A Comparison of Desanding Cyclones & Self-Cleaning Filters for Solids Removal in Produced Water Reinjection and Oil in Water Polishing Line-Ups

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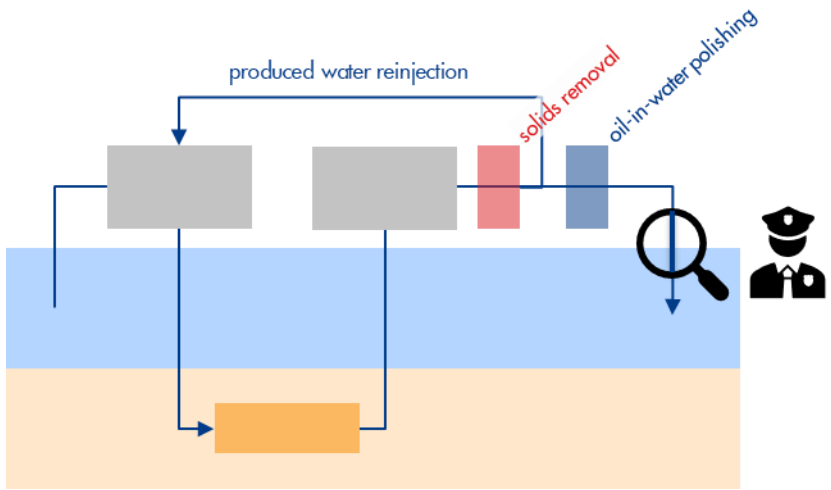
Contents

Background

- A variety of technologies are available for the removal of solids from produced water streams both onshore and offshore, including nutshell media filters (NSF), multimedia filters (MMF), solids removal cyclones and cartridge filters.
- Combinations of these technologies have been typically used for the treatment and removal of solids from produced water in both PWRI and oil in water polishing line ups.
- NSF and MMF are expensive and heavy and require a large footprint. Alternative technologies are available which could offer equivalent removal of total suspended solids and can offer a competitive advantage in terms of cost, space and weight.
- This presentation focuses on two such technologies, namely desanding cyclones & self-cleaning filters.



