Preparedness Decision Making in Offshore Oil and Gas - How much is enough?

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ABSTRACT 2017-125:

A key challenge in offshore oil spill contingency planning is determining how much preparedness is enough. In other words, planning what types and quantities of oil spill response equipment, resources, and expertise ought to be held in readiness and with what mobilisation and deployment times, just in case a major oil spill occurs. For the offshore oil and gas sector much of the information required to plan for a response to a major incident, such as the location of the spill source, oil type, potential release rate and volume, local climate and metocean conditions, and environmental sensitivities, is already known or can be predicted. In this paper a process for determining appropriate levels of preparedness for offshore oil spill risk is proposed and analysed outside the realm of specific national regulatory frameworks. It is suggested that the approach has validity across all jurisdictions and is consistent with the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC). The approach begins with detailed activity and location-specific oil spill risk assessment which produces information on *response needs*, which is subsequently used in strategic and tactical response planning processes to describe the necessary response *equipment and resources*. Once the response resource requirements are established, optimal *preparedness arrangements* can then be designed that are specific to the nature and scale of the risk and the availability/ criticality of the required response resources.

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INTRODUCTION

For spill response planning in the offshore oil and gas (O&G) sector, advance planning is important because of the potentially large spill volumes and long spill durations that can occur as a result of a loss of well control event. The upside is that the very nature of O&G exploration, development and production activity allows high levels of response planning to occur. For example, much of the information required to plan for a response to a major incident is already known or can be predicted, such as the location of the spill source, local climates and metocean conditions, and environmental sensitivities, even the oil types and volumes. Unlike other key sources of marine oil spill risk (e.g. passing ship risk), O&G activity is always tied to pre-activity regulatory approval, meaning that potentially affected environments can be studied in detail and protection priorities worked out in advance, before the risk commences. Further, rather than relying on what response resources may already be available on site or on call, activity-specific risk assessment can be used to tailor response capacity plans and preparedness arrangements to the specific nature and scale of the risk before that risk arises. In some cases relevant regional or area contingency plans may have already been prepared by government and/or industry, possibly with key stakeholders. In all these areas a technical dialog between the regulator and industry can help ensure that response capacity is in line with the location and activity-specific response need.

OPRC speaks to this issue of preparedness decision making, recommending oil spill preparedness arrangements ensure '…pre-positioned oil spill combating equipment, commensurate with the risk involved'. Of course, a common challenge across all jurisdictions is interpreting and developing working measures for the concept of 'commensurate with', in other words, practically defining 'how much is enough?'

Offshore O&G regulators around the world appreciate the challenges faced by operators working to meet their preparedness obligations. A group of national regulators formed in 2013 under the banner of the International Offshore Petroleum Environment Regulators (IOPER) has been working globally with industry for several years to understand the common challenges associated with offshore oil spill response to develop guiding principles and other tools to optimise preparedness.[1] This paper is a continuation of work by IOPER members to develop internationally-applicable advice for developing, demonstrating, and regulating oil spill response preparedness in the offshore O&G industry. In line with the global character of IOPER, the suggested approach for determining appropriate levels of preparedness is discussed outside the realm of specific national regulatory frameworks.

SCOPE

The paper is focused on oil spill contingency planning for large-scale marine oil spills from the exploration and production of O&G from fixed or floating facilities, including their associated seabed infrastructure, such as wellheads, flow lines or pipelines. Related topics of vessel spills, prevention, Spill Impact Mitigation Analysis (SIMA)[2], health and safety, stakeholder engagement, and specific legislative requirements are acknowledged as relevant and important, yet beyond the scope of the paper. The ideas and discussions belong to the authors and do not necessarily represent policies of any particular IOPER member agency.

PROCESS

There is neither a single ‘correct’ way to respond to an oil spill nor a universal standard for preparedness. In fact, approaches to planning and preparedness can differ greatly across jurisdictions. One commonality, though, is the general scope for improvement in pre-incident response need and capacity determination. In other words, in addition to laying out the basic response strategies and sources of equipment, identifying for planning purposes more specifically what the probable response tasks may look like, and determining what resources

[1] See the IOPER website for more detail on guiding principles at http://www.ioper.org/priority-issues/
[2] SIMA is newly proposed terminology for Net Environmental Benefit Analysis (NEBA). The change has been suggested to reflect the feeling that there is no “benefit” created by an oil spill.

