Ethics and Floodwater Engineering – 2

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Couse Description

This course is the 2nd hour of a 4-hour course on engineering ethics and floodwater engineering.

This course satisfies 1-hour of engineering ethics continuing education requirement for Professional Engineer license renewal.

The course in engineering ethics and floodwater engineering is intended to encourage the engineer to consider the big-picture result of decisions using real-world examples from a licensed Professional Engineer with extensive experience in Floodwater Engineering.

The engineer's duty is to make things work. Following instructions, complying with the law, and using current best practices are usually good enough for the present. But the engineer's task to make things work in the future. This requires making projections about future conditions and use. While engineers prefer hard facts, we are sometimes forced to work with "soft data" that require evaluating many possible options. During this evaluation, we use legal requirements and best technology as tools. Ethics can be used as a third tool to make decisions. "Ethics and Flood Water Engineering" contains many examples of using ethics in real-world situations to make engineering decisions.

Objectives

At the conclusion of this course, the student will have read and evaluated:

- Considerations for the long-term implications of design decisions beyond code requirements
- Considerations and implications when forced to work with "soft data" that require evaluating many possible options
- Use of legal requirements and best technology as tools
- Consideration of the use of ethics as a third decision making tool
- Review many examples of using engineering ethics in real-world situations to make engineering decisions

How to Read this Course

The student is required to thoroughly read and comprehend the course material and examples

In order to complete the course, the student must pass the quiz in the final chapter of the course. It is recommended that the student keep these questions in mind as the course is read.

Topics Covered

Introduction, Engineering Ethics, Floodwater Engineering, Real-World Examples of Engineering Ethics in Floodwater Engineering Applications.

Grading

Students must achieve a minimum score of 70% on the online quiz to pass this course.

The quiz may be taken three times.

The student will be asked at the end of the quiz to attest that he or she has personally and successfully completed all chapters of instruction.

The quiz may be viewed in the final chapter of this course.

Couse Inquiry

This course is designed to be interactive. The student is encouraged to contact us to discuss any questions that arise while taking this course. All inquiries will be answered within two days or less. The reader can contact PDH*Now* as follows:

By Email: info@pdhnow.com

By Phone: 1-833-PDHNOW9

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Ethics and Floodwater Engineering – 2nd Hour

In the second hour we will continue with actual examples of ethics applied to floodwater engineering.

After the dam was completed, I went into the flood plain section. I worked on computing flood plains for flood insurance studies and for project economic studies. I was trained by a master. Computing open channel flow in marginally confined irregular areas is more difficult that it sounds. Engineers tend to value concrete above dirt and hence give more esteem to flow computations in concrete structures when in fact analyzing flow outside of confined channels and pipes is far more challenging.

Many times, I have seen “dirt solutions” using zoning be far more cost effective than structural ones.

Hand computations and a backwater computer model are the tools of choice.

We all know that water flows downhill, so how hard could this be? Floodwater engineering analysis uses some relatively simple rules in a highly complex fashion. It is like playing chess. One can learn the rules of chess in under five minutes but spend a lifetime on the complex application of those simple rules.

Balance Risks

After being in the flood plain section for four years I had modeled many actual floods and computed many “theoretical flood plains”. In the last part of the 1970’s our drought ended with a huge snowpack. Runoff from the snowpack threatened one of the towns I had computed flood plains for as part of a flood insurance study. The Corps geared-up for a flood fight. Before the runoff started, I examined the town levees. They were so narrow that I got out of the car and measured my wheels and the top of the levee width. There was less than one foot of clearance between my wheels and the edge of the levee and the edges were starting to slough off. I carefully backed off the levee. I walked and measured. The levee was dotted with small trees and was too narrow to support any traffic. We could never get trucks on the levee to dump rock on levee break, or even to add bank protection in the case of severe erosion. Also levee patrols could not be made driving a car. I recommended that we *lower* the levee. This decision required doing something that was counter-intuitive to many people. But the major risk to levees in our area is failure due to bank erosion rather than a general overtopping. We needed a road wide enough to accommodate a dump truck carrying large rock. As part of our flood fight both sides of the levee were lowered which widened the top.

Ethical concept: Engineering decisions need to balance all risks, no matter how counter-intuitive.

