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PAPER
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WISCONSIN GRAVITY BASE STATION NETWORK

by C. Patrick Ervin

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Geological and Natural History Survey
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Wisconsin Gravity Base Station Network

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INTRODUCTION

Bedrock in Wisconsin is obscured by overlying material, such as glacial deposits in the north and east. In such areas, the geologist must use geophysical methods to infer the nature of the bedrock. One of the most economical methods to investigate bedrock in such areas is the gravity survey, that is, measurement of small changes in the gravitational field that occur between points on the earth's surface. These changes can be interpreted in terms of variations in the nature of the rocks because the strength of the field depends upon horizontal changes in density, which are a function of the structure and the mineral content of the rock. Gravity studies are particularly useful in Wisconsin for investigations of Precambrian basement lithology and structure, in locating groundwater resources, and in determining sedimentary rock structures.

If studies of the gravitational field are to be effective in resolving the geological picture on a statewide scale, measurements in one part of the state must somehow be related, or "tied," to measurements in another part. This problem arises because a gravity meter does not measure the absolute value of the gravitational field; it only measures the difference in the field between two points. Consequently, if the field at a point near Rhinelander in northern Wisconsin is to be compared to the field in Madison, the two must be tied together by an unbroken chain of measurements from one to the other.

The most efficient way to compare gravity from one area with another is to establish a network of base stations throughout the state that have been accurately tied together. If individual gravity measurements are then tied to the nearest base station in the state network, values in one region of the state can be compared to those in any other part of the state. The base station ties must be done with great accuracy as variations in the gravitational field of only a few parts in a 100 million are significant.

There are two sets of gravity base stations within the state of Wisconsin that have been used in the past. One of these will be called herein the DOD network because the station descriptions are maintained in the U.S. Department of Defense, Defense Mapping Agency--Aerospace Center in St. Louis. The second network is a series of bases established by Richard J. Wold while at the University of Wisconsin-Milwaukee.

The DOD network is a composite of bases established by various individuals at different times with varying degrees of accuracy. The network may not be internally reliable and several of the station locations are unmarked or inaccessible.

Wold's network was begun in anticipation of a subsequent gravity survey of the state that was never made. Again several of these base stations are at unmarked or inaccessible locations.

In addition, a number of stations in both systems have been destroyed by subsequent cultural activity.

An evaluation of the old base station system (Ervin and Hammer, 1977) showed the system to be inadequate for the regional gravity surveys anticipated within the state in the next few years as the bases were too few, too widely scattered, and not tied together to sufficient accuracy. Therefore, the Wisconsin Geological and Natural History Survey decided to establish an internally coherent network of base stations.

The text that follows is somewhat more extensive than that which normally accompanies the publication of the principal facts for a gravity base station network. This is intentional in the hope that, in addition to presenting the gravity values for the use of other geophysicists, the publication may also be useful to students and non-geophysicists as a source of information on the motivation, methodology, and problems encountered in constructing such a base network.

NETWORK DESIGN

Base stations have frequently been located in relatively inaccessible places, such as the landing apron of an airport or the basement of a municipal building. Although such sites have some positive attributes, they are quite unsuitable for the frequent, daily use required when conducting systematic, regional surveys. For such surveys, a base station should be readily accessible by auto, no more than 8-10 meters from a road or drive, easy to locate, permanently marked, relatively isolated from foot and vehicular traffic, and have a stable surface upon which to set the meter.

For reasons not related to the density of the underlying rock, the apparent value of gravity at a given point, as measured by a gravity meter, will change with time. This change, called "drift," is approximately linear over short periods of time only. To remove drift from the data, the meter should be returned periodically to the base station to determine how much drift has occurred. A correction factor can then be computed. For this reason, no point in the state ideally should be more than a 45-minute drive from a base station. Therefore, the first step in designing this network was to impose on the state map a grid having a diagonal mesh distance of approximately 100 km. If base stations were located at or near the grid intersections, most locations within the state would be within a 45-minute drive of a base station.

Older survey stations were included in the new network if they apparently met the conditions discussed above, even if they didn't conform to the idealized distribution. Locations for the new stations were then selected to fill-in the gaps in coverage and to approximate the idealized grid distribution.

Next, U.S. Geological Survey vertical control descriptions and topographic maps were searched for apparently suitable benchmarks at the proposed base station locations. Two or three alternative sites were usually selected for each base station. The lack of a suitable benchmark at a few locations necessitated some readjustment of the network at this stage.

Because of the drift problem discussed above, it is imperative that the time between measurements at successive base stations be as short as possible when the stations are being tied together. Hence, the survey crew cannot spend time looking for a suitable site, but must know exactly where they are to go. All proposed station locations therefore were field-checked in the summer of 1978. This proved to be a wise procedure as many of the proposed sites were found to be unusable for various reasons, such as the benchmark having been destroyed. Considerable time was spent searching for alternate sites. In some cases, an ideal site could not be located, so the specified criteria had to be compromised slightly. A written description, a sketch map, and a photograph of the exact location for placing the meter was then made for each selected site (see Appendix). The field-checking took approximately three weeks and resulted in a considerably modified station distribution. The final base station locations are shown in Figure 1.

The base station survey was conducted in the summer of 1980 with funding provided by the Wisconsin Geological and Natural History Survey and by Northern Illinois University. A few supplemental ties were made in 1981.

DATA COLLECTION

The survey was made using two LaCoste and Romberg geodetic gravity meters, numbers 226 and 409, owned by Northern Illinois University. These instruments are particularly well-suited for this type of survey as they have low, nearly linear instrumental drift, a reading precision of 5 microgals, and a large reading range. The calibration tables supplied by the manufacturer were used in making the computations.

The meters were wired directly into the automobile's electrical system by means of a 10 meter cable. This provided a constant source of power and eliminated many of the problems associated with batteries. To insure precision, the meter operators were required to make at least three readings within a range of 5 microgals at each setup.

The "looping" procedure described by Nettleton (1976, p. 84) was utilized throughout the survey. If the first station is designated A, the second B, the third C, and so forth, the sequence of readings is

A B A B C B C A C A . . .

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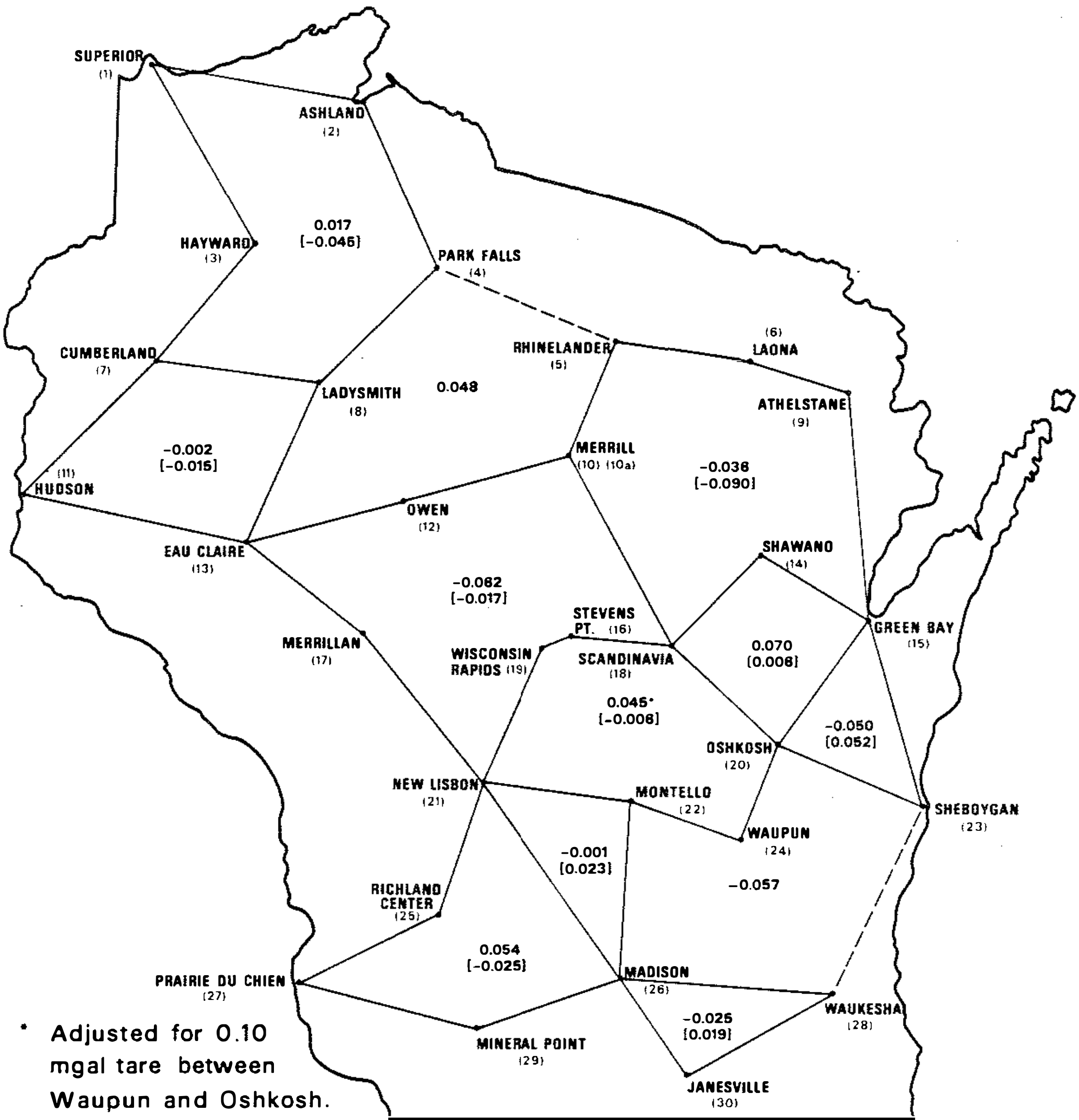

Figure 1. Gravity base station network showing closure error around each traverse loop. Sign of closure error is in clockwise direction. Error for LRG 226 is shown unbracketed while LR 409 error is in brackets.

This gives a series of closed-loop, "minimum-time" ties between adjacent stations. Breaking them out of the sequence, these loops are

Sequence: A B A B C B C A C A . . .

```
Loops: A B A
         B A B
             B C B
               C B C
                   C A C
                     A C A
```

Note that the last leg of the first loop (ABA) is the first leg of the second loop (BAB). Thus, each meter yields two closed-loop ties between each base station, although the two are not completely independent. Since the two meters were operated simultaneously, this procedure results in four closed-loop, minimum-time ties between adjacent stations. Use of two meters gives twice as much data for a minimal increase in cost and facilitates the detection and resolution of errors in the data.

In addition to minimum-time loops between stations, the survey also employed "traverse" loops (Nettleton, 1976, p. 84). This is similar to an elevation survey in which the survey line eventually closes on itself. For example, the illustrative sequence in the preceeding paragraph started with station A and eventually returned to station A. The difference between each pair of stations should sum to zero around the traverse loop. Any deviation from zero is called a closure error and must be distributed around the loop in some manner.

DATA REDUCTION AND ANALYSIS

The data were reduced using the manufacturer's calibration curves. Meter readings were converted to milligals and averaged. The averaged readings were then corrected for earth tides using the Longman (1959) algorithm. Any residual drift was assumed to be linear and was removed as such.

The four loop ties between any pair of stations should all show the same gravity difference and the sum of the differences around any traverse should be zero. This is rarely observed. The four loops usually produce four slightly different values. A major cause of these discrepancies is setup error by the observor, such as slight misleveling of the meter. Also, the use of any meter in a field environment probably produces many small, microgal-magnitude tares, or discontinuous scale shifts, due to vibration and handling. Therefore, the two measured differences between stations for each meter were averaged and the averaged values were used to compute the closure error around each traverse loop for each meter (fig. 1). All closure errors are less than ± 0.1 mgal.

A 0.10 mgal tare between Waupun and Oshkosh necessitated an adjustment to the data for meter 226. Unfortunately, this tare occurred on the common leg of the two loops. However, the magnitude of the tare was fairly obvious from examining the data for meter 226 and was further confirmed by the observed differences for meter 409. The uncertainty in the magnitude of the error is believed to be ±0.01 mgal. It should be noted that if the 0.10 mgal tare were undetected, the drift-corrected error in the gravity difference between the stations would be approximately 0.06 mgal. This is a good example of being able to compensate for a problem in the data because of the presence of a second meter.

Theoretically, closure errors should be random and therefore should sum to zero. Table 1 shows this to be approximately true for the 1980 data. The similarity of the three columns in Table 1 suggests that the distributions of error for the two meters do not differ significantly and can be combined into one data set that characterizes the distribution of error in the network. This hypothesis can be quantitatively tested using two statistical tests.

Table 1
Error of Closure Statistics

	Meter 226	Meter 409	Combined
Sum of Error (mgal)	0.010	-0.008	0.002
Mean Error (mgal)	0.001	-0.001	0.000
Variance ($mgal^2$)	0.00204	0.00166	0.00175
Standard Deviation (mgal)	0.045	0.041	0.042
Number of Samples	10	10	20

The first test is to determine the equality of variances for the two data sets consisting of the closure errors for the two meters. This is the well known F test, which here gives a value of 1.23. With nine degrees of freedom for each data set, this is well below the critical value for all standard levels of significance, indicating that the two data sets have been drawn from populations having equal variance.

Given that the variances are equal, the student's test can then be used to test for equality of the population means. The computed value is 0.104. For 18 degrees of freedom, this is again well out of the critical region. Hence, the two data sets may be assumed to have been drawn from populations with identical means.

The closure errors for the two meters therefore can be combined to form one data set. The distribution of closure errors for the base station network then has a mean value of 0.000 mgal and a standard deviation of 0.042 mgal, indicating that the error is well within acceptable bounds.

The next step is to distribute the closure error around the traverse loop. The simplest way to do this is to distribute it uniformly. This seldom works because many traverse loops have common segments, and the correction computed for the segment from one loop generally is not the same as computed from the other loop, yet they must be identical. To circumvent this, a least-square adjustment algorithm is sometimes used. This approach assumes that all values in the network are known with equal accuracy. If this assumption is not correct, the presence of significant errors in some stations may be masked by redistributing the error throughout the network (Sazhina and Grishinskey, 1971). This would have been true for the present survey.

An additional constraint in the present analysis is that the final values for the two meters must also be in agreement. Closure errors for this survey were therefore distributed in the empirical manner suggested by Nettleton (1976). The error assigned to each segment was based on a subjective evaluation of the probable error along that segment as a result of careful examination of the data.

The evaluation of the probable error associated with each segment was based on several sources of information. As discussed earlier, two measurements of the gravity difference between a pair of stations were obtained for each meter. Hence, a significant discrepancy between these two values is an indication of possible error. Disagreement between the averaged values of the two meters is also an indication of error.

If one of these indicators suggested the presence of an error, the amount of drift for each loop was examined. A large amount of drift in one loop would pinpoint the problem. In addition, the field notes were checked for any observations by the meter operators that might be helpful.

