

United States Department of the Interior
Office of Surface Mining Reclamation and Enforcement



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RECONNAISSANCE MAPS TO ASSIST IN IDENTIFYING ALLUVIAL VALLEY FLOORS

WEST-CENTRAL NORTH DAKOTA

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June 1985

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INTRODUCTION

14 Alluvial valley floors are defined by the Surface Mining Control
15 and Reclamation Act of 1977 as:

17 ...the unconsolidated streamlaid deposits holding streams
18 where water availability is sufficient for subirrigation or flood
19 irrigation agricultural activities but does not include upland
20 areas which are generally overlain by a thin veneer of
21 colluvial deposits composed chiefly of debris from sheet
22 erosion, deposits by unconcentrated runoff or slope wash,
23 together with talus, other mass movement accumulation and
24 windblown deposits [Section 701(1), Public Law 95-87].

22 With the passage of this act, Congress provided for the
23 preservation of alluvial valleys in the semiarid West. Generally, alluvial
24 valley floors are areas in the Western United States which (1) are
located in topographic valleys having an associated stream channel, (2)
are underlain by unconsolidated deposits whose surface usually has a
landform appearance of flood plains or terraces, and (3) have an
agricultural importance derived from water availability. Environmental
characteristics, agricultural uses, and irrigation practices within stream
valleys vary in the different coal regions of the West. Therefore, the
specific rationale used for identifying the role and character of alluvial
valley floors may vary from one area to another.

The objective of this study was to identify surface irrigated and
subirrigated sites in the West to develop an understanding, from a
regional perspective, of the types of stream valleys that may be studied
further for consideration as alluvial valley floors. Further, potentially
surface irrigable sites which also meet the geomorphic criteria were also
identified on the basis of regional agricultural practices. This
information was compiled onto 1:100,000-scale maps for all or part of
four coal regions in the Western United States. Areas studied include
the Fort Union coal region in west-central North Dakota, the Powder
River Basin coal region of southeastern Montana and northeastern
Wyoming, the Yampa and Danforth Hills coal fields of northwestern
Colorado, the Book Cliffs, Grand Mesa, and Somerset coal fields of
west-central Colorado, and the Book Cliffs and Wasatch Plateau coal
fields of central Utah.

These maps represent only a reconnaissance-level effort in
identification of areas which are likely to meet this definition, and these
areas, therefore, are called potential alluvial valley floors. The intent
of this mapping effort is to identify areas which might, at a future
date, be designated as alluvial valley floors. Because
reconnaissance-level data have been used in this study, it is recognized
that detailed data collected for any specific area may more conclusively
prove or disprove the alluvial valley floor findings made in this report.
The following text outlines the basis for the alluvial valley floor
mapping. If further site-specific study is necessary, information

contained in this report can help identify those issues requiring additional study.

Mapping was conducted consistent with the method described in chapter II of the "Alluvial Valley Floor Identification and Study Guidelines" (U.S. Office of Surface Mining, 1983). The data on which these maps are based were obtained primarily by field investigation and supplemented with information from regulatory and land management agencies, from published reports, and from aerial photographs and Landsat imagery.

The study area encompasses parts of the Fort Union coal region in west-central North Dakota, specifically coal fields in parts of Dunn, Mercer, Oliver, McLean, Stark, and Billings Counties. Figure 1 shows the location of the study area, as well as the location of the individual maps of potential alluvial valley floors which accompany this text.

PHYSIOGRAPHY AND CLIMATE

Except for the area north and east of the Missouri River, the study area is located in the Missouri Plateau section of the Great Plains physiographic province. The gently rolling upland surface of the area is dissected by east- and southeast-flowing drainages, which have eroded valleys as much as 200 feet below the plateau surface. Scattered buttes, capped by resistant bedrock, rise above the upland surface. Elevations range from about 3,300 feet (1,000 m) above sea level in the Killdeer Mountains to 1,650 feet (500 m) at the point where the Missouri River leaves the study area.

Although the Knife River basin in the study area was glaciated, most glacial sediment has been eroded away, and the physiography is similar to the unglaciated Dickinson area. Several deep flat-floored valleys carved by glacial melt water cut the present drainages in a northwest to southeast direction.

