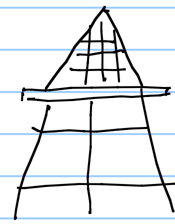
Day 5 06.12.2019

• offshore structures for oil and gas production. what component does the structure must have?

- Facilities for drilling and full intervention. This includes drilling tower, BOP, drilling floor, mud package, cementing pumps, storage deck for drill pipes and tubulars, drilling risers.
- Facilities for light well intervention.
- Processing facilities: separator trains for primary oil, gas and water separation, gas processing train, water processing train.
- Gas injection system
- Gas compression units for pipeline transport
- Water injection system
- Living quarters
- Helideck.
- Power generation.
- Flare system.
- Utilities (hydraulic power fluid, compressed air, drinking water unit, air condition system, ventilation and heating system)
- Bay for wellheads and christmas trees
- Production manifolds
- Oil storage
- Facilities for oil offloading
- Control system
- Monitoring system
- System for storage, injection and recovery of production chemicals (wax, scale , hydrate or corrosion inhibitors)
- Repair workshop

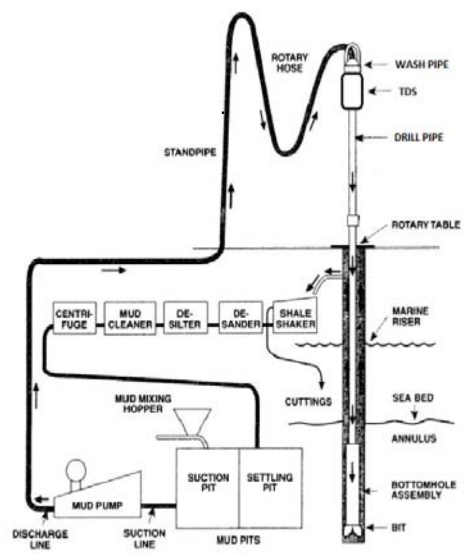
some of components I need

→ drilling package ($)



drilling tower

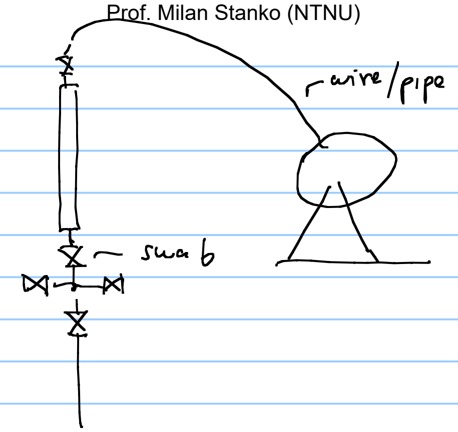
→ gas turbine (20 - 70 MW)

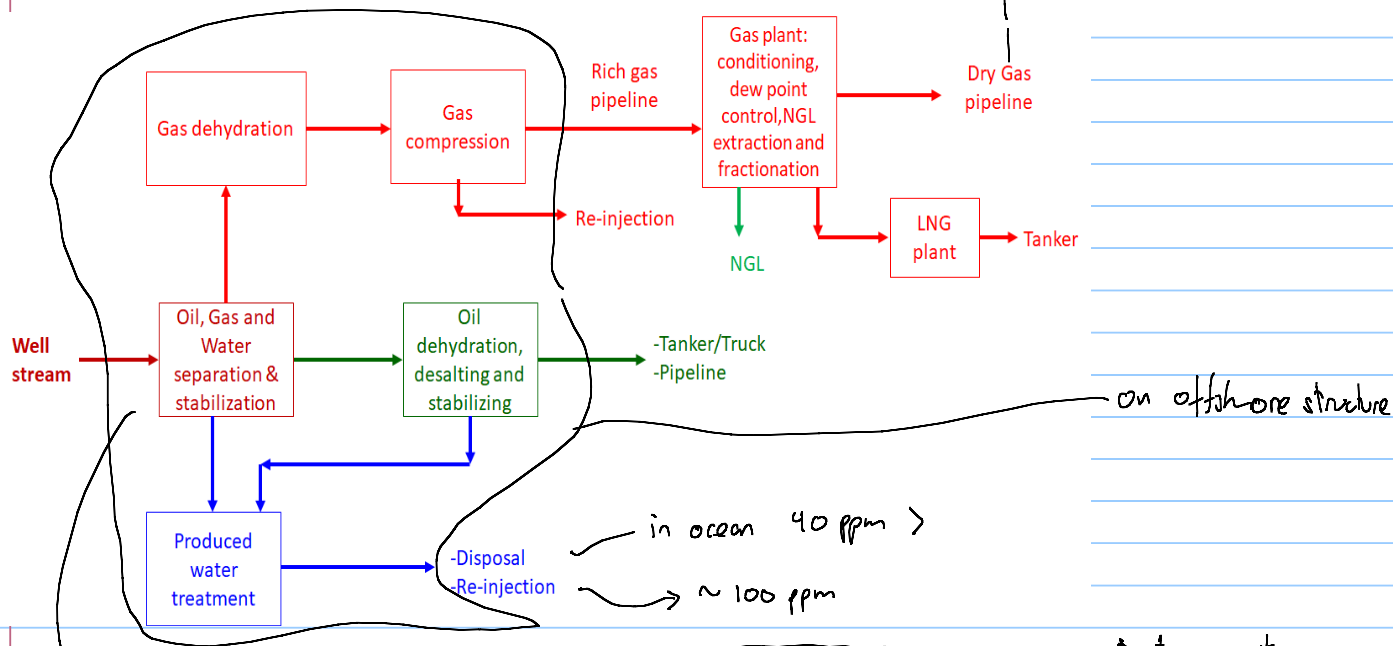


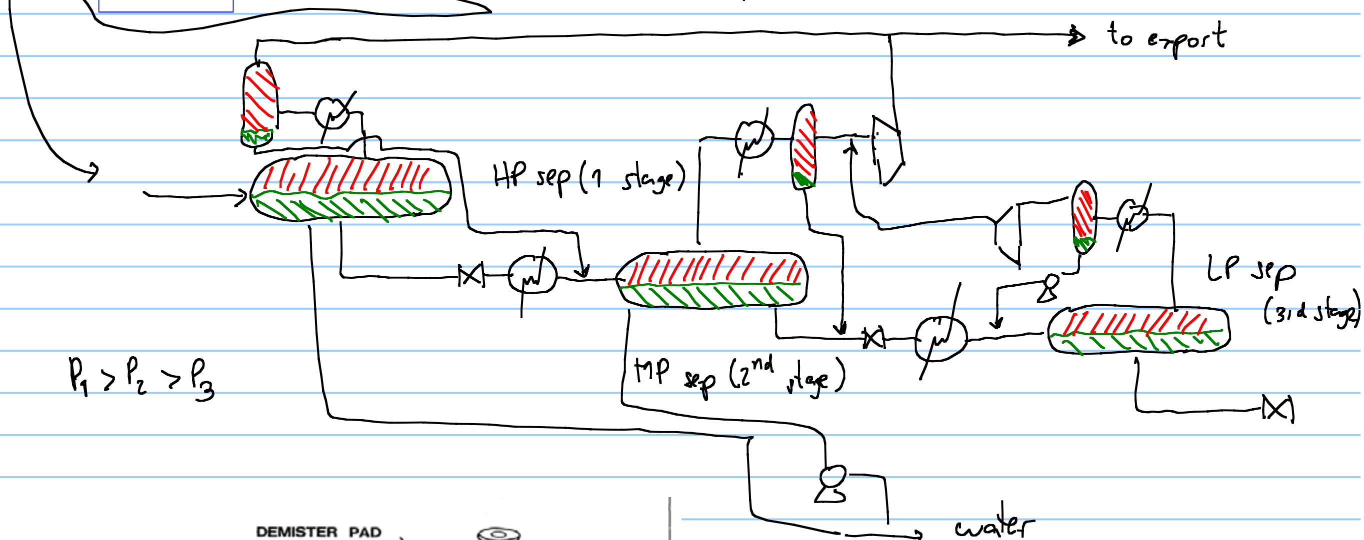
mud package

→ drilling pipe
tubing
casing
} storage

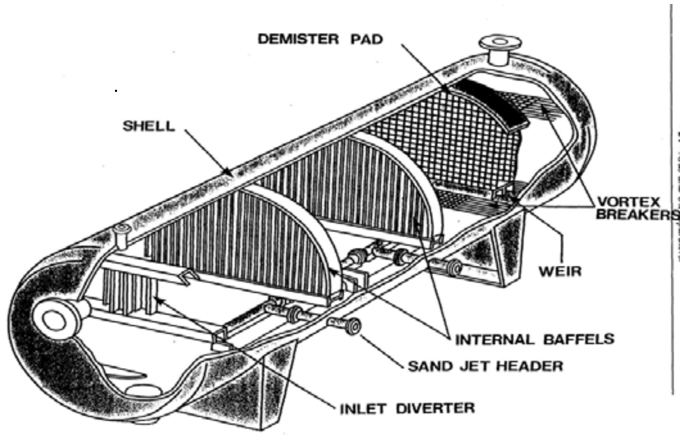
"Light" well intervention: → wireline / slickline
↳ coiled tubing

