Structural and non-structural water management concepts and community participation in managing land and water resources in ancient Sri Lanka

By

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This labor is dedicated to

All celestial and super natural powers and all living beings looked upon us and corrected when and where necessary during the journey in this beautiful planet

Clergies and priests who showed us the risk of not being with the nature and not accepting the change

All doctors and physicians who advised us to keep in faith on the power of natural healing and adjust our consumption patterns within the limits of bio diversity

All teachers who taught us to find the eco-conscious ways and means to negotiate with the nature

All those who produce foods and drinks with plenty of natural energy

All people who shared their time and effort to bring this a successful piece of work

Title: Structural and non-structural water management concepts and community participation in managing land and water resources in ancient Sri Lanka

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Hydraulic civilization was prominent in Anuradhapura and Polonnaruwa eras till the 13 century Anuradha Senaviratne (1987). Cascade system was identified as the managing land and water systems in dry zone areas Madduma Bandara in 1995. Sustainable system of managing each and every component of the landscape and water resources was discussed in details by P.B. Dharmasena in 2010 and emphasized the community participation in managing these systems identified as “Ellangava”. Abayasinghe in 2018 highlighted the need of restoring the cascade system or the “Ellangava” system of management as a remedy for the unidentified conical kidney deices.

Community participation in land and water management could be identified as one of the successful management strategy practiced in ancient hydraulic civilization in Sri Lanka. Structural and nonstructural land and water management techniques used in the ancient past were based on several hydraulic control systems namely, increase of infiltration by providing detention ponds or depression areas, water quality control by using grass covered areas or constructed wetlands or bio retention areas, increase of flow path to increase the time of concentration and thereby to reduce the flow velocity and the discharge quantity, replenish groundwater aquifers by using structural ponds, grass covered swells etc.

All these ancient water harvesting systems help to retain water not only for human consumption but also for other living flora and fauna allowing retaining the bio diversity. Therefore, ecosystem resilience is well managed at micro scale while development work is carried out by the humans to improve their livelihoods at macro scale. Macro scale development model could be identified as an aggregation of several micro level management systems run by the community.

Micro level geographical units of management or micro catchments are managed by the community and community participation was kept at maximum to manage the land and water resources. This model has been now identified as “Ellangava” management system or cascade management system.

Principle behind the cascade or “Ellangava” system could be identified as a system which used to classify the landscape according to the topographical features and manage natural hydrological functions within those micro level catchments without any disturbances to the valuable ecosystem services. This management system also support ecosystem services and to maintain the resilience while improving the livelihoods of the stakeholders with the community participation.

This principle could be used globally to address the climate change scenarios to improve the land and water management strategies adapted in any country with the community participation to improve the ecosystem resilience as well as the livelihoods of the stakeholders.

Present paper discusses four cases to illustrate the present status of the hydrological controls adopted in Rnamasu Uyana, Segiriya lion rock area, Polonnaruwa ruin city and Udawaththa forest reserve in Kandy.

Segiriya

Sigiriya is an ancient rock fortress having height of nearly 200 meters located in the northern Matale District near the town of Dambulla in the Central Province, Sri Lanka. This was built by King Kasyapa (477 – 495 CE). The capital and the royal palace were abandoned after the king's death. It was used as a Buddhist monastery until the 14th century. Later it was abandoned and found by Major Jonathan Forbes in 1831 Wikipediya 2018. Segiriya could be defined as the kingdom of water but now neglected.

Hydrological functions identified by Segiriya builders

Main hydrological functions used as tools could be identified as flow velocity control, control of quantity of runoff discharge, increase of flow path distance, infiltration, temporary ponding, ground water recharging, water fountains, manmade water falls etc.

At the top of the rock, a water pond has been created and that is to collect rain water receives to the top of the rock. Land is graded to drain water to this pond and just above the bottom of the pond and a drainage outlet could be seen.

Figure 1: Top most pond on the top of the Segiriya lion rock

Figure 2: Drainage outlet of the top most Pond

Structural drainage system of Segiriya has been studied and concluded that identification of drainage system is very difficult due to lack of technology Udalamatta 2011.

Most of the water receives from rain storms to the rock are collected to the octagonal pond "Atapattam Pokuna".

