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Precolumbian Causeways and Canals as Landesque Capital

Disciplines

Anthropology | Social and Behavioral Sciences

LANDSCAPES *of* MOVEMENT

**Trails, Paths, and Roads
in Anthropological Perspective**

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Precolumbian Causeways and Canals as Landesque Capital

CLARK L. ERICKSON AND JOHN H. WALKER

The study of past and contemporary trails, paths, and roads is relevant to political economy, history, sociology, urban planning, folklore, development, and anthropology. These features are material expressions of both patterned human movement through everyday repetitive activities and the physical structures that channel human activities through their division of space into place, territory, boundary, access, and orientation (Barrett 1999a, 1999b; Chadwick 2002; Snead 2002; Tilley 1993, 2004). Trails, paths, and roads are simultaneously expressions of agency, practice, and structure (Erickson, Chapter 10, this volume; Ingold 1993). Landscape is a useful concept for understanding the role of these features in everyday lives, a framework within which archaeology provides a unique perspective. Examination of trails, paths, and roads as physical landscape features and formal built environment provides insights about economic infrastructure, social interaction, social organization, engineering, worldview, and indigenous knowledge that are often unavailable to ethnographers and historians. As subtle and sometimes imposing landscape features, trails, paths, and roads recursively structure and reflect ongoing daily and special activities and document change and discontinuity when interpreted as palimpsests.

In this chapter, we show how roads are a central element of the precolumbian agrarian and residential landscape in the savannas of the Llanos de Mojos of the Bolivian Amazon. In this case, formal raised roads or cause-

ways with associated canals provided efficient means of movement and connection between settlements, fields, and resources across the landscape. In addition to their obvious transportation and communication functions these earthworks played a key role in water management, topographic transformation, and engineering of the environment at a regional scale.

In contrast to the Western obsession to drain what are considered marginal wetlands for agriculture, farmers in the Bolivian Amazon may have intentionally expanded wetlands and wetland productivity through earthwork construction, which impedes, rather than enhances, drainage (Erickson 1980, 2006b). The precolumbian farmers did not use causeways as dikes to prevent inundation of fields and settlements, but rather to expand and enhance inundation for agricultural production. At the same time, impounding water with well-placed causeways and the creation of canals improved and extended the season of transportation by canoe across the landscape. The grid-like structure also permanently marked land tenure in a highly visible manner. As a vast investment of labor, innovation, and engineering resulting in permanent land improvement by generations of precolumbian peoples, causeways and canals became important landesque capital. This engineered landscape continues to structure the lives of contemporary peoples and the environment in subtle and direct ways.

THE CONCEPT OF LANDESQUE CAPITAL

Agricultural landscapes are patterned built environments, a large-scale accumulation or palimpsest created by generations of inhabitants who have imposed their structures on the land (e.g., Denevan 2001; Doolittle 2000; Whitmore and Turner 2001). These landscapes are places where people lived their everyday lives, working, traveling, and farming. These same landscapes contain and express elements of the non-routine ritual, sacred, aesthetic, and political realms. An essential attribute of cultural landscape features is their recursive nature; they are both models of and models for society (Erickson, Chapter 10, this volume). In all cases, nature was transformed in the process of production through labor, society, and history. This transformation can result in land improvements and/or degradation over time (Erickson 2006a, 2008; Kirch 2005; Redman et al. 2004). Under good management, the improvements on the land accumulate through the efforts of generations of inhabitants, each exploiting and adding to the per-

manent infrastructure (e.g., canals, terraces, and raised fields) and enhanced soils.

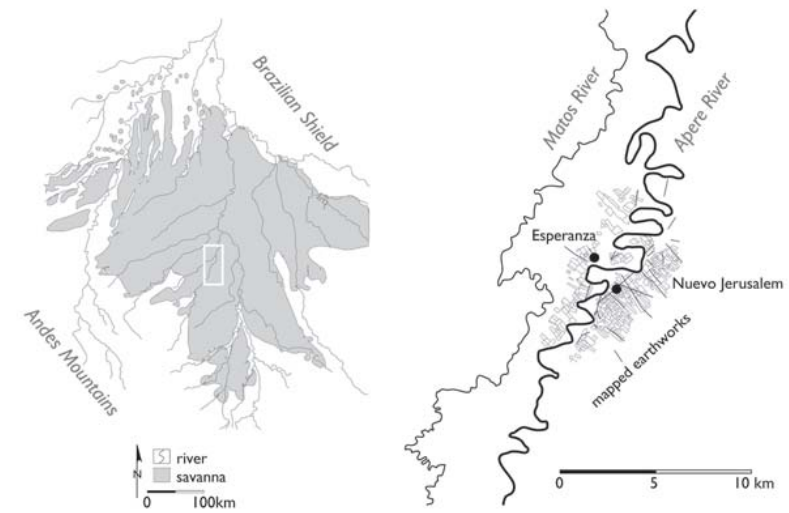
As noted by William Doolittle (1984), substantial landscape accumulation, often at monumental and regional scale, can be made either over short periods with heavy labor investments or through a long-term accretion process. Accumulation can be coordinated or simply the result of piecemeal improvements. Many impressive cultural landscapes are created, used, and maintained by small farming communities over hundreds of generations (Denevan 2001; Erickson 2006b; Walker 2004). Harold Brookfield (2001; Blaikie and Brookfield 1987) proposed the term *landesque capital* or *landscape capital* to describe an important element of this phenomenon. Brookfield (2001:55) defines the landesque capital concept as certain innovations that create enduring fixed capital in the land beyond a single crop or cropping cycle. The innovations can be skills, technology, and labor that are directed towards improving infrastructure and enhancing soils on existing fields or new land that was previously unusable (ibid. 55). Current farmers benefit from permanent landesque capital created by generations of previous occupants. Once created, landesque capital is inherited, used, and maintained by later generations (ibid. 216). These farmers can increase the landesque capital or simply maintain it (ibid. 216). Over time, highly productive, sustainable anthropogenic landscapes are formed.'

