Concawe

Environmental Science for European Fuel Manufacturing

Report

Report no. 11/26

Performance of European cross-country oil pipelines

Statistical summary of reported spillages in 2024 and since 1971

ISBN 978-2-87567-220-9

Report no. 11/26

Performance of European cross-country oil pipelines

Statistical summary of reported spillages in 2024 and since 1971

This report was prepared by:

M. Cech
J. Armstrong
W. Guijt
A. Haskamp
I. Huidobro Barrio

Frontline Integrity LTD (Consultancy)

Under the supervision of:

J. Dekeyser (Concawe Science Executive)

At the request of:

Concawe Special Task Force on-Oil Pipelines performance report (OP/STF-1)

Thanks for their contribution to:

- Members of OP/STF-1

KEYWORDS

Concawe, inspection tool, oil spill, performance, pipeline, safety, soil pollution, spillage, statistics, trends, water pollution

INTERNET

This report is available as an Adobe pdf file on the Concawe website (www.concawe.eu).

CONTENTS

SUMMARY

Data Collection and inventory statistics

Concawe has collected 54 years of spillage data on European cross-country oil pipelines regarding spillage volume, clean-up and recovery, environmental consequences and causes of the incidents. The results have been published in annual reports since 1971. This report covers the performance of these pipelines in 2024 and provides a full historical perspective since 1971. The performance over the whole 54-year period is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party (with theft-related and other intentional events reported separately). The inspected length of in-line inspection tools is also reported.

A total of 68 companies and agencies operating about 35,000 km of oil pipelines in Europe are currently listed for the Concawe annual survey (including around 2,200 km currently out of service). In 2024, 60 operators provided a full set of data representing a combined active length of around 32,000 km. The estimated total reported volume transported in 2024 was 572 Mm^3 of both crude oil and refined products.

No or partial data was obtained from 8 operators and therefore were excluded in the spill statistics. These operators cover approximately 1,300 km of pipeline, and to the best of our knowledge, no spillage incidents involving these pipelines have been publicly reported.

2024 spillage incidents

Nine spillages were reported in 2024, two of these spillages were theft related. Excluding theft, there were 7 non-theft spillages this year which is the highest since 2013 where 8 were reported. This figure exceeds the 5-year average of 3.8 but remains just below the long-term average of 9.86. In terms of frequency this equates to 0.22 spillages per 1000 km of line, significantly higher than the 5-year average of 0.12 and well below the long-term running average of 0.41 spillages per 1000 km of line, which has been steadily decreasing over the years from a value of 1.1 spillages per year per 1000 km of line in the mid ‘70s.

A summary of the 2024 database spill entries is provided below:

- Corrosion / External: 2
- Corrosion / SCC: 1
- 3rd Party / Intentional (Theft): 2
- 3rd Party / Accidental: 1
- Mechanical / Construction Related: 1
- Operational / System: 1
- Operational/ Human: 1

There were no reported fires, fatalities or injuries connected with the spills.

2024 In-line inspections

In 2024 a total of 101 sections covering a total of 13,761 km were inspected by one or more type of in-line inspection tool, 12 sections less than in 2023. Most inspection programmes involved the running of more than one type of inspection tool in the same section, so that the total actual length inspected was less at 6,295 km (19% of the inventory, slightly lower the 10-year average of 23%). This is significantly lower than the inspected length in 2023 (around 24%).

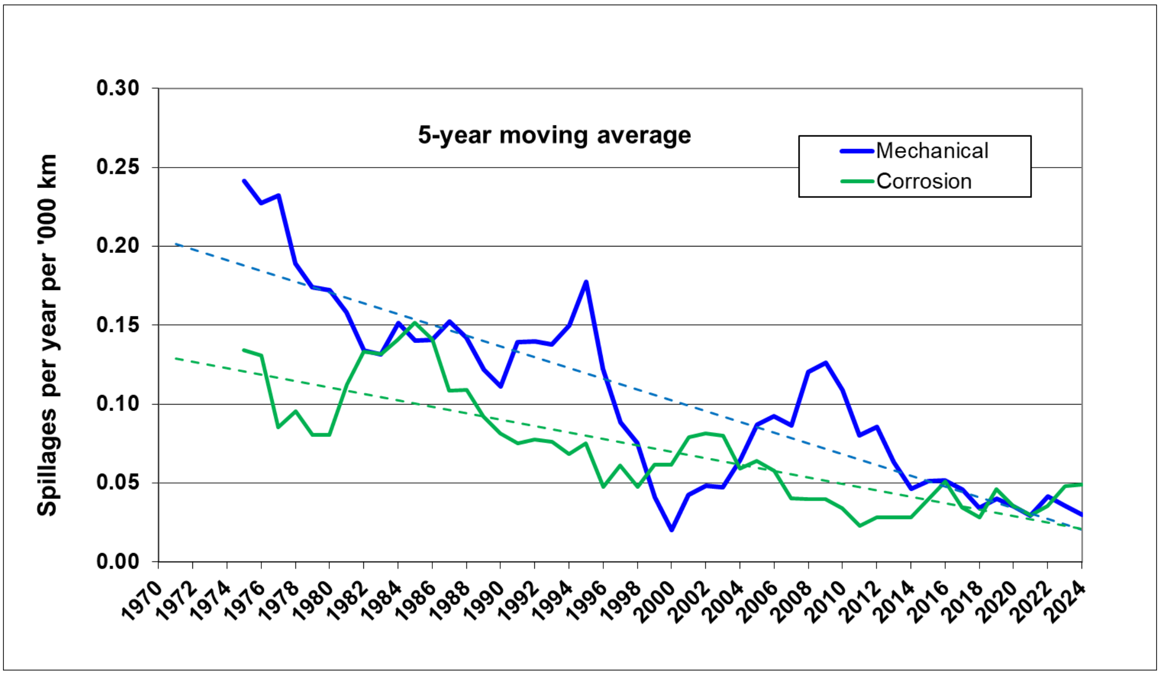
Overview of the main issues affecting pipeline integrity

Mechanical integrity and ageing: a relatively recent issue that requires continued attention.

Most European pipeline systems were built in the ‘60s and ‘70s. Whereas, in 1971, 70% of the pipelines in the inventory were 10 years old or less, by 2024 only 0.68% were 10 years old or less and over 76% were over 40 years old. Over the last two decades, operators and regulators became concerned that ageing lines may be increasingly prone to mechanical (e.g. metal fatigue) or corrosion-related failures.

An increase in the frequency of mechanical failures observed during the first ten years of this century caused some concern. However, a detailed analysis showed that there was no correlation between the actual frequency of reported fatigue-related failures and pipeline age. Over the last fifteen years the downward trend resumed to stabilize somewhat over the past decade at around 0.03 to 0.05 incidents per year per 1000 km. There is therefore no evidence that the ageing of the pipeline inventory implies a greater risk of loss of integrity.

The historical data show a long-term downward trend in the frequency of corrosion-related spillages since the early 1980’s, albeit with notable shorter-term peaks and troughs. The number of cases reported in the last decade suggests that the long-term trend may now be flat lining, in line with the mechanical failure rate.



Dotted lines: regression lines= trend lines; R^2 mechanical =0.66; R^2 corrosion= 0.71

1. INTRODUCTION

The Concawe Oil Pipelines Management Group (OPMG) has collected data on the safety and environmental performance of oil pipelines in Europe since 1971. Information on annual throughput and traffic, spillage incidents and in-line inspection activities are gathered annually.

The OPMG would like to thank all the representatives of the pipeline operators for engaging with this process and providing the relevant information. Without operator participation it would not be possible to produce such an impactful report.

The results are analysed and published annually. Summary reports were compiled after 20 and 30 years. From the 2005 reporting year, the format and content of the report was changed to include not only the yearly performance, but also a full historical analysis since 1971, effectively creating an evergreen document updated every year. This report uses this same format and therefore supersedes the 2023 report. All previous reports have also been superseded and are now obsolete.

In this single annual integrated report, it was, however, not considered practical to include the full narrative description of the circumstances and consequences of each past spillage. We have therefore created a series of separate appendices to this report where this information can be accessed via the following links:

1971-1983/ 1984-1993 / 1994-2004 / 2005+

Concawe holds a seminar, known as "COPEX" (Concawe Oil Pipeline Operators Experience Exchange), generally every four years to disseminate information throughout the oil pipeline industry on developments in techniques available to pipeline operators to help improve the safety, reliability and integrity of their operations. These seminars have included reviews of spillage and clean-up performance to cross-communicate experiences so that all can learn from each other's incidents. The last COPEX was held in March 2022.

Section 2 provides details of the pipeline inventory covered by the survey (length, diameter, type of product transported) and how this has developed over the years. Throughput and traffic data is also included.

Section 3 focuses on safety performance i.e. the number of fatalities and injuries associated with pipeline spillage incidents.

Section 4 gives a detailed analysis of the spillage incidents in 2024 and of all incidents over the last 5 reporting years.

Section 5 analyses spillage incidents for the whole reporting period since 1971.

Section 6 provides a more detailed analysis of the causes of spillage.

Section 7 gives an account of in-line inspections.

Section 8 summarises pipeline theft incidents.

2. PIPELINE INVENTORY, THROUGHPUT AND TRAFFIC

2.1. CRITERIA FOR INCLUSION IN THE SURVEY

The definition of pipelines to be included in the Concawe inventory has remained unchanged since 1971. These are pipelines:

- Used for transporting crude oil or petroleum products,
- With a length of 2 km or more in the public domain,
- Running cross-country, including short estuary or river crossings but excluding under-sea pipeline systems. In particular, lines serving offshore crude oil production facilities and offshore tanker loading/discharge facilities are excluded.
- Pump stations, intermediate above-ground installations and intermediate storage facilities are included, but origin and destination terminal facilities and tank farms are excluded.

The minimum reportable spillage size has been set at 1 m^3 (unless exceptional safety or environmental consequences are reported for a <1 m^3 spill).

All the above criteria are critical parameters to consider when comparing different spillage data sources, as different criteria can significantly affect the results.

The geographical region covered was originally consistent with Concawe's original terms of reference i.e. OECD Western Europe, which then included 19 member countries, although Turkey was never covered. From 1971 to 1987, only pipelines owned by oil industry companies were included, but from 1988, non-commercially owned pipeline systems (essentially NATO) were brought into the inventory. Following the reunification of Germany, the pipelines in former East Germany (DDR) were added to the database from 1991. This was followed by Czech and Hungarian crude and product lines in 2001, Slovakian crude and product lines in 2003 and some of the Croatian crude lines in 2007. From 2013 additional Croatian crude lines were included.

Although Concawe cannot guarantee that every single pipeline meeting the above criteria is actually covered, it is believed that most such lines operated in the reporting countries are included. Notable exceptions are NATO lines in Denmark, Italy, Greece, Norway and Portugal as well as all crude and product pipelines in Poland.

All data recorded in this report and used for comparisons or statistical analysis relate to the inventory reported in each particular year, and not to the actual total inventory in operation at the time. Thus, year-on-year performance comparisons must be approached with caution and frequencies (i.e. figures normalised per 1000 km of line) are more meaningful than absolute figures.

2.2. REPORTING OPERATORS

Around a total of 35,000 km of oil pipelines in Europe, operated by 68 companies and agencies, are currently listed for the Concawe annual survey. This total includes affiliates and joint ventures of large oil companies. This number has remained broadly constant over the years, as the impact of new operators joining in was compensated by various mergers.

For the 2024 reporting year, 60 operators completed the survey. To the best of our knowledge there were no public reports of spillage incidents for the remaining 8 operators, and their data has not been included in the statistics.

2.3. INVENTORY DEVELOPMENTS 1971-2024

2.3.1. Pipeline service, length and diameter

The 60 operators that reported in 2024 account for 141 pipeline systems split into 616 active sections running along a total of 32,205 km plus 34 sections covering 2,200 km which are currently (but not permanently) out of service. The 8 operators from which we received no or partial information represent around 1,300 km, split into 20 systems and 34 sections and to the best of knowledge, no spillage incidents involving these pipelines have been publicly reported.

For the purpose of the spill statistics, we considered the “active” inventory i.e. the 32,205 km mentioned above.

Figure 1 shows the evolution of this "Concawe inventory” over the years since 1971. The two historical step increases occurred when systems previously not accounted for in the survey were added. In the late 80s the majority of the NATO pipelines were included, and, at the beginning of the last decade, a number of former Eastern bloc systems joined the survey. The increase was mostly in the "products" category. The main addition in the crude oil category was the Friendship or "Druzba" system, which feeds Russian crude oil into Eastern European refineries.

A total of 279 sections (~12,000 km) have been permanently shut down since 1971 and have been taken out of the inventory when retired.

Figure 1 represents the pipeline length reported to Concawe in each year and does not give an account of when these pipelines were put into service. Most of the major pipelines were built in the ‘60s and ‘70s and a large number of them had already been in service for some time when they were first included in the Concawe survey. This aspect is covered in the discussion of pipeline age distribution in the next section.

The sections are further classified according to their service, i.e. the type of product transported, for which we distinguish crude oil, white products, heated black products (hot oil) and other products. A few pipelines transport both crude oil and products. Although these are categorised separately in the database, they are considered to be in the crude oil category for aggregation purposes. The three main populations are referred to as crude, product and "hot" in this report. The last one refers to insulated lines transporting hot heavy products.

Figure 1 shows that "cold" lines transporting crude and refined products represent the bulk of the total inventory. Out of the 279 sections (~12,000 km) that have been retired since 1971, 25 (1,160 km) were in the "hot" (i.e. heated) category. The remaining "hot" inventory consists of 32 km distributed in 4 sections transporting heavy fuel oil. Historically 41 km of pipeline in 4 sections transporting lubricant components were considered as "hot" pipelines which were discarded in the statistics since 2023.This reflects the decline in the heavy fuel oil business since the mid-1970s, but also specific action taken by operators because of the corrosion problems and generally poor reliability experienced with several of these pipelines (see **Section 5.1**).

Figure 1 Concawe oil pipeline inventory and main service categories

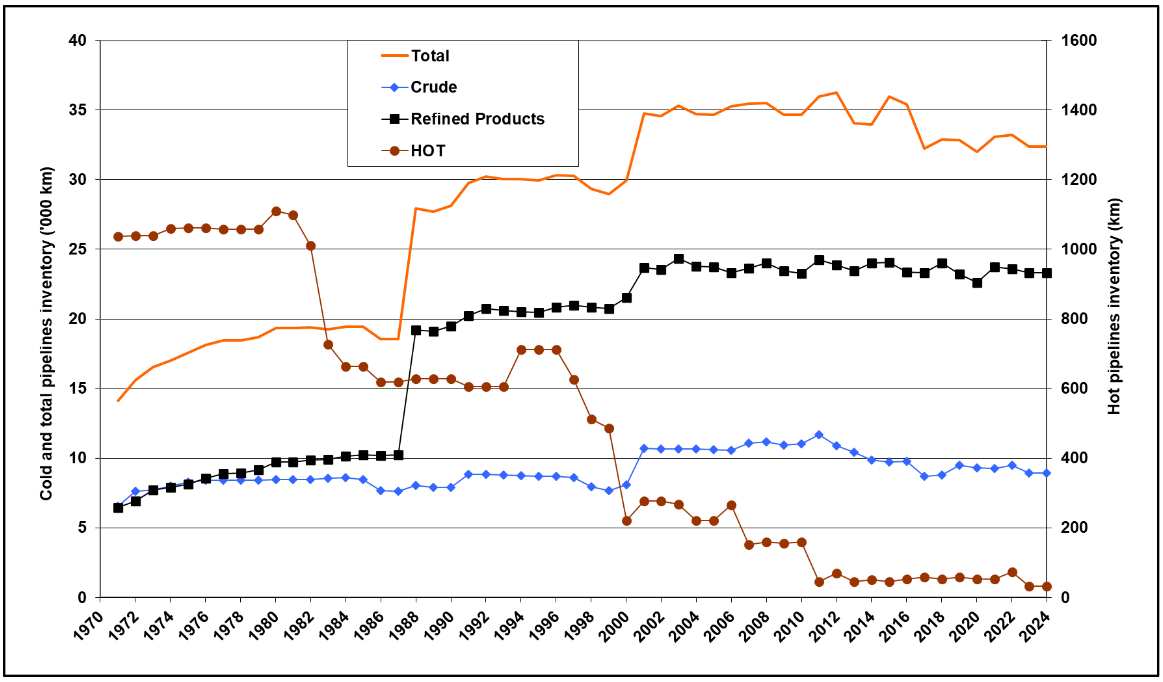
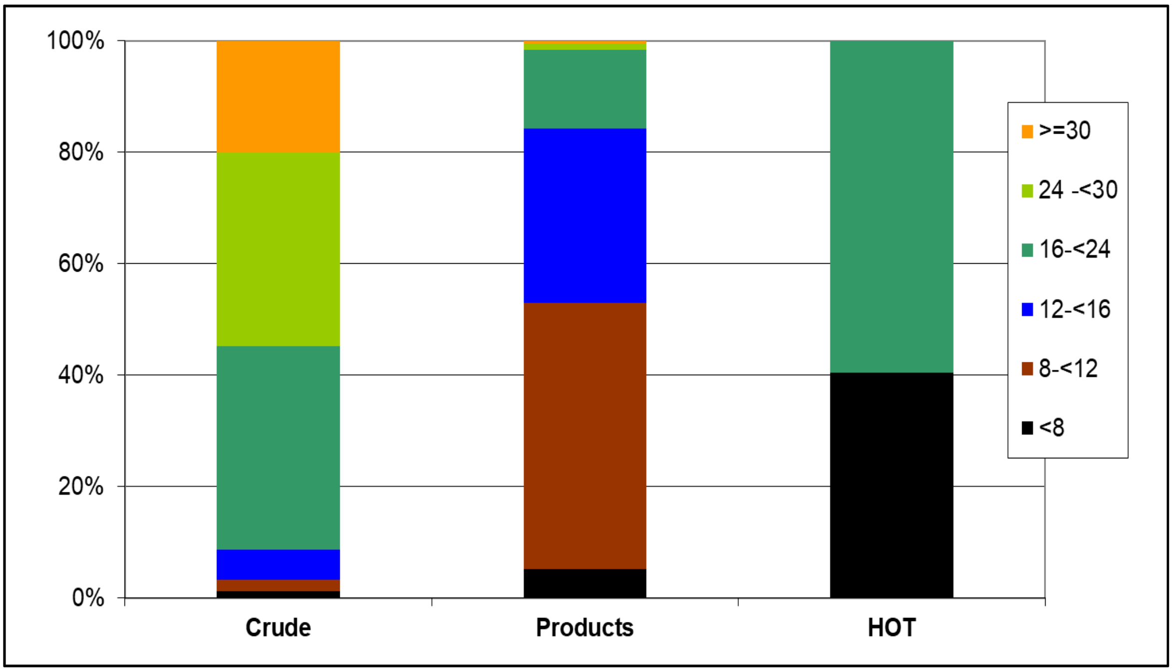


Figure 2 shows the diameter distribution in 2024 for each service category. In general, the crude pipelines are significantly larger than the other two categories. Almost 90% of the crude pipelines are 16" (400 mm) or larger, up to a maximum of 44" (1100 mm), whereas 85% of the product lines are smaller than 16". The largest hot pipeline is 20". The smallest diameter product pipelines are typically 6" (150 mm) although a very small number are as small as 3" (75 mm).

Figure 2 European oil pipeline diameter (inches) distribution and service in 2024

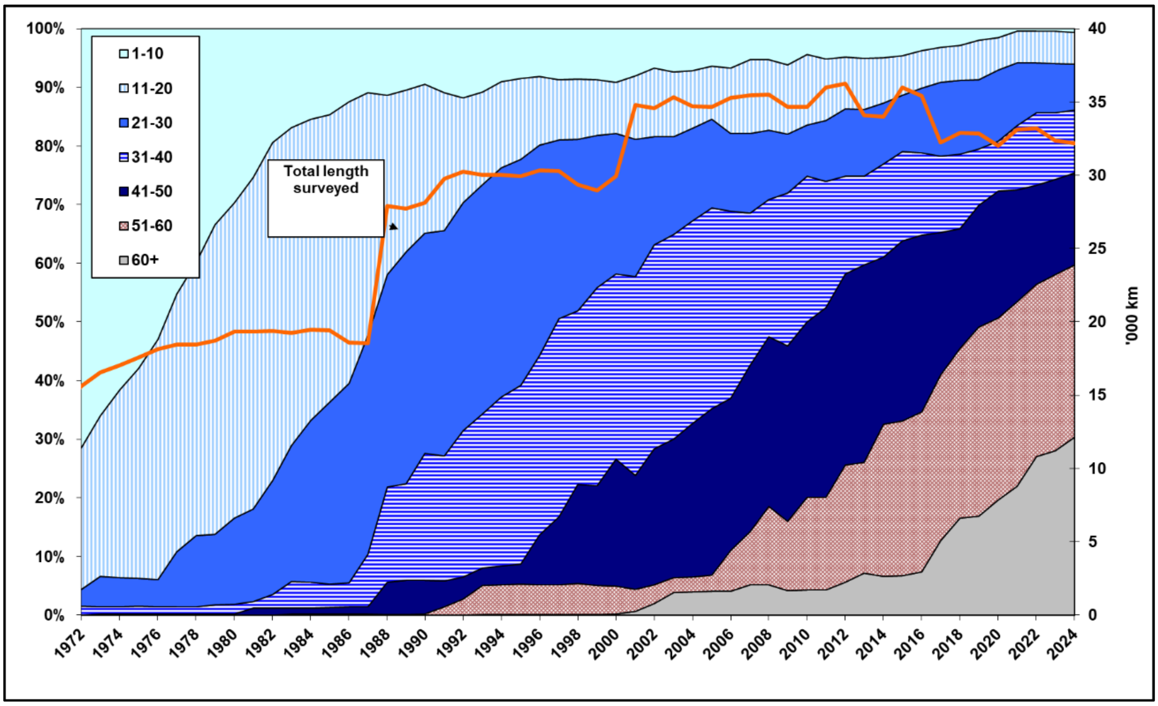


2.3.2. Age distribution

When the Concawe survey was first performed in 1971, the pipeline network was comparatively new, with some 70% being 10 years old or less. The age distribution was quite wide already then, the oldest pipelines were in the 26-30-year age bracket and represented only a tiny fraction of the inventory.