Figure 3: Octagonal pond

(a) (b)

Figure 4

Figure 4 (a) shows the pathway of the water coming down form the upper landscape towards the octagonal pond and this should be covered with vegetation but now it is cleared without knowing the function of the vegetation cover. Vegetation cover helps to filter debris and slow down the velocity and promote infiltration which again flourishes the ground water. Figure 4 (b) shows the upper landscape and the flow path and that area was also cleared to build a foot path. Here structural drainage pipes were not used to drain water instead nonstructural drainage systems were used.

Figure 5: Inlet of the Octagonal pond

Perhaps inlet is closed with rocks and soil to stop the muddy water coming in to the pond during the rainy season.

Landscape features and water harvesting of the area

Rock is at a fairly higher ground and rainwater receives to this land area is collected to structural ponds as well as nonstructural depression areas.

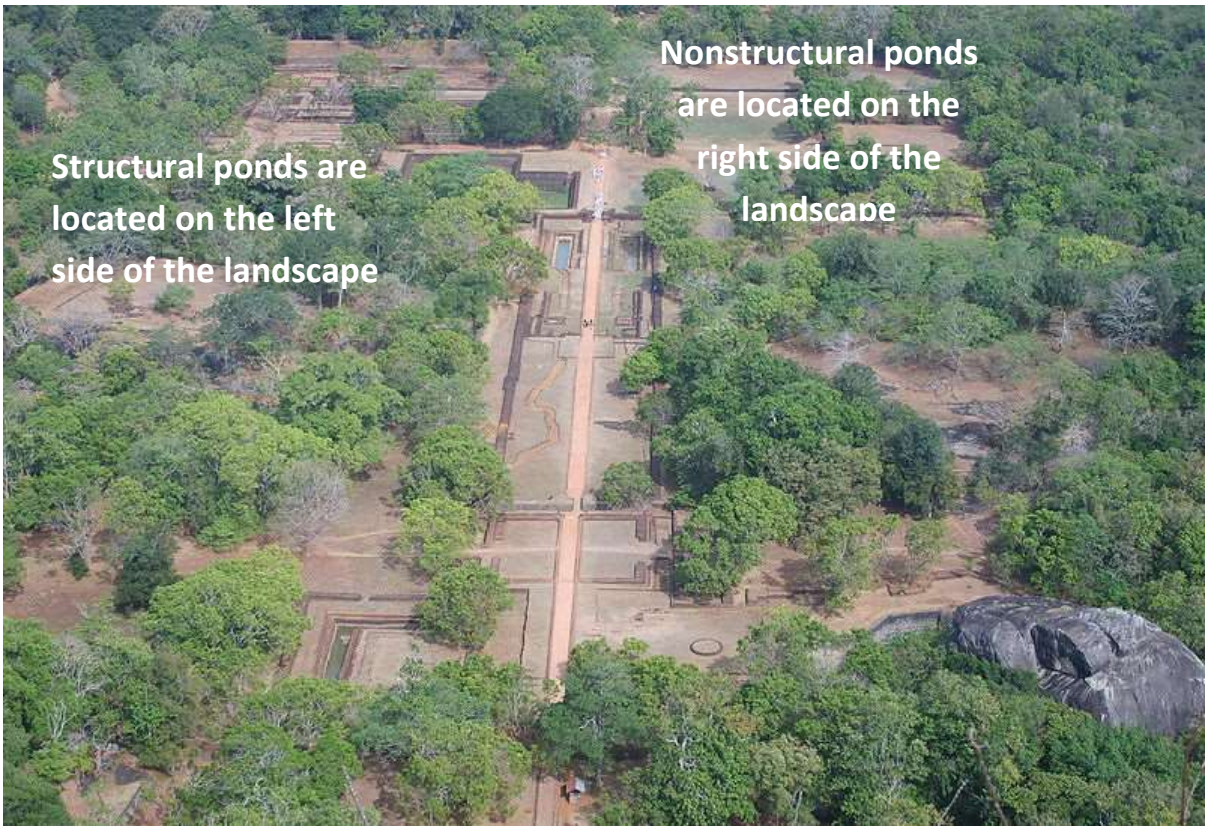

Figure 6: Arrangement of structural and nonstructural ponds

Figure 7: Degrading nonstructural ponds

These structural and nonstructural ponds may be connected through underground drainage lines or surface drainage systems. Nonstructural ponds are getting silt loads from each rainy season due to lack of maintenance of the landscape as hydraulic control structures designed for rainwater harvesting.

