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ESTIMATING MECHANICAL OIL RECOVERY WITH THE RESPONSE OPTIONS CALCULATOR

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ABSTRACT 299854:

Forecasting the actual effectiveness of mechanical oil spill response forces is known to be very difficult. Frequently, linear calculations such as estimated daily recovery capacity (EDRC) are used to predict the volume of oil that a response system can recover. While EDRC provides a standard approach to estimating on-water oil recovery based on a percentage of the skimming efficiency, this approach does not account for all of the real-world factors that may impact the actual recovery capacity of a given response force.

We have developed a method using the Response Options Calculator (ROC) program to estimate the on-water recovery capacity for a defined response force under various oil spill scenarios, incorporating transit times, spill timing, seasonality, and simplified environmental conditions. This provides more realistic recovery estimates than EDRC, and can be developed using a publicly available modeling tool that does not require a technical background.

This paper describes our recent experience applying the ROC to a series of hypothetical oil spills along the Pacific Coast of the U.S. and Canada. We explore the capabilities and limitations ROC, and explain the method we have developed. Our treatment includes a discussion of factors such as secondary storage, transit times, spill timing, seasonality and daylight, as well as model shortcomings and how to interpret the final outputs. The results produced by the ROC analysis may be used to inform oil spill contingency planning, response readiness assessments, and risk management.

INTRODUCTION:

This paper describes recent efforts to use ROC to predict response capacity in northern British Columbia (Nuka Research, 2012a, 2012b) and Washington State (Nuka 2012c). We applied ROC as an analytic tool for three separate response capacity analyses. In the first analysis, we estimated the total forces (vessels and equipment) required to meet an on-water recovery goal for a specified spill size within a given timeframe (Nuka Research 2012a). In the second analysis, we modeled existing forces in a small geographic region, to estimate on-water response capability and evaluate the marginal impacts of adding new pieces of equipment to the response system (Nuka Research 2012b). The third analysis modeled existing forces, this time on a regional scale and over a longer time period, to estimate capacity to recover large spills (Nuka Research 2012c).

All three analyses used the Response Options Calculator (ROC), which is a free, off-the-shelf spill-response performance estimator built by Genwest Systems, Inc. ROC combines a spill spreading algorithm (based on but considerably improved from NOAA's ADIOS 2 model) a built-in oil properties database, and the Spill Tools™ method for estimating oil recovery. [1] ROC was introduced at IOSC in 2011 (Dale, Allen, and Broje, 2011), and detailed information can be found in the user's guide (Dale, 2011) and technical manual (Genwest Systems Inc., Undated). The spreading algorithm is described in detail in a separate report (Galt & Overstreet, undated).

ROC can be used to predict on-water mechanical oil spill recovery capacity at the level of individual response systems. In contrast to approaches like estimated daily recovery capacity (EDRC), which predicts recovery based on skimming and pumping rates, ROC gives a systemic view of forces, taking into consideration multiple factors that can impact on-water recovery rates. We have developed methods for using ROC to determine best-case mechanical recovery in oil spill scenarios, incorporating transit times, spill timing, seasonality, and simplified environmental conditions. This provides more realistic recovery estimates than EDRC, for use in risk analysis and contingency planning. The method does not require a technical background.

METHODS:

The methods used varied slightly based on the scope and objectives of each analysis. This section first describes the three approaches, followed by a more detailed discussion of the methods used to apply ROC to response capacity estimates.

Analysis 1: Force-Size Forecast, British Columbia

The objective of this analysis (Nuka Research, 2012a) was to estimate the quantity of on-water response resources necessary to achieve a hypothetical 100% cleanup[2], for tanker spills of 10,000 m^3 originating from several hypothetical spill sites in Northern British Columbia. ROC was used to calculate an estimate of the equipment and vessels that would be required in direct recovery task forces to contain and recover a 10,000 m^3 oil spill in a generic open water location and a generic channel location in different seasons, and with different spilled product. Based on the ROC model outputs for the 16 simulations run, the number of task forces required to contain and recover the 10,000 m^3 spills under idealized conditions within 72 hours was calculated. The results were expressed as a range of the total number of task forces required, with individual task force components specified so that the results could be used to identify the amount of response vessels, skimming systems, boom, personnel, and secondary storage needed to recover the modeled spill.

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[1] ROC is available for download at Genwest Systems, Inc.: http://www.genwest.com/roc

[2] 100% was a target selected to align with recovery goals proposed in documents relevant to regional oil transport, and to place the results in a clearly understandable context, not as a realistic recovery goal.

Analysis 2: Limiting Factors and Additions to Existing Forces, Washington State

The objective of this analysis was to identify limiting factors on mechanical recovery for response forces currently deployed in a defined geographic area, and to assess the marginal benefit of adding new recovery systems (Nuka Research, 2012b). The study was done for spills in the Strait of Juan de Fuca and offshore into the Pacific, using forces within close range. This investigation was constrained to initial response only, to examine early-spill recovery when response effectiveness is typically higher, and to prevent adding the complexity of cascading forces to the analysis. The ROC was used to simulate on-water recovery using an established set of response forces, based on local response contractor inventory. This created a benchmark for recovery, which was then used to evaluate the incremental changes in recovery expected from the addition of specific response resources, such as additional skimmers, and from changes to the spill location and oil type.