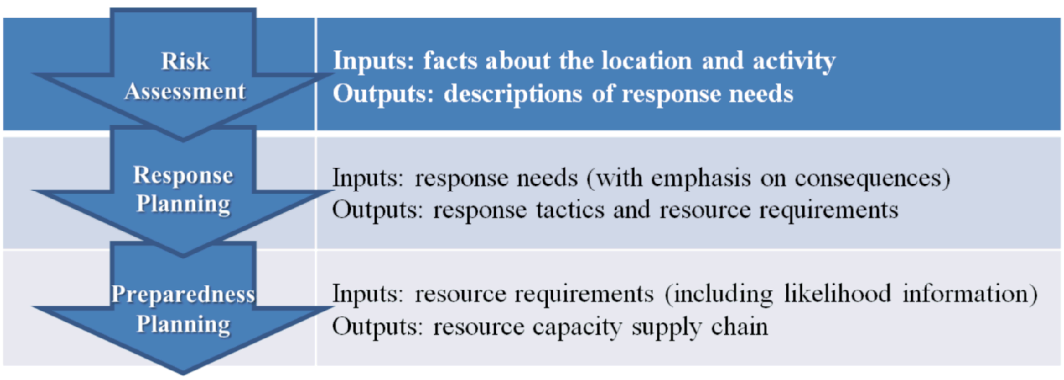
may best match these tasks, for example in terms of quantities, locations and timing. The planner must not only consider assets and personnel to be deployed immediately to the spill site, but also those required for the expected duration of the response, as well as arrangements for holding these assets in a state of readiness. Such systematic and detailed, forward-looking contingency planning is fundamental to sound preparedness.

One approach to response planning is to acknowledge that oil spill contingency planning is really made up of three distinct, yet interrelated, phases:

- Activity and location-specific **risk assessment** to determine the response need based on the spill scenario and threatened resources.
- Strategic and tactical **response planning** to technically evaluate, select and scale response countermeasures to meet the response need.
- Risk-based **preparedness planning** to ensure that sufficient arrangements are in place for the required response resources and expertise.

By clearly differentiating between the risk-based need, the resources best suited to address that need (e.g. equipment, expertise, manpower), and the arrangements to provide those resources when and where required, contingency planners who implement these three phases will be in a position to develop and justify sound estimates for the appropriate quantities, capabilities, and timeliness of supplied equipment and resources. In this way they will be able to answer the 'how much is enough?' question in a defensible manner.

FIGURE 1 – The three phases of contingency planning



Oil spill risk assessment

Oil spill risk assessment [3] is the initial stage of contingency planning when the risk-based oil spill response needs for a specific offshore activity are identified. It begins by gathering together various sources of information relating to the likelihood and consequence of hazardous events arising from the proposed petroleum activity. Among other things this input information should include:

- Description of the activity, including activity type, location, and timing.
- Description of the oil-spill-relevant hazards, including spill-hazard scenarios, potential release duration/flow rates/volumes, and oil characteristics.
- Likelihood of occurrence of the relevant (and possibly aggregated) hazards.
- Information on the physical and environmental characteristics of the receiving environment, including historical metocean conditions and seasonal variations.
- Data on the environmental, cultural, and economic sensitivities and values of the area.

Analysis is then undertaken of likelihood and consequence of hazardous events according to established risk assessment practices. It should be noted, however, that for the ultra-low-likelihood/high-consequence risks discussed in this paper the emphasis at this stage is decidedly on consequence analysis. One reason for this is that focusing too much at this stage on the fact that the likelihood is very low tends to result in excessive discounting of risk and thus insufficient detail in planning. The consideration of likelihood is properly re-emphasized at the preparedness planning stage later, when actual readiness arrangements are developed. These can and should be made with consideration of the expected likelihoods.

While it is a distinct piece of work, the risk assessment is not carried out for its own sake; its outputs provide key information for the response planning stages that follow.

