# A Visco-Elastic Model for Groundwater Level Changes in the Aquifer of *Cho-Shui River* Alluvial Fan After the *Chi-Chi* Earthquake in *Taiwan*

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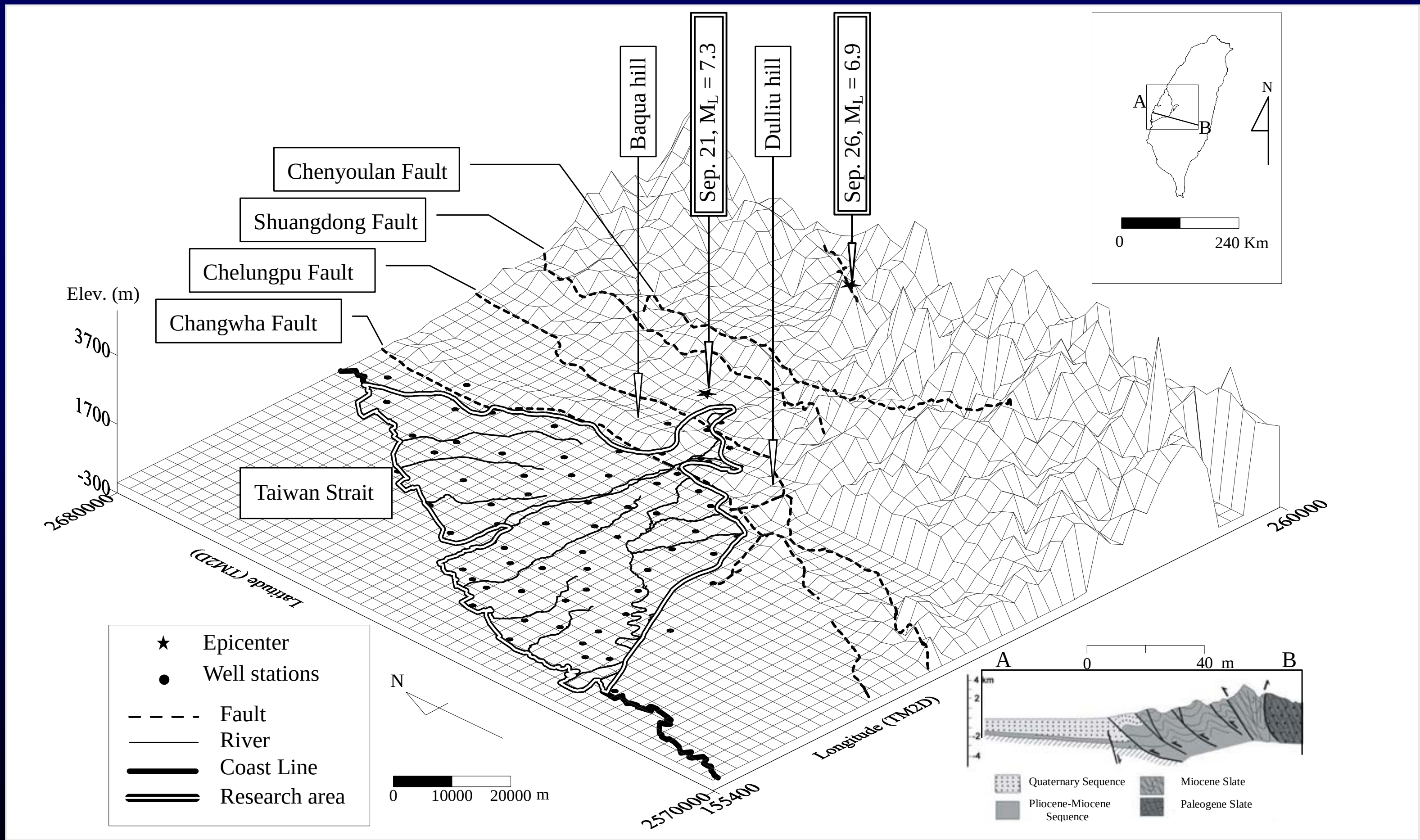
# Content