Ethical Decisions Require a Balance:

The river had levees on both sides. One levee protected most of the town. The other levee protected a rural area with a few expensive homes and the local golf course. The temptation to want to protect every one against the largest possible flood is strong. However, the problem with such a goal is that means the entire levee system would break on both sides at the highest level it could stand. This would send a sudden wave of water through both sides. The damage in town would be devastating and would likely result in loss of life. If the levee break happened while most people slept a greater loss of life would occur. I had to make sure that the levee would break on the sparsely settled side first. That would reduce flow in the river and the combination of overbank and river flow might be enough to pass the flood wave without harming the town.

My experience working on a state highway survey crew as an instrument man came in handy. But what I saw through my level was not reassuring. The upstream "control" that kept water from coming into town was a few piles of uncompacted dirt! There was no guarantee that these wouldn't wash out and flood the town. As part of our flood fight effort the levee was properly wrapped around at the top end of the town side.

I remember looking through the level at the golf course that I was ensuring would flood first. I was a golfer. I visualized the sediment that would cover the course killing the grass and the floodwater that would damage the clubhouse and restaurant. I felt sick.

Ethical concept: Ethical decisions are not always easy.

Ethical concept: Ethical decisions require a balance between doing the greatest good for the greatest number while minimizing extreme harm to the lesser number.

Share Information with Authorities:

Another particular concern was an upstream diversion. This structure was diverting more than twice as much as it was allowing downstream to the town. It the diversion were destroyed, and all the water went downstream then catastrophic property damage and some loss of life would likely occur. The local law enforcement and I talked about this. Should someone threaten the structure, the authorities responding need to make an informed decision.

Ethical concept: Engineers need to share information with appropriate authorities about system sensitivity.

Check Computation Against Reality:

After the levee had been lowered, levee patrols were established, rock and sand bags were stockpiled, and city and county crews were trained to install filter fabric. I was feeling more confident. One evening my flood plain mentor and I were walking on the levee. I was expressing my confidence. He fell silent then said, “What if the model’s wrong?” I was stunned. That possibility had never occurred to me. The backwater model I computed matched calibrated flows and observed depths reasonably well. However, there was more to floodwater hydraulics than average depth. He threw a stick in the river, allowed a few seconds for the current to carry it and started pacing and timing with his watch. For the next several days I compared the velocities given by the computer printout to those observed in the river. There was more variation than I would have thought. As the weather got warmer and the runoff increased, I noticed another change. At first the current meandered more with each river bend. However, as the river rose and became faster, the current tended to go straight over longer distances. It also attacked the levee at new points. We had to dump rock on the river side of the levee to prevent erosion failure. As the water depth and velocity continued to increase the location of the attack points changed. This was not forecast by the backwater model.

Ethical concept: Engineer computer models and computations are only tools. Their results need to be checked against observed reality.

Less Precise:

At this point I would like to point out the variation in “precision levels” in some engineering areas versus others. Some fields of engineering are more of an exact science than others. For example, building a computer hard drive in a clean room is a much more exact science than estimating 100-year floodwater flood plains.

Ethical concept: The less precise the engineering is, the more ethical judgment is required to create a system that will work as needed.

Luck:

One Sunday afternoon I took some time off for nine holes of golf. The seventh hole paralleled the county levee. As I walked up the green I turned and faced the levee. There was a huge seep! I thought of running into the clubhouse and calling the work crew (we didn't have cell phones in those days), but just in played very fast. I got to the clubhouse phone and called the work crew foreman. He was at his son's birthday party and wondered if it couldn't wait until tomorrow. I was silent for a moment and then asked him, "Did you buy him a boat for his birthday?" About an hour later the whole crew showed up. When they saw how bad the seep was no one complained about spending their Sunday working. They installed filter fabric toped by dirt over the top of the seep and the problem was solved.

Mother Nature cooperated during the runoff season. At first the weather warmed-up and the runoff was near system capacity. Then we had a spell of cool weather and flows went back down. Again it warmed up and flows got near capacity. The temperature cooled once more and we dodged another bullet. Finally, it heated up and stayed hot, but by then so much of the snow pack had run through the system that we were able handle the remainder without any problem.

Ethical concept: Our outcome may be determined by luck.

Ethical concept: The Herculean efforts by county and city crews to remove logs from bridge openings enabled the system to function as designed.

Sometimes we think of maintenance as a before or after event, but with flooding maintenance is most critical during the event.

Unethical:

I mentioned that the less precise the discipline the more ethical judgment is needed to create a functioning system. Now we will look at some unethical engineering jobs.

