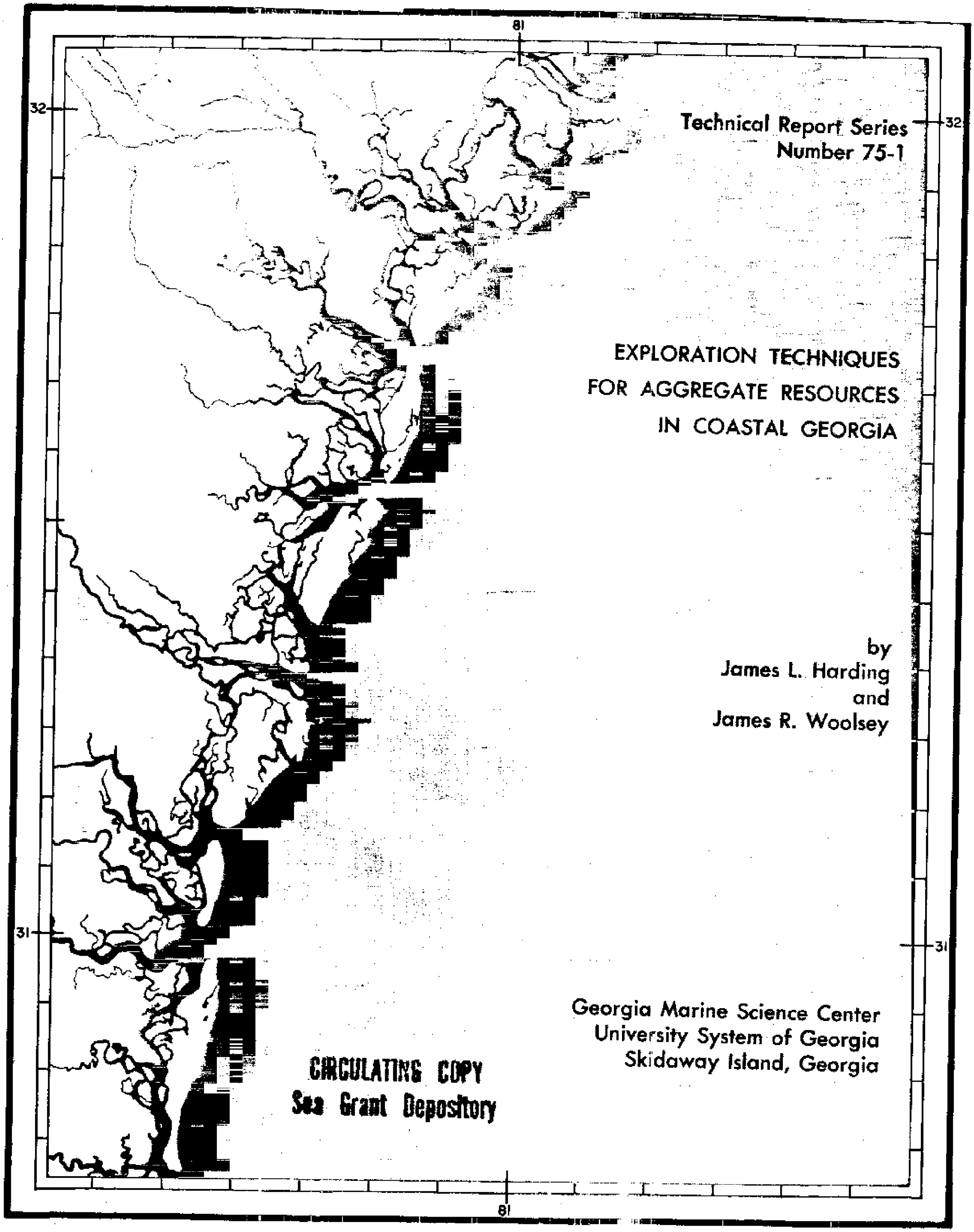

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EXPLORATION TECHNIQUES FOR AGGREGATE RESOURCES IN COASTAL GEORGIA

by
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ABSTRACT

This technical report describes tools and techniques utilized in a reconnaissance exploration program for construction aggregate resources in the rivers, estuaries and on the Inner Continental Shelf of Georgia. In the project, which was conducted under the auspices of the Georgia Sea Grant Program, two types of sub-bottom sampling apparatus were refined and tested in the field: (1) an air-lift system, which on occasion obtained samples from up to 50 feet below the sediment-water interface, and (2) a water-jet-hammer rig, which was used in the shallower water of the investigated area. Both rigs are described in detail within the report. Sampling was conducted in conjunction with acoustical sub-bottom profiling. Sub-bottom profiles from selected areas of the Georgia Coast are presented in the report.

I. INTRODUCTION

A project involving the use of geophysical techniques and the development of sampling apparatus to aid in the evaluation of potential sand and gravel deposits in Georgia coastal waters was initiated under the auspices of the University of Georgia Sea Grant Program in July, 1972.

The original objectives of the project were two-fold: (1) the selection and field testing of the best combination of geophysical and sampling tools and techniques and (2) the application and testing of this technology in selected areas along the Georgia coast.

It was recognized at the onset of the project that a complete exploration and evaluation program for aggregates in the entire Georgia coastal zone was beyond the capabilities of our financial and technical resources. It was therefore decided to limit the geographical areas of investigation and to concentrate on the development of exploration techniques. Hopefully, by presenting the results of the project in this report, those most concerned with the quantitative and qualitative aspects of aggregates in the coastal waters of Georgia will someday continue the investigation.

A. STATUS OF THE PROBLEM

The importance of sand and gravel is often overlooked, even though the demand for such material exceeds the combined demand for the remainder of the non-fuel, nonmetallic minerals. Although this commodity has a low unit value, the total value represented about 20% of the reported 1968 national value for non-fuel, nonmetallic minerals (Cooper, 1970).

As its principal use is in the construction industry, projects ranging from large scale municipal construction endeavors to individual home building sites are directly concerned with the availability and cost of basic aggregate material. As pointed out by Flawn (1970), the best distinction between high and low-value earth resources is in terms of place value. Material that has a low unit value at the site of production, has a high place value, and should therefore be as close as possible to its market-place. In the case of sand and gravel, haulage distance can greatly increase the price to the user in terms of a surcharge in cents per ton mile. Haulage costs can be expected to rise in response to inflationary trends associated with all aspects of transportation.

In many areas of the United States, where unplanned urban expansion, land use restrictions or other causes have rendered sand and gravel pits unusable, some alternate material is available. The alternate material most frequently employed is crushed stone. However, in the case of the Georgia coastal zone, there is no indigenous rock suitable as an alternate source, and crushed stone (usually granite or granite gneiss) is hauled in by rail from the upstate Piedmont area. In the past, some concerns hauled crushed rock to the Savannah area by barge down the Savannah River, but as far as the authors are aware, this practice has now ceased.

The principal source for sand and gravel in the Savannah metropolitan zone is from pits in the vicinity of Eden, Georgia. Prospective buyers can either pick the material up at the pits in their own trucks, or have it hauled to the construction site. Data on reserves in the Eden area are unavailable.

Before initiating this project, the principal investigators talked to several of the sand and gravel producers in the coastal plain area, seeking their opinions as to the need for this type of study. The consensus of opinion was affirmative, all parties concurring with the view that knowledge concerning underwater deposits was sparse to non-existent and that a program involving exploration methods for underwater investigations could turn out to be of great value in the future, especially as nearby land deposits near depletion and haulage costs rise dramatically.

B. AREAS OF INVESTIGATION

Three principal areas of investigation were chosen. Those were the rivers Satilla, Altamaha and Ogeechee along with their associated sounds and estuarine tributaries (see location map, appendix). The rationale behind their selection was primarily geographic, as all field work was logistically supported out of either the University of Georgia Marine Institute on Sapelo Island or the Skidaway Institute of Oceanography near Savannah. Cursory investigations were conducted in the other rivers and sounds of the Georgia coast in addition to several sample stations on the Continental Shelf both inside and outside the three mile limit of currently acknowledged state jurisdiction.

To a certain degree, sample sites were governed by the type of vessel being used. All of the airlift drilling and a large part of the geophysical sub-bottom profiling was done with the R/V Kit Jones, a 52-foot research vessel operated by the University of Georgia under funds from the National Science Foundation. This boat has a navigational draft of 6.5 feet which required the consideration of bar and shoal depths as well as the relative swell and current conditions with regard to vessel safety. In addition to hydrographic conditions exercising a control over the survey tracts and drill sites in several cases, fixed highway or railroad bridges prohibited the use of the large vessel in the upstream portions of the rivers.

In order to sample in the shallow portions of the water bodies, a 20-foot catamaran raft was constructed to carry the coring gear. This raft, or barge (Plate 12, Fig. 5) drew only twelve inches, but as it lacked self propulsion, was restricted by the draft of the various small power boats used to convey it to the sampling sites. Operational depth was usually on the order of two feet of water; although in some cases of point-bar sampling, the barge was often purposely run aground (Plate 13).

C. DESCRIPTION OF EQUIPMENT

The equipment used in this project can be divided into three general groups: (1) geophysical: (2) drill sampling and (3) support apparatus. Much of the gear in the last two categories had to be designed and built in our own shops, as they were not available as shelf items. Where such special equipment was used, enough data will be presented in the following paragraphs to allow an interested party to fabricate same.

D. GEOPHYSICAL GEAR

The past decade has witnessed a rapid degree of sophistication with regard to the development of seismic sub-bottom profiling systems. These developments were coincident with the fast growth of the offshore petroleum industry. In the beginning (early 1950's) most seismic surveys were accomplished with explosives using the refraction technique. Although still used in some areas, explosive refraction has been slowly replaced by non-explosive reflection techniques, using various energy sources such as gas, air, electrical sparking or electrically-induced noise. Reflection seismic techniques are exclusively used in job tasks which require from 10 to 200 feet of penetration with maximum resolution, for which electronically-produced noise is used as the energy source.

The acoustical seismic profiler works on essentially the same principle as do echo sounders which have long been in use for obtaining depth information. Sound pulses are released into the water via a transducer, the sound travels to the sediment-water interface, where it is reflected (echoed) back to a receiver which transfers the echoes unto a recorder thereby producing a graphic cross-section of the bottom topography along the track of the survey vessel.

The principal difference between a depth recorder and a continuous acoustical seismic profiler is the frequency at which the sonic pulses are delivered to the water. The higher the frequency, the greater the attenuation of the acoustical energy. Hence, depth recorders which are high frequency, record only the first interface (the bottom), although it is sometimes possible to differentiate between hard and soft sediments, depending upon the quality of the recorder, etc.

The seismic profiler utilizes lower frequency pulses, which are less attenuated when traveling through sediments, and therefore capable of reflection from additional interfaces below the bottom. Technically, these interfaces represent differences in acoustical impedance, which is the product of the density of the material and the speed of the sonic energy. Therefore, density changes, i.e. sand-silt; sand-clay, gravel-sand, etc are recorded as layers in the sub-bottom.

The seismic profiler used on this project was the EG & G UNIBOOM with which sub-bottom records were obtained with a penetration of over two hundred feet in certain areas. The Uni-boom system consists of a power supply, capacitor banks, a transducer mounted on a catamaran raft, which is towed either aft or abeam the vessel, and a wet-paper 13-inch recorder (Plate 11). Selected examples of various Uniboom records are presented elsewhere in this report (Plates 1-8).

E. GENERAL METHODS

In most offshore operations involving the combination of sub-bottom profiling and coring or sampling, the usual approach is to obtain profile records first, and based on their subsequent study, select the points at which to core. For the most part, this technique was followed with respect to the bulk of the inshore work. However, the offshore stations were often sampled first and correlated with profiles later. This was necessitated by the fact that the sea state conditions under which we could sample were more critical than those for profiling, whereas in the rivers and other protected areas, weather conditions were of little consequence.

When the airlift system was operated from the R/V Kit Jones, it was necessary to anchor the vessel fore and aft in order to ensure the required degree of stability. The two-point anchoring system was also used with the small barge in conjunction with spuds when employing the hammer-waterlift rig.

As in any given offshore sampling project, horizontal control was of prime importance. The offshore sampling sites were located with a combination of line-of-sight bearings, radar bearings and Loran plots, depending upon the distance from shore. It is felt that the integrity of these offshore positions is generally accurate within a 1000-foot radius.

In the rivers and sounds, locations were marked by line-of-sight bearings from fixed points, i.e. channel markers, buoys, etc. where present and from topographical or geomorphologic features shown on available charts and quadrangle sheets. In the case of the samples in the upper reaches of the Altamaha, where no map coverage was available, a set of excellent infra-red prints were obtained from another Sea Grant project and these were used in lieu of maps.

F. GEOLOGY

The sand and gravel deposits of potential economic interest in Coastal Georgia occur in the surface and near surface sediments. This section consists of a relatively thin sequence of Quaternary sediments of paralic and alluvial origin overlying Pliocene deltaic and Miocene alluvial and shelf deposits (Woolsey and Henry, 1974). A diagram of the shallow stratigraphy of the Georgia coast is presented in Plate 9.

Of this section the Quaternary aggregate deposits have been more actively worked; particularly within the Pleistocene alluvium associated with the ancestral Savannah, Ogeechee and Altamaha Rivers such as those deposits currently mined near Eden and Jesup, Georgia. The modern river channels have been worked in scattered localities on a small scale in past years; the Altamaha still producing approximately 10,000 cubic yards of aggregate per year from the south channel near the Highway 17 bridge.

The Quaternary alluvial deposits of both rivers and estuaries as well as the so called "relict gravels" of the inner-continental shelf are a practically untouched source of sand and gravel of definite economic potential. Representative seismic sections of these areas are presented in Plates 1 through 8.

The Quaternary deposits overlie a buried erosion surface developed on Pliocene and Miocene sediments. In Chatham County this surface truncates thin, discontinuous patches of Pliocene sand and gravel overlying the Middle Miocene. The latter is characterized by inter-layered, phosphate-bearing sand and gravel and silty clay (phosphate matrix, Plates 1 and 2). To the south the Pliocene deltaic deposits thicken rapidly along the flank of a scarp developed on Middle Miocene sediments which roughly parallels the present coast (Plates 3 and 11). The Pliocene thins east and west of the scarp axis of maximum thickness; gradually to the east, but abruptly to the west (an in depth work on the stratigraphy of the Georgia coastal region is currently in progress, (Woolsey and Henry, in prep).

The Quaternary sediments are typically less than 20 feet thick. Along a zone extending from 15 to 30 miles inland and parallel to the coast line, within this zone in Glynn County, the underlying Pliocene averages approximately 30 feet and has recently been worked for road fill in the construction of I-95. In McIntosh and Liberty County the Pliocene is relatively thin (less than 10 feet) and overlies a thick tongue of Upper Miocene alluvial gravel extending from the west. The gravels have a variable matrix of sand and clay and occupy a series of valley-like depressions developed on the Middle Miocene. Thicknesses of up to 150 feet have thus far been recorded. The Pliocene and Miocene gravels are currently mined in small operations near Jones and Townsend, McIntosh County. These deposits represent a definite source of aggregate for this two county region.

PLATE DESCRIPTION

General

Seismic sections cover a horizontal distance of approximately .5 miles. The vertical scale reads, left to right, in meters, feet (both approximate) and milliseconds. Locations of the seismic sections are presented on Plate 10.

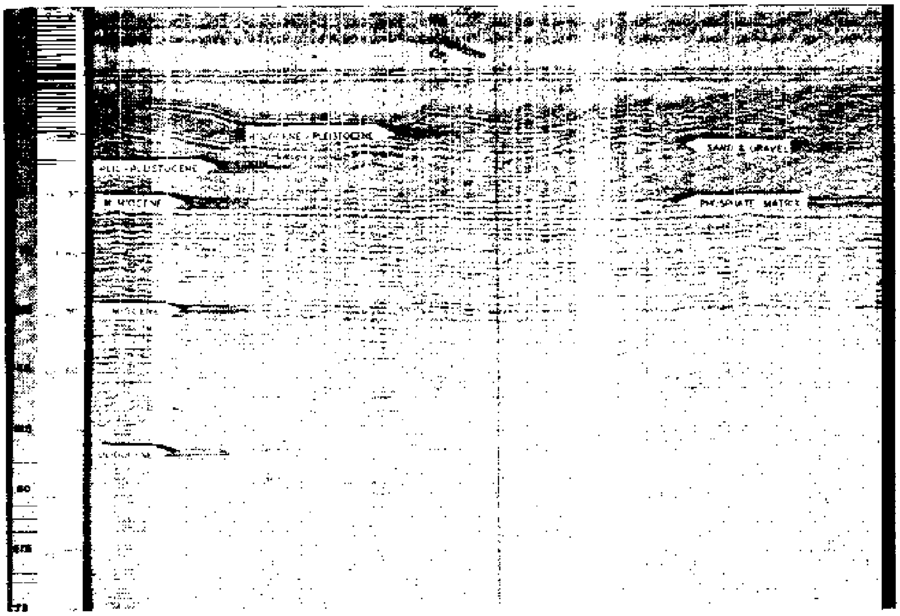


Plate 1 Seismic section, Tybee River at confluence of Lazaretto creek, extending from N. (left) to S. (right).

