Beneficial Uses of Dredge Material from the QPD Intermodal Port Terminal

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16. Abstract

Over the past few years the University of Rhode Island (URI), Marine Geomechanics Laboratory and the Maguire Group Inc., (MGI) have gathered significant data and conducted tests relative to beneficial use of dredge materials from the Quonset Point/Davisville port in Rhode Island. The objective was to determine possible beneficial use options for the various sediment types that will be encountered. The sources of data consist of earlier subsurface investigations, conducted by MGI, and a joint URI/MGI research project sponsored by the URI Transportation Center in 2000 and 2001. In the recent research project, cores were obtained using a Large-diameter Gravity Corer and a vibracorer. Sediments were characterized using a Multi-Sensor Core Logger for bulk density profiles and then classified in a laboratory/testing program that included Atterberg Limits, grain-size analyses, and organic and chemical testing. The sediments consisted of organic and inorganic silts and silty fine to medium sands. Based on the sediment types, bench scale tests were conducted to determine possible beneficial use alternatives. These alternatives included: direct use for landfill and construction applications, brownfield encapsulation with the low permeability sediments, cement enhancement, lime stabilization, and blending with coarser materials such as crushed demolition debris for use as common borrow. Bench-scale testing included compaction tests, strength tests with the additives, permeability experiments and chemical analyses.

The results of unconfined compression strength testing for the cement-enhanced samples achieved strengths commensurate with potential construction materials and flowable fill. Lime stabilization with lime contents ranging from 3% to 7% by weight effectively increased the strength of the inorganic silts. Blending of the fine silty sands with construction debris for use as common borrow fill did not result in practical beneficial use opportunities. Permeability test results indicated that the inorganic silts can be used as a low permeability liner or cover for landfills and for brownsfield remediation. For each of these options, however, more research is needed in terms of their economic viability and the effects of salt and dewatering on the measured properties. The results of this research were oriented toward proposed dredging activities at the Quonset/Davisville Port Facilities, but the methodology is applicable to other similar locations.

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ABSTRACT

Over the past few years the University of Rhode Island (URI), Marine Geomechanics Laboratory and the Maguire Group Inc., (MGI) have gathered significant data and conducted tests relative to beneficial use of dredge materials from the Quonset Point/Davisville port in Rhode Island. The objective was to determine possible beneficial use options for the various sediment types that will be encountered. The sources of data consist of earlier subsurface investigations, conducted by MGI, and a joint URI/MGI research project sponsored by the URI Transportation Center in 2000 and 2001. In the recent research project, cores were obtained using a Large-diameter Gravity Corer and a vibracorer. Sediments were characterized using a Multi-Sensor Core Logger for bulk density profiles and then classified in a laboratory/testing program that included Atterberg Limits, grain-size analyses, and organic and chemical testing. The sediments consisted of organic and inorganic silts and silty fine to medium sands. Based on the sediment types, bench scale tests were conducted to determine possible beneficial use alternatives. These alternatives included: direct use for landfill and construction applications, brownfield encapsulation with the low permeability sediments, cement enhancement, lime stabilization, and blending with coarser materials such as crushed demolition debris for use as common borrow. Bench-scale testing included compaction tests, strength tests with the additives, permeability experiments and chemical analyses.
The results of unconfined compression strength testing for the cement-enhanced samples achieved strengths commensurate with potential construction materials and flowable fill. Lime stabilization with lime contents ranging from 3% to 7% by weight effectively increased the strength of the inorganic silts. Blending of the fine silty sands with construction debris for use as common borrow fill did not result in practical beneficial use opportunities. Permeability test results indicate that the inorganic silts can be used as a low permeability liner or cover for landfills and for brownsfield remediation. For each of these options, however, more research is needed in terms of their economic viability and the effects of salt and dewatering on the measured properties. The results of this research were oriented toward proposed dredging activities at the Quonset/Davisville Port Facilities, but the methodology is applicable to other similar locations.

INTRODUCTION

Over the past few years the University of Rhode Island, Marine Geomechanics Laboratory (MGL) and the Maguire Group Inc., (MGI) have gathered significant data and conducted various tests relative to potential reuse of dredge materials from the Quonset/Davisville channels. The purpose of this report is to synthesize the data and test results and present suggestions for beneficial use options for sediment materials that will be encountered if the channels and turning basins are deepened.

The sources of data consist of studies and borings conducted by Maguire Group Inc. in 1981, and recent URI/MGI research projects conducted in 2000 and 2001. Cores were obtained using the URI Geomechanics Laboratory, Large-diameter Gravity Corer (LGC) on four field studies using the University of Rhode Island/Ocean Engineering Department coastal research vessel, CT-1. On another research cruise, a vibracorer was used to obtain samples to greater depths than could be accomplished with the LGC. Sediments were characterized using a Multi-Sensor Core Logger (MSCL) for bulk density profiles and then subjected to a laboratory testing program that included

Atterberg Limits, grain size analyses, compaction, permeability, unconfined compression, and organic and chemical testing. Based on sediment types and classifications, recommendations for possible uses for the dredge material were made. This study integrated both field work (coring cruises and previous borings) and a laboratory testing program. Funding for this project was from the University of Rhode Island Transportation Center (URITC), and MGI. Publications from this study included two reports titled "Beneficial Uses for Dredge Material from Quonset/Davisville Channel" and "Beneficial Uses of Dredge Material from Quonset/Davisville Port: Phase 2" that were published in May 2000 and June 2001 and two papers (Silva et al. 2000; Silva et al. 2001, and Silva et al. 2002).Sediment samples were analyzed at the URI Geomechanics Laboratory through bench scale testing of possible beneficial use alternatives. Reuse alternatives included: use of the organic silts as a low permeability liner for brownfield encapsulation and landfill applications, cement enhancement, lime stabilization, and blending of sands with other coarser materials such as crushed demolition debris for use as common borrow.

BACKGROUND

The Quonset/Davisville channel was dredged in the 1940's in conjunction with the development of the Quonset Navy base. Because of its location away from the major rivers and streams flowing into Narragansett Bay and natural currents in the area, there has been very little silting of the channel such that maintenance dredging has not been required. A plan view of the study area with the coring locations is shown in Figure 1. The northern Davisville Basin is connected to the southern Quonset Basin by the Davisville Channel. The channel connecting the east passage of the bay to the Quonset turning basin is referred to as the Quonset channel. The original dredge depth for the Quonset channel and turning basin was to an elevation of –35 ft Mean Low Water (MLW) and a width of 1000 ft. The depth for the Davisville channel and basin was to an elevation of –30 ft MLW and a width of 500 ft. These depths are approximate because, at the time, dredging companies were paid for an allowable over-dredge of up to 2 feet below the intended dredge depth.

The withdrawal of the Navy from Quonset has left a large area of land and waterfront property that could potentially be further developed as a port facility. This study assumes that a design channel width of 600 feet and a dredge depth of –40 ft MLW would be sufficient to allow for development of a modest port that would significantly increase and expand the use of this strategic site for a variety of purposes. The analyses in this report of dredge and material volumes are based on a channel of these dimensions.

In 1981, the Maguire Group prepared a report for the possible expansion of the Davisville port (CE Maguire, Inc., 1981). During the site investigation, eighteen soil borings in the Davisville basin and near the existing pier were obtained. The locations of three of these borings, BH-1, 17 and 18 are shown in Figure 2. The logs for these three borings, which are representative of the areas around the existing Davisville pier, are shown in Figures 3-5. The sediment from BH-18 consists of marine silt with overlying layers of sand silt and gravel. The strata change is also evident by a change in casing blow counts from 3 to 10 blows per foot at an elevation –26.5 MLW and a corresponding large change in Standard Penetration Test (SPT) blow counts a few feet deeper. Based on the boring results it was hypothesized that the sediments below the existing channels and turning basins would be similar and that significant quantities of sandy materials would be encountered when these areas are dredged to the proposed depths. However, as will be discussed subsequently, the sediments further from the pier are not predominantly sands and gravel, but the dominant sediments are finer grained silts and fine sands.

OBJECTIVES AND METHODOLOGY

The main objective of this study was to investigate the feasibility of using a significant portion of the dredged sediments for beneficial purposes. Initially the hypothesis that the sediments would be predominantly coarse grained and could be used directly for a variety of construction purposes, later deemed incorrect. The field results showed that the sediments are predominantly silts with lesser amounts of sandy materials; therefore in order to utilize the finer-grained materials they would need to be modified.

The methodology involved a review of all available data, a series of field investigations to obtain representative samples of the sediments that could be used to characterize and quantify (volumes) the materials, a laboratory testing program to classify and characterize the sediments, bench-scale laboratory experiments that included processing, blending, and enhancement with admixtures, and analysis and integration of all the results. In the following sections the various components of the program are discussed in some detail. Additional information is included in the referenced reports.

FIELD PROGRAM

A total of five coring cruises were completed for this study in order to obtain sediment for the laboratory testing program. For the first four cruises, the cores were taken with the URI/MGL Large-diameter Gravity Corer (LGC), which recovers a 10.2 cm (4 in.) diameter sample with a PVC core barrel up to 3m (10ft) long. All of the coring with the LGC was performed on the URI research vessel CT-1. The LGC was dropped from a predetermined free-fall height above the seafloor, which is in this case was controlled by securing the corer at a predetermined distance above the seafloor with a separate nylon line and then “laying out” the required slack in the steel winch cable. The nylon line is then released to allow the corer to free-fall. A core catcher in the nose cone and a ball valve at the top retain the sediment in the core tube during pull-out and recovery. The locations of the twenty-three (23) LGC cores that were successfully recovered are shown in Figure 1 and listed in Table 1.

The fifth coring cruise was accomplished with a vibracorer instead of the LGC. The objective of this coring cruise was to acquire deeper samples of sediment from the entire study area than could be obtained with the LGC. For the vibracoring cruise, a pneumatic vibracore was supplied and operated by CR Environmental. Prior to deploying the vibracore, the boat was anchored over the sampling area using two anchors off the bow and one anchor off the stern. The vibracore was then positioned just above the seafloor, and supplied with compressed air to power the vibrator unit. The vibracore was lowered and vibrated until penetration ceased, between 30 seconds and 3 minutes, and then retrieved with the winch. Twelve (12) vibracores were obtained (Table 1). Locations of all the cores recovered for this project including the vibracores (VC) are shown in Figure 1.

During the first two coring cruises, a total of 15 cores were taken (denoted LGC 1 – LGC 15) using the Large-Diameter Gravity corer. The location of the cores, type of core barrel used, and length of sediment recovered is shown in Table 1. A total length of 15.35 meters (50.4 feet) of sediment was recovered but only three of these cores (LGC 10, 12, and 13) penetrated below the proposed dredging depth of 12.2 meters (40 ft.) MLW. The locations of these cores are shown in Figure 1.

Seven cores were taken during the third cruise (LGC- 16 through 22) with a total recovery length of 9 meters (29.5 feet). None of these cores reached the proposed dredging depth of 12.2 meters MLW (40 feet).

Two cores were obtained on the last coring cruise using the LGC. The first core, LGC-23, was taken from the Quonset Channel, and LGC-24 was taken in the northern part of the study area near Pier No. 1. The results are shown in Table 1.

The vibracoring cruise was successful in obtaining samples to the proposed dredge elevation of -40 ft MLW. On this cruise, 12 cores (Table 1 and Figure 1) were deployed and recovered for a total length of 30.6 meters (100 ft.). Four of the vibracores, VC-3, 8, 9, and 10, reached the proposed dredging depth of 12.2 meters (40 feet).

After coring, all of the cores were stored in a refrigerator at 4°C and transported for further analysis. A detailed description of the handling, storage, and processing techniques can be found in Bradshaw (1999).

SEDIMENT CHARACTERZATION

The Multi-Sensor Core Logger was used with selected LGC core samples to obtain profiles of the bulk density with depth. The MSCL is a computer controlled, automated data acquisition system that measures and records sediment properties at two-centimeter intervals along the length of the entire core while still in the core tube. After logging (some cores not logged with the MSCL), the cores were split lengthwise for further analyses. First, a lithological description of the cores was completed. This analysis included the documentation of the sediment color according to the Munsell Soil Color Charts, and descriptions of odor, strata changes, and sediment type (i.e. silt, clay, sand, etc.).

Other tests included grain size analyses, Atterberg Limits, and shear strength. Grain size analyses were performed according to the ASTM standard D 421 and D 422 for mechanical grain size analysis. This test was completed on several samples from cores throughout the study area. Grain size distributions are presented in Figures 6-15. The liquid limit, plastic limit, and plasticity index, of the sediment was determined according to ASTM D 4318. Results of Atterberg Limit tests are listed in Table 2.

Upon reviewing the results from the various tests the characterization of sediments can be determined. Generally, the top layer of each core consisted of black organic silt. The middle layer consisted of gray clayey silt or inorganic silt or both. In cores where sand was present, the sand was found in the bottom of the cores and consisted of either gray silty sand or brown-coarse sand. Using the Unified Soil Classification System, the gray clayey silt was classified as MH/OH, while the non-plastic silt was classified as ML. Other sediment types that were found in lesser amounts included sands, clays, and mixtures that were classified as SM, CH, CL, and ML/OL. The MH/OH, gray clayey silt, was the predominant sediment that was found within the study corridor.

Another parameter used in the determination of sediment types was shear strength. In most cases the shear strength of the finer grained materials was measured with a special miniature vane apparatus. There is excellent agreement between the MSCL, vane shear and water content results. Generally the sandy materials have densities greater than 1.8 gm/cc and water contents less than about 50%. In five of the bulk density profiles, LGC-02 (Figure 18), LGC-03 (Figure 19), LGC-07 (Figure 22), and LGC-08 (Figure 23) and LGC-09 (Figure 24), there was a sharp increase in the bulk density, and a corresponding decrease in water content. These changes agreed with the visual inspection of the split cores that showed a change in strata from a clayey-silt material to a silty-sand. This abrupt change in density was sometimes an indicator of sand in the cores. Lithology, bulk density and water content for the majority of the cores are shown in Figures 18-33.

DATA INTEGRATION

Based on the coring results and data, four cross-sections (or profiles) were generated to show the subbottom profiles and strata changes between the silt and the sand sediments. The locations of the cross-sections are shown in Figure 34. The core locations were not exactly along the cross-sections, but they are in reasonable proximity to each side and were used in these analyses. A dredge depth of elevation –40 ft (MLW) with an additional 2 ft overdredge allowance is shown in all the profiles.

Davisville Channel

Ten cores were taken in the vicinity of the section line A-A. The cross section developed from these cores is shown in Figure 35. All cores penetrated to the current design elevation of –35 ft., only two cores penetrated to the proposed dredge of elevation –40 ft., but three others were within about one foot of that elevation. There is an evident silt-sand strata change, but it is somewhat erratic. From this cross-section of the Davisville Channel, it is estimated, that about 0.26 million cubic yards (mcy) of sand, and about 0.95 mcy of silt would be removed if the channel were dredged to a depth of –40 MLW, as shown in Figure 36. These volume estimates assume that the channel wall is at a slope of 3:1 (about 18°).

Davisville Turning Basin

Six cores were taken in the vicinity of the section line B-B, as shown in Figure 37. Along the cross-section, an almost complete picture of the silt-sand interface is defined. Because the sand layer lies at such a shallow depth (~32 feet MLW), none of these cores reached the proposed dredging depth of -40 feet MLW. From the cross-section of Davisville Basin, it is estimated that approximately 1.7 mcy of sand and about 0.5 mcy of silt would have to be removed from the basin.

Quonset Turning Basin:

Eight cores were taken in the vicinity of section C-C, as shown in Figure 38. Only two reached the proposed dredging depth and one other was within 2 ft. of the depth. There is no clear evidence of a strata change in this area although one core contained sand (VC-09). However, as indicated in cross-section A-A (Figure 35) there is a considerable amount of sand at the eastern side of this turning basin. From the cross-section of Quonset Turning Basin, it is estimated that about 3.0 mcy of silt and little, if any, of sand would be dredged from the basin.

Quonset Channel:

Five cores were taken in the vicinity of the section line D-D, as shown in Figure 39. Three of the five cores reached the proposed dredging depth and one other was within about one foot of this depth. There is no evidence of sand in the easternmost part of the channel, but there is sand in the western part of the channel near the Quonset Turning Basin. Only one core (LGC-08) showed evidence of sand. There is no clear strata change along this line. From the cross-section of Quonset Channel, it was estimated that about 1.7 mcy of silt and about 0.04 mcy of sand would be removed from this channel.

In summary, approximately 8.44 mcy of sediment, (with a 10% overdredge), would be dredged from the entire study area, with; about 25 percent of which is sand. The volumes of sand and silt that would be dredged are summarized in Table 3. In addition, various laboratory tests were conducted to better characterize the sediments.

LABORATORY TESTING

In order to assess the suitability of the sediments for various prospective beneficial uses, laboratory experiments were conducted to determine key physical properties and behavior. These experiments included organic and bulk chemical testing, compaction and rigid wall permeability tests, unconfined compression tests on samples mixed with Portland cement and lime, and analyses of blending silty fine sands with coarser materials such as demolition debris. The results of these tests are discussed in the following sections.

Organic Testing

Samples of the fine-grained materials were taken from selected vibracores for determination of organic content. Organic content testing was performed using the URI/GSO Standard Operating Procedure 1.05, which determines organic carbon content by loss-on-ignition. The procedure uses 1cm^3 sediment plug sampler to obtain a sample from the core. The wet weight of the sample was then recorded. The sample was then placed in a 110°C furnace for 24 hours to dry the sample. After twenty-four hours, the samples were reweighed and placed back into the furnace for one hour at 550°C. The samples were then reweighed and recorded. The loss-on-ignition (organic carbon) contents were calculated from the difference between the dry weight at 110°C and at 550°C, reported as the percentage based on dry weight. The results are shown in Table 4.

The average organic carbon percentages for the surficial black organic silt, gray clayey silt, and non-plastic silt were calculated to be 1.83% (5 samples), 0.69% (4 samples), and 0.56% (1 sample). The average total organics for black organic silt, gray clayey silt, and non-plastic silt were 4.17%, 1.58%, and 1.28%. This material passes the Rhode Island Resource Recovery Corporation's (RIRRC) most recent Final Interim Alternate Cover Material Policy regarding the use of dredge material as landfill covers material. The RIDEM specification for total organics in dredged material used in alternate cover material is 35%, and all the sediments tested did not exceed a total organic content of 5%.

Bulk Chemical Analysis

During the vibracoring cruise, jar samples were collected at selected depths for bulk chemical analyses. These tests were performed byCEIMIC Corporation, Narragansett, RI. Contaminant testing included Poly Chlorinated Biphenyls (PCBs), hydrocarbons, and heavy metals.

The Rhode Island Department of Environmental management (RIDEM) specifies maximum acceptable levels for total petroleum hydrocarbons (TPHs) and heavy metal contents in materials to be used for alternate daily cover for Central Landfill. Table 5 shows a comparison of the results of chemical analyses on the sediment and the RIDEM's specifications. Most of the specifications are met, but three samples exceeded the commercial specification for concentrations of arsenic and the residential specifications for beryllium (Table 5). Two of the samples were from VC-02 (at depths of ~35 inches and ~28 inches) located at the southern end of Davisville Channel and one sample was from VC-03 (at a depth of ~68 inches) located in the middle of Davisville Channel. In addition, a sample from VC-09 (at a depth of ~164 inches) located in the Quonset Turning Basin exceeded the residential specification for arsenic.

Compaction Tests

Standard and modified compaction tests were performed on the gray clayey silt (Figure 40), which represented the majority of the material in the study area. A 19.8 % optimum water content and 15.5 kN/m^3 maximum dry unit weight were determined for the standard compaction tests. A 15.8 % optimum water content and 16.9 kN/m^3 maximum dry unit weight were determined for the modified compaction tests.

Permeability

The permeability of compacted specimens of the gray clayey silt was measured using the falling head test in a compaction mold permeameter. Seven tests were performed along the standard compaction curve and four tests were performed on the modified compaction specimen. These values are superimposed in Figure 40. As a general specification for capping material used for brownfields remediation, a minimum permeability of $1x10^{-7}$ cm/s is recommended. Using standard compactive effort, the gray clayey silt met this permeability requirement for brownfields remediation near the optimum water content (19.8%) and on the wet side of optimum on the curve. Using modified compactive effort, the gray clayey silt passed the permeability requirement of $1x10^{-7}$ cm/s over the entire modified compaction curve. Therefore it is clear that the permeability requirements for encapsulation could be met with the gray clayey silt.

Blending with Construction Debris

A sieve analysis was performed on a representative sample of construction debris taken from the Quonset Point (Figure 41). The Rhode Island Department of Transportation specification states that common borrow must be gravelly in nature, and contain no more than 17% passing the no. 200 sieve. A sieve analysis of the silty-sand material (Figure 41) showed that it had about 60% passing the number 200 sieve. In order to meet the RIDOT specifications for common borrow, the silty-sand must be blended with a coarser material. The construction debris from Quonset Point contains about 48% gravel and has about 3% passing the number 200 sieve. Prior to actually blending the materials, preliminary calculations were performed to find an approximate mixing ratio of silty-sand to construction debris. The calculations are summarized below for both dry soil conditions and typical water contents of construction debris and silty-sand.

From the calculations, it is estimated that a mixing ratio of construction debris to silty sand of about 2:1-3:1 is required to meet the RIDOT specification for common borrow. This would require upward of 10 mcy of construction debris, which appears to be unrealistic. However, it might be feasible to use natural bank-run gravel as alternative blending material in some cases.

Lime Stabilization

The use of lime stabilization was evaluated to increase the strength of the gray clayey silt. Lime stabilization may be useful for decreasing the natural water content of the dredged material and increasing the strength for use as structural fill.

In order to determine the initial mixing ratio of lime to sediment, a pH test was performed (Table 6). Sediment was mixed with hydrated lime at weight percentages of 0%, 2%, 3%, 4%, 5%, 6%, and 8%. The highest lime content that yielded a pH of 12.4 (pH of free lime) was to be used as the initial lime content for stabilization. (U.S. Army 1994) Sample number 3 (highlighted), which consisted of 3% lime and yielded a pH of 12.4, was used as the initial lime content for strength tests.

Using the Harvard Miniature compaction device, a compaction curve was created by compacting the sample in 3 lifts with 25 tamps per lift. This compactive effort yielded results shown in Figure 42 compared to the results of a Modified Proctor test. The optimum moisture content of the sediment with 3% lime was found to be about 19.5 percent (Figure 42). Unconfined compressions tests were performed on samples mixed with 3%, 5%, and 7% lime at the optimum water content of 19.5% (Figures 43-45). The average compressive strength was much lower for the 1-hour cure than for the other curing times, which yielded very similar strengths. The shear strength of the sample mixed with 3% lime after 1 hour curve was approximately 35 kPa, compared to 109 kP for the 28 day curing time. However there was little or no increase in shear strength after 7 days of curing. Similar results were obtained for samples mixed with 5% and 7% lime (Table 7).

In general, the majority increase in compressive strength occurred within 7 days of curing, after which the compressive strength did not increase significantly. Increasing the lime concentration resulted in a modest increase in compressive strength (Table 7).

Cement Additives

A possible way to increase the usefulness of the gray clayey silt and silty sand is to mix it with Portland cement. This process of soil mixing has been successfully used in the Central Artery project in Boston, MANOT IN REFERENCES. Test mixes of the Quonset/Davisville gray clayey silt and the silty sand with Portland cement were prepared (approximately one part cement to three parts sediment). The gray clayey silt/cement mixes had compressive strengths of 340 to 360 psi (Table 8 and Figure 46). The silty/sand cement mixes had compressive strengths of 1060 to 1170 psi. It is important to note that the sediments were used “as-is”, i.e., the salts were not washing out before doing the experiments. As a benchmark, typical foundation bearing capacities for spread footings are generally in the 10 to 30 psi range and typical concrete strengths are in the 2700 to 4000 psi range. Therefore, it is possible that cement enhanced sediments would be useful as low grade construction concrete depending on the cost of the improvement.