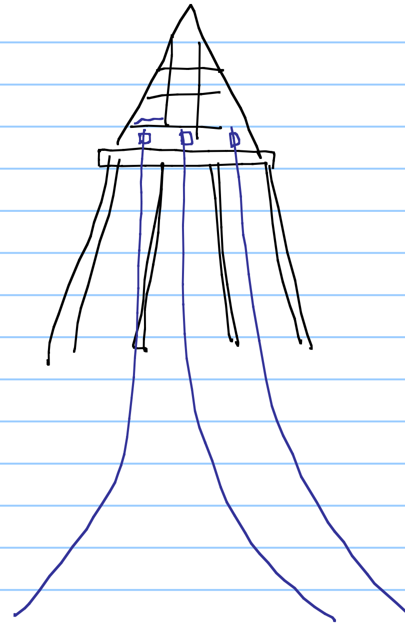


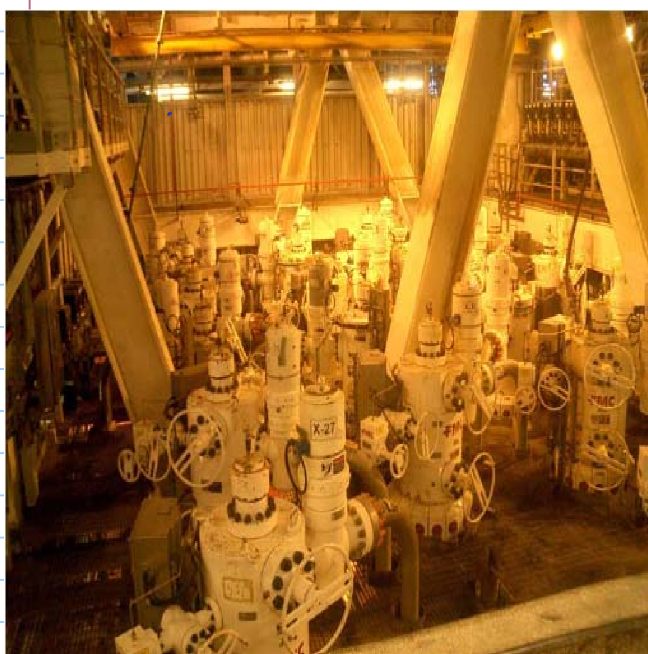




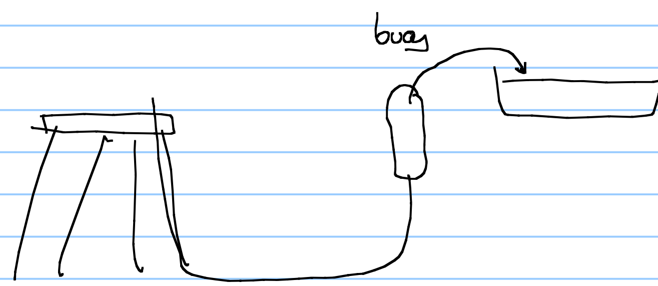
$P_1 > P_2 > P_3$



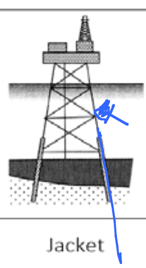
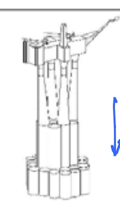
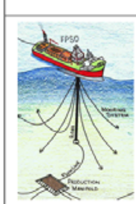
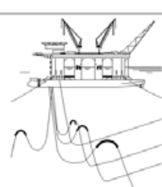
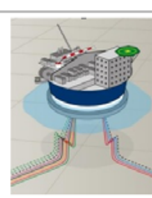
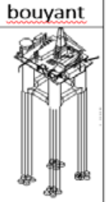


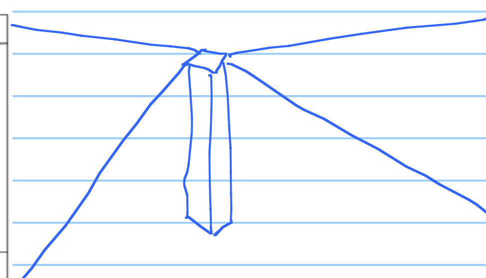


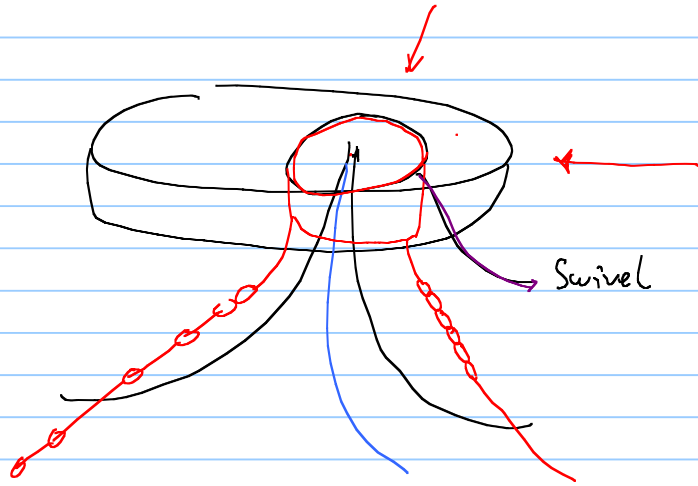
oil offloading



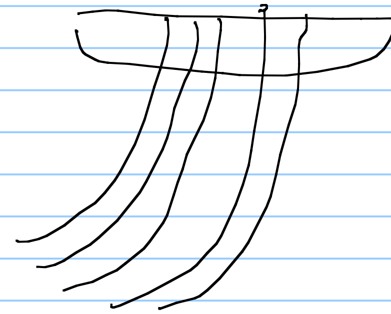
type of offshore structures

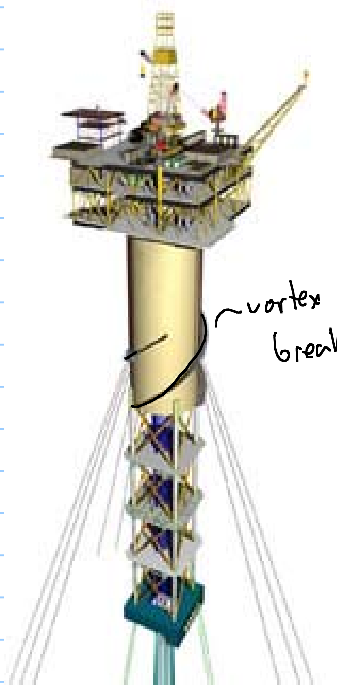
<table>
<tr><td rowspan="3">Bottom-supported</td><td colspan="2">Fixed</td><td colspan="3">Compliant</td></tr>
<tr><td></td><td></td><td colspan="3"></td></tr>
<tr><td>Jacket</td><td>Gravity-Based Structure</td><td colspan="3">Compliant tower</td></tr>
<tr><td rowspan="3">Floating</td><td colspan="4">Neutrally bouyant</td><td>Positively bouyant</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Ship FPSO</td><td>Semi-Sub</td><td>Sevan FPSO</td><td>Spar</td><td>Tension Leg Platform (TLP)</td></tr>
</table>



