Technical Report No. 5

PAWNEE SITE MICROWATERSHEDS: SELECTION DESCRIPTION AND INSTRUMENTATION

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INTRODUCTION

The Pawnee Site of the Grasslands Biome, International Biological Program, was selected for intensive study of the structure and function of a grassland ecosystem. The major objectives for the Pawnee Site research program are to determine the variability and magnitudes of rates of energy flow and nutrient cycling and to encompass the parameters and variables of these processes in mathematical models. It has long been recognized that the flow of energy through the primary producers and the cycling of nutrients in an ecosystem depends on the availability of water to the plants. Therefore, the initial planning stages called for the evaluation of a complete hydrologic budget and its relation to ecosystem processes.

An obvious hydrologic characteristic of grasslands is the absence of stream flow, although overland flow and re-infiltration probably occur much more frequently than commonly supposed. To evaluate the behavior of water in grassland ecosystems emphasis is being placed on the soil water balance, its input (direct infiltration and re-infiltration), and its outputs (evaporation, transpiration, percolation, and runoff). It is the purpose of this paper to describe the criteria for selection and design for construction and instrumentation of eight microwatersheds, the basic units of investigation for studying the behavior of water in grasslands.

In general, microwatershed is a relative term, usually referring to a natural watershed smaller than 10 acres. For this report, a microwatershed refers to an artificially bounded area less than five acres in size over which only overland flow occurs.

GENERAL DESCRIPTION

The Pawnee Site operates with the cooperation of the Agricultural Research Service and the Forest Service. The Pawnee Site derives its name from the Pawnee National Grassland, which is admininstered by the Forest Service. The instrumented experimental studies are carried out in cooperation with the Central Plains Experimental Range, located in the western division of the national grasslands and operated by the Agricultural Research Service, Crops Forage Division. Studies that do not require fixed experimental installations are conducted over the western division of the Pawnee National Grasslands.

Climate

The Pawnee Site is located on the Central Plains Experimental Range in northeastern Colorado, situated about 25 miles southeast of Cheyenne, Wyoming. The site is in the western part of the central Great Plains, where annual precipitation averages about 12 inches per year and varies between 4 and 20 inches. Almost 75% of this precipitation comes as convective rainfall between May and September. Usually, snowfall, as water-equivalent, is a small contribution to the annual precipitation. Its variability can have a major effect however, depending on when the snow occurs, its water equivalent, and its density. Infrequent blizzards can produce major differences in soil water recharge.

Temperature extremes between 1939 and 1953 were 104°F and -10°F. The mean maximum temperature was 78°F and the mean minimum temperature was 47°F for the same period. Although frost has occurred in all months, the average frost-free season is 135 days. Wind is high, especially between November and May.

Soils and Vegetation

Predominant soils on the site include the moderately dark soils of the cool semiarid steppes. About 85% of the soils are loams, varying from clay loams to sandy loams. These soils have been derived from interbedded shales and sandstones. The origin of the sandstones has been traced to both alluvial and aeolian processes.

The most common grasses of this mixed shortgrass prairie are blue grama and buffalo grass. Threadleaf and needle leaf sedges are found in the understory; midgrasses, such as western wheatgrass, little bluestem, and side-oats grama, and tallgrasses, such as big bluestem and prairie sandreed may occur in favored locations or during better years. Forbs include Russian thistle, lambsquarter, scarlet globemallow, and slimflower scurf pea. Fourwing saltbush, fringed sagewort, and winterfat are the major browse species. Snakeweed, a half shrub, and plains prickly pear are locally conspicuous.

Grazing

In 1939, the Central Plains Experimental Range was established by the Forest Service to evaluate cattle grazing practices. Twelve half-section pastures (320 acres) were set up for long-term cattle grazing experiments. Of these 12 pastures, three summer-use pastures (May to October inclusive) with light-, moderate-, and heavy-grazing treatments have been selected for the intensive Pawnee Site investigation. These three grazing treatments are based on the percent weight utilization of the current herbage growth of the major forage species, as determined at the end of the six-month grazing season. For heavy use, approximately 60% of the forage is utilized. For moderate and light use, the figures are 40% and 20% respectively. An alternate rule of thumb has been the amount of forage remaining at the end of the grazing season.

These are 200, 300, and 400 lb. per acre for heavy, moderate, and light use, respectively. A fourth no-grazing treatment, provided by 2.5 acre exclosures fenced in 1939, is available as a control.

Intensive Site Description

The three pastures selected for the intensive Pawnee Site investigations cover the major portion of a natural, internally drained basin. The topography is characterized by gentle hills with smooth slopes. There are no developed channels. When runoff does occur, it flows across the grassed swales in the bottomlands and collects in an ephemeral pond.

In the natural basin, the mapped soils series are Ascalon, Vona, Renohill, Shingle, a Shingle-Renohill complex, and an undifferentiated moderately fine textured soil (Fig. 1). The usual topographic arrangement of these soils is: Shingle soils, above Renohill and Shingle-Renohill complex soils; these are, in turn, above Ascalon and Vona soils, with the undifferentiated moderately fine textured soils occupying the lowest topographic position in the swales. Ascalon, a sandy loam with slopes ranging between 0% and 25%, is the predominant series.

MICROWATERSHED SELECTION

Preliminary criteria for selecting the location were grazing treatments, size, soils, vegetation, slope, aspect, and slope position. The primary criterion was to locate two microwatersheds in each of four grazing treatments; no-, light-, moderate-, and heavy-grazing. To evaluate effects due to grazing it was desirable to locate all eight microwatersheds on the same soil, with the same vegetation, slope, aspect, and occupying the same slope position. Initially, it was decided to select microwatersheds of less than five acres on Ascalon sandy loam soil with blue grama dominant on uniform 5% to 10% slopes with a northeast aspect occupying a mid-slope position.

Reconnaissance began with stereoscopic examination of aerial photos. Overlays of possible areas for field examination were delineated by coordinating information from a low intensity soil photomosaic prepared by the Soil Conservation Service.

Field examination of the delineated areas quickly revealed that some of the initial criteria were mutually exclusive. Most obvious, was that slope did not remain uniform even within (square) areas as large as two acres. Commonly, the maximum horizontal distance within which contours remain uniform is about 200 ft. The maximum distance perpendicular to contours (up and down the slope), within which slope sections remain uniform is about 300 ft. Therefore, the maximum size of an area without complex slopes is closer to about one acre. It was also apparent that, in addition to the size limitation, aspect critera could not be met and at the same time include microwatersheds in the control treatments (no grazing). In addition, the only 30-year exclosures (which represented the control treatment) had slopes that were less than 5% and had aspects different from northeast. Thus the contraints imposed by the natural topography and previous location of exclosures required considerable compromise.

The final design criteria were: to reduce the size of the microwatershed to 1.235 acres (0.5 hectare), to locate them on Ascalon soils, and to select areas of comparable slope, allowing less restriction on aspect requirements. Continued field reconnaissance yielded 12 possible locations.

For the 12 possible locations, field examination and soil sampling by a Soil Conservation Service soil scientist reduced further the number of microwatershed locations because of subsoil differences not apparent from surface examination. The locations remaining were characterized by slope measurements with an Abney level and aspects with a compass. All microwatersheds were located on mid-slope positions. From appearance and the presence of the same species, the vegetation on all locations was considered similar.

Vegetation composition similarity was compared using the Sorenson Index of Similarity which usually ranges between 25% and 90%. The closer the index is to 100%, the more similar the two areas are. This index, computed for March 1969, is given in the table below comparing only the two microwatersheds in the same treatment.

Microwatershed	Grazing[1/] Treatment	Aspect[2/] (°)	Slope[2/] (%)	Similarity Index (%)	Deviation from 0.5 ha (%)
2	no(exclosure)	153	2	72	+.03
8	no(exclosure)	71	3		+.19
4	light	51	5	94	-.10
5	light	42	5		+.50
6	moderate	79	4	94	-.21
7	moderate	74	3		-.27
1	heavy	12	3	91	+.00
3	* heavy	176	3		-.53

1/ Treatment level based on current year forage remaining at end of grazing season (1 May to 31 October); light: 450 kg/ha, moderate: 335 kg/ha, heavy: 225 kg/ha (400, 300, and 200 lb./acre, respectively).

2/ Aspect (magnetic azimuth) and slope measured downhill on center line of microwatershed.

Note: The low intensity soil photo mosaic, which was used to select soils on which to locate microwatersheds, was prepared in 1961. On this soil photomosaic, the soil on which Microwatershed 1 is located is mapped as Ascalon. In the summer of 1968, the SCS soil scientist examined the location before selection and confirmed the soil as a sandy phase of Ascalon. Construction of the microwatersheds was completed in 1968.

In the summer of 1969, a high intensity soil survey of the grazing pastures was completed. With this survey, a detailed pattern of Ascalon and Vona soils emerged, with Microwatershed 1 on Vona soil.

Both soils are sandy loams and share the same general profile characteristics. The main difference between the two soils is that the parent material for Ascalon soils is alluvial sands, whereas the parent material for Vona soils is aeolian sands.

Final approval of the microwatershed locations was made by a group including soil range and watershed specialists in July 1968. After final selection, the exact boundaries, slopes, and aspects were determined by a plane-table and alidade survey. The design, final dimensions after surveying, and one-foot contour maps for each microwatershed are included in the appendix.

Discussion

Comparing preliminary criteria with the final results shows that aspects for the two microwatersheds in the no-grazing and heavy-grazing treatments are quite different but slopes are reasonably close. The two microwatersheds in the moderate and light grazing treatments compare quite favorably. Similarity indexes are exceptionally high except where the most severe constraints were imposed on the control treatments. This was because the exclosures (for the no-grazing treatment) were selected by different standards and fenced in 1939. In general then, the eight microwatersheds provide a reasonable basis for comparing grazing treatments on Ascalon soils.

