Introduction to Exploration and Production
Society of Petroleum Engineers

Safety and Environment in Exploration and Production

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Safety and Environment in Exploration and Production

Today's presentation

- What can go wrong?
  - Process (loss of containment) risks
  - Personal (occupational) risks
- What does the industry do to address the risks?
- What about Fracking?

What can go wrong?
Very serious 'loss of containment' (process) incidents.

Piper Alpha, 1988
UK North Sea

Oil production (processing) incident

167 killed, only 61 survivors

Production stopped at 5 other fields

Loss of exports £1.3 billion 1988-1989

Exxon Valdez, 1989
Alaska

Oil transportation incident

Oil tanker struck a reef

Spilled 260,000 – 750,000 barrels of oil

Oil covered 2,100 km2 of coastline, and 28,000 km2 of ocean

Deepwater Horizon, 2010
US Gulf of Mexico

Oil drilling incident

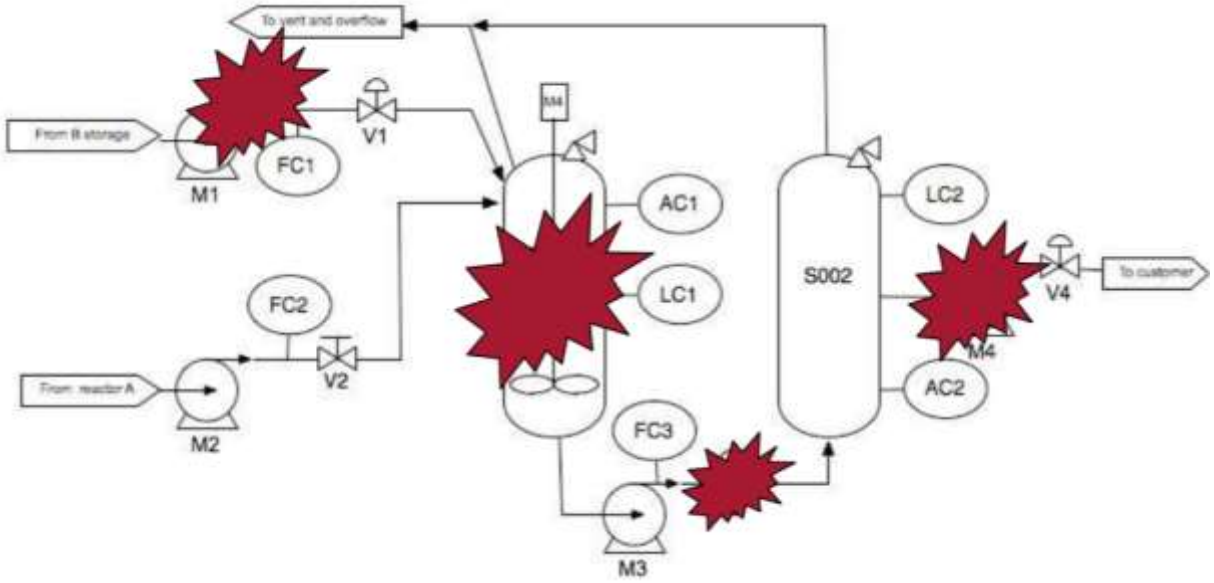
Explosion and fire killed 11 workers

Offshore drilling rig Deepwater Horizon sank

Large oil spill in Gulf of Mexico

What can go wrong?
Process Safety & Personal Safety

Process Safety



Incidents less frequent
Incidents of higher severity
Common to process industries

Personal Safety

Incidents more frequent
Incidents of lower severity
But pose biggest danger to personnel
Common to all industries

Source: ENFORM The Safety Association for Canada's Upstream Oil and Gas Industry

http://www.enform.ca/files/pdf/Personal_vs_Process_Safety_v3.pdf

Personal Safety Hazards

These "Lifesaving Rules" (from Shell) give an indication of the scope of personal safety risks.

Obtain work permit

Dangerous gas

Life protecting equipment

Confined spaces

Respect safety equipment

Working at height

Suspended loads

Do not smoke

No alcohol or drugs

Drive carefully

Wear seat belt

Follow journey plan

Source:

Shell Global

http://www.shell.com/sustainability/safety/personal-safety.html

When and where can things go wrong?

Ringhorne Platform, Norway

Some safety challenges and safety features

When and where can things go wrong? – During construction

Ringhorne Platform and Thialf Construction Barge

14 thousand tonne lift

Eight London busses

Photos approximately to scale.

When and where can things go wrong? – During drilling

Workers on the drilling floor

New generation drilling rigs are fully automated, and don't require workers to handle the drill string (like above)

Rotating equipment

Mechanical handling

Working at height

Exposed to elements

Volatile gases and liquids

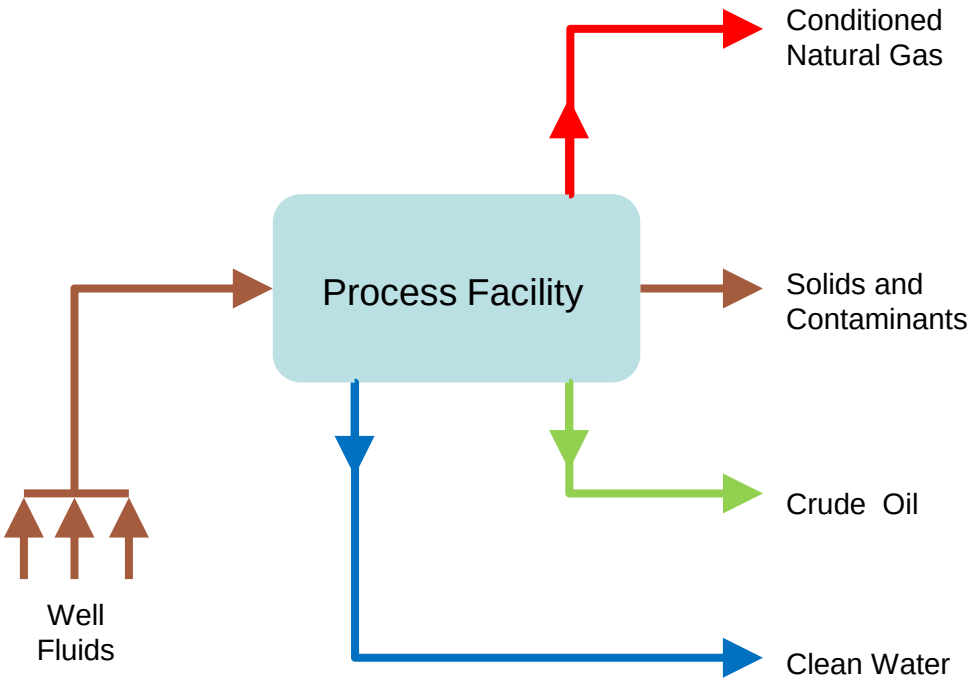
When and where can things go wrong? – During transportation

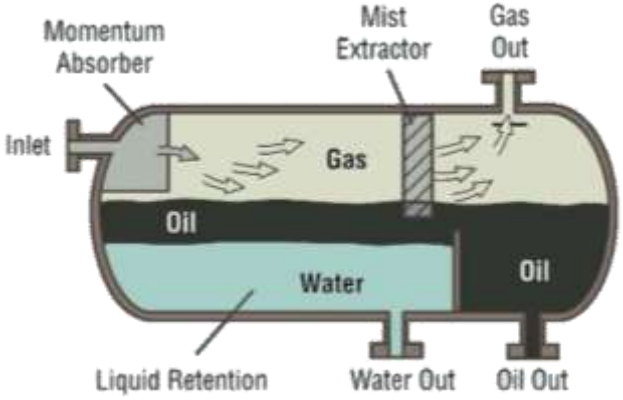
Helicopter transportation is risky

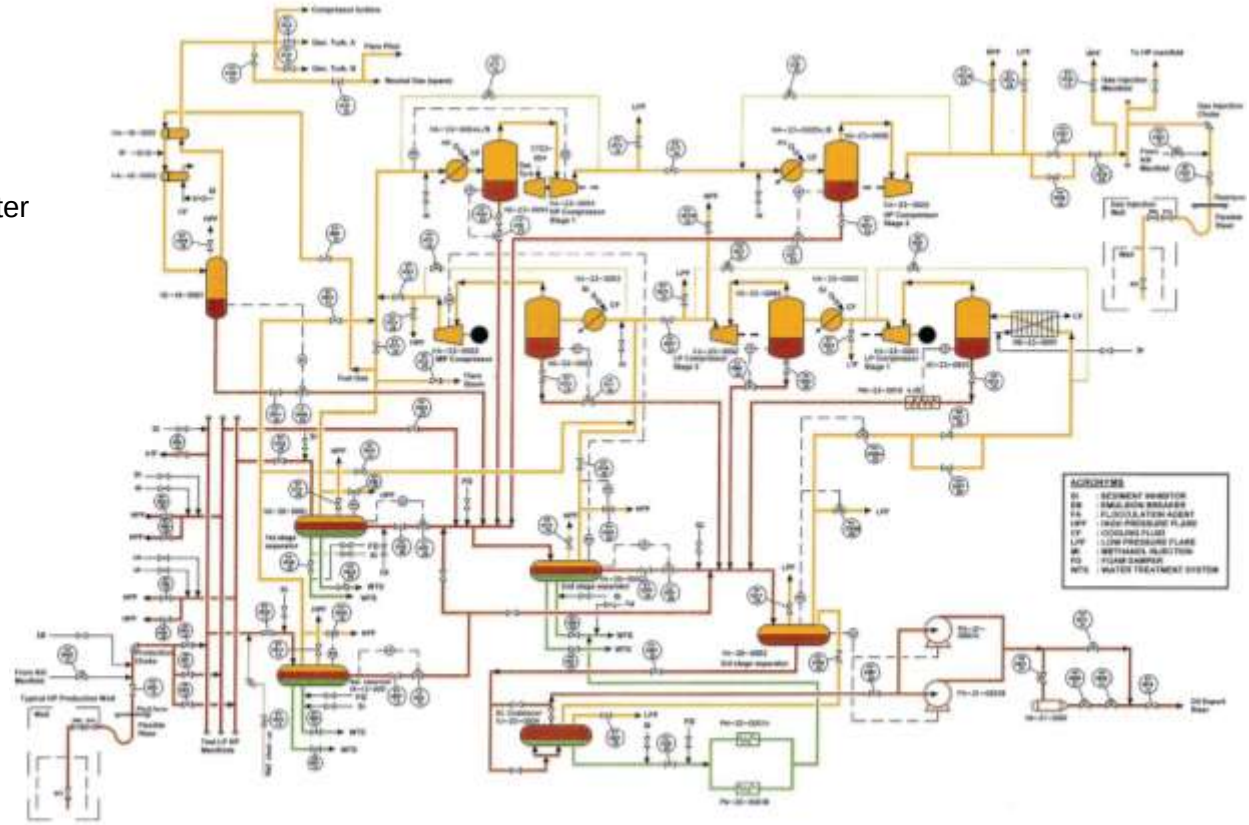
Transfer by 'personnel basket' is dramatic, but safe

However, transport by supply boat is slow.