[3] Risk assessment in general and oil spill risk assessment in particular are well described in the literature. Good starting points are to be found in international standards (e.g. ISO 31000 and ISO 14001), as well as in government/ industry guidance (e.g. IUCN, IPIECA-OGP).

Typical technical outputs from the risk assessment process include:

- Oil weathering information (e.g. dispersion, evaporation, emulsification).
- Description of the overall receiving environment or 'Area that May Be Affected' (AMBA), in particular the geographic envelope where active oil spill response might be required (e.g. AMBA maps from stochastic modelling of fate and trajectory).
- Probability information and detail on the areas that may be affected (e.g. stochastic modelling probability contours, time to shore, and maximum shoreline loadings).
- Potential impacts on key areas and receptors (e.g. from deterministic model runs).
- Prioritised list of sensitive, vulnerable, and indicator receptors in the AMBA (including seasonal/spatial variations, exposure pathways).
- Decision on most appropriate deterministic scenarios for planning use.

In addition to the risk assessment for the petroleum activity hazards (as described above), a further iteration of risk assessment will be required as the oil spill response strategies are considered and tactics are being worked out. The goal for this is to ensure that appropriate controls are in place to minimise and mitigate against impacts from the response itself (e.g. dispersant use in shallow waters, aggressive shoreline clean-up in sensitive areas). The idea is that response actions will only be undertaken if, and to the extent that, they provide overall benefit to the environment.

One final phase of the risk assessment which is often overlooked, in particular if planners prematurely skip ahead to capability analysis (i.e. to where the equipment and resources will come from), is processing and filtering through the technical outputs of the risk assessment to identify and clearly describe the specific *response needs*, i.e. the expected response tasks. Note that these 'needs' are not the *response strategies* (e.g. application of dispersants, shoreline clean-up) or the *response resources* themselves (e.g. the equipment and manpower that make up the response capability); these are determined in a later stage.

Instead, the response needs are the physical and behavioural manifestations of the spill event that must be addressed to mitigate the effects of the oil spill. The response needs will vary according to the specifics of a particular oil spill. Examples might include the need to:

- stop an on-going release at the well-head
- address fresh surface oil slicks in the source area on a daily basis
- address drifting slicks on open water before they contaminate the shore and/or reach specific near-shore receptors
- protect pre-determined priority areas/receptors/sensitivities through other means
- undertake measures to minimise/avoid remobilisation of stranded oil
- clean shorelines of contamination
- respond to and rehabilitate oiled wildlife.

Although these few examples are presented here in relatively general terms, when working in a real contingency planning context the response needs can be described in greater detail, including more specifics on locations and timing, flow rates/quantities, affected receptors/shoreline areas, etc. as modelling results allow.

Oil spill response planning

Oil spill response planning, as defined here, is the phase of contingency planning when response strategy and tactics are developed and operational resource requirements are determined.[4] It is good to be clear on the difference between 'strategy' and 'tactics.'

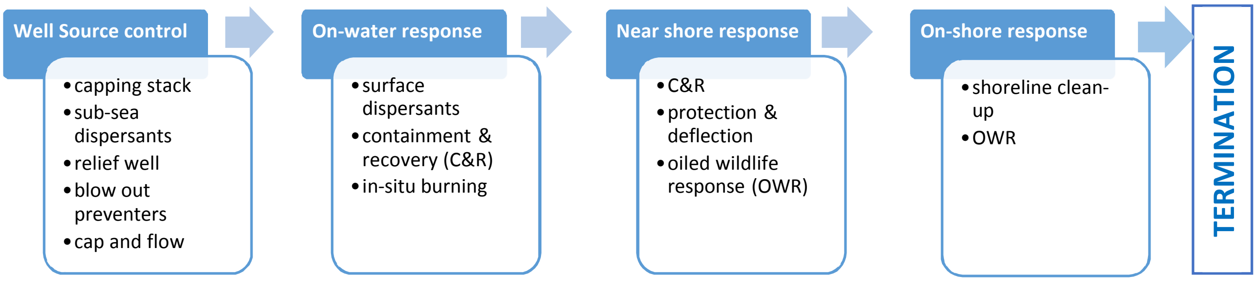
- *Response strategy* is defined as 'what' will be done (e.g. capping stack deployment, subsea dispersant injection, relief well drilling, aerial dispersant application, vessel-based dispersant application, at-sea containment & recovery, shoreline protection & deflection, shoreline clean-up, oiled wildlife response).

