Apply GIS to Explore Analysis of Raining Storage in Community －A Case Study for Tao-Yuan High-speed Railroad District

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ABSTRACT

Land-used have a largely percent impervious cover in city environment. Impervious surfaces cause local decreases in infiltration, percolation and soil moisture storage, reductions in natural interception and depression storage and increases in runoff. More rigorous parameters of raining storage, as a result of recent green building evaluation of Taiwan, are increasingly supplement to system management rather than traditional procedures.

Based on those researches, this study developed a simulation GIS framework and procedures for a screening drainage impact assessment for urban watershed, and applied it to the case of Tao-Yuan high-speed railroad district, a new town of Taiwan.

A generic conceptual model was developed and a set of key indicators was selected: impervious areas, rational formula, surface runoff, flood frequency, return period, rainfall, land use control regulation etc.

This latter point illustrates some zoning control should be revised that can be seen in the affects of flood damage and the other objectionable features.

KEY WORDS: G.I.S, Community Raining Storage, Runfall.

1. INTRODUCTION

The process that urbanalization causes new hydrology of the city and cause the original city a great deal of earth's surface is produced the runfall. This phenomenon causes the flooding of the city and lack raining storage the soil of the city. It is also indirect to cause urban heat island effects.

Aim at this problem government has been promoting the concept of green building aggressively over these few years, an among those items is the index of site water retention.（The Ministry of Interior constructs the institute,2001） Its target lies

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in the increment infiltration the soil of the city. But the index sign of this valuation with single building is foundation, can't be applicable to big region of the scope. Main reason lies in its control the programming the principle, therefore the one base management is a lord, comparing mutually in environment of big dimensions of the city, not whole consideration.

This text is to applies the geography information system to come to inquire into the Zoning Control to influence community raining storage the degree. Based on those researches, this study developed a simulation GIS framework and procedures for a screening drainage impact assessment for urban watershed, and applied it to the case of Tao-Yuan high-speed railroad district, a new town of Taiwan.

So this study main purpose is：

（1）Apply the geography information system to come to inquire into the community raining storage.

（2）Make use of the geography information system the first step of the simulation result

2.Build community raining storage model

This stanza is according to domestic and related cultural heritage and laws, put forward related type of the analysis of community raining storage, carry on the research.

2.1.Community raining storage and rainfall analyze the method

Community raining storage must the factor of the consideration is numerous. Now we make the discussion respectively：

2.1.1.percentage of impervious area

Percentage of impervious areas (IMP) is impervious surface area occupies to watershed area. In urban areas, every kinds of land use have its own impervious characteristic, which IMP could calculate by:

$$I = (\frac{A_p}{A}) \times 100\% = (\frac{\sum_{i=1}^{n} P_i \times A_i}{A}) \times 100\% \text{ --- [2-1]}$$

I：percentage of impervious area（% ）
A_p：total areas of impervious surface in the urban
A：urban areas
P_i：a ratio of impervious surface in every kinds of land use
A：areas of every kinds of land use

Which indicates that Ap is total areas of impervious surface in the urban, A is urban areas, Pi is a ratio of impervious surface in every kinds of land use, Ai is

areas of every kinds of land use. That can be Influence percentage of impervious area including Zoning Control, population density.

2.1.2.Index of Site Water Retention

Aim at this problem government has been promoting the concept of green building aggressively over these few years, an among those items is the index of site water retention, which the index of site water retention could calculate by:

$$\lambda = \frac{\text{開發後基地保水量} Q'}{\text{原土地保水量} Q_0} = \frac{\sum_{i=1}^{8} Q_i}{A_0 \times k \times t} \geq \lambda = 0.8 \times (1.0 - \tau) \quad \text{----------[2-2]}$$

λ ：the Index of Site Water Retention.
Q' ：sum total of after developping site water retention (m^3).
Q_i：sum total of Site Water Retention (m^3).
Q_0：At first Site Water Retention (m^3)，$Q_0 = A_0 \times k \times t$.
A_0：areas of Site (m^2).
k：infiltration of Site (m / s)，less then 10^{-7} m/s.
t：It is biggest to rain time continuously (s)，1985～1994 year the biggest to rain time continuously is 1584500 sec(44 hr) in Taipei.
λ_c：Basis of the Index of Site Water Retention.
γ：building coverage.

