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Evaluation of Oil Spill Barriers and Deployment Techniques for the St. Clair-Detroit River System

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EVALUATION OF OIL SPILL BARRIERS AND DEPLOYMENT TECHNIQUES FOR THE ST. CLAIR - DETROIT RIVER SYSTEM

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ABSTRACT

The Detroit-St. Clair River System is as an area of high ecological sensitivity where there is the potential for a major spill. Under the auspices of the Joint Canada-United States Marine Pollution Contingency Plan, ''Operation Preparedness'' was established to develop operational procedures for dealing with spill incidents in the River System and to formulate an Action Plan incorporating these procedures and other pertinent information.

As one project of ''Operation Preparedness'', a field study was carried out during 1975 in this River System. Three sites were used for testing purposes; the currents at these sites ranged from 0.8 to 1.8 knots. The performance of twelve commercially available barriers was evaluated. Included in the evaluation was a determination of deflection capability using a synthetic bio-degradable oil.

Effective deployment procedures were developed at the three sites. Short lengths of barrier, deployed in an overlapping configuration were found to be most effective as deflectors. It was determined that free-floating oil could be deflected into a quiescent recovery site.

This report discusses in detail the findings of this field study programme.

RÉSUMÉ

Le réseau hydrographique des rivières Détroit et Sainte-Claire est très sensible au point de vue écologique aux endroits où existe le danger d'un déversement important. En vertu du Plan d'urgence Canada/Etat-Unis en cas de pollution marine, on a lancé "Operation Preparedness" afin de mettre au point des techniques de lutte contre ces déversements et d'élaborer une série de mesures où interviendraient ces techniques et d'autres renseignements pertinents.

Parmi l'une des activités de cette opération, figurait une étude réalisée en 1975 en certains secteurs du réseau hydrographique en question. A cette fin, on en a choisi trois, où la vitesse du courant variait entre 0.8 et 1.8 noeuds pour évaluer l'efficacité de douze types de barrières contré les déversements, disponibles sur le marché, notamment leur aptitude à dévier une nappe d'huile synthétique biodégradable.

Des configurations efficaces ont été mises au point dans ces trois secteurs. On a constaté que de courtes barrières disposées en double rang présentaient une plus grande efficacité et permettaient la déviation d'une nappe d'huile libre dans des eaux calmes et se prêtant à sa récupération.

Le présent rapport traite de façon détaillée des résultats de cette étude.

ACKNOWLEDGEMENTS

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The Canadian Coast Guard, Lambton Industrial Society, Ontario Ministry of the Environment, and the Walpole Island Indian Band provided vital operational support for this project. The Marine Sciences Directorate performed the current surveys at Chenal Ecarte and Sombra.

The Centre of Spill Technology, the Ontario Ministry of the Environment and the Hydraulic Research Division of Environment Canada provided many valuable critiques during the preparation of this report.

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1.0 BACKGROUND

The St. Clair Flats, located at the outlet of the St. Clair River, contains important fish and wildlife resources and represents 60% of all wet lands in the lower Great Lakes Basin. These resources account for a considerable portion of the local income in the form of guiding, hunting and fishing. The presence of such an environmentally sensitive area combined with a heavy concentration of industrial activities such as the manufacturing, storage and transportation of oil and other hazardous materials along the St. Clair River produces a high risk area, where there is a potential for a major spill that could have a devastating impact.

Operation Preparedness, Detroit-St. Clair River, was initiated as a result of a recommendation made during the debriefing meeting held after the SYDNEY E. SMITH — PARKER EVANS collision in the St. Clair River at Sarnia in June of 1972. It was recommended "... that a joint Canada/U.S. study be instituted to determine the equipment requirements for the containment and removal of oil in the inter-connecting water-ways in the Great Lakes." SYDNEY E. SMITH-PARKER EVANS collision was the second major incident in the St. Clair River in less than one year, the first being the NETUNO-TRANSMICHIGAN collision in August, 1971. In both cases, there was a potential of a major oil and/or hazardous material spill.

On September 19, 1973, an International Joint Response Team named under the Joint Canada-United States Marine Pollution Contingency Plan, met to discuss a possible outline for the Operation Preparedness programme.

The objectives of Operation Preparedness were two-fold:

(1) to develop operational procedures for dealing with major spill incidents in the St. Clair-Detroit River System and

(2) to formulate an Action Plan which would incorporate these operational procedures in the event of a major spill incident in the area.

The Operation Preparedness programme was established under the auspices of the Joint Canada-United States Marine Pollution Contingency Plan, with the co-operation of local industry, and Canadian and United States Regulatory Agencies such as:

Michigan Department of Natural Resources
United States Army Corps of Engineers
United States Coast Guard
United States Environmental Protection Agency
Environment Canada
Transport Canada
Ontario Ministry of the Environment
Ontario Ministry of Natural Resources
Lambton Industrial Society
Walpole Island Indian Band

Operation Preparedness consisted of twelve projects to examine the entire river system for the purposes of identifying:

(1) high risk areas where spills may occur,
(2) potential sites which may support recovery operations,
(3) ecologically sensitive areas which will require special protection,
(4) strategic locations of recovery equipment including supporting materials such as communications, sorbents, etc.,
(5) potential disposal sites, and
(6) effective operating procedures to control an oil slick in the river system.

2.0 INTRODUCTION TO PROJECT 11

Project 11 was designed to field test different commercially available barriers and recovery equipment at three pre-selected sites in the Detroit-St. Clair River System and to improve or develop barrier deployment procedures using these products. A preliminary field study was carried out in 1974 at the Sombra and the Walpole Island Customs Docks and Chenal Ecarte. It was apparent, because of the limitations of the equipment used and the inexperience of the work crews, that further detailed examination of both equipment and deployment procedures was required. The experience gained during the 1974 field trials formed an important basis for the design of the 1975 program.

This report deals mainly with the results obtained in the 1975 field exercises. The trials were carried out at three recovery sites: Canadian Coast Guard Dock at Amherstburg, the entrance to Chenal Ecarte, and Sombra Customs Dock. The dates for the trials were June 23 to 27, July 14 to 25 and August 18 to 22 respectively. Twelve barriers were evaluated at the three sites and deployment procedures developed for diverting oil into the pre-selected recovery sites.

In addition to the evaluation performed on the twelve barriers three other devices (PACE barrier, Oil Mop, U of T boom deflector) were also tested for their deflecting capacity. The results of these tests are given in Appendix A.1.

3.0 PRINCIPLE FINDINGS

1. Free-floating oil can be successfully deflected in the St. Clair-Detroit River System where currents are less than 1.8 knots.

2. Five of the twelve barriers tested were found to be effective as deflectors.

3. Short (200 foot) sections of barrier can be successfully deployed and anchored as oil deflectors in the St. Clair-Detroit River System. In currents of 1.8 knots, the addition of a centre anchoring point will improve the overall effective deflection of a given barrier.

4. It was found that 200-foot sections of barrier can be utilized most effectively by deploying these in a cascading configuration (see figures 14 and 15), to deflect the free-floating oil across a current to a recovery area.

5. The deployment of an effective barrier as the upstream deflector in a cascade reduces the surface currents downstream which results in an increased deflection capability for each successive length of similar barrier. The reduced surface current patterns also allow the use of marginally effective barriers downstream.

6. Paravanes attached to the upstream and downstream ends of a barrier provided additional buoyancy, improved stability, and assistance in manoeuvering; their use is recommended when barriers are deployed in fast-flowing rivers.

7. Admiralty Stock anchors proved to be effective for securing 200-foot sections of barrier at all three locations tested, and proved to be the anchor preferred for use in deploying barriers.

4.0 DESIGN OF TEST METHOD

The purpose of the testing programme was to conduct a comparative analysis of the selected barriers and to determine the most effective barriers for deflection of oil in the St. Clair-Detroit River System.

4.1 Test Sites

The location of the three test sites is shown in figures 1 and 2 and more detailed diagrams of each site are shown in figure 3. The sites are:

(1) The Canadian Coast Guard Dock at Amherstburg
(2) The entrance to Chenal Ecarte
(3) Sombra Customs Dock

Available data on current modelling and on ice movement were used to assist in determining potential recovery sites in the St. Clair-Detroit River System (Crookshank 1973, Kirchhefer 1974). Additional intelligence gathered by the participants of Operation Preparedness confirmed that the above-mentioned test sites would also serve as potential recovery sites in the event of a major oil spill. During the testing, the currents at the three sites ranged from 0.8 to 1.8 knots, thus providing adequate variation of conditions for comparison of some of the findings of this project.

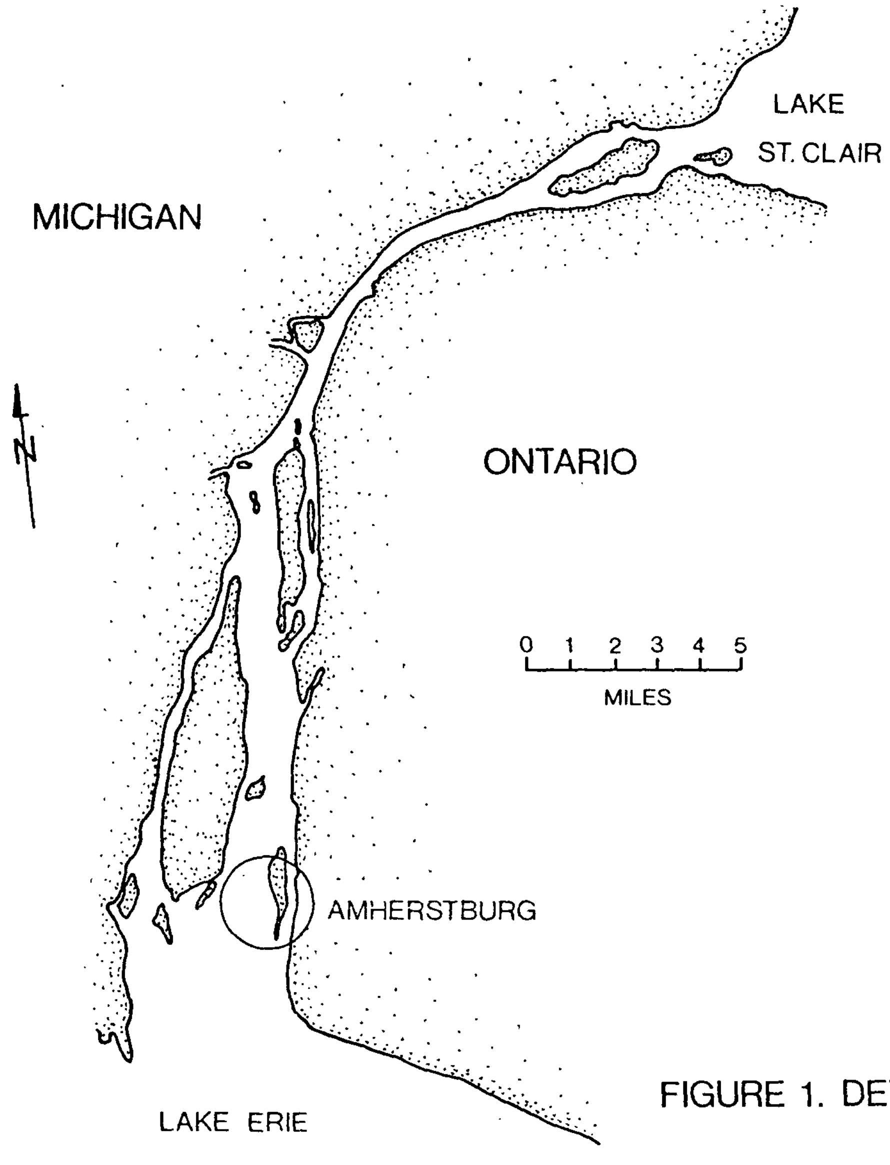


FIGURE 1. DETROIT RIVER

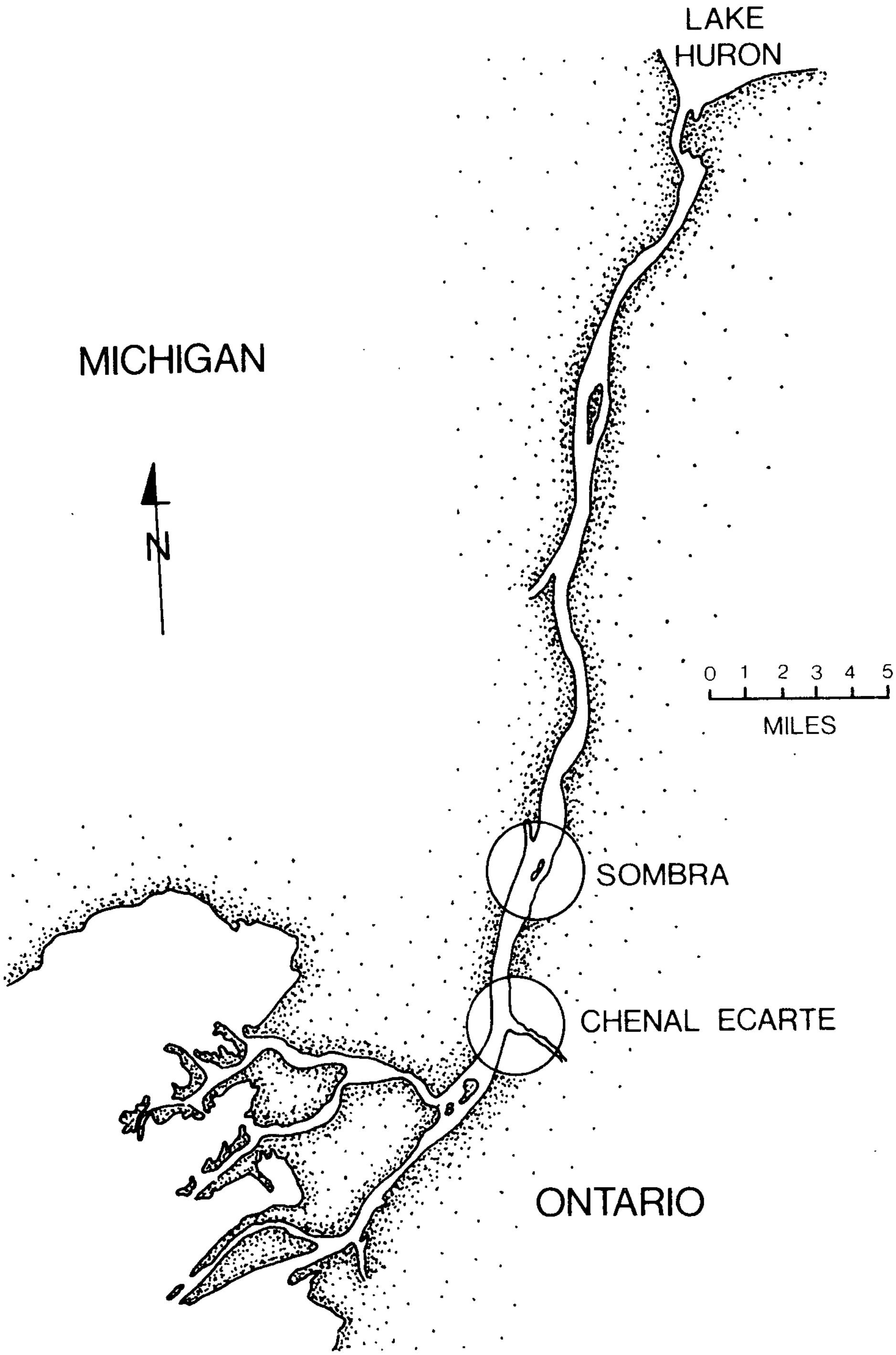


FIGURE 2. ST. CLAIR RIVER

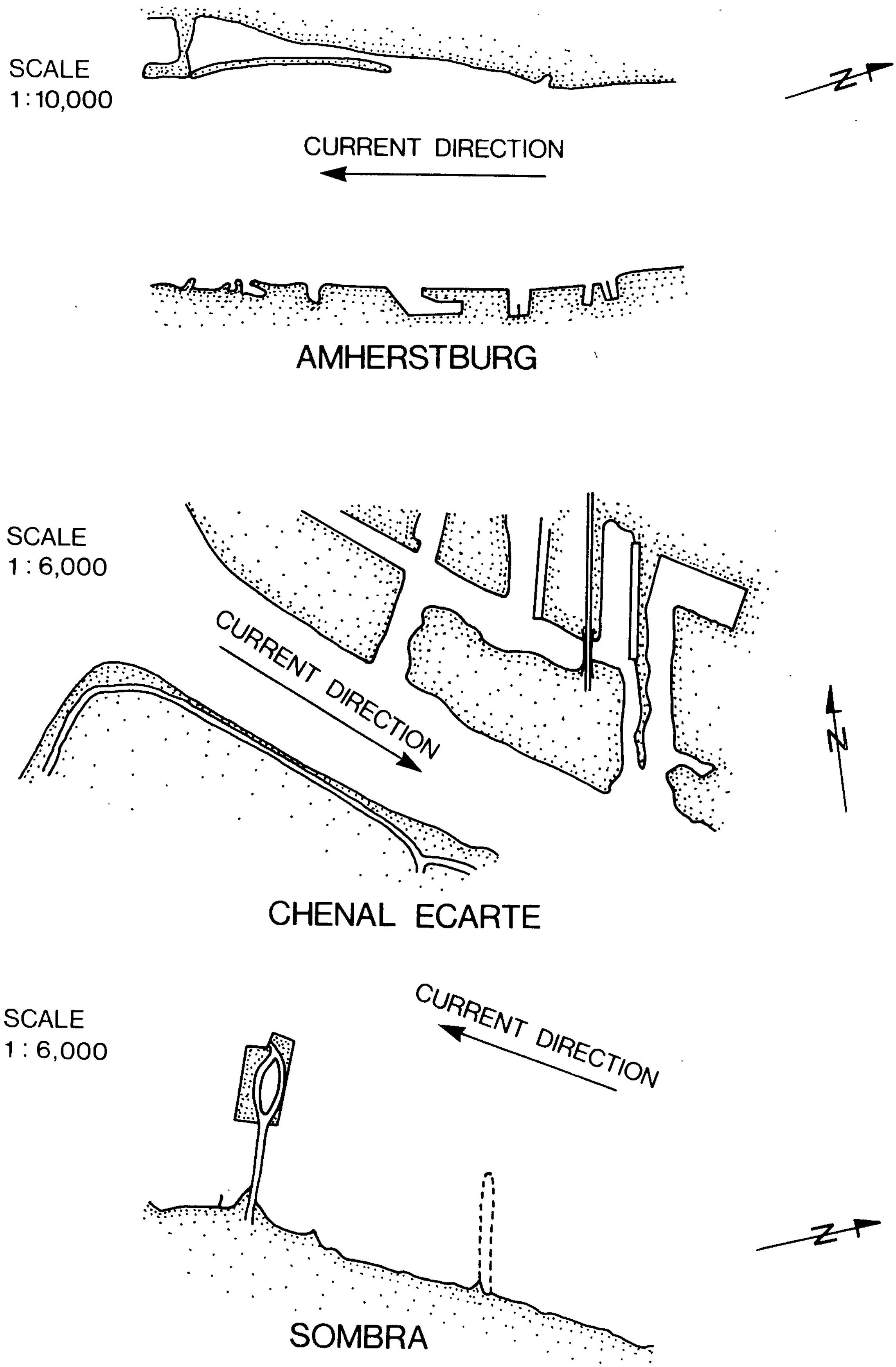


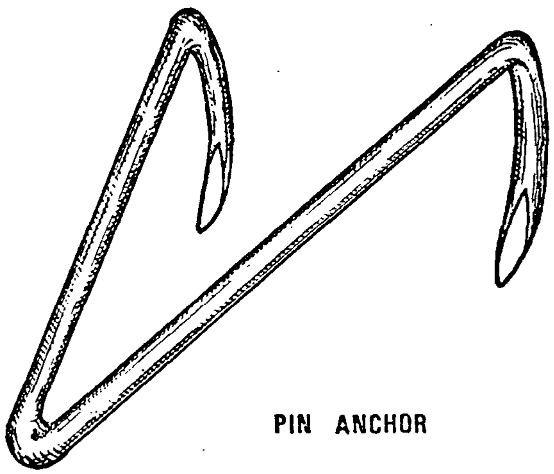
FIGURE 3. TEST SITES

4.2 Anchor Selection

To determine the most stable anchor for the barrier evaluation program, a preliminary evaluation was carried out on the following anchors:

(1) Pin anchor;
(2) Duckfoot anchor;
(3) Admiralty Stock anchor; and
(4) Danforth anchor (see figures 4a and b).

Each anchor in turn was set, and then a steady pull was applied using a Sea Truck. The force was measured using an in-line Sensotec Force Transducer (range: 0-5,000 lbs [0-2268 kg.]) and the behaviour of the anchor during pull was observed by divers. It was concluded that the Admiralty Stock anchor was the most effective anchor for use in conjunction with the barriers.



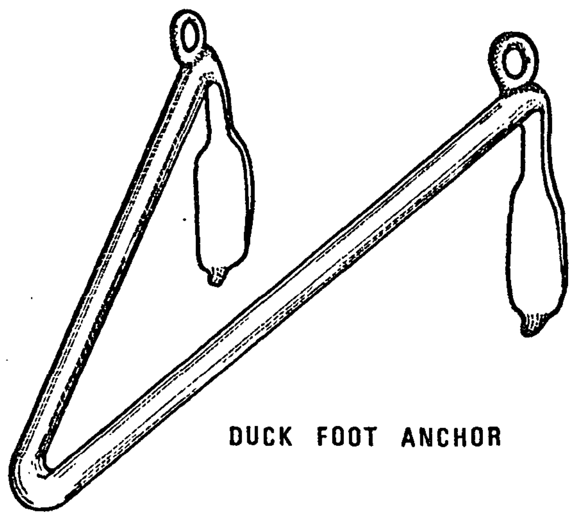
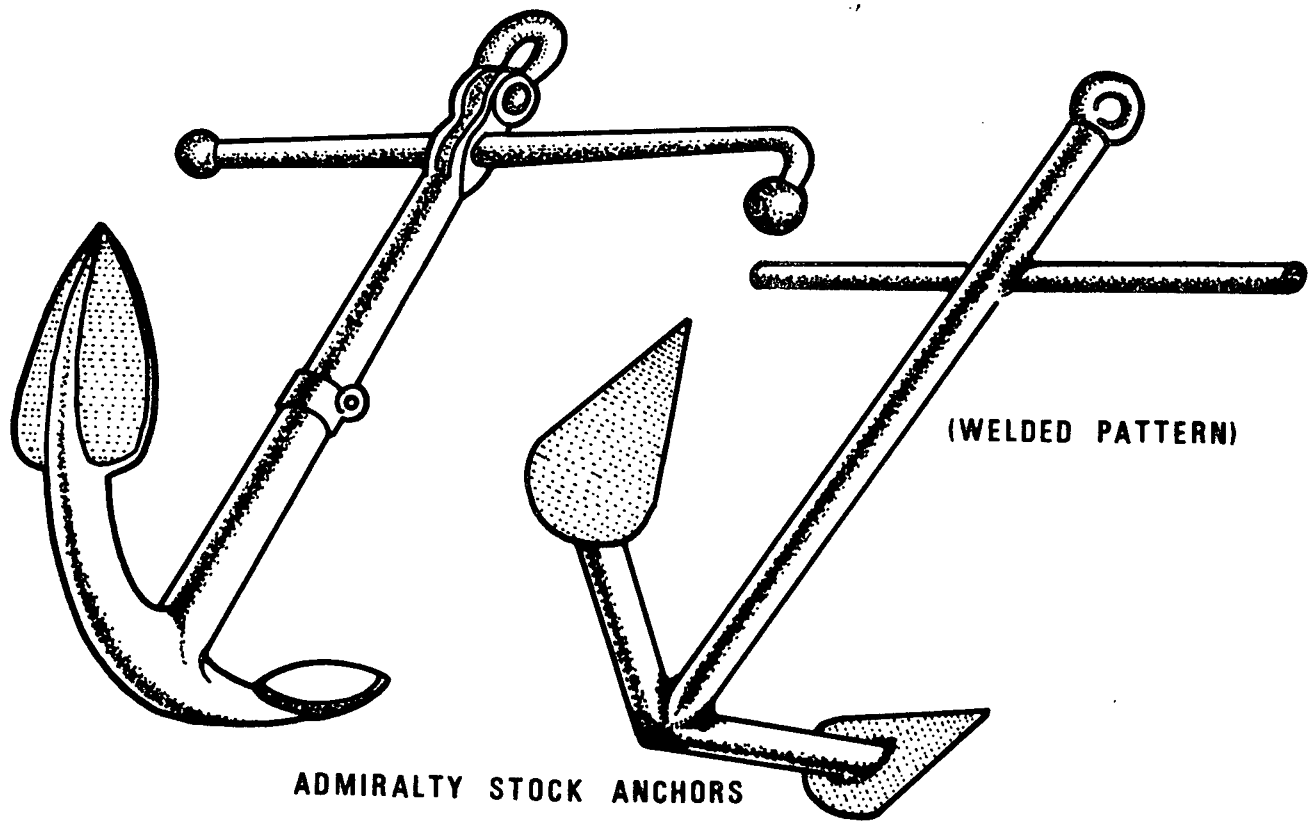
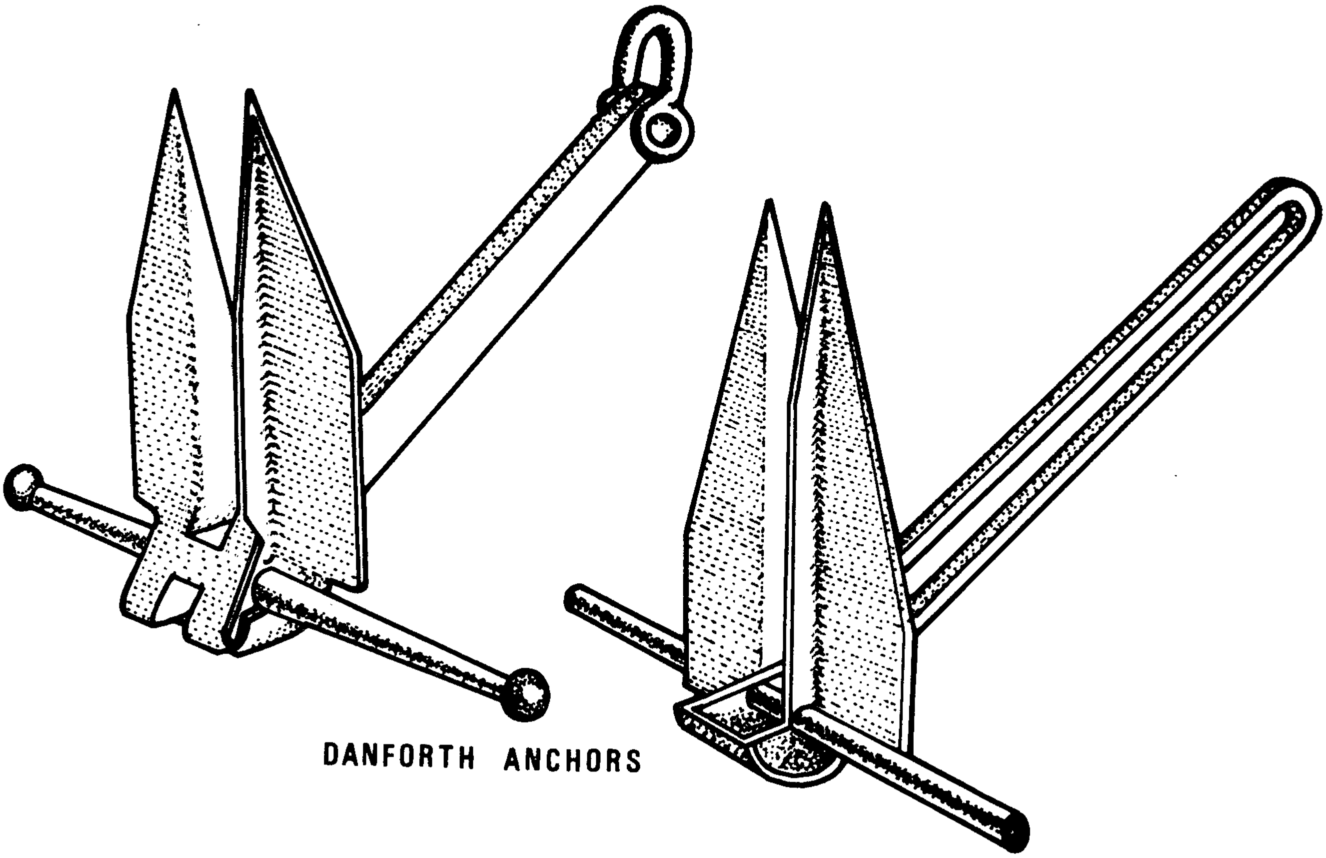


FIG.4a



ADMIRALTY STOCK ANCHORS



DANFORTH ANCHORS

FIG.4b

4.3 Barrier Selection

The initial step in the barrier selection involved the gathering of manufacturers' literature on the different barriers commercially available. This information was tabulated and is set out in Appendix A.2. Taking into consideration the general barrier configuration, the shape and size of flotation, the depth of skirt, the presence or absence of vertical stiffening, and the number and location of load-bearing cables or tension members, twelve barriers were selected as being a representative sample of the available barriers. These barriers are listed in Table I and schematic diagrams of the barriers are presented in Appendix A.3. The cross-section of a typical barrier is shown in figure 5.

TABLE I

MANUFACTURER	SIZE	TRADE NAME
Acme Products	24" (6", 18")	OK Corral
Acme Products	24" (12", 12")	OK Corral
American Marine Co.	25" (7", 18")	Optimax
Bennett Pollution Controls	18" (6", 12")	Inshore Boom
Bennett Pollution Controls	36" (12", 24")	Inshore Boom
Bennett Pollution Controls	18" (6", 12")	River Boom
B.F. Goodrich Co.	18" (6", 12")	18 PFX
Hurum Marine	14" (4-3/4", 9-1/4")	Flexy #2
Hurum Marine	18" (6", 12")	Flexy #2
Hurum Marine	24" (8", 16")	Flexy #2
Slickbar	12" (4", 8")	Mark VI
Slickbar	14-1/2" (6-1/2", 8")	Mark VI

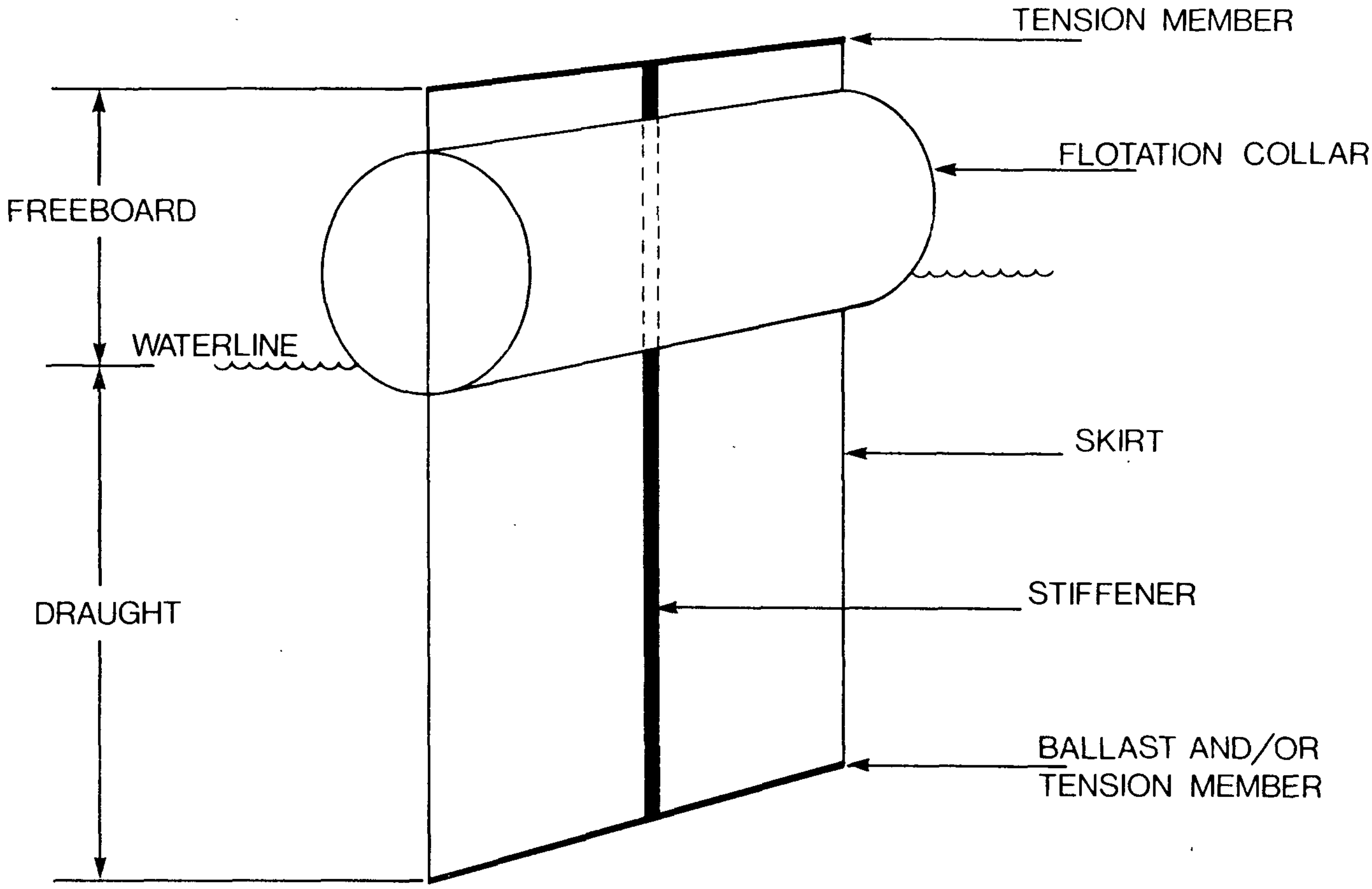


FIGURE 5. TYPICAL BARRIER CROSS-SECTION

4.4 Field Measurement Methodology

4.4.1 ***Weather.*** The weather throughout the entire test program was warm (25°C average), calm and sunny, with the exception of the last day, when there was some rain. At no time was the wind a significant factor in the testing. The water temperature was 20°C ± 2°C.