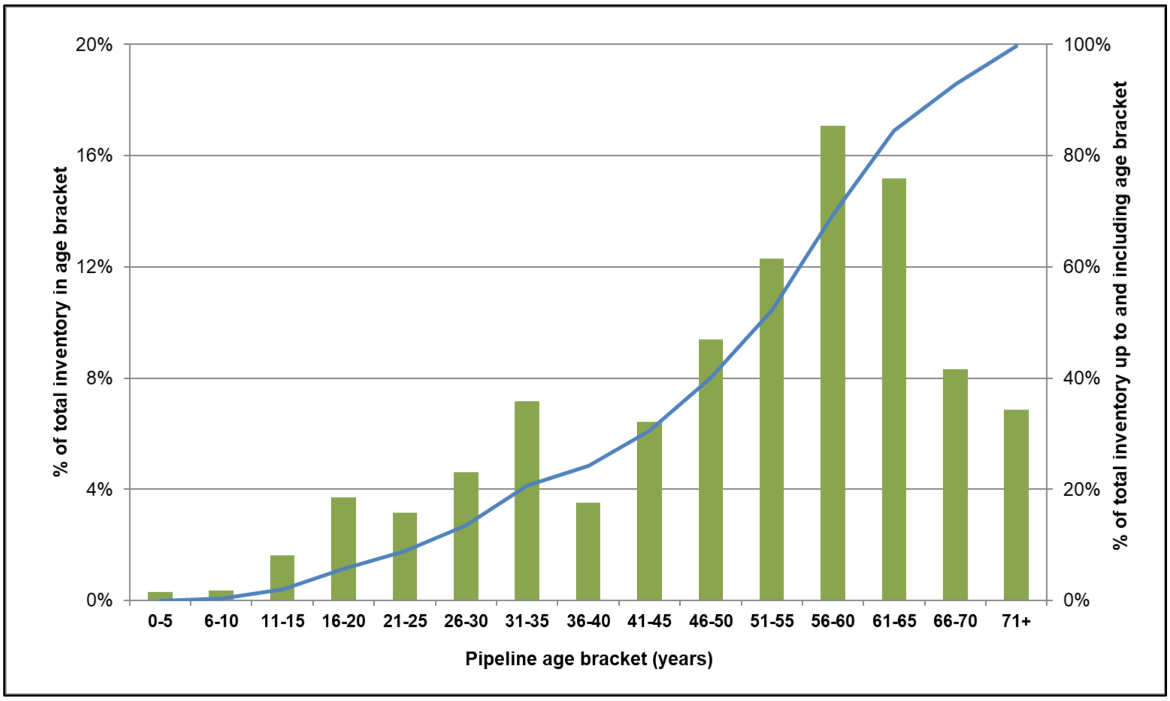
Over the years, a number of new pipelines have been commissioned, while older ones have been taken out of service. As mentioned above, existing lines were also added to the inventory at various stages, contributing their specific age profile. Although some short sections may have been renewed, there has been no large-scale replacement of existing lines. The evolution of the overall age profile is shown in **Figure 3a**.

Figure 3a The Concawe oil pipeline historical age distribution (years)



The network has been progressively ageing. The 2024 age distribution is shown on **Figure 3b** both for discreet age brackets and cumulatively: only 219 km, i.e. 0.68 % of the total, was 10 years old or less while 24,456 km (76%) was over 40 years old. The relevance of age on spillage performance is discussed in **Section 6.3**.

Figure 3b European Oil pipeline age distribution in 2024



2.4. THROUGHPUT

It was reported that a total of 572 Mm^3 of products (323 Mm^3 of crude oil and 249 Mm^3 of refined products) were transported in the surveyed pipelines in 2024. The crude oil transported represents about 60% of the combined throughput of European refineries. It should be realised however, that this figure is only indicative as large volumes of both crude and products pass through more than one pipeline, and whilst every effort is made to count the flow only once, the complexity of some pipeline systems is such that it is often difficult to produce a realistic estimate of the throughput. Additionally, there are a few pipelines that are bi-directional.

Throughput is reported here to give a sense of the size of the oil pipeline industry in Europe. These are not considered to be significant factors for pipeline spillage incidents. Although higher flow rates may lead to higher pressure, line deterioration through fatigue is known to be related to pressure cycles rather than to the absolute pressure level (as long as this remains within design limits). The throughput figure is, useful as a divider to express spillage volumes in relative terms (e.g. as a fraction of throughput, see **Section 4**), providing data that can be compared with the performance of other modes of oil transportation.

3. PIPELINE SAFETY

The Concawe pipeline database includes records of fatalities, injuries and fires related to spillages. Almost all fatalities (apart from one drowning), result from fire related incidents. The 9 fire related incidents were all pipelines transporting either crude (4), naphtha (1) or gasoline (4), thus products with a high vapour pressure.

3.1. FATALITIES AND INJURIES

No spillage-related fatalities or injuries were reported in 2024.

Over the 53 reporting years there have been a total of 14 fatalities in 5 separate incidents in 1975, 79, 89, 96 and 99. All but one of these fatalities occurred when people were caught in a fire following a spillage.

In 3 of the 4 fire-related incidents the ignition was a delayed event that occurred hours or days after the spillage detection and demarcation of the spillage area had taken place. In one incident involving a spillage of chemical feedstock naphtha, 3 persons were engulfed in fire, having themselves possibly been the cause of ignition. In another incident, ignition of spilled crude oil occurred during attempts to repair the damaged pipeline. The repairers escaped but the spread of the fire caught 4 people who had entered inside the marked spillage boundary some distance away. The third incident also involved a maintenance crew (5 people) carrying out repair activities following a crude oil spill, none of whom escaped. These fatalities all occurred after the spillage flows had been stemmed, i.e. during the subsequent incident management and reinstatement period. In all three cases the fatalities were not directly caused by the spillages but by fires occurring during the remediation process. Stronger management of spillage area security and working procedures (Emergency Response Planning) might well have prevented these fires and subsequent fatalities.

In just one case, fire ensued almost immediately when a bulldozer doing construction work hit and ruptured a gasoline pipeline. A truck driver engaged in the works received fatal injuries.

The single non-fire fatality was a person engaged in a theft attempt who was unable to escape from a pit which he had dug to expose and drill into the pipeline. This caused a leak that filled the pit with product in which the person drowned.

A total of 3 injuries have been reported over the years. Single non-fatal injuries were recorded in both 1988 and 1989, both resulting from inhalation / ingestion of oil spray/aerosol. There was one injury to a third party in 2006.

3.2. FIRES

There was no spillage-related fire reported in 2024.

Apart from the 4 fire-related incidents with fatalities, as mentioned in 3.1, five other fires are on record:

- A large crude oil spill near a motorway probably ignited by the traffic.
- A gasoline theft attempt in a section of pipeline located on a pipe bridge. The perpetrators may have deliberately ignited it.

- A slow leak in a crude production line in a remote country area was found to be burning when discovered. It could have been ignited purposely to limit the pollution.
- A tractor and plough that had caused a gasoline spill caught fire, and the fire also damaged a house and a railway line.
- A mechanical digger damaged a gasoline pipeline and an electricity cable, which ignited the spill.

There were no injuries or fatalities reported in any of these incidents.

4. SPILLAGE PERFORMANCE IN THE LAST 5 YEARS (2020-2024)

4.1. 2024 SPILLAGE INCIDENTS

9 spillage incidents were recorded in 2024, 2 of which were related to theft activities (third party - intentional), 3 spillages were associated with Corrosion (Two external corrosion and one stress corrosion cracking), 1 spillage was associated with mechanical damage (Construction), 2 spillages were associated with operational factors (One system related and one human related) and the remaining 1 spillage was related to third-party accidental.

Theft attempt from pipelines has been a concern in the last decade, causing a small number of spillages in 2011 and 2012. The number jumped to 18 in 2013, 54 in 2014, and 87 in 2015. The first sign of decline came in 2016 with 60 spillages followed by 11 in 2017, 10 in 2018, none in 2019, 4 in 2020, 2 in 2021 and 1 in 2022 and 6 in 2023. While theft tended in the past to be an issue in Southern and Eastern Europe it is now more widespread, affecting also central and North/West Europe. The resurgence of theft-related spills in the last few years indicates that, although the efforts by operators to reduce the number and the consequences of theft attempts have borne fruit, the problem still remains though at a low level, and continues to be a challenge. In addition, there are a number of attempted theft events that did not result in a spill (see section 8).

Table 1 gives a summary of the main causes, spilled volumes and environmental impact. For definition of categories of causes and gross/net spilled volume, see **Appendix 1**. The circumstances of each spill, including information on consequences and remediation actions are described in the next section according to cause. Further details are available in **Appendix 2** which covers all spillage events recorded since 1971. The spilled volumes tabulated in "third party intentional" category are a rough estimate.

Table 1 Summary of incident causes and spilled volumes for 2024

Event (1)	Facility	Line size (")	Product spilled	Injury Fatality (2)	Fire	Spilled volume Gross m³	Net loss	Contamination Ground area m²	Water (3)
Corrosion									
External									
798	Underground Pipe	20	Crude Oil	-	-	10	1	1100	
805	Above ground pipe	18	Crude Oil	-	-	0.1	0.1	10	
SCC									
802	Underground Pipe	12	White Product	-	-	487	428	2768	
Mechanical									
Construction									
799	Underground Pipe	10	White Product	-	-	10	10	20	
Operational									
Human									
801	Pump Station	0	Crude Oil	-	-	7.5	0	240	
System									
804	Above ground pipe	0	White Product	-	-	33	0	5	
Third party									
Accidental									
800	Underground Pipe	8	White Product	-	-	8.4	0.1	0	
Intentional									
803	Underground Pipe	8	White Product	-	-	10.0	0	36	
806	Underground Pipe	10.75	White Product	-	-	27	17	100	

(1) Spillage events are numbered from the beginning of the survey in 1971

(2) I = Injury, F = Fatality

(3) S = Surface water, G = Groundwater, P = Potable water

4.1.1. Mechanical

Event 799: Sub-Category 'Construction'

Detected by local residents. A leak was confirmed on a pipe joint under a clock spring (epoxy repair) situated under the driveway of a house.

4.1.2. Operational

Event 801: Sub-Category 'Human'

In May 2024, a colleague working at the pumping station noticed during an on-site visit that oil was gushing out of the leachate drains of three pumps. Upon inspection, three values were confirmed to be in the open condition causing a 50 m^3 slop tank to be filled with crude oil resulting in the overflow.

Event 804: Sub-Category 'System'

Increased pressure during flushing activities resulted in a failure of a weld upstream of the filtering system (33m^3 volume lost).

4.1.3. Corrosion

Event 798: Sub-Category 'External'

Loss of containment due to external corrosion leading to a crack like defect running longitudinally.

Event 805: Sub-Category 'External'

No spillage description provided.

Event 802: Sub-Category 'SCC'

On July 2024, an operator experienced pressure drops on a buried refined product pipeline. The point of failure was identified and confirmed to be SCC (10 cm crack) with a total volume loss of 487 m^3.

4.1.4. Natural causes

There were no spillages in this category in 2024.

4.1.5. Third party activity

Event 800: Sub-Category 'Accidental'

In July 2024, a leak was reported at the main pumping station. No additional information was provided.

Event 803: Sub-Category 'Intentional'

In March 2024, the Product Transport Dispatch Service received a dispatch notification from a member of the public that hydrocarbons were leaking from a pipeline. A leak and illegal tap was confirmed. A volume of 10 m^3 of diesel oil spilled onto the ground, of which approximately 6.5 m^3 was recovered. Approximately 150 m^3 of contaminated soil was extracted from the affected area.

Event 806: Sub-Category 'Intentional'

Following pressure drop on system, the operator inspected a location and confirmed a 4.5 mm drill hole on the bottom of the pipe and a leak. 29 m^3 of gasoline was lost until the line could be depressurised and repaired.

4.2. 2020-2024 SPILLAGE OVERVIEW

Table 2 shows 5-year trends in spill incident causes and also spill volumes, from 2020-2024. Spillage volume due to theft has been excluded from the spill volume statistics so that the baseline performance of the European pipeline network, excluding intentional damage (i.e. product theft) is apparent (and also because the spilled volumes resulting from theft events are mostly unknown or at best rough estimates).

At 7, the number of non-theft related spillages reported in 2024 is significantly higher than average for the last 5 years (3.8) but below the long-term average of 9.86.

The total gross spilled volume reported in 2024 was at 556 m^3. This is significantly higher than the average of 213 m^3 for the last 5 years and lower than 1,518 m^3 since records began in 1971. Only around 21% of the spilled oil was recovered. A single incident caused 487 m^3 of products spillage, where only 9 m^3 were recovered.

Table 2 5-year comparison by cause, volume and impact: 2020-2024

		2020	2021	2022	2023	2024	2020-2024
							Average
Combined Length	km x 10^3	33.8	33.1	33.3	32.4	32.4	33.0
Combined Throughput	m3 x 10^6	615	660	643	604	572	618.8
Spillage incidents							Total
All incidents		**8**	**4**	**5**	**8**	**9**	**34**
Excluding theft		**4**	**2**	**4**	**2**	**7**	**19**
MECHANICAL FAILURE							
Construction		1		2		1	4
Design and Materials		1					1
OPERATIONAL							
System						1	1
Human						1	1
CORROSION							
External			1	1	1	2	5
Internal		1			1		2
Stress corrosion cracking						1	1
NATURAL HAZARD							
Ground movement			1				1
Other							0
THIRD PARTY ACTIVITY							
Accidental		1				1	2
Incidental							0
Intentional (theft)		4	2	1	6	2	15
UNDISCLOSED				1			1
Volume spilled (ex-theft)	m3						**Average**
Gross spillage		101	2	352	55	556	213
Net loss		6.30	0	351	0	439	159
Average gross loss / incident		25	1	117	28	79	59
Average net loss / incident		2	0	117	0	63	44
Average gross loss/1000 km		3	0	11	2	17	6
Average net loss/1000 km		0	0	11	0	14	5
Gross spillage/ throughput	ppm	0.2	0.0	0.5	0.1	1	0.4
Gross spillage per cause							
Mechanical failure		14	0	32	0	10	11
Operational		0	0	0	0	41	8
Corrosion		17	2	26	55	497	119
Natural hazard		0	0	0	0	0	0
Third party activity (ex-theft)		70	0	0	0	8	16
Net loss distribution							**Sum**
(No of incidents when reported)							
≤ 10		4	2	1	2	6	15
11 -100		0	0	2	0	0	2
101- 1000		0	0	1	0	1	2
> 1000 m3		0	0	0	0	0	0
Environmental impact							
NONE or not reported		4	2	4	6	1	17
SOIL (affected surface area)							
< 1000 m2		3	2	1	2	6	14
> 1000 m2		1	0	0	0	2	3
WATER BODIES							
Surface Water		1	0	0	0	0	1
Groundwater		0	0	0	0	0	0
POTABLE WATER		0	0	0	0	0	0

5. HISTORICAL ANALYSIS OF SPILLAGES 1971-2024

As mentioned in **section 4**, any significant growth in theft-related spillage incidents has the potential to skew long term statistics, as it was the case back in 2014 to 2016. Where appropriate, we have presented the statistics with and without these incidents.

5.1. NUMBERS AND FREQUENCY

Over the 54 years survey period there have been a total of 806 spillage incidents, 523 when excluding theft. 68 of these spillages occurred in "hot" pipelines, a disproportionately large number in relation to the share of such pipelines in the total inventory (note that such hot pipelines have now virtually disappeared from the active inventory with only 32.2 km left in operation, from a peak of around 1,100 km).

Figure 4a/b show the number of spillages per year, moving average and 5-year average trends over the 54 years since 1971 for all pipelines, including and excluding theft-related incidents.

Figure 4a shows a long-term downward trend in total spillages per year until the beginning of this decade followed by a major spike due to the sudden rise in product theft.

Figure 4b shows that the overall 5-year moving average, excluding theft, decreased from about 18 spillages per year in the early 1970s to 3.8 in similar 5-year time period ending in 2024 (6.8 when including theft-related spills), which bears witness to the industry's improved control of pipeline integrity. The moving average increases in the late '80s to early '90s and again in the early 2000s are partly linked to the additions to the pipeline inventory monitored by Concawe.

Figure 4a 54-year trend of the total annual number of spillages (all pipelines) **Including theft**

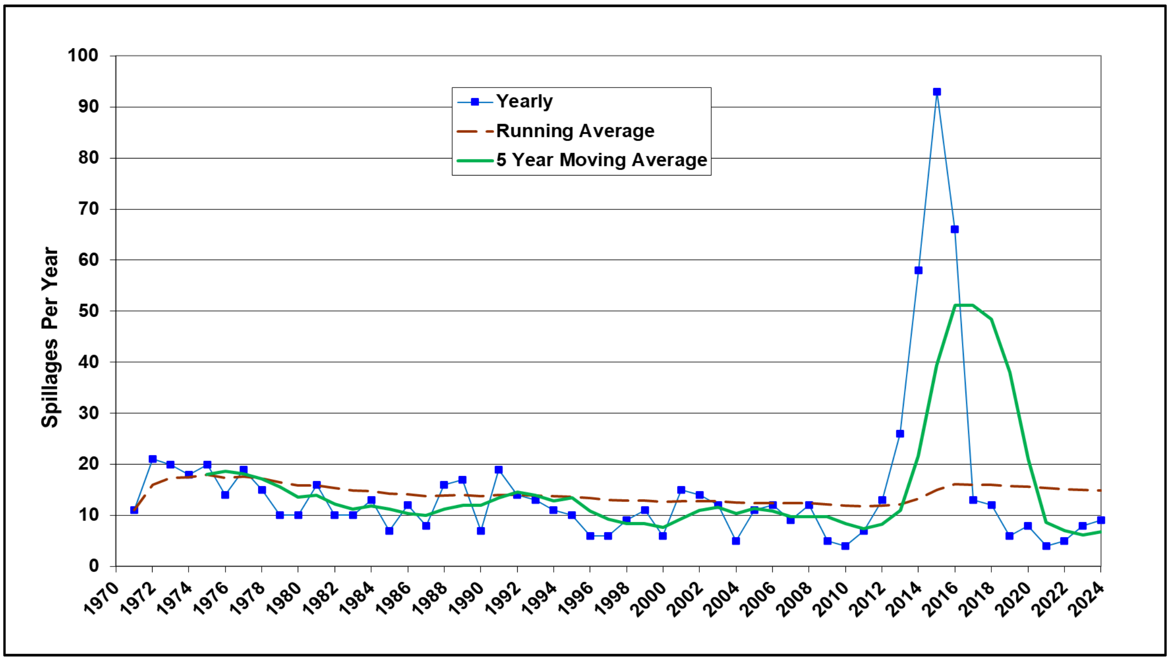
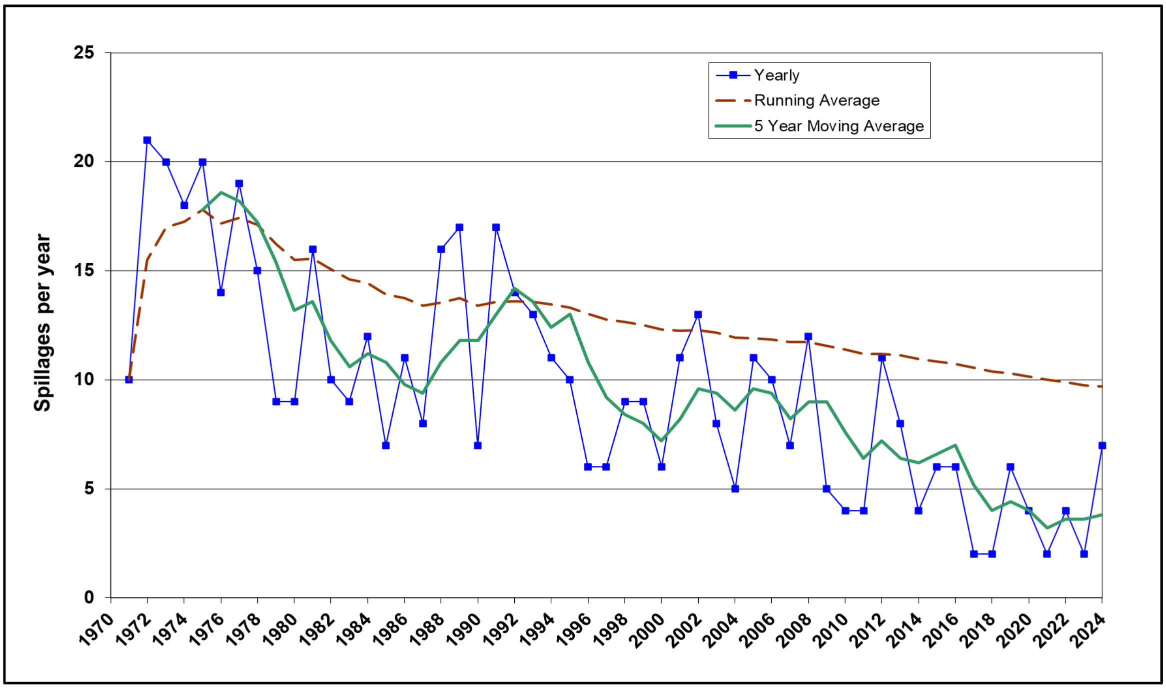


Figure 4b 54-year trend of the total annual number of spillages (all pipelines)
Excluding theft



Several step changes in the inventory surveyed by Concawe over the years make the absolute numbers difficult to interpret. The spillage frequency, i.e. number of spills per unit length of pipeline, is therefore a more meaningful metric. **Figure 5a/b** shows the same data as **Figure 4a/b**, now expressed in spillages per 1000 km of pipeline (as per the reporting inventory in each year). **Figure 5b** shows that the 5-year moving average spillage frequency dropped from around 1.1 in the mid '70s to 0.22 spills per year and per 1000 km of pipeline by 2024. When theft is included (**Figure 5a**) the 2024 value increases to 0.28.

