THESIS

A HYDRAULIC LABORATORY AND A SOIL MECHANICS LABORATORY
FOR MASSACHUSETTS INSTITUTE OF TECHNOLOGY

By FRANCIS R. MEISCH
B. Arch. University of Minnesota 1939

SUBMITTED AS PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY 1940
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Professor K. C. Reynolds
Professor D. W. Taylor
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Professor J. Holt
Mr. H. N. Eaton
Dr. L. G. Straub
Mr. P. Lamson
LETTER OF THESIS SUBMITTAL

Cambridge, Massachusetts,
The Graduate House,
August 23, 1940.

Dean Walter R. McCormack,
School of Architecture,
Mass. Inst. of Tech.,
Cambridge, Massachusetts.

Dear Dean McCormack:


Sincerely,

Francis R. Meisch,
Graduate Class,
School of Architecture.
LETTER OF SUBJECT SUBMITTAL

COPY

Cambridge, Massachusetts,
The Graduate House,
April 6th, 1940.

Dean Walter R. McCormack,
School of Architecture,
Mass. Inst. of Tech.,
Cambridge, Mass.

Dear Dean McCormack:

A great deal of my practical experience in architecture has been work in which I collaborated with engineers in designing structures of a technical character. It occurred to me that a Master's Thesis done in collaboration with some of Technology's technical experts could be an educational experience of great practical value.

Upon investigating the possibilities of such a project, I found that the Institute was greatly in need of enlarged as well as better facilities for river hydraulics and that the future expansion program of the Institute will ultimately require the provision of a new hydraulic laboratory structure. It was also mentioned that a soil mechanics laboratory should be provided for in the same structure.

Regarding this as a pertinent problem, Professor K. C. Reynolds of the Department of Civil and Sanitary Engineering and other members of the Institute staff have assured me of their technical assistance, statistics, and facilities necessary to the design of such a project.

I respectfully submit as the subject of my Master's Thesis in Architecture: 'A Hydraulic Laboratory and a Soil Mechanics Laboratory for the Massachusetts Institute of Technology.'

Sincerely

Francis R. Meisch,
Graduate Class,
School of Architecture.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgment</td>
<td>iii</td>
</tr>
<tr>
<td>Letter of Thesis Submittal</td>
<td>iv</td>
</tr>
<tr>
<td>Letter of Subject Submittal</td>
<td>v</td>
</tr>
<tr>
<td>Index to Figures</td>
<td>viii</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td><strong>Part I — THE NONARCHITECTURAL ANALYSIS.</strong></td>
<td>2</td>
</tr>
<tr>
<td>A - General</td>
<td>3</td>
</tr>
<tr>
<td>B - Hydraulic Laboratory Importance</td>
<td>7</td>
</tr>
<tr>
<td>C - Hydraulic Laboratory Comparisons</td>
<td>11</td>
</tr>
<tr>
<td>D - Hydraulic Laboratory Enrolment</td>
<td>14</td>
</tr>
<tr>
<td>E - Hydraulic Laboratory Work.</td>
<td>16</td>
</tr>
<tr>
<td>F - Hydraulic Trends</td>
<td>18</td>
</tr>
<tr>
<td>G - Hydraulic Model Studies</td>
<td>23</td>
</tr>
<tr>
<td>H - Soil Mechanics Laboratory Importance</td>
<td>25</td>
</tr>
<tr>
<td>I - Soil Mechanics Laboratory Comparisons</td>
<td>27</td>
</tr>
<tr>
<td>J - Soil Mechanics Laboratory Enrolment</td>
<td>28</td>
</tr>
<tr>
<td>K - Soil Mechanics Laboratory Work</td>
<td>29</td>
</tr>
<tr>
<td>L - Hydraulics and Soil Mechanics</td>
<td>30</td>
</tr>
<tr>
<td><strong>Part II — THE ARCHITECTURAL ANALYSIS.</strong></td>
<td>31</td>
</tr>
<tr>
<td>A - General</td>
<td>32</td>
</tr>
<tr>
<td>B - Hydraulic Laboratory Analyses</td>
<td>34</td>
</tr>
<tr>
<td>C - Hydraulic Laboratory Examples</td>
<td>39</td>
</tr>
<tr>
<td>D - Hydraulic Laboratory Equipment</td>
<td>42</td>
</tr>
<tr>
<td>PAGE</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td></td>
</tr>
<tr>
<td>E - Soil Mechanics Laboratory Analyses.</td>
<td>43</td>
</tr>
<tr>
<td>F - Soil Mechanics Laboratory Equipment.</td>
<td>44</td>
</tr>
<tr>
<td>G - Organization.</td>
<td>45</td>
</tr>
<tr>
<td>H - The Site.</td>
<td>46</td>
</tr>
<tr>
<td>I - The Program.</td>
<td>49</td>
</tr>
<tr>
<td>Part III - THE ARCHITECTURAL SYNTHESIS.</td>
<td>53</td>
</tr>
<tr>
<td>A - General.</td>
<td>54</td>
</tr>
<tr>
<td>B - Plot Plan.</td>
<td>55</td>
</tr>
<tr>
<td>C - Planning.</td>
<td>58</td>
</tr>
<tr>
<td>D - Elevations.</td>
<td>66</td>
</tr>
<tr>
<td>E - Construction.</td>
<td>68</td>
</tr>
<tr>
<td>F - Lighting.</td>
<td>71</td>
</tr>
<tr>
<td>G - Heating and Ventilating.</td>
<td>76</td>
</tr>
<tr>
<td>H - Conclusion.</td>
<td>81</td>
</tr>
<tr>
<td>Part IV - THE ARCHITECTURAL SOLUTION.</td>
<td>82</td>
</tr>
<tr>
<td>A - Photographs of Drawings.</td>
<td>83</td>
</tr>
<tr>
<td>B - Photographs of Model.</td>
<td>92</td>
</tr>
<tr>
<td>Appendix.</td>
<td>96</td>
</tr>
<tr>
<td>Figures 1 to 27.</td>
<td>97</td>
</tr>
<tr>
<td>Bibliography.</td>
<td>125</td>
</tr>
<tr>
<td>FIGURE</td>
<td>PAGE</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Present Location - Hydraulics and Soil Mechanics M.I.T.</td>
</tr>
<tr>
<td>2</td>
<td>Hydraulics - M.I.T. Bulletin Description</td>
</tr>
<tr>
<td>3</td>
<td>Hydraulics - Laboratory Locations</td>
</tr>
<tr>
<td>4</td>
<td>Hydraulics - Comparison of Laboratory Facilities</td>
</tr>
<tr>
<td>5</td>
<td>Hydraulics - M.I.T. Student Enrolment by Years</td>
</tr>
<tr>
<td>6</td>
<td>Hydraulics - M.I.T. Student Enrolment by Terms</td>
</tr>
<tr>
<td>7</td>
<td>Hydraulics - Thesis Statistics</td>
</tr>
<tr>
<td>8</td>
<td>Hydraulics - Research Statistics</td>
</tr>
<tr>
<td>9</td>
<td>Hydraulics - Present River Laboratory M.I.T</td>
</tr>
<tr>
<td>10</td>
<td>Hydraulics - Present River Laboratory Annex M.I.T</td>
</tr>
<tr>
<td>12</td>
<td>Soil Mechanics - Laboratory Locations</td>
</tr>
<tr>
<td>13</td>
<td>Soil Mechanics - Comparison of Laboratory Facilities</td>
</tr>
<tr>
<td>14</td>
<td>Soil Mechanics - M.I.T. Student Enrolment by Years</td>
</tr>
<tr>
<td>15</td>
<td>Soil Mechanics - M.I.T. Student Enrolment by Terms</td>
</tr>
<tr>
<td>16</td>
<td>Hydraulics - Basic Flow Diagram</td>
</tr>
<tr>
<td>17</td>
<td>Hydraulics - Analysis of Laboratory Requirements</td>
</tr>
<tr>
<td>18</td>
<td>Hydraulics - U.S. Bureau of Standards</td>
</tr>
<tr>
<td>19</td>
<td>Hydraulics - University of Minnesota</td>
</tr>
<tr>
<td>20</td>
<td>Hydraulics - University of Iowa</td>
</tr>
<tr>
<td>21</td>
<td>Hydraulics - Worcester Polytechnic Institute</td>
</tr>
<tr>
<td>22</td>
<td>Soil Mechanics - Research Laboratory Equipment</td>
</tr>
<tr>
<td>23</td>
<td>Soil Mechanics - Student Laboratory Equipment</td>
</tr>
<tr>
<td>FIGURE</td>
<td>PAGE</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>24 Soil Mechanics - Miscellaneous Equipment.</td>
<td>121</td>
</tr>
<tr>
<td>25 Relationship Diagram - Hydraulics &amp; Soil Mechanics</td>
<td>122</td>
</tr>
<tr>
<td>26 Proposed Site - Hydraulics &amp; Soil Mechanics M.I.T.</td>
<td>123</td>
</tr>
<tr>
<td>27 Natural Lighting - Comparison of Methods.</td>
<td>124</td>
</tr>
</tbody>
</table>
INTRODUCTION

The desire to present the broadest possible picture of the preliminary research, the investigations, and the factors affecting the design of a Hydraulic Laboratory and a Soil Mechanics Laboratory for the Massachusetts Institute of Technology has led to the presentation of this thesis in four distinct parts:

Part I The Nonarchitectural Analysis.
Part II The Architectural Analysis.
Part IV The Architectural Solution.

If the resulting solution has achieved simplicity in plan and elevation, it is not the result of chance or from following the blind dictates of 'form follows function' - but rather the result of a period of intense research and analysis that led to the simplification of factors governing the design. This period of preliminary work was, perhaps, all too short and too hurried - years rather than months of research being the prerequisite to the planning of a building housing such technical functions as hydraulics and soil mechanics.
PART I

A - GENERAL
B - HYDRAULIC LABORATORY IMPORTANCE
C - HYDRAULIC LABORATORY COMPARISONS
D - HYDRAULIC LABORATORY ENROLMENT
E - HYDRAULIC LABORATORY WORK
F - HYDRAULIC TRENDS
G - HYDRAULIC MODEL STUDIES
H - SOIL MECHANICS LABORATORY IMPORTANCE
I - SOIL MECHANICS LABORATORY COMPARISONS
J - SOIL MECHANICS LABORATORY ENROLMENT
K - SOIL MECHANICS LABORATORY WORK
L - HYDRAULICS AND SOIL MECHANICS

THE NONARCHITECTURAL ANALYSIS
A - GENERAL

In recent years, following the trend from abroad, more and more use has been made of hydraulic laboratories in the United States for the study of engineering problems by models rather than for the investigation of hydraulic properties as such. This trend has made the hydraulic laboratory an essential part of modern engineering practice - so much so that the governments of the Netherlands, Belgium, Czechoslovakia, and Switzerland have installed national hydraulic laboratories to deal with engineering problems that affect the economic and social life of the country. The United States and the Soviet Union have built large laboratories for the same purpose.

Hydraulic laboratories in the United States and Canada at the present time exceed one hundred and fifty in number, and these laboratories may be divided into three groups:

1. Commercial and governmental laboratories engaged in specialized work and research.

2. College laboratories engaged in commercial work as well as staff research and student instruction.

3. College laboratories engaged primarily in staff research and student instruction.

All of the commercial and governmental laboratories are specialized laboratories and therefore definitely limited in the variety of their equipment and the scope of their work. The present Hydraulic Laboratory at Massachusetts Institute of Technology falls into the second class as
it does engage in a certain amount of commercial work. In a comparison of the representative laboratories in the second class it was found that the Institute rated fourth place in the types of work and research which it was equipped to perform. It is quite surprising that the present Institute Hydraulic Laboratory has been able to achieve such a high rating in spite of its limited and poorly housed equipment for river hydraulics and the total absence of still other equipment for hydraulics. In this second class the top ranking laboratories in the country are those whose facilities and equipment are of such magnitude and calibre that the United States Engineers Offices for various districts have utilized these college laboratories for various types of experiments. This cooperation has resulted in mutual advantages to both of the parties concerned. The Hydraulic Laboratory at the Institute has been fortunate in securing the model work for the Cape Cod Canal from the United States Army Engineers in Boston, but it stands to lose government cooperation and other work in the future unless it can continue to produce facilities that are on a competitive basis with those of other laboratories throughout the country. The Hydraulic Laboratory at the University of Iowa recently lost the construction of a large scale model of the Mississippi River to the Hydraulic Laboratory at the University of Minnesota because the latter institution had not only the laboratory facilities for such model work but the necessary office space as well. And last but not least, the Institute must recognize this com-
petitive factor and be able to offer its student body facilities for graduate and undergraduate research that are on a par with those obtainable elsewhere.

