

Engineering Student Technology Committee

<http://www.engr.colostate.edu/ESTC>

College of Engineering

Colorado State University

1. Title of Proposal: Enhancing Undergraduate Dam Education via an Instrumented Physical Model

2. Proposal Participants:

Primary Contact for Proposal

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Department/Major: Civil & Environmental Engineering

Check One: **Faculty** **Staff** **Student**

Additional proposal participants

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Department/Major: Civil & Environmental Engineering

Check One: **Faculty** **Staff** **Student**

Additional proposal participants

Name: _____ E-Mail: _____

Department/Major: _____

Check One: **Faculty** **Staff** **Student**

3. Proposal Abstract (limit to 100 words):

Earthen dams, for example the four dams that hold Horsetooth Reservoir above Fort Collins, are a critical component of modern infrastructure. Unfortunately, our current practice is to teach earthen dams through simplified 2-D representations of fundamental processes (i.e., flow nets). The objective of the proposed project is to develop an instrumented physical model (a small scale representation of a larger system) that can be used to construct and fail earth dams with real-time data acquisition. Physical models provide a means to bring real world engineering applications into the classroom, and can be used to enhance student learning and engagement by creating connections between theory and practice. When instrumented with data acquisition technology, a physical model can also allow students to gain experience as to how data acquisition technologies are used in practice to monitor critical infrastructure systems in geotechnical and hydrogeologic engineering and provide student measured data to validate the simple conceptualizations used in the classroom.

4. Proposal Budget

List of items to purchase and cost of each:

The proposed project includes three primary costs: \$3,300 for materials and equipment to construct the physical model, \$6550 for data acquisition (DAQ) system, and \$3200 to support an undergraduate student in design and construction of the instrumented physical model; the cost for supporting an undergraduate student will be paid for by the primary contact for the proposal (Professor Scalia), and is not requested from ESTC. An itemized list of the materials to be purchased for the physical model is included in Table 1. An itemized list of the equipment for the DAQ are provided in Table 2. Funds for undergraduate student assistance are based on an 8-week summer internship at \$10/hr assuming the student will work approximately 40 hr/week. The internship duration includes time required to finalize design, construct the physical model, and optimize data acquisition system for classroom use.

Table 1. Preliminary itemized list of materials for constructing the physical model, water storage tank, and cart for model transport to various CSU classrooms.

Item	Cost per Unit (USD)	Units	Subtotal
Polycarbonate sheets: 2' × 4' × 0.5"	\$180	3	\$540
Polycarbonate sheets: 2' × 2' × 0.5"	\$100	2	\$200
Water tank: 60 gallons	\$500	1	\$500
Wheeled cart for transport: 3' × 6'	\$420	1	\$420
PVC pipe & connections	\$200	1	\$200
Aluminum materials for frame	\$300	1	\$300
Submersible pump	\$240	1	\$240
Wood for tank frame	\$400	1	\$400
Miscellaneous caulk and hardware	\$500	1	\$500
Total			\$3,300

Table 2. Itemized list of materials for DAQ to collect pore pressure distribution through soil cross section.

Item	Cost per Unit (USD)	Units	Subtotal
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Soil Moisture Monitor USB transducers, 0-1 PSI	\$450	11	\$4950
Soil Moisture Porous ceramic plates, 1 bar high flow	\$20	10	\$200
HP ProBook 11 EE G1 Notebook PC	\$600	1	\$600
Pelican 1450 Case	\$100	2	\$200
Fittings and tubing	\$50	10	\$500
Grainger 12 Port USB Hub	\$100	2	\$100
Total			\$6,550

Note: An example physical model that does not include data acquisition, is included in Fig. 3.

