LAND USE, SOIL CONSERVATION AND RAIN HARVESTING STRUCTURES ON A SLOPE LAND ORCHARD AT SUFEN (TAIWAN) DURING OF ACTION OF TYPHOON HERB – ELEMENTARY NUMERICAL EXPERIMENT

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Abstract

Agriculture and water management are inseparable and the most important factors for human life, especially in such subtropical countries as Taiwan (Republic of China) with its typhoons, cyclones, heavy stormy rainfalls and with its very specific agriculture's conditions. The author of this paper during his long term study stay at the International Center for Land Policy Studies and Training (ICLPST) in Taoyuan (Taipei, Taiwan) at 2001 attended the Taichung City in Taichung and Miaoli County. At this hilly landscape, in orchard at Sufen (Tahu District, Miaoli County, Taiwan), were built up in a frame of landscape and water resources protection, soil conservation measures and rain harvesting structures for mitigating of negative impact of hydrological extremes like typhoons, stormy rainfalls, floods or long term droughts. The goal of this paper is to present land use and erosion control structures as are hillside ditch system with grass waterway, which were built in the slope land orchard at Sufen, and to show their technical design parameters. And at last but not least, by elementary numerical experiment to clarify the hydraulic function of land use and surface drainage structures placed in orchard at Sufen, during an activity of Typhoon Herb, which affected Taiwan at 31 July and 1 August in 1996, that means in extremely difficult hydrological conditions.

Key words: orchard at Sufen, Taiwan, Typhoon Herb, hydrological extremes, land use, hillside ditch system, rain harvesting structures, runoff rate, flow velocity, rainfall intensity

INTRODUCTION

Agriculture and water management are inseparable and the most important factors for human life, especially in such subtropical countries as Taiwan (Republic of China) with its typhoons, cyclones, heavy stormy rainfalls and with its very specific agriculture's conditions.

The author of this paper during his long term study stay at the International Center for Land Policy Studies and Training (ICLPST) in Taoyuan (Taipei, Taiwan) at 2001 attended the Taichung City in Taichung and Miaoli County. At this hilly landscape, in orchard at Sufen, Tahu District, Miaoli County, Taiwan, see Photo 1, were built up in a frame of landscape and water resources pro-

Photo 1: Orchard at Sufen with typical slope land around (Tahu District, Miaoli County, Taiwan, photo J. Štibinger, 2001)

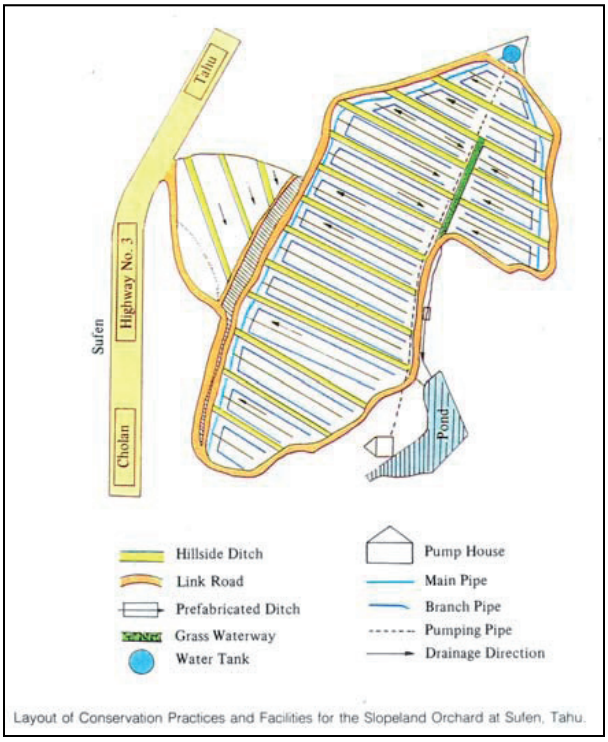
tection, soil conservation measures and rain harvesting structures for mitigating of negative impact of hydrological extremes like typhoons, stormy rainfalls, floods or long term droughts (Photo 1).

