To:	Mr. Scott Hillier Senior Water Resources Engineer Cenovus Energy 500 Centre St SE, Calgary, AB T2G 1A6	From:	Alberto Alva-Argaez Process Ecology Inc.
File:	671484	Date:	June 14, 2019

Reference: Strategic Water Management in Oil and Gas Unconventional Plays: Environmental Net Effects Tool Evaluation

INTRODUCTION

Stantec Consulting International Ltd. (Stantec) is pleased to provide the report on behalf of our collaboration team including Golder Associates and Process Ecology to perform an evaluation of innovative software tools for assessment of the environmental net effects (ENE) of alternative water management strategies in unconventional oil & gas developments. Such tools are needed to support operators in water sourcing and management decisions to arrive at the scenario with the least environmental impact and cost.

For this study, the project team evaluated the environmental net effects of 5 typical water management scenarios for unconventional oil and gas development and used two methods for each case. The evaluation approach applied the same set of metrics for comparison between the alternative scenarios and methods. The first method was adapted from an ENE tool developed for the Canadian Oil Sands Innovation Alliance (COSIA) and modified by PTAC for unconventional oil and gas development (PTAC ENE methodology). The second method is a new tool developed by the project team that incorporates Process Ecology's Hydropti's water optimization software and Golder's Goldset planning framework.

OBJECTIVES

Process Ecology and Golder Associates have developed innovative software tools to assist in the evaluation of water management alternatives. Hydropti is a decision support tool that incorporates powerful algorithms to identify lowest cost water management plans that consider activity schedules, water availability, storage requirements and wastewater disposal.

The objective of this work was to perform an evaluation of five alternative water management strategies in the unconventional developments planned in Central Alberta (MD of Greenview). The scenarios include no water reuse and maximum water reuse, both using different storage and transportation options (Figure 2). For each one of the selected scenarios, the Hydropti software was configured to ensure that all possible water sources can be identified as well as to evaluate the costs associated with water transport, disposal and storage.

The resulting optimal (lowest-cost) water management strategies were then further evaluated via the application of the PTAC ENE methodology and using the decision-support tool, GoldSET, to deliver a comprehensive evaluation of the alternatives.

DESCRIPTION OF TOOLS

Process Ecology's Hydropti

Hydropti is a web-based software system that has been designed to support the efficient allocation of water resources for hydraulic fracturing operations. Hydropti is an innovative decision support software tool that has been designed to help the oil & gas industry identify optimal water management strategies for hydraulic fracturing operations. The software is accessed via a modern web browser and the user defines the drilling and completions schedule, potential water sources, required volumes, disposal and storage options and cost information. The tool implements powerful optimization algorithms to explore all permutations in the system and identifies the lowest cost water management plan. Users can apply risk-based analysis via Monte Carlo simulation to evaluate the impact of uncertain parameters. Optimal locations for water storage can also be identified easily. By comparing alternative development schedules, users can determine the likelihood of water shortages. Alternative plans can also be explored with ease. Hydropti helps to drive down cost and maximize water efficiency. Hydropti assists Water Management Coordinators who need to ensure water is available to frac wells at minimum cost by radically reducing the time and effort required to explore water management scenarios and enabling the definition of water management plans with minimum overall impact (economic, environmental, social) as well as increased confidence in the results since all options have been evaluated.

Golder's GoldSET

In order to assist clients on Corporate Social Responsibility and international best practices on environmental stewardship and social responsibility, Golder developed GoldSET, a web-based tool for evaluating project planning and design. The tool provides design teams the ability to understand and assess the environmental, social, economic and technical risks as well as opportunities during project planning and design. The software implements several elements from ISO 26000 on Corporate Social Responsibility and international best practices on environmental stewardship and social responsibility.

The main functionality of the tool provides users access to a large number of options for evaluation metrics along the four key dimensions of sustainability: Environmental, Social, Economic, and Technical. Once a project is defined in the tool, users have full flexibility to add alternative scenarios for comparison and a set of metrics for each dimension.

A set of weights is then allocated to each metric and each dimension. The weighting exercise is usually achieved via client multidisciplinary workshops where various subject matter experts agree on the appropriate distributions. Each dimension is then evaluated for each scenario and GoldSet provides several analysis and visualization tools to better understand the trade-offs that alternative solution may display.

APPROACH AND METHODOLOGY (Hydropti and GoldSet)

The overall approach used in the Study is provided in the Figure 1 below and described in the following sections.

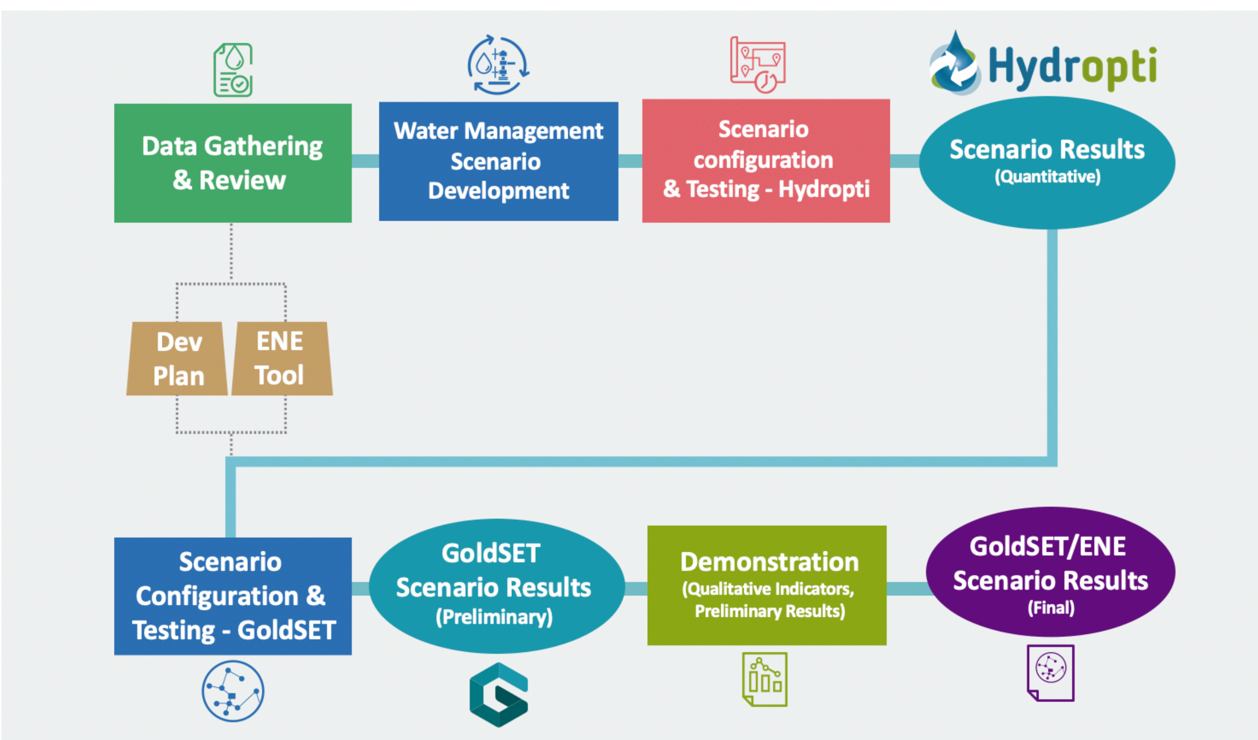

Figure 1: Approach to evaluate Environmental Net Effects

Water Management Scenario Development

The scenarios used for ENE tool evaluation were provided by the PTAC Steering Committee and are presented in the Figure 2 below.

