

Predicting Subsurface Settlement of Marsh Creation Projects and Flood Protection Infrastructure in Coastal Louisiana

By: Navid H. Jafari¹

INTRODUCTION: Louisiana is in the midst of a land loss crisis that has claimed 1,880 square miles of land since the 1930s. Given the importance of coastal waterways, natural resources, unique cultures, and wetlands located in the Mississippi River Delta, the Coastal Protection and Restoration Authority (CPRA) developed a comprehensive protection and restoration master plan to aggressively address wetland loss. This plan includes the nation's largest investment, over \$20 billion in marsh creation (MC) projects and \$10.9 billion in structural protection, which will: (1) protect coastal properties and infrastructure systems from accumulated damage due to storm surges; and (2) create a sustainable coastal environment to booster vital economic, social, and recreational opportunities. Because MC projects build land during construction, the marsh fill will erode and settle over time. A major contributor of this settlement is the consolidation of foundation soils caused by loading exerted by dredged material or levee embankments. Because a limited number of laboratory tests are performed to evaluate the compressibility and permeability characteristics of foundation layers, significant uncertainties exist in these parameters over a large spatial expanse. As the next-generation MC projects are expected to increase in size from 100s of acres to 1,000s of acres, this uncertainty will challenge the CPRA's ability to construct successful coastal restoration projects. To address these uncertainties, we propose to compile all existing geotechnical consolidation data from restoration projects to develop a suite of coastal Louisiana correlations for use on future projects in an effort to improve predictions and expedite the design and engineering phase of MC projects and levee lifts.

BACKGROUND: The compressibility and permeability relationships required for a consolidation analysis are determined from well-established laboratory tests (ASTM D2435 and ASTM D4186) and include: recompression index (C_r), compression index (C_c), permeability versus void ratio (C_k), coefficient of consolidation (c_v), and preconsolidation pressure (σ'_p). Empirical correlations relating consolidation parameters to soil index properties have been developed for local and regional geologic formations. For example, Fig. 1 shows compression index of the Inner Harbor Navigational Canal (IHNC) soils as a function of in situ water content. A direct relationship between the compression index and in situ water content exists in Fig. 1 because both are controlled by soil composition and structure. In essence, any soil that comes to equilibrium at a high void ratio under typical over-burden pressures displays high compressibility at σ'_v beyond the σ'_p . The IHNC

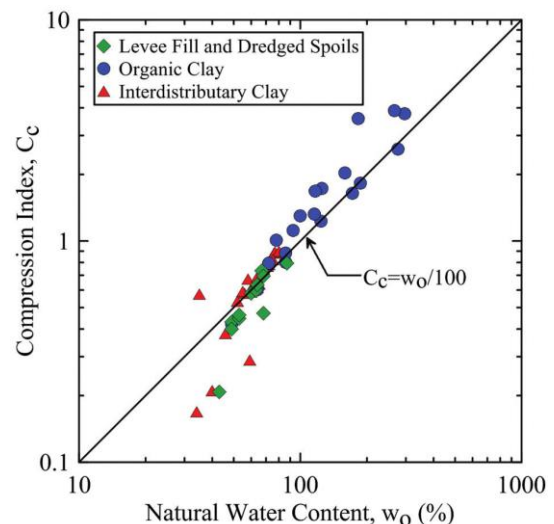


Figure 1. Correlation between compression index and in situ water content for IHNC soils (Stark et al., 2014)

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organic clay deposits come to equilibrium at water contents of 100%–400%, hence they display values of C_c typically in the range of 1–5 because a large amount of water is held within and among the organic particles. The levee fill and interdistributary clay (inorganic clays and silts) exhibit typical in situ water contents below 100% and C_c below 1. In the absence of laboratory testing on high-quality samples, Fig. 1 provides an empirical correlation between C_c and w_o for IHNC soils, i.e., $C_c = w_o/100$.