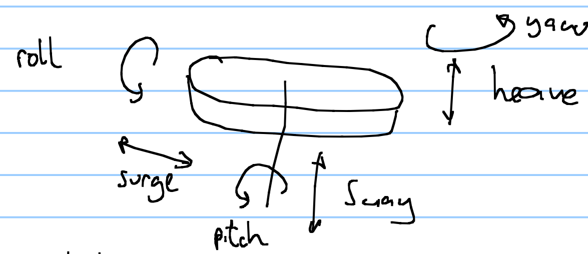


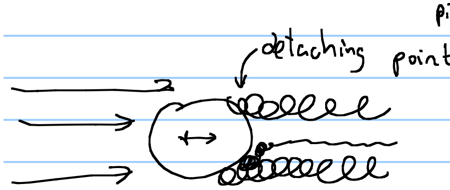
if weather conditions are not harsh and are not changing, we dont need swivel





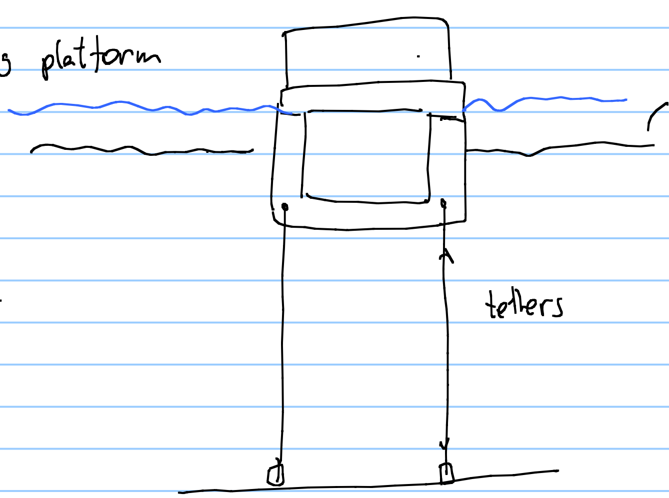
the big draft hinders movement



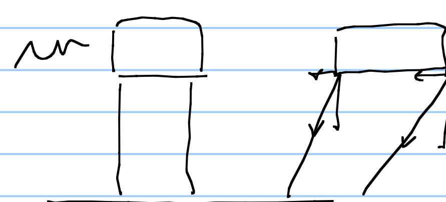


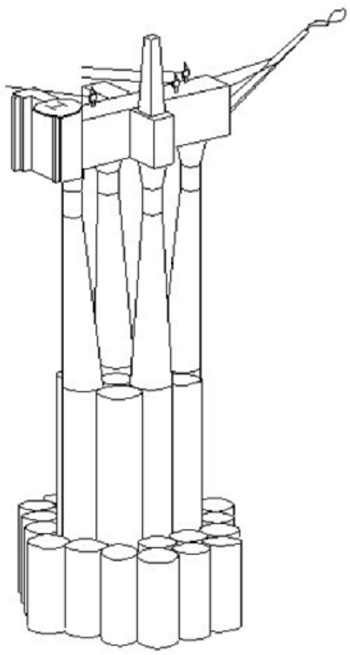
Vortex shedding

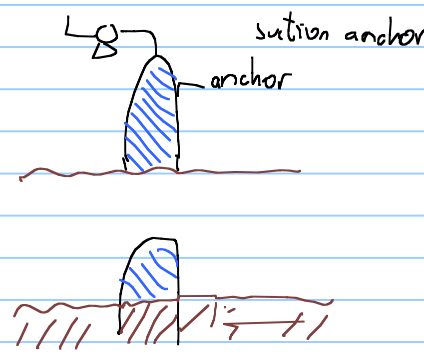
Tension leg platform



limit movement







storage tanks / buffer to avoid interrupting production in case of bad weather

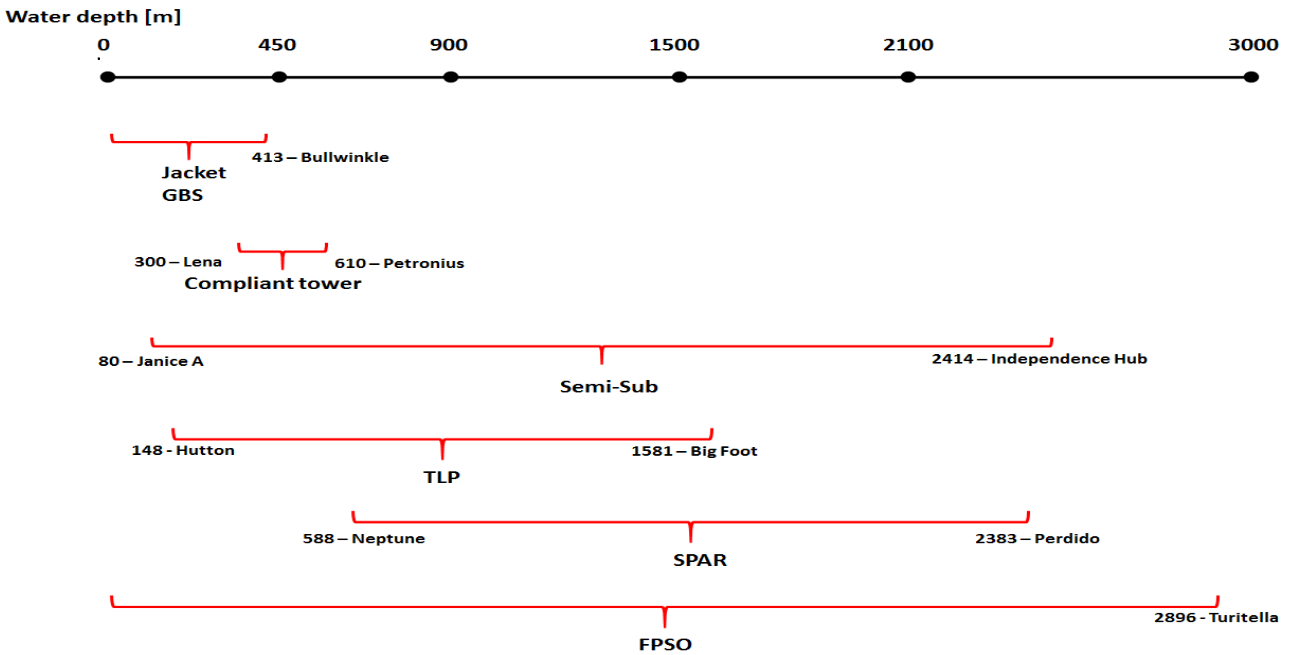
Semi submersible

How do we select offshore structures?

1) Water depth

bottom supported structures are used for water depths below 600 m

floating structures are used for any water depth but typically for > 600 m

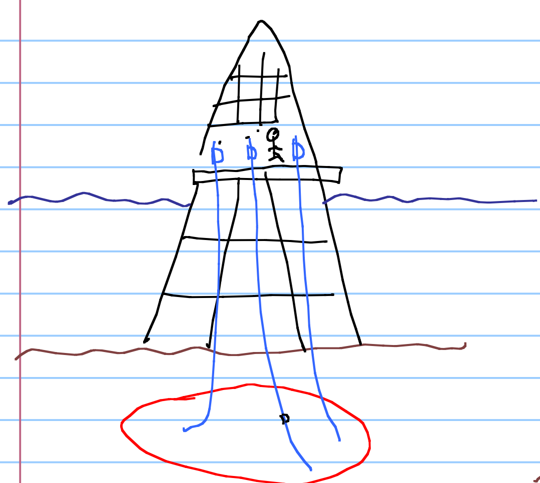


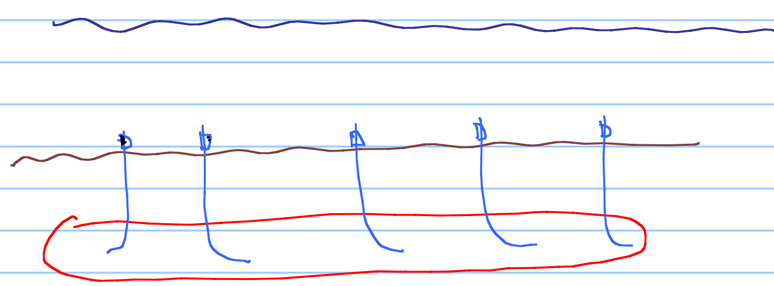
2) Location of X-mas tree → dry (platform)
↳ wet (subsea)

