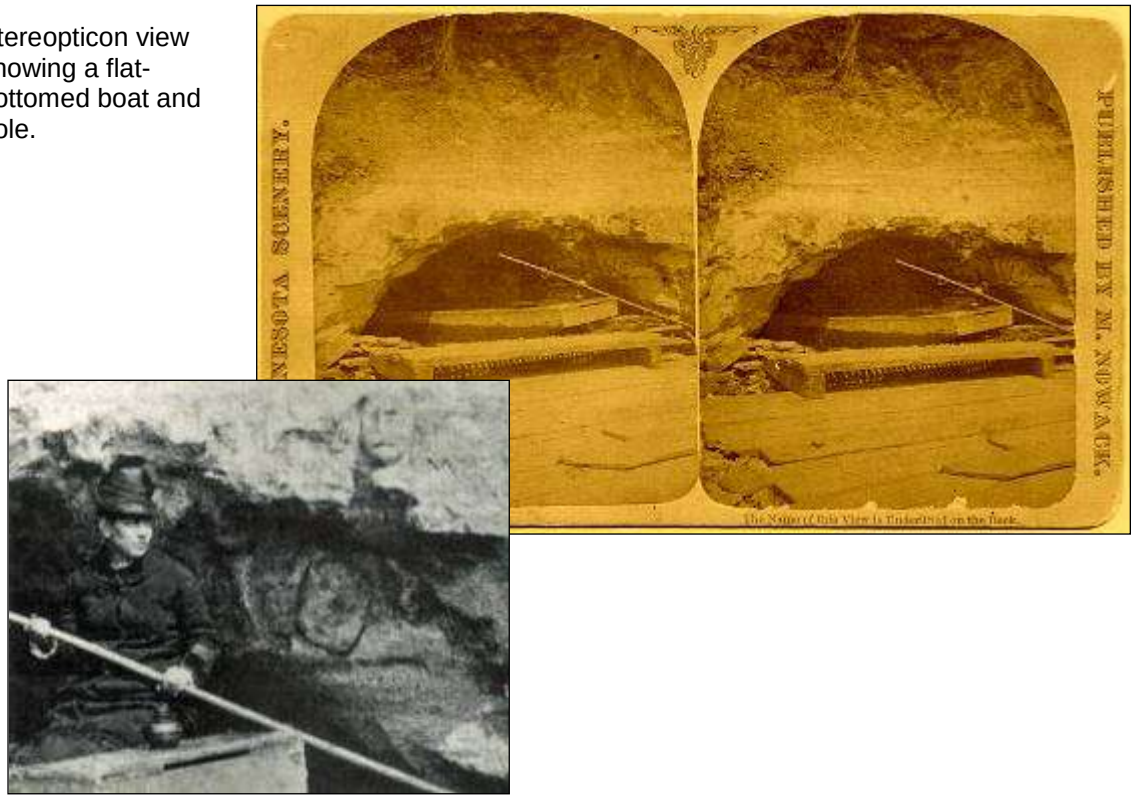
Chute's Cave

Let us briefly move to St. Paul's Minnesota's neighbor, Minneapolis.

When S.H. Chute excavated a 2.5-meter tunnel to provide water to his Phoenix Four Mill in 1864, the project encountered a cave and was abandoned. A bulkhead built during 1875 excavation for a tailrace, however, made the suitable for sub-urban excursions. From the Saint Paul and Minneapolis Pioneer and Tribune, August 26 of the following year,

> *Chute's Cave -- A Boat Ride of 2,000 Feet Under Main Street.*
>
> *The mouth of the "Chute's Cave" is just below the springs, and the bottom of this cave is covered with about eighteen inches of water. For the moderate sum of ten cents you can take a seat in a boat with a flaming torch at the bow, and with a trusty pilot sail up under Main street a distance of about 2,000 feet, between pure white sandstone, and under a limestone arch which forms the roof. It is an inexpensive and decidedly interesting trip to take.*

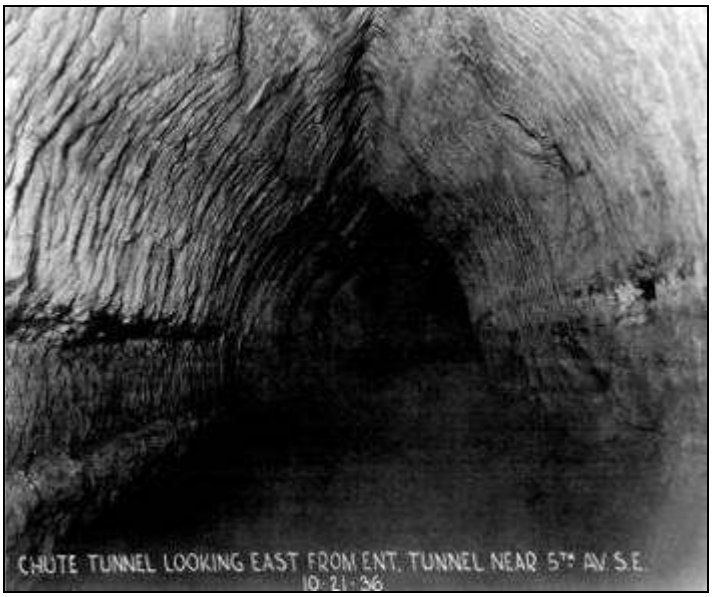
Stereopticon view showing a flat-bottomed boat and pole.




Saint Paul and Minneapolis Pioneer and Tribune, December 1, 1889,

> *But a few years ago not a day passed that did not bring in visitors. A stream of water ran the whole length of the cave, and for the small consideration of a dime, a grim, Charon-like individual would undertake to convey, in a rude sort of a boat, all visitors, who were inclined, for the distance of a quarter or a mile or thereabouts into the gloomy passage.*

The article's "a few years ago" refers to 1881, when a portion of the cave collapsed, taking Main Street with it. The remaining cavern was trussed with wooden beams and closed to the public.




1936

2001

Closed, but not forgotten to the authorities, as evidenced by the Minneapolis Tribune, October 5, 1961, inclusion as a fallout shelter for downtown workers.

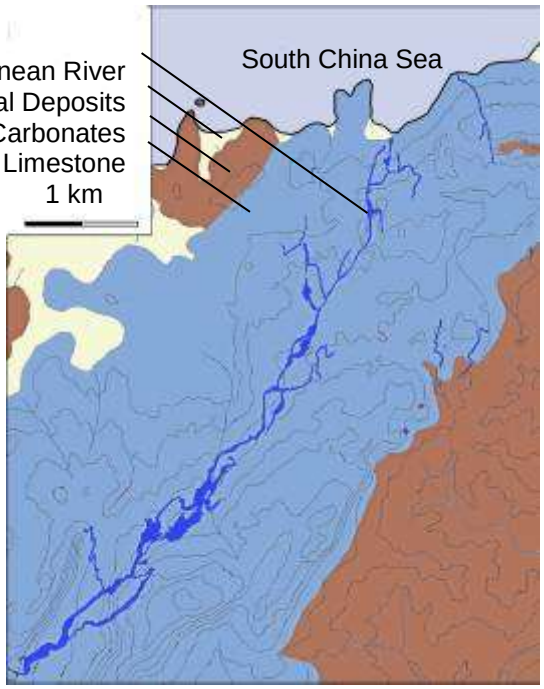

Chute's Cave wouldn't have saved many, however, as radioactive seepage would have continued to drip from the nuclear wasteland above.

Even without fallout, such caverns can be can be deadly. A man died in 2009 when the tunnel he was exploring in Minneapolis-St. Paul filled with rainwater.

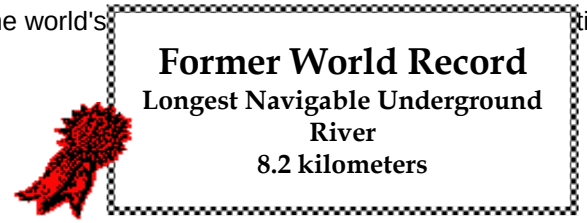
**St. Paul River, Palawan, the Philippines**

And now, a happier story from the Philippines where the St. Paul River flows underground to the South China Sea.

Outlet to the sea.




At 8.2 kilometers in length, the St. Paul was the world's longest navigable underground river until the discovery of the Son Trach in Vietnam.




Outflow daylights 200 meters from the coastline and tides make 6 kilometers of the cavern an underground estuary.

The subterranean river was long believed by locals to be a place of ill omen. There is no documentation of when the underground river was first explored, but painted crosses yet on the walls are said to be markings of Italian priests

The earliest publicized reference to the channel was in an 1887 tour summary by University of Michigan Prof. of Zoology Dean Worcester. “If accounts are to be believed, [there exists] a lake opening to the sea by a Subterranean River.”

Worcester was to become Secretary of the Interior of the Philippine Islands, 1901-1913, during the American rule. From his The Philippines Past and Present (1914),

> *A range of limestone mountains ends at St. Paul's Bay on the west coast of Palawan... Beneath this range lies the scenic wonder of the Philippines, the famous Underground River, up which a ship's launch can run for more than three miles to what is called the "stone pile," caused by the falling of a great section of the roof. One may climb this obstruction, and utilizing native boats dragged over it by my party in August, 1912, may continue for a distance of half a mile, to a point where the roof of the cave drops to the level of the surface of the water, and further progress becomes impossible.*

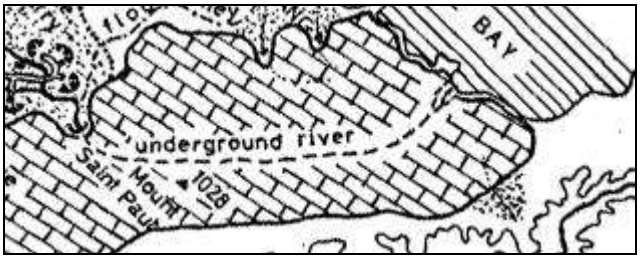
The stone pile and the roof drop call into question the one-time world record claim of 8.3 navigable kilometers, but one might argue that the record book doesn't say "continuous."

> *A trip up this river is an experience never to be forgotten. There is no danger of getting lost, as the three short side passages which run off from the main cavern all end blindly. The channel has been mapped by the Coast and Geodetic Survey and is plainly marked at all critical points.*
>
> *One's launch should be provided with very powerful acetylene lights so arranged as to give a general illumination. Stalactites and stalagmites occur in every conceivable form. There are vaulted chambers which are full of them, and there are long straight passages which lack them and have roofs and walls resembling those of a New York subway. In places the cavern is full of edible-nest-building swifts and of bats. The air in the main passage is fresh. During the rainy season water runs from the roof in many places, and one must expect an occasional shower bath, but this is the only discomfort attendant upon the trip.*

As noted in the New International Encyclopedia of 1918,

> *It has been explored by the Philippine government from its mouth to a point about 3 miles inland, where the roof of the cavern descends to the water's level.*

It wasn't until 1973 that formal geological study began, when D. Balazs of the Geographical Research Institute of the Hungarian Academy of Science and Filipino companions carried out the first documented exploration. A portion of Balazs' map,




Australian speleologists further explored the route in the early 1980s. Italians began explorations in the later 1980s and have extended the surveyed passages (many of which are dry) to 25 kilometers. A sample of their findings: "Recent Explorations in the St. Paul Karst (Palawan, Philippine)," Proceedings of the International Congress of Speleology 15:3 (2009) by Antonio De Vivo, Leonardo Piccini and Marco Mecchia.

> *Cin Galleries (length 1750 m) - This was the most important discovery made in the PPSR* [Puerto Princesa Subterranean River] *during the 2007 campaign. The main gallery is reached through a flooded branch passage, beginning around 1.5 km from the entrance on the left hydrographic side of the main tunnel. The flooded tract is a small size gallery, with a short low passage that is completely closed when the tide is high. Beyond this tract, a wide gallery with a sandy floor is reached, which runs parallel to the main collector. To the S, the gallery continues among large concretion deposits and sand and mud in-fills, and finally reaches a chamber connected to the Navigator's Chamber. Towards the N, the gallery continues wide for ~200 m and then splits into two branches.*

In 2011, bathymetric analysis was carried out from the entrance to Rockpile -- Worcester's "stone pile" -- in which water level and temperature were monitored for 6 days at three sites. Net sea water flux averaged 0.8 cubic meters/second; that of opposing fresh water, just slightly more.

But the most significant work has been outside of the cave.

By the 1970s, the environmentally-disastrous consequence of wholesale logging began to be recognized, culminating in the cancellation of timber license agreements in 1992.

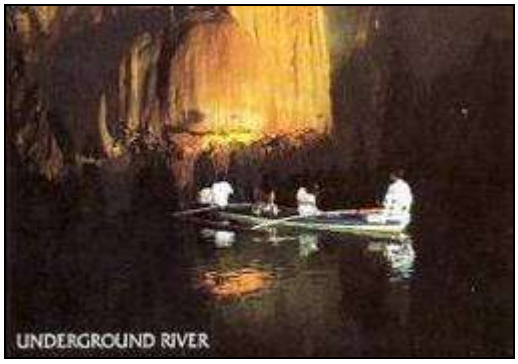
Many conservation efforts came quicker, however. The province was declared a Fish and Wildlife Sanctuary in 1967 and in 1971, the St. Paul Subterranean River National Park was established.

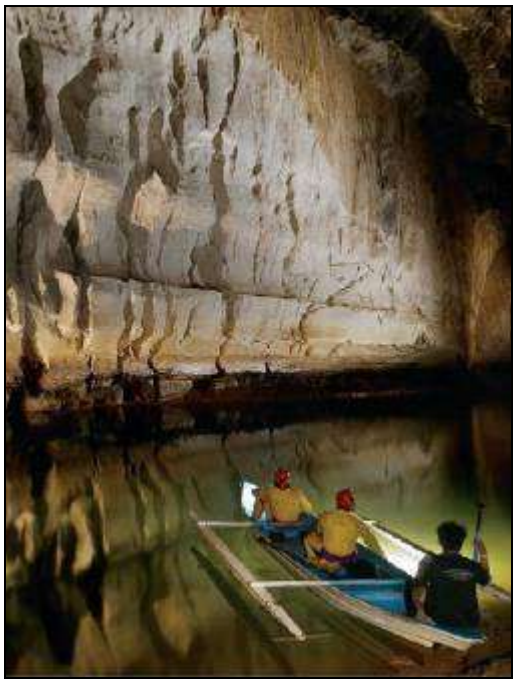
When in 1992, nearby Puerto Princesa City assumed management responsibility, the park was renamed "Puerto Princesa Subterranean River National Park" and the thus cave became the "Puerto Princesa Subterranean River."


An outrigger tour 1.5 kilometers in length-- all that's allowed by the officials -- passes through a cave chamber with a 65-meter ceiling -- there one twice as high further within -- and attracts some 800 visitors daily.

Puerto Princesa Subterranean River
200 pesos

A few photos.



Note the limestone strata to the left.

In contrast with the garish illuminations of many of the world's show caves, Puerto Princesa provides visitors a true cave experience.

A few of the visitors.

After the tour, a 500-peso subterranean river note would buy a hungry family of five each a Jollibee Double Yum w/ cheese, regular fries and regular soft drink.



Puerto Princesa's honors for environmental stewardship are many.

In 1996, the City of Puerto Princesa was officially the “Cleanest and Greenest Component City in the Philippines”

The park was nominated for UNESCO World Heritage status in 1991, but its 5,735 hectares were deemed too small for comprehensive conservation. After land preservation measures brought the total to 20,202 in 1999, the park was awarded the distinction.

The National Geographic named the province as one of the "20 Best Trips of 2011."

And in that same year, the Puerto Princesa Underground River was voted one of the "Seven Natural Wonders of the World."



"Money in the Cave," a get-out-the-vote promotion

St. Paul River of the Philippines marks a victory for both environmental quality and economic development.

**Conclusion**

There are underground river stories that dismay and underground rivers stories that inspire. Tales of St. Paul include both.

# CHAPTER 60
# A SUPERFLUITY OF SURFICIAL STYGIAN STREAMS

Superfluity: an excessively large amount or number
Stygian: of or relating to the River Styx


Our journey has been -- and for most part, will continue to be, -- a subterranean voyage.

The Peloponnesian River Styx of Chapter 1 was named by someone having classical fun with the karst features encircling Lake Pheneus. If there was a pre-Hellenist surficial Styx, we can't be certain, but the Arcadian River Mavroneri is the modern supplication for a Stygian tourist destination.

In Chapter 55, we inspected photos of the Mammoth Cave River Styx. In Chapter 56, we visited the Jenolan Caves River Styx. In Chapter 66, we will visit Ukrainian and British Styx-named excavations. In Chapter 57, we met a River Styx in Oregon. There's also a River Styx Cave in Texas. One comes to anticipate, in fact, that the boatable chamber of any tourist cave will be so named. It's as common as the gift shop.

In this chapter, we will drift a point or two off course to enumerate like-named rivers on the earth's surface. Daylight diversion seems allowable, as all are namesake to the river beneath.

The "River Styx" or the "Styx River?"

As footnoted in Ritchie's Fabulae Faciles, A First Latin Reader (1903) by John Kirtland,

*Stygis fluminis. We say "River Styx," but "Mississippi River."*

Why is this so?

The more-common word-order in naming geographic features is specific identifier, followed by the feature class, but the order is reversed for certain classes.

| Specific/Class | Class/Specific |
|---|---|
| Indian Ocean | Cape Fear |
| Bearing Sea | Port Angeles |
| Atlantic City | Fort Hood |
| Sahara Desert | |
| Baja Peninsula | |
| Suez Canal | |
| Okefenokee Swamp | |
| Mississippi River | |

The order is sacrosanct for most classes. We don't say "Desert Gobi" or "Wayne Fort." The order for lakes, however, is less fixed. We've both "Crater Lake" and "Lake Michigan."

River names can likewise be in either manner, though the preponderance, like the Mississippi, are in specific/class sequence. Rivers in the USGS Geographic Names Information System named in class/specific order include the River Lethe in Arkansas, the River Deshee in Indiana, the River De Chute in Maine, the River Meadow Brook in Massachusetts, the River Raisin in Michigan, the River Rouge in Michigan, the River Gayoso in Missouri, and the River Laurel in West Virginia.

Stygian rivers go both ways -- "River Styx" and "Styx River," according to the mapmakers. For our use, however, we much prefer the former. Inspecting the maps, "River Styx" outnumbers "Styx River" by a factor of 2:1. By Internet hits, it's 6:1.

If we need precedent, Nathan Bailey included "River Styx" in The Universal Etymological English Dictionary (1731).

The general/specific word order has a classical ring, as indeed it should. The Styx mustn't be taken casually.

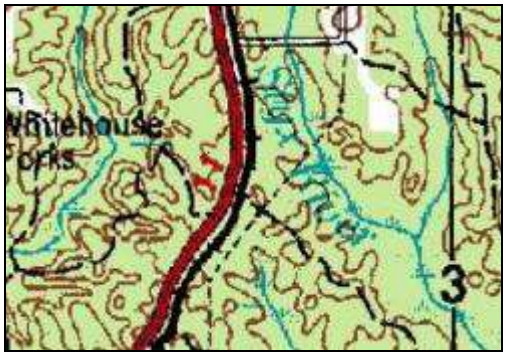
If we're accused of etymologic elitism, we concur. Charon's river is indeed a cut above (or below, as it were) plebian waterways.

So let's look at the Stygian rivers.

**North America**

North America has more than its share of surficial rivers named Styx, 23 of which we'll briefly visit. The map is limited to those on the eastern side for reasons of scale.

Alabama's Styx lies on the Gulf Coast.




Tributary to the Perdido River, Alabama

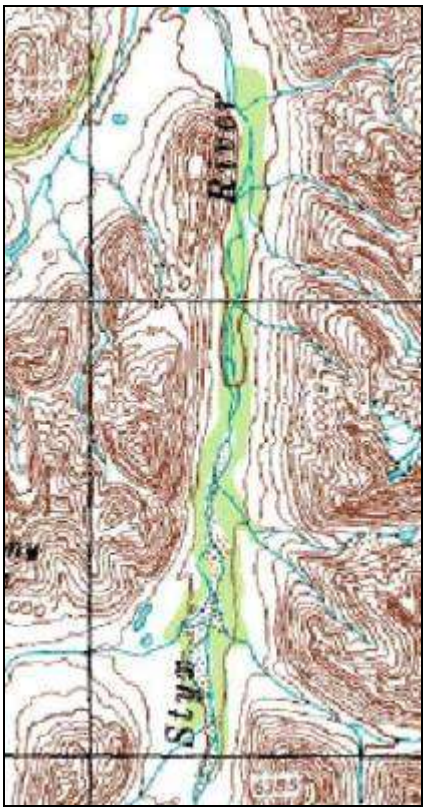
This 50-kilometer river in southwestern Alabama flows into the Perdido River which in turn empties to the west of Pensacola. Given the hurricanes, native population, and swampy environment, Spanish explorers would have indeed felt "perdido," lost. As only Hades could lie up-river, they named it named it the Styx.

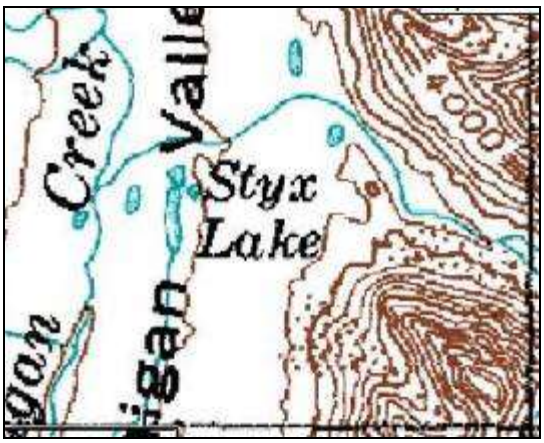
In 1951, an erudite employee of the Alabama Highway Department posted a closure sign at the river crossing, "Charon Retired." The March, 9 Cass City Chronicle reported that local motorists were puzzled.


Robertsdale, Alabama

The resort infrastructure includes the expected, of course, but here there's also the Styx River Water World. Unfortunately, much of its statuary has been vandalized since the attraction was abandoned in 2001.

Alaska's River Styx would have been an exploratory challenge as well.



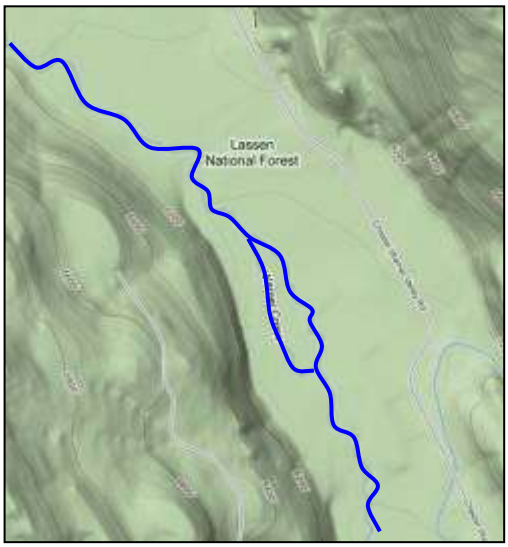




Styx River and Styx Lake, Alaska

Fed by glaciers in the Alaska Range, the river and lake were named by the US Geological Survey in 1898 after the river of Greek mythology.

Although all Stygian rivers share the same etymology, these are the only instances so documented by the USGS.

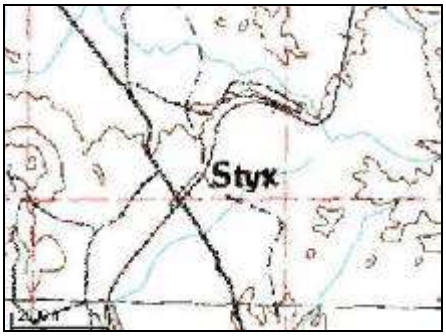
California adds a pair of rivers to our list, one in the north, the other in the south.




Lassen Volcanic National Park, California

*To the west* [of Drakesbad Resort]*, the solfataras of the Devil's Kitchen hiss in the lava-walled "Canyon of a Thousand Smokes," through which flows a tiny stream called the Little Styx.* -- Federal Writers' Project, California A Guide to the Golden State (1939)

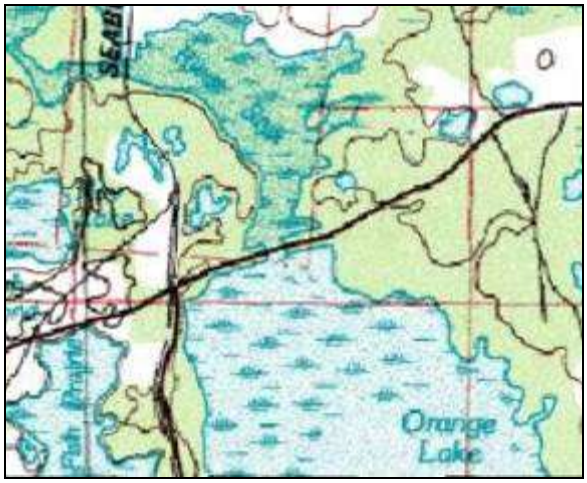
Despite its smoky classical correspondence, the Little Styx has since been renamed Warner Creek




Mojave Desert, California

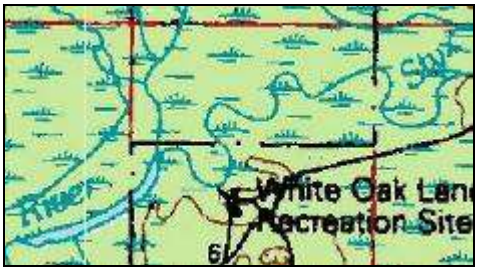
This Styx is easier mapped than found. We'll pass this way again in Chapter 94, The Rio San Buenaventura.

Florida likewise has two.




Alachua County, Florida

River Styx near Gainesville connects Newnan's Lake with Orange Lake through a cypress swamp in which paddlers should be alert for alligators.

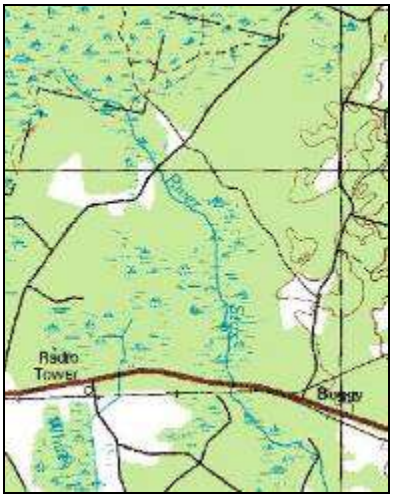



Liberty County, Florida

The Gator State's western Styx flows to the Apalachicola River through the state's least-densely populated county.

The state of Georgia has two small rivers named Styx, both flowing into swamps

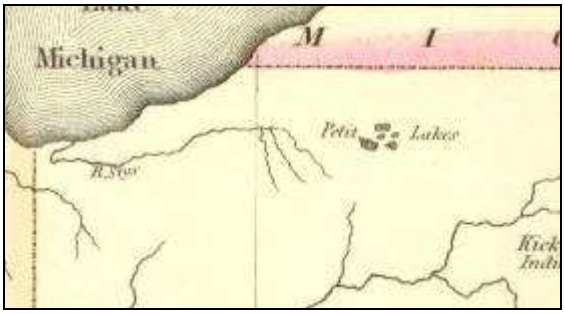

Savannah River Watershed, Georgia




St. Marys Watershed, Georgia

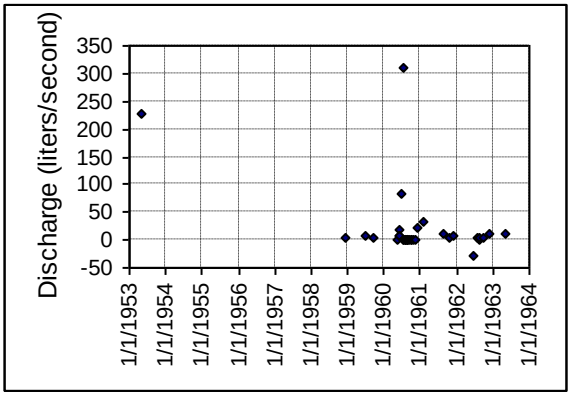
Along the southeastern fringe of Okefenokee Swamp

The River Styx of Indiana Geographical, Statistical, and Historical Map of Indiana (1822), Lucas Fielding, appears to be the east arm of the modern Little Calumet River, a system reasonably preserved near its La Porte headwaters, but increasingly obliterated toward Gary.




As noted in Chapter 55, Mammoth Cave, Kentucky's subterranean River Styx makes a short, sunlight escape to the Green River. As the flow is typically just a few liters/second, the "river" designation is but honorific.


As can be seen from the plot, stream gaging on the Styx has been sporadic and short lived, but the record does catch one instance of reverse flow brought about by flood level in the Green.




Louisiana's River Styx Bayou flows into the Ouachita River. The US Army Corps of Engineers proposes to reduce flooding from interior ponding by an additional pumping station adjacent to River Styx Bayou and improved levee alignments.


Crossing Louisiana's River Styx, circa 1900

Michigan adds two rivers to our collection.


Ives Lake Outlet, Marquette County


Montcalm County

The bay at Hopatcong, New Jersey, is not a river, but none the less called River Styx.


Ohio's River Styx is also a community.



Atlas of Medina County, Ohio (1897)

Legends vary regarding the name.

> The river was named to warn citizens away from Bear Swamp and its bootleggers, robbers and renegades.
>
> Settlers, trying to burn out a rattlesnake den, destroyed the forest and all the game in it. Discouraged and faced with starvation, they nicknamed the settlement, River Styx.
>
> Local residents once kept the Cleveland medical colleges supplied with laboratory material by grave robbing.
>
> Natives called the river "Sticks River" because of the difficulty of paddling canoes on the small, cluttered waterway.
>
> The town was said to be the site of Ohio's first match factory where "fire sticks" were manufactured.

Neither of the last two account of a change of spelling, however.

But we must move on.


Sevier County, Tennessee

As confirmed by the US Geological Survey, the Styx flows through Hell.


Grant County, West Virginia

"Fairfax Lands along Patterson Creek, 1746-1781." This River Styx is now called Stony River.

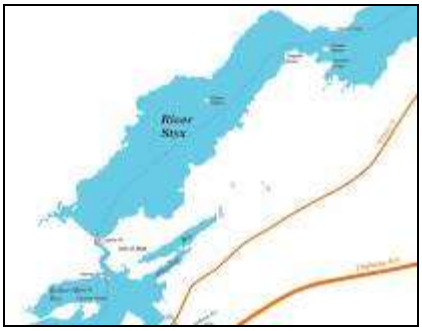

Orellie County, Washington

An international waterway.

Camp Styx, South Carolina, a World War I Army base, returned to life in 1935 as Styx State Fish Hatchery constructed by the Civilian Conservation Corps. In 1985 the facility was renamed the Cohen Campbell Hatchery in honor of a deceased manager.

As the hatchery is proximate only to Congaree Creek, the camp wasn't named "Styx" for its water source. It seems macabre, however, to have named the facility with the doughboys in mind.

As South Carolina is woefully lacking in notable caves -- this is a hydrologic fact -- perhaps the name was the state's grasp for subterranean territory. Further evidence of failed Carolinian subterranean claims may be found in Chapter 80, Railroads and Incrusted Lakes.




Ontario, Canada

This River Styx is today a broad, shallow section of the Cataraqui River flooded for navigation.

Prince Edward Island, Canada

Between Muddy Creek and Union Corner

British Columbia, Canada

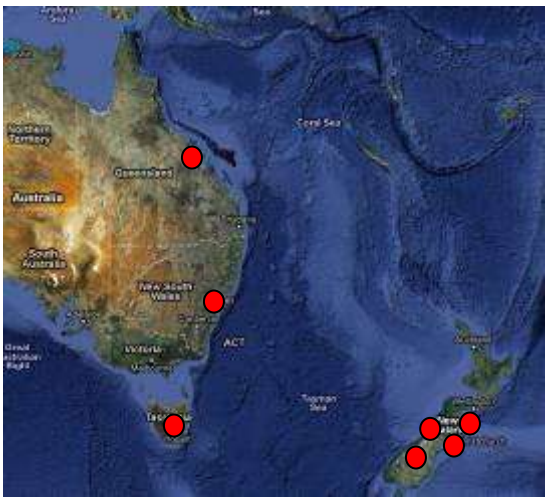
Summer discharge from Styx Glacier

Jamaica

There are three Stygian rivers: at Westmoreland, St. Elizabeth and St. Thomas.

**And Elsewhere**

Australia and New Zealand add another seven.




,

Queensland, Australia

This River Styx is a short channel in Charon Point Conservation Park which delivers significant sediment to Broad Sound. The wide mouth results in a 0.5-meter tidal bore and sharks are known to feed behind the advancing surge.


New South Wales, Australia

This River Styx rises in a spur of the Great Dividing Range and flows initially away from the coast through the Styx River National Forest


Tasmania, Australia

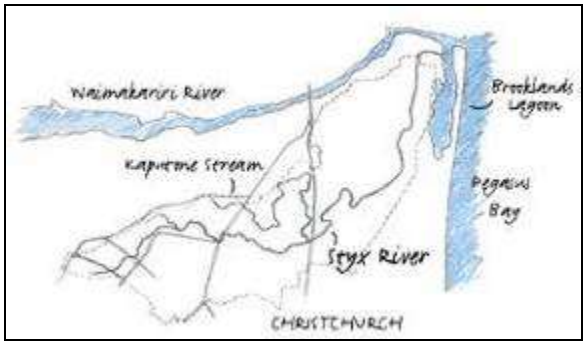
The Styx Valley contains the tallest hardwood on earth, Eucalyptus regnans. Australia's most massive tree, "El Grande," discovered in 2002, was lost to a fire the following autumn.

Western District, New Zealand

This River Styx is noted for its fishing. The valley is bordered by the Tasman Sea to the west and the Southern Alps to the east.

Marlborough, New Zealand

This Styx flows into the Clarence River in New Zealand's northeast. Nearby, of course, is the River Acheron.




Christchurch, New Zealand

In 1856, this Styx and its tributaries were surrounded by extensive wetlands and possibly flowed to the larger Waimakariri River. Today it's a suburban stream.

Otago, New Zealand

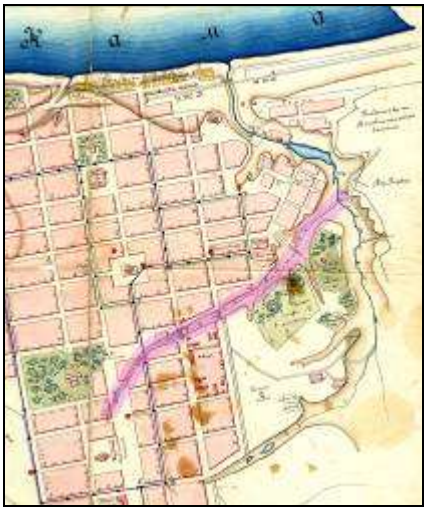
This River Styx was given its name because of its gold-rush-era service as a natural moat around the Paerau Prison. Today it is home to the extensive Taieri wetlands.

There are three versions of how the river near Christchurch received its name. In one, European settlers crossed the river on flax-stick rafts -- hence the name "Sticks." In a second version, the bundles of flax sticks were laid in the bed of the river. The third version suggests that flax sticks were stuck in the ground to guide travelers to a log bridge. In any case, the spelling was changed to "Styx" in the 1865-66 Register.

And still there are more.

Peak Cavern, Great Britain

The tumbling River Styx emerging from the cave mouth known as "The Devil's Arse," Chapter 56, The Tourist Trade Worldwide.



Perm, Russia, 1883

"Styx" in Russian is "Стикс."

New Caledonia

Styx Passage is not a river, per se, but a waterway of peril.


French Southern and Antarctic Lands

Le Styx is a stream in collection of volcanic islands having no permanent population, but issuing postage stamps.

**A Neopolitan Discovery**

We'll insert a relatively-recent discovery, not a surficial stream and thus technically outside of this chapter's surficial scope, but an informative example of how proper names can be cast about.

In the Footsteps of Orpheus: The Story of the Finding and Identification of the Lost Entrance to Hades, the Oracle of the Dead, the River Styx, and the Infernal Regions of the Greeks (1968) describes author Robert Paget's discovery of the classical River Styx on the shores of the Bay of Naples. That "this great archeological discovery by Robert Paget, formerly of the Royal Navy, and by Keith Jones of the United States Navy" lies counter to most academic opinion is of no consequence, we are assured, as

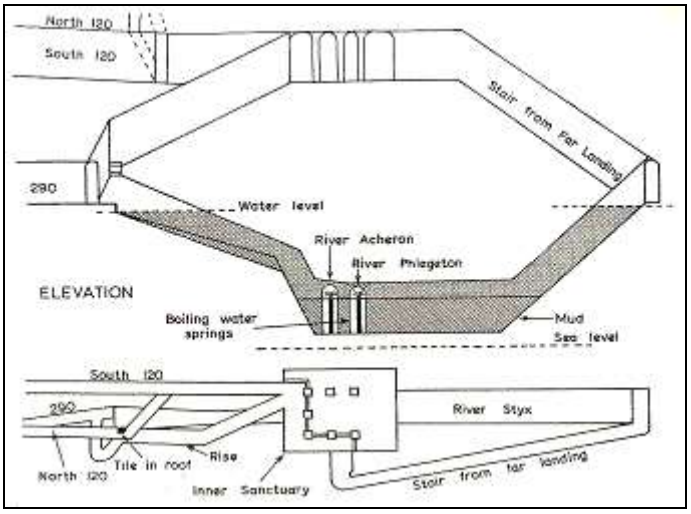
> *One of the great fascinations of archaeology, is that the evidence upon which many of the deductions are made is scrappy, to say the least of it. A piece of broken pot, a fragment of human cranium, the date on a coin -- ten professors will give ten different interpretations, and each swear that his is the only possible version. I have had quite an experience of this in the last five years, and I now have no hesitation in putting forward my own hypotheses, based upon scanty evidence, if they seem likely to provide a starting point from which to work. Most of the deductions in weighty volumes, derived from the fragmentary evidence of pre-history, are little better than intelligent guesswork, however much they may be wrapped up in learned jargon.*

With that surety, we'll summarize the discovery.

Circe's instruction to Odysseus were,

> *Beach your boat here by Ocean's swirling stream and march on into Hades' Kingdom of Decay. There the Flaming River and the River of Lamentation, which are branches of the River Styx, unite round a pinnacle of rock, to pour their thundering streams into Acheron. This is the spot, My Lord, that I bid you seek out.*

Odysseus does this, arriving at what Paget calls the "Great Atrium of the Oracle of the Dead." The tunnels probed by Paget, according to his spelunking, satisfied the specifications for the Great Atrium. Water at the bottom must be the primeval Styx.




"River Acheron" and "River Phlegeton" are author-assigned names for nothing more than thermal vents, respectful labels, we agree, but at the same time, further example of how honored names are transported.

The classical Styx was said to corrode all but a horse's hoof. That the water of today is good to drink apparently documents environmental improvement.

**The Broader Question**

And why, we must ask, are there so many Stygian rivers in broad daylight?

The answer seems to have little to do with subterranean origin, as only one of our survey -- the one in Britain -- is headed at a cave mouth.

The answer seems to have little to do with fluvial geomorphology, as our spectrum ranges from glaciers to bayous, cascades to meanders, bays to arroyos.

The answer may, however, relate to geochemistry. Consulting the Chapter 40 map of karst geology, 16 of the United States Stygian rivers are in or near karst terrain. The Ontario and British rivers are in limestone areas. Jamaica is basically a brick of carbonates. Although the Australian continent is only a few percent karst, none of its Stygian rivers are distant from karst landforms. New Zealand's South Island, on which all four Styx rivers of that nation lie, has notable karst. The river-namers would have been aware of regional geology, and having been educated in an era when the classics were foundational, perhaps made connection to that folklore.

The answer in some cases derives from the toil of exploration. Rivers inhospitable to exploration were named in frustration at best, in tragedy at worst.

As noted in Chapter 36, artists prefer a well-illuminated Styx. An accurately dark realm, we suppose, would be difficult to paint. As with the illustrators, our own imaginations -- and thus our namings -- pull the inky waters into visibility.

In lieu of descending into the darkness to meet Charon, we prefer him to emerge in the noon-day sun.

# CHAPTER 61
# UNDERGROUND RIVERS ON POSTAGE STAMPS

We've already begun using vintage postcards as illustrations along our underground river journey and we will continue doing so. While a digital photo accurately conveys visual reality, even a grainy penny postcard has a social dimension. It's what travelers might have saved as a memento, what friends and relatives might have received in the mail, and in the larger sense, a snapshot of society's awareness.

Postage stamps have somewhat the same quality. Hobbyists collect them over a lifetime, but for those who don't, who among us can't recall childhood awe at a stamp from a distant place and wonder about the wider world?

Postage stamps are today issued in such proliferation (roughly 10,000 issues/year, worldwide) that serious collectors must specialize, most often by country or region. Other hobbyists build topical collections, one group being those who accumulate stamps with geological themes. Speleologists who are also stamp collectors are prone to favor stamps featuring caves, of which there are in the order of 160.

Our collection is yet more focused -- only postage stamps illustrating underground rivers. If we relaxed the criteria to that of caves which have underground waters, we might as well just do caves.

Here is our collection.

**Barbados**


1981
Harrison's Cave, Rotunda Room Stream


1981
Harrison's, Cave Cascade pool


2000
Harrison's Cave. Travel by tram, but visitors are allowed to alight at certain points and approach the formations.

**Belgium**


1976
Remouchamps Cave's boat tour "glides mysteriously and without a sound over the winding subterranean river of almost 600 m in length."


1991
Neptune Cave. The boat ride takes 20 minutes.


1996
Han-sur-Lesse Cave. 3 stars in the Michelin guide. The tram's a century old. There's no bear.

**Bermuda**


2002
Fantasy Cave links to…


2002
Crystal Cave. The cave floor can be seen 17 meters below the water surface.

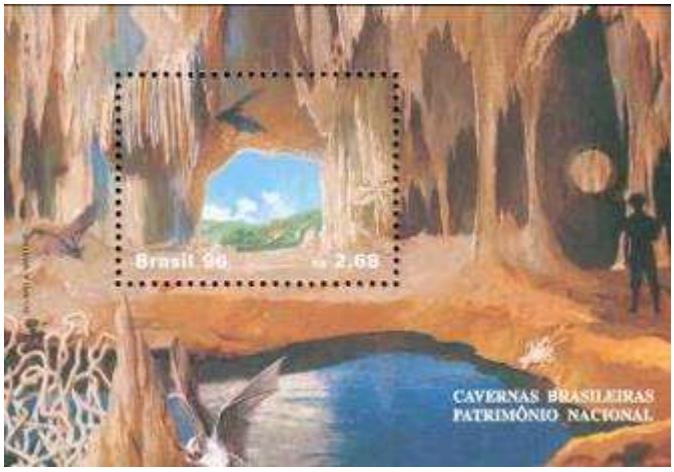

2002
Prospero's Cave contains an underground bar and discotheque.

**Bosnia and Herzegovina**


1999
Buna Cave, the greatest European river springs, 30 cubic meters/second.


2008
Vjetrenica Cave (Chapter 78)

**Brazil**




1996
Gruta do Lago Azul

**Czech Republic**


2003
Punkva Cave (Chapter 56)

**Ethiopia**


1983
Sof Omar Cave. A river rushes between narrow crevices.

**East Germany**


1977
Spring von Plaue, 0.6-0.8 cubic meters/second.

**Gibraltar**


2003
St. Michael's Cave. As the Rock of Gibraltar was thought to be one of the legendary Pillars of Hercules, the Greeks believed this to be a Gate of Hades.

**Greece**


1980
Dyros Cave. *We entered the cave and to our surprise the thing we noticed first was the large cloud of smoke that was lingering about. The staff of ferrymen and assistants smoked in the cave and as the entrance is so small the smoke just lingered about the place... We were instructed to remain seated and not to extend our hands outside the boats as we began our journey through the cave propelled by the standing ferryman who used a long stick to push the boat along.* -- A recent tourist

**Hungary**


1989
Baradla Cave. Another River Styx (Chapter 60)


1989
Tapolcai Cave. The rim-stones of the cave pools were destroyed in 1938 to allow boating. A 25-meter tunnel was blasted to allow a round trip and the creek was dammed outside the cave to raise the water level within.

**Italy**


1982
Frasassi Cave

**North Korea**

2002
Ryongmun Cave

**South Korea**


1973
Kusan-Ni Cave, noted for its pillars formed by stalactite and streams that flow between.


2009
Jeju Lava Tubes. World Natural Heritage, 2007


2009
Jeju Lava Tubes. Rare caves because despite being lava tube caves, they also display limestone formations.

**Kosovo**


2011
Grand Canyon Cave in Peja

**Lebanon**


1967
Jeita Cave (Chapter 56)

**Malaysia**


2009
Deer Cave contains the world's largest karst cavern, large enough to contain London's St. Paul Cathedral five times over and accommodate 40 Boeing 747s side by side.

**Niue**


1950
Makefu Cave. Niue is a limestone block in the Pacific.


1998
Underwater cavern. Niue is best known for its postage stamps and coins.

**Romania**

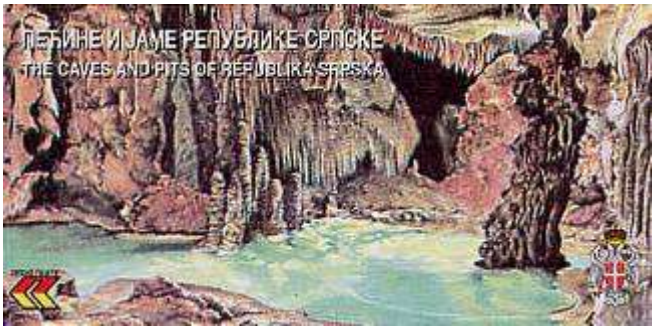

1978
Epuran Cave

**Philippines**


1998
Puerto Princesa


2008
Puerto Princesa

**Serbia**




2001
Cover of stamp booklet. None of the six stamps, however, illustrate water features.

**Spain**


1964
Cueva del Drach (Chapter 54)

**Tonga**


1953
Swallows Cave, a sea cave

**United States**


2010
Cave Habitat. Zazzle Inc., an approved licensed vendor of the US Postal Service, prints valid postage stamps per customer design. Twenty 44-cent stamps cost from $20.60 to $23.15.

**Venezuela**


1960
Curea de Guacharo, Venezuela's first National Monument.

**Viet Nam**


1984
Hang Bo Nau Cave


2006
Xuyen Son Cave

As noted in Chapter 57, The American Tourist Trade, the United States is historically prone to assert world records. We are thus disappointed with the scant American philatelic participation, a single underground river stamp, and even that being of a variety more often produced for wedding invitations. Why a nation that honors the Homer Simpson family with a set of five has issued but one commemorative for Mammoth Cave National Park, and that without the Echo River, we do not comprehend.

The best we can do is to take a stamp from a European nation of which few Americans (other than stamp collectors, that is) have ever heard, affix it to a Mammoth Cave postcard and post it riverside.

**United States**


2006
Mammoth Cave

**San Marino**


1965
Doré's Charon (Chapter 6, Back to the Cross) on the River Styx (Chapter 60, A Superfluity of Surficial Stygian Streams)

While the blasé US stamp was postmarked a mere 140 feet below, ours (as repeatedly noted on the postcards of Chapter 55, Then, Madam, You Should Go and See the Great Cave in Kentucky) would be mailed at minus 360.

# CHAPTER 62
# THE TASTE TEST

*Water, thou hast no taste, no color, no odor; canst not be defined, art relished while ever mysterious.* -- Antoine de Saint-Exupéry, Wind, Sand, and Stars (1939)

*Well, art is art, isn't it? Still, on the other hand, water is water. And east is east and west is west and if you take cranberries and stew them like applesauce they taste much more like prunes than rhubarb does. Now, uh... now you tell me what you know.* -- Groucho Marx, Animal Crackers (1930)

Saint-Exupéry and Marx, notwithstanding, water -- underground river water, in our case -- does have a taste, one imparted by its mineral content, those naturally-occurring substances, solid and stable at room temperature, that have an ordered atomic structure.

Though raindrops contain dissolved atmospheric gasses -- the reason for karst, Chapter 40 -- they are mineral-free until they hit the earth. Groundwater that has had centuries to dissolve soluble ions, on the other hand, can be highly mineralized.

If a subterranean channel is fed from quick runoff into a sinkhole or influent cave, by virtue of its short tenure on the ground, its mineral content is unlikely to have attained high concentration.

In slowly percolating through the topsoil and gradually seeping into the conduit network, however, the water gains constituents. But once flowing in an underground channel, there's little time for additional solute harvesting. A subterranean stream's mineral content will thus be limited. Consider the following water samples.

| Concentration (mg/L) | Spring, Sierra Nevadas, Short residence | Volcanic rocks, New Mexico | Supai Limestone, Grand Canyon | Metamorphic rocks, Canada, Long residence |
|---|---|---|---|---|
| Calcium | 3 | 6 | 144 | 4540 |
| Magnesium | 1 | 1 | 55 | 160 |
| Sodium | 3 | 37 | 27 | 2740 |
| Potassium | 1 | 3 | 2 | 32 |
| Bicarbonate | 20 | 77 | 622 | 55 |
| Sulfate | 1 | 15 | 60 | 1 |
| Chloride | 1 | 17 | 53 | 12600 |
| Silica | 16 | 103 | 22 | 9 |
| Total Dissolved Solids | 36 | 222 | 670 | 20338 |

The dominant constituents at any site reflect the geologic environment, obviously not the same between the locations, but the overall trend is significant. The short-residence Sierra Nevada spring is almost mineral free. The long-detained Canadian water is mineral-laden and salty.

There will, of course, be subterranean conduits bearing high solute loads and fossil groundwaters without many minerals, but it's most likely that underground streamflow will be moderate in mineral content.

**Taste**

What we perceive as "taste" is in fact a combination of taste-bud, smell and tactile sensations. We want our drinking water to be refreshing, odor-free, cold and perhaps with a few bubbles suggesting freshness.

But a word of warning -- Flavor is no guarantee of hygienic quality; what's disagreeable to the tongue is not necessarily adverse to human health.

While there's no metric, per se, of taste, a few chemical measurements may suggest how a particular water will taste. We'll by no means cover all constituents that might affect a water's flavor, but we'll mention a few that are commonly-monitored. We'll go only lightly on the chemistry, as our goal is one of awareness.

Hardness

Taste buds appreciate a subtle bouquet of minerals.

| | | |
|---|---|---|
| Calcium, Potassium Magnesium, and Sodium | in combination with | Chloride, Sulfate, and Carbonate |

Hardness is a measure of calcium sulfate and/or magnesium sulfate, but occasionally ferrous sulfate. Total hardness is reported as its equivalent concentration of calcium carbonate.

| Hardness | mg/L |
|---|---|
| Soft | < 60 |
| Medium | 60 to 120 |
| Hard | 120 to 180 |
| Very hard | >180 |

Pure rainwater, the ultimate "soft" water, is often deemed to taste flat and dull. Groundwater, on the other hand, that has spent centuries dissolving minerals from aquifer rock, can sometimes taste metallic or salty.

For drinking water, hardness of 80 to 100 mg/L as calcium carbonate is a balance between "tasteless" water and that with a mineral aftertaste. Above 500 mg/L is normally considered unacceptable for domestic purposes, though it poses no health hazard. Groundwater in protracted contact with soluble rock can have a hardness exceeding 1000 mg/L.

Streamflow in karst conduits tends to be harder than streamflow on the upper surface, but the degree decrease when recharge -- and thus dilution -- is high.

As the Echo and Styx subterranean rivers of Mammoth Cave, underground rivers with which we shall become more familiar in Chapter 55, are well-documented in terms of water chemistry, we'll use them as examples.

| Hardness (mg/L | Styx River Spring | | Echo River Spring | |
|---|---|---|---|---|
| | January-December | July-September | January-December | July-September |
| Maximum | 294 | 194 | 200 | 153 |
| Minimum | 89 | 120 | 86 | 110 |
| Mean | 144 | 156 | 125 | 131 |

Whereas water in both cave rivers is moderately hard -- not unexpected, given the geology -- there is no record that the hardness has elicited objections from thirsty tourists.

Total Dissolved Solids, Salinity, Chloride

The Total Dissolved Solid (TDS) content of water encompasses all constituents that would remain after evaporation. “Salinity,” on the other hand, reflects what we perceive to a particular taste. Sodium chlorides have this characteristic, but so can nitrate, calcium, magnesium, bicarbonate, and sulfate.

A few examples of natural chloride concentrations,

| Chloride | mg/L |
|---|---|
| Amazon River | 40 |
| Colorado River | 700 |
| California Drinking Water Limit | 1,000 |
| Slightly saline | 1,000 to 3,000 |
| Moderately saline | 3,000 to 10,000 |
| Highly Saline | 10,000 to 35,000 |
| Seawater | 35,000 |

In terms of our perception,

| TDS | mg/L |
|---|---|
| Fresh | < 1,500 |
| Brackish | 1,500 to 5,000 |
| Saline | >5,000 |

Again using springflow at Mammoth as an example,

| Chloride (mg/L | Styx River Spring | | Echo River Spring | |
|---|---|---|---|---|
| | January-December | July-September | January-December | July-September |
| Maximum | 550 | 185 | 740 | 442 |
| Minimum | 1 | 7 | 1 | 1 |
| Mean | 64 | 61 | 18 | 20 |

By any measure, the rivers within the cave are not salty.

Iron

Even a slight concentration of soluble iron can impart a reddish brown color to water. The taste of iron is said to be "rusty," a definition somewhat circular. What's bad to our eye is likewise perceived by our tongue. When iron exists along with certain kinds of bacteria, the organisms leave a reddish slime that can clog plumbing

| Iron | mg/L |
|---|---|
| Reddish color | as low as 0.30 |

Our Mammoth example,

| Iron (mg/L | Styx River Spring | | Echo River Spring | |
|---|---|---|---|---|
| | January-December | July-September | January-December | July-September |
| Maximum | 1.50 | 0 36 | 0.88 | 0.50 |
| Minimum | 0.01 | 0.01 | 0.00 | 0.01 |
| Mean | 0.21 | 0.18 | 0.13 | 0.13 |

While the Mammoth Cave rivers are generally below problem iron concentrations, on same days the levels are higher than desirable. As both springs immediately flow into the Green River, however, dilution mitigates any consequence.

Sulphur

Chapter 51, Snotties, Floating Dumplings and other Earthly Delights, made us aware of how toxic sulfurous cave river water can be, but there is also the potential for issues at lower concentrations.

Even a slight level of hydrogen sulfide can cause water to have a rotten-egg odor. Sulfates are less noticeable.

| Sulphur | mg/L |
|---|---|
| Hydrogen Sulfide | a few tenths |
| Sulfate | 250 |

Sulfur has not been regularly monitored in our two Mammoth springs because there's been no perception of a problem.

**Municipal Water Systems**

Seventy-five percent of American cities draw upon groundwater for water supply, but as we're aware from Chapter 39, we're talking about aquifers, not subterranean streamflow.

That doesn't mean that the public sees it in that light, of course. "We Tapped an Underground River," American City, March 1962, has to do with municipal water supply for Puyallup, Washington.

> *We were making plans here in the water-rich Northwest to harness a standby source by tapping a newly discovered underground river ten feet deep and a mile wide... The floor of the canyon, however, yielded some surprising results. Wherever they drilled, water rose in the pope to a height of six feet above the canyon floor. Analysis of these results and a study of nearby well logs indicated the existence of a stream of course gravel a mile wide that extends in a southerly direction toward Mount Rainier. Overlaid with a six-foot depth of relatively impervious material, this glacial stream bed is responsible for the artesian flows.*

The disquieting aspect is its headline in a professional journal.

For the record, the City of Puyallup today draws water from two springs and five wells and there's no mention of an underground river in the City's informational bulletin. Natural chloride concentrations range from 1 to 14 mg/L; iron ranges from non-detectable to 0.14 mg/L. As with the news item from 1962, there's really not much news involved.

**Bottled Water**


In excess of $100 billion is spent each year on bottled water. At $1 for a 20-ounce bottle, the cost is 5 cents/ounce. At $4/gallon, gasoline is about 3 cents an ounce. Municipal water typically costs less than 1 cent/gallon.

"Mountain Top" natural spring water is not from mountain tops (Chapter 8, Subterranean Engines), but rather from beneath our feet.

Vitapress, a Hungarian company, discovered an "underground river" while drilling a well for its line of soft drinks. Water from the source, bottled under the name Szentkiralyi, is distributed throughout Europe.

> *From a depth of over 200 meters, originating in an underground river several millions of years old, our water travels through 15 layers of strata to develop its mineral composition and unique pure flavor*.

One need only to peruse the advertisements to discover other bottled waters claiming like origin. Millgate Cottage's product "comes from an underground stream." Evamor Natural Artesian Water is "sourced from an underground stream accumulated thousands of years ago."

There are, of course, more-affordable bottling options. Entrance to Cave Spring Cave, Cave Spring, Georgia, is just $1.00. It's not a "show cave," but it's clean and produces 100 liters/second, free for the taking to those with bottles. The water's been featured on Food Network's "Good Eats."

Cave Spring, 1908

Cave Spring, 1915


Cave Spring today

**Beer**


Chapter 43, Insurgent Streams, sorted through some of America's "Lost Rivers." The one in southern Indiana is the inspiration for Lost River Blonde Ale, Cutters Brewing Company, Avon, Indiana.

On the Lost River Blonde Ale bottle,

> *The Lost River. Like southern Indiana's magical waterway, Lost River is a natural wonder... It's no mystery how Lost River can make any thirst disappear.*

There's no claim that the brew contains water from that particular stream, but the inference is marketable not only in Indiana, but also in West Virginia, with its Lost River Brewing Company, Wardensville.

The Silverstream Brewery, built in 1861 in Toowoomba, Queensland, drew its water from what was said to be an underground stream, the finest water in the Commonwealth.

The facility passed to Queensland Brewery Ltd., and then to Carlton and United Breweries, before closing in 1976. The McDonald Printing Group still uses the water for its drinking fountains.

The water of "It's the water" in Olympia Beer, on the other hand, came from mountain streams, but according "Underground River Discovered near Olympia," Oregonian, May 21 1927, that's because the brewers didn't look under their feet.

*"It's the water," was the slogan of the once famous Olympia brewery which flourished prior to the advent of the 18th amendment. But the water is just as important in paper-making, as it is in beer-making, and the owners of the brewery had no idea that any such inexhaustible supply as that just brought on by the Tumwater Paper Mills company existed literally "under their feet." The paper concern is converting the old brewery buildings and installing machinery to make wrapping paper.*


*Seeking a greater water supply, they drilled down 103 feet and struck... 1500 gallons a minute... G.F, Kuenzel and A. Adams who did the drilling assert that the supply is inexhaustible and... that they have tapped an underground river.*

**Whiskey**

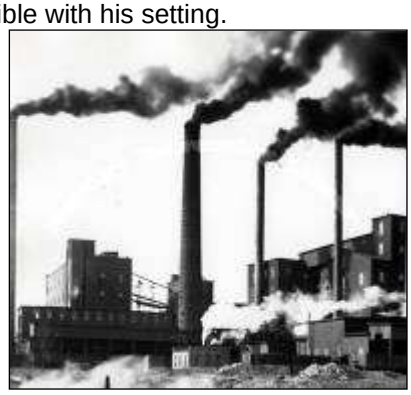
Underground rivers, or at least the speleogenic evidence thereof, have close associations with the production of intoxicating spirits.

From the Frederick, Maryland Daily News, March 9, 1894,

*A message in a bottle was picked up the Potomac, near Cumberland, stating that the writer was penned up in the mountains by moonshiners.*

"Cumberland" sparks our interest, as Cumberland Caverns and Cumberland Gap Cave, Chapters 37 and 57, are situated in Appalachian karst, a landscape well suited for illicit stills. Though just another "I'm being held a captive" hoax, the jokester was plausible with his setting.

Between 1837 and 1919, 24 breweries and 73 distilleries in Peoria, Illinois, produced as much as 70 million liters of alcohol a year Peoria was the world's largest corn-consuming market. Great Western Distillery, built in 1881, was the world's largest distillery.



Great Western Distillery, circa 1915

As recorded in Reports of the Industrial Commission 1 (1900), Peoria was well suited as a distilling center.

*The special water supply is of great advantage. There is an unlimited quantity of water from wells about 30 feet deep, having temperature the rear round of about 54 degrees. This is used for cooling the warm mash and is much more satisfactory and economical than ice.*

What accolade could be higher for an underground river than that of being the best water for whiskey-making. From Prescott Evening Courier, December 29, 1920,

*Flowing at some depths beneath the residence and business section of Peoria is a large subterranean river, the existence of which made Peoria the biggest whiskey distilling center in the country in the pre-prohibition days.*

*The stream, which flows at right angles beneath the Illinois River at the edge of Peoria, is of unknown volume. More than a dozen wells sunk through the bottom of the upper river by*

*distilleries to tap the subterranean body of water have failed to diminish the flow of the lower stream.*

*From these wells comes a water of unusual warmth and softness and it is this water that drew the largest distillery in the world to Peoria, as well as several smaller ones. Practically free from acid and alkali the water required no special treatment before being fit for whiskey distillation purposes.*

Moonshine was brewed in Tennessee's Forbidden Caverns from the early 1920s until 1943. The cave's water supply and isolated locale made the site well suited for its usage.

The paraphernalia remains on display for the visitor.

The history of Robber Baron Cave compiled by the Texas Cave Management Association makes mention of underground rivers, though no such waterbodies are now accessible.

*Ray T. Dixon remembered that in 1927 the cave extended east, well beyond Nacogdoches Road, but its major extent was to the southwest. In that direction about 100 m beyond the Pavilion Room, was the "tunnel to the stream." His estimated distance from the entrance to the stream was about 400 m:*

*"Go in about a quarter mile... step down 4 feet into a passage about 40-50 feet long where you crawl on your hands and knees...step down, turn right, and go 25-30 feet to reach the river."*

*Dixon claimed the river was "about 8 feet wide and 2 feet deep." The river came out of one wall and went into the other.*

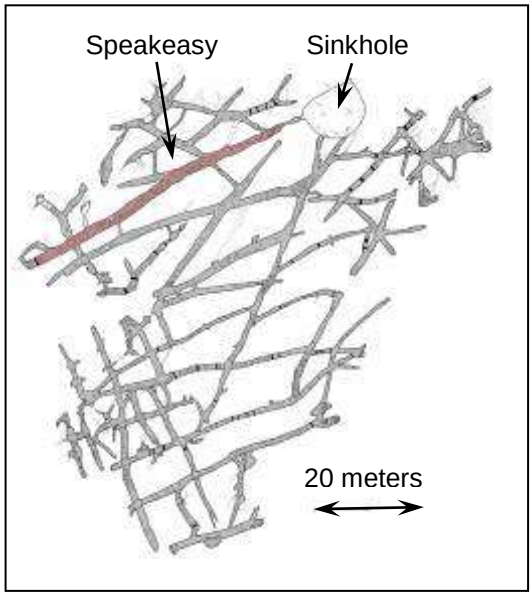
*Dixon also mentioned that he saw pinkish-white eyeless fish in the river.*

*Ted Zettner elaborated on one particular trip he made into the cave in 1925... Eventually they reached a steep mud slope down into a lake room. Like Dixon's river the lake had blind fish in it. Unlike the river, a water well pipe intersected the cave and the lake. Its pump on the surface could be plainly heard in the cave. Zettner and his friends played in the water and then left the cave.*

*In 1925 there was only one windmill in the direction Zettner's group had been traveling. Fifty-one years later, Zettner pinpointed the well's location at 1.4 km southwest of Robber Baron Cave. Upon exiting the cave in 1925, Zettner and company approached the farmer who owned the well to inform him of their discovery. The farmer replied, "So you're the little bastards who muddied my water!" That day had been the only time the farmer pumped muddy water from his well. Connection confirmed.*

Robber Baron was a tourist attraction in the early 1920s with a cable car to the entrance. For 50 cents, the tourists could descend wooden stairs into the sinkhole and then enter the cave, where about 250 meters of passage were illuminated.

1921 Postcard




And why is this cave in a chapter about thirst, one might ask?

Because of its role as a speakeasy.

In 1925, the cave was raided by Prohibition Agents in search of "a still and modern Monte Carlo."

San Antonio Light, July 21, 1925.

> *Primed for a big raid, the agents entered the cave and searched for hours. Nothing could be found – not even the way out. For three and one-half hours every turn was investigated, only to end in a blank wall. Flashlights were growing dim from constant use and matches had all been used... Prospects weren't pleasing.*

Fortunately for the revenuers, a man stationed at the entrance sought help, who led them out before they completed their mission.

The proverbial underground river spoke to opponents of liquor, as well. "Degeneracy and the State," American Advance, May 13, 1911, turns to the Echo River and Darwinism (Chapter 50).

> *Degeneracy is nothing more or less than the accommodation of the human mind and character to circumstance. The evolution in type the horse, the elephant and a thousand forms of animal life prove this in the physical world. In the Mammoth Cave in Kentucky there is a wonderful underground river in which the fish are blind. Having had no use for vision, that sense has become atrophied. It is quite possible that if these fish were removed to sunlit streams the species would in time develop organs of sight.*
>
> *In our big cities and smaller towns the saloon and the blind tiger, the lawless distillery and the protected but illegitimate express trade in liquors are establishing a condition, an influence. Just so surely as the sense of vision has been atrophied in the denizens of Echo River, just as surely is the moral sense, the law-respecting justice, the strength and vigor of American manhood slowly bending itself to the constant and insidious influence of American Liquor Traffic*

**Sake**

It perhaps stands to reason that if underground river water makes exceptional whiskey, it may enhance the quality of other spirits, as well. From the product information of Tentaka Silent Stream sake,

> *The silent stream that lends its name to this sake originates deep in the jagged, snow-covered Nasu Mountains of Tochigi and runs hundreds of miles to the brewery, purifying the clear and untouched water that goes into this sake.*

**Conclusion**

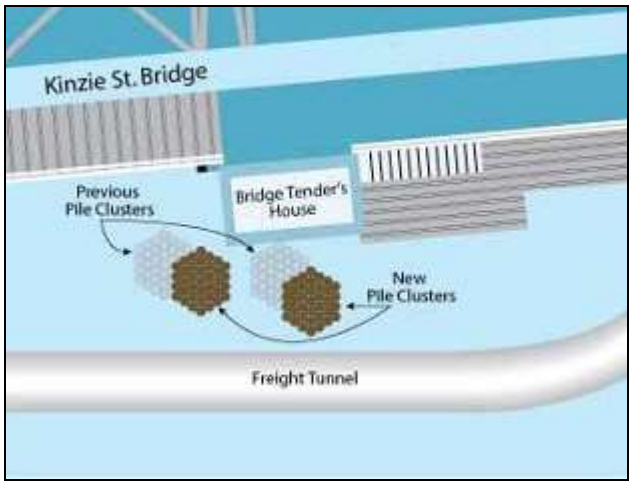
Water that flows in underground rivers indeed has taste, more often than not one that's pleasant. The mineral combination in some instances is well suited for bottled beverages. In most cases, however, the water is nothing more than good $H_2O$. Commercializing the "underground river" attribute is but a marketing ploy.

