集水區水文

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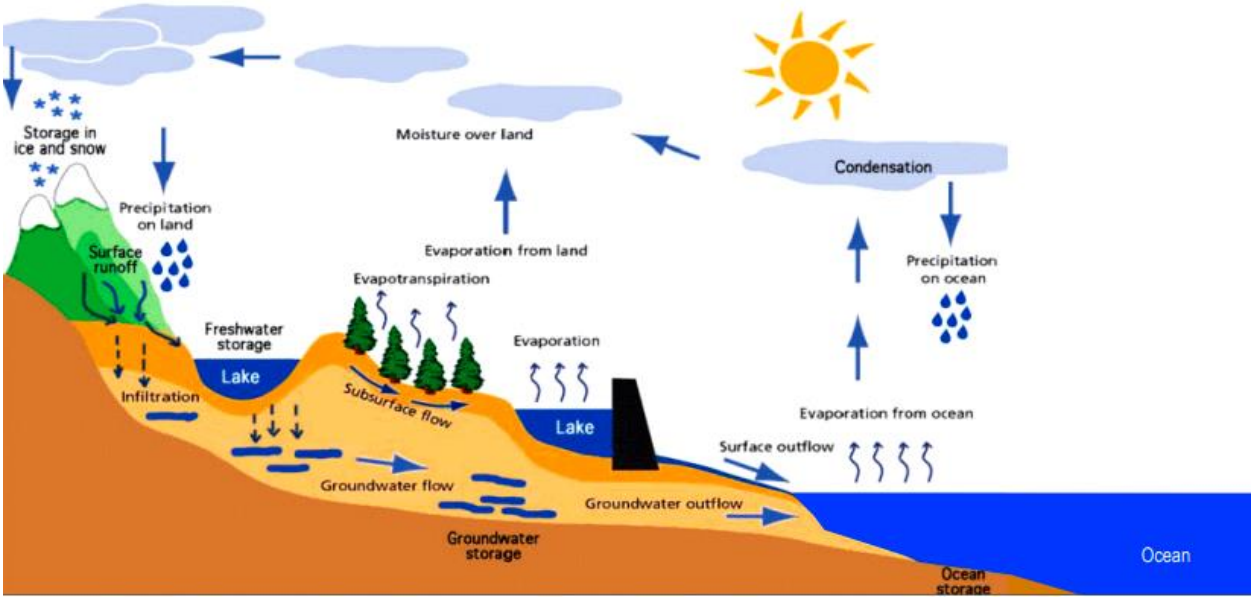
基礎水文學

水文循環

地球上的水文循環可由海洋中水的蒸發作用開始說明。

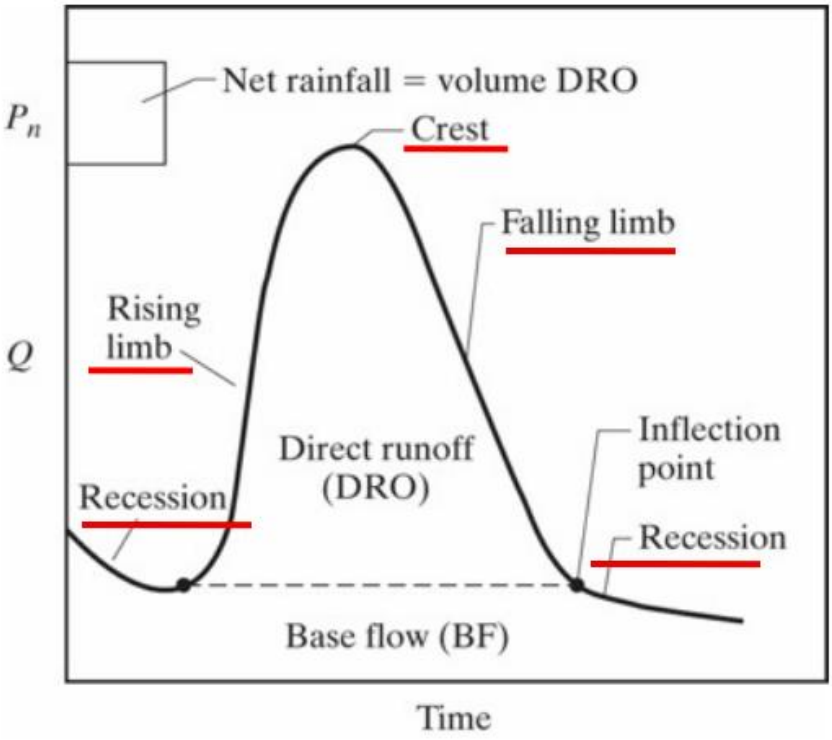
海洋中的水吸收太陽輻射能量之後，由液態水轉變成氣態的水氣，經由空氣運動輸送至陸地上，再經過凝結作用變為雨、雪等降水形式降落至地面。



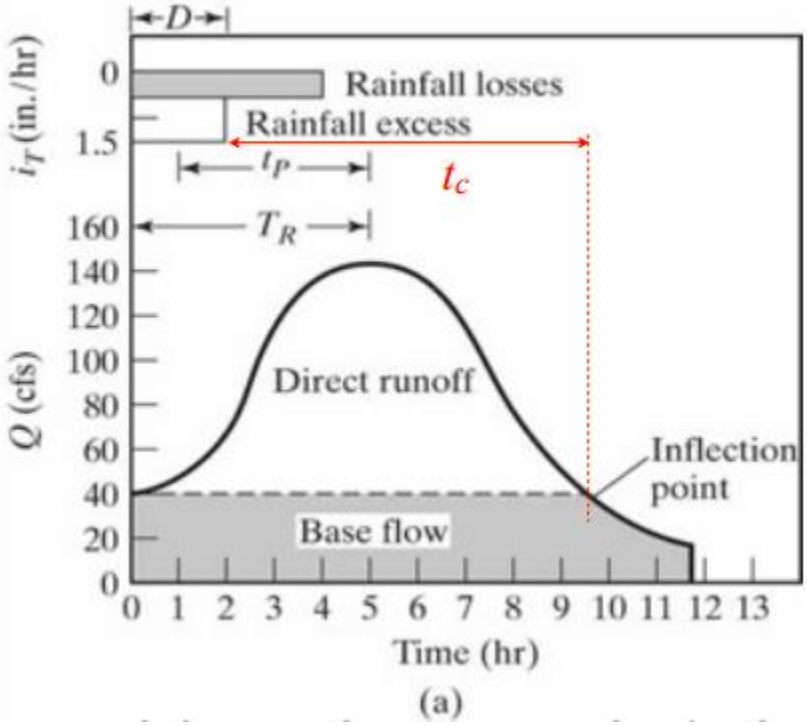
逕流 Runoff 是指雨水或是冰雪融化後的水流經地表產生的水流。

直接逕流 = 觀測河川流量 － 基流

基流 Baseflow 是河道中常年存在的部分徑流。枯季河流所能維持的最小水流，由於枯水季節流域降水補給已終止或甚少，因此基流主要是由地下水補給。



Timing parameters



(a)

面平均降雨 Areal Precipitation

流域平均雨量又叫面雨量，是整個區域內單位面積上的平均降水量，能較客觀地反映整個區域的降水情況。

算術平均法

將流域內各雨量站記錄累加再以站數除之，因未考慮水文站控 制範圍及地形變化與海拔高，準確性差。

徐昇氏法

徐昇多邊形法（Thiessen's Polygon Method）是將 N 個相鄰之測站以直線兩兩相連，形成多個三角形(Delaunay or Voronoi triangulation)，然後由三連線之中垂線求得三角形之外心(Circumcnter)，連接與測站相鄰之所有三角形外心就構成徐昇多邊形法。

