

# Lake Columbia Downstream Impacts Analysis

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Prepared for

**Angelina and Neches  
River Authority and  
Texas Water  
Development Board**

ANR01289



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**ANGELINA AND NECHES RIVER AUTHORITY AND  
TEXAS WATER DEVELOPMENT BOARD**

**LAKE COLUMBIA**

**DOWNSTREAM IMPACTS ANALYSIS**

**SEPTEMBER 2005**

PREPARED BY



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## **1.0 INTRODUCTION**

### **1.1 Background**

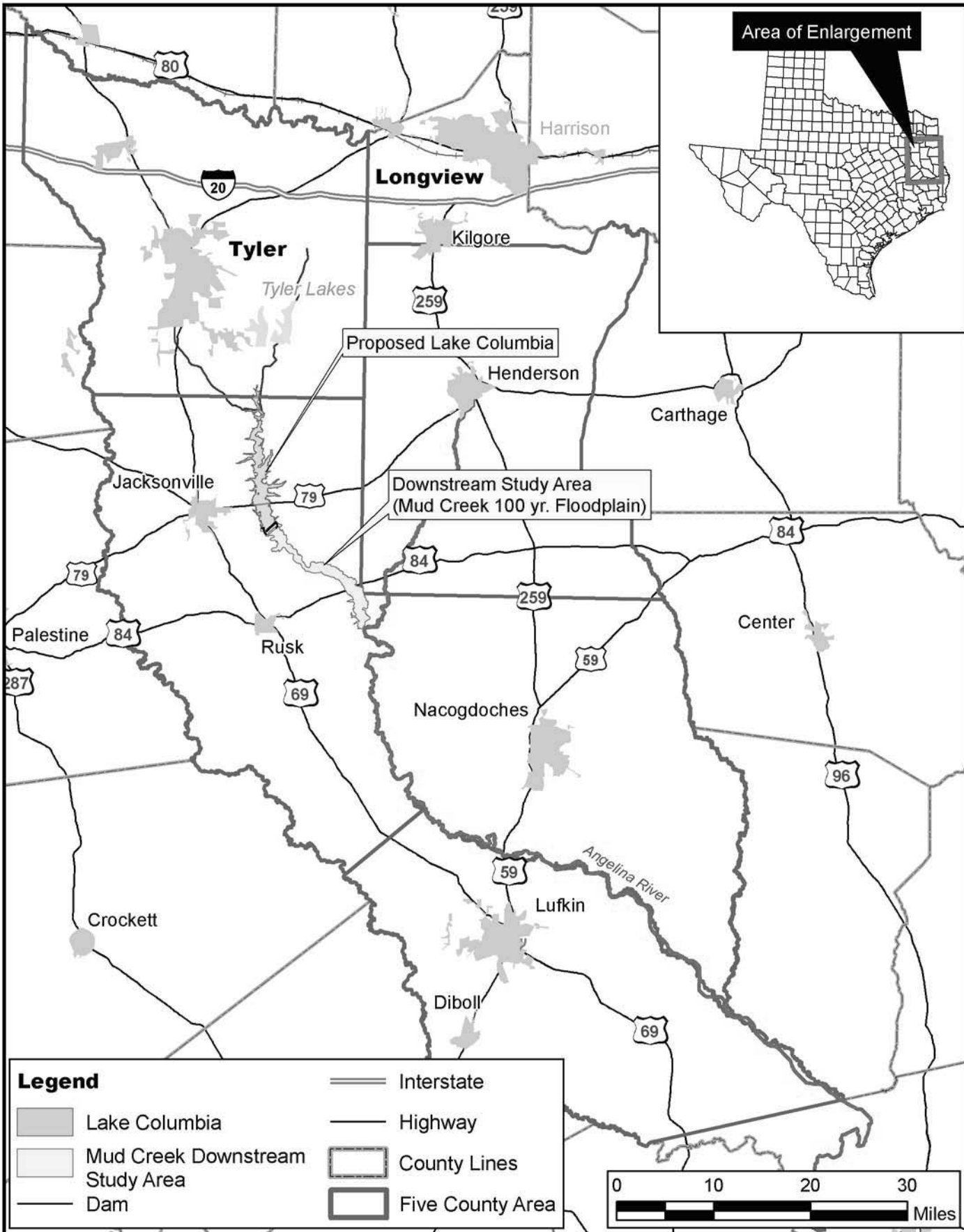
The Angelina and Neches River Authority (ANRA) entered into an agreement with the Texas Water Development Board (TWDB) in March 2001 for a matching grant to conduct planning studies for the proposed Lake Columbia water supply project (TWDB Contract No. 2001-483-385) which was known then as Lake Eastex. Public coordination meetings were held in Jacksonville, Texas, in March and September 2001, and September 2002 during preparation of the planning studies report. A meeting was held at a special session of the ANRA Board of Directors in Lufkin on March 12, 2003, to present a summary of the draft planning studies report. In addition, ANRA provided periodic updates of the ongoing planning studies on its project web site, <http://www.lakeeastex.org>, as well as opportunity for visitors of the web site to provide comments on the planning studies and other aspects of the Lake Columbia project.