[4] There is plenty of good literature on oil spill response strategies, for example the ITOPF Technical Information Paper series, the IPIECA Good Practice Guidelines, or the Cedre Operational Guides. There is less information available on scenario-specific capacity determination that builds on activity-and location-specific risk assessment; the aforementioned IPIECA-OGP JIP Report is a good source.

- *Response tactics* are defined as 'how' the strategies will be undertaken, the approach in terms of the types and amounts of equipment used, the manner and timing of deployment (e.g. x teams of y personnel each undertaking low-pressure flushing of coble shores on out-going tides with sorbents held in place by floating hard boom).

Strategies and tactics are best delegated to a multi-disciplinary team with technical, oil spill, environmental, risk assessment expertise, and local knowledge. One of their first tasks will be to cross-check the scenario-specific response needs identified in the oil spill risk assessment against standard spill response strategies (FIGURE 2).

FIGURE 2 – Four categories of standard oil spill response strategies



Even before any strategic SIMA has begun, it is common that this stage of evaluation rules out some strategy options from the start because they do not address any of the needs identified in the risk assessment, are not feasible in the particular conditions, or are not legally allowed in the given circumstances, etc. For example:

- Source control:
  - An instantaneous release from a vessel tank damaged in a collision might be over so quickly that there is no need for a source control-specific response strategy over and above the vessel's well-documented safety procedures and standard booming.
  - Insufficient water depth at the well site for physical deployment of a capping stack.
  - A well may have such low reservoir pressure as to preclude capping stack use.
- Dispersants: The release may be in/too near shallow waters/shore to legally disperse the oil with chemical dispersants, or the oil may be naturally too light, too heavy, or too

weathered for dispersant application to work effectively.

- Open-water containment & recovery: The characteristics of the oil type (e.g. too light) may not be conducive to booming and skimming operations.
- In-situ burning: The characteristics of the location (e.g. too close to shore, too rough to enclose oil in boom) or the oil type (e.g. too heavy or too light) may not be conducive to burning.
- Protection and deflection: Due to the topography or exposure of the shoreline (e.g. rocky cliffs or high energy) protection and deflection booming may not be feasible.
- Shoreline response: Some shoreline types are considered too sensitive for most active oil spill response work (i.e. beyond monitoring).
- Oiled wildlife: Due to seasonal variations, sensitive species may not be expected in the area at the time of the incident, resulting in no actionable contamination of wildlife. For some species (e.g. whales) rehabilitation may not be feasible.

Fortunately, in most cases there will be a number of feasible response strategies available. This is where strategic SIMA[5] comes into play, analysing the degree to which each technically feasible response strategy has the potential to improve the overall response with the least environmental impact.

Sometimes response strategies may compete with each other in time and space. For example surface recovery and surface dispersant operations could both address the same oil slicks. Planners must prioritise or spatially separate mutually-exclusive operations into clearly-demarcated operational zones. In such cases, the tactics developed for each strategy and thus the required resources will be oriented to the oil expected in the respective zones.

To a large degree, however, emergency response options follow in a natural sequence from source control through to shoreline clean-up and eventual termination (FIGURE 2).

[5] As mentioned above, the practical workings of SIMA/ NEBA are outside the scope of this paper.

