
AC 2011-293: AN INTRODUCTION TO INFRASTRUCTURE FOR ALL DISCIPLINES

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An Introduction to Infrastructure for All Disciplines

WHY A COURSE ON INFRASTRUCTURE?

To the relief of many civil engineers, the word infrastructure has come into vogue with the American body politic; in the most recent State of the Union address, President Obama declared that “Next, we can put Americans to work today building the infrastructure of tomorrow”[1], and he stressed the importance of keeping pace with China, Germany and India in providing infrastructure to support economic development. Across the spectrum of American politics, from local to federal, there is an emerging consensus about the need for greater focus on the renovation and creation of infrastructure. It would be a mistake to believe that this is just a fad. Two previous trends, environmental remediation and sustainability, serve as examples of long-term engineering issues that somewhat suddenly went through a large increase in public awareness, and ten to twenty years later, those issues have simply been folded into the practice of engineering more thoroughly as public focus has remained persistent.

It is exactly that persistent focus across many disciplines which will be required to create sustained programs which can provide robust, efficient and sustainable infrastructure. Part of the system for creating these sustained programs is education. If society is to address the broad and complex problems posed by our decaying existing infrastructure and our demanded future infrastructure, then our nation absolutely requires an educated populous, across disciplines, that understand the realities of how the components, systems and meta-systems that underlie our daily lives actually work. For instance, it is not likely to be particularly productive to have an in-depth conversation about electrical power production with someone who does not understand that there is a need for both baseline and peak electrical generation capacity and that excessive demand, insufficient distribution capacity, or under supply all lead to the same result. That said, the production of electrical power is an exceptionally important topic, and key questions like “Nuke or not?” need to be discussed if there is to be a rational decision process leading to infrastructure creation that is forward-looking and technically sound. Political science or economics majors are never going to design a power plant, but they should absolutely be informed actors within the decision process.

With this in mind, a new course in Infrastructure Engineering has been created at West Point, supporting a growth in awareness and knowledge not just for civil engineers, but for all majors. The class has been deliberately structured to be accessible to anyone who is progressing in West Point’s core curriculum and has basic math and physics knowledge, along with some economics, and political science. Further, the classroom discussion deals with broad topics, including the social, economic and political systems which help envision, create and maintain the infrastructure. It is the opinion of the authors that the massive challenges pointed out in the American Society of Civil Engineers’ “Report Card for America’s Infrastructure”[2] can be only

be solved by citizens possessing a broad knowledge of the issues involved, and cross-talk between engineers and their brethren in the humanities is essential to accomplishing this.

Unfortunately, the truth is that very few universities require even a single course about the composition and function of infrastructure for those not majoring in engineering. This is a puzzle, since the built environment surrounds us in our daily life, simultaneously shaping and expressing our choices, large and small. Understanding infrastructure, viewed in this way, is not specialized knowledge but an essential element in building a whole understanding of the way a society functions and the choices it makes. Infrastructure is not just technical structures but also the facilitator for producing the goods and services necessary that enable an economy and a people to function. Without knowledge of power production and distribution, for instance, how can one discern the changes wrought by the coming of electrification to our cities in the later parts of the 1800s, much less help guide decisions about creating sustainable power for the future? Sustainability, transportation, communications and waste management present similarly daunting, and technically complex, challenges for our university graduates. The current generation of graduates will have to think, decide, act and lead during difficult times absent a basic knowledge of infrastructure, with the result that the decisions of future leaders will be ill-informed, or the leader will be forced to abdicate all responsibility to experts, making tough choices based on trust rather than knowledge. Further, and perhaps more importantly, without a deep understanding of the infrastructure, decisions which emphasize the short-term political gain of deferring expenditures on infrastructure will continue to be the norm, ignoring the long-term risks which accompany those deferrals.

To bridge this knowledge gap, new paradigms are needed which integrate infrastructure as one of the essential elements in the modern graduate's intellectual development, on par with basic mathematics, writing, and the physical and social sciences. This paper discusses the new course, Infrastructure Engineering, which meets this knowledge need and offers commentary on the delivery of the first two offerings of that course. While there is no pretense that the material presented here represents some sort of best or final solution to how such a course should be taught, it is a starting point for what should be a broader conversation within both civilian universities and the military academies, about bringing knowledge of infrastructure engineering to a wider audience.

BACKGROUND

Beginning in about 2006, the civil engineering program at West Point undertook a broad study of the curriculum. The intent was to ensure that the course of study going forward was well-aligned with the needs of our students and the two constituencies we serve: the US Army and the engineering profession. In 2008, the initial results of what can now be described as a broad curriculum reform were presented at the ASEE National Conference in Pittsburg[3]¹. Based on a broad survey of our graduates and focus groups with a variety of stakeholders, the

enquiry led to the clear conclusion that changes in our traditional and long-standing course offerings and progression. Initial proposals for changes to the curriculum are spelled out in the 2008 paper, but can be summed up as removing some math and dynamics requirements, as well as depth in structural engineering, and adding courses in infrastructure (the course described in this paper) and geomatics. At that time, the infrastructure course was envisioned as including water and wastewater, solid waste and basic transportation, topics not covered elsewhere in the curriculum due to our large and humanities-heavy core requirements. As part of this initial refit, it was thought that dynamics and electrical engineering would be covered in a consolidated course, and we would work with the electrical engineering department to ensure that some power and power distribution content, considered essential, would be included in the consolidated course.

By 2010, West Point's Civil Engineering Program had undergone an ABET visit and considerable further work had been done on the curriculum reform, and the results of that work were reported at the 2010 ASEE National Conference [4]. Those interested in the details of the final plan can look at the 2010 summary paper, which describes the curriculum as we are now delivering it. For the course Infrastructure Engineering, there were two key evolutions between 2008 and 2010. First, the course was given considerably greater definition, including the addition of a course description and course objectives and power generation and distribution as well as network modeling were added to the course content. Second, it was decided that Infrastructure Engineering would become the second course in our 3-course engineering sequence, which is taught to non-engineers, mostly humanities majors. This second decision was significant in that it basically required that the course be a stand-alone, with no prerequisites. This is now regarded as a strength of the new course, since those students with room in their schedules, especially future Corps of Engineers officers, can take the course without having planned for that early in their course of studies.

It should be noted that class size at West Point is capped at 18 students, which certainly impacts our teaching methods. The course is presented mostly to juniors in forty 55-minute lessons, with many of the lessons including interactive exercises, discussion and group work on problems. Seniors also take the course, as do a few advance sophomores. The course as it stands is probably not suitable for freshmen. This is partly because students are also asked to contribute to the presentation of material through briefing of course readings via lottery and through scheduled Two Minute Follies, described later. Student accomplishment is evaluated through the course project or portfolio, their in-class presentations, five homework sets and three examinations. This is described in more detail later under "Assessment".

INFRASTRUCTURE ENGINEERING COURSE SUMMARY

In our curriculum, *Infrastructure Engineering* is numbered CE350 and is generally taken during the first semester of the junior year. For our CE majors, it follows, but is not dependent

on, MC300 Fundamentals of Engineering Mechanics and Design and is taken concurrently with ME311 Thermal-Fluid Systems I, CE390 Civil Engineering Site Design, and MC364, Mechanics of Materials. For most, but not all, non-majors it follows MC300.

