	171	0.44
Poison Gases	1	0.00
Radioactive Materials	1	0.00
Poisons (excluding gases)	8	0.02
Uranium	0	0.00
Sub Totals	2023	5.14
Non-Hazardous Materials	27290	69.46
Empty	8806	22.40
Other	1183	3.00
Total	39302	

TABLE 21

OKLAHOMA MOTOR VEHICLE ACCIDENTS - 1970

Type of Vehicle	Type of Collision	Total Vehicles Involved
Passenger Cars	Fatal	735
	Injury	18,823
All Type Trucks Other Than Pickups	Fatal	120
	Injury	1,187
Pickup Trucks	Fatal	160
	Injury	2,433
All Other Vehicles	Fatal	61
	Injury	1,415
Totals	Fatal	1,076
	Injury	23,858

carrier accident is that caused by the transfer of the product from storage to truck, truck to truck, or truck to storage.

Motor carriers with hazardous material have been involved in several credible accidents. Thayer (62) reported a truck-train accident at Everett, Massachusetts in March, 1967. A fuel tank trailer stalled on a railroad crossing. The driver of the truck attempted to flag down a 32-passenger self-propelled railroad car moving toward the intersection. The railroad car could not be stopped in time to avoid the collision. The tank trailer exploded killing 13 occupants of the car and injuring 19 others.

Sears (70) reviewed a single vehicle incident at Hopkinton, Massachusetts, September 15, 1970. A twin 1,000-gallon LPG tank delivery truck failed to slow down in a deceleration lane of a freeway and slammed into an overpass abuttment. The tank truck immediately burst into flame killing the driver who was attempting to escape. The tanks exploded shortly thereafter causing extensive damage to the overpass and to passing automobiles. The cause of the accident was not determined.

Finally, a third type of motor carrier accident involves product transfer. Such an accident occurred August 6, 1970, at Moline, Illinois, as reported by the National Fire Protection Association (71). A truck discharging 7,500 gallons of gasoline at a bulk plant ruptured the discharge hose spraying gasoline over a wide area. A spark from the truck engine ignited the vapors resulting in a fire. The fire was contained to the truck, but 20 feet away were 11 storage tanks of gasoline each containing 15,000 gallons. The potential consequence of the storage tanks exploding was never realized.

A more frequent type of product transfer accident results from internal sparking during loading of intermediate vapor fuel such as JP-4 jet fuel. Bulkley and Ginsburg (72) reported in 1967 that over 60 static ignition incidents occurred. The conditions leading to these loading incidents pointed out the direct relation of charge density in the oil to surface potential of producing internal sparking. (Charge density is expressed as the quantity of electrical charge, in micro-coulombs, per volume of oil in cubic meters or microcoulombs per cubic meter.) When 20 kilovolts of energy are produced approximately 1 inch away from various grounded electrodes, such as the fill pipe, a spark is created causing ignition.

The materials involved in these incidents represented only a small portion of the extra-hazardous cargo carried over the nation's 3 million miles of public roads. The National Board of Fire Underwriters (73) estimated that in 1963, more than 300,000 tons of explosives, 250,000 tons of blasting agents and 200,000 tons of poisonous substances moved over the highways. In addition, some 1200 shipments of radioactive materials and an undetermined amount of etiological agents are moving on the nation's streets and highways.

In 1969, the Bureau of Motor Carrier reported the total property damage due to accidents of motor carriers was $85,045,860 (68). The property damage due to accidents involving hazardous materials amounted to $6,516,930 during the same period. Booz-Allen (74) summarizes the distribution of property damage for motor carriers in Table 22. The 17.1 per cent of hazardous material accidents result in more than $5,000 property damage while only 8.8 per cent of all other

TABLE 22

PROPERTY DAMAGE FOR UNITED STATES MOTOR CARRIERS - 1966

Range (Dollars)	Hazardous Cargo		All Others	
	Number	Percentage	Number	Percentage
0	57	2.6	674	1.8
1 - 250	201	9.3	4,599	12.6
251 - 500	472	21.8	11,670	31.9
501 - 750	246	11.4	4,538	12.4
751 - 1000	211	9.8	3,093	8.5
1001 - 1250	109	5.1	1,703	4.7
1251 - 1500	78	3.6	1,322	3.6
1501 - 2000	109	5.1	1,723	4.7
2001 - 2500	76	3.5	1,193	3.3
2501 - 3000	59	2.7	905	2.5
3001 - 3500	48	2.2	666	1.8
3501 - 4000	52	2.4	505	1.4
4001 - 4500	45	2.1	368	1.0
4501 - 5000	28	1.3	370	1.0
over - 5000	370	17.1	3,204	8.8
Total	2,161	100.0	36,533	100.0

accidents fall into this group.

Damage to the environment has not been easy to compute. Many transportation accidents have occurred doing extensive damage to the environment, but have not been recognized in the property damage figures. The Federal Water Quality Administration has compiled annual fish kills due to transportation causes (75). Table 23 summarizes the 1965 through 1969 fish kills caused by transportation accidents involving hazardous materials. The dramatic increase in total numbers of fish killed may in part be due to the increased surveillance since 1965.

Planning Hazardous Material Incident Control

The National Oil and Hazardous Substance Pollution Contingency Plan (7) has been developed in compliance with the Federal Water Pollution Control Act of 1970. The President delegated authority to the Council of Environmental Quality to provide for the preparation, publication, revision, and amendment of a National Contingency Plan for removal of oil and hazardous substances. The Plan provided for a pattern of coordinated and integrated response by Federal agencies and departments to protect the environment from damaging effects of hazardous material spills.

The Plan provided for assignment of duties and responsibilities, establishment of emergency task forces, a system of notification and reporting, establishment of a National Coordination Center, a schedule of hazardous substance spill treatments, enforcement and investigative powers, public information, and on-scene coordination.

Like the Federal plan, Oklahoma has declared a policy and responsibility under the Plan to eliminate the discharge of oil or hazard-

TABLE 23

TRANSPORTATION FISH KILL ACCIDENTS, 1965-1969

Year	Type	Total Reports	Fish Killed
1965	Rail	6	1,400
	Truck	12	105,940
	Barge	3	2,050
	Pipeline	6	197,420
		27	306,810
1966	Rail	6	12,792
	Truck	11	65,689
	Barge	3	-
	Pipeline	7	24,150
		27	120,631
1967	Rail	4	12,950
	Truck	7	27,062
	Barge	3	80,250
	Pipeline	8	22,861
		22	143,123
1968	Rail	10	283,937
	Truck	5	6,003
	Barge	9	1,839
	Pipeline	15	533,586
		39	825,365
1969	Rail	11	1,653,664
	Truck	8	56,053
	Barge	3	1,520
	Pipeline	10	345,793
		32	2,057,030

ous substances in sufficient quantities to degrade the quality of all water within their jurisdiction (76). The emphasis of each plan deals with pollution of waters without regard to the environment in general.

In Oklahoma, the State Response Team (SRT) acts as an emergency response team to be activated in event of a major oil or hazardous substance incident. The SRT membership includes as primary agencies: Oklahoma State Department of Agriculture, Oklahoma Corporation Commission, Oklahoma State Department of Health, State Department of Pollution Control, State Department of Wildlife Conservation, and the Oklahoma Water Resources Board. The names and telephone numbers of members of each department are listed in the plan to facilitate communication.

Kerr McGee Corporation has adopted an emergency response network for agents dealing with their products. Hazardous materials produced by Kerr McGee have on the label a telephone number to be called 24 hours a day in event of accident. Beckstedt (77) stated that Kerr McGee was the first company to instigate such a system.

The National Agricultural Chemical Association (78) developed in March, 1970, a National Safety Team Network to deal with incidents involving class B poisons and other pesticides. The system works similar to the Kerr McGee system except after calling a central number in Cincinnati, Ohio, a predetermined regional team is alerted. Upon receipt of an emergency message, the operator contacts the manufacturer or producer of the involved product regarding procedures for cleanup or containment. If assistance is necessary, one of 12 participating companies will furnish equipment or technical assistance for the prompt and efficient cleanup and decontamination. The 12 companies representing 40

safety teams are: Chevron, Shell, Stauffer, Monsanto, Dow, Hercules, Chemagro, Diamond Shamrock, Velsicol, Niagra, Union Carbide, and Kerr McGee.