*Dollar or percentage amount requested from ESTC: **\$9,850***

5. Full description of proposal:

The undergraduate Civil Engineering curriculum requires students to take Introduction to Geotechnical Engineering (CIVE 355), and offers as electives Groundwater Engineering (CIVE 423), Groundwater Hydrology (CIVE 531), and Seepage and Earth Dams (CIVE 556). These courses require understanding of the flow of water through engineered earthen structures (e.g., earthen dams, refer to Fig. 1). Currently, flow through earthen structures is taught using a simple 2-D conceptualization known as a flow net (e.g., refer to Fig. 2, from the current CIVE 355 required course textbook). The objective of the proposed project is to enhance the teaching of water-flow through earth dams via an instrumented physical model (a small scale representation of a larger system) that can be used to construct and fail earth dams with real-time data acquisition. An example of a physical model used to visually demonstrate water flow through an earthen dam, and eventual dam failure, is shown in Fig. 3.



Fig. 1. Local example of an earthen dam. Aerial view of Horsetooth Reservoir looking south.
Source: www.northernwater.org.

The proposed physical model will include an array of pressure monitor transducers to measure the pore pressure along a profile of the earthen structure. A 3×3 array of pore transducers will be used to measure pore pressures at multiple locations within the structure cross section. A 10th pore pressure transducer will be used to monitor the water depth in the reservoir. Students will learn the fundamentals of pore pressure monitoring by calibrating pore pressure transducers before use. Data will be collected in real time using Soil Moisture Monitor Software. These data, will then be brought back to the classroom to demonstrate the concepts covered by a flownet. The physical model will also be used to engage prospective engineering students during Colorado State University's Hydrology Days, and E-Days. The model will constructed so as to be portable across the CSU campus.

The proposed physical model system will provide a means to create commonly encountered geotechnical and water resource engineering. Example design scenarios include earth and concrete dams, retaining structures, foundations, and slope stability. These design problems also incorporate applications of groundwater hydrology, fluid mechanics, hydraulic engineering, and soil-structure interactions, which are relevant topics covered throughout the undergraduate curriculum in the Department of Civil and Environmental Engineering. Thus, the proposed physical model system has broad-scale use throughout the department as a hands-on instructional tool. The physical model will also be designed to allow students to configure the arrangement of the nine sensor array, allowing students to learn experience how different sensor configurations can influence interpretations of monitoring data. The proposed physical model, and accompanying data collected from the physical model, will be implemented in Engineering CIVE 355, CIVE 423, CIVE 531, and CIVE 556.

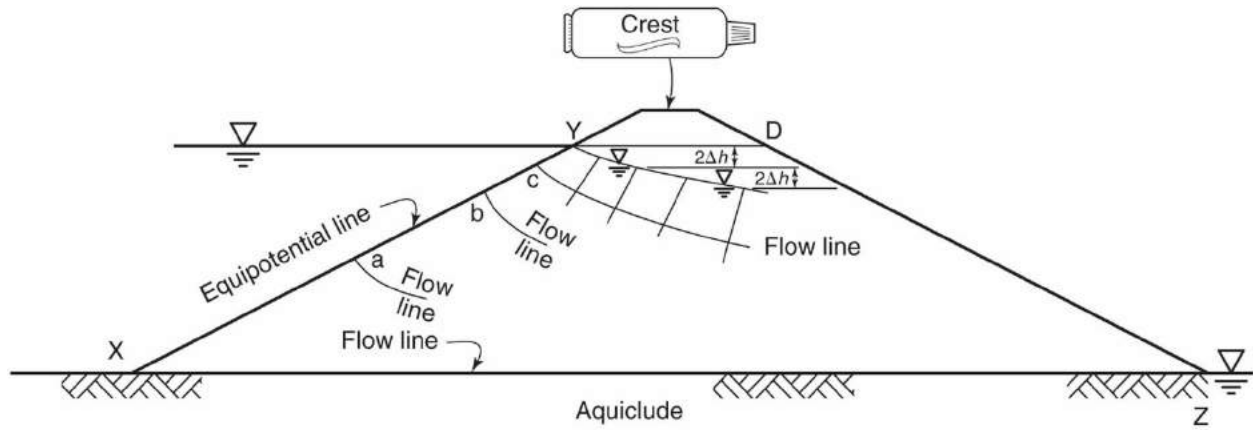


Fig. 2. Explanation of water seepage through earthen dams used in CIVE 355. Source: Fig. 7.25 from Holtz et al. (2011). *An Introduction to Geotechnical Engineering*, Pearson (required course textbook from CIVE 355).