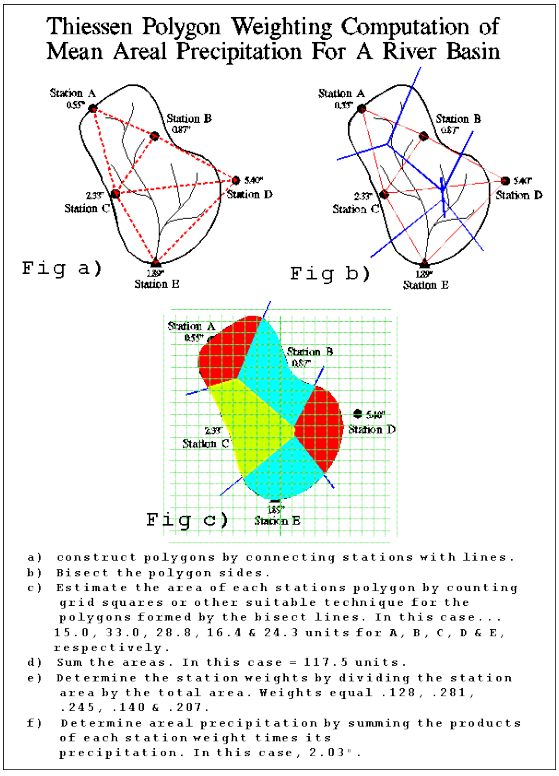
$$\overline{P} = \frac{\sum_{i=1}^{n} P_i A_i}{\sum_{i-1}^{n} A_i}$$

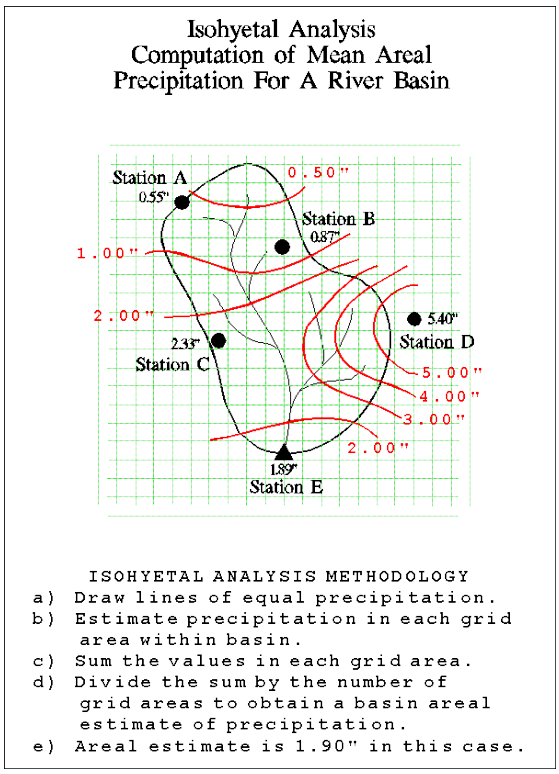
等雨量線法

計算面雨量的一種方法。根據區域內外各站的雨量資料， 繪製等雨量線圖, 然後計算區域平均雨量。

優點：等雨量線來反映降雨量的實際分布情況， 能更完善地說明地形、地面高程變化及其它影響因素對降雨量空間分布的影響。

缺點：每場降雨的等雨量線的分布都不相同，需繪製大最的等雨星線圖，所以該法工作量甚大，計算成果也會因等雨量線繪製的差異而不同。





單位歷線 Unit hydrograph

單位歷線之假設

1. 有效降雨均勻分佈於某降雨延時內

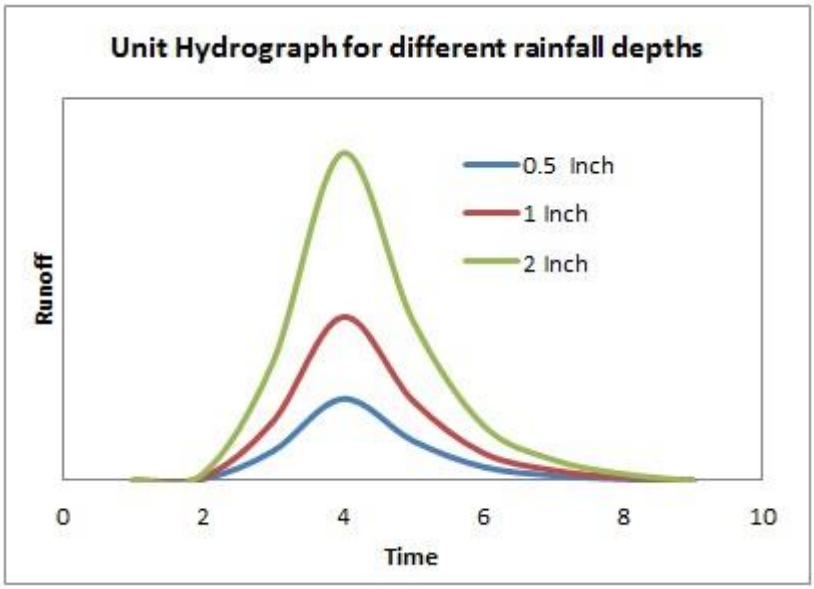
2. 有效降雨均勻分佈於整個集水區

3. 代表該集水區之物理特性

單位歷線之限制

1. 流域面積大於 2000mile2 或 5000km2

2. 由地形引起之雨量變化不適用，因為此種 雨型具有相當之流域特性，如西北雨。



範例 1

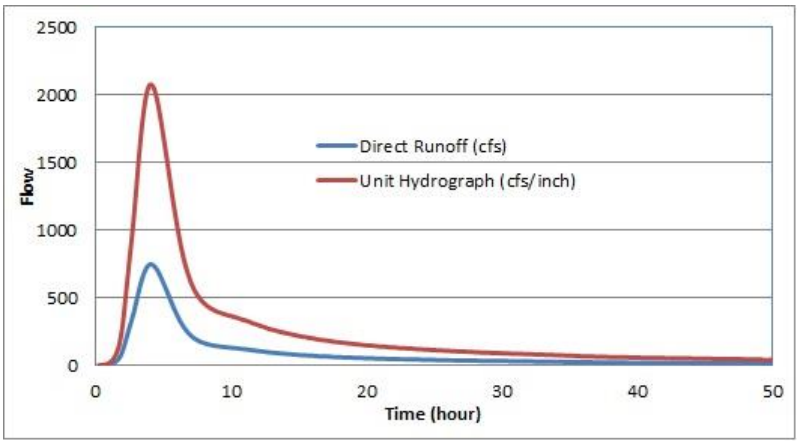
A	B	C	D	E
Date	Time	Excess Rainfall (in)	Direct Runoff (cfs)	
2000/09/25	9:15	0	1.18	
2000/09/25	09 : 30	0.06	1.67	
2000/09/25	09 : 45	0.06	2.87	
2000/09/25	10 : 00	0.06	7.16	
2000/09/25	10 : 15	0.06	15.06	
2000/09/25	10 : 30	0.06	31.05	
2000/09/25	10 : 45	0.06	59.05	
2000/09/25	11 : 00	0.06	114.04	
2000/09/25	11 : 15	0.06	200.04	
2000/09/25	11 : 30	0.06	288.03	
2000/09/25	11 : 45	0.06	373.03	
2000/09/25	12 : 00	0.06	476.02	
2000/09/25	12 : 15	0	582.02	
2000/09/25	12 : 30		667.01	
2000/09/25	12 : 45		724.01	
2000/09/25	13 : 00		748.00	
2000/09/25	13 : 15		741.00	
2000/09/25	13 : 30		710.99	