RESEARCH METHODOLOGY: The proposed research aims to develop coastal Louisiana correlations for predicting foundation settlement. This will be accomplished through the follow four tasks:

1. Assessment of MC project and levee infrastructure sites: Records of soil borings, cone penetration soundings, and laboratory tests will be gathered from CPRA. Specifically, the student will work with Mr. Russ Joffrion and Ignacio Harrouch at CPRA to identify suitable sites across the Mississippi River Delta. Potential MC and levee sites include Barataria Basin (BA-39, BA-48, and BA-164), Lake Borgne, Bonfouca, Biloxi Marsh, and IHNC levees. The soil types, soil index and engineering properties, and in situ tests at each project (MC and levees) will be organized according to the subsurface stratigraphy obtained via soil borings.
2. Identification of correlations for consolidation parameters: Extensive review of geotechnical literature on deltas will be performed to identify the appropriate soil index properties (e.g., particle size, mineralogy, Atterberg Limits) that correlate to consolidation parameters.
3. Development of Louisiana empirical correlations: Using Fig. 1 as guide, plots will be developed for C_c , C_k , C_v , and σ'_p parameters. Statistical regression analyses will be performed to provide best-fit equations for CPRA to include in their design manuals (e.g., Louisiana Flood Protection Design Guidelines, 2015). The analyses will evaluate to what extent the correlations are localized or if they can be applied to coastal Louisiana region.
4. Procedure to predict future marsh and levee elevations: The empirical correlations will be incorporated into a methodology for predicting the change in marsh and levee heights with time. This is important for maintenance of MC projects and levees because they must remain above their design elevations, e.g., above sea level and storm surge level, respectively.

EXPECTED OUTCOMES AND SIGNIFICANCE:

1. The empirical correlations developed for underlying foundation soils will expedite the design and engineering phase of marsh creation projects and levee embankments. As a result, CPRA will more accurately and efficiently determine the required marsh fill volumes, thus reducing the design engineering task time and contractor risk.
2. Foundation settlement is a time-dependent process, so marshes and levees elevations must be maintained above a forecasted flood and storm surge level. The correlations and settlement methodology will enable CPRA to estimate when scheduled lifts are required, and hence reduce maintenance costs.

WORKS CITED: Stark, T.D., Jafari, N.H., Leopold, A.L., and Brandon, T.L. (2014). “Soil compressibility in transient and unsaturated seepage analyses.” *Canadian Geotechnical Journal*, 51(8), 858-868.

EXPERTISE OF PI

My expertise pertinent to this proposed study may be best reflected by some of my recent publications.

1. Stark, T.D., **Jafari, N.H.**, Lopez, S., and Baghdady, A. (2015). "Unsaturated and transient seepage analysis of San Luis Dam." *J. of Geotechnical and Geoenvironmental Engineering*, accepted.
2. **Jafari, N.H.**, Stark, T.D., Leopold, A.L., Merry, S.M. (2015). "Three-dimensional levee and floodwall underseepage." *Canadian Geotechnical Journal*, doi: 10.1139/cgj-2014-0343.
3. Stark, T.D., **Jafari, N.H.** (2015). "Ruling on IHNC floodwall failures during Hurricane Katrina." *J. of Legal Affairs and Dispute Resolution in Engineering Construction*, 7(3), 06715001.
4. Stark, T.D., **Jafari, N.H.**, Leopold, A.L., and Brandon, T.L. (2014). "Soil compressibility in transient and unsaturated seepage analyses." *Canadian Geotechnical Journal*, 51(8), 858-868.
5. Stark, T.D., and **Jafari, N.H.** (2015). "Uncertainty of soil compressibility in transient and unsaturated seepage analyses." *USSD 35th Annual Conference*, Louisville, Kentucky, 1-16.

ANTICIPATED CURRICULUM AND COURSEWORK: The appendix provides the degree requirements for the MS Civil Engineering student with emphasis in Coastal and Ecological Engineering. The anticipated courses the student will enroll are:

CE 4870 Geotechnical Design of Coastal Structures
CE 7300 Advanced Geotechnical Engineering I
CE 7310 Advanced Geotechnical Engineering II
CE 7315 Principles of Soil Behavior
CE 7700 Numerical Methods in Geotechnical Engineering
CE 4320 Coastal Engineering
CE 7701 Coastal Design
OCS 4024 Coastal Morphodynamics
OCS 4372 Estuarine Ecology

CURRENT AND PENDING SUPPORT: Since the PI arrived at LSU in August 2015, he can leverage his start-up funds for necessary equipment and supplies.

