MÁSTER EN INGENIERÍA DE PETRÓLEO Y GAS

OIL & GAS ENGINEERING MASTER'S DEGREE

COURSE DE3:

DRILLING ENGINEERING

COURSE DE3.1

BASIC DRILLING TECHNIQUES

Doc D: Directional drilling

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Mining Technology Innovative Lab

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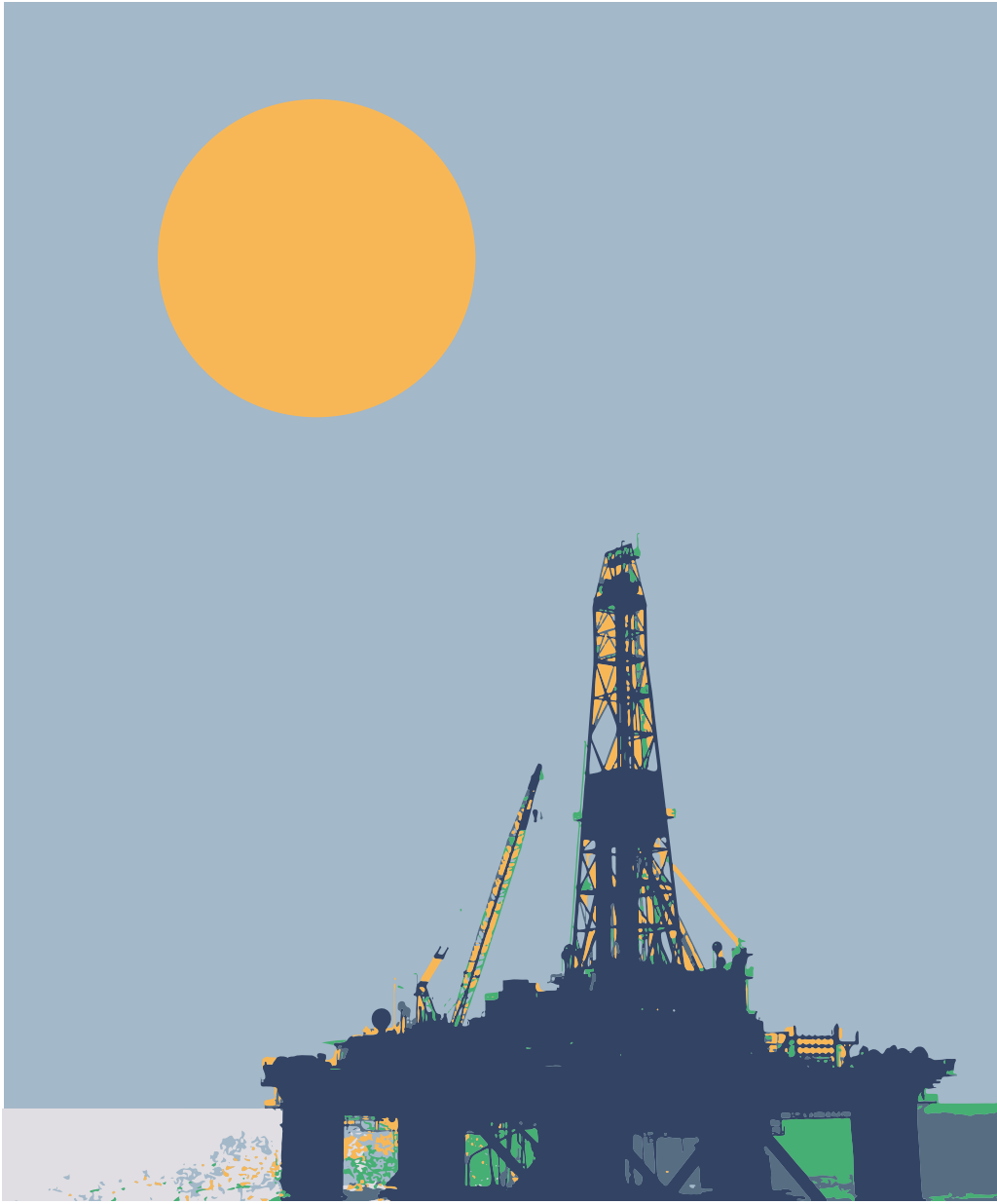

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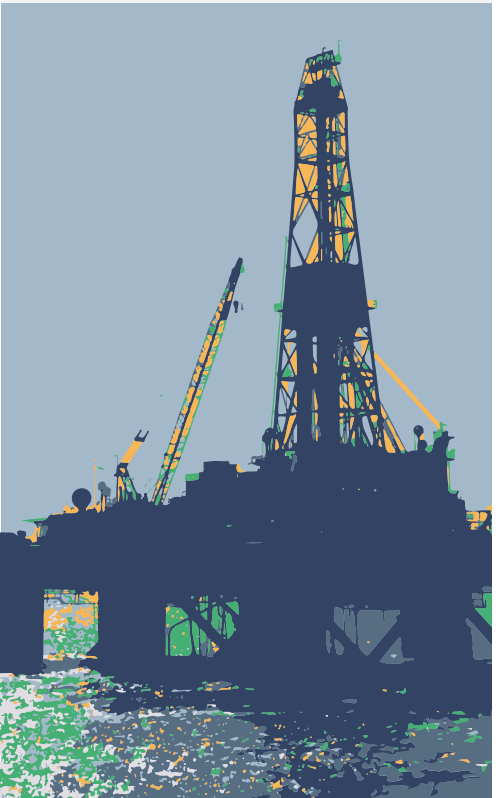

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Before printing it, think about whether a paper copy is needed.

Introduction

- Directional drilling has become a very important tool in the development of oil and gas deposits.
- Current expenditures for hydrocarbon production have dictated the necessity of controlled directional drilling to a much larger extent than previously.
- In the case of horizontal drilling well productivity is improved, reducing technical production costs.

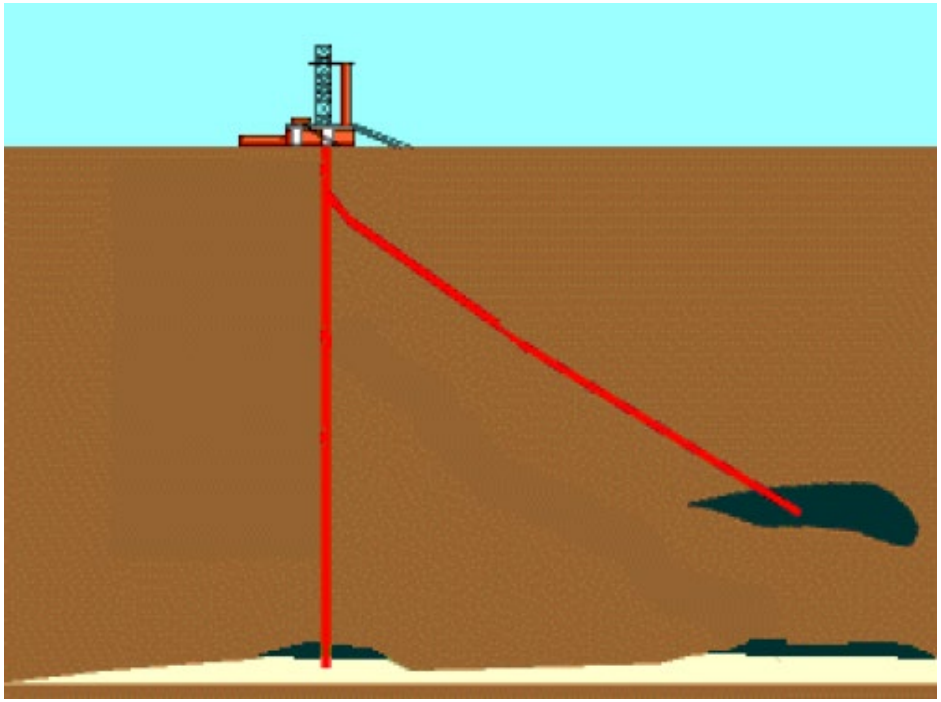
Introduction

- Probably the most important aspect of controlled directional drilling is that it enables producers all over the world to develop subsurface deposits that could never be reached economically in any other manner.

- That is the case of the production of unconventional resources, where the application of horizontal drilling technique is essential.

Basics of Directional Drilling

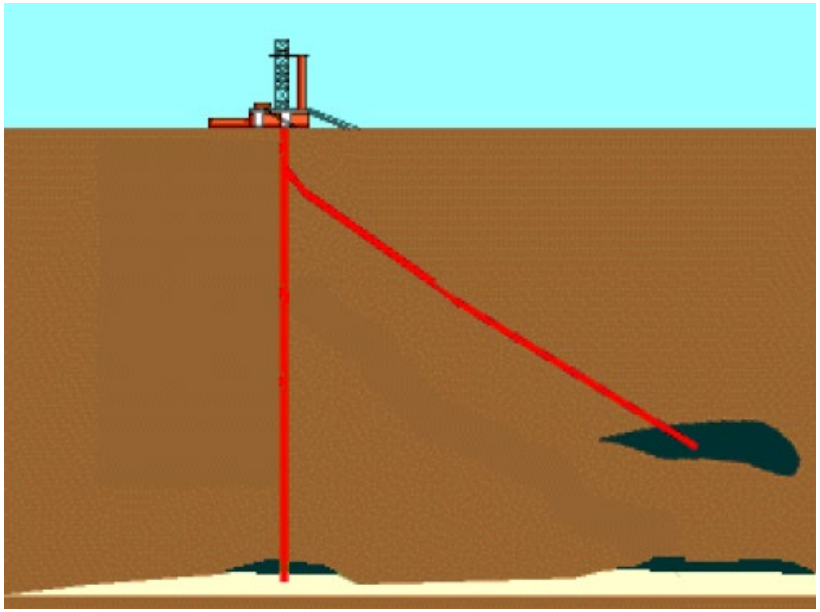
- Controlled directional drilling is the science and art of deviating a wellbore along a planned course from a starting location to a target location, both defined with a given coordinate system.
- Drilling a directional well basically involves drilling a hole from one point in space (the surface location) to another point in space (the target) in such a way that the hole can then be used for its intended purpose.
- A typical directional well starts off with a vertical hole, then kicks off so that the bottom hole location may end up hundreds or thousands of feet or meters away from its starting point.



Basics of Directional Drilling

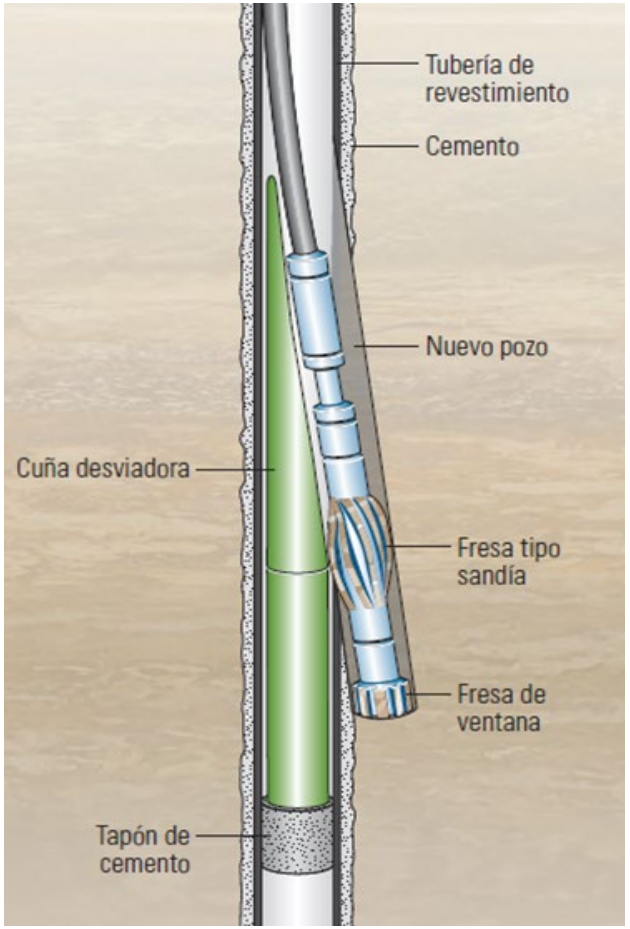
- With the use of directional drilling, several wells can be drilled into a reservoir from a single platform.

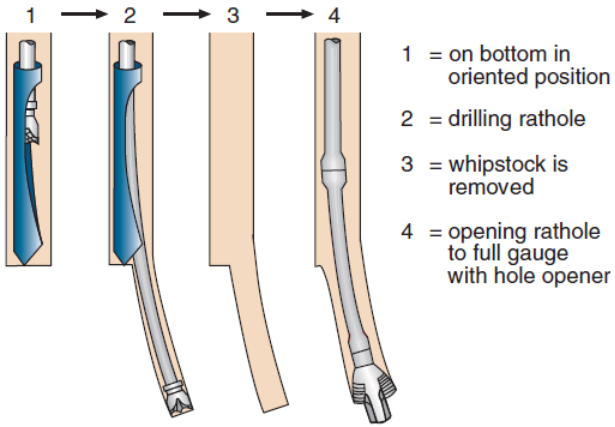
- Directional drilling was initially used as a remedial operation, either to sidetrack around stuck tools, bring the wellbore back to vertical, or in drilling relief wells to kill blowouts.