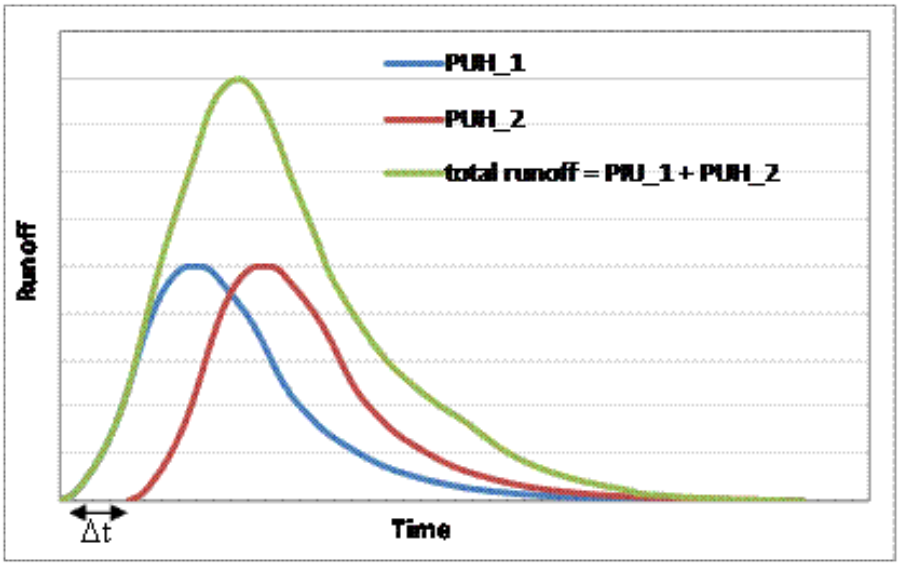
計算直接逕流

Date	Time	Excess Rainfall (in)	Direct Runoff (cfs)
2000/09/25	9:15	0	1.18
2000/09/25	09 : 30	0.06	1.67
2000/09/25	09 : 45	0.06	2.87
2000/09/25	10 : 00	0.06	7.16
2000/09/25	10 : 15	0.06	15.06
2000/09/25	10 : 30	0.06	31.05
2000/09/25	10 : 45	0.06	59.05
2000/09/25	11 : 00	0.06	114.04
2000/09/25	11 : 15	0.06	200.04
2000/09/25	11 : 30	0.06	288.03
2000/09/25	11 : 45	0.06	373.03
2000/09/25	12 : 00	0.06	476.02
2000/09/25	12 : 15	0	582.02
2000/09/25	12 : 30		667.01
2000/09/25	12 : 45		724.01
2000/09/25	13 : 00		748.00
2000/09/25	13 : 15		741.00

Total Direct Runoff Volume = sum(D2:D540)*60*15			
	18383891		cubic feet
Basin Area	21.8		sq. miles
	6.08E+08		sq. ft
Direct runoff depth = volume / area			
	0.030249		ft
	0.36		inch

A	B	C	D	E	F	G
Date	Time	Excess Rainfall (in)	Direct Runoff (cfs)		Unit Hydrograph (cfs/inch)	
2000/09/25	9:15	0	1.18		3.27	
2000/09/25	09 : 30	0.06	1.67		4.64	
2000/09/25	09 : 45	0.06	2.87		=D4/0.36	
2000/09/25	10 : 00	0.06	7.16		19.89	
2000/09/25	10 : 15	0.06	15.06		41.82	
2000/09/25	10 : 30	0.06	31.05		86.26	
2000/09/25	10 : 45	0.06	59.05		164.02	
2000/09/25	11 : 00	0.06	114.04		316.78	
2000/09/25	11 : 15	0.06	200.04		555.66	
2000/09/25	11 : 30	0.06	288.03		800.09	
2000/09/25	11 : 45	0.06	373.03		1036.19	
2000/09/25	12 : 00	0.06	476.02		1322.29	
2000/09/25	12 : 15	0	582.02		1616.72	
2000/09/25	12 : 30		667.01		1852.81	
2000/09/25	12 : 45		724.01		2011.13	
2000/09/25	13 : 00		748.00		2077.79	
2000/09/25	13 : 15		741.00		2058.33	





範例 2:

	Rainfall Hyetograph			Unit Hydrograph	
1					
2					
3	Δt (2.5 hr)	Excess rainfall (inch)		Δt (2.5 hr)	U (cfs/inch)
4	1	0.23		1	3.27
5	2	1.03		2	4.64
6	3	0.13		3	7.96
7				4	19.89
8				5	41.82
9				6	86.26
10				7	164.02
11				8	316.78
12				9	555.66
13				10	800.09
14				11	1688.84
15				12	522.03
16				13	366.33
17				14	282.85
18				15	218.81
19				16	176.99
20				17	149.05

	E	F	G	H	I	J	K	L	M
	Unit Hydrograph			P (inch)	0.23	1.03	0.13		Direct Runoff
	Δt (2.5 hr)	U (cfs/inch)			PUH_1	PUH_2	PUH_3		(cfs)
	1	3.27			=F4*I2				0.75
	2	4.64			1.06784	3.36524			4.43
	3	7.96			1.83144	4.78207	0.42474		7.04
	4	19.89			4.57558	8.20165	0.60356		13.38
	5	41.82			9.61971	20.4906	1.03516		31.15
	6	86.26			19.8388	43.0796	2.5862		65.50
	7	164.02			37.7246	88.8435	5.43723		132.01
	8	316.78			72.8604	168.941	11.2133		253.01
	9	555.66			127.802	326.288	21.3226		475.41
	10	800.09			184.021	572.33	41.182		797.53
	11	1688.84			388.434	824.093	72.2358		1284.76
	12	522.03			120.068	1739.51	104.012		1963.59
	13	366.33			84.2567	537.695	219.549		841.50
	14	282.85			65.0559	377.323	67.8644		510.24
	15	218.81			50.3264	291.337	47.6233		389.29
	16	176.99			40.7072	225.375	36.7707		302.85
	17	149.05			34.2815	182.297	28.4454		245.02
	18	129.44			29.7716	153.522	23.0084		206.30
	19	115.38			26.5385	133.325	19.3765		179.24
	20	101.32			23.3044	118.846	16.8274		158.98

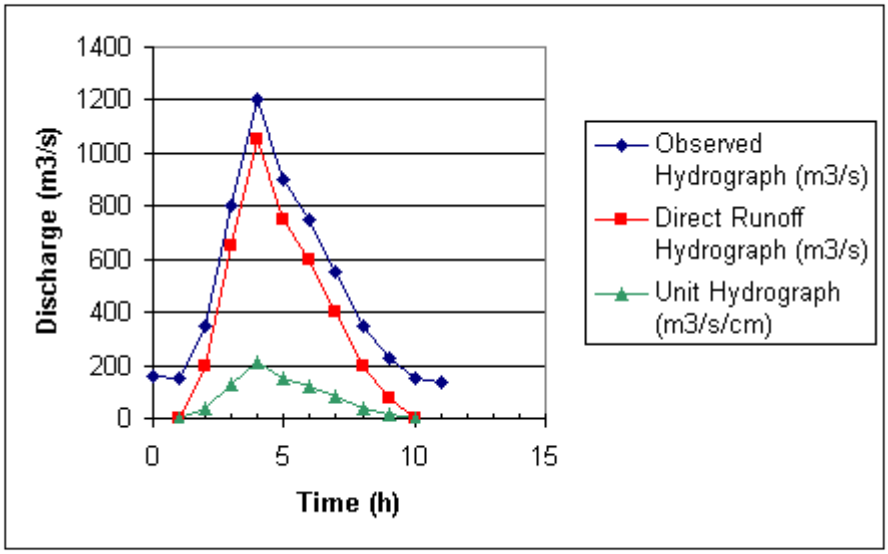
範例 3

1. 單位歷線如下，集水區面積 282.6 km^2

Time (h)	Observed Hydrograph (m^3/s)
0	160
1	150
2	350
3	800
4	1200
5	900
6	750
7	550
8	350
9	225
10	150
11	140