When and where can things go wrong? – During production







When and where can things go wrong? – Anytime, anywhere ...

- The E&P industry is **Risky**
  - Volatile fluids
  - High pressures
  - High temperatures
  - Noxious gases, fluids
  - Offshore environment
  - Working at height
  - Heavy lifting and handling
  - Rotating equipment
  - Confined spaces
- The E&P industry is **Young**
  - A relatively short track record of what can go wrong
  - Unlike mining, agriculture, fishing, manufacturing, railroad, etc.
- The E&P industry is **Innovative**
  - Continually changing
  - New ideas and methods
  - New dangers

Safety is concerned with:

- Risk to workers
- Risk to public
- Risk to environment
- Risk to property
- Risk to business (profitability, reputation)

Safety is not just about major incidents (disasters).

- 'Ordinary' incidents, over time, contribute to more injuries.
- Transportation (road or helicopter) is a major contributor of risk.

Safety Awareness

Safety awareness and performance monitoring are key to managing risk and safety.

“If you can't measure it, you can't manage it”

Typical safety metrics include:

- Lost time incident (LTI), and
- Recordable injury

An LTI is an incident that causes time away from work.

Recording (and publishing) data on 'Lost Time Incidents' is a key way to raise awareness.

The figure below is a "safety triangle“

The safety triangle illustrates the approximate occurrence ratio of incidents with different severities.

Accident investigation indicates

- That there are often many individual causes to an accident
- A series of incidents occur simultaneously to "cause" the accident.

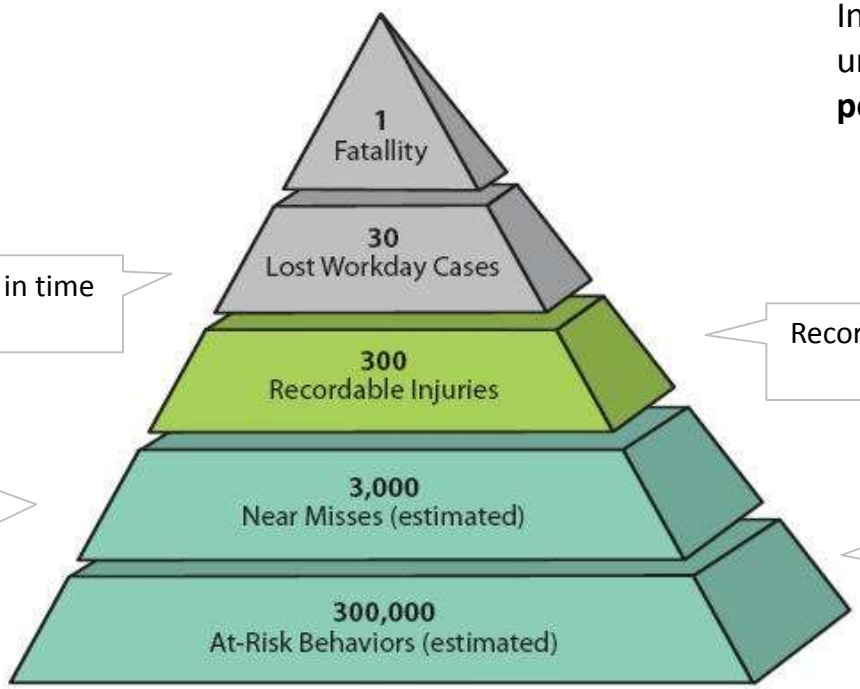
A combination of unsafe acts can result in a fatality.

Addressing safety should begin with the base of the triangle, by trying to eliminate unsafe acts.

This should be straight forward, since most unsafe acts arise from

- Carelessness, or
- Failure to follow procedures.

In practice, reducing the number of unsafe acts requires **management** and **personal commitment**.



Lost workday (LTI) injuries result in time away from work

Recordable (non LTI) incidents or injuries do not result in time away from work

Near misses (or **near hits**) are when an incident causes no injury, but could have, e.g. a falling object hitting the ground, but missing personnel.

At-risk behaviours, or **unsafe acts**, are when no incident occurs, but easily could have, e.g. a poorly secured ladder.

Offshore Installations Safety Case

A **Safety Case** is set of procedures and arrangements that **demonstrate**

- A safety management system is in place
- Risks have been identified and reduced to acceptably low levels
- The likelihood of a major accident has been reduced to an acceptable level
- The effects of an incident, in event of occurrence, have been controlled & mitigated

An old-style **prescriptive** regime can result in

a) Box-ticking mentality,

b) Complacency when prescribed minimum levels have been achieved,

c) Lack of engagement in what unusual events may occur.

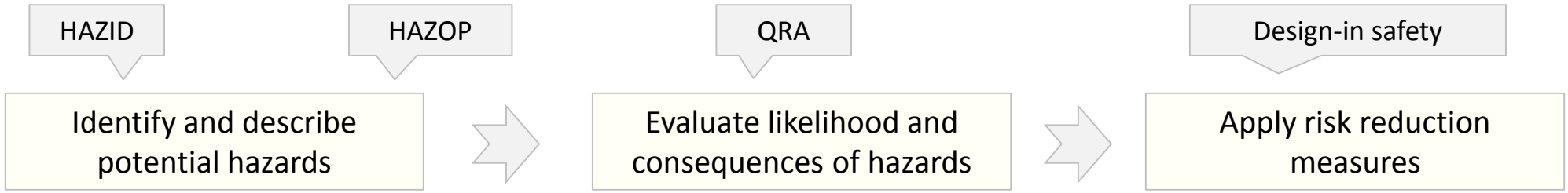
Safety by Design – HAZID and HAZOP

Both are **systematic assessments** to identify hazards and problem areas

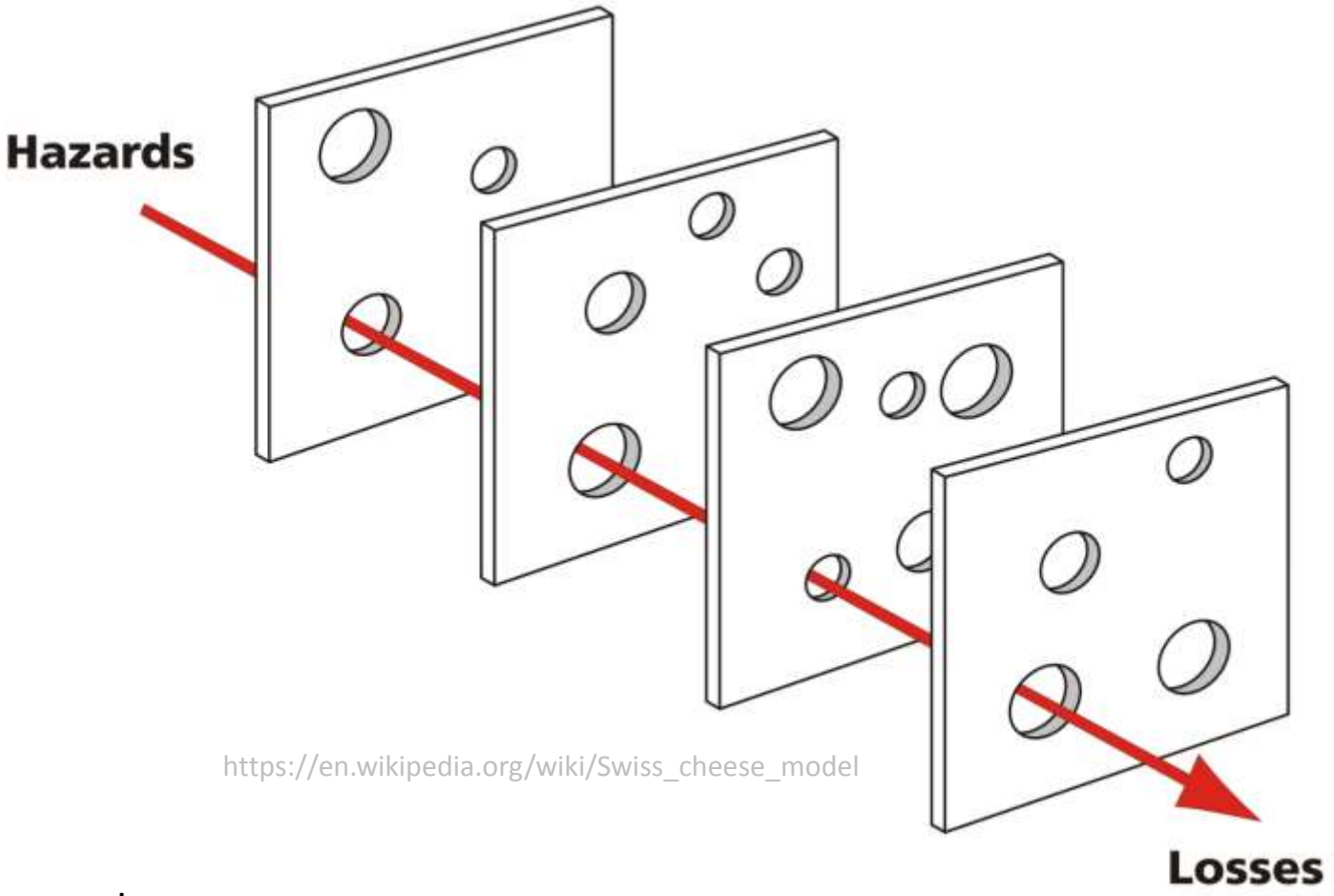
Both result in safer (and more efficient and more reliable) plant

Both are **qualitative** methods

HAZard IDentification (HAZID)	HAZard and OPerability (HAZOP)
Done at early stage	Done when detailed drawings available
Brainstorming technique using personnel with varied backgrounds	Exploits the combined process experience of study team specialists
Applied to all types of situation and plant	Applied to process plant
Looks at hazards "outside the process"	Looks at hazards "inside the process"
Looks at overall context of plant, system, operation, design and maintenance.	Looks within the boundaries of a sub-system (a module or process)
Guided by checklists and an experienced chair person, the team prepares a register of everything that might go wrong.	A process diagram is examined in small sections and possible deviations, causes and consequences to design intent are identified.