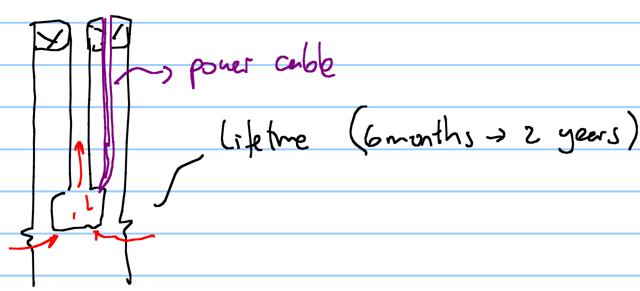
↳ spread of reservoir

Can I reach all reservoir targets from same location?

reservoir structure and spread



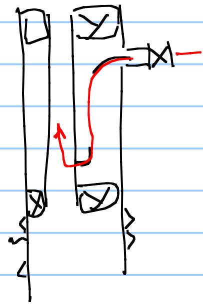




↳ water depth. Dry wells have a limit up to 1500 m

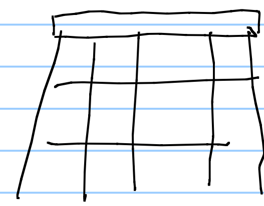
↳ well intervention needs:

if Artificial Lift (Electric submersible pumps or gas lift, then I prefer to have dry wells



gas lift. by injecting gas, ρ_{mix} is reduced, Δp is also reduced.

↳ infill drilling (to prolong plateau, high uncertainty in subsurface)

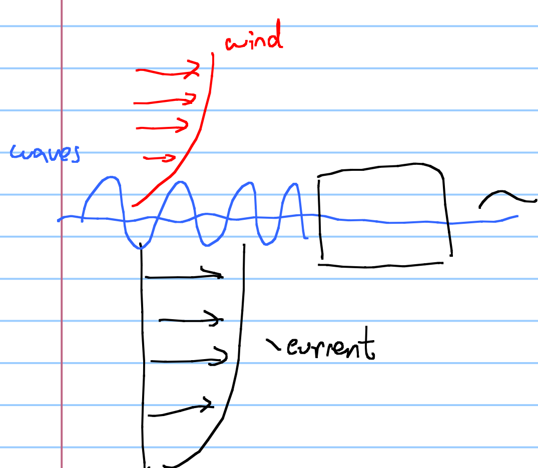


to have spare slots on platform will be very expensive. therefore it is preferred to use subsea wells.

there are only a few structures that allow dry X-mas → Jacket, GBS, compliant tower TLP, (semi-sub), SPAR

- oil storage { harsh weather conditions, social / political uncertainty } that might interrupt regular tanker schedule

GBS ~> 300 000 ~> 500 000 stb
SPAR ~> 150000 stb
FPSO ~> 1.000.000 - 3000.000 . stb

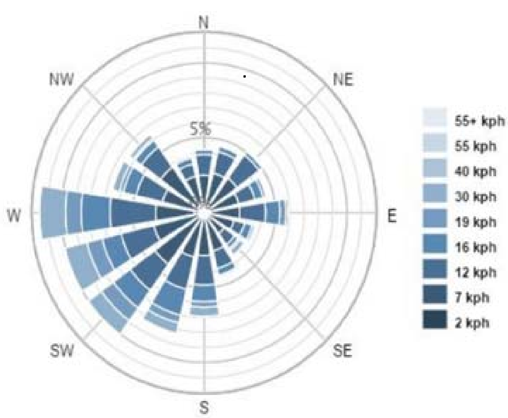


- loads caused by
  - wind
  - waves
  - currents

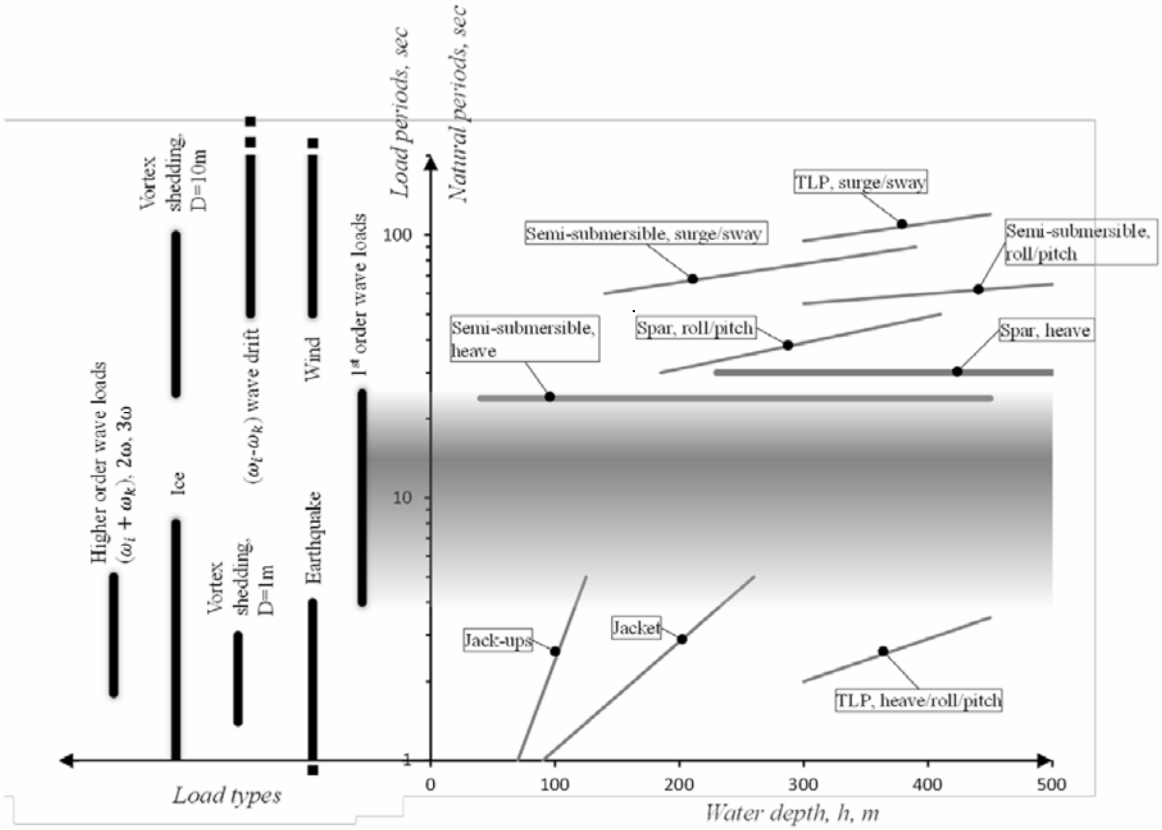
} each offshore location has some characteristic

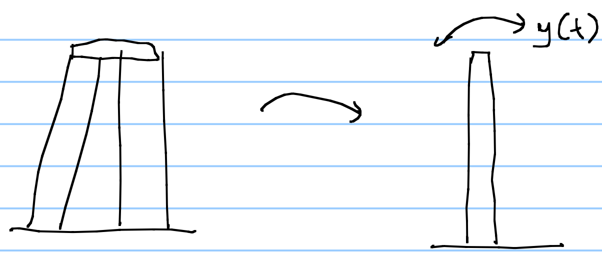
wave, wind, current } magnitude, direction, frequency/period

Causing movement ↳ heave (t), surge (t), sway (t), roll (t), pitch (t), yaw (t)



each structure has a natural frequency which give maximum movement, therefore I have to avoid using structures which their natural frequency coincides with excitation frequency

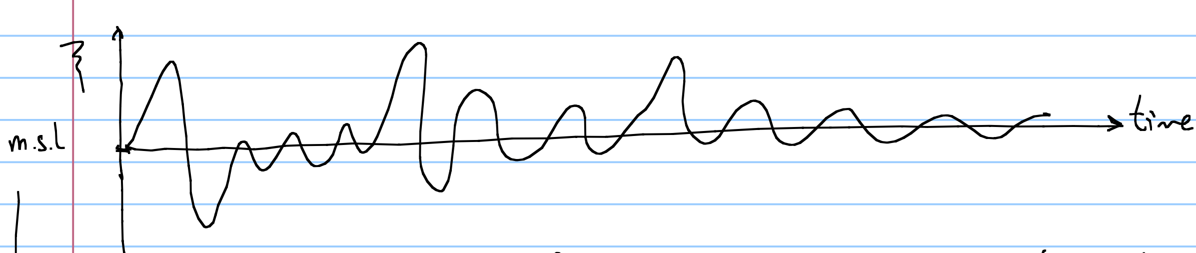




How do we characterize the conditions of wave, wind, current of an offshore location?