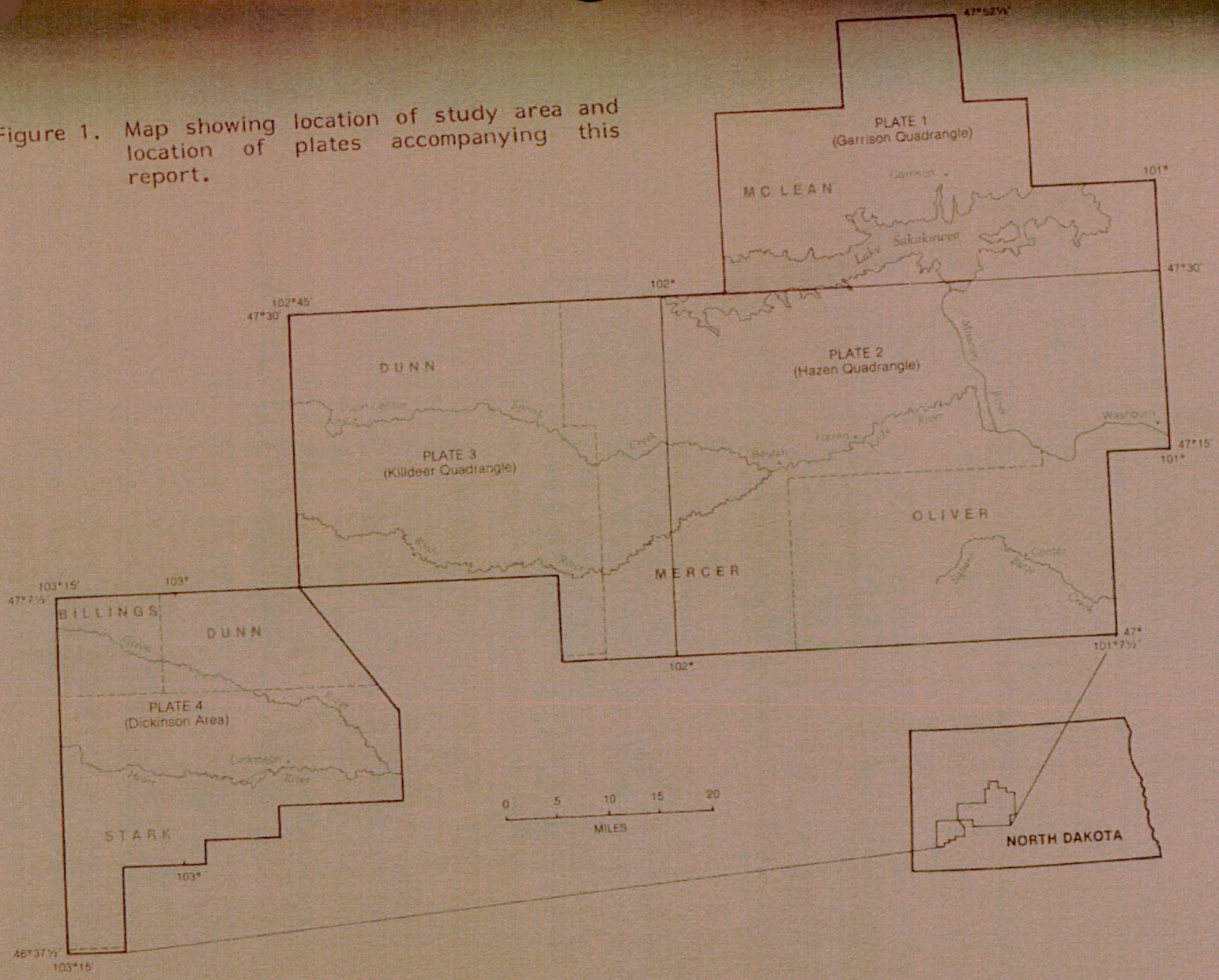
The portion of the study area north and east of the Missouri River is part of the Missouri Coteau of the Central Lowland physiographic province. The bedrock is covered by dead-ice ground moraine which has created a hummocky and irregular surface, quite distinct from the rest of the study area. Elevations range from 1,900 to 2,200 feet (580 to 670 m).

The climate of the study area is uniformly cool and semiarid. Mean annual temperature is about 40°F. Mean annual precipitation is about 16.5 inches, approximately 75 percent of which falls between April and September.

DATA COLLECTED

Detailed information regarding the areas included in this study was compiled through field investigation and an intensive review of published reports, interpretation of aerial photography and Landsat

Figure 1. Map showing location of study area and location of plates accompanying this report.



imagery, review of geologic and soils data, and evaluation of irrigation and agricultural practices for each region. Potential alluvial valley floors were classified and delineated on maps at a scale of 1:24,000, and the information was transferred to the 1:100,000-scale maps that accompany this text. Essentially, the areas mapped are the parts of valleys underlain by unconsolidated deposits: (1) where surface-water irrigation is practiced; (2) where natural flood irrigation occurs, or (3) where ground water occurs at sufficiently shallow depths that irrigation can tap this available supply. Reconnaissance-level data have been collected on each of these topics.

Identification of unconsolidated deposits found in valleys was based on interpretation of aerial photography, topographic maps, bedrock and surficial geologic maps, and field observations. Bureau of Land Management color-infrared aerial photography (scale 1:24,000) flown in August 1980 (Knife River area) and in June and July 1981 (Dickinson area) was utilized. Surficial geologic maps at various scales were consulted (Bluemle, 1971; Carlson, 1973; Clayton, 1969; Trapp and Croft, 1975). Soil surveys are available for the study area (U.S. Soil Conservation Service, 1975, 1978, 1979, 1982). Collectively, these data permitted identification of flood plains, terraces, outwash channels, and some gently sloping areas where colluvium is interpreted to overlie alluvium.

Interviews with local farmers and ranchers as well as resource professionals played a key role in our collection of agricultural data. Data were collected concerning the location and use of irrigated fields, agricultural practices, the importance of stream valleys to farms and ranches, and general perceptions of local agriculture and economics. Attempts were made to talk to as many farmers and ranchers in the study area as possible. Approximately 80 interviews were conducted in the study area.

Data on surface-water irrigation practices were collected from various sources. Unpublished maps of irrigated lands were available from the Soil Conservation Service (SCS) field offices in Dunn and McLean Counties. Unpublished maps showing the location of water permits for irrigation use and water permit records were available at the North Dakota State Water Commission in Bismark. Aerial photograph interpretation, field checks, and interviews with farmers and ranchers, as well as with SCS and Agricultural Stabilization and Conservation Service (ASCS) personnel, further refined and updated the assembled data. To the authors' knowledge, these compiled data represent the most nearly complete surface-water irrigation assessment available for west-central North Dakota.

Areas of subirrigation and natural flood irrigation overlap in many valleys in the study area. The net result of both is increased vegetative production on bottomlands, but distinguishing the relative importance of either at the reconnaissance level of these maps is often not possible. Therefore, one mapping unit is used to indicate one or

the other, or both. The reader is referred to the description of each drainage for any additional information not indicated on the maps.

