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April 23, 1963

A. N. Daniel, Jr.

E. I. DuPont De Nemours & Company
Engineering Department
Louviers Building
Wilmington 98, Delaware

Attention: Mr. A. J. McCullin
Design Division

RE: GENERAL SOILS LETTER
SAVANNAH RIVER PLANT

Gentlemen:

We are sending you herewith a preliminary draft of a general report covering certain factors involved in planning and executing foundation investigations for proposed structures at the Savannah River Plant. In accordance with previous discussions, this draft is submitted to enable the scope of the report to be defined. While the report is still in a preliminary stage, we will, of course, appreciate any specific comments, in addition to scope, regarding technical content and arrangement which you care to make at this time.

Very truly yours,

MORAN, PROCTOR, MUESER & RUTLEDGE

By William H. Mueser
William H. Mueser

WHM:ss
Encl.

MPMR_04-23-1963

(PRELIMINARY REPORT)

FOUNDATION INVESTIGATIONS AND TREATMENT AT SAVANNAH RIVER PLANT

E. I. DuPont De Nemours & Company
Wilmington, Delaware

MORAN, PROCTOR, MUESER & RUTLEDGE
CONSULTING ENGINEERS
415 MADISON AVENUE-NEW YORK 17, N. Y.

April 19, 1963

SYNOPSIS

Subsurface solution of calcareous material in a zone about 60 to 80 feet thick beneath the Savannah River Plant, at depths generally between 100 to 200 feet, has resulted in some subsoil defects and surface subsidences or sinks. While these appear stable and have caused no building movements since major plant structures were constructed over ten years ago, they should always be considered when constructing new facilities and periodic settlement observations should be made on all critical structures. Existing subsoil defects probably will result in no serious structure movements; however, where doubt exists and the structures are critical, remedial grouting can be performed, as was done during 1951-52 beneath selected structures.

The economic advantage of using available excavated materials in compacted fills supporting structures makes it desirable to evaluate probable settlement and possible swell of the compacted soil. Some excavated materials are not high quality fill materials but generally can be used, provided adequate field sampling, laboratory testing and analyses are performed. These are not generally necessary for low fills, but are required where fills more than about 10 to 15 feet thick support structures.

Subsoil information developed for the design of existing plant facilities makes detailed undisturbed sampling and testing unnecessary except for unusual structures or situations. Sources and limitations of existing data are summarized.

CONTENTS

FOUNDATION INVESTIGATION AND TREATMENT AT SAVANNAH RIVER PLANT

PART I: SCOPE

Planning of foundation investigations for proposed structures at the Savannah River Plant should take cognizance of certain unusual considerations that are imposed by local subsurface and geologic conditions and by previous investigations. These considerations include the following:

1. Design for subsoil defects resulting from solution of calcareous material.

2. Design for fill-supported structures.

3. Utilization and limitations of existing subsoil data.

The variable subsoil conditions found throughout the plant and unusual structural and operating requirements make it practically impossible, and undesirable, to follow pre-determined foundation investigation and design procedures when attempting to satisfy Item 1 above. It will generally be necessary to determine specific requirements for each structure, considering its function and possible consequences if it does not perform as intended. Nevertheless, recognition of basic considerations presented in Part II may promote a consistent approach when designing for subsoil defects resulting from solution of calcareous material.

Item 2, pertaining to utilization of compacted fills for supporting structures, is not unique to the Savannah River Plant. However, because compacted fills frequently impose significant foundation stress increases at great depths, they should be given special consideration when used at this project, as discussed in Part III. In addition, many of the subsoils which may become available as borrow are difficult to compact and may consolidate, or even swell under light loads, sufficiently to cause trouble with piping or fill-supported structures.

Item 3, which involves utilization and limitations of the large amount of existing subsoil data, is important because such data may be utilized for future construction provided its applicability is restricted to known conditions. This item is discussed in Part IV.

PART II: FOUNDATION INVESTIGATION AND TREATMENT FOR SUBSURFACE SOLUTION INDUCED DEFECTS

INTRODUCTION

Engineering and geologic studies performed for construction of the plant in 1951-52 established that the surface sinks present throughout the plant area result from subsurface solution of calcareous materials occurring in a relatively well-defined zone, 60 to 80 feet thick, in the McBean formation, which is generally found at depths of about 100 to 200 feet. The extent of solution is variable and is more pronounced towards the southern and eastern portions of the project area. As a result of these investigations, and because the behavior of large and heavily loaded foundations in the southeastern coastal plain was unknown, grouting was performed in 1951-52 beneath selected critical structures to permit their safe and immediate construction. The engineering and geologic studies disclosed that the surface sinks undoubtedly developed very slowly, over geologic time, but there was no assurance that this would continue to be true and, therefore, a conservative approach was adopted.

Principal considerations involved in planning and executing foundation investigations for the Savannah River Plant are discussed with reference to possible subsurface solution. While guides are suggested, these must be considered subordinate to application of judgment as complex operational requirements for structures at the plant introduce numerous special requirements.

PRINCIPAL CONSIDERATIONS GOVERNING SUBSOIL EXPLORATION

Basic Requirements

Adequate subsoil exploration and testing first must satisfy normal requirements for determining soil types, consolidation behavior, shear strength and other physical properties relevant to settlement, bearing capacity, slope stability and foundation design. Planning for these requirements is relatively simple since the overall soil properties are generally well known from the 1951-52 and subsequent exploration and laboratory investigations. Furthermore, surface and near surface subsoil conditions are relatively good and pose few problems.

However, for important structures, additional subsoil considerations are imposed by the solution zone underlying the project and it is frequently necessary to answer questions such as:

1. Is it necessary to explore, by borings, the condition of the solution zone beneath the proposed structures?

2. To what extent is exploration required of soils overlying the solution zone?

3. When is grouting of the solution zone or of the overburden indicated?

Structure and Site Factors

The principal factors involved in planning a subsoil exploration program for new facilities are: (1) type of structure, (2) thickness of soil between subgrade elevation and the top of the solution zone, and (3) the expected prevalence and severity of subsurface solution induced defects in the solution zone and overlying materials. These factors, and associated aspects applying to specific sites, are listed in Table No. 1. The importance of the thickness of soil between subgrade and the top of the solution zone with reference to the building or fill size cannot be over-emphasized.

Because of the southeast dip of the solution zone and the large variations in plant topography, the overburden thickness in one area of the plant may be sufficient to preclude difficulties from subsurface solution defects whereas the converse may be true elsewhere. Special care should, therefore, be exercised when constructing structures where the ground surface elevation is unusually low. Low ground surface elevations decrease the thickness of soil above the solution zone and may have resulted in locally accelerated solution rates. An unusually thin zone of natural soil between subgrade elevation and the top of the solution zone may not provide sufficient protection even for relatively non-critical structures. While voids may be found in the overburden above the solution zone, current knowledge indicates that solution induced defects are restricted to the solution zone in the McBean formation or the material immediately overlying it.

