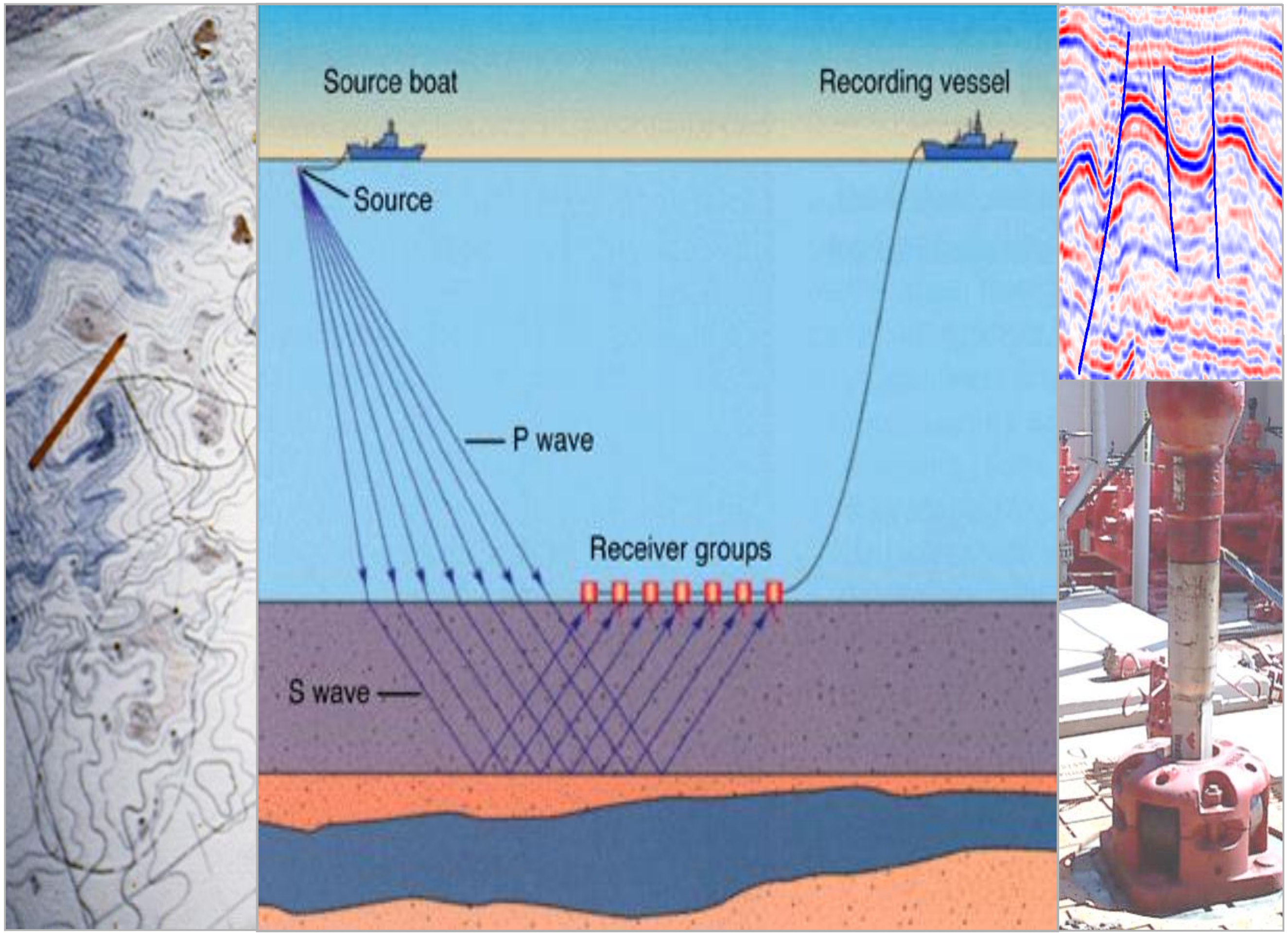
Upstream Process Engineering Course

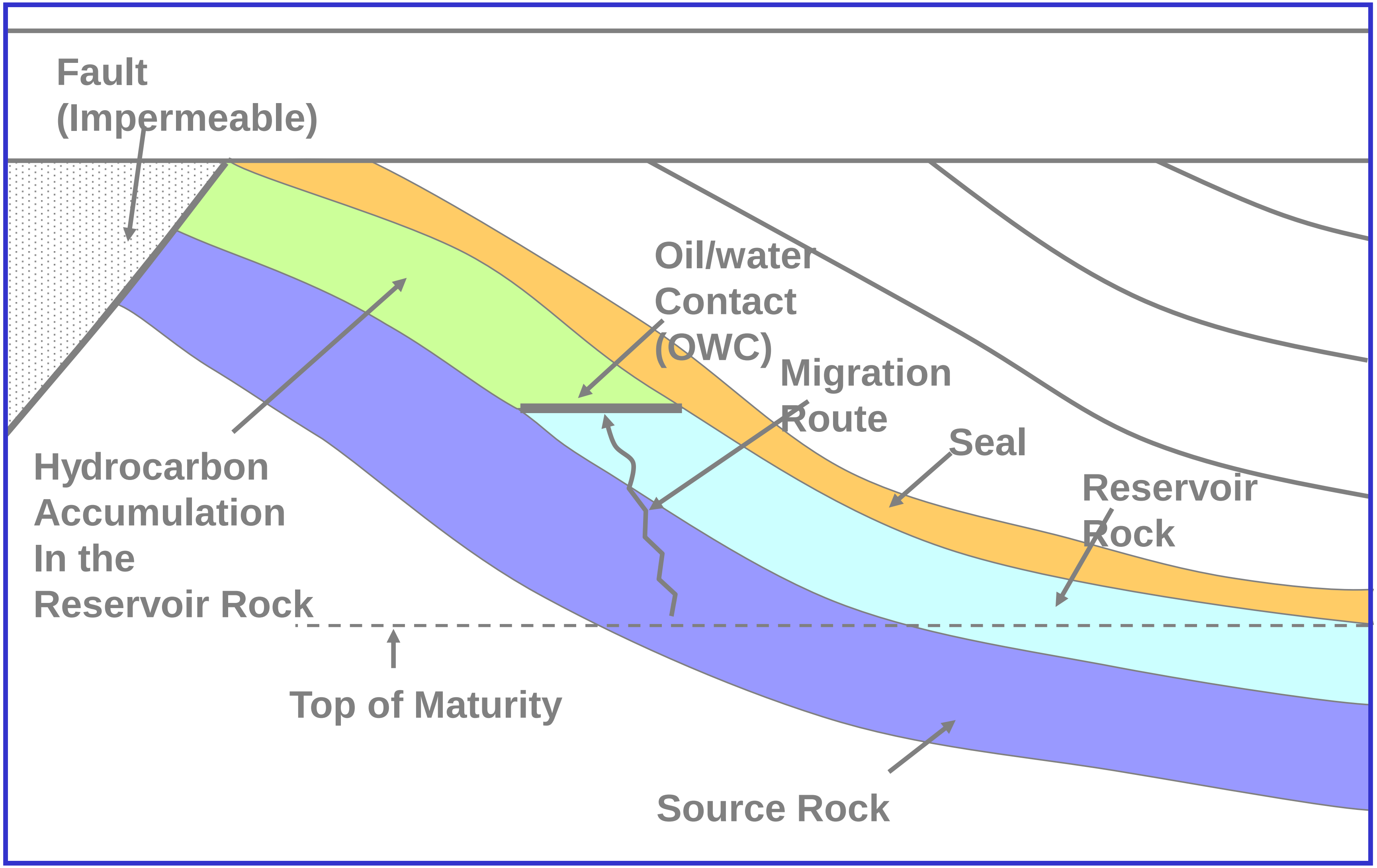
Overview

Finding

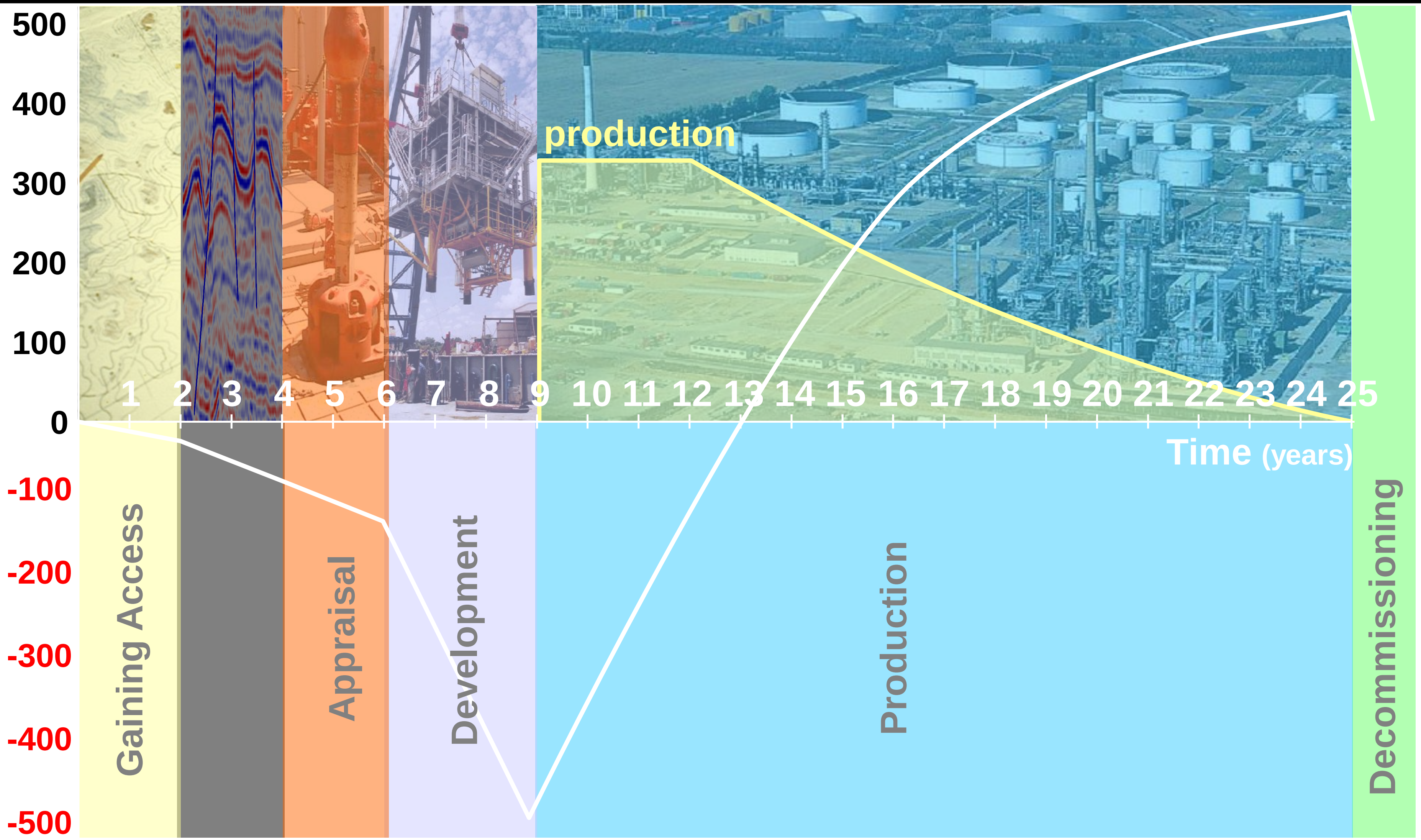


Source boat
Recording vessel
Source
P wave
Receiver groups
S wave

The Geological Trap



The field life cycle



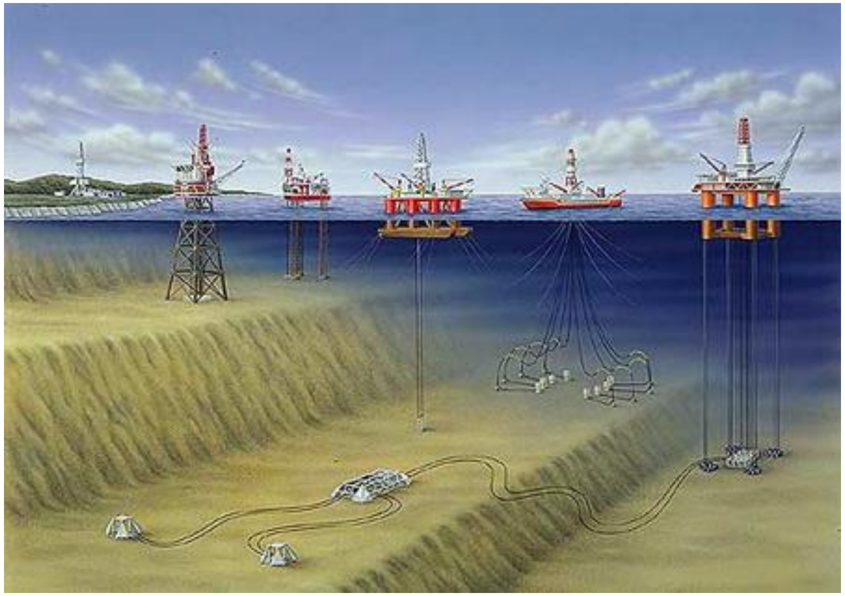
Concept Selection

Understand the Environment

- Location.Terrain/Metocean
- Market
- Infrastructure
- Fiscal & Political Regime etc.