Land use, erosion control structures, hillside ditches, surface drainage and irrigation with water tank and pond reservoir, placed at steep land orchard at Sufen represent unique technical and biotechnical water management system. Project was developed by the 2nd Engineering office of Soil and water conservation Bureau (SWCB) under the Council of Agriculture Taiwan. This integrated surface drainage and irrigation system is ready not only to protect this area against floods, erosion processes, landfalls, etc., but also to mitigate negative impacts of long term droughts (Štibinger, 2001; SWCB, 2001).

All the works (land use, rain harvesting structures and irrigation facilities) of this project of SWBC were completed in January 1989 with the approximated cost of 135 400 US dollars (SWCB, 2001).

The waters of potential runoff in orchard are caught up by system of hillside ditches and then by grass waterway and link road are removed to the farm pond, which is used as water storage, situated in the downer part of orchard at Sufen. From the pond is water transported by pumping system to the water tank reservoir on the hill top, where is ready for irrigation and also to mitigate negative impact of potential long term droughts. Agricultural land use comes from high density Bahia grass as cover of over the all orchard with fruit trees, what make a good base of erosion control measures. The layout of conservation practices and rain harvesting structures for orchard at Sufen is viewed in Figure 1.

Figure 1: Scheme of layout of land use, conservation practices and rain harvesting structures in orchard at Sufen (Tahu District, Miaoli County, Taiwan, by SWCB 2001)



The goal of this paper is to present land use and erosion control structures as are hillside ditch system with grass waterway, which were built in the slope land orchard at Sufen, and to show their technical design parameters. And at last but not least, by elementary numerical experiment to clarify the hydraulic function of land use and surface drainage structures placed in orchard at Sufen, during an activity of Typhoon Herb, which affected Taiwan at 31 July and 1 August in 1996 that means in extremely difficult hydrological conditions.

MATERIALS AND METHODS

Study area

Orchard at Sufen is situated in hilly landscape covered by dens vegetation of grassy surface, bushes and trees. The land was originally mixed woodland with fir, bamboos, wild plums, peaches and with other similar cover of vegetation. Orchard area (area of orchard, area of interest) is about 3.7 hectares and is located in Northern Taiwan, near Lilin Village, Tahu Discrit, Miaoli County, reached at the southern side of Highway No. 3.

Topography conditions demonstrate the slopes range from 20% to 30% with inclination towards the west on altitude between approximately 300 m and 400 m over the sea level.

The soil base comes from sandstone and shale. Soil texture can be described as loam or sandy loam with big amounts of clay particles, which decrease the infiltration capacity of those soils. The root system of dens grassy vegetation, which is developed very well, mitigates the negative impact of clay in the soils from the infiltration point of view.

The climate of orchard at Sufen is warm and humid with the annual average temperature about 22°C, the total annual precipitations is around 2250 mm. Much more rainfalls come in monsoon season between mid May and mid June and, of course, in typhoon season between July and September. The growth period is going during all over the year (Štibinger, 2001).

Rainfall data of Typhoon Herb (1996)

As an example of design rainfall for estimation of efficiency of soil conservation and rain harvesting structures