SUMMARY AND CONCLUSIONS

With proposals that are being considered to redevelop the Quonset/Davisville area, dredging to deepen the channels and turning basins will be necessary. Based on an assumed dredge depth to –40 ft (12.2 m) MLW, approximately 8.4 million cubic yards (6.3 million cubic centimeters) of dredged material is located in the existing channels and turning basins, 25% of which is fine to medium silty sand and 75% of which is silt. This finding is significant because preliminary information from borings near Davisville suggested that significant amounts of clean sand were present. The presence of significant amounts of silts and silty fine sands limits the beneficial use options and requires a detailed technical and economic feasibility analysis. The main reuse options considered in this study included brownfields remediation, landfill cover, and converting it to a construction material through cement or lime enhancement. Findings in this study and beneficial uses options of the various sediment types are as follows:

- Black organic silt, gray clayey silt, and non-plastic silt material passed the appropriate RIDEM criteria for total organics, to be used as landfill and alternate cover material.
- Black organic silts, located within the upper one-meter, are out of compliance with the appropriate chemical regulations for residential or commercial applications. Therefore, this material would need to be disposed of in confined containment. Ideally, a bulkhead could be constructed to span the space between the Davisville piers and used as a confined containment disposal area for the contaminated material.
- The gray clayey silt materials met specified criteria for low permeability, and would be viable for brownfield remediation and landfill capping material.
- The fine-grained silty-sand could be blended with a coarser material in order to meet the RIDOT requirements for common borrow, but it does not seem feasible to used only crushed demolition debris that is being generated at this site. Other coarse material such as gravel could also be used to bring this material into compliance for common borrow. However, it is noted that the fine grained sediments can be used successfully for highway embankments if they are properly compacted and/or surcharged.
- The gray clayey silt mixed with 3%, 5%, and 7% lime by weight resulted in compressive strengths of 16 to 18 psi, which is in the range of typical soil bearing capacities (10 to 30 psi).
- The gray clayey silt and silty sand mixed (without washing to remove salts) with Portland cement resulted in compressive strengths of 340 to 360 psi and 1060 to 1170 psi, respectively. These enhanced strength materials would be suitable for construction applications where low strength concrete or high strength soil is adequate, such as flowable fill in caissons or behind retaining structures

This preliminary study established the technical feasibility of potential beneficial use opportunities for dredged materials expected if the Quonset/Davisville Port is developed.

More work needs to be done to verify the results of this preliminary research to further refine the cement and lime enhancement methodology and toe to explore other possible methods to modify the materials. An important next step is to determine the economic feasibility of the beneficial use options. This can be accomplished by establishing efficient processes for dewatering and enhancement, first with large laboratory scale experiments, then procedurally at the prototype/commercial scale levels. The results of this research and future prototype studies will be applicable to other similar sites.

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REFERENCES

ASTM, (1995) "1995 Annual Book of ASTM Standards." American Society for Testing and Materials. Philadelphia.

Bowles, Joseph E., (1992) "Engineering Properties of Soils and Their Measurements" Fourth Edition. McGraw-Hill, Inc. New York.

Bodnaruk, Ryan and Sharpnack, Robert, (2000), "Beneficial Uses for Dredge Material from Quonset/Davisville Port." Marine Geomechanics Laboratory, University of Rhode Island.

Bradshaw,A.B. (1999). "Geotechnical Properties and Stratigraphy of the Northwest Continental Slope, Gulf of Mexico." Masters of Science Thesis, University of Rhode Island.

Burt, T. N. and Dearnaley, M. P. (1994). "Beneficial Uses of Dredged Material Principles and Practice", Dredging '94, American Society of Civil Engineers, New York, NY.

CE Maguire, Inc. (1981), "Preliminary Engineering Davisville Port Expansion," Rhode Island Port Authority and Economic Development Corporation.

Das, Braja M., (1994), "Principles of Geotechnical Engineering," Third Edition, PWS Publishing, Boston.

Holtz, Robert D. and Kovacs, William D. "An Introduction to Geotechnical Engineering." Prentice Hall, Inc. Englewood Cliffs, New Jersey. 1981.

Joint Departments of the Army and Airforce, USA (1994), TM 5-822-14/AFMAN 32-8010, "Soil Stabilization for Pavements."

Louis Berger Group, Inc., Maguire Group, Inc., and URI Marine Geomechanics and Paleomagnetics Laboratories, (2001) "Quonset/Davisville Channel Study: Final Report," Prepared for State of Rhode Island and Providence Plantations, Office of the Governor.

Maguire Group Inc., (1996), " Feasibility Study Dredge Sediment Recycling and Container Port Development at Quonset/Davisville Port and Commercial Park," December

Murray, L. A., (1994), "Progress in England and Wales on the Development of Beneficial Uses Dredged Material", Dredging '94, American Society of Civil Engineers, New York, NY.

Page, M., S. Palys, A.J. Silva, (2001), "Beneficial Uses of Dredge Material from Quonset/Davisville Port: Phase 2," OCE495, URITC Progress Report.

Rhode Island Department of Environmental Management (1999), "Solid Waste Regulations, Rule 1, Appendix B." File No. 31030 pp. 1-3.

Rhode Island Department of Transportation (1997), "Standard Specifications for Road and Bridge Construction," Providence, RI.

Silva, A.J., C.D.P. Baxter, and V.V. Calabretta (2000), "Beneficial Uses of Dredged Sediment from Narragansett Bay," Maritimes Magazine, University of Rhode Island/Graduate School of Engineering, pp. 13-16.

Silva, A. J., Calabretta, V., and Martin, M., "Beneficial Uses of Dredged Material from the Quonset Point/Davisville Intermodal Port", Proceedings of Dredging '02 Conference, May, 2002, American Society of Civil Engineers.

U.S. Army Corps of Engineers (1996), "Dredging: Building and Maintaining our Underwater Highways," Washington, D.C., pages 12-17.

Table 1: Results of coring program

Sample Type	Site Number	Core Type	Latitude	Longitude	Water Depth (m)	Length of Recovery (m)
LGC	1	Steel	41° 36.655N	71° 24.070W	9.80	1.15
LGC	2	PVC	41° 36.633N	71° 24.135W	9.17	1.17
LGC	4	Steel	41° 36.319N	71° 23.745W	8.97	0.65
LGC	5	PVC	41° 35.902N	71° 23.755W	9.39	1.33
LGC	6	Steel	41° 35.419N	71° 23.808W	9.19	1.42
LGC	7	Steel	41° 35.208N	71° 23.796W	9.33	2.51
LGC	8	PVC	41° 34.976N	71° 23.672W	9.19	0.75
LGC	9	Steel	41° 34.842N	71° 23.160W	10.15	1.66
LGC	10	Steel	41° 34.802N	71° 22.665W	10.52	1.83
LGC	11	Steel	41° 35.905N	71° 23.735W	10.36	1.67
LGC	12	PVC	41° 35.511N	71° 23.764W	10.73	1.92
LGC	13	PVC	41° 34.849N	71° 23.445W	10.90	2.83
LGC	14	PVC	41° 35.036N	71° 23.653W	11.13	0.85
LGC	15	PVC	41° 36.077N	71° 23.792W	10.15	0.61
LGC	16	Steel	41°35.333'N	71°23.996'W	9.80	1.15
LGC	17	PVC	41°35.188'N	71°24.296'W	9.17	1.15
LGC	18b	PVC	41°35.078'N	71°24.195'W	8.97	0.65
LGC	19	PVC	41°34.882'N	71°24.207'W	9.39	1.33
LGC	20	PVC	41°35.000'N	71°23.867'W	9.20	1.42
LGC	21	PVC	41°35.713'N	71°23.762'W	9.33	2.51
LGC	22	PVC	41°36.479'N	71°23.835'W	9.19	0.75
LGC	23	PVC	41°35.934	71°23.761'W	10.67	1.00
LGC	24	PVC	41°36.661'N	71°24.299'W	8.53	1.95

Sample Type	Site Number	Core Type	Latitude	Longitude	Water Depth (m)	Length of Recovery (m)
VC	01	VC	41° 35.064'N	71° 24.270'W	9.96	1.60
VC	02	VC	41° 35.290'N	71° 23.753'W	9.60	2.30
VC	03	VC	41° 35.791'N	71° 23.723'W	10.14	3.43
VC	04A	VC	41° 36.445'N	71° 23.700'W	9.43	0.61
VC	04B	VC	41° 36.445'N	71° 23.700'W	9.39	1.46
VC	05	VC	41° 36.648'N	71° 23.920'W	8.93	2.07
VC	06A	VC	41° 36.763'N	71° 24.238'W	9.11	1.38
VC	06B	VC	41° 36.758'N	71° 24.229'W	9.05	1.75
VC	07	VC	41° 36.037'N	71° 23.661'W	7.75	3.64
VC	08	VC	41° 35.161'N	71° 24.059'W	10.24	4.32
VC	09	VC	41° 35.023'N	71° 24.257'W	9.77	4.18
VC	10	VC	41° 34.615'N	71° 22.226'W	10.01	3.81

Table 2: Atterberg Limit results

Core No.	Depth (cm)	Liquid Limit	Plastic Limit	Plasticity Index	USCS Classification
LGC 2	(84-86)	NA	NA	NA	SM
LGC 5	(45-55)	51	28	23	CH
LGC 5	(105-125)	46	25	21	CL
LGC 6	(215-232)	40	24	16	CL
LGC 7	(66-69)	NA	NA	NA	SM
LGC 8	(35-52)	33	24	9	ML/OL
LGC 9	(15-25)	74	34	40	MH/OH
LGC 9	(164-184)	56	30	26	MH/OH
LGC 10	(38-52)	69	36	33	MH/OH
LGC 10	(182-199)	56	31	25	MH/OH
LGC 11	(23-29)	63	33	30	MH/OH
VC 01	(76.2-114.3)	NA	NA	NA	ML
VC 01	(114.3-116)	NA	NA	NA	ML
VC 03	(119-144)	64	35	29	MH/OH
VC 03	(279-305)	68	52	16	MH/OH

Table 3: Volumes of sand and silt that would be dredged (million cy), for 40ft dredge depth with 2ft overdredge allowance.

Location	*Silt**	*Sand*	*Total*
Quonset Basin	3.0	0	3.0
Davisville Basin	0.5	1.7	2.2
Davisville Channel	1.1	0.4	1.5
Quonset Channel	1.7	0.04	1.74
Totals	**6.30**	**2.14**	**8.44**

* Includes surficial organic silts

Table 4: Organic testing results

Sample	Depth (in)	Description	% WATER	Total% Organic	% Organic Carbon
VC-03	0-16"	Black Organic Silt	75.70	3.78	1.66
VC-04A	0-12"	Black Organic Silt	76.27	3.62	1.59
VC-04B	0-12"	Black Organic Silt	86.16	4.15	1.83
VC-08	35-42"	Black Organic Silt	117.33	4.56	2.01
VC-05	20-30"	Black Organic Silt	123.62	4.72	2.08
VC-05	55-65"	Gray Clayey Silt	21.43	1.13	0.50
VC-03	110-120"	Gray Clayey Silt	68.14	3.34	1.47
VC-03	47-57"	Gray Clayey Silt	37.61	2.74	1.20
VC-10	100-110"	Gray Clayey Silt	47.61	2.84	1.25
VC-08	138-148"	Nonplastic Silt	22.38	1.28	0.56

Table 5: Chemical analyses on the sediment and RIDEM's specifications

	Concentrations Measured (mg/kg)						RIDEM Spec. (mg/kg)	
Sample #	445371	445365	445366	445374	445368	445370	Residential	Commercial
Core	VC-05	VC-02	VC-02	VC-09	VC-03	VC-05		
Depth	34.5-36.5"	90.5"	27-29"	164.5"	67-69"	81.5"		
Antimony	1.1	0.31	0.42	0.15	0.48	0.18	10	820
Arsenic	6.6**	1.6	4**	2.3*	8.5**	0.89	1.7	3.8
Barium	22.5	32.2	15.4	15	18.8	3.4	5500	10000
Beryllium	1*	0.26	0.68*	0.32	0.88*	0.27	0.4	1.3
Cadmium	0.04	0.12	0.15	0.14	0.19	0.02	39	1000
Copper	101	11.9	4.9	13.4	6	5.6	3100	10000
Lead	49.1	7.9	5.7	5.7	7.2	2.7	150	500
Manganese	186	107	161	234	200	46.9	390	10000
Mercury	0.26	0.02	0.03	0.02	0.06	0.03	23	610
Nickle	20.1	8.9	12.4	11.6	14.3	4.5	1000	10000
Selenium	0.85	1.3	1.6	1.5	2	0.48	390	10000
Silver	0.7	0.43	0.53	0.5	0.65	0.39	200	10000
Thallium	0.27	1.4	1	0.2	1.3	0.16	5.5	140
Vanadium	31.8	10	23.5	12.5	28.4	4.9	550	10000
Zinc	162	22.2	41.7	39.5	50.2	17.4	6000	10000

* Fails Residential Specification
** Fails Residential and Commercial Specifications
All Others Pass Residential and Commercial Specification

Table 6: Initial lime content for stabilization

Sample #	1	2	3	4	5	6	7
Sediment weight (g)	20.48	20.48	20.48	20.48	20.48	20.48	20.48
Lime weight (g)	0	0.4	0.6	0.8	1	1.2	1.6
lime %	0	2	3	4	5	6	8
pH	7.87	12.3	12.41	12.47	12.49	12.53	12.55

Table 7: Percent lime and corresponding strength

% Line	Strength (lb/in^2)	
	1 h curve	28 d curve
3	35	109
5	38	118
7	54	127

Table 8: Results from the soil mix compression tests. The natural salts were present (i.e. sediment was not washed). Also see figure 46.

Sample	Aggregate	Curing Time (days)	Compressive Strength (psi)
1	Silt/sand	7	1060
2	Silt/sand	14	1170
4	Silt	7	340
5	Silt	14	360

Figure 1: Plan View of the study area with coring locations

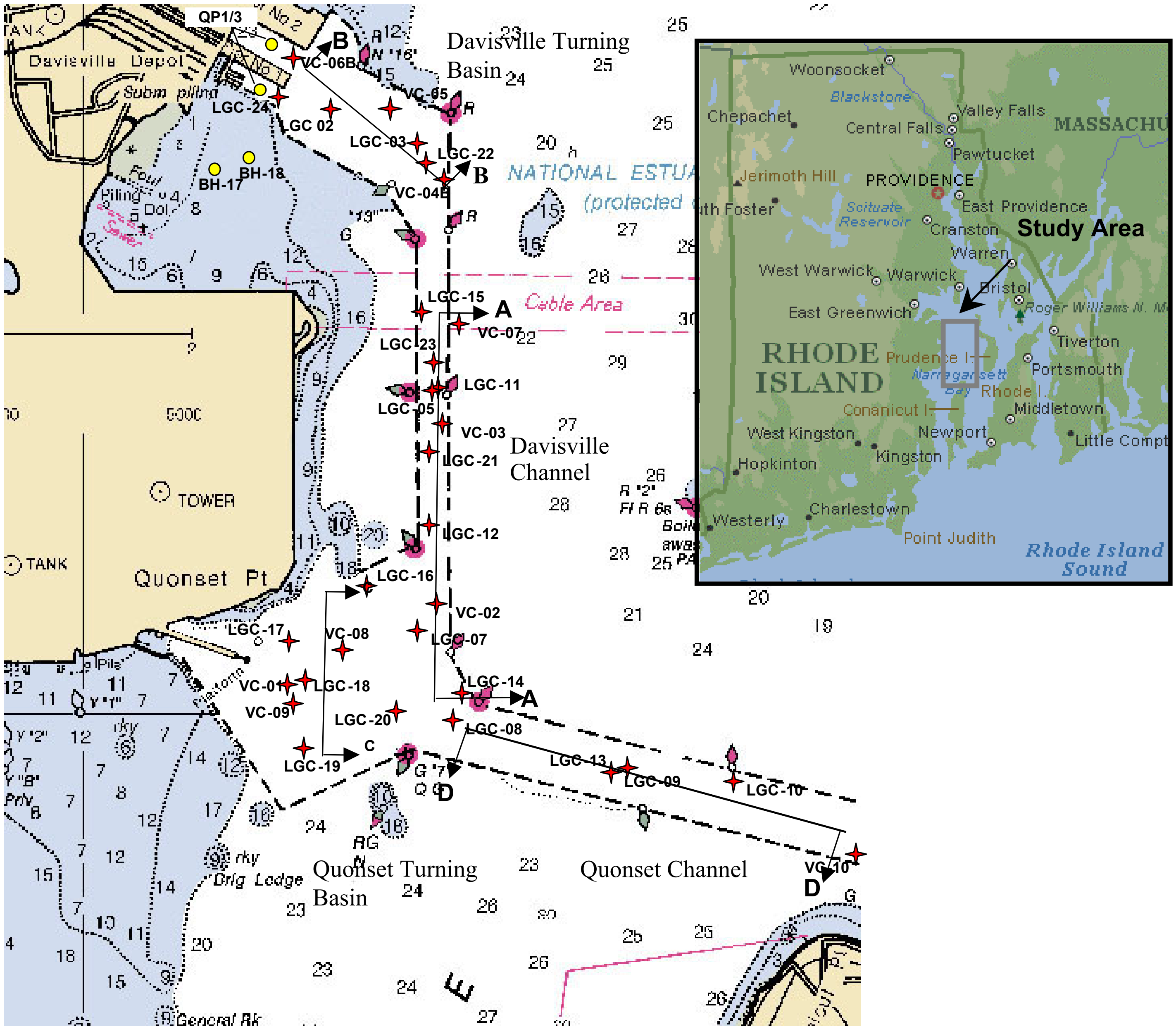


Figure 2: Boring log locations

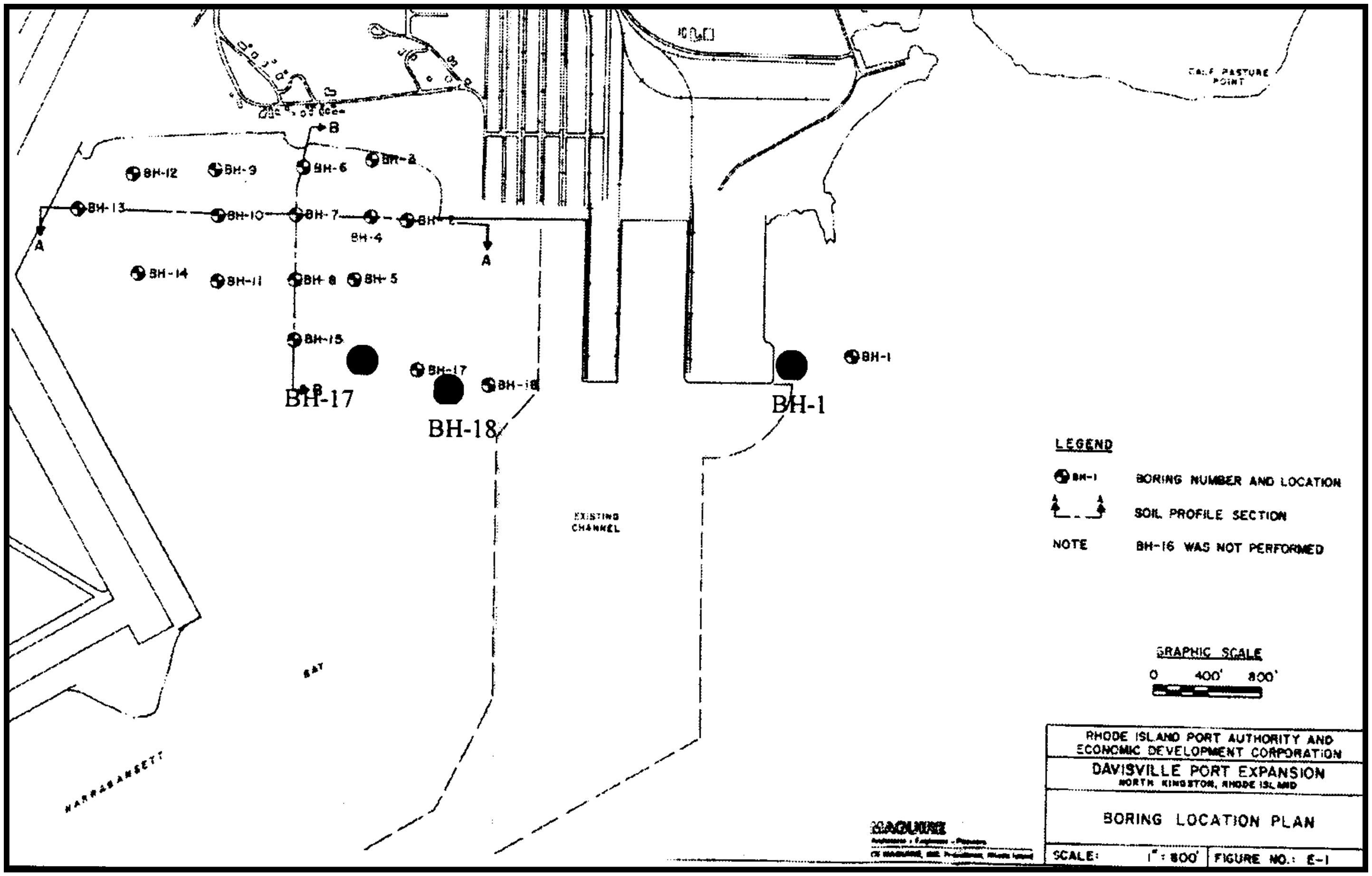


Figure 3: Boring log for BH-1

Boring log BH-1

GUILD DRILLING CO.
To: C.E. Maguire, Inc.
Project Name: Davisville Bulkhead
Report Sent to: : above
Sample sent to: "

Address: Providence, RI
Location: Quonset Point, RI
Project No: 3603
Job No: 80-256

Hole No: BH-1

Groundwater Observations
At: 12.9"
Tide Gauge: 0.0

Rods-"AW"	Casing	Sampler	Core Bar
Type:	BW	S/S	
Size ID:	2.5"	1 3/8"	
Hommer Wt:	300#	140#	BIT
Hommer fall:	24"	30"	

Start: 4/3/80
Boring Foreman: E. Peterson
Inspector: D. Calvi

Case Blows	Sample Depths	Type of sample	Blows per 6" on sampler 0-6	6-12	12-18	Moisture density or consistency	Strata change	Soil identification	Sample No.	Pen.	Rec.	Elevation	Comments
1	0"-1'6"	D	1	2	2	wet			1	18'	18"		
3						soft		Dark gray sandy organic SILT trace of shells					
5													
6													
10						wet		Dark gray organic SILT					
12	5'-6'6"	D	2	3	3	m/stiff	6'		2	18'	12"		
20													
22													
25													
30						wet							
12	10'-11'6"	D	8	9	14	medium			3	18'	18"		
16						dense							
22													
27								Gray brown very fine SAND, little silt (layered)					
35													
24						wet							
30	15'-16'6"	D	3	4	5	loose			4	18'	12"		
26													
28													
28													
25	20'-21'6"	D	5	8	10	wet							
35						medium			5	18'	18"		
39						dense	23'						
46													
50													
26													
42	25'-26'6"	D	5	3	3	wet			6	18'	12"		
52						loose							
55								Gray brown silty very fine SAND (layered)					
56													
	30-31'6"	D	2	3	3	"							
									7	18'	12"		
							35'						
	35'-36'6"	D	1	3	5	wet			8	18'	12"		
						stiff		Dark gray SILT, trace of very fine sand					
							40'						

Ground Surface to   Used: Then:
140lb Wt x 30" fall on 2" O.D. sampler

Sample Type:
D = Dry

Proportions used:
Trace 0-10%
Little 10-20%
Some 20-35%

Cohesionless density
0-10 Loose
10-30 Med. dense
30-50 Dense
50+ Very dense

Cohesive consistency
0-4 Soft
4-8 M/stiff
8-15 Stiff
15-30 V-stiff

Summary
Earth Boring: 84'
Samples: 18

Figure 4: Boring log for BH-17

Boring log BH-17

GUILD DRILLING CO.