Figure 2: Different scenarios for ENE tool evaluation.

Brief description of the identified scenarios

Scenario 1: Considers the exclusive use of freshwater for all well pads and the disposal of all of the resulting flowback. The only water transportation mode considered in this scenario is trucking.

Scenario 2: The opportunity to store flowback for reuse is incorporated in this scenario with the characteristic that trucking is still used to transport flowback to the storage facility and then it is distributed for reuse using HDPE pipe.

Scenario 3: This set up is identical as Scenario 2 however the flowback is distributed for reuse using buried pipeline.

Scenario 4: Same as Scenario 3 with the difference that flowback is distributed for reuse using temporary lay-flat hose.

Scenario 5: This scenario opens the opportunity to eliminate trucking of flowback to storage and instead relies on the use of lay-flat hose to transport flowback to and from storage facilities.

In all scenarios the final disposal of wastewater to an injection well is done via trucking. Similarly, freshwater supply is delivered from the reservoir to well pads via trucking as well. The models do not consider the transport of water from the point of diversion to the reservoir.

Scenario Configuration and Testing - Hydropti

A basic footprint was determined by the project team that included a set of 12 well pads with their corresponding fracking schedule. The time horizon for all scenarios was of 2 years and the schedule was simplified to space evenly the fracking activity.

The footprint for the Study is illustrated below in Figure 3, and the schedule is also displayed in a Gantt chart in Figure 4.

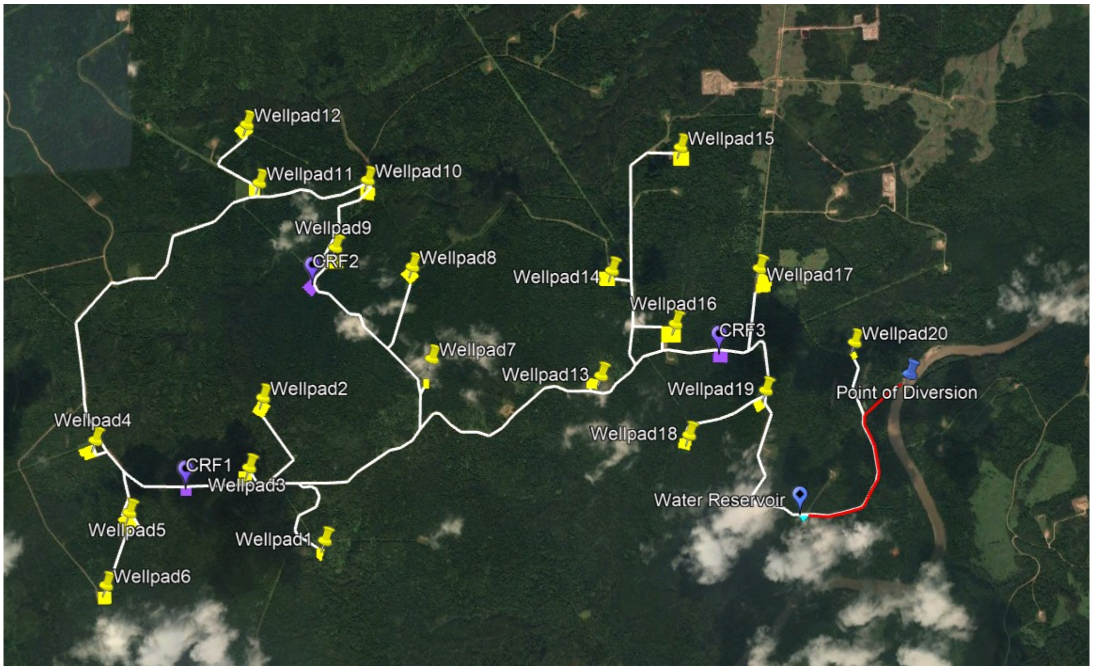

Figure 3: The footprint for the ENE Study area

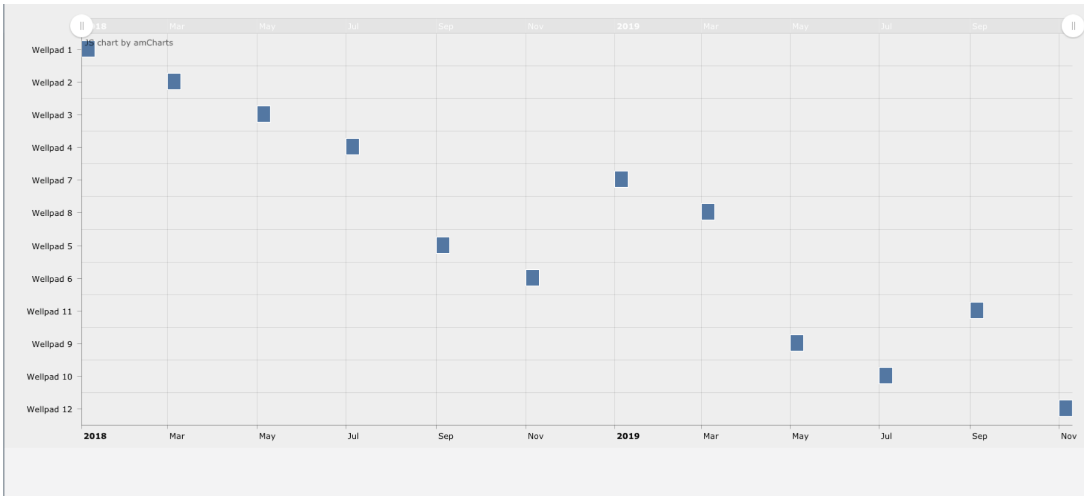

Figure 4: Completion schedule represented in a Gantt chart.

The following parameters were also determined and were used to set up the Hydropti model:

- Required water volume for each well pad: 100,000 m3
- Flowback percent: 30%
- Duration of the fracking/completion: 10 days per well

The cost information associated with transporting water was also provided by the Project team and the following assumptions were used in the Hydropti model:

1- Trucking option would rely on the existing road network in the area
2- Both buried pipeline and HDPE options would be installed following the existing road network to minimize disturbance
3- Layflat hose option installed using linear distance between sources and sinks based on Lat/Long information

It is worth noting that the calculated distances in Hydropti are obtained directly from the Google maps database as the shortest distance connecting a source and a sink using the existing road network.

Shown in Figure 5 below, a single disposal well is located approximately 100 km away from the main development area. The completed Hydropti model is displayed in the graphical user interface below.

