

# Computational Forensics: How an Applied Mathematician Survived Cross Exam

Presented by:

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## Case Study: Debris Flows

Pakistan Debris Flow

Images of Pakistan Debris Flow



## Virgen, Austria Debris Flows

### Images of Virgen, Austria Debris Flows





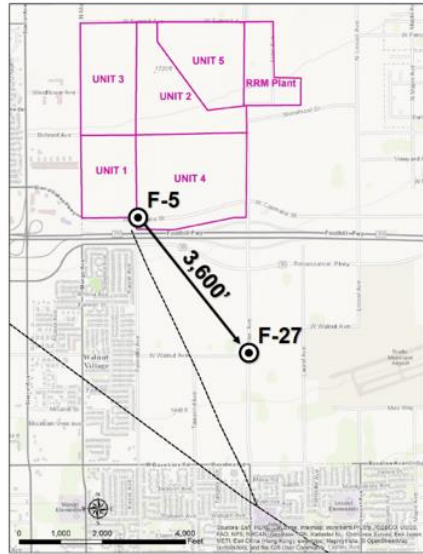
## **Case Study: Groundwater Contamination and Analogous Exhibits**

### **Groundwater Contamination**

At Issue:

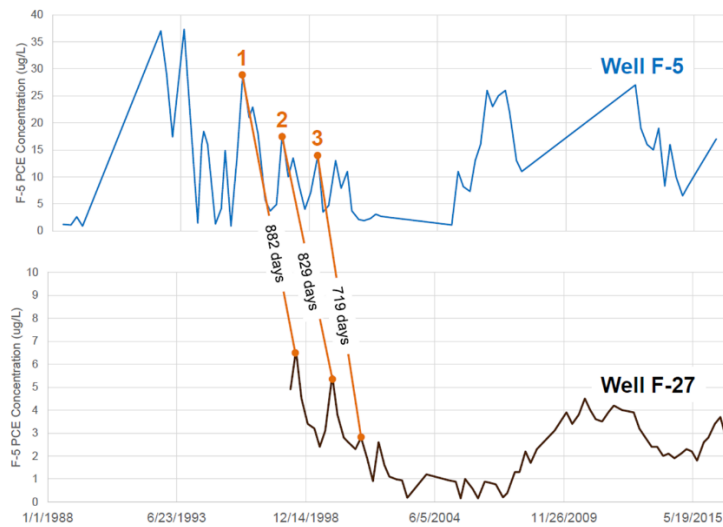
- How to determine the timing of a groundwater contamination event based on chemical readings at spatially separated wells
- Convincing a jury that peak concentrations, even when shifted in time, represent the same underlying data

## Calculating Travel Time Through the Saturated Zone



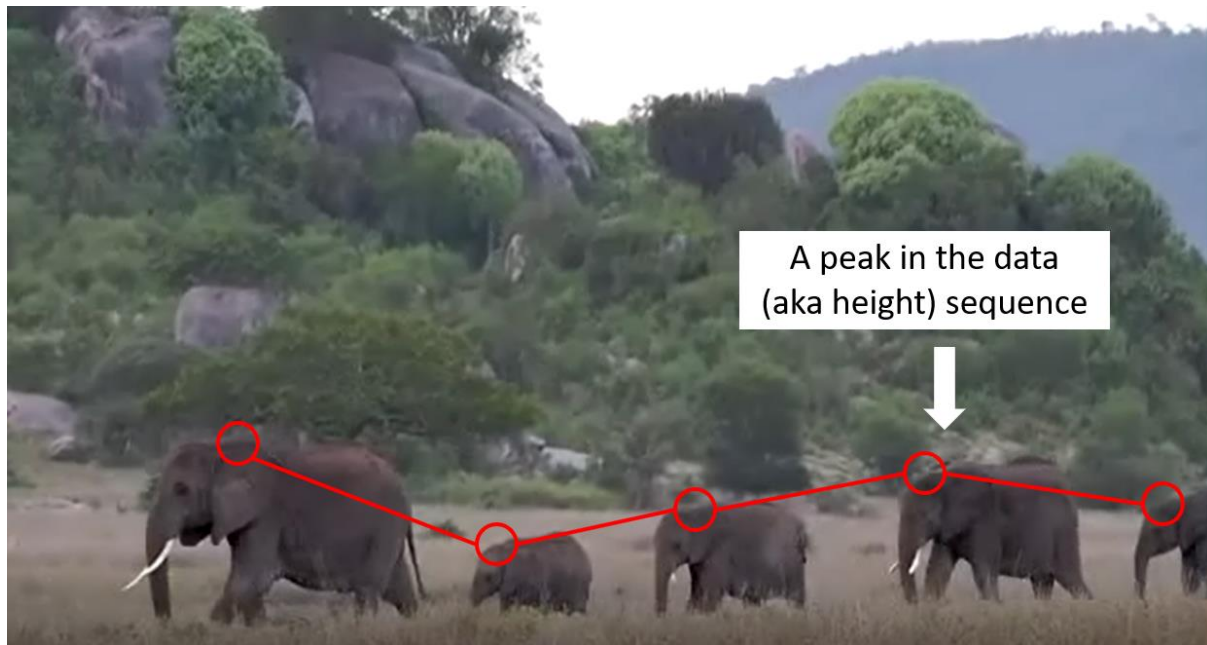
- Calculate travel time of PCE peaks between well pairs
- Back calculate PCE velocity given the known well distance between well pairs
- Distance between wells F-5 and F-27 is approximately 3,600 feet
- PCE travel time between F-5 and F-27 is between 719 and 882 days