The equilibrium of soil overlying solution induced defects often decreases because of variations in surface or ground-water movement, whether resulting from pumping, natural causes, or construction of plant facilities. This was taken into account when the plant was constructed by locating water supply wells away from major structures. However, ground-water seepage from canals or storage ponds may eventually be responsible for some changes in the present equilibrium of soil over solution defects. Careful annual inspections of adjacent areas should provide adequate control as major structures are not located adjacent to canals or storage ponds.

Acceptable Degree of Risk

The cost and delay of a comprehensive foundation investigation and treatment program must be balanced against: (1) structural requirements, (2) consequences of possible differential settlements, and (3) other factors such as contingent operational problems. Structural, operational, and economic considerations may warrant assuming a calculated risk, at least under some circumstances, in lieu of adopting technically desirable and relatively safe foundation exploration and treatment procedures.

The successful behavior of structures constructed during the initial plant construction program over ten years ago is of special interest because the locations and types of structures constructed at that time are probably as critical as may apply for future work. Structures were constructed at some locations, for example, in the D-area, where subsurface solution defects are relatively critical. Yet in this area, and beneath some major structures in other areas, subsurface grouting was not attempted and a modified foundation design and calculated risk were accepted instead. The successful performance of these structures is, therefore, reassuring and significant in indicating that existing solution defects are not highly active and that calculated risks can be assumed under some circumstances.

Sounds premeditated. But was it?

An evaluation of the performance of existing structures at the plant must take full cognizance of the major importance of surface drainage during and after construction and the proximity of each site to deep water supply wells, as these factors are of major importance in determining if subsurface solution defects result in structure settlement. Subsurface solution apparently proceeds very slowly and limited voids or soft areas are expected to remain stable unless subjected to: (1) large stress increases resulting from construction activities, (2) major changes in surface drainage, (3) subsurface water movement resulting from pumping from wells, or (4) shocks such as earthquakes, blasting or explorsions. The importance of these factors was recognized and taken into account when the plant was originally designed, except that parts of Item 4 are of more recent significance.

CLASSIFICATION OF STRUCTURES AS REGARDS SUBSURFACE DEFECTS

Without attempting to formulate rigid design planning procedures, it appears desirable, as a means of promoting consistent design approaches, to classify structures as regards their sensitivity to possible results from subsoil solution defects. This can be done, of course, only by departments concerned with designing and using structures and involves operational and policy elements with which we ~~probably~~ are not familiar. However, as a basis for discussion, a preliminary classification system has been prepared and is shown on Table No. 2. A grouping of this general type would promote, we believe, a consistent basis for either omitting or undertaking foundation grouting at proposed structures, when used with other data available.

SCOPE OF SUBSURFACE INVESTIGATIONS AND FOUNDATION TREATMENT

A proposed scope of foundation exploration and remedial work for each structure classification shown on Table No. 2 is shown on Table No. 3. As a basis for evaluating this table, we believe it can be assumed that a sudden catastrophic settlement of a portion of a building area is unlikely to result from static forces. Also, because the sinks found throughout the project are generally large and do not involve sharp variations in surface elevation within small horizontal distances, we believe it can be assumed, as a reasonable calculated engineering risk, that should any solution induced defects result in future structure movements, these movements will occur gradually and may involve relatively large areas. While these assumptions are considered reasonable, their applicability for specific applications should be examined to determine if the site location or other data indicate limitations in their validity.

The suggested scope of work shown on Table No. 3, is intended primarily for illustrative purposes and ignores the structural design of the facility to be constructed. Obviously, the hazard to a structure from possible movements resulting from subsurface solution depends partially upon the capability of the structure to withstand differential settlements and/or non-uniform subgrade support. In addition, piping and utility lines connected to the structure may impose more severe requirements than those imposed by the structure itself. Consequently, Table No. 3 presents non-rigid guidelines, which should be revised as appropriate for each structure. General comments regarding use of this table are given below.

Category I - Non-sensitive or Minor Structures

Structures in this category would ordinarily not increase the stress at the top of the solution zone and would, therefore, not require subsoil exploration in addition to that for normal foundation design requirements. However, should such structures be placed on deep fills, or be sufficiently heavy to increase significantly the stress at the top of the solution zone, deeper subsoil explorations would be warranted, as proposed on Table No. 3.

Category II - Structures of Medium Sensitivity or Large Cost

A basic requirement for structures to be placed in this category is that serious problems would not arise if cracks developed. Thus, the feasibility of repairing the structure would be one requirement. ~~for a structure to be placed in this category.~~ A second requirement might be that loss of the contents of the structure would not present major hazards.

Structures in this category should receive adequate exploration for normal design purposes and, in addition, fishtail type borings in the overburden above the solution zone to assure that an intact band of soil of adequate thickness separates the foundations of the structure and the top of the solution zone. The thickness of this zone should be sufficient to permit arch action to develop, capable of spanning solution induced defects. In general, a zone at least 75 feet thick between the subgrade and the top of the solution zone should be explored for structures in this category. This suggested thickness is, of course, variable and may be modified according to the size of the structure. At least one such boring should be made for small buildings; additional borings should be spaced on a grid approximately 100 feet square for larger buildings. Special precautions should be taken to observe and record: (1) dropping or slow settling of the drill rods, (2) gradual or sudden losses of drilling water, and (3) presence of calcareous materials.

Category III - Structures of Maximum Sensitivity

The subsoils beneath all structures placed in this category should be explored by fishtail borings to the bottom of the solution zone and all defects in the solution zone and in the overlying soils should be grouted unless they obviously are minor. The spacing of borings in the overburden and in the solution zone depends upon the size of the structure and the loads imposed by it on the subsoil. In general, boring spacings should not exceed the equivalent of a 100-foot square grid with a boring in the center and corners of each square. In areas where significant subsurface defects are revealed, closer spacings and additional borings should be used.

INTERPRETATION OF SUBSURFACE DATA

Upon completion of a subsurface investigation, data available for evaluation of a site will generally present the results from exploratory and fishtail type borings and the aerial photographs analyzed during the 1951-52 engineering and geologic studies showing the locations of sinks. The originals of these photographs are available at the Savannah River Plant and are reproduced in the engineering-geologic investigation reports prepared in 1951-52. Boring data available will generally consist of: (1) soil descriptions, (2) sampling penetration resistances, (3) any depths at which the drill rods settled slowly or dropped suddenly, (4) any depths at which drilling fluid was lost, the approximate quantities of fluid lost, and whether circulation was completely lost or recovered, and (5) depths at which calcareous materials were found.

In many cases, study of the above data will indicate defects, if any, resulting from subsurface solution and whether the site can be used without grouting. In some instances, however, a study of available data will be less definitive and conclusions regarding suitability of the site without remedial grouting can be reached only after consideration of other factors involved, including the type and use of the proposed construction, the degree of risk considered acceptable and the extent and severity of subsurface defects. Basic considerations which may be applied to specific cases in accordance with local conditions, are discussed in following paragraphs.

