Oil Spill Response in Fast Currents – A Field Guide

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Abstract

Efforts to quickly deploy effective fast-water spill response have been hampered by the lack of technology and adequate training. The objective of this manual is to serve as a training aid and a field manual to increase the effectiveness of fast-water responses. It was developed with the cooperation of multiple government agencies, US Coast Guard units and commercial oil spill response firms. This guide starts with a decision guide to determine what techniques can be used in various response scenarios. Additional details are provided for hydrodynamic issues, individual tactics, fast-water skimmers and support equipment such as boats and anchors. A large number of appendices provide additional background information needed to make decisions. Whenever possible, figures are accompanied by pictures to provide a full explanation of each tactic or methodology. This is the first document that puts all of the needed information for responding to spills over 1 knot in one book. It will assist the US Coast Guard, the US EPA and commercial companies in responding to spills on rivers and in coastal areas. Finally, the information may be useful to increase the speed for advancing-type skimmers, such as the Spilled Oil Recovery System (SORS) used on USCG Buoy tenders, for spills in slower moving waters.

1.0 Introduction

Even though between 1992 and 1997 over 58 percent of all oil spilled on US waterways are in currents that routinely exceed one knot, very little research and product development has been conducted on new technologies and strategies to respond to oil spills in currents from one to five knots. (Coe and Gurr, 1999) A lack of effective fast water containment and recovery systems, and limited training and experience in these difficult and dangerous response conditions have hampered response efforts in fast current rivers and coastal areas. The US Coast Guard (USCG) Research & Development Center (RDC) Project, "Innovative Response Techniques (Fast-Water Containment)" goal is to improve the fast-water containment and recovery capabilities for both the USCG and commercial response firms. The first part of this project reviewed existing technology. (Coe and Gurr, 1998) Another part of the effort was to consolidate information needed for fast-water training and response into one document.

The objective of this effort was to create a document that addresses only fast-water issues. There are multiple manuals and guides available for oil spill response but most have limited information on fast-water conditions (Exxon 1992, US Navy, 1991 EPPR, 1998). For example, the Exxon manual provides a decision guide that recommends the use of diversion boom but only contains one page about the maximum angle to use and anchoring methods. Fast water issues in other manuals share space with spills on land or in groundwater. (CONCOWE, 1982) A more recent publication from England (Environmental Consultancy, 1998) provides information that can be used to develop contingency plans but does not contain sufficient details for responders. The training opportunities are also limited. Only three organizations, Texas A&M, DOWCAR Environmental Management and US Environmental Protection Agency (EPA) sponsor courses that directly address fast currents.

An initial guide was developed based on the previous report. (Coe and Burr, 1999) Additional information was added based on the field tests of equipment (Hansen, 1999, 2000) and tests at Ohmsett (DeVitis, 2000, 2001) conducted as part of this project. In June, 2000, a working group composed of USCG, US Environmental Protection Agency (EPA) and commercial oil spill response representatives met to review the preliminary draft. The consensus of the group was that the guide should first be useful as a training tool. This training would specifically assist CG Marine Safety Units in working with CG operational units during an emergency response. This guide would also permit on-scene commanders and area supervisors to define techniques and terminology for the responders in the field. A final version of the guide was released in the Fall of

2001. To augment the manual, a smaller concise version is being developed. Space does not permit exploring the full capability of this manual but the highlights of the manual will be discussed.

2.0 Organization of Guide

The guide contains 9 chapters and 12 appendices (Table 1) with the first chapter containing general information. A decision approach is contained in Chapter 2 followed by a chapter addressing hydrodynamic issues that must be addressed before making deployment decisions. This arrangement places most of the information needed during a response right at the front of the guide. The tactics to be used are documented in Chapter 4 and are listed by operating environment. (see Table 2) Chapters on booming techniques, skimmers, special conditions and support equipment follow. The final chapter provides some specialized equipment and procedures that have found to be useful in fast-water responses. The appendices contain a large amount of pertinent information. The references contain a separate listing of Internet site links.