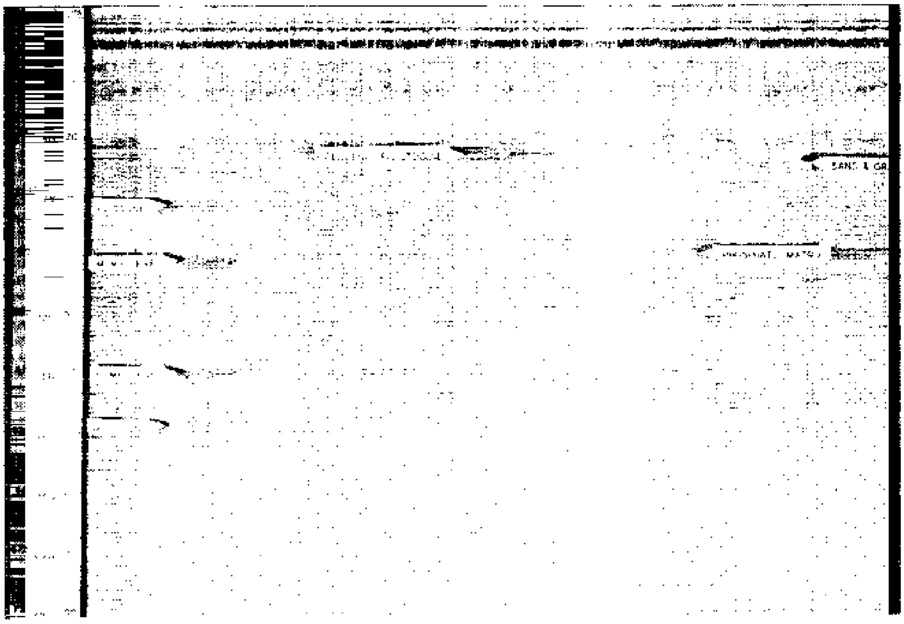


Plate 2 Seismic section, approximately 5 miles southeast of Little Tybee Island extending from S.W. (left) to N.E. (right), showing erosion surface (channel dissection) developed on Pliocene sediments.

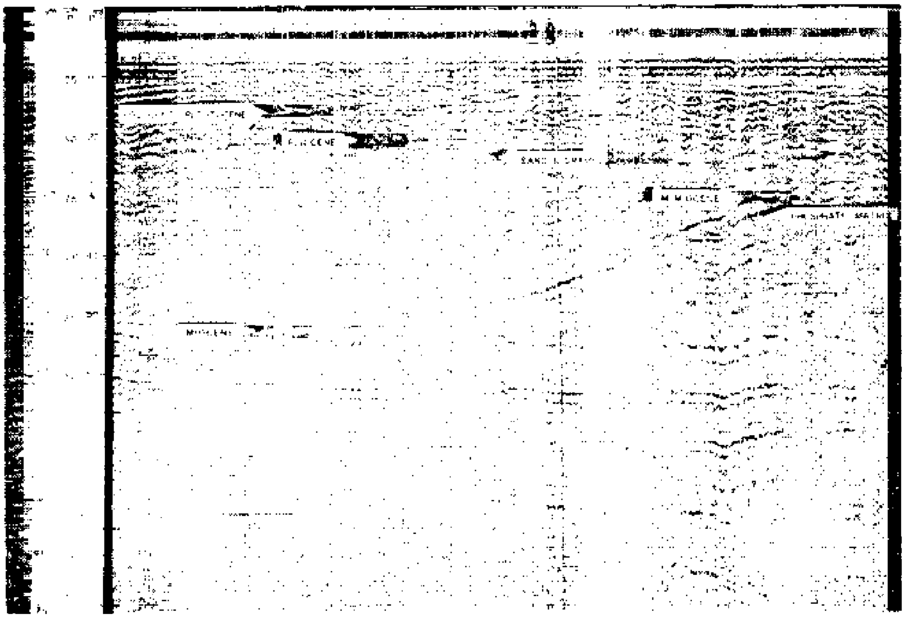


Plate 3 Seismic section, south of Hells Gate, Ossabaw Sound, extending seaward from W. (right) to E. (left) showing sand waves (megaripples) on bottom surface immediately below the direct arrival trace (parallel traces at 23-25 feet). Pliocene deltaic deposits developed on Miocene erosional scrap.

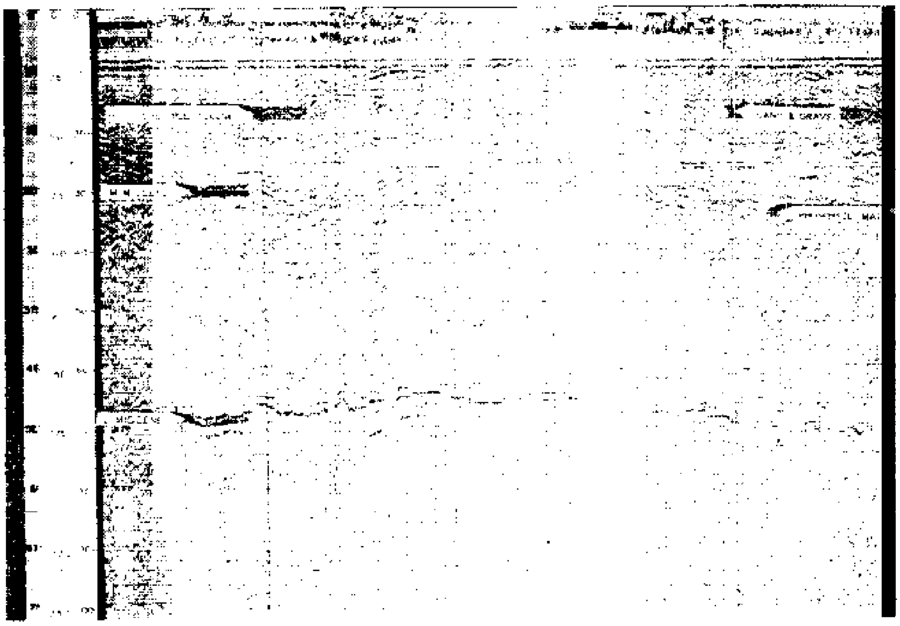


Plate 4 Seismic section, Ogeechee river abeam Rabbit Hill, extending W. (left) to E. (right).

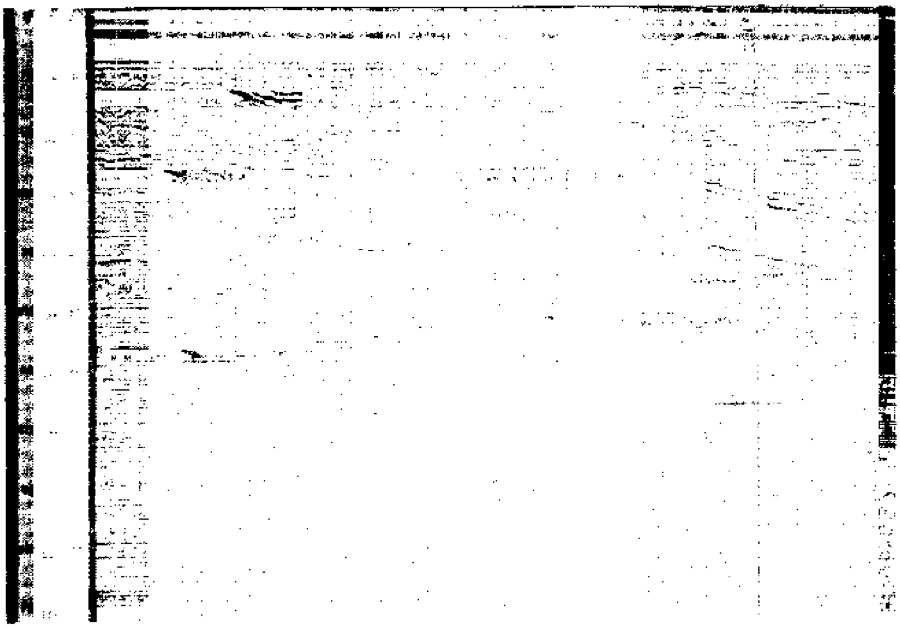


Plate 5 Seismic section South Newport River, vicinity of Johnson's Cut, extending from W. (left) to E. (right). Alluvial gravels of possible Upper Miocene age overlie Middle Miocene marine deposits both of which are truncated by a common erosion surface.

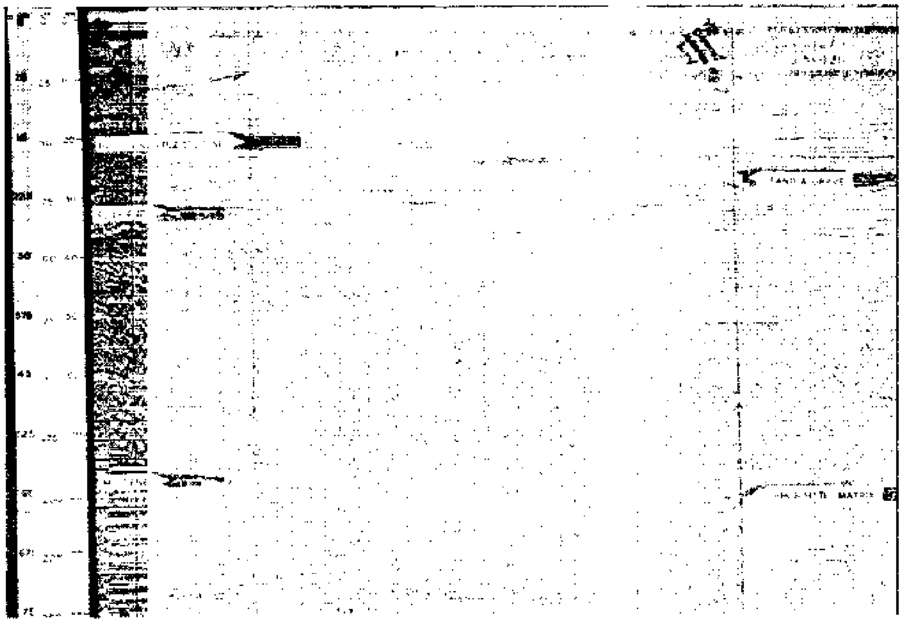


Plate 6 Seismic section, Mouth of Doboy Sound, close abeam south tip of Sapelo Island, extending from W. (left) to E. (right). Erosion surfaces developed on Pliocene deltaic deposits (note forset beds) and the underlying Miocene.

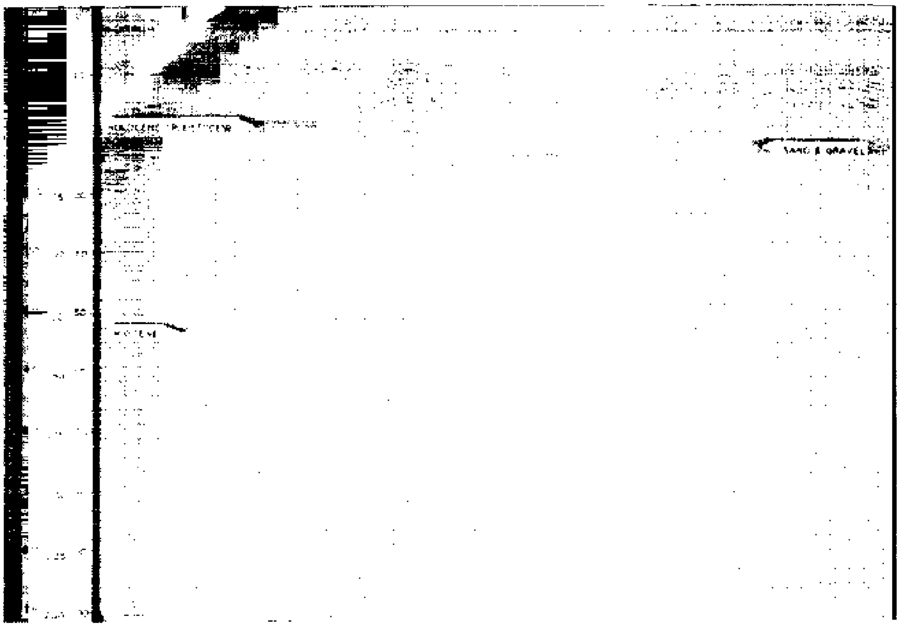


Plate 7 Seismic section, South Altamaha River, large bend, approximately 1 mile east of the Highway 17 bridge, extending from W. (left) to E. (right). Disregard direct arrival trace merging with bottom surface, right side of photo.

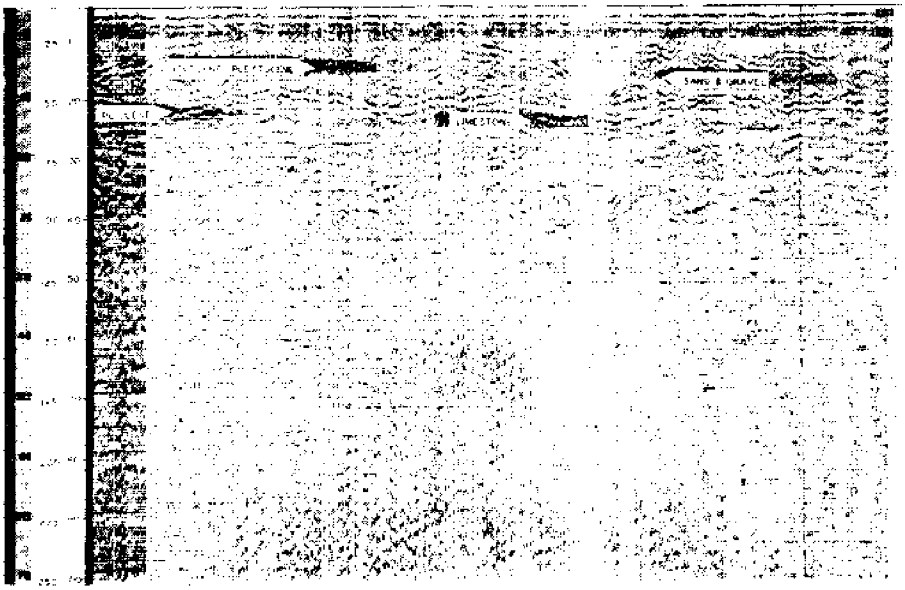


Plate 8 Seismic section, St. Mary's River, abeam Point Peter. Note shallow contact with Pliocene limestone;common to the south of the Little Satilla River.

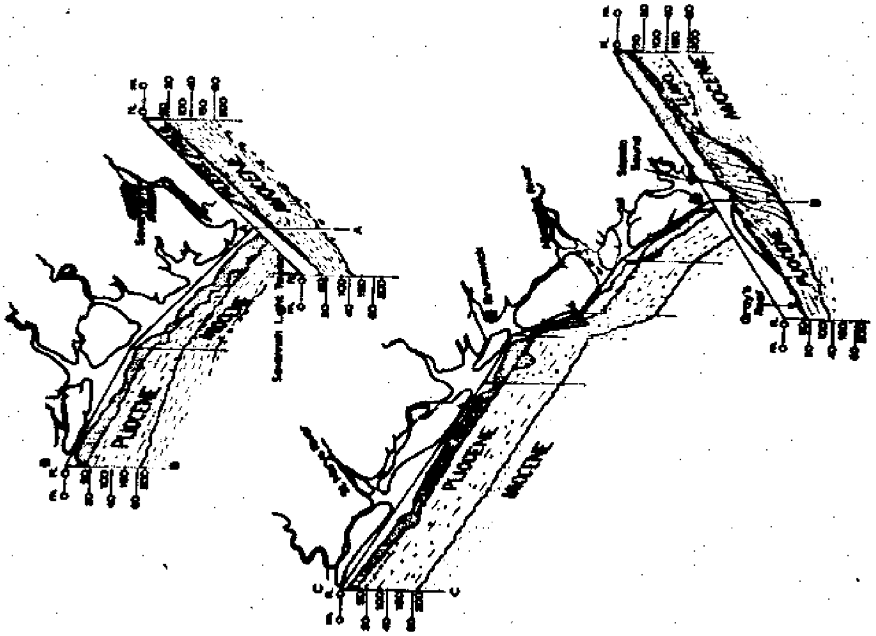


Plate 9 Cross section, (longitudinal and transverse) of the Georgia coast, showing stratigraphic relationships within the Neogene section as interpreted from drill sample and seismic data.

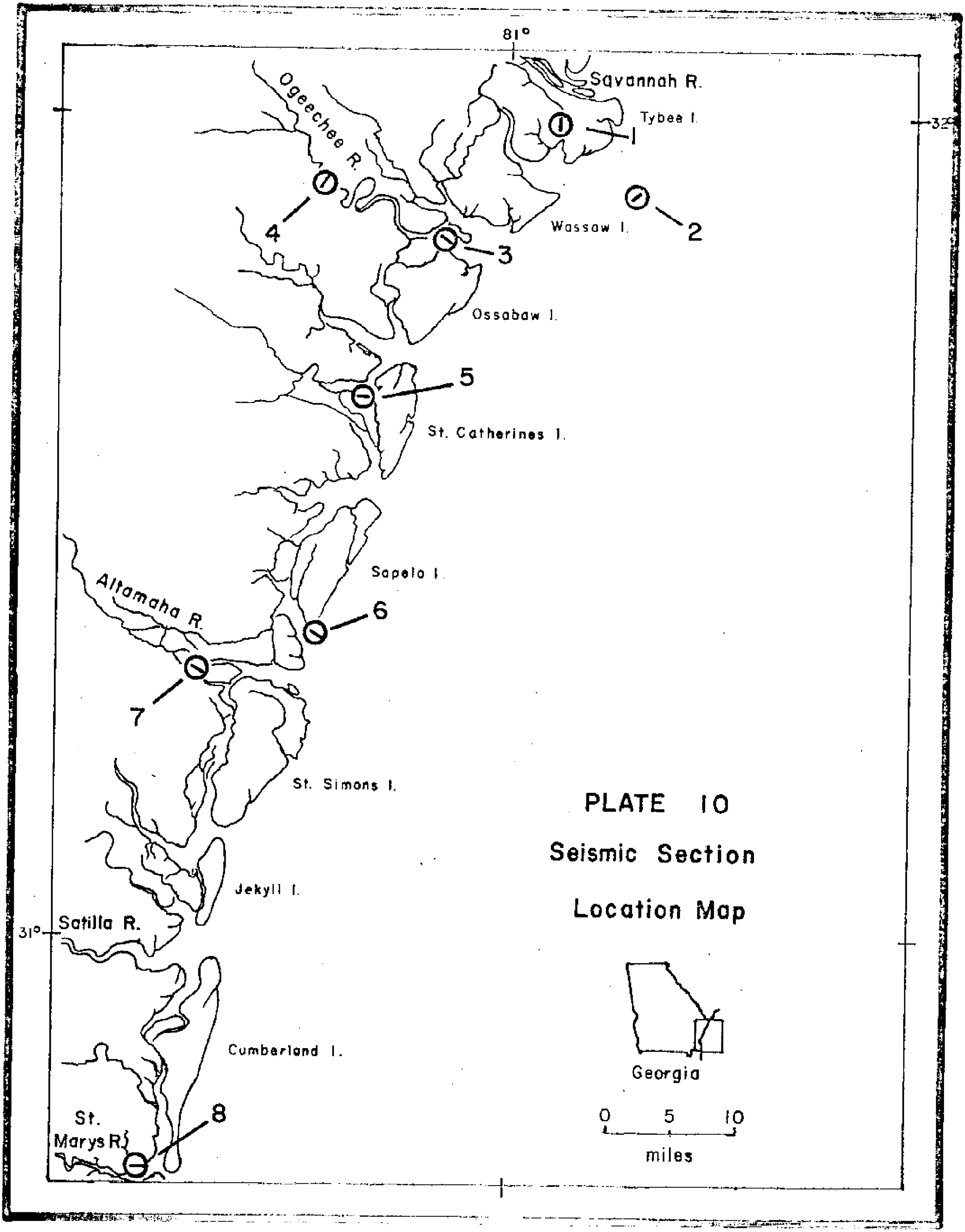


PLATE 10

Seismic Section

Location Map

Plate 11 Seismic recorder with sub-bottom profile record.

