# LESSONS LEARNED FROM DISASTERS AND NEW TECHNOLOGIES

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## Abstract

In recent years there have been number of natural disasters and accidents causing major losses. Natural disasters include flooding, hurricanes, draughts, fires, erosions and earthquakes. Accidents caused by humans include failures of infrastructures, power grids, gas leaks causing fires and cyber-attacks. Cyber-attacks can result in major disruption in various modes of transportations, loss of data, interruption of power supply and government operations. Coastal and urban flooding is the major disaster in the history of mankind. Flooding related to coastal areas, rivers and urban areas and are seasonal in nature is causing billions of dollars in damages just in the United States. Draughts have caused fires and significantly affecting the agricultural activities. One hurricane can affect more than one state and Gulf of Mexico has had 288 hurricanes in the last 166 years. Coastal erosion not only results in continuous loss of land but also affecting the bathymetry, sea animals and sea plants. Also methods to minimize the dynamic physical-biochemical coastal erosion processes must be developed and better quantify erosion must be developed. Damages due to flooding must be minimized by better predicting the flooding areas and also developing temporary storage facilities. Floating Large Wooden Debris (LWD) is not only causing damages to all the surface infrastructures but also delay in the recovery after flooding. Also new technologies are being developed for real-time monitoring using drones and smart cement.

## 1. Introduction

The losses due to disasters are becoming extremely high due to the growth in industrial activities and population together with recreational activities. During one hurricane many states are affected by storm surge, flooding, wind damages and debris accumulation happening at the same time. During the drought many activities are affected and there is greater risk for wild fire. In recent years cyber-attacks have become a major national problem. Like the hurricane, cyber-attacks can also cause number of failures causing major delays in recovery and loss of very valuable data. Also new technologies are being developed for monitoring the damages before, during and after major disasters..

## 2. Objectives

The overall objective was to investigate the lessons learned from disasters and review the applicability of few new technologies. The specific objectives are as follows:

(1) Review the trends and recent disasters including cyber-attacks.
(2) Controlling the large woody debris from undermining the transportation infrastructures.
(3) Evaluating the new technologies including drones and smart cement.

## 3. Hurricanes

In the history of the U.S., Gulf of Mexico states have experienced larges number of hurricanes. In the past 166 years (1851-2016) there have been 288 hurricanes with 89 of them being category 3 or higher (Table 1). West Florida has had the largest number hurricanes in history of Gulf of Mexico. During the period 1880 to 1889, GOM had the largest number of hurries in a decade amounting to 25. During the period 2000 to 2009, there were 7 hurricanes categorized as 3 or higher. Since 2010 there were only 6 hurricanes in the Gulf of Mexico.

**Table 1. Hurricanes in the past decades in the Gulf of Mexico States**

| 10 Year cycle | | | TX | FL (West) | LA | MS | AL | Total (GOM) |
|---|---|---|---|---|---|---|---|---|
| 1851 | - | 1859 | 3/0 | 7/2 | 3/3 | 2/2 | 3/1 | 16/5 |
| 1860 | - | 1869 | 4/0 | 3/0 | 6/1 | 2/1 | 2/1 | 15/2 |
| 1870 | - | 1879 | 2/1 | 11/3 | 3/1 | 0/0 | 1/0 | 19/6 |
| 1880 | - | 1889 | 7/3 | 10/2 | 5/2 | 1/1 | 2/1 | 25/5 |
| 1890 | - | 1899 | 3/0 | 6/2 | 3/1 | 1/1 | 1/1 | 20/7 |
| 1900 | - | 1909 | 4/2 | 5/2 | 3/1 | 3/1 | 2/0 | 17/5 |
| 1910 | - | 1919 | 7/4 | 8/3 | 4/4 | 2/2 | 5/2 | 21/7 |
| 1920 | - | 1929 | 2/0 | 7/4 | 3/1 | 2/1 | 0/0 | 15/5 |
| 1930 | - | 1939 | 5/2 | 4/1 | 2/0 | 0/0 | 2/0 | 18/5 |
| 1940 | - | 1949 | 8/3 | 10/5 | 3/1 | 1/1 | 0/0 | 22/8 |
| 1950 | - | 1959 | 2/1 | 5/1 | 2/1 | 0/0 | 1/0 | 18/7 |
| 1960 | - | 1969 | 3/2 | 5/1 | 4/3 | 2/1 | 0/0 | 15/6 |
| 1970 | - | 1979 | 2/1 | 2/1 | 4/1 | 1/1 | 2/2 | 12/4 |
| 1980 | - | 1989 | 5/2 | 3/1 | 3/0 | 1/1 | 1/1 | 16/5 |
| 1990 | - | 1999 | 1/1 | 6/2 | 2/1 | 1/0 | 2/1 | 14/5 |
| 2000 | - | 2009 | 5/1 | 8/7 | 7/2 | 1/1 | 3/3 | 19/7 |
| 2010 | - | 2016 | 0/0 | 1/0 | 1/0 | 0/0 | 0/0 | 6/0 |
| Total / Cat 3 and Higher | | | 63/23 | 101/37 | 58/23 | 20/14 | 27/13 | 288/89 |
| Remarks | | | Second highest | Largest number of hurricanes | Third highest | Least amount of hurricanes | | Total number of hurricanes – are 288 |