Time (h)	Gross Precipitation (GRH) (cm/h)
0 - 1	0.25
1 - 2	2.75
2 - 3	2.75
3 - 4	0.25

Time (h)	Observed Hydrograph (m^3/s)	Direct Runoff Hydrograph (DRH) (m^3/s)	Unit Hydrograph ($m^3/s/cm$)
0	160	10	--
1	150	0	0
2	350	200	40
3	800	650	130
4	1200	1050	210
5	900	750	150
6	750	600	120
7	550	400	80
8	350	200	40
9	225	75	15
10	150	0	0
11	140	0	0



Time (h)	Effective Precipitation (ERH) (cm/h)
0 - 1	0.0
1 - 2	2.5
2 - 3	2.5
3 - 4	0.0

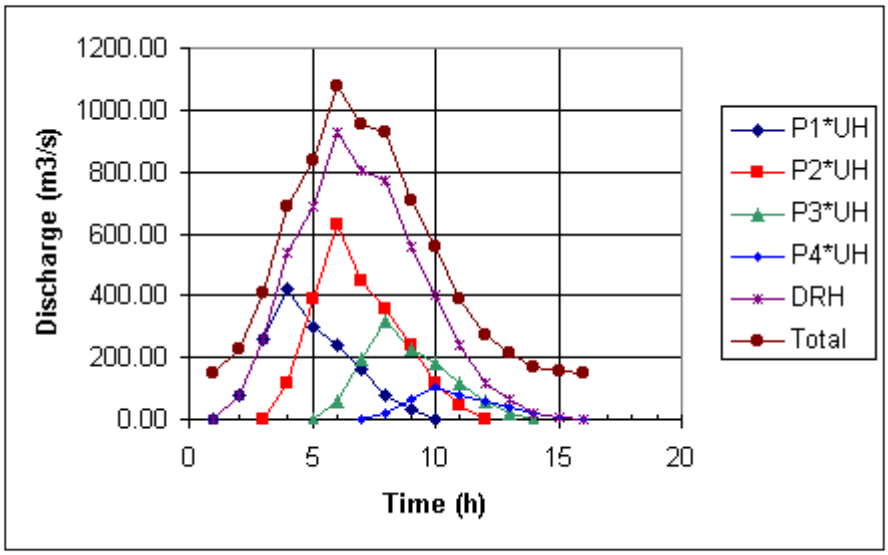
$$Q_n = \sum_{m=1}^{n} P_m U_{n-m+1}$$

Time (h)	Effective Precipitation (ERH)

	(cm/h)
0 - 1	1.0
1 - 2	1.0
2 - 3	1.5
3 - 4	1.5
4 - 5	0.75
5 - 6	0.75
6 - 7	0.25
7 - 8	0.25

Time (h)	P_m (cm)
0 - 2	2.0
2 - 4	3.0
4 - 6	1.5
6 - 8	0.5

	1	2	3	4	5	6	7
Time(h)	UH ($m^3/s/cm$)	P_1*UH (m^3/s)	P_2*UH (m^3/s)	P_3*UH (m^3/s)	P_4*UH (m^3/s)	DRH (m^3/s)	Total (m^3/s)
1	0.00	0.00				0.00	150.00
2	40.00	80.00				80.00	230.00
3	130.00	260.00	0.00			260.00	410.00
4	210.00	420.00	120.00			540.00	690.00
5	150.00	300.00	390.00	0.00		690.00	840.00
6	120.00	240.00	630.00	60.00		930.00	1080.00
7	80.00	160.00	450.00	195.00	0.00	805.00	955.00
8	40.00	80.00	360.00	315.00	20.00	775.00	925.00
9	15.00	30.00	240.00	225.00	65.00	560.00	710.00
10	0.00	0.00	120.00	180.00	105.00	405.00	555.00
11			45.00	120.00	75.00	240.00	390.00
12			0.00	60.00	60.00	120.00	270.00
13				22.50	40.00	62.50	212.50
14				0.00	20.00	20.00	170.00
15					7.50	7.50	157.50
16					0.00	0.00	150.00

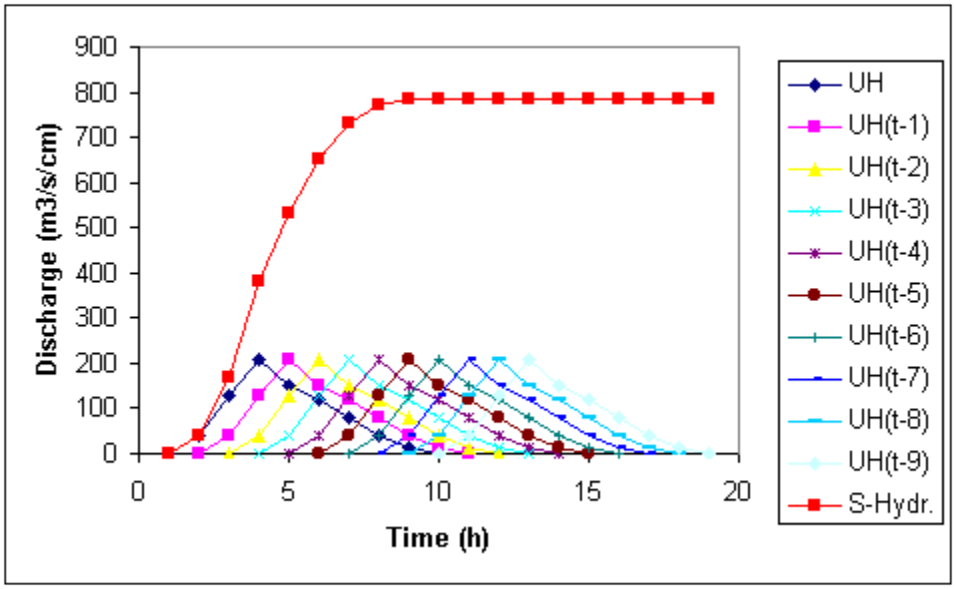


Time (h)	1-H Unit Hydrograph ($m^3/s/cm$)
1	0.00
2	40.00
3	130.00
4	210.00
5	150.00
6	120.00
7	80.00
8	40.00
9	15.00
10	0.00

Time (h)	Effective Precipitation (ERH) (cm/h)
0 - 3	1.0
3 - 6	2.0
6 - 9	1.5

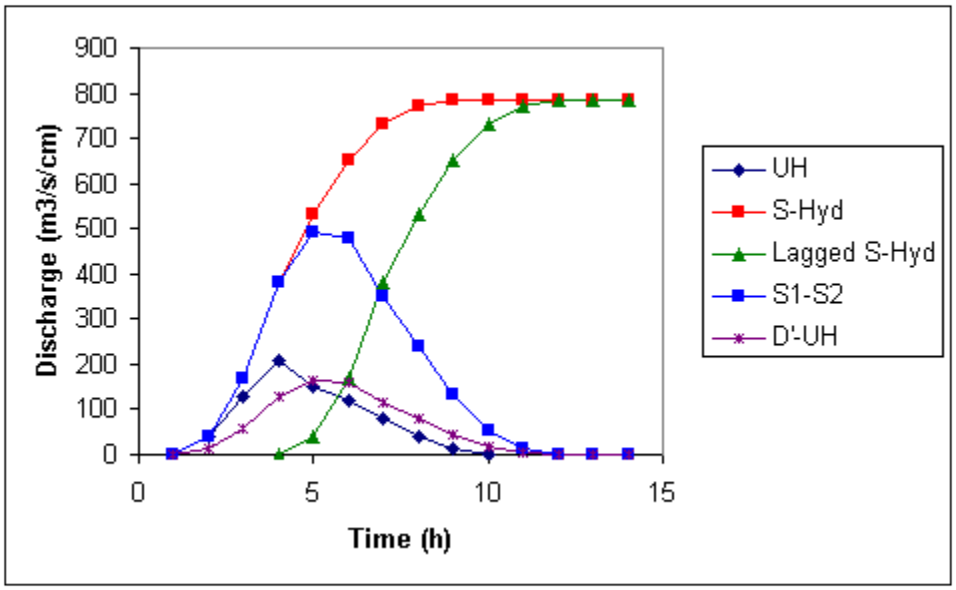
Time (h)	UH ($m^3/s/cm$)	UH(t-1) ($m^3/s/cm$)	UH(t-2) ($m^3/s/cm$)	UH(t-3)	UH(t-4) ($m^3/s/cm$)	UH(t-5) ($m^3/s/cm$)	UH(t-6) ($m^3/s/cm$)	UH(t-7) ($m^3/s/cm$)	UH(t-8) ($m^3/s/cm$)	UH(t-9) ($m^3/s/cm$)	S-Hydr. ($m^3/s/cm$)
1	0										0