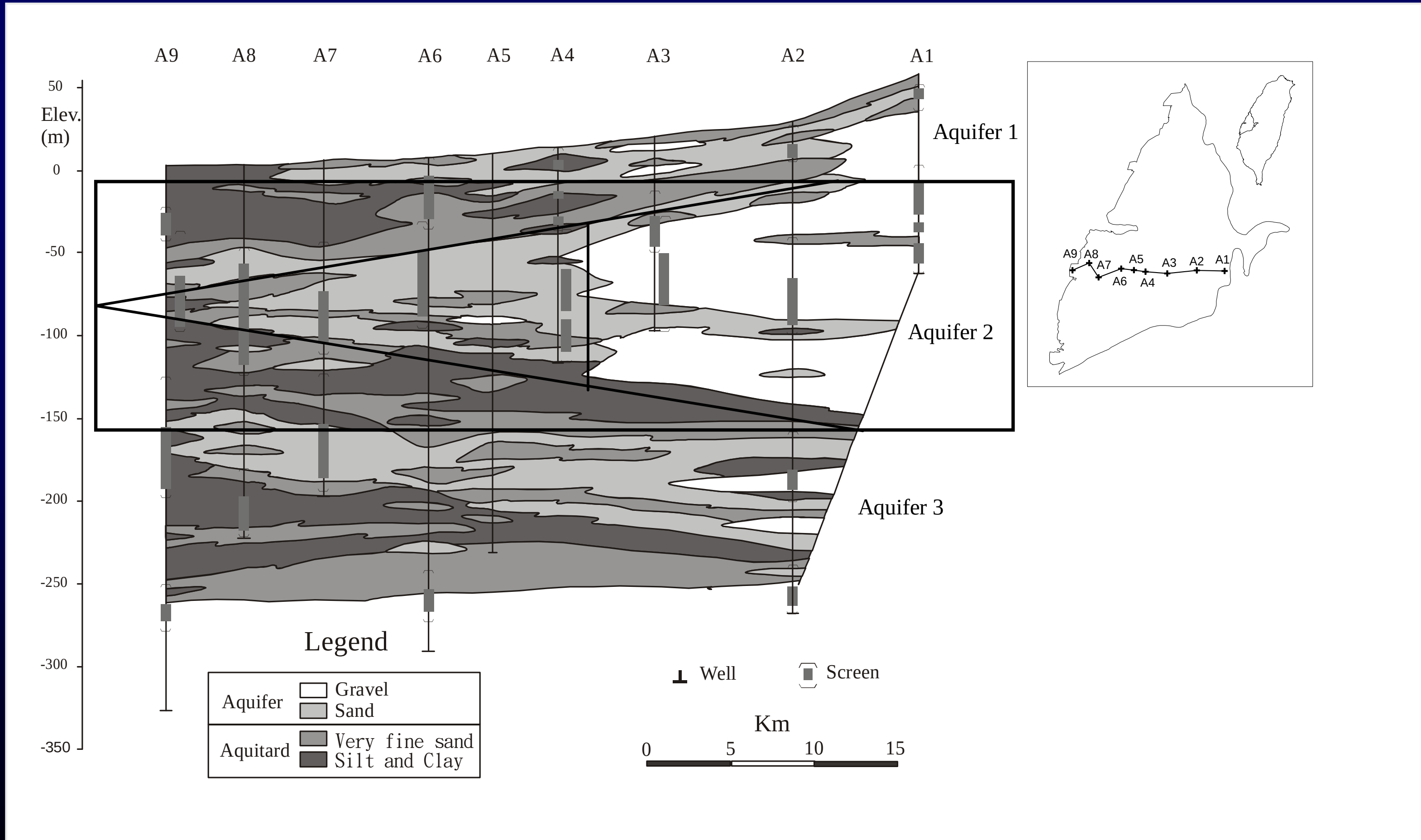
# 1.Introduction (1/3)

