Alberta Energy Regulator

Report 2013-B: Pipeline Performance in Alberta, 1990–2012

August 2013

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Executive Summary

Report 2013-B: Pipeline Performance in Alberta, 1990–2012 is a comprehensive analysis of pipeline data for Alberta on amounts and types, incident statistics, and incident rates. The data used for this report are from January 1, 1990, to December 31, 2012. Data are constantly updated as pipelines are built, discontinued, abandoned, relicensed, or returned to service and inventories can vary daily. Data are also updated as investigations are completed and new information obtained.

All charts and graphs should be interpreted in light of the following definitions:

- Failure—An incident in which product is lost, either by a leak or a rupture.
- Incident—Any incident must be reported to the AER and would include a pipeline leak, a pipeline rupture, or the striking of a pipeline (hit), even if that strike does not cause any loss of product. Note that pressure-test failures, though reportable as incidents, are reported separately in this report to allow a differentiation between operational incidents and qualification incidents.
- Hit—A hit is an incident where a pipeline is struck but no product is lost.
- Leak—A leak is defined as a pipeline failure where a pipeline is losing product but might continue to operate until the leak is detected.
- Release—The loss of product from a pipeline. A pipeline incident or failure may result in more than one release, as gas, oil, and water are counted as separate product releases. This is why some charts indicate more releases than incidents.
- Rupture—A pipeline failure where a pipeline cannot continue to operate.

Regulating Pipelines

The Alberta Energy Regulator (AER) ensures the safe, efficient, orderly, and environmentally responsible development of hydrocarbon resources over their entire life cycle, including the regulation of all energy-related pipelines that fall under its jurisdiction.

Alberta's Pipeline System

At the end of 2012, AER's data tallied 415 152 kilometres (km) of pipelines crisscrossing the province. Of Alberta's total pipeline inventory, 60.3 per cent carries natural gas, 14.8 per cent carries oil effluent (mixed oil, gas, and water production from an oil well; also known as multiphase), 5.9 per cent carries oilfield water, 4.9 per cent carries crude oil, 5.4 per cent carries sour gas (natural gas with hydrogen sulphide concentrations greater than 1 per cent), and 8.7 per cent carries other substances. About 17 per cent of the inventory is discontinued or abandoned. Data indicate that nearly 70 per cent of all pipeline inventory was built after 1990.

As Alberta is a major producer of oil and gas, most pipelines in the province are small, with an outside diameter of 168.3 mm (6 inches) or smaller, and carry production from individual wells to nearby processing facilities. Large-diameter transmission lines 508 mm (20 inches) or more in outside diameter make up just 2.0 per cent of the total AER-regulated inventory, or 8267 km. About 86 per cent of Alberta's pipelines are constructed of steel, with most of the remaining lines made of polymer or fibre composite materials—a portion that continues to increase as these materials are corrosion resistant and are being used more often in corrosive production situations.

Pipeline Incidents and Performance

Individual regulatory jurisdictions use different criteria when collecting incident data. Some only collect data for incidents exceeding specific volumes or where personal injury has occurred or specific monetary damages have been exceeded. This means that direct comparison between jurisdictions can be difficult. Alberta's legislation is very robust, as licensees are required to report each and every incident that results in a spill or release of any volume of pipeline product, or contact or damage to a pipeline or its corrosion-control exterior coating. As a result, significantly more incidents end up being reported in Alberta than in other jurisdictions. Comparison is further complicated by the fact that other jurisdictions have authority over different types of pipeline infrastructure. National regulators typically have jurisdiction over nationwide pipeline systems, which transmit refined products long distances through larger-diameter pipelines. The AER has jurisdiction over some similar pipelines in Alberta, but most pipelines under its jurisdiction are small-diameter oilfield production pipelines carrying raw, unprocessed fluids. It is not appropriate to compare data on incidents related to small-diameter oilfield production pipelines to incidents related primarily to larger-diameter transmission pipelines.

The AER inspects pipeline construction and operations, reviews incidents, and issues noncompliance action and enforcement. All records of these activities and incidents are permanent.

From 1990 to 2012, 17 605 incidents were reported. Of this total,

- 15 609 were leaks,
- 1116 were hits with no release, and
- 880 were ruptures.

Given that Alberta's pipeline infrastructure has steadily increased since 1990, the AER is encouraged that the number of incidents has not increased in step. In fact, the frequency with which incidents have occurred has trended downward over the years from a rate of almost 5.0 per 1000 km in 1990 to 1.5 per 1000 km since 2010. The number of pipeline leaks has also fallen in recent years, likely because of the regulatory revisions introduced in 2005, improved Canadian Standards Association (CSA) standards for pipeline design and construction, more industry effort to mitigate pipeline incidents, and a continued focus on pipeline-related concerns. The number of pipeline ruptures also has decreased over the past two decades—a positive development given the potential seriousness of rupture incidents.

In Alberta, licensees are also required to report the volume of product spilled. Data gathered over the 1990 to 2012 reporting period show that very large pipeline releases are relatively few.

Changes to the *Pipeline Regulation* in 2005 required more pipeline surveillance and leak detection, which resulted in an increase in the number of small leaks being discovered on natural gas pipelines. Since 2005, following repair of the small leaks, the number of failures on gas pipelines has gradually declined.

Overall, internal corrosion remains the leading cause of pipeline failure, representing 54.8 per cent of all releases. This comes as little surprise as most Alberta pipelines transport raw oil and gas before the corrosive components of the produced products are removed.

External corrosion is the second leading cause of pipeline failures, at 12.7 per cent, and is primarily due to external pipeline coatings failing from either age or excessive production temperatures.

The number of failures on crude oil pipelines is quite small, averaging about 20 per year in the last five years, with internal corrosion the cause of just ten failures on these pipelines.

Incidents categorized as “damage by others,” primarily caused by accidental contact during excavation work, averaged around 83 incidents per year over the last 10 years and continue to be of concern to the AER.

1 Introduction

The Alberta Energy Regulator (AER)[1] ensures the safe, efficient, orderly, and environmentally responsible development of hydrocarbon resources over their entire life cycle. This includes the regulation of all energy-related pipelines that fall under its jurisdiction.

All pipelines regulated by the AER must be licensed before they may be constructed. When licensing a pipeline, licensees are required to confirm that the construction, operation, maintenance, discontinuation, and abandonment of pipelines will comply with the *Pipeline Act*, *Pipeline Rules*, and Canadian Standards Association (CSA) requirements.[2] The AER inspects pipeline construction and operations, reviews incidents, identifies noncompliances, and performs necessary enforcement. All records of these activities and incidents are permanent.

This report is a comprehensive analysis of pipeline data in Alberta on amounts and types, incident statistics, and incident rates.[3] Data used for this report are from January 1, 1990, to December 31, 2012. Data are constantly updated as pipelines are built, discontinued, abandoned, relicensed, or returned to service and inventories can vary daily. Data are also updated as investigations are completed and new information obtained. All charts and graphs should be interpreted in light of the definitions in section 6.

Selective operational inspections of licensees are conducted to ensure that pipeline operations comply with requirements and standards, as well as with the company's processes, procedures, and specifications. The process for selecting inspections considers potential risks associated with individual pipelines (e.g., fluid characteristics, location, pipe diameter, and failure history) and with the company's compliance history. Pipelines with greater potential risks are given a higher inspection priority by the AER.

In 2012, Alberta produced 3.7 trillion cubic feet of natural gas, 705 million barrels of crude bitumen, and 203 million barrels of crude oil, most of which was transported to processing facilities and eventually to market through pipelines. At the end of 2012, the AER's data showed there were 415 152 kilometres (km) of pipeline crisscrossing the province. Data indicates that nearly 70 per cent of this inventory was built after 1990.

About 30 000 km of pipeline in Alberta are regulated by the National Energy Board (NEB). This includes about 25 000 km of TransCanada Alberta Systems pipelines (also known as NOVA Gas Transmission Ltd. [NGTL]). These licences were transferred to federal jurisdiction effective April 29, 2009. Before the transfer date, these historical NGTL pipelines were included in AER's total pipeline inventory and inspection failure counts. The other 5000 km of NEB-regulated pipeline are excluded from all data

[1] The Alberta Energy Regulator (AER) succeeded the Energy Resources Conservation Board (ERCB) in regulating the oil and gas industry on June 17, 2013.

[2] The *Pipeline Act* and *Pipeline Rules* are the legislative standards applying to the regulation of pipelines in Alberta. Copies are available at the offices of the Alberta Queen's Printer and can be downloaded from the AER website www.aer.ca.

[3] Previously published pipeline performance reports are available from the AER on its website www.aer.ca or by contacting the AER's Information Product Services Section.

analyses in this report as the AER is not involved in the surveillance, inspection, or regulation of these pipelines, nor does the AER record any failures related to any of these licences. Information on the NEB-regulated pipelines is available from the NEB offices or on their website at www.neb-one.gc.ca.

As of the end of 2012, AER data showed that 11 476 km of rate-regulated natural gas pipelines in Alberta are under the jurisdiction of the Alberta Utilities Commission (AUC). These pipelines became regulated by the AUC as of January 1, 2008. Before 2008, these pipelines were included in the total inventory of natural gas pipelines. As of 2008, these pipelines are a separate category in AER's total pipeline inventory. Through a memorandum of understanding, the AER provides surveillance and inspections, incident response, and failure investigations related to these lines on behalf of the AUC. AUC-regulated pipelines are identified separately on the relevant figures. Information on these pipelines is available from the AUC offices or their website at www.auc.ab.ca.

Pipelines under AER jurisdiction include all other pipelines except

- low-pressure gas distribution network pipelines operating at 700 kilopascals or less (unless they are operated to supply an AER-licensed facility);
- water pipelines (unless they are operated in connection with an AER-licensed facility);
- sewage pipelines;
- pipelines situated wholly within a refinery, processing plant, marketing plant, or manufacturing plant;
- pipelines carrying fuel from a tank and situated wholly on a consumer's property; and
- pressure piping systems under the jurisdiction of the *Safety Codes Act*.

These exemptions are listed here in brief; refer to sections 1(1)(t) and 2 of the *Pipeline Act* for an official interpretation.

2 Data Collection

This report analyzes data collected between January 1, 1990, and December 31, 2012, from the Field Inspection System (FIS) and the Pipeline Registry System (PPR). The data in these systems are constantly updated as pipelines are built, discontinued, abandoned, relicensed, or returned to service. The data may also be updated as incident investigations are completed and new information obtained. Incident reporting must be completed by the end of March each year for the previous year. For this report, data were gathered in January 2013.[4] Data on incidents or failures that occurred near the end of 2012 may have not yet been complete at the time of data collection and may have been updated since then. As a result, a higher-than-normal number of incidents were recorded as "unknown" for 2012.

[4] Any discrepancies in the data presented are due to rounding.

Over the years the systems used to collect pipeline data have changed. In 2010, the PPR was implemented to support the pipeline application process and retire the historical mainframe computer system. As a result, several pipeline data inconsistencies in previous pipeline reports were found. One of which was the discovery of a duplication of about 62 000 km of pipeline segments, which were caused by historical mainframe system upgrades and have now been removed from Alberta's current total pipeline inventory. The values in this report are based on the corrected numbers.

The AER routinely reviews the data on pipeline incidents and failures and updates or removes incorrect or duplicate records as required. These data were also affected by the duplicate pipeline data and were corrected.

The PPR database includes basic licensing and physical information for all pipelines. Pipeline segments identified as not constructed, deleted, or removed are not included in the total pipeline inventory as these lines do not physically exist. The data identifies 286 km of pipeline as having been removed. Permitted pipelines are included in the tally for 2012. The AER does not know precisely when construction is to be completed or when the pipeline is actually put into service, thus it is an assumption that permitted pipelines are commissioned in the year in which they were approved.

Abandoned and discontinued pipelines are included in the pipeline inventory totals because they physically exist, may be struck during excavation work, or could at a future date be requalified for return to service.

The PPR database includes several date fields for each licensed pipeline. The "last occurrence year" field is used in this report to estimate the construction year of the pipeline. Each individual pipeline segment was evaluated separately. The dates on some licence amendments in past years were updated to the then-current date, so despite best efforts, the amount of pipeline attributed to a specific construction year is an estimate and becomes less certain as we look back into previous years.

3 Classification Systems

The following PPR codes represent pipeline substances identified in a licence:

SG Sour gas (natural gas containing more than 10 moles hydrogen sulphide (H_2S) per kilomole of natural gas, [equivalent to 1 per cent H_2S])

HVP High vapour pressure product (natural gas liquids, butane, propane, ethane, ethylene, some condensates)

LVP Low vapour pressure product (refined product, gasoline, diesel, fuel oil, some condensate)

CO	Crude oil (raw crude, synthetic crude, bitumen, diluted bitumen)
OE	Oil effluent (also known as multiphase; mixed oil, gas, and water production from an oil well)
NG	Natural gas (natural gas containing 10 moles of H_2S or less per kilomole of natural gas)
FG	Fuel gas (raw natural gas used for fuel in energy facilities)
SW	Salt water (formation or produced water; brine)
ML	Miscellaneous liquids (sulphur, polymer, methanol, glycol, ammonia, liquefied carbon dioxide)
MG	Miscellaneous gases (air, nitrogen, hydrogen, steam, helium, gaseous carbon dioxide)
FW	Fresh water (surface or natural water, potable water)

Many AER-regulated pipelines are licensed for more than one product. The product carried can change, either when the production stream changes during the year (e.g., enhanced oil recovery schemes) or when there is batch transmission of product. For the purposes of this report, multiple substances are prioritized in the order listed above. For example, a batch-products pipeline licensed to carry HVP, CO, and LVP products is classified as HVP in the summary of inventory. Multiple-product pipelines account for about 6500 km, or 1.6 per cent, of Alberta's current inventory; thus, the statistical significance of the classification uncertainty is small. There are currently 204 multiple-product pipeline licences, most of which are batch-transmission pipelines carrying segregated product and are counted in the HVP substance category.

FIS and its associated databases are used to record pipeline incidents or pipeline failures. FIS also uses the substance codes and the priority classification above. For the purpose of this report, pipeline products with similar characteristics are grouped together into six pipeline substance categories: crude oil, natural gas, water, sour gas, oil effluent (multiphase), and other. As oil effluent is more commonly referred to as multiphase, this term is used throughout the remainder of this report.

Historical pipeline data show many pipeline diameters being recorded as variations slightly off the nominal values. Despite known variations in diameter in older pipelines, many of these are likely because data may have been entered incorrectly. Therefore, similar-sized pipeline was grouped by nominal pipe diameters.

Material classes have been grouped into the following categories: steel, aluminum, composite, fibreglass, polyethylene, and other. Fibreglass denotes the traditional rigid stick-type fibreglass, and composite denotes the newer spoolable composite pipes. The "other" category includes asbestos cement, ductile cast iron, cellulose acetate butyrate, polybutylene, polyvinyl chloride (PVC), and unknown. There are currently 808 km of these “other” materials (less than 0.2 per cent of the total inventory), nearly 75 per cent of which are licensed as abandoned or discontinued.

In Alberta, any pipeline failure, including test failures, or any hit upon a pipeline must be reported to the AER regardless of how much product is released or what the status of the pipeline is—even hits on discontinued or abandoned pipelines must be reported. Records of pipeline incidents include a cause of failure. A loss of pipeline product is called a release or spill. Spills within facilities (such as well sites, satellites, batteries, or plants) are not considered part of the pipeline inventory and so are recorded separately as facility spills.

Pressure-test failures are not included in the pipeline incident data analyses, as they do not occur under normal operating conditions. Results of the analyses on these failures are reported separately. If product is lost during a test failure, it is usually fresh water and is not an environmental concern. Incidents involving damage by others are included in incident counts because they occur during normal pipeline operations and may lead to a pipeline release.

The causes of pipeline failure have been grouped into 13 classes and are shown below in table 1.

Table 1. Classification of the cause of pipeline failure

Cause	Cause of failure*
Construction damage	• Construction damage (improperly applied or damaged coatings, inadequate support, faulty alignment, bending, improper backfilling)
Damage by others	• Damage to the pipeline by other parties (third-party excavation or interference)
Earth movement	• Earth movement (watercourse change, slope movement, heaves, subsidence)
External corrosion	• Corrosion to the external surface of pipe • Mechanical pipe damage (dents, scrapes, gouges leading to corrosion failure)
Internal corrosion	• Corrosion to the internal surface of pipe • Corrosion to the internal surface of girth weld
Joint failure	• Mechanical joint failure (gasket or O-ring failure, internal joint coating failure, mechanical couplings failure) • Miscellaneous joint failure (butt fusion, interference joints, fibreglass bonded or threaded joints, explosive welding)
Overpressure	• Overpressure failure • Operating over the limits of the licence
Pipe	• Pipe failure (pipe body failure due to stress corrosion cracking [SCC], hydrogen-induced cracking [HIC], fatigue, laminations, mechanical damage)
Valve/fitting	• Valve failure (seal blowouts, pig trap failures, packing leaks)

(continued)

* As recorded in the FIS database.

Table 1 Classification of the cause of pipeline failure (cont'd)

Cause	Cause of failure*
Weld	• Girth weld failure (not by corrosion), sulphide stress cracking at the girth weld • Seam rupture (electrical resistance weld [ERW] or other seam weld failure) • Other weld failure (weldolets, thermowells)
Miscellaneous	• Installation failure (at compressor, pump, or meter station) • Miscellaneous (erosion, vandalism, lightning, flooding, animals)
Operator error	• Operator error (operating against closed valve or blind, etc.)
Unknown	• Unknown (pipe cannot be exposed or examined)

* As recorded in the FIS database.

The figures reporting data from pipeline releases indicate that releases occur more than incidents. This is not an error as more than one substance can be released during an incident (e.g., oil, water, and gas), each of which is recorded separately for release measurement purposes. Released fluids are categorized into five substance types: sour gas (contains more than 10 moles H_2S per kilomole of natural gas), hydrocarbon gas, hydrocarbon liquid, water, and other. Bitumen, condensate, and HVP are included under hydrocarbon liquids. Acid gas is included under sour gas.

A measure of overall annual pipeline performance is calculated by dividing the number of incidents recorded during each calendar year (excluding pressure-test failures) by the total length of pipeline on record at calendar year-end. This measure is reported as incident frequency and is expressed as the number of incidents per 1000 km of pipeline per year. Through a memorandum of understanding between the AER and AUC, the AER is the first responder to any incident on an AUC-regulated pipeline. As a result, AUC-regulated pipelines are included in inventory and the calculations of incident frequency. NEB-regulated pipelines (with the exception of the former NGTL pipelines) are not included. NGTL pipelines were included in both inventory and incident count, but only until the end of 2008. Pressure-test failures are not included in the calculation as they do not occur during normal pipeline operating conditions. Incidents due to damage by others are included. There is, of course, some uncertainty in the calculated values due to the constantly changing nature of the pipeline database, as previously discussed.

4 Data Analysis

4.1 Pipeline Inventory

None of the figures, charts, and tables in this report include NEB-regulated pipelines or deleted, unconstructed, or removed pipelines. At the end of 2012, the total length of pipeline recorded in the AER database was 415 152 km. AUC-regulated pipelines are included in the inventory total (11 476 km at the end of 2012) and are identified separately in the figures.

Table 2 shows that as of December 31, 2012, the average length of a pipeline segment was about 1.4 km. This may seem counterintuitive when considering pipelines are generally perceived as long cross-country infrastructure, but in fact it reflects the reality that in Alberta most pipelines are short segments 1 to 2 km long, leading from individual producing wells to gathering facilities for treatment or processing. Larger pipelines then carry the commingled production away but are far fewer in number than the small-diameter flow lines. Some of the longer pipelines are also divided into shorter segments for licensing purposes.

Table 2. Average length of pipeline segments*

	Average length per segment (km)	Total length (km)	Number of segments	Percentage of total length (%)
AUC	2.3	11 476	5 053	2.8
Crude Oil	4.0	20 272	5 018	4.9
Natural Gas	1.4	238 582	166 150	57.5
Sour gas	2.3	22 612	9 681	5.4
Water	1.2	24 473	20 586	5.9
Multiphase	0.9	61 576	68 333	14.8
Other	2.4	36 161	14 882	8.7
Totals		**415 152**	**289 703**	**100**
Average length	**1.4**			

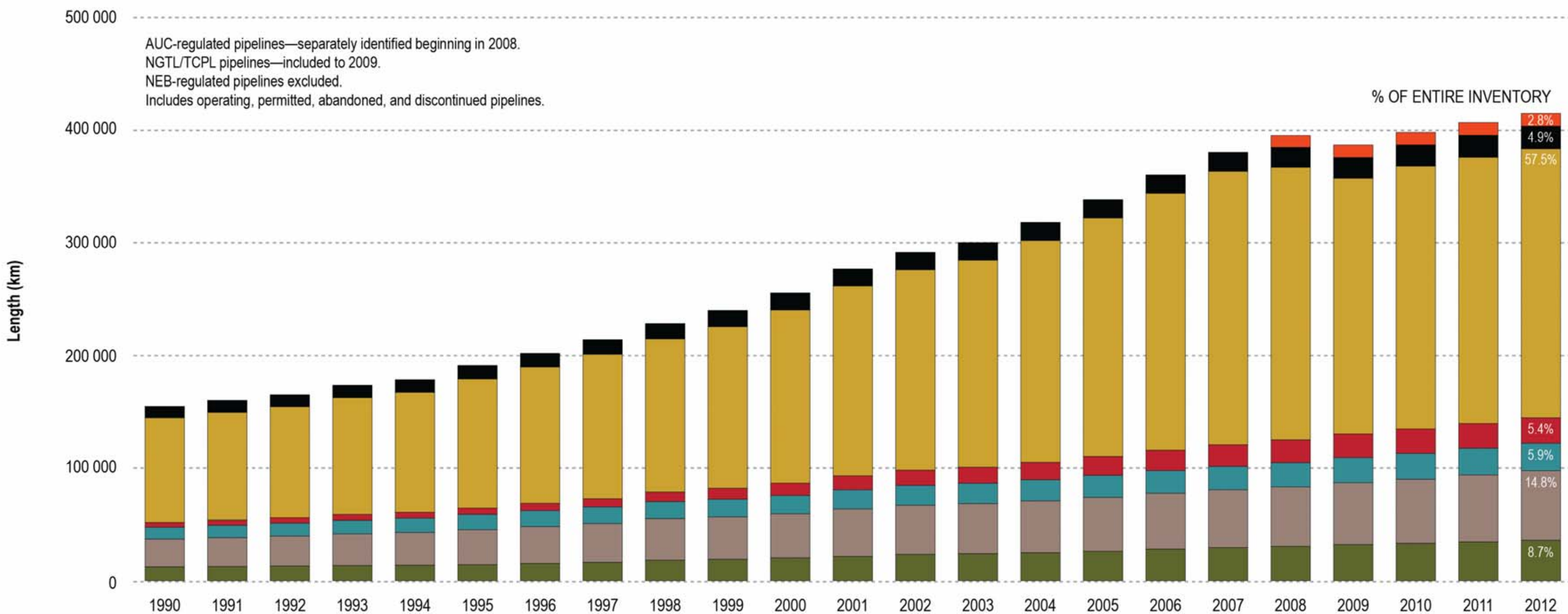
* Current to December 31, 2012, and includes only operating, permitted, abandoned, and discontinued pipelines. All NEB-regulated pipelines are excluded.

More than half of the total provincial pipeline inventory is natural gas pipeline. Natural gas pipeline accounts for 238 582 km (57.5 per cent) of AER-regulated pipelines and nearly all of the 11 476 km of AUC-regulated pipeline, for a total of 250 058 km (60.2 per cent) of total inventory. Under AER licensing protocol, natural gas pipelines may not contain more than 10 moles of H_2S per kilomole of natural gas, which is equivalent to 1 per cent, or 10 000 parts per million H_2S. Pipelines containing more than 10 moles of H_2S per kilomole of natural gas are licensed as sour gas pipelines. Natural gas and sour gas pipelines can also contain amounts of water, other gases, and hydrocarbon liquids.

Pipeline substance categories are generally determined by the connected wells. A gas pipeline is therefore connected to a gas well, even though hydrocarbon liquids and water may also be associated with gas produced from the well. Where the composition of produced fluids results in a well being classified as an oil well, the connected pipeline is licensed as a oil effluent (multiphase) pipeline. Crude oil pipelines generally carry treated product from which initial processing has removed gas and water. However, many short crude oil pipelines carry product from several production facilities that is often still contaminated with water and sediments. Water pipelines either supply water or collect water for disposal or injection. Pipelines classified as “other” carry HVP products such as ethane, propane, butane, ethylene, and mixes of produced natural gas liquids; LVP products such as fuel oil, motor fuel, and condensate; and unique products such as hydrogen, carbon dioxide, nitrogen, ammonia, polymer, and liquid sulphur.

Figure 1a shows an annual increase in the total Alberta pipeline inventory from 1990 to 2012. Pipelines existing before 1990 are included in the year 1990. Average pipeline growth rates for AER- and AUC-regulated pipelines are calculated separately for the last five years due to the transfer of pipelines from the AER to the NEB and AUC, which affected the pipeline inventory. From 1990 to 2007, the length of pipeline added averaged 5.4 per cent per year, with the highest additions in 1995 (7.1 per cent) and 2001 (8.3 per cent). Starting in 2008, AUC-regulated pipelines were identified separately and represented 2.8 per cent of the total inventory. The NGTL pipelines transferred to NEB regulatory control were removed from the inventory in 2009. Although new pipeline was added to inventory in 2009, the NGTL transfer still resulted in a net 2.2 per cent decrease in the overall inventory. From 2010 to 2012, additions to the pipeline infrastructure were lower at 2.9 per cent, 2.2 per cent, and 2.0 per cent, respectively. The length of pipelines added to the inventory in a given year generally parallels the level of oil and gas industry activity of that same year but may lag behind slightly.

