PLACER MINING AND MINERAL BENEFICIATION OF ILMENITE SAND DEPOSITS NEAR LAKEHURST, N.J.

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INTRODUCTION

Ilmenite ($FeTiO_3$) is used mainly in the production of white titanium dioxide. Because of its whiteness, high refractive index and resulting light scattering ability, synthetic titanium dioxide is unequaled as a non-toxic white pigment for paints, paper, rubber, dyes and ceramics.

Ilmenite and rutile (TiO_2) are used in the production of titanium metal. Titanium is one of the space age metals. One hundred years ago it was considered a vexing contaminant in magnetite deposits that often rendered the iron ore worthless. Today titanium is in demand as an alloy of aluminum to strengthen the skins of supersonic aircraft so that they can withstand the high temperatures generated by air friction. It is also used as a refractory alloy to withstand the intense heat of jet engines and rockets.

Titanium pigments were made originally by dissolving ilmenite in sulfuric acid, crystallizing to separate iron, then hydrolyzing the solution and calcining the precipitate. Newer plants utilize the Kroll process whereby titanium tetrachloride is produced in fluidized bed chlorinators. The tetrachloride is then either oxidized to the white dioxide pigment, or is reacted with magnesium under an inert atmosphere to produce titanium metal.

Although titanium is the ninth most abundant element in the earth's crust, it seldom is found in concentrations rich enough to be used as an ore. Thus, natural concentration processes especially placer formation are required to form a significant ore body. The mining of ilmenite in New Jersey by Asarco, formerly the American Smelting and Refining Company, occurs in such placer deposits.

The ilmenite concentrates generated at this operation are sold under a 10 year contract to E. I. du Pont de Nemours and Co. for manufacture of pigments.

Ore reserves are approximately 180 million tons assaying 1.95% total included TiO_2. The production rate is 185,000 tpy (tons per year) of ilmenite concentrates or about 20% of total U. S. production. At this mining rate, ore reserves should last about 20 years.

ACKNOWLEDGEMENTS

We would like to thank John F. Lord, Superintendent of the Asarco Manchester Plant, for his hospitality in expediting this field trip and for giving us access to internal company information regarding the mining property.

GENERAL GEOLOGY

The ilmenite deposits mined by Asarco lie on the Outer Coastal Plain of the Atlantic Coastal Plain Province. Outcropping on this coastal plain are a series of Tertiary deposits that dip gently to the southeast. Beneath the Tertiary deposits are a series of Cretaceous deposits which outcrop on the Inner Coastal Plain and which also dip gently to the southeast. In part covering both coastal plains is a discontinuous veneer of Quaternary deposits. These sediments are the result of the Pleistocene glaciation and sedimentation in the Recent.

THE ILMENITE BEARING DEPOSITS

Commercial deposits of ilmenite are found primarily in three formations: the Kirkwood Fm. of Miocene age, the Cohansey Fm. of late Miocene and perhaps Pliocene age, and the Cape May Formation of late Pleistocene age. Markewicz, Parrillo, and Johnson studied these formations and their titanium bearing sands, for the Bureau of Geology and Topography of New Jersey in the fifties, and the description of the formations and their view as to the origin of the ilmenite deposits which follows, is from their report published in 1958:

> It will be recalled by those familiar with the geology of northern New Jersey that the Delaware River and its tributaries drain a considerable area of Precambrian rock known to contain ilmenite, and the same stream also crosses thick sills of Triassic diabase which likewise are known to carry this mineral. Also, the Millstone River, which now flows north through the gap in Rocky Hill, at one time flowed south and laid down thick deposits of gravelly sand in the Kingston-Plainsboro-Cranbury area. It seemed reasonable to suppose, therefore, that it, too, must have carried ilmenite-bearing sands, and the problem of finding commercial deposits seemed to depend, therefore, on locating an area where waves, shore currents, or stream action had served to concentrate the ilmenite...
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> Expansion of the investigation has shown that most of the material containing three percent or more of heavy minerals occurs in one or another of three geologic formations; namely, the Kirkwood sand of Miocene age, the overlying

Cohansey sand of the late Miocene or Pliocene age, and, in certain localities, the Cape May formation of late Pleistocene age. In this area they have the following characteristics.

KIRKWOOD FORMATION The outcropping material consists of light-colored, fine-grained, micaceous sand and dark clays; but both have a considerable range in color. The formation was deposited unconformably on a relatively level surface of the Shark River-Manasquan deposits of Eocene age. That the Kirkwood sea was rather shallow is evidenced by the contained marine fauna (Horace G. Richards, verbal statement, 1957) and the lack of glauconite. The original deposits possibly extended inland as far as the Triassic formations. Today, however, the maximum northwest extension of the formation is near Clarksburg, 12 miles southeast of the nearest outcrop of Triassic rocks. The fine, floury sand typical of the Kirkwood in the area of its outcrop appears to thin toward the southeast, being as thick as 40 feet in the north and entirely absent in wells to the southeast, at Toms River (see Figures 1, 2). Below this sand in the north are black, lignitic, sandy silts and clays in which pyritized diatoms (Actinoptychus heliopelta) have been found. These are not found in samples of this material from wells northwest of a line from Lakehurst to Lakewood. They do occur, however, to the northeast, southwest, and southeast. It is also significant that in the same area where diatoms are absent in the black silts and clays of the Kirkwood, the earlier Shark River-Manasquan deposits, and, in places, part of the Vincentown formation are absent. Farther down the dip, the Kirkwood consists of fine and coarse, black or dark brown sands and clays which contain a neritic fauna. The maximum thickness in the outcrop area is at least 100 feet and it thickens greatly to the southeast. Data from well borings show the approximate dip to be 11 to 25 feet per mile, the latter figure referring to the base of the formation.