Figure 8: Openings for underground drainage systems

Figure 9: Nonstructural depression areas and drainage patterns

As shown in the Figure 9, nonstructural depression areas and drainage patterns are used to direct rainwater to ponds located in lower elevations. During the delivery water is filtered and velocity is reduced to stop any soil erosion. Surface flow paths may have created to increase the distance or naturally existed flow paths may have used to increase the time of concentration to help the infiltration and to flourish the groundwater.

Velocity of water is controlled by providing grass covered land areas with mild slopes to increase the flow path and the time of concentration Figure 10.

Figure 10: Grass covered sloppy areas

Figure 10 shows the connected grass covered sloppy areas with the earthen canals with grass cover. These hydrologic controls help to slow down the runoff water and increase the infiltration and the time of concentration. Artistically carved steps on the rock were used to slow down the water velocity. Those are appeared as water falls during the rainy season Figure 11.

Figure 11: Steps carved in rocks

This management system could be identified as micro catchment management. Application process of technologies is now recognized as low impact development approach or best management practices in developed countries. This system of micro catchment management is now being practiced in developed countries under many themes like, low impact development approach, best management practices, integrated wetlands management or constructed wetland management, hydrological control systems, hydrological tools etc. used in centuries back in Sri Lanka. But presently, hydrological aspects of the site are neglected and some of the wetlands are now dying due to eutrophication and siltation. With time this may lead to groundwater depletion and due to that resilience of these wetlands could be changed affecting the "Segiriya Weva ".

“Ranmasu Uyana” and its hydrological aspects

Figure 12: Water intake and the flow path to the “Ranmasu Uyana” from the Thisawewa

Figure 13: Structural drainage canal system which carries water from “Thisawewa” to the “Ranmasu Uyana” micro catchment.

Figure 14: Desilting facilities

As shown in the Figure 13, water reaches to several structural ponds in the “Ranmasu Uyana” micro catchment and along the flow path several desilting facilities could be observed Figure 14.

