Determining Best Achievable Shoreline Protection Using GNOME Trajectories

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ABSTRACT

California's Oil Spill Prevention and Response Act mandates best achievable protection (BAP) for sensitive shoreline resources as the standard for preparedness and response. The historic approach of relying on Vessel Response Plans (VRPs) to identify and regulate BAP has been problematic. As a consequence there was a lack of consistence among vessels and which in turn resulted in an uneven playing field among contractors competing to provide shoreline protection services. To remedy this situation, California has newly assumed the responsibility for identifying BAP shoreline protection needs using NOAA's GNOME model to simulate spill trajectories from generic risk sites along the coast. The modeling objective was to simulate adverse spill trajectories requiring timely shoreline protection deployments and identify the envelope of response resources sufficient to address most spills which could occur in the modeled areas. Using these trajectories, timetables of spill impacts to sensitive resources and consequent protection times were generated. The timetables include requisite shoreline protection resources which were identified from the Area Contingency Plans. These response timetables provide a clear statement of the BAP and are currently being incorporated in regulations.

INTRODUCTION

California's Lempert-Keene-Seastrand Oil Spill Prevention and Response Act mandates best achievable protection (BAP) as the standard for preparedness and response for oil spills. BAP is critical to response planning for the protection of sensitive shoreline resources from vessel spills because it poses two important questions: "How many response resources should industry provide?" and "In what time frames should those resources be deployed?" This paper focuses on identifying and providing for BAP for shorelines.

Prior California regulations promulgated to achieve BAP for shorelines produced the opposite results in many instances. Those regulations attempted to achieve BAP by requiring vessels to determine adverse consequences and requisite response resources in vessel response plans (VRPs). Though effective in theory, overall this approach resulted in fuzzy consequences and vague arrangements for adequate response in many VRPs. While some VRPs were very thorough and identifying shoreline protection needs and provisions, many others were not. Because it was neither clear what shoreline sites were to be protected nor in what time frames, and because it was consequentially not clear what response resources were to be engaged to execute protection, validating VRPs and contracted Oil Spill Response Organizations (OSROs) or other resources was not feasible. This situation in turn fostered "paper tiger" OSROs and resulted in an uneven playing field for OSRO competitors. While in some cases VRPs provided for a high level of preparedness, in other cases, preparedness was no more than paper promises.

California's new approach uses many of the original concepts to good effect. This approach provides a number of benefits and solutions to difficult issues identified from the former approach. This paper explains the theory, steps, and details of identifying BAP by using the NOAA GNOME oil spill model for generic vessel risk threats for California ports and along the California coast. As a result of this process, BAP has been standardized and defined in terms of specific site deployments at specific time intervals and presented in tables in regulation. A side benefit has been that Area Contingency Plans have been revised to be more tactically useful and less hypothetical.

HISTORIC APPROACH

The historic approach for identifying and regulating BAP for vessel spills has been problematic. In the past, regulations required that vessel operations with oil spill risks (including non-tank vessels in California) prepare vessel response plans in which consequences from releases would be identified (using risk analysis and trajectory modeling). The resultant spill trajectories were then to be used to identify sensitive resources at risk. Once resources at risk were identified, the responsible party or their plan preparer were to identify response resources required to provide timely protection either from Area Contingency Plans (ACPs) or by local assessment. These response resources could be acquired or contracted and staged and manned to provide requisite timely deployment.

This approach did not work as well as anticipated. The conceptual theory was that vessel operators would be intimately involved with contemplating and preparing for spill risks. In reality, operators relied upon outside sourcing to determine threats and consequences, including referring to trajectories in ACPs to define consequences. Trajectories developed for this purpose were generated with various models, and the assumptions and conditions in the model varied with the preference of the modeler and the modeler's interpretation of regulatory requirements. The problem for regulators was their inability to identify or validate the assumptions and inputs, and often data were not available. Also, trajectory images were not always adequate. So, it was difficult to question results when consequences appeared unlikely, non-intuitive, or data were lacking. Economic and ecologic impacts were identified in varied and irregular patterns and often without a sequential or hourly projection of impacts. Amounts of resources needed and time frames for deployment were not clear, nor was it clear which of the response resources identified in the plan were linked with which locations to be protected. Because times of impact and the response resource demands were not clear, it was not possible to determine if acquired or contracted resources were staged or staffed adequately to provide for timely deployment. Actual preparedness of the vessel in acquiring or contracting adequate resources and the capability of deploying those resources by vessel operators or their contractors was difficult to assess or drill.