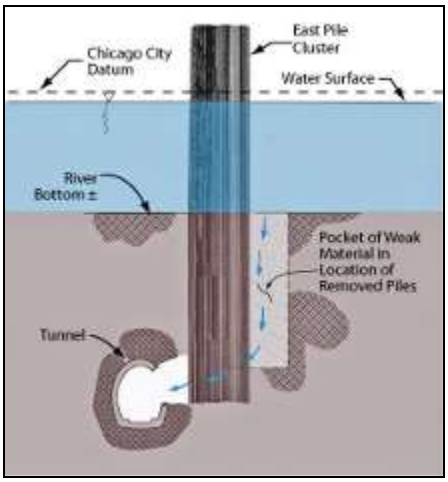
# CHAPTER 63
# CARGO CONVEYANCE

**Freight Tunnels**

Learning as we go, as evidenced by "The Great Chicago Flood," Structure, August 2007, by Jon Wren,

> *In the early morning of April 13, 1992, dozens of downtown Chicago buildings started to mysteriously flood. Soon flooding knocked out utility services to more than 100 buildings. And the worst was yet to come. Flood water seeped into subway tunnels, shutting down the entire subway system. A major expressway inexplicably flooded, causing shutdown of several lanes of traffic. Hundreds of thousands of workers were sent home. Paralysis quickly gripped one of the nation's major economic centers. It took six days to plug the source of floodwater, and over a month and $5 million to dewater building basements. The cost of the flood would ultimately total approximately $1 billion.*
>
> *The original intent of the tunnel system was to carry telephone and telegraph wires and cables. A 1903 ordinance allowed tunnel operators to officially transport merchandise such as coal, and remove solid waste from connections to the basements of over 80 buildings. The tunnel was equipped with a 24-inch gauge track and electric trolleys to convey merchandise. As a point of reference, at its zenith in 1928, the rail system employed 580 workers and had in excess of 3,300 rail cars to handle over 660 tons of goods annually. By 1959, a lack of demand and funds to repair equipment caused the freight system to be functionally abandoned. Currently, the tunnel system houses power and fiber-optic cables.*
>
> *The source of the underground flood was the North Branch of the Chicago River, pouring into a breeched section of an abandoned freight tunnel crossing beneath the river at Kinzie Street. The tunnel was part of a 62 mile network of abandoned freight tunnels, originally built in the early 1900s, crisscrossing downtown Chicago and connecting to building basements.*
>
> *Six months before the flood, two dolphin pile clusters protecting the southeast abutment of the Kinzie Street Bridge were removed; the clusters were relocated approximately three feet to the south (unwittingly closer to the tunnel), and new piles were driven.*




> *The underground flood was caused by driving dolphin piles closer than planned to the freight tunnel resulting in a tunnel breach and eventual flooding of the tunnel system. The effects of the removal and driving of two dolphin pile clusters near the freight tunnel dramatically increased loading on the tunnel, and serve to explain the tunnel breach and subsequent*

*flooding. Thus, Chicago's great underground flood provides many valuable lessons for engineers. For a recovered Chicago, the disaster is a distant memory and, as the old saying goes, "water under the bridge."*

**Timber**

Sunken Lake, on Michigan's Thunder Bay River, has been known to disappear when the lakebed sinkholes become unplugged. The lake reappears the following year when the holes re-plug. Legend claims that loggers would ride atop logs, disappearing down the sinkholes and reappearing 37 kilometers later at Lake Huron, still smoking their pipes.


Michigan; a Guide to the Wolverine State (1941), Federal Writers' Project, makes mention of the water's disappearance.

*Sunken Lake, a sinkhole, which in logging days was full only during spring rains, when Thunder bay River was a torrent. During dry weather the water drained through a hole in the bottom, near the west end. To prevent drainage, the loggers built a dam in the center of the lake. Sinkholes, averaging 200 feet across and 150 feet in depth, are common in this area.*

Regarding Lake Huron's Misery Bay,

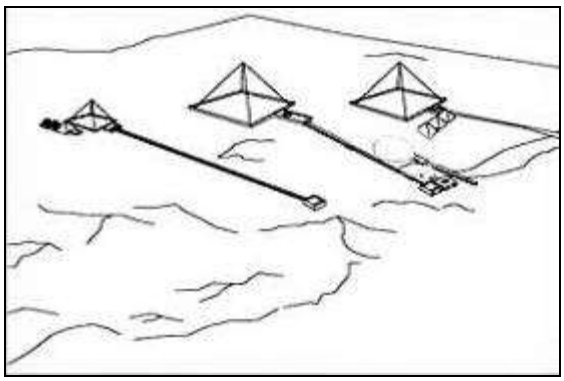
*So called because of a legend that the unsounded bottom of the black water never gives up its dead. The bay is really a channel, 100 to 1,000 feet wide, that meanders one mile inland to a deep hole. The water in this hole is often agitated by an underground force, and it never freezes, despite the extreme cold of this latitude. It is believed to be an outlet of the underground river that drains Alphena County sinkholes and Sunken Lake in Fletcher State Park.*

We'll add further geographical perspective to Sunken Lake in Chapter 85, Beneath the Great Lakes.

**Mummies**

Shafts that penetrate the Giza pyramids appear to the researchers at Earthmilk Ancient Energy to be part of an underground water system that once flowed into the pyramids.

Chamber under Sekhmekhet's pyramid



Approximate location of channels to Nile

From Earthmilk Ancient Energy's internet posting,

> *There are also shafts in the bottom of the water yet to be explored. At one time in history, when the Nile flowed beside the pyramids, the opening here was deep under the surface of the river, and the enormous chamber would fill up with water, directly underneath the pyramids.*
>
> *I know that if those huge holes were filled with water, they could force water to flow through the small narrow horizontal passageways to the pyramids using simple water hydraulics and Bernoulli's principle of moving fluids.*

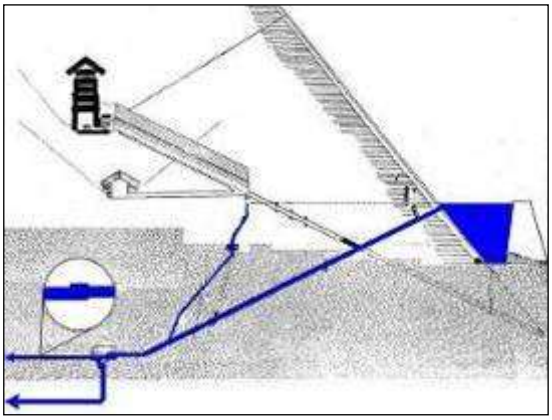
Earthmilk's hydraulic insight, however, appears not to include Bernoulli's principle, an energy balance which employs "moving" as an adjective, not as an active verb.

Tony Bushby, in "Lost History of the Pyramids -- The Underground Labyrinth of Egypt," Nexus Magazine, April-May 2004, offers another pyramid theory, one employing subterranean channels to pump water.

> *A Modified Hydraulic Ram Pump at Giza*
>
> *The pyramid had a tall masonry enclosure that was higher than the pyramid's entrance. Water was flooded between this masonry wall and the pyramid via tunnels from the ancient Lake Moeris. Lake Moeris and the Western Nile were at higher elevations and allowed for water tunnels to gravity feed to this pyramid's moat. One of the water tunnels existed as a "well" in front of the pyramid's entrance. This well has since been covered with pavement.*
>
> *As the moat filled, water flooded the entrance and ran down the descending passage into the subterranean chamber.*
>
> *The pump assembly incorporates the descending passage, subterranean chamber, the "dead end" shaft, the pit, the well shaft and grotto. To complete the basic hydraulic ram, two blocked tunnels need to be cleared. At the end of the "dead end" shaft exists a plane surface that correlates to the backside of a check-valve. The pit hasn't been completely cleared of rubble to expose the horizontal shaft, yet. In the running model the water in the well shaft pulsed at the grotto height even though this is below moat elevation.*
>
> *At the lower end of the descending passage a tunnel leads up towards the lowest of the two upper rooms. This shaft is known as the "well shaft." Until the late 1800s most of the descending passage, the lower part of the well shaft and the subterranean chamber had been buried for a thousand years. Indigenous teachings state emphatically that there is still a buried tunnel that leads from the bottom of the subterranean chamber's pit to the location of the ancient Nile River.*

*This tunnel was a drain that had a mechanical element at its end. This mechanical element is possibly a sliding stone plug, which opened and closed causing a pulsing action. The "dead end" shaft terminates 57' past its entrance. It is my hypothesis that the termination is the back face of a closed check valve, and a tunnel exists beyond.*

*To maintain consistent pulse timing, the pyramid's moat requires a specific static level. To ensure this, the moat is provided more water than is consumed.*



*The excess water was removed by the causeway running down to the Nile River.*

The pyramid's moat is another secret, but not to those of us with access to the Internet.

**Loot**

When an underground river is dry and cargo must be transported, there may yet be a war.

The rogues in The Italian Job (1969) transferred their loot to BMC Minis and escaped through the Milan sewers.

**Tobacco**

We noted the Laotian underground-river tobacco commerce in Chapter 56, The Tourist Trade Worldwide, but here's another, this one from Italy.

Seville's Royal Tobacco Factory, built in the 1700s employed 800 women, Georges Bizet's Carmen (1875) being today the most famous.


*The building is still surrounded on three sides by a deep ditch or moat, whose damp floor is smothered in greenery. And it still has its little guardhouses at each corner... The concierge in his cubbyhole told me there was a hidden embarcadero, a mooring point for boats that could travel via an underground river to and from the Torre del Oro just a few yards down the road towards the banks of the Guadalquivir. He said the secret waterway was once used to bring*

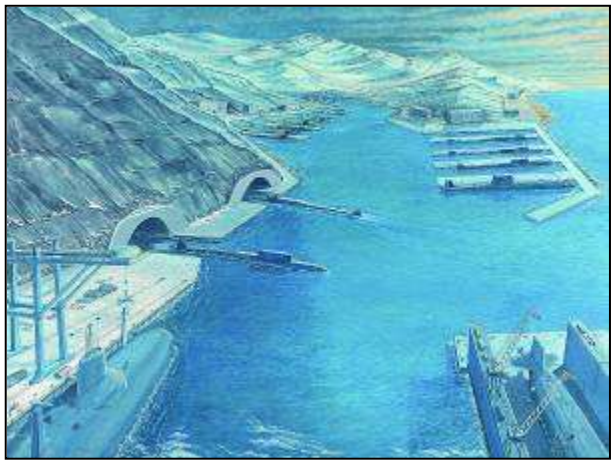
*tobacco in from galleons moored in the river, to prevent the precious cargo being seized by pirates before it reached its destination. He added that the entrance to this underground rivulet was "in the gardens" and "infested by cockroaches." I could not find it, but perhaps it exists, clogged by undergrowth. However, a couple of prints of the sixteenth-century city that I bought nearby clearly show a rivulet winding inland beside the Torre del Oro. It was the Tagarete, a tributary that meandered into the Guadalquivir in this marshy city. The waterway disappears from the maps in the early 1700s, when the factory was built.* -- Elizabeth Nash, Seville, Córdoba, and Granada, a Cultural History (2005)

The maps below show the period factory site and its restoration. The hidden-from-pirate-eyes Tagarete is now the fashionable Calle San Fernando.


**Warheads**

Soviet Typhoon and Delta IV-class strategic ballistic missile submarines deployed in the 1980s from tunnel bases.

The drawing "Soviet Ballistic Missile Submarine Base" (1986) by Brian W. McMullin portrays how such facilities were envisioned.



Since the dissolution of the USSR in 1991, several of these bases have been opened to the public.

The Balaklava Underground Submarine Base, Sevastopol, Ukraine was built in the late 1950s for repair and equipping of Soviet submarines. Having a 600-meter tunnel to the sea, the plant was designed to withstand a 100-kiloton nuclear strike. The tunnel diameter is as much as 22 meters, of which 8.5 are submerged. The entrance was disguised such that a spy would not recognize it, though of course the United States wasn't relying on agents posing as fishermen.

The last submarine left in 1995 and the defunct facility now welcomes tourists.

Balaklava
$2.00

The former Yugoslavia was also a location of submarine bases. Below are two in present-day Croatia.

Vis Island Submarine Base

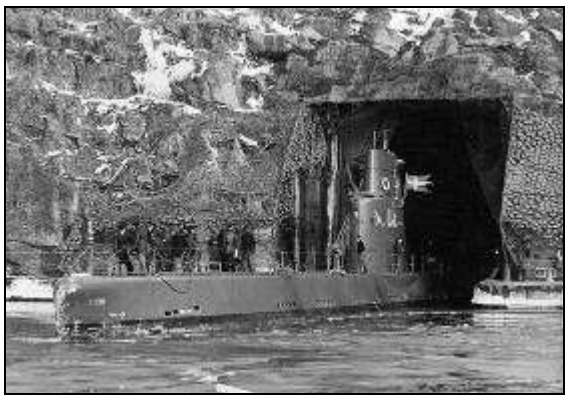
Dugi Island Submarine Base

The Dugi facility is was 7 meters deep, some 200 meters long, 30 meters wide and 20 meters high.

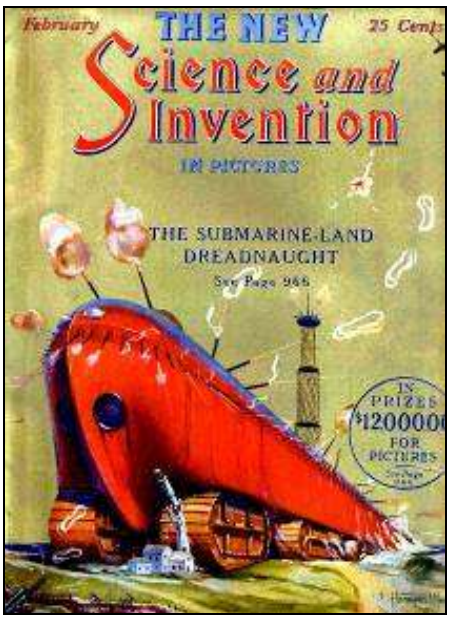
The satellite images of China's Hainan Island reveal a tunnel entrances thought to lead to caverns capable of hiding up to 20 nuclear submarines. A 094 nuclear submarine capable of carrying twelve nuclear warheads has been observed moored at an adjacent jetty.

Excavation Barges, 2005

Completed Tunnel Entrance

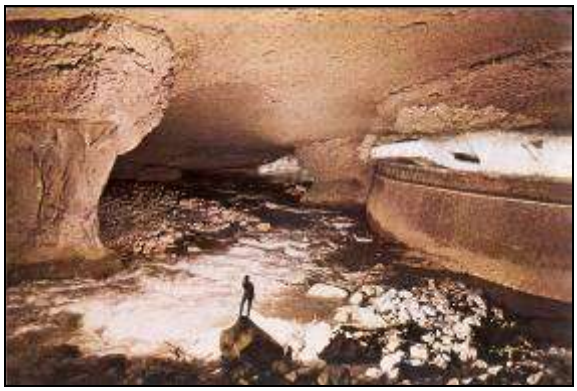


Above, the gate to Sweden's underground Muskö naval facility




And to the right, who says that a submarine can't also navigate on land? "A Submarine-Land Dreadnaught", Science & Invention, February 1924, portrays a 250-meter tall war machine that could sneak up a correspondingly-deep underground river to an enemy's capital

**Highways**



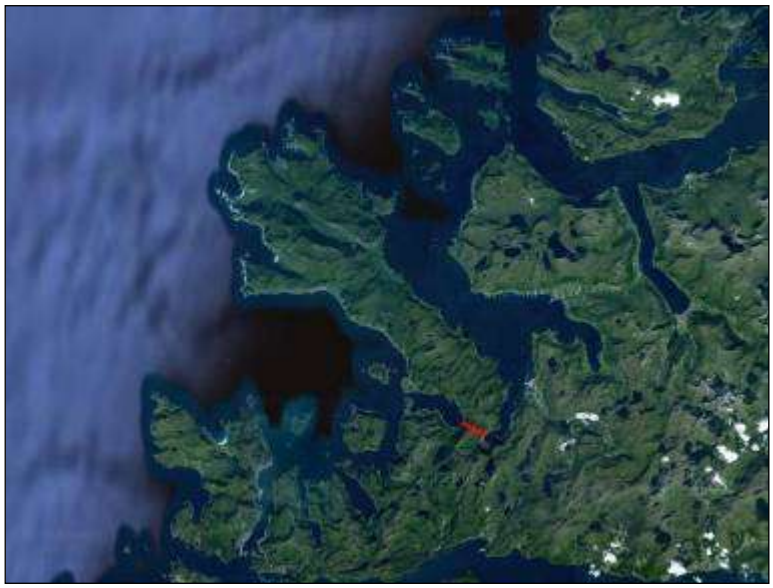
Mas d' Azil Cave in the Pyrenees. In lieu of a costly motor route around the limestone ridge, French road-builders followed the river through it.

Tour de France, 2006, Stage 12

**Stad Skipstunnel**

The combination of ocean currents and submarine topography creates complex and unpredictable wave conditions on the western coast of Norway, causing long delays while ships wait for calmer conditions.

The Stad shipping tunnel was proposed in 2007, a 36 meter wide by 49 meter high rock tunnel with a 12 meter draft, enough to allow ocean-going ships to cut through the 1,800 meter isthmus north of Bergen.



Conceptual entrance

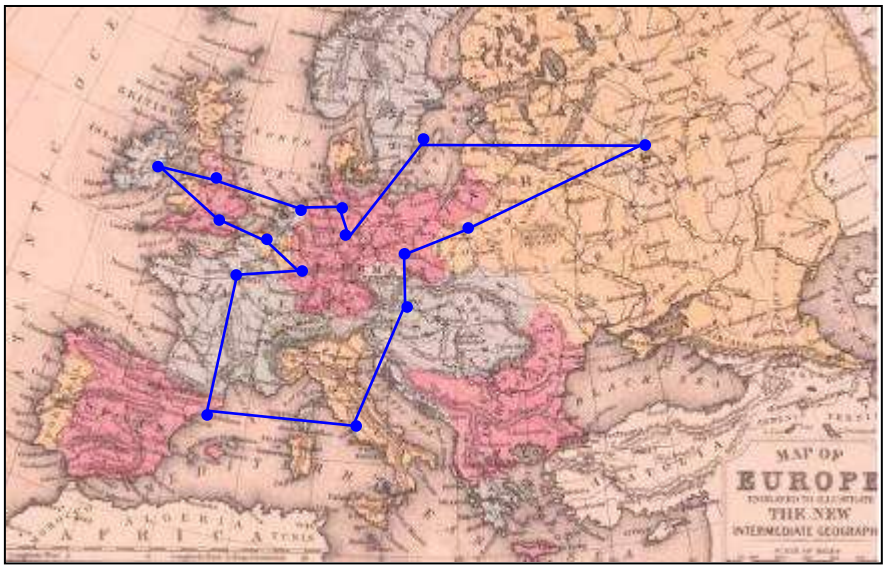
A 2011 report to the Norwegian Coastal Administration, however, concluded that a tunnel would cost between NOK 1,300 and 2,000 million. Benefits, largely the reduced waiting costs, have a present value between NOK 300 and 400 million, insufficient to justify the investment.

There's money to be made in subterranean shipping, but perhaps not in Norway.

# CHAPTER 64
# THE GRAND TOUR, EUROPEAN SEWERS OF DISTINCTION

What became known as the Grand Tour began as a rite of passage in which young upper-class European men of the 17th-century enjoyed an adventurous jaunt about the continent before settling into their staid professions. By the 18th century, a more-gentile Grand Tour provided wealthy American families opportunity to refine language skills, imbibe the cream of European culture and perhaps most of all, associate with the right foreigners.

We'll undertake our own Grand Tour, but ours to be a tour of Europe's more notable underground rivers of sewage. In deference to our topic's rich history, we'll plot our circuit on an 1875 European map.




Sixteen cities, 16 sewers! Plus we'll catch some movies.

A key to understanding the rivers we're to visit cam be found in the Lord Peter Wimsey mystery Thrones, Dominations (1998) begun in 1936 by Dorothy L. Sayers and completed by Jill Walsh. The title comes from Milton's Paradise Lost, a foundational English work about underground rivers (Chapter 17, Underground Rivers in English Fiction).

> *You can bury them deep under, sir; you can bind them in tunnels... but in the end where a river has been, a river will always be.*

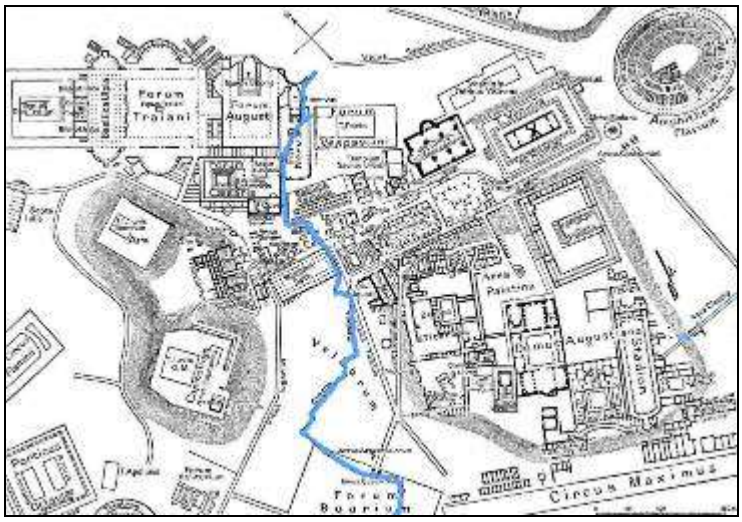
Every buried river on out Grand Tour was long ago a sunlit stream.

**Rome**

Our tour begins with the grandparent of modern sewerage, Rome's Cloacae Maxima, a canal in the sixth century BC and covered four centuries later. From Pliny's National History (c. 77 AD),

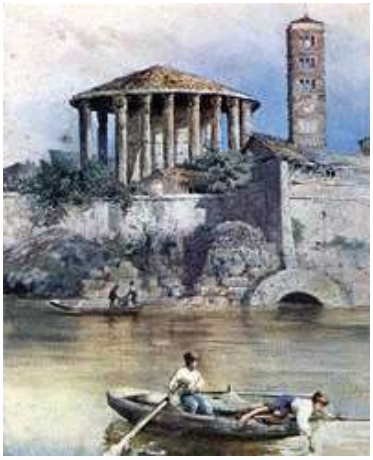
> *Hills were tunneled into the course of the construction of the sewers, and Rome was a "city on stilts" beneath which men sailed when Marcus Agrippa was aedile* [the Roman official in charge of public buildings]. *Seven rivers join together and rush headlong through Rome, and, like torrents, they necessarily sweep away everything in their path. With raging force, owing to the additional amount of rainwater, they shake the bottom and sides of the sewers.*
>
> *Sometimes water from the Tiber flows backwards and makes its way up the sewers. Then the powerful flood-waters clash head-on in the confined space, but the unyielding structure holds firm. Huge blocks of stone are dragged across the surface above the tunnels; buildings collapse of their own accord or come crashing down because of fire; earth tremors shake the ground - but still, for seven hundred years from the time of Tarquinius Priscus, the sewers have survived almost completely intact.*

The Cloacae Maxima yet flows under the Forum, joining the Tiber at Ponte Palatino, though no more a significant component of Rome's sewerage system.





Two 19th-century views



"Sbocca della Cloaca Massima," E. Roesler Franz

Roma (1972), directed by Federico Fellini, uses Rome's subterranean environs as a virtually plotless analogy of the human mind. Under modern tunnels filled with dripping pipes and laboring machines lie ancient catacombs leading to the underground river.

**Barcelona**

The Museu del Clavegueram is our stop, where maps, plans and photographs explain the history of the city's wastewater system.

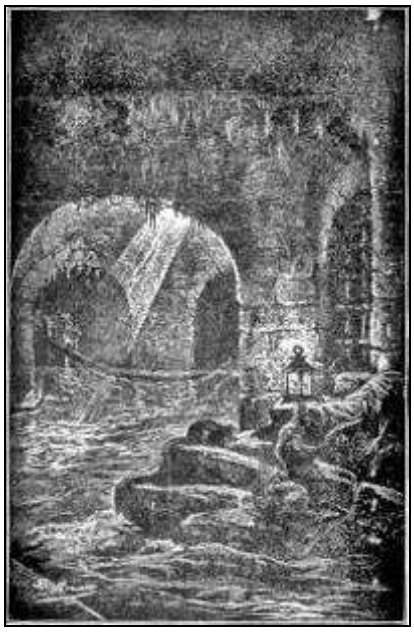
Museu del Clavegueram free

For an actual view of the Barcelona sewer, it's easier to watch actor Christian Bale wade through the gloom in The Machinist (2004).


**Paris**

Subterranean sewerage began in 1370 from the Rue Montmartre to a tributary of the Seine. The system expanded over the next four centuries and in the early 1800s was reconstructed to add another 300 kilometers. By 1878, the system encompassed 580 kilometers.

It took Victor Hugo, however, to make Parisian sewers known to the world. Jean Valjean, the hero of Les Miserables (1862), steals a loaf of bread and is sentenced to forced labor. He escapes, becomes an industrialist and the King appoints him Mayor, but after arousing the suspicion of Javert, the police inspector, Valjean is sent to the galleys. He again escapes and hides in the Paris sewers on the eve of the 1830 revolution.



We don't need the revolutionary plot, however, to sense the reality of the sewers.

> *It was a formidable campaign; a nocturnal battle against pestilence and suffocation. It was, at the same time, a voyage of discovery. One of the survivors of this expedition, an intelligent workingman, who was very young at the time, related curious details with regard to it, several years ago, which Bruneseau thought himself obliged to omit in his report to the prefect of police, as unworthy of official style. The processes of disinfection were, at that epoch,*

*extremely rudimentary. Hardly had Bruneseau crossed the first articulations of that subterranean network, when eight laborers out of the twenty refused to go any further.*

*The operation was complicated; the visit entailed the necessity of cleaning; hence it was necessary to cleanse and at the same time, to proceed; to note the entrances of water, to count the gratings and the vents, to lay out in detail the branches, to indicate the currents at the point where they parted, to define the respective bounds of the divers basins, to sound the small sewers grafted on the principal sewer, to measure the height under the key-stone of each drain, and the width, at the spring of the vaults as well as at the bottom, in order to determine the arrangements with regard to the level of each water-entrance, either of the bottom of the arch, or on the soil of the street. They advanced with toil. The lanterns pined away in the foul atmosphere. From time to time, a fainting sewerman was carried out. At certain points, there were precipices. The soil had given away, the pavement had crumbled, the sewer had changed into a bottomless well; they found nothing solid; a man disappeared suddenly; they had great difficulty in getting him out again. On the advice of Fourcroy, they lighted large cages filled with tow steeped in resin, from time to time, in spots which had been sufficiently disinfected. In some places, the wall was covered with misshapen fungi, -- one would have said tumors; the very stone seemed diseased within this unbreathable atmosphere...*

*Tortuous, cracked, unpaved, full of fissures, intersected by gullies, jolted by eccentric elbows, mounting and descending illogically, fetid, wild, fierce, submerged in obscurity, with cicatrices on its pavements and scars on its walls, terrible, -- such was, retrospectively viewed, the antique sewer of Paris. Ramifications in every direction, crossings, of trenches, branches, goose-feet, stars, as in military mines, coecum, blind alleys, vaults lined with saltpeter, pestiferous pools, scabby sweats, on the walls, drops dripping from the ceilings, darkness; nothing could equal the horror of this old, waste crypt, the digestive apparatus of Babylon, a cavern, ditch, gulf pierced with streets, a titanic mole-burrow, where the mind seems to behold that enormous blind mole, the past, prowling through the shadows, in the filth which has been splendor.*


Parisian sewer tours began in 1867 with white-suited sewer workers guiding visitors aboard special tour barges and wagons. Such excursions wouldn't have been unduly unpleasant, as the underground waterway was for storm runoff alone. Toilet waste wasn't to come until 1894. The rides, however, were to continue for another 80 years

If Les Miserables didn't bring enough fame to the City of Light's underground rivers, The Phantom of the Opera (1910, Chapter 24, Underground Rivers in the Fine Arts) was soon to follow.

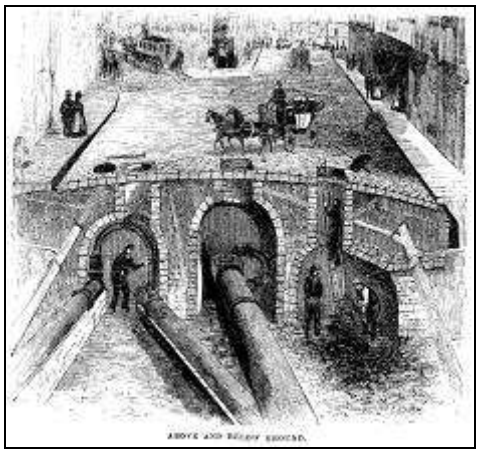
We've a rich history of illustration.

Égout de la Rue Saint-Senis, 1810

1820

Égout de la Rue Thévenat, 1830

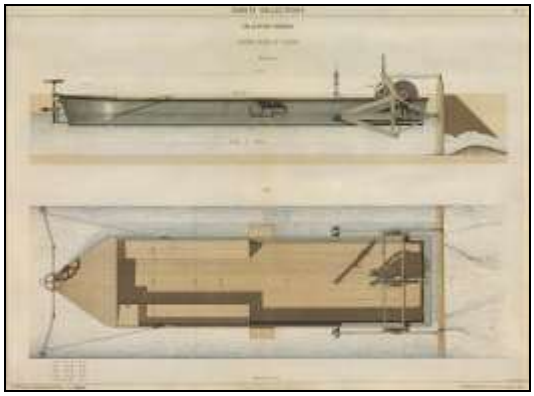
Égout Saint Benoit. Rue de l'Égout Saint Germain, 1840

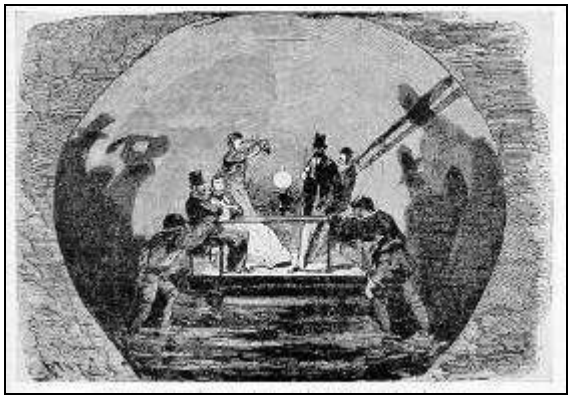


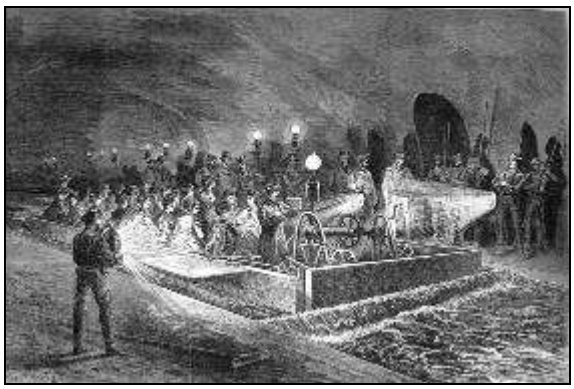
"Life in Paris - Sketches Above and Below Ground," Harper's New Monthly Magazine, February 1854

Égout de la Rue Royale, 1858

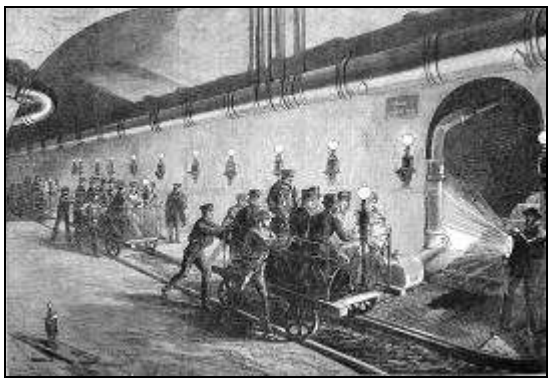
Paris sewers opened for tourism during the World Exposition of 1867, the tour boats piloted by uniformed sewer sewermen.



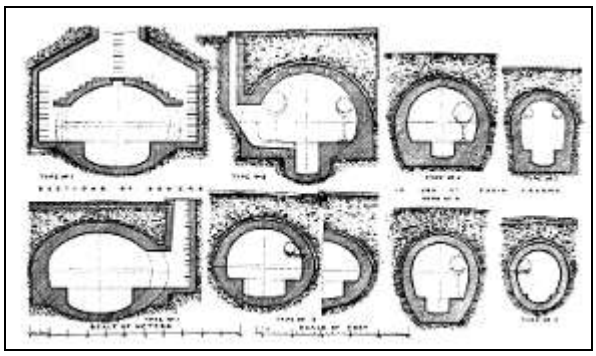




Tour by Boat, c. 1870

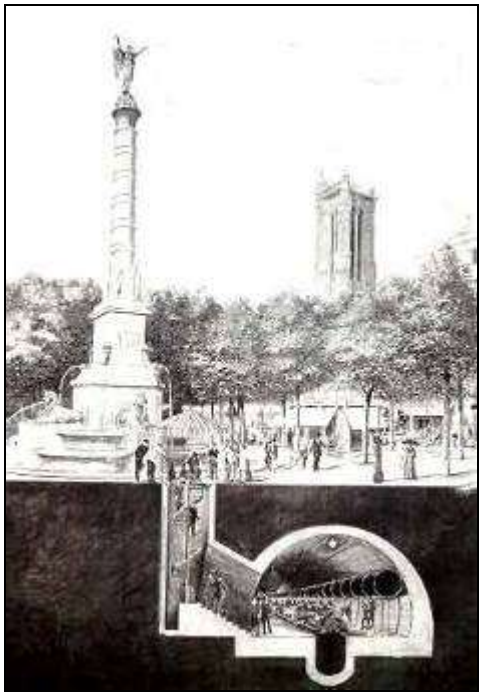


Tour by Rail



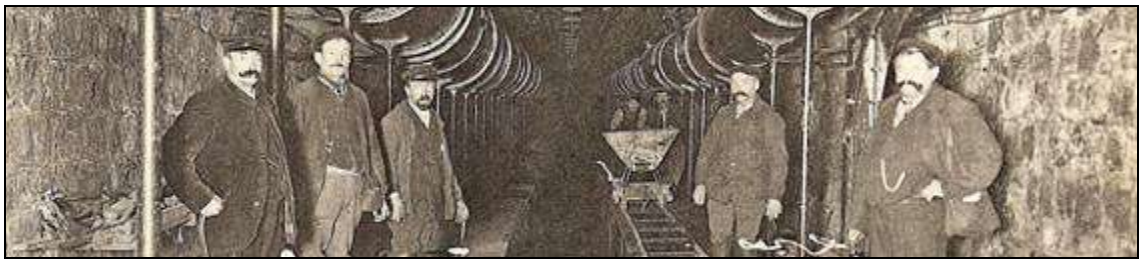
1884 Cross-sections

1896 Boat Tour



Entrée Place du Châtelet, 1892

Chemin de Fer Métropolitain, Égout Collecteur Rue Saint-Antoine, 1914



Workers with sewer cleaning equipment, c. 1930


Modern Égoutiers

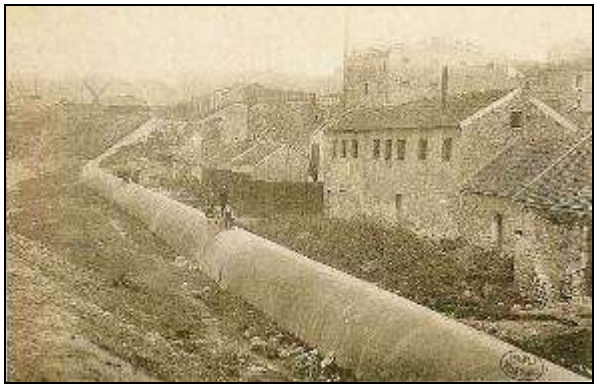
While in Paris, of course, we must attend to our répertoire culturel.

Felix Nadar spent three months of 1865 photographing Parisian sewers with lamps of his own invention to illuminate the 18-minute exposures. The stark images further enhanced the mystery of the eerie waterworks.

To German critic Walter Benjamin, this was "the first time that the lens is given the task of making discoveries."

Shipwreck on the River Bievre.

The River Bievre once flowed into the Seine in Paris, but in 1912 was converted into a collector sewer. In construction, 1910



Hydraulic barge used for sewer maintenance, 1978.

To the right, a panoramic photo of such a craft sunk in the Bievre in 2004

For modern tourists, more than 100,000 per annum, is the Musée des Égouts in the city's historic tunnels.

One display celebrates notable items retrieved, including swords, stolen handbags and false teeth. Another commemorates Eleanor, an 80 centimeter alligator caught by workers in 1984 and dispatched to a Paris zoo. We'll learn more about such urban reptiles in Chapter 89, Alligators Below.


Musée des Égouts de Paris €4.30

**Trier, Germany**

The Kaiserthermen (Emperor's Baths) of the fourth-century capital of the Western Roman Empire are now the gloomy remnants of the Imperial sewer network.

Sewer-arching Roman brickwork.

Kaiserthermen €11.50

**Brussels**

By the late 18th century, Brussels' River Senne had lost its value as a navigable waterway and was replaced by canals. In times of heavy runoff, however, the sluice gates were unable to regulate the flow, inundating the working class neighborhoods along the lower banks. By the mid-19th century, garbage and decaying matter made the drainage a health hazard.

The Senne, 1550.

Covering the Senne, c. 1870

Covering the river began in 1867. The system consisted of two parallel 6-meter tunnels and two lateral pipes. Boulevards created by the project were progressively opened from 1871 to 1873.

In the mid-20th century, the course of the river was rerouted to the downtown's periphery and in 1976 the disused tunnels were converted into an axis of the subway system. The system today totals about 300 kilometers, of which an explorer can traverse about 12 in a straight line.

The Musée des Égouts offers insight into the working of Brussels' modern sewer network.

Le Musée
des Égouts
€3.00

**London**

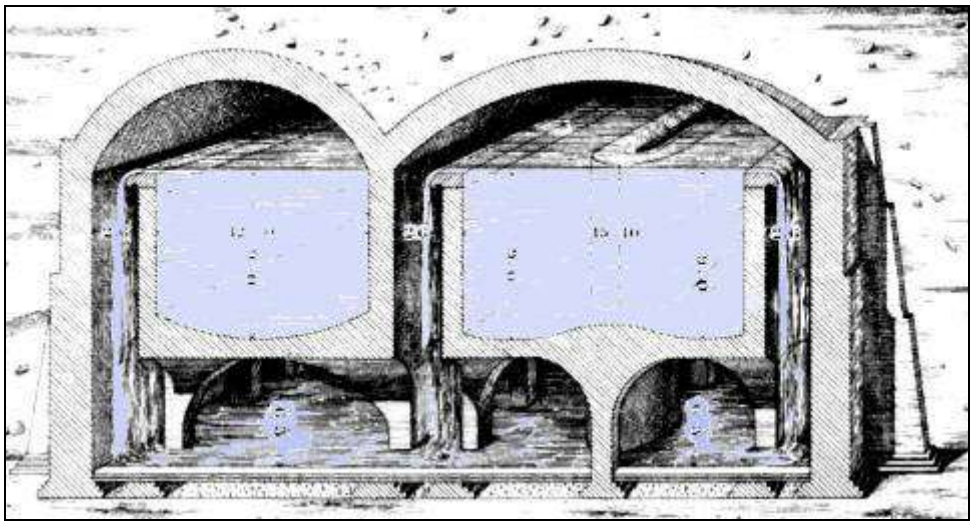
Known as the Victoria Embankment on the Thames' north bank and Albert Embankment on the south, the London floodplain became parks above and sewers and subways below in the later 1800s. Total improvements included 160 kilometers of interceptor sewers, 720 kilometers of mains and more than 21,000 kilometers of local sewers.

In 1836 the Directors of the Bank of England are said to have received an anonymous letter from a man claiming to have access to the institution's bullion, offering to meet them in the vault at any hour they chose. The Directors thus assembled and at the appointed hour a noise was heard from beneath the floor and the mysterious correspondent emerged from below by displacing a few floor boards.

The writer of the letter was a sewerman who in the course of his profession had discovered an abandoned drain under the vault and could have spirited away great sums. But he was an honest man, and for his revelation the Bank is said to have rewarded him with £800.

While the legend's particulars are not verifiable, subsequent correspondences suggest the institution's anxiety that there might be other abandoned waterways providing access.

> In 1837, the Secretary of the Bank wrote to the Commissioners of Sewers asking for plans of the sewers and drains surrounding the Bank building "and as far as can be within the Bank premises also."
>
> Letters were sent to the Curator of the Soane Museum requesting that plans of the drains beneath the Bank should be returned to the Bank.
>
> A February 1839 letter from the Bank Architect to the Building Committee notes, "In May 1836, having had reason to apprehend danger from our sewers, it was discovered that an open and unobstructed sewer led directly from the gold vaults down to Dowgate."



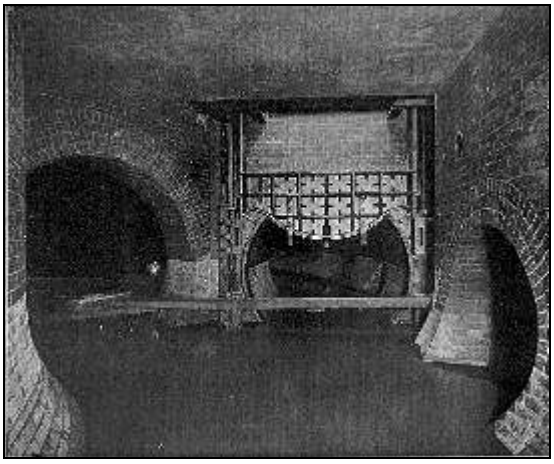
Design of the London system was hydraulically sophisticated, as evidenced by the overflow diversion shown above.

London's some-200 19th-century “toshers” made their living by scouring the sewers for trash and waste to be resold. Toshers earned an average of six shillings a day, ranking them among the better-off of the working class.

Not all agreed, however. From "Life in the Sewers, Living Age, April 12, 1845,

> *Anyone who has walked over Blackfriars or Waterloo Bridge when the tide is down, may have observed men and boys, and occasionally women, waling upon the shores of the river, knee deep in the slime, with baskets upon their backs, or slung over their arms, picking up pieces of wood that have been left behind by the tide, or bits of coal that have fallen from the numerous coal barges that come up laden from the pool, where the collier vessels are moored, to discharge their cargoes at the wharfs further to the west.*
>
> *These "mud-larks," as they are sometimes called, bear generally a bad character, being accused of not contenting themselves with the prizes they find on the shore, but of robbing the coal barges or other vessels, on board of which they can creep at nightfall without detection.*
>
> *However this may be, their functions do not end with the shore, but in the sewer. With torch in hand, to preserve them from the attacks of numerous large and ferocious rats, they wade, sometimes almost up to the middle, through the stream of foul water, in search of stray articles that may have been thrown down the sinks of houses, or dropped through the loop holes in the streets. They will at times travel for two or three miles in this way -- by light of their torches, aided occasionally by a gleam of sunshine from the grating by the wayside -- far under the busy thoroughfares of Cornhill, Cheapside, the Strand, and Holborn, very seldom able to walk upright in the confined and dangerous vault, and often obliged to crawl on all fours like the rats, which are their greatest enemies.*
>
> *The articles they mostly find are potatoes and turnips, or bones, washed down the sinks by careless scullery-maids; pence and half-pence, and silver coins; occasionally a silver spoon or fork, the loss of which may have caused considerable distress and ill-will in some house above; and not infrequently more valuable articles, which thieves, for fear of detection, have thrown down when they have been hard pressed by the officers of justice.*

Flushing a London sewer, 1861



Weir Cavern Chamber under Hammersmith Road, 1905

The simulated Victorian sewer ride in today's London Dungeon -- no relation to the Tower of London, please note -- features a Jack the Ripper animatron.

London Dungeon £12.95

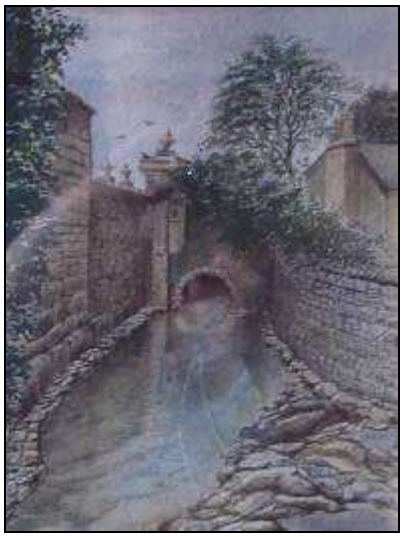
The intrepid can also explore -- albeit by trespass -- the subsurface River Fleet, but we'll leave the details for Chapter 79.

**Dublin**

James Joyce (Chapter 17, Underground Rivers in English Fiction) wasn't the first to write of Dublin's underground rivers. From "The Ancient City of Dublin," Catholic World, April 1892,

> *At the other side of Christ Church and its hill there is another descent to the low-lying streets marking the ancient bed of the Poddle, a mysterious subterranean stream, which, leaving its parent Dodder at a lovely green place behind Harold's Cross, slips away from the sunlight and goes sluggishly under houses and streets and becomes a common sewer, till it spills into the Liffey through a side gate in the quay-walls. A dreadful stream it has always seemed to me since I read long ago of a woman falling into it through a trap-door which she had lifted in her little house-yard in order to draw up water. Imagine the helpless creature swirling away into that living grave! Imagine her dead, floating on and on through the labyrinth in the dark! I have never forgotten the horror of it. There is something ghastly about a subterranean river.*

By the 13th century, Dublin's water supply was inadequate and water from the Dodder was diverted to the Poddle. By the late 19th century, the latter was fully enclosed.

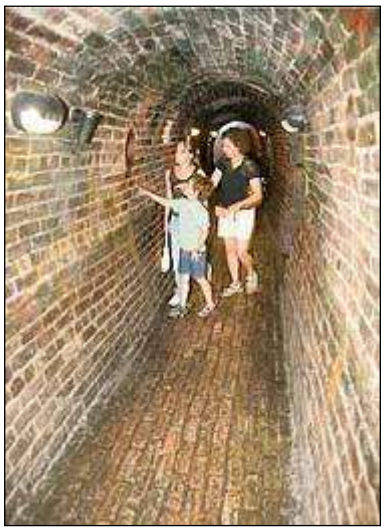


One of the few visible sections of the modern River Poodle

The confluence of the River Poddle and the River Liffey, visible at low tide through a grate in the Liffey walls.

**Manchester**

England's second largest city rose to prominence as an industrial powerhouse in the 19th century. The Manchester Museum of Science and Industry includes a stroll through a simulated sewer crafted from the bricks of an old one, with piped in sounds of scurrying rats, and pumped-in odor.



Museum of Science and Industry
£4.50

**Emmen**

This Dutch town has quite ordinary sewerage, but the Noorder Dierenpark zoo features a plexiglassed simulated 19th-century sewer, home to 90 sewer rats, creatures omitted from Chapter 50, Wrecks of Ancient Life, because they're a product of modern life.

Rather than a photo of the Dutch rodents, we exhibit a card from the game Magic the Gathering (Chapter 28, Virtualizing the Imagined: Underground Rivers in Games).


Noorder Dierenpark
€17.50

**Hamburg**

After the older half of Hamburg burned in the 1840s, the new sewer system was a marvel of innovation, vented through roof drains of the connected buildings and flushed weekly by the tide.

The Abwasser und Sielmuseum (Wastewater and Sewer Museum) includes a wealth of objects fished from the sewers: buttons, dentures, shoes, cigars, bicycles, jewelry, articles of clothing, toys, tins of food, a birth certificate and even a wheelbarrow.

**Berlin**

We're here just for a movie, The Good German (2006). Sewers are regularly employed to express the subterranean desires and activities and practices in post-war Berlin. Here Lena Brandt makes her way towards her husband's hideout.


**Stockholm**

Only a brief stop in the Swedish capital to pay tribute to the Charons of modern times.

**Moscow**

With electric headlights on their craft, Muscovites can adventure into the 7.5-kilometer Neglinnaya River, a once-natural waterway enclosed since 1817. The river ceased being the official municipal sewer in 1887, so now it's an unofficial one.


1695

Today

The park along the Kremlin wall sits above the river. The youth of Moscow go below.

**Warsaw**

Another movie stop, Kanał (1956), is about the Warsaw uprising in which a ragged band of resistance fighters try to flee the Nazi onslaught through the city's sewers.

"Watch them closely, for these are the last hours of their lives," announces the disembodied voice of the narrator.


As we're in Poland during Nazi occupation, we'll take a quick jaunt to the city of Lvov (today in the Ukraine, but then it was Polish).

In Darkness (2011) is based upon a true story of a small time criminal who used his employment as a sewer inspector to hide a group of Jews in the sewers for 14 months. The sewers are not stark, grim and deadly like the setting of Kanal. These sewers are small and inky black, steeped in gloom, cramped and comfortless, wet slime.

The savior does it for money when the story begins, but as the months progress, changes into a fearsomely competent hero who dares to do what others can't, and that very competency eventually helps humanize him.

**Prague**

Completed in 1907, Prague's sewer system changed little until the mid-1960s when it was finally upgraded.

As in Warsaw, Prague's sewer system served as a conduit for the Resistance in World War II.

Prague's Ekotechnicke Museum is housed in the first sewage treatment plant of the Austro-Hungarian Empire.

Ekotechnicke Museum
150 CKZ

**Vienna**

By the mid-18th century, central Vienna had well-functioning sewerage, well before other European cities. Conditions in the suburbs, however, were still far from ideal and in 1830, high waters and ice on the Danube led to wide-spread inundation and a cholera epidemic caused by contaminated groundwater killed over 2000. It was then that tunneling began to integrate the watercourses into a combined storm and sanitary sewer system.

Sewers can create their own social challenges, however. Emil Klager's Durch die Wiener Quartiere des Elends und Verbrechens (Through the Viennese Districts of Poverty and Crime, 1908) called attention to the conditions of the homeless living beneath the city.

Living in the sewers, c. 1900

Graham Greene's The Third Man, written as source text for the 1949 film, elevated the Viennese sewer into noir fiction, par excellence.

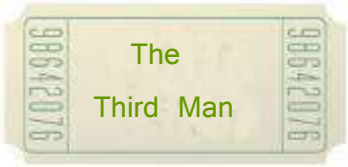

The book version was published the following year.

> *What a strange world unknown to most of us lies under our feet: we live above a cavernous land of waterfalls and rushing rivers, where tides ebb and flow as in the world above. If you have ever read the adventures of Allan Quatermain and the account of his voyage along the underground river to the city of Milosis, you will be able to picture the scene of Lime's last stand. The main sewer, half as wide as the Thames, rushes by under a huge arch, fed by tributary streams: these streams have fallen in waterfalls from higher levels and have been purified in their fall, so that only in these side channels is the air foul. The main stream smells sweet and fresh with a faint tang of ozone, and everywhere in the darkness is the sound of falling and rushing water. It was just past high tide when Martins and the policeman reached the river: first the curving iron staircase, then a short passage so low they had to stoop, and then the shallow edge of the water lapped at their feet. My man shone his torch along the edge of the current and said, "He's gone that way," for just as a deep stream when it shallows at the rim leaves an accumulation of debris, so the sewer left in the quiet water against the wall a scum of orange peel, old cigarette cartons, and the like, and in this scum Lime had left his trail as unmistakably as if he had walked in mud...*
>
> *We moved slowly on, our revolvers trained for a chance, and Lime turned this way and that way like a rabbit dazzled by headlights; then suddenly he took a flying jump into the deep central rushing stream. When we turned the searchlight after him he was submerged, and the current of the sewer carried him rapidly on, past the body of Bates, out of the range of the searchlight into the dark. What makes a man, without hope, cling to a few more minutes of existence? Is it a good quality or a bad one? I have no idea.*

The Third Man film sewer is a labyrinth, vast and sinister, shadowy and echoing, each tunnel leading to another, some large and some narrow, amid twisting and winding staircases. Passages show dead ends. Darkness confounds directions. Flashlight glare bounces of timeworn, shiny stones on curving walls, and flowing water creates a house of mirrors.

In 1999, the British Film Institute designated the film, "Best Film of the Century."

Vienna's Third Man Museum shows clips from the movie in a sewer chamber where a portion of the 7½-minute chase scene was filmed. As negotiating the post-war Vienna underworld would have been difficult for a film crew, however, most subterranean sets were on a London soundstage.

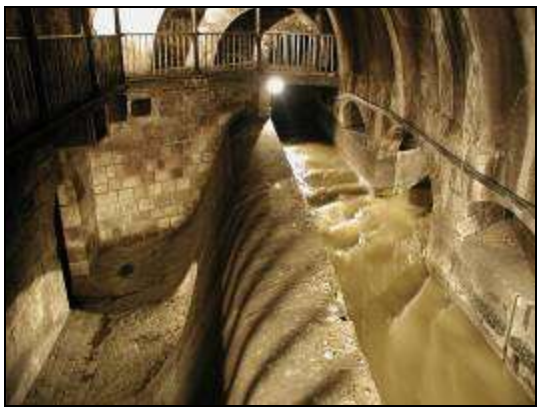



The Movie

The Tour

Vienna's sewer system suffered from 1,800 hits during World War II and not until 1950 was the last of the damage repaired.

Viennese underground rivers of today.



The official City of Vienna Tour covers a small part of the subterranean network, but is hosted by authentic sewer workers who discuss how it is to labor below. There's a multi-media extravaganza loosely tied to the movie and a Welles look-alike who fires a pistol.

Official Vienna Sewer Tour €6.50

Not all of today's Viennese underground is museum quality, however.

A cinemagraphic aside:

The 1948 noir He Walked by Night was loosely based on the life of Erwin "Machine-Gun" Walker, a former cop who unleashed a crime spree of burglaries, robberies and shootouts in the Los Angeles area, 1945 and 1946.

He Walked... concludes with a dragnet through the L.A. sewers in which the criminal's escape is blocked by the wheel of a police car. As the cops fire tear gas, the outlaw staggers, fires and is shot down, a scene notable for its resemblance to that of The Third Man released the following year.

And as a good sewer scene is worth re-repeating, there's the British sci-fi Invasion (1965) in which an alien spacecraft crash-land near a secluded hospital and the aliens set a force field around the building.

**Souvenirs from our Grand Tour**


S.P.O.R. --"Senatus Populusque Romanus"

Barcelona

Musée des Arts et Métiers, Paris

Trier

Brussels

London

Dublin

Manchester

Emmen

Hamburg

Berlin


Stockholm

Moscow


Warsaw

Prague

Vienna

Plus, of course, our movie-ticket stubs.

**An American Alternative**



Viva Las Vegas!

"Lost Vegas" in the September 24, 2009 Las Vegas Sun described the plight of Steven and Kathryn, whose home the storm sewer beneath Caesar's Palace includes a kettle and a makeshift shower, but their bed and most belongings are on crates to keep them off the wet floor.

There are around 350 miles of flood channels under Las Vegas. Of the city's 14,000 homeless, 700 are thought to dwell under the city's strip.

Another sewer dweller, Amy, who has lived in the tunnels for two years, explains, "The main dangers are the floods and the Black Widow spiders. But it's not a terrible place to be if you're homeless.

Matthew O'Brien, author of Beneath the Neon: Life and Death in the Tunnels of Las Vegas (2007), agrees with Amy's concern.

> *It doesn't rain much in Nevada but when it does the tunnels can fill very quickly. There have been 20 drownings in the last 20 years and a lot of those were people who were living in the tunnels... When it pours down three inches of rain in two hours it's clear it's not a home. It's a flood channel.*

# CHAPTER 65
# SUBTERRANEAN AQUEDUCTS

The word "aqueduct" may bring to mind Roman arches spanning a valley, but in fact, the definition isn't architectural. An aqueduct is simply a structure -- or more often, a sequence of structures -- constructed to convey water. Most aqueducts are at ground level because that's where construction is the cheapest. Aqueducts are elevated where it's necessary to maintain potential energy. Aqueducts penetrate the terrain where it's easier to drill than to remove or bypass a topographic obstruction.

Most aqueducts are open channels (channels with a free surface), again because of cost, but some systems operate, at least in part, under pressurized conditions.

Wastewater conveyance is the purpose of sewers -- subterranean aqueducts, too, but a less glamorous subset -- the subject of Chapter 64, The Grand Tour, European Sewers of Distinction.

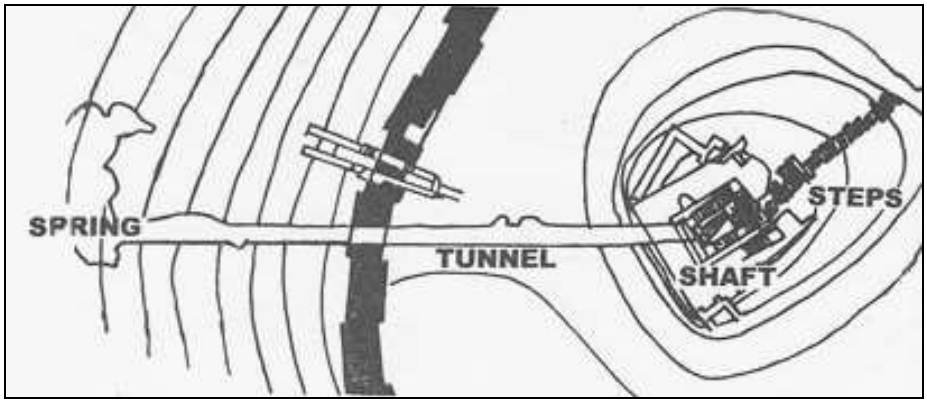
Waterways constructed for navigation also move water, making them aqueducts of another subset, topics of Chapter 63, Cargo Conveyance, and Chapter 73, Tunnels du Canal.

This chapter deals solely with subterranean aqueducts constructed to convey fresh water to users.

**Sinnors**

Ancient cities of Palestine and Syria developed water tunnels (sinnors) to access hidden springs outside of city walls.

Megiddo, a tell south-east of Haifa, is the inspiration for James Michener's The Source (1983). The source of Megiddo's water was a hidden spring outside of the town's defenses. In the time of Ahab (ninth century BC), a 120-meter shaft, 2 meters high and 1 meter wide, was cut to access the spring.



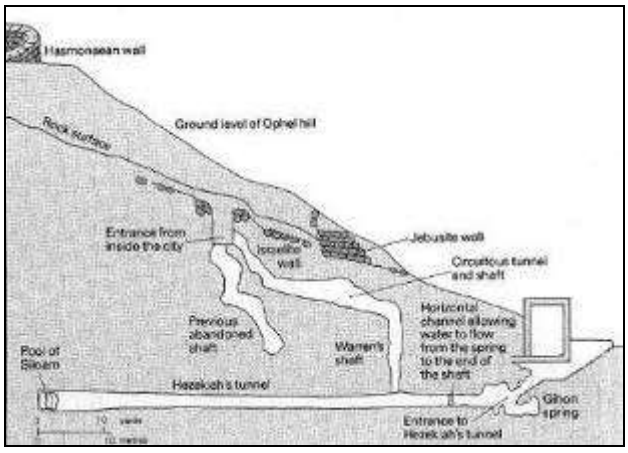
Jerusalem provides another example.

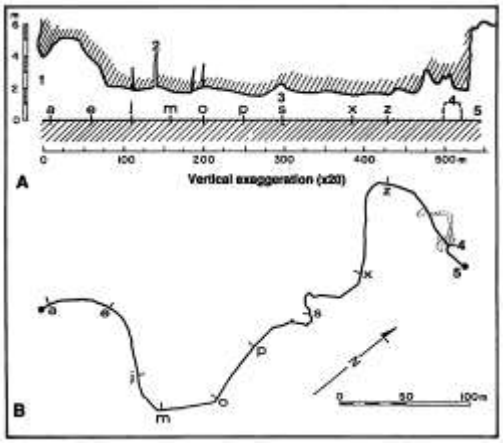
> *And the rest of the acts of Hezekiah, and all his might, and how he made a pool, and a conduit, and brought water into the city, are they not written in the book of the chronicles of the kings of Judah.* -- 2 Kings 20:20

In response to an Assyrian siege, King Hezekiah (eighth century BC) dug from both ends to build a 540-meter sinnor from Gihon Spring to the Pool of Siloam (Chapter 47). Tourists today can wade through the tunnel in thigh-deep water.

Cattle Market Day, Lower Pool of Gihon, 1900

Hezekiah's tunnel's average height is about 2 meters, but increases to about 5 near the outlet.




The alignment lurches about, but even still, the two sides met with remarkable precision. An inscription discovered in 1880 describes the achievement.

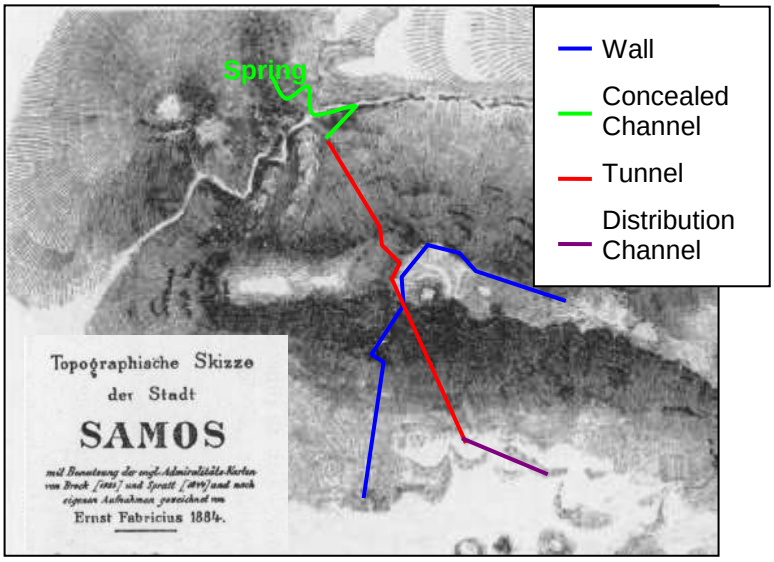
> *While there were still three cubits to be cut through,* [there was heard] *the voice of a man calling to his fellows, for there was an overlap in the rock on the right* [and on the left]. *And when the tunnel was driven through, the quarrymen hewed* [the rock], *each man toward his fellow, axe against axe; and the water flowed from the spring toward the reservoir for 1200 cubits.*

The meandering pathway may pertain to a siege in 1000 BC in which David captured Jerusalem by calling upon volunteers to enter the city through a secret passage.

> *Whosoever getteth up to the gutter, and smiteth the Jebusites ... he shall be chief and captain.* -- 2 Samuel 5:8

David's men may have slipped in via a natural karst passage which centuries later, Hezekiah simply enlarged.

The Tunnel of Eupalinos, a 1,036-meter aqueduct through Mt. Kastro, Samos, Greece, was dug in about 530 BC. The aqueduct received water from a concealed spring and a covered channel secreted to the tunnel mouth. A similarly-hidden channel led from the tunnel exit to the city.

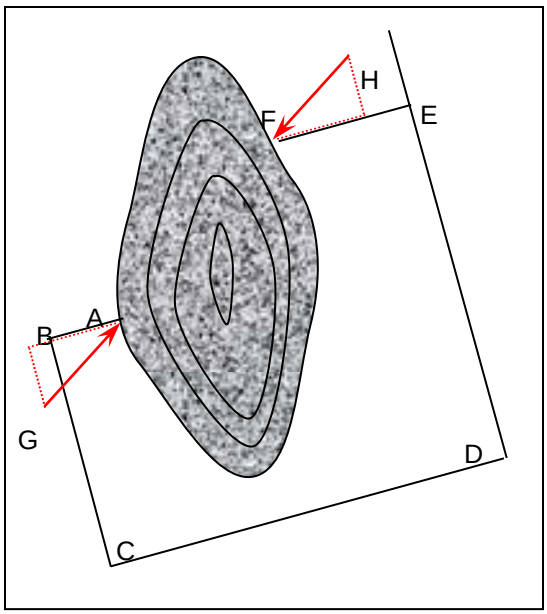



The aqueduct is cited by Herodotus' Histories (fifth century BC),

> *And about the Samians I have spoken at greater length, because they have three works which are greater than any others that have been made by Hellenes:*
>
> *First a passage beginning from below and open at both ends, dug through a mountain not less than a hundred and fifty orguia in height; the length of the passage is seven stadia and the height and breadth each eight feet, and throughout the whole of it another passage has been dug twenty cubits in depth and three feet in breadth, through which the water is conducted and comes by the pipes to the city, brought from an abundant spring: and the designer of this work was a Megarian, Eupalinos the son of Naustrophos.*

The Tunnel of Eupalinos is the first known tunnel aligned from both ends by geometry.

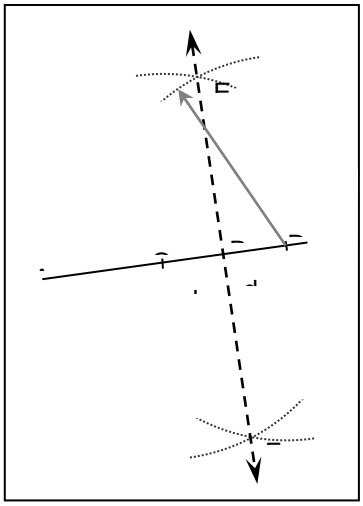
Heron's Dioptra (third century BC) describes how to align a tunnel between opposite points A and F in a mountain, a conceptual approach likely used by Eupalinos some three centuries earlier. As we don't know Eupalinos' computational skills, however, we'll assume he only knew addition and subtraction.




Establish a point B near tunnel end A and call this line AB. Turn a right angle from AB and go to a point C far enough that another right angle passes the mountain. Proceed along this line to a point D such that another right angle passes behind the tunnel's other end F. Proceed along this line to a point E at which a perpendicular hits F. Measure distances AB, BC, CD, DE and EF.

Right triangles having legs of ratio (DE – BC) to (CD – AB – EF) offset from AB and DF establish points G and H. GA and HF, shown in red, are the sighting lines for excavation.

To "turn a right angle" can be done as follows:



To turn a right angle from a line AB at point B, extend AB past B. From B, move both forward and backward on this line an arbitrary distance d, say, 100 "Standard Soldier Heights" to establish points C and D. From C and D, scribe an arc of an arbitrary radius r as shown in the figure. Eupalinos might have done this with a rope. Distance r must be greater than distance d. Points E and F are where the arcs intersect.

Line BE is at a right angle to AB to one side and BF is at a right angle to the other side.