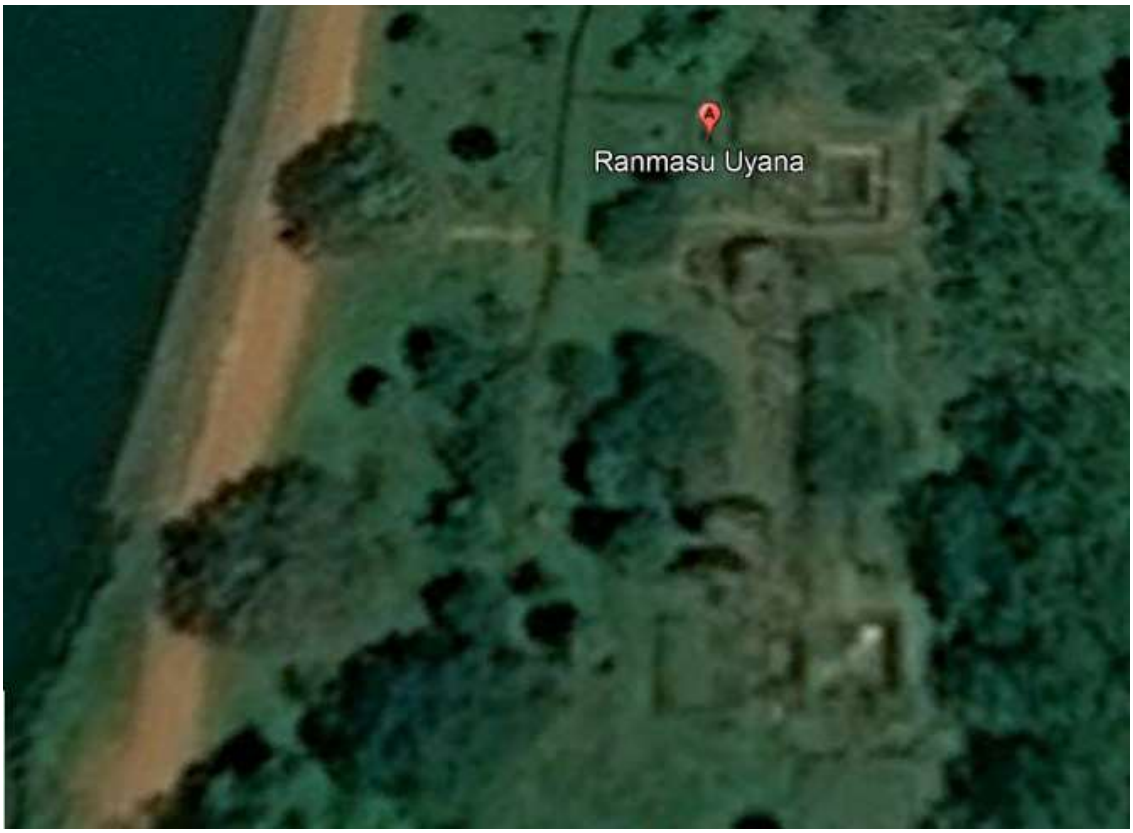

Figure 15: Water intake and two structural bathing ponds at the “Ranmasu Uyana”

As shown in the Figure 15 two structural bathing ponds and drainage facilities could be identified in the area. Several structural controls also could be identified to handle the overland flow during the rainy season to safeguard the pond water quality.

Figure 16: Drainage line of bathing ponds towards the downstream wetland

Figure 16 shows the drainage line running from bathing ponds towards the downstream area where series of wetlands or another nonstructural water bodies are present. Presently these ponds are not fed by the “Thisawewa” any more and therefore these series of wetlands or ponds are not getting enough water and gradual eutrophication and siltation is taking place.

Figure 17: Eutrophication taking place in nonstructural ponds

As shown in the Figure 17 these series of wetlands running towards downstream paddy lands are degrading due to eutrophication and silting.

Figure 18: Drainage outlet of the “Ranmasu Uyana” micro catchment

Water taken form the “Thisawewa” is taken for bathing purposes and finally goes through a series of wetlands and ponds before entering in to the paddy field area. Water use efficiency is maximized with these hydrological control systems and provides cooling and aesthetically pleasing environment for the King as well as purification of used waters.

Figure 19: Concrete lined canal at the downstream of the “Ranmasu Uyana”

Presently, a concrete lined canal has created to take water to the downstream paddy lands and ancient sustainable irrigation system is abandoned. This will seriously affects the long term sustainability of above mentioned series of interconnected wetlands and ponds.

Figure 20: Natural drainage outlet and manmade concrete lined canal

Natural drainage outlet of the micro catchment is blocked and road is constructed to provide transport facilities. Therefore, natural drainage system is not functioning and silting and eutrophication is aggravated in wetlands and ponds in upper catchment areas Figure 20.

It is a must to reestablish the abandoning irrigation network in this area to safeguard the natural hydrological process which was preserved for many thousand years.

Polonnaruwa ruin city and its hydrological control systems

Kingdom of Anuradhapura was fallen down in 1017 to the Chola King and they shifted the capital to Polonnaruwa and ruled Sri Lanka for 53 years. King Vijayabahu I eventually defeated the Cholas and reestablished the Sinhalese lineage. The Kingdom of Polonnaruwa was abandoned in the 14th century, and the seat of government for the Sinhalese kings was moved to Dambadeniya. Although many factors contributed to this, the leading cause of the abandonment of Polonnaruwa was its susceptibility to invasions from south India Wikipediay 2018.

Figure 21: Kings palace, :Parakramabahu Samudraya" reservoir

Palace is saturated near the "Parakrama Samudraya" and form the reservoir side and covered by a large brick wall. Eastern side of the palace is demarcated with an irrigation canal. Entire landscape is sloping towards the canal side and entire landscape is design to harvest the rainfall receives.

This is the huge side wall constructed to protect the palace of the King Parakramabahu, and it has many runoff Water controlling structures.

Figure 22: outer brick wall and nonstructural drainage facility

As shown in the Figure 22, nonstructural drainage facility has provided to store runoff water temporarily. This will also increase the flow path and the time of concentration and facilitate infiltration and thereby replenishes the ground water.

Figure 23: Structural slues gates in the brick wall

Structural slues gates are provided in several points of the brick wall and now some of them are closed purposely. This will alter the hydrology of the entire area and will have adverse effects over the natural ecosystem in the long run.