Data on the extent of natural flood irrigation were collected at specific valley sites through interviews with farmers, ranchers, and SCS personnel. Mapping of natural flood irrigation involved extrapolation of these data throughout the valley system, based on correlation with geomorphic surfaces. Natural flooding occurs in any stream in the Western United States, but in this study area, farmers and ranchers consistently emphasized the value of natural flood irrigation to the productivity of their valley-bottom crops and pastures. Therefore, these naturally irrigated lands have been specifically delineated in this study. The actual width of natural flooding is obviously different every year and, thus, not precisely mappable. Our map unit reflects the area reported by area residents and by resource professionals as frequently inundated. Review of hydrologic data and interviews indicate that this area is flooded approximately 3 years in 5. Because this study is a reconnaissance, it did not involve surveys of cross sections and slopes or detailed flood-height analysis. Therefore, the mapped extent of the natural flood irrigation areas should be considered approximate. Furthermore, areas of natural flood irrigation and subirrigation often are difficult to distinguish. Mapping of this unit is helpful, however, in the sense of indicating those valleys where the phenomenon is important.

Subirrigation was interpreted from Landsat imagery taken during the moisture-stress period of the late growing season in 5 different years (1975-76, 1978-80). Mean annual precipitation ranged from 25 percent above normal to 24 percent below normal in these 5 years. Near-infrared color composites and black-and-white images of Landsat's Band 5 were used because these bands indicate the relative moisture content of vegetation. This approach was necessary because different years vary in moisture regime. This effort is directed at mapping areas which consistently reflect subirrigation, with subirrigated areas being interpreted as those valley-bottom areas which indicated vegetation growth during the late growing season of most of the years of evaluated Landsat imagery. Areas which were apparently subirrigated only in the wettest year have not been mapped. The smallest size area which can be seen on Landsat imagery is limited by the 80- x 80-m size (1.6 acres) of a pixel, or piece of Landsat datum. Areas of subirrigation smaller than this size could not be distinguished and were not mapped. Ground-water-level data from coal mine permits and published reports (Croft, 1970; Klausning, 1971, 1976; Trapp, 1971; and Groenewold and others, 1979) were also used to correlate Landsat imagery with known depths to water. Generally, subirrigated areas have ground-water depths of 15 feet or less.

The crop rotation practice prevalent in the study area--alternating deep-rooting alfalfa with shallow-rooting crops--results in a pattern where, in any 1 year, certain fields may be subirrigated while adjacent fields may not. In subsequent years, the pattern will change as deep-rooted alfalfa is grown in other fields. Because the time span covered

by the Landsat images used is less than the normal rotation cycle, the area of subirrigation is likely to be more extensive than indicated on the maps.

AGRICULTURAL LAND USE

Cattle ranching and grain farming are the two main types of agriculture in west-central North Dakota. The chief crops are wheat, barley, corn, hay, and cattle. In some areas there is greater crop diversity, particularly where highly developed irrigation exists. Several small dairies are scattered throughout the study area. For most operators, though, raising some combination of wheat and cattle provides their main livelihood.

The proportion of each crop grown by a farmer or rancher depends on several factors, the most important of which is the topography of the land controlled by the operation. Individual management preferences and the market demand for agricultural commodities are also important factors. Wheat farming is more suited to flat, upland areas. Cattle ranching is preferred where drainages cross the land (fig. 2). Upland areas, which cover most of the study area, are extensively farmed with dryland grains and some hay. Sporadic fields are in pasture. Valley bottoms, with their better soils, irrigation potential, and water supply for stock watering, are well suited to the various needs of raising cattle. Hay, silage, and small grains are the three crops which are grown in rotation in valley-bottom fields. Good pastureland is found nearby along stream channels and on side slopes, but the familiar "breaks" country which surrounds many drainages is useful only for grazing. Over the years, as cattle prices have declined and as cash crops have become more important, more pasture and hayland has been broken and planted to grains.

The main types of irrigation traditionally used in west-central North Dakota are spreader dikes and pumped sprinkler systems. Contrary to what is possible in much of the West, alfalfa can be grown in upland areas due to good soils and the approximately 16 inches of annual precipitation. This fact, plus the strong reluctance to change traditional practices (which do not include irrigation) has minimized the role of irrigation in the study area.

Spreader dikes are used to spread either tributary or main stem water onto main stem terraces. Most spreader systems completely impound water behind the dikes, and water is released when a headgate in the dike is manually opened. Commonly, water flows through a series of diked fields (fig. 3). Water is diverted to fields with spreader dikes by direct diversion by a dike, by overbank floodflows, or by pumping from the stream. An approximate doubling in production in these irrigated fields over dryland fields was reported in many interviews. The irrigation season is generally short because most systems are used only during high runoff periods. Generally, irrigation is practiced throughout the growing season only on larger streams, such as the Missouri and lower Knife Rivers. Sprinkler



Figure 2. View of Coyote Creek (near Beulah) showing hayfields on the valley bottom, grazing land on valley slopes, and dryland farming on uplands (in distance).



Figure 3. Spreader dike system on a tributary to Branch Douglas Creek, McLean County. Water diverted from the stream by dikes is impounded by dikes in the hayfield. Headgates are opened to release water from upper fields (on the left) to lower fields. Because streamlaid deposits do not underlie these fields, the area is not an alluvial valley floor.

systems with center pivots have begun to be used on both upland areas and valley bottoms within the past 10 years. However, their use is not common.

Irrigation exists along the major drainages but is not generally extensive. Very few small streams have any irrigation development. These smaller tributaries have the potential for more extensive irrigation development, particularly with spreader dikes. This potential is not indicated on the alluvial valley floor maps because irrigation on these small drainages is not considered a regional practice. (See discussion under Minor Drainages.) On the basis of extrapolation from irrigated parts of specific valleys in the study areas, significantly more acres in the larger valleys could be irrigated with either surface or ground water.

The smaller stream valleys are very important to ranchers. They provide stock water, which is commonly springfed, shelter from sun and wind, and highly productive pasture, which is commonly subirrigated or naturally flood irrigated (fig. 4).