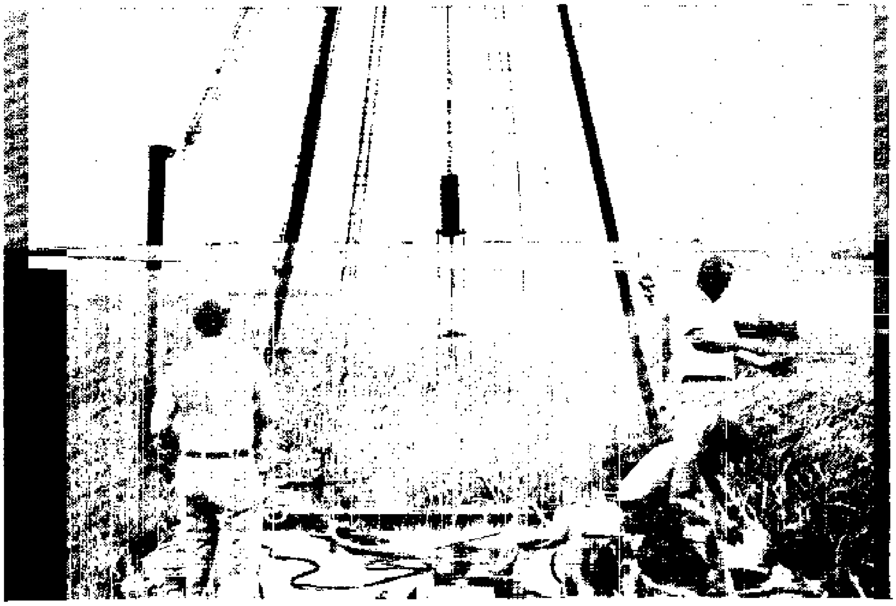


Plate 12 Drill barge, showing early version of the hammer-waterlift without guide system.

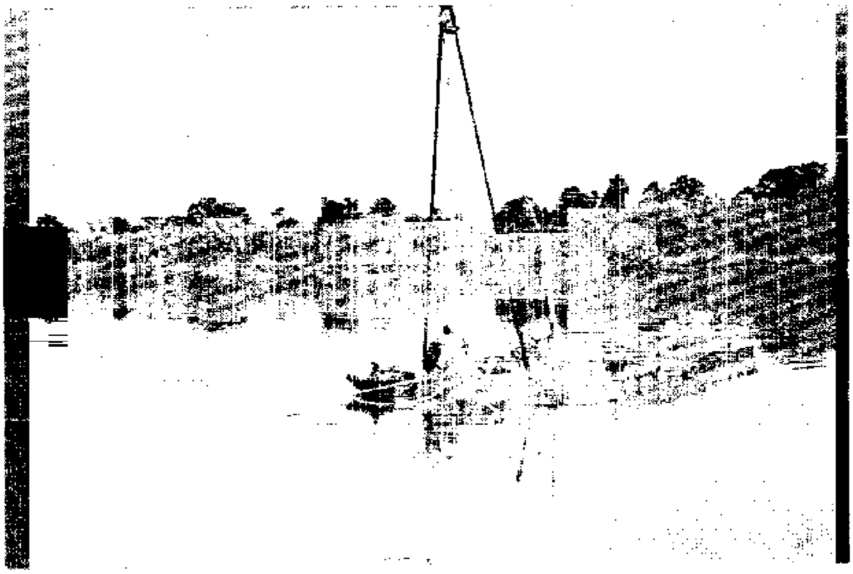


Plate 13 Drill barge; preparing to drill point bar on the Altamaha River.

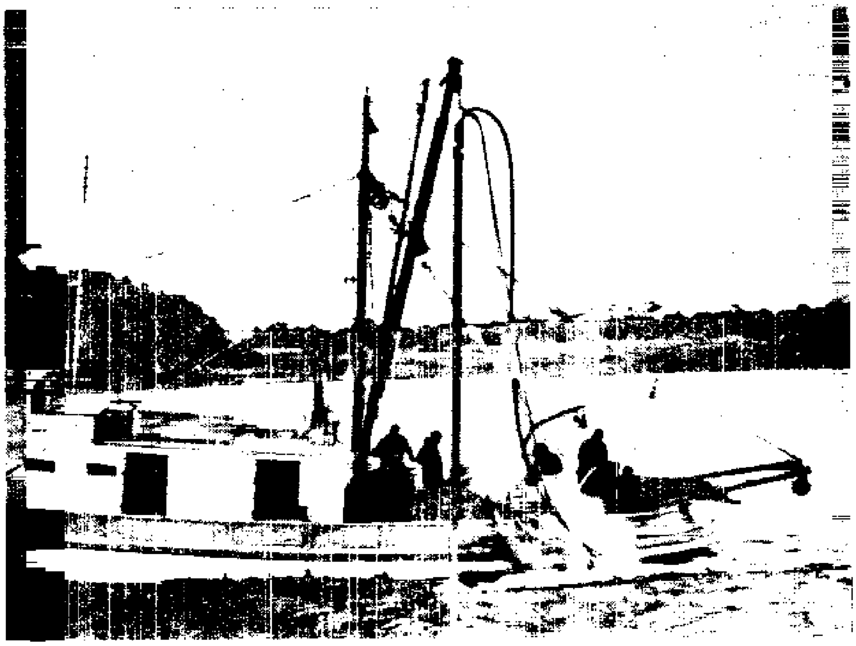


Plate 14 Airlift system mounted on the R/V Kit Jones .

II. METHODS AND TECHNIQUES OF SAMPLING

A. GENERAL

The selection of sub-bottom sampling systems was based on the following criteria:

1. Water depths in areas to be sampled ranged from 1 to 100 feet.
2. Unconsolidated sand and gravel must be sampled to an approximate depth of 20 feet.
3. Samples should have 1.5 feet vertical control with sufficient volume for standard laboratory analysis.
4. A 52 foot work boat, (6.5 foot draft) and a 22 foot barge, (1 foot draft) were available as drilling platforms.
5. Limited funds were available for acquisition and operation of systems.

Two systems were selected; their designs based on proven drilling techniques, modified to meet the above requirements. A jet-airlift was chosen for sampling in water depths greater than 12 to 15 feet and a hammer-waterlift for working shallower areas.

B. JET-AIRLIFT SYSTEM

1. Drill Description and Operation

The jet-airlift operates through the introduction of air at the lower end of the drill-pipe (Fig. 1). Air bubbles are displaced upwards in the pipe due to the density differential with seawater. A negative pressure is developed inside the lower end of the pipe relative to outside hydrostatic pressure, resulting in an apparent suction. Sediment cut by the water-jet is sucked into the intake ports and passed up through a hose to the shipboard processing equipment. (see appendix for detail of operation).

The basic principle of the airlift pumping system has been known for sometime. Its adaptation as a sampling device was presented by Horton and Libby (1968). The effectiveness of the system described is largely limited to bulk sampling due to the potential for excessive sample contamination mainly from upper level caving of unconsolidated surface material.

Experimental work has demonstrated that a casing added to the Horton-Libby system will significantly reduce sample contamination to acceptable levels. A sketch of an airlift drill fitted with a casing is shown in Figure 1 . Such a system attained a hole depth of 50 feet in a near-shore marine deposit consisting of mud-sand-gravel. Horizons considered impenetrable for this system typically consist of dense clay greater than 3 feet in thickness or sedimentary rock of .5 feet or more.

The drill constructed for the project is similar in plan to that shown in Figure 1 with the following dimensions:

a. Eductor - standard pipe, 3 inch I.D. x $11\frac{1}{2}$ feet; fitted with 3 inch quick-disconnect hose coupling.

b. Manifold, inner section - brass pipe, 3 inch I.D. x 14 inch; perforations - 1 hole, 1/8 inch diameter per 1 inch^2.

Manifold, outer section - standard pipe, 4 inch I.D. x 14 inch; fitted with 3) 3/8 inch, threaded, removable plugs at bottom.

c. Intake - heavy duty pipe, 3 inch I.D. x 7 inch; intake ports - 3) pair, spaced 120° apart, $1\frac{1}{2}$inch diameter reinforcement -steel bars, spaced 120° apart (equal distant from intake ports), extending to cutting spade; cutting edge built up with hard weld.

d. Cutting spade - steel bars $\frac{1}{2}$ x 2 inch arranged in a 3) rayed star, 4 inch diameter, 120°, partially inserted in intake with rays coplanar with reinforcement bars; cutting edge built up with hard weld.

e. Water Jet - standard pipe, galvanized, $1\frac{1}{2}$ inch I.D. x $11\frac{1}{2}$ feet. jet nozzle, 3/4 inch diameter; fitted with $1\frac{1}{2}$ inch quick-disconnect hose coupling.

f. Air line - standard pipe, galvanized, $\frac{1}{2}$ inch I.D. x $11\frac{1}{2}$ feet, fitted with $\frac{1}{2}$ inch quick-disconnect hose coupling and one-way valve near as possible to manifold inlet

In addition, the drill is fitted with a 4 inch I.D. pipe (same as outer manifold section), extending the length of the eductor pipe; the annular space filled with lead for added weight. The total weight of the drill is approximately 500 pounds. A lifting bail constructed of 3/4 inch steel rod is rigidly fixed to the upper end of the drill, extending the length by 2 feet for a total of $15\frac{1}{2}$ feet.

Note: See Figure 1 for layout.

2. Drill System Components

a. Air compressor.

As indicated above, the air-compressor is a particularly critical component of the airlift system. Also inferred is the relative importance of volume over pressure in shallow drilling, the latter having only to overcome the hydrostatic pressure at the point of air introduction. A typical low-pressure compressor with a displacement of 40 CFM will have a free-air capacity of approximately 35 CFM at 20 PSI and drop about 1 CFM per 10 PSI increment of increased pressure. The maximum rating of such a compressor may vary from 60 to 100 PSI. A similar unit was used in the test study and found to be effective.

An important part of the compressed air system is a suitable tank of 30 or more cubic feet capacity, fitted with a reliable relief valve and gauge. Also, it is important to have a quick-acting cut off valve at the tank outlet; its use will be explained later.

b. Water pump

The water pump is an integral part of the system, supplying a jet for both cutting the material to be sampled and delivering it in slurry form to the intake ports. An end suction pump, $2\frac{1}{2}$ x $1\frac{1}{2}$ inches, rated at 150 GPM at 150 PSI at 3600 RPM was found to be satisfactory for this purpose in loose to moderately consolidated sediments. It proved to be inadequate for the more dense clays encountered in thicknesses greater than 2 feet. Tests with a similar style pump , 4x3 inches, rated at 200 GPM at 180 PSI proved more effective.

c. Hose

The slurry eductor hose should be a good quality, light weight, pressure-suction type. A three inch I.D., B.F. Goodrich Radial Flex hose was selected for use on the project and found to be sufficiently durable and more easily handled than conventional rubber, wire reinforced P/S hose. The slurry eductor as well as the water conductor hose were made up in 25 and 50 foot lengths and connected with KAM-LOK type, quick-disconnect fittings.

Any light weight hose of suitable pressure rating may be used for the water and air conductors. A standard $1\frac{1}{2}$ inch fire-hose rated at 300 PSI and a 3/4 inch, 300 PSI, air-hose proved satisfactory. The air-hose was connected with standard Dixon type fittings.

3. Deck Handling and Support Equipment

a. Drill suspension/hoist system.

The suspension of the drill-pipe is best handled by an A-frame or boom with a hoist-block height providing adequate clearance from the deck and having a plumb-line within arms reach of the ship's rail. The structure should be capable of supporting two tons, dead-weight. Both the A-frame and boom have been used satisfactorily; the A-frame was generally preferred. Location may be on the stern or beam; the prime consideration being adequate working space (at least 75 square feet). When work space is not critical the stern is the preferred location. The effects of ship roll on the drill are at a minimum when the hoist-block is co-planar with the longitudinal axis of the vessel. Also, in the way the vessel is moored, there is less chance of shifting over the drill when it is suspended astern. In practice, a little roll is beneficial to drilling in that it induces a "churn-drill" effect, however, excessive tool motion (exceeding about 2 feet) makes it difficult to start the hole.

b. Drill hoist winch and cable.

The drill hoist should have a line pull of two or more tons for drill-pipe handling and casing extraction from the hole. It should have a capacity for a sufficient quantity of 7/16 or 1/2 inch drill cable (stainless winch wire) to reach the maximum desired sampling depth. The drill cable should be marked at 5' intervals (taking in to account the drill-pipe length) to enable the hole depth relative to the surface to be determined. Marking can be done by a paint code or better by numbered swaged fittings. Any comfortable retrieval rate is satisfactory; a speed of 5 feet/second is a good average, and any standard power system will do. The only other requirement is a reliable brake system for stopping and holding the drill at desired levels.

c. Anchor winches.

Two anchor winches are required. The bow winch should be considered the main unit and have a line pull commensurate with vessel size. The drum capacity should be sufficient for a suitable cable diameter and length, considering vessel size and maximum water depth anticipated plus a sufficient length for bow/stern anchoring procedures. If properly moored a lighter stern anchor system may be used. Though a drum winch is preferred a cat-head with nylon line has proven successful on vessels up to 65 feet long.

d. Anchors

Danforth anchors were used where possible due to their high holding capacity to weight ratio. Anchors of 90 pounds each were used bow and stern on the 52-foot work boat. On a 90 foot vessel, a 700 pound Navy Stockless was rigged for the bow with a 90 pound Danforth on the stern.

4. Operating Procedures.

a. Positioning and anchoring

A significant advantage of the airlift system is that some ship movement is permissible as all connections from the drill to the surface are flexible. This permits a less rigid mooring system, resulting in a considerable saving of time and expense.

The mooring system consists essentially of a sling between two fixed points, a bow and stern anchor, and a third flexible point effected by the dominant drift of wind or current.

Once the drill site has been established it should be marked by a buoy and the direction of dominant drift noted. The vessel is then manoeuvered to a point down drift of the buoy for a distance that will allow sufficient scope on the stern anchor, also it should be offset enough to permit a run that will pass abeam the buoy (up drift) on a course that will quarter the drift component (Figure 3). The stern anchor is dropped and the run commenced. An equal or greater distance is run out in the up-drift quadrant (beyond the buoy) to insure sufficient scope for the bow anchor. After this anchor is in place the bow cable is played out while the stern cable is hauled in. As the vessel approaches an abeam position with the buoy the bow anchor winch is braked while the stern winch continues to haul in until both bow and stern cables become taut. This insures proper setting of the anchors as well as eliminating excessive slack (Figure 3).

The purpose of quartering the drift is to place the major strain on the bow anchor system, for which it was designed. This permits the use of a stern anchoring system of lighter capacity since a smaller force vector is involved; its main purpose being to prevent the inevitable swing of a single anchor moor.

b. Drill crew.

The drilling crew for a typical shallow to moderate depth operation (less than 100 feet) should ideally consist of 4 men assigned as follows:

1) Driller - controls drill positioning and drilling rate through hand signals to the Winchman - keeps track of drill depth.

2) Winchman - coordinates anchor winch operation, operates drill hoist and monitors water-pump and air-compressor.

3) Sampler - takes samples as directed by the party chief - aids driller with hose handling.

4) Party chief - responsible for the complete operation, including drill site selection.positioning, anchoring and drilling - maintains log of all pertinent aspects of operation, i.e., position, time, water depth, tide (if applicable) sample descriptions and depth, etc.

Note: In a typical operation members of the boat crew may serve on drill crew, particularly in the position of Winchman and possibly Driller and Sampler as well. This is possible due to the simplicity of operation of the airlift, amenable to a short crew break-in time which is another important advantage of the system.

c. Drilling procedure.

1) Starting the hole.

Once the vessel is securely moored, the position and water depth are checked. The drill-pipe is lowered over the side and held at a convenient level permitting attachment of the hoses. Generally, for water depths less than 35 feet, a 25 foot section is used; for depths of 35 to 60 feet, a 50 foot section, etc. When the hoses are secure the drill is lowered to the bottom and then retrieved several feet. In this position the compressor is started. Once the pumping action is established the drill is lowered to the bottom. As soon as a bottom surface sample has been collected the water-jet is actuated and drilling begins.

2) As drilling proceeds the Driller should continually monitor the hole depth relative to the water surface by means of the cable markings. It is the responsibility of the Party Chief to note the time drilling commences and terminates in order that any tidal adjustments to mean sealevel can be made, if applicable.

Samples are normally taken at 5 foot intervals, during which time the drill is held by the hoist brake. In addition to these, the sampler should sample any significant change in lithology. Samples are normally caught in one gallon buckets and after settling of the majority of fines, dumped on a sheet of plywood, fractioned and bagged. The fine fraction remaining in suspension may be estimated. Where clays, muds and peats are encountered in layers they are commonly brought up in chunks, giving a relatively undisturbed sample.

In addition to interval sampling, bulk sampling for heavy minerals can be accomplished by the use of a suitable sluice box and or jig (designed for the minerals of interest) for concentration and some means of volume computation of tailings. The latter may be done through the use of bins of measured capacity or a self-dumping tailing wheel and counter attached to the sluice.