Analysis 3: Regional On-water Response Capacity Estimate, British Columbia

The objective of this analysis was to estimate total possible on-water mechanical recovery across British Columbia based on existing contractor resources in place in British Columbia and neighboring U.S. jurisdictions (Southeast Alaska and Washington). ROC was used to estimate regional response capacity, using scenario spills and methods similar to our work in Washington State (Nuka 2012b). Rather than performing detailed analysis of limiting factors, we then expanded the scenarios to include the addition of cascading forces, and alternative tactics such as nocturnal recovery.

General Method for Force-Size Forecasting

To use ROC to evaluate on-water recovery capacity, response forces must be defined. We approached this slightly differently in each analysis. To estimate the necessary size of a hypothetical force, we began by creating generic on-water task forces based on their response function. For our work in the northern British Columbia, we used as single Open Water Task Force based on an MSRC Oil Spill Response Vessel. However, the method is easily expanded to use multiple component forces, such as:

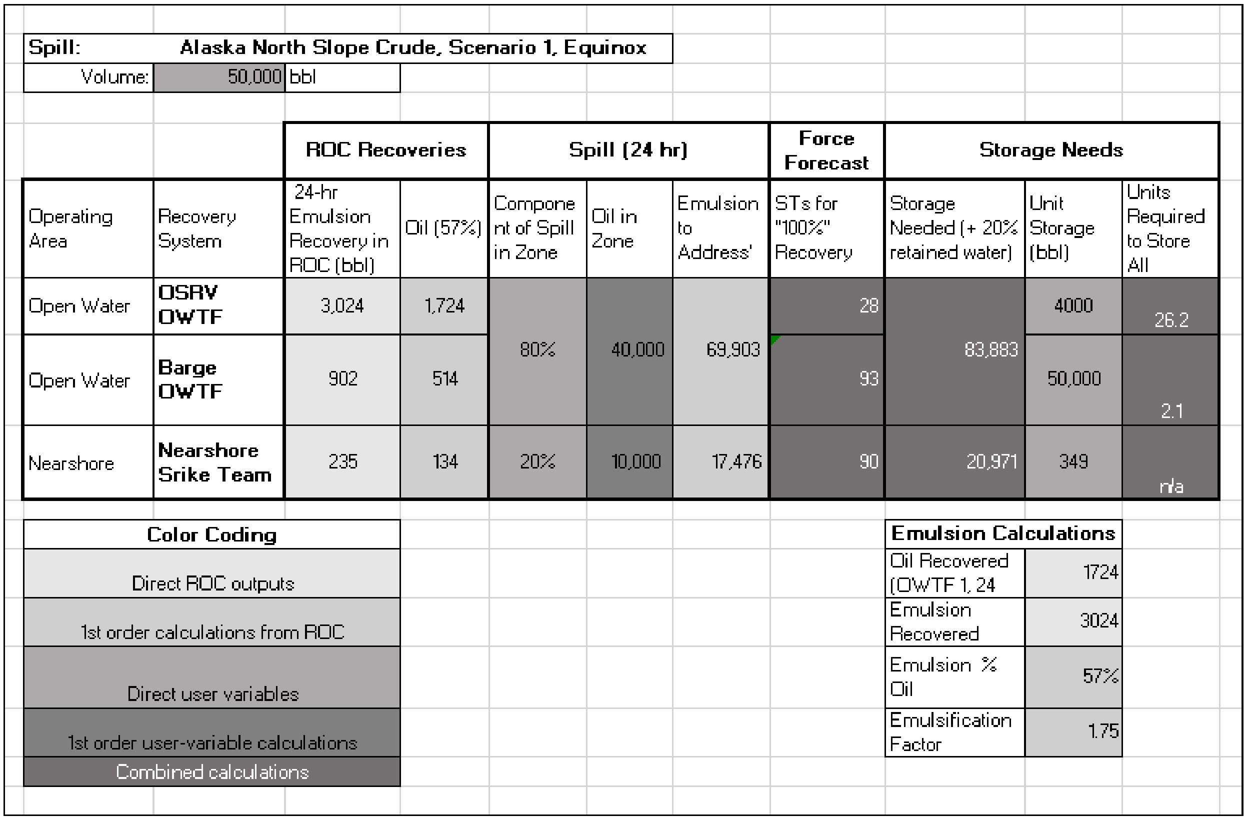
- **Generic Open Water Oil Recovery Task Force (OSRV OWTF).** Basis: Marine Spill Response Corporation (MSRC) Oil Spill Response Vessel (OSRV) equipped with a Transrec 150 skimmer, open water boom, and support vessels.
- **Generic Storage-Barge Based Oil Recovery Task Force (Barge OWTF).** Basis: 30,000 bbl Barge, Tugboat, Transrec 350 skimmer, open water boom, and support vessels.
- **Generic Nearshore Recovery Strike Team (NSTF).** Enhanced recovery boom, mini-barges, disc skimmers, vessels of opportunity.