All of the information discussed above was used in resolving a major problem encountered in one traverse loop. A discussion of this "worst case" problem and its resolution is included here as an illustrative example. It is an especially strong argument for the use of two meters as the problem would have been difficult to detect with only one meter and could not have been resolved without additional field work.

The closure error for meter 409 is -0.017 mgal (fig. 1) in the traverse loop including the station sequence New Lisbon-Merrillan-Eau Claire-Owen-Merrill. Actually, this is not a time-continuous sequence as the New Lisbon to Eau Claire measurements were made one day, while the Eau Claire to Merrill measurements were made several days later.

Although the closure error is reasonable, a 0.070 mgal discrepancy between the averaged values for the two meters between New Lisbon and Merrillan, followed by a 0.057 mgal discrepancy between Merrillan and Eau Claire, suggested the presence of a serious problem. Meter 409 also showed a moderate lack of agreement between its two ties for the New Lisbon to Merrillan segment. When the field notes were checked, it was discovered that the levels on meter 409 had been reset the previous evening. The lack of a positive locking mechanism on the level adjustment screws of the newer LaCoste and Romberg geodetic meters may leave them susceptible to possible "screw-creep" after adjustment. This is apparently what occurred in this instance.

The measurements made with meter 409 between New Lisbon and Merrillan are believed to be invalid and were discarded. The correction of meter 409 for the Merrillan to Eau Claire segment was determined from the resulting consistent discrepancy between the two meters for the stations in the northwest. The problem was further obscured and its resolution complicated by an error of opposite sign in the Eau Claire to Merrill sequence of measurements that was made a few days later. The availability of the two independent data sets, plus careful analysis of the data, permitted a relatively straightforward solution to the problem without additional field work.

Station 10A at Merrill is also a DOD base station and was included in Wold's network. The DOD gravity value (ACIC Ref. Pub. 25, rev. 1974) at this station was assumed to be correct and the values for all other stations were computed relative to it. The final values are shown in the appendix.

In addition to Merrill, one other DOD station (30. Janesville) and five other Wold stations (2. Ashland, 7. Cumberland, 14. Shawano, 20. Oshkosh, and 23. Sheboygan) remain in the network. If the relative differences between these stations and Merrill in the earlier networks are subtracted from the differences determined herein, the following variations are found:

Janesville	0.03 mgal
Ashland	-0.02 mgal
Cumberland	0.03 mgal
Shawano	-0.02 mgal
Oshkosh	0.04 mgal
Sheboygan	-0.01 mgal

The maximum discrepancy does not exceed 0.04 mgal. No information is given on the accuracy of Wold's data, but DOD lists an uncertainty of $\pm$0.1 mgal for Janesville. Hence, the values reported here are in excellent agreement with their earlier determinations. This is especially gratifying in that no reference was made to the earlier surveys while processing the data for this report.

In 1981, meter 226 was used to tie the Wisconsin network to networks in all of the adjacent states except Iowa, which could not be tied due to closing of the bridge at Prairie du Chien. For Michigan, the Athelstane base was tied to DOD base #4597-1 at the Dickinson County courthouse in Iron Mountain, which is part of the base network used by Klasner and Jones (1979) for the gravity map of the Iron River 1^{o} by 2^{o} quadrangle. The measured magnitude for this survey was 980583.24, which is 0.05 mgal less than the accepted value and well within the $\pm$0.1 mgal uncertainty given by DOD.

The Illinois network also includes a station at the Rock County Airport in Janesville, but it is located by the loading gate at the terminal and about 10 feet southeast of DOD base #2011-3 and a coincident base of Wold's (see the sketch map for base 30). Ties were made between these two bases and this survey's base in the parking lot. The Illinois and DOD bases differed by less than instrumental precision and therefore have identical magnitudes for this survey of 980315.52 mgal. This is exactly the DOD reported magnitude and 0.08 mgal higher than Wold's values, but is 1.54 mgal less than the reported Illinois value (McGinnis, 1966). The Illinois network is tied to DOD Base #0388-2 in St. Louis and uses an absolute value for that station that is 1.22 mgals higher than that given by DOD the following year. The remaining error is apparently within the Illinois network.

The Minnesota network, established by R. Ikola for the Minnesota Geological Survey and never published, is tied to DOD base #0528-1 in the basement of Pillsbury Hall, University of Minnesota, Minneapolis. In practice, a secondary base outside the building has been used. The secondary base has a reported value of 980583.93 adjusted to IGSN-71, while the measured value for this survey is 980583.16. The cause of the 0.77 mgal discrepancy is unknown. Three interlocking ties were made between the Hudson and Pillsbury bases, and the three measured differences agreed to within 3 microgals. The error therefore must be in one of the two base values. Since the Hudson base is tied directly to the Cumberland base and the latter has been bound to agree closely with Wold's determination, it is unlikely that the Hudson base contains this much error.

DISCUSSION

There are several unusual features in this base network that require further explanation. The Stevens Point station is quite close to the Wisconsin Rapids station and does not conform to the criteria established for the network. For example, it is in a pasture on private property. It was included because it is located at a benchmark that M.G. Mudrey, Jr. (verbal communication) reports to be situated in bedrock. The network is therefore tied to a point of presumably unchanging elevation at which the gravitational value should not vary due to fluctuations in the water table. This may be of potential use in long-term studies of changes in the gravitational field.

The presence of two stations in Merrill also requires explanation. The textbook approach to a gravity study is to first establish the base station network and then begin detailed studies tied to that network. However, planning and budgetary realities do not always conform to theory. In this instance, a regional survey of northeastern Wisconsin was already in press when the base station survey was made. In order to make the regional survey conform to the base network without delaying its publications, it was tied to the DOD station that is coincident with station 10A in this report. However, during the second year of the regional survey, Merrill moved its government to a new city hall and put the old building up for sale. To maintain the integrity of the data, the regional survey crew quickly tied station 10A to station 10. Station 10 was later used by the crew establishing the base station network.

As noted above, the calibration tables supplied by the manufacturer were used in reducing the data. The use of two meters permits a check on these calibrations. The three readings for each meter at each setup were averaged and converted to milligals. The computed value for each meter can then be treated as an axial coordinate in a rectangular system. The pair of values for the two meters define a point in "meter space." If This is done for each setup at all stations in the network, the resulting plot should define a straight line of slope 1.0 if the two meter calibrations are in agreement. If there is a systematic variation in calibration, the slope will deviate from one.

If the gravity values for meter 226 are treated as the dependent variable, the linear least-square regression line defined by data in this survey has a slope of 1.00002596. The range of measurements in the network is approximately 418 mgal. Over this range, the deviation from the theoretical slope would introduce an error of only 11 microgals. The true discrepancy is probably even less as the data set was not adjusted for the tare in meter 226 between Waupun and Oshkosh. Although this does not prove that the manufacturer's calibrations are correct, it does show that the two are consistent.

ACKNOWLEDGEMENTS

The advice and council of Sigmund Hammer and the assistance of M.G. Mudrey, Jr., is deeply appreciated. The field crew was composed of Greg Hatch (meter 226) and Olaf Aiken (meter 409). Computing was done at the Northern Illinois University Computing Center.

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APPENDIX

Base Station Descriptions and Principal Facts

A comment on the reasons for selecting the format used in this section is appropriate. It is common to publish only a brief written description of a base station. When attempting to reoccupy such base stations, there is sometimes considerable doubt as to whether or not the correct location has been recovered, especially if the station is not monumented or if there have been significant cultural changes in the vicinity. Much of this uncertainty can be eliminated through the use of a sketch map and a site photograph. The format used in this report has been adapted, with only minor modification, from the unpublished network by R. Wold. For quick reference, a table with the stations ordered alphabetically is presented first. All gravity values were reduced using the Geodetic Reference System 1967 and are with respect to the International Gravity Standardization Net-1971.

The accuracy of the network is estimated to be approximately ± 0.05 mgal, although the error for some stations may be larger.

On the following sketch maps, the letter "x" in a circle designates the position of the base station, a filled circle designates the location of the associated bench mark or other monument if not coincident with the base station, and the "eye" symbol shows the camera location and orientation. The maps are not drawn to scale.

Table A1

Alphabetical List of Base Stations

Name	Number	Gravity Field* (milligals)
Ashland	2	634.14
Athelstone	9	545.90
Cumberland	7	501.41
Eau Claire	13	518.48
Green Bay	15	495.10
Hayward	3	602.74
Hudson	11	560.83
Janesville	30	315.60
Ladysmith	8	553.20
Laona	6	524.77
Madison	26	354.77
Merrill	10	501.15
Merrill-DOD	10A	501.89
Merrillan	17	464.19
Mineral Point	29	309.99
Montello	22	382.52
New Lisbon	21	386.19
Oshkosh	20	421.81
Owen	12	493.61
Park Falls	4	576.06
Prairie du Chien	27	377.06
Rhinelander	5	555.21
Richland Center	25	355.87
Scandinavia	18	442.81
Shawano	14	485.78
Sheboygan	23	427.30
Stevens Point	16	416.68
Superior	1	733.05
Waukesha	28	341.98
Waupun	24	382.38
Wisconsin Rapids	19	426.96

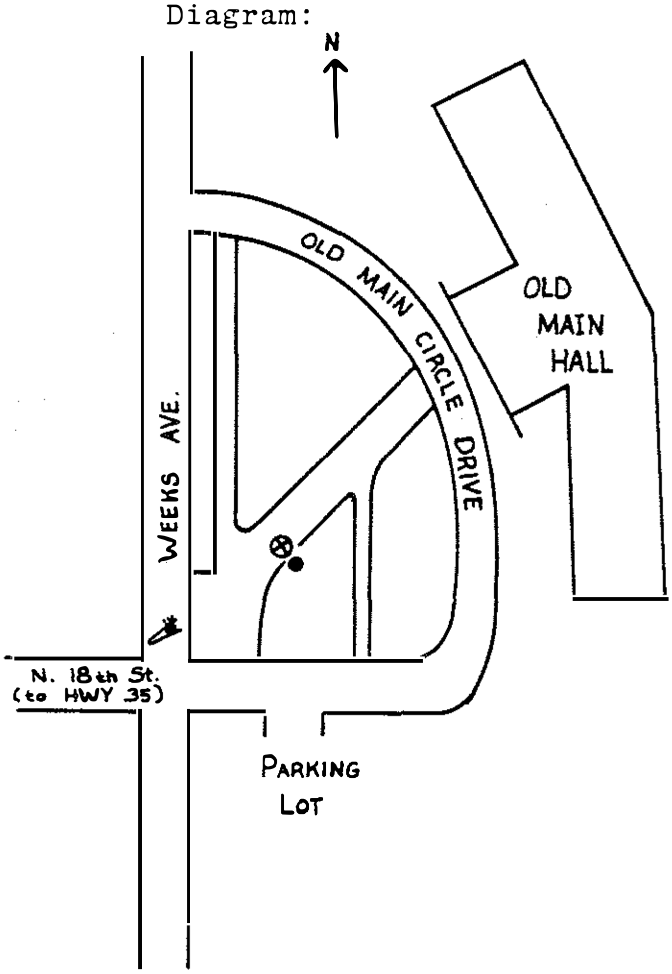
*add 980,000.00 to get absolute value in milligals.

Gravity Base Station Description

Station No.	1	City	Superior
Gravity (mgals)	980733.05	State	Wis.
Elevation (feet)	635	Latitude	46°43.0'
		Longitude	92°05.5'

Description: On sidewalk in front of USCGS BM set on iron post located on the Univ. of Wis.-Superior campus, 24' from the curb of Weeks Ave. near its intersection with N. 18th St.

Diagram:



Photograph:

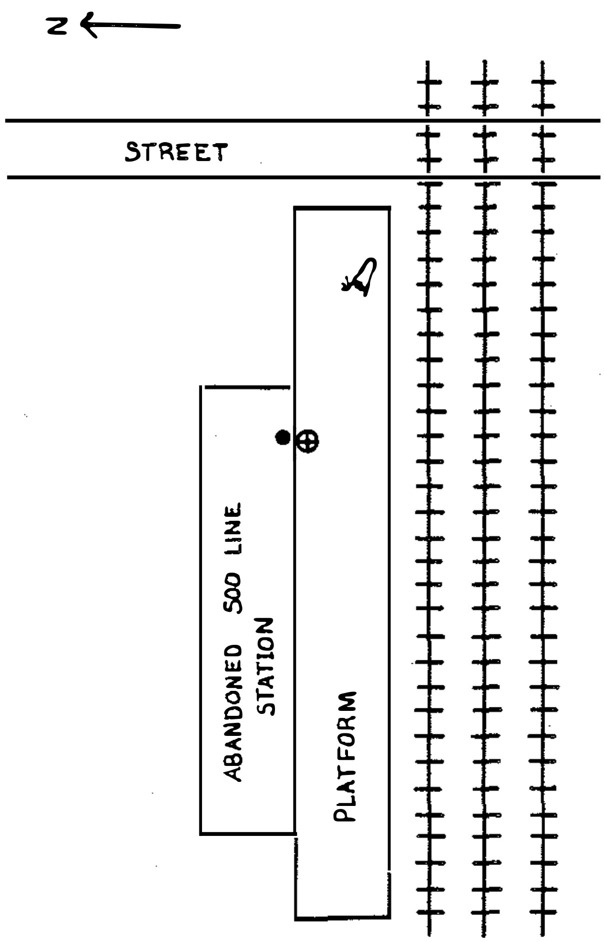
Gravity Base Station Description

Station No.	2	City	Ashland
Gravity (mgals)	980634.14	State	Wis.
Elevation (feet)	668	Latitude	46°35.1'
		Longitude	90°53.3'

Description: On the brick platform directly beneath USCGS BM stamped D16 1934 and set vertically into the south wall near the southeast corner of the abandoned Soo Line Station.

NOTE: There are two Soo Line stations in town.