Most VRPs engage OSROs to provide needed response capability. OSROs were faced with the logistical needs of "clouds" of trajectories with vague demands. In most cases OSROs mounted laudable efforts to acquire and position response resources not only to contain and collect oil but also to protect shorelines. However the vagaries of the VRP trajectory consequences and unclear accountability, in turn, fostered "paper tiger" OSROs which posed as having response assets while actually having few resources or staff under their control which would be necessary to mount rapid effectual response. As a consequence the "playing field" was uneven not only among vessels but also among OSRO contractors competing to provide shoreline protection services.

As a result some players achieved compliance without actual preparedness, while others made good-faith efforts. Whereas the originators of the statutes intended to involve potential responsible parties in the threat preparedness process so they were well versed in their VRPs and engaged with their spill response preparedness, the preparation of spill consequence portions of VRPs often became a mere encumbrance: extra task for VRP prepares, extra VRP pages for the vessel operators to master, and extra information for VRP reviewers to interpret. Ultimately it was impossible to determine if BAP was being met because no standard emerged nor was it feasible to exercise accountability.

CALIFORNIA'S REVISED APPROACH

To remedy this situation, the California Department of Fish and Game, Office of Spill Prevention and Response (OSPR) initiated a new approach by assuming the responsibility of identifying BAP for shoreline protection needs and providing this information to vessel contingency plan holders. The purpose was to provide an objective BAP standard. This task was performed by determining the response resource demand sufficient to address most spills which could occur in the respective operational areas. If response resources could be deployed in a timely fashion to meet this standard, then the Best Achievable Protection would be available for most conditions and spills.

OSPR accomplished this following the same conceptual process that was used in the initial regulation: trajectory modeling from potential risk points assuming adverse conditions. The modeling objective was "… to generate trajectories from origins and under conditions of release which have severe enough consequences to reasonably define the envelope of response resources required for most conditions and spills." It was assumed that those trajectories requiring rapid deployment of substantial resources would be sufficient to establish adequate demand for response staff and equipment to achieve the model objective and would consequently constitute best achievable protection.

To execute this process, OSPR relied upon NOAA for their GNOME (General NOAA Oil Modeling Environment) model and modeling expertise for trajectory modeling in coastal and bay regions. Oil spills were modeled from risk sites, using wind, current, and tide conditions which aggravate the spread of oil; the resulting trajectories were used to identify shoreline resources impacted and requiring protection, and the time by which they must be protected to prevent unmitigated impact. The shoreline protection resources needed for initial protection were drawn from existing protection strategies in respective ACPs. The sites, times of impact, and response resources needed were assembled in tabular form. These response timetables extend to 60 hours, after which resources could be cascaded from outside of California and made available as needed in actual response.

These shoreline protection timetables provide a clear statement of the BAP and are being incorporated into regulations. The details of the trajectory analysis and table development are presented in the sections which follow.

Criterion for Modeling

Statutory BAP mandates specify the assumption of pessimistic spill conditions (including tide, current, wind, and seasons) for dispersal of oil. Consequently, model input variables were based on realistic local conditions which would result in adverse trajectories requiring an urgent need for deployment of substantial response resources. The model inputs and parameters were also selected to provide a representative trajectory regardless of variability between oil products and various possible shipping releases. The following is the criterion used to frame the modeling.

- Locations selected were representative of the California coastal area and sub-regions where ships travel or where ships might pose threats. The specific release locations were those where oil could be released from ships with rapid spreading and serious risk to natural resources which in turn would require demanding mobilization of response resources. The release points reflected both vessel traffic patterns and coastal exposure. At least one site was selected along the respective coastline even if no shipping is currently planned within State waters for that coastal segment (though traffic does transit off shore all along the coast). Release points were often similar to those used in local

ACPs so long as those release sites were adequate to address the BAP modeling objective.

- Environmental conditions were winds, tides, and currents which occur at those sites and which tend to aggravate the spread of oil and maximize response resource demands to protect ACP sensitive sites.
- Volume and type of oil were selected to be widely representative of the products carried and fuels used by most vessels. The volumes and release times selected to analyze the output resulted in the oil trajectory footprint being dominated by the environmental conditions and not the volume or type of oil.
- Releases were continuous, and of sufficient duration to aggravate the consequences.