The performance of each system can be evaluated in ROC, against target spills. The capacities of the task force components, along with some basic assumptions about efficiencies, become the basis for estimating total response capacity. For Analysis 1, the generic task force was built based on the authors' subject matter expertise to reflect best available technology. Figure 1 provides an example of the response variables associated with one of these hypothetical response forces, the OSRV OWTF.

Figure 2 shows the mechanics of calculating a force-needs forecast in a spreadsheet, using ROC. In Analysis 1, total estimated force requirements were calculated for a single type of task force across a range of oil types and spill locations. In an analysis where multiple types of forces are simulated (as displayed by Figure 2), recovery needs and potential can be calculated based on ROC results coupled with the allocation of oil to response area (offshore, nearshore, etc.), storage requirements, or other needs. The ROC results are extrapolated to estimate the total forces required to achieve a given recovery goal.

Specification	**Hypothetical Open Water Task Force**
Vessel(s)	(1) 63m OSRV (1) 10m support boat
Skimmer(s)	(1) TransRec 150 skimmer
Speed	0.33 m/s (0.75 mph)
Decant Efficiency	80%
Boom type and amount	Sea Sentry II (170cm) – 201 m
Swath width	36.5m (120 ft)
Onboard Storage	635 m^3
Nameplate Capacity	400 m^3/hr (weir skimmer)
Decanting Rate	340 m^3/hr
Discharge Pump Rate	1000 m^3/hr
Offload Time	4 hours (with 15 minutes for offload transits)
Start/End Times and Work Day Length	8 hrs 30 min (winter) 13 hrs (equinox) 18 hrs (summer)
Throughput Efficiency	75%
Recovery Efficiency	20%

Figure 1. Hypothetical OSRV-Based Open Water Task Force Characteristics



Spill: **Alaska North Slope Crude, Scenario 1, Equinox**

Volume: 50,000 bbl

		ROC Recoveries		**Spill (24 hr)**			**Force Forecast**	**Storage Needs**		
Operating Area	Recovery System	24-hr Emulsion Recovery in ROC (bbl)	Oil (57%)	Component of Spill in Zone	Oil in Zone	Emulsion to Address'	STs for "100%" Recovery	Storage Needed (+ 20% retained water)	Unit Storage (bbl)	Units Required to Store All
Open Water	**OSRV OWTF**	3,024	1,724	80%	40,000	69,903	28	83,883	4000	26.2
Open Water	**Barge OWTF**	902	514				93		50,000	2.1
Nearshore	**Nearshore Srike Team**	235	134	20%	10,000	17,476	90	20,971	349	n/a

Color Coding
Direct ROC outputs
1st order calculations from ROC
Direct user variables
1st order user-variable calculations
Combined calculations

Emulsion Calculations	
Oil Recovered (OWTF 1, 24	1724
Emulsion Recovered	3024
Emulsion % Oil	57%
Emulsification Factor	1.75

Figure 2. Example of a dynamic spreadsheet used to calculate conclusions from ROC Outputs.

General Method of Predicting the Capacity of Existing Forces

ROC can also be used model the capacity of actual response forces, on the scale of individual recovery systems, providing insight into capabilities and shortcomings of existing forces. For Analyses 2 and 3, the individual strike teams were compiled from a set of available resources based on contractor data.[3] Similar to Analysis 1, these recovery systems were entered into ROC and deployed on scenario spills. Figure 3 displays an example of how we organized existing response forces for Analysis 2, prior to entry into ROC. In this example, three strike teams (Kittiwake, Auklet, and Pintail) were compiled from local equipment caches and assigned to recovery in appropriate operating environments. (Nuka, 2012c)