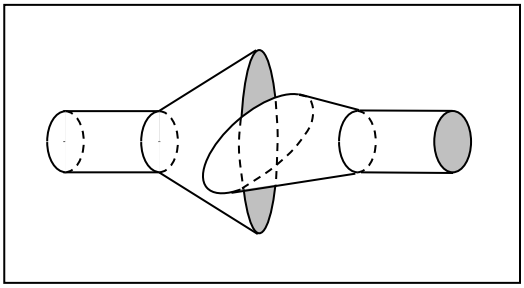
Projecting line BE beyond E will be more precise if the visual sighting is taken from point F (in lieu of B) through point E. Sight from E through F to extend line BF past F.

To make the two red triangles in the geometric layout "right triangles having legs of the ratio of (DE – BC) to (CD – AB – EF)," retain the numeric values of distances AB, BC, CD, DE and EF, but change the units to something smaller. 504 "Standard Soldier Heights" becomes 504 "Standard Soldier Elbow-to-Fingertips," for example. From A or F, move (CD – AB – EF) Elbow-to-Fingertips along AB or EF, make a right turn in the appropriate direction and move (DE-BC) Elbow-to-Fingertips. The result is G or H.

Vertical control tended to be less of a challenge. Eupalinos may have leveled around Mt. Kastro with a chorobates, a grooved 6-meter beam supported on legs. When water poured into the beam's groove was uniformly distributed along its length, the surveyor could project a level line of sight.

When the two sides draw near, flaring one shaft horizontally and the other vertically decreases the chance that the two will shoot past one another.

Correctly guessing that his miners were truer to the vertical than to the horizontal, Eupalinos expanded only moderately in the up-and-down direction, but flared widely, left-to-right.



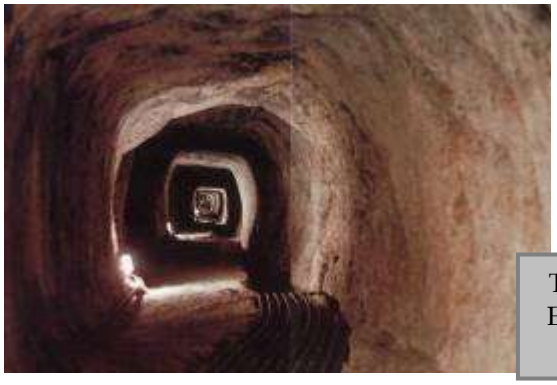
Soil conditions along the north passage forced additional deviations and at least six alignment corrections.

When the digging crews were within earshot, approximately 12 meters for this rock, the tunnels were directed toward each other and met at a dog-leg angle, as shone to the right.

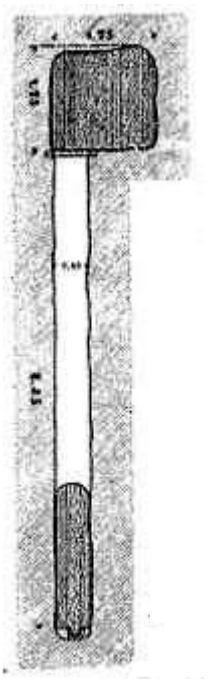
Eupalinos did much better in the vertical. At the rendezvous, the closing error for the two tunnels is just a fraction of a meter.

A typical cross-section is about 1.8 by 1.8 meters, but the northern portion, cut through harder rock, is in places barely wide enough for a worker to pass.

The floor drops only 0.6 meter in its 1 kilometer length, most likely the result of underestimating the slope required for water to flow. A steeper slot, 6 meters deep at the outlet, was cut into the floor at a later date. Grating over the slot in today's tourist-accessible portion can be seen in the photo below.



Tunnel of Eupalinos €4.00



The aqueduct served for a thousand years before being forgotten. Drawing upon the writings of Herodotus, archeologists rediscovered the tunnel in 1886.

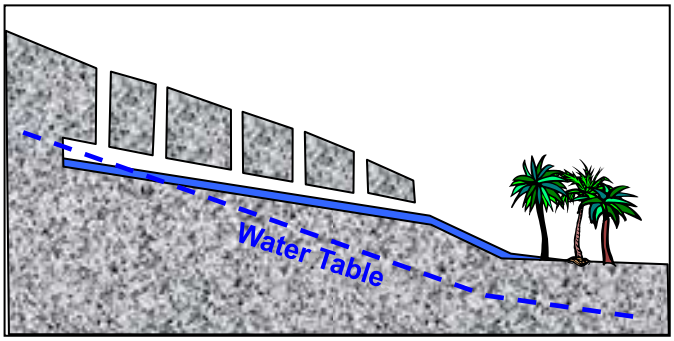
**Qanats**

From the journal of Marco Polo (1254-1324),

> *After those three days of desert you arrive at a stream of fresh water running underground, but along which there are holes broken in here and there, perhaps undermined by the stream, at which you can get sight of it.*

"A stream of fresh water running underground" -- the first European report regarding qanats.

Qanats are a traditional Middle Eastern technology of water supply in which vertical shafts, often 10 to 15 meters in depth, are hand-excavated at typically 20 to 30-meter intervals and laterally connected such that groundwater from the highlands drains via a slightly-sloped tunnel to a point of withdrawal. Connecting tunnels are often brick-floored to minimize seepage.




A brief history

| | |
|---|---|
| Eighth century BC | Persian coal miners improvised qanats to dewater mines. The technology adapted by farmers and spread over the plateau of modern Iran. |
| Seventh century BC | Assyrian king Sargon II reported finding an underground system for tapping water during Persian campaign. |
| 550-331 BC, Persian rule, Indus to the Nile | Persian rulers provided incentive for qanat construction by allowing profits to be retained for five generations. Qanats constructed westward from Mesopotamia to the shores of the Mediterranean, and southward into Egypt. Qanats constructed in Afghanistan, Turkistan and Silk Road oases, Turfan being an example. |
| 209 BC | King Arsaces of Parthia tried to destroy qanats to sever water supply for invading Seleucidians. |
| 118 AD | Qanats introduced into central and western Sahara by Judaized Berbers. |

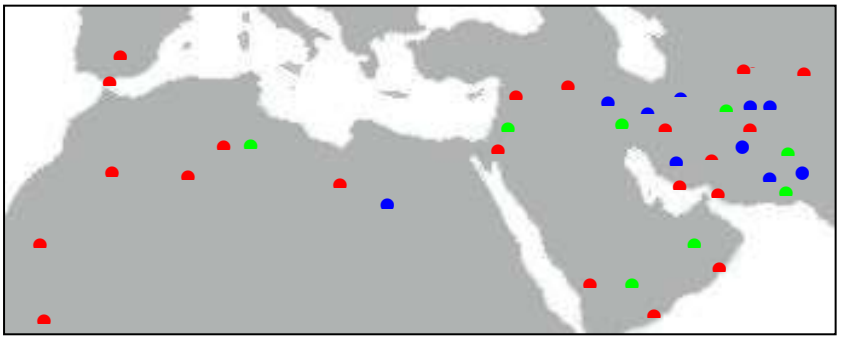
| | |
|---|---|
| 64 BC to 660 AD, the Roman-Byzantine Era | Qanats constructed in Syria and Jordan, and from there, north and westward into Europe.<br>Qanats part of Roman aqueducts in Lyons and Murcia. Evidence of Roman qanats as far away as Luxembourg.<br>Arab-constructed qanats at Crevillente, Spain, most likely for agricultural use, and at Madrid and Cordoba for urban use, based on Roman systems in southern France. |
| Post 1520, the Spanish Conquest | Qanat systems introduced in western Mexico.<br>Some qanats in Atacama regions of Peru and at Nazca and Pica in northern Chile may predate Spanish influence. |

The term for qanat technology varies regionally.

| | |
|---|---|
| Qanat | Arabic for "lance" or "conduit," a word of Assyrian origin via Hebrew and Aramaic. used in Iran, Jordan, Syria |
| Karez | Persian in origin, but now used mainly in Afghanistan, Pakistan and Central Asia. |
| Kanerjing | Western China |
| Khittara | Morocco |
| Falaj | United Arab Emirates |
| Fuqara | Syria, Palestine, and North Africa |
| Galleria | Spain |

Dissemination into northern Africa and western Asia.

- Before Alexander the Great (fourth century BC)
- Before the rise of Islam (eighth century AD)
- The Golden Age of Islam (11th century)



The Turfan (or Turpan) Basin, Xinjiang Province, China, is the second deepest geographical depression in the world, with over 4,000 square kilometers below sea level.


"Karez" means "well" in Uyghur. Dating from the Han Dynasty (206 BC - 24 AD), Turfan's karez qanats conduct snowmelt from the Tianshan Mountains to oases of the Silk Road. In its day, the system's length exceeded 5,000 kilometers, of which 30 were underground. Headwater wells exceed 100 meters while those further downstream were less than 10. Horizontal connectors were roughly 2 meters high.

Karez remnants remain a tourist attraction.

Karez
CNY 20

Qanats are still employed in Iran, where more than 200,000 kilometers of tunnels deliver nearly 600 cubic meters/second, equivalent to 75 percent of the Euphrates. Qanats yet supply the cities of Tabriz, Tehran and Yazd.

Qanats yet serve more than 70 percent of Oman's water use. A traditional greeting queries about the condition of the system, which evokes the reply, "Insha'allah, it is full."

**Roman Aqueducts**

The Romans began building aqueducts in the fourth century BC and by 312 BC had 14 systems with a capacity of 1500 cubic meters/day. Most were chopped into the earth, following the contours of the terrain. The smaller the slope, the slower the flow and the less the erosion, but then again, the less the capacity. The average gradient was between 0.0015 and 0.0030, but there was variation, with 6-kilometers of the Carthage Aqueduct at a rapid-like 0.028.

Vitruvius' (Chapter 3) advice,

> *If there are any hills between the city and the fountainheads... tunnels are to be dug... Air shafts are to be at distance of one actus* [40 meters] *apart.*

As Roman engineers did not distinguished between rate of discharge and velocity of flow, aqueducts were designed on the basis of conservation of velocity, not mass. Water Commissioner Sextus Julius Frontinus (40-103) attempted to balance system inflow with outflow by sizing intake cross-sectional area equal that of the channel, regardless of the latter's slope. As explained in his On the Water Supply of the City of Rome,

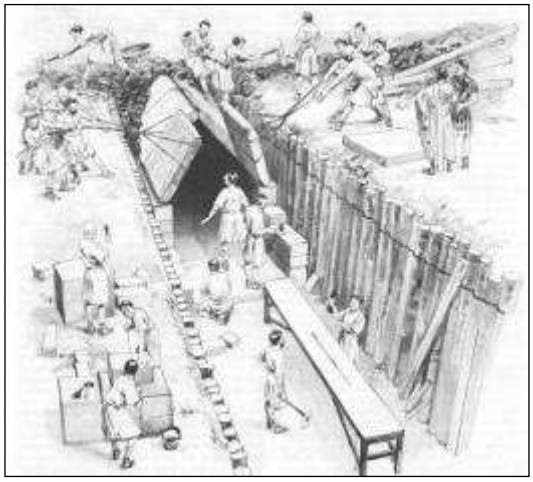
> *Let us remember that every stream of water, whenever it comes from a higher point and flows into a reservoir after a short run, not only comes up to its measure, but actually yields a surplus;*

*but whenever it comes from a lower point, that is, under pressure, and is conducted a longer distance, it shrinks in volume, owing to the resistance of its conduit.*

As long as the aqueducts faithfully served Caesar, Frontinus' superiors didn't question his theory of compressibility.

Soft ground was excavated, the sides shored by timbers. The floor was paved with stone and the walls lined with masonry. Mortar on the floor smoothed the flow. Concrete replaced stone around the time of Christ. When roofed with stone slabs, the trench became an artificial underground river.

Note the chorobates in the sketch.



The **Aqua Traiana**, shown below, was roofed for 58 kilometers.

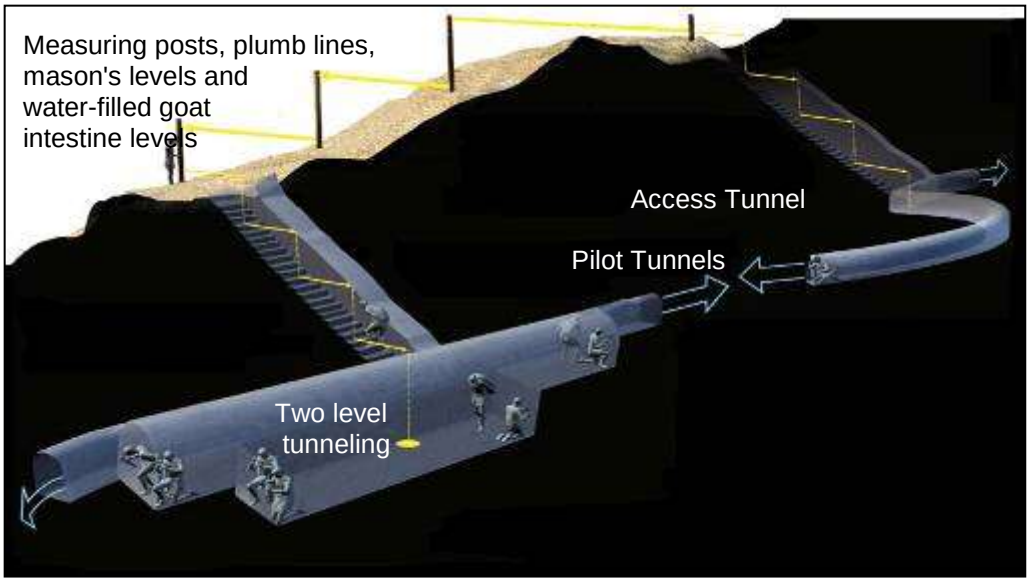
Tunneling was employed only in rare instances, the longest in 52 AD being a just-completed 2.3-kilometer stretch of the Anio Novus Aqueduct. Only as last resort did engineers turn to inverted siphons (Chapter 46) to cross deep valleys.

The 2.3 kilometer record was soon to fall, however, and by a factor of 40.

The Arabic name for the ancient aqueduct to the Jordanian city of Gadara is **Qanat Firaun**, Canal of the Pharaohs. That name is half correct, as the work is indeed a qanat. The aqueduct's not ancient Egyptian, however; it's imperial Roman. Gadara is where Jesus exorcized demons and chased them into a herd of pigs.

The aqueduct began in a Syrian swamp, long since dried out, ran for 64 kilometers on the surface until impassible terrain, and then for 11 kilometers underground. After briefly reemerging to bridge a narrow valley, the terrain became even more grueling and the final 94 kilometers were again below the surface, the longest known tunnel of antiquity.

With an average height of 2.5 meters and a width of 1.5, only four miners -- most likely legionnaires -- at a time could chisel no more than 10 centimeters a day. To expedite the advance, the aqueduct was constructed in the qanat manner with vertical shafts every 20 to 200 meters. Hundreds of soldiers could then labor simultaneously.

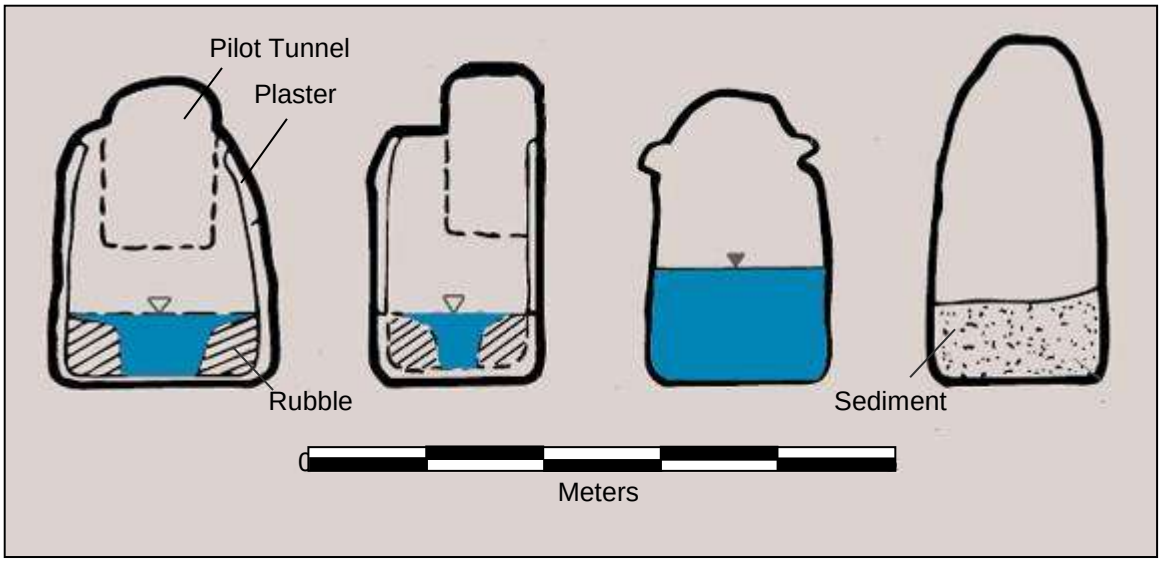



Construction began around 90 AD and continued for another 120 years. The miners chiseled over 600,000 cubic meters of limestone from the ground -- the equivalent of one-quarter of the Great Pyramid of Cheops.

Mineral deposits reveal that 0.3 to 0.7 cubic meters/second flowed through the structure, a decent flow, but not enough to fill the high stone reservoir built to feed Gadara's fountains and the planned temple.

The Romans appear to have been better excavators than surveyors. For the first 60 kilometers, the tunnel's gradient is but 0.0003, astonishingly shallow. Lateral errors greater than 50 meters appear in almost every phase of construction, corrected by S-curves where recognized in time, but by right-angles if not. The route appears to have progressed to the wrong side of the Wadi Hamra and had to be repeated on the other side.

Elevation variation of up to 2 meters between pilot tunnels could sometimes be accommodated by the connecting slope, but greater errors occasionally required new conduits. One section of the tunnel is bypassed by a passage lowered 1.5 meters.




Cross-sections

The Gadara Aqueduct was never fully completed and was put in service only in sections. The tunnel was not entered by archeologists until 2004 and questions remain concerning its design.

As an environmental aside, the fall of Rome was not due to lead poisoning from the municipal water system. The aqueducts fed the public fountains constantly, precluding sufficient detention time for dissolution. In addition, calcium carbonate precipitate created a barrier between the toxic metal and the passing flow.

**More-Recent Aqueducts for Municipal Water**

The **Croton**, **Catskill** and **Delaware** subterranean aqueducts constructed from the 1830s through the 1940s to serve New York City are mentioned in Chapter 88, East Side, West Side, All Around the Town.

Construction of the 364-kilometer **Los Angeles Aqueduct** from the Owens River began in 1908. The population of Los Angeles was around 300,000; the aqueduct would enable the explosive growth that would characterize the region for decades. Some 4,000 laborers worked at breakneck speed, using new technologies such as the Caterpillar tractor. William Mulholland, an Irish immigrant who'd worked his way up from ditch cleaner to Chief Engineer of the Los Angeles Department of Water and Power, oversaw the project.

The aqueduct included

55 kilometers of open unlined channel,
63 kilometers of concrete lined channel,
158 kilometers of cast-in-place covered conduit,
19 kilometers of inverted siphons, and
142 tunnels totaling more than 70 kilometers.

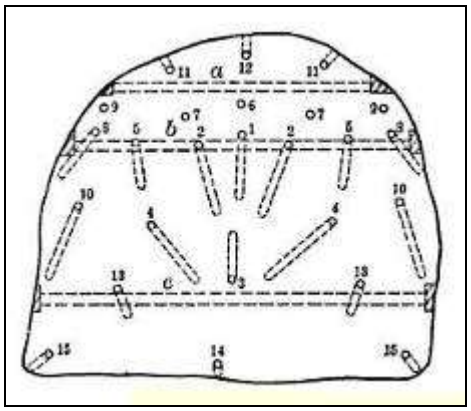
We'll describe the 30 cubic-meters/second Elizabeth Tunnel, at 8.2 kilometers, the longest of the project's tunnels. The tunnel bed is at a grade of only 0.001, but the conduit is pressurized by an energy gradient of 0.0033. Flow velocity is 3.26 meters/second.

California's Coast Range has a double crest with a valley in between. The tunnel is roughly 80 meters beneath the surface

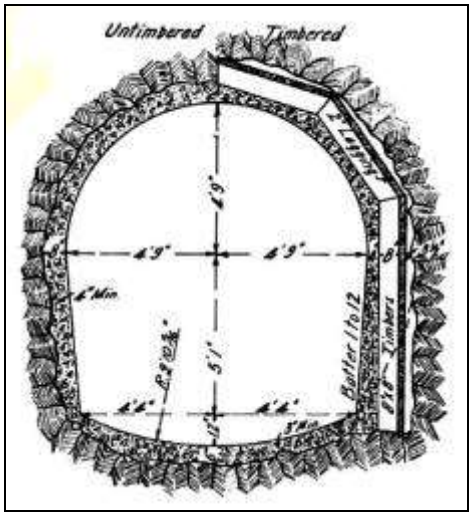
The Elizabeth Tunnel hard rock crew raced with the government men on the Gunnison Tunnel, Colorado (discussed later in this chapter) and beat them, setting the American record for hard-rock tunneling in a single month -- 189 meters in April 1910.

To the right, the map from Complete Report On Construction Of The Los Angeles Aqueduct (1916), Department of Public Service, Los Angeles, and a modern USGS 1:24,000 topo.


Breaking Ground



Blasting Pattern



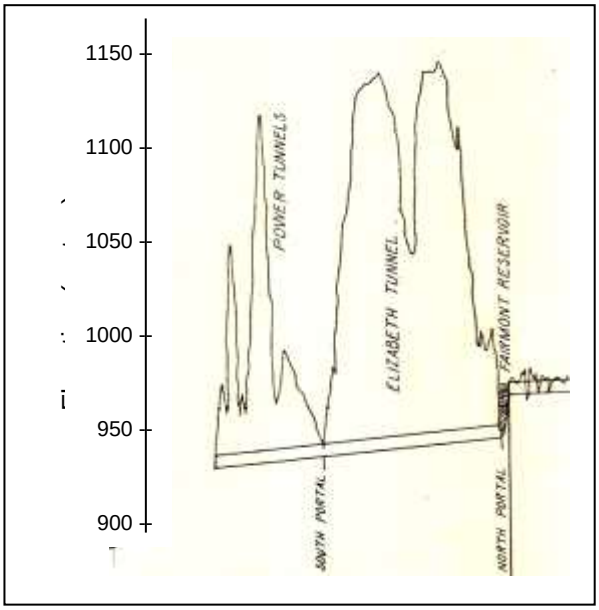

Design

Construction

While the aqueduct's purpose is to supply water to Los Angeles, the elevation of Elizabeth Tunnel allows it to pressurize the penstock of San Francisquito Power Plant #1, an additional project benefit.

Angered that their lands were reverting to desert, Owens Valley farmers blew up portions of the aqueduct in 1924, and again in 1927, a particularly-explosive chapter in the "water wars" that yet divide Californians.

In the early 1940s, the Los Angeles Aqueduct was extended further north through the Mono Basin Project, eventually reaching a total of 544 kilometers.

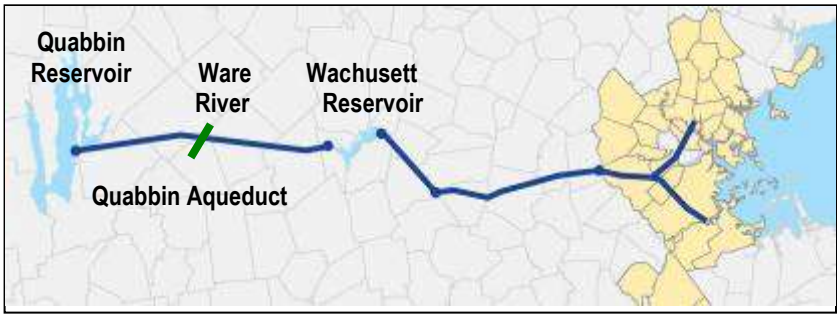


The 39.6 kilometer **Quabbin Aqueduct** supplies drinking water to Boston. Completed in 1933, the concrete-lined horseshoe-shaped rock tunnel, 3.9 meters high by 3.35 meters wide, can deliver 11.3 cubic meters/second.

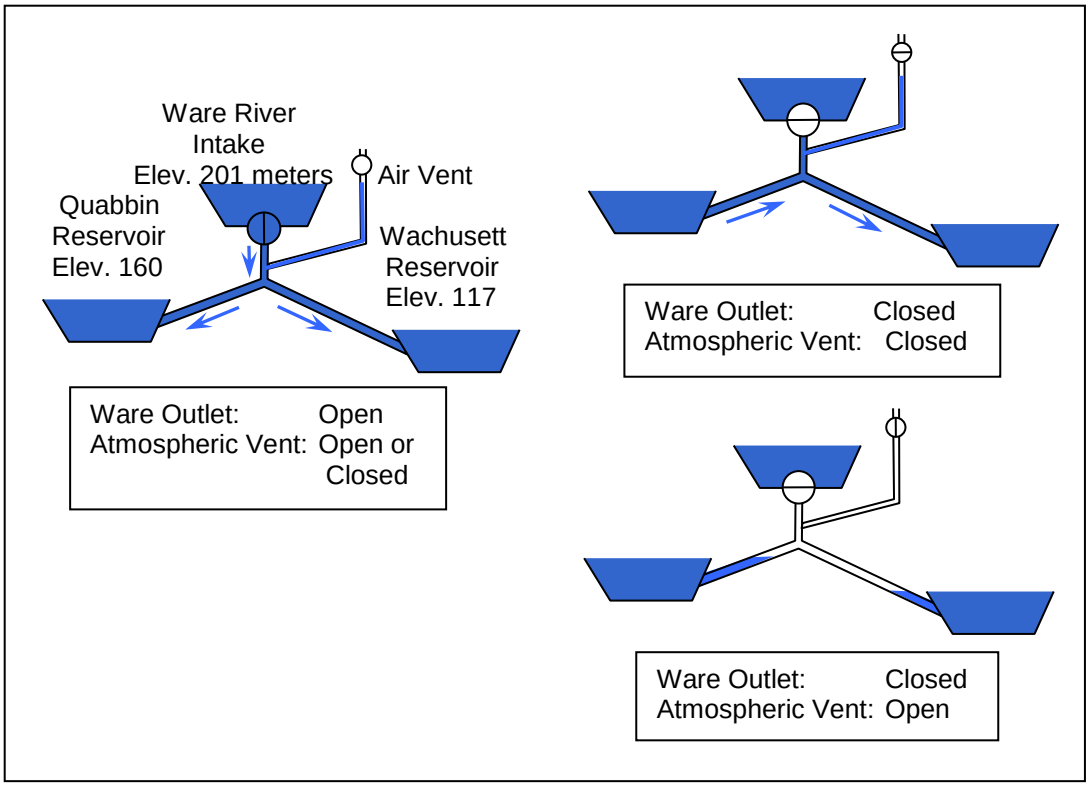
Construction prior to concrete lining.

But Quabbin's no ordinary aqueduct. It can be run in reverse.

The system allows floodwater from the Ware River to be sent both eastward to Wachusett Reservoir (and from there, onward to the consumers) and westward to Quabbin Reservoir where baffle dams enhance the settling of sediment. Water can alternatively be sent directly from Quabbin to Wachusett, or stopped from moving altogether, all of this controlled by just two valves at the Ware Intake, one for water and one for atmospheric air. It's a classic example of a siphon, the subject of Chapter 46.

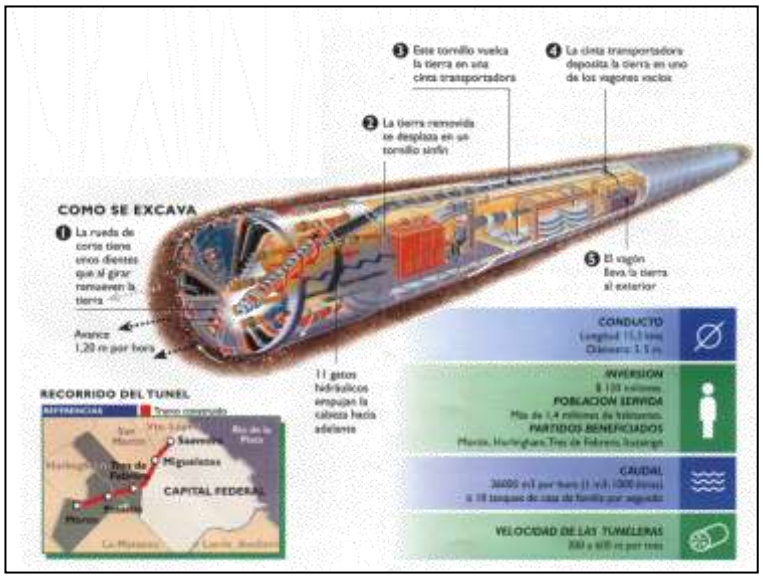



The siphon is primed from the Ware River Intake. Once the Wachusett branch fills and creates sufficient suction, both valves are closed and the Quabbin siphons eastward. The schematic indicates how the system can be operated by opening and/or closing the intake shaft and adjacent air vent.




Being a siphon, the pipes flow full. The system is gravity-driven until entering the municipal distribution system. Additional gates allow lines to be isolated for inspection and maintenance.

Buenos Aires' water utility Aguas Argentinas' $140 million **Rio Subterraneo** supplies water to 1.2 million residents. The tunnel, 35 meters underground, has a length of 15.3 kilometers and a capacity of 10 cubic meters/second. The conduit was bored at 1.2 meters/hour using similar technology to that used for the construction of the channel tunnel linking Britain and France.

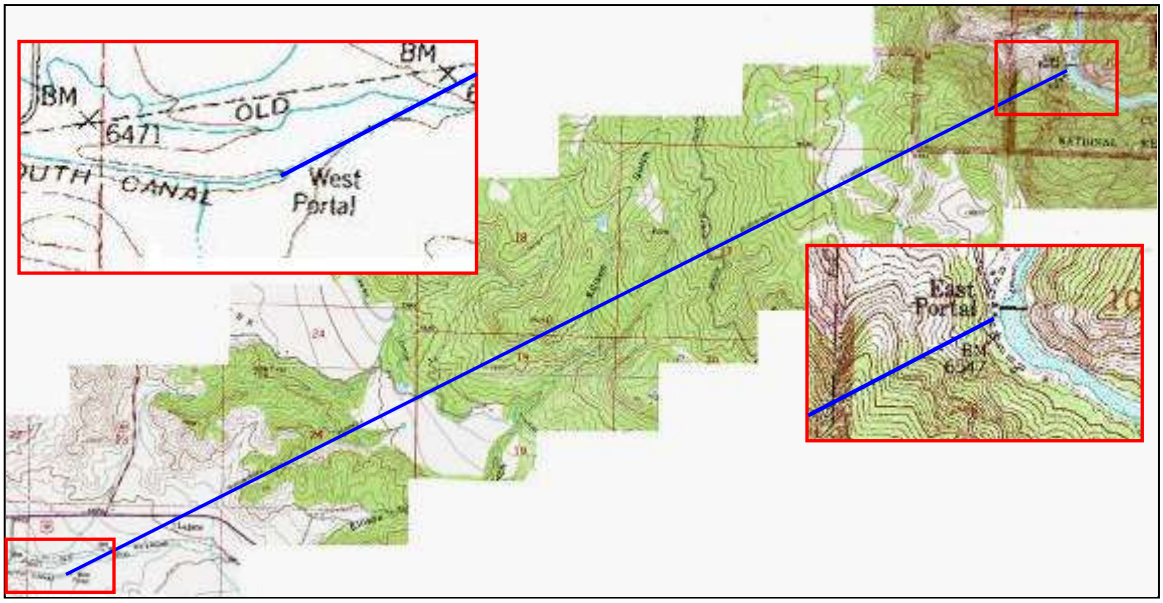



As, the truth be told, the project's nothing more than just another big pipe, we're surprised that the December 1998 Journal of the American Water Works Association, a staid publication, took the title at face value and heralded the work, "Underground River to Supply Potable Water."

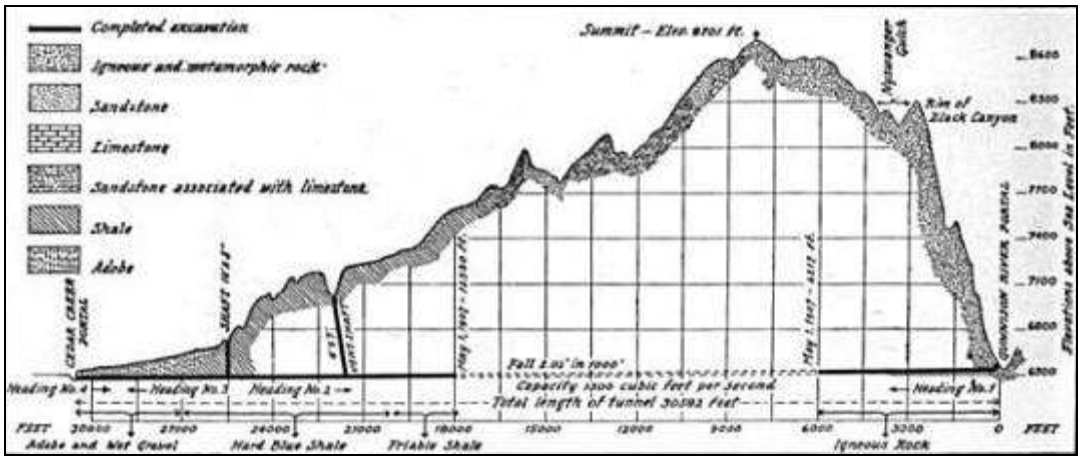
### Aqueducts for Irrigation

**Gunnison Tunnel** is a 9.3 kilometer irrigation tunnel constructed between 1905 and 1909 by the Bureau of Reclamation to divert water from Colorado's Gunnison River to the Uncompahgre Valley. At its completion, Gunnison was the longest irrigation tunnel in the world.

That record was a century ago, of course. Turkey's Sanlıurfa Irrigation Tunnels, completed in 2005, hold today's capacity record, 328 cubic meters/second. South Africa's Orange-Fish River Irrigation Tunnel, 1975, is the now the world's longest irrigation tunnel, 82.8 kilometers. But we'll feature Gunnison because President William Taft isn't otherwise much remembered.




Below, the Gunnison profile from "Running a River Through a Mountain: The Six-Mile Gunnison Tunnel," The World's Work: A History of Our Time 14, August 1907, by Arthur Page.



Excavation was from each end and two intermediate shafts. About 500 men worked on the tunnel, with the average hire lasting about two weeks.

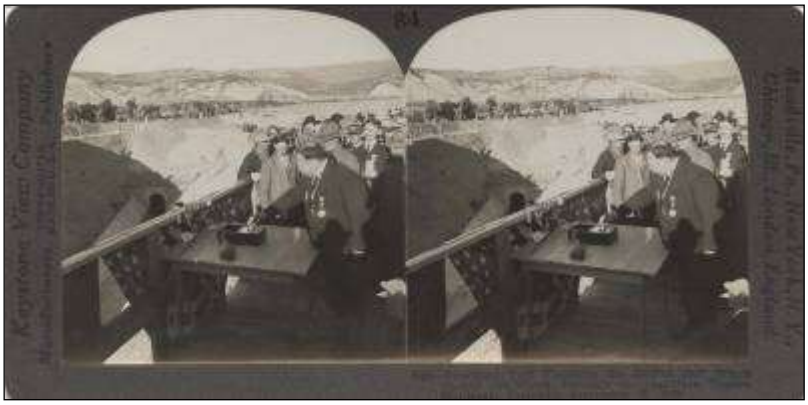
The tunnel is 3.35 meters wide, 3.65 meters high with arched roof, concrete lined, on a grade of 0.002

Tunnel yet to be concrete lined

Workers and removal of excavated materials

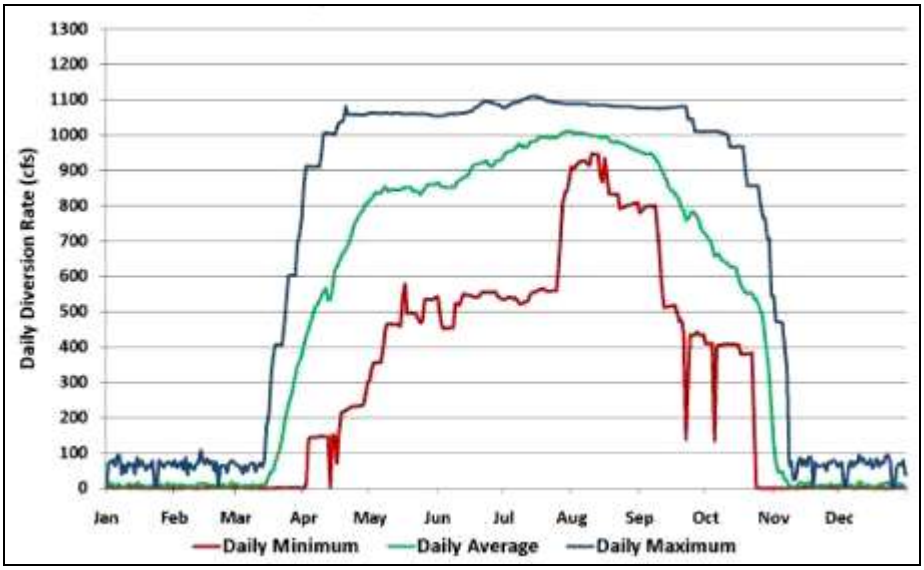
After five years and 26 fatalities, when the shafts met in the middle, they were offset by only 0.5 meter.

The project officially opened when President Taft pressed a golden bell to a silver plate.



Outlet

Diversions at approximately 30 cubic meters/second generally begin in March and end in October




Daily Diversions, 1991-2010

Unlike the Las Angeles and Quabbin aqueducts, the Gunnison tunnel does not flow under pressure. At the irrigation-season discharge, flow is approximately 2.3 meters deep with a velocity of 3.7 meters/second.

The Gunnison tunnel is not open to boating, but that's not to say the conduit's not been run. In the late summer of 1916, the Kolb Expedition canoed the tunnel in 65 minutes. That's 2.3 meters/second.

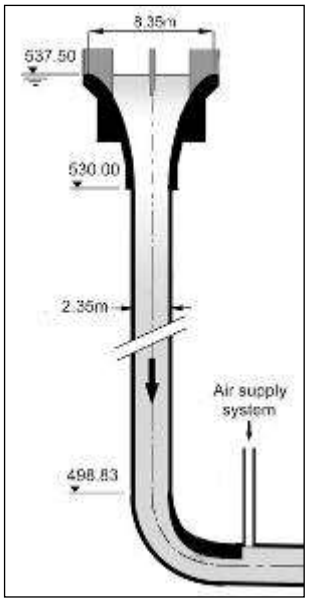
We'll add one final irrigation aqueduct to our survey because it's different. The **Kohala Ditch** once carried water from the rainy mountains to the dry fields of Hawaii's Big Island.

Today's Kohala Mountain Kayak Cruise glides through 10 tunnels, some cut through the porous rock; others coated with mortar. Some curve sharply, leaving kayakers in darkness. Others are arrow straight, a pinpoint of light in the far distance.

The paddle covers nearly 6 kilometers in 2.5 hours.

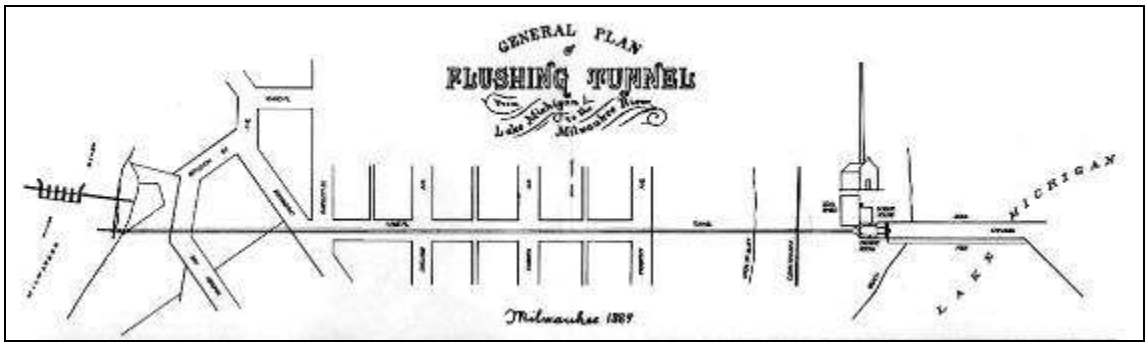
**Spillways**

A photo of a morning glory aqueduct inlet caries our thoughts to the subterrain. The glory hole of Monticello Dam in northern California is shown below. Located about 65 meters before the dam itself, water spills over the circular lip when the lake reaches full storage.




And why not take advantage of wave action?

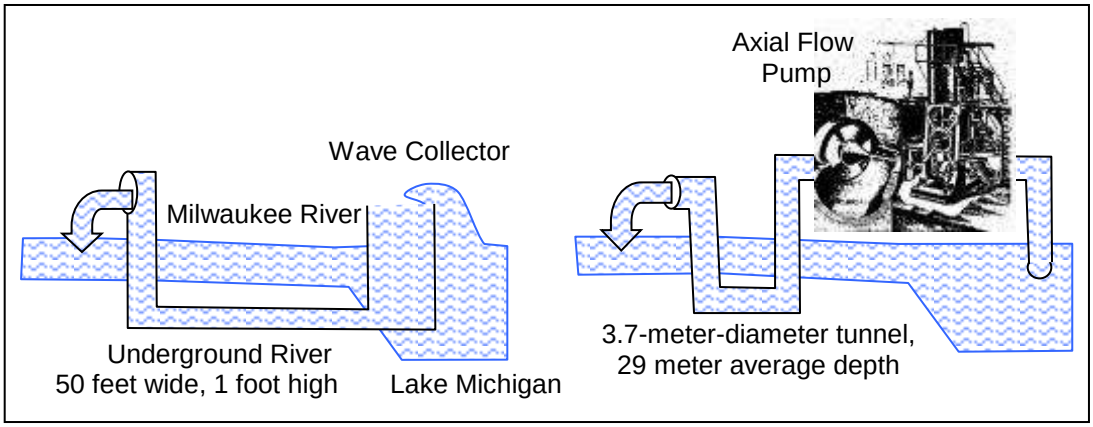
Built in 1888, the Milwaukee Flushing Tunnel used Lake Michigan water to augment the stagnant lower reach of the Milwaukee River.




Other ideas were floated regarding the flushing scheme, one being that of Dr. William Eggers. The Milwaukee Sentinel, November 20, 1888, summarized the scheme.

> [Eggers] *proposed to build an enclosure on the lake, on the theory that the waves would dash over its walls and by raising the water level therein force it through the underground river. He says, "The bottom of it (the tunnel) could not be less than fifty feet wide, according to my view, but perhaps it should be much wider, because the stream through it will perhaps never or seldom exceed one foot in depth."*
>
> [Mayor] *Brown apparently did not think it wise to farther the scheme of building an underground river... and the scheme was put to rest with tons of similar matter in the city clerk's crypt.*

Below is a schematic of Eggars' wave-spillwayed underground river and what Milwaukee actually constructed, now a National Historic Mechanical Engineering Landmark.




**Pipelines**

We'll end the chapter with a brief look at pipelines, conveyance structures not tunneled, but laid from above and often covered. A water pipe was constructed from the River Thames to London-town in 1236, and since then we've laid a lot more. To broaden our perspective, however, we'll briefly relax the "aque" criteria and consider other sorts of ducts.

Pipelines within the United States (kilometers)

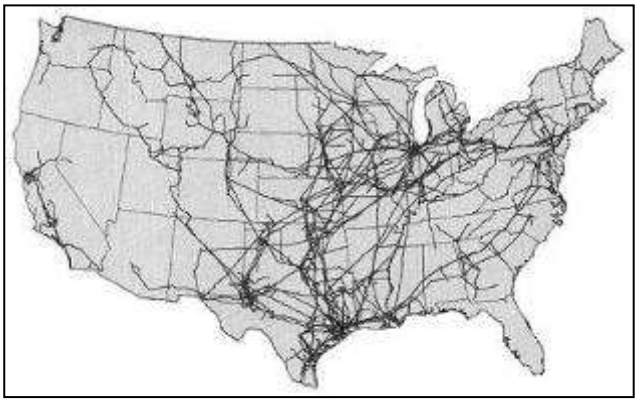
| | 1960 | 1970 | 1980 | 1990 | 2000 | 2002 |
|---|---|---|---|---|---|---|
| Petroleum Products | 307,280 | 351,900 | 351,452 | 335,937 | 284,834 | 259,396 |
| Natural Gas | 1,015,366 | 1,469,689 | 1,692,584 | 1,913,738 | 2,203,567 | 2,271,287 |
| Water Distribution | | | | | | 2,900,000 |
| Sewer | | | | | | 1,900,000 |

Note the steady increase in gas pipelines vs. the decrease in those conveying petroleum.

The first petroduct -- our term, we admit, but it seems proper -- wooden, 15 kilometers in length, was built in Pennsylvania in 1865. By 1880, John D. Rockefeller's Standard Oil Company was laying pipelines to Buffalo, Philadelphia, Cleveland and New York. Edison's electric light bulb reduced the kerosene market, but Henry Ford's mass-produced automobiles accelerated the product demand. Pipelines from the prolific fields of Texas and Oklahoma to made Rockefeller the most powerful man in the world.

Interstate pipelines today deliver more than 2 billion cubic meters of petroleum annually, of which 59 percent is crude oil. Pipelines account for nearly two-thirds of the ton-kilometers of petroleum transport.

It takes several weeks to move petroleum products from Houston to New York City, but the cost is only several cents/liter.



A 1954 American Petroleum Institute pamphlet Underground Rivers of Oil by W.C. Kinsolving covers the history, economics and defense aspects of petroleum pipelines. The API assures us that such underground rivers are difficult to bomb.

Another pipeline item,

In April 1996, National Public Radio scooped plans for a multi-billion-dollar trans-continental coffee pipeline, a javaduct -- so to speak -- from Seattle. Right-of-way negotiations were underway with various governors. Although the source of the coffee was not revealed, it was widely believed to be Starbucks.

Unfortunately for NPR listeners, the broadcast date was April 1.

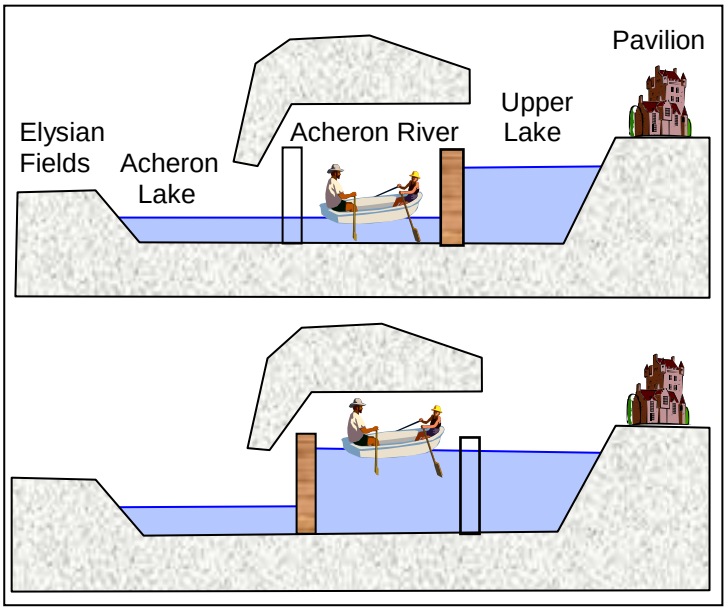
# CHAPTER 66
# AMUSEMENT PARKS

In 1796, Count Stanislav Potocky began construction of a park in the city of Kiev to remind his Greek wife Sofia of her homeland. And what could be more Hellenist than an underground river?

The Acheron River of Sofiyivka Park runs underground for 224 meters under four apertures in its granite ceiling.

The route makes use of a canal lock originally constructed for the Umanka River before the waterway was diverted.

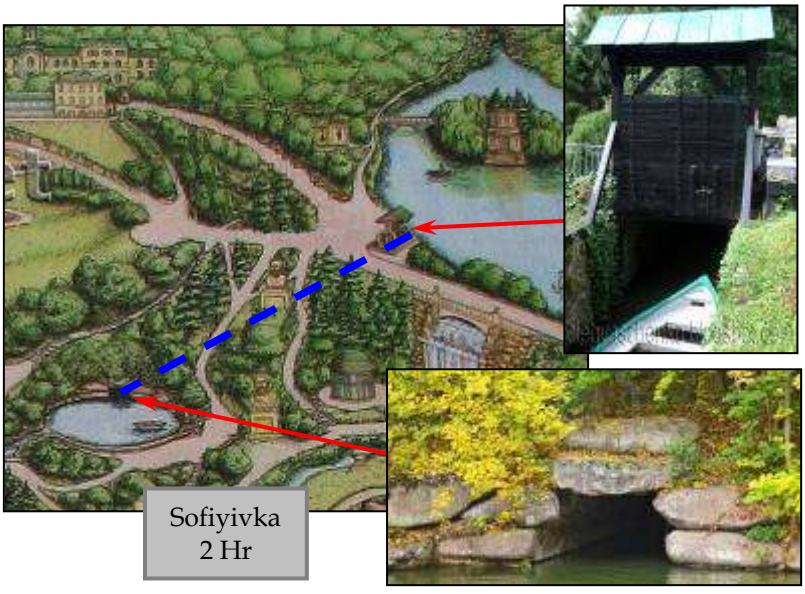
When the lower gate is open and the top gate closed, the boat enters the lock chamber at the elevation of Acheron Lake. When the bottom gate is closed and the top is opened, the chamber fills to the level of the Upper Lake and the boat exits.




Enticing his guests to take a solitary stroll into the park's foreboding grotto, the Count prepared a surprise. The lonely walker would be accosted by a bearded Charon who would place his victim on a boat and silently row him along the gloomy underground river until they emerged at a sunlit Greek pavilion

To the right, the landscaping.

The subterranean boat ride takes 8 to 10 minutes.

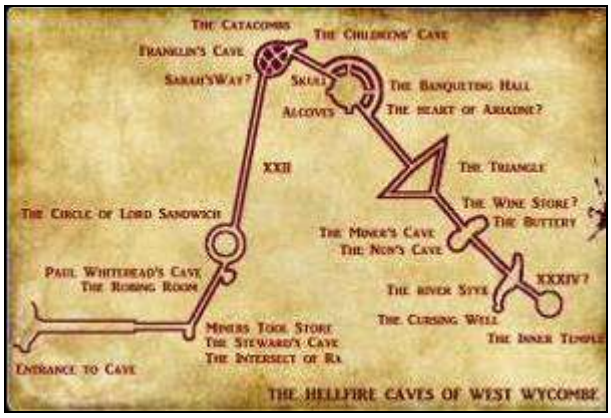



The Count wasn't the first to dig a new River Styx, however. The Great Antrum at the Roman town of Baiae near Naples is a complex of artificial tunnels hewn into volcanic rock as a replica of the Greek Hades. At the end of the entrance tunnel is a fork with a pivoting door. The left passage continues on while the right passage stair steps down to an underground River Styx, 50

meters long, fed by twin springs. The Romans sealed the site 2,000 years ago. Since its rediscovery in the 1962, this River Styx has been closed to the public due to its dangerous access and sulfurous fumes.

The Hell-Fire Caves were hewn into the chalk cliffs of Buckinghamshire in the 18th century, the design inspired by Sir Francis Dashwood's Grand Tour of Europe and the Ottoman Empire. The caves extend 500 meters underground, the chambers connected by passageways, one of which crosses the "River Styx."

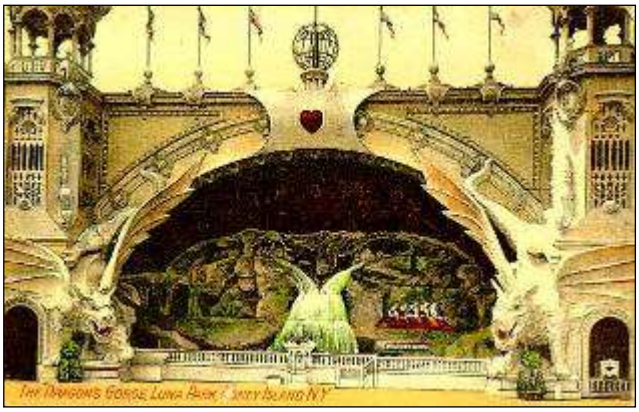
The caves today are operated as spook-house.




The first account of the "river" comes from the traveler and diarist, Lybbe Powys, who in 1796 stated that the pool had to be crossed on stepping-stones, whereas previously there had been a boat. In 1863 the pool was described as the "River Styx."

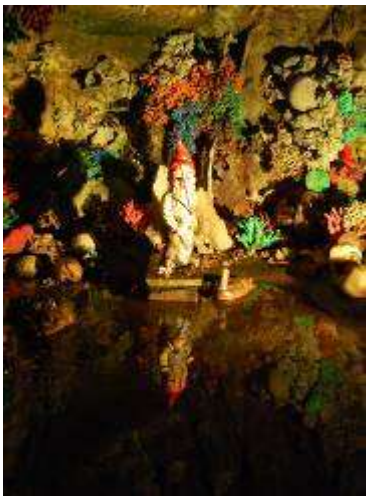
Hell-Fire Cave
£5.00

The original “20,000 Leagues under the Sea” which helped open Coney Island's Luna Park was replaced in 1905 by an indoor scenic railway ride, the “Dragon’s Gorge”, which boasted 10,000 lights and passed along the great waterways of the world, ending with the River Styx. The ride burned in 1944

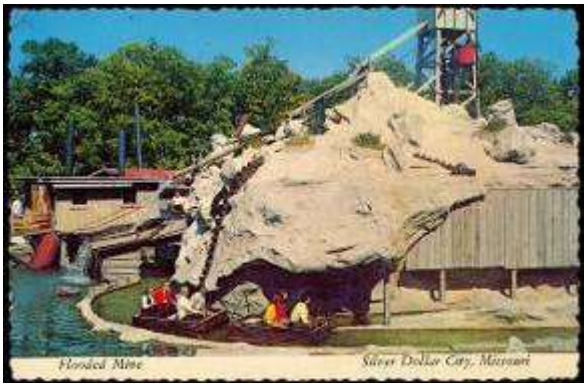


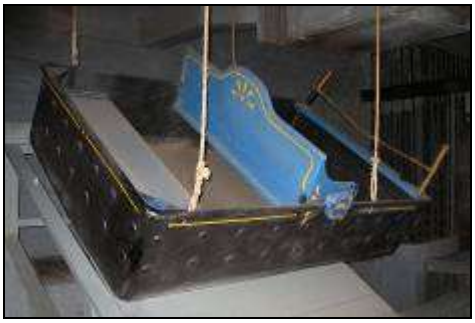
Tennessee's Fairyland Caverns, "the only man-made cave in the world," extends for some 160 meters.

Mirror Lake is its feature attraction. We mercifully show only one of the gnomes.



The Flooded Mine, a dark but gentle underground river ride in Missouri's Silver Dollar City amusement park, became The Great Shootout at the Flooded Mine in 1990, flagrant misuse of even a fake underground river. "Each boat is equipped with pistols that can be used to shoot at targets and ring up points."



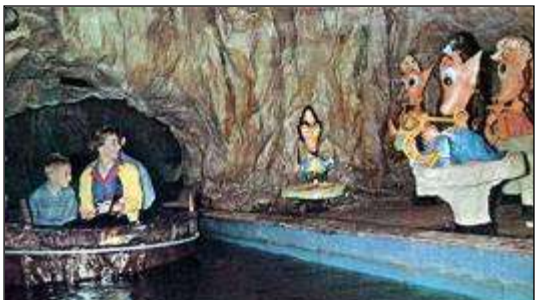
Original Silver Dollar City cave boat

Tennessee's sister Silver Dollar City -- today's Dollywood -- likewise featured a Flooded Mine, featuring such state-of-the-art 1970s technology as strobe lights and animatronic characters with rounded TV screen faces.

The ride closed in 1997, but remnants of the attraction are yet recognizable to those who fondly remember the original.

Spee-Lunker Cave was a favorite at Six Flags Over Texas. The boats drifted in a narrow concrete river into a cave opening, dark and cool, a respite from the Texas summer.

Then things become weird.



Grotesquely-cute Spee-Lunkers with tiny bodies, oversized, stalactite-shaped heads and bulging eyes worked busily along the underground river banks. The animations were single-jointed using reciprocating air cylinders or rotating motors without external control and regular, repeating movements.

The original 3-passenger round bumper boats were replaced by 4-person oval-shaped fiberglass craft in the mid-60s.



The oval boats had submerged, horizontal rubber wheels that when contacting the flume sides, kept the bow facing forward. A post at each corner assisted passenger seating and employees handling the boat.

The boats were later ganged in pairs, a rod connecting the stern of the first to the bow of the next.

In 1991 the attraction was converted into a cartoonish Yosemite Sam and the Gold River Adventure. Yosemite Sam still uses the ganged oval boats, but the ride's now about Loony Tunes.

Blue dye was added to the water.

It is not true that water moccasins occasionally dropped into the boats and bit the guests, but the urban legend is thought by many to be the reason for the demise of Speelunker Cave.

We made mention of San Marcos, Texas in Chapter 53, Diversity in Darkness, Texas Ecology. The San Marcos Springs are among the greatest in the Edwards Aquifer, a.k.a. the Edwards Underground River, per Chapter 69, The Law of Subterranean Streams.

Here, however, San Marcos Springs merits mention as the location of Aquarena Springs Amusement Park, once one of the "Seven Wonders of Roadside America" where glass-bottomed boats allowed a look at the flooded springs bubbling in the sands below. A gondola provided higher perspective. Ralph the Swimming Pig and frolicking mermaids were trademarks.

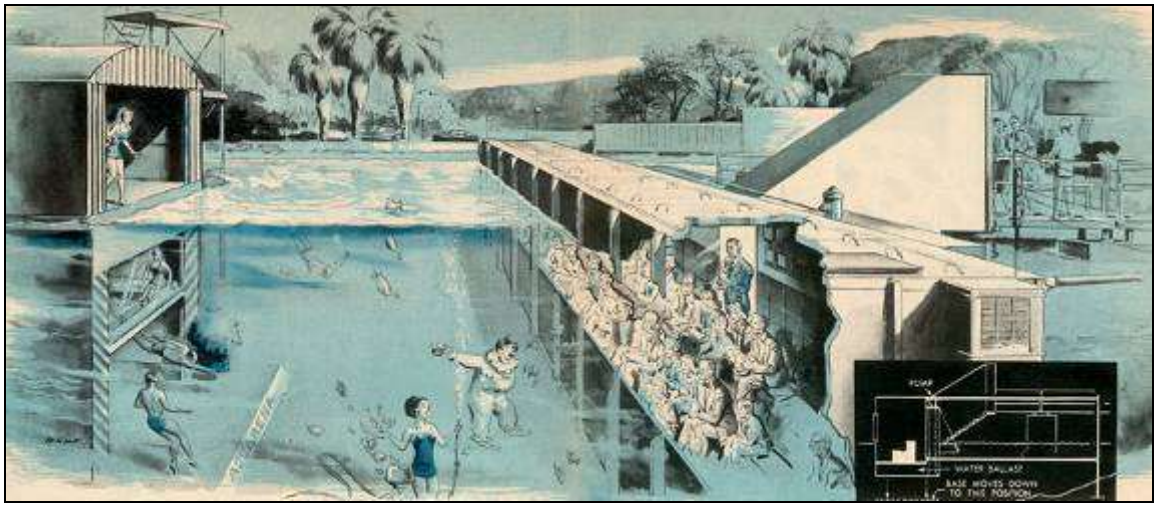


Popular Mechanics, June 1952,

> *At San Marcos, Texas now boasts a venture unique to both the entertainment and educational worlds -- a theater which allows an amazed audience to witness an hour-long program beneath the surface of a crystal-clear lake. It is a submarine theater which, when a special ballast tank is flooded, takes its cargo of people below the surface.*

The mechanical wonder of the facility was the 100-spectator glass-fronted gallery ballasted to submerge 1.1 meters below the pool surface in 11 minutes.

Glurpo, the World's Only Underwater Clown, below center, was another crowd pleaser



Not all were equally amused, however, as suggested by Texas naturalist Del Weniger.

> *Seated in this theater at the mouth of the spring, how can one help but wonder if there is any most unlikely corner of the biosphere humans will not invade and desecrate to their own whims.*

The attraction went out of business in 1996 and Texas State University converted Aquarena into an educational center.

After Disneyland's 1955 opening, Walt Disney proposed attractions for the upcoming 1964 World's Fair that could be moved to Fantasyland when the event was done. Pepsi-Cola agreed to sponsor a UNICEF benefit boat ride and "It's a Small World" came to be.

The 11-minute boat ride, the longest ride in the Magic Kingdom, features international dolls that frolic to the brain-numbing "It's a Small World" melody

The ride has recently been reconstructed for heavier tourists.

It's a Small World is indeed of this world, as the Disney Empire has included it in subsequent theme parks.

Walt Disney World, Florida

Tokyo

Hong Kong

Paris

The Small World theme has been ruthlessly pirated elsewhere.

Small World rip-off, Suzhou Amusement Land, China

Kernie's Wunderland,
The Netherlands

Hyland Hills Water World,
Denver

Dickens World,
London

For the daring, caverns are common to chute rides.

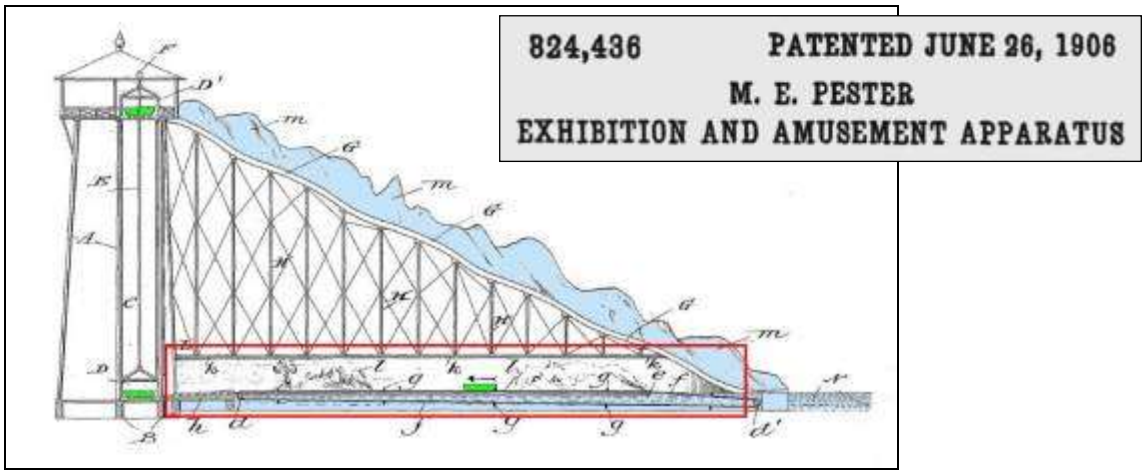
Schlitterbahn, Texas

Valley Fair, Minnesota.

Valley of Waves, South Africa

**Patents**

The patented Exhibition and Amusement Apparatus predates and out-adrenals Splash Mountain, as this boat's not anchored to a track. Note the size of the craft (highlighted in green) vs. the magnitude of the turbulence.




Most of the patent is concerned with the elevator, but we're more interested in the red box.

From the patent documentation,

> *Also the escalator to convey the boat from the lake to the foot of the tower and there deposit it on the elevator may be arranged as over dry land, so as to give the effect of the portage or tramway instead of being submerged in the water and arranged in connection with the lake, simulating an underground river. I very much prefer the latter, however, because then the underground effects and other illusions and pictorial schemes may be more effectively and attractively carried out.*

Which is to say that the craft could be hauled to the elevator on a track, but the experience will be better if the transit resembles a voyage on an underground river,

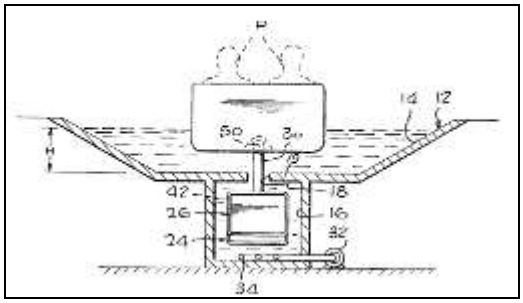
And another patent, "Boat Ride for Amusement Park," 3,930,450, January 6, 1976:

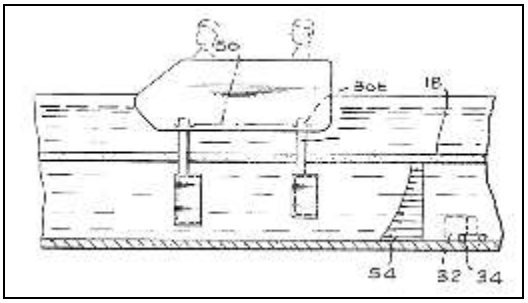
Description:

> *Amusement parks often have "dark rides" in which people are seated in boats that float along a channel that carries them past animated displays. The boats are typically moved along the channel by pumping water along the channel. The cross-sectional area of a boat is typically only a small fraction of the cross-sectional area of the water-filled portion of the channel, so that a large amount of water normally must be pumped through the channel. While this transport system provides a smooth and vibration-free ride, it has several disadvantages. The propulsion system is inefficient, and it is difficult to provide sharp turns along the waterway inasmuch as at such turns the water swirls so that it tends to tip the boat rather than propel it and the water also tends to ride up the outer side of an open channel.*

Summary of the Invention

> *A boat ride apparatus is provided which enables boat propulsion with a minimum of power and along tightly curved paths. The system includes a shallow main channel and an auxiliary channel lying beneath the main channel and isolated from it except along a slot that connects the channels. A boat for carrying people includes a hull floating in the main channel, a pair of paddles lying in the auxiliary channel, and a pair of supports extending through the slot and joining the paddles to the hull. Pumps are provided that move water only along the auxiliary channel, to push the paddles and thereby propel the boat.*




**Underground Rivers that Never Came to Be**

And then there are those underground river rides that never materialized.

To the right, a concept drawing for Treasure Island Cave at Disney World, never implemented.

Designers proposed two alternate ways in which to enter Michael Jackson's intended "Peter Pan's Neverland," both of which would have been attractions in themselves. In one, visitors would arrive by an aerial ride. The other would have been by boat through mysterious caves.

We're not sure whether to classify the Shweeb Monorail as a way to access a subterranean formation or as a futuristic ride that happens to pass through a cavern, but here's a marketing illustration.

**The Tunnel of Love**

A "dark ride" is an amusement park attraction in which guided vehicles travel through specially lit scenes, typically containing animation, sound, music and special effects. The Tunnel of Love is a dark ride in which pairs of riders are taken -- usually by boat -- through dark passages. Spooky frights provide excuse for physical contact. As with Patent 824,436, rowing is unnecessary.