The 1951-52 boring and grouting work indicated that sudden dropping of drill rods results primarily from displacement of soft material, rather than from the drill rods entering a relatively unfilled cavity. Borings made in grouted areas, where relatively large droppings of the drill rods had been observed, failed to reveal thick layers of grout and indicated that probably the most severe common subsoil condition existing throughout the solution zone is a porous, spongy, relatively open strata that has substantial structural competence. Consequently, it is concluded that the mere loss of drilling fluid when making a boring is not in itself indicative of major subsoil defects, automatically requiring remedial grouting. While this is believed to be generally true, there may be exceptional cases where solution has resulted in relatively large cavities, which pose more of a threat to overlying structures than has been revealed by borings to date. If these conditions exist on the project, they are considered most likely to be found where the ground surface is low and surface water has tended to concentrate, thereby accelerating the solution processes and tending to wash out previously formed, partially or completely filled cavities.

Losses of drilling fluid and their frequency and severity, are considered less significant than the behavior of the drill rods during drilling and the observed resistance when recovering samples. Where no rapid dropping or slow settling of the drill rods occurs, and where the sampling penetration in the solution zone is high, a serious open solution cavity condition is not considered probable even though some borings may lose drilling fluid. However, if a large percentage of the borings freely lose drilling fluids, it would be necessary to re-examine critically this conclusion.

Borings made at the Savannah River Plant, regardless of their purpose, should be grouted to prevent free seepage into the solution zone from overlying soils as this might wash out existing cavities. The groundwater level is often at substantial depths below the ground surface (i. e. 50 feet), therefore, the grout will be under relatively high pressure. A thick viscous grout should be used to prevent excessive travel and careful records should be maintained of the quantity required to fill each boring. If drilling fluid was lost, some grout in addition to that required to fill the borehole may be anticipated, but where these quantities are small, a few cubic yards, a serious subsoil condition is not indicated especially if the loss of drilling fluid is the only abnormal event observed in the boring. Grouting the borings constitutes an important test of the solution zone and should be considered together with other data in evaluating the subsoil defects at the site.

Evidence of abnormally soft material, in the overburden above the solution zone, should be given special attention as such behavior indicates an upward development of subsurface defects from the solution zone, the presence of which, between the bottom of proposed structures and the top of the solution zone, would generally require further exploration and probably a need for remedial grouting. The thickness of intact soil between subgrade elevation and the solution zone, with respect to the size of structures and net loadings, is considered of major importance.

The considerations mentioned above, together with stresses to be imposed by the proposed construction where defects may exist, are to be utilized in assessing the safety of a proposed site. Analyses of various items of field information represent aids to engineering judgment, which together with intuitive reasoning based upon previous experiences cannot be expressed in a quantitative manner. Consequently, attempts to formalize criteria for determining when corrective grouting is required should generally be discouraged. Because safety requirements necessitate more conservative procedures than would generally be acceptable when constructing comparable structures elsewhere, grouting should be specified for structures in Category III in all cases where subsurface investigations indicate any doubt as to the acceptability of the foundation. However, for structures in Category II, the evaluation can be based upon a lesser degree of conservatism.

SETTLEMENT OBSERVATIONS

The unusual foundation and geologic conditions which resulted in solution of calcareous material and development of surface sinks, combined with the highly sensitive nature and unusual operating requirements for many structures at the Savannah River Plant, impose a continuing necessity to determine critical structure elevations so as to be aware of possible indications of surface movements. Despite the relative stability of existing structures, we believe that systematic settlement observations, made with extreme care, should be made on critical structures at least semi-annually.

We do not know if, or to what extent, settlement records have been systematically assembled and studied, but recommend that if this has not been done such a program be instituted. Because the surface sinks are believed to develop slowly over long periods of time, study of periodic settlement observations should enable appropriate corrective action to be taken, if required, before large settlements occurred. Settlement observations have value only if performed with unusual accuracy and should be referenced to at least two bench marks, each located a minimum of 1,000 feet from the structure being observed.

Without attempting to list structures which should be included in a program of the type discussed, it appears desirable to make periodic settlement observations on all 105, 221 and 241 structures and, at yearly intervals, on all pump house and powerhouses.

PART III: SUBSOIL INVESTIGATIONS AND DESIGN FOR FILL-SUPPORTED STRUCTURES

BASIC CONSIDERATIONS

The use of well-compacted fills to support structures is an accepted procedure as suitable fill materials can be compacted to densities equal to or higher than natural densities, in many cases. Thus, structures on fills may settle no more, and frequently less, than structures on natural soil. Fills must be well-compacted, however, and normal design requirements for support of structures must be considered together with additional factors introduced because of use of partially saturated compacted soils.

Principal factors to consider when using fills for supporting structures are listed on Table No. 4. In cases where the underlying natural foundation soil is preconsolidated, as it is in many parts of the Savannah River Plant, fill settlements resulting from increased stresses in the foundation soil will be small and occur mainly as recompression during construction, thereby making settlement analyses unnecessary. However, where fills are more than about 20 feet above the adjacent natural ground surface, estimates of foundation and fill settlements may be required.

The compressibility and compaction properties of available fill materials are particularly important at the Savannah River Plant because highest quality materials are not generally available. Sandy clays and clays frequently available from required excavations are often sufficiently plastic to make compaction difficult; nevertheless, they can generally be used provided adequate compaction and control are performed and that rainfall is not excessive.

PROPERTIES OF COMPACTED SOILS

Typical properties of compacted soils are tabulated on Table No. 5 with reference to the Unified Soil Classification System. Soils at the Savannah River Plant which may be available for borrow are identified by an asterick to the left of the group symbol on this Table. Well-graded sand and gravel mixtures make excellent fills but are not available on the project; however, poorly graded clean sands, having the group symbol SP, and silty sands falling in the SM group, are generally found throughout the plant site as a surface layer about 5 feet thick and make good fill materials, when properly compacted. The clayey sands, classified as SC soils, are frequently available from required excavations and make relatively good fill materials where the per cent finer than the No. 200 sieve does not exceed about 25 per cent. Where they contain more fines, compaction becomes difficult and their compressibility increases.

Clayey fine sands with more than 50 per cent passing the No. 200 sieve, classified as ML materials, are not normally found throughout the plant site; however, sandy clays falling in the CL group may be available from required excavations, as may clays falling in the CH group. These materials are generally difficult to compact and should be used only after careful study of their compaction, consolidation and swell properties and the required fill performance.

A general relationship between dry density and moisture content of compacted soils, useful in preliminary planning, is shown on Figure 1.

DESIGN OF FILLS

General considerations involved in design of fills intended to support structures are listed on Table No. 6, which is believed to be self-explanatory. Permissible differential settlements and expected fill and foundation settlements determine if compacted fills can be used for support of specific structures. Permissible differential settlements shown on Table No. 7 are primarily illustrative and values for specific structures should be based on their character and function.