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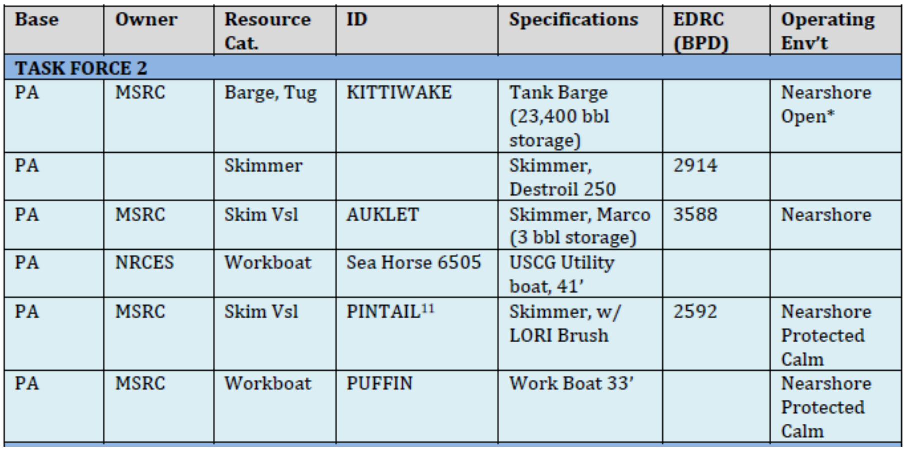
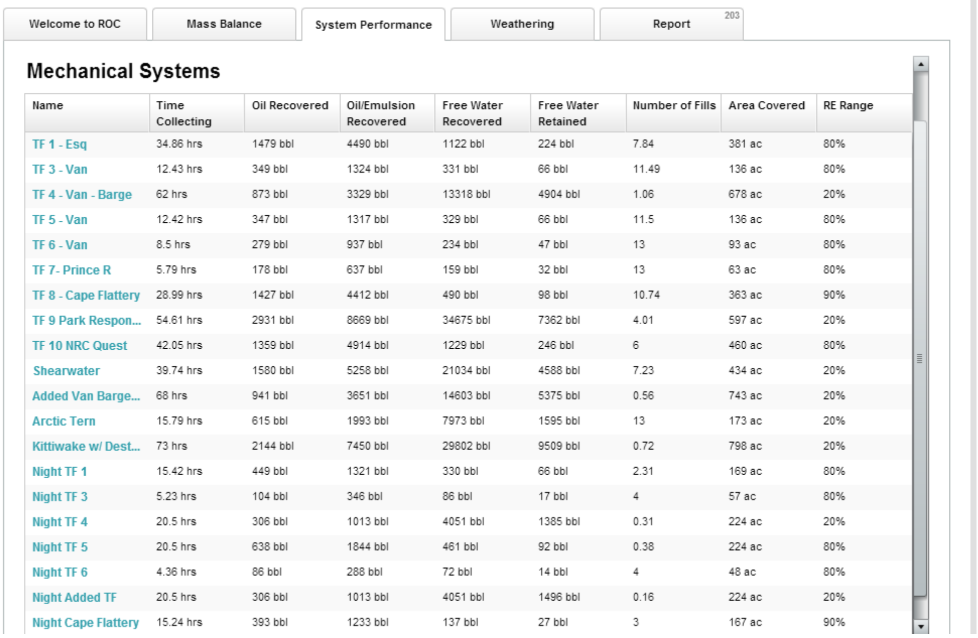
[3] Since most planning-related documents do not contain the full set of data required for a ROC scenario, this methodology involves augmenting planning documents with manufacturer's equipment specifications, industry-standard data sources, and expert opinion. When possible, our methodology involved querying local response managers and applying their rules-of-thumb for response force composition.



Base	Owner	Resource Cat.	ID	Specifications	EDRC (BPD)	Operating Env't
TASK FORCE 2						
PA	MSRC	Barge, Tug	KITTIWAKE	Tank Barge (23,400 bbl storage)		Nearshore Open*
PA		Skimmer		Skimmer, Destroil 250	2914	
PA	MSRC	Skim Vsl	AUKLET	Skimmer, Marco (3 bbl storage)	3588	Nearshore
PA	NRCES	Workboat	Sea Horse 6505	USCG Utility boat, 41'		
PA	MSRC	Skim Vsl	PINTAIL[11]	Skimmer, w/ LORI Brush	2592	Nearshore Protected Calm
PA	MSRC	Workboat	PUFFIN	Work Boat 33'		Nearshore Protected Calm

Figure 3. Spill scenario locations and an assembled Task Force

Once the configured strike teams are entered into ROC and matched to a specific scenario, detailed outputs estimate oil recovery can be produced, as seen in Figure 4. In this figure, the rapid proliferation of forces that occurs in such an analysis is clearly visible. "Night" forces are night-time iterations of all daytime forces, set to reduced encounter rates. Creating the displayed forces required more than 450 individual settings to be entered in ROC, some of which were generated by spreadsheet calculations (for example, spill arrival times).