The final planning studies report (Freese and Nichols, 2003), which focused on the reservoir pool and immediate vicinity of the dam, was completed in May 2003.

The current study was spawned by inquiries of resource agency staff, including the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, Texas Commission on Environmental Quality, and Texas Parks and Wildlife, who participated in the 2001-2003 planning studies effort. They expressed questions about the area of potential effects of Lake Columbia on the stream corridor downstream of the proposed lake. Recognizing this as an important issue from a planning perspective, the ANRA proposed an amendment to the TWDB to add a study to define the area of potential downstream effects to the existing TWDB matching grant. Consequently, the Planning Studies contract between that ANRA and TWDB was modified in April 2003 to include the downstream impacts study. The ANRA contracted with Freese and Nichols, Inc. (FNI) in April 2003 to assist with the downstream study.

### **1.2 Purpose**

The primary purpose of the Lake Columbia Downstream Impacts Study was to identify the potential downstream area of effect in the Mud Creek floodplain based on expected reservoir operation conditions. The limits of the study area was defined as the existing 100-year floodplain of Mud Creek between the proposed dam site and the confluence with the Angelina River, although hydraulic modeling included a portion of the Angelina River upstream and downstream of the confluence in order to make the Mud Creek backwater model behave appropriately. Figure 1.1 shows the location of the study area.





Study components included 1) review of literature on downstream impacts of reservoirs, 2) computer simulation of reservoir operation, 3) hydraulic and hydrologic computer modeling to compare Mud Creek floodplain boundaries with and without the proposed reservoir, 4) delineation of land cover types in the area of effect using remotely sensed data, and 5) preliminary evaluation of impacts on selected natural resources. The study was intended to provide boundaries defining the limits of the area of potential changes in floodplain areas and a macro-scale evaluation of potential downstream impacts due to the proposed Lake Columbia.

**References**

Freese and Nichols, Inc. 2003. Lake Eastex Planning Studies Report. Prepared for Angelina and Neches River Authority and the Texas Water Development Board. Fort Worth, Texas.



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## **2.0 LITERATURE REVIEW**

The objective of the current study was to sample the large body of scientific literature pertaining to the downstream effects of dams with an emphasis on finding studies similar to Lake Columbia in terms of physiographic setting and operation. Downstream impacts of reservoirs having different operating characteristics and located in vastly different geographic regions may not be comparable with respect to type or magnitude of effect. Therefore, a primary objective of the literature survey was to identify downstream impacts studies for reservoirs similar in operation and geographic location to the proposed Lake Columbia.

The literature search yielded nearly 300 titles that were reviewed for this study. These included studies that related specifically to the hydrologic, morphologic, and ecologic downstream effects of dams (e.g., Gergel, 2002; Bergkamp et al. 2000; and Ligon et al., 1995; Hodges and Switzer, 1979; Light et al., 2002; and Trayler, 2000), as well as other papers describing floodplain ecology but not necessarily the impacts of dams (e.g., Batzer and Wissinger, 1996; and Guo et al., 1998). The list of publications reviewed is presented at the end of this section. Key papers are cited in the following discussion.

### **2.1 Common Downstream Effects of Dams**

The effects of dams on rivers have been studied extensively in the United States and elsewhere over the past several decades as dam construction has proliferated to meet the demands for flood control, water supply, hydroelectric power, irrigation, and other uses, and as awareness and interest in the environmental impacts of dams has increased in recent years.