Status of Support: ___Current ___X___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: Progression and Prediction of Marsh Edge Erosion

Source of Support: Board of Regents

Total Award: \$163,685 Period Covered: 06/2016 – 06/2018
mm/year thru mm/year

Location of Activity: LSU

Person-Months or % of Effort Committed to the Project: ___Cal Yr ___Acad ___2___Summ

MASTER OF SCIENCE IN COASTAL AND ECOLOGICAL ENGINEERING

Checklist, Instructions and Degree Requirements

Time Limit: Programs for master's degrees must be completed within 5 years from entrance into a degree program. *(Please note that courses cannot count towards degree requirements if they have been taken over 5 years prior to graduation unless they are revalidated. For more information about how to revalidate courses, please see the Graduate Secretary.)*

Graduate Seminar: All full time graduate students in the Department of Civil and Environmental Engineering are required to enroll in a Graduate Seminar course each and every semester. Coastal and Ecological students should enroll in the 7000-level coastal graduate seminar course or, if that is not offered, then CE 7750. Part time graduate students are excluded from this requirement but are required to enroll in a seminar course during the semester in which they plan to graduate. If a student is unable to enroll in a seminar course, such as in the case of a scheduling conflict, the student should discuss this with their assigned faculty advisor and then contact the faculty member in charge of the seminar course.

CHECKLIST & INSTRUCTIONS FOR 1ST YEAR

- Upon arrival and prior to the beginning of your first semester, **you must attend the orientation sessions prior to registration.** This is especially important for international students, who receive orientation information in their admission and/or I20 packet.
- You must meet with your assigned faculty advisor** to discuss scheduling for your first semester and (if applicable) any details of your graduate assistantship position. The name of your assigned faculty advisor can be found in your admission recommendation letter from the department (sent to you via email).
- After meeting with your assigned faculty advisor, **you must meet with the Graduate Secretary.** You will be given some information about the department and the Graduate Secretary will have you complete a **G104 Graduate Student Information Form** (department form). Also, if you have a graduate assistantship position, you will be given instructions on how to complete payroll forms. These forms should be completed as soon as possible to avoid payment delay.
- During the first year, students (with the assistance of their advisor) must set up an advisory committee. At least three members of the Graduate Faculty, including the major professor (who is chair of the committee) should comprise the committee. To view a list of graduate faculty for our department, go to the Graduate School website (<http://gradschool.lsu.edu>).
- Next, by the end of the first year and definitely before the start of their second year, students should work with their advisor to complete the **G101 Graduate Degree Program form** (department form) to map out their *plan of study*. (Important Note: The Request for Master's Examination (a Graduate School form) will not be approved if submitted during the same semester as the Graduate Degree Program form.) After completion of the Graduate Degree Program Form (signed by the student, advisor and initialed by committee members), the form should be submitted to the Graduate Secretary who will obtain the additional required signatures. After approval is received, the approved form will be kept in the student's departmental file. If, in the future, any changes are made to this plan of study, to the

committee, to the thesis title or if the student changes advisors, the **G102 Revision to Graduate Degree Program form** (department form) must be completed immediately. This form should be signed by the student's original advisor, initialed by the other committee members and then submitted to the Graduate Secretary to obtain the additional signatures.

- ❑ A thesis proposal (which should include the cover page **G103 Master's and Ph.D. Proposal Form** (department form) shall be submitted for department approval at least one semester prior to the anticipated graduation date.