Another item of interest is that the United States Waterways Experiment Station at Vicksburg, Mississippi, operated by the Army Engineers is the only laboratory to have in direct connection with it a Soil Mechanics Laboratory. Since the Institute is so fortunate as to have a Soil Mechanics Laboratory, it is only logical that any thought of a new structure for river hydraulics should include a soil mechanics laboratory as well. This is especially true as the present Soil Mechanics Laboratory is none to perfectly housed at present. This, in brief, is the situation at the Institute. More detailed accounts of conditions will follow.

In as much as a hydraulic laboratory and a soil mechanics laboratory are entirely different in their problems though related in some of their work, they will be considered separately.

Hydraulics in general is taught in four different locations on the present Technology campus. The locations in Building 1 and Building 3 are on the whole used for the study of elementary hydraulics - fundamental principles for undergraduate students. The River Hydraulic Laboratory - primarily a graduate study - is housed in Building 21 and its annex, Building 20. Soil Mechanics is taught in Building 1. For these locat-
ions see Figure 1, Present Location - Hydraulics & Soil Mechanics M.I.T.

This thesis proposes to do nothing with the facilities for hydraulics in Building 1 and Building 3, but to design a specialized laboratory - one for River Hydraulics - that will rehouse the work now being carried on in Building 21 and Building 20, both nonpermanent structures. Hereafter the term 'hydraulic laboratory' when ever used with reference to the present or proposed projects at the Massachusetts Institute of Technology will be understood to mean 'river hydraulic laboratory'.
River Hydraulic Laboratory is defined under Description of Subjects in the Massachusetts Institute of Technology Bulletin as - 'Instruction in the construction of models for river hydraulic experiments, in the method of making such experiments, and in the interpretation of the results thereof. Registration for the subject is limited in accordance with the number of models available in the laboratory.' See Figure 2.

The importance of this course and related laboratory research is not generally recognized. The results of river hydraulic investigations do not end at the laboratory threshold but have a far greater range - often national and international in scope. In these days when the question of national defense is paramount, the hydraulic laboratory assumes an even greater significance.

For example, the Cape Cod Canal project studied in model form at the Institute Hydraulic Laboratory was far reaching in its effects. The canal has aided coastwise shipping by cutting time and the often dangerous journey around Cape Cod. In war time the canal is a valuable link in the system of national defense. Such a project with national and international ramifications and involving a great monetary expenditure must be studied in the laboratory to avoid costly mistakes.

"There is no doubt that the incontestable value of experiments with models will bring about, in the course of time, the state of affairs that all projects for important hydraulic structures will not merely be de-
signed on the drafting board, but will be checked and improved by tests on models." This statement made in 1929 by Th. Rehbock, late director of the Hydraulic Institute at the Karlsruhe Institute of Technology, agrees with the view expressed more recently by the Director of the United States Waterways Experimental Station, in summing up experience gained on over three hundred laboratory projects studied by the Corps of Engineers from 1929 to 1936: "No improvement of waterways should ever be constructed without at least a thorough knowledge of laboratory experiments in that particular field, and in most cases, model experimentation will be necessary."

Besides the regular graduate students, each year a certain number of United States Army men have received their training in river hydraulics at the Institute. In peace times these men after leaving the Institute work on projects that some times affect the economic and social life of great regions - the Tennessee Valley Authority is an excellent example. Flood control, canalization, irrigation, navigation, power projects, bridges, dams, locks, docks, and harbors are a few of the problems that are susceptible to their technical assistance.

The importance to the Institute of a hydraulic laboratory and river hydraulic work is in another direction. First, such a laboratory attracts students to the Institute, and second, it attracts commercial and governmental work and cooperation. Commercial and governmental work add to the prestige and reputation of not only the laboratory but to that of
the Institute as well. This work helps to bridge the gap between theory and practice and endows the laboratory with valuable models that can be used for additional study after the original project has been completed. This source of models for laboratory work is not to be passed by lightly. The performance of commercial and governmental work endows the laboratory with a usefulness and a vigour which are difficult to obtain in any other way.

The latter part of the Institute Bulletin description of River Hydraulic Laboratory, (see Figure 2.), concerning the limitation of registration with respect to the number of models available is significant. Investigation brought to light many qualifying conditions. The present laboratory and its annex are woefully inadequate in area; there being practically a one hundred per cent current utilization of space with an apparent demand for more area. Hydraulic models are rather costly and, therefore, are never demolished until they have outlived their usefulness or until the floor area they occupy becomes, relatively speaking, more valuable than the model itself. Consequently, floor area is in great demand, not only for models, but for the storage of parts of models.

Besides being inadequate in area and overcrowded, Building 21 and the annex, Building 20, are poorly lighted, nonpermanent, nonfireproof structures lacking many proper facilities. These facilities which are usually considered necessary adjuncts to a hydraulic laboratory consist of offices, shops, storage areas, darkroom, locker room, etc. The present
The hydraulic laboratory is located in two structures that were never designed to function as hydraulic laboratories or to shelter work of such a technical nature.
C - HYDRAULIC LABORATORY COMPARISONS

It is impossible to ignore the competitive factor in the study of a hydraulic laboratory and its work. This factor is advantageous in the development of hydraulic research. Unfortunately this is not always true in the development of the laboratory proper. Competition is keen and it is the better laboratories that attract commercial and governmental work as well as graduate students in search of advanced educational and research facilities.

A study of hydraulic laboratories in the United States and Canada was made to determine their geographic location, the type of work that they engage in, and the facilities available. The location of representative laboratories is graphically shown in Figure 3, Laboratory Locations, as well as the type of work they engage in. The map shows a concentration of laboratories in the east, especially in the Great Lakes and the New England States. College laboratories engaged in research and commercial work - the class to which the Institute laboratory belongs - are shown in red on the map and may be seen to be very numerous in this region. Inter-laboratory competition for students and for commercial work is therefore relatively high in this region. The location of many commercial and government laboratories along the seaboard from Massachusetts to Virginia intensifies competition still more in that field. College laboratories used only for instruction and scientific research are very numerous but few of them are outstanding or really representative.
The relative standings of representative laboratories is brought out in Figure 4, Comparison of Laboratory Facilities. This list includes only commercial and governmental laboratories and college laboratories engaged in research and commercial work. The facilities at Massachusetts Institute of Technology are indicated in red. Only the laboratories of the University of California, the University of Minnesota, and the Worcester Polytechnic Institute have more facilities than the Massachusetts Institute of Technology. The Institute's high standing in the light of other qualifying conditions is phenomenal.

Although there are over one hundred and fifty laboratories in the United States and Canada, there are about seventy small or large hydraulic laboratories belonging to universities in the United States. In these laboratories the equipment, in general, is limited and the flow is below twenty cubic feet per second. The construction of the National Hydraulic Laboratory at the Bureau of Standards in Washington, D. C. and other government laboratories throughout the country was justified despite the numerous college laboratories.

That educational standards must be reached and maintained in hydraulics just as in other subjects has been recognized by many institutions. But too many educational institutions have been satisfied with the provision of facilities for only basic hydraulic instruction—fundamentals and theory—and they have neglected the larger and more advanced phases of hydraulics that carry theory over into practice. A lack of college lab-
oratories able to carry out projects of regional and national importance is the result. The fact that the Institute hydraulic laboratory has been able to successfully carry out work of this scope and character is a reason why it should continue to advance itself in this field by an increase and betterment of its laboratory facilities and by housing them in a laboratory structure properly designed for such work.
D - HYDRAULIC LABORATORY: ENROLMENT

Enrolment in the River Hydraulic Laboratory course was studied to discern possible trends and to obtain data as a basis for design work. The results of this survey are presented graphically in Figure 5, Student Enrolment by Years, and in Figure 6, Student Enrolment by Terms. From these graphs it is apparent that student enrolment in this course has been steadily increasing over a period of ten years from a low point of five students in 1931-32 to a high of twenty nine students in 1939-40. The average for the ten year period, 1930-40, is 14, (13.6), students per year.

The distribution of enrolment by terms is enlightening. During the last ten years with the exception of the years 1937-38 and 1939-40, the laboratory has not been used during the second term for class work; though thesis work and research was carried on there. Of interest is the fact that Summer Session enrolment has usually been greater than First Term enrolment. The peak demand on the laboratory for class work has been the enrolment of sixteen students for one term. Summer Session enrolment at the present time appears to be the governing factor. Figure 6, also indicates the relative proportion of graduate students to undergraduates taking the laboratory course to be 11, (10.8), to 1. This is partly because the course is primarily one of graduate study. However, none of the aforementioned statistics take into account the fact that some fifteen to twenty five Civil Engineering undergraduate students taking subject 2.687 Hydraulic Laboratory spend a two hour period in the River Hydraulic Laboratory the second term of each year as part of their basic
training in hydraulics.

From this study it is seen that the laboratory had to take care of an increase in students each year where as there was no corresponding increase in laboratory size until the construction of the Cape Cod Canal model in Building 20. Nevertheless, this was primarily not constructed for student use, and the addition of this area to that of the laboratory proper was not for purpose of meeting increasing enrolments.
E - HYDRAULIC LABORATORY WORK

A key to the demands placed upon the laboratory is the type of work that it is required to perform. Excluding routine class work, already defined under Laboratory Importance, the remaining laboratory functions can be divided into research work and thesis work.

Data on thesis work is tabulated in Figure 7, Thesis Statistics. The work was investigated on the basis of time, space, area, and water required, as to the year, and as to whether it was graduate or undergraduate work. One of the results of this survey was to show that many theses were collaborative projects. Collaboration is an excellent practice and has its merits, but in this case fifty percent of the theses were collaborative projects because of the lack of available floor area and models. Another fact apparent from this same tabulation was the use of the same space or model at the same time for the experimental work of several theses. This is another practice, difficult to manage successfully, that has arisen through lack of models and laboratory area.

Data on research work is tabulated in Figure 8, Research Statistics. Research like thesis work was studied as to time, space, area, and water required, and as to the year and the client. This survey showed that the major portion of research work performed at the Institute was carried on between the years 1930 to 1936. The only apparent answer to this fact is that the present facilities are too limited for more work of this character. Of interest though is the list of clients and the titles of
the research performed. Variety - not limited specialization has been the chief characteristic.

Supplementary to Figures 7 and 8, are the plans in Figures 9 and 10. These sketch plans show the areas occupied by models in the River Laboratory, Building 21, and its annex, Building 20, as well as the space numbers, areas, and titles of the models. These plans present a fair picture of the utilization of floor area - only a two foot maximum working limit being given to each model. The remaining area is utilized for desk space, storage, work areas, lockers, etc. That the remaining area is ill adapted to such functions may be seen by the space shapes in the sketch plans. Literally speaking - a hydraulic slum is the result.
F - HYDRAULIC TRENDS

The future trend of any subject is always difficult to predict, and hydraulics is no exception. Such a prediction can be hardly more than a broad conjecture based upon an analysis of current hydraulic work. The history of the National Hydraulic Laboratory in Washington D. C. and of other laboratories, shows that the designing of a hydraulic laboratory is a very difficult task often requiring years of planning. Successful planning of a laboratory means successful planning for the type of work that it will be called upon to perform. In order to get a quick return from the cost and labors involved, it might seem advisable to first survey the country and to consult power companies, contractors, commercial firms, and government sources with regard to the problems most likely to arise so that the first tasks given to a laboratory may not involve work for which it is least equipped. The magnitude of the survey is apparent and in regard to the limited time available for this thesis, this method of analysis was dropped and other avenues of investigation were followed. These avenues are mainly two - an analysis of problems in experimental hydraulics and an analysis of problems susceptible to laboratory model study. - both investigations being made with due regard to current hydraulic research and studies in the United States.