MICROWATERSHED INSTRUMENTATION

✓The microwatersheds have been instrumented to automatically measure precipitation, runoff, soil water, and soil temperature. Data from each microwatershed site are telemetered via a cable to a central data collection system in the headquarters building at the Pawnee Site. The system was constructed and installed by the Environmental Service Operation of EG & G Sensors at each site are as follows:

Overland Flow

Overland flow is concentrated in concrete troughs and converged through a two-foot metal H-flume. Stage of the water passing through the flume is recorded via a Fischer-Porter water level recorder with a float and stilling well mechanism. The Fischer-Porter recorder is fitted with telemetry contacts which allow the water level to be read remotely. The punch tape recording mechanism provides a backup record of water levels in the event of a system failure.

Precipitation

Rainfall is measured in a standard U. S. Weather Bureau storage rain gage which has been fitted with a sensitive pressure transducer which senses the head of water in the gage. Transducer output is connected to the telemetry system. Gages are shielded with modified Alter windshields to reduce the effects of wind on the precipitation measurements. Gages are also fitted with a simple precipitation snesor which alerts the data collection system at the onset of a storm. Rain gage funnels are removed for winter operation and gages are charged with ethylene glycol to prevent freezing. Gages are also fitted with a small valve which can draw off any accumulated rainfail to a fixed level and provide a measure of total storm rainfall in the event of a system failure.

Soil Water and Temperature

A stack of five Coleman fiber glass resistance units with integral thermistors has been buried in each microwatershed. Units are installed at 2, 10, 20, 40, and 80 cm. A small 90 hz AC bridge is also buried near the soil moisture units so that resistance measurements can be telemetered directly from the site. Soil temperature is read at the same time as soil water.

Operation

The data system is set to measure all variables once per hour during non-event periods. Frequency of interrogation is independently controlled at each microwatershed. On the hour, a clock transmits a pulse to Microwatershed 1 which proceeds to read each sensor in sequence and transmit the data back to the data collection system. When Microwatershed 1 is read, Microwatershed 2 is interrogated in a like manner, and so forth until all stations have been read. In the event of a storm, the precipitation sensor signals the system which commences interrogating all microwatersheds at 30-second intervals.

Incoming data are converted directly to engineering units via a small data processor (i.e., soil water resistance is converted to bars of tension) and held in a central memory unit until all stations have been polled, whereupon the data are transferred to a magnetic tape recorder. A printout of data is also provided, if desired, on a teletype. A block diagram of the data collection system is shown in Fig. 2.

In addition to the recording Coleman units, a network of ten neutron access tubes has been installed in each microwatershed. Most tubes are approximately five feet in depth. However, two tubes on each site are installed to approximately 10 ft. Volumetric soil water readings are taken at 15 cm intervals down to 90 cm and 30 cm intervals between 90 and 270 cm depths.

NATURAL

The central basin study area consists of the natural, internally drained basin with an estimated area of about 1000 acres (Fig. 3). Because of the lack of topographic maps, the boundaries have not been determined, although detailed topographic mapping is currently under way.

Lynn Lake, a small ephemeral pond, located at the southeast end of the basin (Section 23), serves as storage for runoff water originating within the basin. Elevation contours of this pond (Fig. 4) have been completed so that any change in stage of the pond can be directly converted to volume of water (Fig. 5). Thus, any increase in stage during a storm event represents the discharge from the basin.

Since the basin represents a complex of soil types and grazing treatments, the ultimate objective of the natural basin study will be to model a hydrologic system at a greater degree of complexity than the single use, single soil type microwatershed models.

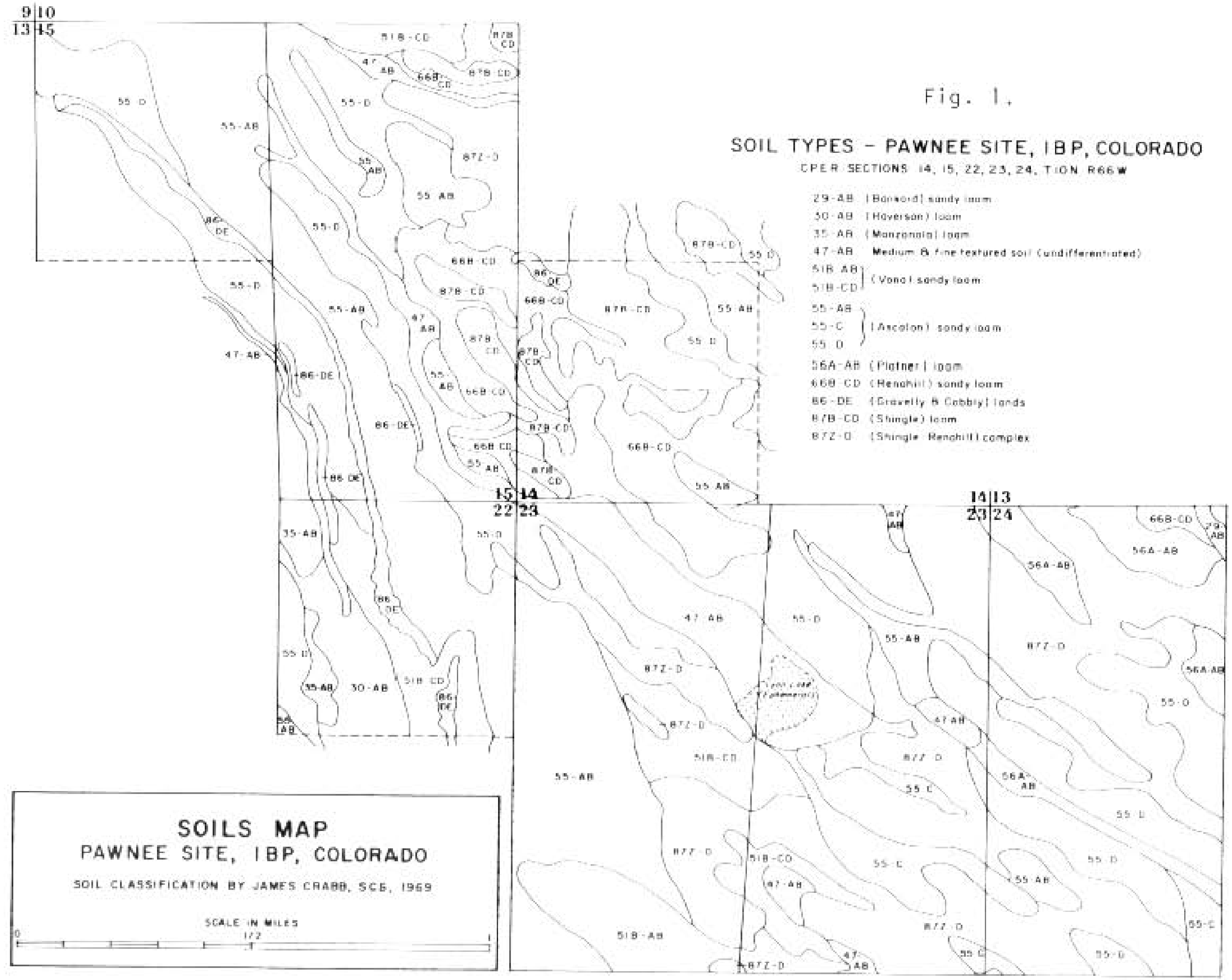
In addition to soil water and rainfall measurements that will be provided by the microwatersheds that are located in the natural basin, the Agricultural Research Service collects rainfall measurements from storage gages during the growing season. This rainfall information and 30 years of historical data will provide input measurements to the basin. Historical data for soil water tension (resistance blocks) is also available from Agricultural Research Service.

Fig. 1.

SOIL TYPES – PAWNEE SITE, IBP, COLORADO

CPER SECTIONS 14, 15, 22, 23, 24, T10N R66W

29-AB (Bonkord) sandy loam
30-AB (Haverson) loam
35-AB (Manzonola) loam
47-AB Medium & fine textured soil (undifferentiated)
51B-AB, 51B-CD (Vona) sandy loam
55-AB, 55-C, 55-D (Ascalon) sandy loam
56A-AB (Platner) loam
66B-CD (Renohill) sandy loam
86-DE (Gravelly & Cobbly) lands
87B-CD (Shingle) loam
87Z-D (Shingle-Renohill) complex



