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Estimating the specific yield in an unconfined aquifer using the gravimetric method: a case study in the Zhoushui River alluvial fan

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ABSTRACT

We use the gravimetric method to estimate the specific yield of an unconfined aquifer at five observation stations on the Zhoushui River alluvial fan in central Taiwan. The principle of this method is to use the ratio of the observed gravity and simulated gravity to find the specific yield. In terms of observed gravity acquisition, we used an FG-5 absolute gravimeter to collect observations in two different periods at each gravity observation station; in terms of simulated gravity computation, we considered both the Bouguer and terrain correction methods to derive the simulated gravity. During the gravity survey at the Shin-Ming OFfice (SMOF) station, the electrical resistivity tomography (ERT) technique was performed simultaneously to obtain a better groundwater surface around the SMOF station. The results show that the specific yield of the five gravity observation stations are between 0.1 and 0.3, indicating that the Zhoushui River alluvial fan has good groundwater resources in an unconfined aquifer. The compound well pumping tests agree well with the specific yield results obtained from the gravimetric method. In addition, if ERT surveys can be used to obtain a better groundwater surface, a more accurate specific yield can be acquired.

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Specific yield; Zhoushui River alluvial fan; groundwater; gravity; ERT

1. Introduction

Taiwan is an island with very scarce water resources. Although the annual accumulated rainfall is as high as 2500 millimeters, the spatial and temporal distribution of rainfall is uneven. For example, the high water period of the Zhoushui River, which is the longest river in Taiwan, is between May and October. The temporal distribution of water resources is extremely uneven. Because the alluvial fan downstream of the Zhoushui River contains a large number of agricultural and aquaculture fisheries, the water demands in this region are quite high. The alluvial fan located upstream of the Zhoushui River is generally considered to have abundant groundwater resources (Taiwan's Central Geological Survey 2014). If these groundwater resources can be effectively developed, they can be used as a solution to replace water sources downstream of the Zhoushui River. This method should effectively solve the water shortage problem in this area.

When evaluating whether a certain area has good water storage conditions, specific yield is one of the important indicators that determines the water storage capacity of unconfined aquifers. At present, the main method used to estimate specific yield is the hydraulic method, that is, compound well pumping tests (Remson and Lang 1955; Boulton 1970; Neuman 1972; Moench 1994). There have been several related studies in Taiwan in recent years, e.g. Wen et al. (2010), Lin et al. (2016), Chang et al. (2017), Huang and Yeh (2018), and Hsu and Chou (2019). However, compound well pumping tests first require drilling, and drilling projects are time consuming and costly. Therefore, it is very inefficient to apply compound well pumping tests to understand the groundwater resources in a large-scale area.

There have also been studies related to the use of the gravimetric method to estimate the specific yield or groundwater level over the past 20 years. For example, Pool and Eychaner (1995) investigated the temporal-gravity survey changes between two reference stations on bedrock and six stations at wells in Arizona and pointed out that temporal-gravity surveys can be used to estimate aquifer-storage change and the specific yield of water-table aquifers where significant variations in water levels occur. Pool (2008) also monitored the gravity and groundwater level changes at 39 wells in southern Arizona, and the results indicate that the significant groundwater level and gravity changes were positively linearly correlated at 15 wells. Gehman et al. (2009) used two high-precision gravity surveys to determine groundwater mass changes at a managed groundwater recharge site in northeastern Colorado. The results showed that temporal microgravity surveys can be used successfully to quantify groundwater storage changes in unconfined aquifers. Pfeffer et al. (2011) combined gravimetric measgurements with dense hydrological surveys to better characterize the annual water storage variability in tropical West Africa. The results showed that the specific yield derived from ground gravity observations is consistent with the magnetic resonance sounding observations. Wen et al. (2010) carried out a superconducting gravimeter test for groundwater storage monitoring in central Texas. The result showed that the specific yield estimate is larger than most

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published values. Chen (2019) monitored several gravity sites close to groundwater wells in the Zhoushui River alluvial fan from 2012 to 2017 to explore the aquifer's storage capacity in the area. Other studies about estimation of specific yield based on gravimetric method in Taiwan can be found in Hwang et al. (2014), Lien et al. (2014), Tsai et al. (2017), Chen et al. (2018), and Chen et al. (2020).

Electrical resistivity tomography (ERT) is a nondestructive underground exploration method that can obtain dense measurement data in terms of spatial distribution and then estimate a more complete groundwater level. In recent years, studies related to hydrogeology combined with the application of gravimetry and ERT have been conducted. For example, Selim, Abdel-Raouf, and Mesalam (2016) integrated gravity, magnetic force, and ERT data to understand the thickness and distribution of the aquifer in the Sinai Peninsula in Egypt, and Laesanpura, Warsa, and Hartay (2017) surveyed the thickness and geological distribution of the aquifer in the study area using relative gravimeter and ERT measurements.

In this study, the gravimetric method was used to estimate the specific yield of the north bank upstream of the Zhoushui River alluvial fan. We performed several absolute gravity survey missions between November 2015 and June 2018 at five selected gravity observation stations. Thirteen ground ERT lines were set around the SMOF gravity station for simultaneous observation to accurately determine the groundwater surface. Compared with the abovementioned previous studies, in this study, most of the groundwater wells adjacent to the gravity observation stations have specific yields obtained from compound well pumping tests (Taiwan's Central Geological Survey 2014), which can be used to evaluate the results obtained from the gravimetric method. In addition, in previous studies, when the specific yield was estimated by the gravimetric method, the groundwater surface was assumed to extend indefinitely in one plane, and the Bouguer correction method (Heiskanen and Moritz 1967) was used for related calculations. In addition to the Bouguer correction method, this paper uses the terrain correction method, which was not mentioned in past research for specific yield estimation. The research process of this study is shown in Figure 1.

