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MINOR FLOODING ON THE LOYALSOCK AND MUNCY CREEK WATERSHEDS ON AUGUST 28 AND 29, 1988

William Babcock and Michael Stewart
National Weather Service Office Williamsport, Pennsylvania

INTRODUCTION

A slow moving cold front combined with moisture from a tropical depression to give some areas of northcentral Pennsylvania between 4 and 7.5 inches of rain in a 26-hour period from 28/1800Z to 29/1900Z. The area of heaviest rain extended from eastern Centre County to northeastern Sullivan County, with the most rain occurring in Sullivan County. (Figure 1)

The precipitation came in two periods between 28/1800Z and 29/2000Z. The initial period of rainfall occurred when an approaching cold front combined with moist unstable air ahead of it to cause thunderstorms, some of them severe, to form in central New York and Pennsylvania between 28/1800Z and 29/0600Z. The second period of rain occurred between 29/0600Z and 29/2000Z when the front stalled and moisture from Tropical Depression Chris flowed up along the front from the south. The result was single-event rain amounts that were second only to those from Tropical Storm Agnes in 1972.

METEOROLOGICAL CONDITIONS

a) THE THUNDERSTORMS

At 28/1800Z...the front was lying northeast to southwest from western New York State through northwestern Pennsylvania and eastern Ohio. Weather conditions across northcentral Pennsylvania were favorable for the development of strong and even severe thunderstorms. The area experienced daytime heating through a broken thin cirrus layer. Convective temperatures were in the mid 80s; Williamsport, PA (IPT) topped out at 87 degrees between 28/1800Z and 28/2100Z. The air mass had a high moisture content, with surface dew points between 65 and 70 degrees. Although by 28/2000Z the moisture convergence change was only around 5 g/kg/hr * 10, it had rapidly increased during the previous two hours with the largest values of increase located in north central Pennsylvania (Figure 2a). By 28/2000Z, SPOT values were high with a maximum of 79 at IPT (Figure 2b) and surface lifted indices in central Pennsylvania were between -2 and -4 C (Figure 2c). Precipitable water values at Pittsburgh and Buffalo were at 1.5 inches.

At 850 mb (Figure 3a), there was a low-level jet northwest of Pennsylvania with a 50 knot maximum at Buffalo at 28/1200Z and a temperature ridge over Pennsylvania with some warm-air advection. There was an area of dew points (Td) of +4 to +5 C extending from northeast Virginia to southeast New York and an area of Td of +12 to +13 C extending from eastern Ohio to western New York (Figure 3b). This area of higher moisture was advecting northeast into Central Pennsylvania.

The 5 C Tdd (dew point depression) line stretched from southwest Ohio northeast to north of Albany New York at 700 mb (Figure 3c). Southeast of this line, the Tdd was greater than 5 C. This dry air was advecting into central Pennsylvania.

At 500 mb (Figure 3d) over central Pennsylvania, there was a weak area of warm air advection and the winds were in the 40-50 knots range.

There was a primary jet at 300 mb (Figure 3e) that extended from Iowa through northern Michigan into Quebec with a maximum of 115 knots over SSM. A secondary jet extended from Kansas to southern Illinois with a maximum of 70 knots at Topeka. Central Pennsylvania was in the southwest quadrant of the primary jet and the northeast quadrant of the secondary jet.

Around 28/1900Z... thunderstorms developed rapidly in Centre County and moved northeast. Over the next 2 hours...these storms increased in intensity as they moved east-northeast and more storms developed on the tail end of these storms in a training effect. By 28/2225Z...there was a line of very strong to intense thunderstorms that stretched from northeastern Lycoming County to Centre County.

A severe thunderstorm warning was issued for a storm in this line located along the Lycoming/Sullivan county border. It displayed a Vertically Integrated Liquid water content (VIL) of 40 kg/m (Figure 4) on the Interactive Color Radar Display system (ICRAD). Past experience had shown that such a VIL value in this region usually indicated a severe thunderstorm was forming. (For more information on RADAP and VIL, see Davis and Drake, 1988).

Thunderstorms with heavy rain amounts continued to move northeastward from Centre County though Lycoming and Sullivan Counties into Bradford County during the evening hours on the 28th. Figure 5 shows the rainfall estimates from ICRAD for the evening hours of the 28th. ICRAD estimated heaviest amounts ranged from 3/4 to nearly 3 inches between 28/1800Z to 29/0600Z. Figure 6 shows amounts through 0600 UTC as reported by Integrated Flood Observing and Warning System (IFLOWS) rain gauges. According to both systems, heaviest rainfall during the evening of the 28th occurred in Lycoming, western and northern Sullivan, and southeastern Bradford Counties.

b) THE MESOLOWS ON THE FRONT

At 29/0600Z (Figure 7), the cold front had slowly weakened and moved to a position from between Avoca (AVP) and Binghamton (BGM) through west-central Pennsylvania near Dubois through the southwestern corner of Pennsylvania into West Virginia. The precipitation associated with the showers and thunderstorms had either dissipated or moved into New York State. Tropical Depression Chris was located in western North Carolina with rain extending from Chris through Virginia and West Virginia into southwestern Pennsylvania.

Moisture from Chris continued to move north from Virginia into Pennsylvania. A small mesolow formed in southwest Pennsylvania along the front and moved northeast. Between 29/0600Z and 29/0900Z a band of heavy rain developed north of Altoona along the stalled cold front and expanded into north central Pennsylvania by 29/1200Z (Figure 9). At this time, IFLOWS gauges reported heavy rain amounts (3/4 to 1 1/2 inches in 3 hours) in Union, Centre, southern Clinton, and southern Lycoming counties.

By 29/1500Z, one portion of the heavy rain area had moved off into northeastern Pennsylvania while the remainder of the heavy rain stayed over Lycoming, Sullivan, and Clinton Counties. This second area moved out through northeastern Pennsylvania between 29/1800Z and 29/2100Z.

Around 29/1600Z (Figure 13), another mesolow moved into southwest Pennsylvania. This feature moved past Franklin (FKL) around 29/1700Z (Figure 14), between Bradford and Dubois around 29/1800Z (Figure 15), and north of Williamsport around 29/2200Z (Figure 19). The heavy rain tapered off ahead of this mesolow, ending an hour or two before it passed. Once this mesolow moved past, skies began to clear from the west around sunset. Tropical Depression Chris moved into southeast Pennsylvania around 29/1800Z (Figure 15) and into northern New Jersey by 29/2100Z (Figure 18).

DISCUSSION

The ground in northcentral Pennsylvania was already saturated by the early morning hours of the 29th because of the thunderstorms the day before. Therefore, a high percentage of any rain received would runoff into the streams.

The heavy rain that occurred during the morning and afternoon of the 29th was generally anticipated regionally. The cold front was forecast to stall either over or just east of Eastern Pennsylvania around midday on the 29th and Chris would move up the East coast adding its moisture to that of the front. The result would be moderate to heavy rains in all of eastern Pennsylvania with the heaviest amounts falling southeast Pennsylvania.

The front had stalled along a line from south of Binghamton to the southwest corner of Pennsylvania by 29/0600Z (Figure 7). A broad zone of higher rainfall amounts was subsequently found along the position of the stalled front. However, instead of being uniform, there was a zone of much higher amounts located from Centre County to southeast Bradford County. No mechanisms were initially apparent on the analyses that day that would create this effect.

Hourly sectional analysis of observations in and near Pennsylvania helped determine the cause. The 29/0600Z analysis (Figure 7) shows a mesolow forming along the front over West Virginia. Figures 8 through 16 show the movement of the mesolow. The heavy rain fell to the east and northeast of the mesolow as it moved up the front. At IPT the period of steady moderate to heavy rain began around 29/0930Z and continued until after 29/1300Z when winds shifted to southerly. Low level flow brought moisture north from Tropical Storm Chris into northcentral Pennsylvania. This moisture overran the front in Lycoming and Sullivan counties causing the heavy rain.

The second phase of heavy rain came after the mesolow passed. The trailing segment of the cold front moved southeast into the warm moist air. This forced low level convergence which lifted the humid air causing condensation and precipitation. At IPT, the heavy rain continued until the winds shifted to the south and the pressure began to fall. These changes occurred when the front stalled just to the north of IPT. (Figure 16). Once the front stalled, the forcing of the low-level convergence ended.

At the same time, Chris moved into southeast Pennsylvania. Because the flow around Chris was pushing moisture into eastern Pennsylvania, a longer period of heavy rain should have fallen there. There was a short period of heavy rain at AVP between 29/1900Z and 29/2000Z. As at IPT, this was caused by low-level convergence forced by the approaching front and ended when the front stalled. Chris moved into New Jersey by 29/2100Z (Figure 18) taking its moisture source with it.

The 29/1200 UTC NGM initial analysis showed a short wave trough through Illinois and Indiana. Four hours later, the second mesolow appeared along the front in southwest Pennsylvania. It subsequently moved northeast along the front to near Bradford at 29/1900Z (Figure 16). The cold front stalled to the north of IPT around this time ending the heavy rain. The mesolow then moved east along the Northern Tier counties of Pennsylvania moving out of the state around 29/2300Z (Figure 20). This pulled the front trailing south out the mesolow through central Pennsylvania around 29/2300Z.

Time series analysis (Figure 21) shows the passage of the first mesolow, the periods of heavy rain, and the passage of the second mesolow. Figure 22 shows rainfall amounts in northcentral Pennsylvania caused by the front while it was stationary.

The two mesolows were not indicated at all on any run of the LFM or NGM on the 28th or 29th. As noted earlier, the NGM initial analysis at 29/1200Z did show a short wave trough in Illinois and Indiana, and this trough did seem lead to the development of the second mesolow. It would seem that these surface features were below the level of resolution of the two models.

Unfortunely, ICRAD could not be used at all for guidance on the 29th because of modem problems at IPT and BGM. It would have helped in defining the heavy rain areas since the majority of the affected areas were out of the operational range of the radar at Harrisburg.

HYDROLOGICAL CONDITIONS

As was the case in much of the eastern 2/3 of the nation, northcentral Pennsylvania was suffering from a rain deficit. As of the morning of August 28, the annual rainfall total at the Williamsport-Lycoming County Airport was 8.22 inches below normal. Many of the small feeder streams in Lycoming and Sullivan Counties were either dry or nearly so. The larger rivers and streams, including the West Branch of the Susquehanna River, were also running very low. Flood indices for northcentral sections of Pennsylvania indicated it would take between 3.5 and 4.0 inches of rain in a 12-hour period to initiate flooding.

Heavy rains from thunderstorms on August 28 caused streams to rise sharply but levels remained well below flood stages. Heavy rains during the early morning of the 29th continued the trend of rising stages; this was especially true in Lycoming and Sullivan counties on Loyalsock and Muncy Creeks...which drain the area affected by the highest rainfall amounts. At 29/1200Z UTC, based on the heavy overnight rain reported at Williamsport and nearby IFLOWS rain gauges, WSFO Philadelphia issued a Small Stream Flood Watch.