TABLE 1 – Need-based tactical response planning

Response need	Strategy	Input information	Output (TRP)
Address oil drifting slicks on open water before they contaminate the shore and/or specific near-shore receptors	Chemical dispersion via aircraft	• Model results on dispersible slicks (area, average thickness, viscosity) • Flight and spray capabilities for various air frame types • Spray drift modeling	• Optimal type, number, timing, and flight patterns for each aerial platform • Dispersant stock requirements
	Chemical dispersion via vessels	• Model results on dispersible slicks (area, average thickness, viscosity) • Wind/sea conditions • Spray swath, vessel speed, dispersant capacity for various vessel/equipment types	• Optimal vessel/equipment combinations, number, sailing patterns for each vessel type/fleet • Dispersant stock requirements
Address threat of oiled shorelines	Protect & deflect (P&D)	• Model results on shoreline loading (shoreline lengths affected, average shoreline loadings per sector and the timings of oil stranding) • Site-specific and logistical information	• Optimal pre-positioning of specific P&D resources
	Shoreline clean-up		• Optimal numbers of shoreline clean-up teams of specific sizes, appropriate equipment, staging areas • Area Plans with coastal mapping of sensitivities and corresponding response strategies for each sensitivity
Address oiled wildlife	Oiled wildlife program	• Model results on slick and stranding conditions and locations relative to wildlife habitat and seasonality • Sensitivity index maps	• Availability of relevantly-qualified experts and the appropriate type of rehabilitation facilities • Area Plans with coastal mapping of sensitivities and corresponding response strategies for each sensitivity
Transport and eliminate waste	Waste management program	• Model results on stranded oil volumes, substrate types (for appropriate waste multipliers)	• ID and prep of temporary storage, lay-down areas, appropriate and sufficient transport, intermediate storage before treatment

The tactical response planning work should consider the character and detail of each of the previously-identified response needs and work out the optimal resource combinations/

timing/methods for each of those response needs. While pre-existing 'Area' or 'All Hazards' tactical response plans for the location will be valuable where available, risk-based response planning also requires tactics to be tailored to specific planning scenarios and needs that were identified in the activity-specific risk assessment. Examples of the kinds of logic behind tactical response planning are described in Table 1.

Tactical response planning will work through all the response strategies, proposing the basic operational approach for each, describing the types/quantities of required response resources[6], and detailing the mobilisation and operational times/locations as relevant for the chosen planning scenarios. In doing so, tactical response planners go a long way to answer the 'how much is enough?' question, as they estimate what resources might be needed on the spot, at any given point in the time during the response.

Oil spill response preparedness planning

Tactical response plans do not tell us exactly what resources to hold in what state of readiness and where (e.g. on or off-site). That is a question for preparedness planning, the subsequent phase of contingency planning, where cost, contracting, procurement, supply, stocking, maintenance, and other logistics matters are considered for the operational resource requirements identified in the previous strategic and tactical response planning stage.

In a sense, the overall process of risk-based contingency planning is a balancing act — on one hand there is the acknowledgment that consequences may be significant, and as a result the understanding that appropriately-detailed planning is to be undertaken however unexpected the hazardous event. On the other hand, there is recognition that because of the very low likelihood of occurrence, because not all response resources are needed at once, and because costs should not be disproportionate to the expected gains, not all potentially required response resources must be held in immediate readiness, e.g. directly on site. A

[6] Note that 'resources' include equipment, materials, and personnel, whether operator-owned or third party.

measured supply-chain approach is typically justifiable. Suitable options may include:

- Holding only immediate-response stocks (e.g. small volumes of dispersants and related spray equipment) in the immediate vicinity of the risk (e.g. on board the petroleum facility or associated vessels) while maintaining additional stocks at more convenient locations for later delivery (e.g. in port lay-down yards), as required.
- Holding specialist stocks (or detailed access arrangements) and relying on local/ regional markets for more generally-available resources (e.g. vehicles, fuel).
- Maintaining access to tiered response structures through appropriate mutual assistance programs and/or memberships to co-ops and other oil spill response organisations.
- Undertaking purchase arrangements from manufacturers for just-in-time delivery.

These options can offer offshore operators flexibility and cost savings in managing their risks, as identifying a need for a particular resource does not mean that an operator must always 'have one of their own'. In fact, access to shared resources opens doors to specialist resources that might not otherwise be available. This might mean, for example, the difference between having a capping stack in the region and having one on the other side of the globe.

There are a number of additional factors that should be considered when determining the optimal state of readiness for any given response resource. Examples include the:

- Expected criticality[7] of the particular response resource to the overall response.
- Market availability[8] of the required resources.
- Logistics of getting the resources in country, to site, and into action.
- 'Window of opportunity' for deployment to achieve optimal effectiveness.