4.4.2 ***Tension Measurements.*** Tension readings were taken with a Sensotec force transducer (see figure 6a and 6b) which was inserted into the anchor line before the paravane. Two units were employed during the testing program with capacities of 0-2,500 lbs. (0-1134 Kg.) and 0-5,000 lbs. (0-2268Kg.) to record the effects of the currents on the barrier.

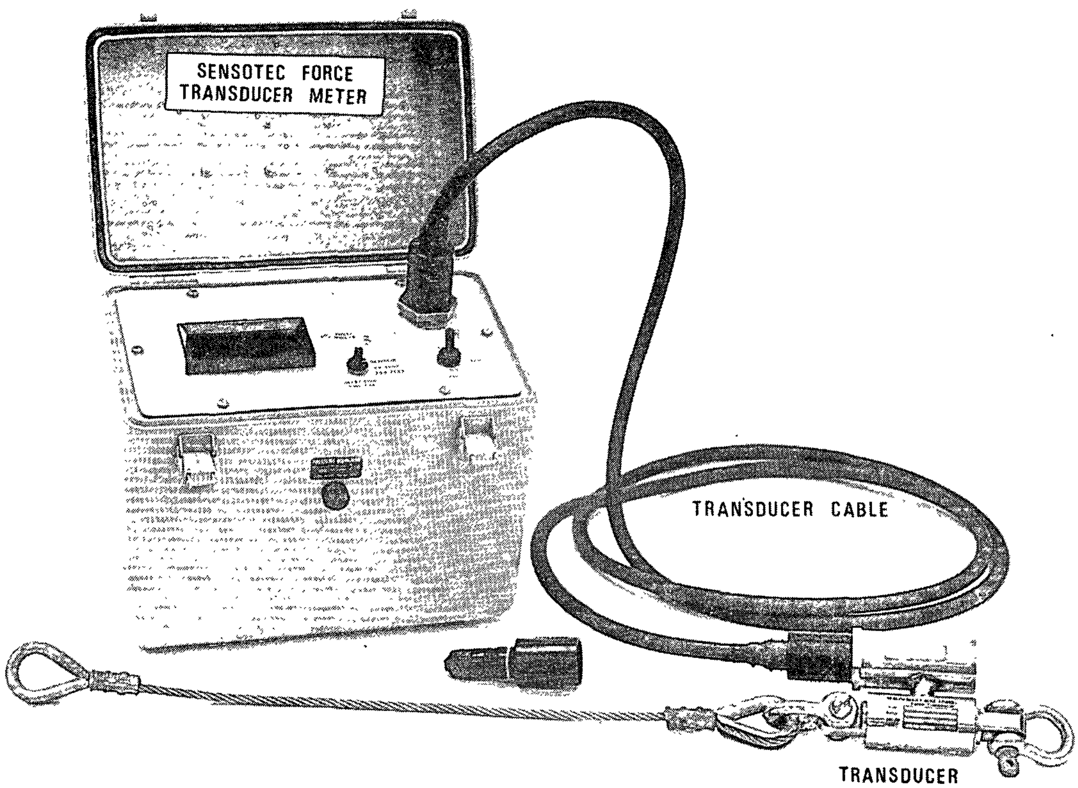
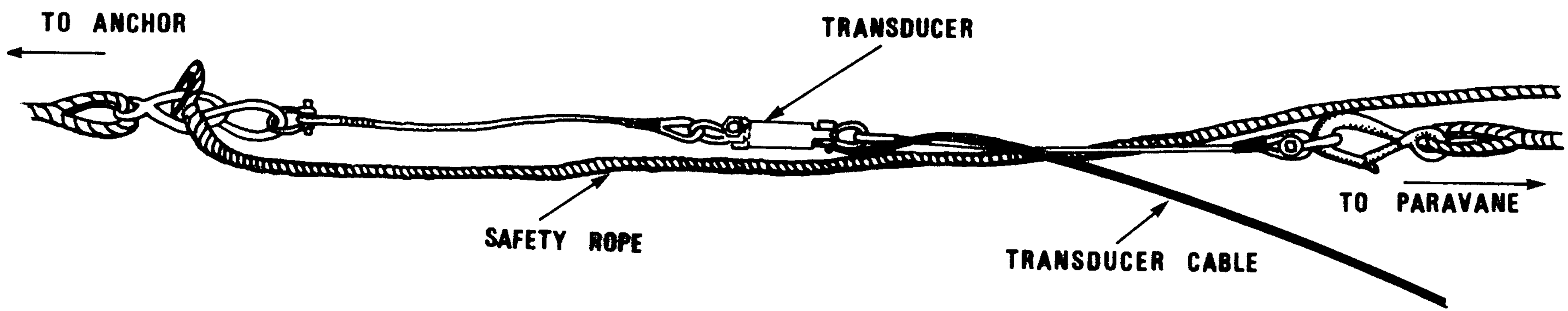


FIG. 6A SENSOTEC FORCE TRANSDUCER



SENSOTEC FORCE TRANSDUCER IN LINE BETWEEN

PARAVANE AND ANCHOR

FIG.6b

4.4.3 ***Current Measurements.*** Currents were measured using a Mead HP-302 velocity meter (see figure 7). Background current data were collected at each test site to provide a current profile (see Appendix A.5). Additional current measurements were also taken at the face of the barriers.

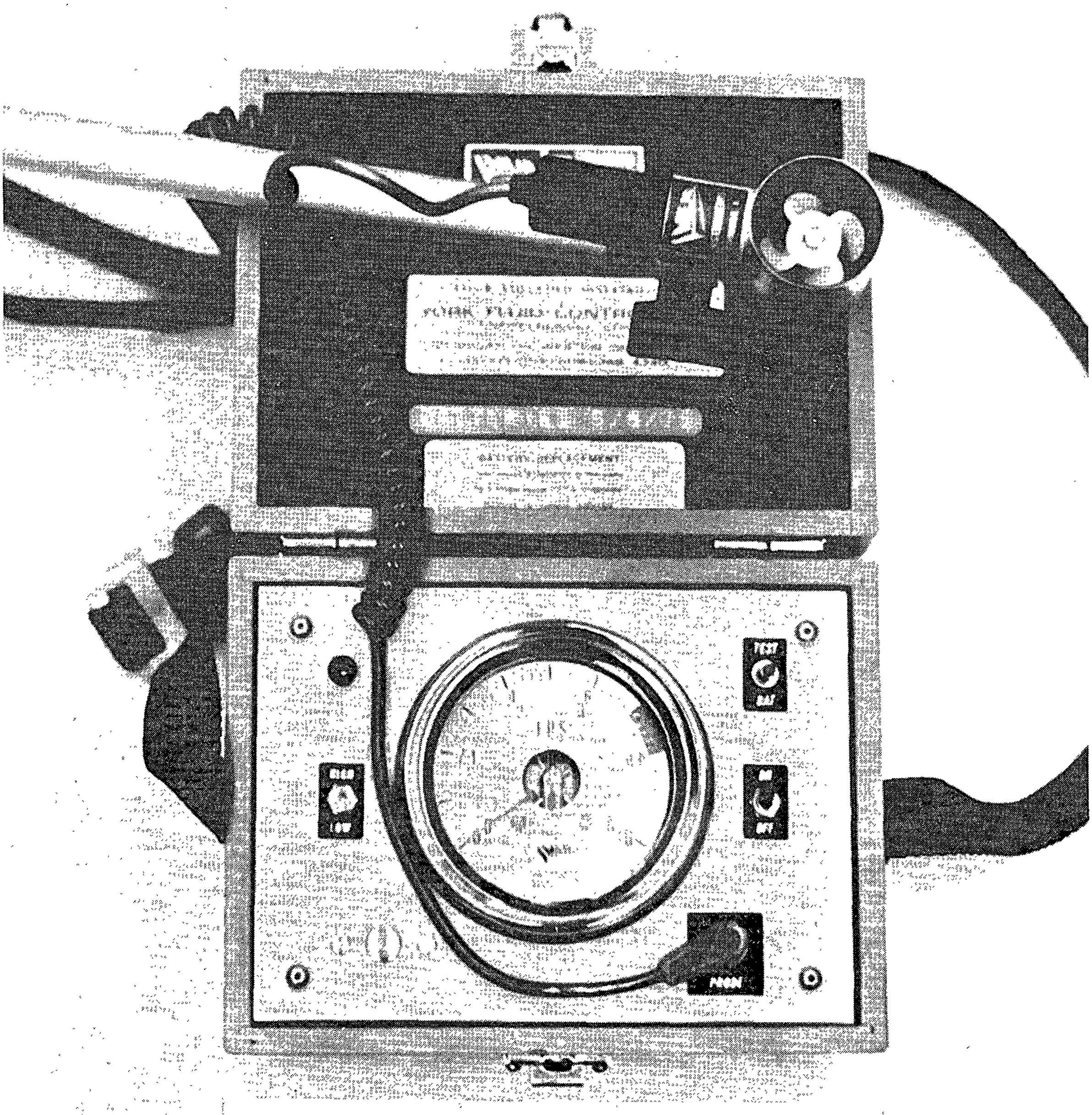


FIG. 7 MEAD HP-302 CURRENT METER

4.4.4 ***Deployment.*** Figure 8 is the schematic of a typical layout at a test site. From the experience gained during the 1974 program, it was determined that 200-foot (61 m.) lengths of barrier were ideal for the test purpose for the following reasons:

(1) ease of handling on shore,
(2) ease of towing and anchoring,
(3) obtained an optimum angle across the currents.

Paravanes, such as the one shown in figure 10, were used during the testing program to provide additional buoyancy at the upstream and downstream ends of the barrier.

Each day, the paravane and tension gauge were assembled and anchored approximately 150 feet (45.7 m.) offshore. A test barrier was then connected to the paravane and allowed to float free. A tension reading was taken and the barriers initial position was plotted by triangulation, using two Wilde T-1 theodolites. Sightings on the barrier were taken and angles recorded every 25 feet (7.6 m.) along the barrier. The configuration and position of the barrier was then plotted.

The downstream end of the barrier was connected to a cable and was pulled towards shore in increments of 20 to 30 feet (6.1 to 9.1 m.). An electric winch mounted on a truck was employed for this purpose. The barrier was allowed to stabilize for 10-15 minutes each time it was pulled in an increment. The position of the barrier was then again determined by triangulation. Tension readings were also noted during the time when the barrier was being pulled and after the barrier stabilized. Observations and measurements were made under current conditions on:

(1) the ability of the barrier to remain upright along its entire 200-ft (61 m.) test length (stability),
(2) the ability of a barrier to traverse the currents (deflection),
(3) the ability of the barrier to transfer oil across the currents (effective deflection).

4.4.5 ***Stability.*** The stability of a barrier for the purpose of this report can be defined as its ability to remain vertical when acted upon by external forces such as current and wind. During the test programme the downstream end of a barrier was pulled across the current towards shore in increments of 20 to 30 ft. (6.1 to 9.1 m.) and after each increment, observations were made on the stability of the barrier.

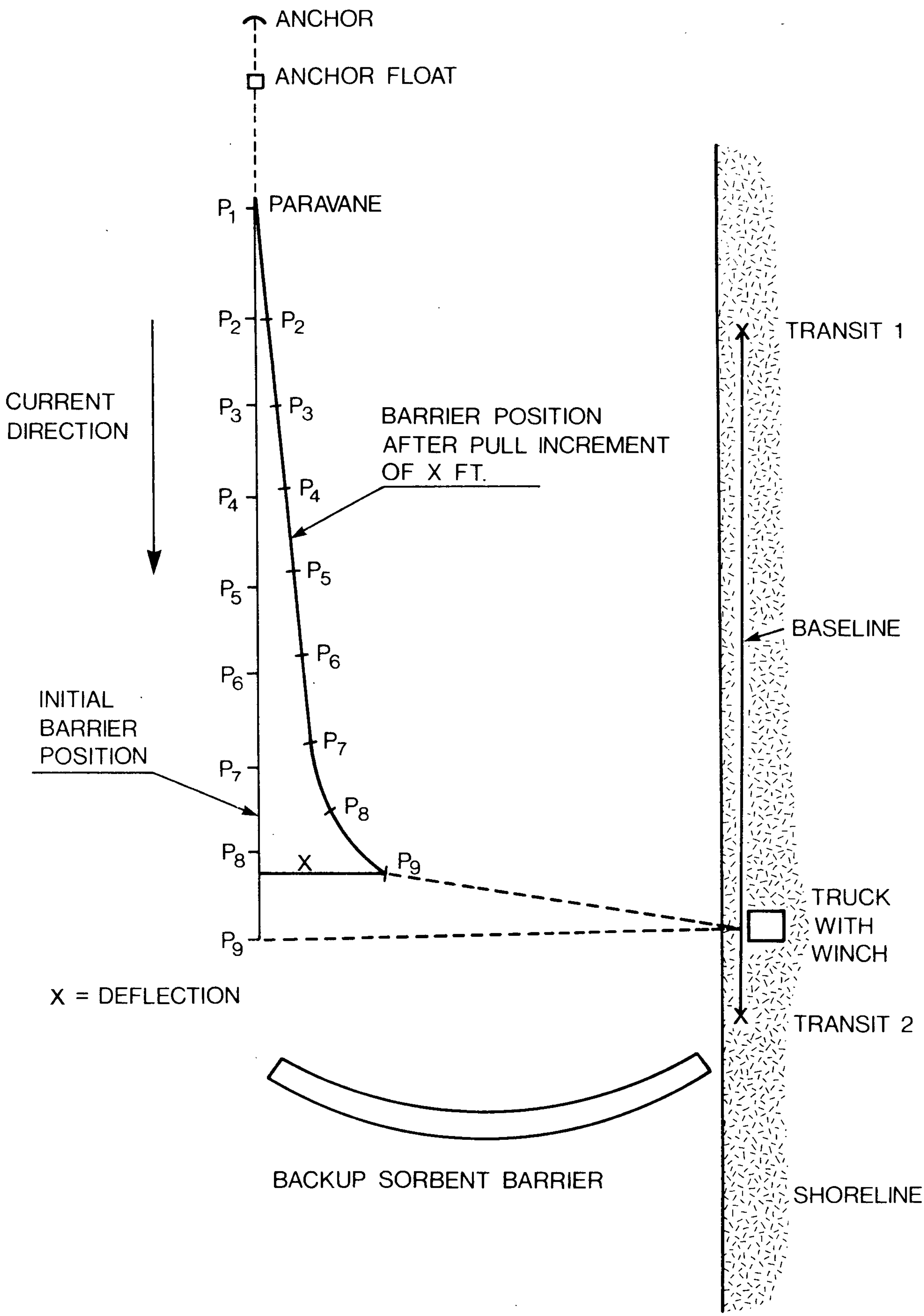


FIGURE 8. TYPICAL EQUIPMENT LAYOUT AT TEST SITE

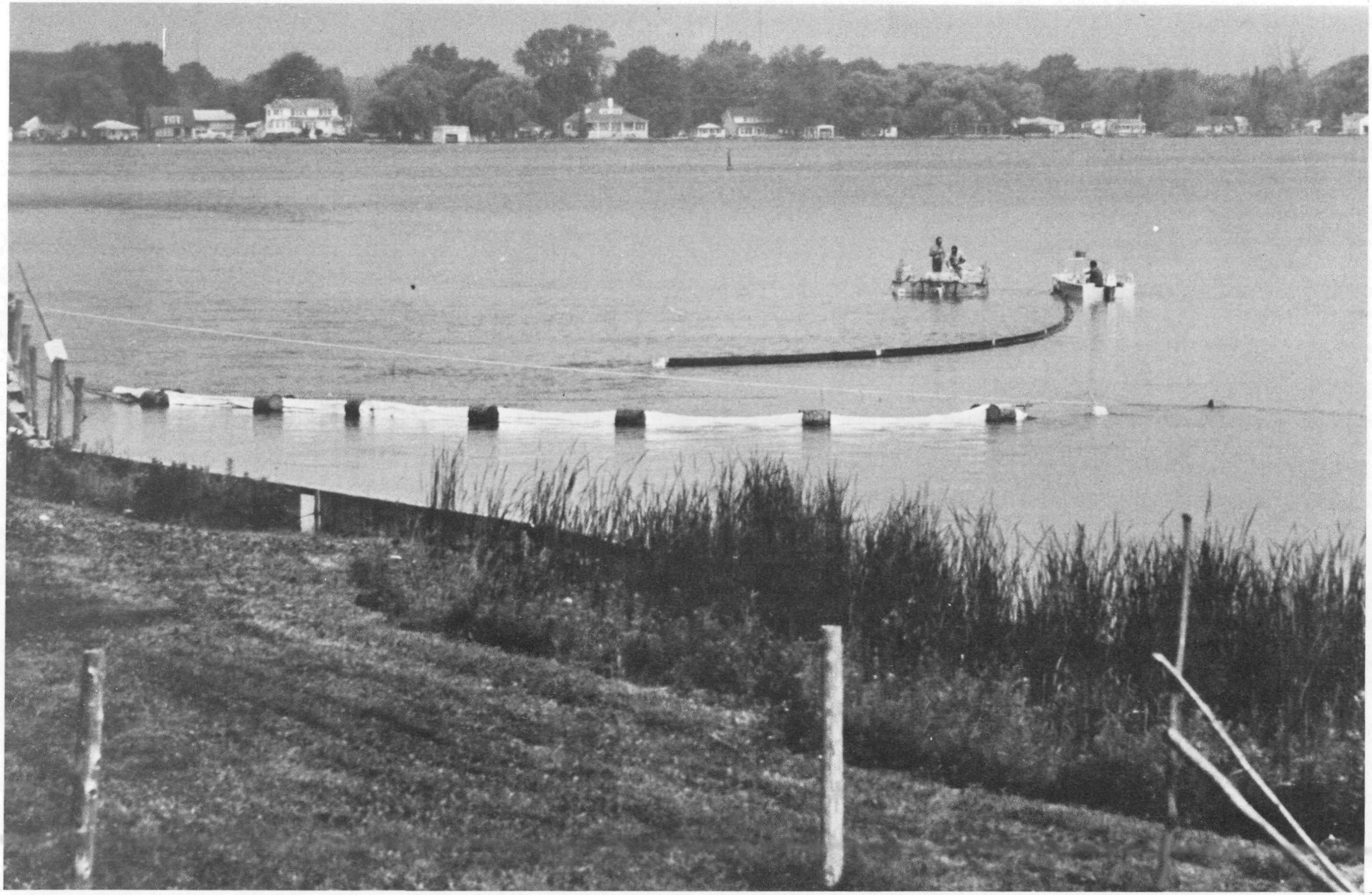


FIG. 9 TYPICAL EQUIPMENT LAYOUT

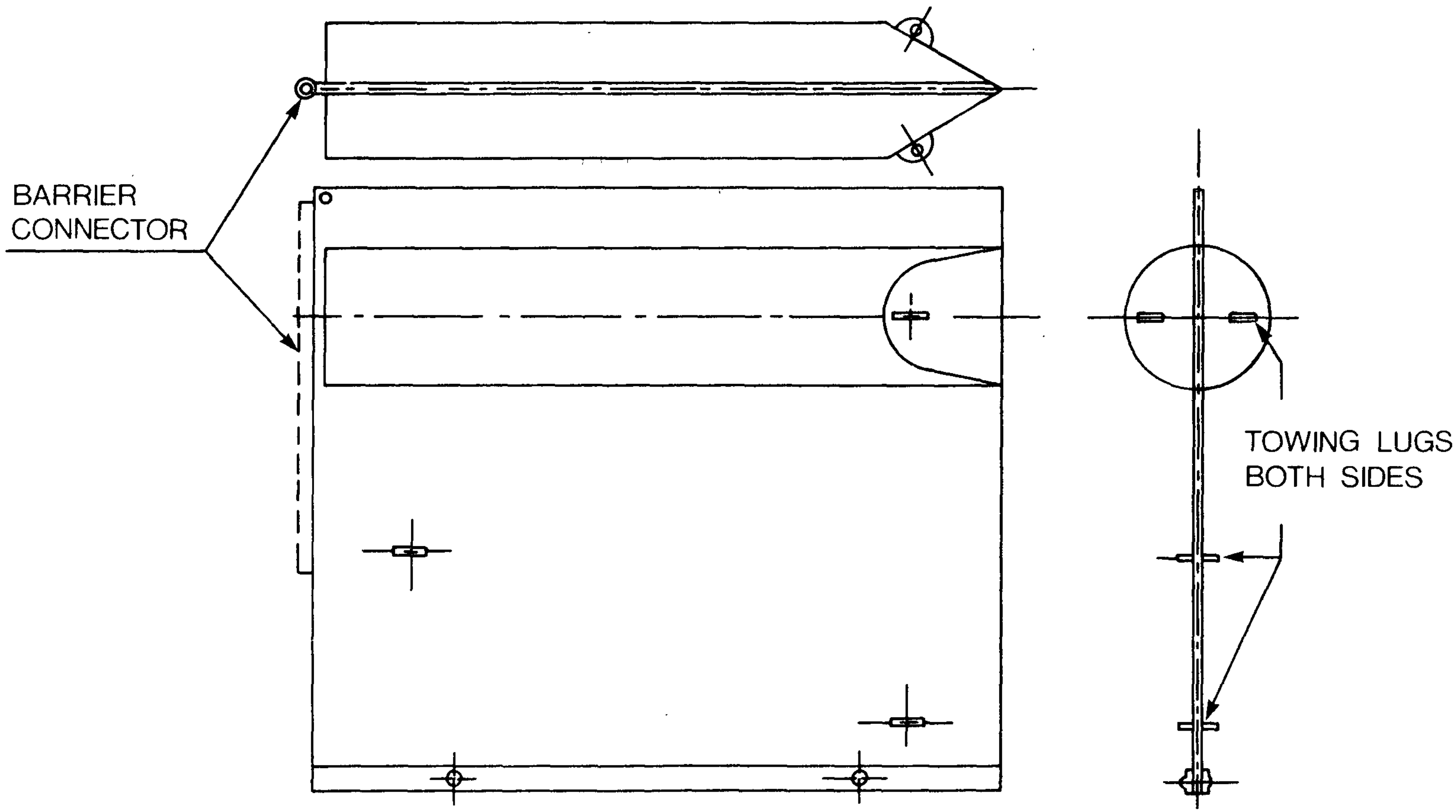


FIGURE 10. PARAVANE

_4.4.6_ **_Deflection._** Deflection (X) is the lateral displacement across a current between the upstream and downstream ends of a barrier (see figure 8). The maximum deflection is considered to be value X_m after which the barrier ceases to remain upright along its entire length. Deflection was measured and the effective deflection, which is the lateral displacement of oil by the barrier, was determined in the following manner:

When the barrier appeared to be stable and achieved a deflection of 40 feet (12.2 m.),(see figure 8 where x = 40 ft. (12.2 m.)), small applications of oil and/or corn cobs were used to determine the effectiveness of that barrier. The oil used during the testing programme was JETCO, which is a biodegradable synthetic oil with a specific gravity of 0.85 and viscosity of 9.6 centipoises at 21°C. Approximately 1-2 gallons (4.5-9.1 l.) of the oil was used for each application. A spill plate (figure 11) was used to minimize the formation of droplets during the application and produce an uniformly thick oil slick. Ground corn cobs were also employed as a preliminary indicator to determine whether the test barrier would potentially transfer the oil laterally across the current. If corn cobs (specific gravity of 0.2-0.3) are not deflected by the test barrier, oil, with a higher specific gravity, will not be deflected. (Lau and Tsang, 1976).

During each application of oil/corn cobs, the observations were made and photographs taken of the movement of oil/corn cobs: if, the oil/corn cobs were dispersed into the water column and if the oil/corn cobs passed underneath. Recovery of the oil was achieved with the use of sorbent material connected to the downstream end of the test barrier and with a back-up sorbent boom as shown in figures 8 and 9.

4.5 Operational Deployment Procedures

The second phase of Project 11 was designed to develop barrier deployment procedures at the pre-designated recovery sites. A series of three 200-foot (61 m.) lengths of barrier were deployed in an overlapping configuration of both Chenal Ecarte and Sombra. The deflection capability of this cascade was tested using ground corn cobs. The observations for this phase of testing appear in section 7.0.

FIG. 11 SPILL PLATE

5.0 OBSERVATIONS ON BARRIER PERFORMANCE

5.1 Stability

Visual observations were made on the test barriers with respect to their stability at the three test sites. The stability of each barrier was rated from excellent to poor, depending upon the angle of the barrier to the vertical, and the fraction of the total length that had angled from the vertical. Table II presents a summary of the observations on stability at different deflections and the rating scale used.

TABLE II STABILITY

BARRIER / DEFLECTION	0–25′ (0–8 m.)	26′–35′ (8 m. to 11 m.)	36′–45′ (11 m. to 14 m.)	46′–55′ (14 m. to 17 m.)	56′–65′ (17 m. to 20 m.)	66′–75′ (20 m. to 23 m.)	76–85′ (23 m. to 26 m.)	86′–95′ (26 m. to 29 m.)
AMHERSTBURG (0.7 – 1.5 Knots)								
OK Corral (Acme) 12″ ϕ float, 12″ skirt	F	F	F	F	F–P	P	P	
OK Corral (Acme) 6″ ϕ float, 18″ skirt	P	P						
River Boom (Bennett) 7″ ϕ float, 12″ skirt	G	G	G	G	F	P		
Inshore Boom (Bennett) 6″ freeboard, 12″ skirt	P							
Flexy #2 (Hurum) 6″ freeboard, 12″ skirt	E	E	E	E	E	E	E	E
Goodrich Boom 6″ freeboard, 12″ skirt	E	E	E	E	E	E	G	
Slickbar Mark VI, 4″ ϕ float, 8″ skirt	G	G	P					
Slickbar Mark VI, 6.5″ ϕ float, 8″ skirt	G	F	P					

CHENAL ECARTE (1 0 - 1 5 knots)

Inshore Boom (Bennett) 18'' (no btm tension)	G	F	F-P	P	P	P	
Inshore Boom (Bennett) 12'' freeboard, 24'' skirt	G	G	P	P			
Flexy #2 (Hurum) 4-3/4'' freeboard, 9-1/4'' skirt	E	E	E	G	F		
Flexy #2 (Hurum) 6'' freeboard, 12'' skirt	E	E	E	E	P		
Flexy #2 (Hurum) 8'' freeboard, 16'' skirt	E	E	E	E	E		
Goodrich Boom 6'' freeboard, 12'' skirt	E	E	E	E	G		
Optimax (American Marine) 7'' ϕ float, 18'' skirt	E	E	E				

SOMBRA (1.7 - 1 8 knots)

Flexy # 2 (Hurum) 6'' freeboard, 12'' skirt	G	F	P				
Goodrich Boom, 6'' freeboard, 12'' skirt	G	F	F-P				
Goodrich Boom, (3 anchor points)	E	E	E	E	E	E	E
Optimax (American Marine) 7 '' ϕ float, 18'' skirt	E	E	E				
Optimax (3 anchor points)	E	E	E	E	E	E	E

STABILITY RATING

- E (Excellent) - barrier upright over entire length
- G (Good) - barrier upright, slight turn to vertical for last 25 ft. (7.6 m.) of barrier
- F (Fair) - barrier upright, slight turn to vertical for last 50 ft. (15.2 m.) of barrier
- P (Poor) - barrier upright, slight turn to vertical for last 100 ft. (30.5 m.) of barrier, with sharp angle to vertical at lower end of barrier.

5.2 Deflection

The ability of a barrier to deflect a free-floating oil slick across the current provides an indication of the efficiency of that barrier. Each time oil was presented to a barrier, observations were made on where the oil escaped from the barrier, either by splash-over or entrainment into the water column. The results of these observations are summarized in Table III. A barrier was considered to be effective when all the oil presented was deflected along the entire test barrier. When any oil escaped anywhere along the downstream 50 feet (15.2 m.), the barrier was rated from good to excellent. Table IV presents the actual effective deflection values achieved by the respective barriers and this information is also graphically displayed in Appendix A.4.

TABLE III: EFFECTIVENESS

DEFLECTION BARRIER	0-25' (0-8 m. m.)	26'-35' (8 m. to 11 m.)	36'-45' (11 m. to 14 m.)	46'-55' (14 m. to 17 m.)	56'-65' (17 m. to 20 m.)	66'-75' (20 m. to 23 m.)	76-85' (23 m. to 26 m.)	86'-95' (26 m. to 29 m.)
AMHERSTBURG (0.7 Knots – 1.5 Knots)								
Flexy #2 (Hurum) 6" freeboard, 12" skirt	–	–	–	–	–	E	F	P
Goodrich Boom 6" freeboard 12" skirt	–	–	–	–	–	–	P	
CHENAL ECARTE (1.0-1.5 Knots)								
Flexy #2 (Hurum) 4-3/4" freeboard, 9-1/4" skirt	–	–	–	–	E			
Flexy #2 (Hurum) 8" freeboard, 16" skirt	–	–	–	E				
Goodrich Boom, 6" freeboard, 12" skirt	–	–	–	G	P			
Optimax (American Marine) 7" ϕ float, 18" skirt	–	–	F					

SOMBRA (1.7–1.8 Knots)

Goodrich Boom, 6" freeboard, 12" skirt	–	–	P				
Goodrich Boom, (3 anchor points)	–	–	–	–	–	–	P
Optimax (American Marine) 7" ϕ float, 18" skirt	–	P					
Optimax (3 anchor points)	–	–	–	–	–	–	P

EFFECTIVENESS RATING

- E (Excellent) – all oil completely deflected
- G (Good) – oil escapes within 5 feet (1.5 m.) of barrier
- F (Fair) – oil escapes within last 25 feet (7.6 m.) of barrier
- P (Poor) – oil escapes 50 (15.2 m.) or more feet from lower end of barrier

TABLE IV: EFFECTIVE DEFLECTION

AMHERSTBURG (0.7 – 1.5 Knots)

BARRIER	BARRIER LENGTH	EFFECTIVE DEFLECTION
OK Corral (Acme) 12" ϕ float, 12" skirt	200 ft. (61 m.)	12 ft. (3.7 m.)
OK Corral (Acme) 6" ϕ float, 18" skirt	200 ft. (61 m.)	2 ft. (0.6 m.)
Inshore Boom (Bennett) 6" freeboard, 12" skirt	200 ft. (61 m.)	25 ft. (7.6 m.)
River Boom (Bennett) 7" ϕ float, 12" skirt	200 ft. (61 m.)	32 ft. (9.75 m.)
Flexy #2 (Hurum) 6" freeboard, 12" skirt	200 ft. (61 m.)	66 ft. (20.1 m.)
Goodrich Boom, 6" freeboard, 12" skirt	188 ft. (57.3 m.)	44 ft. (13.4 m.)
Slickbar Boom 4" ϕ float, 8" skirt	200 ft. (61 m.)	24 ft. (7.3 m.)
Slickbar Boom 6.5" ϕ float, 8" skirt	200 ft. (61 m.)	26 ft. (7.9 m.)

CHENAL ECARTE (1.0–1.5 Knots)

Inshore Boom (Bennett) 18'' total (no lower tension)	200 ft. (61 m.)	20 ft. (6.1 m.)
Inshore Boom (Bennett) 36'' total	200 ft. (61 m.)	16 ft. (4.9 m.)
Flexy #2 (Hurum) 4-3/4'' freeboard, 9 1/4'' skirt	200 ft. (61 m.)	59 ft. (18 m.)
Flexy #2 (Hurum) 6'' freeboard, 12'' skirt	200 ft. (61 m.)	50 ft. (15.2 m.)
Flexy #2 (Hurum) 8'' freeboard 16'' skirt	200 ft. (61 m.)	48 ft. (14.6 m.)
Goodrich Boom, 6'' freeboard, 12'' skirt	188 ft. (57.3 m.)	45 ft. (13.7 m.)
Optimax (American Marine) 7'' ϕ float, 18'' skirt	200 ft. (61 m.)	24 ft. (7.3 m.)

