CHAPTER 8

VTRA 2010 FINAL REPORT

Preventing Oil Spills from Large Ships and Barges In Northern Puget Sound & Strait of Juan de Fuca

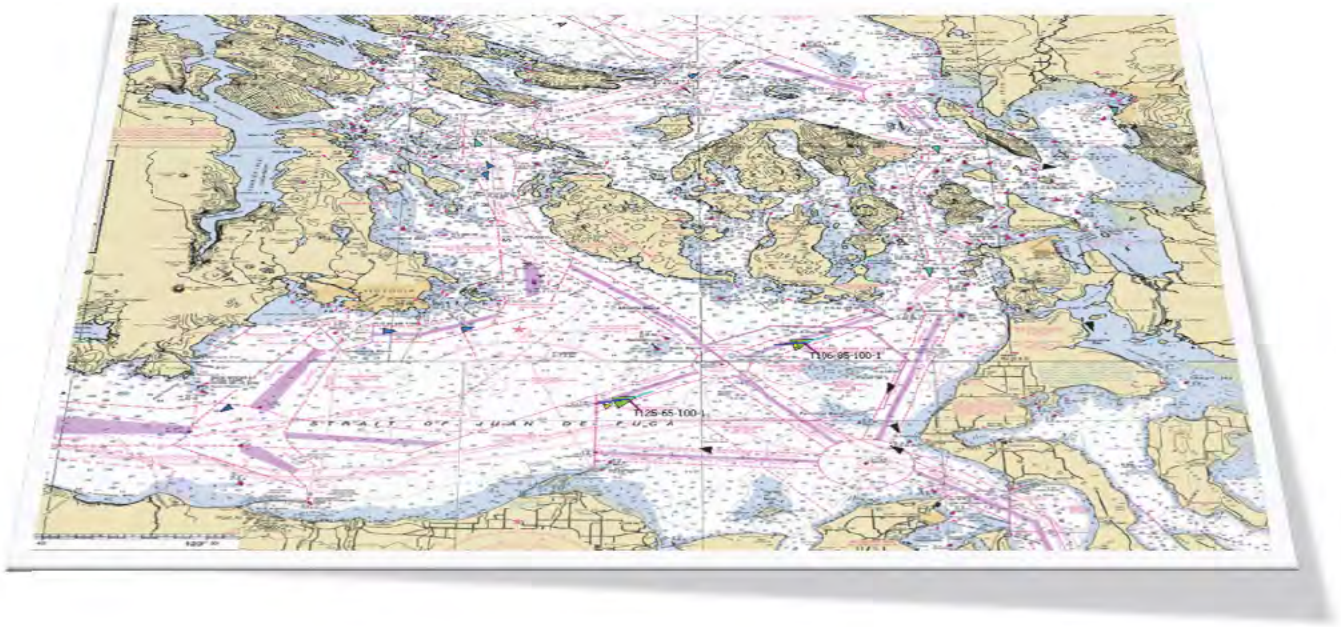

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Table Contents

8. RMM SCENARIOS

In coordination with the VTRA 2010 Steering Committee a number of Risk Mitigation Measures (RMM) were proposed listed in Table 12. While some were informed or suggested by the analysis results from the What-If scenarios described in Chapter 7 others were suggested as measures currently in place or under consideration.

Table 12. Descriptors and short description of Risk Mitigation Measure (RMM) scenarios modeled in VTRA 2010

	CASE P - RISK MITIGATION MEASURE (RMM) ANALYSIS
P - BC & DH100	Base Case year with 100% double hull fuel tank protection for Cargo Focus Vessels
P - BC & HE00	Base Case Year with 100% human error reduction on Oil Barges
P - BC & HE50	Base Case Year with 50% human error reduction on Oil Barges
P - BC & CONT17KNTS	Base Case Year with max speed of 17 knots for container ships
	CASE Q - RISK MITIGATION MEASURE (RMM) ANALYSIS
Q - GW 487 & NB	Gateway expansion scenario and no bunkering support
Q - GW 487 & NB & OH	Gateway expansion scenario and no bunkering support and traversing only Haro routes
	CASE T - RISK MITIGATION MEASURE (RMM) ANALYSIS
T - GW - KM - DP & OW ATB	Case T with ATB's adhering to one way Rosario traffic regime
T - GW - KM - DP & EC	Case T with Cape Class bulk carrier given benefit of+ 1 escort on Haro and Rosario routes
T - GW - KM - DP & EH	Case T with all Focus Vessels given benefit of +1 escort vessel on Haro routes
T - GW - KM - DP & ER	Case T with Cape bulkers, laden Tankers, ATB's given benefit of +1 esc. on Rosario routes
T - GW - KM - DP & 6RMM	Case T with benefit OW ATB, EH, ER, P-HE50, Q-NB and P-CONT17 KNTS

Modeling the Risk Management Scenarios

Risk mitigation measures currently in place or being considered were evaluated by implementing them on the VTRA 2010 Base Case scenario. For example, the RMM Scenario P-BC & 17knots was evaluated on the base case (P) as the max 17 knots speed for container vessels is currently practiced in parts of the VTRA 2010 study area. The RMM Scenario P-BC & 17knots implements a max speed of 17 knots in the VTRA 2010 model for container vessels throughout the entire VTRA study area. Similarly, currently about 40% of Cargo Vessels have double hull fuel protected tanks and was modeled as such in the VTRA 2010 base case analysis. The RMM Scenario P-BC & DH100 assumes that double hull protected fuel tanks are in effect in the VTRA 2010 model for all (100%) of the Cargo Focus Vessels.

A risk mitigation measure that adds one additional person on the bridge of oil barges in US waters is currently under consideration. While it is not clear how much a reduction this would provide in terms of the human error incident category, two risk mitigation measures scenarios P-BC & HE50 and P-BC & HE00 attempt to bound the POTENTIAL benefit of implementing such a risk mitigation

measure. The P-BC & HE50 RMM scenario applies a 50% reduction of the human error incident probability for oil barges across the entire VTRA study area within the VTRA 2010 model. The P-BC & HE00 RMM scenario applies a 100% reduction of the human error incident probability on oil barges. Hence, the analysis results for the P-BC & HE00 RMM scenario ought to be interpreted as a maximum POTENTIAL benefit analysis, whereas the P-BC & HE50 RMM scenario can be interpreted as a conservative evaluation of its POTENTIAL benefit.

The Q - GW 487 & NB RMM scenario in Table 12 was motivated by the observation in Figure 59 that a large part of the overall POTENTIAL collision accident frequency is attributed to oil barges. Given that the Gateway What-If Scenario provides for bunkering support for the additional Gateway vessels combined with the latter collision frequency observation, makes the Q - GW 487 & NB RMM scenario a natural RMM Scenario to be tested. Moreover, the observations in Figure 59 and Figure 60 that a larger part of the POTENTIAL collision accident frequency and POTENTIAL collision oil loss are observed in the Rosario Strait waterway zone, gives rise to the question if it would be a good idea for the added Gateway bulk carriers to avoid this waterway zone and travel solely to and from the planned Gateway Terminal through Haro-Strait/Boundary Pass. If that option were followed, bunkering at Vendovi Anchorage appears to be less meaningful and hence in the Q - GW 487 & NB & OH RMM scenario Gateway bunkering support is also removed from the Gateway What-If Scenario Q - GW 487.

Figure 88 demonstrates the difference in modeling the Gateway What-If focus vessels across these scenarios. Figure 88A depicts the travel time exposure of the Gateway What-If focus vessels for the What-If scenario Q: GW 487. Please observe from Figure 88A the larger spike at the Vendovi anchorages area (see also Figure 66) as a result of Gateway bulk carriers slowing down to anchor. Also observe in Figure 88A the vessel time exposure of oil barges travelling north and south in the Puget Sound. In Figure 88B one observes that the bunkering transits have been removed in the Q: GW 487 & NB RMM scenario as well as the transits of the Gateway bulk carriers to the Vendovi anchorages. In Figure 88C one observes that in the Q: GW 487 & NB & OH RMM scenario Gateway bunkering support has been removed and that Gateway bulk carriers now solely travel through Haro-Strait/Boundary Pass in the VTRA 2010 model.

The T-GW-KM-DP & OW ATB RMM Scenario in Table 12 addresses perhaps a lingering question in the Puget Sound stakeholder community; Would it be beneficial if articulated tug barges would also be subjected to the one-way zone regime in Rosario Strait? Since the inclusion of ATB's can cause additional delays for other vessels destined to travel through Rosario-Strait it seemed prudent to test this risk mitigation measure on the combined What-If Scenario with all three expansion projects assumed operational (i.e. test it on the What-If Scenario with the highest traffic levels added to the 2010 Base Case). The RMM measure T-GW-KM-DP & OC Scenario was

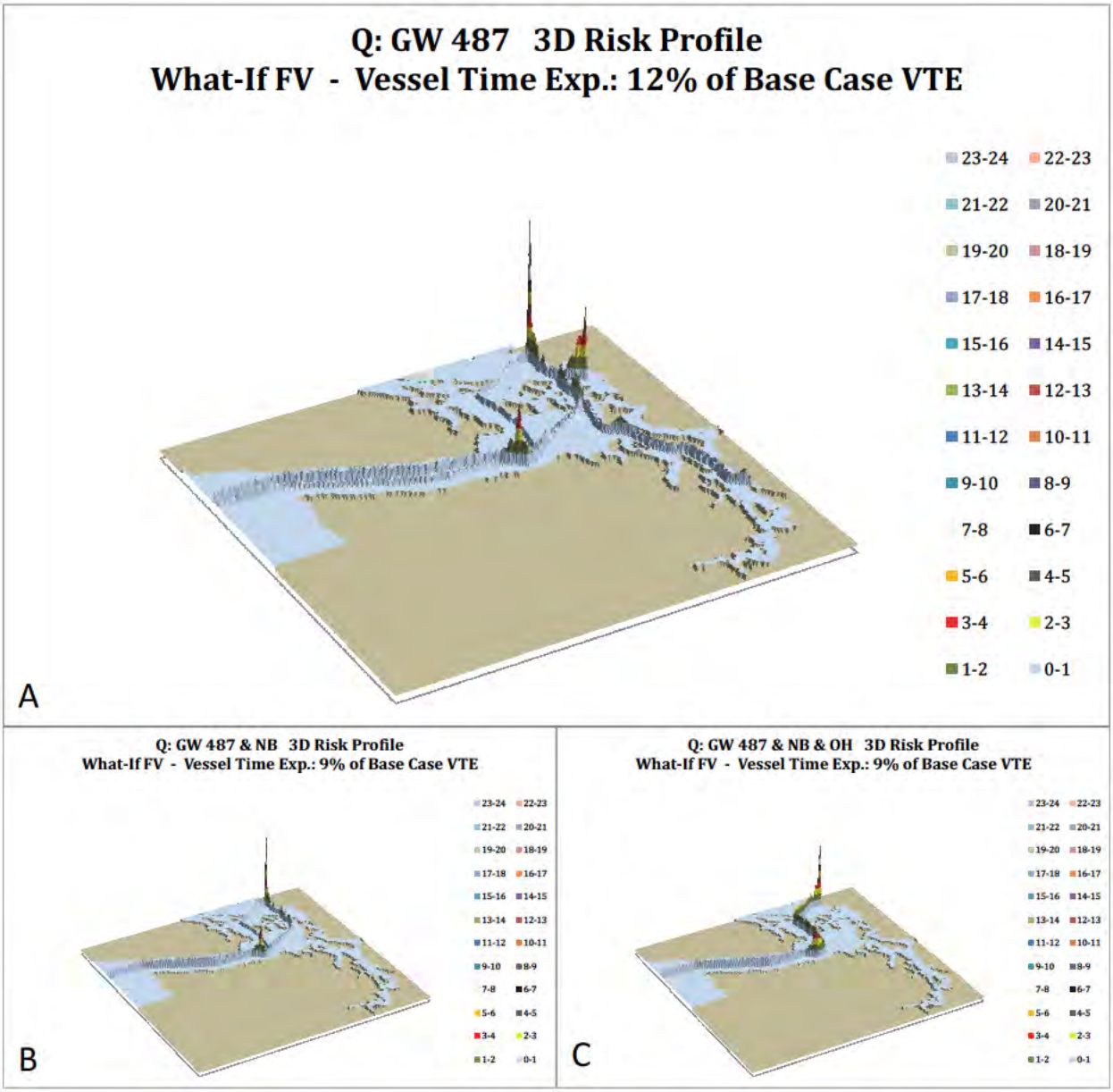

Figure 88. Vessel time exposure of Gateway What-If focus vessels under three Gateway Scenarios