Figure 1a. Length of pipelines in Alberta by year and substance category
Current to December 31, 2012



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
AUC-regulated											
Crude oil	9 875	10 413	10 761	11 184	11 307	12 031	12 437	13 146	13 773	14 583	14 901
Natural gas	92 916	95 793	98 464	103 649	106 552	114 674	121 013	128 431	136 153	143 626	154 014
Sour gas	4 258	4 447	4 596	4 974	5 131	5 669	6 476	7 274	8 499	9 801	10 957
Water	10 542	11 026	11 434	11 958	12 363	13 152	13 797	14 424	15 190	15 658	16 265
Multiphase	24 705	25 659	26 641	28 154	29 191	31 041	32 795	34 570	36 527	37 404	38 840
Other	12 430	12 737	13 202	13 710	13 901	14 539	15 552	16 420	18 423	19 197	20 495
Total (km)	**154 726**	**160 075**	**165 098**	**173 629**	**178 445**	**191 106**	**202 070**	**214 265**	**228 565**	**240 269**	**255 472**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
AUC-regulated								10 807	11 140	11 340	11 458	11 476
Crude oil	15 197	15 555	15 922	16 267	16 407	16 571	17 010	17 674	18 651	18 930	19 698	20 272
Natural gas	168 489	177 840	183 725	196 903	211 716	227 646	242 427	241 773	226 516	232 923	235 996	238 582
Sour gas	12 396	13 647	14 273	15 569	16 975	18 272	19 382	20 326	21 148	21 818	22 098	22 612
Water	17 122	17 675	18 122	18 813	19 597	20 168	20 807	21 586	22 459	23 192	23 793	24 473
Multiphase	41 754	43 270	44 161	45 787	47 529	49 371	51 020	52 667	54 663	56 636	59 326	61 576
Other	21 839	23 601	24 189	25 036	26 371	28 268	29 685	30 646	32 354	33 413	34 605	36 161
Total (km)	**276 797**	**291 588**	**300 392**	**318 375**	**338 595**	**360 296**	**380 331**	**395 479**	**386 931**	**398 252**	**406 974**	**415 152**

Figure 1b shows the construction age of AER-regulated pipelines (grouped by decade) and the AUC-regulated natural gas utility pipelines. This shows that over two-thirds of Alberta's pipelines have either been constructed or modified since 1990. Note that the AUC-regulated pipelines have not been analyzed for construction date.

Figure 1b. Alberta pipelines by decade of construction
Current to December 31, 2012 (excludes NEB-regulated pipelines)

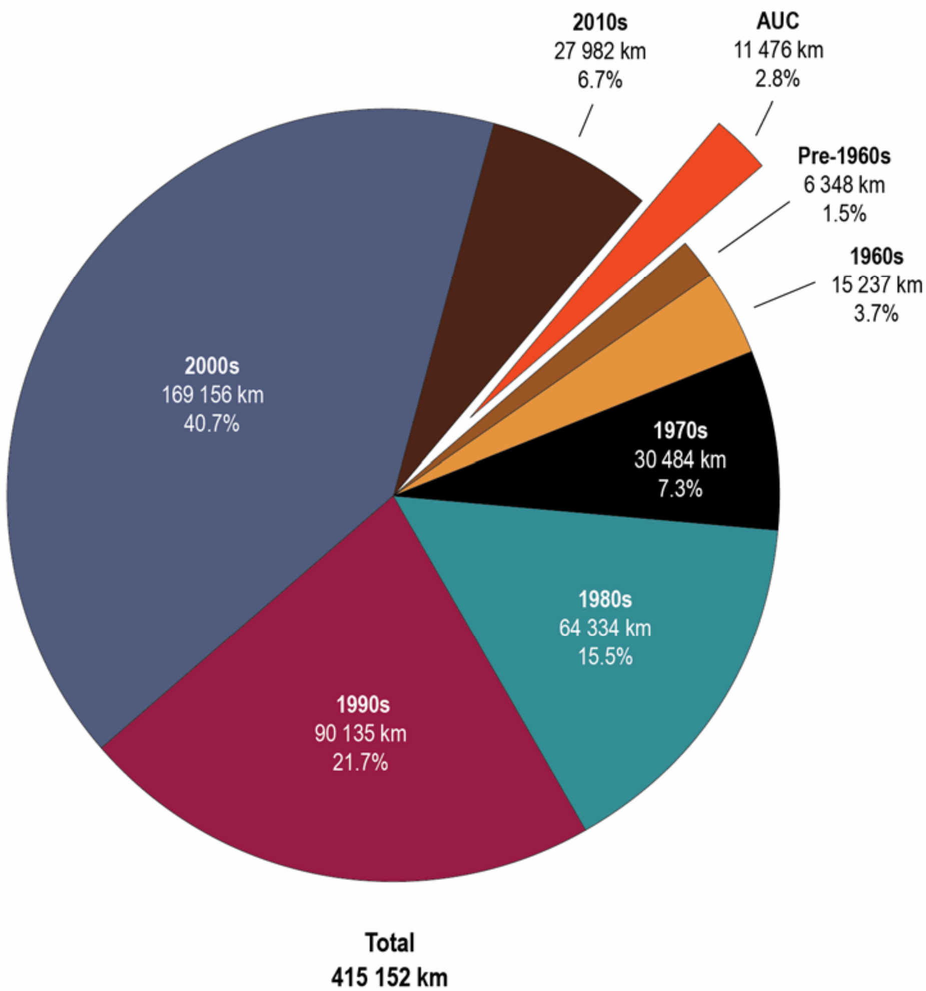
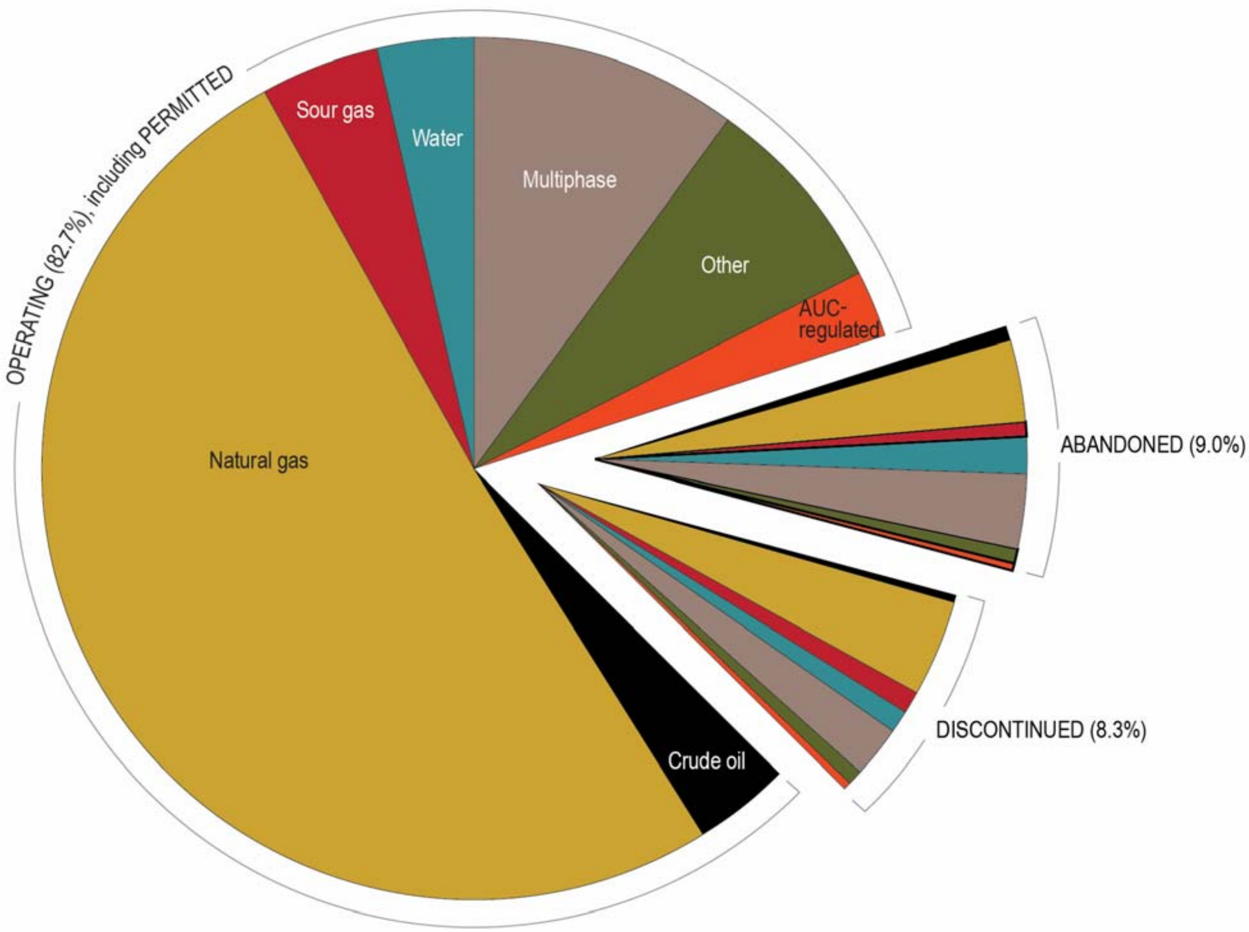


Figure 2 shows that AER-regulated operating pipelines (including new pipelines still licensed as "permitted") constitute 80.3 per cent of the entire inventory, followed by abandoned pipelines at 8.7 per cent, and discontinued pipelines at 8.3 per cent. AUC-regulated natural gas utility pipelines include 89.4 per cent recorded as operating, which increases Alberta's total operating inventory to 82.7 per cent. These numbers fluctuate day to day because pipeline status changes daily as companies amend the statuses of their pipelines.

Figure 2. Length of pipelines in Alberta by status and substance category
Current to December 31, 2012 (excludes NEB-regulated pipelines)



	OPERATING (including PERMITTED) km	OPERATING % of product type	DISCONTINUED km	DISCONTINUED % of product type	ABANDONED km	ABANDONED % of product type	Total km	% of entire inventory
AUC-regulated	10 259	89.4	21	0.2	1 196	10.4	11 476	2.8
Crude oil	16 095	79.4	1 836	9.1	2 341	11.5	20 272	4.9
Natural gas	210 532	88.2	15 298	6.4	12 752	5.4	238 582	57.5
Sour gas	17 910	79.2	3 202	14.2	1 500	6.6	22 612	5.4
Water	15 145	61.9	2 779	11.4	6 549	26.7	24 473	5.9
Multiphase	41 783	67.9	8 729	14.2	11 064	17.9	61 576	14.8
Other	31 739	87.8	2 618	7.2	1 804	5.0	36 161	8.7
Total	**343 463**	**82.7**	**34 483**	**8.3**	**37 206**	**9.0**	**415 152**	**100.0**

In 2005, the *Pipeline Regulation* was amended to require that a licensee either properly discontinue and abandon pipelines that have been unused for over a year or that it properly maintain these pipelines under its corrosion mitigation program. By the end of 2012, the total discontinued or abandoned pipelines was almost double that of the total in 2005, rising from 38 801 to 71 689 km. This indicates that industry has diligently responded to the regulation changes by properly discontinuing or abandoning unused pipelines.

This is a very positive development as it has ensured that many unused pipelines have been properly cleaned and safely suspended in a manner that eliminates the risk of potential leaks or the risk of a safety hazard in the event of the pipeline being struck during excavation.

Most of the total pipeline inventory in Alberta (83.5 per cent) is constructed of steel (see figure 3b). This is a reduction of almost 6 percentage points since 2005 and a result of steadily increasing use of nonmetallic pipeline materials.

The next largest material category is polyethylene, at 8.0 per cent, followed by aluminum, fibreglass, and composite, which are all at around 2 per cent each. Figures 3a and 3b also shows the substances carried by each material type of pipeline.

Figure 3a. Length of pipelines by pipe material and substance category
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

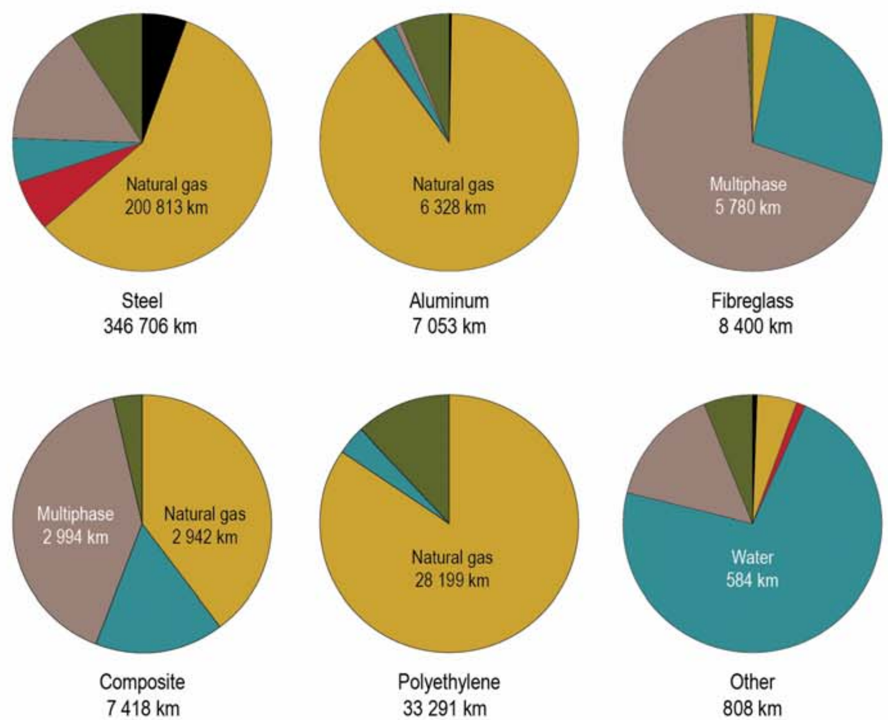
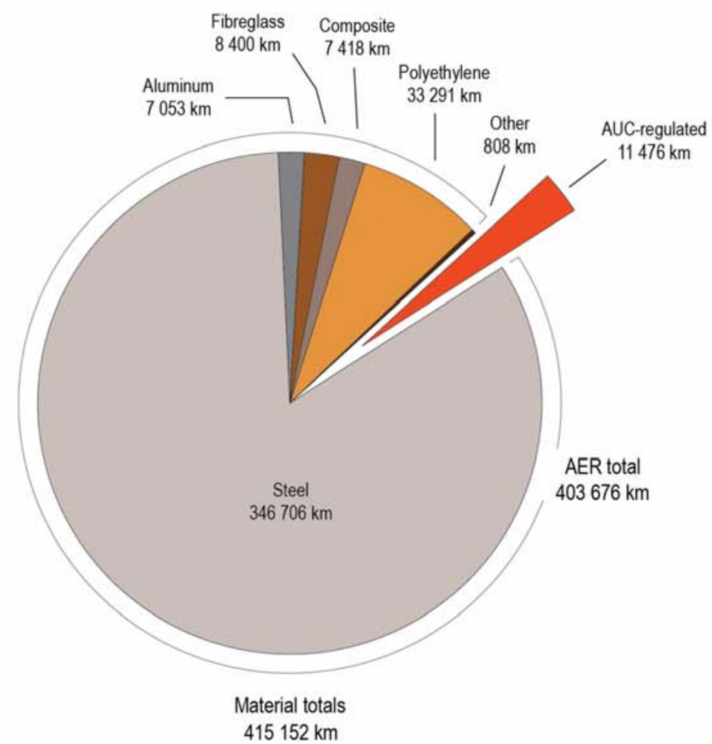


Figure 3b. Length of pipelines by pipe material category
Current to December 31, 2012 (excludes NEB-regulated pipelines)



PIPE MATERIAL CATEGORY

	Steel		Aluminum		Fibreglass		Composite		Polyethylene		Other			
	km	% of material type	km	% of material type	km	% of material type	km	% of material type	km	% of material type	km	% of material type	Total km	% of inventory
AUC-regulated													11 476	2.8
Crude oil	20 204	99.7	31	0.1	14	0.1	17	0.1	0	0	6	<0.1	20 272	4.9
Natural gas	200 813	84.2	6 328	2.7	261	0.1	2 942	1.2	28 199	11.8	39	<0.1	238 582	57.5
Sour gas	22 578	99.9	24	0.1	0	0	1	<0.1	0	0	9	<0.1	22 612	5.4
Water	19 060	77.9	199	0.8	2 288	9.3	1 200	4.9	1 142	4.7	584	2.4	24 473	5.9
Multiphase	52 559	85.4	57	0.1	5 780	9.4	2 994	4.8	65	0.1	121	0.2	61 576	14.8
Other	31 492	87.1	414	1.1	57	0.2	264	0.7	3 885	10.8	49	0.1	36 161	8.7
Totals	**346 706**	**83.5**	**7 053**	**1.7**	**8 400**	**2.0**	**7 418**	**1.8**	**33 291**	**8.0**	**808**	**0.2**	**415 152**	**100.0**

Figure 4a shows that most pipelines in Alberta are small in diameter. Figures 4b-4g show pipeline inventory for each substance category and what sizes of pipe are used. For example, pipe between 60.3 mm (2 inches) and 168.3 mm (6 inches) in diameter makes up 217 832 km, or 91.3 per cent, of the entire 238 582 km of natural gas pipeline (see figure 4b). The length of other diameters of pipe can also be determined from the chart. For clarity, some of the diameters have been combined into one colour band.

A common trend for natural gas, multiphase, water, and sour gas pipelines is the use of smaller pipe sizes. This is because these are typically for carrying raw production fluids produced from thousands of wells to satellites and batteries. Once combined at these locations, they are carried in larger, but fewer, pipelines to processing facilities. The processed product is then carried in an even larger pipe to market.

Figure 4a. Total AER-regulated pipelines by pipe size
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

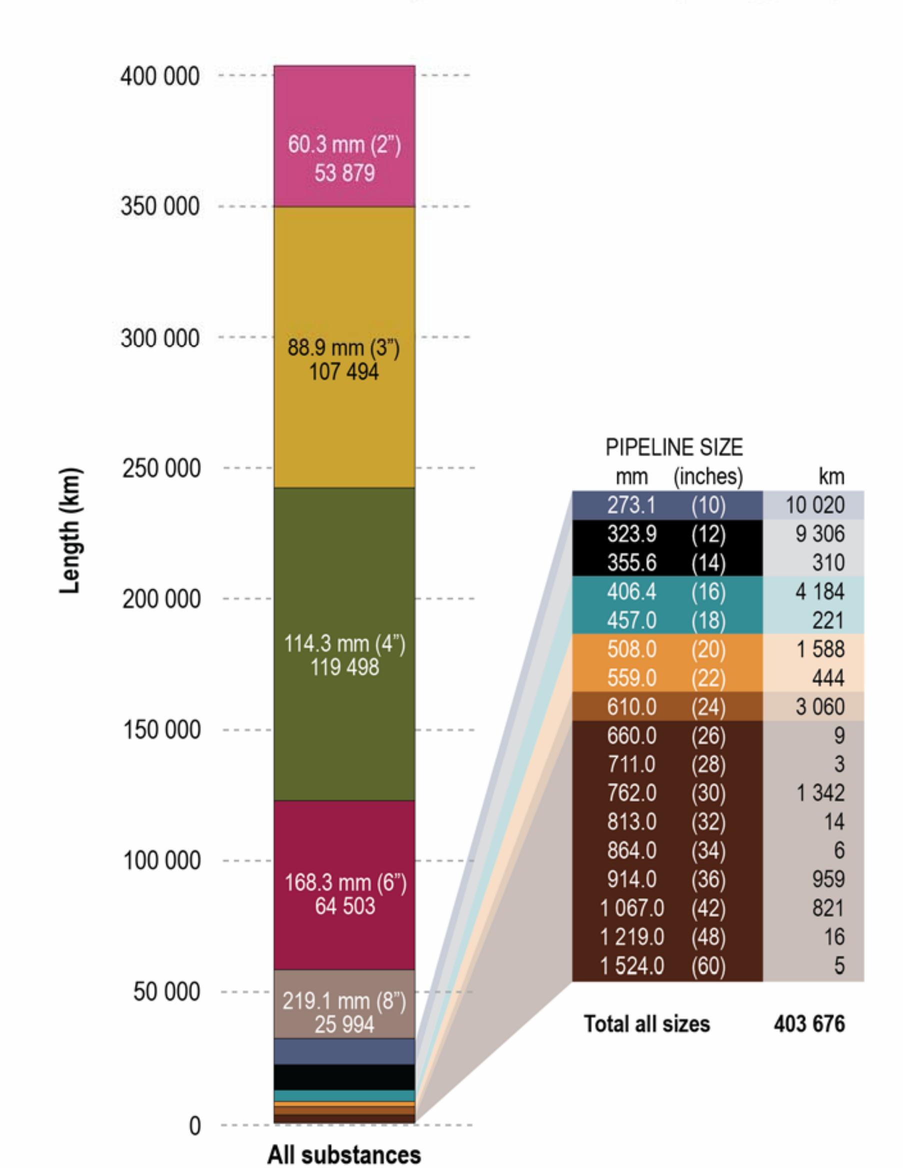


Figure 4b. Installed pipelines by pipe size and substance (natural gas)
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

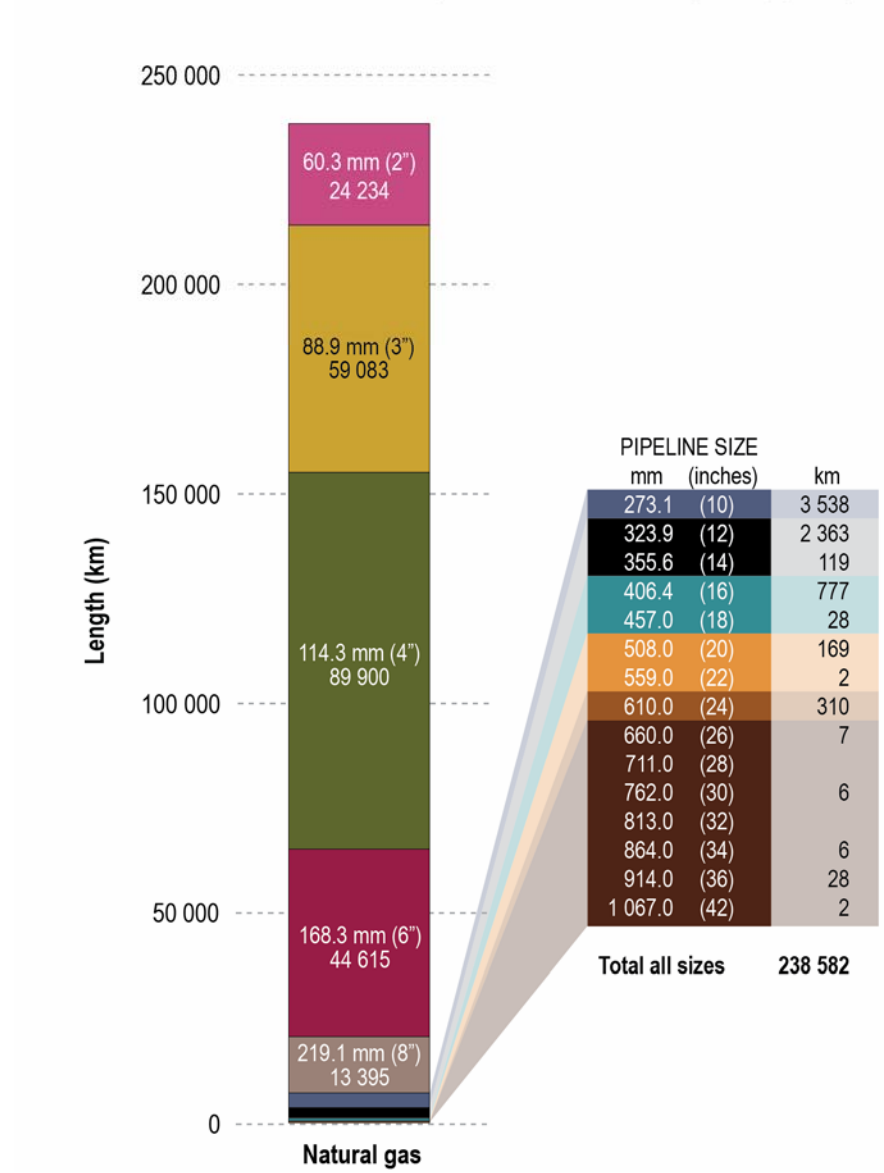


Figure 4c. Installed pipelines by pipe size and substance (crude oil)
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

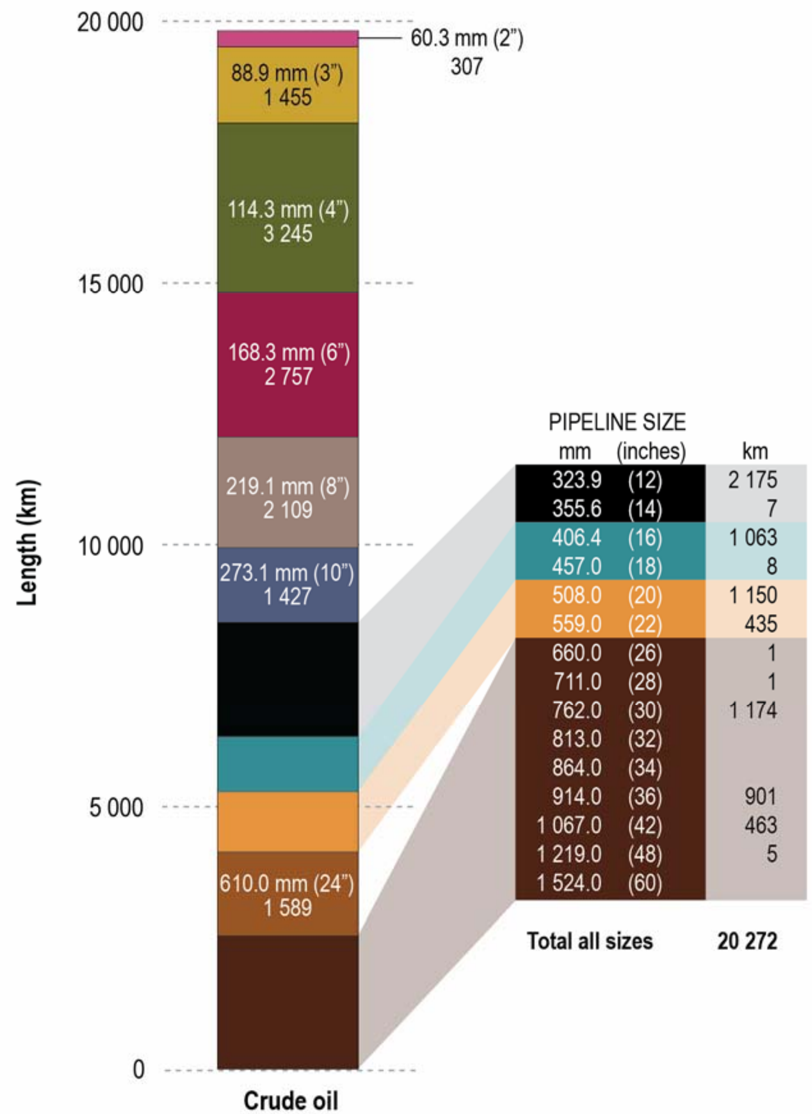


Figure 4d. Installed pipelines by pipe size and substance (sour gas)
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