COHANSEY FORMATION As the Kirkwood sea retreated, drainage developed on the newly exposed surface and deposition of continental origin began. It may well be that the major source of basal Cohansey material was the newly exposed Kirkwood. In general, it consists of medium-grained, poorly sorted quartz sand; with fine and coarse sands not uncommon and even predominating in some area. Yellow clay often coats the sand grains, and thin clay beds are also sometimes present although the percentage of clay to sand is small. These clays are sometimes lignitic, but never contain a recognizable fauna. Obscure casts of molluscan shells have been found in the Cohansey, but these are of no help in determining its age. A flora comparable with certain upper Miocene localities in Europe has been found near Bridgeton. It is common to find gravel at the

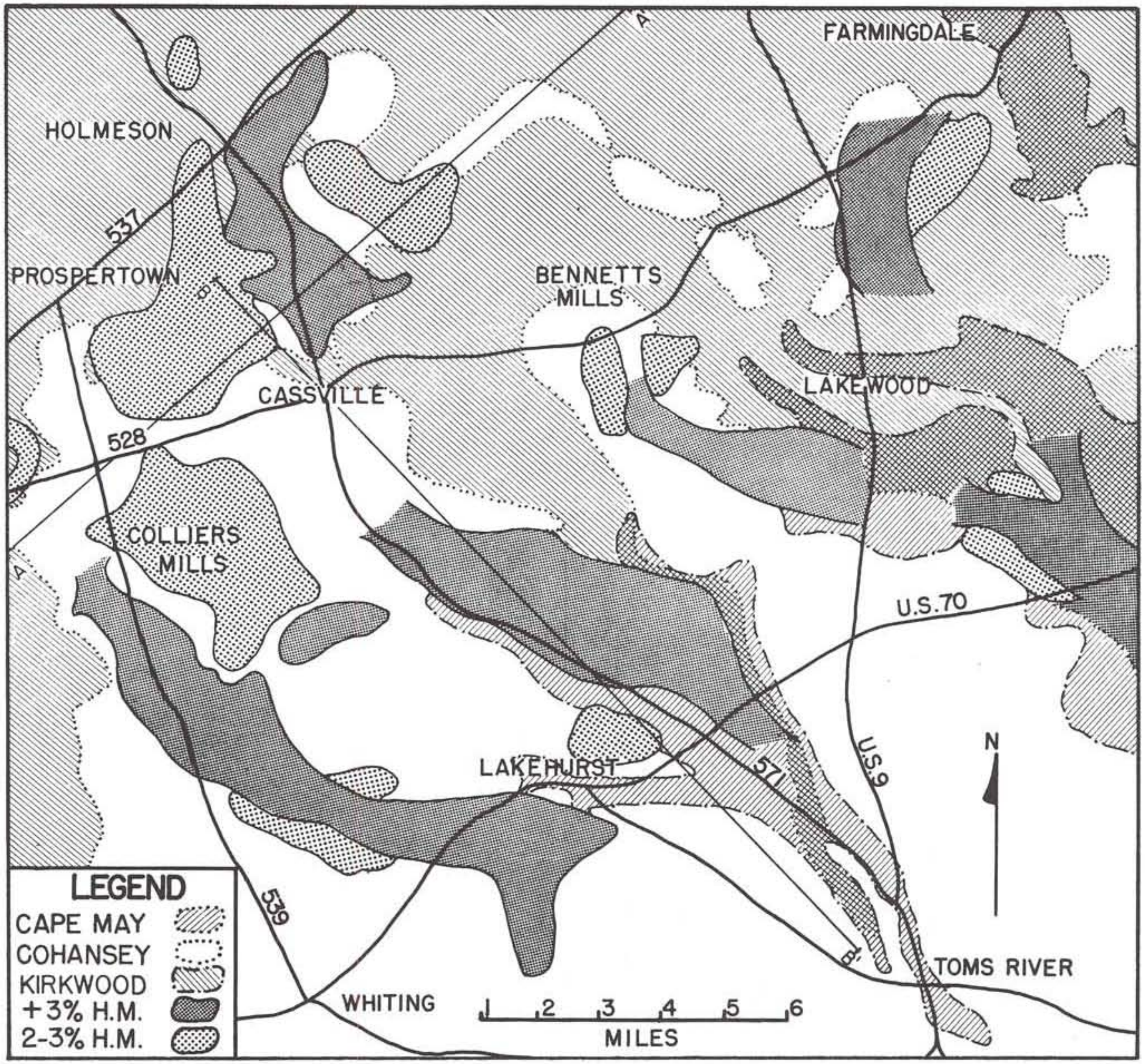


Figure 1. from Markewicz, Parrillo and Johnson, 1958.