2.1.3. The total surface runoff

The total surface runoff (QT) is estimated by three kinds of situation, rainfall flow (Q1), drainage flow (Q2), and surface flow (Q3) from other areas.

$$Q_T = \sum_{i=1}^{3} Q_i \quad \text{----------} \quad [3\text{-}3]$$

QT：The total surface runoff
Q1：the peak flow in *T* return years (m^3/sec.)
Q2：the drainage flow of every kinds of land use
Q3：another point of total surface runoff

2.1.4. Rainfall flow

Rainfall flow (Q1), mean the peak flow in T return years (m3/sec.), is calculated by where IT is rainfall intensity on T return years (mm/hr); A, is areas of watershed (km2). C is the coefficient of runoff surface flow; similarly, it could instead of percentage of impervious areas (IMP).

$$Q_1 = 0.278 \times C \times I_T \times A \quad \text{-------} \quad [3\text{-}4]$$

Q_1：rainfall intensity on T return years (m^3/sec.)
C：the coefficient of runoff surface flow
I_T：rainfall intensity on T return years (mm/hr)
A：areas of watershed (km^2)

2.1.5. Rainfall Intensity

According to volume of rain of Tao-yuan. The year of the base is average to rain the quantity for 1781.4(mm)。

$$\frac{I_t^T}{I_{60}^{25}} = (G + H\log T)\frac{A}{(t+B)^c} \quad \text{---------- [3-5]}$$

$$I_{60}^{25} = (\frac{P}{25.29 + 0.094P})^2 \quad \text{---------- [3-6]}$$

$$A = (\frac{P}{-189.96 + 0.31P})^2 \quad ; \quad B=55$$

$$C = (\frac{P}{-381.71 + 1.45P})^2 \qquad G = (\frac{P}{4289 + 1.33P})^2$$

$$H = (\frac{P}{-6533 + 183P})^2$$

式中，T：return years (year)

t：It is biggest to rain time continuously (min)

I_t^T：rainfall intensity on T return years (mm/hr)

I_{60}^{25}：rainfall intensity on 25 return years (mm/hr)

P：The year is average to decline the volume of rain (mm)

A、B、C、G、H：Coefficient

2.1.6. The drainage flow of every kinds of land use

Besides rainfall flow, the other is drainage flow (Q2) that come from human activities and calculates by every kinds of land use.

Q2, it means the drainage flow of every kinds of land use (m3/ hr). A is the areas of each black (m2); FAR is floor areas ratios (%); α is a ratio for effective flooring use of total floor use areas on the block (%); β is the average consumption water of each person in an hour (l/person hour); γ is a coefficient for average persons per unit of floor area of each kinds of land use (person/m2).

$Q_2 = A \times FAR \times \alpha \times \beta \times \gamma$ ----------[3-7]

Q_2：the drainage flow of every kinds of land use (m^3/hr)

A：the areas of each black (m^2)

FAR：floor areas ratios (%)

α：a ratio for effective flooring use of total floor use areas on the block (%)

β：the average consumption water of each person in an hour (l/人時)

γ：a coefficient for average persons per unit of floor area of each kinds of land use (人/m^2)

2.1.7. Another point of total surface runoff

Meanwhile, surface flow (Q3) is another point of total surface runoff that should analyze the partial flow from upper watershed (η). This could be written by Q3=(Q1+Q2)×η. When we simulate the rainfall intensity on T return years and

calculate total surface runoff (QT) then over the areas of each floodplain, which it is the flood depth.

Q_3：$(Q1+Q2)\times \eta$ ----------[3-8]

Q_3：another point of total surface runoff

Q_1：rainfall intensity on T return years(m^3/s)

Q_2：the drainage flow of every kinds of land use (m^3/hr)

η：the partial flow from upper watershed

3.Apply the community raining storage mode in the geography information system

This stanza is main to discuss how to applied the community raining storage in GIS and simulation analysis of the rainfall and water circulation. Also construct the area of the emulation through GIS of urban stormwater drainage and watershed to simulation the community raining storage that has characteristic and appearance.