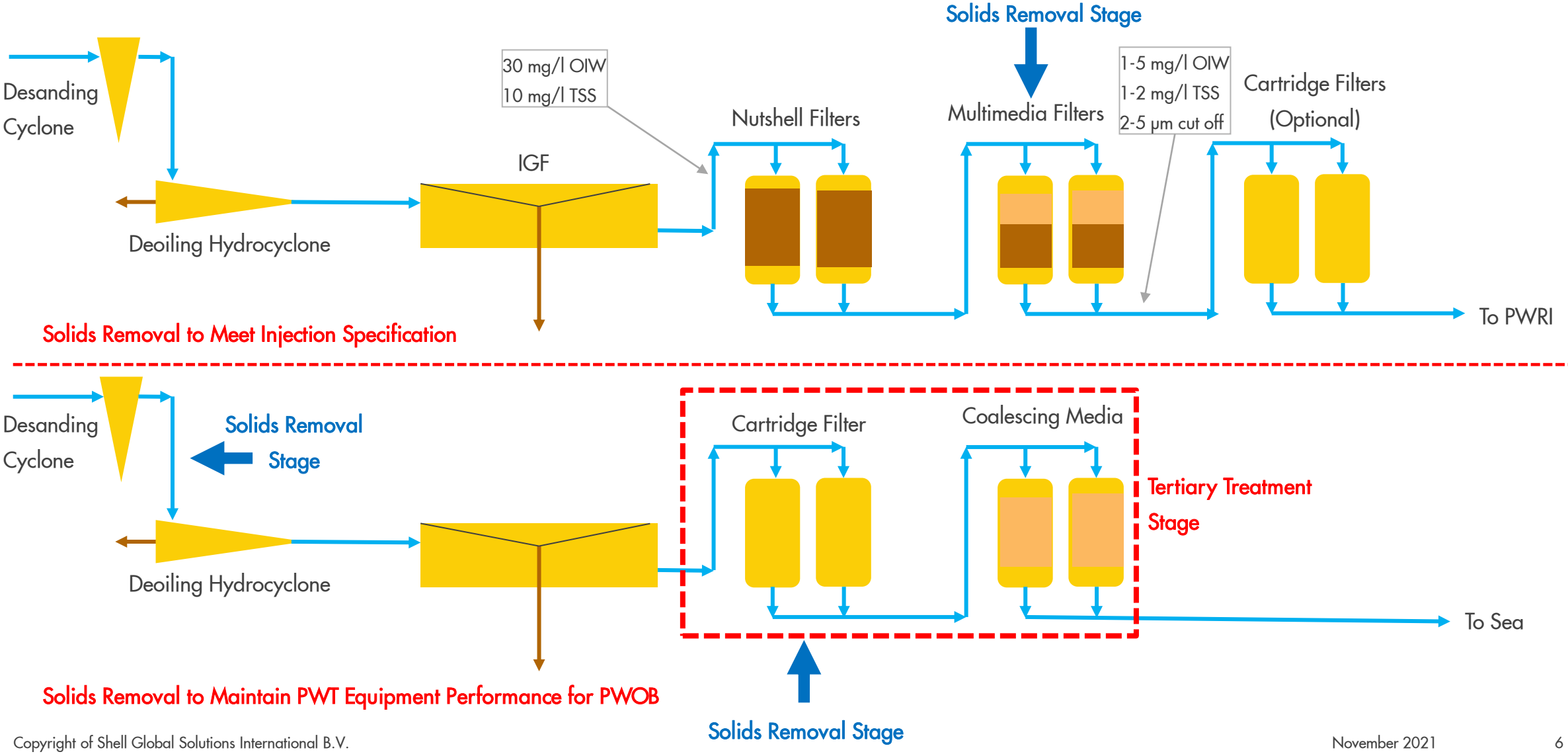
Background

- Why do we remove solids from produced water? Several reasons……
  - To protect equipment integrity, such as equipment in PWT line ups which is not solids tolerant
  - To prevent solids impacting on process – solids build up in vessels, emulsion stabilization, process upset
  - To minimize reservoir impairment through fracture growth or injectivity decline (which translates into a specification for PWRI)

- Why do we remove oil from produced water
  - To meet environmental discharge standards (if discharged to sea)
  - To meet a specification for PWRI

- Possible benefits resulting from use of alternative technologies to NSF and MMF
  - Cost savings – CAPEX and OPEX
  - Space & weight savings

Typical PWRI & PWT Offshore Line Ups



Alternative Technology Options

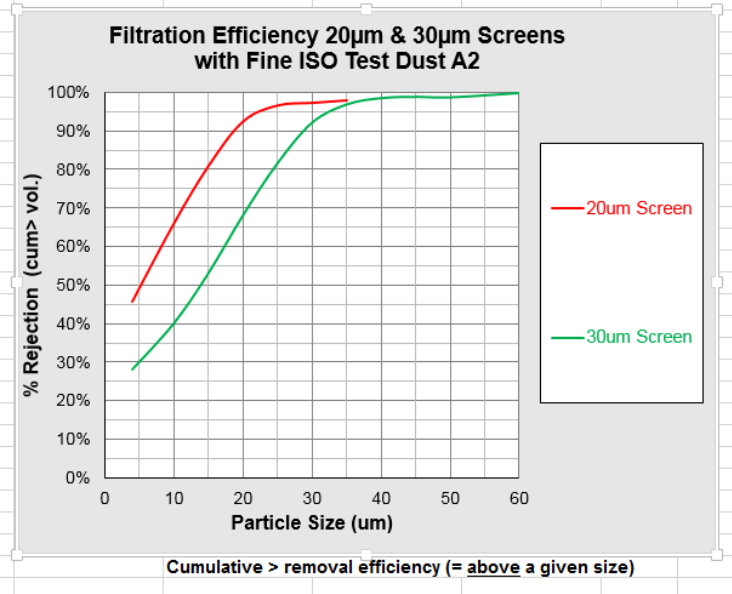
- Self-Cleaning Filters (SCF)
  - Well established technology commonly used to treat seawater in a seawater injection train
  - Now finding application in produced water treatment line ups
  - Can be used in either a PWRI line up to replace MMF or in a PWT polishing line up to replace cartridge pre-filters upstream of coalescing media filters for example
  - Two types – suction scanner SCF and enhanced backwash SCF, several vendors for each type

- Desanding Cyclones
  - Well established technology, used onshore and offshore for many years
  - Can be installed upstream of PWT facilities to protect them from impact of solids, or installed in a PWRI system to remove a proportion of the solids
  - Many vendors

Self-Cleaning Filter – Suction Scanner Design

- In a suction scanner type self-cleaning filter, water flows from inside to outside of the basket during the normal filtration phase
- The filters are backwashed on a timer or after a specific differential pressure across the filter basket is reached
- A suction scanner arrangement is used to employ the backwash, with the backwash liquid routed in reverse through the scanner and then screen to a number of ports installed on a central backwash collector
- Various screen mesh types

		Typical Removal Efficiency (%)
Hydrocarbons	Dispersed	Hydrocarbons are not removed
Solids		Nominally rated down to 6 µm
		Typical Outlet Concentration (mg/l)
Hydrocarbons	Dispersed	As inlet
Solids		Dependent on inlet particle size distribution