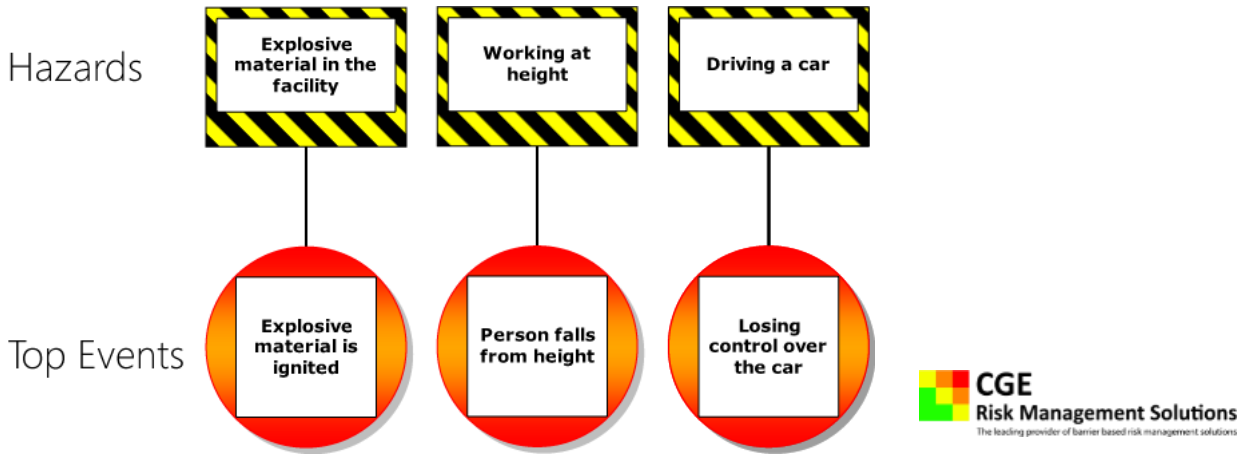
Multiple barriers to losses - Swiss cheese metaphor

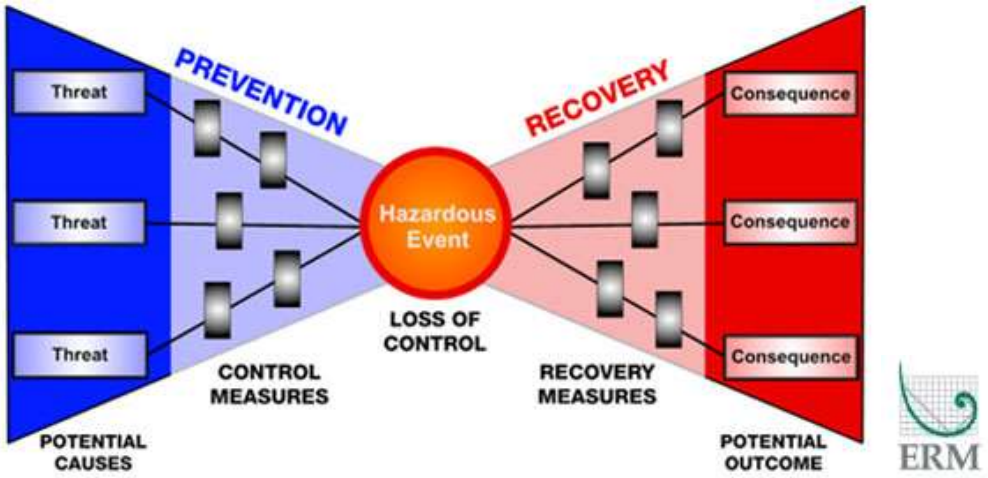


https://en.wikipedia.org/wiki/Swiss_cheese_model

No single barrier can be 100% effective, hence multiple barriers to losses are designed-in

Bowtie diagram - Identify hazards and key (top) events



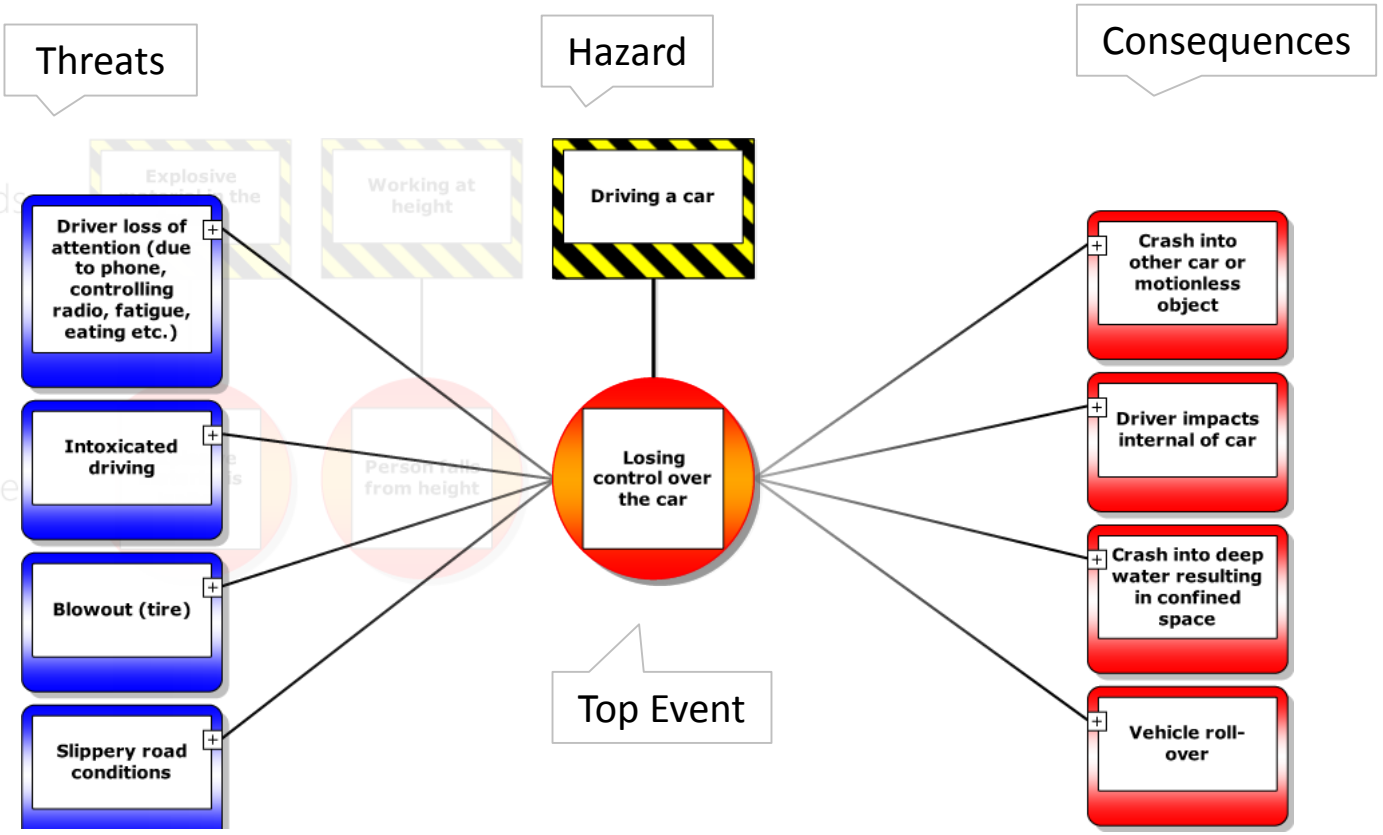


An example of 'multiple-barrier' approach

http://events.r20.constantcontact.com/register/event?llr=6quxcycab&oeidk=a07e5zzlwto9ff6b679

http://www.cgerisk.com/knowledge-base/risk-assessment/thebowtiemethod

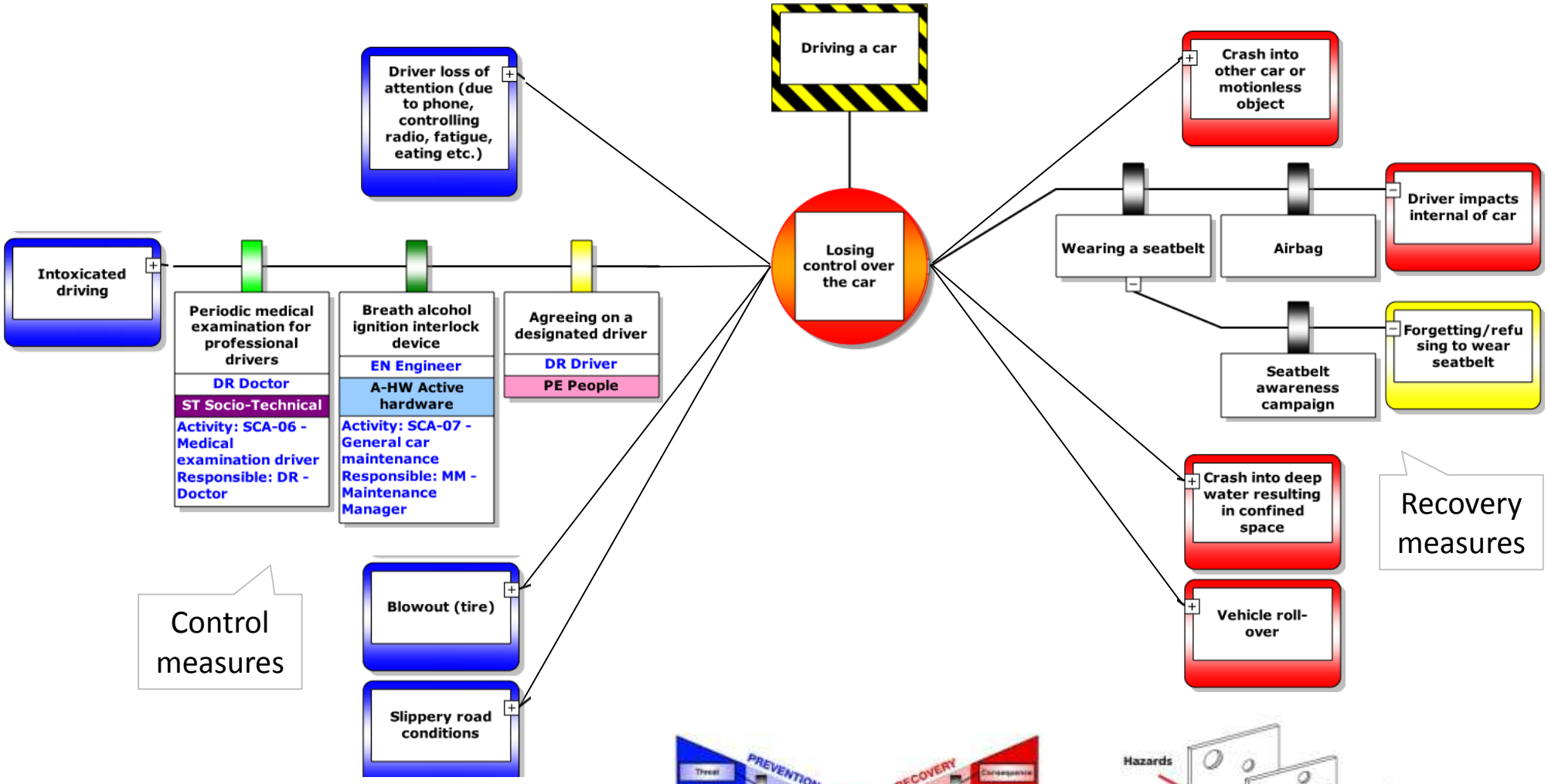
Bowtie diagram - Identify threats and consequences