We let a flood plain computation contract to a large Architect-Engineering firm. It was a model for unethical behavior. The principals of the firm showed up in their expensive suits, with many degrees, appropriate corporate resumes, and charm. They were all smiles while they negotiated the contract. We never saw them again. They dumped the job on some young engineer with a PhD. His book learning was only marginally up to the task of unconfined flood plain analysis. Moreover, they didn't give him enough time to properly do the job. When I saw the flood plains, I knew they were wrong. I took them back to him. I showed him what was wrong. He denied it. I then showed him his own photographs of street flow taken during a rain storm that proved what I was saying. He said, "That job's over. We've been paid for it." I then reported back to my own organization (this project was no longer under my mentor) and eventually wound up spend a long month with considerable overtime correcting their work.

The sequence of events for unethical engineering contacts frequently includes these steps.

1. A charming pitchman who will say whatever it takes to get the job.

2. A strong attempt to "charge what the market will bear". (Imagine if your grocer varied his prices according to how hungry you were in the checkout line.)

3. Delegating the job to an untrained under-resourced subordinate. (Key concepts here are to "treat employees like cattle" and "any warm body can do this".)

4. Closely monitor the subordinate's expenses while completely ignoring job quality.

5. Keep looking for another mark.

The employee of that firm used his employer's unethical model to form his own firm. He learned it well. He landed one job with our firm in the morning and later that afternoon we received a call from his secretary. She was crying. He had come in and thrown the hydrology manual at her and said, "You figure it out!" She wasn't an engineer and wanted to know if we could help her. I called her employer back and told him that the Corps negotiated for a journeyman engineer to do the job, not a secretary.

Fortunately, most firms are ethical. I dealt with one that did excellent work. When I found an error, they corrected it (even after they had been paid). Eventually I hired their most experience engineer to work for me. He was about 20 years older than me and had a wealth of career experience.

Ethical Concept: Charm and credentials are no substitute for competence.

Wall of Water:

One hydraulic concept I learned about was the wall of water. I had heard about such things, but always doubted their existence. One day I was near a large concrete channel and heard the sound of scrapping metal. I went over to the channel and observed a white clothes dryer lying on its side. There was nothing else in the channel. The noise sounded like it came from the dryer, but I could see no evidence of anything to move it. While I was standing there a wall of water about 6 feet high came down the channel and pushed the appliance on the concrete making the scrapping sound. I was stunned. The wall had a base about 3 feet wide which tapered up to the main part of the wall which was about a foot-and-a-half wide. The top 3 feet of the wall was a uniform width of about a foot-and-a-half wide. After about a minute another "wall" came down the channel. It was about the same size as the first. When I looked upstream, I saw 3 more "walls" coming at us. What I had witnessed was "slug flow". (Please consult a hydraulics book for more detail.)

Walls of water can be made other ways. One small watershed had flooded and dumped considerable mud on local business. We found tin cans in the watershed that gave us an excellent geographic definition of the storm. We had eye witness accounts of when it started and how long the intense period lasted. I took cross sections with easily visible high-water marks. I used Manning's Normal Depth equation to determine that the channel had carried 2,500 cfs (cubic feet per second). The hydrologist determined that the maximum flow should have been only 380 cfs with normal losses for infiltration. Even without any losses the model gave a peak flow on only 480 cfs. The observed flows were 5 times greater than the computed flows! This illustrates the phenomenon of "bulking". Bulking is where mud and other debris swell the clean water. I have heard of bulking factors mentioned as high as two (and once even three). So this is more than just bulking. What happens is that the flood wave pushes debris out in front of the flood wave causing a dam (or wall) at the front of the wave. Also, the factor of channel bed friction being greater than "water on water" causes the bottom of the flood wave to be slower than the top. This creates a small dam with water flowing over the top. All of these factors conspire to create the wall of water.

I did another flood investigation on a military base that had suffered a 10-inch rain. Most of the drainage ran through a temporary road bridge. One young military policeman spotted a family stranded out on the structure and radioed that he was going out to help. The radio message was taped. His next and final comment was about a "huge wall of water". All were washed from the bridge. There were no survivors.

My original belief of questioning the existence of the wall of water was based on uniform steady state open channel flow and the fact that I had never met anyone who had actually seen a "wall". Today most design is based on the same assumptions. This means that some bridge openings may be undersized.

Ethical concept: The engineer is responsible for creating structures that work, not just following published design criteria.