In general, the downstream effects of any given dam may be reflected in several of the following ways:

- Changes in downstream hydrology
  - instream flows
  - flood regimes
  - seasonal flows
  - total flows
  - short-term fluctuations in flows
  - extreme high and low flows.
  - reduced overbank flooding
- Changes in downstream morphology
  - reduced size of active floodplain
  - reduced flood peaks and frequency
  - increased erosion
- Changes in downstream water quality
- Reduction in riverine/riparian/floodplain habitat diversity
  - riparian vegetation sensitive to minimum and maximum flows

- Changes in physical and biological processes
- Groundwater recharge

The magnitude of these changes, and indeed whether some of these effects occur at all, depends on the type of dam, how it is operated, and where it is located.

The Lake Columbia dam was described in the initial phase of the current planning study grant (Freese and Nichols, 2003). As noted, the dam will be a rolled earth fill embankment with a maximum height of 67 feet and a length of 6,880 feet. The outlet works will consist of two 48-inch conduits for intended releases. The dam will have an uncontrolled service spillway with a crest elevation of 315 feet National Geodetic Vertical Datum (NGVD) and an emergency spillway with a crest elevation of 324 feet NGVD. The reservoir is not designed for flood control. Thus, all inflows into Lake Columbia when the water surface elevation is at or above the conservation pool level (i.e., 315 feet NGVD), will spill downstream through the service and emergency spillways.

Many researchers have emphasized the difficulty of identifying or predicting the changes that a dam might have on the downstream corridor (Phillips, 2003). In a comprehensive study of the downstream effects of dams in the U.S., Williams and Wolman (1984) noted several common trends between 21 study sites:

“(1) Frequent occurrence of major changes right after dam closure; (2) appearance in many cases of the greatest change just downstream from the dam with progressive decrease or recovery downstream; (3) progressive change toward an apparent new stability at a site in the years after dam closure; (4) continuous or non-reversible character of the change at many locations; and (5) diversity of climatic and physiographic regions in which the [channel change] process has been observed.”

They also pointed out that the geologic record indicates that small changes in climatic factors can produce significant changes in channel morphology, and that these and other natural influences may mask the effects on channel morphology and vegetation that can be attributed solely to the effect of a given dam. As they noted, “some of the [observed] channel changes might well have occurred during the period of observation even in the absence of human interference” (Williams and Wolman, 1984), i.e., dam construction.

## **2.2 Effects on Hydrology, Sediment Transport, and Riparian Vegetation**

Streams are dynamic systems that reflect the effects of all the forces acting upon them, including climatic, geologic and human influences. If these forces remain constant for a relatively long period, a stream may reach a state of so-called dynamic equilibrium, where the channel morphology (e.g., width, depth, and sinuosity) becomes relatively constant.

The primary undisputed downstream impacts of a dam are on the hydrology and sediment transport of a stream (Brandt, 2000; Williams and Wolman, 1984 and others). A particular dam's impact depends on many site-specific factors, such as the dam's structure and operation, local hydrology, basin sediment characteristics, geomorphic constraints, climate, and attributes of the local biota (Bergkamp et al, 2000). A gated spillway dam operated for flood control by capturing peak flows and releasing the stored water gradually affects the hydrology differently than a non-gated dam with a passive spillway operated for water supply or recreation. Both dams will tend to reduce peak flows, but the gradual release of flood waters from the gated structure will prolong and possibly increase baseflow downstream, as observed in studies of Yegua Creek below Somerville Dam in the Brazos River basin, Texas (Chin et al., 2002). Dams built for hydroelectric power generation also may dampen peaks and result in highly variable daily flows, but they might not reduce annual discharge significantly (Jennings, 1999).

Dams alter sediment cycling in rivers by intercepting large masses of sediment that otherwise would be transported downstream (Nilsson and Berggren, 2000). The sediment removal efficiency of large dams often exceeds 99 percent (Williams and Wolman, 1984). The enhanced sediment carrying capacity of water discharged from a reservoir is typically evident by a scoured channel downstream of the dam, though the length of this effect varies greatly among streams and is dependent on the distance required for the stream to recover its pre-dam sediment loads or concentrations. Sediment sources downstream of the dam include the channel bed and banks and tributary inflows.

