**Project Summary – Seepage, Erosion, Collapse, and Filtration in Granular and Porous Media**

**Overview:** The objective of this proposal is to analyze a set of complex, dynamical problems that arise in granular and porous media applications by using a host of newly developed mathematical tools. The problems of interest include: (1) The spatially-variable seepage of groundwater into reservoirs and inference of gross system properties such as aggregate flux and material permeability; (2) The erosion of microscopic constituents of porous media leading to anisotropic macroscopic properties; (3) The occurrence of catastrophic events, such as sink hole collapse, resulting from interaction between groundwater seepage, porous-media transport, and erosion; (4) The efficacy and optimization of man-made filtration systems based on porous membranes. These four problems will be analyzed using a synergetic combination of cutting-edge computational techniques, reduced mathematical models, and laboratory experiments.

**Intellectual Merit:**

The four problems listed above present a host of new mathematical challenges and opportunities. First the range of scales is vast: spatial scales range from microscopic granular constituents to large geological aquifers; timescales range from that of a sudden sinkhole collapse to many years for the grains to be worn by fluid mechanical stresses. The systems are inherently multicomponent, with coupling between the fluid and solid phases. Although the governing PDEs are linear, the presence of moving boundaries introduces nonlinear feedback between geometry and flow. Finally, the inference of macroscopic medium properties from a limited set of seepage measurements requires inverse modeling, whereas the optimization of manmade filtration systems involves control. To tackle these challenges, the PI will combine tools from PDEs, asymptotic analysis, multiphase modeling, numerical analysis and computing, inverse modeling, optimization and control. Additionally, controlled laboratory experiments will be used to guide and verify theory developed herein.

**Broader impacts:**

By gaining a deeper understanding of the underlying physical processes, this investigation offers several potential benefits for managing water resources. First and foremost, a better understanding of sinkhole collapse could lead to policies to prevent these natural hazards. Second, inference of spatially-variable porous-medium properties from seepage measurements could identify locations in natural aquifers vulnerable to contamination and/or collapse. Finally, optimization of manmade filtration systems could save vast money and resource.

(Xiaoming)

Promoting teaching, training, and learning while advancing discovery is an important part of the project. The proposed project will provide ample opportunities for graduate students to get involved in the modeling, analysis, and computation of several physically motivated problems with different levels of difficulties. At least two graduates will be trained if the project is funded.