The landesque capital of complex, patterned, and highly evolved anthropogenic landscapes is amenable to archaeological and historical ecological investigation as a physical record of human activities over the short and long term (Balee and Erickson 2006b; Fisher 2005, 2007; Kirch 1994). Trails, paths, and roads are important categories of landesque capital, although rarely discussed as such. In this chapter, we explore the use of formal roads, specifically causeways and canals, as landesque capital to facilitate movement and channel people and water across the landscape at the local and regional scale.

THE BOLIVIAN AMAZON

The Bolivian Amazon lies between the Andes Mountains to the west and the highlands of southwestern Brazil to the east and the Pantanal and Chaco regions to the southeast. The region is drained by the Madeira River, which flows into the Amazon River some 1500 km to the north. The Llanos de

Mojos (or Llanos de Moxos; Plains of Mojos) is a seasonally flooded tropical savanna located in the Department of the Beni within the Bolivian Amazon (Figure 11.1).



11.1 The Llanos de Mojos (gray) and the Middle Apere landscape of the Bolivian Amazon.

The Llanos de Mojos is a relatively flat landscape, with elevations varying by a few meters. Large, active, sediment-laden rivers with headwaters in the Andes Mountains, such as the Beni, Marnore, and Madre de Dios, meander across the landscape within defined floodplains. In contrast, smaller tributaries such as the Apere River are more stable in their course and have low; forested levees slightly higher than the surrounding savanna. The climate is warm and humid, with sharp seasonality. The wet season peaks between December and March and the inundation produced by the heavy seasonal rains, as well as rising river levels downstream, threatens crop agriculture and ranching. In some years, half of the landscape is underwater. During the dry season from June to September, water becomes scarce and modern farming and ranching are difficult. The environment is a mosaic of forests, savannas, and wetlands, all subject to a strong seasonal cycle of rainfall and inundation.

Today, cattle ranching dominates the cultural landscape. Ranchers move their herds across long distances, from areas near permanent wetlands in the

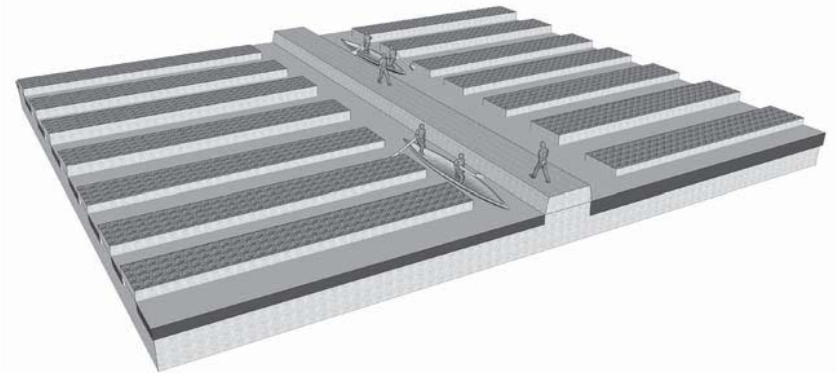
dry season to high refuges during the wet season. Although rarely farmed, ranchers regularly burn the savannas to encourage new grass and keep the forest at bay. (The importance of burning to savanna ecology is illustrated by the encroachment of forest on savanna between 1975 and 2001 as ranching activity declined.) The savanna, wetland, and forest mosaic are rich in fauna and flora. The rivers, lakes, swamps, and seasonally inundated savannas are full of fish, caimans, and river turtles. Major game animals include deer, peccary, capybara, tapir, paca, armadillo, and agouti.

Ranchers, native peoples, and colonists establish gardens, orchards, and slash-and-burn fields within the better-drained gallery forests and forest islands. Key crops today are manioc, maize, sweet potato, squash, New World taro, rice, and tropical fruit trees. Most communities and ranches are in gallery forests and forest islands. The modern situation contrasts sharply with the precolumbian strategies of intensive agriculture on the savannas.

PRECOLUMBIAN CAUSEWAYS AND CANALS IN THE BOLIVIAN AMAZON

The Bolivian Amazon is a highly patterned cultural landscape of earthworks and settlements. Earthworks include settlement mounds, raised fields, causeways, canals, reservoirs, and fish weirs (Denevan 1966, 1991, 2001; Erickson 1996, 2000a, 2000b, 2006a; Erickson and Balée 2006; Walker 2004). Roads, in this case raised earthen causeways with associated canals, are common landscape features that crisscross the savannas, wetlands, and forests of the region (CEAM 2003; Denevan 1966, 1991, 2001; Erickson 2000c, 2001, and Chapter 10, this volume; Lee 1995; Michel 1993; Nordenskiöld 1916; Pinto Parada 1987). Because of the intentionality, design, monumentality, and engineering used in their construction, causeways and canals are classified as formal *roads* rather than informal trails or paths to highlight the intentionality, design, linearity, monumentality, and engineering that were used in their creation.

Causeways are flanked by canals on one or both sides where earth was removed to raise the road platform (Figure 11.2). Although badly eroded by cattle ranching and farming activities, causeways are visible from the air as dark straight lines of trees and bushes that stand out against the grasses of the savanna (Figure 11.3). Canals are marked by aquatic vegetation and standing water during the wet season and darker vegetation and soils during