To: C.E. Maguire, Inc.
Project Name: Davisville Bulkhead
Report Sent to:: above
Sample sent to: "

Address: Providence, RI
Location: Quonset Point, RI
Project No: 3603
Job No: 80-256

Hole No: BH-17

Groundwater Observations
At: 11'6" **Time:** 9:30am

Rods-"AW"	**Casing**	**Sampler**	**Core Bar**
Type:	BW	S/S	
Size ID:	2.5"	1 3/8"	
Hommer Wt:	300#	140#	BIT
Hommer fall:	24"	30"	

Start: 3/28/80
Boring Foreman: E. Peterson
Inspector:

Case Blows	Sample Depths	Type of sample	Blows per 6" on sampler 0-6	6-12	12-18	Moisture density or consistency	Strata change	Soil identification	Sample No.	Pen.	Rec.	Elevation	Comments
												-11.5	
3	0"-1'6"	D	2	3	3	wet			1	18'	12"		
5						loose							
11													
14													
12								Gray fine to coarse SAND, little fine gravel, trace silt ans shells					
8	5'-6'6"	D	4	5	5	"			2	18'	10"		
12													
8													
13													
20						wet	10'					-21.5	
22	10'-11'6"	D	11	10	9	medium			3	18'	12"		Gradation for this test sample showed 30% gravel, 70% coarse sand, negligable silt
25						dense		Brown fine to coarse SAND & fine to medium gravel, some silt (casing bent)					
21													
15													
18													
14							15'					-26.5	
20	15'-16'6"	D	8	8	12	"		Dark brown silt fine to coarse SAND & gravel	4	18'	12"		
27													
31							19'					-30.5	
30						moist							
24	20'-21'6"	D	36	47	60	very		Gray brown fine to medium SAND, silt and gravel, cobbles & boulders (till)					
145						dense			5	18'	12"		
80													
176													
45													
83							25'					-36.5	
126	25'-26'6"	D	35	29	24	wet		Brown fine to coarse SAND & fine to medium gravel, some silt (casing bent)	6	18'	12"		
15						very							
28						dense							
37													
30	30-31'6"	D	26	18	15	wet							
36						dense	31'		7	18'	6"	-43	
45													
33													
30													
26	35'-36'6"	D	15	11	11	wet		Brown fine to coarse SAND, some fine gravel, little silt, cobbles	8	18'	18"		
33						medium							
26						dense							
31													
33												-50	

Ground Surface to 60' Used: BW Then: O.E. Rod to 61'6"
140lb Wt x 30" tall on 2" O.D. sampler

Sample Type:
D = Dry

Proportions used:
Trace 0-10%
Little 10-20%
Some 20-35%

Cohesionless density
0-10 Loose
10-30 Med. dense
30-50 Dense
50+ Very dense

Cohesive consistency
0-4 Soft
4-8 M/stiff
8-15 Stiff
15-30 V-stiff

Summary
Earth Boring: 61'6"
Samples: 13

Figure 5: Boring log for BH-18

Sample sent to: "

Job No: 80-256

Groundwater Observations		**Rods-"AW"**	**Casing**	**Sampler**	**Core Bar**	
At: 14'6"	**Time:** 12:10pm	**Type:**	BW	S/S		**Start:** 3/10/80
Tide Gauge: 0.3		**Size ID:**	2.5"	1 3/8"		**Boring Foreman:** E.Peterson
		Hommer Wt:	300#	140#	BIT	**Inspector:** D.Erickson
		Hommer fall:	24"	30"		

Case Blows	Sample Depths	Type of sample	Blows per 6" on sampler 0-6	6-12	12-18	Moisture density or consistency	Strata change	Soil identification	Sample No.	Pen.	Rec.	Elevation	Comments
												-14.5	
-	0"-1'6"	D	-	L	2	wet		Dark gray oily SILT and	1	18'	18"		
1						soft	2'	fine sand, trace shells				-16.5	
3								Gray silty fine to medium					
4								SAND, trace of shells &					
2						wet		fine to medium gravel					
1	5'-6'6"	D	2	3	4	loose	6'6"	(organic)	2	18'	12"		
1													
1													
1													
1						wet		Gray marine SILT					
1	10'-11'6"	D	1	-	1	soft			3	18'	18"		
3							12'					-26.5	
10													
12								Gray brown coarse to fine					
13								SAND & fine gravel, trace					
10						wet		of silt					Gradation for this test sample showed
13	15'-16'6"	D	6	7	8	medium			4	18'	12"		10% gravel, 90% coarse sand,
13						dense	17'					-31.5	negligable silt
15													
18													
15	20'-21'6"	D	15	17	17	wet							
25						dense		Dark brown fine SAND,	5	18'	18"		Gradation for this sample showed 88%
28								little silt					sand, 12% silt
32													
34													
30							25'					-39.5	
33	25'-26'6"	D	8	11	11	wet			6	18'	12"		
36						medium		Dark brown fine SAND,					
40						dense		some silt, trace of fine to					
43								medium gravel					
44	30-31'6"	D	12	16	16	wet							
48						dense		" trace of fine to coarse	7	18'	12"		
49							33'	gravel				-47.5	
56													
57													
55	35'-36'6"	D	12	16	17	wet		Brown fine to medium	8	18'	12"		
58						dense		SAND, little silt & fine					
65								gravel					
63													
66							40'					-54.5	

Ground Surface to 50' Used: BW Then: O.E.Rod to 51'6"
140lb Wt x 30" fall on 2" O.D. sampler

Sample Type:	Proportions used:	Cohesionless density	Cohesive consistency	Summary
D = Dry	Trace 0-10%	0-10 Loose	0-4 Soft	Earth Boring: 51'6"
	Little 10-20%	10-30 Med.dense	4-8 M/stiff	Samples: 11
	Some 20-35%	30-50 Dense	8-15 Stiff	
		50+ Very dense	15-30 V-stiff	