Figure 5a 54 -year trend of the spillage frequency (all pipelines)
Including theft

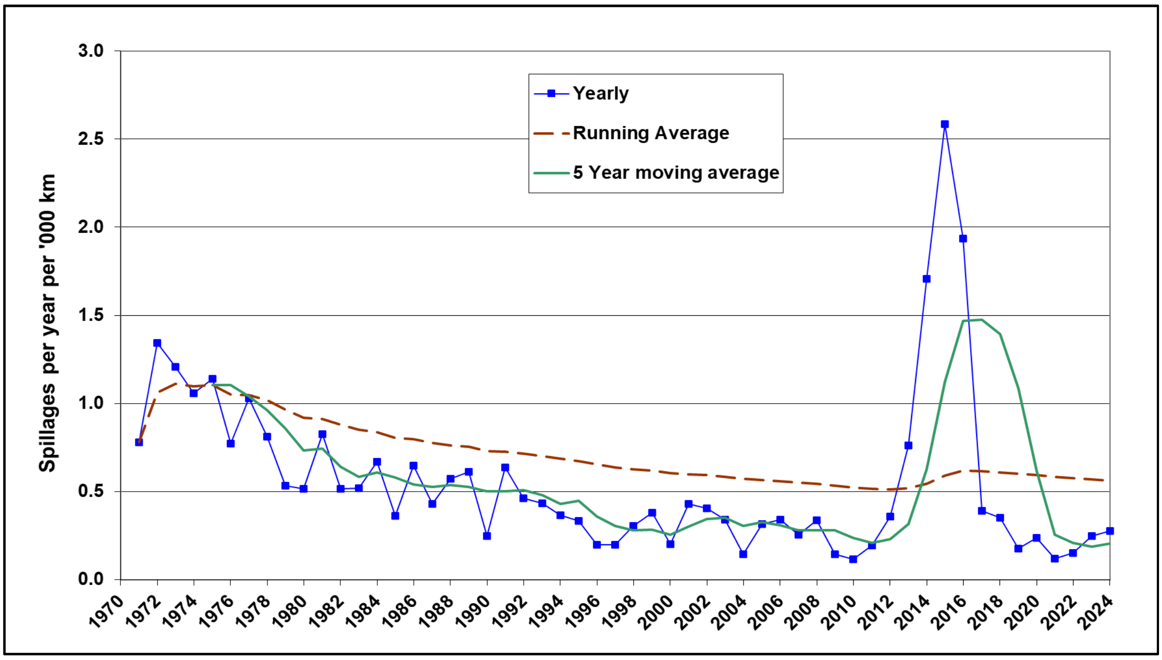
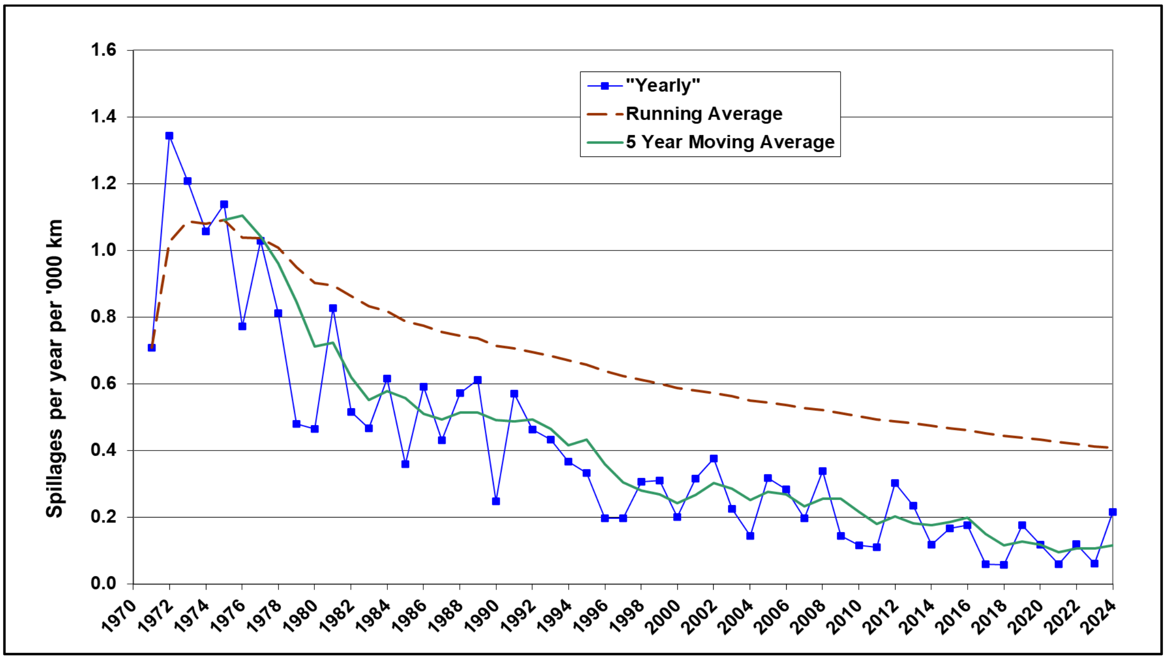
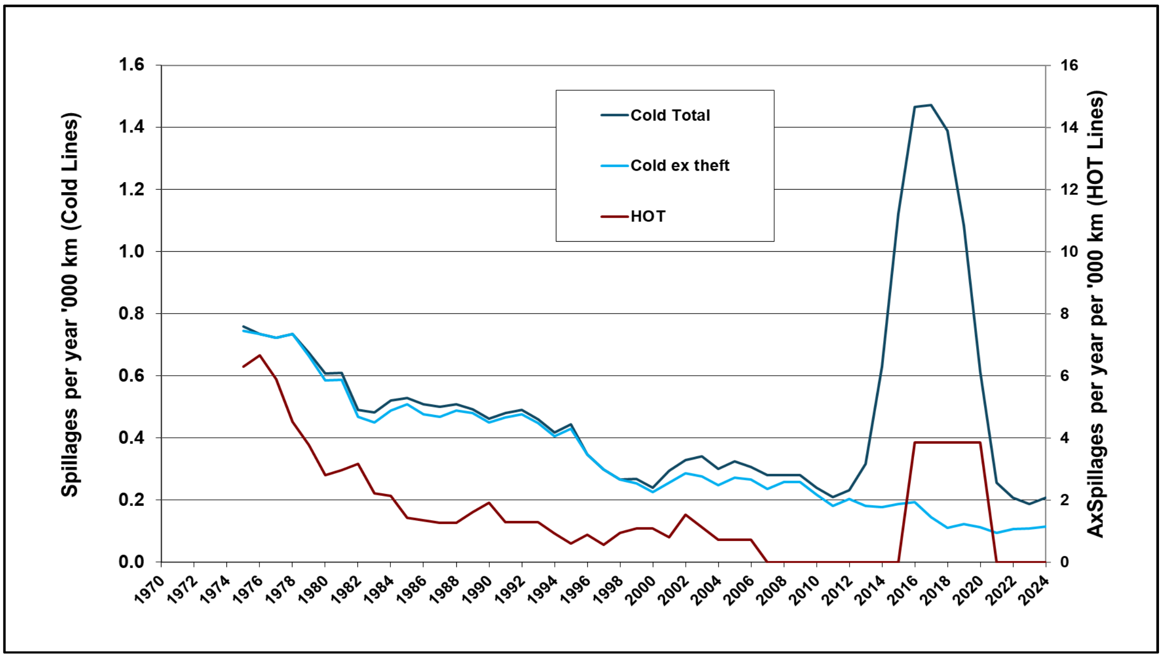


Figure 5b 54-year trend of the spillage frequency (all pipelines)
Excluding theft



These overall figures mask the poorer performance of hot pipelines (related to corrosion issues, see **Section 5.1**), particularly in the early part of the period. This is illustrated in **Figure 6** which shows the spillage frequency for hot oil pipelines to be almost an order of magnitude higher than for cold pipelines. Hot oil pipelines have now been almost completely phased out, hence the low frequency in recent years.

Figure 6 5-year moving average of spillage frequency (hot and cold pipelines)



Figures 7 and **8** show the evolution over 5-year periods of the spillage frequency for hot and cold pipelines respectively, now broken down according to their main cause. For cold pipelines we have presented the figures with (**Figure 8a**) and without theft-related events (**Figure 8b**).

The hot pipeline spillage frequency starts from a much higher base than is the case for the cold pipelines, with a very large proportion of spillage incidents being due to corrosion. In the 1970s and early '80s several hot pipelines suffered repeated external corrosion failures, due to design and construction deficiencies. They were gradually shutdown or switched to clean (cold) product service, greatly contributing to the remarkable performance improvement. There were 3 spillages between 1996 and 2000, one in 2002 and one in 2016. Recent frequency figures are strongly skewed by the 2016 event and are thus not statistically meaningful.

When the hot pipeline data are excluded, the cold pipelines show a somewhat slower improvement trend than for the total data set. Nevertheless, the frequency of spillages has been reduced by nearly three quarters over the last 51 years (when excluding theft). This statistic best represents the performance improvement achieved by the operators of the bulk of the pipeline systems covered in Concawe.

For cold pipelines we have shown theft-related events separately. When excluding theft, there is a gradual decrease in the overall frequency, albeit with a more complex picture when looking at the individual cause categories. Although third party activities (excluding theft) have historically by and large been the most prevalent cause of spillage, there have been relatively few cases in recent years so that the cause structure has become more balanced. Mechanical causes increased during the last decade to be on a par with non-theft third party causes but this trend appears to have reversed in the last few years. Corrosion is a much less prevalent cause of failure for cold than hot pipelines although the frequency has increased in recent years. A more complete analysis of causes is given in **Section 6**.

Figure 7 Hot pipelines spillage frequencies by cause

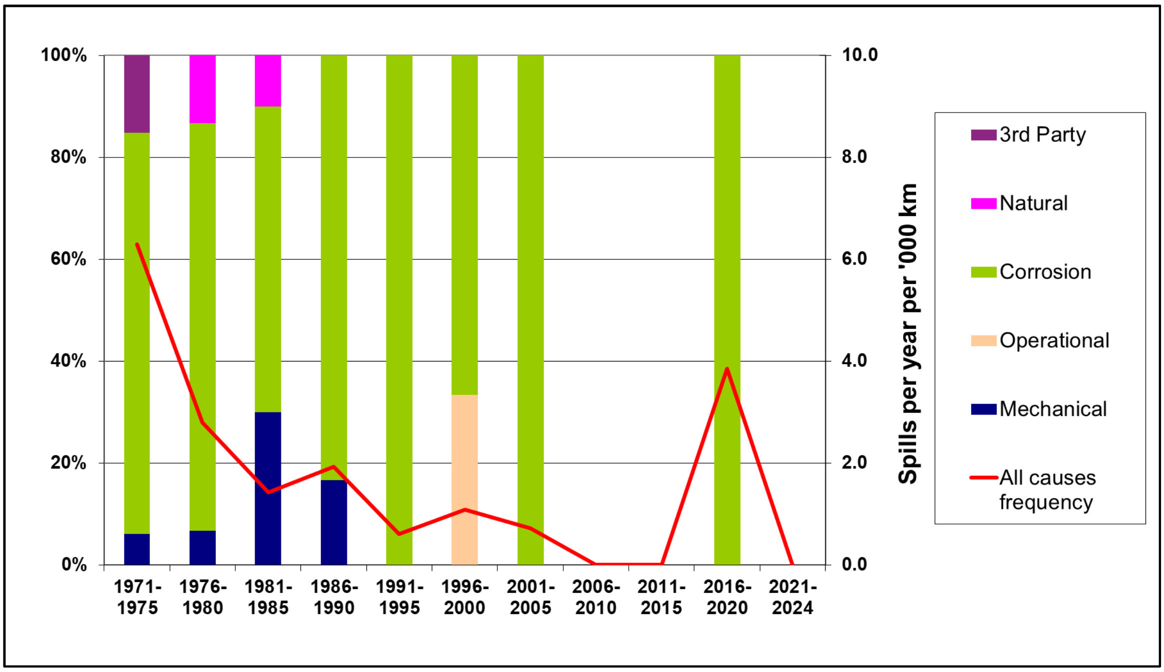


Figure 8a Cold pipelines spillage frequencies by cause
Including theft

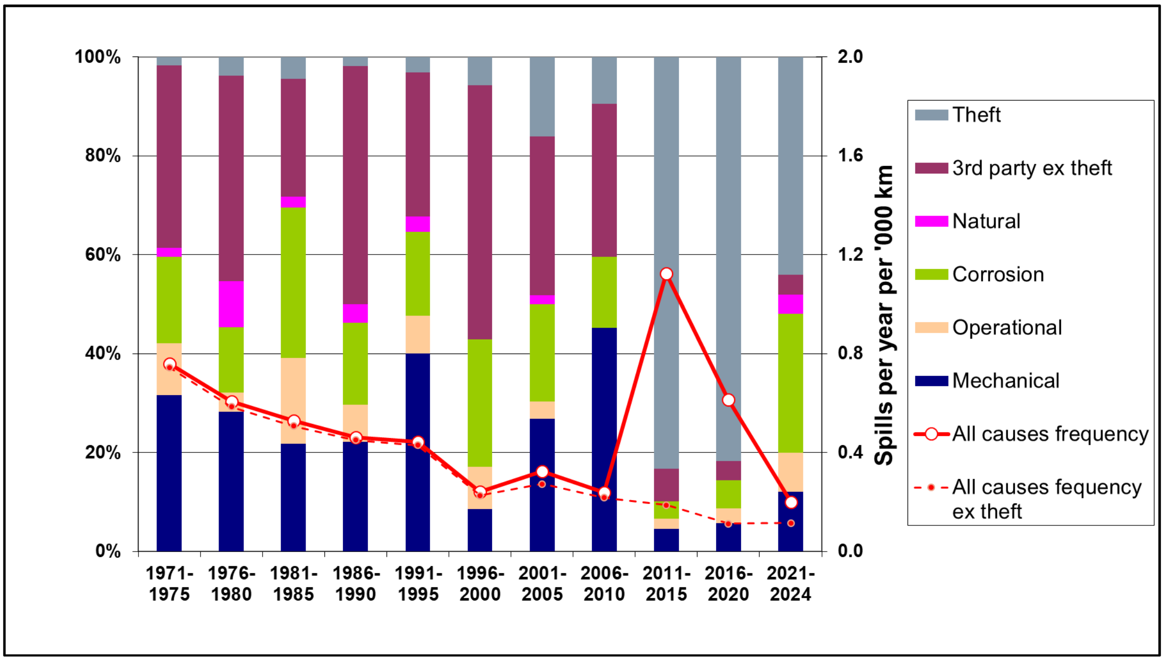
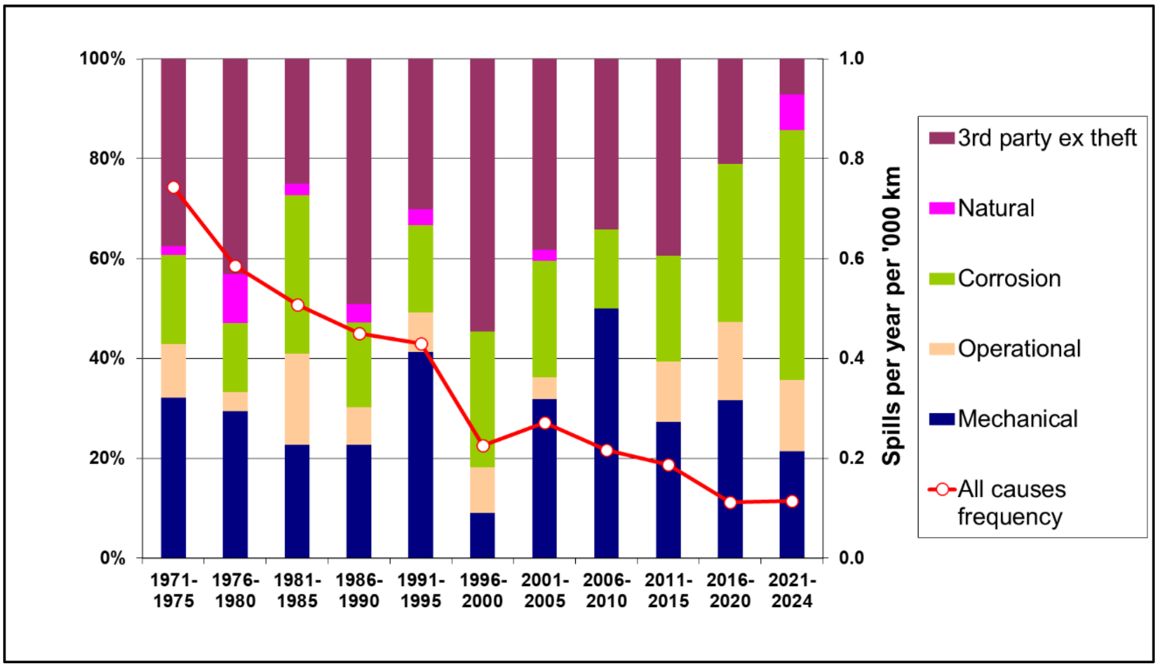


Figure 8b Cold pipelines spillage frequencies by cause
Excluding theft



5.2. SPILLAGE VOLUME

As already noted, spilled volume is generally difficult or impossible to determine in the case of theft-related events, as spillage may have occurred over a period of time and one cannot determine how much was spilled or indeed how much was stolen. **This section therefore excludes theft-related incidents.**

5.2.1. Aggregated annual spilled volume

Figure 9 shows the total reported gross spillage volume over the complete period, year by year and in terms of running and 5-year moving average. The same data is shown per 1000 km of pipeline in **Figure 10** and as a proportion of throughput in **Figure 11**. Although there are fairly large year-to-year variations mostly due to a few very large spills that have occurred randomly over the years, the long-term trend is clearly downwards, probably a consequence of the lower number of spills per year. Over the last 5 years, the gross pipeline spillage has averaged 0.3 parts per million (ppm) of the oil transported.