2. Methodology

Specific yield is defined as the volume of water discharged per unit height of the aquifer per unit area. This value is related to the soil properties, particle size, and pore distribution in the area. Specific yield is an important parameter used to explore the capacity of aquifers in a certain area. The higher the specific yield is, the richer the groundwater resources. Traditionally, the hydraulic method is used to obtain the specific yield. The method consists of carrying out pumping tests of the compound wells in the research area. Although this method is quite accurate, it requires considerable drilling costs to set the compound well. The gravimetric method is a nonintrusive measurement method that can save considerable costs. In this study, the gravimetric method can be divided into two parts, namely, the measured gravity change and simulated gravity change parts. As shown in Figure 2(a), the specific yield S_y of an unconfined aquifer in a certain area is first assumed to equal 1; then, the theoretical gravity change at the surface point P due to changes in the groundwater level in two seasons is A_Z. The difference in the measured gravity change at point P in two seasons is Δg; then, S_y in this area should be

$$S_y = \frac{\Delta g}{A_Z}, \tag{1}$$

where Δg is the measured gravity change observed with an FG-5 absolute gravimeter and A_Z is the simulated gravity change. The groundwater levels in two seasons must be obtained through groundwater observation wells or ERT observations, and then, A_Z can be calculated. In the past, the calculation of A_Z often used the Bouguer correction method (Heiskanen and Moritz 1967). The formula is as follows:

$$A_Z = 2\pi\rho G\Delta H. \tag{2}$$

In the definition of the Bouguer correction, ρ is the geological density ($\rho = 2670\mathrm{kg/m^3}$), G is the gravitational constant ($G = 6.67 \times 10^{-11}\mathrm{m^3kg^{-1}s^{-2}}$) and A_Z is the topographic gravity effect dominated by the thickness of the Bouguer plate ΔH. In this study, since the specific yield is assumed to be 1, $\rho = 1000\mathrm{kg/m^3}$ and A_Z is the simulated gravity change dominated by the groundwater level difference

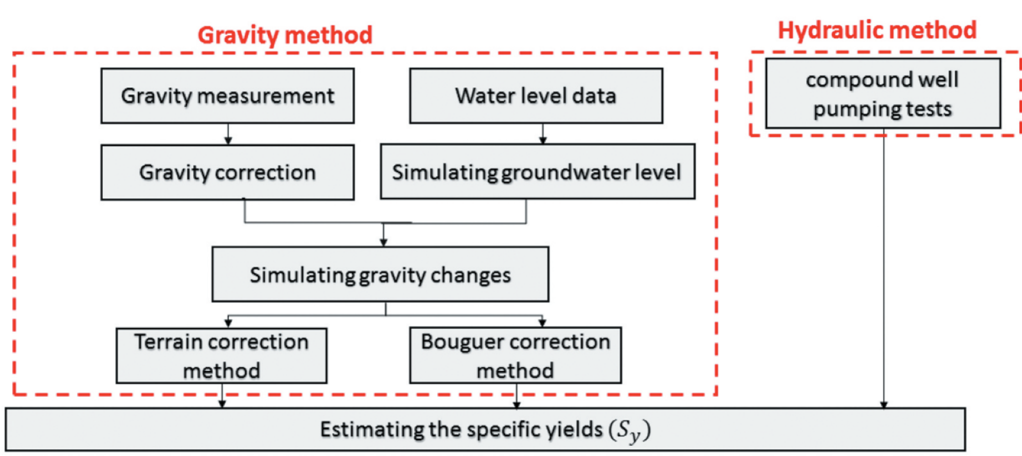

Figure 1. Flowchart of this study.

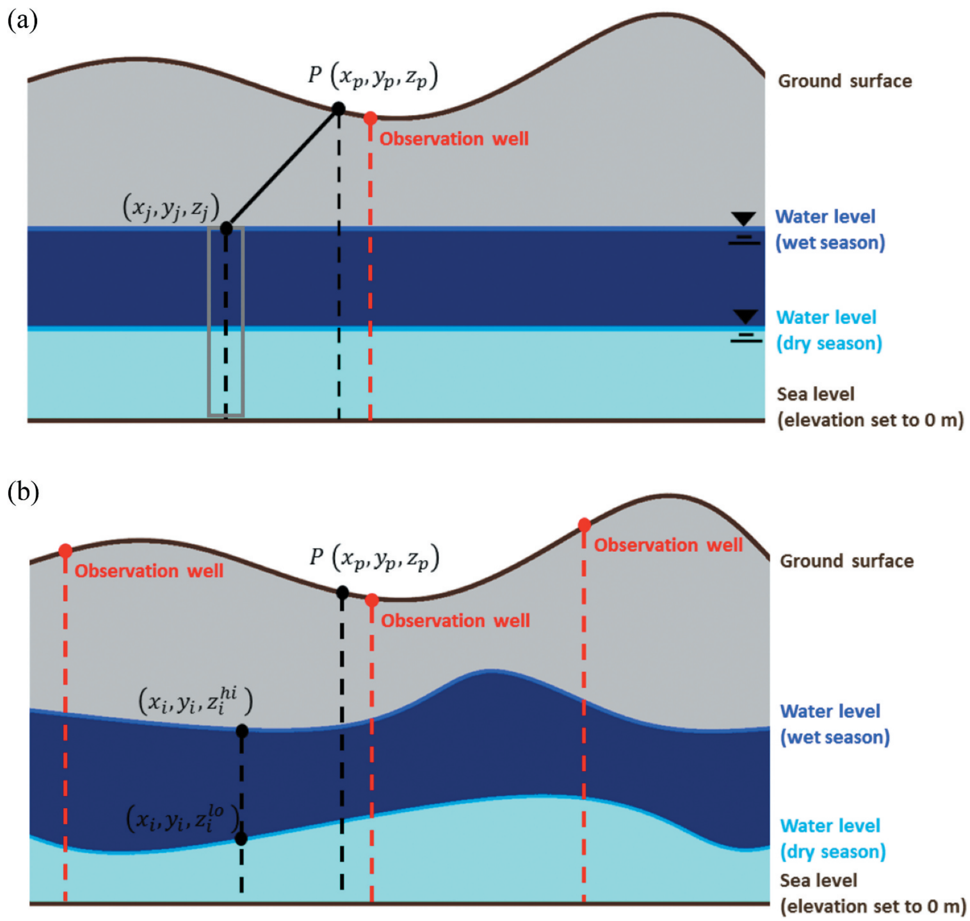

Figure 2. Diagrams showing (a) the Bouguer correction; (b) terrain correction.