Directional Drilling Techniques

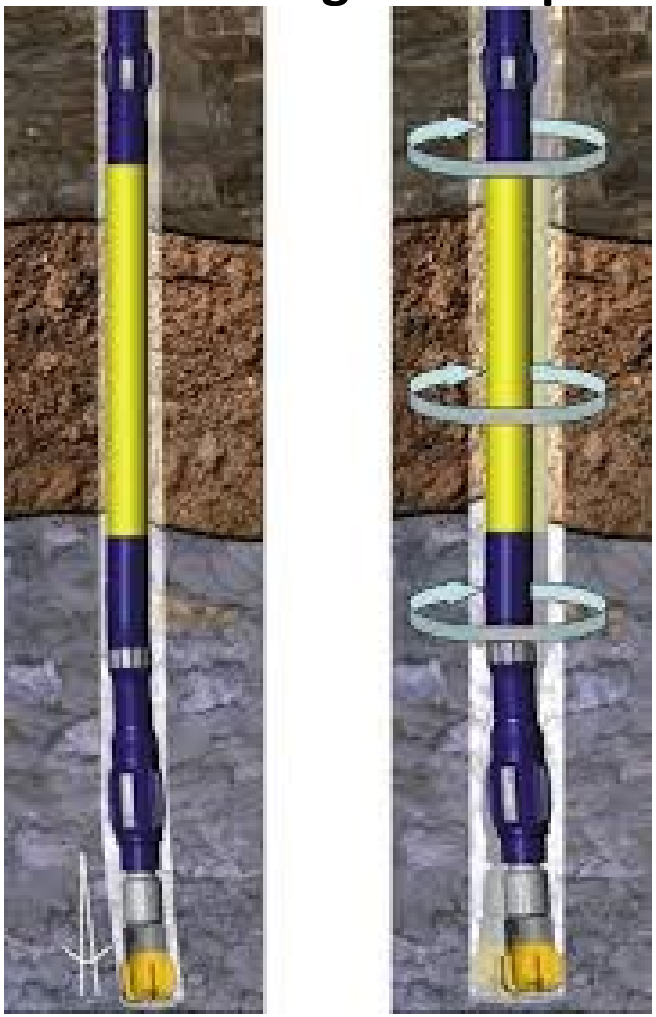
- **Whipstocks**
  - First technique developed for directional drilling was the use of whipstocks to deviate well into desired angle.
  - This technique was used mainly for sidetracking.
  - Nowadays, this technique is still in use because of is a faster and easier system.

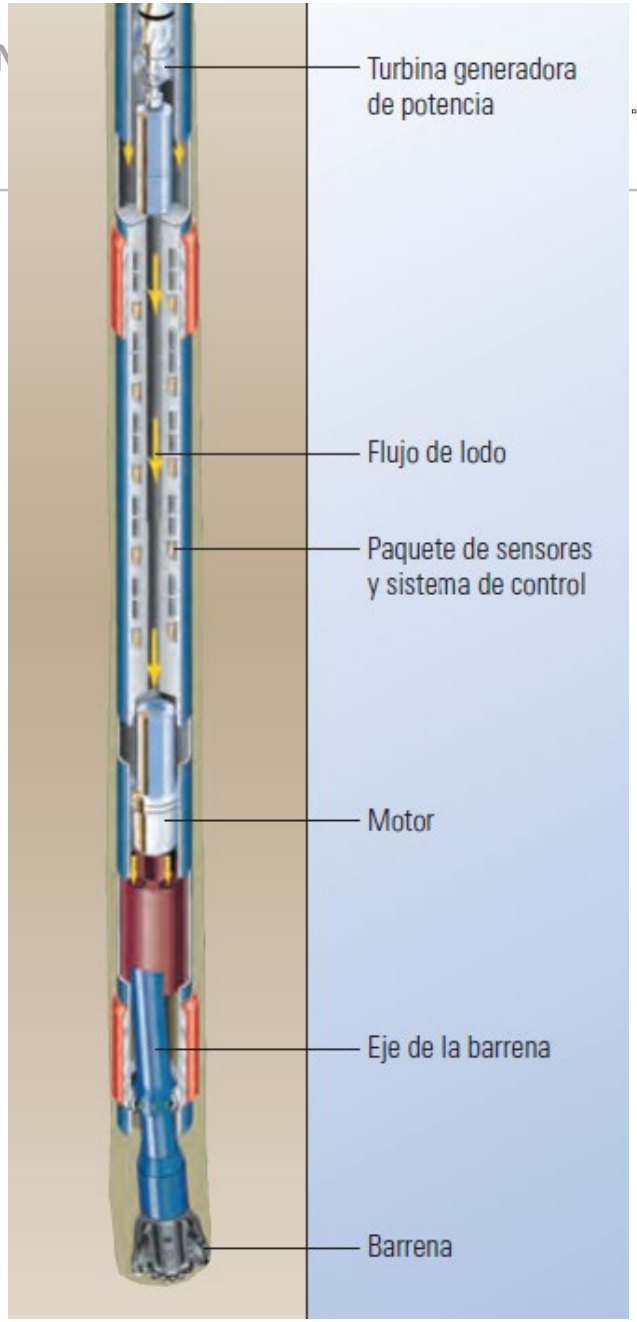




Directional Drilling Techniques

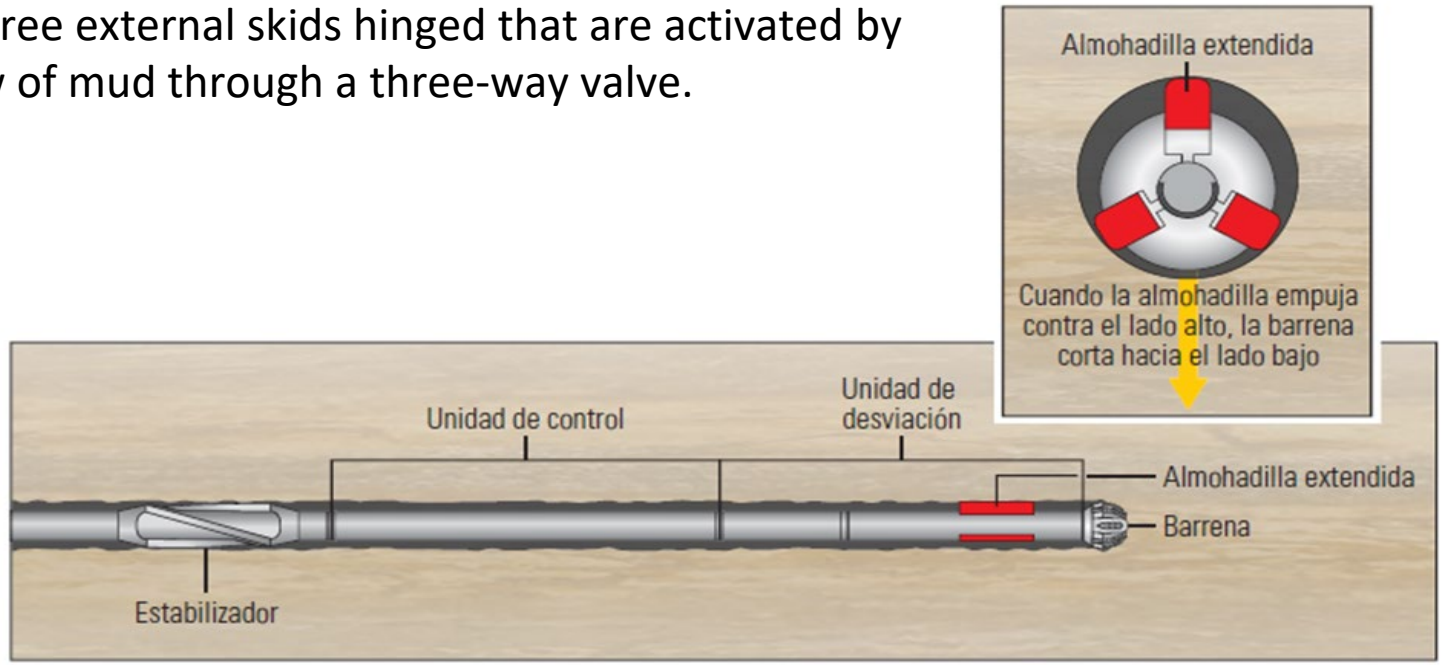
- **Rotary + Sliding**
  - Directional drilling with downhole motor is achieved in two ways:
    - Rotation (rotary).
    - Landslides (sliding).
  - In the rotation mode, the entire drill string rotates and tends to drill forward.
  - In the sliding mode (sliding) is used to initiate direction changes and correction of the trajectory.
  - This system of rotary+sliding has the great problem of creating tortuosity in the well trajectory.



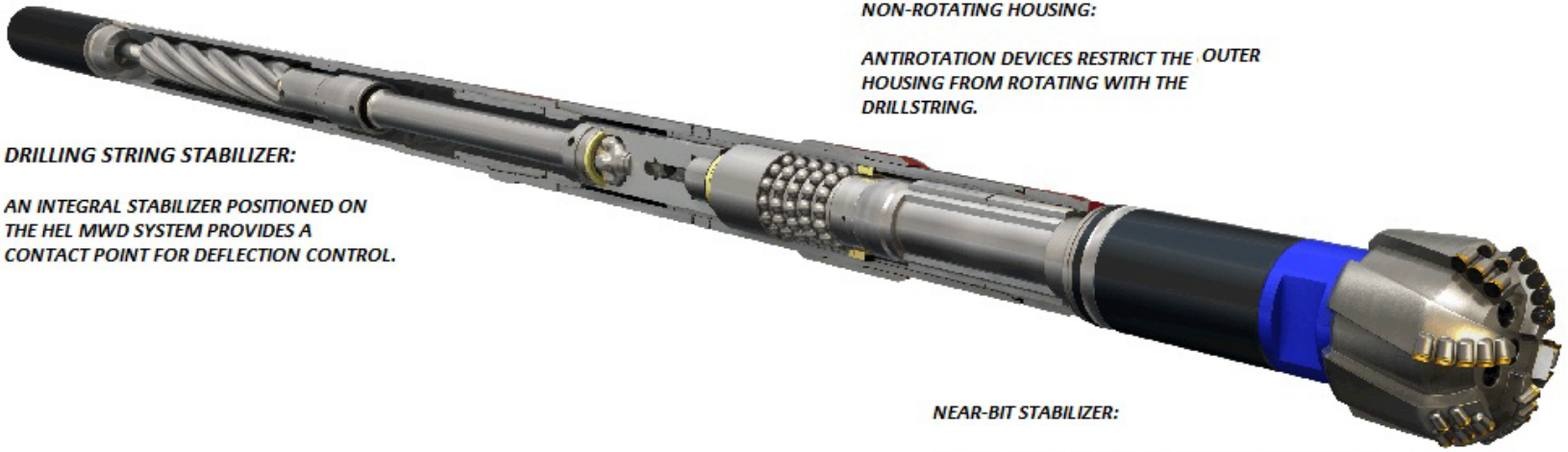

Turbina generadora de potencia
Flujo de lodo
Paquete de sensores y sistema de control
Motor
Eje de la barrena
Barrena

Directional Drilling Techniques

- **Rotary Steereable System "RSS"**
  - The rotary steerable systems allows continuous rotation while the direction of the drill is controlled.
  - Consist on a deflection unit which is located directly behind the drill bit that applies a force on all the bit in a controlled direction while the entire column rotates, using three external skids hinged that are activated by the flow of mud through a three-way valve.



Directional Drilling Techniques



NON-ROTATING HOUSING:

ANTIROTATION DEVICES RESTRICT THE OUTER HOUSING FROM ROTATING WITH THE DRILLSTRING.

DRILLING STRING STABILIZER:

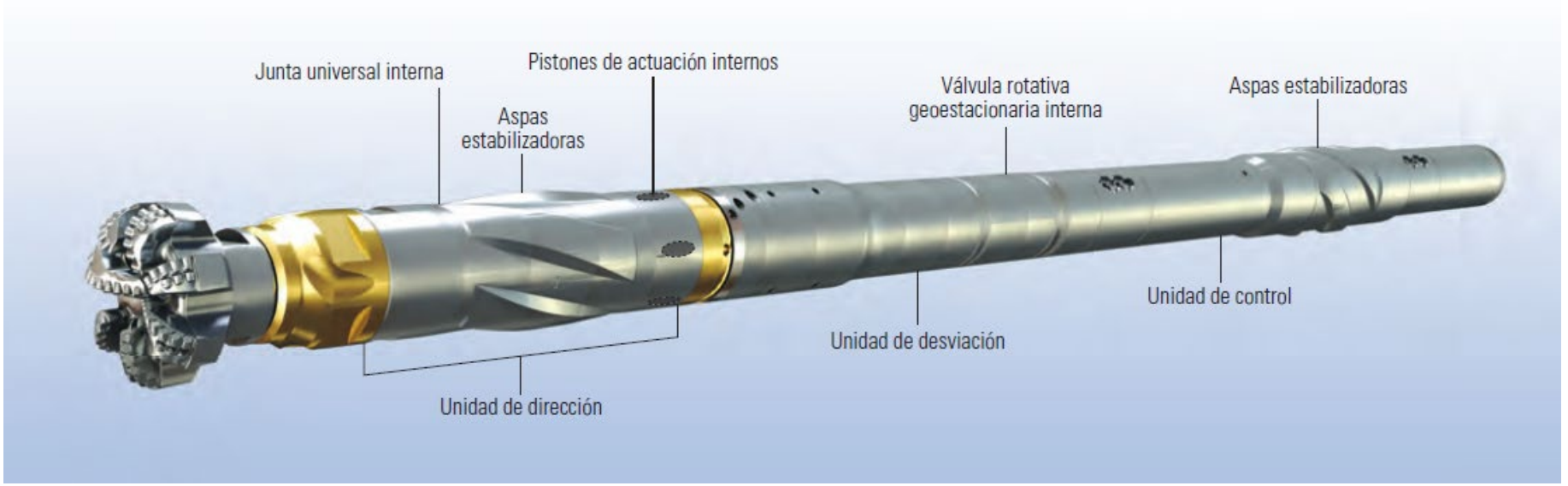
AN INTEGRAL STABILIZER POSITIONED ON THE HEL MWD SYSTEM PROVIDES A CONTACT POINT FOR DEFLECTION CONTROL.

NEAR-BIT STABILIZER:

THE NEAR -BIT STABILIZER PROVIDES THE FULCRUM POINT FOR ROTARY-STEERABLE TOOL DEFLECTION. THE STABILIZER INCREASES BIT STABILITY, FURTHER IMPROVING DIRECTIONAL CONTROL AND HOLE QUALITY.