Figure 9 Gross spillage volume (excluding theft)

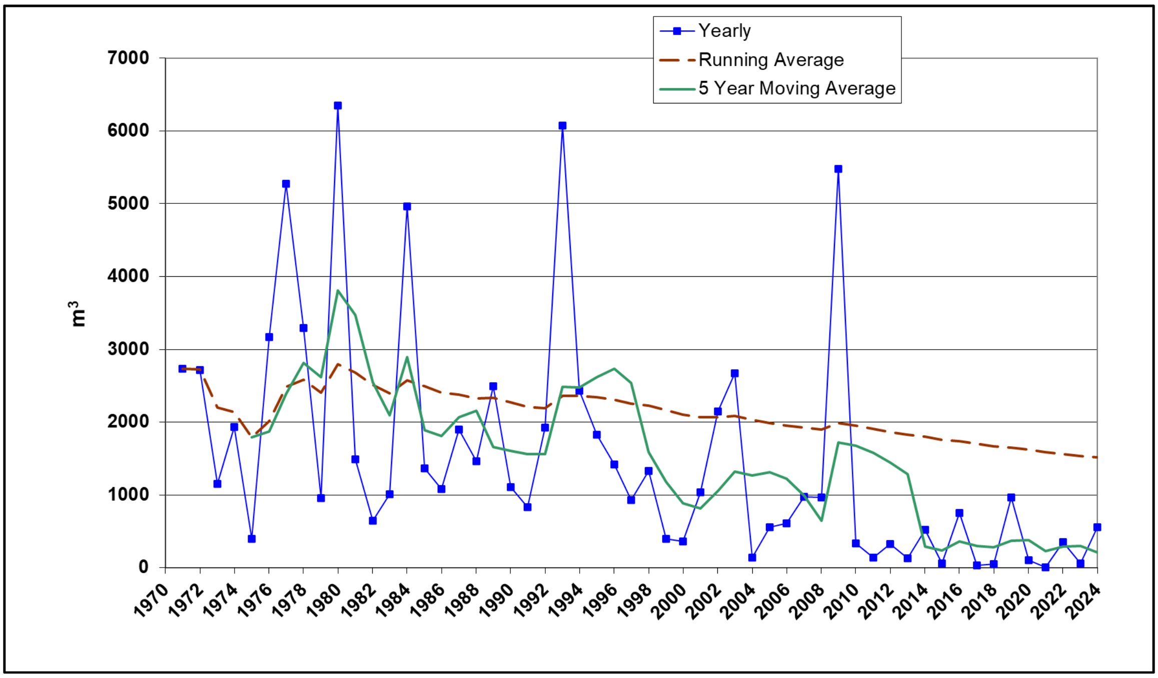


Figure 10 Gross spillage volume per 1000 km (excluding theft)

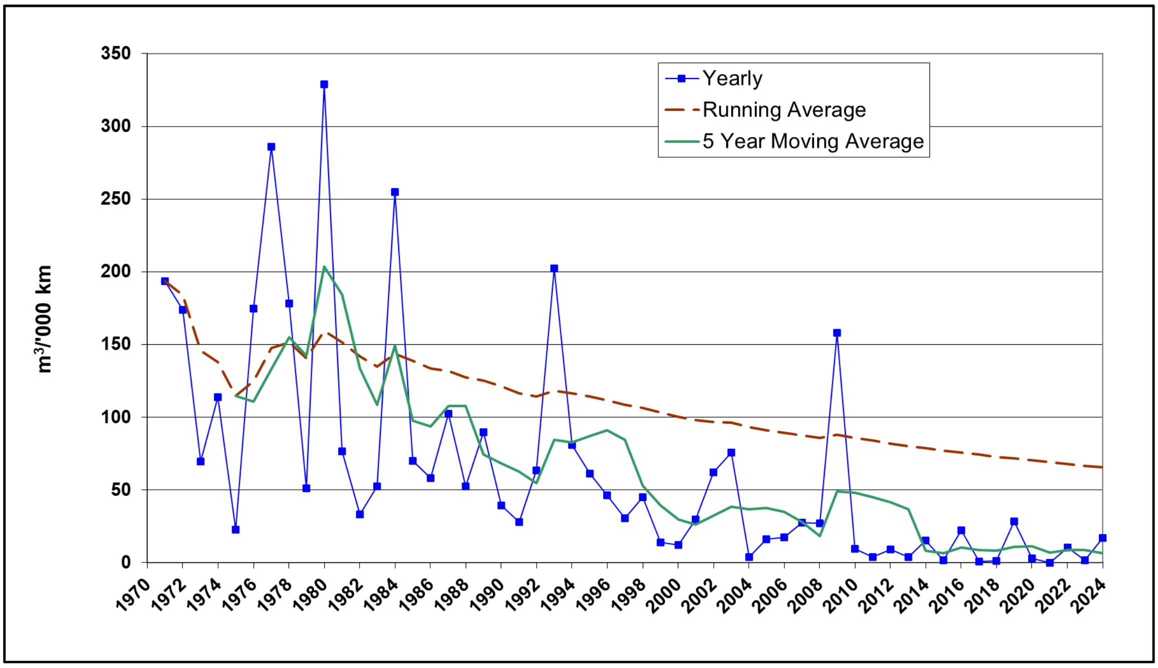
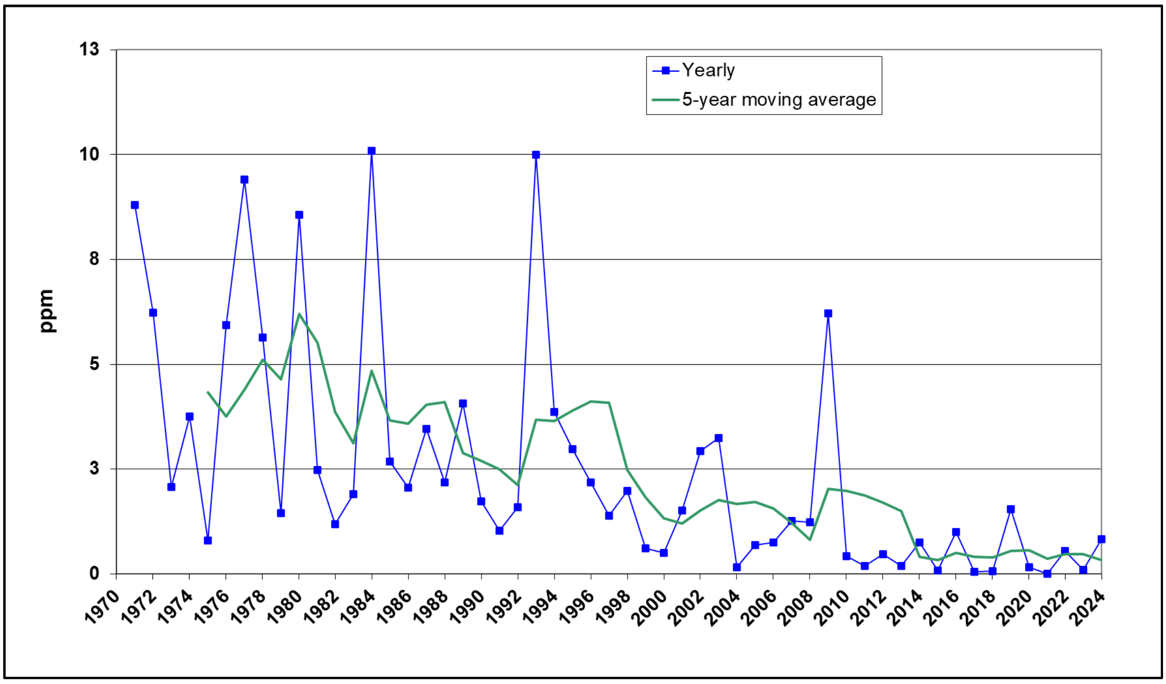


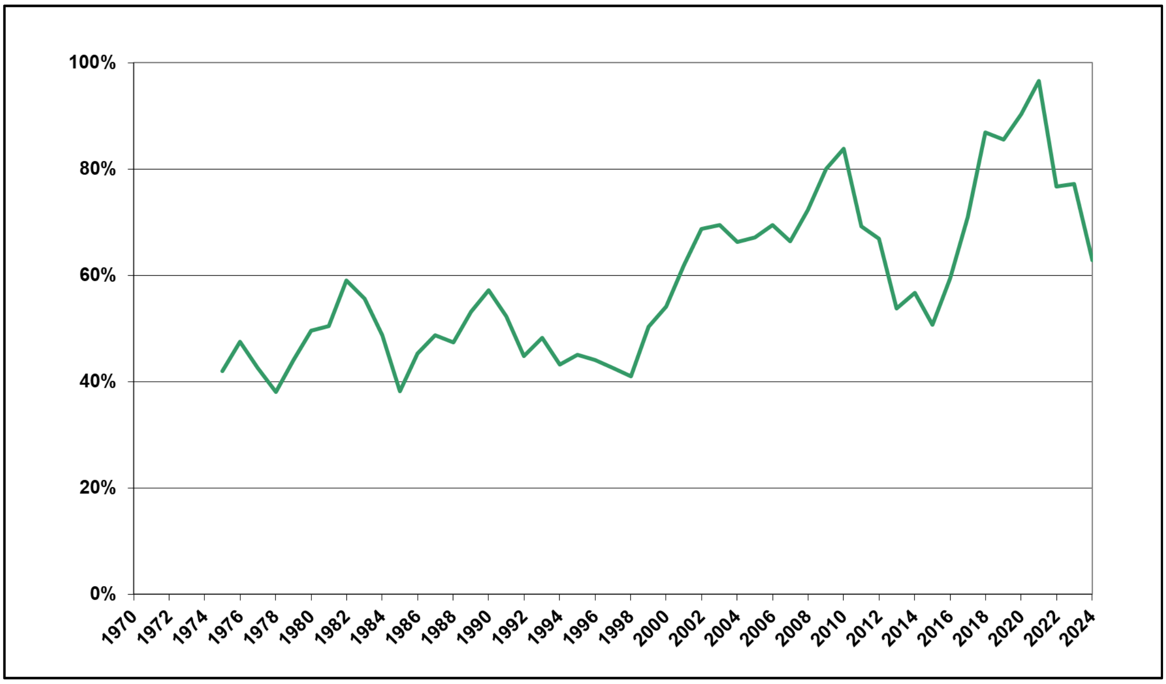
Figure 11 Gross yearly spillage volume as a proportion of throughput (excluding theft)



The spilled volume recovery rate ((gross-net) / gross) varies greatly from year to year and can be skewed by the large spills that have occurred from time to time. **Figure 12** shows that the 5-year running average fluctuates roughly between 40% and 80%. Over the whole period, the average recovery of spilled oil is 60%.

Although it might be expected that the trend in the annual oil recovery would indicate the degree of success in improving clean-up performance, this is not necessarily the case. Maximum removal by excavation of contaminated soil is not always the correct response to minimise environmental damage and this is now better understood than it once was. Another compounding consideration is that the growth in the pipeline inventory has been predominantly for refined product pipelines and it can be assumed that less invasive recovery techniques are justified for white oil products than for fuel oil or crude oil to achieve a given visual and environmental standard of clean-up.

Figure 12 Spilled oil recovery (5-year moving average) (excluding theft)



5.2.2. Spillage volume per event

The gross volume released is one of the measures of the severity of a spillage incident. While a large proportion of spills involve small volumes, one or a few events involving large volumes can have a very large impact on the annual as well as long term averages so that trends can be difficult to discern.

From the turn of this century, the 5-year moving average of the gross volume spilled per event had consistently been lower than the long-term average of 154 m^3 per spill. A single very large spill recorded in 2009 pushed up this figure to 191 m^3 per spill for that year and even higher for the 4 subsequent years. In spite of a relatively large spill recorded in 2019 the current figure is still relatively modest at 44 m^3 per spill. It can be expected that improved monitoring of pipelines and the more general use of improved and automated leak detection systems will lead to a reduction in spill sizes. There is insufficient data on record to establish any trend in the speed of detection or the response time to stem leakages.

Figure 13 shows a modest reduction in the gross spilled volume 5-year moving average over time, with superimposed large year-by-year variations. This indicates that the long-term reduction in total spilled volume (c.f. **Figure 9**) is mainly due to a reduction in the number of incidents, rather than the spill volume per incident. Changes in the mix of spillage causes may also account for this: for example, the proportion of corrosion spillages, which on average are smaller ones, has decreased relative to third party spillages (excluding theft) which tend to be larger (see **Figure 14**).

Figure 13 Yearly gross spilled volume per event (5-year moving average)
Excluding theft

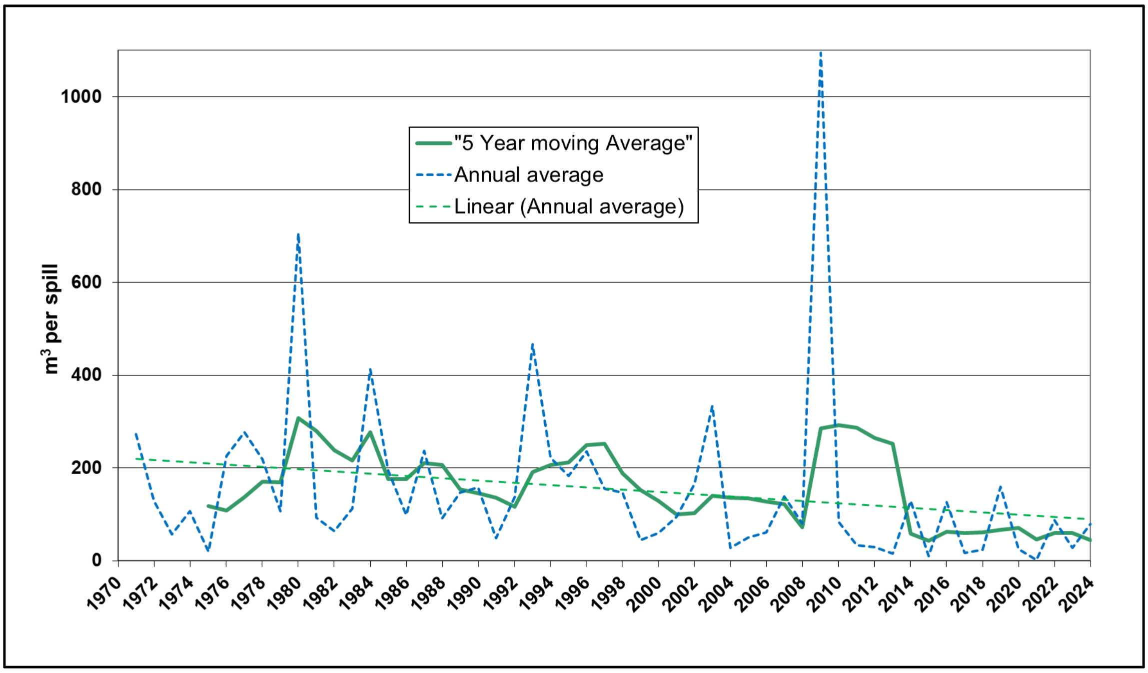
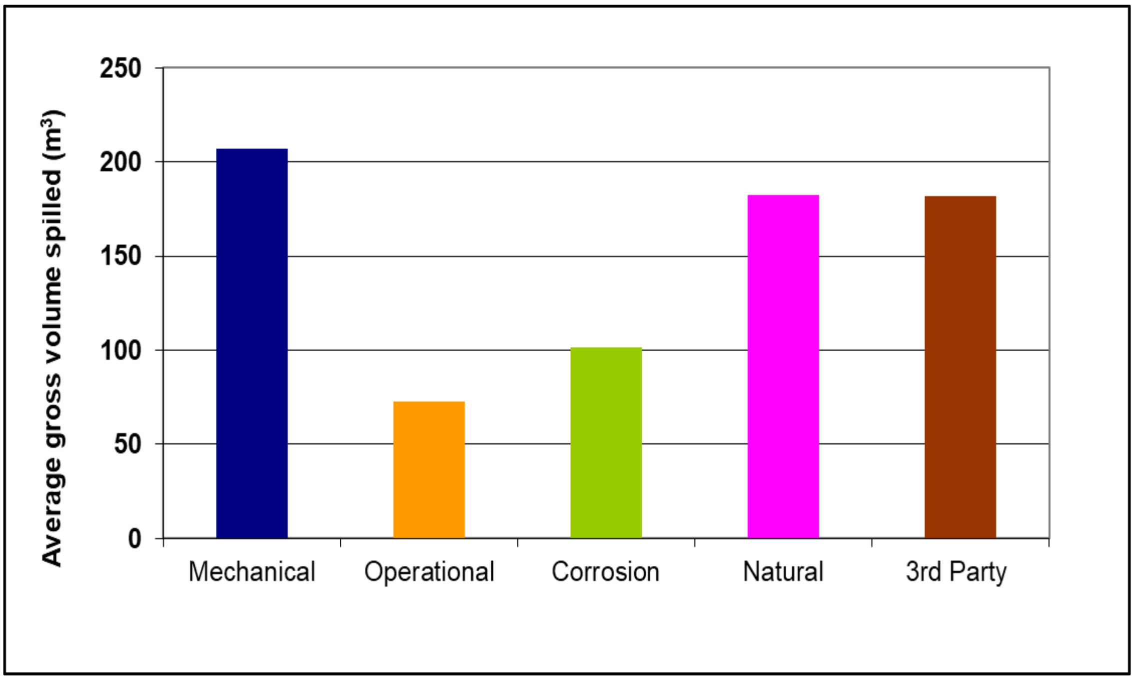


Figure 14 shows the average spill size for each cause category. On average, the largest spillages have resulted from mechanical failure, third party activities and natural hazards, whereas operational problems and corrosion have caused smaller spills. As a rule of thumb, the three "larger spills" categories result in spillages that are twice the size of the two "smaller spills" categories.

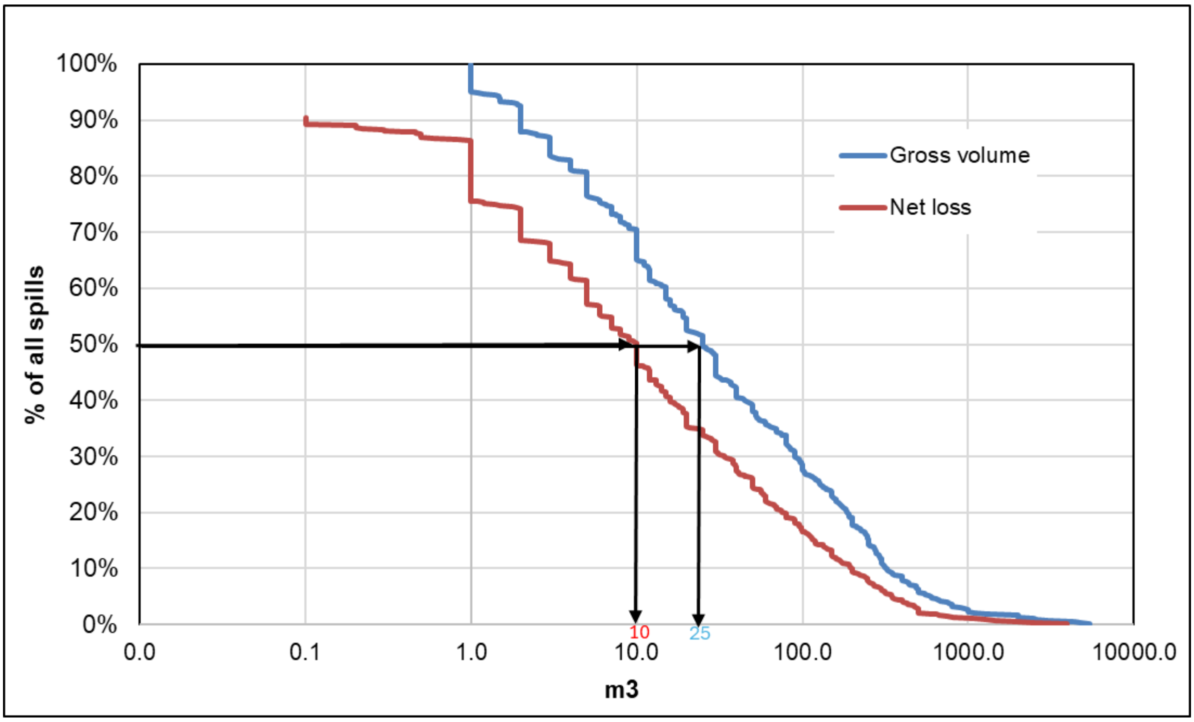
Figure 14 54 -year average gross spillage volume per event by cause
Excluding theft



5.2.3. Distribution of spillage sizes

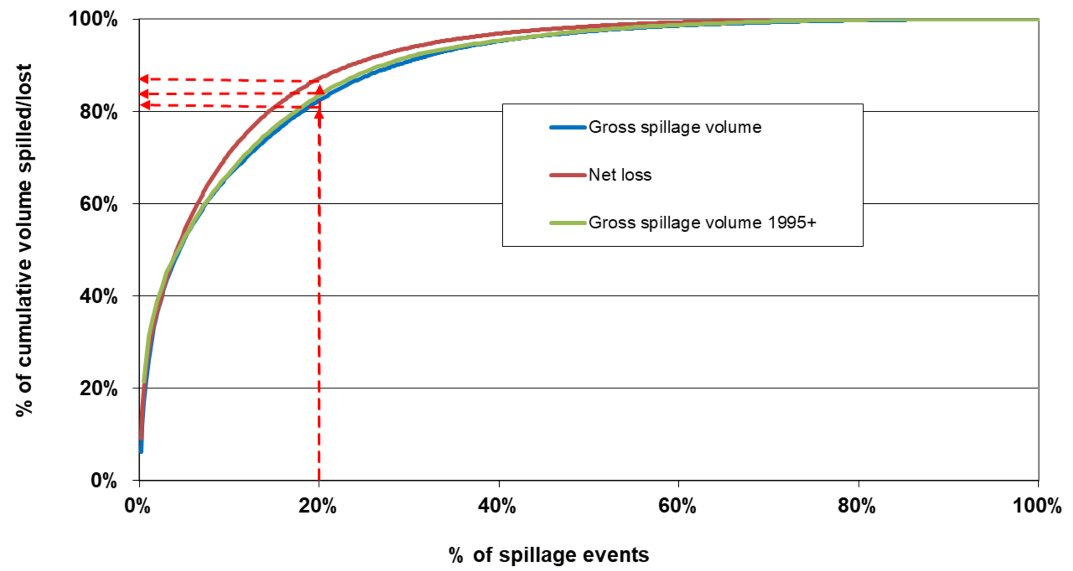
The distribution of spillage sizes is illustrated in **Figure 15a/b.** In 50% of all events the gross volume spilled and net loss were less than 25 and 10 m^3 respectively (**Figure 1a**). In about 5% of all events the gross volume spilled was less than the cut off value of 1 m^3 mentioned in section because of specific circumstances (e.g. some small spillages have contaminated a large area or the cause of the spillage was worth keeping on record). The net loss was less than 1 m^3 in nearly 30% of all cases.

