The Water and Soil Loss Effect of Developing and Constructing Project on Urban Limestone Groundwater Recharge Area

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Abstract: Based on analysis of soil erodible factors for the case study of developing and constructing project in Jinan city, some information about soil erosion in the limestone mountain area, then the surface runoff equation with variable parameters and the Universal Soil Loss Equation were used to compute and predict the volume and the rate of runoff and soil loss in the different period of constructing project. Finally, the soil loss properties in limestone mountain area affected by the artificial engineering and measures are summarized.
Keywords: the limestone mountain area, surface runoff, soil loss

Shandong Province is located in the east of China, northern latitude 34°20′—38°30′ to eastern longitude 114°45′—122°45′ .The area of the limestone is 18,014km^2 in Shandong province, accounting for 12% of total land area, in which there are lot of cities as Jinan, Zibo, Taian, Zaozhuang, Jining etc. Compared with other regions, the economy, culture and transport in the area are developed, and the population towns are gathered. The water supplying for the urban mainly rely on limestone groundwater. But many problems have been resulted in with the fast development of economy, improving the people's living standard and the urban population expanding. For example, the following problems occur in Jinan city: (1).The gap between water supply and demand become more acute. The groundwater overdraft has brought about springs stopping gushing, local ground sinking; (2). the urban areas are quickly enlarged and stretch into the mountains. The natural forest, plants and the geomorphic and topographic hills have been destroyed. The groundwater recharge areas become impermeable hard surface of the earth instead so that the amount of groundwater recharge from rainfall filtration are greatly reduced which made water resource available shorter. According to calculating, as the urban area is enlarged by 1km^2, the volume of runoff will increased by 457 thousand m^3 in jinan city. At the same time, the floods threatening to the urban is increasing. When it is high precipitation season, water and soil loss, the rainfall flood into the roads along the slope of the hills and the traffic is broken off. Low-lying areas at the north often flooded. (3). The economy of the mountains areas blindly develops to some extent under the market condition, for example a lot of stone pits supplying materials for the cement factories or constructing materials and brickfields appear. Mining for limestone and earth in disorder bring some mountainous bodis and gullies to losing the function of water and soil conservation and speed the water and soil loss in the groundwater recharging areas. In addition, some illegal rubbish dumps can been seen in the area, which will slowly pollute the groundwater to some extent for a long term. The nonsustainable development in the mountain area provides a pretext so called "developing under the condition of protection" for real estate agents. (4) A great deal of living areas are built, ensuing garbage and sewage water resulted by the residents will certainly pollute the groundwater. And this kind of pollution will maintain for a long time and might be fatal for the groundwater as main urban water source. Indeed, the urban area expanding and the mountains economy developing have resulted in water and soil loss and made the limestone mountainous ecological system more fragile. We face the two great forces to destroy ecological environment of urban limestone groundwater recharging areas. We must take effective measures to solve the challenge. The following case study analyses the water and soil effect of development and constructing projects on urban limestone groundwater recharging areas in Jinan city in quantity and measures to take.

1 Background

The project area is situated in the middle of a long valley at southern foot of mountain Qianfe. Total watershed area is 2.0 km^2. The project is to build a common residential quarter. The total planning area is 95.47ha, of which the area is 75.37ha of residential district and 20.1ha of public facilities including public green land and road etc. 7,853 sets of apartment will be constructed. The population of 25.9 thousands will live there. Combining with the topographic situation, the original village is pulled down and remove, the land of ground is leveled. Then the project is proceeded with. Based on the equilibrium of excavating and filling earth on the spot, the earthwork is mechanizing construction. The limit time for the project is three years. After finishing the built apartment will be on sale in commercial residential building.

2 Water and soil erosion factors

2.1 Climate

The precipitation and precipitation intensity are dynamic source of producing soil erosion. The project area is near the southern urban district. It is warm temperate zone continental monsoon climate. Four seasons are clear. Average annual temperature is 13℃. Mean annual precipitation from 1956 to 1999 is 663.9 mm. The rainfall is uneven in season. 75% rainfall occurs in flood season. Because the distribution of rainfall in season is concentrated, the type of runoff producing is mixed rainfall excess and surplus of rainfall storage in the limestone area. Raindrop erosion produced by a few storms is serous. In addition the gradient of the watershed area is bigger, and the concentration time is shorter. The seasonal water flow in the valley is larger. So the erosion on the slope worsen due to the runoff. The floods drain away into the natural course of river downstream of urban area in high rainfall period. There is a little rainfall in other periods so that these streams are basically dry.