Figure 6: Grain size distribution of sandy samples

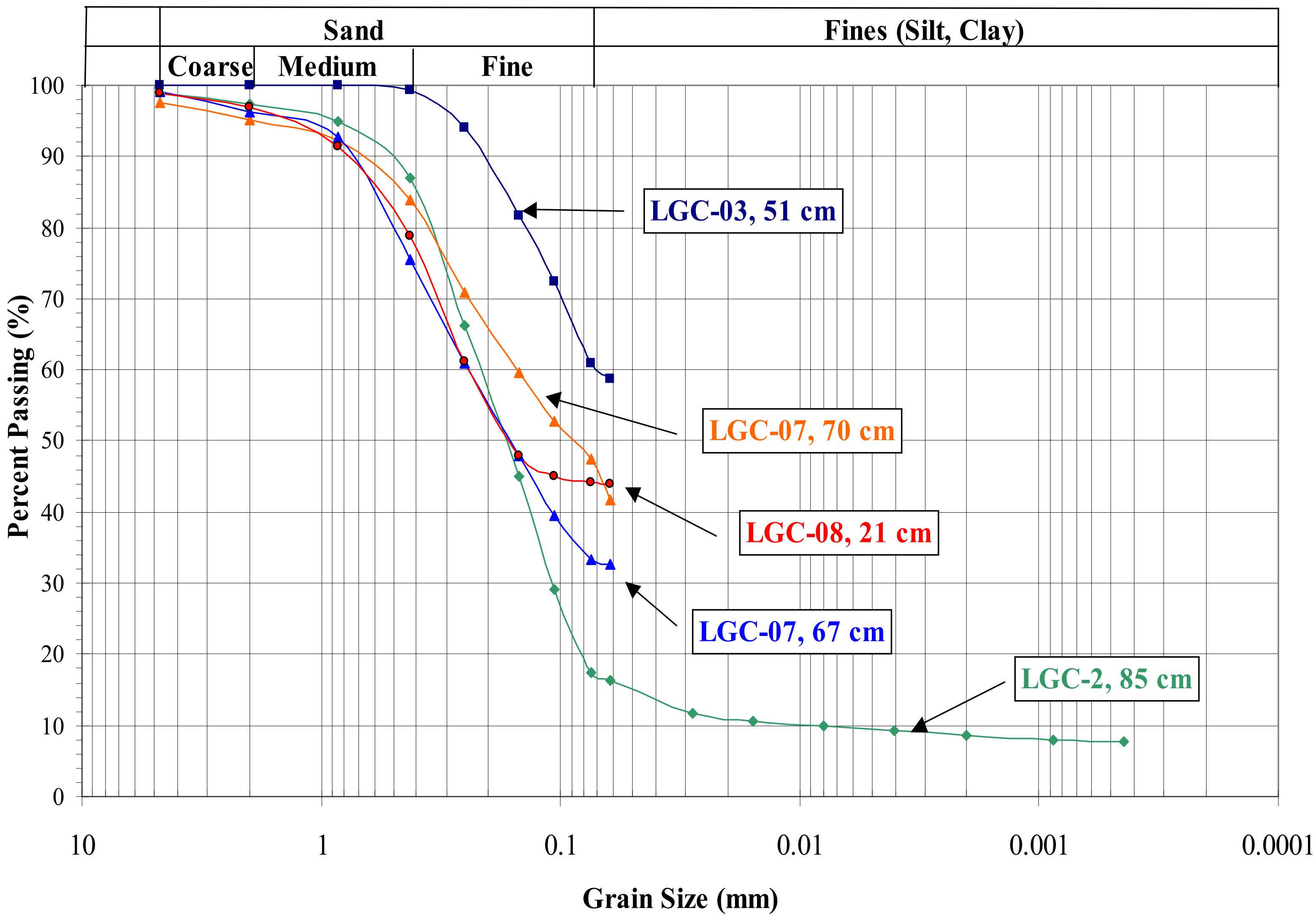


Figure 7: Grain size distribution results for LGC-06

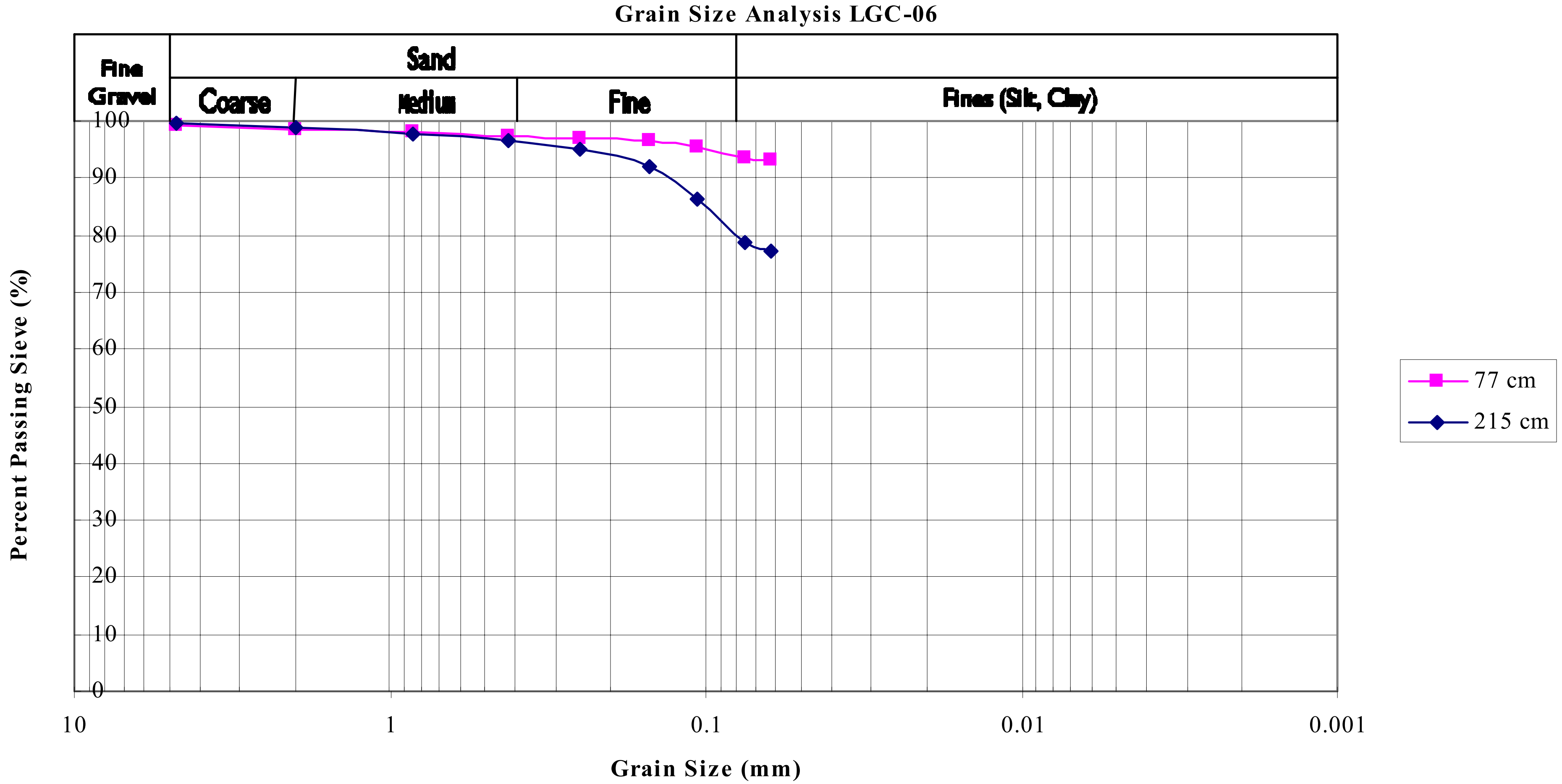


Figure 8: Grain size distribution results for LGC-09

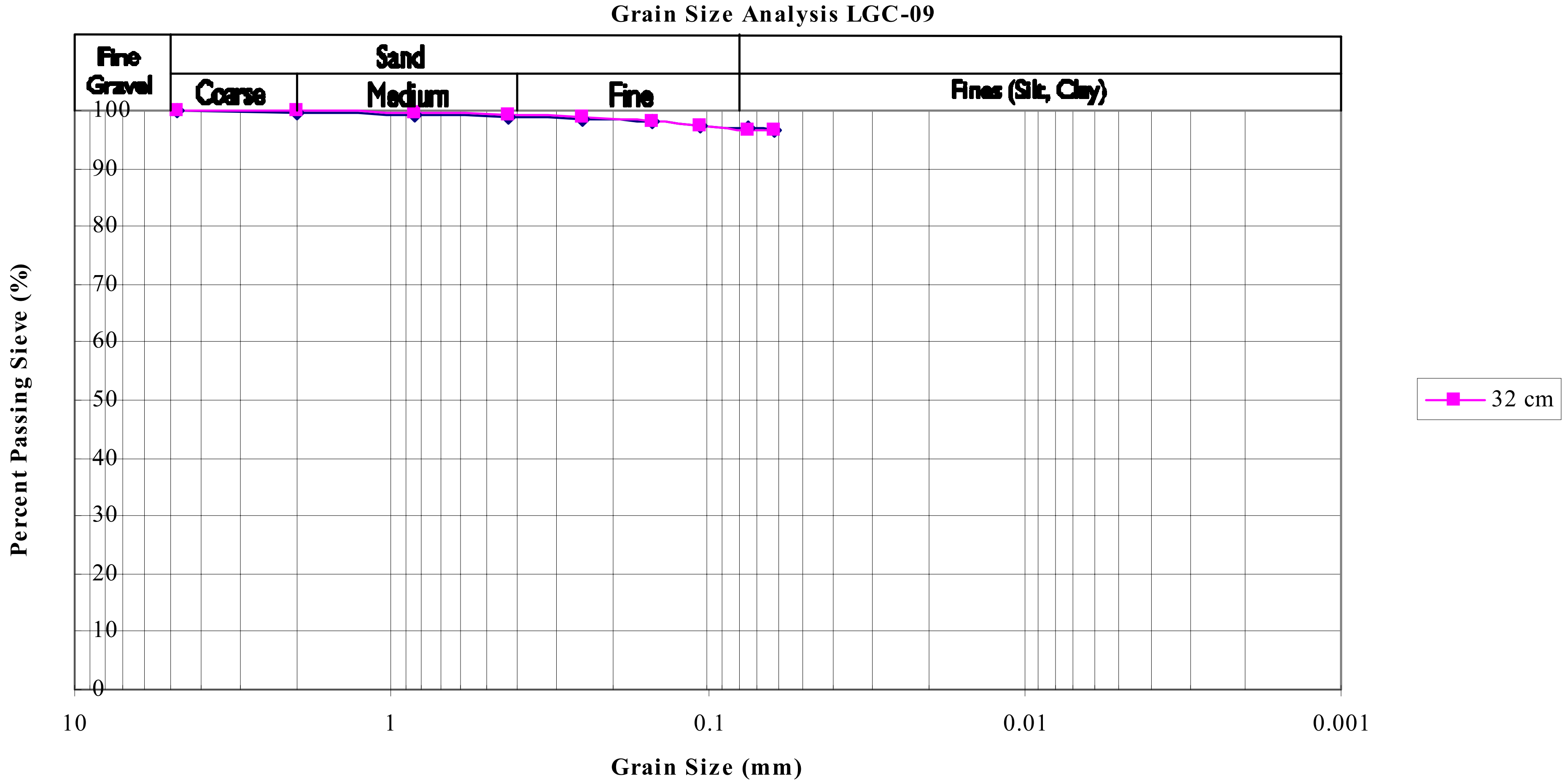


Figure 9: Grain size distribution results for LGC-10

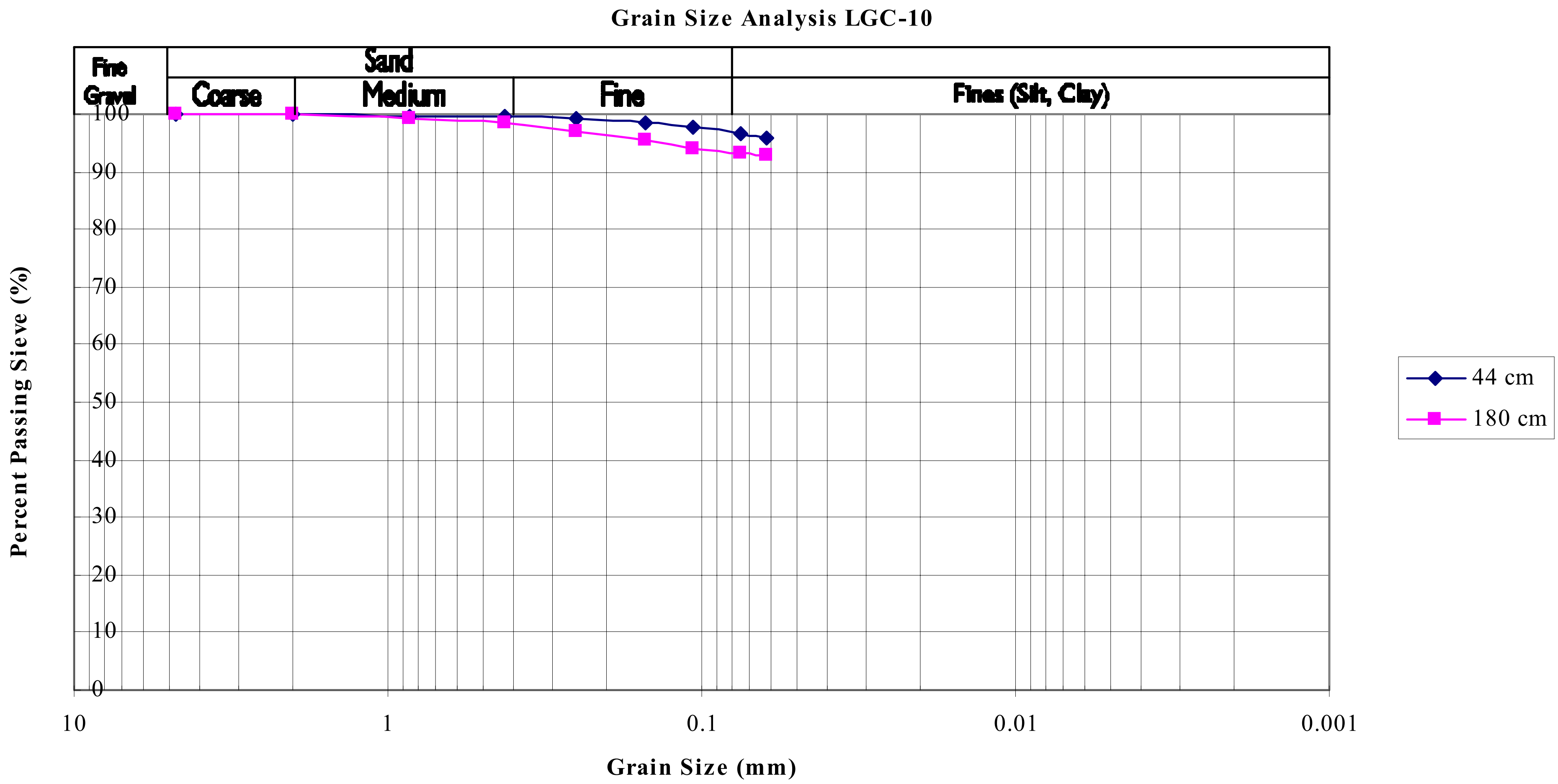


Figure 10: Grain size distribution results for LGC-11

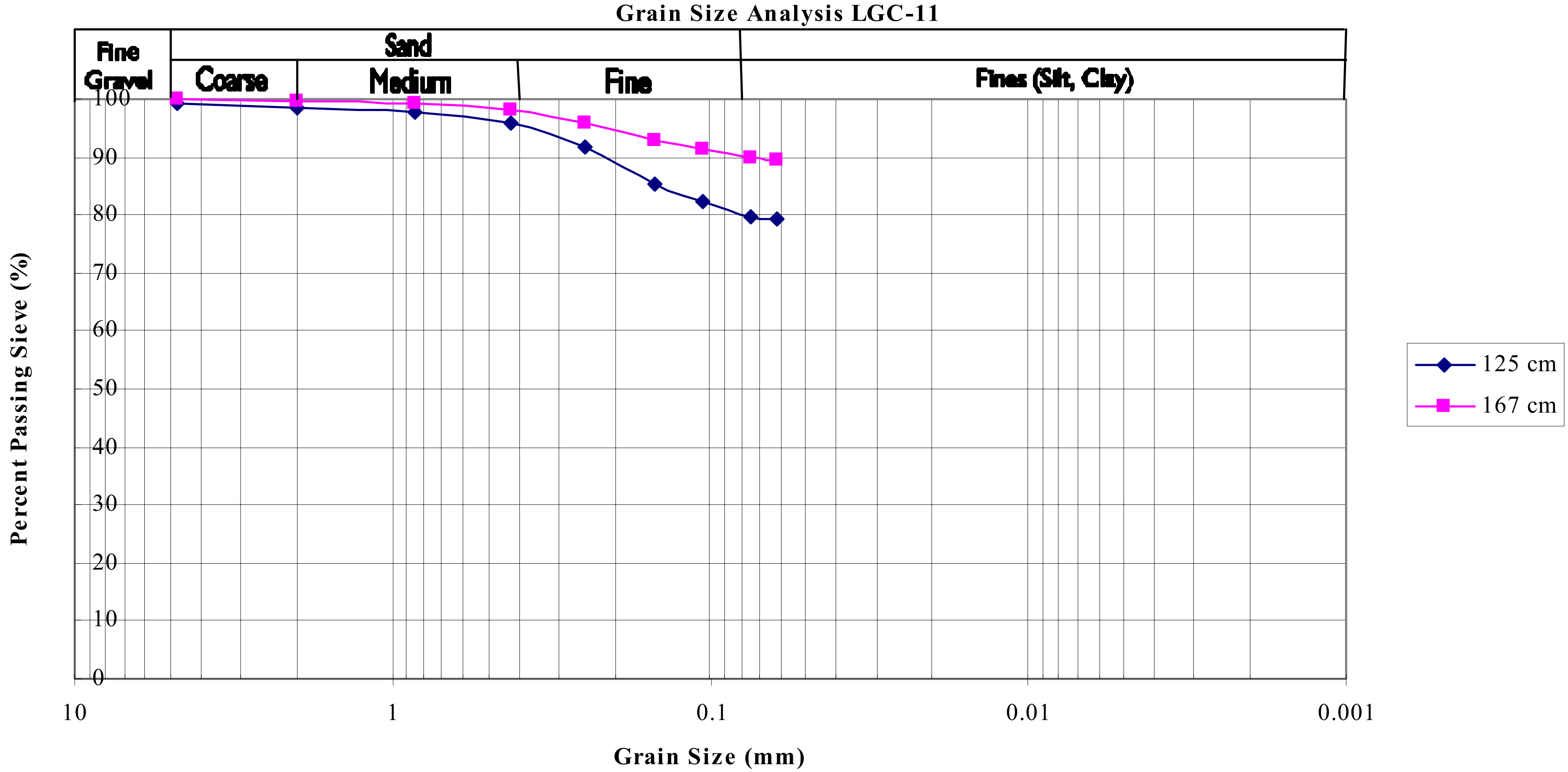
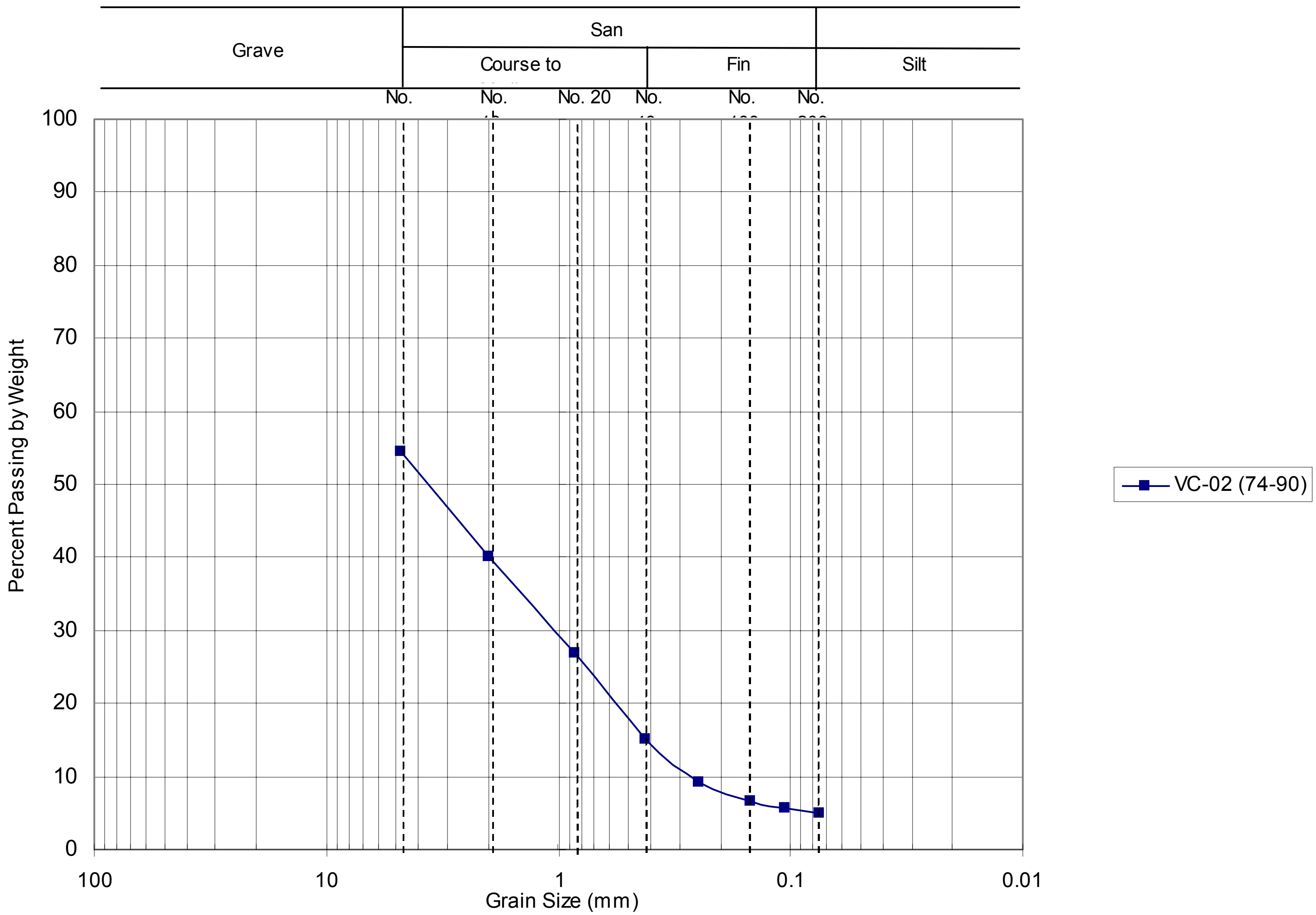
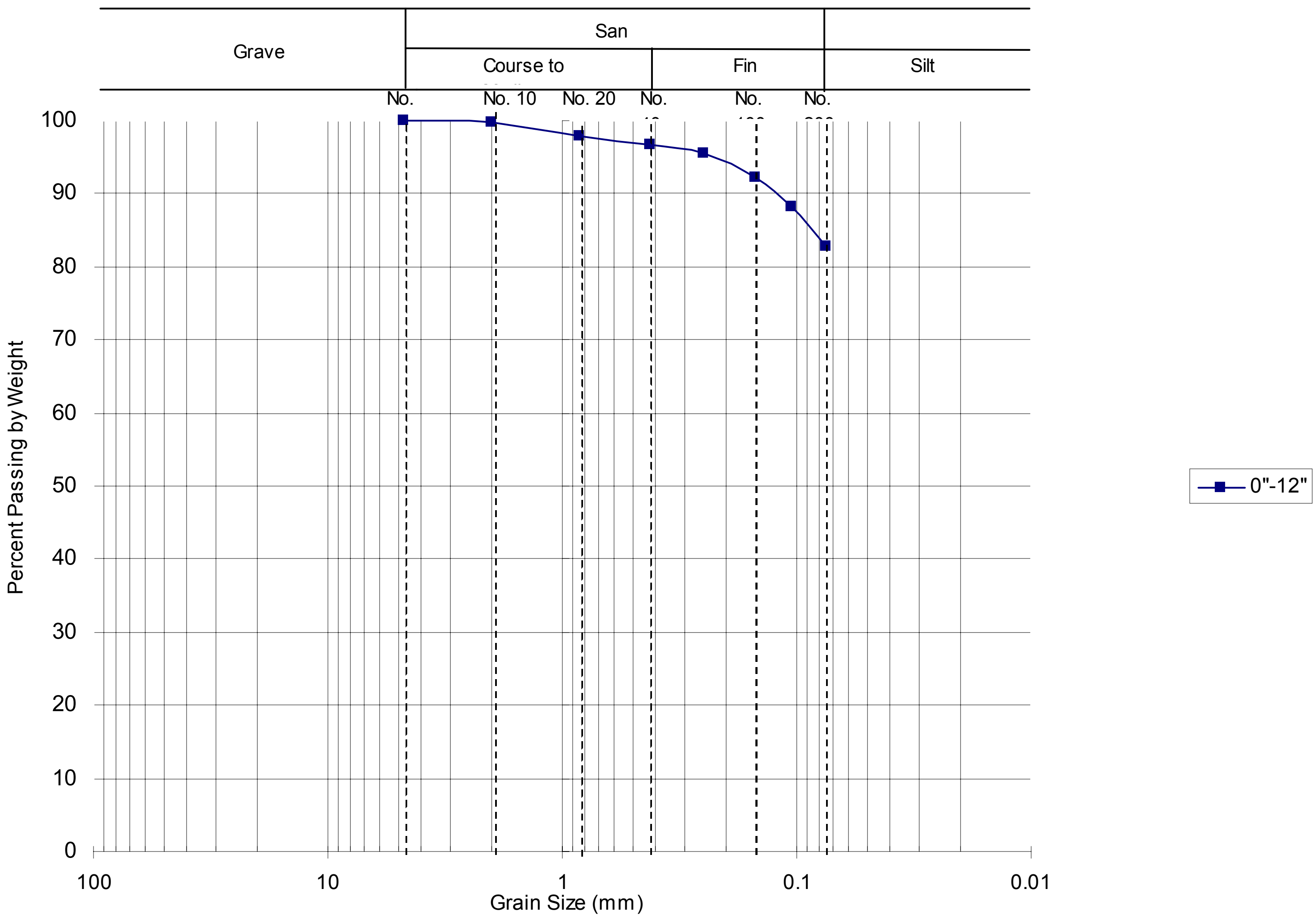


Figure 11: Grain size distribution results for VC-02



Grain Size Analysis of Inorganic Dark Gray Silt (nonplastic)

Figure 12: Grain size distribution results for VC-04b



Grain Size Analysis of VC-04b

Figure 13: Grain size distribution results for VC-05

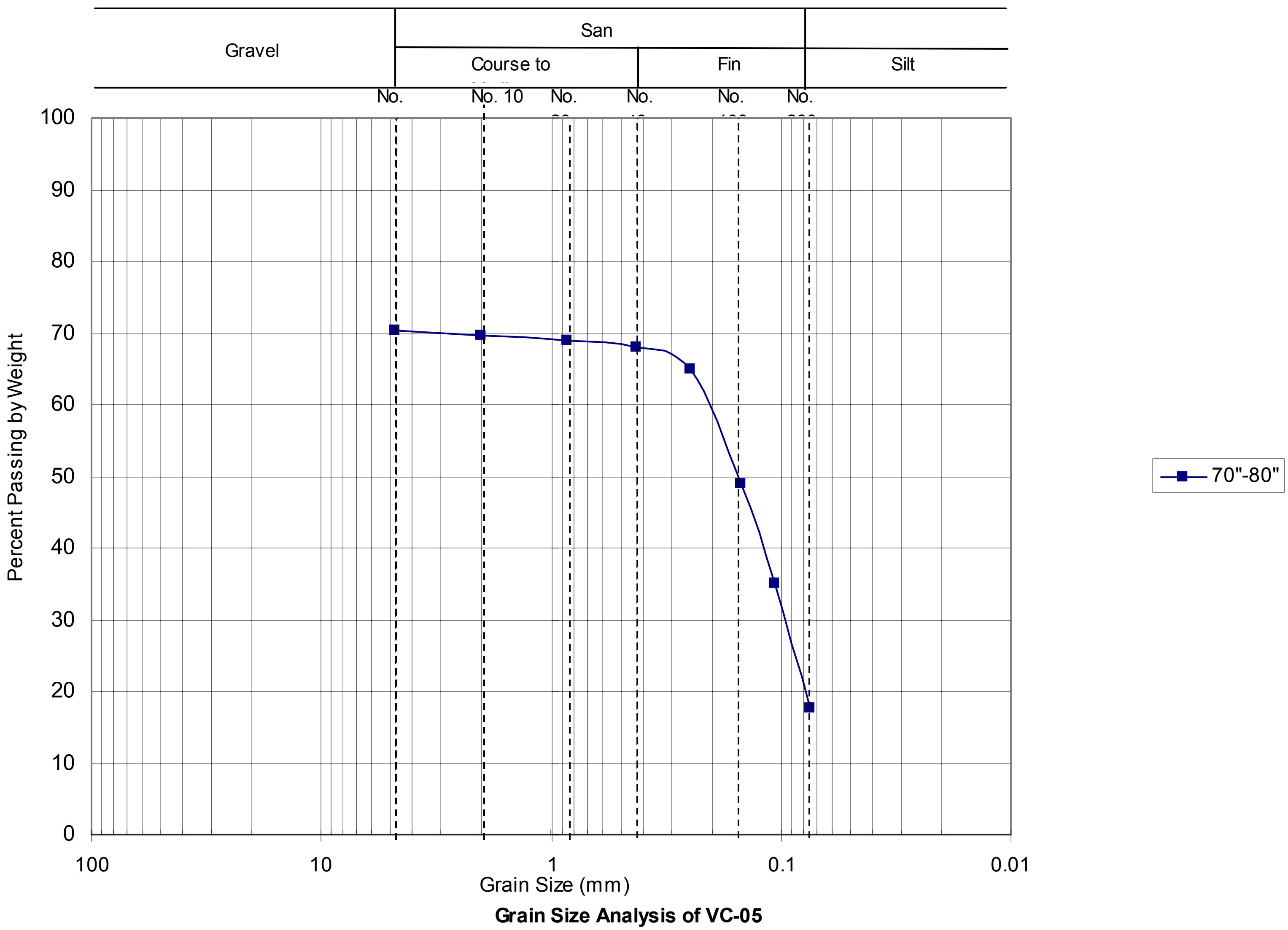


Figure 14: Grain size distribution results for VC-06b

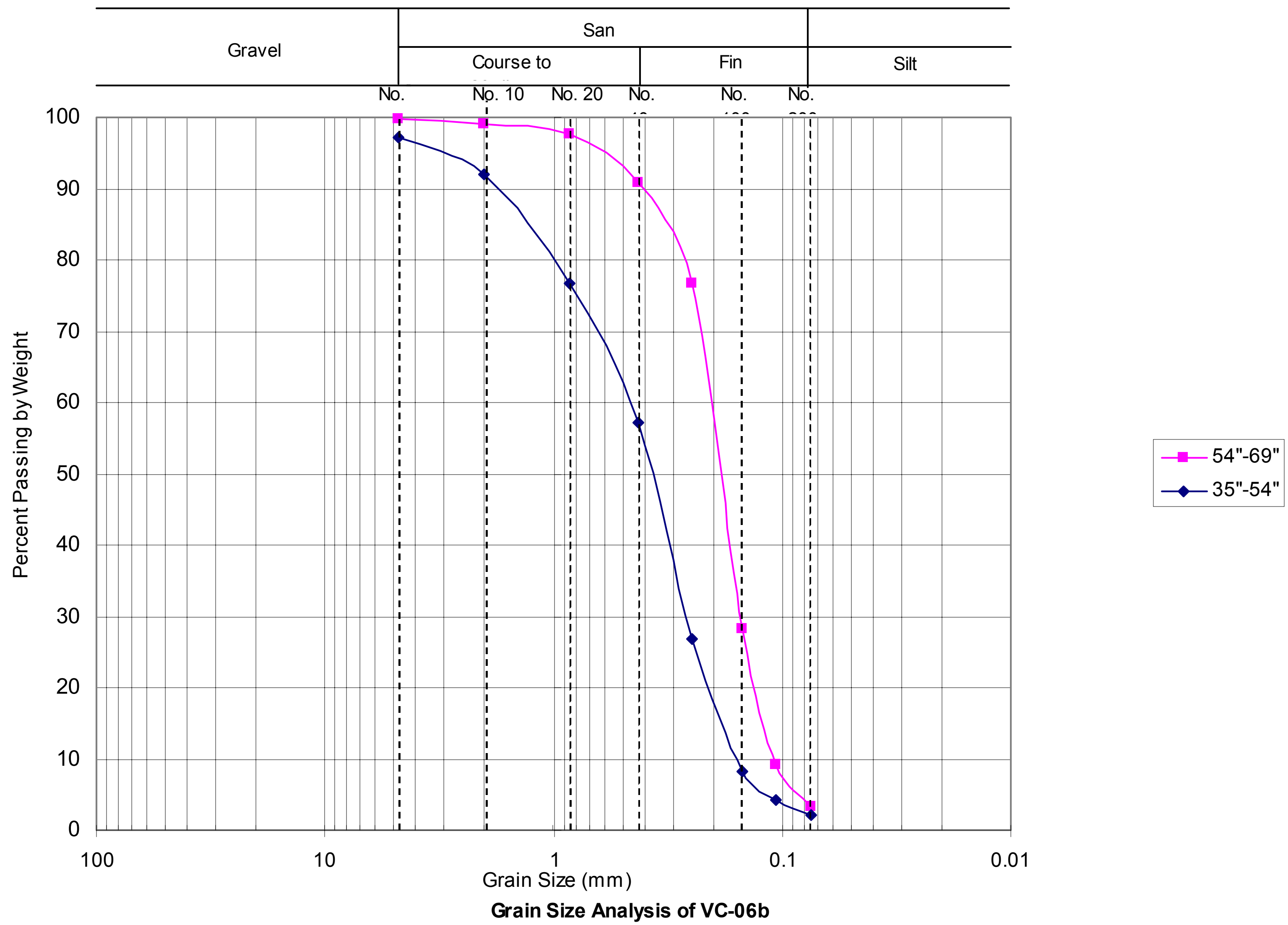
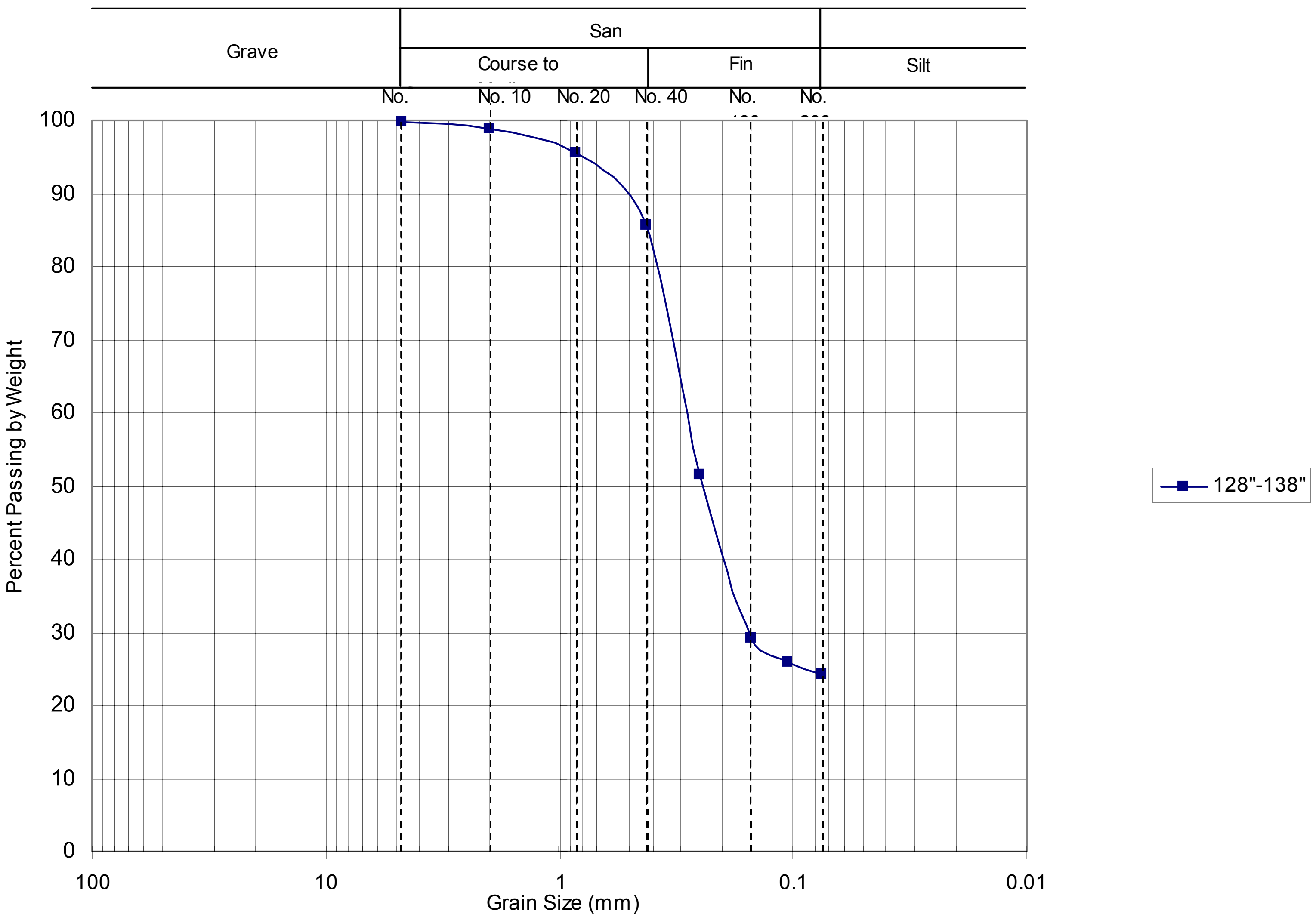


Figure 15: Grain size distribution results for VC-07



Grain Size Analysis of VC-07

Figure 16: Grain size distribution showing before and after separation of fines.
Note: This figure is an illustration of potential gain from separating fines from the dredge material through the dewatering process, no such test was performed