Various behavioral characteristics of compacted soils are listed on Table No. 8 for use in conjunction with Table No. 6. Many items on these tables are minor for low fills and/or light structure loadings, but become significant where: (1) the fill thickness is more than 10 to 15 feet, (2) unit structure loadings are large, or (3) the foundations occupy a large portion of the fill area.

Where clays, sandy clays, or clayey sands with more than about 25 per cent finer than a No. 200 sieve are available from excavations, they can generally be used but increasing caution is required as the proportion of fines increase. Consolidation tests and analyses may be required and possible expansion should be considered where such materials are used as fill beneath warehouse floors or lightly loaded foundations which may be sensitive to heave movements. While clean sands should be densely compacted, it may be necessary to compact highly plastic materials that are lightly loaded to low densities at high moisture contents. When using clayey sands, sandy clays and clays, compacted densities as high as 95 per cent of modified Proctor maximum density should be specified only where required according to detailed analyses and when the fill will not be placed in winter months.

Clean sands compact best when practically saturated, and settle little if they become saturated through infiltration of rain water, prevention of evaporation, and/or inflow of water from the bottom or sides of the fill, but this is not true with clayey sands, sandy clays and fat clays. The possibility of substantial settlement as a result of adsorption of water should be considered where materials other than clean sands are used as fill.

When considering supporting structures on compacted fill, the cost of alternative designs, using piers drilled through the compacted fill or other foundation types, should be estimated. Alternative procedures may be economical where inferior materials are available from excavation or when winter and spring rains and cool days make it difficult or impossible to construct a well-compacted fill with a closely controlled moisture content. When such conditions may prevail during fill placement, clean sands should be used or the structure supported on underlying undisturbed soil.

SPECIFICATIONS AND CONTROL TESTING

Principal factors involved in compaction specifications and control testing during construction are listed on Table No. 9. We generally favor a "method" type specification in which the procedure to be followed in placing and compacting the fill is fully described including such elements as: (1) maximum lift thickness, (2) required placement moisture contents, (3) type of compaction equipment, (4) minimum coverages of specified compaction equipment, and (5) payment for additional coverages if ordered by the owner. This permits the contractor to estimate closely his costs and minimizes the need for contingencies in his bid.

"End-result" type specifications requiring only specified moisture contents and densities involve a hazard of unsatisfactory results. This can be minimized by including additional requirements for maximum lift thickness and minimum coverages of specified compaction equipment but it is necessary to state clearly that if additional compaction is required to achieve the desired results, it shall be accomplished at the contractor's expense and that no claims will be considered for compaction in excess of specified minimum requirements.

Compaction equipment and procedures and construction control testing are discussed on Tables Nos. 9 and 10 and few additional comments are believed required. In general, it is relatively easy to achieve high densities with clean sandy materials and densities of 95 per cent of modified Proctor maximum density can be specified. However, it is generally difficult to achieve 95 per cent of modified Proctor density for clayey sands and finer grained soils and such a high density should be specified only after study of the fill and structure requirements. If densities as high as 95 per cent of modified Proctor is required, test sections to determine compaction procedures and results should be considered where the proposed fill materials contain more than about 25 per cent by weight finer than a No. 200 sieve. Such tests, while most useful when performed before awarding a contract, ~~can be performed during construction~~, if necessary.

Construction control testing, see Table No. 9, should be provided by the owner, not by the contractor, although he should be encouraged to perform such testing for his own purposes if he so desires.

CONSTRUCTION PROCEDURES

The use of various types of compaction equipment, required lift thicknesses, and coverages for securing compacted densities of 95 to 100 per cent of standard Proctor maximum density are presented on Table No. 10. For higher densities, the lift thickness should be maintained the same or decreased slightly but generally it will be sufficient to increase the number of coverages by 50 to 100 per cent, or the inflation pressure of heavy rubber-tired rollers. For large-scale compaction work on cohesive materials, it is frequently desirable to adjust the foot contact area of sheepsfoot rollers in accordance with the bearing capacity of the compacted soil. A sheepsfoot roller having proper foot sizes for the soil being compacted will partially walk out after three or four coverages. If the feet penetrate the fill until the drum is in contact with the soil, even on the last pass, the foot area is too small and equal densities with less tractor effort can be obtained by increasing the foot area.

FIRST

PART IV: USE AND LIMITATIONS OF EXISTING SUBSOIL DATA

DATA AVAILABLE

A large mass of subsoil information relating to existing structures, including borings, laboratory testing, and analyses, is available, as listed on Table No. 11. Items 1 through 8 were prepared by the Corps of Engineers for and with the assistance of the Engineering Department of the Du Pont Company during the plant construction in 1951-52. Item 9 consists of work done subsequently and is probably incomplete. The data shown on Table No. 11 are extensive, generally well organized, and readily useable for new structures that may be constructed at the plant. Consequently, the need for undisturbed sampling and laboratory testing for future structures is minimized.

Available subsoil information should not be used in lieu of additional exploratory borings through the solution zone, or overlying materials, where solution induced subsoil defects may affect the stability of critical structures. When using available data, the decisive importance of the ground surface elevation should at all times be taken into consideration; an unusually low ground surface may result in the subgrade for a structure being close to solution induced defects in the solution zone or overlying materials.

SETTLEMENT RECORDS

Table No. 11 contains no references to settlement information for various structures despite our understanding that such data exist. Settlement observations were made during construction of selected structures in 1951-52 and possibly subsequently; however, since we have no direct knowledge of such information it has been omitted from Table No. 11.

TABLE NO. 1

STRUCTURE AND SITE FACTORS RE SUBSURFACE SOLUTION DEFECTS

Factor	Significant Aspects
Type of Structure	Sensitivity of structure and utility lines to total and differential settlements. Foundation sizes and loads. Subgrade elevation.
Thickness of Soil Between Subgrade and Top of Solution Zone	<u>Location Within Plant:</u> Probable elevation of solution zone is determined by location within project; solution zone dips towards southeast. When constructing in vicinity of present major building areas, determine elevation of "solution" zone from existing boring and grouting records. When constructing in new areas, estimate top and bottom elevations of solution zone from data for nearest building area, and from 1952 geological and grouting reports. <u>Ground Surface at Structure Locations:</u> When ground surface elevation is substantially less than in surrounding areas, subgrade may be relatively close to solution zone and special investigations may be required. <u>Thickness of soil</u> between subgrade and top of solution zone and defects induced by upwards migration of voids from solution zone are key elements in evaluating hazards from subsurface solution.
Stress Increase In Solution Zone	High stress increases in solution zone resulting from fill and/or building construction increase possibility of future settlements or hazards. Small or negligible stress increases suggest possibility of little or no future settlement from construction of structure.
Subsurface Solution Defects in Solution Zone and in Overlying Materials	Frequency and severity of solution defects in solution zone and resulting defects in overlying materials determine, in part, need for grouting. For some structures, grouting of all defects may be required but for less critical structures need for grouting depends upon depth, severity and frequency of solution induced defects. Need for grouting beneath less critical structures should be determined by particular structural requirements and subsoil conditions. Design investigations should include borings to explore condition of overburden and of solution zone in accordance with Tables 2 and 3. Ground water fluctuations or flow may activate solution caused subsoil defects.