motivated by the observation that currently no Cape Class bulker size vessels travel through the VTRA study area and given their size it would seem prudent to consider these Gateway destined vessels be escorted, at least at first. The RMM measure T-GW-KM-DP & EH Scenario was motivated primarily by the Trans Mountain Pipeline What-If Scenario analysis results depicted in Figure 86 and Figure 87. In Figure 86 and Figure 87 larger increases in POTENTIAL accident frequency and POTENTIAL oil outflow are observed in the Haro-Strait/Boundary Pass waterway zone. These

results prompted the question amongst steering committee members if pre-positioning of a rescue escort tug within this waterway zone would make sense. An advantage of pre-positioning over direct escorting is that other vessels also would receive the benefit of a pre-positioned escort tug. Moreover, pre-positioning would not result in an increase of traffic in this waterway zone and elsewhere as a result of escort vessels travelling to and from their destined vessels in the case of direct escorting. Pre-positioning has as its disadvantage however that the response time of the pre-positioned tug tends to be longer than that of a tug directly escorting a vessel. The VTRA 2005 model accommodates for the inclusion of one to two escort vessels within its accident probability model. Hence, to mimic the maximum potential benefit that prepositioning in the Haro-Strait/Boundary pass waterway zone could have, one additional escort vessel was assigned to all focus vessels on Haro-Strait/Boundary pass routes, i.e. to bulk carriers, container ships, chemical carriers, tankers, atb's and oil barges. The green area depicted in Figure 88 defines the location where the (+1) escort assumption in the VTRA 2010 accident probability model is in effect for the T-GW-KM-DP & EH RMM Scenario.

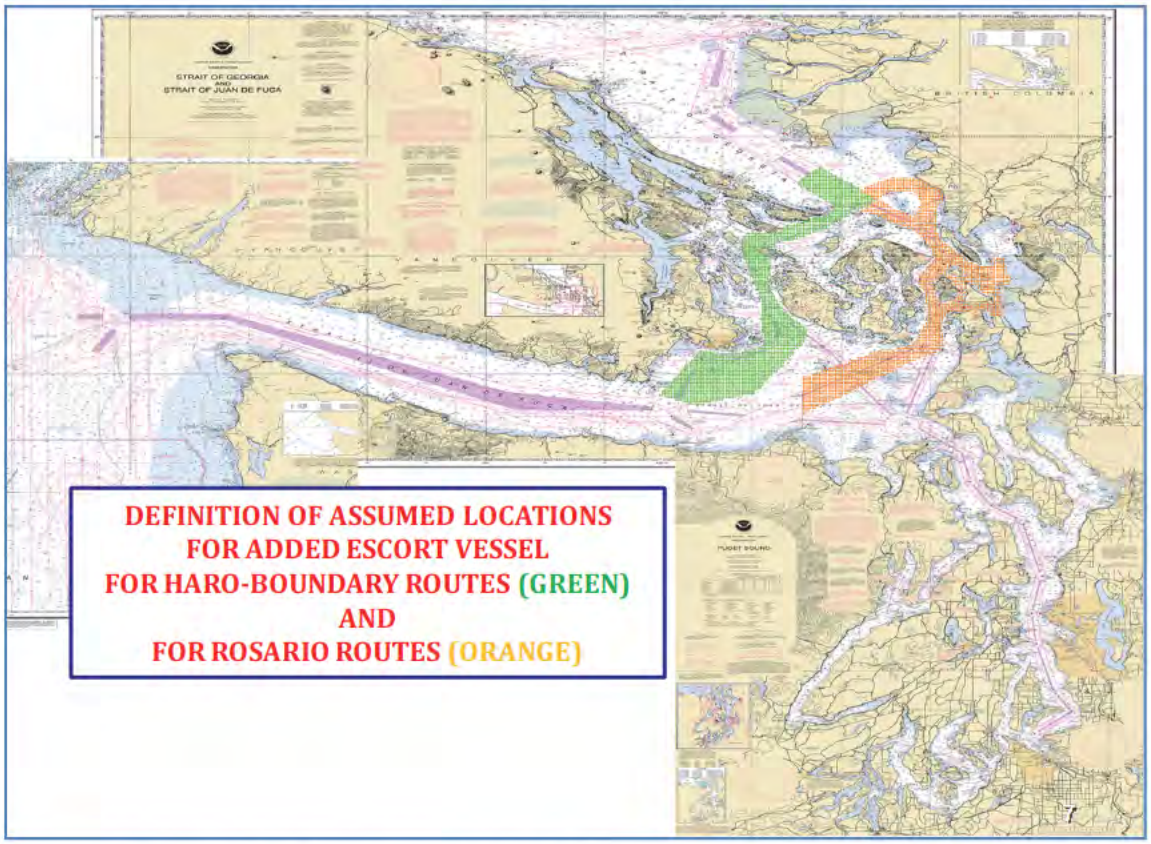

Figure 88. Definition of areas for escorting RMM scenario analyses in the VTRA 2010 model.

As a matter of curiosity, the analysis team also modeled an escorting scenario for the Rosario bound routes with descriptor T-GW-KM-DP & ER. Here, one additional escort would be assumed available in the VTRA 2010 accident probability model for laden tankers, laden chemical carriers and laden ATB's as well as inbound and outbound Cape Class Gateway bulkers. The area where the additional escorting would be assumed in effect for the T-GW-KM-DP & ER scenario is defined as the orange area in Figure 88.

Finally, the T-GW-KM-DP & 6RMM scenario evaluates the POTENTIAL benefit of a portfolio of risk mitigation measures being operational at the same time. The RMM's included in this portfolio are:

1. ATB's also obey the one way Rosario regime
2. Escorting on Haro-Strait/Boundary Pass routes as defined for T-GW-KM-DP & EH
3. Escorting on Rosario routes as defined for T-GW-KM-DP & ER
4. The 17knots max speed rule applied to container vessels in the VTRA study area
5. A 50% human error reduction for Oil barges travelling throughout the VTRA study area
6. Bunkering support for Gateway vessels removed from VTRA 2010 model

Needless to say, other portfolios/combinations of RMM's could have been selected to evaluate the POTENTIAL benefit of a set of RMM's being operational at the same time. While it would appear that potential individual benefits of RMM measure are additive, a more prudent approach toward POTENTIAL benefit analysis is to model them operational at the same time in the VTRA 2010 model to account for potential negative/positive synergistic effects.

Summary of RMM Scenarios Results enacted on Base Case P

Figure 89 depicts the summary analysis results of the POTENTIAL effectiveness of the RMM scenarios enacted on the VTRA 2010 Base Case (P). The effectiveness is evaluated in terms of vessel time exposure, accident frequency and oil outflow. The analysis results in Figure 89 demonstrate that different RMM's may affect different points along the oil spill accident event chain depicted in Figure 3. Note that the P-BC & CONT 17KNTS RMM scenario affects all three metrics, i.e. vessel time exposure, POTENTIAL accident frequency and POTENTIAL oil loss. The RMM scenario's P-BC & HE50 and P-BC & HE00 do not affect vessel time exposure, but do affect the POTENTIAL accident frequency and the POTENTIAL oil loss and finally, the P-BC & DH100 scenario only affects the POTENTIAL oil loss. From Figure 89 it follows that despite the expected increase of vessel time exposure (+4%) as a result of slowing down the container vessels, the POTENTIAL accident frequency reduces by (-4%). The POTENTIAL oil outflow reduction of slowing down the containers vessels is evaluated at (-6%). Both P-BC & HE50 and P-BC & HE00 RMM's Scenario's are most effective amongst the RMM scenario's in Figure 89 in reducing the POTENTIAL accident frequency, whereas the P-BC & DH100 scenario is most effective in terms of reducing POTENTIAL oil outflow. In risk management, however, we believe the question is not so much "which risk mitigation measure to implement?", but more which portfolio of risk mitigation

measures. In designing a portfolio of risk mitigation measures we advocate the application of a "defense-in-depth" principle by selecting risk mitigation measures that address all three drivers of POTENTIAL oil loss, i.e. vessel time exposure, POTENTIAL accident frequency given exposure and POTENTIAL oil loss given an accident has occurred.