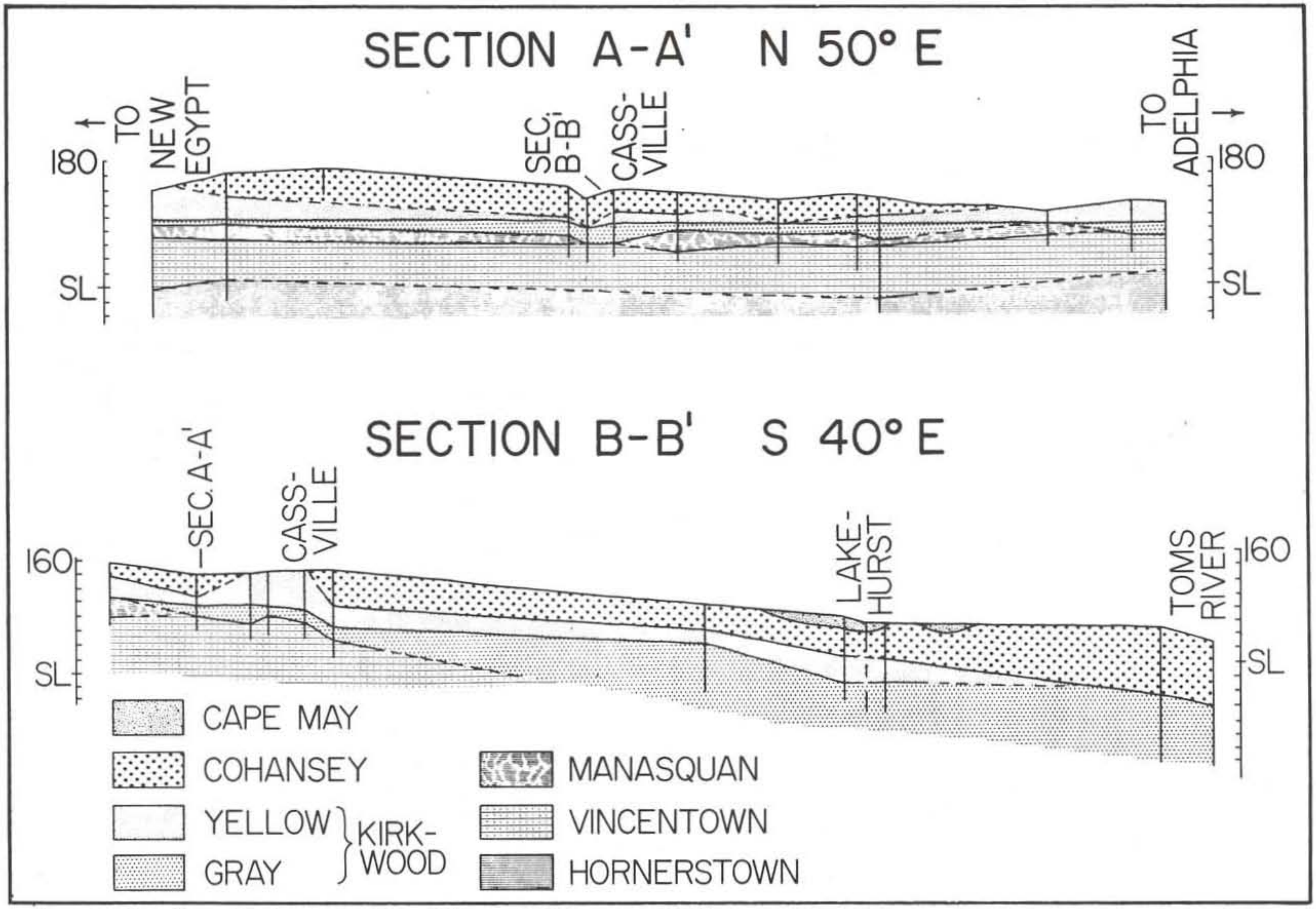


Figure 2. from Markewicz, Parrillo and Johnson, 1958.

surface of the Cohansey where it may be residual from younger formations; however, it is not uncommon to find scattered pebbles usually less than one-half inch in maximum diameter - well down in the section. The formation has a thickness of 100 to 250 feet where not thinned by erosion. There are no regular or continuous members which can be recognized over any appreciable area, all such members being in the form of lenses. Cross-bedding, characteristic of stream-channel deposits, is conspicuous of many exposures. Although there is an unconformity separating the Kirkwood from the Cohansey, the base of the latter has an average dip of 9 to 11 feet per mile to the southeast.

CAPE MAY FORMATION As stated by Kummel (1940), the terraces of Cape May material along the coast do not extend more than 40 feet above sea-level, "but along the tributary streams they rise to greater elevations ..." Thus, at the Eak Pit, one-fourth mile south of Route 70 and on the west bank of Toms River, the top of the gravel deposit is at elevation 50. There the deposit is 6 feet thick and is composed of medium to coarse yellow sand and scattered pebbles. Several gravel-filled channels were noted here; also, the layering of the gravel indicated that the depositing streams flowed towards Toms River.