Problems studied in experimental hydraulics may be grouped under the following headings:

1. Flow of water in general.
2. Hydrodynamic resistance including towing.
3. Hydraulic similitude.
4. Flow in pipes and fittings.
5. Flow in open channels and irrigation.
6. Orifices and weirs.
7. Jets.
8. Waves.
10. Hydraulic machinery,
    a) Water wheels.
    b) Pumps.
    c) Turbines.
11. Flow in granular material.
12. Transportation of sediment.
13. Cavitation.
15. Structures in water – model tests,
    a) Coasts and harbors.
    b) Dams, gates, and locks.
    c) Rivers and streams.

As regards current hydraulic research in the United States, it may be noted that the National Bureau of Standards publishes annually a report on current hydraulic research in the United States in which the subjects studied in about eighty hydraulic laboratories in the United States are reported. According to these bulletins, close to three hundred problems in various fields of hydraulics are being studied in laboratories. Of these problems no fewer than one hundred belong to the group called model tests – number 15. in the above list. These tests are confined to the investigations of particular structures in harbors and waterways, and the results of this work cannot readily be treated with a view to correcting and improving concepts of hydraulics. Few laboratories in the United States are equipped to deal with any test in hydraulics; some restrict their activity to one or two fields of study.
Problems connected with the flow of rivers are studied not only at the various laboratories of the Corps of Engineers, United States Army, but also at various college laboratories. These college laboratories have been mainly those of the Worcester Polytechnic Institute, the University of California, the Massachusetts Institute of Technology, the Carnegie Institute of Technology, and a few others. Case School of Applied Science and Carnegie Institute of Technology restrict their main research to the study of models of hydraulic structures.

The remaining two hundred investigations are carried out in about thirty different laboratories. Flow of water in pipes and channels, in particular, is studied at the Worcester Polytechnic Institute and at the following universities: Cornell, Columbia, Illinois, Iowa, Wisconsin, and Oregon State College.

In as much as model studies are the principal investigations carried on in river hydraulic laboratory, the following list of problems susceptible to laboratory model studies was made:

1. Effects of dikes on the river bed.
2. Effects of cut-offs on river bends.
4. Effects of channel dredging.
5. Mean discharge in various sections of a river.
6. Velocities and directions in rivers after correction.
7. Discharge over dams and spillways.
8. Resistance of cylinders, piers, and submerged sills in streams.
10. Design of stilling pools.
11. Effect of baffle piers on spillway aprons.
12. Loss through trash-racks and screens.
13. Flow through siphons, siphon spillways, etc.
14. Effects of storage basins on flood flow.
15. Progression of flood waves.
16. Flow through diversion floodways.
17. Effects of bends in a river.
19. Transportation of sedimentary and bed material.
20. Distribution of sedimentary material at river divisions.
22. Towing experiments.

All of the problems, except 22. Towing experiments, could be treated in a well equipped river laboratory of average flow and head and sufficient floor area. Towing experiments, however, require towing tanks or channels of great length - three hundred feet being a minimum and thirteen hundred feet a desirable maximum. There is a growing tendency in the United States to direct this type of work to specialized laboratories, and the three and a half million dollar David W. Taylor Model Basin at Carderock, Maryland, is an example.

From the foregoing lists and statements it is safe to draw several conclusions as follows:

1. Hydraulic research, in general, is increasing in number and importance.

2. There is a trend for laboratories to specialize in one or more fields of hydraulic research.

3. About ten out of the sixteen types of problems in experimental hydraulics can be studied in the average river hydraulic laboratory.
4. Out of the sixteen types of problems in experimental hydraulics studied in current research projects over thirty three percent are model studies.

5. River hydraulics and model studies, in particular, are the broadest form of specialization.

6. Model studies are increasing in number and importance. Because of this growth in the importance and number of model studies, they will be treated in detail under a separate heading.
Experimental studies of river hydraulics are becoming so important that the time is approaching when no outstanding work will be undertaken without preliminary tests to determine experimentally the principal characteristics of its behaviour with a model study on a reduced scale; whether it be to verify previous calculations, or, which is more likely, to obtain information on points for which calculation does not apply.

The fact that in the hydraulic laboratories, built during the past ten years, work has been directed chiefly to model studies, rather than to the investigation of hydraulic properties as such, is a sure sign of the growing importance of this type of hydraulic research.

In contrast to the design of electrical devices, the design of hydraulic machines, and still more so, the planning of structures for deflecting or collecting flowing water, constitute an established art rather than a science. While much progress has been made in the study of the fundamental properties of flowing water, the resulting laws are often too cumbersome for use in practice.

On the other hand, the growth in the size of hydraulic structures, such as dams and canals, has been so fast, and some of the undertakings have departed so much from routine, that experience could no longer be trusted as a guide. The method adopted was to make a study of a reduced-scale model from 1:20 or 1:100 of the proposed structure in an artificial miniature stream, a method formerly applied only in shipbuilding.
All the distances in the model are in the same ratio '1' to the corresponding distances in nature. The objection to the use of large scale ratios, that is, small models, becomes apparent when it is realized that, in some cases, the driving or retarding forces acting on the model become so much reduced that the forces neglected in the model test, such as surface tension and external friction, may become important and a series of distorted models may have to be studied.

The cost of a model of an ordinary dam to the scale 1:20 is from $1,000 to $5,000, (2/3 labor, 1/3 material), according to a recent publication by Professor George E. Barnes of the Case School of Applied Science at Cleveland. The present trend is toward the use of larger models, despite higher expense.

Work on models of hydraulic structures, such as dams, gates, locks, and stilling pools merely requires a glass-sided flume, a suitable water supply, a means of measuring the water, and a model. The most common ratios range from 1:20 to 1:60. River models, on the other hand, usually require large unobstructed floor areas as well as a suitable flow and a means for measuring the flow.
Soil Mechanics Laboratory is defined under Description of Subjects in the Massachusetts Institute of Technology Bulletin as - 'Technique of soil testing, including measurements of specific gravity, water content, density and limits of consistency; mechanical analyses; permeability consolidation and shear tests; various special tests.' See Figure 11, M. I. T. Bulletin Description.

'Interest in soil mechanics is increasing among educators as well as practicing engineers. There is evidence that many schools have introduced work in this field while others have it under consideration. Laboratory work is an essential part of any study of soil.' This statement by Edward E. Bauer of the University of Illinois in a recent publication, 'Results of Survey of College Laboratories,' is indicative of the growing importance of this study.

From the Bulletin Description of Subjects and from the above statement by Edward E. Bauer it may be seen that theory courses have preceded laboratory courses but that the latter is an essential and major part of the study of soils. Of importance is the fact that theory courses require classroom facilities in addition to the laboratory where the practical phase is taught and research is performed. Another point to note is that the subject is primarily a graduate study placing it on a par with river hydraulics.

As a desirable and closely related adjunct to the study of river hydrau-
lice, the importance of a Soil Mechanics Laboratory can not be overrated.

The importance of soil mechanics in its broadest aspect is in its relation to engineering and construction projects where a knowledge of soil mechanics with reference to the stability of slopes and retaining walls, earth and masonry dams, and foundations is essential.
I - SOIL MECHANICS LABORATORY COMPARISONS

Competition cannot be neglected with respect to soil mechanics than with respect to hydraulics. Relative to this, a study was made to determine the geographic location of representative laboratories in the United States and to determine to what class they belonged, that is, government, college, or commercial laboratories. The results of this study are shown by the map in Figure 12, Laboratory Locations. College laboratories are indicated in red on the map. Though college soil mechanic laboratories have a better distribution across the country than the college hydraulic laboratories formerly under consideration, there is still a decided concentration of laboratories in the east where the competition factor is the highest. Commercial laboratories are few; the remaining laboratories throughout the country are maintained by the federal and state governments, especially in connection with their highway departments.

The relative standings of the various laboratories is shown in Figure 13, Comparison of Laboratory Facilities. The Institute's facilities are indicated in red and show that the present laboratory is quite well equipped. This equipment at the Institute, however, is in two distinct laboratories - one for research and the other a student laboratory. This separation of the function of student instruction from that of the research laboratory is ideal.
To secure a basis for design data and to attempt to establish a trend in student enrolment statistics were collected. These statistics are graphically illustrated in Figure 14, Student Enrolment by Years. In as much as the course in Soil Mechanics Laboratory was not given until First Term 1936-37 and every first term thereafter, there is none too much data to predict a trend. However, the resulting enrolments in the subject has been such as to require two and three sections. Enrolment during the first term of 1939-40 dropped off somewhat, but this drop was probably the result of the teaching of this course in the summer sessions preceding and following the regular school year 1939-40. On the whole, then, the enrolment in Soil Mechanics Laboratory may be said to be on the increase, though it runs close to being about twenty seven students per year (3 sections).

Since theory courses are essential too, a study was made of the enrolments by terms in the graduate theory courses - 1.491, 1.492, 1.495, 1.496 Soil Mechanics. The results are presented in Figure 15, Student Enrolment by Terms. Here the enrolment from year to year is more erratic and is somewhat on the decrease - making it impossible to predict the future trend of these courses. Nevertheless, despite the decreasing enrolments, two new graduate theory courses, 1.495 and 1.496, were inaugurated in 1939-1940. The enrolment was six students in each course.
K - SOIL MECHANICS LABORATORY WORK

As has been mentioned previously, theory courses as well as laboratory work are an essential part of the study of soil mechanics. Soil mechanics work, however, is roughly divided into the following types:

1. Consolidation.
2. Direct Shear.
3. Compression.
4. Compaction.
5. Capillarity.
6. Permeability.
7. Penetration and Extrusion.
8. Swell.

All but type 9, field tests, are a definite laboratory study. The remaining eight types of laboratory work also serve as a functional classification of soil testing apparatus. This work is often minute in character and requires excellent lighting as well as such facilities as compressed air, water, electricity, and vacuum. A humid room is another essential.

Soil mechanics research seems to be fairly well stabilized and much of the equipment or testing apparatus in use in the various laboratories throughout the country is tending towards standardization.
L-HYDRAULICS AND SOIL MECHANICS

Physically Soil Mechanics and Hydraulics require different types of housing and facilities, but functionally there are regions where their work intermingles or where cooperation is desirable. For example, the study of seepage through a sand dam by model studies is a type of investigation that might be carried on in either laboratory. However if these two laboratories were closely related physically, collaborative work utilizing the laboratory having the best facilities for that particular investigation might be easily arranged.

If physically the laboratories have different requirements there are a few physical adjuncts such as class rooms, shops, and other elements that might be utilized by both laboratory groups thereby increasing the efficiency and the economy of such a relationship.
PART II

A — GENERAL
B — HYDRAULIC LABORATORY ANALYSES
C — HYDRAULIC LABORATORY EXAMPLES
D — HYDRAULIC LABORATORY EQUIPMENT
E — SOIL MECHANICS LABORATORY ANALYSES
F — SOIL MECHANICS LABORATORY EQUIPMENT
G — ORGANIZATION
H — THE SITE
I — THE PROGRAM

THE ARCHITECTURAL ANALYSIS
A - GENERAL

From the foregoing nonarchitectural analysis a number of conclusions and interpretations affecting the architectural program and solution can be made. They are as follows:

(1) The growing importance of both laboratories not only to the Institute but to the country and its future in the performance of research and in the training of men is incontestable.

(2) While the Institute’s rating in these branches of study is high, it can only hope to maintain or advance its position by improvements and increases in facilities and provision of a proper structure to shelter the facilities.

(3) That the improvements and increases must be made is evidenced by the competition of other laboratories and by the increasing enrolment and interest of students in these courses.

(4) Soil mechanics work appears fairly well stabilized, but the analysis of hydraulic laboratory work has shown that in order to meet all possible demands both present and future – the principles of flexibility and the possibility of expansion must be dominant factors.

(5) New requirements must be met and new ideas of laboratory design incorporated into the structure.

(6) The basic concepts of the structure or physical envelope of the laboratories and their adjuncts must be revised, and the latest tested and tried methods and data on structure, materials, lighting, and mechanical equipment must be incorporated.