In a sediment transport study on Loco Bayou downstream of Lake Nacogdoches, Phillips (2001) concluded that, while the channel immediately below Loco Dam had experienced a net loss of sediment, the dam had no effect on sediment supplies at a study site approximately 10 miles downstream. The principal source of sediment at this location was believed to be contributed by erosion from the 14-square mile watershed between the dam and the study site. Furthermore, he observed no evidence of a significant change in channel or floodplain morphology, no reduction in alluvial sedimentation, nor did he find any other indication of a reduction in fluvial sediment supply at the study site 10 miles downstream.

Phillips (2001) raised the question of whether or not sediment from the upper basin was being transported to the lower basin prior to dam construction. He noted that a *decoupling* effect has been demonstrated in some larger basins whereby very little sediment actually migrated from the upper basin to the lower basin and speculated that this might be the case for Loco Bayou. Once a stream reaches its sediment carrying capacity, it is said to be *transport limited*, meaning that more sediment is available than the stream is able to carry. Therefore, any additional sediment input will result in deposition on the stream bed. Streams that have the capacity to transport additional sediment are classified as *sediment limited*.

Trush and McBain (2000) suggest that a river system's foundation is the interaction of flowing water, sediment and riparian vegetation. Chin et al. (2002) and Jennings (1999) studied the effects of Somerville Dam, a flood control dam with a gated spillway, on the hydrology, channel capacity, and floodplain vegetation of Yegua Creek, the boundary between Washington and Burleson counties, Texas. Chin et al. found that channel capacity in the 12-mile reach downstream of Somerville Dam had decreased by an average of 65 percent in 34 years following dam closure. The loss of capacity was attributed primarily to an average depth reduction of 61 percent, indicating sediment deposition due to transport limitation, with a decrease in average width of only 9 percent. The reduction in capacity corresponded to an 85 percent reduction in annual flood peaks. Jennings (1999) reported that riparian vegetation had increased in proximity to the Yegua Creek channel. This change was attributed to the change in hydrologic regime due to operation of the dam. The reduction of peak flows and increased availability of water through summer and early fall apparently provided favorable conditions for survival of seedlings in the riparian zone that, under pre-dam conditions, were lost to flooding or drought.

Chang and Crowley (1997) reported similar results from a study of the downstream effects of Sam Rayburn Dam on streamflow and vegetation in the Angelina River floodplain in East Texas. Sam Rayburn Reservoir is operated by the U.S. Army Corps of Engineers and was authorized by Congress in 1955 for the purposes of flood control, hydroelectric power generation, and conservation of water for municipal, industrial, agricultural, and recreational uses. The dam was originally completed in 1965 and modified in 1996, and includes two 18 feet by 26 feet power conduits and two 10 feet by 20 feet flood control gates through which water is released from the lake. The study compared streamflow and vegetation characteristics between study areas immediately downstream of the reservoir and a relatively undisturbed area along the Neches River approximately 12 miles to the west. The findings indicated that annual streamflow below the dam was not affected, but that flood peaks were lower and flow was higher in the summer months due to reservoir operation. Vegetation comparisons, including woody and herbaceous species in all strata of the forest stands at each site, indicated that the site downstream of the dam had greater species diversity, richness, and evenness. They concluded that reduced flooding and moderation of streamflow variation below the dam made the area a more diverse and stable ecosystem than the Neches River site (Chang and Crowley, 1997).

Conner et al. (1981) concluded that hydrology is the overriding factor controlling recruitment and survival of bottomland hardwood seedlings in their comparison of the effects of different flooding regimes on vegetative composition of three swamp sites in Louisiana. Theriot (1993) studied the relationship between relatively undisturbed bottomland forest species associations and their topographic position in floodplains of the southeastern United States. The study results supported the generally agreed notion that flooding is the dominant environmental factor influencing the makeup of bottomland

forests, due to its effects on regeneration success and soil saturation. Individual species were shown to have flood tolerance levels that reflected the species' optimum position along the hydrologic gradient in the bottomland forest.

Species associations of southern bottomland hardwoods described by Hodges and Switzer (1979) provide an indication of the potential shift in species composition that might be expected at the affected floodplain margins over time (Table 2.1). At the edges of the floodplain where the frequency of flooding might decrease after dam closure, there could be a shift in species composition to a slightly drier assemblage. In humid East Texas, such a shift in composition likely would occur gradually over a long period of time unless a disturbance such as logging or wildfire caused an opening in the existing stand and vegetation was allowed to regenerate unmanaged. Theriot (1993) observed that while established trees in relatively undisturbed areas served as reliable indicators for identifying hydrologic zones within a floodplain, such trees may remain for decades following hydrologic alteration. This is in contrast to the more immediate effects expected in water scarce semi-arid or sub-arctic regions where flood hydrology is typically more important for watering, fertilizing, cleaning, and sowing the land (Nilsson and Berggren, 2000).

**Table 2.1 Representative associations of southern bottomland hardwood species based on topographic position relative to minor streams in the southeastern U.S.**

<b>Wetter Flats in Floodplains of Minor Streams</b>	<b>Drier Floodplain Zones of Minor Streams</b>	<b>Adjacent Terraces of Minor Streams</b>
overcup oak ( <i>Q. lyrata</i> ), willow oak ( <i>Q. phellos</i> ), and possibly Nuttall oak ( <i>Q. nuttallii</i> )	sweetgum ( <i>Liquidambar styraciflua</i> ), cherrybark oak ( <i>Quercus falcata</i> var. <i>pagodifolia</i> ), water oak ( <i>Q. nigra</i> ), swamp chestnut oak ( <i>Q. michauxii</i> ), blackgum ( <i>Nyssa sylvatica</i> ), winged elm ( <i>Ulmus alata</i> ), and hickories ( <i>Carya</i> spp.)	sweetgum, green ash ( <i>Fraxinus pennsylvanica</i> ), Nuttall oak, red maple ( <i>Acer rubra</i> ), white oak ( <i>Q. alba</i> ), southern red oak ( <i>Q. falcata</i> ), yellow poplar ( <i>Liriodendron tulipifera</i> ), many of the hickories, and possibly post oak ( <i>Q. stellata</i> ) and loblolly pine ( <i>Pinus taeda</i> )

Source: Hodges and Switzer, 1979

The Texas Bottomland Hardwood Preservation Program (U.S. Fish and Wildlife Service, 1984) proposed 62 bottomland areas for consideration of some level of habitat preservation or further study. These sites were considered to be important for maintaining populations of mallards (*Anas platyrhynchos*) and wood ducks (*Aix spinosa*). The Mud Creek site, classified as a "Priority 1" area (i.e., excellent quality bottomlands of high value to mallards and wood ducks), is located eleven stream miles downstream from the Lake Columbia site and encompasses the lower Mud Creek floodplain downstream of U.S. Highway 84 to the Mud Creek – Angelina River confluence. The location of the proposed Mud Creek Priority 1 site is shown relative to the existing Mud Creek 100-year floodplain in Figure 2.1. This area covers 4,099 acres of the 100-year floodplain, including 3,566 acres of forest, 527 acres of

grassland/pasture, and less than 10 acres of clearcut land and water. The boundaries of the proposed Priority 1 area appear to have been generously delineated, as they extend well beyond the 100-year floodplain identified in the current study. The report characterized the Mud Creek Priority 1 site as having no upstream reservoir, several large tributaries, a conspicuously braided stream channel, and a flat and fertile floodplain with frequent flooding. This characterization apparently overlooked, or deemed unimportant, the fact that the Tyler Lakes lie approximately 30 miles upstream and regulate 114 square miles of the 520 square mile watershed above U.S. Highway 84, the approximate upper boundary of the Priority 1 site.

In summary, the primary impact of dams on streams relates to their effects on hydrology and sediment transport. Other effects on riparian and floodplain flora, and the fauna that inhabit those areas, are dependent on the hydrologic and morphologic changes in the channel and floodplain that are driven by these processes. The magnitude of the effects and the downstream distance that such effects are manifested are site-specific and depend on the type of dam, its operation, and local variables such as climate, geology, basin sediment characteristics, floodplain vegetation, and human influences in the watershed.





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