ΔH between two seasons. Chang (2016) and Shih (2017) show that 90% of gravity changes are influenced by the groundwater level change within 1 kilometer of the gravity station.

We can further express the standard error of $\boldsymbol{S_y}$ from Equation (1) using error propagation.

$$\delta S_y = \pm\left(\left(\frac{1}{2\pi\rho G\Delta H}\delta\Delta g\right)^2 + \left(\frac{\Delta g}{2\pi\rho G(\Delta H)^2}\delta\Delta H\right)^2\right)^{1/2}, \quad (3)$$

where $\Delta g = g_1 - g_2$;$\Delta H = H_1 - H_2$; $\delta S_y, \delta\Delta g$ and $\delta\Delta H$ are the standard errors of S_y,Δg and ΔH. g_1 and g_2 represent the gravity measured in two seasons, and H_1 and H_2 are the groundwater level measured in two seasons. The standard errors of Δg and ΔH can be written as

$$\delta\Delta g = \pm\left(\delta g_1{}^2 + \delta g_2{}^2\right)^{1/2}, \quad (4)$$

and

$$\delta\Delta H = \pm\left(\delta H_1{}^2 + \delta H_2{}^2\right)^{1/2}, \quad (5)$$

where δg_1, δg_2, δH_1 and δH_2 are the standard errors of g_1,g_2 H_1 and H_2, respectively.

The Bouguer correction method assumes that the groundwater level is an infinitely extending plane, as shown in Figure 2(a). However, the groundwater level distribution is not an infinitely extending plane, as shown in Figure 2(b). Therefore, the Bouguer correction method commonly used before may not be the most suitable method for specific yield estimation. Thus, we consider another method called the terrain correction method (Hwang, Wang, and Hsiao 2003) to calculate A_Z. This terrain correction method was originally applied to calculate the gravity effect of rugged terrain on the surface point (Hwang, Wang, and Hsiao 2003; Hwang et al. 2007; Hsiao and Hwang 2010). This study has tried to apply this method to specific yield estimation. The equation is as follows:

$$A_Z = G\rho \mathop{}_{xy} f_1(x,y)dxdy - G\rho \mathop{}_{xy} f_2(x,y)dxdydxdy, \quad (6)$$

where

$$\begin{aligned} f_1(x,y) &= \frac{1}{\sqrt{(x-x_p)^2+(y-y_p)^2+(z^{hi}-z_p)^2}} - \frac{1}{\sqrt{(x-x_p)^2+(y-y_p)^2+z_p^2}} \\ f_2(x,y) &= \frac{1}{\sqrt{(x-x_p)^2+(y-y_p)^2+(z^{lo}-z_p)^2}} - \frac{1}{\sqrt{(x-x_p)^2+(y-y_p)^2+z_p^2}}. \end{aligned} \quad (7)$$

In Equation (7), x_p, y_p, andz_p are the east-west, north-south, and elevation coordinates of point P; x and y are the horizontal coordinates of the groundwater surface grid; and z^{hi} and z^{lo} are the elevation coordinates of the groundwater surface grid in two seasons. If Equation (7) is given a range interval, the following numerical integration formula can be expressed using a planar approximation:

$$
\begin{aligned}
G\rho\int_{X_1}^{X_2}\int_{Y_1}^{Y_2} f_1(x,y)dxdy &\approx G\rho\sum_{j=1}^{M} w_j^y\left(\sum_{i=1}^{N} w_i^x f_1(x_i,y_j)\right) \\
G\rho\int_{X_1}^{X_2}\int_{Y_1}^{Y_2} f_2(x,y)dxdy &\approx G\rho\sum_{j=1}^{M} w_j^y\left(\sum_{i=1}^{N} w_i^x f_2(x_i,y_j)\right)
\end{aligned}, \tag{8}
$$

where X_1, X_2, Y_1, and Y_2 are calculation intervals that represent the west, east, south, and north boundaries of the calculation range. In this study, the calculation range is the groundwater surface within 8 kilometers of the gravity station (see Figure 4); w_i^xandw_j^y are the weight coefficients of the grid point; x_i and y_j are the grid point coordinates; and M and N are the numbers of x_i and y_j in the intervals $[X_1, X_2]$ and $[Y_1, Y_2]$, respectively (Press et al. 1989). x_i and y_j are grids with a spacing of 5 m in this study.

3. Study area and data

The experimental area of this study is located in the alluvial fan of the upper stream of the Zhoushui River in central Taiwan (Figure 3(left)). Figures 3(right) and 4 show the gravity observation stations and adjacent groundwater observation stations in the study area. A total of five gravity observation stations were set up in this study, including the Er-Lun Primary School (ELPS), the Se-Ju Elementary School (SJES), the Hsi-Yang Junior High School (HYJH), the Liu-He Elementary School (LHES), and the Shin-Ming OFfice (SMOF) stations. The groundwater observation stations were evenly distributed around each gravity station. However, only the groundwater wells within 8 kilometers of the gravity station were used. According to Taiwan's Central Geological Survey (2014), the accuracy of the observed groundwater levels from those wells is approximately 1 cm.