Selected Model Input Variables

Operational zones and release points were identified by OSPR staff with input from industry and environmental groups. Twenty areas were identified, 14 of which were related to vessels engaged in port activity; the other six locales were representative of releases which could occur from coastal passage traffic. From north to south they are listed as follows:

1) Humboldt Bay entry channel
2) Cape Mendocino (northern California coastal)
3) Point Arena (northern California coastal)
4) Point Reyes
5) San Francisco, Central Bay
6) San Francisco, South Bay-Anchorage 9
7) San Francisco, San Pablo Bay
8) San Francisco, Suisun Bay
9) Sacramento-San Joaquin Delta, North Delta
10) Sacramento-San Joaquin Delta, West Delta
11) Sacramento-San Joaquin Delta, Central Delta
12) Sacramento-San Joaquin Delta, East Delta – Port of Stockton
13) Pillar Point

14) Monterey Bay
15) Point Buchon – Morro Bay (southern California coastal)
16) Point Conception
17) Port Hueneme
18) LA/Long Beach Harbor
19) San Diego Bay, mouth
20) San Diego Bay, south Bay / Coronado Bridge

A single fuel type and volume was used for all simulations. The release simulated was 13,000 barrels (bbl) of No. 4 fuel oil. No. 4 fuel oil was selected because it has characteristics intermediate between diesel and crude. The 13,000 bbl quantity was selected because: it is sufficiently large to pose substantial environmental threat; it is a volume well within the fuel or cargo of most ships; it is a volume already used and exercised in California regulations; and, conceptually, results in a typical oil spill footprint from a significant release.

To address statutory mandate for “pessimistic” environmental conditions, variable selections were conditioned accordingly to aggravate oil spread. Iterative modeling was further used to explore ramifications of these conceptually adverse inputs and refine final variable selection. For example, the durations of oil releases were selected to adequately ensure aggravated spread and impacts in respective release environments.

Currents and tides were used which tended to aggravate oil spread. Tides were chosen to simulate threat in both the flood direction and ebb direction from the release site; spring (verses neap) tides were modeled to provide increased tidal excursions. For estuaries, periods of low freshwater outflow were chosen which resulted in flood tide excursions with less opposition from flushing out-flows. Spill releases beginning at the start of the flood tide resulted in the greatest upstream excursions and impacts, followed by the subsequent downstream oil spreading threats; this pattern was also apparent in the nearshore coastal environment. On the outer coast, up-coast and down-coast currents were evaluated to determine which movement provided more adverse consequences. NOAA provided current and tide files for respective modeling locales.

The winds chosen were those which typify threats posed in that area and which tended to aggravate oil spread. Because higher winds tend to force and pin oil along model shorelines and result in minimal spreading and protective response demands, the winds used were usually low winds (10 knots) for short duration (less than 24 hrs and often less than 12 hrs) or no winds in estuaries and bays. In north coastal areas, stronger winds (20 knots) were used because those winds are more typical for that region.

Other variables were shoreline re-floatation and turbulent mixing. Half the beached oil was allowed to refloat every hour which allowed for a large remobilization of oil. Diffusion constants were usually modest (>50,000 cm2/sec) except in less predictable or in turbulent environments such as Central San Francisco Bay (e.g., 100,000 cm2/sec).

Model Outputs and Assessment

NOAA staff post-processed the GNOME output files using the GNOME Analyst software to generate contour maps to display model oil trajectory predictions. Maps were created for the same hour intervals for each locale to address California regulation and to follow the trajectory through the tidal phases: oil spreading was mapped at hourly intervals for the first six hours and thereafter at 6 hour intervals which was at about the end of each tidal cycle. The maps included a 90% confidence boundary estimated from the GNOME uncertainty bounds for the various inputs (Figure 1). The confidence interval provides a