The sand accompanying the gravel at this point is relatively rich in heavy minerals and the same is true of the thin deposit of Cape May gravel seen in excavations for the Brick Township High School 1-1/3 miles west-northwest of the Laurelton traffic circle. Where exposed in a pit 1/3 mile to the north, the gravel deposit is only 2 to 5 feet thick.

At each of the specific sites mentioned, the Cohansey sand contains a lower percentage of heavies than the overlying Cape May formation. It is therefore evident that the sand in the Cape May formation was derived from more distant sources which were richer in heavy minerals, or else the reworking of the Cohansey sand resulted in a greater concentration of heavies.

ORIGIN OF ILMENITE DEPOSITS From evidence now available, it appears that the Kirkwood sea may not have extended many miles farther northwest than the present outcrop limits of the Kirkwood formation. It follows that during Miocene time the sea was retreating from its maximum advance as evidenced by outcrops of the Raritan formation. The fine yellow sand of the Kirkwood therefore probably represents material that was eroded from the older sediments of the coastal plain lying to the northwest which was carried by sluggish streams down to the Kirkwood sea. Regression of the sea continued as the land slowly rose, and during this slow withdrawal it is believed that shore currents and waves worked over the sandy material and eliminated some of the lighter grains. We believe it was this process which created the ten-mile width of yellow, fine-grained Kirkwood sand containing two percent or more of heavy minerals. In further support of this theory of concentration, it was noted in our mapping that heavy-mineral concentrations in the Kirkwood parallel the strike of the formation, trending northeast and southwest.

The continuing uplift of the land mass caused the withdrawal of the Kirkwood sea and a period of erosion followed. This uplift again increased stream gradients and permitted streams to erode and carry their loads to the southeast. It is believed that at this time the ancestral Delaware contributed much of the material now composing the northwestern part of the Cohansey formation. As this major stream reached the Colliers Mills area, its velocity was reduced and its load was spread out in a broad fan as alluvial sheet sands (Figure 1). Growth of this fan undoubtedly caused distributaries to shift their courses from time to time and some of these flowed in a southwesterly direction. Eventually a tributary of the Schuylkill River with somewhat greater gradient worked its way northeast far enough to capture the Delaware drainage.

Though the Delaware deposited sands which undoubtedly contained some heavy minerals, it is believed that a later stage of events involving southeast drainage brought new materials and reworked the previously deposited alluvial sheet sands.

Terrace elevations indicate that during Pleistocene time the Millstone River flowed south because the Pensauken terraces bordering Millstone River decreased in elevation from north to south. More recently, the study of well samples has shown that in the Kingston-Plainsboro-Cranbury area an unusual thickness of gravelly sand exists which can be correlated with The Pensauken formation. It is evident, therefore, that Pensauken deposition must have continued for a considerable time, and finer materials were carried still farther to the south. We believe that the Millstone contributed to and reconcentrated the previous sheet sands by braided streams which constantly shifted their flow pattern across the huge alluvial deposits.

The writers recognize that there are alternate explanations for the origin of these deposits and that some who have studied them believe for example, that the ilmenite in the Cohansey sands may have been concentrated by marine action. This would imply, however, that the Cohansey is of marine origin, and the evidence against this is rather strong, although farther down dip it may be in part deltaic. Subsequent work may disprove some of the ideas as expressed herein, however, pursuit of these principles made possible the discovery and extended exploration of commercial ilmenite deposits.

THE LAKEHURST MINING AREA

There are two mining operations in the immediate vicinity of Lakehurst. Glidden Company lying to the northwest of the Lakehurst Naval Air Station operate a mine and mill. The reserves of this operation are now almost exhausted. The newer operation is that of Asarco lying south of Glidden.

The Asarco Manchester Unit has extensive land holdings southwest of Lakehurst, New Jersey (see Figures 3 and 4). The dredging operation by which the company mines is in the Kirkwood and Cohansey Formations. Overlying these formations in a few areas on the Asarco property is the Pliocene Beacon Hill gravel which is not ore bearing.

The ore occurs in heavy mineral beds ranging from less than one inch to several feet in thickness. They are difficult to correlate because of their lens-like structure except as broad zones (ten to forty feet thick) normal to the dip. Some lens range up to five percent heavy minerals.

Neither the very coarse sand and gravels nor the clay beds contain commercial quantities of ilmenite. Very rich concentrations of ilmenite, however, are sometimes found on top of the clay beds. The richest ilmenite concentrations are found within the very fine-grained sands.

THE MINING OPERATION

The mining and refining processes are shown in Figures 5 and 6. Mining consists of a 25 acre dredge pond, 45 feet deep, from which the sand is dredged and pumped at a recovery rate of 20,000 gpm (gallons per minute) at 20% solids. As the dredge advances across the pond, the mined area behind the dredge is infilled with mill tailings. This is approximately 90-95% of the original ore. The intake slurry of ore is monitored by a series of continuous measuring devices. The intake flow rate is sensed with a Fisher Porter Model 20 flow meter, while the specific gravity and wt.% solids are measured with an Ohmart nuclear density gauge.