	P - RMM SCENARIO REFERENCE POINT			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case	100%	100%	100%	100%
	CASE P - RISK MITIGATION MEASURE (RMM) ANALYSIS			
P - BC & DH100	Base Case year with 100% double hull fuel tank protection for Cargo Focus Vessels			
P - BC & HE00	Base Case Year with 100% human error reduction on Oil Barges			
P - BC & HE50	Base Case Year with 50% human error reduction on Oil Barges			
P - BC & CONT17KNTS	Base Case Year with max speed of 17 knots for container ships			

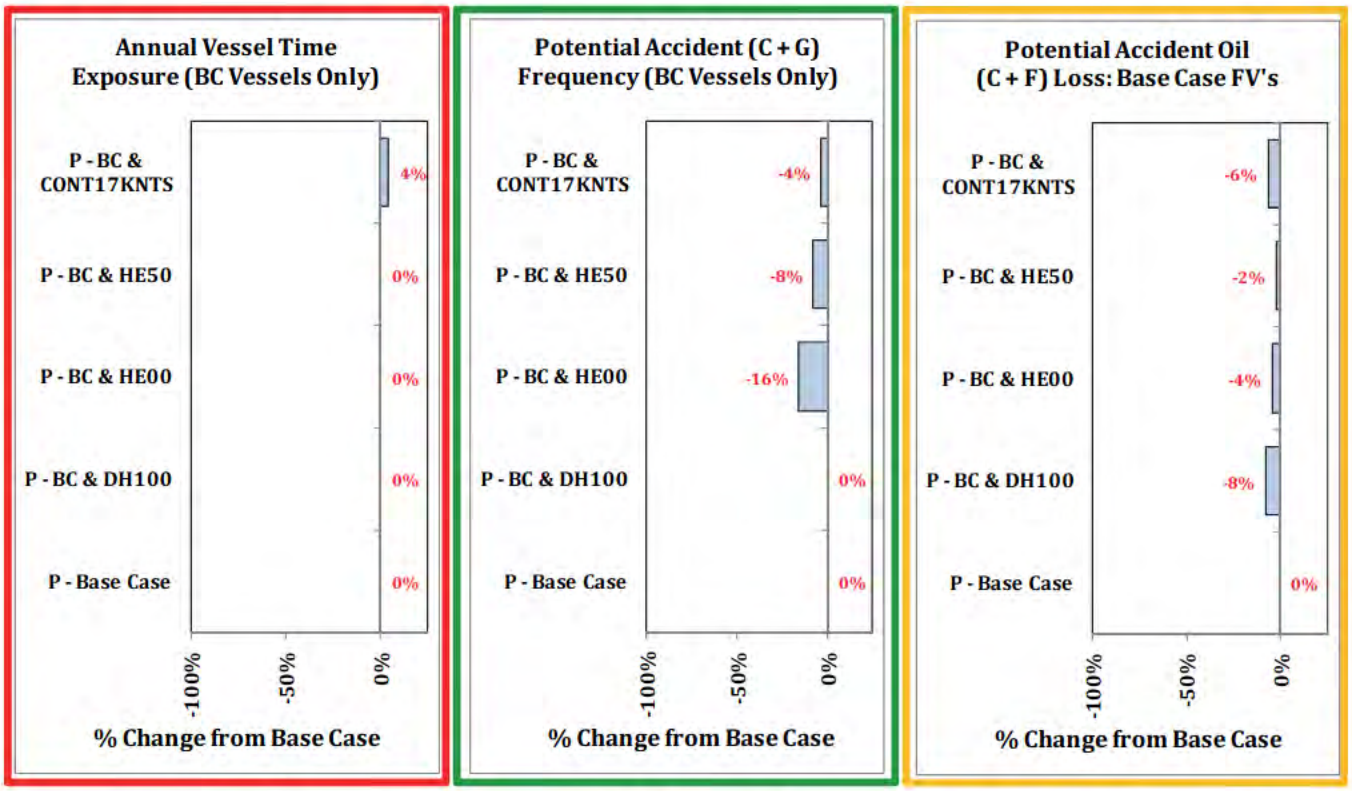

Figure 89. Summary Analysis results of RMM Scenario Analysis enacted on the base case (P).

By waterway zone analysis results of RMM measures enacted on base case (P)

Figure 90 provides a by waterway zone comparison of risk reduction effectiveness in terms of POTENTIAL accident frequency. Figure 91 provides a by waterway zone comparison of risk reduction effectiveness in terms of POTENTIAL oil loss. Observe from Figure 90 that by waterway

zone the P-BC & DH100 RMM scenario has no effect in terms of reducing accident frequency (as to be expected), whereas we observe from Figure 91 a risk reduction in all waterway zones in terms of POTENTIAL oil outflow except for the waterway zones Guemes, Saddlebag and Rosario (where a relative low number of cargo focus vessels traverse). For the other waterway zones the P-BC & DH100 RMM scenario has a virtually across the board reduction effect in terms of POTENTIAL oil loss. In fact, six out of the remaining twelve have relative risk reduction waterway zone factors less than 0.85[12].

Observe from Figure 90 and Figure 91 that the largest absolute risk reduction of the P-BC & CONT17KNTS scenario is attributed to the waterway zone Puget Sound North. In the Puget Sound North also the largest relative waterway reduction factor (0.73) is observed in terms of POTENTIAL oil outflow. In other words, limited to the Puget Sound North POTENTIAL oil outflow the 17 knots speed restriction has a 27% risk reduction effect. A large part of vessel to vessel interactions in the Puget Sound North in the VTRA 2010 model are oil barge – container vessel interactions.

Finally, from Figure 90 on observes an across the board risk reduction effect in terms of POTENTIAL accident frequency in the P-BC & HE00 scenario (and similarly the P-BC & HE50) scenario. The largest absolute risk reductions in POTENTIAL accident frequency of about 2% or higher are observed in those waterway zones where oil barges predominantly travel, i.e. the Puget Sound South, Guemes, Islands Trust and Puget Sound North waterway zones. In the Tacoma South waterway zone the most beneficial relative waterway zone risk reduction factor of 0.74 is observed[13].

Summary of RMM Scenarios Results enacted on Gateway Terminal Case

Figure 89 depicts the summary analysis results of the POTENTIAL effectiveness of the RMM scenarios enacted on the VTRA 2010 Gateway What-If scenario (Q). The absolute effectiveness is evaluated in terms of vessel time exposure, accident frequency and oil outflow in terms of base case percentages. Absolute differences, however, are evaluated in Figure 89 as reductions from Case Q. One observes from Figure 89 about a 5% reduction in vessel time exposure by removing oil bunkering support, resulting in similar reductions in POTENTIAL accident frequency. Most notably, however, is the 10% reduction in POTENTIAL oil outflow in the Q – GW487 & NB RMM scenario. That is, twice the reduction in vessel time exposure and POTENTIAL accident frequency when removing oil bunkering support from the Gateway What-If Scenario. Overall one observes that it appears to be more beneficial for Gateway bulk carriers to have the option to travel using the Rosario Strait routes (The Q – GW487 & NB RMM scenario) than limit their travel to only using the Haro-Strait Boundary pass routes (The Q – GW487 & NB & OH RMM scenario).

[12] Hence, in these waterway zones the RMM has a 15% reduction effect or more in POTENTIAL oil loss.
[13] Hence, in this waterway zone the RMM has a 26% risk reduction effect in POTENTIAL accident frequency.

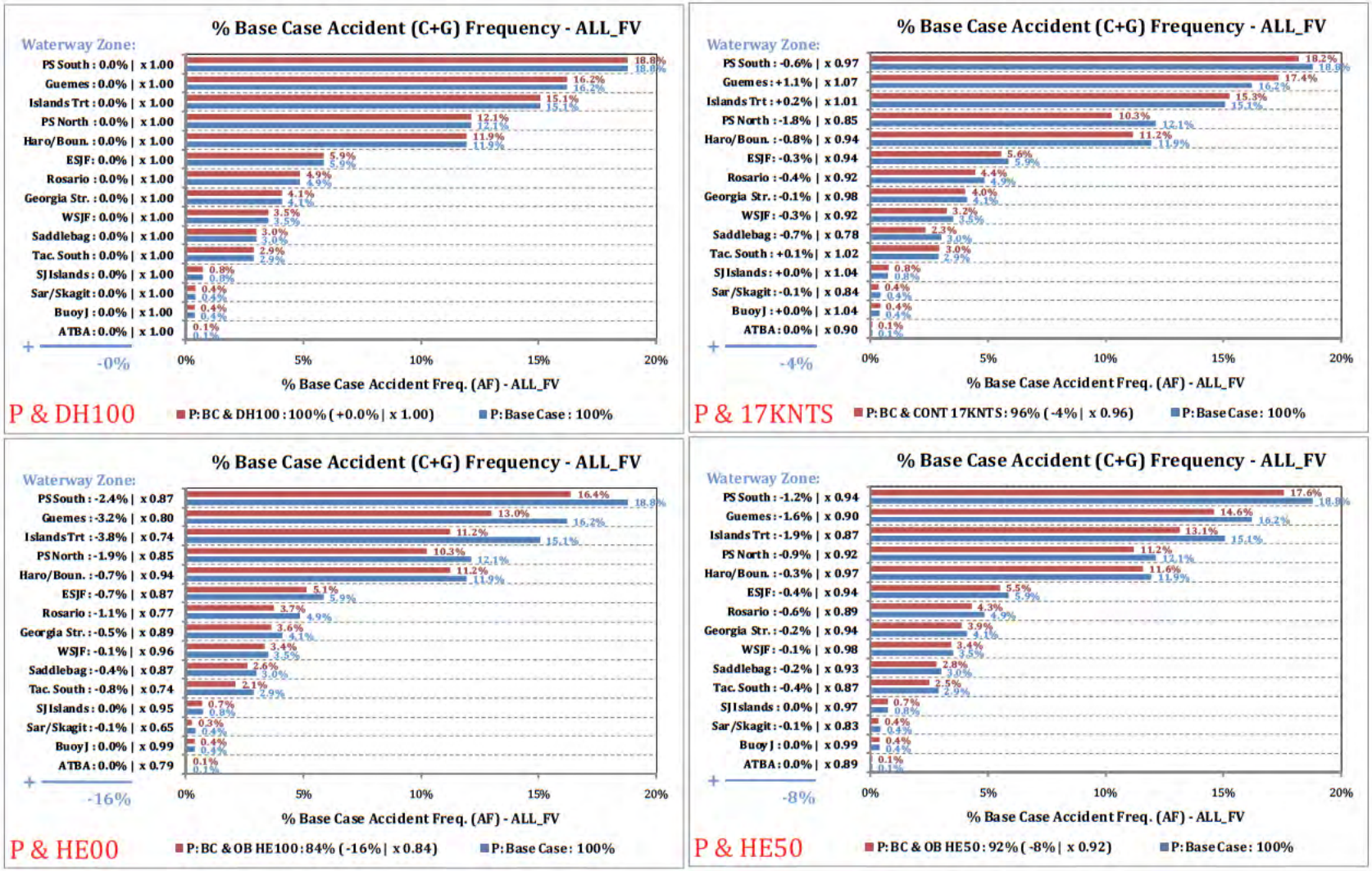

Figure 90. Waterway zone POTENTIAL accident frequency results comparison of RMM's enacted on base case (P). For a detailed explanation of output format see Page 97.