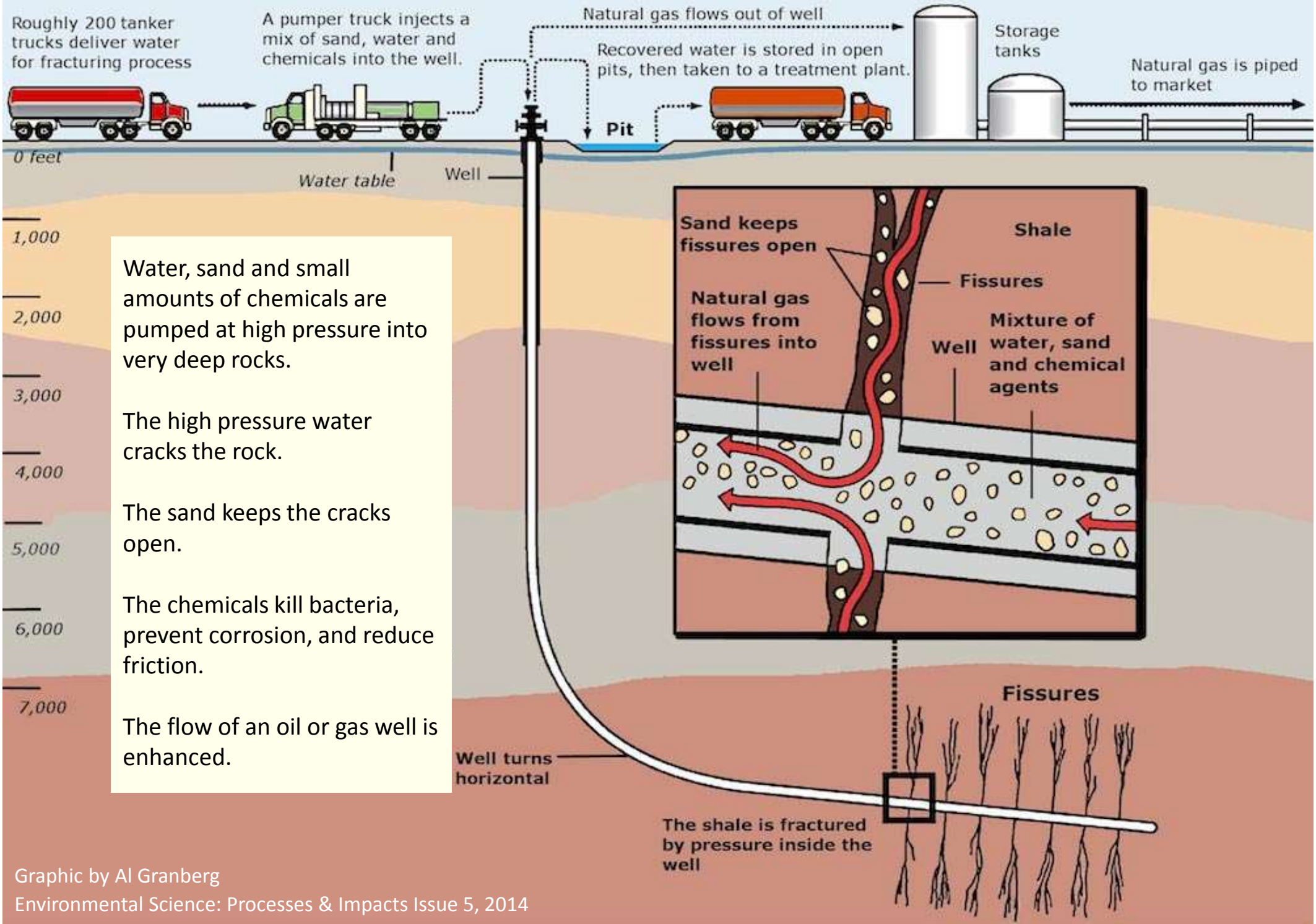
Source:

CGE Risk Management Solutions
The leading provider of barrier based risk management solutions

Bowtie diagram - Specify control and recovery measures



What is fracking (hydraulic fracturing)?



Water, sand and small amounts of chemicals are pumped at high pressure into very deep rocks.

The high pressure water cracks the rock.

The sand keeps the cracks open.

The chemicals kill bacteria, prevent corrosion, and reduce friction.

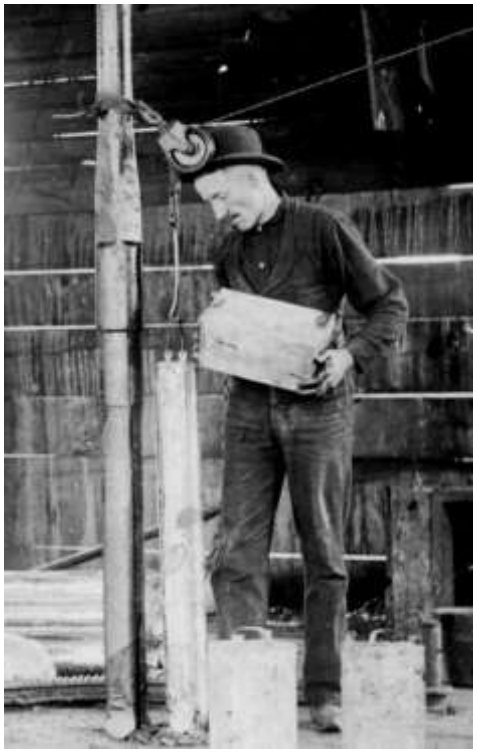
The flow of an oil or gas well is enhanced.

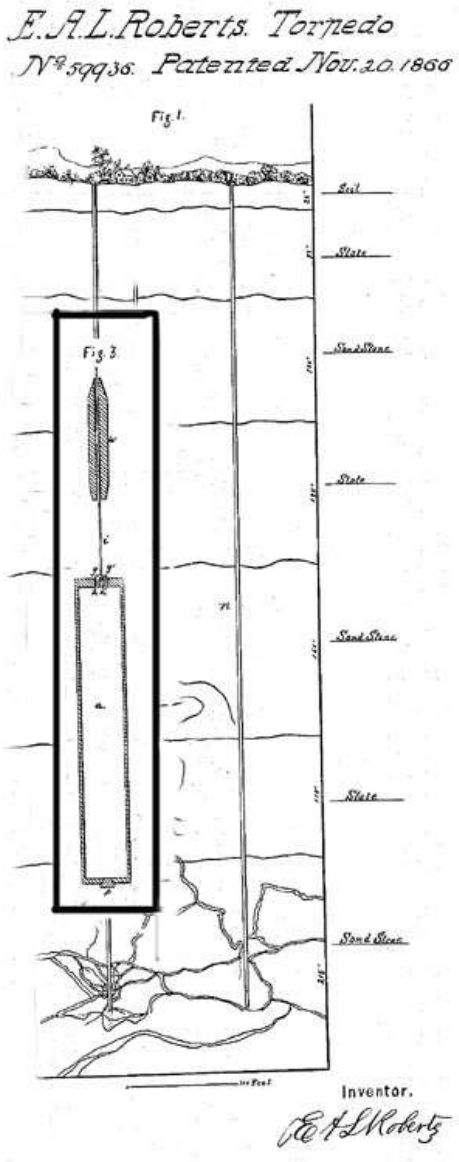
Graphic by Al Granberg

Environmental Science: Processes & Impacts Issue 5, 2014

Fracking is not new

1865 First patent for civil war veteran's "Torpedo"





http://aoghs.org/technology/hydraulic-fracturing/

1949 First commercial fracking, USA

The first commercial hydraulic fracturing of an oil well took place in 1949, Oklahoma, USA.