SOMBRA (1.7–1.8 Knots)

Flexy #2 (Hurum) 6'' freeboard, 12'' skirt	200 ft. (61 m.)	5 ft. (1.5 m.)
Goodrich Boom, 6'' freeboard, 12'' skirt	211.5 ft. (64.5 m.)	17 ft. (5.2 m.)
Goodrich Boom, (3 anchor points)	211.5 ft. (64.5 m.)	10 ft. (3.0 m.)
Optimax (American Marine) 7'' freeboard, 18'' skirt	200 ft. (61 m.)	18 ft. (5.5 m.)
Optimax (American Marine) (3 anchors)	200 ft. (61 m.)	35 ft. (10.7 m.)

6.0 DISCUSSION OF RESULTS ON BARRIER PERFORMANCE

6.1 Stability

Visual observations on the test barriers were made, with respect to the stability of the barrier. Some barriers remained completely vertical at deflections of 80 to 90 feet (24.4 to 27.4 m.). Under identical conditions, the effects of the current caused the downstream 20 to 25 feet (6.1 to 7.6 m.) of other barriers to lie horizontally on the surface of the water, or in other instances, to submerge.

From the many observations made on the characteristic behaviour of the barriers, a number of deduction were made to explain the peculiarities of the current effects on the barriers tested. (Marks *et al,* 1971). These factors are the size and shape of flotation, the location and number of load-bearing cables or "tension members", and the rigidity of the fabric.

Each factor is discussed in more detail in subsequent sections.

6.1.1 Flotation. The size and shape of flotation collar on a barrier are important components which contribute to the stability of the barrier in a current situation. The flotation has to be sufficiently large (Widawsky, 1975) for a barrier to resist the downward pull caused by the currents when the barrier is anchored. The stronger the current, the more flotation is required. The use of paravanes, at the upstream and downstream end of the barrier provided additional buoyancy and assisted in the barrier stability. At several instances during the test program,the addition of such paravanes on a(seemingly) unstable barrier rendered the barrier stable and prevented its submergence.

The shape of the flotation also played a part in maintaining barrier stability. The cross-sections of the barriers that demonstrated the most stable position throughout the entire program are shown in figure 12, types A, B, C. All three types had sufficient area supported by the surface of the water to resist the downward pull. (NOTE: Types D and G were found to be unstable. Although their flotation shapes are similar to Type C, it is possible that the location of the tension members caused the barriers to be unstable.)

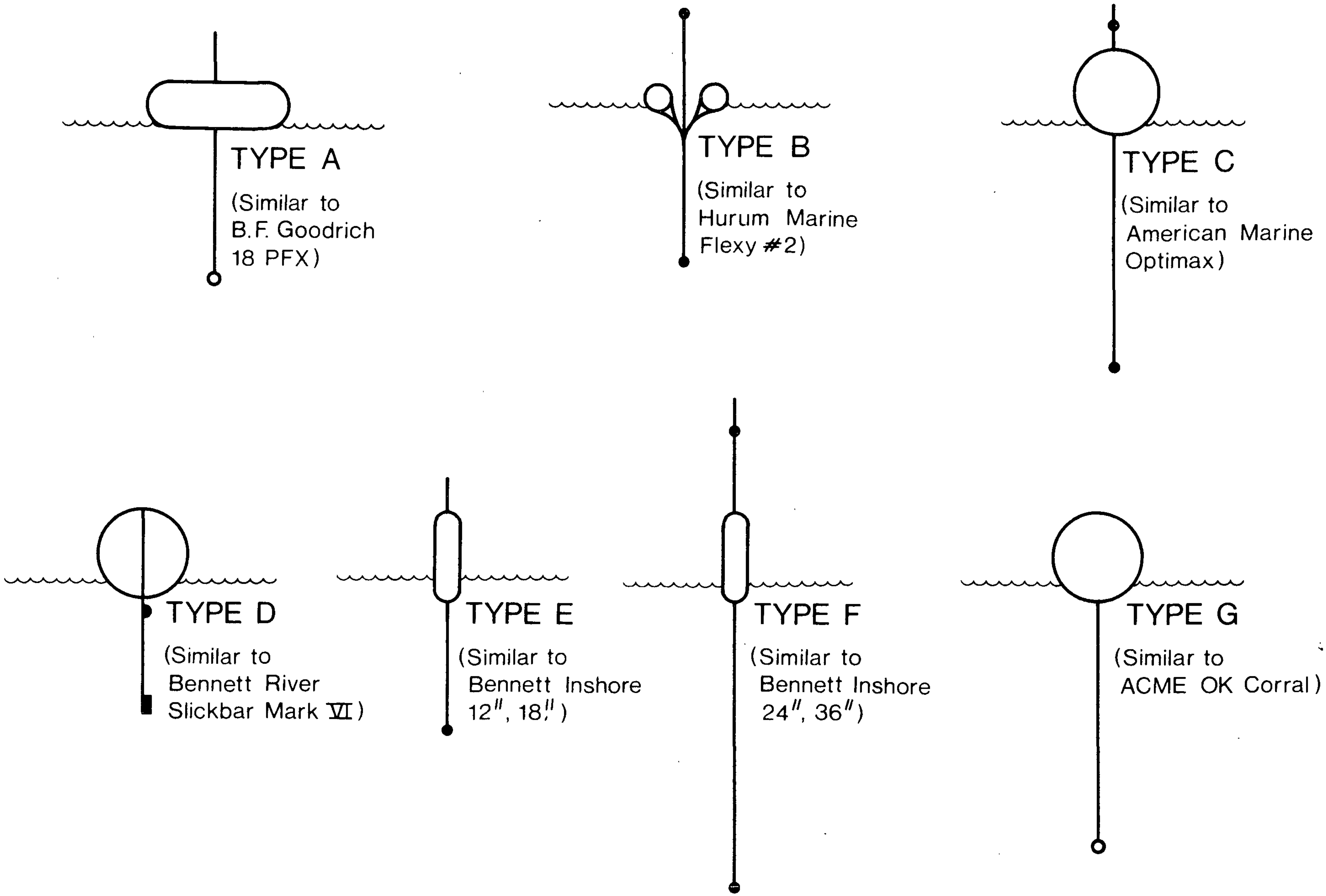


FIGURE 12. TEST BARRIER CROSS-SECTIONS

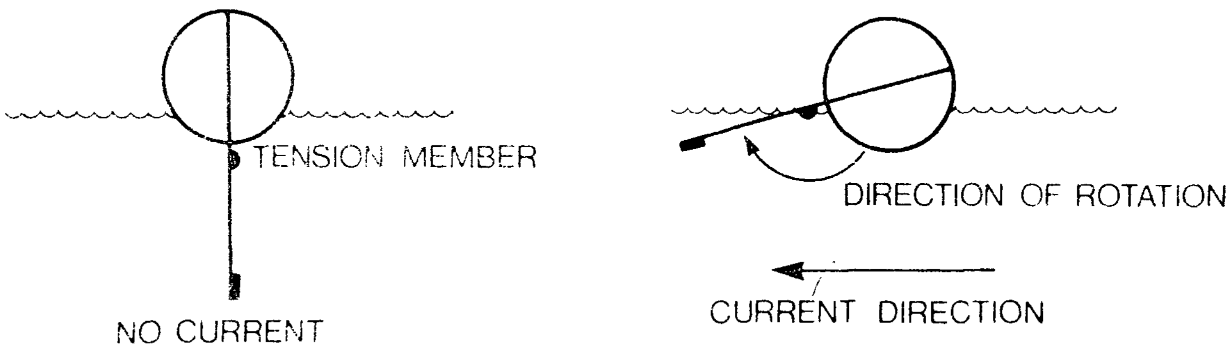
6.1.2 ***Tension Members.*** Tension members or load support cables are cables attached to a barrier or interwoven into a barrier which absorb the forces exerted on the barrier by currents, wind, waves, towing and handling. Three different methods of absorbing the tensile forces are employed. These are:

(1) use of barrier fabric strength alone;
(2) use of one tension member, located either at the lower edge of the barrier or directly beneath the flotation collar;
(3) use of two tension members, located at the top and bottom edges of the barrier.
(See typical barrier cross-sections, figure 12. The tension members are shown by the solid black circles.)

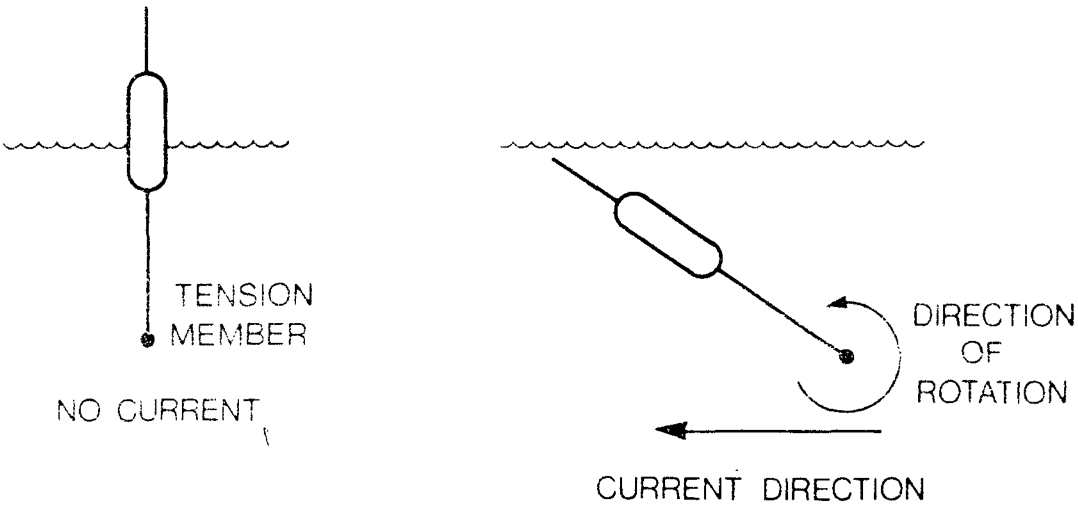
There were two types of barriers tested which did not have any tension members and relied totally on the fabric and the flotation collar to absorb the tensile forces acting on the barrier (figure 12, types G, A). The first type consisted of styrofoam float and a relatively elastic PVC cover material. It was noted that this type of barrier was not stable when placed at any angle across the current. The effects of the current caused the barrier to lie horizontally on the surface of the water thus rendering the barrier ineffective. The second type of barrier consisted of a very rigid non-elastic rubber with no resultant distortion of the barrier when exposed to the river current. It is theorized that because of the rigid fabric, the tensile forces were evenly distributed throughout the barrier and the flotation collar provided sufficient buoyancy to render the barrier stable in all conditions encountered.

The remaining barriers used during the testing program either contained one or two load-carrying or tension members as shown in figure 12. It became quite apparent from the field observation that the currents caused the barrier with only one tension member to rotate about that member. For example, when the tension member was located beneath the flotation collar, the effect of the currents caused the skirt to lie horizontally on the surface of the water. Conversely, when the tension member was located near the bottom of the barrier the effect of the currents caused the barrier to submerge (figure 13).

Considerable improvement in the stability was noted with the barriers containing two tension members as an integral part of their construction as shown in figure 12, types B, C, F. It is theorized that the tensile forces exerted by the currents on the barrier are evenly distributed between the two tension members along the top and bottom edge of the barrier, thus resisting pivoting.



TYPE A



TYPE B

FIGURE 13. BARRIER ROTATION ABOUT TENSION MEMBER

6.2 Deflection

It was observed during the testing program that the barriers which contained two tension members or were constructed of rigid fabric with sufficient flotation (100% reserve buoyancy, M.O.P.S., 1975) were successful at all three test sites. Sample cross-sections of the successful barriers are shown in figure 12, types A, B, C. The amount of maximum deflection decreased somewhat with the increase in current, as shown in Table V.

With higher current conditions present at the Sombra test site a reduction in maximum deflection was obtained. An additional anchor was attached to the mid-point of the barriers in an attempt to improve the deflection of barrier type A, B, C (figure 12). For type A the deflection was increased from 44 to 78 feet (13.4 to 23.8 m.) with an additional anchor and the deflection for type C increased from 35 to 85 feet (10.7 to 25.9 m.). Difficulties were encountered with type B barrier. When an additional anchor was attached there was a tendency for the barrier to submerge thus rendering the barrier unstable.

TABLE V MAXIMUM DEFLECTION ACHIEVED–AMHERSTBURG, CHENAL ECARTE AND SOMBRA

	AMHERSTBURG (0.7 to 1.5 knots)	CHENAL ECARTE (1.0 to 1.5 knots)	SOMBRA (1.7 to 1.8 knots)
Type A	72 ft. (21.9 m.)	49 ft. (14.9 m.)	17 ft. (5.2 m.)
Type B	66 ft. (20.1 m.)	50 ft. (15.2 m.)	6 ft. (1.8 m.)
Type C	N/A	40 ft. (12.2 m.)	35 ft. (10.7 m.)

The deflection values referred to in this report are valid only for a 200-foot (61 m.) test length of barrier, and the reader is cautioned not to linearly interpolate or extrapolate deflection values to other barrier lengths. From earlier field trials it was noted that for some barriers using 100-foot (30.5 m.), 200-foot (61 m.) and 500-foot (152 m.) lengths, the approximate respective deflections were 45 feet (13.7 m.), 70 feet (21.3 m.) and 100 feet (30.5 m.) in currents of the same order of magnitude as encountered during these field trials.

7.0 OPERATIONAL DEPLOYMENT TECHNIQUES

The second phase of the field testing program was to develop operational procedures at the pre-designated recovery sites at Chenal Ecarte and Sombra. Three 200-foot (61 m.) lengths of barrier were deployed at an angle to the current in a cascading formation as shown in figure 14. It is important to note that in the event of a spill the lead barrier should be placed in the river so it will intercept the free-floating slick and deflect it towards shore. The remaining lengths of barrier should be placed below the lead barrier to continue the process until the free-floating slick is directed to the recovery site. The following list summarizes the deployment procedure employed for this purpose:

(1) A two-man crew prepared each 200-foot (61 m.) length of barrier on shore by ensuring the paravanes were connected to the upstream and downstream ends and the sections of barrier were properly connected. The barrier was then placed in the water.

(2) A second crew consisting of a boat operator, an anchorman, and a crew chief placed the barrier in a strategic position.This was accomplished by attaching a 75 lb.(34 Kg.). Admiralty Stock anchor to the upstream paravane and setting it at the pre-designated location. The deployment vessel manoeuvered towards the downstream paravane where the second anchor was attached and placed overboard. A buoy float with a line connected to the anchor acted as a tripping line for removal purposes and as a tow line for placing the anchor.

(3) The float line from the downstream anchor was attached to the deployment vessel and pulled across the currents towards the shoreline until the optimum angle was achieved at which point the anchor was set.

(4) Step 1, 2 and 3 were repeated with each successive barrier until the last barrier reached the recovery site. To place the upstream anchor of the second and third barrier more accurately a modification to step one was made. First, the anchor line was attached to the upstream paravane and then the tripping line was attached to the anchor. The anchor was placed overboard and the tripping line (length equal to depth of water plus 5 feet (1.5 m.)) was attached to the deployment vessel. The vessel then proceeded towards the downstream end of the lead barrier and placed the anchor 25 feet (7.6 m.) from the paravane in an overlapping configuration.

At both the Chenal Ecarte and Sombra test sites, three lengths of barrier were successully deployed in this manner. Corn cobs were presented to the barriers at both test sites, and were successfully deflected by all three lengths of barrier. The maximum deflections achieved were 216 feet (65.8 m.) at Chenal Ecarte and 184 feet (56.1 m.) at Sombra (see figure 14 and 15).

At the Chenal Ecarte test site, a type F barrier (figure 12) was deployed in the river during the testing programme and the downstream end was pulled towards the shore 50 feet (15.2 m.). It was noted that approximately 50 feet (15.2 m.) of the downstream end was lying horizontally on the surface of the water, thus rendering the barrier totally ineffective (see figure 16, barrier B-B). A second barrier (type B, figure 12) was placed immediately upstream of the type F barrier and was pulled towards the shore 52 feet (15.8 m.), see figure 16, A-A. The type B barrier was stable.

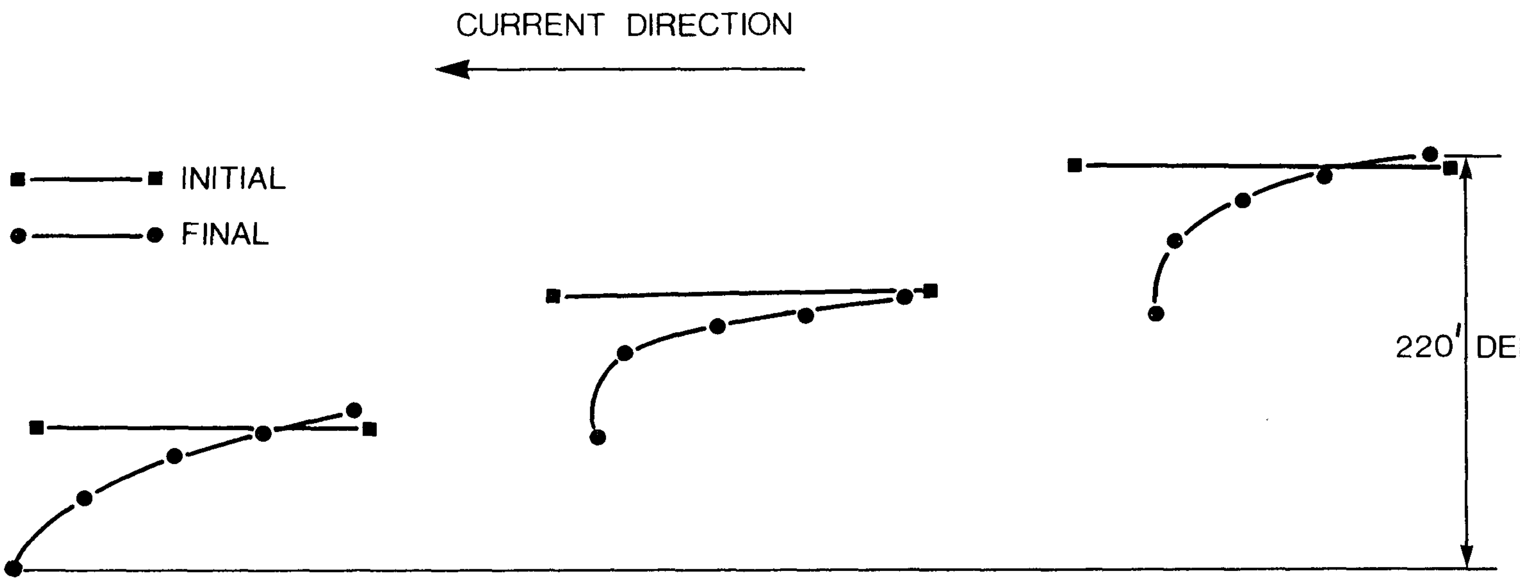


FIG 14a. CONFIGURATION OF 3 LENGTHS OF BARRIER AT CHENAL ECARTE, JUL 24, 1975

FIG.14b

CASCADE OF BARRIERS AT CHENAL ECARTÉ

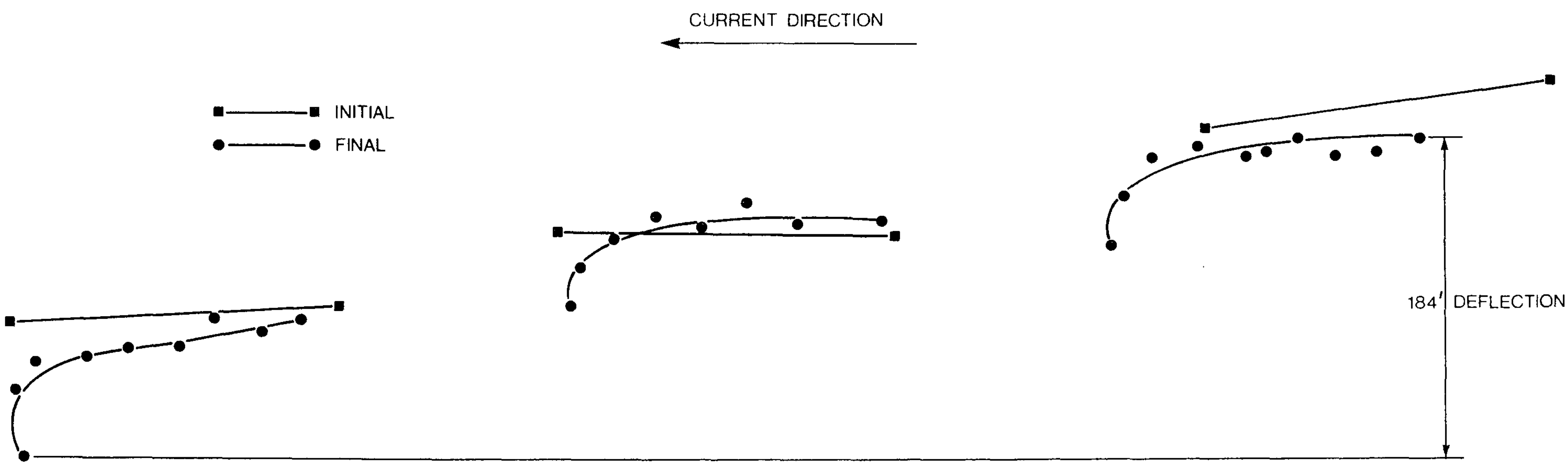


FIGURE 15. CONFIGURATION OF 3 LENGTHS OF BARRIER AT SOMBRA TEST SITE, AUG 21, 1975

Within 5 minutes of deployment, the lower barrier assumed the configuration shown in figure 16 B'-B' and remained upright along its entire 200-foot (61 m.) length. The downstream end of the barrier was then pulled closer to shore (55 feet [16.8 m.]) and remained stable. A subsequent application of corn cobs was effectively deflected by both barriers.

It was noticed that the lead barrier had a definite effect on the surface currents. At the Chenal Ecarte site, the surface currents were reduced from 1.3 knots to 0.9 knots after the lead barrier was deployed at which time the type F (figure 12) barrier became effective. From the observations made it may be concluded that when an effective lead barrier is placed in the river the resultant change in surface current velocities will increase the deflection for successive 200-foot (61 m.) lengths of the same barrier, or allow the successful use of marginally effective barriers downstream.

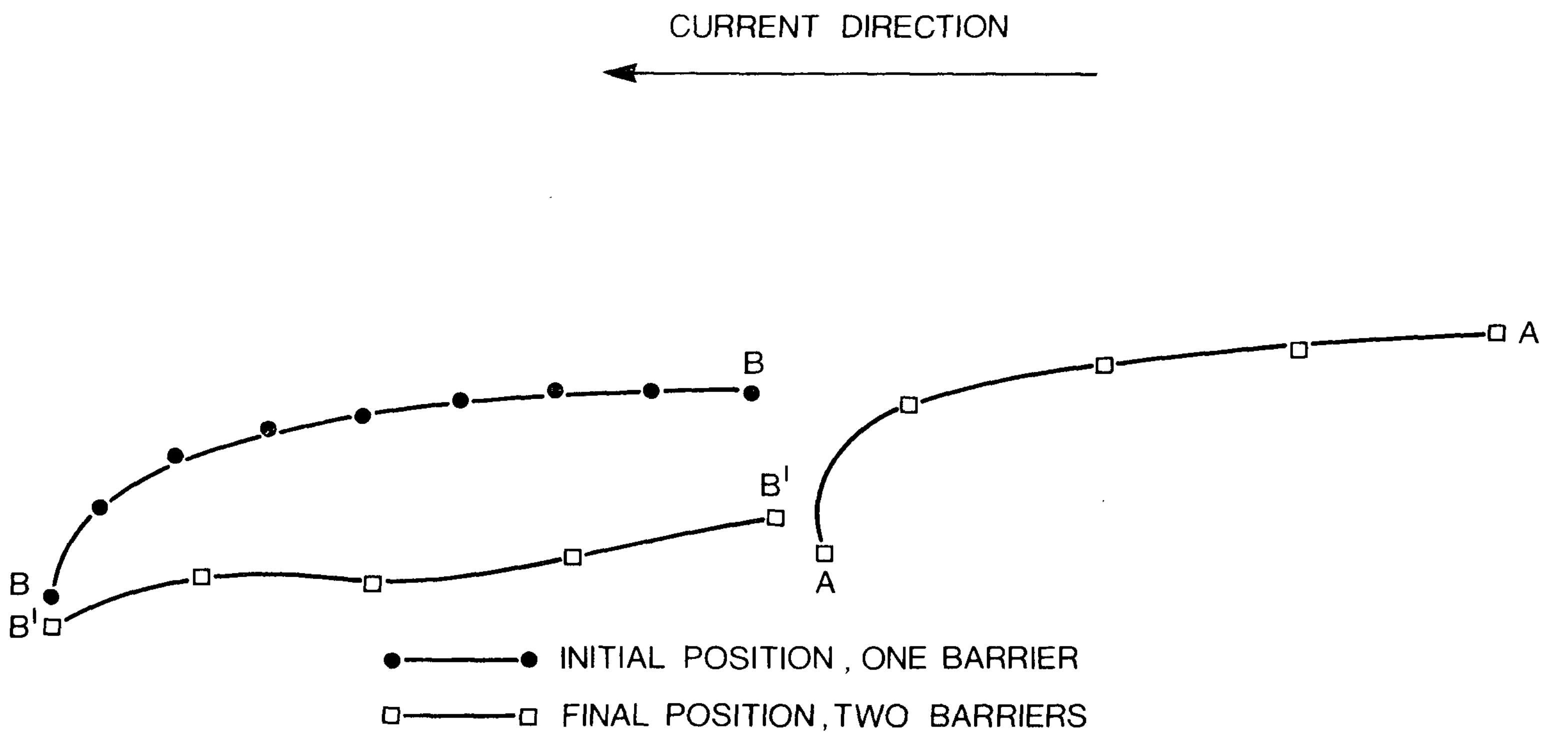


FIGURE 16. CONFIGURATION OF CASCADE WITH TYPE B BARRIER UPSTREAM AND TYPE F DOWNSTREAM, SHOWING CHANGE IN CONFIGURATION OF TYPE F AFTER TYPE B DEPLOYED

8.0 BIBLIOGRAPHY

Marks, W., G.R. Geiss and J. Hirshman, ''Theoretical and Experimental Evaluation of Oil Spill Control Devices''. Conference on Prevention and Control of Oil Spills, 1971.

Milgram, J.H., ''Physical Requirements for Oil Pollution Control Barriers''. Conference on Prevention and Control of Oil Spills, 1973.

Wicks, M., ''Fluid Dynamics of Floating Oil Containment by Mechanical Barriers in the Presence of Water Currents''. Conference on the Prevention and Control of Oil Spills, 1969.

Widawsky, A., ''Development of Harbour Oil Spill Removal Recovery Systems, Phase I''. Conference on Prevention and Control of Oil Spills, 1975.

Wilson, J.E., P.F. Nadeau, and J.S. Premack, ''Navy Harbour Oil Spill Clean-up: A Progress Report''. Conference on Prevention and Control of Oil Spills, 1975.

Maine Port Authority, ''Testing and Evaluation of Oil Spill Recovery Equipment'', EPA #15080, DOZ 12/70.

Moir, J. Personal Communication, August 1975.

Marine Oil Pick-up Service Training Course, Seattle, Washington, July 1975.

Crookshank, N.L., ''Containment of Oil Slicks on the St. Clair and Detroit Rivers''. National Research Council Report No. LTR-HY-34, March 1973.

Kirchhefer, S.A., ''Discussion Report for Hydrographic and Current Survey''. Unpublished Manuscript, 1974.

Lau, Y.L. and G. Tsang. Personal Communications, January, 1976.

Lau, Y.L. and S.A. Kirchhefer, ''A Review of the Dynamics of Contained Oil Slicks In Flowing Water''. EPS-3-EE-74-3, December 1974.

Wilcox, J.D., ''A Hydrodynamically Effective Horizontal Oil Boom''. Conference on Prevention and Control of Oil Pollution, 1975.

APPENDICES

A.0 APPENDICES

A.1 Other Equipment

The following equipment was incorporated into the overall Project 11 programme:

(1) University of Toronto, Department of Chemical Engineering, boom deflectors
(2) Oil Mop, Incorporated, "Oil Mop"
(3) Petroleum Association for the Conservation of the Canadian Environment, (PACE) Boom.

The findings and conclusions are summarized in the following sections.

A.1.1 ***Boom Deflectors.*** The Department of Chemical Engineering, University of Toronto was responsible under the contract for the design and construction of "boom deflectors". The boom deflectors were designed to achieve optimum deflection angles for commercially available barriers utilizing a single anchoring point. The advantages of boom deflectors are: ease of deployment when only one anchoring point is required, and the flexibility in obtaining the angle of deflection by adjusting the deflector arm.

Figure A.1.a illustrates the design of the boom deflectors used at Amherstburg and Chenal Ecarte. The deflector is attached to a barrier by the three hooks. The effect of the current on the deflector arm induces a rotation about the hinge with the resultant effect that the barrier is angled across the current. At Amherstburg and Chenal Ecarte, the boom deflectors were attached to type C and D barriers (figure 12) and the barriers achieved overall deflections ranging from 50 feet (15.2 m.) to 59 feet (18 m.) for 200-foot (61 m.) lengths. Jetco oil was presented to the barriers at Chenal Ecarte and the effective deflection achieved by type C and D barriers was 8 and 15 feet (2.4 and 4.6 m.) respectively. (fig. A2, A3)

The deflectors used during the field trials generated considerable turbulence at the barrier and it is theorized that this turbulence caused the oil to escape. Moir (1975) noted that any object placed in front of or behind a barrier in a current situation caused the oil to escape under the barrier at that point.

Further consideration should be given to the optimum angle of the deflector arm for a given current and barrier size, and to the general design of the deflectors in order to improve the deflector performance and minimize oil loss.