The slurry is pumped to a dewatering barge, screened and dewatered in three 6x14 foot Allis Chalmers double deck vibrating screens. This is done to remove roots, clay balls and other extraneous materials. The +4 mesh material is returned to the pond and the -4 mesh material is further dewatered in a Humphrey plate thickener. The thickened slurry is then pumped to the mill at the rate of 12-13,000 gpm at 40% solids.

THE MILLING OPERATION

The plant consists of two distinct units: the wet and the dry plant. In the wet plant the primary purpose is to eliminate the sand (95%) and generate a heavy mineral concentrate. This consists of 75-85% ilmenite

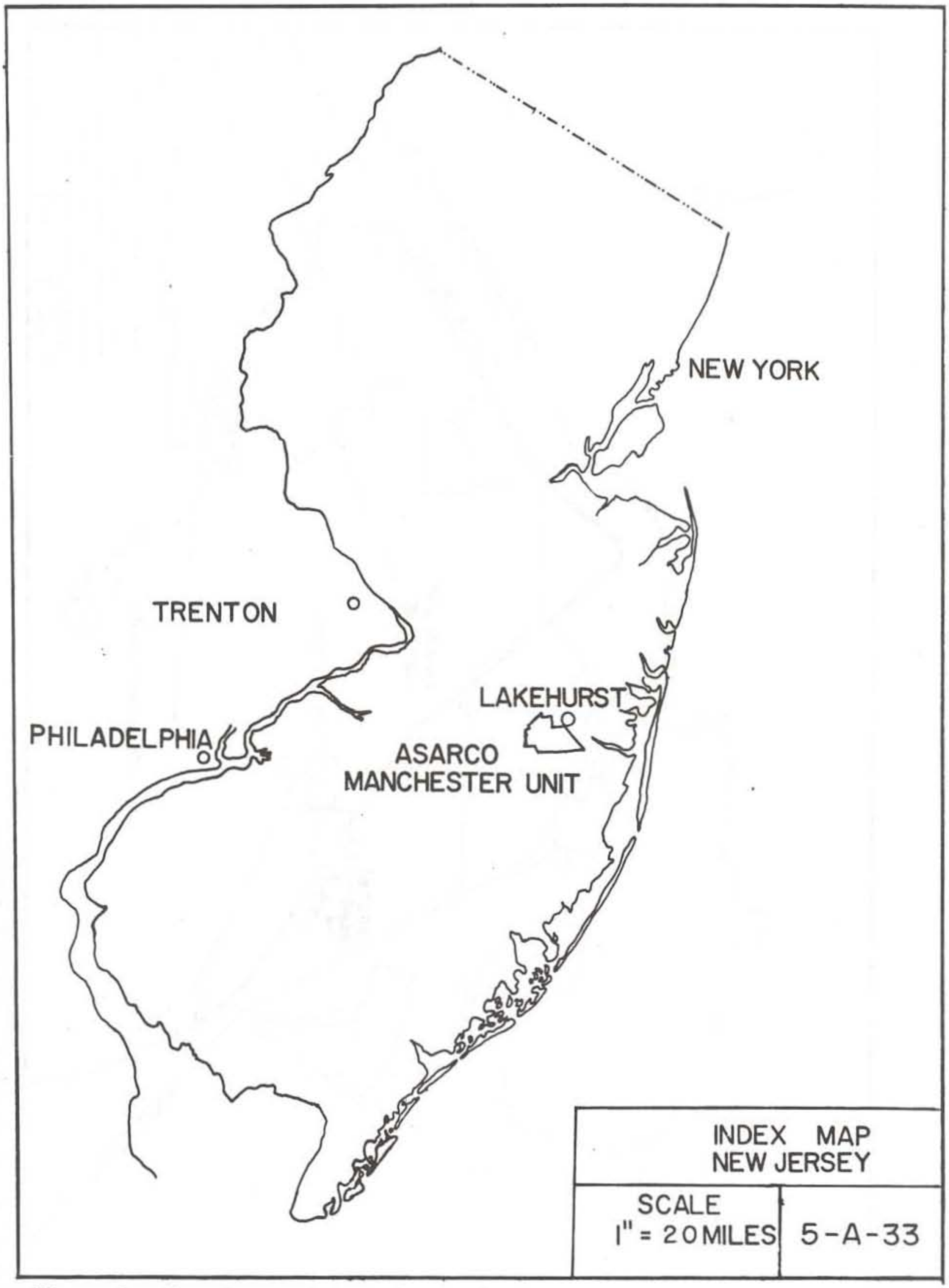


Figure 3. from Asarco internal report.