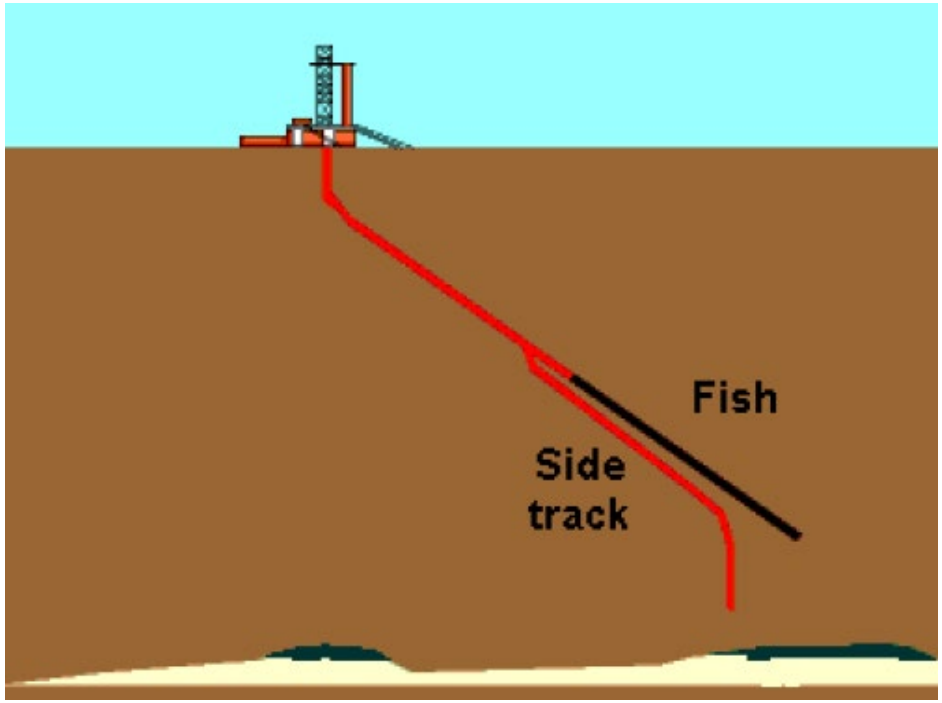
Directional Drilling Techniques

- **Rotary Steereable System "RSS"**
  - The tool can be adapted to the specific needs on the surface and can be preprogrammed according to the expected variations in inclination and direction.
  - The MWD unit and sensors of the control unit transmits the information to the surface by pulse communication system (Power Pulse)



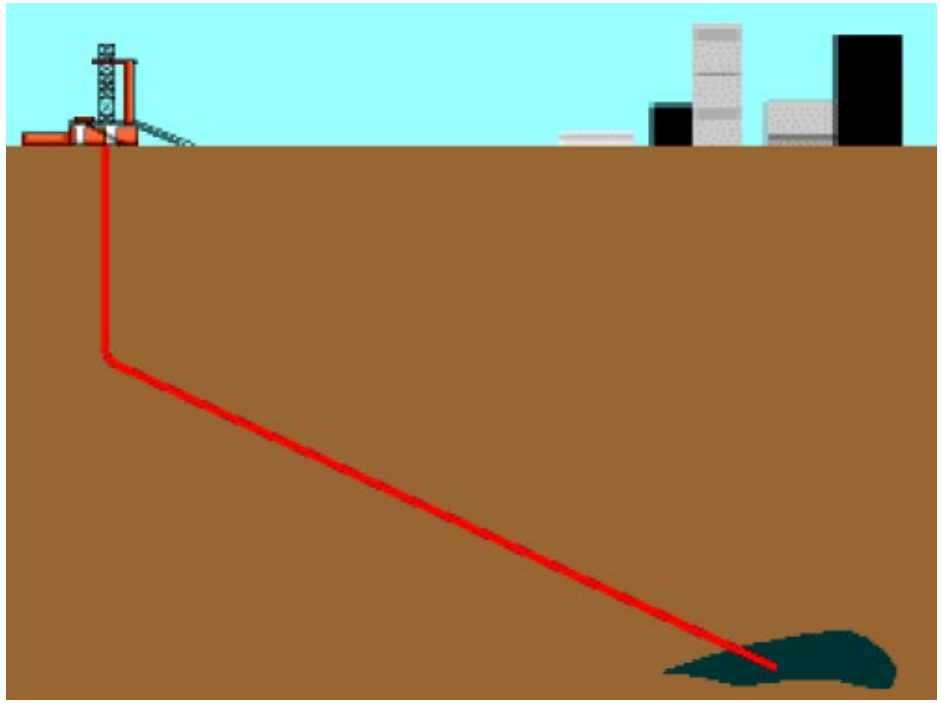
Directional Well Applications

- **Sidetracking**
  - Sidetracking was the original directional drilling technique used to get past fish (obstructions).
  - Oriented sidetracks, the most common type of sidetracking, are performed when there are unexpected changes in geology and obstructions in the path of the wellbore.



Directional Well Applications

- **Inaccessible Locations**
  - Inaccessible locations such as targets located beneath cities, rivers or environmentally sensitive areas make it necessary to locate the drilling rig some distance away from the target.

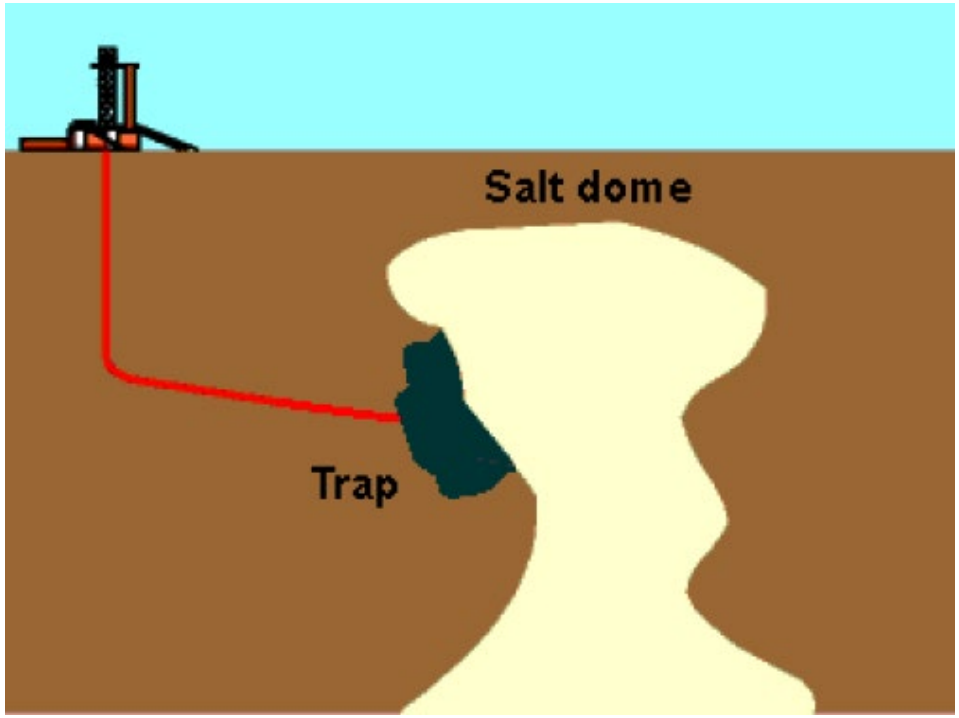


Directional Well Applications

- **Salt Dome Drilling**

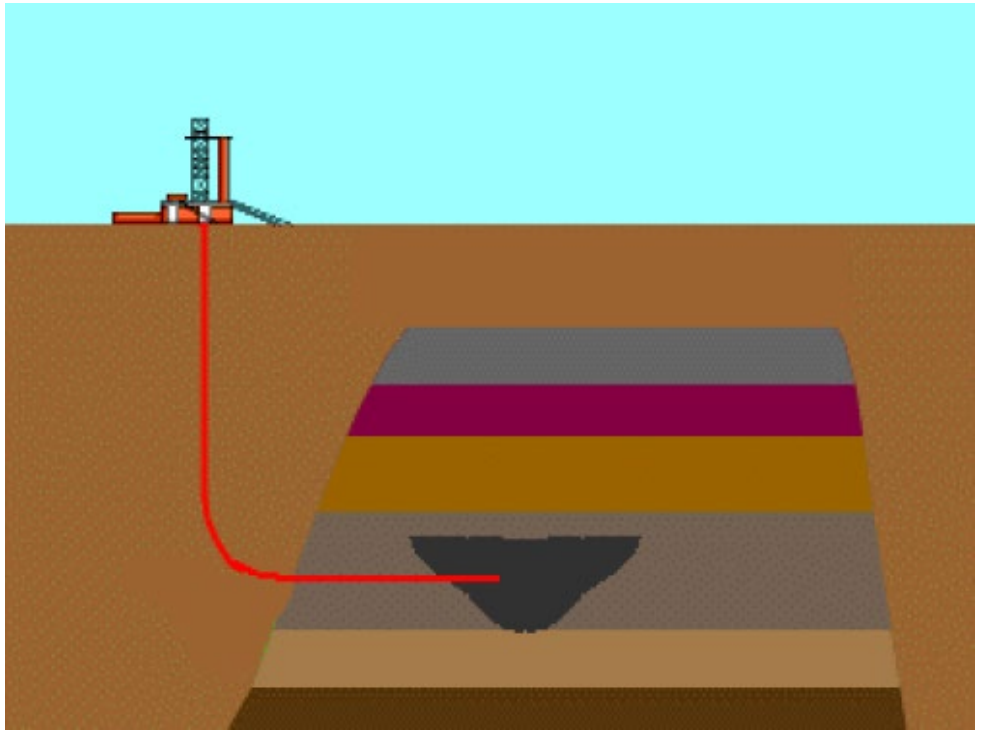
  - Salt domes have been found to be natural traps of hydrocarbons accumulating beneath the overhanging hard cap.

  - A directional well is used to reach the trapped reservoir to prevent the problems associated with drilling a well through the salt formation.



Directional Well Applications

- **Fault Controlling**
  - Fault controlling is an application used to drill a directional well into faulted subsurface formations without crossing the fault line.

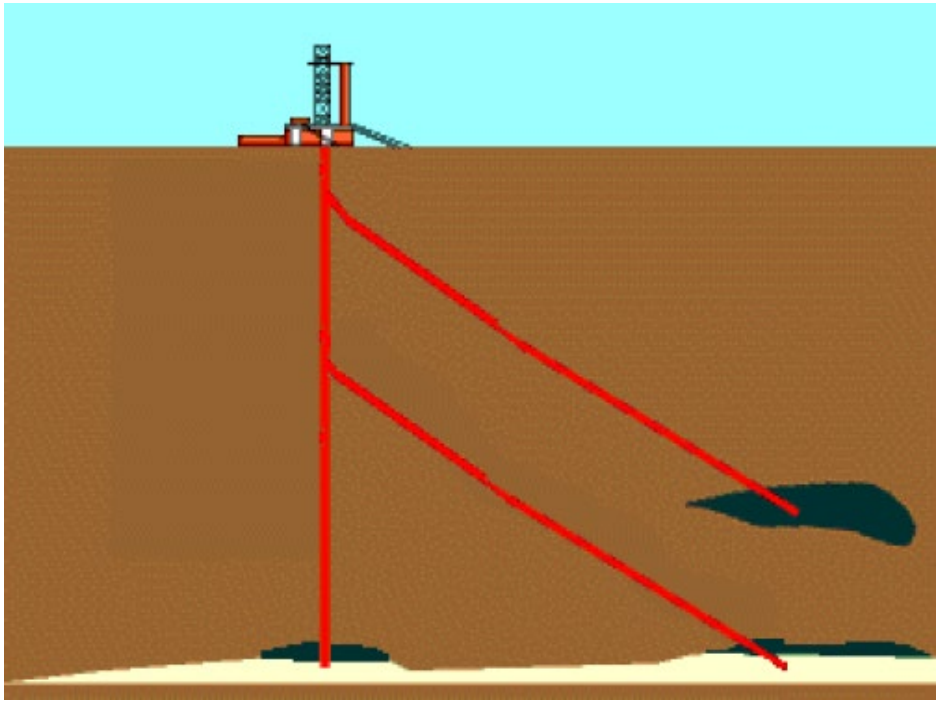


Directional Well Applications

- **Multiple Exploration Wells from a Single Wellbore**

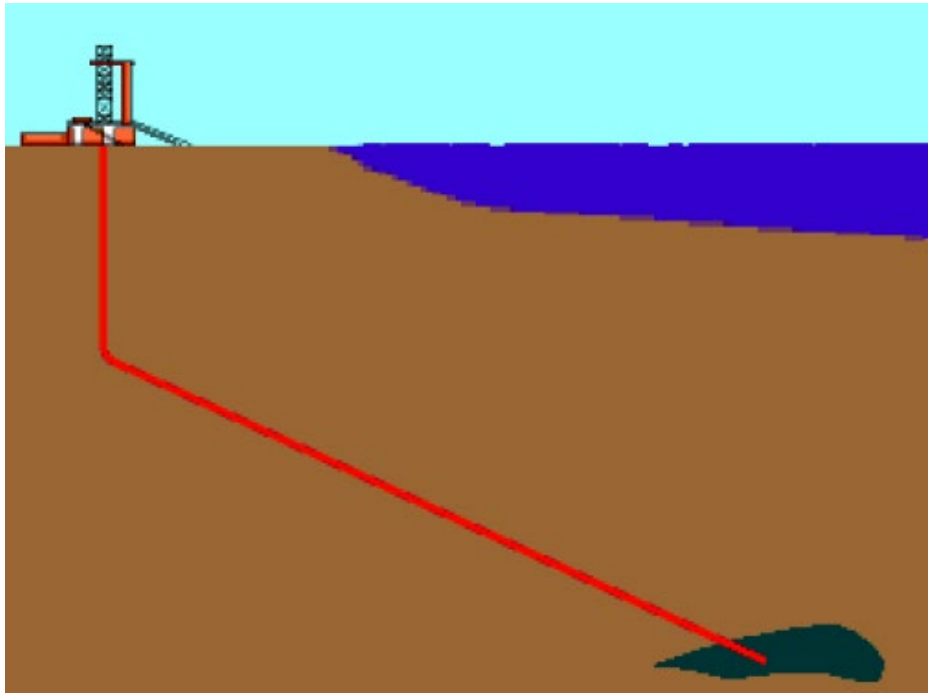
  - Multiple exploration wells from a single wellbore use a single hole to drill multiple new wells by deviating away from the original well at a certain depth.

  - It allows the exploration of structural locations without drilling another complete well..



