Fountain Quail
WATER MANAGEMENT

Successful Oilfield Water Management
5 Unique Case Studies

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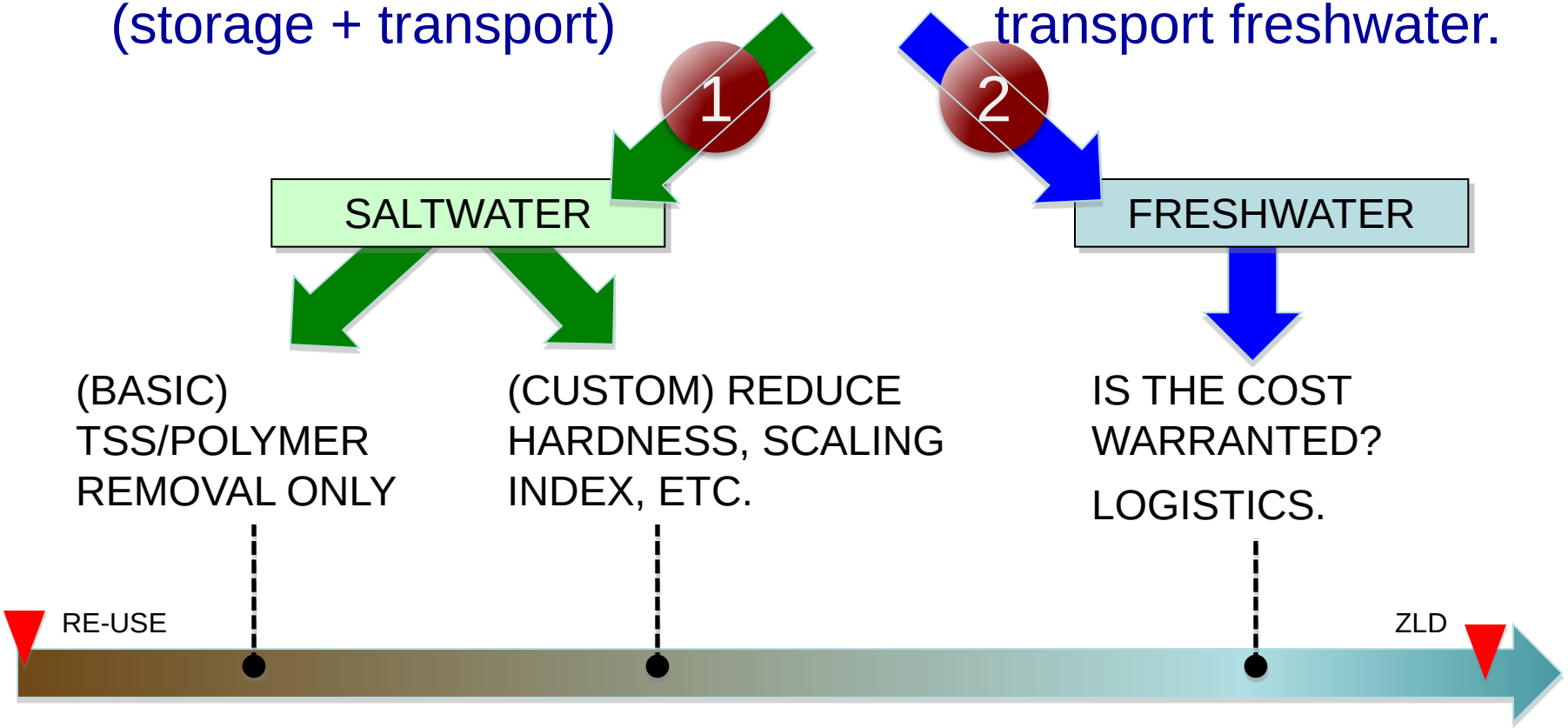
Charting a Logical Path

Saltwater

- Lower cost (minimal treatment).
- Difficult logistics (storage + transport)

Freshwater

- Higher cost (thermal distillation).
- Lower risk – store and transport freshwater.