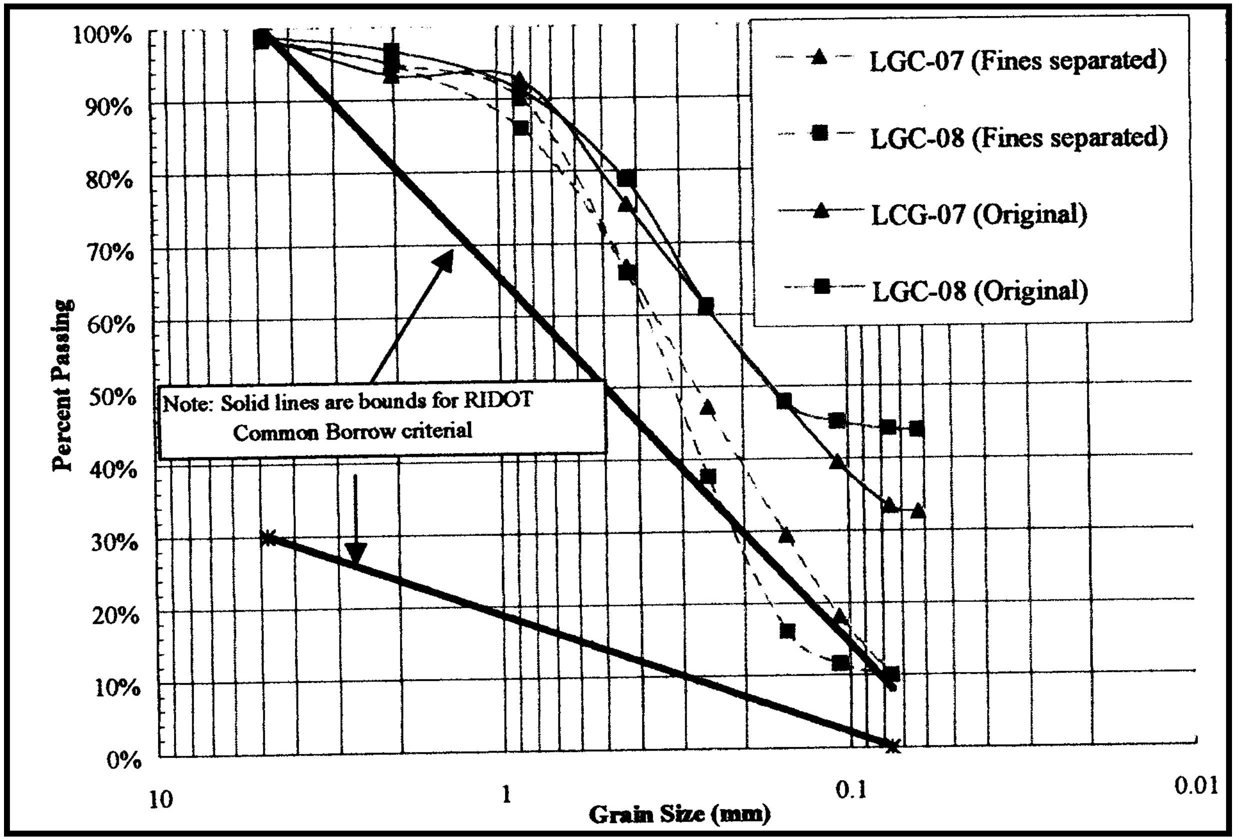


Figure 17: General sediment types throughout the study corridor

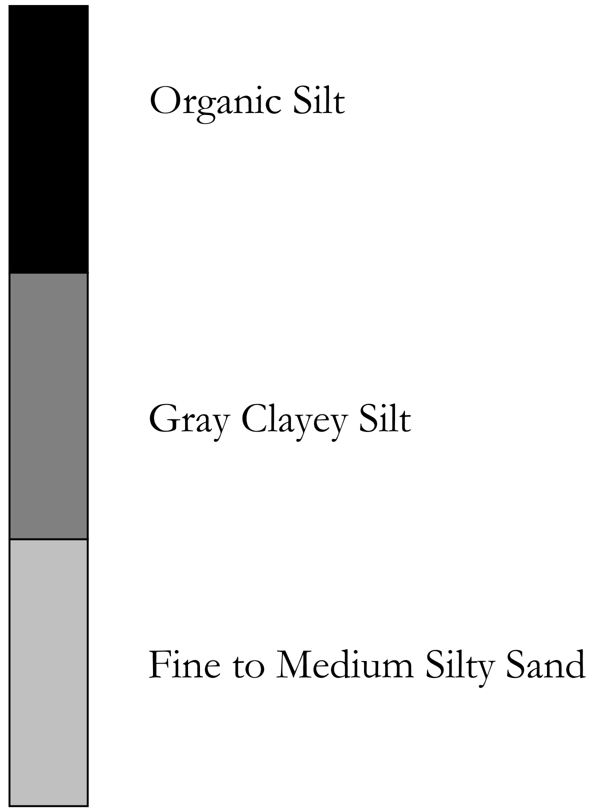


Figure 18: Profile of physical properties for LGC-02

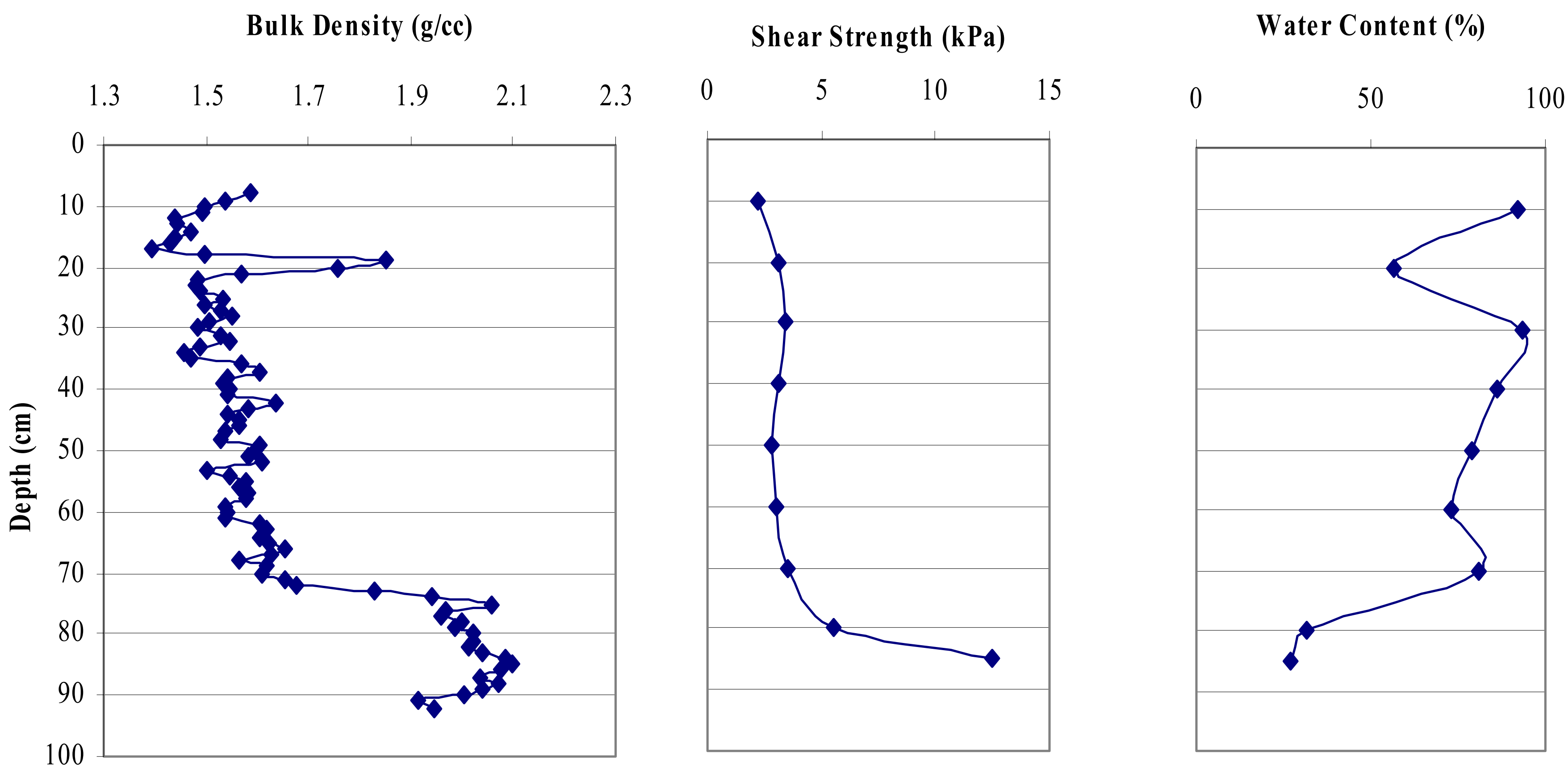


Figure 19: Profile of physical properties for LGC-03

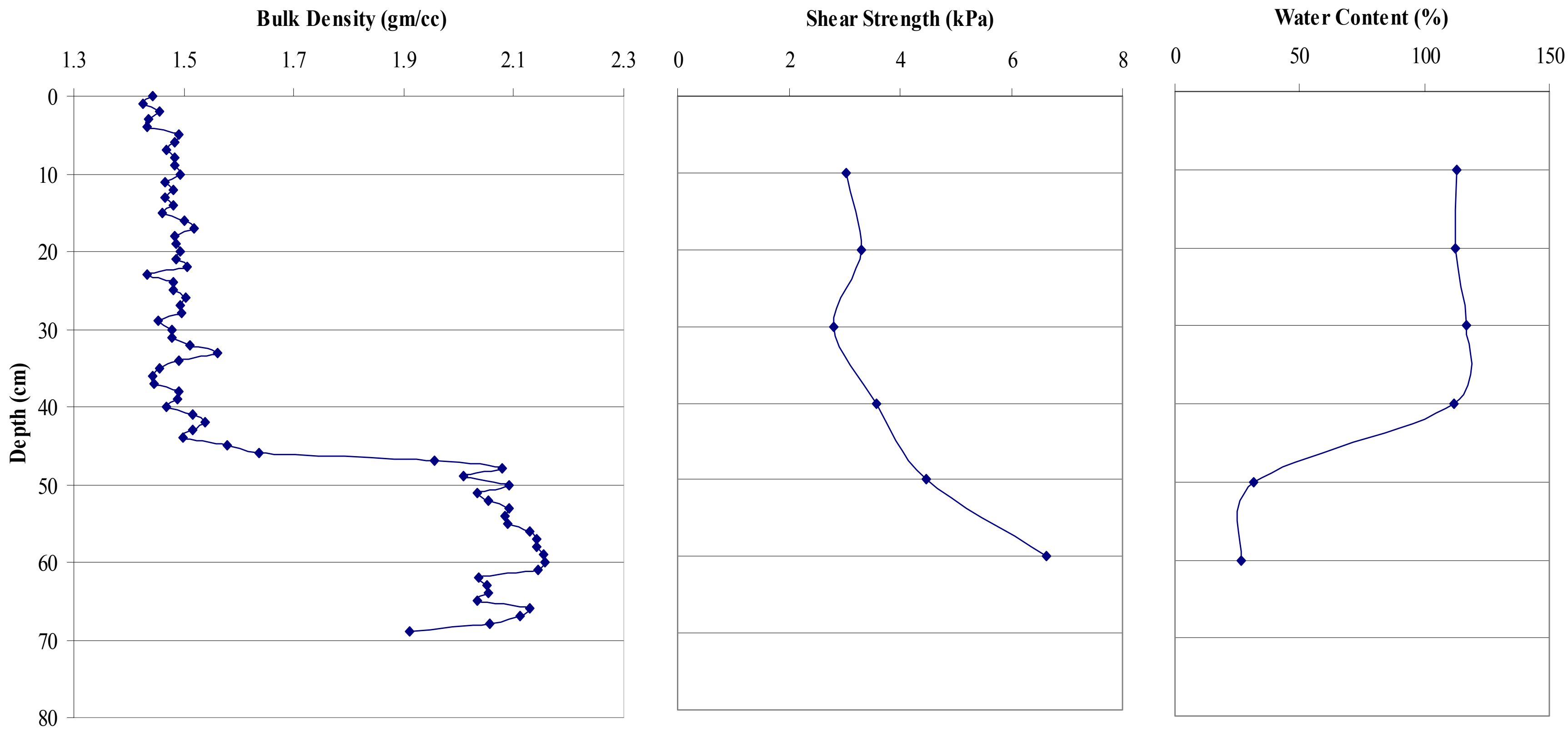


Figure 20: Bulk density profile for LGC-05

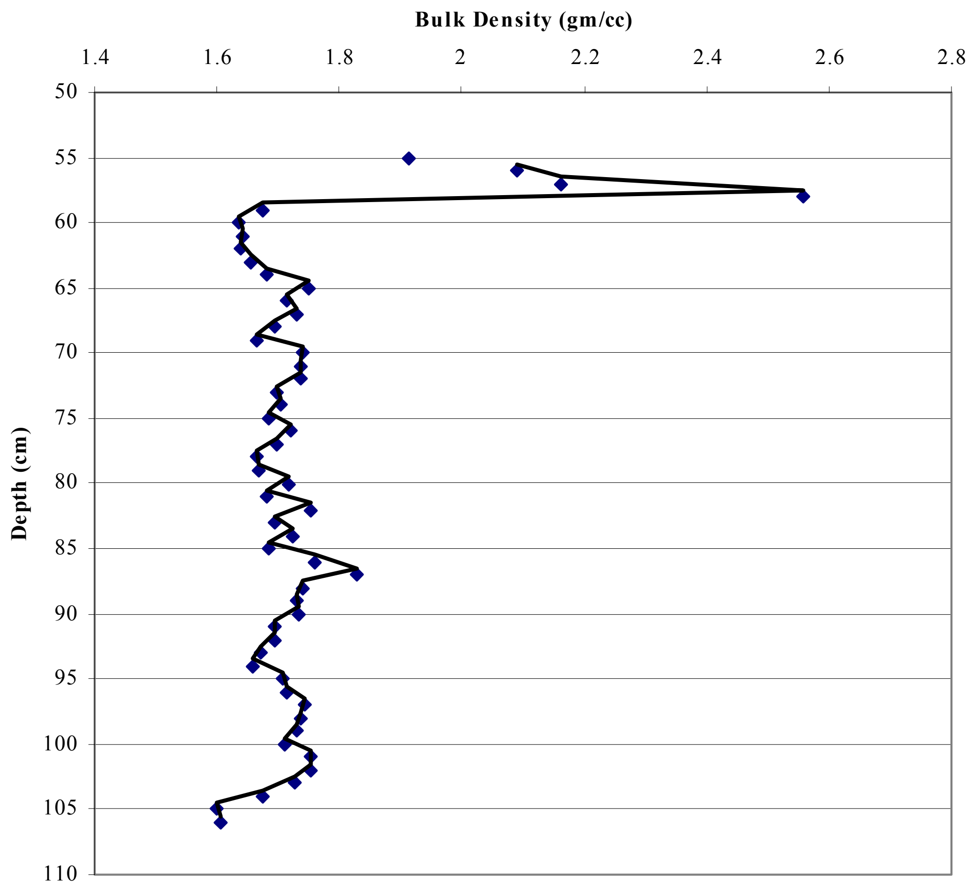


Figure 21: Profile of physical properties for LGC-06

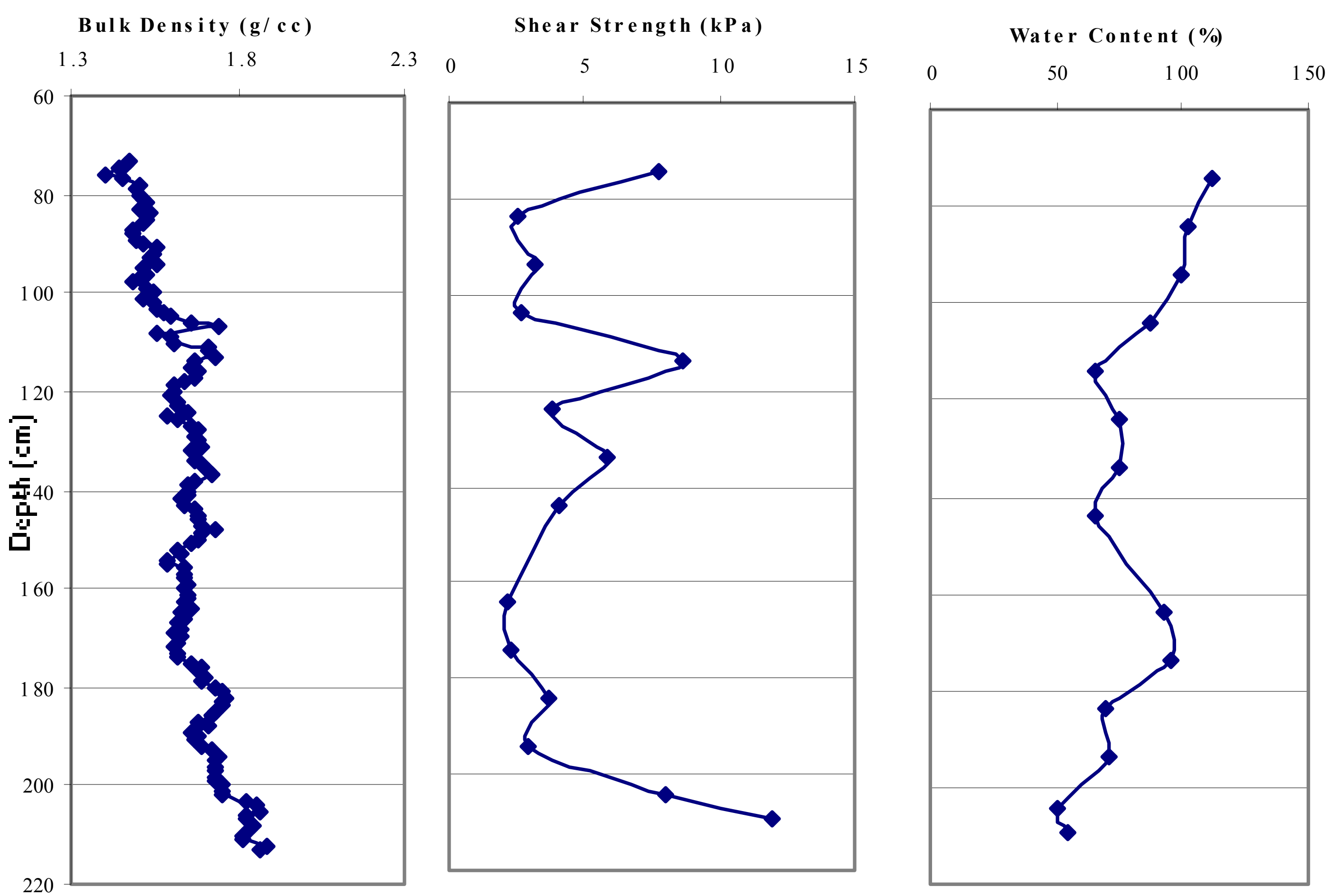


Figure 22: Profile of physical properties for LGC-07

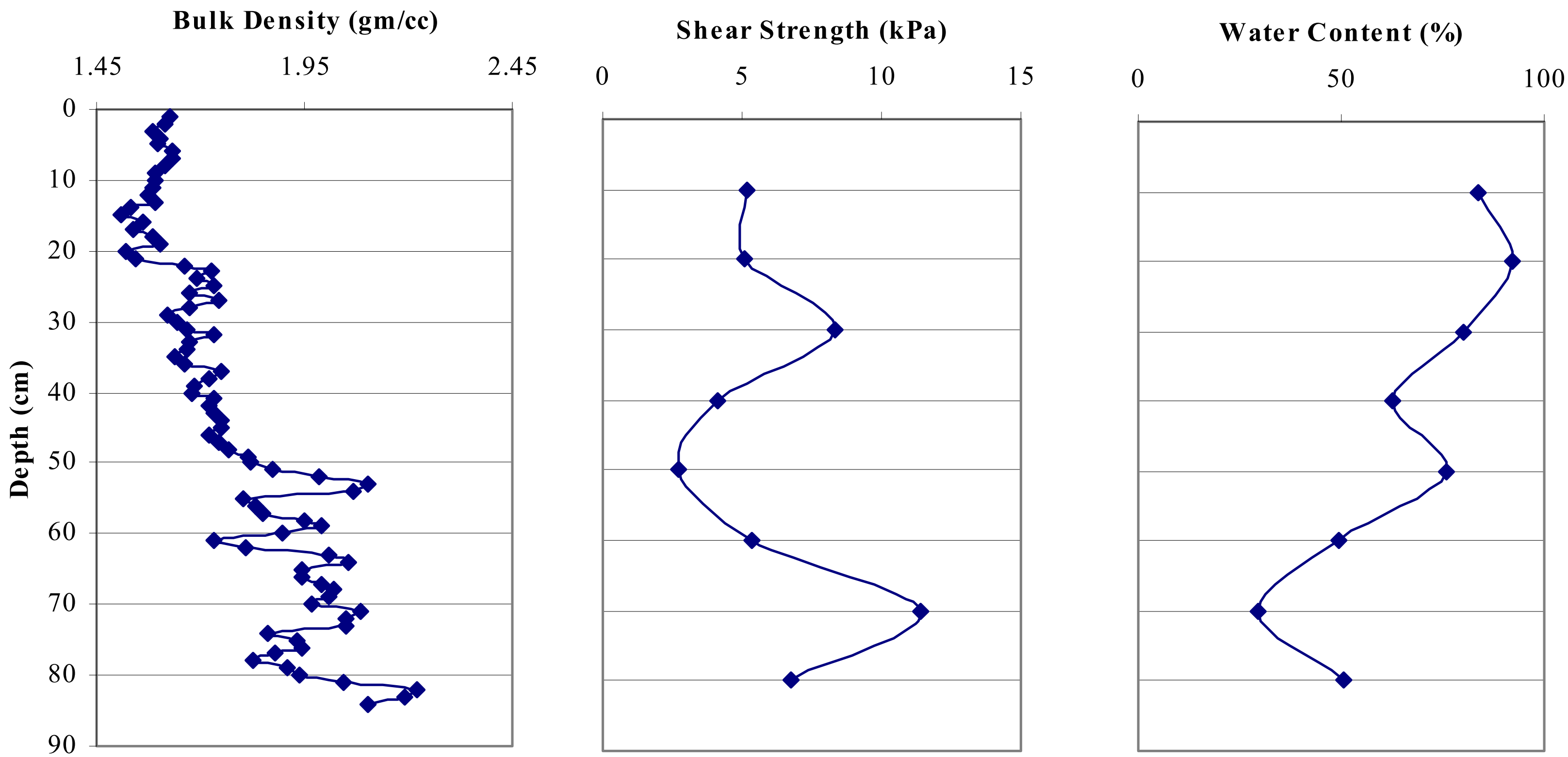


Figure 23: Profile of physical properties for LGC-08

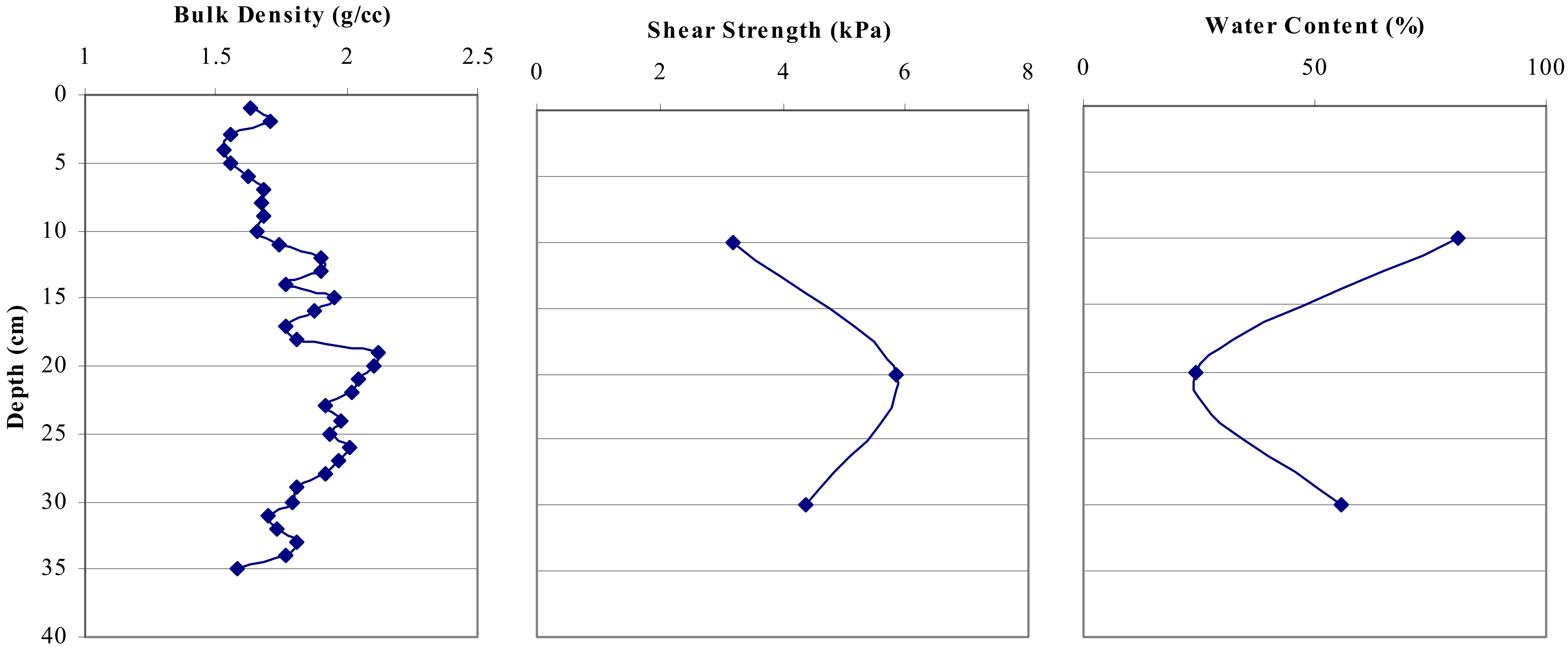


Figure 24: Profile of physical properties for LGC-09