(7) The division of the two laboratories physically, and yet maintaining
a functional integration, must be accomplished.

(8) The human factor must not be overlooked or made subservient to other governing factors of the design.

(9) The basic fact that both laboratories are primarily for education, graduate study, and secondly for practical as well as theoretical research must not be forgotten.

(10) And last, the laboratories are a part of the Institute and as such must conform to the concepts, the ideals, and the probable future expansion policies of the Institute.

As an additional aid to the formulation of a program and a solution and supplementary to the above statements, still other investigations and analyses of a stricter architectural character were conducted.
B - HYDRAULIC LABORATORY ANALYSES

The following analyses and discussion of laboratory design, types, and requirements was made with respect to the clarification of the architectural concepts.

The main part of a hydraulic laboratory is a supply basin, either natural or artificial, for storing a large quantity of water, pumps for raising that water continuously from the basin to a tank at a higher level, measuring weirs over which the tank discharges at a constant level into permanent or temporary flumes housing the hydraulic models which are built on a reduced scale such as 1:20 or 1:50, and return channels to the low level basin. This is diagrammatically shown in Figure 16, Basic Flow Diagram. Stilling chambers for calming the water, current meters or Venturi meters and calibrating troughs for determining the volume of water discharged in unit time must also be provided.

Depending upon the highest water level of the tank, the laboratory becomes a low head (less than about five feet on the scale 1:30), a medium head (over 15 feet), or a high head (over 45 feet) laboratory.

Laboratories with a low water head are intended primarily for the study of the flow of rivers, the sediments transported by flowing water, and the action of waves and tides. Medium head laboratories are intended for tests, by means of models, of power stations and dams, and high level laboratories are used in testing turbines and pumps. The present River Hydraulic Laboratory at the Institute is a low head laboratory,
but in the future some provision should be made for medium head work so as to be prepared for contingencies and emergencies.

The standard design of medium head laboratories for tests on hydraulic structures consists of a storage tank of 8,000 to 10,000 cubic foot capacity under the ground floor, and a group of centrifugal pumps, operating in parallel, with a total output of five to ten cubic feet per second. The pumps deliver through a 10 inch common header to a constant level tank on the second floor, ten to twenty feet above the ground floor, or directly to the supply mains. Flow from the constant level tank takes place through 12 inch or 4 inch supply mains, each line being equipped with a Venturi tube, or another rating device. It is desirable that the discharge from the experimental flumes or channels on the first floor reach the storage basin through pipes or volumetric measuring or weighing tanks.

Additional classification of laboratories as to type may be made on the basis of sheltered versus out of door laboratories and artificial versus natural head.

The principal advantages of an out of door laboratory are the selection of model scales without regard for space limitations, and preservation of models until completion of the prototype projects ends their possible usefulness in further investigations. As a result, such laboratories require shelter only for office work, personnel, shops, instruments, etc.
At the United States Waterways Experiment Station, Vicksburg, Mississippi, much of the laboratory work has been carried on out of doors utilizing a natural head and a site of 245 acres. The location of the laboratory in the southern part of the country where winters are not severe, has allowed out door work the year round. Nevertheless recently a number of the river models have been roofed over and sheltered. In Massachusetts the climatic conditions are by no means as favorable for out of door studies. The Alden Hydraulic Laboratory of the Worcester Polytechnic Institute on a 200 acre site makes use of a certain amount of out door work for studies of models. Extensive protection of the models through the winter has been necessary, and this type of laboratory set up is not recommended in this area. In fact the laboratory has on the site a number of laboratory buildings for all year round indoor work.

Consideration was also given to the idea of securing a site with a natural head for a new Institute laboratory and thereby eliminate pumping costs and recirculated water – or a closed system. However, all the available or possible sights for such a laboratory would be so far from Cambridge that the advantage gained would be a false economy. Disadvantages in the location of the laboratory some distance outside of the Boston Metropolitan Area are many; problems of time and transportation, of communication and cooperation, schedules, and the impossibility of incorporating a soil mechanics laboratory in the same structure.

From the tabulation of river hydraulic laboratory work, discussed in Part
I under Laboratory Work, it was possible to investigate still further and
determine basic laboratory requirements. This study is graphically shown
in Figure 17, Analysis of Laboratory Requirements, and is based on the
data listed in Figures 7, 8, 9, and 10. This analysis covers the water
and space requirements in regard to the time scale. During the Second
Term 1932-33 the water demand reached a peak of 10.2 c.f.s. The space
requirement of 6,600 sq. ft. (that is active utilization of space — mod-
els use space even while not operated) was reached Second Term 1937-38.
The maximum laboratory space available is slightly over 8,000 sq. ft. and
6,875 sq. ft. is utilized by models so that a 6,600 sq. ft. utilization
(not considering area devoted to desk space, etc.) indicates practically
a nifty six per cent use of the present area.

In a new structure greater area and a provision for expansion must be in-
cluded. Soil mechanics, to a limited extent, can take care of increases
in student enrollment by an increase in laboratory sections, but this is
impossible to accomplish in river hydraulic work of the calibre under
consideration.

The trend of water and space requirements as well as peak points do not
parallel each other. Neither do they show a decided relationship to the
relative number of research and thesis projects, though here the relation
is definite. In spite of their being no direct relation of water to space
requirements an increased water supply should be included in a new lab-
oratory. Research project of two years length are the maximum that have been conducted in the laboratory, and projects of this length have been one third of the work so far conducted. The average thesis time is two terms, though three terms is not uncommon and four years was the maximum, this work being for a doctor's thesis. Because time has a direct relation to space it is an important consideration. The length of time for the completion of a project signifies that the area it occupies is not available for other work.

Treated under a separate heading though it is in the realm of laboratory analysis is the discussion of notable hydraulic laboratories erected in the United States.
C - HYDRAULIC LABORATORY EXAMPLES

To provide an architectural background and to study problems of structure, materials, site, planning, etc. a number of hydraulic laboratories in the United States were investigated. A few noteworthy examples have been singled out as standards for a brief discussion because already there has been a great amount of detailed information published about them. For additional information consult the Bibliography. These laboratories are the National Hydraulic Laboratory, the St. Anthony Falls Hydraulic Laboratory, the Iowa Institute of Hydraulic Research, and the Alden Hydraulic Laboratory. Their plans are illustrated in Figures 18, 19, 20, and 21, respectively.

The National Hydraulic Laboratory of the Bureau of Standards, (see Figure 18.), for which the Swiss laboratory at Zurich served in part as a model, is an example of multistory development utilizing a hillside site. It is dependent upon an artificial head and performs both low and high head work. It cost $350,000, practically without equipment, and operating expenses are about $30,000 a year. Expansion is limited because of the hillside site, but provision was made in the original design for the addition of a head house over the measuring basin to balance the one already at the opposite end of the structure. Materials are mainly concrete for foundations and substructure and brick and steel for the superstructure.

The St. Anthony Falls Hydraulic Laboratory of the University of Minnesota, (see Figure 19.), is a very recent example of hydraulic laboratory design. It is a complete hydraulic institute and is constructed entirely of con-
crete - reinforced and masonry, utilizing steel beams for some of the spans wherever it was more feasible or economical. This laboratory was constructed at a cost of over $500,000, and when fully equipped will represent a much larger investment. It is a six story structure covering a unique island site in the middle of the Mississippi River and it has a fifty foot natural head. Flows up to 300 cubic feet per second can be handled in the channels and in the volumetric measuring basins. High to low head experiments in all branches of hydraulics are possible, and many unique features are incorporated into the laboratory. Expansion, except in the form of office space on the seventh floor, is curtailed by the site and accounts for the great initial size of the laboratory and for much of its flexibility.

The Iowa Institute of Hydraulic Research of the University of Iowa, (see Figure 20.), is housed in a five story (relatively speaking - seven) brick and steel structure with a concrete substructure. The site on the Iowa River gives them a ten foot head by means of a dam, but the vertical extension of the laboratory requires the creation of an artificial head for work on the first and second floors. The remaining floors are used for offices, classroom, library, etc. The natural head is of little use in the main laboratory work except in river channel work and the result has been the selection of a site and the construction of a building for which there is little opportunity to expand. Verticality was the solution, and in spite of the area being limited and curtailing their work,
they have produced excellent results.

The Alden Hydraulic Laboratory of the Worcester Polytechnic Institute, (see Figure 21.), was listed here because it is the Institute's nearest hydraulic competitor of major importance. It is an old laboratory, but it occupies a 200 acre site and boasts of a number of laboratory buildings and auxiliary structures, a 30 foot head, and outdoor experimental areas as well. It is well equipped for both student and research work as well as for commercial testing over a wide range of hydraulic subjects.
D - HYDRAULIC LABORATORY EQUIPMENT

The selection of laboratory equipment such as pumps, tanks, piping, and calibrating devices is mainly work for the engineer, and its location in the laboratory is work that must be carried out in collaboration with the engineer. It is debatable how much of the present equipment now in use is worth reincorporation in a new laboratory. Such equipment might be serviceable as a flexible reserve to the permanent equipment of the new laboratory. For this reason none of it is listed whereas with the soil mechanic equipment it is just the reverse. The main items necessary to the laboratory design will be listed in the program.
E - SOIL MECHANICS LABORATORY ANALYSES

Analyses of soil mechanics laboratory requirements brought to light some interesting facts. Long narrow rooms or rooms with plenty of wall space and light are ideal. This is because soil mechanics apparatus requires a wall location. North light is preferable; direct sunlight deteriorates rubber bands used on certain pieces of apparatus. Contrary to the requirements of a hydraulic laboratory, soil mechanics laboratories appear to be much more static units requiring no more area for future expansion than might be incorporated immediately within a new structure planned to meet future needs. The division of laboratory space into two distinct laboratories, one for research and one for student instruction, is ideal. A preparation room or work room is necessary as well as a humid room and storage areas and cabinets. The size of the laboratories and their requirements are governed by the types of apparatus used. Soil mechanics equipment is treated under a separate heading.
No attempt has been made to distinguish between auxiliary equipment such as stools and tables and special soil testing apparatus as listed in Part I under Soil Mechanics Laboratory Work. Instead the present equipment was listed by rooms and is tabulated in Figure 22, Research Laboratory Equipment; Figure 23, Student Laboratory Equipment; and Figure 24, Miscellaneous Equipment. A certain amount of the auxiliary equipment in use at present would be replaced by new or by built-in equipment in any new structure. Most of the soil testing apparatus, however, would be incorporated in a new structure; therefore these lists are only to serve as a design basis for new equipment and room sizes. Soil mechanics apparatus, contrary to hydraulic models and equipment, is much more a standardized element.
Successful organization of the soil mechanics laboratory and the hydraulic laboratory and their dependents must allow for expansion, for functional unity, for physical separation, and for the use of certain elements in common. The use of certain elements in common is justified on the basis of economy and efficiency, and these elements that serve a dual purpose or provide a common function can serve as the physical link for the two units. An expression of this organization or relationship is illustrated in Figure 25, Relationship Diagram. This relationship may be difficult to attain, but it is the ideal rather than the practical.
H - THE SITE

The selection of a sight for a proposed laboratory structure was one of the major problems of this project. As has already been mentioned, the scheme of locating the laboratory away from the Institute near a natural head was abandoned because of the many self-evident disadvantages. That narrowed the selection of a site to the property already owned by the Institute in Cambridge.

With regard to this property and the plan of the Institute as a whole, it is the author's personal opinion that the property west of Massachusetts Avenue should be reserved for student housing, for athletics, and possibly as a partial solution to the parking problem, and that the property should not be used for structures of academic function. And because of the Institute's special character in which a close relationship of buildings is a dominant note, all academic buildings, either classroom or laboratory type, should be located on the east side of Massachusetts Avenue. The student traffic problem across Massachusetts Avenue is bad enough at present without increasing it by a division of the academic group. This eliminates a great area from consideration.

The present Institute plan was studied as to permanent buildings, proposed additions and possible future expansions. The results are shown in Figure 26, Proposed Site, Hydraulics and Soil Mechanics M. I. T. The location of the proposed site is indicated in red and was selected for various reasons that follow:

(1) This is one of the least future unobstructed areas wherein no def-
inite plans for Institute growth have been projected.