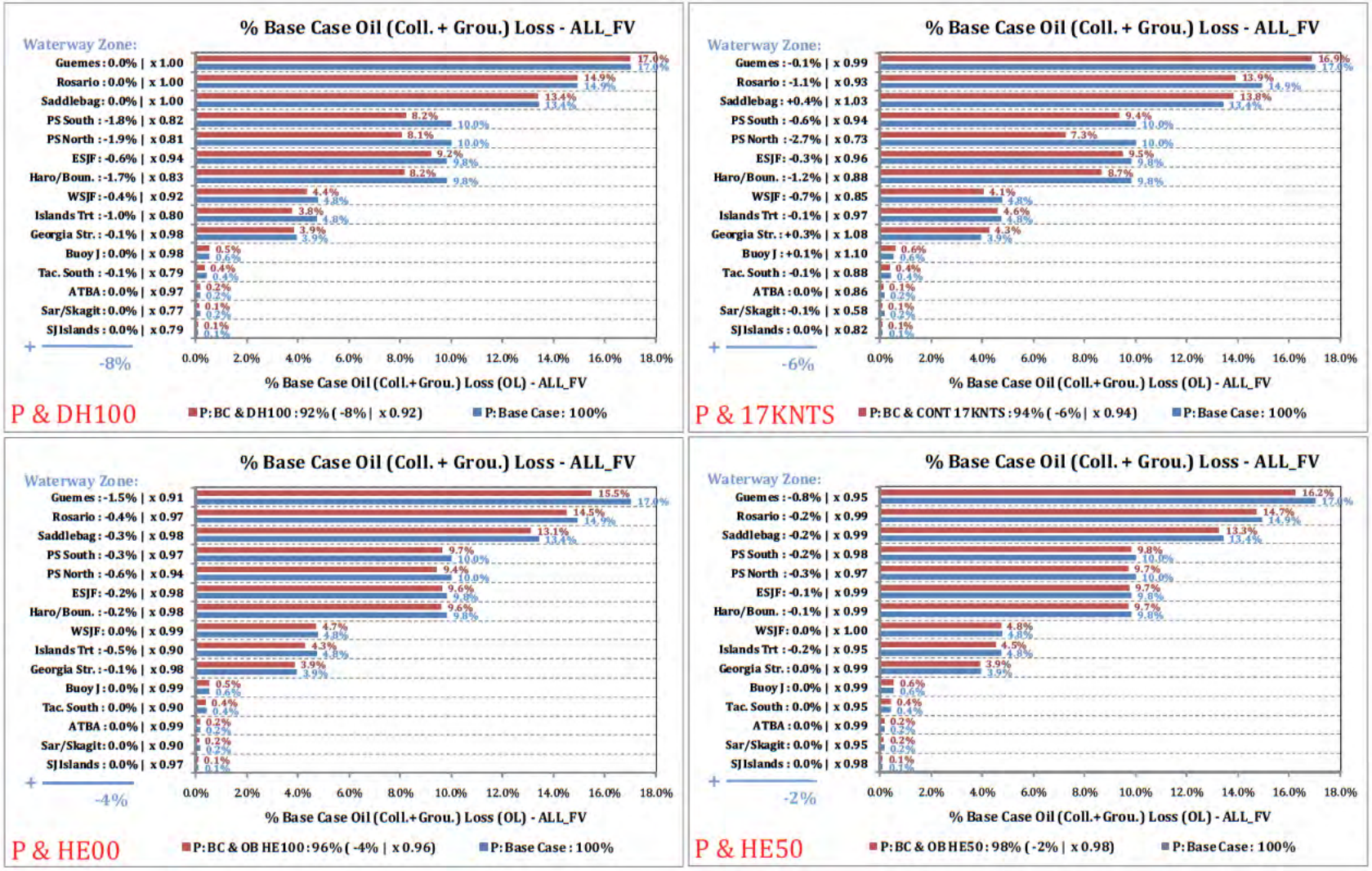

Figure 91. Waterway zone POTENTIAL oil outflow results comparison of RMM's enacted on base case (P). For a detailed explanation of output format see Page 97.

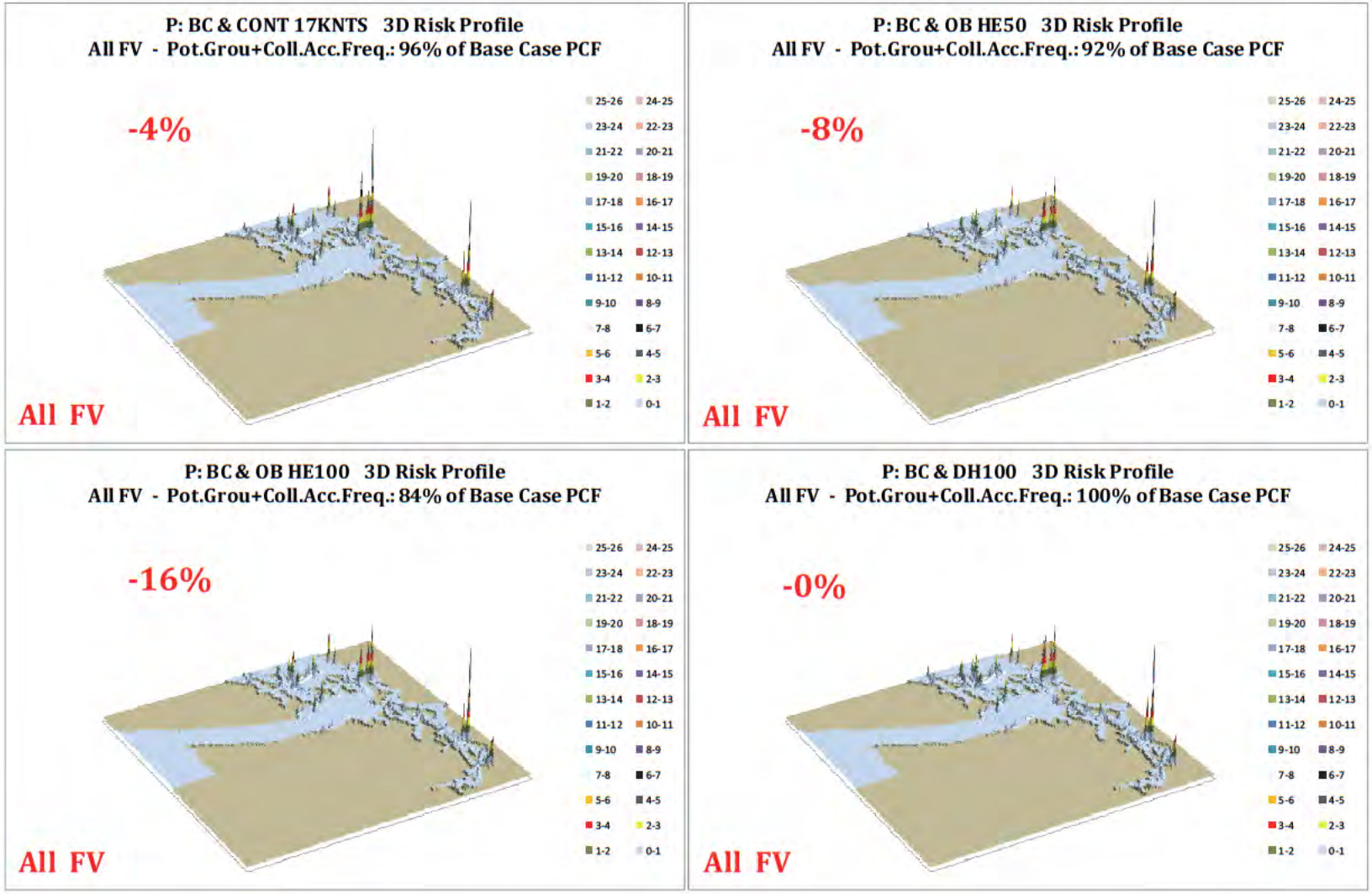

Figure 92. 3D geographic profile POTENTIAL accident frequency results of RMM's enacted on base case (P)

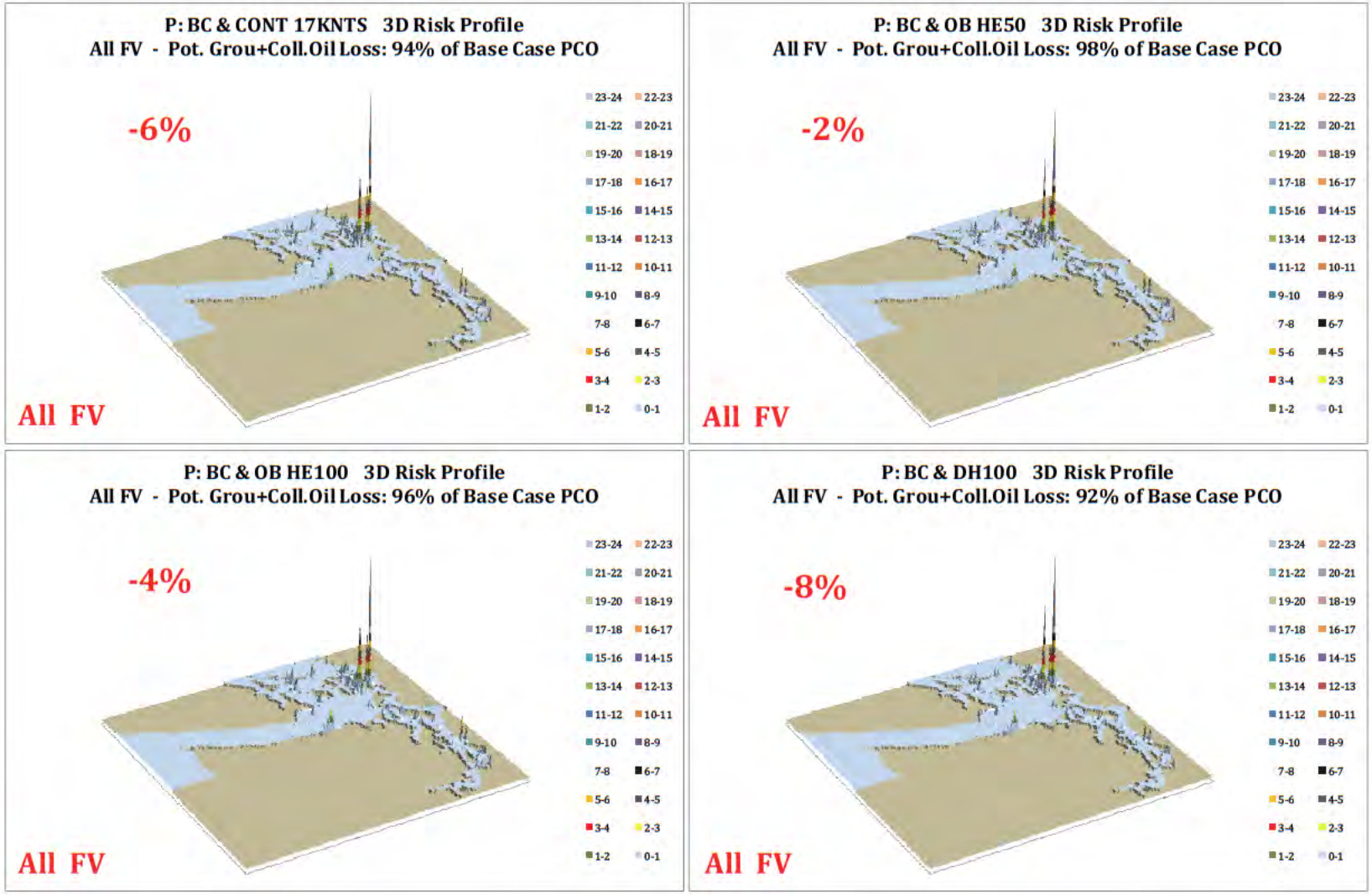

Figure 93. 3D geographic profile POTENTIAL oil outflow results of RMM's enacted on base case (P)

	Q - RMM SCENARIO REFERENCE POINT			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
Q - GW - 487	+13% | 113%	+5% | 105%	+12% | 112%	+12% | 112%
	CASE Q - RISK MITIGATION MEASURE (RMM) ANALYSIS			
Q - GW 487 & NB	Gateway expansion scenario and no bunkering support			
Q - GW 487 & NB & OH	Gateway expansion scenario and no bunkering support and traversing only Haro routes			