IDENTIFICATION OF REGIONS

Part of the process of designating alluvial valley floors is to identify valley floors which are capable of being flood irrigated. One dilemma in this effort is that physically similar valleys experience different use patterns in different parts of the West. Other aspects of the regional physical geography (e.g., proximity to major rivers) and social geography (e.g., agricultural methods) help determine what types of stream valleys are developed in one particular region of the West. Therefore, an assessment of regional agricultural practices within the study area was made. This method is consistent with the method outlined in chapter II of the "Alluvial Valley Floor Identification and Study Guidelines" (U.S. Office of Surface Mining, 1983).

The agricultural land use practices described previously are similar throughout west-central North Dakota. Although the use of any valley is dependent on its size, soils, water availability, and other factors, on a regional basis, the use of any valley is largely dependent on the size of the drainage basin. In evaluating the potential for irrigation development in undeveloped valleys, comparison of developed and undeveloped valleys has been undertaken only in relation to others of similar size. In other words, large valleys have been compared with other large valleys. The following groups of drainages have been formulated:

1. Large perennial streams. The Missouri, Knife, Green, and Heart Rivers and Spring Creek are the main drainages of the study area. Sufficient water for irrigation at many sites is available in each. Depending on the specific reach of stream, zero to 90 percent of the valley may be irrigated currently.



Figure 4. Headwater tributary to Elm Creek. This type of drainage, sometimes called a woody draw, is important to cattle operations due to its subirrigated grasses, stock water supply, and shelter.

2. Major tributaries. Major tributaries to the five large perennial streams are also perennial and generally have drainage areas of over 40 square miles. Examples include Square Butte, Otter, and Crooked Creeks. Irrigation water is usually available for at least one development in each valley, although not all major tributaries are irrigated. Subirrigation and natural flood irrigation are important.
3. Former outwash channels. Glacial outwash channels that no longer have large streams associated with them contain large amounts of ground water but are generally dryland farmed. Upper Antelope and Goodman Creeks are examples. Except for subirrigated areas, these valleys generally are not alluvial valley floors.
4. Minor drainages. The small streams not included in the other three groupings are, for the most part, undeveloped. Subirrigation and natural flood irrigation are sometimes important.

SUMMARY OF RESULTS

All irrigated and subirrigated valleys underlain by unconsolidated deposits were identified as potential alluvial valley floors. Within each grouping of drainages, nonirrigated valleys and nonirrigated parts of valleys with irrigation were also designated potential alluvial valley floors if other valleys of similar size are developed. Further site-specific study may provide data which might indicate that certain valleys or portions of valleys may not be considered alluvial valley floors due to unsuitable soils, topography, or water supply.

LARGE PERENNIAL STREAMS

The major drainages in the study area, while not extensively developed, have numerous irrigation systems. All sites are irrigated during spring runoff, and fewer sites are irrigated during the summer. Pumped sprinkler systems and diversion by pumping or gravity flow to fields with contour dikes are the common methods of surface irrigation.

Missouri River. The terraces along the Missouri River (pl. 2) provide the cropland base for many farms. Alfalfa, grass hay, and silage are grown for livestock or dairy cattle, or else for sale. Row crops are also important. The first and second terraces (10 to 25 feet) are occasionally irrigated by pumping from the river. On the west side of the river south of Stanton, the second and third terraces are irrigated by a canal system. Fields as much as 60 feet above the river are irrigated here. All three terraces are designated as flood irrigable.

Knife River. At its upstream end at the western edge of the study area (above Crooked Creek), the Knife River (pl. 3) is incised

approximately 10 feet into a broad, low terrace. Hay production on this terrace is enhanced by natural flood irrigation that occurs during spring runoff and other large runoff events in most years. Alfalfa hay may also be subirrigated. A second terrace is occasionally present about 5 feet above the first terrace; it experiences floods very rarely and is not specifically utilized in the way that the lower terrace is. No irrigation development exists in this reach of the Knife River, although several operators have applied to the SCS for construction of spreader systems.

From approximately 2 miles west of Emerson upstream to the confluence with Crooked Creek, the river (fig. 5) is more deeply incised (15 feet). The valley floor is not as intensively utilized as it is upstream. Native grass, pasture, and dryland grains are the predominant crops grown. This change in use is probably a result of limited natural flood irrigation due to the deeper channel incision.

Between Crooked Creek and Elm Creek, the Knife River is intensively irrigated. The broad valley flat is a terrace approximately 15 to 20 feet above the river channel. Higher, nonirrigated terraces also exist. Most spreader systems developed on this terrace divert and/or impound the naturally occurring floodwaters (fig. 6); some spreader systems have water pumped to them. Tributary water from Coyote Creek (near Marshall) and North Schaffner Creek is also used. Parts of undeveloped fields receive beneficial moisture from natural flood irrigation. The amount of natural flooding is less below Marshall. The additional runoff contribution from Crooked Creek is probably the primary factor influencing the extent of natural flooding that occurs in this reach of the Knife River. Hay is grown in irrigated fields, whereas grain crops may be planted in the undeveloped higher parts of the terrace.

From Elm Creek to Spring Creek (pl. 2), the river is deeply incised (15 to 25 feet), and no Knife River water is used for irrigation. However, one system utilizes tributary water, and a center pivot system pumps alluvial ground water. Subirrigation is precluded by the depth of channel incision, and natural flood irrigation rarely occurs below Brush Creek.

Below the confluence of the Knife River and Spring Creek, three operations use pumped sprinkler systems to irrigate alfalfa and small grains. Annual flooding does not generally reach the main valley floor, which is 20 feet or more above the channel. Subirrigation does not occur under the main valley floor (fig. 7).