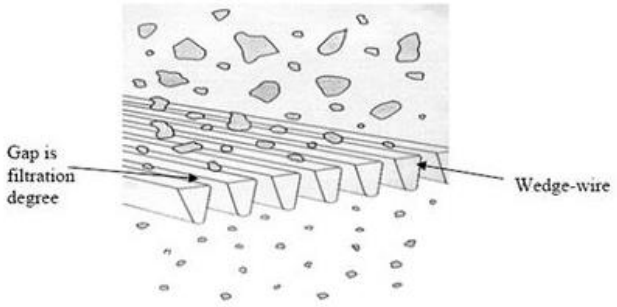
Self-Cleaning Filter – Enhanced Backwash Design (Candle Filter)

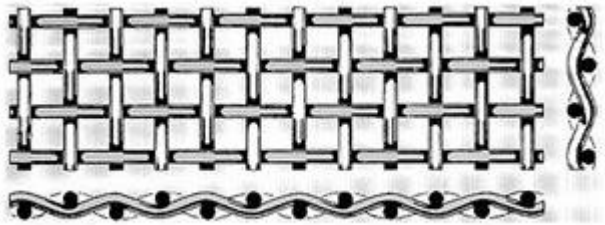
- Self-cleaning enhanced backwash filters contain a number of filter candles in one vessel and are thus also commonly referred to as candle filters
- One or two of these filter candles are backwashed at a time using the filtrate pressure
- This type of filter has not so far been trialled by Shell for solids removal in PWRI
- Pressure drop across the filter during normal operation is typically 0.3-0.5 bar

		Typical Removal Efficiency (%)
Hydrocarbons	Dispersed	Hydrocarbons are not removed
Solids		Screen nominal rating 25 µm
		Typical Outlet Concentration (mg/l)
Hydrocarbons	Dispersed	As inlet
Solids		Dependent on inlet particle size distribution

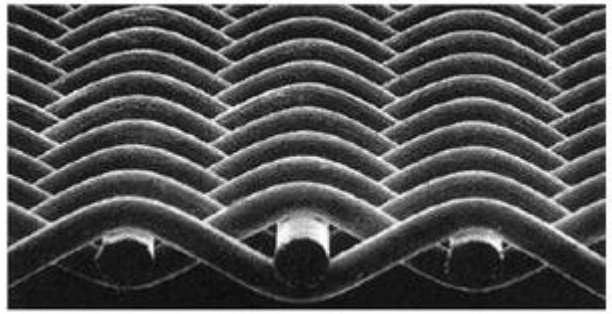
Self-Cleaning Filter – Suction Scanner & Enhanced Backwash

- Pros
  - Wide range of vendors
  - Very light and compact technology relative to other solids removal technologies
  - Filtration performance is maintained whilst the equipment is in backwash, so no need for N+1 arrangement for duty/backwashing
  - To avoid irreversible attachment of such particles to the screen, suction scanners are recommended (provide highest forces for particle removal)
- Cons
  - High solids loads (> 300 mg/l) will result in an increased backwash frequency. At very high loads the filter is backwashing continuously and the production will need to be reduced to keep in operation
  - For removal of sticky components, such as oil wet solids, enhanced backwash filters have a risk of creating a preferential flow during backwash and therefore a reduced backwash efficiency





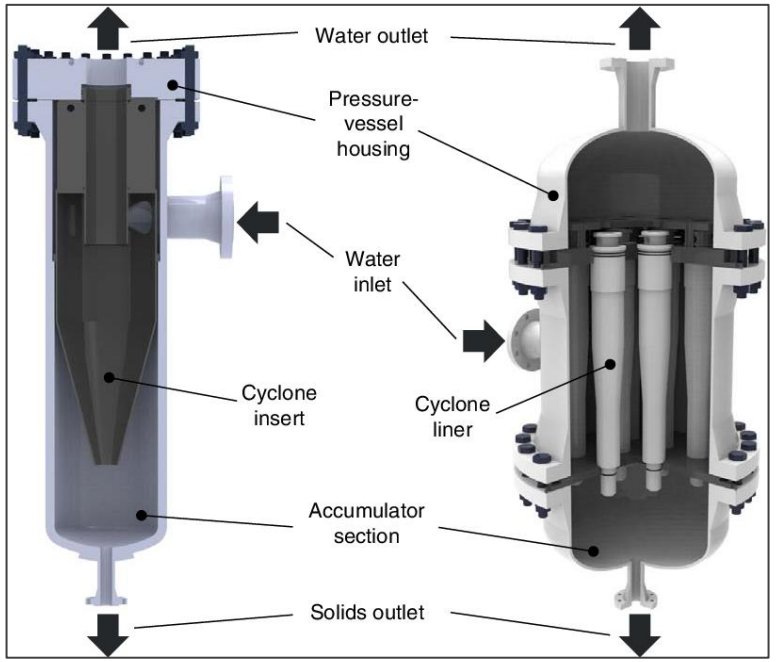
Wedge Mesh



Dutch Weave

Desanding Cyclones

- Operating principle is separation by centrifugal force, which is generated by tangential flow into the liner
- Solids are forced outward toward the wall of the cyclone liner and this displaces the lighter phase (water and residual dispersed oil) which migrates towards the centre where it forms a core
- As a result of the dP across the cyclone liners, the core is forced to flow through the overflow and the heavier solids to the underflow
- The operating experience of desanding cyclones within Shell is limited (anecdotal) and the technology is not yet categorised as D4 technology within Shell.