Understanding the nature of this course begins with understanding what it is not. *Infrastructure Engineering* is not an introduction to various disciplines of civil engineering, nor is it an attempt to ‘lighten up,’ ‘dumb-down,’ or ‘increase accessibility’ of traditional civil engineering topics. *Infrastructure Engineering* is not intended nor can it replace full courses in water resources engineering, power distribution engineering, electrical engineering, or transportation engineering. What *Infrastructure Engineering* does is explain the functioning of different infrastructures, the service those infrastructures perform for society, and the relationships between infrastructures and the societies they serve. Accordingly, the official catalog description of *Infrastructure Engineering* is:

This course identifies, analyzes, and assesses built infrastructure which is the foundation for modern society. The complex and interconnected nature of infrastructures is investigated and demand on critical components calculated. Students explore the non-technical factors necessary for the functioning of infrastructure including supplies, trained personnel, and cross-sector dependencies. The course provides a basis for understanding the complexity and cost of maintaining, rebuilding, and developing infrastructure. Major blocks of instruction include water and wastewater, power, transportation, solid waste, communications systems, and public administration. Several in-class scenarios are provided to synthesize the connectivity between the major items of infrastructure. Finally, as infrastructure is one of the variables in the joint operating environment, the knowledge gained is employed to analyze infrastructure in the context of combat operations.

Course objectives describe, in broad terms, what the student should be able to accomplish upon completion of a course. For *Infrastructure Engineering* the course objectives are:

- a. Identify, categorize, and assess critical infrastructure and cross-sector linkages at the national, regional, and municipal levels.
- b. Calculate the demand on infrastructure components and systems.
- c. Assess the functionality, capacity, and maintainability of infrastructure components and systems.
- d. Describe the links in the infrastructure system.
- e. Analyze infrastructure in the context of military operations.

Because of the unique nature of this course, we were unable to find one textbook to provide the appropriate coverage. We therefore chose to use two books and several electronic resources to provide student readings. *Infrastructure: The Book of Everything for the Industrial Landscape* by Brian Hayes (2005) provides high-quality pictures and descriptions of major physical infrastructures including transportation, water resources, energy, mining, and waste management. While not a textbook, the descriptions contain sufficient technical detail for use in an introductory course when supplemented by other material. This book is used throughout the course with different chapters assigned in each block of instruction. *Electrical Power System Basics for the Nonelectrical Professional* by Steven W. Blume (2007) is the primary reference for the electricity lessons. This book explains the elements of the electrical distribution system from generation to consumption conceptually and without complex mathematics. It is useful for gaining an understanding of system function without delving into system and component design.

The course is supported with numerous references readily available on line. Some of the key references by block of instruction are:

Infrastructure and Networks:

Critical Infrastructure and Key Resources (CIKR) Resource Center website at <http://training.fema.gov/EMIWeb/IS/IS860a/CIKR/index.htm>

Scale-Free Networks by Albert-László Barabási and Eric Bonabeau published in Scientific American, May 2003.

Water, Wastewater, and Trash:

The History of Drinking Water Treatment (EPA816-F-00-006) by the Environmental Protection Agency, February 2000.

Primer for Municipal Wastewater Treatment Systems (EPA 832-R-04-001) by the Environmental Protection Agency, September 2004

Energy and Electricity:

The website of the Energy Information Administration:

<http://www.eia.doe.gov/energyexplained/index.cfm> is extremely useful for information on energy production and consumption

The website: http://www.oe.energy.gov/interactive_grid.htm contains an interactive power grid model useful for explaining the interactions of generation, transmission, and consumption.

Transportation:

Railroad Design and Rehabilitation, US Army Corps of Engineers Technical Instruction 850-2 (TI850-2) of 1 March 2000 provides an excellent primer for the fundamentals of railroad design.

The complete list of references is included in the course study notes. An electronic copy of the study notes along with other course materials may be obtained free of charge by calling 845-938-2600 and requesting to speak to the current CE350 course director.

Within the West Point curriculum, CE 350 *Infrastructure Engineering* is an element of both the civil engineering curriculum and the civil engineering three course engineering sequence. (At West Point, each cadet that does not major in engineering must take a three course sequence in one of the engineering disciplines.) As such, it must appeal to and be relevant to a variety of academic majors. The course was offered for the first time in the 2010-2011 academic year to the student populations shown in Table 1.

Academic Major	Fall 2010	Spring 2011
Civil Engineering	41	5
Other	10	68
Total	51	73

Table 1

BLOCKS OF INSTRUCTION

Infrastructure and Networks

The course begins with an introduction to the infrastructure. Most students, while familiar with the concept of infrastructure, do not understand the scope and interconnectedness of infrastructure systems. Explanation of this interconnectedness is accomplished by building, on the black board using pictures, the infrastructure necessary for an individual to wake up, shower, dress, have breakfast and get to work. Then specific infrastructure sectors are explained in terms of their scope, function, interdependencies, and economic impact. One immediate observation from these explanations is infrastructures are highly connected, interdependent, networked systems and this leads to the next group of lessons.

Three lessons are taught to introduce students to the basic concepts of network analysis. Students learn about three different types of networks, the strengths and vulnerabilities of network types, and the statistical tools used in network analysis. These concepts are applied in a homework assignment where students determine critical nodes in a railroad system. These lessons point out the importance of understanding how infrastructure systems can be modeled as networks.

Water, Wastewater, and Trash

The six lesson water, wastewater, and trash block develops an understanding of managing the water resources specific to any given geographic location, and the interconnections with the other infrastructures. The first lesson compares and contrasts the hydrologic and hydraulic cycles. There is a discussion on water usage by infrastructure elements, and a discussion of legal, regulatory, and engineering developments resulting from water and wastewater management going wrong, namely cholera outbreaks, the Love Canal, and the 1968 burning of the Cuyahoga River. Critical to this lesson is a discussion of the interdependence of this infrastructure element with other infrastructure elements – the students collectively build a web diagram of this on the board that captured the major elements of Figure 1. The second lesson focuses on the collection and treatment of drinking water in both highly developed and developing societies. The third water lesson focuses on wastewater and building an understanding of common treatment techniques that are adaptable for different environments. In the fourth lesson, students size water and wastewater systems for Wilmington, North Carolina, population 100,000. The fifth lesson is a tour of the West Point main Water Treatment and Wastewater Treatment Plants, where the students visualize the processes they studied in the previous four lessons. The trash lesson outlines the different categories of waste that municipalities deal with and students estimate landfill size and service life using common planning factors.