Figure 5(a) shows the terrain of the study area. The ELPS, SJES, HYJH and LHES stations are located in moderate topographies. The elevations are distributed from 20 m to 80 m. The SMOF station is located in a small basin. Figure 5(b,c) represent the hydrogeological profiles over the north bank and the south bank of the Zhoushui River, respectively. The paths of the two profiles are shown in Figure 5(a). According to Figure 5(b,c), from west to east, the sedimentary layers change gradually from a clay/sand layer to a gravel layer, which has been identified as possibly having abundant groundwater resources and potential for development. Therefore, the specific yield estimation of unconfined aquifers in this area has always been a very important research topic in Taiwan.

Each gravity observation station performed several gravity missions from 2015 to 2018. The instrument was an FG5 absolute gravimeter (Micro-g LaCoste 2006) (Figure 6(a)), and the gravity observations during each mission lasted longer than 12 hours. During gravity observations, no rainfall could have occurred on the previous day or previous several days to ensure that changes in soil moisture did not affect the accuracy of the gravity observations. The results of two successful gravity missions were taken at each station, and the dates of each gravity mission are summarized in Table 1. Kao et al. (2017) pointed out that the accuracy of the FG5 absolute gravimeter used in this study can reach 1 μgal. Except for the two missions at the ELPS station, the two missions at the other stations were performed in significantly different months and at least three months apart. In addition, g7 software was used to process the gravity observations, including earth tide, ocean tide, atmospheric pressure, and polar motion, and to perform other necessary corrections (Micro-g LaCoste 2007). During the gravity surveys

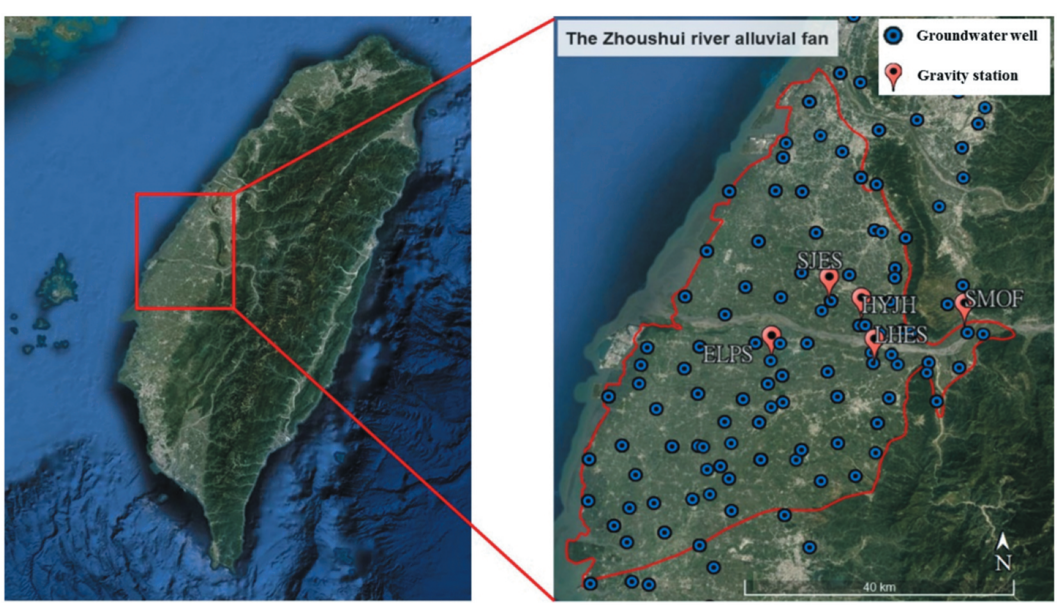

Figure 3. Taiwan imagery form google earth (left). Locations of the groundwater wells and the gravity observation stations over the Zhoushui River alluvial fan (right).

