Landscape Archives, Aerial Photography and Geomorphic Change along the Lower Orange River

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'Each discipline has its own narrative and archive'[1]

Introduction

As an interdisciplinary project, 'Space in Time' sheds light on the different methodologies and research questions of participating disciplines by considering the types of archives used to build narratives of the past. This paper focuses on the geomorphologic archive which is typically composed of by physical material in a state of ongoing change. This disciplinary orientation approaches landscape change in relation to natural processes and human interactions that have left behind physical traces which geomorphologists use as a basis for defining and interpreting change. While typically focused on the physical features of the landscape – such as sediments – this chapter highlights an alternative archive based on historical aerial photography in combination with satellite imagery and runoff data.

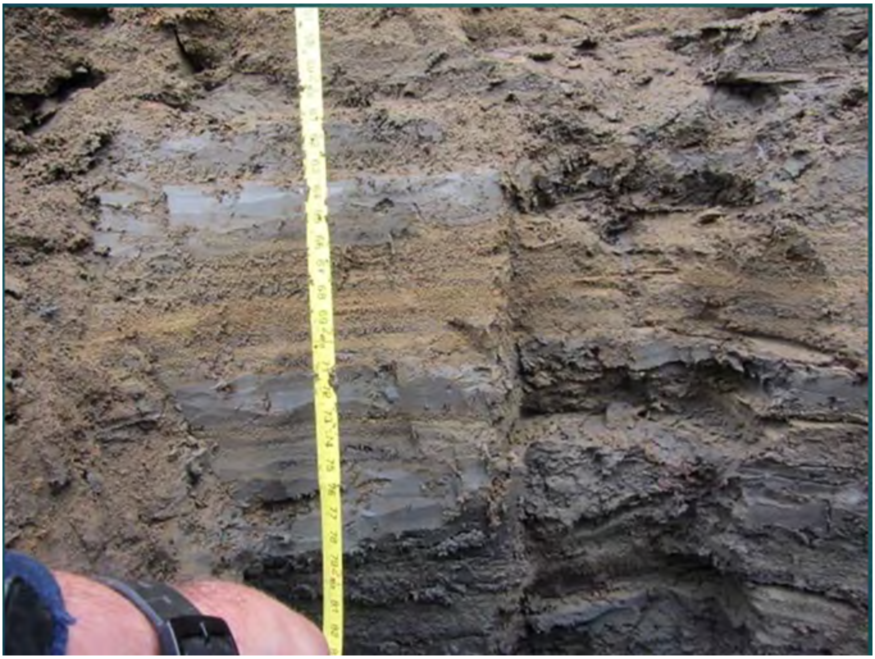
The Geomorphologic Archive

A geomorphologist's archive is typically composed of material dug up from behind a dam wall after a flood has washed sediment down a river (see image below). Once the sediments are retrieved, they are assembled vertically so that layers of compact grey can be contrasted with more sandy ones. The differences in colour and texture provide a starting point for the researcher to narrate the past. For instance, the sediments might show that at one point there was a big rainfall event, while other layers may be indicative of events

1 To quote Giorgio Miescher's statement during the introduction session of the Space in Time workshop that took place in Oranjemund in December 2019.

of lower magnitude. Measuring how quickly the sediment has built up over time aids in climate reconstruction. The amount and conditions of the material therefore tells a story about how the physical landscape has changed over time.

Fig. 1: Sediment Archive (Klaus Kuhn 2018).



Evidence in the form of sediments is typical of the northern Karoo, however not all parts of the semi-arid region have the same archival conditions.[2] The region adjacent to the Lower Orange River has low rates of flooding, and therefore not much sediment is left behind dams. Rather, the water flows through a rock bed – leaving little material behind that could be preserved, dug up, analysed, and studied. Building a climate model, accounting for large scale floods, or narrating the socio-economic history of the region through sediment accumulation, is therefore not possible. But there are alternatives to the traditional geological archives.