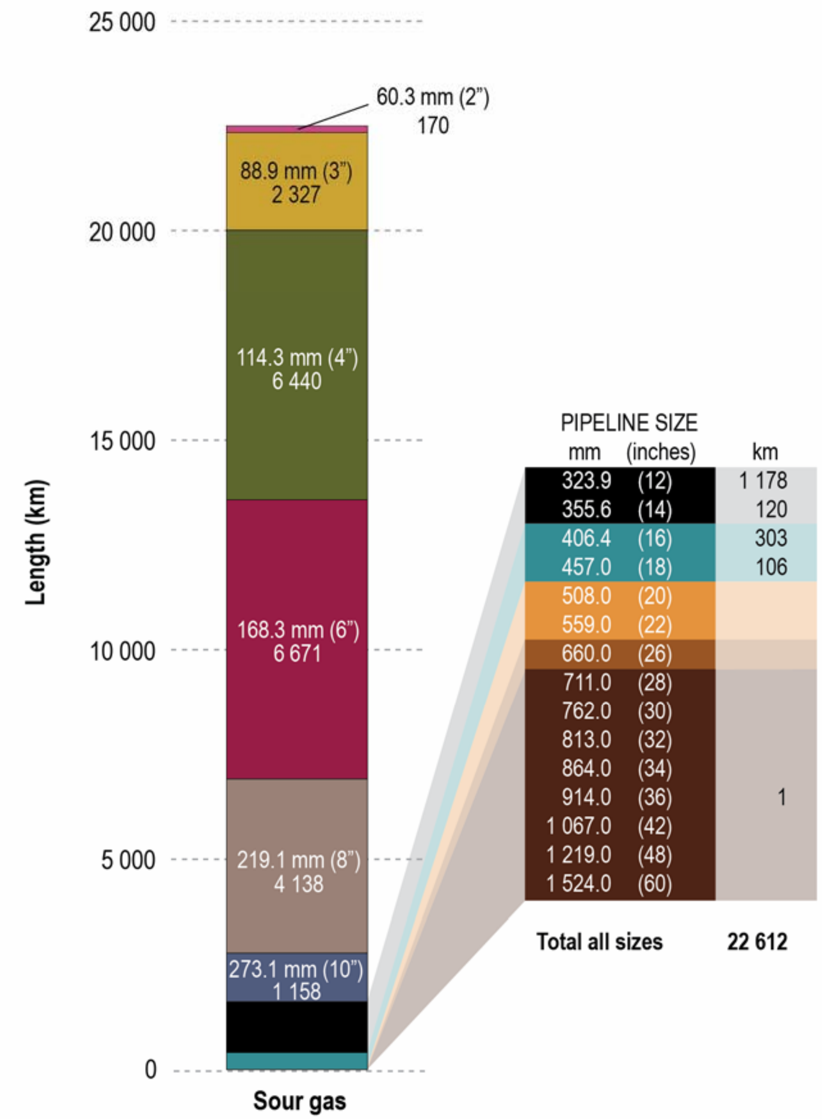


Figure 4e. Installed pipelines by pipe size and substance (water)
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

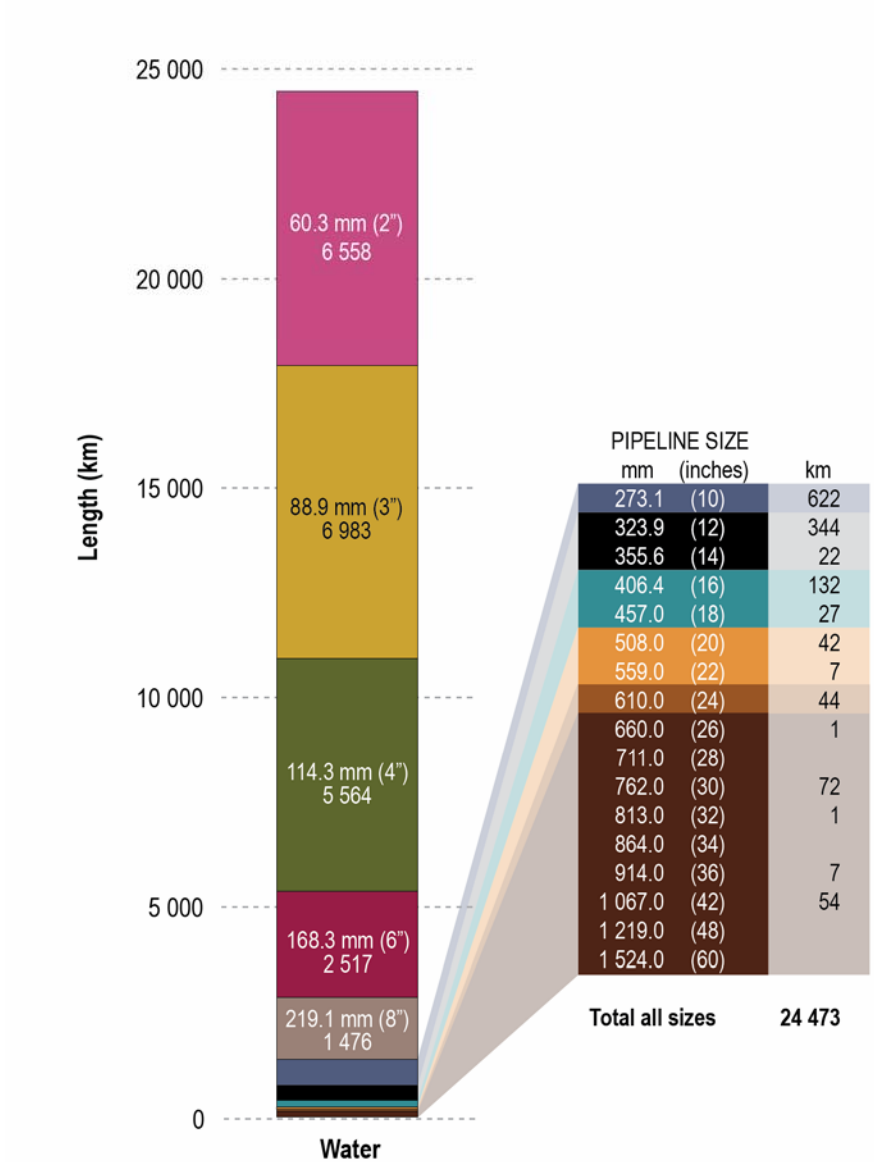


Figure 4f. Installed pipelines by pipe size and substance (multiphase)
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

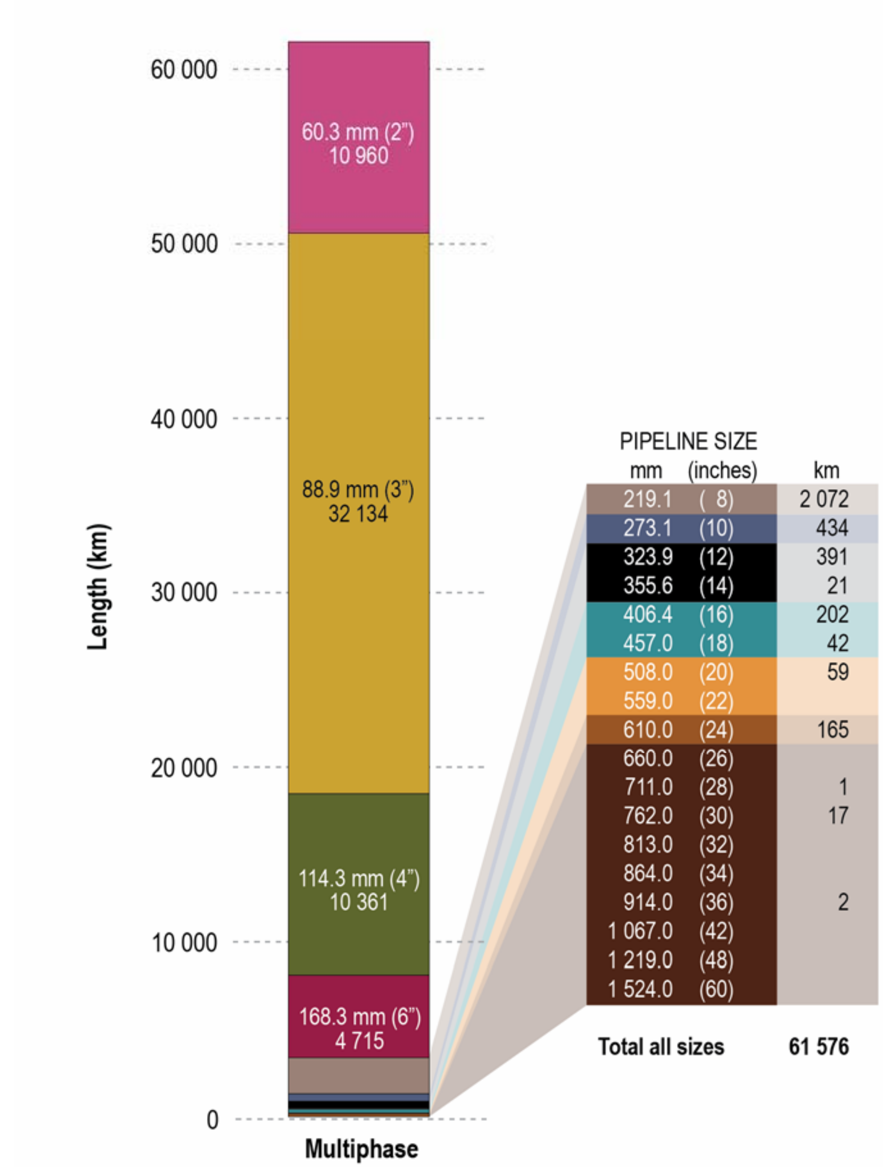
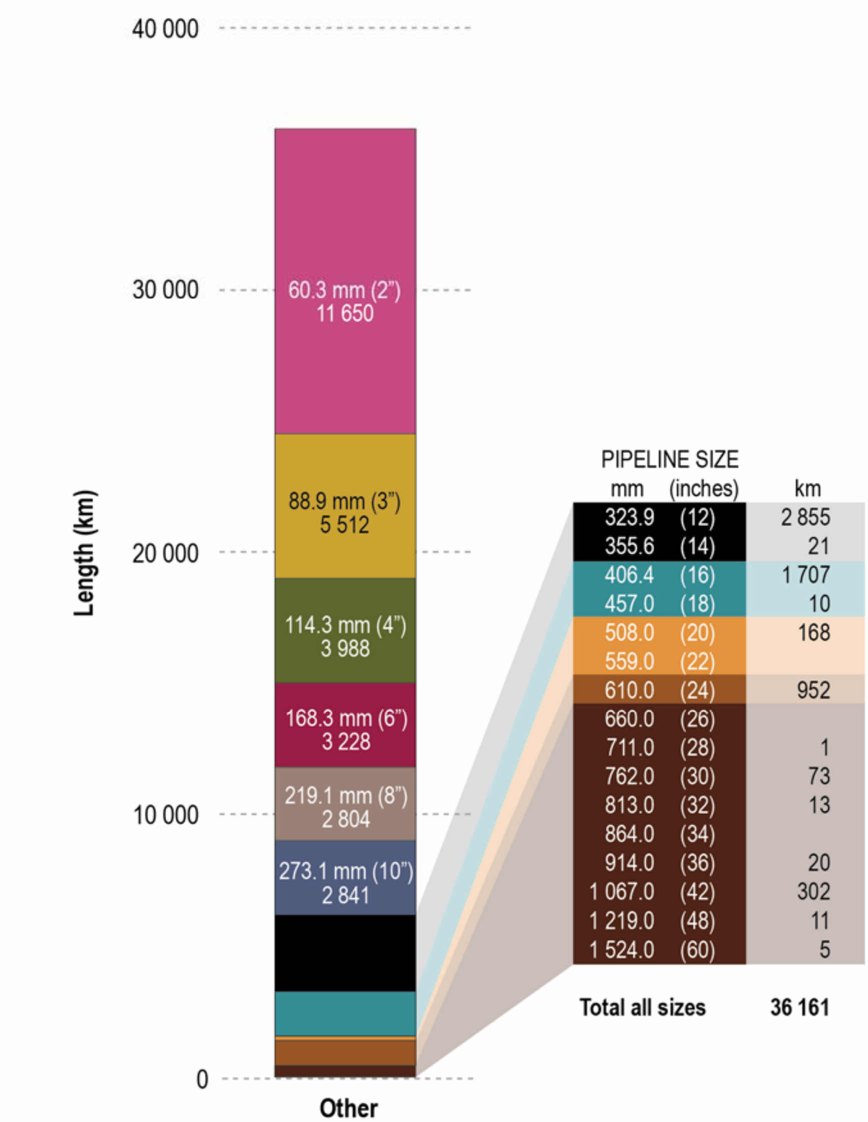


Figure 4g. Installed pipelines by pipe size and substance (other)
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)



Figures 5a and 5b show the relative proportion of each substance category carried in steel pipeline infrastructure in Alberta. Figure 5b shows that 57.9 per cent of steel pipeline is used to transport natural gas. Internal corrosion prevention used in steel carrier pipelines are categorized as follows: none (bare pipe), thin film (baked-on polymer coatings), free-standing liners, cement (bonded lining), expanded liners, or other. Expanded plastic liners are the most frequently used type of corrosion barrier, followed equally by freestanding plastic (or composite) pipe liners and thin-film lining. These barriers must be installed and operated carefully to function reliably.

Figure 5a. Types of internal corrosion prevention installed in steel pipelines by substance category
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)

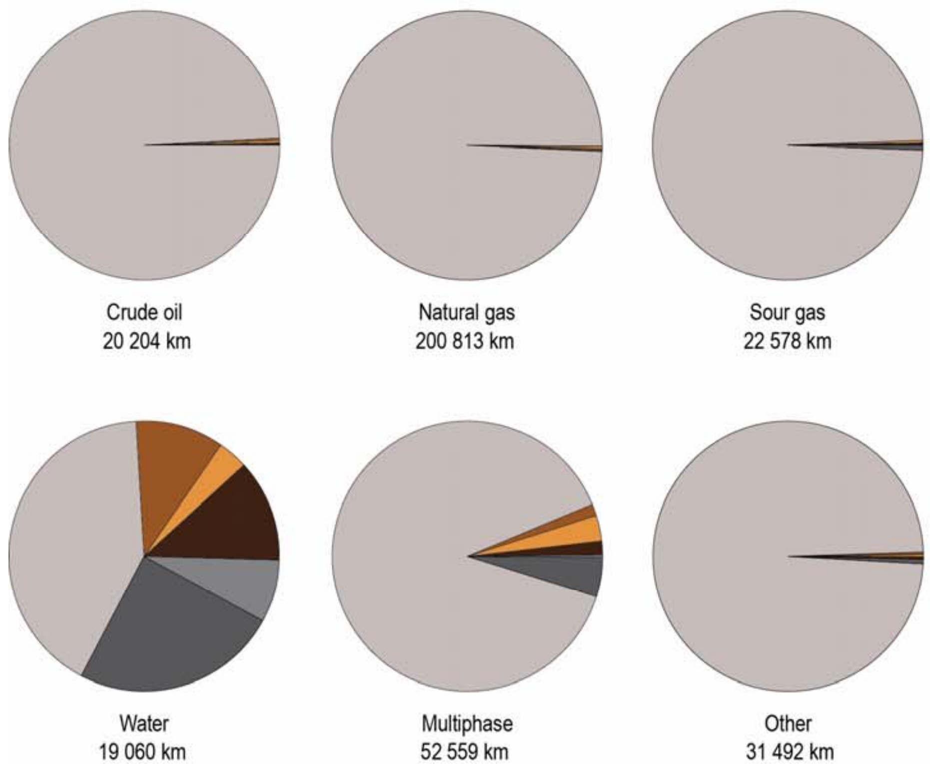
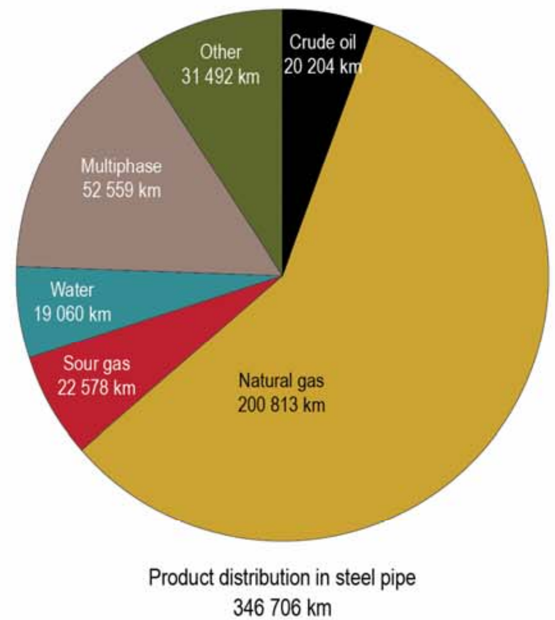


Figure 5b. Length of steel pipelines by substance category
Current to December 31, 2012 (excludes AUC- and NEB-regulated pipelines)



INTERNAL CORROSION BARRIERS

	Cement		Expanded liner		None		Other		Free standing liner		Thin film polymer		Total	% of
	km	%	km	%	km	%	km	%	km	%	km	%	km	inventory
Crude oil	1	<0.1	24	0.1	20 054	99.4	26	0.1	70	0.3	29	0.1	20 204	5.8
Natural gas	57	<0.1	219	0.1	199 496	99.4	181	0.1	662	0.3	198	0.1	200 813	57.9
Sour gas	4	<0.1	165	0.7	22 334	99.0	6	<0.1	58	0.3	11	<0.1	22 578	6.5
Water	1 474	7.7	4 704	24.7	7 865	41.2	2 033	10.7	702	3.7	2 281	12.0	19 060	5.5
Multiphase	215	0.4	2 555	4.9	46 701	88.7	615	1.2	1 606	3.1	868	1.7	52 559	15.2
Other	18	0.1	223	0.7	31 020	98.4	100	0.3	50	0.2	81	0.3	31 492	9.1
Total	**1 769**	**0.5**	**7 890**	**2.3**	**327 470**	**94.4**	**2 961**	**0.9**	**3 148**	**0.9**	**3 468**	**1.0**	**346 706**	**100.0**

Installing an internal corrosion barrier has been one way of combating corrosion on pipelines, particularly high corrosion failure rates in water pipelines. Only 5.6 per cent of all steel pipelines have an internal corrosion barrier (see figure 5a). Of those, 58.7 per cent are installed in steel water pipelines. Polyethylene, fibreglass, and composite pipelines are all inherently corrosion resistant because of their polymeric structure.

Figure 5a also shows that 94.4 per cent (327 470 km) of steel pipelines do not have an internal corrosion barrier. This does not mean that such pipe is operated without any means of preventing internal corrosion. The most common method of protecting steel pipelines against corrosion is the application, either by batch treatment or by continuous injection, of filming corrosion inhibitors (chemicals). Microbial corrosion can be mitigated by adding biocides, and oxygen scavengers are used where the transported fluids have excessive dissolved oxygen. Inhibitor treatments are generally accompanied by regular pipeline pigging (cleaning) to remove water and contaminants. These methods are widely used and can be very effective when properly implemented.

4.2 Pipeline Incidents, Releases, and Performance

From 1990 through 2012, 17 605 pipeline incidents were reported to the oil and gas regulator in Alberta at the time. This includes 155 incidents reported before 2009 on NGTL pipelines.

During this period, 2000 of the incidents reported were failures resulting from pipeline testing. As stated in section 3, because pressure-test failures do not occur under normal operating conditions, they are not included in the pipeline incident data analysis and have been analyzed separately (see figures 25 and 26). If product is lost during these test failures, it is usually fresh water and is not an environmental concern. Licensees conducting pressure tests using nonfresh water test media (such as water with an added freezing-point depressant) are required to develop and implement precautionary measures before using such media.

Incidents resulting from damage by others are included in the incident data analysis because they occur during normal pipeline operations and may lead to a pipeline release. Such incidents might result in an immediate release due to mechanical trauma to the pipe, or they might result in a release at a later date if the pipeline is damaged and not repaired. Damage by others includes incidents where a pipeline licensee strikes either its own or another licensee’s pipeline, as well as incidents where a pipeline is struck by a third party doing any type of excavation (see figures 16 and 17).

The 17 605 pipeline incidents within this period consisted of

- 1116 hits with no release (only recorded starting in 1994),
- 15 609 leaks, and
- 880 ruptures.

A hit is an incident where a pipeline is struck but no product is lost. A leak is defined as a pipeline failure where a pipeline is losing product but might continue to operate until the leak is detected. A rupture is a pipeline failure where the pipeline cannot continue to operate. Figure 6 illustrates the annual number of pipeline incidents.

Since the amount of pipeline infrastructure has generally increased every year, it is encouraging to see that the total number of incidents has not similarly increased. Pipeline incident frequency has continually decreased to 1.5 incidents per 1000 km of pipeline in 2010 and has been steady since then (see figures 27 and 28). Average incident frequency, expressed as *n* incidents per 1000 km per year, means on average that *n* number of pipeline incidents occur on an average 1000 km length of pipeline over a one-year period.

The number of hits on pipelines has gradually increased over the period. This is not unexpected considering the steadily increasing inventory of buried pipelines. The number of hits also closely parallels the level of industry activity—with more industry activity, the number of hits typically increases. The large decrease in 2009 can be attributed to the reduced industry activity, as well as to the decrease in pipeline inventory due to NGTL lines being transferred to the jurisdiction of the NEB. The annual number of hits has fallen slightly since a record high number in 2005, when the requirements for ground disturbance practices, right-of-way surveillance and inspection, and ground disturbance training were strengthened.

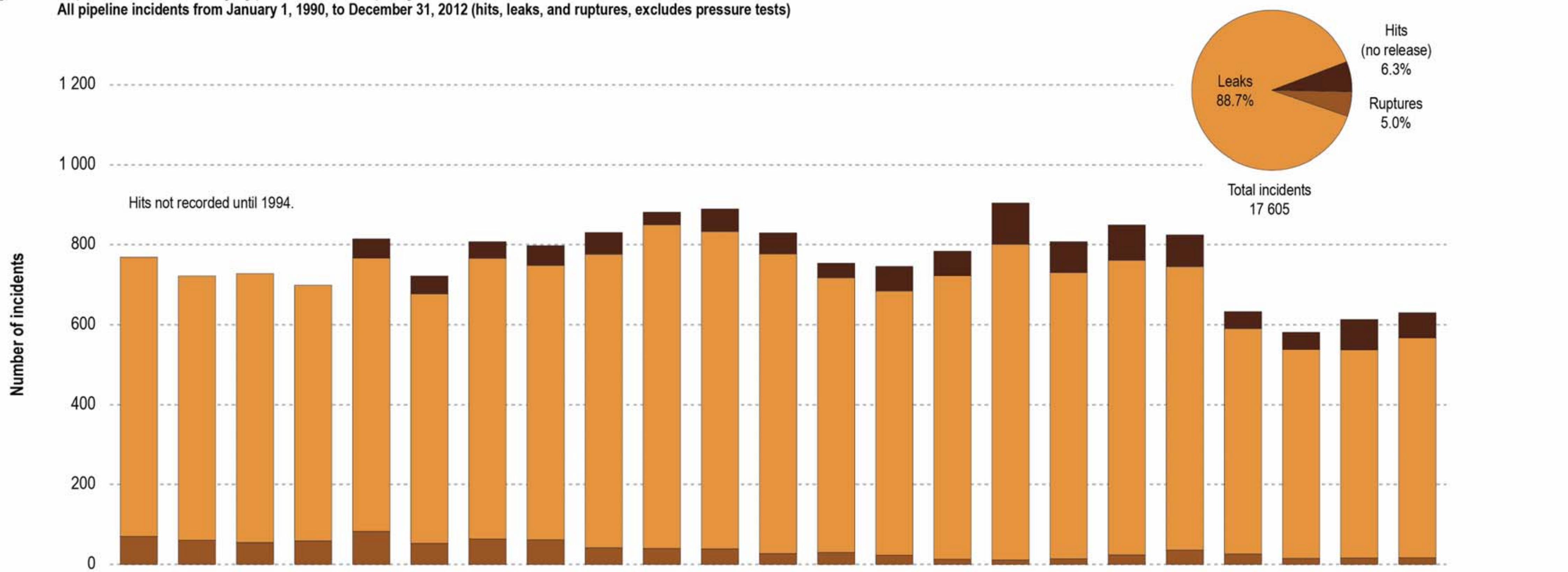
Figure 6 indicates a noticeable decrease in the number of leaks beginning in 2009. This may be due to the regulatory amendments in 2005 and several significant changes to the design and construction requirements in *CSA Z662* in 2005 and 2007 that addressed pipeline construction quality. In 2012, there was a slight increase in the number of leaks and additional scrutiny will be required to determine whether this increase is an aberration or a trend.

The number of pipeline ruptures has also noticeably decreased over the past 23 years, excluding a minor increase in 2008 and 2009. This number of ruptures has remained relatively steady over the last three years. This overall trend is very positive because pipeline ruptures can cause serious damage and injury. The AER is working with companies to ensure that pipeline maintenance and compliance programs are in place to identify areas for improvement and to focus inspections on higher-risk pipelines.

Figure 7 shows the number of incidents for each pipeline substance category by year, including all hits, leaks, and ruptures.

