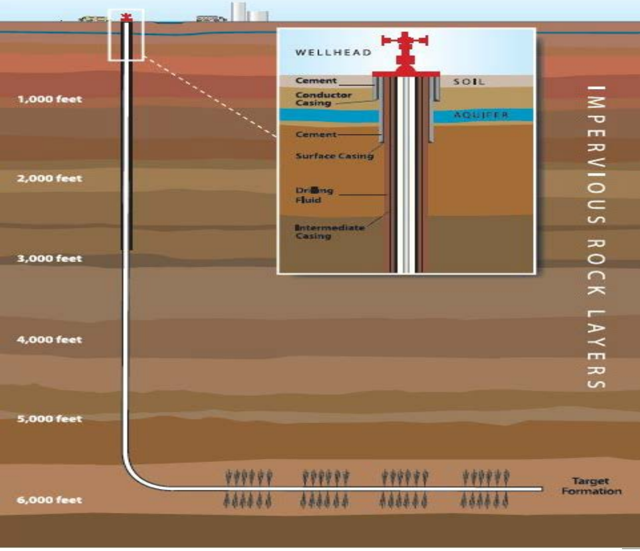


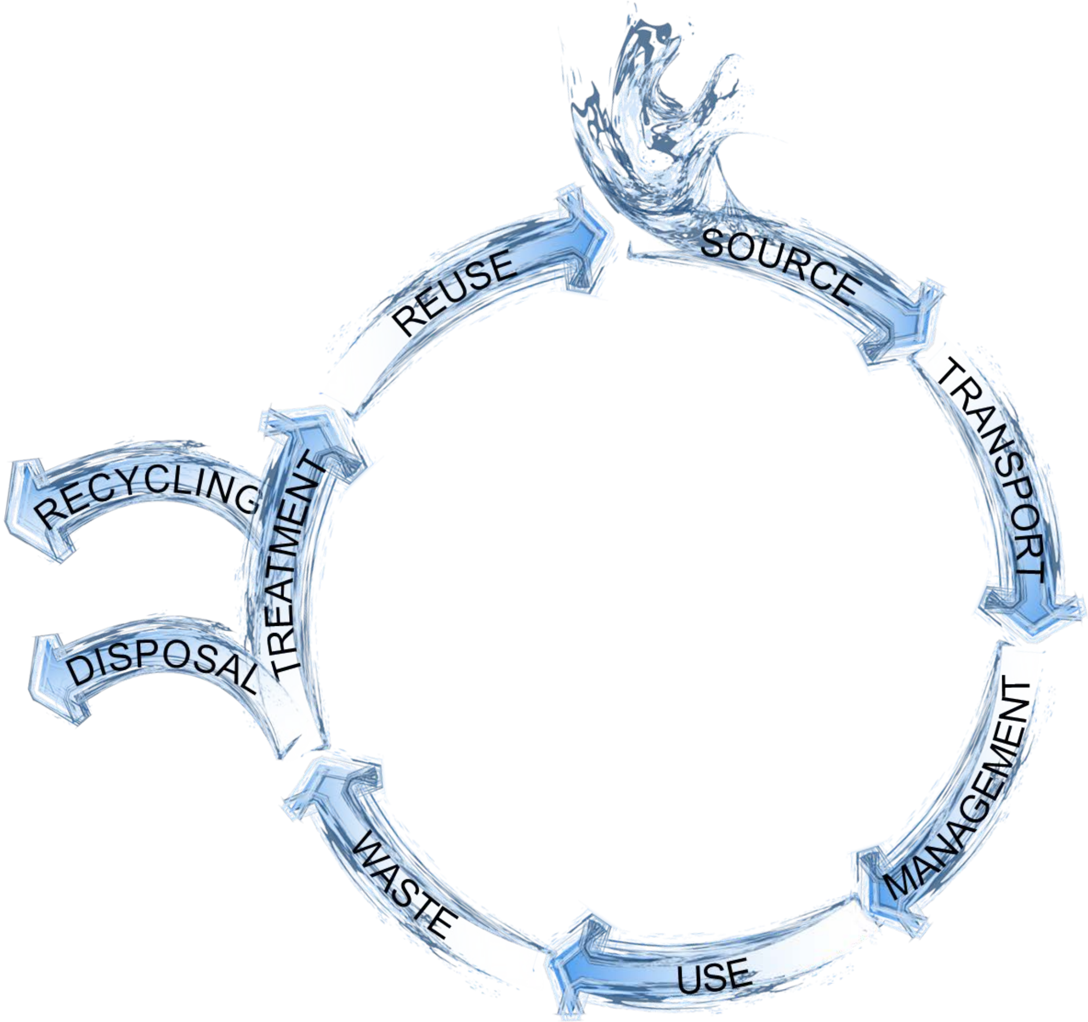

Tools for Implementing Sustainable Water Management

April 11, 2014

Tekla Taylor, R.G.