2	40	0									40
3	130	40	0								170
4	210	130	40	0							380
5	150	210	130	40	0						530
6	120	150	210	130	40	0					650
7	80	120	150	210	130	40	0				730
8	40	80	120	150	210	130	40	0			770
9	15	40	80	120	150	210	130	40	0		785
10	0	15	40	80	120	150	210	130	40	0	785
11		0	15	40	80	120	150	210	130	40	785
12			0	15	40	80	120	150	210	130	785
13				0	15	40	80	120	150	210	785
14					0	15	40	80	120	150	785
15						0	15	40	80	120	785
16							0	15	40	80	785
17								0	15	40	785
18									0	15	785
19										0	785



	1	2	3	4	5
Time (h)	1-h UH (m^3/s/cm)	S-Hyd (m^3/s/cm)	Lagged S-Hyd (m^3/s/cm)	S1-S2 (m^3/s/cm)	D'-UH (m^3/s/cm)
1	0	0		0	0

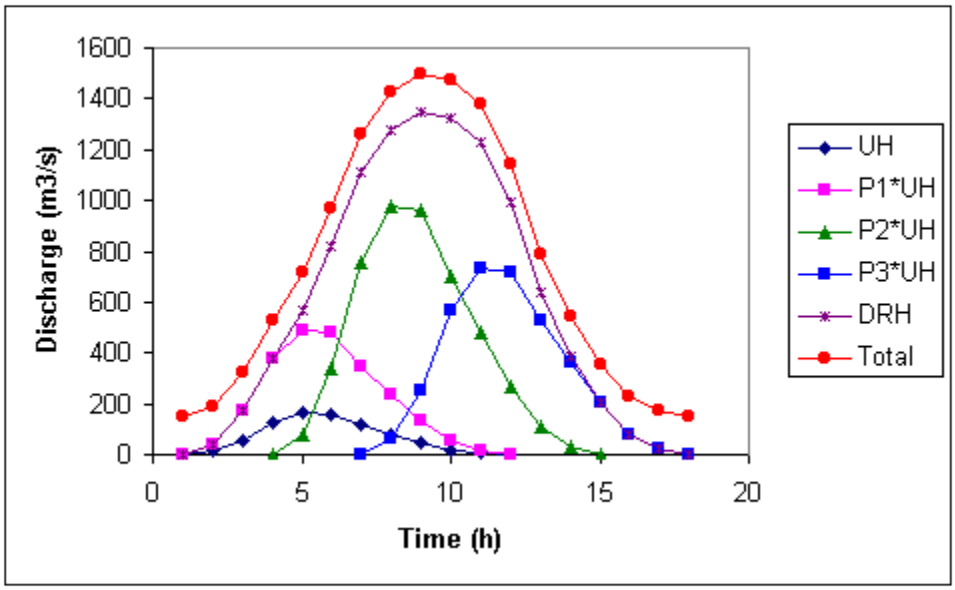
2	40	40		40	13.33333
3	130	170		170	56.66667
4	210	380	0	380	126.6667
5	150	530	40	490	163.3333
6	120	650	170	480	160
7	80	730	380	350	116.6667
8	40	770	530	240	80
9	15	785	650	135	45
10	0	785	730	55	18.33333
11		785	770	15	5
12		785	785	0	0
13		785	785	0	0
14		785	785	0	0



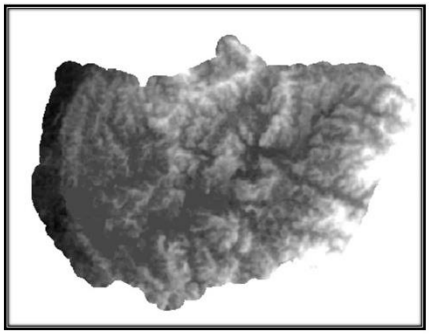
Time (h)	P_m (cm)
0 - 3	3.0
3 - 6	6.0
6 - 9	4.5

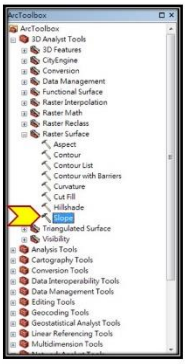
	1	2	3	4	5	6
Time(h)	UH ($m^3/s/cm$)	P_1*UH (m^3/s)	P_2*UH (m^3/s)	P_3*UH (m^3/s)	DRH (m^3/s)	Total (m^3/s)

1	0	0			0	150
2	13.33333	40			40	190
3	56.66667	170			170	320
4	126.6667	380	0		380	530
5	163.3333	490	80		570	720
6	160	480	340		820	970
7	116.6667	350	760	0	1110	1260
8	80	240	980	60	1280	1430
9	45	135	960	255	1350	1500
10	18.33333	55	700	570	1325	1475
11	5	15	480	735	1230	1380
12	0	0	270	720	990	1140
13			110	525	635	785
14			30	360	390	540
15			0	202.5	202.5	352.5
16				82.5	82.5	232.5
17				22.5	22.5	172.5
18				0	0	150

