HOW EFFICIENT ARE CATTLE IN RUGGED TERRAIN?: A GIS ANALYSIS OF LIVESTOCK TRAILS

Dave Ganskopp and Ruben Cruz

SUMMARY

For the last two years we have been using GPS (global positioning systems) and GIS (geographic information systems) technologies to help us understand why cattle use or avoid certain portions of their environment. As a portion of that project we wanted to determine whether or not a GIS system could accurately predict where cattle might establish trails. To accomplish this we used a GPS unit to map all the cattle trails in three 2000-acre pastures managed under a season-long grazing program. Each pasture supported 40 cow/calf pairs. These trails were superimposed on topographic maps of the pastures. Selected points along the trails were chosen, and we asked the GIS system to plot least-effort pathways to those points.

We mapped 31 miles of trails in all the pastures. None of them explored the highest elevations in any of the pastures, but the lowest elevations were visited in two of three pastures. Cattle lowered the energy required for travel by traversing relatively gentle slopes. The average slope in the pastures was 13.5 percent, and the average slope of areas crossed by cattle was eight percent. By moving across slopes, travel effort was further reduced, and the actual slope of the cattle trails averaged five percent. Computer-selected pathways were close approximations of cattle trails, but cattle selected routes about 11 percent shorter and traversed terrain that was not quite as steep as the pathways. We also noted that cattle do not always use the same routes to enter and exit a particular area. We suggest that GIS software might be a useful tool for developing cattle trails, but we need to verify that trail development is an effective means of manipulating livestock distribution. This technology will also help in designing grazing systems and locating range improvements.

INTRODUCTION

Within the last decade, we have seen advances in technology that let us process enormous amounts of information and address questions that we could only ponder in the past. Three of these recently developed tools include the modern personal computer (PCs), geographic information systems (GIS), and global positioning systems (GPS). The personal computers in brief cases and on desktops today greatly exceed the capacities of many mainframe systems on college campuses just 10 years ago. Our geographic information systems use modern computers and recently developed programs to analyze data taken from topographic maps and satellite imagery. One can pose questions about vegetation cover, distances, areas, population densities, or landscape configurations, and receive accurate answers describing thousands of acres in only a matter of seconds. Lastly, global positioning systems the size of handheld calculators allow us to accurately determine the precise location of any point on the earth's surface. Inexpensive systems can guide one back to within 1 yard of these same locations, or the data can be added to existing maps to help us answer questions about how our locations are distributed over the landscape.

For the last 2 years we have been using these technologies to help us understand how and why cattle chose to use certain portions of pastures and avoid others. One portion of this research included using GPS units to map trails that cattle had established in their pastures. After these trails were added to topographic maps of the area, we asked questions about how the cattle moved through rugged terrain and whether or not computers might be useful for designing a system of trails for livestock. Success in this endeavor may allow us to more clearly understand their movements and aid in designing grazing systems and range improvements.

MATERIALS AND METHODS

This research was conducted on the Northern Great Basin Experimental Range near Burns, Oregon in three native rangeland pastures during the summer of 1997. In 1996 and 1997 we allowed 40 cow/calf pairs to graze season-long (May 20-September 18) in each pasture. With the exception of a few replacements, the same cattle were used in each pasture each year, so their distribution patterns were well established. Pasture sizes ranged between 2,038 and 2,123 acres, and each pasture had a single source of water that was serviced by either pipeline or tank truck.

In August and September of 1997 we mapped the locations of all well-used cattle trails in each pasture with a GPS unit. Our GPS receiver was set to record a location once every 5 seconds. Our mapping efforts typically started at the water source in each pasture, and we began with a trail that angled off in a northerly direction. With the GPS unit in hand, one started following a trail on foot and continued until signs of repeated use by cattle were no longer visible. The locations of forks or branches in trails were noted as we progressed, and we subsequently returned to each of these and plotted their locations as well. The endpoints and intersections of trails were marked with flagging to avoid duplicate sampling. After the first trail had been sampled, we returned to the water source, and in a clock-wise fashion, progressively mapped the remaining trails.

When we were close to areas where cattle tended to concentrate, trails were frequently braided in nature. In these instances, two or three intersecting trails, with a common destination at each end, would occur within one to 10 yards of each other. These are caused by groups of animals coming and going at the same time, and the braids are formed so that groups can easily pass one another without stopping. Because we did not map the various braids in these areas, we have slightly underestimated the total length of trail in each pasture. We have, however, provided an accurate picture of the various routes used by the cattle to travel throughout their realm.