Case Study A

Freshwater #1 – Devon Energy Barnett Shale TX

Background:

- Early on everyone used freshwater for fracs.
- Disposal was limited (until Ellenburger used for disposal).
- Devon has a large acreage position held by production.
- FQWM had to become very efficient to compete with low cost Ellenburger disposal.

Objectives:

① Move recycling (disposal + freshwater) close to drilling activity.

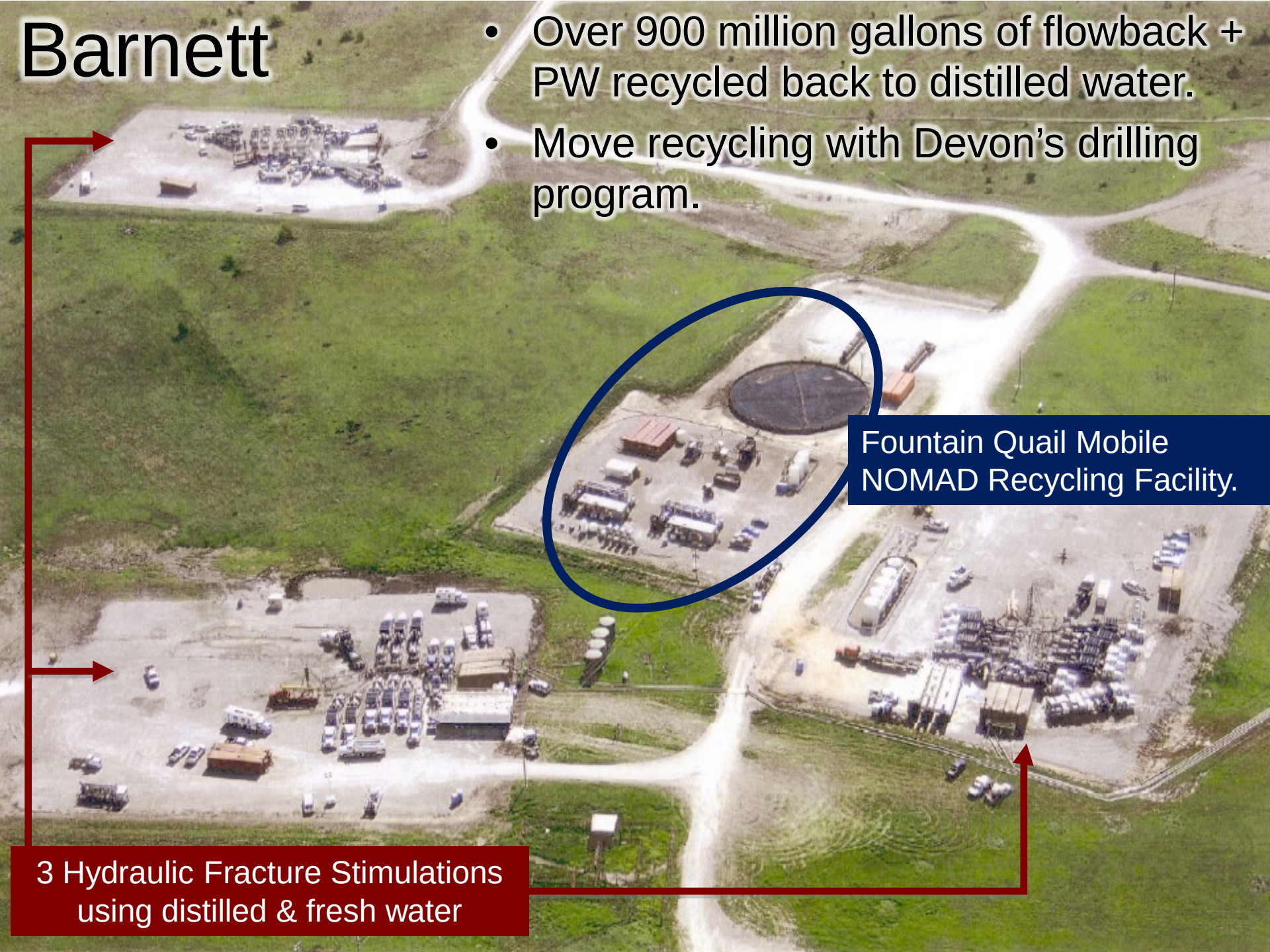
② Frac with freshwater (minimal storage & transport issues).

③ Reduce disposal volume.

④ Tie in nearby well flowback & PW using poly pipe.

Barnett

- Over 900 million gallons of flowback + PW recycled back to distilled water.
- Move recycling with Devon's drilling program.



Case Study B

Freshwater #2 – PW Into Freshwater, Upper Wolfcamp TX

Background:

- Customer has 17 wells tied into central SWD. Dispose of 5,000-7,000bpd.
- Freshwater is limited and costly. Customer prefers fraccing with and handling freshwater.
- Heavy brine (9.5-10#) has value to operator and others in the region.
- Early flowback hauled long distance to disposal.

Objectives:

① Use PW as source water to create freshwater using NOMADs. Become independent of groundwater.

② Reduce SWD volume & extend SWD life.

③ Re-use NOMAD concentrate brine (9.5#) for drilling & completions.

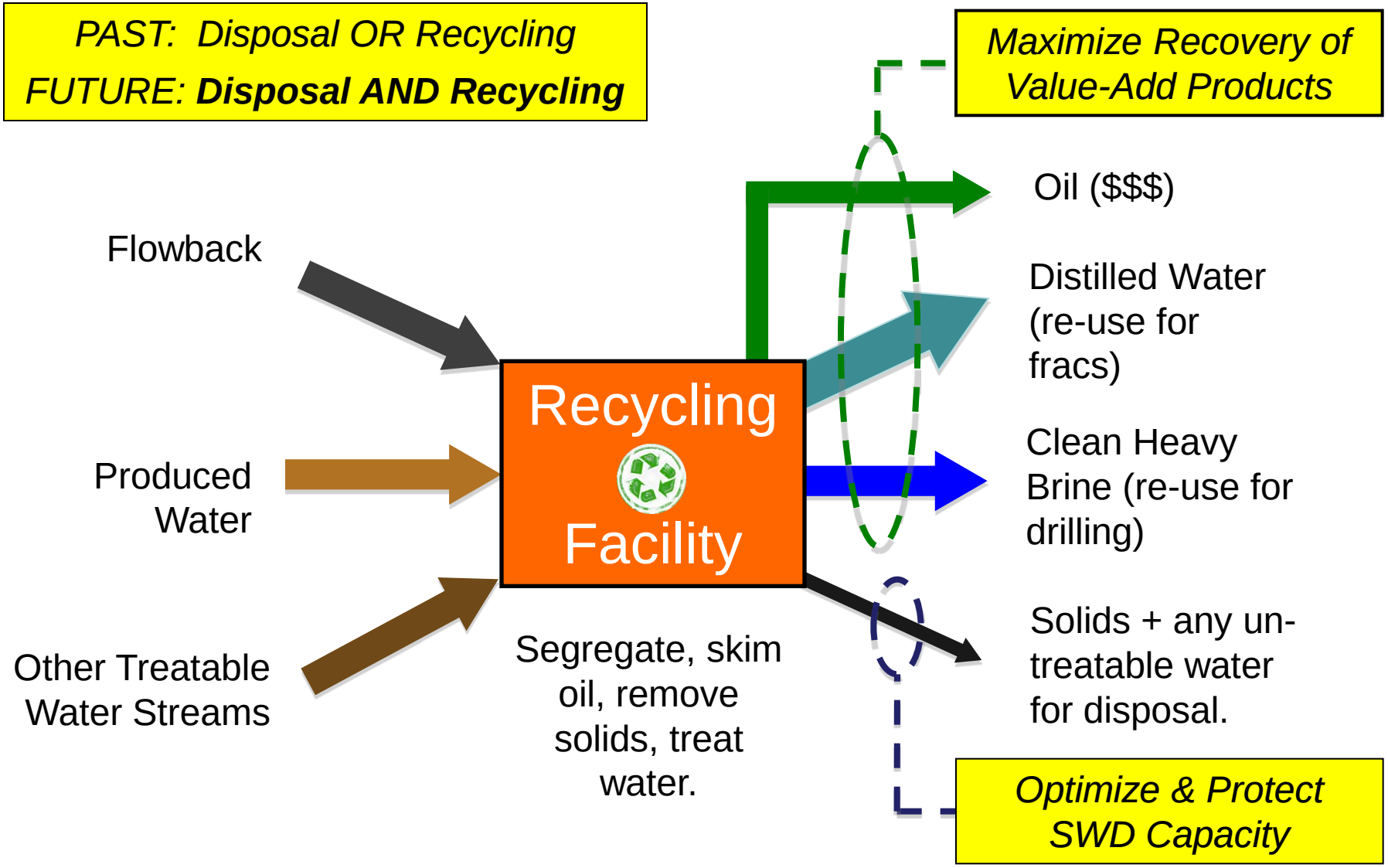
④ Treat high-solids flowback near source.

Case Study B

- Evaporation rate is very high (dry, windy).
- Nature concentrates NOMAD waste brine to 10# *at no cost*.

Recycling Center – Hub for Water

PAST: Disposal OR Recycling
*FUTURE: **Disposal AND Recycling***



Case Study C

Saltwater #1 – Eagle Ford Shale TX

Background:

- The Eagle Ford is in “drill-to-hold” mode.
- Producers need a very mobile solution and can re-use saltwater in nearby fracs.
- Customer objective was to clean flowback and PW for re-use (high capacity, low cost).
- Remove TSS, iron and polymers.

Objectives:

① Test flowback (early, middle and late) and PW removal efficiencies at the well site level.

② Set-up in 12 hours and be ready for flowback.

Case Study C

High capacity (10,000bpd).

Solids removed prior to re-use.

Eagle Ford Flowback

Parameter	Metric	Influent to ROVER (Feed)	Effluent from ROVER	Removal
Alkalinity	mg/L CaCO3	406	206	49%
Iron (Fe)	mg/L	83	trace	100%
Manganese (Mn)	mg/L	1.2	trace	100%
Total Hardness (Ca+Mg)	mg/L	1025	602	41%
Silica (SiO2)	mg/L	148	27	82%
Total Suspended Solids (TSS)	mg/L	180	19	89%
Turbidity	NTU	>100	3	n/a
pH	pH	6.8	6.8	n/a
Total Dissolved Solids (TDS)	mg/L	32,835	34,610	n/a

Case Study D

Saltwater #2 – Woodford/Canadian OK

Background:

- Wells are drilled in “Rows”. All flowback along each row is hard-pipe connected to tanks for re-use.
- Upon completion of a Row, the PW from that Row is connected to the next for re-use.
- The flowback and PW can easily be cleaned with the ROVER prior to re-use (TSS/polymer).

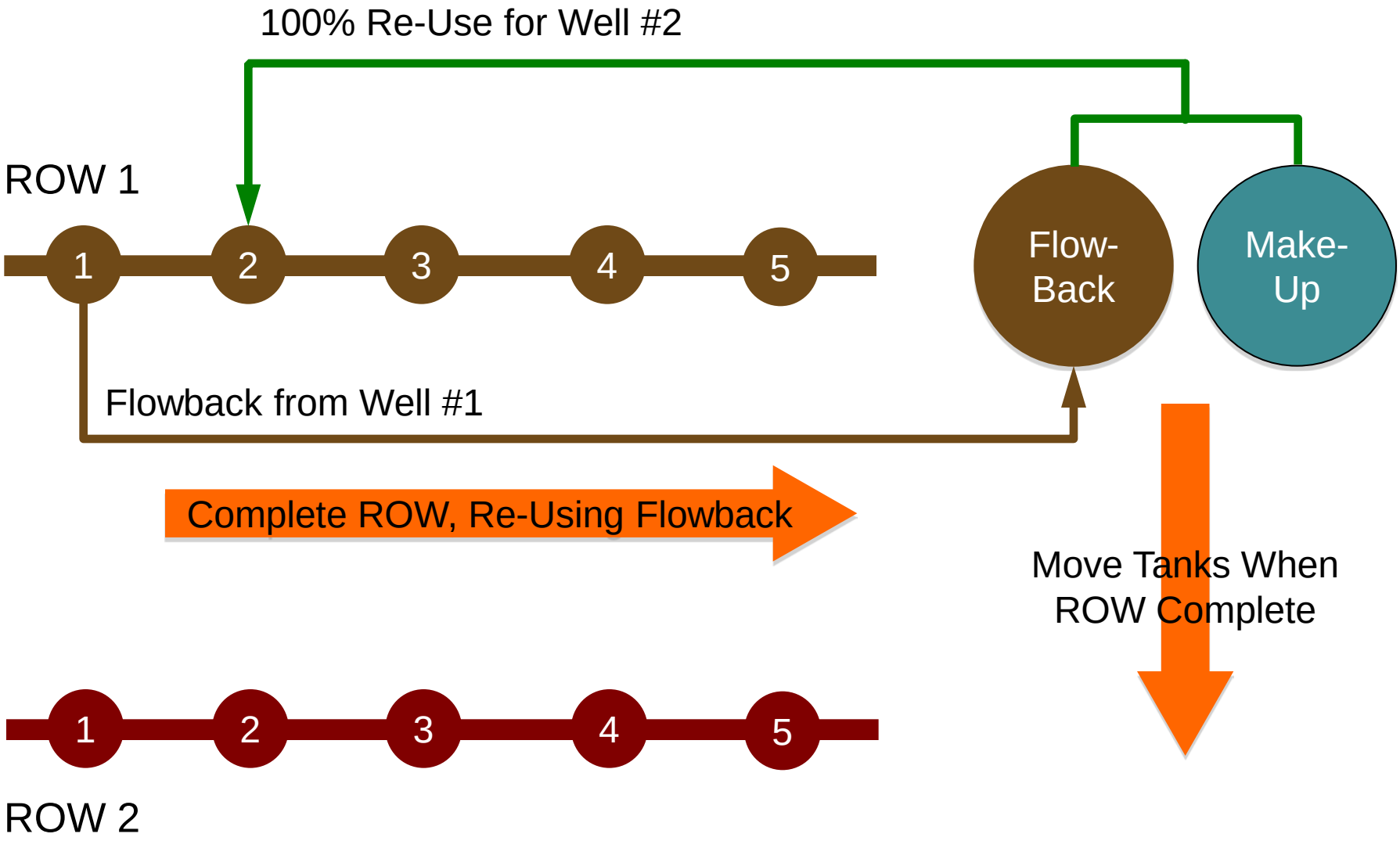
Study Objectives:

① Remove TSS from incoming flowback and PW prior to re-use.

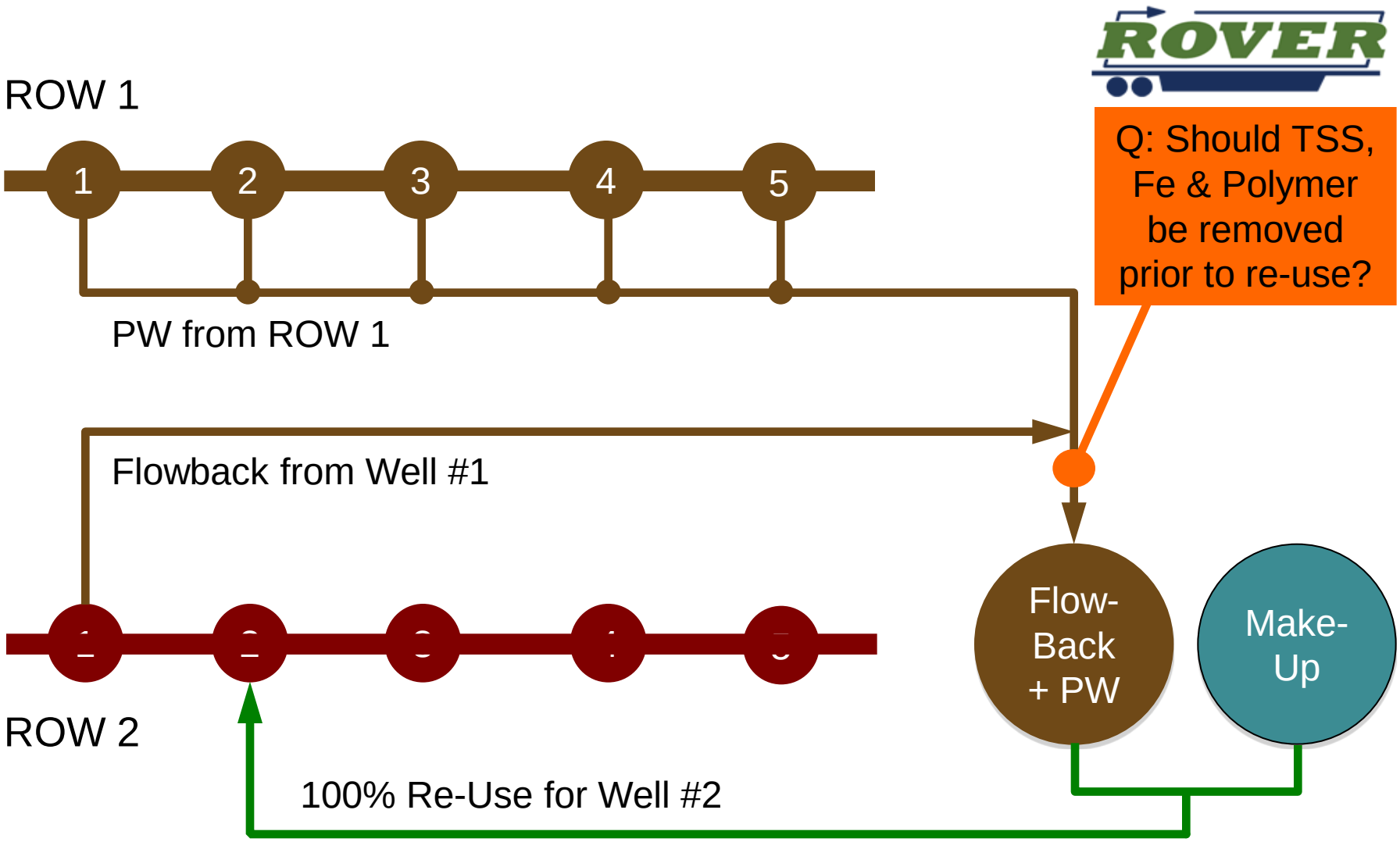
② Prevents expensive clean-up when moving tanks from old Row to new Row.

③ Improve frac performance (reduce scaling index). *Difficult to quantify value*.

Case Study D


100% Re-Use for Well #2
ROW 1
1
2
3
4
5
Flow-Back
Make-Up
Flowback from Well #1
Complete ROW, Re-Using Flowback
Move Tanks When ROW Complete
1
2
3
4
5
ROW 2

Case Study D


ROVER
ROW 1
1
2
3
4
5
Q: Should TSS, Fe & Polymer be removed prior to re-use?
PW from ROW 1
Flowback from Well #1
Flow-Back + PW
Make-Up
ROW 2
100% Re-Use for Well #2

Case Study D

- Water formed good floc using FQWM standard treatments.
- Turbidity dropped from 600 NTU to 5 NTU.

- Proposed ROVER Treatment cost: $0.79/bbl.

Customer opted to continue “as-is” and re-use the water without treatment. They recognize that high solids has potential negative impacts for production, but they cannot quantify whether improved water quality will affect production.

Re-use without treatment can be a valid water management strategy.

Case Study E

Saltwater #2 – RO Brackish, Wise County, TX

Background:

Customer challenged us with this problem:

- They have an area in northern Wise County with limited freshwater.
- There are saltwater wells available.
- They prefer to have a large freshwater pond and use freshwater if possible.
- Is it economic to try to go to freshwater?

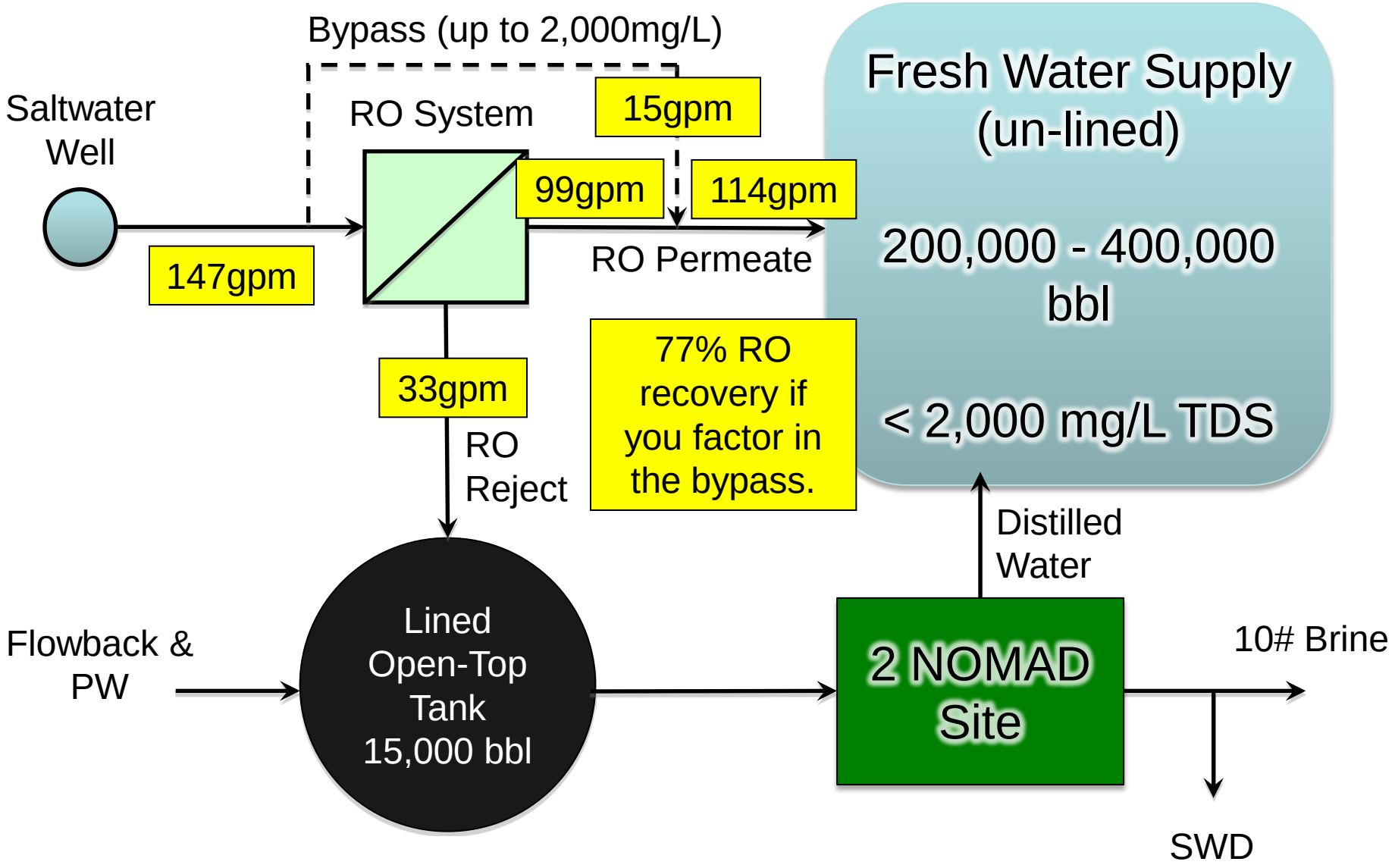
Study Outcome:

①Budget cost: $0.50/bbl for RO.

②RO recovery increased by blending up to 2,000mg/L TDS into the “freshwater” pit.