By 29/1500Z total rainfall amounts in Lycoming and Sullivan counties had reached between 3.5 and 4.0 inches. At this time, the Williamsport Weather Service Office began receiving the first reports that, in the Loyalsock and Muncy Creek drainage basins, the small feeder streams were beginning to overflow their banks. At this time a Small Stream Flood Warning was issued for those basins.

The DARDC stream gauge on Loyalsock Creek at Loyalsockville, where flood stage is 9 feet, indicated a level of 6.7 feet at 29/1500Z, 8.0 feet at 29/1608Z, and 10.1 feet at 29/1715Z. The stage was as high as 12.4 feet at 30/0000Z UTC and remained above flood stage until 30/0600Z UTC. During this time, many roads were closed and some were even washed out. A few bridges were closed because of undermining. Numerous fields and many cabins were flooded.

CONCLUSION

The flooding event of August 28-29 1988 was the result of 1) a large moisture supply from an approaching tropical depression, 2) a cold front which caused heavy thunderstorms in the area the previous evening and then stalled overhead, and 3) a mesolow which developed in northern West Virginia and moved rapidly up the front.

Any time a front stalls near a source for soaking rains, pay close attention to it. Any mesolow that moves up that front may cause the moisture to be focussed in one particular area. This is usually to the north and northeast of the sub-synoptic low center track. In this specific case most attention was focussed on Chris and some on the stalled front. However, the possibility of waves along the front was not explored in depth.

REFERENCES

Davis, Robert S. and Drake, Theresa Rossi, 1988, "The Operational Effectiveness of RADAP-II During The 1987 Severe Weather Season in Western Pennsylvania", 15th Conf. Severe Local Storms, Preprints, American Meteorological Society.

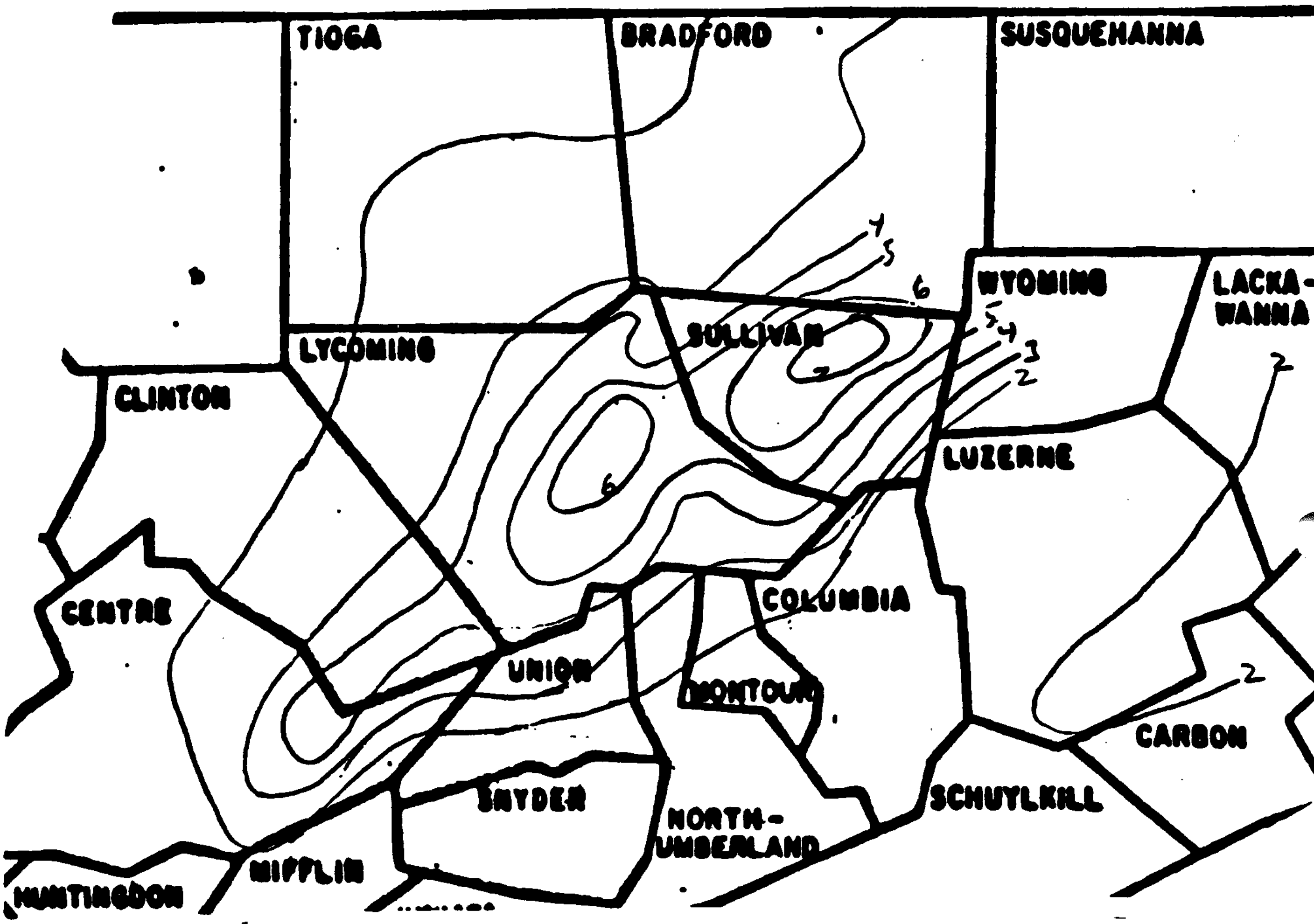

Figure 1. Total Rainfall from 28/1800z to 29/2000z (in.)

Figure 2a. TOTAL MOISTURE FLUX CONVERGENCE CHANGE 28/1800Z - 28/2000Z (G/Kg/Hr * 10)