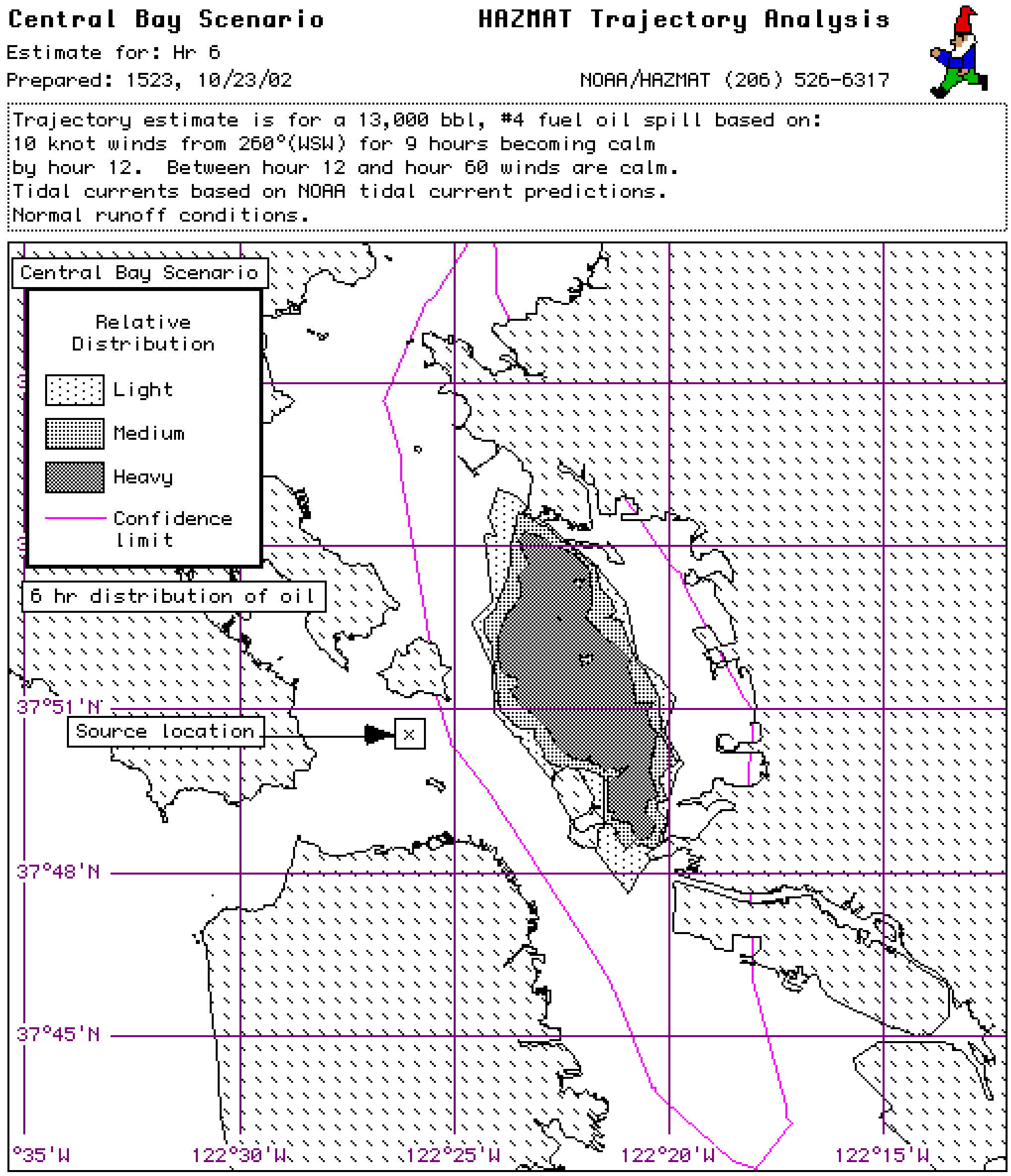

Figure 1. GNOME Trajectory Map for San Francisco Central Bay at Hr 6

viewable boundary of the area within which the oil will actually be found at least 90% of the time, given the inputs to the model. The 90% confidence boundary takes into consideration model and data shortfalls and other unpredictable variability in the oil movement, and reflects the uncertainty assigned to each environmental parameter. The 90% confidence boundary increases with time because the certainty that the oil will follow the projected course and location decreases as the time from release increases.

Once NOAA staff prepared the maps, these trajectory diagrams were reviewed by OSPR scientific field staff scientists local to each area. These scientists were instructed to use their best knowledge and experience to interpret and truth the computer output; and based on this evaluation, they were tasked with determining 1) which sensitive sites would likely be impacted or threatened by the spill trajectory; 2) by what hour impact would likely occur; and 3) which protective strategy would be appropriate for the oil threat (since many sites have alternative strategies, different environmental conditions, or protection levels). The sites projected to be impacted were listed in a table by the hour of impact. The response resources needed to provide primary shoreline protection were identified, using the ACP, and were organized by type: deployment staff, harbor (curtain) boom, river (swamp) boom, anchors, boats, skimmers, etc. (Table 1).