3) Addition of hose

Through careful monitoring of the hole depth the need for additional hose sections can be anticipated. At this time the drill is raised off the hole bottom several feet, water and air are shut off, hoses disconnected from the pump, compressor and sluice as required and additional sections added. Drilling is resumed when air and water are turned on.

d. Drilling techniques

The smoothness of the drilling operation and accuracy of the depth keyed to a given sample is largely dependent on the ability of the driller. It is essential that the Driller acquire a "feel" for the drill through the taut drill cable. With a little experience one can determine the gross lithology encountered by the drill. Hard rock transmits an unmistakable, ringing jar through the cable on drill impact; dense clay, a dull thud; sand and gravel, a grinding crunch; and mud, a soft yield.

The driller should also be attentive to the drilling rate. This is particularly true in mud or loose sand where too rapid penetration will increase the percent solids to the point of slurry stall. The condition is noted by excessive hesitation of slurry flow or complete stoppage. It may be easily corrected by retrieving the drill a few feet and proceeding at a slower rate of penetration. It should be noted that a pulsating slurry flow is normal with solids ranging between 20 to 70% (for loosely packed material). Restriction or complete stoppage may also result from jamming of elongate material in the pipe or hose. This may be remedied by momentarily closing the shut off valve at the tank which in turn allows the slurry column to collapse, freeing the jam. Pressure is commonly allowed to build to maximum in the tank before reopening the valve, thus providing an extra volume burst, inducing an initial accelerated flow rate.

Drilling is most efficient when ship induced motion imparts a "churn-drill" affect to the drill-pipe. In order to take full advantage of this, the Driller should play his cable so that it comes taut on mid-up-heave, lifting the drill-pipe through top-heave and allowing hole bottom impact on mid-down-heave with sufficient cable slack through bottom-heave for penetration. When drilling in calm water, the same effect can be achieved through the use of some standard form of cable-tool, tripping device attached to the drill cable. One of the more simple devices is a line rigged normal, attached to the drill-cable by a suitable snatchblock (one that will not sling open on tension release). The line is manually worked on a cat-head winch by alternately applying tension for haul down (raising drill) and releasing.

C. HAMMER - WATERLIFT SYSTEM

1. Drill Description and Operation

The hammer- waterlift is based on a simple design whereby a casing is driven into the material to be sampled. A representative core is cut from the sediment by a cutting shoe which is then broken down by the combined action of a composite churn bit and waterjet which extends down through the casing from the hammer (Figure 4). The yet unbroken core in the cutting shoe acts as a plug, causing the water/cuttings slurry to flow up through the casing/ jet-bit rod annulus and out through the anvil/ wash-head (Figure 4) to the sampler catcher.

The hammer-waterlift system was modified from a land drill design used by the Humphrey Mining Company for the evaluation of the Folkston, Georgia heavy mineral ore body; the original design was from local well drillers, dating back 50 years or more. The major modifications consisted of: 1) The use of adapter sections to very length of jet-bit rod. 2) the addition of shock rods connecting the hammer and anvil to permit reverse hammering in casing extraction. 3) construction of a drill guide system in which guide rods extending from opposite sides of both the hammer and anvil ride in channel tracks (Figure 5) similar to the stabilizing system in common use on truck-mounted rotary drills.

One of the more critical factors of the hammer-waterlift system is the length of the jet-bit rod, determining the maximum extension of the bit relative to the cutting shoe. Two adapter sections were used; a short adapter (36 inches) giving a 6 inch clearance from the bit to the cutting shoe and a long adapter (40 inches) providing a 2 inch clearance. The purpose is to compensate for the variable reaction of different sediment properties to this method of sampling. Two effects, both of which are detrimental to accurate sampling, should be guarded against:

a. Jet wash cutting through a short core section below the shoe.

b. Build up of frictional resistance with a long core section, resulting in excessive compaction at the shoe mouth, causing sediment bypass.

These effects are best compensated for by controlling the lengths of the undisturbed core plug by adjusting the length or maximum extension of the jet-bit rod. The short adapter is used for sampling unconsolidated sand and gravel (maximum core length) while the long adapter is best suited for use in clay and semi-consolidated sand and gravel.

The basic drill used in the project consisted of a 20 foot casing and jet-bit rod constructed of $1\frac{1}{2}$ and $\frac{1}{2}$ inch schedule 80 pipe respectively (initial section of jet-bit rod, 18 feet). The design of the anvil/wash-head and hammer components is shown in Figure 4 and are of the following specifications:

a. Anvil/Wash-head - 5 inch diameter x 1 inch striking plate with centered 1 inch hole for jet-bit rod, welded to $2\frac{1}{2}$ inch I.D. x 18 inch steel pipe, fitted with $1\frac{1}{2}$ inch I.D. Steel pipe down-spout, (30^{0} to wash-head pipe) in turn fitted with $1\frac{1}{2}$ inch Kam-Lok hose connection. $1\frac{1}{2}$ inch pipe coupling welded in line to lower end of $2\frac{1}{2}$ inch wash-head pipe for casing attachment.

b. Hammer - 5 inch I.D. x 15 inch steel pipe, blanked at one end by 1 inch steel plate with centered 1 inch hole for 3/4 inch pipe coupling (jet-bit rod). Pipe section filled with 100 pounds of lead (to 13 inch level).

c. Guides - Lower end of hammer and upper end of wash-head fitted with 3/4 inch steel plates, normal to and extending from either side for a total spread of 18 inches. Individual plates taper from 4 inches wide at point of attachment to 1 inch at guide pin which rides in guide channel, 1 inch x $1\frac{1}{2}$ inch x 3/16 inch. Each plate drilled with 3/4 inch hole centered $1\frac{1}{4}$ inches from line of attachment for shock rod installation. Extension plates welded directly to hammer, but to swivel ring (1 inch x 5 inch O.D. x 3 inch I.D.) on wash-head.

d. Shock rods - Two, 5/8 x 36 inch steel rods threaded both ends with nuts attached, passing through guide extension plates, connecting hammer to anvil/wash-head.

e. Adapter sections - Two sections of heavy-duty (schedule 80) 3/4 inch steel pipe, 36 inches and 40 inches long, respectively. Sections with standard pipe threads on one end with other end threaded internally with $\frac{1}{2}$ inch pipe threads to receive $\frac{1}{2}$ inch jet-bit rod.

f. Cutting shoe - $1\frac{1}{2}$ inch x 6 inch, heavy-duty steel pipe, threaded one end; cutting edge built up with hard weld.

g. Jet-bit - $\frac{1}{2}$ inch x 6 inch heavy-duty steel pipe, threaded one end; point flattened and built up with hard weld; 6 jet ports, $\frac{1}{4}$ inch diameter.

Note: See Figure 4 for layout.

2. Drill System Components

a. Water pump

The water pump supplies water to the jet-bit to aid in core disintegration and cuttings transport. Almost any of the common, portable, low pressure pumps rated at approximately 30 GPM and 40 PSI are satisfactory. A $1\frac{1}{4}$ inch Jabsco pump driven by a 5 HP gasoline engine was used on the project with satisfactory results.

b. Hose

The water conductor can be any good quality, low pressure hose of approximately 1 inch diameter. The eductor hose should be a light weight type that will maintain its radius so as not to trap the cuttings in kinks. A $1\frac{1}{2}$ inch B. F. Goodrich Radial Flex was used in the survey.

3. Deck Handling Equipment

a. Drill suspension/ hoist system.

The drill may be suspended from an A-frame or derrick to which the drill guide is attached. A 24 foot A-frame was constructed for the project for the dual role of handling both the hammer-waterjet and the jet-airlift. Although the A-frame worked well, it is considered that a light-weight derrick might better incorporate the drill guide system found to be advantageous in handling the 20 foot sections of casing and jet-bit rod.

b. Drill hoist and cable.

A hand winch rated at approximately ½ ton was used as the drill hoist; its main purpose was to extract the casing from the hole. A more substantial winch of at least 1 ton capacity would have better served this purpose. The cable should be a stainless winch wire of about 3/8 inch diameter.

c. Cat-head winch and hammer line.

A 3 HP gasoline-powered, cat-head winch of 200 RPM was built as the power unit for the hammer. A 3/4 inch manila rope was used as the hammer line and was fairleaded from the hoist block to the cat-head by means of a snatch block.

4. Drill Barge

A portable, shallow draft barge drawing less than 1 foot of water was designed and constructed as a drill platform, the specifications of which are presented in Figure 5. The principle feature of the drill barge was a simple means of transferring the A-frame load to the bottom during casing extraction through come-alongs attached to the main stress member and the top of the spuds.

5. Operating Procedures

a. Positioning and anchoring

The barge was powered to the drill sites by a small inboard boat lashed to the stern of the barge (opposite A-frame end). Once on station the barge was manoeuvered so that the bow was into the current. The drill site was over-shot by a distance that provided ample anchor line scope, the anchors dropped, port and starboard (30 pound Danforths), and the barge allowed to drift back over the drill site by playing out the anchor lines. Once on site, the spuds were dropped and the equipment prepared for drilling.

b. Drill crew

Drilling with the hammer-waterlift is a relatively simple operation requiring a minimum of crew training. The drill crew should be made up of 3 men assigned as follows:

1) Hammer Operator - operate hammer through the use of the cat-head.

2) Sampler - Take samples at specified intervals - monitor casing depth and notify Hammer Operator when each

sample depth is reached.

3) Party Chief - responsible for complete operation as in jet-airlift operation described above.

c. Drilling procedure

1) Starting the hole

After the barge is securely moored the drill is lowered to the bottom by the hoist. The Sampler should note casing contact with the bottom and the distance of penetration due to gravity. When gravity settling has ceased (commonly about 1 foot in bed load sand) the pump and cat-head engines are started. Typically an additional foot of penetration must be driven with the hammer before sufficient density of the core is achieved to divert the wash/cuttings slurry up the casing. When the first cuttings appear from the eductor hose the Sampler halts drilling and the cuttings are collected. When the wash water clears, all cuttings above the undisintegrated core in the cutting shoe have been collected and represent the interval cut minus the length of the core plug (2-6 inches depending on rod length) after the depth has been noted from stamped markings (at 1 foot intervals) on the casing, drilling (hammering) of the next interval is commenced. The procedure is repeated until the desired depth is reached.

2) Addition of casing

The procedures for addition of casing are similar to those practiced in standard churn-drilling operations with the difference that the jet-bit rod must be contended with. The anvil/wash head, which is free to swivel in the shockrod/guide assembly after hose removal, is disconnected from the casing in the hole and raised to the hoist block. The next casing which contains a section of jet-bit rod is held in place by hand as the casing is raised into place. The bit rod is first attached, then the casing is lowered and secured. All that remains is to climb the derrick, lower the anvil/wash head over the bit rod attaching it to the hammer and complete by fastening casing to wash head and attaching hose.

D. TRUCK-MOUNTED ROTARY DRILL

1. Drill Description and Operation

A standard truck-mounted rotary rig (Joy) was used in land operations. The system was equipped with (N) drill rod, a 4 inch drag bit and a $3\frac{1}{2}$ inch Shelby tube, thin-walled corer, 2 feet in length.

Standard procedures were followed. Drilling mud was used to hold the hole. Cuttings were monitored and cores driven on change in lithology.

SUMMARY AND CONCLUSIONS

The equipment and techniques described in this technical report readily lend themselves to exploratory operations for sand and gravel deposits in waters of the Georgia Coastal Zone.

An expanded drill sampling program combined with more precise horizontal positioning would allow the delineation of a given deposit to the degree necessary for commercial evaluation, lease applications and exploitation.

The Altamaha River system and its estuarine network of tributary streams appears to contain the best potential for commercial deposits of usable aggregates. As for the remainder of the areas surveyed, the Ogeechee river would rank next, whereas the lower Satilla and St. Marys rivers contain only limited thicknesses of unconsolidated aggregate overlying a shallow limestone bedrock.

At the time of preparation of this report, investigators under the direction of Dr. Gary Hicks, of the Civil Engineering Department at Georgia Tech are continuing this project. Dr. Hicks has obtained representative samples from all of our sample stations, and is analyzing them for suitability as construction aggregates. It is hoped that this phase of the investigation will become a formal project in the next grant year under the Georgia Sea Grant Program.

ACKNOWLEDGEMENTS

The research described herein was accomplished under the auspices of the Georgia Sea Grant Program (NOAA) during fiscal years 1973 and 1974. The greater part of the seismic profiling and offshore drilling program was supported through National Science Foundation grant GA 24086. Shiptime on the R/V *Kit Jones* was furnished by the National Science Foundation.

We also wish to acknowledge the cooperation of Dr. V.J. Henry, who allowed us the use of the EG&G Uniboom profiling system as well as access to his library of profile records. The field assistance of Mr. Jesse Hunt, Capt. Jimmy Rouse and mate, James Gault of the *Kit Jones* , Jim Whitted, Randy Provost and Ron Wallace is also acknowledged.

APPENDIX A

AIRLIFT SYSTEM

Efficiency in an airlift is largely dependent upon the pressure differential at the intake which in turn is related to a number of factors including: 1) water depth, 2) static lift (water surface to point of discharge), 3) volume of air introduced at intake and method of introduction, 4) cross-sectional area of drill-pipe, 5) percent solids of slurry, 6) density of solids. Of these, the factors determined by a particular system (2, 3, 4) and sediment type (5, 6) can be considered constant, within limits, while water depth (1) is the principle variable. The graph of Figure 2 shows the relationship of the slurry velocity with water depth. It is based on a system consisting of an air-compressor delivering an average 35 CFM, free-air, for the range of depth shown, from 10 to 50 feet (approx. 20 to 40 PSI) a fixed static lift of 8 feet and an eductor pipe with 3 inch I.D.

Limited experimental work has indicated that a minimum slurry velocity of approximately 8 feet/second must be achieved to lift a sand and gravel mixture ranging up to .75 inch in diameter. It may be noted from the graph that the critical velocity is not reached in the given system until a water depth of 11 feet is reached. In order to drill in more shallow water either more air must be introduced at the intake, requiring a larger compressor, or static lift must be reduced; considerations which may or may not be practical within the scope of the project.

Formulas used in computing the graph (Figure 2) and relationships between compressor size, pipe diameter, static lift and depth of intake submergence are listed below:

1)* Quantity of air required

$$Q = \frac{H}{K \log_{10} \left(\frac{S + 34}{34} \right)}$$

where:

Q= quantity of air required in Ft^3/gal. (water)

H= total lift in feet from water surface to point of discharge

S= submergence or vertical distance in feet between point of intake and water surface.

K= a constant derived from the below listed table where the submergence ratio = S/S + H

S/S+H (%)	40	45	50	55	60	65	70	75	80	85	90
K	246	272	296	318	335	348	358	366	372	377	380

* Adapted from Water Well Technology

2) Average slurry velocity in drill-pipe/hose assembly.

$$V = \frac{A \quad I}{Q \quad 60}$$

where: V = average velocity in ft./sec
A = free-air capacity of air-compressor in Ft.^{3}/min
I = linear ft./gal. capacity of drill-pipe
3 inch I.D= 2.72 , 4 inch I.D. = 1.53, 5 inch I.D. = .98,
6 inch I.D. = .68
Q, from 1),

3) Volume capacity of air-compressor required for a given system and submergence ratio.

$$A = \frac{V \quad Q \quad 60}{1}$$

where: V, Q, I. from 1) and 2)