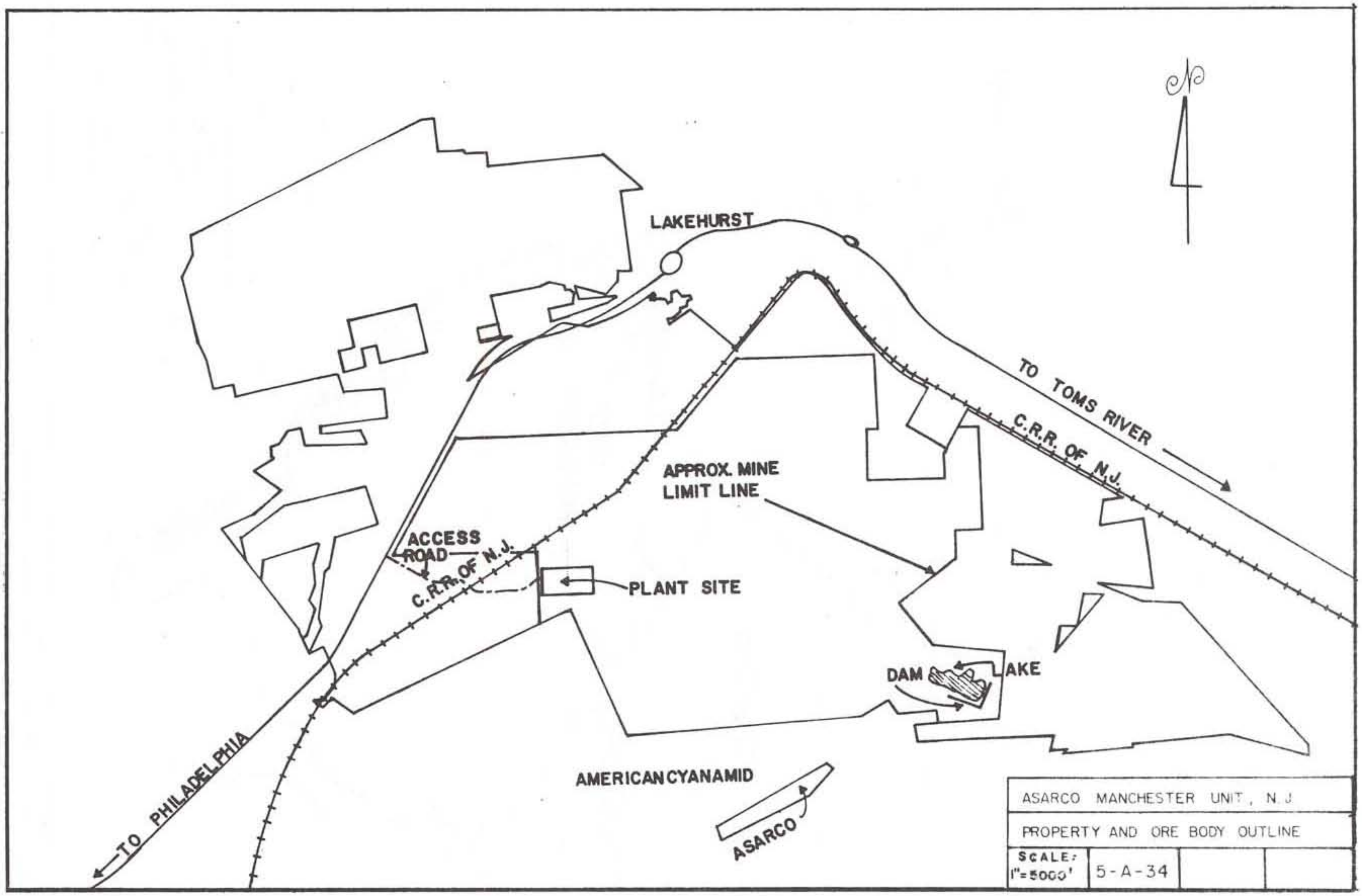


Figure 4. from Asarco internal report.