2.2 Topographic factor

Topographic factors mainly include degree, length of slope and shape of slope. The degree, length of slope, the degree of knob and kettle on the slope are the basic elements of determining runoff scouring and erosion. The type of geomorphy is mountains and valleys. There distribute subsurface feature units of hillsides slope foot, terrace, valley bottom, lower flat land, low-lying land, gully etc. Which are not typical in development owing to the effect of mankind. The neighbor surrounding the valley is hills consisting of Ordovician limestone rock where the height above sea level is 230 m—290 m. Average degree of slope is 15^o—20^o. The length from the south to north 2.1km and average width 450m in the valley where the topographical feature is gentle and the height 117 m—191 m. The tendency is that the north is higher and the south is lower there. But the land form in the local is little different.

2.3 Composition of surface material

The sedimentary deposit comprises Quaternary slope wash and alluvial and flood deposit. The main surface material consists of the soil and weathered rock. The type of the soil is primary brown soil. The coarse skeletal brown soil is much distributed over the uncultivated and terraced fields on the slope and foot of the hills. The soil-forming parent material is residual soil and slope wash from weathered rock. The soil layer is thin, the depth 20 cm—30 cm. The character of the coarse skeletal soil is obvious. The soil quality is main gravelly medium loam. When it rains and runoff is larger, the loose soil is loss easily. In the valley bottom, there are much common and calcareous brown forest soil which soil-forming parent material is slope washing and flooding limestone. Once in a while there is some loessial debris. The depth of the soil is 20 cm—55 cm. The soil mass is rich in calcium carbonate. The soil quality is medium loam. The surface layer is cultivated. Light clay can be seen in the deeper. The soil is dispersed into fine masses when water exists. The gully erosion is clear and obvious. A number of gullies can be seen everywhere in the district.

2.4 Vegetation

The type of plant is monotonous in the area. There are artificial planted oriental arborvitae on the mountain land surroundings and mountain slope. Their height is less than 7m. The structure of forest is simple, lack of bush and herb. The cover rate of forest is 22%. The vegetation is more luxuriant and dense in the east mountain land, forest sparse in the west. Naked rock' area is larger. There are sparse wild glass and a few artificial planted wild jujube trees on the terrace of the slope foot. Few broadleaf tree such as poplar and elm scatter on the gentle place of the valley. The vegetation is sparse and the ecological quality is lower.

2.5 Social and economical factor

Half of the valley land is wild glass, low-lying land and steep slope terrace. Some drought-enduring crops are on the terrace with extensive management and low yield. The other of which is farmland. The main planting crops are wheat, corn, bean and sweet potato. The soil fertility is under medium. The drainage condition is better. But irrigation condition is worse because of water shortage. Drought is the main limiting factor of effecting crops output. In addition there are few orchards and vegetable land. Two villages are separately located in the south and north of the valley with population of 2,500. The agriculture productivity is low. The main economic income is from mining stones and making bricks etc. It is one of not enough developed areas.

3 Computation and forecasting of water and soil loss

Seeing that the project area is located in the direct recharge area for the Jinan' spring areas, the character of water and soil erosion is not only soil loss and surface runoff loss. The volume of direct surface runoff is calculated by empirical formula and soil loss by America Universal Soil and Loss Equation.

3.1 Computation of surface runoff

The empirical formula with variable parameters is adopted to calculate surface runoff, which is results of the observation and experiment for many years by Shandong Water Conservancy Research Institute. The formula for annual runoff and annual runoff coefficient is as follows:

$$R_s = \alpha_s \bullet F \bullet P_I \quad (1)$$

$$\alpha_s = A_s \log P_I - \log P_B + D_s \quad (2)$$

R_s: surface runoff; (m^3); F: calculated area (km^2); P_i: precipitation (mm); α_s : annual runoff coefficient; A_s: surface confluence empirical index; P_B: soil adjustment and transform repeating coefficient. Where A_s, P_B, and D_s are empirical constants of watershed runoff producing. According to the research results of three-water transform, the parameters above in the limestone area can be seen in Table 1.