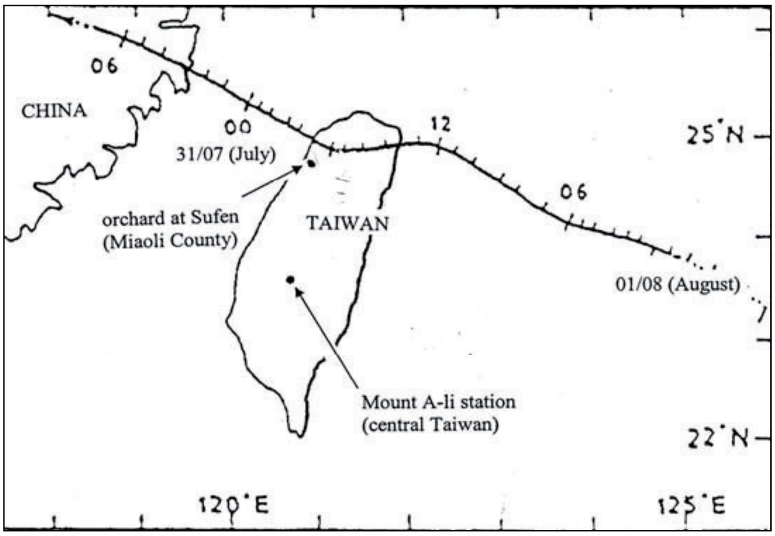


Figure 2: Track of Typhoon Herb going very close to location of orchard at Sufen (Tahu District, Miaoli County), Mount A-li station in Central Taiwan is also indicated (after Sheikh 1999)

in typhoon's conditions, built-up on a slope-land orchard at Sufen, Tahu District, Miaoli County, was chosen rain of Typhoon Herb, which affected Taiwan between 31. July and 1. August 1996.

Typhoon Herb was a special example of a typhoon making landslide on Taiwan, and also was characterized by enormous amount of water. Figure 2 shows the track of Typhoon Herb going very close to location of orchard at Sufen, Tahu District, Miaoli County. During the activity of Typhoon Herb on Taiwan, were identified two main centers of precipitations. One at Mount A-li in Central Taiwan (see Figure 2), where was measured record-breaking of total accumulation of 1978 mm over the 2-day period (1095.5 mm on 31 July, and 892.0 mm on 1 August 1996).

The other center was at Mountain Nio-Dray in northern Taiwan, where was recorded 1044 mm (Chun-Chieh Wu, 1999). The heavy rain of Typhoon Herb at Mount A-li was described by data from local meteorological station, respectively by hourly rainfall analysis over 14 consecutive hours. The maximum heavy rainfall intensity was recorded on 31 July 1996 at 5 p.m. with value of 115 mm/hour (Chun-chieh Wu, 1999). This intensity was selected and determined as a design rainfall intensity r = 115(mm.hour^{-1}) for other estimation of impact of Typhoon Herb on a slope-land orchard at Sufen, Tahu District, Miaoli County in northern Taiwan.

Land use and rain harvesting structures

To increase the prevention against soil erosion and to create a big green scenic orchard, all over the surface field were planted by Bahia grasses (Paspalum notatum) as a surface cover crop and mulching material on the total planting area of 3.4 hectares. The grass stocks were split and planted in triangle with 20 cm × 30 cm spacing. Approximately four month after planting, the grasses provide very good ground cover, which is excellent base of protection against erosion processes and negative impacts of runoff.

To approximate orchard surface flow velocity by elementary hydraulic calculation, the properties of orchard cover, described above, were expressed by landscape surface coefficient N (sec^{-1}), see Table 1 (Holý a kol., 1994). In a case of orchard at Sufen the value of N (sec^{-1}) = 15.0.

The runoff coefficient o (–) = 0.25 was approximated by the topography conditions, soil properties and surface vegetation of the orchard at Sufen, with use of ČSN 75 65 01 (2004), Morgan and Rickson (1995) and Holý a kol. (1994).

To create tourist attraction just directly in the orchard area at Sufen, on the upper 3 hectares of orchard is possible to harvest fruits in the cool fall, because people like very much to walk up there to pick up fruits. Totally were

Tab. 1: Landscape surface coefficients N (sec^{-1})

Landscape surface	N (s^{-1})
Ploughed fields, tillage with the slope	44.0
Ploughed fields, leveled and smoothed surface	25.0
Fields with reed	22.0
Moss-grown fields	18.–15.0
Grassy orchard (Bahia grass)	15.0–11.0
Rough soil (earth), surface with a lot of molehills (hollows)	11.0–6.0

Source: Holy et al. (1994)

Photo 2: Drain hillside ditches in orchard at Sufen (Tahu District, Miaoli County, Taiwan, photo J. Štibinger, 2001).

planted 660 plants of citrus, and on the lower part with area about 0.5 hectares were planted 120 pear plants.