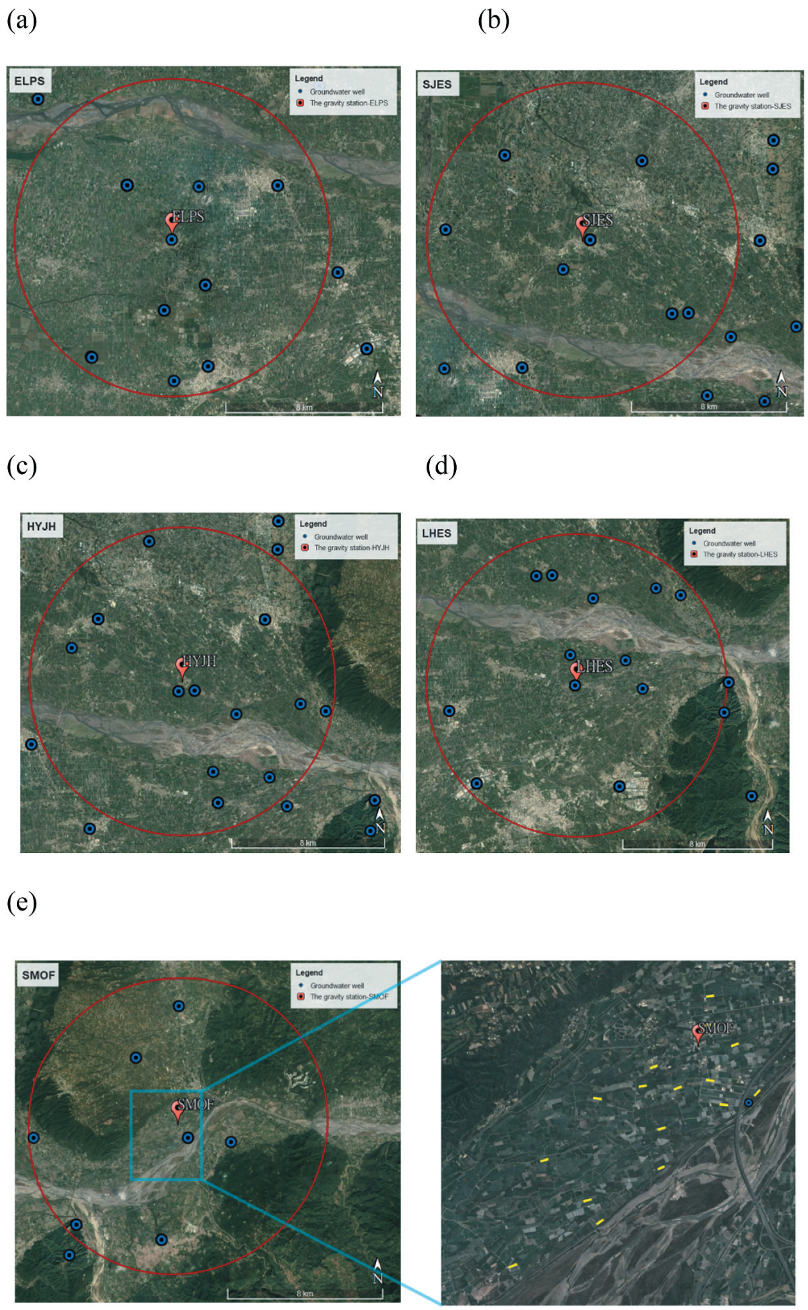

Figure 4. Distributions (magnified view) of the groundwater wells at the (a) ELPS; (b) SJES; (c) HYJH; (d) LHES; (e) SMOF observation stations. The red circle represents the search radius of 8 kilometers. The yellow dots shown in the panel (e) represent the distribution of the ERT survey lines.

at the SMOF station, ERT surveys were performed synchronously surrounding the SMOF station. A total of thirteen ERT survey lines were used (Figure 4(e)) to obtain the groundwater level elevations for the area. The instrument used for the ERT surveys was a 4 point light 10 W earth resistivity meter. Each ERT survey line is 100 meters long with a 1-m electrode spacing (Figure 6(b)). The Wenner–Schlumberger method was used for ERT data acquisition. The method and data processing details for the ERT-based observations are described in Chang et al. (2020).

To confirm the reliability of the gravity observations, we compared the relationship between the gravity observations at each station and the groundwater level observed by the nearest groundwater well station. The results are shown in Figure 7. The groundwater variations were quite consistent with the gravity variations. When the groundwater level was high, the observed gravity value was also high, and vice versa. It is proven that the gravity observed by the FG5 absolute gravimeter in this study was correct and reliable.

4. Design of the experiment

The basic foundation for specific yield estimation in this paper is shown by Equation (1). The simulated gravity change $A_Z$in Equation (1) can be estimated by the Bouguer correction method or terrain correction method. This paper is divided into 5 cases based on different conditions, and each case is

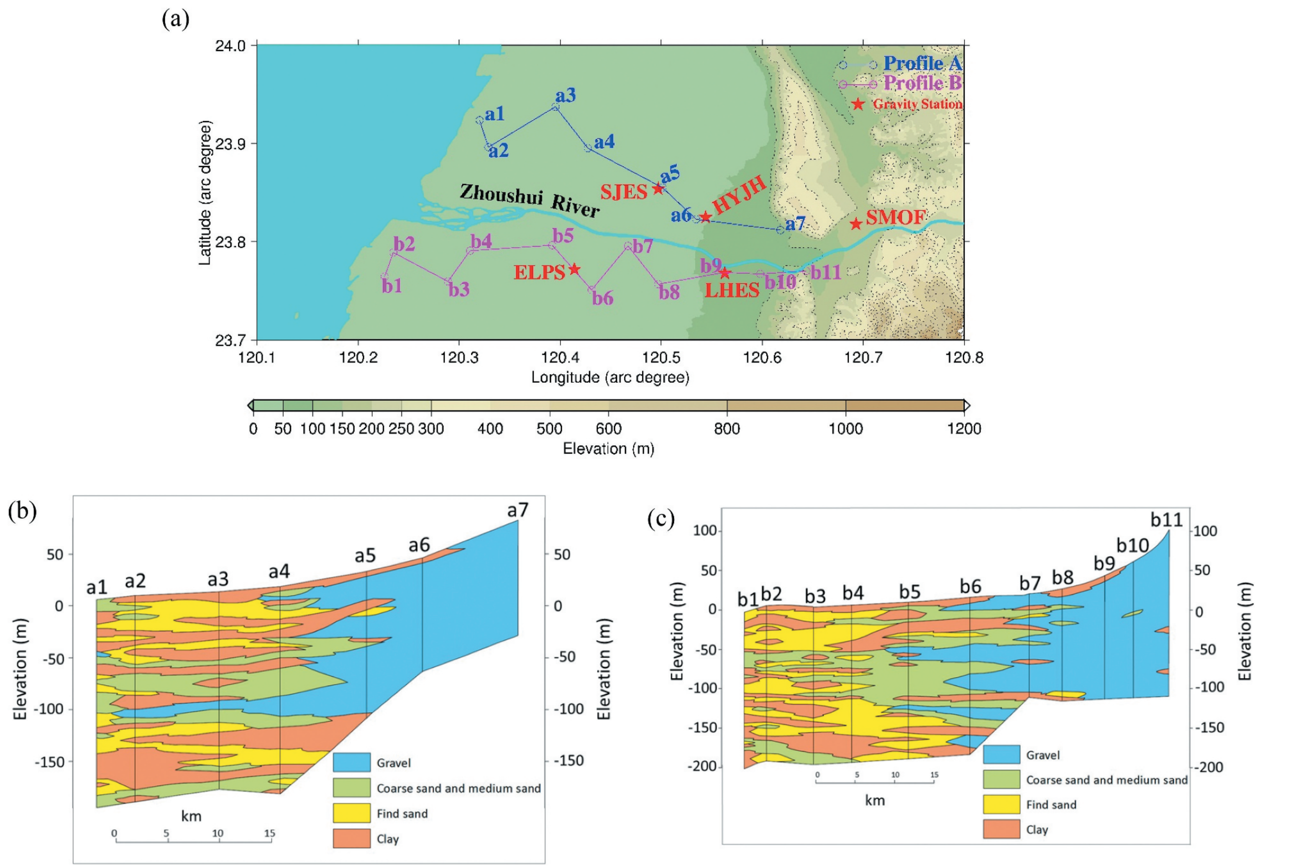

Figure 5. (a) Terrain around the five gravity observation stations; (b) Hydrogeological profile A over the north bank of the Zhuoshui River; (c) Hydrogeological profile B over the south bank of the Zhuoshui River; (b) and (c) are originally from the database of the central geological survey, Taiwan.