A readily available archive of aerial photographs of the Lower Orange River is stored at the National Geo-Spatial Information (NGI) in South Africa. The earliest images from the 1930s were planned along routes that flew directly over the Orange River and were mostly likely produced for strategic reasons, first, and then later for mapping and documenting soil erosion.[3]

2 Hoffman et al. 2007 and Zuziwe 2004.

3 Rizzo 2019

Using techniques in structural photogrammetry, geomorphologists can stitch together photographs of the same place taken at different times to make landscape change visible. Visible features of the landscape (such as buildings and airports) are used to anchor the series of photographs taken of the same location at different times. The stability of landscape features through which the Lower Orange River flows aids the process. Because it is a desert, much of the built environment has not changed much over time making it easy to connect images in reference to features of the landscape – i.e., corners of buildings, roads, airports, and railway lines.

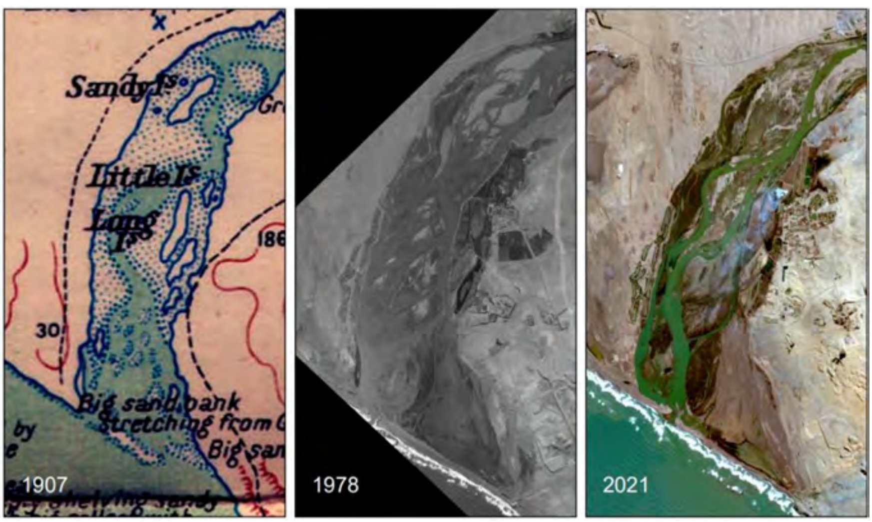
Fig. 2: Airport (Brigitte Kuhn 2019)

Comparing images reveals that there is more terrestrial land between the northern and southern shores of the Orange River than there was 40 years ago. Before the construction of dams in the 1960s there were only a few channel bars – or islands – which shifted during every flood. When the flood receded, sediments were deposited again, creating new islands. The construction of dams upstream, though, has stabilised the river, reducing the rate and frequency of floods. The Orange River has since lost its capacity to wash sediment out to the sea, resulting in a more clear-cut riverbed and more stable islands.

The figure below, assembled by Jonas Laube (2022) puts three different representations side-by-side in order to demonstrate the spatial resolution of the Orange River Mouth: The map from the cartographer's view point, the orthomosaic composed of historical aerial imagery from the National Geospatial Information archives, and a satellite image from Sentinel-2.[4]

The connection between hydrology and morphology visible in the aerial photographs can be strengthened in combination with other sources of information such as runoff data, which links the visual archive with sediment load and morphology showing the annual peak runoff before and after the construction of dams.[5]

Fig. 3: Evolution of spatial resolution of geodata: historical map, orthomosaic created from aerial photography and a satellite image from Sentinel-2 (from left to right). Laube 2022.