## 4. Cyber-Attacks

Cyberwarfare utilizes techniques of defending and attacking information and computer networks that inhabit cyberspace, often through a prolonged cyber campaign or series of related campaigns. It denies an opponent's ability to do the same, while employing technological instruments of war to attack an opponent's critical computer systems. Cyberterrorism, on the other hand, is "the use of computer network tools to shut down critical national infrastructures (such as energy, transportation, government operations) or to coerce or intimidate a government or civilian population".[4] That means the end result of both cyberwarfare and cyberterrorism is the same, to damage critical infrastructures and computer systems linked together within the confines of cyberspace.

In detail, there are a number of techniques to utilize in cyber-attacks and a variety of ways to administer them to individuals or establishments on a broader scale. Attacks are broken down into two categories: syntactic attacks and semantic attacks. **Syntactic attacks** are straightforward; it is considered malicious software which includes viruses, worms, and Trojan horses.

### (i) Viruses

A virus is a self-replicating program that can attach itself to another program or file in order to reproduce. The virus can hide in unlikely locations in the memory of a computer system and attach itself to whatever file it sees fit to execute its code. It can also change its digital footprint each time it reproduces making it harder to track down in the computer.

### (ii) Infrastructures as targets

Once a cyber-attack has been initiated, there are certain targets that need to be attacked to cripple the opponent. Certain infrastructures as targets have been highlighted as critical infrastructures in time of conflict that can severely cripple a nation. Control systems, energy resources, finance, telecommunications, transportation, and water facilities are seen as critical infrastructure targets during conflict. A new report on the industrial cybersecurity problems, using data from as far back as 1981, had found a 10-fold increase in the number of successful cyber-attacks on infrastructure Supervisory Control and Data Acquisition (SCADA) systems since 2000. Cyberattacks that have an adverse physical effect are known as cyber-physical attacks.

## 5. Urban flooding

Urban flooding is the inundation of land or property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems, such as storm sewers. In urban areas, flood effects can be exacerbated by existing paved streets and roads, which increase the speed of flowing water. The flood flow in urbanized areas constitutes a hazard to both the population and infrastructure.

Flooding is usually associated with major infrastructure failures such as the collapse of a dam, but they may also be caused by drainage channel modification from a landslide, earthquake or volcanic eruption. Examples include outburst floods and lahars.

Tsunamis can cause catastrophic coastal flooding, most commonly resulting from undersea earthquakes.

## 6. Large Woody Debris (LWD)

Urban and river flooding can carry fallen trees and damaged infrastructure debris into the nearby storm water drainage systems and rivers causing several problems. There is increasing concern about the large wood floatable debris in the storm water drainage systems, combined sewer systems and rivers causing several problems including undermining bridge structures and blocking highways, rail tracks and river navigation.