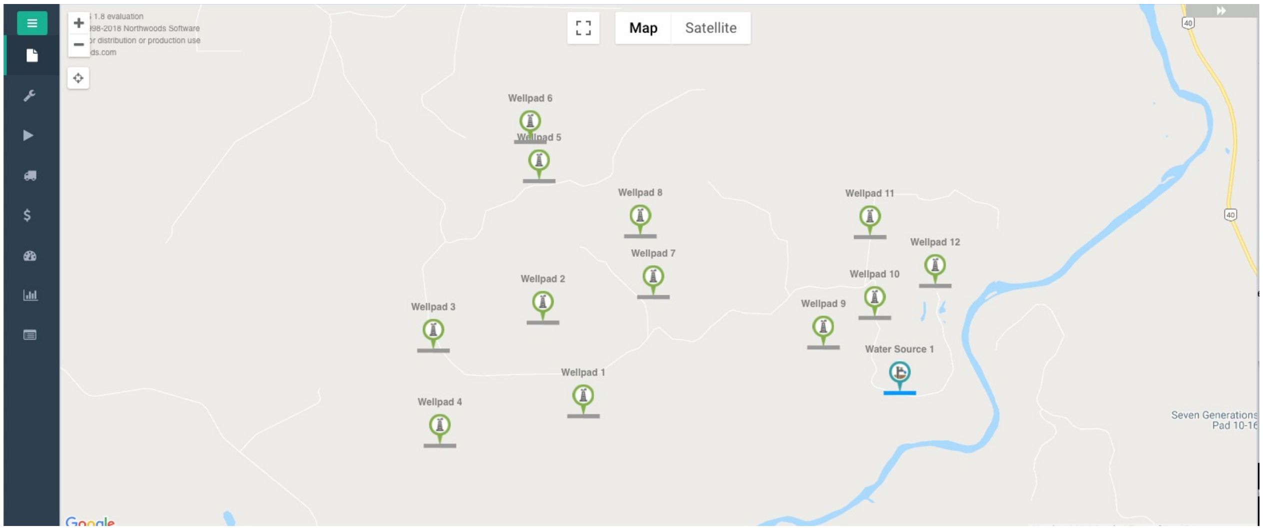

Figure 5: Completed Hydropti Model. A single disposal well is captured approximately 100 km away from the main development area

The alternative scenarios to be evaluated were then created by selecting the transport options for water in separate cases. Hydropti was then used to determine the minimum cost strategies for each scenario. The following cost items are included in the models:

1- Trucking cost as a function of distance driven, truck capacity, truck speed, fuel consumption and operating costs (driver, fuel)
2- Pipeline cost as a function of length, pressure drop, pump efficiency, electricity cost and associated capital/operating costs (includes layflat hose rental cost)
3- Storage cost as a function of capacity

Hydropti's optimization algorithms identified the lowest cost option for each scenario and quantitative indicators reported such as total freshwater use, total cost of the system, storage capacities, air emissions and many others to be used for the ENE.

The "No water reuse" scenario implies all the fracking is performed with freshwater and all the flowback is sent to the disposal well as illustrated in the Hydropti solution below in Figure 6.

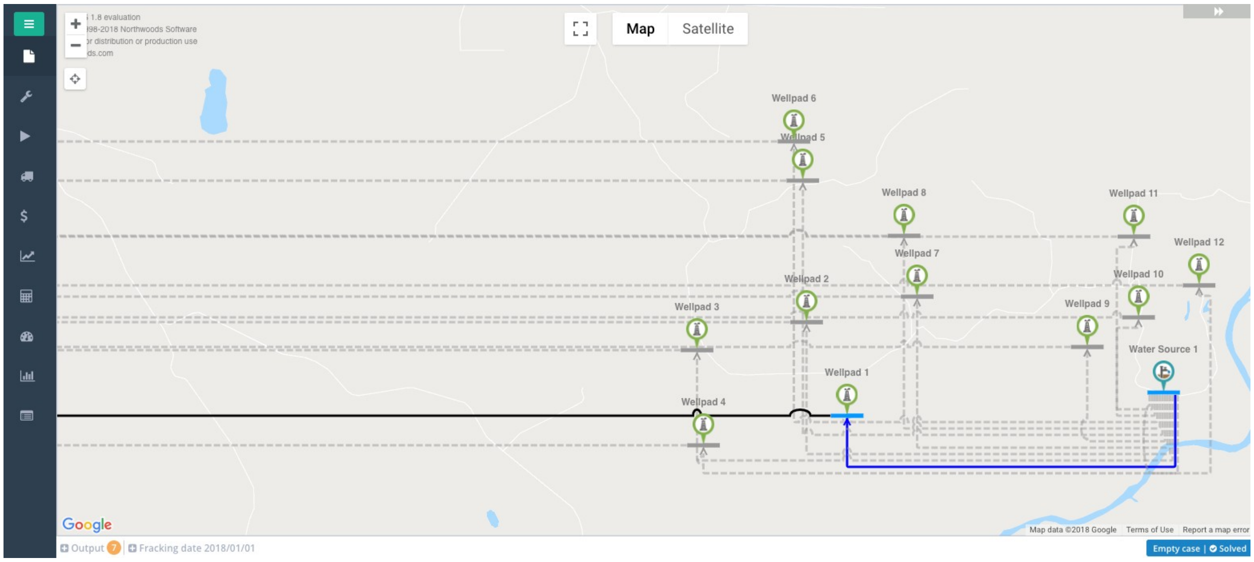

Figure 6: “No water reuse” scenario implies all the fracking is performed with freshwater and all the flowback is sent to the disposal well as illustrated in the Hydropti solution.

Not shown in the interface is the disposal well where all of the wastewater is directed (lines on the left side of the image). Total driven distance in this scenario is reported as 3.7 million kilometers.

As an illustration of the results provided by Hydropti, Figure 7 below displays the lowest cost network for the second scenario where a single storage location is available, and water may be transported using HDPE pipelines.

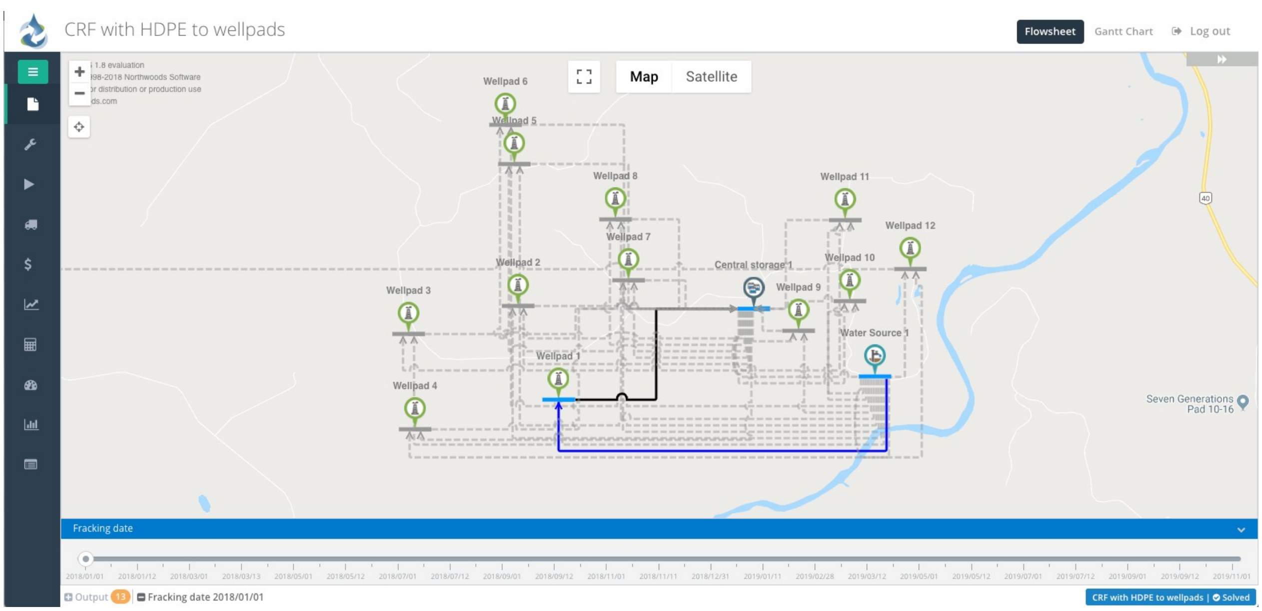

Figure 7: Hydropti displays the lowest cost network for the second scenario where a single storage location is available, and water may be transported using HDPE pipelines.