All first and second terraces of the Knife River are considered flood irrigable on the basis of existing irrigation on these terraces in the drainage.

Spring Creek. All irrigation systems in the Spring Creek valley (pls. 2 and 3) pump water and utilize either contour dikes or sprinklers. The main irrigation occurs for 2 weeks in the spring,



Figure 5. View of the main terrace (15 feet) used for sporadic irrigation on a reach of the Knife River downstream from Crooked Creek. This photograph was taken in T. 143 N., R. 93 W., sec. 31.



Figure 6. Headgates used to divert floodwaters of the Knife River to fields irrigated by spreader dikes. Floodwaters annually rise to the height of these gates, which are located in T. 143 N., R. 94 W., sec. 23, downstream from Crooked Creek.



Figure 7. The Knife River downstream from Beulah is incised 20 feet or more into a broad valley which is used primarily for dryland crops. This valley is considered potentially flood irrigable on the basis of several pumped sprinkler systems along this reach of the river.

during runoff, and a second irrigation is used if summer streamflow is high. Water quality is adequate for irrigation during runoff. Some operators irrigate during low-flow periods even though water quality is considered poor. Additional systems could physically be developed; however, as elsewhere in the study area, management styles, capital, and the short irrigation period are probable reasons for the lack of additional irrigation. Two main terrace levels exist along Spring Creek (fig. 8). Both irrigated and nonirrigated portions are designated irrigable. A higher terrace occurs, more commonly below Goodman Creek, and is not irrigated or considered irrigable.

Natural flood irrigation increases yields on the lower terrace and lower parts of the second terrace (8 to 12 feet). Subirrigation probably also provides some water to deep-rooted crops. These areas are mapped as naturally flood irrigated and/or subirrigated.

Heart River. The Heart River (pl. 4) provides Dickinson with municipal water, and water permits, therefore, no longer exist for irrigation upstream from the city. Several fields between South Heart and Dickinson used to be irrigated; therefore, the valley upstream from Dickinson is designated flood irrigable. Several pump/dike and pump/sprinkler systems still exist downstream from Dickinson and are used throughout the growing season. The second terrace contains the irrigated fields, and the Heart River is designated as irrigable as far upstream as Norwegian Creek. A higher terrace (35 to 45 feet) is not irrigated or designated irrigable.

The second terrace is generally lower above Dickinson (8 to 12 feet) than it is downstream (10 to 15 feet); therefore, natural flood irrigation of this extensive terrace surface is more common upstream. Natural flooding and subirrigation occur in the lower parts along the entire valley.

Green River. At their confluence, the Heart and Green Rivers (pl. 4) are similar in size, and agricultural practices on their valley floors are also similar. The Green River flows through a broad valley, which has several irrigated fields. In stretches, there are broad areas of subirrigated fields. Irrigation development includes some spreader dike systems which catch flood runoff from both the Green River and its tributaries. Most of the irrigation involves pumping water from the river.

MAJOR TRIBUTARIES

The major tributaries of the large perennial streams contain important crop and pasturelands. Although the streams are perennial, water availability usually limits surface irrigation to one or just a few operations on each stream. Some slightly smaller tributaries in this category do not have sufficient water for any irrigation. Generally, the drainage area of these streams is greater than 40 square miles. Natural flood irrigation and subirrigation are important features of these valleys.



Figure 8. View of Spring Creek valley near Dodge. Most of the valley floor is subirrigated, and some pumped sprinkler irrigation systems exist.

A. Missouri River Drainage

Douglas Creek. The three branches of Douglas Creek (pl. 1) are the only major streams north or east of Lake Sakakawea within the study area. The Middle Branch is the largest drainage and has two terrace levels (2 feet and 5 feet). The stream is incised into bedrock in the lower part of the drainage. The broader, second terrace is used primarily as pasture with lesser amounts in hay and grain crops. Alfalfa could be subirrigated on the second terrace of the Middle Branch. Though no irrigation is practiced in this drainage, the character of the stream is similar to the major irrigated drainages of the Knife River. Therefore, Douglas Creek is designated as flood irrigable.

Square Butte Creek (pl. 2). All water rights were acquired by the powerplant near Center during the 1960's, and no irrigation has been practiced since that time. According to our interviews, no one irrigated along the stream prior to the 1960's despite the existence of water permits. Because there is sufficient water for irrigation in the stream and because the valley is similar in size to other major tributaries which are irrigated, the valley is designated as irrigable.

Natural flood irrigation and subirrigation reportedly double yields of alfalfa crops on the main terrace (6 to 10 feet). Croft (1970) reported eight wells along the stream with water levels between 5 and 15 feet; these data, as well as inspection of Landsat imagery, confirm the existence of subirrigation.

B. Knife River Drainage

Antelope Creek. The lower 5 miles of Antelope Creek (pl. 2) have several fields of flood irrigated alfalfa. The potential exists for more development in this portion of the valley. The two main branches of the stream above this portion are primarily dryland farmed. All people interviewed along these two forks claimed the water supply was insufficient for flood irrigation or that the soil was too saline.

Brady Creek. Brady Creek (pl. 2) flows through a small canyon with walls 30 to 50 feet high. The low terraces are small and frequently dissected by the stream. There are numerous springs at the base of the cliffs and the terraces are often subirrigated. This valley floor provides critical pasture for ranches along the stream. Two reaches are irrigable.

Otter Creek. Otter Creek (pl. 2) is a perennial stream with wide terraces throughout most of its length. The upper portion of the valley has subirrigated hayfields and supports some dairy operations. Farther downstream, subirrigated fields also occur. Only one irrigation system has been installed on the stream (fig. 9). Water is pumped into a series of fields bordered by spreader dikes. This new system's success has prompted its operator to enlarge the system, and irrigation



Figure 9. One spreader dike in the spreader dike system on Otter Creek. The pipes (right side) are used to pump water from the stream into the fields bordered by dikes. Three terrace levels are irrigated.

occurs on all three terraces of the valley. On the basis of this example, the terraces of Otter Creek are designated as flood irrigable. The traditional uses of the valley, however, are dryland hay and pasture. These uses alone make the valley floor critical to the success of the bordering ranches.