Figure 24: Plastic pollution

Unfortunately, plastic pollution could be seen in the area towards the canal side Figure 24.

Like Anuradhapura open land areas are not leveled and used to trap Rainwater in depressions and nonstructural drainage systems were used to carry surface runoff water towards the . Runoff Water velocity, has controlled using these depression storage facilities. Ground covet filters silt and derbies

Figure 25: Natural landscape with temporary ponding facilities and nonstructural drainage systems

Figure 26: Kumara pokuna at the Kong's palace

Even today “Kumara Pokuna“ has purified water Figure 26. But maintenance is carried out without giving priority to the hydrological control structures and therefore, these ponds are not functioning properly. Algal blooms and siltation of temporary ponding areas and nonstructural drainage system could be observed.

With or without permission from the archeology department soils have been brought to this area may be to level the ground to avoid the depressions. If it is leveled these depressions will be vanished from the area and rainwater will quickly wash towards downstream areas. Further siltation could lead to block of drainage structure and reduce the infiltration process.

Figure 27: Depression storage areas about to be leveled

Dug well Figure 28, in the site is 100 or 150 Meters away from the Parakrama Samudraya. Today it is dry. If groundwater seepage provides water to this well, water should be available even today. Definitely underground tunnel must exist from the reservoir. Perhaps now it is closed. If this well has water entire area will receive enough soil moisture to grow vegetation. Neglecting such hydrological controls will have long term environmental impacts to the ecological systems in the area.

Figure 28: Dug well

Even though archeology department is safeguarding the structural monuments, has no clear idea about maintaining the hydrological controls used by the King to protect water and to safeguard the entire ecological systems. In the long run entire ecological system could fail due to negligence of these hydrological and ecological factors. Figure 29 shows the modern landscaping approach in pollonnaruwa. Land grading is done and land was flatten to achieve the beauty. No space provided for depression storages and rainwater harvesting was not identified to maintain the pre development hydrological standards.

Figure 29: Modern landscaping in Polonnaruwa

Udawatta Forest Reserve and its hydrological features

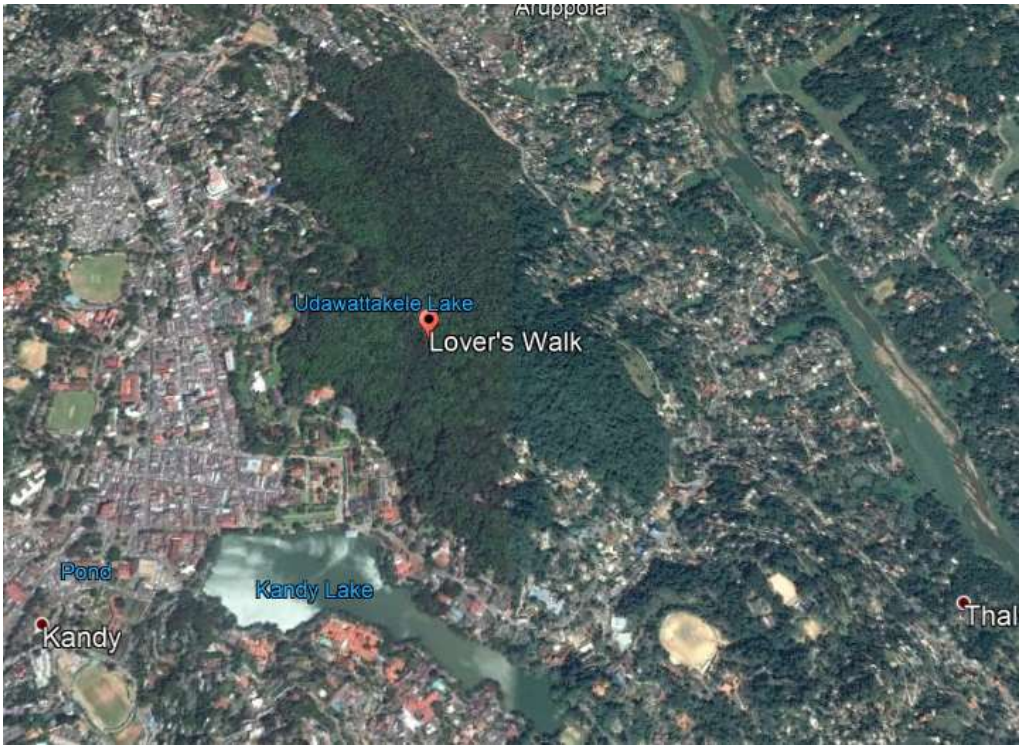

Figure 30: Udawatta Forest reserve and Kandy lake

Udawatta forest reserve is the only natural forest cover exist in the Kandy city area and it represent the natural vegitation type should be kept to safeguard the local weather patterns. Now due to the population pressure natural vegitation is clearing day by day.