In a new town like Tao-Yuan high-speed railroad district, there are 490 hectares surrounding with the farmland in the north of Taiwan. Till now, it just in the planning stage without any development in those areas, thus, it could be a better case to simulate coexistent relationship of zoning control with urban microclimate. These representative rainfall floods was then employed in geographical information system (GIS) consisting of building information to rainfall spatially all over the study areas.

3.1.Basic data establishes

Figure 1 illustrates the modeling area of the simulation and the area of Tao-Yuan high-speed railroad district. The topography of site is flat. The average slope of site is 3% from southwest to east north, and three rivers cross the district from south to north. The model utilized the block system along with planning map. Zoning control codes simulated detailed building information.

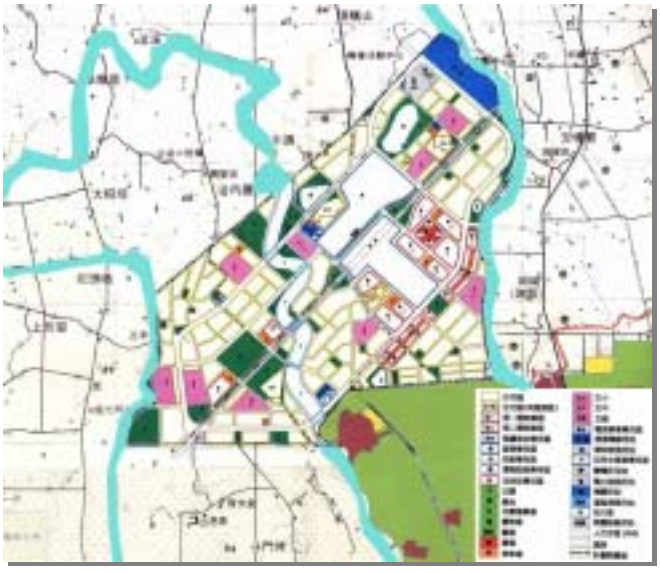


Fig. 1 The simulation area --- Tao-Yuan high-speed railroad district.

3.1.1.Zoning control

Table 1 Zoning control

Zoning control	Area（ha）	building coverage	floor areas ratios	Zoning control	Area（ha）	building coverage	floor areas ratios
Residential district	157.84	50%	200%	Game field(Urban parks)	4.9	---	---
Commercial district	31.19	60-70%	240-300%	Stadium(other Organization)	4.89	50%	200%
high-speed railroad district(Railway station)	19.68	---	---	Square(other Organization)	1.07	---	---
land of Property(Railway station)	21.9	40-50%	240%	Park way(Railway station)	0.3	---	---
Gas station(other Organization)	0.48	40%	80%	Irrigate with ground(other Organization)	2.28	---	---
land of Religion(other Organization)	2.13	---	---	Parking(other Organization)	4.81	80%	400%
land of drinking water(other Organization)	1			elementary school(School)	12.02	40%	120%
land of Telecommunication(other Organization)	1.14	50%	250%	high school(School)	9.36	40%	120%
River	32.93	--	---	Senior high school(School)	3.72	40%	120%
Appropriation in Irrigate with ground(other Organization)	8.13	---	---	Organization	1.79	50%	250%
				metroland(other Organization)	12	20%	50%
Road	104.7			land of environmental(other Organization)	4.2	---	---
other high-speed railroad district(Railway station)	7.53	---	---	land of the electricity(other Organization)	1.15	50%	150%
park(Urban parks)	29.18	5%	---	The facilities of the electric power(other Organization)	0.12	---	---
Greenly(Urban parks)	9.56	---	---				
Total of area	490ha						

The source of the data：Taiwan Provincial Government,1999，"***Plan of Tao-Yuan high-speed railroad district***".