Brush Creek. Brush Creek (pl. 2) is a perennial stream with a baseflow contribution from springs. No irrigation development occurs in the drainage; however, the valley is considered irrigable on the basis of its similarity to adjacent valleys. Only one terrace is present in the upper reach (2 to 5 feet). Pasture use is predominant, although hayfields and cropland are present. Floodwaters will inundate lower parts of the terrace; subirrigation is evident in some areas.

Two terraces are present in the lower reach of Brush Creek. The lower terrace is 4 to 5 feet above the channel and is usually covered by floodwaters; pasture is the primary use. The second terrace (8 to 10 feet) is used for pasture and hay production.

Coyote Creek. Coyote Creek (pl. 2) (near Beulah) is a perennial stream without any irrigation development (fig. 2). The lower reach (below Beaver Creek) is characterized by several terrace levels. The first terrace (5 feet) normally floods, but it is too small for any use other than pasture. The broad second terrace (7 to 10 feet) is extensively used for pasture and hayfields. The lower parts of this terrace flood during high runoff; the other parts could be flood irrigated by spreading and/or pumping runoff water. Deep-rooting alfalfa probably receives beneficial moisture through subirrigation. A higher terrace is occasionally present but is not flood irrigable.

The upper reach of Coyote Creek has a single terrace level 3 to 5 feet above the stream. Lower parts of the terrace will occasionally flood, and all of it is flood irrigable.

Beaver Creek. Beaver Creek (pl. 2) is a perennial tributary to Coyote Creek. A low terrace is present 3 to 5 feet above the channel and is occasionally flooded. Pasture is the primary use. A broad second terrace (6 to 10 feet) is used for pasture, hayfields, and some grain crops. Though not naturally flooded, this terrace could be flood irrigated through use of spreading and/or pumping systems. The valley bottom does not appear to be as intensively used as those in some other drainages.

Mud Creek. Mud Creek (pl. 2) is a small perennial stream that is partially sustained by springs. There is only one major terrace, approximately 4 to 5 feet above the stream channel. Terraces are intensively used as pasture and hayfields. There is no irrigation development in the drainage. However, floodwaters cover parts of the terrace and could be spread or pumped to other parts of the terrace.

Elm Creek. The lower reach of Elm Creek (pl. 3) is characterized by a narrow, deeply incised channel. There is a sporadic terrace (3 to

5 feet) within the primary incision which regularly floods but is too narrow to be developed. A broad second terrace ranges from 7 to 20 feet above the channel; only the lower parts of this terrace are naturally flooded. Hay production and grain crops are the predominant uses of this terrace.

One irrigation development on the second terrace utilizes tributary flow for its spreader system. No other irrigation occurs; however, the second terrace is potentially flood irrigable.

The upper reach of Elm Creek has a channel shallowly incised into a broad outwash surface (fig. 10). There is no preferential use of land adjacent to the stream, probably due to the limited water available in this upstream reach.

Willow Creek. Willow Creek (pl. 3) is slightly different from other northwest-flowing tributaries of the Knife River in Mercer County. The channel gradient is steeper, and the width of the second terrace is narrower. The first terrace (2 to 5 feet) is reported to flood during some spring floods; it is narrow and only used for grazing. The second terrace level (5 to 10 feet) does not flood. Primarily grazing land, this terrace is broad enough in some places for cropland use. There is no irrigation development on Willow Creek. It is not designated as potentially flood irrigable owing to the reported lack of water availability and small terrace areas. There is some subirrigation along the lowest terrace.

Branch Knife River. The channel of this stream (pl. 3) is deeply incised (15 to 20 feet) into a broad valley floor. The land use here is either dryland farming or rangeland. No spreader systems have been installed, although one is planned. The valley floor is potentially flood irrigable.

Crooked Creek. Crooked Creek (pl. 3) is a perennial stream with some irrigation development, primarily on the broad second terrace. Natural flood irrigation occurs on the lowest terrace and the lower parts of the main terrace. Alfalfa hay may receive some subirrigation on both terraces.

C. Spring Creek Drainage

There are no major tributaries in the Spring Creek drainage basin.

D. Heart River Drainage

Ash Creek. The valley bottom soils along this perennial stream reportedly are unsuitable for farm machinery, and the basin is too small to provide sufficient water for irrigation. The valley is, therefore, used for pasture and is naturally flood irrigated and/or subirrigated.



Figure 10. The upper reach of Elm Creek flows through a former outwash channel. This underfit stream is not used for irrigation.

Duck Creek. Ranchers report the water quality to be poor, and no irrigation is used. Natural flood irrigation and/or subirrigation are recognized as being important in the lower reaches of the valley.

South Branch Heart River. This stream is similar to the main stem at their confluence. The valley flat is a second terrace (10 to 15 feet) that is naturally flood irrigated on its lower areas. No irrigation development is currently used, although a system may have existed historically near the confluence with the Heart River. About 5 miles upstream, the South Branch valley changes character. The first terrace (2 to 3 feet) becomes more prominent and is utilized as pasture. The second terrace (12 feet) is still present but is rarely flooded, owing to the increased area of the lower terrace. Designation of flood irrigability extends upstream to the mouth of Bull Creek and includes all of the second terrace.

E. Green River Drainage

Russian Spring Creek. This stream (pl. 4) is spring fed and has extensive subirrigation and/or natural flood irrigation. Some areas are used for hay but many areas are permanent pasture. No ranchers were interested in developing irrigation because the good grazing and subirrigation make it unnecessary.