Diagram:



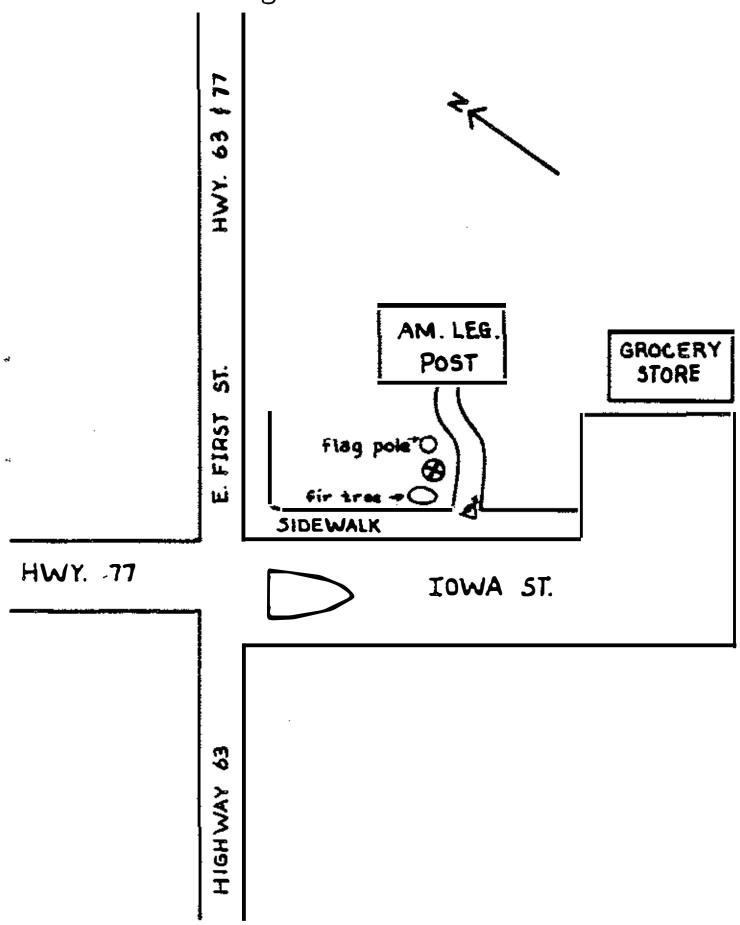
Photograph:

Gravity Base Station Description

Station No.	3	City	Hayward
Gravity (mgals)	980602.74	State	Wis.
Elevation (feet)	1198	Latitude	46°00.8'
		Longitude	91°29.0'

Description: On BM Stamped HAYWARD 1934 set in concrete post located in front of American Legion Post 218, 34' northeast of Iowa St. curb and 4' southwest of flagpole.

Diagram:



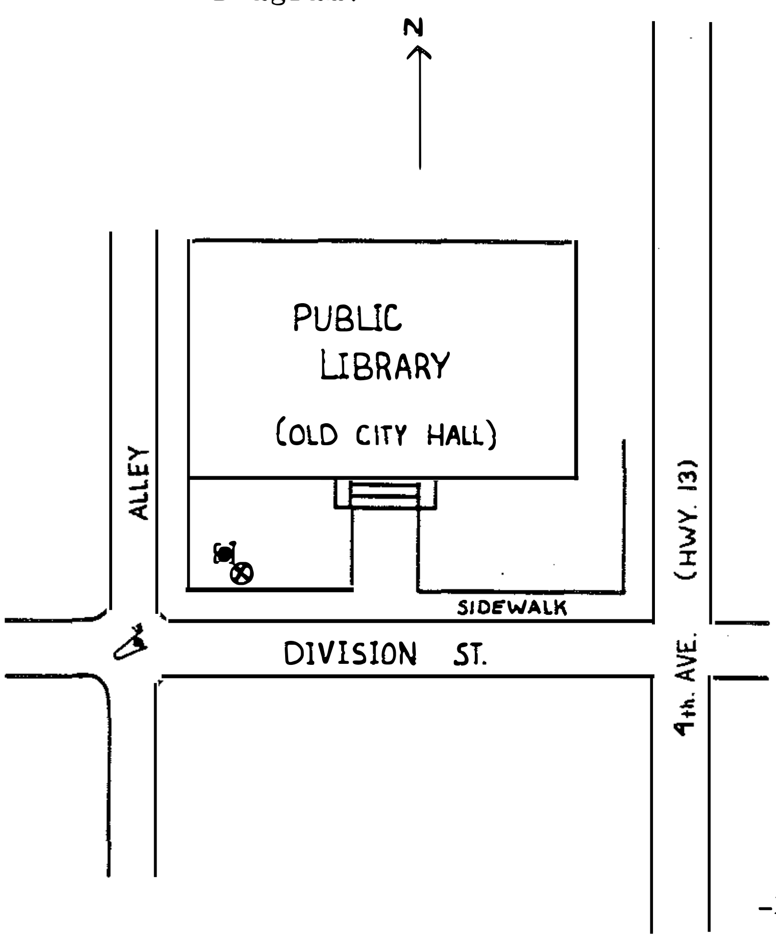
Photograph:

<u>Gravity Base Station Description</u>

Station No.	4	City	Park Falls
Gravity (mgals)	980576.06	State	Wis.
Elevation (feet)	1514	Latitude	45°56.0'
		Longitude	90°27.1'

Description: Adjacent to concrete post containing USCGS BM stamped J40 1934 in southwest corner of public library lawn 3.5' from alley sidewalk and 2.5' from sidewalk adjacent to Division St. (Post may have been disturbed to leaning position due to frost heaving.)

Diagram:



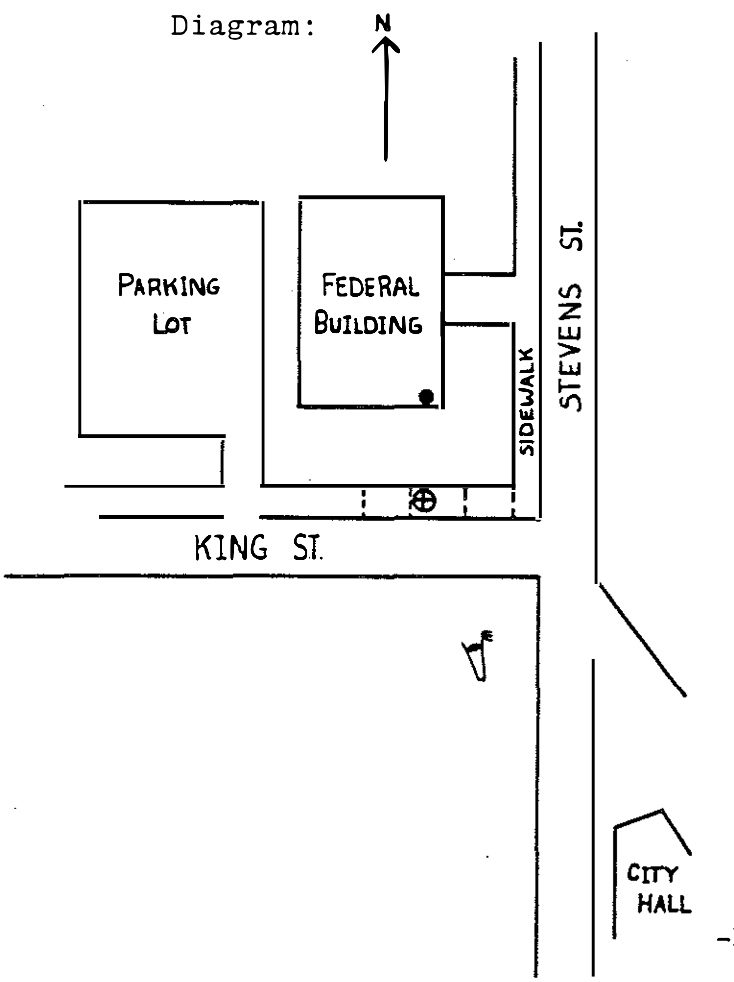
Photograph:

Gravity Base Station Description

Station No.	5	City	Rhinelander
Gravity (mgals)	980555.21	State	Wis.
Elevation (feet)		Latitude	45°38.2'
		Longitude	89°24.7'

Description: On northwest corner of second sidewalk slab west of sidewalk paralleling Stevens St. opposite USCGS BM stamped D2 1922 and set vertically in south face of Federal Building, 10" from the southeast corner and 30" above ground, located at the intersection of Stevens and King Sts.

Diagram:



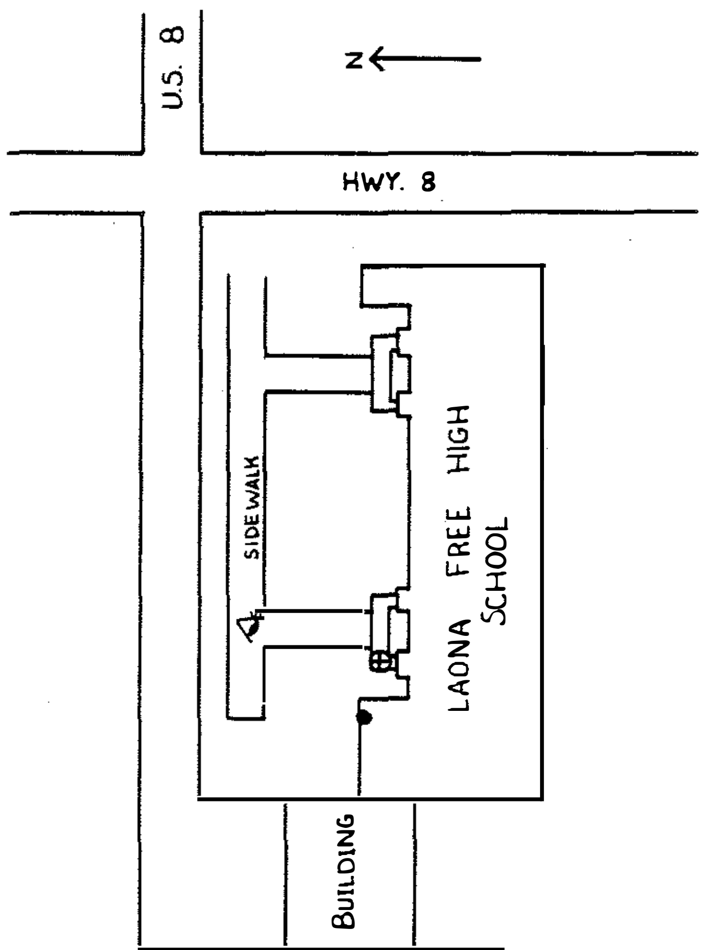
Photograph:

Gravity Base Station Description

Station No.	6	City	Laona
Gravity (mgals)	980524.77	State	Wis.
Elevation (feet)	1578	Latitude	45°33.9'
		Longitude	88°40.5'

Description: On the west end of the first step from the sidewalk of the west entrance on the north side of the Laona Free High School and about 5' east of USCGS BM mounted vertically about 1.5' above the ground in the north brick face of the building and stamped ?2 1922.

Diagram:



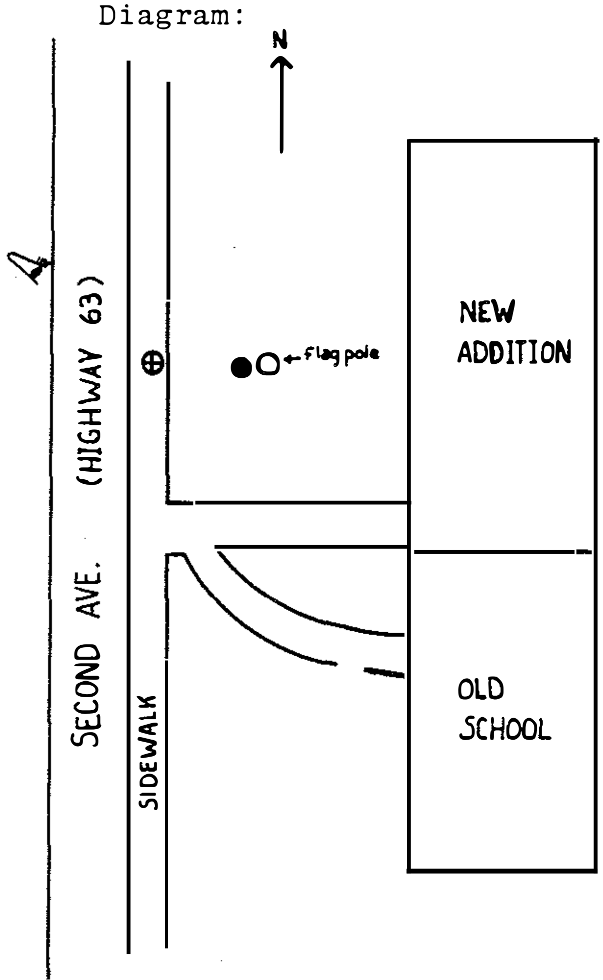
Photograph:

<u>Gravity Base Station Description</u>

Station No.	7	City	Cumberland
Gravity (mgals)	980501.41	State	Wis.
Elevation (feet)	1251	Latitude	45°32.3'
		Longitude	92°01.3'

Description: Along Second Ave. (Highway 63 north of business district) in front of elementary school, 6' west of flagpole, on sidewalk directly opposite the flagpole and a defaced USCGS marker originally stamped F46 1934 and set in a concrete post flush with the lawn.

Diagram:



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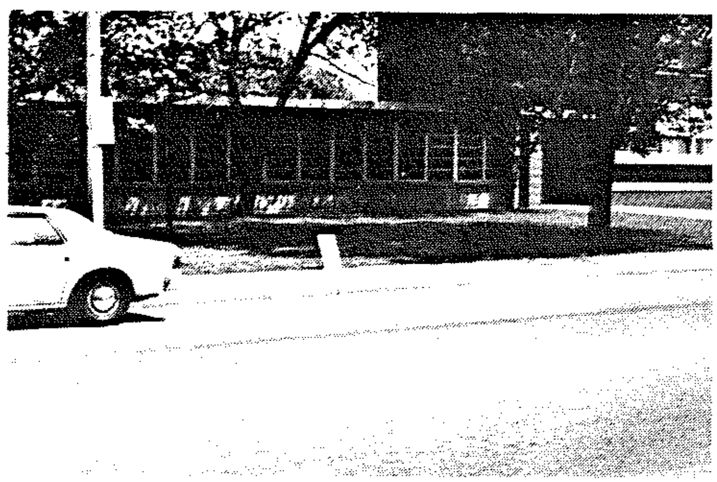
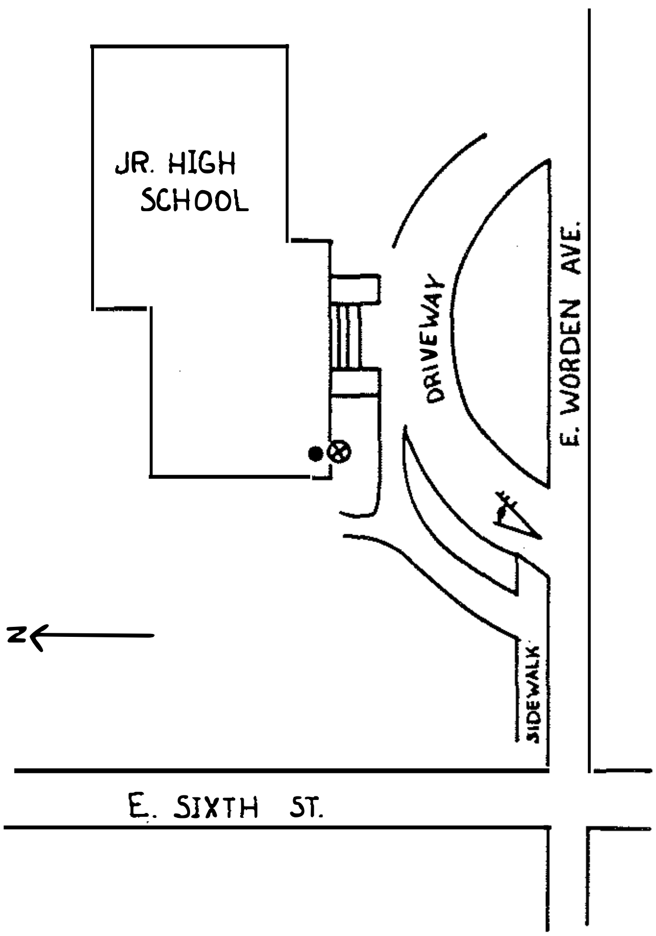


Gravity Base Station Description

Station No.	8	City	Ladysmith
Gravity (mgals)	980553.20	State	Wis.
Elevation (feet)	1155	Latitude	45°27.8'
		Longitude	91°05.6'

Description: At base of wall directly below BM stamped B2 1922 and set vertically in south face of brick Jr. High School building, one foot from west face and two feet above the ground. Building is located at intersection of E. Worden Ave. and E. Sixth St. (Both streets are called East).

