Office of National Marine Sanctuaries
Office of Response and Restoration

Screening Level Risk Assessment Package

Diamond Knot

March 2013

National Oceanic and
Atmospheric Administration

Office of National Marine Sanctuaries
Daniel J. Basta, Director
Lisa Symons
John Wagner

Office of Response and Restoration
Dave Westerholm, Director
Debbie Payton
Doug Helton

Photo: Photograph of *Diamond Knot* sinking
Source: http://john-rawlings.newsvine.com/_news/2008/06/27/1619426-the-wreck-of-the-diamond-knot-jewel-beneath-an-emerald-sea

Table of Contents

Project Background

The past century of commerce and warfare has left a legacy of thousands of sunken vessels along the U.S. coast. Many of these wrecks pose environmental threats because of the hazardous nature of their cargoes, presence of munitions, or bunker fuel oils left onboard. As these wrecks corrode and decay, they may release oil or hazardous materials. Although a few vessels, such as USS *Arizona* in Hawaii, are well-publicized environmental threats, most wrecks, unless they pose an immediate pollution threat or impede navigation, are left alone and are largely forgotten until they begin to leak.

In order to narrow down the potential sites for inclusion into regional and area contingency plans, in 2010, Congress appropriated $1 million to identify the most ecologically and economically significant potentially polluting wrecks in U.S. waters. This project supports the U.S. Coast Guard and the Regional Response Teams as well as NOAA in prioritizing threats to coastal resources while at the same time assessing the historical and cultural significance of these nonrenewable cultural resources.

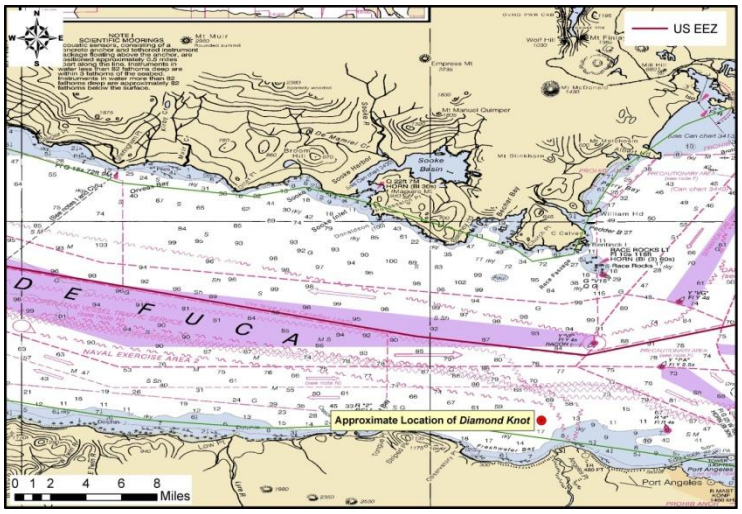
The potential polluting shipwrecks were identified through searching a broad variety of historical sources. NOAA then worked with Research Planning, Inc., RPS ASA, and Environmental Research Consulting to conduct the modeling forecasts, and the ecological and environmental resources at risk assessments.

Initial evaluations of shipwrecks located within American waters found that approximately 600-1,000 wrecks could pose a substantial pollution threat based on their age, type and size. This includes vessels sunk after 1891 (when vessels began being converted to use oil as fuel), vessels built of steel or other durable material (wooden vessels have likely deteriorated), cargo vessels over 1,000 gross tons (smaller vessels would have limited cargo or bunker capacity), and any tank vessel.

Additional ongoing research has revealed that 87 wrecks pose a potential pollution threat due to the violent nature in which some ships sank and the structural reduction and demolition of those that were navigational hazards. To further screen and prioritize these vessels, risk factors and scores have been applied to elements such as the amount of oil that could be on board and the potential ecological or environmental impact.

Executive Summary: *Diamond Knot*

The freighter *Diamond Knot*, sunk after a collision in the Strait of Juan de Fuca in 1947, was identified as a potential pollution threat, thus a screening-level risk assessment was conducted. The different sections of this document summarize what is known about the *Diamond Knot*, the results of environmental impact modeling composed of different release scenarios, the ecological and socio-economic resources that would be at risk in the event of releases, the screening-level risk scoring results and overall risk assessment, and recommendations for assessment, monitoring, or remediation.



Based on this screening-level assessment, each vessel was assigned a summary score calculated using the seven risk criteria described in this report. For the Worst Case Discharge, *Diamond Knot* scores High with 16 points; for the Most Probable Discharge (10% of the Worse Case volume), *Diamond Knot* scores Medium with 13 points. Given these scores, and higher levels of data certainty, NOAA recommends that this site be noted in the Area Contingency Plans and be considered for further assessment to determine the vessel condition, amount of oil onboard, and feasibility of oil removal action. At a minimum, an active monitoring program should be implemented. Outreach efforts with the technical and recreational dive community as well as commercial and recreational fishermen who frequent the area would be helpful to gain awareness of changes in the site. Because it is such a popular dive site, this may be an opportunity to engage local divers as citizen-scientists in monitoring of the wreck for oil releases and changes in its condition.

Vessel Risk Factors		Risk Score	
Pollution Potential Factors	A1: Oil Volume (total bbl)	Med	
	A2: Oil Type		
	B: Wreck Clearance		
	C1: Burning of the Ship		
	C2: Oil on Water		
	D1: Nature of Casualty		
	D2: Structural Breakup		
Archaeological Assessment	Archaeological Assessment	Not Scored	
Operational Factors	Wreck Orientation	Not Scored	
	Depth		
	Confirmation of Site Condition		
	Other Hazardous Materials		
	Munitions Onboard		
	Gravesite (Civilian/Military)		
	Historical Protection Eligibility		
		WCD	MP (10%)
Ecological Resources	3A: Water Column Resources	Med	Med
	3B: Water Surface Resources	Med	Low
	3C: Shore Resources	Low	Low
Socio-Economic Resources	4A: Water Column Resources	High	Med
	4B: Water Surface Resources	High	High
	4C: Shore Resources	High	Med
Summary Risk Scores		16	13

The determination of each risk factor is explained in the document. This summary table is found on page 40.

SECTION 1: VESSEL BACKGROUND INFORMATION: REMEDIATION OF UNDERWATER LEGACY ENVIRONMENTAL THREATS (RULET)

Vessel Particulars

Official Name: *Diamond Knot*

Official Number: 246686

Vessel Type: Freighter

Vessel Class: C1-M-AV1 "Sea Mavi" class cruiser

Former Names: N/A

Year Built: 1944

Builder: Consolidated Steel, Wilmington, DE

Builder's Hull Number: 1219

Flag: American

Owner at Loss: Alaska Steamship Company

Controlled by: N/A

Chartered to: N/A

Operated by: Alaska Steamship Company

Homeport: Seattle, WA

Length: 323 feet **Beam:** 50 feet **Depth:** 26 feet

Gross Tonnage: 3,805 **Net Tonnage:** 2,123

Hull Material: Steel **Hull Fastenings:** Welded **Powered by:** Oil Engines

Bunker Type: Medium Fuel Oil (Marine Diesel) **Bunker Capacity (bbl):** 6,516

Average Bunker Consumption (bbl) per 24 hours: 65 **Liquid Cargo Capacity (bbl):** N/A

Dry Cargo Capacity: Unknown

Tank or Hold Description: Unknown

Casualty Information

Port Departed: Unknown

Destination Port: Unknown

Date Departed: Unknown

Date Lost: August 13, 1947

Number of Days Sailing: Unknown

Cause of Sinking: Collision with freighter *Fenn Victory*

Latitude (DD): 48.1716

Longitude (DD): -123.576

Nautical Miles to Shore: 1.54

Nautical Miles to NMS: 56

Nautical Miles to MPA: 7.2

Nautical Miles to Fisheries: Unknown

Approximate Water Depth (Ft): 140

Bottom Type: Mud/silt

Is There a Wreck at This Location? Yes, wreck has been positively located and identified

Wreck Orientation: Resting on its starboard side

Vessel Armament: None

Cargo Carried when Lost: 154,000 cases of Alaskan canned salmon (cargo was salvaged)

Cargo Oil Carried (bbl): 0

Cargo Oil Type: N/A

Probable Fuel Oil Remaining (bbl): Unknown ≤6,500

Fuel Type: Medium Fuel Oil (Diesel)

Total Oil Carried (bbl): ≤ 6,500

Dangerous Cargo or Munitions: No

Munitions Carried: None

Demolished after Sinking: No

Salvaged: Yes, cargo of salmon was recovered

Cargo Lost: No

Reportedly Leaking: No

Historically Significant: Yes

Gravesite: No

Salvage Owner: Not known if any

Wreck Location

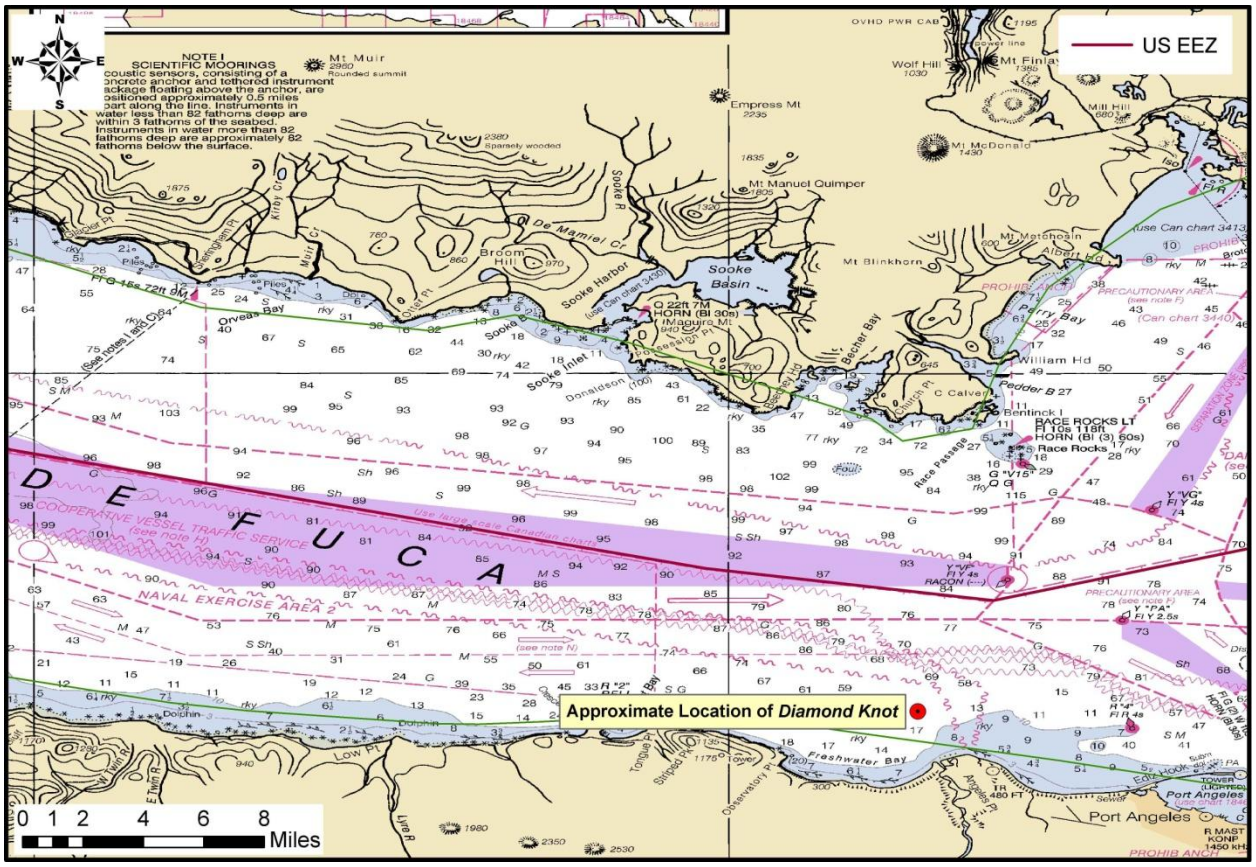


Chart Number: 18400

Casualty Narrative

From the Ottawa Citizen Aug. 13, 1947: "The 5,525-ton Seattle motorship *Diamond Knot*, sliced almost half-way through in a collision with the freighter *Fenn Victory*, sank in the fog-bound strait of Juan de Fuca at 9:05 a.m., Royal Canadian Navy officials said today. The 326-foot vessel, owned by the Alaska Steamship Company, had a $3,000,000 salmon cargo aboard as it disappeared below the water while in tow by two tugs. She was rammed deep amidships by the 10,681-ton freighter shortly after daybreak…"

General Notes

The cargo of salmon was salvaged in the largest salvage operation of its time. Since then the wreck has become an icon in the Pacific Northwest with breweries and beers named in its honor.

Wreck Condition/Salvage History

“Today, the *Diamond Knot* has become a gold mine for Pacific Northwest Technical Divers and advanced recreational divers who have the knowledge and skills to experience her. In addition to the damage inflicted by the collision with the *Fenn Victory*, the massive cutting operations involved in the salvage efforts further weakened the hull and much of the wreck has collapsed upon itself over time. Penetration of the wreck is still possible at some points, but such a venture requires extreme levels of training, skill, and caution.

Time and the nutrient-rich waters of the Strait of Juan de Fuca have taken their toll on the *Diamond Knot*. The vessel is enshrouded with a thick encrustation of anemones, scallops, sponges, giant barnacles, and hundreds of other underwater denizens of the Pacific Northwest. Throughout most of the wreck, it is only the straight and regular edges obviously created by man that mark it as a sunken ship and not a marvelously intricate rocky reef. Serving as an artificial reef, the *Diamond Knot* hosts huge numbers of various species of Northwest Rockfish and Greenling that often will curiously approach divers. The *Diamond Knot* is a dream for both the macro and wide-angle photographer, with life literally covering almost every square inch of the wreck. The invertebrate population quite literally consists of everything from the tiniest of single-celled creatures to the giant Puget Sound King Crab and virtually everything else in between. Huge Ling Cod, Cabezon, Red Irish Lord and Wolf Eel can be found on the wreck and make marvelous photo opportunities when they can be convinced to pose. A healthy population of Giant Pacific Octopus (Enteroctopus dofleini) can also be found living amongst the nooks and crannies of the wreck, feeding on the vast quantities of crustaceans to be found there. Each season individual Octopuses of great size are reported by visiting divers and underwater photographers.