SOILS MAP

PAWNEE SITE, IBP, COLORADO

SOIL CLASSIFICATION BY JAMES CRABB, SCS, 1969

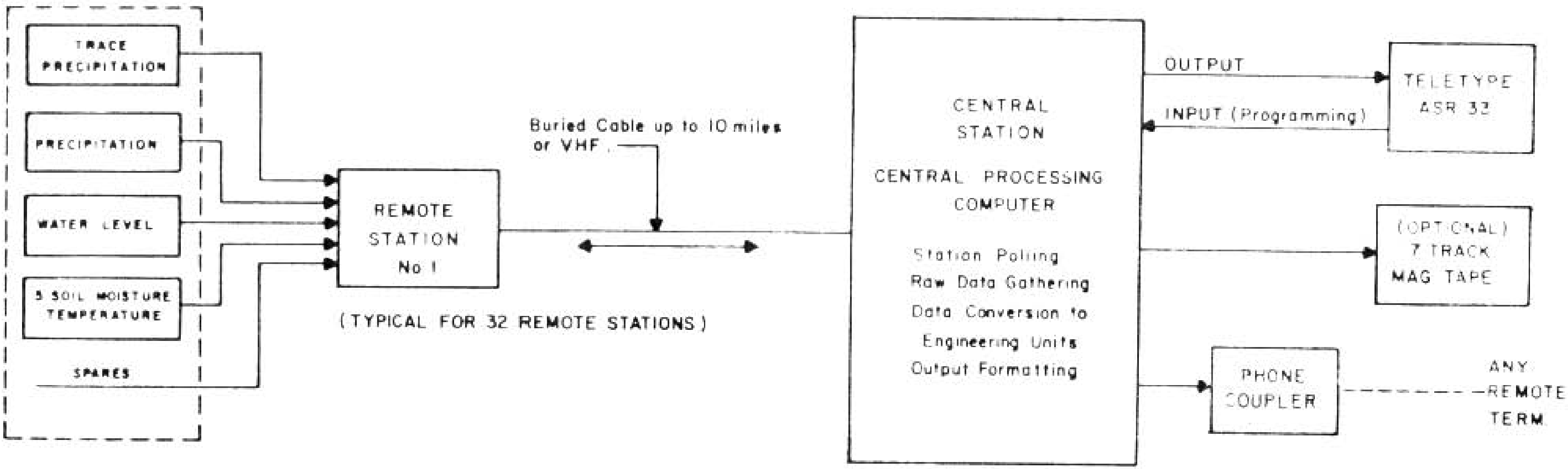


Fig. 2.
HYDROMETEOROLOGICAL
DATA ACQUISITION SYSTEM

EG&G INC.
ENVIRONMENTAL SERVICES OPERATION

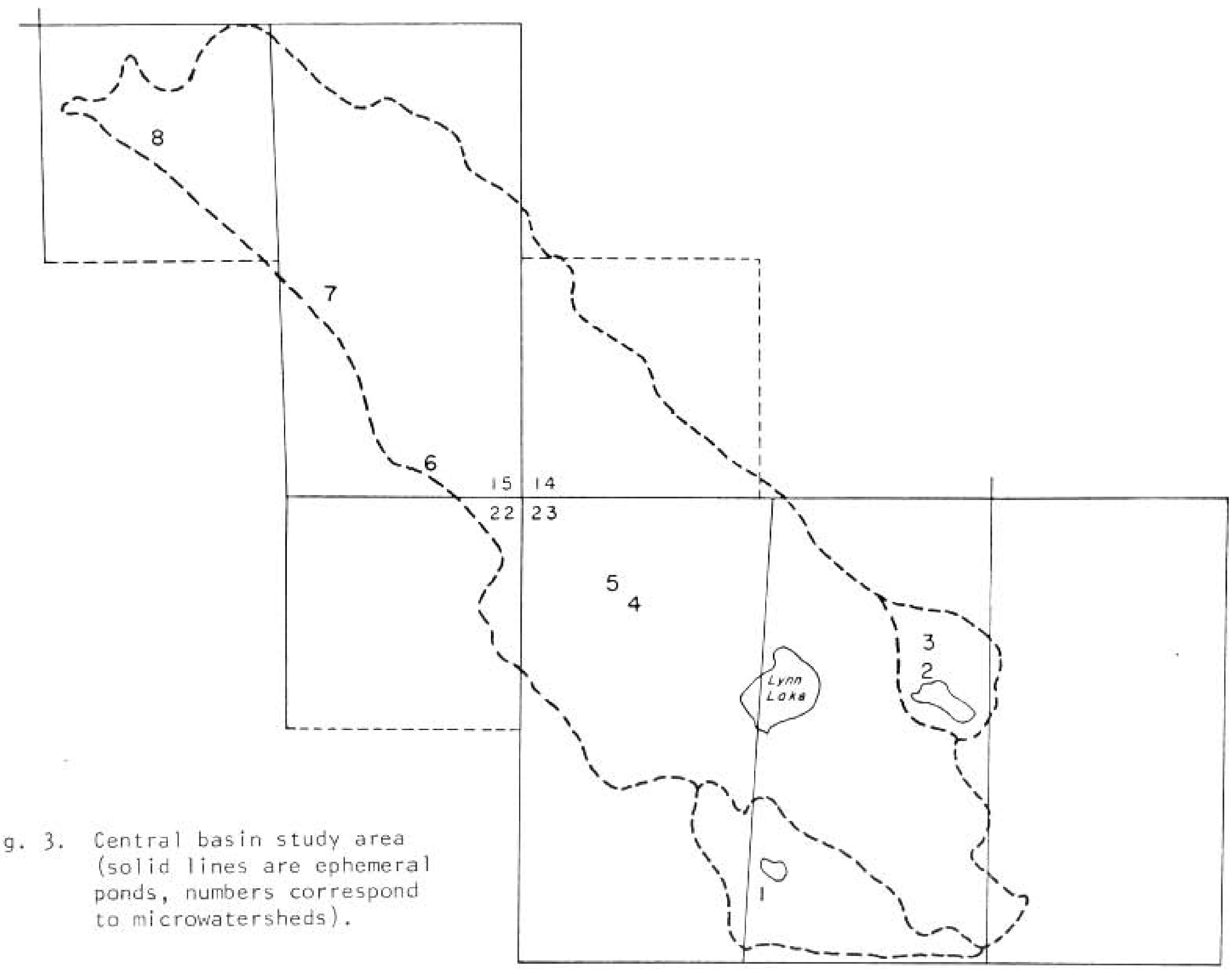


Fig. 3. Central basin study area (solid lines are ephemeral ponds, numbers correspond to microwatersheds).

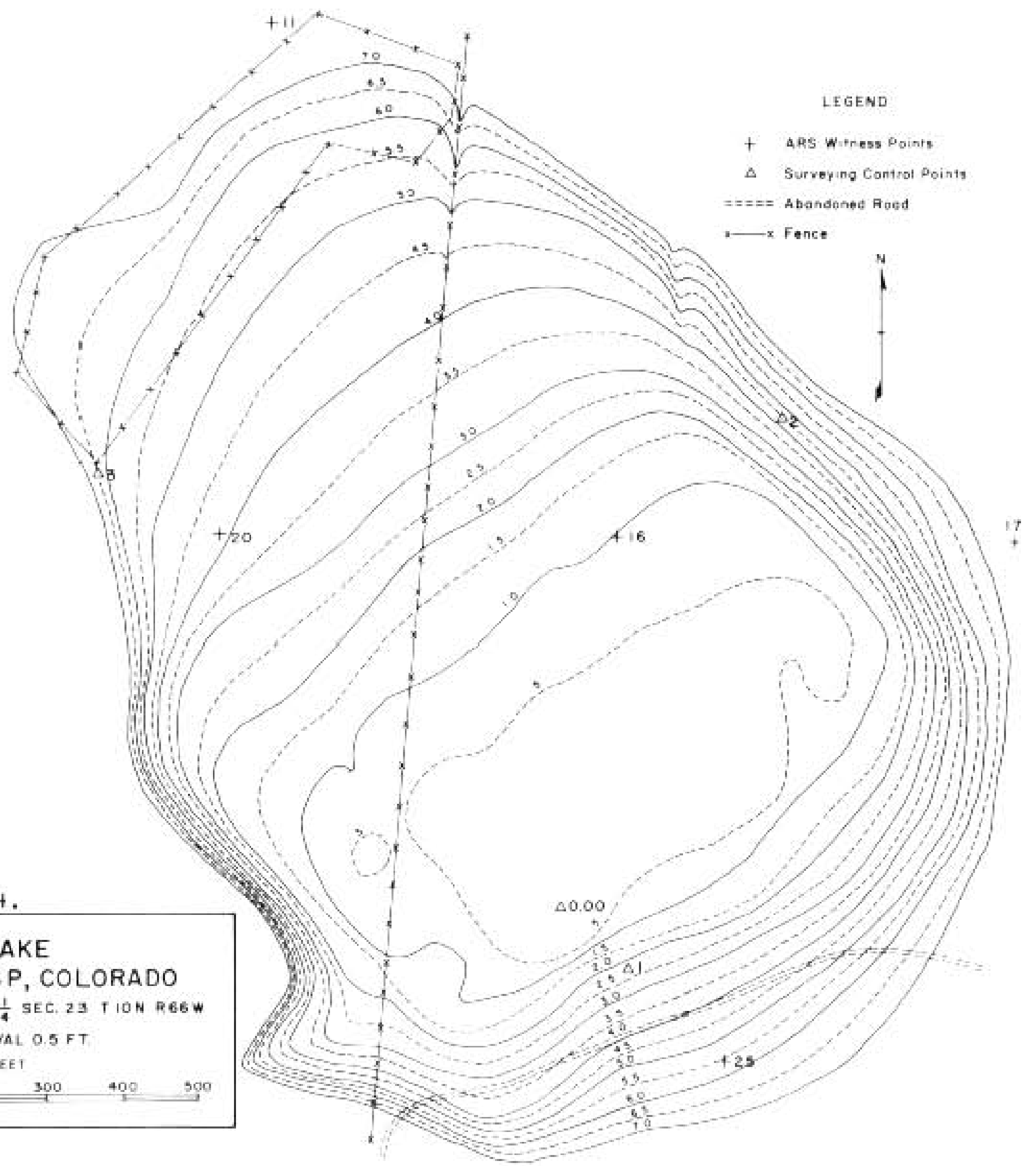


Fig. 4.