classified as shown in Table 2. The simulated gravity change in Case 1 is estimated using the Bouguer correction method. The groundwater surface is modeled by considering only the single groundwater observation station closest to the gravity observation station. The simulated gravity to model the groundwater surface in Case 2 is the same as that used in Case 1. The groundwater surface in Case 3 is derived from the groundwater wells within 8 kilometers of the gravity observation stations (see Figure 4). These groundwater observations are adjusted by fixing the observation at the groundwater station closest to the gravity station, and then are interpolated to a 5 m spatial resolution grid with the kriging interpolation method provided by Surfer 10 software. The groundwater surface in Case 4 is modeled with the ERT-derived observations by fixing the observation at the groundwater station closest to the SMOF gravity station. It is also interpolated to a 5 m spatial resolution grid with the kriging interpolation method provided by Surfer 10 software. In Case 5, the specific yield is derived from the compound well pumping tests, which is the most accurate method. Therefore, the specific yield from Case 5 can be used to verify the specific yields from Cases 1 ~ 4.

Figure 8 shows the groundwater surfaces of Case 3. As shown in Figure 8(a), because the two observation dates at the ELPS station are 11 months apart, almost the same season, the groundwater surface difference at the ELPS station was very small, less than 1 meter. The remaining four gravity stations had significantly different groundwater observation months and seasons (Figure 8(b–e)). The groundwater levels of the remaining four gravity stations changed greatly, with a gap of approximately 1 to 3 meters.

5. Results of specific yield

Table 3 and Figure 9 show the results of the specific yield of all cases. The ELPS gravity observation station has no pumping test results. Table 3 shows that the specific yield of Cases 1 and 2 are the same, which indicates that under the same groundwater surface change conditions, the results from the terrain correction and Bouguer correction methods are consistent. The reason why the Bouguer and terrain correction methods show similar results is that the groundwater surfaces at the five gravity stations are smooth. At the area closer to the gravity station, where the gravity effect for the FG5 gravimeter is also greater, the groundwater difference between Cases 1 and 2 is very small.

In the comparison of Cases 2 and 3, the specific yield differences between the two cases are only 0.01 ~ 0.02, which means that the groundwater surface obtained by one observation well or several observation wells only slightly affects the specific yield result. Although the Case 2 and Case 3 results are similar, the Case 2 results are closer to the Case 5 results. The reason for this result may be that in Case 3, there are not enough groundwater wells within 8 kilometers around the gravity station, especially

(a)

(b)

Figure 6. Photos of the gravity field survey at (a) the SMOF observation station and (b) the ERT field survey around the SMOF observation station.

Table 1. The gravity mission dates.

Stations	Mission date 1	Mission date 2
ELPS	2015/11/25	2016/10/17
SJES	2017/04/06	2017/07/13
HYJH	2017/04/05	2017/07/12
LHES	2016/05/25	2016/10/11
SMOF	2017/09/26	2018/06/26

within 1 kilometer. Therefore, the formed groundwater surfaces in Case 3 cannot truly represent the actual groundwater surface, which in turn causes the error of the specific yield results to be slightly larger in Case 3 than in Case 2.

At the SMOF station, the specific yield in Case 4 is closer to that in Case 5 than the specific yields in Cases 1–3, which indicates that ERT significantly enhance the accuracy of the groundwater surface, and further improve the result of specific yield estimation.

Overall, the specific yields at the five gravity observation stations of Cases 1 ~ 4 are between 0.1 and 0.3. The results are all close to the Case 5 results. This implies that specific yield estimation with the gravimetric method is feasible for the area of the Zhoushui River alluvial fan. In addition, the specific yield at the SJES station is larger than the specific yields obtained at all the other stations. This finding means that the best groundwater resources in the unconfined aquifer are present over the area of the SJES station.

In terms of error analysis, we substitute $\delta g_1 = 1\mu\text{gal}$, $\delta g_2 = 1\mu\text{gal}$, $\delta H_1 = 1\text{cm}$ and $\delta H_2 = 1\text{cm}$ (Kao et al. 2017; Taiwan's Central Geological Survey 2014) into Equations (6) and (7). The standard errors of specific yield δS_y for all cases are summarized in Table 3. The standard errors of Case 1 are obviously larger than those of Cases 2 ~ 4. The groundwater variation of Case 1 is much smaller than that of the other cases, which leads to a rapid increase in the standard error of S_y in Equation (3).

In conclusion, in specific yield estimation over the Zhoushui River alluvial fan, it may be sufficient to simulate gravity changes using the Bouguer correction method with only a single groundwater observation well. However, if ERT data assists the groundwater surface model, the specific yield will be more accurately estimated.

6. Conclusion

In this study, the gravimetric method was used to estimate the specific yield at five gravity observation stations on the alluvial fan of the Zhoushui River in central Taiwan, and the results are verified with compound well pumping tests. In terms of the measured gravity changes, an FG5 absolute gravimeter was used to collect observations in two different periods at each gravity observation station. In terms of the simulated gravity change, we considered both the Bouguer correction method and the terrain correction method and analyzed the differences between the two. During the observations at the SMOF gravity station, the ERT technique was used to observe a highly accurate groundwater surface. The relevant results and future suggestions are as follows:

(1) The specific yield of the five observation stations was estimated to be between 0.1 and 0.3, which is close to the results estimated by the pumping test, indicating that this area has very good groundwater resources and good development potential, especially the SJES station area.
(2) The Bouguer correction method and the terrain correction method resulted in similar specific yield results. The Bouguer correction method is sufficient for specific yield estimation in areas where the groundwater surface cannot be accurately obtained.