Figure 6. Pipeline incidents by type of incident per year

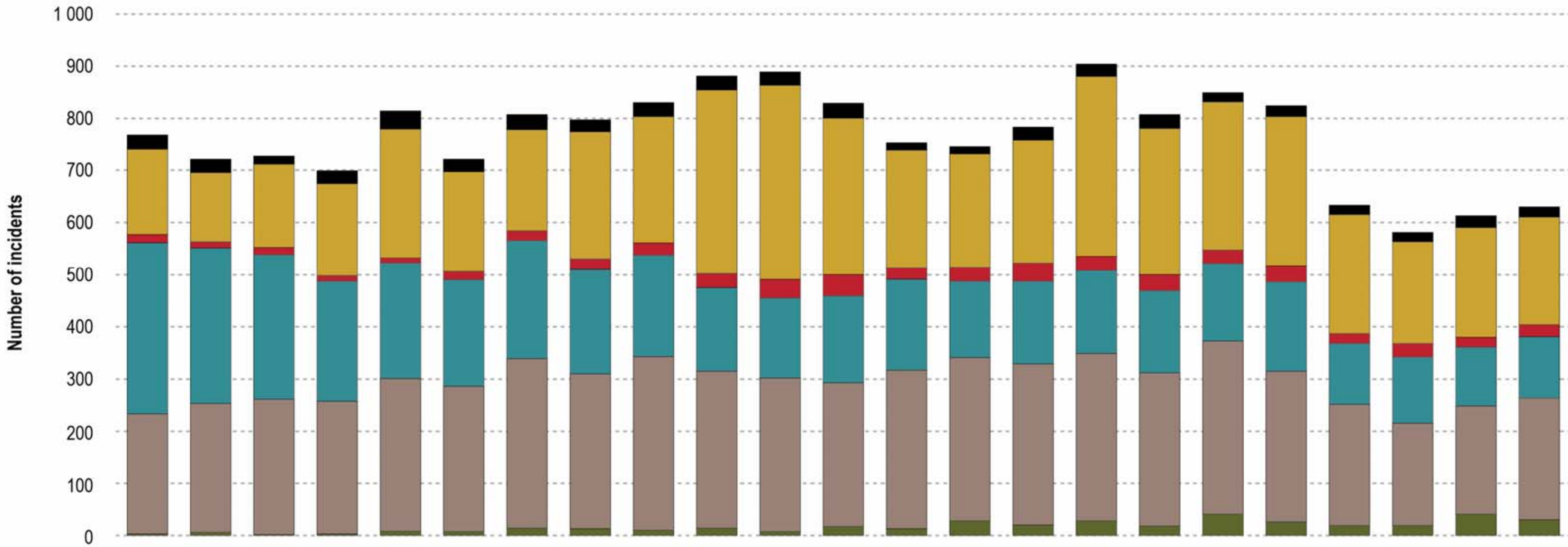
All pipeline incidents from January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



INCIDENT	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of total
Hit	0	0	0	0	48	44	42	50	55	32	57	53	37	61	61	104	78	89	80	43	43	76	63	1 116	6.3
Leak	698	660	672	640	683	624	701	685	733	809	793	749	686	661	709	789	715	736	708	564	523	521	550	15 609	88.7
Rupture	70	61	55	59	83	53	64	62	42	40	39	27	30	23	13	11	14	24	36	26	15	16	17	880	5.0
Total number incidents	**768**	**721**	**727**	**699**	**814**	**721**	**807**	**797**	**830**	**881**	**889**	**829**	**753**	**745**	**783**	**904**	**807**	**849**	**824**	**633**	**581**	**613**	**630**	**17 605**	**100**

Figure 7. Pipeline incidents, by substance category per year

All pipeline incidents from January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



Number of incidents

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total	% of total
Crude Oil	28	26	16	25	35	24	29	23	27	27	26	29	15	14	25	24	27	18	21	18	18	23	20	538	3.1
Natural Gas	163	132	159	176	247	191	194	244	242	352	372	300	225	217	236	345	280	284	286	228	195	210	206	5 484	31.1
Sour Gas	16	12	14	11	10	16	19	20	24	27	36	41	22	27	35	27	31	26	31	19	26	19	23	532	3.0
Water	328	298	277	230	221	204	226	200	194	160	153	166	174	146	158	159	157	148	171	117	127	113	118	4 245	24.1
Multiphase	230	247	259	254	293	279	325	297	333	301	295	276	304	313	309	321	294	332	289	232	196	207	233	6 419	36.5
Other	3	6	2	3	8	7	14	13	10	14	7	17	13	28	20	28	18	41	26	19	19	41	30	387	2.2
Total	**768**	**721**	**727**	**699**	**814**	**721**	**807**	**797**	**830**	**881**	**889**	**829**	**753**	**745**	**783**	**904**	**807**	**849**	**824**	**633**	**581**	**613**	**630**	**17 605**	**100.0**

Figure 8a illustrates the number of pipeline failures (leaks and ruptures) by cause for each year since 1990. Figure 8a and 8b focus on causes of pipeline releases and do not include hits that did not result in any product loss.

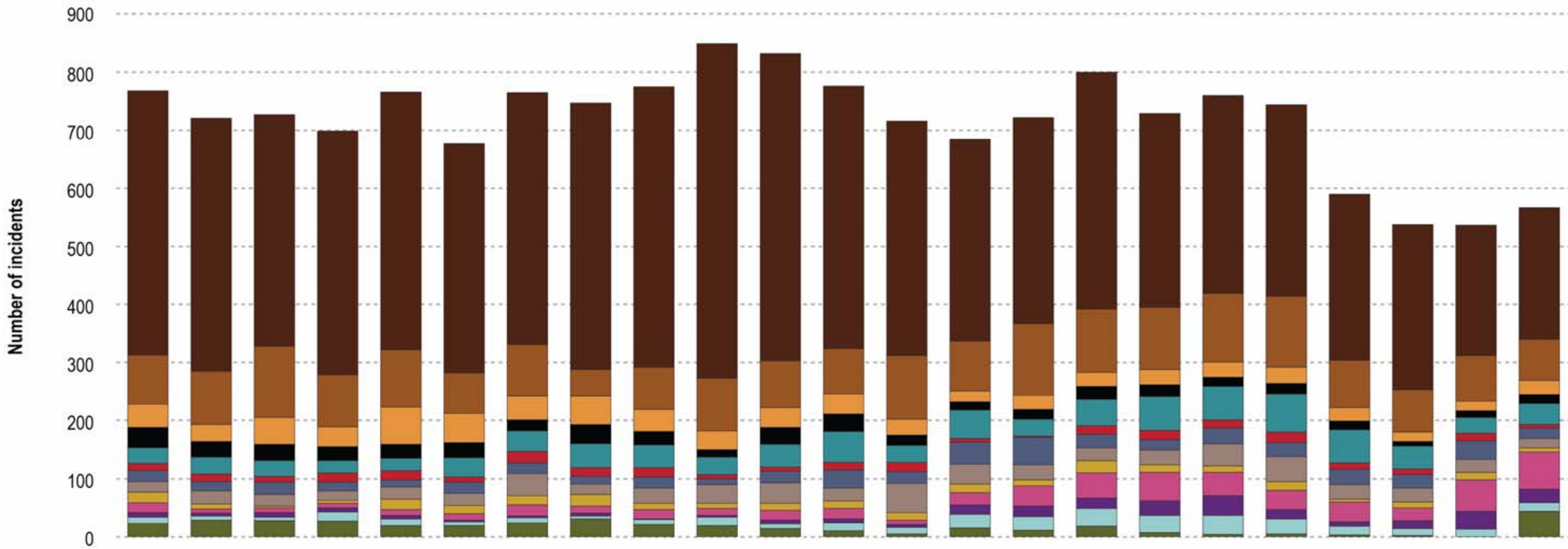
For 2012, a high number of failures have been shown as “unknown” cause. As investigation work is completed and new information obtained, incident data is also updated. Incident reporting must be completed by the end of March each year for the previous year. Data were gathered for this report in January 2013. Therefore data for incidents and failures occurring near the end of the year in 2012 were identified as “unknown” and likely updated after data collection once the investigation was completed.

When considering the effect of corrosion, it is necessary to recognize that different types of pipelines are susceptible to corrosion in different ways. For example, since corrosive components are abundant in multiphase and water pipelines, internal corrosion is responsible for 57.1 per cent and 51.2 per cent of incidents, respectively (figures 10a and 11a) in those substances. In crude oil pipelines, internal corrosion is substantially lower due to the relative absence of water in the crude oil processed for pipeline transport and is responsible for only 21.2 per cent of incidents over the reporting period, with ten failures over the last five years and two in 2012.

External corrosion is related to the type of coating originally applied to the pipeline, to external soil conditions, and to pipeline operating temperature, and is not directly related to the type of product being transported. The percentage of failures caused by external corrosion, range from 6.5 per cent to 16.1 per cent of the incidents for each substance, and average 12.7 per cent of the failures overall. In crude oil pipelines, external corrosion represents 12.6 per cent of all incidents, totalling 33.8 per cent of all crude oil pipeline incidents when combined with those related to internal corrosion. Over the last five years, this corresponds to an average of about 4 failures per year for corrosion failures on crude oil pipelines.

The higher percentages of failures related to internal corrosion in water or multiphase pipelines are expected. Most of Alberta’s pipelines carry raw (unprocessed) oil and gas, which typically contain water of varying chemistry and salinity, along with acid gases. This combination causes internal corrosion which is responsible for 54.8 per cent of all failures for all substances over the reporting period (see figure 8b).

Figure 8a. Total number of failures by cause per year
Current to December 31, 2012 (leaks and ruptures only, excludes pressure tests)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of total
Internal corrosion	455	436	399	420	444	395	434	459	483	576	529	452	404	347	355	408	334	341	330	286	285	225	227	9 024	54.8
External corrosion	85	92	123	90	99	70	89	46	73	91	81	78	110	86	124	109	107	118	122	82	73	79	71	2 098	12.7
Damage by others	40	29	46	34	64	50	41	49	38	32	34	35	27	19	24	24	26	26	28	23	16	16	24	745	4.5
Weld	35	27	28	24	24	26	19	33	23	13	29	30	18	14	17	23	21	16	18	15	8	12	16	489	3.0
Construction damage	27	29	27	21	21	33	35	41	39	30	39	53	29	49	29	45	58	58	66	57	39	27	36	888	5.4
Overpressure	12	13	10	16	16	9	20	15	16	7	7	13	16	6	2	15	16	14	18	11	10	13	6	281	1.7
Pipe	19	16	21	15	12	19	18	13	19	10	20	31	20	38	47	23	18	27	24	26	23	32	18	509	3.1
Joint	18	22	20	16	21	21	38	18	26	32	35	22	50	34	26	22	25	38	43	25	24	22	16	614	3.7
Earth movement	18	9	3	5	18	14	16	20	11	9	12	13	13	15	10	21	13	11	15	5	10	13	7	281	1.7
Valve/fitting	17	7	8	8	10	11	19	12	16	12	17	18	8	21	35	43	49	40	33	34	22	54	64	558	3.4
Operator error	8	5	8	7	6	3	3	5	1	3	7	7	5	16	18	18	25	34	16	8	14	31	23	271	1.6
Miscellaneous	11	7	6	16	12	7	9	5	9	15	8	14	11	24	24	31	30	33	26	15	12	13	15	353	2.1
Unknown	23	29	28	27	19	19	24	31	21	19	14	10	5	15	11	18	7	4	5	3	2	0	44	378	2.3
Total	**768**	**721**	**727**	**699**	**766**	**677**	**765**	**747**	**775**	**849**	**832**	**776**	**716**	**684**	**722**	**800**	**729**	**760**	**744**	**590**	**538**	**537**	**567**	**16 489**	**100.0**

Figure 8b. Pipeline failures by cause for all years combined
All pipeline failures from January 1, 1990, to December 31, 2012 (leaks and ruptures only)

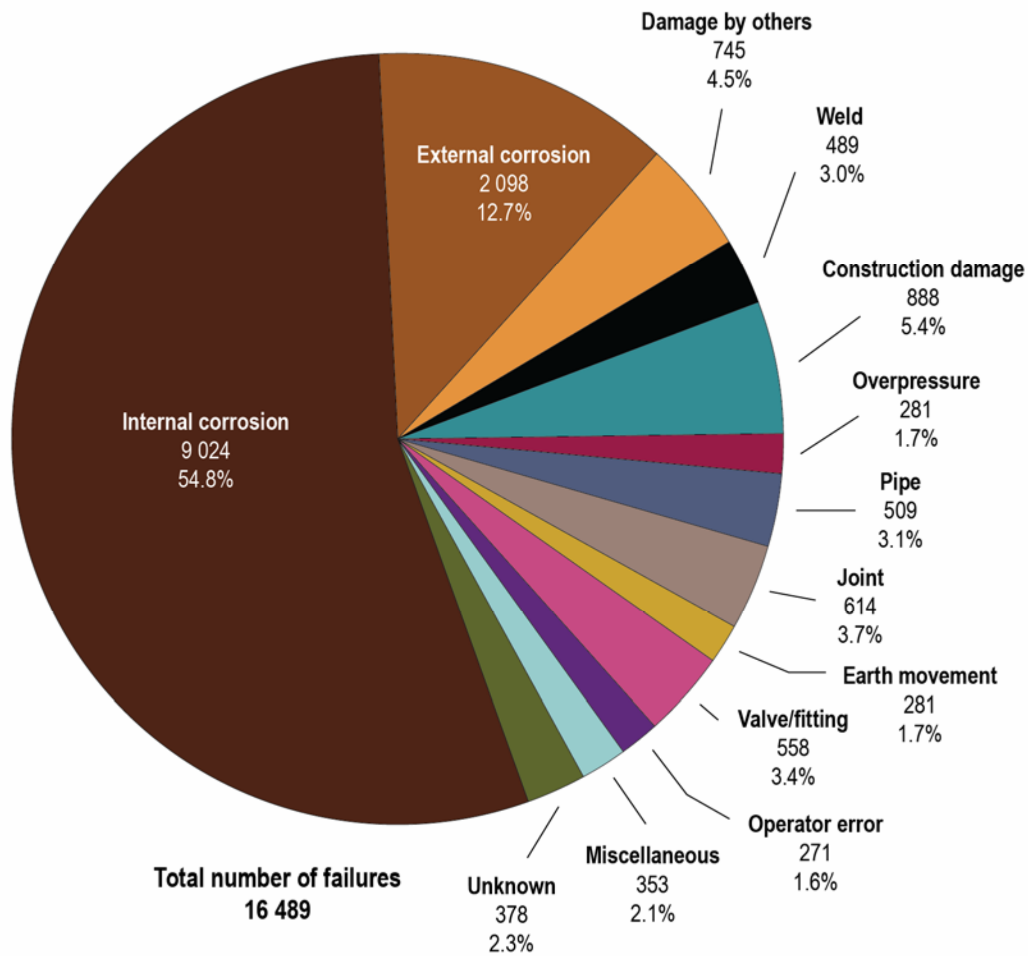
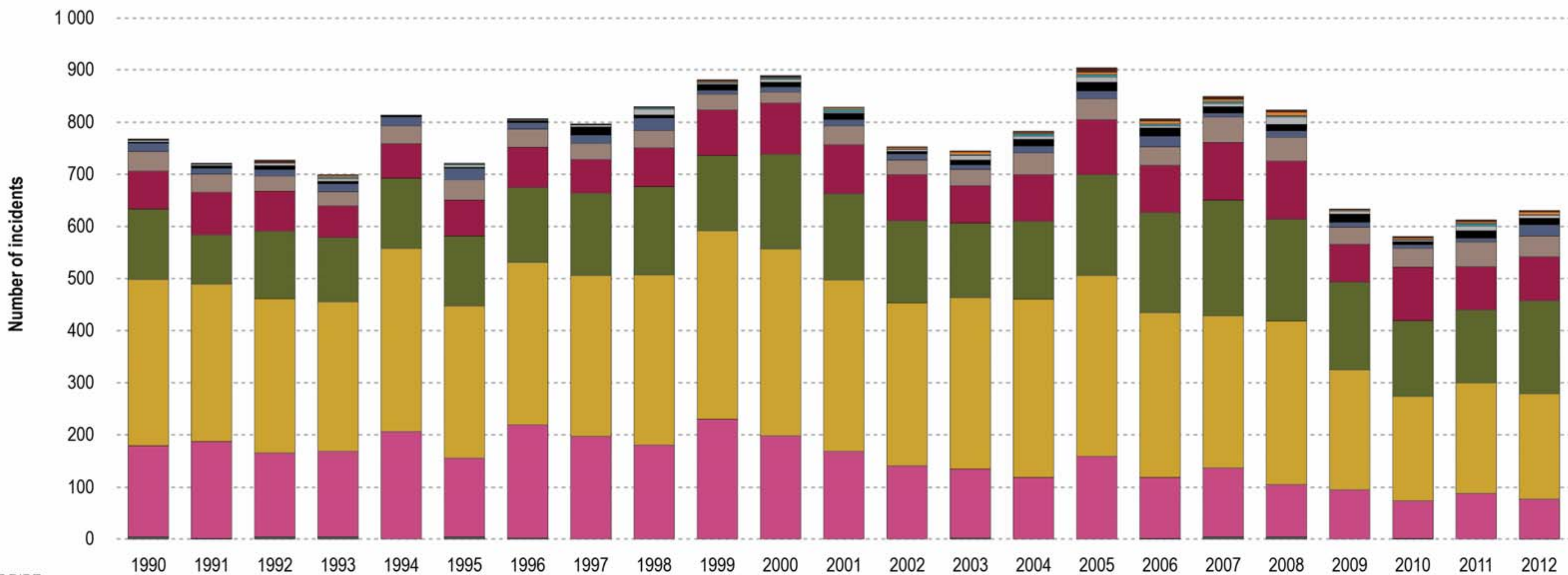


Figure 9 shows that most pipeline incidents occur on small-diameter pipeline, which reflects the actual infrastructure present in Alberta and the corrosive nature of the products carried in those small-diameter pipelines. When averaged over the reporting period, 90.7 per cent of all pipeline incidents occurred on pipeline 168.3 mm (6 inches) in diameter and smaller.

Through targeted surveillance and inspection and more regulatory direction, industry is encouraged to improve its performance on small-diameter pipelines. As a result, fewer failures have occurred on small-diameter pipelines in recent years.

Figure 9. Pipeline incidents by pipe size

All pipeline incidents from January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



SIZE OF PIPE mm (inches nominal)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of total
762–1219 (30–48)	1	1	5	2			1	1	1	3	3	1	1	2	3	9	5	5	5	1	3	4	3	60	0.3
559–660 (22/24)	1		1	3	1	1	1	1	1	2	1	3	3	5	2	4	5	4	6	2	3	3	5	58	0.3
457–508 (18/20)	1	1		3		2			3	1	3	6	1	2	5	5	4	4	3	1	1	5	1	52	0.3
355.6–406.4 (14/16)	3	3	5	5		5	2	4	11	3	6	2	4	9	6	10	4	6	14	6	3	9	6	126	0.7
323.9 (12)	2	5	7	5	3	2	4	16	6	12	9	12	5	9	13	17	16	13	13	15	6	15	12	217	1.2
273.1 (10)	16	11	13	15	17	22	12	16	24	7	10	12	12	9	13	14	20	7	12	9	7	7	21	306	1.7
219.1 (8)	38	35	29	27	34	39	35	31	33	29	20	36	28	31	42	40	36	49	46	33	36	47	40	814	4.6
168.3 (6)	73	81	76	60	67	68	78	65	75	88	99	95	88	71	89	106	91	111	111	73	103	84	85	1 937	11.0
114.3 (4)	135	95	130	124	134	135	143	157	169	144	181	165	158	144	150	193	192	222	196	168	145	139	178	3 597	20.4
88.9 (3)	319	302	296	287	352	292	312	309	327	362	359	329	312	328	341	348	315	291	313	230	200	212	202	6 938	39.6
60.3 (2)	175	186	161	164	206	151	217	197	180	230	198	168	141	133	119	158	118	133	101	95	73	88	77	3 469	19.7
Not specified	4	1	4	4		4	2							2			1	4	4		1			31	0.2
Total	**768**	**721**	**727**	**699**	**814**	**721**	**807**	**797**	**830**	**881**	**889**	**829**	**753**	**745**	**783**	**904**	**807**	**849**	**824**	**633**	**581**	**613**	**630**	**17 605**	**100.0**

Figure 10a shows that 57.1 per cent of water pipeline incidents are caused by internal corrosion. Water pipelines include pipelines drawing water from freshwater bodies for oilfield use as well as pipeline carrying produced water to disposal sites. Much progress has been made in reducing the number of failures on water pipelines since 1990 (see figure 10b). More than half of all water pipelines have some type of internal corrosion protection. More extensive use of internal corrosion protection would be a good way to further reduce the significant number of water pipeline failures caused by internal corrosion.

Water is more corrosive to steel than hydrocarbons. Produced or formation water is especially corrosive because it is typically highly saline, may tend to deposit scales, and may be of low pH due to the presence of acid gases.

Figure 10a. Water pipeline incidents by cause for all years combined

January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)

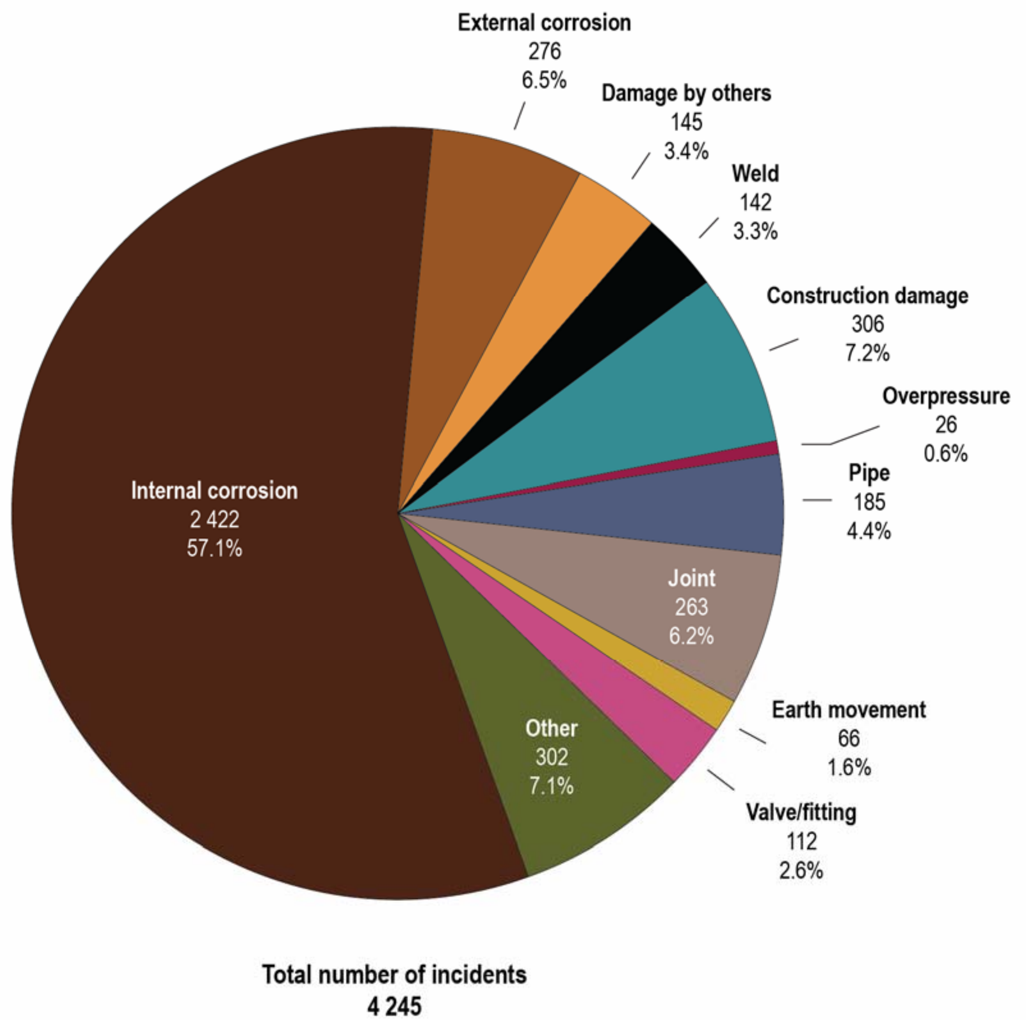
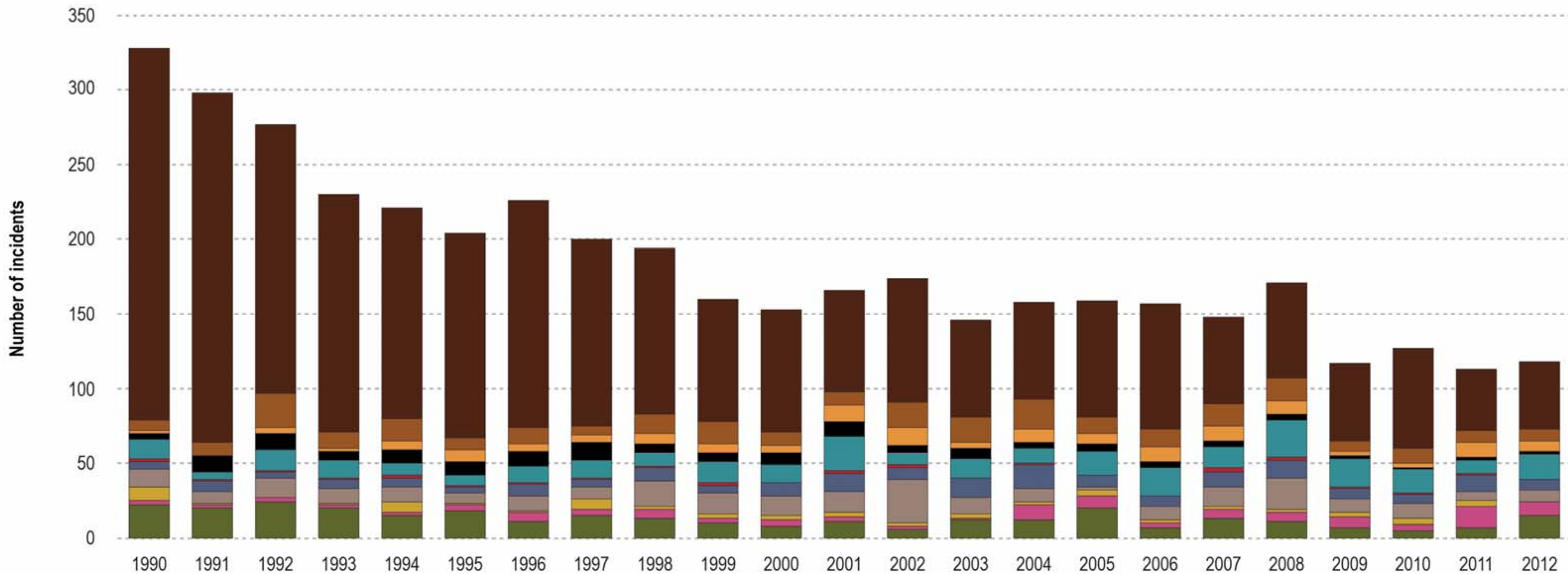


Figure 10b. Water pipeline incidents by cause per year
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



CAUSE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Internal corrosion	249	234	180	159	141	137	152	125	111	82	82	68	83	65	65	78	84	58	64	52	67	41	45
External corrosion	7	9	23	11	15	8	11	6	13	15	9	9	17	17	20	11	12	15	15	7	10	8	8
Damage by others	2		4	2	6	8	5	5	7	6	5	11	12	4	9	7	10	10	9	3	3	10	7
Weld	4	11	11	6	9	9	10	12	6	6	8	10	5	7	4	5	4	4	4	2	1	2	2
Construction damage	13	5	14	12	8	7	11	12	9	14	12	23	8	13	10	16	19	14	25	19	16	9	17
Overpressure	2	1	1	1	2	1	1	1	1	2		2	2		1			3	2	1	1	1	
Pipe	5	7	4	6	6	4	8	5	9	5	9	12	8	13	16	8	7	10	12	7	6	11	7
Joint	12	8	13	10	10	7	10	8	17	14	13	14	29	11	9	2	9	13	21	9	10	6	8
Earth movement	9	1		1	7	1	1	7	2	3	3	3	2	3	2	4	2	2	2	3	4	4	
Valve/fitting	3	2	3	2	2	4	6	4	6	3	4	3	2	1	10	8	3	6	6	7	4	14	9
Other	22	20	24	20	15	18	11	15	13	10	8	11	6	12	12	20	7	13	11	7	5	7	15
Total	**328**	**298**	**277**	**230**	**221**	**204**	**226**	**200**	**194**	**160**	**153**	**166**	**174**	**146**	**158**	**159**	**157**	**148**	**171**	**117**	**127**	**113**	**118**
% of total	**7.8**	**7.0**	**6.5**	**5.4**	**5.2**	**4.8**	**5.3**	**4.7**	**4.6**	**3.8**	**3.6**	**3.9**	**4.1**	**3.4**	**3.7**	**3.7**	**3.7**	**3.5**	**4.0**	**2.8**	**3.0**	**2.7**	**2.8**

Figure 11a shows that 67.3 per cent of all multiphase pipeline incidents are caused by corrosion. Multiphase pipelines carry the effluent from oil wells and will typically carry a mixture of oil, gases, and produced saline formation water. Mitigating corrosion in multiphase pipelines can be difficult, as variations in fluid composition and the presence of substantial amounts of water can make it difficult to select and maintain effective inhibitor films. Multiphase pipelines are also associated with a relatively high number of external corrosion failures, primarily due to external coatings failing or deteriorating from higher operating temperatures that are typical in many multiphase wells.

