STATE OF CALIFORNIA—THE RESOURCES AGENCY GRAY DAVIS, *GOVERNOR*

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STAFF REPORT AND RECOMMENDATION

ON CONSISTENCY DETERMINATION

Consistency Determination No.	CD-89-00
Staff:	LJS-SF
File Date:	8/14/2000
45th Day:	9/28/2000
60th Day:	10/13/2000
Commission Meeting:	9/14/2000

FEDERAL AGENCY: **U.S. Navy**

DEVELOPMENT LOCATION: Horse Beach Cove, San Clemente Island, Los Angeles County **(Exhibits 1 and 2)**.

DEVELOPMENT DESCRIPTION: A one day operational evaluation of the Distributed Explosive Technology (DET) system, designed to clear underwater mines and obstacles in the surf zone to water depths of three feet in support of naval amphibious landing operations. The DET system consists of a 180 foot by 180 foot netting constructed of detonating cord and lateral strength members. The DET system is launched from a Landing Craft Air Cushion (LCAC) amphibious vehicle into the surf zone. Four operational tests of the DET system are proposed in Horse Beach Cove, one of the Navy's primary live fire gunnery ranges on San Clemente Island.

EXECUTIVE SUMMARY

The Navy has submitted a consistency determination for a one day operational test in late October 2000 of the Distributed Explosive Technology (DET) system, designed to clear underwater mines and obstacles in the surf zone to water depths of three feet in support of naval amphibious landing operations. The DET system consists of a 180 foot by 180 foot netting constructed of detonating cord and lateral strength members. The DET system is launched from a Landing Craft Air Cushion (LCAC) amphibious vehicle into the surf zone. Four operational tests of the DET system are proposed in Horse Beach Cove, one of the Navy's primary live fire gunnery ranges on San Clemente Island. The timing, short duration, and mitigation and monitoring measures built into the project will ensure protection of upland and marine habitat and resources, particularly Western snowy plovers and marine mammals, from potential explosive and sound effects at the test site. These measures include prohibiting any test activities until the project hazard area is clear of all marine mammals, and provisions for dedicated fire fighting equipment to minimize potential for accidental wildfire effects on upland habitat. The project is consistent with the marine resources and environmentally sensitive habitat policies of the California Coastal Management Program (CCMP; Sections 30230, 30231, 30240, and 30253 of the Coastal Act). The area offshore of Horse Beach Cove is open to public recreational use and is a popular diving and fishing area. Impacts to public access and recreation will be minor and temporary in nature as the test area at Horse Beach Cove will only be closed to the public during the one day of DET testing in late October. The project is consistent with the access and recreation policies of the CCMP (Sections 30210, 30211, 30212(a), 30213, 30220, 30234.5 of the Coastal Act).

STAFF SUMMARY AND RECOMMENDATION:

I. Project Description.

The Navy proposes to conduct four operational tests of the Distributed Explosive Technology (DET) array on San Clemente Island (Exhibits 1 and 2). The Navy states that it has an urgent need for a better method to clear mines in the surf zone in preparation for amphibious landing operations. The DET system is a shallow-water mine countermeasure system for waters 0-3 feet deep, and is a 180 foot by 180 foot net array made of robust detonating cord plus lateral strength members. The net is deployed from a Landing Craft Air Cushion (LCAC) amphibious vehicle by two small rockets of a type used by the Navy since 1984. The operational evaluation would consist of testing four DET systems, the number the Navy calculates is necessary to clear the required 150-foot-wide lane to the beach. All would be fully live, each with 2,016 pounds of explosives. The DET target area is 300 feet wide by 450 feet long. In addition, since portions of the DET system land on the beach, a beach area 100 feet inland from the high tide line is necessary. This additional beach area is where the expended rockets and the non-explosive front harness of the DET system land after deployment from the LCAC. Exhibits 3-5 illustrate the features and deployment of the DET system. The proposed test day is scheduled for late October 2000. Approximately ten days will be needed to prepare, setup, rehearse, and clean up; the actual tests will last less than one hour. The tests will occur at Horse Beach Cove on the southern shore of San Clemente Island, within the Shore Bombardment Area which has served as the Navy's live fire gunnery range since the 1930s. The Navy examined several alternate locations for the proposed test, including China Cove on San Clemente Island, San Nicolas Island, Camp Pendleton, and sites in Hawaii and the United Kingdom. The Navy determined that Horse Beach Cove was the only location that met all seven criteria necessary to undertake the test.

II. Status of Local Coastal Program.

The standard of review for federal consistency determinations is the policies of Chapter of the Coastal Act, and not the Local Coastal Program (LCP) of the affected area. If the LCP has been certified by the Commission and incorporated into the CCMP, it can provide guidance in applying Chapter 3 policies in light of local circumstances. If the LCP has not been incorporated into the CCMP, it cannot be used to guide the Commission's decision, but it can be used as background information. The County of Los Angeles LCP has not been certified by the Commission.

III. Federal Agency's Consistency Determination.

The Navy has determined the project consistent to the maximum extent practicable with the California Coastal Management Program.

IV. Staff Recommendation. The staff recommends that the Commission adopt the following motion:

MOTION: **I move that the Commission agree with consistency determination CD-89-00 that the project described therein is fully consistent, and thus is consistent to the maximum extent practicable, with the enforceable policies of the California Coastal Management Program (CCMP).**

STAFF RECOMMENDATION:

*Staff recommends a **YES** vote on the motion. Passage of this motion will result in an agreement with the determination and adoption of the following resolution and findings. An affirmative vote of a majority of the Commissioners present is required to pass the motion.*

RESOLUTION TO AGREE WITH CONSISTENCY DETERMINATION:

*The Commission hereby **agrees** with consistency determination CD-89-00 by the U.S. Navy, on the grounds that the project described therein is fully consistent, and thus is consistent to the maximum extent practicable, with the enforceable policies of the CCMP.*

V. Findings and Declarations.

The Commission finds and declares as follows:

A. Marine Resources.

The Coastal Act provides the following:

Section 30230

Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.

Section 30231

The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of ground water supplies and substantial interference with surface water flow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of natural streams.

The Navy's Environmental Assessment (EA) evaluates in detail the potential environmental impacts on marine resources associated with the DET tests. A summary of these potential impacts is provided in Exhibit 6. Marine resources of concern in and adjacent to Horse Beach Cove are water quality, kelp, invertebrates, fish, sea turtles, and marine mammals. San Clemente Island is not a concentration area or destination for sea turtles, and green turtles would be the only species that could be routinely encountered in nearshore waters around the island. Seven species of cetaceans have been observed during NMFS aerial surveys within the boundaries of the study area in low or moderate numbers and include four species of dolphins, and gray, fin, and blue whales. Short-beaked common dolphins would be the most abundant species in the nearshore waters during the test period. Six species of pinnipeds may occur near San Clemente Island, with three recorded in the study area. The EA reported that juvenile California sea lions will be the most common pinniped found in the nearshore waters of the study area during the DET test period, and that perhaps as few as ten sea lions might be hauled out on the shoreline during the late October period. Similarly small numbers of harbor seals and northern elephant seals are expected to be present in Horse Beach Cove in late October. Finally, the EA reports that a maximum of four southern sea otters will be found within the study area during the test period, most likely on the margins of kelp beds and resting at the water's surface during the midday test.

The products of the underwater explosions of the DET arrays are primarily nitrogen, carbon dioxide, water, and oxygen; these elements occur naturally in seawater and will cause no adverse effects on water quality. The explosions will also produce hydrogen chloride and small amounts of hydrogen cyanide; both compounds will be diluted and buffered rapidly by seawater and are expected to pose no long term effect on water quality in Horse Beach Cove. The EA states that while the four DET tests will certainly lead to some loss of marine plant life, invertebrates, and fish in Horse Beach Cove, these losses will be localized within the cove and represent only a minor effect on total populations in and adjacent to the project area.

Extensive analysis was provided in the EA on the potential impact of the DET tests on any marine mammals that may be present in the project area, and in particular the effects of explosion sounds and shock waves that may cause physical injury, death, or auditory system injury (Exhibit 9). The potential impact is primarily from the noise of the explosion since water transmits sound much more efficiently than air. Underwater explosions can kill or injure marine mammals through direct physical effects. Also, marine mammals exposed to strong sounds can experience temporary reduction in hearing sensitivity (Temporary Threshold Shift, or TTS), which can last from minutes to hours to days. The EA summarized that the blast energy from charges detonated off the beach in Horse Beach Cove holds the potential to cause harassment, injury, or death to marine mammals in the cove. Harassment is defined as the onset of TTS. Modeling for the proposed activity showed that the distance to the TTS threshold (which the Navy defines as 182 decibels (dB) [water reference standard] in any 1/3-octave band, and which the Navy states was accepted by NMFS for the Seawolf Shipshock test) would not exceed 500 meters. However due to the complexities caused by both the shallow water environment, and the fact that the explosions would not be typical "point" sources, the Navy acknowledges that the models are not reliable for areas less than 650 meters (720 yards) for the DET test (equal to an area of 0.1 square miles in Horse Beach Cove). The Navy has therefore set the distance for temporary and permanent auditory damage to marine mammals at 650 meters (720 yards) outward from the point of explosion for the DET test (Exhibit 7). The fact that the Navy assumes a TTS at 182 dB, whereas the Commission has generally relied on a 180 dB TTS for pulsed sound, is overshadowed by the fact that the Navy is using its larger model limitation distance (650 m) rather than the area within which a TTS would normally be expected (500 m). In addition, the Navy will verify the acoustic model with near-field and far-field acoustic monitoring.

Thus, while Navy notes that there is normally a low density of marine mammals in the project area, the Navy has nevertheless included in the project a marine mammal avoidance strategy to ensure that no marine mammals are within the Zone of Harassment during the tests. The Navy will establish a safety zone extending 720 yards seaward from the test site to ensure that there are no marine mammals present during each test. Qualified marine mammal observers will conduct a 60-minute pre-detonation aerial monitoring survey (at approximately 100 feet altitude) prior to each test to ensure that no marine mammals or sea turtles are visible within the test area's safety zone. The area will be surveyed several times prior to the test to ensure that mammals that might be below the surface during one survey are detected. In order to ensure that the mitigation is effective, the DET test will not take place if Beaufort sea state conditions are greater than category 3. Additionally, a boat survey of the area will be conducted 20 minutes prior to the scheduled test. This survey method will primarily be used to detect sea turtles. DET tests will be postponed if marine mammals or sea turtles are sighted within the safety zone. These tests will

These tests will resume when two consecutive aerial surveys, conducted at hourly intervals following the initial sighting, no longer indicate that any marine mammals or sea turtles are present.

The Commission agrees with the Navy that the proposed activity is not likely to generate significant adverse effects on marine resources. The timing, short duration, and mitigation measures built into the project will protect sensitive habitats and species, particularly marine mammals that may frequent the test area. The Commission finds that the proposed DET system test at San Clemente Island is consistent with the marine resource policies of the CCMP (Section 30230 and 30231 of the Coastal Act).

B. Environmentally Sensitive Habitat.

The Coastal Act provides the following:

Section 30240

(a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas.

(b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.

Section 30253

New development shall:

(1) Minimize risks to life and property in areas of high geologic, flood, and fire hazard. . . .

The proposed DET test will occur in the very shallow waters offshore of Horse Beach Cove and on a small portion of the sandy beach. However, a small potential does exist for adverse effects on upland sensitive habitat and species from the proposed activity. The consistency determination states that:

The Proposed Action would have a less than significant impact on sensitive habitat areas. While the island is home to ten threatened or endangered species, the navy has an active program in place to ensure preservation of the habitat of these plants and animals. Only two of these species have the potential to be affected by the test: the San Clemente Loggerhead Shrike and the Western Snowy Plover. The nearest nesting area of the shrike is over 1.2 nautical miles distant from the potential test area. The Navy has entered into informal consultation with the U.S. Fish and Wildlife Service regarding the potential impact of the *proposed test. In addition, pre-test nest surveys will be accomplished for any presence of Western Snowy Plover nests in the vicinity of the test site on the beach. The test will be delayed if nests are found during the nest surveys.*

The U.S. Fish and Wildlife Service, in its letter dated August 2, 2000, concurred with the Navy's conclusion that the proposed activity is not likely to adversely affect listed species on San Clemente Island and agreed that formal consultation under Section 7 of the Endangered Species Act is not required (Exhibit 8). The USFWS reached this conclusion based on: (1) avoidance of the nesting season; (2) the short duration and temporary nature of the proposed action; and (3) the low occurrence of snowy plovers during winter months. In addition, the Service stated that the proposed "herding" of snowy plovers detected prior to detonation further reduces the likelihood of harm from deployment of the detonation net, and noted that dedicated fire fighting equipment will be on call for response to any fire caused by the testing in order to minimize potential for wildfire effects on terrestrial listed species and their habitat.

The Commission agrees with the Navy and the U.S. Fish and Wildlife Service that the proposed activity is not likely to affect environmentally sensitive habitat or the listed species that use such habitat. The timing, short duration, and mitigation measures built into the project will protect sensitive habitat. The Commission finds that the proposed DET system test at San Clemente Island is consistent with the environmentally sensitive habitat policies of the CCMP (Section 30240 and 30253 of the Coastal Act).

C. Public Access and Recreation.

The Coastal Act provides the following:

Section 30210

In carrying out the requirement of Section 4 of Article X of the California Constitution, maximum access, which shall be conspicuously posted, and recreational opportunities shall be provided for all the people consistent with public safety needs and the need to protect public rights, rights of private property owners, and natural resource areas from overuse.

Section 30211

Development shall not interfere with the public's right of access to the sea where acquired through use or legislative authorization, including, but not limited to, the use of dry sand and rocky coastal beaches to the first line of terrestrial vegetation.

Section 30212

(a) Public access from the nearest public roadway to the shoreline and along the coast shall be provided in new development projects except where:

(1) It is inconsistent with public safety, military security needs, or the protection of fragile coastal resources. . . .

Section 30213

Lower cost visitor and recreational facilities shall be protected, encouraged, and, where feasible, provided. Developments providing public recreational opportunities are preferred. . . .

Section 30220

Coastal areas suited for water-oriented recreational activities that cannot be readily provided at inland water areas shall be protected for such uses.

Section 30234.5

The economic, commercial, and recreational importance of fishing activities shall be recognized and protected.

The Navy states that the proposed test location was selected to minimize interference with public use of adjacent coastal waters and that the temporary closure will last less than one day. The adjacent waters are popular sites for diving and commercial and recreational fishing. The consistency determination states that:

San Clemente Island is Federal property and access to the island is restricted to those on official business and approved by the Navy on a case-by-case basis. The test area is within three well-publicized safety warning and restricted areas. The first is Warning Area 291 (W-291), a FAA-approved special use airspace designated for hazardous activities. The second is the Shore Bombardment Area (SHOBA) which covers the southern third of San Clemente Island. This area is designated a Navy gunnery range meeting training regulations and land use plans, and has consistently been used for this purpose since the 1930s. The third is a Federally-designated Danger Zone, defined in 33 CFR 334.950, which covers the nearshore and offshore waters surrounding SHOBA. The purpose of these warning and restricted area is to protect public safety, and the public is routinely precluded from entry when hazardous activities are occurring. When not in use this location is a co-use area, and the Navy encourages access in the form of boating, diving, and fishing activities. The Southern California Offshore Range Office (SCORE), the controlling Navy agency, publicizes this availability through their schedule of activities which is conspicuously posted on their web site. Navy ships and boats will be in the area for up to two weeks prior to the test to prepare the site and set up monitoring stations. These activities are not hazardous, and during this period the range will be open to recreational co -use and thus provides a benefit for public access. The only time the range will be temporarily closed for exclusive military use is for less than a full day on the actual day of the test.

In addition, the Environmental Assessment for the proposed activity states that advance notice of the DET test will be made trough Notice to Mariners, Notice to Airmen, and on the SCORE web site. Aerial and surface vessel surveys of the area will be made to detect and clear the area of divers and boaters prior to the start of the tests. There will be two chase boats in the area to ensure that no unauthorized recreation or fishing boats or divers are in the area. Operations will be postponed if there is any threat of intrusion by non-participating boats or divers, and any non-participants in the area will be required to remain beyond the distance deemed safe for recreational divers.

The Commission agrees that the proposed project is designed to ensure public safety in the test area and that the project will generate only minor and temporary effects on public access and recreation and commercial and recreational fishing in the vicinity of the test site at San Clemente Island. Therefore, the Commission finds that the proposed DET system test at San Clemente Island is consistent with the public access and recreation policies of the CCMP (Sections 30210, 30211, 30212(a), 30213, 30220, and 30234.5 of the Coastal Act).

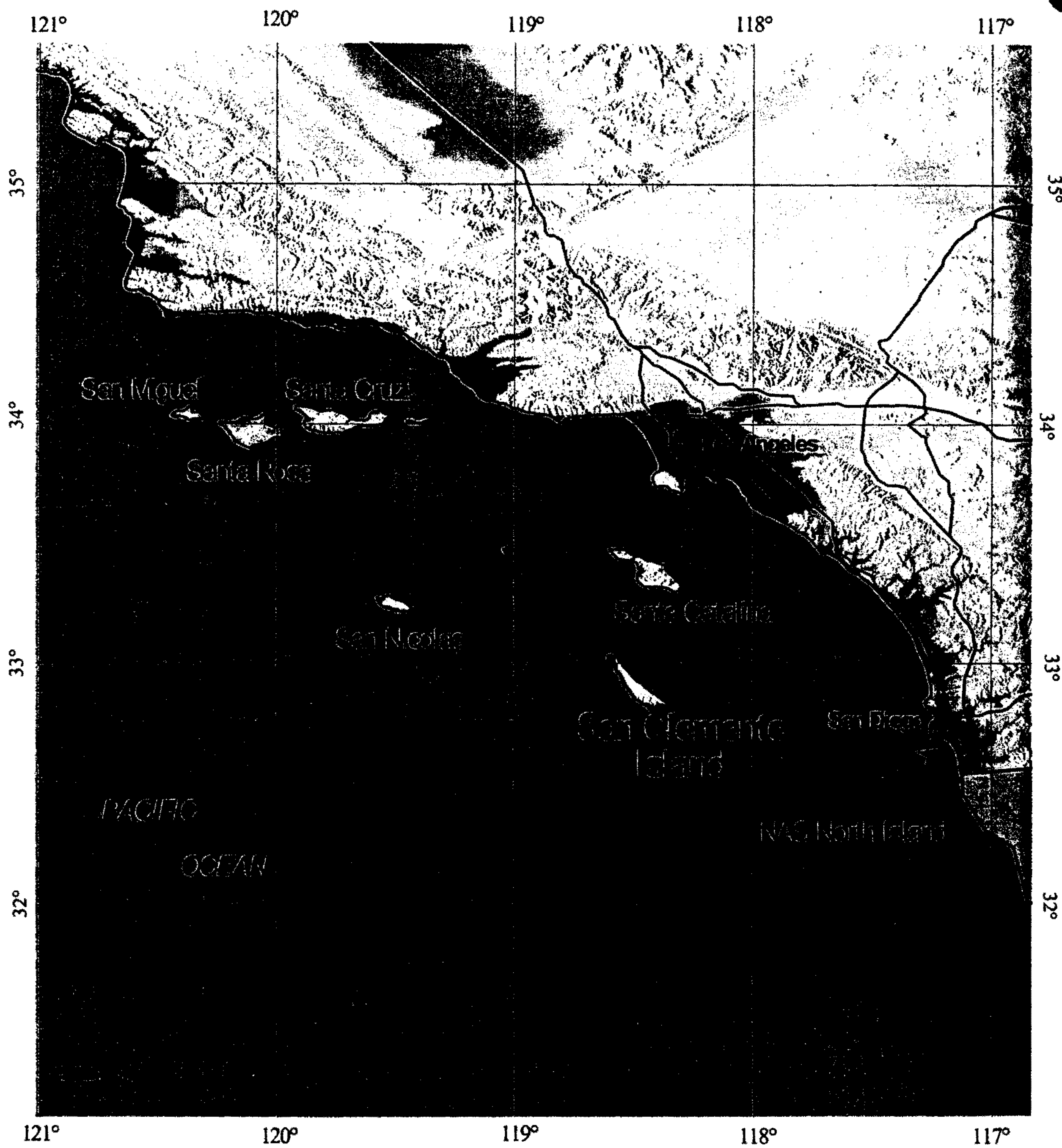

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Figure 1-1 San Clemente Island Regional Area

EXHIBIT NO.

APPLICATION NO.

CD-89-00

California Coastal Commission

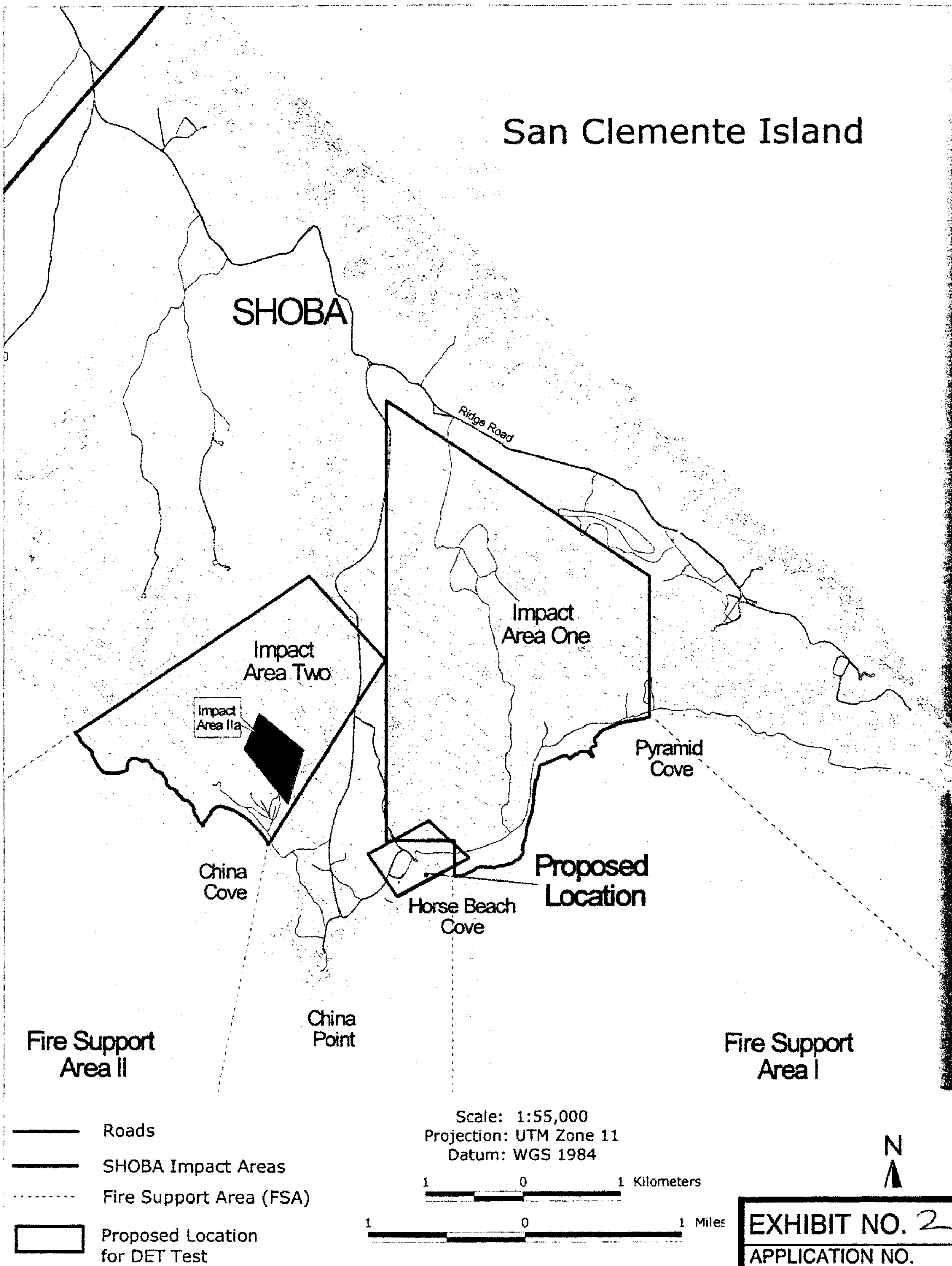


Figure 1-2 DET Proposed Test Area

EXHIBIT NO. 2
APPLICATION NO.
CD-89-00
California Coastal Commission

lands perpendicular to the shoreline. The DET system is launched from the deck of an LCAÇ from a specially designed container by two MK 22 Mod 4 five-inch rockets.

Four DET systems are to be tested. Each DET system has 2,016 pounds (915 kg) of explosive. The reason that four systems are being tested is that the Program Office expects that four systems will be required to clear the required 150 foot (46 m) wide lane toward the beach in 0-3 feet (0 to 1 m) of water. The DET test exercise area in the surf zone is 300 feet (92 m) wide. The 150 foot wide lane is within the 300 foot test area.

The DET system is packaged in a specialized container with the two Mk 22 rockets mounted on top. Figure 2-1 shows the container and the rockets. The rockets are mounted at a 25 degree angle left and right of the container center line. Figure 2-2 shows the size and configuration of the DET system when fully deployed. The rocket motors connected to the DET systems are designed to land on the beach.

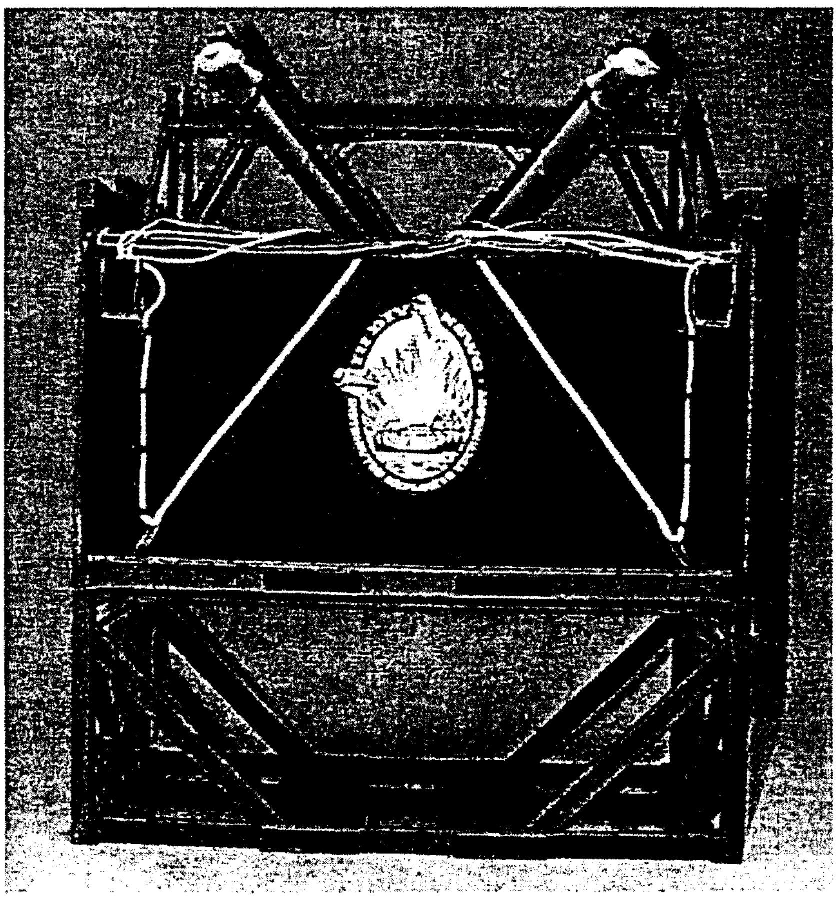


Figure 2-1. DET Container with Rockets mounted (Front View).

Landing Craft Air Cushion (LCAC). LCACs are designed to carry vehicles and cargo ashore from amphibious assault ships. They are 88 feet (27 m) long by 47 feet (14 m) wide. The LCACs have four gas turbine engines that produce 15,820 shaft horsepower each. The vessels ride on high pressure air contained by an inflatable rubber skirt on land and in the water. They are amphibious and can come ashore and clear land obstacles up to four feet (1.2 m) high. The engines provide thrust to two shrouded

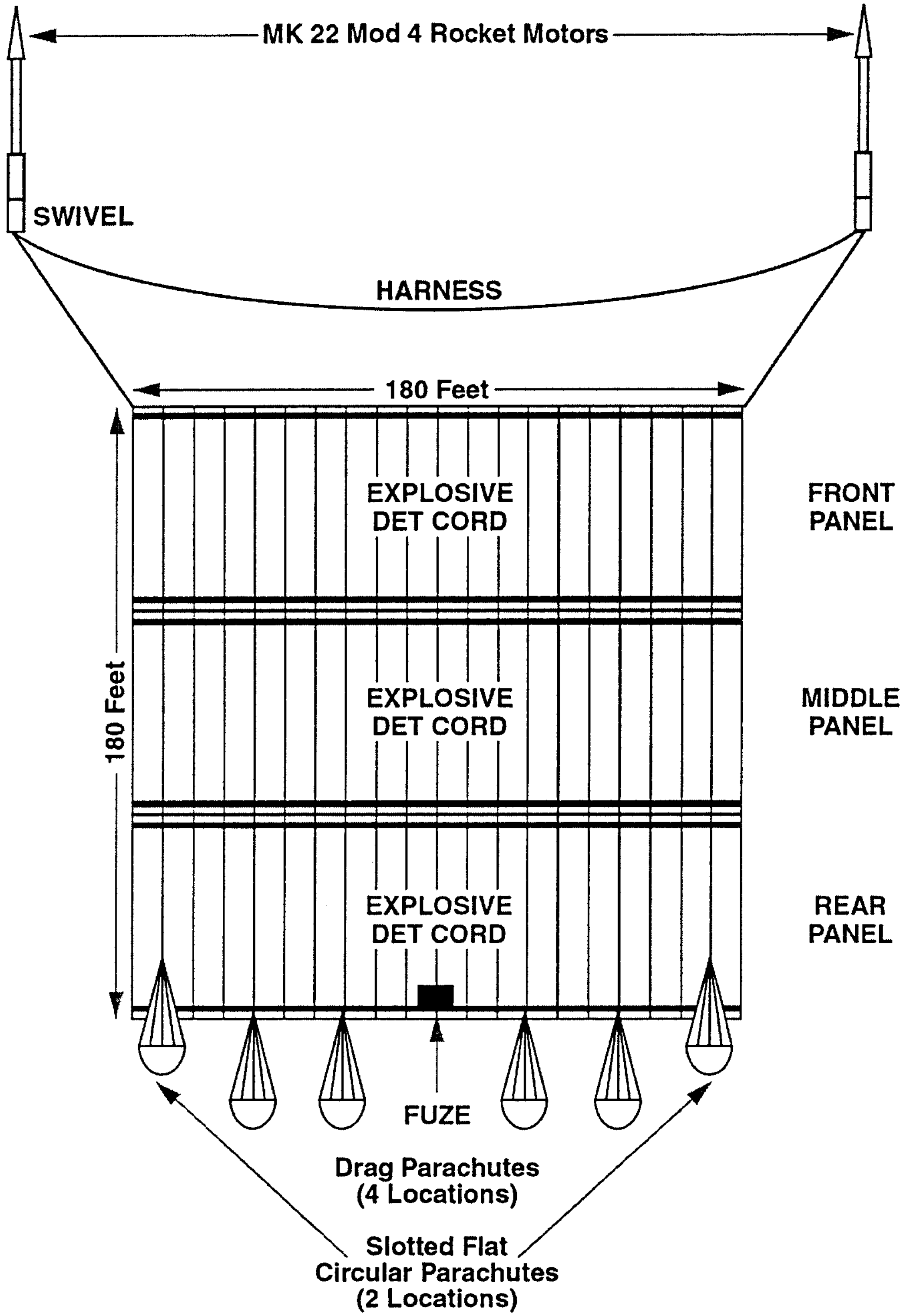


Figure 2-2. DET System Deployed Configuration

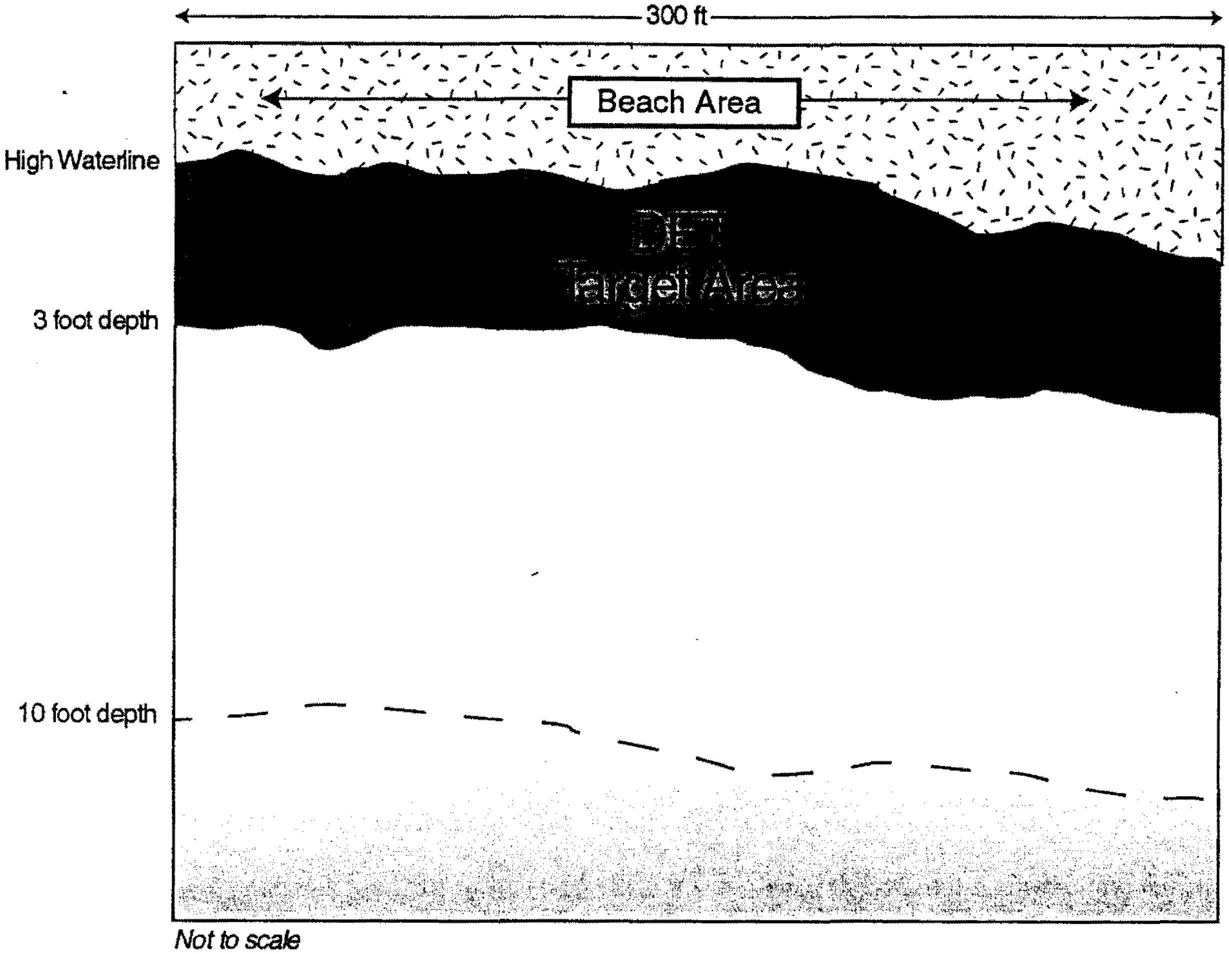


Figure 2-6. DET Target Areas

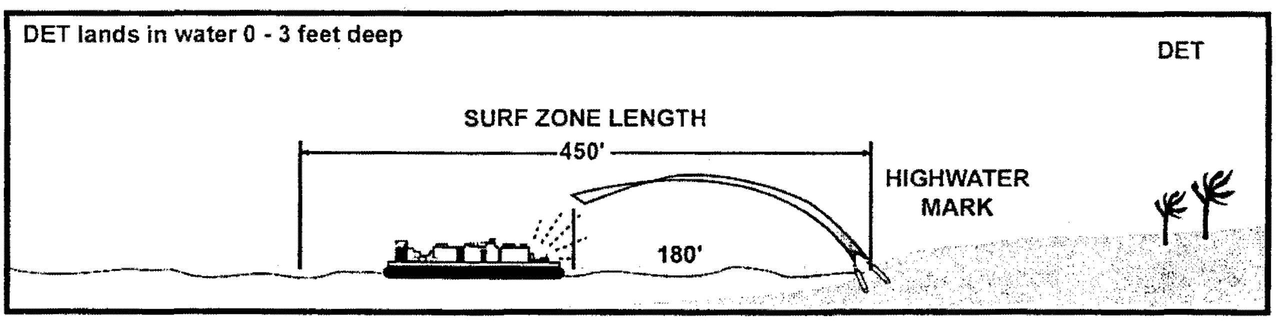


Figure 2-7. DET Employment in the Surf Zone

2.2 Selection Criteria for Alternative Locations

The selection criteria that were used to screen the alternative sites for feasibility have components with both operational and environmental considerations.

EXHIBIT NO. 5
APPLICATION NO.
CD-89-00

Figure 4-8. Environmental Effects of the Proposed DET Tests at Horse Beach Cove, San Clemente Island

	Proposed Action		
Existing Condition	Direct Impacts	Indirect Impacts	Mitigative Measures
Terrestrial Environment			Comments
Geology and Soils	Not significant. Berm formed from explosion, but surf action should rapidly restore surf zone contours	None	None
Air Quality	Not significant. Most emission products from explosives remain entrained in water; LCAC and rocket exhaust emissions in local area are temporary. Less than de minimus emissions.	None	None
Terrestrial Biological Resources	Not significant. No impact on Federally Listed Threatened or Endangered Species.	Possible temporary behavioral effects to vertebrate and invertebrate species	Nearest Loggerhead Shrike nest is 1.24 nm (2.3 km). Nearest Sage Sparrow habitat is 4.3 nm (8 km). Snowy Plover surveys to be conducted to ensure no nesting areas close to testing area
Marine Environment			
Noise	Not significant. Very short explosive impulse noise. Startle reaction in nearby animals	Sea birds will be temporarily scared off from area	Testing area distant from other activities on SCI and marine mammal areas
Water Quality	Not significant. Small amounts of explosive by-products would enter water, but would be rapidly diluted	None	None
Marine Biology	Not significant for populations. Destruction of some plants and invertebrates in the test area	None	None
Marine Fish	Not significant. Potential loss of some fish in test area	None	None
Marine Turtles	Chance for presence is remote, no affects expected.	None	Tests occur in cool water months. Aerial and boat surveys to be conducted. Test suspended if present.
Fish Habitat	Not significant. Effects small compared to natural events. No adverse effect.	None	None
Marine Mammals	No effect on or harassment of marine mammals due to mitigation. Not significant.	None	Affected area will be monitored to ensure impact area is clear of marine mammals
Man-Made Environment			
Cultural Resources	No cultural resources listed or eligible in NRHP testing area.	None	None
Land Use	Not significant. Compatible with Land Use	None	None
Traffic	Not significant. Minimal additional use of existing roads	None	Minimize off road vehicular activity
Socioeconomics	Not significant. Potential loss of use of Horse Beach Cove fishing area for each test for one day	None	A Notice to Mariners (NOTEMAR) will be published to inform the public of the temporary closure of the test area.
Hazardous Materials and Waste	Not significant. Some detonation by-products released to the water and air. Transitory water quality impacts.	Potential effects should marine organisms swim into product plume immediately after detonation, but this is not anticipated	None
Recreational and Commercial Divers	Not significant	None	Area closed to public. Test area will be cleared to ensure none present
Public Safety	Not significant. Potential for dangerous situation if non-participants are present in test area	None	Explosive Ordnance Disposal (EOD) Teams clear testing area. Testing to follow Navy Safety Procedures. Fire Breaks limit potential fire damage. Removal of non-participants from danger area and vicinity of test. NOTEMAR published.

EXHIBIT NO. 6
APPLICATION NO.
CD-89-00

The shock wave travel along a "line of sight" from the nearest land obstruction, and there will be limited diffraction outside this area. This diffraction will extend to about 547 yards (500 m) outside the "line of sight" to the maximum distance of effects (Appendix D). An estimate of the distance to 50 percent tympanic membrane rupture (50 percent TMR) threshold of 1.17 in.lb/in^2 (204.4 Pa-s) was made by adding broadband transmission loss to the broadband directional energy source levels for the DET tests. These correspond to distances of a few hundred meters, which is in the near field. However, the assumptions regarding source level and directivity made here are based on far field approximations and are invalid at distances that are in the near field. In the far field, the source is viewed as a single point. In the near field the source is viewed as an array. Modeling these parameters in the near field is a very complex task and was beyond the scope of this work. Consequently, the distances we suggest for exceeding auditory system injury are based on the minimum distance for which the model assumptions are believed to be valid. The minimum distance at which the model is valid ranges from 5 to 20 times the array dimension (0.65 km to 2 km).

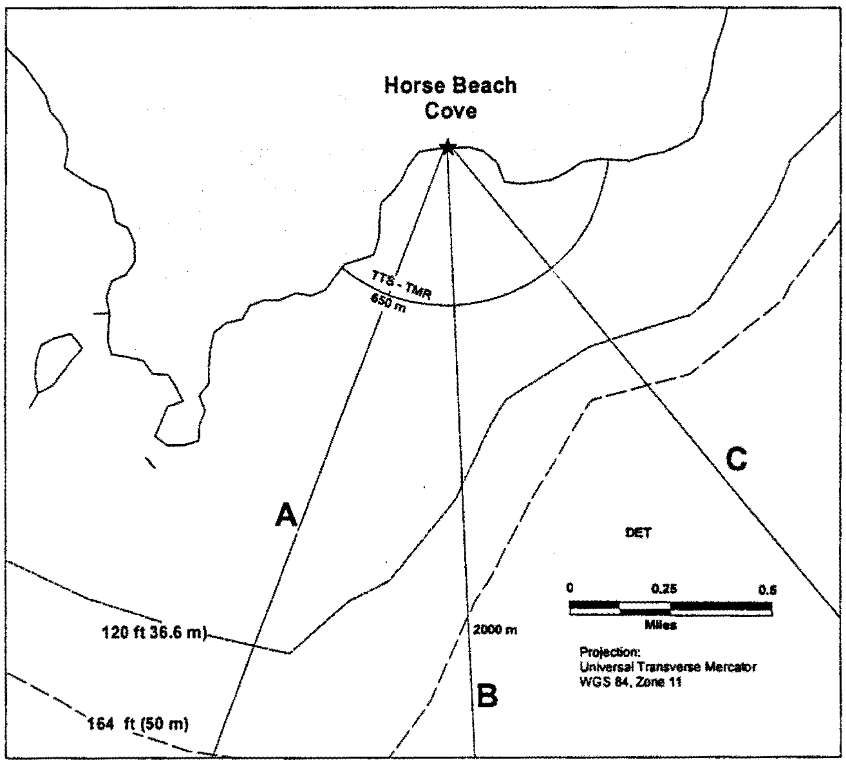


Figure 4-6. Zones of injury and harassment for the DET test in Horse Beach Cove.

EXHIBIT NO. 7
APPLICATION NO.
CD-89-00
California Coastal Commission

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
Carlsbad Field Office
2730 Loker Avenue West
Carlsbad, California 92008

In reply refer to number: 1-6-99-I-55-R

AUG 0 2 2000

Mr. Jan Larson
Director, Natural Resources Office
Commander Navy Region Southwest
937 No. Harbor Drive
San Diego, California 92132-0058

Dear Mr. Larson:

This letter responds to your request for informal consultation regarding one test period for the Distributed Explosive Technology [DET] system on San Clemente Island. We previously consulted with you informally regarding this project in June 1999 (1-6-99-I-55). Since that time, the proposed action has been modified. The current proposal is to test the DET system only, during October, 2000, in the shallow waters off of Horse Beach.

We have reviewed the proposed one-time test and evaluated the potential for the action to affect listed species on San Clemente Island, including the western snowy plover (*Charadrius alexandrinus nivosus*), San Clemente loggerhead shrike (*Lanius ludovicianus mearnsi*), island night lizard (*Xantusia riversiana*), San Clemente Island bush mallow (*Malacothamnus clementinus*) and Santa Cruz Island rock cress (*Sibara filifolia*). We concur with the Navy's conclusion that the proposed action is not likely to adversely affect listed species and, therefore, does not require formal consultation under section 7 of the Endangered Species Act of 1973, as amended (Act). We reached this conclusion based on: 1) avoidance of the nesting season, 2) the short duration and temporary nature of the proposed action, and 3) the low occurrence of snowy plovers on Horse Beach during winter months. The proposed "herding" of any plovers detected prior to detonation further reduces the likelihood of harm from deployment of the detonation net. If further testing becomes necessary, or a repeated testing or training program is developed, we recommend initiation of formal consultation.

We concur that immediate fire suppression capabilities are necessary to minimize the potential for wildfire and potential effects on terrestrial listed species. In addition, we recommend that the beach be returned to its original configuration if rutting or craters result from detonation cord testing, and that any debris deposited on the beach be removed when the test is completed.

EXHIBIT NO. 8
APPLICATION NO.
CD-89-00
California Coastal Commission

Mr. Jan Larson 1-6-99-I-55-R

We appreciate your coordination regarding this project and your continued efforts to conserve the natural resources of San Clemente Island while accomplishing the military mission. Please contact Sandy Vissman of my staff at (619)431-9440 for further discussion.

Sincerely,

Nancy Gilbert

Nancy Gilbert
Assistant Field Supervisor

EX-8 CONT

APPENDIX D

Modeling of Blast Parameters

EXHIBIT NO.	9
APPLICATION NO.	
CD-89-00	

Modeling Blast Parameters for the DET Test: Effects on Marine Mammals and Fish

by

David Hannay and Roberto Racca
JASCO RESEARCH LTD
Acoustical Oceanography, Signal
Processing and Instrumentation.
Victoria, B.C.

for
SRS Technologies, Arlington, VA
and
LGL Limited
environmental research associates
King City, ON

1. Introduction

Acoustic energy generated underwater by detonation of the explosives for the DET mine clearance test has the potential to irritate, injure or kill certain marine wildlife. The purpose of this report is to quantify the acoustic and pressure levels in the vicinity of the identified sources detonated near the beach in Horse Beach Cove so that estimates of their impacts on wildlife can be made.

Predictions of the acoustic energy generated by the DET system was made using well-known formulae based on measurements of large numbers of underwater detonations. The system being considered consists of spatially distributed explosive charges, which together produce non-uniformly distributed energy patterns. A comprehensive treatment of directionality was carried out. The scope of this modeling project limited the final analysis to three specific directions: covering the angular region defined by the mouth of Horse Beach Cove. The directivity analysis showed that the proposed manner for detonating the charges is optimal in the sense that it minimizes the amount of energy broadcast out to sea. Furthermore, these effects produce significantly lower estimated levels than has obtained using a less rigorous treatment of directivity. Acoustic propagation modeling was performed using the RAM parabolic equation model. The environmental information used by RAM included sound speed variation with depth in the water column, range-dependent bathymetry, and range-dependent geoacoustic properties and layering of seafloor sediments along the tracks that were modeled. Modeling with RAM was performed to estimate transmission loss in all 1/3-octave frequency bands between 10 Hz and 10 kHz. These transmission loss results were used to calculate impulse levels and maximum 1/3-octave energy density levels versus range and depth along the tracks, which are presented as color-shaded plots. Two impact factors were considered:

1) Harassment: defined by energy flux density levels exceeding 182 dB re $\mu Pa^2 \cdot s$ in any 1/3-octave band, representing the minimum sound level at which temporary threshold shift (TTS) occurs, and
2) Auditory system injury: defined by energy flux density level causing 50% tympanic membrane rupture in marine mammals. The accepted level is an energy flux density of 1.17 $in \cdot lb/in^2$ (204 dB re $\mu Pa^2 \cdot s$).

Mitigation measures will be put in place to ensure that no marine mammals are within the zone of harassment defined by the range of onset of temporary threshold shift. Thus, no marine mammals will be exposed to mortality. For this reason impulses causing marine mammal mortality were not modeled. Impulses were modeled to estimate potential fish mortality.

2. The Test

Detonation of the DET mine clearance system will be carried out in the surf zone along the beach in Horse Beach Cove at the South end of San Clemente Island in October 2000.

The DET array consists of a 180 ft by 180 ft array of parallel lines of det cord (SX 2 explosive, 417 grains/ft) with a actual total weight of 2016 lbs. The det cord itself is wrapped in a mylar sheath, which is wrapped in a kevlar weave. The array is configured in three panels, each containing 180 cords, each 60 feet long, spaced 12 inches apart and oriented at right angles to the beach. Kevlar members parallel to the beach join the perpendicular det cord lines to give the appearance of a mesh. All three panels contain 2 horizontal det cord re-initiator lines positioned 24 inches in from each of the ends. The first panel, closest the beach, has two additional re-initiator lines: one 276 inches from the front (beachward) end and the other 252 inches from the aft end. The array is detonated on the seafloor at depths from 0 (at the beach) to 3 feet. The TNT-equivalent conversion factor for the DET cord is 1.6 (total actual weight x 1.6 = equivalent weight of TNT). Therefore the net explosive weight is 3225.6 pounds TNT equivalent. The array is detonated from center at the seaward end. The rear (seaward) horizontal cord, running parallel to the beach, detonates the rear ends of the parallel det cord lines. The centerlines of det cord thus detonate earlier than the outer lines. With this configuration the entire array detonates within 10 ms (3.3 ms to travel 90 ft to each side at the seaward end of the array and 6.6 ms to travel 180 ft to the shoreward end of each outermost cord).

3. Source Level

When explosives detonate underwater the solid explosive is rapidly converted to gaseous form at high pressure and temperature. The initial gas bubble expands against the inertial force of the surrounding water. The pressure pulse generated by the initial detonation, referred to as the shock pulse, is characterized by a nearly instantaneous rise followed by an exponential-like decay. The inertia imparted to the water by the highly pressurized bubble causes the bubble to continue to expand even after its pressure falls to ambient hydrostatic pressure. After reaching maximum volume the bubble starts to collapse, eventually reaching a second minimum volume - corresponding to a second pressure peak referred to as the first bubble pulse. The oscillatory behavior of the bubble causes a train of pressure peaks referred to as the bubble pulses. Bubble pulse amplitudes decrease rapidly as energy is lost primarily through heat dissipation. When sources are very shallow, as is the case for a nearshore mine-clearing system, the detonation bubble breaks the surface and bubble pulses are not observed. For this reason, only the energy of the shock pulses of the detonation will be considered.

3.1 Pressure wave characteristics

Experimental measurements taken within a few hundred meters of underwater explosive charges have found that shock pulse pressure decays with range at a slightly higher rate than expected for normal acoustic wave propagation. The higher decay rate is attributed to non-acoustic shock wave effects. At ranges beyond a few hundred meters the amplitudes become sufficiently small that normal acoustic propagation occurs. It has been found that shock pulse pressure as a function time $p(t)$ is described quite accurately by an exponentially decaying function of the form:

$$p(t) = p_0 \exp(-t / t_0) \qquad (1)$$

where p_0 is the peak pressure and t_0 is the time constant for exponential decay. Measurements of pressure waveforms from a wide variety of TNT charge detonations have determined that the peak pressure and time constant in the near field can be calculated as functions of the charge weight W in kilograms, and range r from the source in meters according to:

$$p_0 = 5.24 \times 10^7 \left[\frac{W^{1/3}}{r} \right]^{1.13} \quad \mathrm{N/m^2} \qquad (2)$$

$$t_0 = 9.25 \times 10^{-5} W^{1/3} \left[\frac{W^{1/3}}{r} \right]^{-0.22} \quad \mathrm{sec} \qquad (3)$$

3.2 Energy Density

The energy density parameter, used to assess TTS, represents the energy per unit area normal to the direction of wave propagation. We wish to obtain the energy spectral density function (energy density per unit frequency) so that energy density in 1/3-octave bands can be calculated. The Fourier transform of Equation 1 can be calculated directly:

$$\begin{aligned} P(f) &= \Im[p(t)] \\ &= \frac{p_0}{2\pi i f + 1/t_0} \end{aligned} \tag{4}$$

The energy flux spectral density function $E(f)$ represents the energy flux density per unit frequency. It can be expressed as the product of the characteristic seawater impedance and the spectral density function for the pressure. The spectral density function is simply the square modulus of $P(f)$. The characteristic impedance can be written $1/\rho c$ where ρ is the density of water and c is the speed of acoustic wave propagation. Consequently the energy spectral density function can be written:

$$\begin{aligned} E(f) &= \frac{2}{\rho c}\left\|P(f)\right\|^2 \\ &= \frac{2p_0^2}{\rho c(4\pi^2 f^2 + 1/t_0^2)} \end{aligned} \tag{5}$$

which contains the factor 2 to account for negative frequency contributions in a positive-only frequency scale.

In this report, TTS is based on energy flux density levels in 1/3-octave bands. These levels can be calculated by integrating Equation 5 through the frequency range of the corresponding band. An alternative method for computing the 1/3-octave levels can be applied if it is assumed that the spectral density level is constant over the band. In this case the 1/3-octave energy flux density can be approximated as the product of the bandwidth and the spectral density level in the band. Typically, this method is applied using the spectral density level calculated at the band's center frequency. The band edges, f_1 and f_2, for 1/3-octave bands are related by a factor of $2^{1/3}$. The center frequency f_c for the band is given by: $f_c = (f_1 f_2)^{1/2}$. The bandwidth is thus related to the center frequency by:

$$\begin{aligned} bw_{1/3} &= f_2 - f_1 \\ &= f_c(2^{1/6} - 2^{-1/6}) \\ &= 0.2316 f_c \end{aligned} \tag{6}$$

The total energy flux density in a 1/3-octave band, with center frequency f_c, can be calculated approximately, as described above, by:

$$E_{\text{band}} = \frac{2p_0^2(0.2316 f_c)}{\rho c(4\pi^2 f_c^2 + 1/t_0^2)} \quad \text{J/m}^2 \tag{7}$$

where p_0 and t_0, from Equations 2 and 3, are functions of charge weight and range from the source. Energy density levels in water are typically specified in decibels referenced to the equivalent energy of a 1 μPa *r.m.s.* sine wave over 1 second (dB re μPa^2-sec). Assuming water density is 1000 kg/m^3 and sound speed is 1500 m/s, the reference energy is 6.67×10^{-19} J/m^2. Consequently energy density levels in 1/3-octave bands can be expressed in dB re μPa^2-sec according to:

$$L_{1/3}(\text{dB}) = 10\log(E_{band}) + 181.8 \quad \text{dB re } \mu\text{Pa}^2\text{-sec} \qquad (8)$$

where all input parameters for E_{band} from Equation 7 are specified in mks system units.

The DET array, composed of parallel lines of det cord, is not described well by a system of spherical charges. An approximation has been made nevertheless by modeling each line as a sequence of spherical charges spaced at one cord radius (~0.5 cm). The weights of these model charges have been set so the sum is equal to the total weight of the cord. Each 180-foot cord with mass 4,864 kg is modeled by 10973 individual charges, each of mass 4.433×10^{-4} kg. The 180 parallel cords therefore are composed of 1.975×10^{6} of these model charges. With this representation, the total energy flux density in 1/3-octave bands for the DET system has been calculated using Equations 7 and 8. These results are given in Table 1.

Table 1. Non directional 1/3-octave band source levels for the DET array. Levels are given in units of dB re μPa²-sec.

Center Frequency	1/3-octave band level	Center Frequency	1/3 octave band level
10	222	400	238
12.5	223	500	239
16	224	630	240
20	224	800	241
25	225	1000	242
32	227	1200	243
40	238	1600	244
50	229	2000	244
63	230	2500	245
80	231	3200	246
100	232	4000	246
120	233	5000	246
160	234	6300	246
200	235	8000	245
250	236	10000	245
320	237		

4. Source Directivity

The directivity pattern for single line arrays of discrete charges, detonated simultaneously, is the well-known repeated sine function, *e.g.* Burdic [1]. However, the finite speed of burn for det cord, ~6700 m/s, causes delays in the relative detonation times between charges, thereby modifying the standard pattern. An alternative expression for the pattern considers the phases of signals originating from individual charges. The phase terms for specific charges are modified from the simultaneous-detonation case by introducing an additional change caused by the det cord delay. The result for detonation started at charge number m is:

$$D(f,\theta) = \frac{1}{\sum_{j=1}^{N}\left|P_j(f,W_j)\right|}\sum_{j=1}^{N}\left|P_j(f,W_j)\right|\exp\left[i2\pi fd\left(\frac{(j-1)\cos(\theta)}{c}+\frac{|j-m|}{s}\right)\right] \qquad (9)$$

where $P_j(f,W_j)$ is the complex frequency domain pressure at frequency f for charge weight W_j, given in Equation 4, d is the charge spacing, c is the sound speed, and s is the speed of burn of the det cord, θ is the angle at which the directivity calculation is desired, measured from endfire with 0° in the direction of the first (j=1) charge.

The DET system consists of 180 parallel lines of det cord connected by 8 cross-connecting lines of det cord and is not composed of a series of discrete charges. The 8 cross-connecting lines (fuses and re-initiators) were neglected for determining source levels for the array.

As a starting point, the directivity pattern function for a line charge detonated instantaneously can be derived for example as in Burdic [1]. However the finite burn speed of det cord causes a delay in the detonation times for sections of the DET lines. The expression for directivity pattern of an instantaneously detonated line can be modified to account for the delays. The modified result for detonation starting at an end of a line is:

$$D(f,\theta) = \frac{e^{iL/2s}\sin[u]}{u}, \quad \text{where } u = \pi f L\left(\frac{\sin\theta}{c} + \frac{1}{s}\right) \tag{10}$$

where L is the length of the line, and θ now represents the angle measured from broadside (at right-angles to the line). Positive θ is measured toward the end of detonation.

We now make use of the well-known result that the directivity pattern for an array of identical directional charges is simply the product of the patterns for the charges themselves, with the pattern function for the array assuming omni-directional elements. Therefore, we can calculate the directivity pattern for the array of line charges as the product of the directivity for a discrete line array (Equation 9), with the pattern for each line array (Equation 10). The directivity pattern for the DET system therefore is:

$$D(f,\theta) = \frac{e^{iL/2s}\sin[\pi f L(\sin(\theta)/c + 1/s)]}{\pi f L[\sin(\theta)/c + 1/s]N}\sum_{j=1}^{N}\exp\left[i2\pi f d\left(\frac{(j-1)\cos(\theta)}{c} + \frac{|j-m|}{s}\right)\right] \tag{11}$$

where d is now the line spacing, N is the number of lines, and m is the line number at which detonation is initiated (90 for the DET array). Equation 11 assumes all lines have the same weight. θ is measured from a line at right-angles to the det cord lines, so +90° seaward (along line B).

Figure 1 shows the absolute directivity pattern at 100 Hz for the individual det lines, the pattern for 180 discrete elements (treated as point sources), and finally the product of these two patterns The product (equivalent to Equation 11) has been increased by a factor of 10 so it can be shown in the same plot.

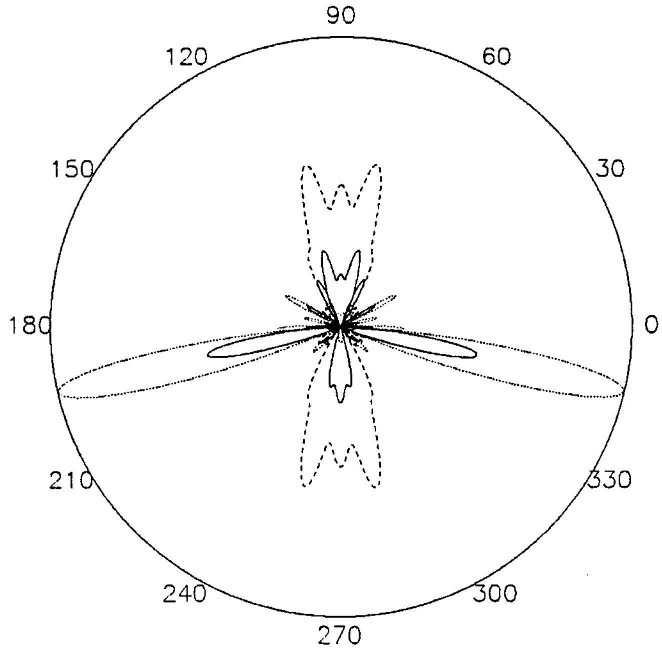


Figure 1. ***a*)** Directivity pattern at 100 Hz for single 180-foot det line (···).
***b*)** Pattern for 180-element discrete line array of omni-directional sources (---).
***c*)** Product of *a* and *b* (x10), representing the pattern for the entire DET array (–).

Acoustic propagation modeling, performed for this report, was carried out along three straight lines, A, B, and C, starting at the detonation point at the center of Horse Beach (Figure 2). Line B is directed nearly due south from the detonation point out through the center of the mouth of Horse Beach Cove. Lines A and C start at the detonation point and respectively just graze the western and eastern shores of the mouth of Horse Beach Cove. It was assumed that the DET is oriented parallel to line B. With this geometry line A is 24° West of line B, and line C is 37° East of line B. The separate analyses of three tracks was carried out to investigate the variations of energy density and impulse levels caused by differences in source directivity and transmission path bathymetry.

Calculation of the DET array directivity, in the directions of lines A, B, and C, has been carried out using equation 11 for all 31 modeled 1/3-octave frequency bands. Table 2 gives the directivity function (magnitude-squared of the pattern function) for all frequencies and directions. Again, the values given for each 1/3-octave center frequency were calculated by averaging directivities calculated at 50 equally-spaced frequencies covering the bandwidth of the respective 1/3-octave band. The averages are given in decibels.

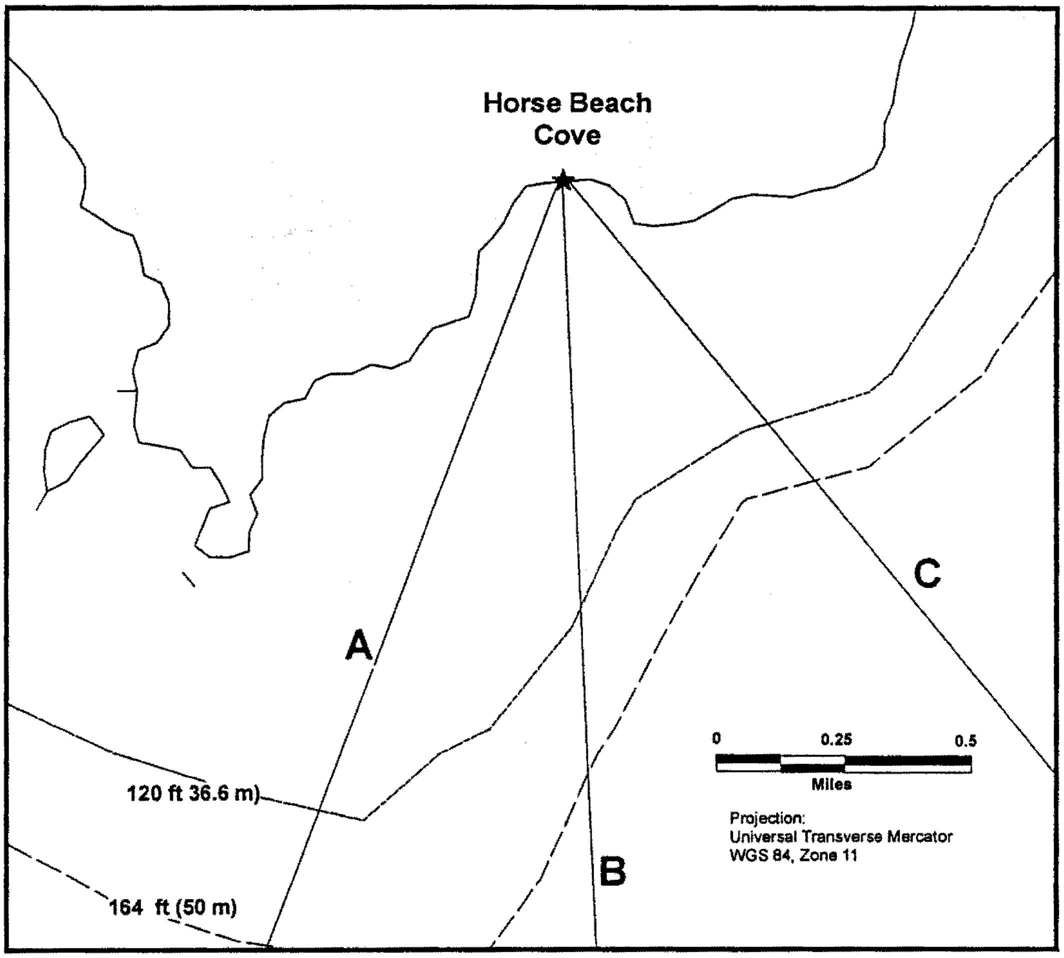


Figure 2. Location of the three lines originating at the test site in Horse Beach Cove that were modeled.

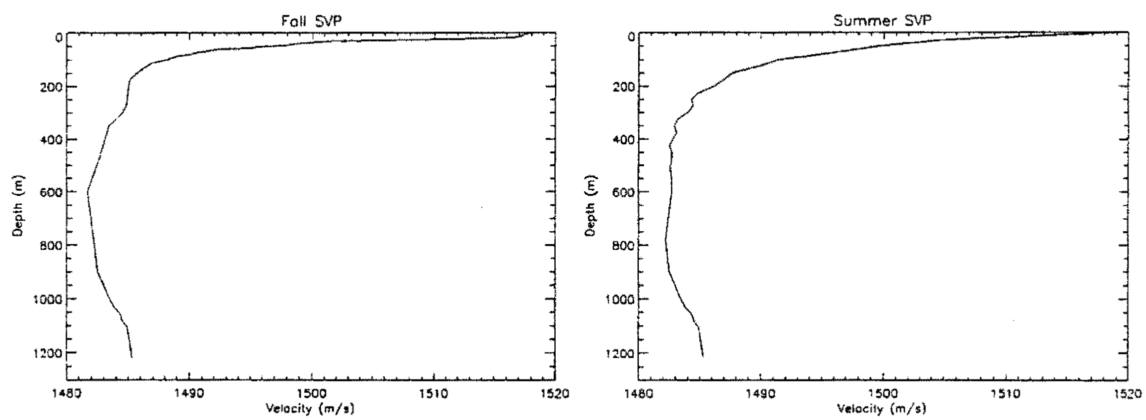
5. Propagation Modeling

Source levels and directivity for the test systems were calculated in the previous sections. These values are used with the output of a propagation model to obtain energy density as a function of range from the systems along lines A to C. The propagation model used in this report is the Range-dependent Acoustic Model (RAM) parabolic equation model developed by Michael Collins. RAM uses the split-step Padé method [2] to calculate acoustic transmission loss for point sources in ocean acoustic environments.

In order to obtain accurate estimates of transmission loss, the geoacoustic profile along each of the tracks was determined to a range of 10 km. The depth profiles along the tracks were picked from a contour map. Water sound speed profiles, typical of fall (DET to be deployed October 2000) were obtained for the area. The fall profile, shown in Figure 3, is similar to that for the summer season in that both are strongly downward-refracting due to warm surface temperatures.

Table 2. 1/3-octave band directivity values in decibels for DET system. Given values are the averages of 50 equally-spaced frequencies within each 1/3 octave band.

Center Freq	Line A 24-deg	Line B 0-deg	Line C 37 deg	Center Freq	Line A 24-deg	Line B 0-deg	Line C 37 deg
10	-3.0	-3.1	-2.8	400	-59.6	-54.7	-67.2
12.5	-4.9	-5.2	-4.6	500	-63.1	-65.9	-70.7
16	-8.4	-9.2	-7.7	630	-72.6	-62.5	-75.2
20	-16.0	-19.1	-13.6	800	-71.1	-69.4	-79.4
25	-25.7	-19.6	-27.5	1000	-77.4	-73.5	-82.1
32	-17.6	-13.9	-25.3	1200	-81.4	-76.8	-87.0
40	-21.8	-20.1	-26.3	1600	-84.8	-82.2	-91.1
50	-33.0	-21.7	-34.0	2000	-89.9	-85.1	-93.9
63	-30.6	-25.1	-28.7	2500	-92.0	-88.8	-97.7
80	-31.9	-25.4	-38.1	3200	-96.1	-93.2	-100.9
100	-34.0	-29.9	-43.1	4000	-99.8	-97.9	-102.7
120	-39.1	-33.6	-49.1	5000	-105.6	-102.3	-99.3
160	-42.2	-37.5	-52.7	6300	-102.6	-107.9	-87.9
200	-47.2	-47.1	-53.4	8000	-90.3	-113.1	-109.8
250	-53.4	-59.0	-59.2	10000	-111.7	-121.2	-109.7
320	-65.4	-51.3	-63.4				



Fall conditions　　Summer conditions

Figure 3: Sound speed profiles for fall and summer (Source McCue 1999[7]).

Ocean bottom sediments properties play a strong role in the attenuation of sound in shallow water. The following description of bottom properties as a function of water depth was obtained for the area:

0 m to 100 m from shore: 3 feet or less of sand over rock,

then

Depth	Bottom Type
3 m to 10 m	bedrock with areas of sand (up to 2 feet thick)
50 m to 500 m	10 feet of fine sand and silt over rock, getting finer with depth.
500m to 1000 m	10 feet of fine silt and clay.

Based on this description, range-dependent environmental models for the tracks were developed. The models consisted of discrete grid representations of the true environments. Grid spacing was 0.5 m in the vertical dimension and 50 m horizontally. The bottom classification scheme incorporated the geoacoustic parameter values for course sand, fine sand, sandy-silt, and clayey-silt from Hamilton [3] for the continental terrace environment. Bedrock parameters, based on North Pacific Basalt, were obtained from Hannay [4]. The parameter values for all bottom types are given in Table 3. The bottom type as a function of range for the three tracks is given in Table 4.

Table 3. Geoacoustic parameters used for modeling by RAM

Bottom sediment Description	Compressional Velocity (m/s)	Density (kg/m³)	Attenuation coeff. (dB/λ)
Coarse sand	1836	2.034	0.6
Fine sand	1749	1.941	0.4
Sandy-silt	1652	1.771	0.2
Clayey-silt	1549	1.488	0.1
Bedrock	2800	2.500	0.05

Table 4. Bottom types versus range along each of the tracks

Bottom Classification	Range Interval		
	Line A	Line B	Line C
0.90 m coarse sand over bedrock	0 to 91 m	0 to 91 m	0 to 91 m
0.31 m fine sand over bedrock	91 to 2760 m	91 to 2140 m	91 to 1234 m
3.05 m sandy-silt over bedrock	2760 to 10000 m	2140 to 10000 m	1234 to 8960 m
3.05 m clayey-silt over bedrock	--	--	8960 to 10000 m

5.1 Energy Flux Density Modeling

Modeling to determine energy flux density versus depth and range along the three tracks was carried out to predict the region where the TTS level for harassment will be exceeded. TTS was defined as an energy density level exceeding 182 dB re μPa^2-sec in any 1/3 octave band. Modeling was carried out at the center frequencies of consecutive 1/3-octave bands between 10 Hz and 10 kHz. Runs of acoustic propagation model RAM were performed to predict the transmission loss versus range and depth at each frequency. The predicted energy density values were computed by summing source level, directivity, and transmission loss values in decibels. The maximum energy density plots for the DET system along Lines A, B, and C are given in Figure 4. These plots show the maximum 1/3 octave band level versus range and depth from the source. The harassment regions were determined by finding the maximum range where the 182 dB re μPa^2-sec TTS threshold is exceeded within the plots. The maximum ranges are given in Table 5. We note the threshold is exceeded only at very short ranges for the DET system. This feature is caused by stripping of low frequency energy by shallow propagation depths in the near-field, and by stripping of high frequency energy by strong DET directivity.

Table 5. Maximum ranges for exceeding the 182 dB re μPa^2-sec threshold for TTS.

System	Line A	Line B	Line C
DET	<500 m	<500 m	<500 m

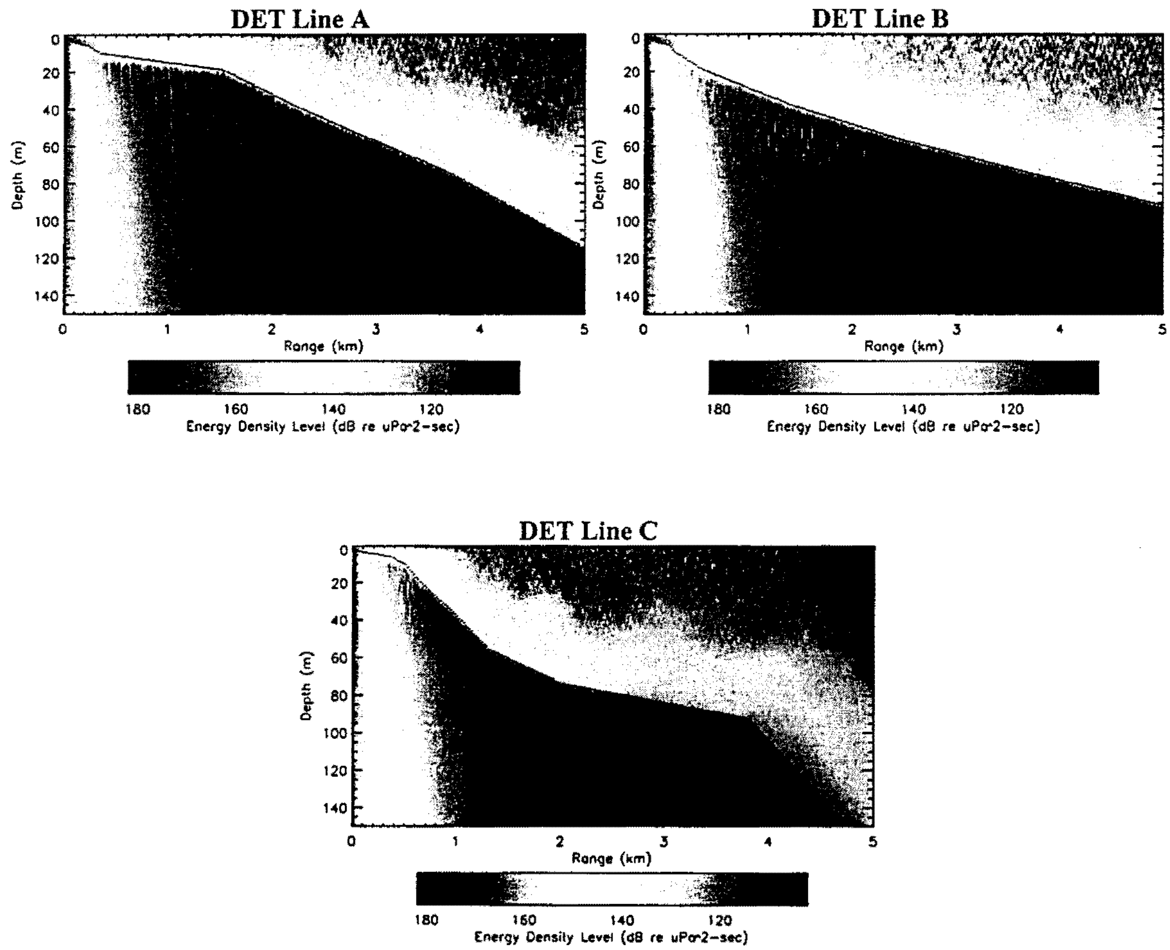


Figure 4: Energy Flux Density levels for DET versus range and depth along tracks A-C. (maximum in any 1/3-octave bands)

5.2 Model Results

Region of Impact

The analyses carried out for this report considered three tracks covering the line-of-site angular region for acoustic propagation, starting on the shore at the center of Horse Beach Cove, seaward out of Horse Beach Cove. Unless otherwise stated, the following impact ranges are based on the maximum predicted level over the three tracks. Some acoustic energy will exist outside of the angular region bounded by tracks A and C due to diffraction. The intensity of the diffracted energy rapidly decays away from the line-of-site boundaries. Typically this energy decays to negligible value within a few wavelengths from the boundary. For the highest frequency (10 kHz), this distance is only a few meters. For the lowest frequency (10 Hz) the corresponding distance will be a few hundred meters. We suggest the region for any specific impact inside the line-of-site region be extended 500 m outside, while maintaining the maximum range limit from the source.

Peak Pressure

Using Equation 2, we find peak sound pressure at 1 km range from a 1 lb. TNT explosive is 204 dB re 1 μPa. Assuming spherical spreading, but neglecting absorption, pressure decays at only 20 dB per decade (in range). Thus the level at 10 km is 184 dB re 1 μPa, and at 100 km is 164 dB re 1 μPa. Absorption attenuates the high frequency content of the explosion shock pulse, thereby reducing the peak pressure at longer ranges. However, Table 1 shows that a substantial fraction of the shock pulse energy occurs at frequencies below 500 Hz.

In Figure 5, we present peak overpressure versus range from the DET system and for comparison the SABRE system as well.. For each system we have chosen an effective charge weight based on the largest amount of explosive that detonates to form a coherent shock pulse. For the DET we have used the weight of a single initiator cord (10.7 lb. PBXN). Peak over pressure is also shown for the SABRE system using the weight of a single charge (9.6 lb. PBX).

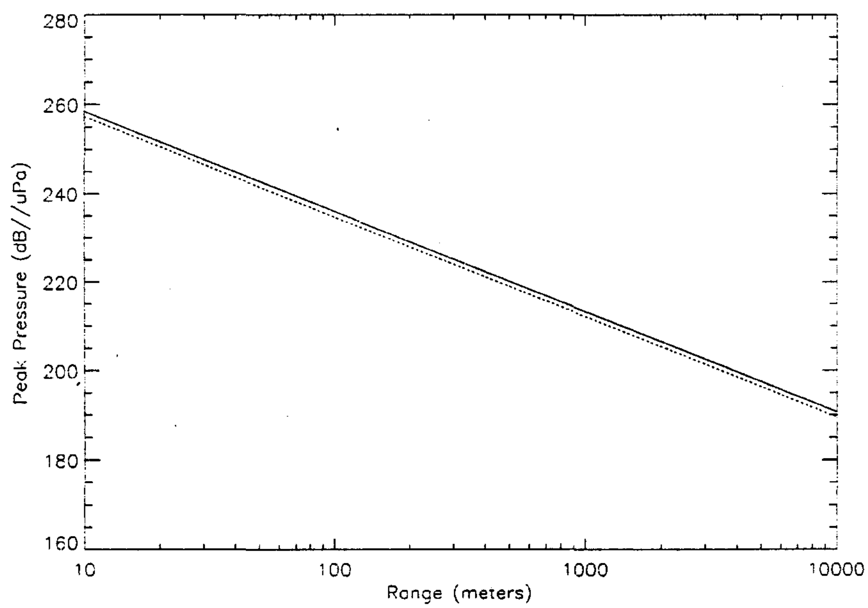


Figure 5. Peak shock pulse overpressure versus range for DET (solid line) and SABRE (dashed line).

Marine Mammals and Sea Turtles

The two levels of biological impact considered here are:

1. Harassment: defined by energy flux density levels exceeding 182 dB re $\mu Pa^2 \cdot s$ in any 1/3-octave band, representing the minimum sound level at which temporary threshold shift (TTS) occurs.
2. Auditory system injury: defined by an energy flux density level causing 50% tympanic membrane rupture in marine mammals. The accepted level is a total energy flux density of 1.17 $in \cdot lb/in^2$ (204 dB re $\mu Pa^2 \cdot s$).

Harassment: Modeling results from the previous sections provide energy flux density levels versus distance and depth. These estimates are shown in Figure 4 and Table 5. The DET system energy is estimated to exceed the threshold only at very short distances (<500 m). These distances are substantially less than estimates obtained from another study which considered similar systems [5]. The cause of the differences is explained primarily by our treatment of directivity, which is discussed in the next section. However, the assumptions regarding source level and directivity made here are based on far-field approximations that treat the source as a single point. Under the model assumptions, results are valid only in the far field. For this reason, the minimum distance at which the model results are valid is approximately 10 times the array dimension (650 m). Consequently, estimates for distances less than these lower limits (near field) cannot be wholly trusted. We therefore suggest a safe range for harassment of 650 m for the DET test.

Auditory System Injury: Auditory system injury is predicted to be exceeded only in the near field at distances of less than a few hundred meters. Consequently, as per the discussion of harassment above, the recommended minimum distance for avoiding auditory system injury is the boundary between the near field and far field which is found at approximately 10 times the array dimension or 650 m for the DET system.

7. Conclusions: Marine Mammals

Estimation of peak pressure levels, impulse levels and energy flux density levels, generated by detonating the DET mine clearance system, has been performed. The results are presented graphically for three tracks in the shaded color contour plots in Figure 4. These estimates are based on analyses that considered source energy flux density and impulse levels, source directivity, and transmission loss characteristics in 31 1/3-octave frequency bands. Maximum distances where the biological impact factors for marine mammals are exceeded have been determined based on the modeling results. These distances are presented in the previous section.

The findings of these analyses indicate that the region of significant energy density impact may be smaller than previously thought. However, some of the approximations upon which these results are based may be invalid at such small distances. Consequently it is recommended that further study be carried out to predict the required parameters in the near-field where impacts may occur.

8. Effects on Fish

Impulses at various depths and distances from the sources were needed to estimate impacts on fish. Impulse I is defined by the time-integral of pressure through the waveform. The time integral of pressure through the shock pulse is given by the simple expression $I = p_0 t_0$. The dependence of impulse (product of p_0 and t_0) on weight is apparent from Equations 2 and 3: $I \propto W^{0.64}$. The question arises whether to use the total system charge weight to calculate a single value for impulse, or to sum the impulses from the individual charges composing each system. We have chosen the more conservative option and used the latter method. The number of charges and charge weights (masses) for each system are the same as used to calculate energy density levels. Impulse was calculated based on p_0 and t_0 values at 100 m range. These impulses were scaled back to a reference range of 1m by assuming spherical decay of pressure. The computed impulse source levels for the DET system is given in Table 6.

Table 6. Impulse levels for the test system. Units are Pa·sec

System	Impulse at 100 m	Impulse at 1m
DET system	1,000,000	100,000,000

8.1 Impulse Modeling

Prediction of impulse is not straightforward because the effects of ocean surface and bottom interactions modify the shape of the pressure pulse in a very complex way. In fact, the resulting impulse can range from 0, to several times the expected value assuming simple spreading-loss decay of the amplitude. Generally, the transmission loss characteristics for shallow ocean acoustic environments are very frequency-dependent. The approach taken here assumes the pressure (and impulse) reduction for each band decays spatially in accordance with its energy decay. First, the energy transmission loss for the charge is calculated by subtracting the total energy density level

Table 7. Look-up table for converting impulse transmission loss levels in Figure 4 to the equivalent impulse values.

System	25 Pa·s	50 Pa·s	75 Pa·s	100 Pa·s	200 Pa·s	310 Pa·s
DET	-132	-126	-123	-120	-114	-110

The impact on fish with swim bladders was determined with reference to impulse level. Generally the thresholds for various levels of impact are dependent on the body mass of the fish. Table 8 can be used to predict the maximum range (any depth) for a specific level of impulse. Typically the ranges are less than those in Table 8 for shallow depths. Figure 6 can be used to determine the corresponding variation with depth.

Table 8. Maximum ranges for exceeding several levels of impulse produced by the DET system

Line	25 Pa·s	50 Pa·s	75 Pa·s	100 Pa·s	200 Pa·s
A	>10000	7700	6700	5000	2500
B	>10000	>10000	9600	7500	4100
C	6600	4000	2700	1700	700

9. Recommendations

1.) The source level directivities used in this report are based on far-field approximations. The maximum ranges for exceeding impact thresholds were found to be near the limits of these approximations. Modeling near-field propagation is very complex and beyond the scope of the current work. A proper near-field analysis should be performed to include shock wave decay, wavefront curvature effects, and the near-field bottom and surface interaction effects. The directivity of end-detonated line-charges has been analyzed in detail by Marshall [6]. A comparison of the developed near-field theory with the results of Marshall's study would lead to better energy flux density and impulse estimates in both the near and far-fields.

2.) Acoustic monitoring of both near-field and far-field pressure at several bearings at the Horse Beach Cove test site is recommended to aid in development of the model. An investigation of the required parameters should be made in advance to determine the optimal placement of monitoring instruments.

10. References

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