LYNN LAKE
PAWNEE SITE, IBP, COLORADO
SW $\frac{1}{4}$ of NE $\frac{1}{4}$ & SE $\frac{1}{4}$ of NW $\frac{1}{4}$ SEC. 23 T10N R66W
CONTOUR INTERVAL 0.5 FT.
SCALE IN FEET
100 0 100 200 300 400 500

Microwatersheds are 1.235 acres (0.5 hectare) in area and lemniscate in shape (Fig. A3). Corresponding dimensions are given in Table A1 and one-foot contour maps for each microwatershed are found in Fig. A4 - A11.

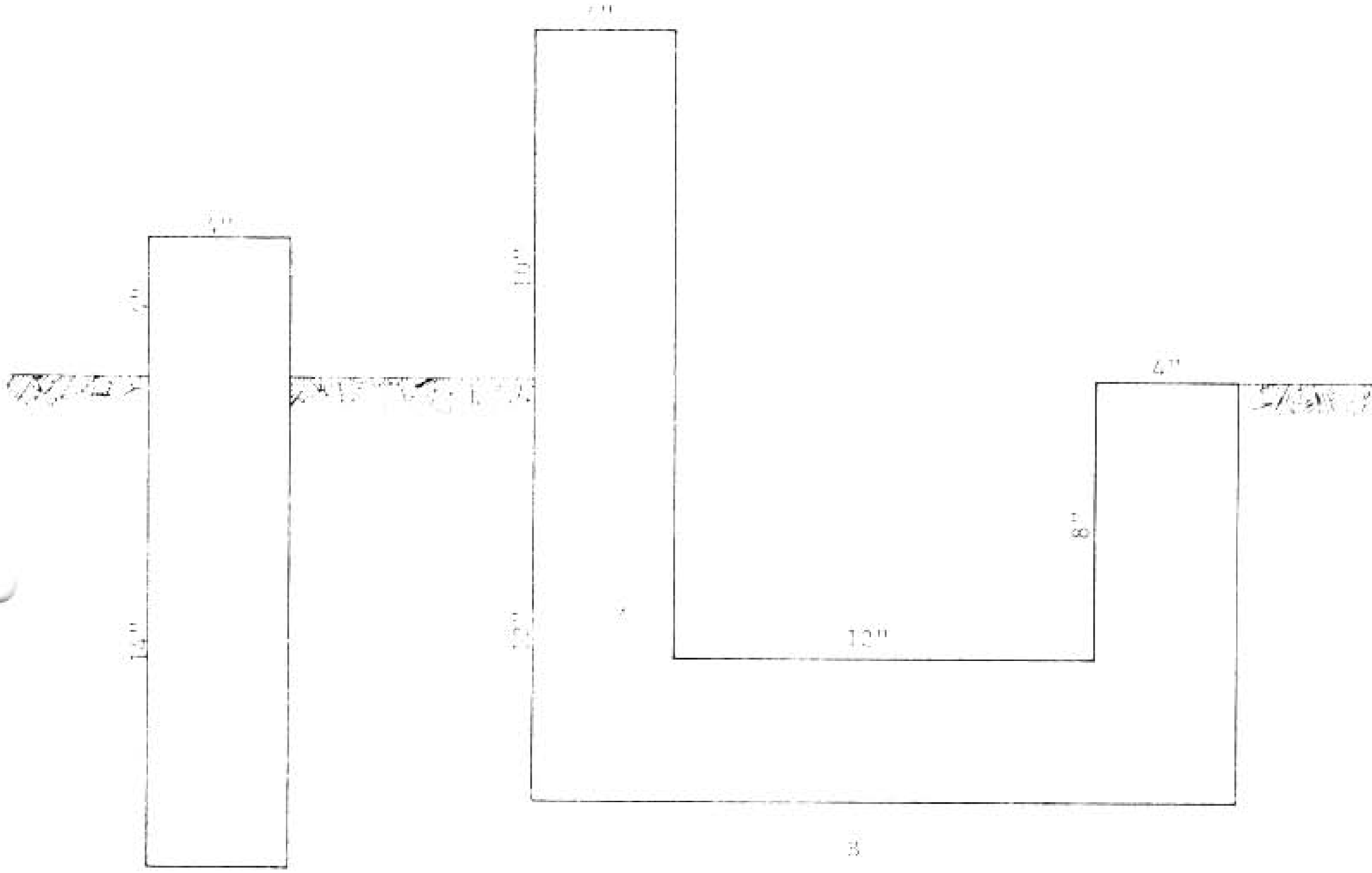
Table A1. Final dimensions of microwatersheds.

Micro-watershed	Location (T10N R66W)	Aspect[1/] (°Magnetic)	Slope[1/] (%)	Area[2/] (acres)	Dimensions (ft)[3/] A	B	C	D	E	F	G
1	SE¼ Sec. 23	11.6	2.99	1.2354	294.65	197.0	197.0	245.1	245.3	17.2	3.8
2	NE¼ Sec. 23	153.0	1.73	1.2360	294.6	197.0	197.2	245.6	245.0	16.95	3.8
3	NE¼ Sec. 23	176.1	2.65	1.2290	292.9	196.7	196.65	244.55	245.5	17.2	3.8
4	NW¼ Sec. 23	51.4	4.92	1.2343	294.45	196.75	197.15	245.0	244.9	17.5	3.8
5	NW¼ Sec. 23	41.9	5.39	1.2417	294.8	198.6	197.1	247.25	245.0	15.5	3.7
6	SE¼ Sec. 15	77.8	3.78	1.2329	294.3	196.8	197.0	245.1	245.1	16.0	3.9
7	SE¼ Sec. 15	73.8	3.06	1.2322	294.2	196.95	196.3	245.2	245.1	17.1	3.7
8	NW¼ Sec. 15	70.8	3.37	1.2379	294.85	197.4	197.3	245.3	245.3	16.6	3.6

1/ Aspect and slope measured downhill on center line of microwatershed.

2/ One-half hectare is equal to 1.2355 acres.

3/ Alphabetic letters correspond to those on Fig. A3.

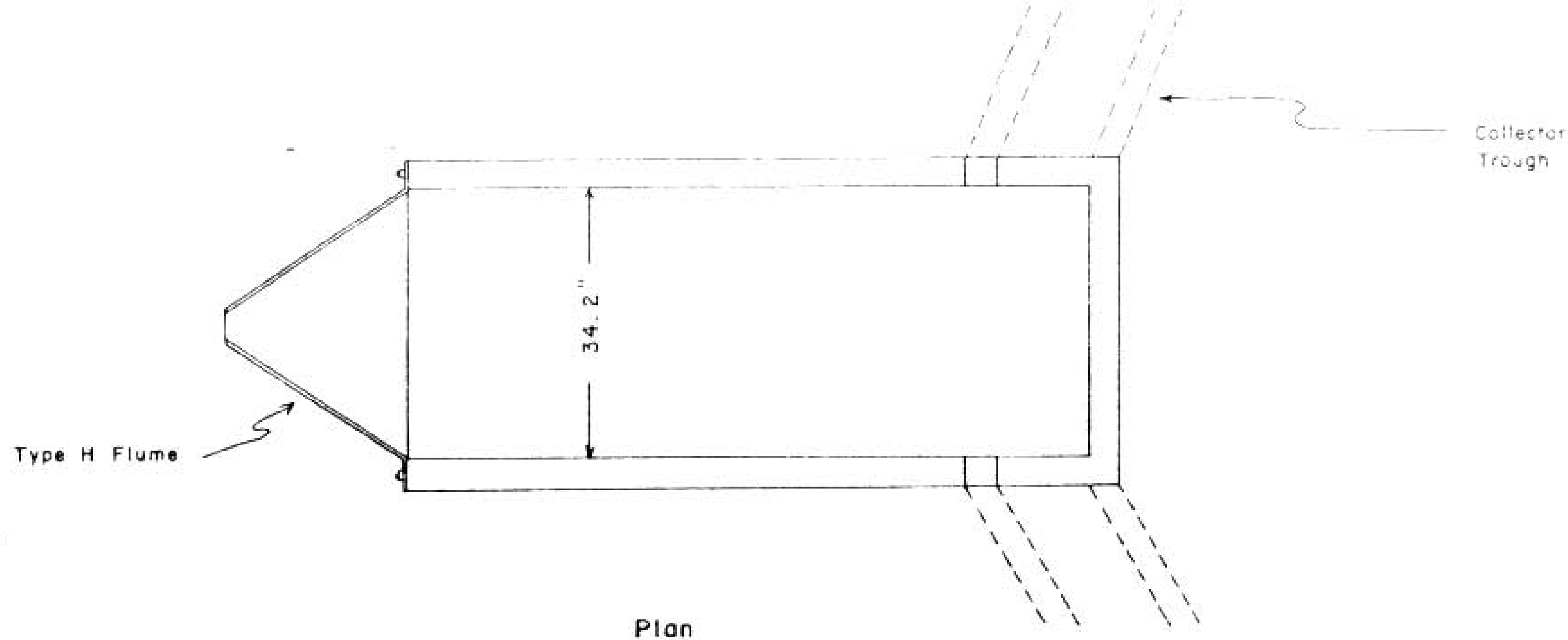


A

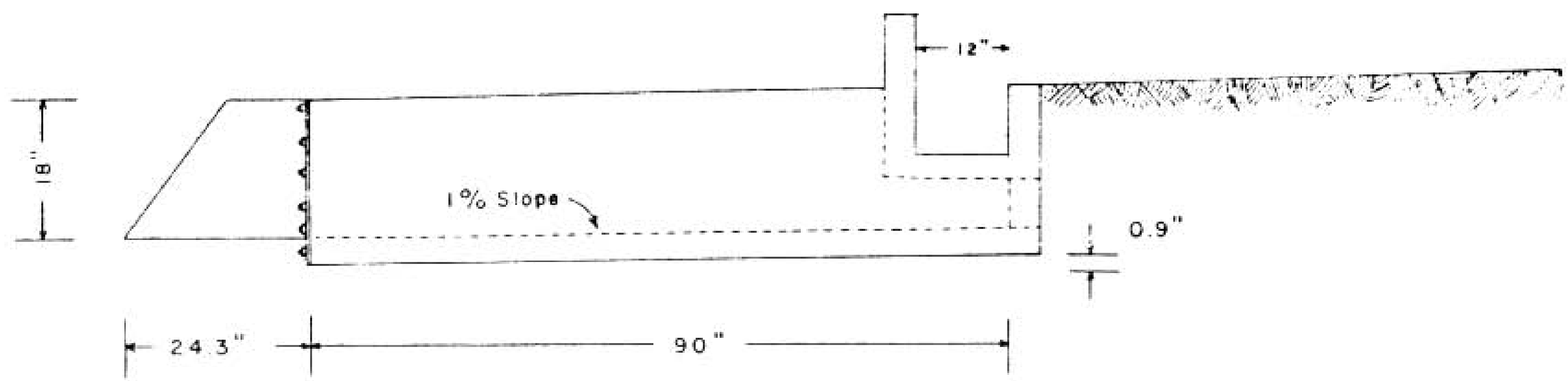
Fig. A1.