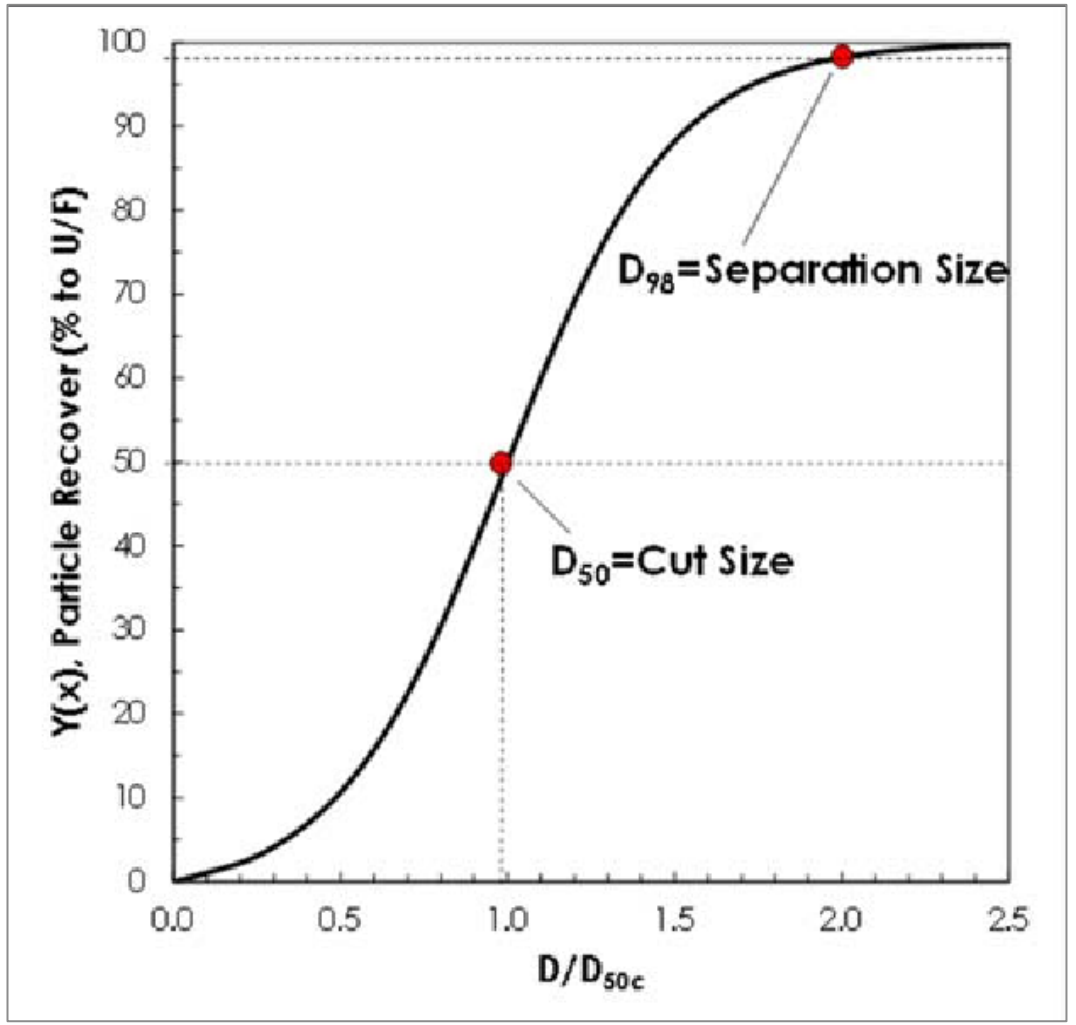


		Typical Removal Efficiency (%)
Hydrocarbons	Dispersed	Not removed
	Dissolved	Not removed
Solids	Non Oil Wet Solids	98% > 11 µm typical
	Oil Wet Solids	Not quoted[1]
		Typical Outlet Concentration (mg/l)
Hydrocarbons	Dispersed	Not removed
Solids		<1

Desanding Cyclones

- Pros
  - Mature well understood compact technology
  - Proven performance in produced water applications
  - Wide range of vendors and materials of construction
  - Compact and light weight relative to other solids removal technologies