FORMER OUTWASH CHANNELS

Melt water from Pleistocene ice sheets carved broad valleys through west-central North Dakota. These valleys contain as much as 200 feet of glacial outwash deposits and younger alluvium and are important ground-water reservoirs. These melt-water valleys, which do not contain major streams, have small ephemeral drainages and are not surface irrigated. Natural flood irrigation and subirrigation are locally present. Dryland farming is their chief use (fig. 11).

Goodman Creek. The valley floor is used for dryland farming and pasture (pl. 3). Some subirrigation and/or natural flood irrigation exists along the stream channel.

Unnamed tributary to Antelope Creek. This valley northeast of Zap (pl. 2) is dryland farmed or is pasture. Ground water is used for irrigation in the valley, but surface water is not.

MINOR DRAINAGES

Most of the study area is drained by small streams, the vast majority of which are not developed. Generally, they are ephemeral or intermittent, and the upper reaches of many, where wheat farming takes place, have been plowed over. Some spreader dike development has occurred, mostly in response to cost-sharing programs sponsored by the ASCS. Although 11 spreader dike systems do exist on small drainages in or near the study area, they are not considered a regional

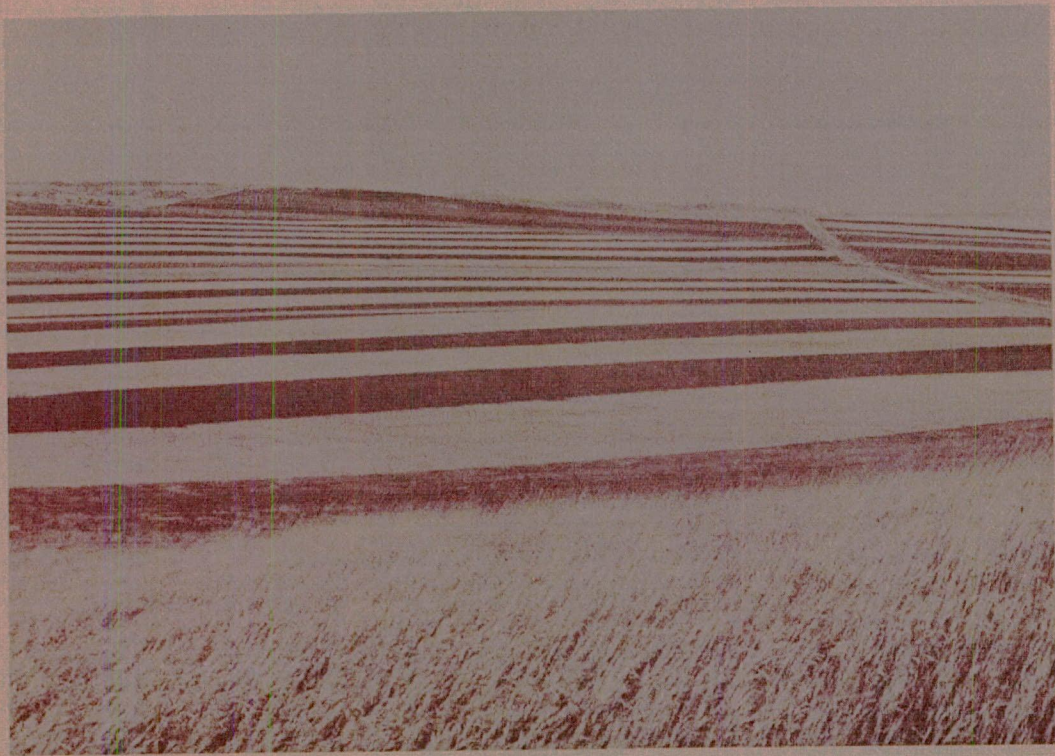


Figure 11. View of strip cropping across an outwash channel. This valley is too dry for irrigation and subirrigation, and the stream channel is only an obstacle to farming. The valley is an unnamed tributary to Crooked Creek in T. 142 N., R. 94 W., sec. 9.

practice and are not used as a criterion for designating flood irrigable valleys.

Four of the 11 systems are located on hillslopes and are not mapped. The rest are on alluvial soils (as mapped by the SCS) and are indicated on our maps. There are five systems on alluvial soils in Dunn County within a small area east and northeast of Killdeer; two in Oliver County (one is in T. 141 N., R. 82 W., sec. 22, just east of the study area); and one is planned for construction (T. 145 N., R. 85 W., sec. 32) in 1983 in Mercer County. About half these systems reportedly work well and are satisfactory to the landowners. The others are less satisfactory. All are used to irrigate haylands.

There are several reasons why these small spreader dike systems are not considered a regional practice. First, there are so few of them used that most farmers and ranchers obviously do not consider them a viable development strategy. Second, the small drainages where spreader dikes would be built are not as crucial to operations as perhaps similar drainages would be in more arid coal regions. Uplands in west-central North Dakota have good soils. Rainfall averages about 16 inches annually, falls mainly during the growing season, and is adequate for dryland crops. Thus, the uplands are chosen for additional cropland over the small valley bottoms.

On the north and east side of the Missouri River (pl. 2), none of the small tributary drainages are developed. These drainages are used primarily for grazing and occasionally for calving and winter feeding. They are important to ranchers because they provide shelter and good water. Several drainages appear subirrigated on Landsat imagery.

Some of the small tributaries on the south and west side of the Missouri River (pl. 2) are large enough to have agricultural development. These include Alderin Creek, the unnamed drainage which crosses Highway 48, and the unnamed tributary south of Mandan Lake. Alderin Creek appears subirrigated on Landsat imagery. The Highway 48 valley is perennial, and four agricultural operations use its bottomland. Based on field observation, the hayfields and pasture appear to be subirrigated in part. The Mandan Lake drainage is not subirrigated, and the productivity of the bottomland pasture is not enhanced by water availability.