Vintage Postcards



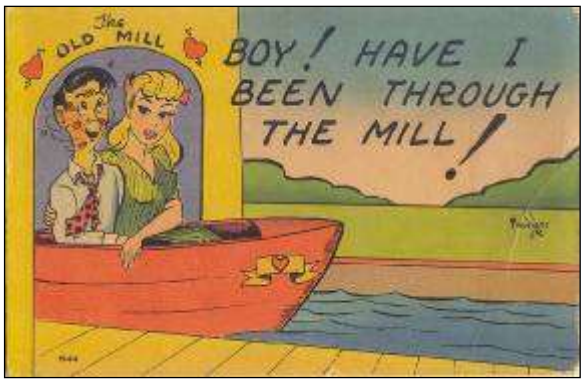
Across the Hudson from New York City, Palisades Amusement Park replaced its old Tunnel of Love boats with chariot-style cars that traveled along a track. The ride was later redesigned with an Arabian Nights theme. The attraction was then renamed Casper's Ghostland, its caverns populated by such characters as Casper, the Villainous Ghostly Trio and Spooky, the Tuff Little Ghost.


As with Palisades Amusement Park, not many tunnels of love remain in operation today, the Gröna Lund in Stockholm being an exception.

Gröna Lund

Kansas State Fair

Debuting in 1921, Ye Old Mill, the 500-meter Iowa State Fair tunnel of love passed by mangy stuffed bears and dioramas of teepees. Renovated in 1996, the sights were replaced by vintage fair posters. The Kansas State Fair has a like-named boat ride (above), but it's a horror tunnel.




1952 Posatcard

The tunnel of love is an established theme of popular music. When Bruce Springsteen's marriage ended, he sang,

*It ought to be easy ought to be simple enough*
*Man meets woman and they fall in love*
*But the house is haunted and the ride gets rough*
*And you've got to learn to live with what you can't rise above*
*If you want to ride on down in through this tunnel of love*

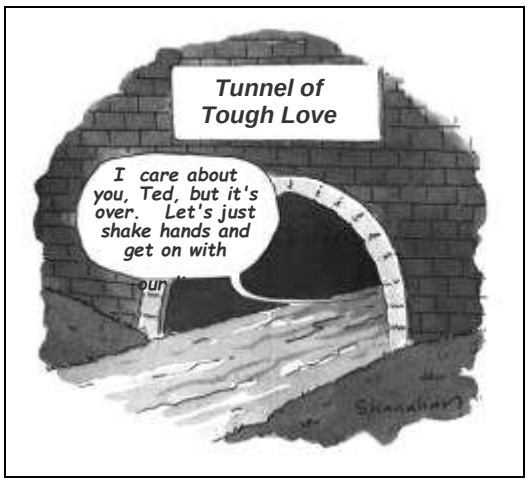
Or take the British band, Dire Straits,

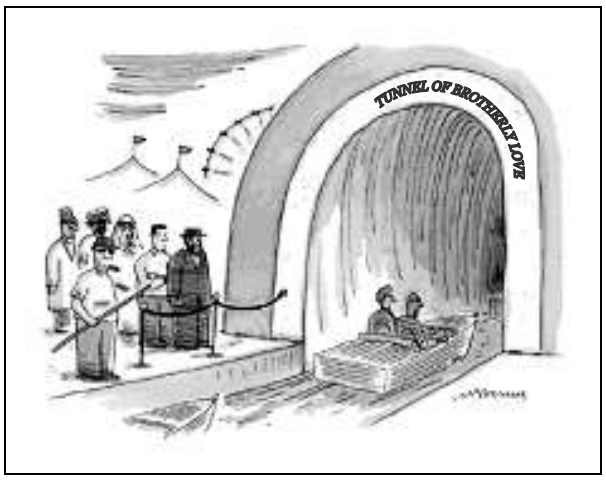
*And the big wheel on turning neon burning up above*
*And I'm just high on the world*
*Come on and take the low ride with me girl*
*On the tunnel of love*

And of course, there have been the movies.

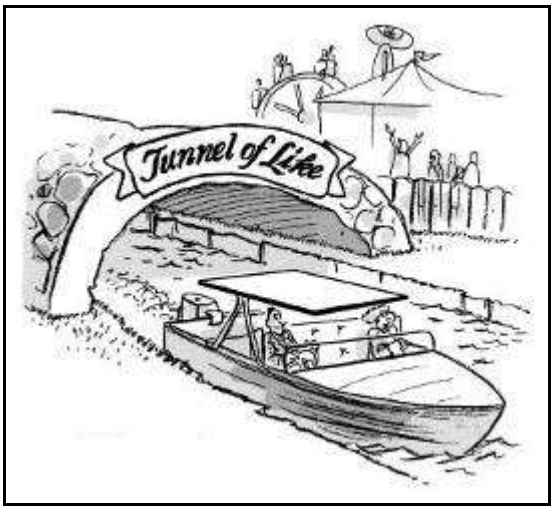

Billed as "Sex in the Suburbs!" and shot in three weeks on a single set, Doris Day and Richard Widmark play a couple battling the bureaucracy of adoption in Tunnel of Love (1958). The film was hated by Day's fans and the actress blamed its failure on a poor script.

There are scores of cartoons about this underground river, far more, in fact, than unique ideas. Here are just a few.

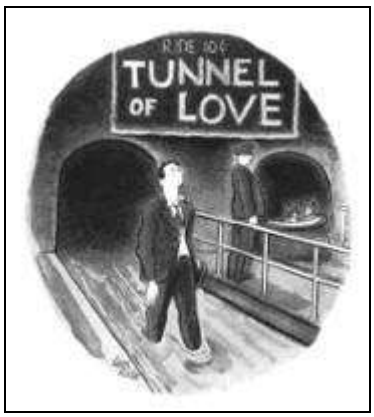


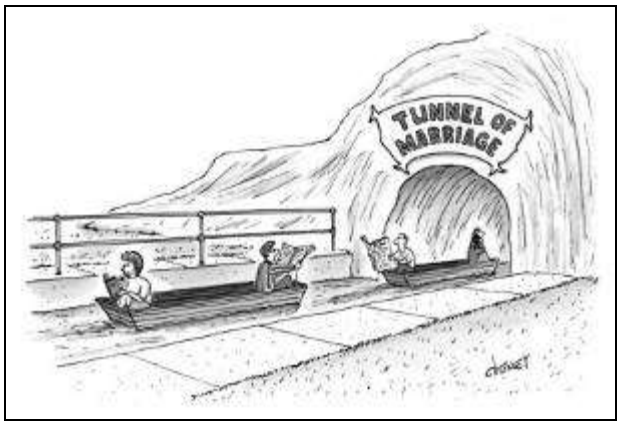





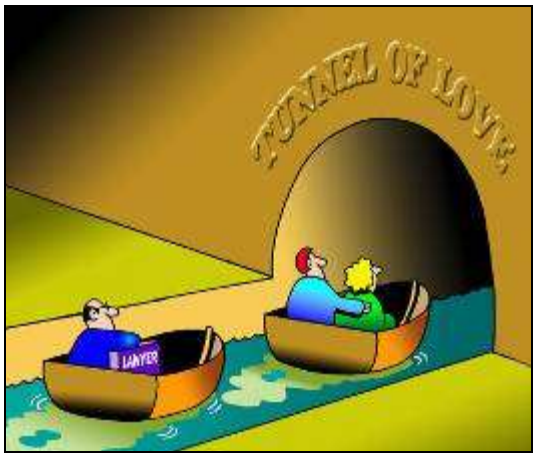



"Er---we'll wait for the next one, thanks."


TUNNEL
OF LOVE

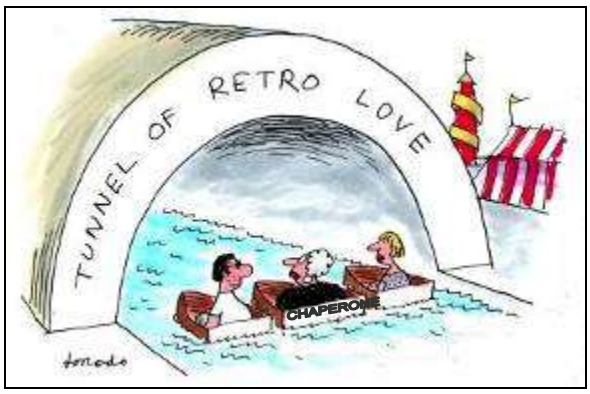

TUNNEL OF
MARRIAGE


Tunnel of Interactivity


TUNNEL OF LOVE
LAWYER

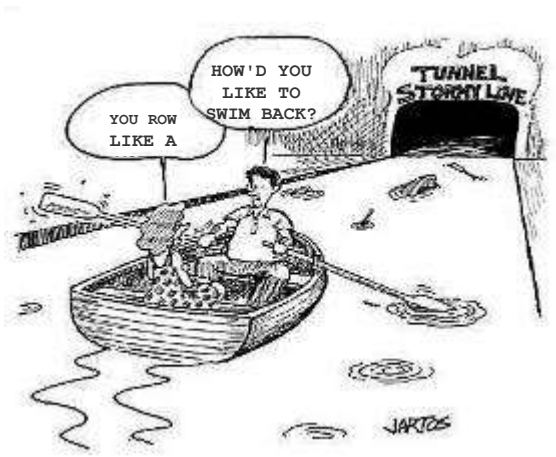

TUNNEL
OF
JERKS

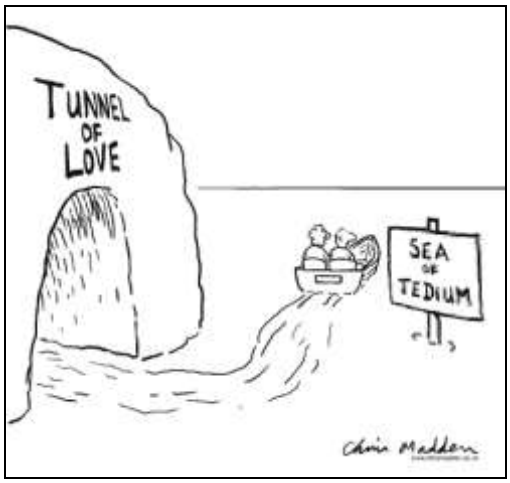

TUNNEL OF COUPLES COUNSELING


TUNNEL OF RETRO LOVE
CHAPERONE
tomodo

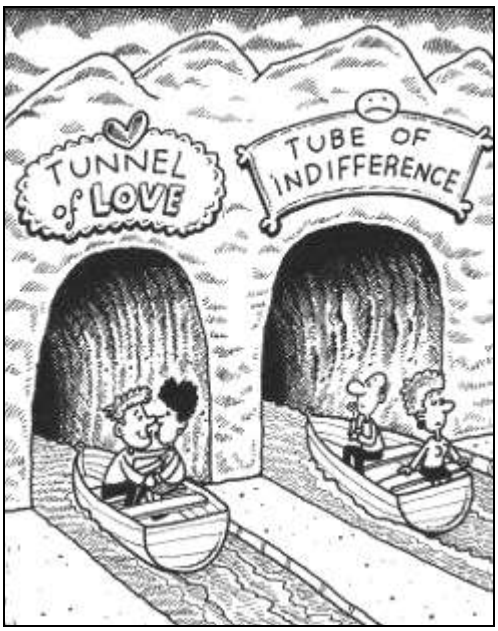

TUNNEL OF SAFETY

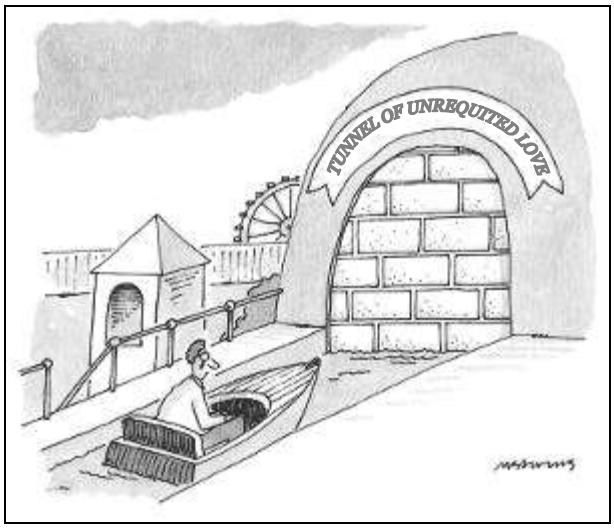

TUNNEL OF LIFE

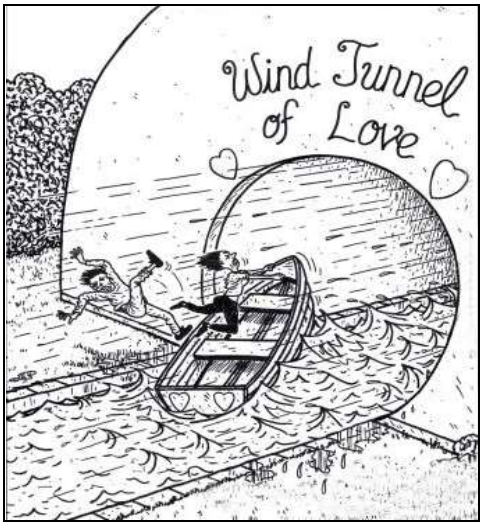

HOW'D YOU LIKE TO SWIM BACK?
YOU ROW LIKE A
TUNNEL STORMY LOVE
JARTOS


TUNNEL OF LOVE
SEA OF TEDIUM
Chris Madden


"We must have made a wrong turn somewhere."


TUNNEL of LOVE
TUBE OF INDIFFERENCE

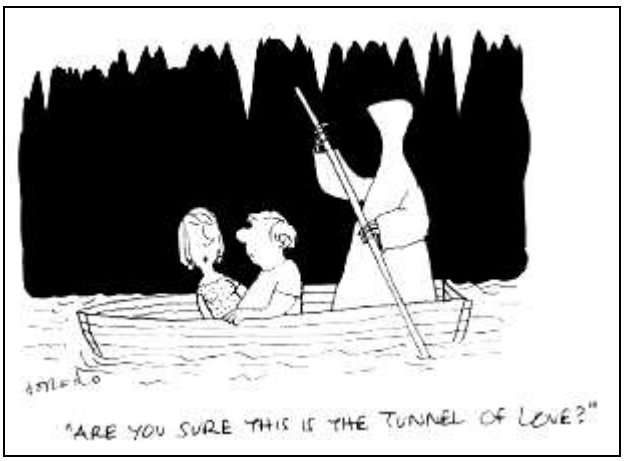

TUNNEL OF UNREQUITED LOVE


Wind Tunnel of Love


WAIT... DO YOU HEAR A WATERFALL?
TUNNEL OF LOVE


TUNNEL OF LOVE
EXIT

Compilation of cartoons brings to mind the theme of Chapter 7, The Concept of Circulation, and we're thus not surprised to once again encounter the still-laboring Charon.




Cartoons of underground rivers, like the primeval river itself and the aged boatman toiling upon it, seem likely to be long with us.

# CHAPTER 67
# DAMMING UNDERGROUND RIVERS

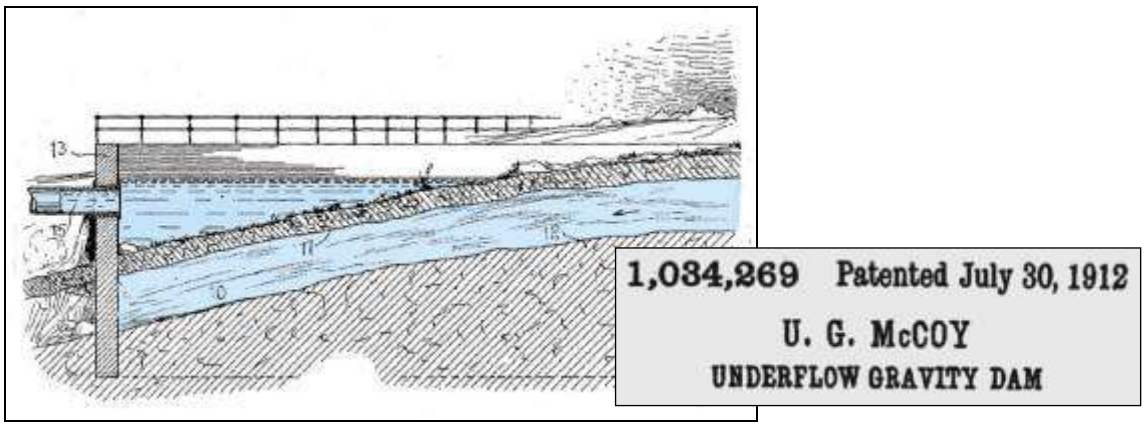
We, as human beings, endeavor to make the earth a more useful place. Surely, then, we can improve on the waterways below.

This chapter deals with the damming of natural subterranean conduits. The chapter to follow considers our other efforts.

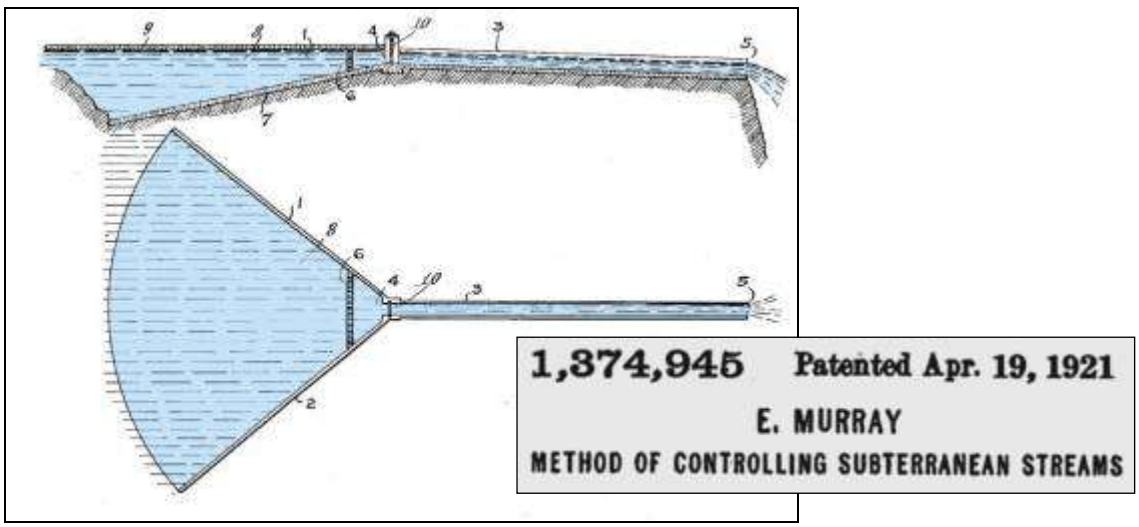
| Conduit | Dammed | Undammed |
|---|---|---|
| Natural | This Chapter | Following Chapter |
| Tunneled | | |

**United States**

We begin with a pair of United States patents.




*A dam for underground waters consisting of a V-shaped structure sunk in the earth a sufficient distance to intercept an underground stream.*




*It is well known that subterranean streams generally flow incessantly and it is generally estimated that there is a drop of at least seven feet to the mile. It is, therefore, obvious that if*

*the power of such stream could be utilized for industrial or commercial purposes, a very valuable adjunct to the industrial development of a community would be provided.*

It turns out, however, that underground rivers were dammed before the patents. A "young man from the East" merited mention in "An Underground Water Supply; a Subterranean River Tapped for the City of Galveston's Uses," New York Times, April 15, 1893.

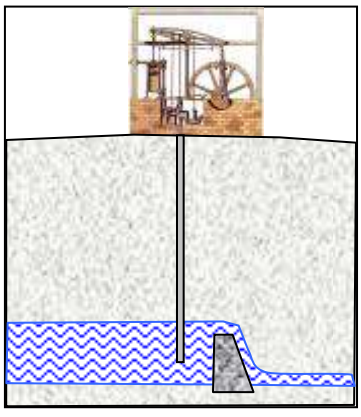
*Gainesville, Texas, April 14 -- One of the most remarkable systems or water supply in the world is to be found in this city. About a mile north of the city is a valley a thousand feet wide, which surveyors determined to be the location or an underground stream, though the valley itself was dry and under cultivation.*

*It was suggested that he wells might tap this stream and give the city a pure supple of water. The City Engineer, a young man from the East, suggested that, in lieu of a reservoir, the hidden stream be dammed, when there would be at all times be an inexhaustible supply*

*Sinking a large one in the center of the valley, he struck living water at the depth of 30 feet, coming in such quantities that a powerful steam pump could not lower it to any perceptible degree. An appropriation enabled him to carry out his plan, which resulted in obtaining an unlimited quantity of pure water.*

*Sinking five wells, 200 feet apart, he covered the entire width of the stream. He next tunneled from well to well, making six-foot excavation the entire distance across the stream. This was enlarged so as to be 6 feet high and 8 feet wide. Then on the lower side he built a substantial stone dam 6 feet high, its foundation being below the bed of the submerged stream, which was clearly defined. The water collected so fast that the central section had to be left until the two wings were completed. When this was done the work was begun on the central unfinished portion, two powerful steam pumps being required day and night to keep down the water so that workmen could complete the structure.*

*Soundings showed that before the connections were made with the mains leading into the city the tunnel was filled with water, and a current flowing over the dam was observed as all five of the wells. The mains were filled as soon as the pumps could be set at work, and although no limit has ever been placed upon the use of the water, the supply has never at any time been lowered below the top of the dam. In rainy weather and in dry weather the volume of water has remained the same. It is free from all vegetable and mineral impurities and is cool and sweet.*




CERTIFICATE OF DEPOSIT

Gainesville Water Company of Gainesville, Texas

No. 9 $1,000

By its location, the 1893 project tapped the Gulf Coast aquifer, a broad sandy stratum 70-150 meters in thickness, not, as favored by journalists of the era, a "hidden stream."

Modern Galveston derives less than 10 percent of its water from the ground, and even at that limited pumping, the water table has dropped more than 100 meters in some locations. The promised "unlimited quantity of pure water" wasn't to be.

Although the underground river in question does not, in fact, exist, the July 18, 1925 St. Petersburg Evening Independent noted the suggestion for damming it in "The Only Thing Now is to Dam up the River,"

> *Most ingenious of the 1,001 explanations of the collapse of the new First Methodist Church, South, was advanced this morning by a woman passing the ruins.*
>
> *"Now my husband is a brick mason, and he knows what caused this building to fall," she said. "There is an underground river running form Mirror Lake to the bay, and that is the reason why the building gave way."*

St. Petersburg, Florida 1919 map, location of the Methodist Church shown in red, the suggested path of underground river, in blue.


The 1930s postcard shows Mirror Lake, and on the skyline, the church steeple.

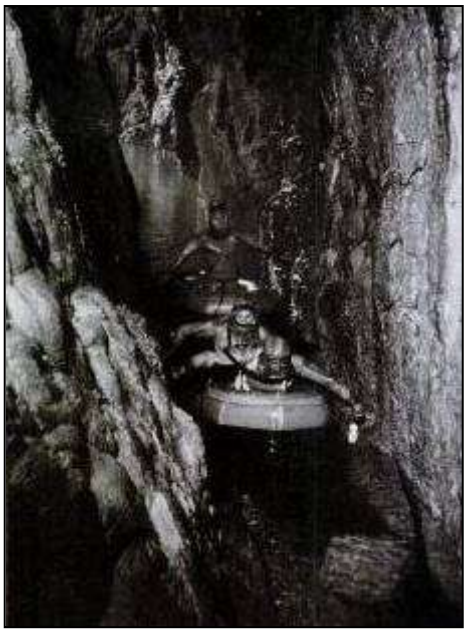
**France**

"Into the Earth Once Again. River Traced, Cascade Found," Life, October 26, 1953, describes the exploration of the caves at Pierre St. Martin in the Pyrenees.

> *Kakaueta Gorge, on surface outside caves, is explored by rubber boat. Explorers found dye put in underground river emerged here, on French soil.*

"Explorers Dispute New Cave Mark," Schenectady Gazette, August 20, 1953, dwelt on claims regarding the cave's depth.

> *All of the team agreed, however, that they had discovered several new underground galleries and a vast underground cavern.*
>
> *They made no comment on whether an underground river discovered last year would possibly be harnessed for electric power.*

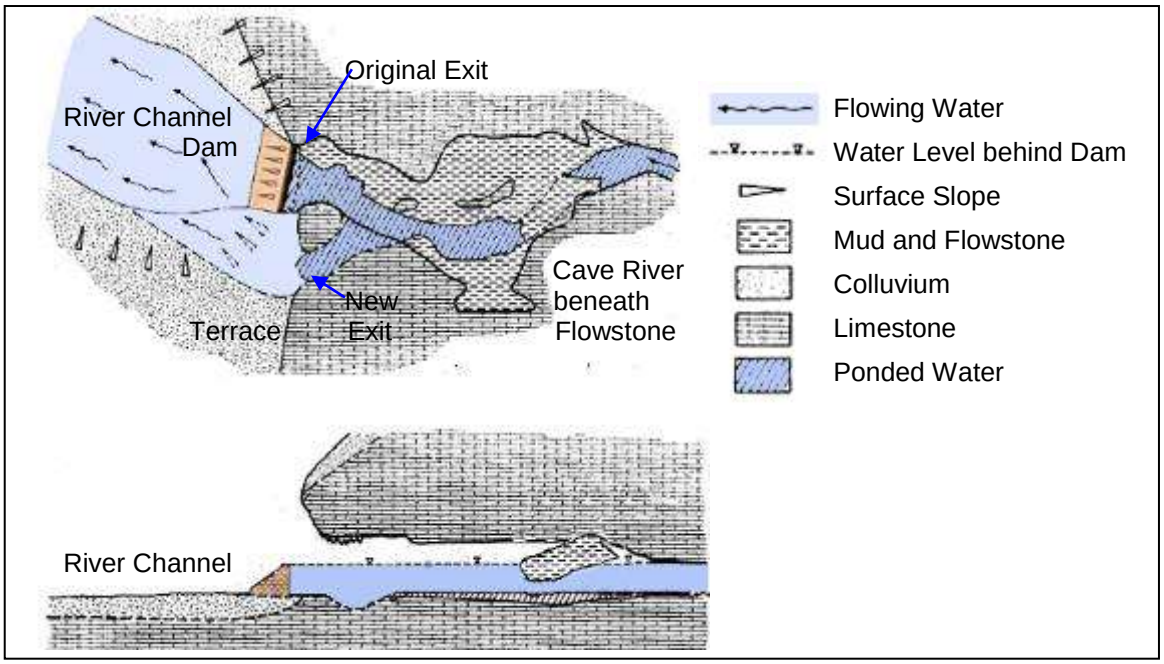


Water 700 meters beneath the surface is an unlikely hydropower source, but cave explorers tend to be bold in ambition.

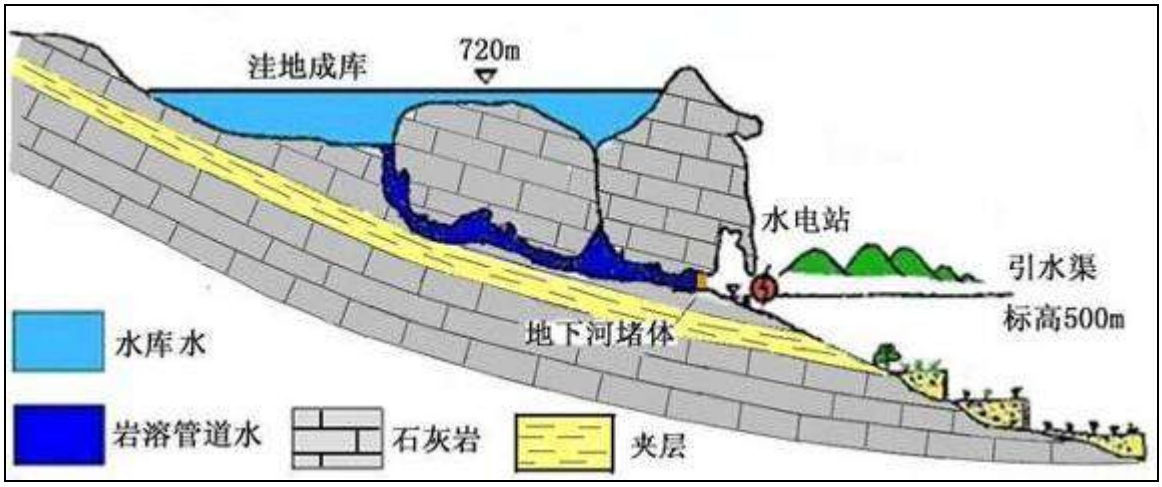
**China**

With its karst terrain and growing energy needs, China is ambitiously pursuing subterranean hydropower projects.

In the Guanyan karst of Guangxi Province, five sites have been developed for the installation of dams: four underground and one, shown below, at the Xiaoheli Yan resurgence.

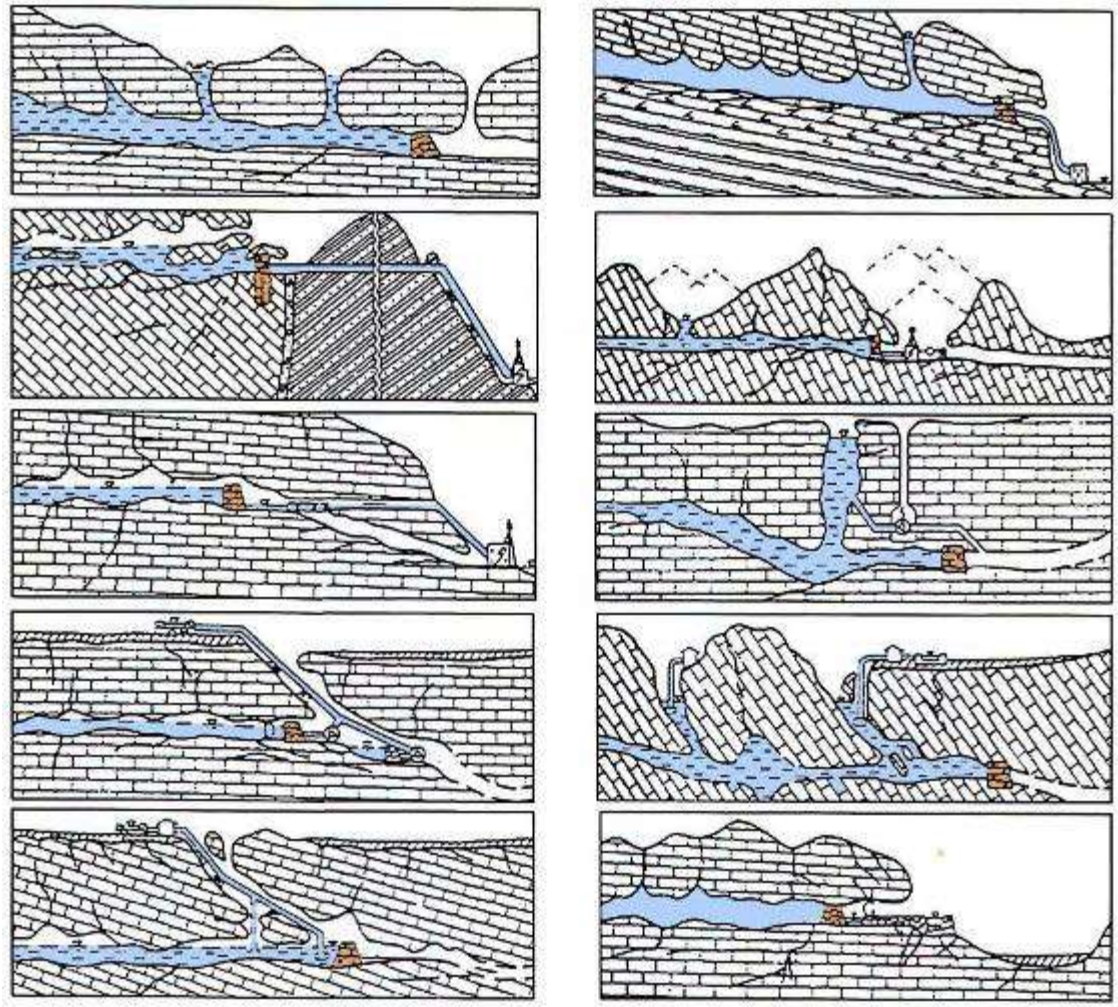



"Geologic Survey on Groundwater and Environment in Southwest China Karst" (2011), Institute of Karst Geology, Chinese Academy of Geological Sciences, suggests building a cave dam to seal an entire karst outlet, causing water to back up into the higher tiankengs (Chapter 41, Sinkholes).

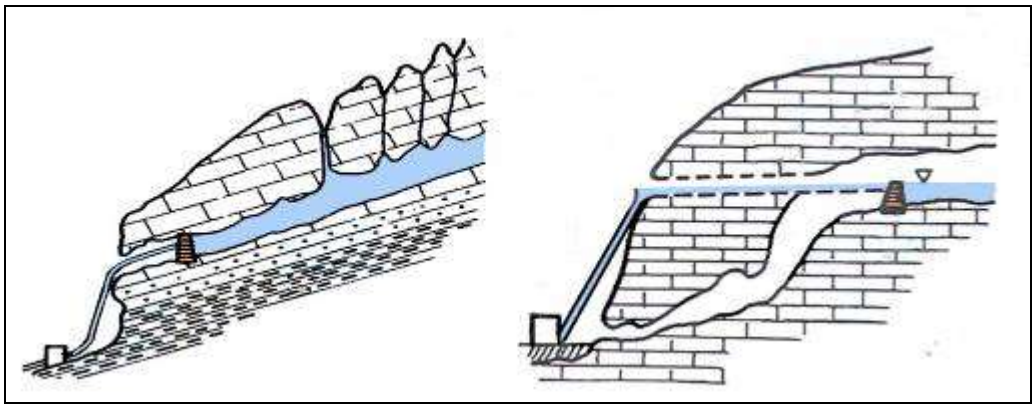



Practicality, however, poses challenges, as karst formations are characterized by interlaced conduits and blocked water would find another way out.

The sections below, taken from Some Problems of Subsurface Reservoirs Constructed in Karst Regions of China (1986) by Y. Lu, illustrate a variety of possibilities.



From the same publication,



Two Chinese Karst Hydropower Plants: Yohong and Beilou

**Indonesia**

In "Survey in a Water Resource Management Project of an Underground River in Indonesia," Boletin de Ciencias Geodesicas 12:1, January 2006, Günter Schmitt and Martin Vetter revive the idea of underground dams also noted in Chapter 65.5. The proposed project makes use of a 3.5 kilometer channel 100 meters beneath the surface.

*The installation of an underground water reservoir is aspired, using appropriate technologies and regenerative energies. The intention is to use the underground water resources by partially damming up the water flow by means of a barrage with an integrated micro hydro power plant. A feasibility study supported by the Federal Ministry of Education and Research found the cave Gua Bribin in the region of Wonosari as suitable for a pilot project. The cave guarantees a storage volume of roughly 400,000 m3 with a minimal available flow of 2000 l/s during the dry season and a potential water height after damming of about 15 m.*

The project will include,

*Partial damming of the water flow system by a reinforced concrete dam with an integrated micro hydroelectric power plant,*
*Energy production for water supply through the construction of a weir and pressure pipeline,*
*Energy production for water supply through a cascade of weir systems with open channel flow.*

The system would provide enough power to provide 75,000 humans with 80 liters of potable water/capita/day.

**Hollywood**

An electrical question about which we've wondered: How in Bela Lugosi's 1943 Frankenstein Meets the Wolf Man were the frightening capacitors charged?

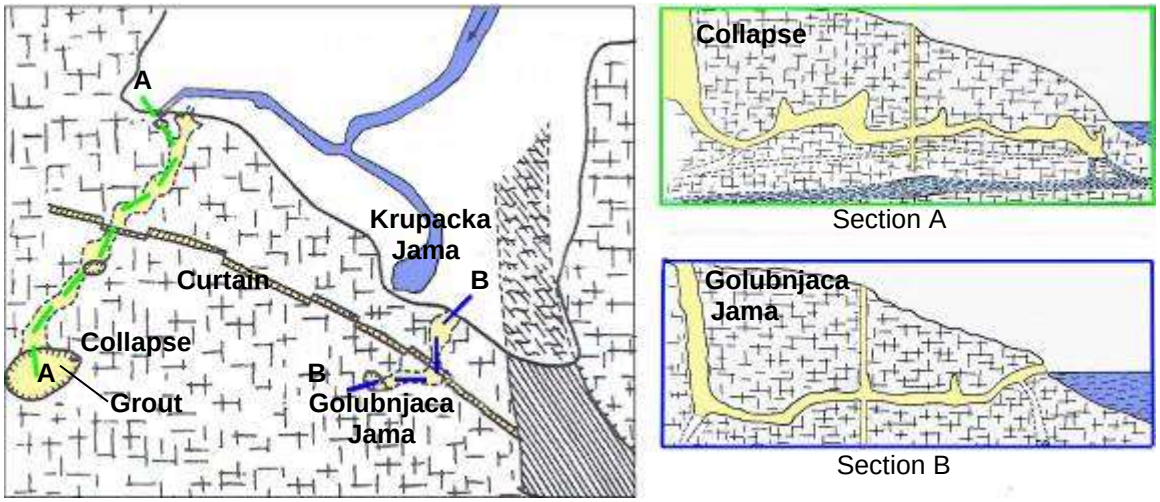
The answer's in the dialog,

*Here runs the underground stream that drives the turbines that Frankenstein installed*.

**Grouting**

Grouting, the injection of an impermeable sealer into the voids of an otherwise-porous media, has long been used to seal underground channels.

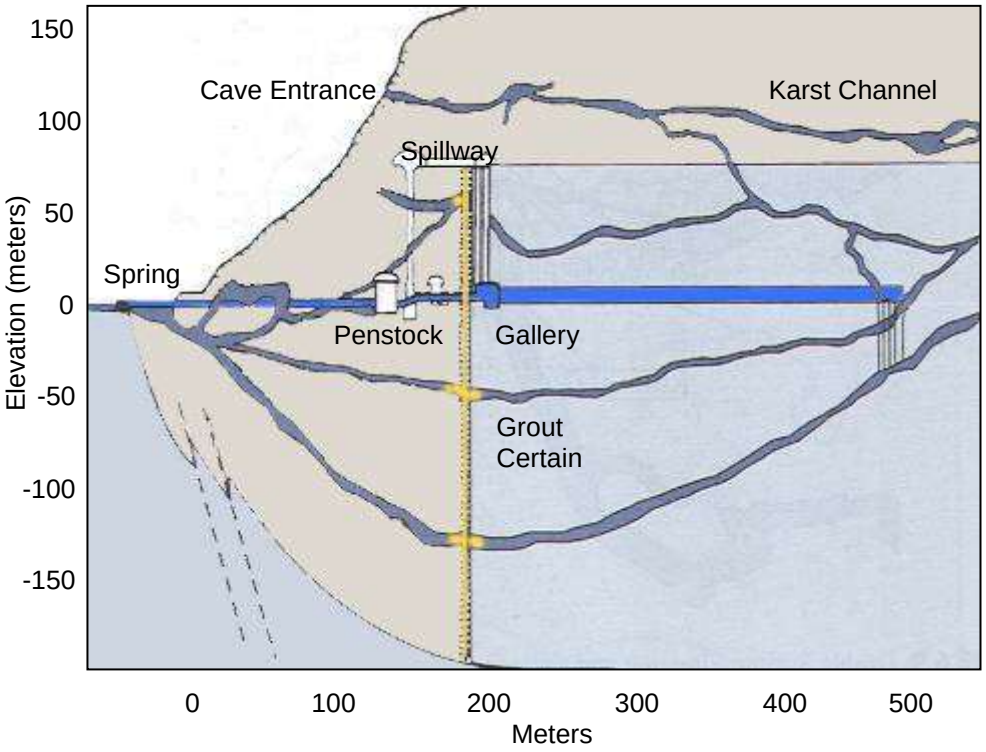
Karst sinkholes causing as much as 4 cubic meters/second of leakage from Montenegro's Krupac Reservoir were grouted in the late 1950s. The diagram shows the two-pronged approach: curtaining the full width of the leaky limestone and directly filling the accessible chambers.




Plugging of the Krupac Sinkholes

One borehole received 750 cubic meters of crushed stone plus sawdust and admixture (70 percent sand, 30 percent cement). Grouting increased the reservoir capacity by 20 million cubic meters. We'll have more to say about Balkan karst in Chapter 78.

Croatia's Ombla River (Chapter 78, Underground and Balkanized) is proposed for a 68-megawatt power plant and a grouted underground reservoir flooding the cavern system to just below the cave entrance.




**Sand Dams**

Sand dams are buried dams designed to retain water in the interstices of sand and gravel on the upstream side. Sand dams are generally situated to cross the bed of a river which on the surface may be seasonally dry, but continues to transmit water through the porous bed material.

As sand dams are for the "underground damming of rivers," as opposed to "damming of underground rivers," and thus perhaps fall somewhat outside the purview of our study, but we include them in our chapter because the public may not always catch the distinction.

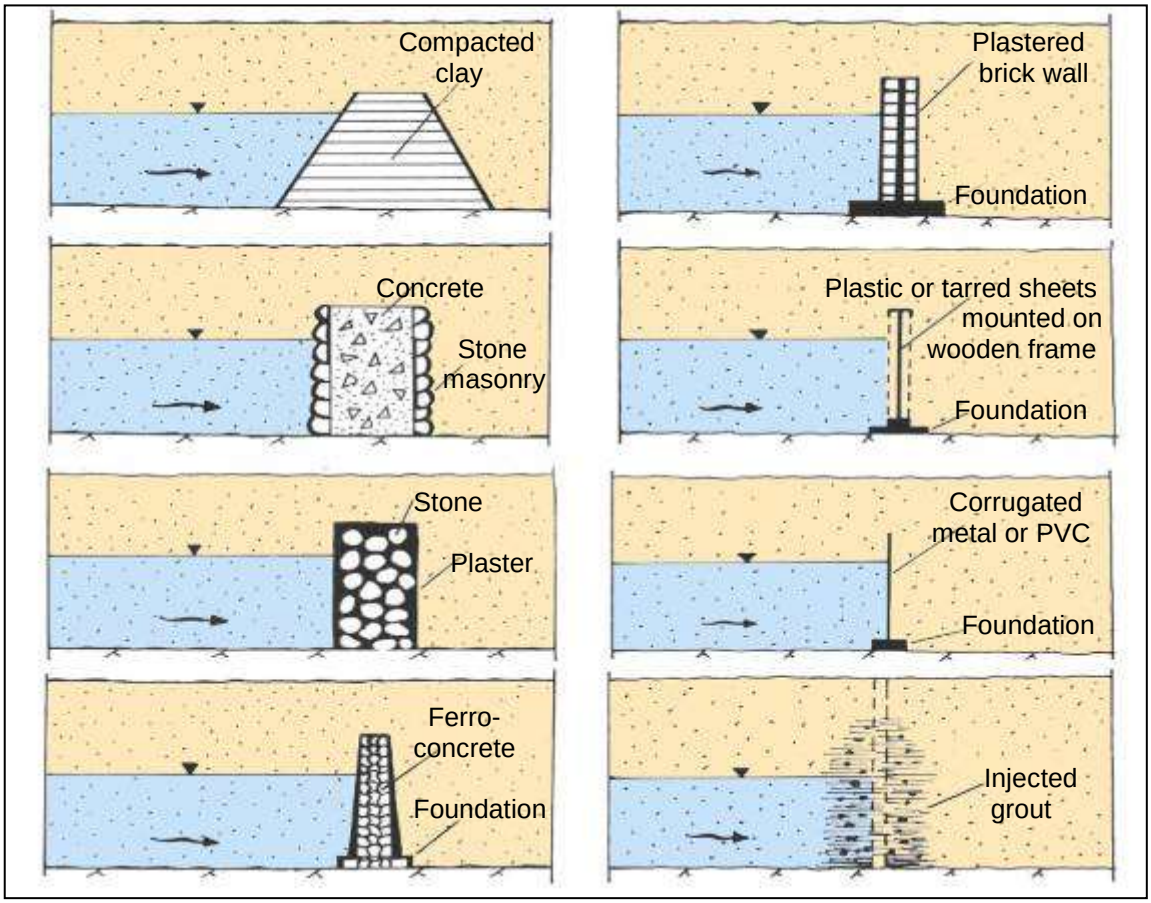
For a sand dam to be effective, it must extend to a less-permeable substrata to prevent the flow from seeping under the structure. Water is most often extracted by shallow wells. A sand dam ceases to function if silt washes in and fills the voids between the sand particles.

At best, a sand dam provides room for only a fraction of the water that would be held in a topographically-comparable surface reservoir, but the water behind a sand dam is slower to evaporate. The passive pressure of river bed material on a sand dam's downstream face provides it structural stability. Unlike catastrophic concerns associated with possible failure of a surface dam, if a sand dam leaks a bit, it's not likely structurally compromised.

The field tests below are from Rain Catchment and Water Supply in Rural Africa: A Manual (1982), by Erik Niessen-Petersen.

| Material | Silt | Fine sand | Medium sand | Coarse sand | Fine gravel | Gravel |
|---|---|---|---|---|---|---|
| Size (mm) | <0.5 | 0.5-1 | 1-5 | 5-19 | 5-19 | 19-70 |
| Porosity | 0.38 | 0.39 | 0.41 | 0.45 | 0.47 | 0.51 |
| Extractability | 0.05 | 0.19 | 0.25 | 0.35 | 0.41 | 0.50 |

Below are several sand dam construction possibilities, all but the last requiring excavation.

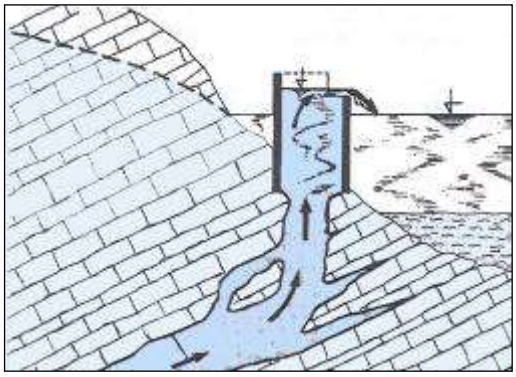



Kenya

Northeast Brazil

**Artesian Springs**

Although here we're talking not about a dam under the ground, but rather about damming the outflow from an underground channel, we'll add to our survey the option of containing an artesian upwelling (Chapter 39, Hydrogeology).



Below, cylindrical dams around Opacica and Slivlje Springs, both in Montenegro

**Conclusion**

If God didn't wish us to dam underground rivers, we might argue, He'd have put them further beneath the surface.

# CHAPTER 68
# MORE HYDROPOWER FROM THE DEEP

This chapter deals with subterranean hydropower derived from tunneled conduits and from undammed natural channels.

**Tunneled Penstocks**

When turbines replaced waterwheels in the late 19th century, pressurized penstocks replaced mill streams. Most penstocks are located within dam structures, however, not "underground." We'll count, however, tunnels for hydropower hewn through the earth.

In 1858 the New York State Legislature authorized the Lockport mill race to be converted into a tunnel for industrial hydropower. Blasting through solid rock produced a head of 17.4 meters and 180 kilowatts.

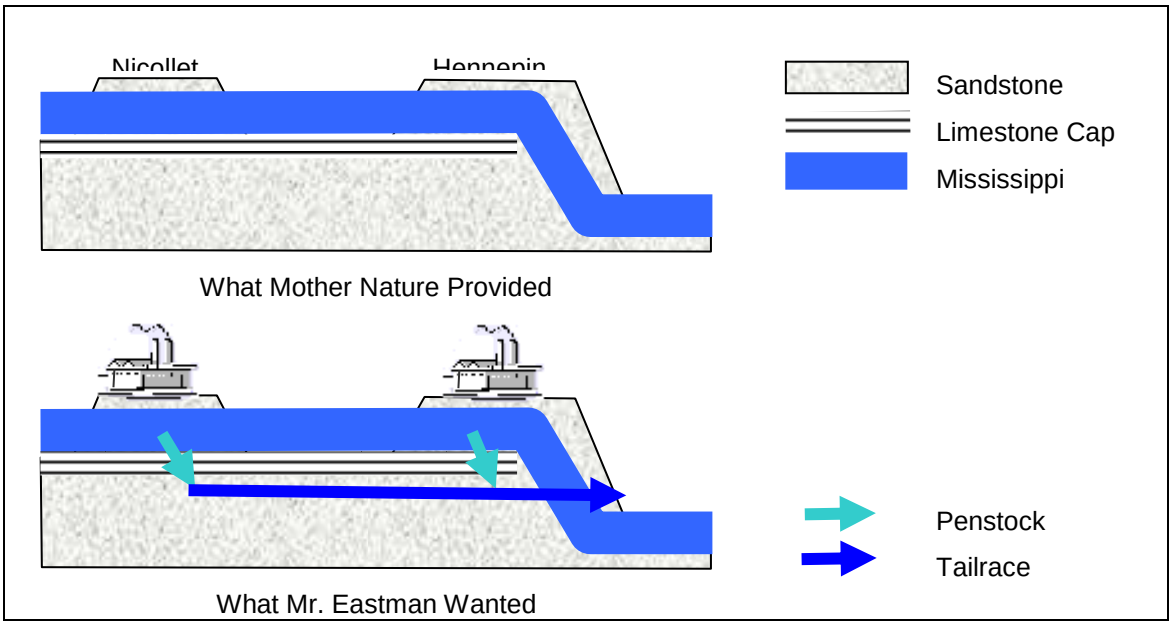
Subsequent reconstruction

Lockport Cave, now part of the Erie Canal National Heritage Corridor, features a cave boat tour focusing on artifacts left by the miners.

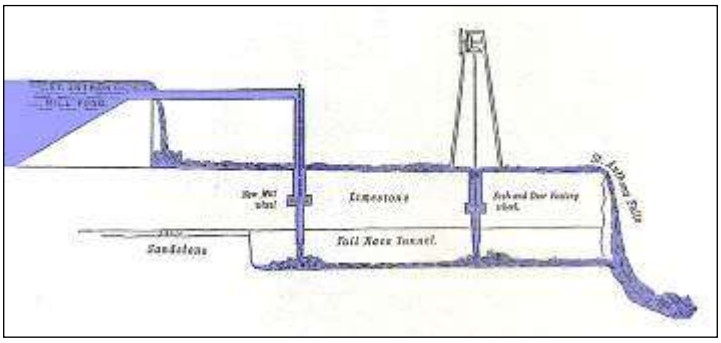


St. Anthony Falls in Minnesota is the Mississippi's only true waterfall, the consequence of a limestone cap perched over softer sandstone. An 1852 photo is to the right.

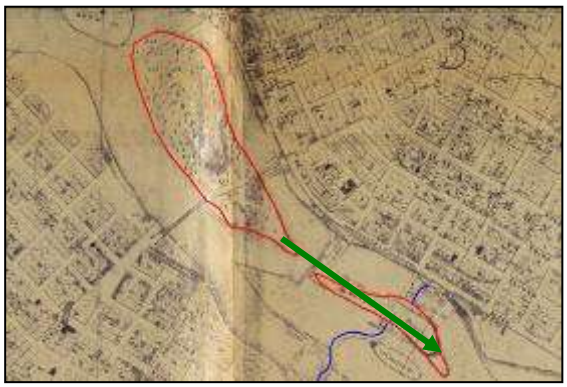
In 1867, industrialist William Eastman gained control over a portion of Nicollet Island above the falls and Hennepin Island at the falls, and began construction of a 760-meter, 2 by 2 meter hydropower tailrace from Hennepin and under Nicollet. The plan amounted to diverting a small portion the Mississippi underground.



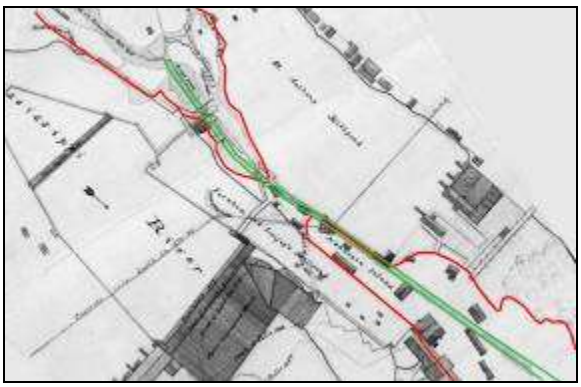

From Report on the Water-Power of the Mississippi River and Some of its Tributaries (1887), Tenth Census of the United States, 1880, J.L Greenleaf,




The maps below show the layout, first as an overlay on an earlier city map and the second, a post-project layout showing the industries. Nicollet and Hennepin Islands are outlined in red, Nicollet being the upper. St. Anthony Falls is marked in blue and the tunnel is in green. Note that the tunnel runs below the riverbed (and thus the limestone cap) between the islands.



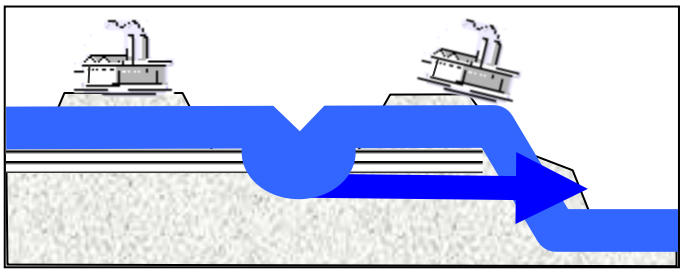
R&F Cook Map (1861)



Corps of Engineers Map (c. 1879)

On October 4, 1869, however, as digging neared completion, Eastman's tunnel became more of an underground river than the capitalist anticipated.

A fracture in the sandstone near the southern tip of Nicollet Island opened an upward passage to the bed of the river. The leak turned into a torrent, quickly scoured the tailrace to a width of as much as 30 meters under Hennepin Island which began to unravel at the outlet. The falls themselves were in danger of collapsing.



What Mr. Eastman Achieved

The October 7 Chicago Tribune reported the calamity.

> *The Tunnel Disaster at the Falls of St. Anthony -- The River Fast Cutting out a New Channel*
>
> *A portion of Hennepin Island, on which is situated a large number of mills and factories, has been washed away, and the break in the channel has not been repaired. The entire island is in danger... Two hundred feet of tunnel have already caved in, and unless the action of the water is checked, Minneapolis men fear the foundation of a new channel, which will destroy the water power, by conducting water away from the wheels of the mills, leaving them high and dry.*
>
> *Monday morning, the eastern tunnel, half a mile long, being excavated for the purpose of making water power on Nicollet Island, pierced a sunken water cavern in the island below the river. The gates at the head of the tunnel were closed, but the rush of the water could not be arrested. Early Tuesday morning a large whirlpool near the shore of the island was discovered, disclosing the mouth of the cavern. All efforts yesterday to close up the hole by rafts, cribs, trees, balls of hay, etc., proved fruitless and the river is making a tremendous effort to cut a new channel for relief. The mills of Hennepin Island are in danger, as the ground is caving in from the passage of the water from beneath. A thousand men are at work, night and day, constructing a coffer dam round the mouth of the whirlpool.*
>
> *The volume of the water rushing into the cavity has been somewhat checked by trees and sandbags... The hole is sixty feet long and twenty broad; depth not known.*

According to a local newspaper, the whirlpool in the Mississippi "tossed huge logs as though they were mere whittlings," standing them on end "as if in sport."

The Chicago Tribune of October 30, 1869, reported some success.

> *One of the new dams of St. Anthony Falls was completed to-day, so that the water can be cut off from the head of the broken tunnel, and the full extent of the break ascertained... An examination of the tunnel at Minneapolis shows the last break to be seventy feet in diameter.*

But the limestone shelf now having been compromised, fixes tended to be temporary. From the Chicago Tribune, January 24, 1870,

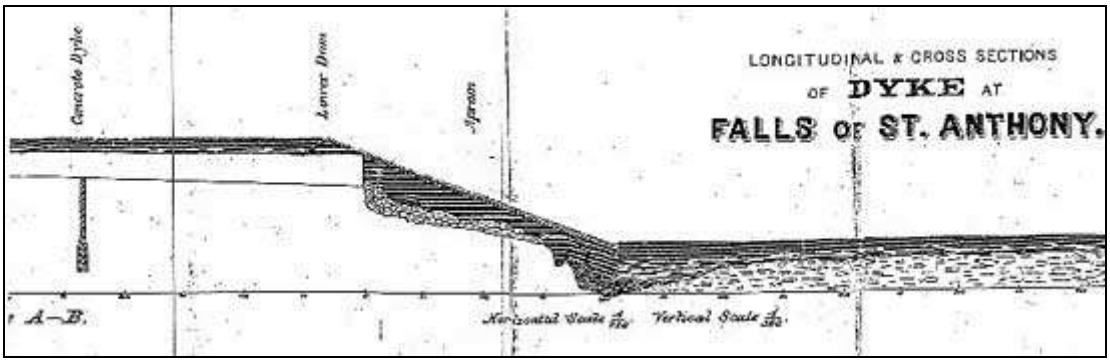
> *The proprietor of the Nicollet Island Tunnel near Minneapolis, in company with two friends, lately entered the tunnel in a boat, and had penetrated about 500 feet from the entrance, when the awful silence of the vault was broken by the continuous crashing fall of masses of the limestone rock which form the roof. Though large fragments struck all about the boat, all the gentlemen were lucky enough to escape unhurt.*

And the situation continued to degenerate. From the Chicago Tribune, April 2, 1870,

> *Another break feared in the tunnel at St. Anthony Falls.*
>
> *A portion of the filling yesterday sank, and it is reported that the rock has broken away from the bottom of the tunnel, through the sane beneath, which, if true, will render it almost impossible to prevent the water from washing away the support of the rocky crust of walls themselves.*

A July 1871 leak originating to the east of Nicollet Island and scoured a new cavity 5 meters wide, 3 meters beneath the limestone. As a result of a similar incident in August, the limestone ledge was resurveyed and found to be riddled with holes. An April 1873 flood destroyed a coffer dam to the west of Nicollet Island, opening a 50-meter gap and again flooding the tunnel.

It took shore-to-shore walls to sub-grade depth, shown below in the 1883 design, to regain control of the river.




Eastman's tunnel, the instigator of the troubles, was backfilled in 1884.

Underground River Plugged and the Mills Saved

Today, the University of Minnesota's St. Anthony Falls Hydraulic Laboratory is located on Hennepin Island. From the lab basement, one can still access the tunnel's lower portion

Greg Brick's Subterranean Twin Cities (2009),

> *Descending through the trapdoor under the lab, I found that the Eastman Tunnel ran under the riverbed as far as my light beam went; I hoped to be able to get all the way up under the dam itself. At one point I peeked up through a grating into the Main Street Power Station, observing the dynamos with wonder. The going soon got rough. When the mud got waist deep, I was ready to turn back, but I could see the end of the tunnel, so l persevered. Finally, I arrived at the concrete bulkhead, a total distance of one hundred feet from the walkway.*

Eastman's tunnel might have provided underground hydropower, had not the Mississippi acted like the Mississippi.

Let's move to modern times and look at the "Underground River Micro Hydropower Plant" enabled by the construction of a wastewater tunnel under Lausanne, Switzerland. Laid in an existing riverbed having a 180-meter drop, the tunnel is sufficient for both the wastewater and the natural streamflow, the former on the tunnel floor and the latter via a 120 liters/second pipe to a 185-kW Pelton wheel. The inlet is shown below.

It's conventional hydropower technology, but as the pipe is in some sense "underground," we must allow the deceitful claim.

**Hydropower from Qanats**

We discussed qanats in Chapter 65, Subterranean Aqueducts. M.L. Khaneiki and A.A.S. Yazdi advocate their hydropower potential in "Extracting Electricity from Groundwater Flow; A New Environment Friendly Source of Energy Case Study: Iran," Eighth EEEIC International Conference on Environment and Electrical Engineering, Karpacz, May 2009.

*First a shaft well is sunk from the bottom of which a tunnel is dug up... This shaft well can be drop tower for a watermill underground where the buildup of water in the well can provide adequate water pressure to rotate the millstone. At the bottom of the well, a small hole is made such that water can spout out of it and hit the rotor blades of the watermill. Thus the rotor blades would run and the movement would be imparted to the upper millstone by a shaft which passes through a hole in the lower millstone and then turns the upper one horizontally...*

*Nowadays this technology has been abolished, because wheat is subsidized and purchased by the government, and is ground in big factories. So the villagers no longer need the underground watermills to grind wheat. Nevertheless the idea of this paper -- generating electricity -- was inspired by the abandoned watermills, and we place turbine on the way of groundwater though this time its product is electricity not flour...*

*We conducted a study in the province of Yazd in Iran on the potential that the qanats have to generate electricity. In this area some 3200 qanats are running, most of which enjoy a head less than 8 meters, so it seems that the suitable turbines for these qanats are Francis, Kaplan and the propeller turbines... In case we take the minimum electricity to be some 400 watts just to provide power needed for light and ventilation in the qanat itself, the qanats with low discharge require a head of 10 meters, which cannot be found in Yazd. But in terms of the qanats with relatively high discharge and low head, the turbines of Powerpal and Nautilus seem suitable.*

*In closing we can conclude that:*

1. *The maximum electricity extracted from such turbines is 1 kilowatt, but considering the length of qanats which is tens of kilometers it is quite possible to install a series of turbines along the tunnel to get more electricity.*
2. *Those qanats whose discharge is below 45 liters per second do not meet the requirements of this project, because this project is in line with the product of net head multiplied by discharge, so in case of lower discharge we need higher head which cannot be higher than 8 meters considering the structural condition of the qanats in Yazd.*

*Due to these requirements, out of 3200 qanats in the province of Yazd, 100 qanats whose discharge is over 45 liters per second providing appropriate head have been singled out. Each of these 100 qanats can house one or several turbines, such that the total electricity generated by them would amount to thousands of kilowatts*

As with this study ant those to follow, however, we're provided neither economic justification nor suggestions regarding maintenance.

**Hydropower from Subterranean Pumped Storage**

Pumped storage isn't a generator of hydropower, per se, but it's a way to bank such energy for times of high demand.

Frank Winde and E.J. Stoch propose a groundwater scheme for pumped storage in "Threats and Opportunities for Post-Closure Development in Dolomitic Gold-Mining Areas of the West Rand and Far West Rand (South Africa) – a Hydraulic View -- Part 2, Opportunities," Water SA 36:1, January 2010.

*The basic principle of underground hydropower generation is based on utilizing elevation differences between adjacent compartments and associated karst cavities in much the same way that the ESKOM pumping scheme at the Sterkfontein Dam in the Drakensberg works, i.e., driving turbines which generate electricity in peak demand times (daytime) and pumping the water back to the upper reservoir at cheaper night-time tariffs. A similar system is currently installed in karst areas of Indonesia, where underground flow drives irrigation pumps bringing the water back to the surface at minimal pumping costs. With deep shafts and large voids created by mining, this technology may be able to utilize not only karst voids and natural gradients but also some of the underground infrastructure such as shafts, haulages and existing mine-water reservoirs. The Kloof Mine is reportedly already using hydropower in its underground operations and may consider a larger scale expansion. Depending on the possible implementation of active groundwater recharge and harvesting schemes mentioned above, post-flooding water levels in the dolomitic compartments could be kept at such elevations that near-surface karst cavities at different levels could be connected through existing shafts or other conduits and utilized for underground hydropower generation even after re-watering.*

Pumped storage is occasionally incorporated with surface reservoirs. In theory, it could work for reservoirs below, but it's yet to be done.

**Hydropower from Spring Elevation**

The phrase "to carry a mill" speaks of earlier times.

*Subterranean Streams. The Hadley Falls Company, in excavating their new raceway, cut into a subterranean stream, large enough to carry a mill, flowing down the Connecticut, thirty or forty feet below the level of the railway*. -- Scientific American, July 15, 1848

*There are said to be underground creeks in the limestone of Georgia with currents of sufficient velocity to carry a mill. There is a government tannery, the bulk of which is driven by one on these subterranean streams.* -- Scientific American, July 29, 1865

Such "underground" streams would have exited the earth before powering a vertical water wheel.

Clark B. Firestone, Bubbling Waters (1938) describes a mill in Mill Springs, Kentucky.

*Fourteen springs gush from the hillside in a stretch of perhaps a hundred yards, and their waters are impounded by a stone wall in a sort of canal shaded by tulip poplars. It is something like an underground river bursting into the sunlight wherever it can force an opening. A flume leads the collected waters to an overshot wheel on the downstream side of the mill.*

"Mysterious Lost Rivers Run Mills and Power Plants," Popular Science, November 1934, describes a similar instance of "underground" hydropower.

*In Morgan County, Alabama is a mill stream noteworthy because it is entirely underground. In a two-mouthed cave, a subterranean creek emerges in the form of a spring, and then flows sixty or seventy feet to the site of an old mill. The water was dammed up, when the mill was built, by piling rocks across the creek in the larger of the cave mouths. Thus the old mill pond is entirely subterranean.*

Dammed within the cave, the water was underground. Flowing out, however, it was just another mill stream.

We will revisit Thousand Springs on the Snake River in Chapter 94, The Rio San Buenaventura, but here we will note the hydropower of this "underground river."

"Developing a Unique Idaho Water-Power," Electrical World, July 6, 1912,

> *Many different attempts have been made in earlier years to collect and utilize the flow from the Thousand Springs, but without success, owing to the peculiar nature of the problem, the difficulty of foundationing structures on the side of the cliff and the long contact outlet of the water. The final solution, carried out in connection with the present development, was the erection of a concrete canal wall on the side of the cliff at the outflow level. This wall is 400 ft. long and in places 16 ft. high. It forms a canal 20 ft. wide, whose other side is the native cliff and in which the water from the numerous spring outlets is collected. At one end for a distance of 150 ft. the canal is widened to 40 ft., forming a forebay opening to the penstocks which are to convey water to the power house beneath.*
>
> *The construction of this wall was especially difficult, both on account of its precarious foundationing on the side of the canyon and owing to the provisions which had to be made for the cofferdam to hold back the water from the concrete forms during building. There is no way of shutting off the flow, of course, and the water had to be deflected while the concrete was setting. Other difficulties were experienced in sealing the ends of the contact crevice to prevent the water from finding its way out of the sides. Although the present is but a partial installation, the canal wall as initially built is provided with two spillways, totaling 90 ft. in length, which is ample to discharge the entire flow from the underground river.*

Cliff-side Capture of Thousand Springs


Powerhouse Construction, 1912. Note the twin spillways on the right.

The plant today has a capacity of 8,000 kilowatts.

Before we leave the topic of mills, we'll quote a letter to the editor of London's General Evening Post, September 23, 1779, regarding a subterranean excursion in the Yorkshire Dales. Reference to "as much water as would turn several mills" was but for quantitative comparison, not as an industrial proposition, we're relieved to say. We like the dramatic prose.