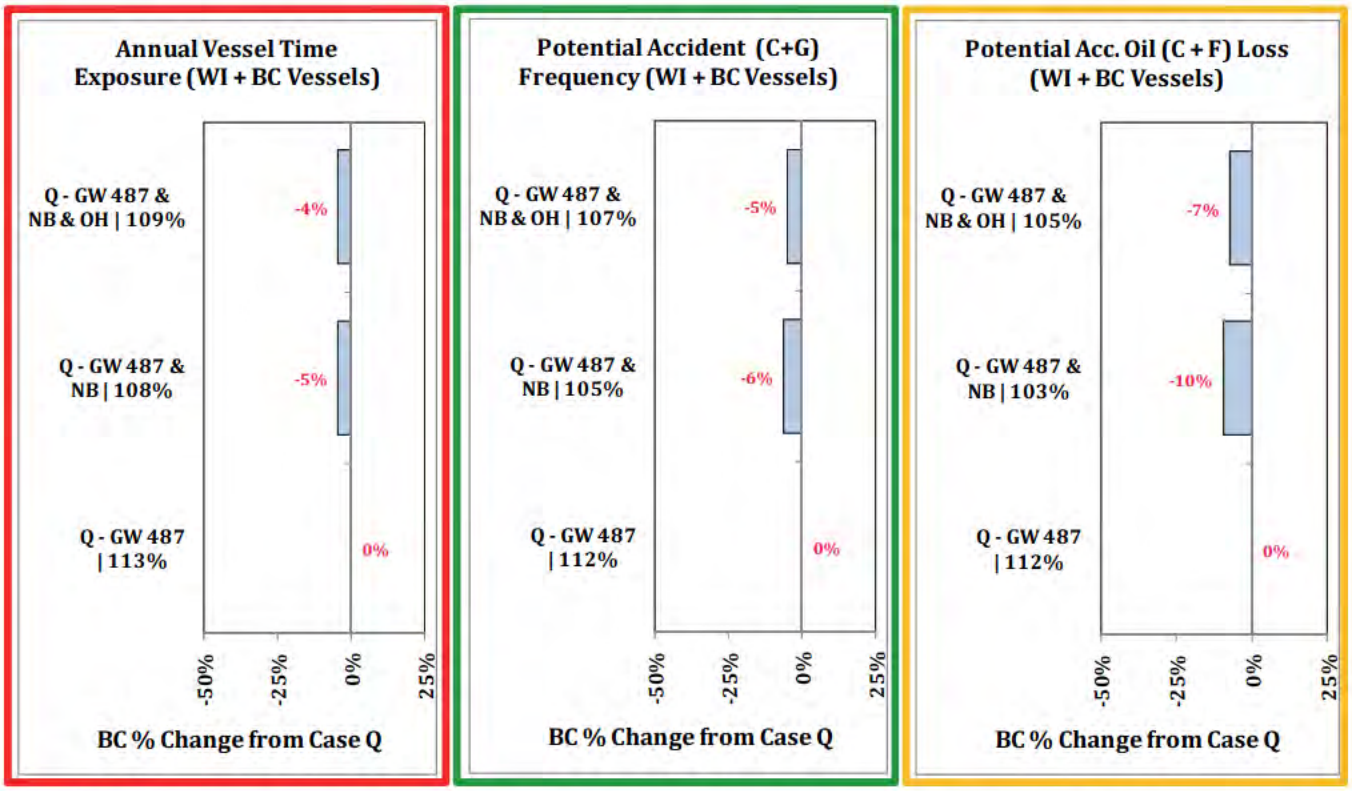

Figure 94. Summary Analysis results of RMM Scenario Analysis enacted on the Gateway What-If Scenario (Q).

By waterway zone analysis results of RMM measures enacted on Gateway What-If Scenario (Q)

Figure 95 depicts the by waterway zone comparison results for both POTENTIAL accident frequency and POTENTIAL oil loss for the RMM scenarios enacted in the Gateway What-If Scenario (Q). Absolute differences, however, are evaluated in Figure 95 as reductions from Case Q. Thus, relative waterway zone reduction factors are evaluated in Figure 95 with respect to waterway zone risk experienced under the Gateway What-If scenario (Q-GW487) in the VTRA 2010 model. The largest absolute reduction in POTENTIAL accident frequency (-1.7%) from the What-If Scenario (Q-GW487) is observed for the Q-GW487 & NB RMM scenario is observed in the Rosario Strait and Saddlebag Waterway zones. This translates for the Saddlebag waterway zone in

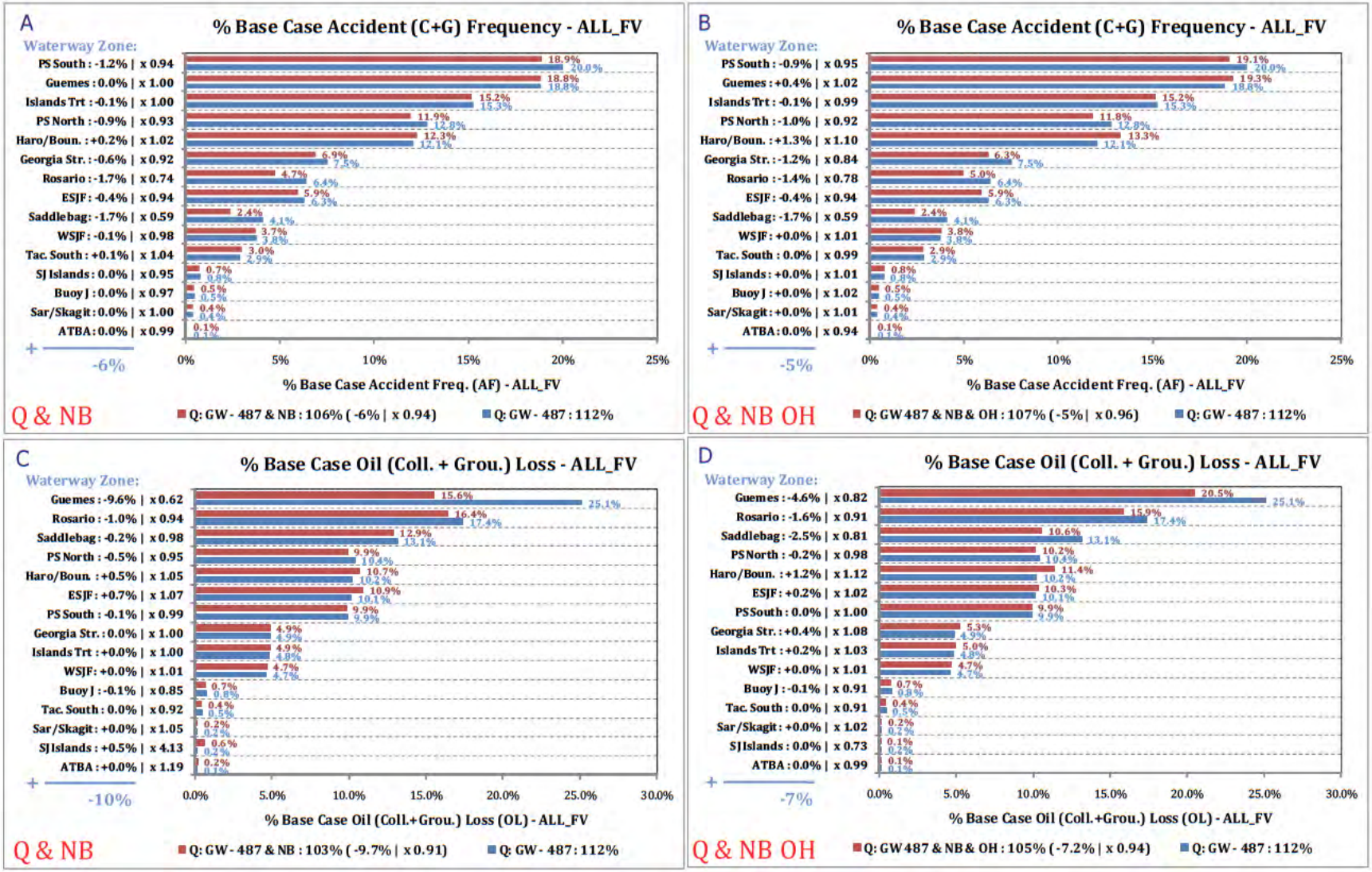

Figure 95. Waterway zone POTENTIAL accident frequency and POTENTIAL oil outflow results comparison of RMM's enacted on Gateway What-If Scenario (Q). For a detailed explanation of output format see Page 97.

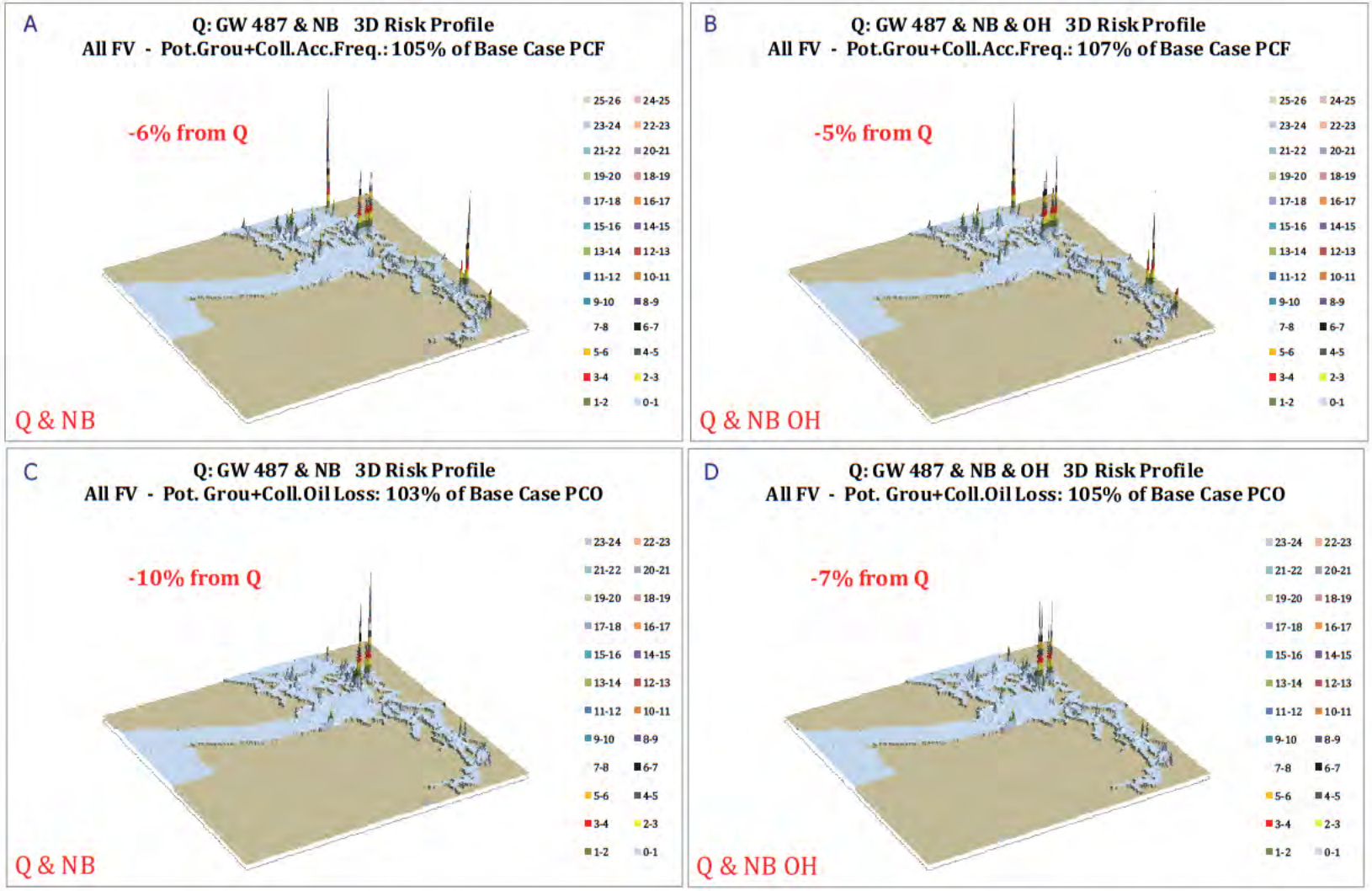

Figure 96. 3D geographic profile POTENTIAL oil outflow results of RMM's enacted on the Gateway What-If Scenario (Q)