A - Concrete barrier, sides and tip of runoff plots.

B - Concrete collection trough, bottom of runoff plots.



Plan



Section on Center Line

Fig. A2.
DROP BOX STRUCTURE FOR H FLUME

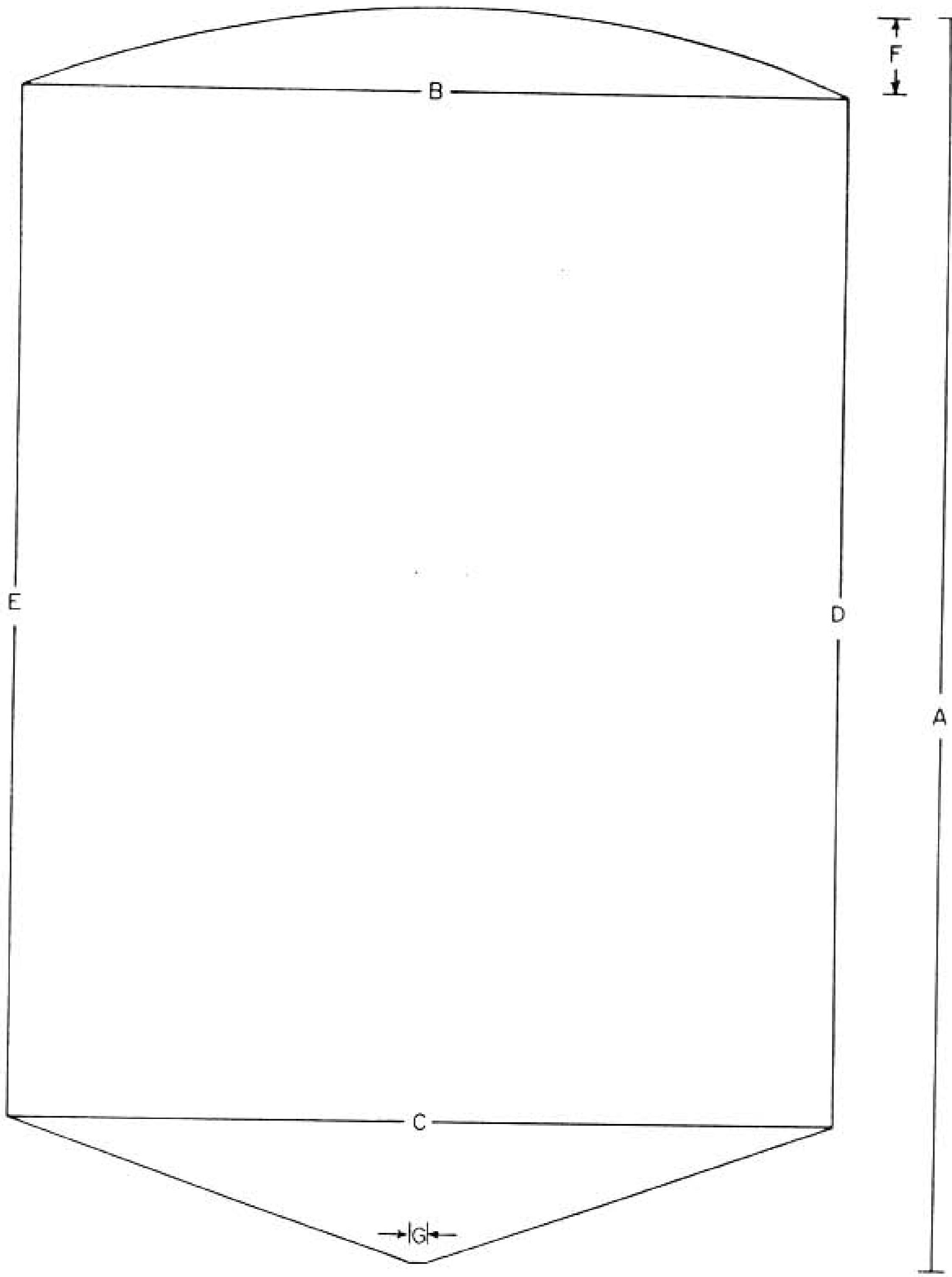


Fig. A3. Outline of microwatershed (to scale).

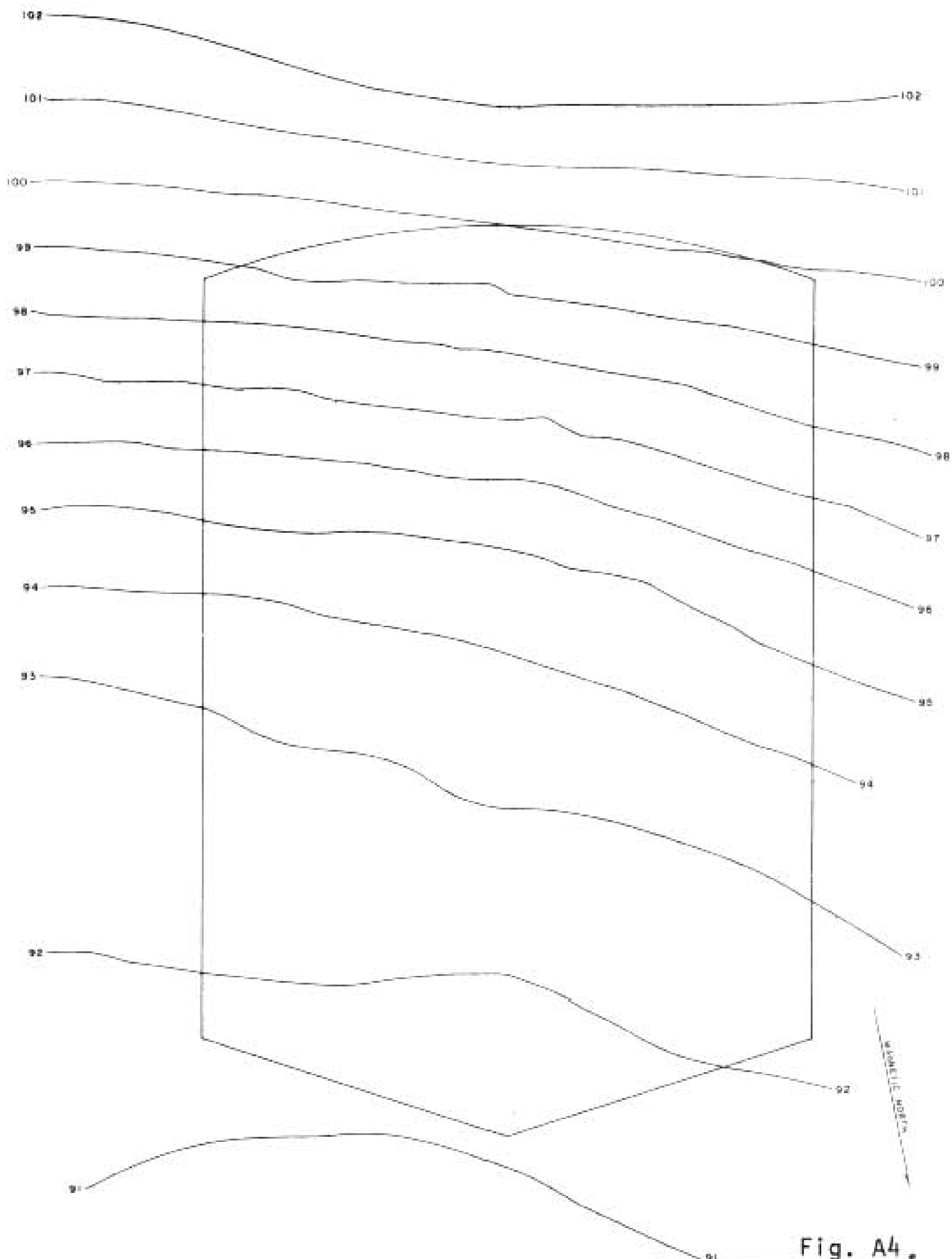


Fig. A4.

MICROWATERSHED NO. 1 (HEAVY USE)
SE $\frac{1}{4}$ SEC. 23 T.10N R66W
PAWNEE SITE, IBP, COLORADO

CONTOUR INTERVAL 1 FT.