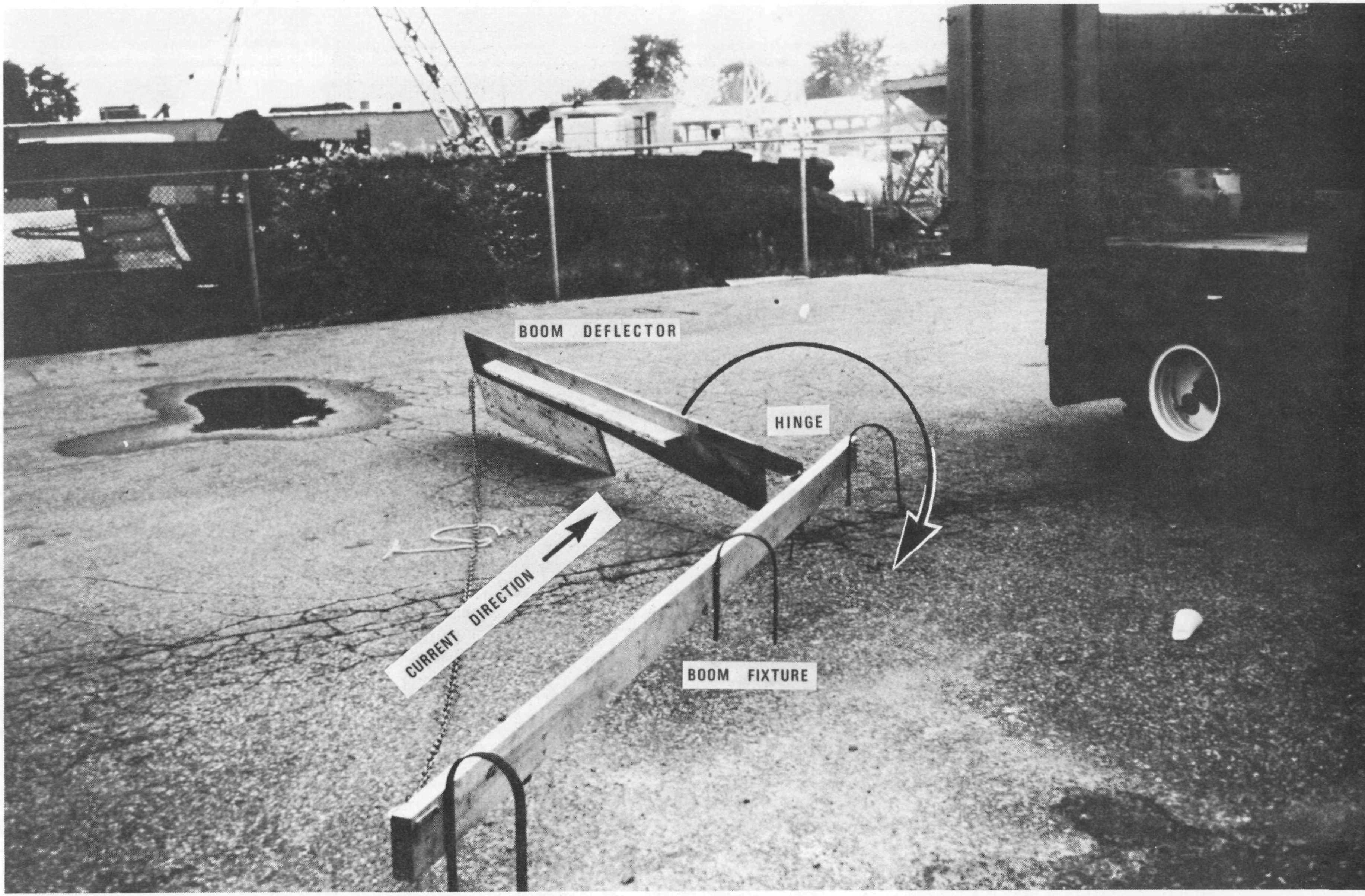


FIG.A.1.a

BOOM DEFLECTOR SHOWING DIRECTION OF ROTATION ABOUT HINGE AND CURRENT DIRECTION

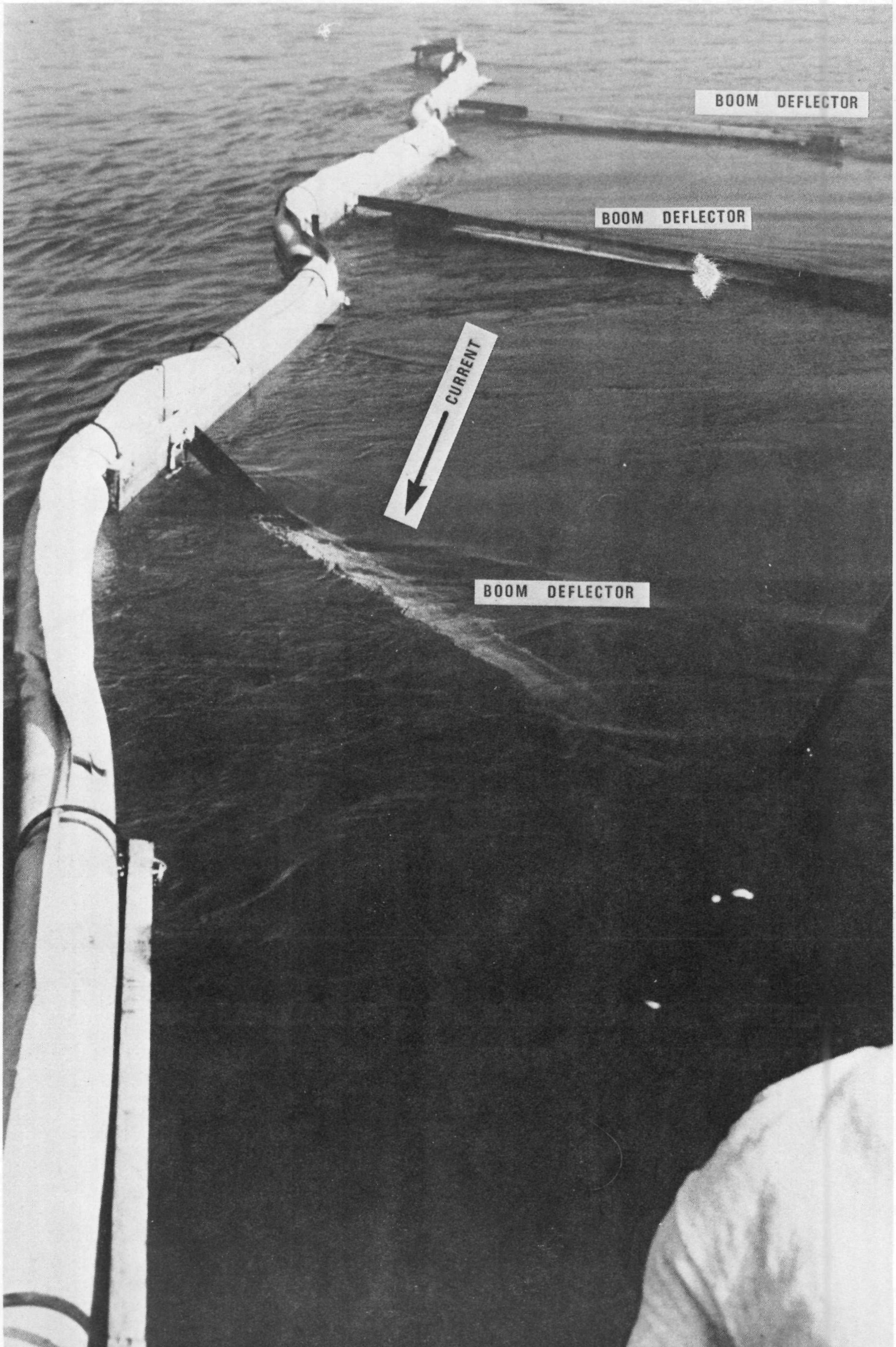


FIG.A.1b

BOOM DEFLECTORS IN PLACE ON TEST BARRIERS

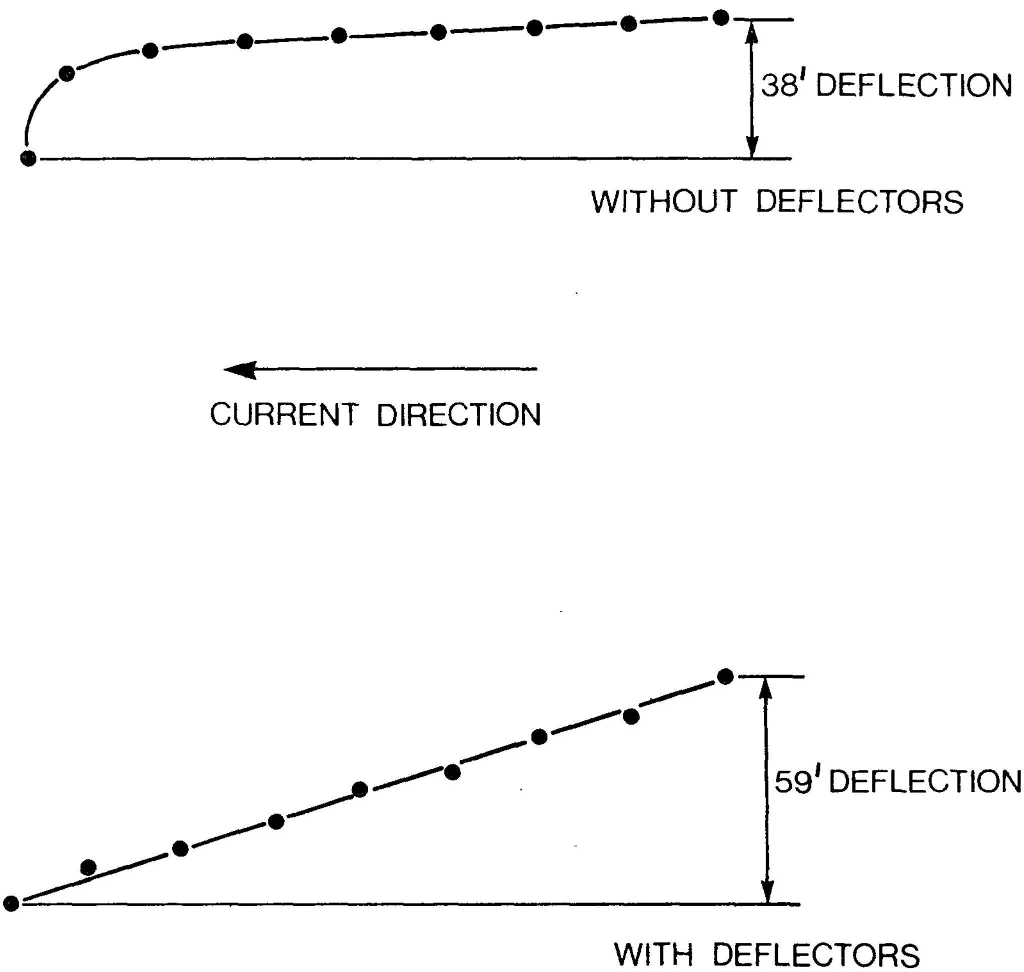


FIGURE A2. CONFIGURATION OF A BARRIER WITH AND WITHOUT BOOM DEFLECTORS AT AMHERSTBURG

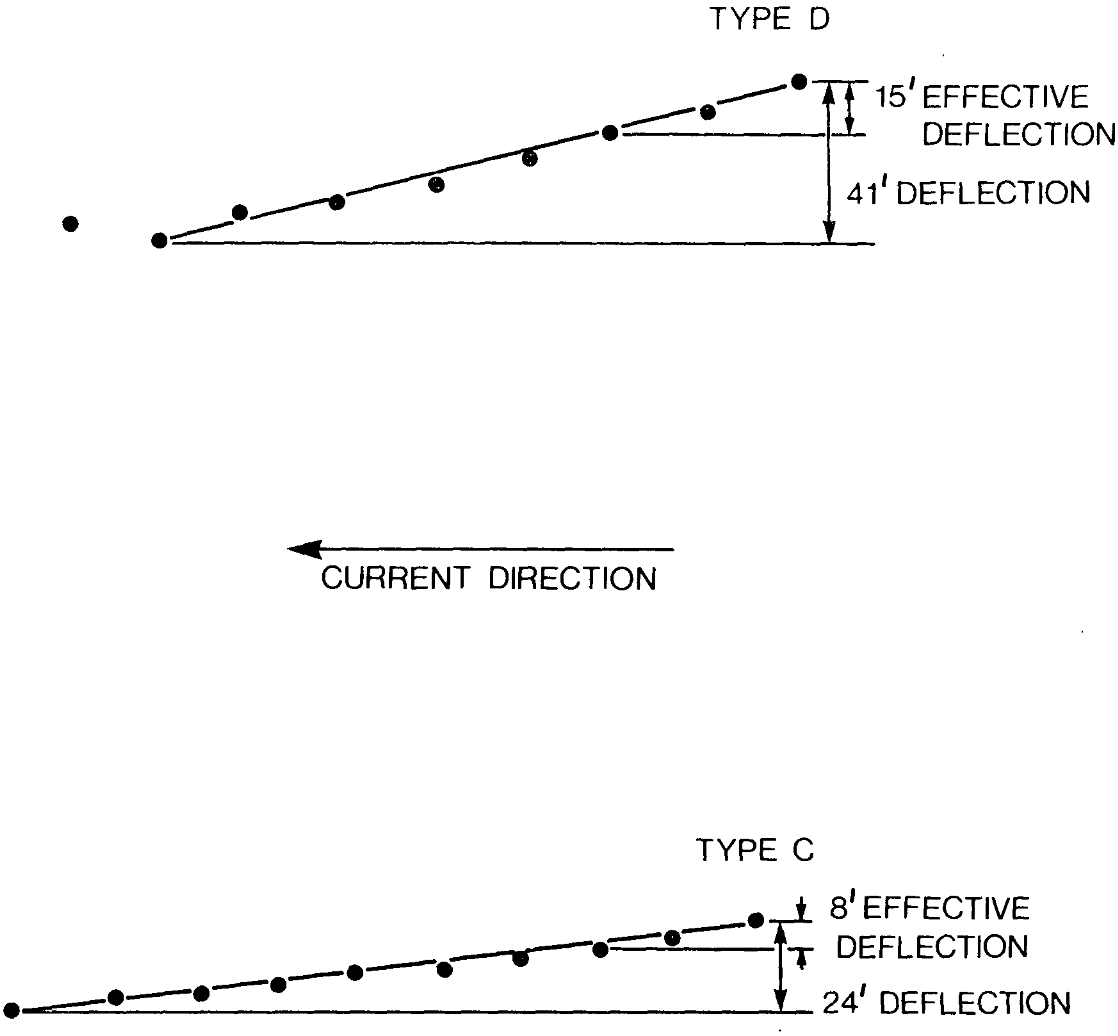


FIGURE A3. CONFIGURATION OF BARRIERS WITH DEFLECTORS AT CHENAL ECARTE

A.1.2 ***Oil Mop.*** The Oil Mop is a floating, endless sorbent belt recovery device. The belt or rope is made of polypropylene yarn entwined in a polypropylene rope. The belt is oleophilic and hydrophobic. Figure A.4 illustrates the principle of operation for the Oil Mop. As shown in the diagram, the rope travels around a pulley and is drawn into wringers in the mop engine. The belt absorbs any oil it contacts. The unit has been evaluated by the Centre of Spill Technology and has been proven effective as a recovery device (FIELD EVALUATION OF SEVEN OIL SPILL RECOVERY DEVICES, EPS 4-EC-76-3).

It was anticipated that with the rotating action of the rope, a surface current towards the shore would be induced, thus reducing the direct impact of the current on the rope. This phenomenon, combined with the buoyancy characteristics of the rope prompted the evaluation of the Oil Mop as a deflection and recovery device.

A Mark IV Oil Mop with 500 feet (152.4 m.) of nine-inch (22.9 cm.) rope was obtained for testing at Chenal Ecarte. Attempts were made using the Sea Truck to tow the rope and tail pulley into the channel and anchor it. This manoeuvre could not be accomplished because the force of the current on the rope was too great for the crew to place the pulley at the pre-designated position. The rope was then shortened to 200 feet (61 m.). Instead of using the Sea Truck to pull the unit into the current, a buoy float was anchored in the channel. A rope was tied to the tail pulley, threaded through an eye on the buoy and the pull was applied from shore. This method of deployment proved very effective. The configuration achieved is shown in figure A.5. The rope was submerged by the force of the current and proved ineffective as a deflector and failed to contain the corn cobs placed in front of it. A second tail pulley was added to the upstream side of the rope. The section of rope from this second pulley to the engine was at a sharper angle to the current (dotted lines on figure A.5). The rope remained afloat and appeared to be an effective deflector. From these observations, as well as the results obtained by the Centre of Spill Technology, it can be concluded that the unit can be used to a limited extent as a deflection unit, but was best suited as a recovery device.

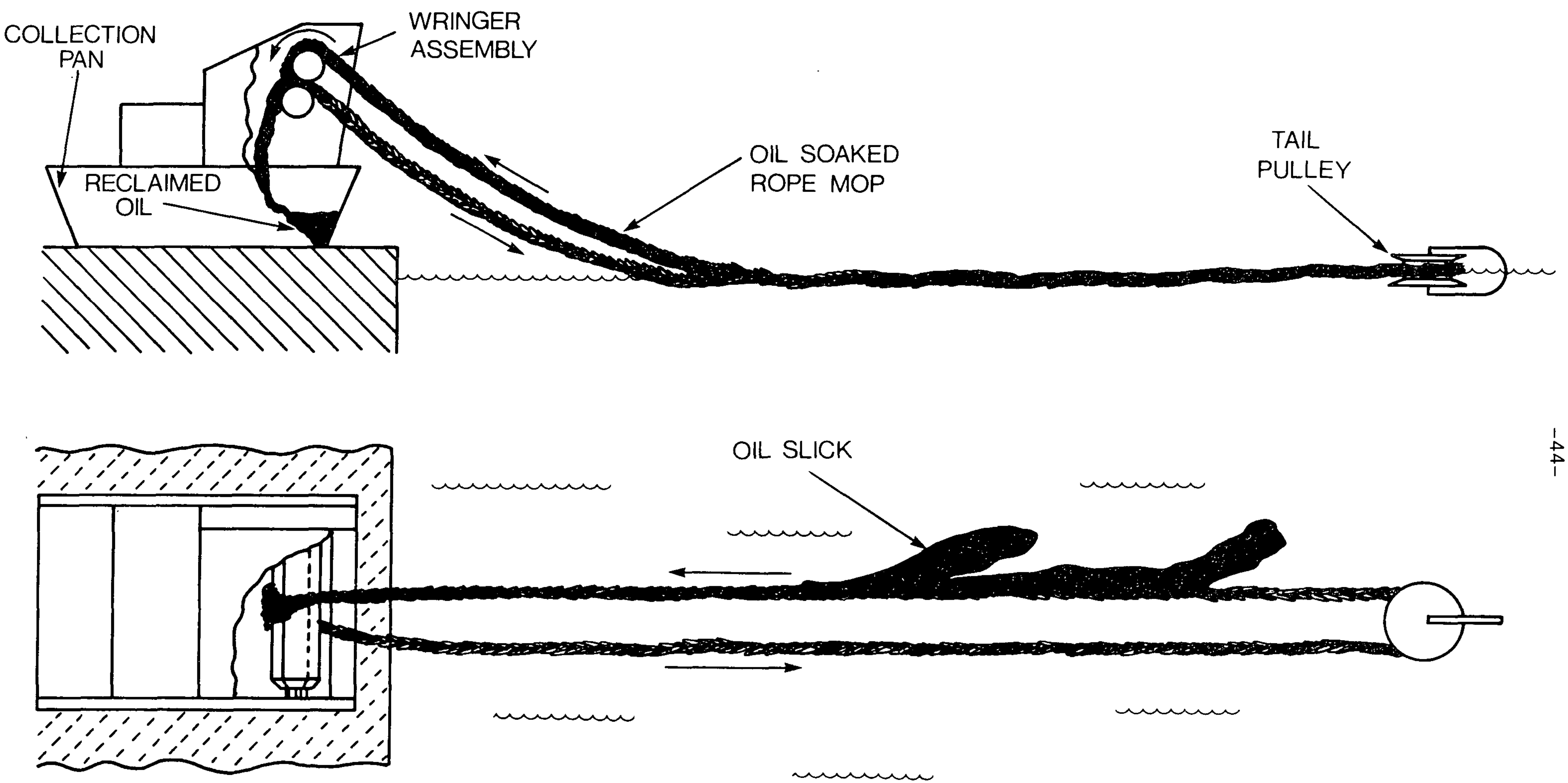


FIGURE A4. PRINCIPLE OF "OIL MOP" OPERATION

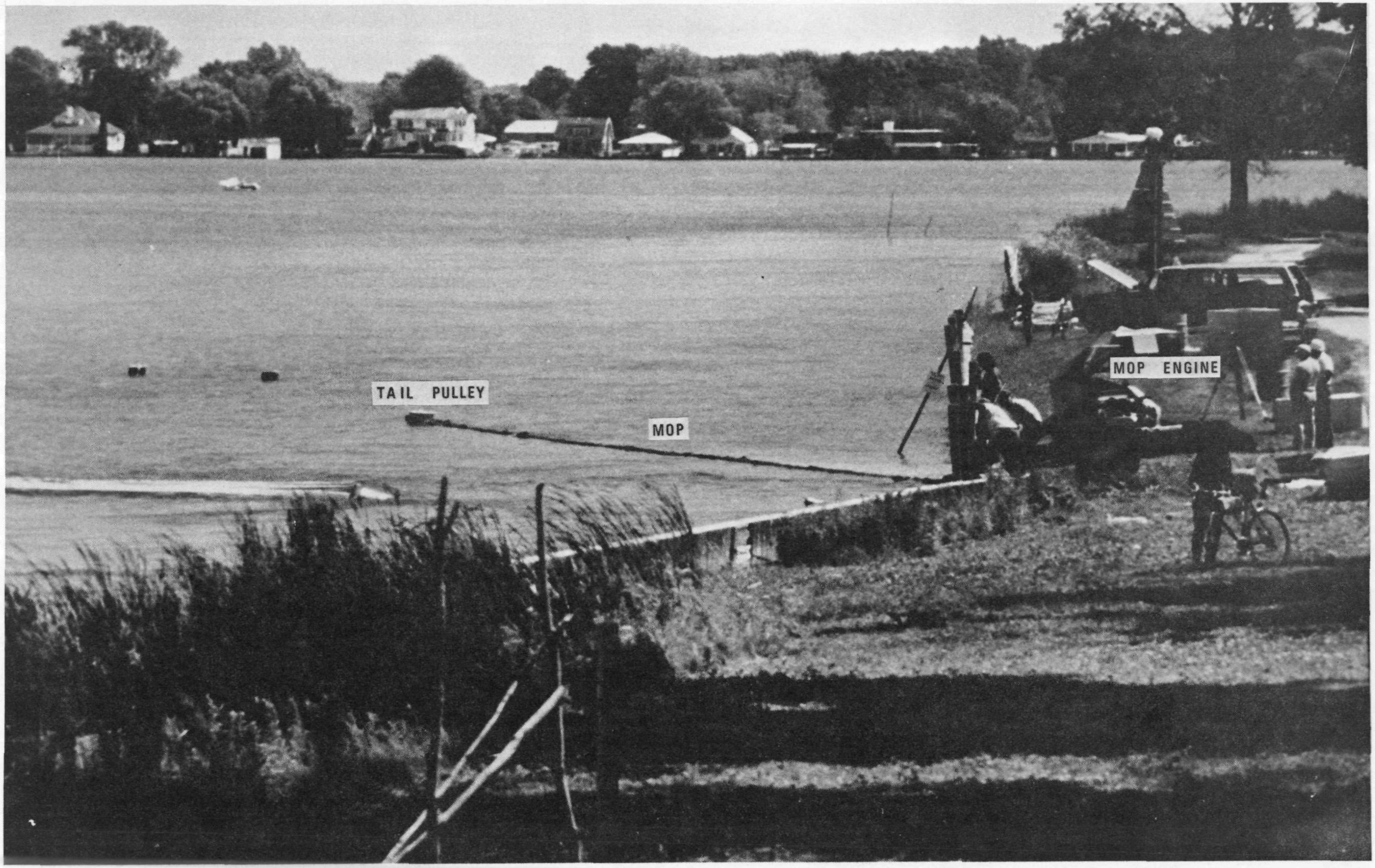


FIG. A4b OIL MOP IN OPERATION

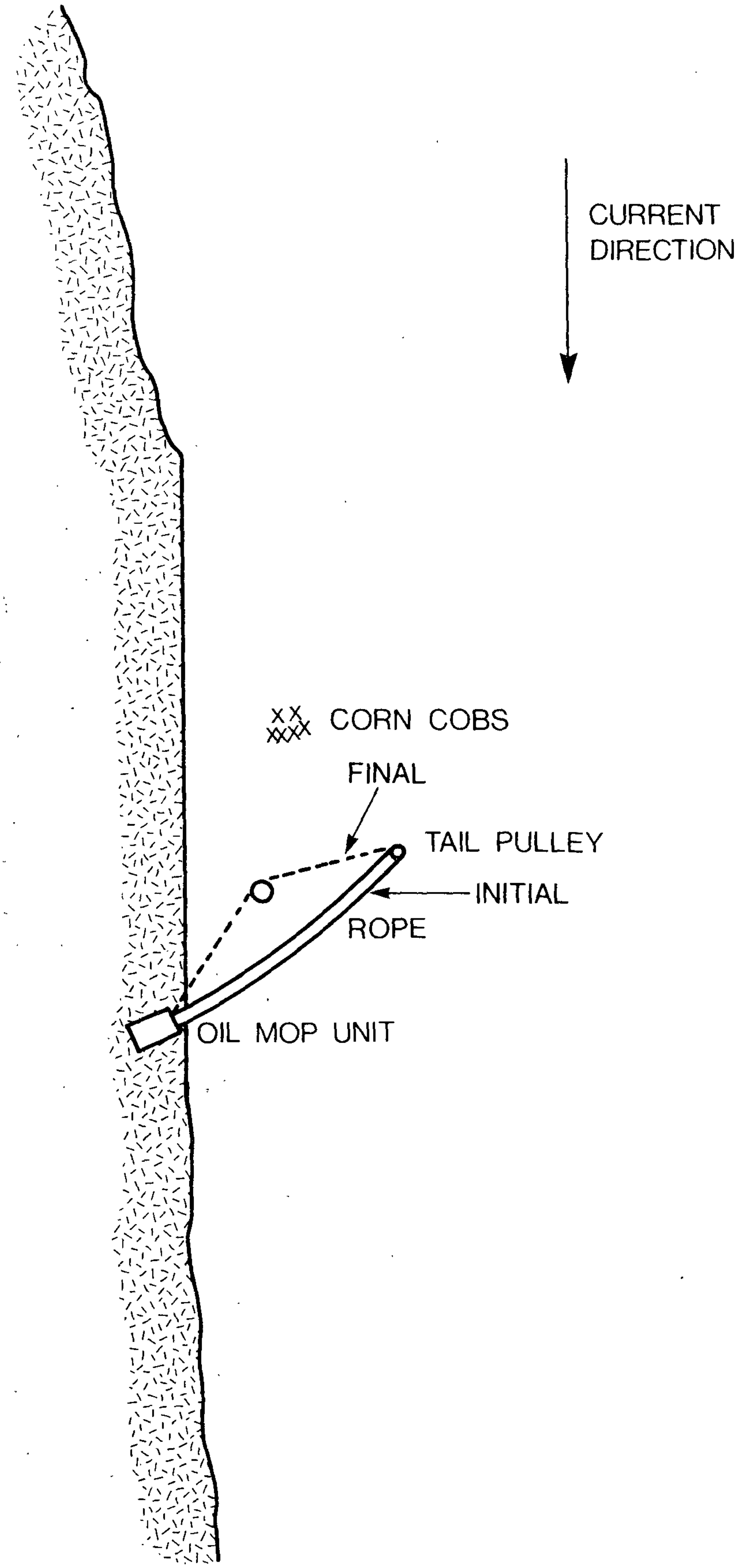


FIGURE A5. USE OF OIL MOP AT CHENAL ECARTE

A.1.3 PACE (Steltner) Barrier. The PACE barrier is an experimental barrier designed specifically for use in currents in excess of those at which conventional vertical barriers become ineffective. Each section of PACE barrier consists of two parallel inflatable floats or tubes, 50 feet (15 m.) long, joined together by a combination of nylon net on the upstream side, comprising one-third of the width, and the remainder is viledon. Viledon is a special non-woven polyester fabric which permits water to flow through, but not oil. Where the fabric joins each float, there are strength members of nylon webbing. The sections are connected by couplings at the strength members and a silver-nickel zipper between the sections of nylon net and viledon, preventing the leakage of oil.

The barrier is deployed at an angle to the current (see figure A.7). In theory, when free-floating oil encounters the barrier, any oil that passes under the upstream float is stopped by the viledon fabric and gathers on the surface between the floats. A tangential current is set up between the floats because the barrier is angled to the current. The oil between the floats is carried downstream by this tangential current and should be removed at this point. A more detailed description of the barrier construction and operation is presented by Wilcox (1975).

A 200-foot (61 m.) length of this barrier was tested at Sombra to compare its performance with that of conventional barriers. In preparation for deployment, the barrier was unreeled, inflated, placed in the water, and the downstream float was flipped over the upstream float. The barrier was then towed out and anchored in the desired location. The downstream end was pulled toward shore and tension readings were monitored. The maximum tension exerted on the upstream anchor by the barrier was 1,900 lb. (862 Kg.) as compared to a maximum of 1,100 lb. (499 Kg.) for a 200-foot (61 m.) length of conventional barrier. When the maximum attainable deflection was reached, the downstream float was flipped back and the barrier was allowed to stabilize. The deflection for the 200-foot (61 m.) length was measured as 120 feet (36.6 m.), see figure A.8. Oil was presented to this barrier and entrainment was first noted at the end of the initial 50-foot (15.2 m.) section. The effective deflection for the PACE barrier was 10 feet (3.0 m.), while the maximum effective deflection achieved by a conventional barrier at this test site was 35 feet (10.7 m.).

The PACE barrier is still in the experimental stage, and it is anticipated that its performance can be improved by further research and development.

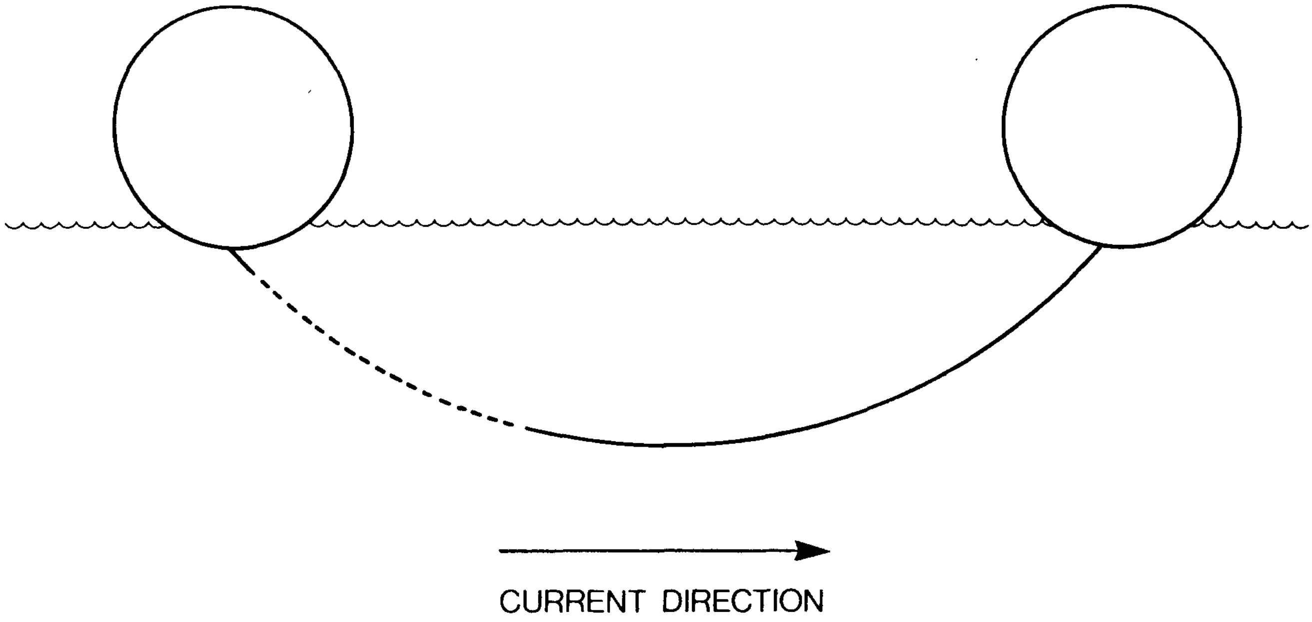


FIGURE 6 A. PACE BARRIER

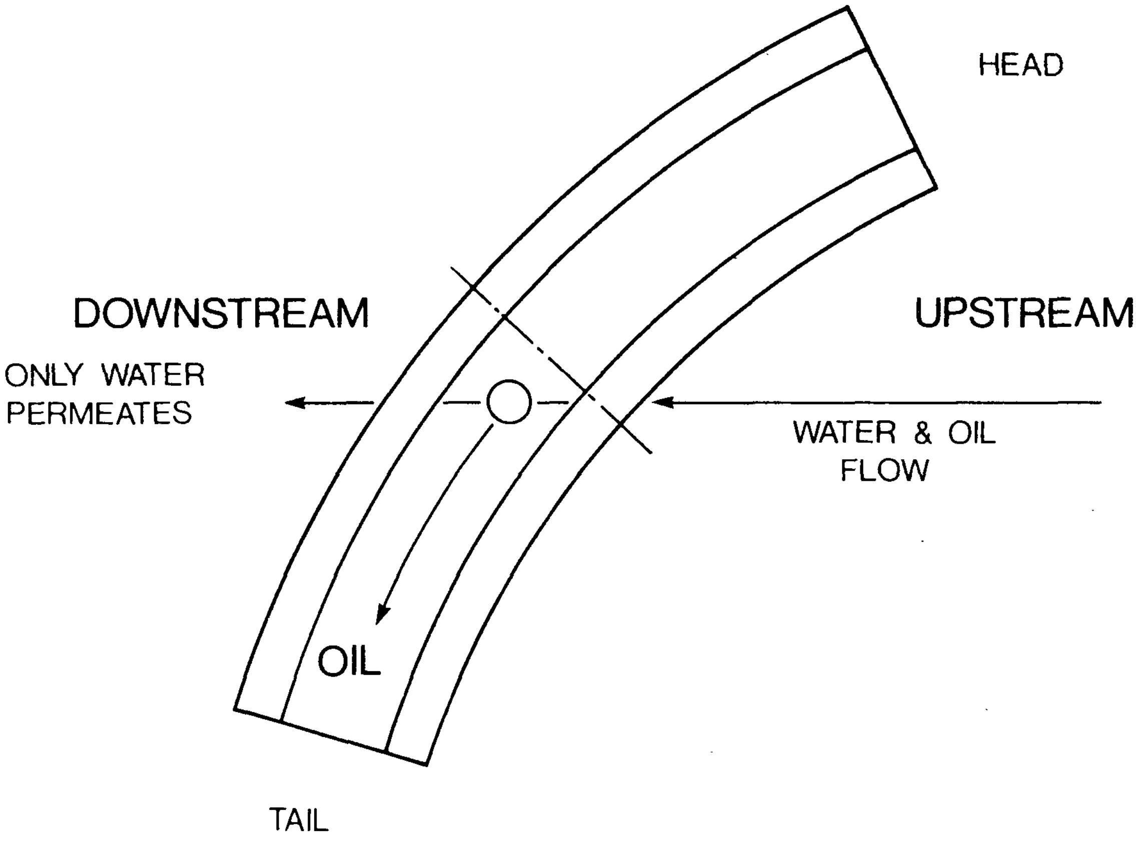


FIGURE 7 A. OPERATION OF PACE BARRIER

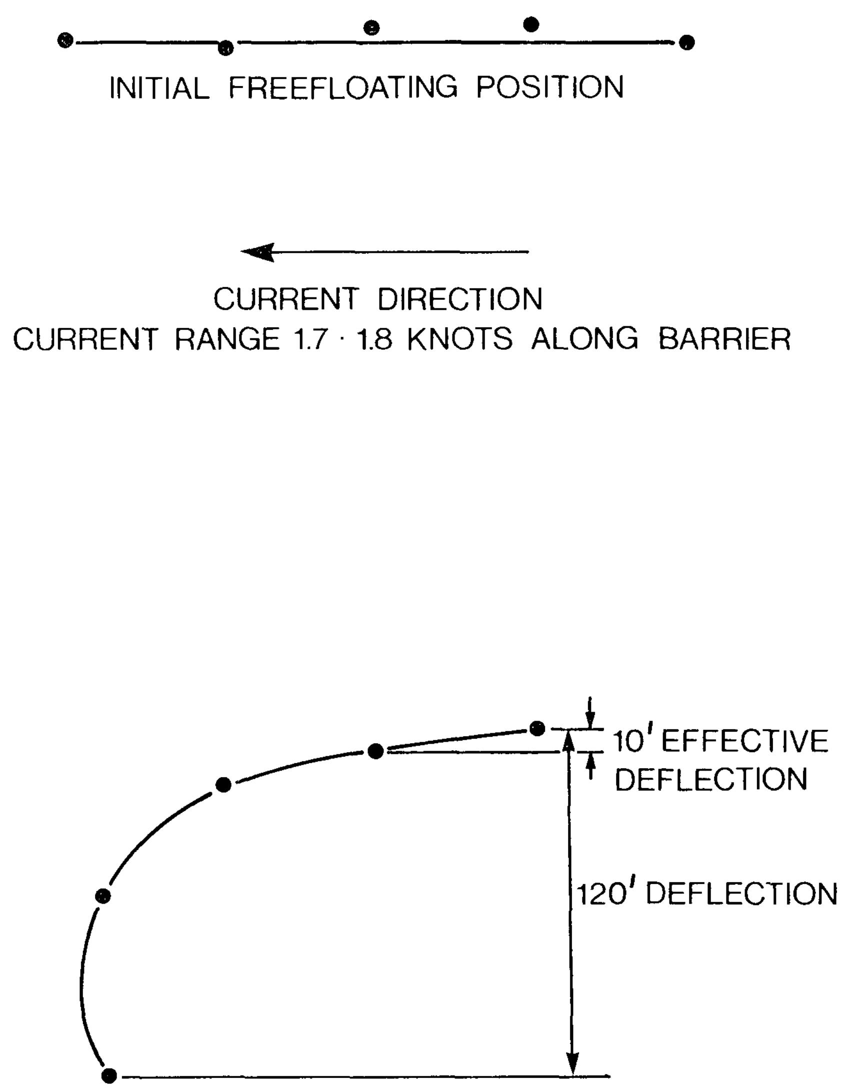


FIGURE A8. CONFIGURATION OF PACE BOOM AT SOMBRA TEST SITE , AUG 20, 1975

APPENDIX A.2

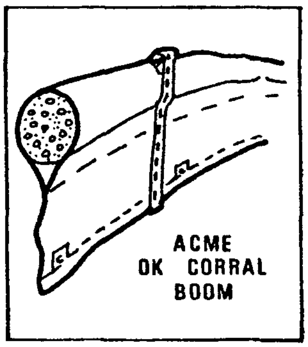
COMMERCIALLY AVAILABLE BARRIERS

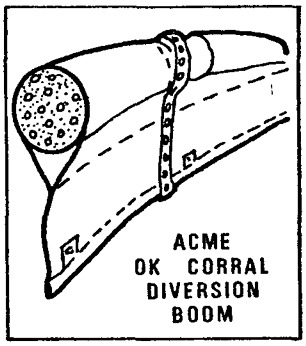
A.2 Commercially Available Barriers

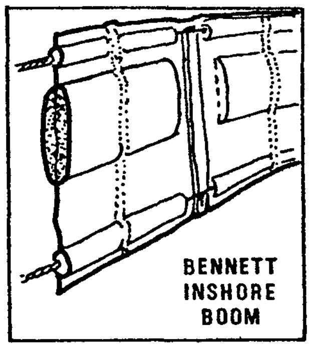
The following tables summarize the barriers available commercially in Canada. The information listed was obtained from manufacturers' literature and was received no later than January 1, 1975. For additional information on specific barriers, the reader should contact the manufacturer or distributor.