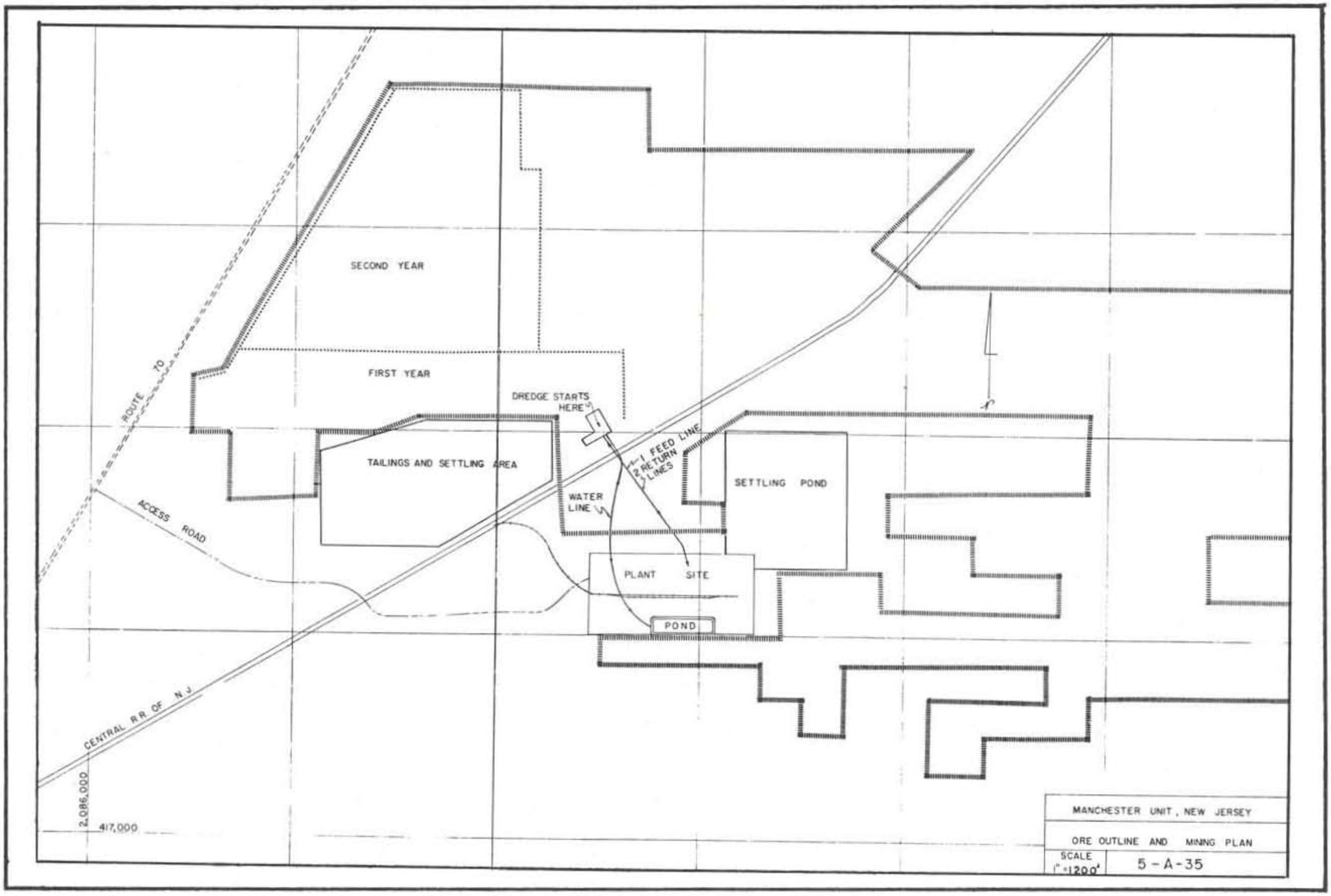
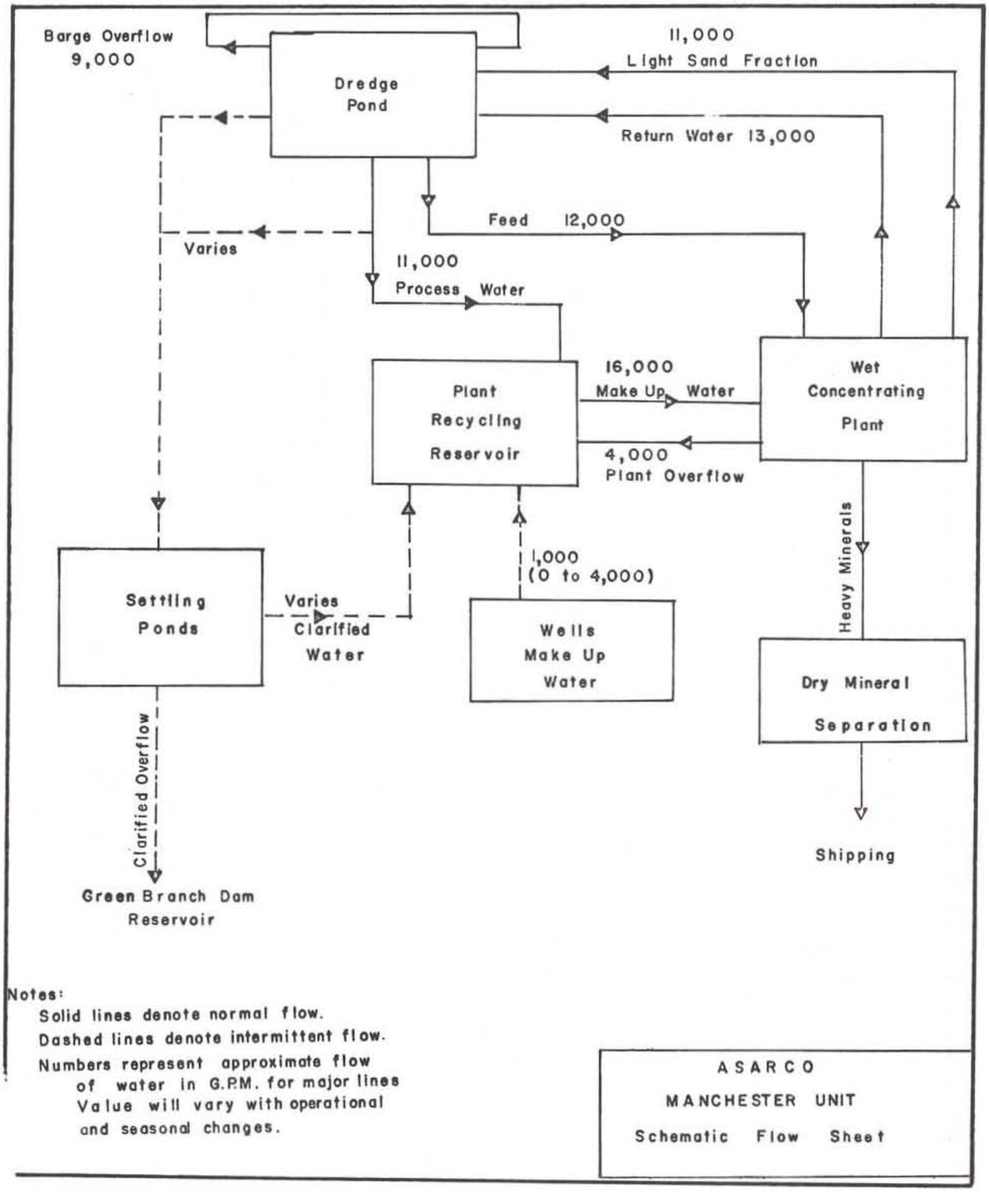