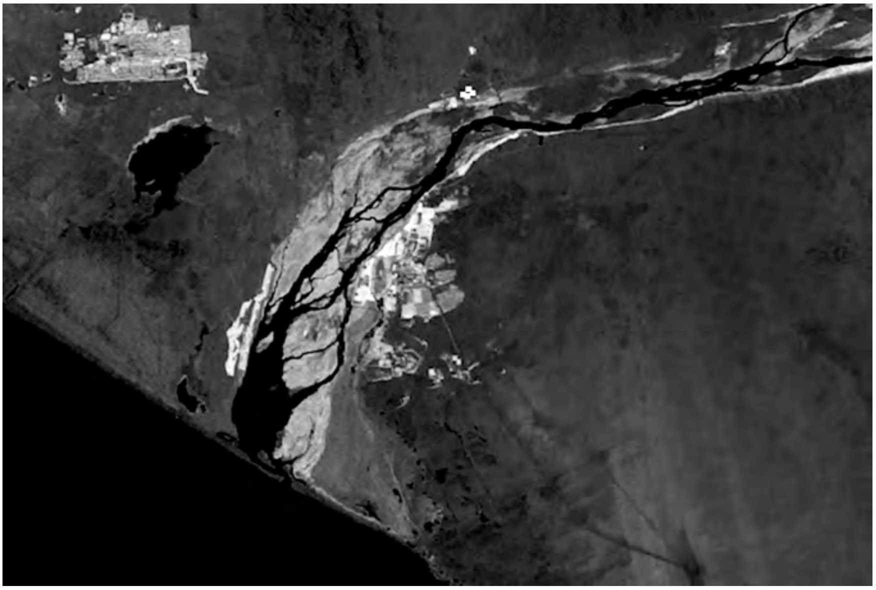


4 Laube 2022

5 Runoff, sediment load and morphology of rivers are intrinsically linked. Lowland rivers with a relatively constant flow and a predominantly fine sediment tend to form a meandering channel pattern. Rivers with highly variable runoff and a sediment load dominated by sand, gravel, and boulders, on the other hand, are characterised by unorganised or braided channel patterns. Therefore, the construction of dams potentially affects channel morphology because peak runoff rates are reduced in magnitude and frequency, and sediment load also often declines.

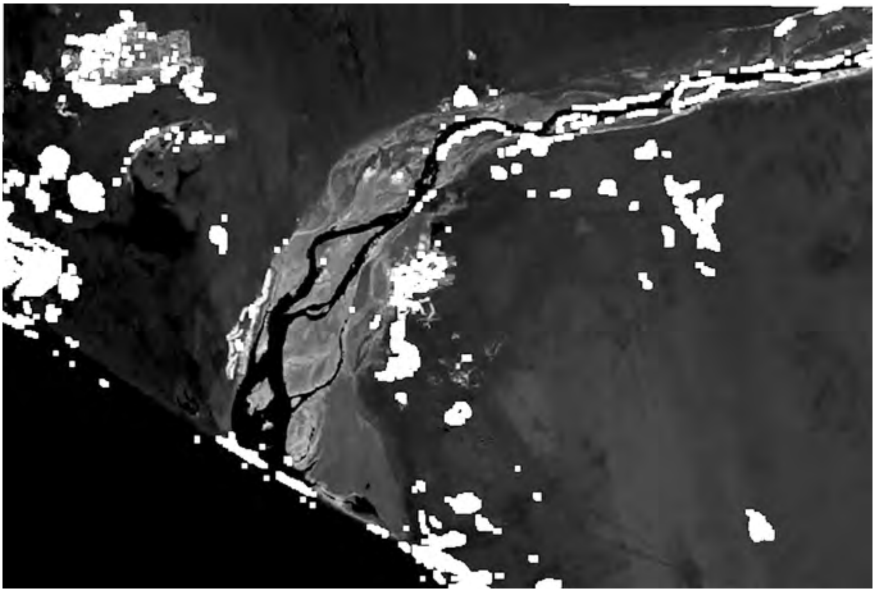
The series of aerial images and runoff data can be further combined with data about the distribution of vegetation. Using satellite images with near infrared reflection[6] and high-resolution topographical maps adds additional data and gives a better sense of terrestrial vegetation. The vegetation index of the river mouth (below) shows an increase in the terrestrial environment and a decrease in the area covered by the river channel. In other words, the stable land forming in the middle of the river due to runoff changes has become vegetated.

Fig. 4: Vegetation Index 1990 (Krenz, 2020).



6 The NDVI – or Normalised Difference Vegetation Index – is a spectral index that measures the difference between the visible and near-infrared sunlight reflected by vegetation. See Shekhar et al. 2019: pp. 74–75.

Fig. 5: Vegetation Index 2020 (Krenz, 2020).



The impact of dams constructed along the Orange River signalled in the time series of aerial photographs in combination with other data shows a dramatic change in morphology due to dam construction. This has had serious ecological consequences, mostly because incoming seawater is mixing with fresh water (blurring the boundary between sea and river). As a contact zone between land and sea that shifts between fluvial and non-fluvial, the tidal estuary which was usually freshwater dominated has become brine and saltwater dominated.