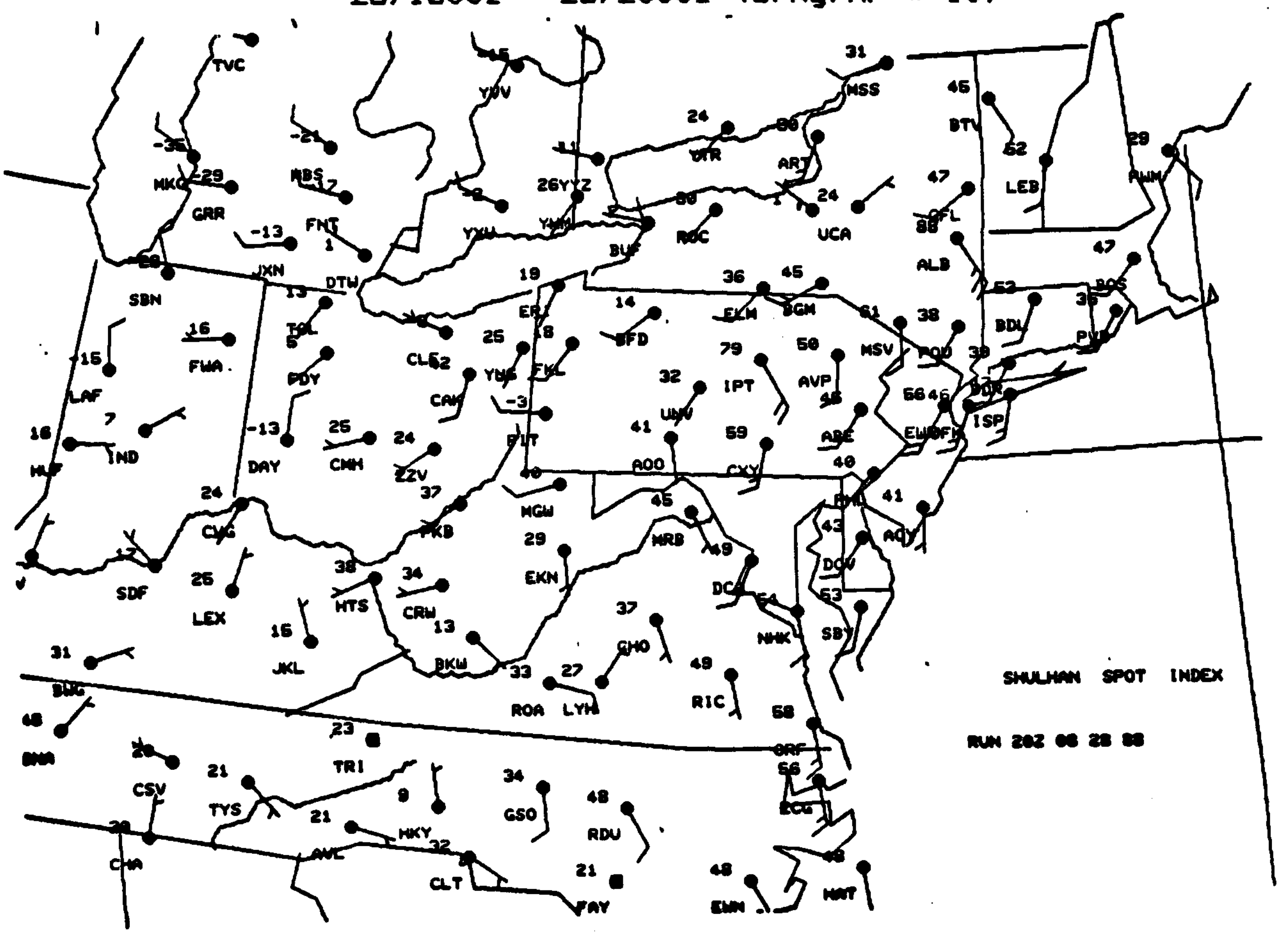

Figure 2b. SHULMAN SPOT INDEX

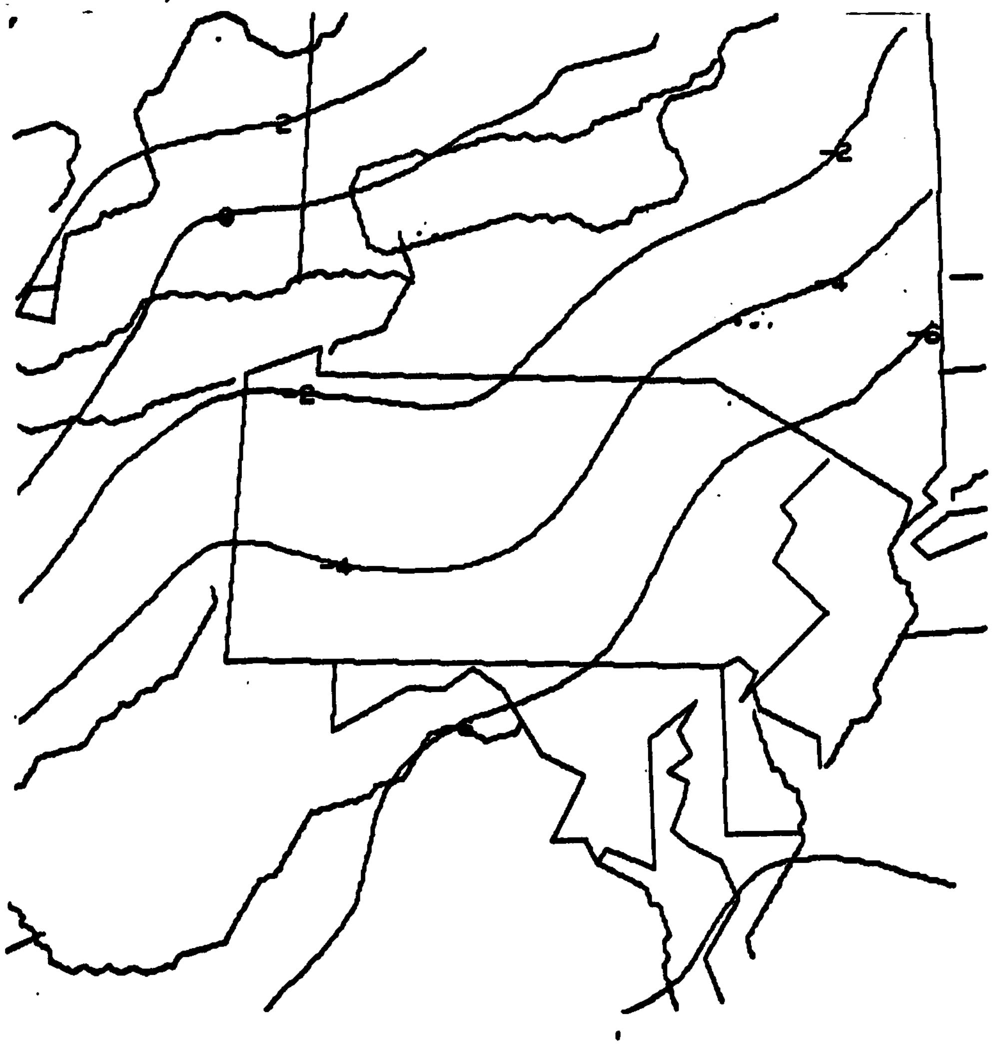

Figure 2c. SURFACE PARCEL LIFTED INDEX AT 500 mb
28/2000Z (°C)

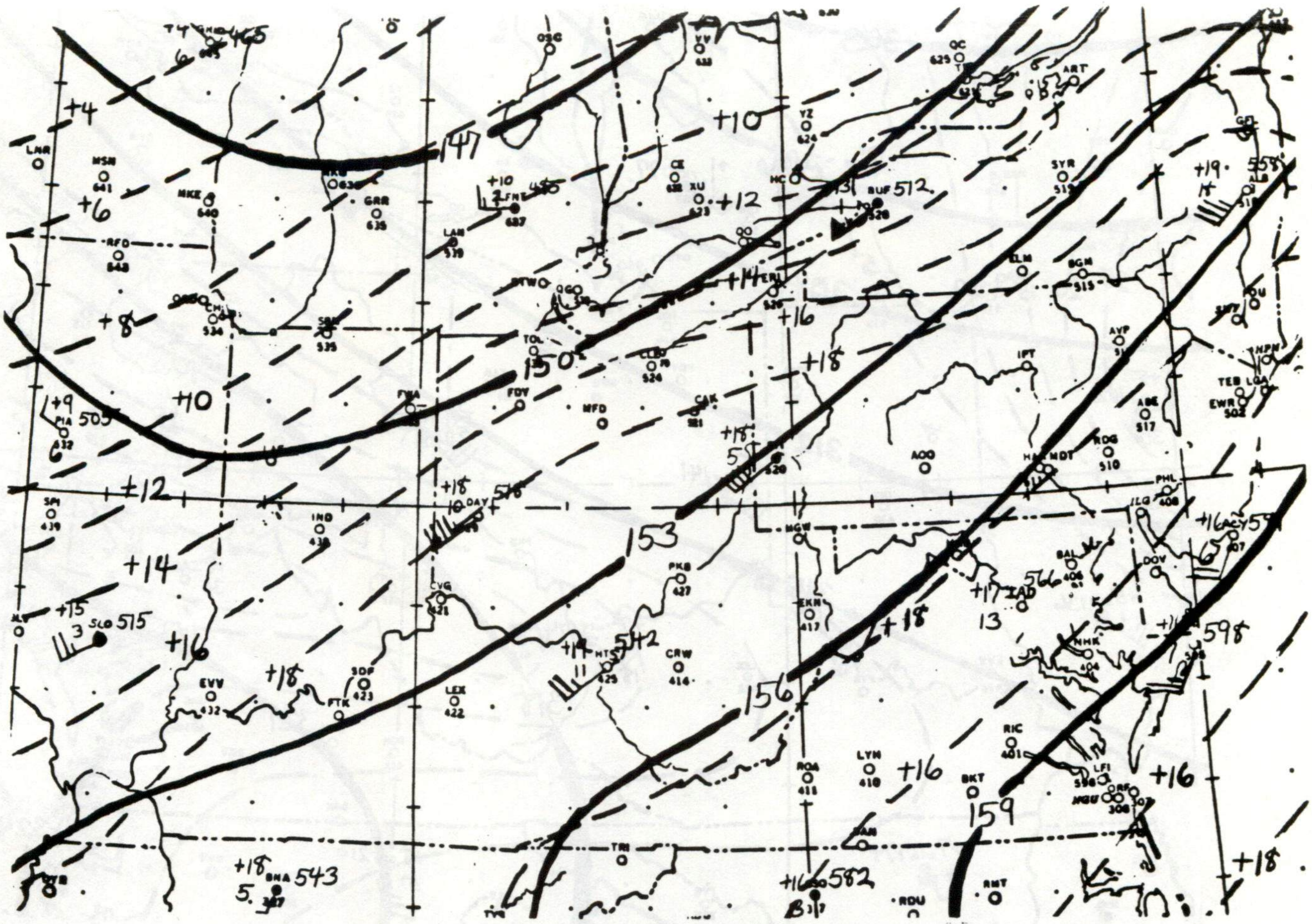

Figure 3a. 850 mb analysis 28/1200Z (Hts in Dm; T in °C)

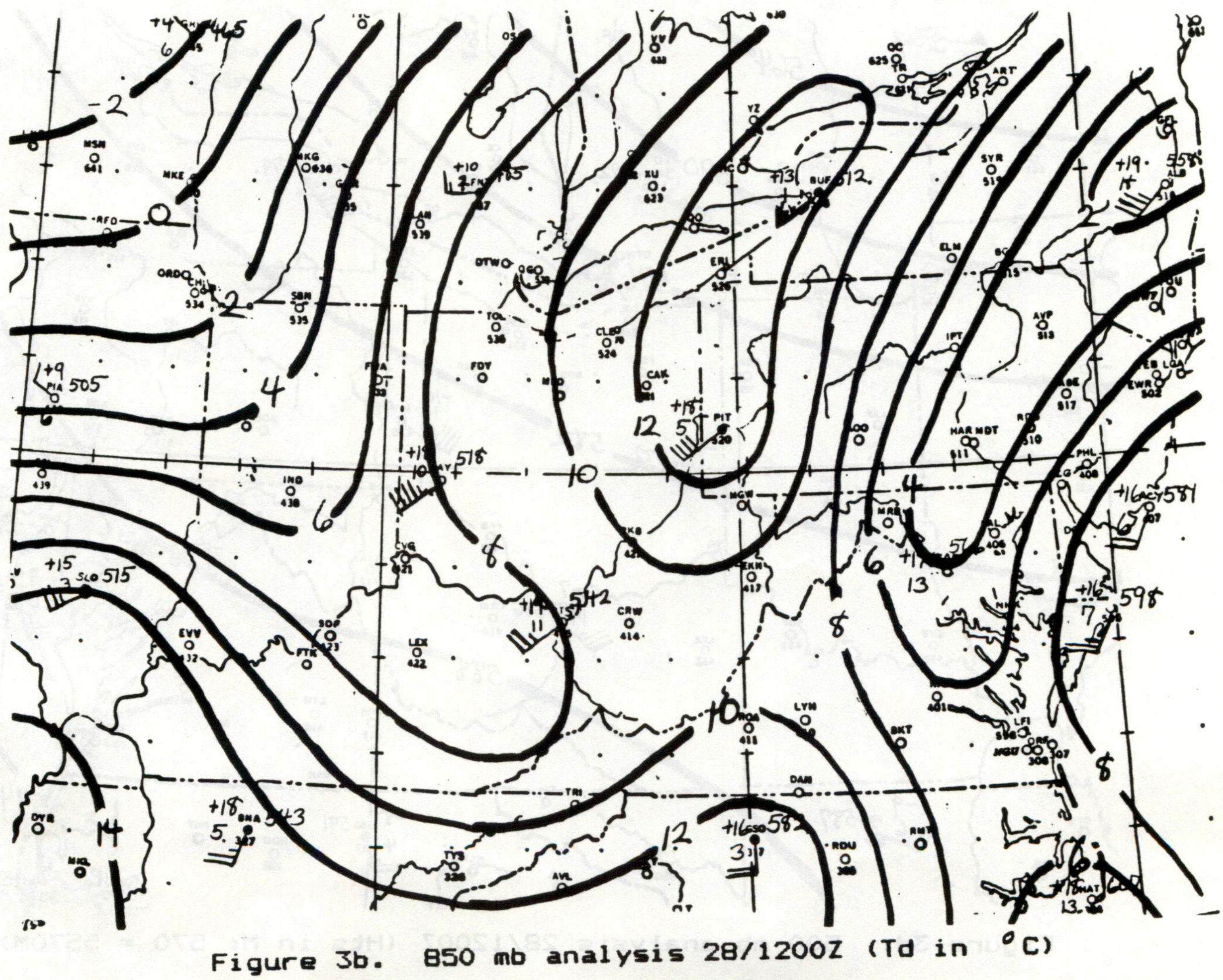

Figure 3b. 850 mb analysis 28/1200Z (Td in °C)