Mechanical Systems

Name	Time Collecting	Oil Recovered	Oil/Emulsion Recovered	Free Water Recovered	Free Water Retained	Number of Fills	Area Covered	RE Range
TF 1 - Esq	34.86 hrs	1479 bbl	4490 bbl	1122 bbl	224 bbl	7.84	381 ac	80%
TF 3 - Van	12.43 hrs	349 bbl	1324 bbl	331 bbl	66 bbl	11.49	136 ac	80%
TF 4 - Van - Barge	62 hrs	873 bbl	3329 bbl	13318 bbl	4904 bbl	1.06	678 ac	20%
TF 5 - Van	12.42 hrs	347 bbl	1317 bbl	329 bbl	66 bbl	11.5	136 ac	80%
TF 6 - Van	8.5 hrs	279 bbl	937 bbl	234 bbl	47 bbl	13	93 ac	80%
TF 7- Prince R	5.79 hrs	178 bbl	637 bbl	159 bbl	32 bbl	13	63 ac	80%
TF 8 - Cape Flattery	28.99 hrs	1427 bbl	4412 bbl	490 bbl	98 bbl	10.74	363 ac	90%
TF 9 Park Respon...	54.61 hrs	2931 bbl	8669 bbl	34675 bbl	7362 bbl	4.01	597 ac	20%
TF 10 NRC Quest	42.05 hrs	1359 bbl	4914 bbl	1229 bbl	246 bbl	6	460 ac	80%
Shearwater	39.74 hrs	1580 bbl	5258 bbl	21034 bbl	4588 bbl	7.23	434 ac	20%
Added Van Barge...	68 hrs	941 bbl	3651 bbl	14603 bbl	5375 bbl	0.56	743 ac	20%
Arctic Tern	15.79 hrs	615 bbl	1993 bbl	7973 bbl	1595 bbl	13	173 ac	20%
Kittiwake w/ Dest...	73 hrs	2144 bbl	7450 bbl	29802 bbl	9509 bbl	0.72	798 ac	20%
Night TF 1	15.42 hrs	449 bbl	1321 bbl	330 bbl	66 bbl	2.31	169 ac	80%
Night TF 3	5.23 hrs	104 bbl	346 bbl	86 bbl	17 bbl	4	57 ac	80%
Night TF 4	20.5 hrs	306 bbl	1013 bbl	4051 bbl	1385 bbl	0.31	224 ac	20%
Night TF 5	20.5 hrs	638 bbl	1844 bbl	461 bbl	92 bbl	0.38	224 ac	80%
Night TF 6	4.36 hrs	86 bbl	288 bbl	72 bbl	14 bbl	4	48 ac	80%
Night Added TF	20.5 hrs	306 bbl	1013 bbl	4051 bbl	1496 bbl	0.16	224 ac	20%
Night Cape Flattery	15.24 hrs	393 bbl	1233 bbl	137 bbl	27 bbl	3	167 ac	90%

Figure 4: ROC-generated System Performance results from modeling BC, WA, and AK forces. *(Image captured from ROC).*

DISCUSSION:

The application of ROC to the three response capacity analyses highlighted both the power and the limitations of this tool. Through our experience, we developed several best practices for applying and interpreting ROC outputs.

Limiting & Compounding Factors

ROC calculates the effectiveness of a tactic based on the interaction of numerous factors, and the outputs provide a means for evaluating a response tactic or force not as a collection of individual parts, but as an integrated system. This process highlights both limiting and compounding factors as they impact on-water mechanical recovery.

Limiting Factors essentially cap the effectiveness of a tactic, regardless of the specifications of other parts of the system. For instance, in ROC, no system – regardless of skimmer nameplate rate or efficiency – can collect more oil than it encounters. This rate is determined by boom swath width, advance speed, and the thickness of the slick.

Compounding Factors are those factors which have a multiplicative impact on recovery. For instance, skimmer nameplate rate, skimmer efficiency, and encounter rate all compound together, to produce oil recovery. A change in any one of these factors (as well as in other factors) will affect recovery.

Interpreting ROC Outputs

Any use of ROC will yield a common set of outputs, which include mass balance diagrams, system performance tables, and weathering charts. Each output informs the evaluation of recovery system performance and limitations.

Mass Balance

The mass balance output gives a high-level view of response force performance, and interpreting it properly provides crucial insights. It reveals behavior over time, which is not visible in the other ROC outputs. Significant features that are displayed in the recovery curve include:

- Decreasing recovery over time; as the spill spreads, recovery rates decline.
- Variations in continuous recovery rates, visible as “angle breaks”, where individual recovery systems either fill their primary storage, or return to recovery operations after offloading oil.
- Flat “plateaus” due to force-wide recovery shut-downs.

The mass balance diagram in Figure 5 reveals a very common pattern in ROC: a stair-step structure overlaid on a large-scale pattern of decreasing recovery over time. There are two recovery plateaus and several early angle breaks. The early stair-step structure (hour 6 to 9.5) is due to a recovery shut-down, caused by late arrival of the secondary storage barge (it did not arrive until hour 9.5). The later plateau is associated with night-time hours (hour 16 to 2.7.5). These are the two common causes of plateaus, and must be differentiated by user investigation.