DEGREE REQUIREMENTS

- ❑ **This degree program only offers a Thesis option.** The thesis option requires a minimum of 24 credit hours of approved course work, plus an additional 6 hours of thesis credit, 1 credit hour for the seminar, and a thesis defense (final examination) administered by the Advisory Committee. For the 24 credit hours, a minimum of 12 must be Coastal and Ecological Engineering core courses and a minimum of 12 must be from the approved electives from the student's concentration (either coastal or ecological engineering; see list of approved electives on department website).
- ❑ **Application for Master's Degree** (form found on the Graduate School website) submitted to Graduate School during the graduating semester and before the semester deadline set by the Graduate School (see graduate school calendar).
- ❑ **Request for Master's Exam** (form found on the Graduate School website) should be submitted to the Graduate School 3 weeks prior to the examination and/or before the semester deadline set by the Graduate School. Once this exam request is approved, the Graduate Secretary will inform the student and their committee members of the approval. If the exam is approaching soon and the student and committee has not received an email regarding the approval, please consult with the Graduate Secretary so that the issue can be investigated. Also, if ANY changes are made to the details of the exam, the student is responsible for advising their committee, the Graduate Secretary, and the Graduate School Records Officer of these changes as soon as they are known.
- ❑ Thesis should be submitted to the Advisory Committee at least **3 weeks** before the final examination date.
- ❑ After the completion of the exam, **the exam results sheets** (pass/fail sheets) and **thesis approval sheets** must be submitted by the committee chair to the Graduate Secretary for submission to the Graduate School. (Important Note: These sheets are not to be submitted to the Graduate School by the student!).
- ❑ Final Examination report and thesis submitted by the major professor and the student, respectively, to the Graduate School before the semester deadline set by the Graduate School. Please refer to the **Thesis and Dissertation Guidelines** document found at <http://etd.lsu.edu>
- ❑ Prior to graduation and leaving the university, if a student held a graduate assistantship position, the advisor (or PI) should conduct a final evaluation interview with the student to evaluate the student's performance. The **RA Evaluation Form** and/or **TA Evaluation Form** for this evaluation should be submitted, by the student's advisor (or PI), to the Graduate Secretary prior to the actual Graduation. The advisor can obtain the appropriate form from the department website or the Graduate Secretary. Please note that the student's signature must be on the form when submitted.

ACADEMIC PROGRAM

For the M.S. in Coastal and Ecological Engineering, there is only a thesis option available. The **thesis option** requires the student to complete a minimum of twenty-four (24) hours of approved course work and to submit an acceptable thesis worth 6 hours. One half of the coursework must be at the 7000 level or above. Coursework for the M.S. degree is divided into two categories: a 12-hour set of core courses for all students in the program, and a 12-hour set of approved electives for students wishing to specialize in either coastal or ecological engineering. Guidelines for selecting courses in this program are given below.

Subject to approval of the advisory committee and program coordinator, students transferring from graduate programs of other institutions can transfer a maximum of 50% credit hours of course work done.

Full time graduate students must register for the one credit hour seminar class (i.e., the 7000-level coastal graduate seminar course or, if that isn't offered, then CE 7750) each and every semester. Part-time graduate students are required to register for this seminar only in their graduating semester. Only one hour of CE 7750 may be applied to satisfy the course requirements.

CURRICULUM

Course Work Breakdown

12 credit hours of core courses (see list provided below)

12 credit hours from approved electives from the student's concentration (see list below of suggested courses)

Sub Total 24

+ Plus 1 credit hour of CE 7000-level coastal graduate seminar or, if that isn't offered, CE 7750.

+ Plus 6 credit hours of thesis are required to graduate in addition to the coursework requirements list above.

Total 31

Major Field Courses

- CE 4320 (3 credit hours) Coastal Engineering
- EVEG 4xxx (3 credit hours) Ecological Engineering (cross listed and co-taught with Department of Oceanography and Coastal Sciences faculty)
- MATH 4038 (3 credit hours) Mathematical Methods for Engineers
- CE 7xxx (3 credit hours) Coastal and Ecological Engineering Design

Elective Course Breakdown

- Select 2 from the coastal list and 2 from the ecological list. Note that these are 4 courses distinct from any of the core course requirements.
- The list of approved elective courses will be kept in the Department of Civil & Environmental Engineering.