Visibility on the *Diamond Knot* is never constant and is heavily dependent on the season as well as both current and weather conditions, occasionally dropping to 10 feet or less (at times, far less!). Divers would do best to explore the ship with the attitude of accepting whatever visibility "Old Juan de Fuca" decides to allow, planning ahead for all possible conditions.

Just as they brought the *Diamond Knot* to her eventual demise, today the tidal currents sweeping over the wreck can still be fierce, and dives should be planned for slack water or periods of low tidal exchange. While exploring the wreck, structure can be used to block much of the force of the current. However, divers need to be constantly aware that those same currents can drastically affect their ascent and should plan accordingly. While the *Diamond Knot* can be planned as a non-decompression dive, those divers planning decompression stops using an anchor line would be well served to carry JON lines as part of their equipment and be thoroughly acquainted with their use in high current. Additionally, a solid knowledge of reel and lift-bag decompression techniques and skills is also recommended should a decompressing diver be swept off the anchor line. Divers and boat crews should discuss and anticipate such events and plan for them before they occur."
-http://john-rawlings.newsvine.com/_news/2008/06/27/1619426-the-wreck-of-the-diamond-knot-jewel-beneath-an-emerald-sea

Archaeological Assessment

The archaeological assessment provides additional primary source based documentation about the sinking of vessels. It also provides condition-based archaeological assessment of the wrecks when possible. It does not provide a risk-based score or definitively assess the pollution risk or lack thereof from these vessels, but includes additional information that could not be condensed into database form.

Where the current condition of a shipwreck is not known, data from other archaeological studies of similar types of shipwrecks provide the means for brief explanations of what the shipwreck might look like and specifically, whether it is thought there is sufficient structural integrity to retain oil. This is more subjective than the Pollution Potential Tree and computer-generated resource at risk models, and as such provides an additional viewpoint to examine risk assessments and assess the threat posed by these

shipwrecks. It also addresses questions of historical significance and the relevant historic preservation laws and regulations that will govern on-site assessments.

In some cases where little additional historic information has been uncovered about the loss of a vessel, archaeological assessments cannot be made with any degree of certainty and were not prepared. For vessels with full archaeological assessments, NOAA archaeologists and contracted archivists have taken photographs of primary source documents from the National Archives that can be made available for future research or on-site activities.

Assessment

The freighter *Diamond Knot* was initially listed as a potential high priority shipwreck because of its close proximity to shore and the good condition of the wreck. The wreck is only about 1.5 miles from shore in the Strait of Juan de Fuca, and it rests on its starboard side in approximately 140 feet of water. The shipwreck is in extremely good condition due to the cold waters in the strait and is commonly regarded as the best shipwreck dive site in the Pacific Northwest. Despite the wreck being in very good condition and resting on its side (an orientation that could enable the wreck to trap oil), however, the frequency with which the site is visited and the lack of reports of any oil coming from the wreck suggests it is likely that little to no oil remains inside the ship.

At the time of its loss, the ship only had a bunker capacity of 6,516 bbl of marine diesel oil. Since the ship was returning from a voyage to Alaska, it is possible that much of this oil had already been consumed prior to the ship sinking as a result of a collision. Although NOAA archaeologists cannot guarantee the presence or absence of oil remaining on this wreck, it seems very likely that most, if not all, of the diesel bunkers would have vented out of the wreck shortly after its sinking or in the 64 years the wreck has spent in the swift currents of the Strait of Juan de Fuca. Given the close proximity to shore and the relatively shallow depth of the site, however, this may be a shipwreck that is easy for the U.S. Coast Guard to definitively assess in regards to its pollution potential.

Should the vessel be assessed, it should be noted that this vessel is of historic significance and will require appropriate actions be taken under the National Historic Preservation Act (NHPA) prior to any actions that could impact the integrity of the vessel. This vessel may be eligible for listing on the National Register of Historic Places.

Background Information References

Vessel Image Sources: http://john-rawlings.newsvine.com/_news/2008/06/27/1619426-the-wreck-of-the-diamond-knot-jewel-beneath-an-emerald-sea

Construction Diagrams or Plans in RULET Database? No

Text References:
http://john-rawlings.newsvine.com/_news/2008/06/27/1619426-the-wreck-of-the-diamond-knot-jewel-beneath-an-emerald-sea
Google newspapers

Vessel Risk Factors

In this section, the risk factors that are associated with the vessel are defined and then applied to the *Diamond Knot* based on the information available. These factors are reflected in the pollution potential risk assessment development by the U.S. Coast Guard Salvage Engineering Response Team (SERT) as a means to apply a salvage engineer's perspective to the historical information gathered by NOAA. This analysis reflected in Figure 1-1 is simple and straightforward and, in combination with the accompanying archaeological assessment, provides a picture of the wreck that is as complete as possible based on current knowledge and best professional judgment. This assessment ***does not*** take into consideration operational constraints such as depth or unknown location, but rather attempts to provide a replicable and objective screening of the historical date for each vessel. SERT reviewed the general historical information available for the database as a whole and provided a stepwise analysis for an initial indication of Low/Medium/High values for each vessel.

In some instances, nuances from the archaeological assessment may provide additional input that will amend the score for Section 1. Where available, additional information that may have bearing on operational considerations for any assessment or remediation activities is provided.

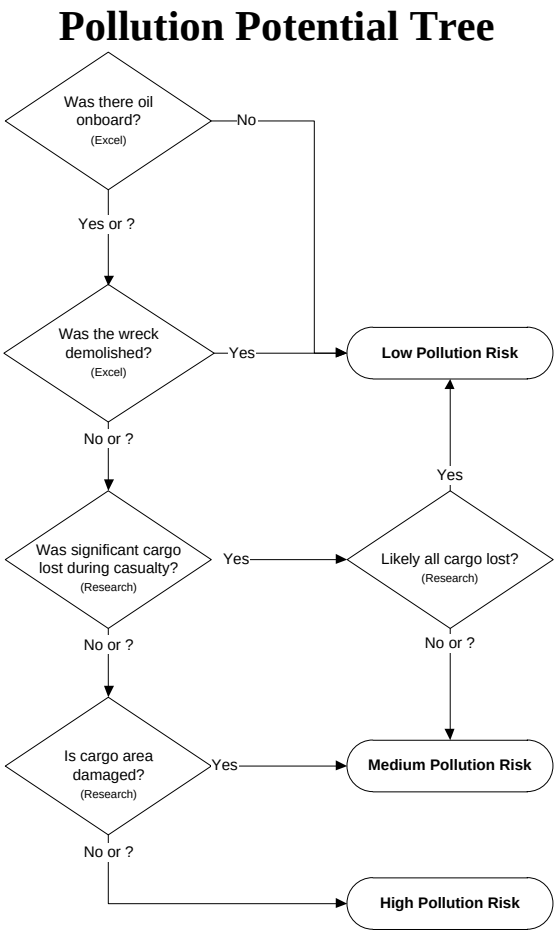


Figure 1-1: U.S. Coast Guard Salvage Engineering Response Team (SERT) developed the above Pollution Potential Decision Tree.

Each risk factor is characterized as High, Medium, or Low Risk or a category-appropriate equivalent such as No, Unknown, Yes, or Yes Partially. The risk categories correlate to the decision points reflected in Figure 1-1.

Each of the risk factors also has a "data quality modifier" that reflects the completeness and reliability of the information on which the risk ranks were assigned. The quality of the information is evaluated with respect to the factors required for a reasonable preliminary risk assessment. The data quality modifier scale is:

- **High Data Quality:** All or most pertinent information on wreck available to allow for thorough risk assessment and evaluation. The data quality is high and confirmed.
- **Medium Data Quality:** Much information on wreck available, but some key factor data are missing or the data quality is questionable or not verified. Some additional research needed.
- **Low Data Quality:** Significant issues exist with missing data on wreck that precludes making preliminary risk assessment, and/or the data quality is suspect. Significant additional research needed.

In the following sections, the definition of low, medium, and high for each risk factor is provided. Also, the classification for the *Diamond Knot* is provided, both as text and as shading of the applicable degree of risk bullet.

Pollution Potential Factors

Risk Factor A1: Total Oil Volume

The oil volume classifications correspond to the U.S. Coast Guard spill classifications:

- **Low Volume: Minor Spill** <240 bbl (10,000 gallons)
- **Medium Volume: Medium Spill** ≥240 – 2,400 bbl (100,000 gallons)
- **High Volume: Major Spill** ≥2,400 bbl (≥100,000 gallons)

The oil volume risk classifications refer to the volume of the most-likely Worst Case Discharge from the vessel and are based on the amount of oil believed or confirmed to be on the vessel.

The *Diamond Knot i*s ranked as High Volume because it is thought to have a potential for up to 6,516 bbl, although some of that may have been lost at the time of the casualty or since the vessel sank. Data quality is medium.

The risk factor for volume also incorporates any reports or anecdotal evidence of actual leakage from the vessel or reports from divers of oil in the overheads, as opposed to potential leakage. This reflects the history of the vessel's leakage. There are no reports of leakage from the *Diamond Knot*.

Risk Factor A2: Oil Type

The oil type(s) on board the wreck are classified only with regard to persistence, using the U.S. Coast

Guard oil grouping[1]. (Toxicity is dealt with in the impact risk for the Resources at Risk classifications.) The three oil classifications are:

- **Low Risk: Group I Oils** – non-persistent oil (e.g., gasoline)
- **Medium Risk: Group II – III Oils** – medium persistent oil (e.g., diesel, No. 2 fuel, light crude, medium crude)
- **High Risk: Group IV** – high persistent oil (e.g., heavy crude oil, No. 6 fuel oil, Bunker C)

The *Diamond Knot* is classified as Medium Risk because the bunker oil is diesel oil, a Group II oil type. Data quality is high.

Was the wreck demolished?

Risk Factor B: Wreck Clearance

This risk factor addresses whether or not the vessel was historically reported to have been demolished as a hazard to navigation or by other means such as depth charges or aerial bombs. This risk factor is based on historic records and does not take into account what a wreck site currently looks like. The risk categories are defined as:

- **Low Risk:** The wreck was reported to have been entirely destroyed after the casualty
- **Medium Risk:** The wreck was reported to have been partially cleared or demolished after the casualty
- **High Risk:** The wreck was not reported to have been cleared or demolished after the casualty
- **Unknown:** It is not known whether or not the wreck was cleared or demolished at the time of or after the casualty

The *Diamond Knot* is classified as High Risk because there are no known historic accounts of the wreck being demolished as a hazard to navigation. Data quality is high

Was significant cargo or bunker lost during casualty?

Risk Factor C1: Burning of the Ship

This risk factor addresses any burning that is known to have occurred at the time of the vessel casualty and may have resulted in oil products being consumed or breaks in the hull or tanks that would have increased the potential for oil to escape from the shipwreck. The risk categories are:

- **Low Risk:** Burned for multiple days
- **Medium Risk:** Burned for several hours
- **High Risk:** No burning reported at the time of the vessel casualty
- **Unknown:** It is not known whether or not the vessel burned at the time of the casualty

[1] Group I Oil or Nonpersistent oil is defined as "a petroleum-based oil that, at the time of shipment, consists of hydrocarbon fractions: At least 50% of which, by volume, distill at a temperature of 340°C (645°F); and at least 95% of which, by volume, distill at a temperature of 370°C (700°F)."
Group II - Specific gravity less than 0.85 crude [API° >35.0]
Group III - Specific gravity between 0.85 and less than .95 [API° ≤35.0 and >17.5]
Group IV - Specific gravity between 0.95 to and including 1.0 [API° ≤17.5 and >10.0]

The *Diamond Knot* is classified as High Risk because there was no report of fire at the time of casualty. Data quality is high.

Risk Factor C2: Reported Oil on the Water

This risk factor addresses reports of oil on the water at the time of the vessel casualty. The amount is relative and based on the number of available reports of the casualty. Seldom are the reports from trained observers so this is very subjective information. The risk categories are defined as:

- **Low Risk:** Large amounts of oil reported on the water by multiple sources
- **Medium Risk:** Moderate to little oil reported on the water during or after the sinking event
- **High Risk:** No oil reported on the water
- **Unknown:** It is not known whether or not there was oil on the water at the time of the casualty

The *Diamond Knot* is classified as High Risk because there is no known report of oil spreading across the water as the vessel went down. Data quality is high.

Is the cargo area damaged?

Risk Factor D1: Nature of the Casualty

This risk factor addresses the means by which the vessel sank. The risk associated with each type of casualty is determined by the how violent the sinking event was and the factors that would contribute to increased initial damage or destruction of the vessel (which would lower the risk of oil, other cargo, or munitions remaining on board). The risk categories are:

- **Low Risk:** Multiple torpedo detonations, multiple mines, severe explosion
- **Medium Risk:** Single torpedo, shellfire, single mine, rupture of hull, breaking in half, grounding on rocky shoreline
- **High Risk:** Foul weather, grounding on soft bottom, collision
- **Unknown:** The cause of the loss of the vessel is not known

The *Diamond Knot* is classified as High Risk because it sank as a result of a collision. Data quality is high.

Risk Factor D2: Structural Breakup

This risk factor takes into account how many pieces the vessel broke into during the sinking event or since sinking. This factor addresses how likely it is that multiple components of a ship were broken apart including tanks, valves, and pipes. Experience has shown that even vessels broken in three large sections can still have significant pollutants on board if the sections still have some structural integrity. The risk categories are:

- **Low Risk:** The vessel is broken into more than three pieces
- **Medium Risk:** The vessel is broken into two-three pieces
- **High Risk:** The vessel is not broken and remains as one contiguous piece
- **Unknown:** It is currently not known whether or not the vessel broke apart at the time of loss or after sinking

The *Diamond Knot* is classified as High Risk because it remains as one contiguous piece despite some structural collapse. Data quality is high.

Factors That May Impact Potential Operations

Orientation (degrees)

This factor addresses what may be known about the current orientation of the intact pieces of the wreck (with emphasis on those pieces where tanks are located) on the seafloor. For example, if the vessel turtled, not only may it have avoided demolition as a hazard to navigation, but it has a higher likelihood of retaining an oil cargo in the non-vented and more structurally robust bottom of the hull.

The *Diamond Knot* is resting on its starboard side. Data quality is high.

Depth

Depth information is provided where known. In many instances, depth will be an approximation based on charted depths at the last known locations.

The *Diamond Knot* is 140 feet deep. Data quality is high.