> *But to resume our journey down this amazing cavern, after descending from ledge to ledge in retrograde motions, through arches of prodigious rocks, thrown together by the rude but awful hand of Nature, at the depth of 70 yards we see a parabolic cascade rushing from a hole nigh at the surface, and falling the whole 70 yards, with a roar, confounds and astonishes the most intrepid ear! The spray arising from this cascade fills the whole cavern, and if the sun happens to shine into it, generates the most vivid and surprising rainbow. Another cascade of not quite so great a fall issues perpendicularly from a projecting rock with equal rapidity as the first and is certainly a part of the same subterraneous brook; they fall together into a narrow pool at the bottom which measures 37 yards in depth; and projecting underground about a mile, break out*

*and form the large brook that runs by Ingleton, and from thence to the river Lune. In the time of great rain, the subterraneous channel that conveys away the water becomes too small and then the cavern fills to the depth of above 100 yards, and runs over the surface.*

*To see as much water as would turn several mills rush from a hole near 70 yards above the eye, in such a projectile as shows its subterraneous fall to be very considerable before it enters the cavern; and to see the fine skirting of wood, with various fantastic roots and shrubs, through a spray, enlivened by a perfect rainbow, so far above the eye, and yet within the earth, has something more romantic and awful in it than anything of the kind in the three kingdoms.*

The upward view sounds like that of Fall Beck -- the latter's drop being a bit over 100 meters -- but the route doesn't seem to correspond to the Gaping Gill complex (Chapter 54, Subterranean Watercraft) as accessed in that era. Subterranean streams able to carry a mill -- or in this case, several mills -- remain forever mysterious, it seems.

**Hydropower from Subterranean Hydraulic Rams**

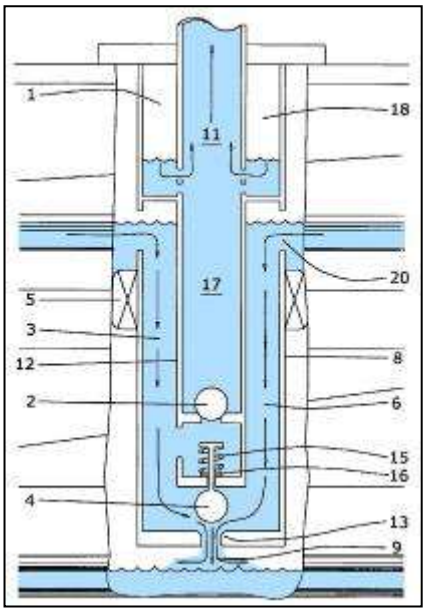
**United States**
**Patent Application Publication** **US 2005/0022997 A1**
**Hardgrave** **Feb. 3, 2005**

**DOWNHOLE HYDRAULIC RAM**

Inventor: **William David Hardgrave**, Carrollton, TX

A hydraulic ram is a mechanical device in which energy derived from the fall of a large stream a short distance is used to elevate a smaller stream a greater distance.

As shown to the right, a bottom outlet is required from which the greater flow can be borne away. Should geologists find one subterranean river flowing above another having unused capacity, Patent Application 2005/0022997 might be useful.

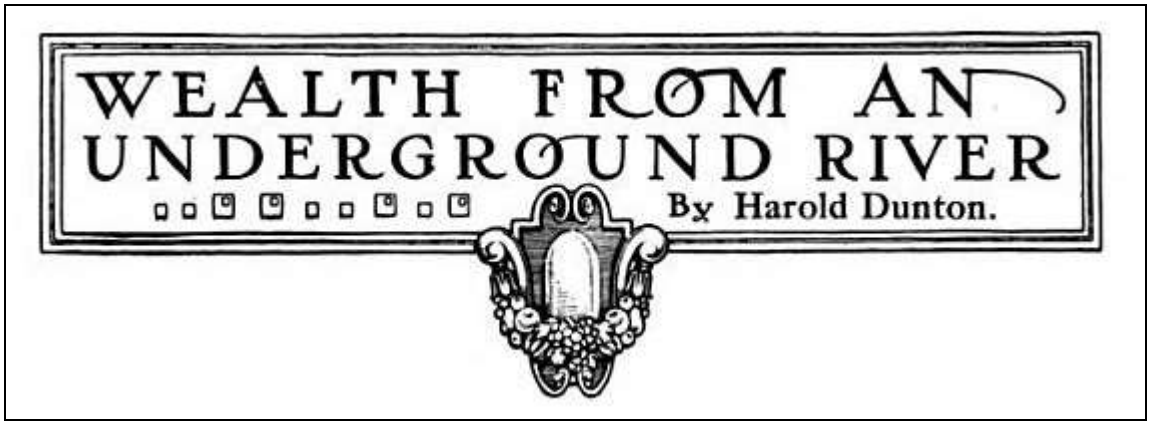



**Conclusion**

Apart from a few subterranean dams and a larger number of tunneled penstocks, little hydropower has been harvested underground, but we remain hopeful.

# CHAPTER 69
# THE LAW OF SUBTERRANEAN STREAMS

But why would lawyers care, a naive hydrogeologist might wonder? Technical World Magazine, March 1909, headlines the answer.




*Much development in the way of government and private projects for the irrigation of the Colorado desert, the Salt River Valley and the barren parts of eastern Oregon has been done, but there is an immense stretch of country, most of it level as a floor, lying to the east of the Siena Madre Mountains in Southern California which yet awaits the plow and the water canal. This is the Mojave Desert, on which it is probable that more men have died in search of gold than any other equal area in the world. Now one man has invaded the Mojave Desert, and, following out a theory of his own, has won from the barren land a home and a large rancho which bids fair, in a few yean, to make him one of the wealthy men of the West.*

Underground water can be worth a great deal.

In the same vein -- no pun intended, William De Witt Hyde's Vocations (1911) was a useful guide for career choice.

*Forward to Parents*

*This book is made up of a series of articles selected from those available for the purpose and put together with the object of presenting a picture of the life and work of the men employed in some branch of the great vocation of the Mechanic Arts. It is hoped that a study of the book will help young men who may be looking in this direction for their calling, to form a worthy conception of what that calling really means.*

*"Wealth from an Underground River" by Harold Dunton*

*If he who makes two blades of grass grow where but one grew before is greater than the builder of cities, then there is a man in southern California, a pioneer of civilization along agricultural lines, who has done more than all the builders of all the cities since time began. He has made, not two blades of grass to grow in place of one, but whole alfalfa fields where there was nothing but a stretch of glaring sand; in place of sage brush and greasewood and juniper he has in successful growth orchards of apples and pears and plums; green fields of barley and corn turn to the yellow of early ripeness under his hand, and where the jack rabbit and the coyote, the crawling lizard and the hissing rattlesnake ruled the land he has set his home, carving the way for other men to come with him and share in the riches of an undiscovered farming land lying at the very doors of civilization.*

*The man is W.G. Dobie, a physician of ability, a globe trotter of years' experience, turned ranchman on the Mojave to prove or disprove an idea which had its origin in a casual trip across the great sand plat. This idea, which was that a great body of water, either lake or river, underlies the entire Mojave desert, he has completely proved, and he is now on the eve of reaping the rich harvest of his idea.*

*Men and teams and drilling outfits were brought in; one, two, three hundred feet, straight down through sand, gravel, hardpan, and finally the bed of cement which is found beneath the entire floor of the desert, until at a depth of more than three hundred feet an abundant supply of sweet, fresh water was found. In addition to his theory of the great subterranean supply, Dr. Dobie had believed there would be force enough to this confined water to raise it to the surface in flowing wells. In this he was disappointed, but he found an endless supply of water, which could be pumped to the top of the ground.*

*Soundings in the well proved it practically bottomless. The lead went down until it could no longer be controlled by the man at the surface, and was carried swiftly to one side, with a strength which the operator was scarcely able to withstand. With the greatest difficulty the cord and lead were withdrawn from the well, and the frayed condition of the cord showed that it had been rubbed on the rock roof of the subterranean channel with great force by the power of the water.*

"Go West, young man," popularized (but not coined) by Horace Greeley, was but half the story. "Go West, young man, and transform the West's underground rivers into riches."

And where there's wealth, swarm attorneys.

**To Swear by the Styx**

The propriety of jurisprudence requires that truth be spoken, and for that end, we employ oaths.

The gods of Greek and Roman mythology would take life-binding oaths in the name of the Styx.

As depicted in the 16th century engraving to the right, Zeus swears by the Styx to give Semele, mother of Dionysus, that which she wishes and is thus obliged to yet comply when he realizes that her request will lead to her death.


Helios similarly pledged his son Phaëton whatever he desired, likewise resulting in the boy's demise.

From the tale of Bacchus and Ariadne in Thomas Bulfinch's Age of Fable (1913),

*Jove gives his promise, and confirms it with the irrevocable oath, attesting the river Styx, terrible to the gods themselves.*

The eighth-century BC Greek poet Hesiod wrote that in breaking such an oath, the gods were unable to move, breathe or speak for one year.

Acknowledging the politics of Niccolo Machiavelli (1469-1527), however, Sir Francis Bacon (1561-1626) remarked in his De Sapientia Veterum (1619) that while the Styx was respected by the gods, the word of a king, solemn and sacred as it might seem, has no authority above itself.

Machiavelli aside, swearing by the Styx has become a common reference to veracity. We'll quote a few examples.

"The First Book of Statius's Thebais, translated in the year 1703," Poetical Works of Pope (1856) by Alexander Pope,

> *For by the black infernal Styx I swear, (That dreadful oath which binds the Thunderer)*

From Lord Rector Rosebery's address, "The High Standard," University of Edinburgh, 1882,

> *Work, my boy, work unweariedly. I swear that all the thousand miseries of this hard fight, and ill-health, the most terrific of them all, shall never chain us down. By the River Styx it shall not!*

Encyclopedia Britannica, a Dictionary of Arts, Sciences, and General Literature (1890),

> *Considering the prominence given by the ancients to an oath by the water of Styx, and comparing the effect supposed to follow from breaking that oath with the destructive power supposed to be possessed by the water, we are tempted to conjecture that drinking the water was originally a necessary part of the oath -- that in fact in the stories of the Styx we have traditions of an ancient poison ordeal such as is commonly employed amongst barbarous people as a means of eliciting the truth.*

A prudent, but not infallible, rule: Trust no lawyer who swears other by the River Styx.

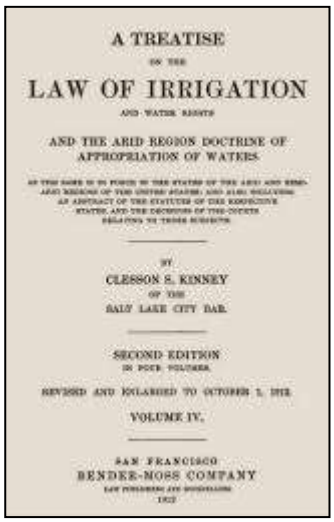
**Common Law**

Underground or subterranean "rivers" are rarely mentioned in legal documents. Rather, there are a plethora of references to underground or subterranean "streams." While a court would deem the terms to be interchangeable, the codified preference for the latter seems to suggest that legal drafters properly recognized that they were legislating relatively small waterways.

In A Treatise on the Law of Easements (1904), John Leybourn Goddard describes the English common law, the underpinning of the American legal framework.

> *Underground streams are of two kinds: viz., those, the course of which is defined and known, and those which merely percolate through the earth, without having any defined course, and in unknown channels. If the course of underground streams is defined and known, they differ in no respect from surface streams as to the natural rights of landowners and easements which landowners may acquire in them, but if water merely percolates through the soil in unknown channels, the same rules of law do not apply, and streams so formed differ altogether from defined streams on the surface of land. An endeavor has been made to establish the principle that if the course of an underground stream is defined it matters not that it is unknown, and that the same riparian rights belong to it as if the course were known. It has, however, been decided that the underground course must be both known and defined to support such rights. -- Chasemore v. Richards, 7 H.L.C. 349, 29 L.J., Exch. 305, (1859).*

Clesson S. Kinney and his A Treatise on the Law of Irrigation (1894). Kinney believed that an inexhaustible supply of water flowed in "subterranean or underground watercourses."


A TREATISE
ON THE
LAW OF IRRIGATION
AND WATER RIGHTS
AND THE ARID REGION DOCTRINE OF
APPROPRIATION OF WATERS
BY
CLESSON S. KINNEY
OF THE
SALT LAKE CITY BAR.
SECOND EDITION
REVISED AND ENLARGED TO OCTOBER 1, 1912.
VOLUME IV.
SAN FRANCISCO
BENDER-MOSS COMPANY

> *A large portion of the great plains and valleys of the mountainous regions of the west is underlaid by a stratum of water-bearing sand and gravel, and fed by the water from the mountain drainage. This water-bearing stratum is of great thickness, the water is moving freely through it, is practically inexhaustible, and, if it can be brought to the surface, will irrigate a large portion of the country overlying it.*

Kinney was deluded, of course, regarding the inexhaustibility, but he didn't stop there.

> *These water-courses are divided into two distinct classes; those whose channels are known or defined, and those unknown and undefined. It is necessary to bear this distinction in mind in our discussion, as they are governed by entirely different principles of law. And in this connection it will be well to say that the word "defined" means a contracted and bounded channel, though the course of the stream may be undefined by human knowledge; and the word "known" refers to knowledge of the course of the stream by reasonable inference. Regarding the laws governing these two classes, it must be known that if underground currents of water flow in well-defined and known channels, the course of which can be distinctly traced, they are governed by the same rules of law that govern streams flowing upon the surface of the earth.*
>
> *The owner of land under which a stream flows can, therefore, maintain an action for the diversion of it if such diversion takes place under the same circumstances as would enable him to recover if the stream had been wholly above ground.*

Given this understanding, it made sense to apply the legal rules of prior appropriation to water supposedly flowing underground in "known channels," as though these channels were also rivers or streams. All other underground water, inexhaustible in supply, was therefore available for pumping under the legal rules of reasonable use.

Joseph R. Long, in his influential A Treatise on the Law of Irrigation Covering All the States and Territories with an Appendix of Statutory Law (1902), endorsed Kinney's pronouncement.

> *Percolating waters have ordinarily no legal existence apart from the soil in which they occur, and therefore are not subject to appropriation for irrigation or other purposes. But where waters collect or are gathered in a stream flowing underground in a defined channel, no distinction exists between such subsurface streams and streams flowing upon the surface. They are such property or incidents to property as may be acquired by grant or by appropriation, and when rights in them are so acquired, the owner cannot be divested thereof by the wrongful acts of another.*
>
> *So far as the right of appropriation is concerned, there is no difference between the water flowing on the surface and the underflow, passing beneath the bed of the stream. One may, by appropriate works, develop and secure to useful purposes the subsurface flow of the stream, and, by so doing, become the legal appropriator of the water, provided he does not thereby interfere with the rights of other persons in the water of the stream.*

If the legal jargon seems tedious, here's a diagram.

| | | |
|---|---|---|
| Surface Water | | Surface water law. Riparian rights inherent with overlying land ownership, and appropriative rights determined by seniority. |
| Groundwater | Subterranean Streams | |
| | Percolating groundwater | Groundwater law. Overlying and appropriative rights gained by pumping and putting to beneficial use. |

Unfortunately, however, such common law distinction conflicts with science. The same water may sometimes be found on the surface and at other times below. What constitutes a "definite channel" is subjective. Whether seepage from the surface is at any particular moment below or not below a surface stream depends on the slope and direction of the medium through which the groundwater is moving at that time, the obstacles it encounters and the topography.

American groundwater law has never fully recovered from its misalignment with science. Most states still use the reasonable use doctrine to govern groundwater and employ a riparian and/or prior appropriation legal framework for surface water. Most states still administratively regulate the "subterranean stream" portion of groundwater as if were on the surface.

We will limit our court reporting to the 17 western states.

Western Contiguous States having Statutory or Judicial Reference to Subterranean Streams

| | |
|---|---|
| Arizona | Ariz. Rev. Stat. Ann. § 45-101(1956) |
| California | Cal. Water Code §§ 1200 and 1201 (West 1971) |
| Colorado | Medano Ditch Co. v. Adams, 29 Colo. 317, 326, 68 Pac. 431 (1902) |
| Idaho | Public Util. Comm'n v. Natatorium Co., 36 Idaho 287, 305, 211 Pac. 533 (1922) |
| Kansas | Kans. Stat. Ann. § 82a-707 (1969) |
| Montana | Ryan v. Quinlan, 45 Mont. 521, 531, 533-534, 124 Pac. 512 (1912) |
| Nebraska | Olson v. City of Wahoo, 124 Neb. 802, 248 N.W. 304 (1933) |
| Nevada | Strait v. Brown, 16 Nev. 317, 321 (1881) |
| New Mexico | Keeney v. Carillo, 2 N.Mex. 480, 495-496 (1883) |
| N. Dakota | Baeth v. Hoisveen, 157 N.W. (2d) 728, 730 (N. Dak. 1968) |
| Oklahoma | Okla. Stat. Ann. tit. 60, § 60 (1971) |
| Oregon | Taylor v. Welch, 6 Oreg. 198, 200-201 (1876) |
| S. Dakota | Metcalf v. Nelson, § S. Dak. 87, 89, 65 N.W. 911 (1895) |
| Texas | Houston & T.C.R.R. v. East, 98 Tex. 146, 81 S.W. 279 (1904) |
| Utah | Chandler v. Utah Cooper Co., 43 Utah 479, 135 Pac. 106 (1913) |
| Washington | Meyer v. Tacoma Light & Water Co., 8 Wash. 144, 146-147, 35 Pac. 601 (1894) |

Wyoming's always been a special case. As reported in toto by the Huron Expositor, July 30, 1886,

> *An underground river has just been discovered in Wyoming Territory. It is just in the nick of time. Had its discovery been postponed until next fall, it would have been too late for an appropriation from Congress this year.*

We're left to wonder what legislative action hung on the timely discovery. As the Huron Expositor published in Ontario, Canada, we wonder why the underground river story merited international coverage, scant as it was.

Of the western states of today, only Wyoming makes no explicit mention of "underground streams" or "underground rivers" in its statutes and rulings. All water below the surface is designated simply as "groundwater."

While each of the remaining states acknowledges a legal distinction between subterranean streams and percolating groundwater, Idaho, Kansas, Nevada, North Dakota and Oregon regulate both as indivisible groundwater.

That leaves Arizona, California, Colorado, Montana, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, Utah and Washington as states where the distinction between subterranean streamflow and percolating groundwater may impact the rights.

This is not to say, however, that one would have a good chance in court of appropriating water beneath one's real estate based on a riparian right.

We will look at the water law of three states that fall into this latter category, states that continue to wrestle with subterranean streams having surface stream status.

**Arizona**

Arizona, where "whiskey is for drinking and water is for fighting," distinguishes "subflow" from percolating groundwater.

The first official water rules came as provisions within the Howell Code of 1864 by the Legislative Territorial Assembly. Groundwater could be distinguished as either subsurface water which flows in definite underground channels or water seeping down into non-tributary permeable soils. Subsurface water flowing in underground channels was subject to the law of prior appropriation. Not thought capable of lateral movement, percolating waters were considered similar to mineral deposits.

To establish the existence of a subterranean stream, the state supreme court specified,

> *While surface indications such as trees, shrubs, bushes, and grasses growing along the course and the topographical features of the surface are the simplest and surest methods of proof, we think they are by no means exclusive. Other methods may be used, such as a series of wells or borings, tunnels, the color and character of the water, the sound of water passing underneath the earth, the interruption of the flowing of other wells on the line of the alleged subterranean stream, geologic formation, and perhaps others.* -- Maricopa County Municipal Water Cons. Dist. No. 1 v. Southwest Cotton Co., 39 Ariz. 65,4 Pac. (2d) 369,377 (1931)

A hydrologist familiar with arid regions would take exception to the "surest methods of proof." Few (if any) dry washes or arroyos sustaining a strip of phreatophytic vegetation overlie anything resembling flowing water. "The sound of water passing underneath the earth" would prove the point, but it's not an Arizona sound.

Fortunately, we note, the art of dowsing is not a court-sanctioned indicator.

To the state's credit, Arizona recognizes the dichotomy between modern hydrology and long-held legal frameworks.

> *The notion of "subflow" is significant in Arizona law, for it serves to mark a zone where water pumped from a well . . . should be governed by the same law that governs the stream. Yet the notion of subflow is an artifice... that rests on a hydrological misconception.* -- General Adjudication of All Rights to Use Water in the Gila River System and Source (1999) 195 Ariz. 411, 415

Rather than reject the deep-rooted common-law distinction between subterranean stream and percolating groundwater, states such as Arizona have simply raised the burden of proof. The ruling continues,

> *But all of these, when examined, must be such as to afford clear and convincing proof to the satisfaction of a reasonable man, not only that there are subterranean waters, but that such waters have a definite bed, banks and current within the ordinary meaning of the terms as above set forth, and the evidence must establish with reasonable certainty the location of such bed and banks. It is not sufficient that geologic theory or even visible physical facts prove that a stream may exist in a certain place, or probably or certainly does exist somewhere. There must be certainty of location as well as of existence of the stream before it is subject to appropriation.*

As the likelihood of such demonstration, at least in arid zones, is negligible, there is accordingly scant history of successful arguments, other than where an underground stream was a discernable and defined result of an artificial water work.

**California**

Recalling a line from the movie Chinatown (1974), "Either you bring the water to L.A. or you bring L.A. to the water," we'll go to the Golden State.

"Property Rights in Underground Water Flowing in Defined but Unknown Channels," The Columbia Law Review 3:2, 1903, summarizes the challenge faced by California.

> *It is well settled that when water flows underneath the surface in a defined and known channel, a riparian proprietor has the same rights to its reasonable use which he would have enjoyed if the stream had been on the surface, that is, in such a case the principles applicable to surface streams, govern, and not to the principles which relate to percolating waters. However, as there have been few decisions in which the right to use water flowing in an underground channel has been directly in issue, some doubt bas existed as to just what qualities are necessary to make an "underground channel" defined and known."*

In Hale v. McLea 53 Cal. 578 (1879), where the course of an underground stream was marked by vegetation which would grow nowhere except above such waters, it was held that the channel was indeed well defined and that a lower riparian proprietor had a right to the flow.

In Bradford v. Ferrand, 71 L.J. Ch. Div. (1902), the plaintiff maintained that a spring issuing from the defendants' land was fed by a subterranean stream flowing in a defined channel. The plaintiff desired to prove his contention by excavating upon the defendants' land (and in logical extension, digging on any number of proprietors and thus extending the stream for miles.) In this case, the court decided that the course of the channel must be ascertainable by the reasonable inference of men of ordinary powers without the use of exploratory excavation.

Hudson v. Dailey, 156 Cal. 617, 627 (1909) adopted a “common source” or “correlative rights” doctrine, providing that where surface and groundwater rights are interconnected, water rights are likewise integrated.

> *In the case of percolating waters feeding the stream and necessary to its continued flow . . . There is no rational ground for any distinction between such percolating waters and the waters in the gravels immediately beneath and directly supporting the surface flow, and no reason for applying a different rule to the two classes, with respect to such rights, if*, indeed, the two classes can be distinguished at all.

The classification was retained in the state's Water Code of 1943

> *Whenever the terms stream, lake or other body of water, or water occurs in relation to applications to appropriate or permits or licenses pursuant to such applications, such terms refer only to surface water, and to subterranean streams flowing through known and definite channels.*

The physical distinction between subterranean streams and percolating groundwater has traditionally been based on the Los Angeles v. Pomeroy, 124 Cal. 597 (1899) "bed and banks" test which ruled that subsurface water should be classified as percolating groundwater unless it can be shown that it flows through known and definite channels, and thus is a subterranean stream.

Judge George H. Hutton, wasn't impressed with the distinction, as evidenced by his contribution, "Underground Waters of California" National Irrigation Congress (1910), but an article doesn't convey the weight of law.

> *An underground river in California is a geological myth. The idea must have been born in some facetious brain and treated literally by a large number of gentle and confiding persons who believe everything they hear, until some serious-minded men took it up and for a time exploited the idea and then exploded it.*

In the Matter of Applications 30038, Waste Management, Inc., Applicant; Yuima Municipal Water District, Protestant; Pauma Valley Water Co., Interested Party -- better known as the Pauma and Pala case (1999) -- however, the SWRCB attempted to reclassify ordinary groundwater as subsurface streamflow despite the fact that no impermeable bank beneath the stream could be demonstrated, arguing that that bedrock mountains flanking the basin constitute "banks." Under such definition, all groundwater basins in California could potentially be classified as subterranean streams.

Prof. Joseph Sax reviewed the legal issues in Review of the Laws Establishing the SWRCB's Permitting Authority over Appropriations of Ground Water Classified as Subterranean Streams and the SWRCB's Implementation of those Laws (2002). Among his findings,

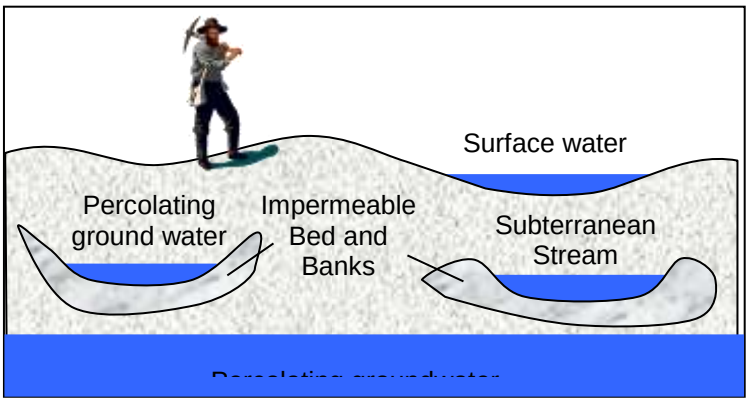
> *The categories that statutes and judicial opinions use, such as "underflow," "subflow," "subterranean streams," and "percolating groundwater," bear little if any relationship to these geological realities...*

Referring to precedent, Sax noted,

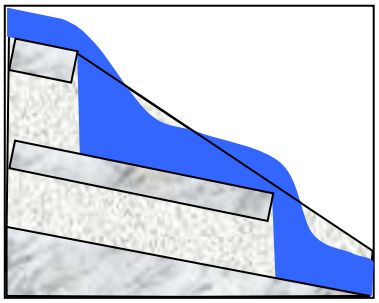
> *The principal point of contention in the case was whether the alluvium from which the well was pumping had "relatively impermeable" bed and banks, which the Board defined as follows.*
>
> > *Is the [material comprising the bed and banks sufficiently] impermeable at the point of diversion to prevent the transmission of all but relatively minor quantities of water through the channel boundary... The test is not that the bed and banks be absolutely impermeable, but rather, relatively impermeable compared to the alluvium filling the channel.*
>
> *If the Board were to take the view that a channel must fit the definition of being like "a trench, furrow, or groove" or "a tubular passage" -- that is, something essentially long and narrow -- it would doubtless be drawn toward the more restricted view of its jurisdiction that some urge, sticking to the immediate confines of the channels of surface streams. On the other hand, if a channel can be quite broad and un-furrow-like, so long as it is enclosed by relatively impermeable beds and banks, subterranean stream jurisdiction could be quite extensive.*
>
> *Assuming a highly impervious enclosure, subsurface water that fits everyone's legal definition of a "subterranean stream flowing through known and definite channels"... should be limited to what is called the underflow of surface streams.*

Water not underlying a surface channel should not be classified as a subsurface stream. Water enclosed by impermeable boundaries beneath a surface stream, however, might constitute a subsurface stream and thus could be regulated as is that flowing above.

In the drawing to the right, it makes no legal difference whether the two perched waterbodies are flowing or quiescent.




A correspondence between a surface channel and a corresponding subsurface flow -- "affinity" in legal jargon -- can make hydrologic sense, as illustrated to the right. Indeed, disappearing and reappearing streams are not uncommon in arid regions. It would make little sense to change the legal model every time the stream takes a subterranean dive.



As summarized by David Aladjem in "Groundwater Management in California, The Sax Report and Beyond," California Water Law & Policy Reporter, July 2002,

> *The Sax Report crystallizes two concepts that have gained some popularity and credence during the past few years. First, the Sax Report advocates that Water Code § 1200, which grants the SWRCB authority over "Subterranean streams flowing through known and definite channels," be read to grant the SWRCB authority over groundwater when the extraction of that groundwater would have an "appreciable and direct impact" on a surface stream. Second, the*

> *Sax Report indicates that the SWRCB possesses and should exercise authority over groundwater, either under the public trust doctrine or under the waste and unreasonable use doctrine, when the extraction of that groundwater might have an adverse impact on instream values.*

Aladjem, on the side opposing the report, provides several legal arguments against Sax's findings, the last being,

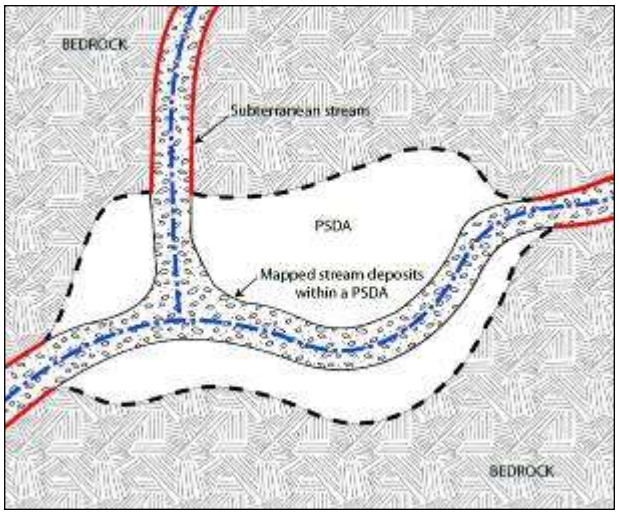
> *Third, and most important, the Sax Report -- like much current dialogue about groundwater – proceeds on the assumption that the interconnected nature of groundwater and surface water requires an integrated legal regime. Examining the differences between groundwater and surface water, however, suggests that there are sound policy reasons that California has decided to treat those two resources separately.*

Only a big-city lawyer could argue that the law working one way and nature, another, is sound public policy, but such arguments prevailed and Sax's contribution was rejected by state.

As things remain in the Golden State, for there to be a subterranean stream, the following conditions must be present:

A subsurface channel must be present;
The channel must have relatively impermeable bed and banks;
The course of the channel must be known or capable of being determined by reasonable inference; and
Groundwater must be flowing in the channel.

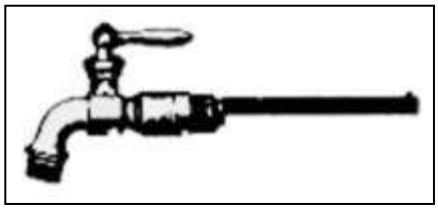
Relationship between subterranean streams, potential stream depletion areas (PDSAs) and mapped stream channel deposits




The contentiousness is not put rest, but argument to justify the presence of subterranean streams (and thus a rash of private-property drilling) appears to be evidentially thwarted.

**Texas**

When in the Great State of Texas, a man's water right is challenged, “Them thar’s fightin’ words, mister.”



To illustrate the economic importance of our topic, here is an item from the Los Angeles Times, October 16, 1925, "Subterranean Stream Found."

> *San Marcos, Texas. Discovery of what is believed to be an underground river of a width of perhaps one-half mile and of undeterminable depth, has transformed the arid region 15 to 25 miles northwest of here into a variable paradise of verdure and growing crops within a period of three months.*
>
> *Is was during the height of the recent severe drought that Ben W. Pyland, a farmer, decided to dig a well on his place in search of water. He was ridiculed for attempting to get water in that locality by digging a well.*
>
> *Pyland commenced digging and at a depth of 20 feet he struck a cap of limestone. Using his pick vigorously he punctured this covering and there immediately gushed forth a small torrent of water. He enlarged the hole by exploding a charge of dynamite, and the water poured into the well, almost filling it to the top.*
>
> *Other farmers in the section began digging wells and several of them obtained water in apparently inexhaustible quantities.*

It's the same aquifer at which we looked in Chapter 53, Diversity in Darkness, but that chapter was about critters. Here we're talking about dollars, lots of them.

The Edwards aquifer has long been an item of contention between Texan landowners and regulators. Farmers and ranchers who draw from the Edwards maintain that what's under their property is theirs to pump, a principal founded in English Common Law.

The Texas Water Commission (TWC, whose Austin headquarters sits above the Edwards) considers the aquifer to be an integral component of the region's water. Just as TWC regulates surface water diversion by a system of permits, TWC claims authority over what's below.

The TWC uses "Edwards Underground River" 86 times in 31 TAC sec. 298, the enabling legislation, e.g.,

> *Except as provided by subsection (b) of this section, the owner of each well which diverts water from the Edwards Underground River, other than a well that is exempt under sec. 298.12 of this title (relating to Permit Exemption for Domestic and Livestock Use), shall, prior to diversion from the well, install and maintain a measuring device designed to indicate the flow rate and the cumulative amount of water diverted by that well.*

As to why it's denoted an "underground river," the Texas Water Code recognizes four classes of water:

1. Natural Surface Water: "The ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state." A central feature of this doctrine is the "first-in-time, first-in-right" rule that during times of scarcity, the water goes to the holder of the most-senior rights. All natural surface waters in are owned by the state and are held in trust for the people.
2. Diffused Surface Water: "Water that does not flow in any defined watercourse, but instead flows across the surface of land in a variant and un-patterned way." This includes rain or snow runoff and water left in upland areas after a flood recedes. Diffused surface waters are the property of the landowner until they enter a natural water course, at which time they become subject to state allocation and control.
3. Percolating groundwater: "Water beneath the land surface which fills the pore spaces of rock and soil material and which supplies wells and springs." In contrast to surface water regulations, Texas allows landowners an absolute "right of capture" to groundwater under their property. A property owner may pump as much water as needed, even if other property owners are affected, similar to the rule for oil and gas.

4. Underground Rivers: "Defined subterranean streams or the underflow of rivers" (Texas Water Code Ann. 52.001(6) Vernon Supp. 1992). The aquifer must show "all of the characteristics of surface water courses, such as beds, banks forming a channel, and a current of water." Underground rivers may be property of the state and governed by surface water rules.

TWC could regulate the Edwards aquifer within established legal theory if the classification were that of an "underground river." Following is a chronology of TWC's attempt to legitimize the designation.

| | |
|---|---|
| June 15, 1989 | Guadalupe-Blanco River Authority (a smaller agency with interests akin to those of TWC) files suit to have the Edwards declared an underground river. |
| April 15, 1992 | TWC moves to designate the Edwards as an underground river on an emergency basis, allowing TWC to regulate withdrawals in the system used for surface streams. |
| | Of notable deficiency in the filing is why the Edwards now qualifies as an "underground river" per the four-class criteria. There is no mention of "bed," but the Edwards moves within its "banks." |
| May 1992 | House subcommittee public hearing to discuss the emergency rule. Opposition from the Texas Farm Bureau: "We oppose the classification of any aquifer as an underground river that would be regulated by the state." |
| July 1992 | TWC argues that the action protects rural landowners from unbridled municipal and industrial pumping. Quoting the attorney, *There is not another aquifer in the state of Texas that exhibits these peculiar characteristics... I have no problem with the legislature passing a bill that says no other aquifers in the state are underground rivers... We took this action not because we wanted to get in the middle of a tug-of-war but because we felt it was necessary to bring about effective management for that resource.* The "effective management" basis would have startled the judge. |
| Sept. 9, 1992 | TWC makes the rule permanent. |
| Sept. 11, 1992 | District Court voids the "underground river" designation on grounds that TWC lacks statutory jurisdiction to alter conventional references to underground water. |
| Oct. 2, 1992 | Judge issues Final Summary Judgment Order. |
| May 1993 | Texas Senate Bill 1477 declares the Edwards to be not an underground river, but a distinctive natural resource. The ranchers prevailed legally -- the Edward's is not a river -- but what was once held to be the private property became subject to river-akin permits and regulation. The attorneys were well paid and gunfire was avoided. |

But here's another Texas case, one of opposite outcome. From the abstract of "Dye Tracing, Its Application to Ground Water Law for Defining 'Subterranean Streams' in Karst Terrains," Proceedings of the Environmental Problems in Karst Terrains and their Solutions (1986), National Water Well Association, by A.E. Ogden,

*The City of Camp Wood, Texas, obtains its water from Old Faithful Spring which emerges from the Glen Rose Limestone. Since the water was considered groundwater, no water-use permit was required. The source of Old Faithful Spring was believed to be sinking water of Camp Wood Creek. When developers planned to place impoundments on Camp Wood Creek, the City became concerned. The sinking stream was then traced to the spring using fluorescein and rhodamine dyes and optical brighteners. The tracer flowed four miles in just twenty-four hours. The hearing examiner and the State's lawyers decided that based on the groundwater traces and the velocity of movement that this water was in a "well defined subterranean stream" and should be considered as surface water. The City of Camp Wood then was required to*

*obtain a water-use permit. Their prior-use superseded in time and importance the desired use of the developers, thus saving the spring.*

Four miles in 24 hours is about 4.5 meters/minute. As the quickest flows in typical aquifers tend to be measured in meters/hour (gravel, per the table of Chapter 39, Hydrogeology), the Glen Rose water is whistling and the hearing officer had physical basis to declare the subsurface water to be a stream, not mere percolation.

**Water Rights**

We'll not kid ourselves about these Arizona, California and Texas cases. They're not about hydrology. They are about property rights.

As noted in this chapter's first table, subterranean streams fall under surface water law, which in the western states is a system of prior appropriation -- "first in time, first in right." The states shown in green exclusively employ this framework. The striped states blend in some aspects of riparian law, but not enough to make effectual difference in regards subterranean streamflow rights.

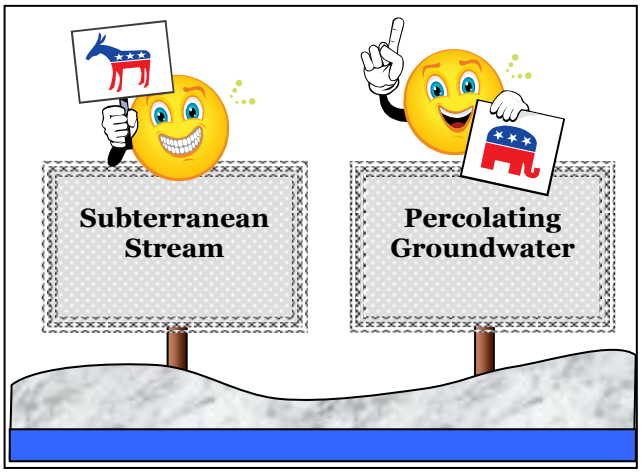
Our examples illustrate a litigation scenario common in the western states. In pursuit of comprehensive water resources policy, the regulator argues for the physical validity of subterranean streams to which the doctrine of prior appropriation would be applied. As this water would not be new water to the hydrologic system -- it's just another tributary to an already-fully appropriated resource -- the doctrine of prior appropriation effectively precludes additional claims. "Sorry, mister, but that there water's already taken. Now get on your horse and move on!"

To sidestep such austerity, the landowner argues that what's in question is percolating groundwater, thus moving the court case to the historically more-lenient domain of groundwater law. Water can be withdrawn from a well regardless of whether senior surface water rights are receiving their full entitlement. "Now listen, buster, this here is my land. Now skedaddle!"

As the state predictably fails to scientifically prove its claim of definite subterranean streamflow, the landowner most often prevails. The demise of Ogallala aquifer (Chapter 39 and the eastern states of the map above) speaks to the wisdom of such management, but we'll not confuse the weighing scale of justice with water balances.

If we favor comprehensive resource management, we tend to imagine subterranean channels beneath us. If, on the other hand, we wish to avoid government interference on what we do on our own land, what we're drilling into is just percolating groundwater.

Given the philosophical difference between the two major American political parties -- though some Democrats act Republican and some Republicans act Democrat -- we can take a guess as to how legislation regarding subsurface waters thus tends to play out.




**Church and State**

In 1869, the Cincinnati School Board banned hymn-singing and Bible reading in the public schools and conservative Christians brought suit to block the ban.

Here's the argument of Rufus King against the ban, quoting from The Bible in the Public Schools, Arguments in the Case of John D. Minor et al. versus the Board of Education of the City of Cincinnati et al., Superior Court of Cincinnati; with the Opinions and Decision of the Court (1870) by John D. Minor.

> *There has been a great deal said here about zoology. I recollect seeing a poor little blind fish, taken out of the subterranean river in the Mammoth Cave; proving, as I suppose, the fact that the river must be subterranean, because it had no eyes whatever. There being no light the organ lost its purpose; it had shrunk away, and there was nothing there but a slight speck and a slight bony process where the eye might have been. And that is what it is proposed to make out of the children of this city. Educated in a medium destitute of the blessed rays of God's light, the only inspiring source of virtue, brought up purposely in blindness and darkness, with no vision to their souls, they are to be kept here groping about without knowledge of the Creator and Giver of all these things that they are reading in these books of exact science; and I suppose the best of them would be in the sad, helpless condition ascribed to Humboldt by one of the orators at the late anniversary of his birthday, who ended his oration, put the climax to it, by declaring that Humboldt died, having discovered that the universe was governed by fixed laws. Wondrous Eureka! Promethean, yea, godlike science! The great Humboldt, whose mind could glance from heaven to earth, and who penetrated all things in space, expiring with the discovery that the world was governed by fixed laws, and yet knew not, as the poorest little child in the public schools in the city, simply holding the Bible in his hands, could have told him, who was the author of those laws: "the hand that made us is divine."*

It's again the Hydrotheology/Theohydrology juxtaposition of Chapter 13.

The Board lost in a two-to-one vote and was enjoined from enforcing its ban on Bible reading. The Scopes trial of 1925 didn't cite underground rivers.

**Buyer Beware**

An aspect of real estate law is addressed in Kleinberg v. Ratett, 252 N.Y. 236, 169 N.E. 289 in which he defendant sold a parcel of real estate without divulging the existence of a buried pipe conveying subterranean streamflow. The ruling:

> *Superficial or subterranean watercourses, not the subjects of grant or prescription, are not legal encumbrances, since nature itself, rather than man's contrivance, is responsible for their origin.*

By common law, natural runoff must be allowed to follow its natural course upon or beneath the land surface. As such, a watercourse is not an encumbrance, i.e., equivalent to a right or claim of another party to a portion of the property or to the use of the property. As nature is responsible for the flow, the undisclosed "underground brook" does not void the purchase.

As summarized by the New York Times, October 12, 1930,

*Underground Watercourse Said Not to Bar Suburban Realty Transaction*

**Europe**

Groundwater law varies between European nations regarding private vs. public rights, the law of Belgium, for example, favoring the overlying landowner, while that of the former Soviet Union retaining a public-ownership bias. With a few exceptions, however, the water beneath the surface of the ground in a particular nation is not further subdivided regarding legal theory.

Great Britain, as we have seen, is an exception, the Queen's view of percolating groundwater different from that regarding defined subterranean streams.

Spain considers waters under a streambed or in the subsoil within 100 meters of a public stream to be public waters. Other groundwater is private property. While stream-associated groundwater is not defined, per se, as a "subterranean stream," the property rights consequence is much the same as that of the United Kingdom, California and Arizona.

Italy subjects thermal and mineral waters to unique regulation, again without reference to "subsurface stream," but seemingly in extension of an historical perspective that thermal and mineral waters travel via confined courses.

In conclusion, let us note that water law based on arbitrary hydrologic partition tends toward problematic enforcement. "Underground rivers" indeed hold an honored place in western culture, but it's unfortunate that they hold any place at all in jurisprudence.

# CHAPTER 70
# CAVE DIVING

While some underground rivers are navigable by boat, there are the darker waters beneath to also explore.




While such photography can make cave diving appear idyllic, not all underwater passages are as well illuminated and spacious, an environment many of us would choose to avoid. But as our underground river voyage beckons us into darker realms, we'll investigate.

Chapter 74, More Aquatic Perils, expands the list of unfortunate outcome possibilities due to underground rivers. As there's so much more to cave diving than danger alone, however, we're granting the subject a full chapter.

We'll not classify cave diving as a recreational sport -- which it is for many -- because it's also a means of exploration and scientific research -- geological, biological, paleontological, and even archeological.

**The Problem of Hypothermia**

Today's divers are outfitted with customized wetsuits, but earlier explorers had to invent their own protection against the cold.


Peter Harvey's internet posting, "Early Days in Dan yr Ogof,"

> *Before the days of wetsuits [or furry suits], Dan yr Ogof was a cold cave. After wading through the lakes, which usually meant getting soaked up to the armpits or higher, one tended to get As this series consisted in the main of large chambers, the caving was not energetic enough to generate much heat. Also there was a considerable draught in the cave which contributed to the general chill. Some of the old hands such as Platten used to cover their bodies with about half an inch thick of lanolin grease before putting on their caving gear.*

Charles Freeman, in the British Caver (1941),

> *Also a wonderful difference can be made by greasing the body all over, when changing into caving rags, with commercial vaseline. A handful should be taken up and rubbed well into the skin, not just smeared on… Its use certainly transforms one into a hero in the eyes of those who have scorned to anoint themselves.*

Norbert Casteret discusses an early wetsuit in My Caves (1947).

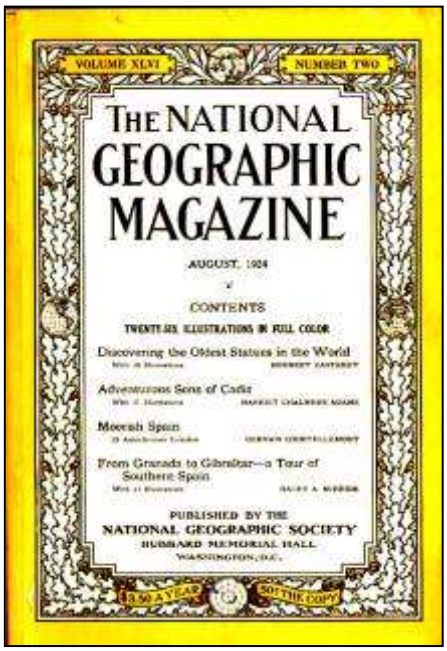
> *The thing weighs just over a pound and a half; it is made of balloon cloth, as thin as a handkerchief but very strong, the lightest of diving dresses, which in no way interferes with the movement of the body. At the same time, a thin skin like this is not meant to be scraped against rough walls or sharp rocks, so it is advisable to put the boots on over it and then the usual cave overall. Thus clad, the diver is completely covered up and protected, and it is great fun to plunge fully dressed into an underground stream, even in winter, to the amazement of friends or sightseers, who fail to realize that the overall and boots are the only things which the water penetrates. If only I had known of this wonderful diving dress for caves fifteen years earlier, I should have been spared the horrible times I have spent with chattering teeth in icy water, and I should have doubtless also avoided the rheumatism that is coming to me in the future, and which, when it has me in its grip, will cause me no surprise and will leave me in no sort of doubt as to how I invited its attack.*

**Free Diving**

There's rudimentary equipment involved -- we've had the mask, snorkel and fins since the 1920s -- but the fundamental limit of free diving is the duration one can hold his or her breath, for most of us probably not much more than a minute. A free dive isn't likely to propel us more than a few meters deep and some tens of meters in distance. In the case of a flooded cavern, of course, the assurance of an air pocket ahead -- the inverted siphon configuration of Chapter 46 -- is denied to the first explorer.

We'll start by looking at an early free dive beneath the foothills of the Pyrenees.

To penetrate Montespan Cavern in 1922, explorer Norbert Casteret had to swim unassisted through two inverted siphons. "Discovering the Oldest Statues in the World, A Daring Explorer Swims Through a Subterranean River of the Pyrenees and Finds Rock Carvings Made 20,000 Years Ago," National Geographic, August 1924, chronicles the feat.




> *Putting my candle on a projection of the wall, I breathed in enough air to last me for two minutes under the water (a habit to which I am accustomed) and plunged into the stream with one hand ahead of me, the other in contact with the submerged roof*
>
> *While thus hurrying forward, suddenly my head emerged from the water and I could breathe. Where was I? I had not the slightest idea. The darkness was absolute. Without doubt I had passed through a siphon tunnel. Immediately I turned around and dived toward the spot from which I had come, for nothing is more dangerous than to lose one's sense of direction in such a case.*

Casteret's field sketch -- not included in the National Geographic report -- suggests that the underwater passage may have been something less, however. The submerged rock wasn't large and, had the route not reopened within the first minute, the explorer would have had breath enough to back out. (The passage is less rigorous today, as the water level has been lowered by excavation.)

How many other cave explorers, we wonder, have blindly dived into longer flooded passages without a subsequent air pocket, thus becoming a news story, not a National Geographic contributor? But back to 1922,

> *Having undressed and hidden my clothes in the bush, I lowered myself into the subterranean stream, holding in-one hand a lighted candle and in the other my rubber bathing cap containing matches and candle*
>
> *This simple case, kept well closed, would permit me to pass under the water and have after each dive into the stream the means of relighting my candles. (May I add, that to supplant this mode of lighting by' an electric pocket lamp is imprudent in a cave, for some dry batteries have a very limited duration and sometimes suddenly go out.)*
>
> *Arrived at the siphon, I took the precaution to orient myself, as on the preceding day, in order to find again the pocket of air, and, diving through the siphon a second time, I found myself on the other side, immersed lip to my chin.*
>
> *I shook my dripping cap before relighting a candle with all tile impatience that was consistent with caution.*
>
> *At last the flickering flame enabled me to observe that, as far as the eye could see, the roof was parallel to the surface of the water, which was separated from it by a thin layer of air.*

*This time my anticipations were realized, for I was exploring a subterranean stream hitherto unknown.*

A more-recent and less fortunate story from Utah:

*Searchers recovered the bodies of two women and two men who had tried to swim underwater through a narrow submerged passageway in a cave in an effort to reach another chamber, officials said Thursday.*

*He said the entrance to the passageway is a hole visible at the bottom of a pool of clear water, about five feet deep, that sits some 30 yards inside the cave.*

*"We believe they'd already been into the cavern and were on their way out when something went wrong," said Lt. Dave Bennett of the Utah County sheriff's office search and rescue team.*

*All the bodies were found in the underwater passageway, facing toward the entrance as if they were swimming out, he said.*

*The chamber is reachable by a water-filled passageway about 15 feet long with a guide rope tied to a rock at the opening and to a piece of wood inside the chamber.*

*"There are 2 or 3 feet of breathable air above the water in that next chamber, which could hold about eight people," he said.* -- Associated Press, Aug 18, 2005

The physiological limit of oxygen deprivation didn't change between 1922 and 2005. Casteret, as well conditioned as he thought himself to be, was fortunate that the siphon was short; the Utah spelunkers weren't as lucky.

**The Standard Helmet Diving Suit**

The Standard Helmet Diving Suit, characterized by its large helmet, heavy boots and durable air lines fed by a surface pump, was invented in 1830. Not substantially changed over the years, it was to remain the basic diving apparatus for more than a century


The first recorded helmeted cave dive, 23 meters into France's Fountaine de Vaucluse, was in 1878 (Chapter 71, Subterranean Shipwrecks), followed by Switzerland's Orbe Spring in 1893 and Austria's Lurloch Cave in 1894.

In 1934, Switzerland's La Grotte du Creugenat was explored with the same standard apparatus.

Wookey Hole (Chapter 56, The Tourist Trade Worldwide) was explored to its seventh chamber in 1935. Divers had to physically walk on the floor of the sumps while the team pumped gas to them using a seesaw pump. To the right is equipment from that era, the pump in this case being rotary.

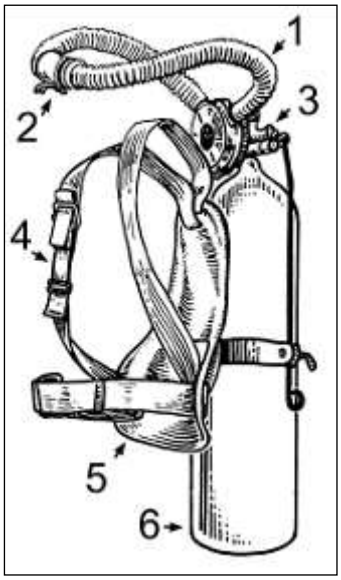
In 1936, divers passed the first sump of Swildon's Hole (a 2.3-kilometer distant feeder to Wookey) using a suit fed by a football inflator/bicycle pump. An oxygen cylinder affixed to the heavy suit allowed passage of the second siphon.

Diving in the spacious third chamber was aired live on BBC radio.

To date, Swildon's has been penetrated as far as the twelfth siphon.

**Scuba**

Jacques Cousteau and others developed the self-contained "aqua lung" In 1942, the breakthrough being the regulator delivering properly pressurized air only when the diver breathed in. Today we know the technology as "scuba" (acronym for self-contained underwater breathing apparatus) gear.





1. Air Hose
2. Mouthpiece
3. Regulator
4. Harness
5. Back plate
6. Tank

Within four years, the Cave Diving Group was established in the UK for cavers who wished to dive, not divers who wished to cave.

The first scuba cave dive in America was in 1951, a descent into Florida's Silver Springs sinkhole.

The first cave dives in Wakulla Springs, Florida (Chapter 57, The American Tourist Trade) occurred in 1955. Divers with virtually no protection from the cold penetrated approximately 150 meters reaching depths of 78 meters, discovering Pleistocene era fossils including camel, deer, sloth and mastodon.

A 1956 photograph is to the right.

In the 1960s, divers with cobbled improvements were penetrating many of Florida's underground rivers. Gas cans (as illustrated), plastic milk bottles or Clorox jugs were used for floatation. Three-watt lights provided illumination.

"Exploring Florida's Treacherous Underground Rivers," Popular Mechanics, April 1968, illustrates how the popular press drew upon cave diving's danger to spice up publications.


*A slight twinge of fear creeps through my body as I slip into the lukewarm water. I've heard that seven divers lost their lives exploring this very spring -- and in just four months four more will die in nearby Jenny Spring.*

*But I push fear aside, as the hollow echo of my own underwater breathing fills my ear. Bob Roth, my diving partner, and I have spent hours rechecking gear. I'm confident. Bob gives the "thumbs up" sign. Mentally, I go over our diving checklist as we drift down to the cold bottom of Hornsby Spring. Everything seems okay.*

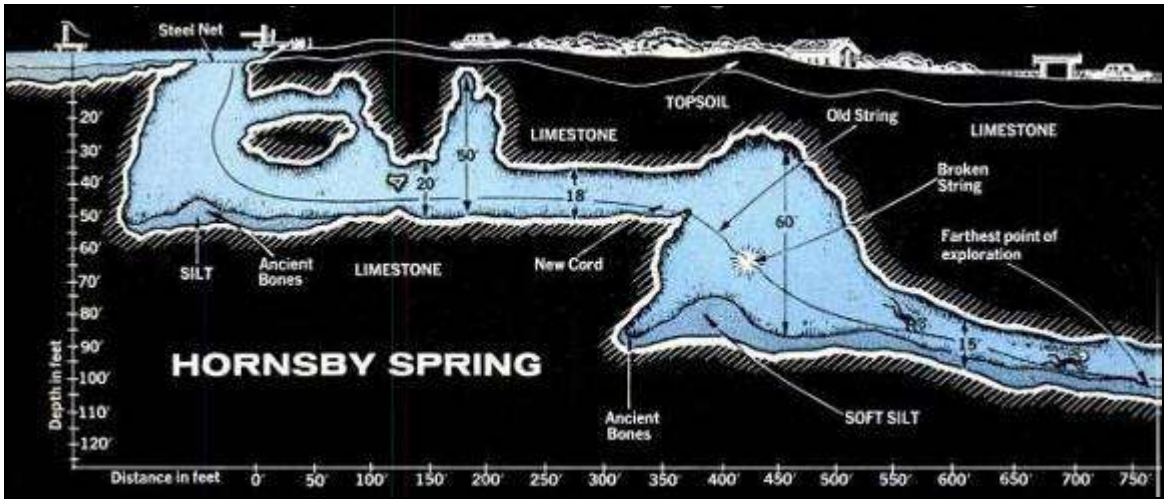
*Though Bob and I have been diving in the wide-open sea for seven years, this is only the second year we've entered the dark, cold, restrictive world of "spelunk" diving in freshwater.*

*We don't know it now, but four active college lads, having fun during the Christmas holidays, will run out of air, will panic and drown deep in the tangled, water filled caves of Jenny Spring.*

*It's 10:34 a.m. My depth gauge shows 50 feet. Bob and I have decided to make an exploratory dive this morning. We just want to see the layout. Usually we take two air tanks, but now we carry only one apiece. We don't plan to stay down long.*

*Hanging from Bob's waist is a spool of quarter-inch nylon cord. We'll use this as a guide rope.*

We'll stop the Popular Science story at this point, but note the ominous "Broken String" in the drawing.




The 1970s saw cylinders a third bigger, buoyancy compensating vests, compact safety reels, 30-watt lights, reliable pressure gauges and surveying improvements. Staging extra bottles extended the limits of exploration.

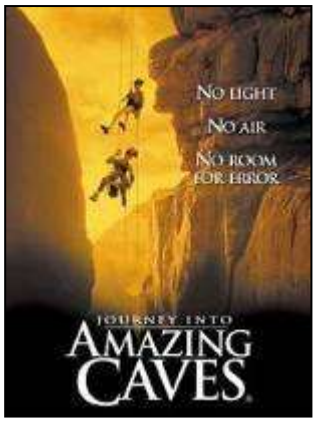
Beyond the technical definition of scuba -- but we'll include it as such -- is the "rebreather," a tank-like apparatus that provides a breathing gas containing oxygen and recycled exhaled gas. The closed circuitry makes the rebreather lighter and more compact than conventional open-circuit scuba.

We can see the impact of improved scuba technology on cave passage penetration. With pools no longer the barrier they once were, cave explorers proceed ever deeper and further.

| Year | Kilometers of explored cave passages |
|---|---|
| 1970 | 10 |
| 1980 | 60 |
| 1990 | 100 |

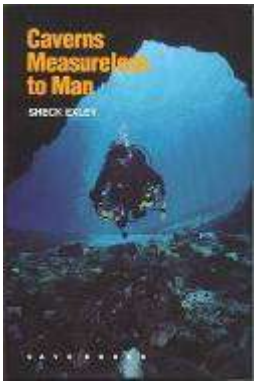
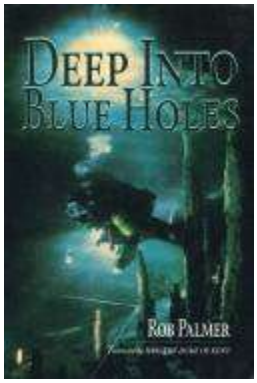
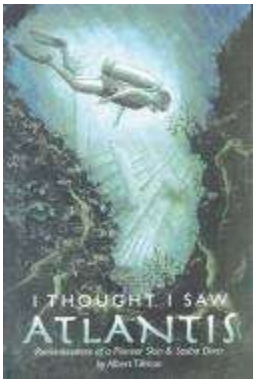
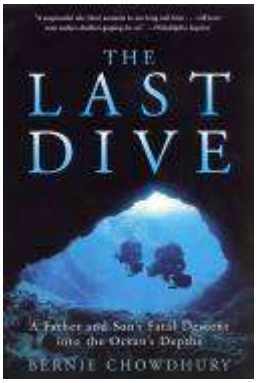
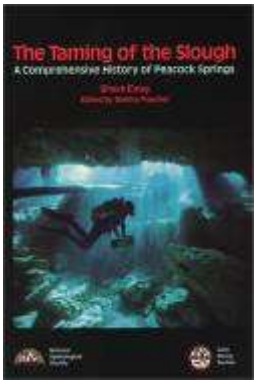
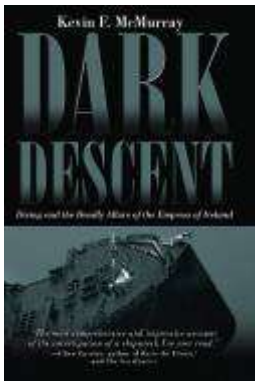
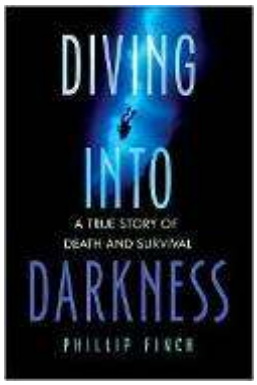
More recently, video documentaries have introduced the world of cave diving to the viewing public.


PBS film series "Water's Journey" (2002)




IMAX film, "Journey into Amazing Caves" (2000)

A few recent cave diving book covers,

| | | | |
|---|---|---|---|
|   |   |   |   |
| Sheck Exley* (1995) | Rob Palmer (1997) | Albert Tillman (1997) | Robert Burgess (1999) |
|   |   |   |   |
| Bernie Chowdhury (2000) | Sheck Exley (2004) | Kevin McMurray (2005) | Phillip Finch (2008) |

*Title from "Kubla Khan," Chapter 31, Down to a Sunless Sea. The author died at age 45, attempting to descend 300 meters in a Zacaton sinkhole, 30 meters less than the world record.

**Diver Safety**

The year 1974 was bad for cave divers -- 26 fatalities in the US alone. Safety has since improved, but there are still fatalities. Following is the National Speleological Society's compilation of American caving fatalities, 1994-2005.

| Year | Location | | Fatalities | Cause |
|---|---|---|---|---|
| 1994 | Sotano de San Augustin | Mexico | 1 | Lost consciousness, solo dive |
| | Zacaton | Mexico | 1 | Lost consciousness, deep dive |
| | Abaco Blue Hole | Bahamas | 3 | Out of air |
| | Convict Springs | Florida | 2 | Out of air |
| | Zoo Hole | Bahamas | 2 | Out of air, inadequate equipment |
| | Bakerton limestone mine | West Virginia | 1 | Equipment problem, rapid ascent |
| 1995 | Lake Apopka Cavern | Florida | 2 | Out of air, inadequate equipment |
| | Cenote Temple of Doom | Mexico | 1 | |
| | Devils Den | Alabama | 1 | Out of air, inexperience |
| | Thunderhole | Florida | 1 | Incorrect gas mixture |
| | Sharks Cove Lava Tube | Hawaii | 1 | Out of air, inexperience |
| 1996 | Paradise Springs | Florida | 1 | Silted out, no guideline |
| | Sea cave, Santa Cruz | California | 1 | |
| 1997 | Four Sharks Blue Hole | Bahamas | 1 | Narcosis |
| | Jackson Blue Spring | Florida | 1 | Embolism |
| 1999 | Wakulla Springs | Florida | 1 | Hypoxia |
| | Jackson Blue Spring | Florida | 1 | Siltation, out of air |
| | Diepolder Springs | Florida | 1 | Oxygen toxicity |
| | Madison Blue Spring | Florida | 2 | Lost guideline, out of air |
| | Forty Fathom Grotto | Florida | 1 | |
| 2000 | Little River Spring | Florida | 1 | Siltation, exceeded training |
| | Little River Spring | Florida | 1 | Inadequate equipment |
| | Poza de Juan Claro | Cuba | 4 | No guideline |
| | Cenote Sabak Ha | Mexico | 1 | Apparent heart attack |
| | Well in Goss Canyon | California | 1 | Bad air in gas pocket |
| | Ceita Core | Brazil | 1 | Deep diving |
| | Vortex Spring | Florida | 1 | |
| 2001 | Royal Springs | Florida | 2 | Inadequate equipment |
| | Cenote Escondido | Mexico | 1 | Inadequate equipment |
| | Clarksville Cave | New York | 1 | Stuck at constriction |
| | Andros Blue Hole | Bahamas | 1 | |
| | Emerald Sink | Florida | 1 | Inadequate equipment |
| | Devils Ear Spring | Florida | 1 | Out of air |
| | Ginnie Springs | Florida | 1 | Intoxication, no equipment |
| | Great Blue Hole | Belize | 1 | |
| | Jackson Blue Spring | Florida | 1 | |
| 2002 | Little River Spring | Florida | 1 | |
| | Devils Ear Spring | Florida | 1 | |
| | Orange Grove Sink | Florida | 1 | Heart attack |
| 2003 | Ocean Blue Hole | Bahamas | 2 | |
| | Cow Springs | Florida | 1 | |
| | Little River Spring | Florida | 1 | |
| | Roubidoux Spring | Missouri | 1 | Out of air |
| | Little River Spring | Florida | 1 | |

| Year | Location | | Fatalities | Cause |
|---|---|---|---|---|
| 2004 | Nohoch Na Chich | Mexico | 1 | Contaminated gas |
| | Cenote Dos Ojos | Mexico | 1 | Contaminated gas |
| | Sea cave on Oahu | Hawaii | 1 | |
| | Resumidero El Oztoque | Mexico | 1 | |
| | Eagles Nest | Florida | 2 | Siltation, lost guideline, out of air |
| | Devils Ear | Florida | 1 | No guideline, out of air |
| | Sac Actun | Mexico | 2 | Lost, out of air |
| 2005 | Peacock Springs | Florida | 1 | Above certification, out of air |
| | Dogwood Spring | Florida | 1 | Inadequate equipment |

The tabled average is 5 or 6 deaths a year. While a census of cave divers depends upon the definition of cave diving, estimates of the number of properly qualified and active cave divers tend to be in the 4000 range. The number of recreational scuba divers, on the other hand, is about 5 million, and the tabulation includes many of the latter population whose final dive was one for which they weren't qualified.


Little River, Florida sign, 1980s

Safer cave dives would be those in tested environments, an example being the former St. Joe Lead Mine, now the Bonne Terre Mine, Missouri. In addition to the boat ride, the facility has a diving platform, a half-million watts of lighting, and 24 dive trails. Diving is only in guided groups.

Bonne Terre
$23.00

Many divers, as we might expect, however, prefer passages more arduous and risky.

Northern Spain's Pozu del Xitu Cave is linked to Cueva Culiembro in the Rio Cares Gorge, "Europe's Grand Canyon," by a cave 15 kilometers long and 1,295 meters deep. As noted by explorer Chris Jewell in the August 16, 2010 MailOnline,

> *It's not just the diving but the bits in between that make it so arduous. Some of the trips underground lasted 15, even 18 hours. The water in the Picos caves is cold -- about seven degrees above freezing. That gives you maybe 40 minutes until the temperature stops you functioning.*

To traverse Pozu del Xitu, one must

Descend 37 vertical shafts as much as 140 meters deep,
Swim six sumps, and
Scale more than 100 meters of overhanging shafts and cascades by drilling expansion bolts into the rock.

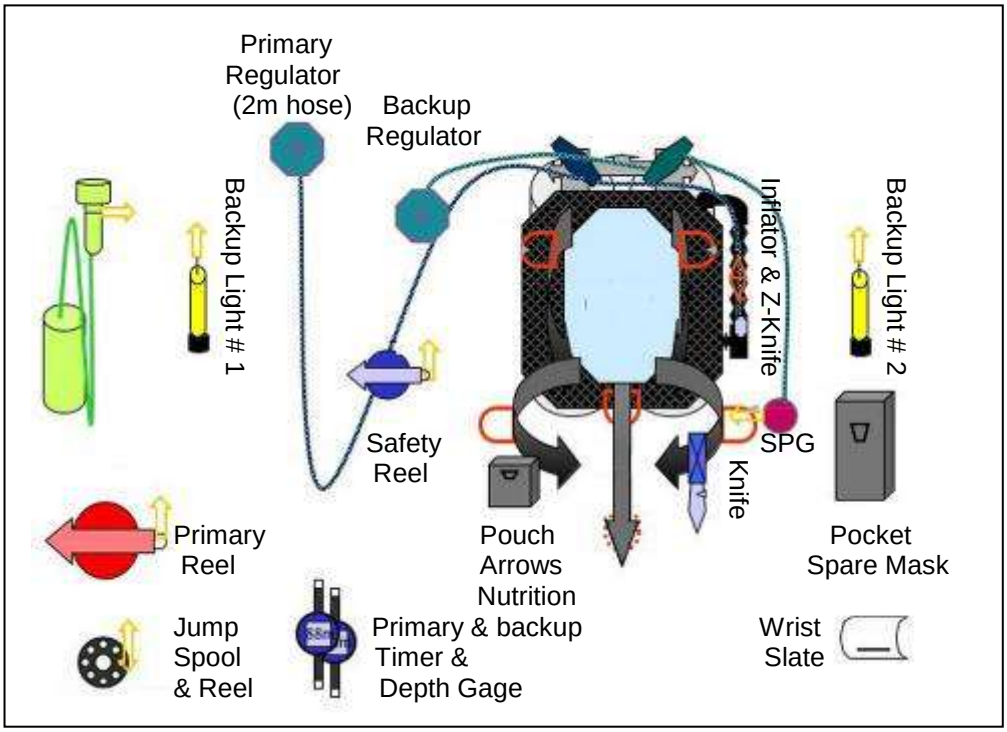
One can appreciate that danger derives from diver exhaustion as much as from hardware failure.