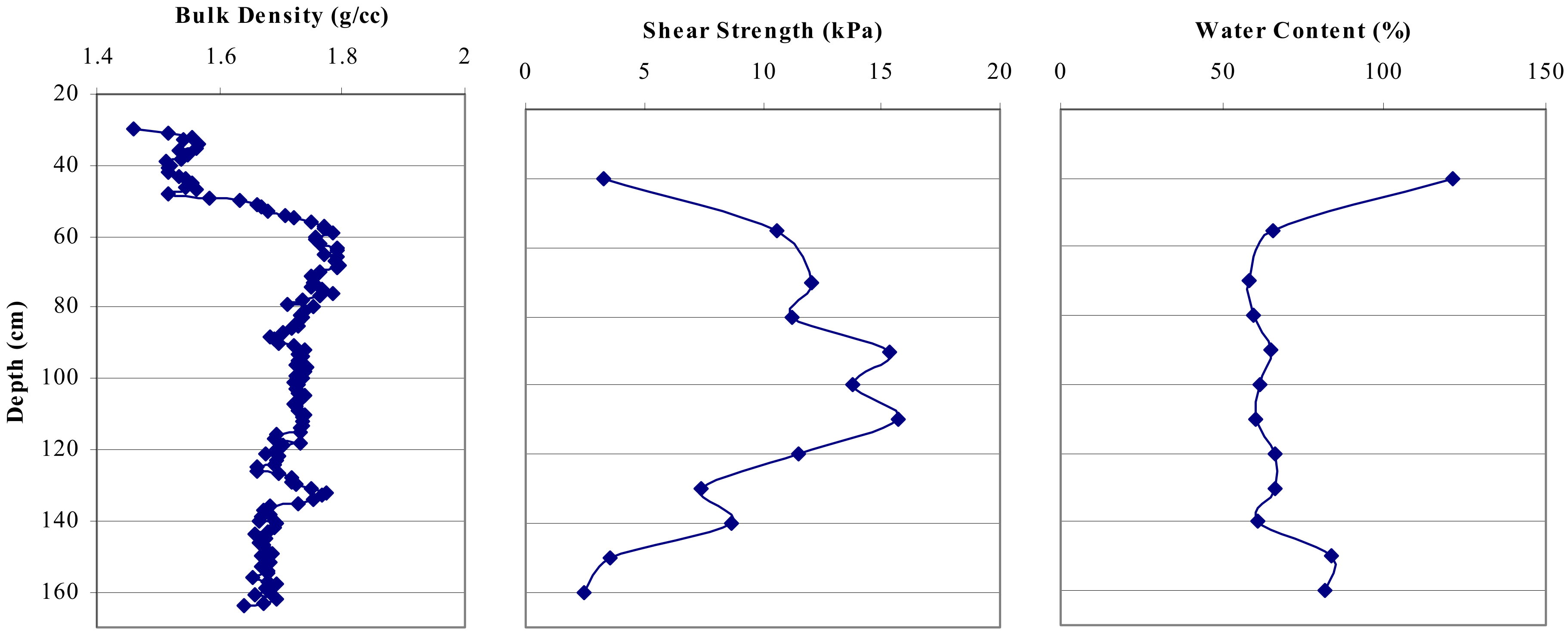


Figure 25: Profile of physical properties for LGC-10

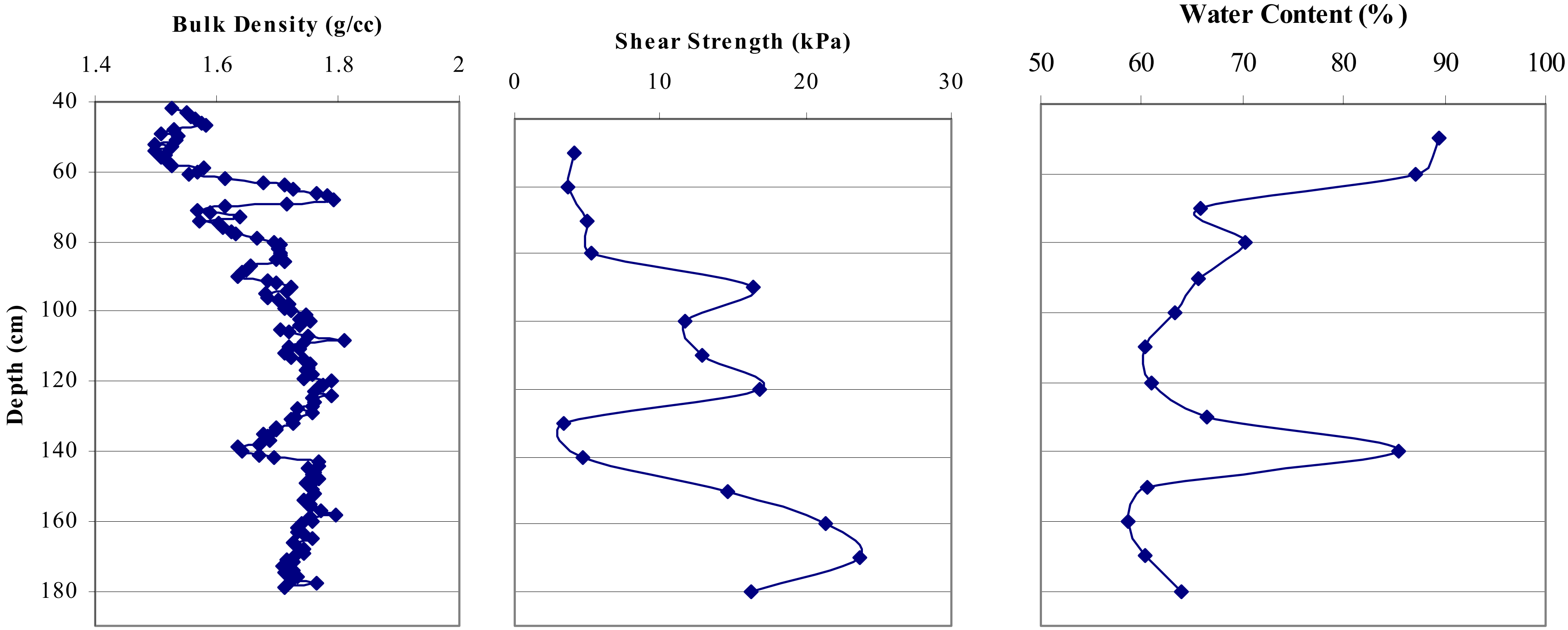


Figure 26: Profile of physical properties for LGC-11

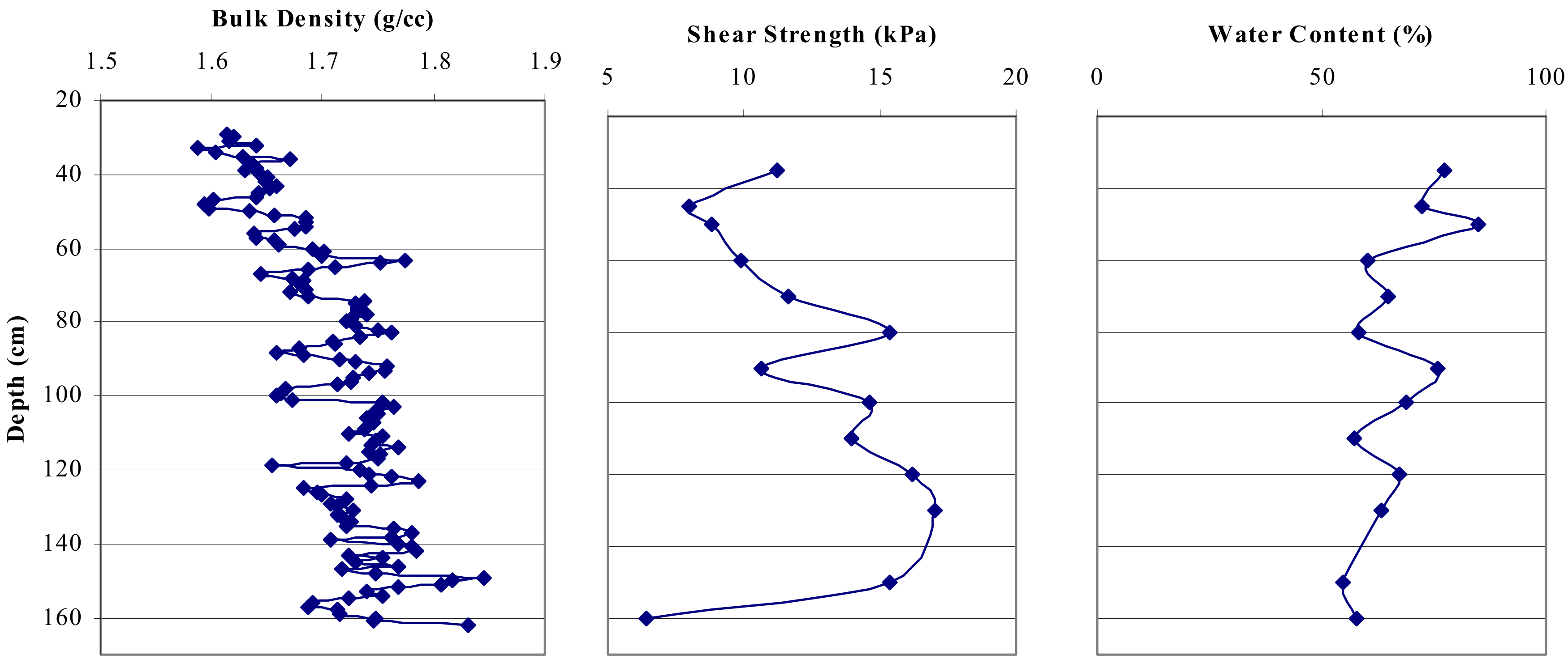


Figure 27: Bulk density profile for LGC-12

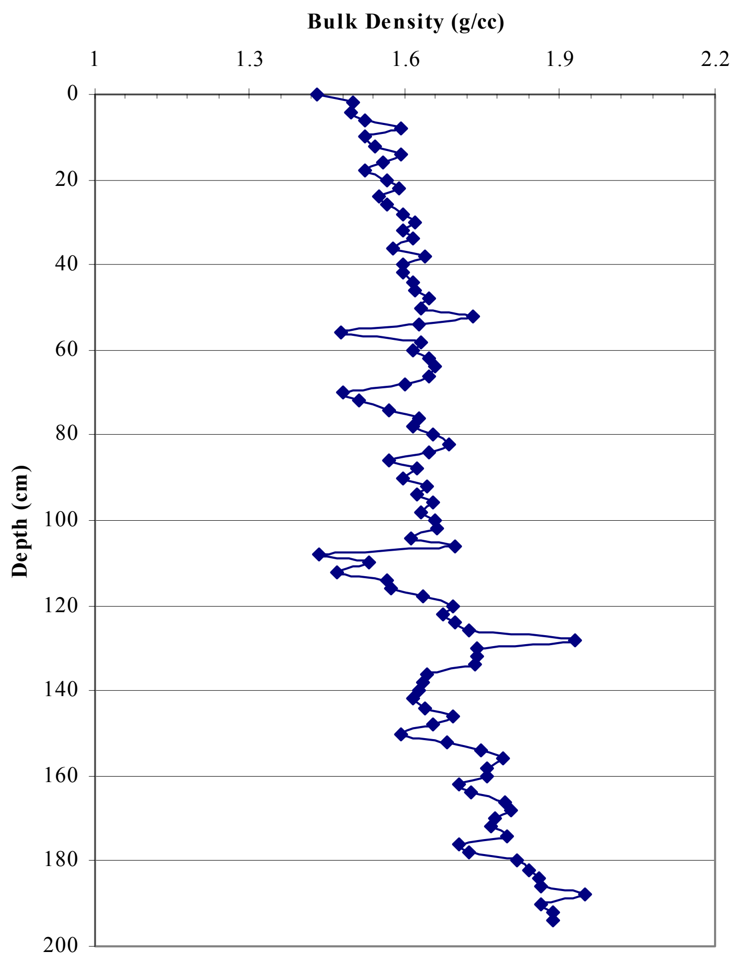


Figure 28: Bulk density profile for LGC-13

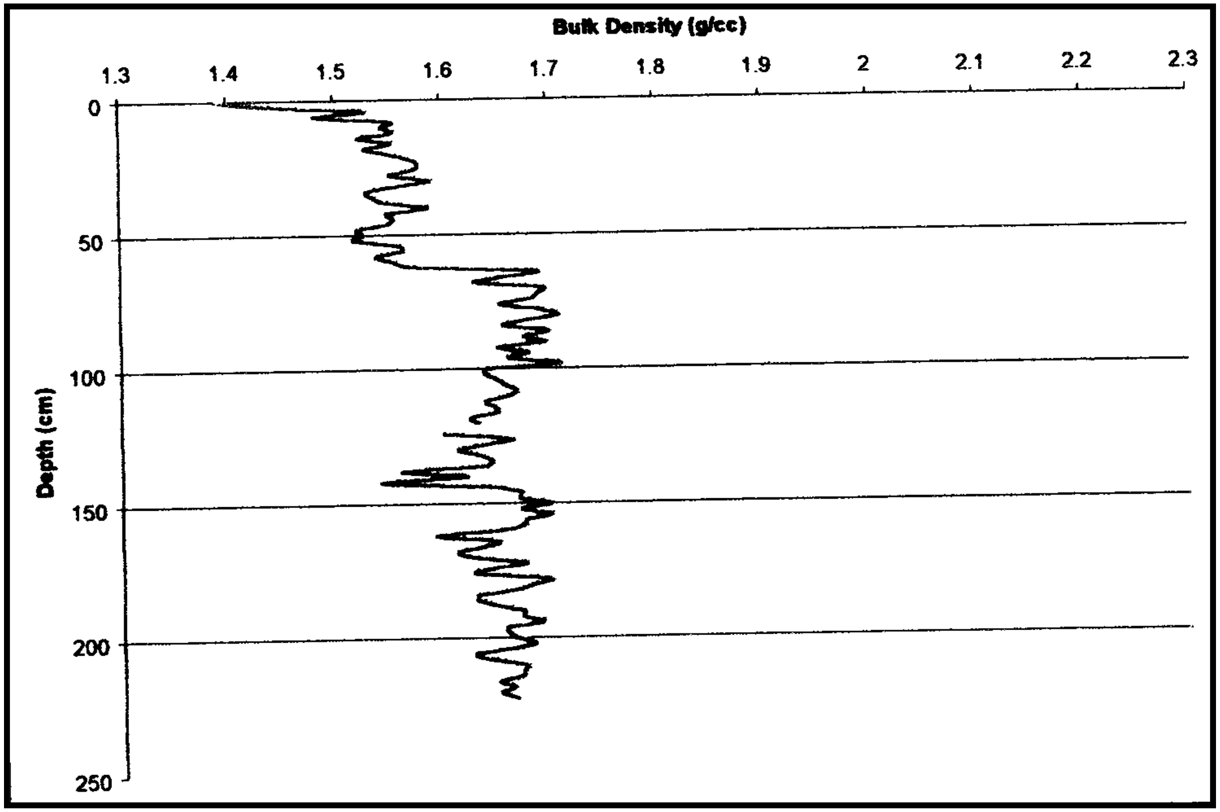


Figure 29: Bulk density profile for LGC-14

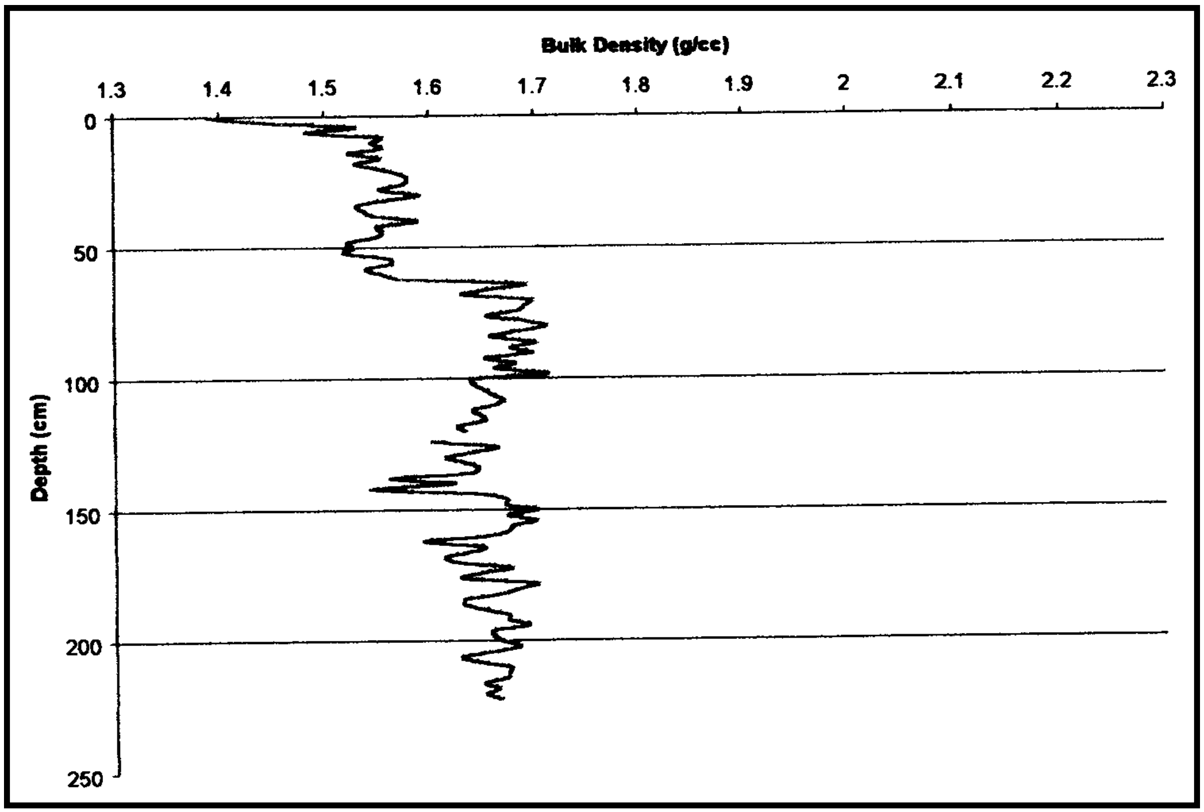


Figure 30: Bulk density profile for LGC-15

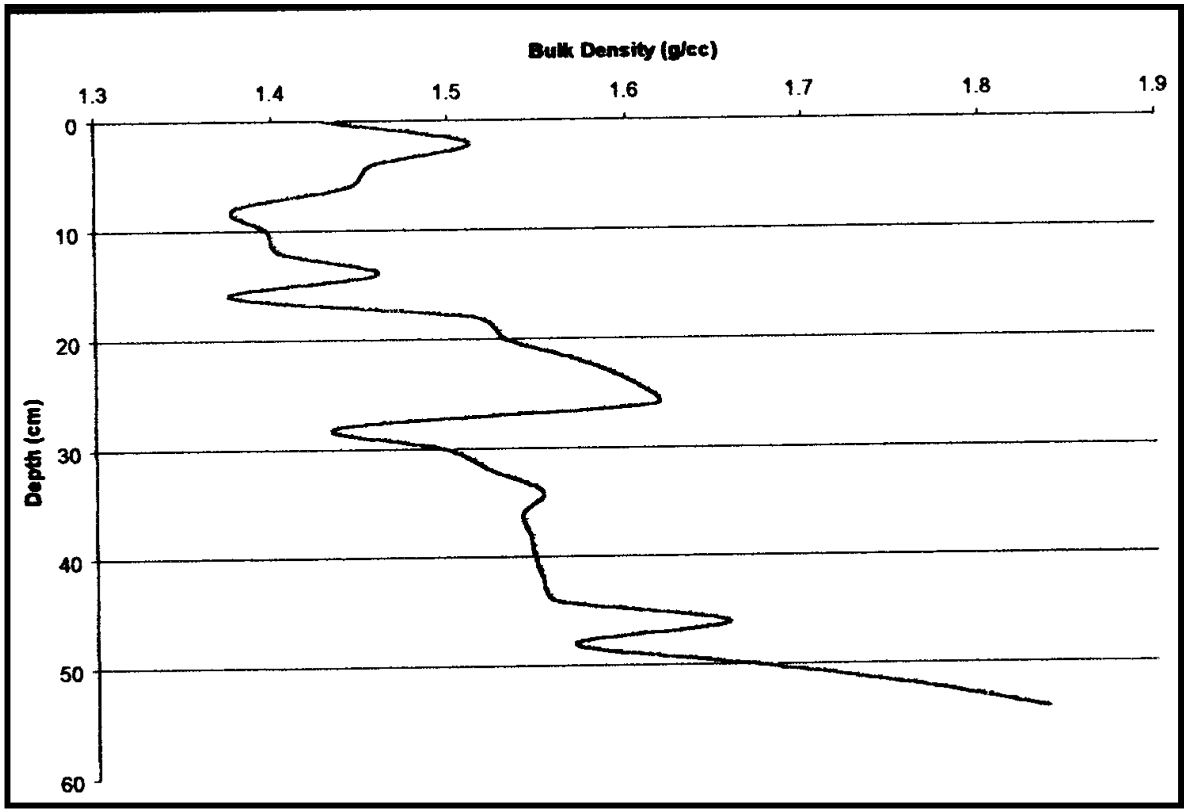


Figure 31: Profile of physical properties for LGC-21

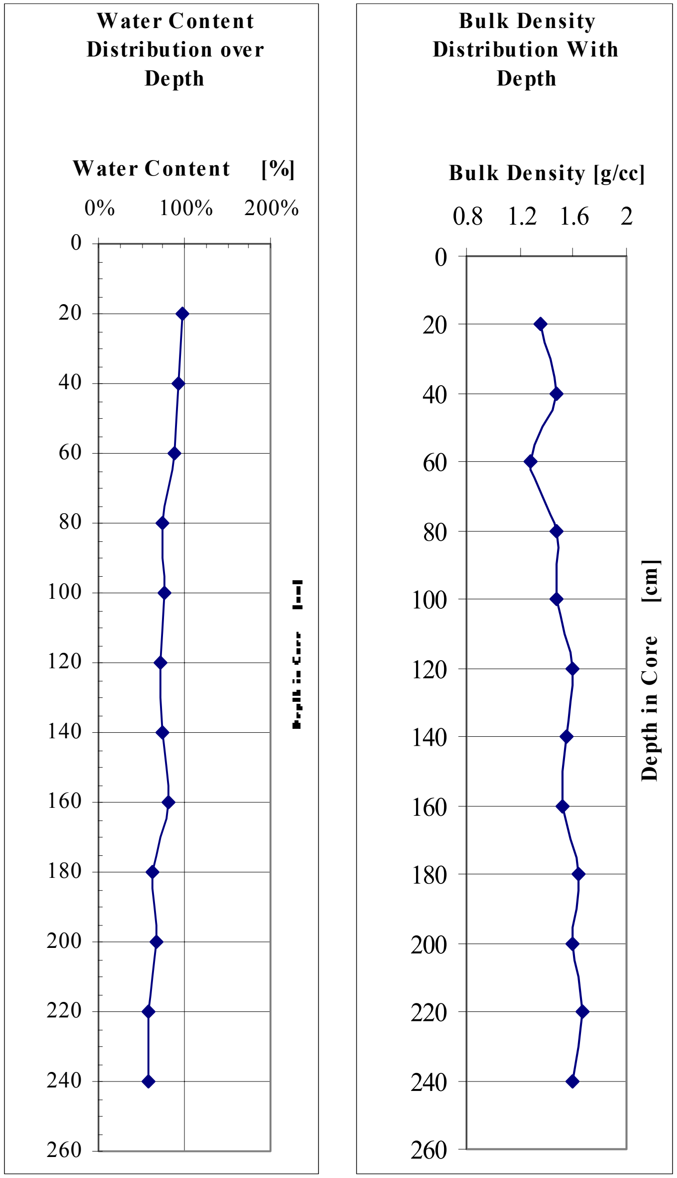


Figure 32: Profile of physical properties for LGC-24

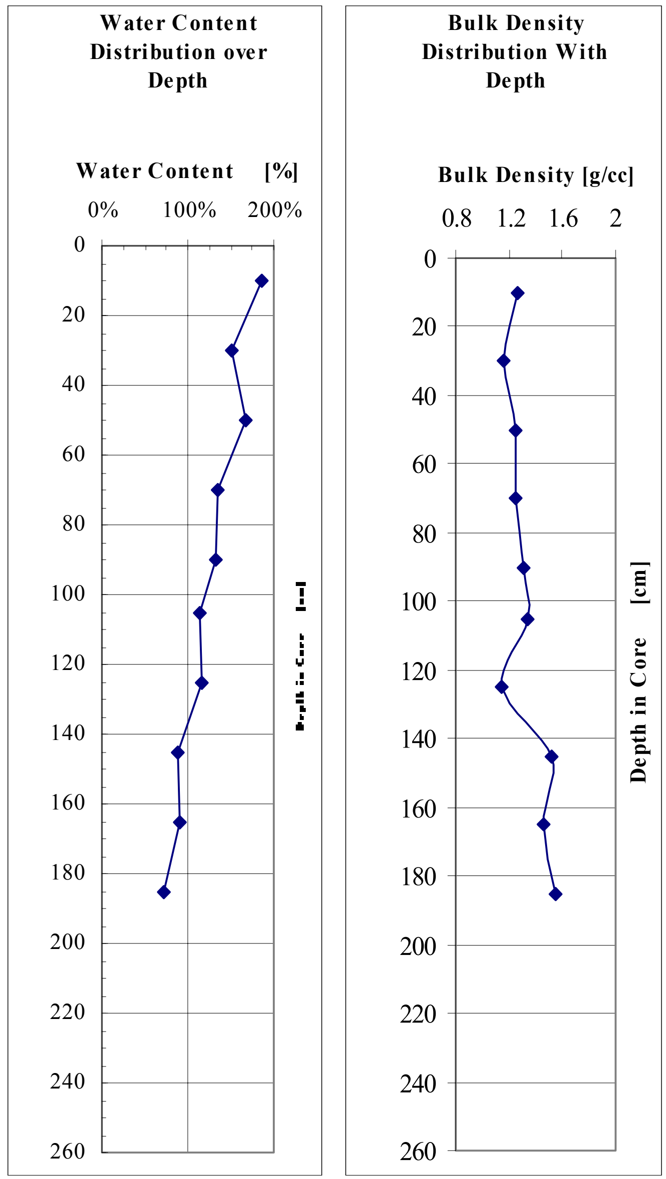
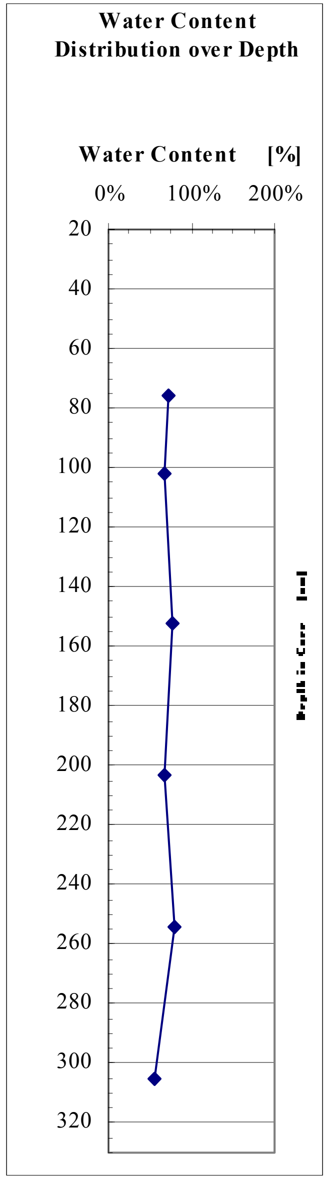