Figure 11a. Multiphase pipeline incidents by cause for all years combined
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)

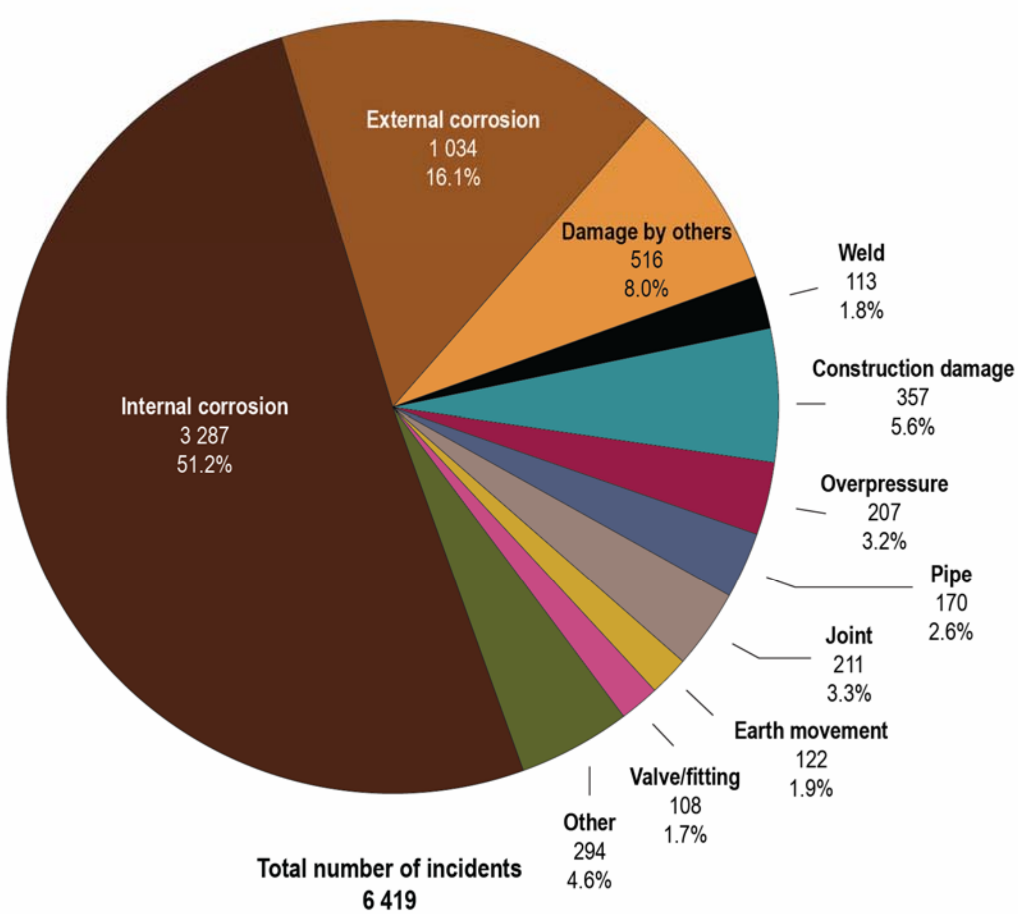
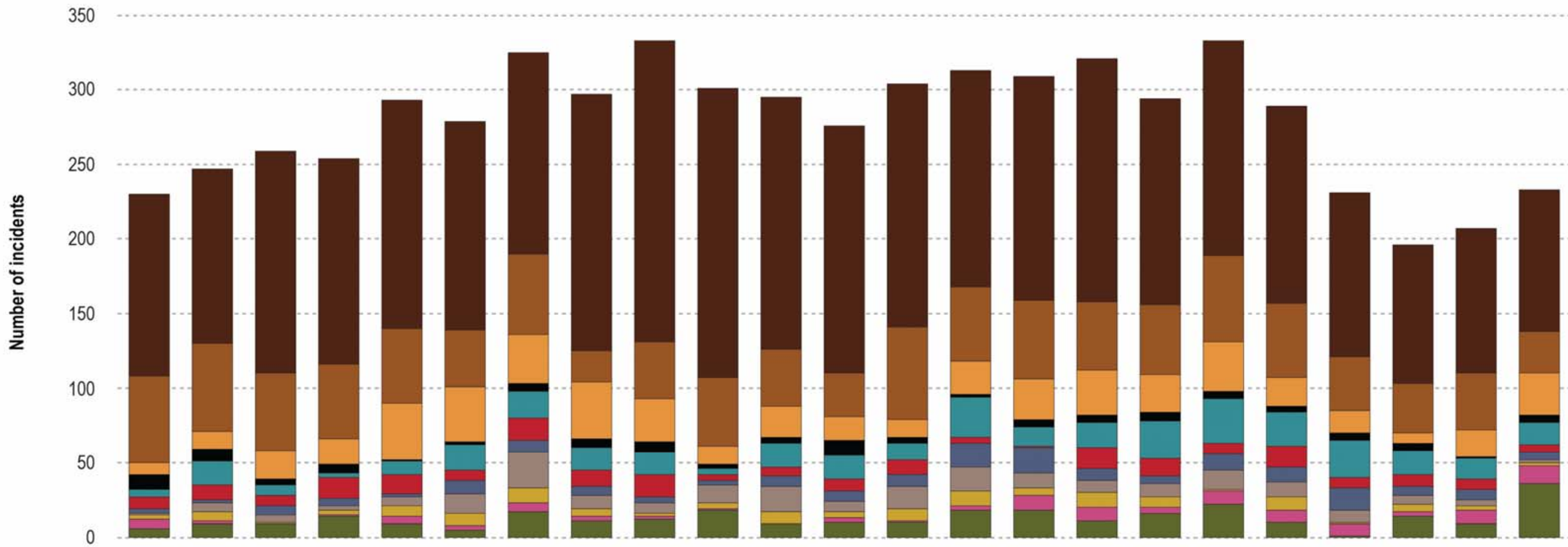


Figure 11b shows that in recent years, operators seem to be succeeding in reducing the number of internal corrosion failures but have been struggling to manage external corrosion issues on multiphase pipelines. This is understandable because while internal corrosion can be treated and mitigated by adding chemicals and pigging (cleaning) the line, the only way to effectively stop existing external corrosion from further damaging the pipeline is to excavate and recoat the pipeline.

Figure 11b. Multiphase pipeline incidents by cause per year
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



CAUSE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Internal corrosion	122	117	149	138	153	140	135	172	202	194	169	166	163	145	150	163	138	144	132	110	93	97	95
External corrosion	58	59	52	50	50	38	54	21	38	46	38	29	62	50	53	46	47	58	50	36	33	38	28
Damage by others	8	12	19	17	38	37	33	38	29	12	21	16	12	22	27	30	25	33	19	15	7	18	28
Weld	10	8	4	6	1	2	5	6	7	3	4	10	4	2	5	5	6	5	4	5	5	1	5
Construction damage	5	16	7	3	9	17	18	15	15	4	16	16	11	27	13	17	25	30	23	25	16	14	15
Overpressure	8	10	7	14	13	7	15	11	15	4	6	8	10	4	1	14	12	7	14	7	8	7	5
Pipe	3	2	6	5	2	9	8	6	4	3	7	7	8	16	17	8	5	11	10	15	6	7	5
Joint	1	6	5	3	6	13	24	9	7	12	17	7	15	16	10	8	9	13	10	8	6	4	2
Earth movement	3	6	1	3	7	8	10	5	2	4	8	4	8	10	5	10	7	1	9	1	5	3	2
Valve/fitting	6	2		1	5	3	6	3	2	1		3	1	3	10	9	4	8	8	9	3	9	12
Other	6	9	9	14	9	5	17	11	12	18	9	10	10	18	18	11	16	22	10	1	14	9	36
Total	**230**	**247**	**259**	**254**	**293**	**279**	**325**	**297**	**333**	**301**	**295**	**276**	**304**	**313**	**309**	**321**	**294**	**332**	**289**	**232**	**196**	**207**	**233**
% of total	**3.6**	**3.8**	**4.0**	**4.0**	**4.6**	**4.3**	**5.1**	**4.6**	**5.2**	**4.7**	**4.6**	**4.3**	**4.7**	**4.9**	**4.8**	**5.0**	**4.6**	**5.2**	**4.5**	**3.6**	**3.1**	**3.2**	**3.6**

Figures 12a and 12b show that the number of incidents on crude oil pipelines is quite small, recently averaging about 20 per year. External corrosion has been responsible for 12.6 per cent of crude oil pipeline failures, and internal corrosion for 21.2 per cent. Over the last five years, internal corrosion was the cause of only ten pipeline failures in total. This is not surprising, as oil—whether it is natural, synthetically derived, or is crude bitumen—is generally treated or processed in some way before it is shipped. Once water and sediments have been removed, the shipped oils are less corrosive than the raw fluids.

Proportionally, the number of incidents due to damage by others appears high for crude oil pipelines. This is the result of the limited number of crude oil pipeline incidents, whereby a couple of additional incidents of any type results in an artificially high proportion. This variability is evident in figure 12b.

Figure 12a. Crude oil pipeline incidents by cause for all years combined
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)

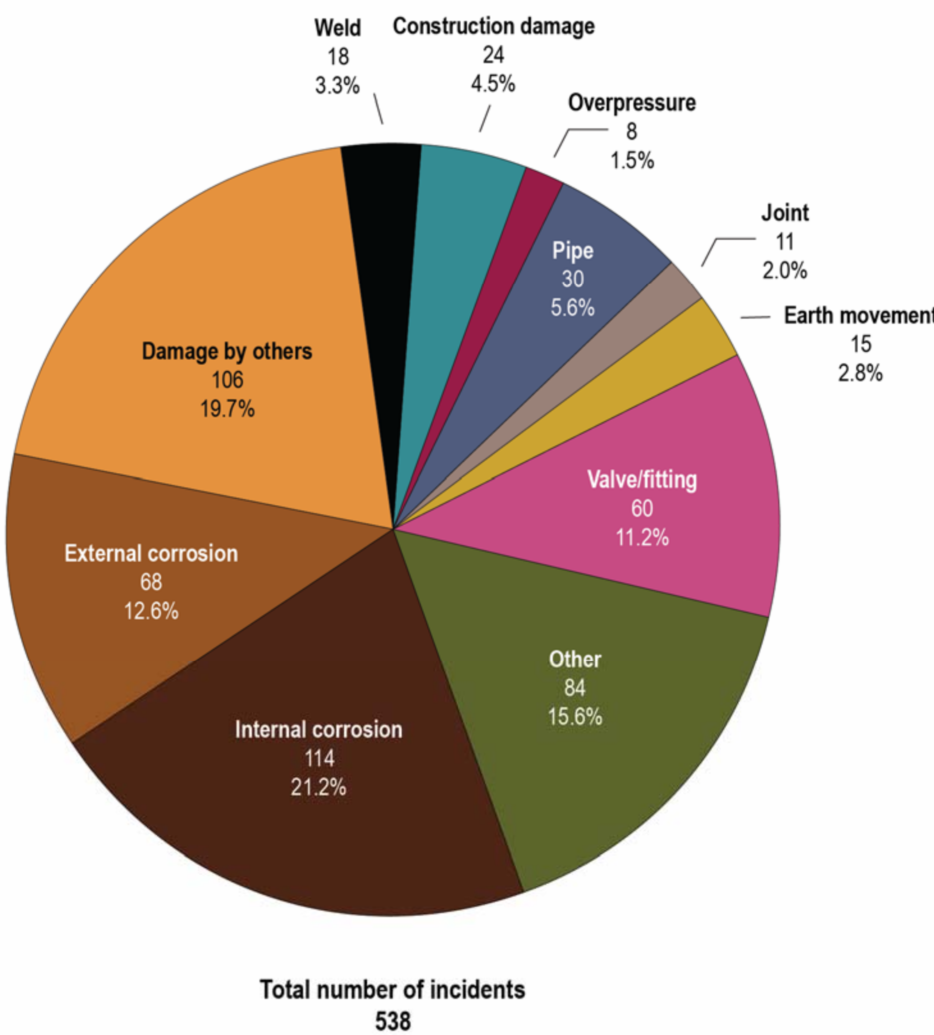
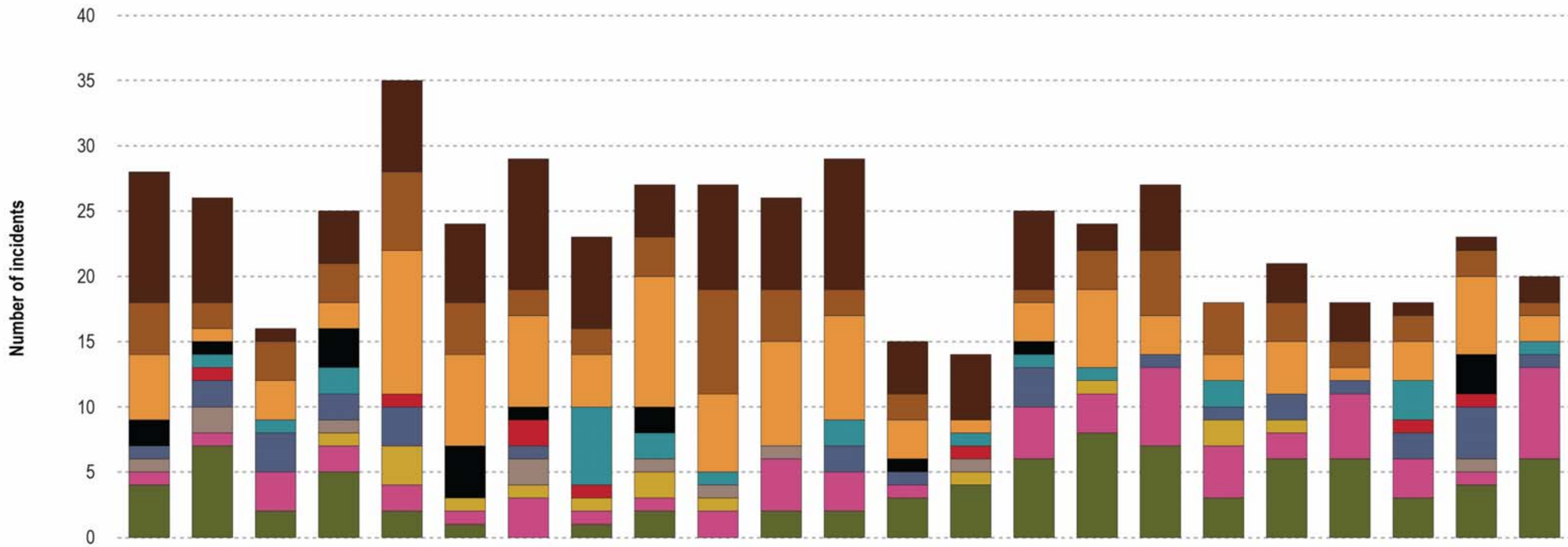


Figure 12b. Crude oil pipeline incidents by cause per year
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



CAUSE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Internal corrosion	10	8	1	4	7	6	10	7	4	8	7	10	4	5	6	2	5		3	3	1	1	2
External corrosion	4	2	3	3	6	4	2	2	3	8	4	2	2		1	3	5	4	3	2	2	2	1
Damage by others	5	1	3	2	11	7	7	4	10	6	8	8	3	1	3	6	3	2	4	1	3	6	2
Weld	2	1		3		4	1		2				1		1							3	
Construction damage		1	1	2				6	2	1		2		1	1	1		2			3		1
Overpressure		1			1		2	1						1							1	1	
Pipe	1	2	3	2	3		1					2	1		3		1	1	2	1	2	4	1
Joint	1	2		1			2		1	1	1			1								1	
Earth movement				1	3	1	1	1	2	1				1		1		2	1				
Valve/fitting	1	1	3	2	2	1	3	1	1	2	4	3	1		4	3	6	4	2	5	3	1	7
Other	4	7	2	5	2	1		1	2		2	2	3	4	6	8	7	3	6	6	3	4	6
Total	**28**	**26**	**16**	**25**	**35**	**24**	**29**	**23**	**27**	**27**	**26**	**29**	**15**	**14**	**25**	**24**	**27**	**18**	**21**	**18**	**18**	**23**	**20**
% of total	**5.2**	**4.8**	**3.0**	**4.6**	**6.6**	**4.5**	**5.4**	**4.3**	**5.0**	**5.0**	**4.8**	**5.5**	**2.8**	**2.6**	**4.6**	**4.5**	**5.0**	**3.3**	**3.9**	**3.3**	**3.3**	**4.3**	**3.7**

Figures 13a and 13b show that internal corrosion continues to be the primary cause of sour gas pipeline incidents, which is expected because of the very corrosive nature of sour gas production. The AER conducts high-level technical reviews and surveillance on sour gas pipelines and looks for opportunities to help licensees improve their operations and maintenance. Due to the small number of sour gas pipeline incidents, a small change in the number of incidents per cause category will significantly affect the failure-cause distribution from year to year. However, the total number of incidents has been generally decreasing over the last nine years.

Figure 13a. Sour gas pipeline incidents by cause for all years combined
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)

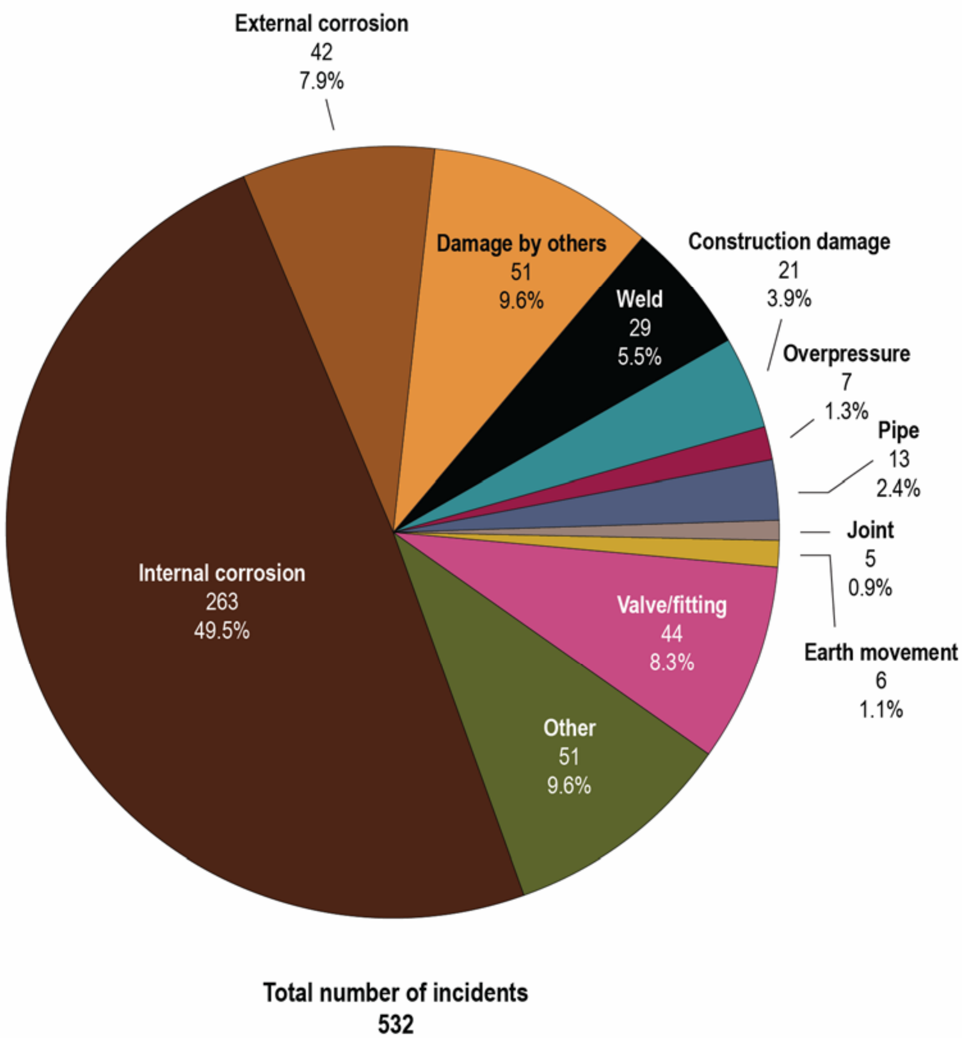
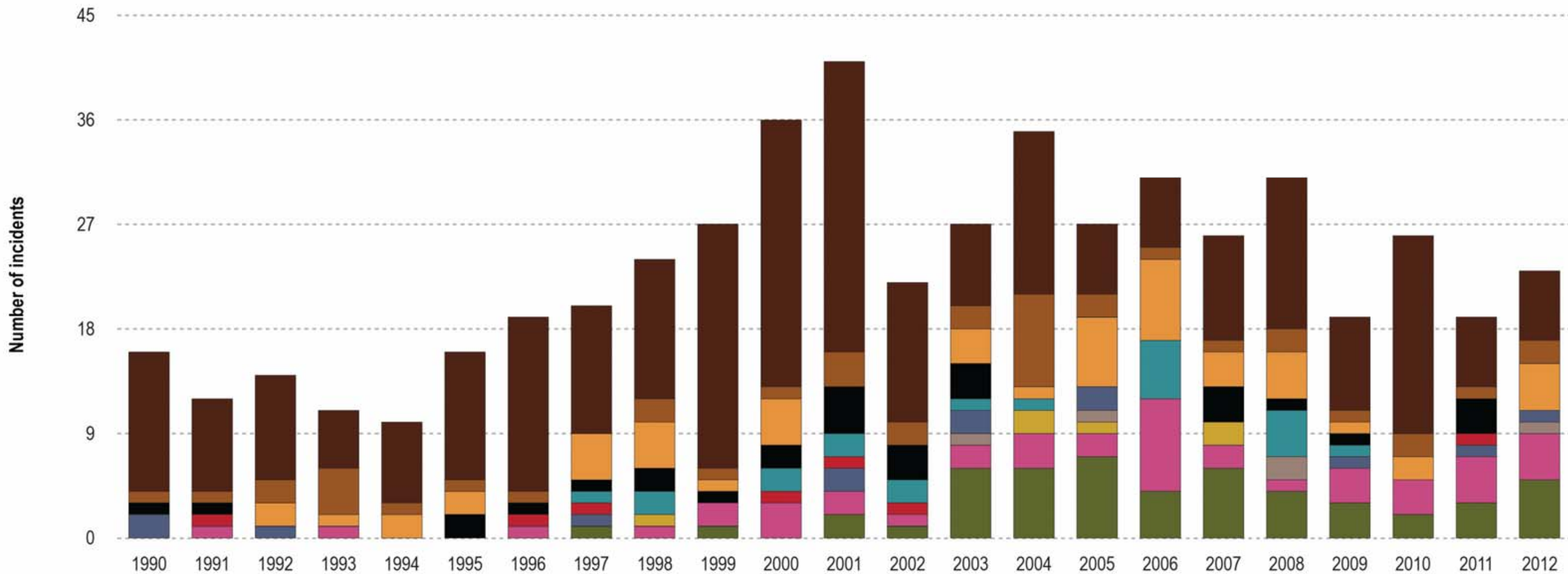


Figure 13b. Sour gas pipeline incidents by cause per year

January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



CAUSE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Internal corrosion	12	8	9	5	7	11	15	11	12	21	23	25	12	7	14	6	6	9	13	8	17	6	6
External corrosion	1	1	2	4	1	1	1		2	1	1	3	2	2	8	2	1	1	2	1	2	1	2
Damage by others			2	1	2	2		4	4	1	4			3	1	6	7	3	4	1	2		4
Weld	1	1				2	1	1	2	1	2	4	3	3				3	1	1		3	
Construction damage								1	2		2	2	2	1	1		5		4	1			
Overpressure		1					1	1			1	1	1									1	
Pipe	2		1					1				2		2		2				1		1	1
Joint														1		1			2				1
Earth movement									1						2	1		2					
Valve/fitting		1		1			1		1	2	3	2	1	2	3	2	8	2	1	3	3	4	4
Other								1		1		2	1	6	6	7	4	6	4	3	2	3	5
Total	**16**	**12**	**14**	**11**	**10**	**16**	**19**	**20**	**24**	**27**	**36**	**41**	**22**	**27**	**35**	**27**	**31**	**26**	**31**	**19**	**26**	**19**	**23**
% of total	**3.0**	**2.3**	**2.6**	**2.1**	**1.9**	**3.0**	**3.6**	**3.8**	**4.5**	**5.1**	**6.7**	**7.6**	**4.1**	**5.1**	**6.6**	**5.1**	**5.8**	**4.9**	**5.8**	**3.6**	**4.9**	**3.6**	**4.3**

Natural gas pipelines include a wide range of products that include wet and dry gas production that may contain zero H_2S or H_2S at levels up to and including 10 moles H_2S per kilomole of natural gas. Fuel gas pipelines, which supply natural gas to energy facilities for fuel, are included in the natural gas category. An analysis shows approximately 12 per cent of Alberta's natural gas pipelines contain some amount of H_2S below the 10 moles criterion.