Diagram:



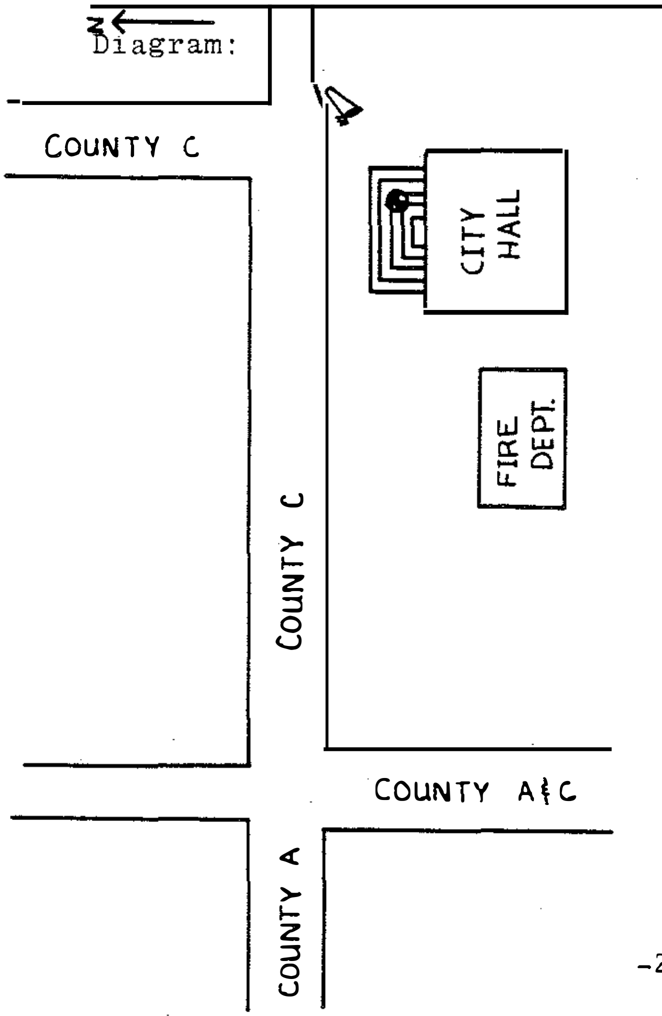
Photograph:

Gravity Base Station Description

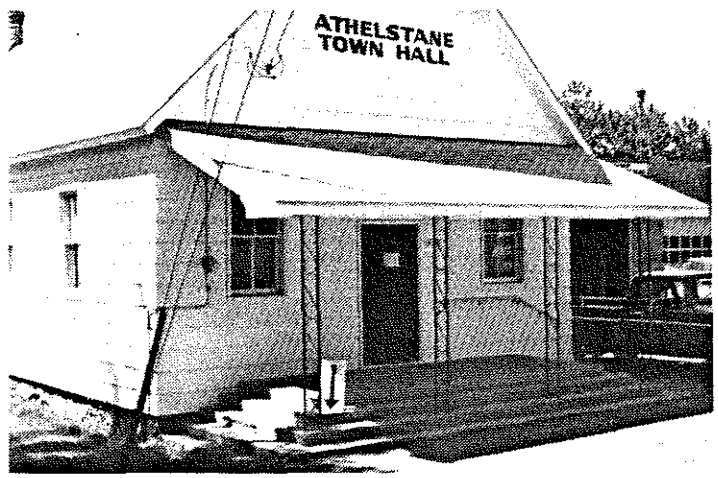
Station No.	9	City	Athelstane
Gravity (mgals)	980545.90	State	Wis.
Elevation (feet)	933	Latitude	45°25.4'
		Longitude	88°05.7'

Description: On east end of third step of City Hall on USCGS triangulation BM set flush with step and stamped 7 WRM 1971.

Diagram:



Photograph:

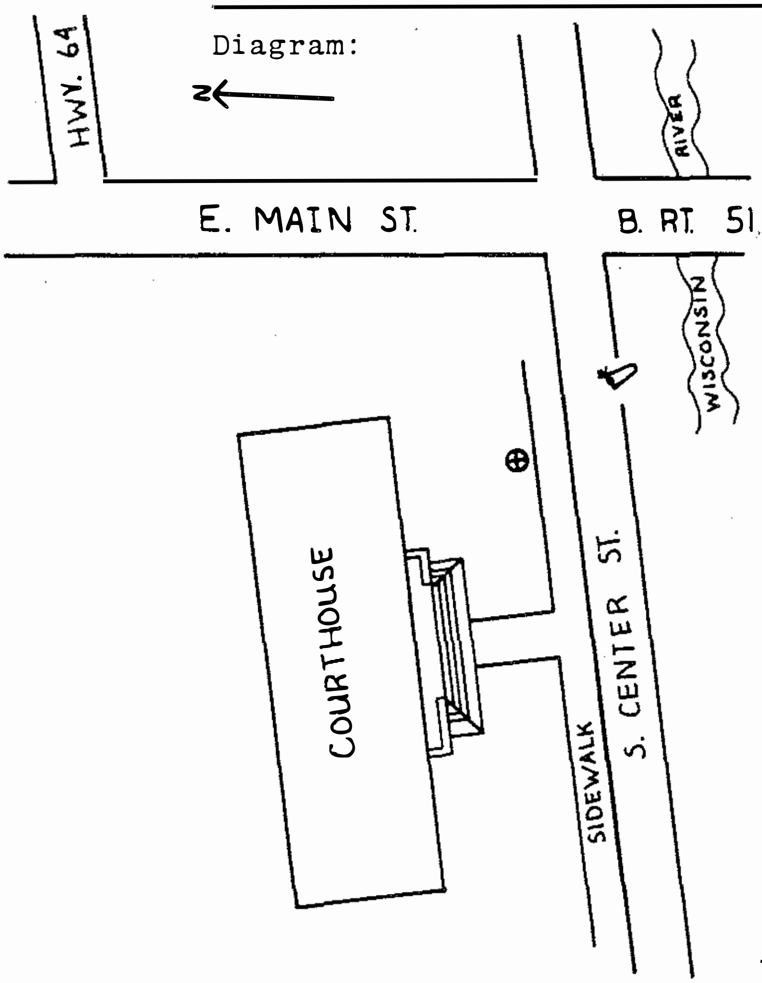


Gravity Base Station Description

Station No.	10	City	Merrill
Gravity (mgals)	980501.15	State	Wis.
Elevation (feet)	1268	Latitude	45°10.8'
		Longitude	89°41.0'

Description: On defaced BM originally stamped D32 1934 and set flush with lawn and located 15' from curb of S. Center St. and opposite second window from east end of courthouse.

Diagram:



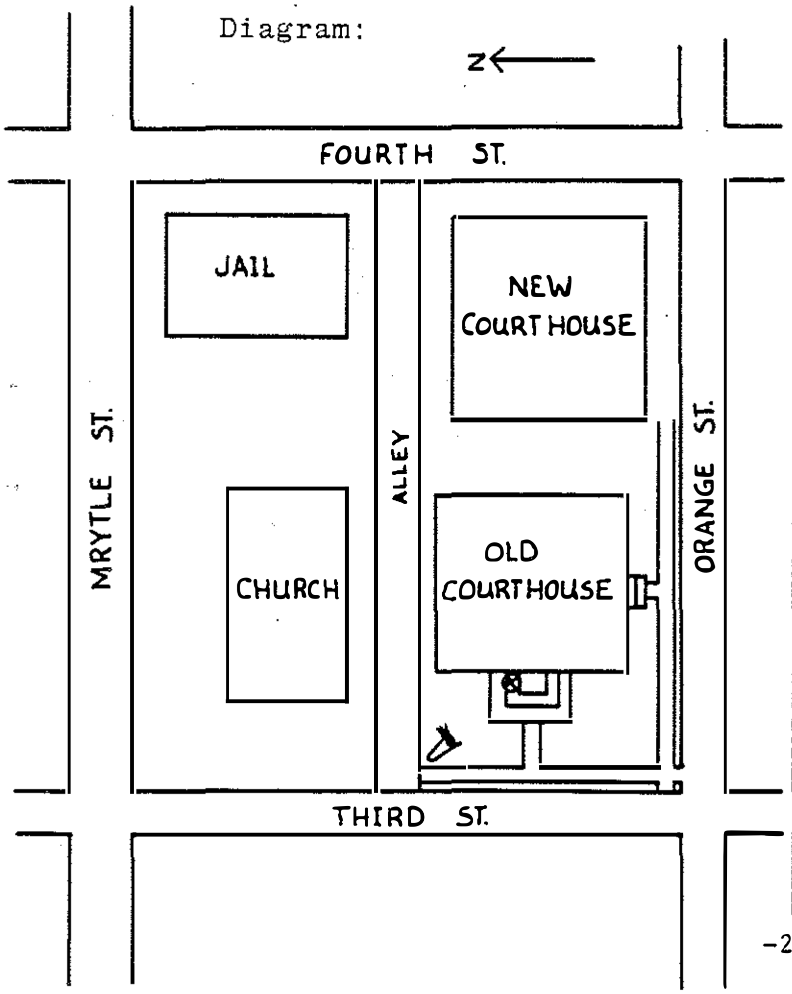
Photograph:

Gravity Base Station Description

Station No.	11	City	Hudson
Gravity (mgals)	980560.83	State	Wis.
Elevation (feet)	761	Latitude	44°58.8'
		Longitude	92°45.3'

Description: On the second step of the west entrance of the old courthouse directly below a USCGS BM mounted in the wall and stamped RIO 1933, 28' south of the edge of the alley.

Diagram:



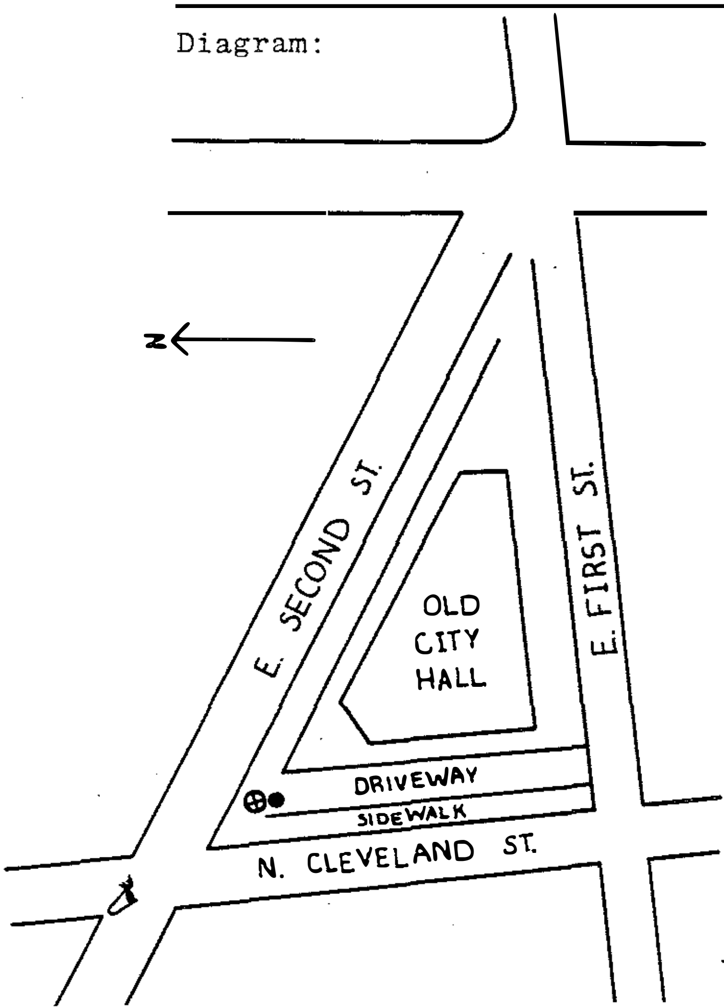
Photograph:

Gravity Base Station Description

Station No.	10A	City	Merrill
Gravity (mgals)	980501.89	State	Wis.
Elevation (feet)	1258	Latitude	45°10.8'
		Longitude	89°41.4'

Description: On sidewalk 4" below and on north side of USCGS BM stamped E32 1934 mounted in cement post located in driveway in the northwest corner of the old city hall at the intersection of E. Second St. and N. Cleveland St.

Diagram:



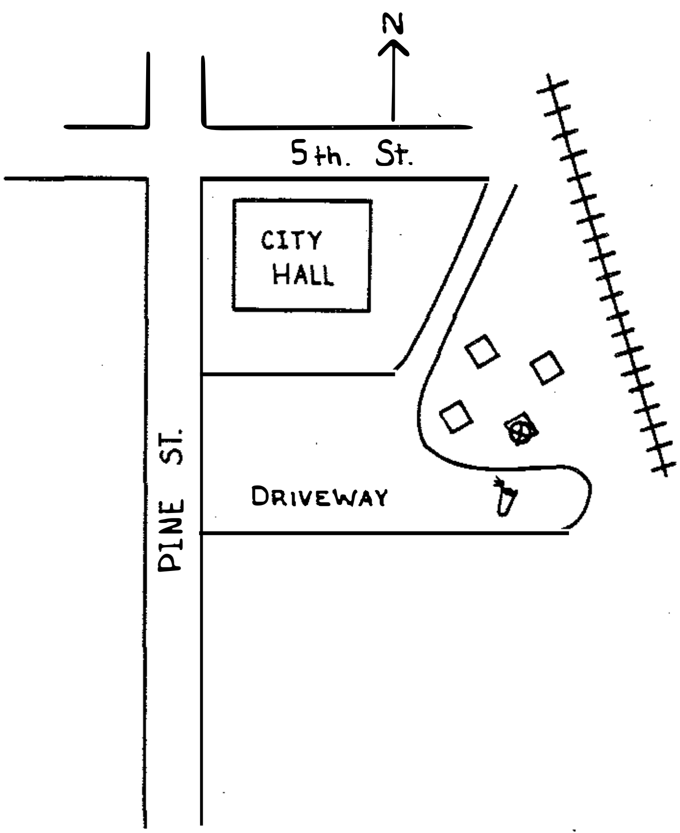
Photograph:

Gravity Base Station Description

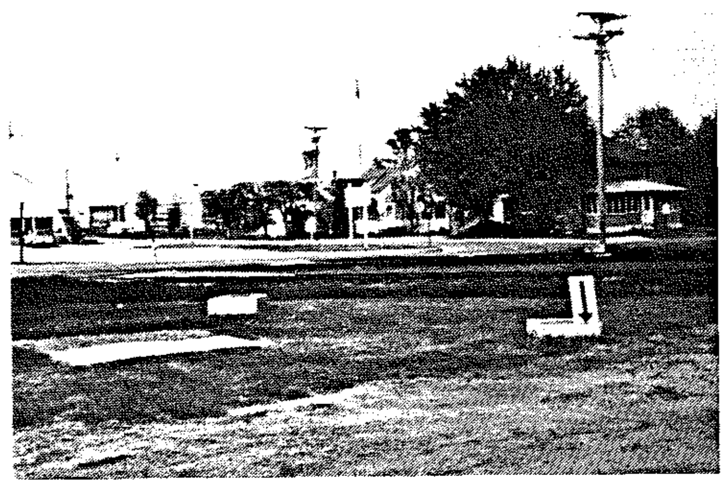
Station No.	12	City	Owen
Gravity (mgals)	980493.61	State	Wis.
Elevation (feet)	1245	Latitude	44°56.9'
		Longitude	90°33.7'

Description: On BM stamped 15 FWK 1962 and set in southeast concrete base for the demolished city water tower located southeast of the city hall at the intersection of 5th and Pine Sts.