the largest relative waterway zone reduction factor of 0.59 in terms of POTENTIAL accident frequency[14]. It is important to realize here that the 0.59 risk reduction factor is evaluated relative to the risk experienced in the Saddlebag waterway zone when the Gateway expansion is assumed operational within the VTRA 2010 model. However, observe from Figure 95 that the reduction in POTENTIAL accident frequency in the Saddlebag waterway zone does not translate in a reduction in POTENTIAL oil outflow. In fact, the largest waterway zone risk reduction factor in terms of POTENTIAL oil outflow of 0.62 is observed in the Guemes waterway zone, which did not experience a similar risk reduction effect in terms of POTENTIAL accident frequency. Hence, these effects are a result in a change of vessel mix and timing that different vessels see as they traverse the Saddlebag and Guemes waterway zones when oil bunkering support for Gateway is removed from the VTRA 2010 model.

Similar risk reduction effects are observed in the Q - GW487 & NB & OH RMM scenario, i.e. when removing bunkering support for Gateway and having all Gateway bulk carriers travel through Haro-Strait. Here, however, the POTENTIAL oil spill risk reduction previously experienced only in the Guemes Waterway zone now appears to be split between the Guemes and Saddlebag waterway zones. Notably, in the Q - GW487 & NB & OH RMM scenario one observes absolute increases in POTENTIAL accident frequency and POTENTIAL oil outflow of about 1% in Haro-Strait/ Boundary Pass which translate in a waterway zone relative risk increase factor of 1.10[15]. While the Rosario waterway zone experiences a larger waterway zone reduction factor 0.91 in the Q - GW487 & NB & OH RMM scenario (as opposed to 0.94 in the Q - GW487 & NB RMM scenario), such a larger decrease is not observed in terms of POTENTIAL accident frequency. Hence, it would appears that increases in POTENTIAL accident frequency in the Haro-Strait/Boundary Pass waterway zone under the Q - GW487 & NB & OH RMM scenario are not off-set by similar decreases in POTENTIAL accident frequency in the Rosario-Strait waterway zone in the VTRA 2010 model.

Summary of RMM Scenarios Results enacted on Combined Case T

Figure 97 depicts the summary analysis results of the POTENTIAL effectiveness of the RMM scenarios enacted on the VTRA 10 Combined What-If scenario (T – GW – KM - DP). Their absolute effectiveness is evaluated in terms of vessel time exposure, POTENTIAL accident frequency and POTENTIAL oil outflow in terms of base case percentages. Absolute differences, however, are evaluated in Figure 97 as reductions from Case T. Note, that in the three escorting scenarios ER, EH and EC no increases are observed in terms of vessel time exposure since the additional transits of escorting vessels from and to their assignment are not represented in these RMM scenario

[14] Hence, in this waterway zone the RMM has a 41% risk reduction effect in POTENTIAL accident frequency.
[15] Hence, by Gateway bulk carriers using only the Haro-Strait/Boundary pass routes the risk in this waterway zone increases by about 10% from the What-If Scenario Q-GW487.

analyses. Hence, the subsequent reductions in POTENTIAL accident frequencies and POTENTIAL oil outflow ought to be interpreted as maximum POTENTIAL benefit analyses. Most notably, amongst these escorting RMM scenarios ER, EH and EC, is the 24% percent reduction in POTENTIAL oil loss in the EH RMM scenario. No doubt, this is the result of the assumption of (+1) escort for all focus vessels to mimic prepositioning in the VTRA 2010 model, but also because the Case T experiences a significant waterway zone increase factor (3.75) in terms of oil time Exposure (OTE) in Haro-Strait/Boundary pass (see Figure 98) in the VTRA 2010 model.

	T - RMM SCENARIO REFERENCE POINT			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
T - GW - KM - DP	+25% | 125%	+59% | 159%	+18% | 118%	+68% | 168%
	CASE T - RISK MITIGATION MEASURE (RMM) ANALYSIS			
T - GW - KM - DP & OW ATB	Case T with ATB's adhering to one way Rosario traffic regime			
T - GW - KM - DP & EC	Case T with Cape Class bulk carrier given benefit of+ 1 escort on Haro and Rosario routes			
T - GW - KM - DP & EH	Case T with all Focus Vessels given benefit of +1 escort vessel on Haro routes			
T - GW - KM - DP & ER	Case T with Cape bulkers, laden Tankers, ATB's given benefit of +1 esc. on Rosario routes			
T - GW - KM - DP & 6RMM	Case T with benefit OW ATB, EH, ER, P-HE50, Q-NB and P-CONT17 KNTS			

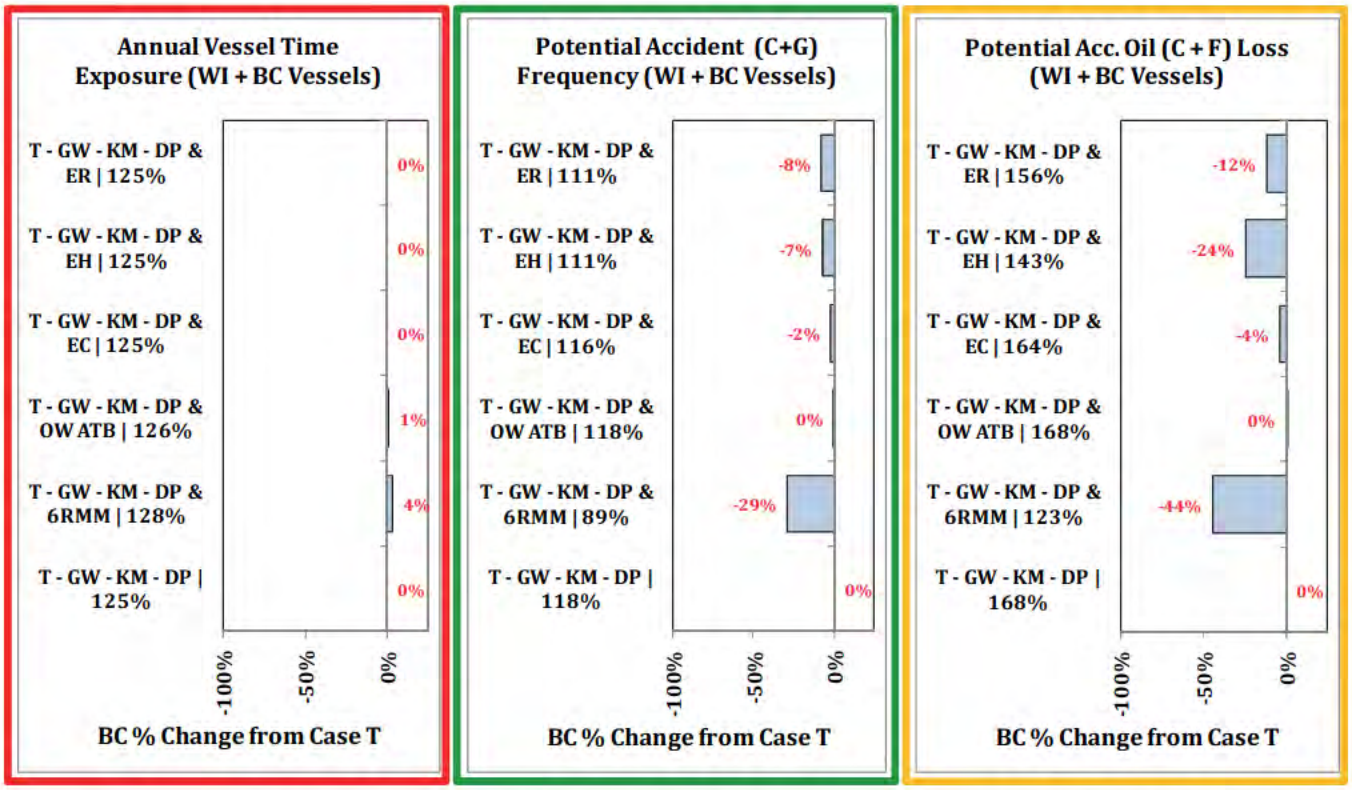

Figure 97. Summary Analysis results of RMM Scenario Analysis enacted on the Combined What-If Scenario (T).

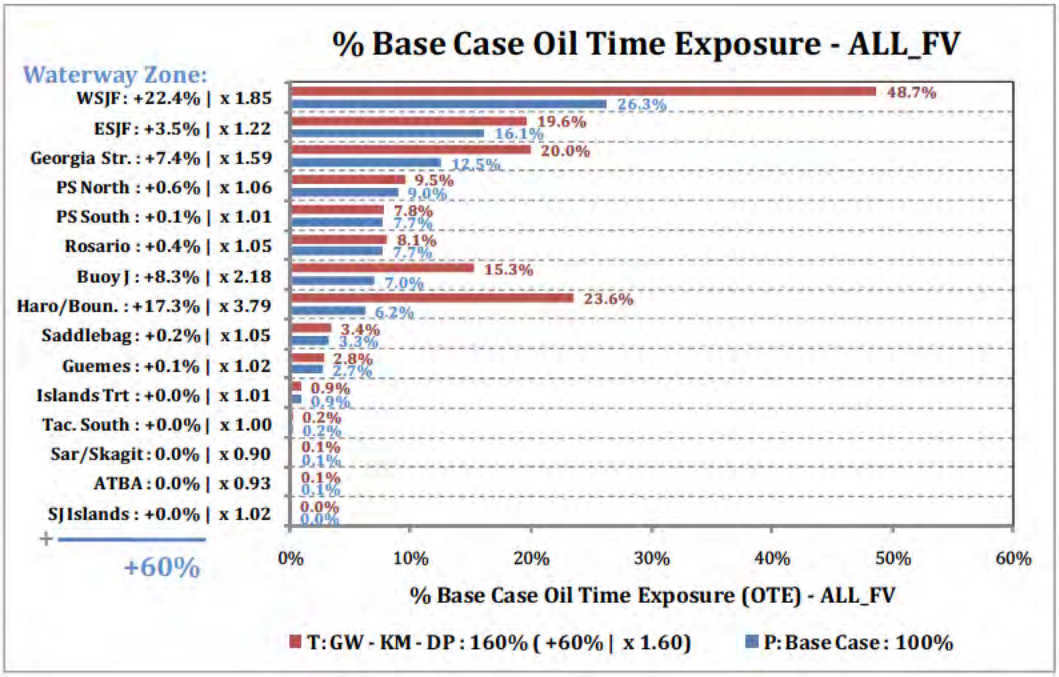

Figure 98. Waterway zone Oil Time Exposure comparison between Combined What-If Scenario (T) and the Base Case (P). For a detailed explanation of output format see Page 97.