(2) The site is in the rear of the Institute where special types of laboratory buildings with requirements of the more unusual variety are already located.

(3) The site offers some possibilities of future expansion - not as great as would be available on the opposite side of Massachusetts Avenue, but, nevertheless, of sufficient magnitude to guarantee the future possibility of expansion.

(4) The site or rather the area under consideration is somewhat flexible and would not too rigidly govern the design of the building with regard to the interior functions.

(5) A close connection with the main Institute buildings is possible and even might be made into a direct connection by the expansion of one of the Institute's wings.

(6) This site offers an ease of service access.

(7) Possible unobstructed north orientation for certain elements is obtainable on this site.

(8) The architectural character of a building on this site need not conform to the present Institute monumental facades that face Memorial Drive and Massachusetts Avenue.

(9) In keeping with the trend of modern architectural design, the new laboratory structure will probably harmonize more closely with the new athletic unit than with Institute academic unit.
Selection of this site, however, seems to require that classroom facilities or a lecture hall or reasonable capacity be provided in the new structure because of there being no such facility in the immediate vicinity and those in the Institute proper are too inconveniently located. A small department library would be required for river hydraulics. Problems of heavy traffic and vibrations from passing trains are almost impossible to escape and would have to be taken into account in building anywhere upon the Institute property. Such problems will have to be solved by construction.
I - THE PROGRAM

The following program for a Hydraulic Laboratory and a Soil Mechanics Laboratory for the Massachusetts Institute of Technology is proposed for a structure on the site previously described and illustrated in Figure 26, Proposed Site. Because the subjects previously treated have provided an adequate background, just the definite physical architectural requirements will be indicated here.

HYDRAULIC LABORATORY

Office Facilities:

Administrator's office.
Secretary's office.
Assistant's office.
Research assistants' office.
Desk space for thesis men.
Library - might be a portion of the secretary's office.
Drafting room - might be included in research assistants' office.
Conference room - might be a seminar room.
Files and vault space.
Office space for commercial investigators.

Classroom Facilities:

Lecture room - minimum seating capacity - 100.
Seminar room or rooms - one might serve as conference room.

Laboratory Facilities:

Minimum laboratory area of 12,000 sq. ft.
Area designed for flexibility and expansion.

Area possibly divided as to equipment or function.

Five ton overhead power operated crane required.

Low head facilities: 12 foot minimum head.
Supply basin 40,000 cu. ft. minimum not including capacity of return channels.
Four constant level tanks each 7'0" x 7'0" x 7'0".
Pumps connected in series or parallel:
2 - pumps of capacity 1 c.f.s.
4 - pumps of capacity 2.5 c.f.s.
1 - pump of capacity 5 c.f.s.
12" and 4" supply lines equipped with Venturi meters.

Medium head facilities: 25 foot minimum head.
Supply basin 20,000 cu. ft. minimum not including capacity of return channels.
Two constant level tanks each 7'0" x 14'0" x 7'0".
Pumps connected in series or parallel:
1 - pump of capacity 1 c.f.s.
1 - pump of capacity 2.5 c.f.s.
1 - pump of capacity 5 c.f.s.
12" and 4" supply lines equipped with Venturi meters.

One pump of 10 c.f.s. capacity for either use in the high or medium head systems.

A flexible calibration system - two weighing tanks of 300 cu. ft. capacity and scales. Small portable volumetric basins not part of permanent equipment.

Other Facilities:

Locker room and showers.

Heating, ventilating, and power control.

Machine shop.

Carpenter shop.

Shop storage facilities.
Small photographic laboratory.

Toilets.

Janitor.

General laboratory storage facilities for dyes, liquids, sands, gravels, pipes, valves, fittings, boats, current meters, weir boxes, and large objects in general.

SOIL MECHANICS LABORATORY

Office Facilities:

Administrator's office - space for secretary as well as plenty of storage and filing space.

Assistant's office - 2 men - library space to be included in this room.

Assistant's office - 4 men - space for files, 2 drafting tables as well as for flat storage of drawings.

No need for intercommunication between offices.

Laboratory Facilities:

Student laboratory - 16 students maximum - about 1,000 sq. ft.

Equipment listed elsewhere.

Research laboratory - about 1,000 sq. ft. Equipment is listed elsewhere.

Preparation room or work room.

Humid room - about 100 sq. ft. - access from preparation room.

Other Facilities:
Small shop – with storage space.

Room for mechanical equipment – air compressor etc.

Toilets.

Facilities such as lecture room and seminar rooms can be used in common.

The same is true for entrance and circulation systems. If a second floor is developed, it may be necessary to install a service elevator for the lifting of apparatus and other equipment.
PART III

A — GENERAL
B — PLOT PLAN
C — PLANNING
D — ELEVATIONS
E — CONSTRUCTION
F — LIGHTING
G — HEATING AND VENTILATING
H — CONCLUSION

THE ARCHITECTURAL SYNTHESIS
A - GENERAL

The crystallization of the design was a fairly rapid process after the previously minute analyses and detailed program. A description of this process, relative factors, and the special problems encountered are explained in the following architectural synthesis. The complete solution of the program is illustrated by photographs in Part IV, and these illustrations are supplementary to the written material that follows.
B - PLOT PLAN

The advantages of the site have been previously enumerated, but the location of the building within the proposed area was a difficult problem because of the various factors involved. Numerous schemes presented themselves for development, but these schemes after minute examination with due regard for the aforementioned factors resolved themselves into the final solution.

Of major importance in determining the shape of the building was the plan from within balanced against the problem of designing the building for future expansion, not only of itself, but with regard to the future development of the Institute. The building was so placed on the site as to adapt itself to the particular conditions of the site and so as to secure a maximum of natural light during the time that the building is in use. The problem of placing the building so that it would not cast shadows on other buildings was partially solved by the site itself, but in the present scheme of Institute development the elimination of shadows caused by one building on another is an impossibility. Maximum utilization of the site was secured with the placement of the building so that future additions may be made without interfering with other buildings. The problems of access and service not only for the students but for visitors as well was solved not so much on the basis of present conditions as with regard to future development of the Institute.

Planning of the building so that work of a related type was near together was accomplished with the location of the hydraulic laboratory section.
to the west in the direction of the present laboratory developments. The possibility of expanding the laboratory by a future addition to the west of the laboratory is one of the advantages of the plan. Another possibility of expansion for the laboratory section is to the east of the storage areas and shops of the proposed laboratory. This is not recommended, but it still remains a possibility in the face of an emergency. Expansion of office facilities could be accomplished by the addition of a third story to the wing paralleling Vassar Street or by a second story addition over the shops and storage areas.

Relative to the future development of the Institute, the building was located so that it falls within a geometrical pattern of building lines. The corridor or circulation space paralleling the hydraulic laboratory is an extension of the lines of the north-south corridor in the present Institute Building No. 4. The open area formed by the L shape of the building was provided so that there would be a more spacious setting opposite the main entrance to the proposed future athletic unit. This area is open to development as either a grass plot or as a parking area. The latter suggestion seems to be the most probable and gives the maximum utilization of the site. To secure as great as possible an area in this space the east-west wing was made parallel to Vassar Street. This development orientated some of the rooms more toward the west than if the wing were at right angles to the laboratory proper; however these rooms still face near enough to the true north so that the orientation is not object-
ionable. The main hydraulic laboratory wing was located north and south so as to secure east-west monitor lighting. Outside of lighting the orientation of the building had no influence or effect upon the planning.

All attention was given to the problem of designing the building so as to meet future Institute development, yet an unsought for condition resulted. This condition was the fact that the building as designed could be erected at present by moving only the Solar Energy Experiment and without the demolition of any of the present Institute structures. The relationship of the building to its site under present and probable future conditions is illustrated in Part IV. A discussion of the internal planning of the building follows in the next section.
C – PLANNING

The planning of the building was primarily a three dimensional proposition; consequently, the sections are as important as the plans in the explanation of the manner in which the building functions.

At first it was thought that the separation of hydraulics and soil mechanics could be attained by their location in separate wings, but the conditions of the site and the ideal internal planning of the units of each study resulted in a solution of levels. Soil Mechanics was located on the second floor of the east-west wing.

Of the facilities used in common, the lecture hall is the most important. It was placed so as to serve both units with its main entrance on an intermediate level easily accessible to both units and the main entrance. Access and exit on the first floor level both from the lobby and from the hydraulic laboratory for students and for service was achieved. The location by the main entrance makes its use for other Institute functions outside of the regular class hours a definite possibility. The permanent seating capacity is 156 and space for 40 temporary seats is available thus making a total seating capacity of approximately 200 persons. The stepped seating arrangement makes the room an ideal one for demonstration lectures, and a projection room is also provided to serve this lecture hall.

The large entrance lobby was planned so as to serve the lecture hall, the east-west office wing, the second floor, and the hydraulic laboratory.
Its size will allow for a certain amount of museum and exhibition space for the hydraulic unit on the first floor and a similar space on the second floor balcony overlooking the lobby for the soil mechanics unit. A lobby of this size is also desirable as an architectural prelude to the hydraulic laboratory just beyond. This entrance lobby is the main access to the building for visitors and for those using it who will be arriving by automobile. If the building were connected to the Institute proper by future additions this lobby would serve as the formal entrance to the Institute for this section of the campus.

The major student entrance to the building would undoubtedly be from the south and the Institute main buildings and not through the main entrance as provided. The reason why the main entrance was not located here is obvious when it is considered that future expansion would quite possibly and effectively close this entrance to outside access of a direct nature. In addition this access is not direct enough to serve as the main entry to the building except as an extension of the corridor system.

Entrances are placed by each of the stairs to provide the necessary exits and to best serve the circulation within and without the building. The service access is in the north west corner of the building where the two wings meet. It is directly off of Vassar Street and reaches the second floor soil mechanics unit by means of a hydraulic elevator or by means of the adjacent stairway. Service for large objects is direct to the hydraulic laboratory.
The main item of planning was the river hydraulic laboratory and this was governed primarily by the principle of flexibility. An area of the greatest width and length that could be economically roofed and served by an overhead crane was sought after. The entire planning of the substructure, that is the basement work area and channel system was based upon flexibility. The channels are all covered by removable steel plates so that there is access at any desired section.

The basic hydraulic flow system is from a reservoir at the base of the tower through the pump level, the gate valve level to the surge tanks and constant level tanks. From the constant level tanks the supply pipes traverse the entire length of the laboratory on one side in a pipe gallery fifteen feet above the laboratory floor. The pipes are suspended in a concrete trough and are accessible through removable steel floor grating. The concrete trough equipped with drains would serve to catch all water that might arise from leaks or from fitting connections on to the supply pipes. Access to this pipe gallery is by a service stairs at one end of the building, by stairs in the tower, and by vertical steel ladders placed at strategic points along the laboratory. Water after having gone through the experiment or model under examination is discharged into one of the return channels where it will flow back to the reservoir. If it is desired to measure the flow of this water, it can be directed into the work area or gallery in the basement where weighing tanks on rails that cover the length of the laboratory can calibrate the flow and
then discharge the water into return channels. Just before entering the reservoir the return channels reach a point where it is possible to divert the flow into the sewer system. The channels are very flexible elements in themselves. By means of stop logs and stop log guides the various portions of the channels can be converted into special reservoirs that would serve portable pumping units and thus supplement the main system. The reservoir itself is of a capacity of fifty thousand cubic feet of water. Construction and foundation conditions made a change from the requirements of the program necessary and the low head and medium head reservoirs were combined with a corresponding reduction in capacity of ten thousand cubic feet. Water from the return channels when entering the reservoir strikes a wall and is deflected downward and into two stilling chambers equipped with baffles where foreign elements either are settled out or float to the top and are prevented from entering the main part of the reservoir and the pump lines.