Diagram:



Photograph:

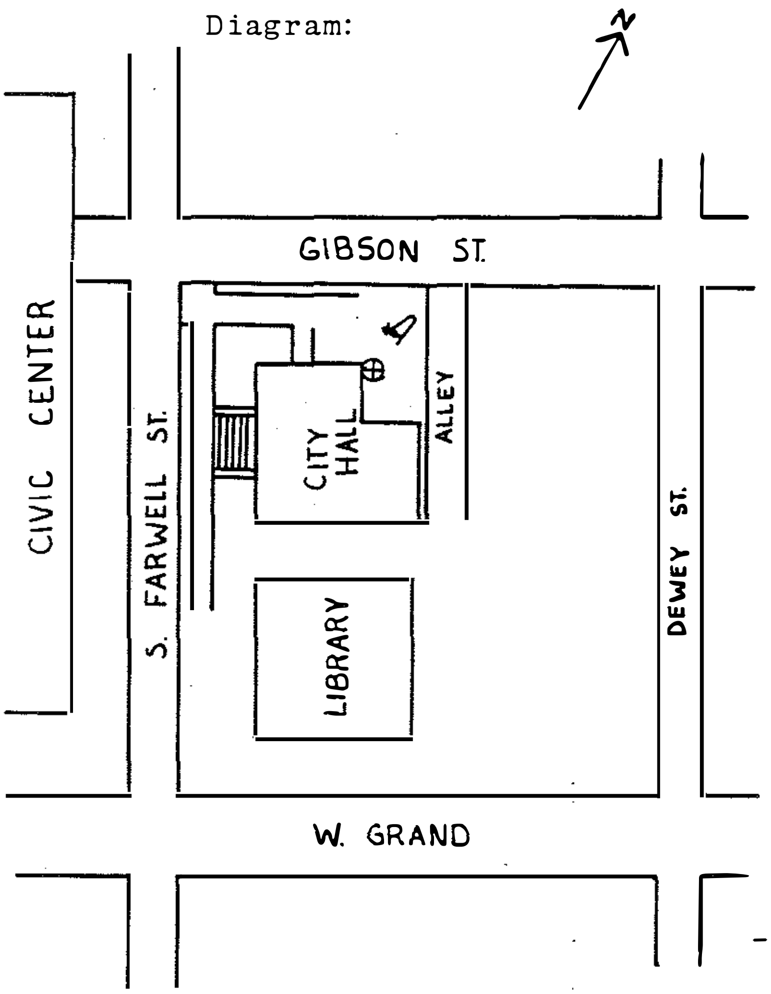


Gravity Base Station Description

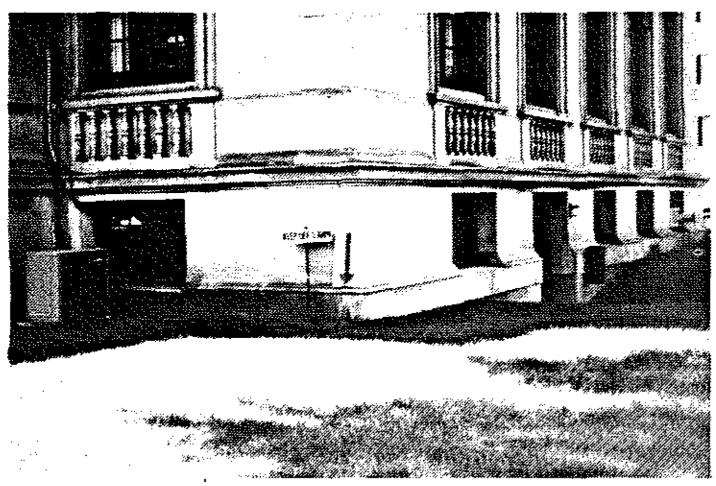
Station No.	13	City	Eau Claire
Gravity (mgals)	980518.48	State	Wis.
Elevation (feet)	798	Latitude	44°43.7'
		Longitude	91°29.9'

Description: Directly below USCGS BM stamped EAU CLAIRE 1934 and mounted in foundation 6" above ground and 8" from corner of building, 23' from alley curb and 37.5' from Gibson St. curb.

Diagram:



Photograph:

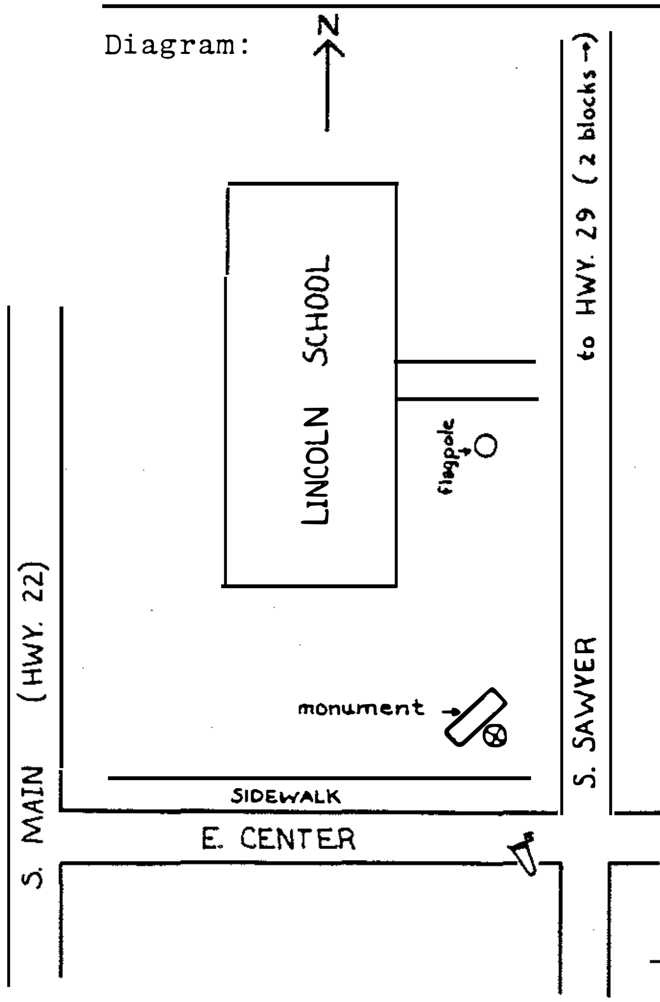


Gravity Base Station Description

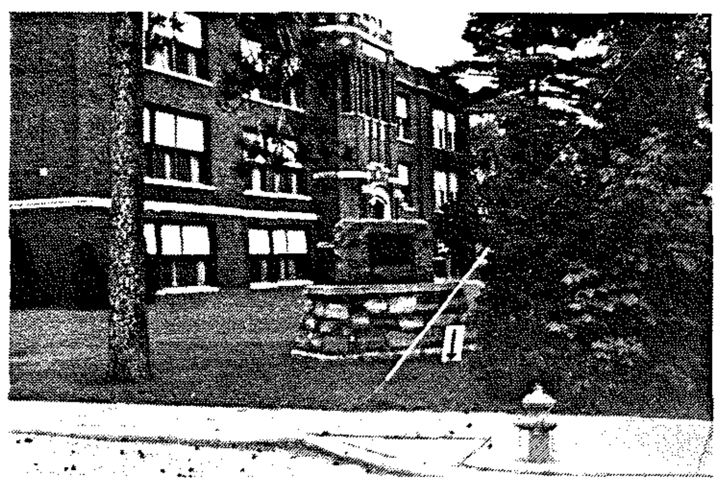
Station No.	14	City	Shawano
Gravity (mgals)	980485.78	State	Wis.
Elevation (feet)	819	Latitude	44°46.7'
		Longitude	88°36.5'

Description: On USCGS BM stamped M22 1934 and set in a concrete post in the southeast corner of the grounds of Lincoln School, 4' southeast of the center of a monument, about 5 yards west of the S. Sawyer Street sidewalk and 4 yards north of the E. Center St. sidewalk.

Diagram:



Photograph:

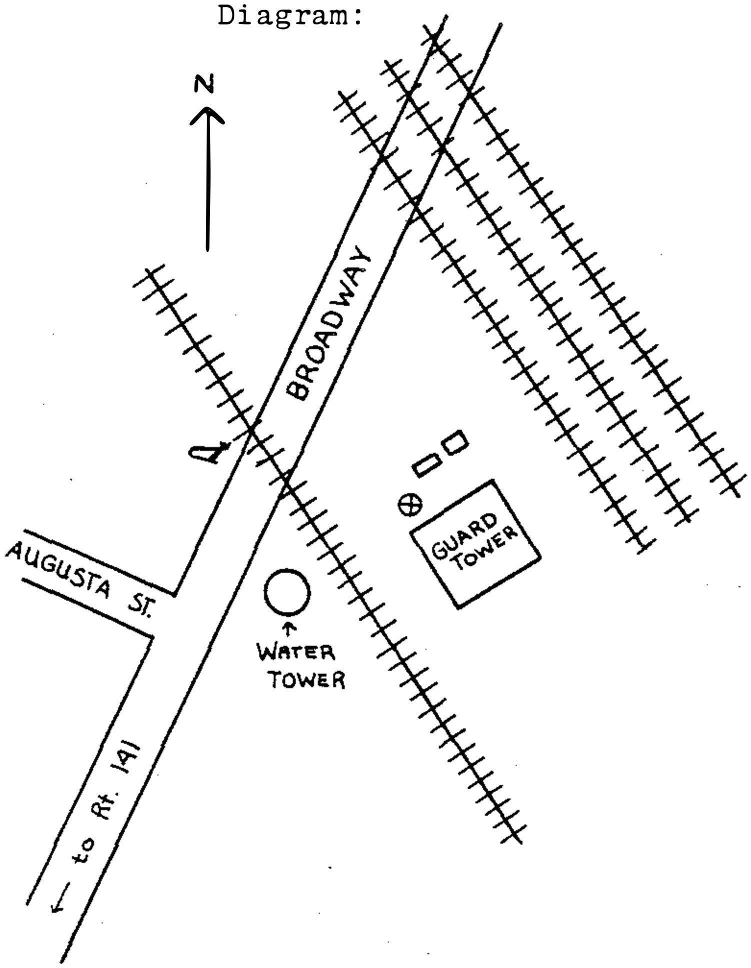


Gravity Base Station Description

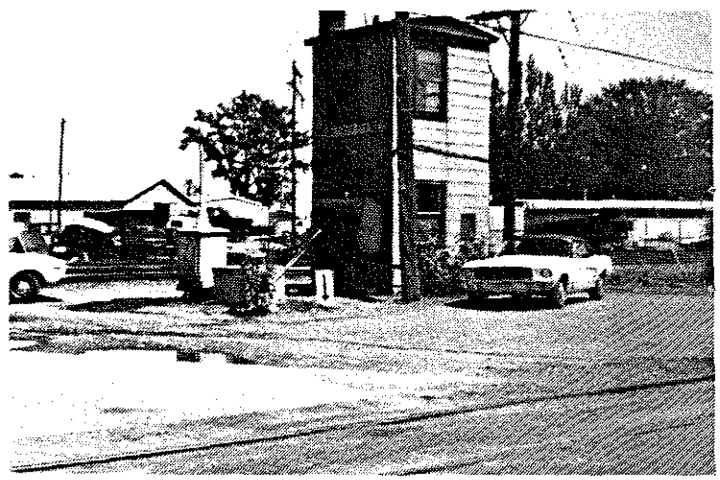
Station No.	15	City	Green Bay
Gravity (mgals)	980495.10	State	Wis.
Elevation (feet)	588	Latitude	44°31.6'
		Longitude	88°00.8'

Description: By BM mounted on top of concrete post extending 2" above ground between crossing guard tower and electrical control box. BM is stamped USCGS B6 RESET 1966 and is located 27' from the street and 8' from the northwest corner of the guard tower between Chicago and Northwestern tracks.

Diagram:



Photograph:

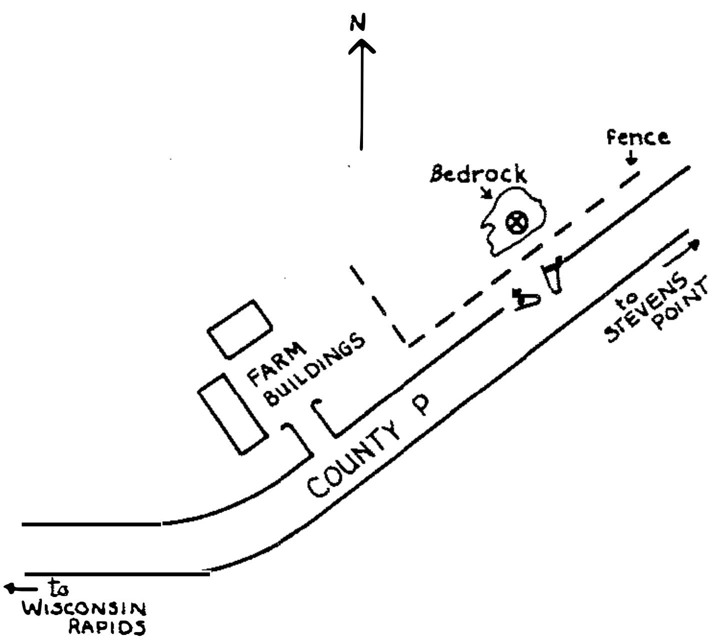


Gravity Base Station Description

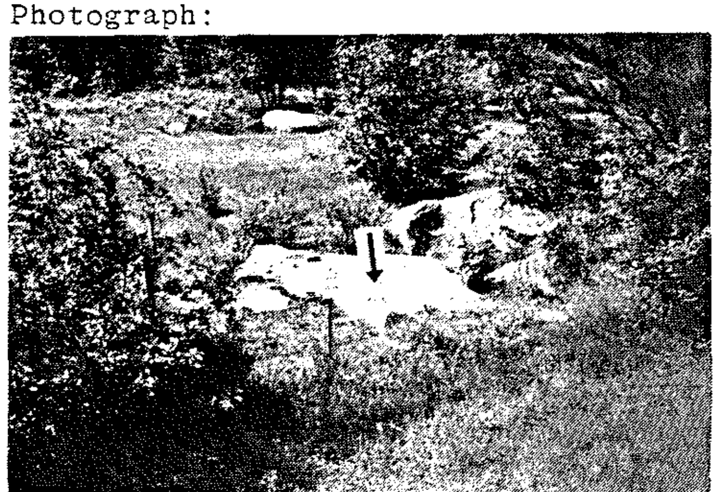
Station No.	16	City	Stevens Point
Gravity (mgals)	980416.68	State	Wis.
Elevation (feet)	1075	Latitude	44°29.3'
		Longitude	89°37.5'

Description: On BM set in bedrock in field adjacent to and north of County P about 2.7 miles southwest of the junction of U.S. 10 and County P in Stevens Point and located in T. 23 N., R. 7 E., sec. 12 just northeast of the pictured farmstead.