In other words, such a reduction would not be experienced without the Trans Mountain Pipeline expansion being in effect. On the other hand, a large part of the reduction of the 12% - 4% = 8% under the ER RMM scenario (i.e. adding (+1) escort to laden tankers, chemical carriers, ATB's and Cape Class Gateway bulkers) on Rosario bound routes can be expected when the Trans Mountain Pipeline and the Gateway expansions are not in effect[16]. Of course, a separate analysis conducted of the ER RMM scenario enacted on the base case (P) would need to be conducted to confirm such a reduction in POTENTIAL oil loss. Note that while the T-GW-KM-DP EH RMM scenario is more effective in terms of reduction of POTENTIAL oil loss compared to the T-GW-KM-DP ER RMM scenario, the reverse is observed for the reduction in POTENTIAL accident frequency.

Observe from Figure 97 that the RMM scenario of ATB's also obeying the one way zone regime does not appear to be an effective RMM measure in the VTRA 2010 model, neither in terms of POTENTIAL oil loss nor in terms of POTENTIAL accident frequency. In fact, a (+1%) increase in vessel time exposure is observed in the T-GW-KM-DP & OW ATB RMM scenario as a result of additional delays as an effect of adding ATB's to the Rosario one way zone regime in the VTRA 2010 model.

[16] We are subtracting the 4% benefit evaluated for the EC escorting scenario to get to 8%.

Finally, it would be interesting to conclude if the six RMM's in the T-GW-KM-DP & 6RMM scenario have an overall additive effect. Since absolute effectiveness of the RMM scenarios listed in Table 12 are all evaluated in terms of base case percentages, we can combine the overall benefit percentage changes evaluated on the Base Case (P) RMM, Gateway (Q) RMM and Combined (T) RMM scenario's. In terms of the benefit of absolute POTENTIAL accident frequency reduction we have for P-BC & 17knts (-4%), P – BC & HE50 (-8%), Q – GW487 & NB (-1%), T-GW-KM-DP & ATB (-0%), T – GW-KM-DP EH (-7%) and finally T – GW-KM-DP EH (-8%), summing to (-27%) which is close to the evaluated reduction (-29%) evaluated for the T-GW-KM-DP & 6RMM scenario. In terms of the benefit of absolute POTENTIAL oil loss reduction we have for P-BC & 17knts (-6%), P – BC & HE50 (-2%), Q – GW487 & NB (-10%), T-GW-KM-DP & ATB (-0%), T – GW-KM-DP EH (-24%) and finally T – GW-KM-DP EH (-14%), summing to a (-55%) which is a greater reduction than the evaluated reduction (-44%) evaluated for the T-GW-KM-DP & 6RMM scenario. The latter is indicative of our position that once risk reduction in a particular waterway has been addressed that it will become progressively more difficult to reduce risk even further in that waterway zone. Note, that in the T-GW-KM-DP & 6RMM scenario analysis the P – BC & DH100 was not included which resulted in a POTENTIAL oil outflow reduction of (-8%). Hence, if enacted in addition on Case T next to the other 6RMM's one could expect an additional 8% reduction. Of course, once again, this would have to be confirmed by evaluating the benefit of adding the DH100 RMM to the T-GW-KM-DP & 6RMM scenario.

By waterway zone analysis results of RMM measures enacted on Combined What-If Scenario (T)

Figure 99 and Figure 100 depict the by waterway zone comparison results for both POTENTIAL accident frequency and POTENTIAL oil loss for the RMM scenarios enacted on the Combined What-If Scenario (T – GW – KM - DP). Absolute differences, however, are evaluated in Figure 95 as reductions from Scenario T. Relative waterway zone reduction factors are evaluated in Figure 99 and Figure 100 relative to waterway zone risk experienced under the Combined What-If scenario (T – GW – KM - DP) in the VTRA 2010 model.

As a first observation, observe from Figure 99 and Figure 100 that the T-GW-KM-DP & 6RMM scenario results in risk reduction across virtually all fifteen waterway zones, whereas the escorting RMM scenarios ER and EH alternate their benefit primarily in the waterway zones Rosario Strait and Haro-Strait/Boundary Pass. From the legend in Figure 99 it follows that the POTENTIAL accident frequency (89%) in the T-GW-KM-DP & 6RMM scenario is evaluated as less than the POTENTIAL accident frequency (100%) of the Base Case (P)!

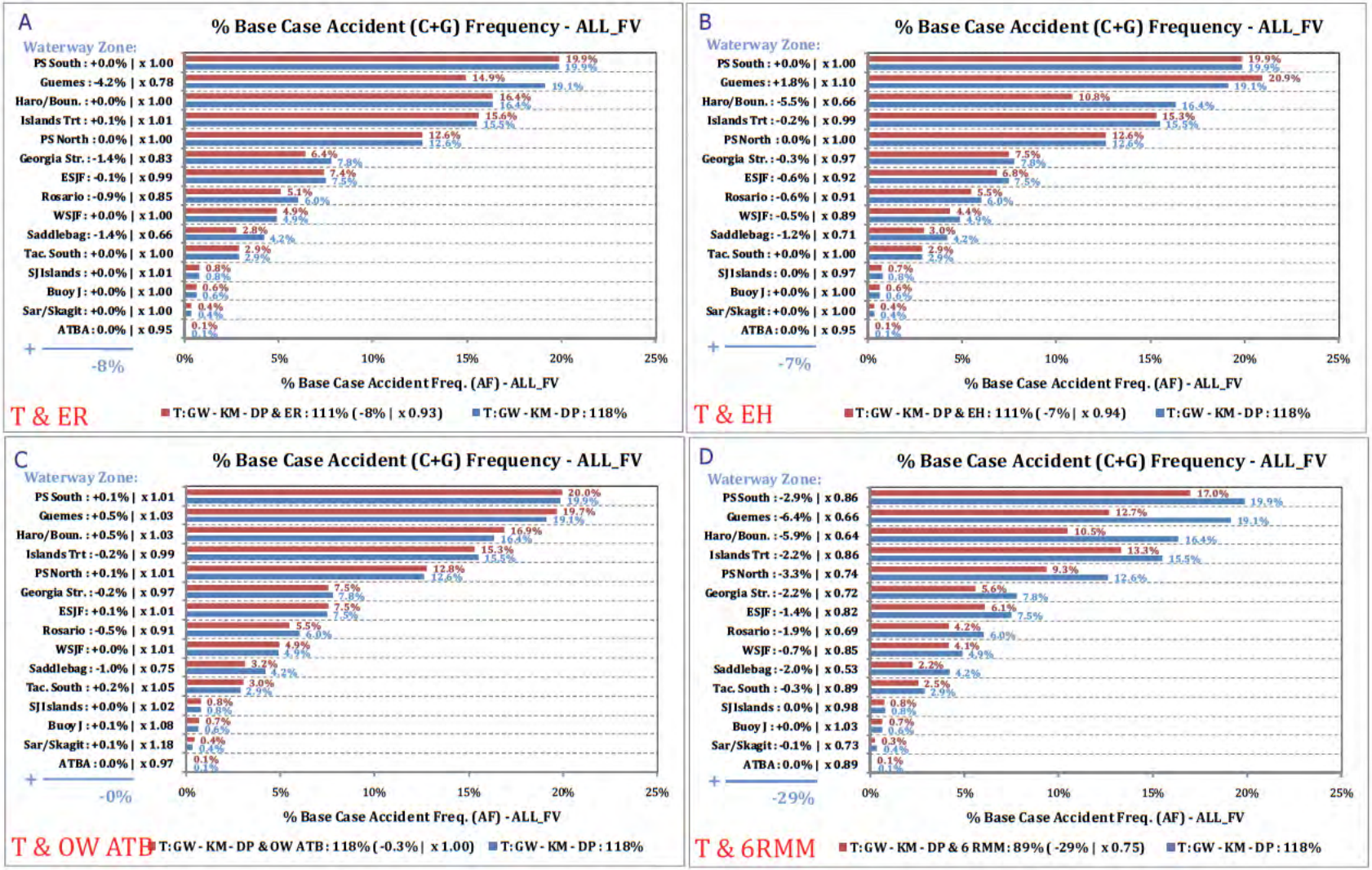

Figure 99. Waterway zone POTENTIAL accident frequency results comparison of RMM's enacted on Gateway What-If Scenario (Q). For a detailed explanation of output format see Page 97.