All those land use mentioned above can serve not only for agriculture, orchard tourist attraction, garden and landscape architecture, but, and what is the most important from the point of view of water regime, as a good tool of protection of orchard area at Sufen against erosion processes and negative impacts of typhoons.

The waters from potential runoff in an orchard are drained by system of open hillside ditches and then by grass waterway and link road are removed to the farm pond, which serves as a water storage, situated down the orchard at Sufen.

The goal of the drainage hillside ditch system is not only to remove the potential runoff waters. It plays key role in protection of the soils against erosion, and last but not least, also facilitating farming practices (farming paths) create a good foundation of labour-saving management on slope land of orchard.

The drain hillside ditches were projected and built horizontally on the slope, with drain spacing (distance between ditches) L = 15–18 m. Individual ditches with a gradient of 1.0% to 1.5% are very shallow to make possible the movement of the farmers machines on the ditches. The shape of ditches can be defined approximately as trapeze or rectangle with dominant parameter of 2.5 m in the bottom of ditch and by height about 0.1 m (see Photo 2).

For hydraulic calculation was approximated water profile of hillside ditch as 0.1 m × 2.5 m = 0.25 m^2, the value of wetted perimeter of ditch was estimated to 2.75 m and the value of hydraulic radius was determined as 0.091 m. The average of orchard area situated above the corresponding hillside ditch is about S_d = 1296.0 m^2.

All surfaces of hillside ditches, as well as all orchard, is covered by very dens Bahia grass, then Manning's roughness coefficient for cover of hillside ditch was approximated as n = 0.035 $m.s^{-1/3}$, see Table 2.

In the orchard at Sufen were in all built 16 ditches with a total length of 1090 m, in the orchard area of 3.7 hectares. Hillside ditches are entered to the grass waterway and to the link road to transfer the potential runoff to farmer pond (see Figure 1).

Tab. 2: Some selected Manning's roughness coefficients

Ditch surface	Manning's roughness coefficients n ($m.s^{-1/3}$)
Plastic materials	0.009
Smooth concrete	0.013
Stone paving	0.028
Dens grass (Bahia grass)	0.035
Mud ditch	0.070

Source: Havlík (1994)

Theoretical

The verification of efficiency of land use, soil conservation and rain harvesting structures situated on a slope land orchard at Sufen, Tahu District, Miaoli County in Taiwan (Republic of China) is based on a description of surface runoff processes, which were involved by heavy rainfall of Typhoon Herb. Simplified analysis of runoff processes comes from constant typhoon intensity r ($M.T^{-1}$) at the certain time (T), the velocity of runoff v ($M.T^{-1}$), of course, will be changed with distance x (M). Runoff Q ($M^3.T^{-1}$) can be globally expressed by equation of continuity in form Q = v × S, where symbol S (M^2) is water-filled area of cross section. For unit S (M^2) is valid S = y × 1, where y (M) is height of the water on the landscape surface. M is unit of length and T is time unit.

Velocity of runoff v ($M.T^{-1}$) will be described by a form of Chezy's equation in a shape $v = y \times N \times I^{0.5}$, where by symbol N ($sec^{-1}$) is characterized landscape surface. The values of N (sec^{-1}) are presented in Table 1 (Holy et. al., 1994). By substituting $B = N \times I^{-0.5}$ we get v = y × B.

The scheme on Figure 3 shows simplified process of runoff, which was involved by intensity of rainfall of typhoon r ($M \times T^{-1}$).

Place (1) is situated at the top part of slope and has water head y (m), velocity flow v ($m.s^{-1}$) runoff rate Q1 = y × v. Place (2) is situated down the slope and because of typhoon rainfall intensity r ($m.s^{-1}$) at place (2) the head y (m) will be increased to y + dy, velocity v will be (v + dv) and Q2 = (v + dv) × (y + dy), see Figure 3.