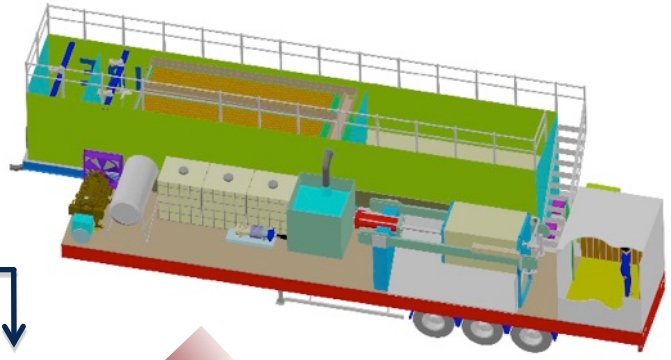
③The RO reject is sent to NOMAD treatment and is handled along with flowback and PW.

Case Study E


Bypass (up to 2,000mg/L)
Saltwater Well
RO System
15gpm
99gpm
114gpm
147gpm
RO Permeate
Fresh Water Supply (un-lined)
200,000 - 400,000 bbl
< 2,000 mg/L TDS
33gpm
RO Reject
77% RO recovery if you factor in the bypass.
Distilled Water
Flowback & PW
Lined Open-Top Tank 15,000 bbl
2 NOMAD Site
10# Brine
SWD

Flexibility

ROVER



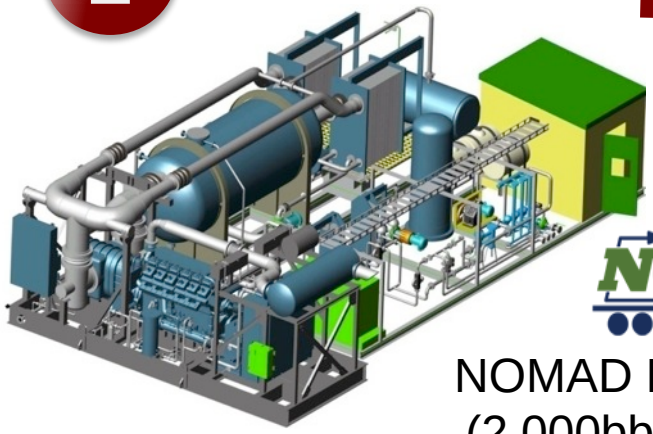
ROVER
Mobile Clarifier
(10,000bbl/d capacity)

1

TSS Removal

TSS + TDS Removal

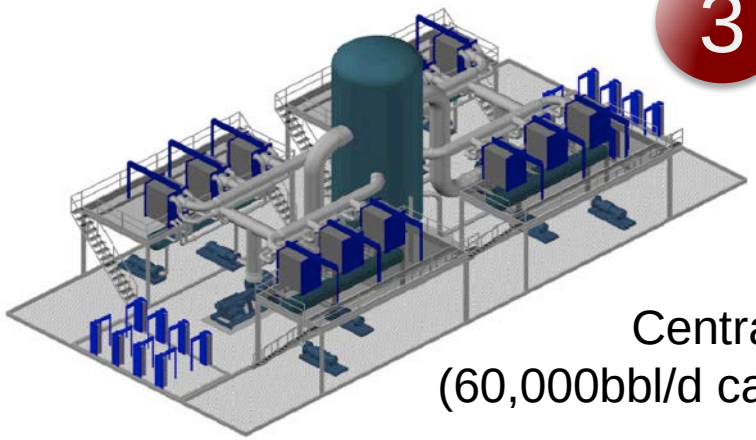
2



NOMAD

NOMAD Mobile Plant
(2,000bbl/d capacity)

3



Central Plant
(60,000bbl/d capacity)

New Trends

- Pit covers (prevent evaporation).
- Combine Recycling & Disposal (not Recycling *OR* Disposal).
- More use of brackish water and saltwater – be careful about hydrogeology.
- Have a common sense discussion with parties involved:
  - Landowners are often writing leases stating that E+Ps must buy groundwater from them.
- Incentivize, not mandate recycling (i.e.: TWRA). www.txwra.org

What is Needed?

1. Common Sense Approach.
   - Ask the right questions & keep it simple (saltwater or freshwater).
2. Range of Solutions.
   - Look for a proven track record. Talk to the customers.
   - Technology must be based on real science backed up with real results.
3. Flexibility.
   - Solution must be adaptable to the changing needs of the industry.
4. Cooperation.
   - Share results and experiences (good and bad). We can learn as much, or more, from what has not worked.