Figure 15a Distribution of gross and net spillage sizes
Excluding theft



A small number of big spills contribute to a large proportion of the cumulative gross volume spilled and net loss (**Figure 15b**). Indeed, 20% of all spillages respectively account for 82% and 87% of the cumulative gross and net volume spilled, with little change over the years.

Figure 15b Cumulative distribution of gross and net spillage sizes (over 54 years and since 1995)
Excluding theft



5.3. HOLE SIZE

The following definitions have been adopted within this report for classifying hole size:

- No hole = failure of a gasket or seal, or a mechanical breakage in a piece of equipment or fitting other than the pipeline itself,
- Pinhole = less than 2 mm x 2 mm,
- Fissure = 2 to 75 mm long x 10% max of the feature's length,
- Hole = 2 to 75 mm long x 10% min of the feature's length,
- Split = 75 to 1000 mm long x 10% of the feature's length,
- Rupture = >75 mm long x 10% min of the feature's length.

Note that the "no hole" category was only introduced in the mid-00s. Before that time the hole size for such events was reported as "unknown" or left blank.

Hole size data is only available for 387 (48 %) out of the 806 spillages recorded (307 out of 523 or 59 % excluding theft). The corresponding statistics are shown in **Table 3** for all spillages (excluding theft).

Table 3 Distribution of spillages by hole size (excluding theft)

Hole type	No hole	Pinhole	Fissure	Hole	Split	Rupture	Overall
Number of events	19	42	50	78	54	64	307
%	6%	14%	16%	25%	18%	21%	100%
Hole caused by							
Mechanical	14	5	14	14	18	8	73
Operational	4	0	1	2	4	5	16
Corrosion	0	32	13	27	17	6	95
Natural hazard	0	1	2	0	2	2	7
Third party (ex theft)	1	4	20	35	13	43	116
Gross average spillage per event m3	29	45	230	82	230	353	162

Spillages not involving a hole in the lines normally relate to failures of fittings and other ancillary equipment (gaskets, valves, pump seals, etc), hence the strong link to mechanical failures. Pinholes are mostly caused by corrosion. Larger holes are often the result of third-party activities, although corrosion and mechanical failures also take their share. The majority of third-party incidents result in larger holes.

A relationship may be expected between hole size and spilled volume for an operational pipeline on the basis that higher leakage rates arise from larger holes, and because hole sizes are to an extent related to the pipeline diameter, which in turn sets the potential flow rate available for leakage. However, there are many other factors involved, including the pressure in the pipeline, the volume of pipe available to leak after shut in (a/o drain down volume resulting from elevation changes) and the duration between the start of leakage, the leak being detected and pipeline shut in. **Table 3** suggests that there is indeed some correlation between the average gross spillage size and the hole size.

Table 4 shows the evolution of the number of events) by hole type and for 5-year periods. Note that early figures (say before 1985) are not very representative as hole type was not commonly reported at the time. There is no discernible trend.

Table 4 Number of spills by hole size

Number of Events	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2024
No hole	0	0	0	0	0	0	0	11	4	3	3
Pinhole	0	5	2	2	4	2	7	6	9	6	5
Fissure	1	6	4	7	6	7	6	3	14	0	2
Hole	1	3	8	13	11	16	22	10	33	18	7
Split	0	12	8	11	7	3	7	1	3	2	1
Rupture	0	5	6	8	13	5	9	10	4	4	1
Not reported	88	37	28	19	26	5	6	1	8	5	7
Total	90	68	56	60	67	38	57	42	75	38	26

Note: total figures exclude multiple theft events for which no details are available

5.4. PART OF FACILITY WHERE SPILLAGE OCCURRED

Table 5 shows this data expressed in both percentage of all spills within each category and percentage of all reported events (non-theft related). 61% of all non-theft related leaks and 86% of theft-related incidents occur in underground pipeline sections, which form a major part of the overall pipeline system.

However, particularly for Mechanical and Operational causes, a sizeable proportion of incidents are related to valves, flanges, joints and small-bore connection failures indicating that these and other fittings are vulnerable items. Adding seemingly useful features such as more section block valves, instrument connections or sampling systems can therefore potentially have a negative impact on spillage frequency. Small bore lines are also associated with a higher spillage frequency because they are mechanically vulnerable and often subject to corrosion. Wherever possible, these more vulnerable features should be designed out of the pipeline system.

Table 5 Part of facility where spillage occurred, by main cause

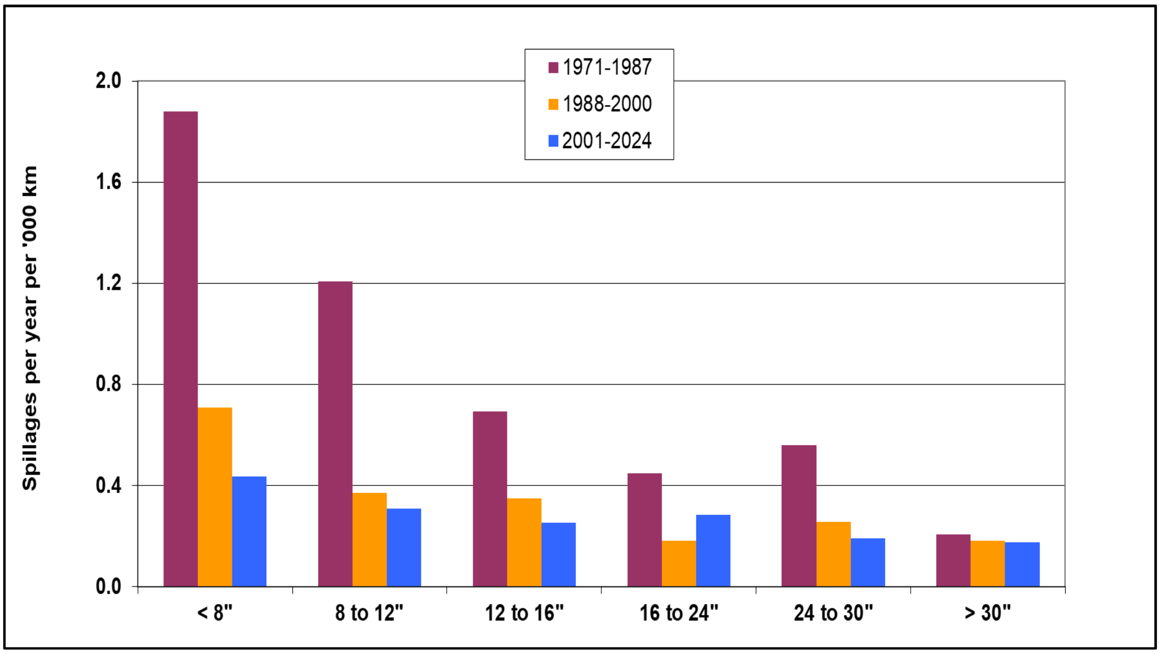
	Total	Bend	Joint	Pipe run	Valve	Pump	Pig trap	Small bore	Not reported
Mechanical	*143*	7.0% *1.9%*	32.2% *8.8%*	24.5% *6.7%*	14.7% *4.0%*	2.8% *0.8%*	1.4% *0.4%*	11.2% *3.1%*	6.3% *1.7%*
Operational	*40*	2.5% *0.2%*	5.0% *0.4%*	15.0% *1.1%*	30.0% *2.3%*	2.5% *0.2%*	10.0% *0.8%*	15.0% *1.1%*	20.0% *1.5%*
Corrosion	*152*	0.7% *0.2%*	6.6% *1.9%*	86.2% *25.1%*	0.0% *0.0%*	0.0% *0.0%*	0.7% *0.2%*	2.6% *0.8%*	3.3% *1.0%*
Natural	*16*	0.0% *0.0%*	6.3% *0.2%*	81.3% *2.5%*	0.0% *0.0%*	0.0% *0.0%*	0.0% *0.0%*	12.5% *0.4%*	0.0% *0.0%*
3rd party (ex theft)	*171*	0.6% *0.2%*	1.2% *0.4%*	93.0% *30.5%*	0.6% *0.2%*	0.0% *0.0%*	0.0% *0.0%*	1.8% *0.6%*	2.9% *1.0%*
All (ex theft)	522	*2.5%*	*11.7%*	*65.9%*	*6.5%*	*1.0%*	*1.3%*	*5.9%*	*5.2%*
3rd party (theft)	*283*	0.0%	0.4%	79.9%	11.3%	0.0%	0.0%	0.7%	7.8%

Percentages in italic are related to the total of all non-theft -related events

5.5. SPILLAGES PER DIAMETER CLASS

In **Figure 16** the spillage frequency has been calculated for the average length of each diameter class for the periods 1971 to 1987, 1988 to 2000 and 2001 to 2024. These periods have been chosen because of the major change in the reported pipeline inventory between 1987 and 1988 following the inclusion of the non-commercially owned pipelines and from the beginning of this century when a number of Eastern European pipelines operators joined the survey.

Figure 16 Spillage frequencies per diameter class



Clearly smaller pipelines are more liable to develop leaks than larger ones. A number of possible reasons for this could be postulated, but there is no way of determining from the available data what each risk-increasing factor might contribute. Depth of cover, pipeline diameter and wall thickness could be factors but we have no data that could indicate a relationship between these parameters.

5.6. ENVIRONMENTAL IMPACT

5.6.1. Land use where spillage occurred

We differentiate between spillages occurring either in the pipeline itself or in pumping stations and also record the type of land use in the area. Not surprisingly, most incidents occurred in the cross-country pipelines themselves (81% in underground lines). The type of location has been reported for a total of 542 spillages (out of 806). The results of this analysis are provided in **Table 6**.

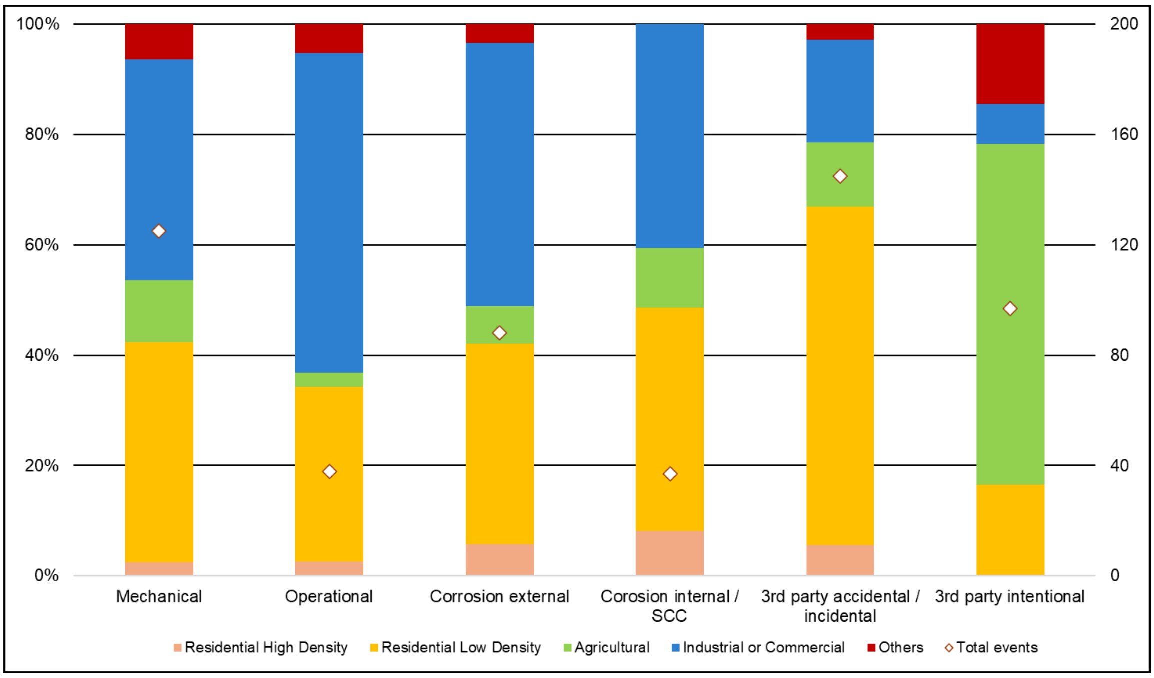
While we do not have statistics for the length of pipeline installed for each land use type, it is clear that the number of spillages in commercial and industrial areas is higher than would be expected from consideration of installed length alone. Evidently, the vulnerability of the pipelines is significantly increased in such areas by a factor of possibly as much as ten compared to other areas. The majority of the spillages from pump stations occur in industrial/commercial areas simply because this is where most of them are located.

Table 6 Location of spillage incidents

	Underground pipe			Above ground pipe		Pump Station	
	Number	Crude/ Product	%	Number	%	Number	%
Residential high density	18	3/15	4%	2	5%	0	0%
Residential low density	201	55/146	46%	12	28%	9	14%
Agricultural	93	8/85	21%	4	9%	5	8%
Industrial or commercial	91	25/66	21%	22	51%	52	79%
Forest, Hills	21	3/18	5%	1	2%	0	0%
Barren	6	2/4	1%	0	0%	0	0%
Water body (near)	3	0/3	1%	2	5%	0	0%
Total	433			43		66	
Unspecified	263						

Figure 17 shows the same data now split by main cause category. For all categories, most spillages occur in either industrial, commercial of low-density residential areas, except for third party intentional (theft) for which, not entirely surprisingly, agricultural land is the preferred target area.

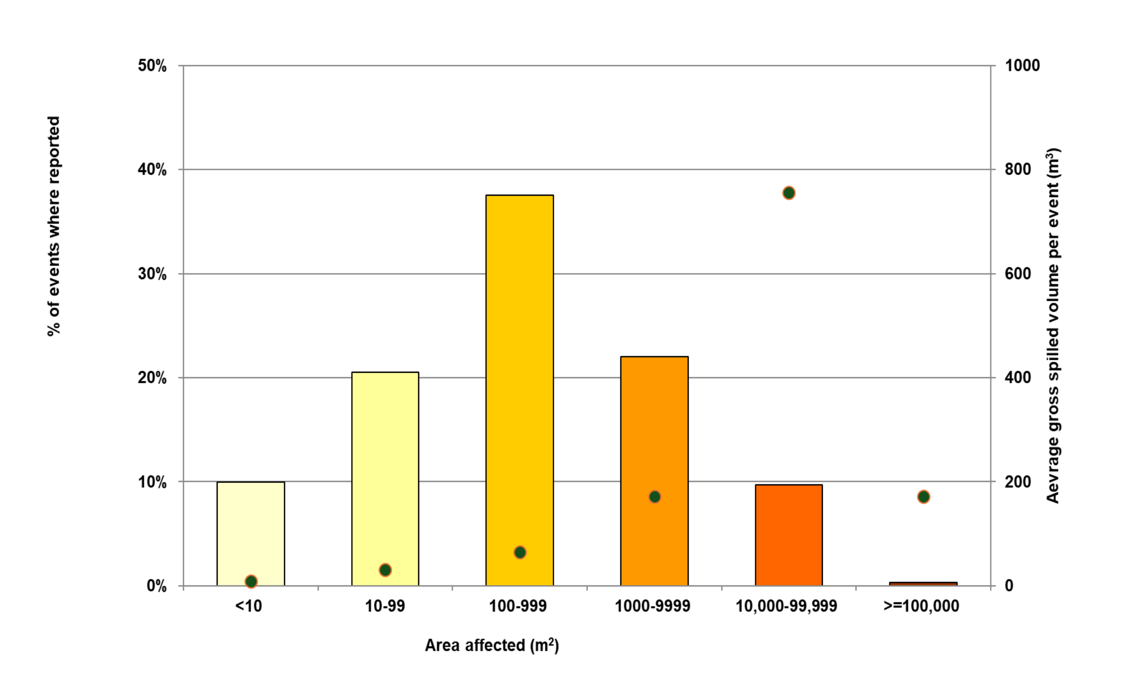
Figure 17 Spillages by cause and land use



5.6.2. Ground area affected

The current Concawe pipeline performance questionnaire, in use with minor changes since 1983, requests reporting of the area of ground (m^2) affected by the spillage. Before that date, area data were reported infrequently. Area data is available for 341 events (42% of all recorded spillages). For these events, the percentages that fall within the area ranges are shown in **Figure 18** together with the average spill size for each category.

Figure 18 Ground area (m^2) affected by spillages (% of number reporting)



In the history of the survey only one spillage affected more than 100,000 m^2, although the gross volume spilt was relatively modest (172 m^3). For all other spillages, there appears to be a direct relationship between spill size and area affected, with the area affected increasing slowly at first and then more rapidly where the average spill volume exceeds 100 m^3. This suggests that very large spills behave differently from smaller releases, which could happen, for example, if product escaping at a high flow rate was to migrate across the surface, rather than in the subsurface.

It should be noted that small spilled volumes can affect larger areas at the surface if fine sprays are directed upwards and spread around by winds, or if material is spread over larger areas by flowing water. Conversely, comparatively large spills, particularly those that occur over extended periods of time and in the lower quadrants of the pipeline circumference, can have their main effect underground with relatively little impact on the surface. Porous ground and hot, arid conditions can also lead to the surface consequences being limited.

5.6.3. Impact on water bodies

The Concawe survey records whether spillages had consequences for the abstraction of potable water. 14 spillages, representing 1.7% of the total, have had some effect. It is understood that all of these effects have been temporary.

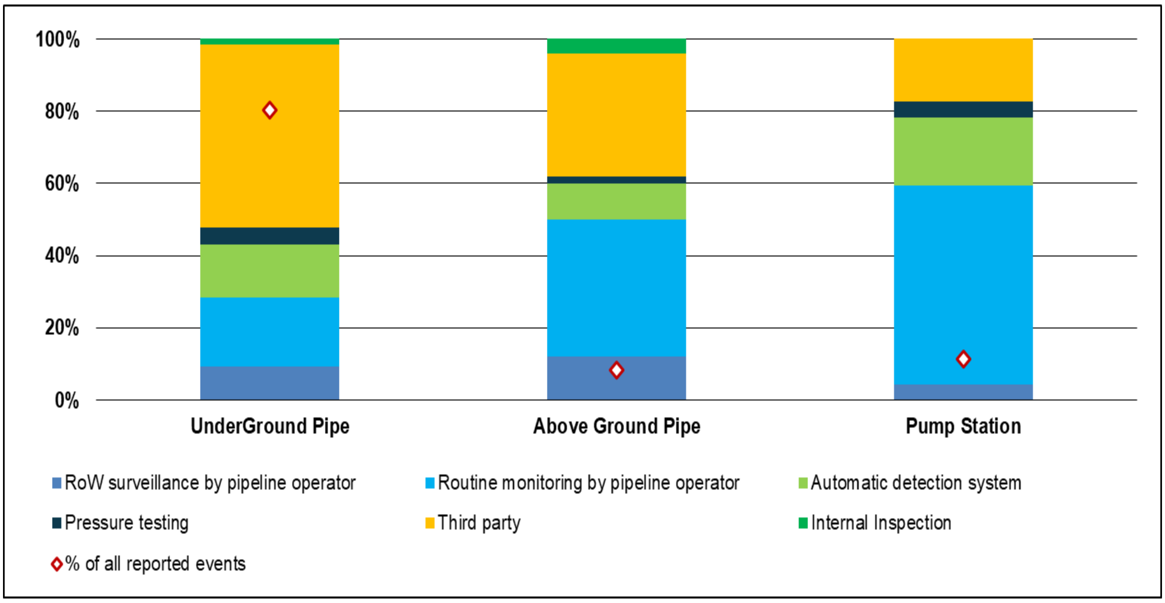
Since 2001 impacts on other types of water have been included. Of the 427 reported spillages since then, 20 have affected surface water, 18 have affected ground water but only 2 have impacted potable water supplies. In 2024 none were reported.

5.7. SPILLAGE DISCOVERY

The way in which the occurrence of a spillage was detected is reported in 6 categories (**Figure 19**) and for three types of facility.

In above ground facilities, including pump stations, the majority of leaks are detected by pipeline company resources presumably because they tend to be located in areas where personnel are more routinely present. This is especially the case for pumping stations.