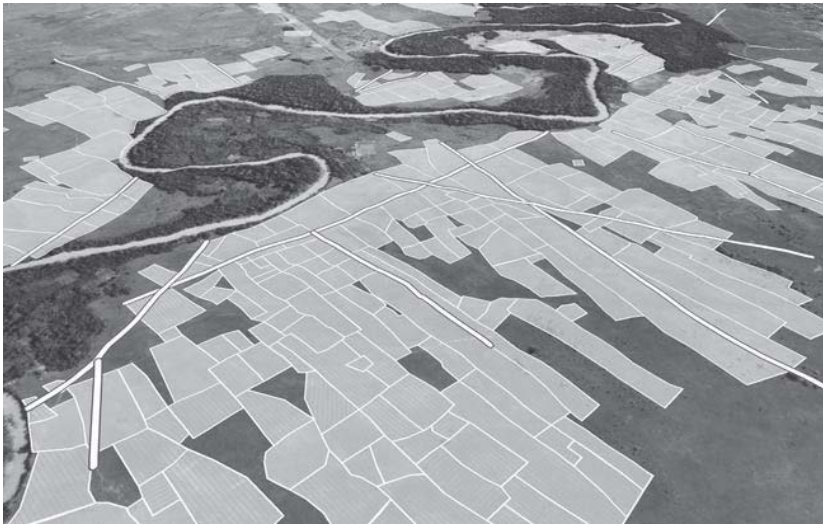
11.2 Detail of an engineered landscape in the Bolivian Amazon. Causeways are flanked by canals on one or both sides where earth was removed to form the road platform. Raised field platforms and canals fill the landscape on both sides of the causeway. (Artwork by Clark Erickson)

the dry season. Causeways range in elevation from 0.2 to 2 m and in width from 1 to 20 m. Most causeways are straight over lengths ranging from tens of meters to kilometers. Causeways are generally found in seasonally inundated areas of poor drainage, but are rarely found in permanent wetlands, deeply flooded zones, or well-drained gallery forest and forest islands. Causeways connect archaeological settlements, raised fields, resources, rivers, wetlands, and other causeways, forming physical networks of local and regional scale.

CAUSEWAYS AND CANALS AS ENGINEERED HYDRAULIC WORKS

Most of the seasonal inundation of the Bolivian Amazon is what is termed 'benign flooding' (Siemens 1996:133). In these hydraulic regimes, overflowing rivers with sources in the Andes and within the region, local rainfall, runoff, rising water tables, and backup of drainage in the lower reaches of river systems gently cover much of the flat landscape with a sheet of water. In the savannas and low-lying forests, this inundation generally ranges from a few centimeters to several meters deep. Although relatively shallow; the mass of water at the height of the rainy season is millions of cubic meters (Hanagarth 1993; Langstroth 1996).

The "wetland margin," the surface affected by the rise and fall of the



11.3 Precolumbian causeways (white lines), associated raised field blocks (gray polygons), gallery forest, and levees (black forested areas) on the savanna near the Jerusalem and Esperanza ranches, Middle Apere River (computer-generated oblique perspective of an aerial photograph layered over a digital elevation model).

floodwaters (Siemens 1996), is vast and heterogeneous in a flat landscape such as the Bolivian Amazon. In Amazonian studies, the classic distinction between floodplain and upland (*várzea* and *terra firme*) (Lathrap 1970) does not apply because most of the landscape is inundated to some degree at various times. The highest ground is often adjacent to the rivers themselves—the linear levee formations of sediments dumped by the slowing of flow velocity during hundreds of years of inundation. These geomorphological features support gallery forests and are exploited using slash and burn, agroforestry, and gardening. The *bajios* (back swamps or wetlands) between rivers are generally the lowest elevations and often hold water year round. The savannas, wetlands, and forests are crosscut by abandoned river channels, meander scars, and their associated levees. The larger levees support forest islands and gallery forest. Other prominent features include shallow "oriented lakes" (both open and choked with vegetation) and other permanent wetlands (CEAM 2003; Denevan 1966; Hanagarth 1993; Plafker 1963).

To many modern inhabitants, government institutions, and non-government agencies, the seasonal cycles of inundation are limitations to

growth and development of the region. In contrast, the precolumbian farmers of the Bolivian Amazon were attracted to this dynamic landscape and took advantage of the seasonal cycles of inundation. The inhabitants practiced a form of passive recessional floodwater agriculture: enhancing and exaggerating its effect through massive transformation of the landscape. In contrast to traditional irrigators in arid and temperate environments, they exploited the natural cycles of water using simple earthworks to channel and manage water at a regional scale. In other settings of benign flooding such as the Southwest United States and Mali, farmers use check dams and dikes to retain moisture in soils that are planted after floodwater and runoff recede (Brookfield 2001; Doolittle 1984). In contrast, the precolumbian farmers in the Bolivian Amazon planted their crops *during* the period of inundation, taking advantage of the water management provided by a variety of earthworks including causeways, canals, and raised fields.

Our hypothesis that causeways and canals were used to manage inundations and enhance wetlands comes from numerous observations of *unintentional* pooling of water behind modern raised causeways in the Bolivian Amazon. In 1979, a massive lake was formed to the south of the newly constructed raised road between San Borja and San Ignacio. In 1985, the raised road between Trinidad and Puerto Almacén blocked the floodwaters and created a huge body of water that washed over and destroyed the road surface, which made it impassable for many weeks (Figure 11.4). In both cases, engineers determined that the road construction crew failed to install the required number of drains in the raised road.'

During the wet season in the Bolivian Amazon, causeways only a meter in height that link areas of higher ground can impound significant amounts of water with minimal effort (Figures 11.5, 11.6). A single square kilometer of raised fields and canals can control 250,000 m³ of water during a flood of 0.5 m and retain it long after the floods recede (Erickson 2003c, 2006a). Grids of causeways and canals also significantly enhance water control capacity. In such cases, the canals of raised fields and associated causeways function as micro-catchment basins connected to a network of canals, streams, rivers, and other water bodies. For the precolumbian peoples who built them, these earthworks would have significantly extended growing seasons and reduced agricultural risk. The presence of aquatic fauna and flora would have been an additional benefit, both for subsistence and because recycled organic material enhanced production on the raised fields.