A large number of the natural gas pipelines are small in diameter, as previously shown in figure 4a. Most of these carry raw gas, which can include amounts of H_2S, CO_2, and water and will therefore be corrosive. These wet production gas lines represent a significant number of natural gas pipeline failures. As shown in figure 14a, internal corrosion causes 53.2 per cent of natural gas pipeline incidents.

Figure 14a. Natural gas pipeline incidents by cause for all years combined
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)

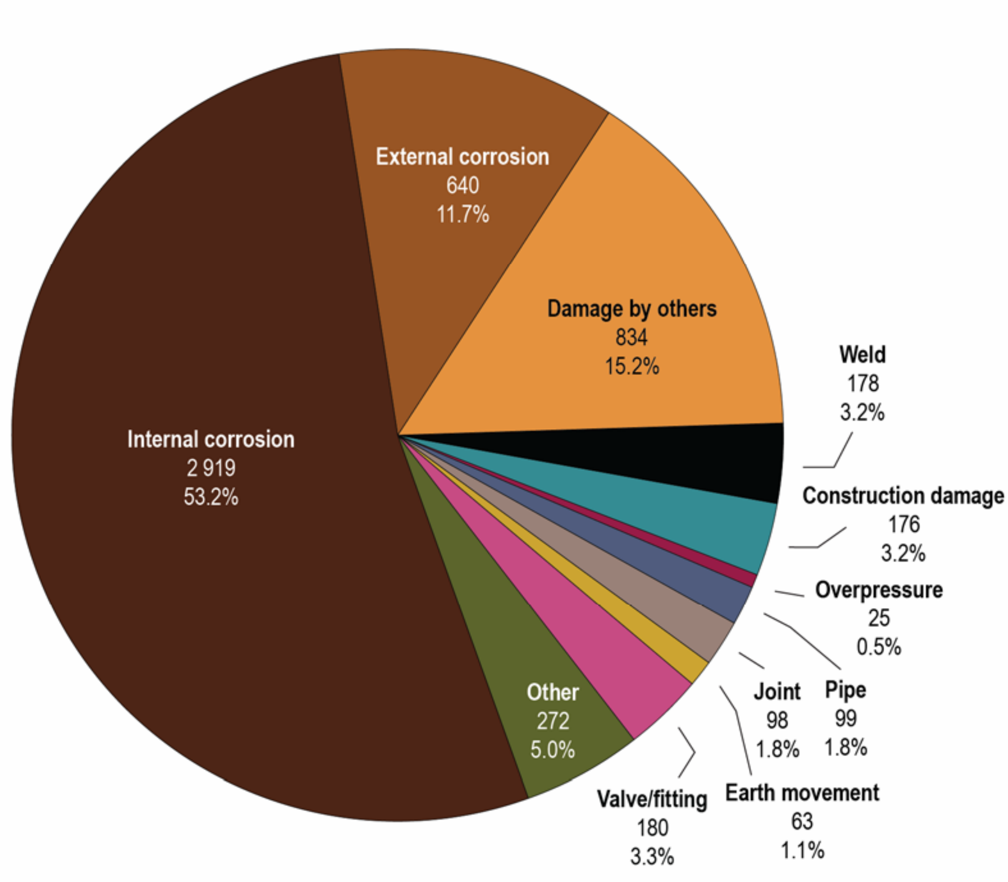
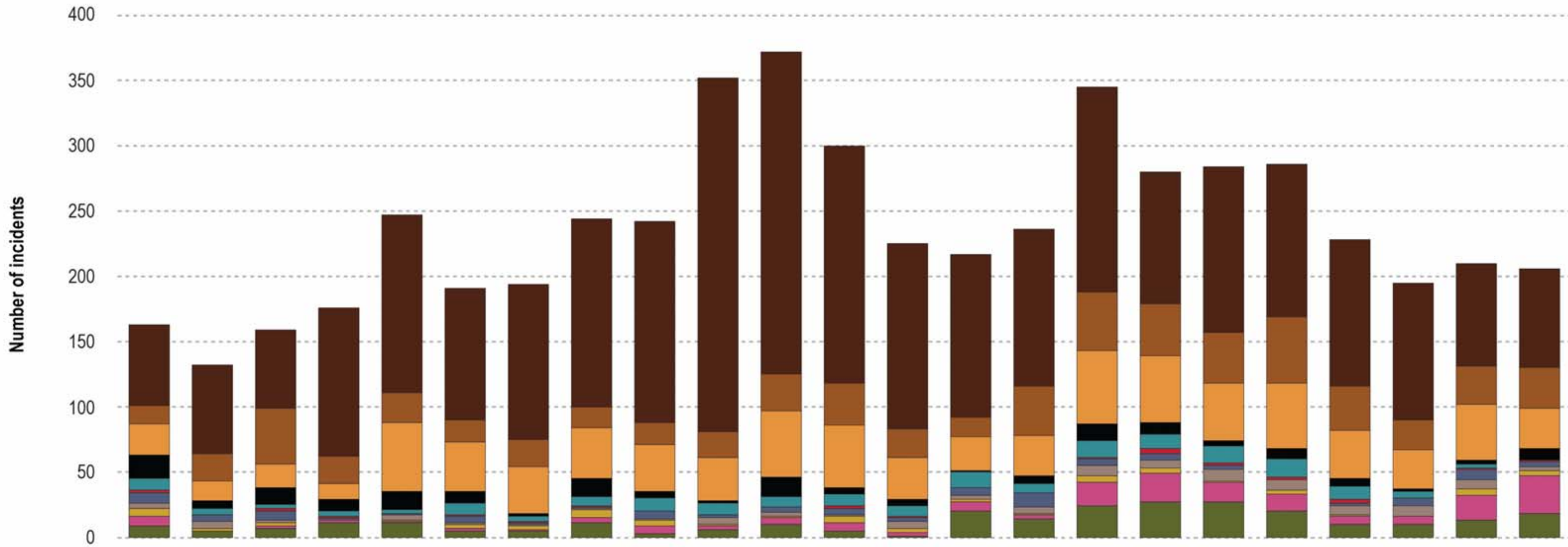


Figure 14b shows that the number of natural gas pipeline incidents jumped noticeably in 2005 and then slowly began declining again. The reason for the increase is not clear, although regulatory changes in 2005 requiring additional right-of-way surveillance and leak detection may have resulted in the detection and subsequent repair of numerous small leaks.

Figure 14b. Natural gas pipeline incidents by cause per year
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



CAUSE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Internal corrosion	62	68	60	114	136	101	119	144	154	271	247	182	142	125	120	157	101	127	117	112	105	79	76
External corrosion	14	21	43	21	23	17	21	16	17	20	28	32	22	15	38	45	40	39	51	34	23	29	31
Damage by others	24	15	18	12	53	38	36	39	36	33	51	48	32	26	31	56	51	44	50	37	30	43	31
Weld	18	6	13	9	14	9	2	14	5	2	15	5	5	1	6	13	9	4	8	6	2	3	9
Construction damage	9	5	3	4	3	9	4	7	10	9	8	9	8	12	7	13	11	13	14	10	5	3	
Overpressure	2		2	1		1	1	1				2	1			1	4	2	2	3		1	1
Pipe	8	5	7	1	1	5	1	1	6	2	4	5	3	6	11	5	5	3		2	6	8	4
Joint	4	5	2	1	4	1	1	1	1	5	3	1	5	3	5	8	6	9	8	7	8	7	3
Earth movement	6	2	2		1	3	3	6	4	1	1	5	3	2	1	5	4	1	3	1		5	4
Valve/fitting	7		2	2	1	2	1	4	6	3	5	6	3	7	3	18	22	15	13	6	6	19	29
Other	9	5	7	11	11	5	5	11	3	6	10	5	1	20	14	24	27	27	20	10	10	13	18
Total	**163**	**132**	**159**	**176**	**247**	**191**	**194**	**244**	**242**	**352**	**372**	**300**	**225**	**217**	**236**	**345**	**280**	**284**	**286**	**228**	**195**	**210**	**206**
% of total	**3.0**	**2.4**	**2.9**	**3.2**	**4.5**	**3.5**	**3.5**	**4.4**	**4.4**	**6.4**	**6.7**	**5.5**	**4.1**	**4.0**	**4.3**	**6.3**	**5.1**	**5.2**	**5.2**	**4.2**	**3.6**	**3.8**	**3.8**

Figures 15a and 15b show varying causes of incidents in the "other product" category. As most of the pipelines in this category carry processed or single-substance products, corrosion is infrequent. The highest number of incidents are due to damage by others; this is due to the relatively small number of other types of incidents. This pipeline category includes a number of LVP and HVP product pipelines installed in the 1960s and 70s. These LVP and HVP product pipelines have been encroached upon by more densely populated urban and suburban areas, which may partially be the reason for an increase in incidents over the last decade. Operators are constantly vigilant in those areas, ensuring that rights-of-way are patrolled frequently and that the public is aware of these pipelines.

Figure 15a. All "other product" pipeline incidents by cause for all years combined
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)

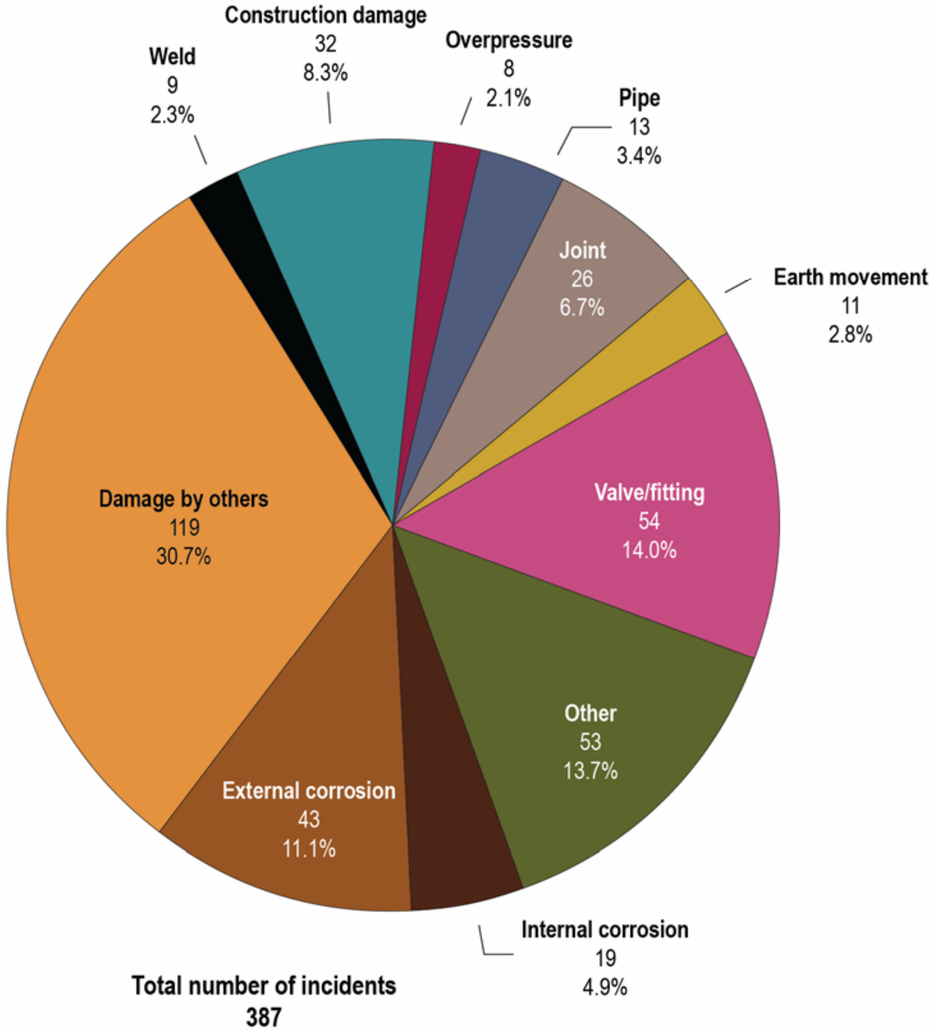
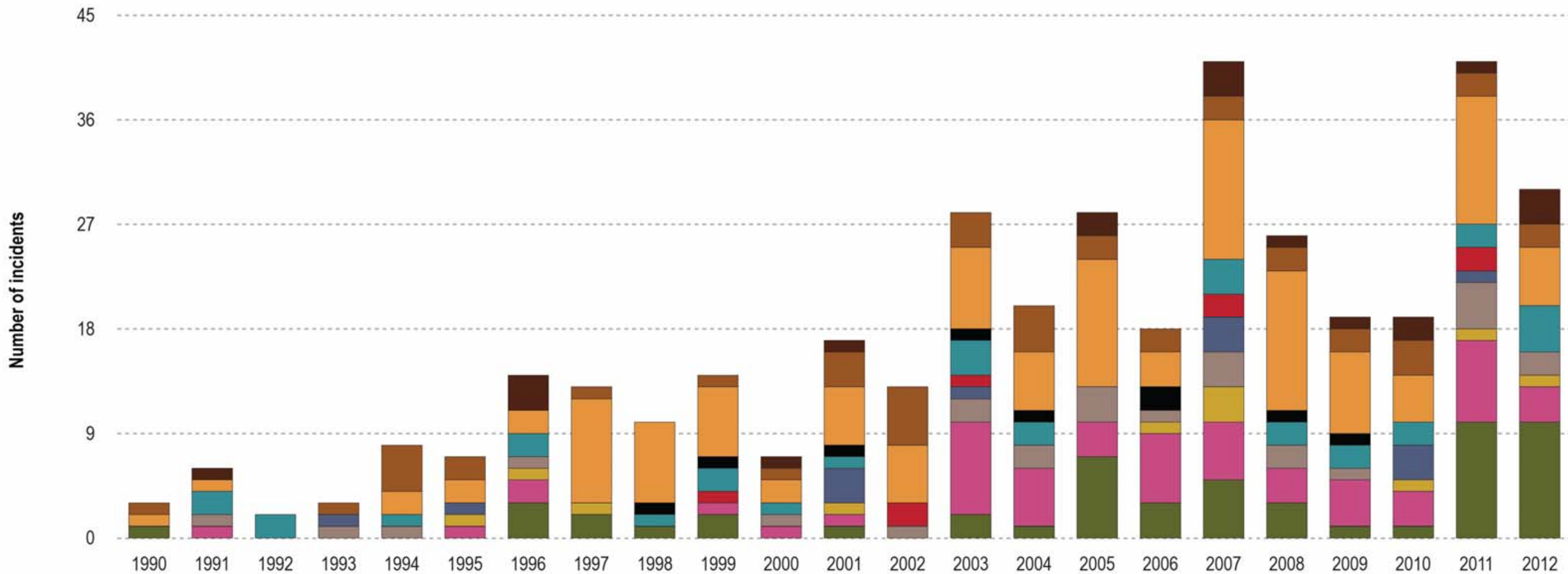


Figure 15b. All "other product" pipeline incidents by cause per year
January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



CAUSE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Internal corrosion		1					3				1	1				2		3	1	1	2	1	3
External corrosion	1			1	4	2		1		1	1	3	5	3	4	2	2	2	2	2	3	2	2
Damage by others	1	1			2	2	2	9	7	6	2	5	5	7	5	11	3	12	12	7	4	11	5
Weld									1	1		1		1	1		2		1	1			
Construction damage		2	2		1		2		1	2	1	1		3	2			3	2	2	2	2	4
Overpressure										1			2	1				2				2	
Pipe				1		1						3		1				3			3	1	
Joint		1		1	1		1				1		1	2	2	3	1	3	2	1		4	2
Earth movement						1	1	1				1					1	3			1	1	1
Valve/fitting		1				1	2			1	1	1		8	5	3	6	5	3	4	3	7	3
Other	1						3	2	1	2		1		2	1	7	3	5	3	1	1	10	10
Total	**3**	**6**	**2**	**3**	**8**	**7**	**14**	**13**	**10**	**14**	**7**	**17**	**13**	**28**	**20**	**28**	**18**	**41**	**26**	**19**	**19**	**41**	**30**
% of total	**0.8**	**1.6**	**0.5**	**0.8**	**2.1**	**1.8**	**3.6**	**3.4**	**2.6**	**3.6**	**1.8**	**4.4**	**3.4**	**7.2**	**5.2**	**7.2**	**4.7**	**10.5**	**6.7**	**4.9**	**4.9**	**10.5**	**7.8**

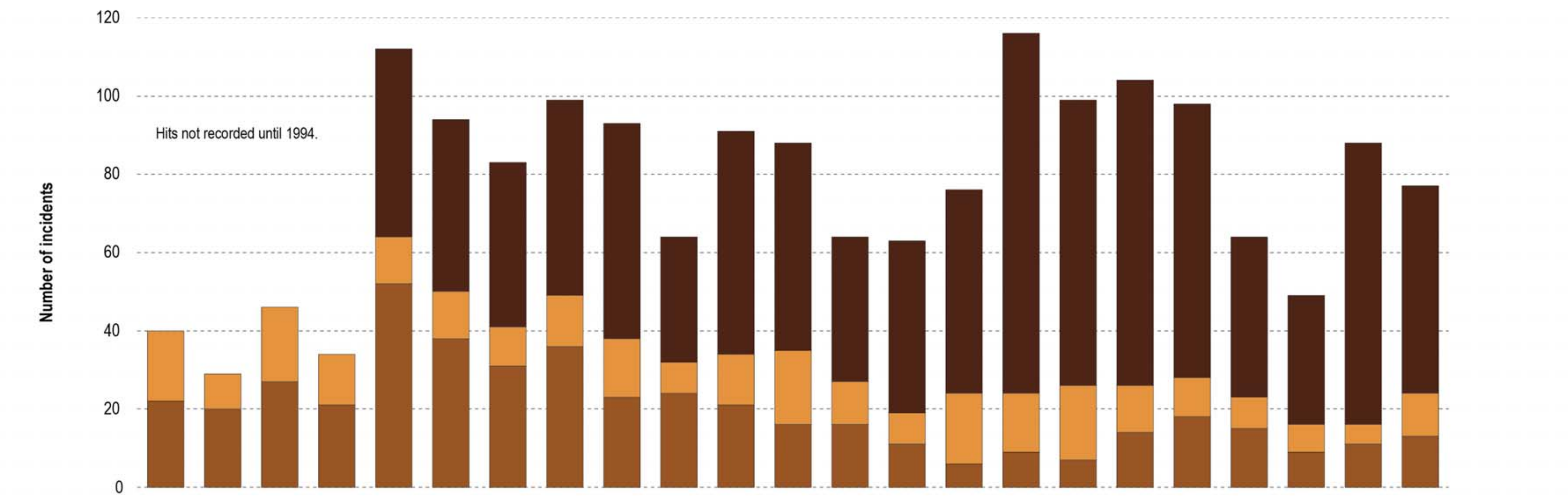
Figure 16 shows the annual number of pipeline incidents attributed to damage by others and whether those incidents resulted in hits, leaks, or ruptures. Before 1994, pipeline hits that did not result in product being lost were not recorded. There is a strong correlation between the number of damage-by-other incidents and the level of industry activity: incident numbers increased in 2004 and 2005, reflecting the robust oil patch activity, and decreased significantly in 2009 and 2010 with the economic slowdown. Damage-by-other incidents then increased as soon as industry activity levels picked up again in 2011.

In the years leading up to 2007, a trend showed an encouraging decline in the number of ruptures resulting from pipeline strikes, which suggested that excavation work around pipelines was being done carefully. However, in 2007 and 2008 this trend reversed because of increased field activity levels, resulting in a significant increase in the number of pipeline strikes. This is of concern to the AER because with the ever-growing inventory of pipeline in the province and the increased density of buried infrastructure, excavation protocols must be of the highest calibre. The AER also believes that staff turnover due to an ever aging workforce may also be affecting the number of pipeline hits as there are fewer experienced workers. Maintaining the competency of excavation supervisors through frequent training is therefore imperative. Modern surveying, locating, and global positioning data tools, as well as readily available hydrovac excavation, should make locating and exposing pipelines easier and more accurate. The AER expects that these measures will help reduce the frequency of strikes.

Figure 17 shows that damage by others occurs most often on pipelines between 60.3 mm (2 inches) and 168.3 mm (6 inches) in diameter, which corresponds to the pipe sizes that make up most of the pipeline inventory in the province. Figure 17 also shows that damage by others occurs infrequently on large-diameter transmission pipelines probably because the licensee and the pipeline existence in the area are well known, the pipelines are well marked, and the rights of way are obvious. Licensees typically conduct frequent right-of-way surveillance, which may detect encroachment in time to prevent a third-party incident.

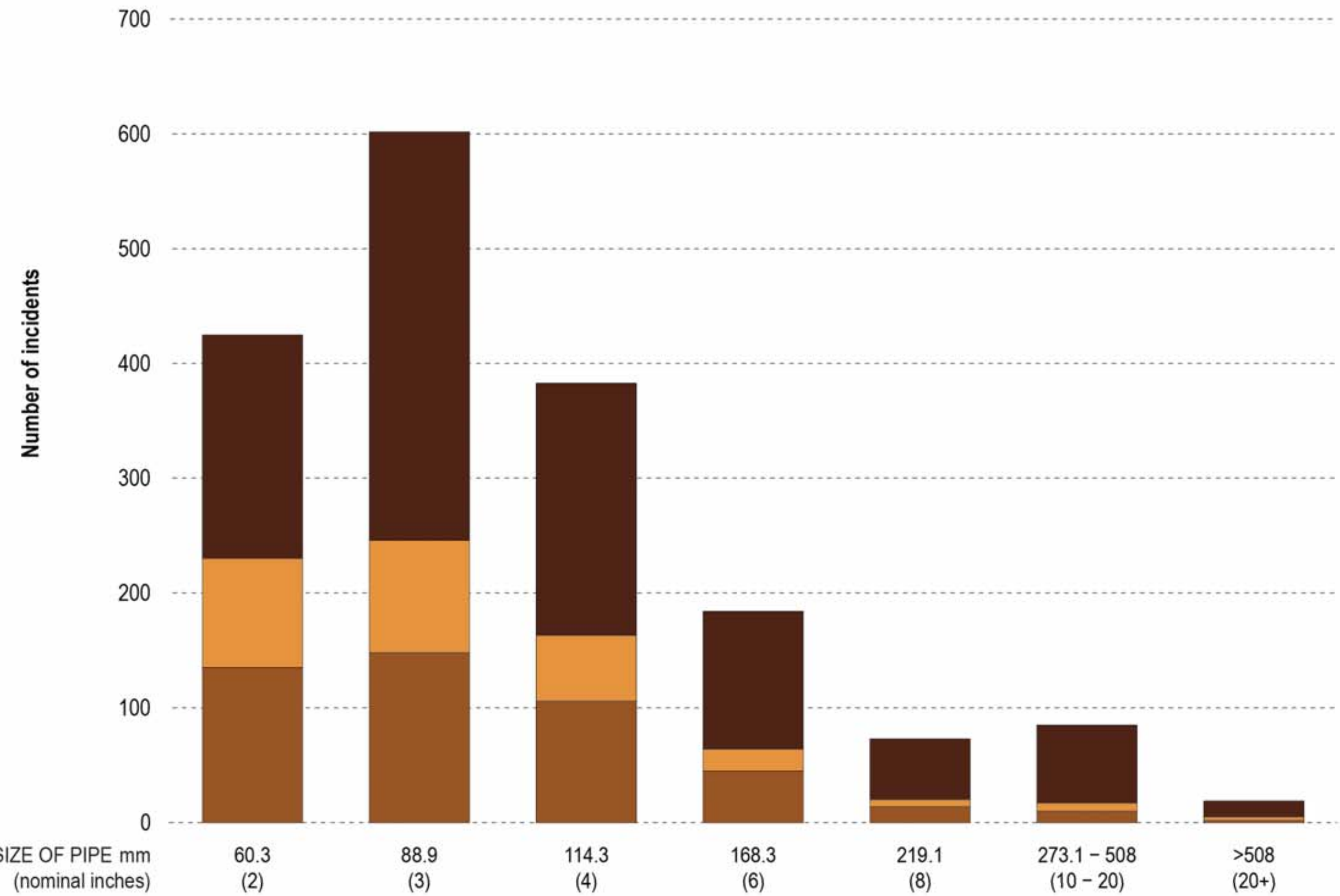
Figure 16. Pipeline incidents due to damage by others per year

All pipeline incidents from January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of total
Hit (no product loss)					48	44	42	50	55	32	57	53	37	44	52	92	73	78	70	41	33	72	53	1 026	57.9
Leak	18	9	19	13	12	12	10	13	15	8	13	19	11	8	18	15	19	12	10	8	7	5	11	285	16.1
Rupture	22	20	27	21	52	38	31	36	23	24	21	16	16	11	6	9	7	14	18	15	9	11	13	460	26.0
Total number incidents	**40**	**29**	**46**	**34**	**112**	**94**	**83**	**99**	**93**	**64**	**91**	**88**	**64**	**63**	**76**	**116**	**99**	**104**	**98**	**64**	**49**	**88**	**77**	**1 771**	**100.0**

Figure 17. Damage by others by pipe size for all years combined
All pipeline incidents from January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



	60.3 (2)	88.9 (3)	114.3 (4)	168.3 (6)	219.1 (8)	273.1 – 508 (10 – 20)	>508 (20+)	Total number	% of total
Hit (no product loss)	195	356	220	120	53	68	14	1 026	57.9
Leak	95	98	57	19	6	7	3	285	16.1
Rupture	135	148	106	45	14	10	2	460	26.0
Total number incidents	**425**	**602**	**383**	**184**	**73**	**85**	**19**	**1 771**	
% of total	**24.0**	**34.0**	**21.6**	**10.4**	**4.1**	**4.8**	**1.1**		**100.0**

Figure 18 shows the number and percentage of substance releases due to pipeline failures over the reporting period. More substance releases occurred than incidents since raw fluid production often involves multiple substances that are recorded separately when estimating spill volumes. Spills from pressure tests are evaluated separately in figures 25 and 26. Freshwater releases are included in the water category.