Our GPS information was loaded into the computer, and with the aid of a GIS program we overlayed the trails on a topographic map of each pasture. Now we could ask questions about the landscape and trails and have many of our answers in just a matter of seconds. First we described each pasture. How much area did the pasture cover? What was its lowest, highest, and average elevation? What was the slope of the landscape? In this instance we expressed slope on a percentage basis. If one travels horizontally for 100 feet and rises 10 feet because the land is not level, he/she has just climbed a 10-percent grade. In extremely rugged terrain, one may encounter slopes exceeding 100 percent. If one climbed 115 feet while moving 100 feet horizontally, he/she would be on a 115 percent grade.

We also asked questions about the trails. What was their total length? What was the slope of the land crossed by the trails? And, because animals typically move across hillsides, rather than straight up or down, what was the actual slope of their trails?

Finally, many GIS programs are asked to design least-cost or least-effort pathways across the landscape. Most often these features are used by engineers to layout highways, pipelines, or power lines. The obvious goal is to reduce costs by minimizing distances or construction difficulties. In each pasture we selected three or four distant locations that had cattle trails going to them, and asked the computer to select least-effort pathways from water to these same points. Degree of slope was used by the computer to decide how difficult it might be to cross a particular piece of ground, and the computer also recognized that walking down or across a slope was much easier than going uphill.

RESULTS AND DISCUSSION

Characteristics of the pastures and trails

In the following discussions we will provide information in the tables that was derived from all three pastures. Illustrations, however, are furnished for only one pasture to conserve space and avoid clutter. Figure 1, on the following page, illustrates the general layout and topography of one of our pastures. Some elevations for a few points are listed, along with the location of the only water tank in the pasture. The highest elevation in Range 1 was 5,277 feet, slightly left of center; and the lowest elevation (4,578 feet) occurred near the north-west corner. Our water tank was located near the south-central portion of the pasture at an elevation of 4,907 feet. The second pasture used in this project (Range 2) was immediately south of Range 1, and the third pasture (Range 7) was immediately east of Range 1. Headquarter buildings and corrals for the Northern Great Basin Experimental Range are just outside the south-east corner of Range 1.

Some descriptive data for all three pastures and the trails in each are found in Table 1. The numbers there suggest the pastures were remarkably similar in size and elevation. Water sources were within 40 to 70 feet of the average elevation for each pasture, so cattle were not forced to begin at the lowest elevations as they moved away from water to forage. In two of the three pastures (Ranges 1 and 2) cattle trails explored the lowest elevations possible, but their trails never reached the highest elevations in any pasture. In Range 7 a trail came within 60 feet

Table 1. Acreage, elevation characteristics and number of data points describing three pastures and livestock trails on the Northern Great Basin Experimental Range near Burns, Or. in 1997

	Range 1		Range 2		Range 7	
	Range	Trails	Range	Trails	Range	Trails
Area (acres)	2,038	--	2,109	--	2,123	--
Lowest elevation (ft.)	4,578	4,578	4,592	4,592	4,638	4,654
Highest elevation	5,277	5,084	5,480	5,035	5,180	5,120
Average elevation	4,864	4,805	4,866	4,830	4,881	4,820
Water tank elevation	4,907	--	4,935	--	4,820	--
Number of data points (n)	308,620	2,871	319,340	2,698	321,484	2,009

of the highest elevation. In the other two pastures, trails came within about 200 to 450 feet of reaching the uppermost sites.

To gain an appreciation for the number-crunching ability of today's personal computers, one might also look at the values in the lowermost row of Table 1. Note that well over 300,000 data points were used to describe each pasture, so each time we asked questions about a pasture's slope or elevation, the computer would have to process all of those numbers to provide an answer. Typically this was accomplished in 3 to 4 seconds. On our computer screens, the image of a pasture is made up of very small dots called pixels. For these data, each of the 300,000+ pixels represented an area of 287 square feet, or an area measuring 16.96 feet for each side.