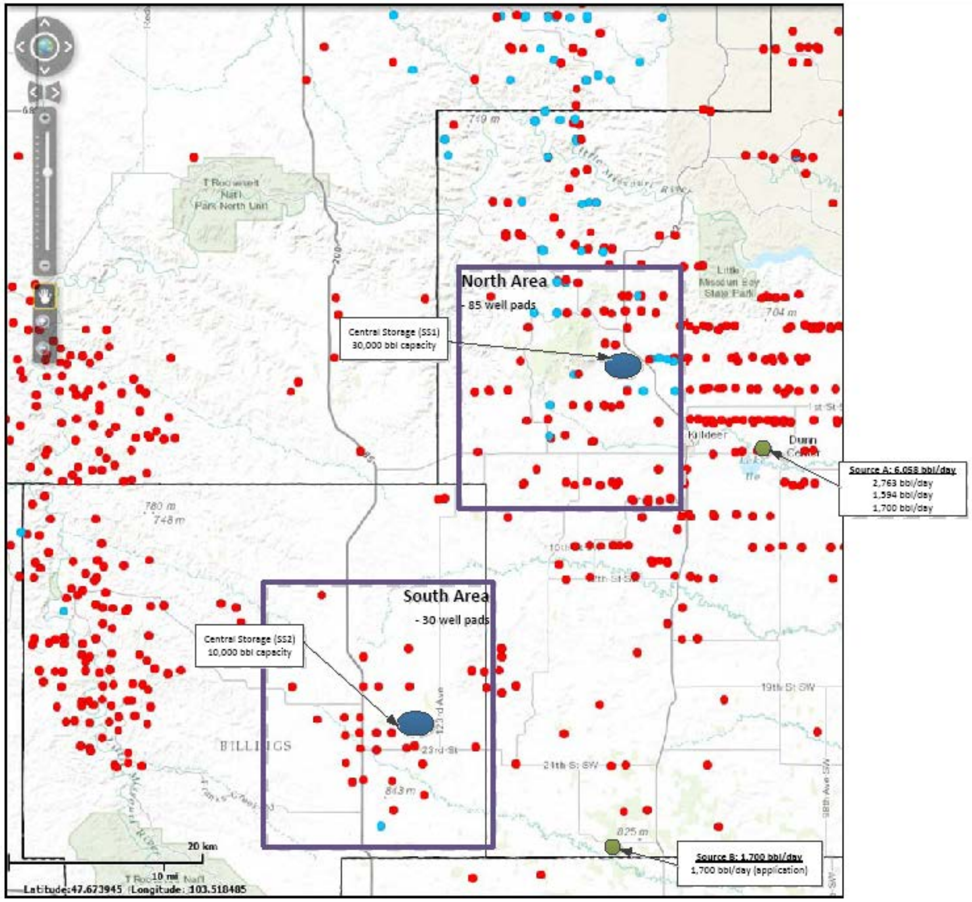
Golder Associates

Understanding Water Risk



Using Dynamic Simulation to Predict Water Costs and Risks

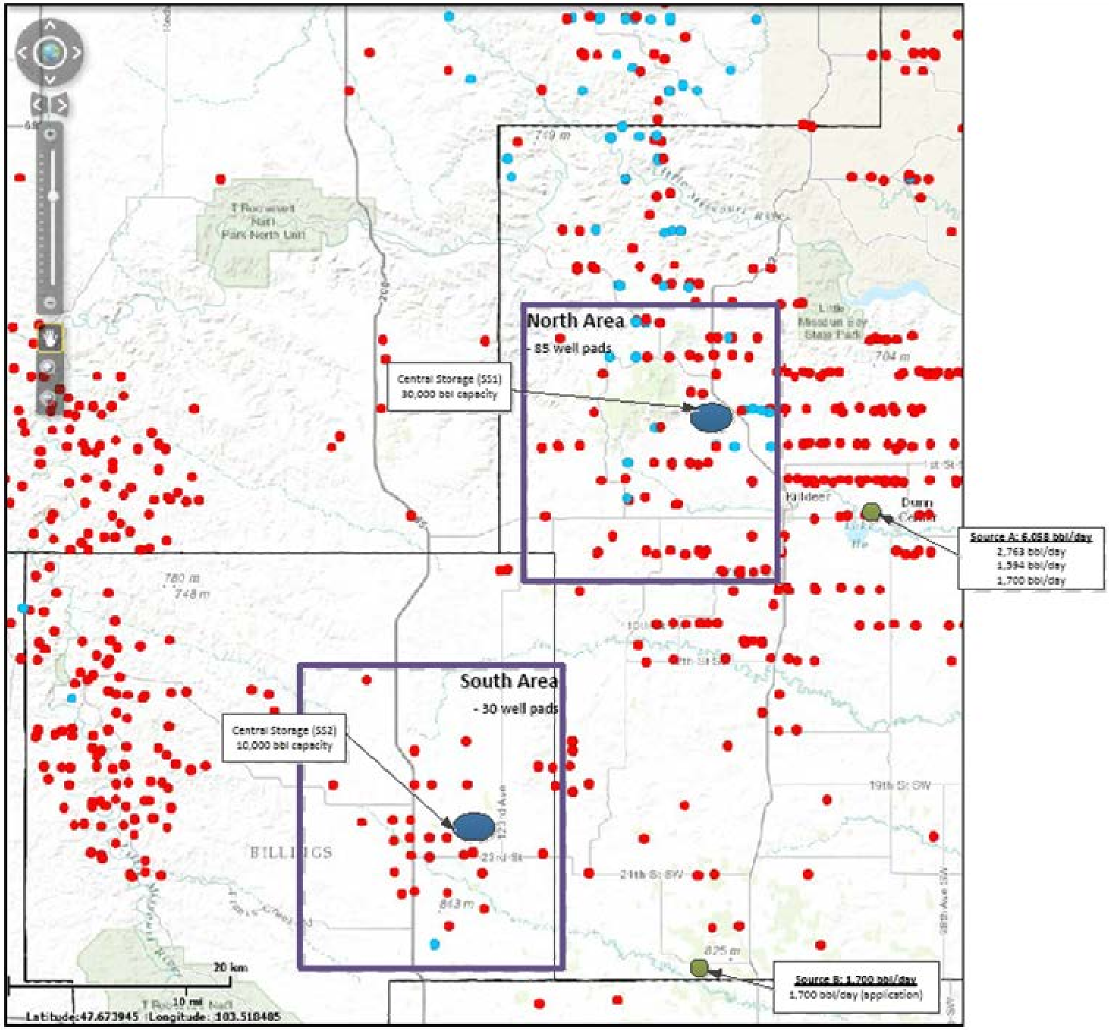
Example: Unconventional Oil and Gas Development



Scope and Objectives

- Develop, evaluate and understand water management strategies throughout the entire life cycle
- Evaluate the viability of options to meet project demands
- Identify the most cost effective water management alternatives
- Support early stage engineering and operational decisions
- Optimize water management strategies at later stages of development as field data is collected