## 1.1 The geographical features of the Cho-Shui River's alluvial fan



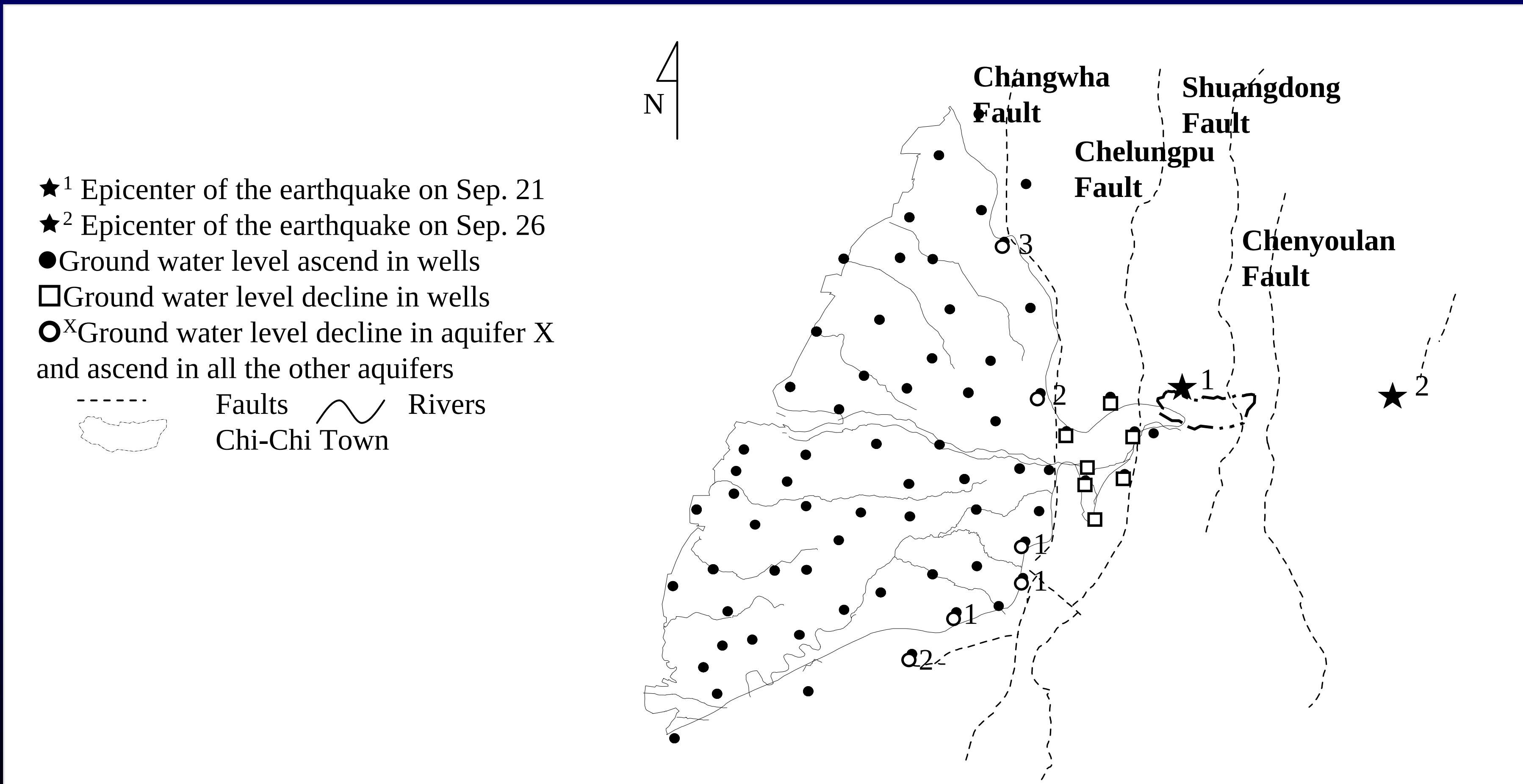
# 1.Introduction (2/3)