Directional Well Applications

- **Onshore Drilling to Offshore Locations**
  - Onshore drilling takes place when a reservoir is located below large bodies of water that are within drilling reach of land.
  - The wellheads are located on land, and the borehole is drilled directionally underneath the water to reach the reservoir.
  - This technique saves money because land rigs are much cheaper than offshore rigs

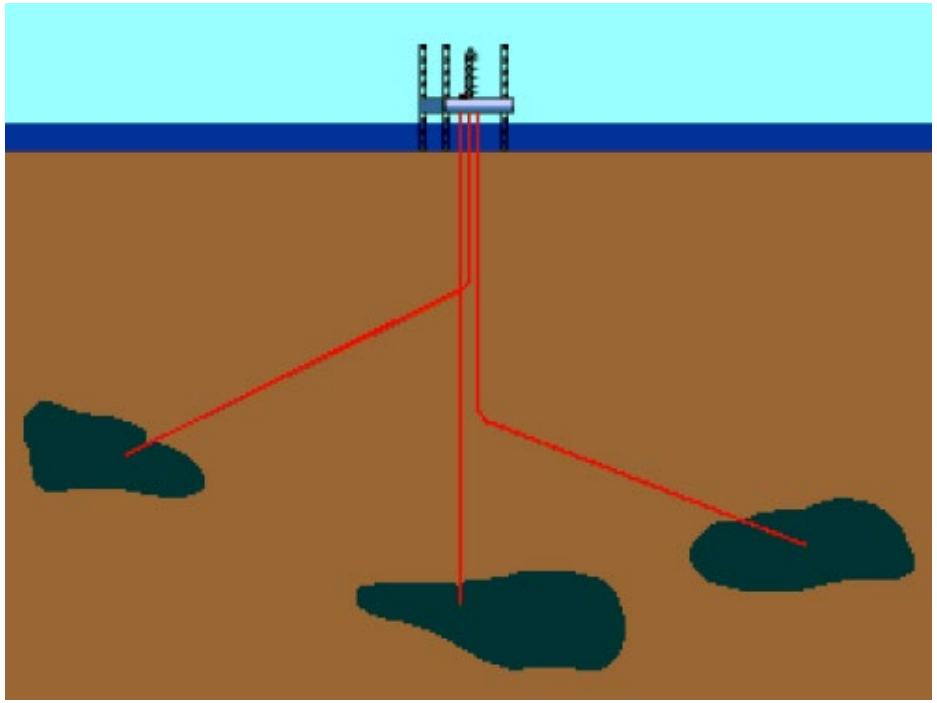


Directional Well Applications

- **Offshore Multiwell Drilling**

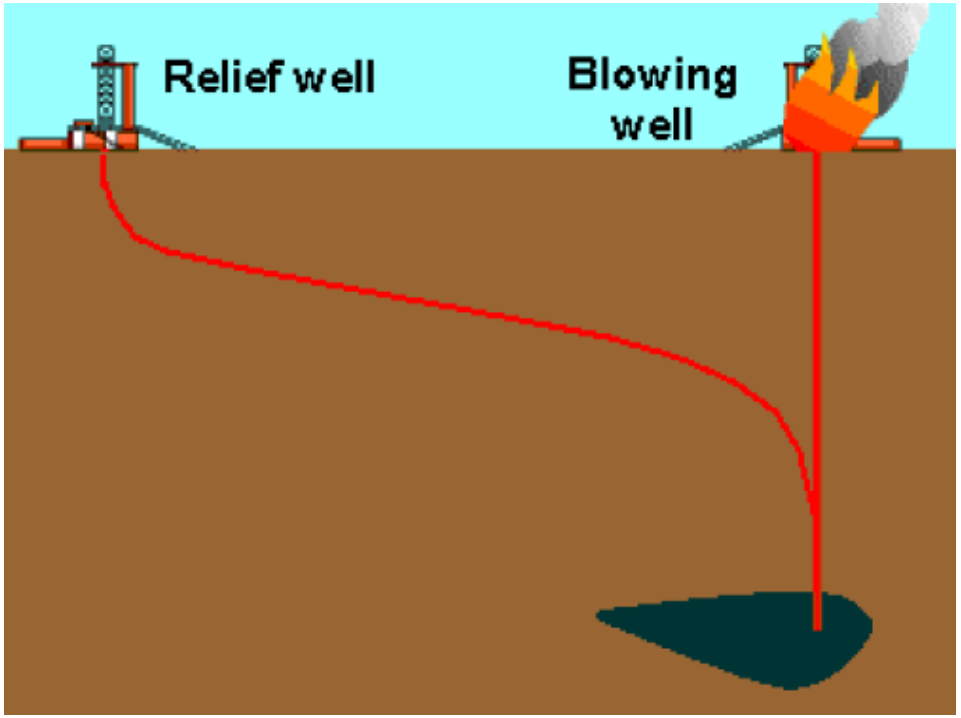
  - Offshore multiwell drilling is the most economical way to develop offshore fields.

  - Several directional wells are drilled in "clusters" on a multiwell offshore platform.



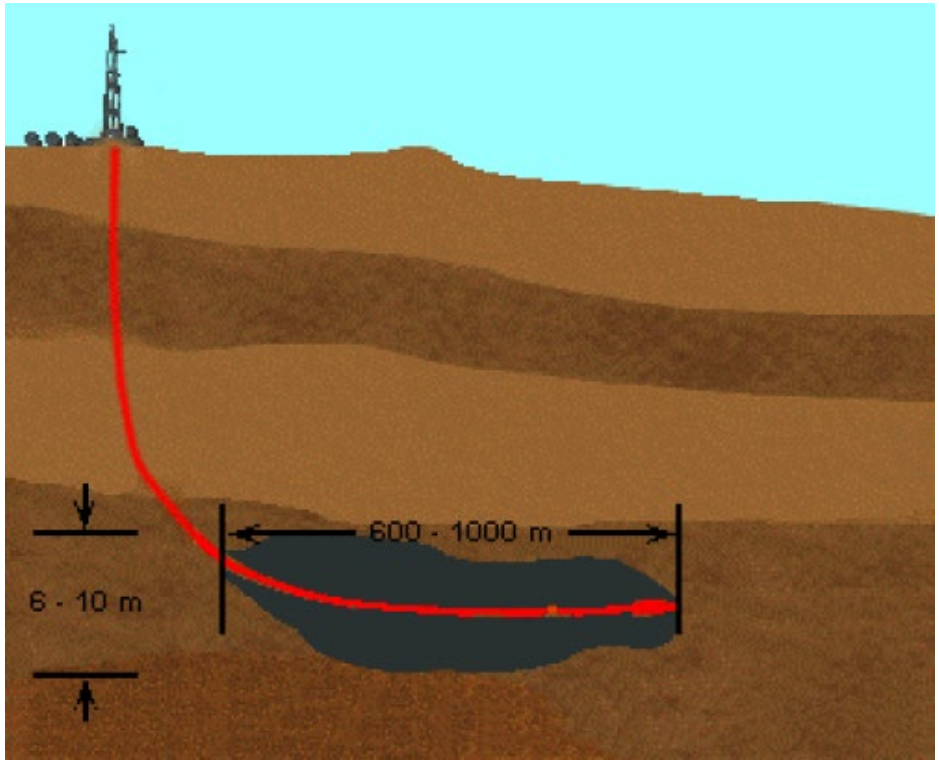
Directional Well Applications

- **Relief Wells**
  - Relief wells are used to kill wells that are blowing by intercepting the borehole. A carefully planned directional well must be drilled with great precision to locate and intercept the blowing well's borehole



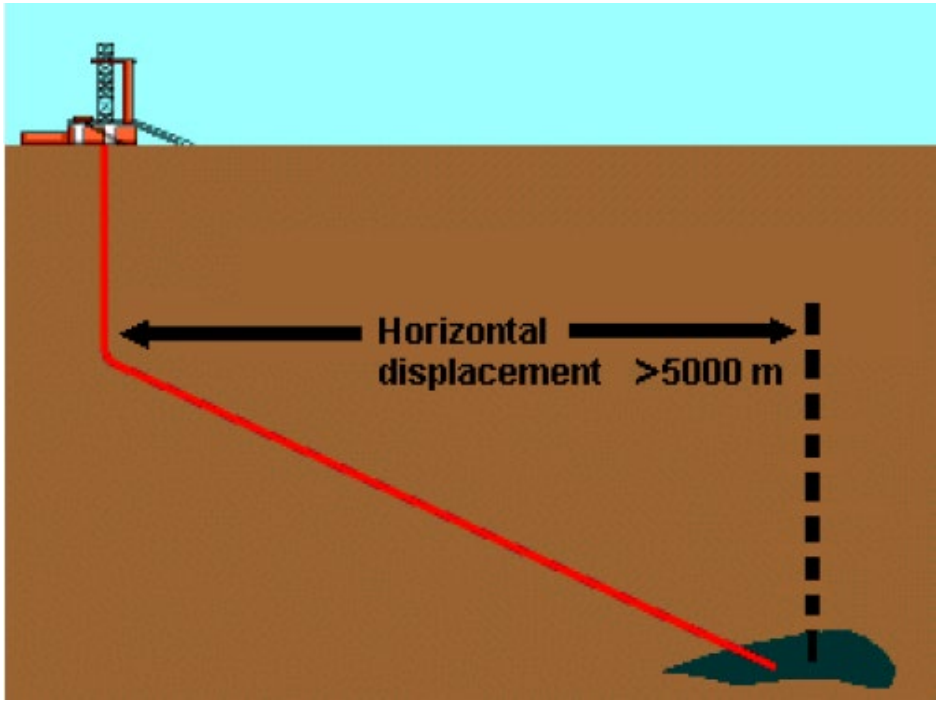
Directional Well Applications

- **Horizontal Wells**
  - Horizontal wells are used to intersect a producing formation horizontally to better produce the reservoir.
  - Horizontal drilling increases the surface area of a producing formation. For example, a vertical well may give exposure to a reserve with a depth of 20 to 30 ft (6 to 10 m) while a horizontal well drilled into the same reservoir may give exposure to 2000 to 3000 ft (600 to 1000 m).
  - Horizontal wells can make a platform profitable, where it was not previously.



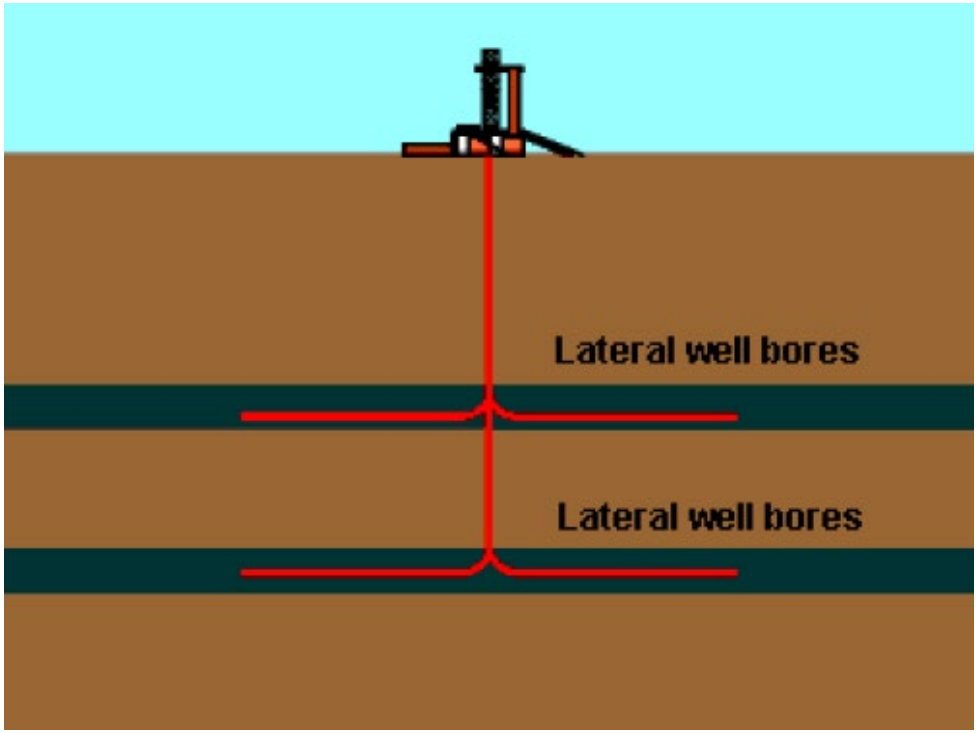
Directional Well Applications

- **Extended Reach Wells**
  - Horizontal wells are used to reach reservoirs that have a horizontal displacement in excess of 16,400 ft (> 5,000 m) from the starting point (extended reach wells).



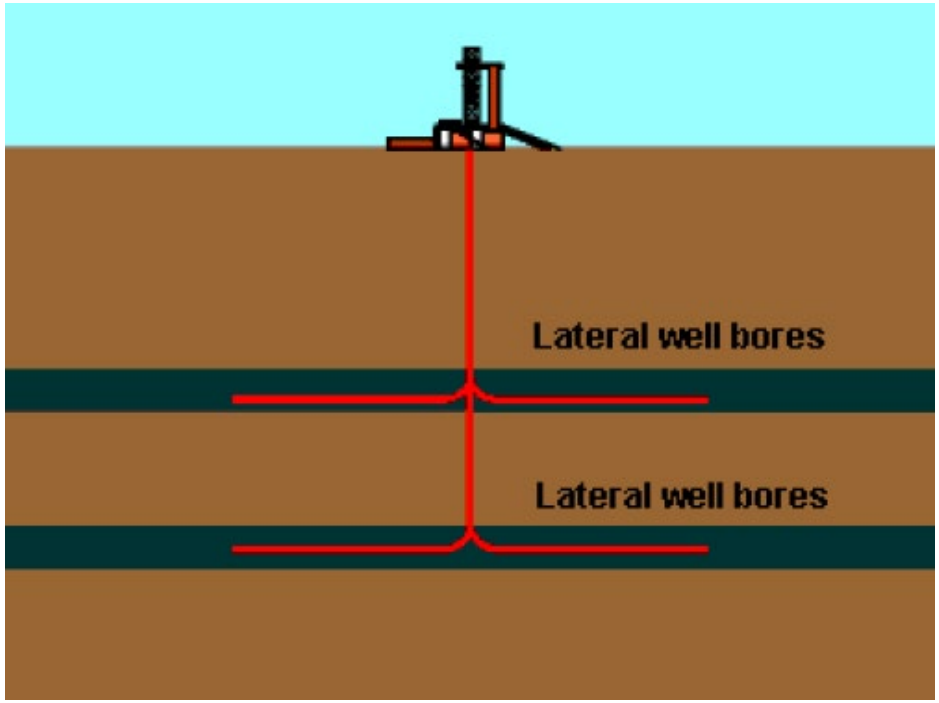
Directional Well Applications

- **Multilateral Wells**
  - Multilateral wells have several wellbores running laterally and originating from one original hole.