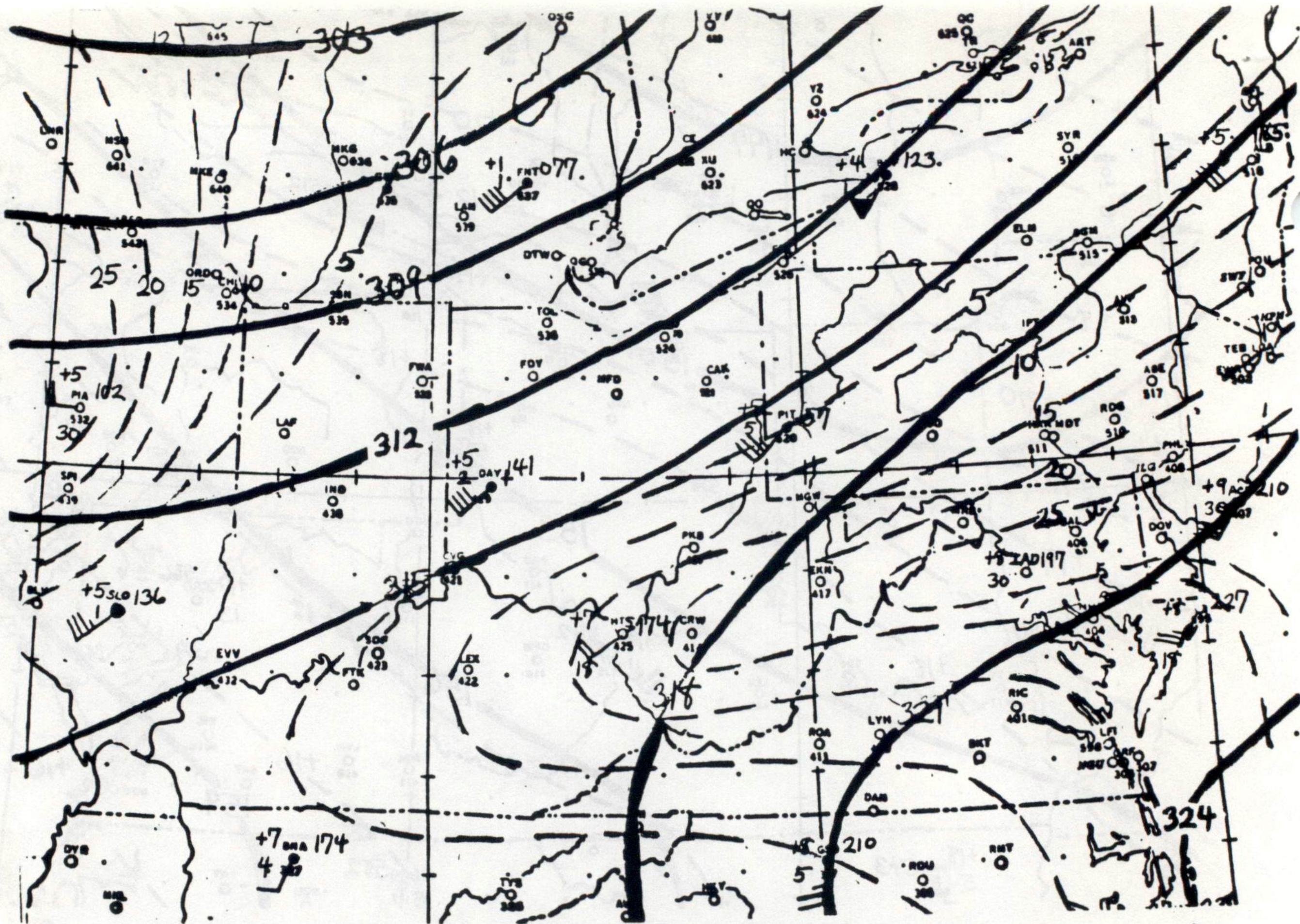

Figure 3c. 700 mb analysis 28/1200Z (Hts in Dm; Tdd in °C)

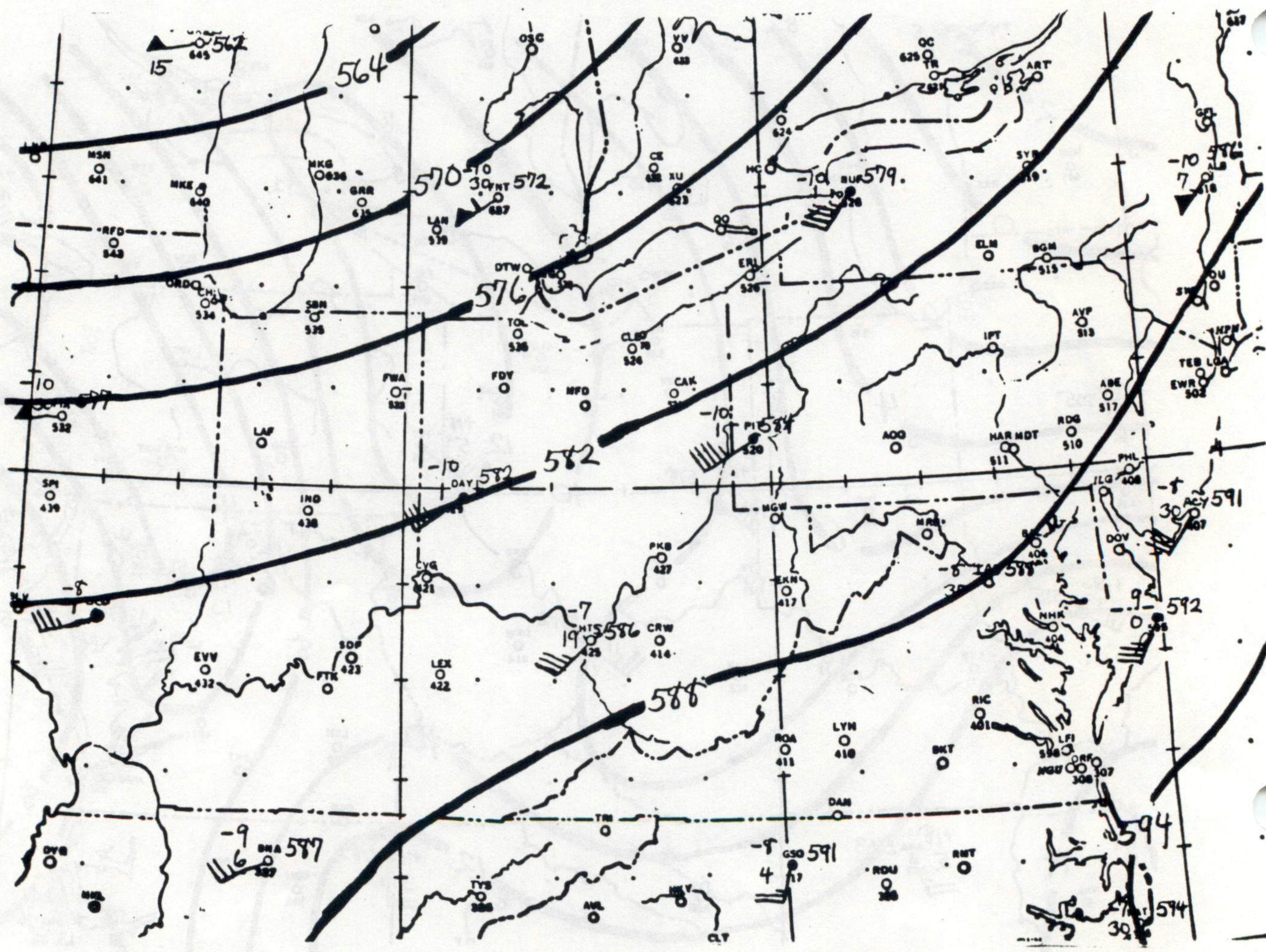

Figure 3d. 500 mb analysis 28/1200Z (Hts in M: 570 = 5570M)

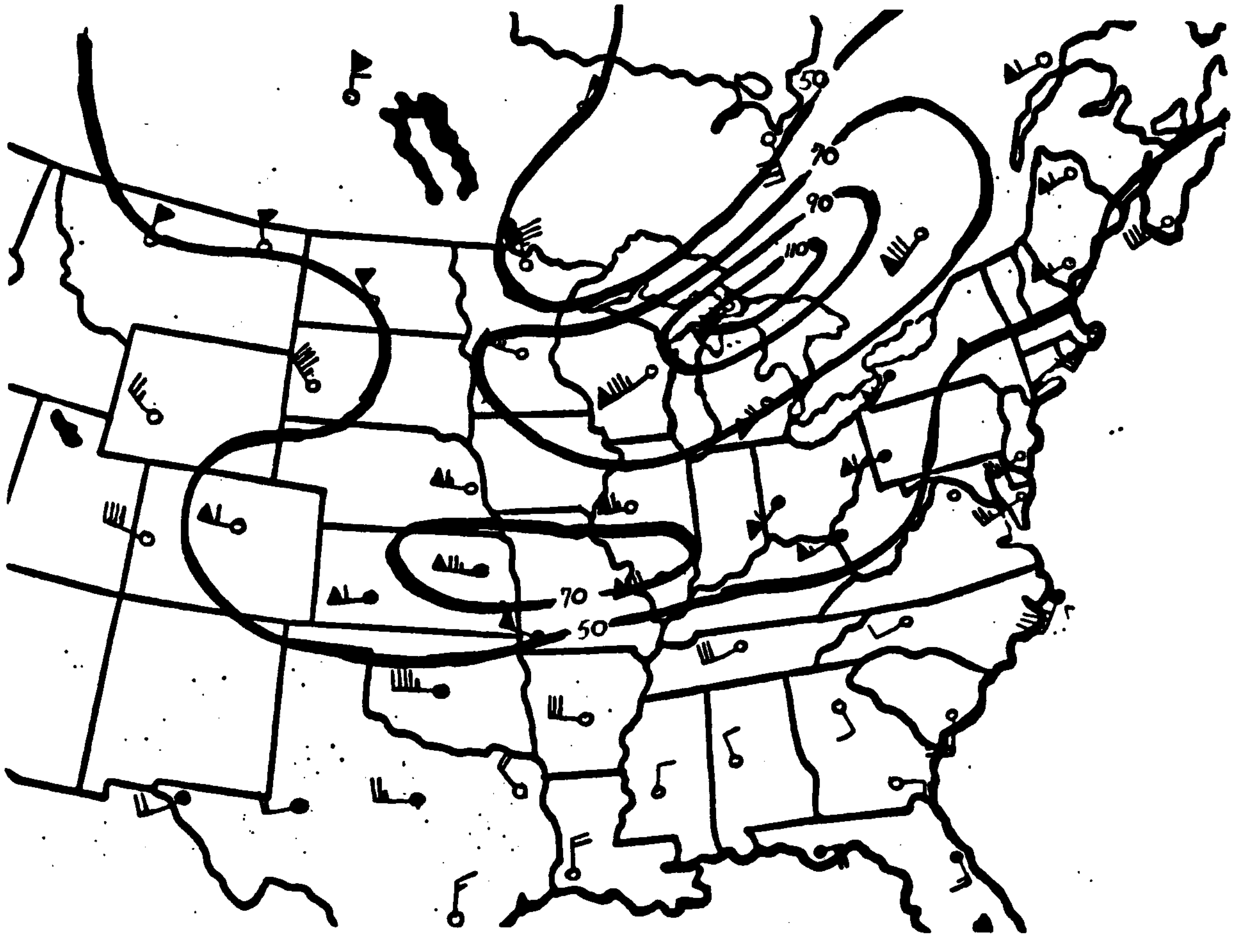

Figure 3e. 300 mb winds 28/1200Z (knts)

CODE VALUE......	1	2	3	4	5	6	7	8	9	A	B	C
VIL(KG/M**2)....	5	10	15	20	25	30	35	40	45	50	55	60

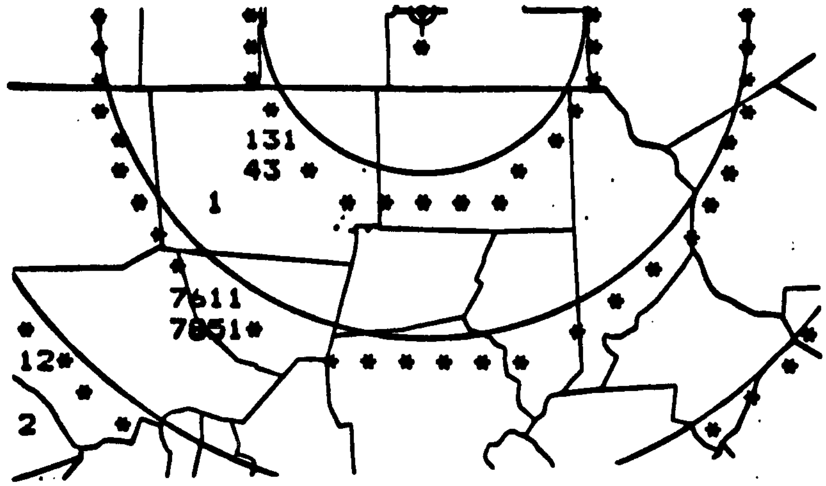

Figure 4. VIL at 28/2200Z from ICRAD (kg/m²)