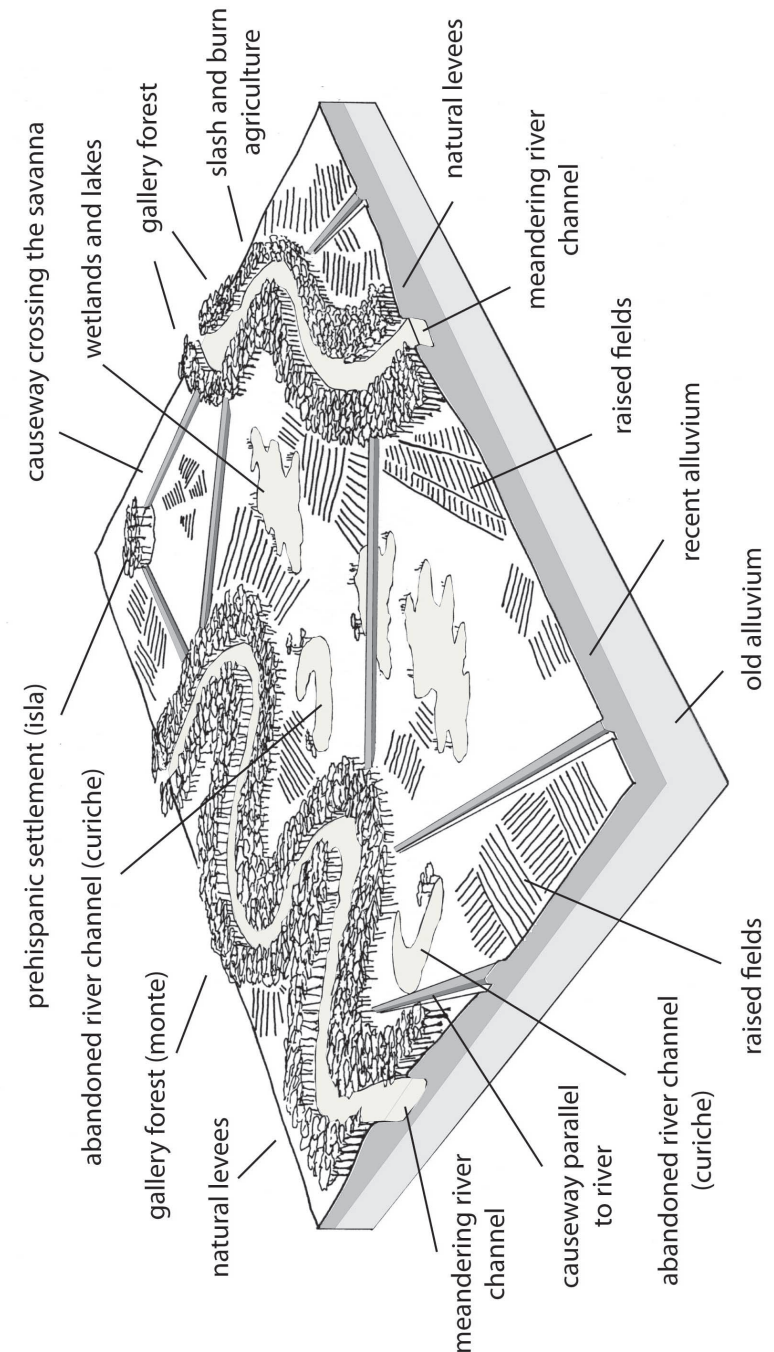
11.4 Modern raised road between the city of Trinidad and Puerto Almacén unintentionally impounding a large lake (right) in 1985.

The tens of thousands of kilometers of linear terrestrial-aquatic interface created by construction of causeways and canals, and raised field platforms and canals has the potential to significantly raise agricultural productivity, biomass, and biodiversity at the local and regional scales (Erickson 2006a, 2008).