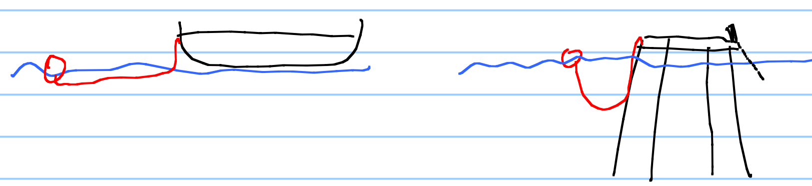
usually considered fixed in magnitude and direction

Waves



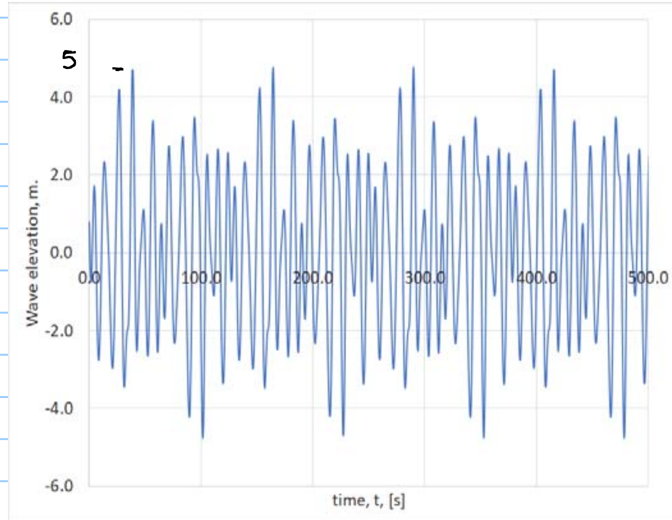
mean sea level

Surveys are made in the area for a few years (2 years)

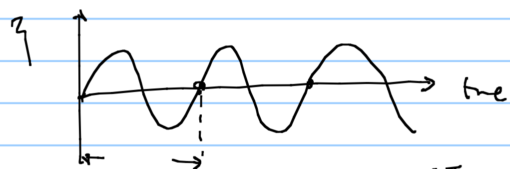


Exercise 9

Time [s]	Elevation [m]
0.0	0.8
0.5	0.0
1.0	-0.5
1.5	-0.8
2.0	-0.6
2.5	-0.1
3.0	0.5
3.5	1.1
4.0	1.6



our intention is to determine a characteristic period / frequency



T (s) $f = \frac{1}{T}$ $\omega = \frac{2\pi}{T}$

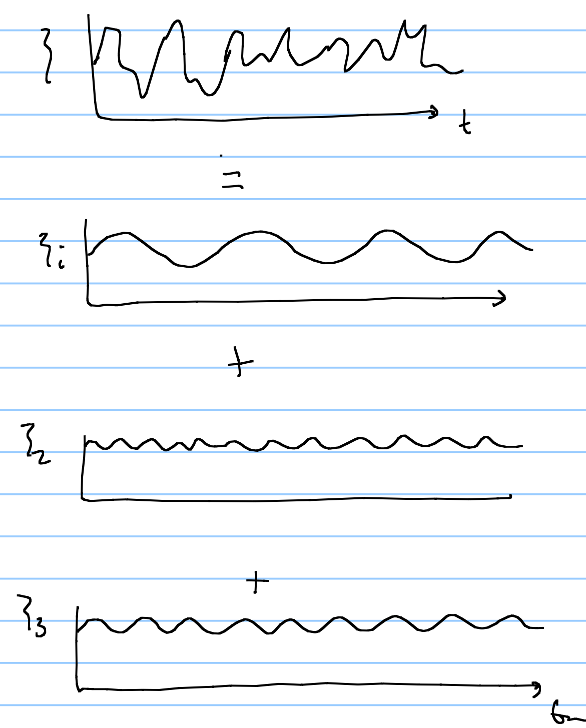
$\frac{1}{s} = Hz$ $\left[\frac{rad}{s}\right]$

$\frac{cycles}{s}$ $\frac{2\pi\ rad}{1\ cycle}$

Fourier (french mathematician)

all signals can be expressed as a sum of sinusoidal functions

$$\eta(t) = \sum_{i=1}^{N} A_i \sin(\omega_i t + \delta_i)$$

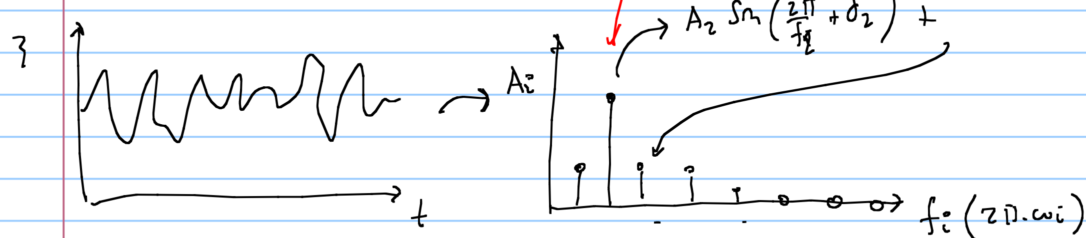


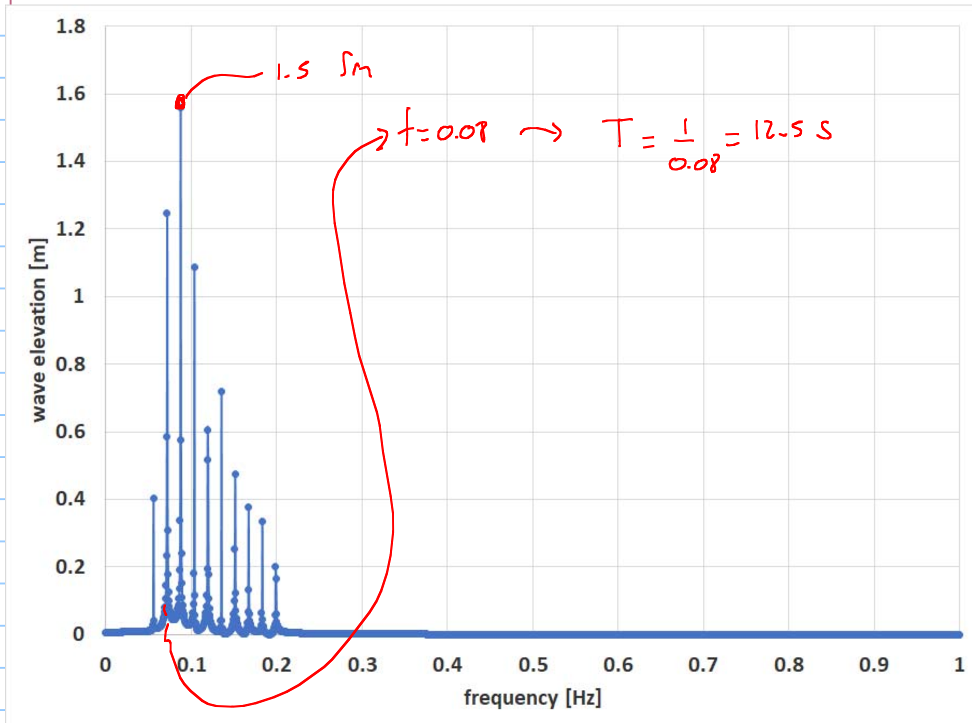
to process wave signals, we typically use Fourier transform (FFT) fast fourier transform

η vs t → $\{ A_i \quad \omega_i \quad \delta_i$

dominant frequency in the signal

$A_2 \sin\left(\frac{2\pi}{f_2} + \delta_2\right) +$





this frequency analysis is typically made for "sea states" (periods of time of about 3hrs) during which it is assumed they exhibit a dominant magnitude and period

3h → A T
3h → A, T
3h → A, T

} repeat this analysis for 2 years

Apply a frequency analysis on the results

	Spectral Peak period (T_p) [s]																				
Hs [m]	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23
0-1	15	290	1367	2876	3716	3527	2734	1849	1138	656	362	192	101	52	26	13	7	3	2	1	0
1-2	1	81	1153	5308	12083	17323	18143	15262	10980	7053	4169	2316	1229	631	315	155	75	36	17	8	4
2-3	0	2	94	1050	4532	10304	15020	15953	13457	9752	5991	3403	1795	894	426	197	88	39	17	7	3
3-4	0	0	2	72	686	2782	6171	8847	9189	7493	5082	2991	1577	762	345	148	61	24	9	4	1
4-5	0	0	0	2	51	433	1645	3495	4807	4750	3638	2286	1229	584	251	100	37	13	5	1	0
5-6	0	0	0	0	2	39	294	1037	2069	2664	2440	1709	968	463	193	72	25	8	2	1	0
6-7	0	0	0	0	0	2	32	215	692	1264	1485	1228	767	382	159	57	18	5	1	0	0
7-8	0	0	0	0	0	0	2	27	157	447	730	762	555	302	130	46	14	4	1	0	0
8-9	0	0	0	0	0	0	0	2	23	112	276	392	355	223	104	38	11	3	1	0	0
9-10	0	0	0	0	0	0	0	0	2	19	77	160	192	148	79	31	9	2	0	0	0
10-11	0	0	0	0	0	0	0	0	0	2	16	50	85	85	55	24	8	2	0	0	0
11-12	0	0	0	0	0	0	0	0	0	0	2	12	29	40	33	18	7	2	0	0	0
12-13	0	0	0	0	0	0	0	0	0	0	0	2	8	15	17	12	5	2	0	0	0
13-14	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	6	4	1	0	0	0
14-15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	2	1	0	0	0
15-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0
16-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	16	373	2616	9308	21070	34410	44041	46687	42514	34212	24268	15503	8892	4587	2143	921	372	146	55	22	8

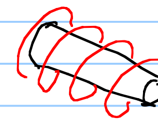
flow assurance considerations in field development

ensure the uninterrupted flow of hydrocarbons from reservoir to processing facilities

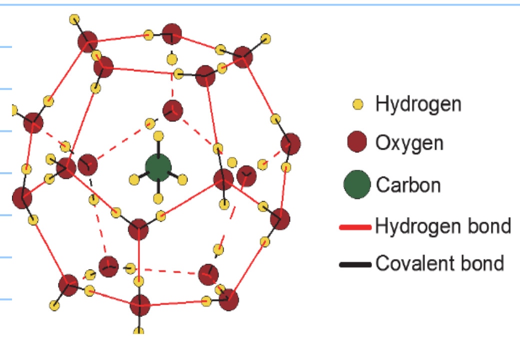
- wax C12 → long chain alcanes that precipite from oil at low temperature

cause plugging of pipelines, cause malfunctioning of equipment.

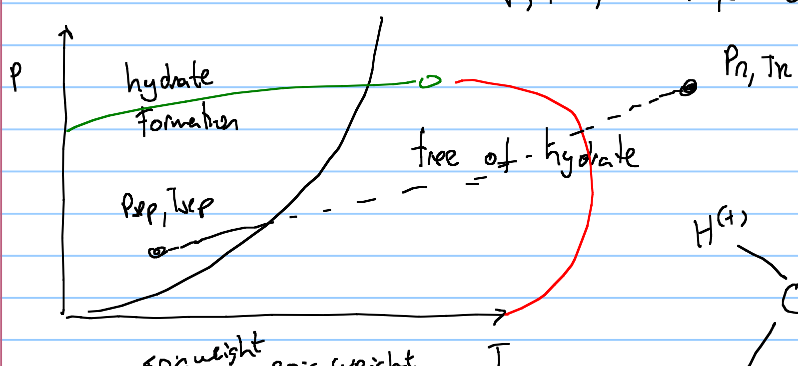
to avoid wax: ◦ wax inhibitor
- use better pipe insulation
- use pipe heating

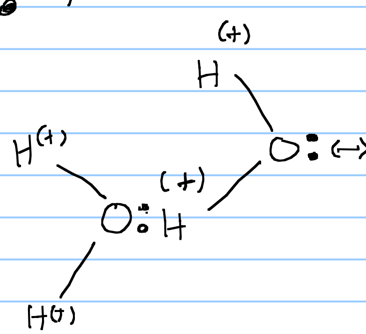


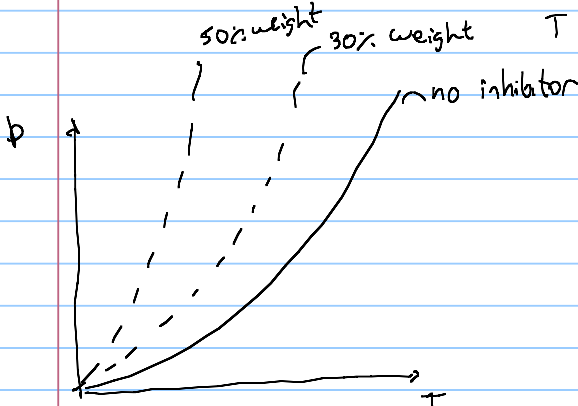
- hydrates

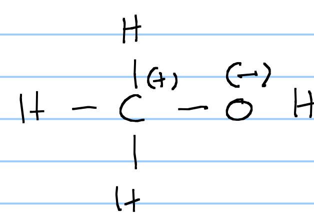


- free water
- small molecules of HC, C_1, C_2, CO_2 9 Å
- P, T, low temperature, high pressure









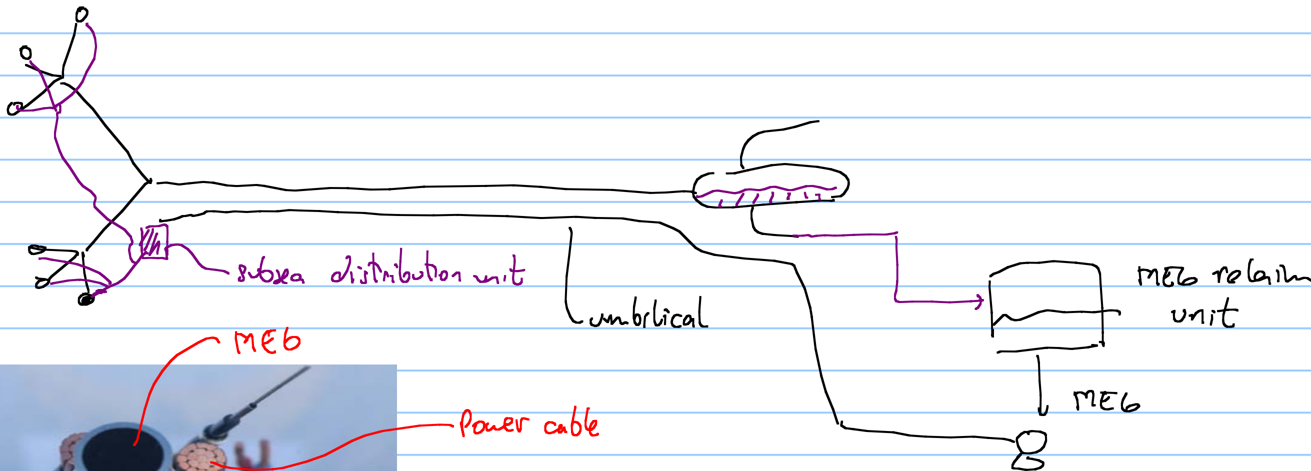
How to avoid hydrates?
- avoid cooling fluid
- heat the fluid
- chemical inhibitor → MeOH (methanol) MEG (mono ethylene glycol)

