The Impacts of the Earthquake that Struck near Mineral Virginia on Groundwater Resources in Northern Virginia

Presented by:
Peter J. Foster

Coauthors:
James M. Emery
Kenneth C. Hardcastle
Introduction

• Emery & Garrett Groundwater Investigations, LLC Collected Water Level Data in 50+ Wells Before-During-After the Mineral, Virginia Earthquake at Three Separate Project Sites.

• This Discussion will Focus on Site A Located in the Culpeper Rift Basin.

• As a Result of the Earthquake Groundwater Level Variations of up to 20 feet were Observed.

• A Cone of Depression Established Over 20 Years of Pumping was Significantly Refilled Following the Mineral Earthquake While the Production Wells Continued to Withdraw Groundwater at a Rate of 300,000 – 400,000 gpd.
Site A
Geologic and Hydrogeologic Setting
Regional Geologic Setting
Site A – Geologic Setting
Pre-Earthquake Groundwater Level Elevations
Site A – Historic Groundwater Elevations and Well Locations
Total Groundwater Withdrawal is 300,000 – 400,000 gallons per day
Post-Earthquake
Groundwater Level
Fluctuations
Site A – Earthquake Water Level Changes

Water Level Changes 24hrs following Mineral Earthquake
(feet)
- -3.08 to -2.54
- -2.539 to -0.68
- -0.67 to 0
- 0 to 4.52
- 4.52 to 11
- 11.01 to 19.6
Example Hydrographs
Water Level Decline

Monitoring Well 2

Plot of Water Level versus Time for August 3 to September 12, 2011

2.5 – Foot Decline – Observed 24-hours After Earthquake

Influence of 5.8 Magnitude Earthquake in Mineral, VA on August 23, 2011 at 1:51 PM

Influence of Tropical Storm Lee
Water Level Rise

Back-up Production Well

Located 485 feet from the Production Well Location

Influence of Tropical Storm Lee

Influence of 5.8 Magnitude Earthquake in Mineral, VA on August 23, 2011 at 1:51 PM

10 – Foot Rise – Observed 24-Hours After Earthquake

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Water Level Rise

Production Well

Upper Portion of Production Well Hydrograph
Not Available

Influence of 5.8 Magnitude Earthquake in Mineral, VA on August 23, 2011 at 1:51

11 - Foot Rise –
Observed 24-hours
After Earthquake

Plot of Water Level versus Time for August 3 to September 12, 2011
What Happens to the Local Bedrock Aquifer?

Conceptual Model of Groundwater Level Change
Schematic Representation of the Pre- and Post-Earthquake Pumping-Induced Water Level Drawdown.

- **PW 1**, **PW 2**, and **PW 3** represent production wells.
- Before the earthquake, the pre-earthquake established pumping-induced water level drawdown is shown.
- The established cone of depression refilled 10-20 feet within 24 hours following the earthquake.
- Post-earthquake pumping induced water level drawdown, with production wells continuing to pump to meet public water supply demand.

**Interbedded Sandstone and Siltstone Bedrock Aquifer**

**Non-Pumping/Historic Water Table**

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How is it Possible?

A Hypothesis.
Earthquake fault solutions indicate reverse faulting on north to northeast planes (basalt-siltstone contact) which could have removed a barrier providing better connection to the aquifer and hence a rise in the pumping water level in the production and backup production wells.
Bacteriological Contamination of Existing Production Well
Bacteriological Samples Collected From Production Well

August 23, 2011
Mineral, Virginia
Earthquake

E. coli = 1.0 on August 24, 2011
Impact to Production Well Construction and/or Water-Bearing Fractures
Schematic Diagram of Production Well – Pathways for Bacteria to Enter Well

UNCONSOLIDATED SEDIMENTS

New/Opened Fractures Observed in Video Log at 62 and 63 feet

Compromise to Cement Well Grout?
CONCLUSIONS

• The Earthquake Appears to have Permanently Changed the Bedrock Fracture System and Bedrock Aquifer Surrounding Site A.

• The Earthquake has Adversely Affected a Community’s Water Supply Well (Damaging the Sanitary Well Seal and Generating Poor Water Quality).

• The Result of the Earthquake also caused the Pumping Cone of Depression that was Established Over a 20 Year Period to be Significantly Filled In (i.e. the water table rose approximately 20 feet).

• The Unpredictable Nature of Earthquakes May Make Some Water Utilities in Certain Geologic Settings Vulnerable to both Short Term (e.g. turbidity) and long term Water Quality Changes (e.g. bacteria).
REPAIR OF A BACTERIOLOGICALLY CONTAMINATED WELL LOCATED IN NORTHERN VIRGINIA
Bacteriological Sample Results, Prior to and After the Drainage Improvements Were Made Around Production Well

Plot of Bacteriological Results versus Time for October 15, 2011 to September 1, 2013
Loudoun County, Virginia

- Total Coliform
- Preliminary bacteriological testing after the drainage system was installed.
- Pitless Adaptor Repaired January 9, 2012
- All bacteriological samples collected to date have been absent for both Total Coliform and E. coli following the repairs.
Well Rehabilitation to Correct Bacteriological Contamination

Pump House for Community Water Supply Well

Area where significant shallow groundwater flow was intercepted.

Drainage pipes directed down gradient of the Wellhead to an existing drain pipe.

Excavation Around Well to Install Perimeter Drains.
Well Rehabilitation to Correct Bacteriological Contamination

Example of Drain Pipe, Construction Fabric, and Crushed Stone Installation.
Well Rehabilitation to Correct Bacteriological Contamination

Excavation of Pump House
Concrete Floor and Soil Around the Wellhead and
Identification of Leaking Pitless Adaptor

Hose hooked to vacuum truck, utilized to remove soil around wellhead.

Plastic sheeting installed inside pump house to protect the pump house during excavation/grouting.

Preparation to Remove Soil Around Wellhead.
Well Rehabilitation to Correct Bacteriological Contamination

Hose hooked to vacuum truck, utilized to remove soil around wellhead.

Vacuuming of Soil From Around Wellhead.

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Well Rehabilitation to Correct Bacteriological Contamination

Temporary shoring used to stabilize excavation. All shoring material was removed prior to any grouting.

Excavation Complete Around Wellhead.
Well Rehabilitation to Correct Bacteriological Contamination

Tremie pipe installed down to refusal on top of existing cement grout.

Cement Grout Added Around Well Casing.

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Well Rehabilitation to Correct Bacteriological Contamination

Hardened Neat Cement Around Wellhead.

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Bacteriological Sample Results, Prior to and After the Drainage Improvements Were Made Around Production Well

Total Coliform

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Pileless Adaptor Repaired January 9, 2012

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