Diagram:



Photograph:

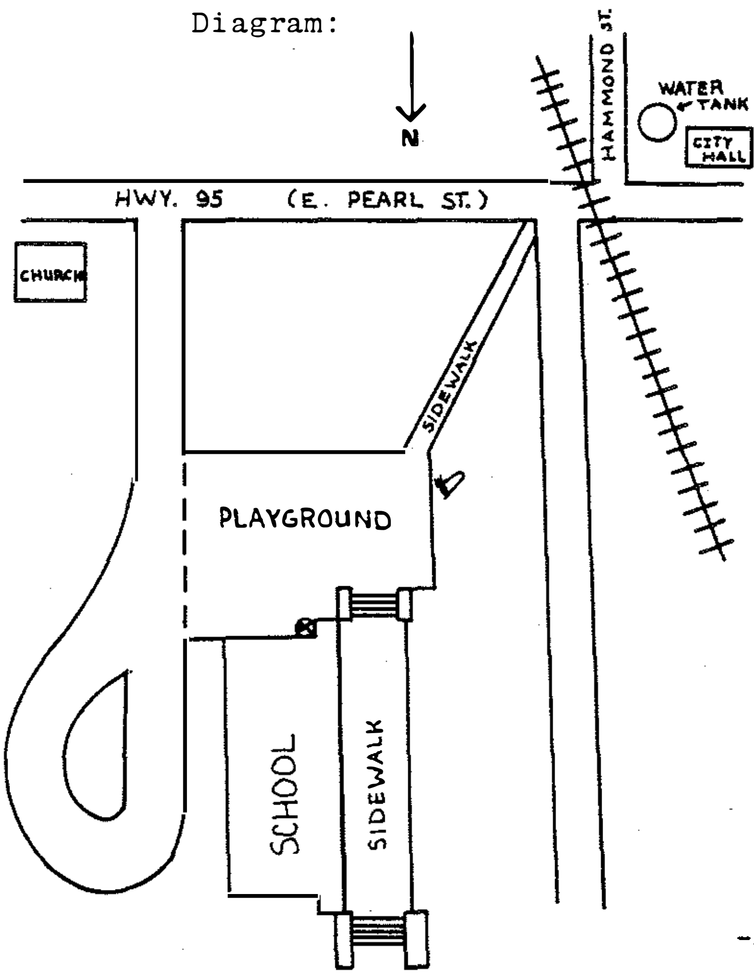


Gravity Base Station Description

Station No.	17	City	Merrillan
Gravity (mgals)	980464.19	State	Wis.
Elevation (feet)	937	Latitude	44°27.1'
		Longitude	90°50.4'

Description: On bronze table stamped T WIS 1923 set in concrete post on south side of schoolhouse near the southwest corner and east of steps to playground.

Diagram:



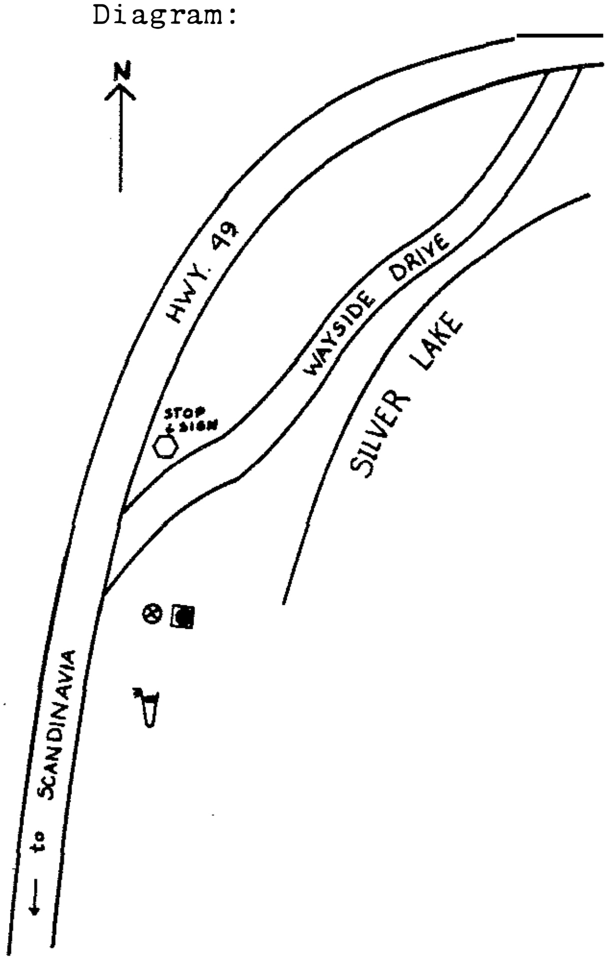
Photograph:

Gravity Base Station Description

Station No.	18	City	Scandinavia
Gravity (mgals)	980442.81	State	Wis.
Elevation (feet)		Latitude	44°27.9'
		Longitude	89°08.7'

Description: On west side of Wisconsin Conservation Department Biology Division BM in concrete post at south entrance to Silver Lake wayside park on State Highway 49 at north edge of Scandinavia.

Diagram:

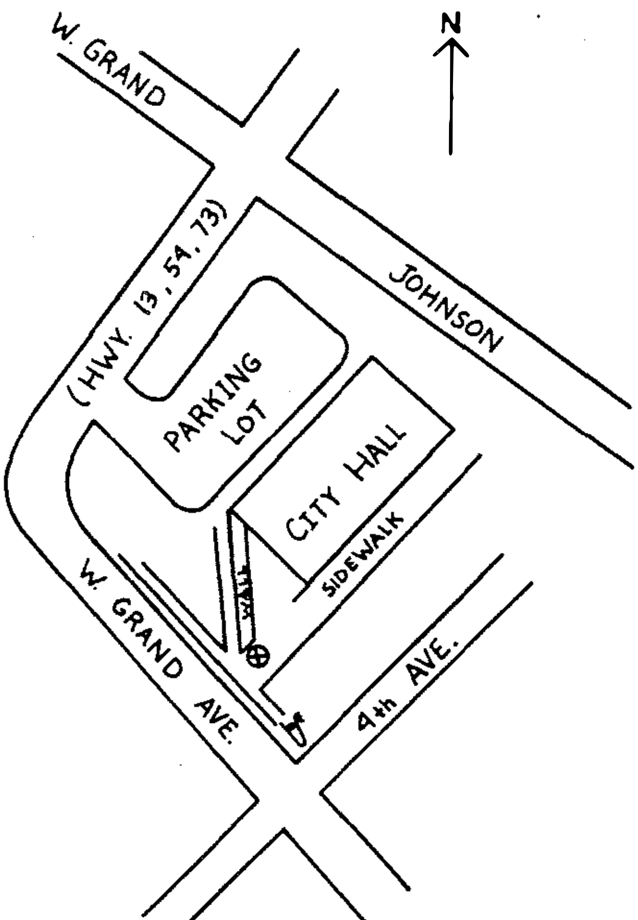


Photograph:

<u>Gravity Base Station Description</u>

Station No.	19	City	Wisconsin Rapids
Gravity (mgals)	980426.96	State	Wis.
Elevation (feet)	1010	Latitude	44°23.7'
		Longitude	89°49.9'

Description: On sidewalk above BM stamped E8 RESET 1977 and set in bottom of 7" deep hole in sidewalk covered by removable, iron, disk-shaped plate, located at end of wing wall from city hall and 18.5' from curb of W. Grand Ave.



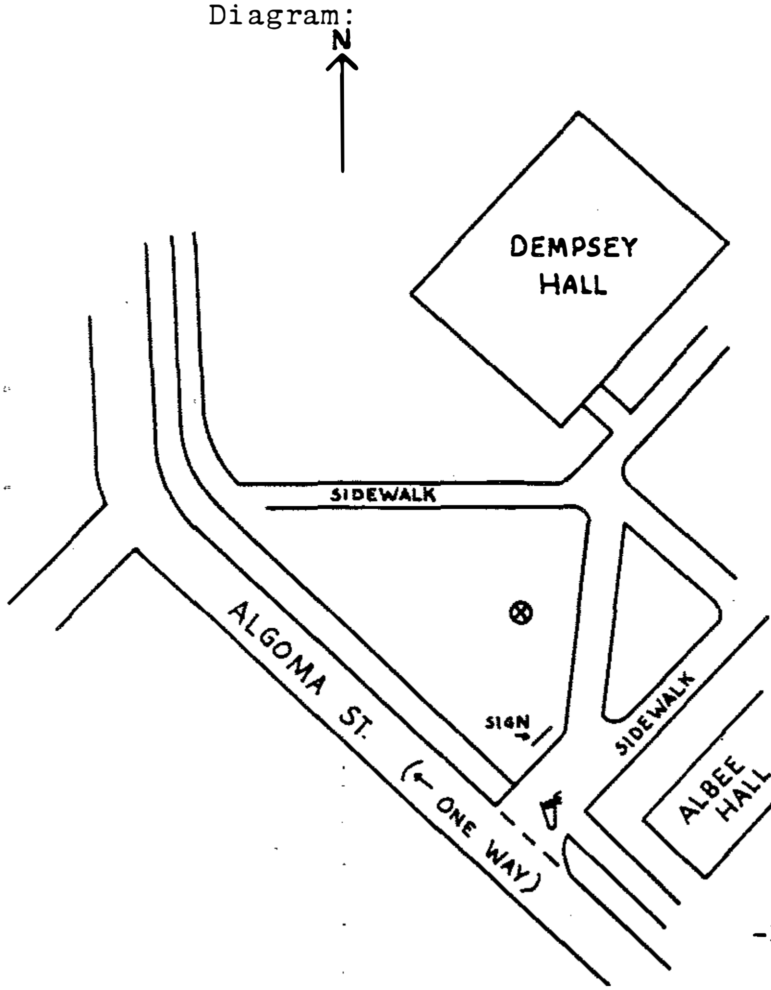
Photograph:

Gravity Base Station Description

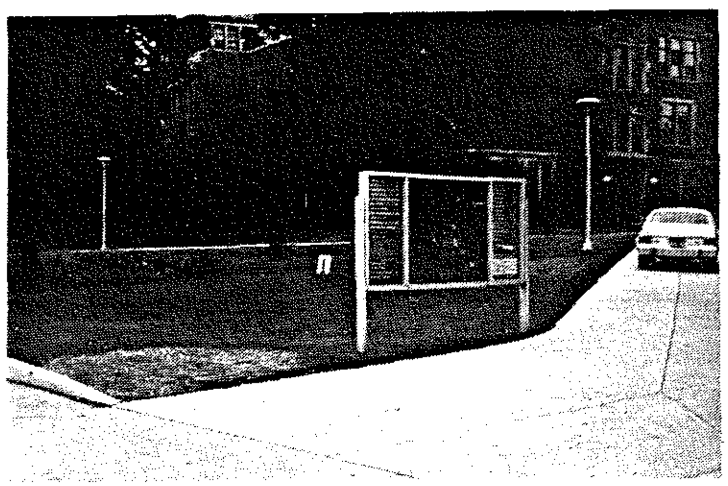
Station No.	20	City	Oshkosh
Gravity (mgals)	980421.81	State	Wis.
Elevation (feet)	765	Latitude	44°01.6'
		Longitude	88°33.0'

Description: On USCGS BM stamped OSHKOSH 1954 and set in concrete post about 25' west of sidewalk running north from Algoma St. to the south corner of Dempsey Hall on the University of Wisconsin-Oshkosh campus.

Diagram:



Photograph:

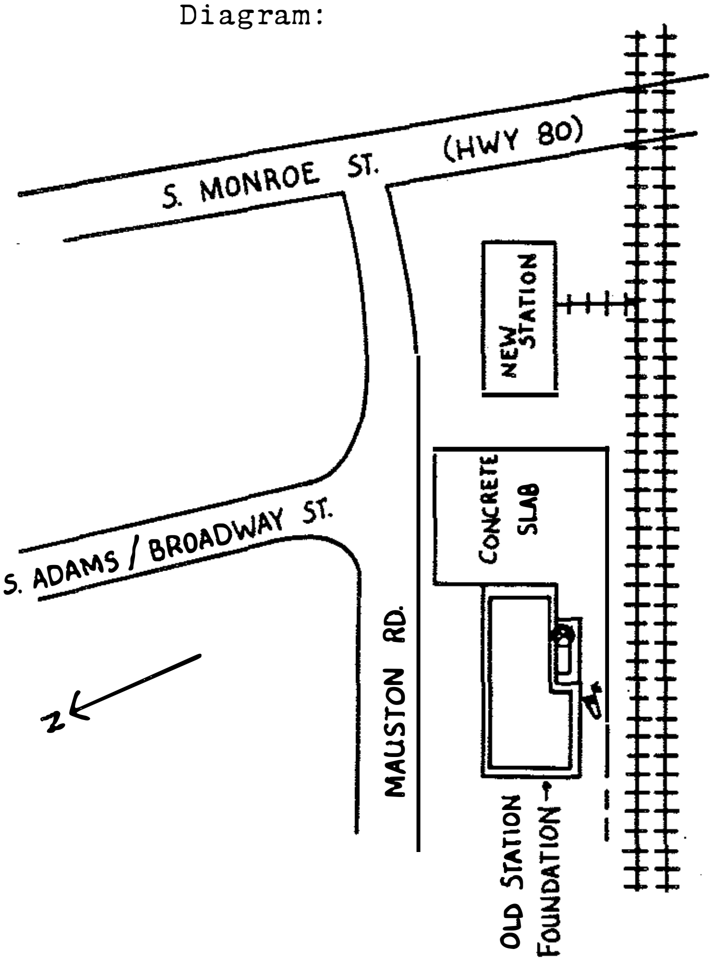


Gravity Base Station Description

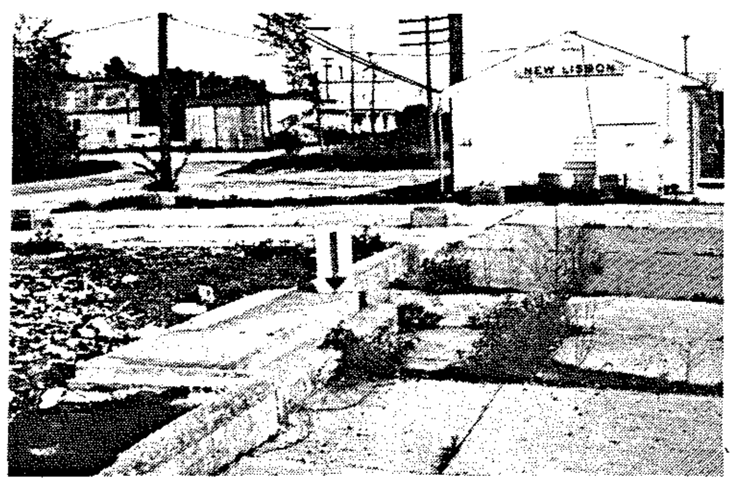
Station No.	21	City	New Lisbon
Gravity (mgals)	980386.19	State	Wis.
Elevation (feet)	891	Latitude	43°52.2'
		Longitude	90°10.0'

Description: On USCGS BM stamped A 83 1934 set in the south corner of the top concrete step at the entrance to the demolished (foundation remains) C.M. St. P. and P. RR Station.

