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Water Disposal 2021: Four Reservoir Pillars that Define the Best Geological Formations for Disposal in Western Canada; How Much? How Fast?

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Summary

Essential to oil and gas exploration, development and production is responsible waste fluid management and disposal. In 2020, the volume of oil and gas related water and waste fluid generated in the three Western Provinces was an astounding 469 million m3 or 1.28 million m3/day. This equates to roughly ***1.5 barrels of waste fluid generated for every one BOE of produced oil and gas***. Current industry activity and disposal demand has been strong and steady over the last several years and it is anticipated that it will remain strong for many years to come.

Many formations throughout the geologic column have been utilized to accommodate the large historical water and waste volumes through disposal into more than 6500 wells dispersed across Western Canada's broad production base. Roughly 60% of disposed fluids have been into clastic reservoirs, notably the Mannville formation in eastern Alberta and Saskatchewan, where high porosity and permeability sands are abundant and numerous. The remaining 40% of disposal is into carbonate reservoirs including Devonian reefs (Leduc, Nisku, Swan Hills) in central and western Alberta, and Devonian to Mississippian non-reef formations (Winterburn, Wabamun, Debolt, Pekisko, Mission Canyon) throughout western and central Alberta and Saskatchewan.

Recent industry oil and gas activities have been directed toward high profile unconventional resource plays in the Montney, Duvernay and Deep Basin, spanning large areas across northwest Alberta and northeast British Columbia where it is often a challenge to find good disposal formations to handle large volumes of produced fluids.

All formations are not suitable for fluid disposal, only the better ones are. Unlike oil and gas production where new economic reserves are being exploited from increasingly tighter formations, the search for good disposal zones remains in the identification of high permeability 'conventional' reservoirs. Evaluation of suitable formations for disposal is focused on the ability of a prospective formation to achieve high daily disposal rates, and large volumes of disposed fluid over time.

With a goal to attain the highest disposal rates and volumes, attention is focused on evaluation of the four foundational pillars that define reservoir quality. They are: ***Permeability, Porosity, Thickness, and Area*** (Figure 1).

Permeability: Attained primarily through core data, permeability is the key factor in determining potential disposal rate of any formation. Application of a 10 millidarcy (md) cutoff is the first step in identifying a zones potential 'permeable' thickness. Also, permeability, when correlated to porosity (porosity vs permeability cross-plots), establishes the base for effective porosity determination.

Porosity: Is an essential component in pore volume determination (porosity x thickness x area). Also, in the absence of core data, log porosity, through its correlation to core porosity and related core permeability, provides the best proxy for estimated formation permeability. It is through the porosity-permeability correlation that an effective (and unique) porosity cutoff can be applied to determine porosity range, average porosity, and net thickness.

Thickness: Disposal zone thickness is also needed for pore volume determination***.*** Through application of effective porosity cutoffs, net thickness is defined.

Area: The final component needed for pore volume calculation. Area is primarily established through geological and engineering input to estimate effective disposal reservoir continuity, or 'distance' (area) away from the wellbore.

Evaluation of any formation's suitability for disposal begins with understanding the interrelationship between the first two pillars ***(porosity and permeability).*** From here, effective porosity cutoffs are established such that the third and fourth pillars ***('net' thickness and area)*** can be determined. Altogether, through evaluation of the four pillars, any zone can be evaluated for disposal suitability and the important questions of Volume and Rate (How Much? How Fast?) can be answered.

Core Porosity-Permeability Cross-Plots (Figure 2 and Figure 3)

Inherent in the understanding of any formation's suitability for disposal begins with evaluation of the interrelationship between the first two pillars (porosity and permeability). Core porosity-permeability cross-plots serve as a key tool to understand these relationships.

Observations*:*

Figure 2: Clastic Formations Core Porosity - Permeability Trends

- Note: ***0 - 50 % porosity scale*** and 0.1 – 10,000 md logarithmic permeability scale.
- Each ***formation*** has a unique porosity-permeability trend and corresponding unique porosity cutoff.
- High porosity-permeability trends in known excellent, high volume, high rate, Dina and Cambrian disposal formations set the 'Gold Standard' for trend comparison.
- Paddy (conglomerate), Cambrian and Dina porosity–permeability trends occur well above the 10 md permeability cutoff and are excellent, high rate disposal formations.
- Cardium, Bluesky, Falher, Cadomin, Belloy, and Paddy (fine-grained sandstone) all have porosity-permeability trends that span above and below the 10 md permeability cutoff line.
- Each ***lithology*** within dual lithology formations Falher and Cadomin (conglomerate vs sandstone), and Paddy (coarser-grained vs finer-grained sandstone) have distinct porosity-permeability trends and corresponding unique porosity cutoffs associated with each lithology within the same depositional environment.

- Coarse-grained lithologies within dual lithology formations (Cadomin, Falher, Paddy) have notably better porosity-permeability trends than their finer-grained counterparts.