1973 Elswick gas field, Lancashire, UK

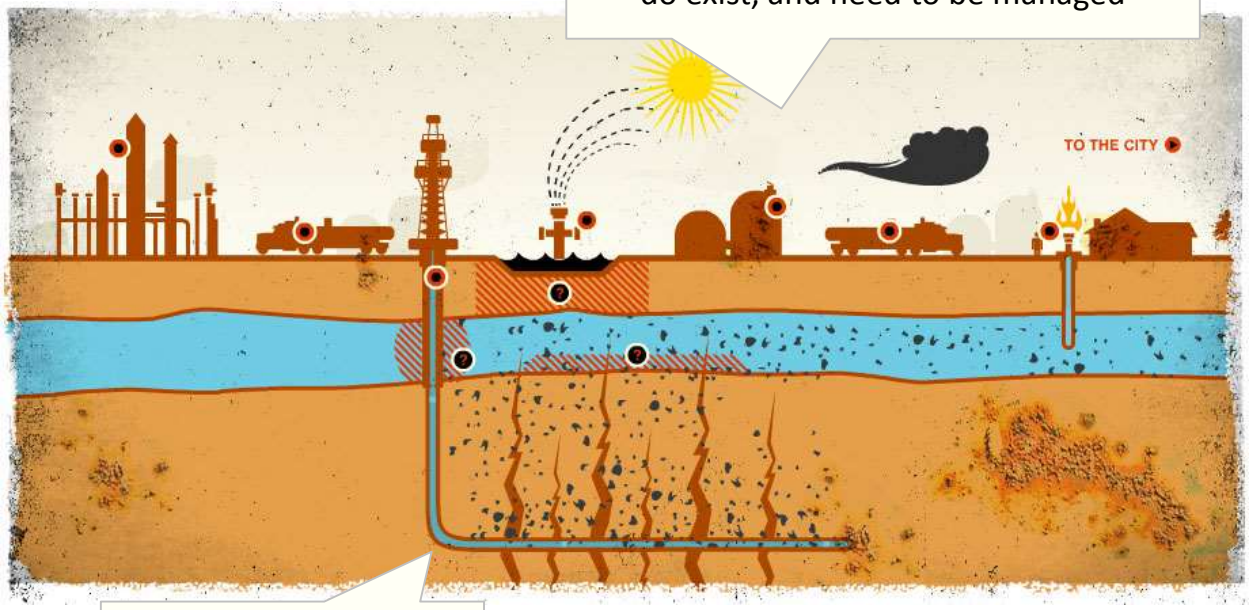
Fracked in 1993, still generating 1 MW electricity

But the **scale** of fracking for shale oil/gas **is** new

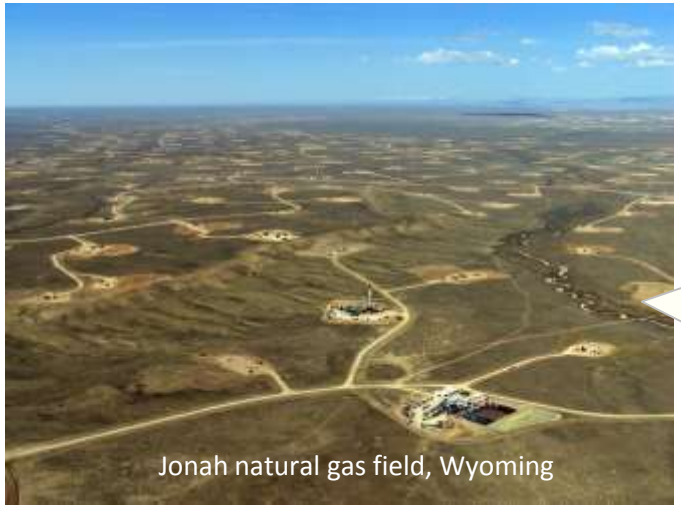
The public (mis) conception of fracking

Methane in tap water can be caused by any well, and usually water wells, that are badly drilled. It is very unlikely to be caused by gas wells

As with all heavy industry, surface risks do exist, and need to be managed



Shale gas wells are very, very deep. It is not feasible that fracks will extend into water acquifers



Jonah natural gas field, Wyoming

This dense well spacing will not be allowed in Europe

Earthquakes (caused by fracking) did not cause this road damage.

Source: BGS NERC

As with all heavy industry, there are risks (and benefits)

Risks

- Radiation (naturally occurring)
- Well blow outs
- Chemical spills
- Gas migration
- Visual impact
- Environmental footprints
- Road traffic, noise, dust, accidents, damage
- CO2 footprint (burning fuel and seepage)
- Emissions & odor
- Induced seismic activity
- Soil erosion
- Higher cost of living
- Competition for resources (esp water)
- Negative impact on tourism
- Influx of workers
- Crime
- Pollution (Water)

Benefits

- Jobs (less unemployment)
- Career opportunities
- New businesses
- More service offerings
- Better infrastructure
- Higher salaries (more money)
- New restaurants, bars, shops

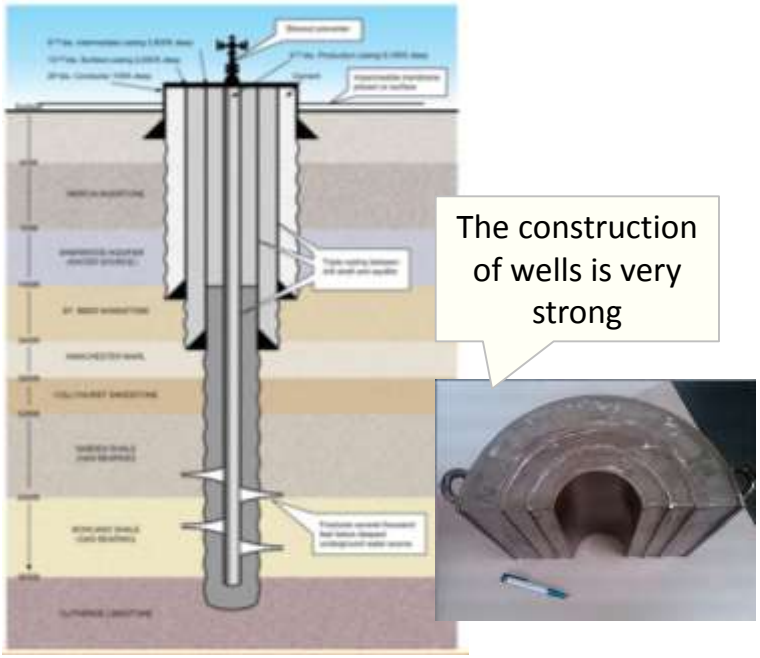
- Increased tax revenue (for schools, hospitals, ...)
- Energy security
- Lower energy prices (eventually)
- Less CO2 emission (than oil or coal)

This does not mean that these things **will** happen.

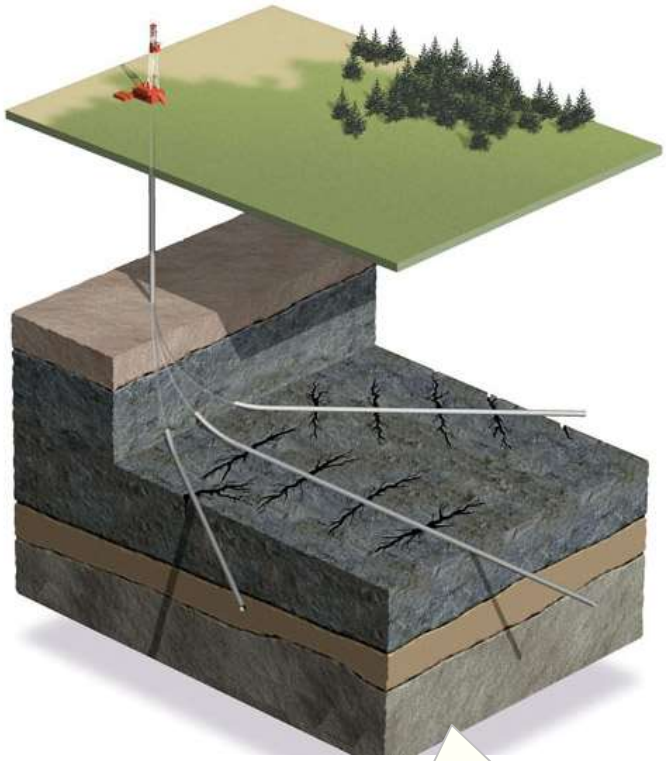
Good management and comprehensive regulation can mitigate the risks