The Power of the Archive

A geomorphological gaze sees landscape change as an ongoing process that can be studied in reference to the traces that are left behind, such as layers of alluvium that wash down a river and collect behind a structure (like a dam). These materials constitute a specific type of landscape archive and sediment deposits make it possible to understand how the flow of the river has changed. These archives only emerge, however, where surface processes have left behind traces that have been preserved and can be analysed from a fixed position.

In the dry desert environment through which the Lower Orange River flows, there is a limited amount of surface processes unfolding which reduces the number of potential archives that could be interrogated. In locations where hardly any surface processes unfold, different landscape archives are required such as those housed at the National Geospatial Information (NGI) in South Africa (which can be combined with a heterogenous assemblage of other data such as runoff and spectral imagery).

But the archive is more than just a repository of retrievable information about the past. It is constituted by a discursive and epistemological order that determines what counts as information and what sorts of narratives can be built. Focusing here on data sources in the form of aerial photographs, while the spatial archive is not constituted by the same materiality and process and it is not 'living' in the same sense that a sediment archive is, it is founded on a different logic, system of classification and order that engenders a different set of epistemologies.

This switch from the material physical landscape to the discursive visual archive therefore raises questions about the power structure and ideology that underlay how the landscape is imagined, depicted, and conceptualised. The power of the archive is thus lodged in forms and practices of knowledge production, and what is preserved as landscape is not contingent simply on natural processes. Rather it is the result of selection and rejection, of inclusion and exclusion, and is constitutive of value systems based on a hierarchical order of material evidence.

The landscape as both a material and discursive archive thereby requires attention to questions of perception and vision, to examine how the materiality of the landscape produces regimes of vision that determine what is made visible and what remains invisible.[7] Therefore information that is physically disconnected from the absolute space constituting a material landscape through remote sensing data raises critical issues of the power of these archives to make some things visible while concealing others. Working with visual archives therefore entails a closer look at what the photographs show, and what is hidden beyond the frame.

Lorena Rizzo has recently offered a way to understand this complexity, and how aerial photography simultaneously reveals and keep things hidden.[8] Using spatial information that is disconnected from material landscape therefore raises key methodological problems that can be traced back to the early days of aerial photography, which has implications for analysing the ethical and political consequences of spatial databases in general. While useful for answering environmental questions, the spatial archive is bound up with a longer history of its production and the consequences of 'seeing like a state' which effectively reduced the richness of how people inhabited their landscape.[9]

Situating the Technique

The Lower Orange River is a site of academic knowledge production that has rarely been shared with local audiences who often remain marginalised and excluded from the academy. Thus, the critical issues related to landscape archives include how knowledge is shared and used, and the political and ethical responsibilities of researchers toward an interested local audience. Questioning the structure of landscape archives is therefore one way to address how they can be used beyond the academy and for public debates.

7 Miescher and Lenggenhager 2020
8 Rizzo 2019
9 Scott 1998

As a technique for making comparisons, aerial photographs can be used to understand patterns of change beyond the Orange River Mouth. They can be combined with satellite images and spatial databases to generate accurate geo-reference points that create maps that have a higher resolution and better accuracy than conventional maps. These representations can empower people who are concerned with environmental change along the Lower Orange River who need accurate data to support open political debates. This data could then be upscaled to make generalisations about the impacts of dams in the region, as well as their ongoing ecological and political consequences.

The wider political impact of documenting the movement of the river relates to issues of boundary demarcation, struggles to identify which islands belonged to which state, and determining private riparian owners' rights.[10] Namibia and South Africa share a 1,000 km border, most of which runs along the Orange River. The two countries disagree over the exact location of the political border which currently runs along the northern high-water mark, rather than being in the middle of the river – as is common international practice. The location determines the 200 nautical sea miles boundary which potentially affects mining prospects and opportunities for marine resource exploitation. The exact position of the point of boundary at the river's mouth has further implications for demarcating the exclusive economic zone with its valuable gas fields and diamond reserves.[11]