3.0 Using the Guide

The approach for fast water response usually means moving the oil, and as little water as possible, to the shoreline for recovery. To perform this, the right equipment must be deployed using the correct methods. Decision steps are provided (Table 3) to facilitate the selection and deployment of equipment. Additional assistance is provided in an appendix in the form of a worksheet (Table 4). This worksheet summarizes all of the steps listed in Table 3. The main part of this form dealing with fast water is section 10, Selection of Strategies. The recommended scenarios are listed in Table 5 along with amplifying information. The tactics are similar among the regions with minor modifications within the different environments. For example, single diversion boom can be used almost anywhere but the conditions faced in a coastal environment differs from rivers. Along the coast where the currents tend to be slower and waves are present, booms with deeper drafts and higher freeboards are recommended. In addition, the lengths of boom deployed in the coastal region tend to be longer so heavier anchoring gear may be needed to handle the loads.

Methods are provided that can facilitate decision-making and implementation issues. For example, many times response personnel have difficulties estimating the actual speed of the current. The exact current can be calculated by using the Chip Current method. A piece of wood is tracked in the current to determine the time that it takes to drift 100 feet and Table 6 provides the actual current based on this measurement. Chapter 3 provides hydrodynamic information such as the maximum boom deployment angle. This is a crucial value and is the one least understood by many responders. Oil will flow under a boom at about 0.75 knots and is independent of the boom draft. In fast water, the velocity of the current perpendicular to the boom must be kept lower than those provided in Figure 1 to keep the oil flowing along the boom and not under it. Since most currents are lower closer to the shoreline, adjusting the catenary can slowly increase the angle and the oil easily redirected to a pocket for clean up.

New information that has been generated by this project is a method to quickly estimate the load on a boom that is anchored at an angle of between 10 and 30 degrees to the current. The following formula can be used: (Hansen, DeVitis, Potter, Ellis, and Coe, 2001):

$$T = K * A * V^2$$

where:
- T = tensile force, lb_f
- K = constant, $lb_f /(ft^2 \times knots^2)$
- A = projected area of the submerged portion of the boom, ft^2
- V = tow speed, knots

The projected area of the boom was calculated based on the boom draft, and the length of the boom normal to the water current (i.e., the direction of travel):

$$A = d * L * \sin\theta$$

where:
- A = projected area of the submerged portion of the boom, ft^2
- d = boom draft, feet
- L = boom length, feet (100 ft)
- θ = diversion angle (10°, 20°, 30°)

The results of the equations are shown in Table 7 for a 100-foot boom with a 6-inch draft. Multiply the values given by 2 for a 12-inch draft and by 3 for an 18-inch draft boom. The first table is used for calm water and the second table for short-crested waves.

The chapter on tactics provides information for each tactics in each environment. Special considerations are mentioned and recommendations are provided on the techniques for deployment. Whenever possible, a figure (see Figure 2) is provided along with a photograph (Figure 3) to reemphasize the concept. Situations are also shown from actual spills Approaches for inland streams and culverts can also be used for coastal inlets.

The chapter on unique booming techniques includes photographs and figures of specific techniques that have been show to be successful, such as the Trans Mountain Pipeline technique and DOWCAR Environmental method. Details on the use of newer products that have been shown to be successful for river deployments such as Boom Deflectors and Boom Vanes are also given. A chapter devoted to skimmers describes those that can operate independently and those than can be used with other equipment such as a Vessel of Opportunity Skimming System (VOSS). The systems described have been successful in recovering oil in currents greater than 2 knots. Ice conditions and special techniques such as water jets and pneumatic boom issues, including information to implement these approaches are described in one chapter.

The chapter on support equipment contains a large amount of information on anchoring, rigging, boat selection and temporary oil storage. Figures and pictures are again used to describe the systems. Anchor holding power, shoreline moorings and vessel powering issues are also addressed. A table (Table 8) is included that provides the amount of force that a boat must overcome to tow a boom lengthwise through the water. To determine the total force, the value in the table is multiplied by the total length of boom. The amount of horsepower needed can then be determined by dividing the total force by 15 for an outboard and 20 for an inboard motor.

The appendices include definitions, conversion factors, safety factors and a description of how oil spill processes are affected by fast water. Details about the DOWCAR Environmental approach, methods to calculate loads on booms and additional information about heavy oil response and flow through culverts are contained in separate appendixes. A description of vector analysis is also included. An assessment of the technologies was performed by the American Society for Testing and Materials (ASTM) Committee F20, Hazardous Substances and Oil Spill Response is also included.