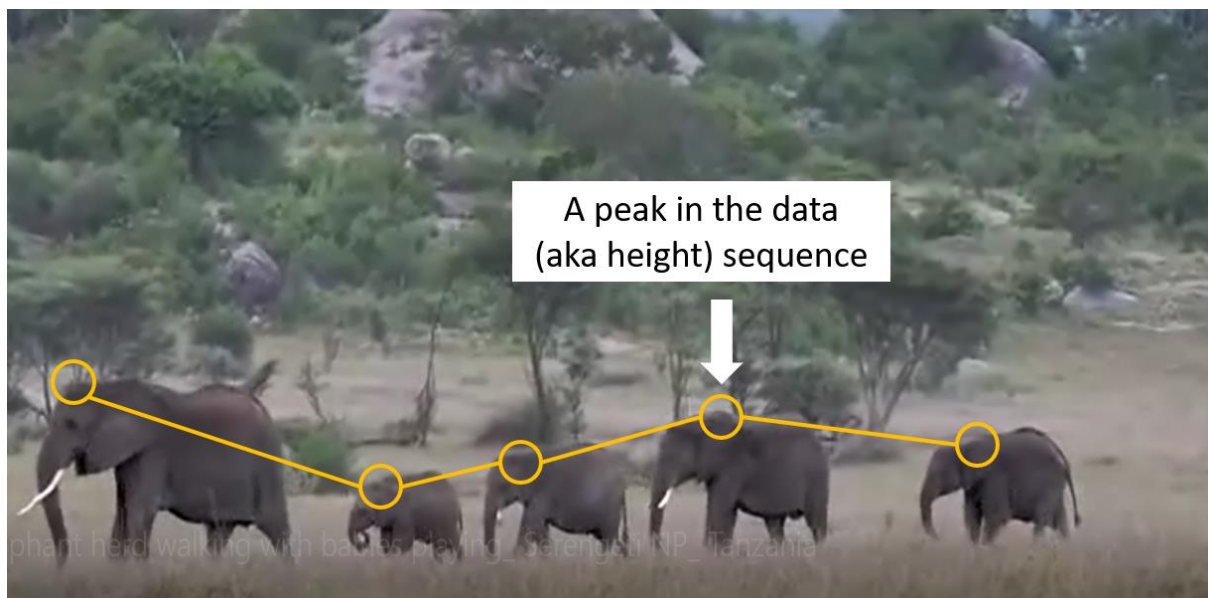
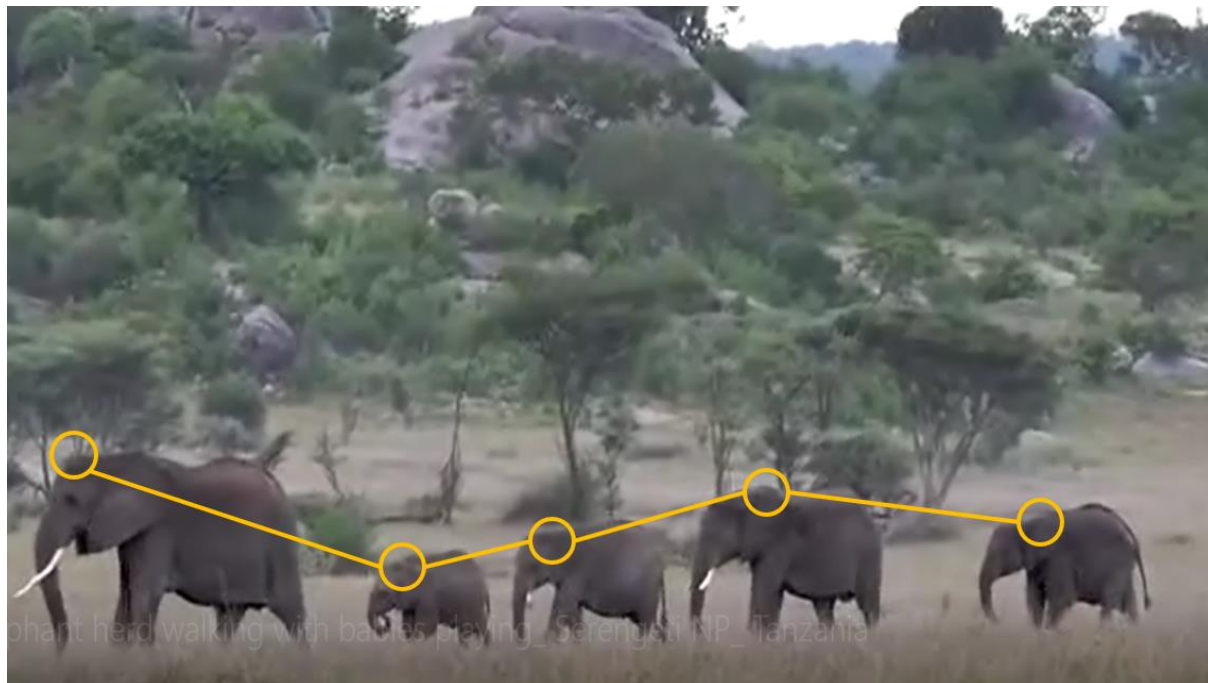
## Calculating Travel Time Through the Saturated Zone