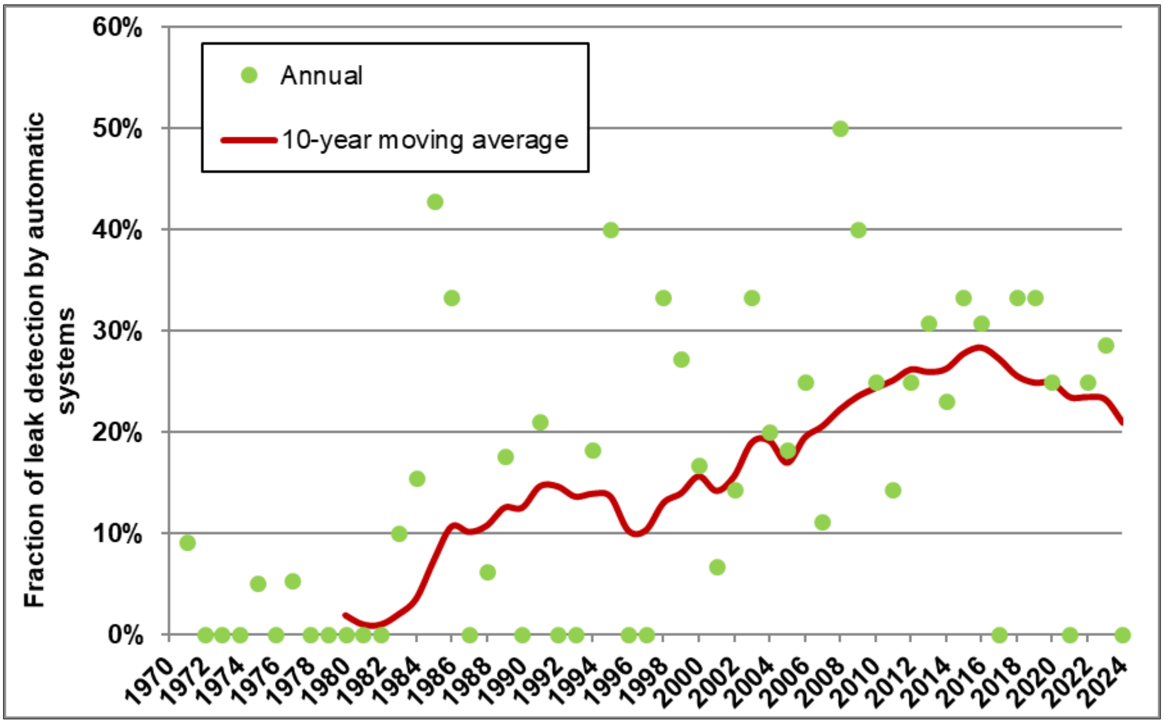
Figure 19 Discovery of spillages



Underground pipeline leaks were most commonly first detected by a third party (51%), sometimes by those who caused the incident in the first place. This underlines the importance of our efforts in involving stakeholders as landowners in our activities.

Automatic leak detection systems (LDS) were involved in detecting only 15% of those spillages. Although this may seem a rather small proportion, one has to realise that third parties are often on the scene when the leak occurs. As the technology improved and more such systems were installed, their effectiveness and contribution increased. Indeed, over the last 10 years 24% of underground spills were discovered via leak detection systems. This is further illustrated in **Figure 20**. Although the annual percentage shows considerable variation, the 10-year moving average clearly shows an upward trend towards almost 30% in the proportion of all spills discovered via LDSs until 2016, but the last years declining to about 20%, because of reduction in leak sizes. It worth mentioning that generally speaking, leak size has decreased making it more challenging for leak detection systems.

Figure 20 Proportion of all annual spillage discovered via leak detection systems

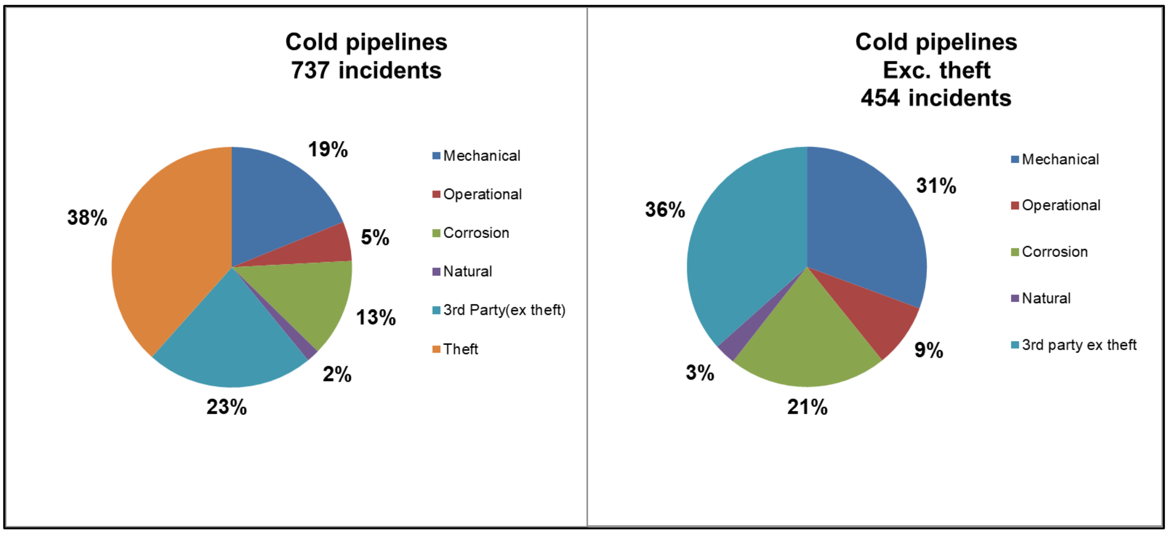


6. DETAILED ANALYSIS OF SPILLAGE CAUSES

Concawe traditionally classifies spill causes into five major categories: mechanical failure, operational, corrosion, natural hazard and third party. These are then further divided into sub-categories (see definitions in **Appendix 1**). As discussed in the previous chapter theft-related incidents are now shown separately, as a sixth main category. The survey returns provide more detailed information on the actual cause and circumstances of spillage incidents and these are analysed in this section.

As already discussed in **Section 5**, the causes of spillage incidents are different for hot and cold pipelines. For hot oil pipelines spillages are mainly corrosion related (81%), whereas for cold pipelines mechanical problems and third-party activities dominate, with corrosion accounting for only 13% of the total (21% when excluding theft). This is illustrated in **Figure 21**.

Figure 21 Distribution of major spillage causes for cold pipelines



Figures 22 and **23** further show the distribution of primary and secondary causes, for all pipelines and for cold pipelines respectively, illustrating again the prominent impact of corrosion for hot pipelines. Secondary causes are unremarkably distributed except perhaps for the large proportion of accidental causes within third party-related incidents (largely related to excavations).

There is a wider debate regarding the increasing age of the EU pipeline inventory and potential integrity issues related to ageing infrastructure. Of the five main causes of spillage mentioned above, age-related defects are anticipated to play a role in the Mechanical and Corrosion categories and so these are further analysed in **section 6.1 and 6.3** below.

Figure 22 Distribution of major and secondary spillage causes – All pipelines

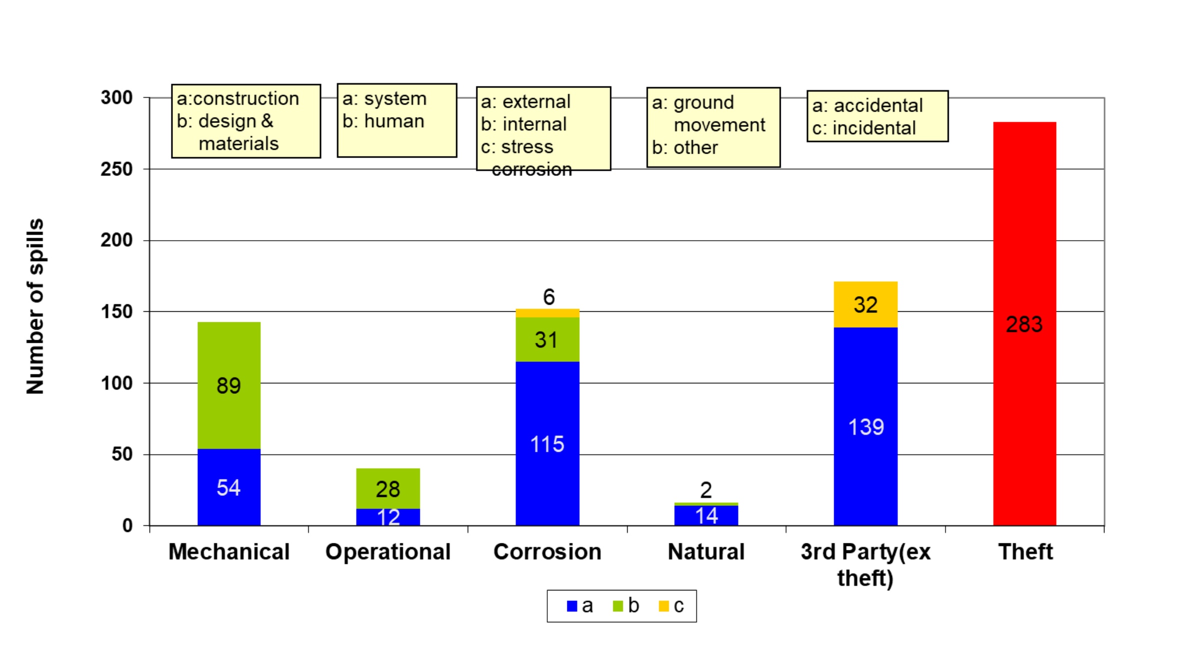
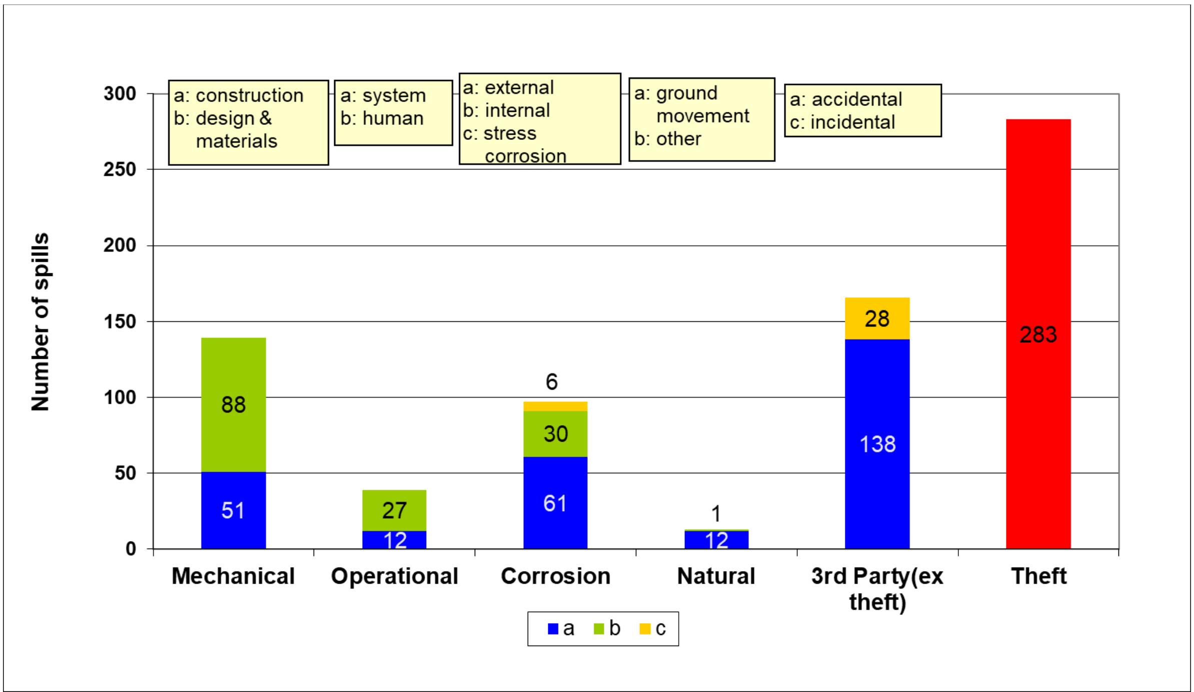


Figure 23 Distribution of major and secondary spillage causes – Cold pipelines



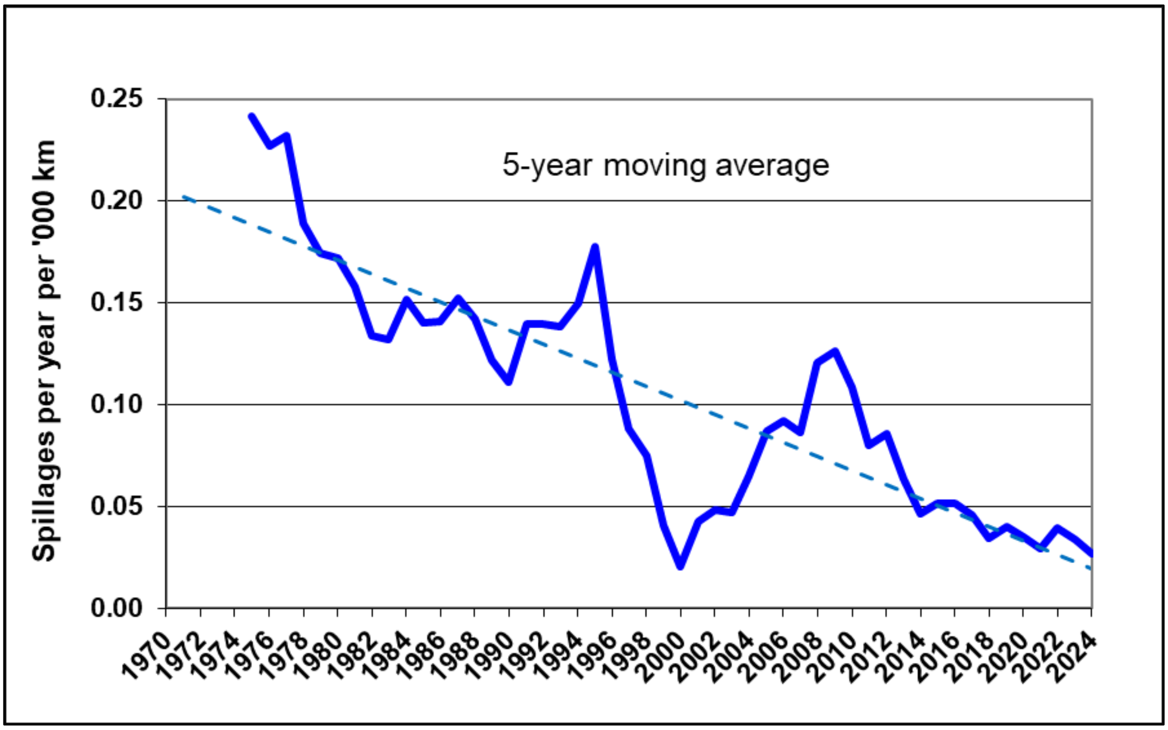
6.1. MECHANICAL

There have been 143 cases of mechanical failure (18% of all spillage events, or 27% excluding theft). This is an average of 2.6 spillages per year. 54 failures were due to construction faults and 89 to design or materials defects.

Note: It is not always straightforward to classify the cause of a spillage. For instance, a number of leaks can be attributed to pipeline damage (e.g. a dent). If it is clear that such damage was caused after the pipeline was installed it is classified as “third party / incidental”. If no such evidence is available, it is classified as “mechanical / construction”.

The 5-year moving average frequency of mechanical failures is shown in **Figure 24**.

Figure 24 Frequency of mechanical failures for cold pipelines



The downward historical trend which appeared to have reversed from the beginning of the century appears to have resumed in the last decade.

Within each of the sub-categories, the most common reasons for mechanical failures are illustrated in **Table 7**.

Table 7 Reasons for mechanical failures

Number of spills due to					
Construction	Faulty weld	Construction damage	Incorrect installation		Not reported
	15	7	15		17
Design & Materials	Incorrect design	Faulty material	Incorrect material specification	Age or fatigue	Not reported
	10	35	3	10	31

The total number of reported age- or fatigue-related failures is low. None of the 10 registered events occurred in the last 10 years.

The increasing occurrence of mechanical failures observed between 2000 and 2010, combined with the appearance of an increase in fatigue-related failures caused some concern as it may have been an indication of the ageing process, defined as the deterioration of the metal structure of pipelines resulting from fatigue caused by normal operation (pressure cycles etc). In order to gain more insight into this point all 34 mechanical failures reported between 2001 and 2010 were further investigated in cooperation with the relevant operators. It was found that only 4 events could be linked with certainty to ageing according to the above definition, a further 7 being undecided because of lack of appropriate information.

The trend has been reversed since the beginning of the last decade which reinforces the view that the frequency of mechanical failures is not directly linked to ageing of the metal structure. This remains, however, an area of focus for the pipeline operators and for Concawe.

6.2. OPERATIONAL

There have been 40 spillage incidents related to operation 5 % of all spillage events, or 8 % excluding theft). This is an average of 0.7spillages per year. 28 incidents were due to human errors and 12 to system faults. The most common reasons for operational incidents are illustrated in **Table 8**.

Table 8 Reasons for operational incidents

Number of spills due to					
System	Equipment	Instrument & control systems			Not reported
	4	3			5
Human	Not depressurised or drained	Incorrect operation	Incorrect maintenance or construction	Incorrect procedure	Not reported
	3	13	5	6	1

6.3. CORROSION

There have been 152 failures related to corrosion 19% of all spillage events, or 29% excluding theft). This is an average of 2.8 spillages per year. As noted earlier though, a large proportion of these events (55) occurred in the more vulnerable hot pipelines and in the early years (with the exception of 1 event in 2016).

For cold pipelines, the number of failures is 97 (12% of the total or 21% excluding theft). The average spillages was 1.8 spillages per year.

The events have been subdivided into external and internal corrosion and stress corrosion cracking (SCC) that was introduced as an extra category in the late 80s. The number of spillages in each sub-category is shown in **Table 9**. Note all but one event in hot pipelines stemmed from external corrosion (in many cases under insulation).

Table 9 Corrosion-related spillages

Number of spills due to			
	Hot	Cold	All
External corrosion	54	61	115
Internal corrosion	1	30	31
Stress corrosion	0	6	6

Internal corrosion is much less prevalent than external corrosion. (24 out of the 30 cold pipeline internal corrosion incidents occurred in crude oil service, although crude pipelines only account for less than a third of the cold pipeline inventory. Thus crude pipelines appear to be more vulnerable to internal corrosion than product pipelines. This is to be expected, as crude oil is more corrosive than refined products. Only one of the pipelines suffering a spill reported that inhibitor was used, one did not report and the others did not use inhibitors.

Although there have only been five Stress Corrosion Cracking (SCC) related spillages to date (plus one re-categorised from external corrosion), these have been relatively large spillages, possibly as a result of the more severe failure mechanisms.

As already mentioned in **Section 5.1**, the number of corrosion- related spillage incidents in hot pipelines has fallen significantly over the years as these have been taken out of service.

In cold pipelines, 29 out of 97 corrosion-related failures were related to special features such as road crossings, anchor points, sleeves, etc. which therefore appear particularly vulnerable.

In cold pipelines, the historical data show a long-term downward trend in the frequency of corrosion-related spillages since the early 1980's, albeit with notable shorter-term peaks and troughs. The relatively high number of cases reported in 2015, 2016 and 2019 (**Figure 25**) elicited some concern that the long-term downward trend might be stalling or even reversing (**Figure 26**), possibly in relation with the increasing age of the network. With three incidents in 2024 the average for the last 10 years is 1.7 event per year, slightly higher than the long-term average. Concawe will be a watching brief on this in the coming years.