The Manufacturing Chemists Association (79) has developed the Chemical Transportation Emergency Center to give assistance involving any chemical spill in transportation. This system provides a toll free number to call in Washington, D.C. for emergency assistance. This emergency system does not have safety teams but will assist the local authorities with information regarding the characteristic of spilled chemicals and how best to handle the situation. They also publish the Chem-Card manual carried by police, fire, and emergency response people for quick identification of the hazards of selected chemicals. Truckers also carry the manual when handling dangerous materials.

Hutchinson (80) has proposed six objectives of a transportation system:

a) Minimize travel time between land use areas.

b) Maximize transportation safety.

c) Minimize operating costs of transportation systems.

d) Maximize the development of the planned land use configuration and intensity of development.

e) To minimize capital cost.

f) To balance the capacity of the system with the capacity of the environmental land use areas to accept transportation.

Transportation planners would generally agree to these goals and at the same time overlook the nature and characteristics of vehicles within the transportation systems. The planning process should have included built-in precautions to prevent hazardous material

incidents.

Leimkuhler (81) asks the question, "How much precaution is needed and what special safeguards can be justified for shipments of hazardous materials?" A wide variety of special precautions have been suggested to maintain the integrity of cargoes, including: escorts, buffer vehicles, convoys, special tie-down systems, enroute inspection, local police coordination, and restriction to certain traffic systems.

Beals (82) suggested that external climatic conditions must be examined from existing meterological data to determine transportation needs. He considered as a transportation environment, those conditions of heat or energy that serve as "initiating stimuli" in causing fire or explosions. He further suggested that when the hazardous substance involved in an incident results in a vapor cloud, either poisonous or explosive, the atmospheric conditions determine the extent of the denger. The contributing factor is the ability of the atmosphere to disperse such a cloud, this ability being dependent on local topography, wind speed, time of day, and season. Those climatic conditions of particular emphasis to hazardous material transportation are temperature, radiant energy day and night, extremes of humidity, atmospheric pressure, and atmospheric turbulence.

Edgerton (83) recommended 14 steps for reducing probability of accidents with hazardous materials:

a) Transportability of shipping containers.

b) Reliability of containers and vehicles.

c) Administrative controls, checklists, and standards of operation.

d) Improved container design and manufacturing.

e) Performance standards.

f) Labeling and placarding.

g) Driver and carriers briefings.

h) Inspection of vehicles.

i) Careful selection of shipping routes and schedules.

j) Centralized accident reporting and analysis.

k) Check and control points during transport.

l) Time control of shipment passing through congested areas.

m) Escorts for shipments.

n) Speed control of vehicle.

He further suggested for reduction of hazardous material accidents, that adequate damage reporting systems, special investigation of accidents, instrumentation to measure characteristics of load and monitoring to observe movement and cargo stress and vibration data must be accomplished.

The National Transportation Safety Board (84) discussed the different requirements of packaging for different modes of transportation. An analysis was made from selected data as seen in Table 24:

> "The mode with the lowest safety value setting permits the highest filling density, while the smallest 'package' with the highest minimum working pressure has the lowest filling density limit. Retest requirements for the smallest 'package' are the most stringent, while there are no retest requirements for the mode which carries massive continuous flows of the commodity."

Retesting of tank barges is not routinely required while the mode with continuous flows and the potential for the largest spills has the lowest test-to-working pressure ratio. Still another example of difference in regulatory requirements occurs in control of low temperature brittleness

TABLE 24

PACKAGING REQUIREMENTS FOR ANHYDROUS AMMONIA BY MODES

Requirement	Modes				
	All Air Cylinders	Highway	Rail	Pipeline	Marine
Working Pressure (lowest)	300.00	265.0	225.0	no set limit	250
Maximum Allowable Filling Density (percentage)	54.00	56.0	57.0	not applicable	57
Periodic Retest Years	10.00	5.0	10.0	none	discretionary
Pressure PSI	700.00	397.5	337.5	required	discretionary
Test Working Pressure	2.33	1.5	1.5	1.14	-
Retirement Criteria	fail retest	fail retest	fail retest	none	fail retest

of vehicle tank materials. Railroad tank cars for anhydrous ammonia are not required to have steel which remains tough at low pressures, but cargo tanks for motor carriers must be made of steel which passes toughness tests at -30° Fahrenheit.

Morgan et al. (85) prepared tables regarding the cost of a hazardous material motor carrier incident. Using radiological material as an example, they devised six categories of accident situations:

Category I - Shipment delayed in route, local police furnish surveillance. $200-500

Category II - Load surface radiation raised. AEC furnishes a 2-man survey team. Surveillance and special parking required. $2,000-5,000

Category III - Limited release confined to truck. Surface decontaminated. Surveillance and special parking required. $5,000-10,000

Category IV - Release to ground. Area cleared causing temporary work stoppage. Detours required. Driver hospitalized. $20,000-50,000

Category V - Truck-trailer overturns and burns. Release to environment. Evacuation of four square blocks. Driver hospitalized. $50,000-100,000

Category VI - Liquid release to water via ground. Community water supply damaged for three days. Extensive detours. $1,000,000-2,000,000

These figures are subject to many variables, particularly if the incident occurred on a county road in rural Oklahoma in contrast to a metropolitan downtown street. Only major types of hazardous material incidents are reported to DOT; therefore, the small spills and incidents occurring without serious injury or damage are not recorded. The costs of restoring the environment to its original state are difficult to compute, and in many cases, when considered, would run higher than the actual physical property damage.

Rath *et al.* (86) referred to economic constraints affecting the willingness of carriers to report each incident. Carriers fear that increased regulations will result, making hazardous material shipments more expensive to handle. Public pressure could force the improvement of packaging regulations, heavier walls on tankers, impositions on maximum quantities and a greater emphasis on separation of commodities. Public pressure could also force expensive and time consuming routing for bulk shipments avoiding inhabited areas.

CHAPTER II

PURPOSE AND SCOPE

Evidence had indicated that controls of hazardous material transportation by motor carrier in Oklahoma has been inadequate. It has been demonstrated that the character and degree of hazardous materials on Oklahoma highways is not known. It was the purpose of this study to analyze the characteristics of hazardous material movement on the major highway systems of Oklahoma to determine relative numbers, varieties, and movements within the state. It was also the purpose of this study to provide recommendations for hazardous materials transportation in Oklahoma based on available data. From these recommendations it was felt that state and local hazardous materials control programs could be formulated.

The truck weight studies conducted by the Oklahoma State Highway Department in 1970, 1971, and 1972 were reviewed to determine hazardous material movement through selected highway scale houses. Specifically, data were recorded for the hour of day passing the scale house, direction of travel, state of registration, station location, body style of hazardous material truck, and the specific commodity aboard. The data for each scale house was tabulated and compared for each of the 3-year periods.

It was felt that the investigative technique as well as the information obtained from this study could be used by local and state governmental agencies to determine the need for hazardous material safety programs. Communities within Oklahoma might also benefit from this information to better understand the nature and complexity of their individual hazardous material problems. It was also intended by this study to acquire the basic knowledge and data regarding movement of hazardous material in Oklahoma for promotion of additional study and research, particularly in the areas of truck safety and cargo security.

CHAPTER III

METHODS AND PROCEDURES

The data for this study was assimilated from the Oklahoma Department of Highways annual truck weight study. The truck weight studies are done by a five- to seven-man crew each summer at selected scale houses throughout the state. A variety of information is collected on each truck passing through the stations during the survey period. The information once recorded on survey sheets was coded and placed onto computer tape.

The coded data for 1970, 1971, and 1972 were available for review. The data from the highway department computer tapes were transferred to a University of Oklahoma Health Sciences Center computer tape and made compatible with the O.U. computer. The program was then run on the University of Oklahoma Health Sciences Center IBM 360 Computer. Computer services were utilized between a period from September 1, 1972, and February 2, 1973.

A Fortran program was written to retrieve pertinent data from the highway department tapes. The following information was recorded from the available data for each year:

a) A listing of all trucks and commodities passing through each station.

b) The total number of trucks surveyed per station.

c) Hour of the day truck passes through station by commodity aboard.

d) Direction of travel for each truck.

e) Hour of the day hazardous material trucks pass through each station.

f) Body style of truck for each hazardous material shipment.

g) Direction of travel for each hazardous material.

h) Number of hazardous material trucks for each station.