- Cons
  - Lower limit D98 for solids removal is ~10 µm
  - Performance sensitive to turndown
  - In most cases, requires feed pressure of at least 5 barg



Technology Comparison - Operating Parameters

	Self-Cleaning Filter	Desanding Cyclones
Particle Cut Size	▪ 6 µm nominal ▪ Variety of screens available with higher nominal ratings	▪ Diameters between 10 and 140 mm typically available ▪ 10 µm cut size is typical lower limit, 25 µm and 50 µm more common
Turndown	▪ 10-20% of design flow is typical (at least equal to backwash flowrate)	▪ 3:1 or a third of the nominally rated flow is the typical lower limit
Typical Operating Pressure	▪ 2-10 barg feed pressure typical ▪ 2 barg feed pressure is minimum (assuming atmospheric backwash slurry routing)	▪ In PWT systems, up to 15 barg typical
Pressure Drop	▪ 0.3-0.5 bar typical before backwash initiated	▪ Minimum 0.3 bar, maximum 7.0 bar for PWT duty (typical)
Slurry Stream	▪ Non-continuous flow, only occurs during backwash ▪ Backwash stream requires to be disposed of via a suitable route (re-route upstream or separate treatment and disposal of backwash water) ▪ Backwash slurry stream is typically <2% of feed stream volume ▪ Possible disposal route for backwash slurry to cuttings disposal well	▪ Solids continuously discharge from cyclones to either bottom of pressure vessel, or to a separate accumulator which can be isolated and periodically emptied ▪ Solids slurry can be routed to a sand cleaning vessel for cleaning and disposal to sea (if regulations permit), or routed to a sand bagging facility for shipping to shore

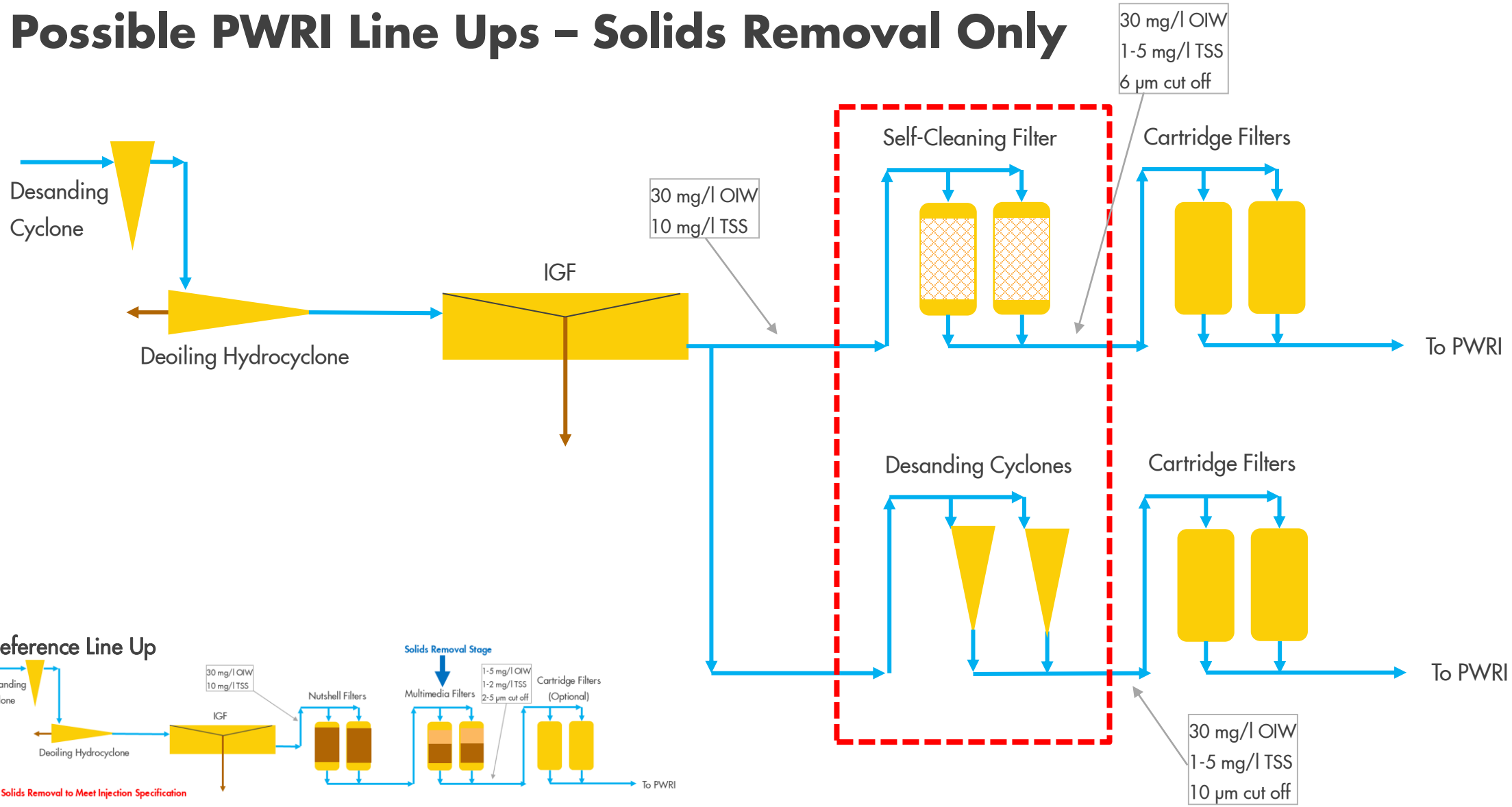
Technology Comparison – Waste Stream Disposal