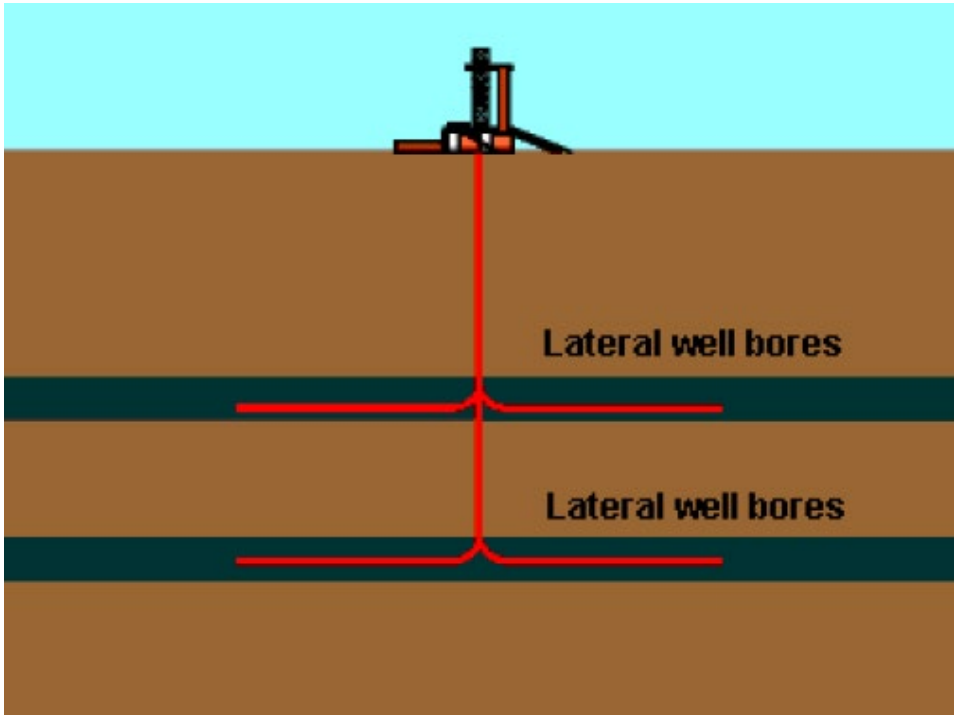
Directional Well Applications

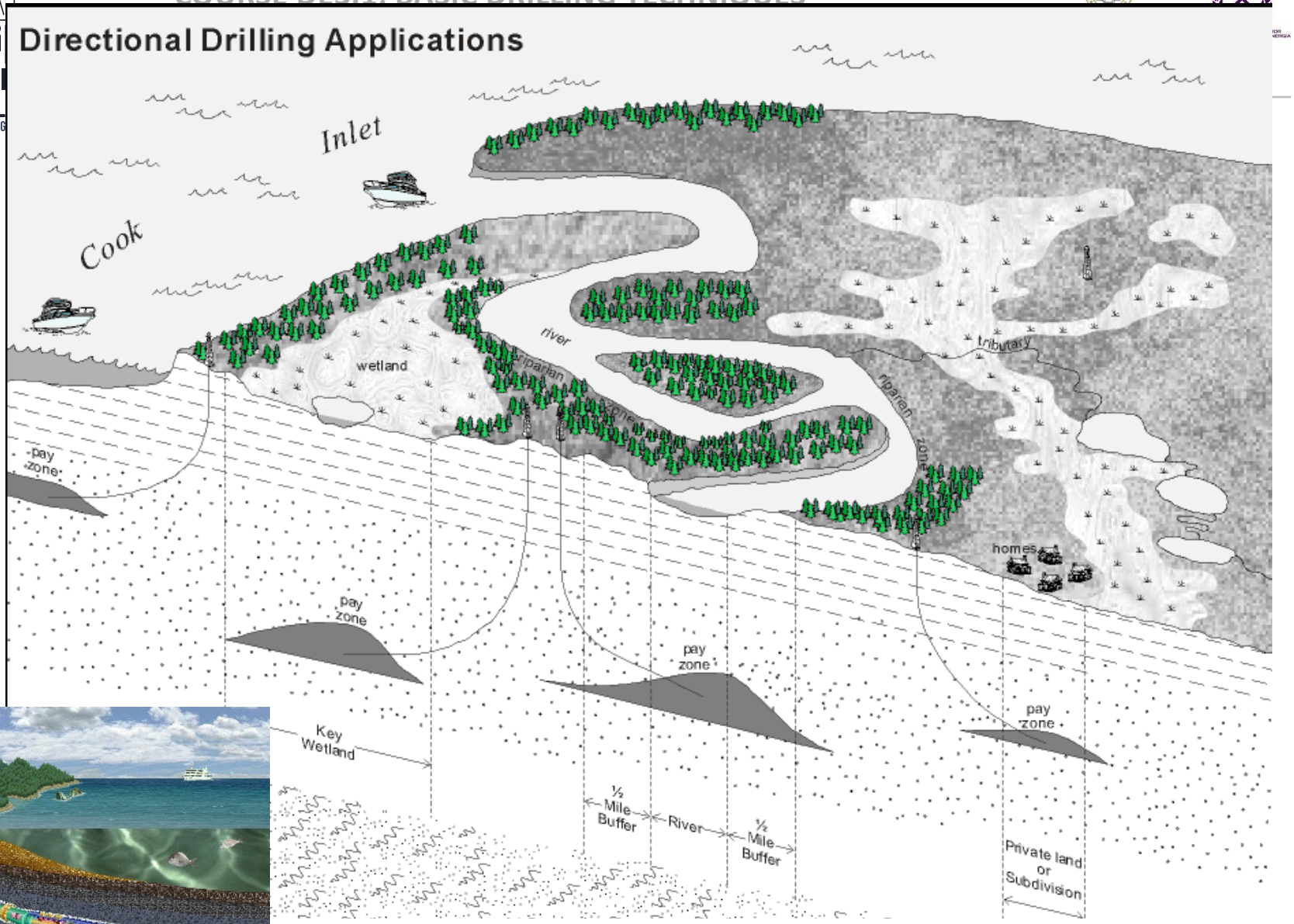
- **Short, Medium, and Long Radius Wells**
  - Short radius wells, typically re-entries of old vertical wells, have curves with a 143 ft (44 m) radius or smaller that cannot be drilled with conventional motors. They are used to isolate higher-/lower-pressured production zones or water sands without setting and cementing a liner.
  - This type of drilling is desirable when kicking off below a problem formation.

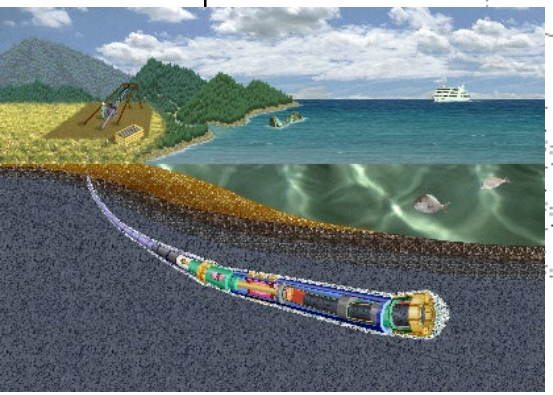


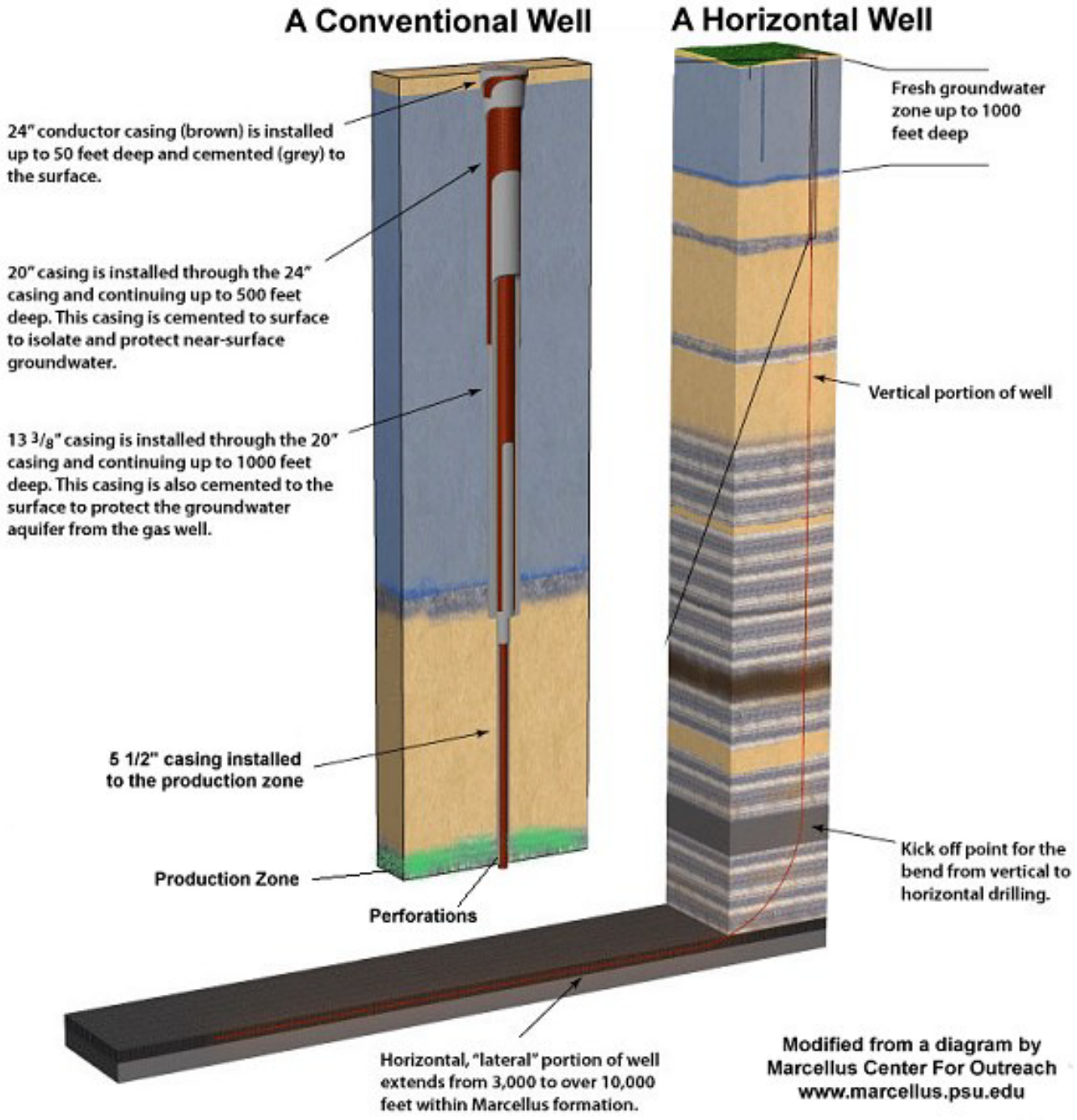
Directional Well Applications

- **Short, Medium, and Long Radius Wells**
  - Medium radius wells have curves with a 200-500 ft (61-152 m) radius that can be drilled with conventional motors.
  - Long radius wells have curves with a 750 ft (229 m) radius or larger that can also be drilled with conventional motors..



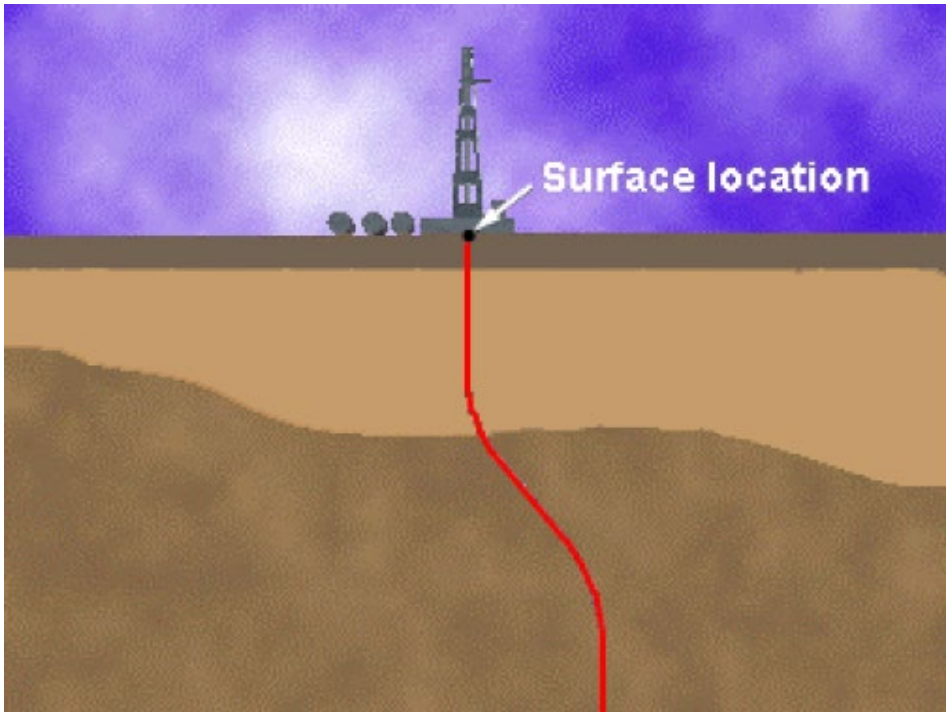

Directional Drilling Applications
Inlet
Cook
wetland
river
riparian zone
tributary
riparian zone
homes
pay zone
pay zone
pay zone
pay zone
Key Wetland
½ Mile Buffer
River
½ Mile Buffer
Private land or Subdivision