PEAK TOTAL ACCUMULATED RAINFALL FOR EACH GRID BOX
IN WHICH IT HAS RAINED DURING THE PAST HOUR

CODE VALUE	1	2	3	4	5	6	7	8	9	A	B	C	D	E
RAIN(100TH IN)	10	20	30	40	50	60	70	80	90	100	110	120	130	140

15

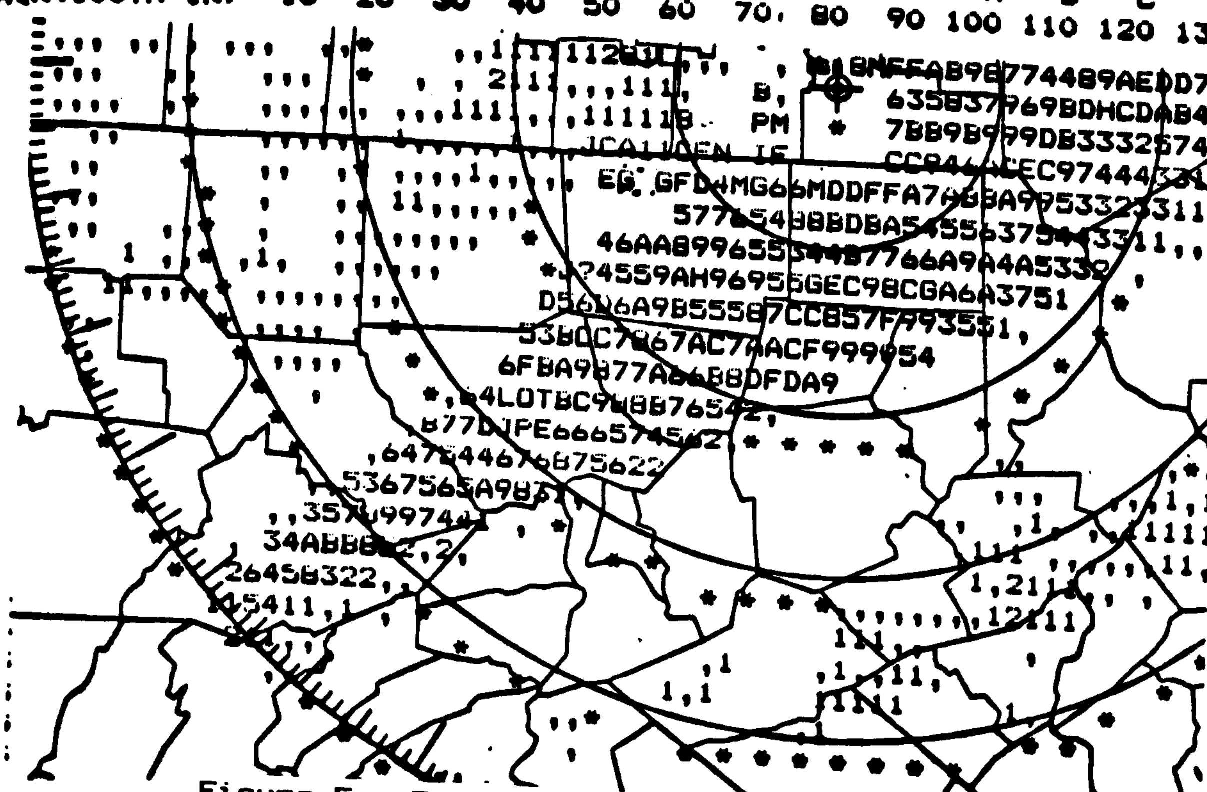

Figure 5. Estimated Rainfall from ICRAD from 28/1800z to 29/0600z (in.)

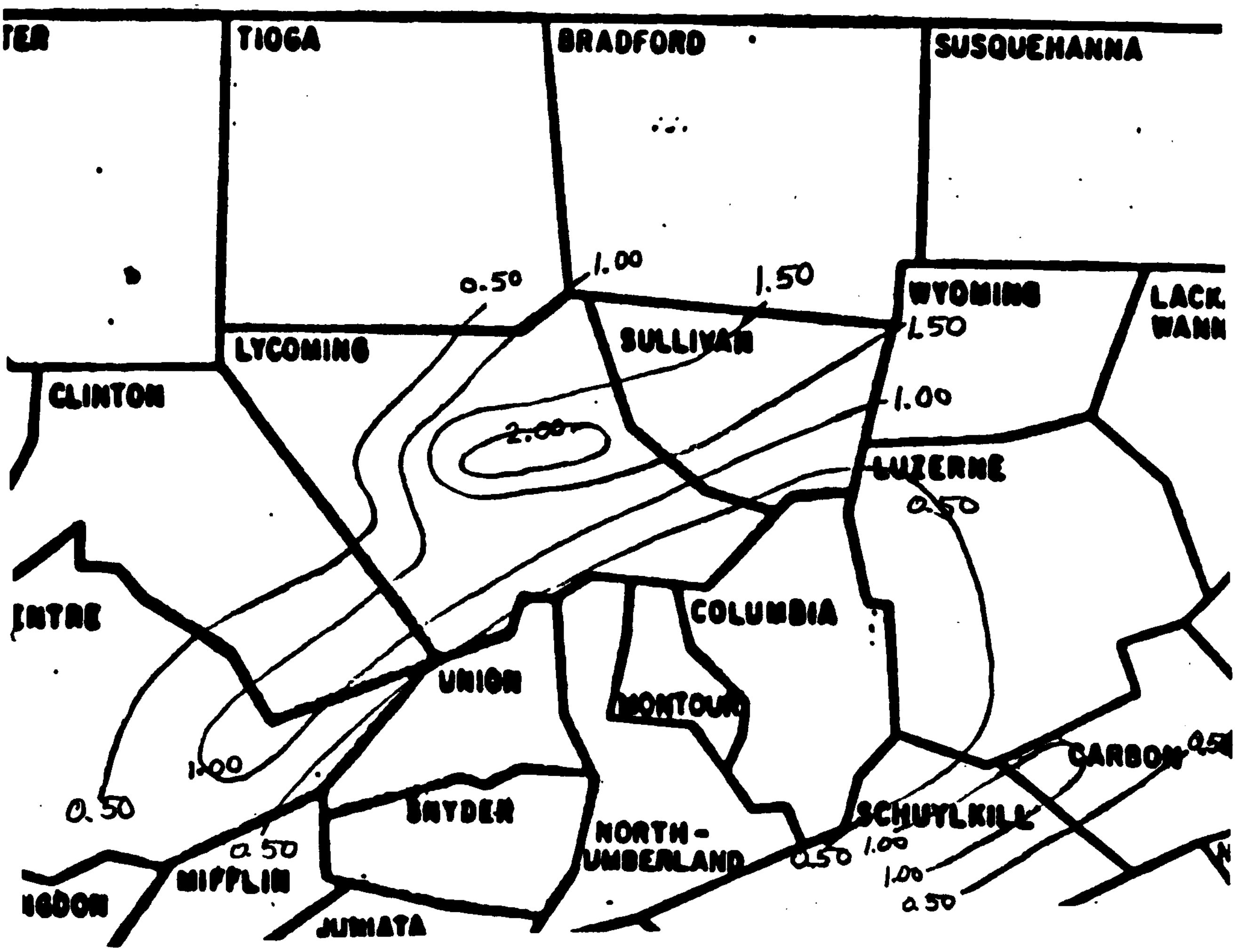

Figure 6. Actual Rainfall from 28/1800Z to 29/0600Z (in.)