Table 2 Zoning control of Percentage of pervious area

Zoning control	Residential district	Commercial district	Railway station	Urban parks	School	Organization	other Organization	River	Road	Total of area
Area（ha）	157.84	31.19	39.21	38.74	25.1	1.79	58.5	32.93	104.7	490

The source of the data：The sorting of this research

3.1.2.Build Tao-Yuan high-speed railroad district of CAD

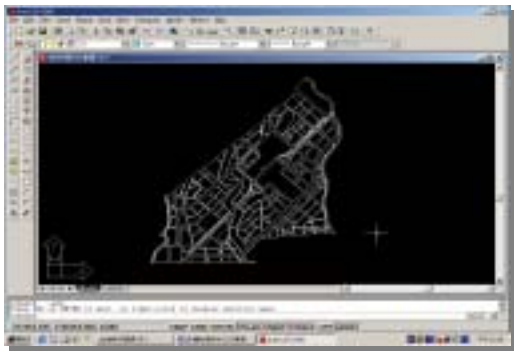


Fig. 2 Cad data --- Tao-Yuan high-speed railroad district.

3.1.3.Volume of rain

Table 3 weather bureau Taoyuan stands data in 2001

Month	1	2	3	4	5	6	7	8	9	10	11	12
the volume of rain (mm)	157.5	34	150	156.5	179	48.5	162	48.5	998.5	10.5	7	23.5
evaporate the quantity mm(120cm)	42.8	40.9	53.1	14.8	22.7	44.1	6.4	10.3	7.5	81	2.9	46.7

The source of the data：weather bureau Tao-yuan stands data http://www.cwb.gov.tw

Table 4 weather bureau Taoyuan stands data in 2002

Month	1	2	3	4	5	6	7	8	9	10	11	12
the volume of rain (mm)	39	60.5	170.5	22.5	101	32	161	57	104.5	47	—	—
evaporate the quantity mm(120cm)	47.4	54.1	50.8	73	77.6	107.7	136.9	111.7	116.2	68.9	—	—

The source of the data：weather bureau Tao-yuan stands data http://www.cwb.gov.tw

3.2.Community Raining Storage mode establishes

Fig. 3 Drain the system

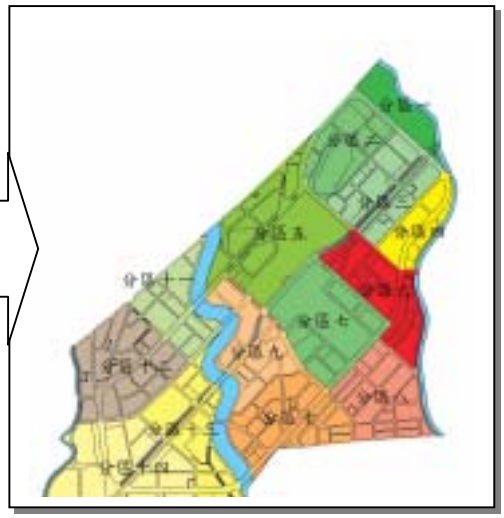
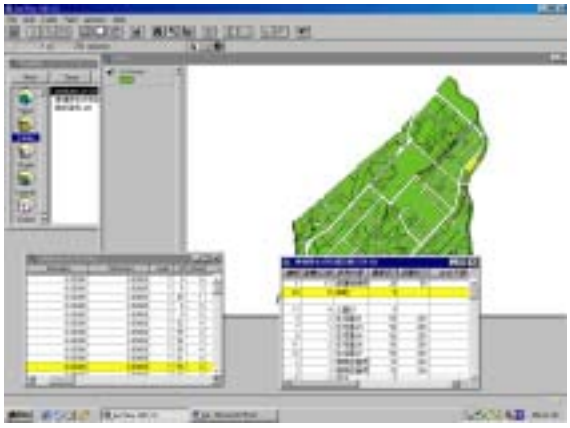


Fig. 4 14 cent District

Figure 3 is divide the line base as 14 cent district according to drain the system, like figure 4. Last simulation the community raining storage mode according to figure 4.