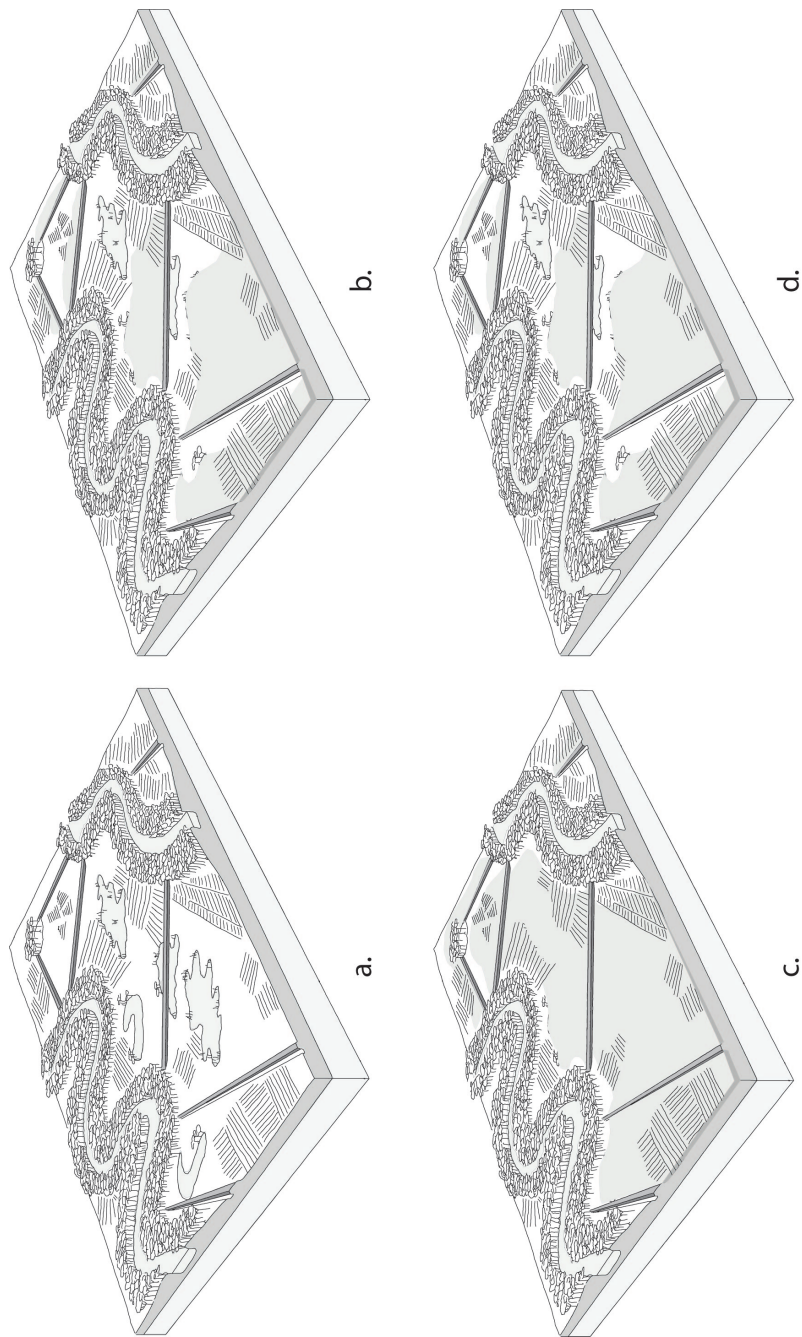
THE MIDDLE APERE RIVER LANDSCAPE

Precolumbian causeways and canals in the Bolivian Amazon are found along the tributaries of the Mamore River, which crosses the region south to north, and in the northeastern part of the region, around the modern town of Baures (Erickson, Chapter 10, this volume). Some of the most impressive causeways, canals, and raised fields are found on the Middle Apere River (Figure 11.7). Although flat and featureless to the untrained eye, the Middle Apere River region has considerable ecological and topographical heterogeneity. The local savanna is broad and open, and forests are generally confined to galleries along the rivers. Causeways, canals, raised fields, settlement mounds, and occupation sites cover an area larger than 60 km²

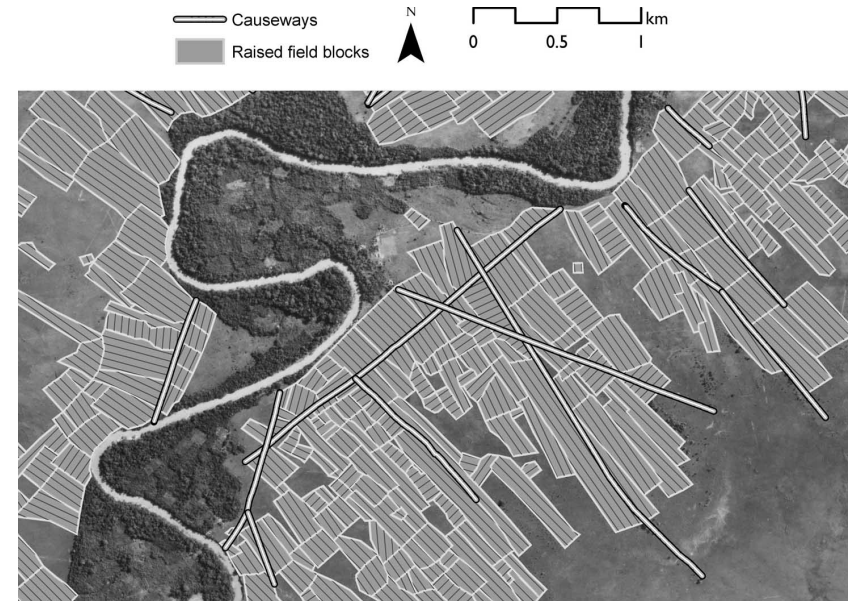
Prehispanic Hydraulic Systems in the Llanos de Moxos



11.5 Reconstruction of causeways, canals, and raised fields between adjacent rivers in the Bolivian Amazon (Artwork by Clark Erickson).



11.6 Reconstruction of causeways, canals, and raised fields between adjacent rivers in the Bolivian Amazon: (a) early wet season, (b) late wet season, (c) early dry season, and (d) late dry season. (Artwork by Clark Erickson)



11.7 Precolumbian causeways (wide white lines) and raised field blocks (thin white lines) overlaid on an aerial photograph.

along both sides of the river. Raised fields extend nearly continuously on the levee backslope from the river channel to the edge of permanent wetlands, a distance of 3 km. Numerous long causeways crisscross the area of raised fields. Here, we compare a model of the natural flow of water on the landscape based on general geomorphology and hydrology to a model of the anthropogenic flow of water after transformation by the construction of earthworks (causeways, canals, and raised fields). Precolumbian farmers of the Bolivian Amazon superimposed their anthropogenic, cultural landscape as a complex dynamic palimpsest on nature.