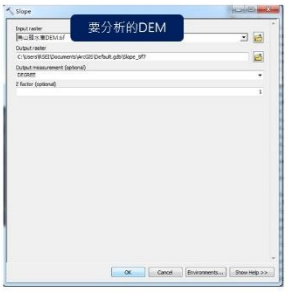


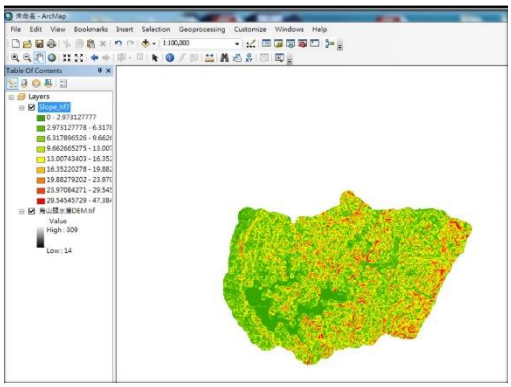
GIS創建集水區

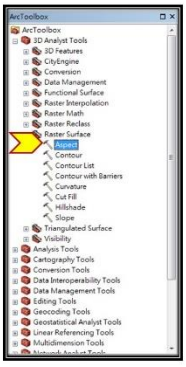




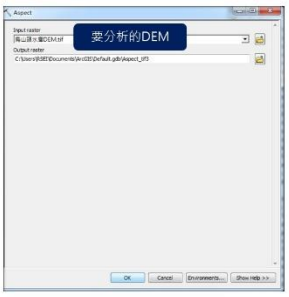
坡度Slope

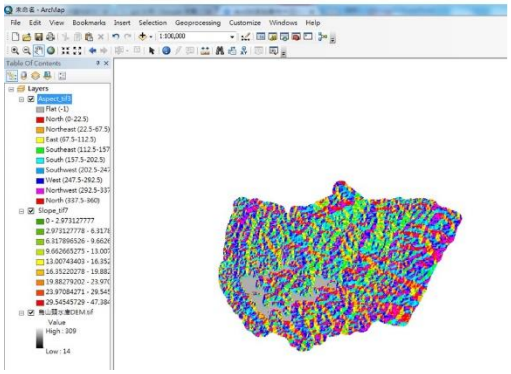






坡向Aspect

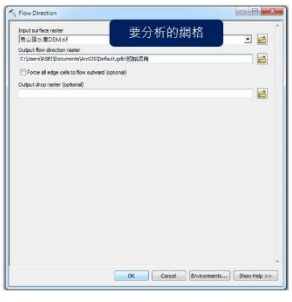


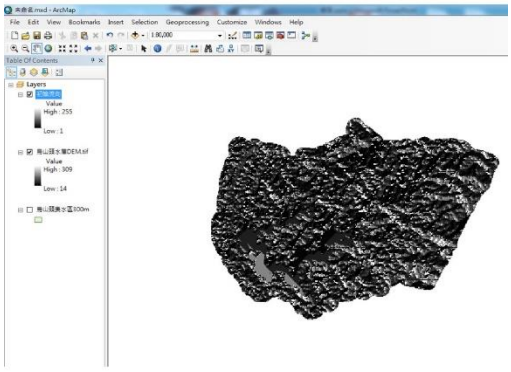


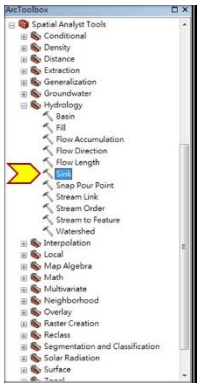
無窪地DEM處理

* 將DEM填滿窪地

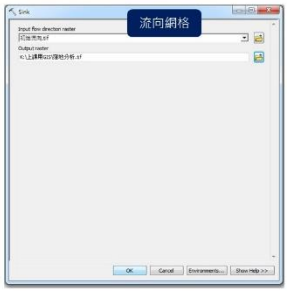
水流方向 Flow Direction

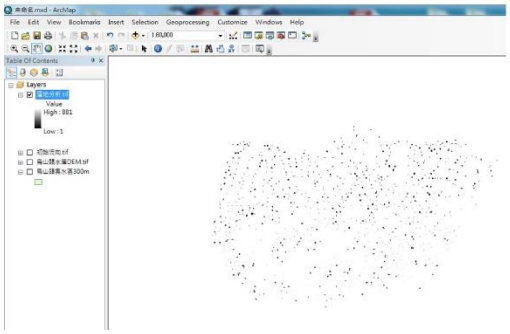




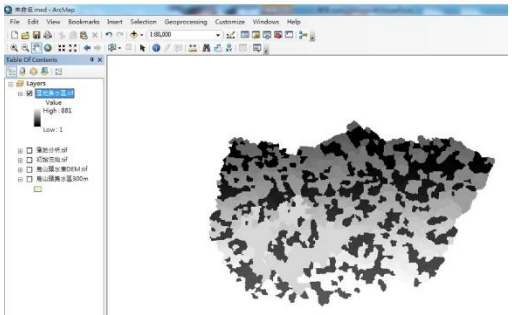


窪地分析



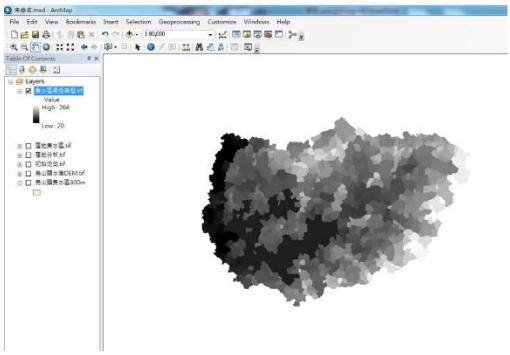


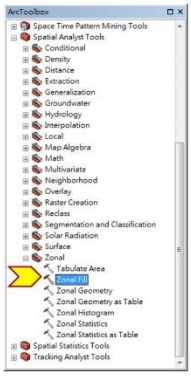
窪地集水區分析



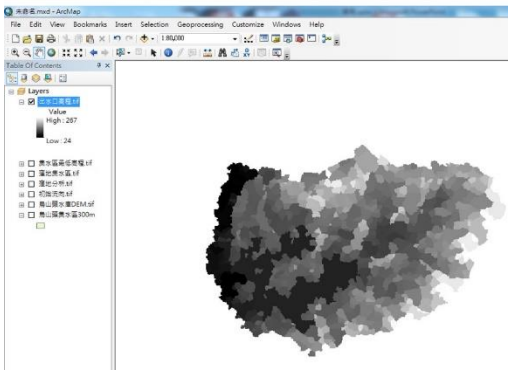
* 黑色區塊=流向窪地的集水區

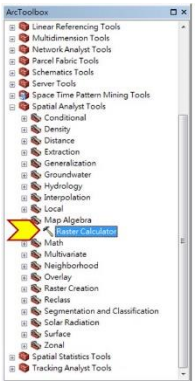
窪地集水區最低高程



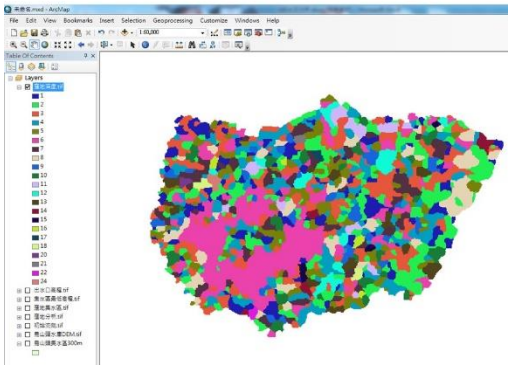


出水口最小計算

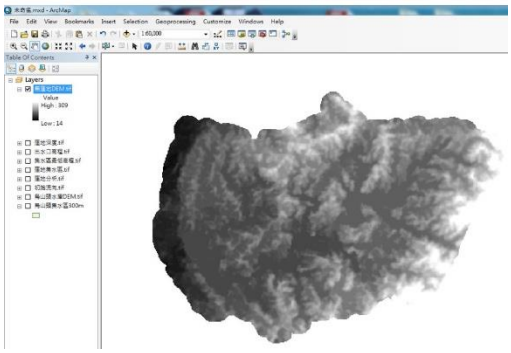




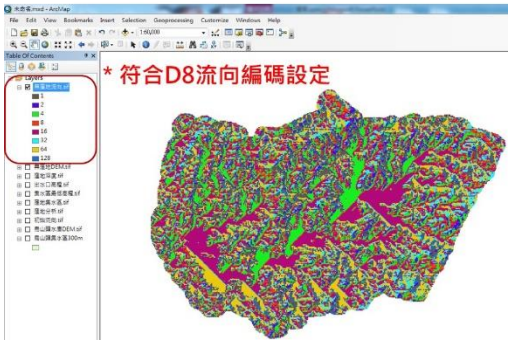
窪地深度



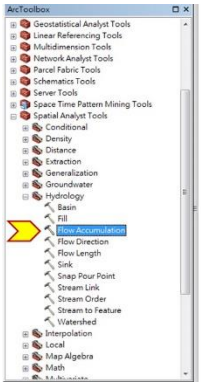
窪地填充



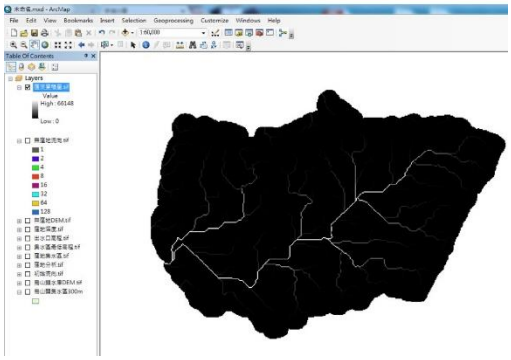
無窪地DEM流向

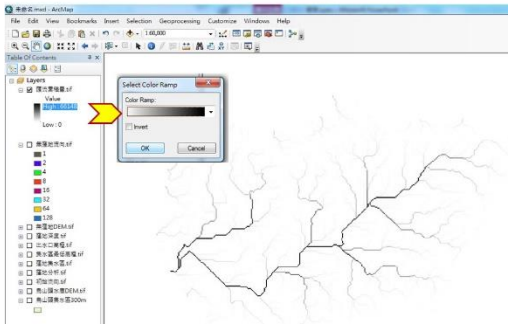


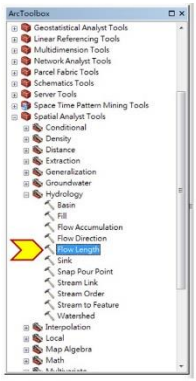
匯流累積量及水流長度分析



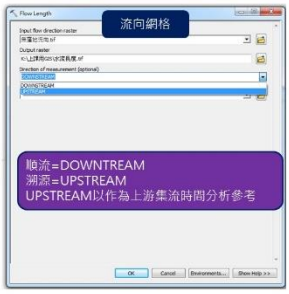