[7] 'Criticality' is a function of the expected effectiveness and the availability of alternative options for addressing the same response need.

[8] 'Market availability' refers to the availability of the item for general purchase, loan or hire versus the need to have it especially manufactured. Is it available in country or must it be imported? What is the lead time for manufacturing?

Taken together, these factors enable preparedness planners to optimise stocking and supply chains. As a result, the answer to the ‘how much is enough?’ question will differ between tactical response planners and preparedness planners.

DISCUSSION

Although the approach appears straightforward in theory, practical experience in regulating oil spill response preparedness confirms that there are a number of discussion points worth considering.

1) Capability statements alone do not demonstrate appropriate preparedness

Capability statements, including reference to stockpile access, membership to oil spill response organisations, or integration in a tiered response system alone do not demonstrate that *sufficient* response capability is in place, regardless of the strength of these arrangements. The only way to know ‘how much is enough?’ is to map capability to the specific risk and the specific response need that arises from it. In other words, contingency planning must begin with a risk assessment and develop relevant response strategies and appropriate response tactics before assembling appropriate response resource capability arrangements.

2) Contingency planning should be both activity and location-specific

No two oil spills are alike. The same petroleum activity with the same oil type/ volume/flow rates in two different locations can produce entirely different oil spill consequences due to the nature of receptors affected in the different locations. Indeed, the same activity in the same location at different times of year can result in entirely different outcomes, given variances in metocean conditions as well as seasonal differences in receptor presence and vulnerability.

O&G operators will naturally find much of the material in their contingency plans will carry over from one activity to another for similar activities in similar regions, but differences in the activity and location-specific risk across activities, however subtle, will dictate adaptations in tactical plans and therefore resource requirements at the very least. There will never be a universal, or even repeatable, answer to the 'how much is enough?' question.

3) Detail and arrangements should be commensurate to the nature and scale of the risk

In the same way that capability should be commensurate or 'equal' to risk, the level of detail in assessment and planning should be commensurate to the nature and scale of the particular risk. In other words, when deciding how deep into planning detail to go and how binding to make preparedness arrangements, planners should be sensitive to the likelihood of occurrence and potential magnitude of consequence. For example, where risk assessments predict lesser-scale consequences, planners need not work to not provide the same level of detail as where the risk assessments indicate greater consequences for the same level of likelihood. Consequently, where models predict low exposure levels for receptors, relatively small areas of oil concentration above key threshold levels and/or transient sub-lethal effects, planners can justify working to a lower level of detail than with large and long-term releases, significant exposure of receptors to oil, non-transient sub-lethal effects, and mortality.

4) Both stochastic and deterministic models should be used to assess risk and plan response

Pre-spill deterministic (i.e. single-run) modelling of spill trajectories produces a detailed depiction of an oil spill over time. *For a specific release and weather scenario* it shows planners where and when the oil may end up geographically as well as the oil budget over time i.e. how much oil is on the surface, how much is oil is dispersed in the water column, expected shoreline accumulations, etc. While very useful for working out detailed response plans or conducting training, deterministic modelling can be very inaccurate because, by definition, each model run represents only one of countless possible realities.

This is where stochastic modelling really comes to bear. By batch-modelling hundreds of deterministic runs using a wide range of historic weather combinations and seasonal oceanographic variations, stochastic modelling results provide planners with probability maps showing, for example, where the oil is more and less likely to drift and accumulate. In terms of presentation, probability levels can be assigned different colour shades so that the visual representation looks something like a heat map. While the information provided on possible stranding locations and probabilities is really helpful, one downside to using stochastic modelling is that it is easily misinterpreted by those not familiar with its use.[9] Further, stochastic modelling results alone say nothing about the actual quantities of oil or the scale of impacts to be expected from a single spill. Most importantly for planners, stochastic modelling results don't actually provide any single spill run to plan to. One could never answer the 'how much is enough?' question based on stochastic modelling results alone.