## 1.2 The hydrogeological profile of the Cho-Shui River's alluvial fan



# 1.Introduction (3/3)

## 1.3 The distribution of ground water level changes induced by the Chi-chi earthquake



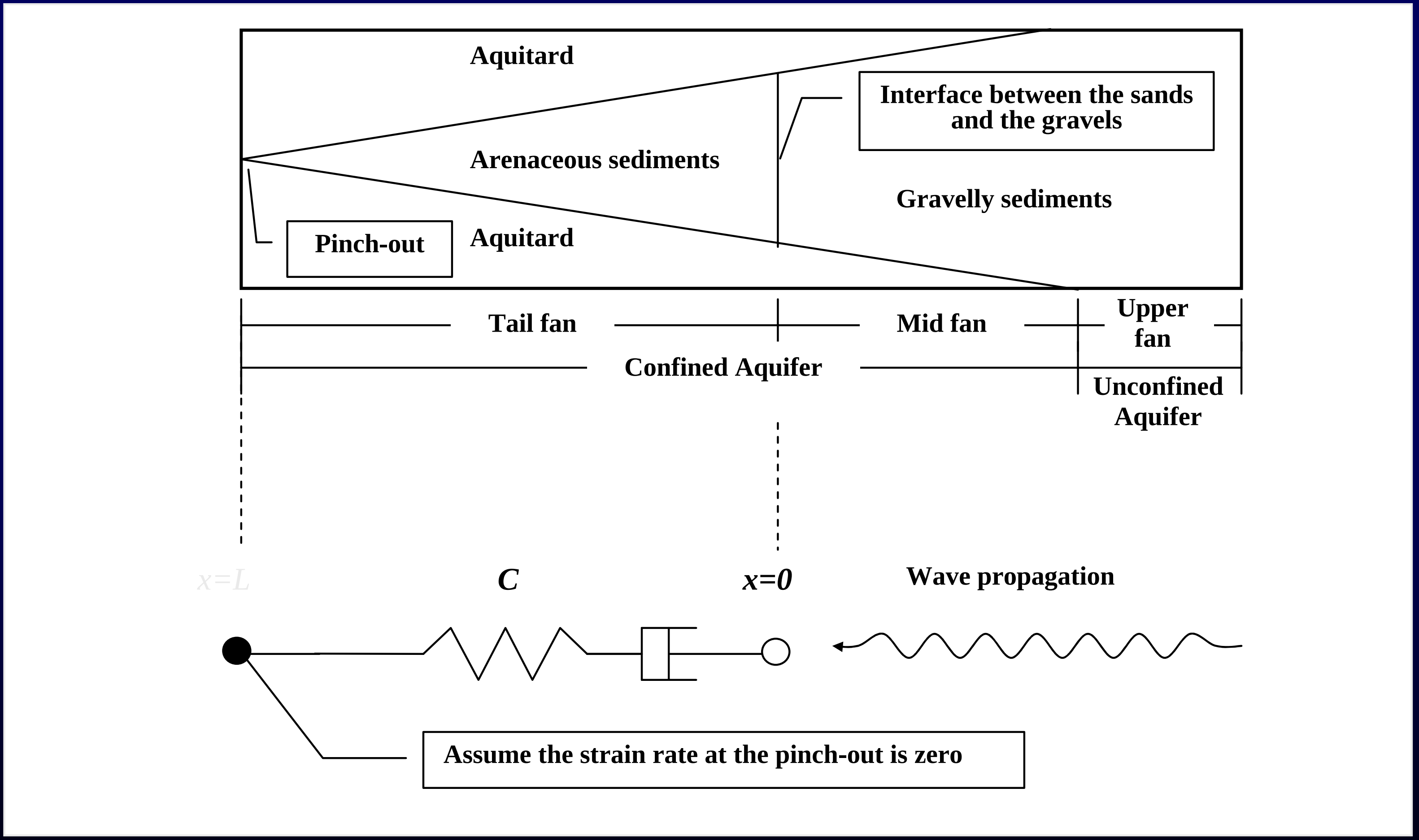
# 2. Hypotheses (1/1)

## 2.1 Conservation of energy

When the wave propagates from the east to the west, the change of the velocity of the wave will be more significant towards the pinch-out of the aquifer.  The influences of the inertial force on the ground water level fluctuations increase toward the pinch-out.

# 3. Mathematical Model (1/3)

## 3.1Conceptual model illustration



# 3. Mathematical Model (2/3)

## 3.1 Governing eauqtion

The wave equation of the liquid phase in the porous media can be described as

$$-\nabla\cdot\left(\varepsilon_f \nabla p^f\right)=\frac{\partial^2}{\partial t^2}\left(\rho_{sf} e+\rho_{ff}\varsigma\right)+b\frac{\partial}{\partial t}(\varsigma-e)+\upsilon^d\nabla\cdot b$$

## 3.2 Constitutive Equation

Considering the liquid phase as the Maxwell-Fluid

$$\left(-\varepsilon_f p^f\right)+\frac{\eta}{C}\frac{\partial}{\partial t}\left(-\varepsilon_f p^f\right)=\eta\frac{\partial}{\partial t}\left(\nabla\cdot\left(\varepsilon_f u^f\right)\right)$$

# 3. Mathematical Model (3/3)

## 3.3 Derived equation

The final equation can be described as

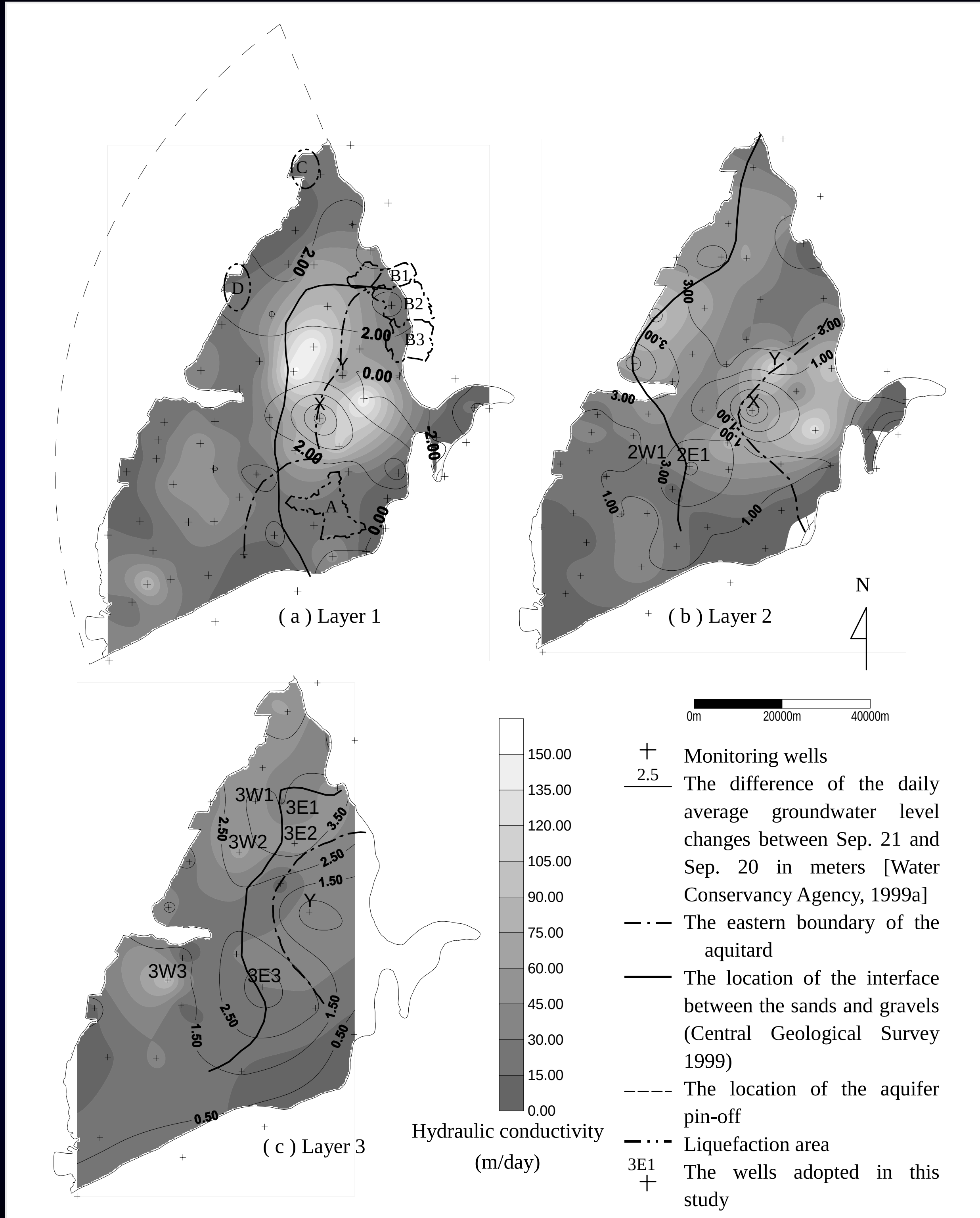
$$\frac{\partial^2 U^f}{\partial x^2} - \frac{\rho^f}{\eta}\frac{\partial U^f}{\partial t} - \frac{1}{{v_f}^2}\frac{\partial^2 U^f}{\partial t^2} = 0$$