There are two classes of debris accumulation observed at the bridges: single –pier accumulations and span blockages (Diehl (1997)). Most debris accumulated on a single pier is usually less than 50 ft wide depending on the channel width and flow patterns. Logjams are natural accumulations of LWD that may span an entire width of stream channels and create a partial obstructions to streamflow resulting in flooding, erosion and also undermine the bridge infrastructures. The rate of accumulation of LWD is largely dependent on the size distribution, concentrations magnitude of the flood and the obstructions within the river. During a normal flooding, it may take several hours before debris could accumulate enough to pose a threat to a bridge. Diehl (1997) proved in his studies that debris accumulation is highly dependent on the relationship between the length of debris and width of upstream channel.

### (a) Bridge Failures

On March 16, 1980 (Sunday) around 11:00 p.m. there was a collapse of a part of the Perkins Road Bridge over Nonconnah creek in Memphis, Tennessee, that the accumulation of floating debris in the form of tree trunks and limbs during flood event played critical role in scour at the bridge piers (NCHRP 653). The bridge failure resulted in one death. In the investigation that followed the Perkins Road Collapse, it was found that 20% blockage between piers altered the flow conditions and undermined the 12 ft. of embankment on the piles supporting the pier that failed. In 1989, during a flood event, a bridge collapsed over the Great Miami River in Ohio and two people died as a result (NCHRP 445). In 1993, bridge collapsed over Florida Creek near Skidmore, Missouri.

### (b) Mitigation Methods

Management tools currently being used are focused on controlling the debris accumulation on the bridge pier include river channel stabilization at the bridge site and placement of debris deflectors, guides or collectors immediately upstream of the bridge.

#### (i) Debris Fins

Debris fins are walls or rows of piles (Fig. 1) placed directly upstream of bridge piers for which protection from debris accumulation is desired. Though commonly direct extensions of the bridge pier structure – sometimes referred to as “pier nose extensions” – debris fins can also be independent of the bridge. The fins are oriented parallel to the flow of the river to maximize effectiveness, as a greater possibility exists for debris collection when flow is oblique to the fin. In addition, when the debris is oriented in the direction of flow and the debris does not squarely make contact with the pier, the impact is lessened, reducing the effects on the bridge pier (Haehnel and Daly 2002). Note that Haehnel and Daly found the likelihood of direct impact to be rare even when debris has been aligned with the direction of flow. The effectiveness of fins varies and is most dependent on flow velocity. Debris fins are most effective in higher velocity flows and have been shown to be very effective in areas where large amounts of debris are accumulated . Though largely effective, note that debris fins may require some regular debris removal.

**Figure 1. Debris fins upstream of bridge piers (NCHRP 653)**

(ii) **Debris Sweepers**

Debris sweepers are polyethylene devices that rotate around a vertical axis, under the force of flowing water. The rotating structure floats (Fig. 2) at the water surface, and travels up and down the vertical axis as water levels rise and fall. Floating debris is redirected if necessary, and guided through the bridge opening by the vortices surrounding the rotating sweeper (Iowa DOT (2012)).

Sweeper

**Figure 2. Debris Sweeper Installed Using Pier Attachment (Bradley et al. 2005)**

### (iii) Debris Deflectors

Debris deflectors are piles/columns/poles placed upstream of bridge piers to not only deflect debris away from the bridge pier and guide the debris through the bridge opening but also collect the debris (Fig. 3 (a) and 3(b)). They are normally arranged in different configuration as shown in Fig. 4 as 1 2 3 4

The V-shaped configuration (Fig. 4 2 ) is considered is the most effective configuration with the apex upstream. These cylindrical pile debris deflectors have been widely used throughout the United States and there effectiveness as a debris accumulation must be designed to suite the rivers and the environment.

**Figure 3a. Cylindrical Pile debris deflectors installed in an Indiana River (Lyn et al 2005)**

**Figure 3b. Debris accumulation at the column debris deflectors (Lyn et al 2003)**

The Circular piles/posts are can be driven into the channel bed, spaced to match the minimum length of debris for which entrapment is desired without impeding the water and sediment flow. This is analogous to the sieves used in geotechnical engineering to filter the larger soil particles and allow the fine the finer particles to go through..