Figure 18. Number of pipeline releases by substance type released, total for all years

All pipeline releases from January 1, 1990, to December 31, 2012 (excludes pressure tests)

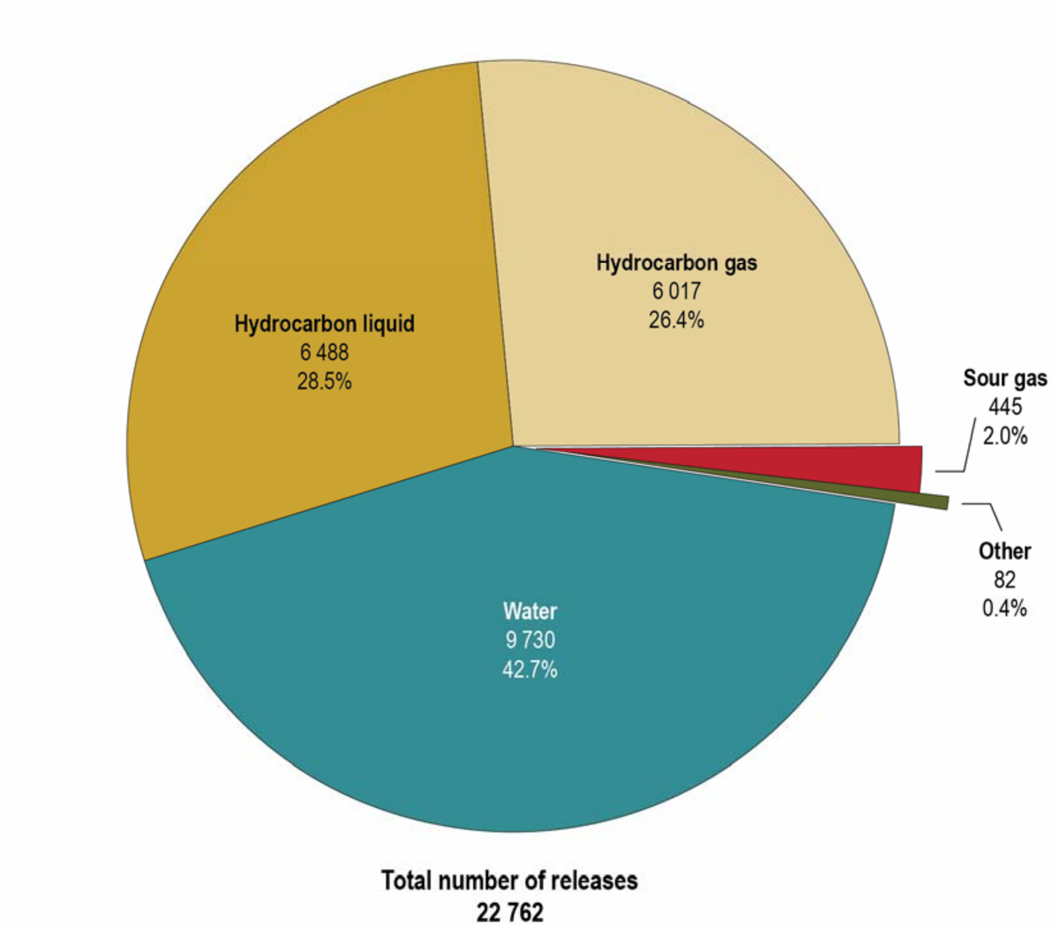
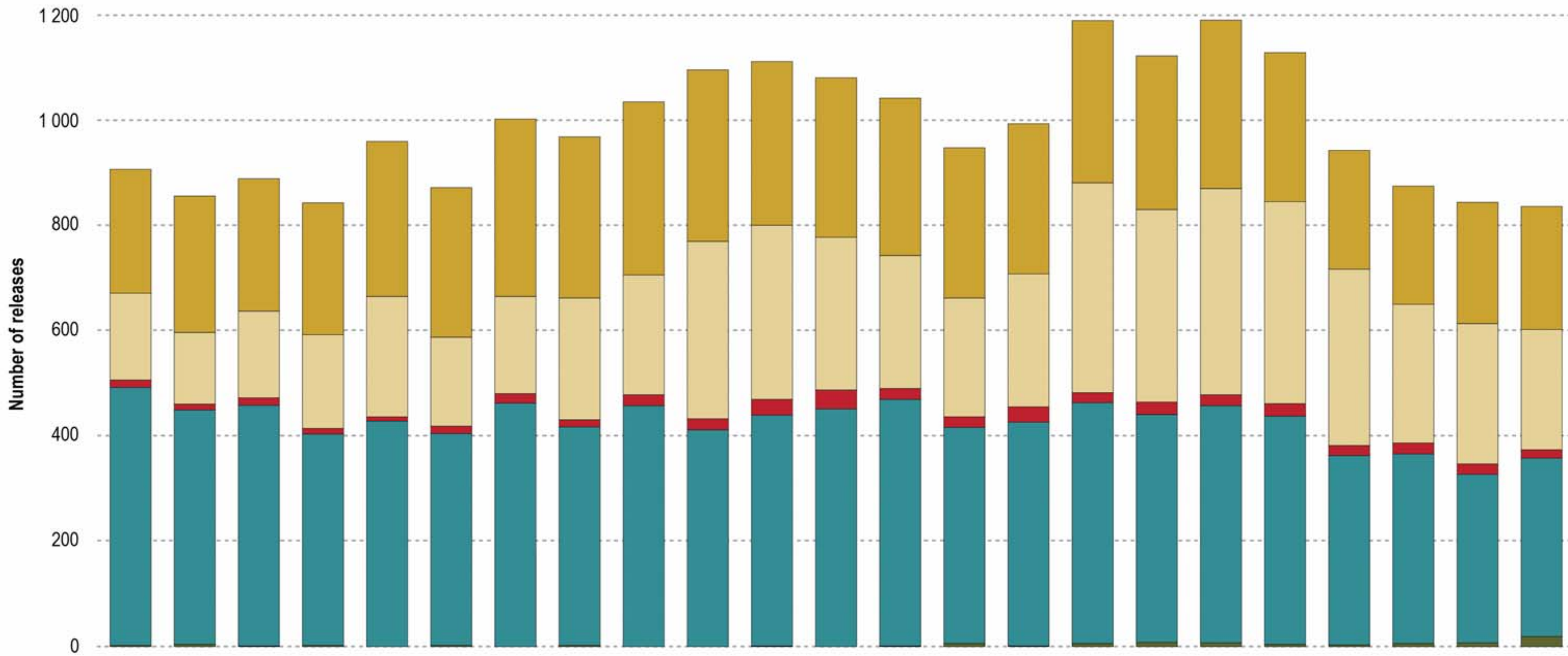


Figure 19 shows that more pipeline substance releases occurred in 2005 and 2007 than in other years. Over the last five years, the number of releases has declined noticeably in all substance classes.

Figure 19. Number of pipeline releases by substance type released per year
All pipeline releases from January 1, 1990, to December 31, 2012 (excludes pressure tests)



PRODUCT	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of total
Hydrocarbon liquid	236	260	252	251	295	285	338	307	329	326	312	303	299	286	286	309	293	321	284	226	225	231	234	6 488	28.5
Hydrocarbon gas	165	136	165	178	229	169	185	232	228	338	331	291	253	226	253	399	366	392	384	336	264	268	229	6 017	26.4
Sour gas	14	11	14	11	8	14	18	13	21	21	30	36	21	20	29	19	24	21	24	19	21	20	16	445	2.0
Water	491	446	458	402	429	403	463	416	458	412	439	452	469	411	426	458	433	451	434	360	360	320	339	9 730	42.7
Other	2	4	1	2		2		2			1		1	6	1	6	8	7	4	3	6	7	19	82	0.4
Total number releases	**908**	**857**	**890**	**844**	**961**	**873**	**1 004**	**970**	**1 036**	**1 097**	**1 113**	**1 082**	**1 043**	**949**	**995**	**1 191**	**1 124**	**1 192**	**1 130**	**944**	**876**	**846**	**837**	**22 762**	
% of total	**4.0**	**3.8**	**3.9**	**3.7**	**4.2**	**3.8**	**4.4**	**4.3**	**4.6**	**4.8**	**4.9**	**4.8**	**4.6**	**4.2**	**4.4**	**5.2**	**4.9**	**5.2**	**5.0**	**4.1**	**3.8**	**3.7**	**3.7**		**100.0**

The AER requires that the volume of a released substance be reported when a pipeline release has occurred. The accuracy of the reported released volumes varies, as not all pipelines are equipped with metering and sometimes the starting time of an event is unknown. Best estimates are based on production rates, pipeline capacities, metering, and measurement of contaminated area. In the case of gas production, the gas disperses, making accurate measurement difficult.

Released volumes are divided into the following four volume classes:

- less than 100 m^3 of liquid or 100 10^3 m^3 of gas
- 100 to 1000 m^3 of liquid or 100 to 1000 10^3 m^3 of gas
- 1000 to 10 000 m^3 of liquid or 1000 to 10 000 10^3 m^3 of gas
- greater than 10 000 m^3 of liquid or 10 000 10^3 m^3 of gas

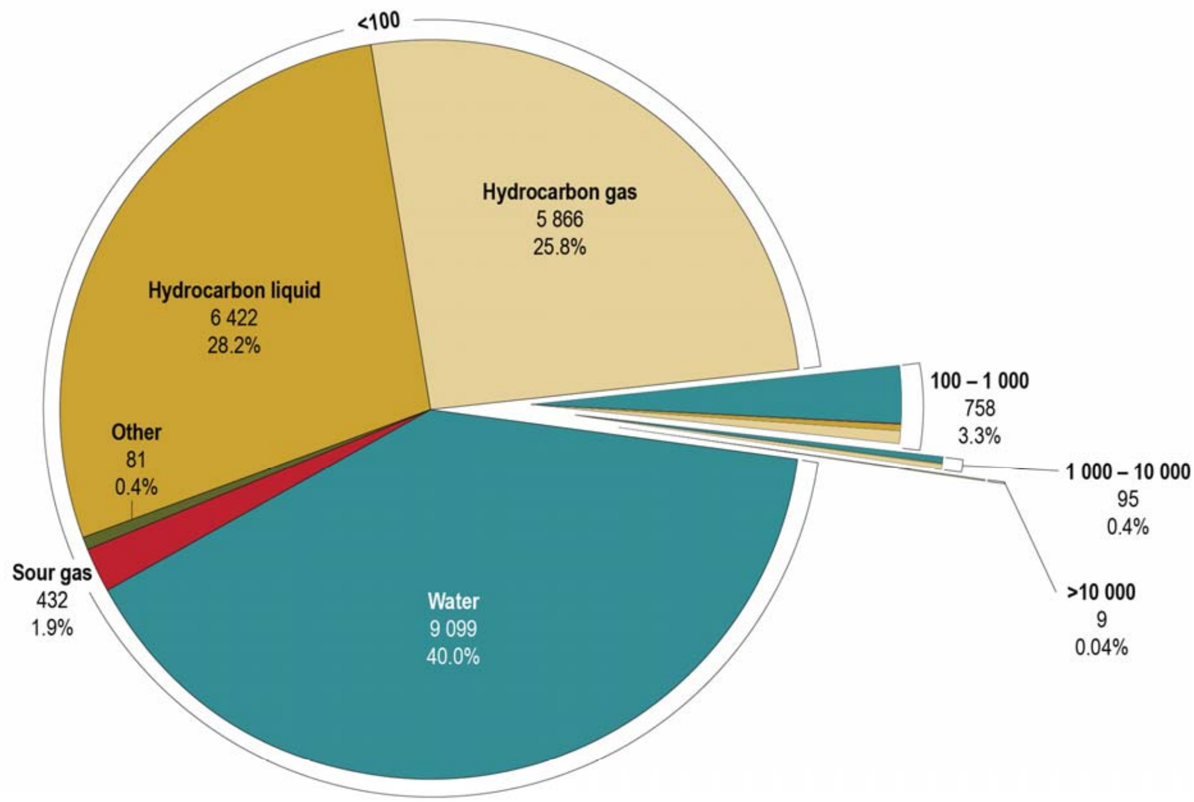
Figure 20 shows that of the 22 762 releases, 96.2 per cent fall into the smallest volume class. Another 3.3 per cent are between 100 and 1000 m^3. Releases greater than 1000 m^3 liquid or 1000 10^3 m^3 gas accounted for only 0.5 per cent of the events, with only 13 exceeding 100 10^3 m^3 and which contained sour gas.

Figure 21 shows the release breakdown for the smallest volume category of releases by substance and year. In this volume class, the water, liquid hydrocarbon, and gaseous hydrocarbon releases are each responsible for about a third of the recorded releases. There is also a small number of sour gas and “other” substance releases. The releases in this volume class account for just over 96.2 per cent of all pipeline releases, which is about the same as what was reported in 2007.

Figure 22 details the releases in the second volume class, which accounts for 3.3 per cent of the total number. The higher proportion of water pipeline releases of medium volume suggests the spills resulting from water pipeline failures are not readily detected or the pipeline flow rates are high, or both.

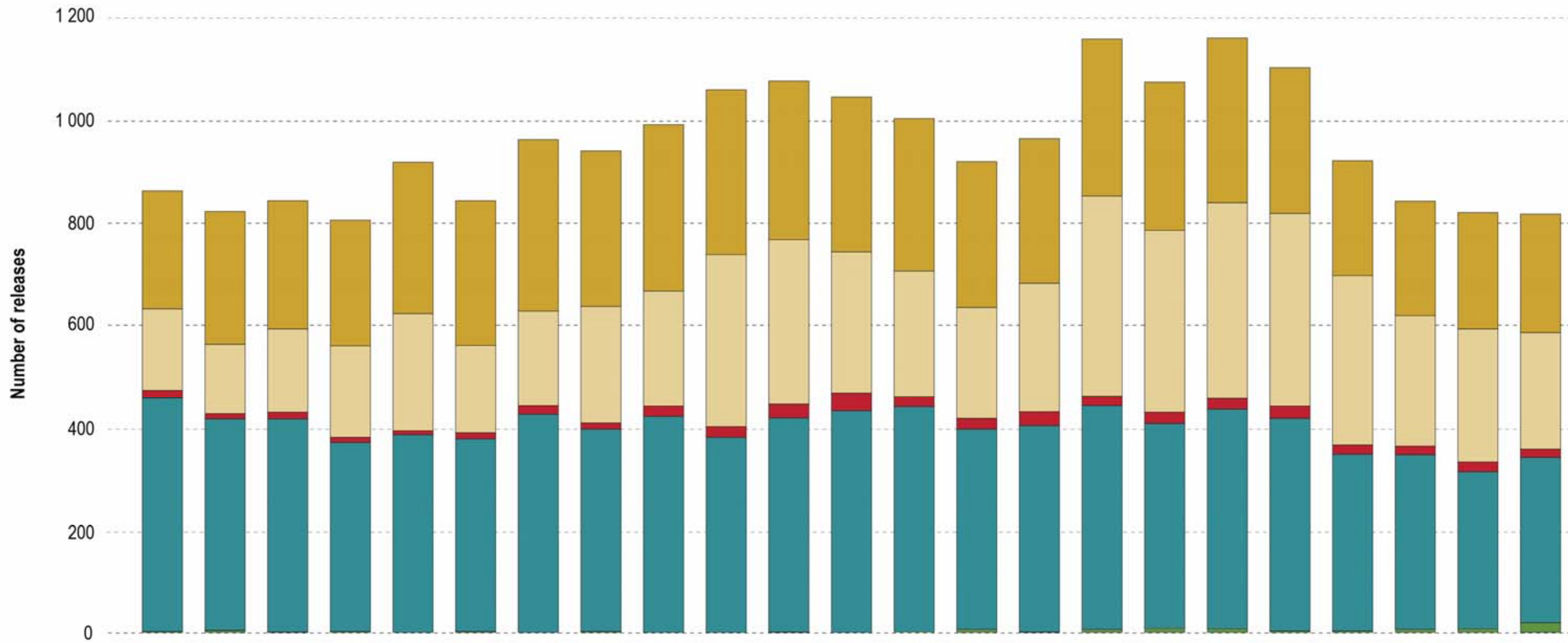
Figure 23 identifies the third volume class, which represents 0.4 per cent of all releases. These large releases have remained at two or fewer occurrences per year for the last five years, down from 11 releases in 2001.

Figure 20. Number of pipeline releases by substance type released and volume
All pipeline releases from January 1, 1990, to December 31, 2012 (excludes pressure tests)



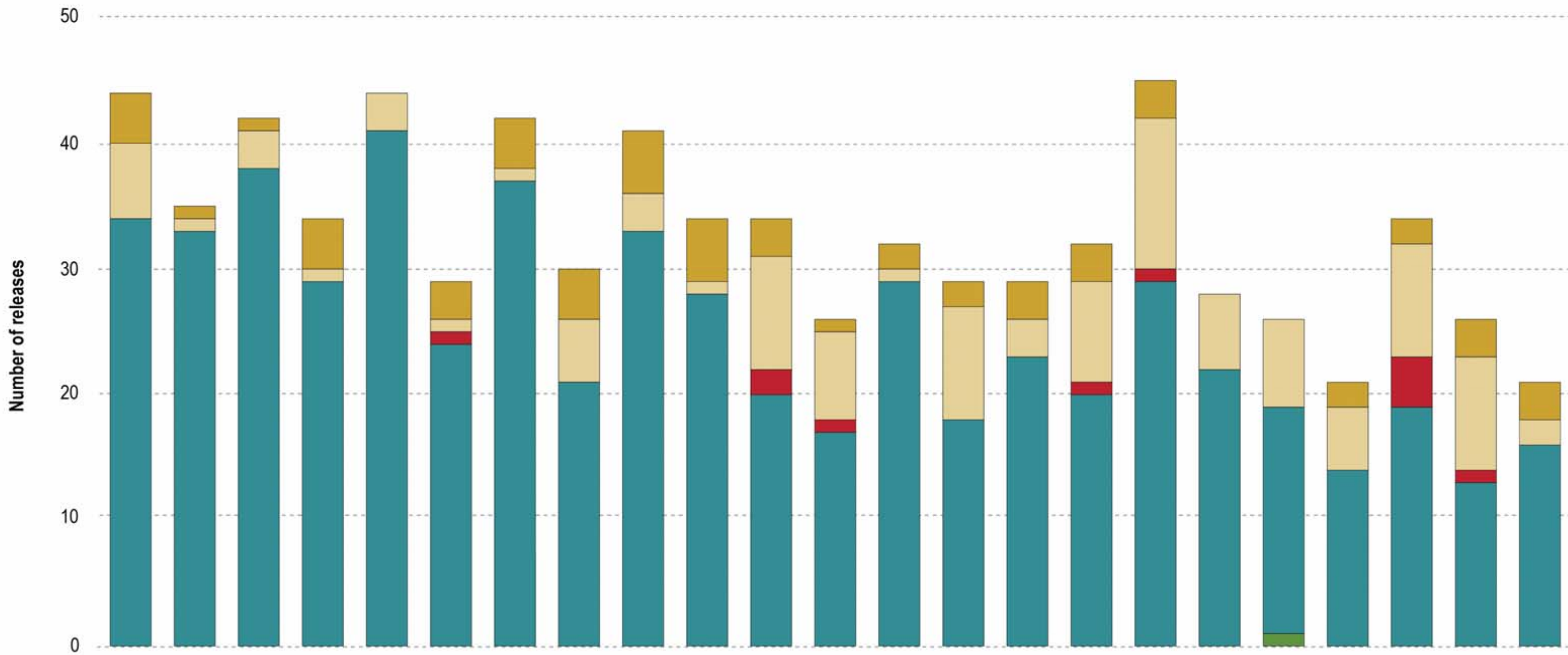
	RELEASE VOLUME, m³ (LIQUIDS) OR 10³ m³ (GAS)				Total
	<100	100 – 1 000	1 000 – 10 000	>10 000	number
Hydrocarbon liquid	6 422	58	8		6 488
Hydrocarbon gas	5 866	112	34	5	6 017
Water	9 099	576	51	4	9 730
Sour gas	432	11	2		445
Other	81	1			82
Total	**21 900**	**758**	**95**	**9**	**22 762**

Figure 21. Number of pipeline releases <100 m^3 (liquid) or <100 10^3 m^3 (gas), by substance type released and year
All pipeline releases from January 1, 1990, to December 31, 2012 (excludes pressure tests)



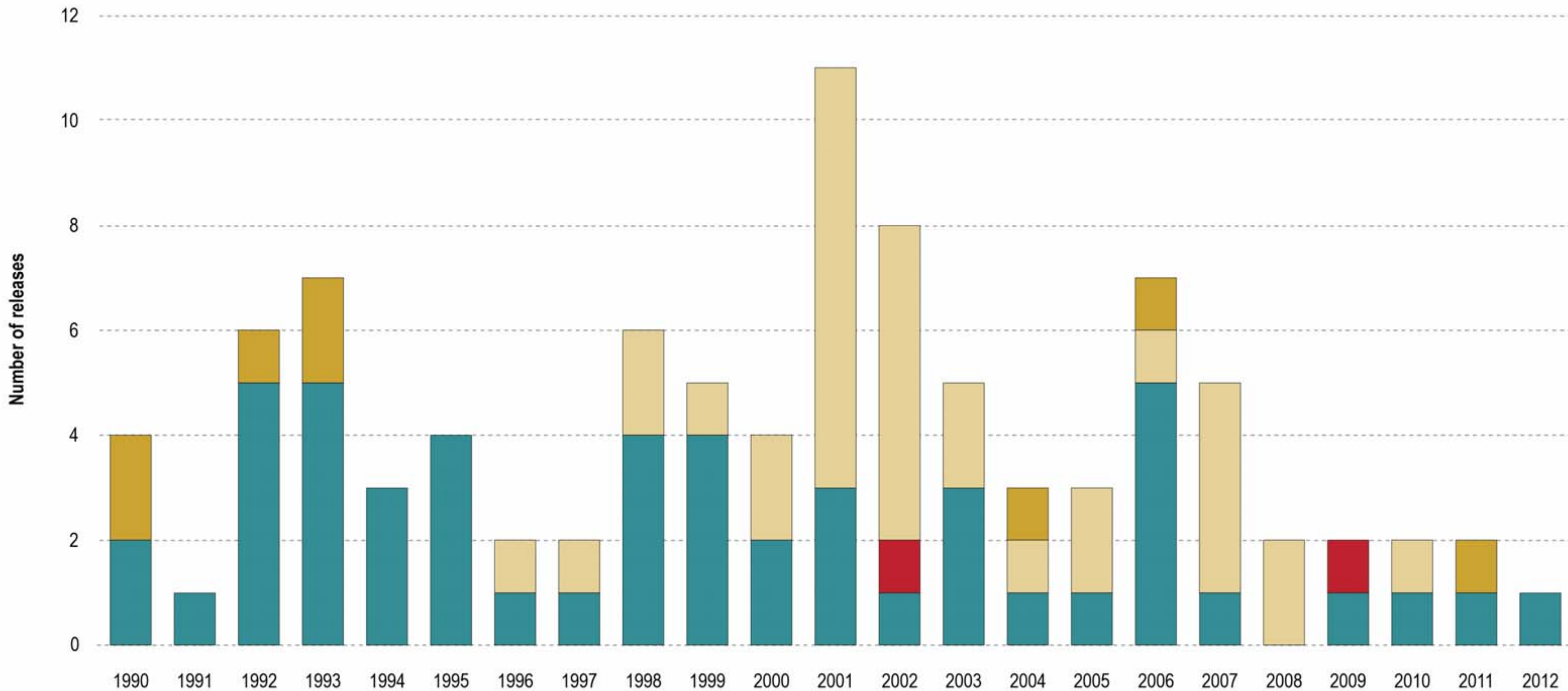
SUBSTANCE TYPE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of all releases by number
Hydrocarbon liquid	230	259	250	245	295	282	334	303	324	321	309	302	297	284	282	306	289	321	284	224	223	227	231	6 422	29.3
Hydrocarbon gas	159	135	162	177	226	168	183	226	223	335	320	275	245	215	249	389	353	381	375	330	254	259	227	5 866	26.8
Sour gas	14	11	14	11	8	13	18	13	21	21	28	35	20	20	29	18	23	21	24	18	17	19	16	432	2.0
Water	455	412	415	368	385	375	425	394	421	380	417	432	439	390	402	436	399	428	414	344	340	306	322	9 099	41.5
Other	2	4	1	2		2		2			1		1	6	1	6	8	7	3	3	6	7	19	81	0.4
Total number releases	**860**	**821**	**842**	**803**	**914**	**840**	**960**	**938**	**989**	**1 057**	**1 075**	**1 044**	**1 002**	**915**	**963**	**1 155**	**1 072**	**1 158**	**1 100**	**919**	**840**	**818**	**815**	**21 900**	**100.0**

Figure 22. Number of pipeline releases 100–1 000 m^3 (liquid) or 100–1 000 10^3 m^3 (gas) by substance type released and year
All pipeline releases from January 1, 1990, to December 31, 2012 (excludes pressure tests)