SCALE IN FEET
0 10 25 50

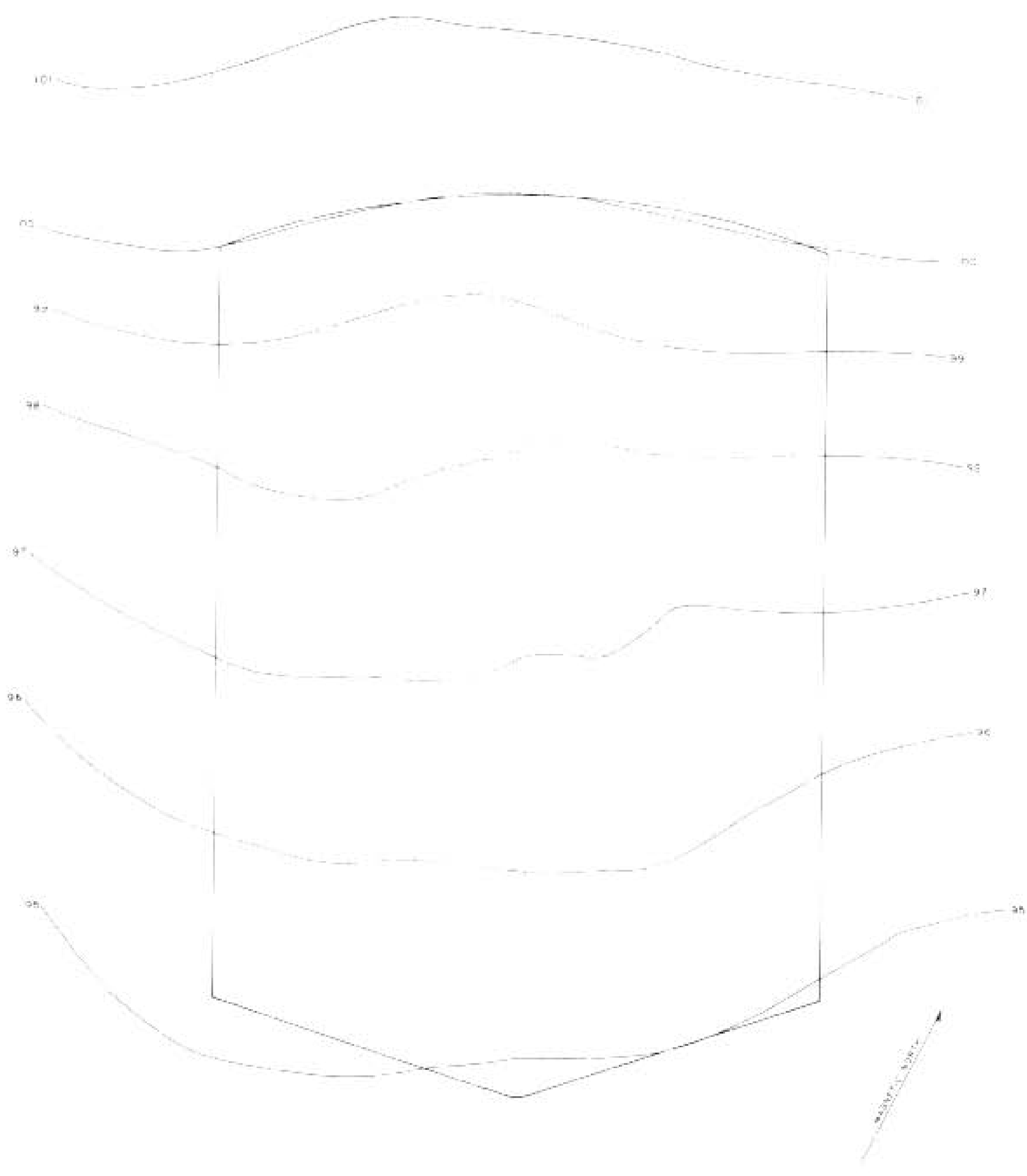


Fig. A5.

MICROWATERSHED NO 2 (EXCLOSURE)

NE $\frac{1}{4}$ SEC. 23 T 10N R66W

PAWNEE SITE, IBP, COLORADO

CONTOUR INTERVAL 1 FT.

SCALE IN FEET

0 10 25 50

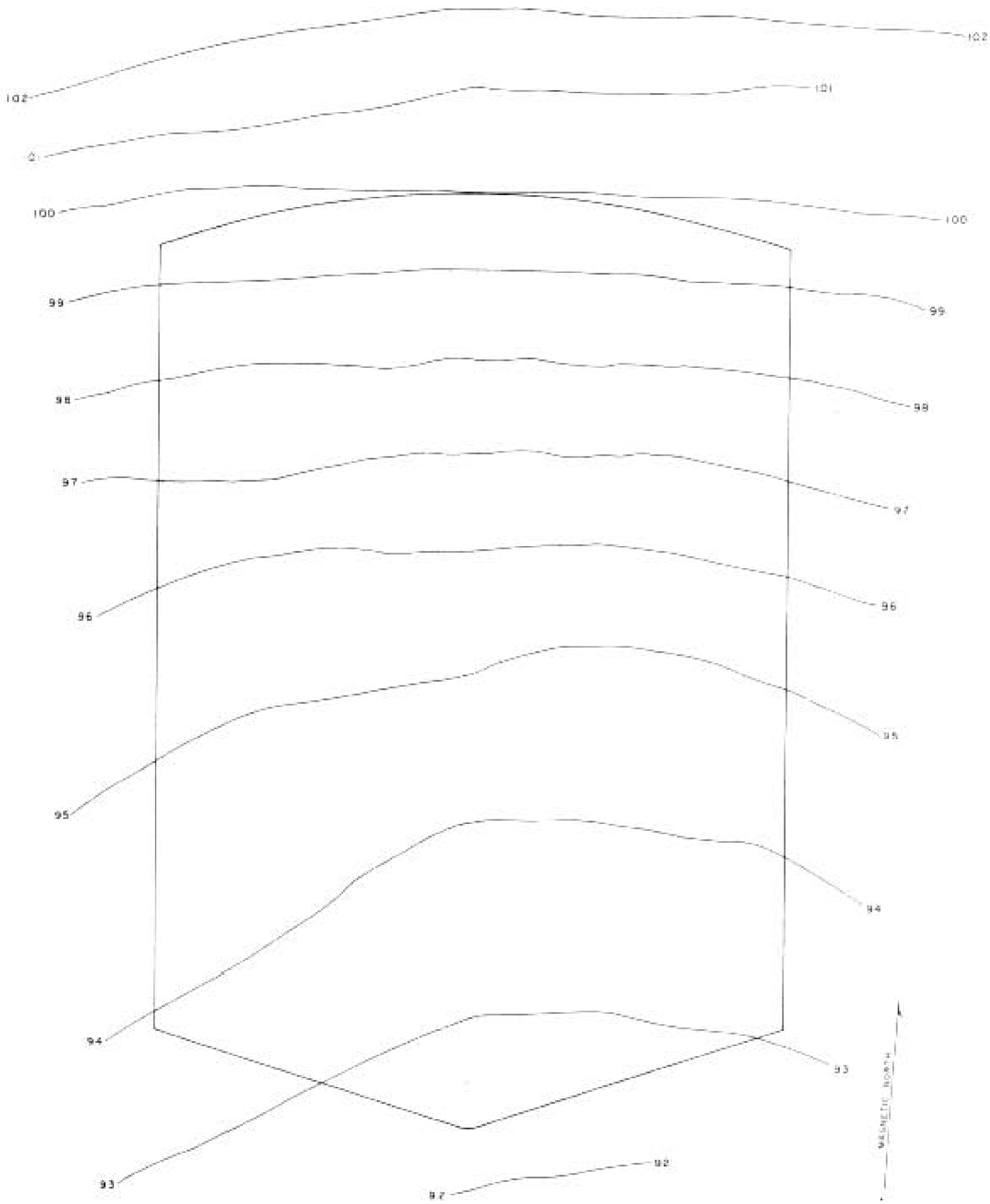


Fig. A6.

MICROWATERSHED NO. 3 (HEAVY USE)

NE $\frac{1}{4}$ SEC 23 T10N R66W

PAWNEE SITE, IBP, COLORADO

CONTOUR INTERVAL 1 FT.