4.0 Summary

This guide is the first attempt at placing all of the special information needed for a fast-water response in one document. The resulting format is a trade-off among competing requirements, but information from multiple references has been bought together in a document that will be useful for training, planning and responding to spills both in the private and government oil response sectors. When the manual is used for training, individual pages can be printed out and used as aids. These pages can also be taken into the field during a response or as many responders continue to bring laptops and palmtops out into the field the gaps will close between the training, planning and response communities resulting in readily accessible information and faster responses.

5.0 Acknowledgements

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Table 1. Summary on How to Use this Guide

CHAPTER 1	INTRODUCTION
CHAPTER 2	DECISION GUIDE
CHAPTER 3	HYDRODYNAMIC CONSIDERATIONS • Estimating currents and boom deflection angles Selecting the best control points considering flow and topography • Determining forces on boom and the effects of mooring line angles
CHAPTER 4	SCENARIOS & TACTICS
CHAPTER 5	UNIQUE BOOMING TECHNIQUES
CHAPTER 6	SKIMMING TECHNIQUES
CHAPTER 7	SPECIAL CONDITIONS/ALTERNATE TECHNIQUES
CHAPTER 8	SUPPORT EQUIPMENT • Mooring Systems and Techniques • Boats & powering considerations and Aircraft • Temporary Oil Storage: Floating & Land
CHAPTER 9	SPECIALIZED METHODS AND TECHNIQUES
Appendixes A. Table and Worksheet for Fast Water Response B. Definitions C. Conversion Tables D. Processes Accelerated in Swift Current E. Cascade Tactic for Booming a River (DOWCAR, 1997) F. Current Estimation and Mooring Line Issues G. Diversion Boom Mooring Line Force Worksheet H. Vector Analysis for Currents and Wind I. Heavy Oils J. Culvert Calculations K. Safety L. Technology Assessment	
REFERENCES	

Table 2. Chapter 4 Table of Contents•

Table 3. Decision Table •

Decision Steps for Selecting Fast Water Strategies
1. Gather information: Use the list in Appendix A for reminders. The table and worksheet can be printed out and the information filled in as needed.
2. Determine Oil Trajectory: Where is the oil going? Use Area Contingency Plan and/or Environmental Sensitivity Index to identify areas to be protected or where oil can be recovered along the route of the oil trajectory. Determine the time of oil impact on land and identify locations where a protection or collection strategy is warranted. Look for natural collection points.
3. Identify Potential Tactics: Use Table 2-1 to select tactics that can be used for each location. Table 2-2 contains a brief description of factors that should be considered. For additional details, refer to other sections of this guide. If multiple tactics are applicable, evaluate with respect to the equipment available in combination with the next step below.
4. Risk/benefit analysis: Conduct a human health risk assessment (see example in Appendix K) and a net environmental benefit analysis for each strategy and alternative at each location.
5. Choose the final strategy: Select the option that yields the highest net human health and environmental benefit.
6. Implement strategy: Place equipment and personnel into position. Preposition equipment in optimal locations whenever possible.
. Monitor and adjust strategy as appropriate.

Table 4. Fast Water Worksheet

FAST WATER WORKSHEET	**1. Incident Name:**	**2. Date/time prepared:**	**3. Operational Period**	**4. Attachments**
5. Fast Water Type	Rivers/Canals (non-tidal) ☐ Rivers/Canals (tidal) ☐ Small Streams/Culverts/Creeks ☐ Coastal areas ☐ Harbors/Bays ☐ Breakwaters and Harbor entrances ☐ Other (specify):			

	Oil Type	Oil Amount	Temperature F	Humidity %	Evaporation in 24 hours %	Wind (mph)	Visibility (Ft)	Rain, Sleet, Snow	Water (F) Temperature	Other
6. Background Info										