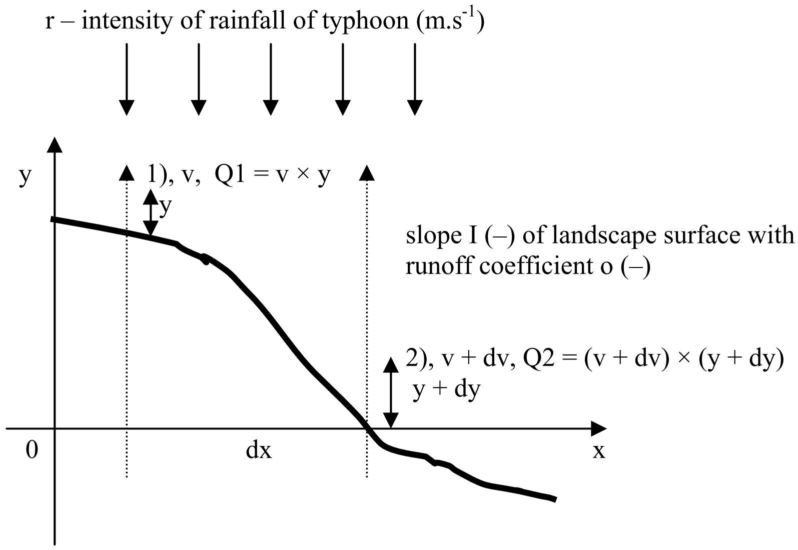


Figure 3: Scheme of simplified process of runoff developed by rainfalls intensity r ($m.s^{-1}$) from typhoon

Where:

x, y = coordinates of two-dimension orthogonal system (M)

dy = the change of head of water on the landscape surface (M)

dx = distance between place 1) and place 2), in horizontal projection (M)

I = slope of the landscape surface (–)

If $v = B \times y$, then $dv = B \times dy$, with $v = y \times N \times I^{0.5}$ and substitution $B = N \times I^{-0.5}$ we get $v = y \times B$, so we get

$Q1 = v \times y = B \times y^2$

and

$Q2 = (v + dv) \times (y + dy) = (B \times y + B \times dy) . (y + dy)$
$= B \times (y + dy) \times (y + dy)$,

water from rainfalls decreased by infiltration can be expressed as $Q2 - Q1 = r \times o \times dx$

$r \times o \times dx = B \times (y + dy)^2 - B \times y^2$
$= B \times y^2 + 2 \times B \times y \times dy + dy^2 - B \times y^2$

dy^2 is negligible and can be eliminated, so we get $r \times o \times dx = 2 \times B \times y \times dy$, by solution of this ordinary differential equation and after substitution we get $y^2 = (r \times o \times x)/B = (r \times o \times x)/(N \times I^{-0.5})$ and then we can write equation (1) for height of the water on the landscape surface y (M) as

$$y = \left(\frac{x.r.o}{N.I^{0.5}}\right)^{0.5} \quad (1)$$

and with use $v = y \times N \times I^{-0.5}$ we get equation (2) for calculation of velocity flow v ($M.T^{-1}$)

$$v = (x.r.o.N.I^{0.5})^{0.5} \quad (2)$$

The drain ditches discharges (orchard hillside ditch discharge, grass water way discharge) Q_D ($m^3.s^{-1}$) were calculated with help of the Manning's empirical velocity formula and equation continuity. For Q_D ($m^3.s^{-1}$) is valid:

$$Q_D = S_D \frac{1}{n} R^{(2/3)} I_D{}^{0.5} \quad (3)$$

where S_D (m^2) represents water profile of the drain ditch, n ($m.s^{-1/3}$) is Manning's roughness coefficient, R(m) is hydraulic radius and I_D (-) is the slope of the bottom of ditch. In Table 2 are presented the values of some selected parameters of n ($m.s^{-1/3}$), recommended by Manning.