BAP SHORELINE PROTECTION TABLE - S.F. SECTOR - CENTRAL SAN FRANCISCO BAY

Protect by Hour	Strategy/ Site Number	Site Name	Harbor Boom	River Boom	Other Boom Amt	Other Boom Type	Sorbent Boom	Skimmers No.	Skimmers Type
		Flood 0-6 hours	**12100**	**500**			**2000**	**0**	
3	2-351.1	Yerba Buena Island	3000					0	
5	2-453.1	Brook's Island	2300	0	0		0	0	
5	2-458.1	Emeryville Lagoon/Mudflats	4500				2000	0	
5	2-457.1	Berkeley Eelgrass Beds	0	500	0		0	0	
6	2-456.2	Albany Marsh	2300	0				0	
		Ebb 7-12 hours	**2500**	**2500**	**4000**		**3200**	**0**	
7	2-454.1	Richmond Inner Harbor/Hoffman Marsh	2500	1100			200	0	
9	2-150.2	Point Bonita and Bonita Cove	0		2000			0	
9	2-151.2	Pt. Diablo to Lime Point	0		2000			0	
11	2-147.1	Redwood Creek/Big Lagoon/Muir Beach	0	200			1000	0	
11	2-148.1	Rodeo Lagoon	0	1200			2000	0	

Table 1. Example of BAP Table (abbreviated and only one tidal cycle shown)

These tables, then, show the sites to be protected, the hour by which they should be protected, and the response resources required to provide initial protection under the release conditions. This approach and the resultant tables provide a standard for BAP and answer the key questions posed: "How many response resources should industry provide?" and "In what time frames should those resources be deployed?"

IMPLICATIONS FOR RESPONSE RESOURCE PLANNING

To assess the implications of the new approach relative to historic levels of preparedness, a comparison was made between trajectories used in the San Francisco Bay-Delta ACP and the new trajectories. Since the mid 1990's, the San Francisco Bay-Delta ACP (2000-05 ACP) has several scenario trajectories which are adverse and have aggressive impact schedules for sensitive sites. These scenarios have remained unchanged since at least 1998. Since some VRPs use these ACP trajectories to meet plan requirements and, presumably, have contracted with OSROs to provide adequate response resources capability to meet these impact schedules, these response schedules represent the theoretical level of response preparedness. So, using these ACP scenario schedules provides a sense comparison.

To make this comparison, response resources for the 2000-05 ACP scenario impact schedules were drawn from the ACP in exactly the same fashion as they were for comparable BAP tables and compiled into parallel tables. Since slightly different sets of sites were affected by each trajectory, the appropriate comparison was for response resources totals for each tidal cycle (every 6 hours).

For example, the resources for the first six hours for the new trajectories were summed as shown in Table 1 and similarly for the existing trajectories in the 2002-05 ACP. The equipment sums for each tidal phase can then be listed for each tidal excursion in a comparison table (Table 2). The comparisons for San Francisco Bay Central Bay and

RESPONSE RESOURCE COMPARISON BETWEEN GNOME BAP AND 2000-05 ACP TRAJECTORY IMPACT SCHEDULES							
Post Spill Time Period	Response Resource Projections From	San Francisco Bay Central Bay			San Francisco Bay Suisun Bay		
		Harbor Boom	River Boom	Other Boom	Harbor Boom	River Boom	Other Boom
0-6 hours	GNOME BAP	12100	500	0	11300	2600	0
	2000-05 ACP	18000	5200	0	12950	5150	0
7-12 hours	GNOME BAP	2500	2500	4000	6000	4250	0
	2000-05 ACP	9100	3400	0	6000	0	0
13-24 hours	GNOME BAP	27900	4150	0			
	2000-05 ACP	41500	4150	2600			
25-48 hours	GNOME BAP	38200	7300	3600			
	2000-05 ACP	7400	6000	2000			

Table 2. Comparison of Response Resource Schedule of ACP and GNOME Trajectories

Suisun Bay indicate that both trajectory schedules require rapid deployment of large amounts of resources in each time interval, and resource amounts are comparable. The GNOME BAP amounts and deployment time frames, while still challenging and resource intensive, were actually less demanding in some instances; these differences may be attributable to more realistic trajectory variables that were chosen to represent local conditions.