Totaled among all three pastures, we mapped 31.1 miles of cattle trails. Overall, our GPS unit recorded a location about every 21.7 feet as we walked along, and we averaged about 3.2 miles of trail for each square mile of pasture (Table 2). Figure 2, on the following page, illustrates the extent and distribution of trails in Range 1. Cattle appeared to traverse the lowermost saddles when passing between prominent hills, and they typically paralleled the major drainages when moving straight down hill. They seldom traveled in the bottom of a drainage, probably because of its stony nature, so the trails were usually 5 to 10 yards either side

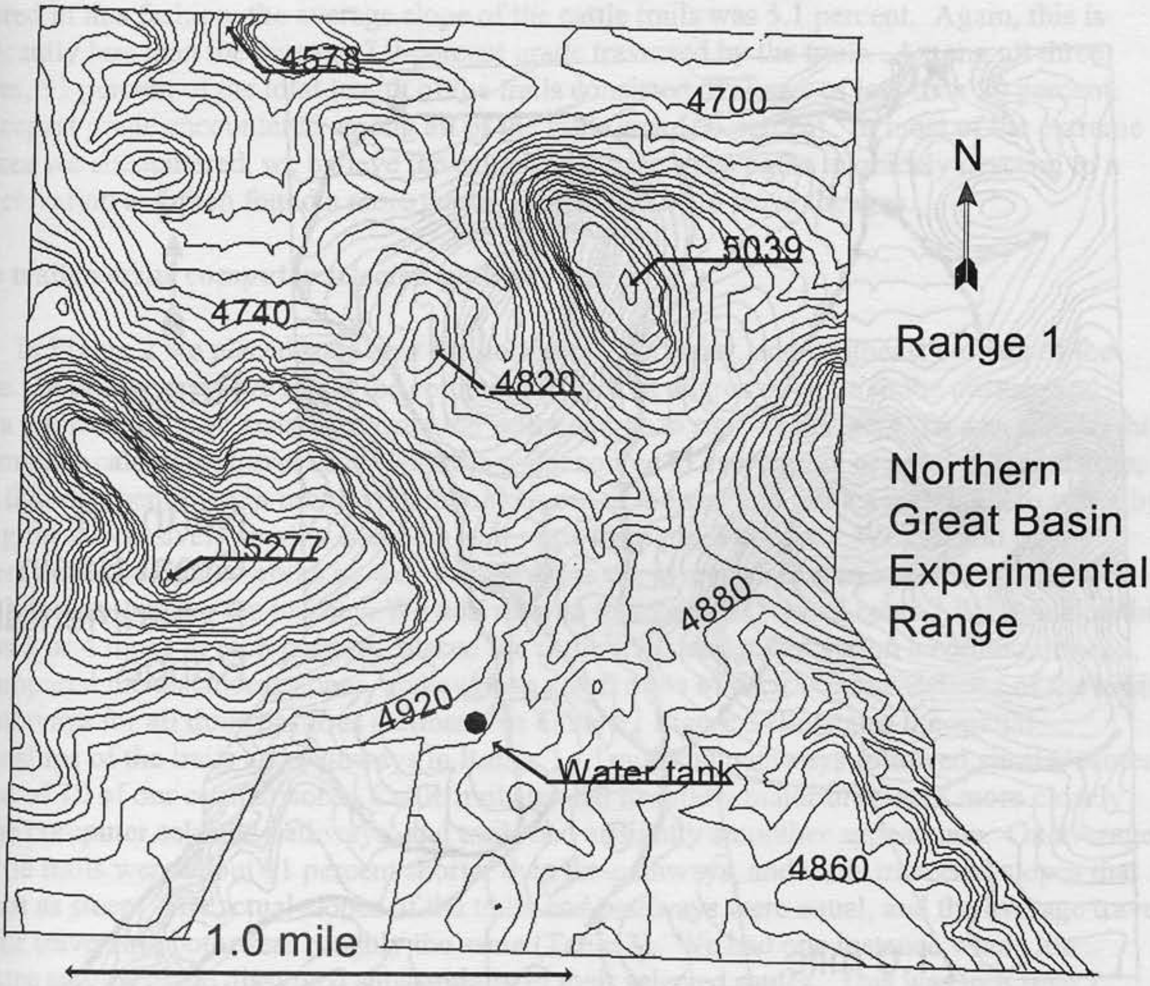

Figure1. A topographic map, with 20-foot contour lines, of Range 1 on the Northern Great Basin Experimental Range near Burns, Or. Elevations (feet) are noted for selected areas along with the location of the only water source in the pasture.

of the drainage proper. Also noteworthy was that trails very seldom directly challenged the steep slopes of the major hills. In this instance, our GIS system is particularly well suited for looking at the relationships between the trails and the degree of slope in the pastures, and some results of these analyses are found in Table 2.

The most extreme slope in the pastures was a 167-percent grade. Typically though, 95 percent of the area in each pasture occurred on ground having less than a 30 to 40-percent grade. The average slope among all three pastures was 13.5 percent. Figure 2 illustrates that trails were seldom established in the steepest terrain, and on average the trails traversed areas having a slope of 7.9 percent, which is significantly less than the average for all three pastures (Table 2). Among pastures, the maximum grade crossed by trails ranged between 61 and 69 percent. Ninety-five percent of the total length of the trails, however, occurred on slopes of less than 24 percent. Readers are reminded that the previous values reflect the slope of the terrain crossed by cattle trails and not the actual slope of the trail itself. Travel effort can be further moderated if one chooses to walk across a slope rather than straight up or straight down. This behavior is evidenced in cattle when we measure the slope from point to point along their trails. When

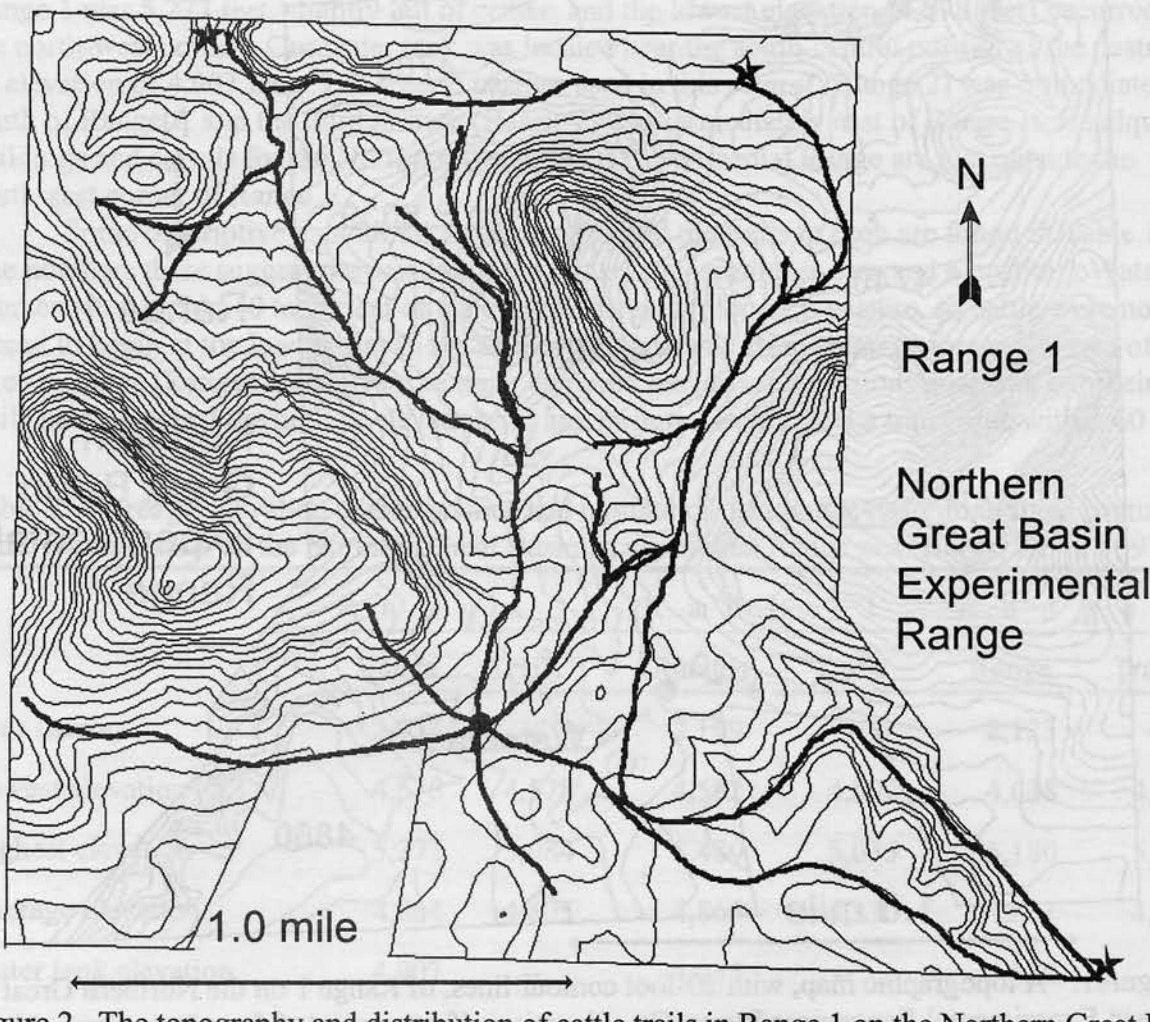

Figure 2. The topography and distribution of cattle trails in Range 1 on the Northern Great Basin Experimental Range near Burns, Or. in 1997. Contour lines are on 20-foot intervals.

Table 2. The composition of pastures and cattle trails as they relate to the slope (percent) of the landscape in three pastures on the Northern Great Basin Experimental Range Near Burns, Or. in 1997.

	Range 1	Range 2	Range 7
Average slope of pasture (%)	15.2	12.5	12.7
95 percent of pasture on slopes less than...(%)	42.0	41.0	30.0
Average slope of areas where trails occur (%)	8.7	7.1	8.0
Average actual slope of cattle trails (%)	5.4	4.5	5.3
Total length of cattle trails (miles)	12.2	10.9	8.0
Miles of trail / square mile of pasture	3.8	3.3	2.4

measured in this fashion, the average slope of the cattle trails was 5.1 percent. Again, this is significantly less than the average 7.9-percent grade traversed by the trails. Among all three pastures, 95 percent of the total length of the trails consisted of slopes of less than 20 percent. The steepest grade encountered among all of the trails was 106 percent. In most of the extreme instances we encountered, we believe the cattle used these steep paths to quickly descend to a lower elevation and then found a more gentle alternate route to leave the area.

Cattle trails versus computer selected pathways

In Figure 2 we placed stars near the northwest, northeast, and southeast corners of the pasture. In this exercise we asked the computer to look at degree of slope in the pasture and select a pathway of least resistance from the water source to each of the stars. To accomplish this the computer calculates travel costs from the water source to every point or pixel in the pasture, writes that number down in each pixel, then goes out to the star and plots a path back to water by looking for successively smaller numbers as it steps from pixel to pixel. We can add up the numbers as the computer works its way back and use the average value as a measure of how difficult it was to make the journey. We will refer to this value as "travel costs." We repeated this process 3 or 4 times in each pasture, placed the cattle trails and pathways on a common image, and compared the distances, slopes, and average travel costs of each. Characteristics of the trails and pathways for all three pastures are found in Table 3. Figure 3 illustrates the spatial relationships of the trails and pathways in Range 1. Trails and pathways followed similar routes in 9 out of 10 of our comparisons. Cattle trails tended to follow major drainages more closely than the computer selected pathways, and trails had a slightly smoother appearance. On average, the cattle trails were about 11 percent shorter than the pathways, and trails traversed slopes that were not as steep. The actual slopes of the trails and pathways were equal, and the average travel costs for traversing both were roughly the same (Table 3). We had one instance where the computer and the cattle disagreed substantially in their selected routes. This was in Range 7, with trail number two (Table 3). This trail went from water to the top of a ridge by

Table 3. Length and slope characteristics of trails and computer selected pathways in three pastures on the Northern Great Basin Experimental Range near Burns, Or in 1997. Underlined trail/pathway averages are not significantly different (P<0.05).

Range #	Trail number	Distance (yards)		Average (%) Slope traversed		Average (%) Actual slope		Average Travel costs	
		Trail	Pathway	Trail	Pathway	Trail	Pathway	Trail	Pathway
1	1	3,070	3,352	9.6	11.0	5.5	6.8	174	161
	2	3,083	3,255	7.5	9.6	4.7	6.4	214	187
	3	2,795	2,795	8.1	10.2	7.1	7.1	165	172
2	1	2,385	2,539	3.0	2.3	2.0	1.8	148	154
	2	2,215	2,418	6.4	6.5	3.8	4.0	177	167
	3	2,493	2,803	10.7	11.0	7.8	7.5	182	160
7	1	2,185	2,271	5.7	7.2	4.0	4.2	164	160
	2	2,038	3,308	13.7	14.4	8.2	6.1	315	260
	3	2,355	2,476	5.0	5.8	3.2	3.8	144	141
	4	1,019	1,083	11.2	11.5	8.6	8.3	143	142
Average		2,364	2,630	8.1	9.0	5.5	5.6	183	170

going up and around a hill at a relatively constant grade. The computer selected a longer (1270 yards) pathway that went around the bottom of the hill and then followed a relatively gentle drainage to the top. When we asked the computer to select a route from the top of the hill back to the water source, it went down the same way the cattle trail had come up.