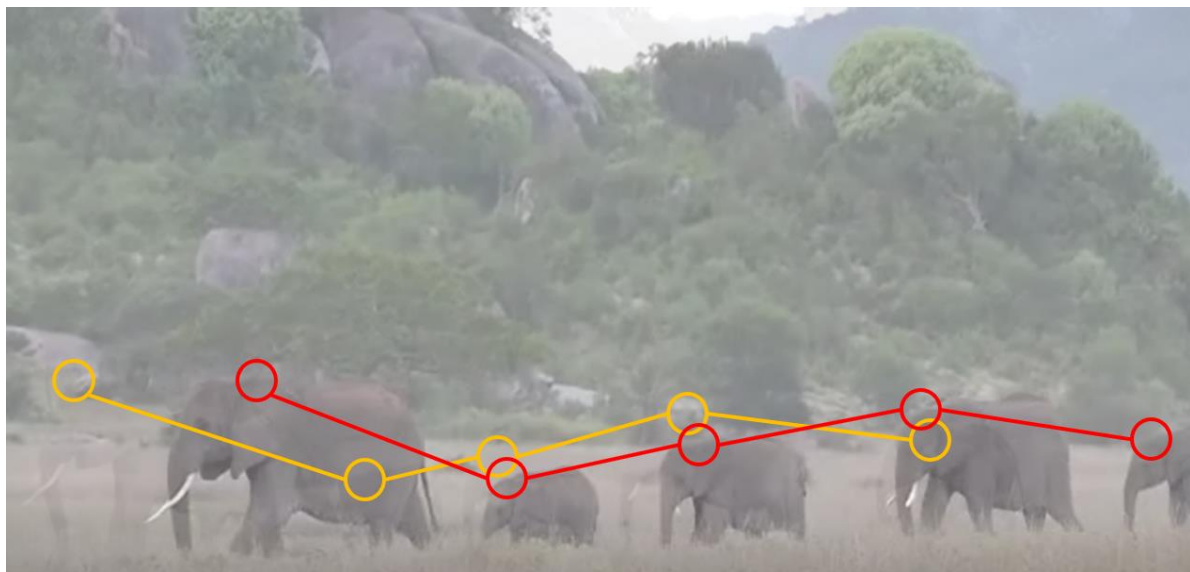
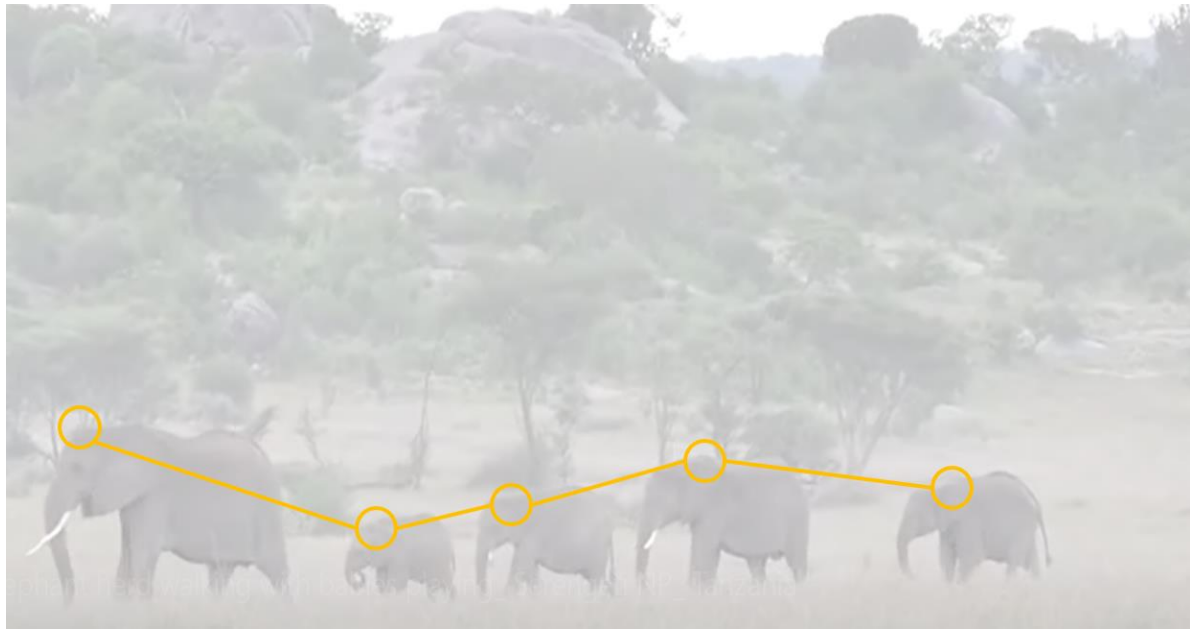




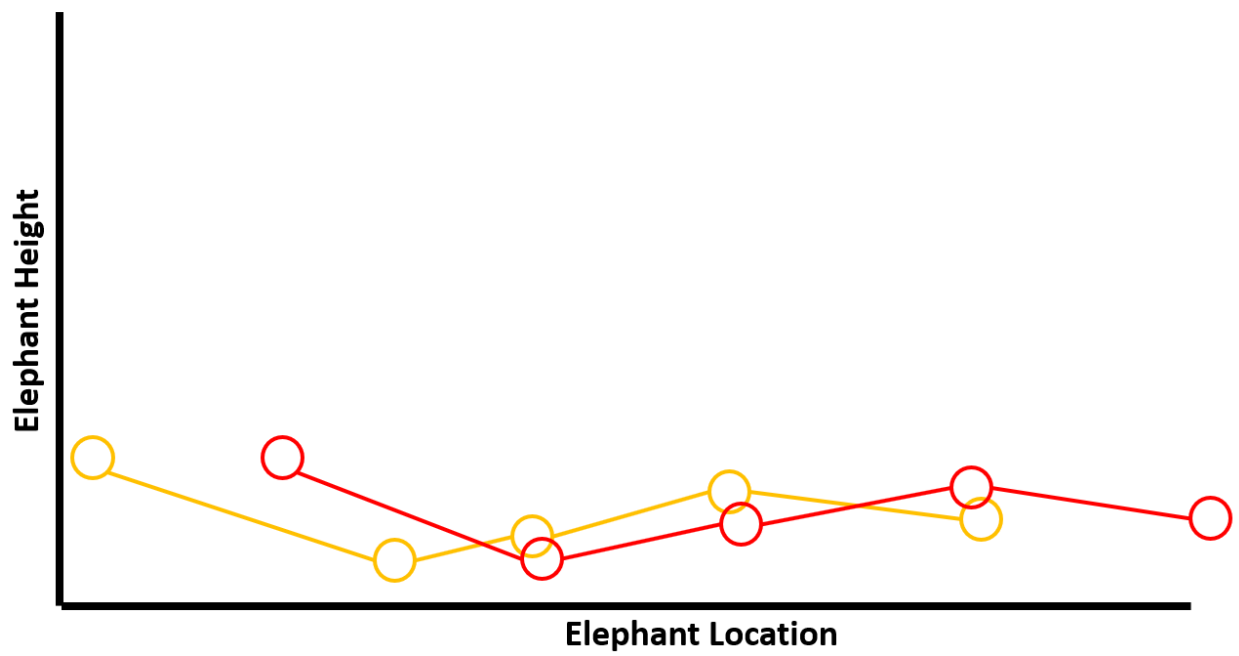
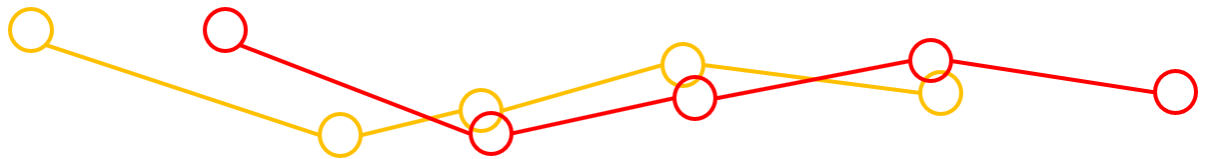