Visual or Remote Sensing Confirmation of Site Condition

This factor takes into account what the physical status of wreck site as confirmed by remote sensing or other means such as ROV or diver observations and assesses its capability to retain a liquid cargo. This assesses whether or not the vessel was confirmed as entirely demolished as a hazard to navigation, or severely compromised by other means such as depth charges, aerial bombs, or structural collapse.

The location of the *Diamond Knot* is a popular dive site. Data quality is high.

Other Hazardous (Non-Oil) Cargo on Board

This factor addresses hazardous cargo other than oil that may be on board the vessel and could potentially be released, causing impacts to ecological and socio-economic resources at risk.

There are no reports of hazardous materials onboard. Data quality is high.

Munitions on Board

This factor addresses hazardous cargo other than oil that may be on board the vessel and could potentially be released or detonated causing impacts to ecological and socio-economic resources at risk.

The *Diamond Knot* did not carry any munitions. Data quality is high.

Vessel Pollution Potential Summary

Table 1-1 summarizes the risk factor scores for the pollution potential and mitigating factors that would reduce the pollution potential for the *Diamond Knot.* Operational factors are listed but do not have a risk score.

Table 1-1: Summary matrix for the vessel risk factors for the *Diamond Knot* color-coded as red (high risk), yellow (medium risk), and green (low risk).

Vessel Risk Factors		Data Quality Score	Comments	Risk Score
Pollution Potential Factors	A1: Oil Volume (total bbl)	Medium	Maximum of 6,516 bbl, not reported to be leaking	**Med**
	A2: Oil Type	High	Bunker oil is diesel, a Group II oil type	
	B: Wreck Clearance	High	Vessel not reported as cleared	
	C1: Burning of the Ship	High	No fire was reported	
	C2: Oil on Water	High	No oil was reported on the water	
	D1: Nature of Casualty	High	Sank as a result of a collision	
	D2: Structural Breakup	High	Vessel remains as one contiguous piece	
Archaeological Assessment	Archaeological Assessment	High	Detailed sinking records and site reports of this ship exist, assessment is believed to be very accurate	**Not Scored**
Operational Factors	Wreck Orientation	High	Resting on its starboard side	**Not Ranked**
	Depth	High	140 feet	
	Visual or Remote Sensing Confirmation of Site Condition	High	Location is a popular dive site	
	Other Hazardous Materials Onboard	High	No	
	Munitions Onboard	High	No	
	Gravesite (Civilian/Military)	High	No	
	Historical Protection Eligibility (NHPA/SMCA)	High	NHPA	

SECTION 2: ENVIRONMENTAL IMPACT MODELING

To help evaluate the potential transport and fates of releases from sunken wrecks, NOAA worked with RPS ASA to run a series of generalized computer model simulations of potential oil releases. The results are used to assess potential impacts to ecological and socio-economic resources, as described in Sections 3 and 4. The modeling results are useful for this screening-level risk assessment; however, it should be noted that detailed site/vessel/and seasonally specific modeling would need to be conducted prior to any intervention on a specific wreck.

Release Scenarios Used in the Modeling

The potential volume of leakage at any point in time will tend to follow a probability distribution. Most of the discharges would tend to be relatively small, though there could be multiple such discharges. There is a lower probability of larger discharges, though these scenarios would cause the greatest damage. A **Worst Case Discharge** (WCD) would involve the release of all of the cargo oil and bunkers present on the vessel. In the case of the *Diamond Knot* this would be about 7,000 bbl (rounded up from 6,516 bbl) based on estimates of the maximum amount of oil remaining onboard the wreck.

The likeliest scenario of oil release from most sunken wrecks, including the *Diamond Knot*, is a small, episodic release that may be precipitated by disturbance of the vessel in storms. Each of these episodic releases may cause impacts and require a response. **Episodic** releases are modeled using 1% of the WCD. Another scenario is a very low chronic release, i.e., a relatively regular release of small amounts of oil that causes continuous oiling and impacts over the course of a long period of time. This type of release would likely be precipitated by corrosion of piping that allows oil to flow or bubble out at a slow, steady rate. **Chronic** releases are modeled using 0.1% of the WCD.

The **Most Probable** scenario is premised on the release of all the oil from one tank. In the absence of information on the number and condition of the cargo or fuel tanks for all the wrecks being assessed, this scenario is modeled using 10% of the WCD. The **Large** scenario is loss of 50% of the WCD. The five major types of releases are summarized in Table 2-1. The actual type of release that occurs will depend on the condition of the vessel, time factors, and disturbances to the wreck. Note that, the episodic and chronic release scenarios represent a small release that is repeated many times, potentially repeating the same magnitude and type of impact(s) with each release. The actual impacts would depend on the environmental factors such as real-time and forecast winds and currents during each release and the types/quantities of ecological and socio-economic resources present.

The model results here are based on running the RPS ASA Spill Impact Model Application Package (SIMAP) two hundred times for each of the five spill volumes shown in Table 2-1. The model randomly selects the date of the release, and corresponding environmental, wind, and ocean current information from a long-term wind and current database.

When a spill occurs, the trajectory, fate, and effects of the oil will depend on environmental variables, such as the wind and current directions over the course of the oil release, as well as seasonal effects. The magnitude and nature of potential impacts to resources will also generally have a strong seasonal component (e.g., timing of bird migrations, turtle nesting periods, fishing seasons, and tourism seasons).

Table 2-1: Potential oil release scenario types for the *Diamond Knot*.

Scenario Type	Release per Episode	Time Period	Release Rate	Relative Likelihood	Response Tier
Chronic (0.1% of WCD)	7 bbl	Fairly regular intervals or constant	100 bbl over several days	More likely	Tier 1
Episodic (1% of WCD)	70 bbl	Irregular intervals	Over several hours or days	Most Probable	Tier 1-2
Most Probable (10% of WCD)	700 bbl	One-time release	Over several hours or days	Most Probable	Tier 2
Large (50% of WCD)	3,500 bbl	One-time release	Over several hours or days	Less likely	Tier 2-3
Worst Case	7,000 bbl	One-time release	Over several hours or days	Least likely	Tier 3

The modeling results represent 200 simulations for each spill volume with variations in spill trajectory based on winds and currents. The spectrum of the simulations gives a perspective on the variations in likely impact scenarios. Some resources will be impacted in nearly all cases; some resources may not be impacted unless the spill trajectory happens to go in that direction based on winds and currents at the time of the release and in its aftermath.

For the large and WCD scenarios, the duration of the release was assumed to be 12 hours, envisioning a storm scenario where the wreck is damaged or broken up, and the model simulations were run for a period of 30 days. The releases were assumed to be from a depth between 2-3 meters above the sea floor, using the information known about the wreck location and depth. It is important to acknowledge that these scenarios are only for this screening-level assessment. Detailed site/vessel/and seasonally specific modeling would need to be conducted prior to any intervention on a specific wreck.

Oil Type for Release

The *Diamond Knot* contained a maximum of 6,516 bbl of marine diesel (a Group II oil) as fuel oil. Thus, the oil spill model was run using light fuel oil.

Oil Thickness Thresholds

The model results are reported for different oil thickness thresholds, based on the amount of oil on the water surface or shoreline and the resources potentially at risk. Table 2-2 shows the terminology and thicknesses used in this report, for both oil thickness on water and the shoreline. For oil on the water surface, a thickness of 0.01 g/m^2, which would appear as a barely visible sheen, was used as the threshold for socio-economic impacts because often fishing is prohibited in areas with any visible oil, to prevent contamination of fishing gear and catch. A thickness of 10 g/m^2 was used as the threshold for ecological impacts, primarily due to impacts to birds, because that amount of oil has been observed to be enough to mortally impact birds and other wildlife. In reality, it is very unlikely that oil would be evenly distributed on the water surface. Spilled oil is always distributed patchily on the water surface in bands or tarballs with clean water in between. So, Table 2-2a shows the number of tarballs per acre on the water surface for these oil thickness thresholds, assuming that each tarball was a sphere that was 1 inch in diameter.

For oil stranded onshore, a thickness of 1 g/m^2 was used as the threshold for socio-economic impacts because that amount of oil would conservatively trigger the need for shoreline cleanup on amenity beaches. A thickness of 100 g/m^2 was used as the threshold for ecological impacts based on a synthesis of the literature showing that shoreline life has been affected by this degree of oiling.[2] Because oil often strands onshore as tarballs, Table 2-2b shows the number of tarballs per m^2 on the shoreline for these oil thickness thresholds, assuming that each tarball was a sphere that was 1 inch in diameter.

Table 2-2a: Oil thickness thresholds used in calculating area of water impacted. Refer to Sections 3 and 4 for explanations of the thresholds for ecological and socio-economic resource impacts.

Oil Description	Sheen Appearance	Approximate Sheen Thickness		No. of 1 inch Tarballs	Threshold/Risk Factor
Oil Sheen	Barely Visible	0.00001 mm	0.01 g/m^2	~5-6 tarballs per acre	Socio-economic Impacts to Water Surface/Risk Factor 4B-1 and 2
Heavy Oil Sheen	Dark Colors	0.01 mm	10 g/m^2	~5,000-6,000 tarballs per acre	Ecological Impacts to Water Surface/ Risk Factor 3B-1 and 2

Table 2-2b: Oil thickness thresholds used in calculating miles of shoreline impacted. Refer to Sections 3 and 4 for explanations of the thresholds for ecological and socio-economic resource impacts.

Oil Description	Oil Appearance	Approximate Sheen Thickness		No. of 1 inch Tarballs	Threshold/Risk Factor
Oil Sheen/Tarballs	Dull Colors	0.001 mm	1 g/m^2	~0.12-0.14 tarballs/m^2	Socio-economic Impacts to Shoreline Users/Risk Factor 4C-1 and 2
Oil Slick/Tarballs	Brown to Black	0.1 mm	100 g/m^2	~12-14 tarballs/m^2	Ecological Impacts to Shoreline Habitats/Risk Factor 3C-1 and 2

Potential Impacts to the Water Column

Impacts to the water column from an oil release from the *Diamond Knot* will be determined by the volume of leakage. Because oil from sunken vessels will be released at low pressures, the droplet sizes will be large enough for the oil to float to the surface. Therefore, impacts to water column resources will result from the natural dispersion of the floating oil slicks on the surface, which is limited to about the top 33 feet. The metric used for ranking impacts to the water column is the area of water surface in mi^2 that has been contaminated by 1 part per billion (ppb) oil to a depth of 33 feet. At 1 ppb, there are likely to be impacts to sensitive organisms in the water column and potential tainting of seafood, so this concentration is used as a screening threshold for both the ecological and socio-economic risk factors for water column resource impacts. To assist planners in understanding the scale of potential impacts for different leakage volumes, a regression curve was generated for the water column volume oiled using the five volume scenarios, which is shown in Figure 2-1. Using this figure, the water column impacts can be estimated for any spill volume.

[2] French, D., M. Reed, K. Jayko, S. Feng, H. Rines, S. Pavignano, T. Isaji, S. Puckett, A. Keller, F. W. French III, D. Gifford, J. McCue, G. Brown, E. MacDonald, J. Quirk, S. Natzke, R. Bishop, M. Welsh, M. Phillips and B.S. Ingram, 1996. The CERCLA type A natural resource damage assessment model for coastal and marine environments (NRDAM/CME), Technical Documentation, Vol. I - V. Office of Environmental Policy and Compliance, U.S. Dept. of the Interior, Washington, DC.

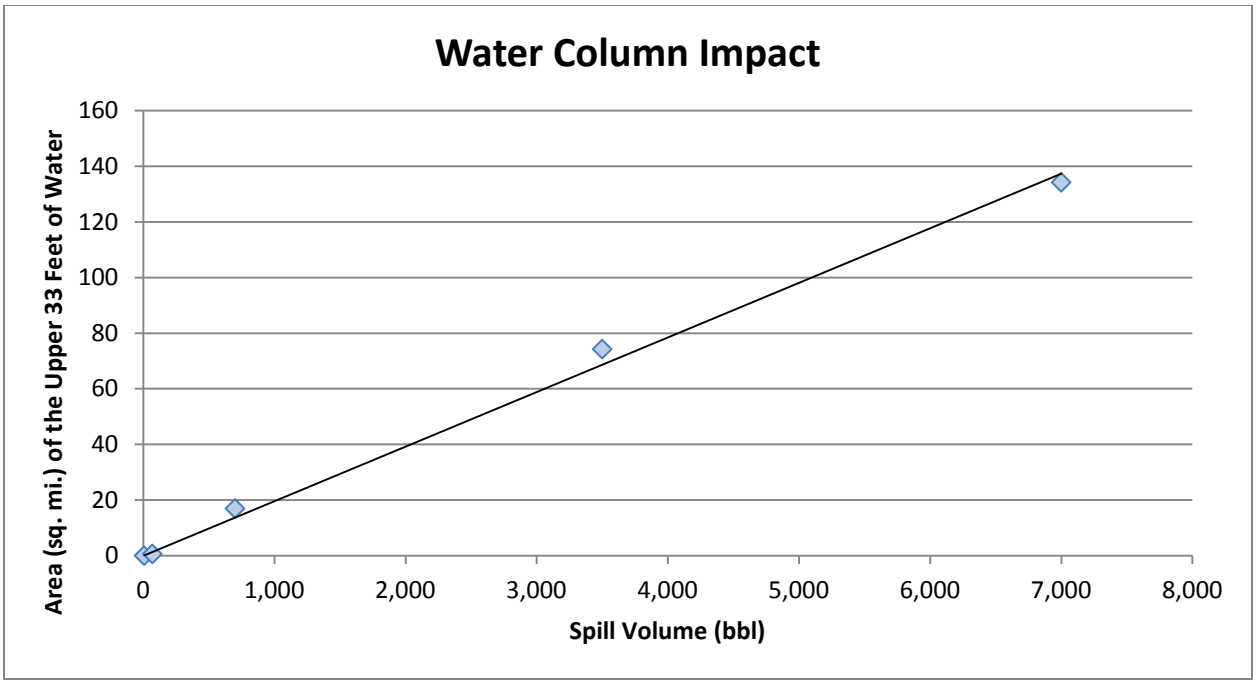


Figure 2-1: Regression curve for estimating the volume of water column at or above 1 ppb aromatics impacted as a function of spill volume for the *Diamond Knot*.

Potential Water Surface Slick

The slick size from an oil release from the *Diamond Knot* is a function of the quantity released. The estimated water surface coverage by a fresh slick (the total water surface area "swept" by oil over time) for the various scenarios is shown in Table 2-3, as the mean result of the 200 model runs. Note that this is an estimate of total water surface affected over a 30-day period. The slick will not be continuous but rather be broken and patchy due to the subsurface release of the oil. Surface expression is likely to be in the form of sheens and streamers.

Table 2-3: Estimated slick area swept on water for oil release scenarios from the *Diamond Knot*.

Scenario Type	Oil Volume (bbl)	Estimated Slick Area Swept Mean of All Models	
		0.01 g/m²	10 g/m²
Chronic	7	61 mi²	24 mi²
Episodic	70	170 mi²	77 mi²
Most Probable	700	400 mi²	225 mi²
Large	3,500	990 mi²	480 mi²
Worst Case Discharge	7,000	1,600 mi²	700 mi²

The location, size, shape, and spread of the oil slick(s) from an oil release from the *Diamond Knot* will depend on environmental conditions, including winds and currents, at the time of release and in its aftermath. The areas potentially affected by oil slicks, given that we cannot predict when the spill might occur and the range of possible wind and current conditions that might prevail after a release, are shown in Figure 2-2 and Figure 2-3 using the Most Probable volume and the socio-economic and ecological thresholds.

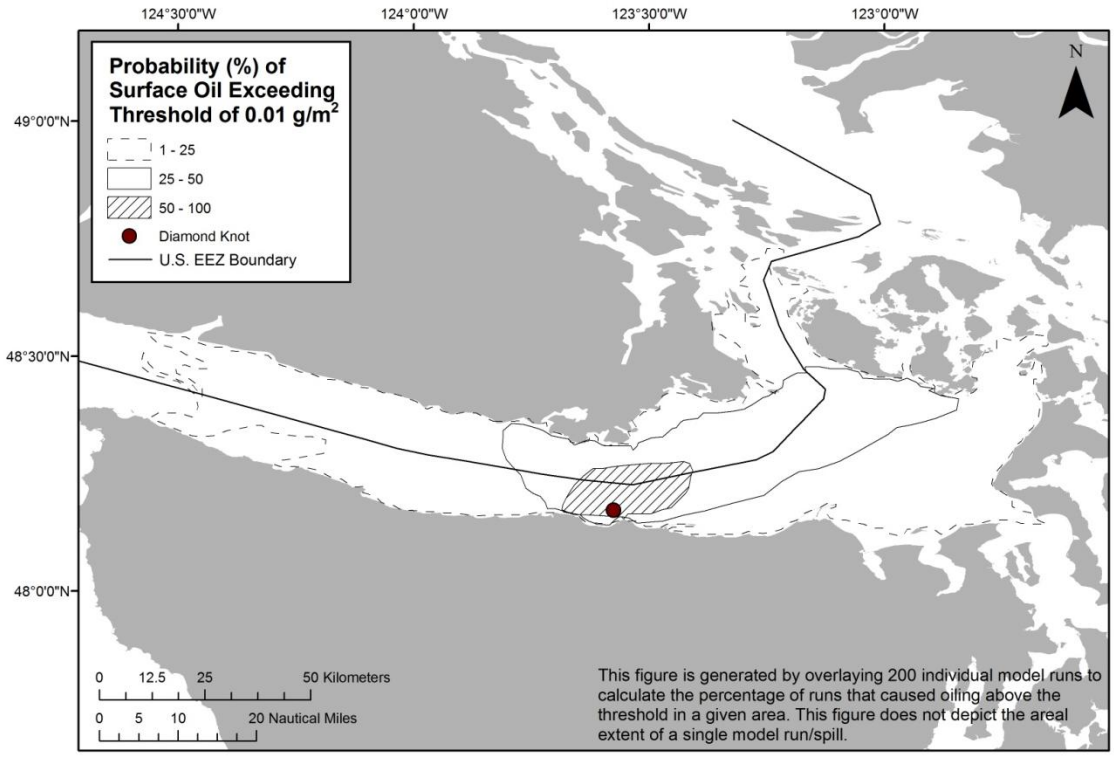


Figure 2-2: Probability of surface oil (exceeding 0.01 g/m^2) from the Most Probable spill of 700 bbl of light fuel oil from the *Diamond Knot* at the threshold for socio-economic resources at risk.

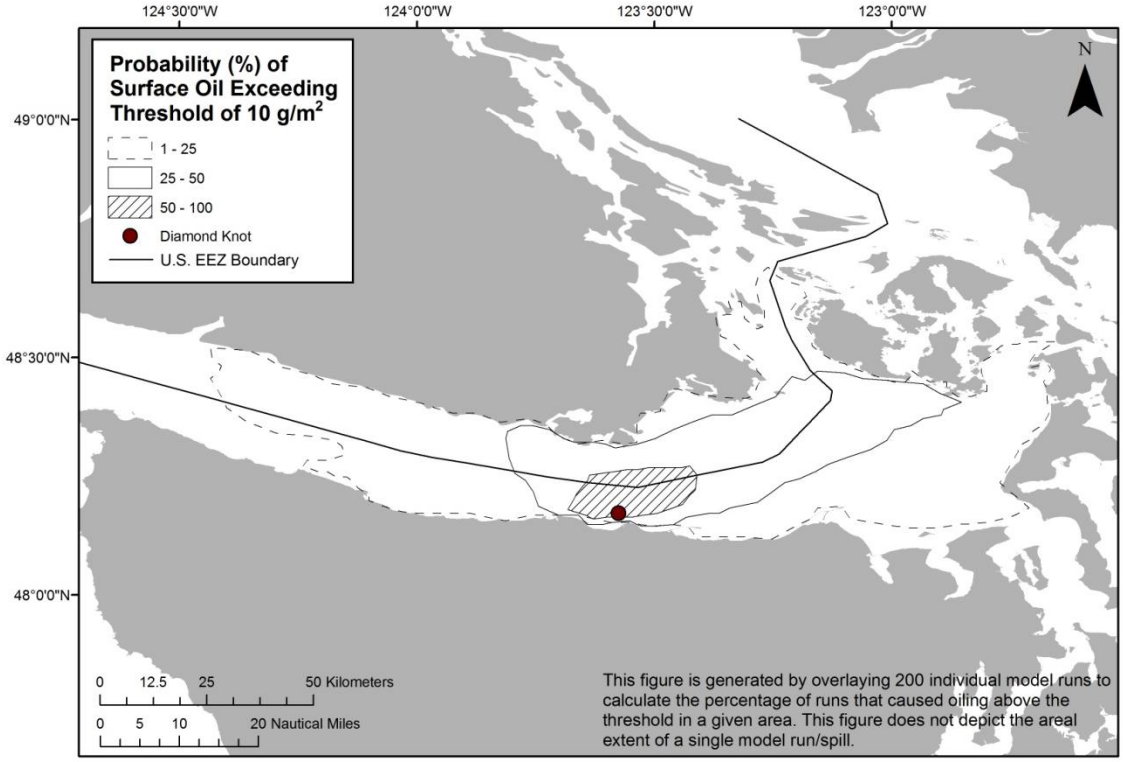


Figure 2-3: Probability of surface oil (exceeding 10 g/m^2) from the Most Probable spill of 700 bbl of light fuel oil from the *Diamond Knot* at the threshold for ecological resources at risk.

The maximum potential cumulative area swept by oil slicks at some time after a Most Probable Discharge is shown in Figure 2-4 as the timing of oil movements.

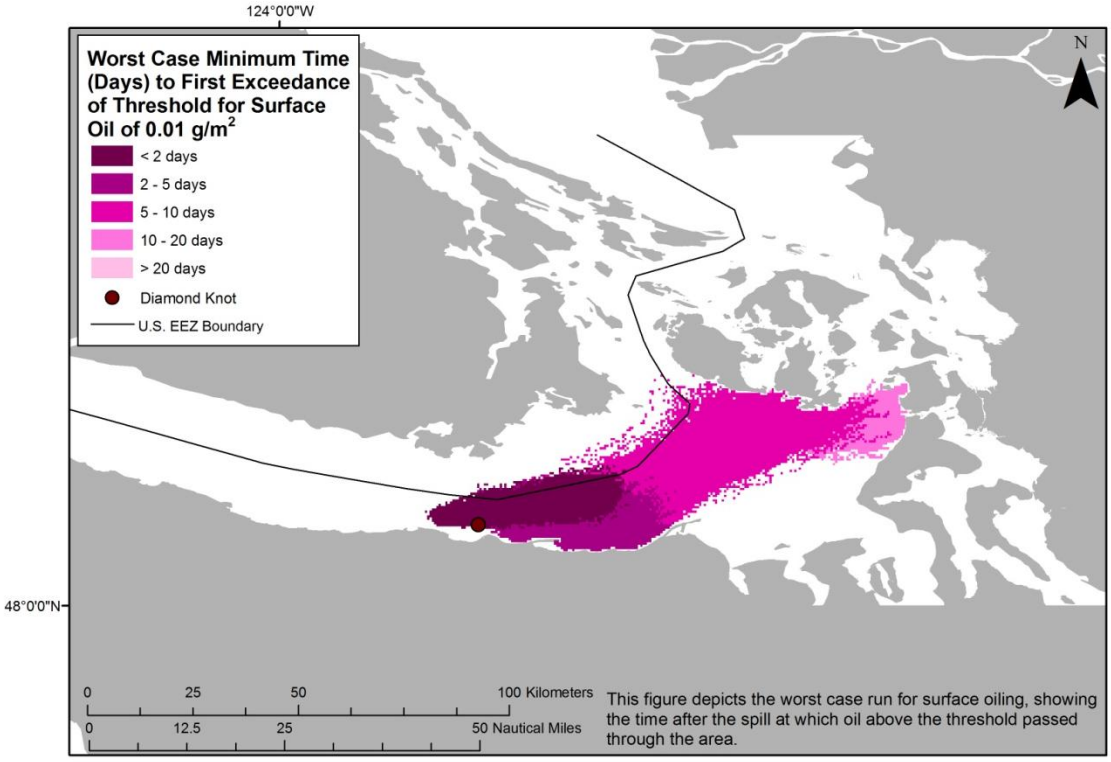


Figure 2-4: Water surface oiling from the Most Probable spill of 700 bbl of light fuel oil from the *Diamond Knot* shown as the area over which the oil spreads at different time intervals.

The actual area affected by a release will be determined by the volume of leakage, whether it is from one or more tanks at a time. To assist planners in understanding the scale of potential impacts for different leakage volumes, a regression curve was generated for the water surface area oiled using the five volume scenarios, which is shown in Figure 2-5. Using this figure, the area of water surface with a barely visible sheen can be estimated for any spill volume.

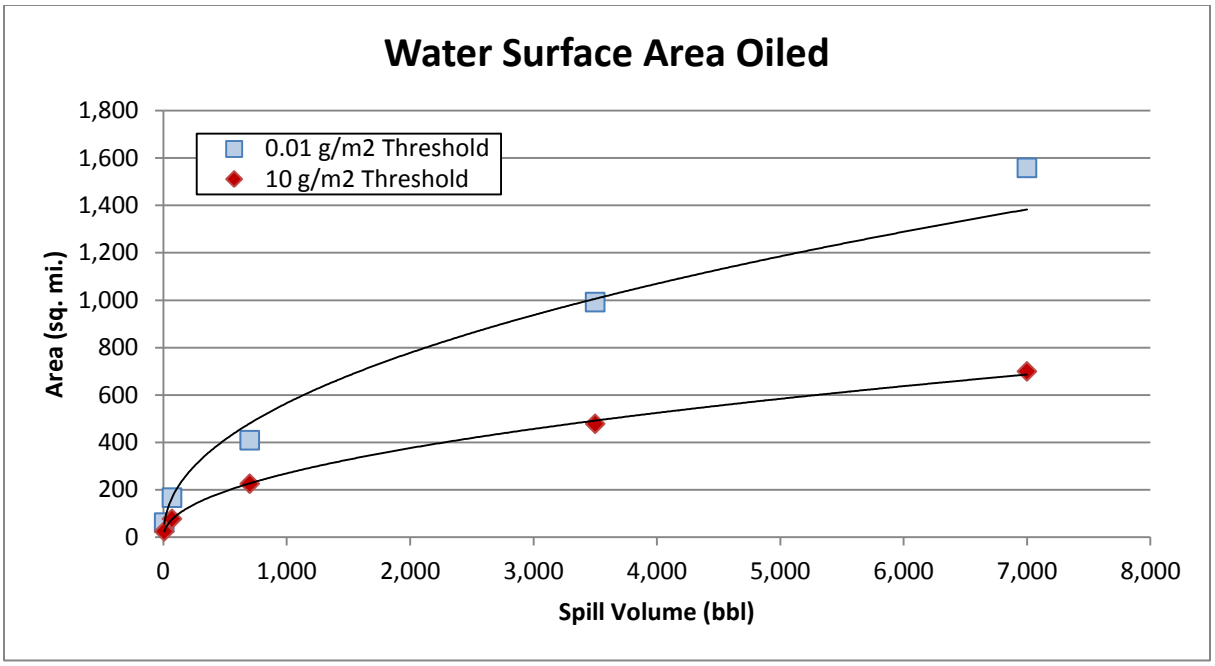


Figure 2-5: Regression curve for estimating the amount of water surface oiling as a function of spill volume for the *Diamond Knot*, showing both the ecological threshold of 10 g/m^2 and socio-economic threshold of 0.01 g/m^2.

Potential Shoreline Impacts

Based on these modeling results, shorelines on both the U.S. and Canadian sides of the Strait of Juan de Fuca, in Canada from Victoria to Sydney Island, the San Juan Islands, and from Anacortes to Dungeness Spit are at risk. Figure 2-6 shows the probability of oil stranding on the shoreline at concentrations that exceed the threshold of 1 g/m^2, for the Most Probable release of 700 bbl. However, the specific areas that would be oiled will depend on the currents and winds at the time of the oil release(s), as well as on the amount of oil released. Figure 2-7 shows the single oil spill scenario that resulted in the maximum extent of shoreline oiling for the Most Probable volume. Estimated miles of shoreline oiling above the threshold of 1 g/m^2 by scenario type are shown in Table 2-4.

Table 2-4a: Estimated shoreline oiling from leakage from the *Diamond Knot*. (U.S. and Canada)

Scenario Type	Volume (bbl)	Estimated Miles of Shoreline Oiling Above 1 g/m^2			
		Rock/Gravel/Artificial	Sand	Wetland/Mudflat	Total
Chronic	7	0	0	0	0
Episodic	70	0	0	0	0
Most Probable	700	2	0	0	2
Large	3,500	4	0	0	4
Worst Case Discharge	7,000	6	0	0	6

Table 2-4b: Estimated shoreline oiling from leakage from the *Diamond Knot*. (U.S. only)

Scenario Type	Volume (bbl)	Estimated Miles of Shoreline Oiling Above 1 g/m^2			
		Rock/Gravel/Artificial	Sand	Wetland/Mudflat	Total
Chronic	7	0	0	0	0
Episodic	70	0	0	0	0.3
Most Probable	700	2	0	0	2
Large	3,500	3	0	0	3
Worst Case Discharge	7,000	5	0	0	5

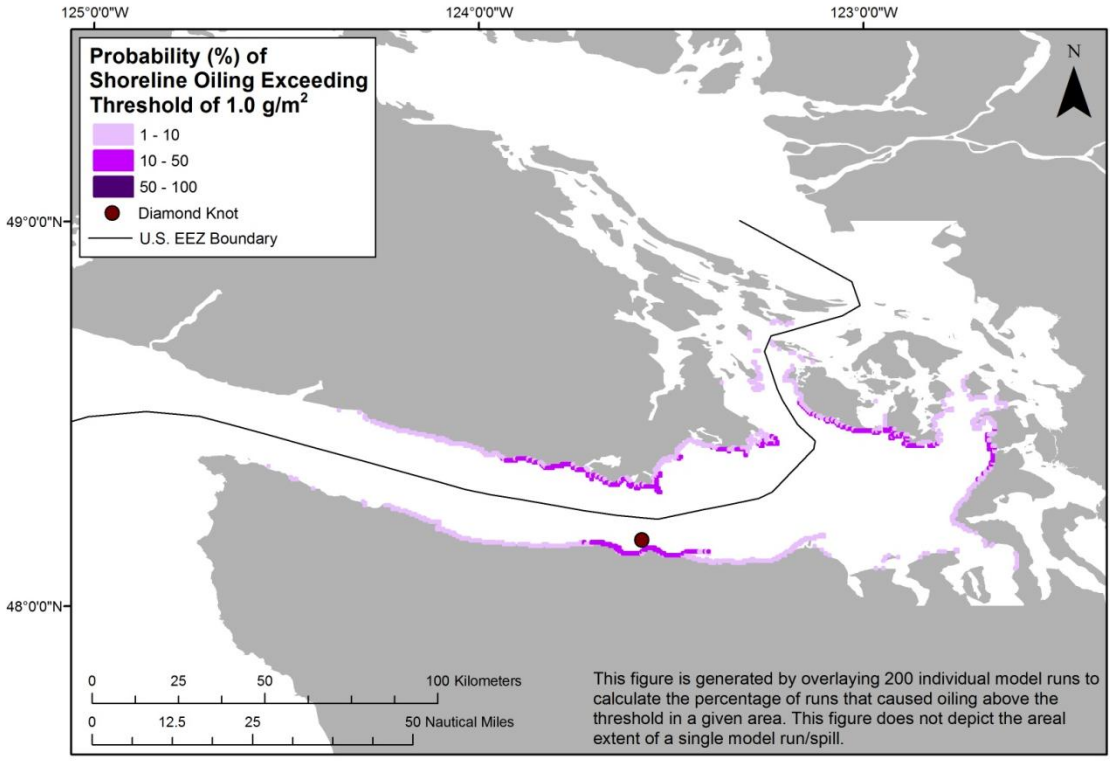


Figure 2-6: Probability of shoreline oiling (exceeding 1.0 g/m^2) from the Most Probable Discharge of 700 bbl of light fuel oil from the *Diamond Knot*.

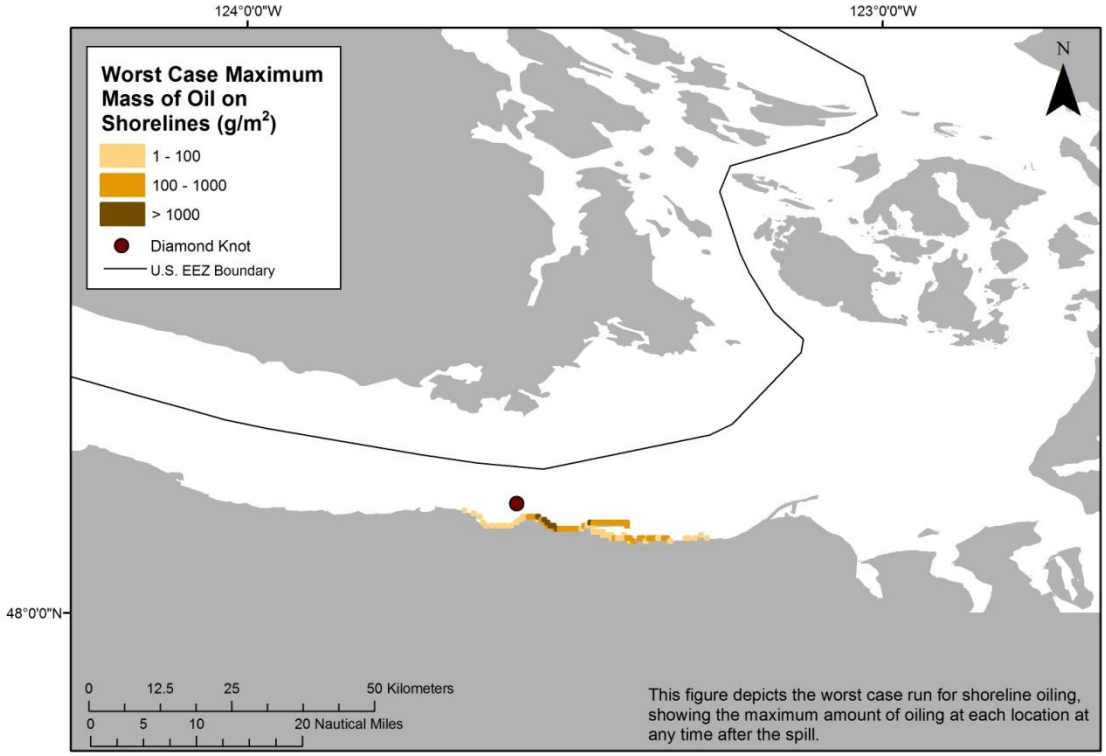


Figure 2-7: The extent and degree of shoreline oiling from the single model run of the Most Probable Discharge of 700 bbl of light fuel oil from the *Diamond Knot* that resulted in the greatest shoreline oiling.

The actual shore length affected by a release will be determined by the volume of leakage and environmental conditions during an actual release. To assist planners in scaling the potential impact for different leakage volumes, a regression curve was generated for the total shoreline length oiled using the five volume scenarios, which is shown in Figure 2-8. Using this figure, the shore length oiled can be estimated for any spill volume.

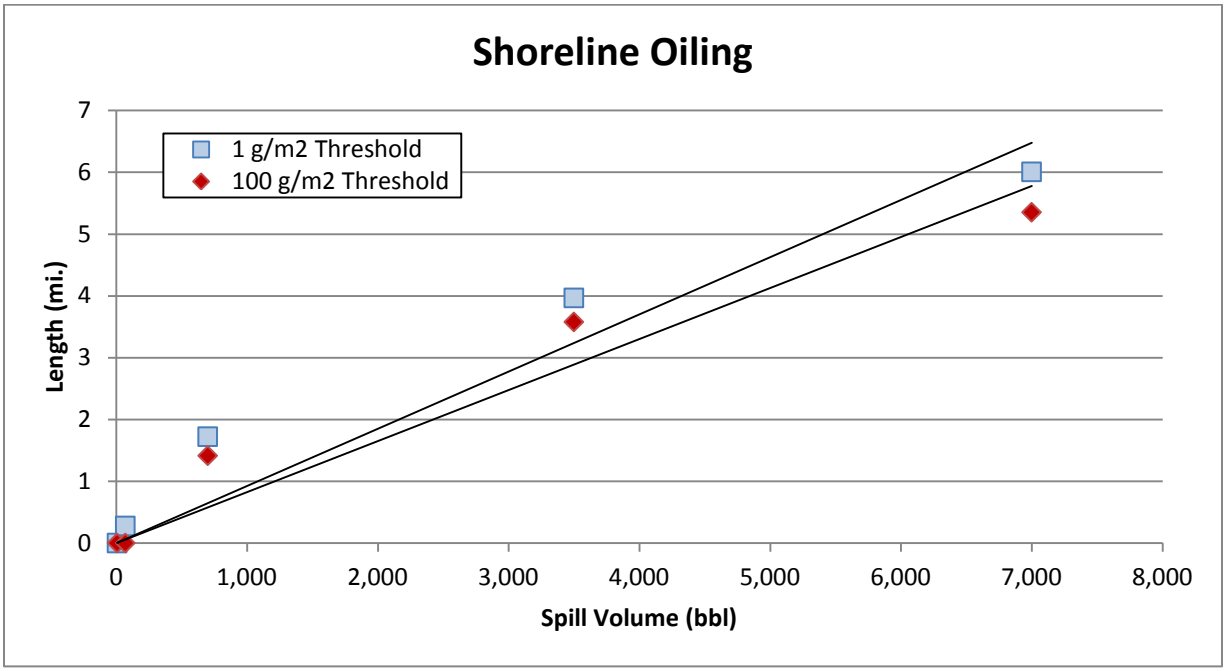


Figure 2-8: Regression curve for estimating the amount of shoreline oiling at different thresholds as a function of spill volume for the *Diamond Knot*.

The worst case scenario for shoreline exposure along the potentially impacted area for the WCD volume (Table 2-5) and the Most Probable volume (Table 2-6) consists of rocky shores and gravel beaches.

Table 2-5: Worst case scenario shoreline impact by habitat type and oil thickness for a leakage of 7,000 bbl from the *Diamond Knot*.

Shoreline/Habitat Type	Lighter Oiling Oil Thickness <1 mm Oil Thickness >1 g/m²	Heavier Oiling Oil Thickness >1 mm Oil Thickness >100 g/m²
Rocky and artificial shores/Gravel beaches	19 miles	17 miles
Sand beaches	1 mile	0 miles
Salt marshes and tidal flats	0 miles	0 miles

Table 2-6: Worst case scenario shoreline impact by habitat type and oil thickness for a leakage of 700 bbl from the *Diamond Knot*.

Shoreline/Habitat Type	Lighter Oiling Oil Thickness <1 mm Oil Thickness >1 g/m²	Heavier Oiling Oil Thickness >1 mm Oil Thickness >100 g/m²
Rocky and artificial shores/Gravel beaches	8 miles	5 miles
Sand beaches	0 miles	0 miles
Salt marshes and tidal flats	0 miles	0 miles

SECTION 3: ECOLOGICAL RESOURCES AT RISK

Ecological resources at risk from a catastrophic release of oil from the *Diamond Knot* (Table 3-1) include numerous guilds of birds, particularly those sensitive to surface oiling while rafting or plunge diving to feed and are present in nearshore/offshore waters. As can be noted in the table, large numbers of birds winter in both coastal and offshore waters, and many of the beaches are very important shorebird habitat. In addition, this region is important for commercially important fish and invertebrates. The Salish Sea is the second largest estuary in the U.S. and is a hotspot for marine biodiversity.

Table 3-1: Ecological resources at risk from a release of oil from the *Diamond Knot*.
(*FT = Federal threatened; FE = Federal endangered; ST = State threatened; SE = State endangered).

Species Group	Species Subgroup and Geography	Seasonal Presence
Seabirds	Commonly found in the area: Ancient murrelet, pigeon guillemot, common murre, rhinoceros auklet, common loon, cormorant, Pacific loon, red-throated loon, western grebe, gulls, shorebirds, bufflehead, goldeneye, harlequin duck, long-tailed duck, scaup, scoter spp., waterfowl, great blue heron Productive waters of the Strait of Juan de Fuca support populations of foraging and nesting seabirds • Western half of the Strait has the highest density of marbled murrelets (FT) in Washington and possibly U.S.; nesting in forests along the Strait • River deltas support large foraging and roosting flocks of gulls (Heermann's in late summer and Thayer's in winter) and substantial winter flocks of black oystercatcher • Seabird nesting colonies present at Race Rocks, Sooke Bay Islets, Argyle Islets, Parkinson Cliff, San Simon Point, Freshwater Bay, Port Angeles, Dungeness Bay; alcids, cormorants and black oystercatchers are common colonial nesters • High abundance of great blue herons nesting at Freshwater Bay • Bald eagle nests common along the Strait • Port Angeles Harbor: Thousands of gulls, regularly >100 great blue heron, largest wintering concentrations of Barrow's and common goldeneyes, and harlequin ducks on northern Olympic Peninsula *Dungeness Bay* • Sandflats and mudflats are foraging area for 10,000s of shorebirds, gulls and waterfowl migrating and wintering • Brant, diving ducks, seabirds, loons, grebes, and diving birds forage in eelgrass beds *Deception Pass* • Large numbers of common and Pacific loon, cormorants, grebes, mergansers and alcids foraging in the winter • Large numbers of red-throated loons from Nov-Apr, peak Dec-Feb • Black oystercatcher present in winter, nesting on at least 1 island in summer • Greater than 300 pigeon guillemots mate and nest on cliffs *Chain Islets and Great Chain Islet* • Largest colony of glaucous-winged gulls in British Columbia • Up to 2,000 Brandt's cormorants (>2% of the world population); pelagic cormorants also present in low abundance	Bufflehead: Nov-Apr Ancient murrelet: Nov-Apr Murre: Aug-Mar Loons: Sep-May Grebe: Oct-Apr Scoters: Aug-May Waterfowl: Sep-Jun Rhinoceros auklet: Mar-Sep Pigeon guillemot present year round, nests Jul-Aug Shorebirds most common spring/fall *Nesting* Gulls:May-Sep Harlequin ducks: Apr-Aug Great blue herons: Feb-Jul

Species Group	Species Subgroup and Geography	Seasonal Presence
	• Other nesting species include double-crested cormorants (100s), pigeon guillemots and black oystercatchers • Harlequin ducks found seasonally	
Marine Mammals	Harbor seal haul-outs and rookeries are common throughout the area • High densities (counts >500) recorded at Smith and Minor Island • Areas with large aggregations (counts >100) recorded: Colville Island, Goose Island, Race Rocks, Chain Isles, Trial Islands, D'Arcy Island Elephant seals can be found at Dungeness Spit and on Smith/Minor Islands. Some pupping has been observed but not in high numbers Trial Island and Race Rocks are haul-outs for California (common) and Steller sea lions (less common) Sea otters are rare in Juan de Fuca Strait; normal range is west from Pillar Point	Harbor seals pup May-Aug, molt Aug-Oct Steller sea lions more common in winter California sea lions present Sep-May Otters present year round
Cetaceans	*Common*: Gray whale, killer whale (FE), minke whale, harbor porpoise, Dall's porpoise all commonly occur in interior waters • Interior Washington waters are critical habitat for killer whales • Southern resident population of killer whales (87 animals) common in inland waters (especially Haro Strait); disperse to coastal ocean during the winter • Inland WA harbor porpoise population estimate is 10,682	Minke whales present spring-fall Gray whales present Feb-Dec, calves present in spring Harbor porpoises present year round, calve Jun-Aug
Fish and Invertebrates	*Anadromous* • Chinook salmon (FT), coho salmon (FE), steelhead (FT), bull trout (FT), chum salmon, pink salmon, sockeye salmon, coastal cutthroat trout and green sturgeon (FT) populations spawn in coastal rivers • Elwha River is critical habitat for eulachon (FT) • Southern shore of Juan de Fuca strait is green sturgeon critical habitat • San Juan Islands are critical habitat for Chinook salmon • Juveniles and adults forage in estuarine and coastal environments • Adults forage in ocean waters prior to upstream migration *Beach spawning fish* • Surf smelt spawn in the upper intertidal zone of coarse sand/gravel beaches; eggs adhere to the substrate; spawning beaches are found along the south shore of Juan de Fuca Strait and on Guss Island • Sand lance spawn on Whidbey Island, Mackaye Harbor, Dungeness Harbor *Intertidal fish and invertebrates* • Rocky intertidal areas are habitat for tidepool sculpin, wolf eel, juvenile lingcod and greenling, gunnels, eelpouts, pricklebacks, cockcombs, and warbonnets • Beaches along the Strait of Juan de Fuca have high abundance and diversity of clams and other invertebrates, including Pacific oysters *Nearshore subtidal* • Dungeness crab move nearshore to spawn near sand beaches • Pacific geoducks common in subtidal sandy beach areas • Pinto abalone present in nearshore subtidal habitats • Pacific herring spawn adhesive eggs on nearshore seagrass and algae in Dungeness Bay, Westcott Bay, Sooke Harbor and Esquimalt Lagoon; adult form aggregations in nearshore waters prior to spawning *Demersal*	Cutthroat trout spawn winter-May Juvenile salmon migrate to coastal waters in spring but are present year round Chum adults present in coastal waters Jul-Oct Smelt spawn year round Herring spawn Jan-Apr Oysters spawn in the summer Rockfish and halibut spawn in deeper waters in winter/spring

Species Group	Species Subgroup and Geography	Seasonal Presence
	• Many species of rockfish, including boccacio (FE), canary rockfish (FT) and yelloweye rockfish (FT) are found in the area and can be associated with rocky reef habitats and kelp beds • Larval stages of these animals use epipelagic waters and juveniles recruit to structurally complex nearshore habitats • Bottom features support productive halibut habitat in the Strait of Juan de Fuca	
Benthic Habitats	Extensive coastal eelgrass beds are present from Dungeness point west, along the southern shore of San Juan Islands, Oak Bay Islands and in Sooke Harbor • Dungeness Bay has one of the largest eelgrass beds in the western U.S. Large kelp beds are present along the southern and northern shore of Strait of Juan de Fuca and the shoreline around Victoria Other species of kelp and turf grass common in intertidal areas	Kelp canopy is fullest Mar-Nov

The Environmental Sensitivity Index (ESI) atlases for the potentially impacted coastal areas from a leak from the *Diamond Knot* are generally available at each U.S. Coast Guard Sector. They can also be downloaded at: http://response.restoration.noaa.gov/esi. These maps show detailed spatial information on the distribution of sensitive shoreline habitats, biological resources, and human-use resources. The tables on the back of the maps provide more detailed life-history information for each species and location. The ESI atlases should be consulted to assess the potential environmental resources at risk for specific spill scenarios. In addition, the Geographic Response Plans within the Area Contingency Plans prepared by the Area Committee for each U.S. Coast Guard Sector have detailed information on the nearshore and shoreline ecological resources at risk and should be consulted.

Ecological Risk Factors

Risk Factor 3: Impacts to Ecological Resources at Risk (EcoRAR)

Ecological resources include plants and animals (e.g., fish, birds, invertebrates, and mammals), as well as the habitats in which they live. All impact factors are based on both the Worst Case and the Most Probable Discharge oil release from the wreck. Risk factors for ecological resources at risk (EcoRAR) are divided into three categories:

- Impacts to the water column and resources in the water column;
- Impacts to the water surface and resources on the water surface; and
- Impacts to the shoreline and resources on the shoreline.

The impacts from an oil release from the wreck would depend greatly on the direction in which the oil slick moves, which would, in turn, depend on wind direction and currents at the time of and after the oil release. Impacts are characterized in the risk analysis based on the likelihood of any measurable impact, as well as the degree of impact that would be expected if there is an impact. The measure of the degree of impact is based on the median case for which there is at least some impact. The median case is the "middle case" – half of the cases with significant impacts have less impact than this case, and half have more.

For each of the three ecological resources at risk categories, risk is defined as:

- The **probability of oiling** over a certain threshold (i.e., the likelihood that there will be an impact to ecological resources over a certain minimal amount); and
- The **degree of oiling** (the magnitude or amount of that impact).

As a reminder, the ecological impact thresholds are: 1 ppb aromatics for water column impacts; 10 g/m^2 for water surface impacts; and 100 g/m^2 for shoreline impacts.

In the following sections, the definition of low, medium, and high for each ecological risk factor is provided. Also, the classification for the *Diamond Knot* is provided, both as text and as shading of the applicable degree of risk bullet, for the WCD release of 7,000 bbl and a border around the bullet for the risk for the Most Probable Discharge of 700 bbl.

Risk Factor 3A: Water Column Impacts to EcoRAR

Water column impacts occur beneath the water surface. The ecological resources at risk for water column impacts are fish, marine mammals, and invertebrates (e.g., shellfish, and small organisms that are food for larger organisms in the food chain). These organisms can be affected by toxic components in the oil. The threshold for water column impact to ecological resources at risk is a dissolved aromatic hydrocarbons concentration of 1 ppb (i.e., 1 part total dissolved aromatics per one billion parts water). Dissolved aromatic hydrocarbons are the most toxic part of the oil. At this concentration and above, one would expect impacts to organisms in the water column.

Risk Factor 3A-1: Water Column Probability of Oiling of EcoRAR

This risk factor reflects the probability that at least 0.2 mi^2 of the upper 33 feet of the water column would be contaminated with a high enough concentration of oil to cause ecological impacts. The three risk scores for water column oiling probability are:

- **Low Oiling Probability:** Probability = <10%
- **Medium Oiling Probability:** Probability = 10 – 50%
- **High Oiling Probability:** Probability > 50%

Risk Factor 3A-2: Water Column Degree of Oiling of EcoRAR

The degree of oiling of the water column reflects the total volume of water that would be contaminated by oil at a concentration high enough to cause impacts. The three categories of impact are:

- **Low Impact:** impact on less than 0.2 mi^2 of the upper 33 feet of the water column at the threshold level
- **Medium Impact**: impact on 0.2 to 200 mi^2 of the upper 33 feet of the water column at the threshold level
- **High Impact:** impact on more than 200 mi^2 of the upper 33 feet of the water column at the threshold level

The *Diamond Knot* is classified as High Risk for oiling probability for water column ecological resources for the WCD of 7,000 bbl because 100% of the model runs resulted in contamination of more than 0.2 mi^2 of the upper 33 feet of the water column above the threshold of 1 ppb aromatics. It is classified as

Medium Risk for degree of oiling because the mean volume of water contaminated was 130 mi^2 of the upper 33 feet of the water column. For the Most Probable Discharge of 700 bbl, the *Diamond Knot* is classified as High Risk for oiling probability for water column ecological resources because 86% of the model runs resulted in contamination of more than 0.2 mi^2 of the upper 33 feet of the water column above the threshold of 1 ppb aromatics. It is classified as Medium Risk for degree of oiling because the mean volume of water contaminated was 17 mi^2 of the upper 33 feet of the water column.

Risk Factor 3B: Water Surface Impacts to EcoRAR

Ecological resources at risk at the water surface include surface feeding and diving sea birds, sea turtles, and marine mammals. These organisms can be affected by the toxicity of the oil as well as from coating with oil. The threshold for water surface oiling impact to ecological resources at risk is 10 g/m^2 (10 grams of floating oil per square meter of water surface). At this concentration and above, one would expect impacts to birds and other animals that spend time on the water surface.

Risk Factor 3B-1: Water Surface Probability of Oiling of EcoRAR

This risk factor reflects the probability that at least 1,000 mi^2 of the water surface would be affected by enough oil to cause impacts to ecological resources. The three risk scores for oiling are:

- **Low Oiling Probability:** Probability = <10%
- **Medium Oiling Probability:** Probability = 10 – 50%
- **High Oiling Probability:** Probability > 50%

Risk Factor 3B-2: Water Surface Degree of Oiling of EcoRAR

The degree of oiling of the water surface reflects the total amount of oil that would affect the water surface in the event of a discharge from the vessel. The three categories of impact are:

- **Low Impact:** less than 1,000 mi^2 of water surface impact at the threshold level
- **Medium Impact:** 1,000 to 10,000 mi^2 of water surface impact at the threshold level
- **High Impact:** more than 10,000 mi^2 of water surface impact at the threshold level

The *Diamond Knot* is classified as Medium Risk for oiling probability for water surface ecological resources for the WCD because 29% of the model runs resulted in at least 1,000 mi^2 of the water surface affected above the threshold of 10 g/m^2. It is Low Risk for degree of oiling because the mean area of water contaminated was 700 mi^2. The *Diamond Knot* is classified as Low Risk for oiling probability for water surface ecological resources for the Most Probable Discharge because 0% of the model runs resulted in at least 1,000 mi^2 of the water surface affected above the threshold of 10 g/m^2. It is classified as Low Risk for degree of oiling because the mean area of water contaminated was 225 mi^2.

Risk Factor 3C: Shoreline Impacts to EcoRAR

The impacts to different types of shorelines vary based on their type and the organisms that live on them. In this risk analysis, shorelines have been weighted by their degree of sensitivity to oiling. Wetlands are the most sensitive (weighted as "3" in the impact modeling), rocky and gravel shores are moderately sensitive (weighted as "2"), and sand beaches (weighted as "1") are the least sensitive to ecological impacts of oil.

Risk Factor 3C-1: Shoreline Probability of Oiling of EcoRAR

This risk factor reflects the probability that the shoreline would be coated by enough oil to cause impacts to shoreline organisms. The threshold for shoreline oiling impacts to ecological resources at risk is 100 g/m^2 (i.e., 100 grams of oil per square meter of shoreline). The three risk scores for oiling are:

- **Low Oiling Probability:** Probability = <10%
- **Medium Oiling Probability:** Probability = 10 – 50%
- **High Oiling Probability:** Probability > 50%

Risk Factor 3C-2: Shoreline Degree of Oiling of EcoRAR

The degree of oiling of the shoreline reflects the length of shorelines oiled by at least 100 g/m^2 in the event of a discharge from the vessel. The three categories of impact are:

- **Low Impact:** less than 10 miles of shoreline impacted at the threshold level
- **Medium Impact:** 10 - 100 miles of shoreline impacted at the threshold level
- **High Impact:** more than 100 miles of shoreline impacted at the threshold level

The *Diamond Knot* is classified as High Risk for oiling probability for shoreline ecological resources for the WCD because 99% of the model runs resulted in shorelines affected above the threshold of 100 g/m^2. It is classified as Medium Risk for degree of oiling because the mean weighted length of shoreline contaminated was 10 miles. The *Diamond Knot* is classified as Medium Risk for oiling probability to shoreline ecological resources for the Most Probable Discharge because 47% of the model runs resulted in shorelines affected above the threshold of 100 g/m^2. It is classified as Low Risk for degree of oiling because the mean weighted length of shoreline contaminated was 3 miles.

Considering the modeled risk scores and the ecological resources at risk, the ecological risk from potential releases of the WCD of 7,000 bbl of light fuel oil from the *Diamond Knot* is summarized as listed below and indicated in the far-right column in Table 3-2:

- Water column resources – Medium, because of the importance of shallow, nearshore habitats as rearing and spawning habitat for listed and commercial species
- Water surface resources – Medium, because of the very large number of wintering, nesting, and migratory birds present and at risk from even light sheens
- Shoreline resources – Low, because mostly exposed rocky shores and gravel beaches are at risk, where light oil do not persist

Table 3-2: Ecological risk factor scores for the **Worst Case Discharge of 7,000 bbl** of light fuel oil from the *Diamond Knot*.

Risk Factor	Risk Score			Explanation of Risk Score	Final Score
3A-1: Water Column Probability EcoRAR Oiling	Low	Medium	High	100% of the model runs resulted in at least 0.2 mi^2 of the upper 33 feet of the water column contaminated above 1 ppb aromatics	Med
3A-2: Water Column Degree EcoRAR Oiling	Low	**Medium**	High	The mean volume of water contaminated above 1 ppb was 130 mi^2 of the upper 33 feet of the water column	
3B-1: Water Surface Probability EcoRAR Oiling	Low	**Medium**	High	29% of the model runs resulted in at least 1,000 $mi^2$of water surface covered by at least 10 g/m^2	Med
3B-2: Water Surface Degree EcoRAR Oiling	**Low**	Medium	High	The mean area of water contaminated above 10 g/m^2 was 700 mi^2	
3C-1: Shoreline Probability EcoRAR Oiling	Low	Medium	High	99% of the model runs resulted in shoreline oiling of 100 g/m^2	Low
3C-2: Shoreline Degree EcoRAR Oiling	Low	**Medium**	High	The length of shoreline contaminated by at least 100 g/m^2 was 10 mi	

Considering the modeled risk scores and the ecological resources at risk, the ecological risk from potential releases of the WCD of 700 bbl of light fuel oil from the *Diamond Knot* is summarized as listed below and indicated in the far-right column in Table 3-3:

- Water column resources – Medium, because of the importance of shallow, nearshore habitats as rearing and spawning habitat for listed and commercial species
- Water surface resources – Low, because of the relatively small area and short persistence of sheens from light fuel oils
- Shoreline resources – Low, because of the small amount of shoreline impact on mostly exposed rocky shores and gravel beaches are at risk, where light oils do not persist

Table 3-3: Ecological risk factor scores for the **Most Probable Discharge of 700 bbl** of light fuel oil from the *Diamond Knot*.

Risk Factor	Risk Score			Explanation of Risk Score	Final Score
3A-1: Water Column Probability EcoRAR Oiling	Low	Medium	High	86% of the model runs resulted in at least 0.2 mi^2 of the upper 33 feet of the water column contaminated above 1 ppb aromatics	Med
3A-2: Water Column Degree EcoRAR Oiling	Low	Medium	High	The mean volume of water contaminated above 1 ppb was 17 mi^2 of the upper 33 feet of the water column	
3B-1: Water Surface Probability EcoRAR Oiling	Low	Medium	High	0% of the model runs resulted in at least 1,000 $mi^2$of water surface covered by at least 10 g/m^2	Low
3B-2: Water Surface Degree EcoRAR Oiling	Low	Medium	High	The mean area of water contaminated above 10 g/m^2 was 225 mi^2	
3C-1: Shoreline Probability EcoRAR Oiling	Low	Medium	High	47% of the model runs resulted in shoreline oiling of 100 g/m^2	Low
3C-2: Shoreline Degree EcoRAR Oiling	Low	Medium	High	The length of shoreline contaminated by at least 100 g/m^2 was 3 mi	

SECTION 4: SOCIO-ECONOMIC RESOURCES AT RISK

In addition to natural resource impacts, spills from sunken wrecks have the potential to cause significant social and economic impacts. Socio-economic resources potentially at risk from oiling are listed in Table 4-1 and shown in Figures 4-1 and 4-2. The potential economic impacts include disruption of coastal economic activities such as commercial and recreational fishing, boating, vacationing, commercial shipping, and other activities that may become claims following a spill.

Socio-economic resources in the areas potentially affected by a release from the *Diamond Knot* include very highly utilized recreational beaches in the Puget Sound of Washington. The area has significant coastlines devoted to state beaches and parks to preserve the natural beauty of the coast. Many areas along the entire potential spill zone are widely popular seaside resorts and support recreational activities such as boating, diving, sightseeing, sailing, fishing, and wildlife viewing.

A release could impact shipping lanes that accommodate important ports in the Puget Sound and Columbia River, as well as along the Pacific coasts of Washington and Oregon. There are over 3,100 vessel port calls annually with over 210 million tonnage. Commercial fishing is economically important to the region. Regional commercial landings for 2010 exceeded $121M. Tribal nations in the area also conduct a significant amount of subsistence fishing in these waters. There are six Tribal Nations with total populations of over 19,000 that are present in the area of potential impact.

In addition to the ESI atlases, the Geographic Response Plans within the Area Contingency Plans prepared by the Area Committee for each U.S. Coast Guard Sector have detailed information on important socio-economic resources at risk.

Spill response costs for a release of oil from the *Diamond Knot* would be dependent on volume of oil released and specific areas impacted. The specific shoreline impacts and spread of the oil would determine the response required and the costs for that response.

Table 4-1: Socio-economic resources at risk from a release of oil from the *Diamond Knot*.

Resource Type	Resource Name	Economic Activities
Beach Communities	Clallam Bay Coupeville Dungeness Friday Harbor Gardiner Greenbank Lopez Oak Harbor Port Angeles Port Angeles Port Hadlock Port Stanley Port Townsend Similk Beach	Potentially affected beach resorts and beach-front communities in Washington provide recreational activities (e.g., swimming, boating, recreational fishing, wildlife viewing, nature study, sports, dining, camping, and amusement parks) with substantial income for local communities and state tax income. Many of these recreational activities are limited to or concentrated into the late spring through the early fall months.

Resource Type	Resource Name	Economic Activities
National Parks	Olympic National Park	National parks provide recreation for local and tourist populations while preserving and protecting the nation's natural shoreline treasures.
National Wildlife Refuges	Dungeness NWR Protection Island NWR San Juan Islands NWR	National wildlife refuges in Washington may be impacted. These federally managed and protected lands provide refuges and conservation areas for sensitive species and habitats.
State Parks	Deception Pass State Park Fort Casey State Park Fort Ebey State Park Fort Townsend State Park Fort Worden State Park James Island State Park Jones Island State Park Joseph Whidbey State Park Limekiln State Park Mystery Bay State Park Posey Island State Park Sequim Bay State Park South Whidbey State Park Spencer Spit State Park Stuart Island State Park	Coastal state parks are significant recreational resources for the public (e.g., swimming, boating, recreational fishing, wildlife viewing, nature study, sports, dining, camping, and amusement parks). They provide income to the states. State parks in Washington are potentially impacted. Many of these recreational activities are limited to or concentrated into the late spring into early fall months.
Tribal Lands	Lower Elwha Klallam Indian Reservation Lummi Indian Reservation Makah Indian Reservation Port Gamble Indian Reservation Swinomish Indian Reservation Tulalip Indian Reservation	The Puget Sound area of Washington includes six Tribal Reservations with over 19,000 members.
Commercial Fishing	A number of fishing fleets use the surrounding waters for commercial fishing purposes.	
	Anacortes-LaConner	Total Landings (2010): $13.6M
	Bellingham	Total Landings (2010): $26.9M
	Blaine	Total Landings (2010): $9.0M
	Neah Bay	Total Landings (2010): $7.7M
	Olympia	Total Landings (2010): $16.2M
	Port Townsend	Total Landings (2010): $4.1M
	Seattle	Total Landings (2010): $22.1M
	Shelton	Total Landings (2010): $17.6M
	Tacoma	Total Landings (2010): $3.8M
Ports	There are a number of significant commercial ports in the Pacific Northwest that could potentially be impacted by spillage and spill response activities. The port call numbers below are for large vessels only. There are many more, smaller vessels (under 400 GRT) that also use these ports.	
	Anacortes, WA	11 port calls annually
	Bellingham, WA	3 port calls annually
	Bremerton, WA	3 port calls annually
	Cherry Point, WA	271 port calls annually
	Everett, WA	81 port calls annually
	Ferndale, WA	101 port calls annually
	Manchester, WA	14 port calls annually
	March Point, WA	188 port calls annually
	Olympia, WA	22 port calls annually
	Point Wells, WA	14 port calls annually
	Port Angeles, WA	325 port calls annually
	Port Townsend, WA	1 port call annually

Resource Type	Resource Name	Economic Activities
	Seattle, WA	1,046 port calls annually
	Tacoma, WA	1,035 port calls annually
	Westport, WA	13 port calls annually

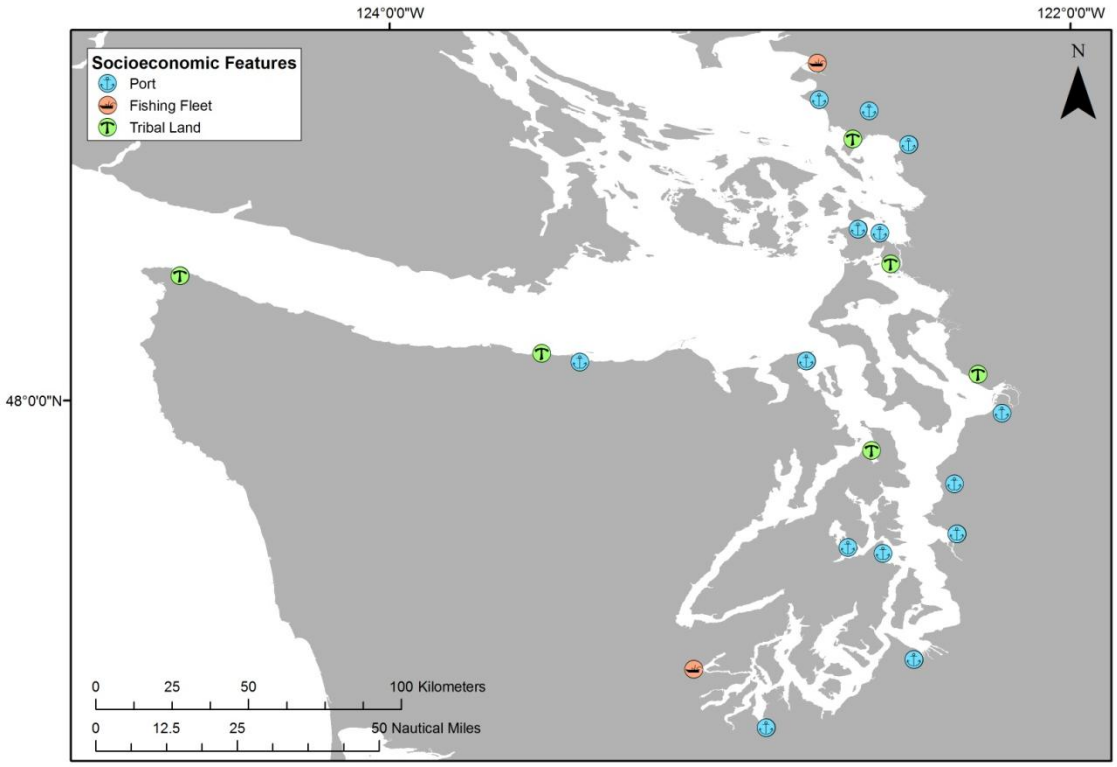


Figure 4-1: Tribal lands, ports, and commercial fishing fleets at risk from a release from the *Diamond Knot*.

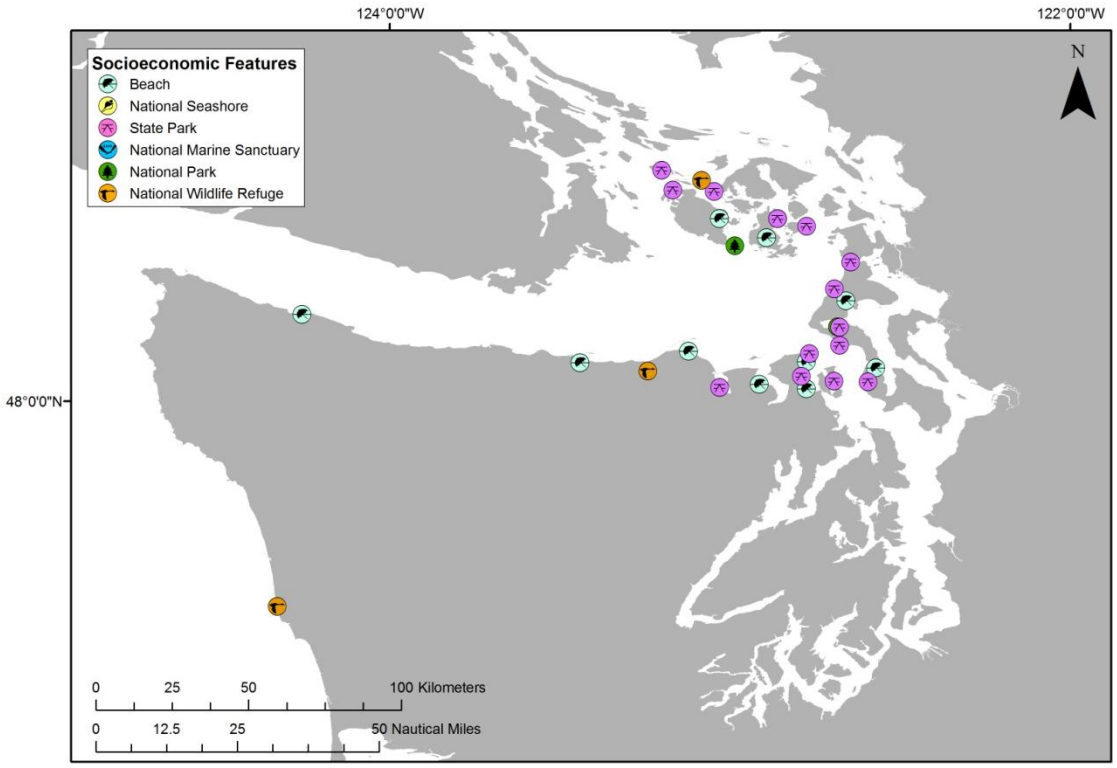


Figure 4-2: Beaches, coastal state parks, and Federal protected areas at risk from a release from the *Diamond Knot*.

Socio-Economic Risk Factors

Risk Factor 4: Impacts to Socio-economic Resources at Risk (SRAR)

Socio-economic resources at risk (SRAR) include potentially impacted resources that have some economic value, including commercial and recreational fishing, tourist beaches, private property, etc. All impact factors are evaluated for both the Worst Case and the Most Probable Discharge oil release from the wreck. Risk factors for socio-economic resources at risk are divided into three categories:

- **Water Column:** Impacts to the water column and to economic resources in the water column (i.e., fish and invertebrates that have economic value);
- **Water Surface:** Impacts to the water surface and resources on the water surface (i.e., boating and commercial fishing); and
- **Shoreline:** Impacts to the shoreline and resources on the shoreline (i.e., beaches, real property).

The impacts from an oil release from the wreck would depend greatly on the direction in which the oil slick moves, which would, in turn, depend on wind direction and currents at the time of and after the oil release. Impacts are characterized in the risk analysis based on the likelihood of any measurable impact, as well as the degree of impact that would be expected if there were one. The measure of the degree of impact is based on the median case for which there is at least some impact. The median case is the

"middle case" – half of the cases with significant impacts have less impact than this case, and half have more.

For each of the three socio-economic resources at risk categories, risk is classified with regard to:

- The **probability of oiling** over a certain threshold (i.e., the likelihood that there will be exposure to socio-economic resources over a certain minimal amount known to cause impacts); and
- The **degree of oiling** (the magnitude or amount of that exposure over the threshold known to cause impacts).

As a reminder, the socio-economic impact thresholds are: 1 ppb aromatics for water column impacts; 0.01 g/m^2 for water surface impacts; and 1 g/m^2 for shoreline impacts.

In the following sections, the definition of low, medium, and high for each socio-economic risk factor is provided. Also, in the text classification for the *Diamond Knot* shading indicates the degree of risk for the WCD release of 7,000 bbl and a border indicates degree of risk for the Most Probable Discharge of 700 bbl.