SUBSTANCE TYPE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of all releases by number
Hydrocarbon liquid	4	1	1	4		3	4	4	5	5	3	1	2	2	3	3	3			2	2	3	3	58	7.6
Hydrocarbon gas	6	1	3	1	3	1	1	5	3	1	9	7	1	9	3	8	12	6	7	5	9	9	2	112	14.8
Sour gas						1					2	1				1	1				4	1		11	1.5
Water	34	33	38	29	41	24	37	21	33	28	20	17	29	18	23	20	29	22	18	14	19	13	16	576	76.0
Other																			1					1	0.1
Total number releases	**44**	**35**	**42**	**34**	**44**	**29**	**42**	**30**	**41**	**34**	**34**	**26**	**32**	**29**	**29**	**32**	**45**	**28**	**26**	**21**	**34**	**26**	**21**	**758**	**100.0**

Figure 23. Number of pipeline releases 1 000–10 000 m³ (liquid) or 1 000–10 000 10³ m³ (gas) by substance type released and year
All pipeline releases from January 1, 1990, to December 31, 2012 (excludes pressure tests)



SUBSTANCE TYPE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total number	% of all releases by number
Hydrocarbon liquid	2		1	2											1		1					1		8	8.4
Hydrocarbon gas							1	1	2	1	2	8	6	2	1	2	1	4	2		1			34	35.8
Sour gas													1							1				2	2.1
Water	2	1	5	5	3	4	1	1	4	4	2	3	1	3	1	1	5	1		1	1	1	1	51	53.7
Total number releases	**4**	**1**	**6**	**7**	**3**	**4**	**2**	**2**	**6**	**5**	**4**	**11**	**8**	**5**	**3**	**3**	**7**	**5**	**2**	**2**	**2**	**2**	**1**	**95**	**100**

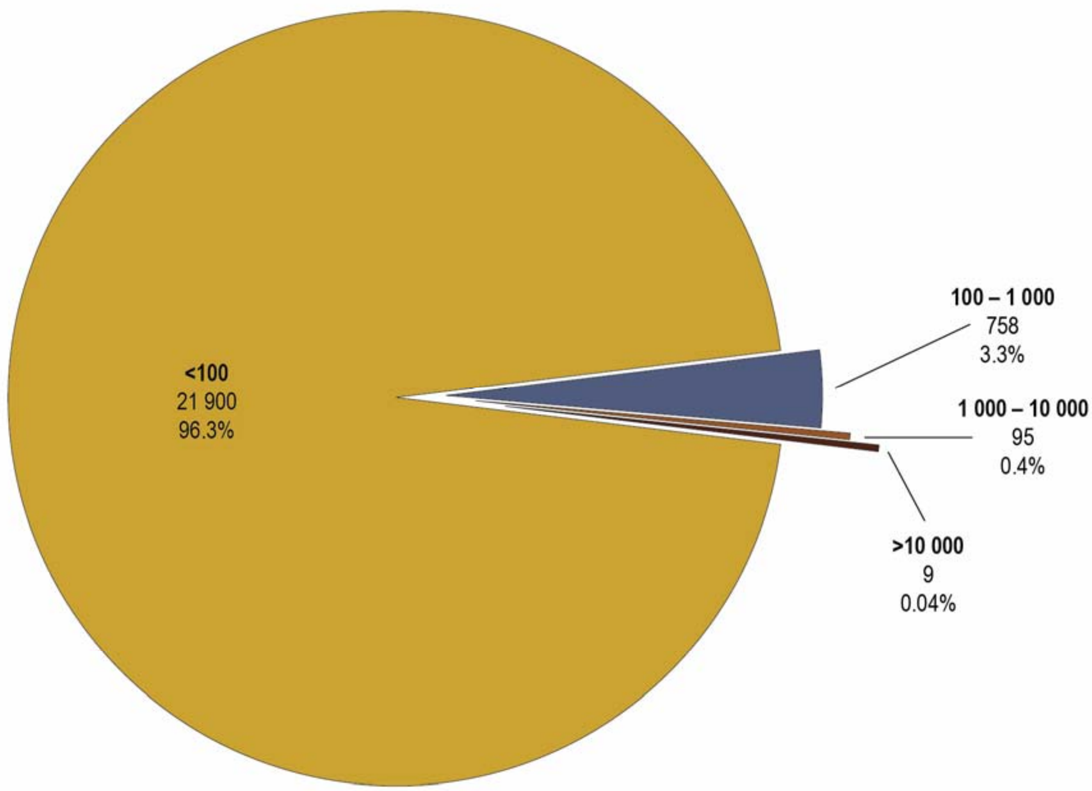
Fortunately, very large releases are rare, as shown in table 3. Nine large releases have been reported since 1990: four water releases (three of which were of fresh water) and five natural gas releases. The few isolated pipeline failures on sweet gas transmission pipelines resulted in large volumes of released gas due to the large diameter and long length of the transmission line segments. The released gas either disperses or burns if it is ignited.

Table 3. Pipeline releases >10 000 m^3 (liquids) or 10 000 10^3 m^3 (gas), 1990–2012

Year	Cause of failure	Released substance	Type of pipe	Size of pipe (mm)
1999	Corrosion internal	Gas production (raw)	Steel	273.1
2001	Corrosion internal	Gas production (raw)	Steel	114.3
2002	Corrosion internal	Gas production (raw)	Steel	168.3
2005	Corrosion internal	Fresh water	Steel	114.3
2007	Construction damage	Fuel gas	Steel	60.3
2008	Miscellaneous joint failure	Fresh water	Steel	355.6
2008	Construction damage	Salt/produced water	Fibreglass	114.3
2009	Construction damage	Fresh water	Steel	168.3
2009	Construction damage	Gas production (raw)	Steel	323.9

Figure 24 shows the proportion of each release volume class in relation to the total number of releases.

Figure 24. Number of pipeline releases, by volume
All pipeline releases from January 1, 1990, to December 31, 2012 (pressure tests excluded)

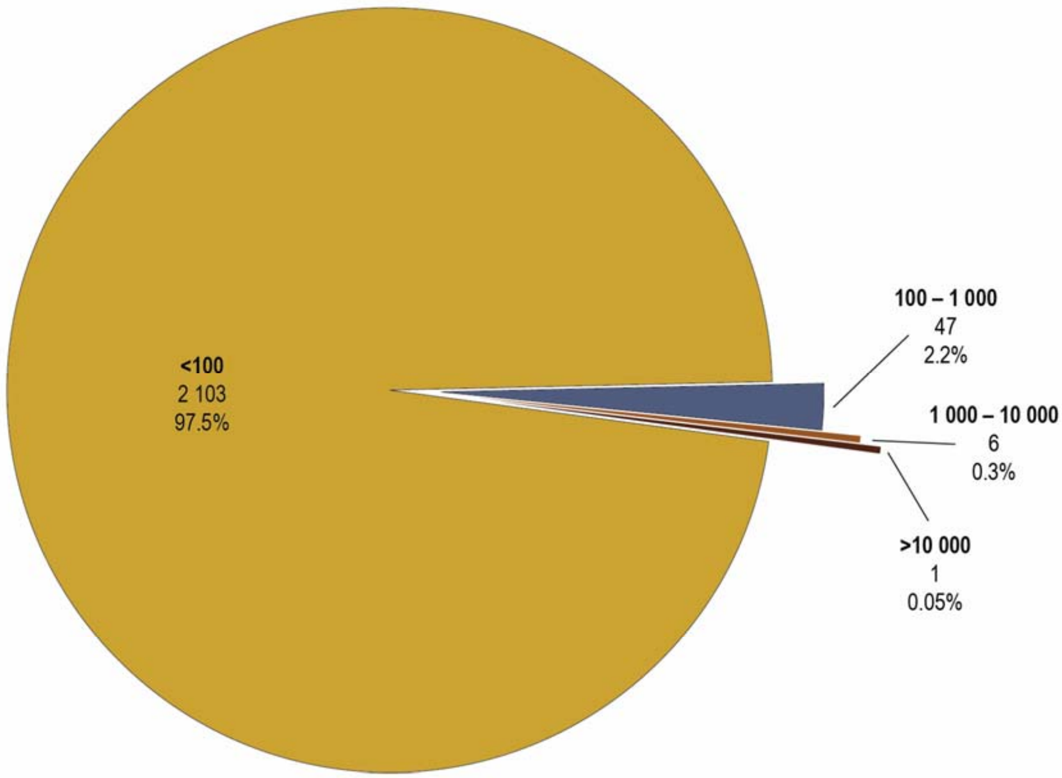


	RELEASE VOLUME, m^3 (LIQUIDS) OR 10^3 m^3 (GAS)				
	<100	100 – 1 000	1 000 – 10 000	>10 000	Total number
Total	**21 900**	**758**	**95**	**9**	**22 762**

Pipeline releases that occur when a pipeline is being pressure tested (whether to qualify a new pipeline or requalify an existing pipeline) have not been included in the previous figures because such releases do not occur under normal operating conditions. In most cases, fresh water is used and test pressures are well above normal operating pressures. Pressure tests are conducted for a number of reasons, such as proving out new construction, verifying integrity, requalifying for a higher operating pressure or change of substance, and identifying near-critical defects. A pressure-test failure is generally a positive event as it has successfully located a weakness in a pipeline that might have been at risk of failure during operations.

Since 1990, 2000 pipeline pressure-test failures resulted in 2157 substance releases. Figure 25 shows the proportions of each volume class in relation to the total number of releases.

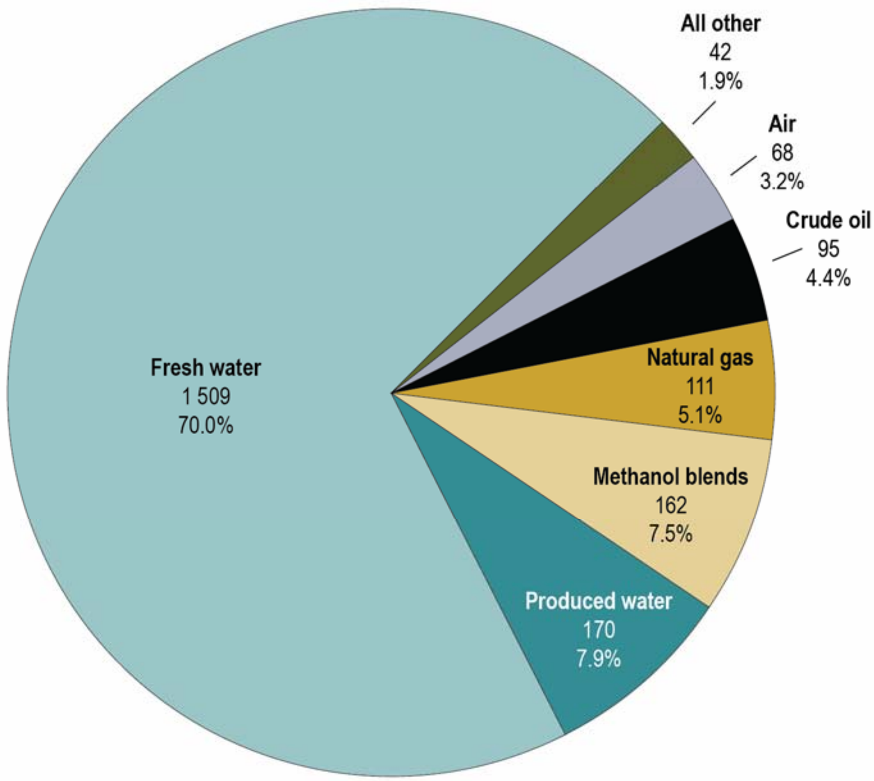
Figure 25. Number of pipeline releases from pressure tests by volume types released
All pipeline releases from January 1, 1990, to December 31, 2012 (leaks and ruptures only)



	RELEASE VOLUME, m^3 (LIQUIDS) OR 10^3 m^3 (GAS)				Total
	<100	100 – 1 000	1 000 – 10 000	>10 000	number
Total	**2 103**	**47**	**6**	**1**	**2 157**

In 70.0 per cent of the releases, the released substance resulting from pressure-test failures was fresh water (see figure 26). Another 7.5 per cent were of methanol blends commonly used for pressure testing in sub-zero temperatures. The remaining 22.5 per cent were of a variety of other pipelined products. Pressure tests with transported fluids are permitted in some circumstances, mainly to find an existing leak, provided that the locations of the pressure tests are remote and pose no risk to the public. Such tests may also be done using a lower test pressure than would be used for a pressure test using water. Failure of a pipeline undergoing a liquid media pressure test usually results in only a small volume of fluids being spilled at the break site and is usually a simple clean-up exercise. Fluids containing H_2S may not be used to conduct a pressure test.

Figure 26. Number of pipeline releases by volume from pressure tests by substance types released
All pipeline releases from January 1, 1990, to December 31, 2012 (leaks and ruptures only)



2 000 actual events resulted in 2 157 released volumes

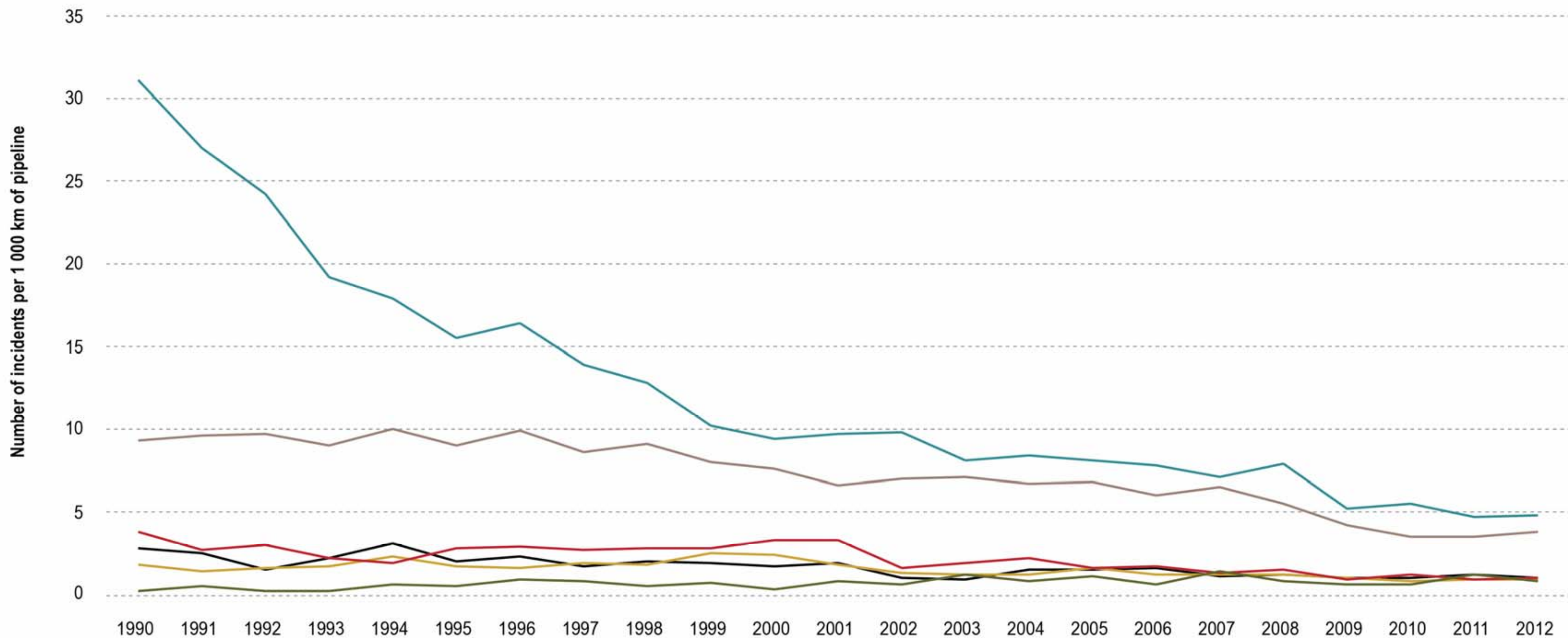
Incident frequencies are used to quantify the overall pipeline performance in Alberta. Incident frequency is calculated by dividing the number of incidents per year (excluding pipeline test failures) by the total pipeline length for the year, and then expressing the number as incidents per 1000 km for that year. Pipeline test failures are not included because they do not occur during normal pipeline operations. All NGTL pipelines and related incidents are included in the data up to the transfer date of NGTL pipeline to federal jurisdiction. AUC-regulated natural gas utility pipelines are included in the totals for the entire period. The average pipeline incident frequency for all substances continued to decrease over the period to 1.5 incidents per 1000 km of pipeline in 2010 and has been steady since then (see figures 27 and 28).

Figure 27 illustrates the incident frequency by substance category. Most of the pipeline substances exhibit a low, and steady, incident frequency of about 1 incident per 1000 km per year. The exceptions are water and multiphase pipelines, which continue to be a challenge. In fact, data for 2012 show a slight increase in these substance categories. Water pipelines are very susceptible to corrosion unless protected by an internal corrosion barrier. Industry has made significant progress in bringing down the water pipeline incident frequency, and is still working on this. Multiphase pipelines are also very susceptible to corrosion, as they typically carry a combination of oil, water, and corrosive gases, which makes effective corrosion protection challenging. The incident rates for crude oil, natural gas, sour gas, and other pipelines were relatively steady over the reporting period, although it appears a year-to-year variability is becoming less pronounced. The incident rate of natural gas pipelines has shown increasing stability over the last four years, averaging about 0.9 incidents per 1000 km per year. This is significant considering that more than half of all pipelines in Alberta carry natural gas, which frequently is a raw production fluid.

The incident frequency has displayed a steady, gradual decrease in the number of incidents per 1000 km of installed pipeline. The relative flatness of the frequency curves in recent years for some of the substances may suggest that current practices may not result in much further improvement. For those, it may be necessary to pursue new technologies or management strategies to achieve any further significant improvement.

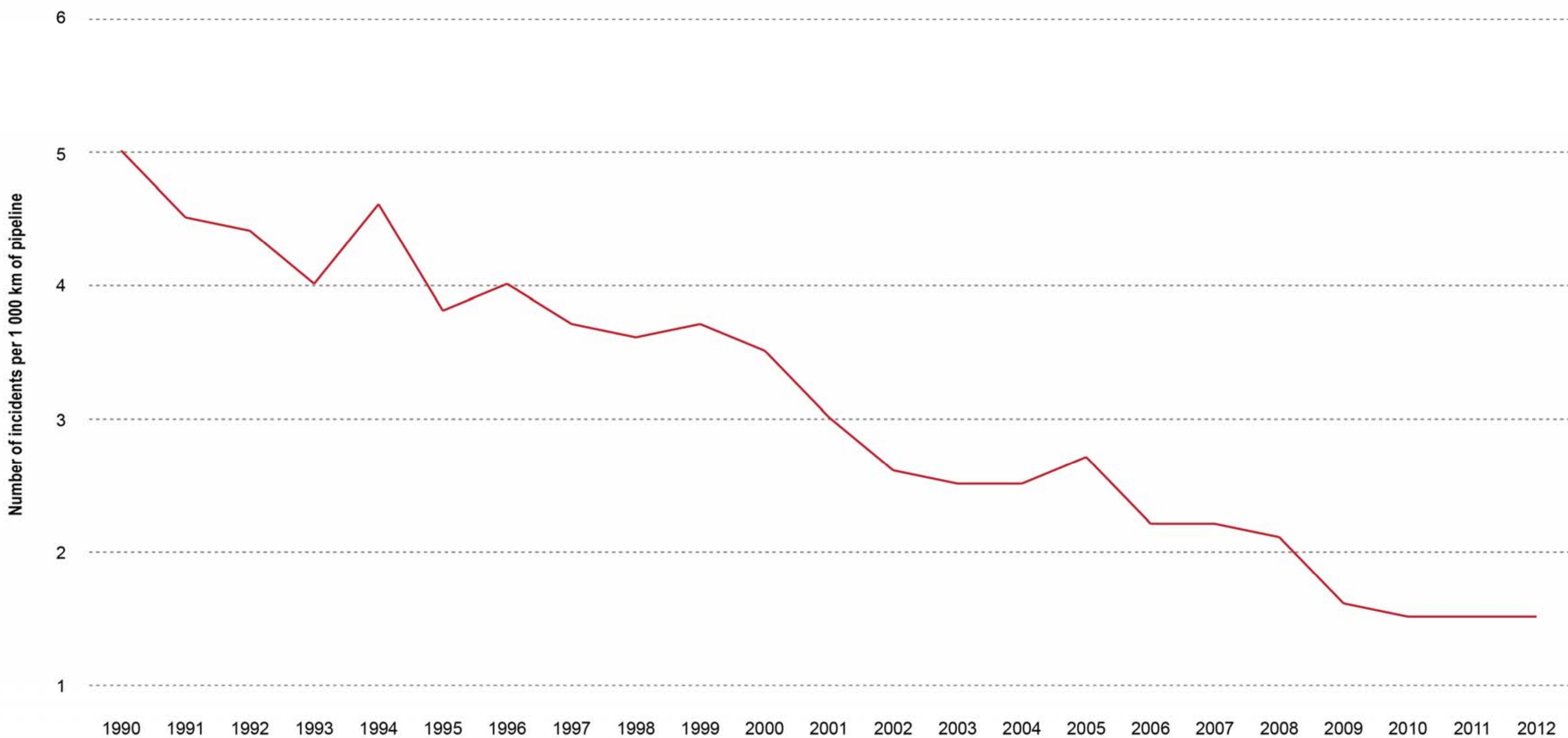
Figure 28 shows that the number of incidents per 1000 km of pipeline has been in decline through the reporting period, dropping from 5.0 in 1990 to a low of about 1.5 in 2010. The incident frequency has not changed since then. This indicates that industry has steadily and measurably reduced the frequency of pipeline incidents. Pipeline incidents are very costly in terms of lost production and royalties, environmental damage and cleanup, increased greenhouse gas emissions, and loss of public confidence. The AER continues to work with industry in seeking out and implementing new methods and processes for reducing the frequency of pipeline incidents and continuing improvement.

Figure 27. Average frequency of pipeline incidents by year and pipeline substance
All pipeline incidents from January 1, 1990, to December 31, 2012 (includes all hits, leaks, and ruptures)



Crude oil	2.8	2.5	1.5	2.2	3.1	2.0	2.3	1.7	2.0	1.9	1.7	1.9	1.0	0.9	1.5	1.5	1.6	1.1	1.2	1.0	1.0	1.2	1.0
Natural gas	1.8	1.4	1.6	1.7	2.3	1.7	1.6	1.9	1.8	2.5	2.4	1.8	1.3	1.2	1.2	1.6	1.2	1.2	1.2	1.0	0.8	0.9	0.9
Sour gas	3.8	2.7	3.0	2.2	1.9	2.8	2.9	2.7	2.8	2.8	3.3	3.3	1.6	1.9	2.2	1.6	1.7	1.3	1.5	0.9	1.2	0.9	1.0
Water	31.1	27.0	24.2	19.2	17.9	15.5	16.4	13.9	12.8	10.2	9.4	9.7	9.8	8.1	8.4	8.1	7.8	7.1	7.9	5.2	5.5	4.7	4.8
Multiphase	9.3	9.6	9.7	9.0	10.0	9.0	9.9	8.6	9.1	8.0	7.6	6.6	7.0	7.1	6.7	6.8	6.0	6.5	5.5	4.2	3.5	3.5	3.8
Other	0.2	0.5	0.2	0.2	0.6	0.5	0.9	0.8	0.5	0.7	0.3	0.8	0.6	1.2	0.8	1.1	0.6	1.4	0.8	0.6	0.6	1.2	0.8

Figure 28. Average frequency of pipeline incidents by year
All pipeline incidents from January 1, 1990, to December 31, 2012 (hits, leaks, and ruptures, excludes pressure tests)



Incidents/1 000 km	5.0	4.5	4.4	4.0	4.6	3.8	4.0	3.7	3.6	3.7	3.5	3.0	2.6	2.5	2.5	2.7	2.2	2.2	2.1	1.6	1.5	1.5	1.5

5 Other Information

Regulatory requirements, technical standards, and other related pipeline information can be found in the following documents:

- Pipeline Act
- Pipeline Rules
- American Society of Mechanical Engineers (ASME) B16.5 Pipe Flanges and Flanged Fittings
- ASME B31.3 Process Piping
- Canadian Standards Association (CSA) Standard Z662: Oil and Gas Pipeline Systems
- CSA Standard Z245.1: Steel Pipe
- CSA Standard Z245.11: Steel Fittings
- CSA Standard Z245.12: Steel Flanges
- CSA Standard Z245.15: Steel Valves
- CSA Standard Z245.20: Plant-applied external fusion bond epoxy coating for steel pipe
- CSA Standard Z245.21: Plant-applied external polyethylene coating for steel pipe
- CSA Standard Z245.22: Plant-applied external polyurethane foam insulation coating for steel pipe
- CSA Standard B137 Series 9: Thermoplastic Pressure Piping Compendium
- AER Directive 026: Setback Requirements for Oil Effluent Pipelines
- AER Directive 056: Energy Development Applications and Schedules (also contains a number of reference tools for pipeline applications)
- AER Directive 071: Emergency Preparedness and Response Requirements for the Upstream Petroleum Industry
- AER Directive 077: Pipelines – Requirements and Reference Tools
- AER Pamphlet publication: Safe Excavation Near Pipelines – Requirements for Landowners and Industry
- AER ST57-2013 - Provincial Surveillance and Compliance Summary 2012; also previous years' annual ST-57 Summaries
- NACE MR0175/ISO 15156: Materials for use in H_2S-Containing Environments in Oil and Gas Production

6 Definitions

Failure—An incident in which product is lost, either by a leak or a rupture.

Incident—Any incident must be reported to the AER and would include a pipeline leak, a pipeline rupture, or the striking of a pipeline (hit), even if that strike does not cause any loss of product. Note that pressure-test failures, though reportable as incidents, are reported separately in this report to allow a differentiation between operational incidents and qualification incidents.

Hit—A hit is an incident where a pipeline is struck but no product is lost.

Leak—A leak is defined as a pipeline failure where a pipeline is losing product but might continue to operate until the leak is detected.

Release—The loss of product from a pipeline. A pipeline incident or failure may result in more than one release, as gas, oil, and water are counted as separate product releases. This is why some charts indicate more releases than incidents.

Rupture—A pipeline failure where a pipeline cannot continue to operate.