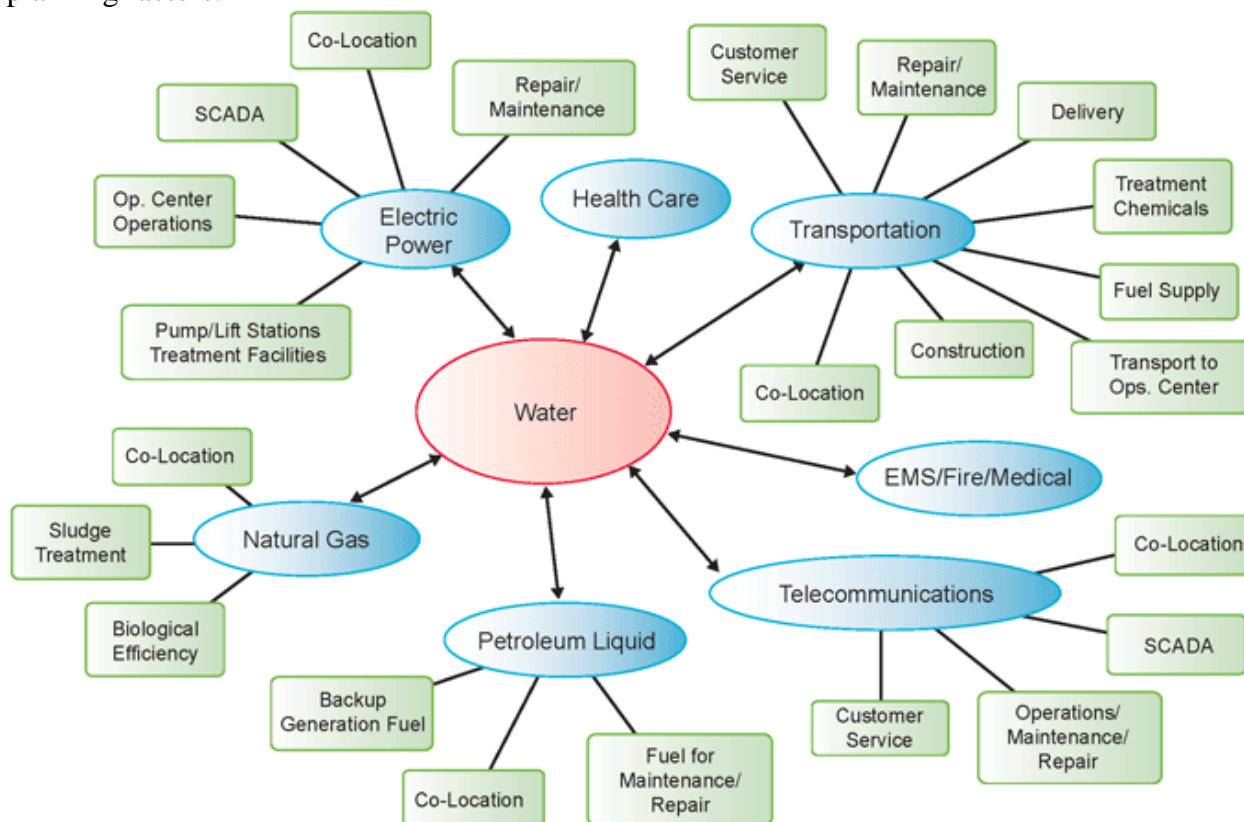


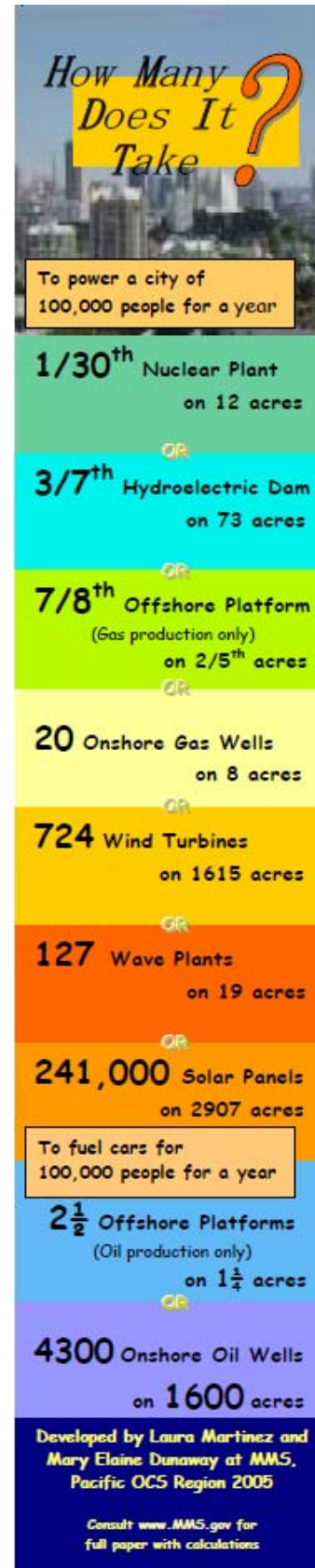
Figure 1. Water Sector Interdependencies with other Critical Infrastructure elements Bibliographical reference: <http://training.fema.gov/EMIWeb/IS/IS860a/CIKR/water1text.htm>

The purpose of these lessons is not to replace coursework in environmental engineering or to teach design of water treatment systems. Rather, these lessons address the functions and processes required in water and waste water treatment, the interdependencies between this infrastructure and others, and the function of this infrastructure in society. After completing this module, the students can describe the functions of elements of the water infrastructure, explain different methods of water treatment, and assess the appropriateness of these methods based on societal factors.

Energy/Electricity

The energy block consists of eight lessons, of which seven focus on electricity. Electrical energy is singled out because the electrical system is familiar to the students, has a relation to their course in physics, has direct relevance to their future service as Army officers, and provides a vehicle for understanding how other energy infrastructures function. The first lesson is an overview of the energy sector where students are exposed to sources of energy supply and the corresponding sectors of demand. In an in-class exercise, students use the information from Figure 2 to determine the area required to meet the electrical energy demands of the United States in 2050 based on a projected population of 400 million. The first lesson concludes with the discussion of the need for a coherent energy policy for the United States.

Lessons two through seven explain the electrical generation, transmission, distribution, and consumption system from generator to customer. Topics presented include electrical terminology, generator basics, electrical substation functioning, transmission and distribution systems, and different forms of electrical consumption. Lesson 7 is the ‘Electrical Consumption Laboratory’ which uses the physical model shown in Figure 3. This model contains the typical electrical components found in an average American household. Instrumentation provides real time measurement of voltage and current and different electrical loads like hair dryer, miter saw, lights, and air conditioners are connected to the system. Circuits are deliberately overloaded to demonstrate the functioning of circuit breakers. A short extension cord with the neutral and ground cross-wired is used to demonstrate the functioning of a ground-fault-



interrupter (GFI) outlet. We have not gone so far as to throw a hairdryer into a bucket of water, but that action is being contemplated! This lesson is one of the students' favorites. The block of instruction concludes with a discussion of electrical system assessment tools and alternative energy sources.

The purpose of these lessons is not to replace coursework in electrical engineering or teach design of power systems. Rather, the lessons provide an understanding of the element of the electrical grid, the principles that govern its functioning, and both the resilience and vulnerabilities of the system. At the conclusion of the Energy/Electricity block, students can explain basic electrical concepts, describe the elements of the electrical grid, explain how electrical power is generated and consumed, and conduct basic assessments of electrical systems.

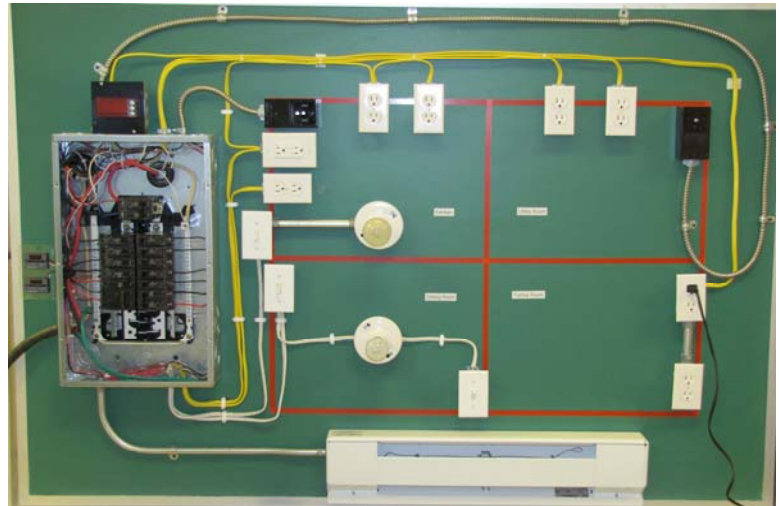


Figure 3 – Electrical Demonstration on Roll-Around Chalk Board

Transportation

The transportation block of lessons was developed to focus on understanding the transportation system, rather than the specific design of transportation elements. The block includes an introductory lesson that describes the six major transportation systems: aviation, roads, rail, shipping, and mass transit. Next follow four system analysis lessons based on roads and three lessons based on rail.