Table 1 The parameters of runoff producing in the limestone area

Type of geomorphology	A_s	P_B	D_s
Mountainous land	0.50	300	1.290
Plain	0.15	340	2.165

Precipitation statistics data is from the year 1956 to 1998 at the station of Shaoer in the south of Jinan City. Before project, the surface runoff of total area is calculated by the parameters based on the geomorphic type of mountain land. During construction period, the surface runoff of the valley bottom is calculated by the parameters based on the geomorphic type of plain due to soil layer disturbed and subsurface flow increased. But runoff of the other mountain land is still calculated as the same as the mountain land. After project, the ground in planing area is hardened, the surface runoff coefficient becomes larger. 0.75 is adopted. That of the mountain land is the same above. The following table2 shows surface runoff in different frequency in project area.

Table 2　Surface runoff in different frequency in project area　uinte 10 thousand m^3

Frequency (%)	Precipitation(mm)	Before project	During construction	After project
20	807.3	49.08	31.11	83.29
50	648.0	30.97	19.62	62.40
75	533.8	19.28	12.30	48.15
95	399.7	7.59	4.90	32.47
Mean annual	663.9	32.53	20.68	64.38

3.2　Computation of soil loss

Because rainfall causes sheet erosion in the area, the soil erosion is calculated by way of USLE.

$$E=0.224R\bullet K\bullet LS\bullet C\bullet P \quad (3)$$

Where E: soil erosion modulus(kg/(m^2 • a)); R: rainfall erosivity index; K: soil-erodibility factor; LS: topographic factor; C: cropping-management factor; P: conservation practice factor.

$$R=\sum_{i=1}^{12}1.735\times 10^{\left(1.5\log\frac{P_i^2}{P}-0.8111\right)} \quad (4)$$

Where: P_i: monthly precipitation; P: yearly precipitation.

$$100K=2.1\times 10^4(12-M_0)\times M^{1.14}+3.25(S-2)+2.5(P-3) \quad (5)$$

Where:M_0: organic content; S: soil structure index; P: Permeability grades; M: fine and silty sand percentage.

$$LS=\left(\frac{1}{22.13}\right)^m(0.065+0.045S+0.0065S^2) \quad (6)$$

where: L: length of slope(m); m=0.6; S: degree of slop(%).

The rainfall data is from statistics of mean annual result, and soil parameters is in the light of analysis on typical soil profile in those formulae above. The parameters of the surface soil layer are used as follows : M_0=1.03%; S=2; P=4; M=70.67.

Vegetation cover factor C is according to Elwell. A. , Stocking M. A (1975) and Lang R. D. Who derived nonlinear graph between erosion ratio and seasonal vegetation cover percentage. 22% of average watershed vegetation cover percentage is taken. 0.30 of C is gotten. Because of basically no water and soil conservative measures, P is 1.0.

The degree of slope and length of slope are different from construction before and after. Before construction, the length of slope is adapted by average value of 850m, ie 18% of watershed average degree of slope. After construction, no soil is eroded because the surface of the valley is solidified. Soil loss is calculated only in the hill area of 1.05 km^2 in which average length of slope is 340m and average degree of slope is 35%. During constructing, as soil layer of the valley is disturbed, soil erosion modulus is calculated that it is 1.5 times as great as nature. In hill area, average length of slope is 340m and average degree of slope is 35%.

The mean annual water and soil losses are different from before project, during constructing and after project according to the calculation above (Table 3).

Table 3 Comparison of mean annual water and soil losses in the watershed

Time period	Before project	During constructing	After project
Surface runoff ($10^4 m^3 \cdot a^{-1}$)	32.5	20.7	66.1
Soil loss ($t \cdot a^{-1}$)	3,394.0	4,200.0	1,151.0

4 Conclusion

In view of sustainable development, ie protecting Jinan springs, urban area expanding toward the south of groundwater recharging area should be prevented and the structure of industry in the mountain hill areas should be adjusted and transformed into ecological agriculture and tourism. Through comparison analysis above, we find the following distinguishing features: (1) Water and soil loss of the original area is small in degree. (2) After construction, not only soil loss but also surface runoff loss will be resulted. (3) During construction, soil erosion will be increased thanks to soil surface layer disturbed, but surface runoff is relatively reduced. (4) After implementation, surface runoff will double but soil loss will decrease due to the valley being changed into residential district and erodible area being reduced.

Two aspects of the following indirect effect on water of soil losses will be produced: (1) Groundwater recharge permeated by rainfall will decrease because surface runoff will increase. It would bring negative effect on Jinan' springs if measures of flow collection and infiltration promotion were not adapted. (2) With increment of surface runoff, runoff erosion to the downstream and gully erosion are aggravated and outlet sediment of the watershed will increase.

It will not only aggravate the valley land and fluvial on the downstream deposite but also enforce the pressure of flood carrying on the downstream.

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