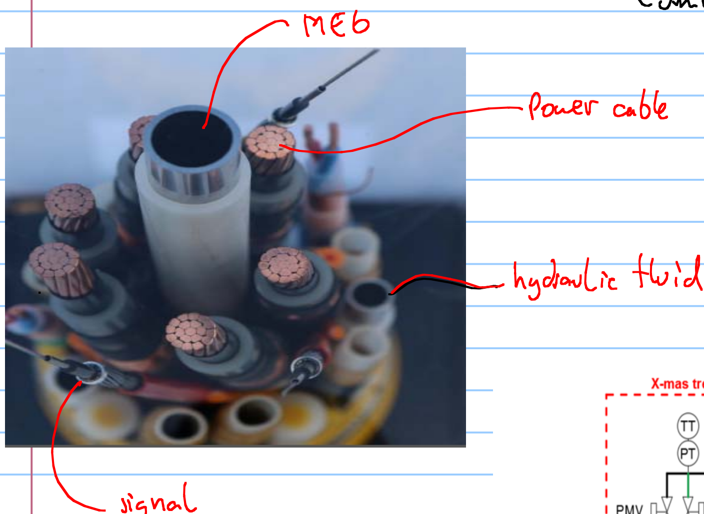
$$\text{weight\%} = \frac{\text{mass of inhibitor}}{\text{mass of inhibitor} + \text{mass water}}$$

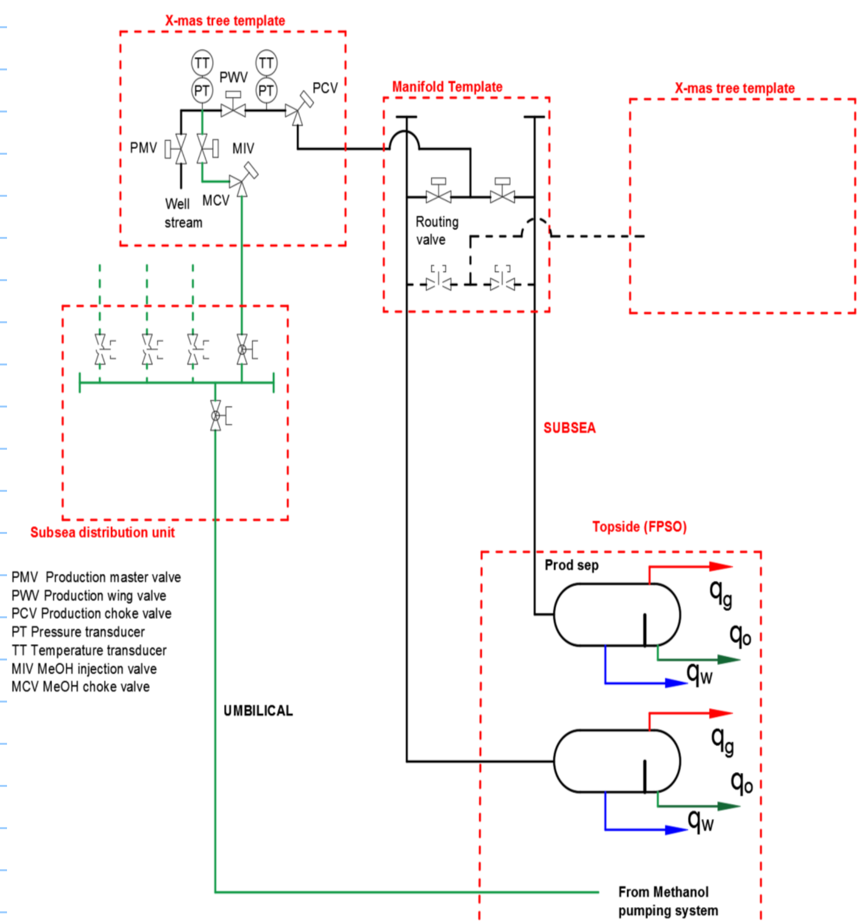
50 bbls of water ~ 50 bbls of MEG

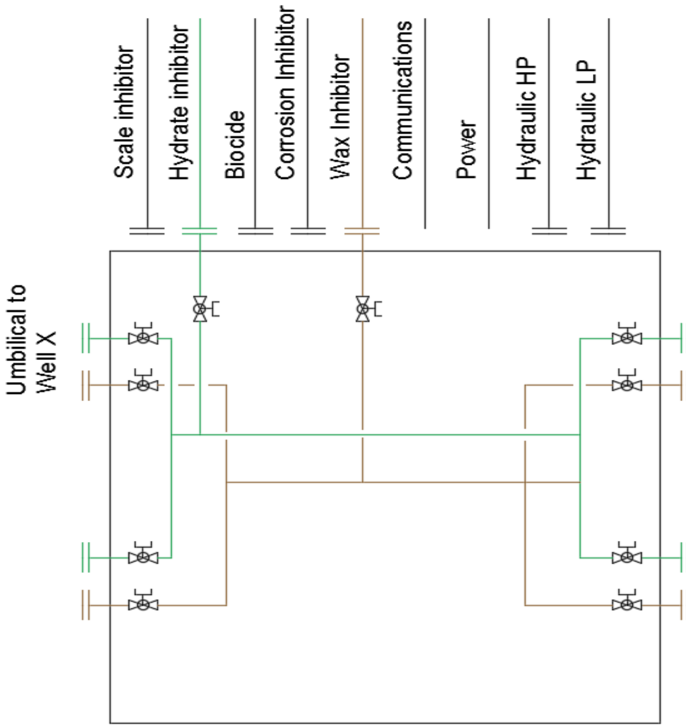
if MEG or MeOH are not recovered (reclaim) this can lead to huge expenses!

So usually this fluid is recovered from the production stream





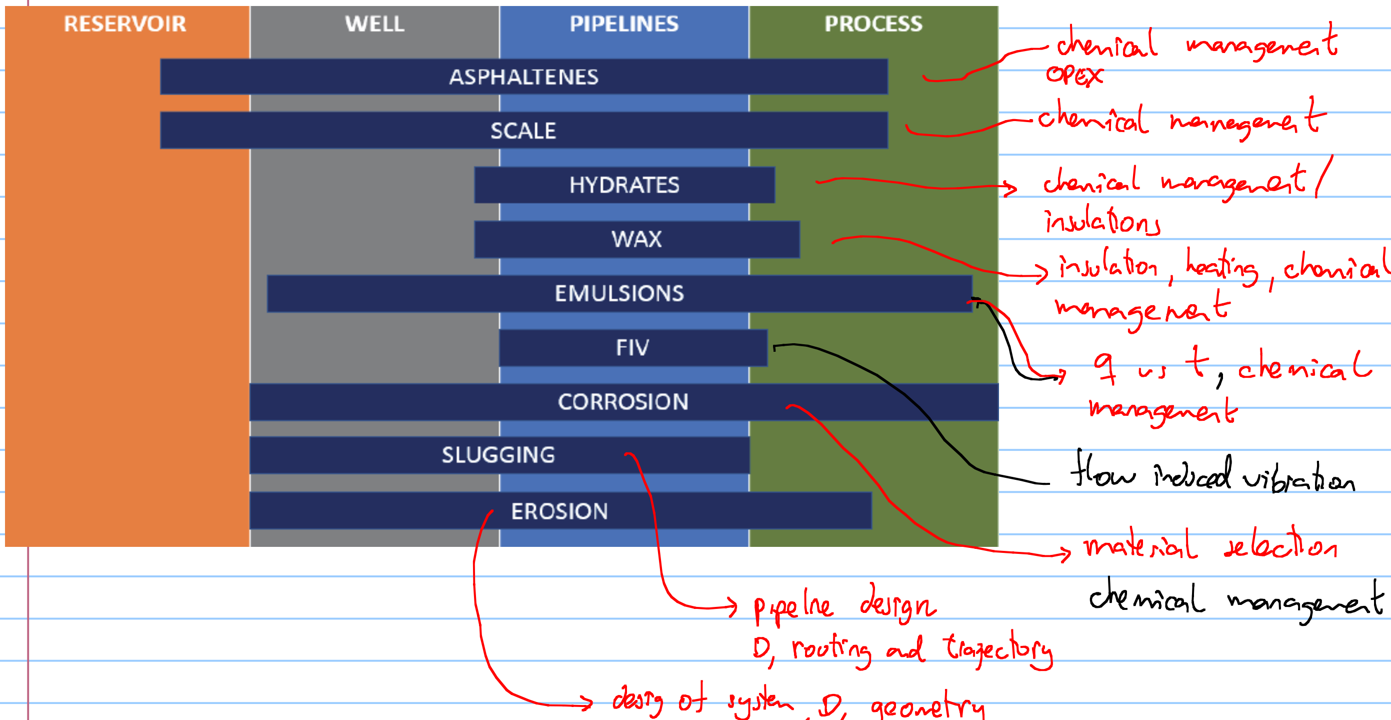




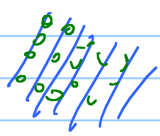
• scale → precipitation of minerals from water