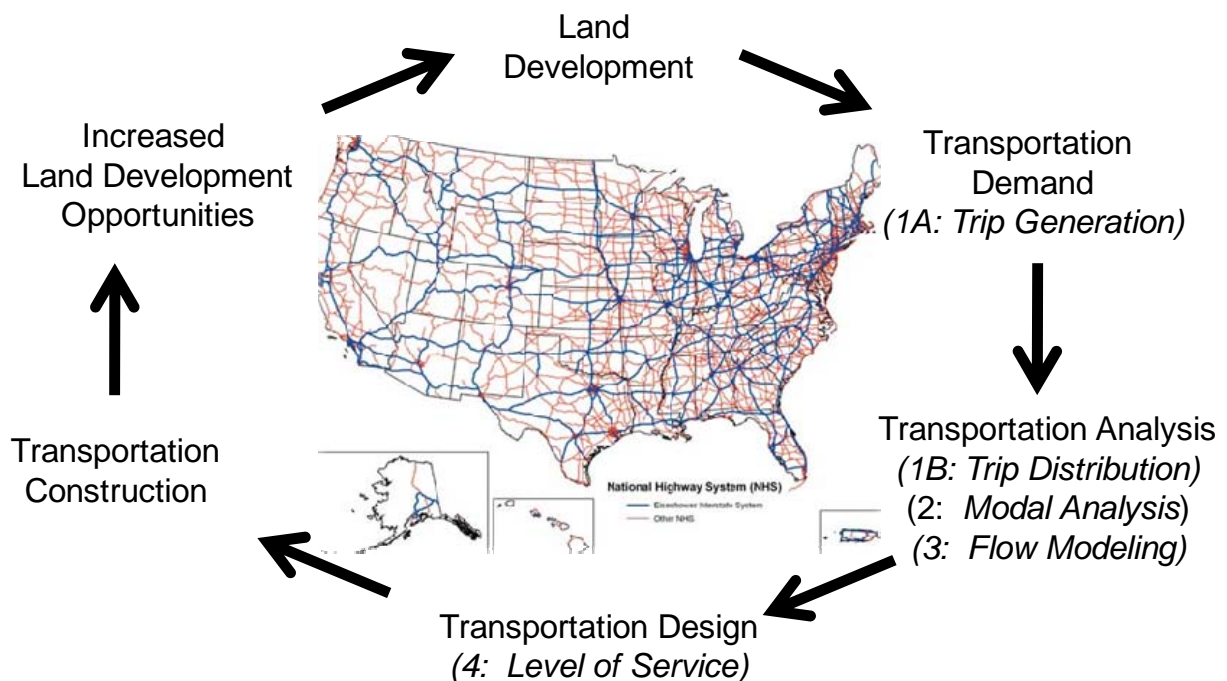


Figure 4 - Transportation Growth Model

The four road transportation lessons focus on the Continuous Transportation Growth Model, as shown in Figure 4.

The first analysis lesson considers the source of increased transportation demand (*1A: Trip Generation*) and then the distribution of those new trips (*1B: Trip Distribution*). Trip generation is based on the Institute of Transportation Engineers' (ITE) well-established factors; trip distribution was done via Alan Manners Voorhees' gravity trip distribution theory. The second lesson addresses how those new trips may be allocated to the various modes (*2: Modal Analysis*) according different utility function; such as the logit model. The third lesson considers the flow of a transportation system, specifically highway traffic flow (*3: Flow Modeling*) using Greenshield's Transportation Flow model. The fourth and final analysis lesson considers the level of service associated with flow of a transportation system based on the Highway Capacity Manual.

The first rail lesson begins by describing the elements of a rail transportation system and calculating the tractive effort to move loads on a straight and level track. In the second lesson, the impacts of grade and curvature are considered and locomotive tractive effort is explained. In the third lesson, students used what they have learned to suggest a preliminary route for a rail line from Lynchburg to Danville, Virginia. Traditional music fan will recognize that as the setting for the famous railroad song, "Wreck of the Old 97," which is, in fact, used to start the class!

It is recognized that these eight transportation system analysis lessons only scratch the surface of transportation engineering, but they provide some foundational understanding of the topics. In the subsequent classes in our Civil Engineering program, the students are also exposed to geometric highway design in another mandatory course; and furthermore they can extend their transportation engineering education with and elective in this field. Overall, the transportation block appeared to fit well into the infrastructure course, but it's linkage to the other infrastructure components requires additional work as the course develops.

Infrastructure Models

As the primary objective of the course is the identification and assessment of infrastructure systems, we have built the course around the "CE350 Infrastructure Model" which consists of :

Production—extracting, generating, or procuring the raw desired product

Processing—converting the raw product into a usable and transmittable form

Transmission—movement of product from point of processing to area of consumption

Distribution—connection high volume transmission systems with low volume customers

Consumption—use of the desired product by the person or organization paying for it

By-product disposal—removal and disposal of waste

Regulation—both the societal regulatory environment and the required supervisory, control, and data acquisition (SCADA) systems

Financing—a means of customers paying for services and owners paying for systems

Examples of how this model applies to common civil infrastructures are shown in Table 1.

Civil Infrastructure Model Components	Water Treatment Application	Railroad Application	Electrical Application
Production	Wells, rivers, lakes	Locomotives, fuel supply, and rolling stock	Gas, coal, nuclear, hydro, or other power plants
Processing	Drinking water treatment plant	Switching yards,	Transformer substations
Transmission	Pressurization systems, large mains	Inter-city rail lines	High voltage transmission lines
Distribution	local distribution lines	intermodal sites, loading facilities	Low voltage distribution lines
Consumption	industrial production, agricultural irrigation, and residential use	commodities shipped and passengers transported	residential and industrial use
By Product Disposal	processing and disposal of solid residuals from sludge	Air pollution from engines, polluted runoff, noise pollution	Pollution from generation plants
Regulation	Pressure controls, Clean Water Act, Safe Drinking Water Act	Federal railway laws and regulations, automatic train control, signaling	System reliability, frequency management, federal and state law
Financing	Billing and collection	Shipping fees	Metering and billing, Impact of smart meters

Table 1. Civil Infrastructure Systems Model and Examples

This model is consistently reinforced as a system for thinking about infrastructures and their functions. If any element is missing, the infrastructure will not function. The model tends to work very well for infrastructures that rely on a physical backbone. Through this model, students are provided a vehicle to identify and assess both the infrastructures introduced and those not discussed in depth that they may encounter in subsequent classes, employment, or life.

COURSE PROJECT AND EVALUATION TECHNIQUES

Because detailed design is not a major component of the course, the homework load tends to be light. To keep the course from being merely an ‘infrastructure appreciation’, a course project is assigned cause the students to truly engage with some of the aspects of Infrastructure Engineering and to provide a firm basis for evaluation of student accomplishment. The project provides a thread of continuity throughout the course and an opportunity for students to apply their knowledge to infrastructure related problems. In the project, students move beyond the defining, identifying, and describing infrastructure and engage in selection, assessment, evaluation, and synthesis.

Engineering Design Project (Fall 2010)

In the Fall term, teams of six students completed an Engineering Design Problem (EDP) requiring them to develop a plan to extract, process, transport, and market the mineral wealth of Afghanistan for the benefit of its people. The EDP focused on the minerals Bauxite, adobe clay, and dimensioned stone and the energy, transportation and water infrastructure needed to support the mining and transport of the three natural resources. A member on each team focused on one of the areas mentioned above. Afghanistan’s general lack of supporting infrastructure creates an environment ripe for infrastructure identification, analysis, and assessment. Since many of the students will serve in Afghanistan upon earning their commission’ there is great value in students recognizing the connection between an improvement in Afghanistan’s infrastructure and self-sustaining economic growth. Several cadets, faced with an unfamiliar environment, devised innovative solutions, recognized the importance of specific infrastructure components and planned for the interdependent nature. Possible improvements for this project include reducing the scale from all of Afghanistan to a specific area and reducing the breadth of the topic to enable cadets to learn about more infrastructure components.