The runoff flow rate, respectively the recharge Q_R ($m^3.s^{-1}$) to the open drain ditch from the corresponding area S_d (m^2) situated above the ditch, was calculated by "intensity formula" in a shape

$$Q_R = S_d .r.o \quad (4)$$

where r ($m.s^{-1}$), respectively o (–), is the rainfall intensity of typhoon, respectively runoff coefficient.

Runoff flow rate, respectively the recharge Q_R ($m^3.s^{-1}$) can be also approximated with use of rainfall-runoff models as KINFIL, HECRAS or WBCM (Kovář, 2005), (Štibinger, 2009) which need, besides their special calibration of models, different hydrological data and information.

RESULTS

The hydraulic function of the soil conservation and some selected rain harvesting structures built up in orchard at Sufen, Tahu District, Miaoli County (Taiwan), under the extreme hydrological conditions, developed by Typhoon Herb, was evaluated by the elementary numerical experimental calculations of the orchard surface flow velocity and by comparison of discharge and recharge at the orchard hillside ditch.

Value of coefficient N (sec^{-1}) = 15.0 for the surface at orchard at Sufen was determined by Table 1.

Value of the runoff coefficient o (–) = 0.25 for the same environment was estimated from the topography conditions, soil properties and surface vegetation of the orchard at Sufen with use of ČSN 75 65 01 (2004), Morgan and Rickson (1995) and Holý et al. (1994a). The maximum value of the surface slope is I = 27.0%, so I = 0.27 (–). Design rainfall intensity r = 115 ($mm.hour^{-1}$) = $3.2.10^{-5}$ ($m.s^{-1}$) was determined as a maximum recorded heavy rainfall intensity of Typhoon Herb, which was measured on 31 July 1996 at 5 p.m. This data are the results of the hourly rainfall analysis over 14 consecutive hours from the records of Mount A-li station Mount A-li in Central Taiwan.

Orchard surface flow velocity

Flow velocity, respectively the velocity v ($m.s^{-1}$) of the runoff, which was caused by Typhoon Herb in the conditions of orchard at Sufen, was calculated by equation (2). Symbol x (M) in the right part of equation represents the length of the slope in its horizontal projection (see Figure 3).

Because of layout of soil conservation and rain harvesting structures in orchard at Sufen is maximum length of slope in its horizontal projection 18 m, so x = 18 m. The values of the other parameters as N (s^{-1}), o (–), I (–) and r ($m.s^{-1}$) are presented above.

By equation (1) was also calculated y (M), that is a height of the water above the surface at the corresponding distance x (M).

For x = 18 m (the horizontal projection of the maximal distance between the orchard hillside ditches at Sufen (see Figure 3) was calculated v = 0.033 ($m.s^{-1}$) and y = 0.0042 m = 4.2 mm.

Tab. 3: Calculated hypothetical runoff velocities v ($m.s^{-1}$) and corresponding hypothetical water heights y (mm) developed by Typhoon Herb – orchard at Sufen, Tahu District, Miaoli County (Taiwan)

x (m)	V (m/s)	y (mm)
10	0.025	3.2
20	0.035	4.5
50	0.056	7.2
100	0.080	10.0
200	0.110	14.3
1500	0.300	39.2
3000	0.430	55.5

Hypothetical velocities v ($m.s^{-1}$) and their hypothetical corresponding heights y (mm) of water flow for the various values x (m) calculated by equation (2), respectively by equation (1) for y (mm), in the conditions of orchard at Sufen, are presented in the Table 3.

From the results of long term research of Research Institute for Soil and Water Conservation (RISWC) Prague-Zbraslav (Holý et al., 1994) the maximum allowed velocity v_A ($m.s^{-1}$) for the soils derived from sandstone and shale, with dens grass on the surface, can be expressed by value v_A ($m.s^{-1}$) = 0.7.