Diagram:



Photograph:

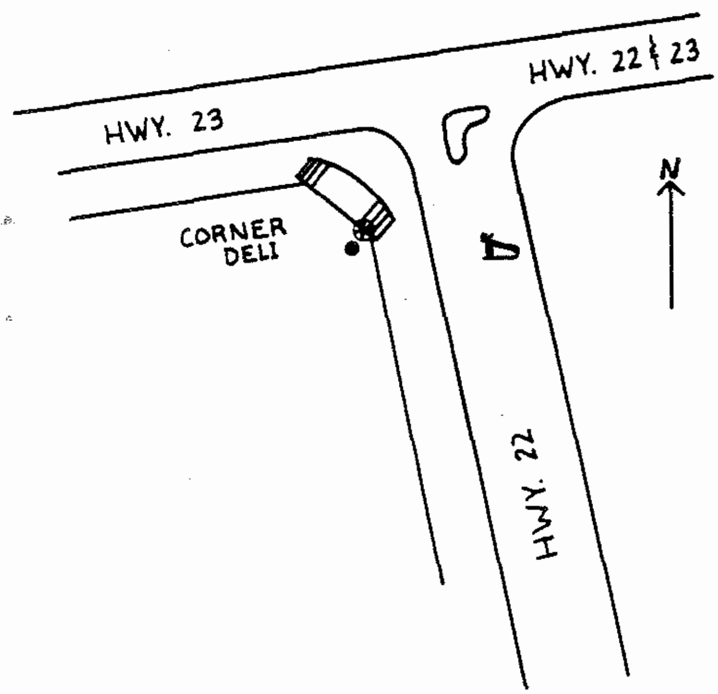


Gravity Base Station Description

Station No.	22	City	Montello
Gravity (mgals)	980382.52	State	Wis.
Elevation (feet)	781	Latitude	43°47.5'
		Longitude	89°19.7'

Description: On third step up from sidewalk and 1.3' below USCGS BM stamped E95 1934 and set vertically in brick wall on southeast side of door in northeast corner of building at intersection of Highways 23 and 22.

Diagram:



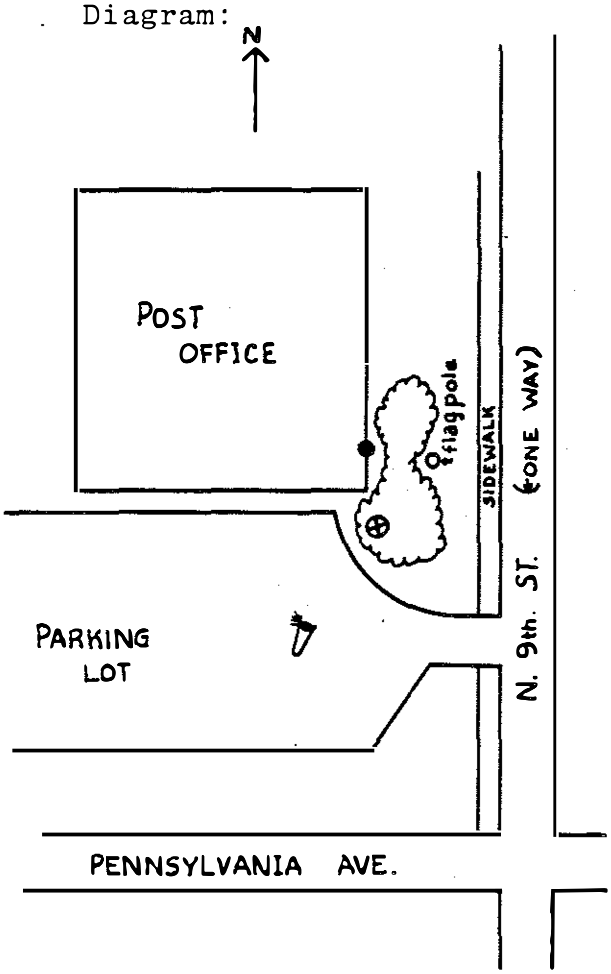
Photograph:

Gravity Base Station Description

Station No.	23	City	Sheboygan
Gravity (mgals)	980427.30	State	Wis.
Elevation (feet)	628	Latitude	43°45.0'
		Longitude	87°42.9'

Description: On a small concrete pedestal about three feet off the southeast corner of the post office near a USCGS BM stamped YS 1954 mounted vertically on east face of building located at the intersection of N. 9th St. and Pennsylvania Ave.

Diagram:



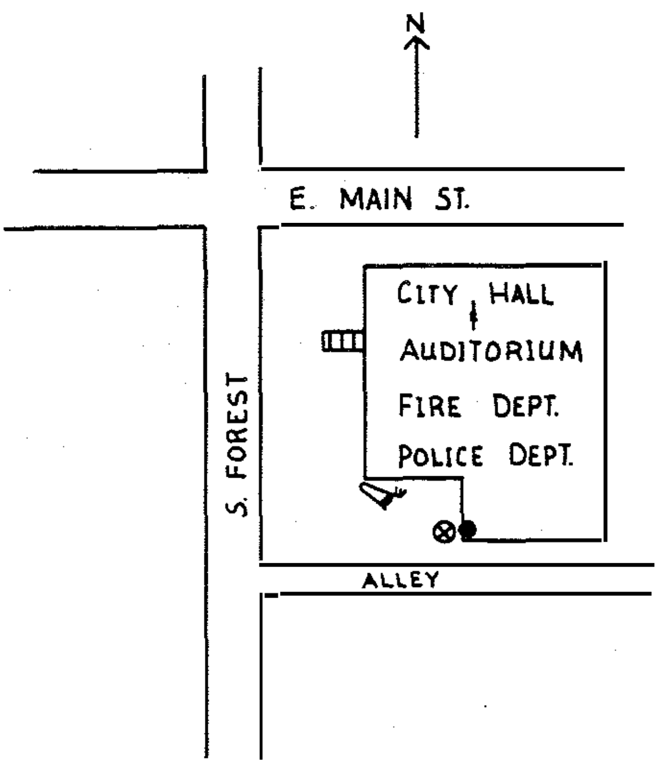
Photograph:

Gravity Base Station Description

Station No.	24	City	Waupun
Gravity (mgals)	980382.38	State	Wis.
Elevation (feet)	900	Latitude	43°37.9'
		Longitude	88°44.0'

Description: On pavement below USCGS BM stamped L105 1934 and set vertically in west brick wall near southwest corner of city hall located at intersection of E. Main St. and S. Forest St.

Diagram:



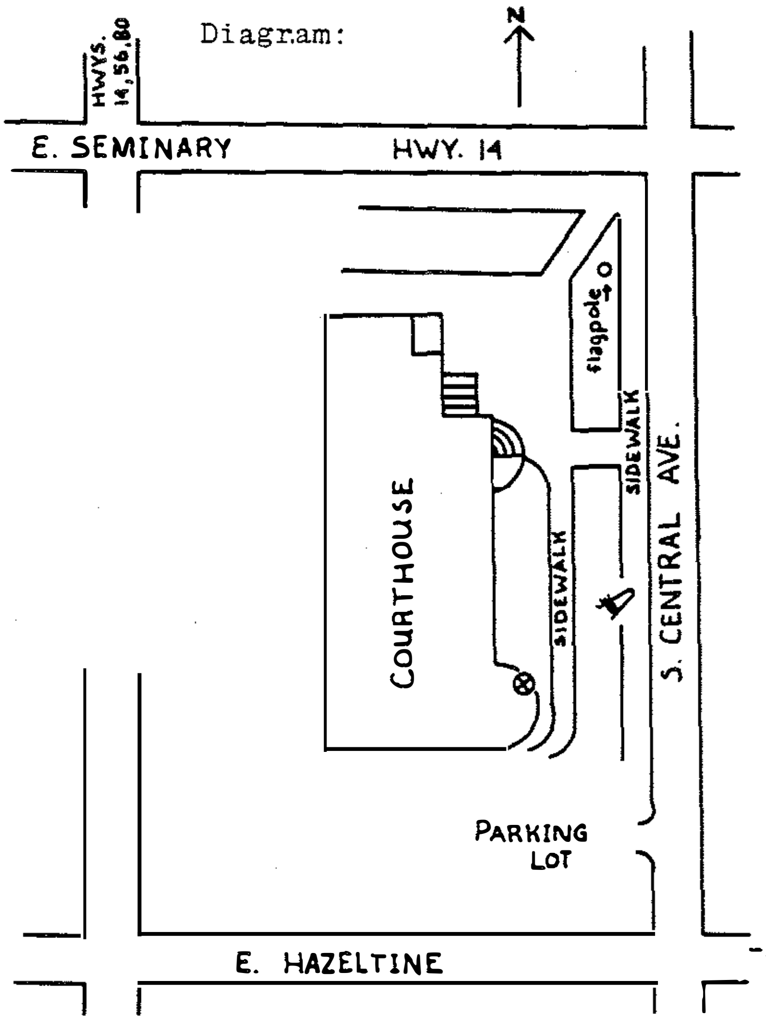
Photograph:

Gravity Base Station Description

Station No.	25	City	Richland Center
Gravity (mgals)	980355.87	State	Wis.
Elevation (feet)	737	Latitude	43°20.5'
		Longitude	90°23.1'

Description: On USCGS BM stamped 764 DBQ set in basement window sill in northeast side of rounded extension of southeast corner of courthouse on S. Central Ave.

Diagram:



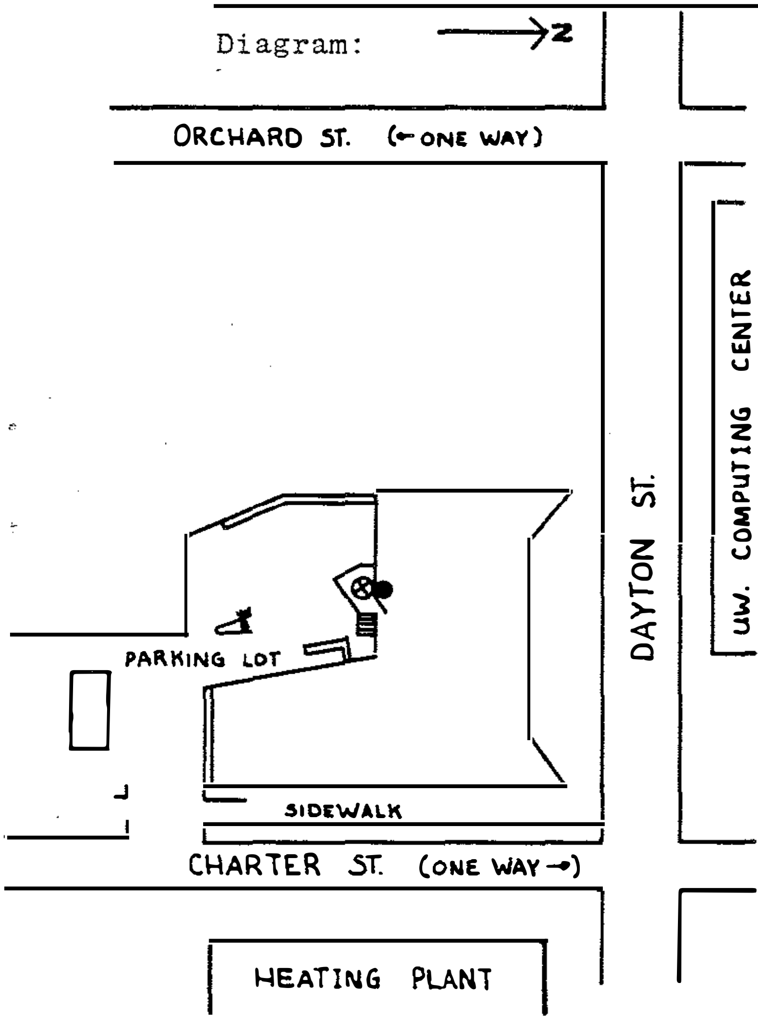
Photograph:

Gravity Base Station Description

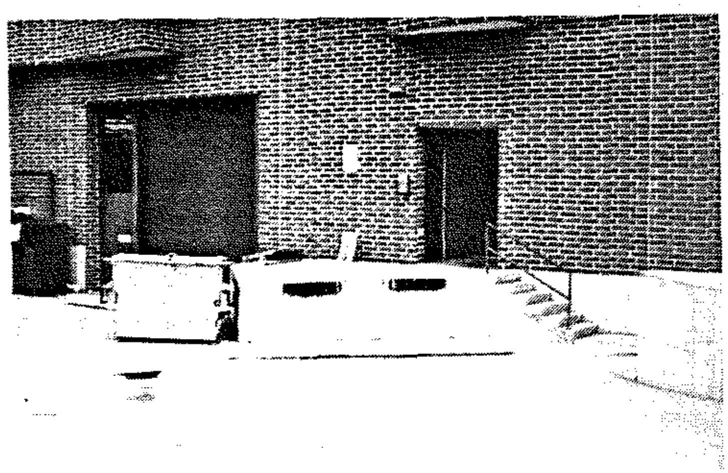
Station No.	26	City	Madison
Gravity (mgals)	980354.77	State	Wis.
Elevation (feet)	862.5	Latitude	43°04.2'
		Longitude	89°24.3'

Description: On loading dock one foot immediately below monument mounted vertically in brick wall on south side of Weeks Hall at the University of Wisconsin and stamped NIU-WGNHS GRAVITY 1980.