	Reject Stream & Backwash Liquids		
	Volume	Solids Present?	Oil Present?
Desanding Cyclones	Typical volume per accumulator is 200 to 500 litres, with each vessel/accumulator emptied once in a 24 hr period. This volume would comprise a concentrated sand slurry (dependent on inlet solids loading).	Yes. Concentrated sand slurry will need to be removed from the accumulator typically once a day.	Yes. Residual oil present as dispersed oil or coated on solids within the accumulator. Oil would be removed in a downstream sand washing system (if present).
Self-Cleaning Filter	Total volume per backwash is typically 0.5-1.0% of the total feed flowrate.	Yes. Solids which have built up on the filter elements will exit with the backwash water.	Yes. Residual dispersed oil (same as feed stream oil content) will be present in backwash water.

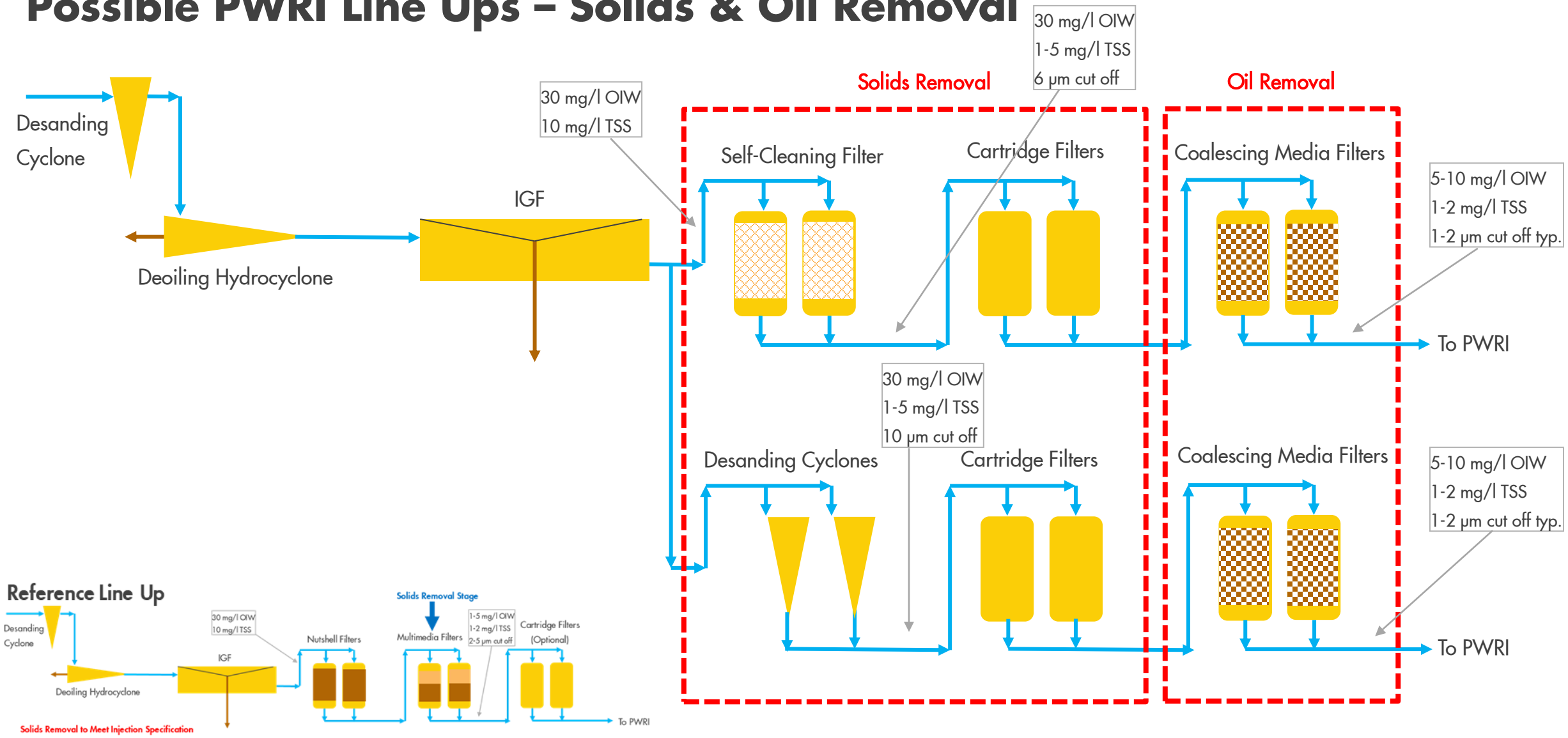
Technology Comparison – Impact of Suspended Solids Type

