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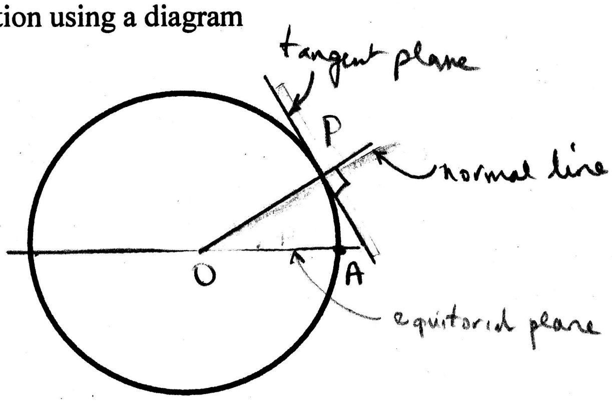
GIS in Water Resources Midterm Exam **Fall 2014**

There are four questions on this exam. Please do all four. They are not all of equal weight.

Question 1. Earth Location and Distance (20%)

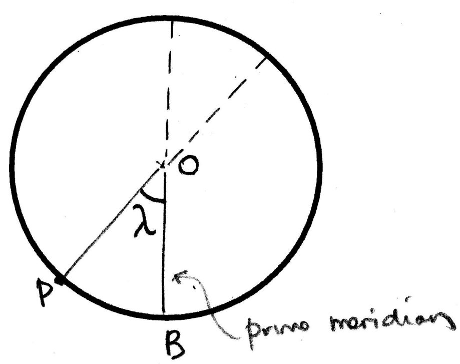
(a) Define the term *Latitude* and illustrate your definition using a diagram

(6) The Latitude of point P on the earth's surface is the angle POA formed by the intersection of the normal line PO with the equitorial plane. PO is perpendicular to the tangent plane on the earth's surface at point P

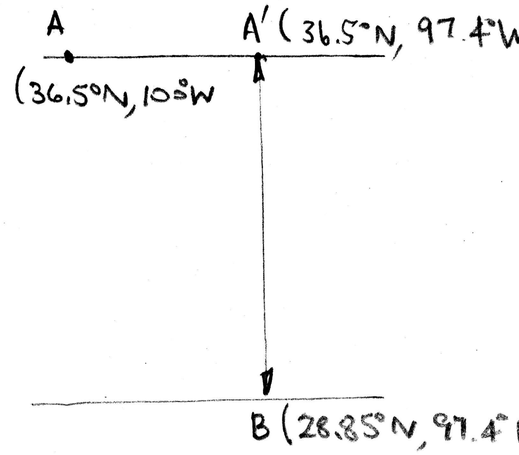


(b) Define the term *Longitude* and illustrate your definition using a diagram

(6) The Latitude, λ, of a point P is the angle between two cutting planes: one through the meridion at P and the other through the prime meridian (OB)



(c) How tall is Texas? Two points, A and B are shown on the map in Question 2. Point A is at (36.5°N, 100°W), point B is at (28.85°N, 97.4°W). If the radius of the earth is 3959 miles, what is the *north-south distance* in miles between points A and B?



(8) Let A' be the point on the same parallel as A and directly North of B. Hence A' = (36.5°N, 97.4°W)