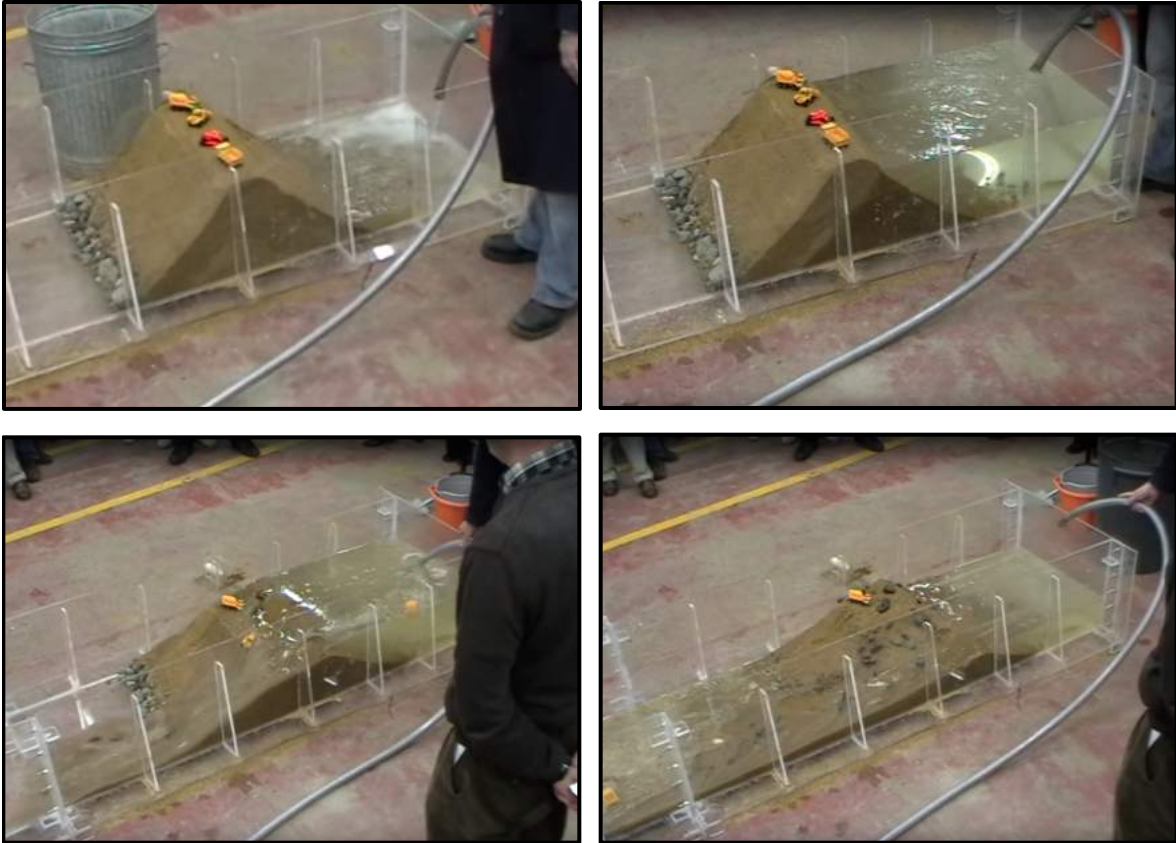


Fig. 3. Example earth dam physical model. Note: This physical model is purely visual, and fails to provide pressure data to allow engineering students to analyze flow of water and failure mechanisms through the earth structure as is included in this proposal. Source: <https://youtu.be/bWEWVw7TGk4> (see link for video of physical model operation).