Figure 33: Profile of physical properties for VC-03



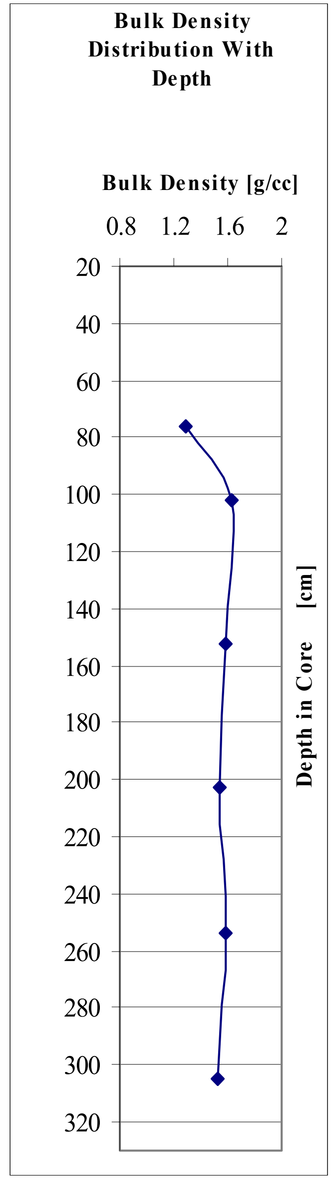


Figure 34: Location of cross-sections

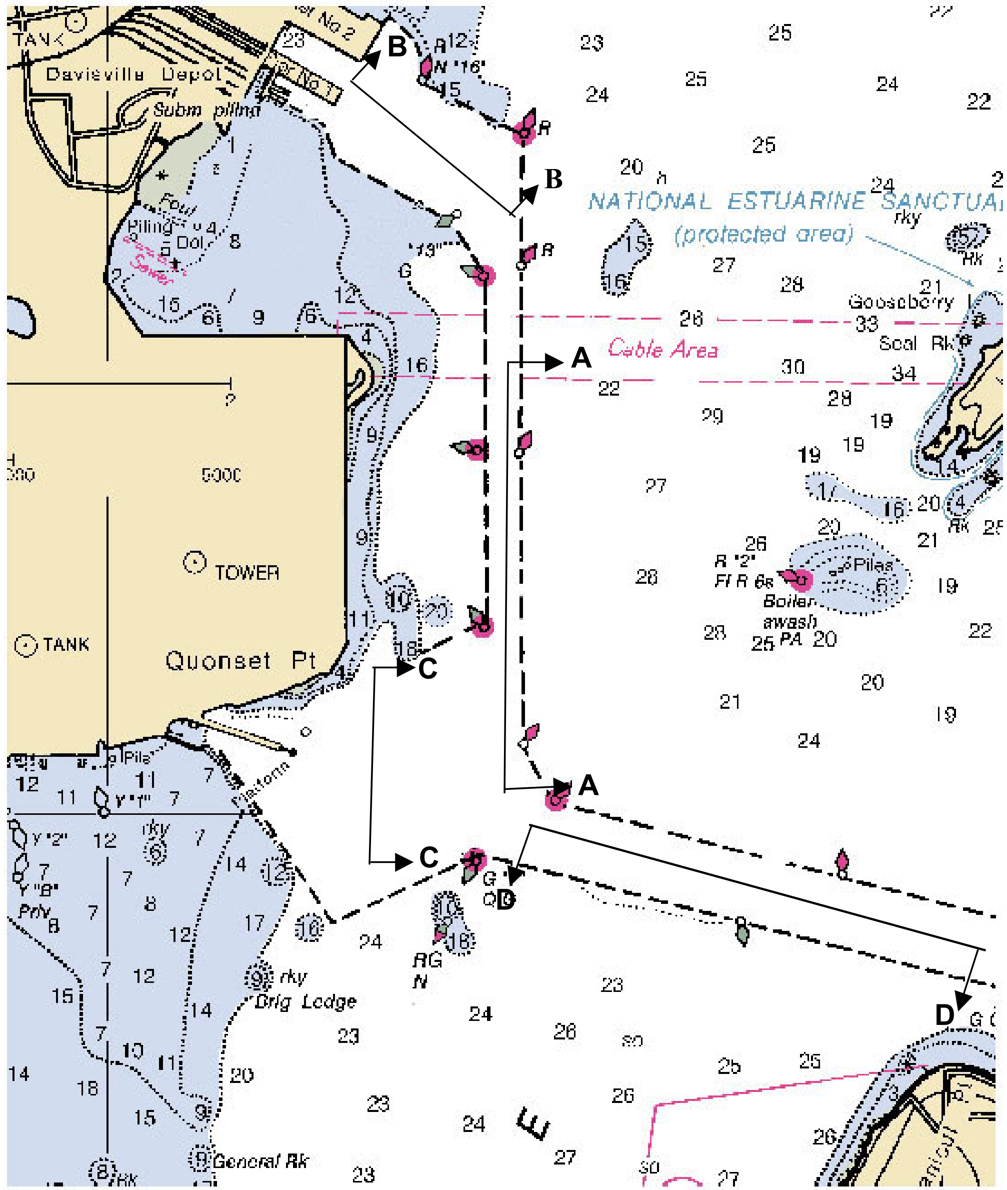


Figure 35: The cross-section of A-A, Davisville Channel

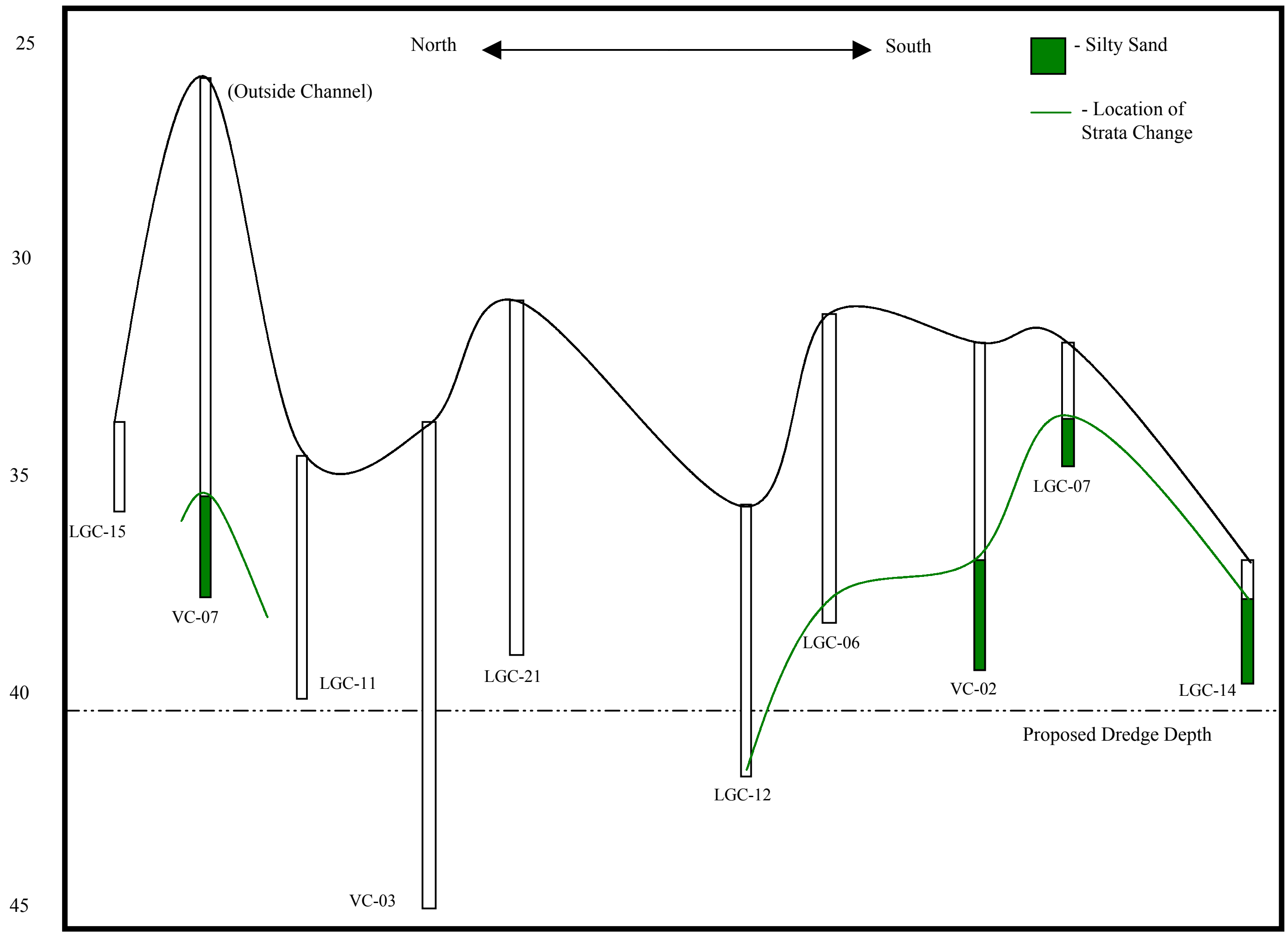


**Figure 36: Channel configuration,
assumed dredge depth is -40 MLW**

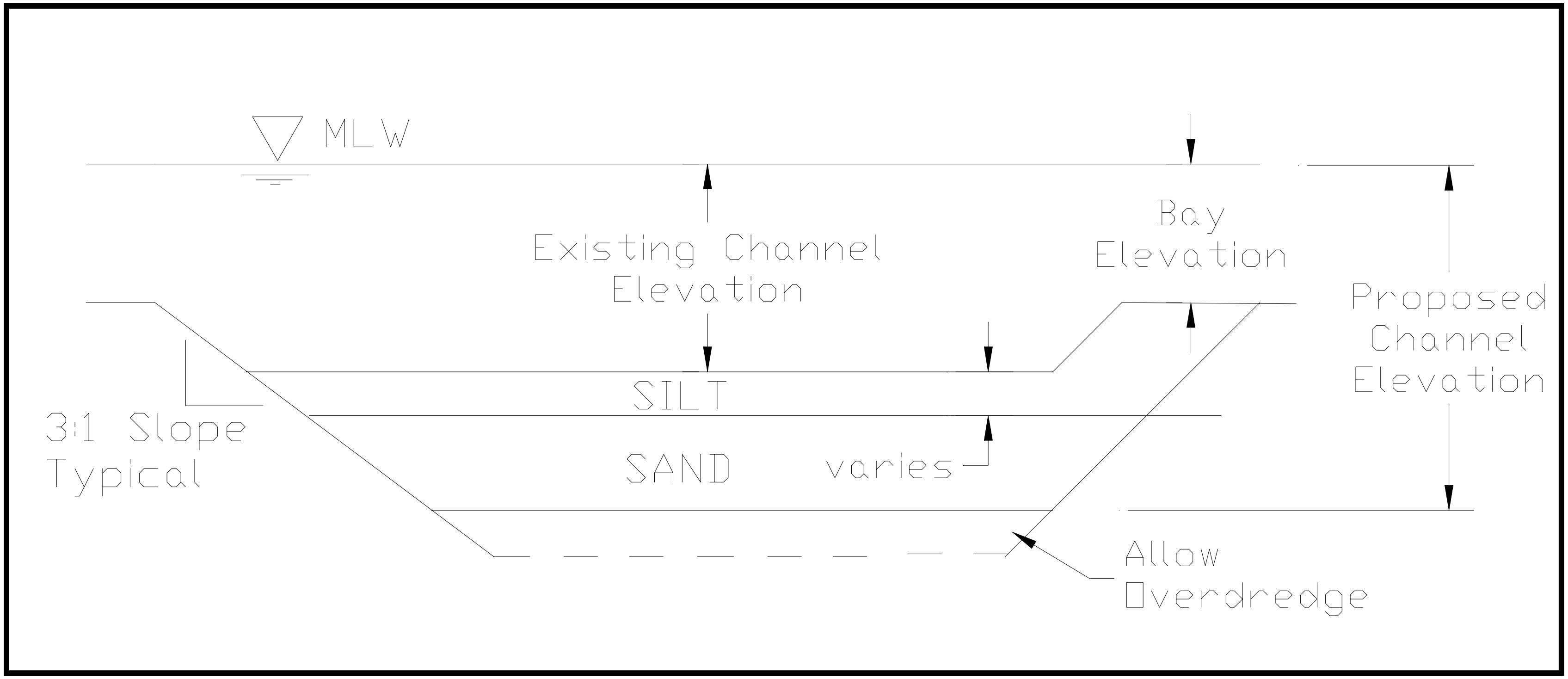


Figure 37: The cross-section of B-B, Davisville Turning Basin

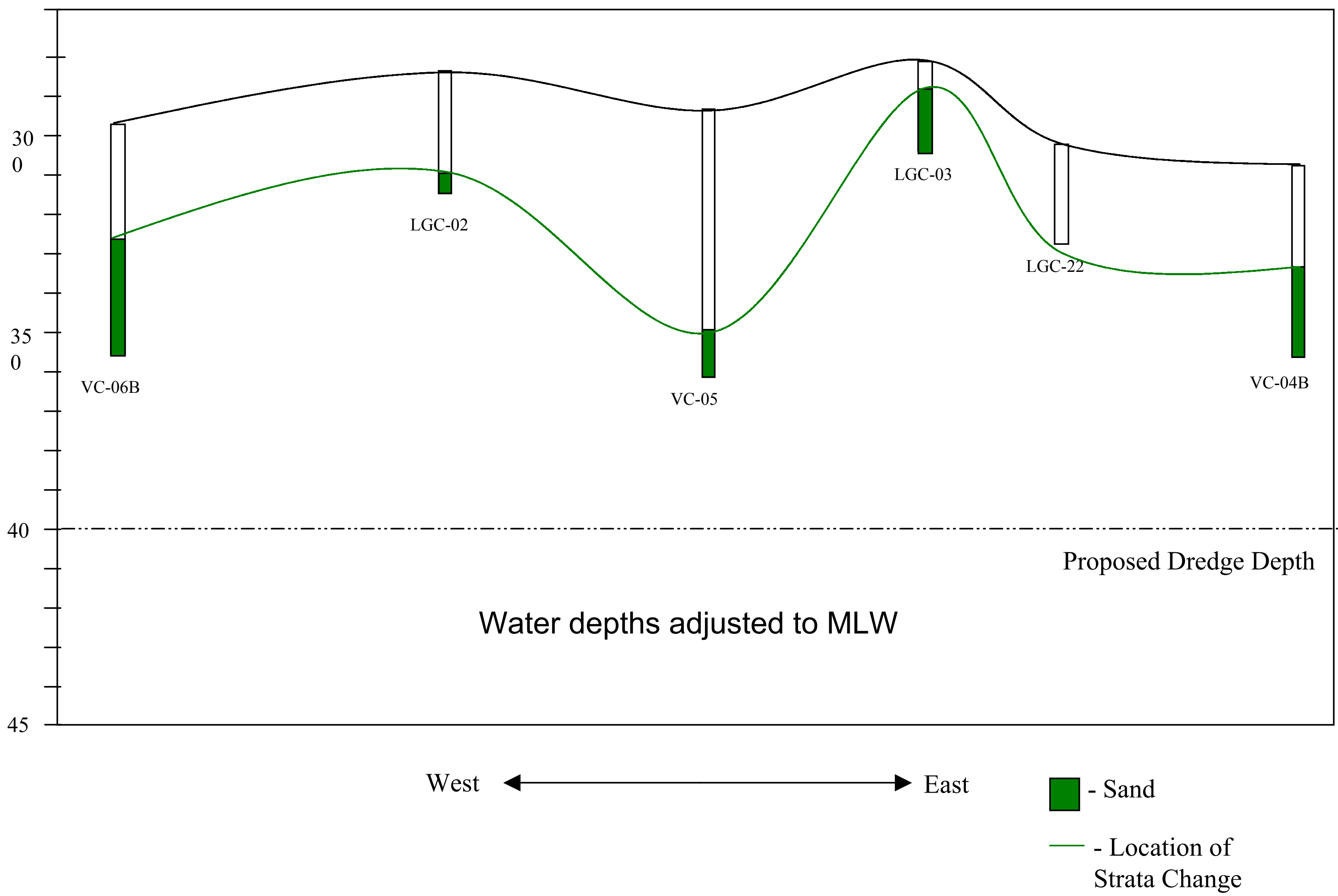


Figure 38: The cross-section of C-C, Quonset Turning Basin

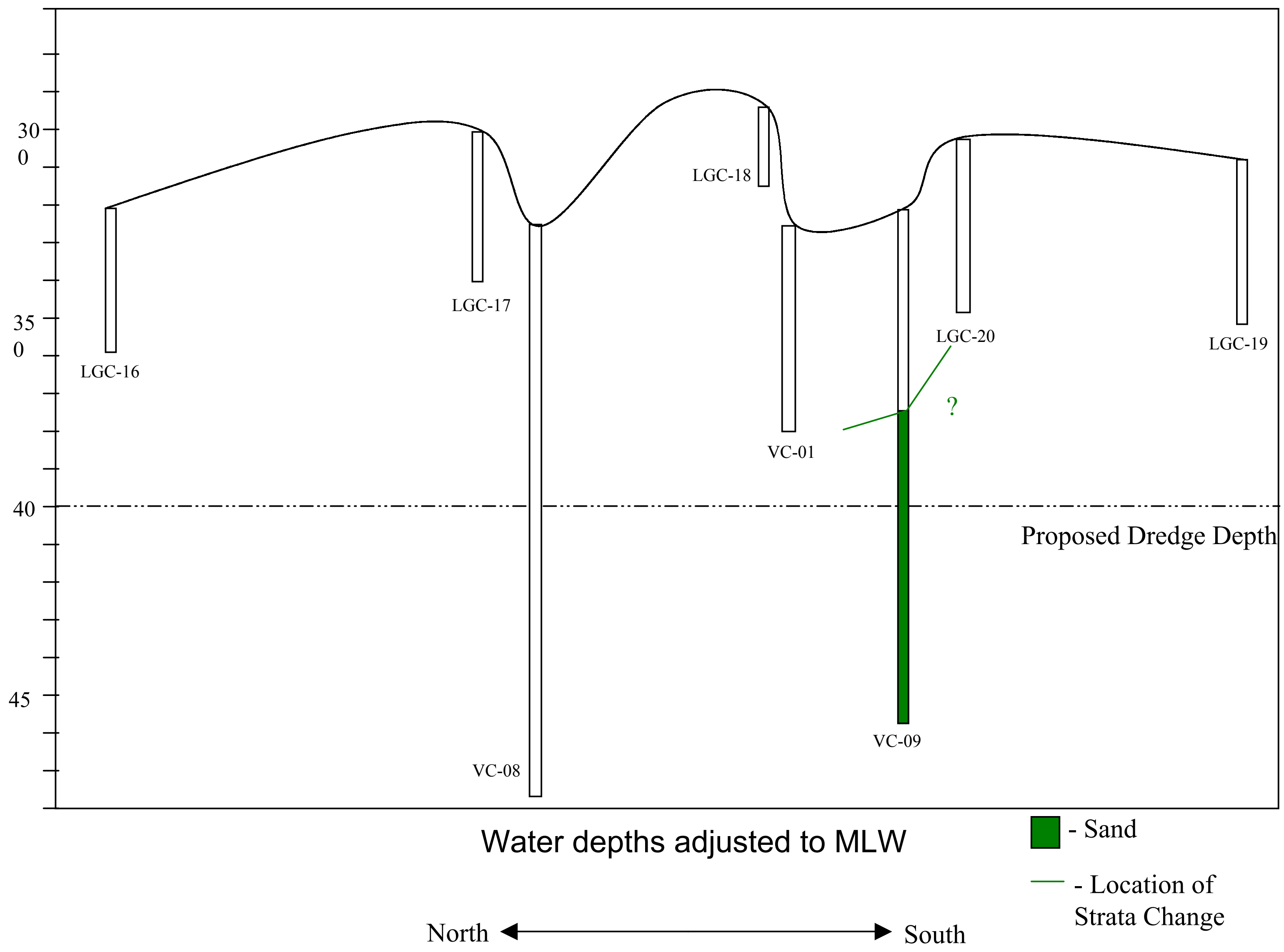


Figure 39: The cross-section of D-D, Quonset Channel

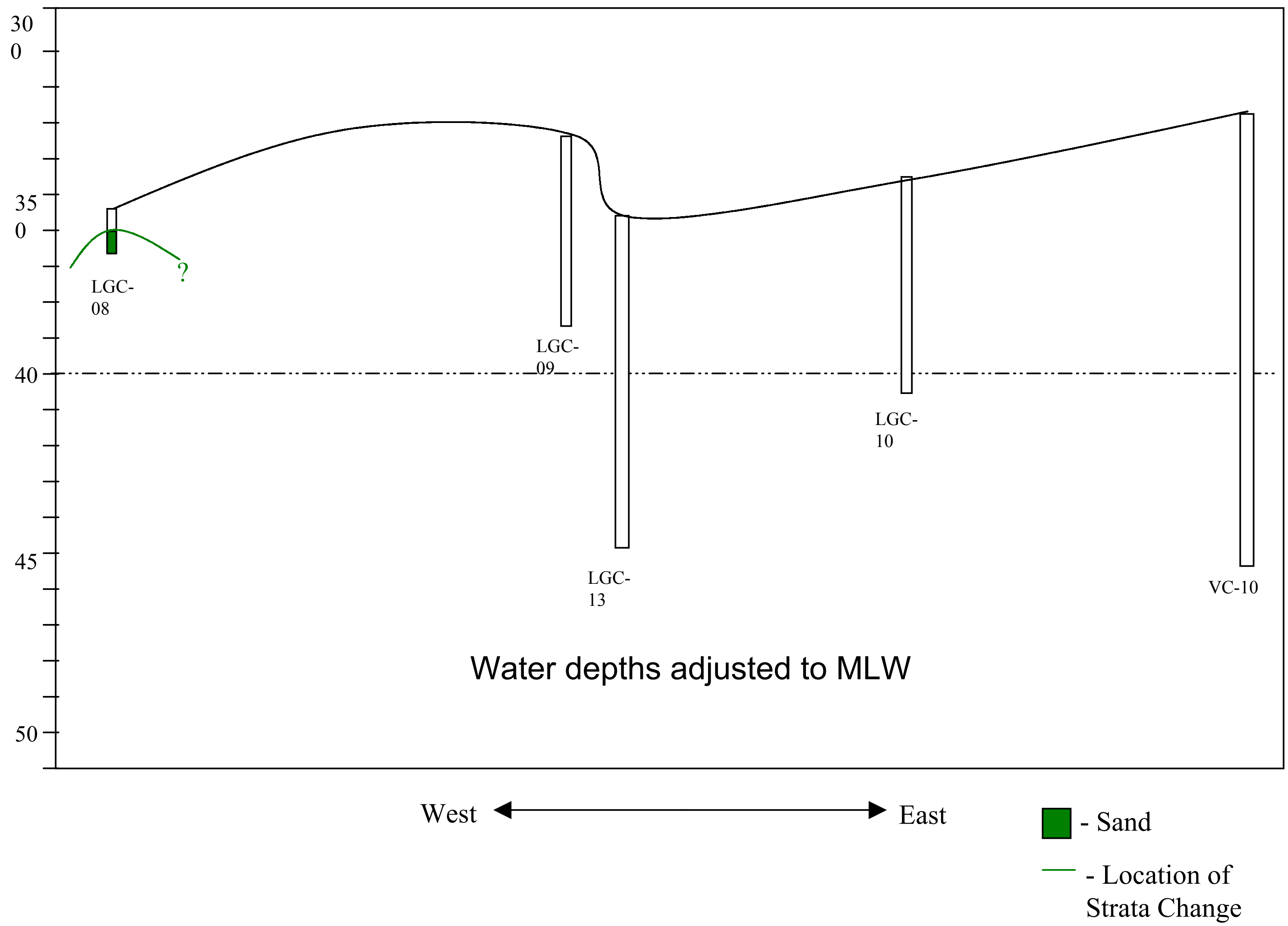


Figure 40: Standard and modified compaction tests with permeability points

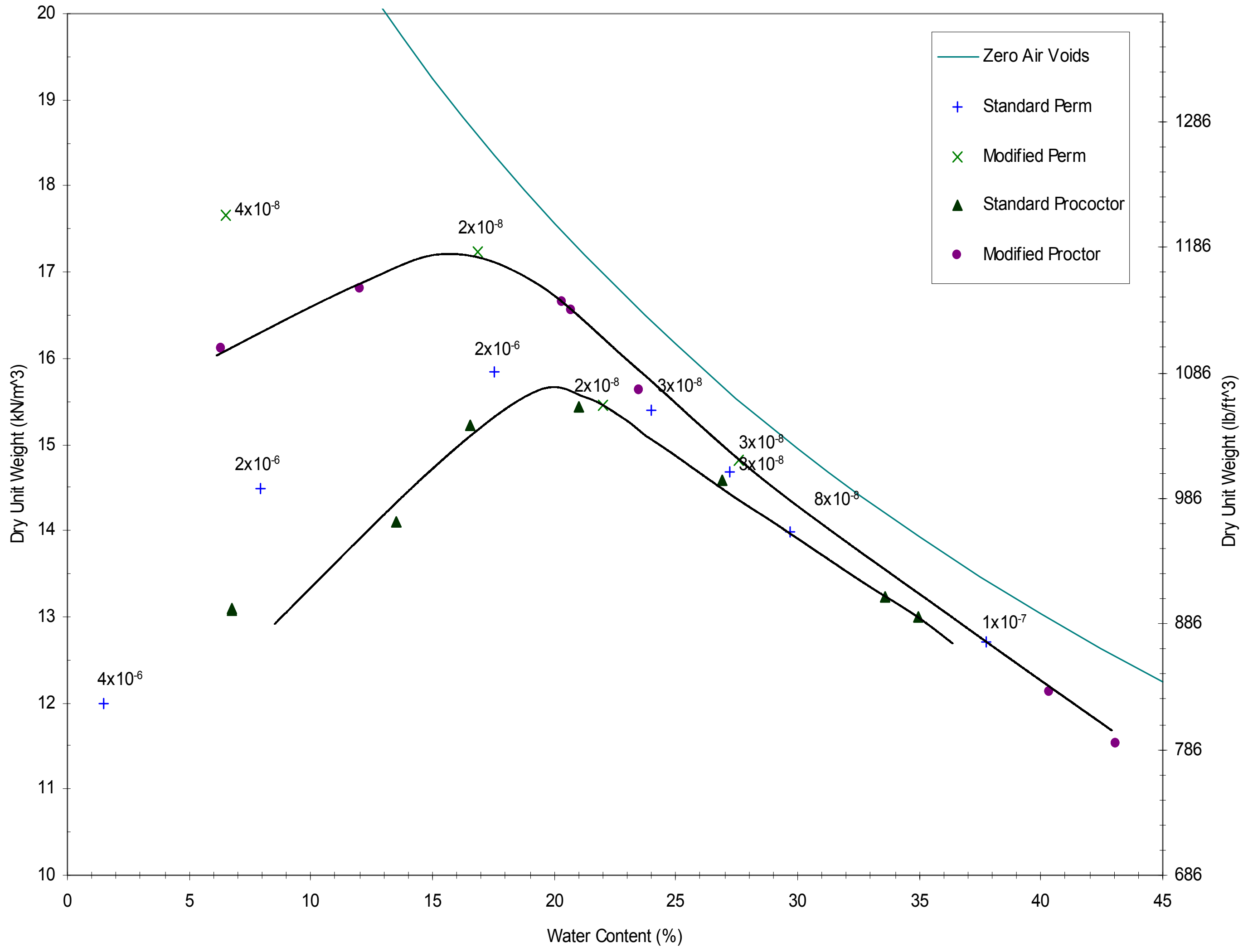