TABLE NO. 2

CLASSIFICATION OF STRUCTURES AS REGARDS SUBSURFACE DEFECTS

No.	Category	General Characteristics	Typical Structures
I.	Non-sensitive and Minor Structures.	Differential settlement and cracking of structure would present no safety or other problems which could not be overcome at small cost and without significant hazard. Repairs to structures would introduce no serious contingent operational problems. Minor settlements and structural distress would affect mainly esthetics of structure.	Warehouses Office buildings Minor process structures Service structures
II.	Medium Sensitivity or Large Cost.	Differential settlement and cracking of structure would present definite safety problems but of a type which could be overcome without excessive hazard or uncertainty. Temporary deactivation of structure would result in minor hazards or contingent operational problems. Relatively high initial cost of structure, indicating practicality of partially investigating and correcting subsurface defects as conservative preventive procedure.	Power houses Evaporator buildings Ruboff bldg, 244-H
III.	Maximum Sensitivity or Exceptional Cost.	Differential settlement or cracking of structure would present major safety hazards difficult to overcome, or of serious potential consequences. Temporary deactivation of structure would result in major economic losses or contingent operational problems. Extremely high initial cost or importance of structure - interference with use not justified to gain minor cost savings in design and construction.	Waste storage tanks 105 buildings 221 buildings Major pump houses

TABLE NO. 3

SCOPE OF SUBSURFACE INVESTIGATION AND GROUTING

Structure Category and Sensitivity to Differential Settlements	Scope of Foundation Exploration and Grouting: - Normal - As Required to Determine Bearing Capacities, Settlements and Foundation Design	Scope of Foundation Exploration and Grouting: Additional Explorations Required Because of Subsurface Solution: In Overburden Above Solution Zone*	Scope of Foundation Exploration and Grouting: Additional Explorations Required Because of Subsurface Solution: Through Overburden to Bottom of Solution Zone	Remarks
I. Non-sensitive or Minor Structures				
A. Stress at top of solution zone is unaffected.	Yes	No	No	Exploration of soils overlying solution zone may be appropriate where thickness of overlying soils is small, as when ground surface elevation is unusually low.
B. Stress at top of solution zone is increased significantly.	Yes	Yes (Grout defects if considered serious for proposed structure)	No	Necessity for grouting defects in subsoil above solution zone to be determined separately for each structure and to be determined after study of: (1) type, sensitivity and cost of structure, (2) stress increase in solution zone and in overlying soil, (3) depth, severity and frequency of subsoil defects, and (4) consequences of differential settlements.
II. Medium Sensitivity or Large Cost				
A. Stress at top of solution zone is unaffected.	Yes	Yes (Grout defects)	No	Defects in subsoil above solution zone to be grouted for all work in this category, except where defects are minor.
B. Stress at top of solution zone is increased significantly.	Yes	Yes (Grout all defects)	Yes (Grout defects if considered serious for proposed structure)	Defects in solution zone to be grouted unless minor and infrequent.
III. Maximum Sensitivity or Exceptional Cost	Yes	Yes	Yes	All defects in solution zone and in overlying soils to be grouted.

*Select depth of borings to explore a zone at least 75 feet thick between subgrade and top of solution zone; and thicker if loaded area is large or if stress at top of solution zone is increased significantly.

Note: Grout all borings, regardless of depth; record quantity required.

TABLE #3

TABLE NO. 4

PRINCIPAL CONSIDERATIONS AFFECTING USE OF FILLS SUPPORTING STRUCTURES

Factor	Significant Features
Foundation Soil	Soil type, water content, and compressibility. Maximum past loading (preconsolidation load). Settlement under fill load. Settlement under structure load. Time-rate of settlement.
Fill Material	Availability, variability and cost. Compaction, shear strength, consolidation and swelling properties. Practicability of using available fill for seasons of year. Natural water content.
Foundation Design	Permissible total and differential settlement of structure. Fill thickness. Fill settlement under own weight. a. During construction. b. Subsequent to construction. Settlement or heave of fill under structure load. Bearing capacity of fill. Interval between completion of filling and construction of structure.
Compaction Specifications	Procedure vs. end result vs. combination specifications. Lift thickness. Minimum compaction effort. Suitable equipment. Required water contents and densities.
Construction	Construction Control: a. Lift thickness. b. Water contents and densities. c. Coverages. d. Sampling frequency. Sloping and sealing of fills for drainage. Compaction equipment. Extent of construction control to be provided.
Surface and Ground Water	Existing ground-water levels. Changed ground-water levels after filling. Seepage into fill - perched water levels.

TABLE 5
Typical Properties of Compacted Materials

Group symbol	Soil type	Range of maximum dry unit weight, p.c.f.	Range of optimum moisture, percent	Typical value of compression: At 1.4 t.s.f. (20 p.s.i.) percent of original height	Typical value of compression: At 3.6 t.s.f. (50 p.s.i.) percent of original height	Typical strength characteristics: Cohesion (as compacted) p.s.f.	Typical strength characteristics: Cohesion (saturated) p.s.f.	Typical strength characteristics: φ(Effective stress envelope) degrees	Typical strength characteristics: Tan φ	Typical coefficient of permeability ft./min.	Range of CBR values	Range of subgrade modulus k lb./cu. in.
GW	Well graded clean gravels, gravel-sand mixtures.	125 - 135	11 - 8	0.3	0.6	0	0	>38	>0.79	5×10^{-2}	40 - 80	300 - 500
GP	Poorly graded clean gravels, gravel-sand mix.	115 - 125	14 - 11	0.4	0.9	0	0	>37	>0.74	10^{-1}	30 - 60	250 - 400
GM	Silty gravels, poorly graded gravel-sand-silt.	120 - 135	12 - 8	0.5	1.1	....	....	>34	>0.67	$>10^{-6}$	20 - 60	100 - 400
GC	Clayey gravels, poorly graded gravel-sand-clay.	115 - 130	14 - 9	0.7	1.6	....	....	>31	>0.60	$>10^{-7}$	20 - 40	100 - 300
SW	Well graded clean sands, gravelly sands.	110 - 130	16 - 9	0.6	1.2	0	0	38	0.79	$>10^{-3}$	20 - 40	200 - 300
* SP	Poorly graded clean sands, sand-gravel mix.	100 - 120	21 - 12	0.8	1.4	0	0	37	0.74	$>10^{-3}$	10 - 40	200 - 300
* SM	Silty sands, poorly graded sand-silt mix.	110 - 125	16 - 11	0.8	1.6	1050	420	34	0.67	5×10^{-5}	10 - 40	100 - 300
SM-SC	Sand-silt clay mix with slightly plastic fines.	110 - 130	15 - 11	0.8	1.4	1050	300	33	0.66	2×10^{-6}	....	
* SC	Clayey sands, poorly graded sand-clay mix.	105 - 125	19 - 11	1.1	2.2	1550	230	31	0.60	5×10^{-7}	5 - 20	100 - 300
ML	Inorganic silts and clayey silts . .	95 - 120	24 - 12	0.9	1.7	1400	190	32	0.62	10^{-5}	15 or less	100 - 200
* ML-CL	Mixture of inorg. silt & clay, silty or clayey fine sand.	100 - 120	22 - 12	1.0	2.2	1350	460	32	0.62	5×10^{-7}	....	
* CL	Inorg. clays of low to med. plasticity, sandy clays.	95 - 120	24 - 12	1.3	2.5	1800	270	28	0.54	10^{-7}	15 or less	50 - 200
OL	Organic silts and silt-clays, low plasticity.	80 - 100	33 - 21	....	....	....	....	....	.....	....	5 or less	50 - 100
MH	Inorganic clayey silts, elastic silts.	70 - 95	40 - 24	2.0	3.8	1500	420	25	0.47	5×10^{-7}	10 or less	50 - 100
* CH	Inorganic clays of high plasticity	75 - 105	36 - 19	2.6	3.9	2150	230	19	0.35	10^{-7}	15 or less	50 - 150
OH	Organic clays and silty clays . . .	65 - 100	45 - 21	....	....	....	....	....	.....	....	5 or less	25 - 100