A few of the several organizations promoting cave diving safety:

The cardinal rules:

1. Be trained for cave diving, and remain within the limits of your training.
2. Maintain a continuous guideline to the cave exit.
3. Keep two thirds of your starting gas volume in reserve to exit the cave.
4: Remain within the safest possible operating limits for your breathing media.
5: Use three sources of light.

A safety equipment check list:

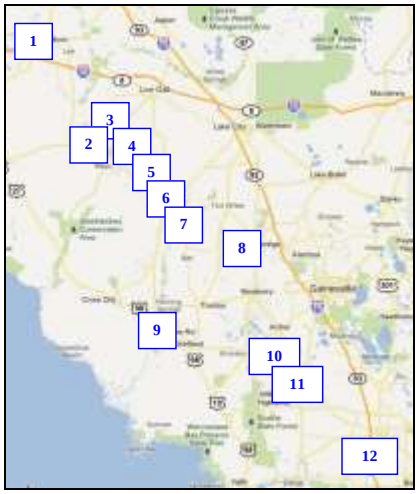



Central to diving safety is diver certification. In a safety-assessment sense, "cavern diving" is the recreational exploration of overhead environments while remaining within sight of the entrances. Cavern divers generally venture no further than 40 meters below the surface and maintain a guideline.

"Cave diving," on the other hand, requires specialized equipment, e.g. a single gas supply feeding separate valves and regulator first stages. Should an O-ring rupture or a regulator begin to free flow, the diver can shut off the offending equipment and exit using the alternate regulator and valve.

An illustration of how particular sites can be restricted according to a diver's capability.

| North Central Florida Dive Sites | Open Water Diving for any certified diver | Cavern Diving for any certified diver | Cavern Diving for certified cavern diver only | Cave Diving for certified cave diver only | Key |
|---|---|---|---|---|---|
| Madison Blue Spring | ● | | ● | ● | 1 |
| Telford Spring, El Dorado | | | | ● | 2 |
| Waterhole III | | | | ● | 3 |
| Peacock I | | | ● | ● | 3 |
| Peacock II | | | | | 3 |
| Peacock III | | | | ● | 3 |
| Olsen Sink | | | | ● | 3 |
| Orange Grove Sink | | | ● | ● | 3 |
| Cow Spring | | | ● | ● | 4 |
| Royal Spring | | | | ● | 5 |
| Troy Spring | | | | ● | 6 |
| Little River Spring | | | ● | ● | 7 |
| Ginnie Spring | ● | ● | | | 8 |
| Devils Eye and Ear | ● | | ● | ● | 8 |
| Manatee Spring | ● | | ● | ● | 9 |
| Catfish Hotel | ● | | ● | ● | 9 |
| Freidman Sink | | | | ● | 9 |
| Devil's Den | ● | ● | | | 10 |
| Blue Grotto | ● | ● | | | 11 |
| Paradise Spring | | ● | | | 12 |




Certification's not inexpensive. Below are the training fees charged by a dive shop in Ginnie Springs.

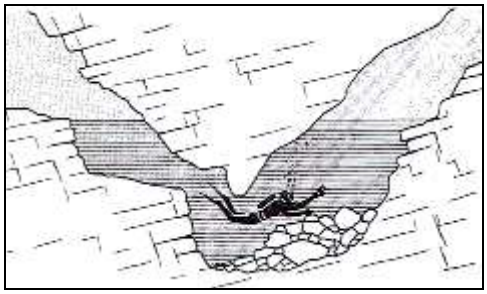
| Course | Days | Fee |
|---|---|---|
| Cavern Diver | 2 | $350 |
| Cave Diver | 2 | $600 |
| Stage Cave Diver Specialty | 2 | $600 |
| Stage + TDI Extended Range | 3 | $600 |
| DPV Cave Diver Specialty | 2 | $600 |
| Extended Range Cave Diver | 7 | $2,100 |

"Using Revealed and Stated Preference Data to Estimate the Scope and Access Benefits Associated with Cave Diving," Resource and Energy Economics (33), 2011, by O. Ashton Morgan and William Huth, estimates the economic impact of a diver at Florida's Blue Springs to be $146

to $167 per trip, translating into a total impact of roughly $575,000 annually. Since the survey, however, the number of divers has doubled, raising the sum to something above $1 million.

**Conclusion**

Our plunge into cave diving has been mostly historical with a few safety warnings. We cited a few books for those wishing to read more, but it requires a visual experience to catch the underwater majesty. The fullest immersion, of course, requires just that, but this chapter's but one of many and we've not the time to properly certify. We wish not to take one of this year's five or six definitively-final cave dives.



# CHAPTER 71
# SUBTERRANEAN SHIPWRECKS

Having earlier devoted Chapter 54 to submarine boating, we should likewise recognize subterranean shipwrecks. We will visit five sites.

**Mammoth Cave, Kentucky**

We spent time at this wonder in Chapter 55, but we'll return to note an incident reported in the January 18, 1904, New York Times,

> *Tourists Near Death in Mammoth Cave -- Boat Carrying Eighteen Passengers Sinks In Echo River -- Coolness of a Guide and a Member of the Party Saves All from Drowning.*
>
> *Eighteen persons who came to this city to attend the convention for the National League of Commission Merchants are telling a story of a remarkable escape from death in the depths of Mammoth Cave. Only the coolness of their guide, John Nelson, and the courage of Charles A. Muehlbronner of Pittsburgh saved them.*
>
> *The party was composed principally of delegates from Chicago and the wives of some of them. Included in it were Mr. and Mrs. Muehlbronner and S.P. Craig of Pittsburgh, H.C. Rogers of Buffalo, and Miss Lucie Patch of Boston.*
>
> *The party started on the regular route through the cave, which included a journey in boats on the Echo River, the largest stream of water in the great underground passage.*
>
> *In going past some of these places the men and women in the boat were compelled to stoop far over in order to keep from striking the roof. It was while they were doing this at one point that the boat got beyond control of the guide for a moment and swerved toward a bank. The heads of the persons on that side were scraped by the roof, and they bent still lower.*

In a later account, one of the passengers was reported to have joked that the cavern roof should perhaps be raised to allow the next party additional headroom and then to have put his back against the roof as if to shove it up. Instead he pushed down the bow of boat and the rest of the story -- as they say -- is history. But back to the Times,

> *One side of the boat dipped into the water in consequence, and the craft began to fill.*
>
> *The guide saw the danger and called to Mr. Muehlbronner to jump and take the chain. This he did, landing on a steep bank, which offered only a slight foothold. Lying down on his face, he held to the chain and pulled the boat toward the bank.*
>
> *The boat sank in eight feet of water, but further back where there was no landing the water is eighteen feet deep.*
>
> *By the light of a single lantern the party escaped by climbing over Mr. Muehlbronner's prostrate form, and after waiting several hours for a boat, were brought in safety to daylight.*

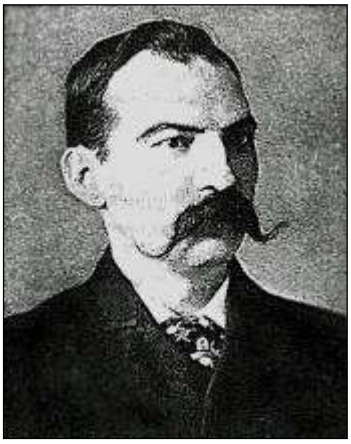
By most accounts, however, it was the guide, John Nelson, who pulled the group to shore while Muehlbronner held the light and announced, "Attention! Do as the guide says, or none of us will get out of here alive."

The account was run in the St. Louis Republic as "Thrilling Experience in Mammoth Cave." The Pittsburgh Gazette proclaimed, "Charles A. Muehlbronner Saves Seventeen Lives in Mammoth Cave."

The unfortunate vessel would have been one of the 20-passenger models introduced in the 1880s.

Returning to the Mammoth Cave Hotel, the grateful passengers formed the Echo River Club, Charles A. Muehlbronner, President for Life.

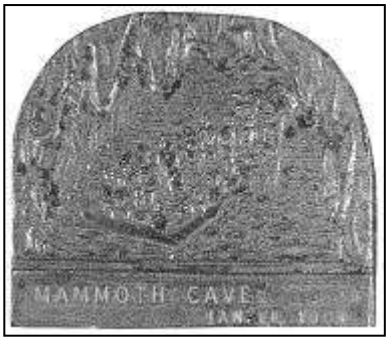
As for Mr. Muehlbronner -- the one who alerted the newspapers -- the honor was but one of many. Not only was he a leading merchant, banker and state senator, Muehlbronner was also a 32nd degree Mason, a noble of the Mystic Shrine, a member of the Independent Order of Odd Fellows, the Knights of Pythias, the Benevolent Protective Order of Elks and a contributing member of the German Lutheran Church.



The Echo River Club held annual reunions for several years. To the right is the silver medal presented to Nelson at the club's first anniversary.

Nelson retired in 1907, having guided 4504 tours.

Horace Hovey, the era's authority on Mammoth Cave, changed the subsequent edition of his guidebook from, "The voyage is replete with pleasure" to "The voyage is usually replete with pleasure."



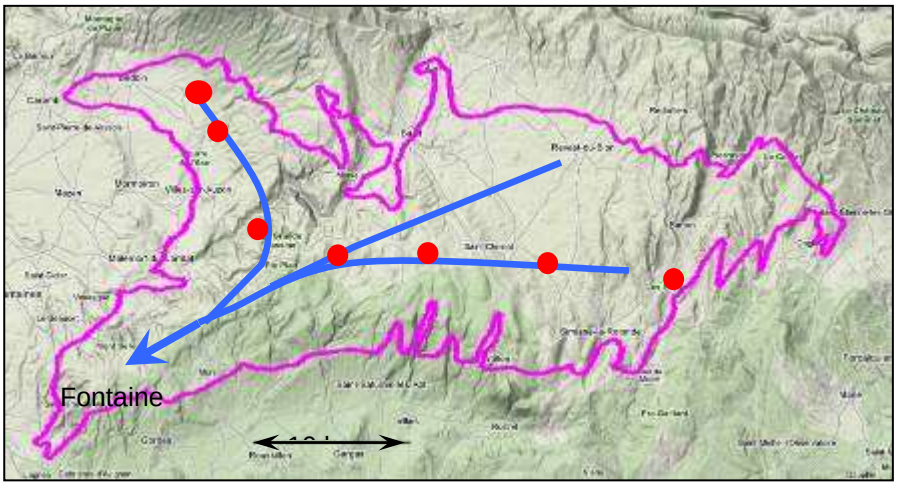

**Fontaine de Vaucluse, France**

The Fontaine de Vaucluse issues from a collapsed cave system in the Côte d'Azuris. The water-filled shaft at the foot of a 240-meter cliff is the source of the River Sorgue.

1870

The spring discharges the entire runoff from 1200-square-kilometers of the Plateau de Vaucluse and the Vaucluse and Lure Mountains.

Red dots mark basin's major sinkholes, four of which exceed 500 meters in depth.

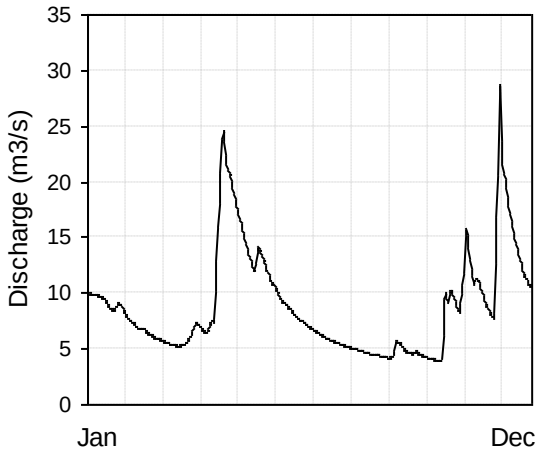



Low water

High Water

The water table, usually below the rim of the shaft, drains to springs in the riverbed, but after heavy rainfall, the water table rises and the fountain spills.

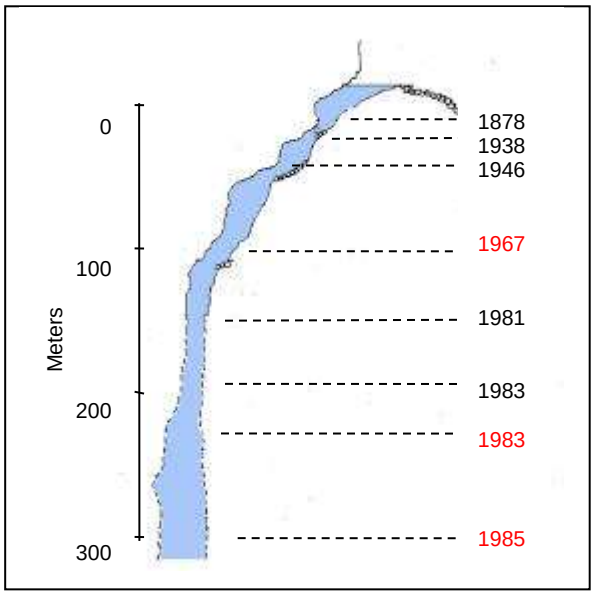
Average discharge is 22 meters/second, the highest in France, and can increase to 200 cubic meters/second after snowmelt and heavy rainfall. Daily flows, 2005, are shown to the right. Springflow derived from porous aquifers varies with season as a dampened and protracted hydrograph. Sharply-ascending spiked hydrographs indicate steep surface streams, or as in this case, lengthy subsurface conduits of large diameter.



The sketch indicates the galleries and approximate inclination of the spring. Sand closes the conduit at 308 meters, but the karst cavity likely continues far under the watershed.

From the sketch's scale we can compute a rough estimate of up-flow velocity. At typical conditions, the water ascends at perhaps a meter/minute. When discharge spikes, velocity increases proportionally.

The chronology of exploration is on the right because the Fontaine's exploration includes some notable events. Robotic endeavors are indicated in red.




Nello Ottonelli explored the upper 23 meters in 1878, dropping a zinc weight another 10 meters. A metal boat yet submerged beneath the surface is believed to have tethered Ottoneli's heavy diving equipment.

Senor Negri thought he'd reached the bottom at 30 meters in 1938, a microphone in his helmet recording his observations.

Negri's claim was found to be erroneous, however, when in 1946, Jacques Cousteau (Chapter 70) and Frederic Dumas used scuba equipment to reach 46 meters. The two nearly died when carbon-monoxide from a diesel air compressor was sucked into the intake used to fill their aqualungs.


Reacting to divers' commercial interests, a 1974 municipal decree prohibited further explorations, but diving resumed in 1981 and Claude Touloumdjian reached 153 meters using a self-contained underwater breathing apparatus. In 1983, Jochen Hasenmayer reached 205 meters.

That same year, the wire-guided miniature submarine Sorgonaute I reached 245 meters, halted by lack of cable.

The following year was less productive, Sorgonaute II imploding at 233 meters.

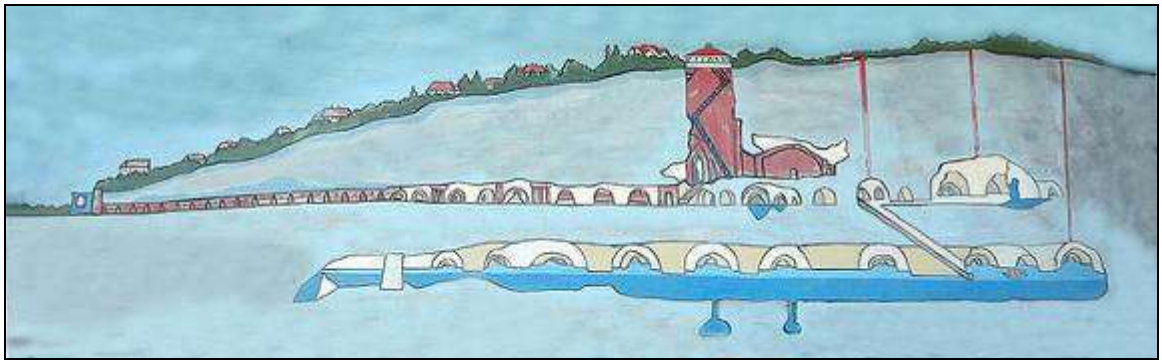
In 1985, a robot belonging to the Spelunking Society of Fontaine de Vaucluse hit sandy bottom at 308 meters.

Attempting to recover Sorgonaute II in 1986, Sorgonaute III was lost as well, leaving 150 meters of cable in the abyss. Two years later, Sorgonaute IV couldn't recover either of its predecessors. There are thus one metal rowboat and two submarines resting in the deep.

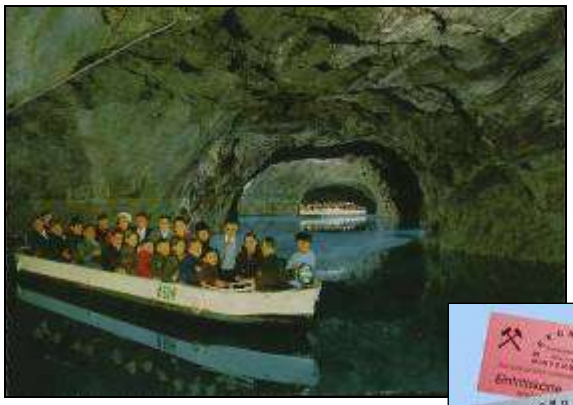
The Spelenaute's since become the sub of choice, but there remains need for a vehicle slim enough to enter the galleries at 135 meters noted by Cousteau.

**Seegrotte, Hinterbruhl, Austria**

Seegrotte's 6,200-square-meter underground lake came to be in 1912 when an accidental dynamite explosion flooded a gypsum mine with 20,000 cubic meters of water.



The Viking-like vessel that sailed under the Bastille in Disney's “The Three Musketeers” (1993) is moored in the tourist attraction of today.



Seegrotte
€9.00

But the grotto's history hasn't always been as Disneyesque.

During World War II, the former mine was dewatered to build military aircraft safe from Allied air raids. The world's first jet aircraft, the Heinkel HE 162, was built there by 1800 slave laborers, most of whom were killed just before the war's end. The Red Army destroyed the factory, but the cave remains.

And as for why we've included Seegrotte in this chapter, the tale's a sad one. In 2004, five tourists, including a German couple celebrating their golden wedding anniversary, drowned there after being trapped under their capsized catamaran-converted-to-trimaran tour boat, just 150 meters from conclusion of the 45-minute excursion.

Falling into the water, some passengers held on to the boat, contributing to its overturn. The helmsman tried to right the boat, but the 1.5 ton craft was too heavy. Trapped beneath the hull for 45 minutes, the victims drowned in the chilly water.

Some 100 firemen, four divers, seven doctors and psychologists as well as a helicopter were rushed to the scene, but rescue efforts were hampered by the narrow width of the cavern.

"They probably didn't have much chance," said a police spokesman.

The starboard pontoon may have leaked and the passenger weight on that side was some 200 kilograms more than on the other. The tour operator and crew were sentenced to prison.

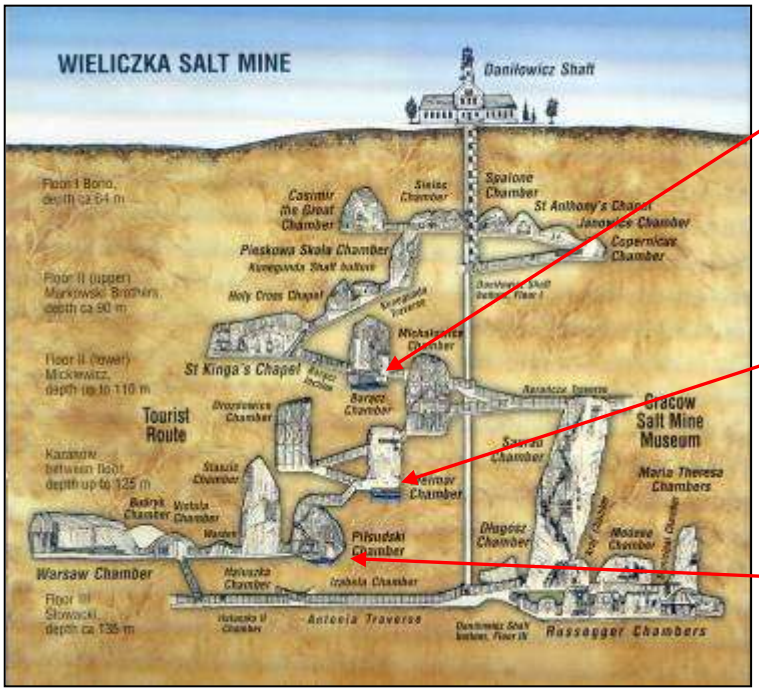
**World Record**
**Subterranean**
**Shipwreck Fatalities**
**5**


Unlike the dragon-headed Viking ship, however, this boat isn't on display.

**Wieliczka Salt Mine, Poland**

The Wieliczka mine produced salt for 700 years until it was fully converted to tourism in 1996. The mine is a UNESCO World Heritage Site because of its salt-crystal carvings of historic figures, mythical creatures and chapels with ornate chandeliers, many crafted by the miners themselves

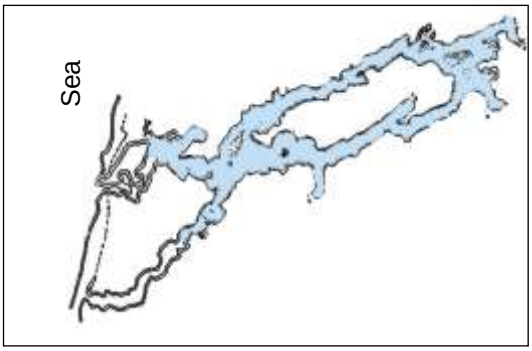
The mine operated tourist boats until 1919 when one capsized. The high concentration of salt water kept the victims -- the reported numbers differ -- afloat, but also prevented them from diving to escape. The pools are now lit with colored lights, but not navigated.




**Diros, Peloponnesia, Greece**

Lest the subject of subterranean shipwrecks quench our enthusiasm for boating in blackness, we'll conclude the topic with a visit to Greece.

There have been no subterranean shipwrecks in Diros Cave, but were there to be such an occurrence, note the safety features.

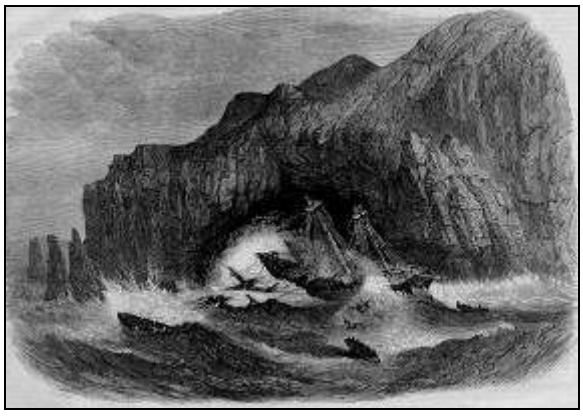




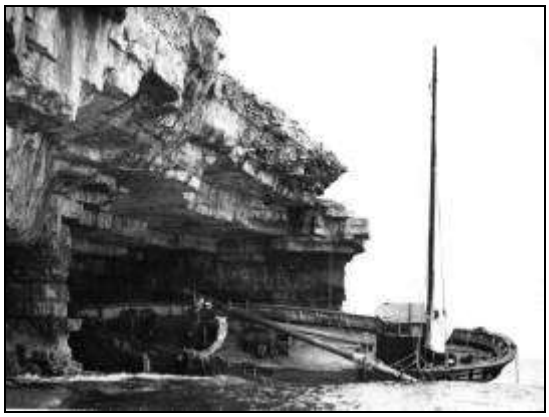
**Sea Cave Disasters**

****

While perhaps an ocean-going vessel wrecked on the shore and shoved by the waves into a sea cave pushes the definition of a subterranean shipwreck, we'll include two by virtue of their illustrations. The General Grant's cargo included 2576 ounces of gold, more of which was said to have been secreted in the ballast.



The General Grant, Aukland, 1866, 48 fatalities



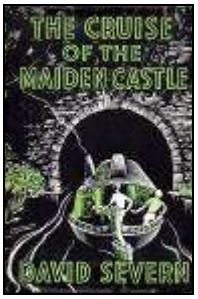
The Reliance, Dorset, 1949, 1 fatality

# CHAPTER 72
# MINEWATERS

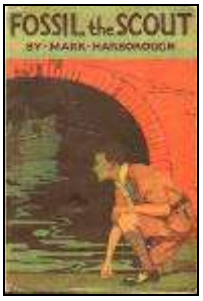
We've traveled through mines in earlier chapters, the more recent being a pair of European mines, Seegrotte, Wieliczka, is search of subterranean shipwrecks. We'll visit more mines in chapters ahead. But here we'll consolidate the bulk of our hard-rock excursions. In at least a few cases, the hard-hat precaution has been relaxed for the tourists whose admission fees keep the mine open.

But before we proceed, let us tip our hats to the authors of British children's literature for their attention to boating into "adits," which as s British schoolchild would know, is a horizontal or nearly horizontal tunnel entrance. A few illustrations,

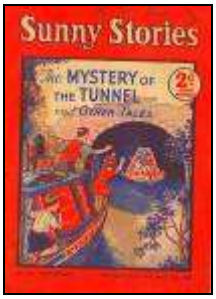
Explorers Afloat (1940) by Garry Hogg




Cruise of the Maiden Castle (1948) by David Severn




Fossil the Scout (1933) by Mark Harborough




"Mystery of the Tunnel," Sunny Stories, May 1954

## Pb Lead Mining

We visited the Speedwell lead mine in Derbyshire as tourists in Chapter 56 and dove into Missouri's Bonne Terre Mine, Chapter 70, but there are many flooded lead mines, world-wide. We'll mention just three, all in England.

Lead mines in Cumberland County, northwestern England, provided the 19th-century scientific establishment opportunity to peer into the depths of the earth. Ale Burn Cavern owned by the London Lead Company was a favorite. From "A Subterranean Adventure," The Family Magazine, 1830,

> *About a mile and a half from the town, on the steeply-sloping side of one of its must barren mountains, called Ale Fell, is a range of what are locally called "Swallow-holes."*
>
> *The cavern gradually widened till they came to a ledge where the water, which had now collected its whole force, had a fall of about five feet. Stepping down this ledge, they stood in a long narrow chamber of very irregular form, supported in the middle by a huge pillar.*
>
> *The stream, as if proud to display itself to the best advantage, spread abroad as it approached the fall into a wide sheet, issuing like a streak of condensed light from the black cavern beyond it; after tumbling down it again contracts into a narrow channel, and, giving the base of the pillar a friendly hint that all things here continue but for a season, it merrily pursues its way. It is indeed a strangely beautiful and romantic place, though there was something of gloom about it -- here the gentle murmurings of the stream were prolonged by gentler echoes into a sweet and plaintive melody, to which the deeper rumblings of the waterfall added a harmonious bass.*

A paper on Ale Burn Cavern, read before the Royal Physical Society, in January, 1830, by Charles Slee.

> *We entered with some difficulty into a small circular opening in the limestone, just large enough to permit our creeping along it on hands and knees. On proceeding a few fathoms in this uncomfortable posture, the noise of rushing waters was heard increasing until it became very loud, and we soon found ourselves near the summit of a spacious vault or natural cavern 23 feet high, 13 feet wide, and 16 feet long. We climbed down the nearly perpendicular side to a stream of water which passes the whole length of the cavern, and at this time containing as much water as Ale Burn. This rivulet seems partly fed by the springs of Ale Burn, and in rains is much increased by the surface water poured into it by means of numerous swallow holes. Having descended, we turned past a projecting screen of rock, and from thence gained access to the continuation of the cavern westward.*
>
> *At length the stream of water entered a very low and narrow passage, into which we waded on our hands and knees until nearly all our lights being lost, we were compelled to return. Chaff put into the water here is said to have come out at the surface at Barhagh about three miles distant.*

In Frost and Fire, Natural Engines, Tool-Marks and Chips, with Sketches Taken at Home and Abroad by a Traveler (1865), John F. Campbell describes a lead mine in Buckinghamshire.

> *In Park Mine, near Wrexham, the course of a subterranean river was cut in looking for lead. It can be got at by scrambling, and it is a curious place. A large cavern is water-marked from top to bottom, and old sand-beaches in passages mark a water-level fifty or sixty feet above the stream... In the bed of the stream are pebbles washed from a distance. A clear murmuring brook can he followed for a great way upstream; downstream it plunges into a hole, and disappears with a roar. It breaks into Minera Mine lower down, and where all the water goes at last no one seems to know or care, so that it is got rid of.*

And bringing us to the present, Moulds Level lead mine, North Yorks. The water would have been pumped out in its days of production and one could have traveled more than 10 kilometers underground.

Few hard-rock mines would merit such masonry, but when the value of the ore is high and the structural integrity of the overburden isn't, the shaft construction accordingly adjusts.

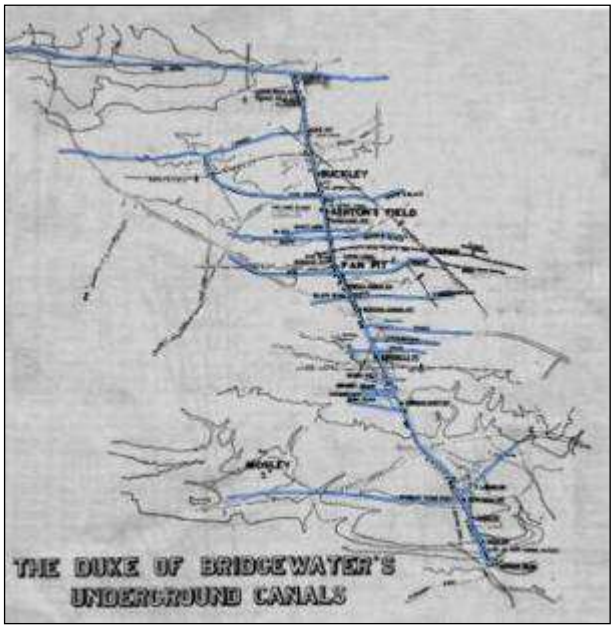
## C Coal Mining

As can be seen in Winter Hill, Lancashire, coal mines tend to offer little in the way of aesthetic formations.

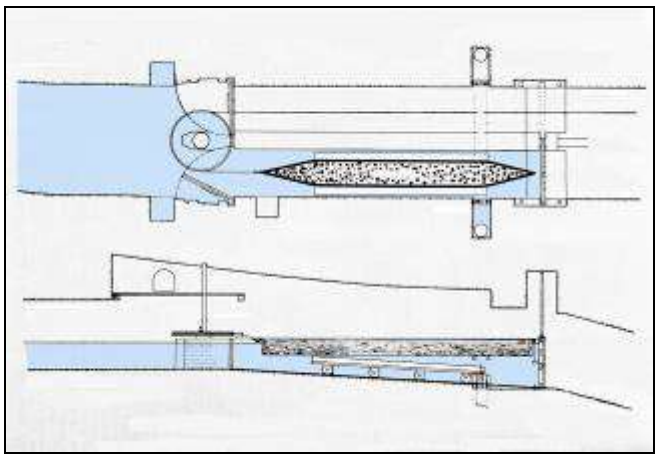
If there's a flooded portion, it tends to be a grimy inundation.

Evidence of coal mining near modern Manchester dates to the 14th century. Until the 18th century, extraction was primarily from shallow open pits, but increasing urban demand required more efficient production and transportation. The Bridgewater Canal from Booth's Bank to Worsley, and then to Manchester was completed in 1765.

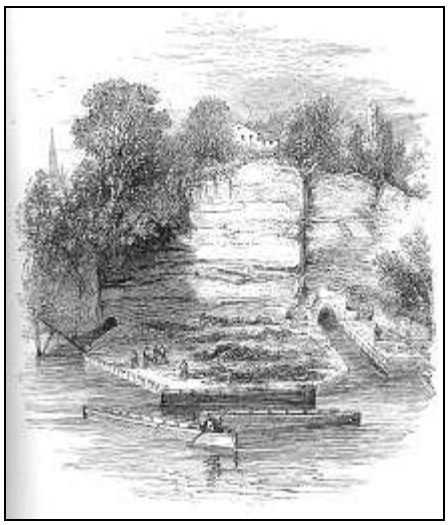
Construction of an underground canal extending along the coal seam at the Worsley Mine began in 1759 and grew to 74 kilometers, serving coal faces on multiple levels.




Miners boated to their place of work where their output was boxed into wooden or iron cases and loaded onto boats known as “starvationers” due to the crafts' pronounced ribs. The coal was boated out of the mines by means of subterranean locks and inclined planes, and then floated onward to Manchester. It was a forerunner of today's container shipping.



A railway line from Worsley to Wigan came to be in 1864 and use of the main-level canal for coal transport ended in 1887.



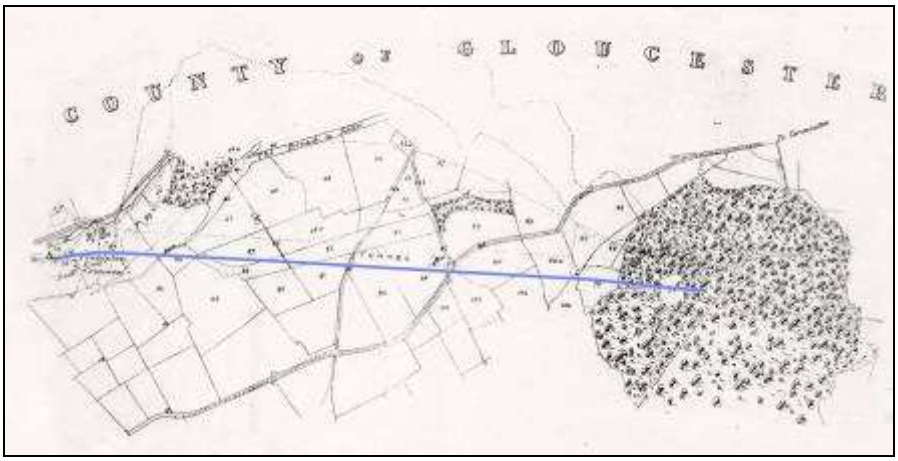
Left, "Worsley Basin and Starvationer Boats," Lives of the Engineers: Brindley and the Early Engineers (1874) by Samuel Smiles. The empty boats returning to the mine.

Above, Disused starvationers following closure of the mines, c. 1890

Today the mine is flooded. The distinctive orange water is due to iron salts leached from the penetrations. Efforts are ongoing to reduce the effluent's tint.

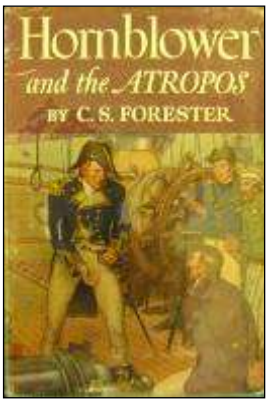
Although the Sapperton Tunnel is Gloucestershire is not a mine work, per se, we include it because it was constructed to transport a mine product, coal. Built at dead level through a limestone mountain in 1789, at 5 kilometers, Sapperton was the longest tunnel in the country.

Below, a halfpenny token issued by the Thames and Severn Canal Co. in 1795 to pay wages to the workmen.




As described by William Bernard Cooke in The Thames (1811),

> *This tunnel was excavated in a direct line of two miles and a quarter though a variety of strata, though consisting chiefly of rock, underneath a hill, and presents a very novel and striking effect to those whose curiosity attracts them to visit it. A boat is kept in constant attendance for the purpose of entrance next to the village of Cotes.*




Set in 1806, C.S. Forester's Hornblower and the Atropos (1953) tells of Horatio Hornblower's canal boat experience after the boatman's assistant is incapacitated. A-third of the first chapter is devoted to the Sapperton tunnel. Lacking a towpath, boats were propelled through the passage by "legging."

A few lines,

> *And not far ahead was Sapperton Tunnel, the engineering marvel of the age, the greatest achievement of the new science. He certainly wanted to see that.*
>
> *The steersman pointed with his hook at the black forbidding tunnel mouth in the castellated entrance.*
>
> *"No tow path through the tunnel, o' course, Captain," he said "So we leaves our horses here an' we legs through. We puts a pair o' swings' on the bows — sort o' catheads, in a way. Charlie*

*lies on one an' I lies on the other, wi' our heads inboard an' our feet agin the tunnel wall. Then we sort o' walks, and we gets the boat along that way, and we picks up another pair o' horses at the south end."*

*It was obvious that it would be far easier to maintain gentle way on the boat than to progress in fits and starts of alternate stopping and moving. Hornblower hurried to the starboard-side wing and laid himself down on it as the bows of the boat crept into the dark tunnel. Lying on his right side, with his head inboard, he felt his feet come into contact with the brick lining of the tunnel. He pressed with his feet, and then by a simple backward walking motion he urged the boat along.*

*A tunnel two miles long, driven through the solid rock of the Cotswolds! No wonder it was the marvel of the age. The Romans with all their aqueducts had achieved nothing to compare with this. Farther and farther into the tunnel they went, into darkness that increased in intensity, until it was frightfully, astonishingly dark, with the eye recording nothing at all, strain as it might. At their entrance into the tunnel the women had chattered and laughed, and had shouted to hear the echoes in the tunnel.*

*So they went on through the darkness, in the strangest sort of mesmeric nightmare, suspended in utter blackness, utterly silent, for their speed was not sufficient to raise a ripple round the Queen Charlotte's bows. Hornblower went on thrusting with his feet, urging his aching legs into further efforts; he could tell by the sensations conveyed through the soles of his shoes that the tunnel was no longer brick-lined -- his feet pressed against naked rock, rough and irregular as the tunnellers' picks and gunpowder had left it.*

*An underground spring here broke through the roof of the tunnel and tumbled roaring into the canal. The water fell down on them in deafening cataracts. It thundered upon the roofs of the cabins, quite drowning the cries of the women within. The weight of its impact pressed the tarpaulin upon him. Then the torrent eased, fell away to trickles, and then they were past it.*

*His eyes were by now accustomed to the darkness, and in that massive darkness, incredibly far away, there was something to be seen, a minute something, the size apparently of a grain of sand. It was the farther mouth of the tunnel. He worked away with his legs with renewed vitality. The tunnel opening grew in size, from a grain of sand to a pea; it assumed the crescentic shape to be expected of it; it grew larger still, and with its growth the light increased in the tunnel by infinitesimal gradations, until Hornblower could see the dark surface of the water, the irregularities of the tunnel roof.*

*It seemed unbelievable to Hornblower that he did not have to work his legs any more, that he was emerging into daylight, that no more underground springs would cascade upon him as he lay suffocating under a tarpaulin. The boat slowly slid out of the tunnel's mouth, and despite its slow progress, and despite the fact that outside the sun shone with only wintry brilliance, he was quite blinded for a while.*

Sapperton Tunnel was abandoned in 1927 and the water levels today fluctuate with the ground water. The clay canal bed is prone to rupture with ground water rise; the resultant holes release water when the ground water falls. Springs in the tunnel have been vented to outlets above the canal level, but even so, the pressure has been sufficient to lift and break the concrete lining. About 300 meters remain navigable.

But let us move on from England.

An unfortunate coal-mining event in Mexico, "Thirty-Five Miners Drowned," New York Times, January 3, 1898,

*A dispatch from Guannajuta, Mexico, says that the San Puerta coal mine near there was flooded suddenly with water from an underground river, and thirty-five miners were drowned. The men were at work in one of the lower levels of the mine. There were no suspicions that an underground river existed anywhere in the vicinity of the mine, although that portion of the mine was exceedingly damp.*

*The rush of water came without warning. There was a sharp crack like an explosion, the wall of coal and slate gave way, and before the men could seek safety on an upper level the rush of water followed, and the men were swallowed up almost before they could drop their tools. An expedition will be send into the mine as soon as possible to recover the bodies.*

One can be less morbid regarding coal mines and water, of course. Take, for example, "Five Men Trapped in 1935 Mining Disaster Emerge after 64 Years -- ALIVE & WELL!" Weekly World News, October 26, 1999.

*Harrisburg Pa. -- The never-say-die heroes, who survived for decades by fishing from an underground lake, used primitive mining implements to tunnel their way out of a seemingly hopeless predicament.*

*"It's truly a miracle," declared a physician who examined the hardy miners. "How these gentlemen survived more than 60 years underground is something we may never completely understand."*

As the astonished physician declared, truly a miracle!

## Fe Iron Mining

The gates at the Magpie Sough iron mine in Derbyshire were used to increase the water level to float ore boats.

## Au and Ag Gold and Silver Mining

Gold is precious enough that we'll give it a full chapter, Chapter 92, Underground Rivers of Gold. We'll include an Alaskan gold mine in this chapter, however, by virtue of its location in permafrost. From "Klondike Miners Tap a Swift Subterranean Stream," San Francisco Call, November 26, 1902,

*Miners of Bonanza spent yesterday afternoon trying to save their buildings and shafts and the rich gold dumps from the most furious winter flood that has ever occurred in the Klondike. From a distance of more than 210 feet up through the rock and frozen clay of El Dorado Creek a gush of water is coming that is causing more excitement and threatens more damage than any similar phenomenon ever witnessed in the north.*

*Yesterday at noon the men were down 210 feet. At that depth the ground was still frozen with ice that could be measured only by the lapse of centuries, and thawing machines and powder in plenty had to be used, the same as above ground.*

*Yesterday the miners left for dinner and the steam thawers were hard at work. When the men returned they found water at the bottom, and the men who first descended had to return to the surface immediately to escape drowning. In six hours the shaft was filled to the brim. Then the overflow began to run down the hill. The torrent ran through part of the town of Bonanza, causing some damage by undermining small buildings and making a new stream to the main river.*

We've also an example from a silver mine that is unique. Case Western Reserve University's Large Underground Xenon dark-matter experiment is housed in the abandoned Homestake gold mine in Lead, South Dakota, the same cavern where the work of physicist Ray Davis gave rise to the solar neutrino problem in the 1950s. The photo shows Davis taking a dip in the pool surrounding his neutrino detector, 375 cubic meters of chlorine solution, 1.5 kilometers below the surface.

The medallion is Homestake silver.

Part of former silver mine in Tarnowskie Góry, Poland, the 600-meter Black Trout Adit was bored in 1821-1835 and still empties to the river.

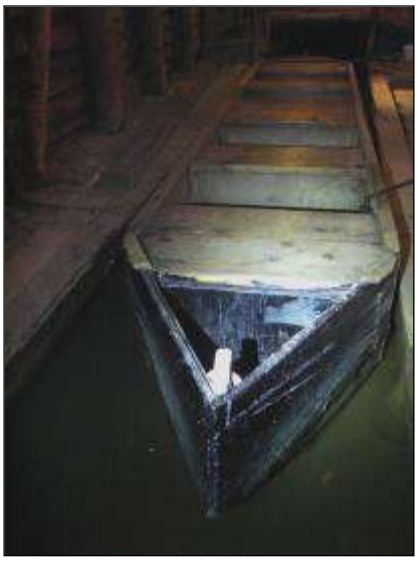
To today's tourists 25 meters under the earth, the trout passing under their boats seem black because of the darkness, and thus the adit's name.

Black Trout Adit
27.00 PLN

Mining of copper, lead and silver began around Lautenthal, Germany in about 1225 and the number of mines reached 28 by 1690.

With the closure of the mines in 1959, the Glück Silver Mine was transformed into a museum in 1975.

The tourist boats are patterned from the original ore boats, but for the added benches.



## Cu Copper Mining

The area of Anglesey, Wales has been mined from the Bronze Age. Minerals in the copper mine pool to the right give it its red tint.

## $CaCO_3$ Limestone Quarrying

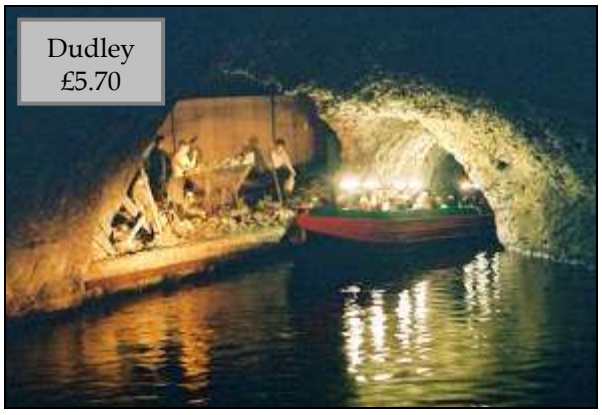
The Dudley Canal and Tunnel in the West Midlands was begun in 1775 to transport limestone extracted from the surrounding hills. At 2.9 kilometers, the tunnel remains the second longest in the UK canal network.

"A Canal Tunnel near Leeds" by English Romantic Painter, Joseph Mallord William Turner (1775-1851)

Restored in 1973, the canal forms part of the popular Stourport Ring narrowboat cruising route. A battery-powered vessel hauls tourists through the tunnel and adjacent mines.

1917 mine boat

Legging



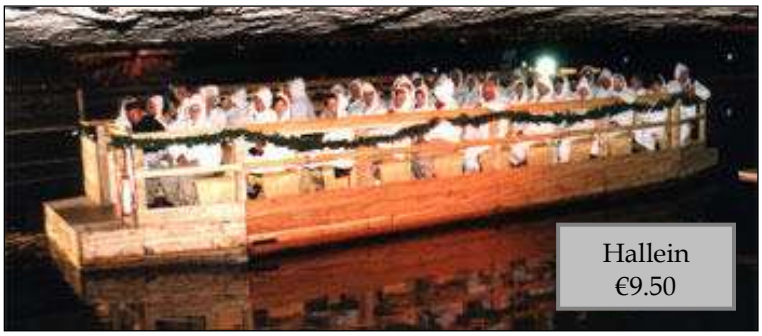
# NaCl Salt Mining

"Pinch of Salt," Putnam's Monthly Magazine of American Literature, Science and Art, December 1868, describes salt mining in Eastern Europe.

> *Gradually the passages become lower; the ceiling sinks more and more on the left, and at last the traveler is forced to bend, until he fairly creeps along on all fours. But suddenly he sees before him a fairy scene: dark waters, sparkling bright in the light of torches fastened to the glistening walls. Like a vast black mirror, the subterranean lake, silent and motionless, stretches far into the endless darkness. Never has wing of bird clipped its feathers into the mysterious water. Never has a breath of air ruffled its placid, patient surface.*

Salzburg means "salt town," and for that reason has been a trading hub along today's German-Austrian border. Several of the mines are open to tourists.

Hallein Salt Mine, a.k.a. Salzbergwerk Dürrnberg, was worked by the Celts 2500 years ago. Today's 90-minute tour includes a boat ride.




Berchtesgaden salt mine has been in operation since 1517. The lake within the mine is 100 meters long and 40 meters wide.

Berchtesgaden, 1875

Nova Scotia's Malagash salt mine was opened after brine was discovered in a water well and mined until 1956. The photo is from 1944.

The Salina Turda salt mine in Transylvania is mentioned in records of 1075. The mine was closed in 1932, but since 1992 has been a halotherapy center and tourist attraction.

Rock salt was discovered near Hutchinson, Kansas in 1887. By the turn of the century, the landscape was perforated by short-used and unplugged brine wells and the subterrain was riddled with unrecorded solutioned-out cavities.

Resultant sinkholes were noted by the Morton Salt Company in 1914, the Carey Salt Company in 1925 and the Barton Salt Company in 1952, but it wasn't for another 22 years that the geotechnical consequence of unfettered brine mining was fully realized.

In the morning October 21, 1974, the land surface subsided under the Cargill salt plant rail tracks near Hutchinson. By noon the tacks were suspended over a crater having a diameter of 70 meters. Two days later, the crater's diameter was nearly 95 meters, its walls nearly vertical. The water within was 11 meters deep, its surface, 7 meters below the surrounding land. The crater's volume was 75,000 cubic meters.

October 21, 1974 November 12, 1974

Note that the tree to the left of the sinkhole in the October photograph is within the sinkhole three weeks later. The railroad tracks have been relocated.

Cargill officials expressed surprise, but not the railroad maintenance personnel who'd had to frequently re-align a switch over the site and had raised the sagging track at intervals over several years. As will be noted in Chapter 80, encrusted lakes beneath the tracks isn't a new topic to railroaders.

Cargill produced salt by continuous water injection and brine extraction through an annular tubing in the same well casing, or from a nearby well when cavities coalesced to form a gallery. The fresh water was from three wells in alluvial sands and gravels. Total discharge was roughly 1 cubic meter/minute, not a high rate, but minute-by-minute, day-by-day, decade-by-decade, sufficient to dissolve hundreds of thousands of cubic meters of crystalline salt.

The 1974 sinkhole was due to the formation of a cavity configuration which exceeded the span capability of the overlying strata. The failure progressed upward by sequential collapse until the topmost rock ledge was breached, cascading tens of thousands of cubic meters of Kansas soil down the opening.

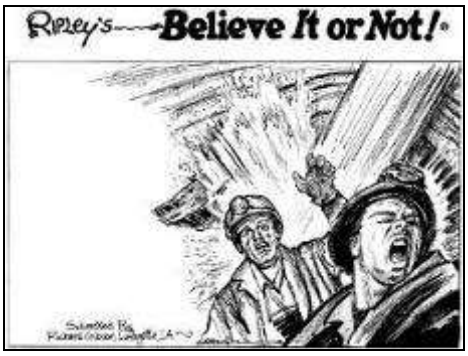
The Northwich, Cheshire subterrain has been exploited for its salt since Roman times. When in the 19th century it became uneconomical to mine the salt, hot water was pumped through 15 hectares of abandoned shafts 100 meters below to dissolve the saline strata. The brine was pumped out and the salt extracted. This technique weakened the mine columns, however, and led to land subsidence as they failed. A surface major collapse occurred in 1880 when the River Weaver flowed into a subsidence pit.

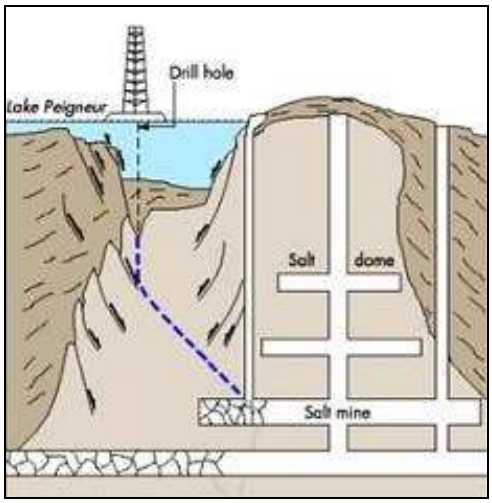

Texaco was exploring for petroleum beneath the floor of Lake Peigneur on November 20, 1980, while the Diamond Crystal Salt Company was excavating a cavity 400 meters beneath.

When the oil company's 36-centimeter drill bit punctured the mine cavern, the 50-meter rig dropped beneath the surface of a lake only 3 meters deep. As the aperture widened, the vortex pulled with it 11 barges, a tugboat and 26 hectares of forest. The drain became the state's tallest waterfall, 50 meters.

Flow in the lake's 20-kilometer canal to the Gulf reversed direction, a unique moment in history during which the Gulf of Mexico flowed north.

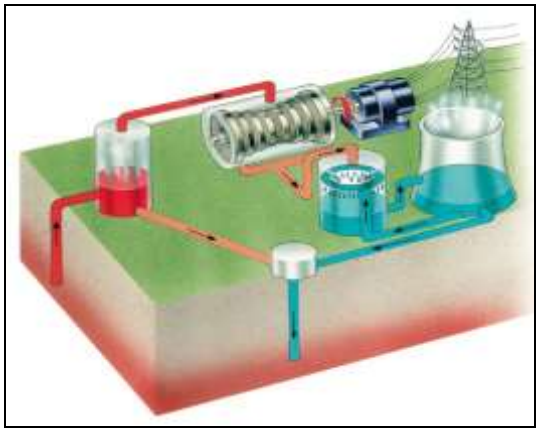
The downward flow displaced subterranean air that blasted out of the ground as a geyser 50 meters in height. Nine of the barges later popped out of the whirlpool.



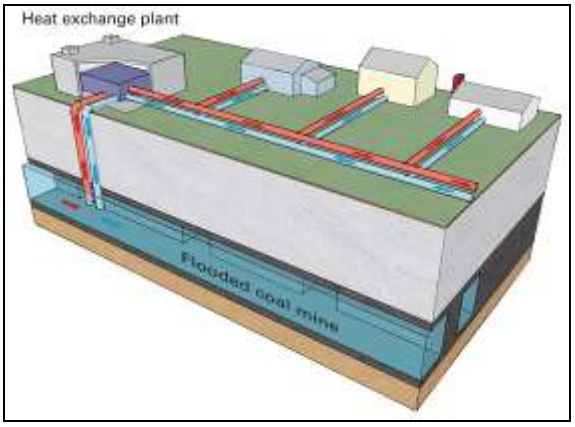




*Oil drillers accidentally punched into a salt mine beneath Lake Peigneur, Louisiana in November 1980 and the resulting whirlpool sucked in a dozen boats and part of an island!* -- May 28, 2006

**Geothermal Energy**



Geothermal water was discussed in Chapter 48, Subterranean Geophysics. While such energy can indeed be drawn from beneath the earth's surface, it's the temperature gradient, not the water, per se, that produces the power.




Above, a scheme for using the water from a flooded Ohio coal mine to heat and cool buildings on the surface by means of a heat pump. Heat extracted from the minewater is used to heat buildings in the winter and the cycle is reversed during warmer periods.

**Morbidity**

Mining is a dangerous occupation, but to what degree is water the agent of death? First we'll look at a few morbid examples where it is and then we'll look at the broader statistics.

During an unusually-heavy 75-minute thunderstorm at Cornwall's East Wheal Rose lead mine in 1846, water was rushing down the hills within five minutes. Despite efforts to divert the flood from the shafts, the mine was rapidly flooded to the 100-meter level and of the 200 miners underground, 39 drowned.

"Subterranean Stream Trapped 350 Miners. One Report Says All Have Perished -- Nine Bodies Recovered," Geneva [New York] Daily Times, March 3, 1914,

> *Brussels. Three hundred and fifty coal miners were trapped today by a rush of waters to a mine in the province of Hainaut, when a subterranean stream burst through the walls of one of the chambers. Within a few hours the bodies of nine men had been recovered. The danger alarm was sounded as soon as the inflow of water began. Many miners were able to reach the surface, but many were cut off and their fate is unknown.*

The Wangjialing coal mine in China's Shanxi province was flooded on March 28, 2010 when workers broke into an abandoned water-filled shaft. Over 100 miners managed to escape, but 153 were trapped in nine different platforms.

Twenty-two the 26 miners were rescued from the Qitaihe coal mine in Heilongjiang province on August 30, 2011, seven days after being trapped when 40,000 cubic meters of water gushed into the pit.

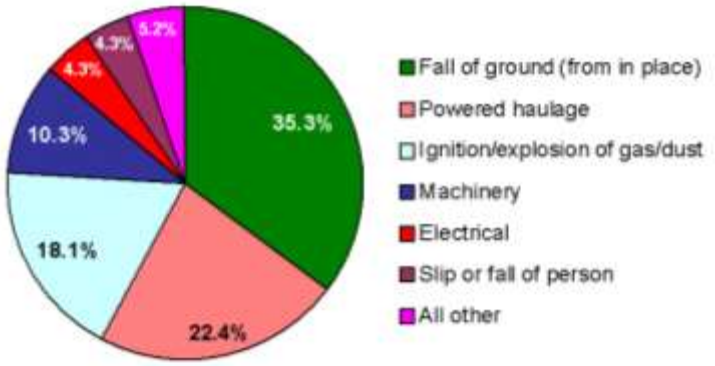

Graphic from CCTV

Note the last sentence in the June 24, 2002 Associated Press dispatch.

> *Accidents in China's mines have killed 3,393 people this year, the official Xinhua News Agency reported Monday. The figure puts the notoriously deadly industry on track to match or exceed last year's toll of 5,670 deaths despite repeated attempts to boost safety and close hazardous mines. Most mining deaths are caused by explosions of gas pockets and floods caused by the breaching of underground rivers.*

But such deaths are much rarer in the United States, as evidenced by chart of deaths in underground mining fatalities, 2003-2007, of which there were 116.

Drowning may comprise some portion of one or two of the lesser categories, but the number is small.



A 1997 Mine Safety and Health Administration alert sheds additional light on the subject. Of the 23 drowning deaths at mining (including dredging) sites in the United States, 1990-1997,

12 were due by mining equipment falling into water.
10 were due to individuals falling into water.
1 was while swimming from the shore.
12 were at a quarry or strip-mining operation.
10 were at dredging operations.
1 was at a mill.
0 were underground

Minewaters have historically been the cause of massive tragedy and the danger is only now -- we can hope -- being mitigated in many parts of the world. Minewaters in the United States, however, have become less lethal.

# CHAPTER 73
# TUNNELS DU CANAL

In the previous chapter we toured British canal tunnels once associated with mining. Now we will cross the Channel to France and its 40-plus canal tunnels constructed for commodity transport, the aggregate length of which was nearly 30 kilometers by the mid-1800s. We'll visit the underground waterways exceeding 1000 meters in length, and then a few of the shorter ones.

Canal Tunnel Locations

- Tronquoy, Riqueval
- Ruyalcourt, Panneterie
- Saint Aignan
- Braye
- Billy le Grand
- Liverdon
- Foug
- Saint Martin
- Mauvages
- Arzviller
- Chérimont
- Saint Albin
- Pouilly
- Besancon
- Balesmes
- Saint Léonard
- Rove
- Malpas


**Rove Tunnel, Marseilles-Rhône Canal**

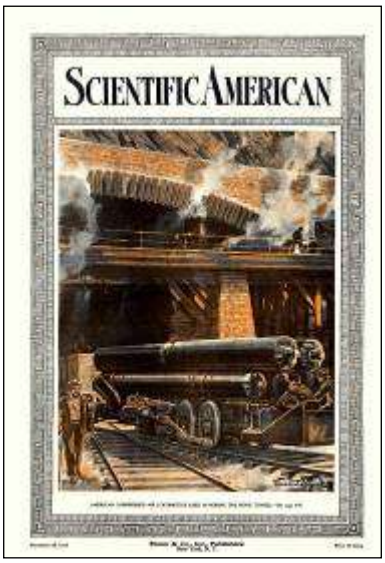
Length: 7,120 meters. Width: 22-meters, sufficient to cross two 1500-ton barges. Height: 15 meters, 4 of which are below the water line.

**World Record**
**Longest Navigable Canal Tunnel**
**7,120 meters**

The idea of a canal connecting Marseilles to the Rhone was advanced from the 17th century, but it wasn't until 1911 that work began on the Rove, linking Marseilles Harbor to Berre Lake, a salt water body. The project employed 3000 workers, mostly Spanish and Italian immigrants and German prisoners of war. As two 70-ton American steam shovels did not prove satisfactory, much of the excavation was by jackhammer and blasting.

To the right, "American compressed air locomotive used in boring the Rove Tunnel," Scientific American, November 25, 1916.

At the time of construction, Rove was the world's largest tunnel, in terms of excavation. The project was said to be one of the greatest pieces of engineering since the Panama Canal.




**Former World Record**
**Greatest Tunnel Excavation**
**2,500,000 cubic meters**

The tunnel was opened to barge traffic in 1926.

Above, photos from 1913. Note the cofferdam at the tunnel mouth and the multi-arched structure along the cliff above. We'll return to it later. The second photo documents an official visit.

1916

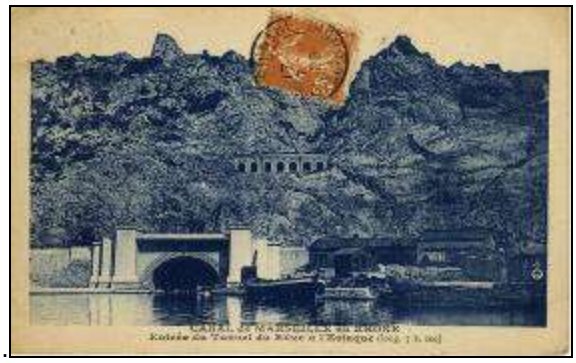
1920. The tunnel opened seven years later.

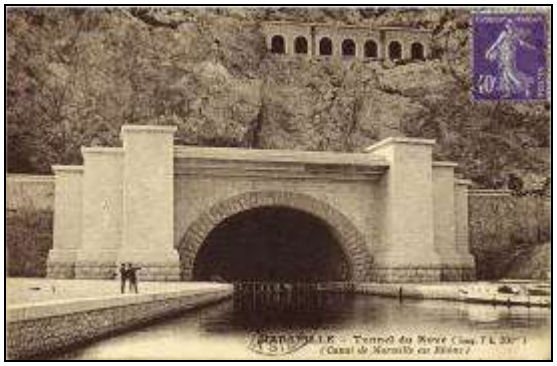
1933

Today

Chapter 55 included decades of fairly-similar postcards showing Mammoth Cave's Echo River, far more photographs than needed to simply illustrate the physical water. The many postcards illustrate how the idea of an underground river continues to intrigue.

Attention to the Rove was similar, as illustrated by postcards of the entrance from the Marseilles marina,



In 1963, 200 meters of roof collapsed at roughly the tunnel's midpoint, leaving a 15-meter crater on the land surface. The Rove has since been closed to all traffic.

Today's traffic-free interior.

There is effort to bring the tunnel back to life as water supply for the eutrophic Berre Lake. A bypass pipe through the blockage is scheduled to be constructed in 2013.

The multi-arched structure above the Rove entrance is a portion of the Roquefavour Aqueduct, a structure more known for its 393-meter span a few kilometers to the north. There's something else notable at that site, a 200-meter canal tunnel feeding the aqueduct, a subterranean waterway becoming aerial.

Looking upstream from the aqueduct

Looking downstream

**Riqueval Tunnel, Canal de Saint-Quentin**

Length: 5,670 meters. Width: 6.6 meters after one of the towpaths was removed in 1861.

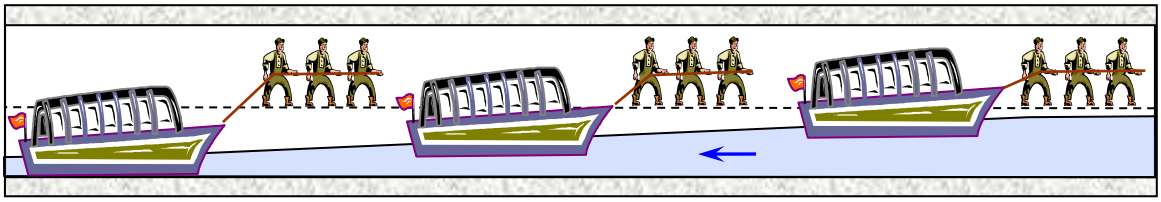
Acclaimed as the "Grand Souterrain," the Riqueval was inaugurated by Napoleon in 1810

In his Through France and Belgium by River and Canal in the Steam Yacht "Ytene" (1876), William Moens recounts a tale from that time.

> *When the tunnel was first made, nothing would induce the men working the barges to use it, so great was their dread of it; but a reward offered by the administration, to free the first barge that went through it from tolls forever, soon brought forward a volunteer, whose barge is still in use, and in a good state, though it has been so repaired from time to time that probably little of the old vessel remains.*

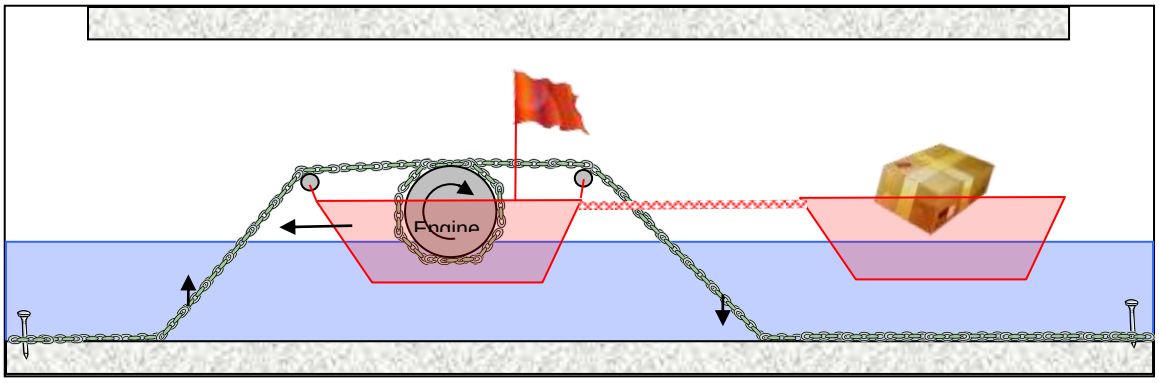
Barges were initially hauled by 7 or 8 men from towpaths on either side of the channel, a 12 to 20-hour endeavor. The Annual Report of the Chief of Engineers to the Secretary of War (1876) contains a translation of Annales des Ponts et Chausseés (1863) by M. Lermoyez regarding a hydraulic difficulty.

> *The nature of the work obligates boats to navigate in fleets or convoys, because they cannot pass each other, not only in the tunnels, but also in the narrow portions of the trunk between them. Consequently when a fleet entered the tunnel it formed a long piston and drove the water before it, as the flow along the sides was insufficient, since a space of only 8 inches was left between the sides of the boats and of the walls of the tow-paths. The wave thus driven forward by the fleet, spread in the level, and advanced rapidly until it met an obstacle which compelled it to retrace its steps; it then came back, re-entered the tunnel, where it caused a current opposed to the course of the fleet, stopped the boats, and created a resistance that the haulers were unable to overcome. The latter, when the wave came, instead of exhausting themselves in useless efforts to overcome it, contented themselves with preventing their boats from going backwards, and only resumed their march after an equilibrium had been established.*
>
> *This movement of the waters caused an appreciable lowering of the water surface at the end of the fleet, and formed a veritable incline which the boats were compelled to ascend. The difference in level, which was nearly half an inch per boat, became so great for long fleets that the last boat of the convoy had not sufficient water to float it, and became stranded on the bottom of the canal.*



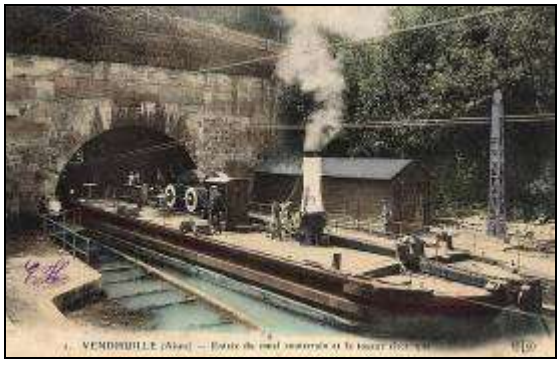
Horses were later used, but time of transit was in fact increased due to the additional resistance on ever larger barges.