A Conventional Well
A Horizontal Well
24" conductor casing (brown) is installed up to 50 feet deep and cemented (grey) to the surface.
20" casing is installed through the 24" casing and continuing up to 500 feet deep. This casing is cemented to surface to isolate and protect near-surface groundwater.
13 3/8" casing is installed through the 20" casing and continuing up to 1000 feet deep. This casing is also cemented to the surface to protect the groundwater aquifer from the gas well.
5 1/2" casing installed to the production zone
Production Zone
Perforations
Fresh groundwater zone up to 1000 feet deep
Vertical portion of well
Kick off point for the bend from vertical to horizontal drilling.
Horizontal, "lateral" portion of well extends from 3,000 to over 10,000 feet within Marcellus formation.
Modified from a diagram by Marcellus Center For Outreach
www.marcellus.psu.edu

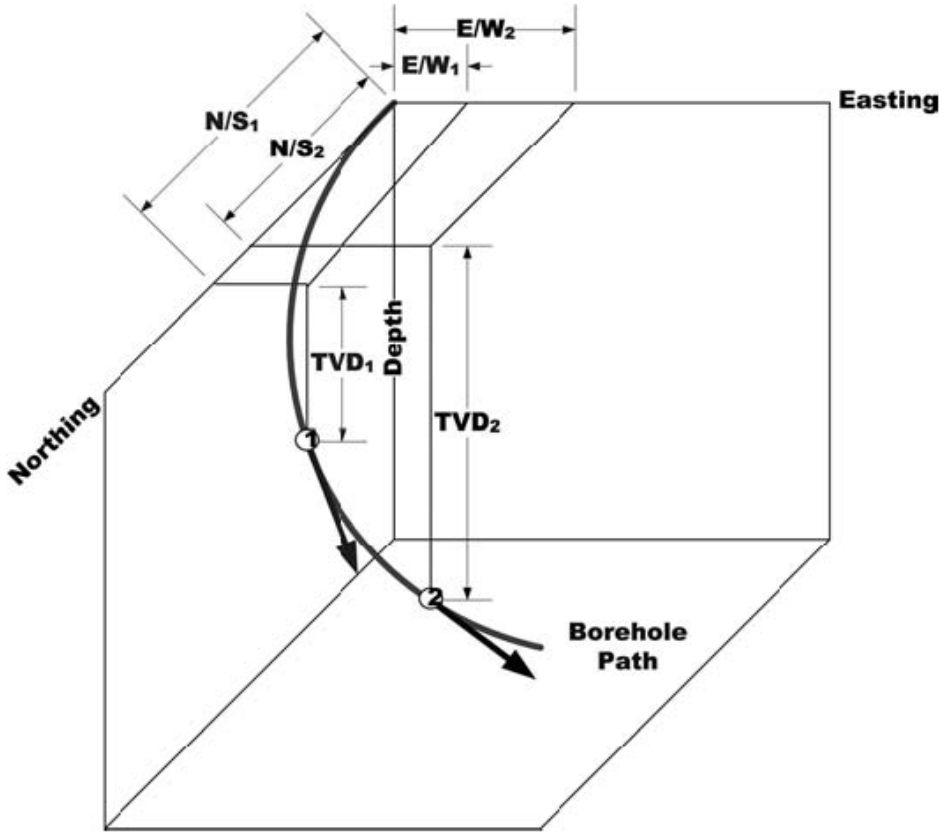
Features of a Directional Well Profile

- A directional well profile is the planned well trajectory from the surface to the final drilling depth by projecting the wellbore onto two plotted planes. In order to determine the best geometric well profile from the surface to the bottomhole target, the following information must be known
  - the position of the surface location,
  - the position of the target location, and
  - the true vertical depth (TVD).

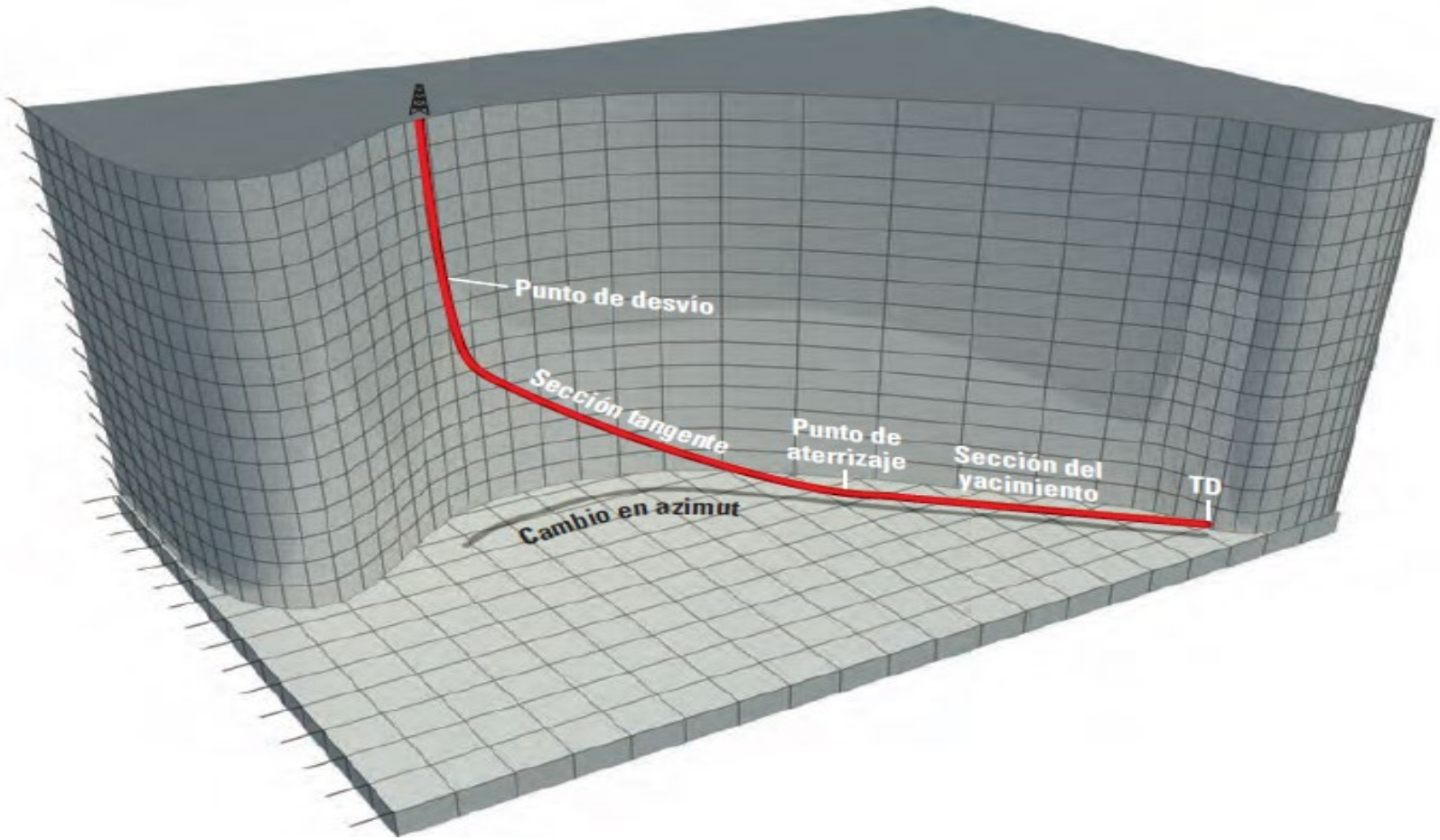


Features of a Directional Well Profile

- The most important aspect of directional drilling is maintaining orientation in a three dimensional space.
- Three measurements are needed to reference the drilling from the surface: tilt, azimuth and depth
  - Tilt (ϕ), angle relative to the vertical.
  - Azimut (θ): Angle to True North in the horizontal drilling.
  - Depth (MD-Measuerd depth): distance along the survey.

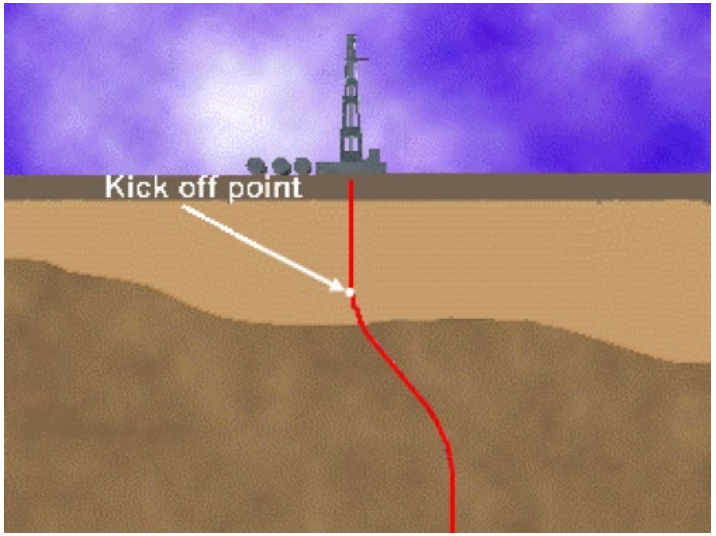


Features of a Directional Well Profile

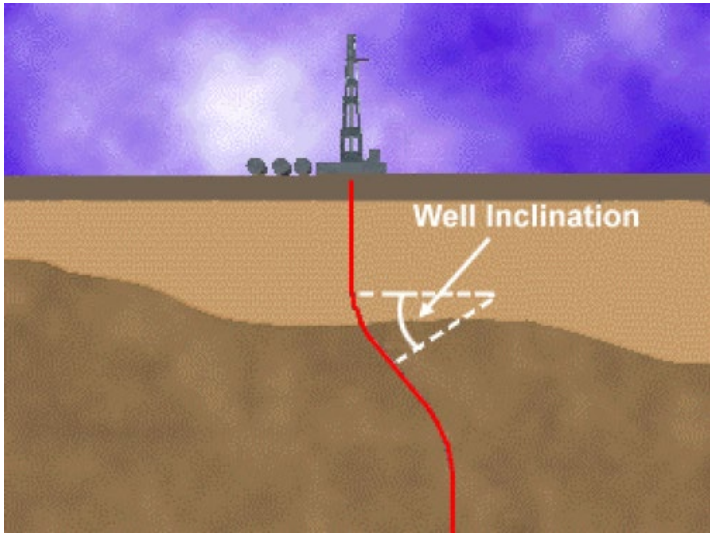


Features of a Directional Well Profile

- **Kickoff Point (KOP)**
  - The kickoff point is the location at a given depth below the surface where the wellbore is deviated in a given direction

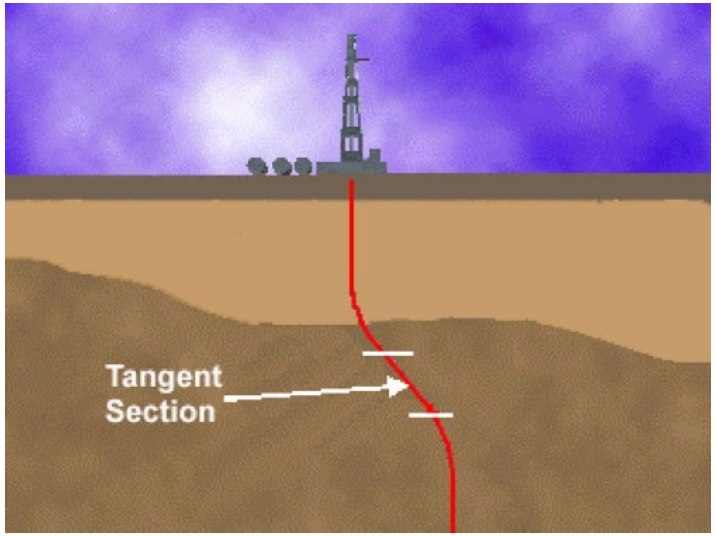


- **Well Inclination**
  - The well inclination is the angle by which the wellbore deviates from the vertical.

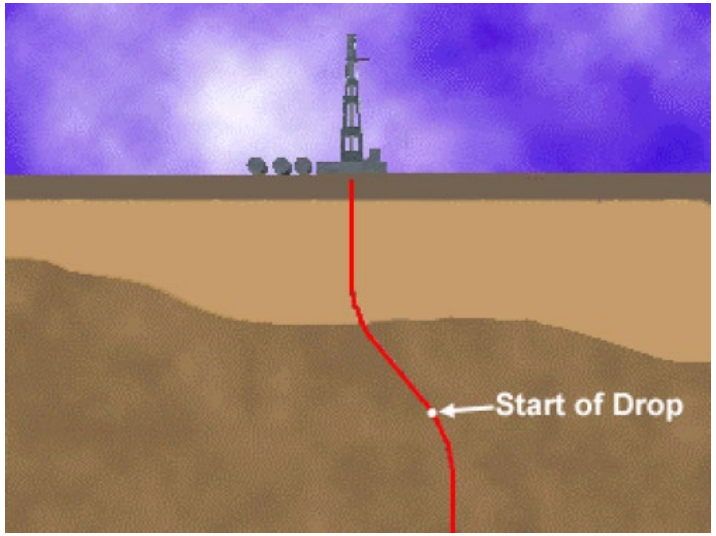


Features of a Directional Well Profile

- **Tangent Section**
  - The tangent section (hold section) occurs after a buildup where the inclination of the borehole is held constant for a certain distance.
  - There could be an additional build or drop before reaching the target.