* Soils which may be available for borrow at SRP.

Notes:

1. All properties are for condition of "standard Proctor" maximum density, except values of k and CBR which are for "modified Proctor" maximum density.
2. Typical strength characteristics are for effective strength envelopes and are obtained from USBR data.
3. Compression, values are for vertical loading with complete lateral confinement.
4. (>) indicates that typical property is greater than the value shown. (-) indicates insufficient data available for an estimate.

TABLE #5

TABLE NO. 6

FILL DESIGN CONSIDERATIONS

Item	Principal Considerations
Interval Between Completion of Fill Placement and Start of Construction of Structure.	When less than two months, evaluate possible continuation of primary consolidation of fill into structure construction period. At SRP, this may be important where: a. Fill is high, more than 10-15 ft. b. Surface drainage is poor or a portion of fill is placed below normal groundwater level. c. Fill is placed wet of optimum moisture content.
Distance to Edge of Fill.	Locate structures away from edge of fill to avoid local settlements resulting from shear deformations and from possible erosion. a. Where possible, locate service roads between structure and edge of fill. b. Minimum distance betweed edge of fill supported structure and top edge of fill to be equal to height of fill above adjacent natural ground surface..
Borrow Availability and Variability.	Design should be based upon known availability of suitable materials; their expected variability determines conservatism required in design and compaction control which is feasible.
Anticipated Compaction Control.	Difficulty of securing desired compaction results for borrow materials selected, and experience of inspection personnel, should be evaluated when determining probable variations in compacted water contents and densities. Fill performance assumed should be consistent with practicability and probability of achieving desired compaction results.
Post-construction Fill and Structure Settlements.	Where settlement of structure and/or post-construction settlement of fill must be a minimum or cannot exceed specified amounts: a. Estimate settlement of natural soil beneath fill from previous or specially performed consolidation tests on undisturbed samples. b. Estimate settlement of fill using consolidation tests on samples compacted to most critical water contents and densities. c. Consider possibility of future water content increases in fill and assume they will occur, unless special means are provided for avoiding this. d. See Table 5 for typical settlement values for compacted fills.
Permissible Structure Settlements.	Magnitude of total and differential settlements depends upon proposed structure use. See Table No. 7 for guide values, but determine these for each structure.
Construction Season.	Time of year when fill is to be placed may determine probable settlements, type of fill to be used, and practicability of relying upon fill for structure support. Where fill must be placed during winter or rainy seasons, use fill material insensitive to moisture content, such as clean sand or sand and gravel.
Compacted Densities.	Do not require densities of clayey soils in excess of actual requirements; high densities are not permanent under light loads and may cause swelling.

TABLE NO. 7

PERMISSIBLE DIFFERENTIAL SETTLEMENTS FOR GENERAL USE STRUCTURES

Type of Structure	Permissible Differential Settlements: Radians	Permissible Differential Settlements: Inches Per 20' Distance	Qualifying Conditions
One or 2-story steel frame, truss roof; warehouse with flexible siding.	0.006 to 0.008	1-1/2" to 2"	Tolerable differential settlements are probably less and are determined by overhead cranes, utility lines, or use of fork-lift trucks on warehouse floor.
One or 2-story buildings with brick bearing walls and light structural frame.	0.0015 to 0.002	3/8" to 1/2"	Larger value is tolerable if some settlement can be expected during construction.
Structures with sensitive interior or exterior finish, such as plaster, ornamental stone, or tile facing.	0.0015	3/8"	Larger values are permissible if significant settlement occurs before interior finish is complete.
Structures with relatively insensitive interior or exterior finish such as dry wall or movable panels.	0.002 to 0.003	1/2" to 3/4"	Damage to structure frame may limit tolerable settlements.