Risk Factor 4A-1: Water Column: Probability of Oiling of SRAR

This risk factor reflects the probability that at least 0.2 mi^2 of the upper 33 feet of the water column would be contaminated with a high enough concentration of oil to cause socio-economic impacts. The threshold for water column impact to socio-economic resources at risk is an oil concentration of 1 ppb (i.e., 1 part oil per one billion parts water). At this concentration and above, one would expect impacts and potential tainting to socio-economic resources (e.g., fish and shellfish) in the water column; this concentration is used as a screening threshold for both the ecological and socio-economic risk factors.

The three risk scores for oiling are:

- **Low Oiling Probability:** Probability = <10%
- **Medium Oiling Probability:** Probability = 10 – 50%
- **High Oiling Probability:** Probability > 50%

Risk Factor 4A-2: Water Column Degree of Oiling of SRAR

The degree of oiling of the water column reflects the total amount of oil that would affect the water column in the event of a discharge from the vessel. The three categories of impact are:

- **Low Impact:** impact on less than 0.2 mi^2 of the upper 33 feet of the water column at the threshold level
- **Medium Impact:** impact on 0.2 to 200 mi^2 of the upper 33 feet of the water column at the threshold level
- **High Impact:** impact on more than 200 mi^2 of the upper 33 feet of the water column at the threshold level

The *Diamond Knot* is classified as High Risk for oiling probability and Medium Risk for degree of oiling for water column socio-economic resources for the WCD of 7,000 bbl because 100% of the model runs resulted in contamination of more than 0.2 mi^2 of the upper 33 feet of the water column above the

threshold of 1 ppb aromatics, and the mean volume of water contaminated was 130 mi^2 of the upper 33 feet of the water column. For the Most Probable Discharge of 700 bbl, the *Diamond Knot* is classified as High Risk for oiling probability for water column socio-economic resources because 86% of the model runs resulted in contamination of more than 0.2 mi^2 of the upper 33 feet of the water column above the threshold of 1 ppb aromatics. It is classified as Medium Risk for oil degree because the mean volume of water contaminated was 17 mi^2 of the upper 33 feet of the water column.

Risk Factor 4B-1: Water Surface Probability of Oiling of SRAR

This risk factor reflects the probability that at least 1,000 mi^2 of the water surface would be affected by enough oil to cause impacts to socio-economic resources. The three risk scores for oiling are:

- **Low Oiling Probability:** Probability = <10%
- **Medium Oiling Probability:** Probability = 10 – 50%
- **High Oiling Probability:** Probability > 50%

The threshold level for water surface impacts to socio-economic resources at risk is 0.01 g/m^2 (i.e., 0.01 grams of floating oil per square meter of water surface). At this concentration and above, one would expect impacts to socio-economic resources on the water surface.

Risk Factor 4B-2: Water Surface Degree of Oiling of SRAR

The degree of oiling of the water surface reflects the total amount of oil that would affect the water surface in the event of a discharge from the vessel. The three categories of impact are:

- **Low Impact:** less than 1,000 mi^2 of water surface impact at the threshold level
- **Medium Impact:** 1,000 to 10,000 mi^2 of water surface impact at the threshold level
- **High Impact:** more than 10,000 mi^2 of water surface impact at the threshold level

The *Diamond Knot* is classified as High Risk for oiling probability and Medium Risk for degree of oiling for water surface socio-economic resources for the WCD because 62% of the model runs resulted in at least 1,000 mi^2 of the water surface affected above the threshold of 0.01 g/m^2, and the mean area of water contaminated was 1,600 mi^2. The *Diamond Knot* is classified as Low Risk for oiling probability for water surface socio-economic resources for the Most Probable Discharge because 5% of the model runs resulted in at least 1,000 mi^2 of the water surface affected above the threshold of 0.01 g/m^2. It is classified as Low Risk for degree of oiling because the mean area of water contaminated was 410 mi^2.

Risk Factor 4C: Shoreline Impacts to SRAR

The impacts to different types of shorelines vary based on economic value. In this risk analysis, shorelines have been weighted by their degree of sensitivity to oiling. Sand beaches are the most economically valued shorelines (weighted as "3" in the impact analysis), rocky and gravel shores are moderately valued (weighted as "2"), and wetlands are the least economically valued shorelines (weighted as "1"). Note that these values differ from the ecological values of these three shoreline types.

Risk Factor 4C-1: Shoreline Probability of Oiling of SRAR

This risk factor reflects the probability that the shoreline would be coated by enough oil to cause impacts to shoreline users. The threshold for impacts to shoreline SRAR is 1 g/m^2 (i.e., 1 gram of oil per square

meter of shoreline). The three risk scores for oiling are:

- **Low Oiling Probability:** Probability = <10%
- **Medium Oiling Probability:** Probability = 10 – 50%
- **High Oiling Probability:** Probability > 50%

Risk Factor 4C-2: Shoreline Degree of Oiling of SRAR

The degree of oiling of the shoreline reflects the total amount of oil that would affect the shoreline in the event of a discharge from the vessel. The three categories of impact are:

- **Low Impact:** less than 10 miles of shoreline impacted at threshold level
- **Medium Impact:** 10 - 100 miles of shoreline impacted at threshold level
- **High Impact:** more than 100 miles of shoreline impacted at threshold level

The *Diamond Knot* is classified as High Risk for oiling probability for shoreline socio-economic resources for the WCD because 99% of the model runs resulted in shorelines affected above the threshold of 1 g/m^2. It is classified as Medium Risk for degree of oiling because the mean length of weighted shoreline contaminated was 13 miles. The *Diamond Knot* is classified as High Risk for oiling probability and Low Risk for degree of oiling for shoreline socio-economic resources for the Most Probable Discharge as 56% of the model runs resulted in shorelines affected above the threshold of 1 g/m^2, and the mean length of weighted shoreline contaminated was 3 miles.

Considering the modeled risk scores and the socio-economic resources at risk, the socio-economic risk from potential releases of the WCD of 7,000 bbl of light fuel oil from the *Diamond Knot* is summarized as listed below and indicated in the far-right column in Table 4-2:

- Water column resources – High, because there would be a significant impact on the water column in important fishing grounds
- Water surface resources – High, because although there would be a moderate area of impact on the water surface in areas of shipping lanes, there are important subsistence fishing areas of tribal nations that may be impacted. It should be noted that oil on the surface will not be continuous but rather be broken and patchy and in the form of sheens and streamers
- Shoreline resources – High, because although a moderate area of shoreline may be impacted it has many high-value socio-economic resources

Table 4-2: Socio-economic risk factor ranks for the **Worst Case Discharge of 7,000 bbl** of light fuel oil from the *Diamond Knot*.

Risk Factor	Risk Score			Explanation of Risk Score	Final Score
4A-1: Water Column Probability SRAR Oiling	Low	Medium	**High**	100% of the model runs resulted in at least 0.2 mi^2 of the upper 33 feet of the water column contaminated above 1 ppb aromatics	**High**
4A-2: Water Column Degree SRAR Oiling	Low	**Medium**	High	The mean volume of water contaminated above 1 ppb was 130 mi^2 of the upper 33 feet of the water column	
4B-1: Water Surface Probability SRAR Oiling	Low	Medium	**High**	62% of the model runs resulted in at least 1,000 mi^2 of water surface covered by at least 0.01 g/m^2	**High**
4B-2: Water Surface Degree SRAR Oiling	Low	**Medium**	High	The mean area of water contaminated above 0.01 g/m^2 was 1,600 mi^2	
4C-1: Shoreline Probability SRAR Oiling	Low	Medium	**High**	99% of the model runs resulted in shoreline oiling of 1 g/m^2	**High**
4C-2: Shoreline Degree SRAR Oiling	Low	**Medium**	High	The length of shoreline contaminated by at least 1 g/m^2 was 13 mi	

Considering the modeled risk scores and the socio-economic resources at risk, the socio-economic risk from potential releases of the Most Probable Discharge of 700 bbl of light fuel oil from the *Diamond Knot* is summarized as listed below and indicated in the far-right column in Table 4-3:

- Water column resources – Medium, because there would be a moderate impact on the water column in important fishing grounds
- Water surface resources – High, because although there would be a moderate area of impact on the water surface in areas of shipping lanes, there are important subsistence fishing areas of tribal nations that may be impacted. It should be noted that oil on the surface will not be continuous but rather be broken and patchy and in the form of sheens and streamers
- Shoreline resources – Medium, because although a relatively small area of shoreline may be impacted it has many high-value socio-economic resources

Table 4-3: Socio-economic risk factor ranks for the **Most Probable Discharge of 700 bbl** of light fuel oil from the *Diamond Knot*.

Risk Factor	Risk Score			Explanation of Risk Score	Final Score
4A-1: Water Column Probability SRAR Oiling	**Low**	**Medium**	**High**	86% of the model runs resulted in at least 0.2 mi^2 of the upper 33 feet of the water column contaminated above 1 ppb aromatics	**Med**
4A-2: Water Column Degree SRAR Oiling	**Low**	**Medium**	**High**	The mean volume of water contaminated above 1 ppb was 17 mi^2 of the upper 33 feet The mean volume of water contaminated of the water column	
4B-1: Water Surface Probability SRAR Oiling	**Low**	**Medium**	**High**	5% of the model runs resulted in at least 1,000 mi^2 of water surface covered by at least 0.01 g/m^2	**High**
4B-2: Water Surface Degree SRAR Oiling	**Low**	**Medium**	**High**	The mean area of water contaminated above 0.01g/m^2 was 410 mi^2	
4C-1: Shoreline Probability SRAR Oiling	**Low**	**Medium**	**High**	56% of the model runs resulted in shoreline oiling of 1 g/m^2	**Med**
4C-2: Shoreline Degree SRAR Oiling	**Low**	**Medium**	**High**	The length of shoreline contaminated by at least 1 g/m^2 was 3 mi	

SECTION 5: OVERALL RISK ASSESSMENT AND RECOMMENDATIONS FOR ASSESSMENT, MONITORING, OR REMEDIATION

The overall risk assessment for the *Diamond Knot* is comprised of a compilation of several components that reflect the best available knowledge about this particular site. Those components are reflected in the previous sections of this document and are:

- Vessel casualty information and how the site formation processes have worked on this vessel
- Ecological resources at risk
- Socio-economic resources at risk
- Other complicating factors (war graves, other hazardous cargo, etc.)

Table 5-1 summarizes the screening-level risk assessment scores for the different risk factors, as discussed in the previous sections. The ecological and socio-economic risk factors are presented as a single score for water column, water surface, and shoreline resources as the scores were consolidated for each element. For the ecological and socio-economic risk factors each has two components, probability and degree. Of those two, degree is given more weight in deciding the combined score for an individual factor, e.g., a high probability and medium degree score would result in a medium overall for that factor.

In order to make the scoring more uniform and replicable between wrecks, a value was assigned to each of the 7 criteria. This assessment has a total of 7 criteria (based on table 5-1) with 3 possible scores for each criteria (L, M, H). Each was assigned a point value of L=1, M=2, H=3. The total possible score is 21 points, and the minimum score is 7. The resulting category summaries are:

Low Priority	7-11
Medium Priority	12-14
High Priority	15-21

For the Worst Case Discharge, *Diamond Knot* scores High with 16 points; for the Most Probable Discharge, *Diamond Knot* scores Medium with 13 points. Under the National Contingency Plan, the U.S. Coast Guard and the Regional Response Team have the primary authority and responsibility to plan, prepare for, and respond to oil spills in U.S. waters. Based on the technical review of available information, NOAA proposes the following recommendations for the *Diamond Knot*. The final determination of what type of action, if any, rests with the U.S. Coast Guard. Because it is such a popular dive site, this may be an opportunity to engage local divers as citizen-scientists in monitoring of the wreck for oil releases and changes in its condition.

Diamond Knot	**Possible NOAA Recommendations**
✓	Wreck should be considered for further assessment to determine the vessel condition, amount of oil onboard, and feasibility of oil removal action
	Use surveys of opportunity to attempt to locate this vessel and gather more information on the vessel condition
✓	Conduct active monitoring to look for releases or changes in rates of releases
✓	Be noted in the Area Contingency Plans so that if a mystery spill is reported in the general area, this vessel could be investigated as a source
✓	Conduct outreach efforts with the technical and recreational dive community as well as commercial and recreational fishermen who frequent the area, to gain awareness of changes in the site

Table 5-1: Summary of risk factors for the *Diamond Knot*.

Vessel Risk Factors		Data Quality Score	Comments		Risk Score
Pollution Potential Factors	A1: Oil Volume (total bbl)	Medium	Maximum of 6,516 bbl, not reported to be leaking		**Med**
	A2: Oil Type	High	Bunker oil is diesel, a Group II oil type		
	B: Wreck Clearance	High	Vessel not reported as cleared		
	C1: Burning of the Ship	High	No fire was reported		
	C2: Oil on Water	High	No oil was reported on the water		
	D1: Nature of Casualty	High	Sank as a result of a collision		
	D2: Structural Breakup	High	Vessel remains as one contiguous piece		
Archaeological Assessment	Archaeological Assessment	High	Detailed sinking records and site reports of this ship exist, assessment is believed to be very accurate		**Not Scored**
Operational Factors	Wreck Orientation	High	Resting on its starboard side		**Not Scored**
	Depth	High	140 feet		
	Visual or Remote Sensing Confirmation of Site Condition	High	Location is a popular dive site		
	Other Hazardous Materials Onboard	High	No		
	Munitions Onboard	High	No		
	Gravesite (Civilian/Military)	High	No		
				WCD	**Most Probable**
Ecological Resources	3A: Water Column Resources	High	Shallow, nearshore habitats are rearing and spawning habitat for listed and commercial species	**Med**	**Med**
	3B: Water Surface Resources	High	Large numbers of birds are at risk from larger releases that are more persistent	**Med**	**Low**
	3C: Shore Resources	High	Limited shoreline impact from light fuel oils that do not persist on rocky shores and gravel beaches	**Low**	**Low**
Socio-Economic Resources	4A: Water Column Resources	High	Significant impact on the water column in important fishing grounds	**High**	**Med**
	4B: Water Surface Resources	High	Although there could be a moderate area of impact on the water surface in areas of shipping lanes, there are important subsistence fishing areas of tribal nations that may be impacted	**High**	**High**
	4C: Shore Resources	High	Although a moderate area of shoreline could be impacted, it has many high-value socio-economic resources	**High**	**Med**
Summary Risk Scores				**16**	**13**