Extrapolating data to make claims about much larger areas perceived to be similar enough for direct comparison puts into focus, though, the limitations facing users who require tools to combine various forms of data – including aerial photographs, satellite images, and location information provided by GPS – and how this data can be stored, used, and shared. This limitation and foreseen uses of the landscape archives puts into focus the role of national archives – such as the NGI – in dealing with the uneven production of spatial data. As a landscape archive, the NGI operates against a backdrop of various discriminatory land administration exploits following colonial practices and apartheid in South Africa. Ironically, the availability of historical spatial data created by oppressive regimes has become a key resource in decision-making to redress or compensate for past injustices. As a national mapping organisation, the NGI exists to deliver highly accurate geospatial information including those than can provide historical context on land administration over time.[12]

Personal computers, and the democratisation of spatial data – such as aerial photographs, satellite imagery, and runoff data – has made public participation in remote sensing and spatial computing possible. This is linked to the wider application of remote sensing defined as the ability to monitor and collect data about something without the data collection instrument encountering the object or objects it is monitoring.[13] This definition is wide enough to include historical aerial photographs such as those used by geomorphologists to interpret landscape change along the Orange River. But beyond the genre of before-and-after images, linking these photographs with modern system of

10 Evans 1993: p. 134
11 Erasmus et al. 1987
12 Denner and Raubenheimer 2017
13 Shekhar et al. 2019: p. 61

location accuracy (such as GPS) and geographic information systems (GIS) can further improve the veracity of evidence generated by the public and used in political debates. Historical aerial imagery at the scale required for national boundary mapping and documenting soil by the South Africa state is one component. Beyond this is an assemblage of spatial technologies that have shifted from military to public use since at least the 1990s.

Modern remote sensing began with the Landsat satellites which were launched in the 1960s.[14] Still in operation, the Landsat program has more than 40 years of consistently archived visual imagery of Earth's surface (making it a massive landscape archive in its own right). Today, scientists from around the world use Landsat images to study changes to Earth's surface over time. But while the sensors used today are much more sensitive and advanced than they were in the 1960s, the complex systems for gathering data about the Earth and monitoring areas at a distance have limitations. A major hurdle has been accessing computer processing power since the images created by satellites are huge compilations of data and transferring the data to a machine is time consuming. Since the 1990s, equipment has become more openly available and it takes a relatively short amount of time to load the necessary geographic information to perform the operations necessary to, for instance, make representations of and claims about river morphology.

Combining data is a function of geographic information systems (GISs) in general, which fuse together geographic and map data from multiple sources (including historical aerial images). An individual GIS can then store, analyse, and manage the data, and then provide visualisations of this data in the form of a map. Spatial database management systems (SDBMSs) provide the backbone of many of these technologies, which have made significant advancements with the development of cloud computing platforms, such as Google Earth Engine.[15] Lower cost computing equipment and open-source platforms have offered greater flexibility to map-making than ever before. As computing power, computer storage and remote-sensing tools are continuing to improve, another technological shift has been underway as Internet-based GIS made it even easier to access GIS technologies. Maps that were once viewed from a desktop computer are now accessed via mobile devices using cloud-based storage systems for their geographic databases.[16]

Conclusion

Every discipline has its own landscape and its own archive, as Giorgio Miescher pointed out during the workshop in Oranjemund in 2019. Typically, the geomorphological archive is composed of sediments that are washed up behind a structure, such as a dam, which can then be dug up and studied. However, the lack of surface processes along the Orange River has made it necessary to explore alternatives. One of these exists in the form of remotely sensed data, such as historical aerial photographs and satellite imagery, which can be linked up with additional information such as runoff data. Open-

14 Mack 1990

15 Shekhar et al. 2019 : p. 10

16 Shekhar et al. 2019: pp. 99–100

source computer platforms and cloud-based tools, together with national archives that have democratised spatial information, have empowered the public to use and interact with new mapping techniques and spatial representations which potentially shape public debates. Thus, while not living in the same sense as the sediment archive, historical aerial photographs continue to shape perceptions and engagements with landscapes. The democratisation of spatial information and tools has, on the other hand, make it possible for the public to shape these technologies and archives through their continual engagement with them.

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