step 1-Basic data turns into Digital data



step 2- Digital data turns into GIS data

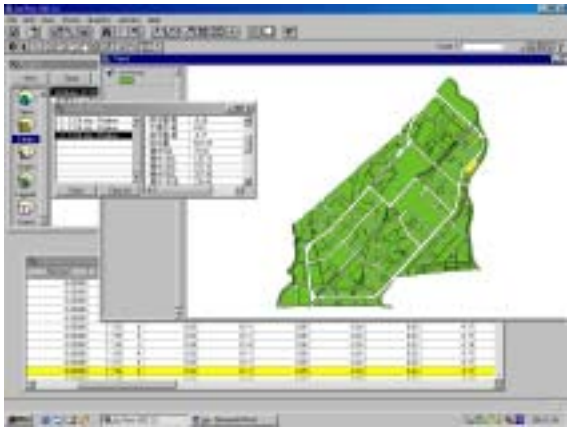


Table 5. All Zoning control data in Tao-Yuan high-speed railroad district

ENTITY	LAYER	ELEVATI	THICKNE	ID	面積(公頃)	使用分區	建蔽率(%)	容積率(%)	不透水-領	保水差-領	不透水-初	保水差-初	用水量	積水5後	積水10後	積水25後
Polyline	0	0.00000	0.00000	0	0.66	商業區13	60	300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polyline	0	0.00000	0.00000	6	0.65	商業區14	60	300	0.86	-0.30	0.63	-0.14	1021.20	48.46	85.37	103.82
Polyline	0	0.00000	0.00000	49	1.04	商業區18	60	300	0.81	-0.22	0.70	-0.18	79.20	93.97	226.39	292.60
Polyline	0	0.00000	0.00000	0	1.06	商業區19	60	300	0.85	-0.24	0.63	-0.17	527.70	70.74	126.00	153.63
Polyline	0	0.00000	0.00000	0	0.54	自來水專用區	70	240	0.85	-0.24	0.63	-0.17	527.70	70.74	126.00	153.63
Polyline	0	0.00000	0.00000	52	0.54	停車場06	100		0.86	-0.30	0.63	-0.14	1021.20	48.46	85.37	103.82
Polyline	0	0.00000	0.00000	55	0.28	兒童０４	5		0.85	-0.24	0.63	-0.17	527.70	70.74	126.00	153.63
Polyline	0	0.00000	0.00000	54	0.24	兒童０３	5		0.85	-0.24	0.63	-0.17	527.70	70.74	126.00	153.63
Polyline	0	0.00000	0.00000	60	0.44	兒童０５	5		0.85	-0.24	0.63	-0.17	527.70	70.74	126.00	153.63
Polyline	0	0.00000	0.00000	61	2.54	住宅區87	50	200	0.86	-0.30	0.63	-0.14	1021.20	48.46	85.37	103.82
Polyline	0	0.00000	0.00000	56	2.61	住宅區88	50	200	0.86	-0.30	0.63	-0.14	1021.20	48.46	85.37	103.82
Polyline	0	0.00000	0.00000	18	1.77	住宅區89	50	200	0.86	-0.30	0.63	-0.14	1021.20	48.46	85.37	103.82
Polyline	0	0.00000	0.00000	17	1.93	住宅區93	50	200	0.85	-0.24	0.63	-0.17	527.70	70.74	126.00	153.63
Polyline	0	0.00000	0.00000	0	0.78	住宅區94	50	200	0.86	-0.30	0.63	-0.14	1021.20	48.46	85.37	103.82
Polyline	0	0.00000	0.00000	0	0.78	住宅區95	50	200	0.86	-0.30	0.63	-0.14	1021.20	48.46	85.37	103.82
Polyline	0	0.00000	0.00000	0	2.3	住宅區90	50	200	0.78	-0.24	0.64	-0.17	533.10	32.60	81.88	106.52

4.Case simulation and result

4.1.percentage of impervious area

4.1.1. Data of Tao-Yuan high-speed railroad district（The assumption is for land before developping）

桃園市分區(1區)	總面積(公頃)	法定建蔽率	不透水率	不透水面積(
機關	0	50%	50%	
學校用地	0	40%	40%	
商業區	0	70%	70%	
高鐵車站特定區	12	70%	70%	8.4
其他公共設施	0	80%	80%	
住宅區	0	50%	50%	
公園綠地	0.22	5%	5%	0.011
自然地面區		0%		
人工地面區	0.66	0%	100%	0.66