TABLE NO. 8

BEHAVIOR CHARACTERISTICS OF COMPACTED SOILS SUPPORTING STRUCTURES

Characteristic	Descriptive Features	Remarks Re Savannah River Plant
Material Type	Utilization: 1. Almost any inorganic soil can be incorporated in earth fills when controlled compaction is required and soil properties are determined in advance. 2. Some soils compact readily to high densities and are stable thereafter, select these when possible.	For support of structures, select materials in following order of preference: 1. Clean sands found on surface throughout most of plant. 2. Silty sands. 3. Lean clayey sands, liquid limits 35, % No. 200 less than 25. 4. Clayey sands and sandy clays. For support of major structures or those sensitive to differential and/or total settlements, determine consolidation properties if soils are not clean sands.
	Sensitivity to Compaction Moisture Content: 1. Coarse-grained, cohesionless soils with less than 4% passing the No. 200 sieve for well-graded soils, or with less than 8% for uniform gradation, are insensitive to compaction moisture content. 2. Other soils are sensitive to moisture content and have typical compaction curves.	Surface sands are uniformly graded and should be compacted at highest practicable moisture content, preferably saturated, when not over 8-10% is finer than No. 200 sieve. Compact other soils near optimum moisture content determined by laboratory compaction test.
Laboratory Compaction Tests for Design and Control Purposes	Use standard Proctor compaction test for average structure loads and fill thicknesses.	Where borrow other than clean sand is to be used, also perform modified Proctor compaction test where structure load and/or fill thicknesses are large.
Bearing Capacity of Compacted Soil	Determine, when required, from triaxial compression tests on laboratory compacted samples.	Bearing capacity of well-compacted soils is high and has not been a problem for structures constructed at SRP. Laboratory strength tests not required except for unusual structures or conditions, or where footing loads are more than 3000 psf.
Settlement of Fill	Settlement During Fill Placement: 1. Magnitude depends upon fill type, placement water contents and densities, and thickness but occurs rapidly and is ordinarily not significant. 2. Assume as 1-2% of fill thickness for estimating purposes. 3. Determine from laboratory consolidation tests on compacted samples where required by special considerations, such as settlement of embedded pipes, etc., see Table No. 5 for typical values.	Not considered significant unless pipes are embedded during construction.
	Post-construction Settlement Under its Own Weight: 1. Settlement from primary consolidation is generally complete upon completion of fill placement or within 1-2 months thereafter. 2. Settlement from secondary compression occurs slowly unless surcharge fills are used to reduce magnitude. 3. Post-construction secondary compressions may approximate 0.1 to 0.2 per cent of fill height in 3 to 4 years and 0.3 to 0.5 per cent in 15 to 20 years. 4. Additional settlement will occur if fill absorbs water.	Of importance only where fill thickness is large (more than 10-15 ft) and structure is sensitive to minor settlements. Allow few months interval between completion of filling and construction of structure, where required. Use surcharge fills only under unusual requirements. Good surface drainage during and subsequent to construction is important.
	Post-construction Settlement Under Load From Structure: 1. Estimate from results of consolidation tests on compacted samples, where required. Assume as 0.2 to 0.4 per cent of fill thickness for preliminary estimates, for each 1500 psf increase in stress on well compacted fills. (Compute stress distribution beneath footings. 2. Additional settlement will result when fill can absorb moisture from shallow ground water or from ponding within fill.	For structures constructed on well compacted fills, settlements can be assumed minor for small structures not particularly sensitive to small settlements. Where structure cannot tolerate small settlements, and also where fill thickness is substantial (more than 10-15 ft) estimate settlement from consolidation test data, assuming that fills may become soaked. Perform tests for range of expected placement water contents and densities.
Swelling of Fill and/or Heaving of Structure	Clays and soils containing plastic fines may expand when compacted to high densities at normally used water contents, unless confined by structure loads or weight of overlying fill.	Swelling of compacted fills beneath warehouse floors may occur when sandy clay and clayey sands from required excavations are used as fill. When clayey sands contain less than about 20% finer than the No. 200 sieve, only minor movements should occur; for support of warehouse floors compaction moisture content should be close (±1-1/2%) to standard Proctor optimum and density should be about 98-100% of maximum standard Proctor density. Heaving of building foundations is unlikely unless bearing load is small (1500 psf) or fat clays, sandy clays or plastic clayey sands are used as fill and are compacted to high densities.

TABLE NO. 9

COMPACTION SPECIFICATIONS AND CONTROL TESTING

Item	Requirements
Type of Specification	Use "methods" type specification or "end result" specifications with additional requirements for: a. Maximum lift thickness. b. Minimum coverages of specified compaction equipment.
Compaction Equipment and Methods	See Table No. 10 for equipment and procedures to achieve 95-100% standard Proctor maximum density. Where 95% of modified Proctor maximum density is required, use heavy rubber-tired rollers with: a. Minimum tire inflation pressures of 120 psi. b. Maximum compacted lift thickness of 8 inches. c. Minimum number of coverages of 4. d. Minimum wheel loads of 25,000 lbs. Where heavy rubber-tired rollers are not available, use 60" diameter drum sheepsfoot roller with: a. Minimum foot area of 12 sq in. b. Maximum foot contact pressure that will permit roller to partially "walk out". c. Maximum compacted lift thickness of 6 inches. d. Minimum number of coverages of 12. Where compacted densities above 100% of standard Proctor maximum density are required and fill material is clay, sandy clay, or clayey sand with more than 25% by weight finer than No. 200 sieve, a field test section may be desirable to determine compaction procedures. Consider performing in advance of or as part of fill placement, in accordance with equipment available and type of contract.
Drainage Control During Fill Placement	Require sloping of fills to drain properly and seal fill surface with rubber-tired rollers before possible rains and on weekends.

Item	Requirements
Construction Control Testing	Field Density Tests: Schedule the following minimum number of tests: a. One for every 2,000 cu yd of material for mass earthwork. b. One for every 200 to 800 cu yds of fill for structure support, depending upon total quantity involved. c. At least one test for every full shift on mass earthwork. d. Two or more tests on each lift. e. One or more test where quality of moisture control or effectiveness of compaction is doubtful. Vary locations where density tests are made but locate so that density profiles can be prepared. Laboratory Compaction Tests: Prior to starting fill placement, obtain a family of compaction curves representing typical materials. During fill placement, perform additional compaction tests on field density test samples, approximately one for every 10 or 20 field tests, depending on material variability. Analysis of Control Test Data: Compare each field determination of moisture and density with appropriate compaction curve, to evaluate conformance with requirements. Moisture Control: a. Close control is indicated if two-thirds of field values are within ±1% of median moisture content specified. b. Erratic control is indicated if only two-thirds of values are within ±2-3% about specified median content. c. To improve moisture control, by-pass overly wet borrow material, or blend materials from wet and dry sections of borrow area. Density Control: a. Suitable compaction methods are being utilized if two-thirds of field densities are within ±2-3% about required density. b. Insufficient or erratic compaction is indicated if only two-thirds of values are within ±4-5% about required value. c. To improve compaction, effect more uniform moisture control, increase size and/or tire pressure of compaction equipment, increase coverages, or decrease lift thickness.

TABLE #9

TABLE NO. 10

COMPACTION EQUIPMENT AND METHODS

Equipment Type	Applicability	Requirements for Compaction of 95 to 100 PCT Standard Proctor Maximum Density: Compacted Lift Thickness, In.	Passes or Coverages	Dimensions and Weight of Equipment	Possible Variations in Equipment
Sheepsfoot Rollers	For fine-grained soils or dirty coarse-grained soils with more than 20 per cent passing the No. 200 sieve. Not suitable for clean coarse-grained soils. Particularly appropriate for compaction of impervious zone for earth dam or linings where bonding of lifts is important.	6	6 to 12 passes for fine-grained soil 6 to 8 passes for coarse-grained soil	Soil Type / Foot Contact Area Sq. In. / Foot Contact Pressures psi: Fine-grained soil PI > 30 / 5 to 12 / 250 to 500 Fine-grained soil PI < 30 / 7 to 14 / 200 to 400 Coarse-grained soil / 10 to 14 / 150 to 250 Efficient compaction of soils wet of optimum requires less contact pressures than the same soils at lower moisture contents.	For earth dam, highway and airfield work, drum of 60-inch diameter, loaded to 1.5 to 3 tons per lineal foot of drum generally is utilized. Foot contact pressure should be regulated so as to avoid shearing the soil on the third or fourth pass.
Rubber Tire Rollers	For clean, coarse-grained soils with 4 to 8 per cent passing the No. 200 sieve.	8 to 10	3 to 5 coverages	Tire inflation pressures of 60 to 150 psi for clean granular material or base course and subgrade compaction. Wheel load 18,000 to 25,000 lbs.	Wide variety of rubber tire compaction equipment is available. For cohesive soils, light-wheel loads, such as provided by wobble-wheel equipment, may be substituted for heavy-wheel load if lift thickness is decreased. For cohesionless soils, large-size tires are desirable to avoid shear and rutting.
	For fine-grained soils or well-graded, dirty coarse-grained soils with more than 8 psi passing the No. 200 sieve.	6 to 8	4 to 6 coverages	Tire inflation pressures in excess of 65 psi for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use large size tires with pressures of 60 to 90 psi.	
Vibrating Baseplate Compactors	For coarse-grained soils with less than about 12 per cent passing No. 200 sieve. Best suited for materials with 4 to 8 per cent passing No. 200 sieve, placed thoroughly wet.	8 to 10	3 coverages	Single pads or plates should weigh no less than 200 lbs. May be used in tandem where working space is available. For clean coarse-grained soil, vibration frequency should be no less than 1600 cycles per minute.	Vibration pads or plates are available, hand-propelled or self-propelled, single or in gangs, with width of coverage from 1-1/2 to 15 feet. Various types of vibrating-drum equipment should be considered for compaction in large areas.
Crawler Tractor	Best suited for coarse-grained soils with less than 4 to 8 per cent passing No. 200 sieve, placed thoroughly wet.	6 to 8	3 to 4 coverages	No smaller than D8 tractor with blade, 34,500 lbs weight, for high compaction.	Tractor weights up to 60,000 lbs.
Power Tamper or Rammer	For difficult access, trench backfill. Suitable for all inorganic soils.	4 to 6 in. for silt or clay, 6 in. for coarse-grained soils	2 coverages	30-lb minimum weight. Considerable range is tolerable, depending on materials and conditions.	Weights up to 250 lbs, foot diameter 4 to 10 in.