MOVING CONCEPT TO REGULATION AND APPLICATION

The trajectory analyses and response timetables were shown to and reviewed by stakeholders, including industry, OSROs, Area Committees, and environmental groups. As a result of their input and concerns, the process was improved in several ways. Tables were shortened to included site-by-site response needs for the first 24 hours, but after that response resources were only summed for each succeeding 6 hour increment (or in some cases longer intervals). OSROs felt that many response resources indicated after 24 hours would be addressed with non-local convergent resources and deployed at the direction of the Unified Command organization. The trajectories would remain appropriate estimates of response capability needed for each time interval to identify the kinds and amounts of response resources needed. However, logistic plans for deployment would not likely improve response preparedness for operational periods beyond the first 24 hours.

OSPR agreed that sensitive site protection strategies within the first two hours would be impracticable. Since response requirements in previous regulations granted a similar deferral, and since OSROs need to mobilize, assess for safety, and deploy, this delay was deemed consistent with BAP. On the other hand, OSPR did require that any sites which might be exposed in the first two hours still needed protection since exposure might not result in irrecoverable site destruction such that site protection may well benefit the sites.

OSROs were concerned that staff and deployment vessels indicated in the ACP might not credit the greater capabilities of some of their response vessels and staffing. ACP response vessels (boom boats and skiffs) and staff numbers are based on a rapid response by a hypothetical type “average vessel.” OSROs have vessels with delivery capacities and speeds which vary from this “type.” OSPR agreed that execution of the site protection strategies at the times indicated was paramount and that any combination of response resources capable of demonstrating deployments in a timely fashion would be certified as adequate. Consequently, OSROs which have been certified as adequate to meet the BAP, may be cited in VRPs to meet the BAP requirement.

Another consequence the approach was that many ACP improvements were made. The BAP process clarified the need to identify primary protective responses in the ACPs which would be required in spill events with severe time and response resource constraints; such initial protective responses need to be distinctly separate from additional alternatives such as backup, collection, and response resource intensive prophylactic options. These strategy improvements were necessary to provide better assessments of BAP. The consequence of this revised approach to ACP strategies is that the ACPs became much more tactical and useful for response situations. Strategy refinements and strategy testing are continuing through the ACP process in California, and as improvements are advanced that affect response resource needs, BAP tables will revised accordingly in regulation updates. The BAP trajectories themselves will hopefully be adopted by Area Committees to represent one or more of the ACP scenarios which are required by Federal mandates to assess response resource preparedness needs. In turn, Area Committees may be a source for improvement of the BAP efforts.

CONCLUSIONS

OSPR has addressed the statutory mandates for BAP by creating a BAP standard though a cooperative effort with NOAA, using NOAA GNOME oil spill model trajectories. NOAA modeling expertise and local OSPR scientific expertise combined to identify the consequences of these trajectories, including ACP sites impacted and impact times. Resulting site protection timetables objectively define the envelope of response resources sufficient for most spills and conditions likely to occur in California. Former reliance upon VRPs to define BAP was problematic and produced neither a standard nor clear statements of trajectory assumptions, consequences, response resource needs, or logistics of timely protection. It was not clear from these plans what BAP was nor if it was being met by individual planning efforts or collectively through all plans. Consequently, these sections of VRPs amounted to voluminous complexities that were, in some cases, of little value to either vessel operators or reviewing regulators.

The benefits of this new approach are many. VRP preparation is simplified, thereby removing a layer of complication and potential controversy regarding trajectories, resources at risk, and requisite response requirements. Review and approval of VRPs for shoreline protection has been reduced to a simple comparison of operational areas to contracted OSRO approvals to assure BAP is being met. The playing field among vessels has become more level by clearly defining the amounts and kinds of resources, and the times by which those resources must be deployed. The playing field among OSROs is also more level because the requisite capability required to meet vessel requirements is defined. This BAP standard incorporates ACP strategies and has focused Area Committees on making strategies more tactical and useful for actual response. In turn, BAP regulations may be improved as ACP strategies continue to be improved. Most important, there is a clear standard defining BAP for shorelines and addressing: “How many response resources should industry provide?” and “In what time frames should those resources be deployed?”