7. Safety Hazards	Confined Space ☐ Noise ☐ Heat Stress ☐ Cold Stress ☐ Electrical ☐ Animal/Plant/Insect ☐ Ergonomic ☐ Ionizing Rad ☐ Slips/Trips/Falls ☐ Struck by ☐ Water ☐ Violence ☐ Excavation ☐ Biomedical waste and/or needles ☐ Fatigue ☐ Other (specify)
8. Personal Protection	Life Jackets ☐ Oil resistant gloves ☐ Shoulder length resistant gloves ☐ Level D ☐ Eye protection ☐ Cold WX Gear ☐ Level C ☐ Splash Suits ☐ Hearing protection ☐ Fall protection Water ☐ Sun screen ☐ Wet Suits ☐ Dry Suits ☐ Portable first aid kits ☐ Other (specify)

9. Potential Booming Locations	ETA Oil Impact	Natural Collection Point	Shoreline wave energy	Current Speed & Direction	Access	Water Depth	Tidal Influence	Bottom Amenable to Anchors	Debris, Ice	Shore Sensitivity	Historical Economic Concern	Nav Traffic	Strategy Selection
		Yes ☐ No ☐	High ☐ Med ☐ Low ☐		Land ☐ Water ☐ Air ☐		High ☐ Med ☐ Low ☐	Yes ☐ No ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	
		Yes ☐ No ☐	High ☐ Med ☐ Low ☐		Land ☐ Water ☐ Air ☐		High ☐ Med ☐ Low ☐	Yes ☐ No ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	
		Yes ☐ No ☐	High ☐ Med ☐ Low ☐		Land ☐ Water ☐ Air ☐		High ☐ Med ☐ Low ☐	Yes ☐ No ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	
		Yes ☐ No ☐	High ☐ Med ☐ Low ☐		Land ☐ Water ☐ Air ☐		High ☐ Med ☐ Low ☐	Yes ☐ No ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	
		Yes ☐ No ☐	High ☐ Med ☐ Low ☐		Land ☐ Water ☐ Air ☐		High ☐ Med ☐ Low ☐	Yes ☐ No ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	
		Yes ☐ No ☐	High ☐ Med ☐ Low ☐		Land ☐ Water ☐ Air ☐		High ☐ Med ☐ Low ☐	Yes ☐ No ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	
		Yes ☐ No ☐	High ☐ Med ☐ Low ☐		Land ☐ Water ☐ Air ☐		High ☐ Med ☐ Low ☐	Yes ☐ No ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	High ☐ Med ☐ Low ☐	

10. Selection Strategies	**Current < 2 Knots**	**Current > 2 Knots**	**Room to Maneuver**	**Collection Possible on Opposite Sides**
Rivers/Canals (non-tidal)	Single Diversion Booming (Skirt < 12 inches) (SDB<12) Sorbents (isolated areas) (SRB) Exclusion Booming (EXB) Encircle Booming (ECB)	Single Diversion Booming (Skirt < 6 inches) (SDB<6) Cascade Booming (CSC)	Skimmers (SK)	Chevron Booming (CHV)
Rivers/Canals (tidal)	Double SDB<12, ECB, SRB	Double SDB<6, CSC	SK	CHV
Small Streams /Creeks/Culverts	Fill, Dams, Weirs Underflow/Overflow Dams (UFD/OFD) SRB		SK (small)	
Coastal Areas	ENC, SDB<12 (no waves), SRB	CSC	SK	
Harbor/Bays	SDB<12, ECB, SRB	SDB<6, CSC	SK	CHV
Breakwaters/Harbor Entrances	SDB<12, ECB, SRB, Fill, Dams, Weirs, UFD, OFD	SDB<6, CSC	SK	CHV

Prepared by:	**Notes: Use codes in section 10 to complete strategy section in section 9.**	Page _____ of _____