Fortunately, both model types can be used together to gain the advantages of both. The stochastic model can be run first to establish the AMBA, contact probabilities, and other key variables that can be used to define a planning scenario. With this data, vulnerability trends can be established for priority resources. Deterministic models can then be run against various 'worst case' scenarios[10] as well as against the individual protection priorities to provide realistic simulations against which to plan, prepare and test response.

5) Response plans should be based on representative scenario(s)

While it is very tempting to define a 'worst-case' oil spill scenario in terms of a single metric, like the largest volume spilled or the largest volume ashore, these may not be sufficiently representative of the spill impacts that may occur. For example, the stochastic model run that results in the largest volume ashore might see oil going to a less sensitive

[9] The most common mistakes are to fail to understand that the results show "swept area" rather than slicks and cumulative, rather than single spill results.

[10] Note that there is no single, agreed definition of 'worst case'; in practice it is very subjective, depending on the perspective of the user. For one person it might be the most oil spilled, or the release that creates the largest oil slicks; for others it might be the spill that arrives first on shore, the spill that leaves the largest shoreline accumulations, the spill that affects the greatest number of species, or the spill that hits particular receptors (e.g. endangered species, commercial fisheries). Still others might define it in terms of the resources required, i.e. that case where mutual aid and cascading of resources becomes necessary.

receptor or easier-to-clean beach. However, responders are likely to be much more interested in learning if and how the oil ends up on more sensitive or difficult-to-clean shores, even if this occurs only in lower-volume scenarios. The problem with poorly defined planning scenarios is that they may lead planners to focus on a subset of potential receptors and thus leave responders ill-equipped on the day when the actual spill occurs.

To ensure the appropriate readiness and mix of response resources, good contingency planning should identify and work to planning scenarios that are sufficiently realistic and representative of the full range of different possible spill events, in particular as they have impact on indicator/sensitive/vulnerable receptors prioritised in the risk assessment. Typically, this involves identifying one or more deterministic model runs chosen on the basis of probability-of-contact information from stochastic model results. Where individual priority receptors are not adequately covered by the spill response planning scenarios chosen, it may be appropriate to work out additional strategic and tactical plans for those receptors.

6) The independence of controls should be respected

A well understood feature of good risk management is having multiple layers of independent controls (i.e. response options). Redundancy is good; having controls linked to/reliant on each other is not. As discussed above (See Figure 2), many oil spill response strategies follow each other consecutively. In other words, source control at the well head is urgent and planned for immediate activation, whereas surface dispersant application or shoreline clean-up are planned for subsequent activation. A natural *and inappropriate* approach in contingency planning is to design and scale later-occurring response tactics to meet conditions that one hopes will arise following the successful application of earlier response actions. The classic example is when shoreline response plans are omitted, or at least under-developed, because it is assumed that a capping stack/subsea dispersants/aerial dispersants will make shoreline response redundant. However, unless it can be sufficiently demonstrated that there are no reliability or effectiveness questions about these early-implementation controls, those response controls that follow should not be designed or scaled on the assumption that the previous response actions will be effective. After all, what if events line up in such a way, like holes in slices of Swiss cheese[11], that the early controls cannot actually be deployed?

Naturally, respecting the independence of controls can have significant ramifications for determining the quantity, quality and timeliness of resources required. However, as discussed above, this doesn't mean that all the potentially required resources must be stationed nearby and held in a state of continual readiness; simply that risk-appropriate tactical plans and supply chain arrangements are developed, implemented and maintained.

7) Risk-based preparedness works best with performance standards in place

Risk-based preparedness means putting in place arrangements for the amount and type of resources that the expected situation will require, based, among other things, on defensible effectiveness and reliability assumptions for the use of those resources. The risk-based approach really only works to the degree that the planning standards used are realistic, observable and as far as possible, crafted as measureable statements of performance. Where a good suite of relevant performance standards are in place, responders are in a better position to maintain preparedness before an incident (i.e. when they have few actual opportunities to calibrate their operational performance 'in anger') and regulators will be able to test compliance when it matters most (i.e. before an incident, when there is still time to ensure appropriate rectifications are made if required).[12]

8) Response tactics and preparedness plans should satisfy the ALARP principle

One successful decision-making approach is to use the ALARP (as low as reasonably

[11] See literature on cumulative act effects developed by Jim Reason and others, including an application for the BP Deepwater Horizon incident by Andrew Hopkins.