In this solution it can be observed that there is a single wastewater stream that is sent to disposal as the flowback is contained in the storage facilities and reused to supplement freshwater as required. As an illustration of the differences, this scenario reports much lower total driven distance as 0.7 million kilometers. Another interesting feature of the solution is the determination of the timing for water reuse.

In Figure 8 below Hydropti displays the water management strategy for the duration of the project. In the chart it can be observed that the first well pad requires the use of freshwater, however the flowback is sent to storage to build inventory such that the remaining well pads can be fracked partially with reused water leading to minimum total cost of the system.

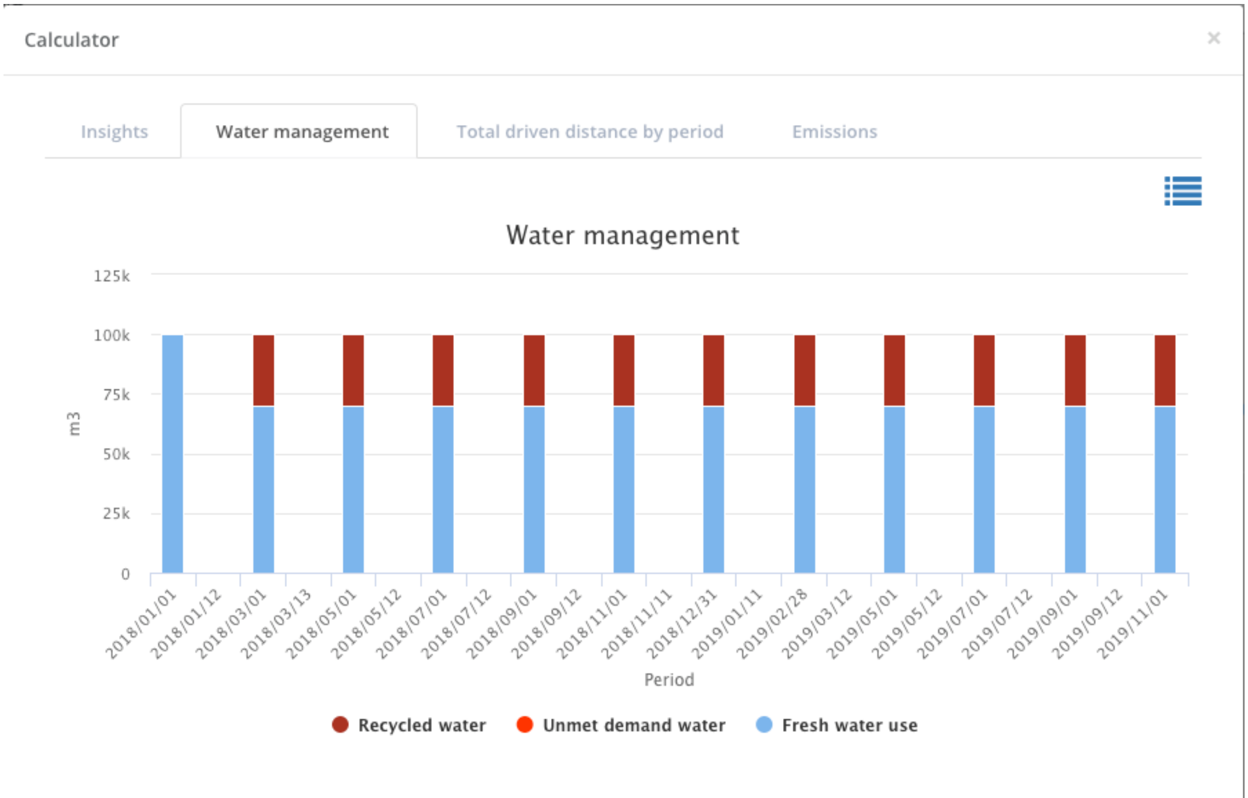

Figure 8: Hydropti displays the water management strategy for the duration of the project.

Scenario Configuration and Testing - GoldSET

The following sections describe the steps taken to configure the GoldSET version of the PTAC ENE tool. A GoldSET account containing the ENE tool has been setup for PTAC and may be accessed using the following instructions:

Website Address: www.goldset.com

Username: PTAC

Password: Hydr0pt1 (where the 0=zero)

Filename: PTAC - WORKING 11-29 – FINAL

A backup copy (copy 1) of the model has also been provided.

Indicator Selection and Weighting

The indicators were selected based on those present in the original PTAC ENE spreadsheet tool. Efforts were made to duplicate the configuration present in the PTAC ENE tool to the maximum extent possible. However, two new quantitative indicators were introduced to the GoldSET tool; Traffic Accident Risk and Spill Risk (Transport). All indicators are described in Appendix A.

Quantitative Evaluation of Options

The numerical values for all indicators which could be described quantitatively are provided per dimension in Appendix B. For spatial indicators, e.g. Overall Footprint, Recreational Area Disturbed, Grizzly Bear Zone, Watercourses Disturbed, etc., the Geographical Information System (GIS) ArcGIS™ was used to query the Project footprint against all known, publicly available spatial datasets obtained for the study area as provided in Appendix B.

Other quantitative metrics such as distance travelled, volumes of water used and produced, and GHG emissions were output by Hydropti. The key indicators that Hydropti provides to the analysis also include all cost related information (CapEx and OpEx) for each scenario. Specific indicators such as total cost of flowback per unit volume and total cost of freshwater per unit volume are also included.

In addition, Hydropti provides all the water volumes in the system such as total freshwater demand, volume of recycled water, volume of disposed wastewater and a set of air emissions indicators associated with water transport (CO_2, NO_x, methane). Energy requirements as fuel or electricity are also reported

A summary of all quantitative indicators is provided in Appendix C (Table C-1)

Qualitative Evaluation

Indicators which were not evaluated quantitatively in the original PTAC ENE tool, were also evaluated qualitatively in GoldSET. The qualitative rating scale used a 5-point system (e.g. High, Moderately High, Moderate, Moderately Low, Low) where applicable. The qualitative evaluation of options is presented per dimension in Appendix D. Normalized scores (between 0 and 100) have been assigned for each applicable indicator.

PTAC ENE Tool Configuration

A copy of the original PTAC ENE tool in Excel™ spreadsheet format was provided by PTAC and was configured identically to the GoldSET model described in the sections above. An electronic copy of the model has been provided as part of the deliverables.