Construction of shale gas (fracked) wells

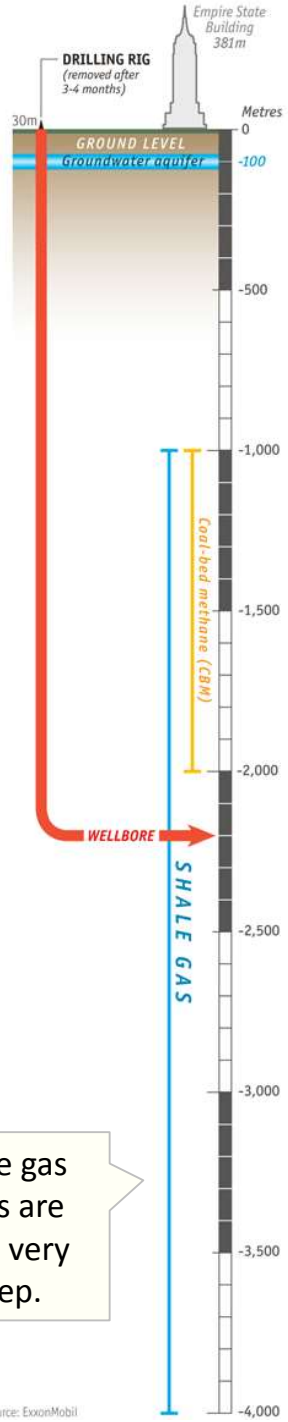
A shale well site in Poland



The construction of wells is very strong



Many wells can be drilled from one well-site, to drain a large area

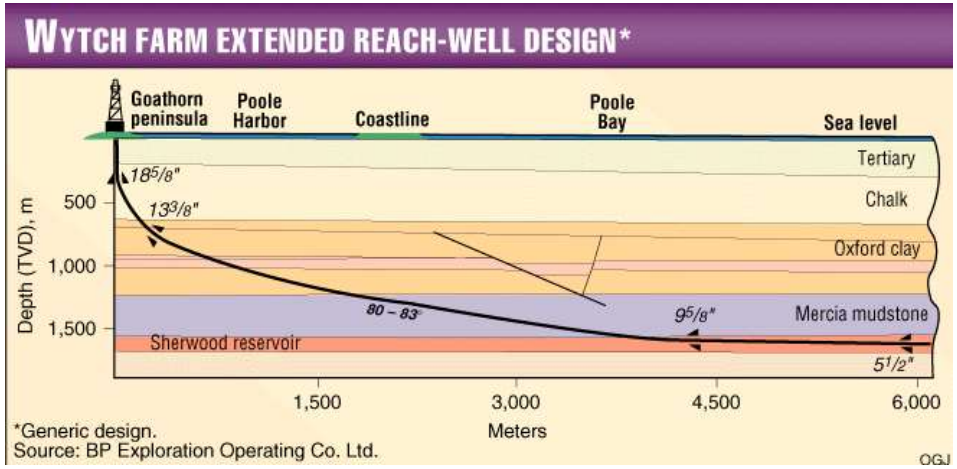


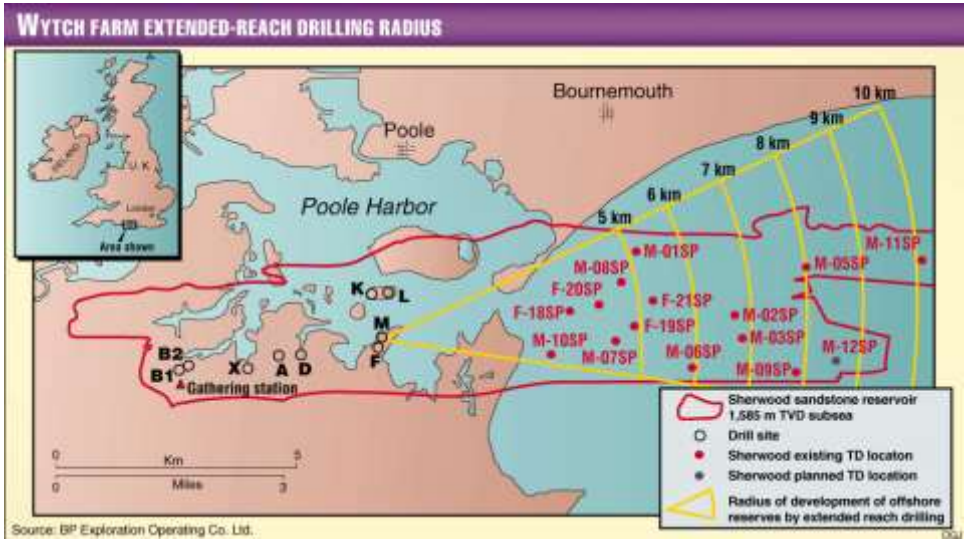
Shale gas wells are very, very deep.

Oil production Wytch Farm, Purbeck, Dorset

The largest onshore oil field in Western Europe, in an area of outstanding natural beauty

Although not shale gas or oil, it has involved fracking, and is a good example of responsible exploration and production.





End

Other potential content

Sources of information on fracking

THE ROYAL SOCIETY

ROYAL ACADEMY OF ENGINEERING

Shale gas extraction in the UK: a review of hydraulic fracturing

June 2012

BGS 1835

British Geological Survey

The Economist

Sorting frack from fiction

Shale gas's poor image in Europe is largely unjustified

Jul 14th 2012

People should worry less about fracking, and more about carbon

Nov 26th 2011

Despite its poor image, fracking causes little mess or disruption

Jul 14th 2012

Summary

The benefits of energy production and usage (and wealth creation in general) must outweigh the risks

- They are not fundamentally bad things
- But
    - Energy should be generated and used responsibly.
    - Wealth should be created and shared equitably

The safety record of the exploration & production sector is good and improving

- Despite some recent big events.

The key thing is to strike the right balance between benefits and impacts.

Hydraulic fracturing – Chemicals used

The primary chemicals used are all commonly used in other sectors of the petroleum industry and elsewhere in everyday life.

In the UK, approx 0.25% of fracturing fluid consists of chemicals, the rest being water (~95%) and proppant (~5%).

Regulators require operators to disclose the chemical constituents in fracturing fluids.

Gelling agent

Reasons for use
Improves proppant placement

Consequences of not using chemical
Increased water use, natural gas recovery may decrease in some cases by 30 to 50% when fracturing fluids are not gelled

Other uses
Used as a thickener in cosmetics, ice cream, toothpaste, sauces

Acid

Reasons for use
Cleans mineral deposits from rock formations enabling more efficient production

Consequences of not using chemical
Higher treatment pressures required, reduced production efficiency

Other uses
Used as swimming pool cleaner, household cleaner, and in cosmetics

Oxygen scavenger

Reasons for use
Prevents corrosion of well tubing and casing by oxygen

Consequences of not using chemical
Corrosion sharply increased, well integrity (containment) potentially compromised

Other uses
Used in food packaging to aid preservation; aids in the protection of boilers from corrosion

Biocide

Reasons for use
Controls bacterial growth which causes blockages

Consequences of not using chemical
Higher treating pressure, possible growth of bacterial sludge within the well causing plugging of perforations

Other uses
Used in drinking water, cosmetics and wipes, cleaning products, toothpaste, laundry detergents and general disinfectants

Corrosion inhibitor

Reasons for use
Used in conjunction with acid to prevent corrosion of pipes

Consequences of not using chemical
Sharply increased risk of pipe corrosion from acid, well integrity potentially compromised

Other uses
Used in pharmaceuticals, acrylic fibres and plastics

Friction reducer

Reasons for use
Decreases pumping friction

Consequences of not using chemical
Significantly increased surface pressure and hydraulic fracture pump engine emissions

Other uses
Used in cosmetics, including hair, make-up, nail and skin products

energy institute

Source: Shale Gas Essentials (EI)

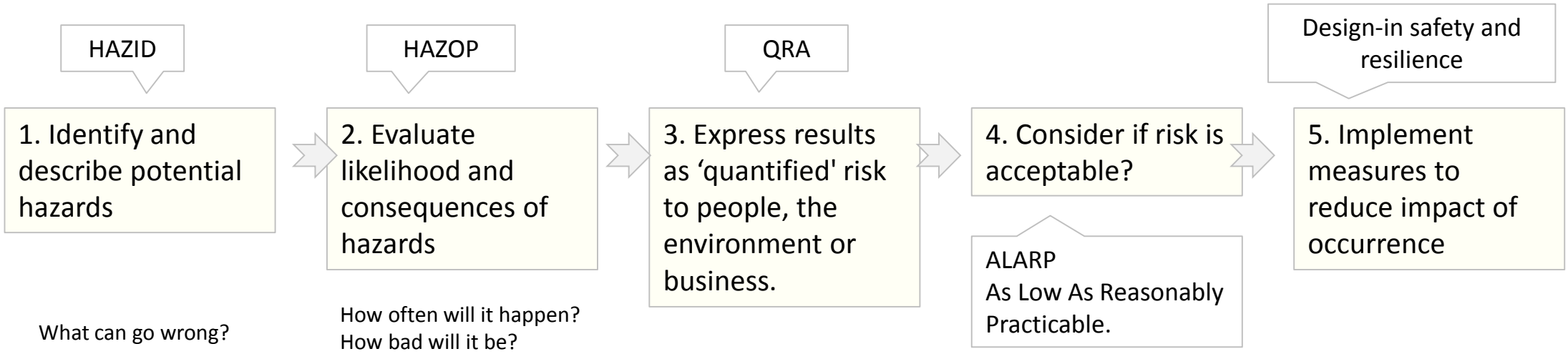
Safety by Design – Quantitative Risk Assessment (QRA)

Quantitative risk assessment (QRA)

- A formal, specialist, quantitative method.
- Evaluates risk levels to workers, the public, the environment, property and business
- Risk levels are compared with criteria defined by the operator in accordance with the post-Cullen goal-setting regime

Limitations of QRA

- Relies on theoretical and numeric models. Theory can be wrong.
- Sensitive to uncertainties and assumptions.
- Can divert attention from 'common sense' indicators.
- Requires historic data on reliability and probability of events (OK if industry is mature)
- Tends to be used on hardware and physical systems. Not so good on human factors, or more general 'softer' issues.



As low as reasonably practicable - ALARP

ALARP is central to UK & Norway non-prescriptive, goal-setting safety regimes

Other regimes adhere to:

- standards
- 'good engineering practice‘
- prescribed absolute levels of safety

ALARP is sufficiently radical that the European Commission took the UK to court

- Despite the UK having the best occupational safety record in Europe.

The EC claimed 'ALARP' watered down the EU safety framework, which directed:

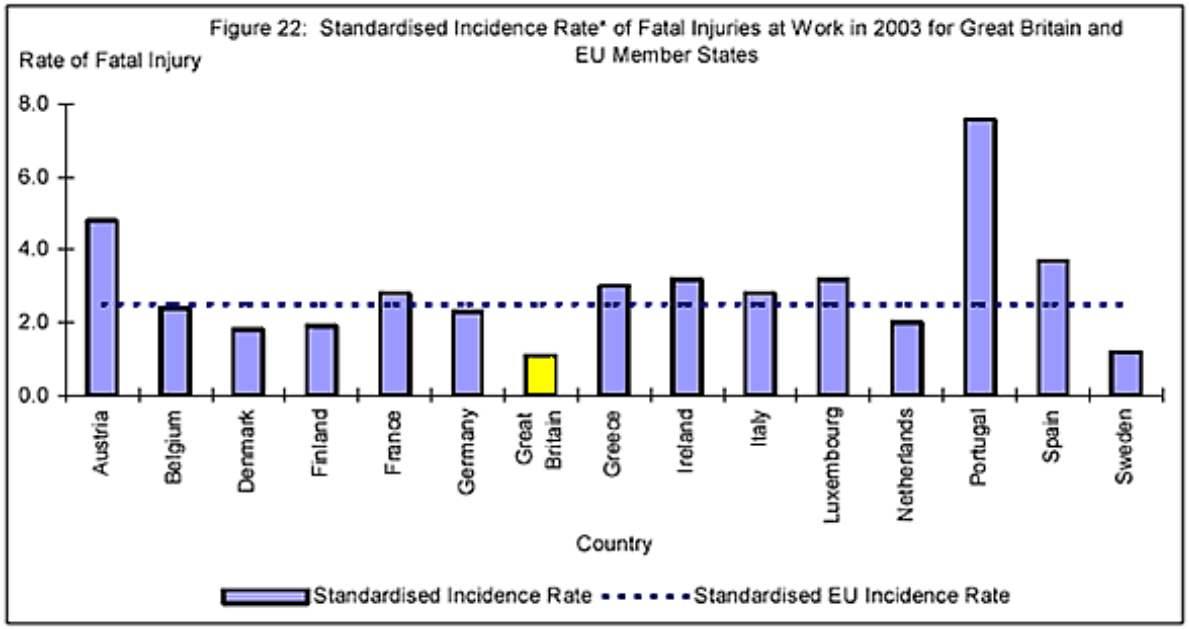
- “a duty upon employers to ensure the safety and health of workers in every aspect related to the work“

In 2007 the European Court of Justice ruled in UK favour

- And the EC had to pay the UK costs

“[The] right way forward is a **proportionate and risk-based approach** protecting employees and others effectively, whilst allowing **common-sense to be applied** when deciding on what protective measures to adopt.”

Bill Callaghan, Chair of the Health and Safety Commission (HSC)



http://www.hse.gov.uk/press/2007/c07007.htm

Safety and Environment in Exploration and Production

Oil and gas exploration and production is risky

The risks are high
- Death, injury, pollution, losses

But so are the benefits delivered
- Wealth
- Medicine, health, education
- Leisure
- Modern life

We need to get a balance
- A tricky subject, even to discuss
- No worthwhile endeavour is risk free

The industry is doing a pretty good job
- In difficult circumstances
- Things have improved
- Lessons have been learned
- It is worth doing

“Safety & environment” is a big subject

In this presentation we will focus primarily on
- ‘Safety’
- of people, property and the environment
- exposed to ‘incidents’ or ‘accidents’

What risk is acceptable?

Any worthwhile endeavour involves risk

Nothing is without risk

To assess the acceptability of a particular risk, we compare it with other risks that the public find generally "acceptable", such as:

- Road transportation
- Leisure activities
- Routine domestic activities

A common metric of risk is 'incidents (injuries, deaths) per 100,000' of the population.

Hence, in the UK, there are 4 road deaths per year per 100 k of the population

Risk = **Likeliness** of Occurrence X **Consequences** of Occurrence

This concept of risk seems to be commonly accepted

We are less concerned with risks, even if severe, if they are rare

This principle is applied in industry when assessing risks

Risk should be ALARP – as low as reasonably practicable

Risk of dying on the road

The risk of death and injury on the road is often quoted when comparing other risks

Country	Per 100k inhabitants per yr	Per 100k vehicles per yr	Per 1 bn vehicle-km	Total latest year
Australia	5	7	5.2	1,196
Austria	5	7	6.9	453
Brazil	23	68	55.9	43,869
China	21	133		275,983
Denmark	3	6	3.4	167
Eritrea	48	4,400		
France	5	9	6.3	3,250
Germany	4	7	4.9	3,520
Japan	5	7	8.3	6,090
Netherlands	4	7	4.9	650
Norway	3	4	3.3	145
Spain	4	6	8.5	1,903
UK	4	6	4.3	2,175
USA	12	14	7.6	36,166

http://en.wikipedia.org/wiki/List_of_countries_by_traffic-related_death_rate

The table includes all road fatalities, not just those related to oil and gas

Risk of dying by sporting activity

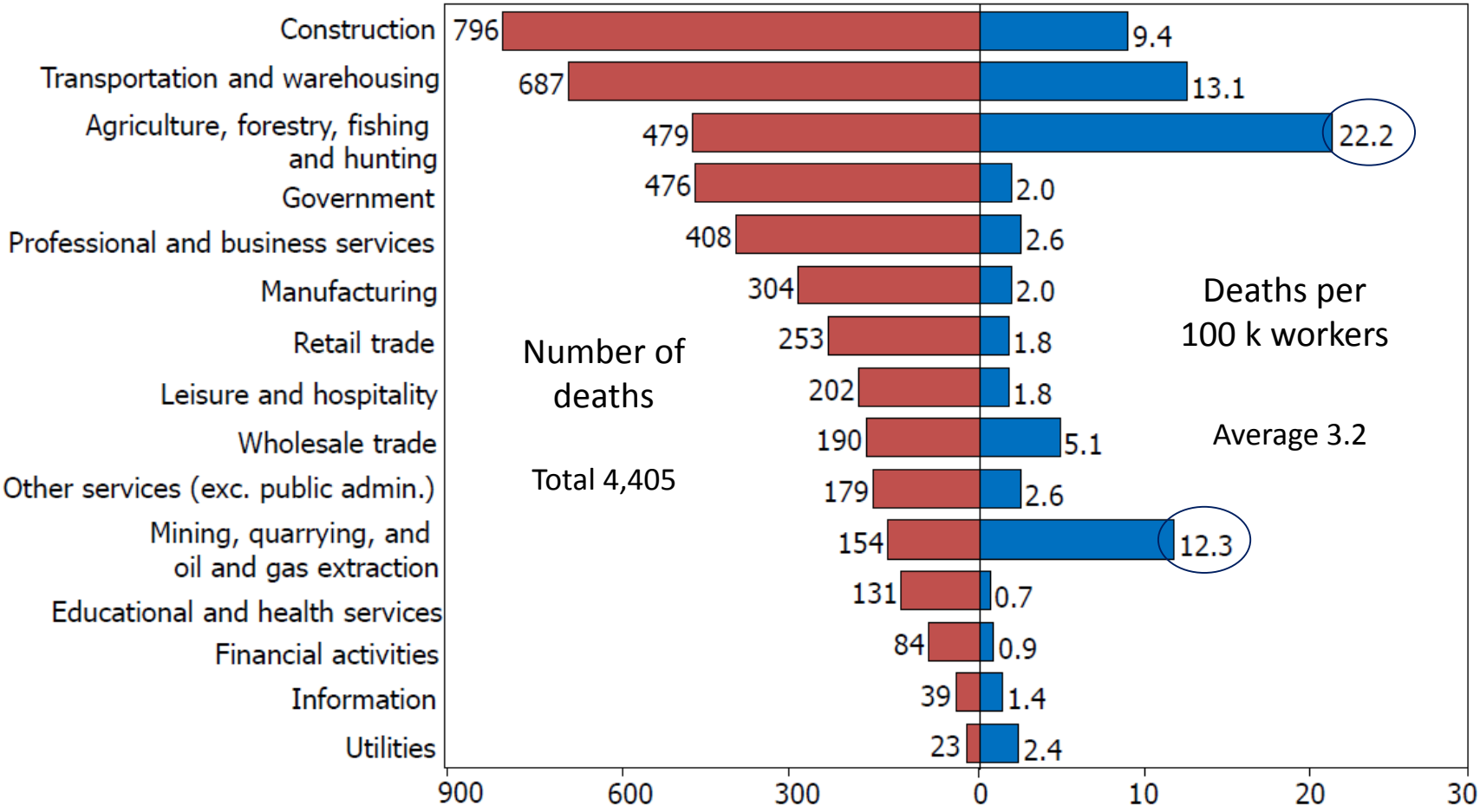
The risk of dying associated with most sporting activities is surprisingly low, even with skydiving or hang gliding.

Cause of Death	Crude Rate per 100k	Odds of Dying (1 in)
BASE Jumping	43.2	2,317 jumps
Swimming	1.77	56,587
Cycling	1.08	92,325
Running	1.03	97,455
Skydiving	0.90	101,083 jumps
Football	0.97	103,187
Hang-gliding	0.86	116,000 flights
Tennis	0.86	116,945
Sudden cardiac death whilst running a marathon	0.79	126,626 runners
Horse Riding	0.57	175,418
American Football	0.55	182,184
Scuba Diving		200,000 dives
Table Tennis	0.40	250,597
Rock Climbing	0.31	320,000 climbs
Canoeing	0.13	750,000 outings
Skiing	0.06	1,556,757 visits

http://www.medicine.ox.ac.uk/bandolier/booth/risk/sports.html

Risk of dying at work, by industry sector, USA

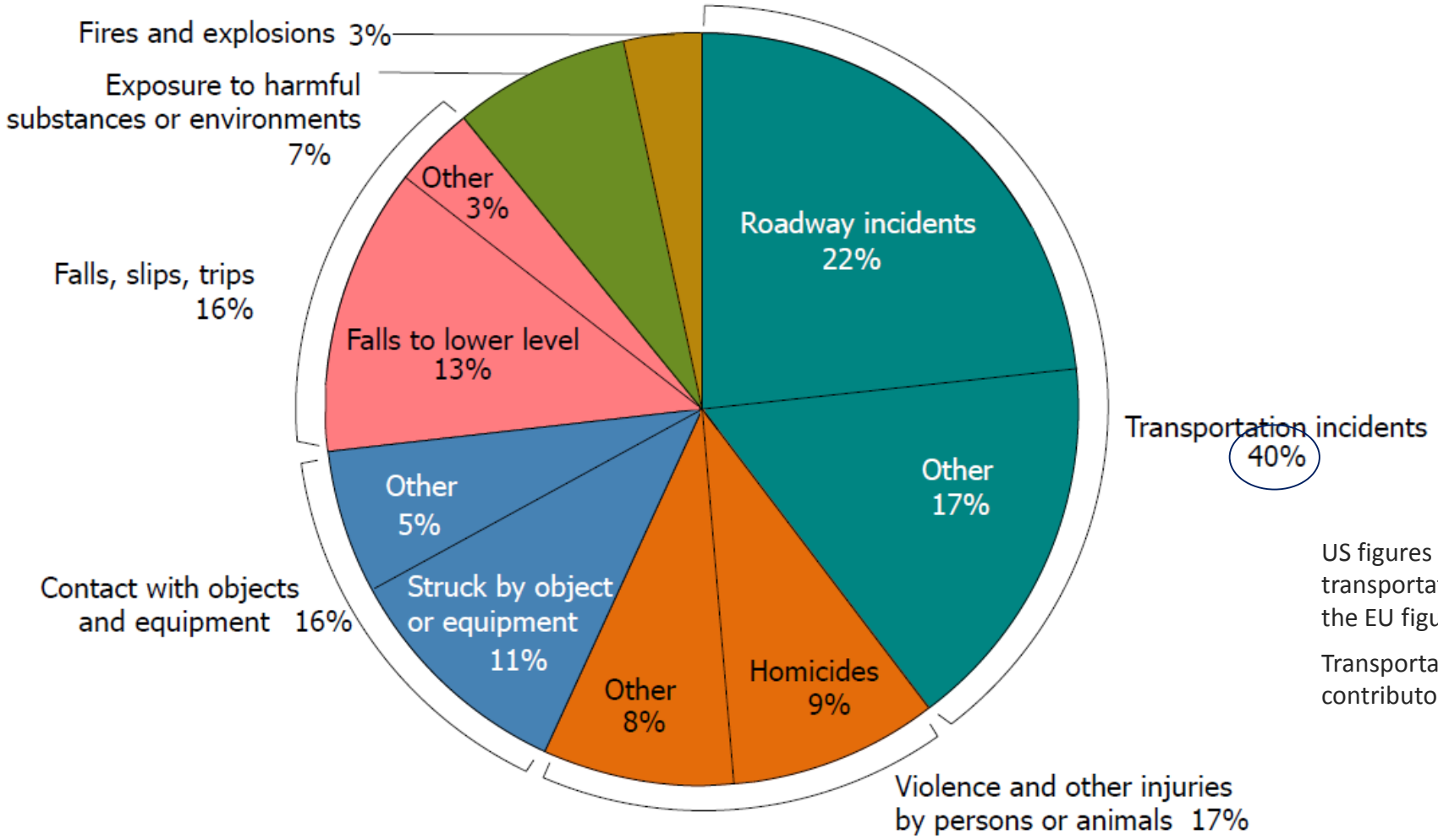
Occupational deaths, by industry sector, 2013, USA



http://www.bls.gov/iif/oshwc/cfoi/cfch0012.pdf USA US Bureau of Labor Statistics

Risk of dying at work, by type of incident, USA

Occupational deaths, by major event, 2013, USA



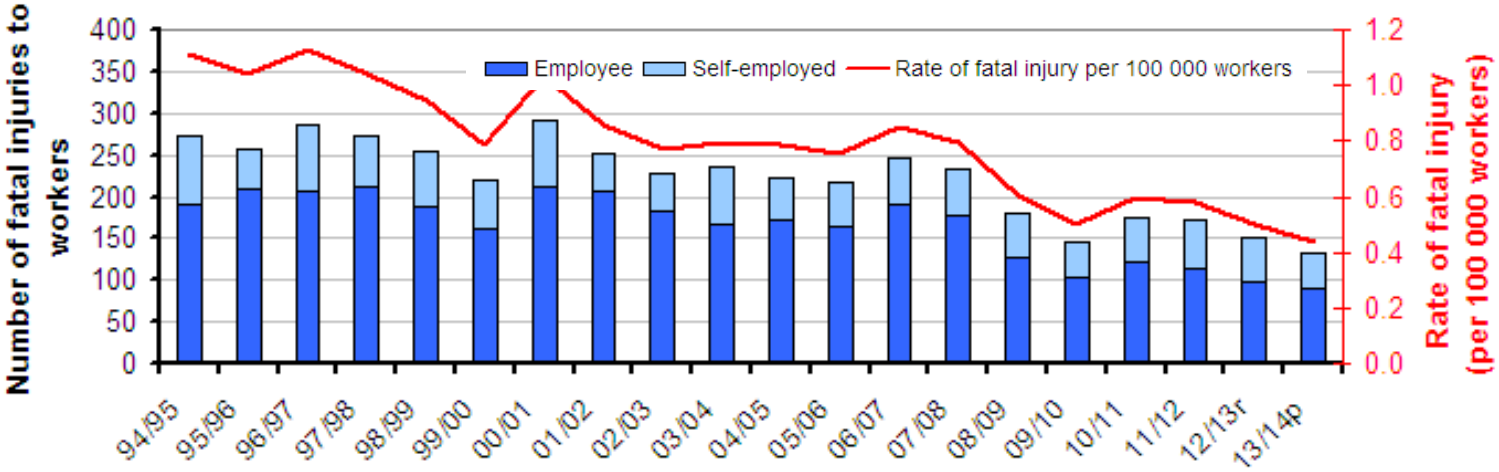
US figures include transportation incidents, the EU figures do not.

Transportation is a large contributor to risk.

http://www.bls.gov/iif/oshwc/cfoi/cfch0012.pdf

Risk of dying at work, UK & EU

Fatal injury to workers, UK



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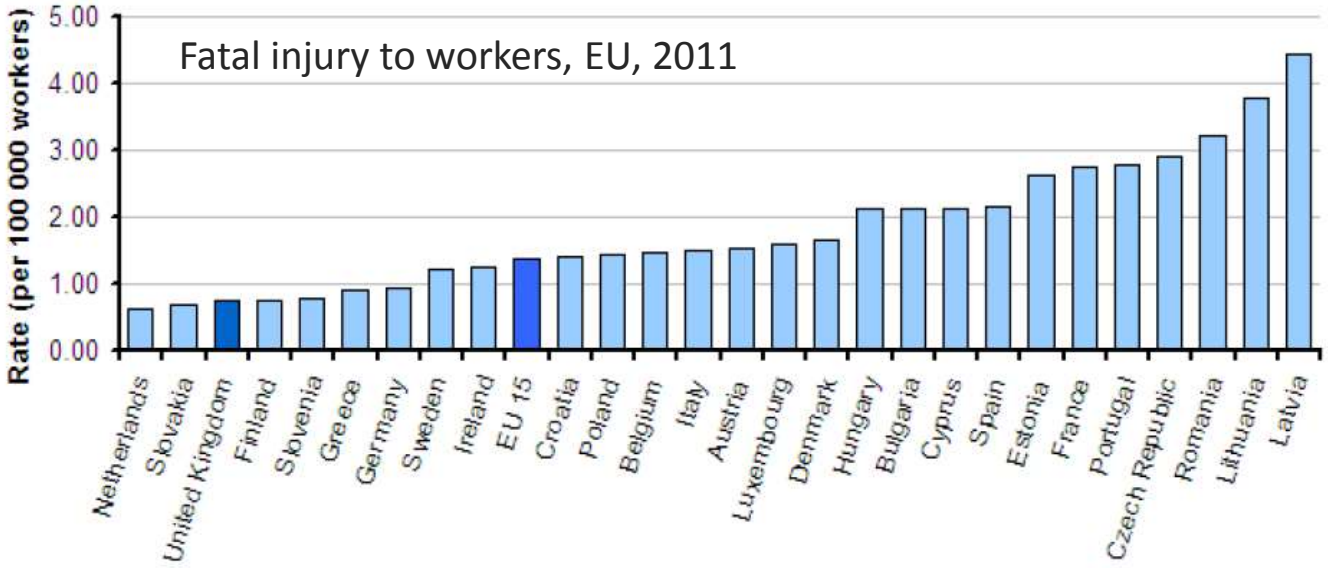
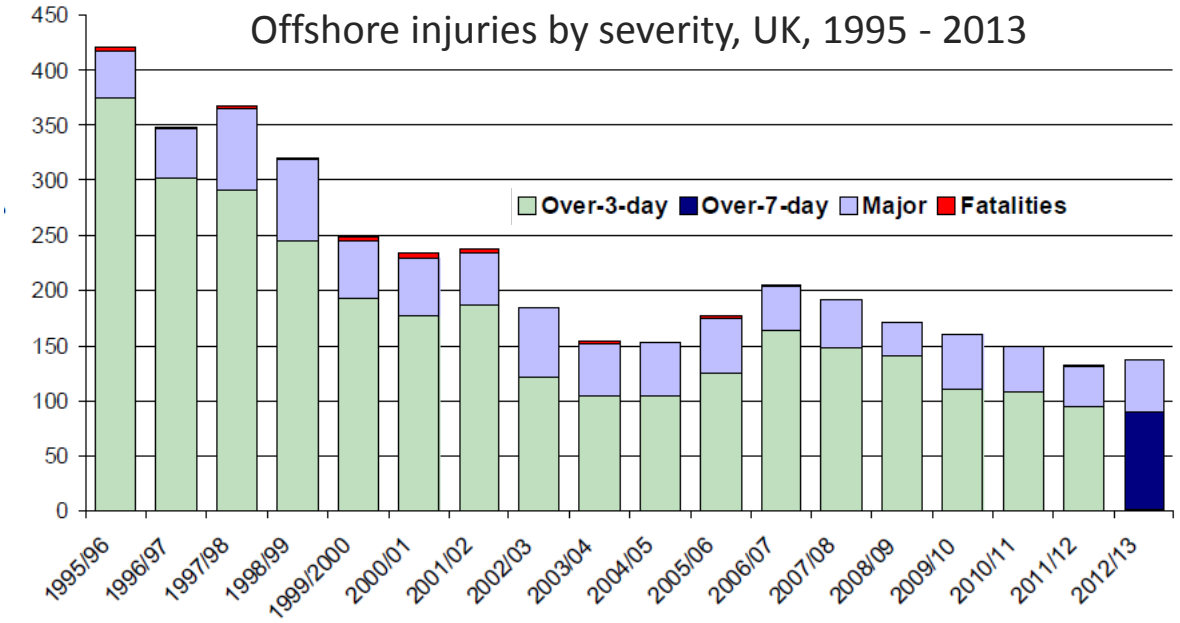


The above chart indicates a general reduction in injuries over time.

The below chart indicates a wide variation of injury rates across Europe

http://www.hse.gov.uk/statistics/pdf/fatalinjuries.pdf

Risk of dying offshore UK



Offshore deaths and death rate, UK, 1995 to 2013

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Deaths	5	2	3	1	2	3	3	0	3	0	2	2	0	0	0	0	2	0
Deaths per 100k	17.2	7.4	13.0	3.9	10.5	12.9	12.9	0	16.0	0	8.7	7.1	0	0	0	0	6.9	0
Workforce	29k	27k	23k	26k	19k	23k	23k	21k	19k	19k	23k	28k	28k	28k	27k	28k	29k	32k

Average 6.5 deaths per 100k in this period

Excludes transportation deaths

http://www.hse.gov.uk/offshore/statistics/hsr1213.pdf

Safety and Environment in Exploration and Production

What can be (has been) done?

Following the Piper Alpha incident in 1988

- British supervisory system overhauled
- Safety management system introduced
- Safety awareness programmes for personnel
- External safety audits

- Freefall lifeboats, from heat shielded slipways
- Emergency shutdown valves on seabed and topsides, incoming and outgoing pipelines
- Multiple protected escape routes with heat shielded stairways
- Physical separation of accommodation modules from drilling & process
- Computerised control and shutdown of process equipment

Following the Exxon Valdez catastrophe in 1989

- High-profile hearing held
- Massive compensation payments awarded
- Large number of regulations and technical measures introduced.

Safety and risk management has become important to all parts of the field life cycle.

They involve all technical and support functions.

Operators recognise that good safety and environmental management

- Makes economic sense
- Is essential to remain in business.

Following the Deepwater Horizon incident in 2010

- MMR disbanded, on account of perceived conflicts of interest.
- BOMRE regulatory body created
- Heavy fines and compensation payments
- Additional regulations proposed by BOEMRE

- EU Offshore Safety Directive 2013/30/EU, with emphasis on environmental damage