Input: Site Data

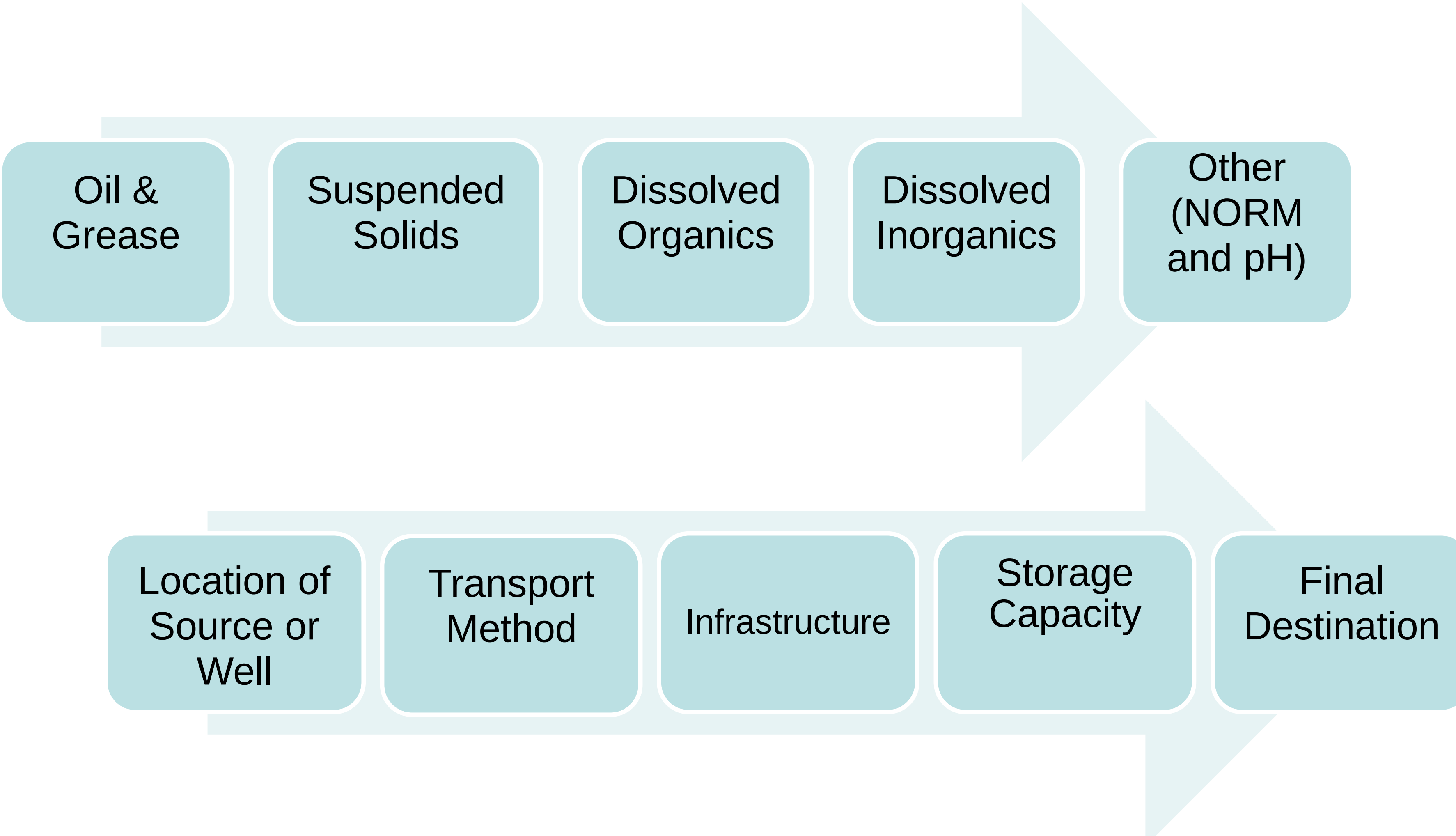


Input: Water Source and Disposition Options

- Surface water stream
- Surface water body
- Surface runoff
- Fresh groundwater
- Brackish groundwater
- Potable water provider
- Reclaimed wastewater
- Produced water
- Acid mine drainage
- Power plant cooling water

- Reuse for well completion
- Underground Deep Injection
- Publically Owned Treatment Works
- Commercial Water Treatment
- Aquifer storage and recovery
- Surface water discharge
- Agricultural Irrigation
- Evaporation Pond
- Site dust control
- Livestock Use
- Industrial Use

Input: Water Treatment Processes and Logistics



Golder Associates

Input: Scheduling

Well Drilling
- Days per well times the number of wells
- Water demand per well

Well Completion
- Days per well times the number of wells
- Water demand per well

Production
- Number of days of hydrocarbon production
- Early produced (flowback) water
- Long-term produced water

Water Demands

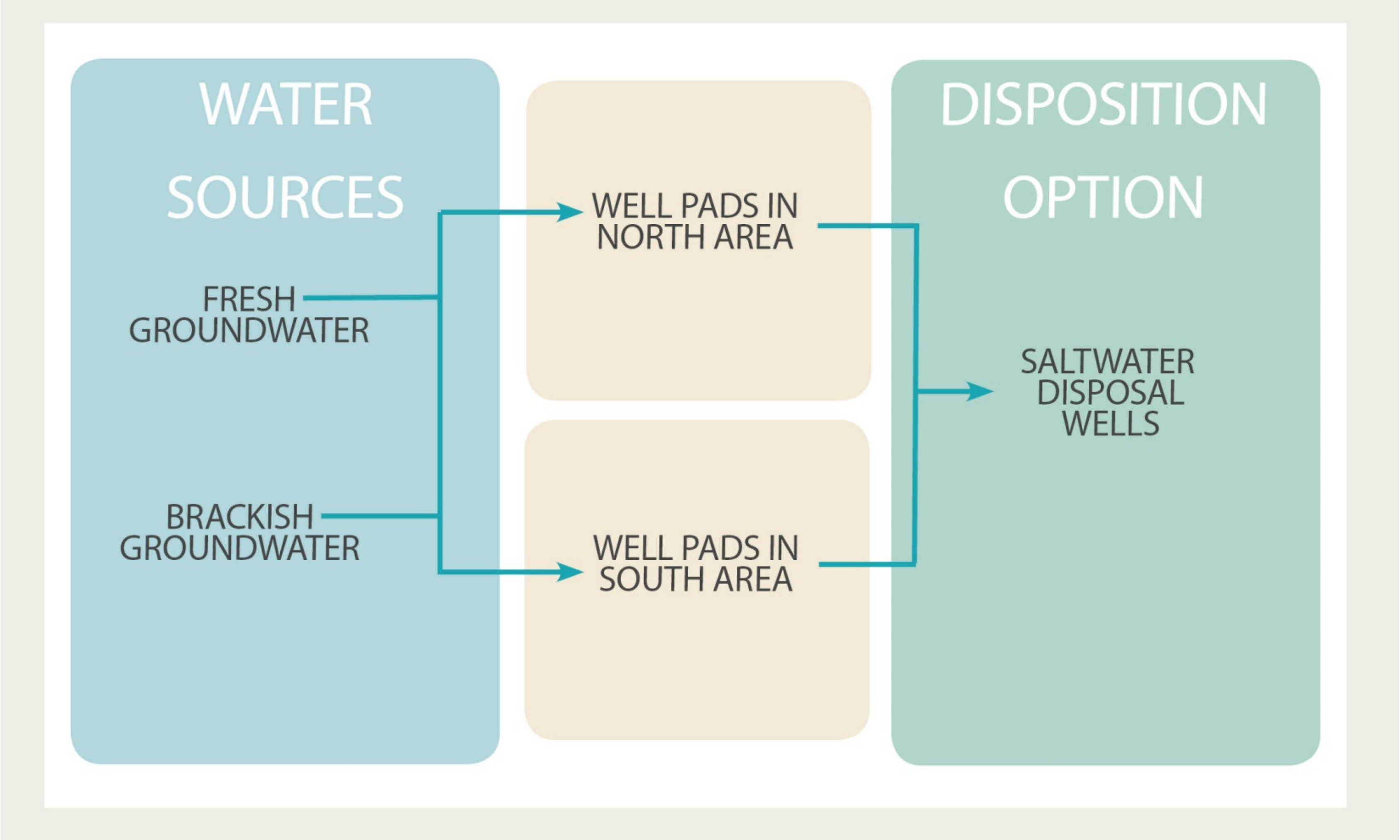
The timeline of events is created to project water demands and production over time.