Forest reserve contains a great variety of plant species, especially lianas, shrubs and small trees. There are several giant lianas. Many of small and medium size mammals that inhabit Sri Lanka can be seen here. Udawattakele was designated as a forest reserve in 1856, and it became a sanctuary in 1938.

According to the Wikipedia 2018, that the brahmin called Senkanda, from whose name the city's original name Senkandagalapura derives, lived in a cave in this forest. The rock-shelter or cave now known as the Senkandagala-lena is on the slope above the temple of the tooth and can be visited. The Senkandagala-lena collapsed in a landslide in 2012. It was used as a pleasure garden by the Kandyan kings. The forest was reserved for the Royal family, and the pond in the forest was used for bathing. The public was restricted from accessing the forest hence the name Thahanci kele (Sinhalese for Forbidden forest).

Figure 31: Present status of the Royal pond

Even though the pond has been used for bathing, now water quality has been severally degraded due to siltation and eutrophication.

Figure 32: Thalweg line of the stream connected to the royal pond

A stream could be observed coming towards the royal pond form a micro catchment in the forest reserve. Due to heavy siltation stream area is mostly silted and base flow could be observed during the beginning of the July 2018. Kandy experienced heavy rainfall during previous months. But now only a weak base flow could be observed. Soil mass of the forest reserve may not have enough soil moisture to feed the stream during dry periods.

Figure 33 shows the part of the small bridge constructed accord the stream. Lots of derbies and silts are accumulated at the either side of the bridge.

Figure 33: Debris accumulated along the bridge crossing the stream and area is heavily silted

Figure 34 shows the view of upper catchment area from the bridge and that area is not covered with the enough vegetation to control the runoff water velocity and filter the debris and silts coming along.

Figure 34: Silted upstream of the royal pond

There are two micro catchments and you can see two thalvege lines with two base flows running down towards the pond.

Figure 35: Two streams coming down form two sub catchments or micro catchments in the forest

(a) (b)

Figure 36: Right (a) and Left (b) streams coming from micro catchments

As shown in the Figure 37 (a), access roads have been built for recreational purposes and lots of ground cover is been removed Figure 37 (b). This is the main cause for the siltation of the royal pond.

Figure 37: Road construction and removal of ground cover in upper catchment areas

Figure 38: silting pond

Figure 38 shows the siltation taking place in everywhere around the pond. Quality of water is degrading and the pond is getting shallow day by day. Need immediate action to restoration of these micro catchments, if not within another decade or two the forest will be gone.

Due to lack of proper ground cover, rainwater quickly runs towards the pond with a heavy load of silt. At the same time infiltration is not taking place as in a natural forest and soil mass of the Udawatta forest is incapable of storing enough soil moisture to feed the stream during the dry periods. That is why this base flow is at its minimal even with heavy rainfall last month.

Figure 39: Kandy city from the Udawatta forest reserve

Figure 40: Kandy Lake and a part of the city

Figure 41: Segiriya

Figure 39 and 40 shows the population pressure and the environmental degradation happening in the evergreen forests in Sri Lanka. Figure 41 shows the abandoned fertile lands in the dry zone areas. Segiriya could be identified as a model of water kingdom which was badly neglected and now we are experiencing consequences.

Figure 42, shows the stream running towards the Kandy Lake from the Udawatta Forest area. It is another micro catchment belongs to the forest. Fortunately it is covered with the stream bank vegetation and may be filtering derbies and silt coming from uplands.

Figure 42: Stream running down form the Udawatta forest to the Kandy Lake

This could be a very good field laboratory for the University of Peradeniya to demonstrate the ecological and hydrological processes going on in micro catchments.

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