Particle Type	Sand	Scale Particulates	Corrosion Products	Clay Fines	Schmoo	Microbial Solids
Typical Size & Density	>62.5 µm 2800 kg/m^3	Circa 20 µm	5-40µm individual particles, up to 65 µm agglomerated	1-4 µm	Solid particles (inorganic component) ~1 µm	
Qualitative Assessment of Particle Removal Effectiveness						
Desanding Cyclones	Effective removal	Effective removal if particle size > 10 µm, otherwise performance compromised	Effective removal if particle size > 10 µm, otherwise performance compromised	Particle density and size not be suitable for effective removal	Particles can become neutrally buoyant, which results in them exiting via the overflow	Particulate size likely to be too small for effective removal
Self-Cleaning Filters – Suction Scanner	Effective removal	Effective removal if particle size > 6 µm, otherwise performance compromised	Effective removal if particle size > 6 µm, otherwise performance compromised	Particle density and size not be suitable for effective removal. Clay fines could get pushed through screen.	Particles can become neutrally buoyant. May also be pushed through filter element, though agglomerated particles could be trapped.	Particulate size likely to be too small for effective removal

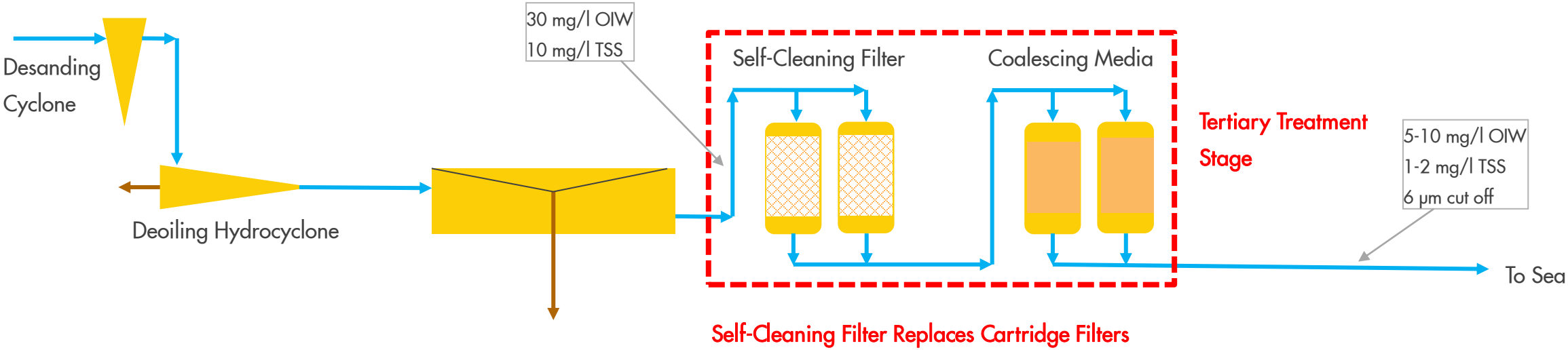
Possible PWRI Line Ups – Solids Removal Only



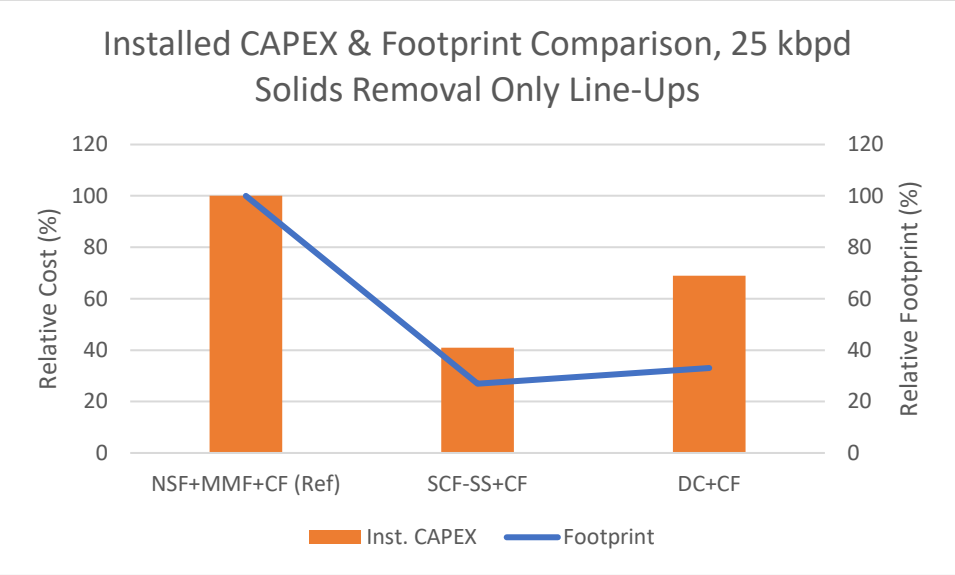
Possible PWRI Line Ups – Solids & Oil Removal