Figure 3: Carbonate Formations Core Porosity - Permeability Trends

- Note: ***0 - 25 % porosity scale*** and 0.1 – 10,000 logarithmic permeability scale.
- Porosity–permeability trends of limestone and dolomite lithologies in both reef (Leduc, Swan Hills), and non-reef (Pekisko, Wabamun) formations represented.
- Each carbonate lithology (limestone, dolomite), deposited in a similar geologic setting, has a unique porosity-permeability trend and corresponding unique porosity cutoff related to deposition and diagenesis.
- All formations have a broad permeability range spanning above and below the 10 md permeability cutoff line.
- Fractured zones within both Swan Hills (limestone) and Leduc (dolomite) reef trends have distinctly different porosity-permeability ranges compared to respective non-fractured zones.
- Dolomite facies in Pekisko (non-reef) has a notably higher porosity-permeability range compared to Pekisko (non-reef) limestone facies.
- Wabamun limestone has a broad porosity-permeability range with a high associated porosity cutoff (9%).

Figure 1

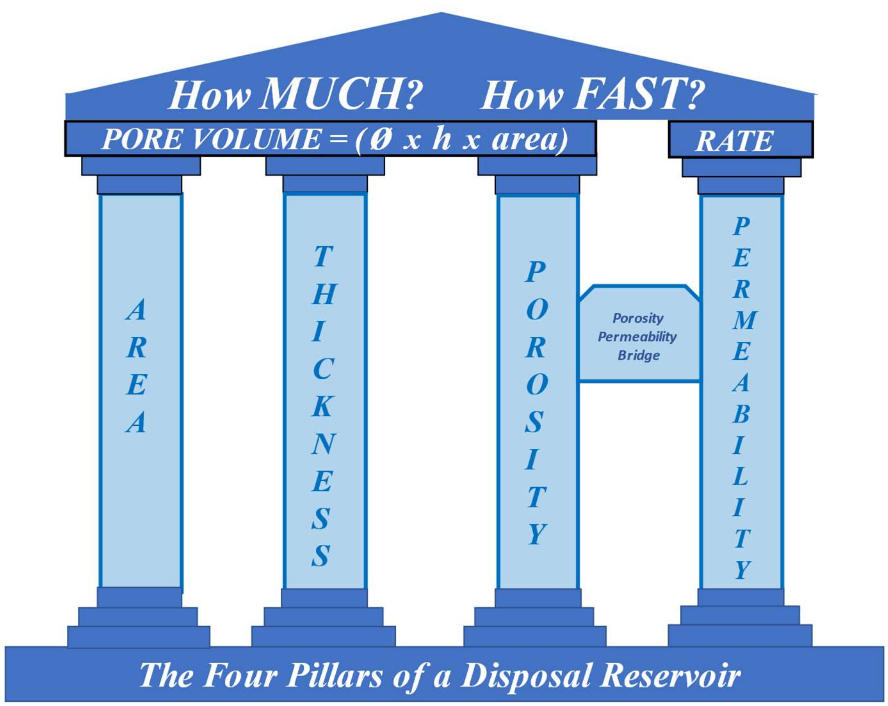

Figure 2

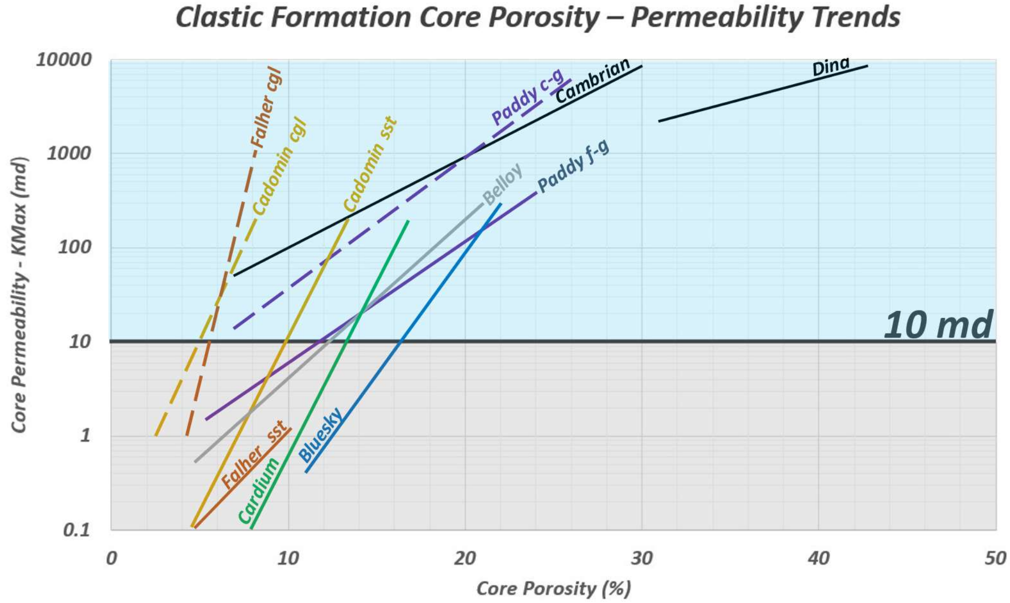

Figure 3