COMMERCIALLY AVAILABLE BARRIERS - MECHANICAL

	Acme "OK" Corrall *Containment Boom*	Acme "OK" Corral *Diversion Boom*	Bennett Inshore *Boom*
Total Height	10" - 48"	42" - 126"	12" - 36"
Freeboard	4" - 12"	6"	5" - 12"
Draught	6" - 36"	36" - 120"	7" - 24"
Flotation Size	4" - 12"ϕ, 9 ft. long	6" ϕ, 9 ft. long	2" x 6" x 4'
Flotation Mat.	Ethafoam	Ethafoam	Ethafoam
Barrier Mat.	JaTon fabric	JaTon fabric	PVC coated nylon fabric
Tension Member	None-material claimed *to be sufficiently* strong 1/4" chain along bottom	None-material claimed *to be sufficiently* strong 1/4" chain along bottom	1/4" steel cables
Ballast	1/4" chain along bottom	1/4" chain along bottom	Lead weights on bottom cable
Section Length	50 - 200 ft.	50 - 200 ft.	50 ft.
Vertical Stiffeners	None	None	P.V.C. bars every 4 ft.
Weight	1.5 - 4.0 lb/ft.		1.8 - 3 lb/ft.
Price (Jan. 1/75)	\$7 - \$17/ft.	\$9.81 - \$12.78/ft.	\$7 - \$12/ft.
Distributor	Industrial Mechanical Specialties 33 Glencameron Rd. Thornhill, Ontario 416-889-5237	Industrial Mechanical Specialties 33 Glencameron Rd. Thornhill, Ontario 416-889-5237	Bennett Pollution Controls Ltd. 119 Charles St. N. Vancouver, B.C. 604-929-5451
Configuration and Remarks			

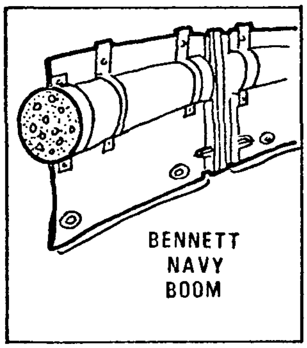


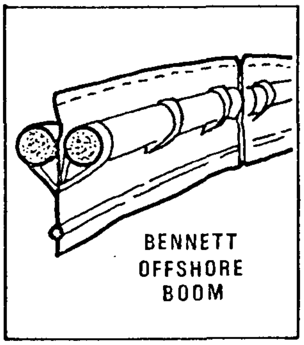


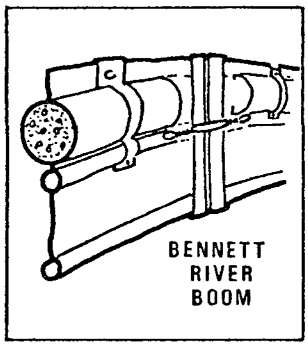


COMMERCIALLY AVAILABLE BARRIERS - MECHANICAL

	Bennett Navy Boom	*Bennett Offshore Boom*	*Bennett River Boom*
Total Height	13" - 36"	72"	18"
Freeboard	5" - 12"	24"	6"
Draught	8" - 24"	48"	12"
Flotation Size	5" - 7" ϕ, 7' 6" long	8" ϕ	7" ϕ
Flotation Mat.	Closed-cell polyethylene foam	Ethafoam	Ethafoam
Barrier Material	P.V.C. coated fabric	Top half, P.V.C. coated, Bottom - semi-permeable	P.V.C. coated nylon fabric
Tension Member	see remarks	1/4" cables - top/bottom, 3/4" cables inside skirt	3/8" steel cable beneath flotation
Ballast	Lead riveted to bottom of barrier	Lead poured into bottom of vertical stiffeners	Chain along bottom
Section Length	50 ft.		50 ft.
Vertical Stiffeners	None	2" square steel tubes	None
Weight	1.6 - 3.4 lb/ft.		2.75 lbs/ft.
Price (Jan. 1/75)	\$10 - \$13/ft.	\$48/ft.	\$11/ft.
Distributor	Bennett Pollution Controls 119 Charles St. N. Vancouver, B.C. 604-929-5451	Bennett Pollution Controls 119 Charles St N. Vancouver, B.C. 604-929-5451	Bennett Pollution Controls 119 Charles St. N. Vancouver, B.C. 604-929-5451
Configuration and Remarks			

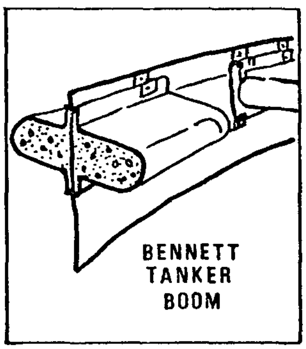


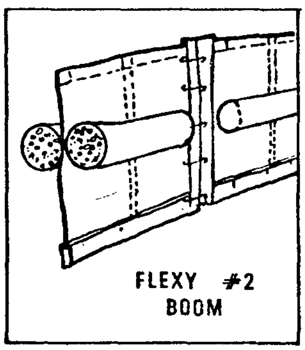


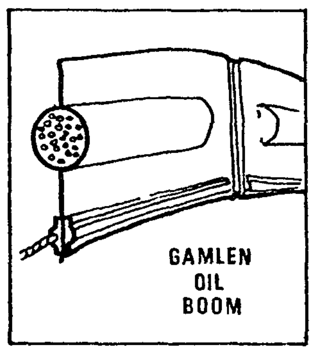


COMMERCIALLY AVAILABLE BARRIERS – MECHANICAL

	Bennett Tanker Boom	Flexy #2 Boom	Gamlen Oil Boom
Total Height	24" – 36"	14" – 36"	18"
Freeboard	10" – 12"	4-3/4" – 12"	5"
Draught	14" – 24"	9-1/4" – 24"	7"
Flotation Size		2" – 6" ϕ	6" ϕ, 6ft. long (in 3 sections)
Flotation Mat.	Urethane-filled polyethylene	Ethafoam	1/4" polystyrene foam beads
Barrier Material	Polyurethane coated polyester	P.V.C. coated nylon fabric	Vinyl-coated fabric
Tension Member	None	1/8" – 1/4" steel cables, top and bottom	5/32" stainless cable at bottom
Ballast	Lead weights	Lead weights on bottom cable	High density P.V.C.
Section Length	Optional	50 ft.	100 ft.
Vertical Stiffeners		Aluminum – every 2 ft.	None
Weight	10 – 14 lb/ft.	1.8 – 3.0 lb/ft.	2.2 lb/ft.
Price (Jan. 1/75)	$29 – $31/ft.	$5.90 – $11.75/ft.	$14.20/ft.
Distributor	Bennett Pollution Controls 119 Charles St. N. Vancouver, B.C. 604-929-5451	Hurum Shipping & Trading Board of Trade Building 300 St. Sacrament St. Montreal, Quebec 514-842-5211	Gamlen Chemical Co. 595 Guimond Blvd. Longueuil, P.Q. 514-679-6060
Configuration and Remarks	Designed as a permanent harbour barrier		

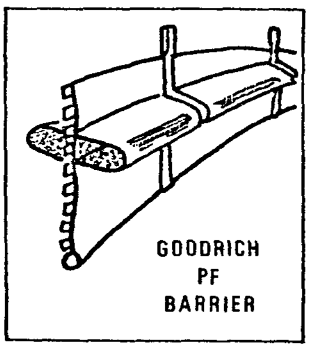


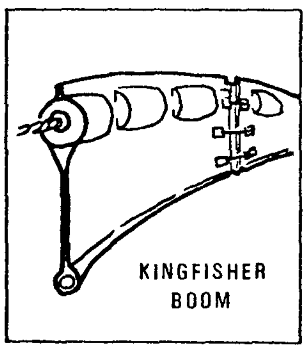


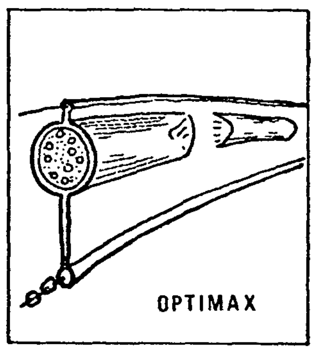


COMMERCIALLY AVAILABLE BARRIERS - MECHANICAL

	Goodrich PF Barrier	Kingfisher Boom	Optimax
Total Height	18", 36"	19"	19" - 31"
Freeboard	6", 12"	5 1/2"	7"
Draught	12", 24"	13 1/2"	12" - 24"
Flotation Size	3 1/2" x 10 1/2" x 23.5 ft	6" ϕ, 7 1/2" long	6" ϕ - 7 ft. long
Flotation Mat.	Searethane™	P.V.C.	Ethafoam
Barrier Material	1/4" vinyl sheet	Nylon fabric	Vinyl impregnated nylon
Tension Member	None	5/8" tow line centre of float	Steel cable top, galvanized chain bottom
Ballast	Integral ballasting	Lead on cable at bottom	Galvanized chain
Section Length	23.5 ft.	200 ft.	100 ft. (50 ft. optional)
Vertical Stiffeners		None	None
Weight	8 - 12 lb/ft.	0.88 lb/ft.	2.5 lb/ft.
Price (Jan. 1/75)	\$20 - \$32/ft.	\$4.53/ft.	\$8.15/ft.
Distributor	B.F. Goodrich Canada 50 Jutland Rd., Toronto, Ontario 416-255-1101	Gundry Bilmac Ltd. 996 Powell St. Vancouver, B.C. 604-255-3511	American Marine Canada P.O. Box 1660 Kingston, Ontario 613-389-3118
Configuration and Remarks			

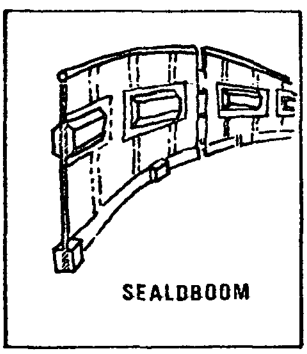


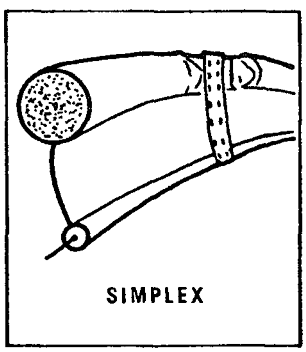


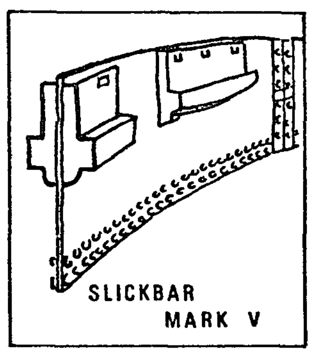


COMMERCIALLY AVAILABLE BARRIERS - MECHANICAL

	Sealdboom	Simplex	Slickbar Mark V
Total Height	18", 36"	19" - 31"	36"
Freeboard	6", 12"	7"	12"
Draught	12", 24"	12" - 24"	24"
Flotation Size	1.4" x 4" x 27" 1.4" x 5.5" x 27"	6" ϕ, 7 ft. long	
Flotation Material	Closed cell Ensolite	Ethafoam	Polyurethane
Barrier Material	Paracril-OZO-nylon	Vinyl-impregnated nylon	P.V.C. coated polyester fabric
Tension Member		Galvanized chain on bottom	3/8" cable below float
Ballast	Lead weights on bottom	Galvanized chain	Lead weights at skirt bottom
Section Length	40 ft.	100 ft. (50 ft. optional)	Optional
Vertical Stiffeners	Elastomer coated springsteel every 20"	None	Not required due to nature of fabric
Weight	1.5 - 5.8 lb/ft.	2 lb/ft.	
Price (Jan. 1/75)	$13.45 - $24.40/ft.	$6.75/ft.	$18.85/ft.
Distributor	Uniroyal Ltd. 51 Breithaupt St. Kitchener, Ontario 519-744-7171	American Marine Can. P.O. Box 1660 Kingston, Ontario 613-389-3118	Industrial Plastics Canada P.O. Box 93 Fort Erie, Ont. 416-871-0412
Configuration and Remarks			



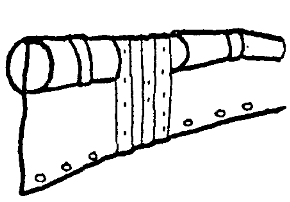


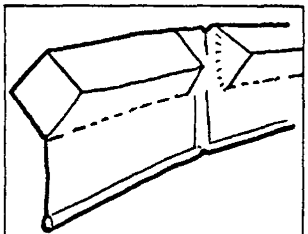


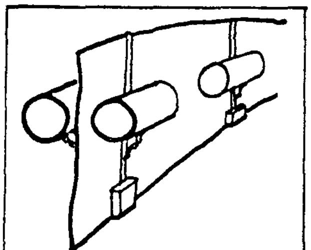
COMMERCIALLY AVAILABLE BARRIERS - MECHANICAL

	Slickbar Mark VI	Supermax	T-T Boom
Total Height	10'' - 18.5''	36''	36''
Freeboard	4'', 6.5''	12''	12''
Draught	6'' - 12''	24''	24''
Flotation Size	4'', 6.5'' ϕ, 50'' long	8'' octagonal, 7 ft. long	
Flotation Mat.	Polyethylene foam	Expanded polystyrene	Expanded plastic
Barrier Material	P.V.C. coated polyester fabric	Vinyl-impregnated nylon	P.V.C. coated nylon
Tension Member	1/4'' stainless cable below floats	Vinyl sheathed steel cable along bottom	Chain along bottom line along top
Ballast	Lead weights along bottom edge	Vinyl sheathed steel cable	Lead weights on bottom
Section Length	Optional	50 ft.	164 ft.
Vertical Stiffeners	None	None	Vertical stiffeners every 2 ft.
Weight	0.95 - 4.12 lb/ft.	3.5 lb/ft.	2.7 lb/ft.
Price (Jan. 1/75)	\$5.52 - \$16.68/ft.	\$14.95/ft.	\$15.24/ft.
Distributor	Industrial Plastics Canada P.O. Box 93 Fort Erie, Ontario 416-871-0412	American Marine Canada P.O. Box 1660 Kingston, Ontario 613-389-3118	Delta Hydraulic Power Ltd. 175 Kent Ave. Vancouver, B.C. 604-327-6351

Configuration and Remarks

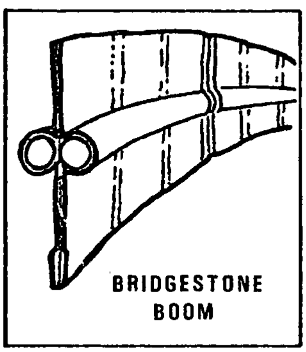

SLICKBAR MARK VI

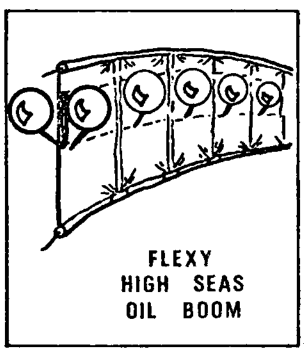

SUPERMAX

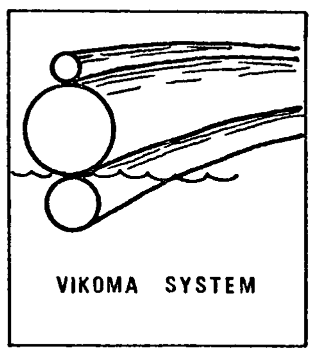

T-T BOOM

COMMERCIALLY AVAILABLE BARRIERS - PNEUMATIC

	Bridgestone Boom	Flexy High Seas Oil Boom	Vikoma System
Total Height	32", 40"	72"	47"
Freeboard	12", 16"	24"	30"
Draught	20", 24"	48"	17"
Flotation Size	Rubber hoses either side of barrier	Inflated plastic floats every 3 ft. on both sides	27" ϕ + 3" ϕ rubber hose
Flotation Material	Air	Air	
Barrier Material	Rubber with pleated skirt	P.V.C. coated nylon	Coated nylon fabric
Tension Member	Rope at floats	Steel cable top and bottom	
Ballast	Lead weights along bottom		17" ϕ rubber hose filled with water
Section Length	65.5 ft.	50 ft.	800 ft. or 1600 ft.
Vertical Stiffeners	Glass rods	Aluminum channel stiffeners every 3 ft.	
Weight	7 - 10 lb/ft.	8 lb/ft.	3 lb/ft.
Price (Jan. 1/75)		$67.50/ft.	$90,000/Seapack unit
Distributor	Pains-Wessex (Canada) P.O. Box 2971 Postal Station D, Ottawa, Ontario 613-828-9738	Hurum Shipping & Trading 300 St. Sacrament St. Montrèal, P.Q. 514-842-5211	
Configuration and Remarks	Unit is submersible		Unit comes with seapack, compressor and pumps







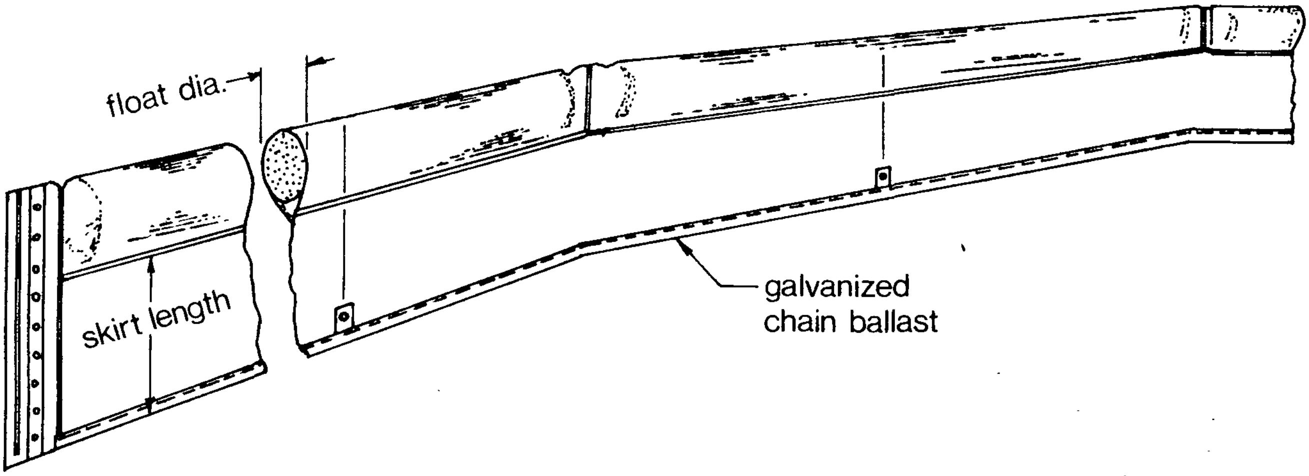
APPENDIX A.3

DESCRIPTION OF BARRIERS EVALUATED

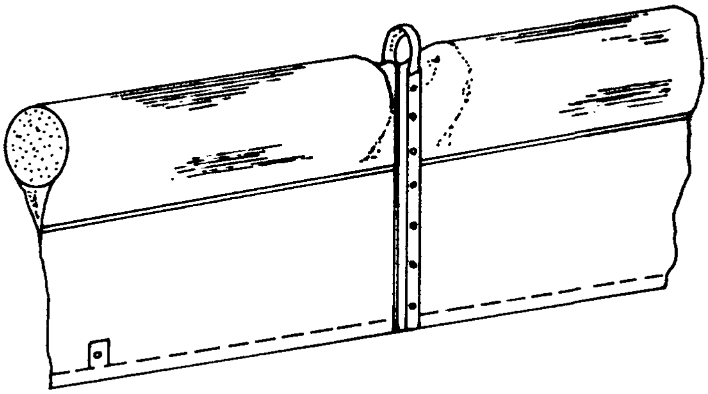
A.3 Description of Barriers Evaluated

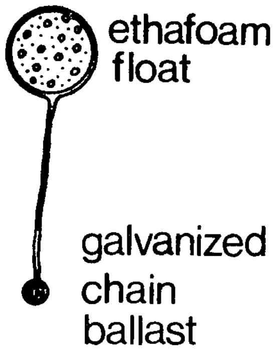
The following schematics are detailed illustrations of the barriers that were part of the evaluation programme. The selection of these barriers was made to obtain a representative cross-section of the commercially available units and also on the immediate availability for the testing programme. Their use in this programme does not constitute endorsement or approval by Environment Canada.

ACME OK CORRAL BOOM



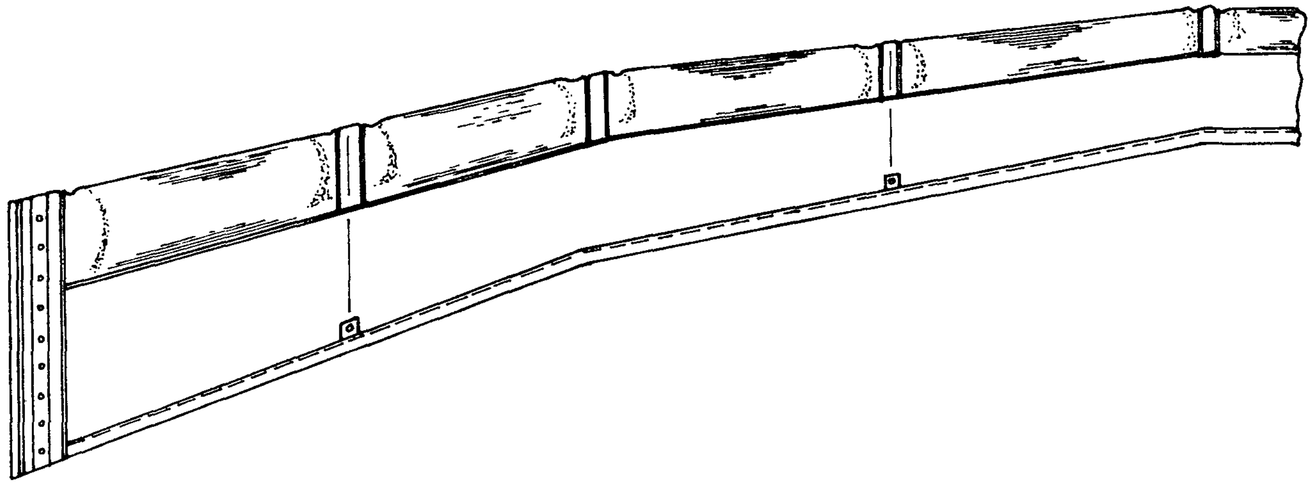
SECTION FLEX COUPLER

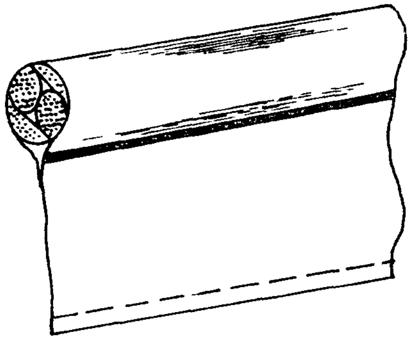




Specifications	Boom Size
Section length	10 to 300 ft.
Freeboard	4", 6"
Draught	6" to 120"
Weight per foot	1.5 to 2.2 lb.
Top strength member	None
Ballast	Galvanized chain
Boom fabric	Jaton^{tm}
Flotation material	Ethafoam
Flotation size	4", 6" diameter x 9' (4½' optional)

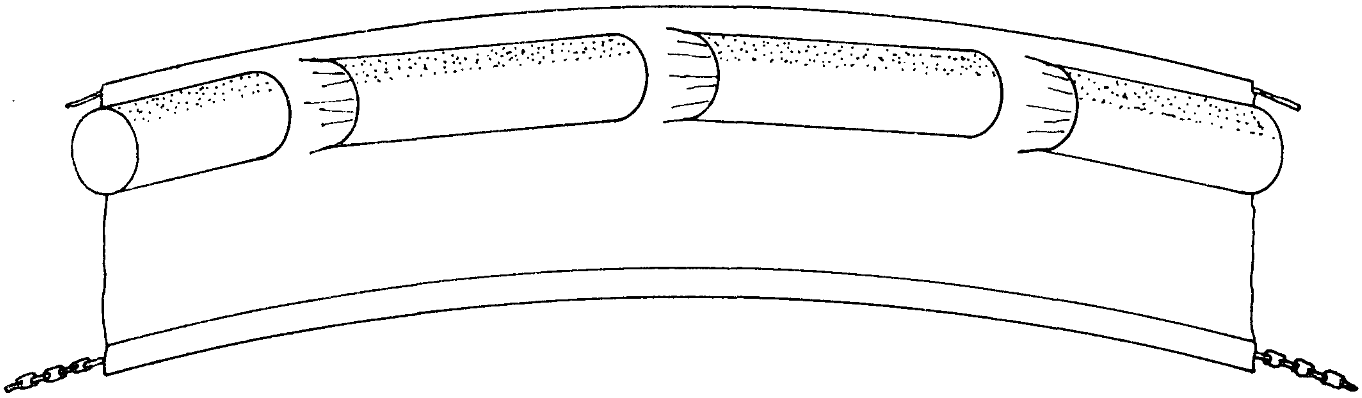
ACME OK CORRAL BOOM

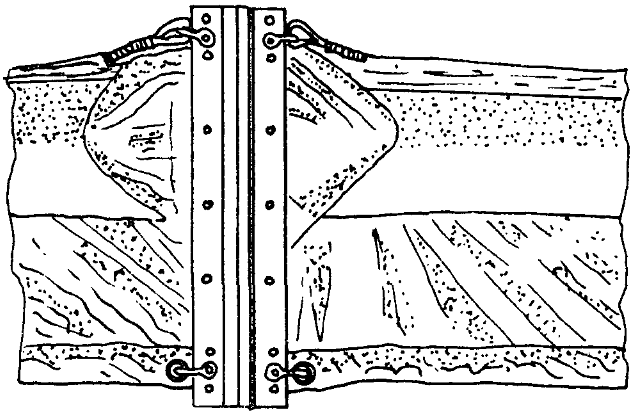


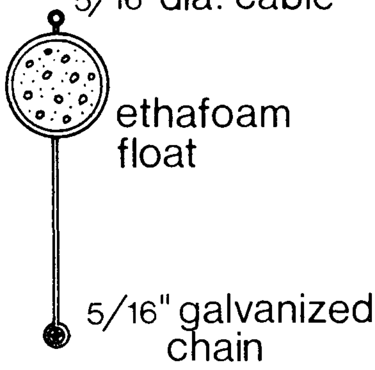


Specifications	Boom Size
Section length	Optional
Freeboard	12"
Draught	6" to 36"
Weight per foot	3.6 to 4.0 lb.
Top strength member	None
Ballast	Galvanized chain
Boom fabric	Jaton^{tm}
Flotation material	Ethafoam
Flotation size	12" diameter x 9' (4½' optional)

AMERICAN MARINE OPTIMAX

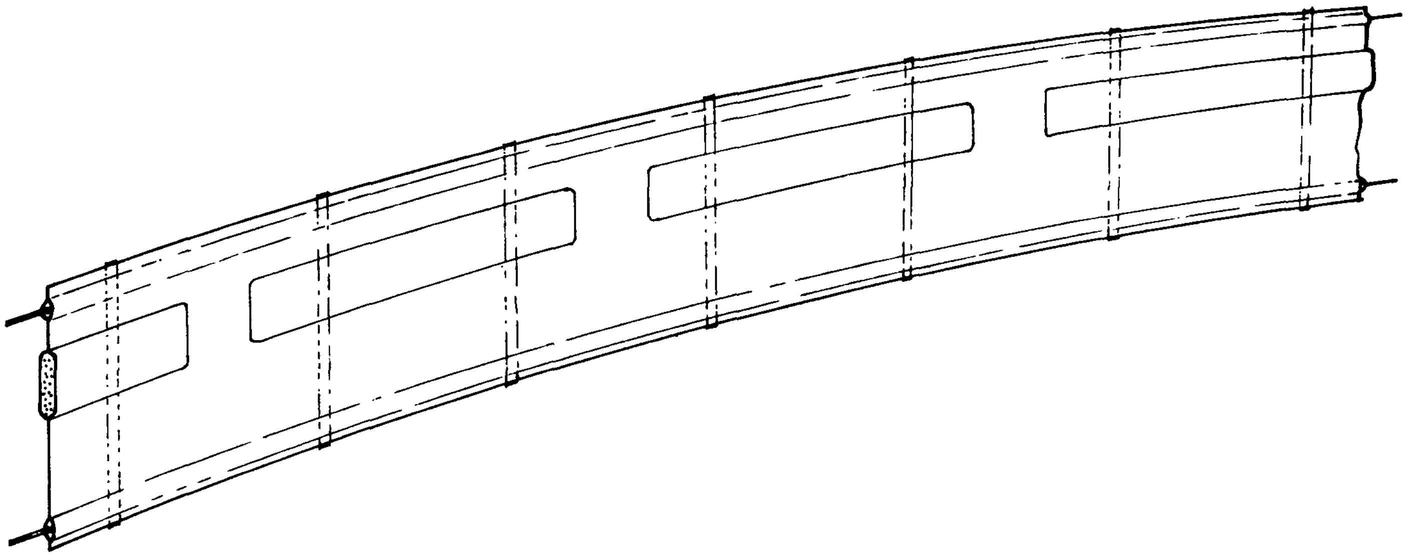


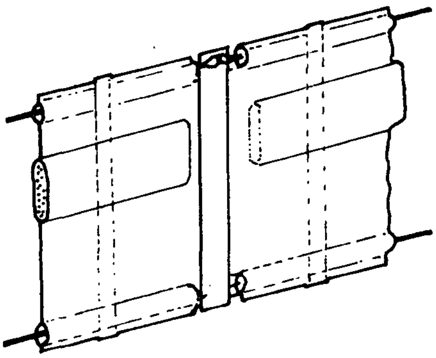


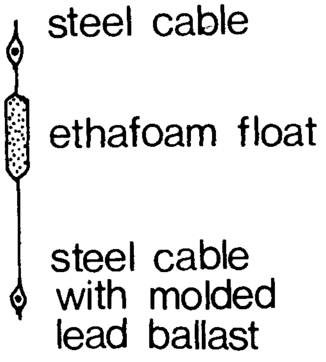


Specifications	Boom Size
Section length	100 ft (50 ft. optional)
Freeboard	7"
Draught	12" - 24"
Weight per foot	2.5 lb.
Top strength member	5/16" steel cable
Ballast and/or bottom strength	5/16" galvanized chain
Boom fabric	Vinyl coated nylon
Flotation material	Ethafoam
Flotation size	6" diam. x 7 ft.
Tensile strength	5,300 lb. break test chain