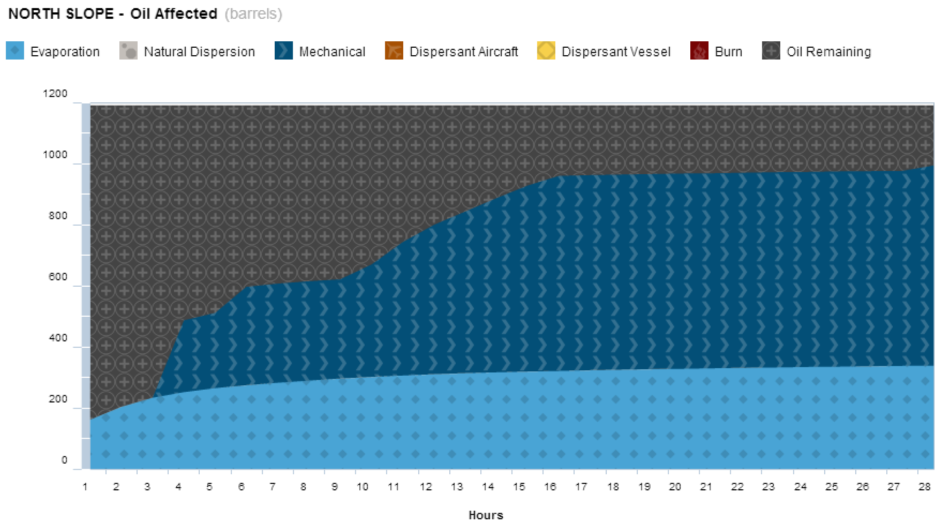


Figure 5: ROC-generated Mass Balance Diagram for actual forces responding to a 50,000 gallon spill of crude oil *(Nuka, 2012c, image captured from ROC).*

For our analyses of existing response capacity in Washington State (Nuka 2012b) and British Columbia (Nuka 1012c), the mass balance diagram was central. In Washington, it revealed that the addition of more skimming capacity to existing forces had marginal impact, due to limits on primary storage – and that although adequate secondary storage could be mobilized immediately, it did not arrive at 2 out of 3 scenarios in a timely fashion, and therefore the critical consideration for on-water storage was not *quantity* but *arrival time*. In British Columbia, the mass balance diagrams revealed similar challenges, as well as the marginal impact of most cascading forces, which arrived too late in the spill to have a major effect. In all three analyses, the mass balance diagrams revealed the impact of seasonality on mechanical recovery. The mass balance diagram also revealed the different recovery patterns over time expected on large spills (where total recovery is higher, but recovery percentage is lower) and small spills (where, conversely, total oil recovered is lower, but the percentage of spill recovered is higher), and highlighted the diminishing returns expected from deploying additional forces on smaller spills.

System Performance

The system performance output contains granular data on the performance of each response system. The data summarized as system performance outputs, shown in Figure 4, provides insight to operational factors. For instance, "number of fills" indicates how many offloading cycles a given system had. This provides insight on offloading congestion, and may inform overall resource management during a spill response.

For example, if one Nearshore Strike Team had 12 fills in 24 hours, and 15 Nearshore Strike Teams are required to make the recovery objective, that yields (12 x 15) = 180 offloading operations. At 4 hours for each offloading operation, this is 720 offloading hours. For this to be achieved in 24 hours, the secondary storage barges must have 30 offloading stations. By this model, 2 storage barges with 15 stations each, manned 24 hours/day, would technically be adequately *if fill and offloading cycles were perfectly staggered.* Since they will not be perfectly staggered, more stations will be required to keep up with the rate of oil recovery. This level of information can be used when making decisions about resource procurement and stockpiling.

Oil Weathering Charts

ROC produces 8 separate charts on oil weathering, including slick thickness, area, emulsification, and viscosity. The charts that proved the most relevant information for our analyses were viscosity and emulsification.

Viscosity is a key constraint on recovery. As spilled oil weathers and emulsifies, viscosity increases. Although some newer pumps can process high viscosity oils, many skimmers experience declining effectiveness with increased viscosity.[4] Our best practice included examining the oil viscosity chart and comparing it to skimmer limits, as shown in Figure 6. Modeled for a McKay Heavy Bitumen spill, this ROC weathering output suggests that weir skimmers may be effective for the first 24-36 hours (approximated from the 32 hour ROC prediction). After that time, high viscosity skimmers may be required. The ROC weathering model is only an approximation, but it does yield an indication of probable viscosity problems, and recommends follow-up research with laboratory analysis. In all three of our analyses, viscosity emerged as a key limitation, particularly for heavy (Class IV-V) oils.