Figure 41: Sieve analysis on a sample of construction debris from Quonset Point

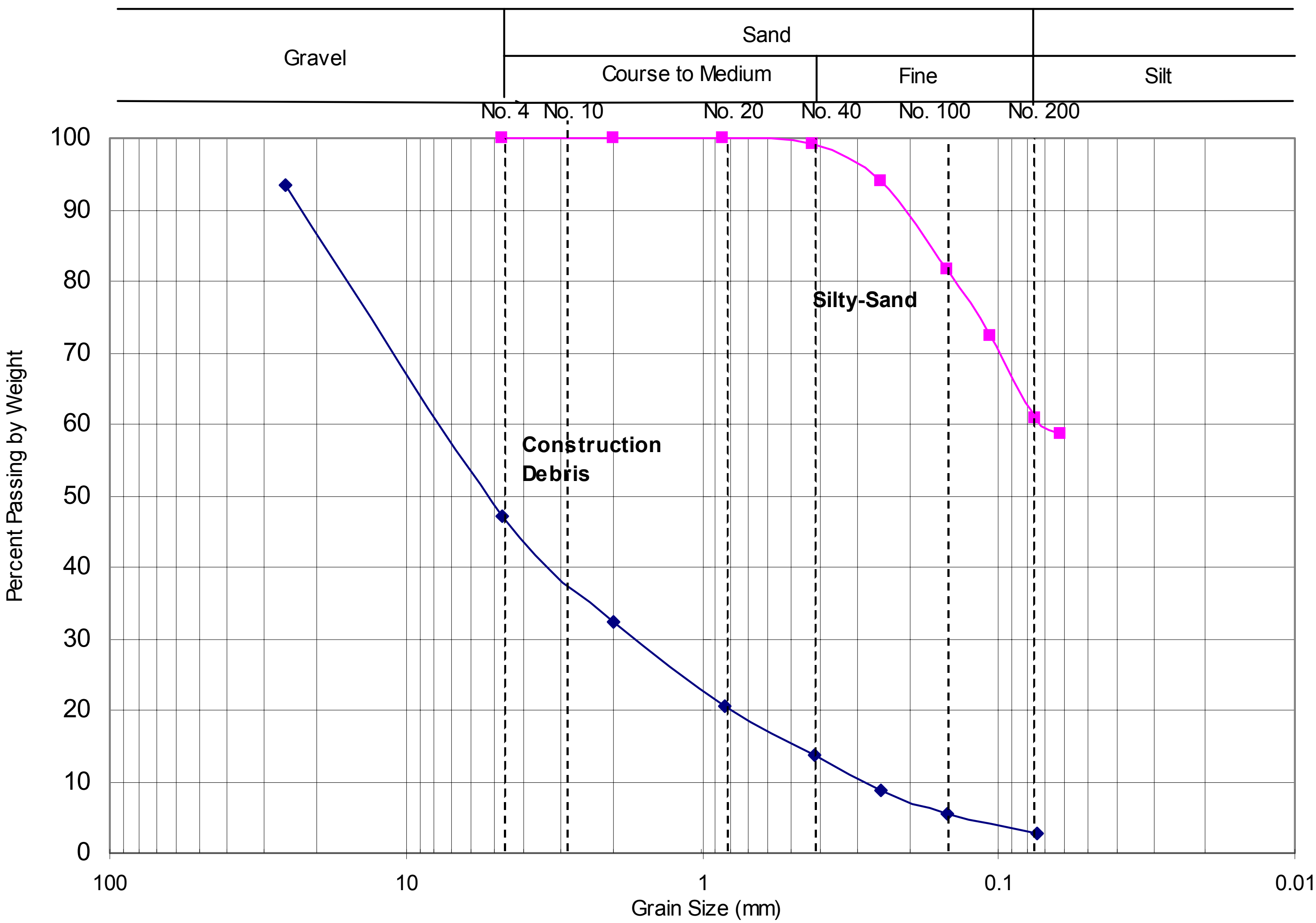


Figure 42: Harvard miniature compaction curve of sediment mixed with 3% lime

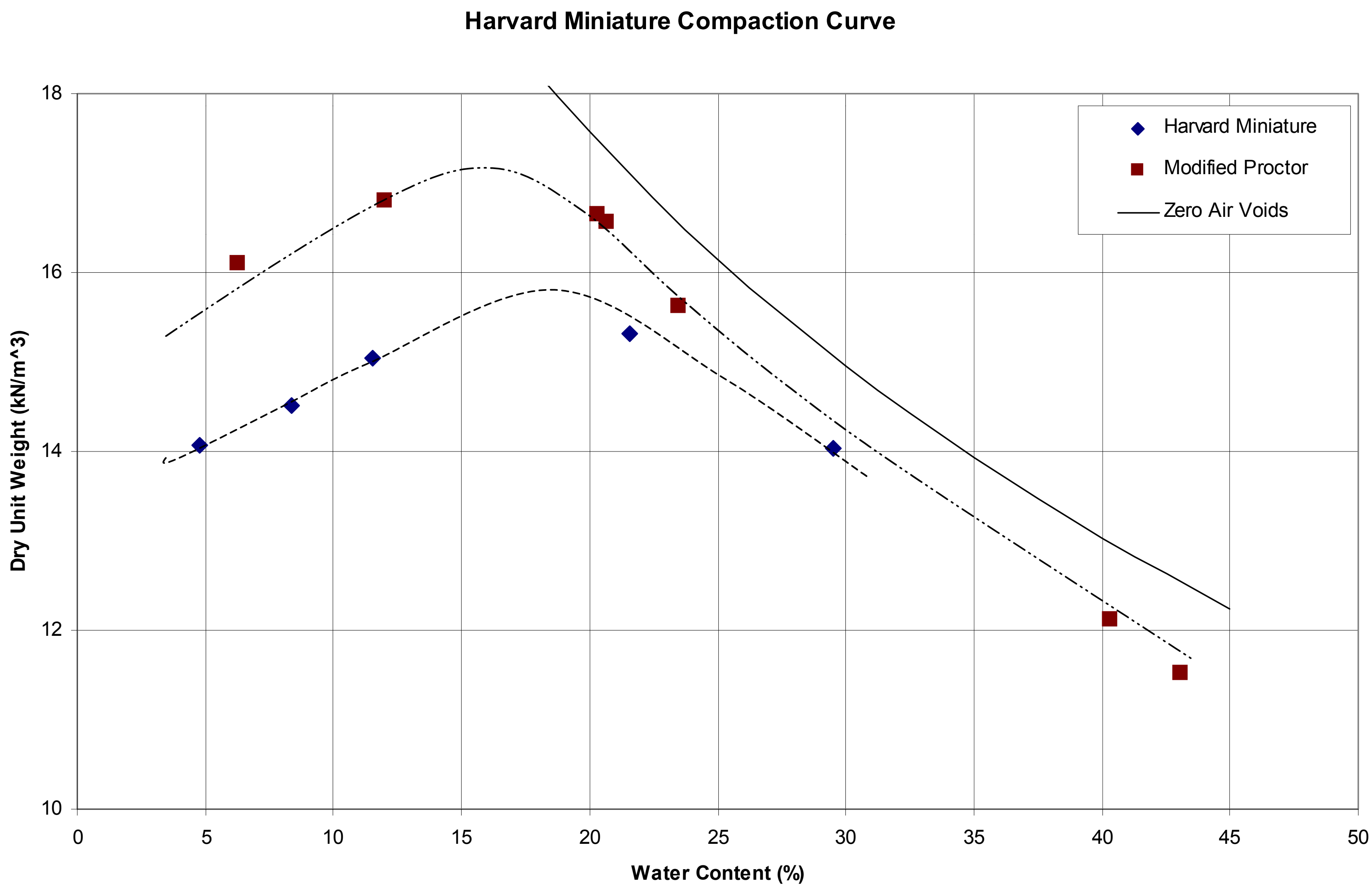


Figure 43: Stress-strain curve of sediment stabilized with 3% lime (samples cured for 1 hour, 7 days, and 28 days)

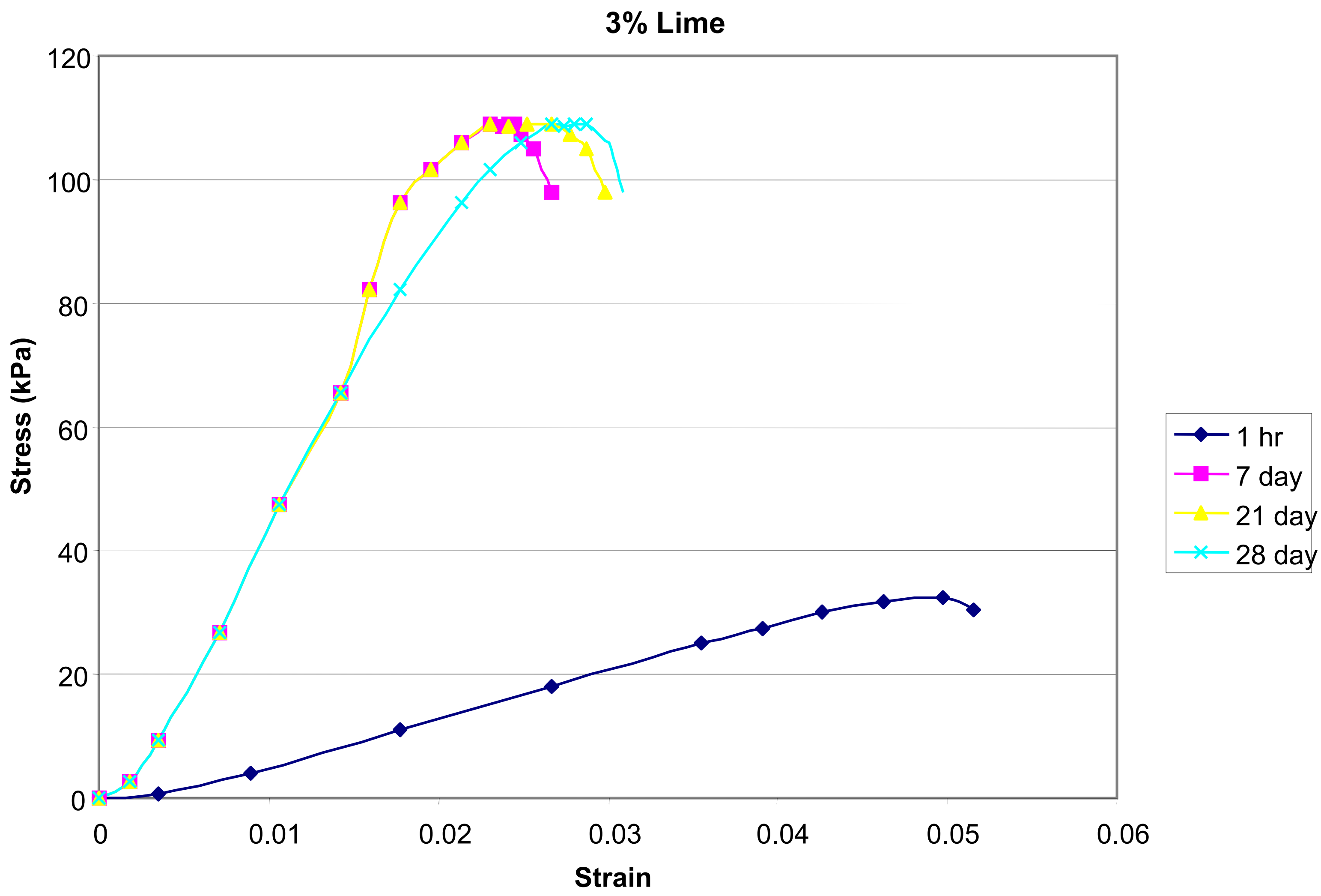


Figure 44: Stress-strain curve of sediment stabilized with 5% lime (samples cured for 1 hour, 7 days, and 28 days)

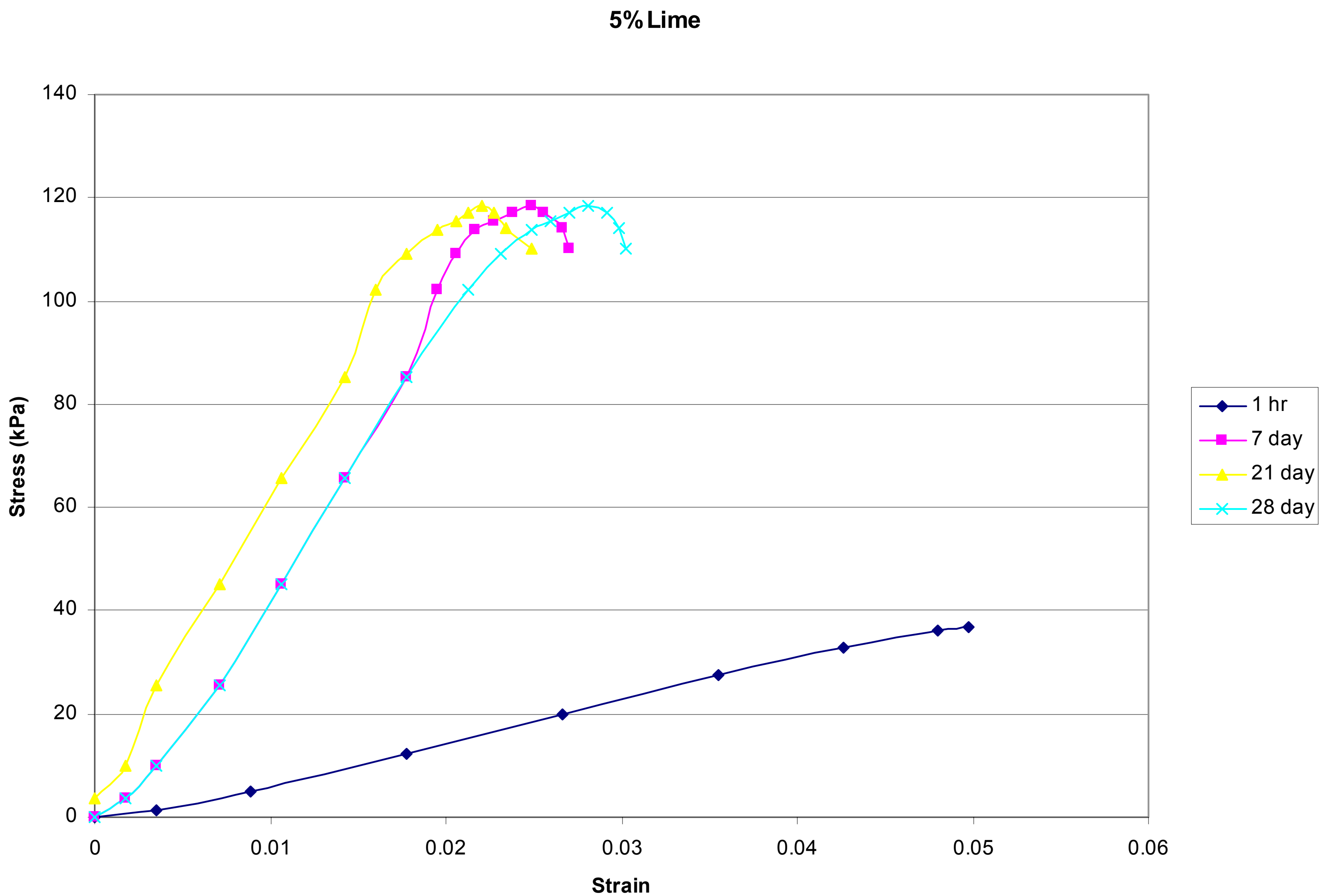


Figure 45: Stress-strain curve of sediment stabilized with 7% lime (samples cured for 1 hour, 7 days, and 28 days)

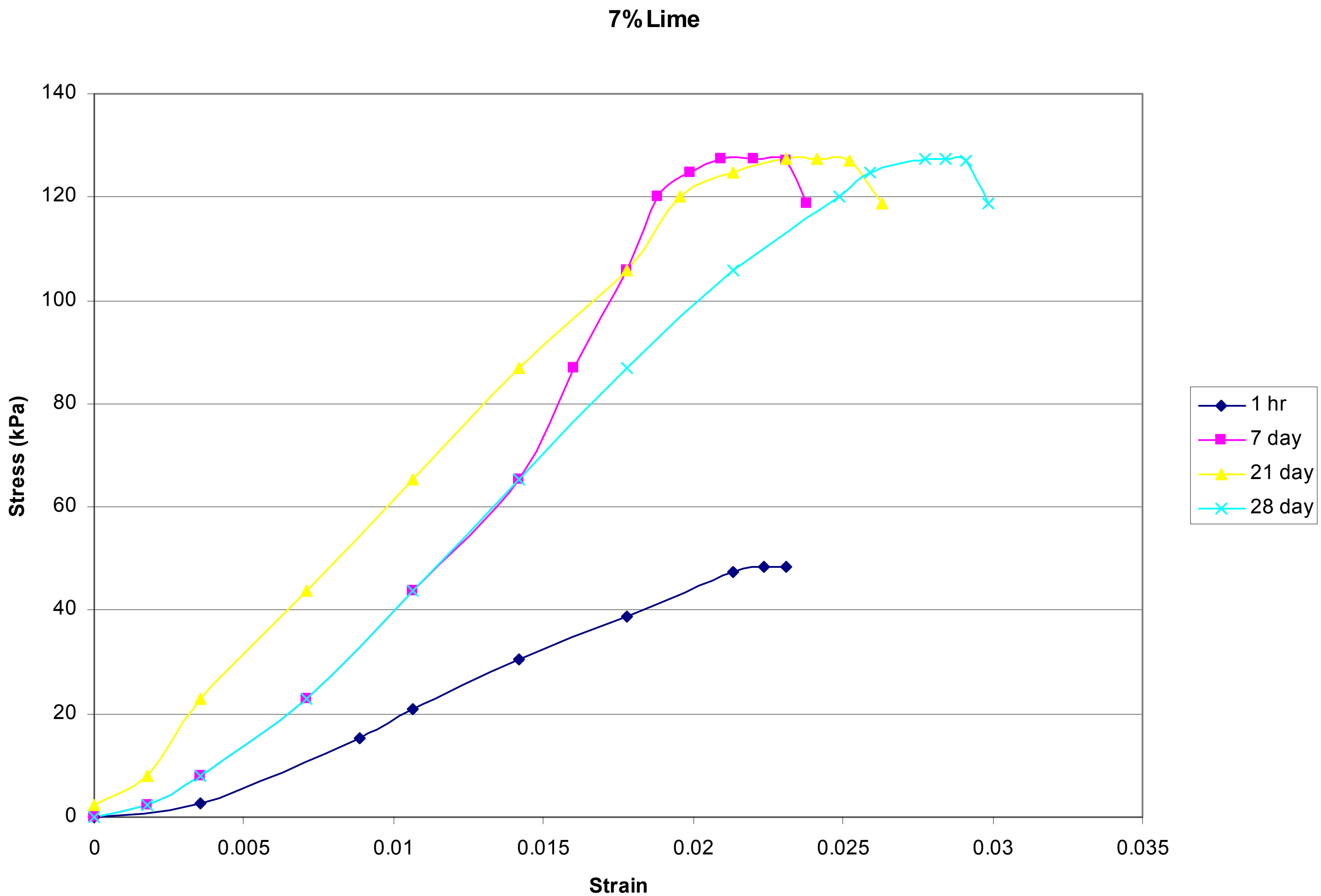


Figure 46: Compressive strength of soil/cement mixes as a function of curing time
(Note: Sediments were not washed to remove salt)