Ecological Engineering Electives	Coastal Engineering Electives
EVEG 4159 Design of Wetlands for Wastewater Treatment	CE 4445 Hurricane Engineering
CE 4200 Hydrology	CE 7*** Coastal Hydromechanics
CE 7180 Water Quality Simulations	CE 7*** Sediment Transport Mechanics
OCS 4308 Plants in Coastal Environments*	CE 7200 Free Surface Flow
OCS 4372 Estuarine Ecology *	CE 7260 Advanced Hydrology
OCS 4128 Wetland Hydrology and Hydrodynamics	CE 7325 Marine Geotechnics
OCS 4410 Ecosystem Modeling and Analysis*	OCS 4024 Coastal Morphodynamics
OCS 4465 Coastal Zone Management	OCS 4164 Deltaic Processes and Products
OCS 4560 Wetland Loss, Restoration and Management*	OCS 4170 Physical Oceanography
OCS 7001 Coastal Systems Ecology	OCS 4210 Geological Oceanography
OCS 7010 Concepts of the Ecosystem*	OCS 7122 Gravity Waves in Shallow Water
OCS 7124 Applied Coastal Plant Ecology*	OCS 7123 Oceanographic Data Analysis
OCS 7165 Biogeochemistry of Wetland Soils and Sediments	

During a student's last semester, each student is required to pass a comprehensive Master's examination covering work related to research and course work. This examination will be administered by the student's advisory committee and may be oral and/or written. The Graduate School's Request for Master's Examination form (found on the [Graduate School](#) form page) for scheduling and reporting results of this examination must be filed with the Graduate School three (3) weeks prior to the date of the examination. This examination may be re-taken only once.

THE THESIS COMMITTEE

The advisory committee, required for each student, will be comprised of a minimum of three faculty representing both Civil and Environmental Engineering and Oceanography and Coastal Sciences. An engineering faculty member will be the major advisor of the student although faculty from the Oceanography and Coastal Sciences can serve as a co-advisor. Representation from Oceanography and Coastal Sciences is required on every M.S. committee.

To ensure an orderly and thorough procedure in thesis preparation, students should proceed as follows:

1. **Thesis Proposal**

The student, after selecting the thesis topic in cooperation with his/her adviser, is required to submit a thesis proposal. Preparation and typing of the proposal is the responsibility of the student. The thesis proposal format should include:

- Cover Page (Form G103)
- Abstract (not more than 200 words)
- Introduction
- Literature Review
- Objectives/Method
- Scope of Study (state limitations)
- Work Plan and Schedule
- References

It is expected that an informative thesis proposal showing the student's interest, background and general grasp of the project will not be less than 5 and not more than 10 double spaced typed pages.

Thesis research proposals, for unfunded research, must include an estimate of computer and/or other costs associated with fulfilling the objectives of the project. Student should review this matter with his/her advisor so that a reasonable estimate of the costs can be included in the proposal.

The formal typewritten thesis proposal together with the graduate degree program (Form G101) should be submitted for approval by the CEGPC at least one semester prior to graduation. The student will be notified of the Committee's decision and recommendations through the Chairman of the Department.

1. **Conduct of the Research**

Each graduate student is responsible for the performance of the thesis research. Progress will be reported to the assigned faculty advisor on a regular basis.

2. **Preparation of the Thesis**

- a. Instructions on the preparation and submission of the Master's degree thesis may be obtained from the [Graduate School](#).

- b. The Request for Master's Examination form (found on the [Graduate School](#) website's form page) is to be filed with the Graduate School three (3) weeks prior to the date of the Master's Examination.
 - c. Copies of the thesis must be in the hands of the student's examination committee at least two (2) weeks prior to the scheduled Master's Examination.
 - d. The student is responsible for providing a finalized bound version of the thesis to the members of his/her advisory committee and the Department.
3. **An "S" or "U" will be awarded as the final grade for the thesis.** This grade is not averaged into the student's semester or cumulative average.

Students should review the official [Thesis and Dissertation Guidelines](#).