Diagram:



Photograph:

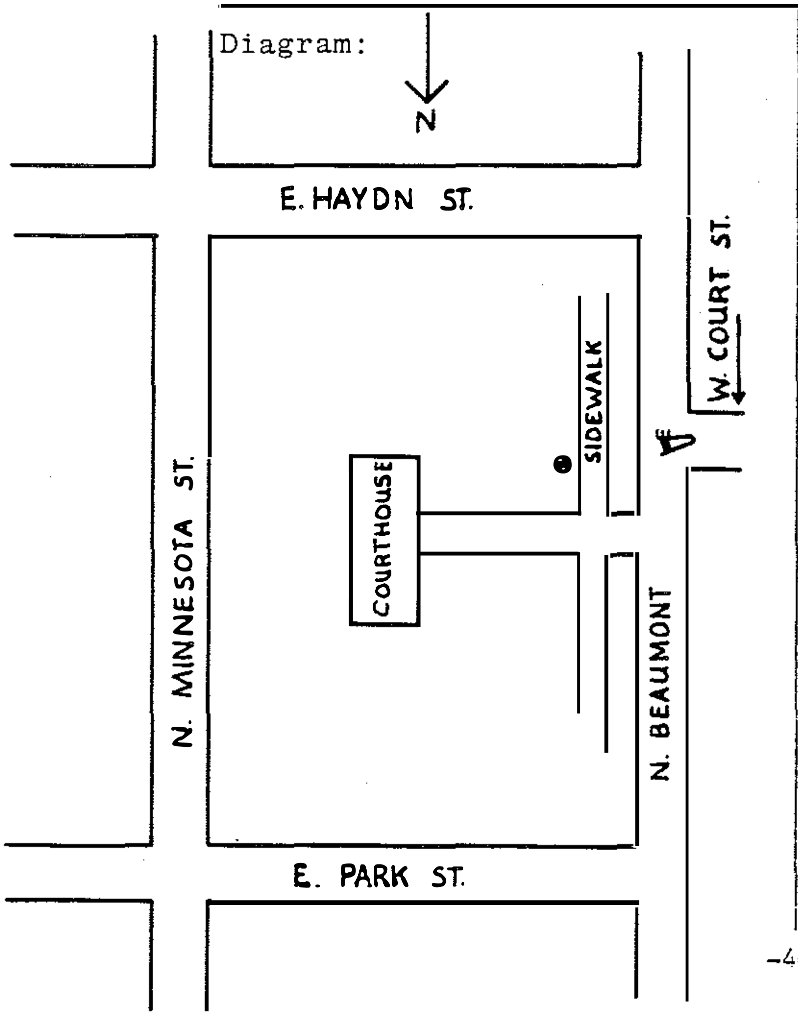


Gravity Base Station Description

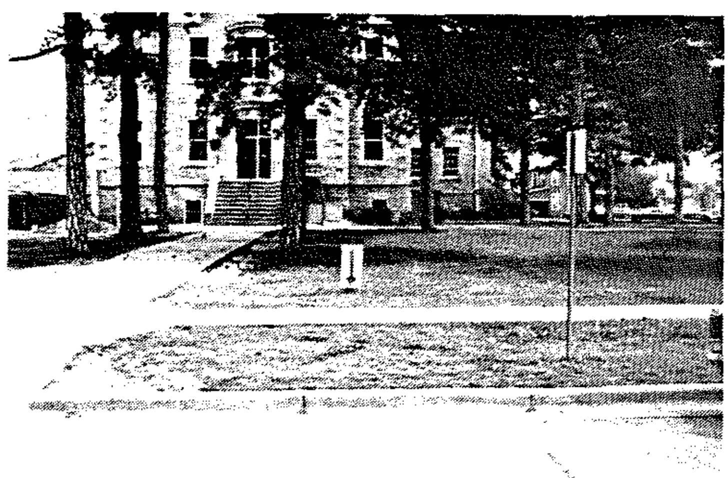
Station No.	27	City	Prairie du Chien
Gravity (mgals)	980377.06	State	Wis.
Elevation (feet)	644	Latitude	43°03.3'
		Longitude	91°08.9'

Description: On USCGS BM stamped PRAIRIE DU CHIEN NO 2 1933 and set in concrete post in the west lawn of the county courthouse, 22.7' east of the east curb of N. Beaumont Rd., 99' west of the west steps to the courthouse, and 7.8' south of the south side of a sidewalk leading to the west entrance.

Diagram:



Photograph:

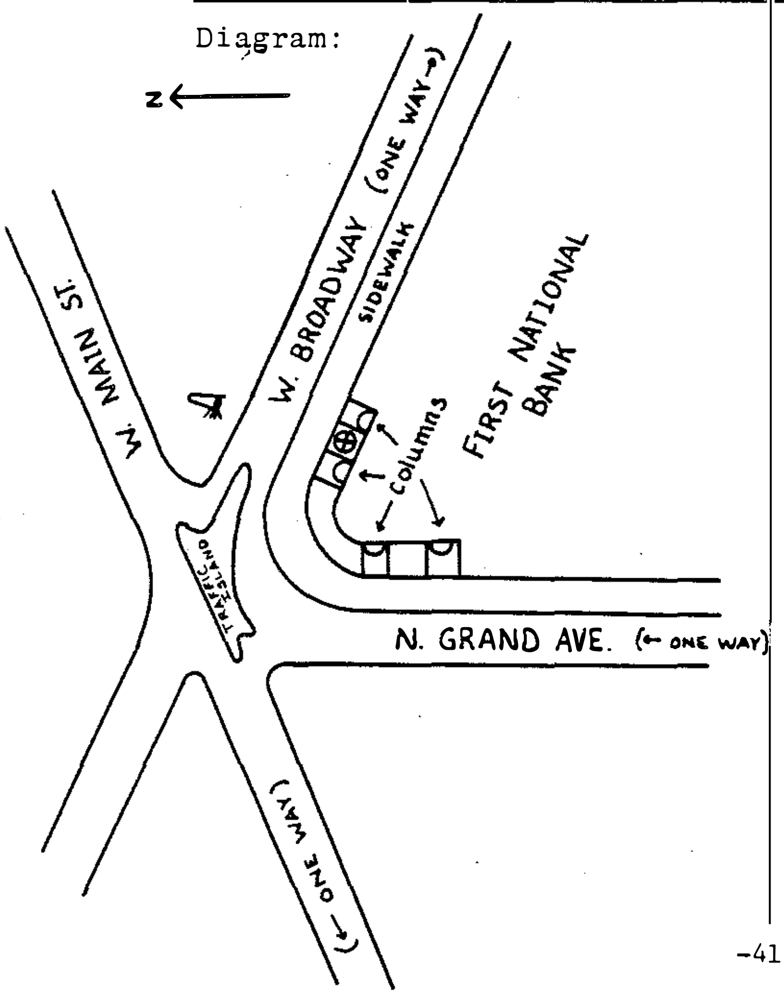


Gravity Base Station Description

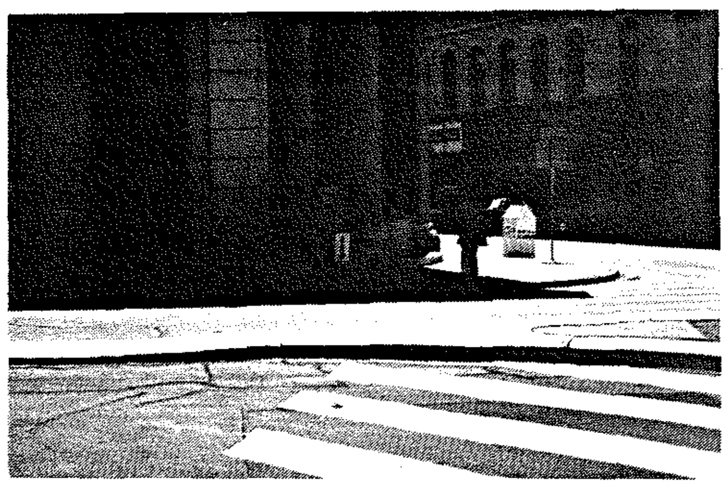
Station No.	28	City	Waukesha
Gravity (mgals)	980341.98	State	Wis.
Elevation (feet)	820	Latitude	43°00.7'
		Longitude	88°13.9'

Description: On stone step over USCGS BM stamped K114 1934 and set between columns on northeast side of north corner of First National Bank.

Diagram:



Photograph:

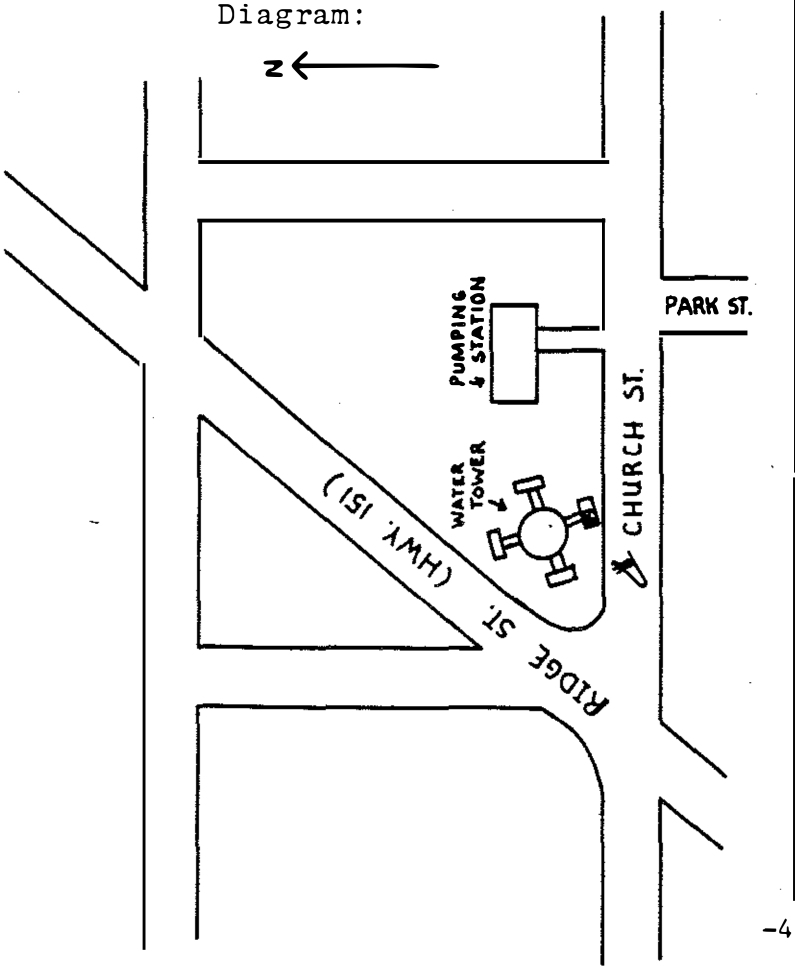


Gravity Base Station Description

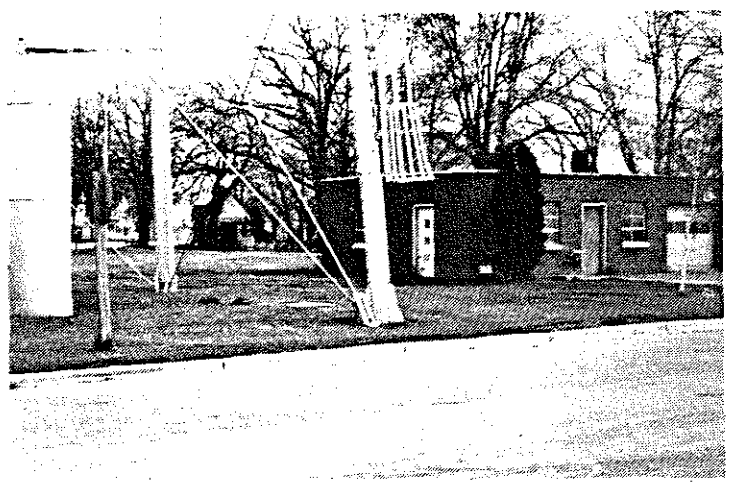
Station No.	29	City	Mineral Point
Gravity (mgals)	980309.99	State	Wis.
Elevation (feet)	1135	Latitude	42°51.7'
		Longitude	90°11.2'

Description: On BM stamped 18 ERS 1951 set in concrete base supporting the southeast leg of the city water tower.

Diagram:



Photograph:

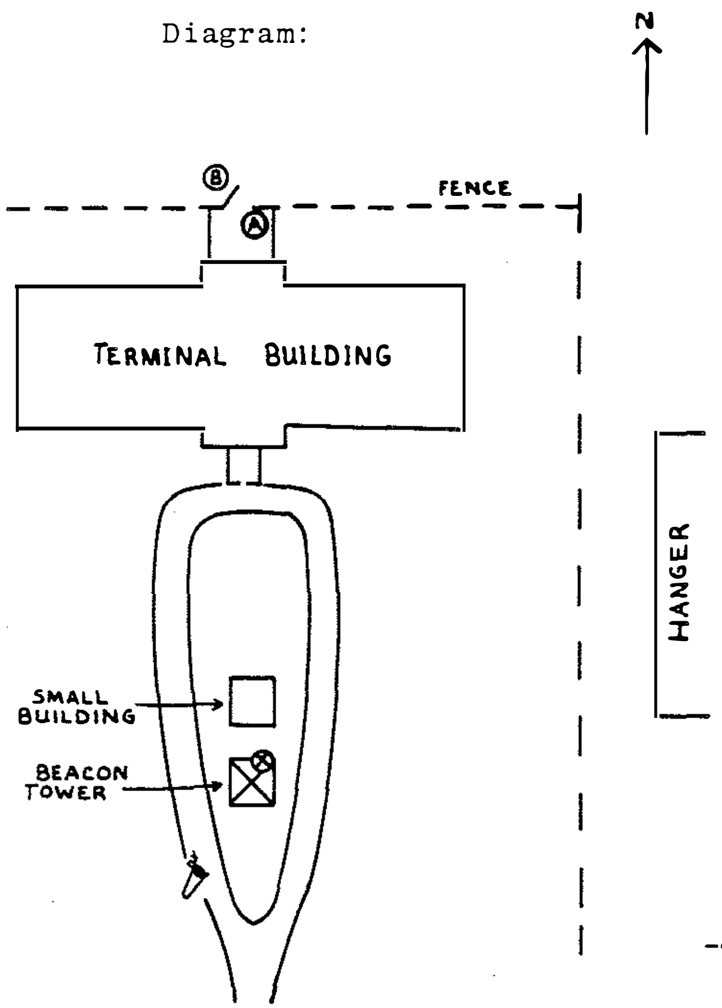


Gravity Base Station Description

Station No.	30	City	Janesville
Gravity (mgals)	980315.60	State	Wis.
Elevation (feet)	801	Latitude	42°36.9'
		Longitude	89°02.4'

Description: Station is located at the Rock County Airport about 3.5 miles south of Janesville on US 51 and is on the BM (USCGS L64 1957) set in concrete footing at the base of the ladder to the beacon tower situated at one end of the traffic circle in front of the terminal building. On May 27, 1981, the airport manager reported that the tower was scheduled for demolition, but that he would preserve the BM. Illinois State Base 1 and DOD Base 2011-3 are also shown in the diagram as the circled A and B, respectively.

Diagram:



Photograph: