Are all river reaches created equal? Identifying erosion hotspots for catchment management

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Abstract

SedNet is a predictive sediment budget model that can be used to model erosion and sedimentation processes across catchments. By identifying key sediment sources (hillslopes, gullies, riverbanks) and sediment sinks (channel beds, floodplains, lakes and reservoirs), SedNet can be used to direct management works to areas where the greatest benefits are derived from targeted effort.We present a case study for the upper Barwon River catchment in Southern Victoria. This catchment suffers from high rates of riverbank erosion. The SedNet sediment budget shows that an average of 147 kt/yr of sediment is eroded from the study area each year and that bank erosion is the most important source of sediment input, accounting for 65% of the sediment yield. However, sediment derived from riverbank erosion is predominantly sourced from only a few river links.The SedNet model provides an estimate of mean annual values averaged over 100 years. Hence model results can be used to identify potential "hotspot" locations for future erosion control works or observation over time. The SedNet tool is also ideal for identifying knowledge gaps and checking whether resources for the control of erosion and sedimentation have been allocated in a pattern that matches the distribution of hotspot areas.

Keywords

SedNet, sediment budget, stream sediment, GIS, Barwon River

Introduction

Catchments cleared of native vegetation have an increased susceptibility to erosion, but erosion risk varies from place to place within a catchment. The majority of sediment transported to the catchment outlet may be sourced from relatively few "hotspot" locations, hence it is useful to prioritise management works to areas where the greatest benefits are derived from targeted effort.

Historically, a catchment-scale appreciation of erosion and sedimentation processes has been difficult to acquire. Catchment-scale field measurement is expensive and time consuming, and it is difficult to justify the extrapolation of limited field measurement over larger areas, which potentially differ in soil type, topography and vegetation cover (amongst other things). Without an appreciation for catchment-scale trends in erosion and sedimentation, it is near impossible to maximise the efficiency of resource allocation and to justify expenditure for potentially important management works.

This paper examines how a sediment budget model (SedNet) can be used to better understand the erosion and sedimentation processes operating across catchments and guide catchment managers in future investigations and works. A case study is presented for the upper Barwon River in Victoria.

Background

The Barwon River rises on the high-rainfall upper slopes of the Otway Ranges to drain some 3,880 km^2 of southern Victoria. The headwaters are composed of numerous small creeks that flow in a generally northerly direction off the ranges. At Inverleigh, the Barwon is joined by the Leigh River, a major left-bank tributary, before turning easterly. In its lower reaches the Barwon is joined by the Moorabool River and then flows through Geelong and Lake Connewarre to debouch into Bass Straight at Barwon Heads.

The study area addressed herein is defined as the Barwon River and catchment upstream of Warrambine Creek (Figure 1). The upper Barwon Catchment suffers from high rates of riverbank erosion that dates from the early 1900s, when swamps and wetlands were drained and sections of tributary streams channelised to increase the area of arable land. Boundary sediments tend to be dispersive silts. Straightening of the tributaries has increased stream power and this has led to bed incision and bank instability. Riverbank erosion continues to occur through a number of processes, including slumping and scour, derived from natural meander processes, stock damage and scour around willows.

The stabilisation of the streams, and the consequential slowing of sediment supply, is a priority for the catchment's managers. The deposition of fine sediment downstream has caused negative environmental and amenity impacts in the Barwon River through Geelong, Lake Connewarre and the Barwon Estuary. Furthermore, the upper Barwon Catchment is used to supply part of the Geelong urban water demand. Most of the flow is sourced from the West Barwon Reservoir and the East Barwon River. Diversions are passed down the Wurdee Boluc Inlet Channel, which picks up supplementary flows from the tributaries it crosses (e.g. Callahan Creek, Matthews Creek and Pennyroyal Creek) on the way to the Wurdiboluc Reservoir. Ideally, the supply of suspended sediment to streams above the diversion points should be minimised, as poor water quality increases treatment costs and impacts negatively on the taste and clarity of potable water supply.

Method and results

The SedNet model was used to derive a sediment budget for the upper Barwon River. Sediment budgets identify sediment sources (hillslopes, gullies, riverbanks) and sediment sinks (channel beds, floodplains, lakes and reservoirs) and can be used to identify catchment-scale trends in erosion and sedimentation (see Wilkinson *et al*., 2004).

SedNet requires spatially explicit input data (geographic grids and shapefiles), as well as time series data (stream-flow) and parameter information. Much of this information can be sourced from existing data sets. However, we chose to supplement existing data with inputs derived from a refined digital terrain model (DTM) and field observation and measurement. The DTM of the study area was fundamental to achieving good outcomes from the SedNet modelling. The DTM was used to derive information such as ground slope, water flow direction, catchment areas and drainage network. Additional SedNet inputs include grid files describing gully density, hillslope erosion, riparian vegetation and floodplain width.

The above inputs are used by the model to calculate rates of sediment input to each river reach, or link, from hillslope, gully and riverbank erosion. SedNet then computed a sediment budget for each link. Computations consider imported sediment at the top of the link, exported sediment at the bottom of the link and deposition within the link. Where sediment is exported from a link this material is added to the budget of the downstream link and so on to the lowest link in the system at the catchment outlet.

The sediment budget for the study area indicates that, over the past 100 years, bank erosion has been the most important source of sediment input to the upper Barwon River, accounting for two thirds of the sediment yield (Table 1).

Table 1. Summary sediment budget.

Budget item	**Mean annual rate**	
	(kt/yr)	**(%)**
Hillslope erosion	3	2
Gully erosion	48	33
Bank erosion	96	65
Total inputs	**147**	**100**
Net reservoir and channel deposition	5	4
Net Floodplain deposition	24	16
Export from the study area	118	80
Total outputs	**147**	**100**

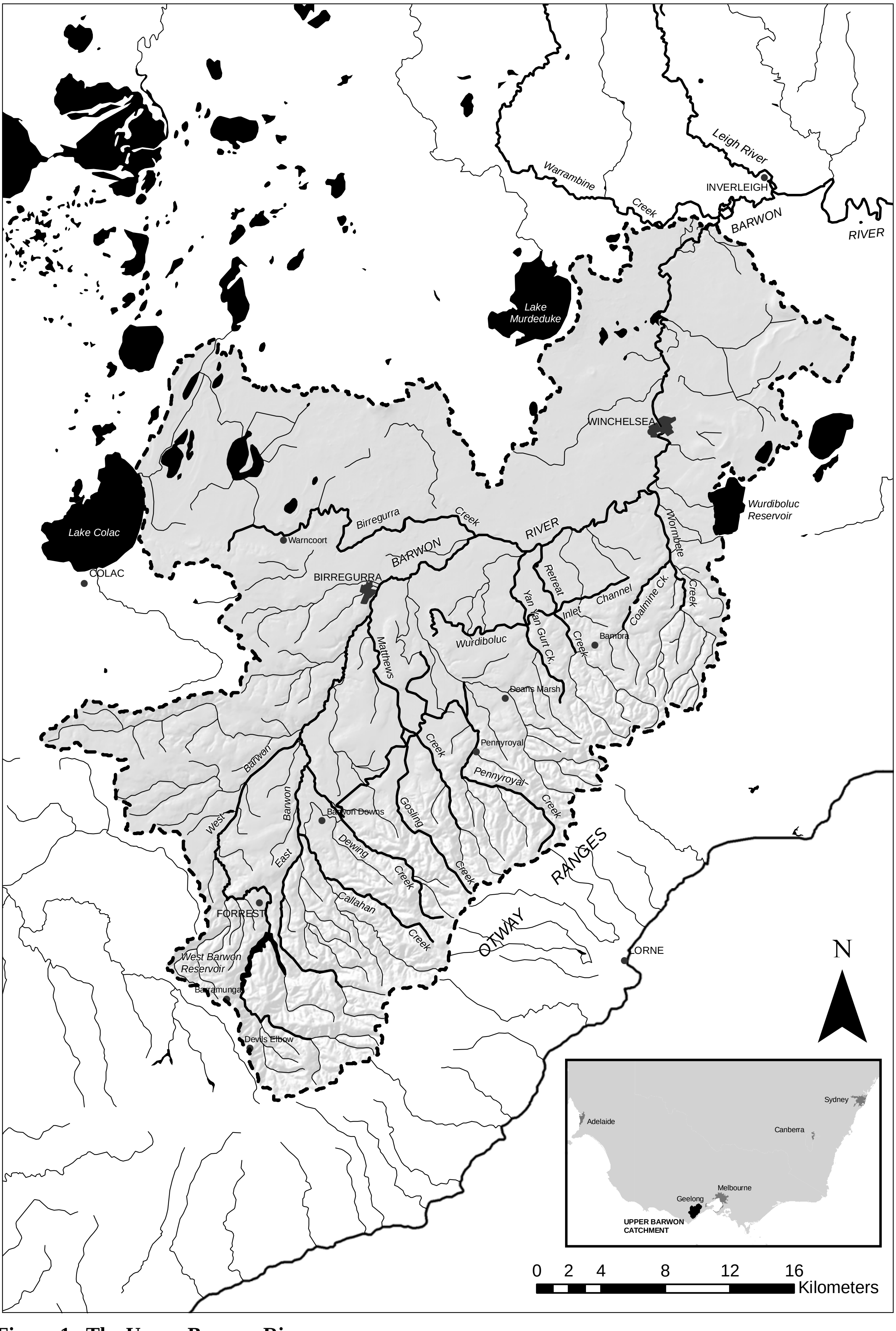

Figure 1. The Upper Barwon River.

Moreover, approximately 80% of sediment mobilised from source areas within the catchment is exported from the study area. The majority of sediment that remains in the study area is stored on the floodplain, with only 20% stored as bedload in the river channel or deposited in reservoirs. SedNet model outputs generally correspond well with field observations.

Discussion

SedNet modelling indicates that the judicious management of hotspot reaches has the potential to improve river health and water quality, and to restrict the downstream supply of fine sediment. For example, while hillslope erosion (sheetwash and rills) makes up only 2% of the total sediment input, hillslope inputs constitute a larger portion of the sediment budget in hotspot links as only one third of stream links supply 80% of the sediment to the upper Barwon River. Like hillslope erosion, the majority of sediment sourced from gully erosion is input to only a fraction of river links. In this case, 80% of the sediment sourced from gullies is input to just a third of river links. Similarly sediments derived from riverbank erosion (65% of total supply) is predominantly sourced from only a few river links. Overall, SedNet attributes 90% of the sediment supply from riverbanks to just a quarter of river links across the study area.

As an example, Figure 2 shows the distribution of high, moderate, and low rates of riverbank erosion. We derived the ranking by sorting SedNet streamlinks according to the rate of riverbank erosion (in units of tonnes per kilometre) and summing their stream length. High rankings are given to the third of the stream length with the highest values, moderate to the next third of stream length, and low rankings to the third of streamlink length with the lowest values.

Like all models, SedNet outputs require interpretation. SedNet provides an estimate of mean annual values averaged over 100 years and thus may not represent the current situation. And, in order to calculate a catchment wide sediment budget, SedNet makes various generalisations about the relationships between physical parameters and rates of erosion and sedimentation. For the purpose of the upper Barwon River case study, we found that the SedNet tool is ideal for:

- identifying knowledge gaps;
- checking whether resources for the control of erosion and sedimentation have been allocated in a pattern that matches the distribution of hotspot areas; and
- identifying potential hotspot locations for possible erosion control works or observation over time.

These three points are explored in further detail below.

Identifying knowledge gaps
As indicated in Figure 2, SedNet predicts that the highest rates of riverbank erosion are found along the Barwon River and Matthews, Pennyroyal, Deans Marsh and Retreat Creeks. Overall, the agreement between the rate of riverbank erosion predicted by SedNet and the riverbank conditions observed in the field was good. Streams with high incidence of incision, slumping, stock access etc. were generally “High” and “Moderate” SedNet streams. Streams that appeared stable in the field, with only localised evidence of damage, were generally rated “Low” or “Negligible”.

The only exception to the above was the case of Wormbete Creek. Wormbete Creek was one of the first tributary streams to be drained in the early 1900s in order to promote farming lands. The straightening of Wormbete Creek has increased stream power and this has led to bed and bank incision. Wormbete Creek is now severely incised. For example, just upstream of its confluence with Coalmine Creek, the channel is 21m wide and 12m deep. However, the severity of the erosion problem in Wormbete Creek was not reflected in the SedNet output. Our modelling indicates that Wormbete Creek has mean annual flow, link slope, riparian cover and floodplain width comparable to other streams draining the Otway Ranges. The overall result was a “Moderate” SedNet result for riverbank erosion in this reach.

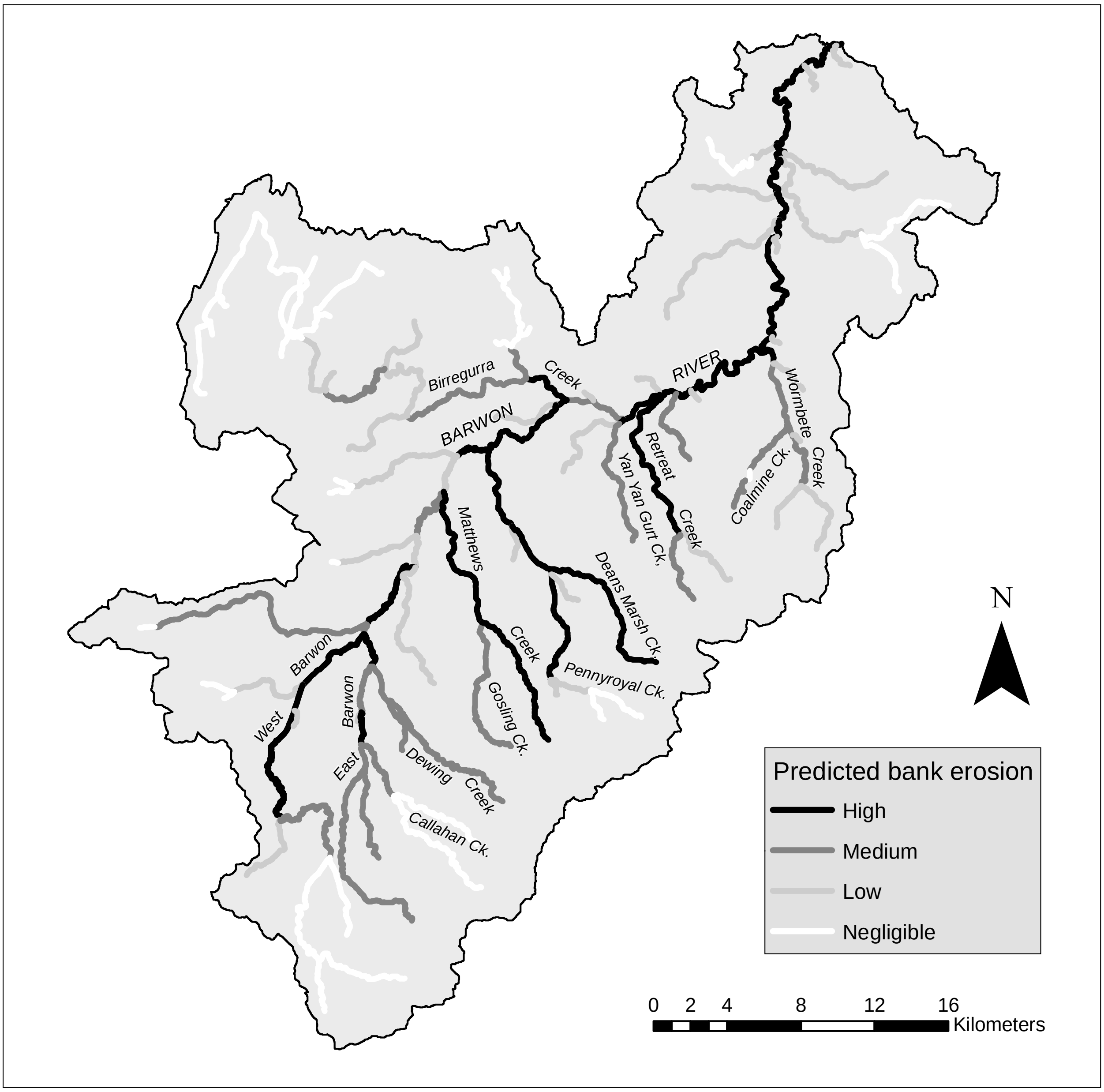

Figure 2. Predicted rates of riverbank erosion in the upper Barwon River.

Further investigations are required to determine what processes are working to incise Wormbete Creek and, perhaps more importantly, whether other tributary streams are at risk of incision or further incision. As sediment from riverbank erosion makes up 65% of the sediment budget, the treatment of riverbank erosion has the greatest potential to stem the supply of suspended sediment to downstream reaches and early intervention will limit impacts even further.

The allocation of resources for the control of erosion and sedimentation

A number of organisations have taken an active role in managing erosion and sedimentation in the upper Barwon River. There are several Landcare groups operating within the Barwon area, and some of these groups have undertaken pest plant and rabbit control, tree planting and pasture renovation works. The Soil Conservation Authority, Landcare and the Corangamite Catchment Management Authority (CMA) have each been involved in re-vegetation works. Other activities include fencing high risk areas and landslide management.

A recent focus of Corangamite CMA activities has been the construction of grade control structures on key streams, for example Wormbete and Matthews Creeks. Bed and bank incision has also been actively managed by the Soil Conservation Authority and Landcare. Grade control structures, rock chutes and gabions have been built along Wormbete, Coalmine, Yan Yan Gurt, Retreat, Matthews and Pennyroyal

Creeks. Other activities within the catchment have aimed to stabilise riverbanks by fencing and re-vegetation of the riparian zone. Some willow removal has also been undertaken.

A “next step” is to monitor and map the location of existing on-ground works. Mapping of works can then be compared to the distribution of hotspot areas as identified using SedNet, to see if the areas correspond.

Identify potential hotspot locations
Sites that have a propensity for erosion or sedimentation problems may not currently show signs of degradation. Potential hotspot locations can be investigated over the long term for the early detection of potential problems. For example, in-stream sediment deposition occurs where the coarse sediment supply exceeds the sediment transport capacity of a given flow. SedNet results indicate a high risk of sedimentation for the Barwon River between Birregurra Creek and Wormbete Creek. But, while we know that there is some sand moving through the system, no particular sand deposits have been observed. However, over the long-term bedload may well accumulate here and could potentially contribute to the loss of in-stream habitat in an otherwise healthy reach of river. In any case, our results suggest that it is worthwhile keeping an eye on this reach from time to time.

Conclusion

We used SedNet to develop a sediment budget for the upper Barwon River. Our budget shows that an average of 147 kt/yr of sediment is eroded from the study area each year and that bank erosion is the most important source of sediment input, accounting for 65% of the sediment yield. Moreover, the majority of sediment liberated from riverbanks is sourced from only a few river links. So managing hotspot reaches, rather than the entire system, has great potential to improve river health and water quality, and to restrict the downstream supply of fine sediment.

SedNet model outputs generally correspond well with field observations. A notable exception was the predicted rate of riverbank erosion modelled for Wormbete Creek. Wormbete Creek was one of the first tributary streams to be drained in the early 1900s and is now severely incised in parts. However, the severity of the erosion problem was not reflected in the SedNet output.

Differences between field observations and model outputs do not necessarily indicate a deficiency in the model. SedNet provides a 100-year average and generates a catchment-wide sediment budget based on generalised relationships that model complex erosion/sedimentation processes, so reach-scale differences are to be expected. However, these differences can provide valuable information on potential future sites of erosion and sedimentation and can identify clearly the existence of knowledge gaps.

Our study has indicated that further investigations are required to determine what processes are working to incise Wormbete Creek and whether other tributary streams are at risk of incision or further incision. We have also identified potential hotspot locations to be investigated over the long term for the early detection of potential river health problems.

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