## 3.4 Convolution

The solution obtained via *Laplace* transfer from the derived equation should be taken convolution with the pore pressure dissipation at the interface.

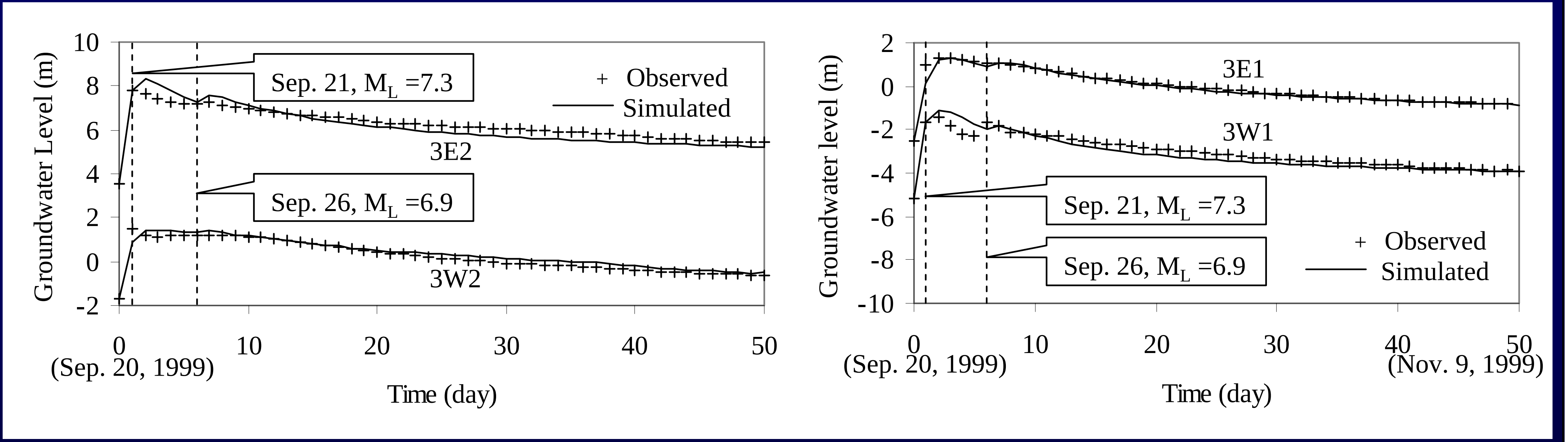
# 4. Applications & Discussions (1/4)