Figure 5. from Asarco internal report.



Notes:
- Solid lines denote normal flow.
- Dashed lines denote intermittent flow.
- Numbers represent approximate flow of water in G.P.M. for major lines Value will vary with operational and seasonal changes.

Figure 6. from Asarco internal report.

and leucoxene, with smaller amounts of rutile, zircon, staurolite, kyanite, sillimanite and some remaining quartz. In the dry plant a titanium-rich concentrate is produced by processing the feed through a series of magnetic and high tension machines.

In the wet plant the solids content of the slurry is upgraded to 43% TiO_2 using 1,024 Humphrey Spirals. The ore is separated from sand by differences in specific gravity. The higher density materials cling to the inside turn of the spirals while the lighter materials are washed to the outer wall by a combined centrifugal and sluicing action. The resulting slurry bands are discharged through a system of vaned ports which splits the pulp into 3 fractions: rougher concentrate, middling and rougher tails. The rougher tails are returned to the dredge pond to be used as backfill. The middlings are returned to incoming feed, and the rougher concentrate is passed to another bank of spirals to further purify the concentrate. The cleaner concentrate is then dewatered in Denver single pitch screws and stockpiled.

The stockpiled wet mill heavy mineral concentrate is then dried at 300°F to 0.5% moisture. This is followed by screening on 20 mesh. The oversize is wasted and the undersize is processed through the dry plant. The critical step in the dry plant is the processing through the Carpco High Tension separators when the difference in conductivity of rutile and ilmenite (high) with zircon and other silicates (low) is utilized.

Since rutile and ilmenite are conductors they proceed through the separator as though there were no static field. On the other hand the low conductive silicates become charged and are pinned to the rotor. In this manner a separation is achieved. Ilmenite is then separated from rutile in standard magnetic separators in which ilmenite passes into the magnetic fraction and rutile into the non-magnetic fraction.

The plant recovery efficiency is reported to be 97% in the dry mill. However this extremely high recovery is considerably offset by poorer recovery in the wet plant.

SOME ENVIRONMENTAL CONSIDERATIONS

The impact of the dredging operation on the landscape environment has been considerably reduced by use of the enclosed lagoon mining method plus the immediate return of mill tailings (sand) to the lagoon behind the advancing dredge. Some 95% of the original material is returned in very short time to the lagoon and the original topsoil which is stored separately, is easily reused during land reclamation. According to Asarco approximately 4,000 gpm of make-up water is added to the lagoon to maintain the lagoon water table which is independent of the general water table.

As a gesture of goodwill Asarco recruited more than 90% of its employees during plant startup from the local township and in addition donated 100 acres of land for the construction of a local high school.

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ROAD LOG

Cumulative Miles	Miles from last point	Description
0.0	0.0	Assembly Point: Hofstra University. Drive west on Hempstead Turnpike to Clinton Street.
1.0	1.0	Turn right onto Clinton Street and proceed North to the Long Island Expressway, Route 495. Clinton Street will change its name to Clinton Road, Glen Cove Road, and Guinea Woods Road as you progress through the various communities on it.
6.8	5.8	Take cloverleaf and travel West on the Long Island Expressway to the Brooklyn Queens Expressway, Route 278.
23.4	16.6	Go South on the Brooklyn Queens Expressway over the Verrazano Bridge to Staten Island, and then over the Goethals Bridge to the entrance to the New Jersey Turnpike (all on Route 278 to the New Jersey Turnpike).
47.8	24.4	Take the New Jersey Turnpike South (Route 95) to Exit 7.
94.5	46.7	Take Route 206 South to its junction with Route 70.
111.5	17.0	Take Route 70 East to the Asarco Manchester Plant.
132.7	21.2	Arrive at Asarco Manchester Plant, turn into Asarco private road and drive South to the parking lot.
		Return to Hofstra University by reversing the above directions. Take Exit 13 off the New Jersey Turnpike for the Verrazano Bridge.

NOTES