APPENDIX B

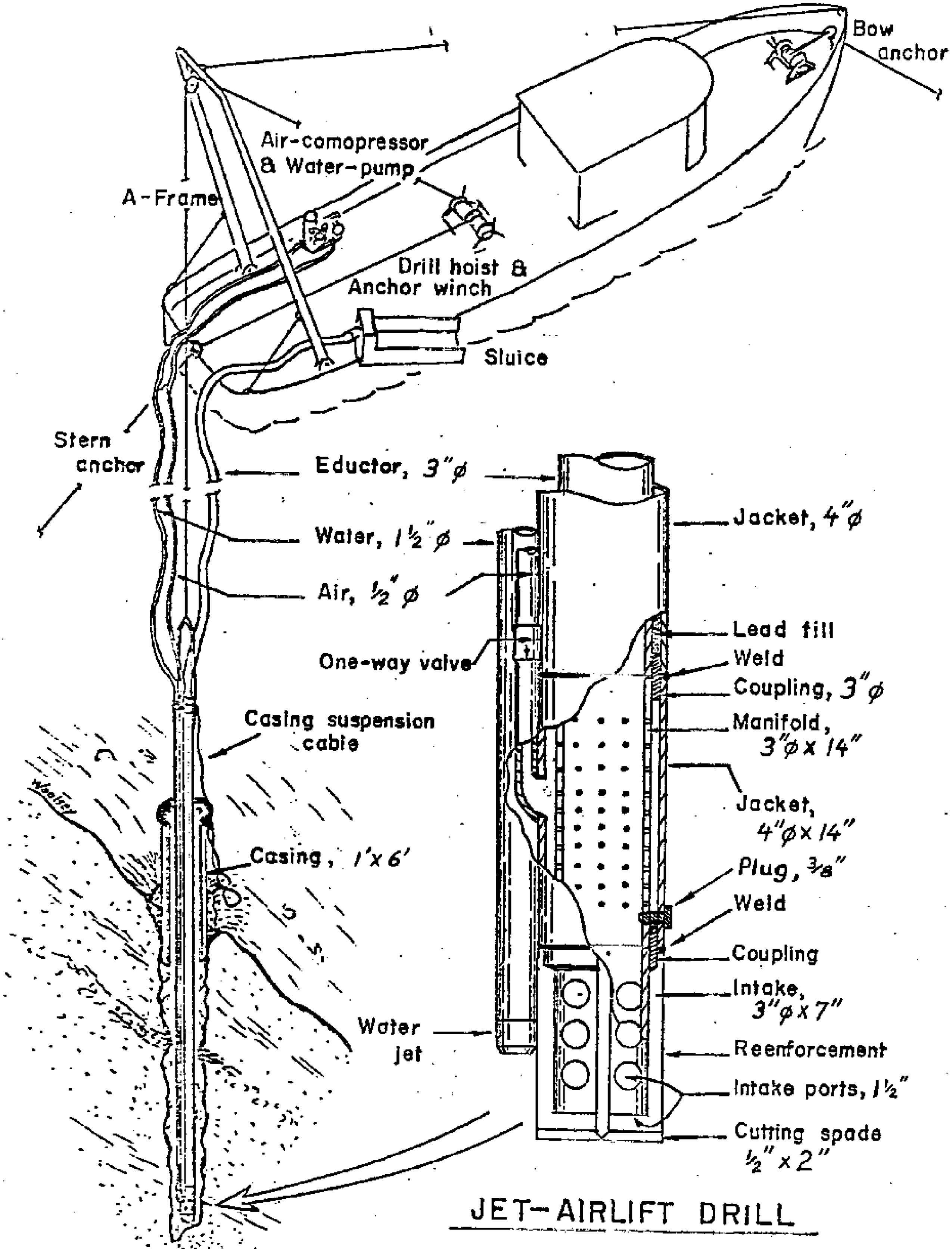


Figure 1

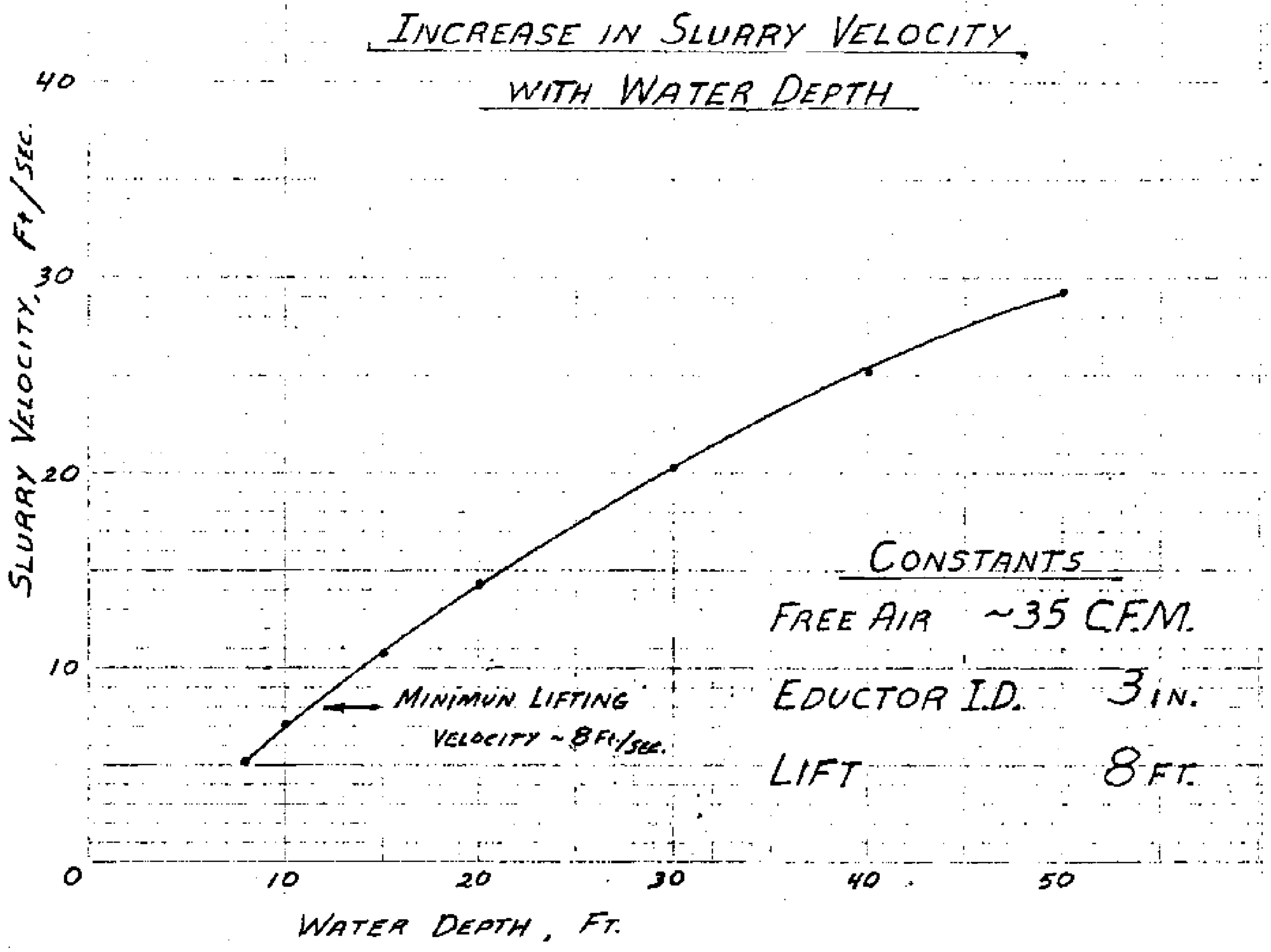
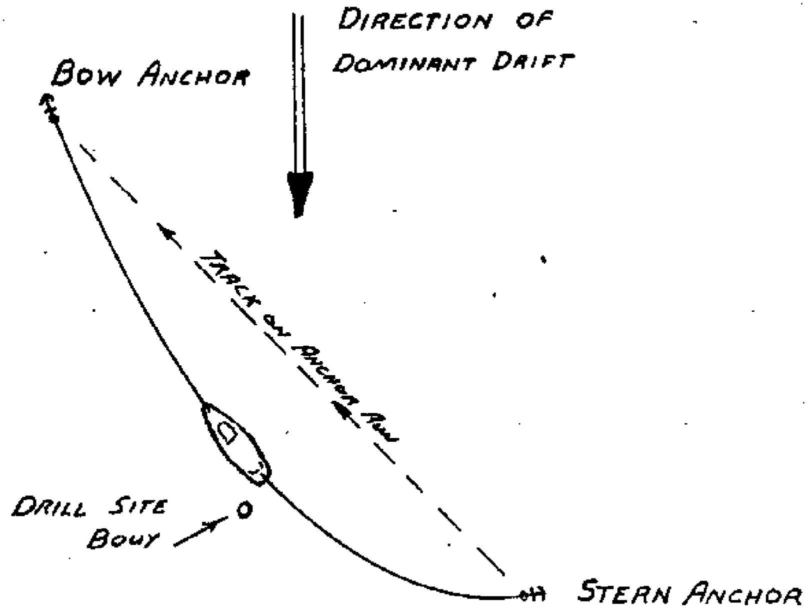
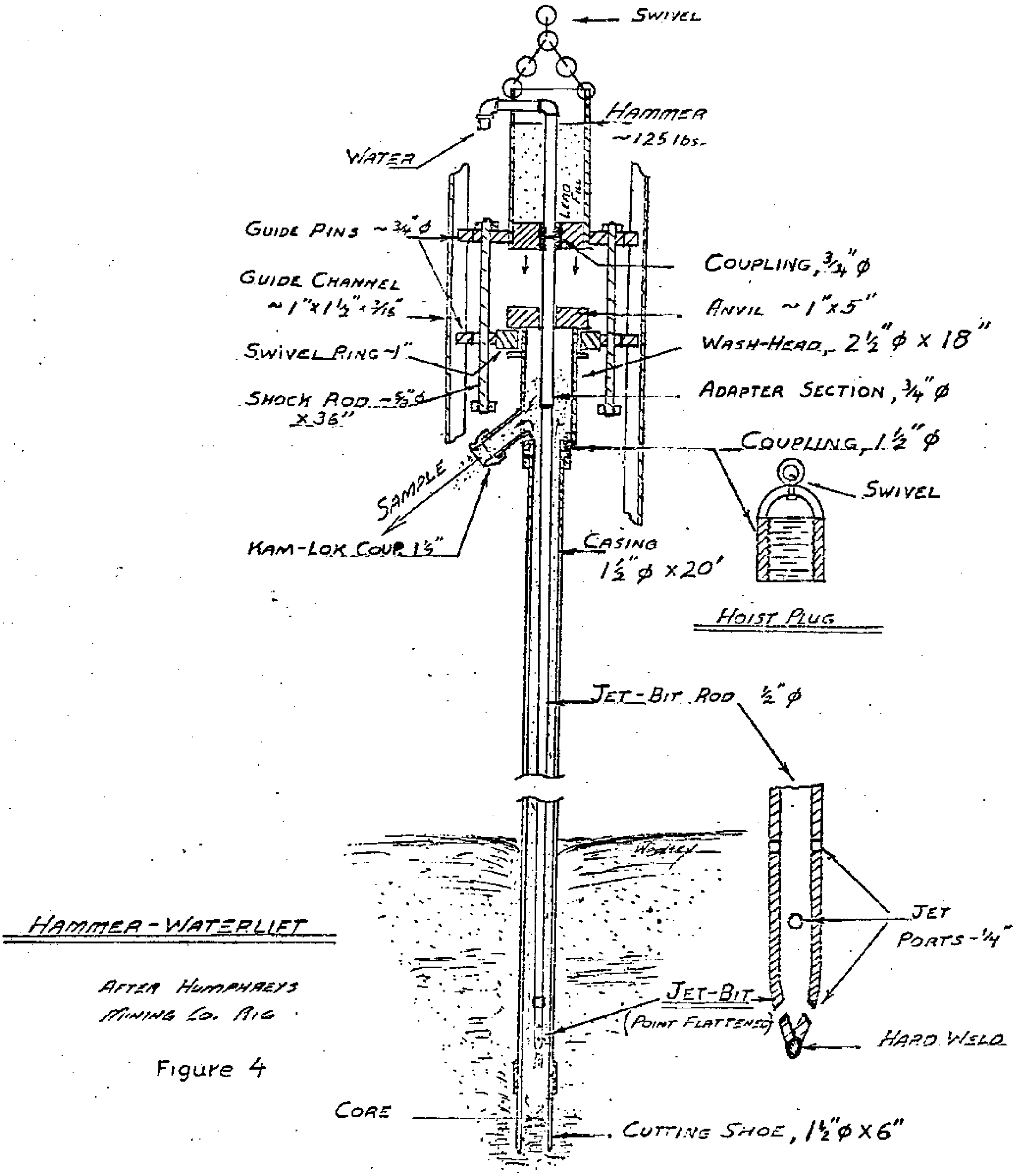


Figure 2



DRILL VESSEL POSITIONING & ANCHORING Figure 3



HAMMER-WATERLIET

After Humphreys Mining Co. Rig

Figure 4

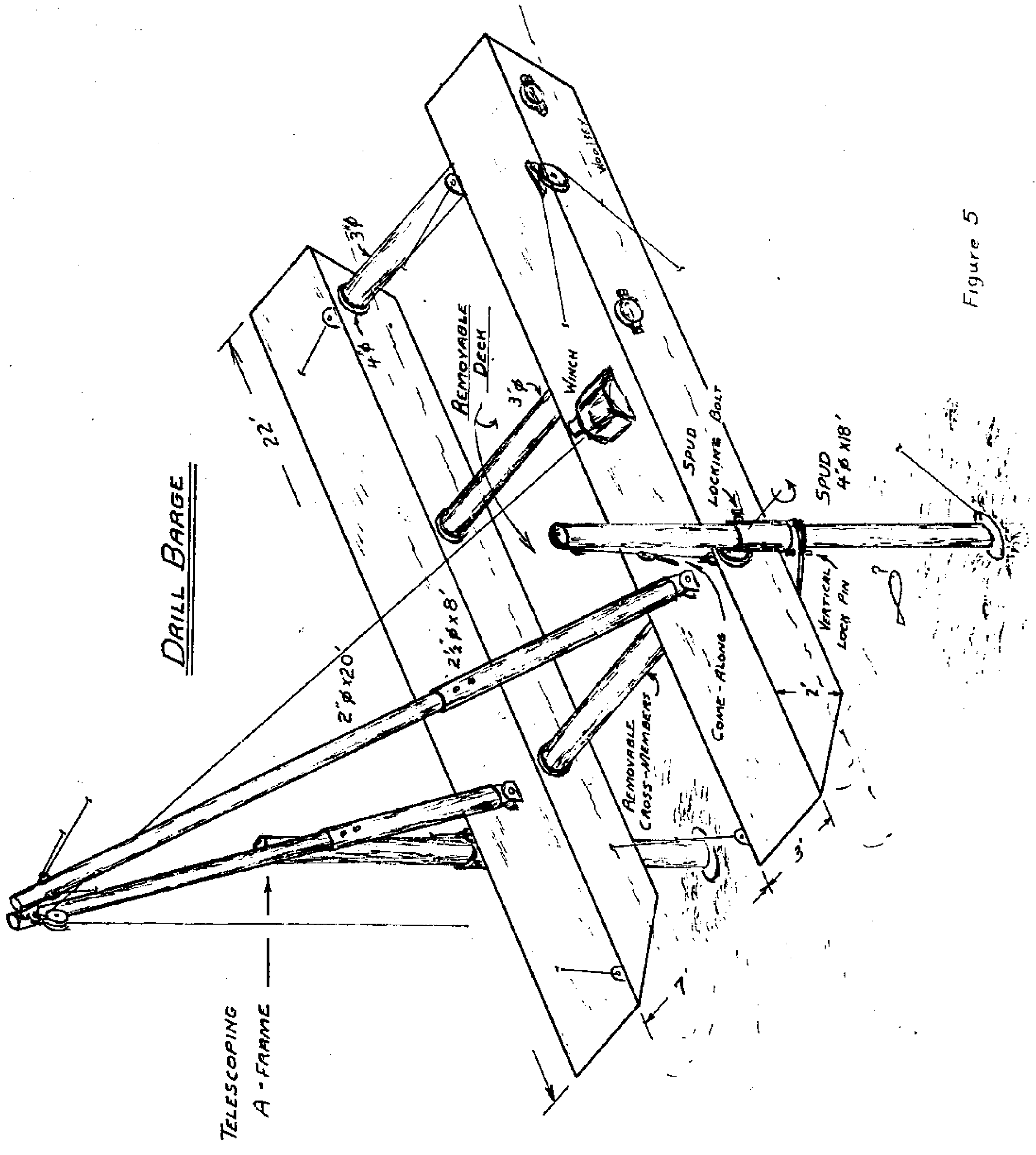
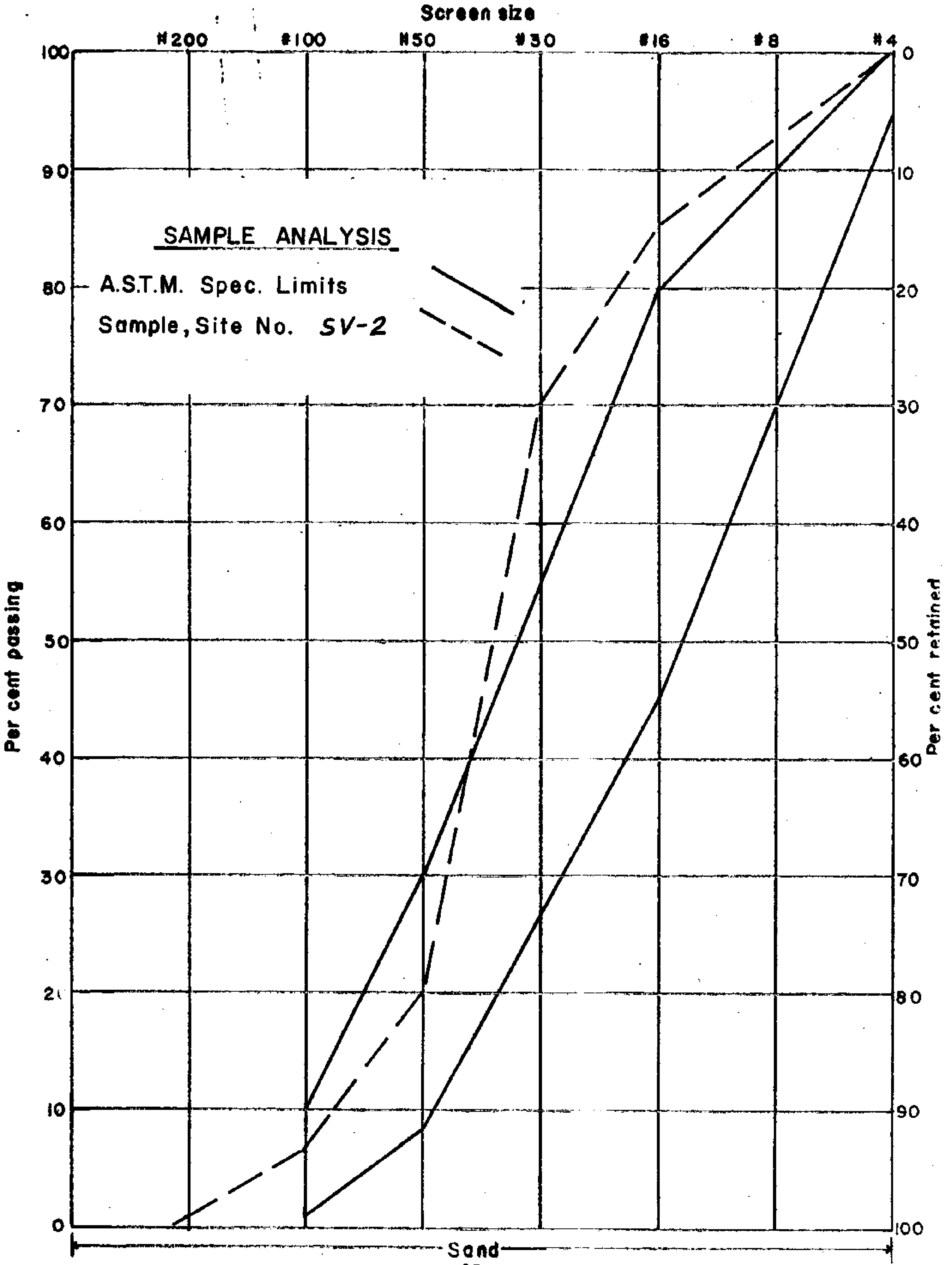

DRILL BARGE
22'
4'φ
3'φ
REMOVABLE DECK
3'φ
WINCH
SPUD LOCKING BOLT
SPUD 4'φ x18'
VERTICAL LOCK PIN
COME-ALONG
2'
3'
7'
REMOVABLE CROSS-MEMBERS
2½'φ x 8'
2"φ x20'
TELESCOPING A-FRAME
WOOLSEY