Figure 25 Corrosion-related spillages for cold pipelines between 2015 and 2024

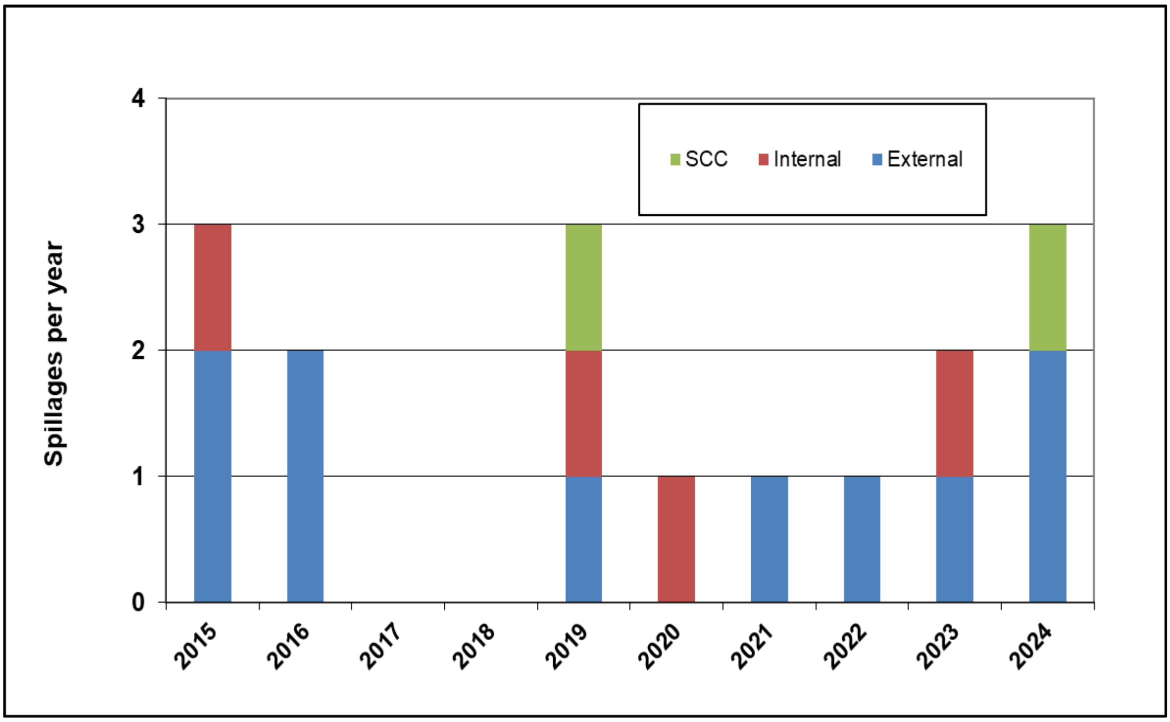
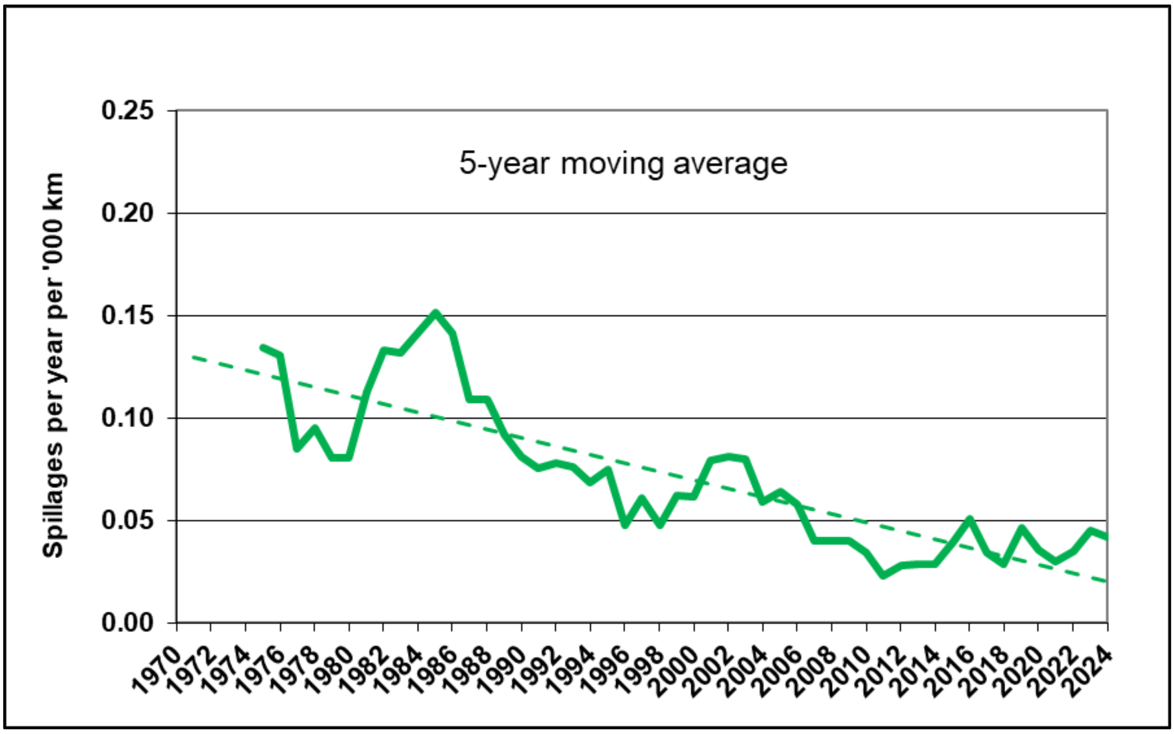


Figure 26 Corrosion-related spillage frequency (all types) for cold pipelines



Pipeline operators undertake regular monitoring to identify and rectify any weaknesses before they develop to the point of failure. Inspection programmes include, for example, the use of in-line tools to monitor pipeline condition and to enable early identification of the onset of corrosion. These techniques, together with the general adoption of integrity management systems by all EU pipeline operators, should prevent any increase in the frequency of age-related spillages.

6.4. NATURAL HAZARDS

There have been 16 spillage incidents related to natural hazards (2%) all spillage events, or (3% excluding theft). This is an average of 0.3 spillages per year. 14 spillages were due to some form of ground movement and 2 to other hazards.

The event that occurred in this category in 2021 caused a very small spill but has been included to highlight the potential impact of floods.

Another significant example is a spill in 2002 on a 24” pipeline, which resulted in approximately 250 m^3 of gross product release.

No less than 10 out of the 14 natural hazards’ spills have occurred in the same country. This appears to be a direct consequence of the difficult terrain and hydrological conditions that apply to a significant part of that country’s pipeline network.

Table 10 Details of natural causes due to ground movement

Number of spills due to					
Ground movement	Landslide	Subsidence	Earthquake	Flooding	Not reported
	5	3	1	4	1

6.5. THIRD PARTY

Third parties have caused the largest number of spillages with 454 events, an average of 8.4 per year and 56% of all spillage events. 139 events were accidental, 32 were incidental i.e. resulting from damage inflicted to the pipeline by a third party at some point in the past, and 283 were intentional (almost exclusively theft attempts). When excluding theft, accidental and incidental third-party events caused 33% of all spills. As discussed in **Section 5,** third party activities also result in relatively large spills and account for the largest total volume spilled of all causes.

6.5.1. Accidental damage

The most common causes of accidental third-party spills are shown in **Figure 27**.

The vast majority of events were caused by direct damage from some form of digging or earth moving machinery. Damage by machinery may occur due to a combination of lack of communication and awareness and lack of care or skill. Pipeline operators are not always made aware of impending groundwork and so cannot provide appropriate advice on exact pipeline location and working procedures or exercise adequate supervision of the work. Even when good communication has been established between the pipeline operator and the third-party company, despite the regular surveillance of the pipeline route the actual machinery operator may be left partially or completely unaware of a pipeline's existence or fail to apply the requisite care or skill.

Figure 27 Causes of accidental third-party spills

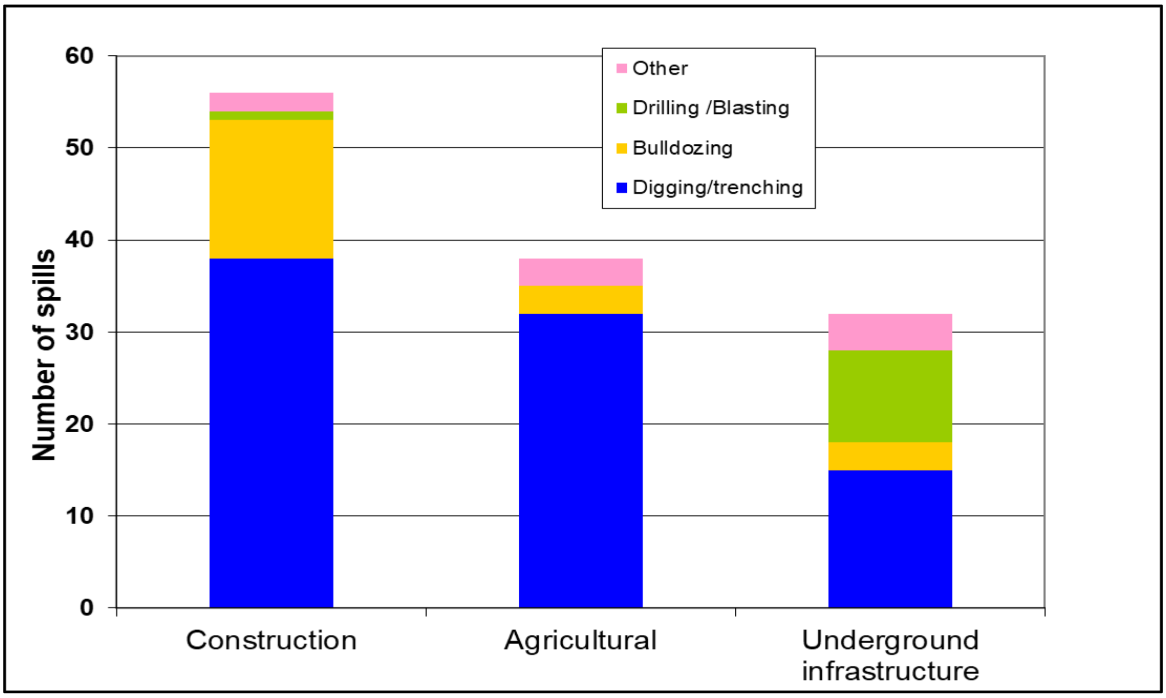
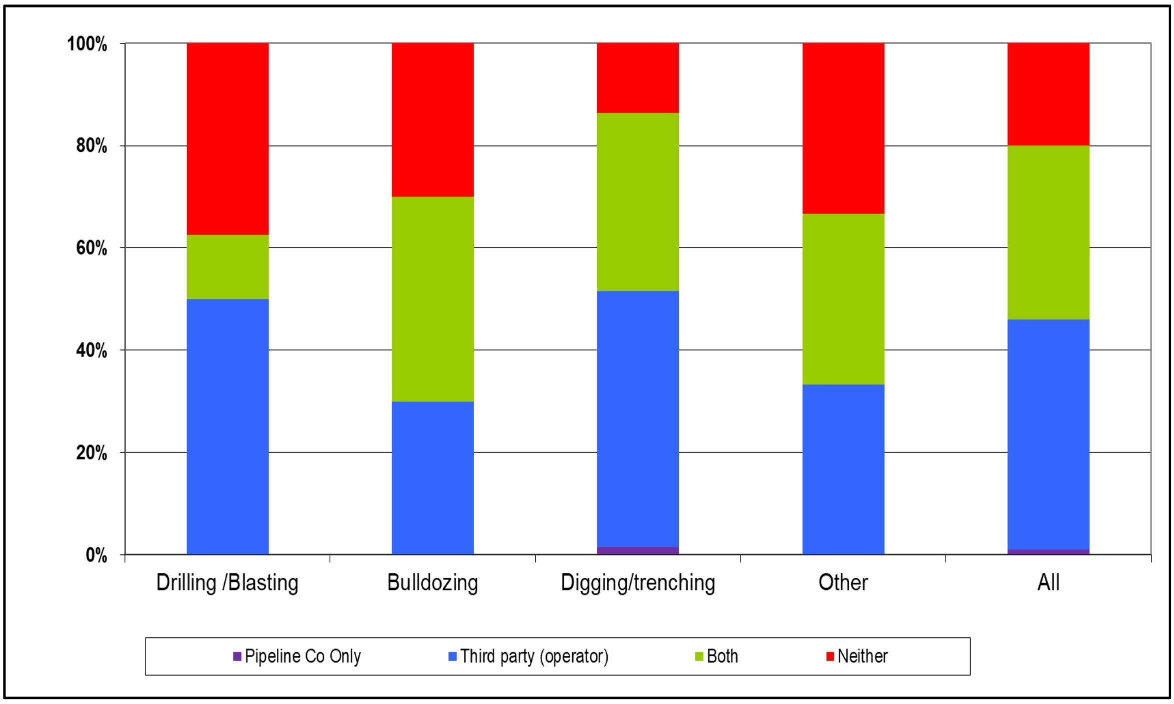


Figure 28 shows the percentage of third-party-related spillages where pipeline operators were aware of the impending activity, or third parties were aware of the pipeline location (this data was reported for about 75% of the third party-related accidental spillages).

In 43% of cases, third parties undertook some form of excavation activity in the knowledge that a pipeline was present in the vicinity, but without notifying the pipeline operating company. In contrast, 1 case was reported where the pipeline company was aware of the impending work, but the third party was not informed of the presence of the pipeline. In about 23% of the cases neither party was aware of the other. In 33% of the cases the pipeline was hit in spite of the fact that the pipeline operator knew about the work and the third party was aware of the presence of the pipeline. These cases often denote a lack of communication at the working level or a lack of proper care or skill by the third party.

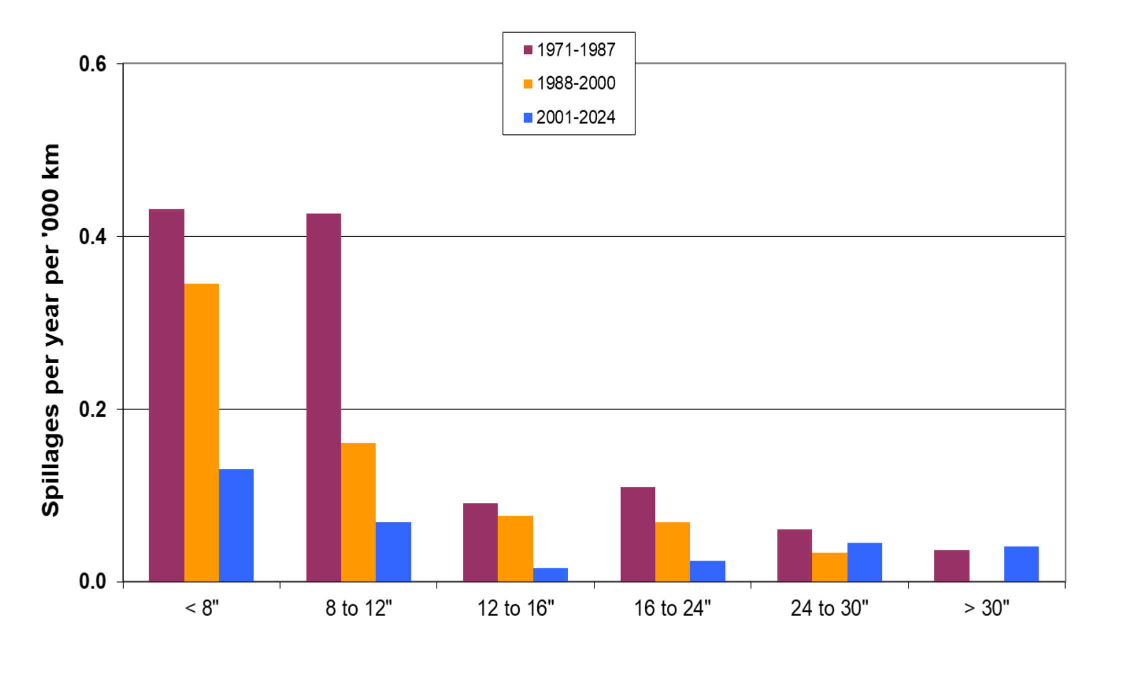
Figure 28 Awareness of impending works and of pipeline location



The strong relationship between spillage frequency and diameter noted in **Section 5.5** is also apparent for accidental damage (**Figure 29**), possibly suggesting a lower level of awareness around the location of smaller pipelines (which are also potentially more vulnerable.

While third party accidental damage was historically a leading cause of spillage, the risk has effectively mitigated through improved communication (especially in countries with effective "one-call systems") and mutual awareness, and the sharing of good practice between pipeline operators from different companies and countries. The number of 3rd Party incidents has significantly reduced from 21 incidents during 2005-2014 period to 5 incidents during 2015-2024 period, highlighting the effectiveness of one-call systems and communication programs.

Figure 29 Third party accidental spillage frequencies per diameter class



6.5.2. Incidental damage

This category captures those incidents where damage was done at some unknown point in a pipeline's lifetime, which subsequently suffers deterioration over time resulting eventually in a spill. In general, they result from unreported damage done after the original construction when a pipeline has been knowingly or unknowingly hit during third party groundwork activities.

There have been 32 incidental damage spillage incidents which all originated from dents, scrapes or other physical damage to the pipeline. Thus, they share the characteristic that they might be detectable by in-line inspections.

6.5.3. Intentional damage

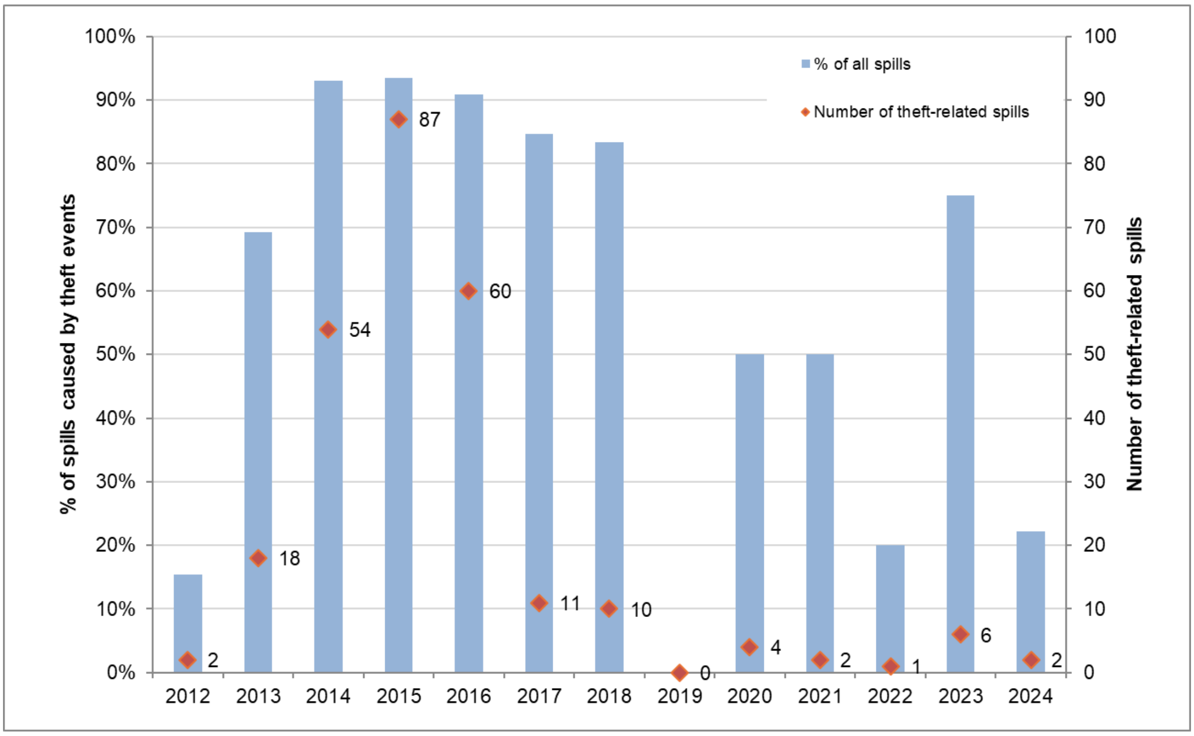
283 spillages were caused by intentional damage by a third party:

- 2 due to terrorist activities
- 6 due to vandalism
- 275 were caused by attempted or successful product theft, 183 of which occurred in the last 10 reporting years.

Only one of the terrorist or vandalism incidents was on an underground pipeline; one was from an above-ground section of pipeline, all the rest were at valves or other fittings at pump stations or road / river crossings, etc.

From the turn of the century, only a few spillages caused by product theft attempts were recorded. The sudden increase to 18 recorded in 2013, 54 in 2014 and 87 in 2015 was extremely concerning. The 2016 figure was somewhat lower although still very high in the historical context, but the downward trend was amplified with only 11 and 10 events in 2017 and 2018 respectively, none in 2019, 4 in 2020, 2 in 2021 and 1 in 2022. There was an increase in the number of spillages due theft in 2023, reaching a total of 6. The reported number of spillages was reported as 2 in 2024 in theft category. This bears witness to the efficacy of the measures taken by operators and law enforcement authorities. Although only 2 cases were recorded in 2024, the problem has not completely gone away (it must also be realised that there are still a number of theft attempts that do not cause a spill, see **section 8**). Theft activities still occur at a significantly higher level that used to be the case before the recent spike. They also account for a very large proportion of all spillage incidents (**Figure 30**).

Figure 30 Number and percentage of all spills due to theft activities



It is important to note that product theft is more widespread than is apparent from the spills data alone, since a large number of tampering events do not result in a spill (even when they are successful in terms of extracting product). An analysis of additional data on product theft events, which has been collected by the Concawe survey since 2015, is presented in **Section 8**.

7. IN-LINE INSPECTIONS

Concawe has been collecting data on in-line inspection activities (with “intelligent” tool) for 45 years, including a one-off exercise to collate data from paper records generated when inspection tools were first used around 1977. Separate records are kept for metal loss, crack detection and for geometry (calliper) inspections. Each inspection may entail one or more passes of a tool along a pipe section. Leak detection tools are also frequently used, but their function is quite different. They can reduce the consequences of a leak that has already started, by detecting it earlier. They cannot, however, help prevent the leak occurring in the first place.