REVALIDATION OF COURSE WORK

Graduate student's coursework can be revalidated for master's degree older than 5 years subject to the following guidelines:

1. Following an oral or written examination the student's graduate committee may approve by majority vote a course or courses it elects to revalidate.
2. The student's graduate committee then recommends the revalidation of course/courses to the CEGPC for approval and transmittal to the Graduate School.
3. Each class may be revalidated only for a period of two years. Classes for master's degree older than 5 years must be revalidated.

ARTICULATION COURSES

For students without an engineering background, a series of articulation or preparatory courses will be required to prepare students with a calculus-based, science background to understand and apply coastal and ecological engineering principles. Minimum articulation requirements are as follows: MATH 1550, MATH 1552, MATH 2057, MATH 2065, CE 2450 (Statics), CE 2200 (Fluid Mechanics), CE 2250 (Fluid Mechanics Lab), EVEG 3200 (Water Resources II), CE 3300 (Geotechnical Engineering 1). The advisory committee may identify additional articulation requirements in the course of planning the program of study.

CONTACTS

CEE: Clinton S. Willson, Ph.D., P.E., LSU Department of Civil and Environmental Engineering, 102 ELAB, cwillson@lsu.edu, 225-578-8672

DOCS: Robert Twilley, Ph.D., Executive Director, Louisiana Sea Grant College Program and Profess, Oceanography and Coastal Sciences, 239 Sea Gran Building, rwtalley@lsu.edu, 225-578-6445

Principal Faculty:

Q. Jim Chen, Ph.D., P.E. LSU Department of Civil and Environmental Engineering, 105 ELAB, qchen@lsu.edu, 225-578-4911

Scott Hagen, Ph.D., P.E., D.CE, D.WRE, F.ASCE, LSU Department of Civil and Environmental Engineering, 106 ELAB, shagen@lsu.edu, 225-578-0446

Celalettin Emre Ozdemir, Ph.D., LSU Department of Civil and Environmental Engineering, 3418G Patrick F. Taylor Hall, cosdemir@lsu.edu; 225-578-5045

John Pardue, Ph.D., P.E., LSU Department of Civil and Environmental Engineering, 3516 Patrick F. Taylor Hall, jpardue@lsu.edu, 225-578-8661

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Larry J. Rouse, Jr. Ph.D., LSU Department of Oceanography and Coastal Sciences, 318 Howe-Russell Geoscience Complex, lrouse@lsu.edu, 225-578-2953

IMPORTANT REMINDERS AND RESOURCES

Graduate Program Coordinator

Dr. Ayman Okeil
Room 3513E Patrick Taylor Hall
Phone: (225) 578-7048
Email: aokeil@lsu.edu

Graduate Program Secretary

Julie Mueller
Room 3508 Patrick Taylor Hall
Phone: (225) 578-9170
Email: jmueller@lsu.edu

Important Reminders

- This checklist was created as a guide to students in the Coastal and Ecological Engineering graduate program. It is not meant to replace the Graduate School Bulletin, which is the official document for Graduate Student rules and regulations. The current Graduate School Bulletin can be found online at the Graduate School website: <http://gradschool.lsu.edu>
- All forms requiring either the Graduate Program Coordinator or Department Chair's signature should be submitted to the Graduate Program Secretary at least two business days prior to the due date to allow adequate time to acquire these signatures.
- It is the student's responsibility to be aware of and to adhere to all established deadlines and due dates. The Graduate School Calendar (issued each academic semester) is available on the Graduate School Website and, as a courtesy, will also be emailed to all students at the beginning of each semester.
- A student's assigned faculty advisor should be the student's first point of contact for all questions regarding graduate issues.
- To schedule a meeting with the Graduate Program Coordinator, a student and/or the student's advisor should email the Graduate Secretary to coordinate a meeting.
- All forms must be TYPED (hand-written is strongly discouraged)

For **Department forms**, please visit our forms page on our website:

<http://www.cee.lsu.edu/academics/graduate/current/forms>

For **Graduate School forms**, please visit their forms page on their website:

<https://sites01.lsu.edu/wp/graduateschool/current-students/forms/>

For academic deadlines, visit the **LSU Academic Calendar**

Go to the LSU website <http://www.lsu.edu> and on the main page you will see "Calendar and Events"