Infrastructure Portfolio Project (Spring 2011)

In the Spring Term, the course project changed from an EDP to individual student portfolios. The purpose of the portfolio is to help the students organize a large body of knowledge and apply the infrastructure principles learned in the course to contemporary debates and current topics on infrastructure. The portfolios consisted of structured reading notes paired with reflection questions to provide a forum for cadets to reflect on their reading. Supplementary portfolio items, such as Op-Ed pieces and sketches, were added to the mix to encourage the student to view course readings and topics from a variety of perspectives. The desired end-state is a student who both comprehends the broad topic of infrastructure and is ready to participate in the broad thinking necessary as they confront the highly variable and difficult problems of our infrastructure. In doing so, they explore the connections and interdependencies that characterize infrastructure. Similar to the EDP, the portfolio provides the opportunity for immersion in the material but in an exploratory and individualized manner.

Two Minute Follies

A distinct attempt has also been made to provide cross-disciplinary discussion via the two-minute-follies. Each class session, one student introduces their classmates to an infrastructure component, system or process that they find intriguing. Not surprisingly, the students tend to bring with them the special viewpoints common to their disciplines, enhancing the experience for all by increasing awareness of what each discipline has to offer and emphasizing the multidisciplinary nature of the infrastructure.

ASSESSMENT

Student performance was assessed through a variety of graded events. These events, shown with their relative weights, are shown below. The final grades in this course were comparable to student performance in peer courses.

Homework	15%
Course Project	17.5%
Reading Assignments, quizzes, daily work	12.5%
Infrastructure Reconnaissance	5%
Mid-Term Exams	20%
Final Exam	30%

One challenge in establishing a new course is to ensure that it should be neither a ‘complete kick in the teeth’ nor ‘so easy a caveman could do it.’ This was especially important for our civil engineering students as this course runs concurrently with Thermo-Fluid Systems and Mechanics of Materials, both difficult courses. To this end, at the end of the Fall term, students were asked to evaluate Infrastructure Engineering relative to their other courses using the following table.

Compared to the other courses in my major which is _____, in CE 350...

Circle the appropriate number	1 A lot less	2 A little Less	3 About the Same	4 A Little More	5 A lot More
...the level of difficulty is...					
...the amount of work required is...					
...the interest/motivation on my part is...					
...the return on investment is ...(the relationship of the amount you are learning to the effort you are giving)					
...changes my view of the world...					
...helps me understand the relevance of other courses to my major...					

Thus a score of '3' would indicate that Infrastructure Engineering is a comparable course to other courses in a student's major. The results of this survey are shown in Figure 5.

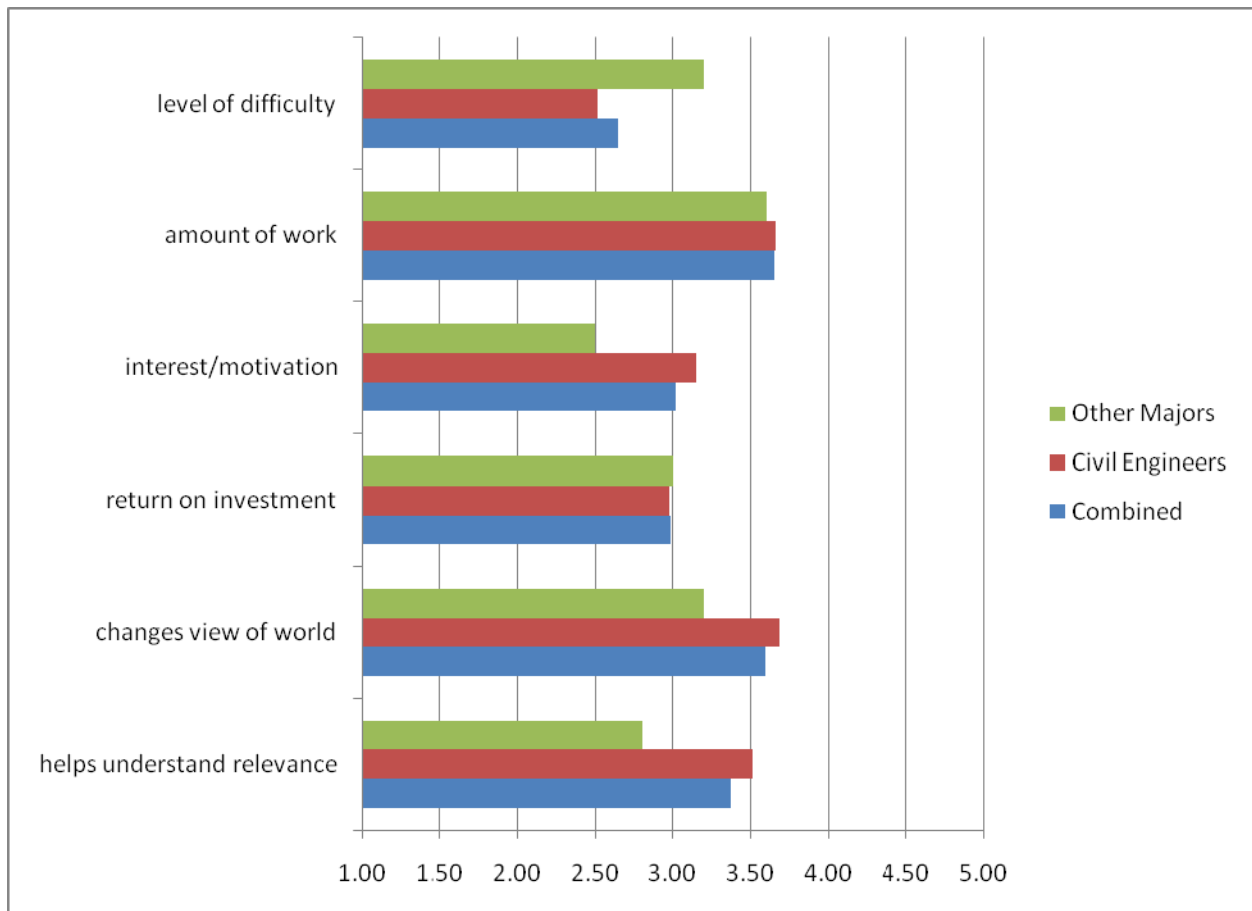


Figure 5 – Initial Assessment of CE350

On average, though the students perceived the courses a slightly easier than other courses, it was more work. This is probably due to the extensive reading requirements and the depth of the EDP. Interest and motivation is comparable to other courses, but this hides the fact that of 51 students, 19 answered this question with 4 or 5 and 19 answered with 1 or 2; a clearly bifurcated group response. Those that liked open ended, global problems without single, fixed solutions tended to like the class much more than those looking for a specific answer. Students of all majors felt the class was a comparable return on investment in relation to other courses.

One of the goals of this course was to cause the student to broaden their daily view and actually see the infrastructure they have taken for granted all their lives, thereby better understanding the relevance of engineering in their lives, and for the majors other courses in the civil engineering curriculum. The survey shows this was well accomplished for the civil engineering majors and reasonably accomplished for students of other majors.

Student perceptions are best assessed through comments. The last question of the six reading assignments asked students to list the most surprising fact from the chapter read. Here are some sample responses.