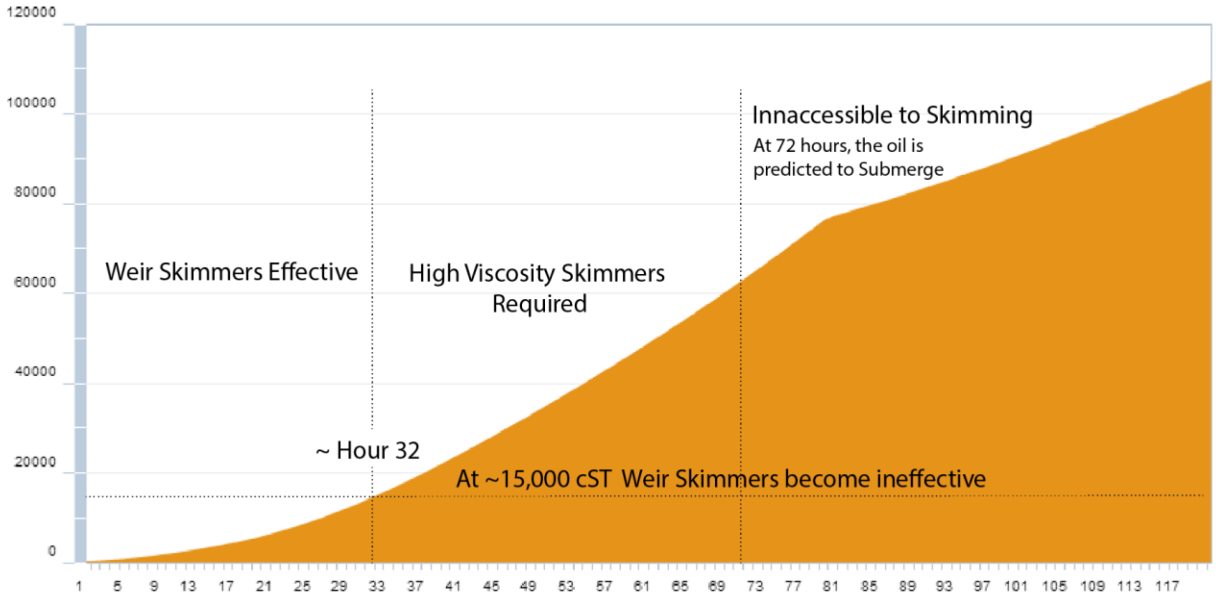


Figure 6: Viscosity graph used to identify critical skimming threshold.

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[4] High viscosity skimmer heads, now in development and production, may be able ingest more viscous oil, but their rate of recovery under practical conditions is not well established. Most skimmers in existing caches are not high-viscosity capable.

The emulsification chart can also inform the overall system analysis. As shown in Figure 2, we use recovery results to calculate an emulsion factor from system performance when discussing the likely total emulsion (and hence storage needs) for each response period, rather than simply taking a number from the emulsification chart and using it to predict storage requirements. The latter would be inaccurate, since it would not account for different emulsions recovered, in different quantities, over time. Including the emulsification chart, however, is still important for two reasons:

- **To display ROC's emulsion assumptions.** This allows reviewers and users of the final outputs to compare to the analysis outcomes to real weather data for a representative oil, where it is available, and adjust their conclusions. ROC emulsion is an assumption, equally as important as skimmer efficiencies or vessels speeds.
- **To develop comparative analyses** of early vs. late spill recovery efficiency and storage needs. The emulsion curve indicates the "cost" of delayed recovery, in terms of additional skimmer capacity required, storage needed, and potential skimmer failure.

Submerging Oil

In ROC, oil always remains on the surface and accessible for recovery. However, if a time can be established for plausible oil submergence, it can be used as a hard cut-off for recovery. At that time of submergence, on-water tactics are considered to lose their effectiveness. Such a "cut-off time" is displayed in Figure 6.

Transit Times, Working Periods, & Spill Timing

In ROC, the timing of forces arriving at a spill has a significant impact on the recovery results, and should be carefully considered. The fundamental timing of the scenario couples with transit times to create two key factors in recovery: the delays until recovery begins, and the lengths of the first working periods. In all three of our analyses, we found transit times needed to be assessed carefully in a dedicated spreadsheet, and our methodology for arriving at them needed to be clearly described in the final report.

Our transit time estimates considered geographic distance, water speeds of individual vessels, and expected mobilization time, plus allowances for spill notification and dispatch. Day length and its resultant impact on the length of the first working period is critical to recovery estimates. Wherever possible, these assumptions should be verified to improve ROC estimate accuracy. The influence of these assumptions on recovery estimates are summarized in Table 1.

Table 1: Spill Timing & Transit Time:

Forces Arrive At:	Performance Given:
Dawn of the 1st working period	Best-case performance.
At a time that gives them their mathematically expected 1st working period	Expected /average performance.
Dusk of the 1st working period, and loiter overnight	Bad-case performance.
Forces have varied arrival times	*Varied, complex.*

In all three of our analyses, we relied on the optimistic assumption that all forces arrive at dawn of the first working period, thus maximizing recovery potential.[5] When modeling real forces distributed over different home ports, arrival times will vary, and the recovery implications of mobilization and deployment times may be complex. Conversely, the ROC model could be applied to evaluate potential staging areas based on transit times to high priority recovery areas.

Consistent Bias

Throughout all three analyses, we were faced with a series of judgment calls that had the potential to bias model outputs. For consistency, we chose to apply an optimistic bias across the board (Figure 7). By introducing a systematic bias towards optimistic results into assumptions, the resulting outcome will yield a best-case performance. We found this approach to generally align with the implicit optimistic bias in the ROC model, which always assumes recovery takes place in the thickest oil. ROC reduces recovery efficiencies based on the assumption of fully developed seas, from the scenario windspeed, but does not account for various other environmental-based limits on recovery, like vessel icing, crew safety, and shore stranding. Consistent application of assumption bias provides a level field for evaluating and comparing results across simulations. It is also a reminder that ROC recovery estimates do not provide absolutely accurate, real-world recovery estimates, but instead provide bounding estimates ("best case" etc.) and effective means of comparing relative performance for different response forces and different spills.