## 4.1 Field data



# 4. Applications & Discussions (2/4)

## 4.2 Applications

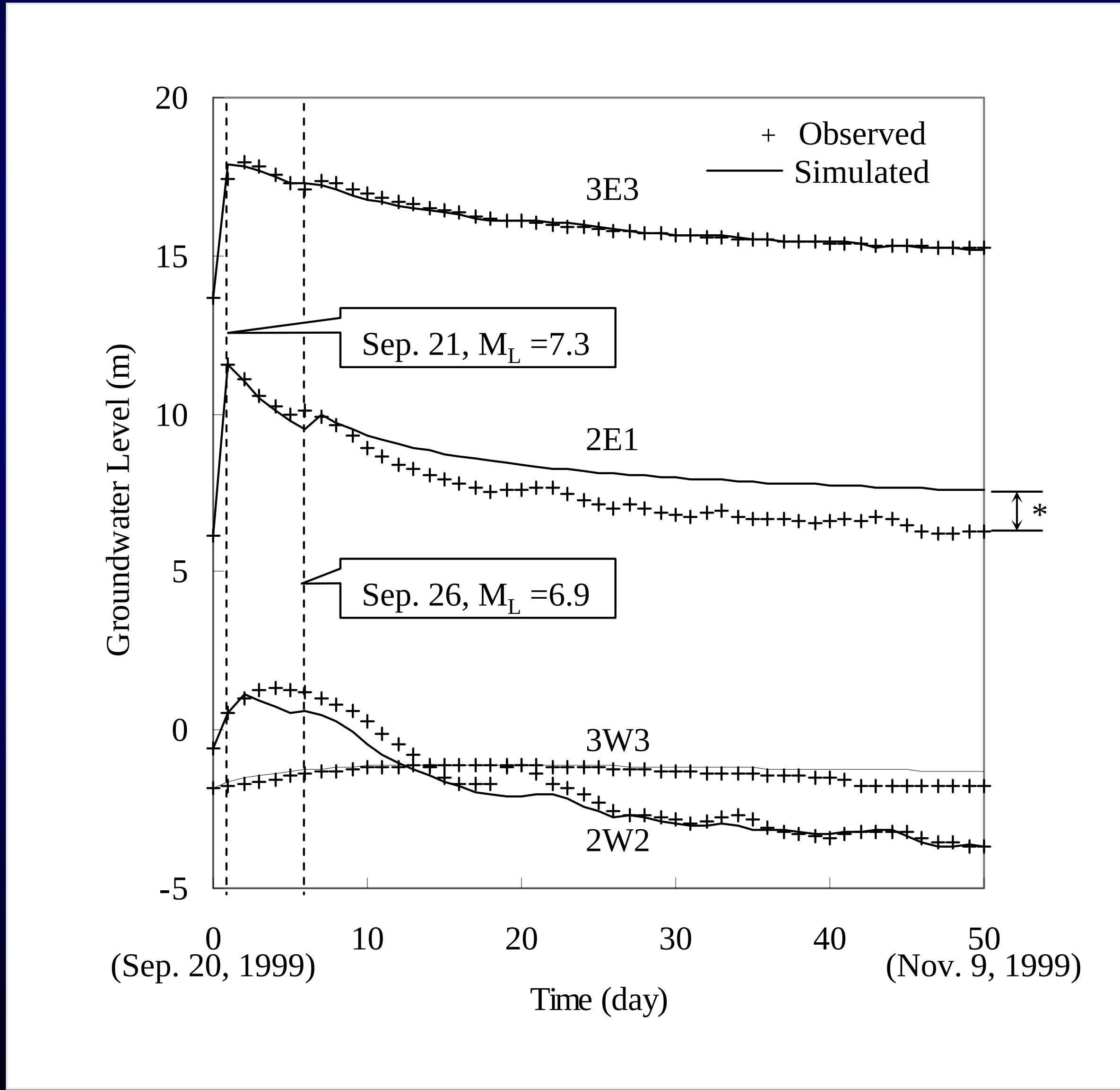


# 4. Applications & Discussions (3/4)

## 4.2 Applications

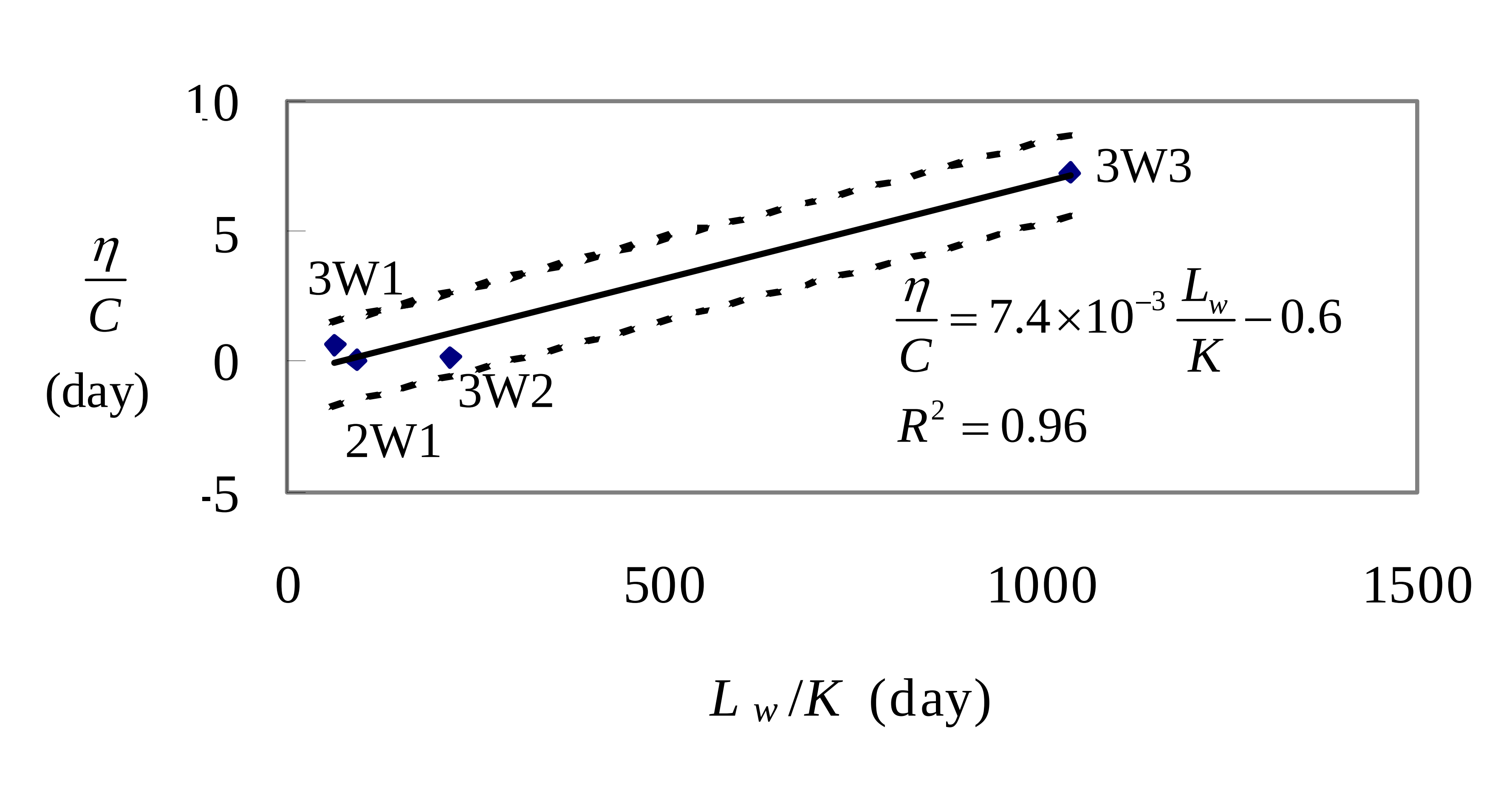
Note:

*The pore pressure dissipation doesn't obey the one dimensional diffusion model of equation (29) due to the vertical flow in the unconfined aquifer, but the observed data still can be substituted into equation (30) as the boundary condition.



# 4. Applications & Discussions (4/4)

## 4.3 Regression



# 5. Conclusion (1/2)

5.1 A one-dimensional visco-elastic model is developed to describe the groundwater level changes in the wells in the Cho-shui River alluvial fan after the Chi-Chi earthquake. The model adequately reproduced the observed groundwater level changes after the earthquake. The result supports our hypotheses that acceleration is important in the confined portion of the aquifers, while diffusion is the dominant process in the unconfined portion of the aquifers.

# 5. Conclusion (2/2)

5.2 Furthermore, we showed that the viscosity coefficient strongly correlates to the hydraulic conductivity of the aquifer. However, a general three-dimensional, heterogeneous model may be necessary to accurately describe groundwater changes in the fan.

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