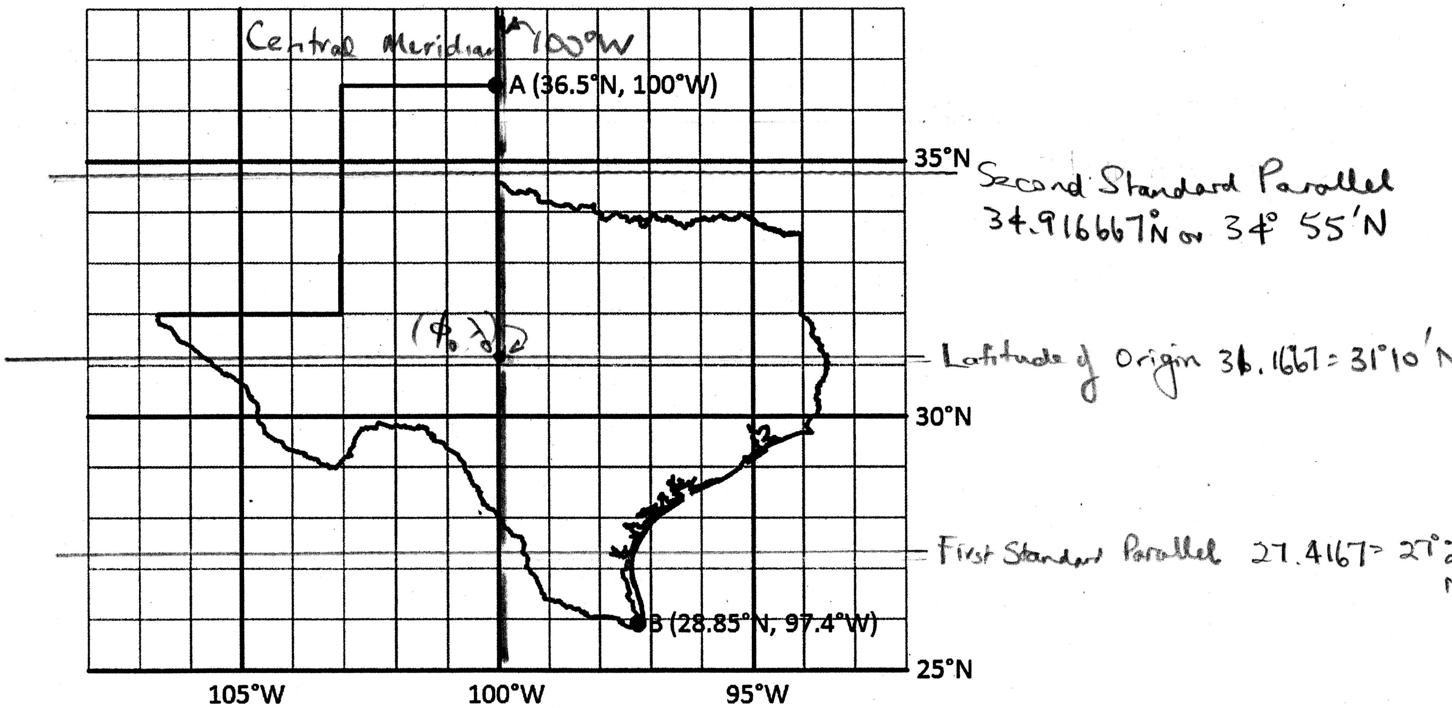
$\Delta\phi$ = difference in latitude A' → B = 36.5 − 28.85
= 7.65°

in radians $\Delta\phi = 7.65 \times \frac{\pi}{180}$
= 0.13358 radians

$A'B = R_e \Delta\phi = 3959 \times 0.13358$
= 528.6 miles

Now that's a tall Texan!

Question 2. Map Projection and Coordinate Systems (20%)



NAD_1927_Texas_Statewide_Mapping_System
WKID: 3080 Authority: EPSG

Projection: Lambert_Conformal_Conic
False_Easting: 3000000.0
False_Northing: 3000000.0
Central_Meridian: -100.0
Standard_Parallel_1: 27.41666666666667
Standard_Parallel_2: 34.91666666666666
Latitude_Of_Origin: 31.16666666666667
Linear Unit: Foot (0.3048)

Geographic Coordinate System: GCS_North_American_1927
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_North_American_1927
Spheroid: Clarke_1866
Semimajor Axis: 6378206.4
Semiminor Axis: 6356583.799998981
Inverse Flattening: 294.9786982

A map of Texas and a set of map projection parameters for the state are given above.

(8) (a) Please draw and label on the map: the central meridian, the latitude of origin, and the two standard parallels.

(2) (b) Give the numerical values (in degrees and minutes) for (ϕ_0, λ_0): (31° 10′ N, 100° 0′ W)

(2) (c) Give the numerical values for (X_0, Y_0): (3000000 (E), 3000000 (N))