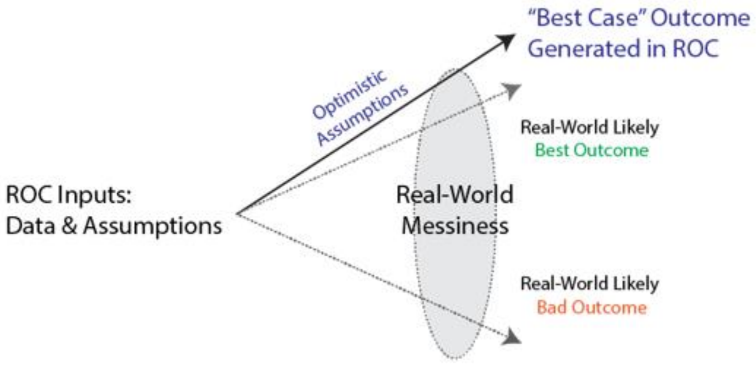

Figure 7: Using optimistic assumptions to create a systematic bias, making the results into a meaningful "best case" bracket on recovery.

A more sophisticated approach would be to automate input of scenarios into the ROC program, adjusting variables (like wind, temperature, encounter rate, and forces deployed) across realistic value distributions, and then input them through ROC in a Monte Carlo analysis. The resulting set of outputs would represent a numerous realistic scenarios, and the user could then

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[5] A more mathematically complex, but realistic, method is to calculate the average expected first working period, and adjust transit times accordingly. This method is beyond the scope of this paper. Also, in some situations, timing the spill so that the first forces to arrive do so at dawn will *not* result in best-case recovery. This occurs when small forces arrive earlier, and large definitive forces arrive later, and thus receive only a truncated first shift. The user must consider this possibility.

aggregate the results to produce statistical summaries of the recovery outcomes and optimal force configurations.

Limitations of ROC

ROC does not account for the many variables of a real oil spill and has a number of inherent limitations that should be considered in presenting and interpreting oil recovery results. For example:

- ROC is sensitive to assumptions. Assumptions should always be clearly stated.
- Support forces such as crew shuttle, spill tracking and observation, logistics, and human services are not considered in ROC.
- Environmental conditions are considered only in simple form. Wind and water temperature are taken into account for spill weathering and spreading rates, and sea state is modeled from wind to affect oil weathering and reduce recovery efficiency (Galt & Overstreet, undated). Degradation of response effectiveness based on the interaction of environmental conditions with equipment function is considered only in the forms of working period length (daylight) and reduction of recovery efficiency due to wind-derived sea state.
- ROC allows for a delayed arrival of secondary storage, but otherwise does not account for secondary storage limits to overall response. Secondary storage arrangement can reduce or halt recovery when storage is filled, when congestion occurs during offloading, or when temporary storage device transit times are increased.
- Decanting is only supported in primary storage, not secondary storage. Real-world experience has confirmed that, particularly for small temporary storage containers, decanting is not practical during primary storage, but that it is frequently practical in large secondary storage containers, such as barges.
- Total storage required is not directly listed in ROC, and must be manually calculated.
- The simplicity of the ROC weathering model and the deterministic nature of its calculations must be acknowledged.

Relationship to ESRP

Our ROC work was conducted separately from and concurrently with the development of the new Estimated Recovery System Potential (ERSP) method for evaluating on-water mechanical recovery systems (Allen, Dale, Galt & Murphy, 2012). There are many similarities in our approaches, and it bears note that ROC was itself originally developed by the developers of ERSP, and was itself used as a basis for developing ERSP. ERSP incorporates the most salient factors that determine a system's recovery capacity into a more streamlined, but slightly less sophisticated, package. ERSP is designed to be a meaningful way to rate response systems' potential, and thus it produces a comparable, relatively "portable" rating for each system. ROC, in contrast, produces results that are specific not merely to the system chosen, but to a given spill scenario and oil type.

The efforts of Allen et al. (2012) support our observation that EDRC does not provide a realistic predictor of spill recover potential. Like our ROC analyses, the ERSP work considers spill response systems holistically and attempts to integrate some of the subtleties and complexities that influence actual on-water mechanical recovery.

CONCLUSIONS:

The Response Options Calculator was applied in three separate analyses to answer three distinct questions: (1) “how many task forces are required to recover a representative spill volume?”; (2) “how much oil could be recovered with a given resource set under certain conditions?”; and (3) “what the impact of adding or moving key equipment on overall on-water recovery capacity?” In all three cases, ROC provided a way to quantitatively analyze mechanical recovery, allowing us to evaluate overall capacity and consider how changes to spill characteristics and response forces may impact on-water spill response. The recent publication of the ERSP model may provide a (deliberately) less specific and more portable, accessible tool that can be applied to similar planning or preparedness analyses.

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