Velocity flow calculated by equation (2) v = 0.033 ($m.s^{-1}$) is definitely smaller then allowed velocity v_A ($m.s^{-1}$) = 0.7. Is valid v = 0.033 ($m.s^{-1}$) < < < 0.7 ($m.s^{-1}$) = v_A. Now is evidently clear, that orchard at Sufen, where maximum of x = 18 m, is successfully protected against erosion processes which could be developed by negative impacts of Typhoon Herb.

Orchard hillside ditch – discharge and recharge

The maximum ditch discharge Q_{Dmax} ($m^3.s^{-1}$), when orchard hillside ditch is full up water, was calculated by equation (3). Hydraulic radius R (m) was calculated from expression $R = W_D/O_D$, where W_D (m^2) is a water profile of full up water hillside ditch. At this case, if the orchard hillside ditch be full up water, can be W_D (m^2) approximated as $W_D = 0.25\ m^2$. Symbol O_D (m) represents wetted perimeter and at this case is O_D = 2.75 m. Then R = 0.25 m^2/2.75 m = 0.091 m. If I_d = 0.01 (see part MATERIALS AND METHODS, Land use and rain harvesting structures) and n = 0.035 $m.s^{-1/3}$ (see Table 2), so by equation (3) the maximum of ditch discharge is: $Q_{Dmax} = W_D\ (1/n).\ R^{0.666} \times I_D^{0.5} = 0.25 \times (1/0.035) \times 0.091^{0.666} \times 0.01^{0.5} = 0.1446\ m^3.s^{-1}$. The maximum of ditch discharge is $Q_{Dmax} = 0.1446\ m^3.s^{-1} = 144.6\ l.s^{-1}$.

The runoff flow rate, which was developed by Typhoon Herb, respectively the recharge Q_R ($m^3.s^{-1}$) to the orchard hillside ditch from corresponding area S_d (m^2) situated above the ditch, was calculated by "intensity formula", represented by equation (4), where r = $3.2.10^{-5}$ ($m.s^{-1}$), respectively o = 0.25 (–), is the rainfall intensity of Typhoon Herb, respectively runoff coefficient of orchard at Sufen (see the beginning of the part RESULTS – CALCULATED VALUES of this article). The value of area S_d (m^2) was approximated as S_d = 1296.0 m^2 (see part MATERIALS AND METHODS, Land use and rain harvesting structures).

Then by (bb) we get for recharge to the ditch $Q_R = S_d \times r \times o = 1296.0 \times 3{,}2.10^{-5} \times 0.25 = 0.01037$ ($m^3.s^{-1}$) = 10.37 ($l.s^{-1}$), so Q_R = 0.01037 ($m^3.s^{-1}$) = 10.37 ($l.s^{-1}$). Q_R < < Q_D. The comparison Q_R = 10.37 ($l.s^{-1}$) <<< Q_{Dmax} = 144.6 ($l.s^{-1}$) shows, that recharge Q_R = 0.01037 ($m^3.s^{-1}$) =

10.37 ($l.s^{-1}$) from Typhoon Herb to the ditch is definitely much more smaller (more than one row) then the potential maximum of ditch discharge Q_{Dmax} = 0.1446 ($m^3.s^{-1}$) = 144.6 ($l.s^{-1}$). This fact shows, that is possible to say, that orchard hillside ditches were able to remove surface runoff water from Typhoon Herb and protected the slope-land orchard at Sufen against flooding. By the same principles was estimated the flow capacity of the grass water way ditch, with its parabolic shape and concrete material. By hydraulic calculations, which were run in the same style as in a case of orchard hillside ditch estimation, was demonstrated, that also the grass water way is able to remove the water from surface runoff of Typhoon Herb to the link road, which can be used also for drainage purpose and which can transport the water by gravity to the pond, serving as a water reservoir situated down the slope land orchard at Sufen (see Figure 1).