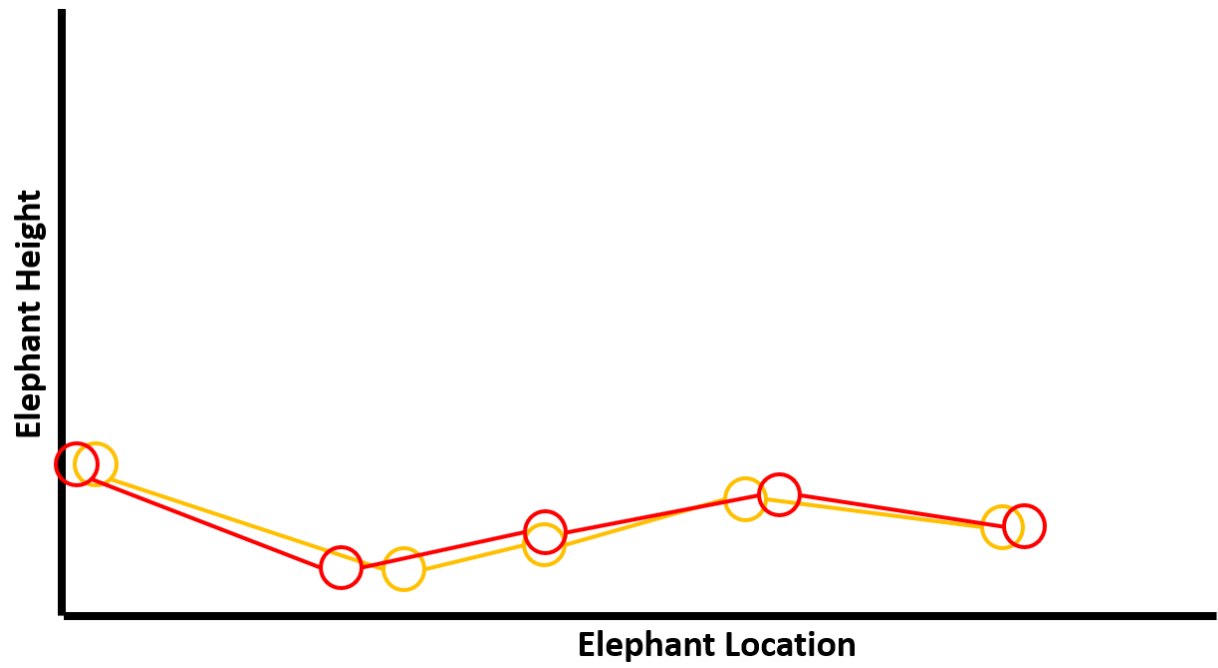
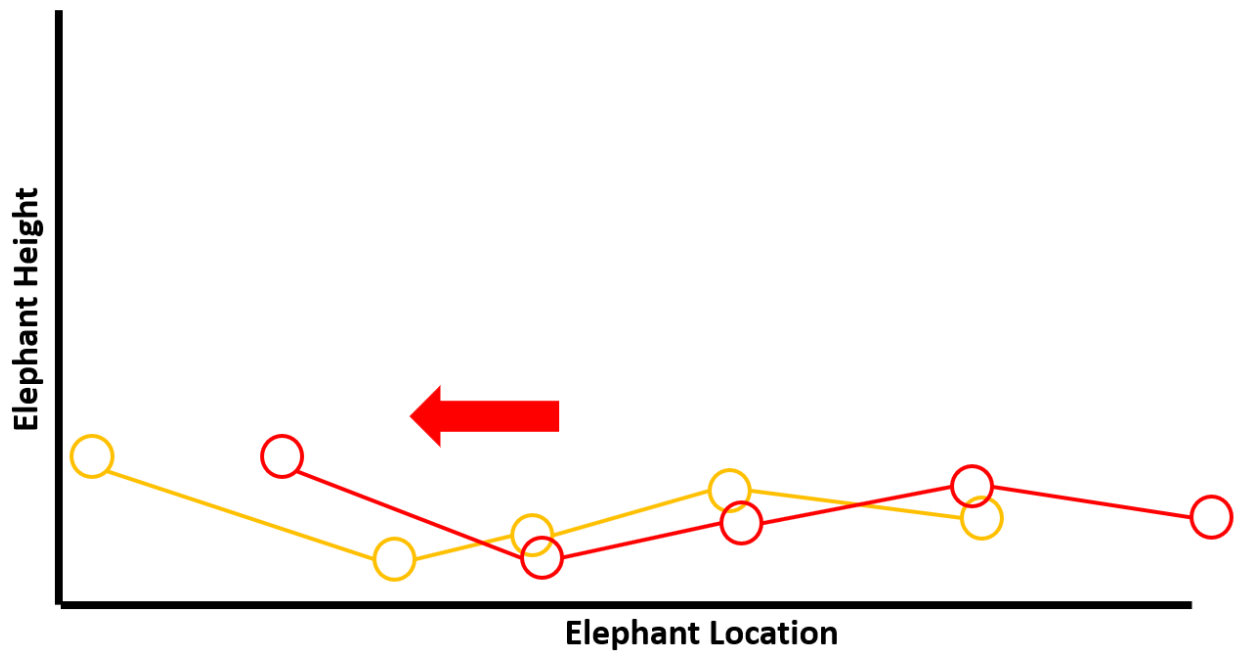