• changes in solubility of these minerals
• changes in T, p, mixing water from different sources (formation water + sea water)

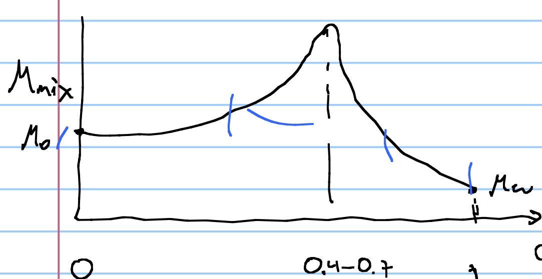
preventive action: • scale inhibitor
• proper design of injection strategy
• mechanical removal



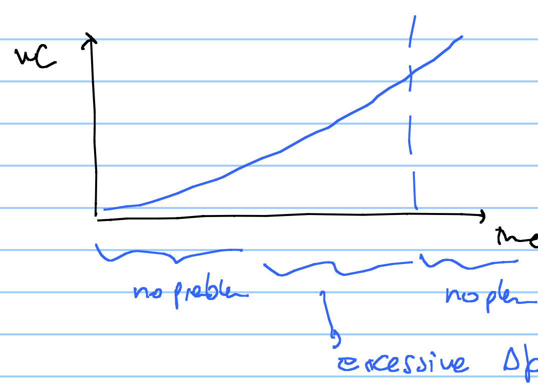
Emulsions: stable small size dispersion of oil in water
water in oil



Longer separation time required
bottlenecking the system

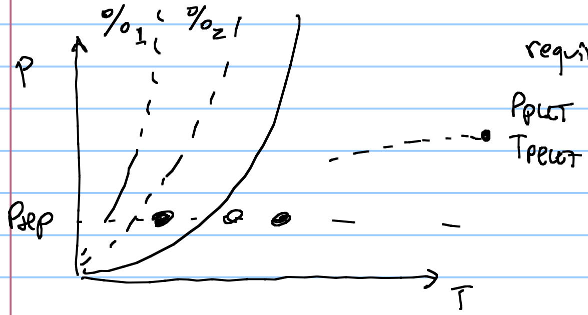


$\alpha_w = \frac{V_w}{V_o + V_w}$



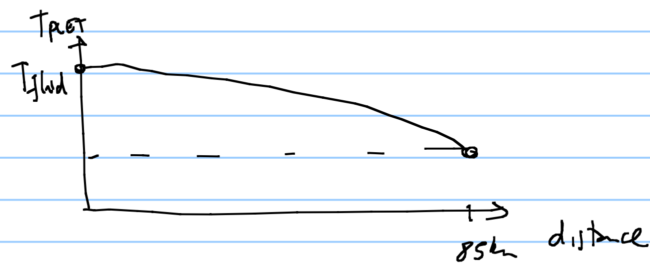
to deal with emulsions we use
demulsifiers → breaks stability of emulsions

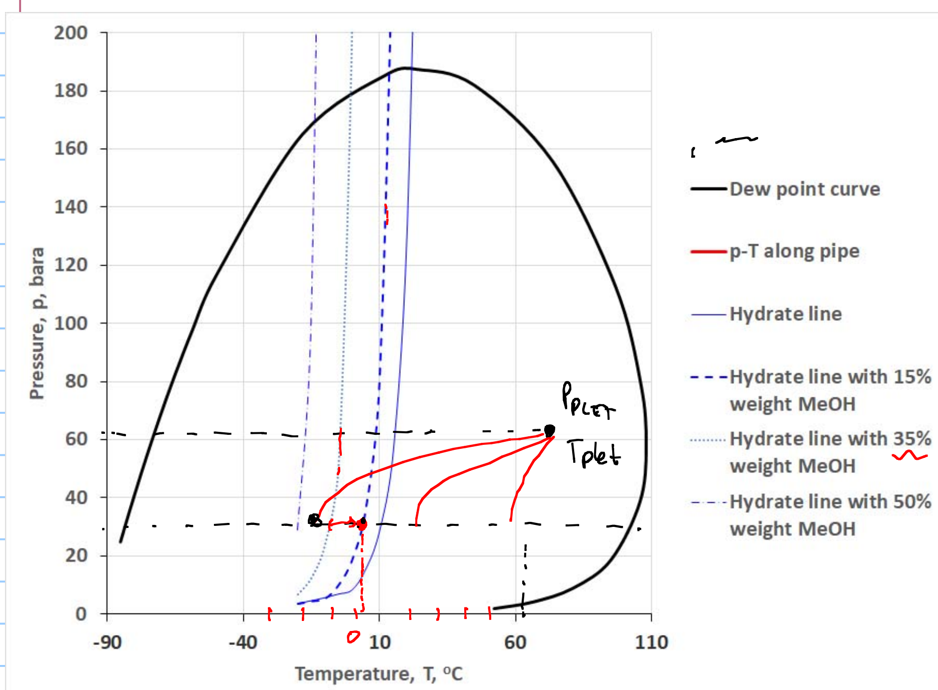
Class exercise: Analyzing hydrate risk in transportation pipeline of B2. Estimate amounts of inhibitor required. (nr. 3)

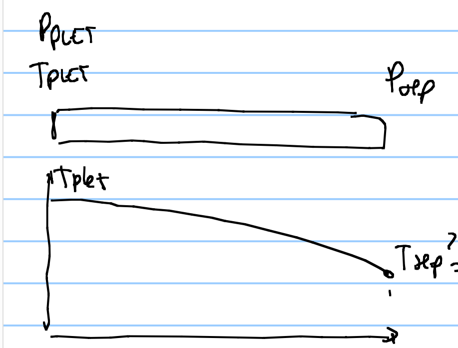


required information: hydrate line without inhibitor
with inhibitor

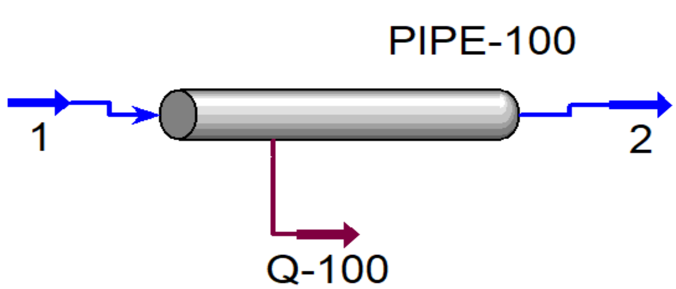
- inlet conditions to pipeline
  P_{PLET}
  T_{PLET}
- Psep
- gas rate
- pipe diameter, length, heat transfer coefficient, Tamb (subsea)

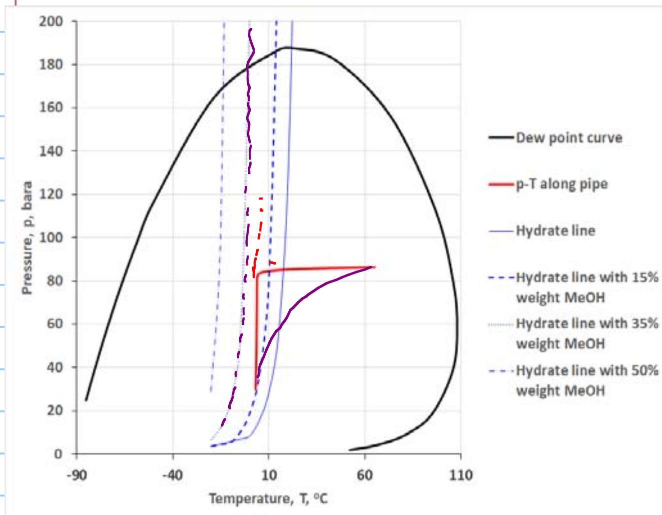






$T_{sep} = 3°C$, therefore, there is hydrate formation risk!





Solution: inject 35 % w of MeOH

THE END