TABLE #10

TABLE NO. 11

SUBSOIL INFORMATION AVAILABLE FOR SAVANNAH RIVER PLANT

Item No.	Date	Description
1	Various 1951-53	Field logs of borings.
2	Various 1951-53	Results of laboratory tests.
3	March 1951 (2 volumes)	"Report of Preliminary Studies, Foundation Investigations, Savannah River Plant". Appendices to this report present a surface drainage study and map and an engineering soil study and map, both prepared from aerial photographs of the Savannah River area.
4	Various 1951-52	Soils engineering reports for individual constructions areas summarizing laboratory testing; settlement, bearing capacity and other soils engineering analyses; and foundation recommendations.
5	1951-53	Reports of soil compaction of fill areas supporting wings of 105 buildings.
6	1951-53	Progress reports of grouting, including logs and plan of grout holes, and grouting records for each hole. Includes summaries showing depths of grout holes and depths of rod droppings, soft spots, mud losses and calcareous material.
7	March 1952 (2 volumes)	"Geologic-Engineering Investigations, Savannah River Plant". This report presents results of completed geological investigations, interpretation of significance of surface sinks, study of ground and surface water supplies, drainage conditions, aggregate sources, and air-photo interpretations. Volume 2 presents geological cross-sections through plant and for individual construction areas.
8	1952	Grouting report.
9	1953 to date	Additional investigations performed for: a. Tanks in the F and H areas. b. Par Pond dam. c. Building 244-H. d. C and R Effluent Canals. e. Deep waste storage studies.

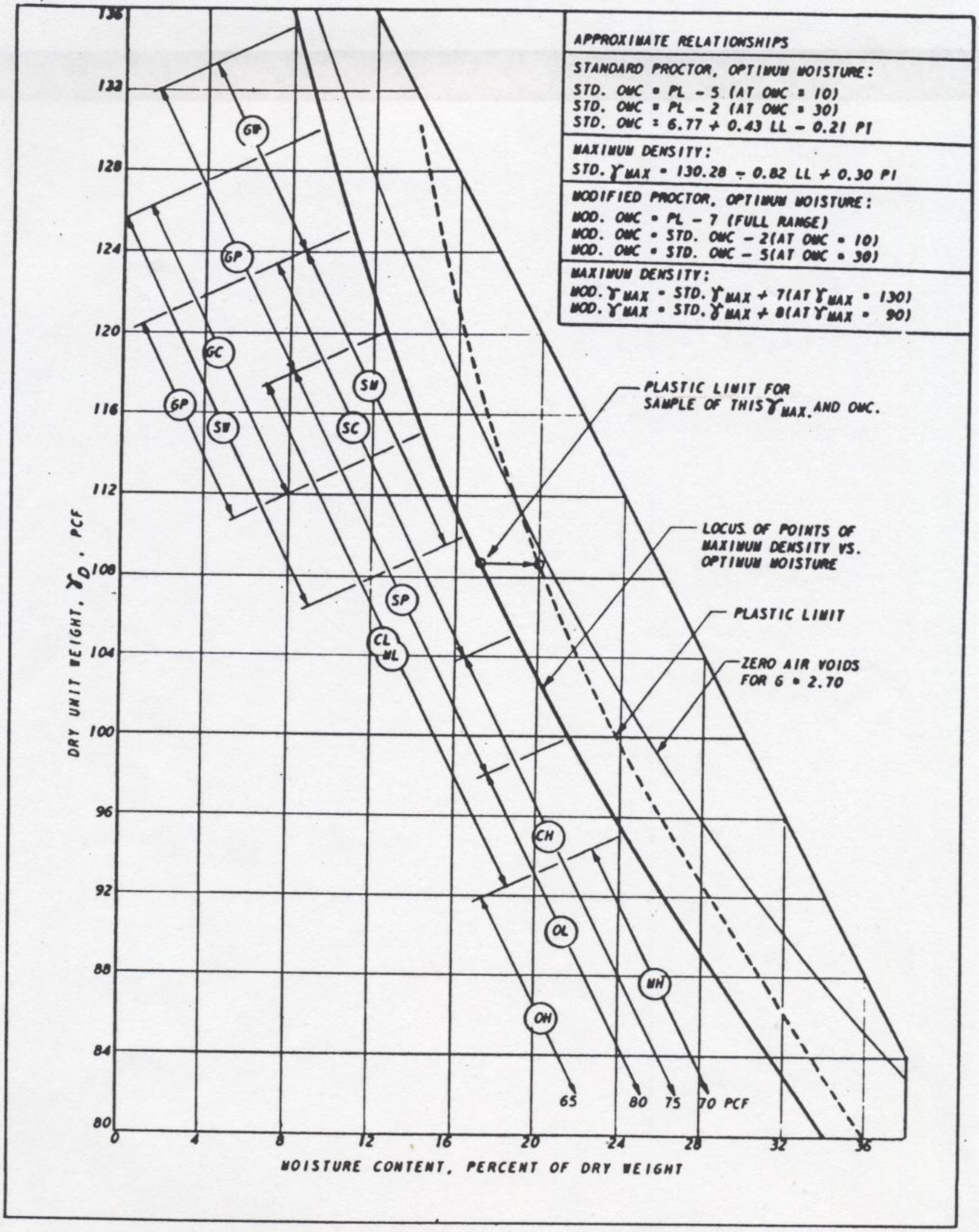

FIGURE 1
Compaction Relationships