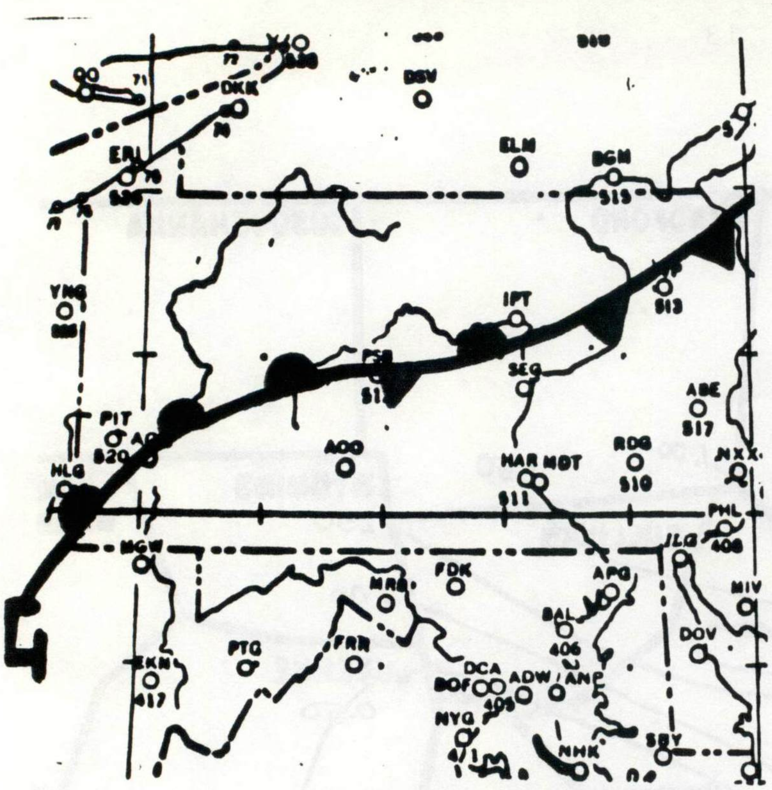

Figure 7. Frontal Position at 29/0600Z

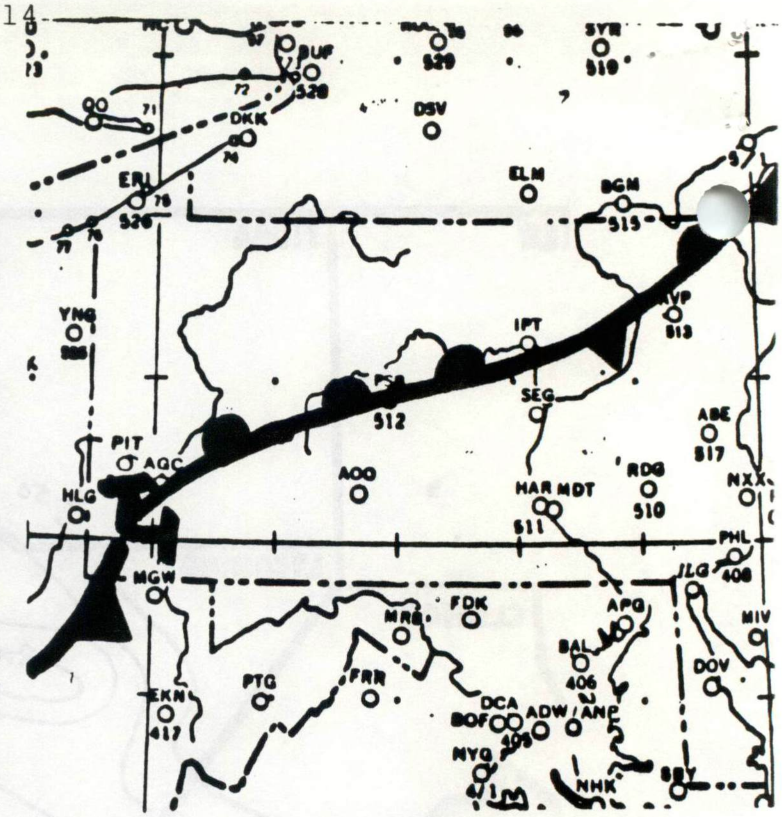

Figure 8. Frontal Position at 29/0900Z

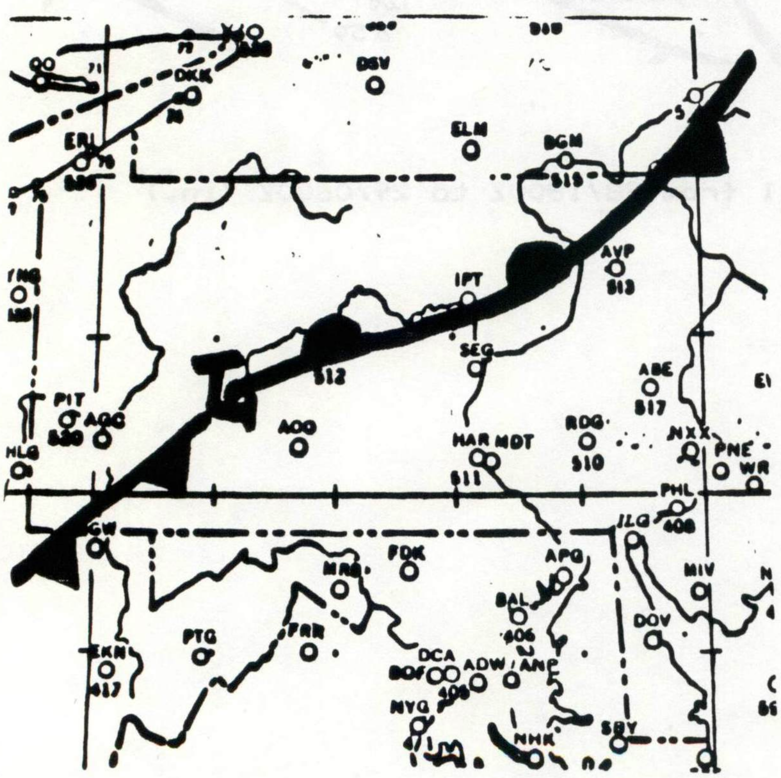

Figure 9. Frontal Position at 29/1200Z

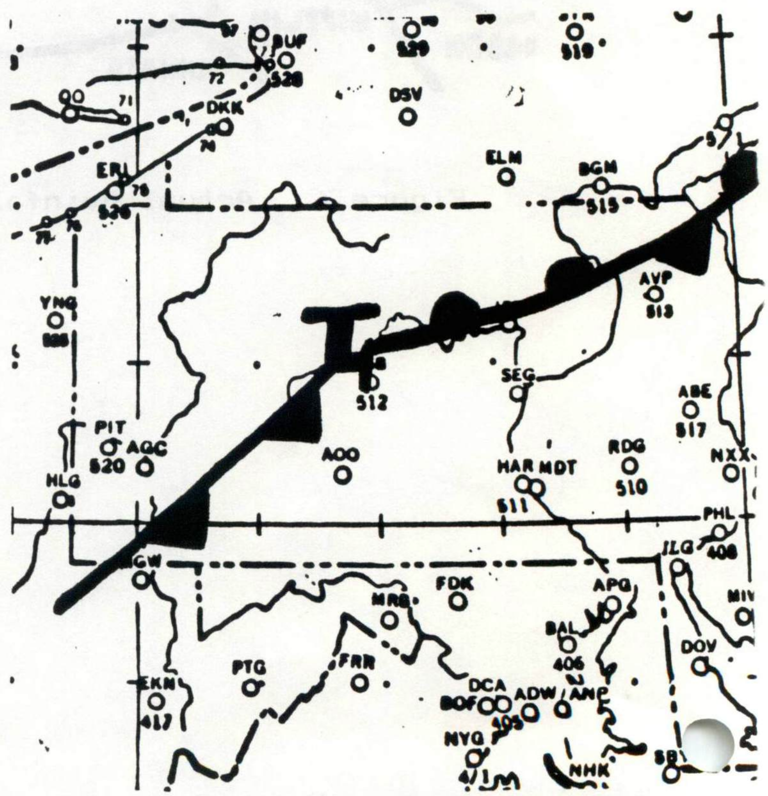

Figure 10. Frontal Position at 29/1300Z.