In the southwestern part of the study area (pl. 4), specifically in the Heart and Green River drainages, many small tributaries appear to be subirrigated based on inspection of Landsat imagery. This indicated late-season vegetative productivity, however, is probably a result of increased soil moisture due to natural flooding rather than subirrigation (Horak, oral commun., 1984).

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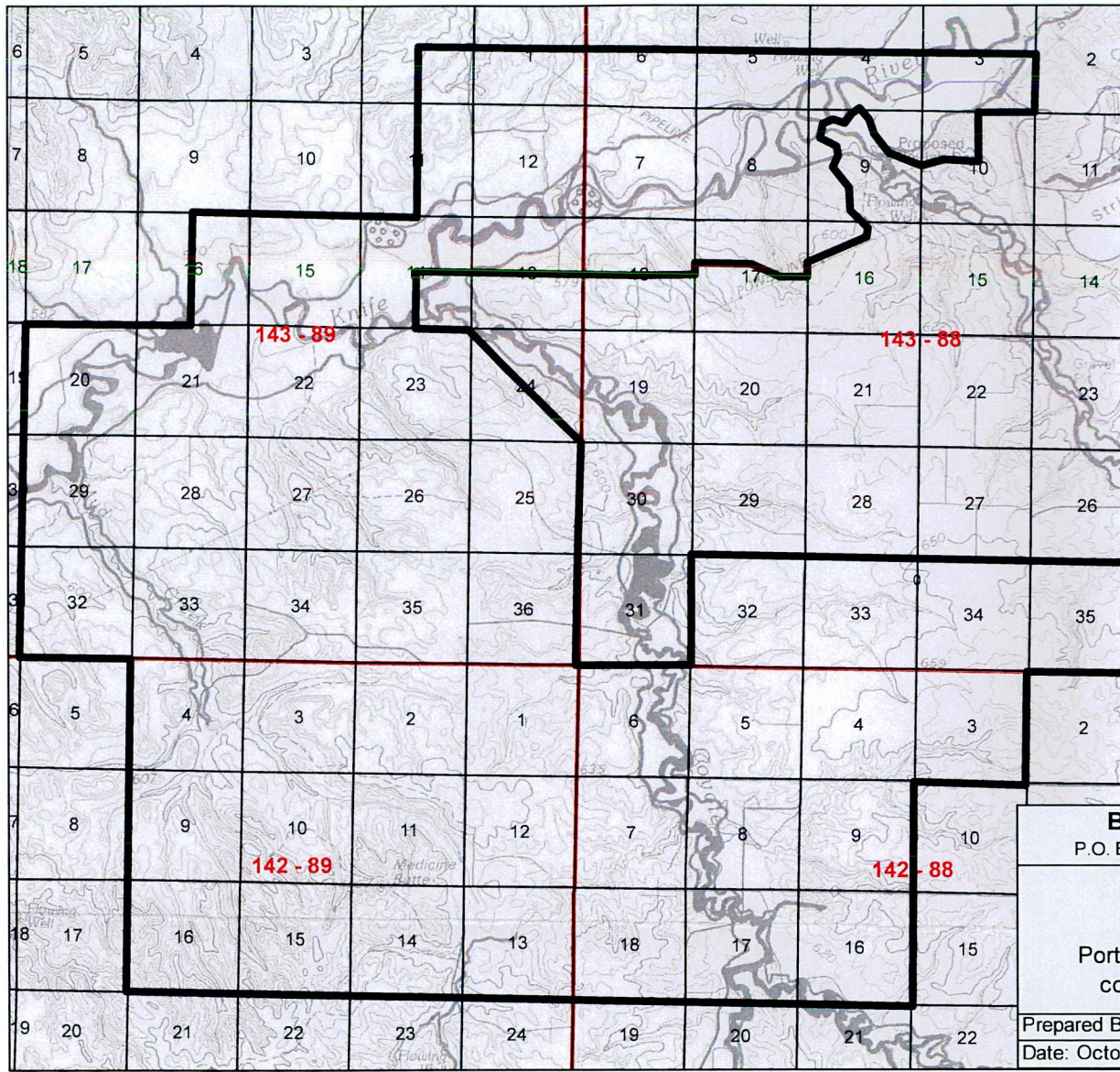
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EXPLANATION

Please refer to the accompanying text for an explanation of the methodology used to delineate alluvial valley floors, for descriptions of specific drainages, and for a discussion of regional agricultural practices.

Areas indicated by the first three map units described below meet the water availability criteria and the geomorphic criteria of alluvial valley floors and therefore are designated potential alluvial valley floors.

-  Surface irrigated sites: Areas irrigated by spreader dikes or sprinkler systems with water diverted or pumped from a stream.
-  Subirrigated and/or naturally flood irrigated sites: Areas believed to be subirrigated in most years based on interpretation of Landsat imagery, color-infrared aerial photography, water-level data, and field inspection; and/or areas believed to be naturally flood irrigated based on interviews and field inspection. The width of the zone in a particular year is variable and depends upon the annual hydrologic regime. Where irrigation development overlaps subirrigation or natural flood irrigation, subirrigation or natural flood irrigation is shown as a constant width band along the stream channel. In some valleys, the upstream end of the indicated subirrigated or naturally flood irrigated area may not meet the geomorphic criteria of an alluvial valley floor.
-  Potentially irrigable sites: Areas that have surface water availability sufficient for irrigation or spreader dike development consistent with regional agricultural practices.
-  Study area boundary.

25	30	29
36	31	32
1	6	5

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Exhibit B
 Coyote Creek Mine
 Portion of OSMRE, 1985, Plate 2
 covering the AVF Study Area

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