Methods

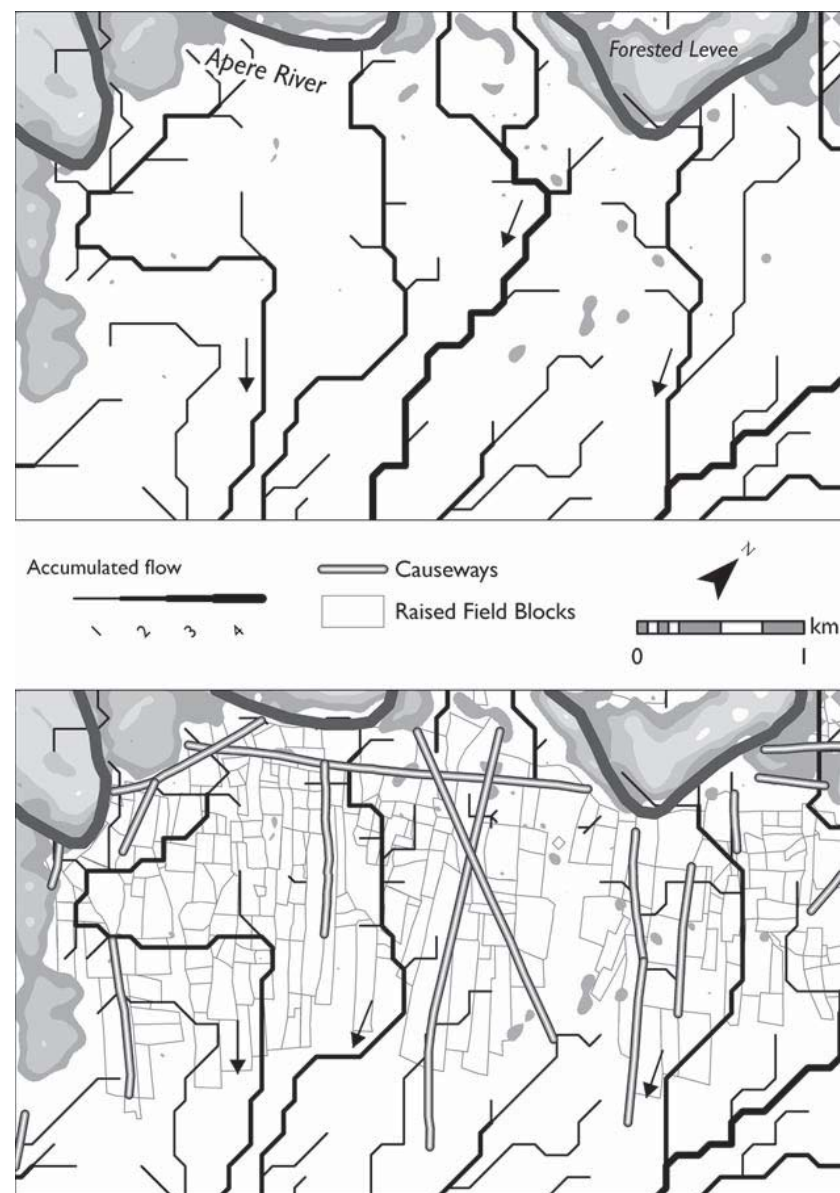
In our case study, the indigenous knowledge of engineering is embedded in the physical structure of the landscape. Our approach is to do "reverse engineering" using mapping, survey, excavations, and modeling to determine the structure, function, and meaning from the highWy patterned archaeological remains. Causeways were mapped using digitized aerial photographs, which were georeferenced using CPS points and landmarks vis-

ible on LANDSAT/ETM images. Causeways and blocks of raised fields were digitized on-screen. A digital elevation model (OEM) is based on shuttle-borne radar data (SRTM). The SRTM OEM is unsuitable for comparing the ground elevations of forested and non-forested areas, because the radar records the tops of trees rather than the surface of the earth. However, for comparisons across non-forested savanna where most earthworks are located, the data are useful.

The OEM was used to create two models of water flows. The Natural Landscape Model (Figure 11.8) was based on the original SRTM OEM, processed to "fill in" basins created through flaws in the data. This model simulates the flow of water over the landscape without taking into account the effect of causeways. The Modified Landscape Model (Figure 11.9) is based on the same processed SRTM OEM. In this model, the elevations of pixels crossed by the digitized causeways were raised by 1 m to simulate original causeway elevations, which are too small in scale to be recognized in the 90 m pixel OEM. Comparison of the two models shows the difference between a hypothetical natural landscape and an imposed anthropogenic landscape. The differences between these two models represent the hydraulic effects of causeways. Note that the study site only includes one of two adjacent river levees.

Analysis and Interpretation

Figures 11.5, 11.6, and 11.10 show the river levee and river levee back-slope in relation to the river channel and bajios. The hypothetical movement of water from rainfall, overbank flooding, and bajio flooding is presented in Figure 11.10 to illustrate the discussion below. In the Natural Landscape Model (Figure 11.8), floodwater movement across the savanna is primarily determined by the local river levee backslope that directs flow towards the southeast rather than the overall regional slope of the landscape towards the north-northeast. The change in elevation is approximately 1 m per 1 km down the local river levee backslope and 1 m per 10 km over the course of the Apere River and overall regional slope. As a result, overbank floodwater first drains away from the Apere River to the southeast and later drains to the north-northeast along the bajios between the rivers. Although flow dynamics are complex, the first determinant of the floodwater movement is down the river levee backslopes and the secondary determinant is the overall regional slope.



11.8 The Model of Natural Landscape. The Model shows how water moves down the levee backslopes and away from the Apere River. Progressively lighter shades of gray represent the accumulation of moving water.

11.9 The Model of Modified Landscape. The Model shows how causeways alter the flow of water down the levee backslopes and away from the Apere River. Progressively lighter shades of gray represent the accumulation of moving water with overlay of causeways (black lines) and raised field blocks (light gray).

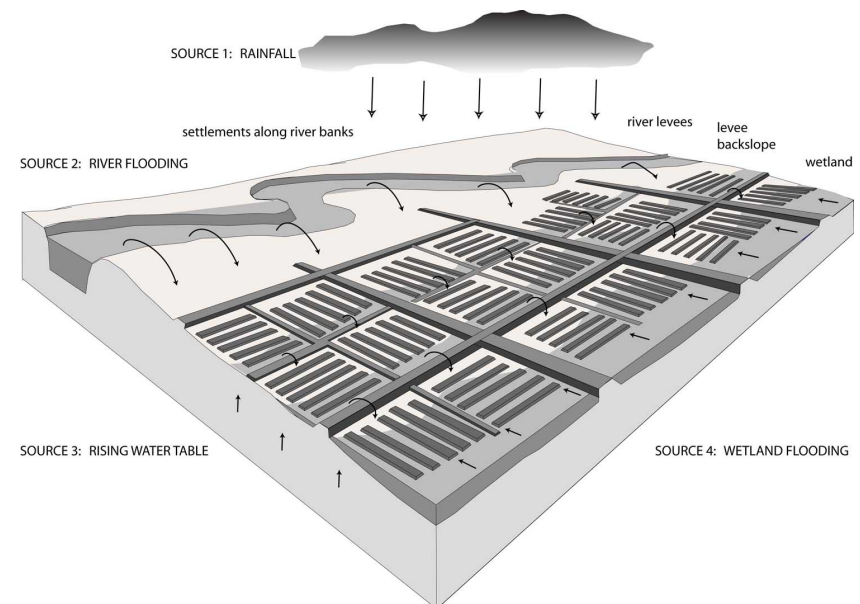
Other drainage characteristics can be inferred from the local topography. During local rainfall, most runoff flows down the levee backslopes perpendicular to the river to the *bajios* rather than entering the river. When the rivers crest, overflow also moves down the levee backslope perpendicular to the river. Later, as the entire drainage becomes saturated, water backs up in the *bajios*, river channel, and seasonal rivers from downstream. At this time, rising regional floodwaters can creep up the levee backslope from the *bajios*.