[12] Importantly, in the post-incident context when evaluating performance the many exogenous variables that make every incident different must be considered along with the planning standards.

practicable) principle which basically recommends taking on alternative methods/quantities/ timings to the extent that these variations reduce overall risk at costs that are less than grossly disproportionate to the environmental benefit gained. It involves a notional computation whereby the quantum of risk is placed on one scale and the sacrifice involved in averting the risk (i.e. 'cost') is placed in the other. If the sacrifice is not grossly disproportionate to the risk reduction achieved, then the alternative should be adopted.[13]

As described above, *tactical* response planning goes a long way to answering the question 'how much is enough?' in that it produces lists of operational resource requirements. Subsequent *preparedness* planning closes the loop by proposing the appropriately dynamic supply chain to meet those requirements in space and time, delivering response resources where they are needed and as they are needed. As definitive as that sounds, planners are still faced with challenges. For example, determining just how much of a promising strategy to propose, or dealing with trade-offs between variations in approach, whether in terms of effectiveness, reliability, or cost. In practice, consideration of ALARP requires an initial, studied proposal on the optimal tactical response, and variations of the proposal's attributes in terms of quality, quantity, and timing to see if improvements in effectiveness and reliability can be achieved. To the extent that a variation can achieve an improvement and the extra cost is not grossly disproportionate to that improvement, the variation thus reduces the risk of the petroleum activity and should be considered for inclusion.

Similarly, the ALARP principle can help guide preparedness planners when they decide on the optimal supply chain mix. Given the tactical plans in front of them, they should first consider expected delivery performance versus the urgency of need to decide if they can rely on regional/global resource stocks or if the required resources should be held more locally. They should then look at the cost of local stocking and decide if it is grossly disproportionate

[13] The legal definition of Reasonably Practicable was set out in England (in 1949) by Lord Justice Asquith in Edwards vs. National Coal Board

to the associated risk reduction.

Because the average cost of a given level of capability provision depends on the number of activities/ operators which rely on it, where ALARP demonstrations can reach to multiple activities of a single operator or activities of multiple operators, lower average costs of preparedness provision will tip the ALARP level of provision towards greater, better, and/or faster preparedness arrangements. This is in fact, the reason why non-profit stockpiles exist and the explanation, for example, as to how a group of oil companies were able, together, to justify the expense of developing the current capping stack technology following the 2010 Deepwater Horizon incident and maintaining availability to this day.

CONCLUSIONS

While the offshore O&G industry has a very good track record overall in terms of the very low frequency of serious marine oil spills, when an incident does occur it can be of a very serious nature. High standards in both prevention and risk mitigation reduce the probability of incidents occurring in the first place and minimise the expected consequences should they occur.

In regards to risk mitigation through oil spill response preparedness, many of the attributes of offshore oil spill risk are known or can be predicted before the risk activity commences. This allows for exceptionally high levels of risk-assessment-based planning, area planning, and readiness arrangements. Optimal response strategies and effective operational tactics can be worked out in ‘peace time’ using experience-based and field-tested effectiveness assumptions. Risk-based supply chains can be devised in the preparedness planning stage to optimise arrangements for the most promising and cost-effective response approaches. This risk-based approach allows industry to make precise activity and location-specific capability demonstrations to the regulator who will thereby be put in a good position to assess acceptability of the activity and its risk in the first instance, and to test compliance of the emergency arrangements as the activity progresses and in the event of a spill.

In summary, while risk-assessment-based planning and preparedness is an efficient and defensible approach, it relies on consideration of the following:

- Capability statements alone do not demonstrate appropriate preparedness.
- Contingency planning should be activity and location-specific.
- Planning detail should be commensurate to the nature and scale of the risk.
- Both stochastic and deterministic modelling should be used to plan response.
- Response plans should be based on scenario(s) representative of the key consequences.
- The independence of controls should be respected.
- Risk-based preparedness works best if appropriate performance standards are in place.
- Response tactics and preparedness plans should satisfy the ALARP principle.

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