匯流累積量

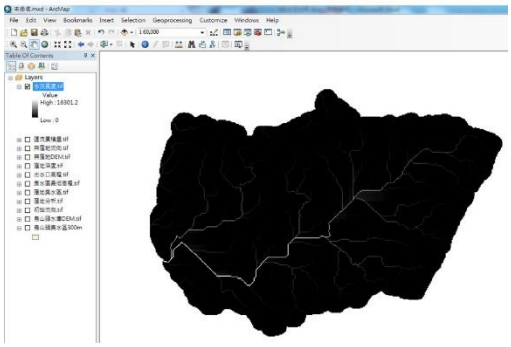




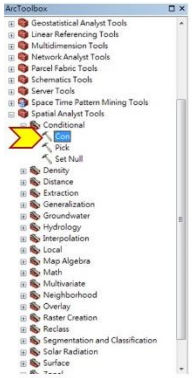


水流長度分析

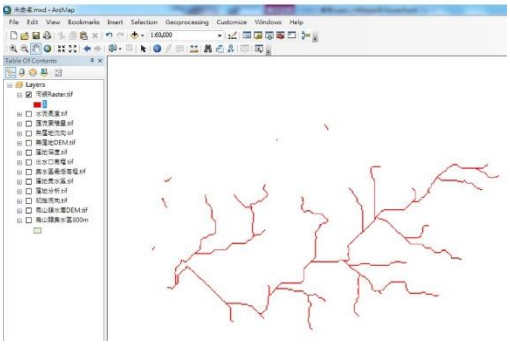


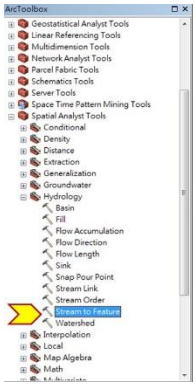


河川網絡分析

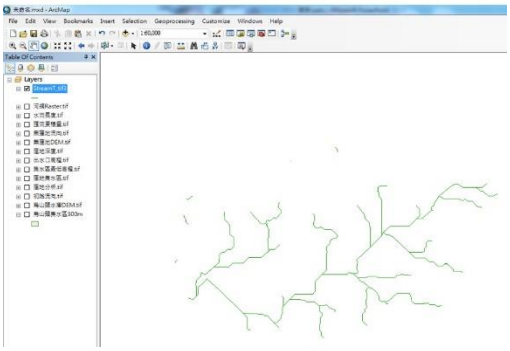


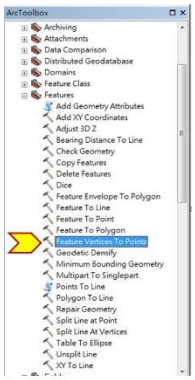
河網萃取



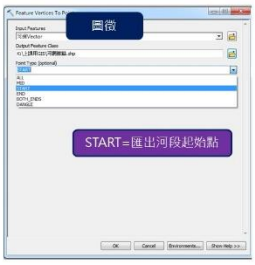


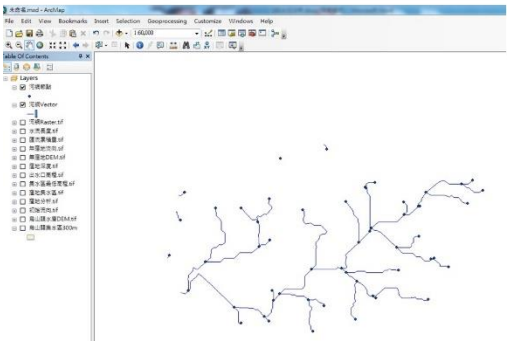
河網網格轉線段圖徵



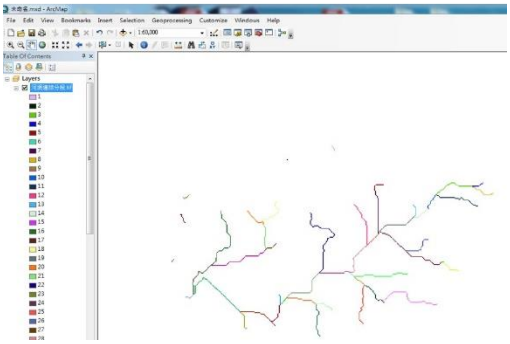


畫出節點

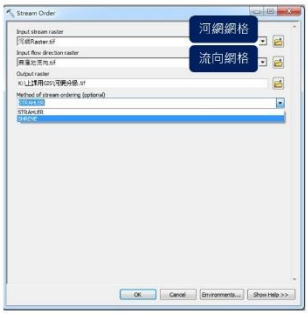


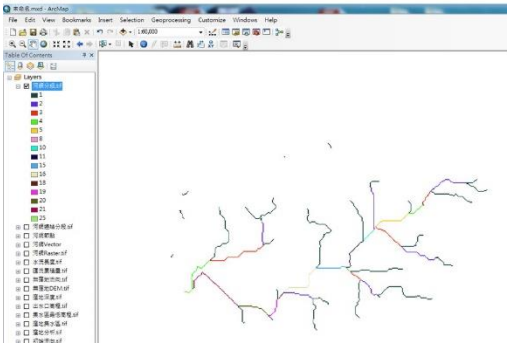


河網連結分段



河段分級

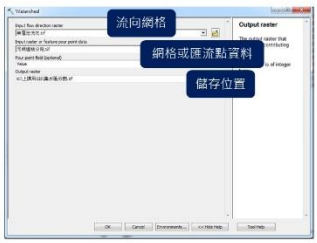


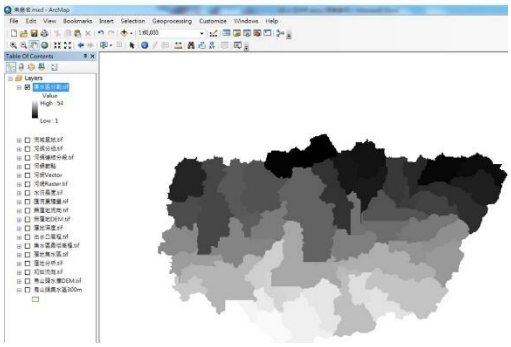


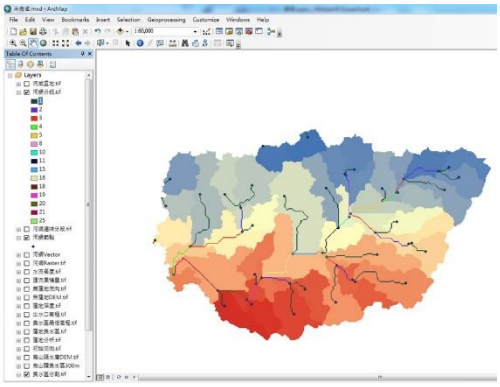
流域分析

集水區分割


ArcToolbox
Editing Tools
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Multidimension Tools
Network Analyst Tools
Parcel Fabric Tools
Schematics Tools
Server Tools
Space Time Pattern Mining Tools
Spatial Analyst Tools
Conditional
Density
Distance
Extraction
Generalization
Groundwater
Hydrology
Basin
Fill
Flow Accumulation
Flow Direction
Flow Length
Sink
Snap Pour Point
Stream Link
Stream Order
Stream to Feature
Watershed
Interpolation
Local