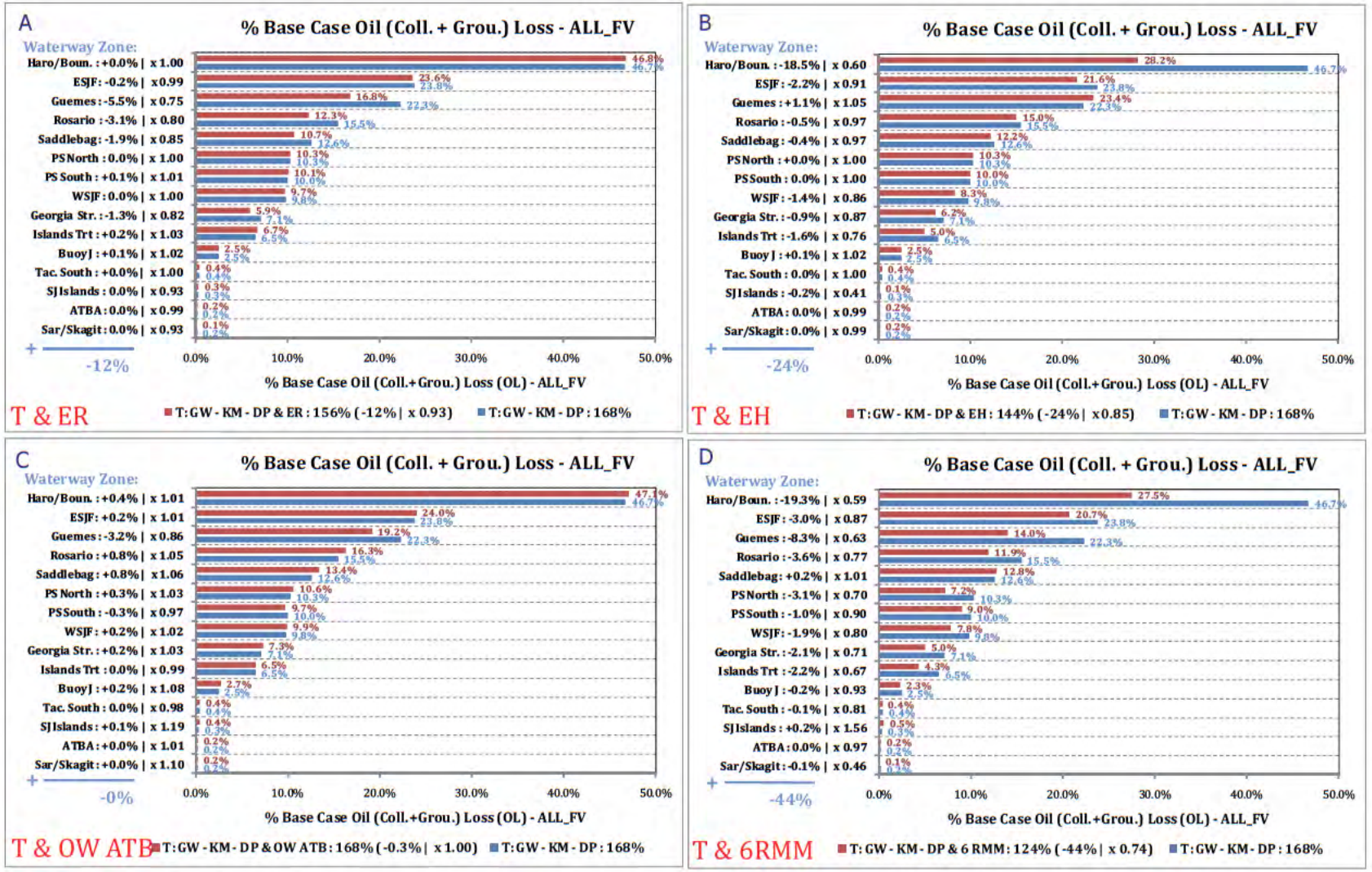

Figure 100. Waterway zone POTENTIAL oil outflow results comparison of RMM's enacted on Gateway What-If Scenario (Q). For a detailed explanation of output format see Page 97.

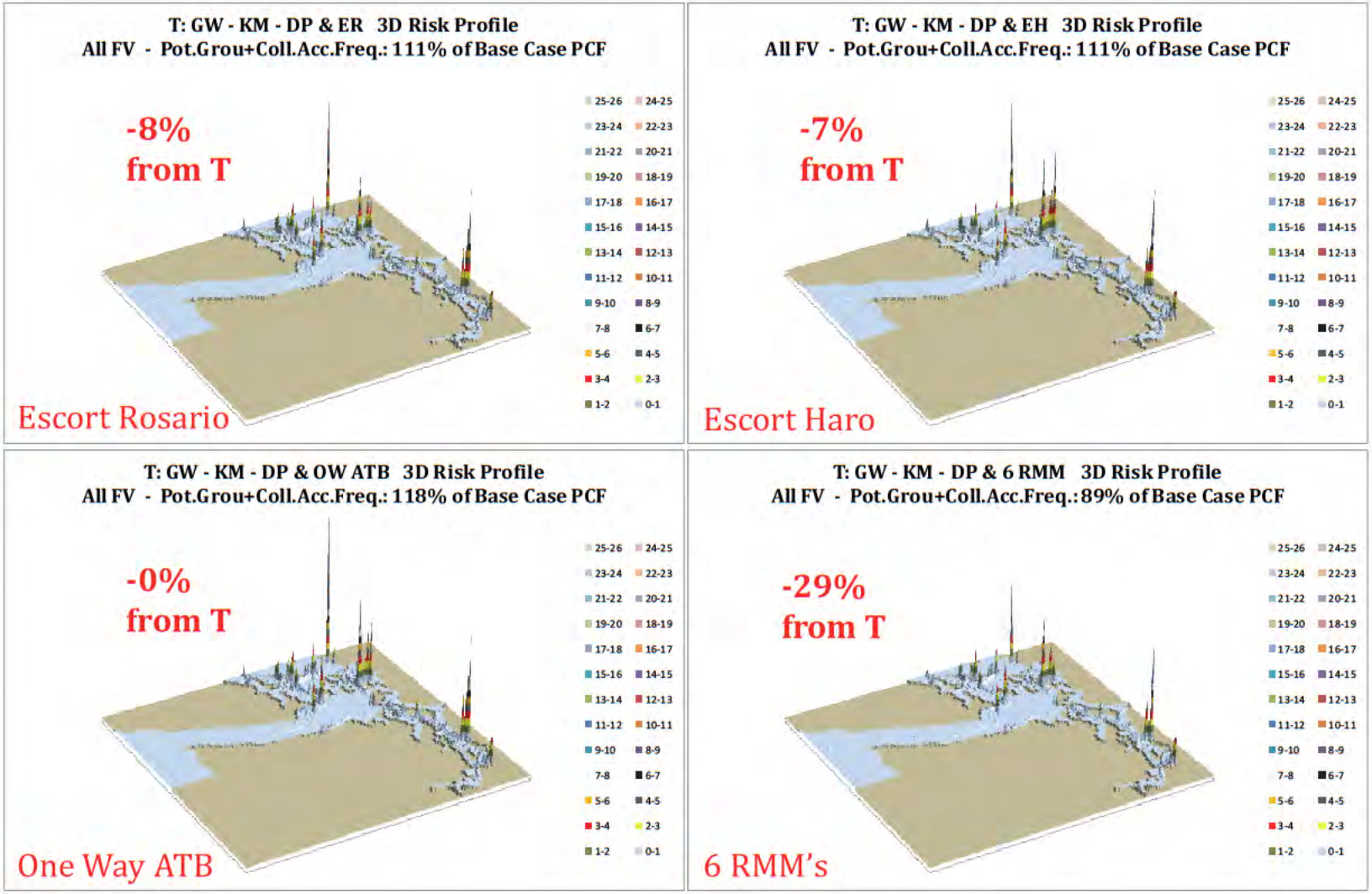

Figure 101. 3D geographic profile POTENTIAL accident frequency results of RMM's enacted on the Combined What-If Scenario (T)

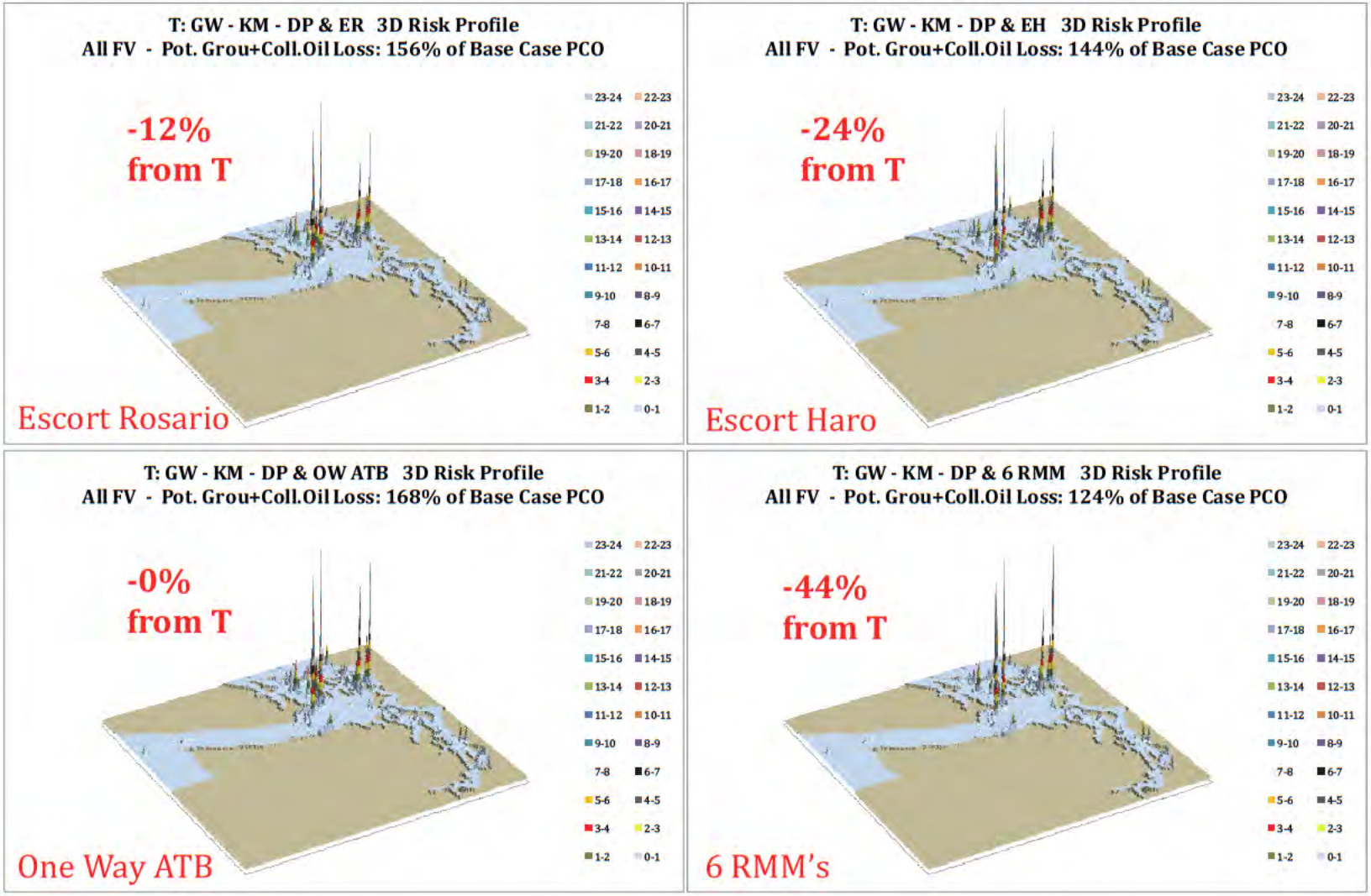

Figure 102. 3D geographic profile POTENTIAL oil outflow results of RMM's enacted on the Combined What-If Scenario (Q

For the ER RMM Scenario one observes an absolute risk reduction of 1% in terms of POTENTIAL accident frequency and 3.1% in terms of POTENTIAL oil outflow in the Rosario Strait waterway zone. These translate in waterway zone relative risk reduction factors of 0.85 in POTENTIAL accident frequency and 0.80 in POTENTIAL oil loss in the Rosario Strait waterway zone. Most notably, one observes a 0.66 relative risk reduction factor in POTENTIAL accident frequency in the Saddlebag waterway zone and 0.75 in terms of POTENTIAL oil loss[17]. We attribute this to the additional escorting of laden ATB's which are currently not escorted. The difference in benefit between the Rosario Strait and Saddle bag waterway zones we attribute to laden tankers already being assigned an escort vessel. Similar relative waterway zone risk reduction factors are observed in the Haro-Strait/Boundary Pass waterway zone under the EH RMM scenario (0.66 in terms of POTENTIAL accident frequency and 0.64 in terms of POTENTIAL oil outflow). These translate into an absolute (-5.5%) reduction in POTENTIAL accident frequency and an (-18.5%) reduction in POTENTIAL oil loss in the Haro-Strait/Boundary Pass waterway zone.

[17] Hence, this RMM results in a 34% and 25% risk reduction in this waterway zone in POTENTIAL accident frequency and POTENTIAL oil outflow respectively.