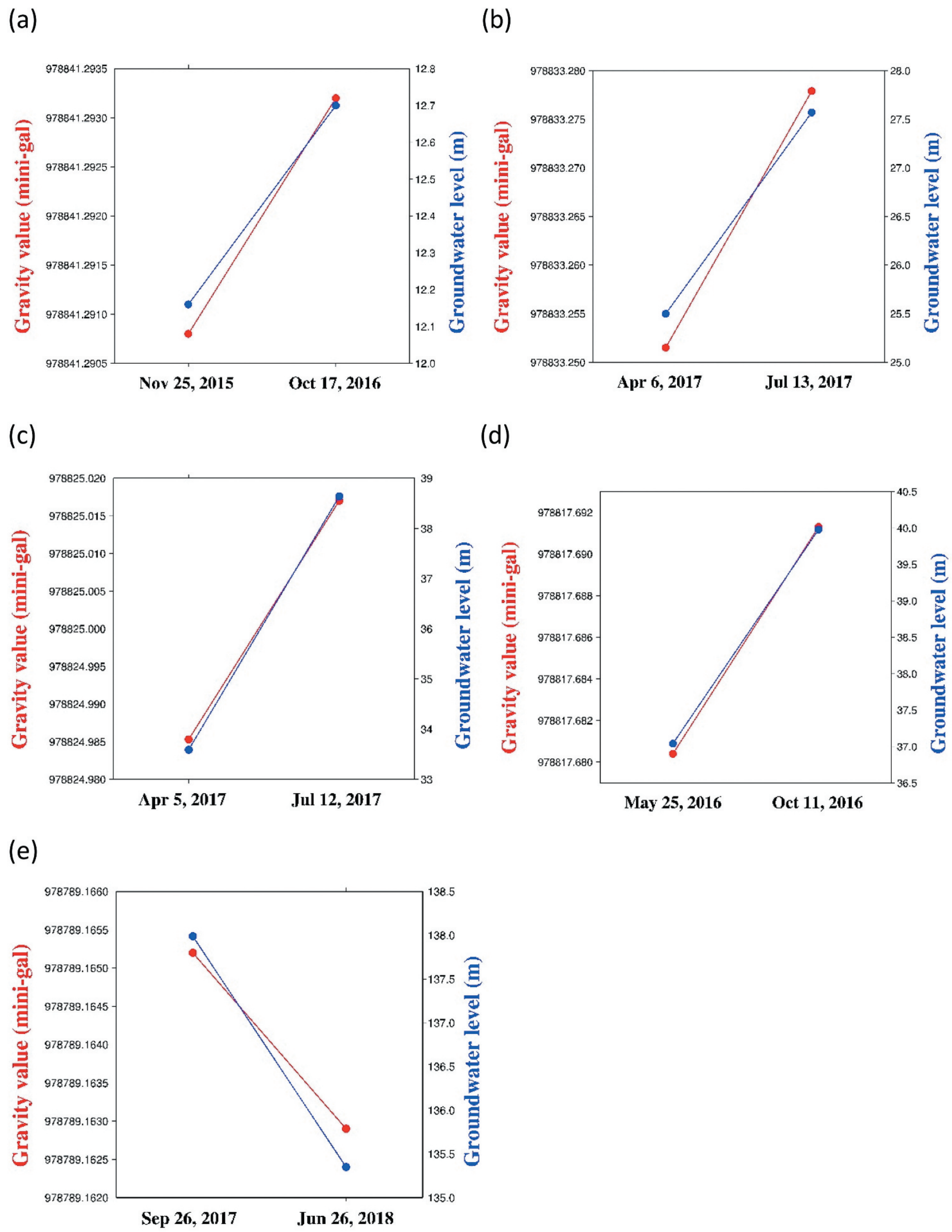

Figure 7. Relations between the gravity observations and the groundwater levels at the (a) ELPS, (b) SJES, (c) HYJH, (d) LHES, and (e) SMOF observation stations.

Table 2. Method for computing the simulated gravity changes and source for gridding the groundwater surfaces in the five cases.

Case	Method for computing simulated gravity changes	Source for gridding the groundwater surface
Case 1	Bouguer correction	Single well
Case 2	Terrain correction	Single well
Case 3	Terrain correction	Several wells
Case 4	Terrain correction	Single well +ERT
Case 5	Well pumping tests	-

(3) If the groundwater surface can be precisely modeled with ERT assistance, the specific yield estimated from the gravimetric method will be more accurate.

(4) The gravimetric method is a nonintrusive observation method. Compared with compound well tests, the gravity method has the advantages of rapid observation and low cost. Therefore, gravity surveys are important methods for obtaining the specific yield over a large area, providing the relevant units to quickly understand the groundwater resources over a large area, which can be used as a reference for the development of groundwater resources.