4.1.2. Data of Tainan（The assumption is for land after developping）

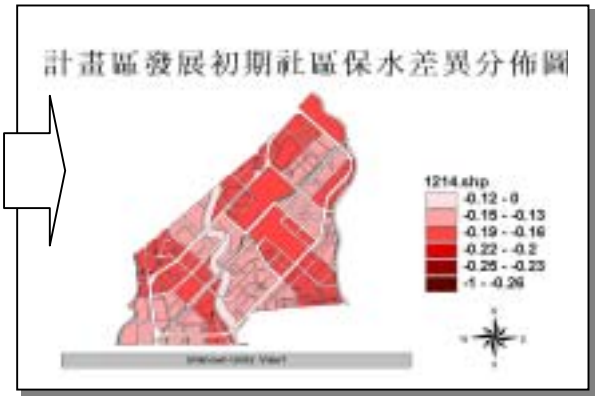
台南市分區(1區)	總面積(公	法定建蔽率	不透水率	不透水面積(公頃)
機關	0	50%	91%	
學校用地	0	40%	68%	
商業區	0	70%	100%	
高鐵車站特定區	12	70%	81%	9.72
其他公共設施	0	80%	81%	
住宅區	0	50%	86%	
公園綠地	0.22	5%	36%	0.0792
自然地面區		0%		
人工地面區	0.66	0%	100%	0.66
12.88	12.22		0.8120	

Consequently, community through after developping the percentage of impervious area increment 0.2-0.22, display because the urbanalization turns to make the community percentage of impervious area increment.

4.2. Index of Site Water Retention

4.2.1. Data of Tao-Yuan high-speed railroad district（The assumption is for land before developping）

台南市分區(1區	總面積(公頃	開發後區域流	開發區域流	入(基地流	入d(目標流	基地流
機關	0	0	0	0	08	0
學校用地	0	0	0	0	08	0
商業區	0	0	0	0	08	-08
高鐵車站特定區	12	1901	191	1	08	02
其他公共設施	0	0	0	0	08	0
住宅區	0	0	0	0	08	0
公園綠地	022	0084	0084	1	08	02
自然地面區		0	0	0	08	-08
人工地面區	066	0104	0104	1	08	02
1288	1222	0226	0226	0333	08	-0111



4.2.2. Data of Tainan（The assumption is for land after developping）

機關	0	0	0	0	04	0
學校用地	0	0	0	0	048	0
商業區	0	0	0	0	024	-024
高鐵車站特定區	12	0571	191	03	024	006
其他設施	0	0	0	0	016	0
住宅區	0	0	0	0	04	0
公園綠地	022	0033	0084	005	076	019
自然地區		0	0	0	08	-08
人口地區	066	0	0104	0	08	-08
1288	1222	0067	0225	0138	0475	-0176

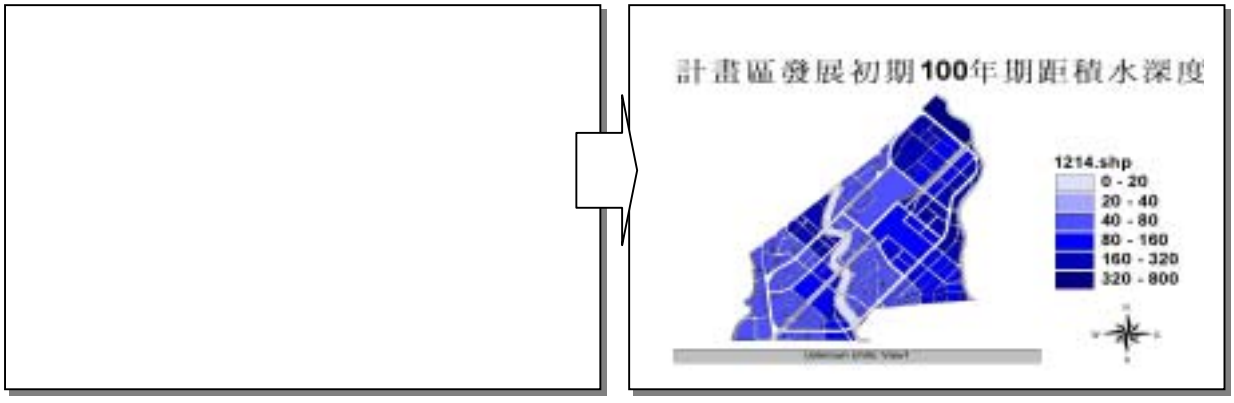
Find through emulation, because under the influence of the factitiousness develop, the earth's surface spreads and artificial thing of the facilities is right alone of increment, community index of site water retention reduces. Half lands reduce 0.26 above, other reduce 0.23-0.25.