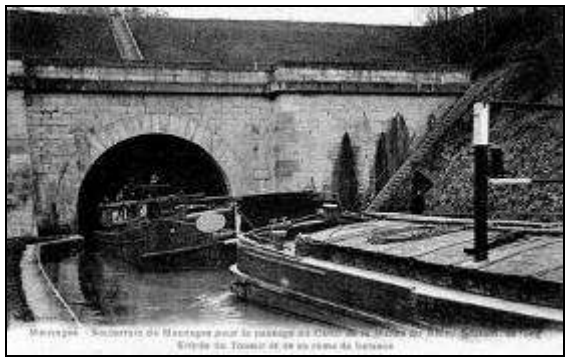
Enter the chain tugboat ("toueur"), a vessel that hauls itself along a heavy chain pinned at each end of the channel floor and integral to the boat in both directions. Adhesion is obtained by several windings on a capstan located at the vessel's midpoint. As the craft cannot turn around, the bow and stern are identical.



The canal's first chain tugboat, Le Rougaillou, was powered by eight horses plodding carousel-style on the deck to rotate the capstan.

Steam-powered chain tugboats introduced in 1867 allowed up to 35 vessels to progress at 1.1 kilometers/hour. Passengers were subjected to heavy smoke. As the boat train impeded canal outflow, the water level rose within in the tunnel by 25 to 45 centimeters and it took up to an hour to drain this impoundment.





Moens recalls his steam-era experience.

> *Three miles ahead was the long tunnel of Riqueval, which the men in the barges expected to be six hours in going through.*
>
> *Night had now come on; it was pitch dark and raining hard, and were we to remain where we were* [in the queue]*, we might, too, have to pass six hours in the bowels of the earth, with the atmosphere in a charming state, from the smoke of the tug steamer, to say nothing of the thirty*

*odd fires of the barges moving slowly behind it. I quickly made up my mind to pass them all, and became the leading vessel instead of the hindmost... We gradually passed them all, and reached the entrance, mooring the Ytene just ahead of them all...*

*Suddenly, at about nine o'clock, we heard a great outcry in the tunnel, and men came running along the towing path, asking if we had a pump. We said yes, several, but not movable; and they explained that one of the barges had struck violently against a stone in the side of the tunnel and had been stove in, and there was a great fear lest she should sink in the tunnel itself with the 270 tons of coal with which she was laden. This was a pretty state of things, and we soon thought that our route to Belgium would be barred for weeks and that we might have to retrace our way back again. The tug steamer soon, however, emerged from the arch, and came to a standstill where three or four barges were out of the tunnel. It was the first that was injured, and she was already sunk to within three or four inches of the gunwale.*

*Long planks were soon put out to the shore and a crowd of excited Frenchmen assembled, each with a large galvanized pump borrowed from the barges behind us. They were all soon at work pumping... It was a curious and exciting sight, all those collected together having large lanterns with them; loud and hurried orders being heard from those in charge...*

*I ordered my men to go on board and assist at the work, and at last, after great exertions, it was found that the vessel did not sink deeper in the canal, and after some time the pumps, increased in number, began to gain on the water, and the hole was discovered in her starboard bow. There had formerly been a towing path on each side of the tunnel, but it had been found that the water space was not wide enough, that on the left hand was cut away, but leaving rough stones and projections against one of the unfortunate vessels had struck, being towed at too rapid a pace by the tug. Some planks and nails were obtained and I contributed some cotton waste, and after some work the leak was stopped.*

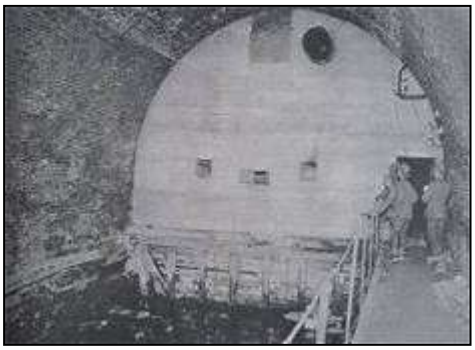
*It was half-past twelve o'clock before we turned in, the occurrence that had just happened not tending to cheer us, or to make more pleasant the prospect of going through the tunnel, which was nearly four miles long, and the sides of which were not as smooth as one could wish.*

By 1878, up to 110 barges were traversing the Riqueval on a daily basis.

Six-hundred-volt DC chain tugboats, 25 meters bow to stern, 5 meters wide and 1.7 meters high, 90-ton displacement, were introduced in 1906.

During the First World War, the Riqueval "Schiffstunnel" (canal tunnel) served as a German Hindenburg Line bunker fortified at both ends and occupied by 34 barges serving as barracks.

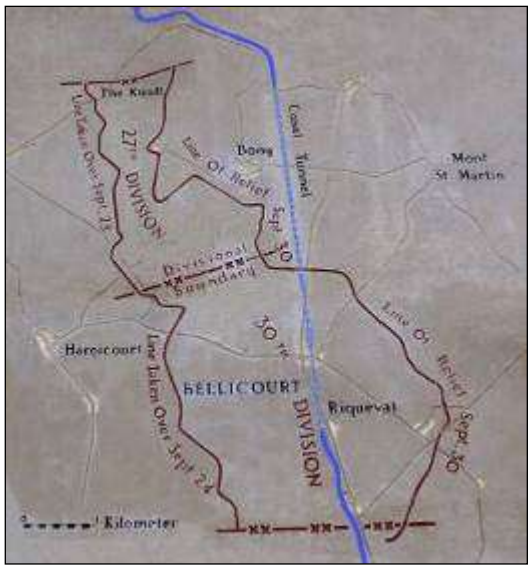
A network of tunnels led to two lines of trenches. The defenses incorporated the steep banks of the canal.



German defenses

By late September of 1918, the British were approaching and the attached US 2nd Corps was assigned the attack.

On September 29, the American captured the tunnel entrance, inside the molehill fortress finding a field kitchen littered with German bodies, one of them in a cooking cauldron. That the enemy was boiling down its dead was exploited by the Allies' propaganda machine, but subsequent investigation proved that an exploding shell in the improvised kitchen killed the unfortunate cooks and threw one into the pot.



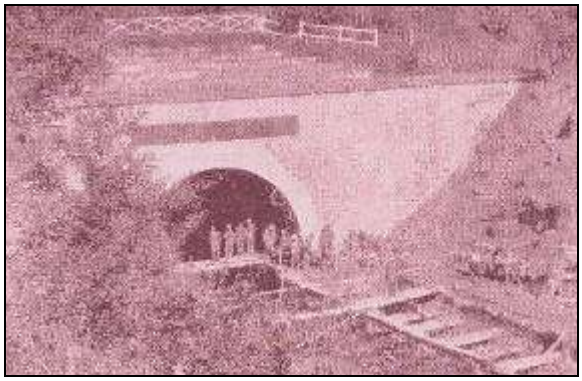

A newspaper account, "Huns Lay in Ambush for the Yanks. Germans Waited in Canal Tunnel for American Onrush. Fight under Mountain Lasted from Yesterday Evening until Early this Morning -- No Huns Left," Lawrence Journal-World, October 1, 1918,

> *The St. Quentin canal tunnel runs for more than five kilometers under the mountain. The canal was held by a large number of Germans who were aboard electrically lighted barges. There are wide towpaths and galleries leading from each side of the canal and in them the entire garrison had quarters.*
>
> *This section probably is one for the strongest parts of the entire Hindenburg system and the Americans have found it to ne literally lined with tunnels, dugouts and galleries which require a great deal of mopping up. Large numbers of Germans have been killed, but they were silenced they worked their machine guns with the greatest vigor.*
>
> *When the Americans swept past the southern end of the tunnel, the Germans remained hiding until the Americans got past and then they surged up and plunged into the fight. They were engaged first by the Americans and then by the Australians. The tunnel mouth was choked with dead.*

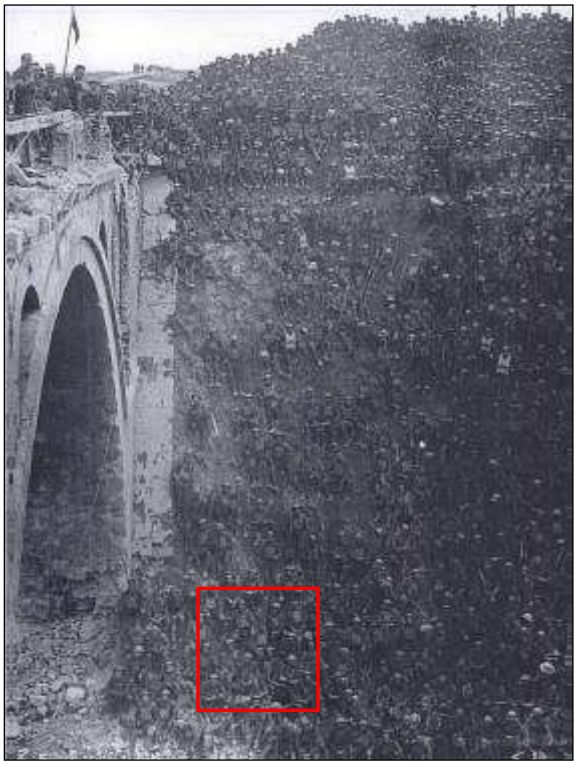
From the official history of the American 30th Division, "Old Hickory,"

> *The large tunnel, through which the canal ran, was of sufficient capacity to shelter a division. This tunnel was electrically lighted and filled with barges. Connecting it with the Hindenburg trench system were numerous tunnels. In one case a direct tunnel ran from the main tunnel to the basement of a large stone building, which the enemy used for headquarters. Other tunnels ran from the main tunnel eastward to the City of Bellicourt and other places. This complete subterranean system with its hidden exits and entrances, unknown to us, formed a most complete and safe subterranean method of communication and reinforcement for the German sector.*

While the canal locks were entirely destroyed and many dikes breached, the vault -- except apparently the kitchen -- was little damaged.

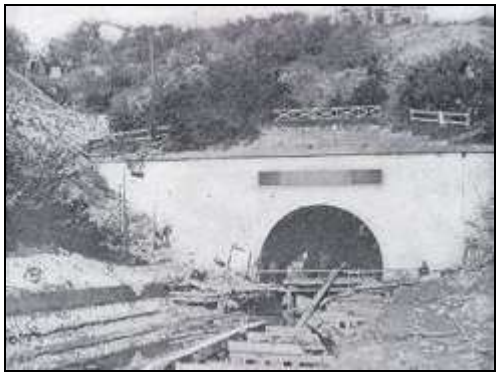


American forces



*Went up to Bellicourt this afternoon to see the famous canal tunnel. Found the entrance about half a mile from the town. Got a candle and went into the tunnel. It is a dark, evil-smelling place. The canal in the tunnel is full of barges, which have been used as billets by the Huns, but how they could bear to live in such a place I don't know. Went along for about half a mile in the tunnel, but was glad to get out and leave it. --* The World War I Diary of Percy Smythe, Monday, 7, 1918

British troops at Riqueval Bridge



"Bellicourt Entrance, St Quentin Tunnel," 1918 watercolor by Australian painter Arthur Streeton, commissioned to record the involvement of his countrymen in the battles taking place along the Somme River.

A 1924 chain tugboat today hauls mostly pleasure boats. This underground river train ("rame"), averaging 30 craft, departs at 07:10 and 15:10 in the northern direction and at 09:30 and 17:30 to the south.


Power is obtained via contact with a copper wheel to venerable overhead lines visible in the photos above. At each point of suspension, a crew member guides the wheel over the high point of the overhead line with copious of sparking. Moving 3 kilometers/hour, the voyage takes 2 hours with each boat's crew vigilant to prevent their hull from scraping the tunnel wall.

"Canal de Saint-Quentin" by Mouringh van der Vinne, a poem in Dutch, loosely translated, catches the spirit of the transit.

| | |
|---|---|
| *De kettingsleper trekt zich voort* | *The tug pulls forth* |
| *met veel lawaai en weinig gang* | *with great noise and slight progress* |
| *naar 't lichtje dat mijlenver gloort* | *towards the light that glimmers miles ahead* |
| *aan 't einde van de duistere gang.* | *at the end of the dark corridor.* |
| *De schepen, weerloos aangelijnd,* | *The ships, helpless leashed,* |
| *stuiten soms stevig op de wanden.* | *scrape against the walls* |
| *De galm van schurend ijzer schrijnt* | *The reverberation of abrasive iron hurt the ears* |
| *terwijl de schippers knarsetanden.* | *while the skippers gnash their teeth.* |
| *In 't donker flitst de bovenleiding,* | *In the dark the flashes overhead,* |
| *hier is het erger dan de hel,* | *are worse than in hell,* |
| *maar eindelijk daagt toch de bevrijding* | *but freedom dawns at last* |
| *en schijnt de zon ongekend fel.* | *and the sun shines brightly.* |
| *Er is weldra weer blauwe lucht,* | *There is soon again blue sky,* |
| *een schipper slaakt een diepe zucht.* | *a skipper sighs.* |

Another vintage chain tug, the Ampère, was retired after 75 years and is displayed at the entrance of Le Musee du Touage. The photo illustrates how the chain is lifted to and dropped from the vessel.


The year 2010 was both the bicentennial of the tunnel and the centennial of its electric chain tugboats.'

**Mauvages Tunnel, Canal de la Marne au Rhin**

| |
|---|
| Length: 4,877 meters. Width: 5.2 meters. Height: 5.7 meters. |

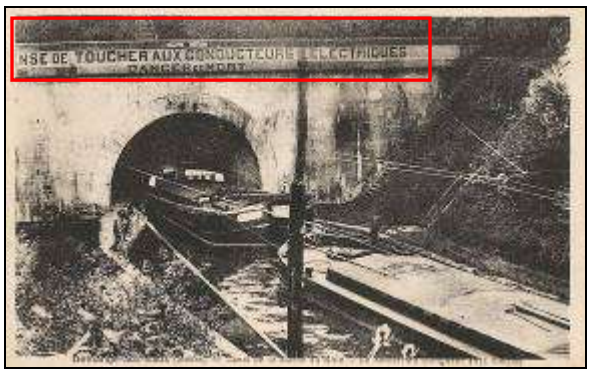
France's only other active electric chain tugboat operates in the Mauvages. As the tunnel is not straight, piloting is difficult.

Begun in 1842 and put into operation in 1853, two steam-driven chain tugs moved trains of 17 ships at 1.25 kilometers/hour.

Since 1912, electrically-powered chain tugs have done the hauling, pulling up to four vessels at about 2.5 kilometers/hour. The tugboat of 1933 is still working.

Steam Chain Tugboat, Undated

Undated


1936

Undated

1912 chain tug still in operation


Today's interior and exterior

"Notice to Shipping" includes the following:

> *Towing with the electric tug is compulsory for all ships in order to avoid emissions in the tunnel. Motors and generators must be turned off. Cooking, baking, heating and open flames are prohibited. Smoking is also prohibited. For security reasons, up to 8 people are allowed per boat. In order not to contact ceiling power lines during the passage, do not leave the interior of the ship. It is prohibited to scream. If you have a problem, make it known by repeatedly honking the tug personnel.*

**Balesmes Tunnel, Marne à la Saône**

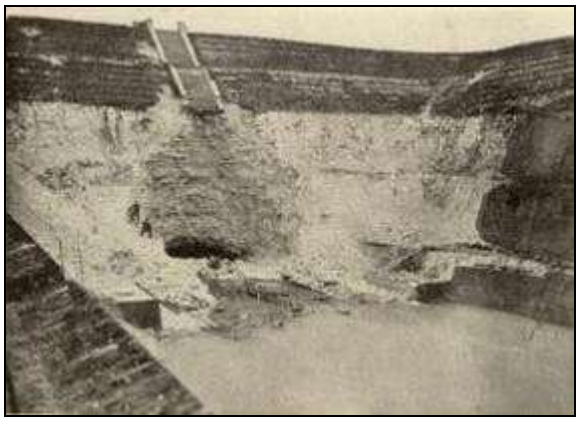
Length: 4,800 meters

Constructed in the 1880s, the Balesmes spans the summit between Balesmes-sur-Marne and Noida -Chatenoy.


A chain tug driven by horses operated until 1946 when it was converted to diesel. Towing was abandoned in the 1960s and today's voyagers sail under their own power.

**Ruyalcourt Tunnel, Canal du Nord**

Length: 4,354 meters



Damage from the Great War

Today

Painting by Pierre Lemoine

1000-meter passing zone in the center.

**Pouilly-en-Auxois Tunnel, Canal de Bourgogne**

Length: 3,000 meters.  Width: 5.8 meters.

Tunnel construction was completed in 1832.  Originally, the sailors manhandled their boats through the passage, the effort requiring 8 hours.  In 1867, a steam-powered chain tugboat drew several barges at a time.

Electric chain tugs, 15 meters long, 3.2 meters wide and a 0.5-meters draft, replaced the steamers in 1893.  Water released from locks powered a 22 kW turbine.

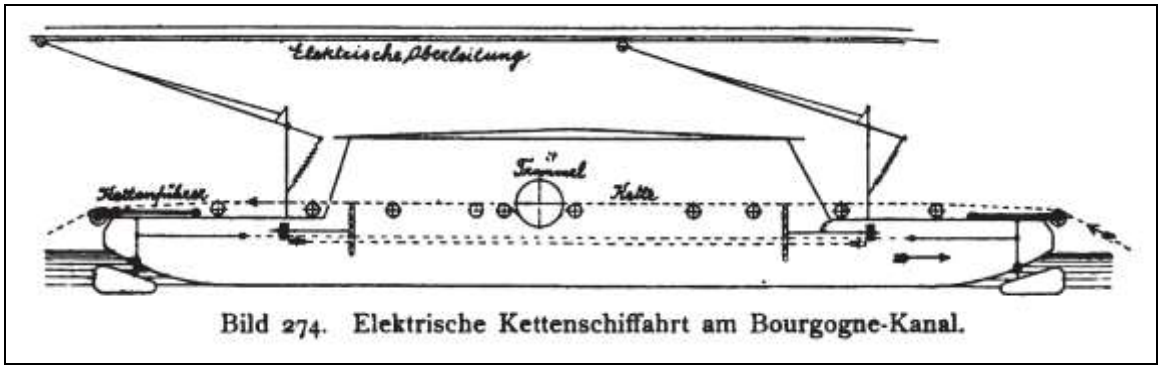
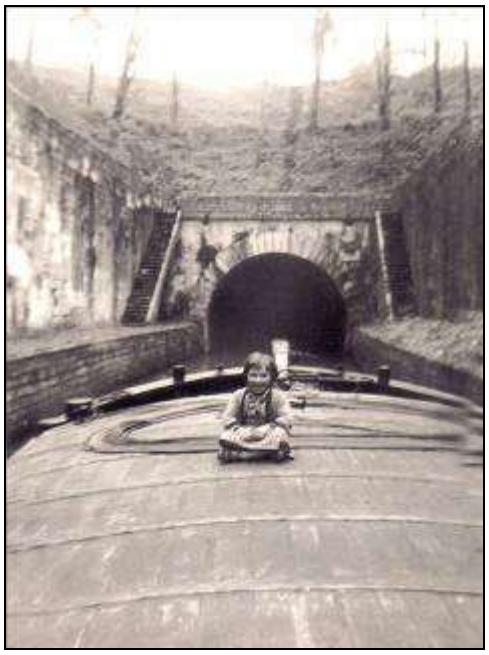



Bild 274. Elektrische Kettenschiffahrt am Bourgogne-Kanal.

Electricity not only propelled the craft, it also lighted the way, as noted by Thomas Martin in Electrical Boats and Navigation (1894)

> *The tunnel of 3.3 kilometers mentioned is lighted by incandescent lamps which are branched in multiple on the power circuit. It may be said that this electric canal installation has given such satisfaction that it is certain that before long similar methods will be largely employed in France*

The 1921 photo shows the chain and the metal arm touching the cables above. Boat speed reached 4 kilometers/hour



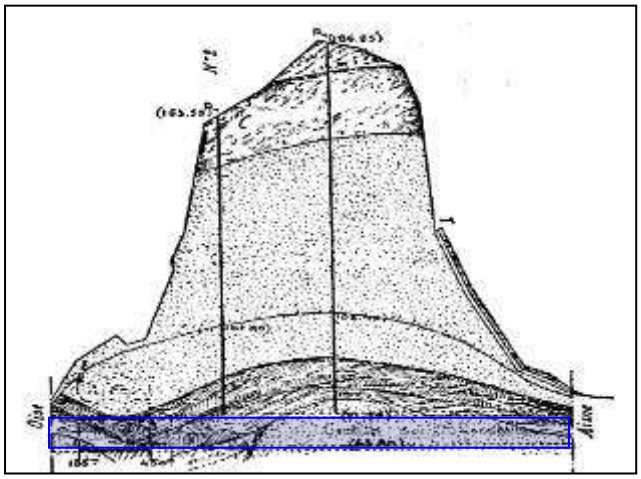
Left: The boatman's daughter, we'll hypothesize, enjoying the ride, undated.

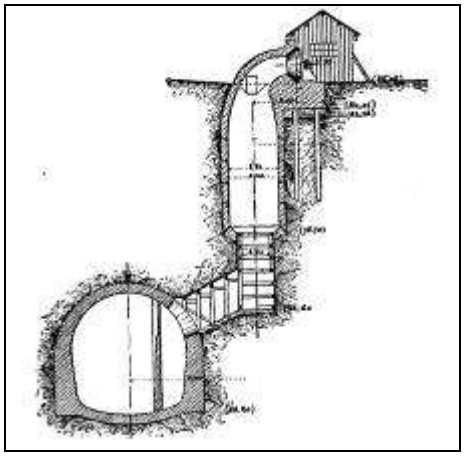
Below: A chain tug on display in a shell that simulates the dimensions of the tunnel.

**Braye Tunnel, Canal de l'Oise à l'Aisne**

Length: 2,365 meters

The Canal de l'Oise à l'Aisne is a summit level canal about 100 kilometers north-east of Paris. To counter infiltration, construction workers had to labor under compressed air conditions. Fires ignited by the elevated oxygen and lignite in the rock killed 17 in 1884.

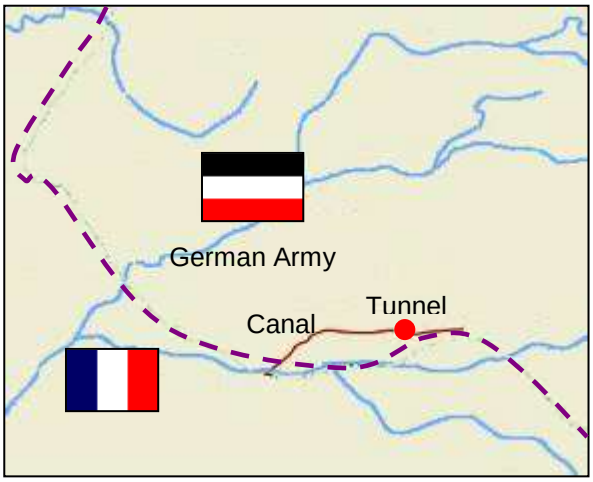




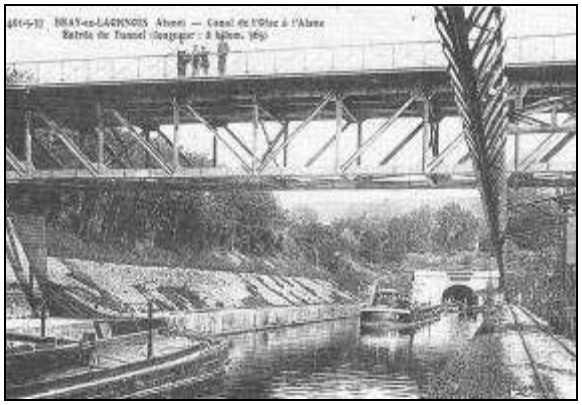
Ventilation works


Braye Tunnel lies 110 meters below Chemin des Dames Ridge, the scene of one of the most costly engagements of the Great War. Germans casualties numbered 163,000, French, 271,000.

Front line, early 1917




The Braye was not reconstructed until 1931.



Towing traction was provided by a 600-volt tractor riding a monorail, a towing system that remained in operation until the 1960s.

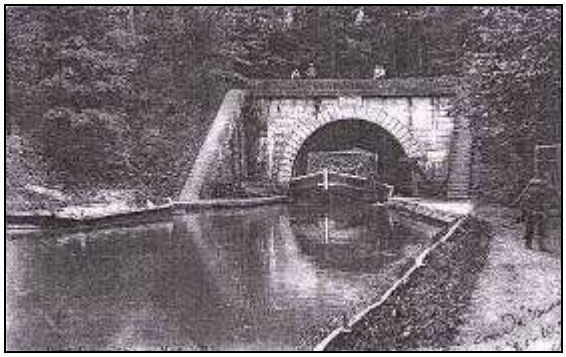
The command post at the southern entrance. An aeration system was added in 1972 when boats were motorized. Traffic is one way, signaled by lights

Ballasted boats waiting their turn at the north entrance. The wait can sometimes take an hour.

The Braye remains a major bargeway, avoided by pleasure-craft.

**Billy le Grand Tunnel, Canal de la Marne au Rhin**

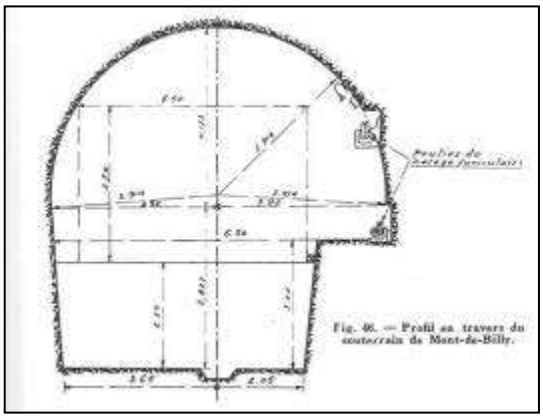
Length: 2,330 meters



1913

Undated

Above, right and to the right. Billy le Grand was originally equipped with a looped towing cable operated by a fixed outside steam engine. The first boat of the train was attached to the cable by a tether weighted with lead balls. There was telephone communication between the ends of the tunnel.



1935 Cross-section

The loop moved at 4 kilometers/hour. Barges could be started or stopped by connecting or disconnecting the cable grip with a device on the boat.

1940, the final year of the tow cable

Today

Electric tugs operated between 1940 and 1974, able to tow a train of seven at 4 kilometers/hour. In 1955 the large pulley at the entrance had been removed to allow passage of tugs, but the other pulleys were still visible. Boats today rely on their own power.

**Arzviller Tunnel, Canal de la Marne au Rhin**

Length: 2,306 meters

Arzviller was drilled between 1839 and 1849. Barges were originally pulled along the towpath by horses, and later, by small steam engines. It is now forbidden to cross the tunnel by foot for safety reasons.

British Troops exiting the Arzviller, 1919

**Tronquoy Tunnel, Canal de Saint Quentin**

Length: 1,097 meters. Width: 5.2 meters

As the Riqueval is the "Grand Souterrain," the Tronquoy Tunnel on the same canal is "Le Petit Souterrain."

Before the chamber was flooded, Napoleon himself came to inspect the works on horseback, preceded by an honor guard and followed by a platoon of lancers. As a result of a misunderstanding, however, the lighting wan not completed and, the emperor found himself in the dark. When his mount stumbled on a ladder forgotten by the miners, Napoleon immediately surmised an attack and cried, "À moi ma garde," "I'll keep to myself," spurring his horse through his horrified protectors.

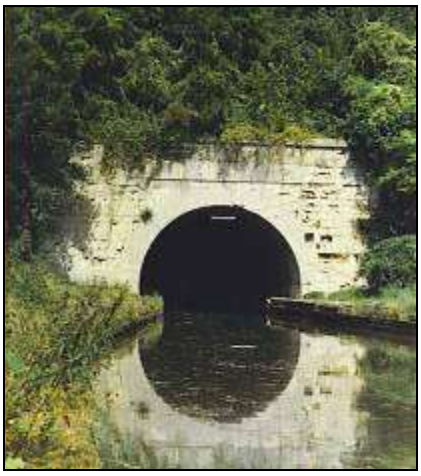
William Moens, whom we quoted regarding the Riqueval, likewise commented on the Tronquoy.

> *We reached the first tunnel, that of the Tronquoy at 4:26; the route was clear and it was not very long, only about three-quarters of a mile; so without any hesitation we entered it, the height of the vault being about seventeen feet, thus giving two feet clear above our funnel. It is not a pleasant thing imagining that some stone or other may fall on your head, and though the light was visible as a speck at the other end, it was as dark as possible after we had entered a few yards. The large masthead light was placed in the extreme bows of the vessel, and a hand on each bow held a light directed against the walls; but when a tunnel is quite straight, and it is possible to see the light of day at the exit, the best guide is to get the edge of the funnel in one position against the light, and keeping it there steadily, the vessel goes straight as an arrow.*

*Guiding her this way, we emerged into the light of day in eleven minutes, without once touching the sides, though there was not much room to spare, the width of the water channel being only seventeen feet.*

*When we had steamed a short way on the other side of Tronquoy Tunnel, to our horror, we saw at least a kilometer, or five-eighths of a mile, of barges connected together, and all towed by means of the submerged chain, one small tug doing all the work. It was impossible to pass them with safety, so we hooked on behind them and entered into a conversation with the owner of the hindmost vessel. He told us that they had been one hour and a half in passing through the tunnel, in which we had been only eleven minutes.*

Electric chain tug waiting at the entrance, early 20th century



Today

**Saint Léonard Tunnel, Canal Marans La Rochelle**

Length: 1,830 meters. Width: 8 meters

Construction stretched through much of the 1800s with the forced labor of prisoners. It is not navigable today.

**Canal Saint-Martin, Paris**

Length: 1,830 meters. Width: 7.8 meters

The Canal Saint Martin anal was constructed from 1802 to 1825 to provide an additional freshwater source for a burgeoning Paris. The works were funded by a sur-tax on wine. Unlike the other canals in this chapter, this waterway was fully constructed in open air and the enclosure was came later

The canal's lowest lock was moved upstream from the river bank in 1862 and the lower reach of was vaulted between Place de la Bastille and Avenue de la Republique to improve the docking, creating Boulevard Richard-Lenoir. The enclosure was further extended to Rue du Faubourg du Temple, creating Boulevard Jules-Ferry in 1906.


Underground section in green


Turn of century

1970s


Locks

The tunnel uses sunlight from portals above.


1890 and today

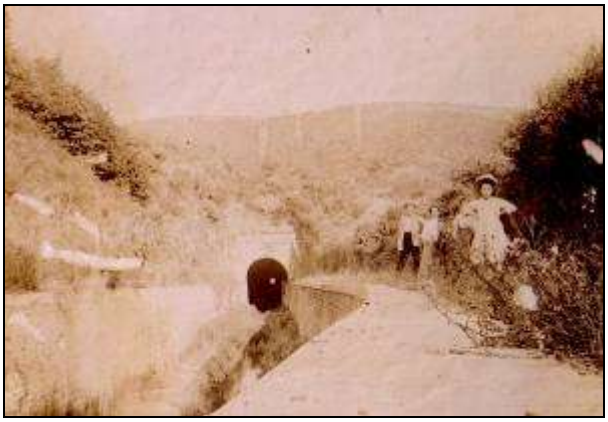
Today's visitors can explore the canal by boarding tour boat at the yacht harbor Port de l'Arsenal, delving into the darkness below the Bastille and floating beneath the remains of some 500 victims of the 1830 revolution.

Canal Saint Martin
€16.00

**Chérimont Tunnel, Canal de la Haute-Saône**

Length: 1,330 meters

Constructed in the latter 19th century to compensate for the loss of infrastructure to the Germans, the Chérimont was intended for coal haulage.




Family outing, 1911

Undated

Today the canal's a route for pleasure boats.

**Panneterie Tunnel, Canal du Nord**

Length: 1,061 meters, Width: 6.1 meters

The entrances were mined during World War I, but the refurbishment wasn't completed until in 1965. The tunnel is one-way.

World War I

Today

**Foug Tunnel, Canal de la Marne du Rhin**

Length: 866 meters

1909

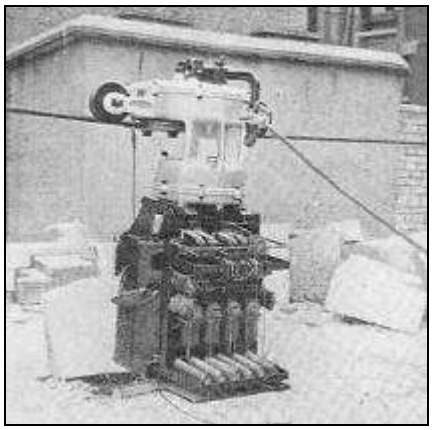
Since its construction in 1845, barges have been towed through the tunnel first by mules, then horses, then with an electric winch and then until 1980, by electric trolleys

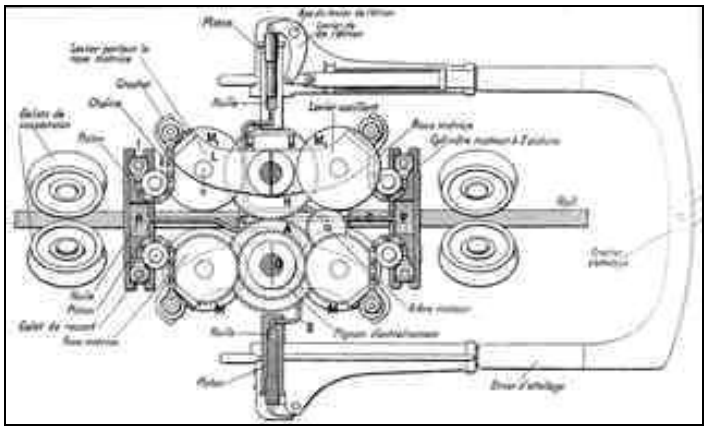
Today, barges motor through under their own power.

**Liverdun Tunnel, Marne-au- Rhine**

Length: 388 meters

Liverdun is noteworthy for two reasons, the first being that in 1924 it hosted the prototype "zinzin," a 600-kilogram locomotive suspended on a fixed cable. A trolley-line parallel to the cable powered the motor.

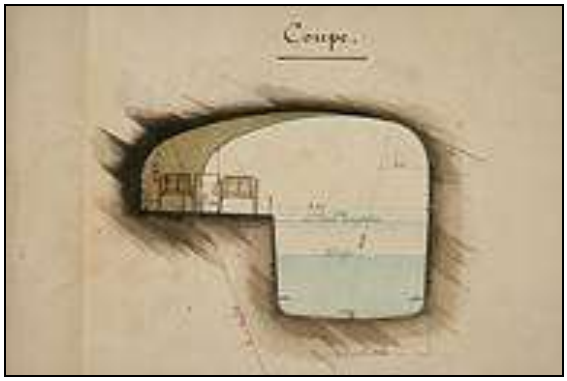


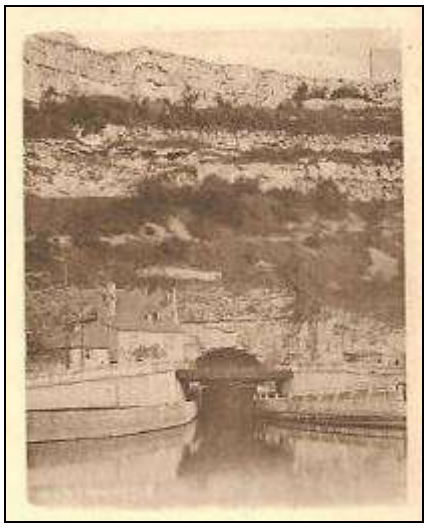


Liverdun's other distinction is that the canal was refilled in 1978.

**Besancon Citadelle Tunnel, Canal du Rhône au Rhin**

Length: 388 meters



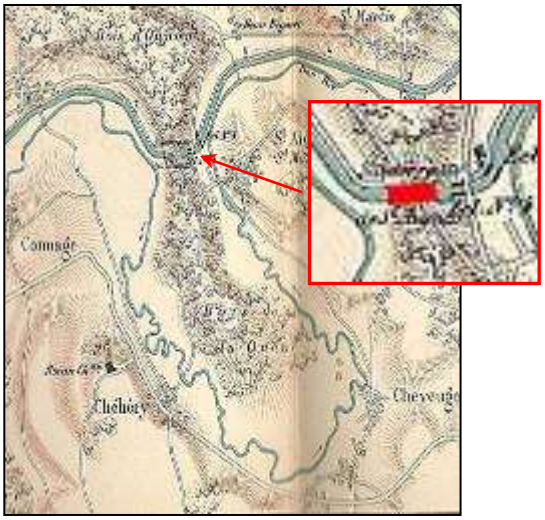




Interior lock

**Saint Aignan Tunnel, Canal des Ardennes**

Length: 195 meters

The transport distance saved by the short Saint Aignan is apparent from the 1885 map.




Barge traffic

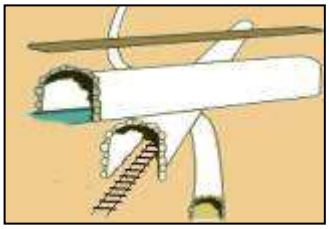
Bike traffic

**Malpas Tunnel, Canal du Midi**

Length: 173 meters. Height: 8.4 meters.
Width: 6.8 meters

The Malpas, excavated in 1679, was Europe's first navigable canal tunnel.

The Chevalier de Clerville, architect to Louis XIV, advised to cross the River Aude rather than tunnel through the hill, but chief engineer Pierre-Paul Riquet maintained his preference for a subterranean route.



By the time the Malpas was excavated, the hill had already for centuries been the site of a tunnel to drain the Étang de Montady. A third tunnel, between the two, was excavated in the 19th century as part of the Béziers to Narbonne railway line.

**Voyage de Fin**

We've boated a beaucoup of French canal tunnels, a few still commercial arteries, but most now holiday routes.

We've increased our French vocabulary.

"Toueur," a tugboat,
"Rame," a train of barges,
"Touage," towage, of course, and
"Flottage," a floatage, if that's an English word.

As well as our German.

"Schiffstunnel," canal tunnel.

But now we must bid au revoir to these particular subterranean waterways and venture where the danger is more than that of spilling our glass of vintage wine in the darkness.

# CHAPTER 74
# MORE AQUATIC PERILS

We're on no nancy-pancy journey. Perils lurk at every dark river bend. In Chapter 41 we saw dire consequences of sinkholes. We dealt with the dangers of flash floods in Chapter 43, with cave diving in Chapter 70, with underground boating in Chapters 54 and 69 and with mining in Chapter 72. This chapter will mention a few more risks associated with underground rivers.

**Swimming**

Hawaii's legendary goddess of fire, Pele, guards the lava-tube entrances to her molten domain. The Wailuku River on the Big Island is famed for its Rainbow Falls. Above the falls are the aptly-named Boiling Pots where the river churns through a succession of Jacuzzi-like "pots" where flow dives beneath a stratum of old lava.

Question and Answer from hilo-hawaii.com concerning 'au'au (bathing),

*Q: My guidebook says we can swim at Boiling Pots.*

*A: Absolutely do Not!..And don't climb down below the viewing area. Besides the chances of leptospirosis, the Boiling Pots area is laced with lava tubes, some horizontal, some vertical like hourglasses. The water appears to boil as it goes into, then shoots back out of these tubes. Most are underwater, out of sight, and it is too easy to be sucked into these tubes, even when the water appears low. There is no way out alive. It has happened for so long. Hawaiians had legends about a great mo'o, or lizard, that lived in the river. Occasionally it would pull someone under, and release the body several days later. "Wailuku" means "river of destruction." It is an "ai kanaka." It "eats men."*

**Wading**

The rule of thumb is that it's dangerous to wade if the product of depth in meters and velocity in meters/second exceeds 1. And that assumes that we can see where we're stepping.

For an underground water wading reference, we have "Underground Current" from Imperial Valley Press, August 23, 1902

*William Moore has just completed a new well near his ranch near Coldwater, from which he pumps water to irrigate his ranch. The well is only sixteen feet deep with a stream of water three feet deep running through the bottom. Mr. Moor says, "I can hardly stand up in the well, the current is so swift... It seems to be an underground river."*

*Mr. Moore raises some very large watermelons, and yesterday cut one that weighed sixty pounds. He is expected to arrive in Phoenix today with one that will weigh eighty pounds. This sounds pretty big, but it is a fact.*

The melon indeed sounds big and the farmer, foolish.

**Falling In**

"A Wonderful Escape," The Youth's Companion, October 27, 1898, provides an account from northern Florida.

> *Recently a party of twelve negroes were fishing in the creek, when two of them, losing their balance on the slippery bank, fell into the water and were whirled into the underground stream by the swift current.*
>
> *Their horrified companions tried to rescue them, but in vain, for almost instantly they were swept out of sight. The party rushed to the lower end of the land, where the creek reappears.*
>
> *Scarcely had they reached the place when both negroes shot into sight. They were still alive, and were seen to be feebly struggling in the rapid stream.*
>
> *A dozen men plunged into the water and brought them to shore, where, after much rubbing and work on the part of their friends, they were restored to full consciousness. They could tell nothing of their perilous experience, except that it was very dark and the current was swift.*

The same incident was reported in the San Francisco Call of June 11, 1895, as "Two Negroes Swept Through an Underground River and Escape Death. They were Fishing and Falling Into the River Were Carried Half a Mile."

> *Nathan Brooks and Joseph Gillen fell into the water and were almost instantly whirled into the underground creek by the swift current... They were swept away uttering loud screams of horror and terror.*
>
> *The party hastily rushed to the lower end of the land where the creek reappears. Shortly afterwards both men shot through, feebly struggling in the swift current and showing slight signs of life. Several men plunged in and brought them to shore, and they were worked over for half an hour before they were out of danger.*

The Chicago Daily Tribune, June 11, 1895, added that,

> *This is the first time that such an escape has been made, as many lives have been lost in the place and hundreds of cattle.*

Quincy Daily Whig, September 17, 1890, offers an account of a plume-hunter's misadventure.

> *Presently I saw a good sized stream glimmering through the trees, the silver river seemed to end abruptly, and it looked very puzzling until I reached the bank, when I saw that I had run across one of Florida's natural wonders, of which I had often read.*
>
> *But I was after the water, which was clear and cold. So I stepped down the bank quite a distance above the cataract and tried to unscrew the cover of my tank. The obstreperous piece of metal was stuck tight, and while I was wrestling with it, the crumbly clay bank gave way and I slipped into the water, still clinging to my water tank, which buoyed me up as a life preserver. I clung to it and kicked for the shore.*
>
> *I had about a hundred feet to drift, and although I could touch the bank at time, I could find nothing to grasp but the treacherous crumbling clay. Buoyed up by life preserver, I swung round in a swirling eddy, and with one last cry for help and a kind of dreamy wonder as to how far down I would drop, my breath left me. After the first antagonizing plunge down -- it seemed to me hundreds of feet -- my head shot out into the air for a moment, and I saw that the stream was running horizontally through a black, rayless cavern on whose walls the spray was splashing...*
>
> *When my senses returned, I was floating quietly on the surface of a body of water, my arms still held by the strap of my life preserver, which had indeed saved me... I paddled slowly to the nearest shore and fell down in the grass, bruised and wearied. In the moonlight I saw that the pool I had just left was circular and about a hundred yards in diameter, black and deep, but without a ripple.*

Farmers' Review, March 8, 1898,

*A queer accident happened to Michael Magona, at Rutherford, Tenn., last week. He was digging a well to supply the cattle with water during the summer. At the depth of sixty feet the bottom fell out of the well and Magona plunged headlong into an underground river and was drowned. The rushing waters below acted like a suction, and the windless and dangling apparatus were drawn in. Magona's associates, panic-stricken with fear, gave the alarm, and the whole neighborhood turned out, but no trace of the unfortunate man could be found until after several days, when is body was discovered floating in the Obion River, four miles below.*

**Traversing Above**

Staying dry while crossing an underground lake can be difficult. There are three ways to do so.

Swimming. Chapter 70 describes the danger.

Boating. Chapter 71 gives evidence to the risk.

Eco-hangers. The climber traversing the 30-meter Midroi lake, waters we boated in the "Microbe," Chapter 27, illustrates the feat.

**Earthquakes**

"Voices from the Tomb Talks with the Spirits of Pythagoras and Grant," St. Louis Globe-Democrat, December 9, 1886, features an interview with Dr. Amos S. Waterman, who

*Professes to have daily, and indeed, hourly communication with members of the spirit world, and has for his particular friends two mysterious personages, one claiming to be that of U.S. Grant, another that of Pythagoras.*

*He then proceeded to make the following statement which, he explained, was the theory of Pythagoras who had personally ascertained the truth of every feature of it.*

A recent shift in the spirit world has

*Shortened the period of the solar year to exactly 365 days and 42 seconds, moved the earth 2,000,000 miles closer to the sun and altered the angle of polar inclination, the result causing earthquakes in Charleston.*

*The water that produced these wonderful, though terrible, events is far below the earth's surface, running in underground rivers. The immediate source of the river, having one outlet in the Atlantic Ocean near Charleston and another in the Gulf of Mexico near Florida, is in the polar seas near the North Pole.*

*The sources of this river been obstructed by icebergs, mountain high. But the change in the earth's center of gravity led to several of these losing their moorings and floating into warmer seas, where, as a matter of record, they have been seen.*

*The volume of water passing into this subterranean channel was immeasurably increased by this means and the flow became greater that the river could dispose of. All along the line of this underground river geysers have opened.*

*There was no actual fissure, or Charleston would have been wholly annihilated, but the rocks bulged upward in the center of the channel, thus producing the disturbance which led to so much misery.*

*To all such questions as "Is all danger to Charleston over yet," and "Would it now be wise for those living over the subterranean river to seek more secure locations?" the spirit was silent, and the interview soon afterwards terminated.*

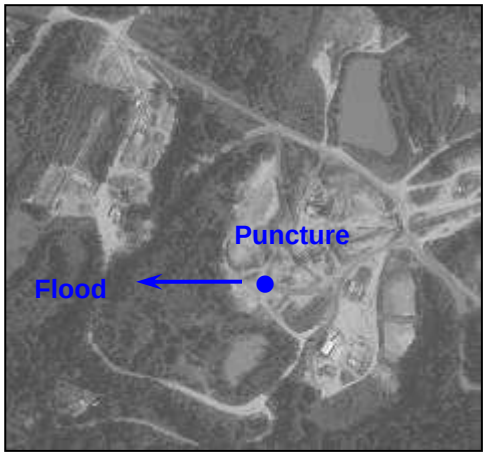
This revelation is to some degree a Rosetta Stone of underground rivers. We've the wisdom of the Greek Philosophers and the spiritualism of the late 19th century. We've further information regarding the causation of earthquakes, the polar sea connection, Chapter 16, and the Floridian submarine springs, Chapter 76.

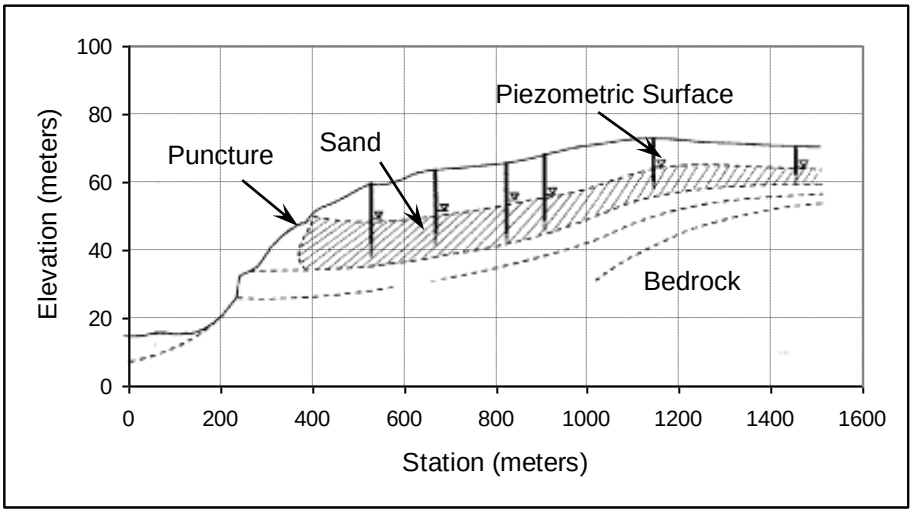
**Explosion**

An "underground stream" perforated from the side can "explode," as headlined in the November 1, 1993, Seattle Times, "Wetland Flooded; Homes Left Dry -- Underground Stream Explodes."

In removing clay hill-slope covering a deposit of sand and gravel near Monroe, Washington, quarrymen laterally perforated an aquifer in the hillside behind.

The puncture spewed water at 125 liters/second, carrying 25,000 cubic meters of silt into the valley below. .The following day, water from the new spring was flowing at about 30 liters/second and wells above the site were going dry



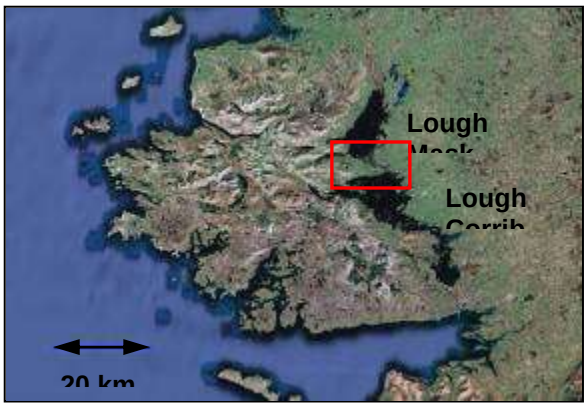

The water table dropped some 6 meters behind the break and roughly 1 meter a kilometer upstream.

**Lost Canals**

The Letters of 'Norah' on Her Tour through Ireland (1882) by Margaret Moran Dixon McDougall was a best-selling travelogue of the day.

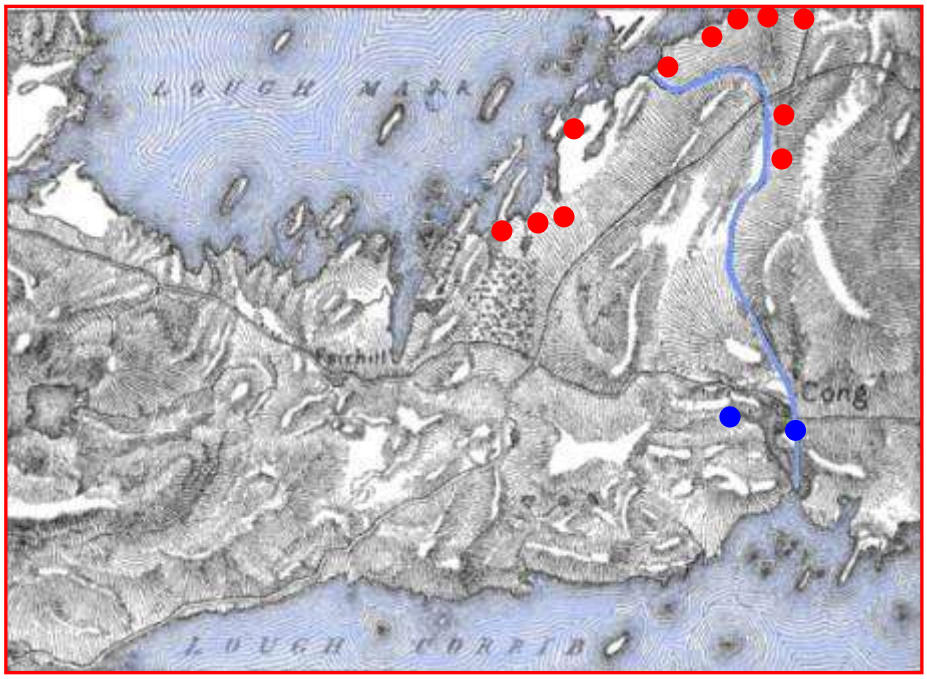
> *It was determined to make a canal to connect Lough Corrib and Lough Mask. The canal was made at the expense of much blasting, much building of strong and costly stone work. If they could only have resurrected the famous Irish architect Gobhan Saer, he would have advised making a well-cemented bottom for the canal considering that a subterraneous river runs from one lake to the other under it. They did not do this, however, and when the grand canal was finished and the water let on the bottom fell out in places and the waters fell through to their kindred waters. The next famine they will require to dig and blast downward and still downward till they find the underground river and the runaway water.*

As the geology is karst limestone, the architect's advice was well founded, as evidenced by the photo of the completed project.




Hydrologic detail of the red rectangle is shown in the next figure.

The map below is from "The Underground Emissary of Lough Mask" from The Earth and its Inhabitants with hydrogeologic features overlaid.




The Earth and its Inhabitants (1876) by Elisee Reclus,

> *The great Lough Mask, which fills a rock basin in Connemara, has no outlet, except through an artificial canal connecting it with the still larger Lough Corrib. But on closer examination it has been found that it is drained by an underground river, which reappears in copious springs at Cong.*

The subterrain between the lakes has been described as resembling Gruyere cheese.

**Lost Rivers**

There are any number of "Lost Rivers" (Chapter 43), but none as consequential as the feared loss of the Danube. "The Theft of a Great River," Literary Digest, November 10, 1900, warns of the danger.

> *Geologists have long known that one stream may appropriate the waters of another by gradually encroaching upon its watershed and diverting its tributaries one by one. This kind of*

*theft is at least frank and open. It takes place on the surface and every one -- at least every geologist -- can see what is going on. The river Danube, according to expert authority, is suffering from a more insidious form of robbery, by which the Rhine profits, part of the Danube's water being drawn off underground into the Rhine valley. And this may be of great importance to future dwellers by the Danube, for if it is not stopped it may end by causing the river below the point of absorption to become permanently dry.*

*Now it is remarked by Professor Penck that, unless this loss of Danube water is stopped in some way, it will go on increasing gradually until it will take the whole of the river's supply, leaving the lower river-bed quite dry, as it is left occasionally now, according to Quenstedt, in years of drought. Then the gradual deepening of the Danube valley will end at the point of absorption. Below Mohringen will extend a dry valley, while above a "blind valley" will be drained by a subterranean river. This is not a flight of the imagination, for the same thing has happened to the river Foiba in Istria and the Reka near Trieste. The author adds that these and other cases, notably in Dalmatia, show what threatens the Danube valley unless man intervenes. The length of time that elapses before the reappearance of the water at Aach (sixty hours) shows that it must make a long circuit, or that it encounters great obstacles underground.*

Dynamite was used to access the Riverbed Room, a 90 by 10-meter riverine chamber of Wisconsin's Eagle Cave. Unfortunately, the blast also drained the cave river.

The Riverbed Room has sparked a spooky story about a young couple, Mary and Jonathon, who planned to be married in the cave. Mary went to ahead to dress, but never returned. When the wedding party searched for her, all they found was her veil and a shoe lying on the ledge above the then-unknown underground river.

Jonathan returned sometime later to the cave to again search for his beloved. He, too, disappeared, leaving behind his pipe and hat on the same ledge. Rumor is that both of them slipped off the ledge and drowned, and that their ghosts can still be seen in the Riverbed Room.

**Lost Lakes**

In Chapter 72, we lamented the sudden loss of Louisiana's Lake Peigneur to a mining misfortune, but let us also note that nature itself -- and perhaps the CIA -- can be equally disruptive.

Native Americans believed that Medicine Lake, Jasper National Park, Alberta, vanished each autumn due to "big medicine." The "medicine" is a sinkhole in the lake's karst floor.

Medicine Lake fills when the rate of snowmelt exceeds the lake's subsurface capacity to drain, 24 cubic meters/second. The lake is full by late spring and in September, when inflow diminishes, the stage rapidly falls. The karst channel resurfaces 17 kilometers downstream, forming Canada's longest underground river.

In pre-park times, attempts were made to plug the lake's drain, once using old mattresses, another time using two truckloads of Saturday Evening Posts. Parks Canada/Parcs Canada wont, however, allow further efforts.

We can't be sure that it's the same lake, but Appleton's' Annual Cyclopaedia and Register of Important Events (1887) provides a similar story.

> *Abbe Petitot, a Canadian missionary, who has traversed the vast and little explored territory between Great Slave Lake and the Arctic Sea in every direction, found that several of the lakes and chains of lakes were drying up. The deep granite basin of one of the lakes he found completely bare, and in it he saw a yawning chasm shaped like a funnel, through which the waters had been drawn into some subterranean channel. The Indians believe that there are several of these underground rivers in this region.*

And from Pravda, May 20, 2005

> *The landscape on the forest edge near the village looks like the water has gone under the ground from an unplugged gigantic bathtub.*
>
> *A large lake disappeared in Russia's Nizhni Novgorod region overnight. Residents of the village of Bolotnikovo discovered a huge trench instead of a million cubic meters of water on Thursday morning. No other lake appeared in the area.*
>
> *Dmitry Zaitsev, the chief of the local firefighting brigade, said that a large number of trees had been sucked under the ground. "If a human being finds himself in the middle of such a disaster, there will be no chances for a person to survive," Zaitsev said.*
>
> *Local residents were shocked to find out that their lake had literally vanished from the area. Village fishermen came to the lake early in the morning. "I was amazed to see that there was no water there. All I could think of was -- oh, my God," a local resident said. One of the men assumed that the USA had been involved in such an amazing natural phenomenon: "I think that America got us here," a man said.*
>
> *An official from a neighboring village, Alexander Kluyev, believes that the lake has flown into an underground river. "I think that the vault of a large underground cave came down and connected with a river there. We believe that there is a certain underground river flowing here in the area, and the water of the lake has gone under the ground," said he.*

The accusation against the United States was not substantiated.

The same story reported by UPI as "Russian Lake Disappears Overnight" suggests a linkage to pre-revolutionary leadership.

> *"It looks like somebody has pulled the plug out of a gigantic bath," an NTV correspondent said about the vanished lake.*
>
> *Village youngsters said the lake had been shrouded in "dark mystery" ever since it appeared during the reign of Ivan the Terrible.*

**Lost Explorers**

Lowell Daily Citizen and News, July 18, 1872,

> *We are treated to some new details on the matter of Dr. Livingston. He has a few points of research to settle before returning to daylight; and although his clothes are shabby, his gilt hatband tarnished, and his feet ulcerous, settle them he must and will. He has heard of four*

*fountains and an underground river, each which must be seen to be appreciated, and this may consume a year and a half.*

**Lost Sustenance**

For the worst-case lost-waterbody scenario, we turn to Edouard Martel, whom we met in Chapter 54, Subterranean Watercraft.

"Must Humanity Perish of Thirst? The Possible Desiccation of the Earth through the Depredations of Underground Watercourses," Scientific American, October 1921, summarizes the subterranean explorer's grave concern.

*Much interest has been felt by men of science of late years with respect to what many of them believe to be the inevitable though, of course, very gradual desiccation of the earth which, of course, implies the eventual destruction of all life as we know it, since vital functions are impossible without moisture.*

*But most of all it is the recent researches in the interior of the ground itself which have "transformed from a hypothesis to a certainty the idea that the waters are gradually making their escape into the sub-soil or calcareous regions, and that there is a substitution among these lithological formations of a modern subterranean circulation for an ancient surface circulation.*

*M. Martel enumerates and describes a great many very curious examples of the disappearance of springs, the deepening of subterranean rivers, the going dry of wells, etc., which make the future desiccation of our globe seem inevitable.*

*One of the most convincing of the arguments offered to this effect is the perforation of the bottom of the upper galleries in caverns where subterranean rivers have dried up in the course of ages through an actual drawing off of their waters into profounder depths.*

SUBTERRANEAN RIVER ENTRANCE IN THE ROCKY MOUNTAINS

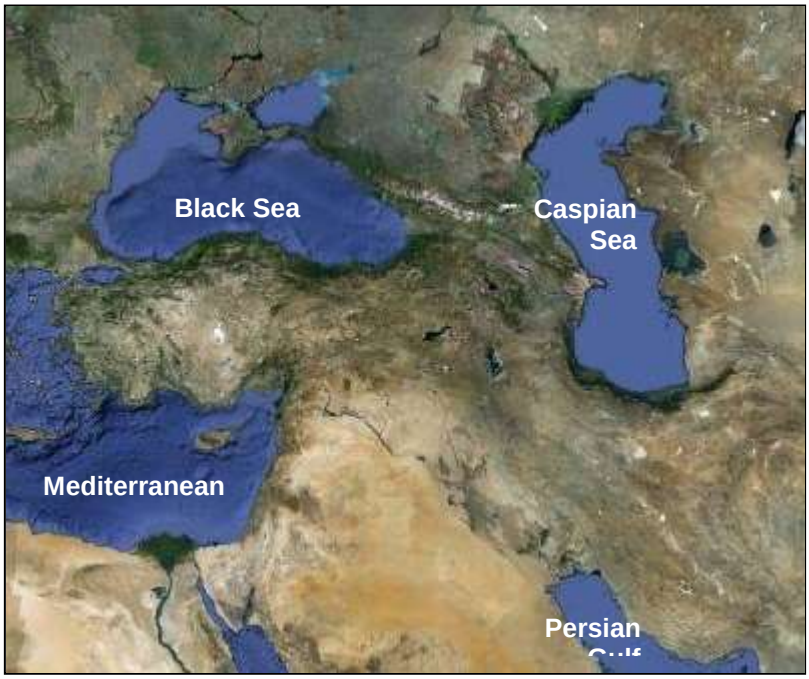
In short, because water will flow downward, those of us dwelling on the topside will be first to be denied.

Given so many perils, there are certain to be occasional causalities. Fortunately for the departed, our ancient boatman's still on the job, digitally, at least.

*Axiom's Charon Cemetery Management Suite (CMS) offers unprecedented integration and ease of use that is unmatched in the death-care industry.*

*For the first time in the industry, Charon CMS provides a one-stop cemetery management system. All aspects of the Charon system are integrated to operate cohesively and to maximize efficiency in the day-to-day operation of your cemetery.*

# CHAPTER 75
# THE CASPIAN CONNECTION




The Caspian Sea became landlocked about 5.5 million years ago as a result of tectonic uplift and sea level decline. Today it is the globe's largest inland water body, containing more than 40 percent of the earth's lacustrine waters. The Volga contributes 78 percent of the inflow. The Caspian's salinity is 1.2 percent, about a third that of seawater

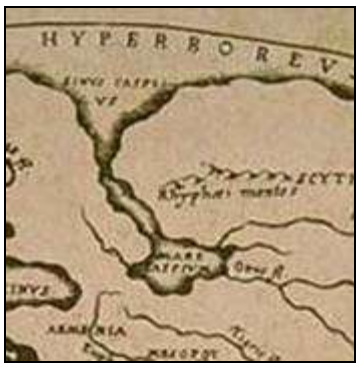
Caspian Water Balance, 1900-1985
(cubic kilometers/year)

| | | |
|---|---|---|
| River Inflow | + 298 | (3.8 times the sea's volume) |
| Direct Precipitation | + 74 | |
| Evaporation | - 370 | (roughly 1 meter/year) |
| Outflow | - 14 | |
| Total | - 12 | |

The only outflow is to the adjacent Kara-Bogaz-Gol lagoon from where it evaporates. A dam constructed in 1980 to block this loss was dismantled in 1992. From the sixth century BC to the present, the Caspian's water surface has varied from 20 to 34 meters below sea level.

**The Lore**

The ancients' perception of the Caspian as a gulf of the Northern Ocean can be seen in various maps.




Posidonius' World Map
(150-130 BC)


Marcus Vipsanius Agrippa's
reconstructed Orbis Terrarum
(20 AD)

Dionysius Periegetes'
reconstructed World Map
(124 AD)

Not until the second century did Ptolemy establish the fact known to Herodotus and perhaps to Aristotle that the Caspian is landlocked on all sides, engendering presumption of a subterranean outlet. Such outflow, we must agree, is a logical explanation for a sea that has no visible way to expel its excess.

In the words of Elisee Reclus in The Earth: A Descriptive History of the Phenomena of the Life of the Globe (1871),

> *In the view of the natives, this inland sea could be nothing but an abyss, a "black gulf," as is expressed by the name Karaboghaz, into which the waters of the Caspian dive down in order to flow through subterranean channels into the Persian Gulf or the Black Sea. It is, perhaps, to some vague rumors as to the existence of the Karaboghaz that we must attribute the statements of Aristotle about the strange gulfs in the Euxine, in which the waters of the Hyrcanian Sea bubble up after having flowed hundreds of miles through the realms of Pluto.*

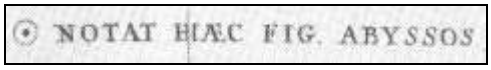
Islamic scholarship (Chapter 5, The Crescent) wasn't immune from perpetuating geographic errors, an example being Monument of Places and History of God's Bondsmen by Persian geographer ibn Muhammad al-Qazwini (1203-1283)

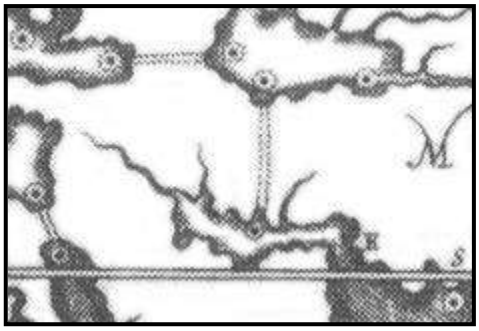
> *The sea of Georgia and Dailam (the Chazarian Sea)* [the Caspian Sea] *is separated from all others, and is not united with any of the seas mentioned. Large rivers and springs, which never fail, discharge their waters into it. Alhaucali reports, that this sea is black at the bottom, and that it unites itself with the Black Sea underground.*

Da Vinci (Chapter 7, The Concept of Circulation) fell into step.

> *In the Bosporus the Black Sea flows always into the Aegean Sea... The Caspian, 400 miles east, always flows through subterranean caves into this sea of Pontus* [Black]*; and the Don does same as well as the Danube.*

The misperception was to be further perpetuated by Kircher's Mundus Subterraneus (1665) world map (Chapter 16, the Maelstrom) showing subterranean connections between the Persian Gulf and the Caspian, the Caspian and Black Sea and the Mediterranean and Red Seas along the line of today's Suez Canal.