It was not possible from the coded data to determine in each case the specific commodity aboard every truck; therefore, it was necessary to manually examine each survey sheet collected for the 3-year periods. Approximately 23,000 reports were reviewed for specific hazardous material aboard and the state of registration for the truck.

The scale houses used as survey points were the same each year of the study. The length of time the survey was conducted in each scale house was also the same for each year. Each station was not, however, surveyed the same number of hours. Ten stations were operated for 16 hours, 6 a.m. to 10 p.m., but never more than 8 hours in any one day. Four stations were operated for 24 hours, but never more than 8 hours for any one day. Surveys were conducted on weekdays only, Saturday and Sunday being excluded.

Fourteen scale houses were used in the study. The location and length of time for survey for each station are as follows:

1) Sayre - 2 miles west of Sayre on I-40 (24 hours)

2) Boise City - north edge of town on U.S. 385 (16 hours)

3) Woodward - 1 mile N.E. on U.S. 270 (16 hours)

4) Davis - for 1970 and 1971 the scale house was located 2 miles north of Davis on U.S. 77. I-35 was completed for 1972 study and the scale house was relocated 5 miles south of junction of State Highway 7 and I-35 (16 hours)

5) McAlester - 1 mile south of McAlester on U.S. 69 (16 hours)

6) Durant - 2 miles north of Durant on U.S. 69 (24 hours)

7) Warner - east of Warner on U.S. 64 (16 hours)

8) Tulsa - at north end of Turner Turnpike at U.S. 75 junction (24 hours)

9) Vinita - 4 miles west of Vinita on U.S. 66 (16 hours)

10) Blackwell - 5 miles north of U.S. 60 exit on I-35 (24 hours)

11) Ada - Main St. junction State Highways 99 and 3 (16 hours)

12) Hugo - 3 miles south of Hugo on U.S. 271 (16 hours)

13) Drumright - junction of State Highway 33 and State Highway 16 (16 hours)

14) Altus - 2.5 miles east on U.S. 62 (16 hours)

Identification of a hazardous material was made from the materials listed in the Department of Transportation Code of Federal Regulations, Title 49, Section 172.5. In addition, any commodity that would probably cause dramatic environmental damage but was not listed on the federal list was also included.

Traffic volume characteristics were obtained from the highway department annual traffic studies. These studies are conducted on a continuing basis throughout the year. Average daily traffic and truck traffic flows were available for 1970, 1971, and 1972. Each scale house was represented in these studies.

Commodities aboard all trucks passing through the scale house were tabulated for each of the three years. Comparisons were made for

total number of trucks by commodity and determinations were made regarding the percentage of each commodity for the total number of trucks.

The total number of trucks passing each station during the survey was tabulated by year. Comparisons were made to determine changes in traffic flow at each station over the three-year period.

A listing of each hazardous material load was recorded as to state of registration for the truck. Comparisons were made regarding the frequency of states and total number of states represented. The state of registration for hazardous materials was listed for each scale house. These data were reviewed to determine the influence of the adjoining states on a particular station.

A comprehensive listing of hazardous materials passing through each scale house by year was compiled. Changes in frequency of particular hazardous materials were noted. Changes in the total species of hazardous materials per year were also determined.

The hazardous material flow characteristics for each scale house were reviewed. The total volume of hazardous materials was tabulated for each station by year. The direction of hazardous material flow was also determined and listed for each year.

Each scale house was examined for specific hazardous materials passing during the survey. The frequency of each material by year was recorded.

Net positive flow of hazardous materials for each station was calculated. General characteristics of the movement of hazardous material through Oklahoma were made from these data, and recommendations were formulated.

CHAPTER IV

OBSERVATIONS AND DISCUSSION

The proportion of hazardous material shipments by motor carrier in Oklahoma was 8.94 per cent in 1970, 9.11 per cent in 1971, and 10.01 per cent of total motor carrier shipments in 1972. Direct comparison with data from other states and the United States have not been available, but estimates have been computed. Sonnenberg (24) has estimated that, nationally, 4 per cent of all motor carrier shipments are hazardous materials. Extracting from the 1967 Truck Inventory and Use study by the Department of Commerce, trucks used for shipping petroleum and chemicals equaled 4.96 per cent (66). From the same study, the west-south-central district, which included Arkansas, Louisiana, Texas, and Oklahoma, equaled 4.37 per cent. These data indicate that Oklahoma has experienced up to 2.5 times the hazardous material shipments predicted for adjoining states or the Nation (see Table 25 and 26).

The most frequent hazardous materials noted were gasoline, lube oils, tar-asphalt, bombs, jet fuel, and ammonium nitrate. Gasoline lead all categories in 1970 and 1972 with 21.13 per cent and 24.59 per cent. Lube oils headed hazardous material categories in 1971 with 20.54 per cent with gasoline second at 17.82 per cent (see Table 27).

TABLE 25

UNITED STATES CHEMICAL AND PETROLEUM SHIPMENTS
BY MOTOR CARRIER, 1967 TRUCK INVENTORY
AND USE STUDY

	Total Surveyed	Chemicals	Petroleum
Agricultural	3,710,000	22,260	11,130
Forestry	156,000	0	936
Mining	104,000	1,664	3,120
Construction	1,144,000	21,660	17,328
Wholesale-Retail	1,887,000	81,141	198,135
For Hire	677,000	14,895	20,987
Manufacturing	372,000	15,996	5,580
Total	8,350,000	157,615	257,216
Total Percentage	100	1.88	3.08

TABLE 26

OKLAHOMA, LOUISIANA, TEXAS, AND ARKANSAS CHEMICAL AND PETROLEUM SHIPMENTS BY MOTOR CARRIER, 1967 TRUCK INVENTORY AND USE STUDY

	Total Surveyed	Chemicals	Petroleum
Agricultural	600,000	600	600
Forest	24,000	0	0
Mining	27,000	162	1,458
Construction	169,000	3,380	2,704
Manufacturing	36,000	1,224	324
Wholesale-Retail	224,000	10,080	24,192
For Hire	66,000	924	4,554
Total	1,146,000	16,370	33,832
Total Percentage	100	1.42	2.95

TABLE 27

INVENTORY OF HAZARDOUS MATERIALS
FOR ALL STATIONS

	1970	Per-centage	1971	Per-centage	1972	Per-centage
Gasoline	75	21.13	72	17.82	105	24.59
Tar-Asphalt	41	11.55	47	11.63	25	5.85
Bombs	34	9.57	22	5.44	18	4.23
Jet Fuel	25	7.04	9	2.23	13	3.04
Lube Oil	23	6.48	83	20.54	53	12.41
Ammonium Nitrate	16	4.51	16	3.96	37	8.68
Ammunition 30 mm +	12	3.38	3	0.74	3	0.70
Miscellaneous Inorganic and Organic Chemicals	11	3.10	21	5.19	32	7.49
Propane	9	2.54	11	2.72	26	6.10
Paint	9	2.54	8	1.98	3	0.70
Detergents	8	2.25	7	1.73	3	0.70
Diesel	6	1.69	11	2.72	16	3.76
Salt	6	1.69	6	1.48	9	2.12
Surry Oil	6	1.69	-	-	-	-
Butane	5	1.41	4	0.99	3	0.70
Glues and Adhesives	4	1.13	13	3.21	4	0.94
Lime	4	1.13	9	2.22	10	2.35
Liquid Oxygen	3	0.85	4	0.99	4	0.94
Cleaning Fluids	3	0.85	-	-	1	0.23
Crude Oil	3	0.85	5	1.23	-	-
Insecticides	3	0.85	1	0.25	1	0.23
Sulphuric Acid	3	0.85	1	0.25	6	1.42
Benzene	3	0.85	2	0.50	1	0.23
Sodium Alkali	3	0.85	5	1.23	-	-
Chemical and Petroleum Waste	3	0.85	1	0.25	-	-