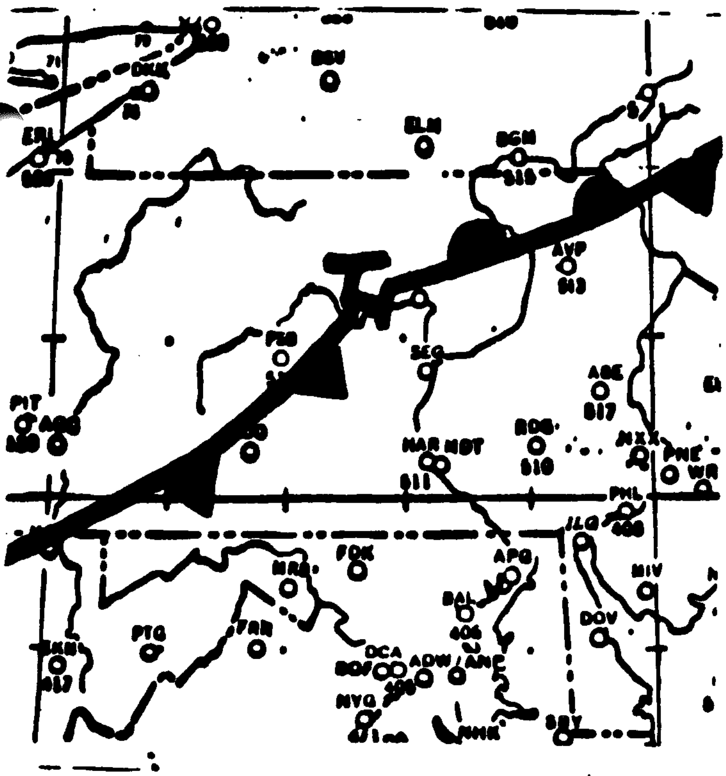

Figure 11. Frontal Position at 29/1400Z

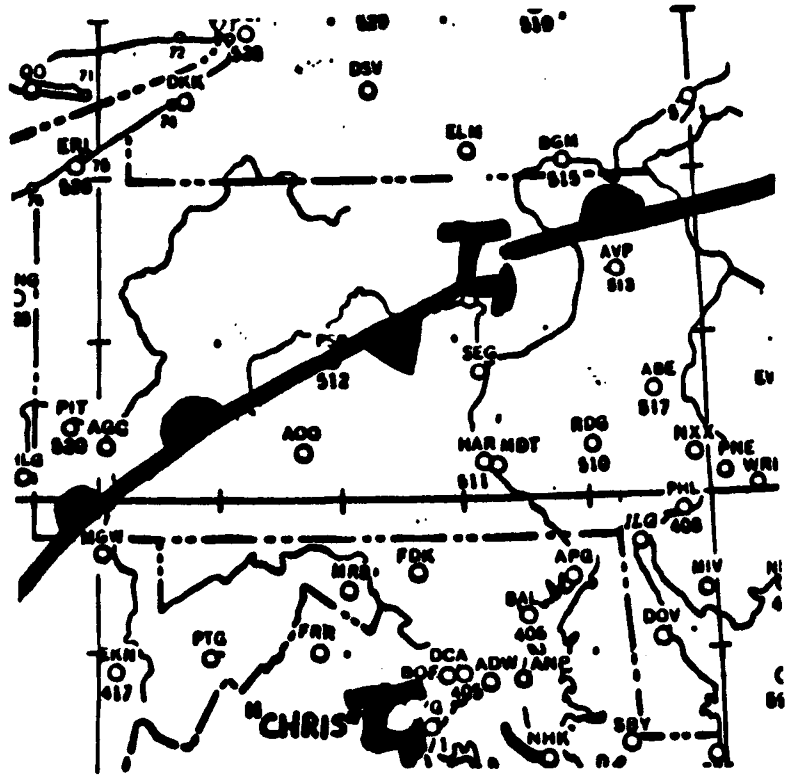

Figure 12. Frontal Position at 29/1500Z

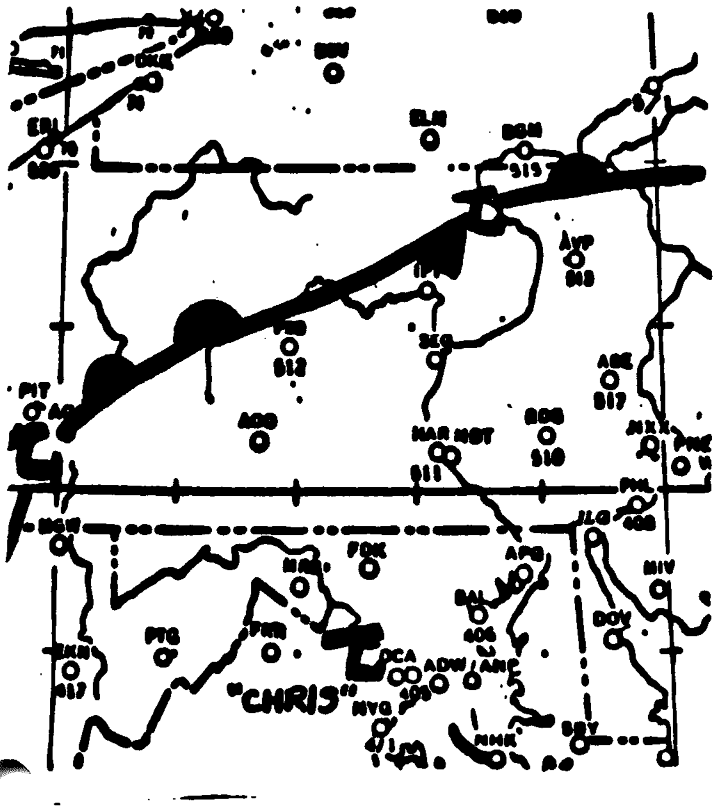

Figure 13. Frontal Position at 29/1600Z

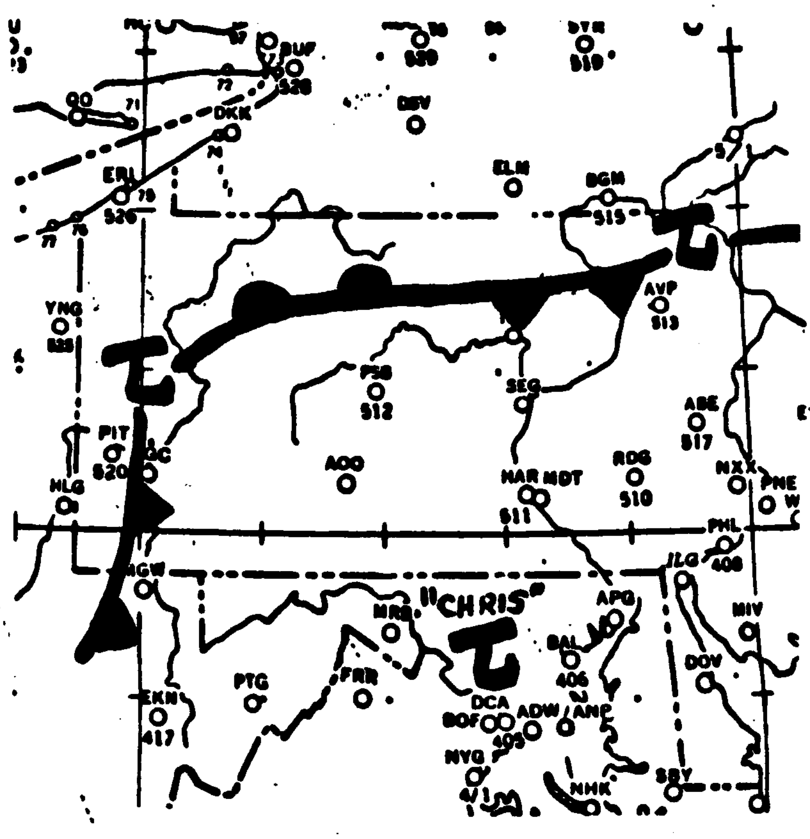

Figure 14. Frontal Position at 29/1700Z

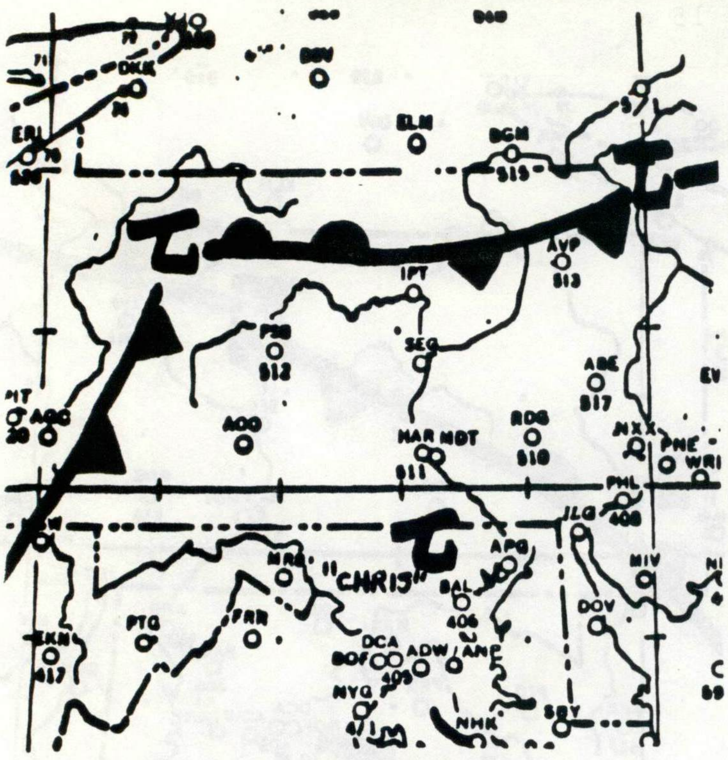

Figure 15. Frontal Position at 29/1800Z

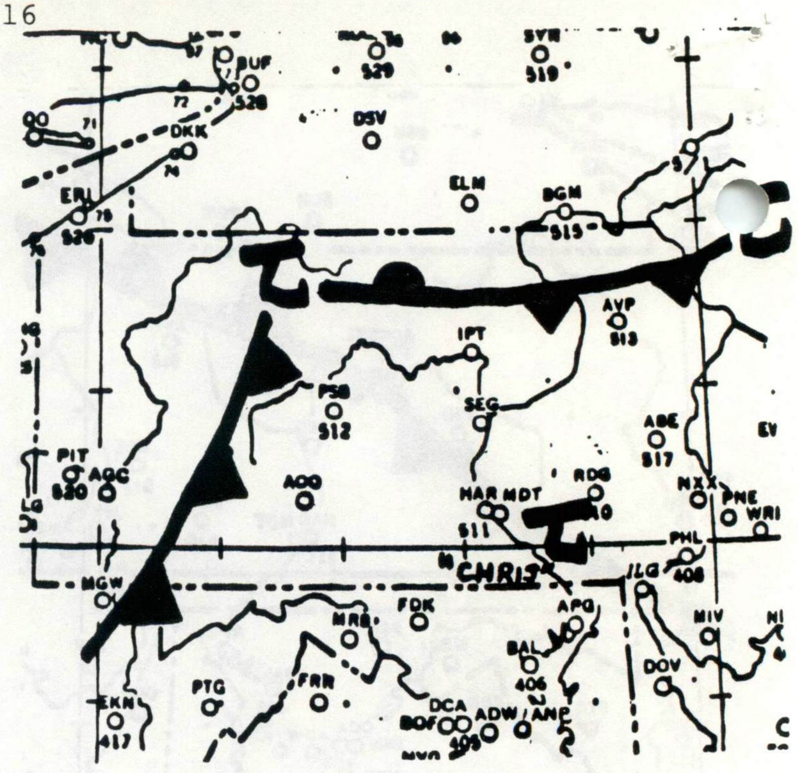

Figure 16. Frontal Position at 29/1900Z

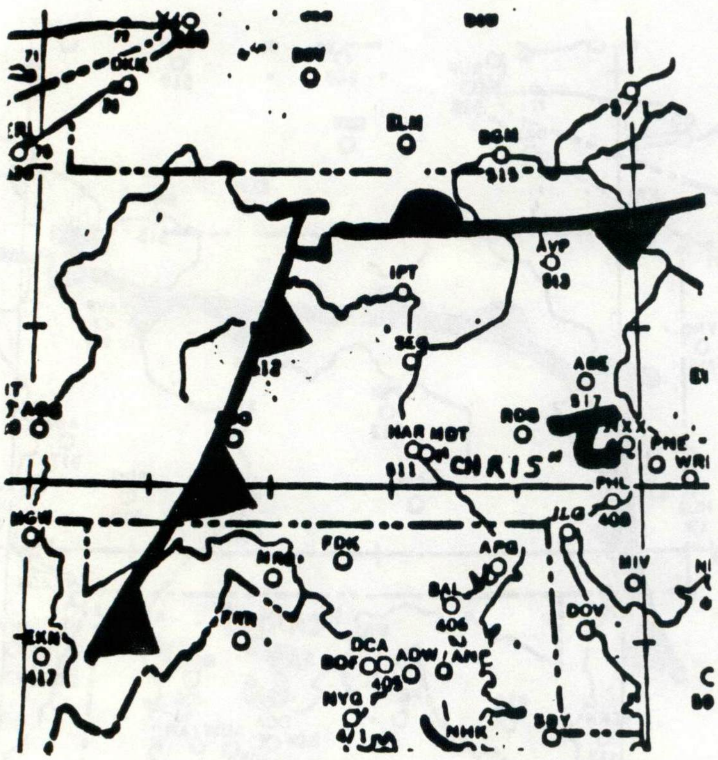