4.3.Flooding height

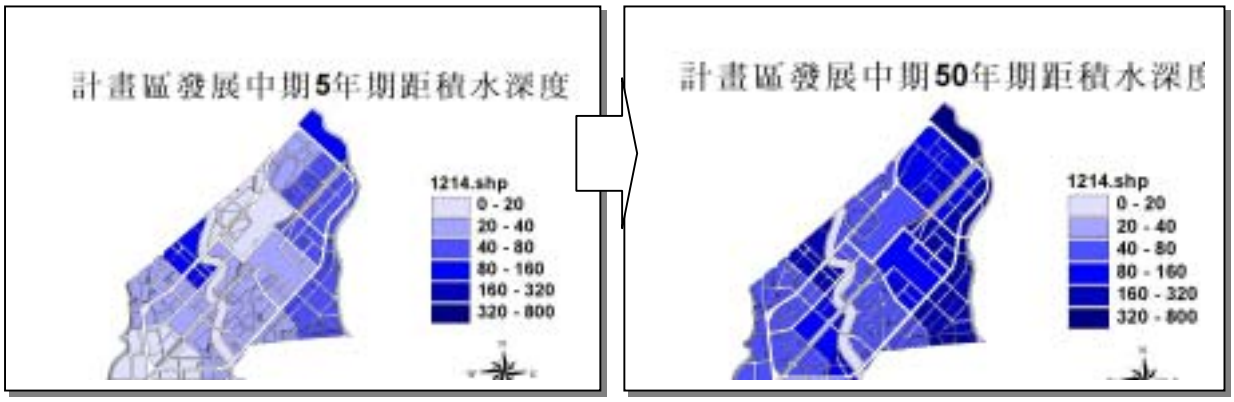
Table 6. Flooding height

初期發展情況(以桃園為例)			降雨逕流									
分區	面積(km2	平均C值	降雨量	下水道排水量	逕流量Q1	用水量 Q2 (m3/sec)	基地排水小計	上游流域排入水量	總逕流量 QT	積水深度 cm	尖峰小時之總逕流量	尖峰小時之積水深度 cm
1	0.1288	0.70427	0.630435	0.2472	0.383232	0.02	0.40523	3.157211	3.562443	0.28	12824.794	995.714
2	0.2634	0.64306	1.1772	0.4616	0.715603	0.15	0.8637	1.8442	2.707904	0.10	9748.455	370.101
3	0.3146	0.63635	1.391355	0.5456	0.845785	0.28	1.12948	1.313011	2.442486	0.08	8792.950	279.496
4	0.1611	0.63057	0.706016	0.2768	0.429177	0.15	0.57576	1.313011	1.888775	0.12	6799.591	422.073
5	0.5339	0.71335	2.646977	1.0379	1.609059	0.24	1.8442		1.8442	0.03	6639.120	124.351
6	0.2885	0.72478	1.453245	0.5698	0.883407	0.15	1.03762	2.626021	3.663639	0.13	13189.101	457.161
7	0.4215	0.76460	2.239846	0.8783	1.36157	0.30	1.66036	0.965664	2.626021	0.06	9453.677	224.287
8	0.3056	0.60687	1.288947	0.5054	0.783532	0.35	1.12885	1.342447	2.471301	0.08	8896.684	291.122
9	0.2768	0.62077	1.194219	0.4683	0.725948	0.24	0.96566		0.965664	0.03	3476.392	125.592
10	0.3614	0.66198	1.662718	0.6520	1.010742	0.33	1.34245		1.342447	0.04	4832.808	133.725
11	0.236	0.53593	0.879036	0.3447	0.534353	0.17	0.70137	1.61141	2.312779	0.10	8326.006	352.797
12	0.4161	0.63957	1.849569	0.7252	1.124326	0.49	1.61141		1.61141	0.04	5801.077	139.415
13	0.3354	0.53646	1.250514	0.4903	0.760169	0.02	0.78107	1.629372	2.410443	0.07	8677.594	258.724
14	0.4851	0.62498	2.107101	0.8262	1.280877	0.35	1.62937		1.629372	0.03	5865.738	120.918