TABLE 27--Continued

	1971	Per-centage	1971	Per-centage	1972	Per-centage
Synthetic Resin	3	0.85	1	0.25	-	-
Oil Field Chemicals	2	0.56	1	0.25	-	-
Liquid Carbon Dioxide	2	0.56	5	1.23	1	0.23
Fireworks	2	0.56	-	-	-	-
Chlorox	2	0.56	-	-	-	-
Miscellaneous Petroleum Products	2	0.56	-	-	-	-
Gas-Oil	2	0.56	-	-	-	-
Oxygen	2	0.56	1	0.25	1	0.23
Aviation Gas	2	0.56	1	0.25	-	-
Hydrogen	2	0.56	1	0.25	1	0.23
Alcohol	2	0.56	2	0.50	1	0.23
Urea	1	0.28	1	0.25	-	-
Explosives	1	0.28	-	-	2	0.47
Argon	1	0.28	-	-	-	-
Toluene	1	0.28	2	0.50	-	-
Kerosine	1	0.28	1	0.25	-	-
Distillate Fuel	1	0.28	-	-	-	-
Ammonium	1	0.28	1	0.25	9	2.11
Rockets	1	0.28	-	-	-	-
Rocket Fuel	1	0.28	-	-	-	-
Liquid Nitrogen	1	0.28	-	-	5	1.17
Coal Tar	1	0.28	1	0.25	-	-
Rodenticide	1	0.28	-	-	-	-
Ethylene	1	0.28	-	-	-	-
Blasting Caps	1	0.28	-	-	-	-
Acetylene	-	-	1	0.25	8	1.87
Nitroglycerine	-	-	1	0.25	-	-
Synthetic Detergent	-	-	1	0.25	-	-
Natural Gasoline	-	-	1	0.25	-	-

TABLE 27--Continued

	1970	Per-centage	1971	Per-centage	1972	Per-centage
Radioactive Materials	-	-	2	0.50	2	0.47
Solvent	-	-	1	0.25	2	0.47
Paint Solvent	-	-	1	0.25	-	-
Helium	-	-	1	0.25	-	-
Chlorine	-	-	2	0.50	3	0.70
J P 4 Gasoline	-	-	8	1.98	-	-
Nitric Acid	-	-	1	0.25	-	-
Vinegar	-	-	2	0.50	1	0.23
Ammonium Hydroxide	-	-	1	0.25	-	-
Antifreeze	-	-	1	0.25	-	-
Hexane	-	-	1	0.25	-	-
Hydrocyanic	-	-	-	-	1	0.23
Carbonic Acid	-	-	-	-	1	0.23
Hydrochloric Acid	-	-	-	-	1	0.23
Nitric Oxide	-	-	-	-	1	0.23

No particular flow pattern was noted for gasoline. Gasoline cargoes were detected at all survey stations, and in only one case, Drumright, was gasoline noted moving predominantly in one direction for each of the 3-year periods.

Bombs and ammunition were detected almost exclusively at the Sayre station and were moving predominantly westward. A total of 74 bomb shipments were noted for the three years in Oklahoma, 65 listed at Sayre with 63 of them moving west. Of all bomb and ammunition shipments, 85.13 passed the Sayre station. It was determined that the majority of the bomb and ammunition trucks originated at the McAlester arsenal with a small proportion coming from the Red River Arsenal in Texas. These data support that on a given day, 18 to 34 bomb, ammunition, or other classified military explosive trucks crossed through metropolitan Oklahoma City and west into Texas.

For the 3-year period, hazardous materials increased 16.87 per cent overall at the survey stations. The totals were 355, 404, and 427, respectively, for 1970-72. Fallwell (29) reported chemical production up 4.2 per cent in 1970, up 1 per cent in 1971, and down 1 per cent in 1972. These data would suggest that annual production of hazardous materials does not immediately affect the frequency of movement in Oklahoma.

Figure 2 and Figure 3 show the total number of hazardous material trucks per station and direction of flow. The survey stations located on State and U.S. highways showed relative stability for frequency over the 3-year period. This can partially be explained by the fact that these highways are feeder roads to local communities, and hazardous materials remained constant to the needs of the community.

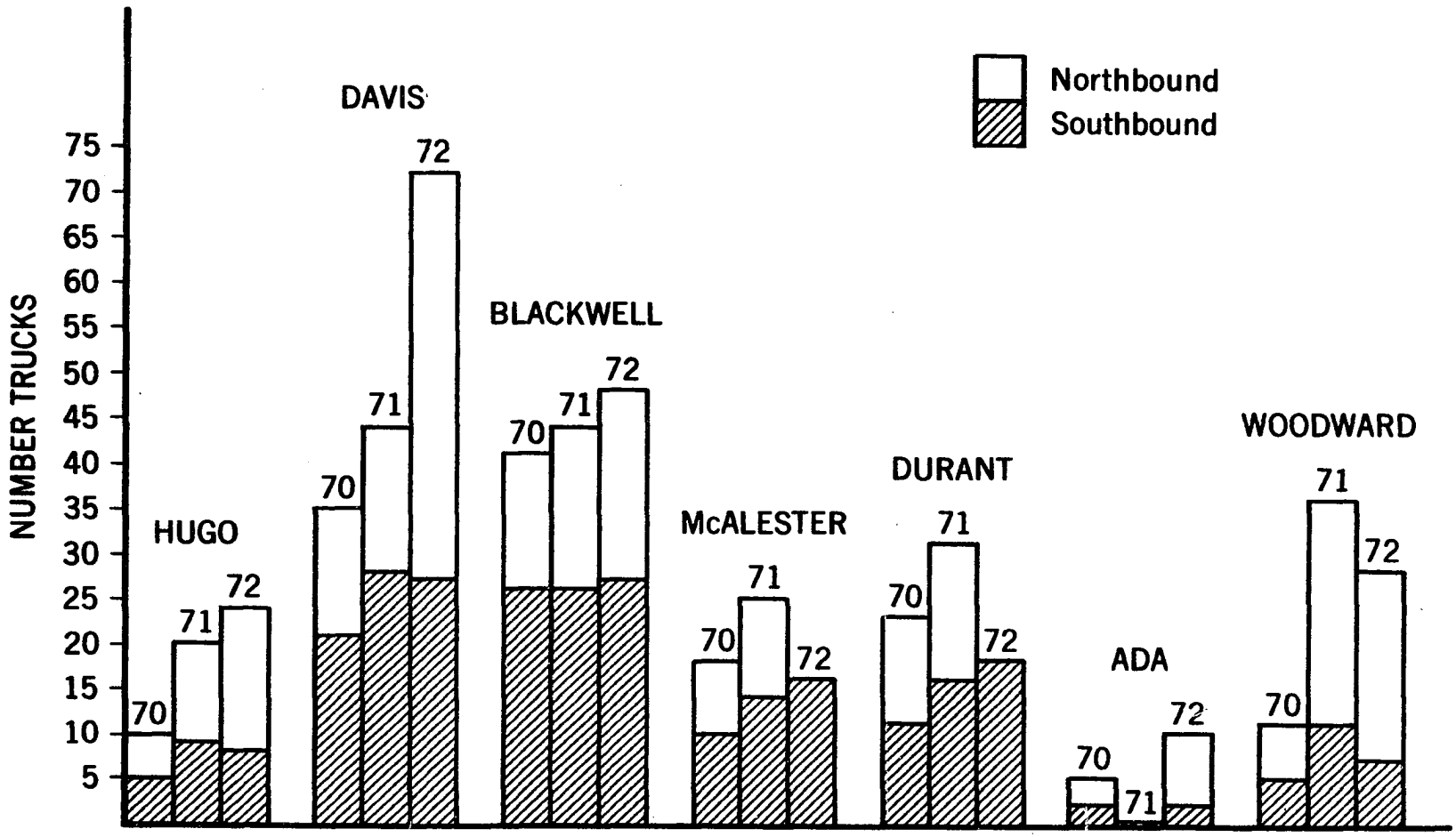

Figure 2.--Volume and Direction of Hazardous Materials, Oklahoma Stations (Northbound and Southbound).