When precolumbian causeways are added to the OEM and the hydrological analysis is run a second time to create the Modified Landscape Model, the anthropogenic impact on local drainage is clear (Figure 11.9). The causeways that are parallel and close to the river channel may block some rainfall runoff from draining into the river or may have helped distribute water for more even flow down the levee backslope, but their effect is minimal on hydrology at the height of the inundations. These causeways may have functioned to protect the upper levee backslope gardens and settlements from floodwater from the river, but their height (less than 1 m) suggests their impact on flooding was relatively insignificant.

Causeways that are perpendicular to the river divert and isolate some of the flow of water down the backslope, but do not impede the general flow of water or impound large bodies of water due to their low elevation, small cross-section, and downslope orientation. These causeways were not meant to block large volumes of water from riverbank overflow. Instead, they probably channeled, organized, and stored rainwater runoff in the beginning of and during the wet season, and the rising waters in the wetlands between the rivers at the end of the wet season. Most of the year, water soaks into the soil rather than running off due to the relatively flat slope and low water table. Instead of wholesale diversion of overbank flow from the river onto the levee backslope, the primary hydrological function of the causeways may have been to create local catchment areas where local rainfall and floodwater were harvested for agriculture and the period of canoe access to wetlands during the dry season was extended. Throughout the year, access to the wetlands for fishing, hunting, and collection of aquatic resources was improved through causeway construction and impounding of water. The resulting expansion of seasonal wetlands on the levee backslopes also improved nutrient capture and production within the blocks of causeways.

The raised fields between the causeways also had hydraulic functions. Individual raised fields are organized in bundles or blocks averaging 3.2 ha, oriented roughly to the intercardinal directions. The alternating orientations of raised field blocks produce a checkerboard pattern, although the blocks vary in size and in shape from squares to long rectangles. Some exceptions to these orientations are found on the levee backslopes of abandoned river channels on the larger present-day Apere River levee backslope and within the wide, sweeping meanders of the Apere River. Similar to the causeways, most raised field blocks are oriented either perpendicular to the river course or to the direction of local slope.

These orientations and the checkerboard pattern are intentional. Because the individual raised fields and raised field blocks have multiple orientations, the overall intent was to drain and retain water (Figure 11.10). Many raised field canals have no outlets and raised field blocks are encircled by low earthen bunds (which also functioned as raised field platforms and as a means of pedestrian circulation through the raised fields). The overall effect of these features was the creation of micro water-catchment basins.



11.10 Reconstruction of water movement across the engineered landscape of the Middle Apere River. (Artwork by Clark Erickson)

When optimal water levels within raised field blocks were reached, excess water would drain over the bunds into lower-lying raised field blocks further down slope or into the larger canals along perpendicular causeways into the *bajios*. These catchments provided drainage, water control, traps for sediment and nutrients, and aquatic routes for canoe traffic.

Thus, through building individual raised fields, raised field blocks, bunds, canals, and causeways, precolumbian farmers created a sophisticated integrated system of water management. Because the runoff from each block of raised fields affects neighboring blocks, farmers would have had to cooperate at the local level. In addition, the grid or checkerboard pattern of field blocks, some surrounded by clear bunds, probably marks land tenure and reflects the size and organization of the different groups responsible for their construction, use, and maintenance (Walker 2004). In turn, these blocks are combined in higher-level units covering square kilometers bounded by causeways and canals. In contexts where *landesque capital* is highly developed and agriculture is intensive, formal marking of family and community land holdings is expected and often necessary. Causeways provide a highly visible marker of land tenure.

When local topography and associated raised fields are considered, causeways appear to function to create, expand, and manage wetlands at a local and regional structure. In addition, these water management systems enhanced the productivity of economic resources of natural wetlands. The expansion of wetlands through earthworks provided habitats for fish, the main source of protein for precolumbian Amazonian peoples. Finally, by slowing and changing the flows of sediment-rich water, causeways could have increased the accumulation of sediment and resulted in enhanced soil fertility.

The orientations, positions, and patterning of most causeways and raised field blocks show clear integration. Associated causeways and field blocks have the same orientations (with a few exceptions) and causeways rarely divide individual blocks. The analysis suggests that most causeways and raised fields were designed, built, and maintained as locally integrated farming systems. In most cases, parallel and perpendicular causeways are oriented with the general orientations of the raised field blocks within them. The integration suggests that the causeways and raised fields were created at the same time or gradually co-evolved as generations of farmers learned how to engineer the local hydrology and invested in permanent *landesque capital*.