RESULTS – GoldSET

The summary results obtained from this evaluation are presented in the Figure 9 below. The larger the diamond the higher performing the option against the four dimensions.

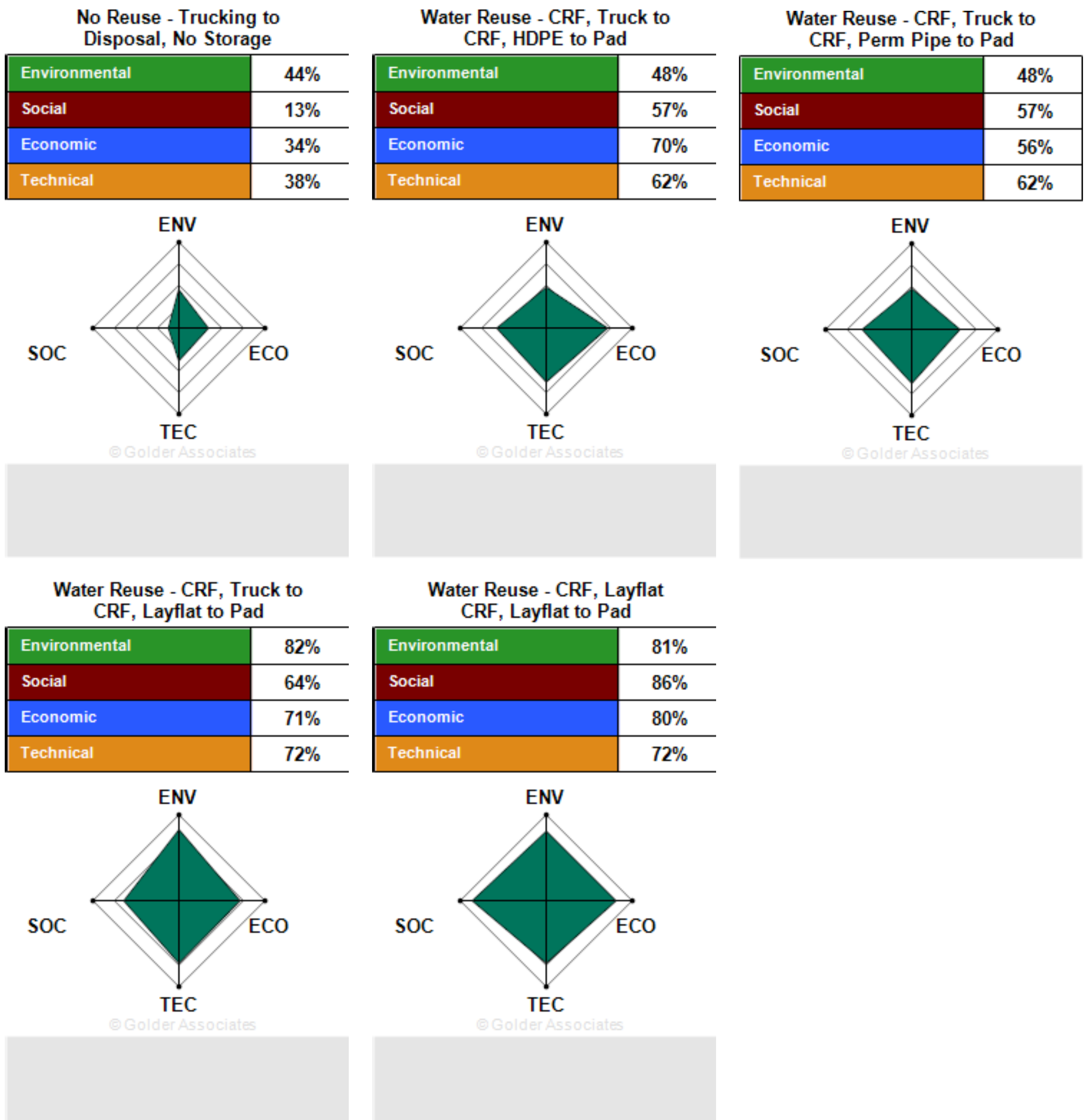

Figure 9: Summary results from GoldSet evaluation.

As can be seen from the diagrams, scenario 5 “Water Reuse- CRF, Layflat CRF, Layflat to Pad” displays the best performance across all dimensions.

GoldSET allows users to explore in more detail the outputs of the analysis via histograms for each indicator for all dimensions and these are presented in Appendix E. Another valuable representation of the data is achieved by selecting a “differential review” that presents only those indicators that make a difference in the decision. Several indicators are very similar or identical among options, thus the review of these data points would not provide key information in the selection of the best option.

Figures 10-13 below display the differential analysis for the five scenarios under review.

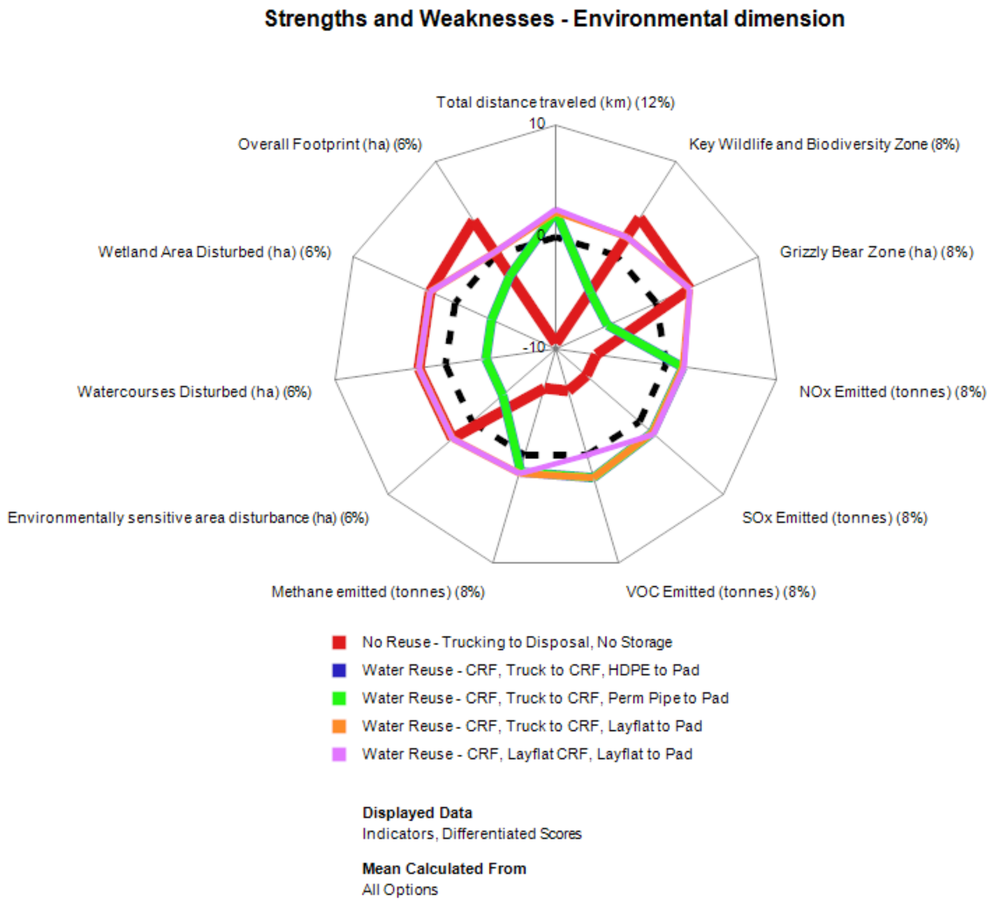

Figure 10: Differentiated scores- Environmental dimension.

