TIP WHITE PAPER

SOCIETAL CHALLENGE:
CIVIL INFRASTRUCTURE: ADVANCED SENSING TO ASSURE SAFETY OF EARTHEN DAMS AND LEVEES

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Critical National Need

Flooding is the most common natural disaster to strike the United States. In an average year, flooding kills about 140 Americans and causes more than $6 billion in damage. The American Society of Civil Engineers has assessed the health of the nation's dams, which have an average age of 51 years, at a "D" rating. Examples of the danger to human life and destruction of property that can occur can be found in the events in New Orleans after Hurricane Katrina. In the state with which we are the most familiar, Iowa, serious flooding has occurred nine of the last 16 years, leading to eight Presidential declarations of disaster[i]. The health of earthen dams and levees can have severe impacts on the safety and economics. Examples of local concern included the state wide devastation that brought President Clinton to Des Moines in 1993, the more recent flooding of the Cedar Rapids area, the failure in the Birdland neighborhood in Des Moines. Most recently, in August 2010, the city of Ames, Iowa and many surrounding communities suffered damage including 20 buildings on the Iowa State University campus. With over 4,000 dams and levees in the state (over 75,000 dams nationally) and discussion underway about building additional flood protection, there is much to be concerned about. The importance of this issue at the national level is signified by the National Levee Safety Program Act of 2007 which established the National Committee on Levee Safety[ii], to support levee safety programs through coordination and information exchange among federal and nonfederal entities concerning the implementation of levee safety guidelines.

The structural integrity of earthen dams and levees is critical to the protection of property and human life, particularly with the incidence of flooding on the rise. New methods are needed to assess the health of dams and levees, given the advancing age and unknown construction/maintenance history for many of these structures. The issues associated with levee health are numerous and begin with the makeshift nature of many of the structures that the public believes protect them. Many levees were constructed over a hundred years ago by earlier settlers without consideration of good engineering practices or adherence to federal specifications that would be followed today. In Iowa, the management of levees falls under the responsibilities of the Department of Natural Resources[iii] with "authority to regulate construction on all floodplains and floodways in the state for the purpose of establishing and implementing a program to promote the protection of life and property from floods and to promote the orderly development and wise use of the flood plains of the state." While much of their focus is on support of new construction and dealing with concerns as they arise, funding and staffing has not been provided to support assessment of the existing levee system. Iowa has 236 major levees spanning over 1,000 miles which are included in a US Army Corp of Engineers database[iv]. Of the 236, only 106 meet Corp's specifications and are regularly inspected and eligible for federal funding for maintenance and repair[v]. The Corp only inspects those levees that it designed and built or that it has certified as meeting standards. The remaining levees are maintained by a mixture of local community, county, private and public entities. Compounding the problem is the concern with liability should something go wrong. Many private engineering firms will not provide support to levee design and maintenance because of unclear guidance on liability, flood insurance regulations, etc. In many cases the records regarding construction methods do not exist. As defined in the US Army Corp of Engineers report, knowledge of embankment conditions provides for timely

repairs before damage occurs. Conditions of concern include anomalously visible water seepage that could come from fracture zones, cavities, or poorly mixed fill. Other concerns include buried drainage pipes or electrical lines.

Societal Challenge:

Given the above discussion, there is no doubt that continued inattention to this item could negatively affect the overall function and quality of life of the nation. At a national scale, the losses associated with Hurricane Katrina have been amply documented. At a regional scale, the State of Iowa has experienced three, 100 year floods since 1993. Whether this is due to mere chance, or is a consequence of global warming is still subject to discussion. However, the bottom line is the same. There is a demonstrable loss associated with the failure of the aging earthen dams and levees in the United States.

Transformational Opportunity:

There are technical solutions that could make a difference. Several geophysical evaluation methods have been used to assess the health of levees with limited success. Examples include the self-potential (SP) method, electromagnetic profiling (EM), electrical resistivity and profiling, ground penetrating radar (GPR), seismic refraction and reflection. Other methods often used in supporting roles include dye testing, surface seepage water conductivity and temperature measurements, microgravity measurement, magnetic and microacoustic surveys. Each of these methods has their own strengths and shortcomings. Broadly speaking, this is because, while the measured response is affected by the condition of interest, it is generally also affected by other issues such as soil type and other site conditions, limited penetration depth, sensitivity to aboveground and buried metallic objects, attenuation, limited resolution is some cases, etc.

A transformational opportunity is afforded by advances in sensing capability associated with modern processing hardware and novel sensors and sensor materials, information processing capability, and continuing advances in the understanding of the physics controlling the measurements. In each of these cases, the advances have occurred in other fields, driven by their respective needs. For example, the increase in computational capability described by Moore's Law is well established, and better understanding of the physics controlling various measurement techniques is being developed by both the geophysics and nondestructive evaluation communities. It is now time to bring these new capabilities to bear on the critical national need of better managing our dams and levees. Key elements of that program would include quantifying the understanding of the relationship of measurement response to indirect seepage conditions and other failure related conditions of small embankment dams (requiring both theoretical and field experimental efforts, quantifying the sensitivity of those techniques to competing factors, developing strategies for the use of complementary measurements to obtain sufficient information to better isolate the failure related conditions of interest from those causing interference, developing improved sensors designed to gather the required information, developing inversion strategies to best extract the needed information, and putting these in a form such that they can be used by personnel available in the field.

It is clear that the above research cannot be accomplished without the engagement of a broad, interdisciplinary team. Disciplines that would be required include physics, geophysics, earth sciences, hydrology, instrumentation development, computer scientists, construction and civil engineers, and others.

The final envisioned output would be recommendations for federal/state regulations regarding inspection methods for use in assessing the health of earthen dams and levees. It is doubtful that such guidance will be systematically developed without a TIP program, given the spotty nature of the funding support for work on this problem, thus strongly demonstrating the need for federal support.

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[i] "How Can We Reduce Flood Damages?", Wayne Gieselman, IA DNR Environmental Services Division

[ii] http://www.leveesafety.org/index.cfm

[iii] http://floodplain.iowadnr.gov/

[iv] http://data.desmoinesregister.com/results/index.php?info=ialevees

[v] http://www.desmoinesregister.com/apps/pbcs.dll/article?AID=/20080623/NEWS, "Many Levees Rarely Inspected", Perry Beeman, June 23, 2008.