BENNETT INSHORE BOOM

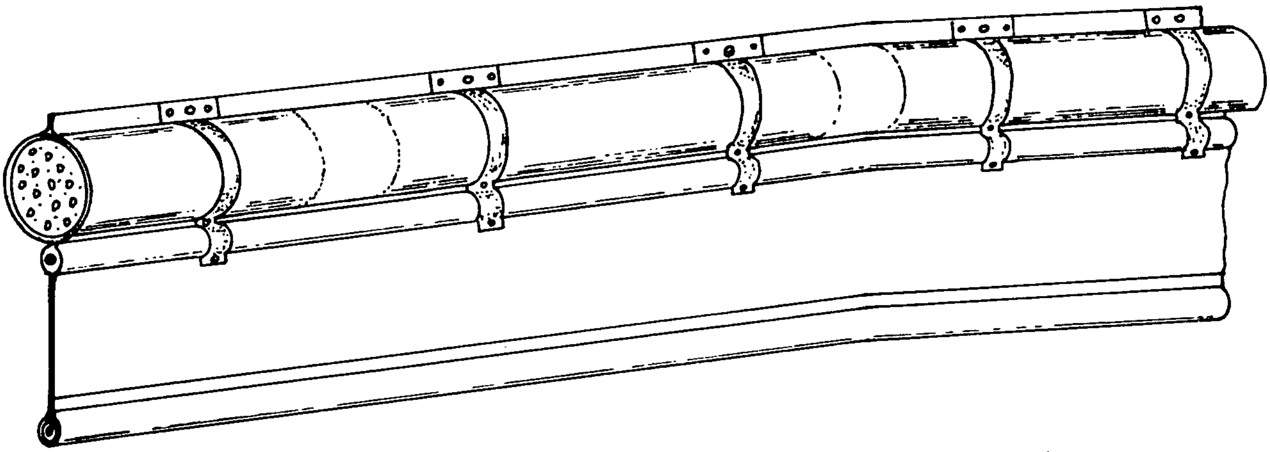


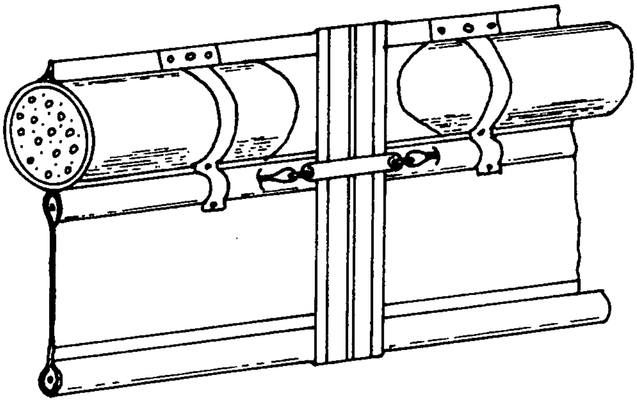


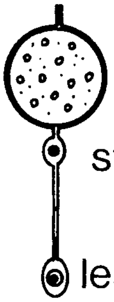


Specifications	Boom Size			
	12"	18"	24"	36"
Section Length	50 ft.			
Freeboard	5"	6"	8"	12"
Draught	7"	12"	16"	24"
Weight per foot	1.8 lb.	2 lb.	2.5 lb.	3 lb.
Top strength member	N/A	N/A	¼" steel cable	
Ballast and/or bottom strength	Lead weights molded to ¼" steel cable			
Boom fabric	P.V.C. coated nylon			
Flotation material	Ethafoam			
Flotation size	2" x 6" x 4'			
Total grab tensile strength	7,000 lb.		14,000 lb.	

BENNETT RIVER BOOM

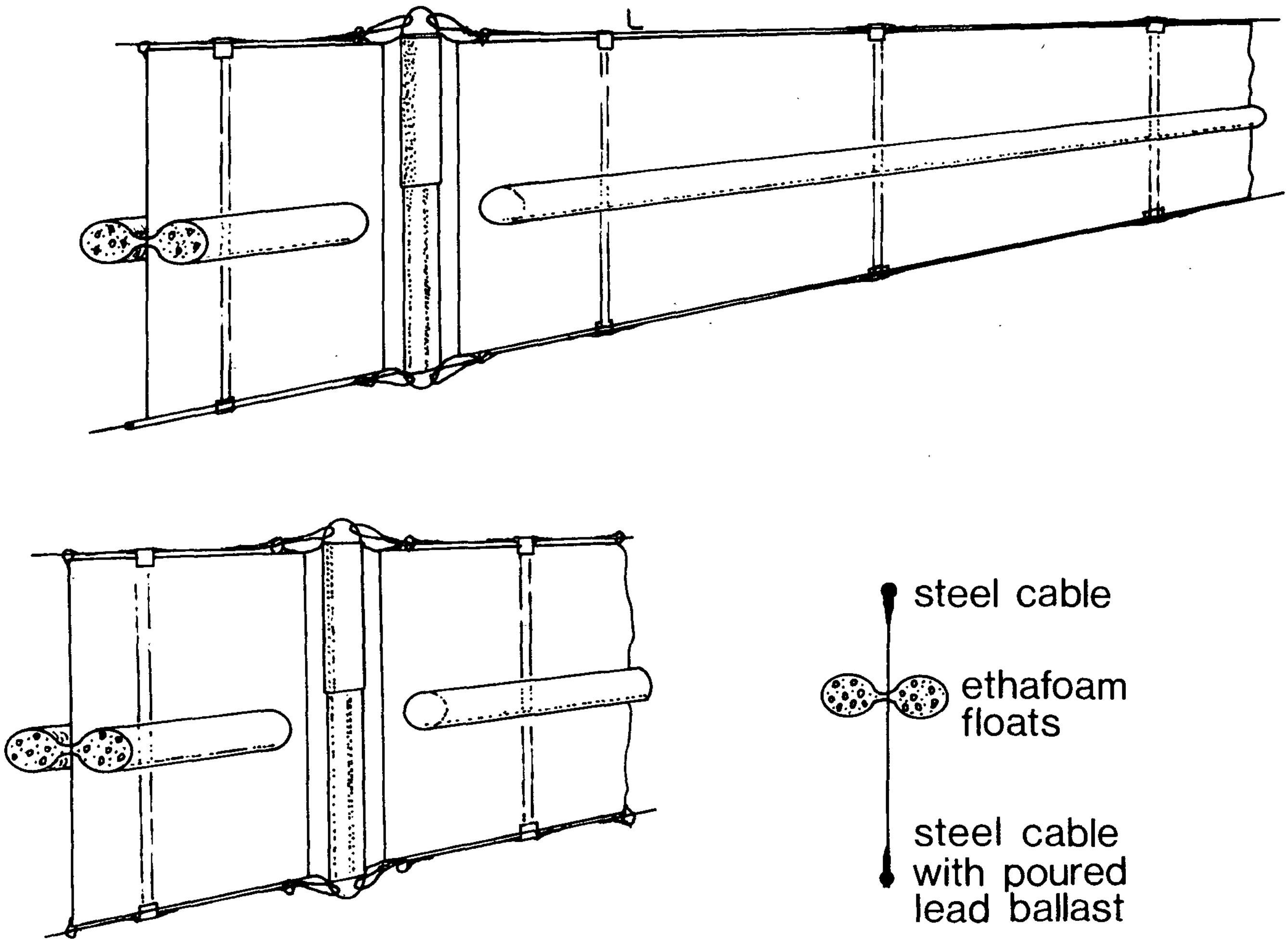






Specifications	Boom Size
Section length	50 ft.
Freeboard	6"
Draught	12"
Weight per foot	2.75 lb.
Top strength member	3/8" steel cable below float
Ballast	Lead weights
Boom Fabric	P.V.C. Coated nylon fabric
Flotation material	Ethafoam
Flotation size	7" diameter
Total grab tensile strength	14,000 lb.

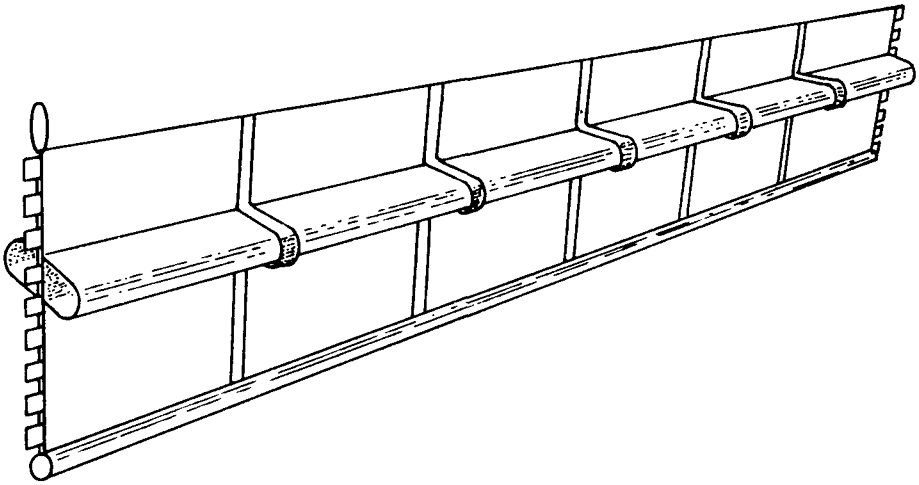
"FLEXY II" OIL BOOM

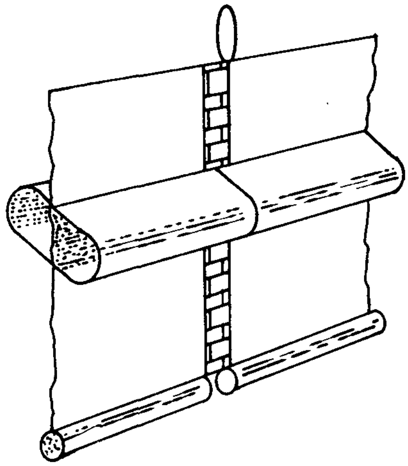


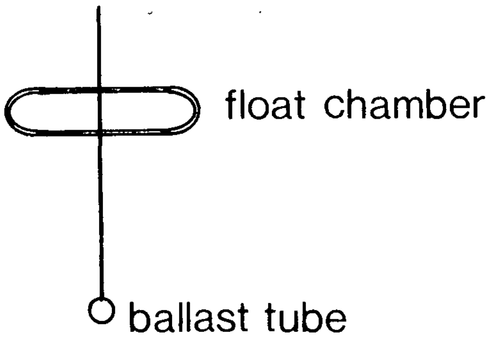
Specifications	Boom Size			
	14"	18"	24"	36"
Section length	50 ft.			
Freeboard	4.75"	6"	8"	12"
Draught	9.25"	12"	16"	24"
Weight per foot	1.0 lb.	1.5 lb.	2.6 lb.	3.0 lb.
Ballast and/or bottom strength	1/8" steel cable		¼" steel cable	
Boom fabric	P.V.C. Coated nylon fabric			
Flotation material	Ethafoam			
Flotation size*	2" diameter		3" diameter	

*larger flotation available

B.F GOODRICH SEABOOM

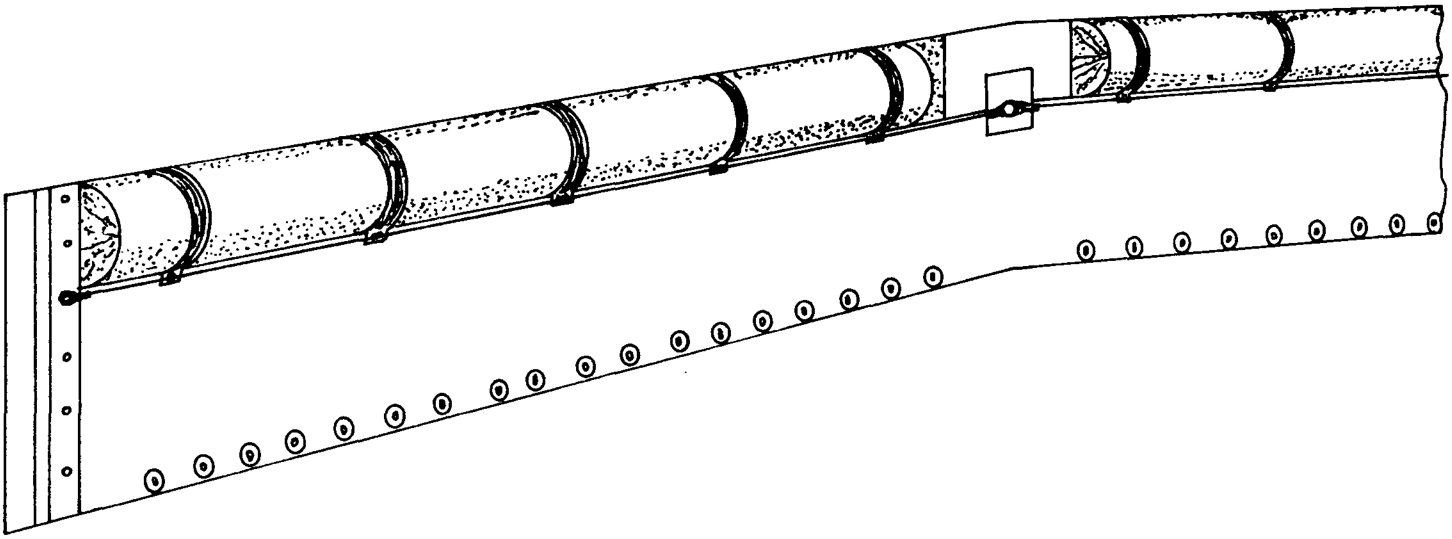


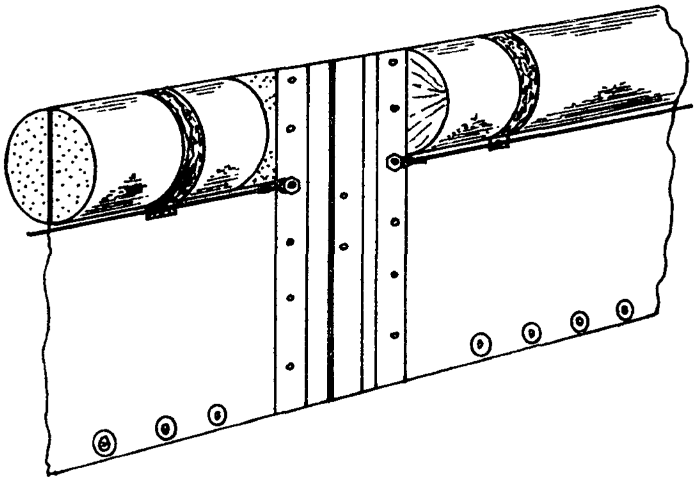


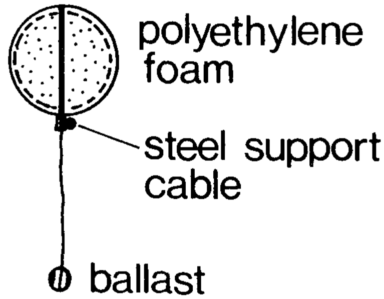


Specifications	Boom Size	
	18"	36"
Section length	23.5 ft.	
Freeboard	6"	12"
Draught	12"	24"
Weight per foot	8 lb.	12 lb.
Top strength member	None	
Ballast and/or bottom strength	None-integral ballasting	
Boom fabric	Vinyl sheet	
Flotation material	Closed cell foam	
Flotation size	3.5" x 10.5" x 23.5 ft.	
Tensile strength	6,000 lb.	10,000 lb.

SLICKBAR BOOM







Specifications	Boom Size	
Section length	Optional	
Freeboard	4"	6.5"
Draught	6", 8"	6", 8"
	10", 12"	10", 12"
Weight per foot	0.9 lb - 4.1 lb.	
Top strength member	¼" stainless cable below floats	
Ballast	Lead weight on bottom of skirt	
Boom fabric	P.V.C. coated polyester fabric	
Flotation material	Polyethylene foam	
Flotation size	4" diam. x 50"	6.5" diam x 50"
Tensile strength	In excess of 5,000 lb.	

APPENDIX A.4

CONFIGURATION OF TEST BARRIERS

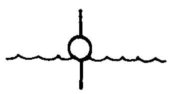
A.4 Configuration of Test Barrier Positions

The following diagrams summarize the test results of all the barriers evaluated. The configuration of each barrier was plotted by the use of triangulation and the initial free-floating position and the final configuration are shown schematically.

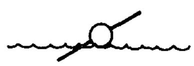
The current measurements were taken along the face of the barrier in its optimum configuration and the minimum and maximum values were recorded. It was generally found that the maximum readings were measured at the upstream end of the barrier and the lowest values were recorded downstream.

The schematics also include appropriate notations on the stability, effectiveness, deflection and effective deflection. The interpretation of these results are discussed in more detail in Section 4.0 and 5.0.

General observations were made and recorded on the angle of each barrier to the vertical in its optimum configuration. When a barrier is upright, the angle of the barrier to vertical is 0° and when it is lying horizontally on the surface, the angle of the barrier to vertical is 90°.



0° to Vertical



30° to Vertical

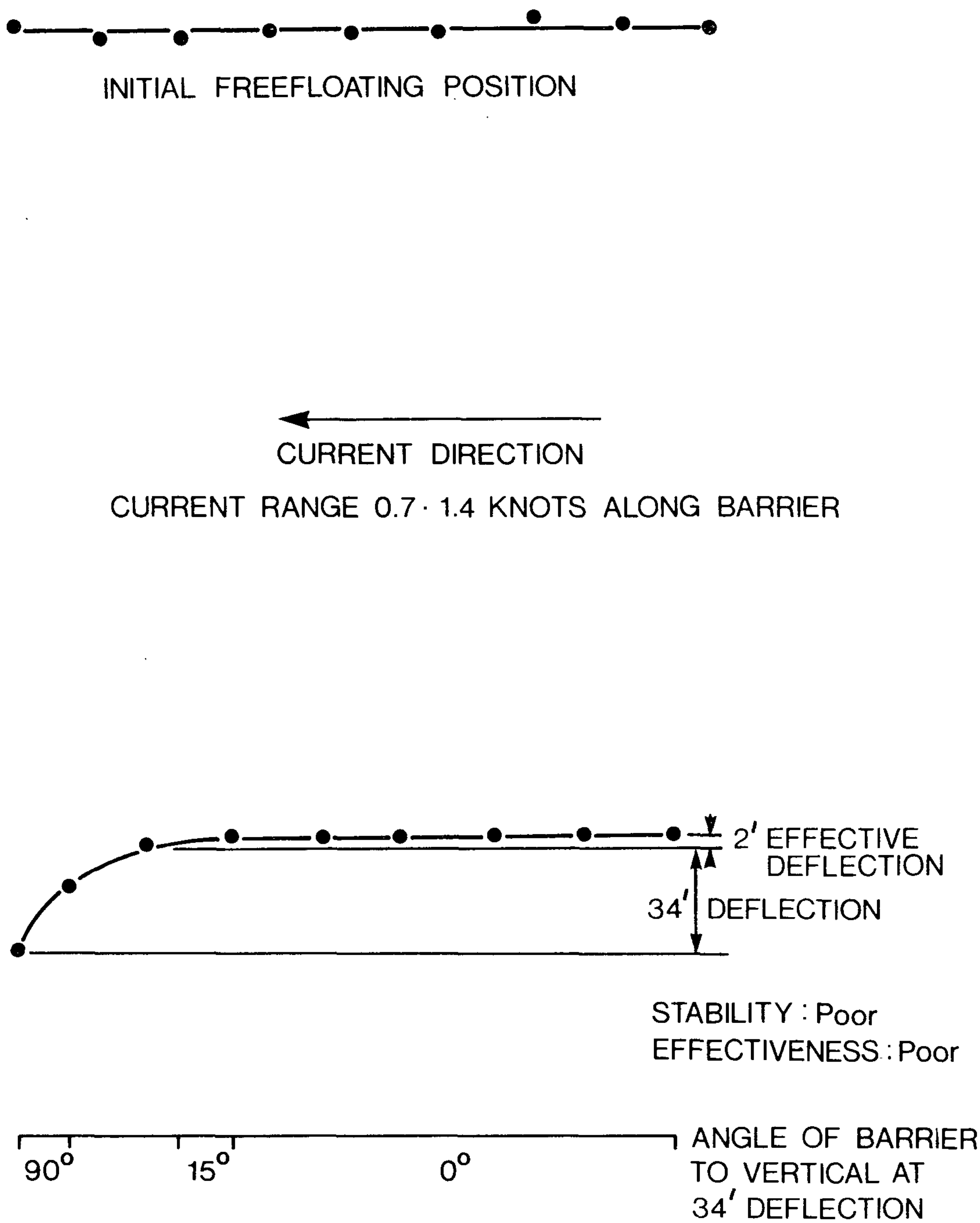
90° to Vertical

The diagrams are presented by test site.

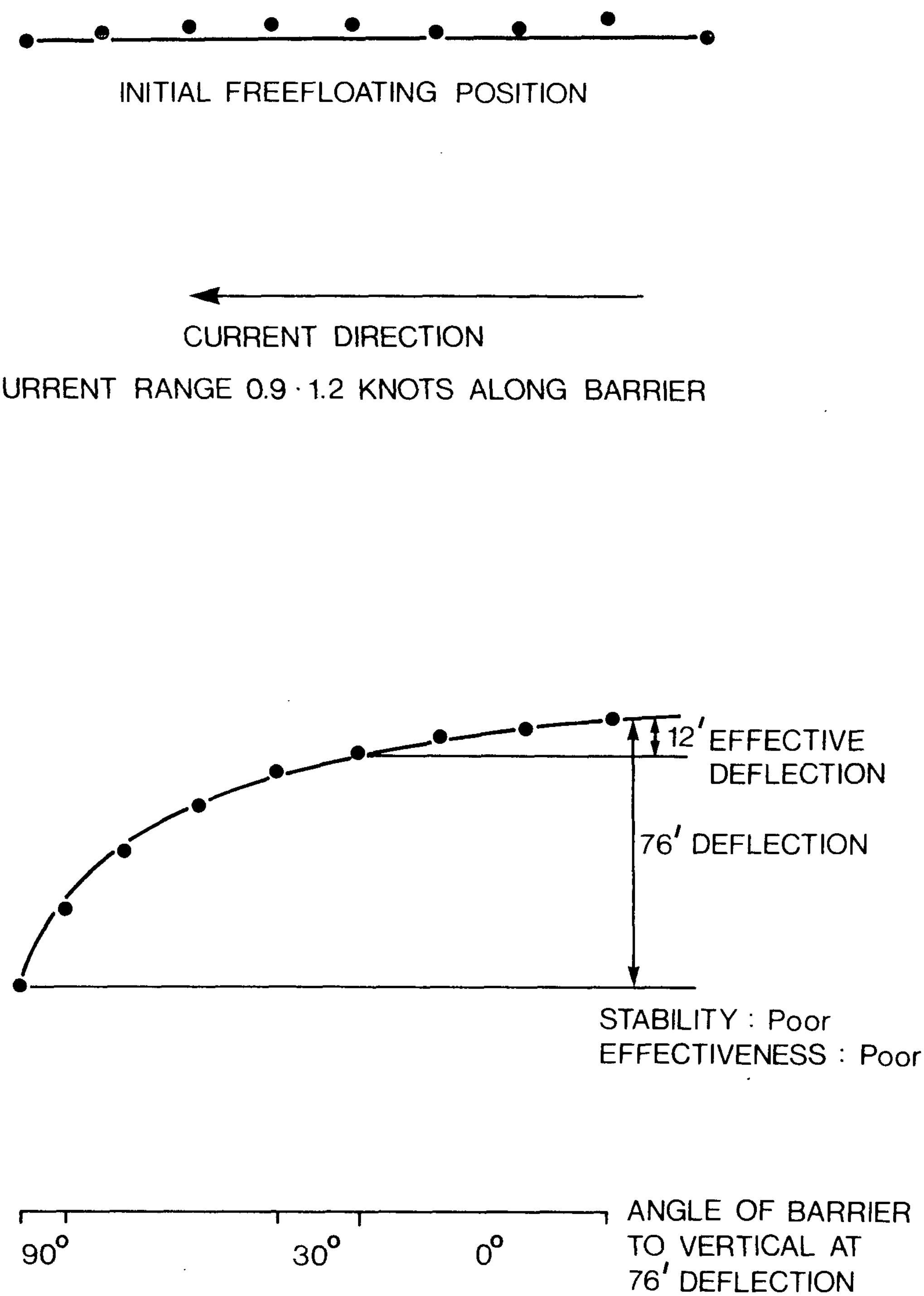
AMHERSTBURG TEST SITE

June 23-26, 1975

CONFIGURATION OF ACME OK CORRAL, 6" DIAMETER FLOAT, 18" SKIRT, AT AMHERSTBURG TEST SITE, JUN 24, 1975

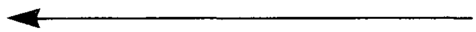


CONFIGURATION OF ACME OK CORRAL, 12" DIAMETER FLOAT, 12" SKIRT, AT AMHERSTBURG TEST SITE, JUN 24, 1975



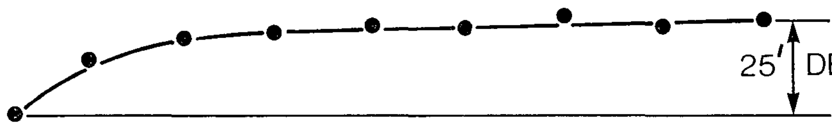
CONFIGURATION OF BENNETT INSHORE BOOM, 6″ FREEBOARD, 12″ SKIRT AT AMHERSTBURG TEST SITE, JUN 26, 1975