Figure 17. Frontal Position at 29/2000Z

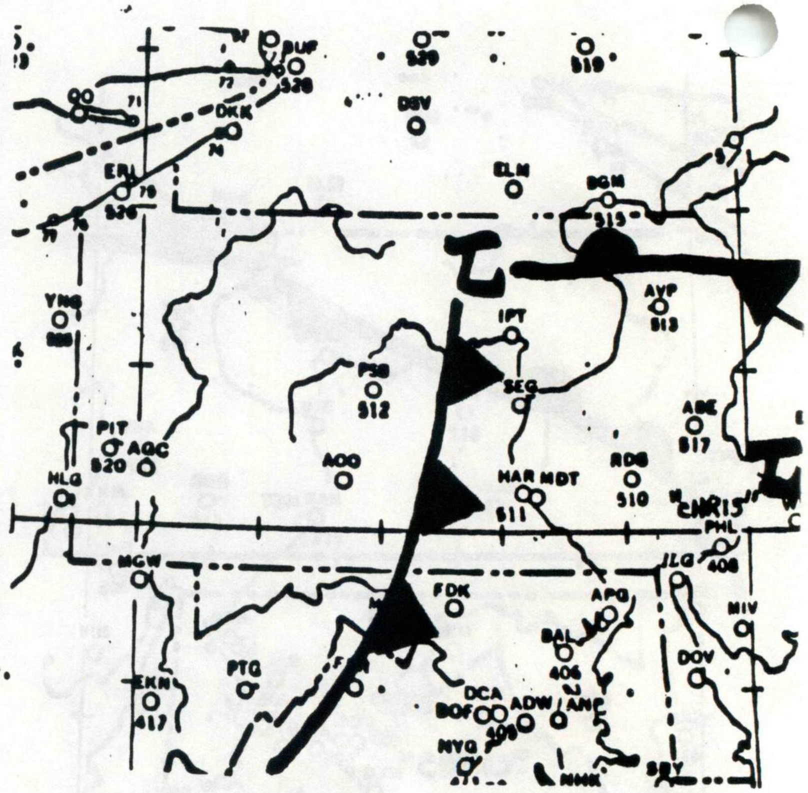

Figure 18. Frontal Position at 29/2100Z

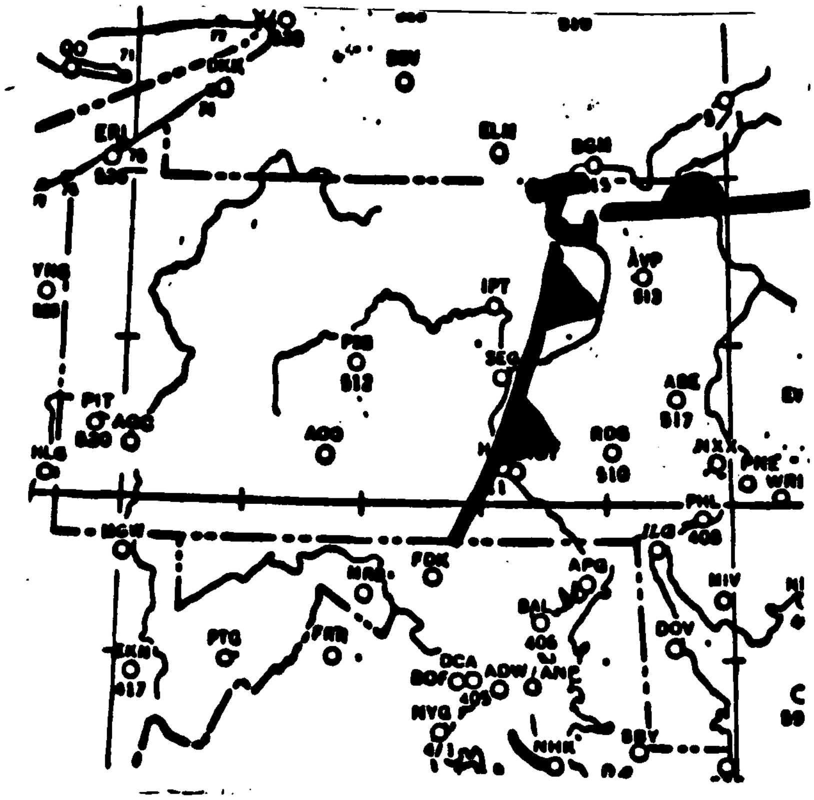

Figure 19. Frontal Position at 29/2200Z

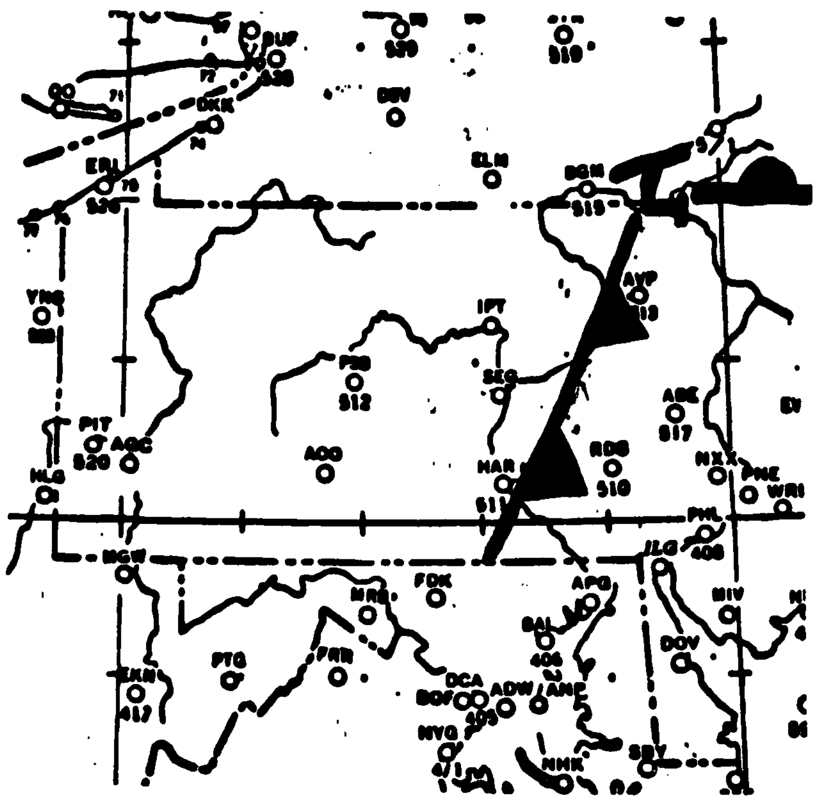

Figure 20. Frontal Position at 29/2300Z

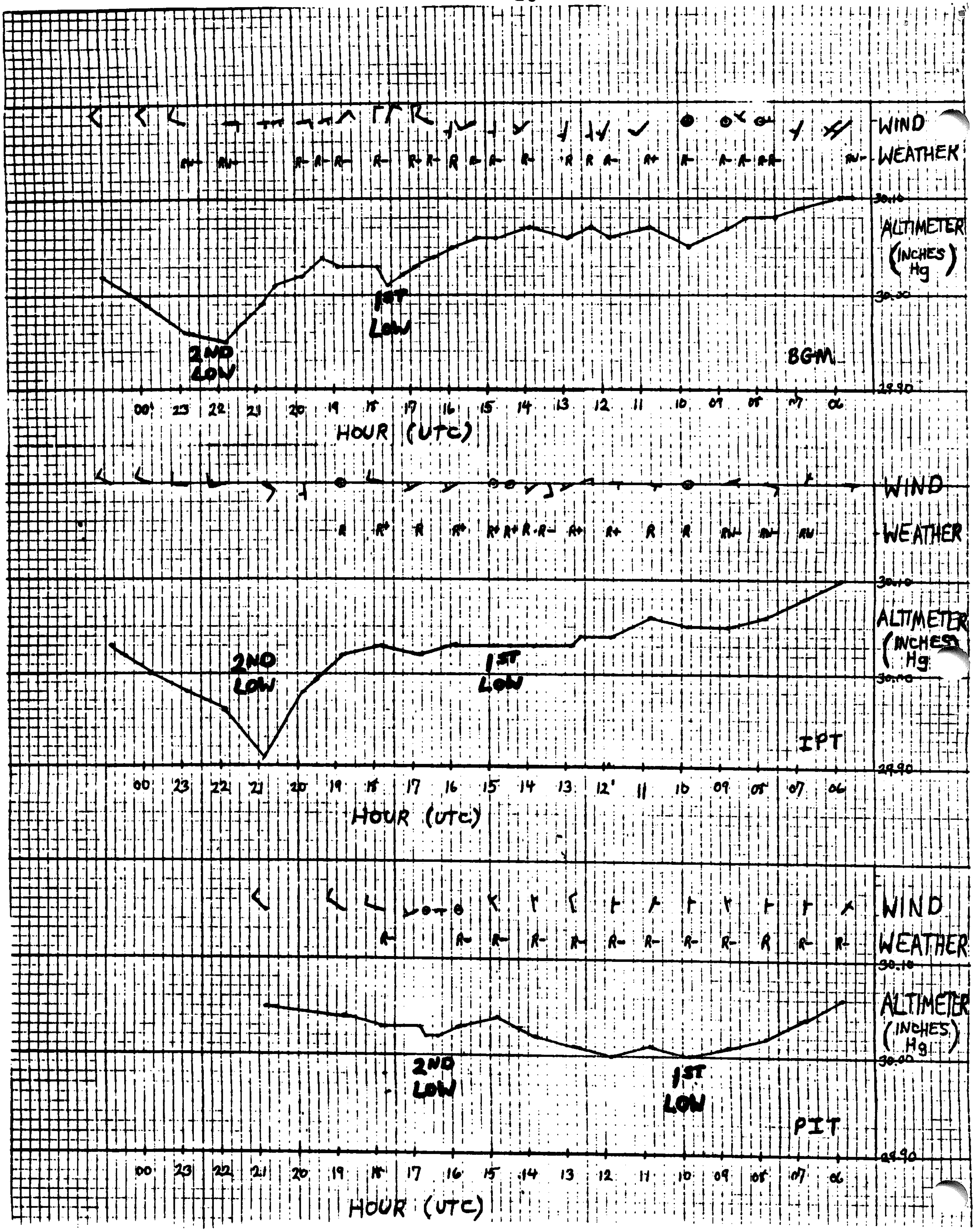

Figure 21. Time Series Analyses for PIT, IPT, and BGM from 29/0600Z to 30/0000Z

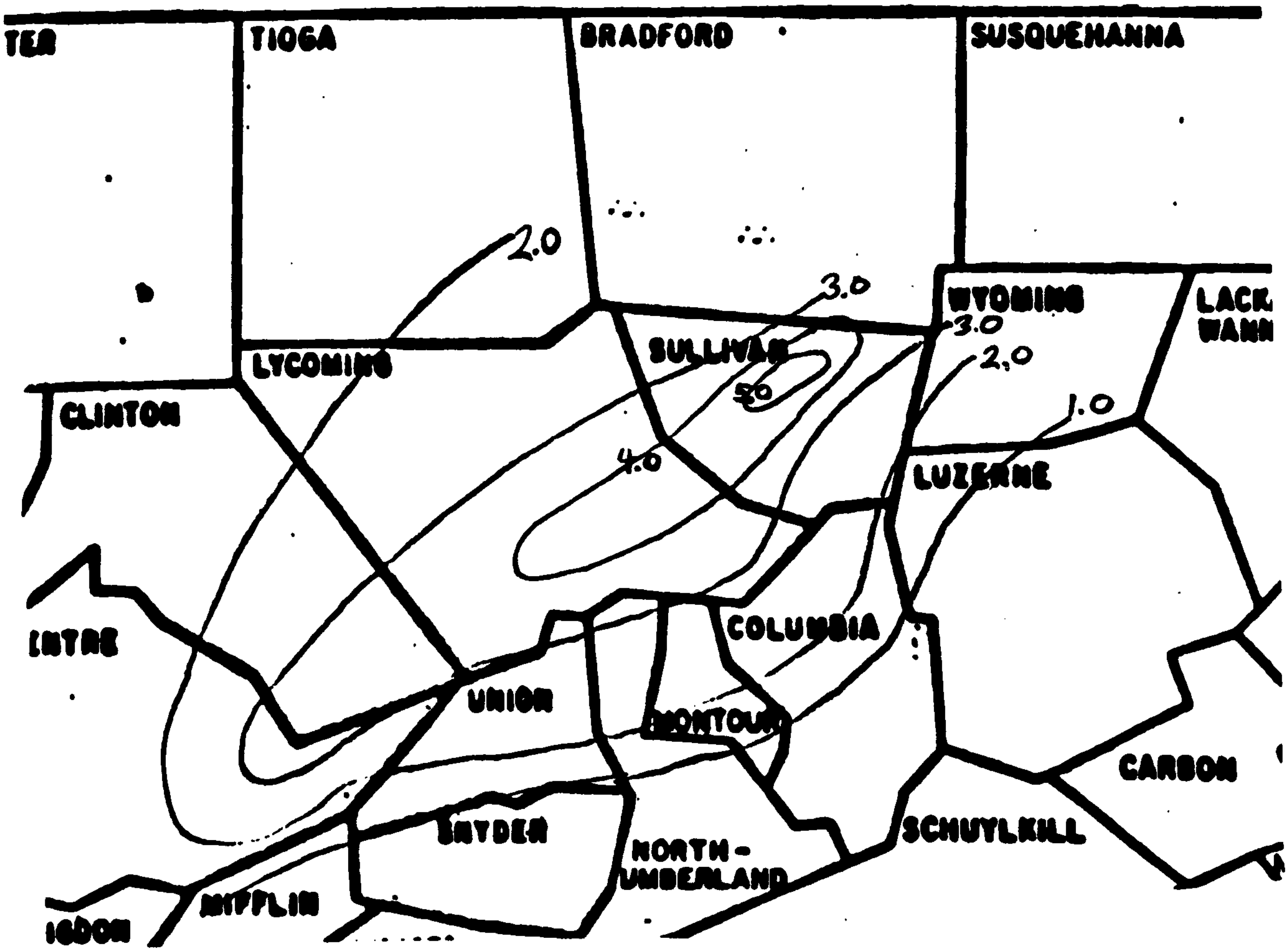

Figure 22. Actual Rainfall from 29/0600Z to 29/2000Z (in.)