Similar to the overall results, these radar charts indicate that scenarios with the largest areas are more attractive across the respective indicators. Scenarios 3 and 4 perform very similar in the Environmental dimension where the main differences are related to total distance travelled. Although both the layflat hose and the permanent pipe option alleviate the impacts associated with truck driving, the layflat scenario provides additional benefits with reduced impact on watercourses disturbed and sensitive zones. The main reason is that the permanent pipe scenario is assumed to follow the road network with several incursions into sensitive areas and water body crossings whereas the layflat hose is assumed to be run using linear distances between sources and demand points.

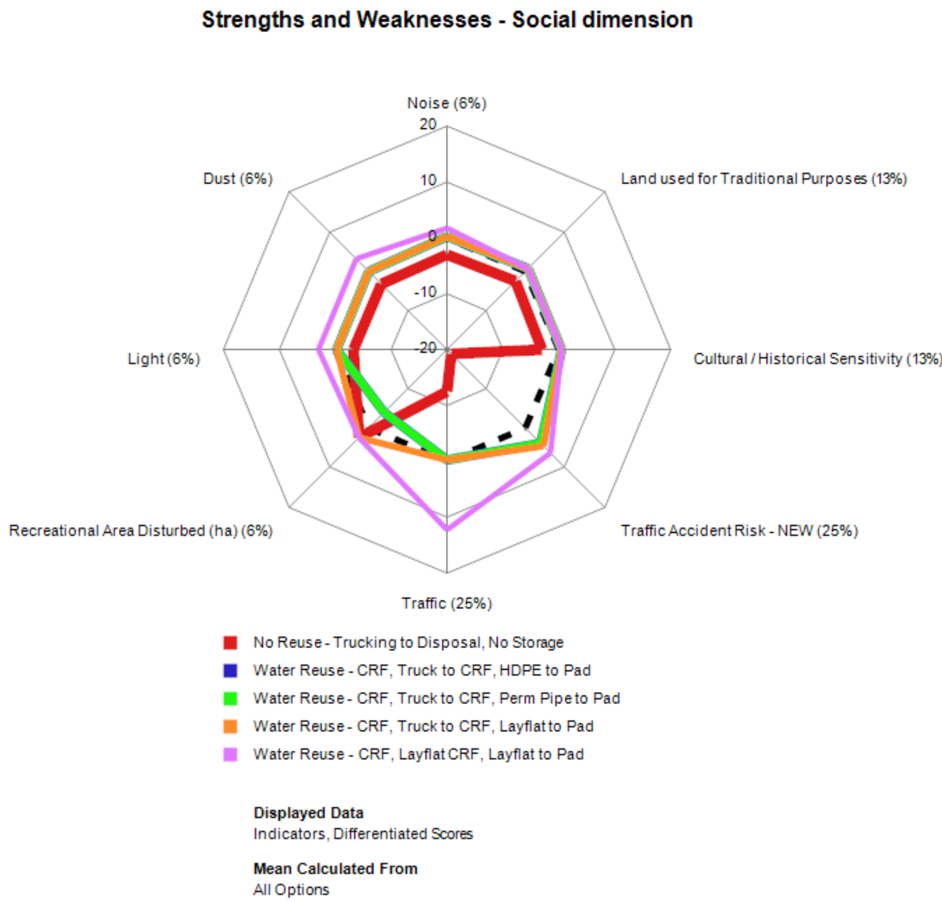

Figure 11: Differentiated scores- Social dimension.

In the Social Dimension, Scenario 5 displays clear advantages across indicators through the reduction in trucking activity.

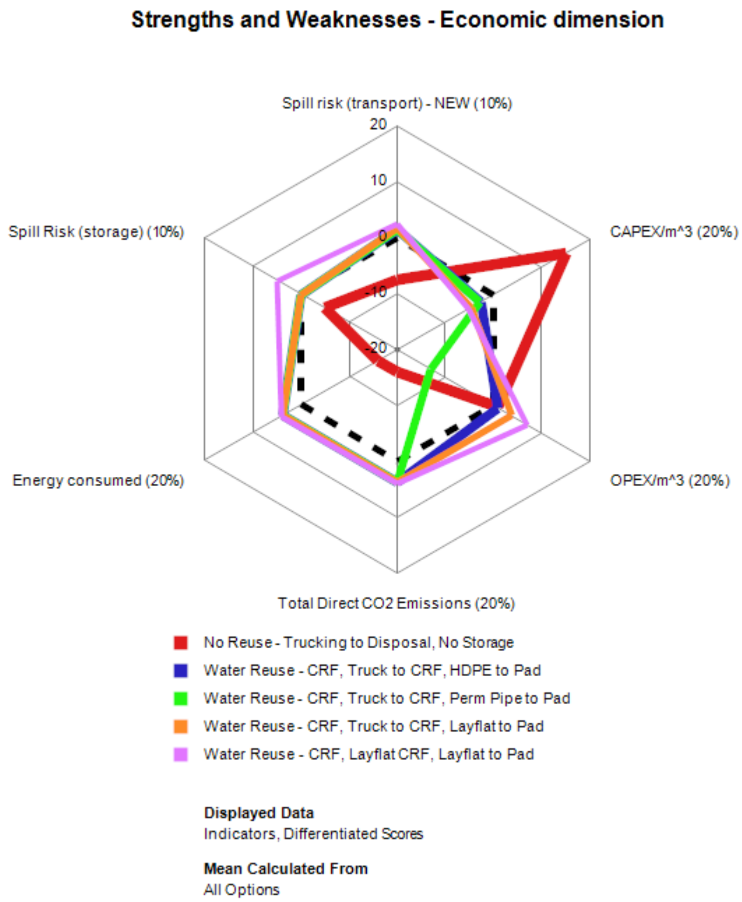

Figure 12: Differentiated scores- Economic dimension.

In the Economic Dimension several significant differences arise among options. Scenario 1 with no requirement for storage/treatment and relying on trucking and disposal wells has the lowest CapEx with all other options at similar levels. However, in terms of other main OpEx items Scenario 1 performs the worst. Decision makers face a trade-off between investments in capital items (e.g. storage) and reduced operating cost.