4.3.1. Data of Tao-Yuan high-speed railroad district（The assumption is for land before developping）



4.3.2. Data of Tainan（The assumption is for land after developping）



Find through emulation, community flooding height probability increment.

5.Conclusion and suggestion

5.1.Conclusion

5.1.1.Build apply the community raining storage mode in the geography information system

Through this research, make use of the mode of community raining storage to geography information system, in turning to present by sense of vision.

5.1.2.Geography information system the first step imitates the result

Find according to emulation, plan the area that increment of percentage of impervious area and decrease of index of site water retention all in same area. And big part of usage of land in the area of these cents is commercial district and organization. Show the influence of the Zoning Control to influence the community raining storage.

5.2.Suggestion

The index sign of this valuation with single building is foundation, can't be applicable to big region of the scope. SO build the community raining storage that applicable to big region of the scope. And promote effectively infiltration of the district of the city. Reduce percentage of impervious area of the earth's surface of the city.

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REFERENCES

Brun,S.E.;Band,L.E.,2000,"***Simulating runoff behavior in an urbanizing watershed Computers, Environment and Urban Systems***"Volume:24,Issue:1,pp.5-22

Chang, Hsiao-Tung;Chen-Hsin-Lee,2002,"***Strategies and issues for raining storage zoning for community sustainability-A case study for Tao-Yuan high-speed railroad district***",Science of the district masters.

Chang-Chou-Tsang,2001,"***Experimental analysis in the relation between the performance of soil water contention and surface runoff in urban are***a",National Cheng Kung University.

Engineering adviser incorporated company,2001, "***Plan of Tao-Yuan high-speed railroad district***"

Lenzi,M.A.;Di Luzio,M.,1997 "***Surface runoff, soil erosion and water quality modelling in the Alpone watershed using AGNPS integrated with a Geographic Information System***" *European Journal of Agronomy* Volume:6,Issue:1-2,pp.1-14

Liao-ming-chang;Huang-Chih-Hung,2002,"***Quantifying the Mechanism of Infiltration of Precipitation in Urban Areas***",Architectural institute of the republic of china.

LUM,2001,"***INVESTIGATION AND ANALYSIS ON THE PERFORMANCE OF PERMEABILITY IN URBAN ENVIRONMENT OF TAIPEI CITY***",National Cheng Kung University.

Taiwan Provincial Government,1999，"***Plan of Tao-Yuan high-speed railroad district***".

The Ministry of Interior constructs the institute,2001,"***Green building explains and evaluates the manual*** ",The Ministry of Interior constructs the institute.

Tzu-Ping Lin,2002,"***A Study on Urban Water Cycle—The Investigation on the Percentage of Imperviousness and the Experimental Analysis of Surface Runoff***",National Cheng Kung University,

Tzu-Ping Lin;Hsien-Te Lin;LEE JEN-HAO,2001,***"the research on the performance of raining storage in building site in Tainan***",Architectural institute of the republic of china.

Wiliam M.Marsh,2002,"***Planning and application the landscape of the environment***",Landscape Planning-Environmental Applications.

Xu, Ming-Xi,1996,"***Drain the project***",The base programs the introduction.