- The most interesting aspect of this chapter is the directional interchange intersection. I have studied the pictures and feel like I understand the concept. I am positive that I have traveled through intersections that look like this, but I never think about the complexity of it when I am driving. It is truly a marvelous system of engineering that I will take note of next time I am on the highway.
- The thing I found most interesting in Chapter 9 (Railroads) was the different methods of connecting lengths of track. In learning about these connections I am beginning to see a little more clearly the applications of MC364 like failure theories, stresses, and different material properties.
- Speaking of nuclear energy, it is surprising to find learning objectives from Thermal Fluid Systems class, ME311, in this reading assignment. In the Pressurized Water Reactor, water is subjected to high pressures increasing the boiling point of water to more than 600 degrees Fahrenheit. We just learned that changing the pressure of water causes a change in the saturation of water therefore boiling point increases. Just as sectors of infrastructure are interdependent so are the classes in CME.

Finally, one question on the final exam asked students, “What is the most pressing infrastructure need in the United States today?” One student, a kinesiology major, answered, “Education—people need to be better educated on what it takes to keep them living the way in which they are accustomed.” She then went on to explain how understanding the important concepts of Infrastructure Engineering could lead to changes in societal behavior.

FURTHER WORK

The course described here is new; it is currently in its second semester of being offered at West Point. Others have also pursued infrastructure as a point of focus within the curriculum, most notably Roberts et al (2007) at the University of Wisconsin – Platteville [5]. Though a similar multi-disciplinary course probably exists within the constellation of academia, the authors identified no other university offering a course on infrastructure specifically targeted at and required for non-engineers. Further research is needed into the curriculum of other institutions to broaden the base of knowledge in this area. Further, as time progresses, more in-depth assessment data will become available through West Point’s normal ABET channels to help gauge not only student accomplishment within the confines of the given course, but also the contribution of this broadened curriculum to their overall success after graduation. Longitudinal data of this kind is not yet available and only student grades from a single semester, a mediocre indicator of the success of the course, are available. The authors will provide assessment data of this kind as it becomes available.

CONCLUSION

The authors firmly believe that it is absolutely essential that an educated person, ie a college graduate, have a firm grounding in what modern infrastructure consists of and an understanding of how the seemingly disparate infrastructure systems interact to support modern life. By looking at infrastructure in the context of not just technological issues, but also in terms of society, the student builds a sense of the interconnectedness of political, financial, social and built systems. At West Point, a course has been created which brings together the basic technological issues with the overarching societal issues, providing a firm foundation for both STEM and humanities majors. As can be seen from the student self-assessment, it may be difficult for some students to take a broad view of infrastructure, and having no single “right” answer is challenging for some. However, ill-defined problems are the norm in the modern world, and by providing this foundational course, it is hoped that technical and non-technical graduates of our program can both participate fully in the decision processes that support the creation, operation and use of infrastructure systems.

---References---

- [1] New York Times; 2010. “Text: Obama’s State of the Union Address”. Published January 27, 2010.
- [2] American Society of Civil Engineers, 2009. “Report Card for America’s Infrastructure”. Accessed 13JAN2011 at <http://www.infrastructurereportcard.org/>.
- [3] Meyer, Conley, Hanus, and Klosky (2008). “A “Global” Curriculum to Support Civil Engineering in Developing Nations”. National Conference of the American Society for Engineering Education.
- [4] Meyer, Conley, Hamilton, Hanus, Hart and Klosky (2010). “A “Global” Curriculum to Support Civil Engineering in Developing Nations: The Final Result”. National Conference of the American Society for Engineering Education.
- [5] Roberts, Parker, Curras, Penn and Anderson (2007). “An Innovative Infrastructure Curriculum for 21st Century Civil Engineering.” National Conference of the American Society for Engineering Education.

APPENDIX 1
CE350, INFRASTRUCTURE ENGINEERING
COURSE SCHEDULE

Lesson		SUBJECT
1	IS-1	An Introduction to Infrastructure
2	IS-2	Infrastructure and You
3	IS-3	The Infrastructure of the United States
4	IS-4	Stakeholder Analysis
5	IS-5	Network Theory
6	IS-6	Network Modeling
7	IS-7	Building Resilient Networks
8	W-1	Water Resources and Distribution Systems
9	W-2	Dams and Levees
10	W-3	Water System Demand
11	W-4	Water Treatment Models and Methods
12	W-5	Waste Water Treatment Models and Methods
13	W-6	Landfills (US and Afghanistan)
14	W-7	Water Treatment and WW Treatment Plant Tours
15	CS-1	Case Study I
16	WPR-1	Written Partial Review 1
17	E-1	Introduction to the Energy Sector
18	E-2	Electrical System Overview and Terminology
19	E-3	Electrical Generation and Transmission
20	E-4	Electric Sub-stations
21	E-5	Distribution of Electricity
22	E-6	Electricity Consumption
23	E-7	Electricity Consumption Laboratory
24	E-8	Electrical System Assessment & Alternative Energy
25	T-1	US Transportation Infrastructure
26	T-2	System Analysis I-Trip Generation and Distribution
27	T-3	System Analysis II—Modal Analysis
28	T-4	System Analysis III—Flow Modeling
29	T-5	Transportation Levels of Service
30	T-6	Railroads: Traffic and Load Carrying Requirements
31	T-7	Railroads: Route Profile and Alignment
32	T-8	Railroads: Route Selection
33	CS-2	Case Study II
34	WPR-2	Written Partial Review 2
35	D-1	Infrastructure in Doctrine
36	D-2	Infrastructure Reconnaissance and Assessment
37	D-3	Infrastructure Reconnaissance and Assessment
38	D-4	Infrastructure Reconnaissance Field Trip
39	CS III	Case Study 3
40	Review	Course Review and The Road Ahead

APPENDIX 2 SELECTED EXAM QUESTIONS

Exam 1

After conducting a network analysis of a water distribution system in your brigade's area of operations, you conclude that it is a small world network with the histogram shown. You brief your commander on your results and recommend spending 80% of the brigade's assistance and development funds on protecting only two of the 122 nodes in the system. The commander says, "Lieutenant, do you realize how many problems that is going to cause me? If I spend all that money on only two projects, I'm going to have 75% of the tribal elders on my case because they are not getting any money! Besides that, if we protect only 2 of the 122 nodes, the bad guys will just move on to one of the 100 nodes we did not protect and the city will still be without water. Then, every tribal elder will be on my case. Now is that what you want Lieutenant?" What do you say? Your answer cannot exceed five simple sentences (no semicolons, no compound sentences).

You have been assigned to develop a new, modern drinking water treatment plant for the city of Ghazni, Afghanistan. The city has a functioning distribution system, functioning water meters, and a functioning water department (it really does!!). What it needs is a new drinking water treatment plant. Before you begin your design, the magic genie in the bottle (he really doesn't exist) will answer any five questions you ask provided you tell him how you will use the information. So, what five questions will you ask and how will you then use the information in your design? Your answer should be five concise, focused questions and five concise focused statements on how the information influences the design.

Exam 2

Fast forward a year or two...you find yourself assigned as the "Special Project Lieutenant" (that means you are waiting for your platoon and how well you do in this job determines if you get the really cool platoon of your choice or the mess kit repair platoon). In the command and staff meeting, the battalion commander says to you, "Lieutenant, we are going to establish several micro-hydro power plants within our area of operations to support local development. You are going to act as our liaison with the US Army Corps of Engineers area office. There are 10 potential sites in our AO. I want you to go out to each one and conduct a recon, then get with the USACE office and figure out how to make this work." What will be the 5 most important things will you focus on during the reconnaissance and why?

APPENDIX 3 SAMPLE LESSON PACKAGE

Lesson W-1***Water Resources and Distribution Systems*****Learning Objectives:**

1. List the three elements of water resource management and the academic and professional disciplines that support these elements.
2. Describe the Hydraulic Cycle and Hydrologic Cycle.
3. Differentiate between the Hydraulic Cycle and Hydrologic Cycle.
4. Describe the connections between the Water Resources Sector and other infrastructure sectors.
5. Describe the regulatory structure that governs water quality and use.



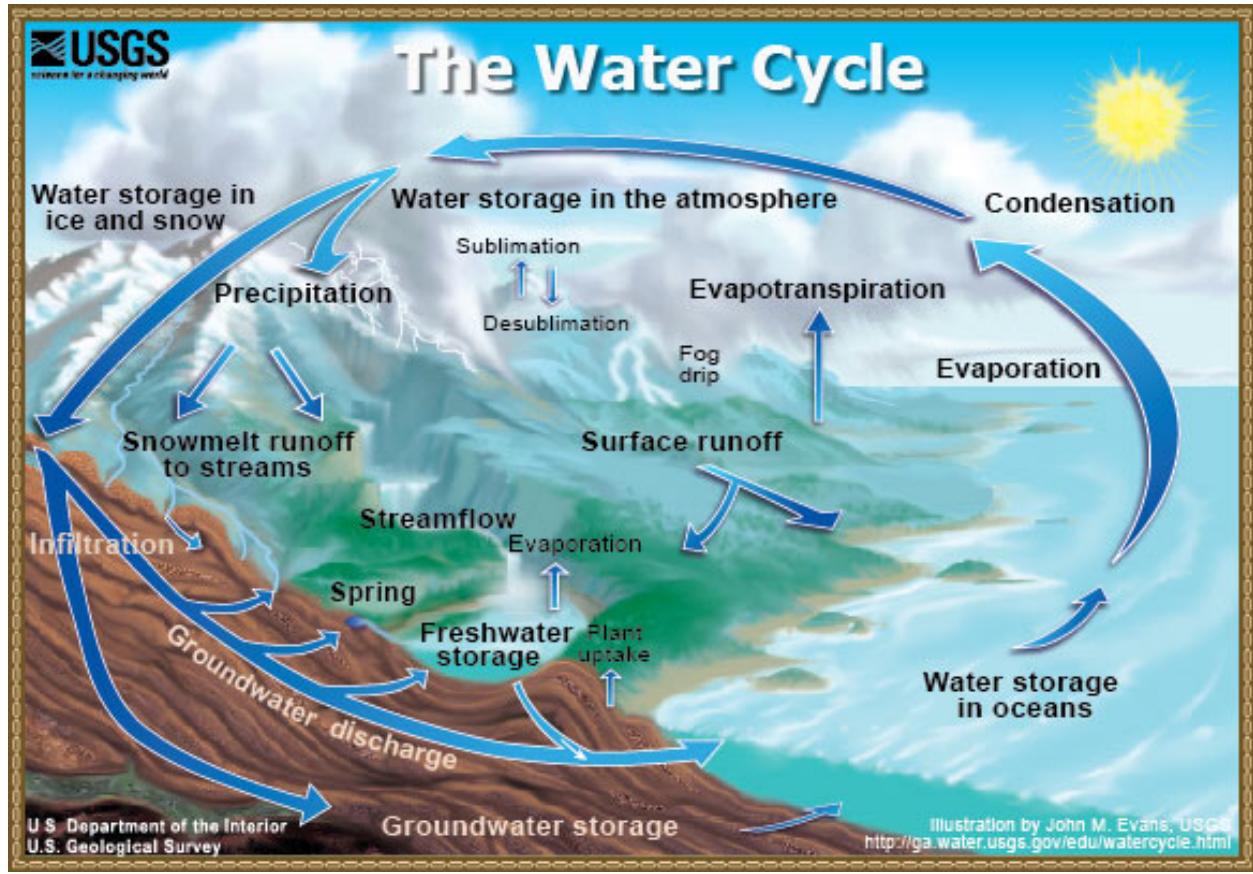
Drinking water reservoir Tampa Bay, Florida (*Source St. Petersburg Times*)

Study Assignment:

Revisit the Critical Infrastructure and Key Resources (CIKR) Resource Center website at <http://training.fema.gov/EMIWeb/IS/IS860a/CIKR/index.htm>. Review the water sector information and focus on understanding how the water sector interacts with the other sectors it has interdependencies with.

Hydrologic Cycle—study this website: <http://ga.water.usgs.gov/edu/watercyclesummary.html>

Hydraulic Cycle—study the below diagram.



Notes:

How Water Works

ILLUSTRATED PROCESSES, EQUIPMENT, AND TECHNOLOGY

A Typical Water System: From Source to Tap and Back

How Water Works looks at the processes, equipment, and appearances of a water supply system. This month's image provides an overview of the basic parts of a water system: source, treatment, distribution, collection, sewage treatment, and reuse. In subsequent issues we'll explore the inner workings of the drinking water system components, beginning with the source and flowing through to the tap. Next month: surface water sources

- 1a and 1b. Water is taken from its source, which may be a reservoir (1a), river, or well (1b). Water is pumped or flows by gravity to the treatment plant.
2. At the treatment plant, impurities in the water are removed or inactivated, and fluorides may be added.
3. Clean drinking water is stored in an elevated tank.
4. Distribution mains carry water from the treatment plant or tank to service lines. Mains also provide water to hydrants for fire protection.
5. Service lines connect distribution mains to building plumbing systems.
6. Used water from sanitary sewers is piped to the sewage treatment plant.
7. At the sewage treatment plant, used water goes through a multiple-step cleansing process.
8. Cleaned water is returned to the river where it re-enters the water cycle or is additionally cleaned and reused for irrigation purposes, such as golf course watering.

Illustration elements exaggerated for emphasis.

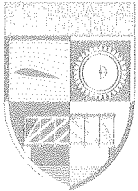
PIPELINE KEY

■	UNTREATED WATER
■	TREATED WATER
■	WASTE WATER
■	RECYCLED WATER

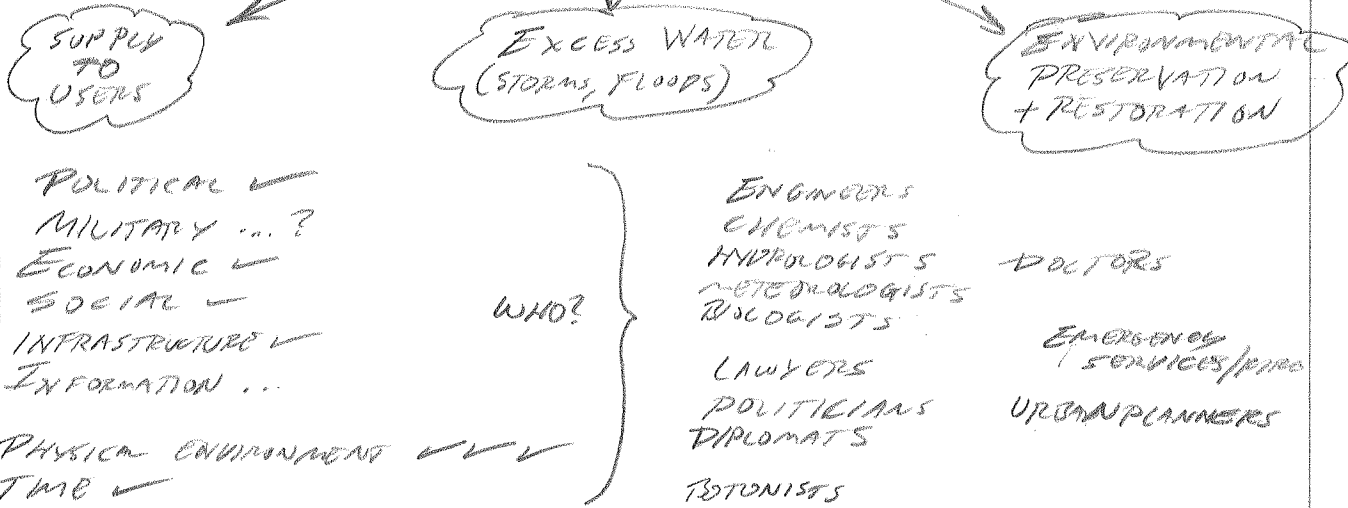
Water Resources Regulatory Structure

Water Resource Function:	Water Supply Management		Environmental Restoration	Excess Water Management		Water Supply Management
		Waste Water				
	Drinking Water	Surface Water	Ground Water	Storm Water Management	Flood Control	Water Distribution
What	Safe Drinking Water Act	Clean Water Act	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or SUPERFUND	State legislation	Federal Legislation	Regional Water Compacts, Federal Legislation
Who governs? Who enforces?	EPA State Departments of Environmental Protection	EPA—NPDES, National Pollution Discharge Elimination System	EPA	State environmental departments, typically	USACE, TVA, BLM	USACE, courts, regional authorities
When	1974, amended 1986, 1996	1972, amended 1977, 1987	1980, amended 1986			since early 1800s
Why						
Protects	Public drinking water, ≥15 taps or ≥25 individuals	Against point source contamination and underground injection	groundwater by remediating previously contaminated sites. Fund is currently bankrupt	Runoff quality in storm event	Life and property	

--what is constitutional authority?



WATER RESOURCE MANAGEMENT

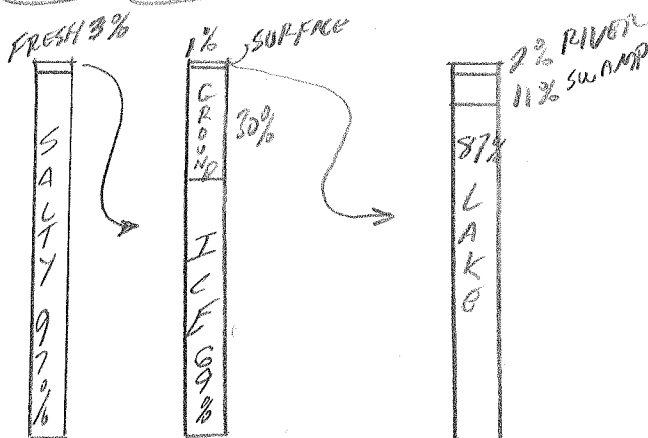


THIS IS A PROBLEM OF CONCERN TO WHOLE SOCIETIES!

HYDROLOGIC CYCLE

SEE STUDY NOTES! (SLIDE)

WHERE IS WATER?

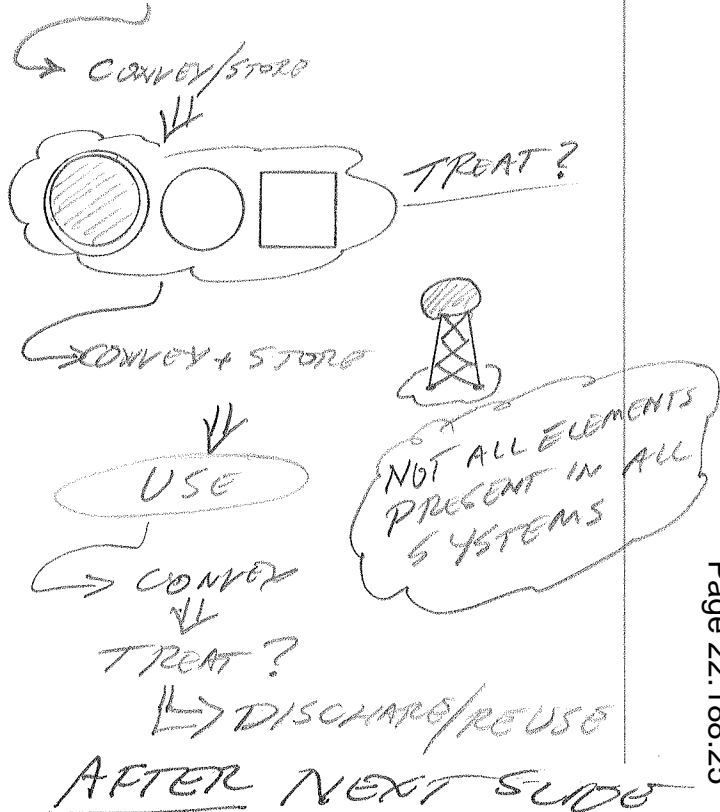


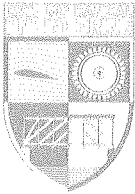
BOTTOM LINE - WEATHER EVENTS & PATTERNS HAVE A HUGE EFFECT ON OUR LIVES

HYDRAULIC CYCLE - SUPPLY

EXCESS WATER MANAGEMENT - NEXT TIME!

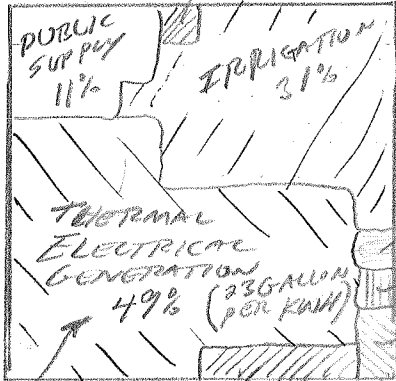
SURFACE + GROUND SLIDE





WHO USES WATER?

410 BGD USED IN US, 85% FRESH
 o 80% SURFACE (!)
 o 20% GROUND

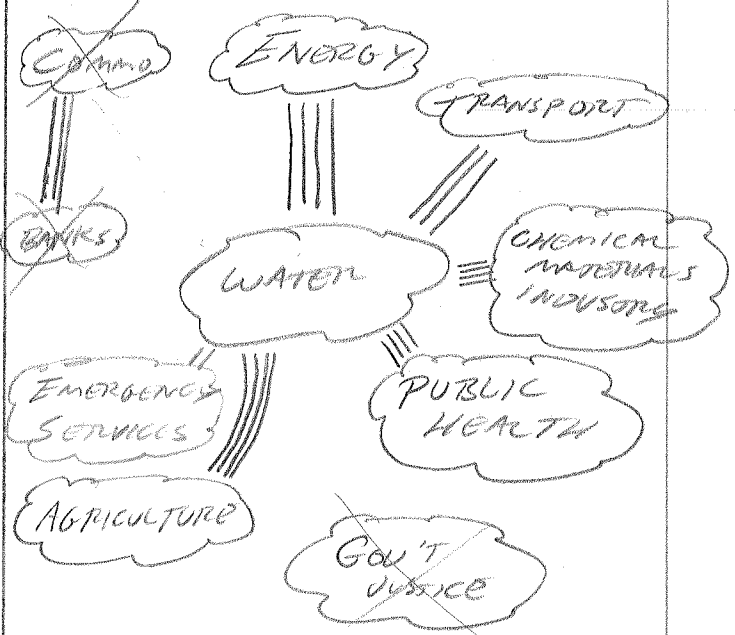


DOMESTIC SUPPLY 1%

BEFORE
LAST
SLIDE

STEAM!

WHICH TIERS REQUIRE H₂O?



SLIDES ON NEW ORLEANS
 LINK TO LAST LESSON

COVER EXCESS WATER NEXT
 TIME WITH DAMS + LEVEES