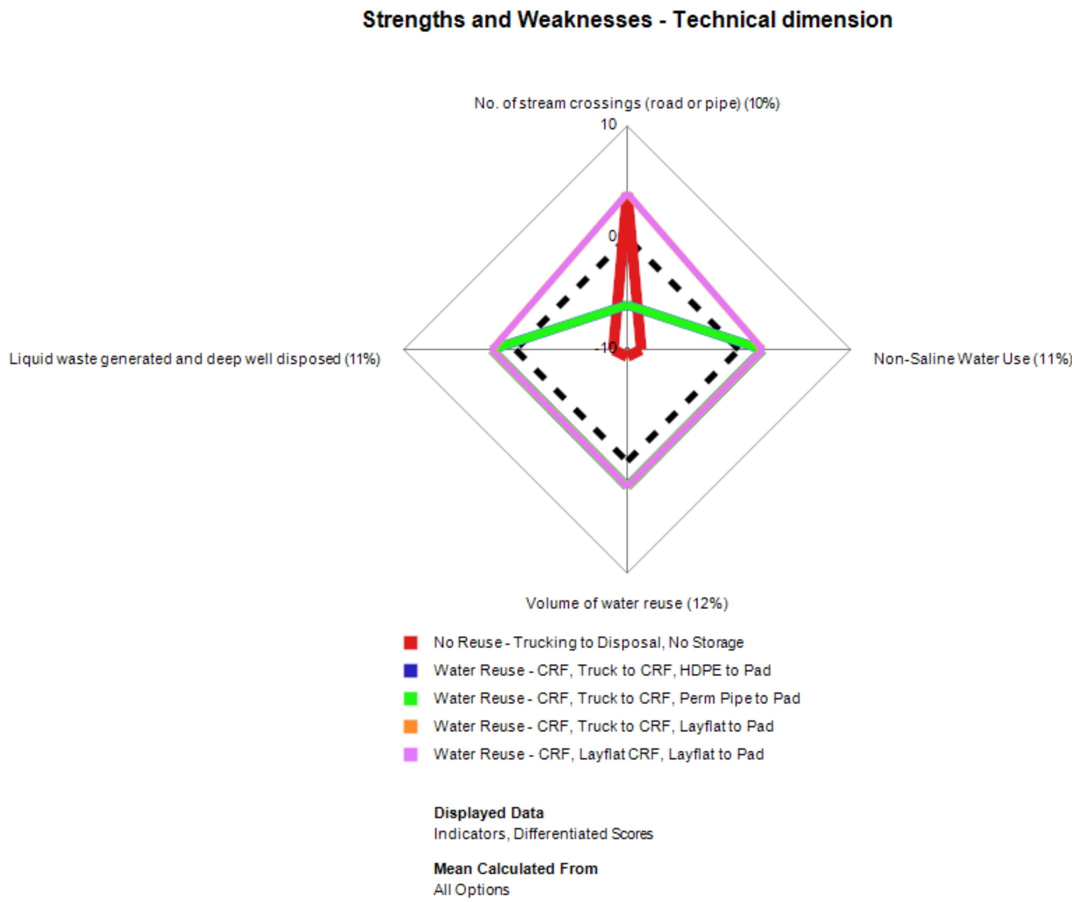

Figure 13: Differentiated scores- Technical dimension.

Finally, in the Technical Dimension large benefits resulting from water reuse can be appreciated independent of the water transport mode. It is worth noting that a reduction in freshwater use is reflected by a reduction in wastewater disposal with benefits in operating cost, environmental impacts and social impacts alike.

RESULTS – PTAC ENE Tool

The Water Innovation Planning Committee at PTAC has developed an initial version of a MS Excel based tool for ENE evaluation. This tool originated from a similar initiative in the Oil Sands sector and the tool was adapted from the version owned by the Canadian Oil Sands Innovation Alliance to meet the requirements of unconventional oil & gas production. The MS Excel tool differs slightly from the approach presented earlier in this report in that the user must determine all inputs for the ENE evaluation separately. Unlike the Hydropti software tool, the user is expected to determine the values of all indicators for the evaluation.

The main categories identified in the PTAC ENE tool include technical, economic, environmental and social metrics but categorized differently as shown in Figure 18 below.

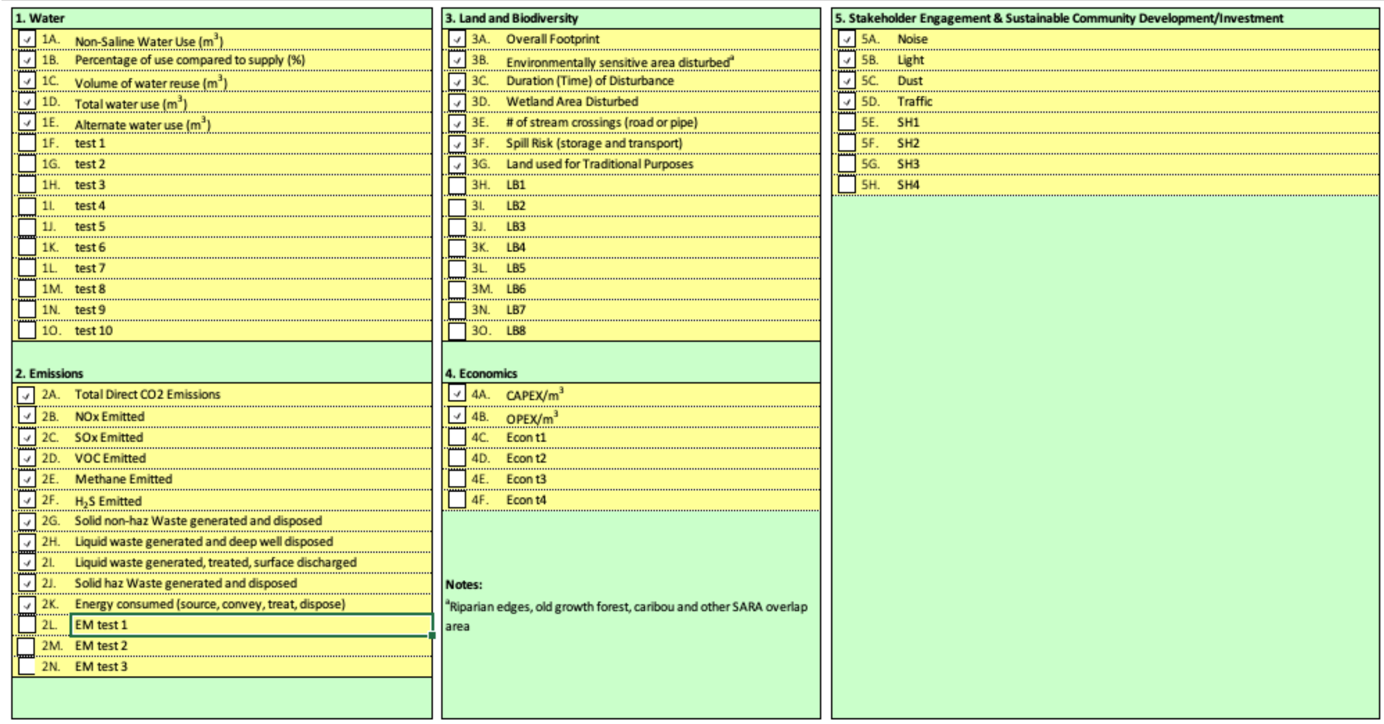

Figure 18: Key metrics in the PTAC ENE tool.

The PTAC ENE tool was setup to model the same five scenarios considered earlier and although the metrics are not identical across the various dimensions, all efforts were made to ensure the weighting factors and the key metrics were comparable between these approaches. The main results provided by the PTAC ENE tool are presented in Figure 19. As it can be observed from these results, both approaches (PTAC ENE and Hydropti-GoldSET) reach similar conclusions regarding the attractiveness of Scenario 5.