The area under the pipe gallery running the full length of the laboratory is the main line of circulation for the laboratory as well as the direct connection in the future with the Institute proper. Opening off this circulation system or corridor are the shops and storage areas for the laboratory, service to and exit from the lecture hall, access to the basement work level, the tower, the main entrance lobby, and the service stair to the second floor and to the pipe gallery. Off this corridor too is located the laboratory telephone booth (private – public phone booth is in the entrance lobby).
The shops and storage areas are so located as to be of the greatest service to the laboratory, so as to be a flexible unit within themselves, and so as to reduce the possibility of shop noises disturbing the office wing. The carpenter shop and the machine shop are given a common storage area although should it become desirable for each to have their own separate area, the space could be subdivided or else some of the storage area designed for the laboratory proper could be utilized as shop storage. Laboratory storage is essential and the present area has been subdivided into space for small items and sand and gravel and a space for large objects in general. Instrument storage is in a wall cabinet (built in) off of the circulation system.

The adjacent hydraulic office space is in a connecting wing so as to completely differentiate between the two functions of office and laboratory work. On the south side there are in a series a seminar room, the administrator's office, combination secretary's office and library, and the assistant's office. In as much as the laboratory is only two stories high all the toilet facilities are located on the first floor. On the north side of the wing are located the lockers and showers with access to the men's toilet room, the photographic laboratory with a daylight work area, the research assistants' office, office space for thesis men, and office space for commercial investigators.

The administrator's office is centrally located with respect to the laboratory as a whole. It is in easy reach of the laboratory, the lecture
hall, the main entrance, and is directly opposite the research assistants' office. It is so located and fixed with accesses that it can utilize the seminar room as a private conference room, and is in direct connection with the vault and files, as well as the library, and the secretary.

At first appearance the lockers and shower room may seem out of place, as if they should be directly related to the laboratory and shops. But when it is considered that the great majority of the men working in the laboratory and utilizing the shops will have desk or office space in the east-west wing, the present location of the lockers and showers off the circulation between the two elements is the ideal solution.

The photographic laboratory was located next to the research assistants' office and given a direct connection to it because one of the research assistants is the most likely person to operate the laboratory. By the use of light removable partitions, flexibility in the size of the office areas allotted to research assistants, thesis men, and commercial investigators is obtainable, and increases or decreases can be taken up from within accordingly.

In the northwest corner where the service access is located, there is also located the transformer units on the exterior and a power vault on the interior. Directly overhead and directly below are corresponding vaults with power panels. Besides serving as access for supplies and electrical power, into this corner of the building is also brought the steam line for heating at the basement work level. Here is the heating control
point for the entire structure as well as the power control.

Planning of the second floor of the east-west wing for soil mechanics is somewhat similar to that of the first floor especially on the south side. On this side are the combination seminar and conference room, the administrator's office combined with space for a secretary, and the research assistants' offices. The first office for two men contains the library for the soil mechanics unit. The second office for four men contains the drafting tables and files. On the north side of the wing are respectively located the student laboratory, the preparation and humid room, the research laboratory, the work shop and storage room. The administrator's office here again is centrally located with ease of access to the student and research laboratories, the lecture hall, main entrance, etc.

The student and research laboratories are long narrow rooms with an abundance of north light. The necessary wall space for backing up soil testing apparatus and for carrying the supply lines of water, compressed air, vacuum, and electric power is supplied by short spur walls three feet high perpendicular to the windows. These walls do not cut down on the light but still divide the room into various work areas and provide a secondary circulation area next to the corridor partition. This partition because of its depth for structural members and for ducts is of sufficient size to accommodate sinks and work areas and built in storage cabinets, all of which are accessible from the secondary circulation.
The student laboratory is located near the main entrance lobby and the lecture hall as well as the seminar room. The preparation room which contains the humid room is located between the student laboratory and the research laboratory where it can serve both rooms. The research laboratory is located opposite the offices of the research assistants. A small workshop with a storage area beyond is directly connected to the research laboratory. In this storage area where noise is least likely to become a disturbing factor the machinery for compressed air and vacuum should be located. Service for the soil mechanics unit is by means of the elevator and the adjacent service stairs. The janitor's closet for the second floor is also located in this service unit. On the first floor the janitor's closet is directly off the corridor facing the service stairway. Access to the projection booth for the lecture hall is from either the pipe gallery off of the hydraulic laboratory or else by a spiral staircase from the intermediate level of the lecture hall.

All of the floors or levels in the tower with the exception of the top floor are devoted to hydraulic equipment. The top floor is where the air conditioning equipment and ventilating equipment for the laboratory is located.
D - ELEVATIONS

The proportions of the elevations and the masses of the building were simply determined by the requirements of the plans and sections. Because of the underlying functional treatment of the building, no attempt was made to preserve in it the present architectural unity of the main Institute buildings. The only concession to this unity was in the use of brick so as to maintain a continuity of materials as used in the rear of the main Institute buildings and in the new swimming pool.

Brick was also chosen as the exterior material for the building because of its suitability to this region as a facing material and to preserve a certain architectural homogeneity in that section of the Institute grounds. Brick is also cheaper than stone. The economy resulting from the abandonment of false monumental stone facades can be diverted into the design of a better interior. Then too, brick lends itself well to various methods of surface treatment and gives scale to a structure. The use of alternately projecting brick courses to break the blankness of certain walls and to provide accents at various points is the only condescension to decoration. This decoration, however, is integral with the material itself and is in no way applied.

The fenestration was governed by the requirements of the rooms within. No difference in the fenestration of the locker room, shower room, or toilets was made from that of other rooms except in the use of frosted glass. These rooms need an abundance of natural light, partly for sanitation and partly to secure a well lighted spacious effect. There is
no legitimate reason why the fenestration area of these rooms should be reduced in size.

Glass block is used in a number of places, such as the stairways and in storage areas, but its principal use is in the monitor lighting of the hydraulic laboratory. The lighting of this laboratory will be discussed separately.

Sun shields are used over the windows on the south side of the east-west wing in order to reduce the amount of direct sunlight entering these rooms. Yet they do not cut off too much of the normal natural light.

The use of blank walls for the hydraulic laboratory was dictated by the possibility of future expansion either by an addition to the laboratory or by another Institute structure. This would have created a lighting problem had normal fenestration been used, but instead, monitor lighting was one system that was not likely to suffer from expansion.

The effect of this building when seen in perspective is shown in the accompanying photographs of the architectural model which was constructed at the same scale as the presentation drawings.
E – CONSTRUCTION

The construction of the building was influenced by a number of factors such as foundation conditions, problems of lighting, planning, etc. Basically the building is constructed as a skeleton steel structure, fire-proofed with concrete, and built over a reinforced concrete substructure. Column action is carried through the substructure to spread column footings resting on the sand lens at an elevation about six feet above the Boston Blue Clay. Floor and roof construction is of reinforced concrete slabs between beams. Trusses are used to span the hydraulic laboratory because of the span width; beams are used elsewhere. Walls are carried on beams between the column foundations. Exterior walls rest on concrete beams that are carried down far enough so as to be below the frost line. Construction of the walls is of face brick backed up with hollow tiles. Stone trim is used for window sills, copings, steps, etc.

Because of the height of the tower, its variable loads, the depth of the reservoir, and the foundation conditions; the tower was designed as a separate free standing structure so that it could move without affecting the remainder of the building. In the hydraulic laboratory the walls and columns are designed to act independently of the laboratory floor and the return channel system below so that the danger of structural stresses cracking the return channels will be reduced to a minimum.

The roofing of this laboratory area was first considered on the basis of a sixty by forty foot bay which is by no means uncommon and its cost is frequently no greater than that of the old short spans. However the in-
installation of an overhead crane required a closer spacing of columns in the line of the crane rail so that a twenty by sixty foot bay was ultimately adopted. Spacing of the roof trusses twenty feet on centers over a sixty foot span allows them to be constructed out of very light sections. The type of roof truss illustrated in the construction detail was selected as best complying with both structural and lighting requirements. The cambered lower chord is especially adapted to the monitor system of lighting. Longitudinal bracing trusses are a part of the structural system as is indicated in the construction detail of the hydraulic laboratory section. Diagonal bracing in the plane of the roof is also used in certain bays. Fire-proofing of the roof trusses partially by a furred ceiling and partially by direct covering with metal lath and cement plaster had an additional advantage in aiding the solution of the natural and artificial lighting problems by hiding the light devouring truss work.

A cantilevered system for the floor and roof is used on the north side of the east-west wing so as to make the use of continuous strip windows possible and thus improve the lighting within.

The interior finish of the east-west office and laboratory wing, the main entrance lobby, stairhalls, and corridors is plastered walls and ceilings (furred) and terrazzo floors. Acoustical board is used on the ceilings of the offices. The interior trim is of wood. All exterior doors and door frames are of metal. Metal sash are used throughout the building. In the hydraulic laboratory the interior finish is a cement plastered
ceiling and the walls are of face brick, the same as is used on the exterior. The lower six feet of the wall surface is of salt glazed tile where the danger of permanent staining or soiling of the walls is greatest. The same wainscoting is used in the hydraulic laboratory storage rooms and shops and in the circulation area under the pipe gallery.
F - LIGHTING

One of the special problems encountered in this design was that of lighting - both natural and artificial. Light is one phase of the environment which, inside the limits of a building, it is the function of the building designer to control. Natural light is constantly fluctuating in intensity, direction, and chromaticity, and is not subject to the degree of control which it is possible to achieve with artificial light. Further, there are seeing tasks, for the most efficient performance of which, luminous environments different from the natural one are desirable. Control of light within buildings is therefore increasingly accomplished by efficient and specialized artificial light sources.

Lighting design is concerned with intensities as well as spectral distribution; the concealment of the light source to prevent glare may involve problems of structural integration; the selection of interior finishes will be affected by their reflection characteristics; sound-absorptive materials tend to be light-absorptive as well, and this consideration, too, may influence the choice of materials. Control of intensities also involves problems of temperature control. Maintenance of air purity is also an important factor; it has been estimated that loss of lighting efficiency because of dust deposits on equipment and reflecting surfaces may be as much as one-third. It is in the integration of lighting with the other operational systems in the building that the technic of light control is mastered.

Nature provides a luminous environment by which human eyes are condition-
ed and to which they are adapted. The average characteristics of this environment are the features of the ideal luminous environment for activities normal to outdoor conditions. However, some of the conditions surrounding visual tasks in artificially lighted interiors differ from outdoor conditions, and the tasks separately vary in their optical needs, requiring the synthesis of different 'ideal' luminous environments, each one best suited to a particular type of visual activity and 'surround'.

Outdoor seeing, for instance, is mainly parallel seeing, that is, the objects seen are sufficiently distant and the details large enough to permit the eyes to remain parallel. Indoor conditions, with the nearness of everything to the eyes, causes them to converge and so many indoor seeing tasks require practically continuously converging vision. Surgical operating is an example. Intense concentration of vision is aided by a similarly intense concentration of light accompanied by generous relaxation zones in the area outside of the operating field.

Reflected glare is a minor and intermittent condition in outdoor seeing. Polished or semi-polished surfaces that cause reflected glare are widely found in artificial environments. It is becoming increasingly possible to control glare from light sources. The indirect method temporarily brought both direct and reflected glare within tolerable limits, while the refinements in direct illumination relieved direct glare. The evolution of the direct lighting method has made possible the control of direct glare up to levels of daylight; and where lenses or louvres are
combined into areas of respectable size, plus control of the reflecting characteristics of the environment, reflected glare is also materially reduced and even eliminated. An illustration of this general principle of controlled direct lighting is in the use of hanging fixtures equipped with lenses or louvres in the bottom to provide controlled direct light and yet so designed that part of the light is sent to the ceiling to aid in indirect illumination.

At present one definite trend is toward controlled direct lighting: the need of other systems within buildings are in its favor; for direct lighting requires furled ceilings, thus providing space for pipes, ducts, etc., and so creating job conditions favorable to air conditioning, which also requires such space. Further, other things being equal, it puts a smaller refrigeration load on the air-conditioning system. It also does not depend upon light reflection from the upper areas of the interior and so helps sound control by permitting the use of efficient sound-absorbing media (which tend to be light-absorbing).

The indirect method, up to the present, has depended upon diffuse reflection from the surroundings. This results in as much light coming directly to the eye from the walls and ceiling as reaches the work. The light that strikes the work is partly absorbed, so that when it reaches the eye from the work the latter appears darker in contrast to the walls and ceiling, causing reversed contrast. There are a number of ways of overcoming this, the most common of which is in the use of the combination direct-indirect
fixture aforementioned.