DISSCUSION

From the results of calculations, where recharge of Typhoon Herb Q_R = 0.01037 ($m^3.s^{-1}$) <<< maximum of hillside ditch discharge Q_{Dmax} = 0.14460 ($m^3.s^{-1}$), and from the values of the basic design parameters of hillside ditch system (drain spacing L = 18 m, width of ditch bottom is 2.5 m) it seems, that all rain harvesting system is, from the intensity runoff point of view, slightly overdesigned, even for the such type of hydrological extreme, which is represented by Typhoon Herb.

On the other hand, Taiwan unfortunately goes under the countries where is the presence of large hydrological extremes as stormy rainfalls, typhoons, tropical cyclones, etc. very frequent. Let exist certain probability that during close future can come in Taiwan some typhoon, which will be much more hydraulically aggressive and more watery then Typhoon Herb.

From this facts, mentioned above, results, that the land use, soil conservation, erosion control and rain harvesting structures (integrated surface drainage and irrigation system) in orchard at Sufen, Tahu District, Miaoli County, Taiwan is ready to solve also the hydrological extremes, which will be greater then Typhoon Herb.

CONCLUSIONS

Typhoon Herb, which affected Taiwan during 31 July and 1 August 1996, is typical example of typhoons, which are devastating Taiwan 3–4 times per year. Typhoon Herb, with its extremely big amount of rain, made a few devastating landslides (e.g. debris flow along the New – Central Cross – Island Highway) took 70 lives and caused damage to agriculture and industry in course of 0.25 billion of US dollars.

Slope land orchard at Sufen, Tahu District, Miaoli County, Northern Taiwan situated very close to the track of Typhoon Herb (see Figure 2) remained saved and was not even destroyed in no way. Land use, soil conservation, erosion control and rain harvesting structures that means integrated surface drainage and irrigation system in orchard at Sufen protected this area against negative impacts of Typhoon Herb very well. This reality was verified by elementary experimental hydraulic and hydrologic calculations, which confirmed correctness and efficiency of projected and realized land uses with rain harvesting structures in orchard at Sufen under the activity of Typhoon Herb that means in extremely difficult hydrological conditions.

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REFERENCES

ČSN 75 61 01 (2004): Stokové sítě a kanalizační přípojky (Sewer systems and drains), ČR.

Havlík V., Marešová I. (1998): Hydraulika I. Příklady. ČVUT Praha, FS, Vydavatelství ČVUT Praha, ČR; ISBN 80-01-01162-3.

Holý M. a kol. (1994). Eroze a životní prostředí. ČVUT Praha, FS, Vydavatelství ČVUT Praha, ISBN 80-01-01078-3ČR.

Chun-Chieh Wu, Ying-Hwa Kuo (1999): Typhoons Affecting Taiwan: Current Understanding and Future Challenges. Bulletin of the American Meteorological Society, 80 (1): 67–80.

Kovář P. (2005): Simulation of land use impact on significant rainfall-runoff events. Scientia Agriculturae Bohemica, 36 (4):147–151.

Morgan R.P C., Rickson R.J. (1995): Slope Stabilization and Erosion Control: A Bioengineering Approach. Silsou College, Cranfield University, UK; ISBN 0 419 15630 5.

SWCB (2001): Soil conservation and erosion control measures in orchard at Sufen (Tahu District, Miaoli County, Taiwan. Project of 2nd Engineering office of Soil and water conservation Bureau (SWCB) and the Council of Agriculture Taiwan, Taipei, Taiwan, Republic of China.

ŠTIBINGER J. (2001): Soil conservation in orchard at Sufen (Tahu District, Miaoli County, Taiwan). Papers from ICLPST, Taoyuan, Taiwan. The 84th Regular Session on Land Tenure and Rural Development, Dept. of Land Use and Improvement, Faculty of Environmental Sciences, CULS Prague, ČR.

ŠTIBINGER J. (2009): Odhad drenážních odtoků a jejich vliv na odtokové poměry v krajině. Stavební obzor 1: 18–23. ČVUT Praha FS, ČKAIT, ČSSI, fakulta stavební VUT Brno, fakulta stavební VŠB-TU Ostrava; ISSN 1210 – 4027.

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