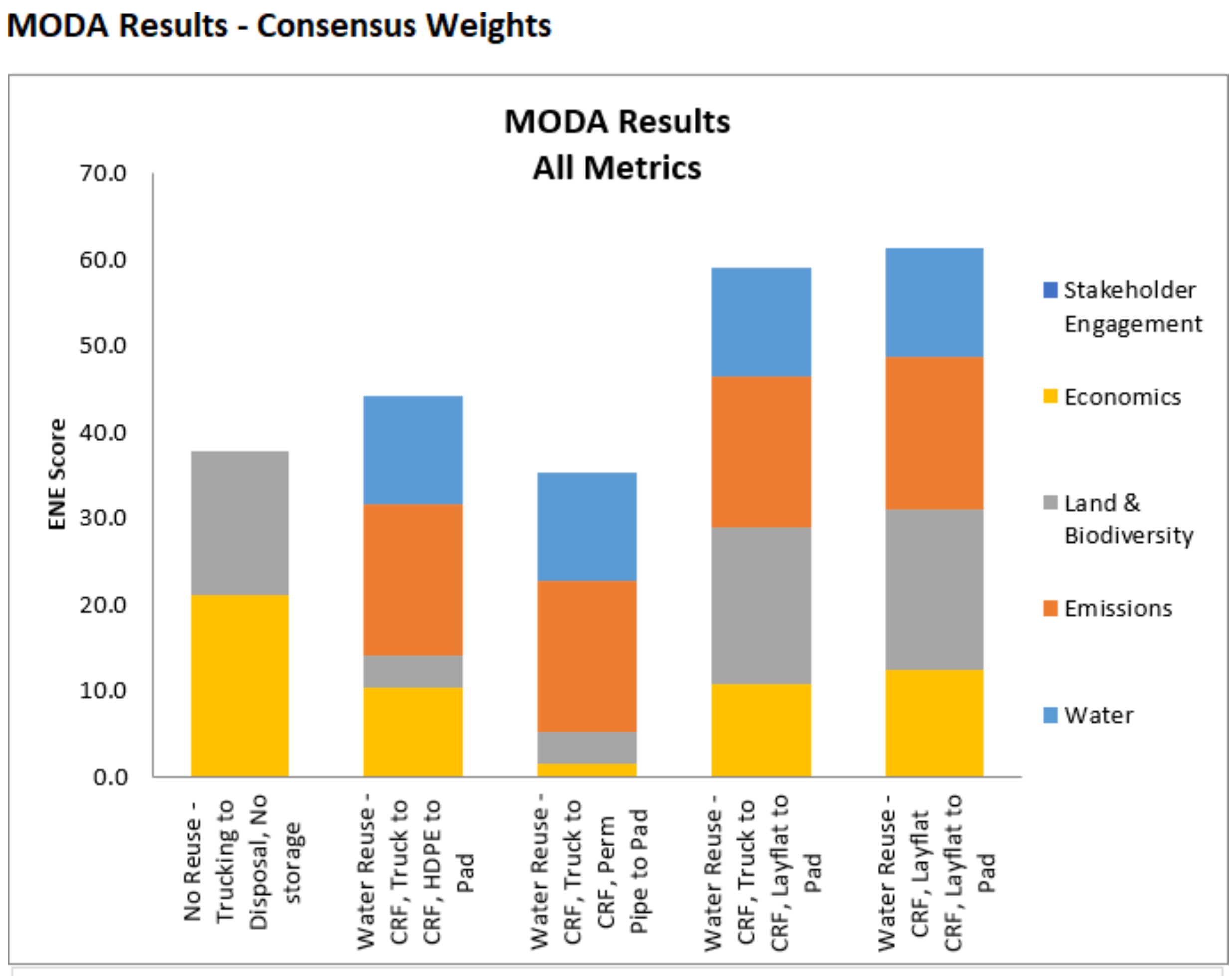

Figure 19: Multi-Operational Decision Analysis Results through ENE tool.

Key Findings

The key findings are as follows:

- The original PTAC ENE results were successfully replicated by the combined Hydropti and GoldSET tools.
- The results could be explored and interpreted graphically in far greater detail using the Hydropti GoldSET approach.
- Because Hydropti is able to compute the optimum version of each water management scenario, the user can be assured that they are evaluating the “best” and lowest-cost version of the scenario. This is not the case with the PTAC ENE tool where the user must rely on quantitative information calculated by other means which are likely not optimal.

Challenges encountered by the Study included:

- As this was a proof-of-concept study only, the process of evaluating and setting indicator weights was not done through a consensus workshop. Thus, all indicators in both models were evaluated equally. In reality, this would not be the case as many indicators are likely more important than others in the evaluation of water options. The evaluation of weights should be considered as a subsequent phase of the project.
- A further challenge related to the assessment of weights is the ability for users to “game” the model by adjusting indicator weights to best suit their desired outcomes. This could be avoided by locking the weights to some acceptable level. Ideally, these levels would be agreed upon by industry subject matter experts as well as the regulator and should be considered in a subsequent phase of the project.
- The calculation of the spatially derived metrics requires the use of sophisticated GIS analysis and access to public databases which may not be possible by all operators. A simpler approach to these metrics may be the use of presence / absence or yes / no qualifiers where operators can more easily screen for constraints and other risks. For example, the presence of a constraint corresponding to the footprint would be scored at 1, and an absence would be zero. The more constraints obtained would elevate the level of risk for these indicators and subsequently reduce the performance of that option against the corresponding dimension (e.g. environmental, social, technical or economic). These options can be implemented directly into the Hydropti tool.
- As noted earlier, the use of Hydropti means that the scenario results have been optimized which is not possible using the PTAC ENE Excel™ version of the tool.
- Manual data entry must still be done to configure the indicators regardless of the tool or approach selected. This can be time-consuming and introduces the possibility of data entry errors. A better approach would be to automate the exchange of data between the various tools. This could be accomplished in the next stage of work by expanding the Hydropti software to include a subset of the ENE metrics as well as similar graphics as presented in the GoldSET reports.

CONCLUSION AND RECOMMENDATIONS

Calculation of environmental net effects are required to support Water Act applications by operators. This project has evaluated two methods of measuring ENE using a fictitious well development program and several water management scenarios to meet the given water demand. Both tools are capable of measuring ENE with each method having their pros and cons. A common and simple to use method for operators to estimate ENE for given projects would be ideal and help support engagement with internal and external stakeholders.

To advance the development of an efficient, easy to use and transparent tool for operators to measure ENE of water management strategies we provide the following recommendations:

- Review results of current project with operators to get feedback and assess value to industry

- If there is value in developing an industry wide tool, launch a new project to work with industry to (1) define the tool framework (e.g. building Goldset algorithms into Hydropti tool) (2) optimum spatial indicators, and (3) initial indicator weightings

- Once tool is developed review results with AER and AEP and refine tool as required

In closure, we appreciate the opportunity to submit this report and have tried to be thorough in our assessment of services required to complete this assignment. We trust this report meets your current requirements. Should you have any questions or would like to clarify anything within this report, please do not hesitate to contact Alberto Alva-Argaez at (403) 690-0550 at your convenience.