In Range 2 we had an instance of a 1-way trail, where cattle left water, went around the south side of Paiute Butte, and quickly dropped off a high plain to lower ground. When they returned to water, the cattle took a different, more gentle, route around the north side of the butte. When we asked the computer to plot a pathway back to water, it selected roughly the same route that the cattle followed. We may have been dealing with a 1-way trail in Range 2, where the trail and computer-selected pathway differed substantially, because that was the steepest trail we measured. We will make additional observations to confirm this.

In closing, we suggest that GIS software may be a useful tool for developing cattle trails in large rangeland pastures. In most instances our projected pathways closely paralleled established trails. In rugged terrain, however, we should probably plot pathways both in and out of targeted areas, because cattle and computers do not always select the same routes to enter and exit an area. In cases where one might expect 1-way travel routes, we suggest that cattle will use some short reaches of steep slopes to descend to lower elevations, but they are likely to select a more gentle route to exit the area. Some additional research is needed, especially in areas where cattle have well established systems of trails, to verify that trail development is an effective way of manipulating livestock distribution.

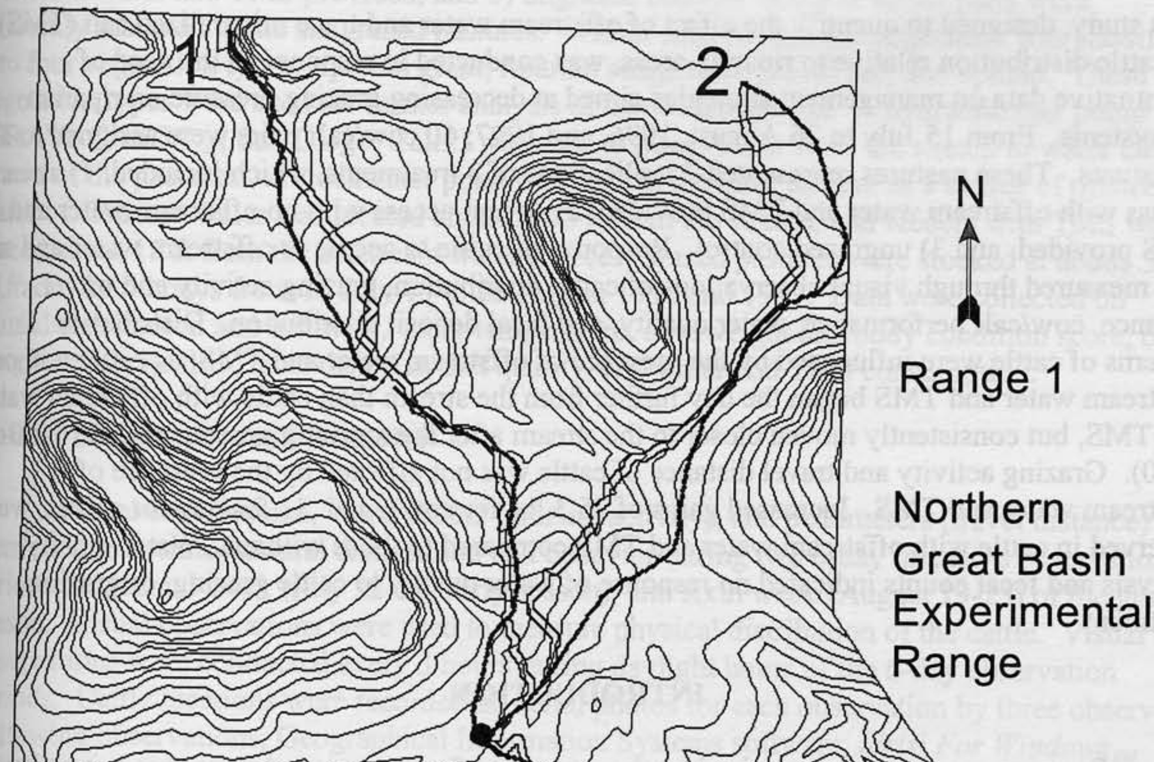

Figure 3. Actual cattle trails (dark solid lines) and computer-selected pathways (open parallel lines) from the water source to 3 selected points in Range 1 on the Northern Great Basin Experimental Range near Burns, Or. in 1997.