Figure 5

APPENDIX D

The following figures present selected graphs of unprocessed samples representative of the respective drill sites. Sample, grain-size data is presented relative to ASTM (sand) specification limits (ASTM, 1948).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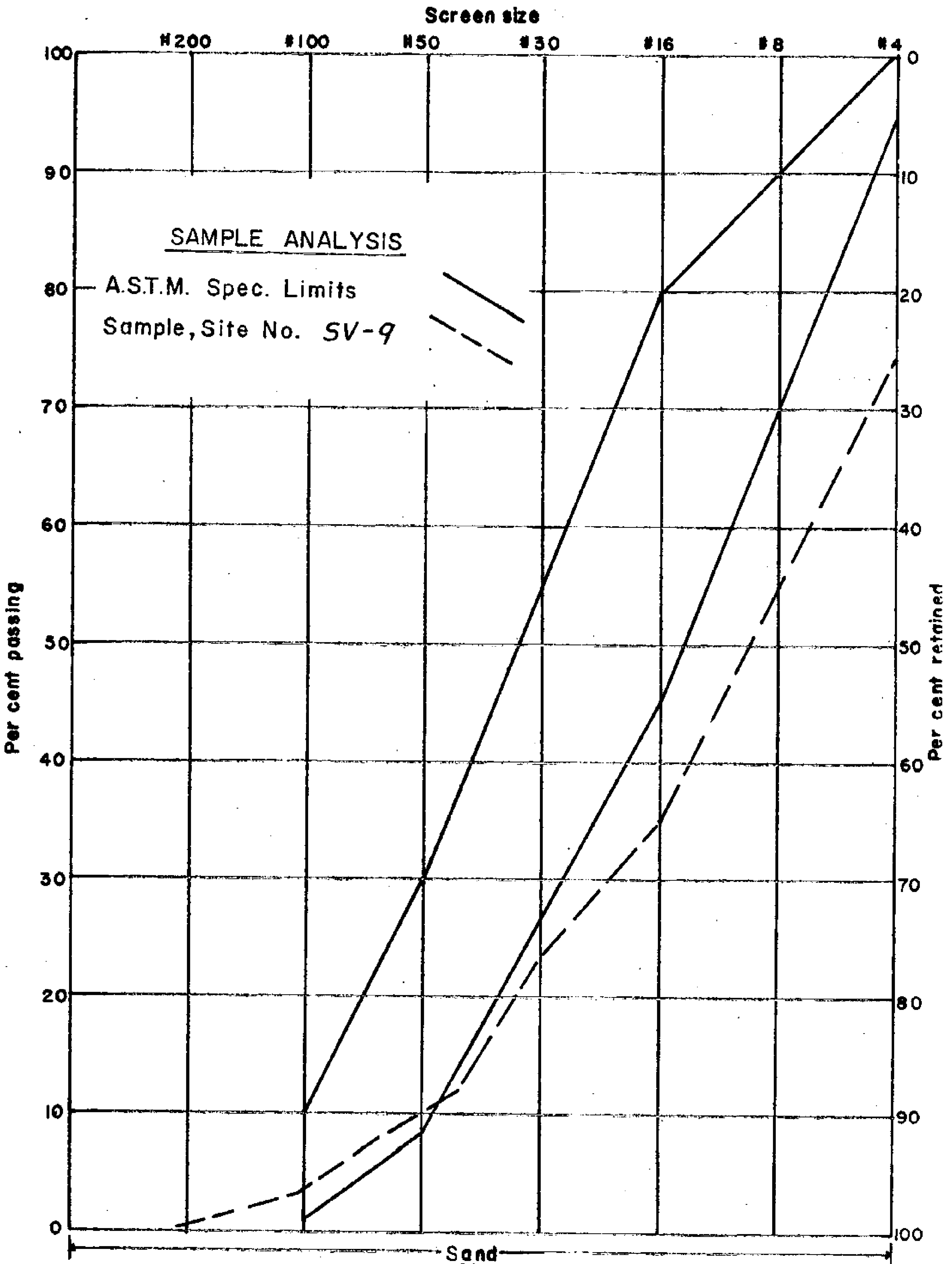

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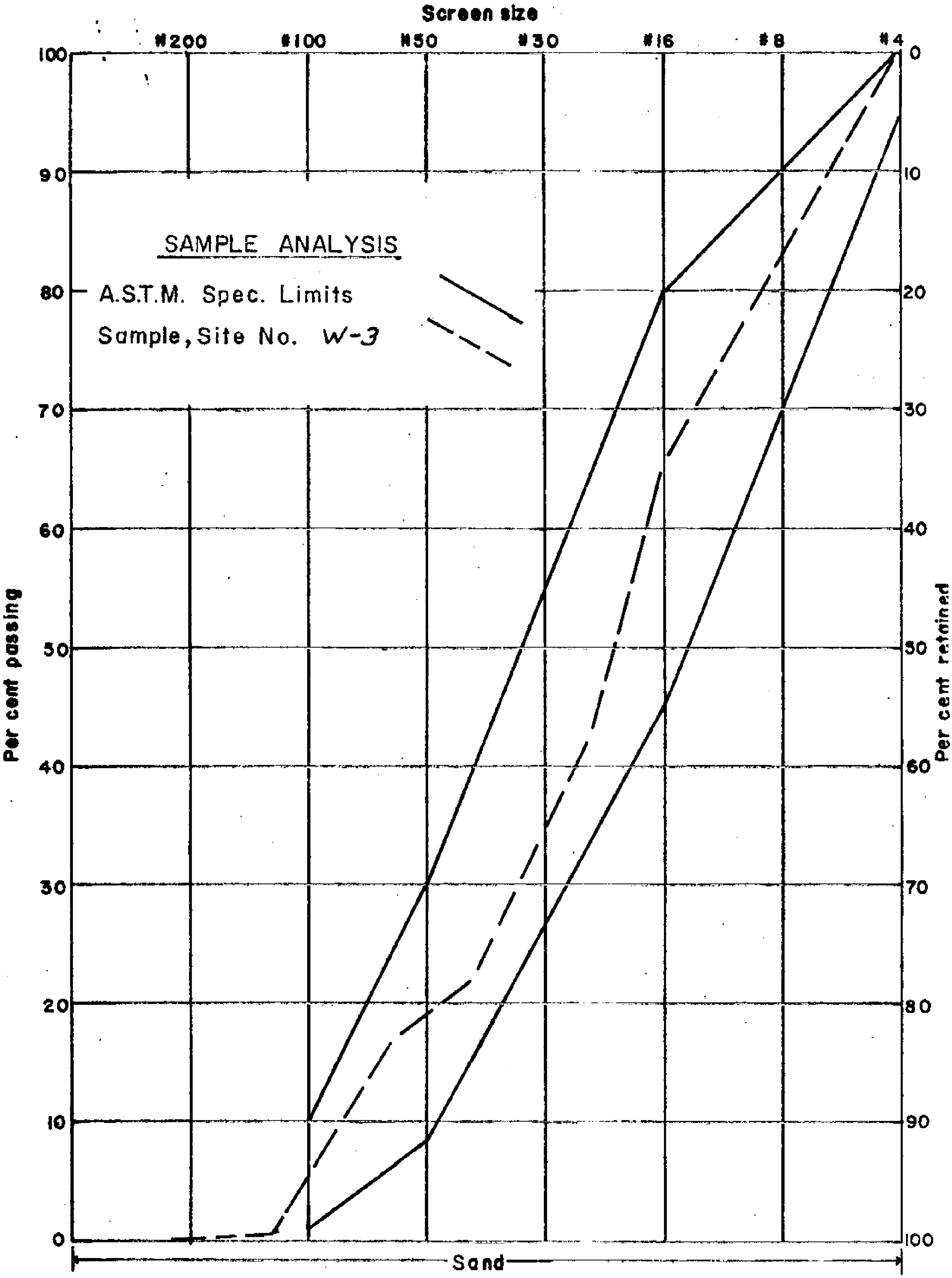