INITIAL FREEFLOATING POSITION



CURRENT DIRECTION

CURRENT RANGE 1.0 · 1.2 KNOTS ALONG BARRIER



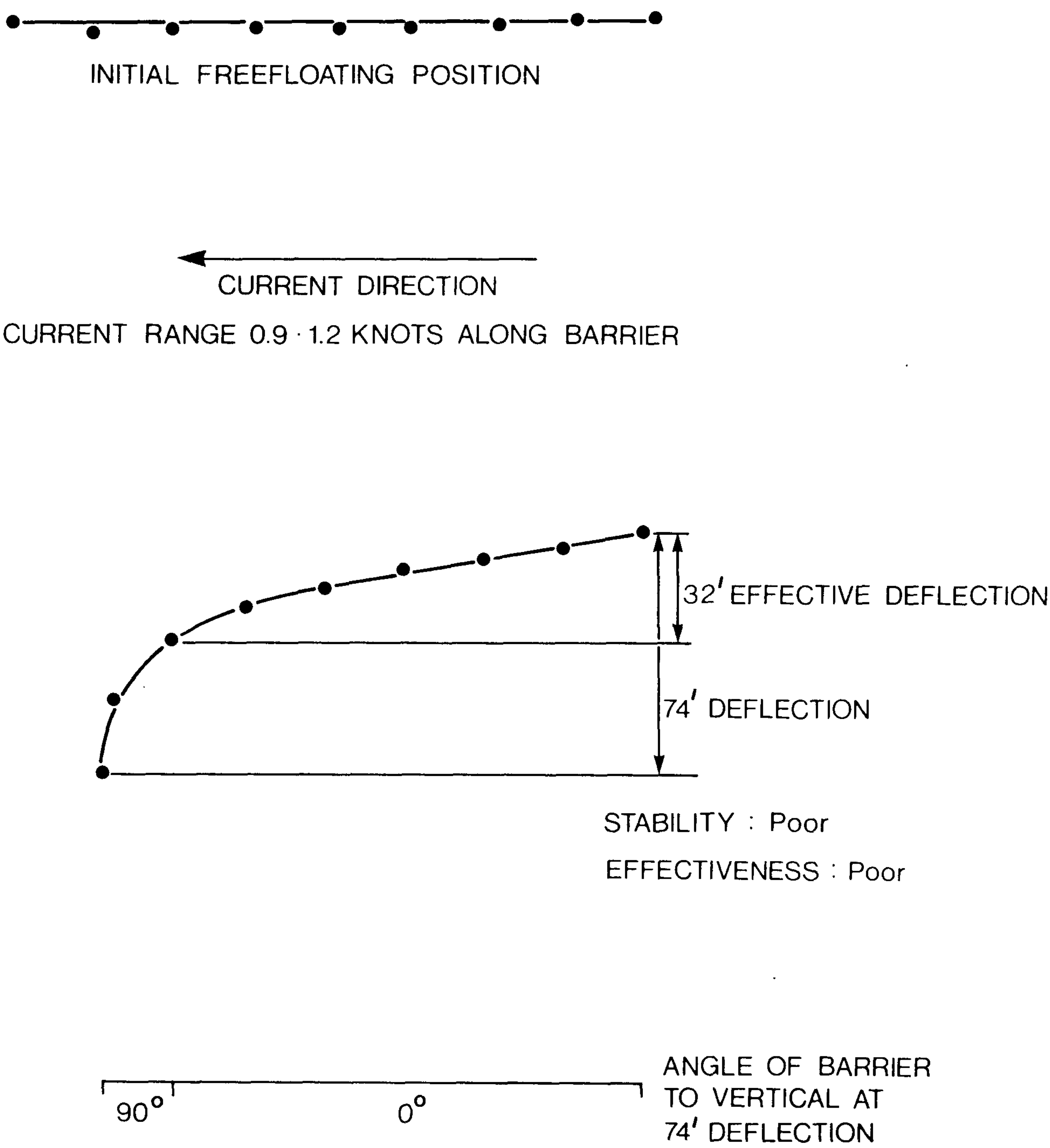
25′ DEFLECTION

STABILITY : Poor
EFFECTIVENESS : Poor

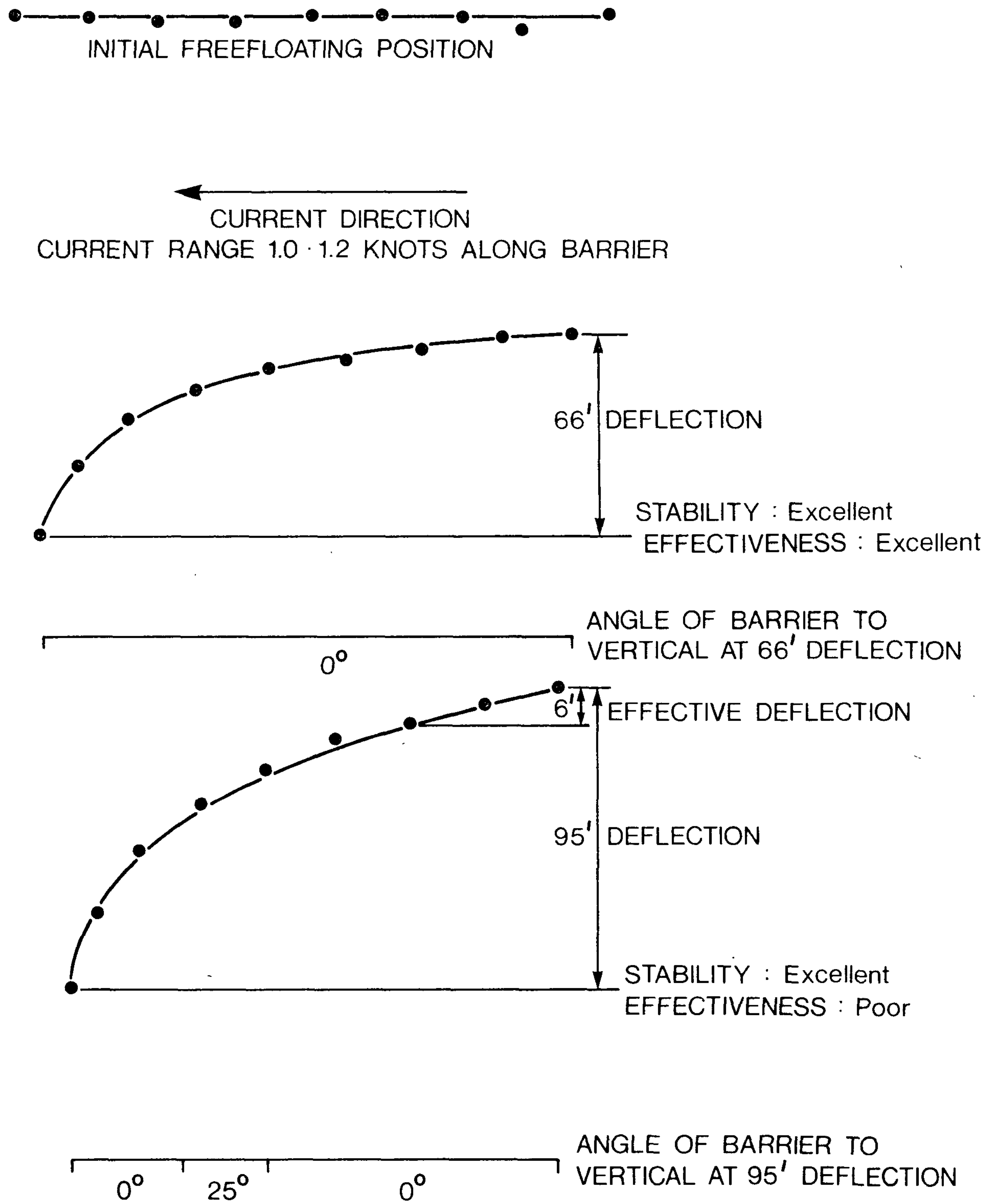
0°

ANGLE OF BARRIER
TO VERTICAL AT
25′ DEFLECTION

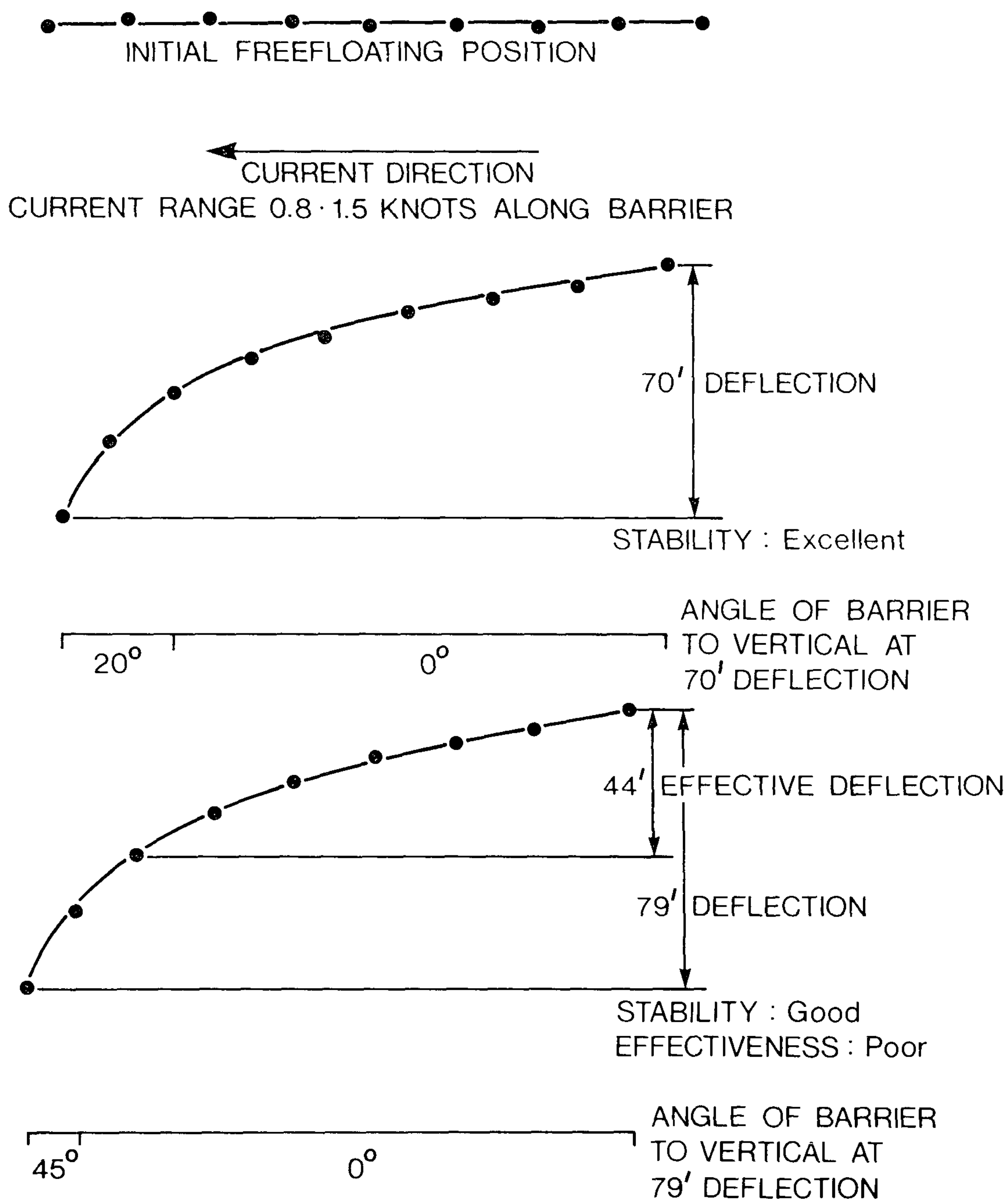
CONFIGURATION OF BENNETT RIVER BOOM, 6" DIAMETER FLOAT, 12" SKIRT AT AMHERSTBURG TEST SITE, JUN 25, 1975



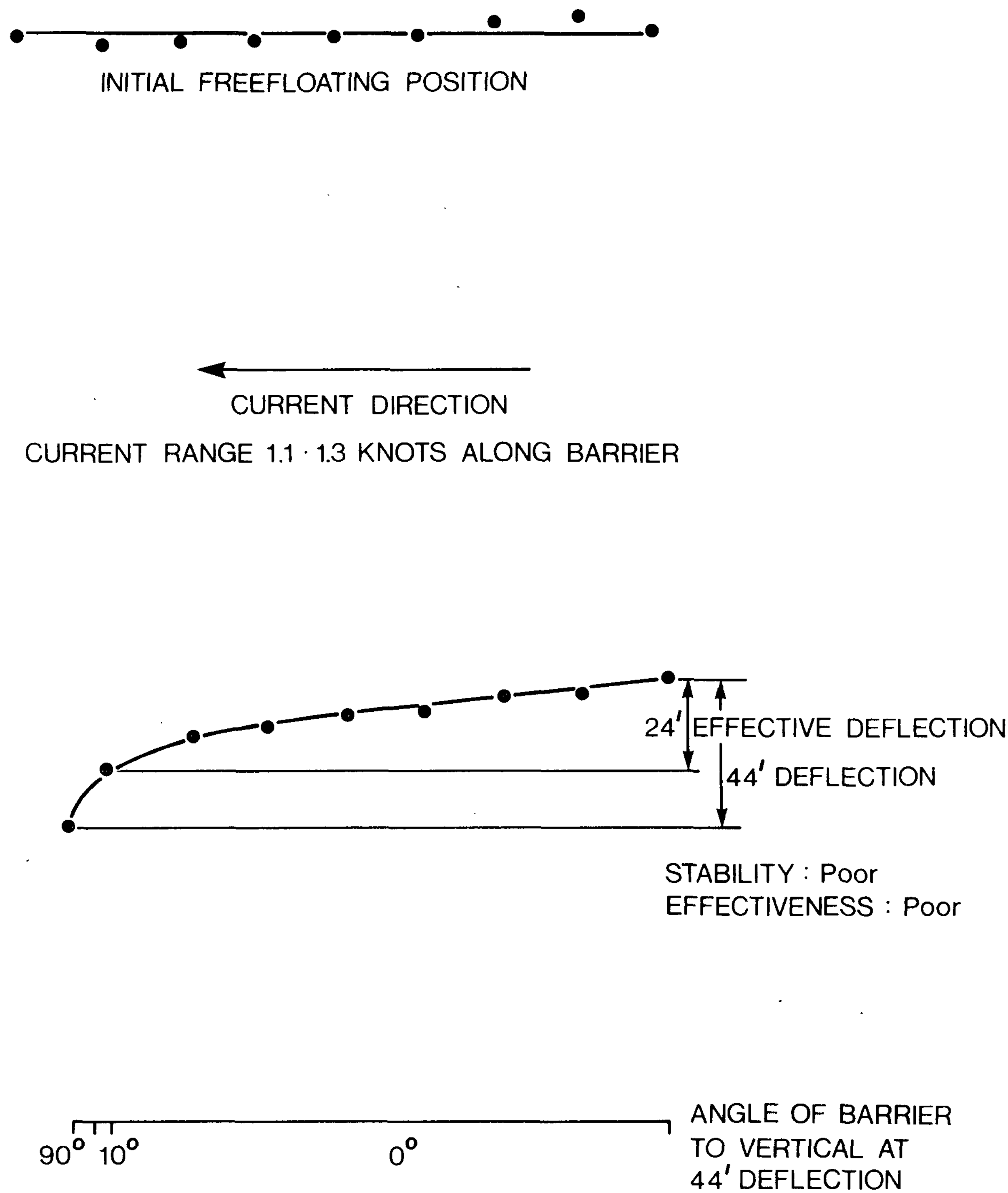
CONFIGURATION OF FLEXY #2 BOOM, 6" FREEBOARD, 12" SKIRT AT AMHERSTBURG TEST SITE, JUN 25, 1975



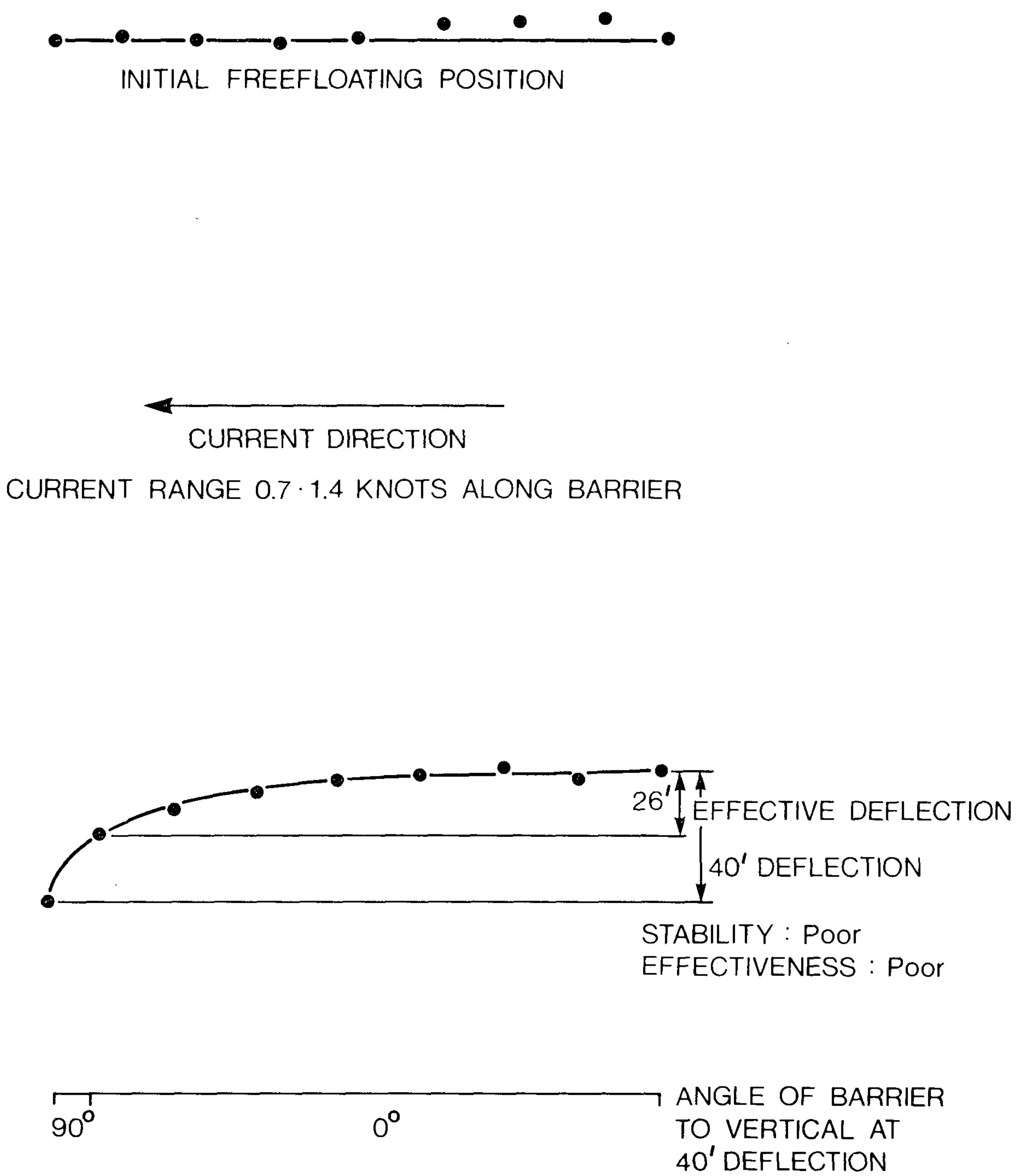
CONFIGURATION OF GOODRICH BOOM, 6" FREEBOARD, 12" SKIRT AT AMHERSTBURG TEST SITE, JUN 26, 1975



CONFIGURATION OF SLICKBAR BOOM, 4" DIAMETER FLOAT 8" SKIRT AT AMHERSTBURG TEST SITE, JUN 24, 1975



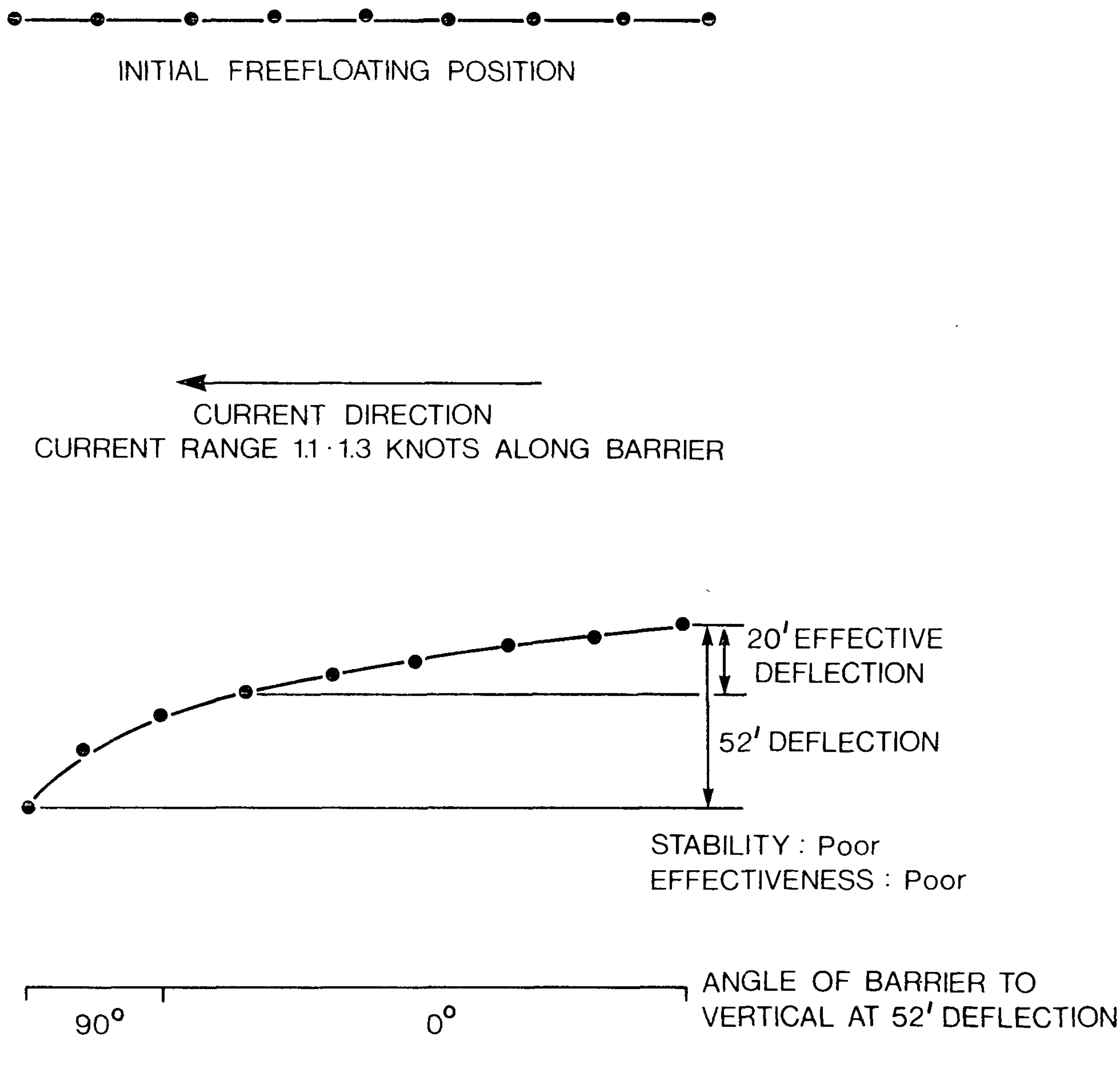
CONFIGURATION OF SLICKBAR BOOM, 6.5" DIAMETER FLOAT, 8" SKIRT, AT AMHERSTBURG TEST SITE, JUN 26, 1975



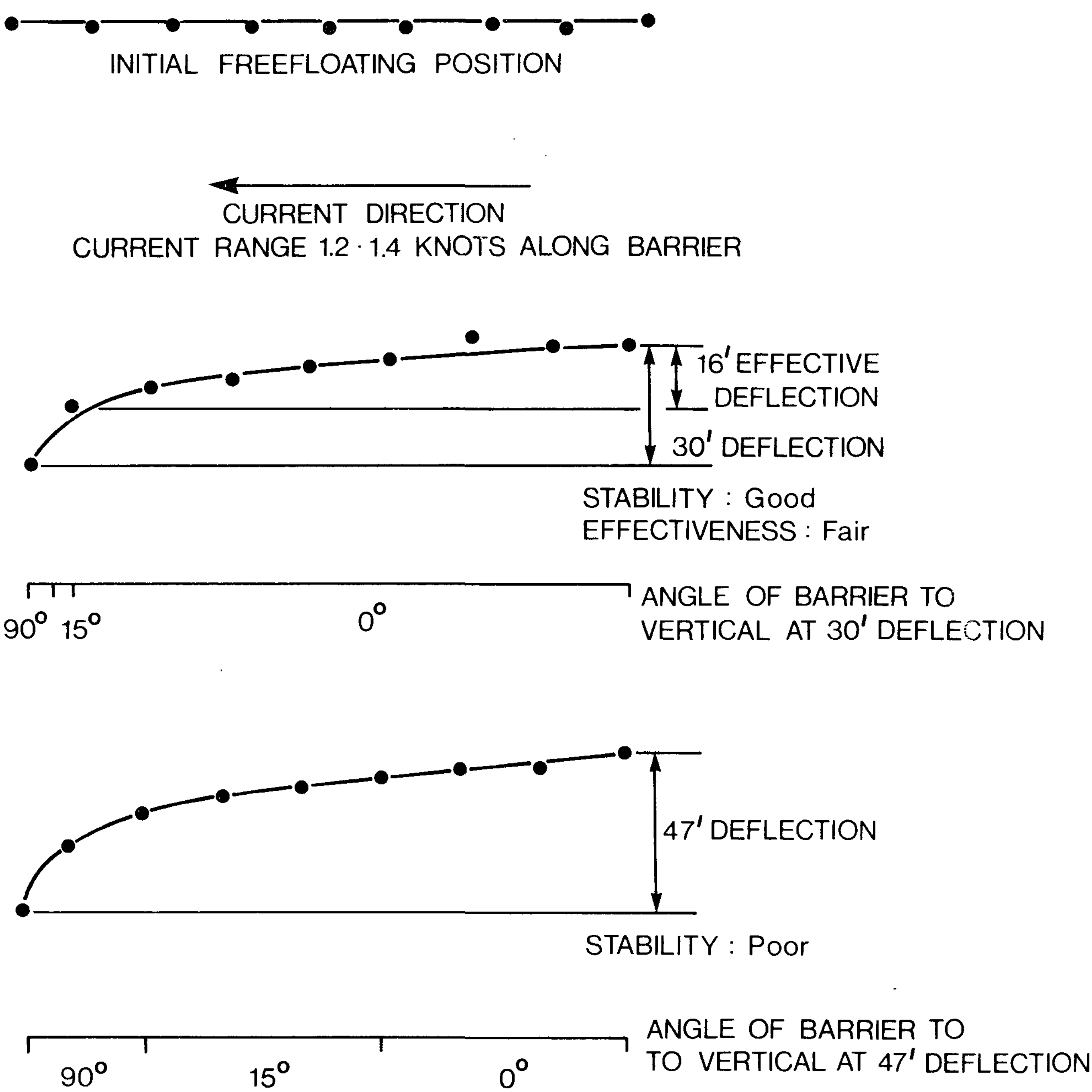
CHENAL ECARTE TEST SITE

July 14-25, 1975

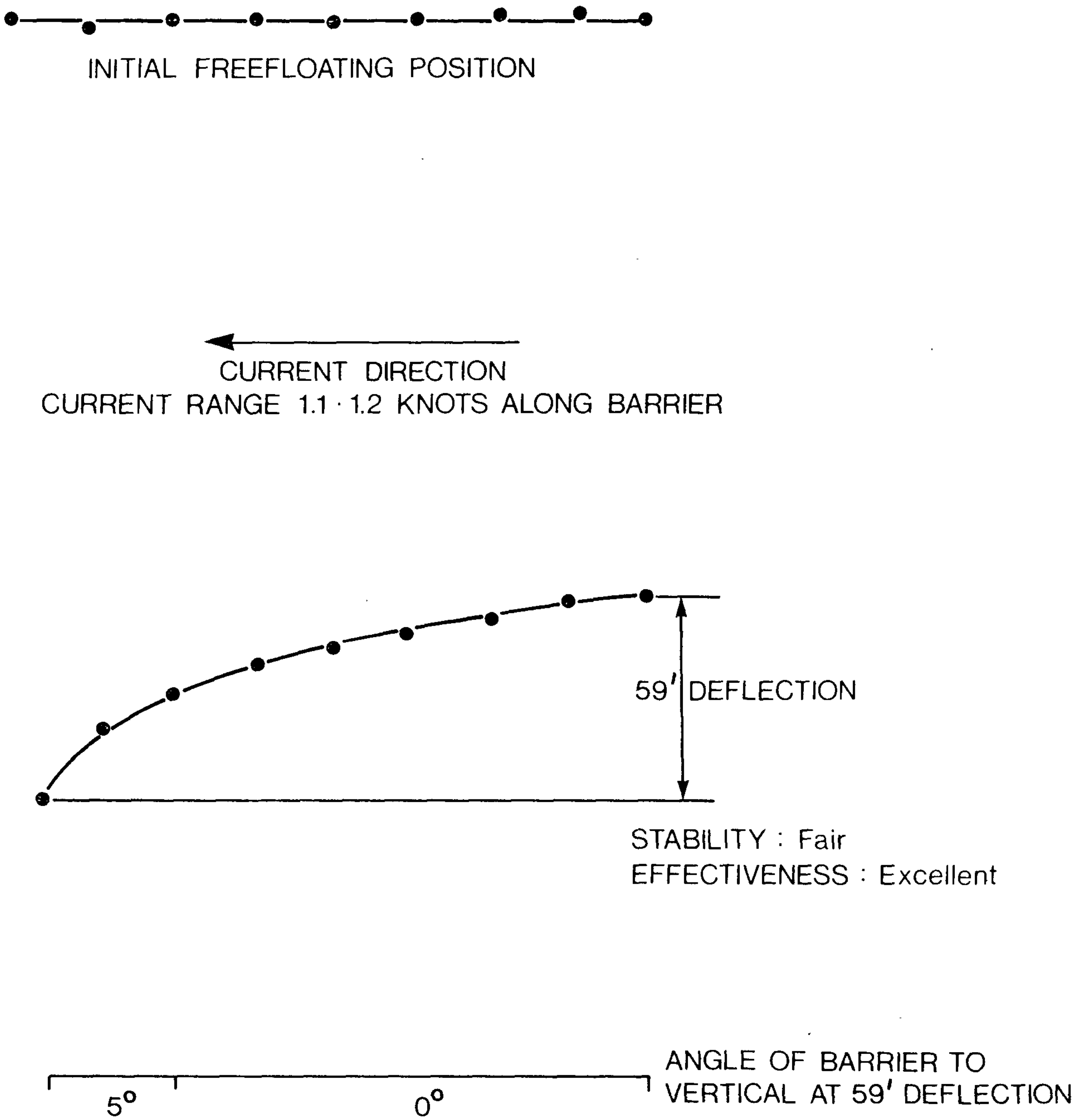
CONFIGURATION OF INSHORE BOOM (BENNETT), 6" FREEBOARD, 12" DRAUGHT AT CHENAL ECARTE TEST SITE, JUL 17, 1975



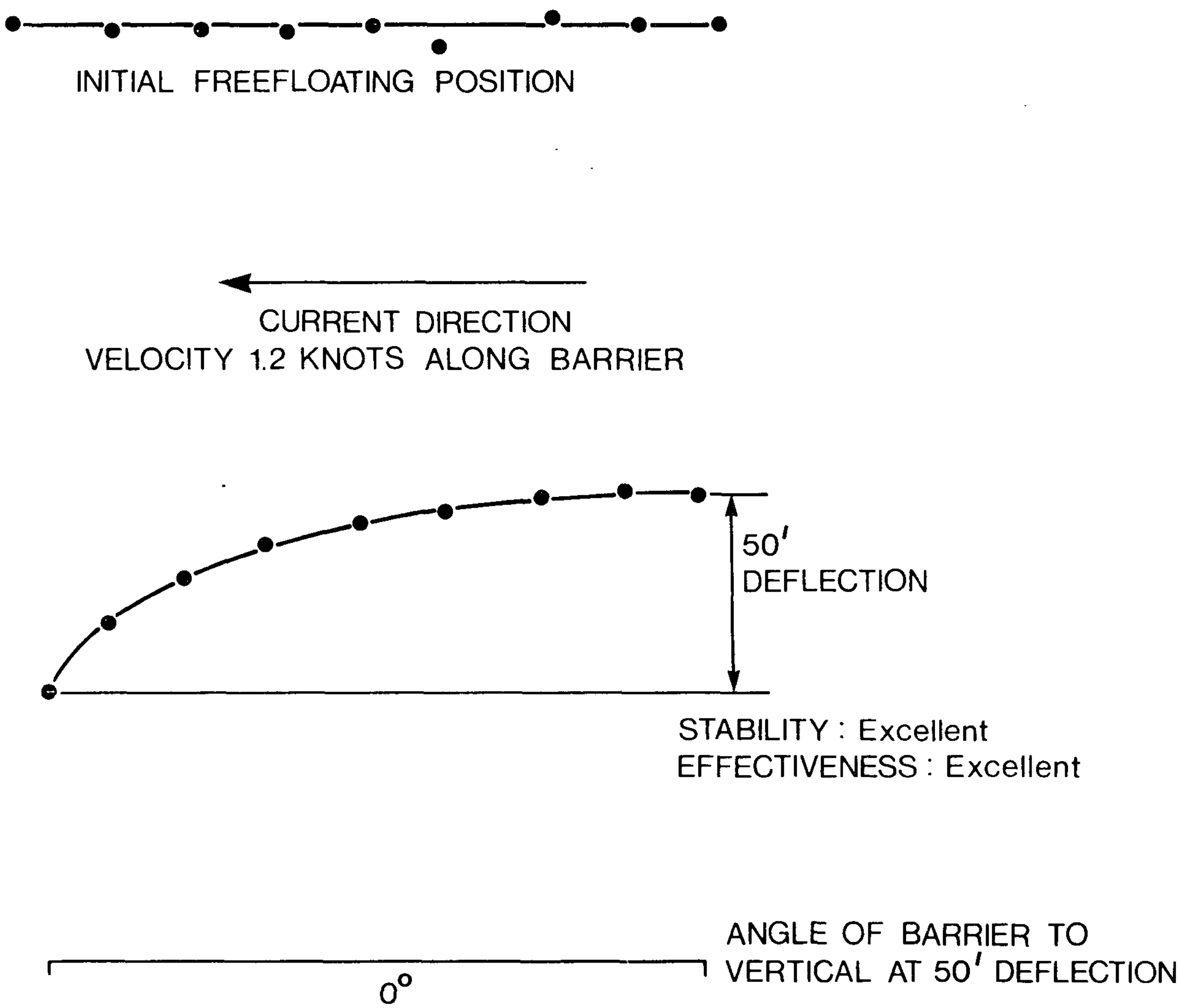
CONFIGURATION OF INSHORE BOOM (BENNETT), 12" FREEBOARD, 24" SKIRT AT CHENAL ECARTE TEST SITE, JUL 21, 1975