In 2024 the 60 operators that reported their data, inspected a total of 101 sections with at least one type of inspection tool, compared to 113 sections in 2023, covering a total combined length of 13,761 km, split as follows amongst the individual types of tools:

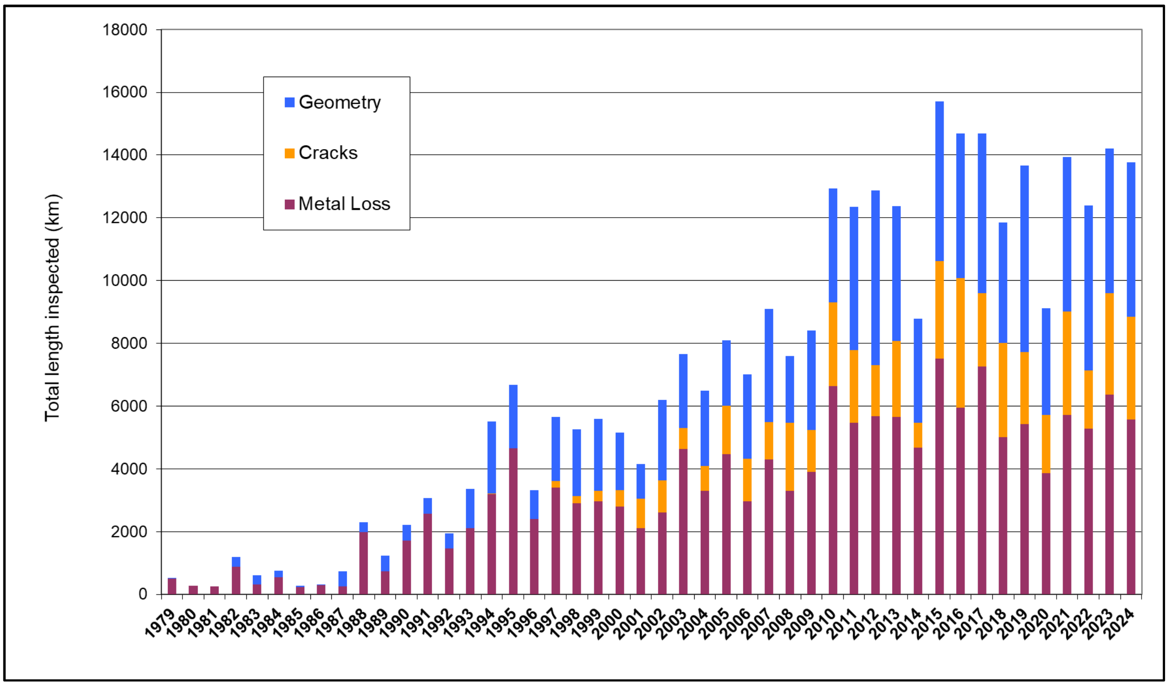
- Metal loss tool 5,565 km, 91 sections
- Crack detection tool 3,288 km, 39 sections
- Geometry tool 4,908 km, 82 sections

Most inspection programmes involved the running of more than one type of tool in the same section so that the total actual length inspected was less at 6,295 km (19% of the inventory, slightly below the 10-year average of 21%).

As shown in **Figures 31 and 32**, the use of inspection tools for internal inspection of pipelines grew steadily up to the mid 90s, stabilising around 12% of the inventory every year. This further increased to around 15% in the first decade of the new millennium and above 20% in the last decade. Following a relatively low figure in 2020 the total increased again in 2021 and is now back to a more “normal” level. Although one can only speculate, it is possible that the pandemic caused a partial curtailment of such operational activities.

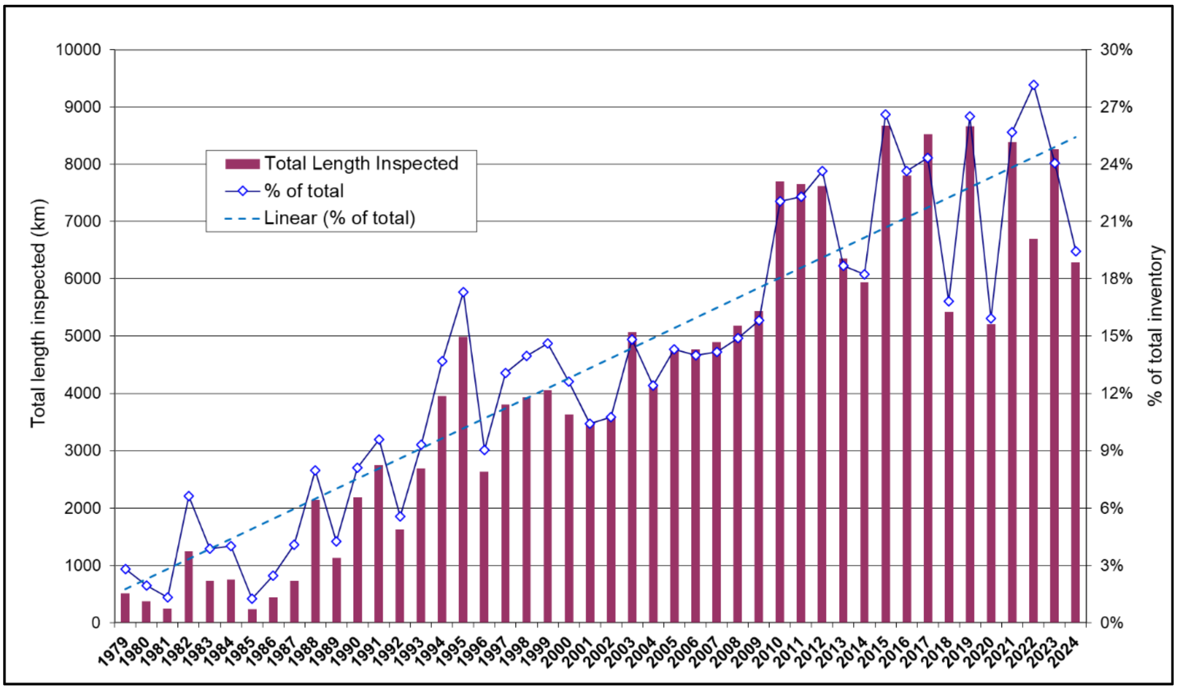
Over the last ten years (a period considered as a reasonable cycle for this type of intensive activity), 452 (73%) of the total of 616 active sections included in the 2024 survey were inspected at least once by at least one type of tool, representing 97% of the total length of the surveyed network. This suggests that the inspected sections are longer than average. There are certainly some pipeline sections (mainly older ones) which were not designed to be internally inspected and which, because of small size or tight bends or lack of suitable tool launchers or receivers, cannot be internally inspected. Also, a number of pipeline operators in Eastern Europe have joined the survey in recent years, but have provided few previous inspection records. The length of un-inspected pipelines is therefore certainly less than the above figure and should continue to decrease in future years.

Figure 31 Annual length inspected by each type of inspection tool



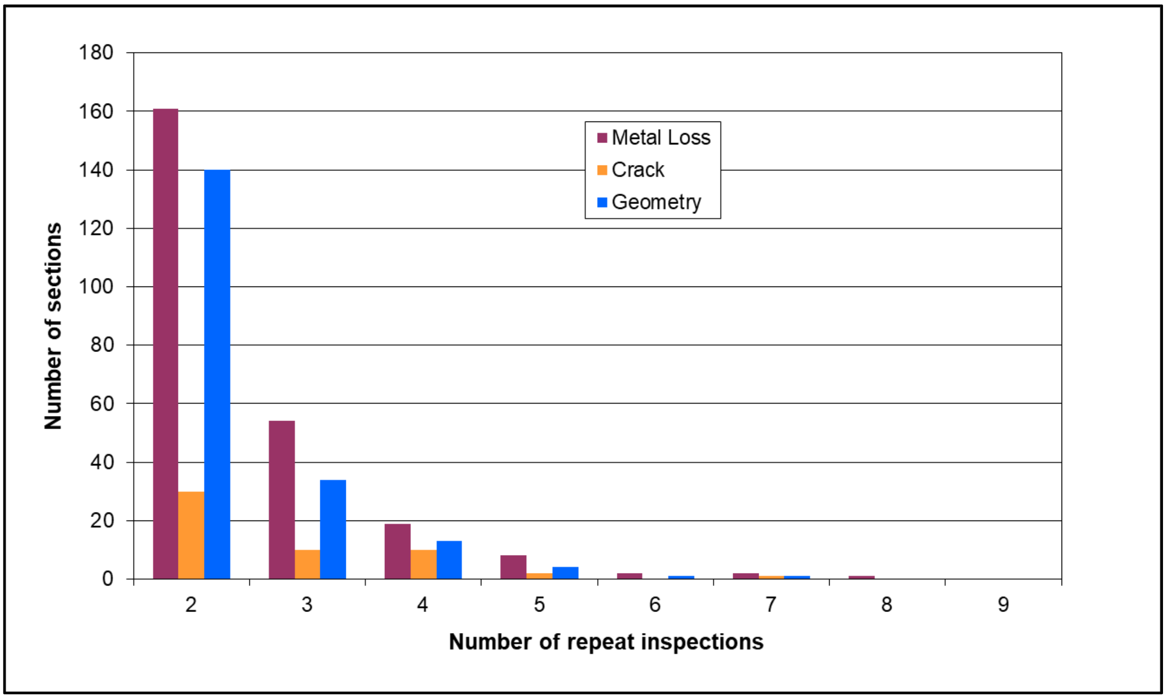
Note: the total length shown above may be higher than shown in Figure 32 as some sections may have been inspected by more than on type of inspection tool

Figure 32 Total annual portion of the inventory inspected by inspection tools



As shown in **Figure 33**, a number of sections have been inspected more than once during the last 10 years. Indeed, for some pipelines, regular inspections are required by the authorities.

Figure 33 Repeat inspections in the last 10 years



In-line inspection technology can detect flaws, corrosion and other sorts of damage in or on the pipe inner or outer walls. Over the past 54 years, 22 spills were caused by faulty welds or construction defects and 32 were caused by some kind of damage inflicted by third parties at some undetermined time (5 and 0 respectively in the last 10 years). All these could, in principle, have been detected by the most technologically advanced inspection tools. There were also 115 spillages related to external corrosion and 31 to internal corrosion, at least some of which could in principle have been detected. Note that nearly two thirds of the spillages related to external corrosion occurred in hot pipelines, most of which have now been retired. For the last 10 years these numbers are reduced to 11 and 4 events related to external and internal corrosion respectively.

8. PRODUCT THEFT FROM PIPELINES

The recent emergence of theft or attempted theft as a new threat to pipelines in Europe has been discussed in **section 6**, which addresses theft events that resulted in a reportable spill. However, there are many theft-related events that do not cause a spill either because thieves do not succeed in drilling through the pipe wall or because they install a product withdrawal system with sufficient integrity to ensure containment. Also, operators are increasingly able to detect tampering early enough to avoid causing a spill.

From the 2015 reporting year a new section was added to the annual survey requesting respondents to report the characteristics of all theft attempts, whether or not they were successful or resulted in a spill. In 2024, a total of 9 theft-related incidents were reported from 4 different operators, 2 of which resulted in a reportable spill. All were on refined products pipelines.

The results for 2024 are summarised in **Table 11** although the figures reported for each item have little or no statistical significance in view of the small number of events and incomplete reporting.

Table 11 Summary of 2024 (2023) - attempted theft events attributes
(note that not all attributes were reported for all events)

Number of events	**9**	**(18)**						
Successful thefts	**8**	**(15)**						Number reported
Spills caused	**2**	**(6)**						
Code	1	2	3	4	5	6	7	
Service (%) (type of product transported)	0 (0)	100 (78)	0 (17)	0 (0)	0 (6)	0 (0)		9
Facility part (%)	100 (100)	0 (0)	0 (0)	0 (0)				9
Connection type (%)	0 (11)	44 (44)	33 (33)	22 (11)				9
Hole size (%)	11 (13)	67 (33)	22 (27)	0 (27)				9
Detection (%) (how was tampering detected)	13 (22)	0 (11)	50 (17)	13 (0)	13 (17)	13 (33)	0 (0)	8
Flow rate (%) (estimated abstraction rate)	50 (38)	50 (38)	0 (25)					8
Location (%) (type of environment)	67 (83)	22 (0)	11 (17)	0 (0)				9
Distance (%) (between pipeline and abstraction point)	33 (47)	56 (53)	11 (0)	0 (0)				9
Storage (%) (facility installed by thieves)	89 (79)	0 (0)	11 (21)					9

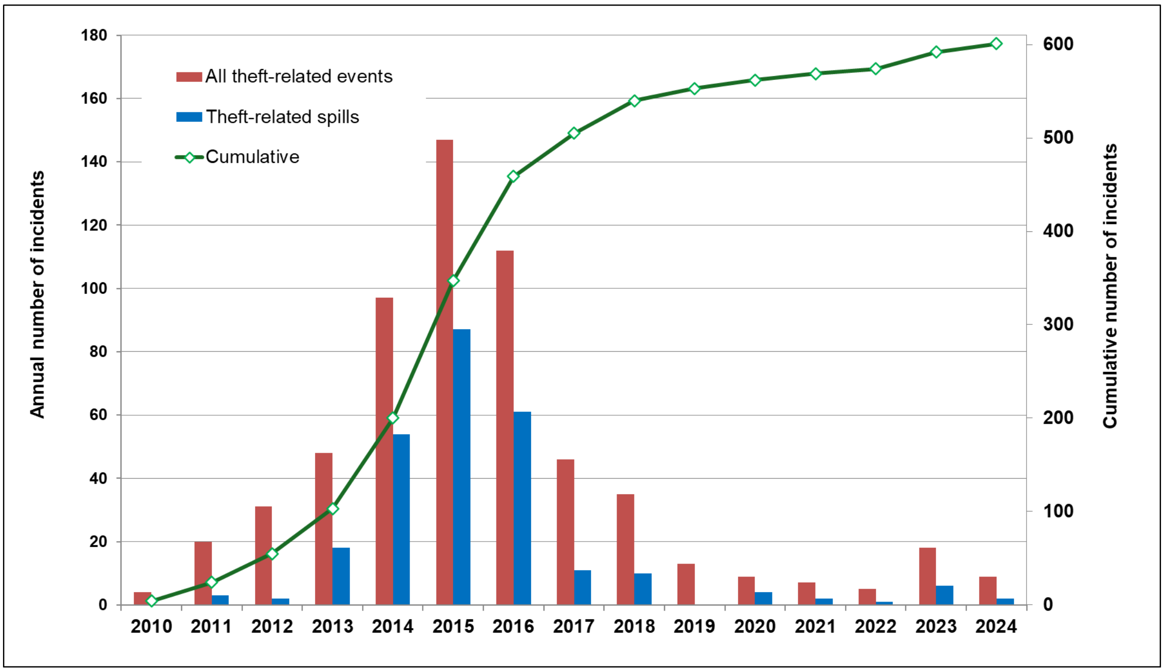
Key

Service (type of product transported) 1 Crude oil 2 Multi product 3 Gasoline 4 Diesel 5 Jet 6 Other	**Detection (how was tampering detected)** 1 Automatic detection system 2 Operational monitoring 3 Routine surveillance 4 Ultrasonic LD pig 5 Line internal inspection 6 Third party 7 Other
Facility part 1 Underground pipe 2 Overground pipe 3 Valve station 4 Other	**Flow rate (estimated abstraction rate)** 1 < 1 m^3/h 2 1-5 m^3/h 3 > 5 m^3/h
Connection type 1 Clamped 2 Welded 3 Screwed 4 Other	**Location (type of environment)** 1 Open land 2 Car park / Lay-by 3 Shrub / wooded area 4 Building
Hole size 1 No hole 2 < 3 mm 3 3-6 mm 4 6-10 mm 5 > 10 mm	**Distance (between pipeline and abstraction point)** 1 < 10 m 2 10-100 m 3 100-1000 m 4 > 1000 m **Storage (facility installed by thieves)** 1 None 2 <1 m^3 3 >1 m^3

Figure 34 shows the evolution of the number of theft incidents since 2010, when significant increases were noted across Europe. Prior to this date, only 23 theft spillages were recorded since 1971. Faced with this serious new threat, operators reacted promptly, enhancing surveillance, improving leak detection system capabilities, increasing awareness of the problem with own staff and contractors and enhancing their capability for fast response and quick repairs. Relevant information was shared within Concawe and best practices established and disseminated amongst operators. These efforts have clearly paid off and the trend was reversed with 112 events recorded in 2016 to 46 in 2017, 35 in 2018,13 in 2019, 9 in 2020, 7 in 2021 and 5 in 2022 and 6 in 2023 and 2 in 2024. Although it may not be statistically significant at this point, this may be the result of increased "professionalism" of thieves and/or early detection by operators.

It should be noted that there are reasons to believe that the total number of theft events is somewhat higher than that reported in this report. As these events are generally classified as criminal activity, there are sometimes legal restrictions that can delay reporting to CONCAWE. In addition, not all pipelines are included in the Concawe inventory (for example NATO lines in Denmark, Italy, Greece, Norway and Portugal as well as all crude and product pipelines in Poland).

Figure 34 Evolution of the number of theft-related events since 2010



APPENDIX 1 DEFINITIONS AND CODES

Spillage volume

Gross spilled volume: the estimated total quantity, expressed in m^3, of hydrocarbons released from the pipeline system as a result of the incident.

Recovered oil: the estimated quantity, expressed in m^3, recovered during the clean-up operation, either as oil or as part of the contaminated soil removed.

Net loss: the difference between gross spilled volume and recovered oil.

Categories of spillage causes

Concawe classifies spill causes into five major categories: mechanical failure, operational, corrosion, natural hazard and third party.

Mechanical: a failure resulting from either a design or material fault (e.g. metallurgical defect, inappropriate material specification) or a construction fault (e.g. defective weld, inadequate support, etc.). This also includes failure of sealing devices (gasket, pump seal, etc.).

Operational: a failure resulting from operational upsets, malfunction or inadequacy of safeguarding systems (e.g. instrumentation, mechanical pressure relief system) or from operator errors.

Corrosion: a failure resulting from corrosion either internal or external of either a pipeline or a fitting. A separate category is foreseen for stress corrosion cracking.

Natural hazard: a failure resulting from a natural occurrence such as land movement, flooding, lightning strike, etc.

Third party: a failure resulting from an action by a third party, either accidental or intentional. This also includes "incidental" third party damage, undetected when it originally occurred but which resulted in a failure at some later point in time.

These main categories are subdivided into secondary causes and “Reasons” as shown in **Table 1.1**.

Table 1.1 Cause categorisation tree

Primary		*Secondary*		*Reason*	
A	Mechanical	Ab	Design and Materials	1	Incorrect design
				2	Faulty material
				3	Incorrect material specification
				4	Age or fatigue
		Aa	Construction	5	Faulty weld
				6	Construction damage
				7	Incorrect installation
B	Operational	Ba	System	8	Equipment
				9	Instrument & control systems
		Bb	Human	10	Not depressurised or drained
				11	Incorrect operation
				12	Incorrect maintenance or construction
				13	Incorrect procedure
C	Corrosion	Ca	External	14	Coating failure
				15	Cathodic protection failure
		Cb	Internal	16	Inhibitor failure
		Cc	Stress corrosion cracking		
D	Natural	Da	Ground movement	20	Landslide
				21	Subsidence
				22	Earthquake
				23	Flooding
		Db	Other		
E	3rd Party	Ea	Accidental	17	Construction
				18	Agricultural
				19	Underground infrastructure
		Ec	Incidental		
		Eb	Intentional	24	Terrorist activity
				25	Vandalism
				26	Theft (incl. attempted)

APPENDIX 2 SPILLAGE SUMMARY

Key to table

Cause categories: see **Appendix 1**

Service

1	Crude oil
2	White product
3	Fuel oil (hot)
4	Crude oil or product
5	Lubes (hot)

Facility

1	Underground pipe
2	Above ground pipe
3	Pump station

Water Bodies

S	Surface Water
G	Ground Water
P	Potable Water

Leak First Detected By

1	R/W surveillance by pipeline staff
2	Routine monitoring P/L operator
3	Automatic detection system
4	Pressure testing
5	Outside party
6	Internal Inspection

Facility Part

1	Bend
2	Joint
3	Pipe run
4	Valve
5	Pump
6	Pig trap
7	Small bore
8	unknown

Land Use

1	Residential high density
2	Residential low density
3	Agricultural
4	Industrial or commercial
5	Forest Hills
6	Barren
7	Water body

Hole Type

0	No Hole
1	Pinhole
2	Fissure
2	Hole
4	Split
5	Rupture
6	Not Known

Appendix 2 Data

- Non-Theft Related Spillage Summary from 1971 to 2024
- Theft Related Spillage Summary from 1971 to 2024

See Appendix 2

Environmental Science for
European Fuel Manufacturing

Concawe
Av. des Nerviens 85
B-1040 Brussels
Belgium

Tel: +32-2-566 91 60
Fax: +32-2-566 91 81
e-mail: info@concawe.org
http://www.concawe.eu

ISBN 978-2-87567-220-9