SCALE IN FEET

0 10 25 50

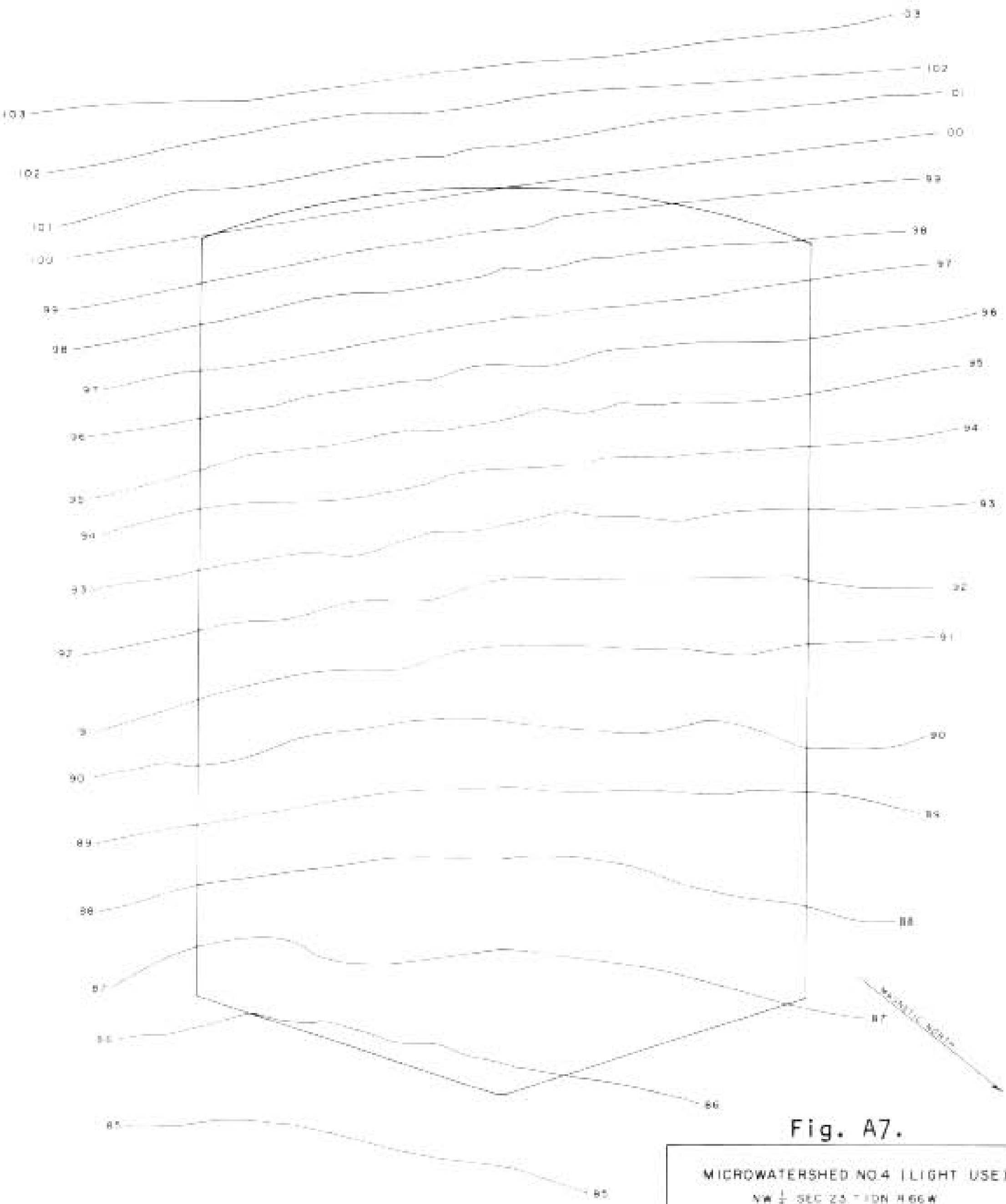


Fig. A7.

MICROWATERSHED NO.4 (LIGHT USE)
NW $\frac{1}{4}$ SEC 23 T 10N R 66W
PAWNEE SITE, IBP, COLORADO
CONTOUR INTERVAL 1 FT.
SCALE IN FEET
0 10 25 50

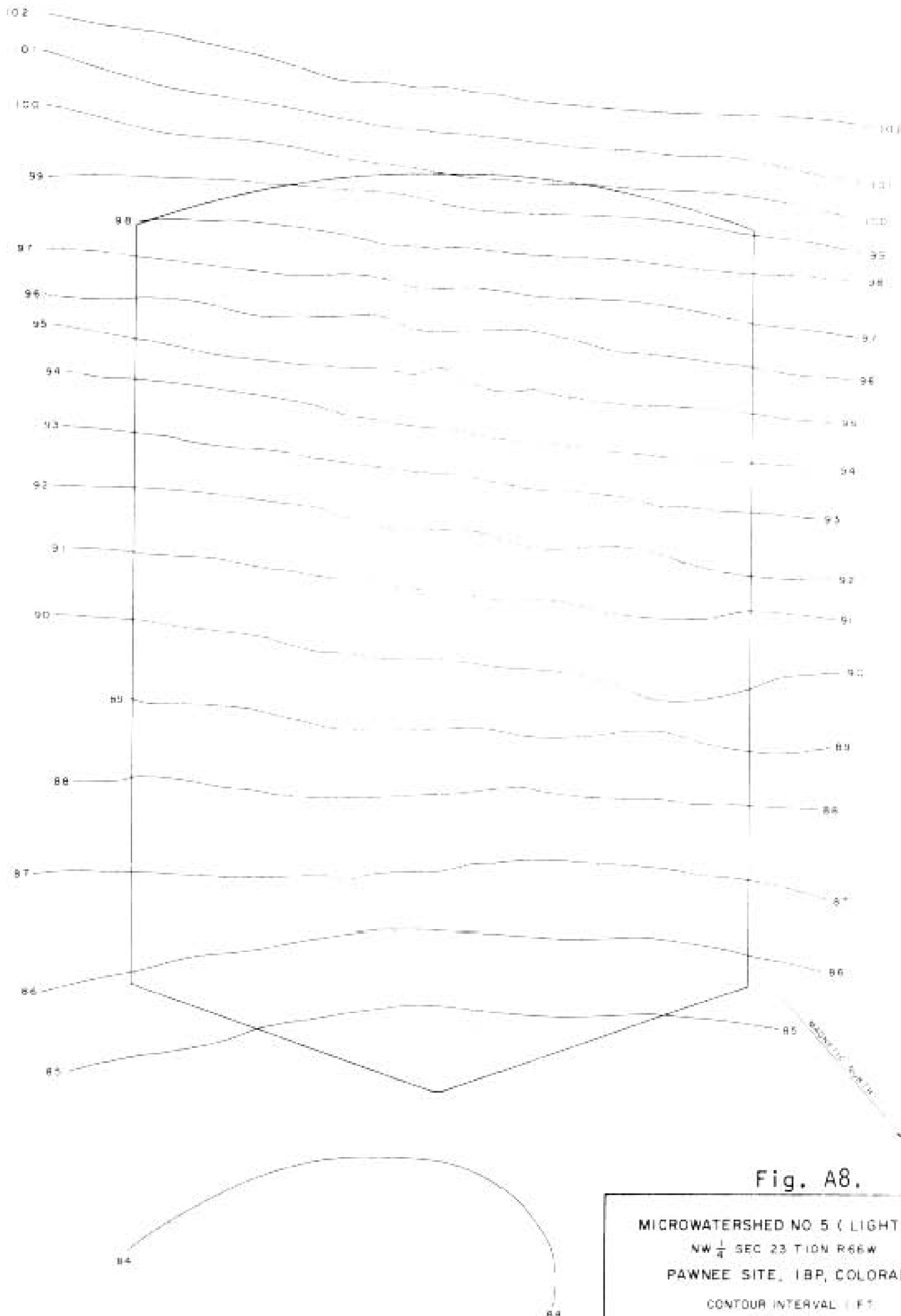


Fig. A8.

MICROWATERSHED NO. 5 (LIGHT USE)
NW $\frac{1}{4}$ SEC 23 T10N R66W
PAWNEE SITE, IBP, COLORADO
CONTOUR INTERVAL 1 FT.
SCALE IN FEET
0 10 25 50

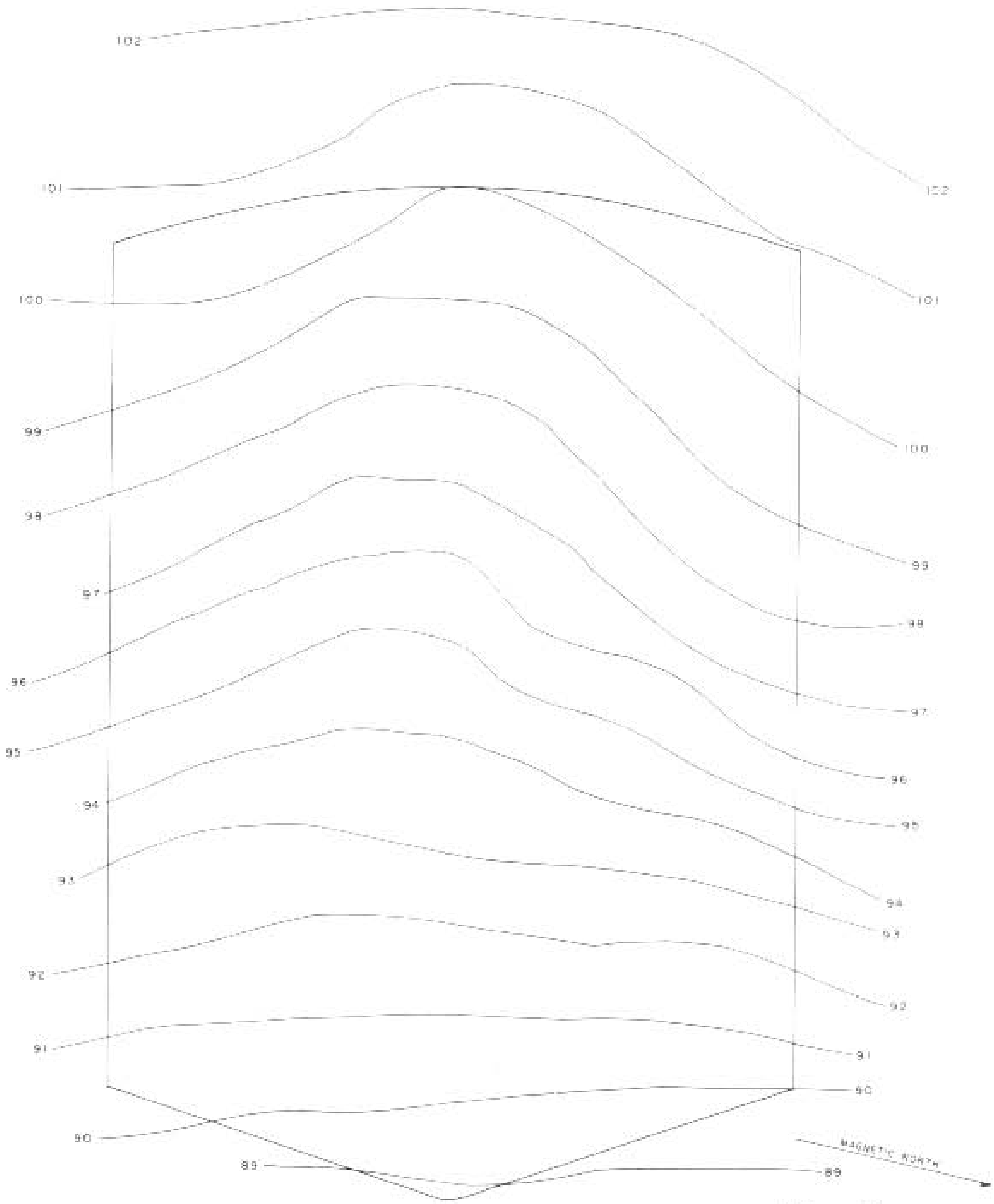


Fig. A9.