Ethical concept: Make allowance for unusual challenges

Absence of Precise Evidence:

Sometimes we just can't tell exactly what happened. I was sent to the field to investigate a bridge collapse (it wasn't one of ours) that resulted in one fatality. The family of the deceased was considering suing. The central pier had been undermined. The family contended that the pier should have been designed deeper. The highway had once been a major traffic carrier but was now replaced by the interstate. As a parallel frontage road carrying relatively light traffic the road was certainly up to standard generally. The bridge was old and had withstood many decades of flooding, so there was nothing weak about this structure. The question then became "was the size of the flood over the design limit?". However, it was impossible to determine the size of the flood because I didn't know how deep the water was in the channel during the flood. With most overland floods the ground doesn't erode much at first so the flood can be analyzed using the existing ground line. However, this flow was in a confined rectangular arroyo. The high-water mark was only a few feet from the top of the channel sides. I looked at the rocks in the stream. They had a fresh disorganized look. The stream had a relatively constant slope so the old adage "the river brought it down, the river will take it away" was operating. I looked at the considerable delta of deposited material where the stream opened up in a farmer's field downstream from the bridge. This told me at the peak flow the ditch had an eroded bottom (which means the cross-sectional area greater than would normally be viewed on a "dry" day). The rocks flowing with the water would strike the pier with no small force. I conclude that no exact measurements were possible, the flood that destroyed the bridge was very large and that there was no evidence that pier was undermined at some "small flow".

Ethical concept: In the absence of precise evidence one must use judgment and experience.

System Sensitivity:

The field of floodwater engineering involves developing values with a wide standard deviation. For example, frequency analysis of data from a river gage may have 90% confidence limits that vary by an order of magnitude!

Using the 100-year rainfall to determine runoff is subject to some statistical error in determining the 100-year rainfall, another error in applying it uniformly to the basin in question, and even a greater error by assuming normal watershed infiltration (as opposed to a basin that has just been scorched by a fire).

The key to working with wide variation answers is to consider the impact on the drainage system if one of the answers turns out to be lower than the one Mother Nature might give us. Sometimes extra flow is not a problem and other times it is deadly.

Ethical concept: Engineering computations with large standard deviations need to be applied considering the sensitivity of the system.

Questions to Consider – 2nd Hour

There is frequently more money and glory in structural solutions that natural ones.

Does your organization favor expensive concrete structural solutions over natural flood plain zoning ones?

Is there anyone in your organization that can analyze “outside the box channel”?

The project management model is a strong one, but it tends to promote sales over technical knowledge.

If you are part of a large organization does your group encourage development of technical experts?

In what work situations would you be responsible for making engineering decisions that consider loss of life or catastrophic property damage as parameters?

Lowering a levee to get it wide enough to drive trucks on is counter-intuitive to the flood overtopping model that the public has. Once they understand that the trucks are needed to dump large angular rock at levee erosion points to prevent levee failure before the water ever gets to the top, public support is given.

Have you ever had to make a counter-intuitive engineering decision?

Have you ever had to sell that decision to public officials?

The reason that counter-intuitive concepts are in a course on ethics is that the ethical choice can be a counter-intuitive one. It is much easier to go along with popular delusions than have the strength of character to say “No”.

In your own field how would you go about explaining your counter-intuitive idea?

The notion of equal protection under the law is a foundation concept in our legal system. It is one of the bedrock ideas that our culture is based on.

The basic idea that each individual is as important under the law and entitled to the same rights as anyone else is another good ethical idea.

However, ethics is a battle of good ideas.

We would like to protect everyone and we would like to do it equally. In every situation I would like to do so, if I could.

There are many levels of engineering ethical response. The simple one is the cost-benefit model we are all trained in.

Wise use of resources is another good ethical idea. Resources are not limitless. Resources get allocated considering property damage and loss of life. In low density population areas it is simply not cost effective to provide the same level of protection as in higher density population areas.

The notion of equal protection changes to equal protection per dollar spent to provide that protection. Equal protection per dollar is the quantitative application of the "greater good" ethical model.

Have you ever had to make decisions based on social good per dollar spent?

Most engineering decisions require some kind of cost-benefit analysis.

The decision is made for us. If there are more benefits than costs, then do it!

This is the first level of the "quantitative greater good" ethical model.

The second level of the quantitative greater good model is another offshoot of benefits per dollar. It involves grouping populations and providing more protection for the majority while minimizing the harm this causes to the minority.

This type of ethical decision is observed where large heavily traveled interstates have bridges that are designed for the 100-year frequency flood and many state highways are designed for the 50-year frequency flood.

Have you ever made a decision that favors the larger population group while providing less protection for a smaller group? How did you feel about doing this?

The third level of the "quantitative greater good" ethical engineering response is catastrophe avoidance. The emergency spillway on large dams is an example. The notch for the spillway lowers the volume the reservoir could hold but avoids catastrophic dam break by passing all flows safely.

In the flood fight example, the two different levels of protection provided by the two levees allowed a low population density to flood first and relieve some pressure on the system through town. This was a better alternative than having both levees with equal protection and having them overtop at the same time with catastrophic consequences.

Are you willing to sacrifice some protection for one group to avoid a catastrophe for both groups?

If we just follow the Code won't we be behaving ethically? Typically, many elements of all three levels of the "greater good" ethical model are in codes. However, care needs to be taken to be sure that all three levels are accounted for when planning or designing a project.

The 3 levels are: cost-benefit, big/little group, and catastrophe avoidance.

How does your job require you to deal with these?

Some situations are not covered by any written code. We looked at a case of a diversion that might be attacked and cause major damage or loss of life.

Are you willing to bring this to the attention of local authorities?

If asked are you willing to render your personal opinion as to a proper response by law enforcement officials?

If you are asked what would you say?

What if the model is wrong?

We discussed field tests measuring river current with a stick and stop watch. While the water surface level was closely predicted by the computer model, the impact points on the levee varied and were not discernible from the computer model.

Are you prepared to field check your work?

Are you willing to revise your technical opinion about the situation you are planning for?

Ethics versus Precision

Are you comfortable with the notion that the less precise the engineering is, the more ethical judgment is required to create a system that will work as needed?

We discussed a case where our largest emergency seep repair was based on a lucky observation.

Are you comfortable with the notion that the less precise the engineering is, the more likely our outcome may be determined by luck?

Summation of 2nd Hour

During the second hour we looked at the following ethical concepts:

- **Engineering decisions need to balance all risks, no matter how counter-intuitive.**
- **Ethical decisions are not always easy.**
- **Ethical decisions require a balance between doing the greatest good for the greatest number while minimizing extreme harm to the lesser number.**
- **Engineers need to share information with appropriate authorities about system sensitivity.**
- **Engineer computer models and computations are only tools. Their results need to be checked against observed reality.**
- **Our outcome may be determined by luck.**
- **The Herculean efforts by county and city crews to remove logs from bridge openings enabled the system to function as designed.**
- **Charm and credentials are no substitute for competence.**
- **The engineer is responsible for creating structures that work, not just following published design criteria.**
- **Make allowance for unusual challenges.**
- **In the absence of precise evidence, one must use judgment and experience.**
- **Engineering computations with large standard deviations need to be applied considering the sensitivity of the system.**

Ethics and Floodwater Engineering - 2

1-Hour

Quiz Problems

1. One of the problems with ethics is
    - A. I can't afford them.
    - B. I will feel guilty if I "charge what the market will bear" instead of time plus a reasonable profit.
    - C. People take advantage of me when I am ethical.
    - D. I feel confused. There are so many different perspectives to view things from.

2. When formulating an ethical strategy, the emphasis should be on
    - A. Finding a plan that is "good enough" for all the players
    - B. Finding a plan that is best for all the powerful and popular players
    - C. Finding a plan that is best for me
    - D. Doing it to them before they do it to me

3. According to game theory how many variables can we maximize at one time?
    - A. As many as we like
    - B. One
    - C. Three, if we use a 3-dimensional graph
    - D. Group theory has superseded this branch of mathematics.

4. Do unethical people eventually have any problems?
    - A. Not if they keep moving
    - B. Not if they avoid those who really know their character
    - C. A tarnished reputation may result
    - D. Charm conquers all

5. No craftsman likes to do
    - A. Work in the rain
    - B. Good work
    - C. Overtime during the Super bowl
    - D. Substandard work

6. Unethical people can be
    - A. Any of these
    - B. Evasive
    - C. Practiced at bait and switch
    - D. Lacking in respect for the law or social customs

7. Unethical clients may want to
    - A. Have the engineer build project the too cheaply.
    - B. A, C, and D
    - C. Blame the engineer when an underfunded project fails.
    - D. Use the property for activities for which it was not designed.

8. Which of the following should an engineer do?
   - A. B, C, and D
   - B. Design to the maximum allowed by code to save the client money.
   - C. Make it stronger than code and easier to construct.
   - D. Subcontract difficult or unpleasant jobs.

9. You are coding a hydraulic computer model. The bridge data you are inputting is for a two 4'x4' box culvert. The flow area in square feet is
   - A. 32
   - B. 64
   - C. 48
   - D. 28

10. Contractor monitoring firms should be paid
    - A. Directly by the customer
    - B. Directly by the contractor
    - C. Directly by the government
    - D. All of the above