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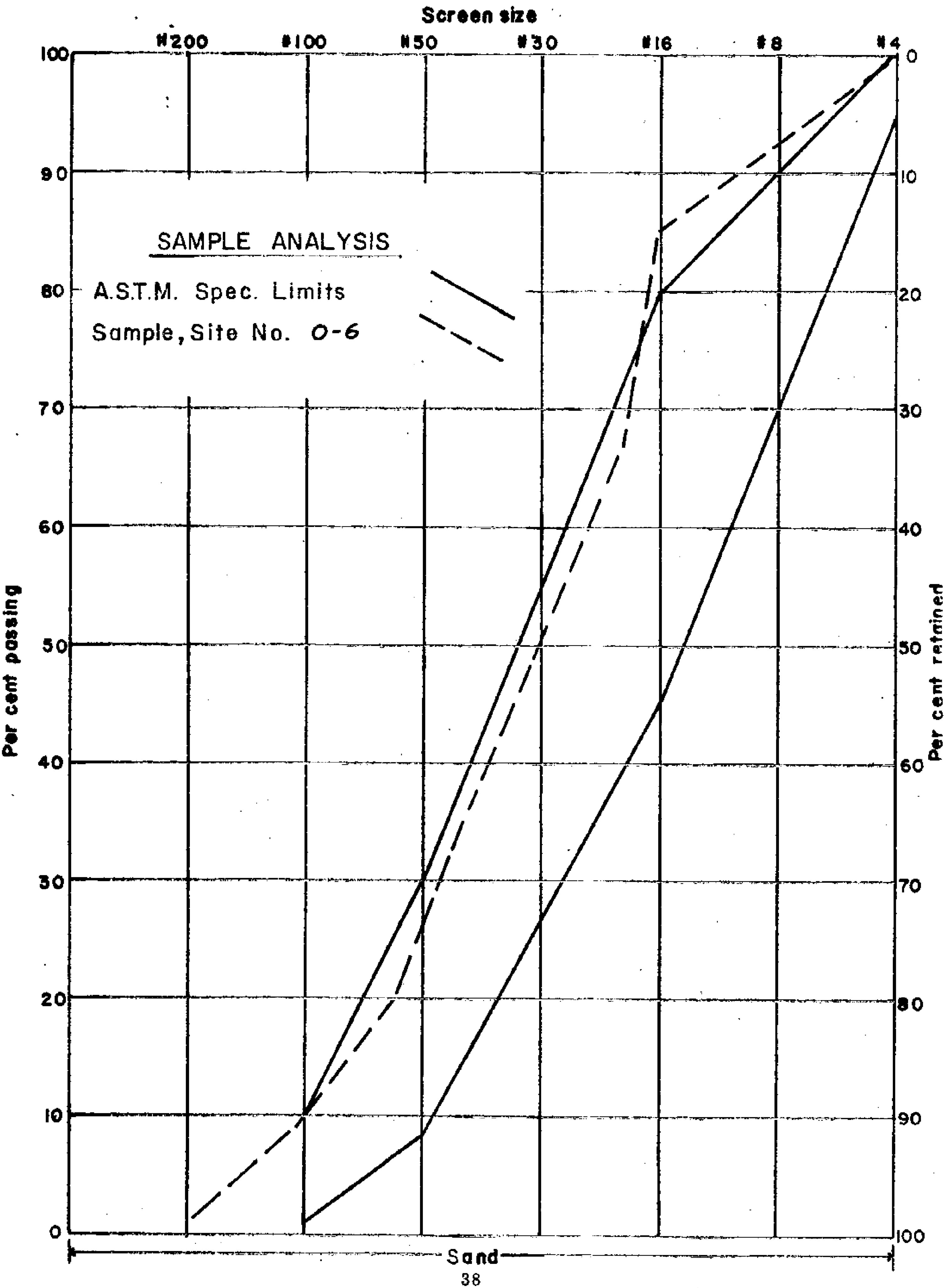
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Sample, Site No. O-6
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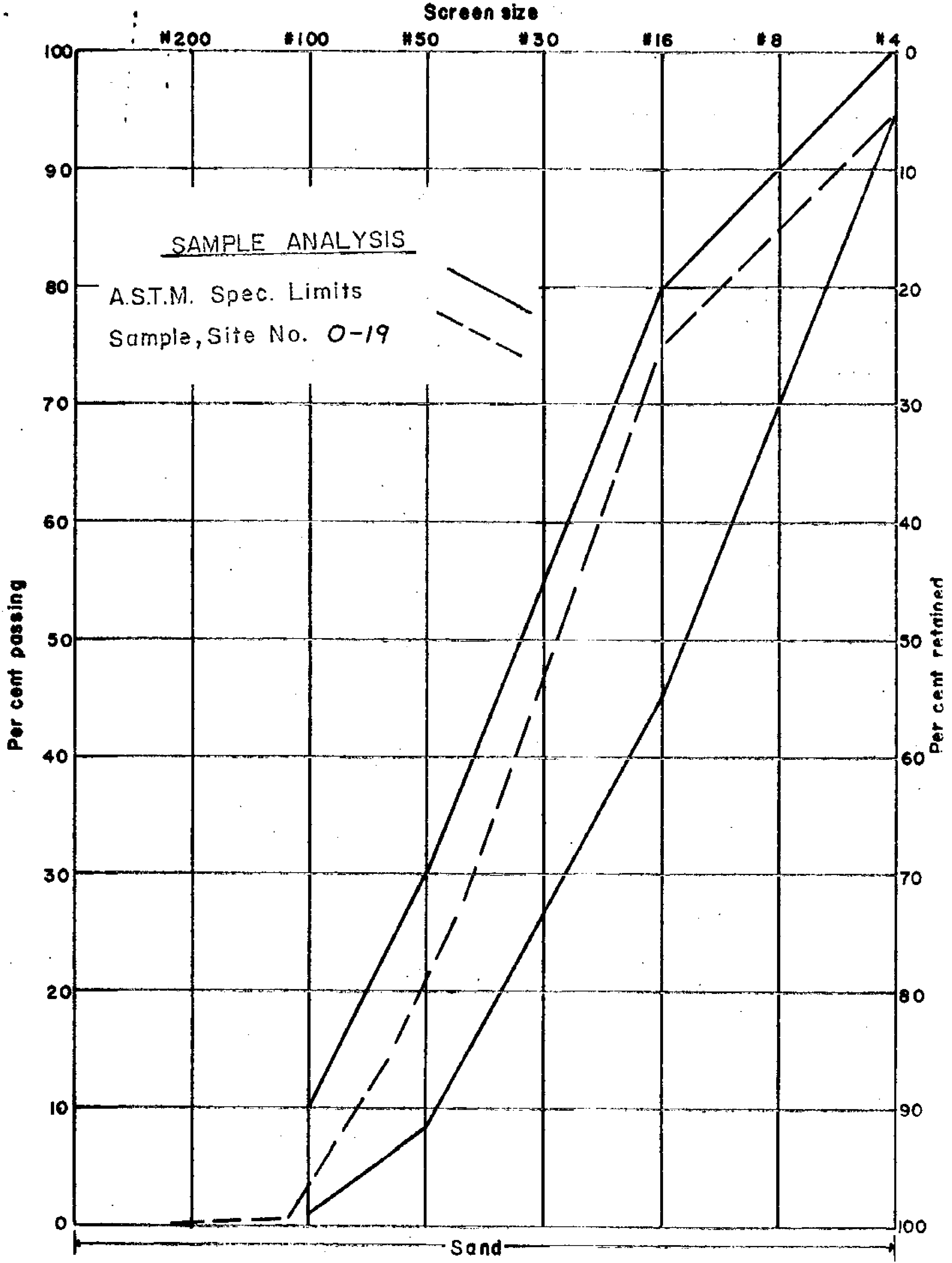
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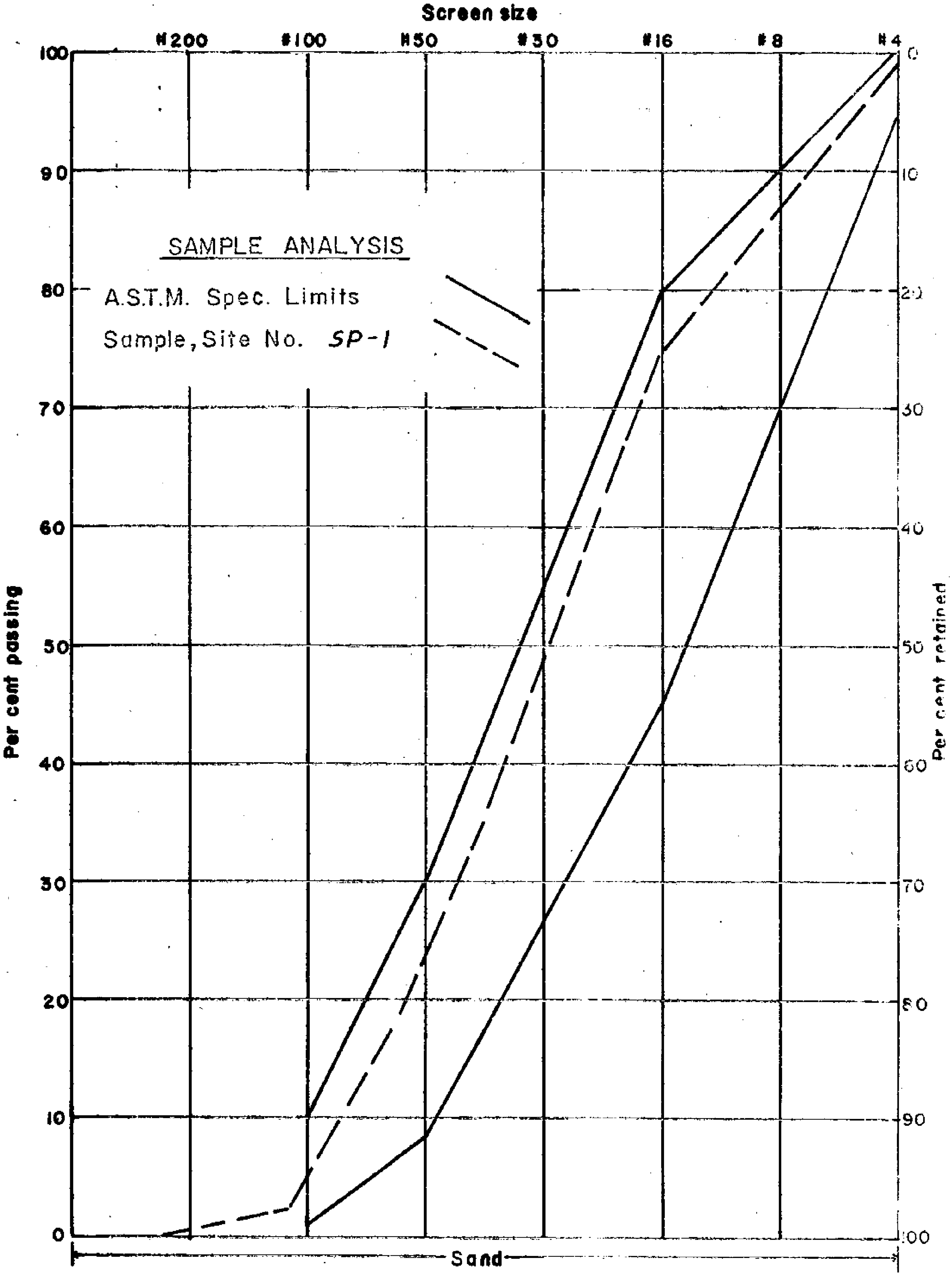
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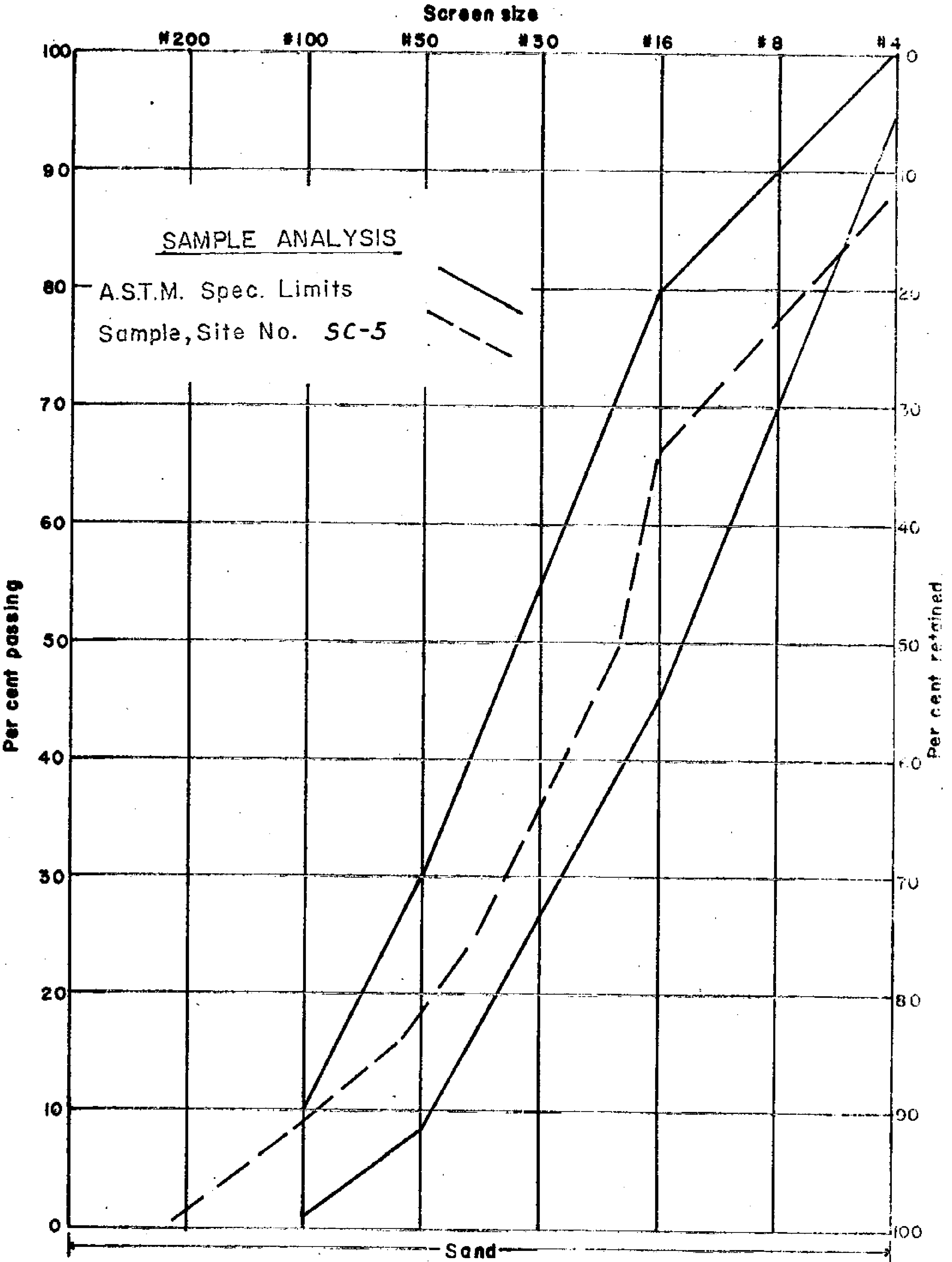
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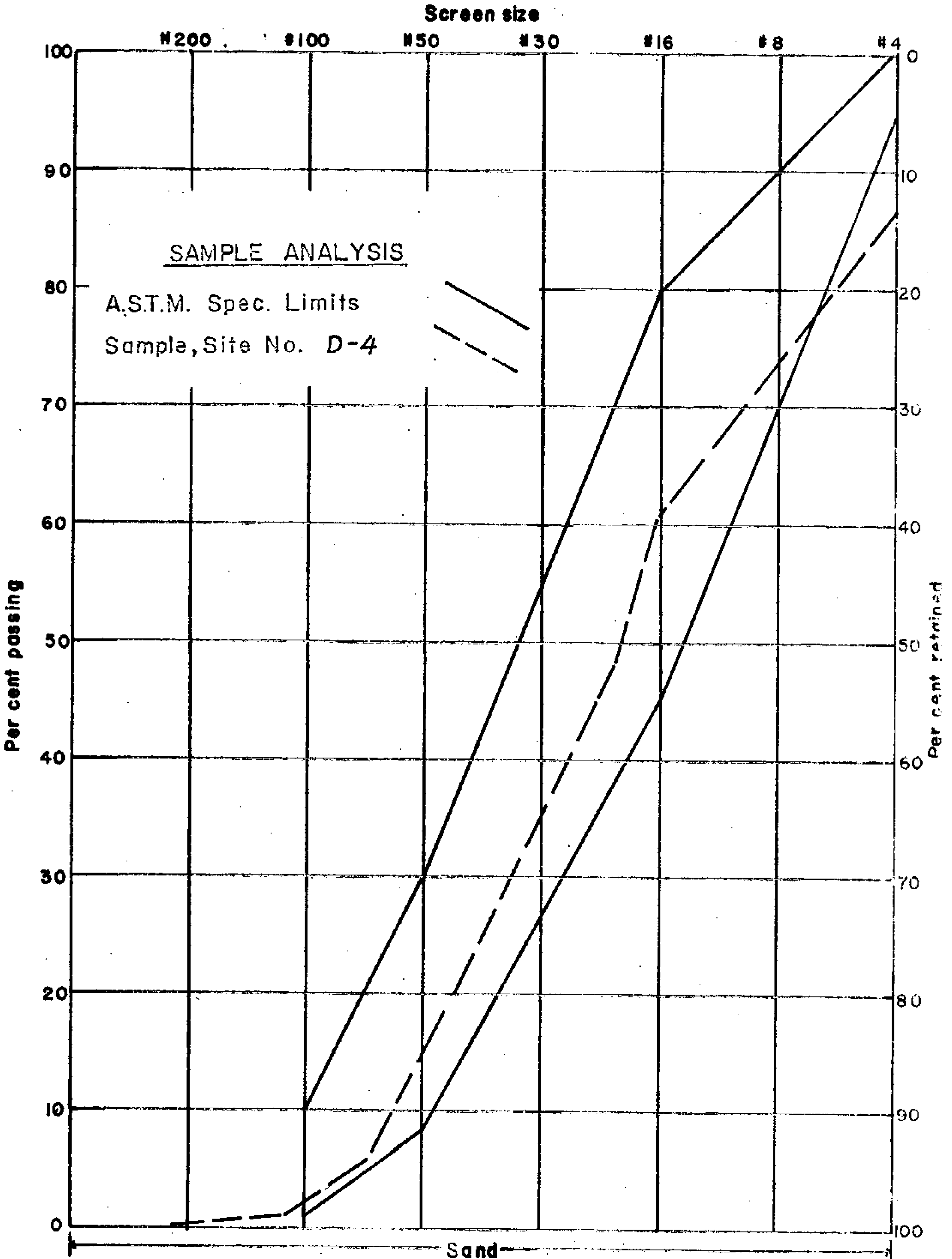
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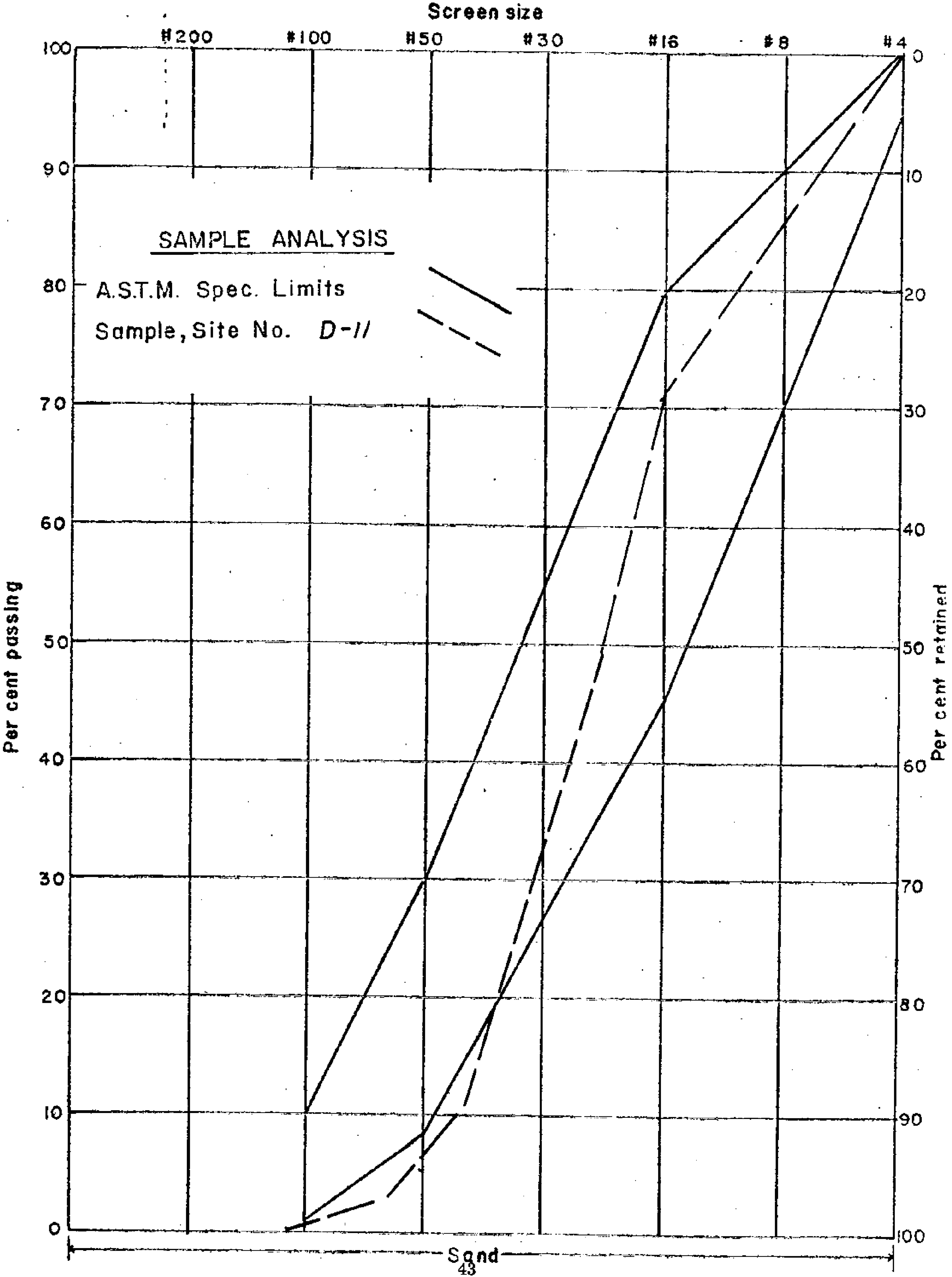
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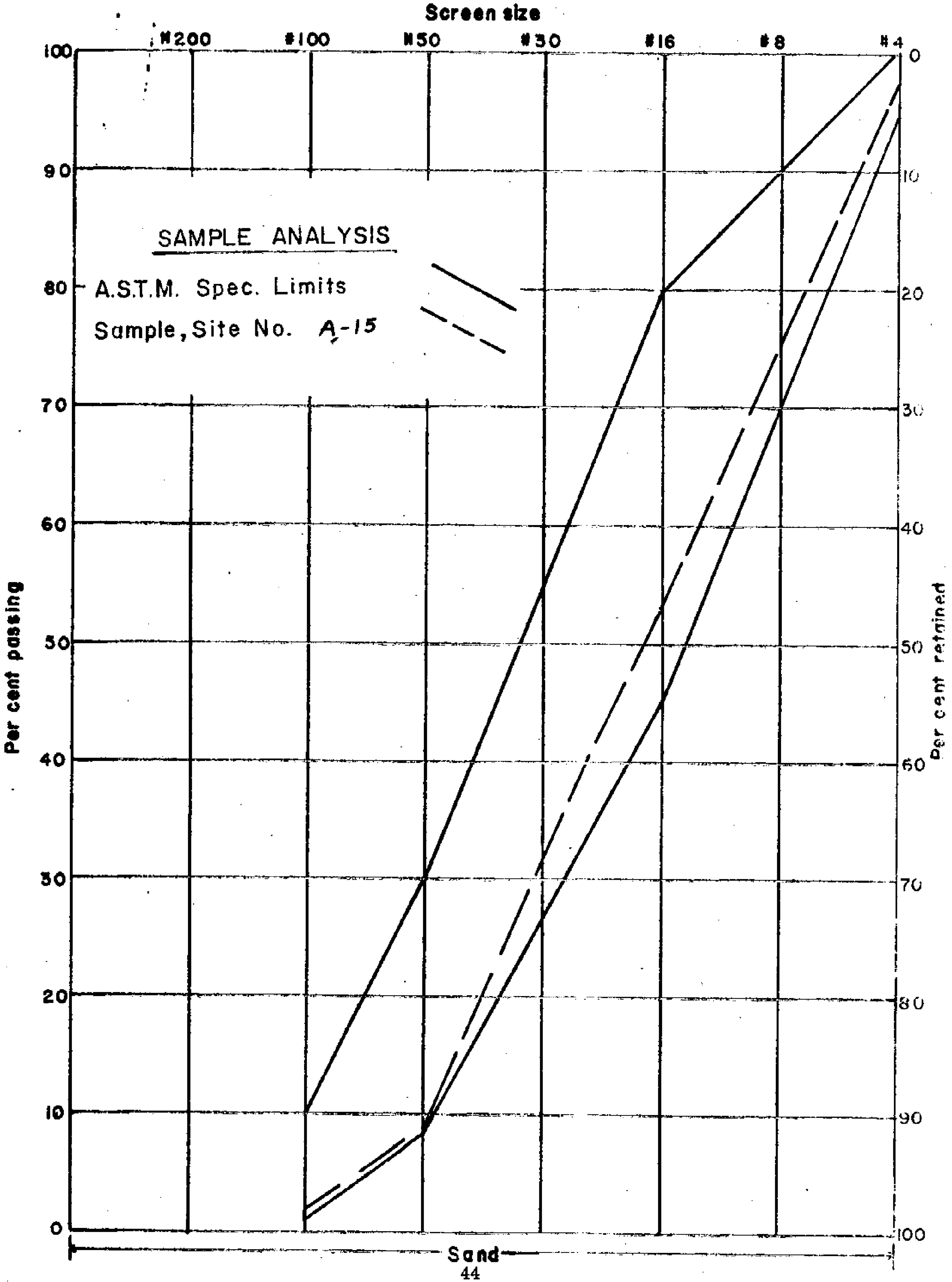
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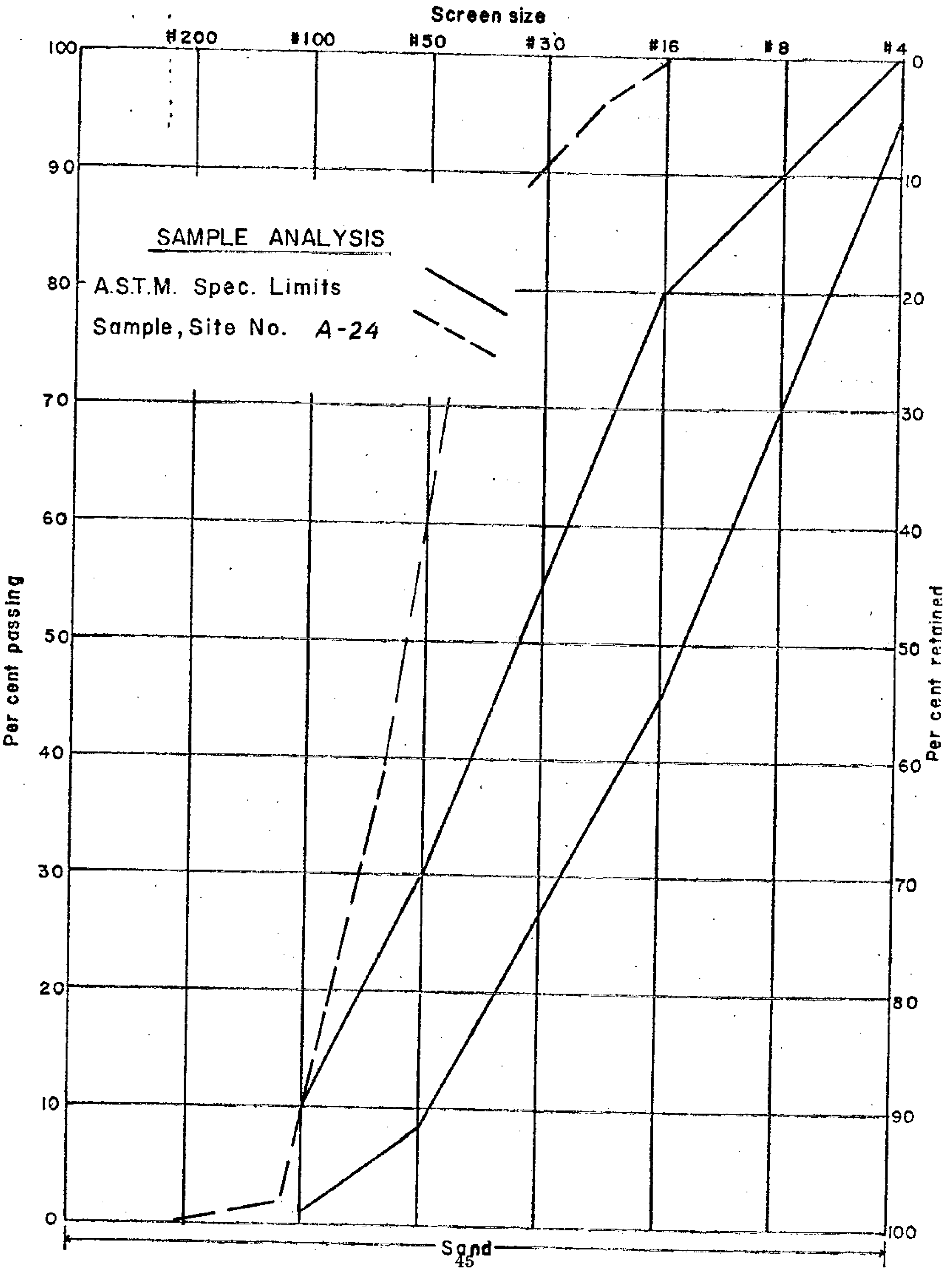
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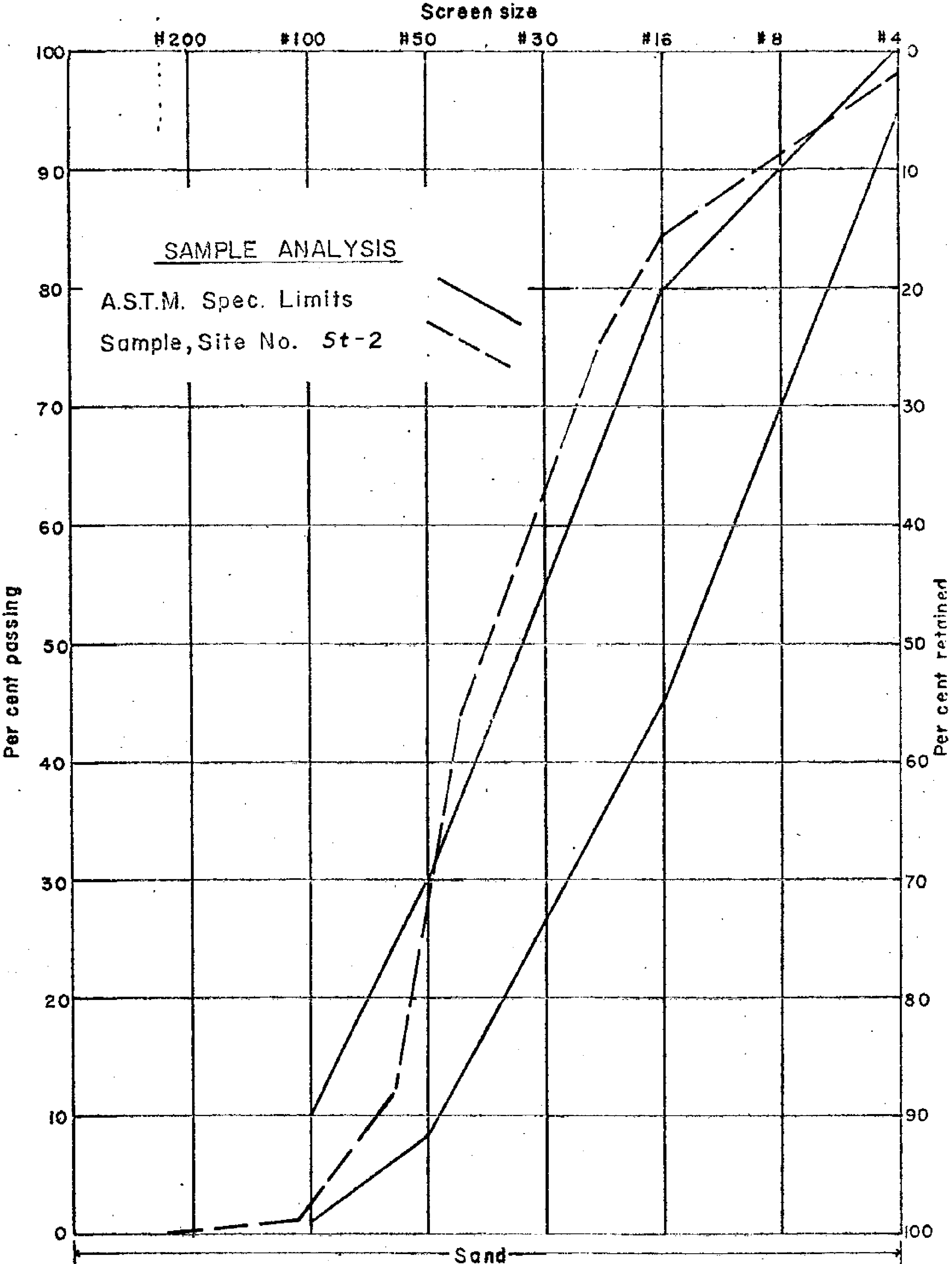
Sample, Site No. A-24
Sand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#4
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90
80
70
60
50