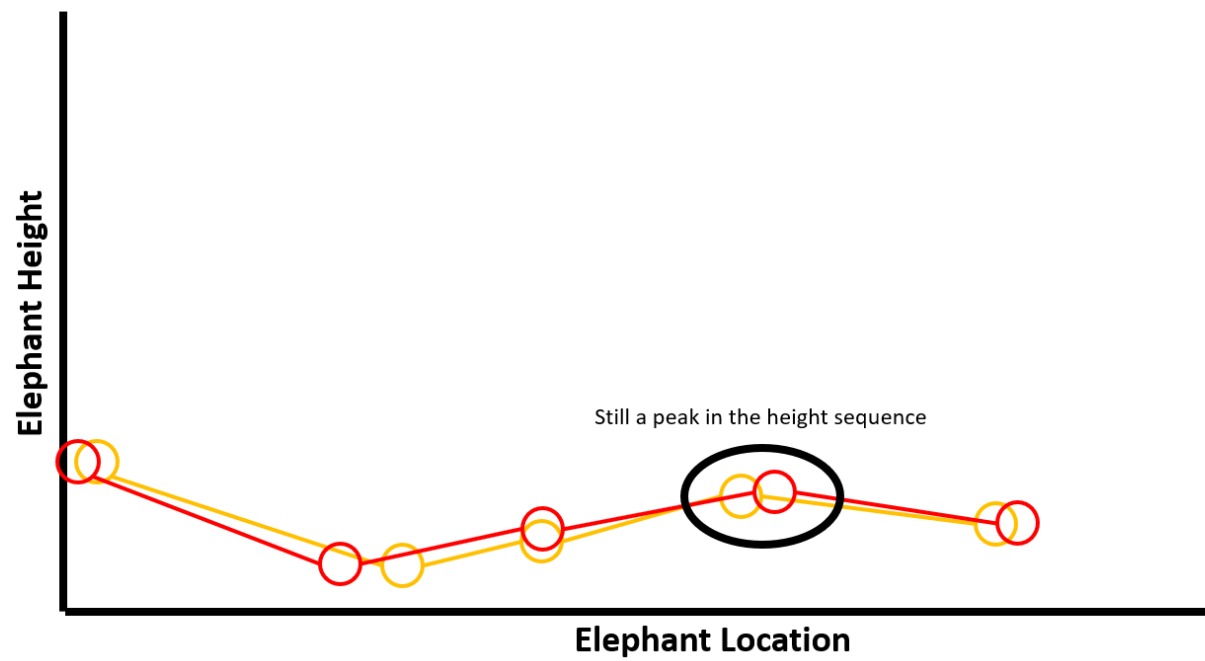




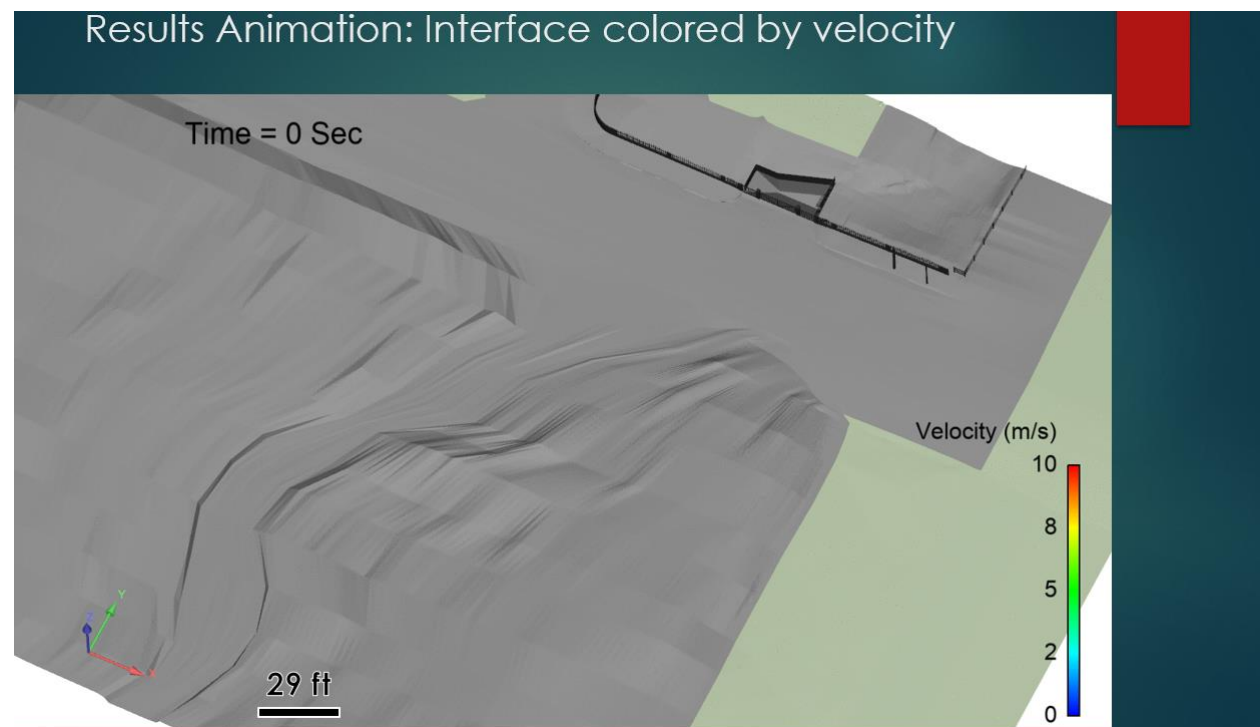




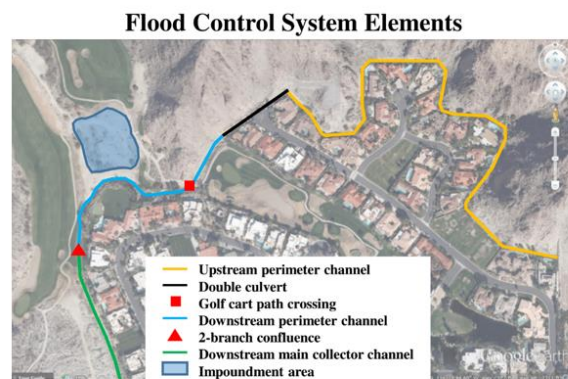
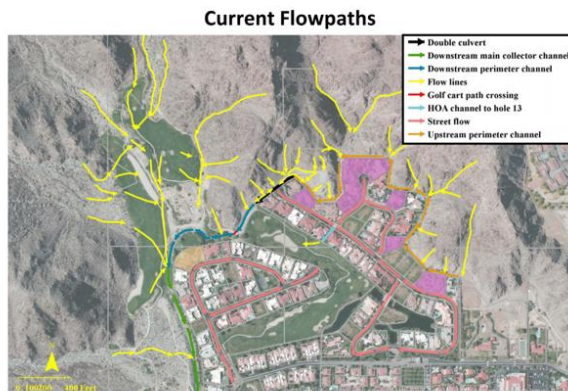




### Case Study: Channel Crossing and Severe Flooding



## Case Study: Impoundment Breach and Flooding



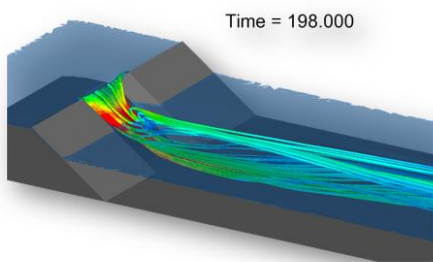
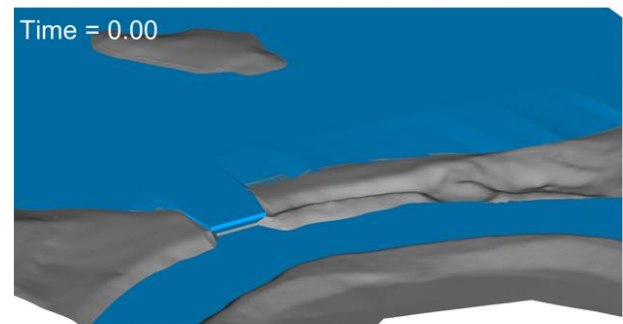
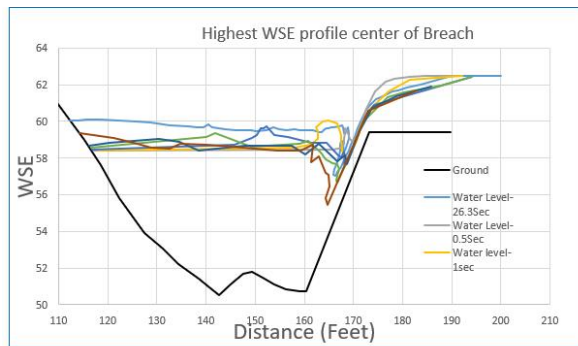
### Impoundment Breach and Flooding: Overview



### Breach and Flooding: Physical Mock-Up

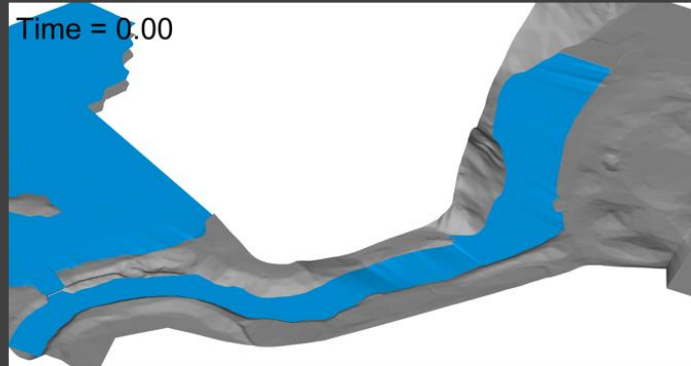


## Breach and Flooding: Physical Mock- Up Images



Breach and Flooding:  
Computational Fluid Dynamics

# Breach and Flooding: Computational Fluid Dynamics



## **Case Study: PEPCON Explosion**

Henderson, NV: PEPCON Explosion

- May 4, 1988
- Conflagration and several explosions occurred at the Pacific Engineering and Production Company of Nevada (PEPCON)
- Two (2) fatalities and 372 injuries, over \$100 million in damages
- Damage radius of 10 miles



## **Case Study: West, Texas Fertilizer Plant Explosion**

City of West, Texas: Fertilizer Plant Explosion

- April 17, 2013
- Ammonium Nitrate explosion occurred at the West Fertilizer Company storage and distribution facility
- 15 fatalities, 160+ injuries, 150 buildings damaged or destroyed



## **Case Study: Other Flooding Events- Dam and Levee Failure**



Ka Loko Dam Failure



**Fernley flood victims win \$18.1M  
settlement from 2008 canal  
break**



## Levee Failure in Nevada



## Missouri River Flooding



## Case Study: Other Events



Amtrak Train Derailment (1997)– Kingman, AZ



MV Brightfield Rams New Orleans Riverwalk

## **Case Study: La Conchita Landslide**

### La Conchita Landslide

- January 10, 2005
- Prior 15-days had low intensity rainfall
- ~ 250- year return frequency at closest gage
- Previous slides at site examined
- Developed Rainfall Threshold

January 10, 2005 at ~ 12:30 pm  
(Images of live footage)