Possible PWT Offshore Polishing Line Up



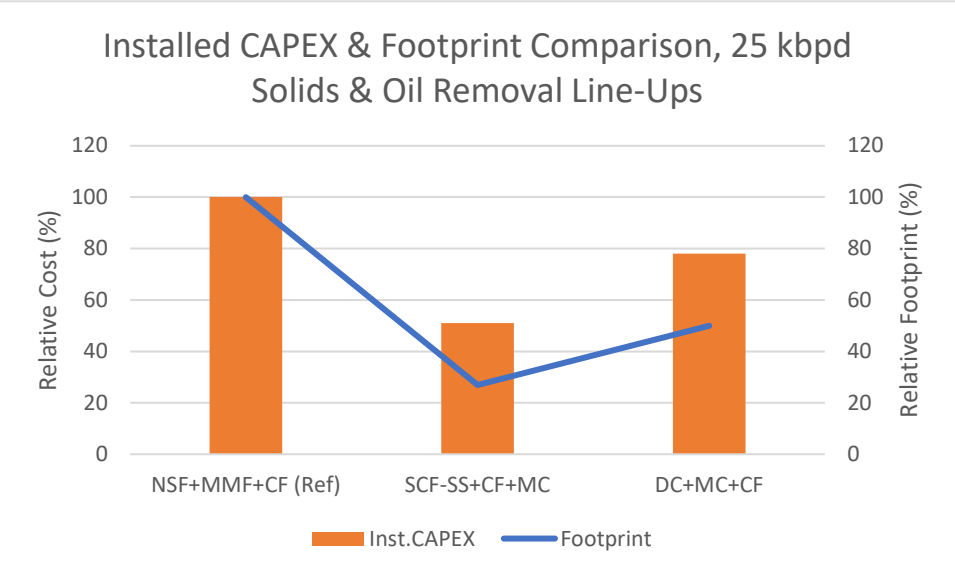
CAPEX & Footprint Comparison & Conclusions



- NSF = Nutshell Filters
- MMF = Multimedia Filters
- SCF-SS = Self Cleaning Filter – Suction Scanner
- DC = Desanding Cyclones
- CF = Cartridge Filters

- Self-Cleaning Filters
  - The technology is suitable for sand and scale removal and possibly larger corrosion products. It is not suitable for agglomerated oil coated solids, i.e schmoo and similar.
  - The technology is significantly smaller & lighter than traditional options such as multimedia filtration and unlike a multimedia filter the feed stream oil content does not have to be treated to a stringent specification.
  - SCF technology could be used in combination with coalescing media technology for combined oil & solids removal
  - The upper limit for SCF flux rates in produced water service is not well understood and is worthy of further investigation as part of any future field trials (this could impact the business case)

CAPEX & Footprint & Conclusions



- NSF = Nutshell Filters
- MMF = Multimedia Filters
- SCF-SS = Self Cleaning Filter – Suction Scanner
- DC = Desanding Cyclones
- CF = Cartridge Filters
- MC = Media Coalescence Filter

- Desanding Cyclones
  - Desanding cyclones are well established and have been used by many operators at locations around the world, both onshore and offshore. The lower limit of their performance envelope is about 10 µm and if the removal of finer solids were required, then the use of downstream cartridge filtration would be required.
  - Desanding cyclone technology is suitable for sand removal and larger scale and corrosion particle removal if the particle size is within cut size limits.

Conclusions

- Technology Comparison
  - Self-Cleaning Filters and Desanding Cyclones can provide effective solids removal as part of a PWRI or PWT polishing line at significantly lower CAPEX and space and weight requirements relative to traditional options such as Nutshell Filters and Multimedia Filters
  - They do not remove oil, hence in applications where oil removal is also required, they must be used in combination with a deoiling stage, but this combination is still competitive relative to traditional line ups
  - The technology can be equally applied onshore and offshore