(2) (d) What earth datum is used? North American Datum (1927) - NAD 27

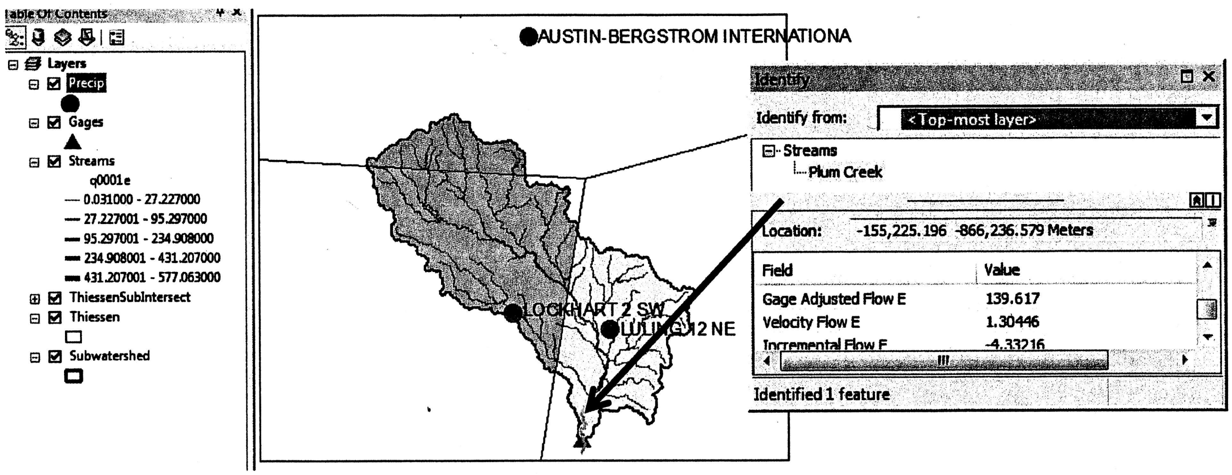
(2) (e) What spheroid is used? Clarke (1866)

(2) (f) What map projection is used? Lambert Conformal Conic

(2) (g) What are the distance units in the coordinate system? Feet

Question 3. Watershed Analysis (30%)

The following map shows a Thiessen Polygon analysis of mean annual precipitation for Plum Creek Watershed in Texas. **Map units are in meters.**



The identify query above shows that the Gage Adjusted Flow E for the outlet stream is **139.6 ft^3/s**. This is an average annual flow.

Following is the ThiessenSubIntesect attribute table obtained from intersecting the Thiessen Polygon layer with Subwatershed layer

Table

ThiessenSubIntersect

OBJECTID *	Shape *	stname	AnnPrecip_in	Shape_Length	Shape_Area
1	Polygon	AUSTIN-BERGSTROM INTERNATIONA	34.515	63639.360278	93905871.938164
2	Polygon	LOCKHART 2 SW	36.125	122112.653296	416396474.696638
3	Polygon	LULING 12 NE	36.803	113002.435736	301747653.501483

1 (0 out of 3 Selected)

ThiessenSubIntersect

Following is the Subwatershed attribute table

Table

Subwatershed

OBJECTID *	Shape *	HydroID	SiteID	SiteName	Shape_Length	Shape_Area
1	Polygon	330	08173000	Plum Ck nr Luling, Tx	218999.999491	812050000.136302

1 (0 out of 1 Selected)

Subwatershed

a) Prepare a table showing the gaged precipitation (inches) and the area associated with the gage (km^2)

(6)

Gage	Precipitation (in) (P)	Area (km^2) (A)	PA (in - km^2)
1	34.515	93.906	3241.17
2	36.125	416.396	15042.31
3	36.803	301.748	11105.23
		812.05 (km^2)	29388.7 (in - km^2)

b) Calculate the areal averaged mean annual precipitation over Plum Creek in inches.

(6)

$$\bar{P} = \sum_{i=1}^{3} \frac{P_i A_i}{A_T} = \frac{29388.7}{812.05} = 36.19''$$

c) Calculate the annual average volume of precipitation received by Plum Creek in ft^3 (1 km = 3281 ft)

(6)

$$Vol(P) = \bar{P}_{(in)} \cdot \frac{1 ft}{12 in} \cdot 812.05_{(km^2)} \times \left(\frac{3281 ft}{1 km}\right)^2$$

$$= 36.19 \times \left(\frac{1}{12}\right) \times 812.05 \times 3281^2$$

$$= 26\,363\,469\,778$$

$$Vol(P) = 26.36 \times 10^9 \ ft^3$$

d) Calculate the annual average volume (in ft^3) of streamflow from Plum Creek based on Gage Adjusted Flow E. (1 day = 86,400 sec, 1 year = 365.25 days)

(6)

$$Vol(S) = 139.6 \frac{ft^3}{s} \times \frac{86400 s}{d} \times \frac{365.25 d}{1 yr}$$

$$= 4\,405\,440\,960$$

$$Vol(S) = 4.405 \times 10^9 \ ft^3$$

$$\frac{4.405 \times 10^9}{812.05 \times (3281)^2} = 0.5039' = 6.05''$$

average over watershed

e) Calculate the fraction of mean annual rainfall that is manifested as runoff (i.e. the runoff ratio) for Plum Creek based on this information.

(6)

$$\therefore C = \frac{Vol(S)}{Vol(P)} = \frac{4.405 \times 10^9}{26.36 \times 10^9}$$

$$C = 0.167$$

$$= \frac{6.05}{36.19} = 0.167$$ as before

Question 4. Raster Analysis of DEMs (30%)

The following diagram gives elevation values on a **25 m** DEM grid.

a) Identify any pits and indicate the elevation to which they need to be raised to drain the DEM.

(4)

13	13	13	11	12	11
13	14	12	10 (11)	12	10
13	14	9 (11)	12	15	14
14	15	14	16	15	14
14	14	13	14	14	13

Cell Top Left 14 → 12 Slope = 2/1 = 2
14 → 11, Slope = $3/\sqrt{2}$ = 2.12 ✓

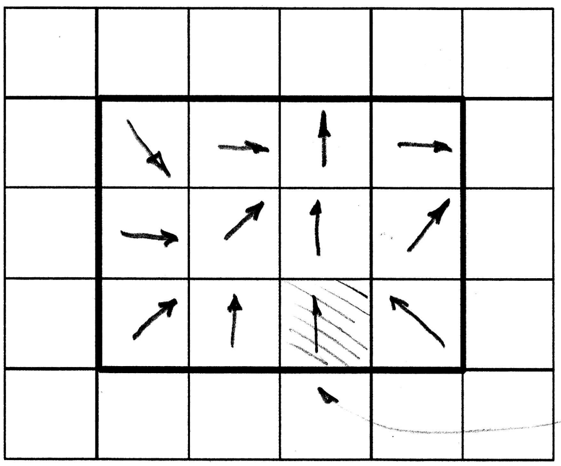
Cell Elev 16 16 → 12, Slope = 4/1 = 4 ✓
16 → 11, slope = $5/\sqrt{2}$ = 3.53

Cell Elev 15 15 → 10, slope = $5/\sqrt{2}$ = 3.53 ✓
15 → 12, slope = 3

b) Calculate the D8 **flow direction** and show **arrows** for the flow direction for grid cells in the inner bold 3 x 4 box on the diagram below.

Flow Direction

(6)



cell with steepest slope

c) Indicate which cell in the above grid has the steepest hydrologic (D8) slope and calculate the value of this slope.

(4)

Steepest Slope is from 16 to 12 ; Slope = 4/25 = 0.16

d) Calculate the **flow accumulation** for all cells in the inner block using the ESRI convention of number of grid cells draining in to each grid cell. Show numbers for the flow accumulation on the diagram below

Flow Accumulation

	0	0	9	0	
	0	4	2	0	
	0	0	0	0	

watershed

(8)

e) On the above flow accumulation diagram draw a **border around the watershed** draining to and including the grid cell in the inner block with largest flow accumulation. What is the **area** of this watershed (square meters)?

each cell = 25m x 25m

area = 10 cells = 10 x 25 x 25 m^2

area = 6250 m^2

f) Following is a Soil Type Grid and associated soil type and available soil water storage table

Soil Grid Code

2	2	2	1	1	1
2	2	2	1	1	1
2	1	1	2	2	2
1	1	2	2	2	2
1	1	2	2	2	2

(8)

Soil Type Attribute Table

Soil Grid Code	Soil Type	Available soil water storage (cm)
1	Loam	27
2	Sand	14

4 cells Loam

6 cells Sand

(i) Calculate the percentage of each soil type in the watershed you delineated in (e) above

Loam % = 4/10 = 40%

Sand % = 6/10 = 60%

(ii) Calculate the volume of available soil water storage in the watershed you delineated in (e) above in m^3 (1m = 100cm)

Area = $6250 \, m^2$

average available water capacity

= $0.4 \times 27 + 0.6 \times 14$

= 19.2 cm

∴ Volume of Soil water storage

= $6250 \times \frac{19.2}{100}$

= $1200 \, m^3$