### **La Conchita Landslide**



## SIAM: Graduate Education for Science and Engineering

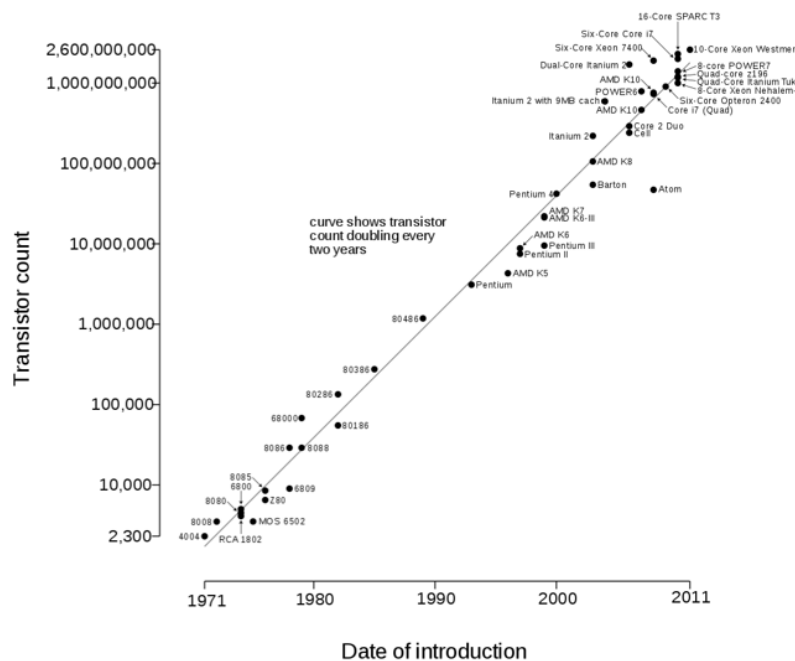
- What is it? A multidisciplinary area with connections to Applied Mathematics, Computer Science, and Engineering/Science
- Why is it important? Computation is now regarded as an equal and indispensable partner, along with theory and experiment, in the advance of scientific knowledge and engineering practice. Numerical simulation enables the study of complex systems and natural phenomena that would be too expensive or dangerous, or even impossible, to study by direct experimentation.
- For more information see:

<https://www.siam.org/students/resources/report.php>

## Moore's Law

- Generally: Computer processing power will double approximately every two years
- Specifically: the number of transistors on an affordable CPU will double approximately every two years
- Gordon E. Moore
  - Co-founder Intel
  - Author Moore's Law

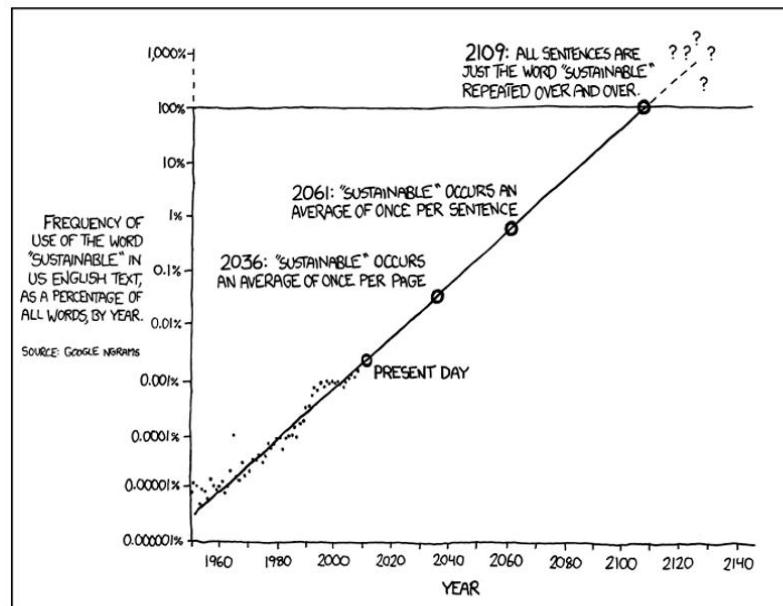
## Microprocessor Transistor Counts 1971-2011 & Moore's Law



**“All models are wrong,  
but some are useful.”**

George E. P. Box

Misusing  
Statistics



THE WORD "SUSTAINABLE" IS UNSUSTAINABLE.

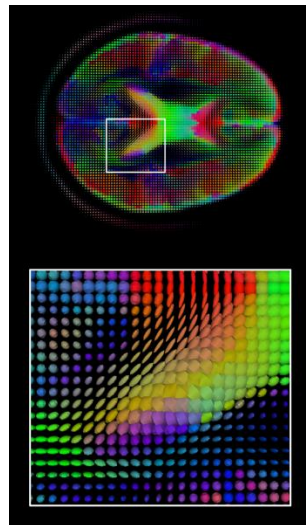


## **Topics in Computational Engineering Mathematics**

- Computational Biology
- Computational Finance
- Computational Fluid Dynamics
- Computational Geosciences
- Computational Heat Transfer
- Computational Hydrology and Hydraulics

### **Computational Biology**

- Computational Biology is the development and application of computational models, simulations, and numerical methods to study biological, behavioral, and social systems.
- Applications include: anatomy, genomics, neuroscience, pharmacology, evolution, cancer research, and much more.
- To the bottom, a probabilistic brain map used for normalization of group analysis



### **Uses of Computational Biology**

- Drug research
- Cellular modeling
- Biomedical device design
- Artificial intelligence and Machine Learning
- Image and signal processing

## Computational Finance

- Computational Finance is the development and application of computational models, simulations, and numerical methods to solve problems of practical interest in finance.
- Applications include: financial trading and investing, financial risk management, financial modelling

## Uses of Computational Finances

### Algorithmic Trading

- Development of automated trading algorithms which input market data and output trading orders