CONFIGURATION OF FLEXY #2, 4 $\frac{3}{4}$ FREEBOARD, 9 $\frac{1}{4}$ SKIRT AT CHENAL ECARTE TEST SITE, JUL 15, 1975

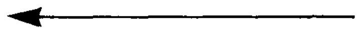


CONFIGURATION OF FLEXY #2, 6" FREEBOARD, 12" SKIRT AT CHENAL ECARTE TEST SITE, JUL 15, 1975

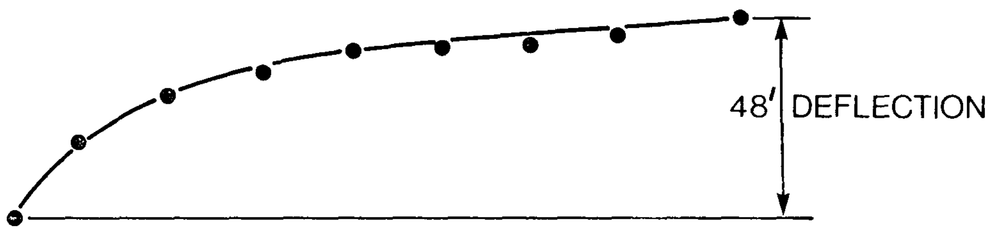


CONFIGURATION OF FLEXY #2, 8" FREEBOARD, 16" SKIRT
AT CHENAL ECARTE TEST SITE, JUL 15, 1975

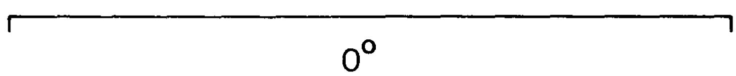
INITIAL FREEFLOATING POSITION



CURRENT DIRECTION
VELOCITY 1.2 KNOTS ALONG BARRIER

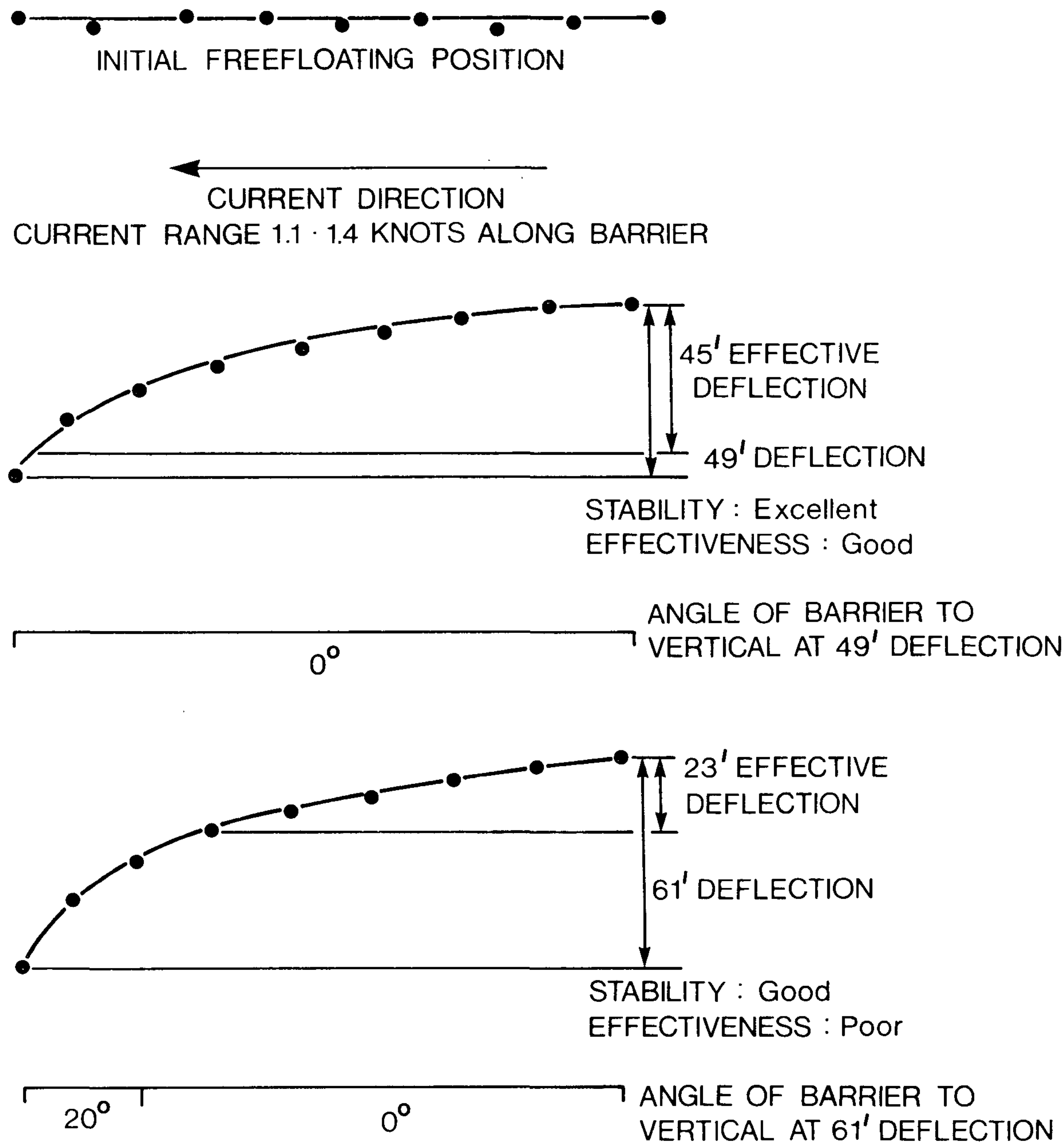


STABILITY : Excellent
EFFECTIVENESS : Excellent

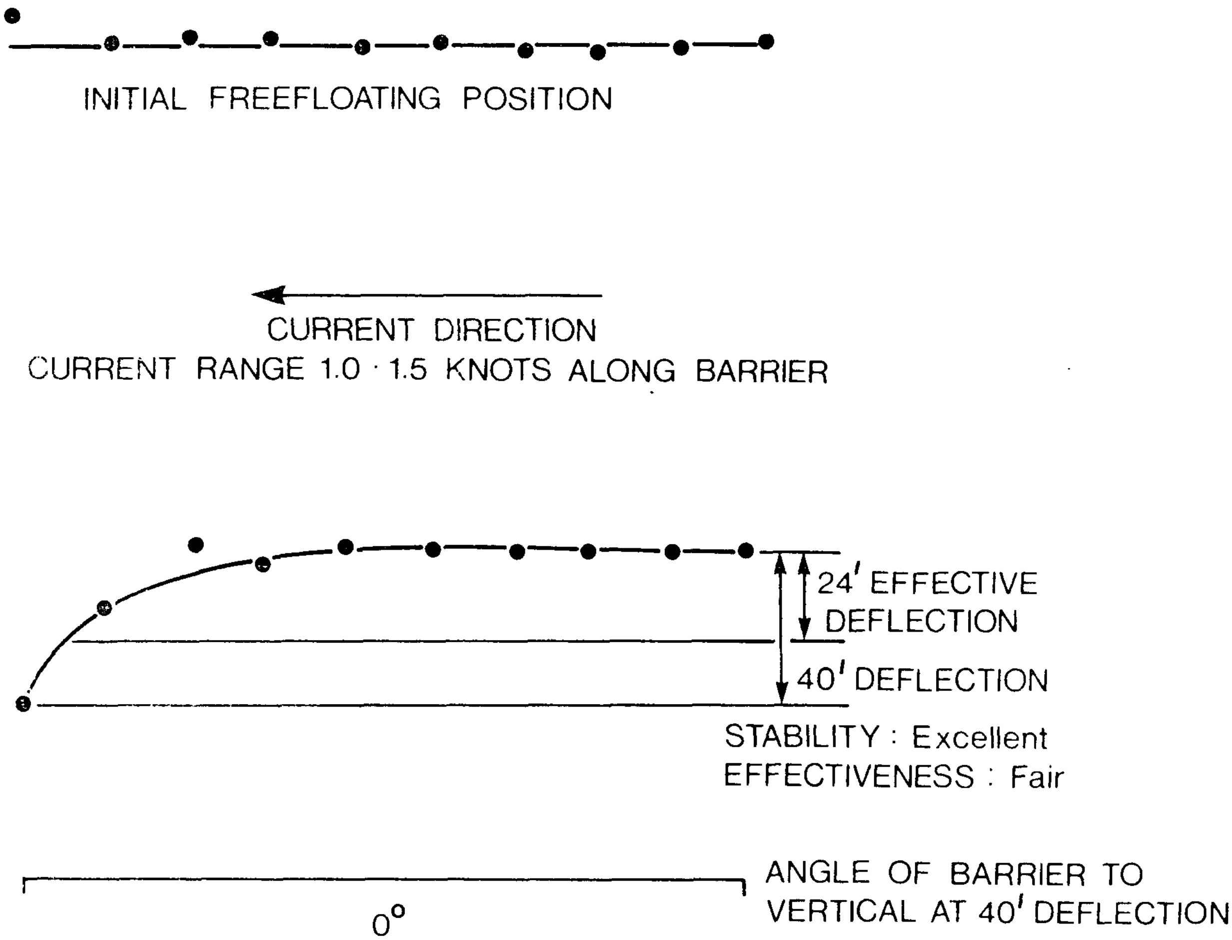


ANGLE OF BARRIER TO
VERTICAL AT 48' DEFLECTION

CONFIGURATION OF GOODRICH BOOM, 6" FREEBOARD, 12" DRAUGHT AT CHENAL ECARTE TEST SITE, JUL 17, 1975



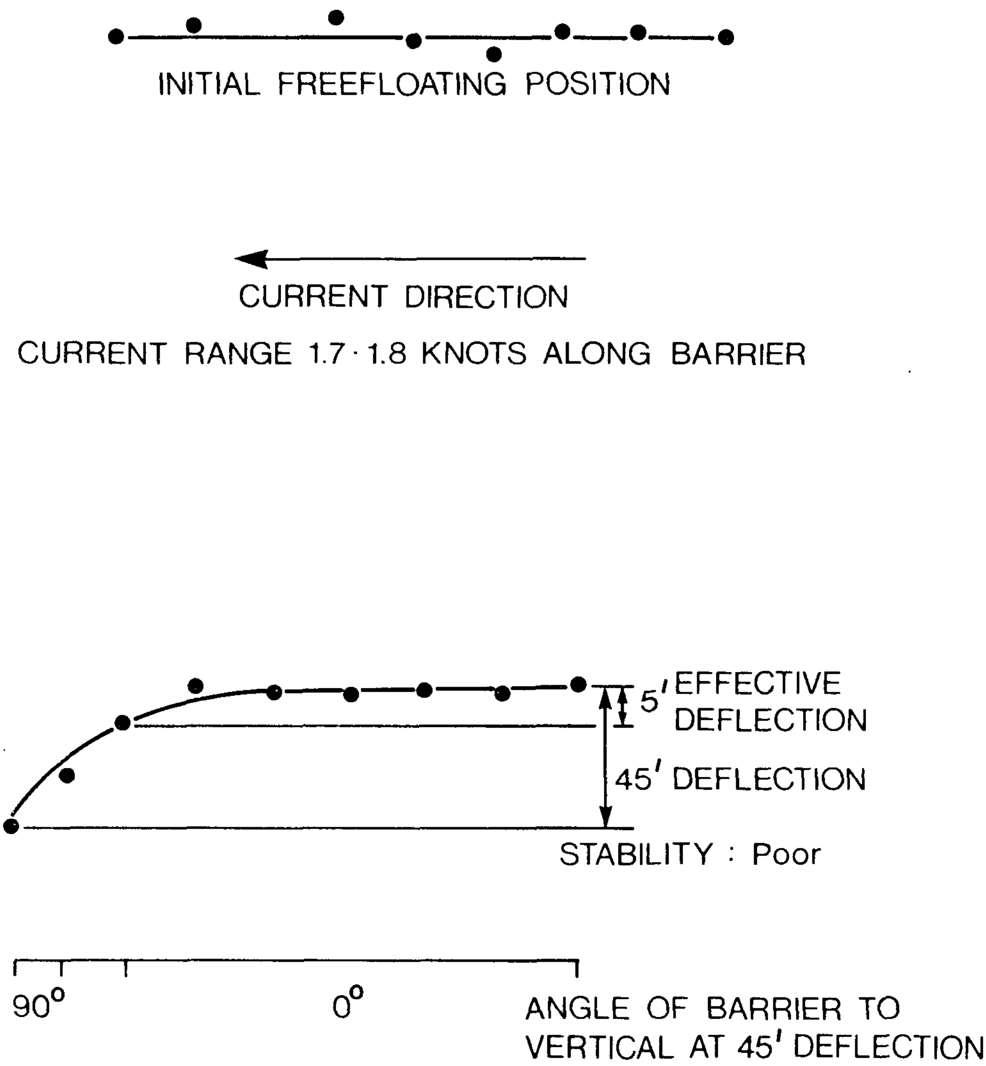
CONFIGURATION OF OPTIMAX BOOM, 6" DIAMETER FLOAT, 18" SKIRT AT CHENAL ECARTE TEST SITE, JULY 23, 1975



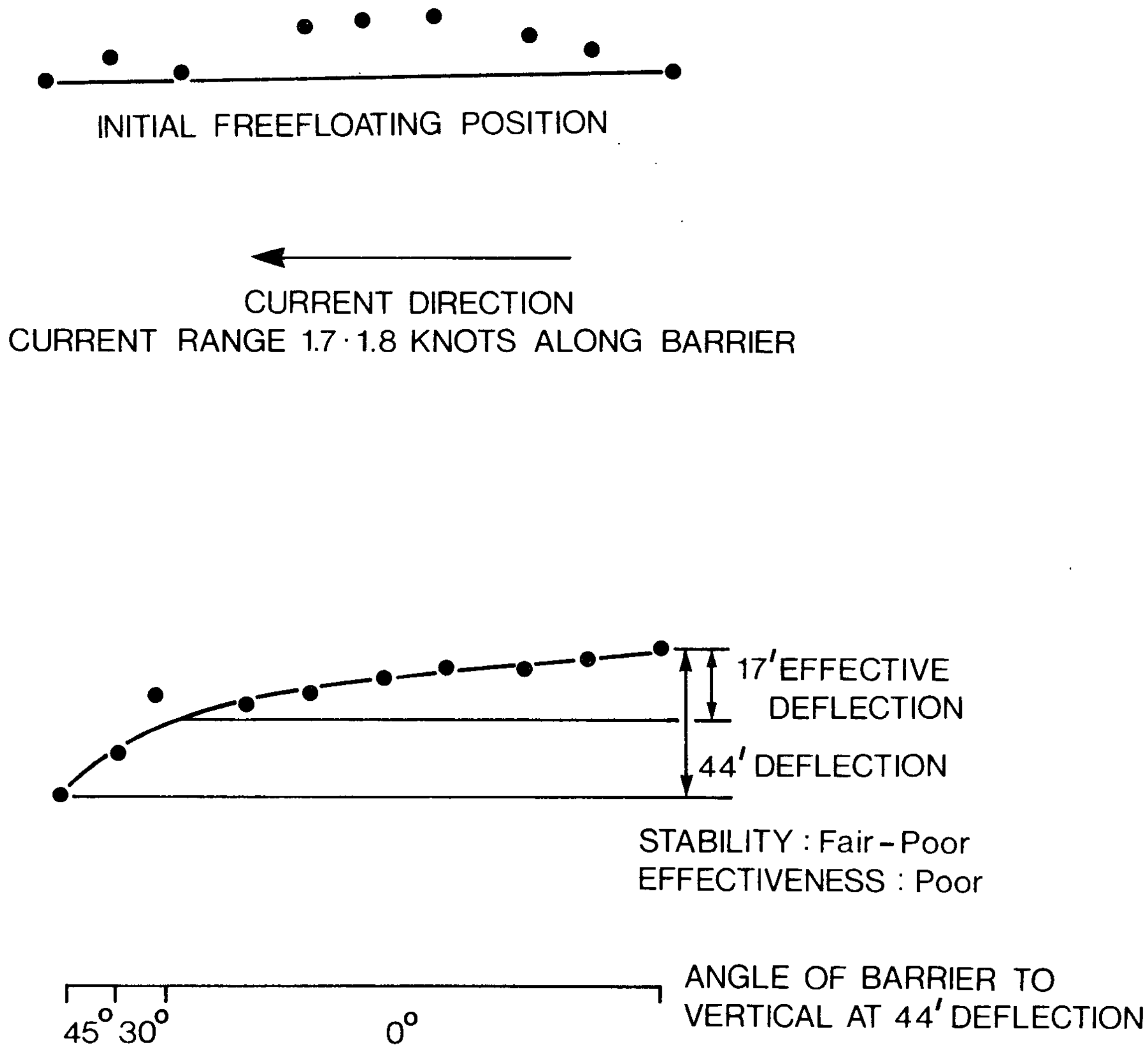
SOMBRA TEST SITE

August 18-22, 1975

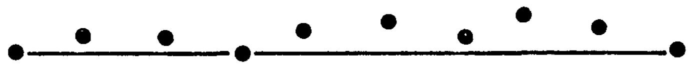
CONFIGURATION OF FLEXY #2, 6″ FREEBOARD, 12″ DRAUGHT AT SOMBRA TEST SITE, AUG 18, 1975



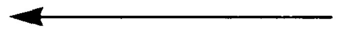
CONFIGURATION OF GOODRICH BOOM, 6" FREEBOARD, 12" DRAUGHT AT SOMBRA TEST SITE, AUG 19, 1975



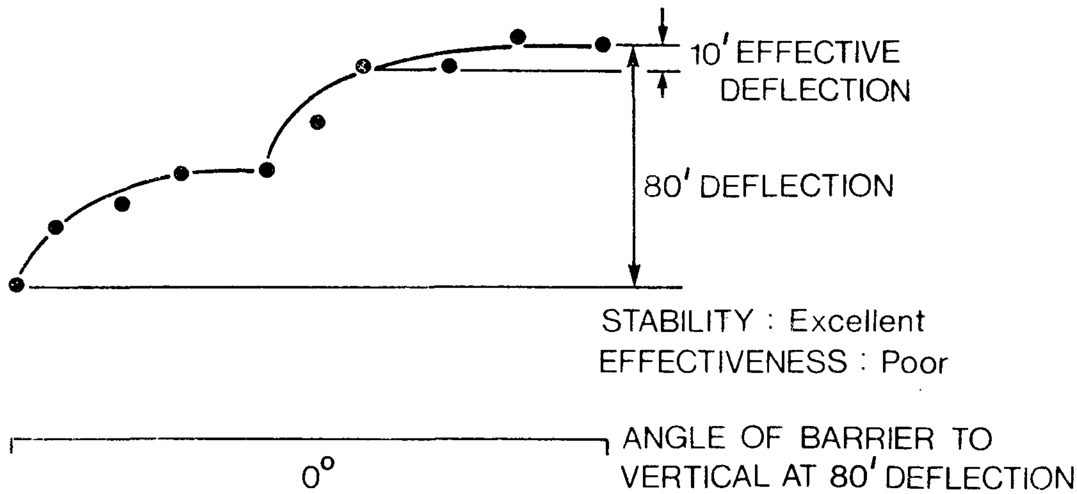
CONFIGURATION OF GOODRICH BOOM (ADDITIONAL ANCHOR POINT) 6" FREEBOARD, 12" DRAUGHT AT SOMBRA TEST SITE, AUG 19, 1975



INITIAL FREEFLOATING POSITION



CURRENT DIRECTION
CURRENT RANGE 1.7 - 1.8 KNOTS ALONG BARRIER

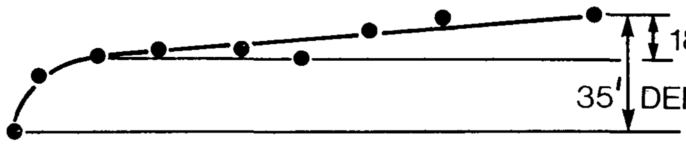


CONFIGURATION OF OPTIMAX BOOM, 7" FREEBOARD, 18" DRAUGHT AT SOMBRA TEST SITE, AUG 18, 1975

INITIAL FREEFLOATING POSITION

CURRENT DIRECTION

CURRENT RANGE 1.7 · 1.8 KNOTS ALONG BARRIER



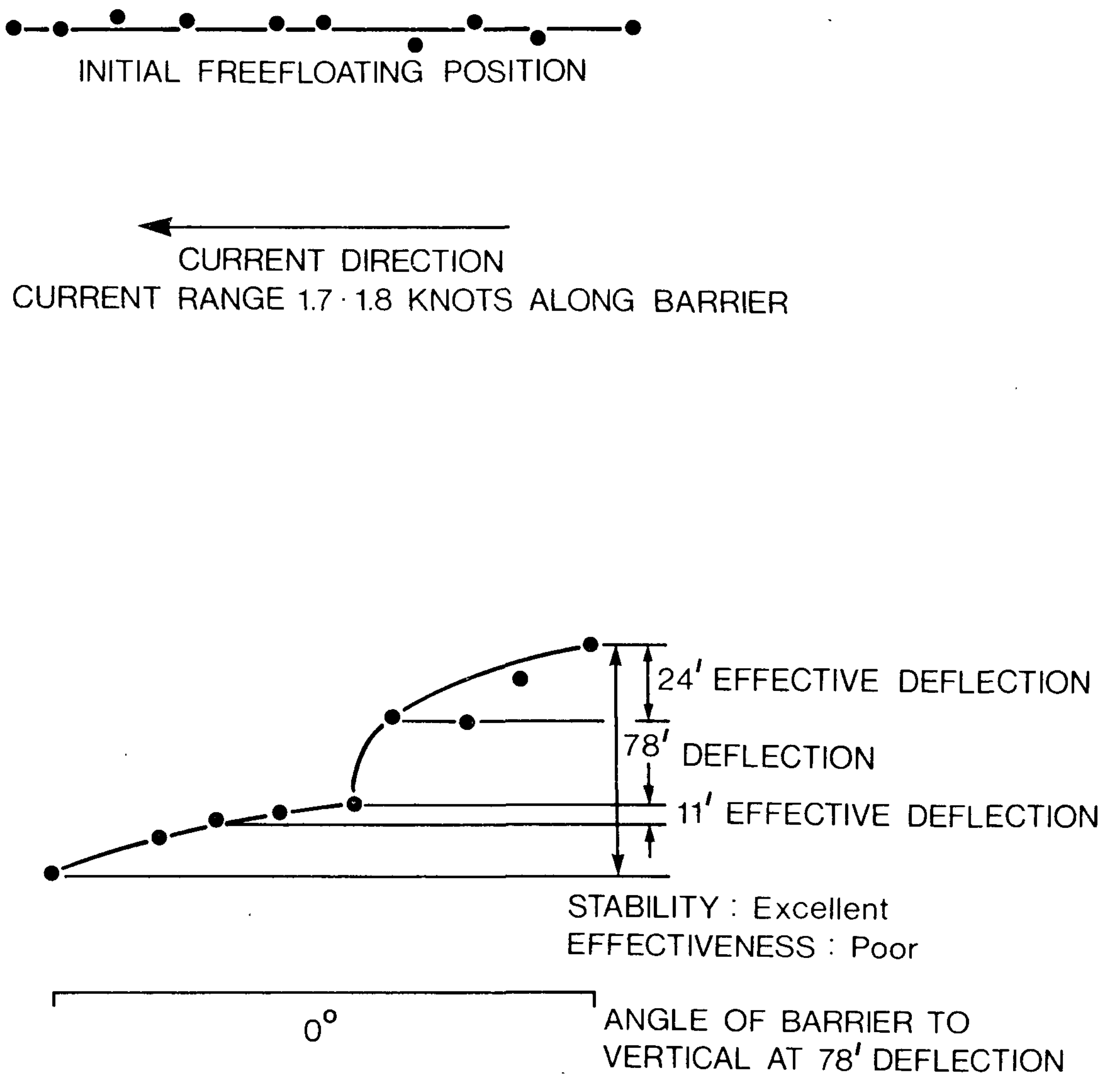
STABILITY : Excellent

EFFECTIVENESS : Poor

0°

ANGLE OF BARRIER TO VERTICAL AT 35' DEFLECTION

CONFIGURATION OF OPTIMAX BOOM (ADDITIONAL ANCHOR POINT) 7" FREEBOARD , 18" DRAUGHT AT SOMBRA TEST SITE , AUG 19 , 1975



APPENDIX A.5

CURRENT SURVEY

A.5 Current Survey

The results of the current data collected during the programme are summarized on the diagrams shown in figure A9, A10, and A11. The measurement program was designed to provide baseline current data for each site in order to determine flow patterns. Readings were taken at the face of the barrier to provide additional information on the effect of the currents on the barriers during the testing programme.

The detailed data for the current survey are presented in an unpublished manuscript "St. Clair River Current Survey, 1975 Data Report" written by W.P. Budgell of the Marine Sciences Directorate of Environment Canada.

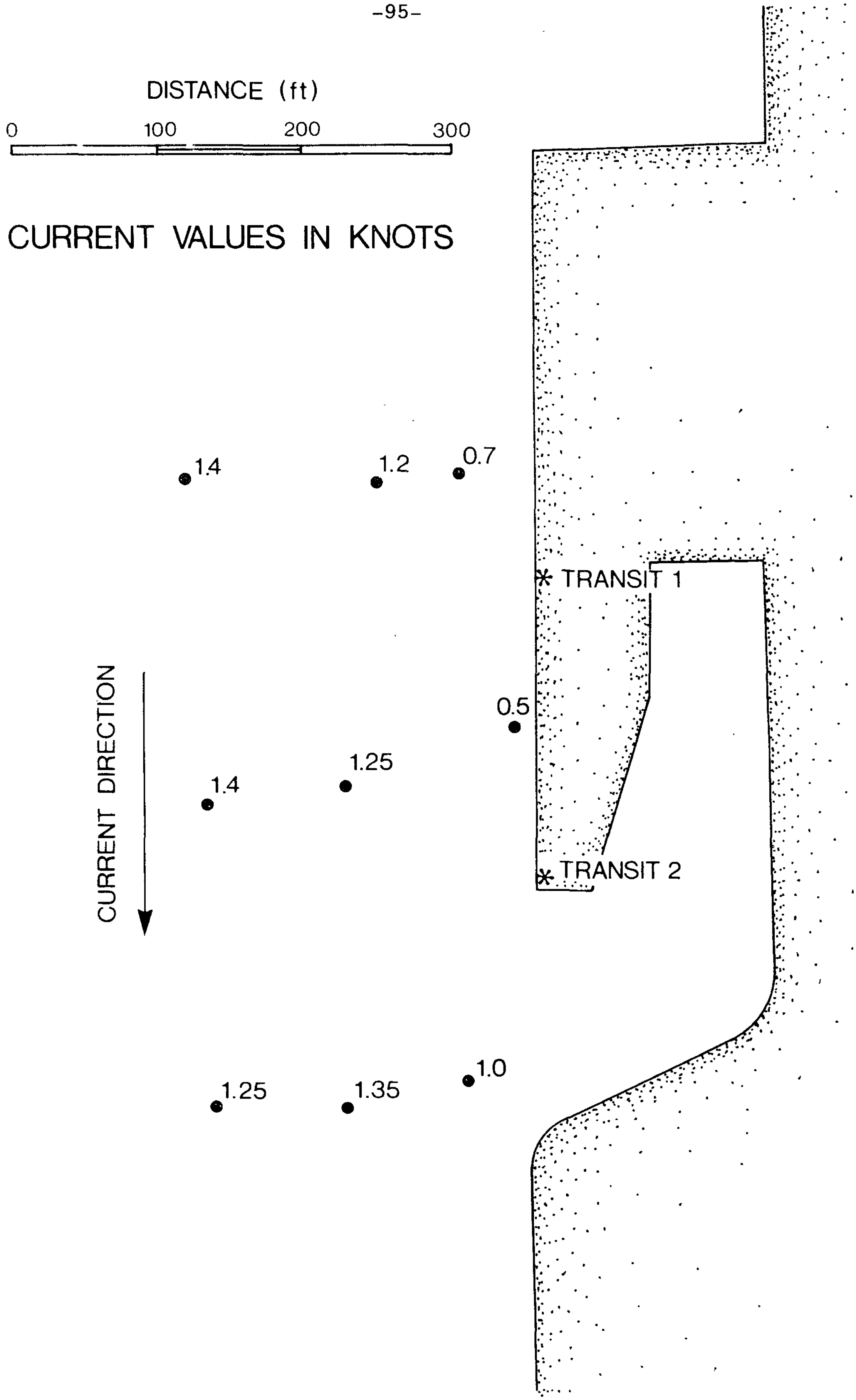


FIGURE A9. AMHERSTBURG TEST SITE

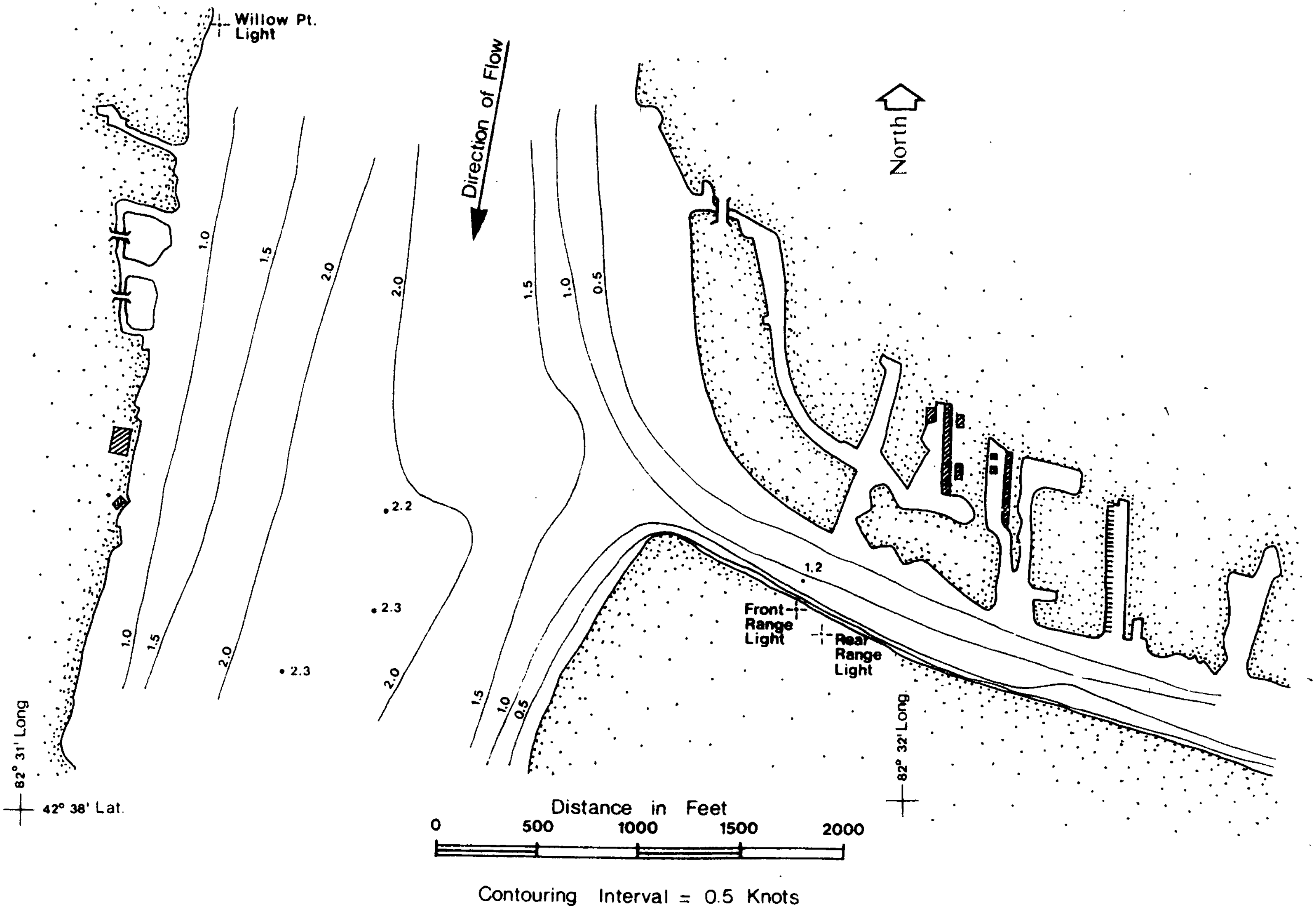
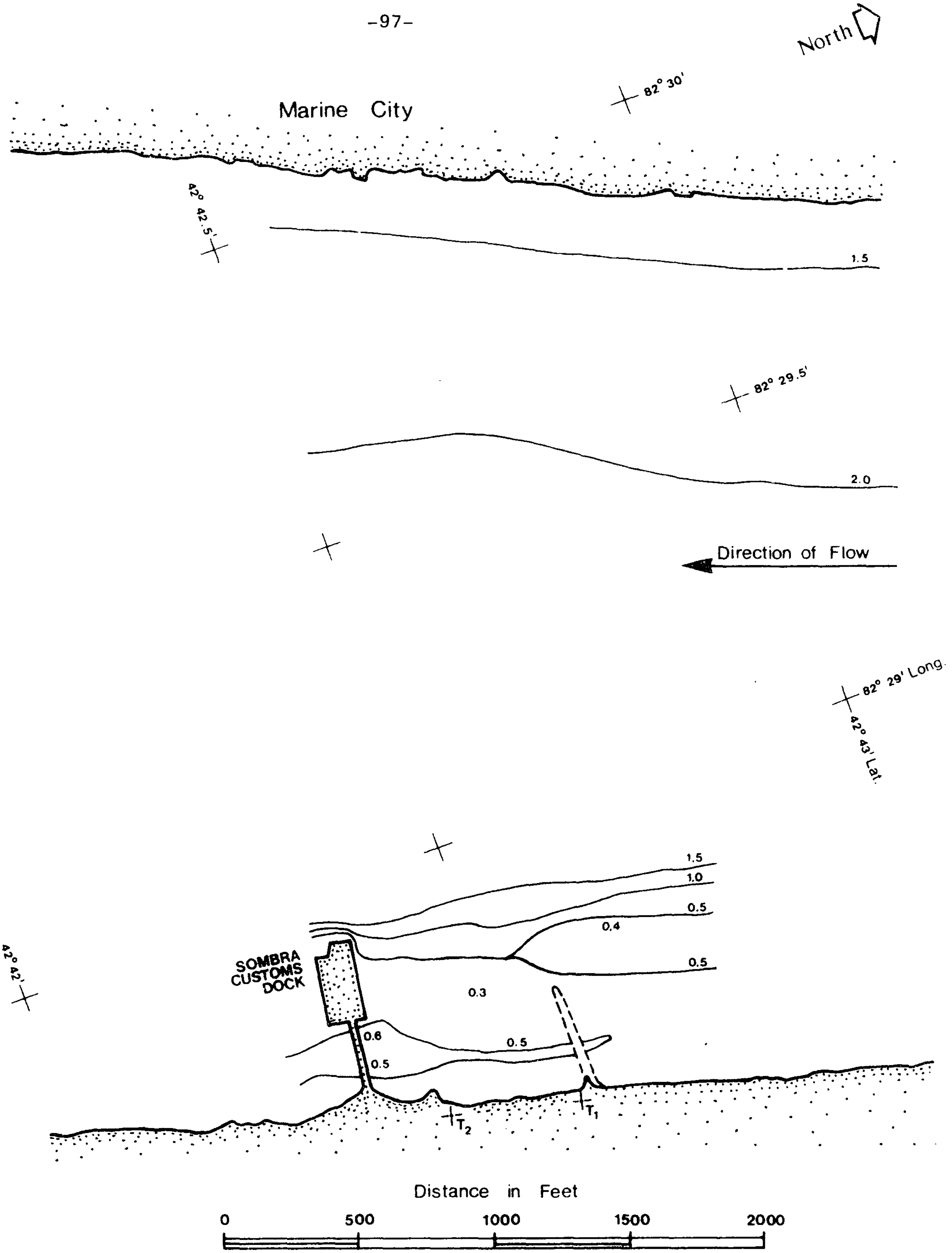


Fig. A10 - SURFACE CURRENT DISTRIBUTION AT CHENAL ECARTE



T_1 and T_2 are Transit Positions
Contouring Interval = 0.5 Knots

Fig. A11 - SURFACE CURRENT DISTRIBUTION AT SOMBRA