流向網格
網格或匯流點資料
儲存位置
Output raster

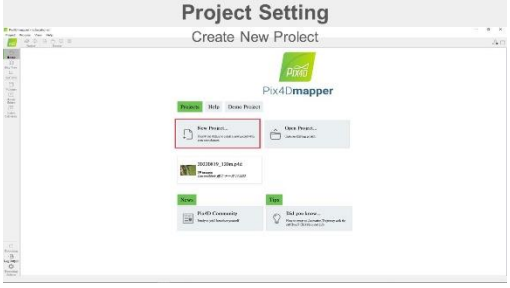




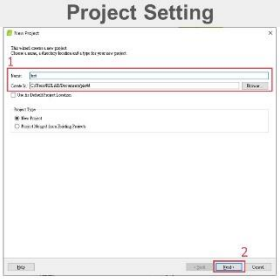
PIX4D

Project Setting

Create New Prolect

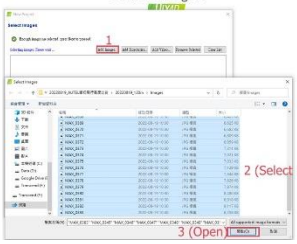


Project Setting



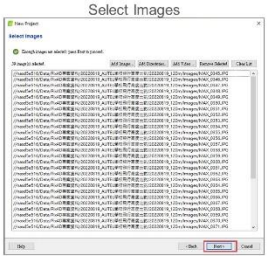
Project Setting

Select Images

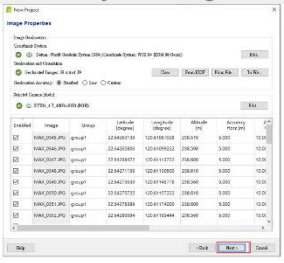


Project Setting

Select Images

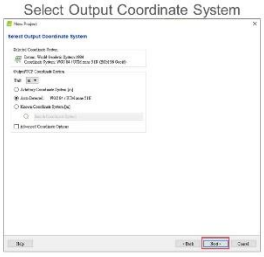


Project Setting



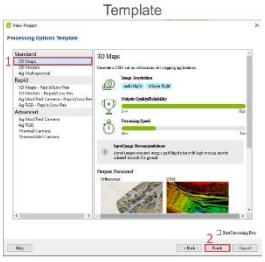
Project Setting

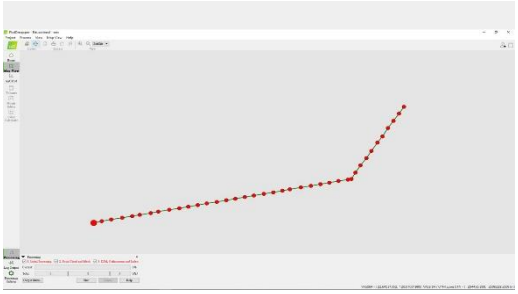
Select Output Coordinate System



Project Setting

Template

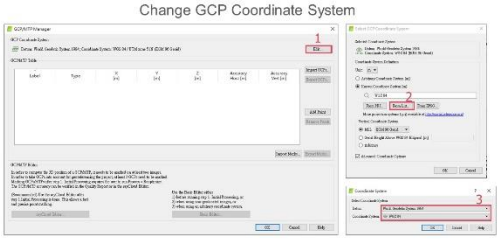




GCP Manager

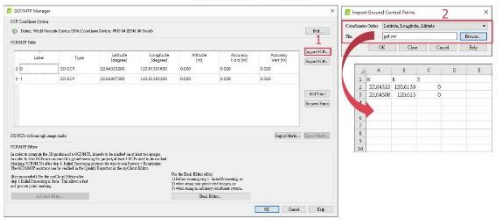
GCP Manager

Change GCP Coordinate System



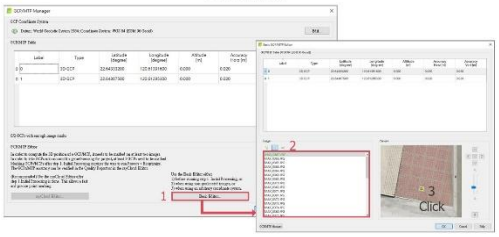
GCP Manager

Input GCP Points



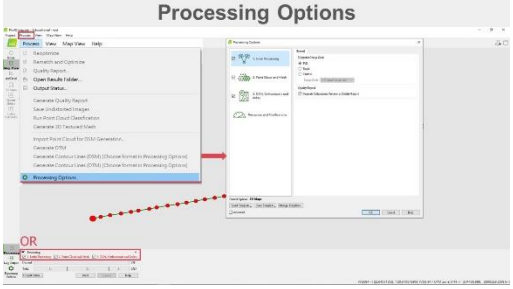
GCP Manager

Basic Editor

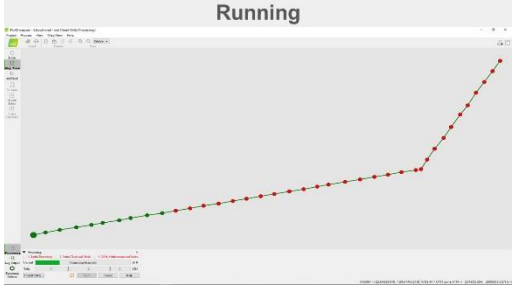


GCP Manager

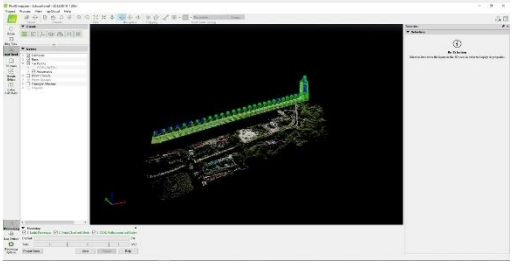
Processing Options



Running

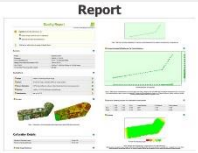


Result



Output

Report

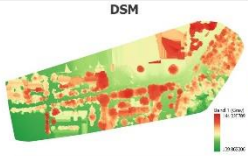


3D Mesh

Report	..\<*Project_Name*>\1_initial\report
3D Mesh	..\<*Project_Name*>\2_densification\3d_mesh
DSM	..\<*Project_Name*>\3_dsm_ortho\1_dsm
Mosaic	..\<*Project_Name*>\3_dsm_ortho\2_mosaic

Output

DSM



Mosaic

Report	..\<*Project_Name*>\1_initial\report
3D Mesh	..\<*Project_Name*>\2_densification\3d_mesh
DSM	..\<*Project_Name*>\3_dsm_ortho\1_dsm
Mosaic	..\<*Project_Name*>\3_dsm_ortho\2_mosaic