Table 5. Fast Current Scenarios and Tactics

Scenario	Amplifying Information	Tactics
Rivers/Canals (Non-Tidal): Depth is greater than typical boom skirt depth May have tidal influence, but current always goes in same direction	Current speed dependent Vessel traffic dependent	Single Diversion Boom • Current < 2 knots use boom skirt of 12 inches • Current > 2 knots use boom skirt 6 inches or less
	Currents over 2 knots	Cascading Diversion Boom • Use short skirts, shorts boom lengths and sufficient overlap
	Collection areas available on both sides	Chevron Booms • Open for vessel traffic • Closed if no traffic
	Currents less than 2 knots and river is wide	Single Diversion Boom Exclusion Boom for Sensitive Areas Encircle & Divert to Collection Area
	Sufficient room to maneuver	Skimmers for Collection
	Vessels not available	Boom Vane Flow Diverters
	Special Conditions	Air and Water Jets
	Isolated Areas	Sorbents and Pom-Poms
Rivers/Canals- **(Tidal):** Depth is greater than typical boom skirt depth Current reverses direction	Current speed dependent Vessel traffic dependent Special methods needed to compensate for tides	Diversion Boom – need double set • Current < 2 knots use boom skirt of 12 inches • Current > 2 knots use boom skirt 6 inches or less
	Currents over 2 knots	Cascade Boom - may need double set • Use short skirts, shorts boom lengths and sufficient overlap
	Collection areas available on both sides	Chevron - may need double set • Open for vessel traffic • Closed if no traffic
	Currents less than 2 knots and river is wide	Encircling
	Isolated Areas	Sorbents and Pom-Poms
	Sufficient room to maneuver	Skimmers
	Vessels not available	Boom Vane Flow Diverters
	Special Conditions	Air and Water Jets
	Isolated Areas	Sorbents and Pom-Poms
Small streams, creeks, culverts: Depth is less than boom skirt depth	Dependent upon flow rate (see Appendix H)	Single Diversion for volume greater than about 10 cubic feet/second
	Block for low volume flow	Sealing • Fill • Dams • Weirs
	Design for volume	Overflow/Underflow dams
	Low Flow	Sorbents and Pom-Poms

Table 5. Fast Current Scenarios and Tactics (continued)

Scenario	Amplifying Information	Tactics
Coastal Areas: Near shore wave dependent Includes near shore and straits Various depths Usually tidal		Single Diversion Boom • Current < 2 knots use boom skirt of 12 inches if no waves
	Currents over 2 knots	Cascade Boom • Use short boom lengths and sufficient overlap
	Currents less than 2 knots and river is wide	Encircling
	Sufficient room to maneuver	Skimmers
		VOSS/SORS
	Isolated Areas	Sorbents and Pom-Poms
Harbors/Bays: Near shore wave dependent Depth is usually greater than typical boom skirt depth	Use river techniques in specific areas Current speed dependent Vessel traffic dependent	Single Diversion Boom • Current < 2 knots use boom skirt of 12 inches if no waves • Current > 2 knots use boom skirt 6 inches or less if no waves
	Currents over 2 knots	Cascade Boom • Use short skirts, short boom lengths and sufficient overlap
	Currents less than 2 knots and area is large	Encircling
	Sufficient room to maneuver	Skimmers
	Special Conditions Isolated Areas	Air and Water Jets Sorbents and Pom-Poms
Breach ways and Harbor Entrances: Various depths Usually tidal	Current speed, vessel traffic and wave dependent	Single Diversion Boom • Current < 2 knots use boom skirt of 12 inches if no waves • Current > 2 knots use boom skirt 6 inches or less if no waves
	Currents over 2 knots	Cascade Boom • Use short skirts (if no waves), shorts boom lengths and sufficient overlap
	Collection areas available on both sides	Chevron - • Open for vessel traffic • Closed if no traffic
	Block for low volume flow	Sealing • Fill • Dams • Weirs
	Design for volume	Overflow/Underflow dams
	No Vessels Available	Boom Vane Flow Diverters
	Isolated Areas	Sorbents and Pom-Poms

Table 6. Current chip log and maximum boom deflection angle.

Time to Drift 100 Feet (seconds)	Velocity (ft/sec)	Velocity (m/sec)	Velocity (knots)	Max Boom Deflection Angle (degrees)	Boom Required for 100-foot Profile to Current (feet)	Anchors if Placed Every 50 feet (number)
6	16.7	5.1	10.00	4.0	1,429	30
8	12.5	3.8	7.50	5.4	1,071	22
10	10.0	3.1	6.00	6.7	857	18
12	8.3	2.5	5.00	8.0	714	15
14	7.1	2.2	4.29	9.4	612	13
17	5.9	1.8	3.53	11.4	504	11
20	5.0	1.5	3.00	13.5	429	10
24	4.2	1.3	2.50	16.3	357	8
30	3.3	1.0	2.00	20.5	286	7
40	2.5	0.8	1.50	27.8	214	5
60	1.7	0.5	1.00	44.4	143	4
>86	≤1.2	≤0.35	≤0.70	90.0	100	3