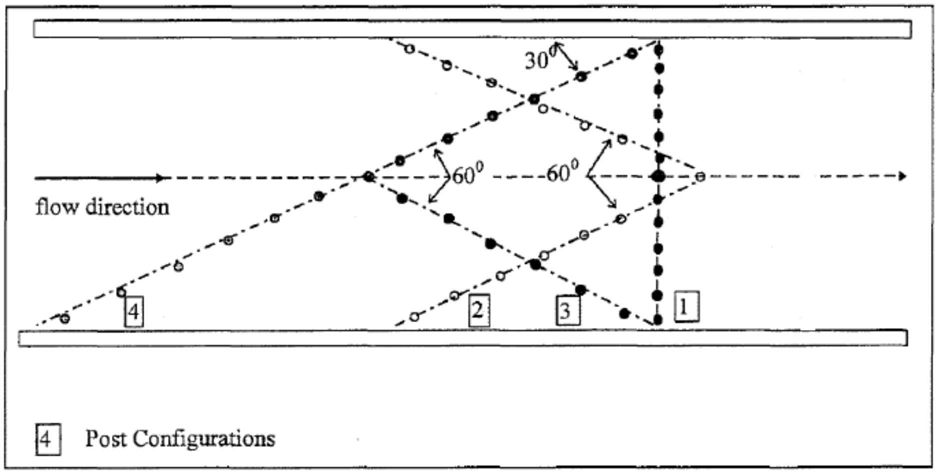

**Figure 4. – Debris Deflection Pile Configurations (Wallerstein and Thorne 1997)**

### 7. *Smart Cement*

Well cementing is performed to provide a protective seal around the casing, prevent lost circulation and/or a blowout, and promote zonal isolation. The API standards suggest the chemical requirements determined by ASTM procedures and physical requirements, determined in accordance with procedures outlined in API RP 10B and ASTM. There are several cement classes, A through H, which can be used to cement oil or gas wells.

Cement slurry flow ability and stability are the major requirements in well cementing. Oil and gas well cements (OWCs) are usually made from Portland Cement clinker or from blended hydraulic cements. OWCs are classified into grades based upon their $Ca_3Al_nO_p$ (Tricalcium Aluminate – $C_3A$) content: Ordinary (O), Moderate Sulphate Resistant (MSR), and/or High Sulphate Resistant (HSR) types. Each class is applicable for a certain range of well depth, temperature, pressure, and sulphate environments. OWCs usually have lower $C_3A$ contents, are coarsely ground, and may contain friction-reducing additives and special retarders such as starch and/or sugars in addition to or in place of gypsum.

Cements such as Class G and Class H are considered to be two of the most used cements in OWC applications. These cements are produced by pulverizing clinker consisting essentially of calcium silicates ($Ca_nSi_mO_p$), with an addition of calcium sulphate ($CaSO_4$) (John, 1992). Class H cement is produced by a similar process, except that the clinker and gypsum are ground relatively coarser than for a Class G cement, to provide a cement with a surface area generally in the range 220 - 300 $m^2$/kg (John, 1992).

When admixtures are added with cement, tensile and flexural properties are modified. Also, admixtures will have an effect on the rheological, corrosion resistance, shrinkage, thermal conductivity, specific heat, electrical conductivity and absorption (heat and energy) properties of cement. Cement slurries are pumped down the casing several thousand feet below ground level and back up the outside of the casing (casing annulus) – formation; hence, because of the changes in velocities, pressures, and temperatures and unknown hole sizes, as well as mixing and cement – formation interaction questions, determining cement setting time is always challenging.

A smart cement has been developed (Vipulanandan et al. 2014a,b; Vipulanandan and Mohammed 2015a,b ) which can sense any changes going on inside the borehole during cementing and during curing after the cementing job. The smart cement can sense the changes in the water cement ratio, different additives, and any pressure applied to the cement sheath in terms of piezoresistivity (Vipulanandan and Mohammed 2015a). The failure compressive strain for the smart cement was 0.2% at peak compressive stress (Vipulanandan et al. 2015b) and the resistivity change is of the order of several hundreds making it over 1000 times more sensitive.

## 8. Conclusions

The lessons learned from disasters requires better monitoring, control and developing effective protection systems.

## 9. Acknowledgement

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