Develop Water Planning Options and Scenarios

Option	Scenario 1	Scenario 2	Scenario 5
Fresh groundwater source	Truck	Truck	Truck
Brackish groundwater source	Truck	Truck	No
Centralized source water storage	No	No	30,000 bbl
SWD Wells	Truck	Truck	Truck
Reuse	No	Truck	Truck
Storage of flowback water for reuse	No	15,000 bbl	15,000 bbl
Storage of long-term produced water for reuse	No	50,000 bbl	50,000 bbl

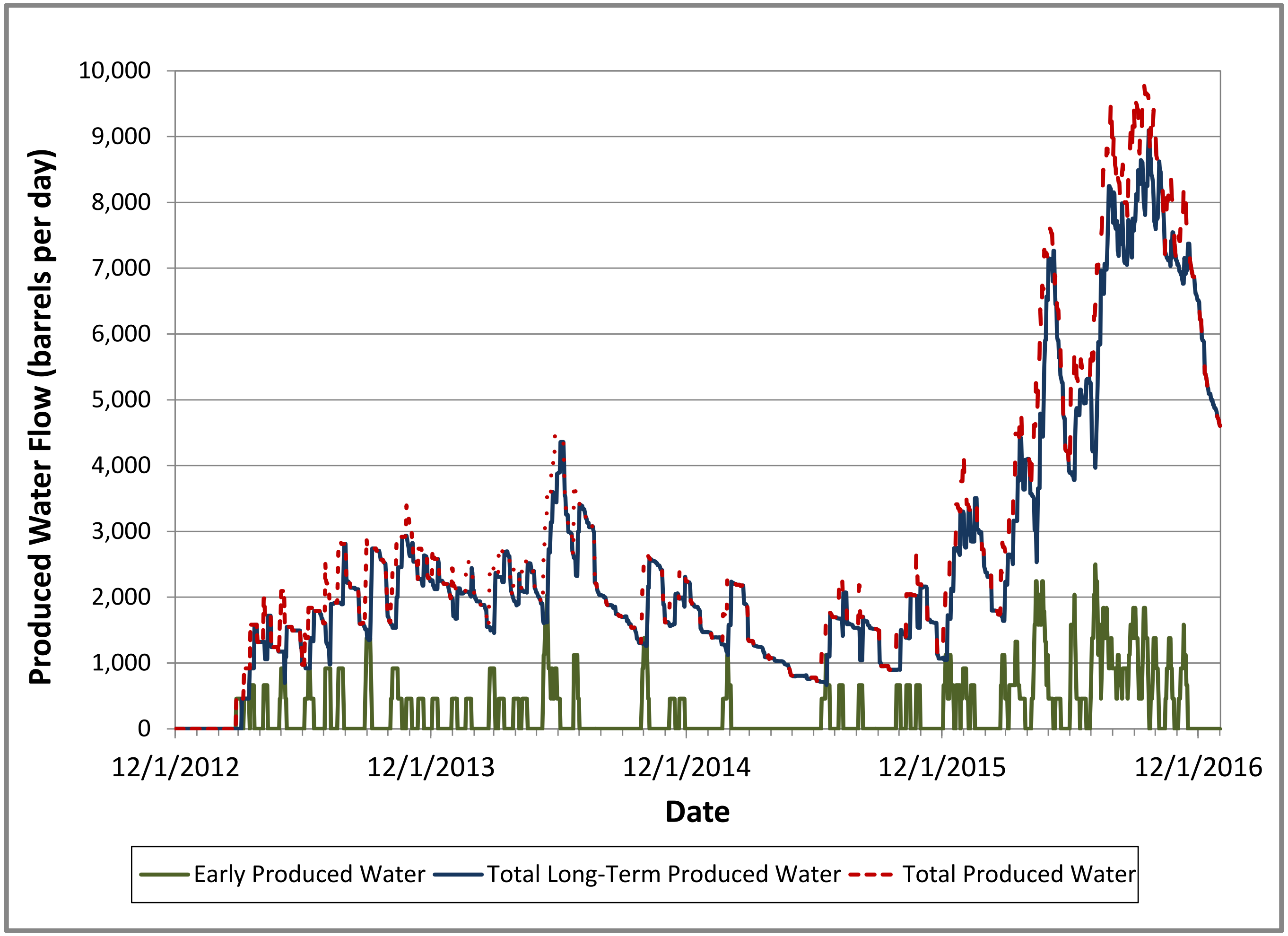
Scenario 1: Trucking, no storage, no reuse
Scenario 2: Trucking, no storage, reuse
Scenario 5: Trucking, centralized source water storage, reuse

Run Water Planning Scenario: Sourcing and Disposition



Run Logistics Options: Transportation and Storage

Create Supply, Demand and Produced Water Projections



Summarize and Evaluate Options Analyses Results

Water Sourcing Summary

Simulation Period: 12/1/2012 – 1/1/2017

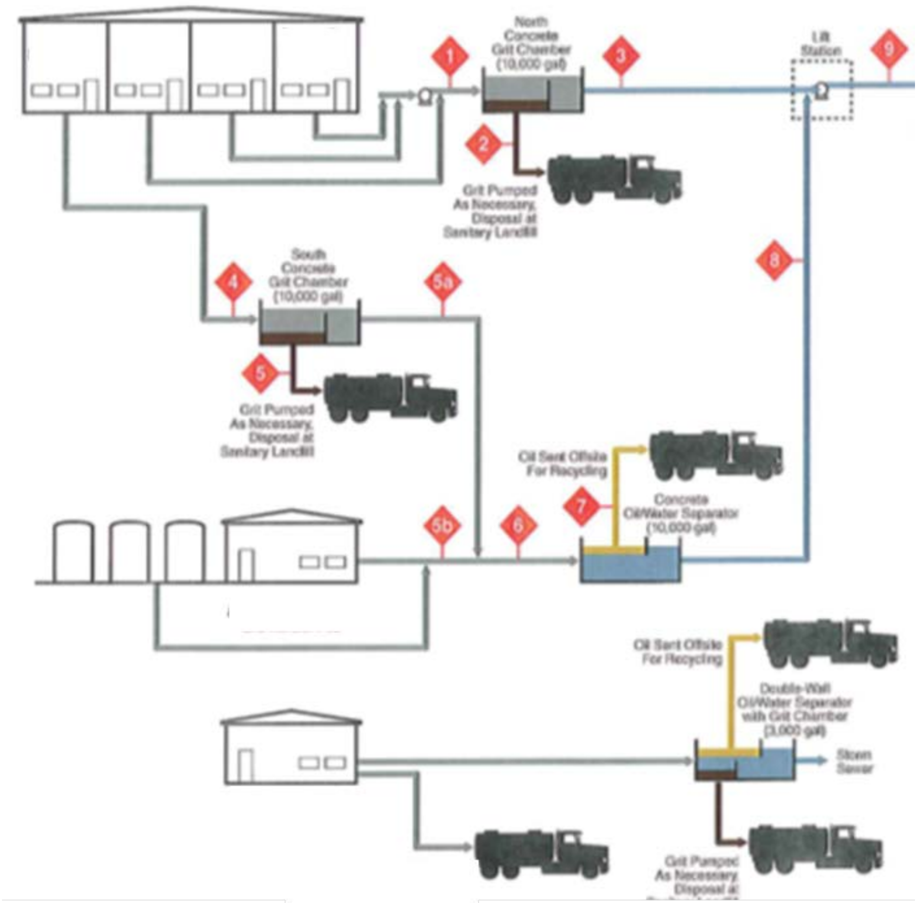
Parameter	Water Management Scenario				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Cumulative Source Water Used (bbl)	5,701,179	2,843,197	2,829,588	5,969,179	3,034,024
Cumulative Source Water Cost ($)	23,951,190	29,280,511	29,857,225	24,852,280	31,340,313
Unit Source Water Cost ($/bbl)	4.20	10.30	10.55	4.16	10.33
Cumulative Insufficient Source Water Capacity (bbl)	(178,464)	(22,186)	(22,186)	(26,964)	0

Water Sourcing Summary

Parameter	Scenario 1
Cumulative Source Water Used (bbl)	5,701,179
Cumulative Source Water Cost ($)	23,951,190
Unit Source Water Cost ($/bbl)	4.20
Cumulative Insufficient Source Water Capacity (bbl)	(178,464)

Using Sustainability Analysis to Select and Optimize Water Treatment Alternatives

Example: Industrial Facility Expansion



Golder Associates

Scope and Objectives

Objectives:

- Capture and treat of all sources of industrial wastewater from maintenance and fueling operations
- Comply with discharge regulations
- Identify the most sustainable technology
- Meet stakeholder expectations

Stakeholders:

- Regulators
- Neighbors
- Local community

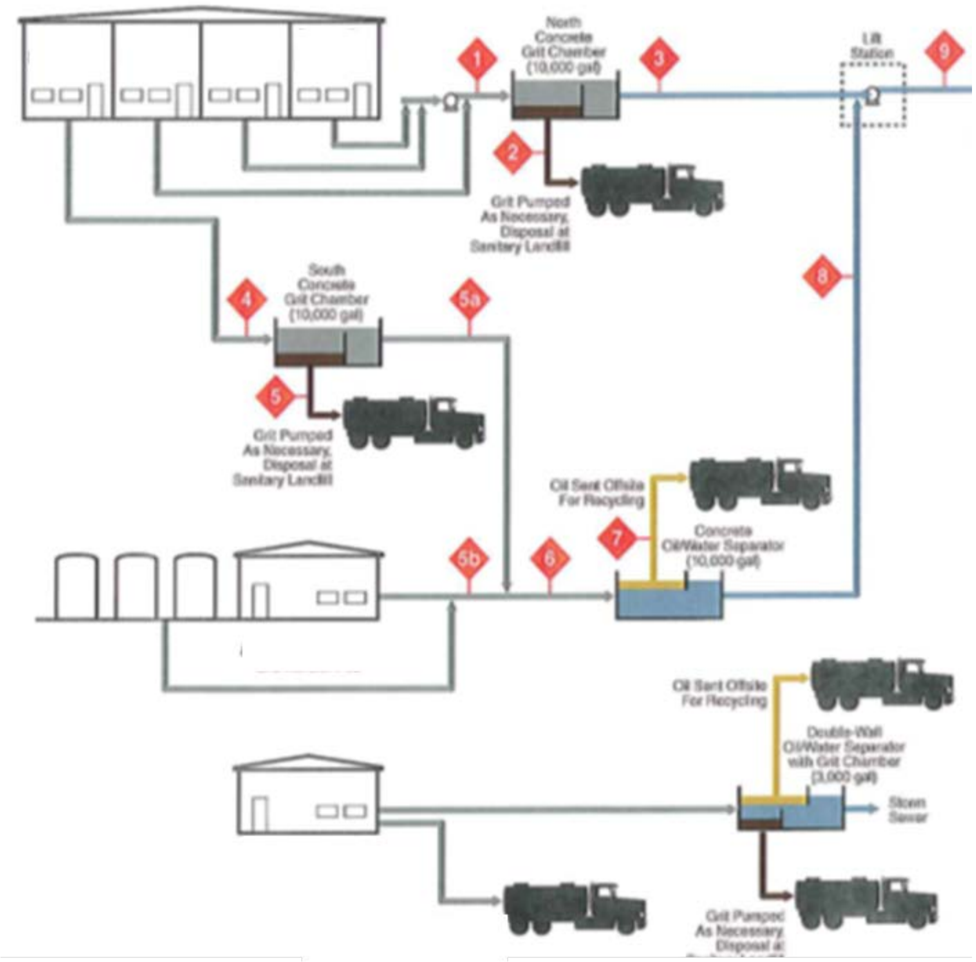
Evaluating Sustainability of Water Treatment Options

Wastewater Inflow:

- Average flow: 60 gpm with 100 gpm peaks
- Oil and grease, 700 mg/L

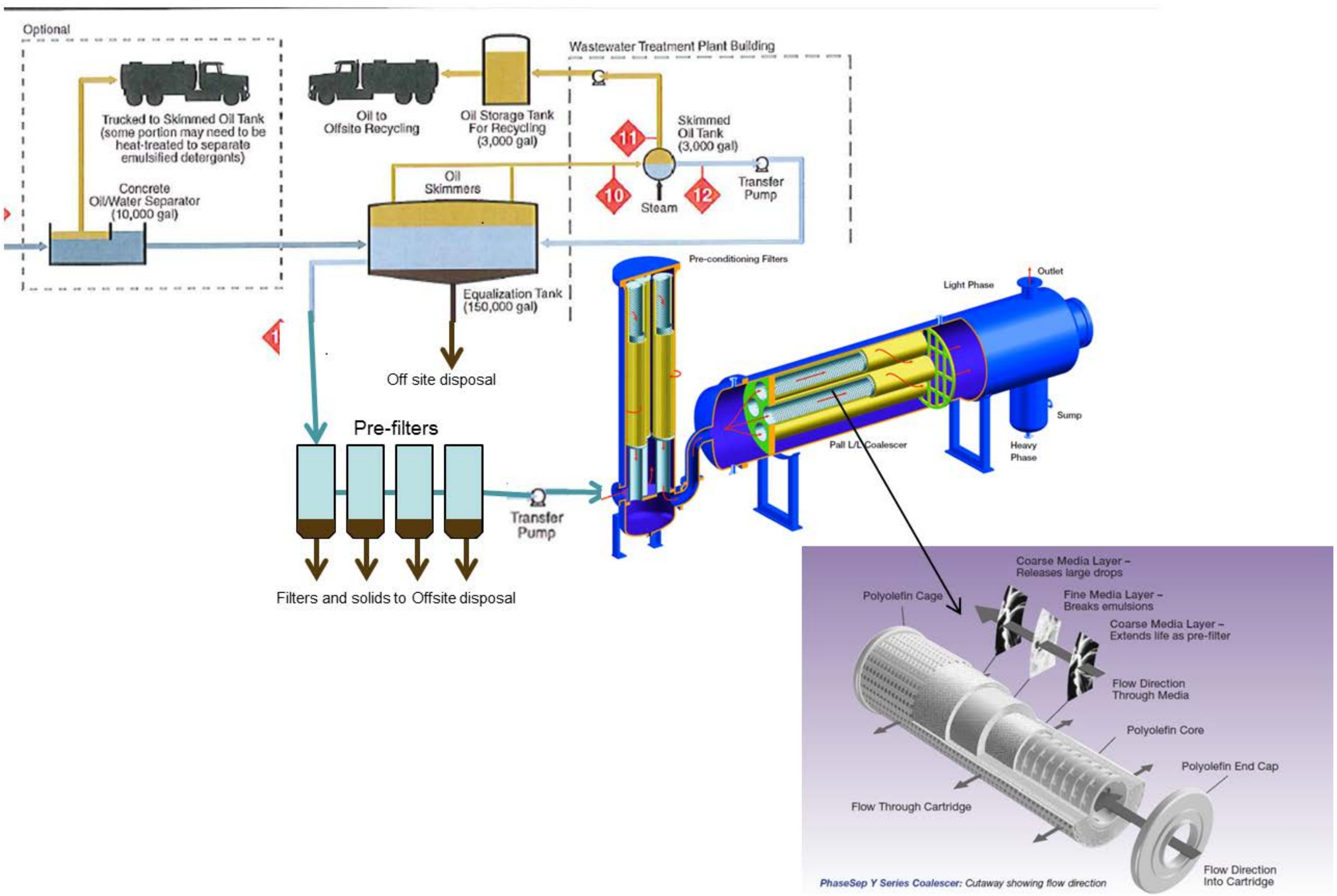
Discharge Requirements

- Oil and grease, < 60 mg/L

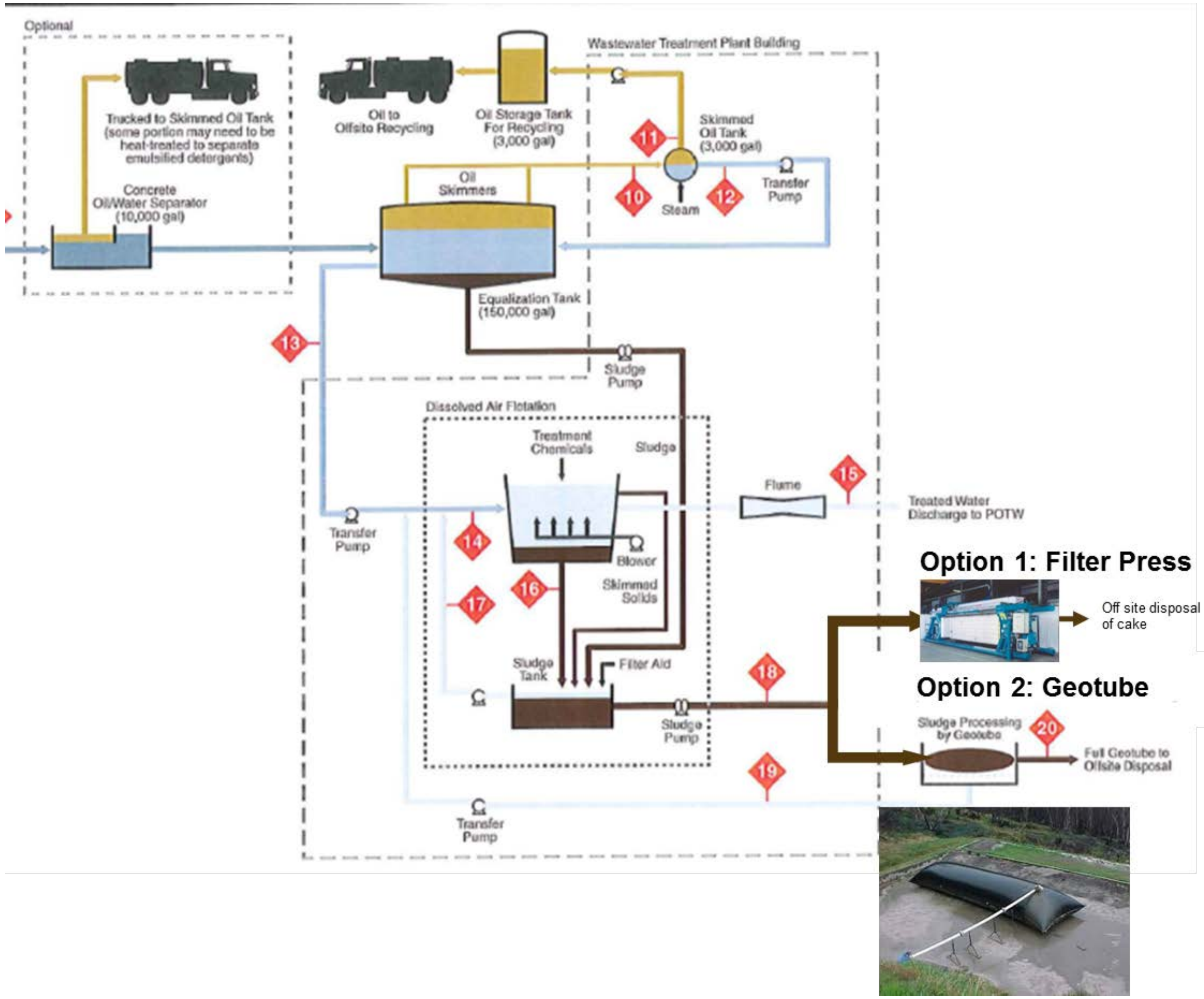


Golder Associates

Option – Coalescing Filters



Options – DAF With 2 Sludge Treatment Options



Benefits of a Multi-Criteria Sustainability Analysis

Characteristic	Benefit
Collaborative	Provide a framework to engage and solicit input from various parties involved in the decision
Holistic	Incorporate goals important to the organization and its external stakeholders (technical and non-technical; short- and long-term)
Transparent & Traceable	Document supporting information and reasoning behind the decision Facilitate communication within the organization and with external stakeholders
Adaptive	Assure continuity and ability to incorporate new information
Defendable	Inform decision based on an explicit understanding of the strengths, weaknesses and tradeoffs among alternatives

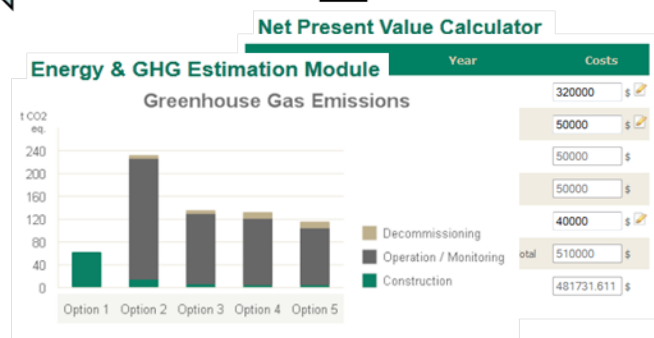
5 –Step Evaluation Process

Environmental Aspect					
Code	**Indicator**	**OPTION 1**	**OPTION 2**	**OPTION 3**	**Weight**
ENV-1	Are offset gains additional to future trajectory based on status quo?	50	100	50	3
ENV-2	Can the offset site be expanded upon, or, the method intensified, to incorporate future offsets?	150	50	100	2
ENV-3	Complimentarity of offset with regional conservation goals.	50	100	0	1
ENV-4	Does the offset site create the opportunity for buffering of important site(s), or, to enhance connectivity in landscape?	50	100	50	2
ENV-5	Ratio of impact footprint area versus area required for NNL offset . (= 'offset efficiency').	25	50	25	1
ENV-6	Offset enhancement technology performance risk.	100	100	50	2
Social Aspect					
Economic Aspect					

OPTION A	
ENVIRONMENT	62%
SOCIETY	75%
ECONOMICS	39%
TECHNICAL	46%

OPTION B	
ENVIRONMENT	64%
SOCIETY	79%
ECONOMICS	71%
TECHNICAL	51%

OPTION C	
ENVIRONMENT	75%
SOCIETY	79%
ECONOMICS	54%
TECHNICAL	91%



Golder Associates

Define Project Objectives

Develop Options

Golder Associates | GoldSET

Active Project :
Current Version : Version 1 (16/10/2013)

Contact

Project Selection | General Information | Project Description | Option Development | Indicator Selection | Weighting | Quantitative Evaluation | Qualitative Evaluation | Interpretation

Step 2 - Option Development

Option	Name	Status	Actions
1	Coalescing Filter	Selected	

Option Description

General description of the approach versus objective(s)

Provide a general description of the approach and explain how the approach will meet the project objective(s):

The coalescing filter will be used as part of a treatment train (described below) for water coming from the fueling service area, the diesel fueling area, and the fuel

Is the proposed approach expected to meet the objectives ? Yes

Description of technology

Technology

Provide a summary of the technology and explain how the technology will meet physical site constraints if any :

The treatment train will be : - equalization tank- oil-water seperator (oil to off-site recycling)- Bag filters to 10um- coalescing filters

Additional Testing Required

Golder Associates

Select Target Indicators

Step 3a - Indicator Selection

New Indicator | Import Indicator

Environmental Aspect

Selection	Theme	Indicator	Description
☑	Water Use (inputs to the system)	Potable water use	
☑	Energy (inputs to the system)	Energy consumption/generation	
☐	Input Materials (inputs to the system)	Recycled input materials (consumables)	
☑	Input Materials (inputs to the system)	Quantity input materials used	
☑	Input Materials (inputs to the system)	Environmental hazard (input materials)	
☐	Input Materials (inputs to the system)	Recycled input materials (construction)	
☐	Land (impact of the system)	Site footprint	
☑	Ecological Integrity (impact of the system)	Impacts of Failure on Natural Environment	
☑	Ecological Integrity (impact of the system)	Potential impacts upon ecological integrity	
☑	Solid outputs (outputs from the system)	Quality of solid waste	
☑	Solid outputs (outputs from the system)	Quantity of solid ouput	
☐	Solid outputs (outputs from the system)	Solid output re-use	
☑	Gaseous outputs (outputs from the system)	Greenhouse gas emissions	
☑	Gaseous outputs (outputs from the system)	Air quality	
☑	Liquid outputs-discharge (outputs from the system)	Quality of wastewater discharge	

Weight Indicators

Step 3b - Weighting

Weighting Management

Environmental Aspect			
Theme	**Theme Weighting**	**Indicator**	**Indicator Weighting**
Water Use (inputs to the system)	1	Potable water use	-
Energy (inputs to the system)	1	Energy consumption/generation	-
Input Materials (inputs to the system)	2	Quantity input materials used	2
		Environmental hazard (input materials)	3
Ecological Integrity (impact of the system)	3	Impacts of Failure on Natural Environment	3
		Potential impacts upon ecological integrity	3
Solid outputs (outputs from the system)	2	Quality of solid waste	2
		Quantity of solid ouput	2
Gaseous outputs (outputs from the system)	1	Greenhouse gas emissions	1
		Air quality	2
Liquid outputs-discharge (outputs from the system)	3	Quality of wastewater discharge	3
		Quantity of wastewater discharge	2
		Fuel / Oil recovered	2

Social Aspect			
Theme	**Theme Weighting**	**Indicator**	**Indicator**

Golder Associates

Quantitative Indicators

Step 4a - Quantitative Evaluation

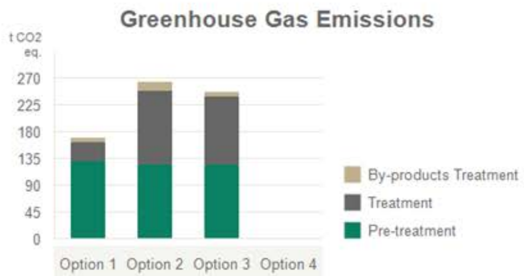
Environmental Aspect

Code	Indicator	Units	Coalescing Filter	Dissolved Air Flotation with Filter Press	Dissolved Air Flotation with Geotube	No action (for comparison)
ENV-1	Potable water use		0	3	3	0
ENV-2	Energy consumption/generation		21305.85	33299.21	30947.57	0
ENV-3	Quantity input materials used	kg/min	0	0.46	0.46	0
ENV-8	Quantity of solid ouput	kg/min				
ENV-9	Greenhouse gas emissions	Tonnes CO2e				
ENV-12	Quantity of wastewater discharge	L/min				
ENV-13	Fuel / Oil recovered	L/min				