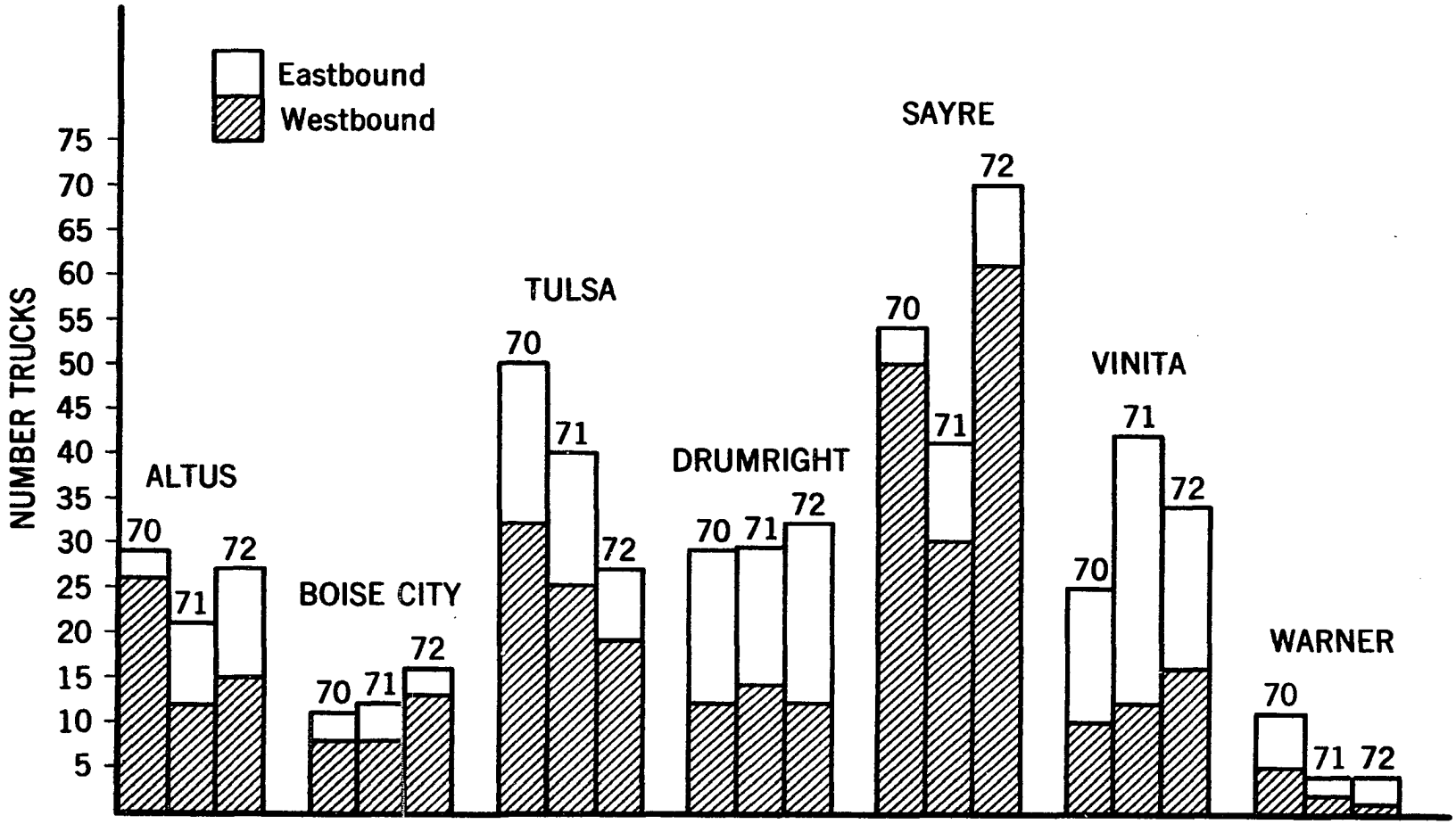

Figure 3.--Volume and Direction of Hazardous Materials, Oklahoma Stations (Eastbound and Westbound).

Examination of the three interstate highway stations indicated annual increases of hazardous materials. These stations are listed as Blackwell, Davis, and Sayre, and represented increases of 16.32, 22.85, and 51.38 per cent, respectively. The significant increase at Davis was due in part to the opening of I-35 Interstate between Oklahoma City and the Texas border in the Fall of 1970. These data indicate that a large portion of northbound hazardous materials which moved through Durant in 1970 and 1971 shifted to the new interstate in 1972.

Figure 4 illustrates the net positive flow for each station for each year. The net positive flow has been determined as the direction at each station that the greatest number of hazardous materials trucks were moving. This comparison reveals that there was a funneling of hazardous materials from Tulsa, Blackwell, and Davis toward Oklahoma City and westward toward Sayre. These data further support that the movement of hazardous materials was concentrated toward the densely populated areas of Oklahoma.

It was also observed (Table 28) that Oklahoma registered trucks outnumbered the trucks registered in all other states for each year; however, the total percentage of Oklahoma trucks to out-of-state trucks decreased, indicating that out-of-state trucks played a bigger role in transporting hazardous materials through Oklahoma. These data support the belief that Oklahoma has been the intersection for national transportation.

All survey stations had a majority of Oklahoma registered trucks moving through during the test period. Stations located other

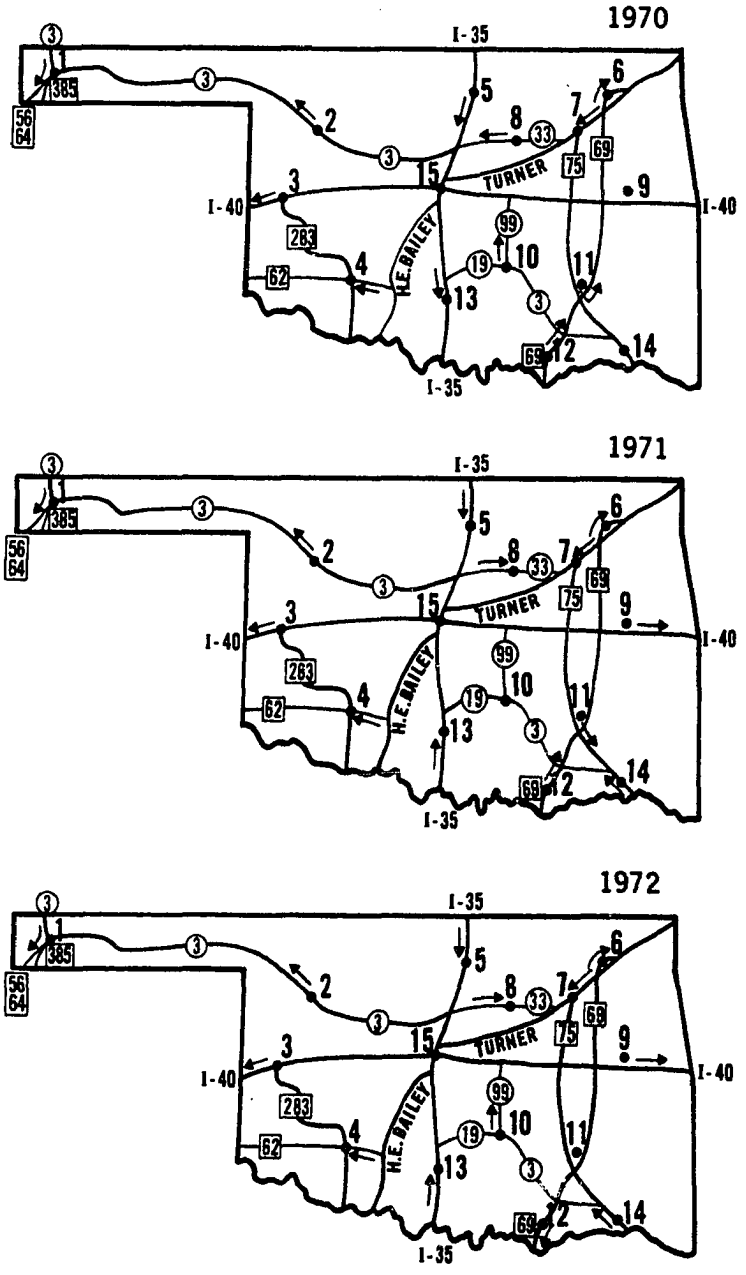

Figure 4.--Net Flow of Hazardous Materials at Oklahoma Stations, 1970-1972.

TABLE 28

STATE OF REGISTRATION FOR HAZARDOUS MATERIAL SHIPMENTS

	1970	Per-centage	1971	Per-centage	1972	Per-centage
Oklahoma	281	79.16	301	74.75	300	70.25
Texas	37	10.44	45	11.13	62	14.52
Missouri	12	3.39	20	4.95	8	1.87
Kansas	12	3.38	8	1.98	33	7.73
Nebraska	2	0.56	4	0.99	5	1.20
New Mexico	2	0.56	-	-	-	-
Arkansas	1	0.28	5	1.24	3	0.70
Tennessee	1	0.28	-	-	1	0.23
California	1	0.28	-	-	3	0.70
Wisconsin	1	0.28	-	-	-	-
Delaware	1	0.28	3	0.73	-	-
Colorado	1	0.28	4	0.99	3	0.70
Iowa	1	0.28	5	1.24	-	-
Florida	1	0.28	1	0.25	-	-
Indiana	1	0.28	-	-	-	-
Mississippi	-	-	2	0.50	2	0.47
Ohio	-	-	2	0.50	1	0.23
Illinois	-	-	1	0.25	2	0.47
Michigan	-	-	1	0.25	-	-
Minnesota	-	-	1	0.25	-	-
Alabama	-	-	-	-	2	0.47
New Jersey	-	-	-	-	1	0.23
Louisiana	-	-	-	-	1	0.23
Total	355	100.00	404	100.00	427	100.00

than on interstate highways reported predominantly Oklahoma trucks with a small influence from the nearest border states. For example, at Boise City, the majority of hazardous materials were on Oklahoma trucks with a few trucks from Colorado and Texas, and at Hugo, the majority was from Oklahoma with several trucks from Texas. At the three stations on interstate highways, the out-of-state influence increased beyond just the nearest border state and included a broad spectrum of states.

A certain sequence of events has occurred which was felt to be a problem regarding the transportation of hazardous materials in Oklahoma. As the interstate highway system has been improved, hazardous material shipments as well as other commodities have been shifted to the new improved highways. It also appeared that improved interstate systems attracted the out-of-state transporter of hazardous material, possibly using Oklahoma as a short cut to points east and west, north or south.

Tank trucks transported 49 to 58 per cent of all hazardous materials, while closed van-type trucks handled 22 to 26 per cent. A total of 23 different body types were noted including flatbed, open top van, hopper, stock, grain, and pick-up trucks (see Table 29). The integrity of a hazardous material shipment involved in an accident has been considered a serious problem, particularly with vehicles of open-type body styles.

Miscellaneous freight shipments represented 18.18 per cent of all commodities surveyed. The miscellaneous category included shipments with two or more commodities. It was felt that a certain proportion of these shipments contained hazardous materials further increasing the

TABLE 29

BODY STYLES FOR HAZARDOUS
MATERIAL SHIPMENTS

Body Types	1970	1971	1972
Pickup	1	1	15
Flatbed	12	22	24
Low Boy	2	1	-
Rack	4	-	2
Canopy	3	-	-
Open Top Box or Van	21	11	17
Dump	4	28	3
Hopper	2	5	11
Van	92	90	110
Insulated	4	9	12
Moving	1	-	1
Tank	53	37	51
Petroleum Tank	153	191	161
Bottler	2	1	5
Utility	1	-	1
Panel	-	2	-
Stock	-	1	4
Grain	-	5	2
Pipe	-	-	1
Express	-	-	1
Bituminous	-	-	4
Mixer	-	-	4
Container	-	-	1
Total	355	404	427

total percentage of hazardous material shipments. These data and the literature suggest that mixed cargoes represent problems of compatability and cross contamination.

CHAPTER V

SUMMARY AND CONCLUSIONS

The research was designed to determine the extent of hazardous materials transported by motor carrier in Oklahoma. A total of 19,418 motor carriers were surveyed from 1970 to 1972 at 14 Oklahoma highway scale houses. The data collected for each motor carrier were commodities aboard, directions of movement, State of motor carrier registration, body styles of unit, and time of day passing the scale house. A review of State and local hazardous material controls was also conducted, including accident response and cleanup proceedings.

Based on the observations and results of this study, the following were concluded:

1. The total number of hazardous material shipments by motor carrier in Oklahoma has increased over the 3-year period. A total of 1,186 trucks contained hazardous materials for an overall proportion of 9.38 per cent. The data support that motor carrier transportation of hazardous materials in Oklahoma may be several times above the national average.

It is recommended that the State of Oklahoma, including its constituent communities, enact legislation controlling the movement of hazardous materials. Adequate regulation does not exist presently in

Oklahoma to deal with intrastate movement of hazardous materials. Consideration should also be given to special city and state routing where necessary, standards for special placarding, and controls on movement of hazardous materials in metropolitan areas during peak traffic congestion. Legislation should also include control of hazardous material shipments during periods of inclement weather such as ice, snow, fog, smoke, and severe storms.

2. The net positive flow of hazardous material on interstate highways moved predominantly toward Oklahoma City and westward to Sayre. This concentration of hazardous material toward densely populated areas increases the potential for accidents resulting in loss of life, property damage and environmental degradation. The literature supports the belief that Oklahoma communities have not been adequately prepared or knowledgable to handle incidents involving these materials.

It is recommended that the Oklahoma Department of Public Safety revise their accident reporting system to include the nature of the commodity aboard motor carriers involved in accidents. The record should include not only the specific name of the commodity but also information regarding commodity loss and general integrity of the load. The reporting system should also include information regarding final deposition of the lost commodity and particular facts regarding clean up.

The data available from this record system would provide valuable information regarding hazardous material accidents and aid responsible agencies toward better control of hazardous materials.

3. Oklahoma registered trucks shipping hazardous materials were reported over 70 per cent of the time for the 3-year period. A 10

per cent decrease in Oklahoma trucks was noted for the 3-year period indicating a greater influence from out-of-state motor carriers. This out-of-state influence can be expected to increase the total number of hazardous material shipments through the densely populated areas of Oklahoma because of the transient nature of out-of-state trucks and their extensive use of interstate highways which intersect near metropolitan areas.

It is recommended that a port-of-entry system be established in Oklahoma to provide a constant monitoring of interstate shipments of hazardous materials. The system would require 24-hour operation of scale houses on major highways near state borders. This system would provide the mechanism for the Oklahoma Department of Public Safety to enact a hazardous material safety program and at the same time increase tax revenue and provide needed weight controls for motor carriers. Such a program would accumulate valuable information regarding various kinds and amounts of hazardous materials. The safety program should also include motor carrier inspection and provide special routing requirements for particular commodities and restrictions to movement during severe climatic conditions.

4. Gasoline and petroleum products were the most frequently detected hazardous materials transported by motor carrier in Oklahoma. These materials were detected at all stations and can be expected to move on every highway and every major street in the State of Oklahoma. Potential danger exists from the total numbers and ubiquitous nature of these vehicles.

5. These data indicate that 85.13 per cent of all ordinance and

ammunition transported through Oklahoma moved west through Oklahoma City on I-40. This has suggested a disproportionate hazard to metropolitan Oklahoma City from accidents involving explosives. In addition to the inherent danger of these materials, the question of national security has been raised. The bombs, ammunition, and other hazardous materials have been manufactured with a relatively good degree of security, but once loaded onto a truck all security vanishes until reaching a final destination. The American society has been vulnerable to the radical and revolutionist bent on disruption and destruction.

It is recommended that the Federal Government investigate methods for securing the safe delivery of extra hazardous materials and study the possibility of sabotage and hijacking of certain hazardous materials.

6. Tank trucks transport over 50 per cent of all hazardous materials in Oklahoma. The second most frequent group was closed vans representing 25 per cent. The remaining 25 per cent were open type vehicles such as dump trucks, flatbeds, and open vans.

These data suggest that a considerable amount of hazardous material has been transported in open-type vehicles. The integrity of such loads are in doubt when involved in accidents.

It is recommended that additional research be conducted regarding the stability of hazardous materials transported in open-type vehicles, particularly its ability to remain intact through accident conditions.

Due to the large number of closed vans transporting hazardous materials and the equally high number of trucks classified miscellaneous

freight, it is felt that the compatability of mixed cargoes needs investigation and study. The literature indicate that hazardous materials have been shipped with foodstuffs and, in other cases, spillage within the cargo container has not been sufficiently removed before food products are loaded.

Additional study is also needed on the micro environment within the closed van including temperature, pressure, humidity, and vibration, and the effects of these on the stability of various types of hazardous materials.

7. It is recommended that the Department of Public Safety require special drivers training for hazardous material transportation and provide special licensing requirements.

8. Additional study is suggested to determine the extent of spilled and damaged hazardous materials and determine methods for cleaning and disposal of waste material from the accident site.

9. The literature indicate that intercity movement of hazardous materials has been difficult to determine. It is recommended that a study be conducted to determine a method for evaluating hazardous material movement within large communities.

10. It is recommended that the Oklahoma Water Resources Board conduct an inventory of the various hazardous materials moving across major water sheds of Oklahoma. Irreversible damage to the environment and to public drinking water supplies could be averted from such a study.

11. Accident investigation research is needed for hazardous material incident control and prevention. Sufficient numbers of

hazardous material accidents have occurred in Oklahoma to justify the study.

12. It is recommended that research and study be conducted regarding other modes of hazardous material transportation in Oklahoma.

13. It is recommended that the Oklahoma State Health Department prepare a comprehensive plan to deal with hazardous material incidents and include coordination of emergency response personnel, training for accident site control and establishment of a statewide system of disposal sites for hazardous material wastes.

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APPENDIX

TABLE 30

TOTAL TRUCKS SURVEYED PER STATION

Station	1970	1971	1972
Boise City	253	319	297
Woodward	196	253	203
Altus	227	225	283
Ada	195	361	506
Hugo	268	319	374
Durant	571	674	493
Vinita	427	501	523
Tulsa	673	557	509
Blackwell	698	954	1,160
Sayre	655	674	756
McAlester	392	473	418
Davis	683	844	869
Drumright	189	230	234
Warner	333	343	306
Total	5,760	6,727	6,931

TABLE 31

NUMBER OF TRUCKS BY COMMODITY

Commodity	1970 No.	1970 Per Cent of Total	1971 No.	1971 Per Cent of Total	1972 No.	1972 Per Cent of Total
Empty	1,791	31.11	2,295	34.11	2,697	38.91
Farm Products	576	10.00	640	9.51	617	8.90
Non Metalic Minerals	69	1.20	146	2.17	145	2.09
Ordinance & Accessories	49	0.85	25	0.37	23	0.33
Food & Kindred Products	681	11.82	668	9.93	578	8.34
Basic Textiles	29	0.50	32	0.48	22	0.32
Apparel	21	0.37	20	0.30	16	0.23
Timber & Wood Products	76	1.32	88	1.31	110	1.59
Furniture & Fixtures	336	5.83	343	5.10	263	3.79
Pulp, Paper & Allied Products	36	0.63	64	0.95	61	0.88
Chemicals & Allied Products	99	1.72	110	1.64	151	2.17
Rubber & Misc. Plastic Products	56	0.97	48	0.71	49	0.71
Stone, Clay, & Glass Products	96	1.67	124	1.85	106	1.52
Primary Metal Products	116	2.01	224	3.33	203	2.93
Fabricated Metal Products	107	1.86	95	1.41	175	2.52
Machinery, Except Electrical	196	3.40	234	3.48	196	2.83
Electrical Machinery	53	0.92	56	0.83	109	1.57
Transportation Equipment	131	2.28	186	2.77	162	2.34
Instruments, Photo, Optics	8	0.14	9	0.13	8	0.12
Misc. Products of Manufacturing	27	0.47	19	0.28	143	2.06
Waste & Scrap Metal	15	0.26	35	0.52	29	0.42
Misc. Freight Shipments	799	13.87	869	12.92	770	11.12

TABLE 31--Continued

Commodity	1970 No.	1970 Per Cent of Total	1971 No.	1971 Per Cent of Total	1972 No.	1972 Per Cent of Total
Empty Shipping Containers	58	1.01	64	0.95	27	0.40
Small Packaged Freight	68	1.18	45	0.67	0	0.00
Petroleum & Coal Products	237	4.11	264	3.92	217	3.13
All Others	29	0.50	24	0.36	54	0.78
Total	5,760	100.00	6,727	100.00	6,931	100.00

TABLE 32

AVERAGE DAILY TRAFFIC AT SELECTED STATIONS

Station	Year	Total All Vehicles	Per Cent Trucks	Avg. No. of Trucks
Boise City	1970	2,252	22.64	510
	1971	2,045	24.86	508
	1972	2,187	26.74	584
Woodward	1970	1,717	19.62	337
	1971	1,744	19.43	339
	1972	1,851	25.44	470
Altus	1970	2,255	12.01	271
	1971	2,121	11.55	245
	1972	1,827	18.44	336
Ada	1970	1,032	8.33	86
	1971	997	8.92	89
	1972	1,007	10.32	104
Hugo	1970	3,090	18.89	584
	1971	2,423	11.84	287
	1972	2,533	11.44	290
Durant	1970	5,923	24.71	1,464
	1971	5,390	26.32	1,419
	1972	5,247	24.94	1,306
Vinita	1970	1,585	14.60	131
	1971	1,674	12.99	217
	1972	1,743	13.14	228
Tulsa	1970	40,066	-	-
	1971	41,124	7.10	2,920
	1972	46,549	7.85	3,654
Blackwell	1970	4,834	25.11	1,214
	1971	5,302	23.17	1,228
	1972	5,820	26.13	1,519
Sayre	1970	6,940	14.79	1,026
	1971	7,358	18.30	1,347
	1972	7,941	17.36	1,374

TABLE 32--Continued

Station	Year	Total All Vehicles	Per Cent Trucks	Avg. No. of Trucks
McAlester	1970	5,340	23.20	1,239
	1971	5,174	23.15	1,198
	1972	5,181	24.91	1,290
Davis	1970	7,649	26.17	2,002
	1971	8,362	20.41	1,707
	1971	14,038	17.17	2,400
Drumright	1970	2,445	13.98	342
	1971	2,602	10.79	281
	1972	2,772	11.36	313
Warner	1970	4,758	22.65	1,078
	1971	4,958	20.77	1,030
	1972	8,773	16.85	1,475

TABLE 33

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR BLACKWELL STATION

Material	1970	1971	1972
Crude Oil	1	1	-
Misc. Inorganic & Organic	3	3	5
Hydrogen	2	-	-
Sulfuric Acid	2	1	-
Paint	3	1	1
Insecticide	1	-	1
Salt	2	3	5
Gasoline	8	2	9
Jet Fuel	1	5	-
Aviation Gas	2	-	-
Lube Oils	7	11	11
Tar-Asphalt	3	1	1
Diesel	2	3	1
Benzene	2	-	-
Distillate Fuel	1	-	-
Propane	1	-	2
Radioactive	-	1	-
Helium	-	1	-
Chlorine	-	2	2
Carbon Dioxide	-	1	-
Alcohol	-	1	-
Detergents	-	1	-
Sodium Alkali	-	2	-
Chemical & Petroleum Waste	-	1	-
Butane	-	1	-
Ammonium Nitrate	-	1	4
Bombs	-	1	-
Ammonia	-	-	2
Caustic Soda	-	-	2
Naphtha	-	-	1
Solvent	-	-	2
Total	41	44	51

TABLE 34

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR SAYRE STATION

Material	1970	1971	1972
Crude Oil	1	-	-
Bombs	28	14	16
Ammunition 30 mm +	7	-	-
Liquid CO_2	2	-	1
Cleaning Fluid	1	-	1
Fireworks	2	-	-
Blasting Caps	1	-	-
Gasoline	2	5	14
Lube Oils	6	-	-
Surry Oil	6	-	-
Propane	-	1	4
Benzene	-	1	-
Salt	-	1	-
Glue-Adhesives	-	3	1
Detergent	-	1	-
Oxygen	-	1	-
Sodium Alkali	-	1	-
Hydrocyanic Acid	-	-	1
Uranium	-	-	1
Caustic Potash	-	-	1
Paint	-	-	1
Tar-Asphalt	-	-	1
Misc. Organic Chemicals	-	-	5
Ammonium Nitrate	-	-	5
Lime	-	-	2
Jet Fuel	-	-	2
Carbonic Acid	-	-	1
Hydrochloric Acid	-	-	1
Chlorine	-	-	1
Nitric Oxide	-	-	1
Diesel	-	-	1
Total	54	41	70

TABLE 35

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR DAVIS STATION

Material	1970	1971	1972
Gasoline	4	12	16
Jet Fuel	6	1	-
Tar-Asphalt	17	6	14
Ammunition 30 mm +	1	-	-
Detergent	1	-	-
Propane	1	1	4
Butane	1	1	2
Diesel	1	-	2
Synthetic Resin	1	-	-
Argon	1	-	-
Salt	1	-	-
Bombs	-	3	-
Liquid Oxygen	-	3	-
Carbon Dioxide	-	2	-
Hydrogen	-	1	-
Alcohol	-	1	-
Ammonium Hydroxide	-	1	-
Misc. Inorganic Chemicals	-	7	8
Paint	-	2	-
Ammonium Nitrate	-	4	6
Antifreeze	-	1	-
Lube Oil	-	10	12
Hexane	-	1	-
Toluene	-	2	-
Caustic Potash Solution	-	-	4
Acetylene	-	-	2
Sulfuric Acid	-	-	1
Total	35	59	71

TABLE 36

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR TULSA STATION

Material	1970	1971	1972
Bombs	5	4	-
Ammunition 30 mm +	1	1	3
Sodium Alkali	2	-	-
Oxygen	1	-	-
Misc. Inorganic Chemicals	2	3	5
Synthetic Resin	2	-	-
Detergent	2	2	-
Cleaning Solvent	1	-	-
Paint	1	1	-
Ammonium Nitrate	4	1	2
Gasoline	4	-	9
Kerosine	1	-	-
Lube Oil	2	12	3
Tar-Asphalt	13	2	1
Diesel	1	2	1
Toluene	1	-	-
Propane	2	-	2
Butane	2	-	-
Misc. Petroleum Products	1	-	-
Chemical & Petroleum Waste	1	-	-
Sulfuric Acid	1	-	1
Glue-Adhesives	-	1	-
Carbon Dioxide	-	2	-
Total	50	40	27

TABLE 37

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR McALESTER STATION

Material	1970	1971	1972
Bombs	1	-	-
Ammunition 30 mm +	1	2	-
Liquid Oxygen	1	-	-
Detergent	1	-	-
Paint	1	-	-
Ammonium Nitrate	2	3	2
Salt	1	1	1
Gasoline	4	2	7
Rocket Fuel	1	-	-
Lime	1	-	-
Misc. Organic & Inorganic Chem.	-	2	1
Cool Tar Products	-	1	-
Sodium Alkali	-	1	-
Jet Fuel	-	1	1
Asphalt-Tar	-	6	-
Propane	-	2	1
Synthetic Detergent	-	1	-
Glue-Adhesives	1	-	3
Total	18	25	16

TABLE 38

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR DURANT STATION

Material	1970	1971	1972
Misc. Organic Chemicals	2	3	-
Alcohol	1	-	-
Chlorox	2	-	-
Detergent	1	3	2
Paint	2	3	-
Sulfuric Acid	-	-	1
Urea	1	1	-
Explosives	1	-	-
Gasoline	2	-	5
Lube Oil	2	2	2
Diesel	1	-	-
Benzene	1	-	-
Propane	1	2	2
Lime	3	-	-
Ammunition 30 mm +	1	-	-
Ammonium Nitrate	2	1	1
Jet Fuel	-	2	-
Glues-Adhesives	-	6	-
Lime	-	3	-
Kerosene	-	1	-
Synthetic Resin	-	1	-
Nitric Acid	-	1	-
Vinegar	-	2	1
Asphalt-Tar	-	-	2
Chromic Acid	-	-	1
Ammonia	-	-	1
Total	23	31	18

TABLE 39

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR
WOODWARD STATION

Material	1970	1971	1972
Rockets	1	-	-
Ammonium Nitrate	1	1	2
Ammonia	1	-	2
Gasoline	6	8	7
Tar-Asphalt	2	11	2
Natural Gasoline	-	1	-
Glue-Adhesives	-	1	-
Lube Oils	-	10	7
Diesel Oil	-	3	2
Propane	-	1	1
Liquid Oxygen	-	-	1
Salt	-	-	1
Sulfuric Acid	-	-	1
Misc. Inorganic Chemicals	-	-	2
Total	11	36	28

TABLE 40

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR DRUMRIGHT STATION

Material	1970	1971	1972
Sodium Alkali	1	-	-
Detergent	1	-	1
Gasoline	20	15	16
Jet Fuel	2	-	-
Diesel	1	-	2
Gas-Oil	2	-	-
Misc. Petroleum Products	1	-	-
Chemical & Petroleum Waste	2	-	-
Crude Oil	-	2	-
Misc. Organic & Inorganic Chem.	-	1	2
Lube Oil	-	5	3
Tar-Asphalt	-	2	2
Butane	2	2	1
Paint	-	1	-
Lime	-	1	-
Acetylene	-	-	2
Propane	-	-	1
Alcohol	-	-	1
Benzene	-	-	1
Total	32	29	32

TABLE 41

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR ALTUS STATION

Material	1970	1971	1972
Liquid Oxygen	1	-	2
Ammonium Nitrate	1	-	-
Salt	1	-	-
Gasoline	7	7	5
Jet Fuel	15	-	11
Lube Oil	1	4	-
Propane	3	1	3
JP-4	-	8	-
Diesel	-	1	2
Uranium	-	-	1
Acetylene	-	-	2
Tar-Asphalt	-	-	1
Total	29	21	27

TABLE 42

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR
BOISE CITY STATION

Material	1970	1971	1972
Misc. Organic & Inorganic Chem.	2	1	2
Alcohol	1	-	-
Paint	1	-	-
Ammonium Nitrate	2	-	3
Glue-Adhesives	1	-	-
Gasoline	2	3	1
Tar-Asphalt	2	1	-
Radioactive Material	-	1	-
Ammonia	-	1	4
Solvent	-	1	-
Paint Solvent	-	1	-
Lube Oils	-	2	1
Diesel Oil	-	1	-
Propane	-	-	2
Bombs	-	-	2
Photographic Chemicals	-	-	1
Total	11	12	16

TABLE 43

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR VINITA STATION

Material	1970	1971	1972
Crude Oil	1	2	-
Liquid Nitrogen	1	-	-
Coal Tar Products	1	-	-
Misc. Organic Chemicals	2	-	-
Detergents	2	-	-
Insecticides	1	1	-
Ammonium Nitrate	3	1	9
Salt	1	-	1
Gasoline	8	5	5
Lube Oils	2	5	3
Tar-Asphalt	1	17	1
Jet Fuel	1	-	-
Propane	1	3	2
Sodium & Potassium Alkalies	-	1	-
Misc. Inorganic Chemicals	-	1	-
Lime	-	5	4
Nitroglycerine	-	1	-
Sulfuric Acid	-	-	1
Acetylene	-	-	3
Explosives	-	-	1
Diesel Oil	-	-	2
Phosphorous	-	-	1
Hair Spray	-	-	1
Total	25	42	34

TABLE 44

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR
WARNER STATION

Material	1970	1971	1972
Liquid Oxygen	1	-	-
Insecticide	1	-	-
Rodenticide	1	-	-
Gasoline	4	1	2
Tar-Asphalt	3	-	-
Ethylene	1	-	-
Lube Oils	-	1	-
Aviation Gas	-	1	-
Benzene	-	1	-
Phenyl Ethylene	-	-	2
Total	11	4	4

TABLE 45

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR HUGO STATION

Material	1970	1971	1972
Gasoline	-	3	5
Liquid Oxygen	1	1	1
Acetylene	-	1	-
Oil Field Chemicals (Treating Compound)	2	1	-
Ammonium Nitrate	-	4	1
Salt	-	1	1
Lube Oils	2	5	1
Diesel Oil	-	1	1
Tar-Asphalt	-	1	-
Glue-Adhesives	2	2	-
Explosives	1	-	1
Cleaning Fluid	1	-	-
Paint	1	-	-
Propane	-	-	1
Sulfuric Acid	-	-	1
Lime	-	-	4
Liquid Nitrogen	-	-	5
Misc. Organic Chemicals	-	-	2
Total	10	20	24

TABLE 46

INVENTORY OF HAZARDOUS MATERIALS LISTED FOR ADA STATION

Material	1970	1971	1972
Ammonium Nitrate	1	-	2
Gasoline	4	-	4
Diesel	-	-	2
Oxygen	-	-	1
Paint	-	-	1
Total	5	0	10