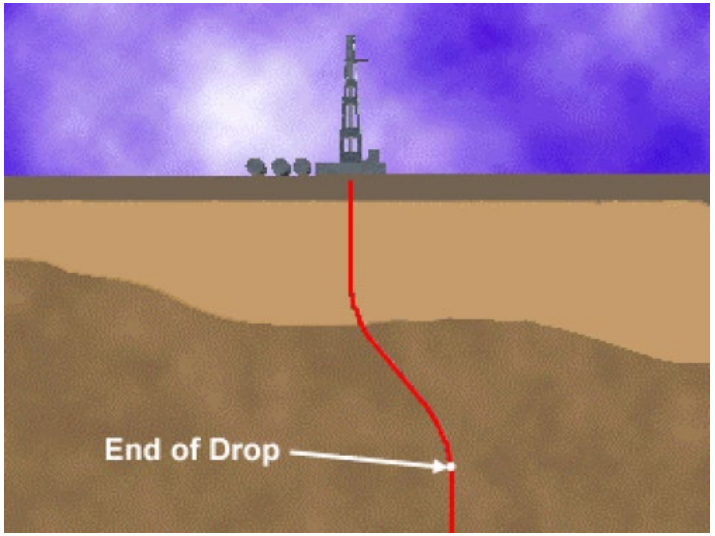


- **Start of Drop**
  - The start of drop is the location where the wellbore starts dropping inclination.

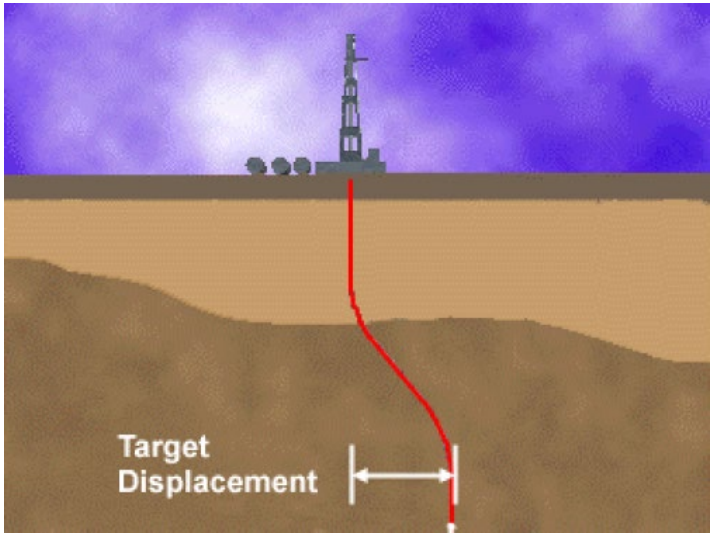


Features of a Directional Well Profile

- **End of Drop (EOD)**
  - The end of drop is the location where the wellbore finishes dropping inclination..



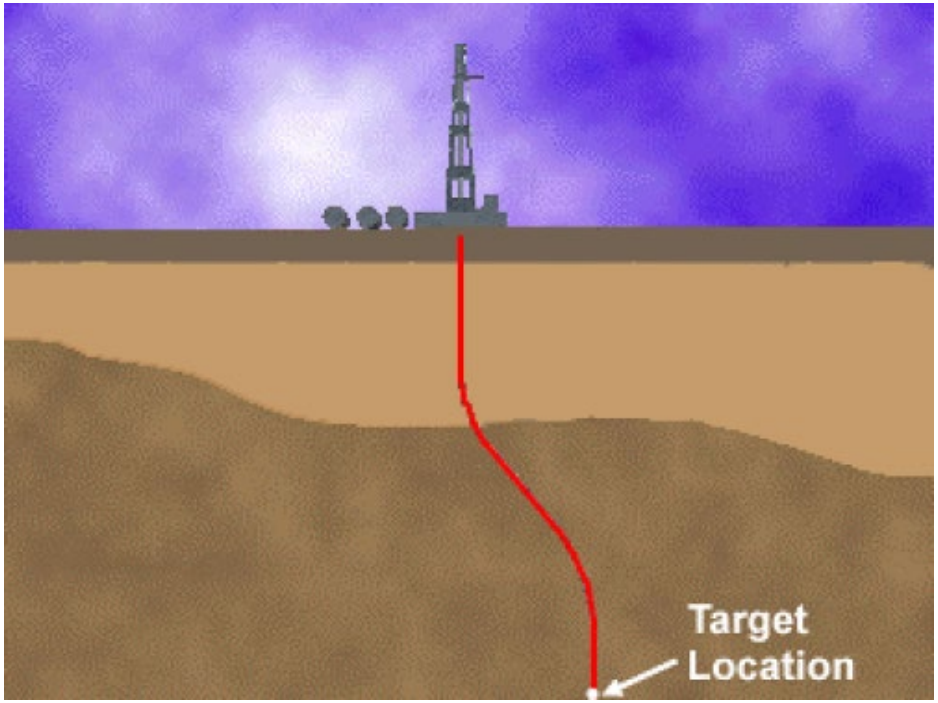
- **Target Displacement**
  - The target displacement is the lateral distance from the surface location to the target.



Features of a Directional Well Profile

- **Target Location**
  - The target location is a point defined in space by geographical coordinates at a given true vertical depth.
  - A well profile could have multiple targets.

- **Drop Off Rate (DOR)**
  - The drop off rate is the rate at which the inclination decreases. The rate is usually expressed in degrees per 100 ft or degrees per 30 m of the course length.



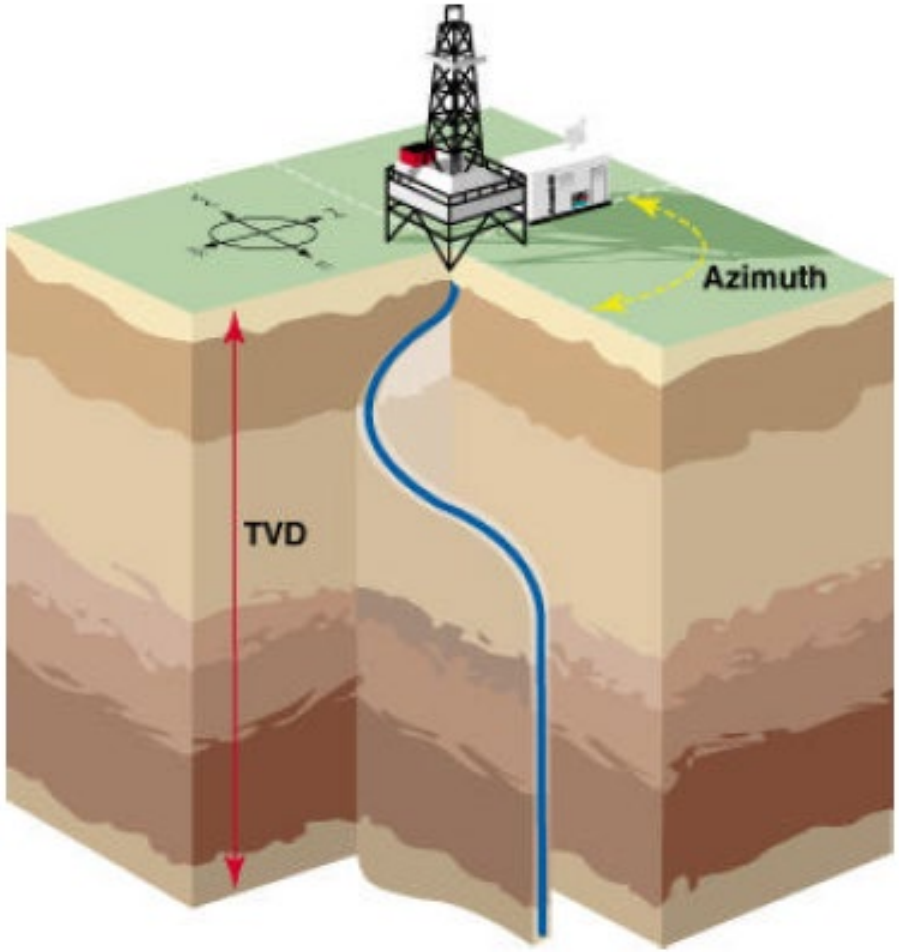
Features of a Directional Well Profile

- **Buildup Rate (BUR)**
  - The buildup rate is the change of inclination of a wellbore where the angle is increased.
  - The rate is usually expressed in degrees per 100 ft or angular increase per 30 m of the measured depth.

- **Turn Rate**
  - The turn rate determines the rate a well profile turns in azimuth direction. Usually expressed in degrees per 100 ft or degrees per 30 m.

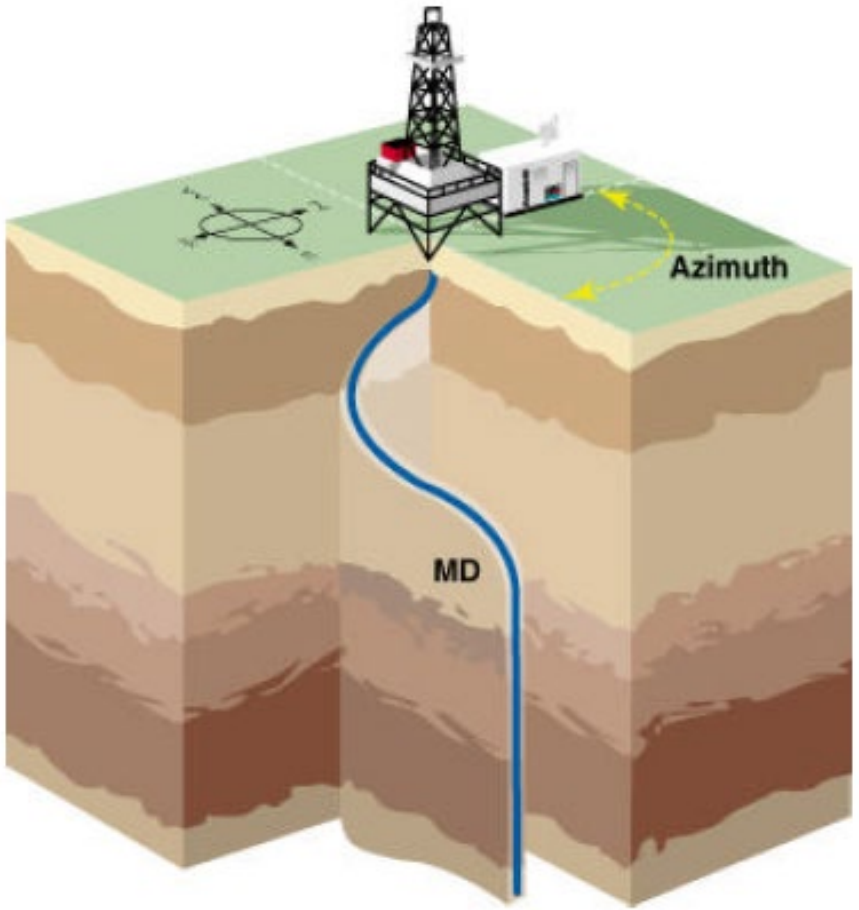
Features of a Directional Well Profile

- **True Vertical Depth (TVD)**
  - The true vertical depth of any point or station along a wellbore is the vertical distance from the well surface reference point to the station of interest.



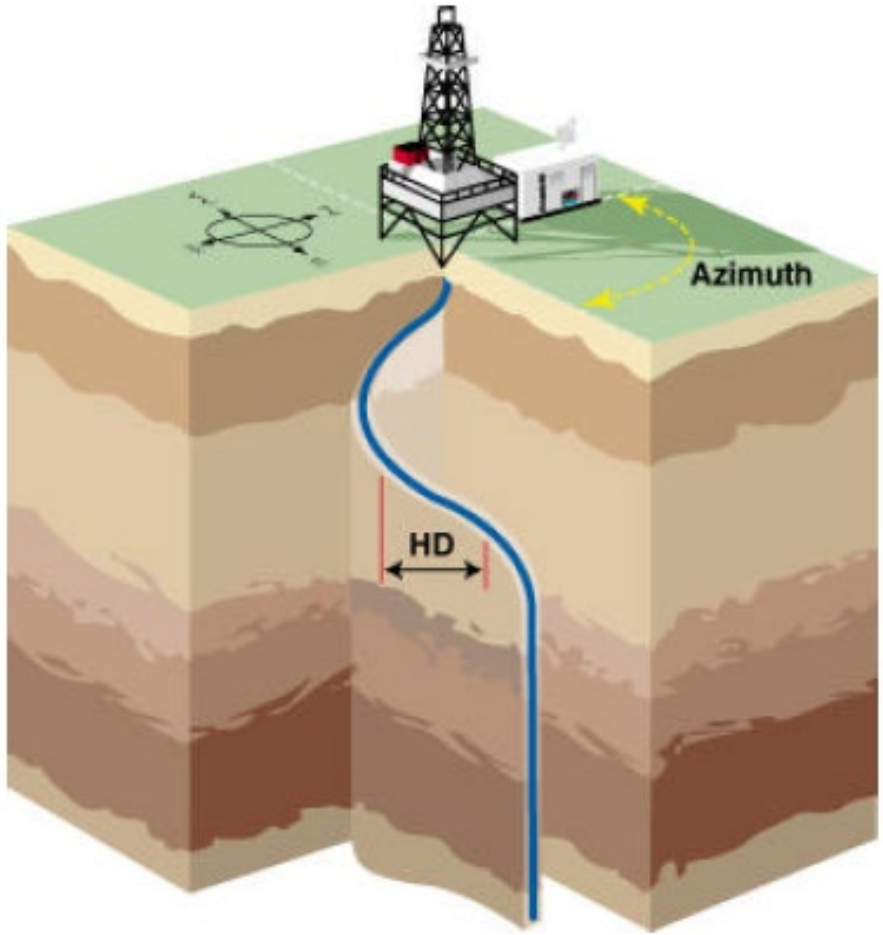
Features of a Directional Well Profile

- **Measured Depth (MD)**
  - The measured depth of any point or station along a wellbore is the distance from the well surface reference point to the station of interest along the actual well path.