Table 7. Force on One-Hundred Feet of Diversion Boom

(Angle between 10 and 30 degrees)

Calm Water

Angle	Area	Speed (knots) 2	3	4	5	6
10	8.68	198.15	445.83	792.59	1238.42	1783.33
20	17.10	390.28	878.12	1561.10	2439.22	3512.48
30	25.00	570.54	1283.72	2282.18	3565.90	5134.90

Waves

Angle	Area	Speed (knots) 2	3	4	5	6
10	8.68	396.30	891.67	1585.18	2476.85	3566.66
20	17.10	780.55	1756.24	3122.20	4878.44	7024.95
30	25.00	1141.09	2567.45	4564.35	7131.80	10269.80

Table 8. Pounds of force per foot of boom (towed from end).

Skirt Depth (inches)	Current (knots) 1	2	3	4	5	6	7	8	9	10
4	0.03	0.11	0.24	0.42	0.66	0.95	1.30	1.69	2.14	2.65
6	0.04	0.16	0.36	0.64	0.99	1.43	1.95	2.54	3.22	3.97
8	0.05	0.21	0.48	0.85	1.32	1.91	2.59	3.39	4.29	5.29
12	0.08	0.32	0.71	1.27	1.98	2.86	3.89	5.08	6.43	7.94

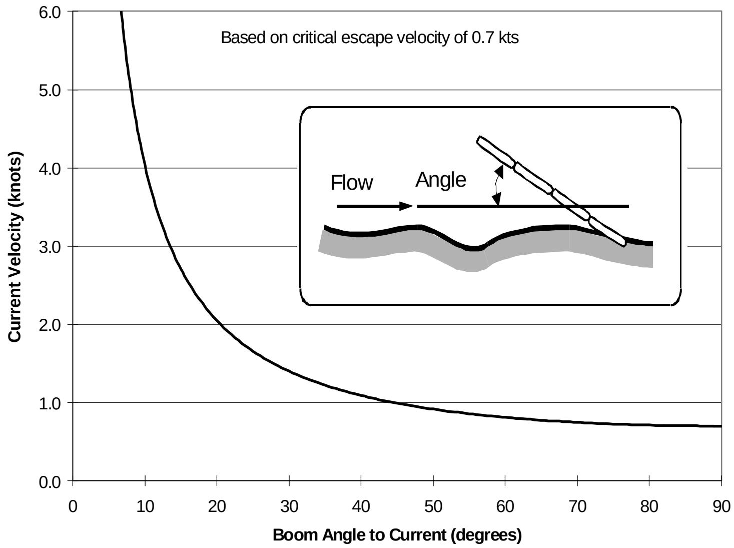

Figure 1. Maximum Boom Angle for Boom Deployments

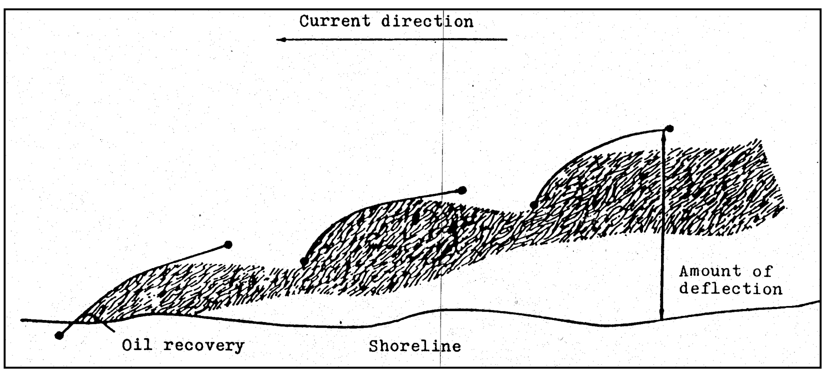

Figure 2. Drawing of Cascade Diversion Boom

Figure 3.Photograph of Cascade Diversion Booming