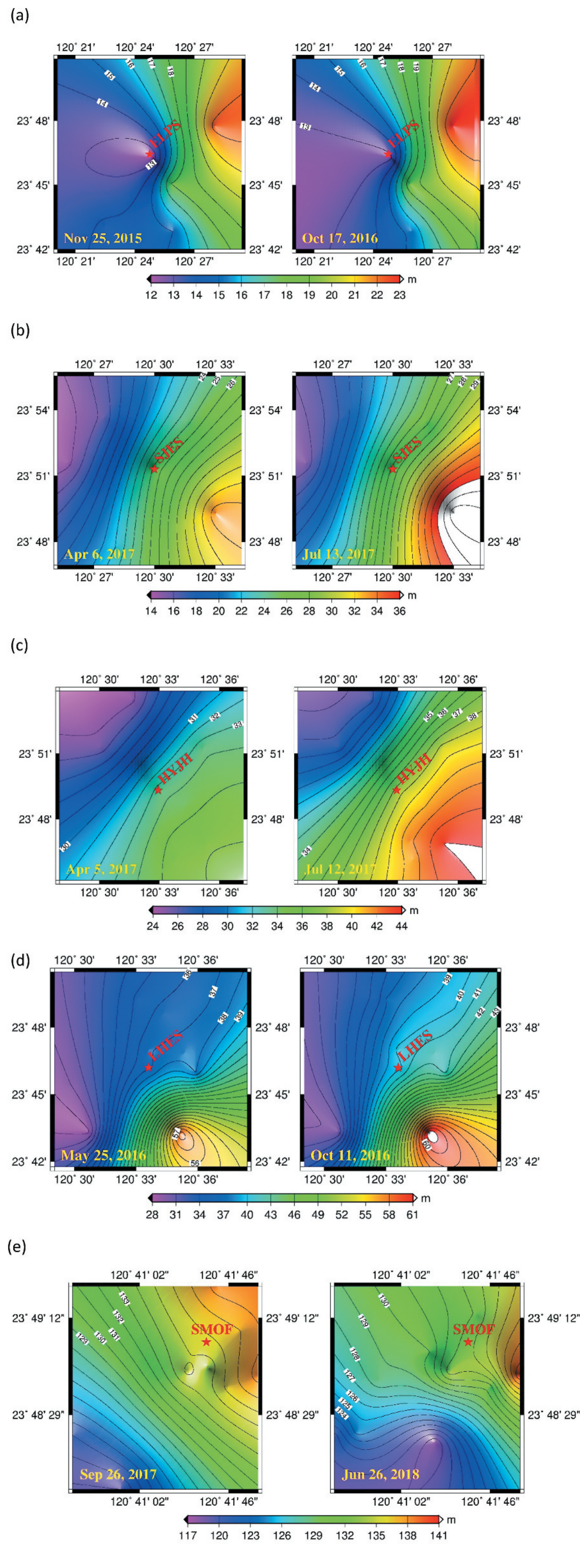

Figure 8. Groundwater surfaces for case 4 (unit: meters) at the (a) ELPS, (b) SJES, (c) HYJH, (d) LHES, and (f) SMOF observation stations. The left and right panels represent the results of the first and second missions (see Table 1), respectively.

Table 3. Summary of the estimated specific yield (S_y) and the standard error (δS_y).

Station	Case 1	Case 2	Case 3	Case 4	Case 5
ELPS	0.10 ± 0.05	0.10 ± 0.05	0.11 ± 0.05	-	-
SJES	0.28 ± 0.02	0.28 ± 0.02	0.30 ± 0.02	-	0.24
HYJH	0.14 ± 0.01	0.14 ± 0.01	0.16 ± 0.01	-	0.12
LHES	0.11 ± 0.01	0.11 ± 0.01	0.09 ± 0.01	-	0.12
SMOF	0.11 ± 0.01	0.11 ± 0.01	0.10 ± 0.01	0.15 ± 0.01	0.16

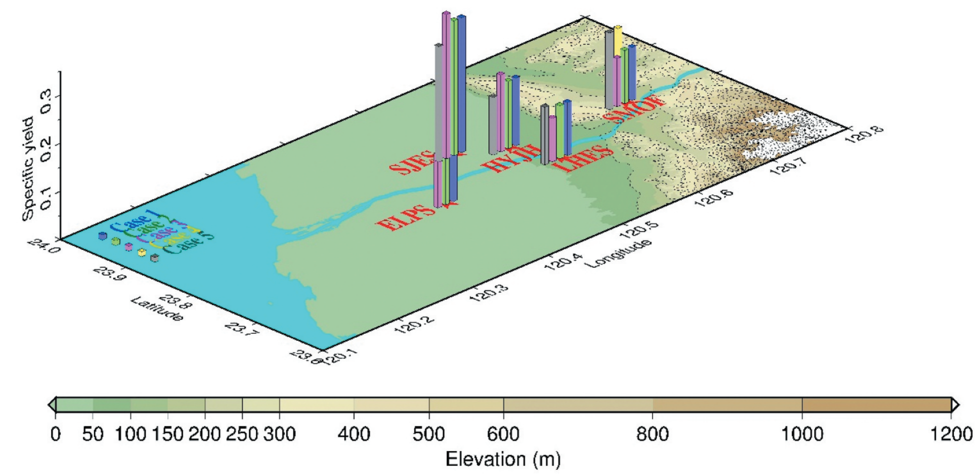

Figure 9. Specific yield estimated for cases 1 ~ 5 at the five gravity observation stations.

Nomenclature

ρ	geological density
G	gravitational constant
x_i and y_j	grid point coordinates
S_y	specific yield
Δg	measured gravity change
M and N	numbers of x_i and y_j
A_Z	simulated gravity change
X_1, X_2, Y_1, and Y_2	the calculation intervals representing west, east, south, and north boundaries
x_p, y_p, andz_p	the east-west, north-south, and elevation coordinates of point P
z^{hi} and z^{lo}	the elevation coordinates of the groundwater surface grid in two seasons
g_1 and g_2	the gravity measured in two seasons
x and y	the horizontal coordinates of the groundwater surface grid
δS_y	the standard errors of S_y
$\delta\Delta g$	the standard errors of Δg
$\delta\Delta H$	the standard errors of ΔH
H_1 and H_2	the groundwater level measured in two seasons.
δg_1	the standard errors of g_1
δg_2	the standard errors of g_2
δH_1	the standard errors of H_1
δH_2	the standard errors of H_2
ΔH	the thickness of Bouguer plate
w_i^x and w_j^y	the weight coefficients of grid point

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The gravity and ERT data generated and analyzed in this study are available from the corresponding author on reasonable request.

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