Another form of automatic control is spreading - the use of photoelectric cell equipment to replace manual control of lights by automatic. The cell is adjusted so that when the daylight in an interior falls below a predetermined point, the lights are turned on by the device and turned off again, if and when the daylight again rises to the desired level. This also removes the uncertain results due to the fallible judgment of the human observer.

The heat produced by a lighting system is a major factor in the design of cooling systems. Fluorescent lamps radiate less heat per lumen than do filament lamps. Most of the waste energy is conducted from fluorescent lamps and radiated from filament lamps. Conducted heat tends to remain at the ceiling and may be removed with relatively little effect on air temperature. But radiated heat accompanies the light with obvious effects on the comfort of the persons in the room. Thus, for equal lumens from the two light sources, approximately one-fourth as much heat is radiated from fluorescent as from incandescent lamps.

The fluorescent lamp is a light source of low brightness and extended area. It does not operate at full efficiency if the air temperature about it exceeds 90 degrees F. or drops below 30 degrees F. The main disadvantage of fluorescent tube lighting is that the lamps are thus far not available in the higher wattages and many units are therefore required to
light a room. Their future development appears to be partly limited by inherent characteristics. Equipment is now available that corrects the power factor of these lamps to 85% or higher over the former 60% factor.

An examination of various methods of lighting was made and some general conclusions were reached. Good natural or artificial lighting involves uniformity of distribution in addition to proper intensity. A proof of the effectiveness of east-west monitor lighting is indicated by the fact that while work in the Hamilton Standard Propeller Company, Hartford, Connecticut, (Albert Kahn Inc., Architects) is most exacting, involving tolerances of 1 / 10,000 of an inch, there are no individual lights on machines. There is a complete absence of shadows. With the correct spacing of high intensity fixtures, the same results are obtainable with artificial lighting.

North lighting, formerly widely used, has few advantages, save in special industries such as textiles, and consequently has been practically abandoned. The effect of north light in any interior (from a saw tooth skylight) is such that either the person is casting a shadow on his work or his equipment casts a shadow. This is illustrated in Figure 27, Natural Lighting - Comparison of Methods. Here also is illustrated east-west monitor lighting utilizing both clear glass and glass block.

Because of the problem of expansion and the elimination or normal fenestration in the hydraulic laboratory, the provision of high intensity lighting for this laboratory was a major problem. East-west monitor
lighting was selected as the solution to this lighting problem from the standpoint of natural illumination. This monitor lighting is approximately 40% of the total floor area—a figure way above the required standards.

This system of lighting in turn influenced the roof truss design. The furred ceiling besides serving to fire-proof the roof trusses acts as a reflecting and diffusing surface for artificial illumination, and the splayed returns up to the monitor lights do the same thing for the natural illumination. The fire-proofed fins or knee braced sections of the trusses act as louvres on the natural illumination and aid in light diffusion.

Glass block was selected for the monitor lights in order to diffuse and distribute light, reduce solar radiation, reduce thermal conductivity, and to reduce condensation. Further it is a material easy to clean and its maintenance cost is low.

Artificial lighting of the laboratory is accomplished through the use of combination controlled direct and indirect lighting fixtures equipped to use fluorescent tubes. With regard to artificial illumination it was desired to secure a type of fixture that would not create powerful reflections on water surfaces and so hinder the successful photographing of laboratory experiments. Maintenance of these fixtures and the replacement of tubes is possible by using the overhead crane as a working base.
Since the laboratory will be air conditioned, the reduction in efficiency of the indirect fixtures due to accumulated dust will be at a minimum.

The effect of ordinary natural lighting within rooms as compared with lighting in rooms of the same size utilizing strip window lighting is illustrated in Figure 27, Natural Lighting - Comparison of Methods. In the soil mechanics laboratories where an abundance of north light was desired cantilever construction and strip windows were used to solve the problem of natural lighting.

Sun shields are used to control the amount of sunlight in the rooms on the south side of the east-west wing. The lighting problems of the rooms in this wing vary with each room as far as the artificial illumination is concerned. The offices that are used also as drafting rooms are a small problem which is solvable through the use of high intensity indirect lighting fixtures.

The lighting of the lecture hall is entirely artificial. A more positive control of the light is the result. The lighting when properly designed will allow the room to be used for note taking, for demonstrations, for lectures less note taking, and for use in connection with the projection room in complete or partial black out.
G - HEATING AND VENTILATING

The heating and ventilating of the building had one unusual phase. Because of the large quantities of water circulated through the hydraulic laboratory, high humidities are bound to result. In summer solar radiation is bound to heighten this effect; hence the use of glass block to reduce the effect of solar radiation within the laboratory. In the winter condensation is likely to occur, especially on windows; hence the use of glass block to reduce condensation. But this alone does not solve the condensation problem, nor does it get at the real source of the trouble. The effective temperature of rooms involves the relationship between temperature and humidity. As the temperature of the room is increased its humidity should be decreased. This must be done, if only to secure conditions in which work can be done efficiently and comfortably.

The standards proposed by the American Society of Heating and Ventilating Engineers are given in the following quotation;

VENTILATION STANDARDS Section I: Air Temperature and Humidity

The temperature and humidity of the air in such occupied spaces, and in which the only source of contamination is the occupant, shall be maintained at all times during the occupancy at an effective temperature, as hereinafter stated.

The relative humidity shall not be less than 30 per cent, nor more than 60 per cent in any case. The effective temperature shall range between 64 degrees and 69 degrees when heating or humidification is required, and between 69 degrees and 73 degrees when cooling or dehumidification
is required.

These effective temperatures shall be maintained at a level of 36 inches above the floor.

From this statement it is seen that mechanical means must be used to treat the air and that the air conditioning is inseparable from the heating and ventilating systems of the laboratory. For this purpose the top floor of the tower was used for air conditioning and ventilating. Here is located the fresh air intake for the building, the fan system, and the cooling and heating apparatus for the air circulated through the hydraulic laboratory. Because of ground water conditions a refrigeration unit will be necessary for cooling and dehumidification. Positive heating control of the rooms in the east-west wing is accomplished through the use of convector type radiators concealed under the windows in the exterior walls. Ventilation is supplied by ducts from the tower intake and fans. The air in the hydraulic laboratory is drawn out of the laboratory through ducts that open up at the bases of alternate columns along the circulation area. Upon reaching the tower it is mixed with a certain percentage of fresh air, cooled and dehumidified by condensation, or else it is passed through the heating coils and then returned to the laboratory. The supply ducts to the laboratory run the length of the laboratory over the pipe gallery and from the ducts louvred openings direct the air out and up toward the lighting monitors. At this level high air velocities are possible without affecting either the room occupants or the water surface of
experiments in the laboratory. Both the main entrance lobby and the lecture hall are heated and ventilated from the tower unit. Because of its completely enclosed position artificial ventilation is very essential in the lecture hall. The projection room has its own separate fan system.
H - CONCLUSION

Many of the problems encountered in this design, strictly speaking, were in the realm of the engineer and specialist, but in as much as they involved problems of structural integration the architect is responsible for their solution by the proper authorities. Problems of vibrations resulting from passing street traffic and trains can not be solved in the structure by economical means and must be met in the design of experimental apparatus likely to be affected by such factors. Machinery within the structure can be so treated as to reduce vibration or prevent it from affecting the structure. The problem of acoustics only assumes a major proportion in the design of the lecture hall where it is subject to careful control.

No attempt was made to study the financial aspect of the design. The structure and its problems differ quite radically from most buildings and estimates of its cost would only be approximations with little basis unless working drawings were completed and estimates taken, not only for the building itself but for the hydraulic equipment as well.

In Part IV following is the solution graphically illustrated by photographs of the drawings and the model.
PART IV

A — PHOTOGRAPHS OF DRAWINGS

NO. 1 M.I.T. PLOT PLANS
NO. 2 BASEMENT LEVEL PLAN
NO. 3 CHANNEL LEVEL PLAN
NO. 4 FIRST FLOOR PLAN
NO. 5 SECOND FLOOR PLAN
NO. 6 CROSS SECTIONS
NO. 7 N. & E. ELEVATIONS
NO. 8 S. & W. ELEVATIONS
NO. 9 CONSTRUCTION DETAIL

B — PHOTOGRAPHS OF MODEL

THE ARCHITECTURAL SOLUTION
A - PHOTOGRAPHS OF DRAWINGS

M.I.T. PLOT PLANS

NO. 1
B - PHOTOSGRAPHS OF MODEL
APPENDIX

FIGURES 1 TO 27
BIBLIOGRAPHY
PRESENT LOCATION
HYDRAULICS & SOIL MECHANICS M.I.T.

- HYDRAULICS.
- HYDRAULICS - RIVER LABORATORY - 21.
- ANNEX - 20.
- SOIL MECHANICS.
HYDRAULICS
LABORATORY LOCATIONS

- Commercial and Government Laboratories.
- College Laboratories Engaged in Research and Commercial Work.
- College Laboratories Used for Instruction and for Scientific Research.

LOCATION OF REPRESENTATIVE HYDRAULIC LABORATORIES
IN THE UNITED STATES AND CANADA
## HYDRAULICS COMPARISON OF LABORATORY FACILITIES

<table>
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<th>Equipment Type</th>
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HYDRAULICS
M.I.T. STUDENT ENROLMENT BY YEARS

RIVER HYDRAULIC LABORATORY 1.691

1930-31 9

1931-32 5

1932-33 7

1933-34 8

1934-35 8

1935-36 18

1936-37 9

1937-38 23

1938-39 20

1939-40 29

136 TOTAL FOR TEN YEAR PERIOD
HYDRAULICS
M.I.T. STUDENT ENROLMENT BY TERMS

RIVER HYDRAULIC LABORATORY 1.691

1 UNDERGRADUATE TO 10.08 GRADUATE STUDENTS.
This figure is based upon a ten year average 1930 to 1940.

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<td>360</td>
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<td>Charles T. Main, Inc., Boston.</td>
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<td>Model of Floating Drydock, N. Y.</td>
<td>II</td>
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<td>Dynamics of Suppressed Weir Discharge.</td>
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<td>Investigation of Wave Phenom. in Channels.</td>
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<td>Effect of Overboard Discharge on Destroyer Speed.</td>
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* Model of Cape Cod Canal and Approaches - 115' x 55'.
' Model of Proposed Mooring Basin for the Cape Cod Canal - 50' x 11'.
SKETCH SHOWING AREAS OCCUPIED BY MODELS IN THE RIVER LABORATORY - BUILDING 21.

MAXIMUM WORKING LIMIT GIVEN IS 2 FEET.
TOTAL AREA EQUALS 3850 SQ. FT.
TOTAL AREA OCCUPIED BY MODELS EQUALS 2850 SQ. FT.

SPACE I A TROUGH FOR RIVER MODELS 840 SQ. FT.
SPACE I B TROUGH FOR RIVER MODELS 300 SQ. FT.
SPACE II MODEL OF A FLOATING DRY DOCK 300 SQ. FT.
SPACE III GLASS CHANNEL 340 SQ. FT.
SPACE IV WOODEN TROUGH 240 SQ. FT.
SPACE V MODEL OF DAM 360 SQ. FT.
SPACE VI WOODEN FLUME 240 SQ. FT.
SPACE VII CHANNEL FOR DIKES 130 SQ. FT.
SPACE VIII GLASS CHANNEL 80 SQ. FT.
SPACE IX AREA BY TROUGH 80 SQ. FT.
SPACE X AREA OVERLAPPING TROUGH 40 SQ. FT.
HYDRAULICS
PRESENT RIVER LABORATORY ANNEX M.I.T.

SKETCH SHOWING AREAS OCCUPIED BY MODELS IN THE RIVER LABORATORY ANNEX - BUILDING 20.

MAXIMUM WORKING LIMIT GIVEN IS 2 FEET.

SPACE XI 12" WOODEN CHANNEL 440 SQ. FT.
SPACE XII SWIMMING POOL 170 SQ. FT.
SPACE XIII 2" WALLED CHANNEL 265 SQ. FT.
SPACE XIV CAPE COD CANAL MODEL 4025 SQ. FT.
SPACE XIV A CAPE COD CANAL MODEL 700 SQ. FT.
SOIL MECHANICS LABORATORY LOCATIONS

- College Laboratories.
- Commercial Laboratories.

LOCATION OF REPRESENTATIVE SOIL MECHANICS LABORATORIES IN THE UNITED STATES
# Soil Mechanics

Comparison of Laboratory Facilities

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SOIL MECHANICS
M.I.T. STUDENT ENROLMENT BY YEARS

Laboratory course on the technique of soil testing first given First Term 1936 and each First Term thereafter. The Summer Session laboratory course first given 1939.

1936–37 One Section
1937–38 One Section
1938–39 Three Sections
1939–40 Two Sections

1936–37
4

1937–38
26

1938–39
28

Summer
6

1939–40
21

Summer
6

91 Students TOTAL FOR FOUR YEAR PERIOD
SOIL MECHANICS
M.I.T. STUDENT ENROLMENT BY TERMS

SOIL MECHANICS 1.491 1.492 1.495 1.496
(Graduate Theory Courses)
HYDRAULICS
BASIC FLOW DIAGRAM

SKIMMING WEIRS

CONSTANT LEVEL TANK

VENTURI METER

SUPPLY MAIN

OVERFLOW PIPE

MODEL STUDY OR
EXPERIMENTAL APPARATUS

DIVERSION BOX

WEIGHING TANKS

SCALES

RETURN CHANNEL

SUPPLY BASIN
HYDRAULICS
ANALYSIS OF LABORATORY REQUIREMENTS

Requirements based upon statistics from river laboratory theses and research projects, 1930-1940

WATER REQUIREMENTS

SPACEN REQUIREMENTS

PROJECTS

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HYDRAULICS
UNIVERSITY OF MINNESOTA

ST. ANTHONY FALLS HYDRAULIC LABORATORY - MINNEAPOLIS

Tower Floor Level

Office Floor Level

Mezzanine Floor Level

Main Laboratory Floor Level

Turbine Laboratory Level & Volumetric Basins Plan
HYDRAULICS
UNIVERSITY OF IOWA

IOWA INSTITUTE OF HYDRAULIC RESEARCH - IOWA CITY

Fifth Floor Plan

Fourth Floor Plan

Third Floor Plan

Second Floor Plan

First Floor Plan

Pump and Reservoir Floor

Plan of Lab. River Channels

117
SOIL MECHANICS RESEARCH LABORATORY EQUIPMENT

Laboratory 26' x 36' in size.

Open shelf storage – 1'6" x 9'0" x 6'0" – 5 shelves.

Storage cabinet – closed and glazed – 26" x 80" x 7'0".

Compression machine – museum object – 30" x 30" x 6'0".

Cylindrical triaxial – museum object – 21" x 30" x 8'0".

Two cylindrical triaxial compression machines 30" x 42" x 5'0".

One cylindrical triaxial compression machine 24" x 60" x 5'10".

All triaxial compression machines to be located 24" from wall. Compressed air, electricity, and vacuum required.

Also a combination sink and work table must be nearby.

Table and oven 30" x 48" x 4'6". Electricity required.

Balance table and scales 24" x 37" x 4'0".

Direct shear machine 32" x 60" x 4'0" – located in room center – electricity for power required.

Table and storage unit 42" x 102" x 3'0" – located in center of room.

Work bench 42" x 144" x 3'0" – electricity and gas required.

Model retaining wall 30" x 14'0" x 7'0".

Two dimensional strain apparatus 34" x 8'6" x 10'0".

Two drafting tables, stools, chairs, small tables, etc.
SOIL MECHANICS
STUDENT LABORATORY EQUIPMENT

Laboratory 26' x 38' in size.

Sinks and work areas (drain boards) 24" x 14'0".

Table 4'0" x 8'0" x 3'0".

Storage space for about 12 cans 24" high and 20" in diameter.

Nine drafting tables.

Quicksand demonstration 33" x 20".

Original shear machine 7'0" x 6'0" - a museum piece.

Four consolidation machines 48" x 36" x 6'0".

One consolidation machine 60" x 48" x 6'0".

Consolidation machines require a wall location and north light if located next to a window. Compressed air and vacuum required.

Tables and chairs.
SOIL MECHANICS
MISCELLANEOUS EQUIPMENT

Work room 19'0" x 12'0".

Permeability sink 24" x 32" and work table.

Sample storage cabinet 30" x 48" x 8'0" - depth desirable.

Additional storage areas and cabinets - 12" x 72" x 6'0".

Space for 24 cans 24" high and 20" in diameter.

Inside present work room - humid room 5'0" x 8'0" - water and electricity required.

Closet space adjacent.

Administrative office 12'0" x 18'0".

Three desks.

One table.

Six bookcases 12" x 48".

Assistants' office 12'0" x 26'0".

Three desks.

One drafting table.

Bookcases.

Steel filing cabinets.

Cabinet 24" x 48" x 5'0".

Cabinet 36" x 8" x 3'6".
RELATIONSHIP DIAGRAM
HYDRAULICS & SOIL MECHANICS

SOIL MECHANICS

ADMINISTRATION

2 ASSISTANTS

4 ASSISTANTS

DRAFTING

STORAGE

SHOP

RESEARCH LABORATORY

HUMID ROOM

PREP. ROOM

STUDENT LABORATORY

JANITOR

SERVICE ACCESS

LECTURE HALL

SEMINAR

ENTRANCE AND LOBBY

T.

HYDRAULICS

ADMINISTRATION

SECRETARY

LIBRARY

FILES VAULT

1 ASSISTANT

3 RES. ASST.'S

DRAFTING

THEESIS MEN

OFFICE SPACE

COMMERCIAL

INVESTIGATORS

PHOTOGRAPHY LABORATORY

LOCKERS AND SHOWERS

RIVER HYDRAULICS LAB.

RESERVOIR PUMPS

C.L. TANKS

HEATING VENTILATING

POWER CONTROL

LABORATORY STORAGE

MACHINE SHOP

CARPENTER SHOP

SHOP STORAGE
PROPOSED SITE
HYDRAULICS & SOIL MECHANICS M.I.T.

- AREA OF PROPOSED SITE
- PROPOSED FUTURE ADDITIONS
- PRESENT PERMANENT BUILDINGS
NATURAL LIGHTING
COMPARISON OF METHODS

A. NORTH LIGHTING. MAN CASTS SHADOW. APPARATUS CASTS SHADOW.

35
20
10 WORKING PLANE FLOOR LINE
FOOT CANDLES - WINDOW BRIGHTNESS OF 100 C.P. PER SQ. FT.

B. EAST-WEST MONITOR LIGHTING - HAMILTON STANDARD PROPELLER COMPANY.

80
60
40
20
0 FOOT CANDLES ON 30" WORKING PLANE - CEILING PAINTED WHITE.

C. EAST-WEST GLASS BLOCK MONITOR LIGHTING - INDUSTRIAL RAYON CORPORATION

D. CONTINUOUS STRIP WINDOWS. INDIVIDUAL UNIT WINDOWS.
BIBLIOGRAPHY

GENERAL:

EVEN DEN, E. S.
STRAYER, G. D.
ENGELHARDT, N. L.
   Standards for College Buildings.
New York, Bureau of Publications, Teachers College, Columbia University,
1938.

NELSON, Paul
   A Method of Procedure in Architectural Design.
pp. 52 - 57 (Design Trends).

Federal Institute of Technology, Zurich, Switzerland.
Black line prints of the laboratory plans, sections, and elevations.
Received through Herbert N. Eaton, Director of the National Hydraulic
Laboratory, Bureau of Standards, Washington D. C.

HYDRAULICS:

EATON, Herbert N., Editor.
   Current Hydraulic Laboratory Research in the United States.
Washington D. C., National Bureau of Standards, Hydraulic Laboratory

HOOPER, Leslie J.
   Representative Hydraulic Laboratories in the United States and Canada.
Journal of the Boston Society of Civil Engineers - Hydraulic Section,
Boston, Boston Society of Civil Engineers, January 1938. pp. 49 - 290.

MAVIS, F. T.
   Hydraulic Research at the University of Iowa.
Reprinted from the Engineering News-Record, September 26, 1935.

REYNOLDS, K. C.
   State Laboratory in Berlin.
Typewritten report with diagrams.

RUDY, R.
   New Hydraulic Laboratories and Their Work.
Ottawa, National Research Council of Canada, May 1938.
STRAUB, Lorenz G.
St. Anthony Falls Hydraulic Laboratory, University of Minnesota.
Guide for Members and Guests of the Junior Association of Commerce.
Minneapolis, University of Minnesota, May 1940.

SWEETSER, W. J.
The University of Maine Hydraulic Laboratory.
Paper presented at the S. P. E. E. meeting at Cornell University.
June 1934.

** ** ** **
Innovations Mark Construction of Experimental Model Basin.
pp. 33 - 37 (Building News)

** ** ** **
St. Anthony Falls Hydraulic Laboratory.

SOIL MECHANICS:

BAUER, Edward E.
Results of Survey of College Mechanics Laboratories.
University of Illinois, 1938.

JOHNSON, Clement M.
BARBER, E. S.
Reprinted from the proceedings of the Eighteenth Annual Meeting of the

ARCHITECTURAL DESIGN:

FALUDI, Eugenio.
Architecture di Eugeno Faludi.
Milano, Italy, 1939.

GESCHEIT, H.
WITTMAANN, K.
Neuzeitlicher Verkehrsbaul.
Potsdam, Germany, Muller and J. Kiepenheuer, 1931.
KARANTINOS, Patroclae.
Ta Nea Scholika Ktirid.
Athens, Greece, Technikon Epimelitirion tis Ellados, 1938.

HAMILTON, Talbot F.
Architecture of the T. V. A.
pp. 721 - 732.

KIMBALL, Russell.
TAYLOR, Percy I.
WARNE, William E. Editors.
Dams and Control Works - A Description of Representative Storage and
Diversion Dams and High-Pressure Reservoir Outlet Works constructed by
the Bureau of Reclamation, United States Department of the Interior.

MINNUCCI, Gaetano.
Scuole - Asili d'infanzia, scuole all' aperto elementari e medie case
del balilla, palestre ed., impianti sportivi.
Milano, Italy, Ulrico Hoepli Editore, 1936.

MULLER-WULCKOW, Walter.
Bauten der Arbeit und des Verklers, Aus Deutscher Gegenwart,
Leipzig, Germany, Karl Robert Langewiesche, 1929.

NELSON, George.
Industrial Architecture of Albert Kahn Inc.

PIO, Angnoldomenico.
Nuova Architettura Nel Mondo.
Milano, Italy, Ulrico Hoepli Editore, 1937.

REID, Kenneth.
Design in T. V. A Structures.
pp. 689 - 720.

** ** ** **
Buildings for Commerce and Industry.
** Ny Svensk Arkitektur.  

** Architecture and Furniture *A Alto.  

** Modern Architecture in England.  

** Modern Architecture; International Exhibition.  

** STRUCTURAL DESIGN: **

BARROWS, H. K.  
Water Power Engineering.  

FULLER, Almon H.  
KEREKES, Frank.  
Analysis and Design of Steel Structures.  

GRAF, Don.  
Pencil Points Data Sheets.  

** Pocket Companion.  

** Architectural Concrete Information Sheets.  
Chicago, Portland Cement Association.

** Simplified Design of Concrete Floor Systems.  
Chicago, Portland Cement Association.
* * * * * * *
Reference Manual for Architects and Engineers.

* * * * * * *
Illuminating Design Data.
Cleveland, Ohio, General Electric Company, Nela Park Engineering Company,
1936.

PRESENTATION:

BRINTON, Willard C.
Graphic Representation.

CORBUSIER. (Charles Edouard Jeanneret-Gris).
Des Canons, des Munitions? Merci des Logis... S.V.P.
Boulogne France, Editions de l'architecture d'aujourd'hui. 1938.

MARTIN, J. L.
NICHOLSON, Ben.
GABO, N. Editors.
Circle; International Survey of Constructive Art.

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(Graphic Representations)