40
30
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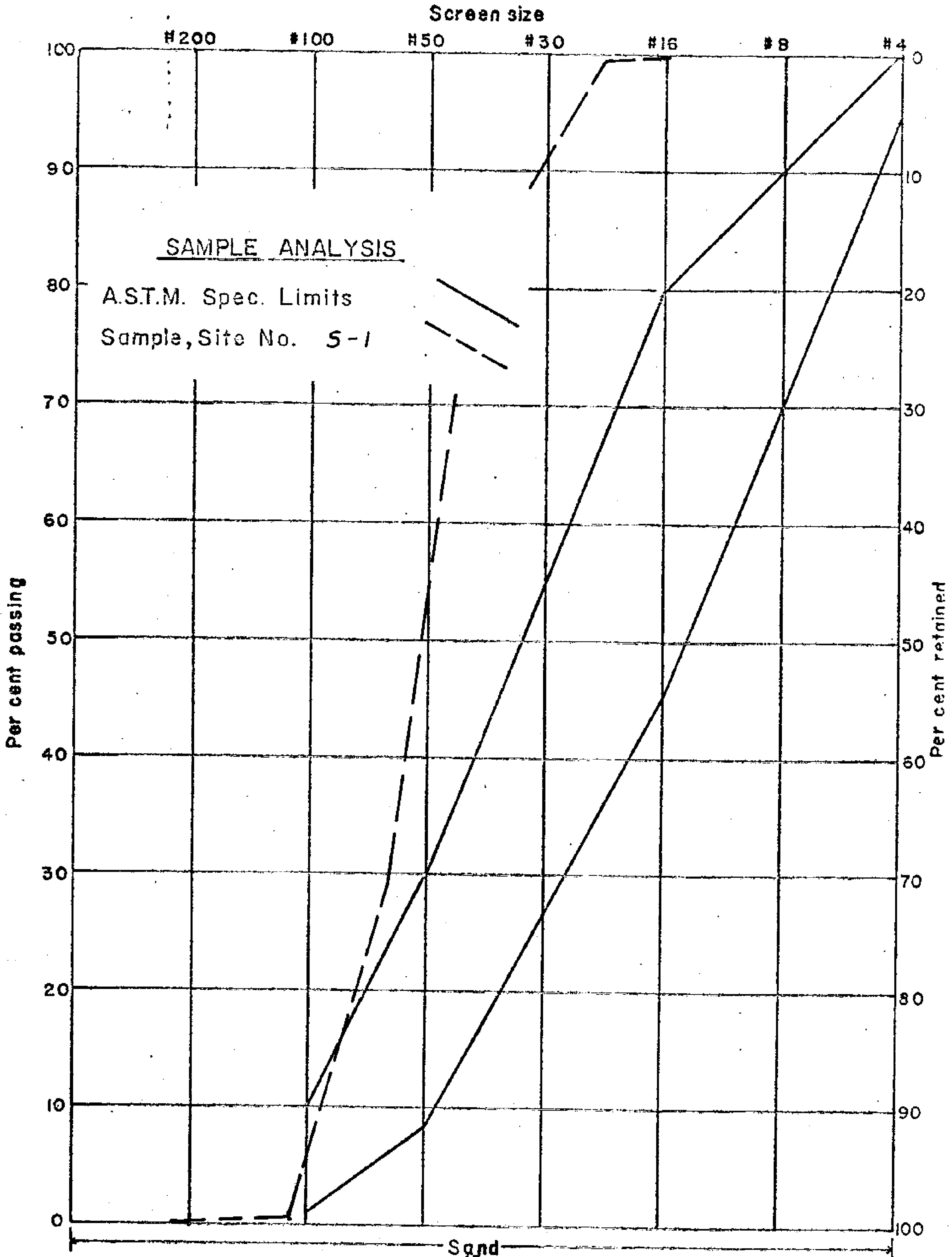
10
0
0
10
20
30
40
50
60
70
80
90
100
Per cent passing
Per cent retained
SAMPLE ANALYSIS
A.S.T.M. Spec. Limits
Sample, Site No. 5t-2
Sand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Per cent passing
0
10
20
30
40
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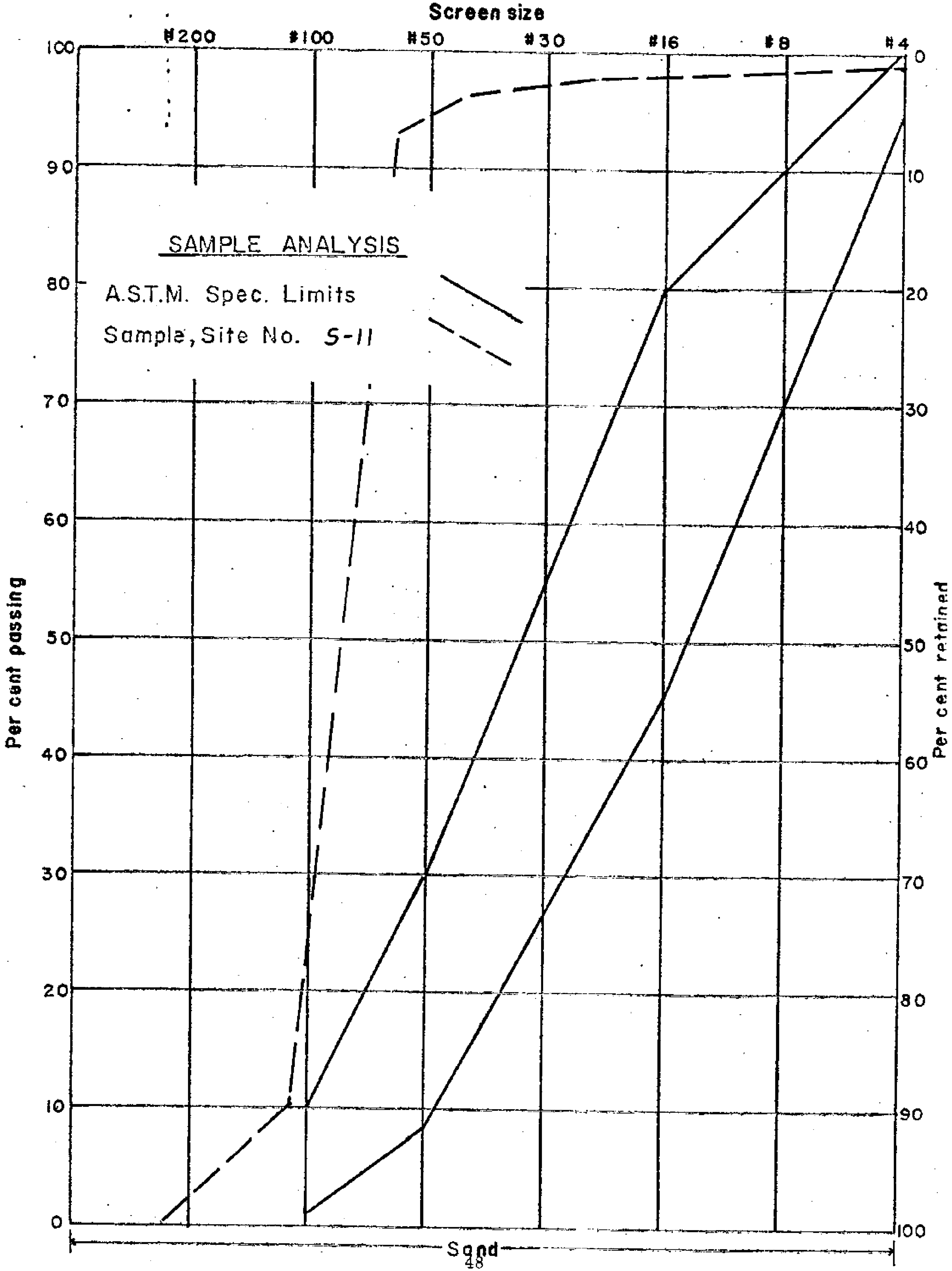
70
80
90
100
Per cent retained
SAMPLE ANALYSIS
A.S.T.M. Spec. Limits
Sample, Site No. 5-1
Sand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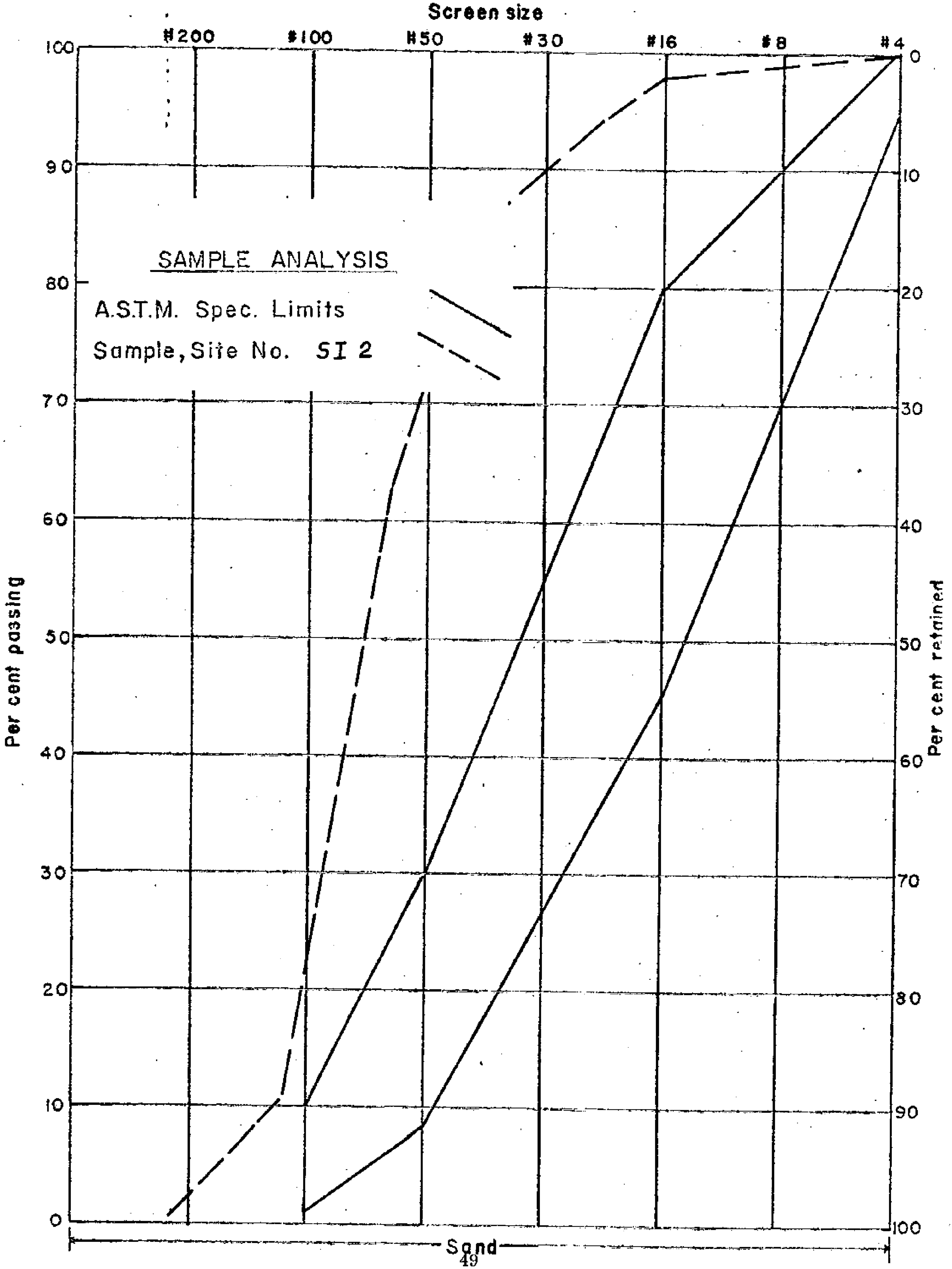
10
0
Per cent passing
0
10
20
30
40
50
60
70
80
90
100
Per cent retained
SAMPLE ANALYSIS
A.S.T.M. Spec. Limits
Sample, Site No. S-11
Sand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#8
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Per cent passing
100
90
80
70
60
50
40
30
20
10
0
Per cent retained
0
10
20
30
40
50
60
70
80
90
100
SAMPLE ANALYSIS
A.S.T.M. Spec. Limits
Sample, Site No. SI 2
Sand

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