Energy & GHG Estimation Module

VIEW ALL | COALESCING FILTER | DISSOLVED AIR FLOTATION WITH FILTER PRESS | DISSOLVED AIR FLOTATION WITH GEOTUBE | NO ACTION (FOR COMPARISON) | RESULTS

GHG Emissions	Option 1 : Coalescing Filter	Option 2 : Dissolved Air Flotation with Filter Press	Option 3 : Dissolved Air Flotation with Geotube	Option 4 : No action (for comparison)
	t CO2 eq.	t CO2 eq.	t CO2 eq.	t CO2 eq.
Pre-treatment	129.69	122.28	122.28	0
Treatment	30.75	125.24	114.13	0
By-products Treatment	7.41	14.82	7.41	0
Total	167.85	262.34	243.81	0



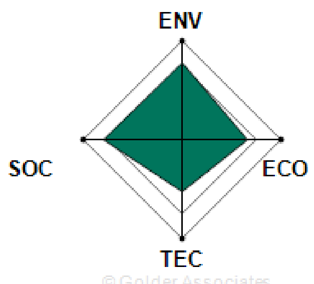
Golder Associates

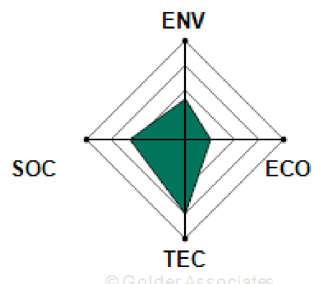
Summary Results

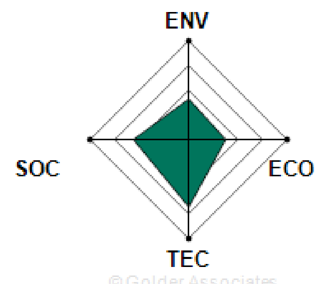
Step 5 - Interpretation & Decision Making

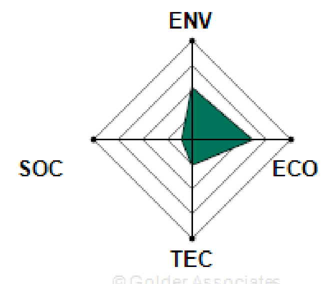
Detailed Results

	Coalescing Filter	Dissolved Air Flotation with Filter Press	Dissolved Air Flotation with Geotube	No action (for comparison)
Environmental	78%	41%	41%	52%
Social	79%	55%	55%	11%
Economic	65%	26%	38%	60%
Technical	53%	74%	68%	25%





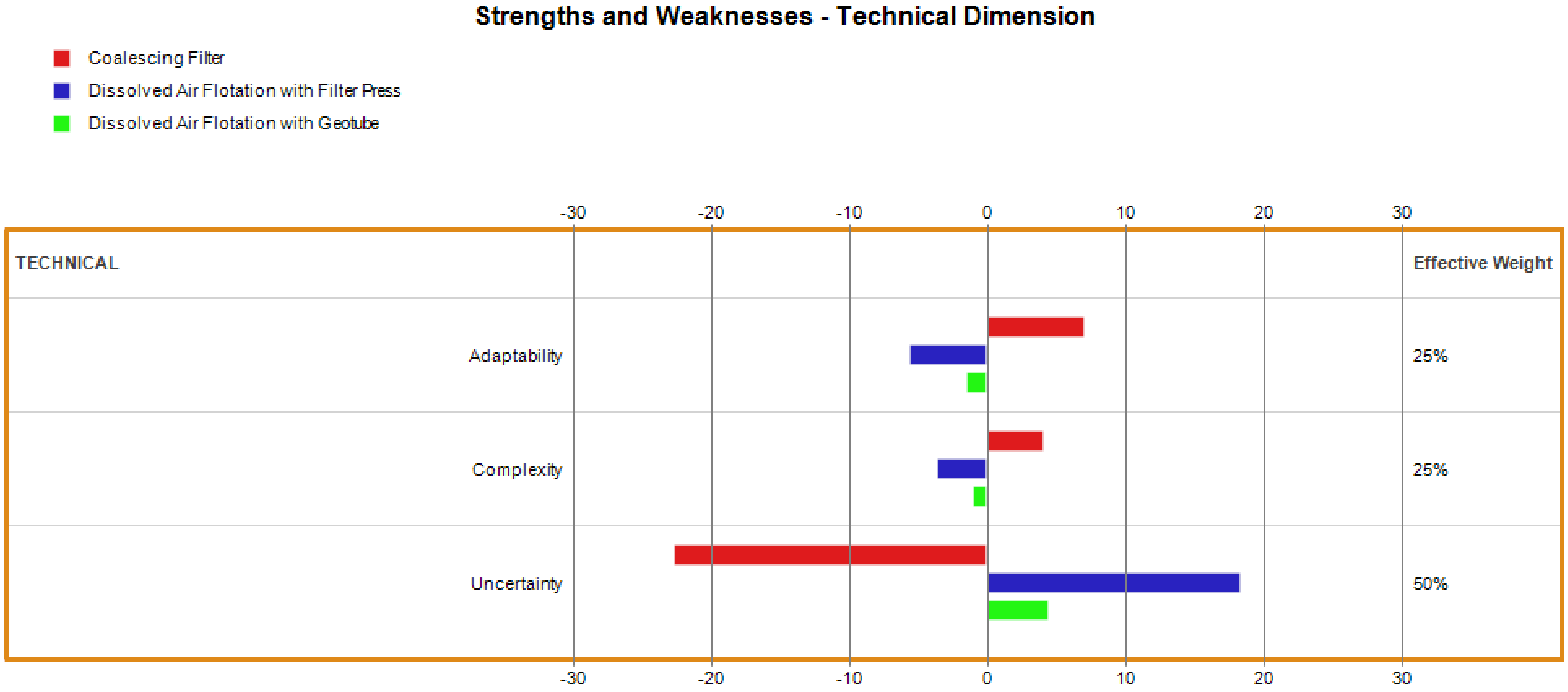




Reports

Indicators :	Results :	Custom :
Word	Word	Word
	Excel	

Detailed Results



Reports

Indicators :
Word

Results :
Word
Excel

Custom :
Word

Detailed Results for Optimization

Sustainable Water Management Planning Benefits

- Provides a risk-based approach for comparing alternative water management scenarios and answering “what if” questions
  - Viability of sources
  - Most cost effective logistics
  - Water treatment needs
  - Reuse/disposal evaluation
  - Impact of regulatory changes
- Communicates the decision-making process to stakeholders
- Optimizes planning, design and negotiations

Questions

Tekla Taylor
US Energy Initiative Leader
Golder Associates Inc.
tekla_taylor@golder.com
(303) 980-0540