MICROWATERSHED NO 6 (MODERATE USE)

SE $\frac{1}{4}$ SEC 15 T 10N R66W

PAWNEE SITE, IBP, COLORADO

CONTOUR INTERVAL 1 FT

SCALE IN FEET

0 10 25 50

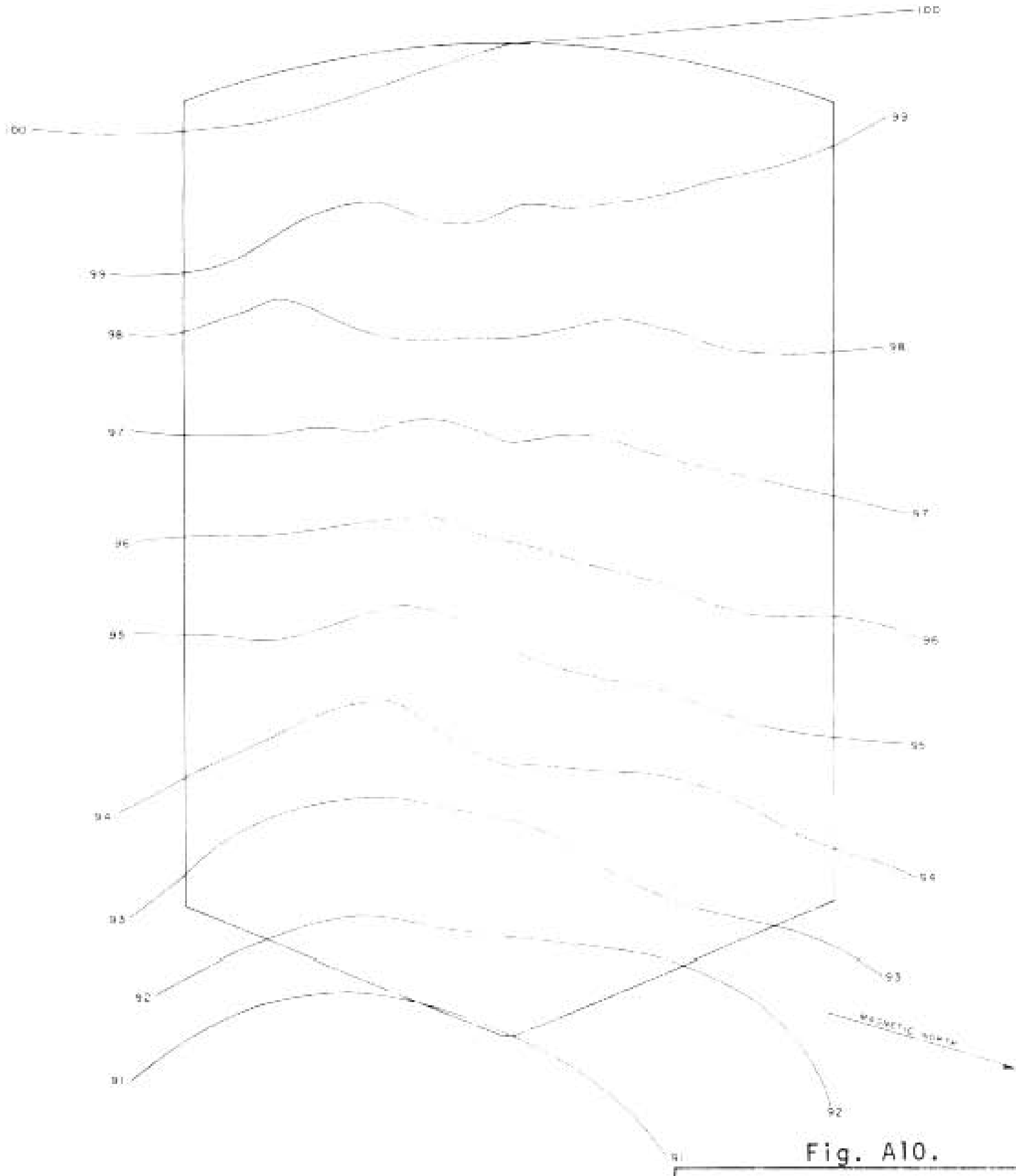


Fig. A10.

MICROWATERSHED NO. 7 (MODERATE USE)
SE $\frac{1}{4}$ SEC 15 T10N R66W
PAWNEE SITE, IBP, COLORADO

CONTOUR INTERVAL 1 FT.
SCALE IN FEET
0 10 25 50

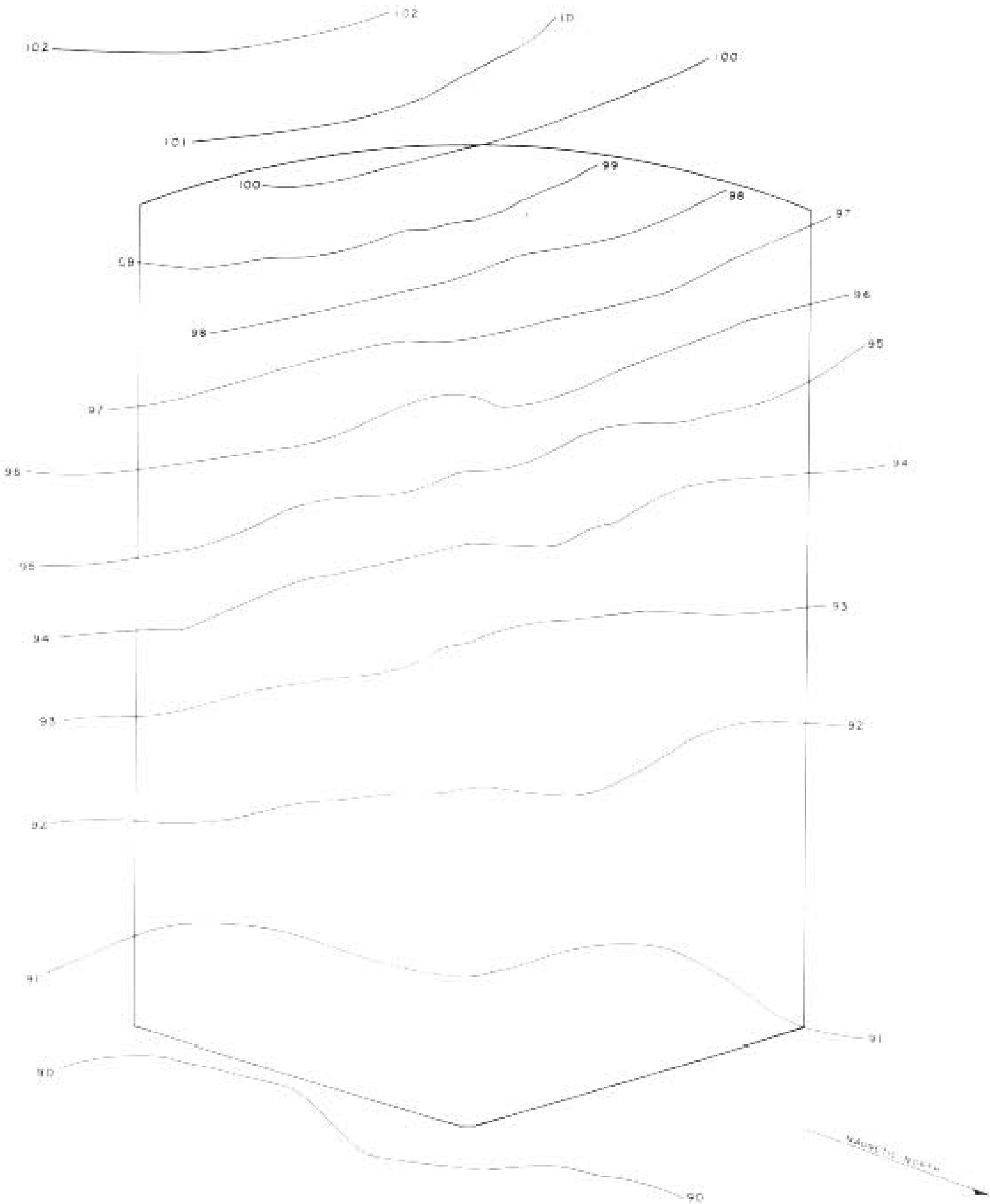


Fig. A11.

MICROWATERSHED NO. 8 (EXCLOSURE)

NW $\frac{1}{4}$ SEC 15 T10N R66W

PAWNEE SITE, IBP, COLORADO

CONTOUR INTERVAL 1 FT.

SCALE IN FEET

0 10 25 50