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An Investigation of the Feasibility of Building a Harbor on the West Side of the Coast of South America Using Nuclear Explosives

H. H. Zootner

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AN INVESTIGATION

of

the feasibility of building a harbor on the west coast of South America, using explosive power of Nuclear Weapons.

A Preliminary Report

H. H. Zodtner

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There is an interest in discovering the various peace time uses of nuclear explosives. One of the proposals is the building of harbors. There are several ports along the west coast of South America where lighterage is necessary. This implies a need for expanded harbor facilities.

The problem is to find a good location for creating a harbor, and the feasibility of accomplishing this with the use of nuclear force.

Feasibility includes blast effects, radiation hazards, the number of weapons needed, and economic considerations. Economic considerations include the cost of creating a harbor of sufficient depth and area, the building of harbor facilities, and the estimated savings and advantages of the new harbor.

Several meetings were held with naval personnel of the Military Liaison group at UCRL to discuss the general problems of harbors.

On the subject of what constitutes a good harbor, the following points were made:

1. The protection should be from swell and prevailing winds.
2. Accessibility should be readily available both from sea and shore.
3. Maneuvering room should be ample so ships could berth ideally without the aid of tugs.

Size, shape, and depth of harbors were also discussed. One size suggested was 450 yards by 1100 yards. Information indicates the ships calling at ports on the west coast of South America are of the C-2 type hull for overseas ships and smaller for coastal shipping. Accordingly the minimum depth of the water should be 36 feet, based on maximum draft of 23 feet of basic C-2 hull. The relative merits of creating a harbor

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by blasting a deeper channel or by cutting into the land was discussed. It was pointed out that cutting a deeper channel and also using part of the shore line might give us an ideal situation, but this matter is open. The size of the harbor is also open, and the final determination will be based upon the economic considerations of the volume of business, type of ships, and the type of cargo which will be handled.

Chile with 2800 miles of coast offered the largest number of opportunities since in most harbors lighterage must be used because insufficient depth prevents construction of docking facilities. Several locations in Peru were examined but not included in this report as they seemed to have minimum promise.

With the above information as background, thirty-three different ports were given a preliminary investigation.

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ARICA has a population of 30,000. This is the most northerly Chilean port. It is at 18° 29' S. latitude.

The town is built at the foot of the Morro headland and is fringed by sand dunes.

There is no rain, winter or summer. The average winter temperature is 14.9°C. (59°F) and the average summer temperature is 21.8°C (71° F).

A short railroad connects the town with Tacna 39 miles away. Another railroad connects with La Paz the capital of Bolivia 285 miles away. About half of the imports and exports of Bolivia move over this railroad. The Pan-American Highway runs south from Arica.

A Free Zone has been created in the department of Arica. Vessels, aircraft, and other means of transport together with merchandise may enter the ports of Chacalluta and Arica without payment of customs duties and other charges. Vessels and merchandise leaving the free zone are exempt from export charges. New industries and new building in the free zone are granted relief from taxation for 15 years.

PISAGUA lies at the foot of lofty hills surrounding the extensive Bay of Huaina Pisagua, 13 miles from the now neglected Mejillones Cove. There is ample anchorage in 10 to 15 fathoms. Loading by lighterage. Fresh water is brought from the hills, but there is also a condensing plant. Other provisions are obtainable, and there are repairing shops. There is railway communication with Iquique. Chief exports: nitrate and iodine. Imports: coat and general merchandise.

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CALETA HUNIN, 19° 40' S. latitude, lies at the foot of steep cliffs, up which an inclined railway is laid. The anchorage is safe, though quite unsheltered. The port has a population of a little over 100, but Alto Junin on the top of the cliff is a fair-sized place. There are engineering shops here, with facilities for ship repairs. There is an excellent supply of water, which is also utilized to work cranes on the mole. Trade is almost entirely confined to export of nitrate and import of coal and provisions.

CALETA BUENA, 19° 54' S. latitude, in the province of Tarapaca, situated at the foot of a cliff some 19 miles north of Iquique, has replaced Mejillones as an exporting center of nitrate. Inclined railways are provided for bringing down the nitrate. There is safe anchorage in from 8 to 10 fathoms in the southern part of the bay, and there are two piers 500 feet long and three smaller piers, which serve to load the lighters. The town itself is built both on the shore and on the bluff.

IQUIQUE, the most important of the northern ports, has an excellent harbor, the roads being protected by Iquique island, which lies close to the coast and is connected by a causeway 5 feet high. The anchorage lies to the north of the island and town, there being extensive accommadation for both sailing vessels and steamships, though at certain seasons the harbor is inconveniently crowded. Sailing vessels have to be berthed by tugs. Loading and discharging is by means of lighters. The loading piers are to the southward of the island, and there is a mole along the rocks practically an extension of the 500 yards along causeway. The large town has a population of over 45,000 and although almost entirely built of wood, is well planned, and has many conveniences. Railways connect the port with the nitrate fields and with other towns. The exports are chiefly nitrates and iodine, and the imports coal and provisions.

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TOCOPILLA, latitude 22° 5' S., lies in the southern part of the bay of Algodonales in the province of Antofagasta. An English company, owning mines and smelting furnaces, has a long pier, along which the railway from Toco, 50 miles inland, runs. But ore is shipped from Bella Vista and Duendas as well as Tocopilla itself. Both fresh and distilled water is procurable.

GATICO, 22° 29' S. latitude, in the province of Antofagasta provides safe anchorage in 13 fathoms. A port of call, with copper ore as chief export.

GUAYACAN, on the north-east shore of port Herradura, 29° 58' S. latitude, a safe, land-locked harbor in Coquimbo Bay, exporting copper.

ANTOFAGASTA, in Moreno Bay, 23° 29' S. latitude, capital of province of the same name is of importance not only for its export trade of nitrate, silver, and copper ores and borate of lime, but it is the terminus of one of the railways of Bolivia, over which much of the traffic (passengers and goods) to and from that republic passes. For small vessels and passenger boats there are several piers in La Paz Cove, the largest belonging to the Antofagasta-La Paz Railway company. The railway company has repairing yards for ships. Coal, water (brought from the hills by a pipe line), and fresh beef are abundant, but other provisions scarce and expensive. There is a hospital, and telegraphic communication for all ports.

CALETA COLOSO, is the port for the nitrate district of Aguas-Blancas, Antofagasta, with which it is connected by rail. There is a good sheltered anchorage in 10 fathoms, and a landing mole.

TALTAL, latitude 25° 25' S., is at the bottom of the bay of Nuestra Senora, over a mile and a half across and three-quarters of a mile deep. This bay is

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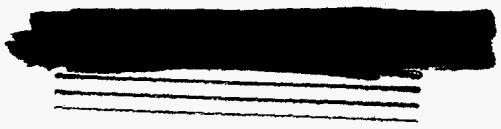

well protected. The Taltal Railway has five piers fitted with cranes. Lighters are also provided. It is one of the centers of nitrate and copper mining industries, these commodities being the principal exports, while imports include coal and foods.

CHANARAL, is in the large but exposed bay of Chanaral de las Animas, and lies in one of the richest mineral districts of Atacama. There are large smelting works here, and the exports consist chiefly of gold, silver, and copper, while the imports are coal and general merchandise. The anchorage is close to the southern shore, with about 6 to 8 fathoms, with sandy bottom. Loading by lighters. There are three piers, one 450 feet long connected with the railway, the town and customs landing-place and one east of Piedra Negra Point. There is railway communication with Copiapo via Puquios, and with Inca del Oro. Supplies are to be procured, but they are all imported. There is a general hospital.

CALDERA is the port for Copiapo, capital of the province of Atacama, with which it is connected by rail. It is fairly protected, with anchorage in 12 fathoms off Caleta Point. There is a jetty 740 feet long, with 20 feet of water.

CARRIZAL BAJO in the bay of that name, just a mile northeast of Herradura de Carrizal Bay, 28° 6' S. latitude, is chiefly engaged in exporting copper and manganese ores and importing coal and general merchandise. But both Carrizal Alto and Carrizal Bajo are unimportant in themselves.

HUASCO, 28° 27' S. latitude, lies in a small bay, with excellent anchorage. The town is the shipping port of Vallenar and the mining districts of Huasco

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and Santa Rosa. There are smelting works here. In the neighborhood are situated some of the best known Chilean vineyards. The exports are minerals, wine, raisins, and hides. There is a narrow gauge railway to Vallenar, which is carried down a long pier fitted with cranes.

COQUIMBO, on the western shore of the bay of that name, is provided with a good landing pier, several cargo piers, and a pier set aside for copper ores. There are good supplies here. It is the terminus of the Ovalle and the Elqui Valleys Railways.

PAPUDO is the outlet for large quantities of cereals, timber and copper. Coal is imported in large quantities for the mines and smelting works.

VALPARISO lies in a semicircular bay between Angeles and Gorda Points in latitude 33° 2' S. The bay affords safe anchorage for a large fleet in all weathers, except when the winter north winds blow. Then the port is dangerously exposed. But this is fast being remedied by the construction of breakwaters and mooring stages, a sum of $4,579,500 have been voted in 1910 for these harbor improvements. At present the Fiscal Mole, running from north to south for 1,000 feet is available for vessels of considerable tonnage, one-half having a low-water depth of 43 feet and the other of 36 feet. On this mole are large electric cranes, tramways, and other facilities for quick unloading and loading. There are two floating docks, the "Santiago", 300 feet long by 49 3/4 feet wide, 17 feet over the sill, and having a lifting capacity of 6,000 tons; and the "Valparaiso", 265 feet long by 80 feet wide, 15 feet over sill, and lifting capacity of 2,500 tons. The port is provided with tugs and pilots. There are two general hospitals, also hospitals maintained respectively by the British and German communities. Supplies of

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provisions, coal, and water are ample. There is a fortnightly service by the Pacific Steam Navigation Company with Liverpool, and a weekly service by the Kosmos line with Hamburg. Several lines of cargo steamers from Europe call regularly. There are also coastal services, from Puerto Montt to Panama, kept up by the Pacific Steam Navigation Company and the Compania Sud-Americanna de Vapores. The Italian Lloyd del Pacifico keeps up communication with Genoa, a Japanese line with Japanese ports, Hong Kong, Callao, and Arica. The leading exports are wheat, flour, bran, alfalfa hay, beans and cattle. The imports include coal, food products, machinery, and general merchandise. The town has been well laid out since the terrible earthquake in 1906, and contains all the conveniences of a busy commercial port. It is enclosed by cliffs, so that the city is built on two levels, joined together by means of lifts. Valparaiso is in direct railway communication with Santiago, 115 miles off, and by means of the Transandine Railway with Buenos Aires. In 1912 the entries were: steamers from overseas, 560 of 1,731,767 tons, coasting steamers, 568 of 520,137 tons; sailing vessels over seas, 74 of 124,005 tons, coasting vessels, 46 of 9,530 tons.

PUERTO SAN ANTONIO, often referred to as Puerto Viejo, lies two miles to the north of Maipo River. It has a very restricted and poor anchorage, but provisions are abundant and cheap, and there is a large export of wheat, barley, and wool.

CONSTITUCION lies in 35° 19' S. latitude at the mouth of the river Maule. A bar has to be negotiated which has an opening from September to February close to the Lobos Rocks, and has between 11 and 16 feet of water at low tide. Then from March to April the channel shifts to the north, and has only from

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6 to 8 feet of water at low tide. Once within the bar there is good anchorage off the south shore. There is railway communication with Talca on the Central Railway.

CURANIPE, in the province of Maule, exports wheat and timber. It is an open roadstead with few facilities.

TALCAHUANO, is situated in the southwest part of concepcion bay. There is a fine pier with ample space in 4 to 5 fathoms of water, and every facility for handling cargo. For large vessels there is anchorage in 7 fathoms to the southward of Belen Shoal. It is a pleasant town, with hospital and home for sailors. There is telegraphic and telephone service, and railway connection with the Central line. A railway connects the town with the Government Dry Dock (which is in two sections), 605 feet long, 83 feet entrance, 30½ feet over sill. It is provided with telescopic anti-earthquake shores. There is a patent slip to take vessels of 2,000 tons. The town is well supplied, and is in a rich agricultural district. The exports consist of cereals, flour, and bran, timber; imports agricultural implements and general merchandise.

PENCO is a small port in the southeastern part of Concepcion Bay. There is a good pier. Large vessels find anchorage in 7 fathoms to the north of the pier.

TOME' a busy port in the small bay southeast of Huily Head, with safe anchorage in 8 to 12 fathoms. There is a long pier with a crane having a lifting capacity of two tons.

CORONEL, in the province of Concepcion, has a very extensive export trade in coal (being connected by rail with Lota), also timber, cereals, wine,

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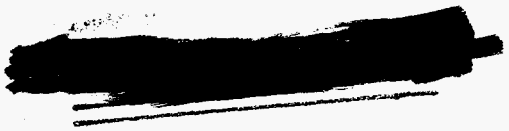
cotton, etc. There is good anchorage. Loading is by means of lighters. There are two landing-stages. Railway communication with Concepcion.

LOTA lies in Lota Bay, northward of the Lobos Island, and has excellent anchorage in from 5 to 6 fathoms. There is a long iron pier with a depth of 21 feet at its head, and there is an extensive mole between the inner and outer bays. The Customs House, eastward of the mole, has its own pier. There are large smelting, brick and tile, and other works here. It is the chief port of the coal trade. The towns of Bajo and Alto Lota have a joint population of over 10,000 and afford all conveniences for shipping. The port is in railway communication with the south.

LEBU is a fairly large town at the mouth of the river of the same name on the east side of Tucapel Point. The port is in a bay two miles wide and one mile long, with anchorage in 7 to 8 fathoms. It is the center of a coal mining and a rich agricultural district.

VALDIVIA lies some 9 miles up the river Valdivia, which is the name of the lower reaches of the Rio Calle Calle. It is a big city with plenty of conveniences and good supplies. It is in railway connection with Osorno and Temuco. Exports cereals, wool, leather, and imports machinery and general merchandise. Only vessels drawing not more than 9 3/4 feet can reach Valdivia. Vessels are usually unloaded and loaded by lighters of a capacity ranging from 60 to 100 tons.

MAULLIN stands on the south bank at the mouth of the navigable river of the same name, which empties itself in the Gulf of Choronades. It is a small town, but does a considerable trade in timber. The anchorage for large steamers



is northward of the town.

PUERTO QUELLON is on the Chiloe' shore, has a safe anchorage in moderate depth of water, a large export in timber and forest products, and provides excellent provisions, which are usually exchanged by barter.

PUERTO MONTT is situated at the north end of Tenglo Island, separated from the mainland by a narrow channel. It is the capital of Llanquihue, with a growing population and trade, and is in railway and telegraphic communication with the rest of the republic. There is a quite small harbor, with 5 fathoms, sheltered from all winds. The anchorage, on the bank for about half a mile below the town, varies from 5 to 17 fathoms.

ANCHUD, formerly known as San Carlos de Ancud, stands on the Huihuen heights on the east shore of the Bay of Ancud on the south-east side of Lacuy peninsula, 41° 51' S. latitude, province of Chiloe'. The entrance to the port is between Cochinos islet and Ahui Point, about two miles apart. The anchorage off the town itself is not very safe, but in fine weather vessels drawing 12 feet can remain here. For large vessels the best berthage is off Balcurra Point in 5 or 6 fathoms of water. Loading and unloading is by means of lighters. There is a small mole, affording good loading for ships and boats in full tide. Supplies are good, there is railway communication with Castra, 59 miles distant. Direct communication with Europe is maintained by the Kosmos line, and it is a port of call for the Pacific Steam Navigation Company and the Compania Sud-Americana de Vapores running between Valparaiso and Puerto Montt, and also for a small coasting steamer. There is a large free general hospital and a wireless telegraphic station.

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After studying all the sites as indicated in the preceeding section, it was decided that Arica offered the best possibilities in terms of the study we have in mind. Therefore, it has been decided to concentrate our studies on the area of Arica.

A hydrographic map indicates that about three quarters of a mile from the shore there are breakers which extend up and down the coast. The depth of the water between the breakers and the shore line is shallow. At this point the water could be deepened to form a harbor, and if desirable the crater could be made in such a way to go back on to the shore, creating part of the harbor from the present shore line as well as from the deepening of the sea.

It is proposed to use weapons of smaller size so that we stay within the kiloton range. It is estimated that this will give us pressures which will be tolerable in Arica, a city of some 30,000 at a distance of some $2\frac{1}{2}$ to 3 miles.

The meteorological data which is attached to this report indicates temperature conditions to be ideal the year around. There is very little rain, winds are of moderate intensity, and the humidity is low. This particular point was selected because the harbor of Arica is the outlet for much of the import and export of Bolivia. Also, a short railroad line connects Arica with Tacna which is in Peru. So, there are three countries which could profit from a successful venture of this type. A Free Zone has been created in the department of Arica. This should further increase the volume of business in this area and be of an additional aid in shipment of material to and from Peru and Bolivia. The population density of this area generally is low, being about four per square mile. Population back of Arica is practically non existent. There is no wild life to consider and no vegetation. The matter of fishing is being considered.

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After studying all the sites as indicated in the preceding section, it was decided that Arica offered the best possibilities in terms of the study we have in mind. Therefore, it has been decided to concentrate on the area of Arica. Many of the problems associated with this location will be common to others. The selection of Arica does not mean there are no other good sites, indeed there are several which are promising.

The following points aided in the selection of Arica:

1. This site offers opportunity for major harbor improvement.
2. The volume of trade seems to justify harvor development.
3. This area of Chile has a low population density, there is no vegetation and no wild life.
4. Three countries are served.
5. A Free Zone is being established in this area.
6. Arica is on the Pan American Highway.
7. Meteorological conditions seem favorable.
8. There are no islands to the west.

According to the 1957/58 edition of the South American Handbook, Arica has a population of 30,000. The Hydrographic Office Pub. No. 174, Sailing Directions, South America, Vol. III says, " The streets are laid out with regularity and the houses are of adobe or concrete and mostly of one story. There is a six story hotel. - - There are two moles -- the passenger mole and the railroad mole. In 1942 the railroad mole was reported to have a depth of 18 feet alongside. This is the mole commonly used by lighters. Cargo is handled by lighters."

Fig. I shows the position of the proposed harbor in relation to Arica. It is 2 1/2 to 3 miles north of the city on a flat strip of land. There

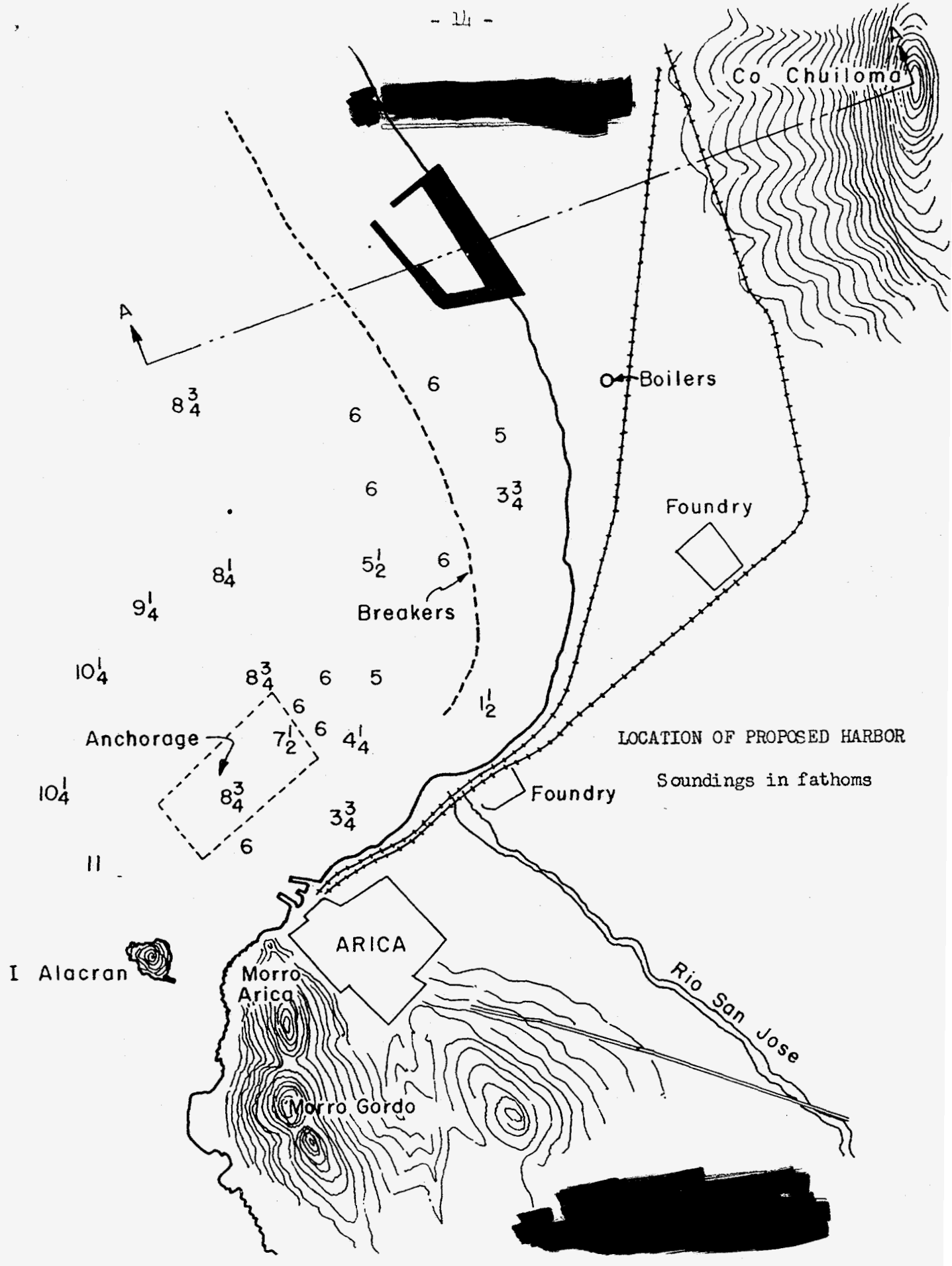
Co Chuiloma
A
Boilers
Foundry
Breakers
Anchorage
LOCATION OF PROPOSED HARBOR
Soundings in fathoms
Foundry
ARICA
I Alacran
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Fig. 1

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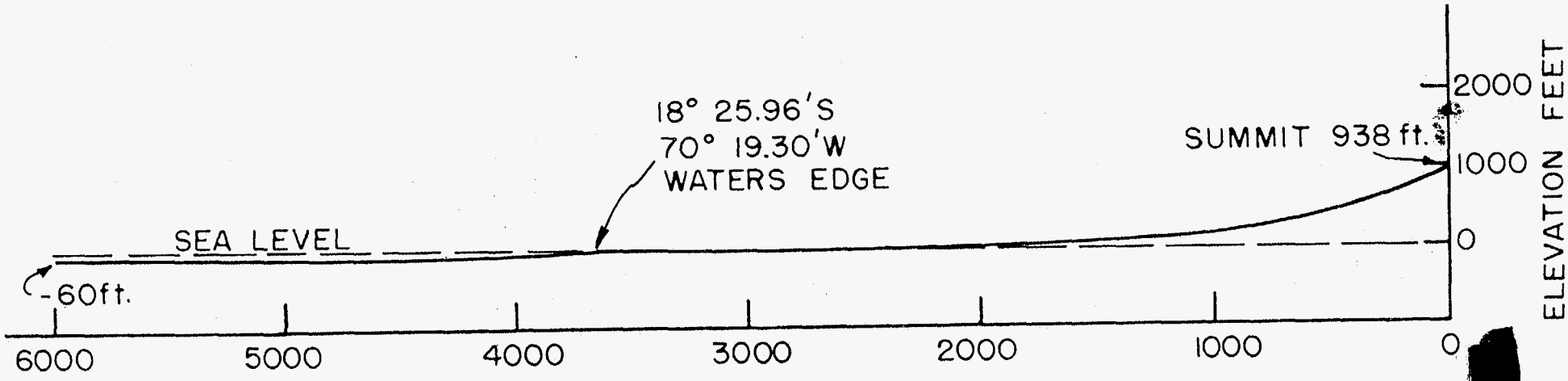

SECTION A-A

Ground profile of Arica, Chile through proposed harbor location. Profile along a line bearing 251½ degrees true from the summit of Co Chuiloma.

Fig. 2

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are sand dunes and the slope toward the water is gradual. Fig. II shows a profile view from Co Chuiloma to sea as indicated in line AA in Fig. I.

The nautical chart H.O. number 1265 shows breakers extending up and down the coast at a distance of three quarters of a mile off shore. The depth of the water between the breaker and shore line is shallow. At this point the water could be deepened to form a harbor, and if desirable the crater could be made in such a way to go back on to the shore, creating part of the harbor from the present shore line as well as from the deepening of the sea.

The savings by avoiding lighterage at Arica are not known but C. M. Bacigalupi in a memo gives this information:

"SUBJECT: Ship Off-loading Costs

The following information was obtained from Holmes and Narver on the off-loading of ships at Eniwetok.

A. Average time required to off-load at deep water pier

1. Cargo Ships	5 days
2. Refrigerator Ships	2 days
3. Tankers	1 day

B. For a total of 16 Cargo Ships, 11 Refrigerator Ships, and 9 Tankers, the savings by off-loading directly on to the deep water pier rather than lightering are as follows:

1. Total direct labor for lightering	$136,885.
2. Equipment Usage	35,777.
3. POL Operations	3,490.
4. Indirect and Operational expenses	309,795.
Total.....	$485,947.

C. The average savings for unloading the various types of ships at a pier rather than lightering is as follows:

1. Cargo Ships	20,080. per ship
2. Refrigerator Ships	8,032. " "
3. Tankers	4,016. " "

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The above savings do not include any allowance for the maintenance of the pier. It is estimated that the cost of maintenance per year is approximately five percent (5%) of initial construction costs. This item would have to be deducted from the savings shown in Items B and C above."

The Chilean Publication "Exterior Commerce" lists the import and export tonnage handled through the Port of Arica during 1950 as follows:

Chilean imports	22,000	gross tons
" exports	4,341	" "
Bolivian imports	61,268	gross tons
" exports	38,653	" "
Peruvian imports	1,576	gross tons
" exports	524	" "
Total Tonnage	129,362	

Based on this tonnage a saving in cargo handling of $250,000 to $300,000 per year is indicated.

Based on the 1950 report the following information gives the volume of business of each port in tons:

Port	Export	Import
Arica	4,341	22,000
Iquique	416,246	27,000
Tocopilla	1,222,000	270,000
Ollague	- -	1
Antofogosta	253,000	165,000
Chanaral	52,000	90,000
Coquimbo	28,000	45,000
Los Andes	24,000	16,000
Valparaiso	108,000	800,000
San Antonio	263,000	80,000
Santiago		980
Talacahauno	34,000	303,297 [redacted]
Valdivia	60,000	11,285

[redacted]

Port	Export	Import
Puerto Montt	11,000	6,595
Puerto Natales	- -	22
Chancalluta	3,500	- -
Taltal	114,000	- -
Caldera	4,700	15,878
Cruz Grande	36,000	280,048

To Bolivia from Arica	61,268
To Bolivia from Antofogosta	183,445
To Peru from Arica	1,576
From Bolivia to Arica	38,653
From Bolivia to Antofogosta	128,538
Peru to Arica	524
Bolivia to Mejillones	30,352

These figures do not include coastal shipping within the boundaries of Chile.

The Harbor of Arica is connected by rail with Tacna (39 miles) in Peru, and with LaPaz in Bolivia which is 278 miles away. There is no railroad to the south. Fig. 3 shows the railroad system of Chile.

In the past over half the imports and exports of Bolivia passed through Arica. The above information given in "Exterior Commerce" for the year of 1950 shows that Arica handled less than one fourth of Bolivia's imports and exports through the west coast, while Antofogasta now handles three times as much Bolivian tonnage as Arica. This may be significant because Antofogasta now has an improved harbor with docking facilities. This is particularly significant because shipment by rail is expensive and it is 278 miles from Arica to LaPaz and 722 from Antofogasta to LaPaz.

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CHILE RAILWAY SYSTEM

Fig. 3

[redacted]

Since three countries, Chile, Bolivia, and Peru are served, stability and growth potential of the port should be good. A Free Zone has been created in the area served by the harbor. Vessels, other means of transport, and merchandise may enter Arica without payment of customs duties and other charges. Merchandise leaving the free zone are likewise exempt from export charges. New industries and new building in the free zone are granted relief from taxation for 15 years. This should stimulate trade and increase the tonnage of the port.

The Pan American Highway runs south from Arica to the Aconcaqua Valley where one branch runs to Santiago and another runs east over Upsallata Pass to Mendoza in Argentina. Roads are now being built in preference to railways.

The above indicates a real need for improved harbor facilities.

The approach to making a harbor at Arica, Chile, has been of deepening the water at the shore line and surrounding the area with a breakwater. To create a land-locked harbor would require bomb yields far in excess of those allowed by safe blast and fallout criteria. The size and shape of the area to be deepened, i.e., the harbor, depends, of course, on the volume of shipping and types of ships used.

Because of the limited information available three sizes of harbors have been considered with capacities for berthing 12, 6, and 3 ships at a time. The dimensions are based on the size of the C-2 type cargo ship. Plan views, cross sections, and dimensions of these are shown in the drawings following this section of the report. All three of the harbors are served by channels which extend 700 to 800 yards from the shore, at which distance the water is deep enough for safe navigations. Minimum water depth was considered to be 36 feet, with a depth of 40 feet probably resulting from

the bomb layouts shown.

The shape of the 12 ship harbor is based on the one currently in use at Antofogasta, Chile. It was felt that this harbor was representative of what would be a successful one for Arica. The 6 ship harbor is a modification of the 12 ship, and the 3 ship one is merely a breakwater pier. Additional factors limiting the size of the harbor are blast and fallout considerations.

The simplest method of creating a harbor would be the detonation of a single bomb of sufficient yield to give the desired dimensions. However, since crater size is not directly proportional to the yield, the efficiency of this method is quite low, and the yield required would be far in excess of that allowed by blast and fallout considerations. The alternate method, therefore, would be the simultaneous firing of a number of low yield bombs. Simultaneous firing is desirable because a better crater would be formed, and the time required to fire one bomb at a time would be excessive and costly. The better crater form would be due to a single throw-out of earth, a reduction of the cusps of earth occuring between craters, and less material thrown back into previous craters.

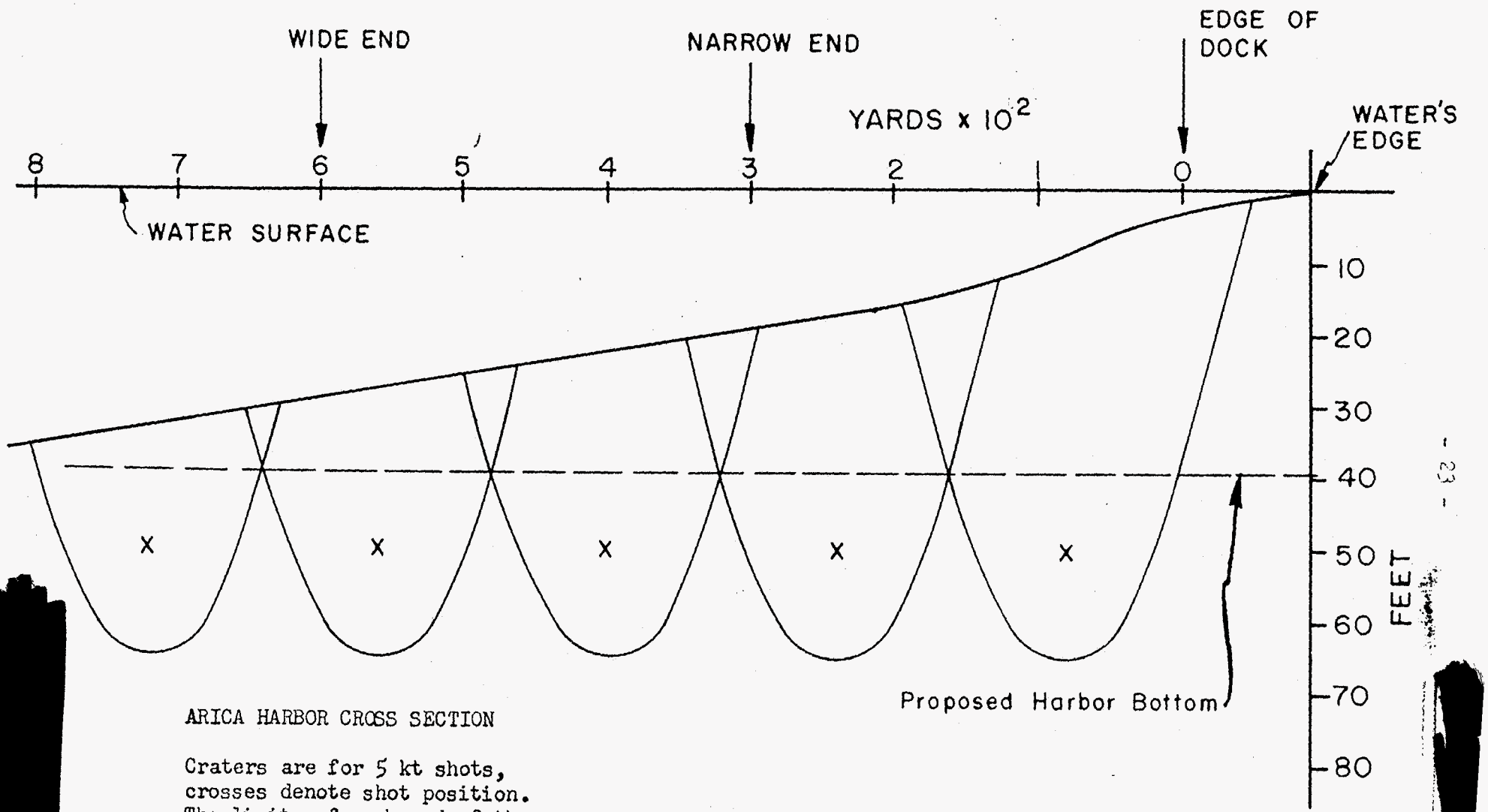
The time required for individual firing would be excessive because of the required wait for decay of fission products from previous bursts, the time required to drill the holes in the bottom for placing the bombs, which would have to be done one at a time, and the waiting for proper meteorological conditions for each shot. As will be seen, the total yield from the simultaneous firing of small bombs can be kept below the maximum allowed by blast and fallout. An advantage of using a number of small bombs is that the crater can be shaped to conform with the harbor plan, instead of having to build a harbor over a circular crater.

Two bomb sizes were tried, 1 KT and 5 KT. The diagrams show the suggested location of each bomb. The 12 ship harbor would require twenty 5 KT or forty 1 KT bombs for total yields of 100 KT and 40 KT respectively, the 6 ship harbor, ten - 5 KT or twenty - 1 KT bombs for totals of 50 KT and 20 KT, and the 3 ship one, five - 5KT or ten - 1 KT bombs for 25 KT or 10 KT total yields.

The proposed location of the harbor is approximately 5000 yards from Arica. An overpressure of .07 psi (5 millibars) was considered the maximum allowable on Arica, along with a maximum crest-to-trough wave height of 3 feet.

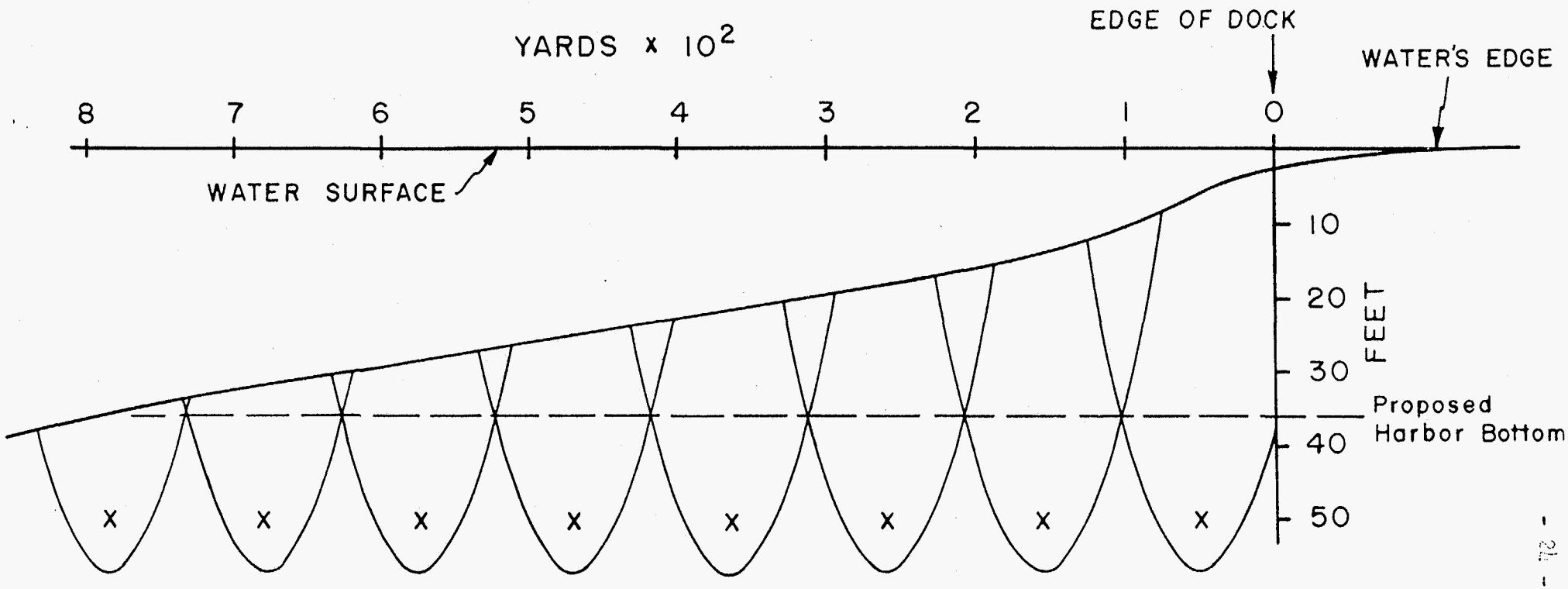
The bombs would be buried 50 feet below the water surface for both yields. This permits larger craters with a resultant lowering of the number of bombs required, lower overpressures, wave heights, etc. The composition of the bottom is sand and pebble, so the cratering data for saturated soil applies. The general profile of the area (Section A-A on the general map) indicates that this composition should extend well below the 50 foot-below-the-water surface level, or is at least deep enough so that it would be the only material which would have to be drilled through for placing the bombs. The holes, of course, would have to be cased. If the strata below the 50 foot level is close enough to that level, however, the shock reflection from it would create even larger craters than those shown in this report, with a consequent reduction in the number of bombs required and the total yield.

The following table gives the maximum overpressure and wave height at Arica for each of the total yields, and the maximum base surge radius. Underwater shock was omitted since data applying to this situation is not presently available.



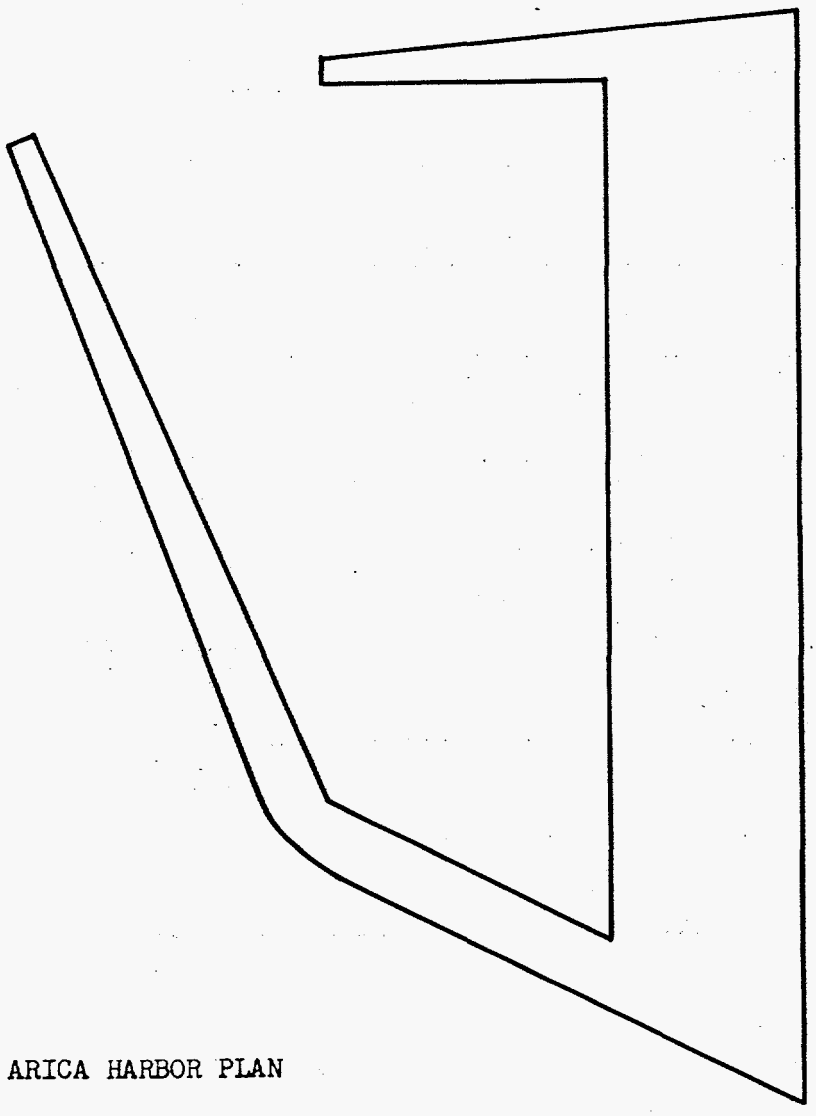
ARICA HARBOR CROSS SECTION

Craters are for 5 kt shots, crosses denote shot position. The limits of each end of the 12 ship harbor are indicated.



ARICA HARBOR CROSS SECTION

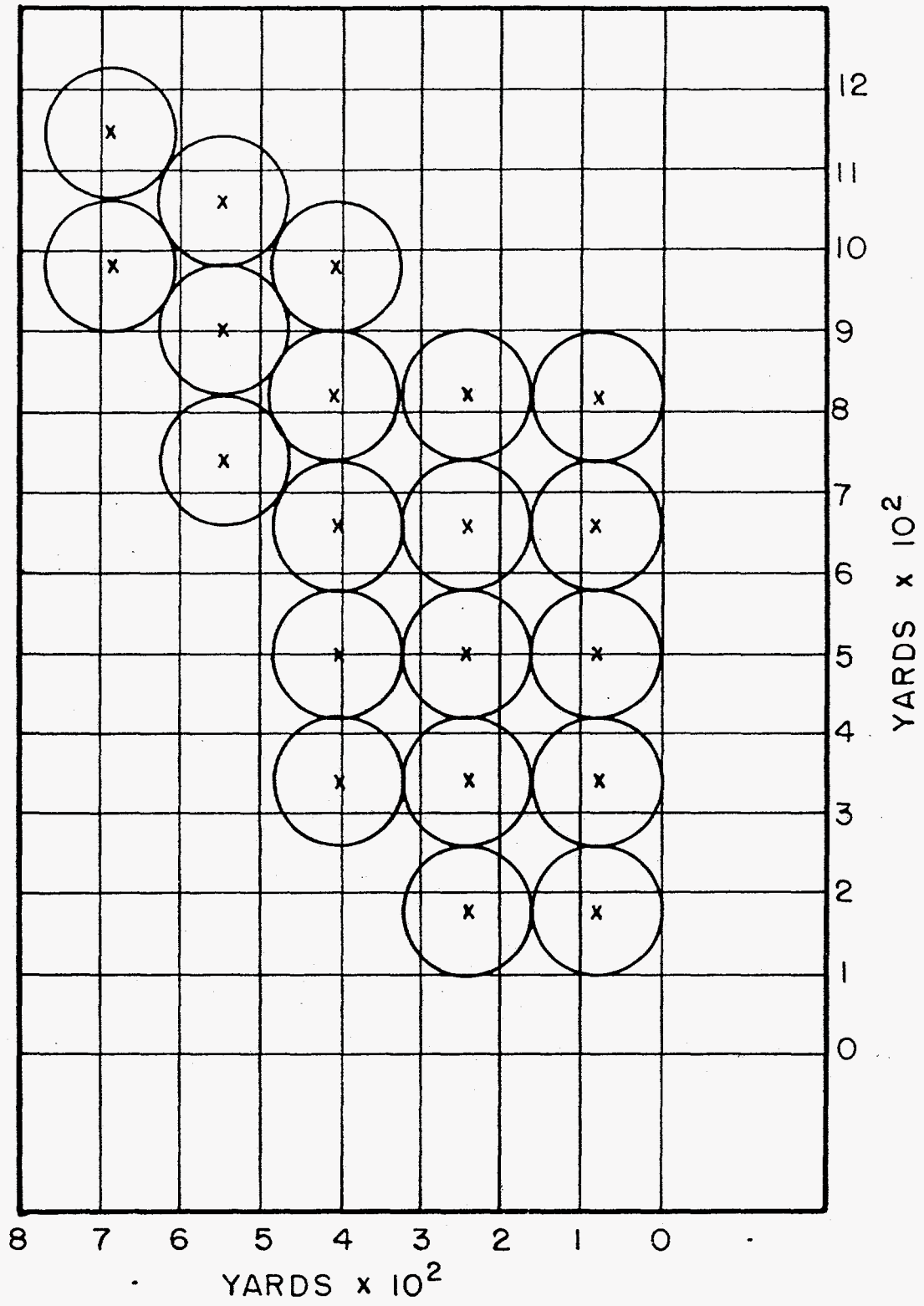
Craters are for 1 kt shots,
crosses denote shot position.



ARICA HARBOR PLAN

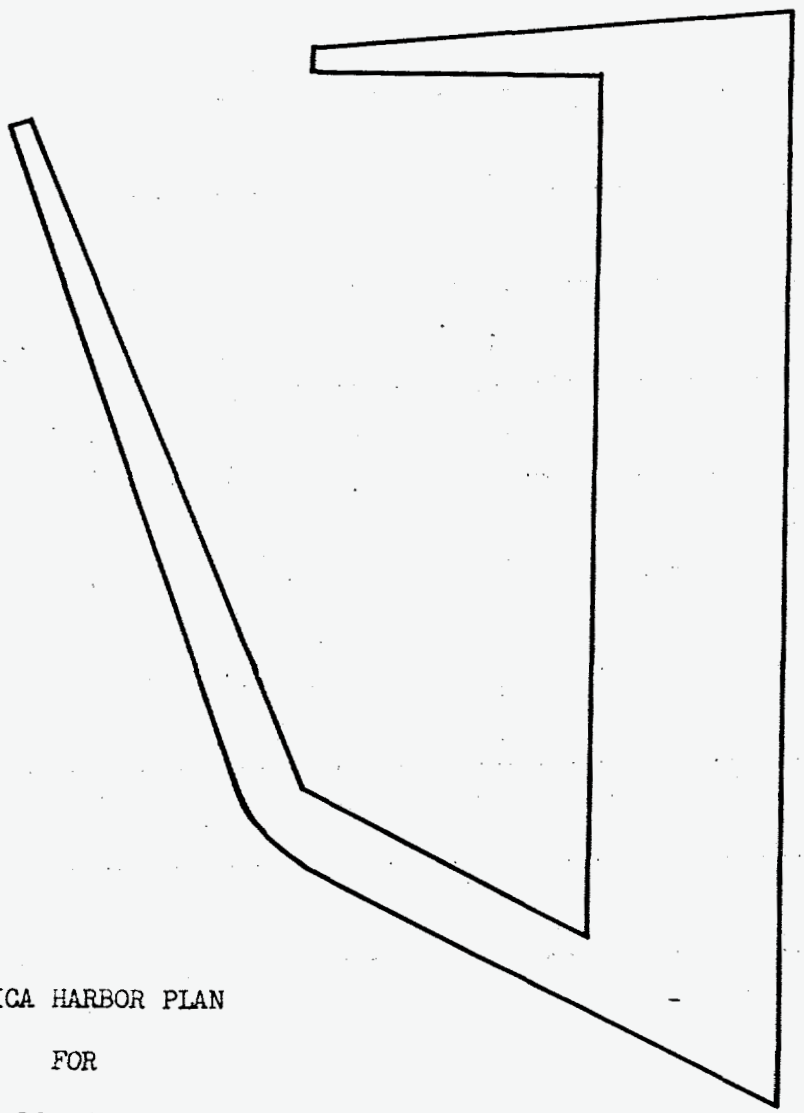
FOR

12 SHIPS



Bomb layout for 12 ship harbor using 5 kt shots at 50 feet below the water surface. Circles are crater rims at 40 foot depth of water.

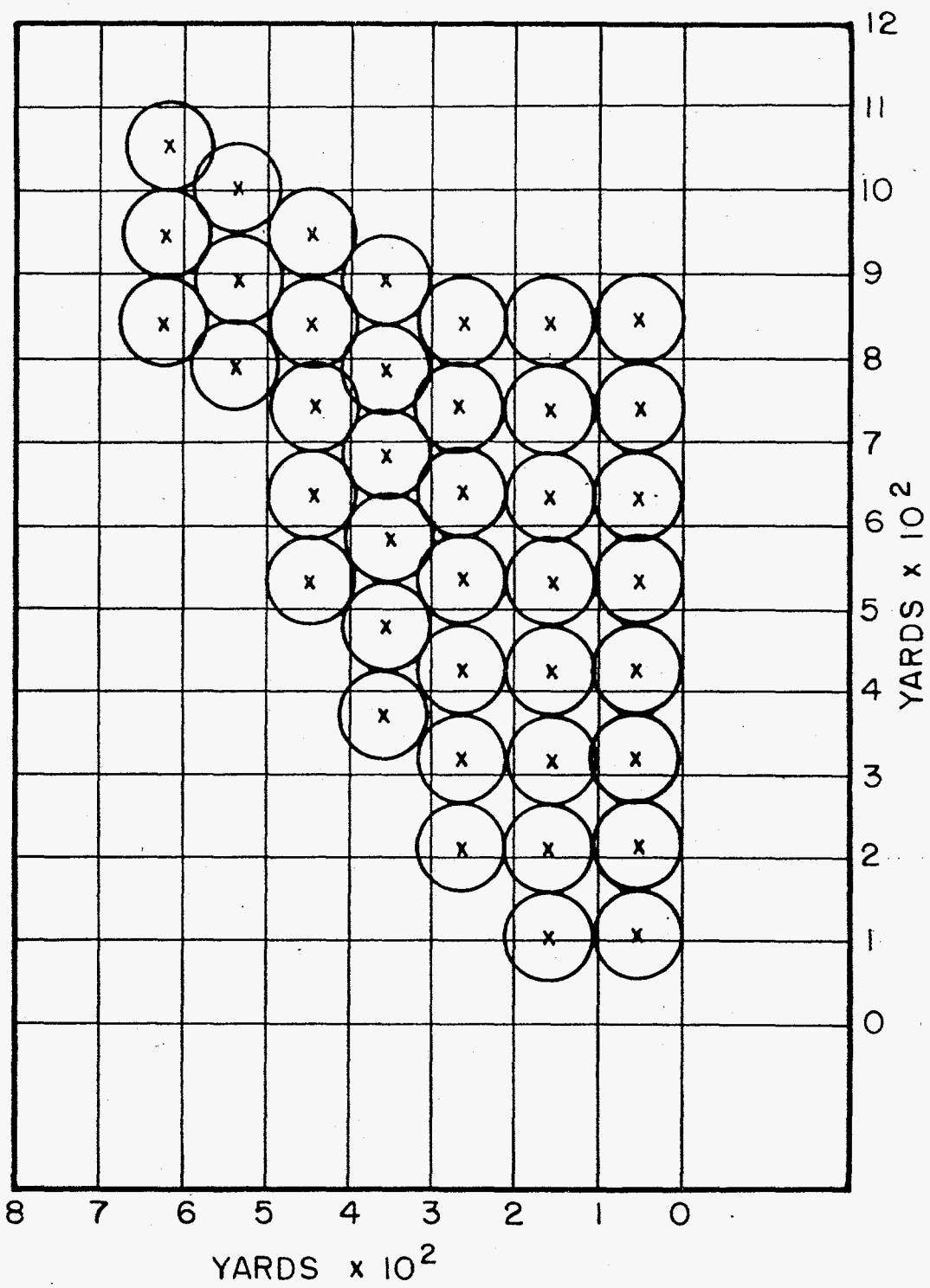
[redacted]



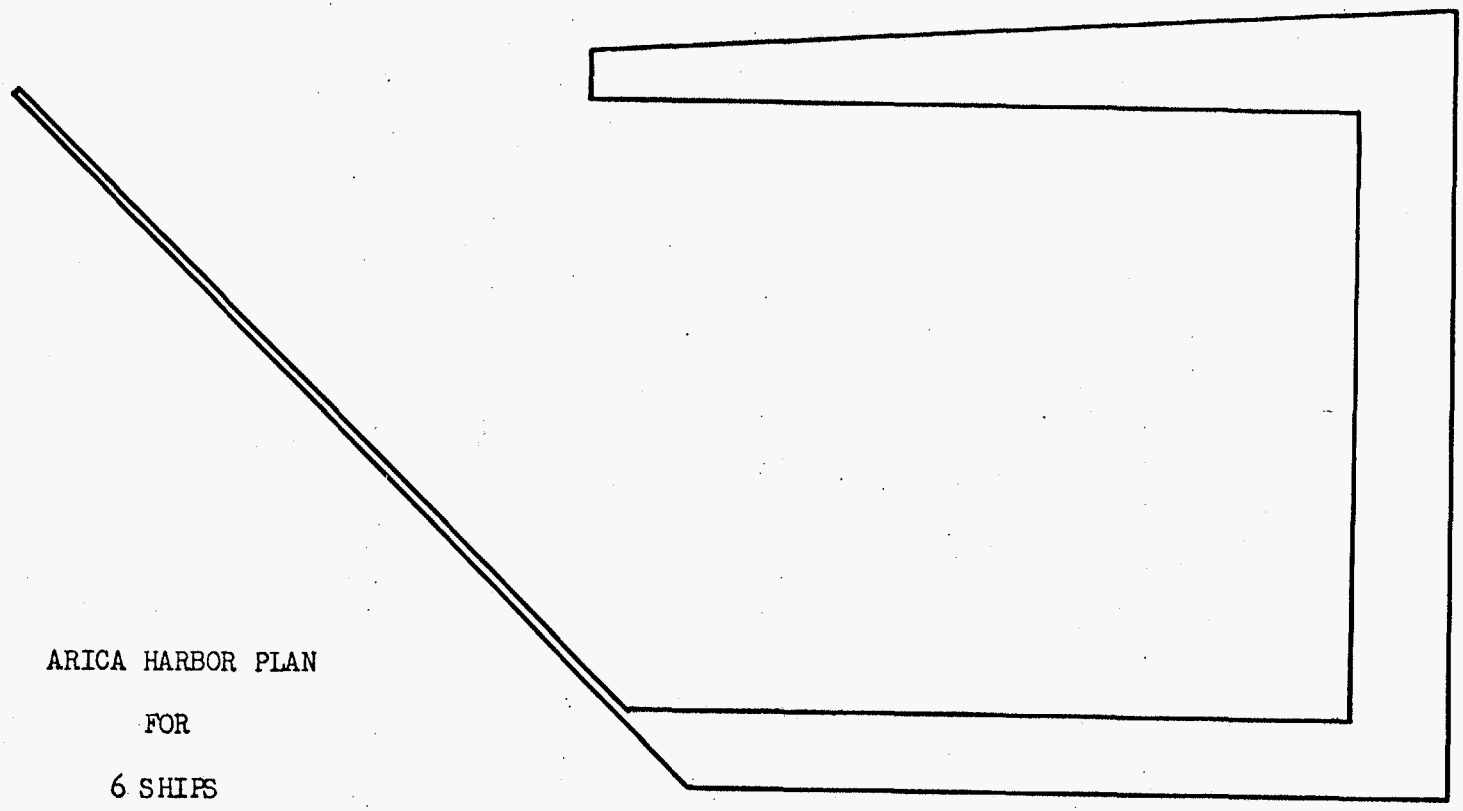
ARICA HARBOR PLAN

FOR

12 SHIPS



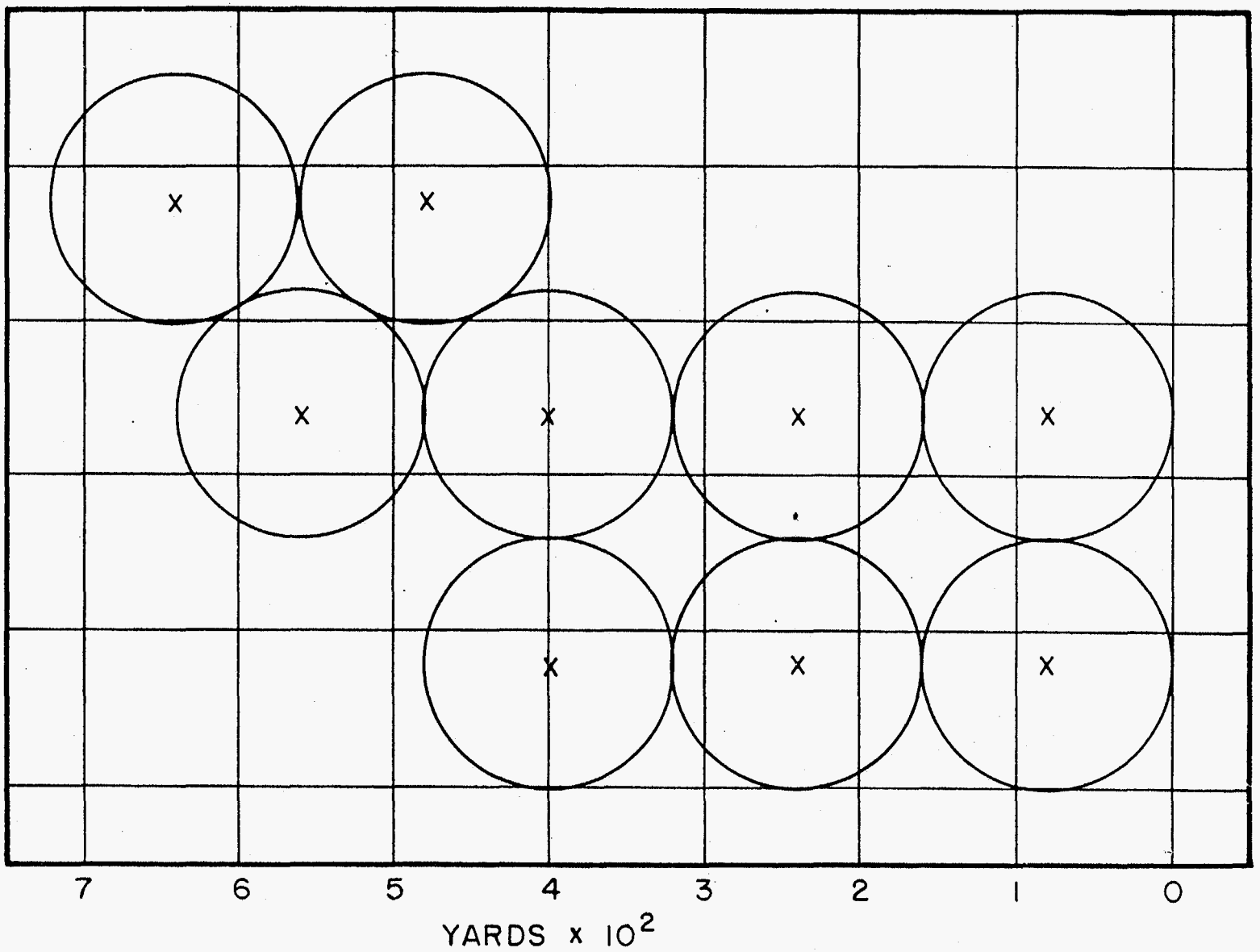
Bomb layout for 12 ship harbor using 1 kt shots at 50 feet below the water surface. Circles are crater rims at 36 foot depth of water.



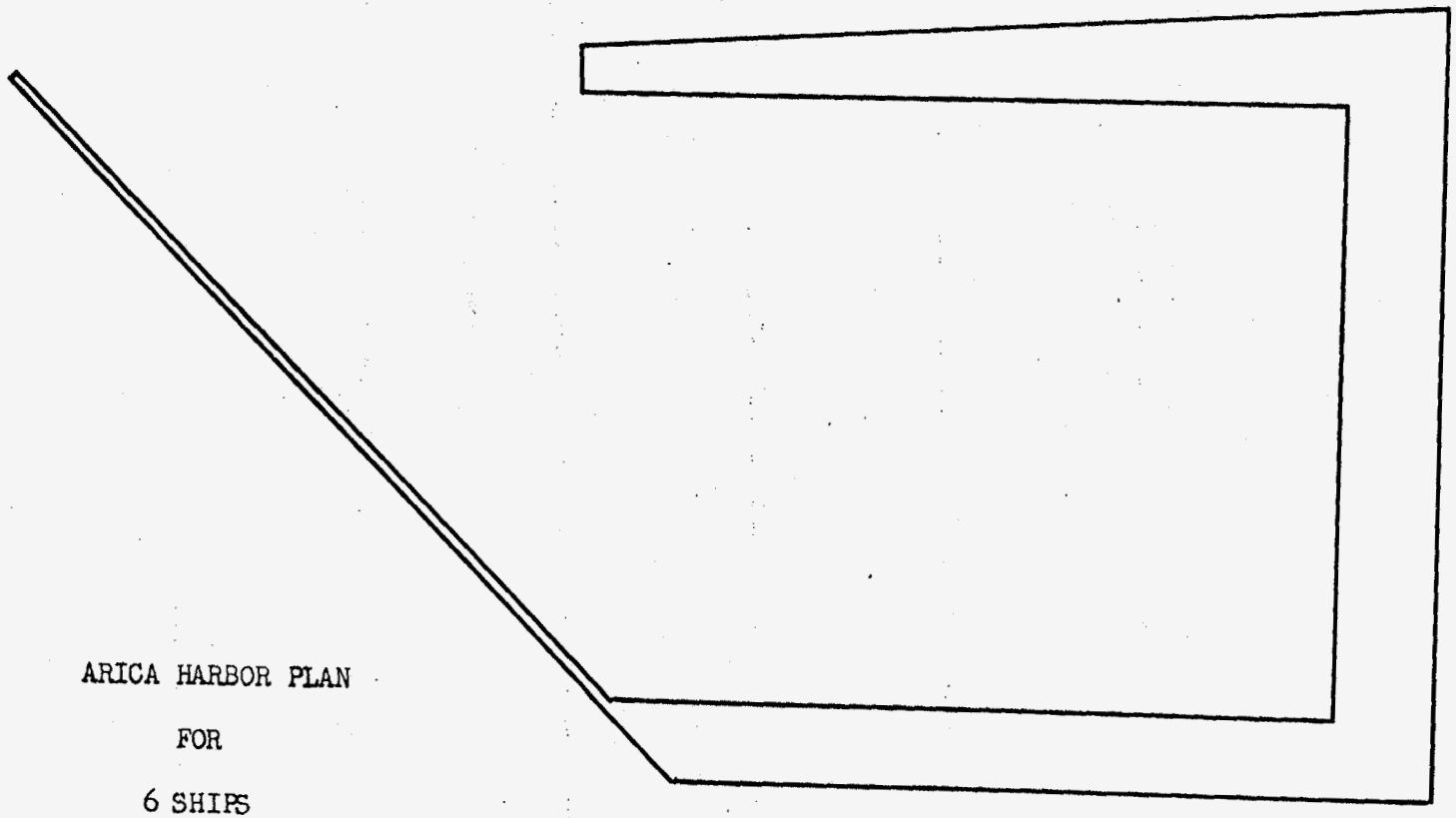
ARICA HARBOR PLAN

FOR

6 SHIPS



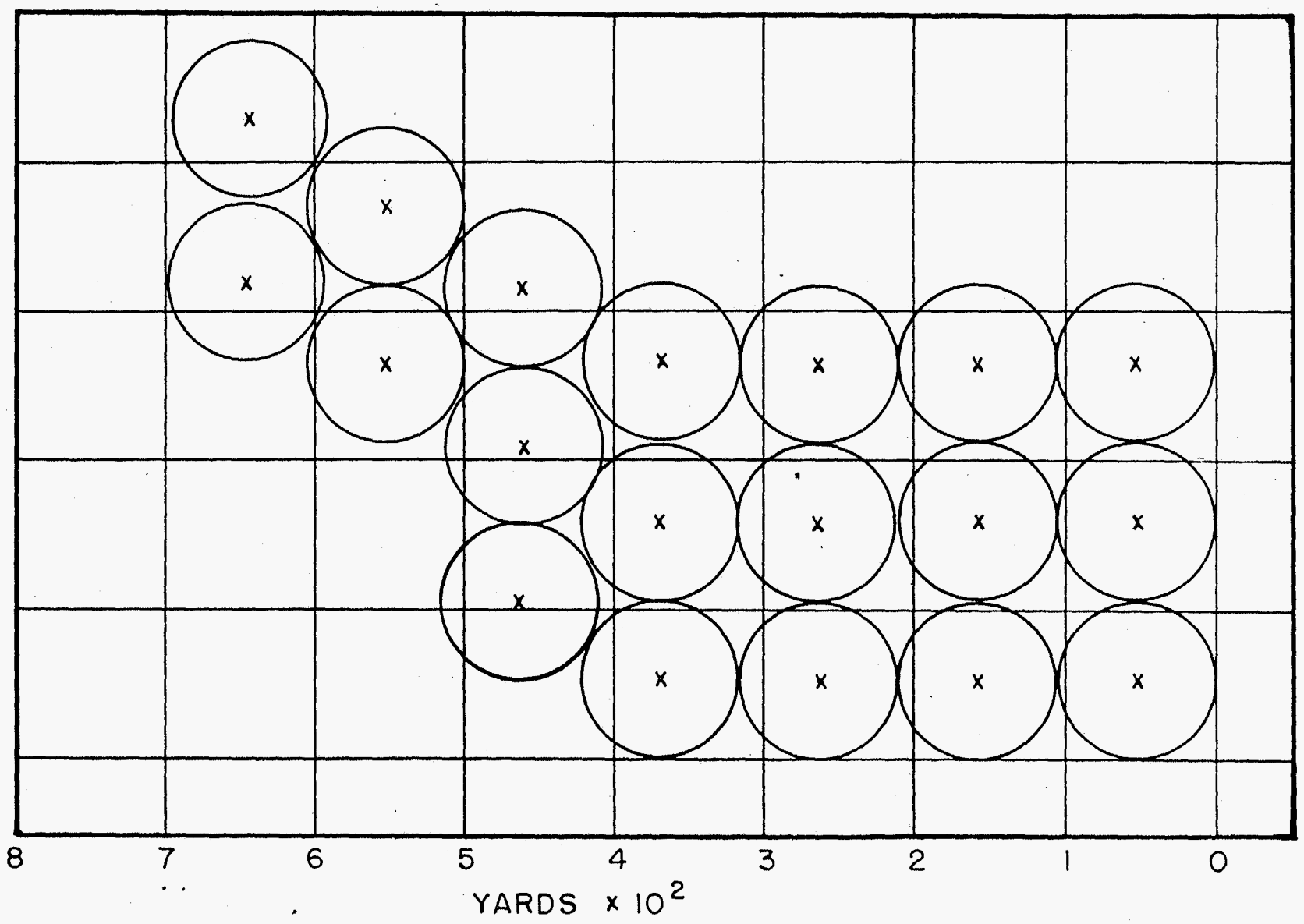
Bomb layout for 6 ship harbor using 5 kt shots at 50 feet below the water surface. Circles are crater rims at 40 foot depth of water.



ARICA HARBOR PLAN

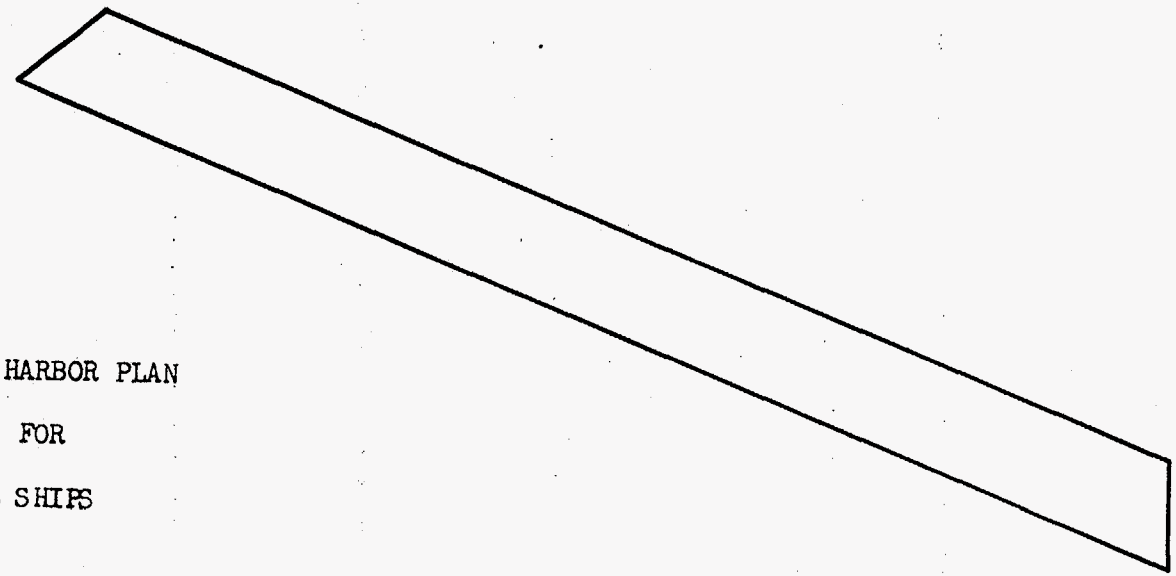
FOR

6 SHIPS



Bomb layout for 6 ship harbor using 1 kt shots at 50 feet below the water surface. Circles are crater rims at 36 foot depth of water.

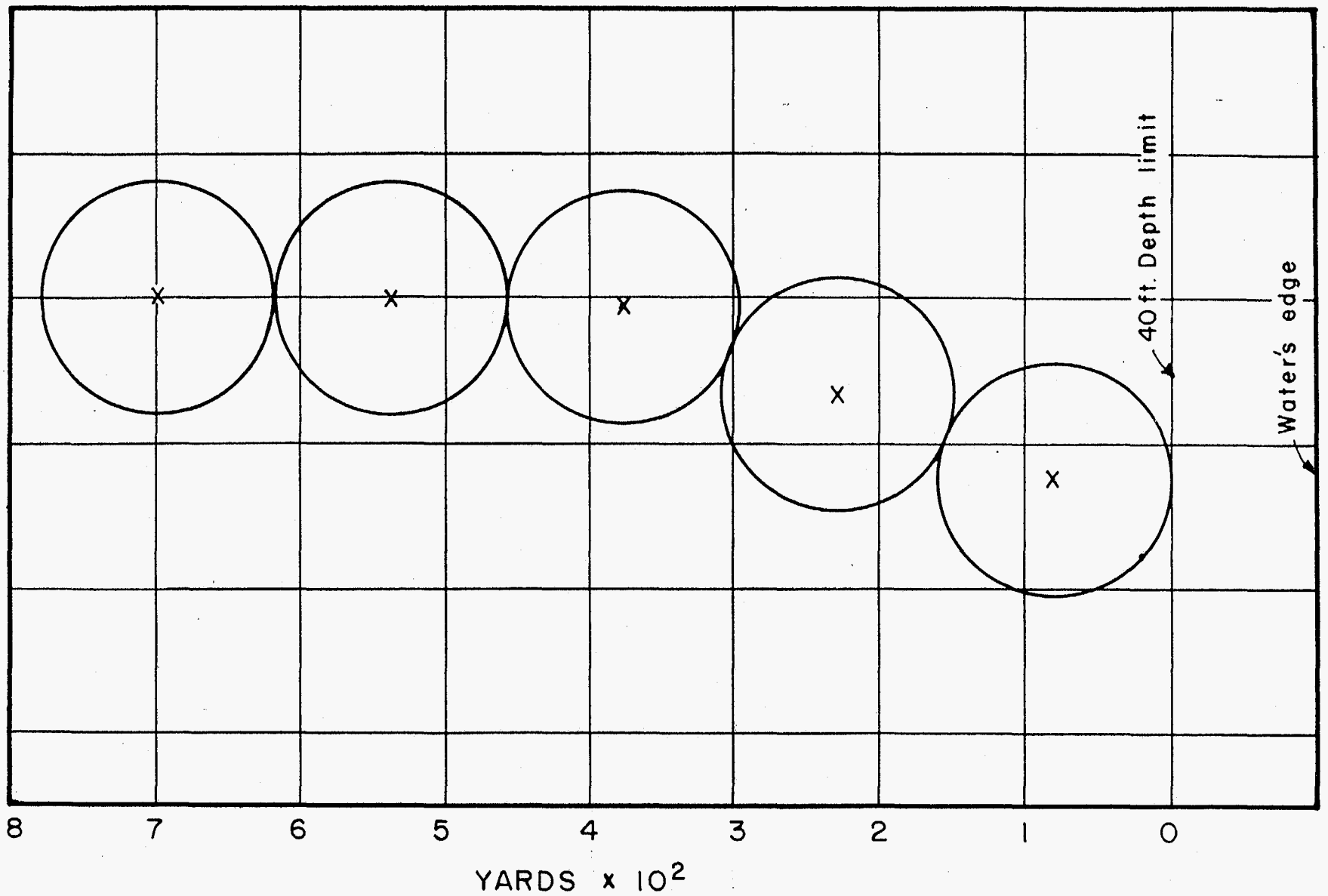
28281-1



ARICA HARBOR PLAN

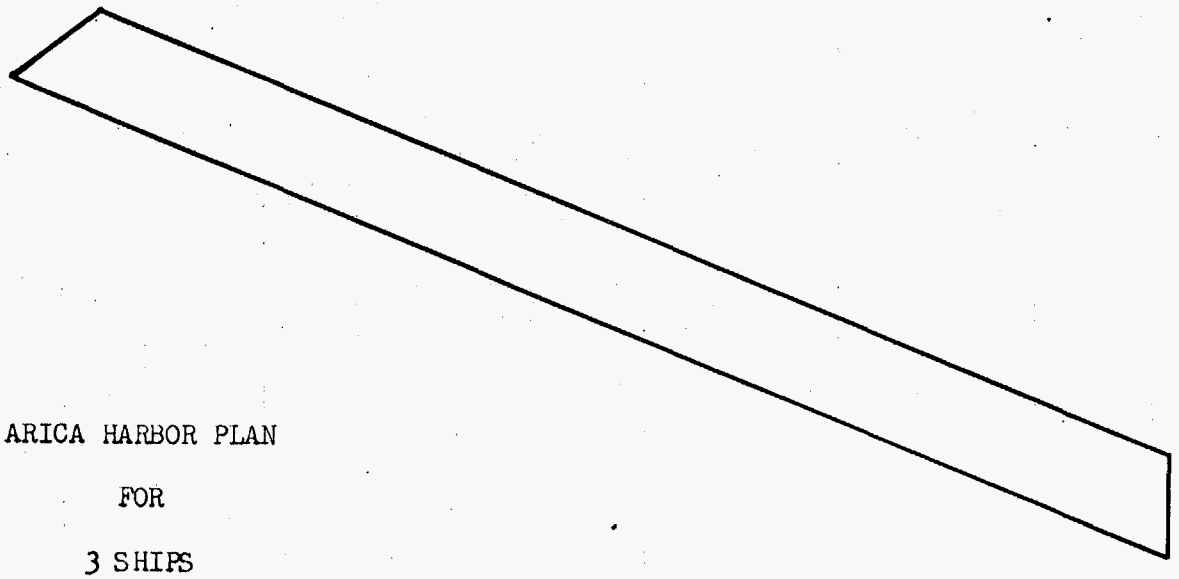
FOR

3 SHIPS



Bomb layout for 3 ship harbor using 5 kt shots at 50 feet below the water surface. Circles are crater rims at 40 foot depth of water.

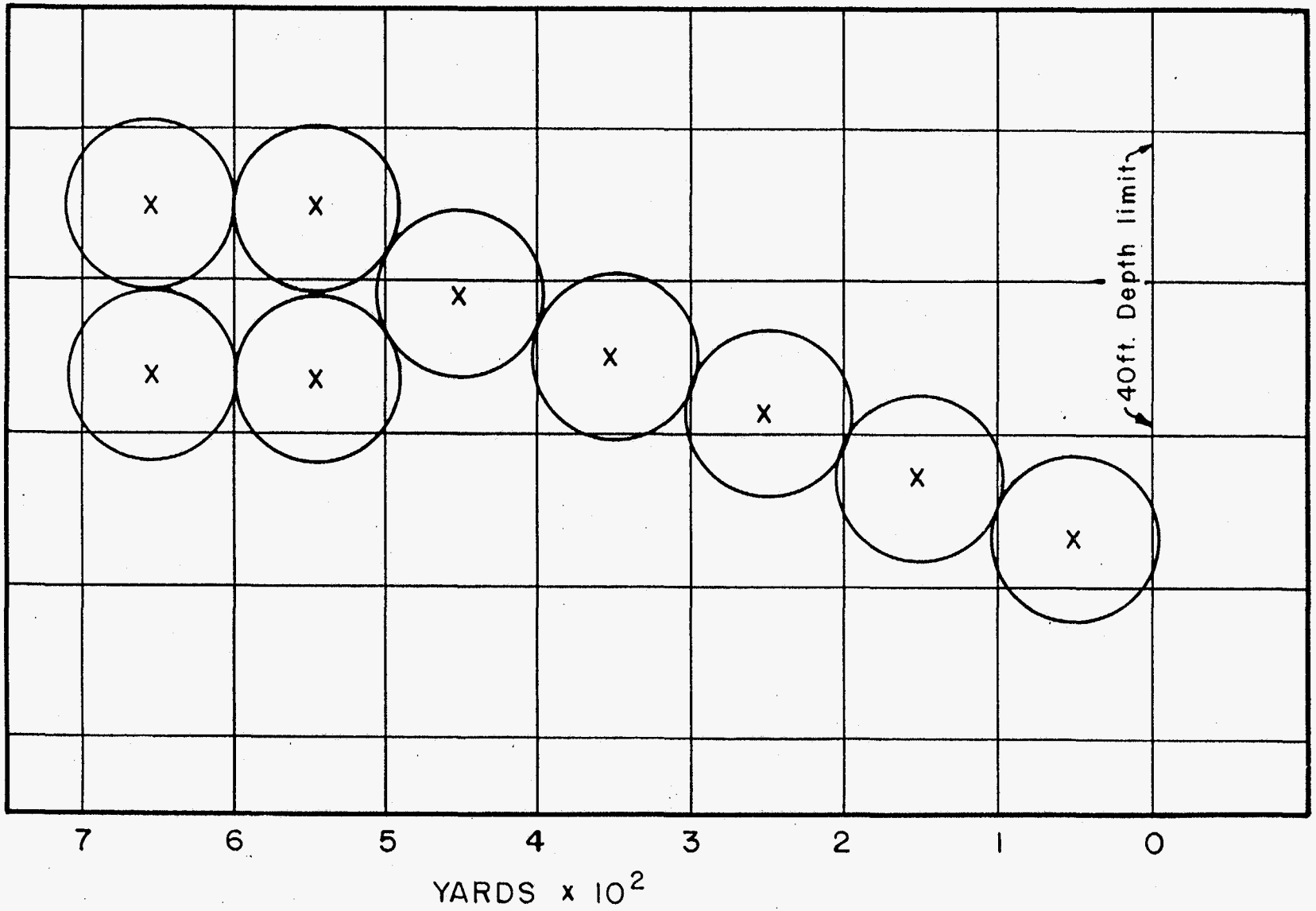
28273-1



ARICA HARBOR PLAN

FOR

3 SHIPS



Bomb layout for 3 ship harbor using 1 kt shots at 50 feet below the water surface. Circles are crater rims at 36 foot depth of water.

Harbor	Bomb Size and Total Yield, KT	Overpressure p.s.i.	Wave Height Crest - Trough, ft.	Base Surge Radius, yds.
12 ship	5 - 100	0.146	4.70	3810
	1 - 40	0.068	2.97	2990
6 ship	5 - 50	0.080	3.32	3140
	1 - 20	0.048	2.10	2490
3 ship	5 - 25	0.043	2.35	2560
	1 - 10	0.020	1.49	2080

From the table, then, using 5 KT shots the total yield for the 12 and 6 ship harbors would be too high. The other proposals, however, would be quite feasible from this standpoint.

Construction costs for the twelve ship harbor are given in memos from C. M. Bacigalupi as follows:

"SUBJECT: Construction Costs for Arica Harbor

Following is a summary of the costs of constructing a breakwater harbor for the Port of Arica. This Port is to be similar to the existing facility at Antofogasta.

A.	Sheet Piling in Place	$ 8,096,000.
B.	Support Piling in Place	11,872,300.
C.	Miscellaneous Pier Material	1,268,200.
D.	Earth Fill	2,149,000.
E.	Railroad	347,600.
F.	Paving	714,600.
G.	Lighting	452,000.
		$24,899,700.
	15% contingency	3,734,955.
		$28,634,655.
	5% Arch-Engr. fees	1,431,733.
		$30,175,388.

The above prices are for the construction of the harbor after the bottom has been dredged or blown to the proper depth. The cost does not include connecting railroads, roads, warehouse buildings, or power stations.

In addition to the above would be the cost of transportation of material from the United States to Arica and the cost of an LST or other supporting vessel used as a base facility for the construction crews. It should be noted that the above costs are based on the utilization of United States labor working at an overseas site. A considerable savings would be effected if native labor were used."

Similar costs estimates for the six ship harbor:

A.	Sheet Piling in Place	$ 3,933,000.
B.	Support Piling in Place	6,440,000.
C.	Misc. Pier Material	1,037,000.
D.	Earth Fill	1,392,000.
E.	Lighting	106,500.
F.	Paving	317,700.
G.	Breakwater	5,602,500.
		$18,828,700.
	15% contingency	2,824,300.
		$21,053,000.
	5% Arch-Engr. fees	1,053,000.
	Total Cost	$22,106,000.

The cost of the three ship harbor using only the breakwater as pier was estimated at $12,484,500.

Rough estimates of the amount of earth to be moved are:

Twelve ship harbor	1,925,000 cubic yards
Six ship harbor	1,600,000 " "
Three ship harbor	875,000 " "

The meteorological data which follows indicates temperature conditions to be ideal the year around. The mean winter temperature is approximately 60°F. There is very little rain, the average being about 1 mm. per year.

[redacted]

METEOROLOGICAL TABLE FOR ARICA

Position, latitude, 18°28' S., longitude, 70°20' W. Altitude, 16 feet

Month	Air temperature, °F.			Relative humidity (percent)	Rainfall			Wind									Number of days with-			Cloud amount (0-10)
									Percentage of observations from--											
	Mean	Mean maximum	Mean minimum	7 a.m.	Average amount (inches)	Number of rainy days	Maximum in 24-hours (inches)	Mean velocity (knots)	North	Northeast	East	Southeast	South	Southwest	West	Northwest	Calm	Gales	Fogs	Thunderstorms	7 a.m.
January.....	70	76	64	77	0.03	0.1	0.39	1.6	2	0	2	1	13	34	1	1	46	0	0	0	6.1
February.....	71	77	65	75	0	0	0	1.6	4	0	3	1	12	33	1	1	45	0	0	0	5.1
March.....	70	76	65	76	0	0	0	1.6	4	0	2	2	14	35	0	0	43	0	0.1	0	4.8
April.....	66	73	60	74	0	0	0	(1)	3	1	2	3	11	37	1	1	41	0	.3	0	5.7
May.....	64	71	58	75	0	0	0	2.1	2	1	7	3	5	37	2	2	41	0	.1	0	8.1
June.....	62	68	56	75	0	0	0	2.1	3	1	9	3	8	38	1	0	37	0	0	0	9.1
July.....	60	67	54	77	0	0	0	2.4	3	1	6	4	11	39	1	0	35	0	0	0	9.1
August.....	60	66	55	78	0	0	0	2.1	2	1	5	2	12	41	0	0	37	0	0	0	9.4
September....	62	67	57	78	0	0	0	2.1	2	0	1	1	11	44	2	0	39	0	.1	0	9.2
October.....	62	68	57	77	0	0	0	2.4	1	0	1	1	11	46	2	0	38	0	0	0	9.0
November.....	64	70	59	76	0	0	0	2.4	0	0	1	1	12	45	2	0	39	0	0	0	7.8
December.....	68	73	62	75	0	0	0	2.1	1	0	2	0	13	39	1	1	43	0	0	0	7.0
Mean.....	65	71	59	76	---	---	---	1.9	2	0	3	2	11	39	1	1	41	-	---	-	7.5
Total.....	--	--	--	--	.03	.1	---	---	-	-	-	-	---	---	-	-	---	0	.6	0	---
Extreme.....	--	--	--	--	----	---	.39	---	-	-	-	-	---	---	-	-	---	-	---	-	---
Number of years.....	25-31	25-29	26-31	19-24	13	16	13	4					14					8	9-10	4-5	13-16

1 Less than 1 knot

[redacted]

[redacted]

Winds are of moderate intensity and generally from the southwest. Ground swells are from the southwest. The breakwater is placed to protect shipping from the swells.

Since rainfall averages one millimeter per year, there is no vegetation or wild life on the inland slopes. There are small villages scattered through the nearby mountains which are accessible only by pack trail. The population density of this area of northern Chile is four per square mile.

In view of the distribution of population along the cost both north and south, and since the maintransportation arteries are just east of the harbor site, a fallout pattern on land cannot be considered. This leaves the ocean to the west as the obvious area in which to allow the fallout to be deposited. A line to the southwest from the suggested site and passing one mile to the northwest of the lighthouse located on the Island of Alacran just offshore from Arica gives a bearing of approximately 230°. A bearing of 310° to the northwest is sufficient to clear any populated areas along the coastline of Peru, which gives an allowable fallout sector of 80° to the west.

Upper air data is not available at this writing but 14 years of recorded observations show that easterlies on the surface occur most frequently during the months of May through August. The greatest percentage of observations, even during these months, show winds from the southwest at velocities averaging less than 2 1/2 knots.

Tentative studies indicate the harbor excavation could require fifteen 5 KT bursts. Scaled from the Teapot underground shot, Ess, the 12-hour dose rate at a distance of 50 nautical miles for a single 5 KT burst is approximately 17 mr/hr and for a total of 75 KT the 12-hour equivalent land dose rate is 250 mr/hr, although the actual intensities as seen by

[redacted]

a ship at sea would probably be considerably less than these values. Plans should be made to clear the over-water sector of all shipping at least to a distance of 50 nautical miles.

There is some fishing off the coast of Arica, and the problem of uptake of fission products by marine life is being studied. Work by Gong and Shipman of the U. S. Naval Radiological Defense Laboratory and studies on Columbia River Fish and Plant Life by Lauren Donaldson carried on at Hanford have been reviewed.

The Humboldt Current flows offshore and would carry away radioactive debris and thus reduce intensities. It does not seem fallout would constitute a hazard to fishing.

[redacted]

Conclusion:

There is a need for a harbor at Arica.

There is a probable economic justification for at least the smallest harbor studied.

Fallout problems appear to be controllable.

Based on the above preliminary study it seems feasible to build a harbor at Arica using nuclear weapons.

[redacted]