On a flat, seasonally inundated landscape, the construction of earthworks such as causeways, canals, and raised fields will affect local and regional hydrology, regardless of intent. Because normal annual inundation during the wet season and drying out of the landscape in the dry season are substantial processes in scale and intensity, causeways, canals, and raised fields could not completely control water. However, we have shown that the imposition of causeways, canals, and raised fields on the landscape significantly altered the benign flooding in positive ways and improved human circulation on the landscape for foot and canoe traffic. The combination of raised fields, canals, and causeways enhanced natural wetlands and artificially expanded wetlands over large areas. The engineering features also captured early rains and impounded water well into the dry season when most of the savanna dried out. The builders of these raised fields and causeways were familiar with the syncopated rhythm of the river, rain, and seasons. Farmers used earthworks to create a structured anthropogenic landscape and appropriated those rhythms and the local topography to enhance farming, hunting, and fishing, complementing their other functions as transportation and communication between settlements and people and resources.

CAUSEWAYS AND CANALS AS MODES OF TRANSPORTATION AND COMMUNICATION

The hydraulic model explains the presence and organization of many causeways and canals, but not all. As stressed above, the causeways and canals that best fit the hydraulic model also were used for the circulation of farmers and goods between settlements, their fields, and the resources of the *bajio*, river, and forest. Although the river provided the most accessible year-round means of transportation and communication for canoe-using communities living on the levee, straight causeways and canals parallel to the rivers were more direct routes than following the meandering river, reducing travel time. Although most settlement was dispersed along the highest river levee, the causeways and canals permitted farmers to live anywhere on the landscape and still maintain social connections. Farmers dispersed over the landscape could also use the web of causeways and canals to commute to fields and share labor with neighbors in times of need.

In three areas, causeways and canals radiate from common points that

are either on or near archaeological sites high on the river levee. For example, seven causeways-canal radiate from the Providencia Mound, a small settlement or burial mound overlooking a vast complex of raised fields (Figures 11.3 and 11.7). These causeways bisect individual raised field blocks and "go against the grain" of the overall grid, suggesting that these were built after the raised fields were established (Figure 11.7). These causeways clearly prioritized pedestrian and canoe traffic between settlements (or settlements and resources) over hydraulic functions (Figure 11.2). Although created primarily to move people and goods across the landscape, radial causeways and canals also had intentional effects on hydrology by facilitating distribution of floodwaters over the upper backslope for more even and slower flow through the raised fields. In addition, the footprints of radial patterns of causeways probably mapped individual community territories and social networks (similar to those of the Baures Hydraulic Complex, Erickson, Chapter 10, this volume). In summary, the need for efficient transportation and communication trumped the hydraulic function in the above cases.

CONCLUSIONS

The precolumbian peoples of the Middle Apere River created a formal landscape of movement through the construction of earthworks that improved, channeled, and controlled human and water circulation. Although far from seamless, this integration of settlements, transportation, communication, fields, land tenure, resource enhancement, and water management is a clear example of accumulated *landesque capital*. As *landesque capital*, successive generations inherited a rich infrastructure imposed on the landscape. They were highly visible statements of the organization of labor by the community, and the ties between that community and the land. The people who created and maintained this *landesque capital* invested their labor and probably considered these improvements as aesthetic components of an orderly cultural landscape and highly visible ties to their lands and communities.

The remarkable preservation of the landscape and lack of overlay by other land-use strategies until the Colonial and Modern periods is further evidence of pre-columbian *landesque capital*. The engineered landscape was used over a considerable period. Estimated labor for construction of the causeways and raised fields of the 65 km² Middle Apere Complex is 28,716

person-days and 638,500 person-days respectively (based on movement at a rate of 2.5 m' per person per 5-hour day; Appendix 2). No earthworks discussed here required large groups of workers to build any specific feature.

Determining whether these landscapes were built through accretion or were constructed all at once depends on other evidence. The overall design of the Middle Apere River cultural landscape was laid out from the beginning, including the orientation and the spacing of raised fields and causeways. Once established, the structure imposed on the landscape was maintained and fine-tuned as needed by later generations. Based on the repetitive, formal patterns of earthworks, we argue that most of the cultural landscape was intentionally designed rather than the unintentional result of long-term farming and settlement.

The Bolivian Amazon provides a valuable comparative case for other wetland-focused complex cultures in the Americas, including the savanna cultures of South America, the Aztecs and the Maya of Mesoamerica, and the Mississippians of North America. In these cultures, wetland environments were sought out rather than avoided. This case study shows that the concept of *landesque capital* can be understood through the archaeological record. The archaeological study of *landesque capital* also contributes to an understanding of precolumbian indigenous knowledge. This case shows how multigenerational local knowledge conserved, enhanced, and managed water, aquatic resources, and soils; facilitated and determined human movement and settlement; and ordered society through the engineering of the landscape. Archaeology is uniquely positioned to study the local and regional histories of particular landscapes and show how its inhabitants were able to sustain resources and populations over centuries and millennia through the creation of *landesque capital*.

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NOTES

1. Brookfield and colleagues originally used the landesque capital to explain land degradation whereby neglect of maintenance of infrastructure results in decline of agricultural productivity and environmental quality. In contrast, many contemporary studies including Brookfield (2001) emphasize the positive implications of the concept, as we do in this chapter.
2. Kenneth Lee (1979, 1995) proposed that earthworks of the Bolivian Amazon were used as temporary water enclosures for sustained agricultural production. Fields would be flooded for a period of years for the cultivation of water hyacinth (*tarope*) and other aquatic flora and fauna, which would later be incorporated into the soil as a green manure when the fields were drained. Enhancement of soils and resources through water management in integrated complexes of raised fields, causeways, canals, and lakes is documented archaeologically (CEAM 2003; Erickson 1980, 2000a, 2000c, 2008 for the Bolivian Amazon; Erickson 1980, 1993, 1996, 2006a; Flores and paz 1987; Lennon 1982, 1983; Smith, Denevan, and Hamilton 1968:361 for the Andes) and experimentally (CEAM 2003; C. Pérez 1995; T. Pérez 1996; Saveedra 2006; Stab and Arce 2002).
3. The appropriateness of this approach is confirmed by the USGSHydrosheds project, which is carrying out the same procedure using SRTM around the world (<http://hydrosheds.cr.usgs.gov/>).