Understand the Reservoir & Quantify Uncertainties

- Reserves
- No of Wells
- Well rate
- Reservoir management strategy

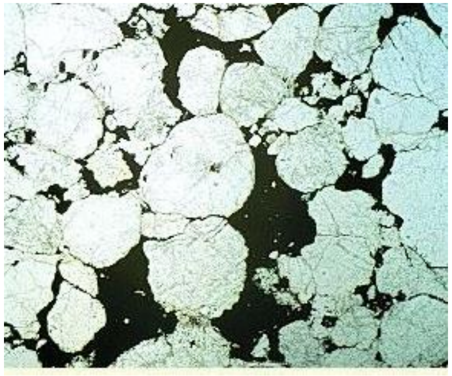


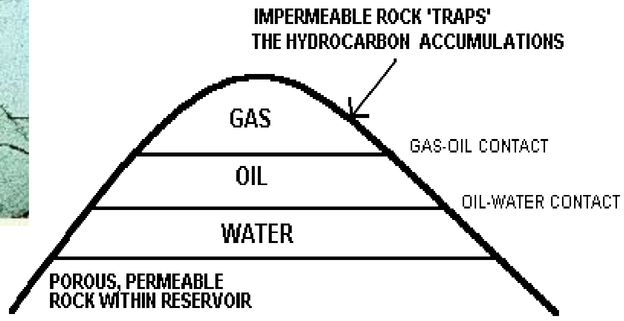
Understand the Drilling

- Maximum step-out
- Cost per well
- No of drill centres required
- Intervention frequency and cost
- Wet vs Dry trees pros & cons

Reservoir Management

- Reservoir Features
  - Porous rock
  - Impermeable layer
  - Permeability
- Reservoir Management
  - Pressure
  - Gas-oil contact
  - Oil-water contact
  - Withdrawal rates
  - Gas injection rates and composition
  - Water injection rates
  - Prediction of oil rate, GOR, water cut and composition with time

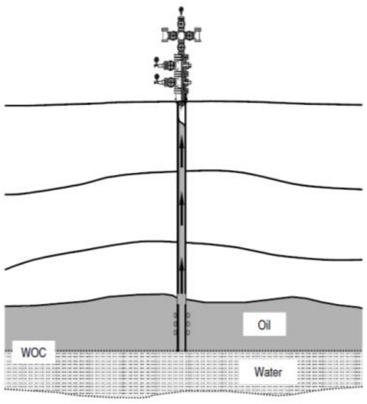




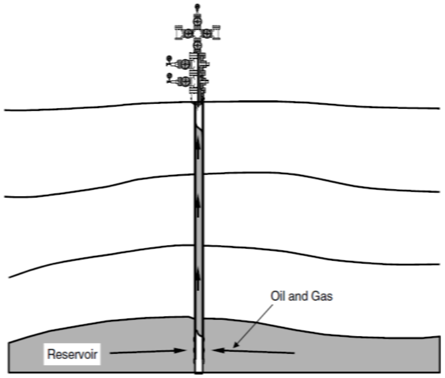
The formation pressure will normally be determined by the water column to surface at the oil-water contact

Primary Recovery

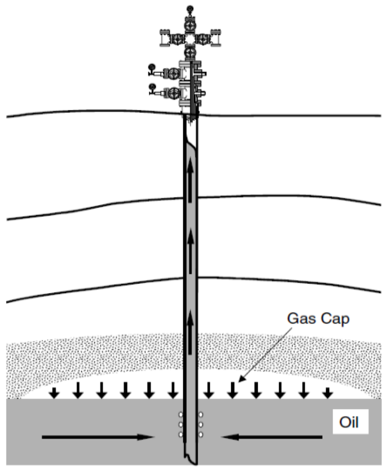
- Primary recovery techniques yield a wide range in recovery factor; between 5-30%
- Solution Gas Drive
  - Oil is produced by the natural expansion of dissolved gas in the oil
- Natural Water Drive
  - The reservoir pressure reduces as oil is produced allowing the aquifer to expand and flow into the reservoir
- Natural Gas Cap Drive/Gravity Drainage
  - The reservoir pressure reduces as oil is produced allowing the gas cap to expand and assist recovery



A sketch of a water-drive reservoir.



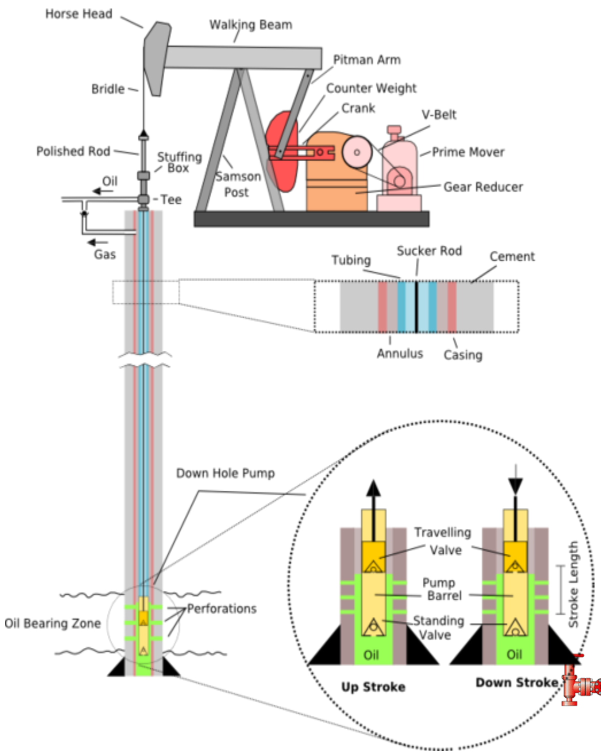
A sketch of a dissolved-gas drive reservoir.

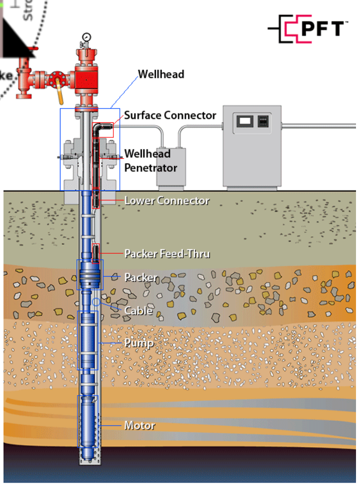


A sketch of a gas-cap drive reservoir.

Reservoir Management

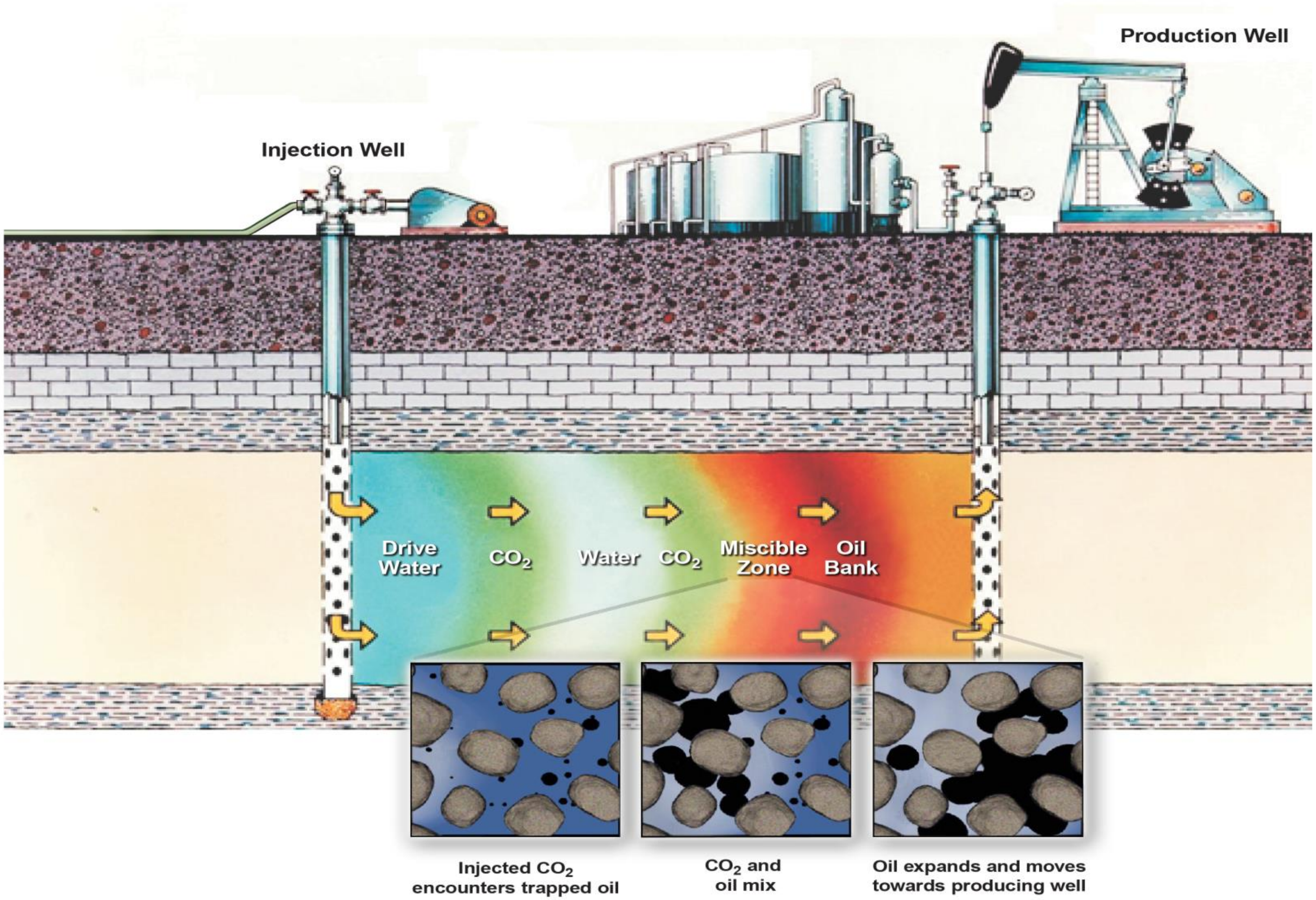
- **Secondary Recovery**
  - Gas and/or water injection
    - If the natural drives are insufficient, as they very often are, then the pressure can be artificially maintained by injecting water into the aquifer or gas into the gas cap.
  - Artificial lift
    - Gas,
    - Electric Submersible Pumps
    - Hydraulic Pumps
    - Sucker Rod Pumps





- **Tertiary/Enhanced Oil Recovery**
  - Miscible gas – Hydrocarbon, CO_2, N_2
  - Surfactants
  - Polymers
  - Microbial
  - Thermal/steam flood

CO_2 Enhanced Oil Recovery



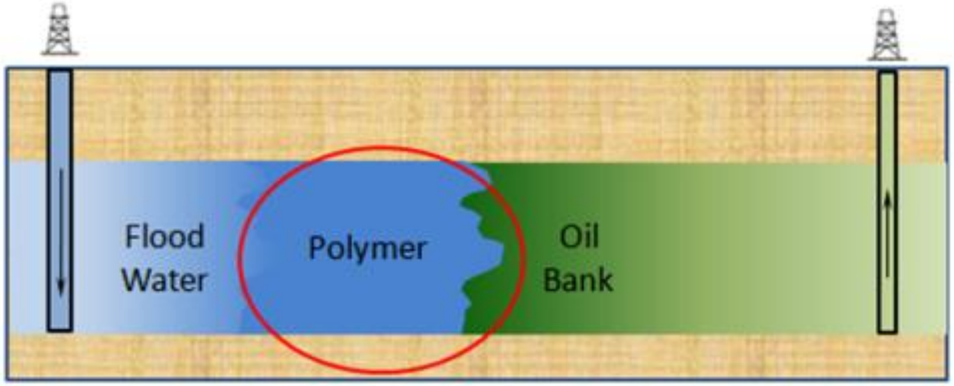
Solar Steam Generation

World first in Oman

Polymer Enhanced Oil Recovery

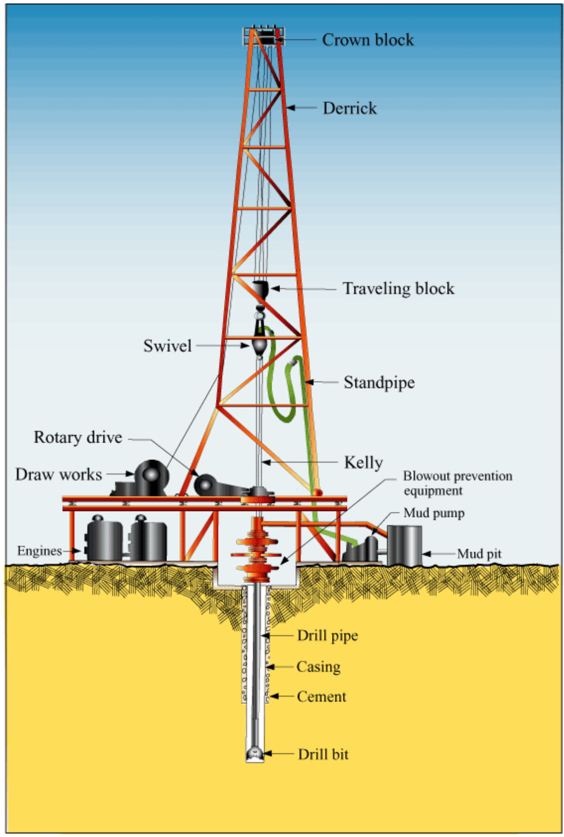
Polymer EOR is a process in which polymer is added to the injected water in order to increase its viscosity and, hence, sweep efficiency. Polymer selection is based on the temperature and salinity of the reservoir as well as the formation permeability.

In polymer EOR, high molecular-weight, water-soluble polymers are injected with the water. These polymers are typically either polyacrylamides or polysaccharides. Care must be taken to ensure that the polymer does not degrade as it moves through the reservoir. Polymer flooding increases oil recovery by improving areal sweep, improving vertical conformance, and reducing water production.

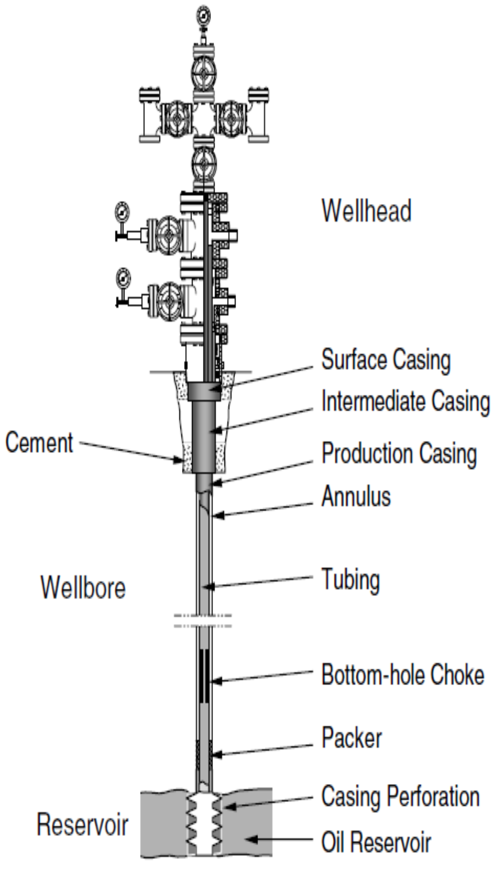


Drilling

- Drilling involves the successive addition of lengths of drill pipe to the drill string as depth is achieved.
- Once the hole is drilled to the desired depth, pipes of successively smaller diameter are inserted into the hole and cemented in place. These are known as “casings”. The “liner” or “tubing” is the production pipe, which is inserted into the casings and cemented in place.
- The tubing is then perforated in the producing zone and the Xmas tree (the production valves and instruments) is installed at the top of the tubing.
- This process is called “completion”.

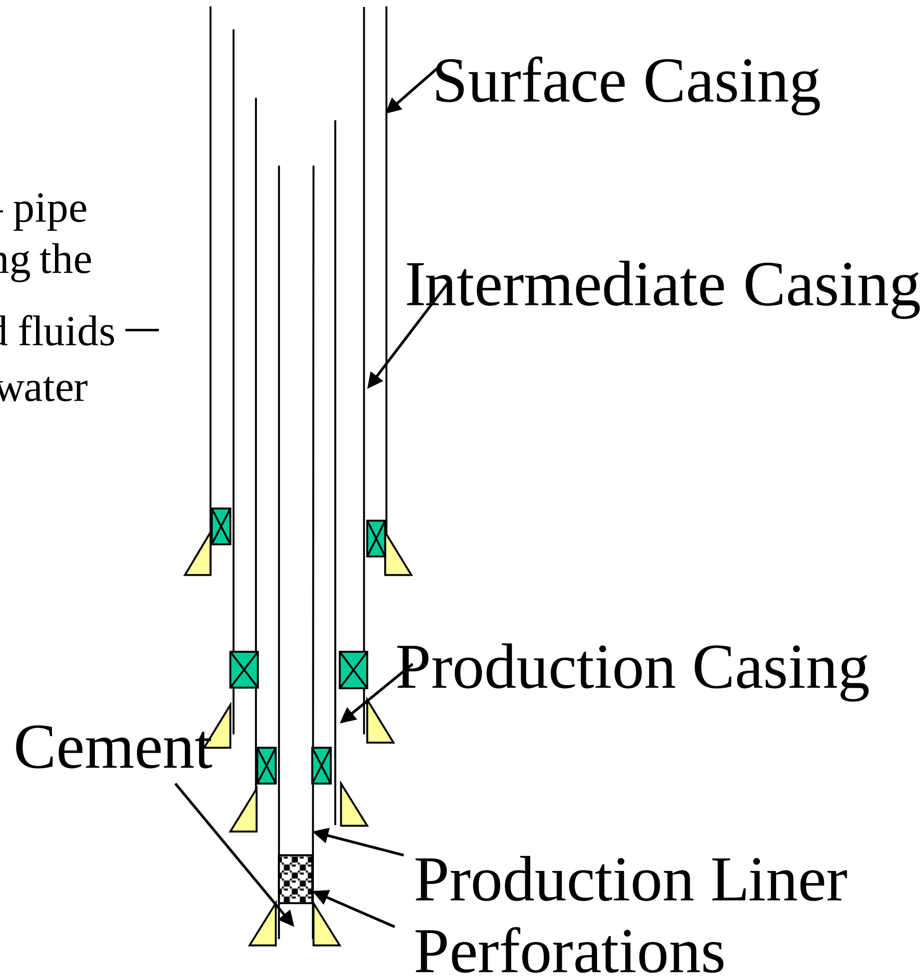


Well Completion

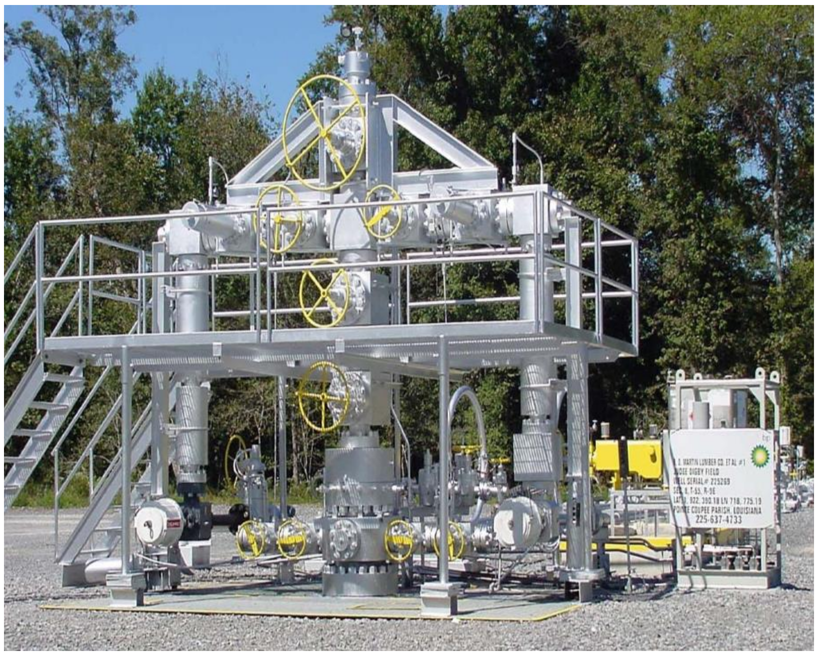


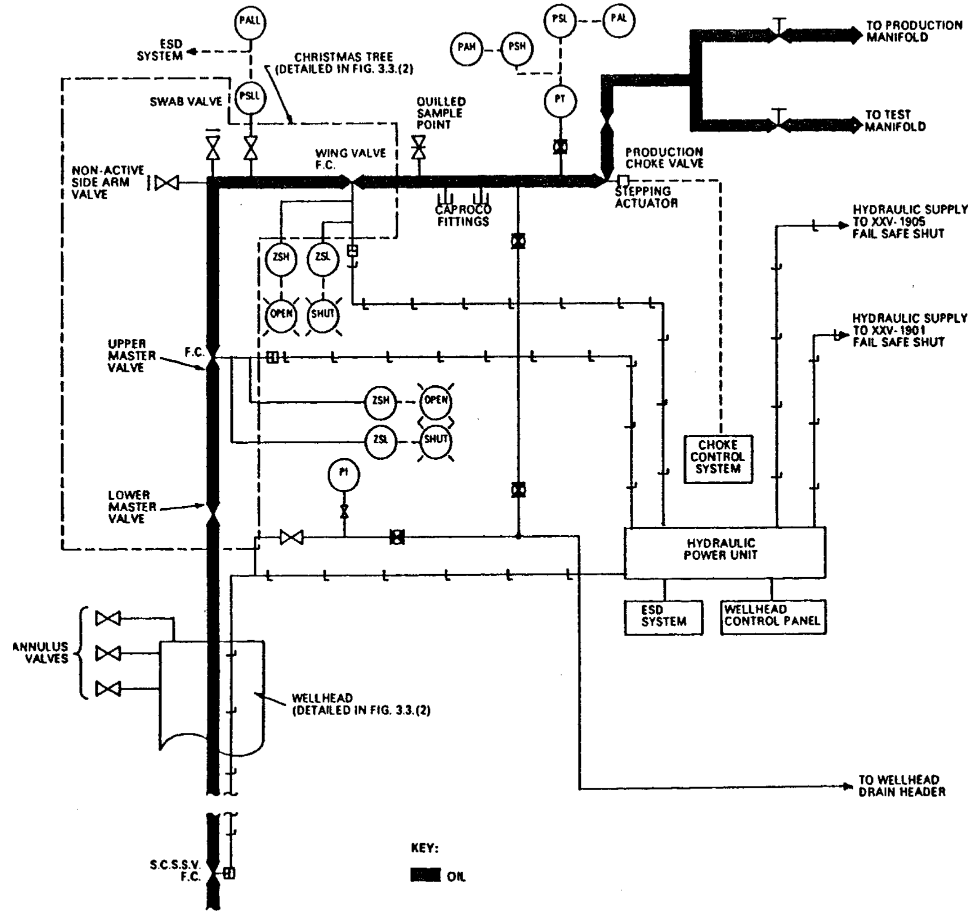
A sketch of a typical flowing oil well.

Tubing – pipe containing the produced fluids – oil, gas, water



Wellhead




PALL
ESD SYSTEM
CHRISTMAS TREE (DETAILED IN FIG. 3.3.(2)
PAH
PSH
PSL
PAL
TO PRODUCTION MANIFOLD
SWAB VALVE
PSLL
QUILLED SAMPLE POINT
PT
TO TEST MANIFOLD
NON-ACTIVE SIDE ARM VALVE
WING VALVE F.C.
PRODUCTION CHOKE VALVE
STEPPING ACTUATOR
CAPROCO FITTINGS
HYDRAULIC SUPPLY TO XXV-1905 FAIL SAFE SHUT
ZSH
ZSL
OPEN
SHUT
HYDRAULIC SUPPLY TO XXV-1901 FAIL SAFE SHUT
UPPER MASTER VALVE
F.C.
CHOKE CONTROL SYSTEM
PI
LOWER MASTER VALVE
HYDRAULIC POWER UNIT
ESD SYSTEM
WELLHEAD CONTROL PANEL
ANNULUS VALVES
WELLHEAD (DETAILED IN FIG. 3.3.(2)
TO WELLHEAD DRAIN HEADER
KEY:
OIL
S.C.S.S.V. F.C.

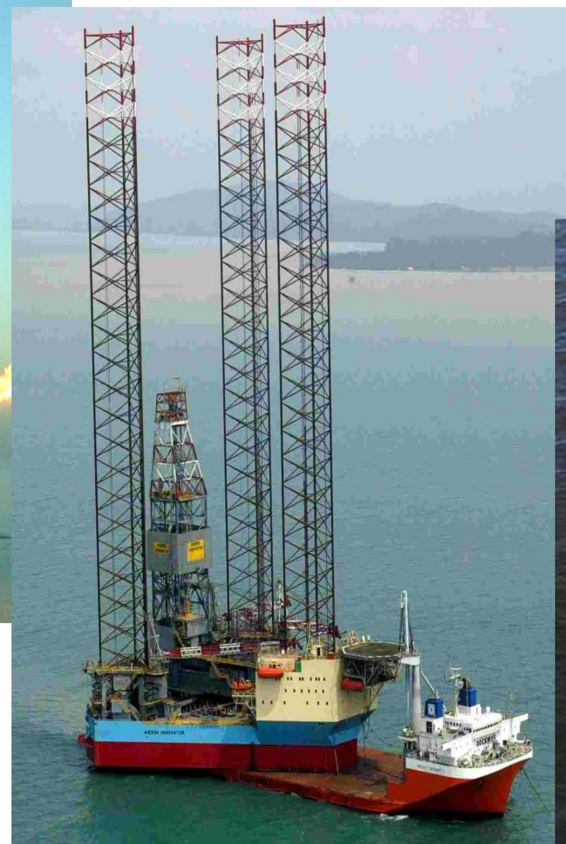
Drilling Options – Onshore

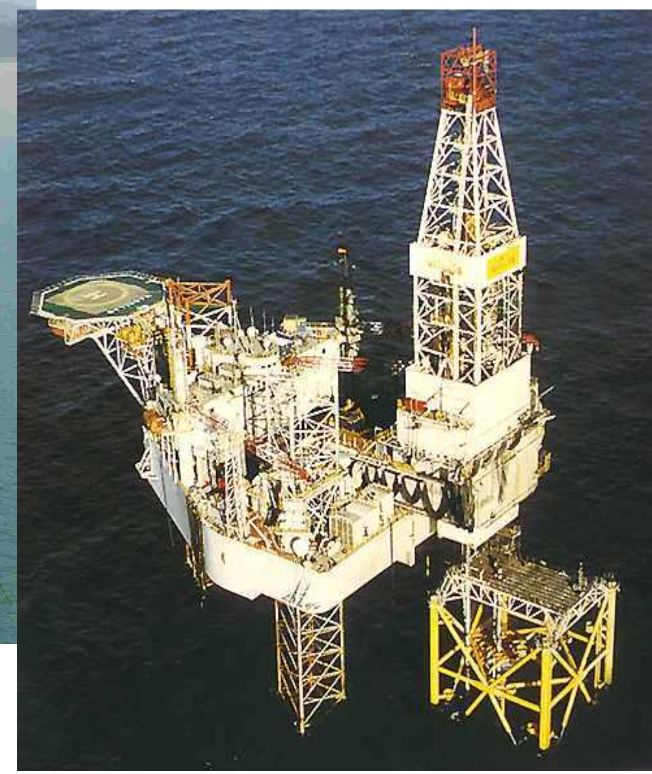
Drilling Options – On Platform

End Bay Drilling

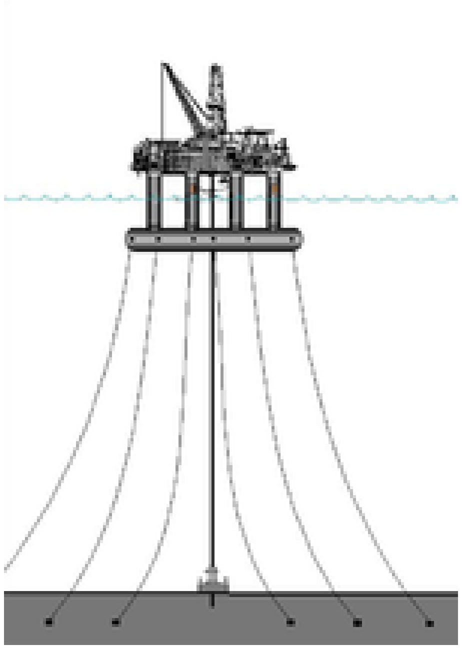
Centre Bay Drilling

Drilling Options – Jack Up

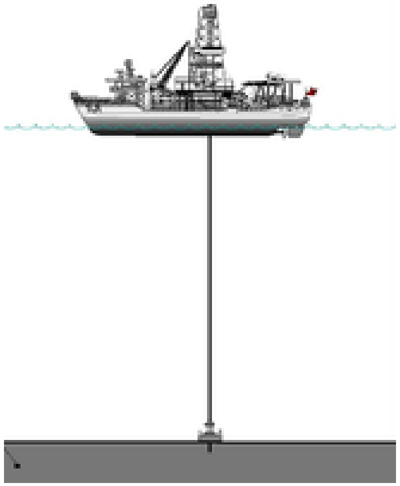




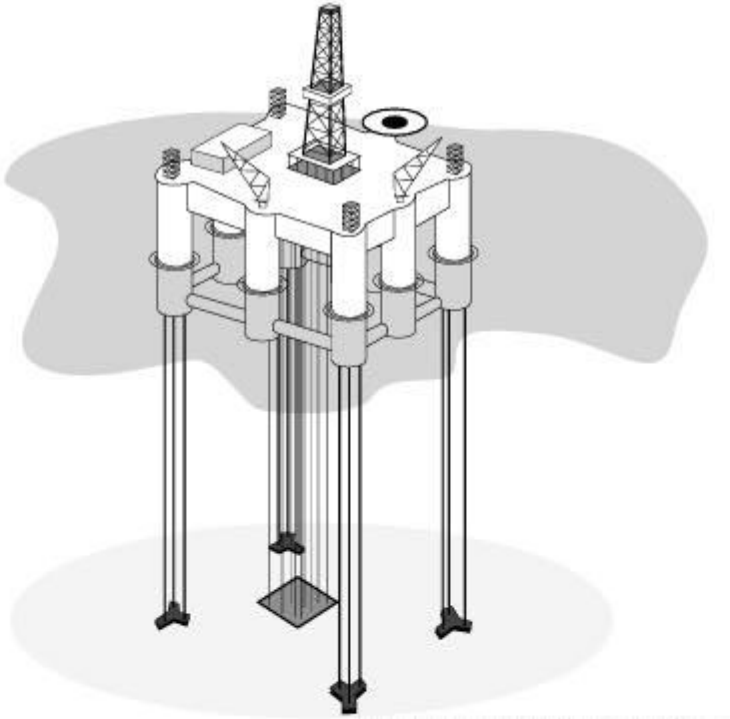
Drilling Options – Semi-Submersible



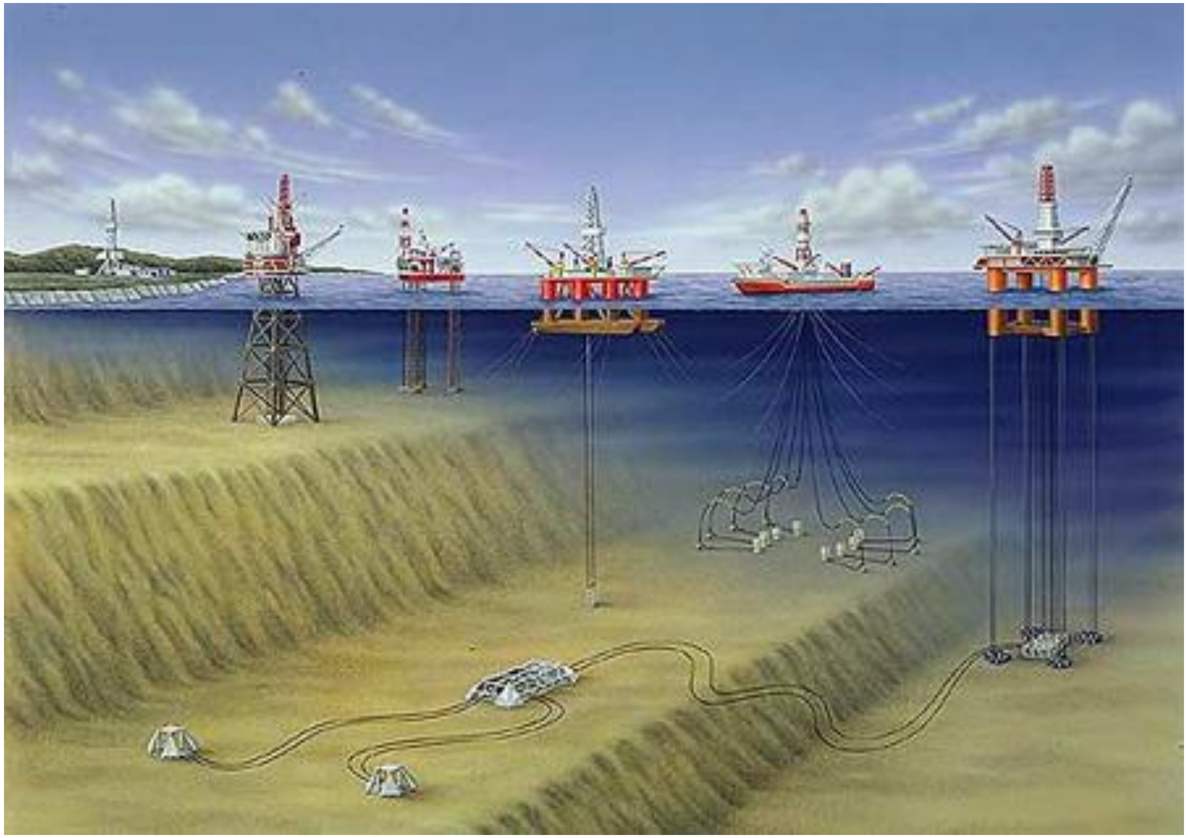
Drilling Options – Drill Ship



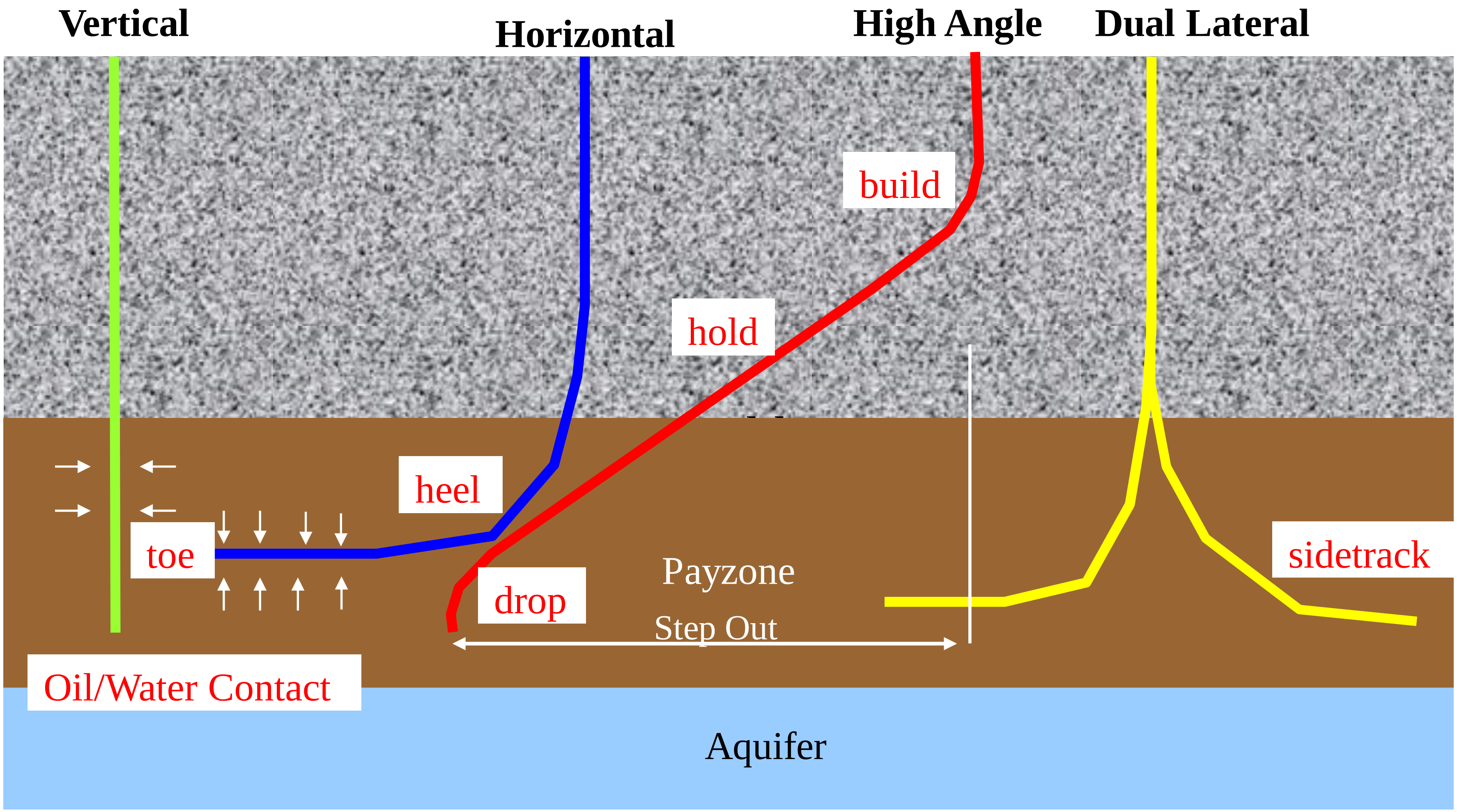
Drilling Options – Tension Leg Platform



Drilling Options

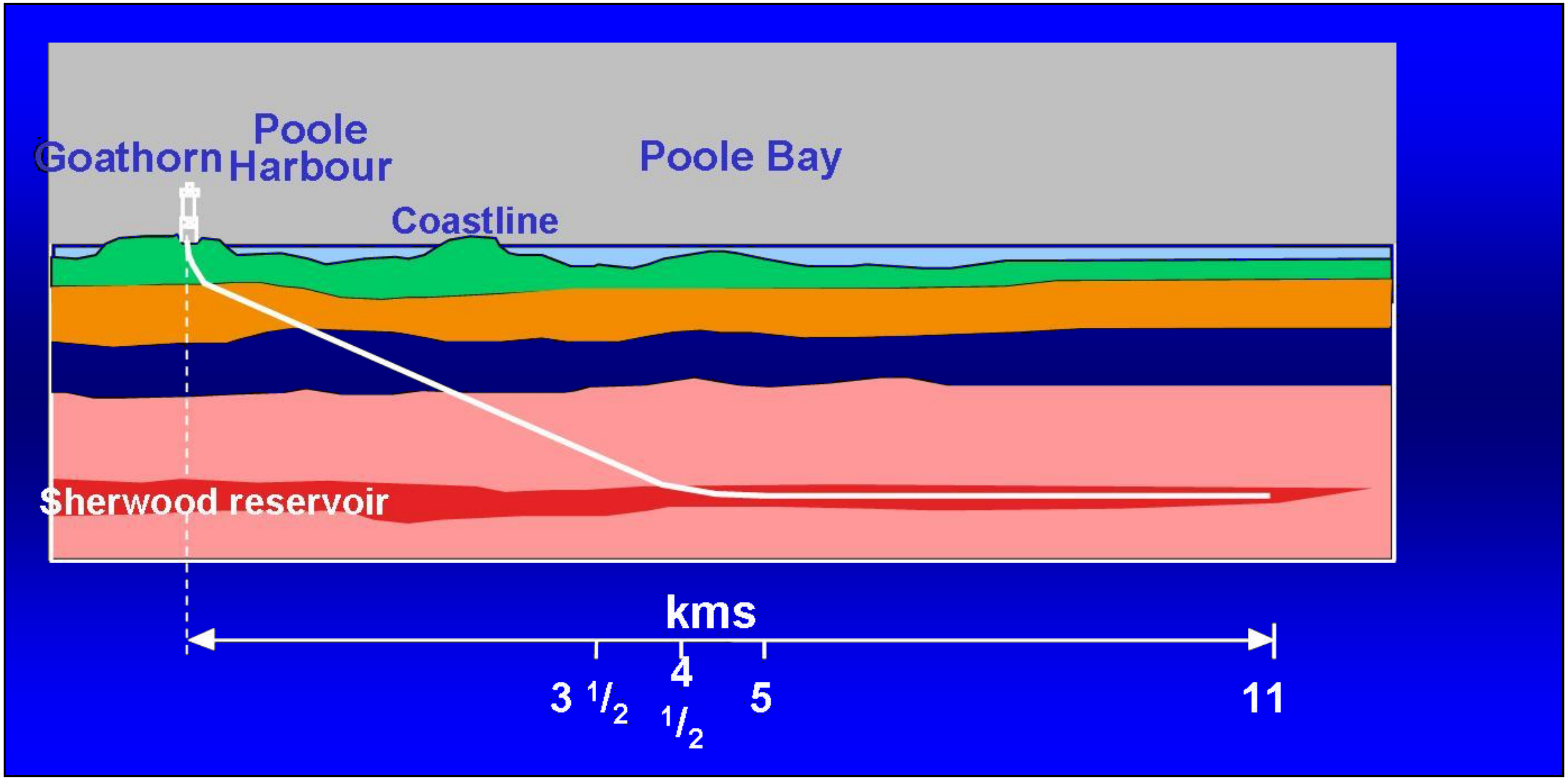


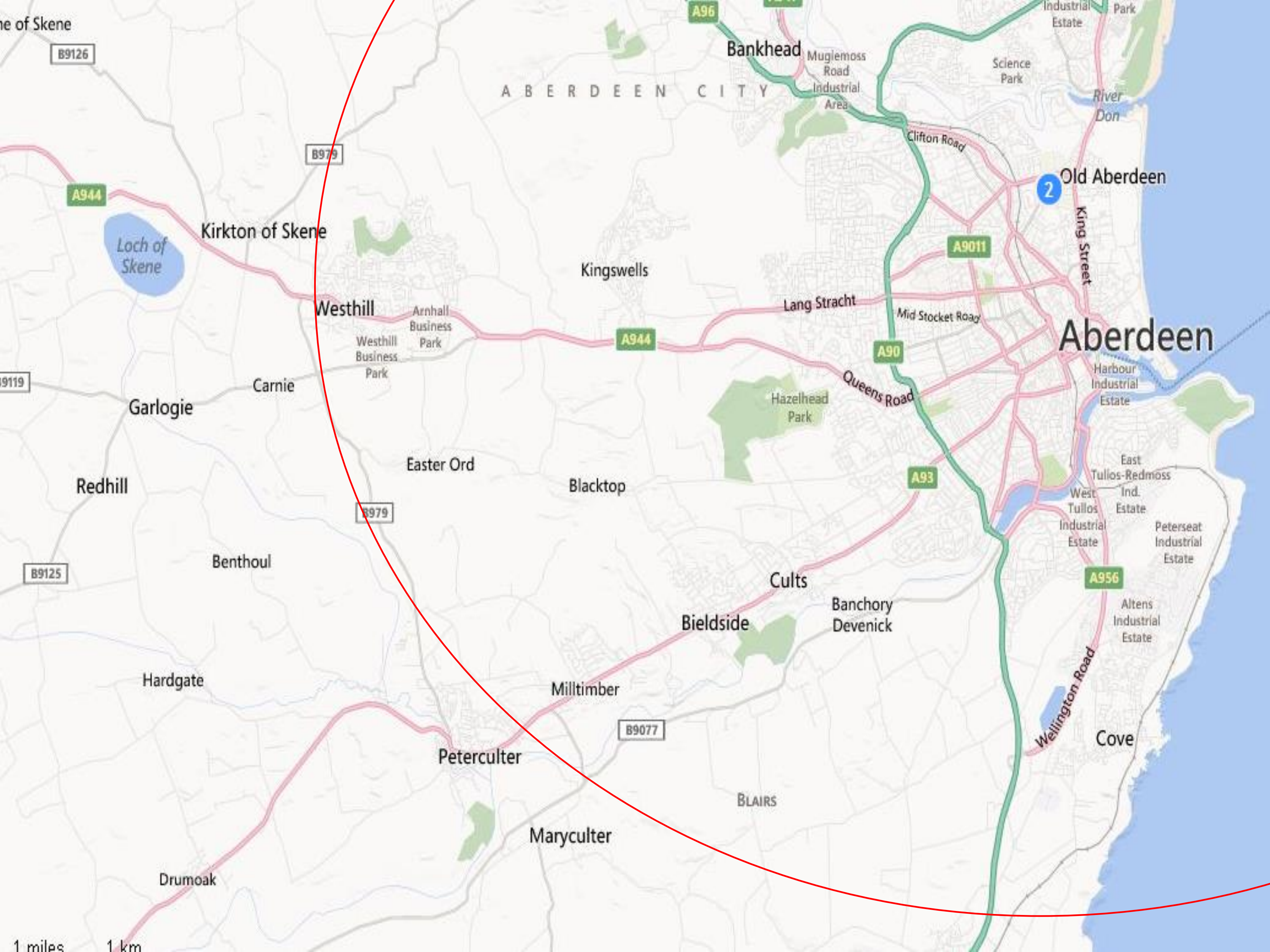
Well Types



Vertical
Horizontal
High Angle
Dual Lateral
build
hold
heel
toe
drop
Payzone
Step Out
sidetrack
Oil/Water Contact
Aquifer

Wytch Farm Extended Reach Drilling – record in UK

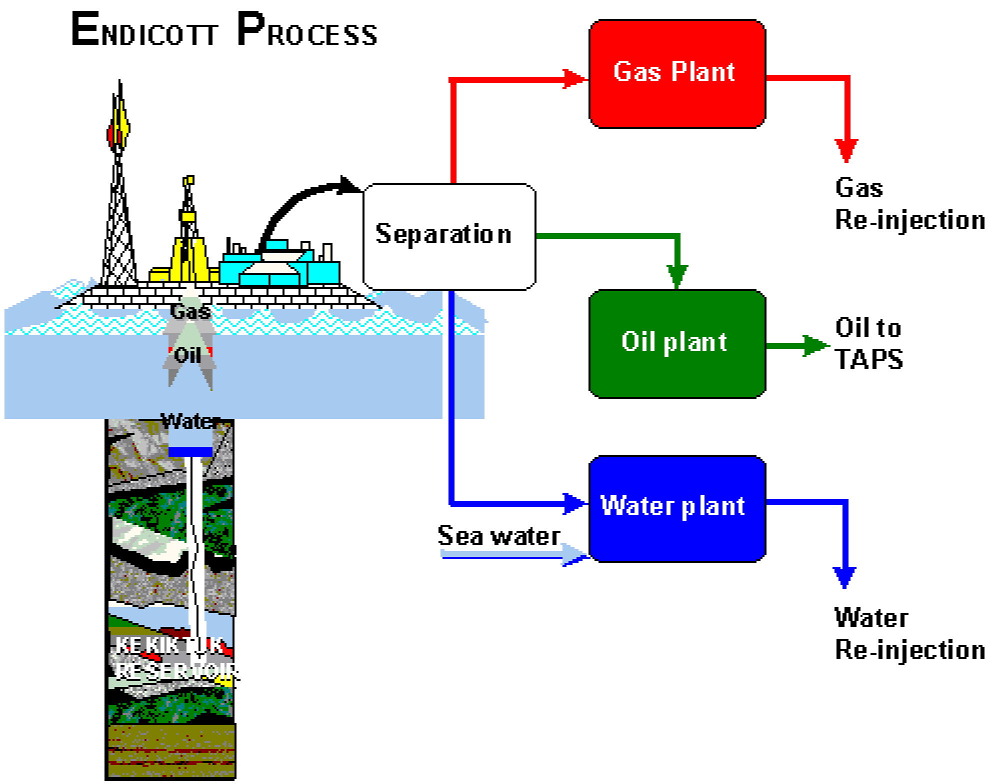




ne of Skene
B9126
A96
Bankhead
Mugiemoss Road Industrial Area
Industrial Estate
Park
Science Park
River Don
A B E R D E E N   C I T Y
B979
Clifton Road
Old Aberdeen
2
A944
Kirkton of Skene
Loch of Skene
Kingswells
A9011
King Street
Westhill
Arnhall Business Park
Westhill Business Park
Lang Stracht
Mid Stocket Road
A944
A90
Aberdeen
Harbour Industrial Estate
B9119
Carnie
Garlogie
Hazelhead Park
Queens Road
Easter Ord
Blacktop
A93
East Tullos-Redmoss Ind. Estate
West Tullos Industrial Estate
Redhill
B979
Peterseat Industrial Estate
B9125
Benthoul
A956
Cults
Banchory Devenick
Altens Industrial Estate
Bieldside
Hardgate
Milltimber
Wellington Road
B9077
Peterculter
Cove
Blairs
Maryculter
Drumoak
1 miles
1 km

Onshore

Endicott Island - an example of a near shore development off the north coast of Alaska



Offshore Concept Types

- Steel Jackets (Single, Twin, Triple, Launched, Lifted)
- Jack-ups (With and w/o WHT)
- Concrete Structures (GBS)
- FPSOs (with and w/o WHT)
- TLP (Tension Leg Platform)
- SPAR
- Compliant Tower
- Subsea

Factors Affecting Offshore Concept Selection

- Infrastructure
- Water Depth
- Topsides Weight
- Installation
- Soils
- Drilling/Reservoir Management Philosophy
- Field Life
- Schedule
- Safety
- Construction Yard Capability
- Abandonment

Process Plant Support Steel Jackets

Barge Launched

Lifted

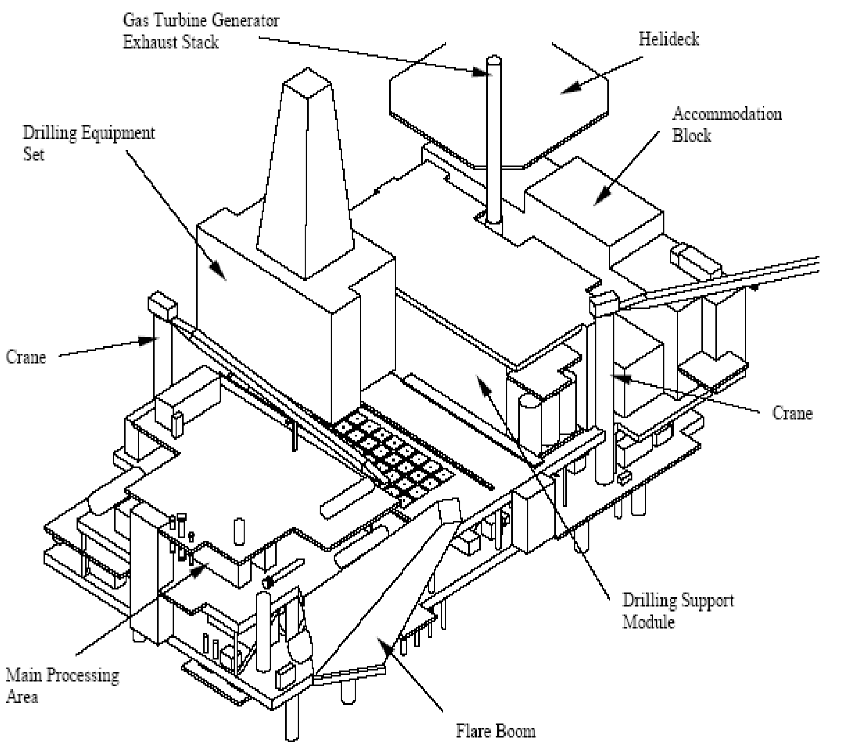
Suitable for water depths from 0 - 400m depending on environmental conditions. Greater than 180 m in the North Sea is not really feasible due to environmental loads leading to excessive weights and thus cost (Magnus 186m – Kvitebjorn 190m) . However, in Gulf of Mexico where environmental conditions are more benign, jackets can be located in 400m .

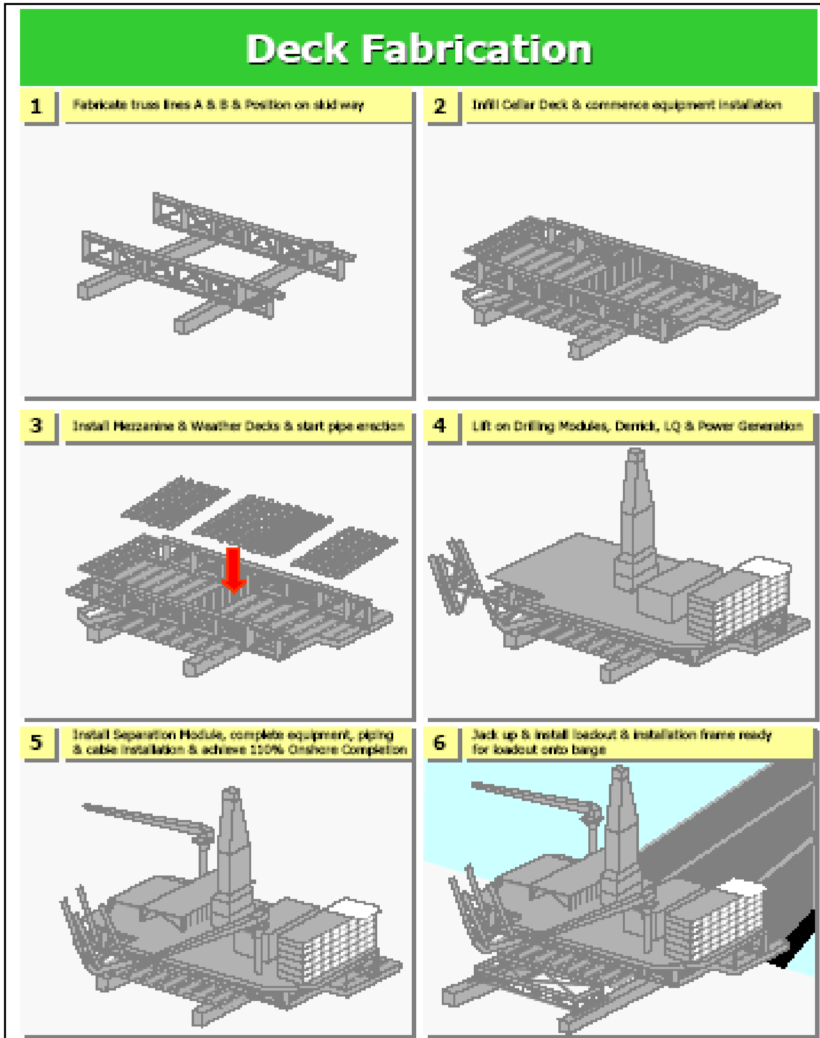
Jackets under 10,000 te can be lifted into place. Larger jackets require to be launched and are specifically designed for this with buoyancy aids etc. Jackets are normally piled in place, suction pods can be used where soil conditions do not favour piling.

The number of jackets in a concept will depend on a number of factors including, single lift weight limitations, modular vs. integrated deck construction, safety, layout and cost.

Fabrication/Installation

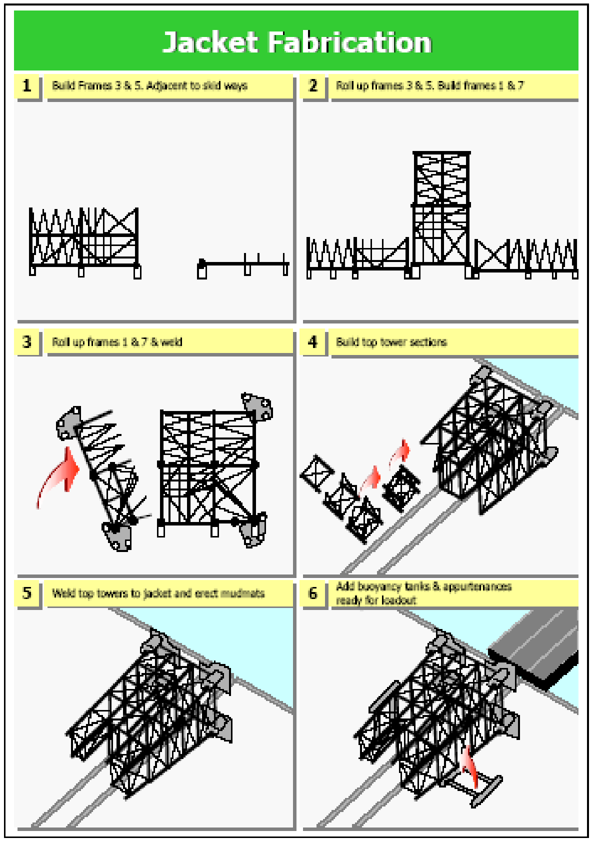
The construction and installation stage safety risks must be evaluated.

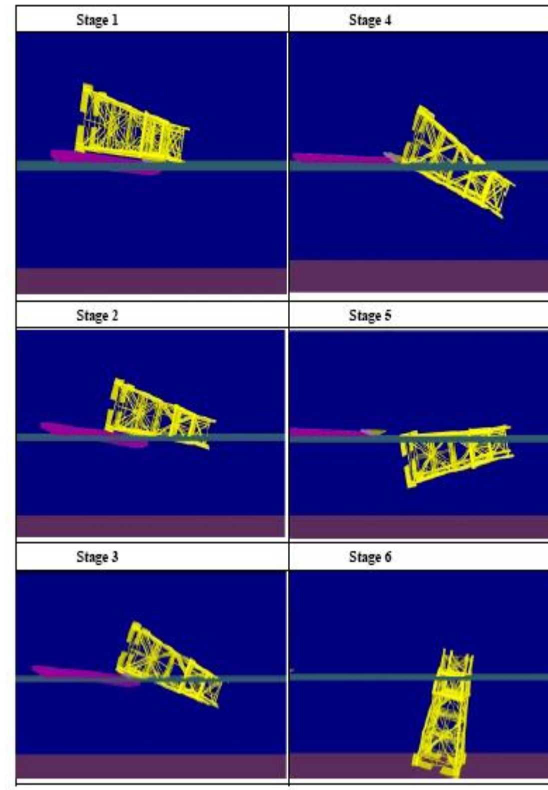




Fabrication/Installation

UNIVERSITY OF ABERDEEN

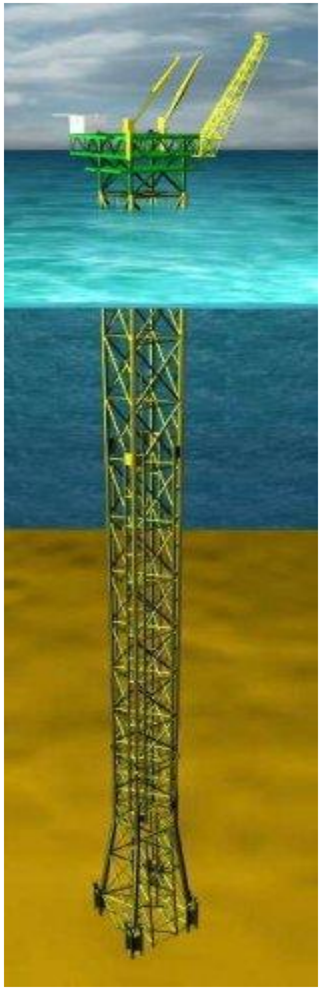


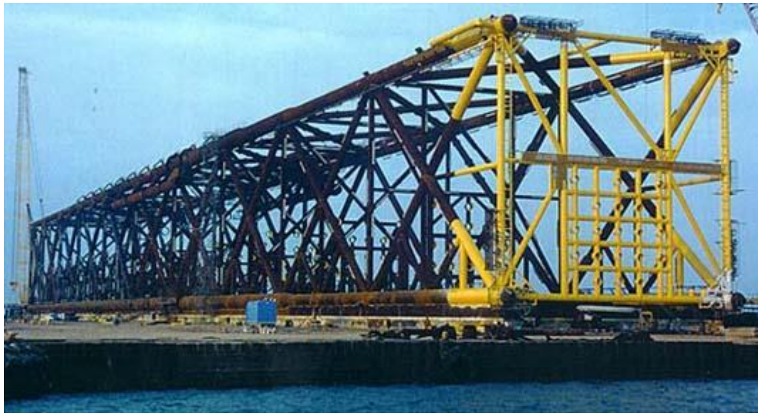


Compliant Tower

A Compliant Tower is a bottom fixed slim steel structure. It is designed such that the natural frequency of the structure is substantially different from the sea states.

CTs have been installed in the GOM in water depths 1500 – 1700 ft.





Drilling Template

Pre-drill and suspend wells prior to substructure placement.

Early oil and revenue.

TPG/Jack-Ups

The main advantage of a jack-up type concept is that it is a self-installing concept. The topsides can be built and commissioned in the construction yard thus minimising offshore HUC hours.

The water depth for this type of concept is limited to the jack-up leg length. Current maximum length is approx. 110-140 m. They can be used in deeper water depths if the seabed is artificially raised, by use of a GSB storage

Often used in conjunction with a Wellhead Tower.

A well known form of this concept is the TPG. Examples include Harding and Elgin/Franklin.

TPG/Jack-Ups

Harding

Tension Leg Platforms

The Tension Leg Platform (TLP) is a very deep water application which allows the ability to drill (direct vertical well access) . It is fixed to the seabed by cables (or tendons) which are effectively in tension. Suitable for depths up to 1200m. Most common in the Gulf of Mexico although there is one in the North Sea (Hutton).

Improved motion characteristics compared to Spars and Semisubmersibles. Full integration and commissioning prior to installation Deeper than 1200m , the cost of TLP's increase dramatically because of the resulting increase in weight of tendons.

Tension Leg Platforms

Semi-Submersible

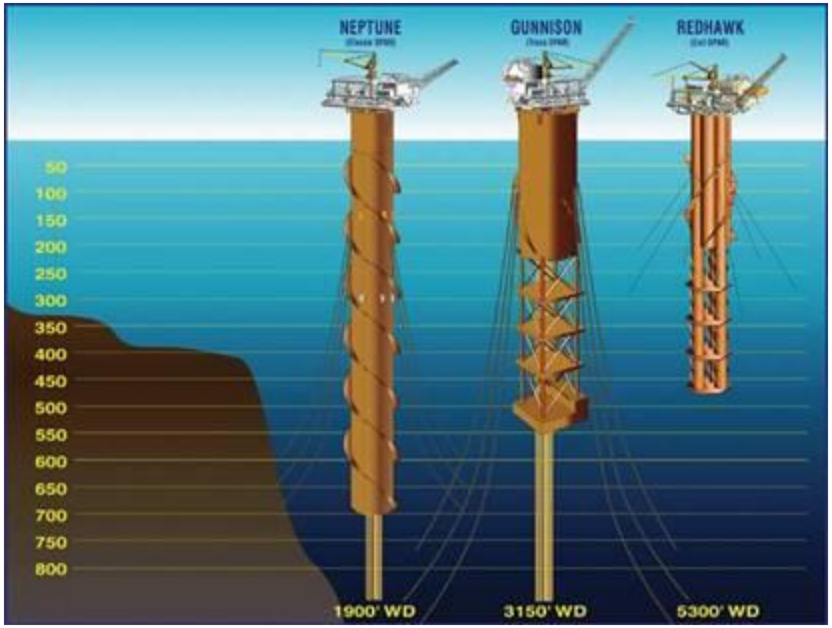
BP's Thunder Horse (GOM) production-drilling-quarters (PDQ) is the world's largest production semi-submersible ever built. The platform's topside area is the size of three football fields.

SPAR

A SPAR (Single Point Articulated Riser) is a cylindrical hull fabricated from either steel or concrete.

The hull operates in a constant deep draft and is moored to the seabed. Spars can be built to incorporate oil storage if necessary.

Drilling is possible from a SPAR.



Kikeh SPAR Float Over

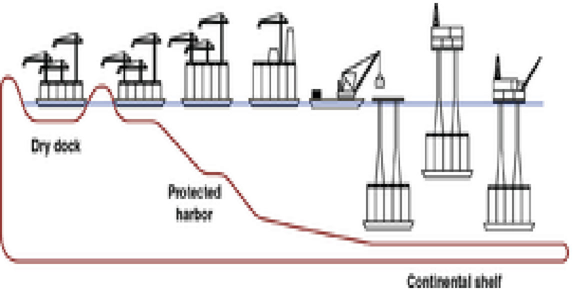
Concrete

Concrete structures are often referred to as Gravity Base Structures (GBS). They can be built with or without the ability to store oil. An advantage of the concrete concept is its ability to support very high topside weights (cf. steel jackets).

These structures normally require to be constructed in (or near) very deep water in order to allow the topsides to be floated on. Topsides modules can also be lifted on once the jacket is installed but one of the main advantages of this concept its ability to completely commission inshore.

Very deep water is required for their construction (to allow full submergence to float on topsides). Hence the fjords of Norway are popular construction sites.

Brent D



Hibernia

Troll C is the largest concrete structure built to date at 305 m

Ice Scour Protection

FPSO

Floating Production Storage and Offloading (FPSO) vessels have become increasingly popular concepts in recent years. Their main advantage is the ability to operate without the need for a specific export infrastructure. Crude can be exported by shuttle tanker. Gas however, must either be flared or exported by pipeline so FPSO's suit low GOR fields especially. Other advantages include:

- relatively short schedules (oil tankers can be converted relatively cheaply)
- can often be leased instead of bought, hence making very small fields economic
- can be used in any water depth
- Early Production
- Large payload/deck space
- Easy to remove and re-use

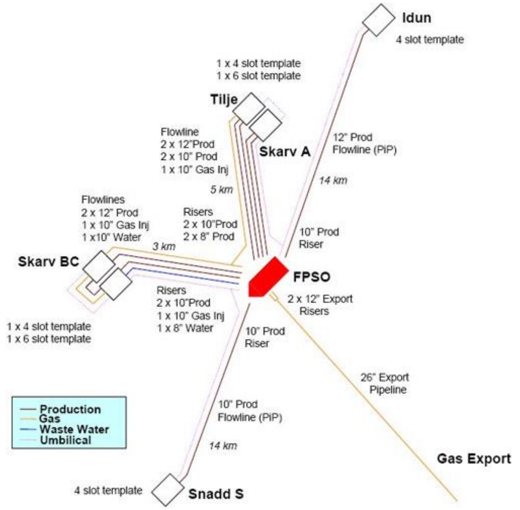
Key feature of FPSO's is the turret and mooring system. Various types exist. No drilling possible from this concept - subsea wells only.

FPSO


BP Fionaven


BP Skarv


BP Schiehallion

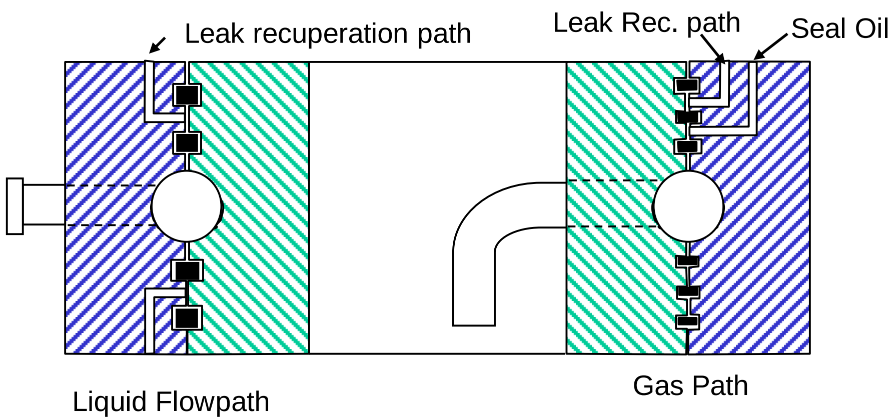

Idun
4 slot template
1 x 4 slot template
1 x 6 slot template
Tilje
Flowline
2 x 12"Prod
2 x 10" Prod
1 x 10" Gas Inj
Skarv A
12" Prod
Flowline (PiP)
14 km
5 km
Flowlines
2 x 12" Prod
1 x 10" Gas Inj
1 x10" Water
Risers
2 x 10"Prod
2 x 8" Prod
3 km
10" Prod
Riser
Skarv BC
FPSO
2 x 12" Export
Risers
Risers
2 x 10"Prod
1 x 10" Gas Inj
1 x 8" Water
1 x 4 slot template
1 x 6 slot template
10" Prod
Riser
26" Export
Pipeline
Production
Gas
Waste Water
Umbilical
10" Prod
Flowline (PiP)
14 km
Gas Export
4 slot template
Snadd S

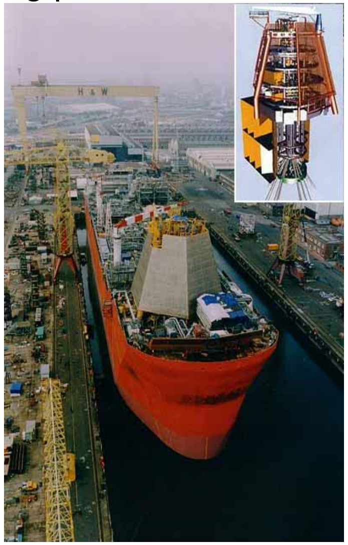
Turrets

The turret is a key part of many FPSOs. It is the point around which the FPSO weather vanes and at which all risers are gathered. The number of risers is the key parameter which defines the diameter and size of the turret. The turret is also the part of the FPSO which is moored to the seabed. Any turret therefore has a “fixed” part (moored to the seabed) and a rotating part (part of the hull).

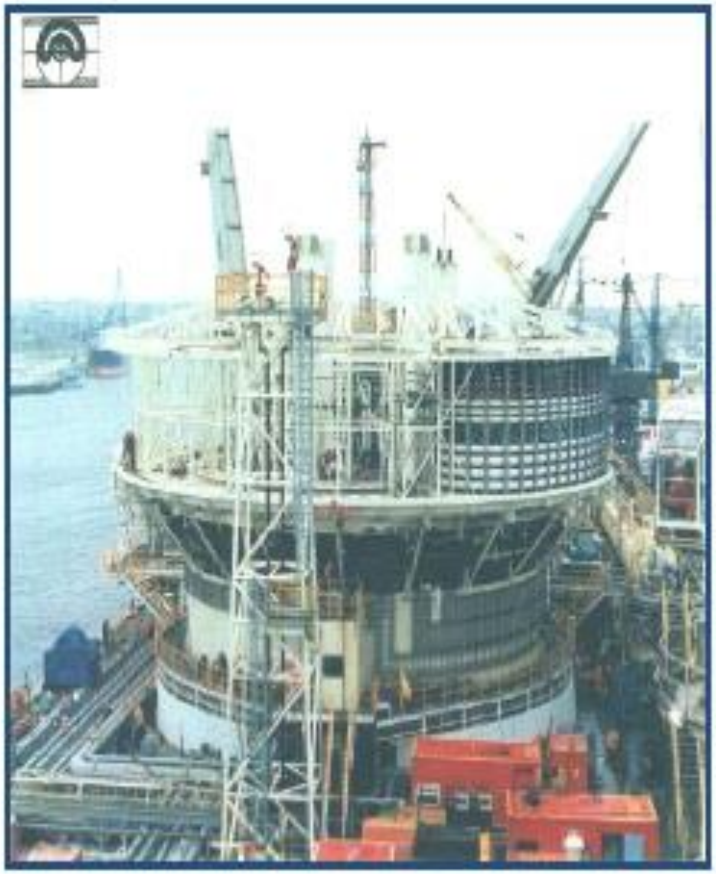
There are many designs of turret available. Turrets can be designed to be permanent or disconnectable (e.g. Cossack Pioneer, Australia). They can also be internal or external.

A key component of a turret system of the swivel which contains fluid path swivels to transfer all production and utilities fluids from the fixed to the rotating part of the FPSO.





Drag Chain



Picture : During installation

Large bobbin with flexible pipe.

As ship weathers flexibles are let out or wrapped in.

Ship cannot fully rotate hence thrusters are required to re-set vessel heading.

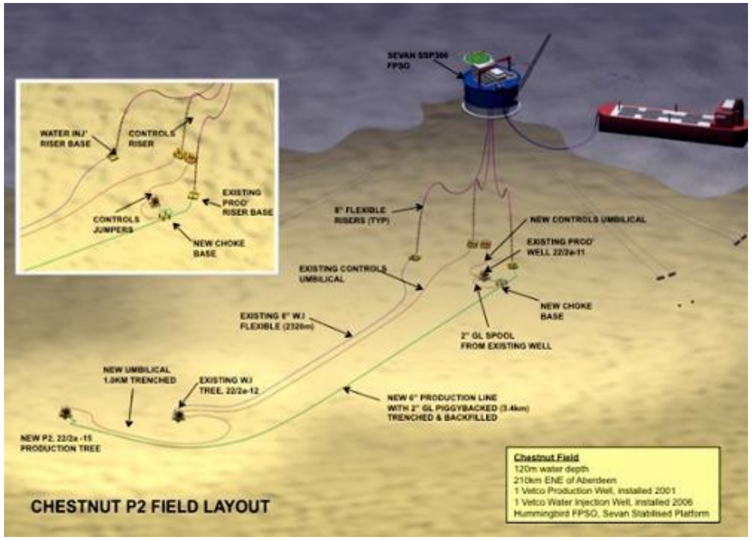
Sevan FPSO

Relatively new concept:

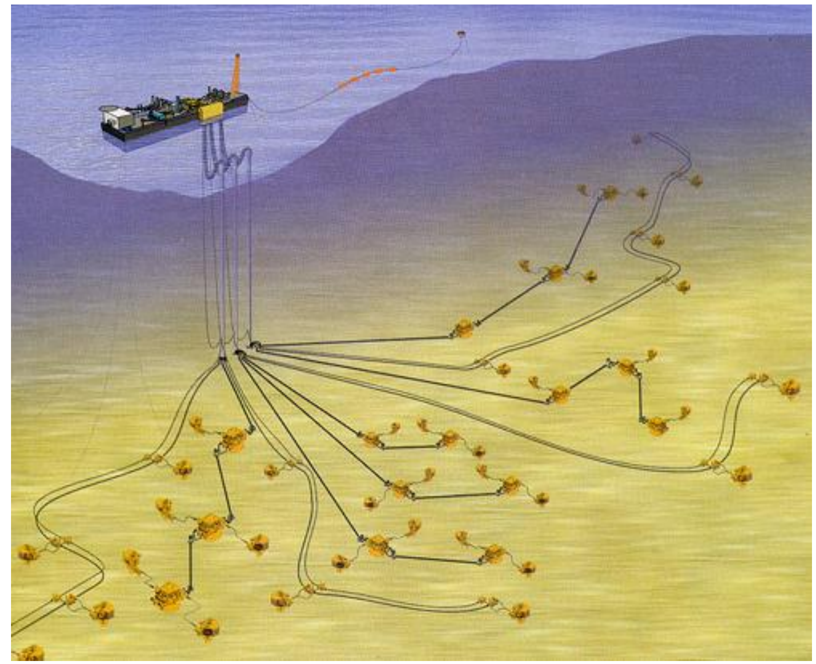
Claimed to offer cost and schedule savings by not requiring turret.

Limited in size.

Deployed on Chestnut (Hummingbird), Huntington (Voyager) on UKCS.

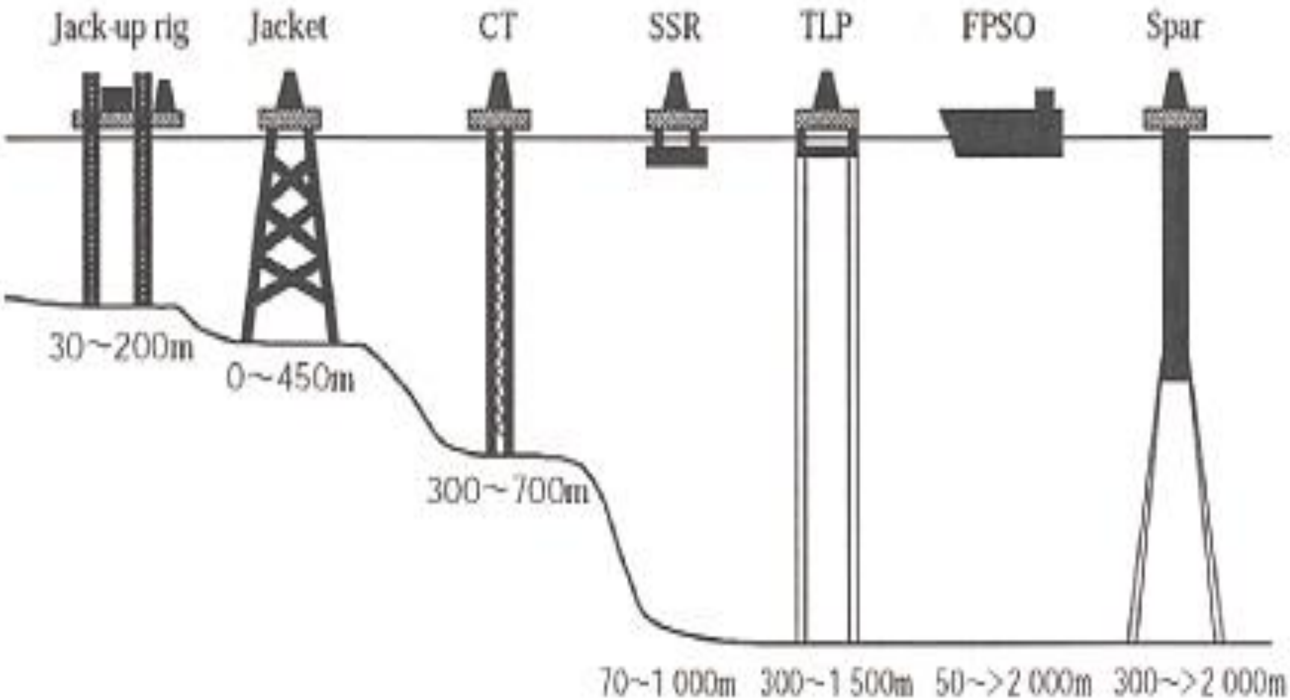


Greater Plutonio – Spread Moored



Hull does not weather vane – suitable for consistent directional environmental loadings

Depth Summary



Subsea Concepts

Due to significant advances in technology, Subsea concepts are a mainstay for the UKCS.

Main advantages are:-

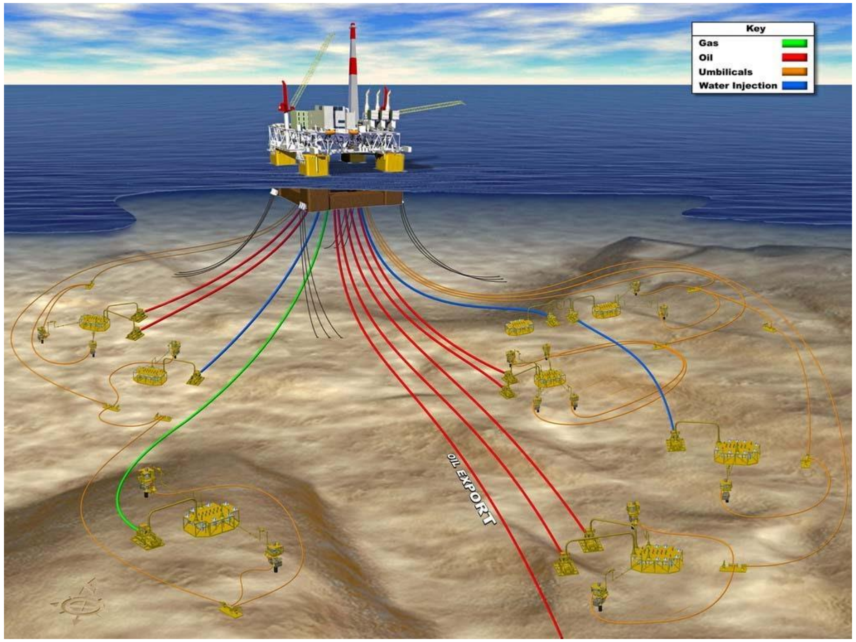
- No support structure required
- Can cover a wide area - larger than from a single drill centre
- Allow existing offshore facilities to “widen their reach”
- Good for deep water

Disadvantages:-

- Subsea equipment is expensive
- Intervention for repair is expensive
- Well access cab be restricted

Latest technology is considering:-

- Subsea separation
- Subsea pumping
- Subsea water injection systems
- Subsea compression



Minimum Facilities Platforms

An option which is common where an infrastructure is already in place, for field close to shore, is a minimum facilities platform. This effectively covers two categories:-

Minimum facilities - the minimum equipment required to receive and control well flow in order to pass it on to a host treatment facility. Often just the wells and a manifold. However , facilities often extend to basic gas-liquid separation, metering and pumping. In principle, very similar to a subsea tie-back but some issues can force the necessity for a WHT eg.:

- Dry trees
- HP/HT wellheads

Unmanned facilities - Not strictly minimum facilities. However, also common when infrastructure is nearby. If process plant is automated sufficiently, the cost of providing life support facilities (accommodation, support, logistics) etc can be significantly reduced.

Minimum/Unmanned Facilities

Safety

- The offshore facility will be designed to the highest possible safety standards.
- Structured review techniques are required to ensure that all aspects of risk are identified and managed.
  - HAZID - Hazard Identification
  - HAZOP – Hazard and Operability Review
  - ESSA - Emergency Systems Survivability Analysis
  - EPR - Explosion Protection Review
  - FEA - Fire and Explosion Analysis
  - SIA - Smoke Ingress Analysis
  - SCA - Structural Consequence Analysis
  - TR/EERA - Temporary Refuge/Escape, Evacuation and Rescue Analysis
  - QRA - Quantitative Risk Assessment
  - EA - Environmental Assessment

Environment

Concept Selection

- Safety
- Environment
- Capital Cost
- Operating Cost
- Schedule
- Revenue
- Technical Risk

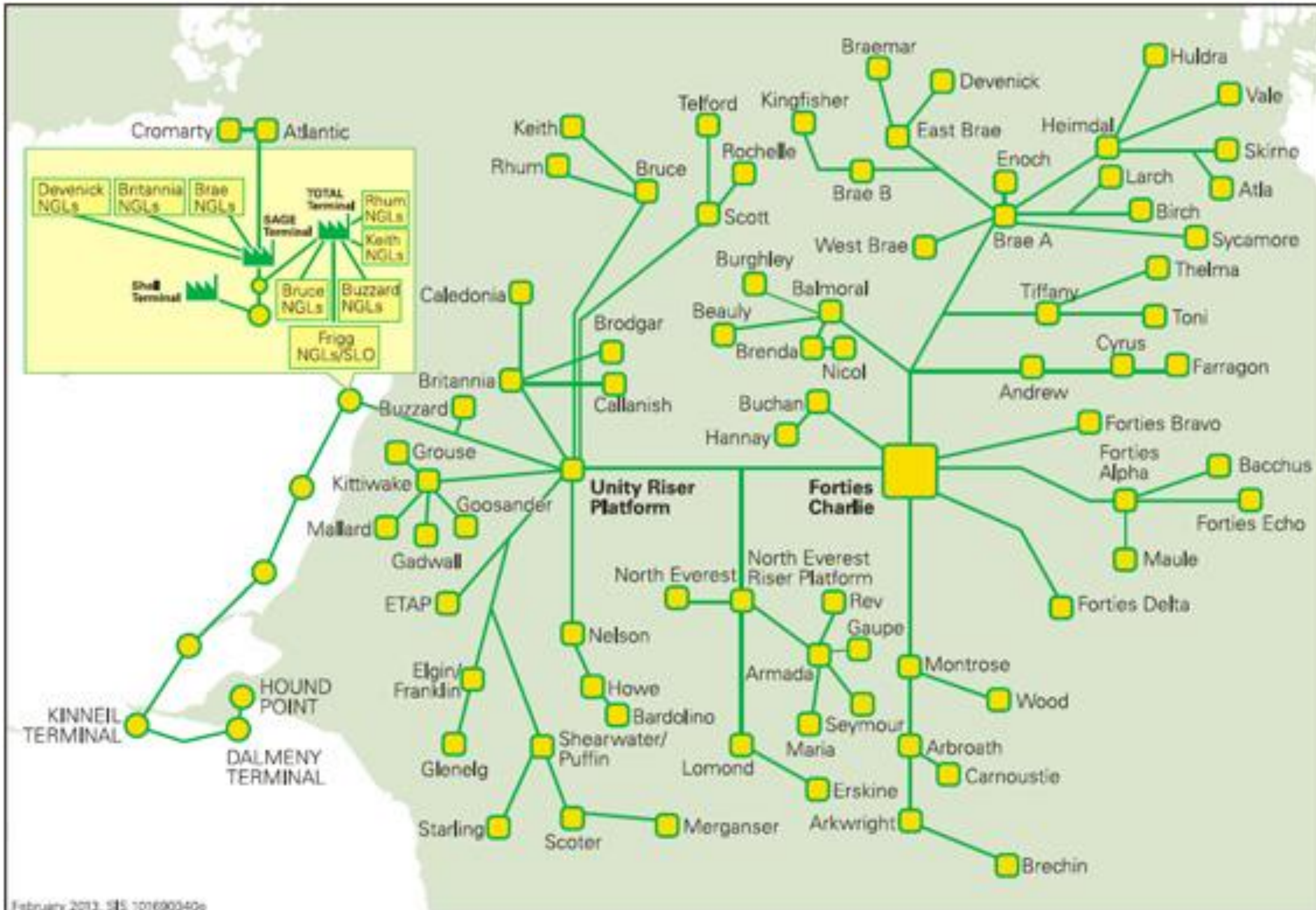
Pipelines/Transportation

- Delivering gas and oil from offshore to market is often via subsea pipelines.
- The pipelines are designed for pressure containment, internal and external corrosion
- Pipeline integrity management is key part of the offshore business
- Pipeline costs can be very significant


Lay barge


Reel barge

Onshore Terminals



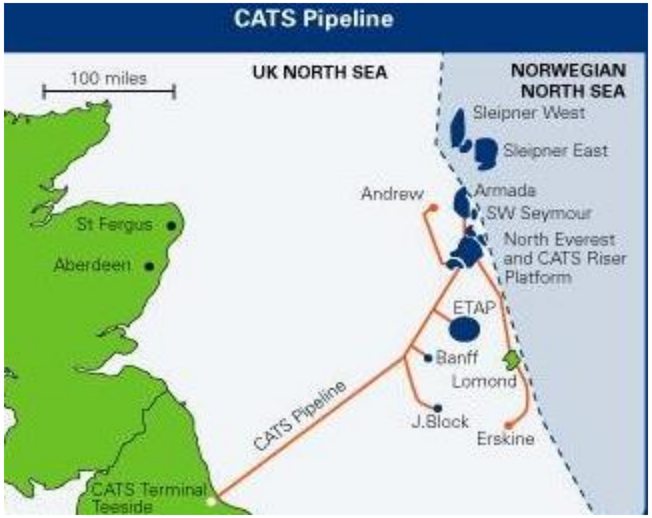
Oil Terminal Functions

- Oil terminals are intermediate oil gathering and distribution stations between (offshore) oil production locations and onshore oil processing facilities (refineries).
- The UK has 6 oil terminals: Shetland (Sullom Voe), Orkney (Flotta), Teesside (Ekofisk), Liverpool Bay, Dorset (Wytch Farm), Kinniel (FPS)
- Basic oil terminal functions are:
  – Reception of crude oil from pipelines or shuttle tankers
  – Stabilisation of crude oil (including dehydration/desalting, gas/water treatment)
  – Fractionation of associated gas into:
    - Lighter gases (methane and ethane) normally used as fuel for power generation
    - propane
    - butane

    LPG – liquefied petroleum gases
  – Storage of stabilised crude and LPG
  – Export / trans-shipment of products into tankers or pipelines for distribution to refineries for further downstream processing

Gas Terminal Functions

- Gas terminals are intermediate gas treatment facilities collecting partially processed gas from offshore facilities.
  - Reception of gas from pipelines
  - Treatment of the gas for sale to the onshore gas grid
    - Gas dehydration
    - Removal of natural gas liquids – ethane, propane, butane and heavier components
    - Removal of carbon dioxide and sulphur dioxide
    - Removal of other unwanted components – mercaptans, mercury



Definitions

- **STC - Stock Tank Conditions - Oil**
  - Standard temperature and pressure, usually 60 ºF and 14.7 psia
- **STB - Stock Tank Barrel**
  - One barrel of oil at stock tank conditions
- **SCF – Standard Cubic Foot – Gas**
  - 1 cubic foot of gas at standard conditions
- **GOR - Gas/Oil Ratio**
  - The volume of gas produced divided by the volume of oil produced measured at stock tank conditions
- **GLR - Gas/Liquid Ratio**
  - The volume of gas produced divided by the total volume of liquid produced (oil and water)
- **Bo - Oil Volume Factor**
  - The volume in barrels (bbl) occupied by one STB of oil and associated gas when recombined to a single phase liquid at a given pressure and temperature
- **Rs - Solution Gas/Oil Ratio**
  - The volume of gas in a standard ft^3 that will dissolve in one STB of oil at a given pressure and temperature

Definitions

- **Productivity Index**
  - The volume flow into the well expressed as barrels per day per psi of drawdown
- **Oil Recovery**
  - Percentage of oil recovered to that originally in place
- **API - American Petroleum Institute – Crude API ; specific gravity = 141.5/(131.5+^{o}API)**
- **TPR - Tubing Performance Relation**
  - The relation between the bottomhole flowing pressure and the surface oil flow rate for a given wellhead pressure
- **IPR - Inflow Performance Relation**
  - The relation between the wellbore flowing pressure and the surface oil rate
- **STOIIP - Stock Tank Oil Initially In Place**
  - A measure of the oil reserves in place at stock tank conditions
- **Drawdown**
  - Difference in pressure between the reservoir pressure and pressure at the bottom of the wellbore
- **Drainage Radius**
  - Production well will only drain a part of a reservoir - each well has a radial limit beyond which there is no influence on reservoir depletion

Definitions

- **Wet Gas**
  - Gas which contains water and/or hydrocarbons as a small amount of liquid
- **Dry Gas**
  - Gas that has been treated to remove water
- **Acid Gas**
  - Gas which contains Carbon Dioxide and/or Hydrogen Sulphide
- **Sour Gas**
  - Gas which contains Hydrogen Sulphide
- **Natural Gas**
  - Marketable gas which is predominantly Methane
- **Natural Gas Liquids - NGL**
  - Liquids which have been condensed from a gas – typically a mixture of methane, ethane, propane and butane. Often referred to as **Condensate**
- **Liquefied Natural Gas - LNG**
  - Natural gas which has been liquefied.
- **Liquefied Petroleum Gas – LPG**
  - Propane, Butane or a mixture of the two which has been compressed and liquefied.