### Quantitative Finance

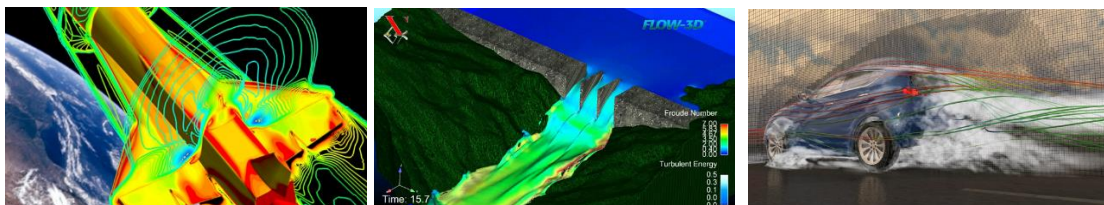
- Derivative pricing and risk/portfolio management

### High-frequency Trading

- Similar to algorithmic trading except positions are moved into and out of in seconds or milliseconds

## Computational Fluid Dynamics

- Computational Fluid Dynamics (CFD) is the development and application of computational models, simulations, and numerical methods to solve and analyze problems involving fluid flow, both liquids and gases.
- Applications include: automotive, aerospace, marine, defense, chemical, biomedical, electronic, environmental



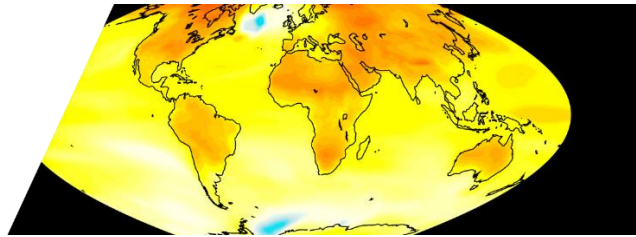
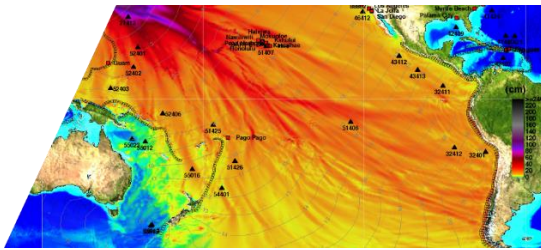
## Uses of Computational Fluid Dynamics

- Simulation of Physical Processes: fluid flow, mass transport, heat transport, particle tracking, plasma, chemical reactions
- Examples:
  - Vehicle aerodynamics
  - Heat management of electronic components

- Urban drainage systems
- Hull design
- Wind turbine placement

### Computational Geoscience

- Computational Geoscience is the development and application of computational models, simulations, and numerical methods to solve complex physical problems arising in the Earth Sciences.
- Applications include: subsurface, surface, and atmospheric processes in addition to signal processing and data imaging
- To the right, NOAA models of a tsunami and surface air temperature change (left)

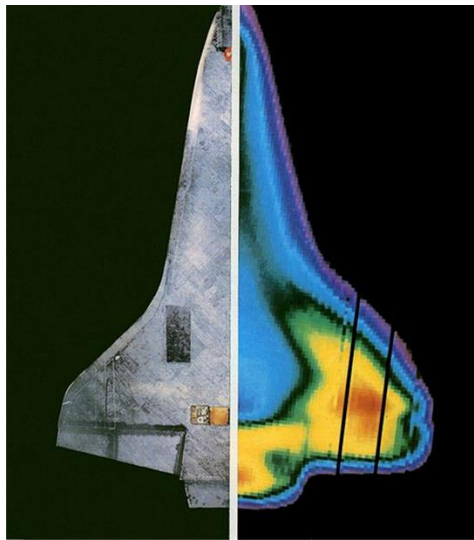


### Uses of Computational Geoscience

- Climate modelling
- Earthquake and tsunami modelling
- Petroleum geology
- Reservoir planning and construction
- Radar imaging
- Carbon capture and storage
- Geophysics
- Seismic reflection data analysis

## Computational Heat Transfer

- Computational Heat Transfer is the development and application of computational models, simulations, and numerical methods to solve and analyze the physical processes involved in the transport of thermal energy.
- Applications include: manufacturing processes, chemical reactions, electronics, environmental, and many more
- To the bottom, a thermal image of the space shuttle taken via infrared imagery during reentry



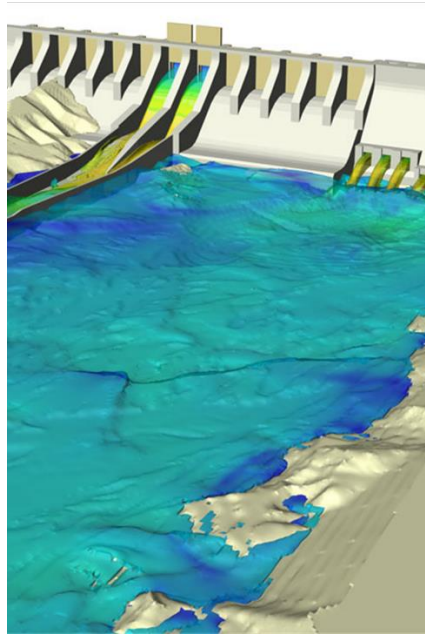
## Uses of Computational Heat Transfer

- Simulation of physical processes: conduction, convection and radiation
- Examples:
  - Soil-water phase change
  - Semiconductor manufacturing
  - Heat management in electronic components
  - Sheet metal hot-forming
  - Engine efficiency optimization
  - Building and vehicle HVAC systems



## Computational Hydrology and Hydraulics

- Computational hydrology is the development and application of computational models, simulations, and numerical methods to solve complex physical phenomena related to the movement of Earth's water.
- Computational hydraulics is focused on Earth's water movement as it relates to bulk fluid flow, which may include natural processes such as river flow or involve interaction with man-made objects such as urban sewage and drainage system and dams.
- To the bottom, a simulation of a dam, the color represents the absolute velocity



## Uses of Computational Hydrology and Hydraulics

- River management
- Water contamination
- Urban drainage and sewage design
- Dam construction
- Flood forecasting
- Drinking water safety