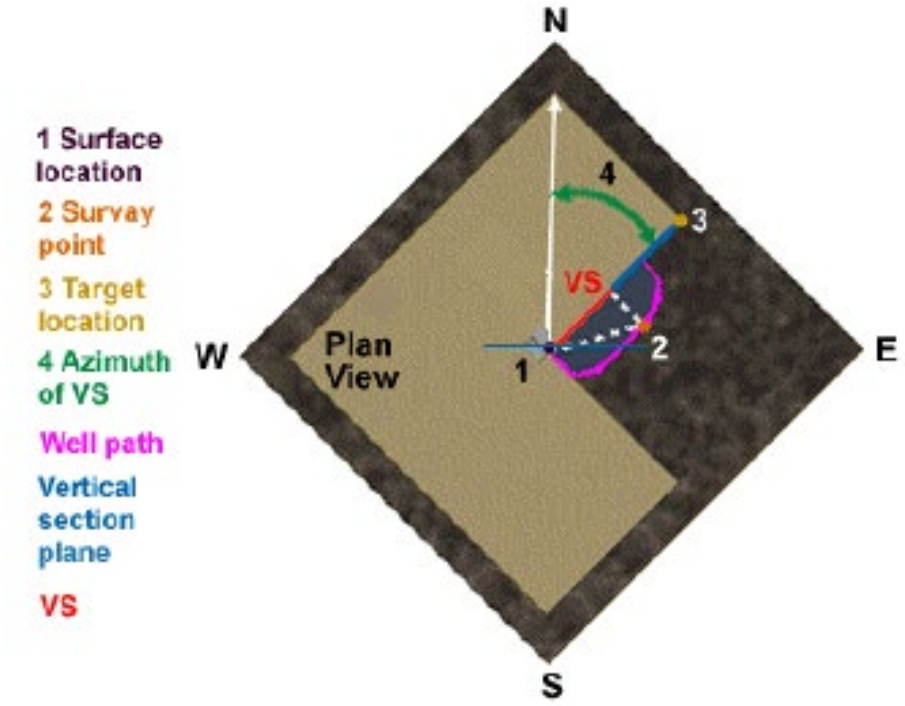
Features of a Directional Well Profile

- **Horizontal Displacement (HD)**
  - The horizontal displacement is the distance between any two points along a wellbore projected onto a horizontal plane or plan view.



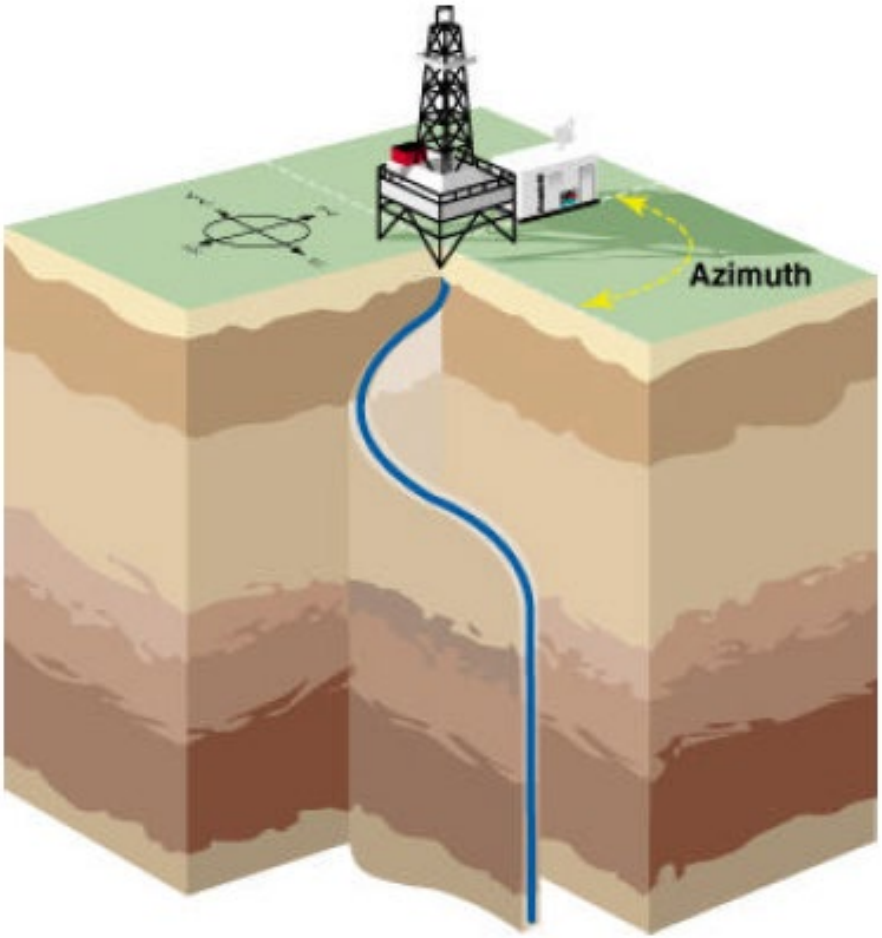
Features of a Directional Well Profile

- **Vertical Section (VS)**
  - The vertical section is the distance between any two points along a wellbore projection onto a vertical section plane.



Features of a Directional Well Profile

- **Azimuth**
  - The azimuth is the angle in the horizontal plane measured from a fixed reference direction (such as True North), usually measured clockwise.



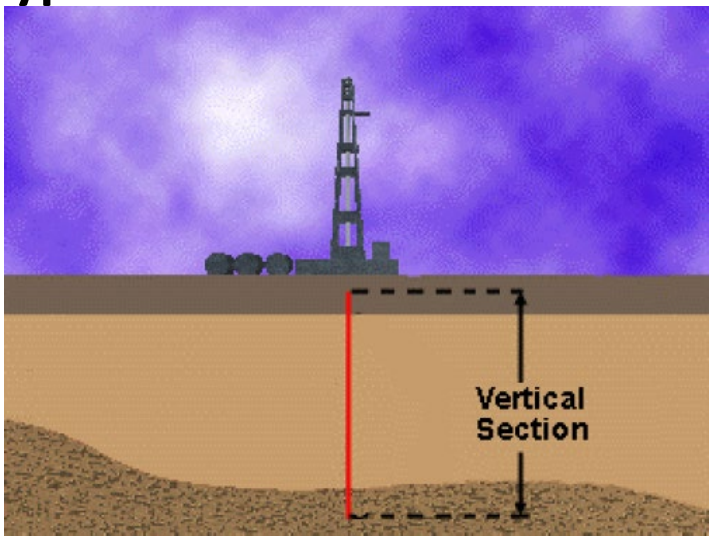
Types of Directional Well Profiles

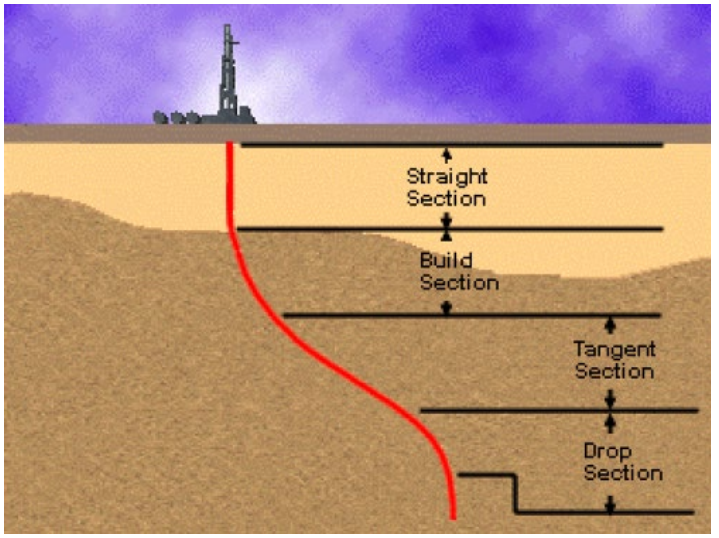
- In general, directional wells can be either:
  - Straight (Vertical),
  - S-type,
  - Slant (J-type), or
  - Horizontal.
- The type of profile selected will depend upon the geological objectives and the production mechanism of the well.

Types of Directional Well Profiles

- **Straight Well (Vertical)**
  - Straight wells have a bore with no planned deviation from vertical

- **S-Type Well**
  - S-type wells have a bore with a straight section, a build section, a tangent section, and a drop section.
  - This type of well is drilled to improve the efficiency of the well and to assist in the location of a blown-out well. In offshore drilling, S-type wells can ensure accuracy in bottomhole spacing when multiple wells are drilled from the same platform.



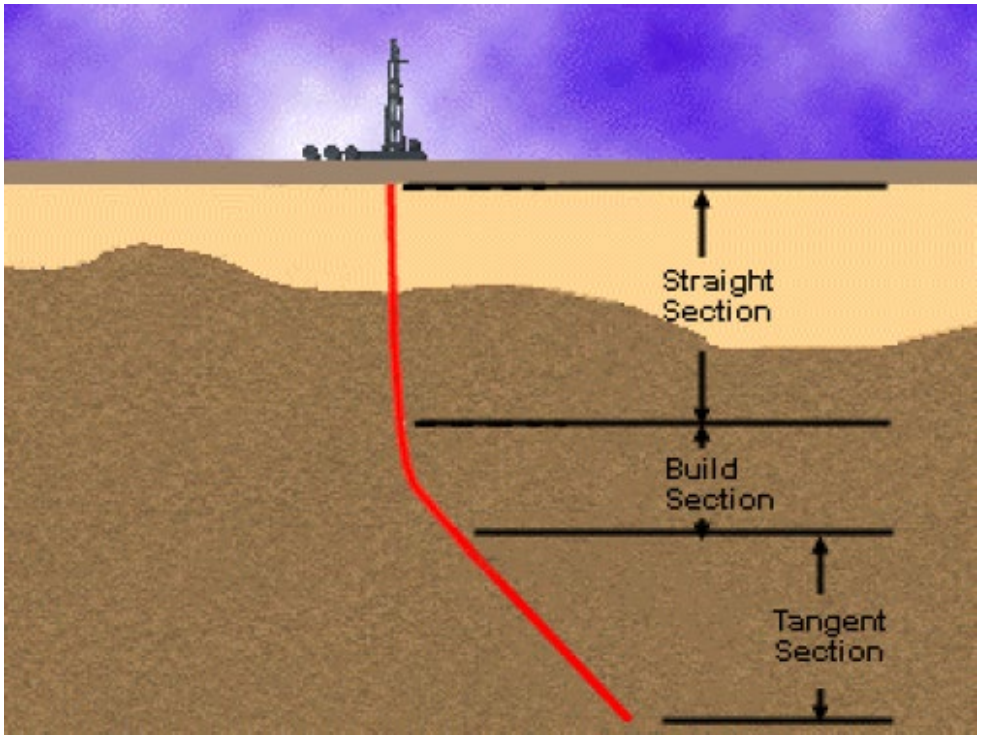


Types of Directional Well Profiles

- **Slant Well (J-Type)**

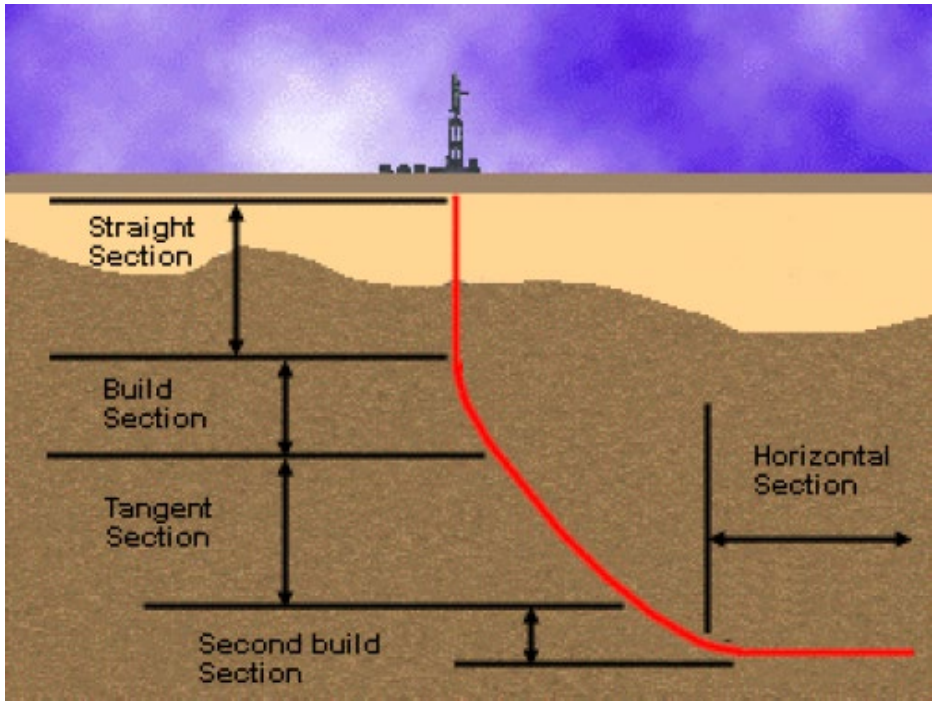
  - Slant wells, sometimes called J-type wells, have a bore with a straight section, a build section, and a tangent section straight to the target

  - Slant or J-type wells are drilled where it is not desirable or possible to locate the surface location directly above the target or a multiwell platform.



Types of Directional Well Profiles

- **Horizontal Well**
  - Horizontal wells have a bore with a straight section, a build section, tangent section, a second build section (most of the time), and a horizontal section.
  - The well is drilled to a point above the reservoir; then it is deflected and the angle increases until it reaches 90 degrees or more.
  - When properly applied, one horizontal borehole can produce a reservoir better than several vertically drilled wells.



Well Planning

- Well planning is an organized process used to put together data that will be used to design a successful well. A well plan is a very important stage prior to the commencement of the drilling operation to ensure that all aspects are tailored to meet the specific objectives of that well. The drill well plans are often developed in a Drilling Engineering Center (DEC) by a well planner.

- Understanding how to design a well plan (proposal), is one of the most important duties of the directional driller. He must be able to understand the plan and make any required changes.

- The data provided by the client is used by the well planner to develop a geometric profile for the safest and easiest path from the surface location to the target. The planner has access to a computer program to help develop the best possible profile. The needed data is put into the program so that a well profile can be printed, plotted and used for the drilling project.

Well Planning

- **Components of a Well Plan**
  - There are many components to take into consideration when designing a successful well plan.
  - Components of a Well Plan

    - Surface Location
    - Target Location
    - Kickoff Point
    - Buildup Rate
    - Turn Rate
    - Hold Angle
    - Start of Drop
    - True Vertical Depth
    - Target Displacement
    - Azimuth
    - Vertical Section
    - Quadrant
    - Polar Coordinate
    - Rectangular Coordinate
    - End of Drop
    - Tangent Section
    - Measured Depth
    - Well Inclination
    - End of Buildup
    - Horizontal Displacement
    - Drop Off Rate