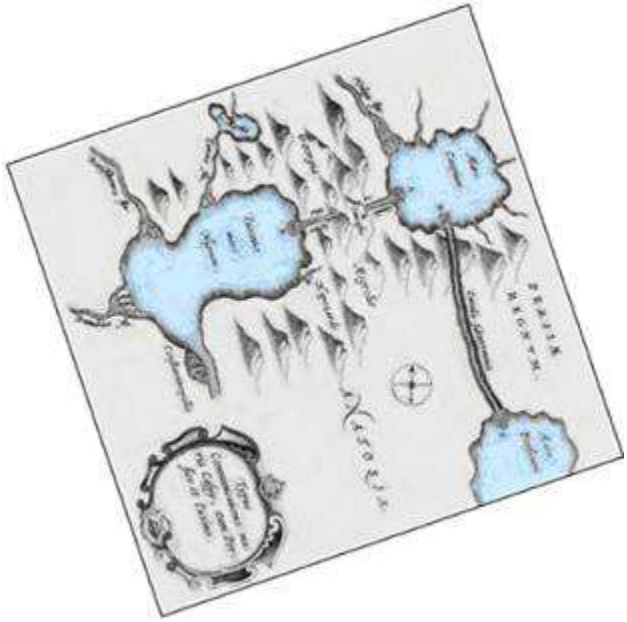


A reason for imagining an "abysso" eastward from the Caspian is suggested in the 1902 Encyclopedia Britannica.

> *In ancient maps of the united Aral-Caspian Sea, two whirlpools are represented. Near the position laid down there are in the river Amu-Daria two whirlpools at the junction of several channels. These have been recently examined and found to arise from the river flowing over two conical hollows in its bed, respectively 120 and 60 feet deep; these do not appear to have been formed by running water, but closely resemble craters of mud volcanoes.*

Kircher's Typus Communicationis Maris Caspy, cum Persico et Euxino (1665) likewise shows conduits from the Caspian to both the “Mare Persicum” and under the mountains to the “Mare Nigrum." We've rotated the map so that north is upwards.



A subterranean Caspian outlet to the Persian Gulf was reported by Jan Struys in Voyages and Travels (1684), and again by Jesuit explorer Philippe Avril in Voyage en Divers Etats d’Europe et d’Asie (1692). The fact that for 1500 years, such geography was re-verified seems odd, but we should keep in mind that early travelers tended to report not only what they themselves witnessed, but what they heard in passing.


As evidenced in the Methodist Magazine, April 1812, credence in an underground river was to persist until modern times.

> *The Caspian Sea, which receives the torrents of the Volga, and of upwards of a hundred large rivers besides, though reckoned in length no more than one hundred and twenty German*

*leagues, and ninety in breadth, has no visible communication with any ocean, into which it can discharge its waters. Necessity, therefore, compels us to allow some secret subterranean passages through which the productions of these enormous rivers are carried off.*

*This necessity will appear still more imperious, when we consider that the Caspian Sea neither ebbs nor flows; and that no visible increase or diminution has ever taken place in the quantity of its waters, though that which is brought to it annually by the Volga alone, has been deemed sufficient to cover the globe.*

The claim regarding the Volga is quite checkable. While in terms of discharge, the Volga is the world's 22nd greatest river, were its annual discharge to be spread over globe, its depth would be but 0.5 millimeter.

Kircher was considered a geologic authority long after his passing. From no less than the Scientific American of June 19, 1847,

*Subterranean Rivers*

*According to Dr. Kircher, the river Volga poured such a quantity of water into the Caspian Sea in the course of one year, that there was not some invisible outlet, it would be sufficient to cover the whole of the earth. According to his account this was in a vast cavern passing under Mount Caucasus into the Euxine* [Black] *Sea, by which the water of one sea disburdened and discharged themselves into others, and the whole kingdoms of Georgia and Mingrelia, under which they ran, were a bridge to these subterranean waters. The same was said of the Persian Bay which is said to be the reservoir of the Caspian Sea. It has also been alleged that there was a subterranean communication between the Red Sea and the Mediterranean. The Niger and the Nile are supposed to run under the mountains of Nubia. A subterranean river wends its obscure race through darksome dens and rocky cliff in the Great Schoharie Cave, and far in the caves of the Cumberland mountains streamlets roar and rush on continually. Above us and below us, the heavens and the earth are full of wonders.*

"According to Dr. Kircher," as if he were on the faculty of Harvard.

**Explanations**

The bar for scientific explanation was slowly being been raised, however. (Not that high, we today might reflect, but at least to a level requiring some degree of mechanics.)

Here we have a pair of Caspian phenomena based on a stab at geochemistry.

In A Phylosophical Essay, Treating of the most Probable Cause of that Grand Mystery of Nature, the Flux and Reflux, or Flowing and Ebbing of the Sea (1673), Thomas Philipot proposed that communication between the Black, Baltic and Caspian is regulated the mechanical power of salts. Volatile salts are “check’d and depress’d” by fixed salts of "sulphur, nitre, and bitumen." so “benumb’d” that it is “impossible for the united influence of the Sun and Moon, to excite their so stupified vigor.”

In other words, salinity benumbs the sway gravity. Philipot continues,

*The water that is treasured up in the cells and caverns of the earth, which, it is probable, here are more than ordinary copious, entice and allure back the marine waters, per motum nexus, by a motion of adherence, aggregation, union, and connection, and so by a continual circulation, reimburse and new-stock the rivers, with additional streams which are daily paid, in so profuse a tribute, to the vast exchequer of their watery sovereign.*

"Aggregation, union, and connection," according to the author, serve to maintain the subterranean flow.

The Encyclopedia Britannica of 1797 noted the underground channels' contribution to the sea's hydrocarbons.

*It is certain that this bitumen flows from the mountains, sometimes in all its purity, and sometimes mixed with other substances which it acquires in its passage through subterranean*

*channels, from the most interior parts of these mountains to the sea, where it falls to the bottom by its specific gravity.*

Eighteenth-century cartographer George Lowitz provided an estimate of the Caspian's elevation, 17 meters below sea level by his barometric reckoning, a determination that would cause any subterranean pipe not to draw from the Caspian, but to promptly fill it with seawater.

Following are three excerpts, one from the popular press and two from texts, dismissing the subterranean conduit for the simple reason of the Caspian's elevation.

Not only does "The Works of God Displayed," Wesleyan-Methodist Magazine, 1812, give credence to the Caspian story, it extends the hydrologic misconception to the entire Mediterranean.

*It is generally believed, and with sufficient evidence, that an immense body of water lies concealed within the bowels of the earth. By what secret aqueducts the internal and external waters have a communication with each other, we know not; but several circumstances concur to confirm us in the opinion that it must be so.*

*The Caspian Sea, which receives the torrents of the Volga, and of upwards of a hundred large rivers besides, though reckoned in length no more than one hundred and twenty German leagues, and ninety in breadth, has no visible communication with any ocean into which it can discharge its waters. Necessity, therefore, compels us to allow some secret subterranean passage through which the productions of these enormous rivers car carried off. This necessity will appear still more imperious when we consider that the Caspian Sea neither ebbs nor flows, and that no visible increase of diminution has ever taken place in the quantity of its waters, though that which is brought to it annually by the Volga alone had been deemed sufficient to cover the globe. It is to be observed, as a remarkable exception to the statement given of the stability of the waters of the Caspian Sea, that though it has no tides, yet once every 14 or 15 years, the waters rise several fathoms.*

*Nor is the case of the Mediterranean a matter of less astonishment that that of the Caspian Sea. The amazing tides which are bringing immense quantities of water into it through the Straits of Gibraltar, and those of the Marmora, or the Black Sea, without any visible means of discharge, would long since have inundated that part of the world, were there not some secret channels which carry off its waters, to say nothing of the numerous rivers which empty themselves into its copious bodies.*

The Scots Magazine and Edinburgh Literary Miscellany, November 1816:

*Some years ago, Messrs Engelhardt and Permt undertook a journey to the countries that divide these two seas, partly to examine the Caucasus, but chiefly with a view to subject the relative heights of the surface of these two seas to a barometrical measurement.*

*They found the difference between the surface of the two seas, 92 meters. It was the opinion of Pallas that the level of the Caspian Sea had formerly been much higher than at present. This opinion is confirmed by Perrot and Engelhardt, who place the ancient height 234 meters... above the present level; so that the quantity of water lost must be immense... They conceive that it has made its escape by means of subterranean channels, which occasionally open. But the possibility of such an escape, at least into the Black Sea, seems problematical. The surface of the Black Sea being so much higher than that of the Caspian, if any such channels had existed, the water ought to have moved the contrary way, and increased, instead of diminished, the size of the Caspian.*

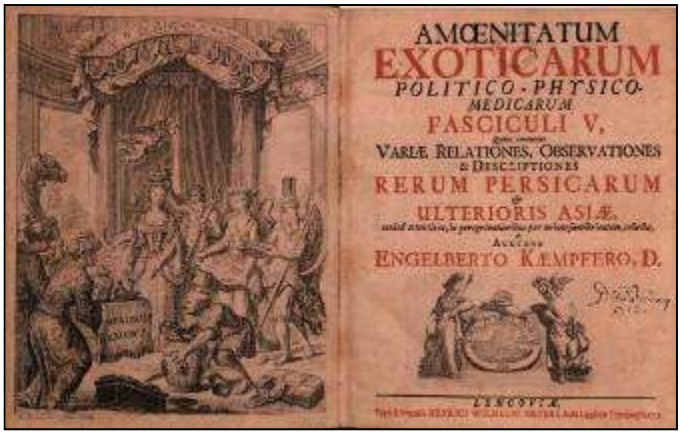
Physical Geography of the Sea (1855) by Matthew Fontaine Maury:

*As far as we know, the level of these seas* [the Dead Sea, the Caspian and the Aral] *is as permanent as that of the ocean, and it is difficult to realize the existence of subterranean channels between them and the great ocean. Were there such a channel, the Dead Sea being the lower, it would be the recipient of ocean waters; and we cannot conceive how it should be such a recipient without ultimately rising to the level of its feeder.*

School Geography (1864) by James Clyde:

> *The Caspian Sea is the largest salt lake in the world. It receives many rivers -- of which the Volga is by far the largest -- and has no outlet; yet it is gradually subsiding. The ancients supposed a subterranean channel, by which its superfluous waters were discharged into the Euxine; but that cannot be, since its level is 80 feet lower than that of the Euxine.*

An underground river was deemed unlikely for an entirely different reason by naturalist Engelbert Kaempfer in Amoenitatum Exoticarum (1712). Willow leaves found in the Persian Gulf did not need to come from the Caspian shore; the banks of the Euphrates were sufficient to furnish them.




Thanks to Edmond Halley's 17th-century measurements (Chapter 12, Superterranean Metrics) were, the magnitude of a sea's evaporation was well recognized, as noted in a pair of magazines.

The Christian Miscellany, and Family Visitor, August 1853:

> *The volume of water poured into the Caspian by the Volga, and its other numerous affluents, must undoubtedly be very considerable: it has, however, no visible outlet; and to account for the disposal of its superfluous waters, it has been supposed that these are carried off by a subterranean channel; though it is asserted by others that the evaporation from this extensive surface, comprising an area of 147,000 square miles, is sufficient to account for their disappearance,*

Scribner's Monthly, August 1871:

> *The* [Caspian Sea] *receives several large rivers into its bosom, from which they never emerge. No outlet carries off this eternal flow of water, which in olden times gave a mysterious character to it. Some dark subterranean channel was supposed to constitute the outlet; but modern science has shown that the water escapes by evaporation. Notwithstanding this endless influx of fresh water from several broad rivers, this inland sea of between six and seven hundred miles long is never freshened. Sunk nearly 400 feet lower than the ocean, as though the crust of the earth had once given way where it spreads, its yellow, turbid, tideless waters lave a desolate, sickly shore.*

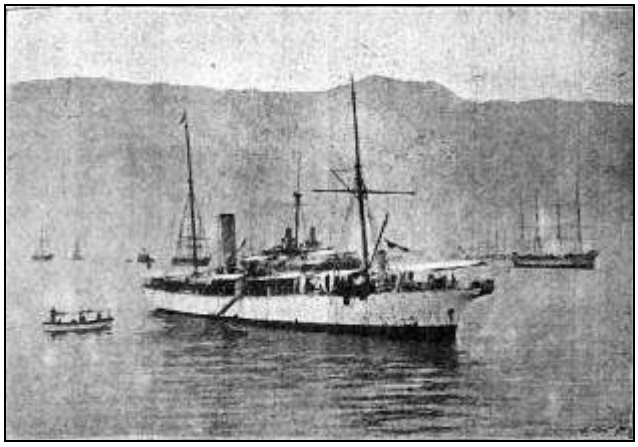
As would the nearby Aral Sea disappear a century later, thus disappeared the Caspian's subterranean river. A very liquid Aral was lost by environmental mismanagement. The Caspian's underground river, on the other hand, a product of logic in itself, was at last dismissed by logic.

# CHAPTER 76

# ON SOME REPAIRS TO THE SOUTH AMERICAN COMPANY'S CABLE


We're in the waning years of the 19th century. Intercontinental telegraphic communication have been at lightning speed since the completion of the transatlantic cable in 1858 and now the engineering marvel is being extended by cable-laying steamships to all corners of the world.

Our story deals with the difficulties encountered in laying a 3-centimeter cable from St. Louis, Senegal, West Africa to the island of Fernando Noronha, 400 kilometers off Pernambuco, Brazil.

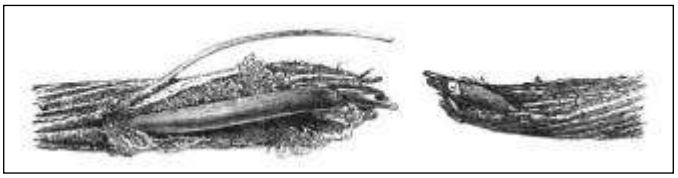


CS (Cable Steamship) Relay, belonging to the Central and South American Telegraph Company, 1898

Eastern terminus, Pernambuco - St. Louis cable

The frustration was a series of cable breaks occurring not as the cable was laid -- an engineering problem -- but after the cable was at rest on the ocean floor and telegraphic signals had been successfully transmitted.

To the right is the break of 1893 grappled from the seabed 2200 meters below.



The paper "On Some Repairs to the South American Company's Cable off Cape Verde in 1893 and 1895" read by Henry Benest to the Institute of Electrical Engineers in 1897 and subsequent professional discussion provides insight into the era's scientific understanding of submarine springs and rivers, geology of which we introduced in Chapter 39.

Benest's presentation was reported in numerous journals:

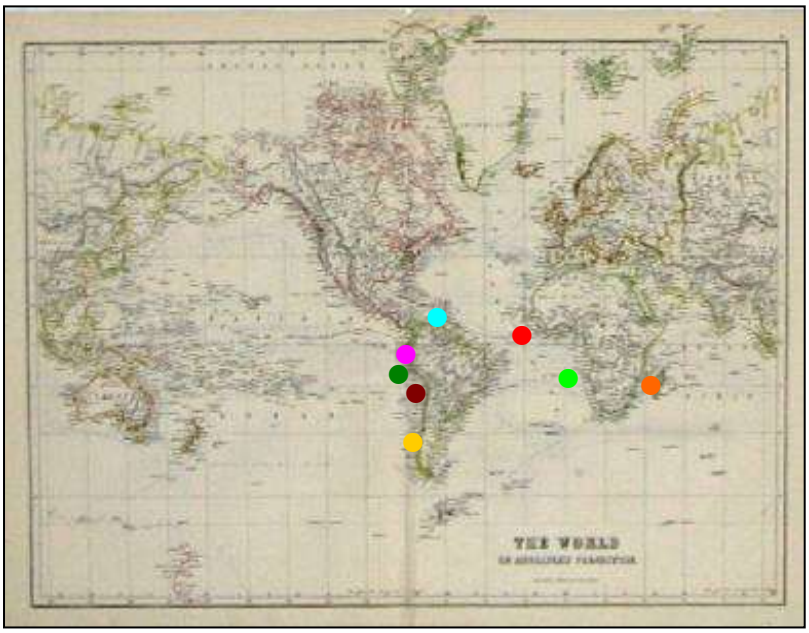
"Repairing a Submarine Cable," Engineering, March 12, March 19, March 26, 1897
"On Some Repairs to the South American Company's Cable off Cape Verde in 1893 and 1895," Electrician, March 25, April 2, 1897
"On Some Repairs to the South American Company's Cable off Cape Verde in 1893 and 1895," Journal of the Institution of Electrical Engineers, April 2, 1897
"On Some Repairs to the South American Company's Cable off Cape Verde in 1893 and 1895," Electrical Engineer, April 2, 1897
"Proceedings of Societies, Institution of Electrical Engineers, Discussion on Mr. H. Benest's Paper," Electrical Review, April 9, 1897
"Submarine Gullies, River Outlets, and Fresh-Water Escapes Beneath the Sea-Level," Geographical Journal, October 1899

To avoid excessive citations, we'll consider the above articles to be one continuous piece and likewise consolidate the published discussion (sometimes appended to the original article and sometimes in later issues of the respective journal) into that compilation. Much of the contents deals with electrical technology, but we'll confine our review to thoughts regarding submarine springs and rivers. We'll update geographic references to modern naming and employ metric units to assist comparison.

For his contribution to the profession, Benest was awarded the Institute of Electrical Engineers Fahie premium of £5, the gold coin of that denomination to the right.

Benest's report dealt with a cable break off Senegal, but the topic evoked similar stories which we'll mark on the period map.

- Senegal
- Talara
- Punta Pescadores
- Chile
- Ecuador
- West Indies
- Sao Thome
- Mozambique



**Senegal**

As the original portion of Benest's contribution concerned the cable breaks off the coast of Senegal, we, too, will begin there.

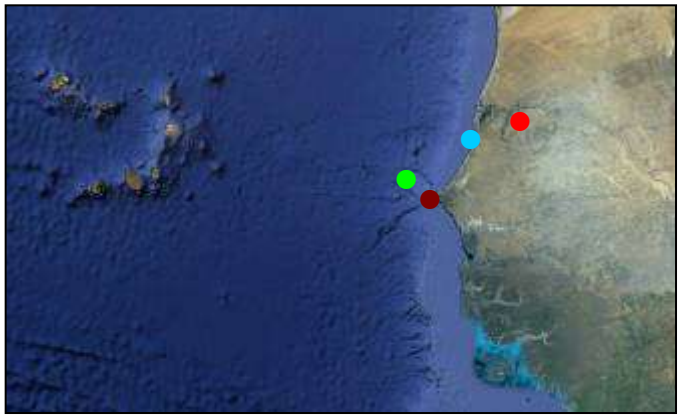
> *A very remarkable phenomenon, strongly favoring the theory that a submarine river outfall now exists near to Cape Verde* [the peninsula, not the islands further west]*, was witnessed during the afternoon of April 23, 1895. While engaged in grappling [for the broken cable 21 kilometers*

*from the coast], the ship was gradually surrounded by great quantities of vegetable growth, having the appearance of river weed. There were also birds' feathers, pieces of orange-peel, whole and broken gourds, scraps of carpet, pieces of driftwood, small branches, etc., and the color of the sea had changed to dirty brownish green.*

*On the following morning all this had disappeared, and the sea had regained its usual tint of a pale green. The nearest surface river outlet is that of the Senegal, 125 kilometers distant in a north-easterly direction, and it would appear most unlikely that such flotsam as pieces of carpet could have been carried by the coast current, which sets to the south-south-west, to so great a distance.*

*If the coast current had brought these masses of weed and refuse of human habitation out of the Senegal River, it would have been a more or less constant and familiar appearance, as would also the color of the water; but the discoloration of the sea-surface with the accompaniment above described was local, and would appear to be due to a sudden outburst of river-water in the vicinity and below sea-level.*

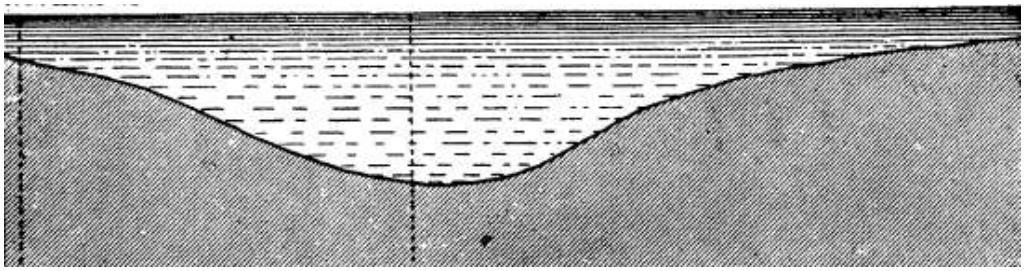
- Senegal River
- St. Louis
- Dakar, Cape Verde Peninsula
- Cable Break



Cape Verde Islands Senegal

*Well-known authorities agree that in the tropics the month of March is a rainy month, therefore it is fair to assume that heavy falls of rain take place about this period in the unknown interior of Africa and America; while on the shore-lines near where the cables have been broken, there is nothing but sand for miles around,, and comparatively little rain. The rains from the interior find their way to the sea by surface rivers in some cases, and by subterranean rivers, in all probability, in others, their subterranean flow being not merely percolation through porous strata, but large volumes of water flowing through caverns and crevices in the Earth's crust. These volumes of water have their source in the mountains, and find their outlets at sea.*

*The river shown on the map of Cape Verde point is probably a small stream fed locally, but the lagoons are created by springs from artesian water. Then, carrying the eye from these lagoons to the sounding of 420 meters, a crust of water-covered shore sand will have been traversed, and seaward of the 420-meter spot there is the head of a large gully. That gully, by the formation in its neighborhood, could never have been formed by a surface river, because one finds 420 meters increasing almost precipitously to 1100 and 1280 meters. Mr. Gray believes that at about 1100 meters from the surface, and at about 110 to 130 from the bottom, the outlet of the river will be found, and that at certain seasons, in the month of March probably, a geyser-like effect is produced.*



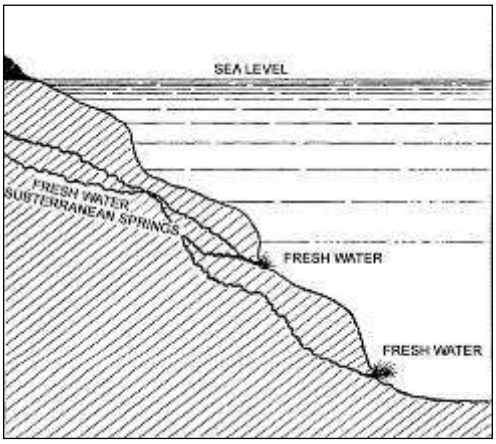
Section Across Gully at Cape Verde, Narrowest Part

*A river, the higher reaches of which are crossed the railway between St. Louis and Dakar, now discharges, in the wet season, into these lagoons, but in the dry season the water disappears in the sandy bed before reaching the neighborhood of the coast. Water is always present; the river exists behind these lagoons which are in a direct line between that river and the head of the gully. These facts are significant of a former surface outlet, and a submarine connection between river, lagoons, and the sea at the present time.*

*The limits to which water gravitates into the earth is beyond the powers of direct observations, but, as it is known from the formation of many basins, that the strata of which they are composed reaches a thickness of from 6200 to 9400 meters, it is reasonable to infer that they are permeated by water to an equal depth. It would be equally reasonable to infer from this, that artesian outbursts may, and very likely do, occur at various depths in which submarine cables are laid.*

Benest's assertion of the submarine spring drew a multitude of responses.

The Journal of the Institution of Electrical Engineers produced a graphic, entirely correct in today's understanding.




Robert K. Gray noted that within the last eight or ten years, "Capt. Martele" [the Martel of our Chapter 54, Subterranean Watercraft] had been making "considerable investigations in the direction of cave hunting" and there was no reason why limestone should not exist under the sea. Subterranean conduits egressing from the submarine continental slopes may indeed be "the cause of cable interruptions which occur at the period of the year which coincides with the season of heavy rains in the interior."

The remedy for the cable problem, concluded Gray, would be placing the cable at an elevation higher than the outlets, "so that the intermittent vomiting of terrigenous debris, though continuing to cause submarine landslips would no longer find a cable laying at right angles to its path."

Sir Henry Mance, President of IEE, saw no reason why there should not be fresh water streams 200 or 300 kilometers from shore, but judiciously withheld calling them rivers.

> *Now, without giving these submarine fresh-water streams the dignity of calling them rivers, we may easily imagine (in fact, we know to a certainty they exist) streams of water making their way for many miles out to sea before breaking ground.*

Mance was extravagant in his estimate of distance, however, as the conduits would have been formed before submersion. The world's longest terrestrial karst systems extend no more than tens of kilometers as the crow flies, and that's with occasional breaks to the surface. The highest sub-sea level karst opening would preclude submarine flow further down the pipe.

James Anderson, another Knight of the British Empire, expressed no doubt that submarine streams are the cause of cable failure.

But there were those who disagreed with Benest's contention, and generally for valid reasons.

Mr. W.H. Precce found proof lacking for a submarine river, but rather that Benest had proven the existence of a submarine current. The proliferation of journal discussion only confirmed the writer's long-held contention that "it was absurd to lay a submarine cable unless something was known of the bottom on which it was to rest."

Admiral Sir William James Lloyd Wharton, hydrographer to the Admiralty, doubted --and correctly so, we add --that there would be sufficient head behind a submarine outflow to move matter violently along the sea bottom and he thought some other cause must be sought for the power to move sea bed matter. Nobody, however, seemed to recognize the admiral's logic.

Mr. Chas. Bright was likewise not in agreement with Benest's submarine spring culpability.

> *It was highly improbable that pieces of carpet and other refuse of human habitation should be discharged from an artesian well. The proximity of the month of the Senegal River was a more likely explanation of the appearance of these fragments.*

The bulk of discussion then turned toward reports elsewhere. We'll begin with those from Peru.

**Talara, Peru**

> *Reverting to the subject of cable repairs as being the indirect source of our knowledge of underground rivers having their outlets under the sea, a remarkable experience occurred during a repair conducted by Captain Lugar of the Central and South American Telegraph's Company steamer Relay to the cable connecting Paita, in Peru, with Santa Elena, in Ecuador. The fracture had been located at about 15 kilometers west from the small harbor of Talara... The section of cable affected was noted for the regularity of its rupture nearly every year, about the end of March or early in April. The weather was fine, with light breezes and smooth water; in fact, in this locality gales are unknown, and rain seldom falls near the coast; but, beyond 80 kilometers inland from Talara, at times the downpour is exceedingly heavy.*

Seasonal correlation between inland precipitation and submarine cable breaks was a perception shared by many.

| | | |
|---|---|---|
| Proposition: | When A, then B for reason C | where, |
| Observed: | Cases of A and B | A = Terrestrial flood season |
| Observed: | Cases of not B and not A | B = Submarine cable break |
| Therefore: | C | C = Cable snapped by submarine flood surge |

To test the logic, let A be Easter, B be showers and C be precipitation caused by Easter eggs.

The next excerpt falls within a larger collection of underground river lore, detailed reports attributed to unnamed observers.

> *Some few months later, during a conversation with one of the officials of the Talara Petroleum Company about the nature of the bottom outside their harbor, this gentleman informed Captain Lugar that a Peruvian half-caste he had employed at the wells asserted that beyond the Amotape mountains, which lie at the back of Talara, there exists a chain of lakes which has an outlet through a hole in the mountain-side, and that canoes and paddles lost on the lakes had*

*been found on the coast between Talara and Parina point. This evidence certainly goes far towards proving the existence of a submarine river in this particular locality, and the period of the greatest outflow would appear to be in the months of March and April. These months coincide with the time of the heaviest of the rainy season in the Cordilleras and Amotape ranges.*

Artifacts -- canoes and paddles, in this case -- lost on lakes and found on the coast are a staple of underground river legend. While the testimony of a "half cast" alone might be dismissed by the readership, that both an official of a business firm and a sea captain deem the report worth repeating affixes a stamp of legitimacy.

**Punta Pescadores, Peru**

Several of the following paragraphs seem to concern the same cable failure, not all. In any case, the story's the same. As with the Gospels, it can take multiple accounts to chronicle a saga.

*Another remarkable experience has been communicated by Captain D. Morton, who was at the time (March, 1884) in command of the West Coast of America Telegraph Company's steamer Retriever. During a repair to that company's cable on March 4, 1884, in 1200 meters of water, 19 kilometers off Pescadores point, and while picking up towards the break, and when close to it, the cable came up completely surrounded with twigs and branches of olive trees to such an extent that they bad to send men over the bows with axes to clear them away so as to allow the cable to come in over the bow-sheave.*

*The Ocoña River, 21 kilometers north from the position of the break, does not flow into the sea, but into a basin or lagoon a quarter of a mile from the sea, and during heavy rainstorms in the mountains this river is transformed into a torrent carrying everything with it. Rapidly pouring into the basin or lagoon, it raises the water-surface above the sea-level, and no doubt, when a certain pressure is relieved by the water in the basin or lagoon again reaching the sea- level, a subsidence of the sea-bottom takes place, carrying the bight of the cable with it. The nearest river outlet flowing into the sea is the Quilca River, 85 kilometers east-south-east from Pescadores point.*

It's odd how the Ocoña is dismissed with such ease, as seamen of the day would have known that flotsam can drift much further than 85 kilometers.

*Mr. E.W. Parsone relates that, during some cable repairs carried out... in the neighborhood of Pescadores. The cable at this spot was repaired many times, and ... was got up with difficulty, bringing up with it masses of branches and trunks of trees, which had to be cut away with axes before, the cable could be got inboard. These branches and boles were the remains of olive trees, which do not grow along the coast; they doubtless came from the Arequipa district* [i.e., *the* Quilca]*, some 130 kilometers inland, where olive groves abound.*

Masses of branches and trunks of tress "disappeared... underground to emerge at sea by a submarine exit" adds drama, and as we appreciate olives, we feature of the Peruvian green variety

*It would appear that these remnants of vegetation had drifted with the surface river water from the interior, and had disappeared with it underground to emerge at sea by a submarine exit. To support this idea, the breaks in the cable generally occurred after freshets due to rain in the interior. The cable was eventually diverted towards the shore, and no further trouble has been experienced, which would seem to prove that the cable had been laid shoreward inside and above the submarine river outlet.*

It's the same A-B-C logical error as before.

The next excerpt isn't about a cable break, per se, but rather an on-shore observation.

> *A very remarkable instance of a river having its course underground exists to the north of Arica, a port on the coast of Peru* [today part of Chile]. *The bottom of the river valley consists of loose sand, no evidence of water being apparent. At a depth of some 5 meters, however, a firmer stratum of sand is found, and a continuous current of fresh water is distinctly observed as the water rapidly filters through the sand into and out of the pit. This subterranean stream is met with as a rapidly flowing river some distance inland and among the higher foothills of the great mountain ranges, but speedily disappears on entering the sandy and rainless coast region again.*

We've nothing remarkable in an arid coastal region -- a losing stream that feeding an aquifer 5 meters below it which in turn percolates to the ocean.

**Chile**

> *During the month of October, 1878, the West Coast of America Telegraph Company's steamer Retriever, then newly out from England, under the command of the writer, repaired the section of cable between Valparaiso and La Serena... The writer was told, after the repair in 1878, by people... well acquainted with the Limari valley, that, during floods inland in the winter season, this river rose and inundated its banks for many miles, carrying away cattle and buildings, shrubs and trees, but none of these could possibly have escaped to sea through its surface outlet.*

Why the flood debris couldn't wash to the sea -- a dubious pronouncement, given the visible channel -- we're not informed.


**Ecuador**

> *The Central and South American Company's officials off Point Esmeralda, in Ecuador, had a similar experience, and surmounted the difficulty by laying the cable above the supposed submarine river outlet.*

We've a similar problem (a submarine cable break), a remedy (replacing the cable with one at a higher elevation), and the inference of causation (a submarine river outlet). Again the A-B-C logic.

**West Indies**

> *Captain Lugar cites one other instance of a submarine outburst of fresh water which had come under his personal notice off the Dutch island of Saba, a volcanic cone 470 meters high, 66 kilometers north-west of St. Kitts, in the West Indies. He visited by boat a spot in the sea about one-third of a mile from the shore on the south-west side of the island, and saw the fresh water bubbling up in small circles. He sampled some, and found it brackish to the taste. The native who guided him to the spot averred that sloops and schooners frequently filled up their barecas from this submarine stream of artesian water... He thought this suggested that there were such things as submarine streams and that cables were broken by them.*

*Mr. H.C. Donovan related a case of a West Indian cable repair in comparatively shallow water. Considering the cable had been down only four years, it was surprising how it was coated with vegetable growth. In deeper water, however, as they got to the break it was scoured, and presented signs of severe distress. The galvanized iron was scoured bright. That was between Martinique and Dominica, in 2900 meters. There could be no question of any rivers there. He, however, knew of various cases of brackish water due to submarine outflows.*

As the West Indies have both karst aquifers and thermal vents, it is indeed conceivable that water might well up in the shallow offshore, though there's no modern marine springs sufficient to provision a ship. A karst outlet could not sever a telegraph cable, but as the region is volcanically active, it stands to reason that a seafloor tremor might part a taunt cable.

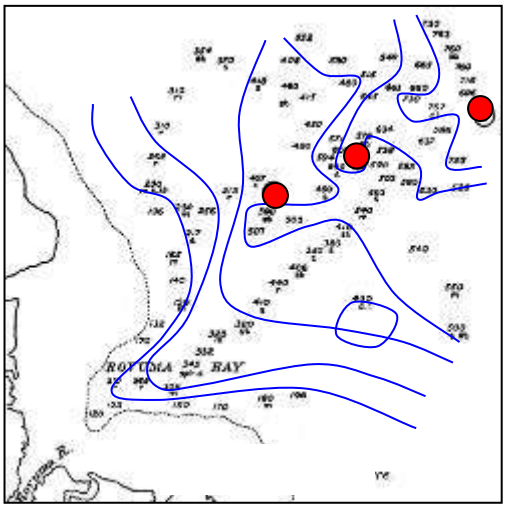
**Sao Thome**

*Immense masses of mud are in continual movement off the Congo River, and extend to some hundreds of miles to the westward; but here is a very deep river debouching right into the sea, and scouring out a channel hundreds of fathoms in depth. The West African Telegraph Company's cable between Loanda* [modern Gabon] *and the island of Sao Thome has been broken seven or eight times since its laying in 1880, and some hundreds of miles of cable have been used in repairs.*

The mighty Congo is feared to be slicing open the seabed, decimating whatever lies in its path.

**Mozambique**

To the right is the survey of Romuva Bay reported by Benest, the 100-fathom (183-meter) contours added. The three cable breaks (red circles) lie within the trough.




*On other similar occasions a like course had been adopted, notably off the Rovuma River, in the cable between Zanzibar and Mozambique. The last mentioned of these two cables broke down eight years in succession. Since it has been relaid inshore, some twelve years ago, it has never broken down, and this is doubtless due to the cable being laid shoreward of the submarine river outlet, which probably still continues to periodically throw out its debris.*

Once again, the A-B-C logic.

*Captain Lugar: Off the Rovuma River on the East Coast of Africa... similar conditions have been met with in repairs to telegraph cables... Much trouble had been experienced with the cable between Mozambique and Zanzibar, and the conclusion arrived at was that the cause originated in fresh water making its way to the surface from the sea-bottom, disturbing the ground and fracturing the cable.*

The Captain is correct that fresh indeed rises, but he's incorrect that it does so at a cable-fracturing velocity.

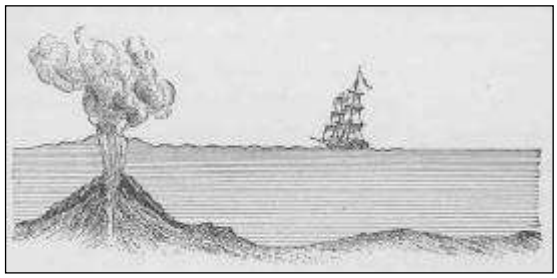
**The Chairman's conclusion**

The Chairman's summary, per the 1897 minutes of the Institute of Electrical Engineers,

*Benest's theory that the cable breaks, described in his paper, were caused by a submarine river found a number of supporters, though the majority of the authorities appeared to think the evidence was insufficient.*

**But if submarine rivers were not to blame, why, then, did the cables break?**

Were the breaks due to submarine volcanoes?



An illustration from Sonrel's Bottom of the Sea (1872)

From the discussion of Benest's contribution,

> *Mr. Pierce said the paper... showed how much geographers were indebted to telegraph engineers. He considered that the high temperature at the sea bottom was evidence of the existence of a current, though it perhaps was not sufficient to prove the existence of the Benest river... He had no doubt that cables were sometimes broken by volcanic agency, and instanced some examples on East African and Australian cables. The proposed Pacific cable would run over a region known to be subject in some parts to volcanic action, and, therefore, it was of the greatest importance that a previous survey should be made of the sea bottom. In a paper read in 1859 he had said that the sea bottom should be surveyed before a submarine cable was laid. His proposition was met by the derisive laughter with which ignorance always greets words of wisdom, but since then wisdom had, as usual, been justified of her children.*

We applaud the concluding sentence regarding ignorance. A further century of cable laying, however, has never spanned a submarine volcano.

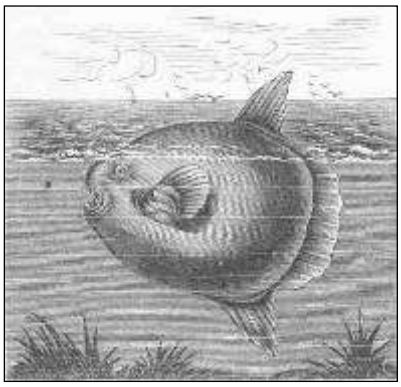
Were the cables broken by whales?

"A Whale Breaks a Submarine Telegraph Cable," Scientific American, December 14, 1889, described an experience of the Western and Brazilian Telegraph Company's CS Viking.

> [The vessel] *brought up to the surface a monster dead whale, measuring about 50 feet long, intact with the exception of the upper part (the belly) from which all skin had been worn or eaten away... The tail of the whale had two complete turns round the shank and three or four across the flat or fan part.*

> *The above, by Mr. Peters of the Viking, is the third instance in which whales have broken telegraph cables... The supposed cause is that the cables were hung like festoons through being laid too tightly over uneven ground, and that the whales used them as rubbing posts.*

Were the cables severed by other sea creatures?



"Dangers that Beset Submarine Cables," New York Times, July 6, 1878,

> *In many cases, owing to the inequalities of the bottom or the sea, the wires... hang like festoons. Then they are liable to accidents from the larger denizens of the sea, among which we may particularly mention the sun-fish (Orthagoriscus). When swimming it turns round like a wheel and moves with great rapidity... Specimens have been caught weighing 500 pounds... Not long since the interruption occurred in a cable, on examination it was found that it had been penetrated by one of the caudal spines of the sun-fish.*

Or were the cables broken by turbidity currents, a phenomenon described in Chapter 44, Submarine Springs and Rivers?

A 7.2-magnitude earthquake off Newfoundland in 1929 triggered a submarine landslide of 200 cubic kilometers in volume down the Grand Banks slope, snapping a dozen submarine telegraph cables in route, the sequence of which provided the 40-80 kilometers/hour estimate of flood-pulse velocity.

Following a cable break off Columbia's Magdalena River in 1935, cable retrieved from 1500 meters had large masses of shallow-water marsh grass twisted around it, evidence of extensive sub-oceanic sediment flux.

Like cable failures yet to occur elsewhere, the South American Company's difficulties seem to have been due to turbidity currents, infrequent in occurrence, but massive in submarine havoc.

But as we're well aware, it's hard to rid our imagination of streams blow. From "Fallacy of the Deep-Sea Erosion Theory," Surveyor and Municipal and County Engineer, October 12, 1906, by Gerald Case,

> *In very deep water telegraph cables have been broken and buried under large masses of materials. Such local displacements of the ocean floor are due to earth movements and also to submarine springs.*

And from where did Case draw his submarine springflow add-on, we ask?

From "On Some Repairs to the South American Company's Cable off Cape Verde in 1893 and 1895."

As with much lore of underground rivers -- under the land, under the sea, it matters little -- refuted conjecture again and again reworms its way into our knowledge base.

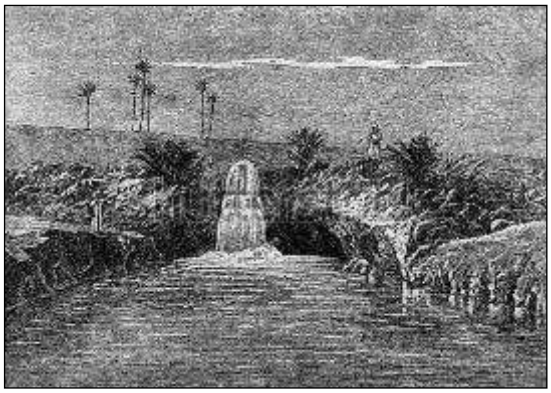
# CHAPTER 77

# SUB-SAHARAN STREAMFLOW, THE SARASVATI AND SHAMBHALA

In this chapter we will visit one underground river in Africa and two in Asia, or at least stories thereof, where we can observe how such stories resemble, if not reinforce, persistent beliefs in Western culture.

**Sub-Saharan Streamflow**

The desert wellspring is one of our more-beloved images.



"Artesian Spring in Algeria" from Starting Course of Geography (1926)

We encountered Pliny the Elder in Chapter 14, where the Roman geographer wrote of a marvelous underground river flowing eastward from what is now Morocco to a lake in what is now Algeria or Tunisia, then sinking once more and at last re-emerging as headwaters of the Nile.

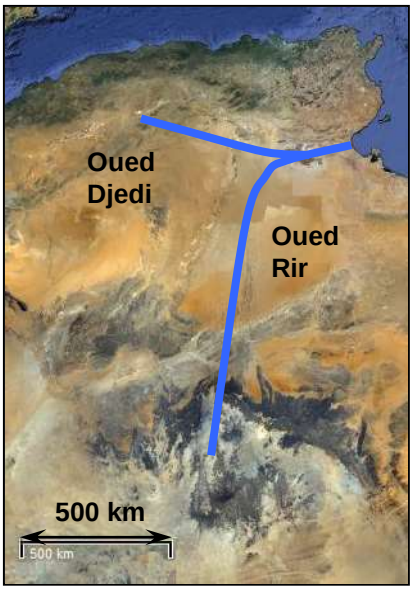
In this chapter we'll not seriously argue for the Nile connection, but we'll look a bit more closely at the middle reach of Pliny's river, the portion that would cross -- perhaps over, perhaps under -- the Sahara. We may think that part unlikely also, but, as we will see, many have argued for its existence.

In the sixth century, Olympiodorus of Alexandria wrote of 200-meter spouting wells across the Sahara. The 14th-century Tunisian historian Ibn Khaldoun considered them "a miraculous fact."

By the time of documentation by Northern European geographers, evidence of Sub-Saharan waters was limited to a few oases, but speculation for systems vastly larger remained. "Artesian Wells and the Great Sahara," Popular Science Monthly, February 1880, by Seaton Schroeder, designates the dry wadies of the desert as "underground streams" having histories of surficial flow.

*Nearly all the fluvial network of the Algerian Sahara converges toward the Igharghar. Formed by the confluence of several small streams on the slopes of the Ahaggar, it flows northward, and soon sinks through the light sands and pursues its underground course to the western part of the basin that the French contemplate inundating, bearing in that part of its course the name of Oued Rir, or River Rir. Into this same depression flows another subterranean stream, the Oued Djedi, which has its sources on the plateau of Laghouat in the west. The two streams in all probability united in past ages, and possibly even connected with the Mediterranean.*

The Algeria/Tunisia map to the right indicates the locations of the supposed ancient free-flowing rivers, uniting and connecting with Mediterranean.




**The French**

While stories of a great Sub-Saharan river have been told since antiquity, we will not re-enter the chronology until the time of French colonialism in the mid-1800s. The French "explorateurs" were quick to note Saharan soils rich in nutrients, lands prime for irrigation.

A significant perceptual difference between the French tapping of underground waters and what was likewise occurring in the United States -- the subject of chapters to come -- was that the French reasonably understood with what they dealing, while most American farmers did not.

As groundwater hydrology (Chapter 39) had its scientific roots in 18th-century French academics, an officer of the French Foreign Legion was likely to recognize a natural fountain in an otherwise-arid landscape for exactly what it was, a "fontaine artésienne," not a "rivière souterraine." In subsequent chapters dealing with water in the American west, the popular reporting will contain less stratigraphic edification and more fanciful tales mysterious below-ground rivers.

"Wells in Sahara," New York Times, September 17, 1882, illustrates the French attention to permeability, inclined aquifers and aquicludes, the precise sort of geologic metrics required for successful water resource development.

*As for the rocks which underlie the sandy deposits, what we know of them is due to numerous wells sunk by the Frenchmen all along the northern boundaries of the Sahara, particularly in the Province of Constantine. The learned engineer, M. Jus, who during 20 years has directed those admirable works, ranges in the Pliocene formation the different rocks, limestone, sandstone, marls, gypsum &c., crossed by the soundings, as well as the impermeable water-bearing clay which forms at the bottom of wells. This clay presents the most astonishing discrepancies in its level, being sometimes many hundred feet under the surface of the soil, and sometimes approaching it very near. So for instance, in the region of the Oued Rir, two wells named Ain-Kerma and Un-el-Thier, are distant one from the other about 40 miles, and still the depth of the first is only 44 feet, and that of the second 321 feet.*

In "Artesian Wells and the Great Sahara," Popular Science Monthly, February 1880, Seaton Schroeder describes the French well-drilling success at Sidi Rached.

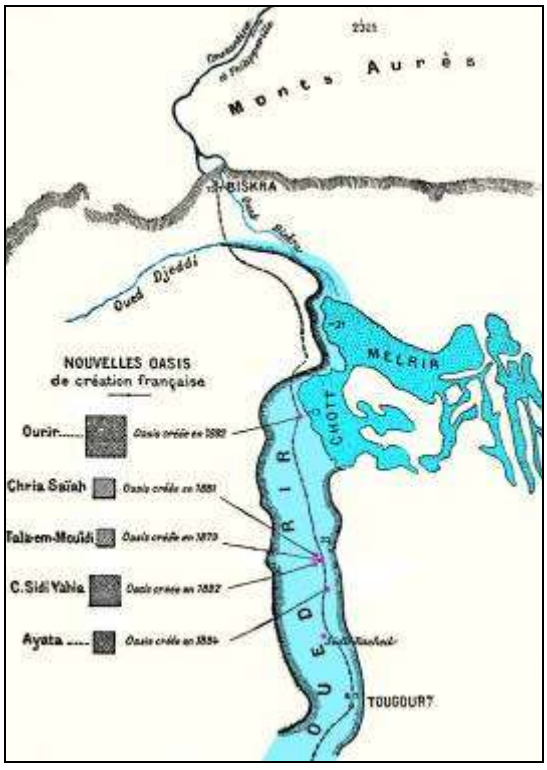
*General Desvaux, however, commanding the subdivision of Batna, kept studying assiduously to find means of fertilizing the barren regions around him.*

*He experienced some delay, of course, but finally in 1856 the material arrived at Tamerna, and on the 1st of May of that year the first blow was struck by Ali-Bey, the Caid of Tugert. The work was pushed rapidly forward, and on the 9th of June water issued in volumes. Lieutenant Rose, of the French army, describes the scene as being most affecting, comparing it to the miracle of Moses drawing water from the rock by the touch of his rod; the old sheik prostrates himself, mothers bathe their children in it, and it is blessed and named the Fountain of Peace. The issue of water was 69,725 gallons a day, temperature of 70° F.*

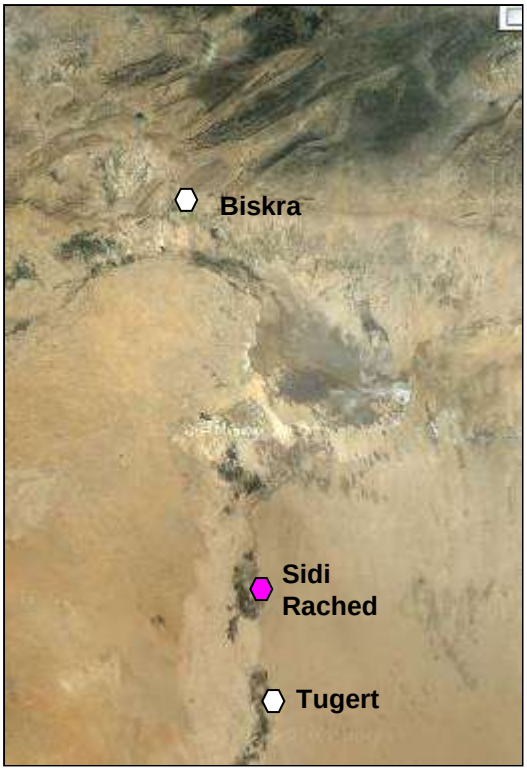
*In eight years, 1856 to 1864, the French Government established in that vicinity (between the Ziban oases and the river Rir) seventy-two artesian wells, of which twenty-four had been previously abandoned in course of execution by the natives... The deepest was at Chegga, 364 feet; the least depth at which water was found was twenty feet. The ordinary depth was between 160 and 225 feet, and the average temperature 76° F. The largest issue of any was 1,267 gallons a minute from that of Sidi Amran, 255 feet deep.*

By the end of 1879, 434 wells had been bored by the Arabs and 68 by the French between Biskra and Tugert.

The map below shows French artesian wells in the wadi of the Oued Rir. For reference, Biskra and Tugert are 200 kilometers apart.




L'Oued Rir et Ses Nouvelles Oasis de Création Française (1889)




Modern Aerial Photo

Below are two of the French successes.


Sidi Amran (Sidi Rached) Oasis

Tugert

Sketches from Gabriel Hanotaux and Alfred Martineau, Histoire des Colonies Françaises et l'Expansion de la France dans le Monde, (1932)

Such news was of great interest to Americans, and in an era of free-wheeling journalistic plagiarism, stock news items circulated freely and not uncommonly, even reappeared in the same newspapers as new news.

Two news clippings illustrate the popular reporting, each identifiable by its poetic title and each retrievable from any number of archived periodicals.

> *Modern science is literally making "the desert to blossom as a rose." In the great desert of Sahara in 1860, five Artesian wells had been opened, around which, as vegetation thrives luxuriantly, thirty thousand palm trees and one thousand fruit trees were planted, and two thriving villages established. At the depth of a little over five hundred feet, an underground river or lake was struck, and from two wells live fish have been thrown up, showing that there is a large body of water underneath.* -- "The Desert to Blossom as a Rose," Scientific American Mar 12, 1864

> *Perhaps no more hopeless enterprise could be undertaken than to attempt to reclaim the great African desert of the Sahara, where no rain ever falls, and there are but occasional oases to give relief to the weary and fainting caravans that traverse it. Modern science, however, laughs at seeming impossibilities. Skillful engineers in the French Army in Algiers proposed to sink Artesian wells at different points, with the strong confidence that thus water could be reached and forced to the surface. In 1860 five Artesian wells had been opened, around which, as vegetation thrives luxuriantly, thirty thousand palm trees and one thousand fruit trees were planted, and two thriving villages established. At the depth of over fife hundred feet, an underground river or lake was struck, and from two of them live fish have been thrown up, showing that there was a large body of water underneath.* -- "In the Wilderness," The Friend, a Religious and Literary Journal, May 21, 1864

Numerous American newspapers drew upon the correspondent of the Moniteur de l'Armes, a French military newspaper, to report upon the piercing of the well at Sidi Rached.

> *At the moment of water bursting forth, no Arab was present, but the news quickly spread, and in a few minutes the whole population of the village rushed to the spot and threw themselves upon the works with such frenzy that force was necessary to remove them. Women and children lay down in the stream, as if they had never seen water before. The Sheik of Sidi Rached could not repress his emotion; he threw himself on his knees by the trough and wept for joy. The next day the inhabitants of the neighboring Arab villages cam to thank the engineers and to bless then fountain, while in the evening there was a dance and great merry-making, and this festival was kept up for six days.*

We can safely say that most Americans in 1864 would have been exposed to some version of the Sidi Rached story. Readers would have enjoyed the account of live fish and the belly-dancing harem (though it didn't exactly who was dancing or what was being danced). Given our retention of envisionable information -- we'll have more to say about this in Chapter 99, Why Do We

Believe What We Believe? -- the description, "an underground river or lake," would have persisted as well.

Many American children would have been somewhat informed on the topic, as well, thanks to periodicals aimed at their readership. Take, for example, the Christian Advocate, February 26, 1880, "Our Little People's Club, A Talk by the Professor."

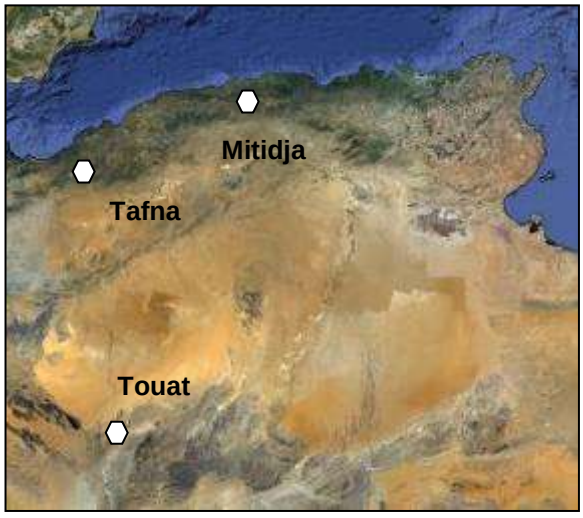
> *In the great African Desert of Sahara deep wells... were dug long ago, the present inhabitants doing no more than to keep them in repair. Gangs of men, called Kertassas, go about to cleanse these wells from the sand which soon chokes them up. They are useful indeed, for the traveler depends on the oases in which they abound for the water to help him over the scorching sands. The wells are what we call artesian, where water rises to or above the ground in a jet. A Kertassas would look strange enough to a member of our Club. He is emaciated to the last degree, showing how severe his work. The process of clearing a well is thus described.*
>
> *When the well is to be "cured," a gang of Kertassas is employed, and one of them prepares his windless to make the descent. First, he stops up his ears with wax, and rubs his head for a while with the cold, brackish water. When his system has recovered from the shock, he invokes the blessing of Allah and is lowered down, carrying a basket. In two or three minutes he gives a signal, and is drawn up, with his basket, which he has filled with sand. While he is resting and warming himself, another descends in like manner; and so on alternatively through the whole gang.*
>
> *The work is very exhausting, and most of the older Kertassas are mere skeletons, but they endure the work better than their younger companions. Frequently when drawn up they are perfectly livid, bleeding at the nose, then pulse having fallen to fifty-five beats in a minute. Each gang consists of six or eight men. Their pay is about ten cents a basket; and a man cannot make more than six descents in a day. As it requires from two hundred and fifty to three hundred basketfuls to clear out a well, the operation is a long and tedious one, and it must be repeated every three or four years.*

Mr. Rogers would have toned down the physiologic aspects, however, for his viewership a century later.

French development was not confined to the Oued Rir. We'll mention three additional wells.

Haouch-Baraki was on the Mediterranean plains of Mitidja. From (but as are most of our news clippings, not at all exclusively) the New York Evangelist, June 5, 1862,

> *In a well sunk at Haouch-Baraki, in the plains of Mitidja, at about 137 yards, a jet of water was met, giving 120 gallons a minute. The boring continued to 154 yards, the supply of water was increased, and rose above the soil.*




The next report, "An Underground Lake," New York Times, July 27, 1879, seems somewhat Sinbadian (our Arab hero of Chapter 17, Underground Rivers in English Fiction).

> *The Tlemcen Courier (Algeria) describes a wonderful discovery recently made at the picturesque cascades of that place. Some miners had blasted au enormous rock near the cascades, and, on removal of the debris, found it had covered a large opening into a cave, the door of which was covered with water. Constructing a rude raft and providing themselves with*

> *candles, the workmen sailed along this underground river, which, at a distance of 60 meters was found to merge into a large lake of limpid water. The roof of the cavern was very high and covered with stalactites, the brilliant colors of which sparkled under the light of the candles. Continuing their course, tile workmen and at certain places to navigate their craft between the stalactites, which, meeting stalagmites from the bad of the lake, formed enormous columns, which looked as If they had been made expressly to sustain the enormous arches. They thus reached the extremity of the lake where they noticed a large channel extending toward the south, into which water quietly made its way. This is supposed to be a large fissure which has baffled exploration hitherto at Sebdou, and which connects the cascades with that locality, and thus with the mysterious sources of the Tafna. It is possible that here they have found an immense natural basin, supplied by powerful sources, and sending a part of its waters toward the lake, while the rest goes to Sebdou. The workmen estimated the distance underground traversed by them at three kilometers, and the breadth of the lake at two*

Since that report, however, such a North African waterway hasn't been rediscovered. What seems more likely than a large underground lake is journalism shaped by discoveries in American karst regions, of which we'll peruse in subsequent chapters

Frank G Carpenter's "Through the Garden Spots of Great Desert of Sahara," Atlanta Constitution, April 28, 1907, employs

> *Much of the desert has a bed of stiff clay under it. The water may sink down through a hundred or more feet of gravel and rock, but when it comes to a clay bed it flows on until it strikes a hollow and if the hollow is high enough and deep enough, the result is an oasis. In the district known as El Erg depressions of this kind furnish wells which can irrigate eight millions of date palms, and where I am not is the Wadi Sacora, a great underground stream which flows far below the surface for several hundred miles and then rises and supplies the oases of Touat, which are among the largest of the western Sahara.*

We're unsure if the descriptions of a "hollow... high enough and deep enough," and "a great underground stream" are metaphoric or otherwise, but the imparted impression -- as we will see time and time again in the popular press -- is more dramatic than the sandy and grimy reality.

If nothing else, the title "The Underground River of the Oasis," Popular Magazine, November 7, 1923, by James Francis Dwyer enhanced a hydrologic impression. The article was written when Dwyer and his wife traveled throughout the Middle East and Africa, producing a story for every issue of the bi-weekly magazine.

In addition to oft-speculative news reporting, there's the Saharan underground river fiction. In Chapter 22, Boys Club Singles, we quoted from S. Fowler Wright's The Hidden Tribe (1938). Below the Sahara, or Frank Reade, Jr. Exploring an Underground River with his Submarine Boat (1896) by Luis Senarens, another Chapter 21 author, would be another example of the popular dissemination of desert lore.

"The Million Dollar Mystery" (1914) was a 23-episode film serial and run in more than 200 newspapers. The plot was one of international intrigue revolving around a millionaire and his lost fortune. Note the line, "AN OASIS IN THE SAHARA."


AMUSEMENTS AND FUNCTIONS.

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Ashburton Guardian, September 16, 1916

**Fish**

We noted the Algerian fish story in passing, but it perhaps it deserves closer scrutiny. As discussed in Chapter 50, Wrecks of Ancient Life, fish are indeed found in the earth's recesses, but -- and this is not a minor detail -- only where their metabolism can be sustained by photosynthetic nutrients.

In the chapters ahead dealing with American fish tales, exaggerated as some may be, most are set in regions of karst caves where aquatic life can be verified within the entrances. Most of the artesian sites of this chapter, on the other hand, are distant from any open water and we must remain skeptical of veracity.

This is not to imply that cave fish can't exist in deserts. Phreatichthys andruzzii and Garra barreimiae are native to Somalia in eastern Africa and Oman on the southeastern Arabian peninsula, but both cases involve caves, not deep wells.

According "Fish in the Depths of the Earth," New York Times, August 6, 1865, however.

> *M. Desor, the eminent Swill naturalist, who has recently returned from an exploration to the northern Sahara... states in a recent letter that he found fish in the stream leading from of one of the wells at the oasis Ain-Tala where fish were observed when the water first rose to the surface... The most curious thing is that these fish, although coming from the interior of the earth, from a depth of more than 150 feet, having nothing sickly or misshapen about them... Beside these artificial wells, there are ponds in several oases, especially that of Urlana, fed by rich sources... These ponds harbor the same little Cyprinodonts which rise in the water of the artesian wells, by witch I conclude that a subterranean connection exists between the ponds and the wells. Probably they visit those ponds periodically, perhaps to spawn; this would explain their eyes, and their formation in general, shows nothing abnormal.*

Some accounts indicated that the Sub-Saharan fish are blind.

> *They brought out with them a quantity of fish, which swarmed round the craft, and which were found to be blind.* -- "An Underground Lake," New York Times, July 27, 1879

How did these fish get down beneath the Sahara? That they have been imprisoned there for a very long time -- for many thousands perhaps millions of years -- is indicated by the fact that they are nearly all blind. -- "Find Evidences of Ocean Life Below Surface of the Sahara," Washington Post, June 15, 1924

Others reported the opposite. "Fishes of Sahara Survive from Pre-Desert Period," New York Times, June 8, 1924, cites Dr. E.W. Gudger of the American Museum of Natural History,

> *It might be supposed that fish drawn up in this way from underground bodies of water would be blind, like those of Mammoth Cave, or otherwise especially adapted to the conditions prevailing in their habitat. But this is not the case.*

As speculated by French scientist, M. Edouard Blanc,

> *These fish are extremely hungry and reduced to the utmost degree of famine they can endure. They are generally very thin... The minute algae, small crustaceans and organic debris which might be found in waters below the surface were not enough to keep the fish alive for any considerable length of time. They must have some way of passing to and from the surface of the ground, not only through artificial wells, but through natural connections.*

Could these artesian wells be connected to the Nile, supporting a hypothesis of Chapter 14?

> *A peculiarity of the wells is that tiny little fish, resembling small whitebait, are brought up in the water. They were first noticed by General Zickel in the water spouting from the well of Ain-Tala, which is 145 feet deep. The length of these little creatures does not exceed one and a quarter inch. Their eyes are well shaped, although they emerge from regions so dark. They are malacopterygians, of the species Cyprinodon cyanocaster. Similar specimens have been found in some of the ancient wells of Egypt that were cleared by M. Ayme; as these, in all probability came from the Nile, and as the sand excavated from those wells is much the same as that of the Algerian borings, it is supposed that in both cases the fish infiltrate through with the water to the subterranean sheets.* -- "Artesian Wells and the Great Sahara," Popular Science Monthly, February 1880

> *An artesian well at Ain-Sulu, in Algeria, not only throws up an immense volume of fresh water, but also numbers of small fishes, averaging half an inch in length, and furnishing a delicate morsel for the epicure. As the sand extracted from this well is identical with that found in the bed of the Nile, it is conjectured that a subterranean connection must exist with the river.* -- Appletons' Journal of Literature, Science and Art, July 31, 1869

And what's for dinner?

> *Another curious phenomenon which the sinking of the Algerian wells has revealed is the discovery of fishes, crabs and fresh-water mollusks at considerable depths. This interesting fact has been ascertained in the artesian well called Mezer, situated on the desert of Oued Rhir, quite near one of the brackish lakes (Chott or Sobka of the Arabs) which are so numerous in the region between Biskra and Tugert. When the sounding line brought those creatures from a depth of 230 feet they were perfectly alive, and M. Just even boiled a crab, and found it of excellent taste.* -- "Wells in Sahara," New York Times, September 17, 1882

> *In the Algerian Sahara there are numerous subterranean lakes in which a number of small fish and mollusks live and multiply. Moreover, the artesian wells of the Sahara often throw out fish that are sometimes two inched in length. The governor of the oases of Thebes and Garbes, in Egypt, asserted that he took from an artesian well 440 feet deep, near his residence, fish in sufficient quantity to supply his table.* -- Scientific American, May 12, 1888

**The Saharan Sea**

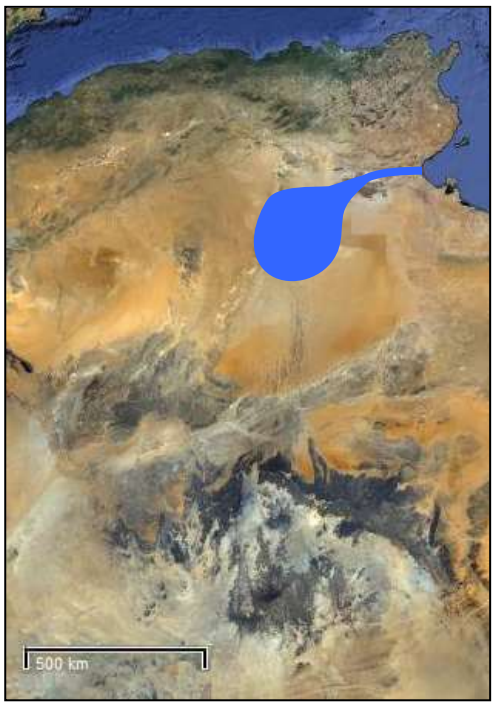
We add this section to illustrate that suppositions of Algerian waters don't have to be underground to be astonishing. Take, for example, converting the area into a great inland sea.

French designs for North Africa coincided with that nation's endeavors in Panama and the Suez. Coupled with faulty land surveying -- the 1889 Oued Rir map earlier in this chapter shows "-31" as a Chott Melrir elevation -- an ambitious French engineer discovers another cause for excavation, an inland sea that's begging to be filled.

Quoting from Handbook for Travelers in Algeria and Tunis (1891) by Robert Lambert Playfair,

*Between a place 70 kilometers S. of Biskra and the sea, exists an immense depression, 375 kilometers long, occupied by three chotts or salt lakes, all of which are below the level of the sea. The isthmuses which separate them are of varying heights, but both considerably above the sea level. The whole of this area is separated from the sea by a third isthmus, also considerably above the Mediterranean.*

*The quantity of water necessary to flood this depressed area would be 193 millions of cubic meters. M. Roudaire proposed to cut through the narrowest portion of the inland isthmuses, thus leaving the three basins prepared to receive the waters of the Mediterranean. He then intended to cut a canal between it and the sea, about 15 kilometers N. of Gabes, at a place where the work would be facilitated by the presence of another small chott, and by the depression through which the Oued el-Melah flows into the sea.*




The illustrated inland sea is geographically conceptual, at best, as Capt. (at the time) Roudaire was operating under topographical delusion. American news accounts of the proposition took their liberties, suggesting in some cases that the sea might be a million square miles, somewhat larger than the modern Algerian nation.

"Fishes of Sahara Survive from Pre-Desert Period," New York Times, June 8, 1924, even provides the sea's historical background.

*Another project, more recently discussed, has been cutting of a channel in the coast of the Gulf or Gabes, in Eastern Tunis, thus letting the waters of the Mediterranean into a vast tract of desert south of the Atlas Mountains. According to L.M. Phillips, whose In the Desert was published a few years ago, the voyage of the Argonauts, in Grecian legend, must have been into a sea which occupied this region. Shells, marks of erosion and old shore lines are said to prove the existence of this body of water.*

Ensuing discussion was protracted and by no means definitive, but in light of environmental awareness, looks like a prelude to concerns that would rarely surface for yet another century. We'll cite a few reactions.

Christian Union, September 3, 1879,

*The latest advices from Paris indicate that the conversion of the Desert of Sahara, in order to flood a vast depression that has been discovered, and return it into an inland sea might not be so much a blessing to the Continent of Africa as was claimed when the project was first broached. Its shores would be as arid as those of the Mediterranean at Tripoli, and if the climate should change, the date crop, which is the principal support of the natives, would be ruined... It is also predicated that the pressure of the mass of water would produce perturbations in the subterranean currents which feed the artesian wells in the oases, and might cause them to fail.*

New York Times, July 15, 1883,

*Speaking of the proposed Saharan Sea, Dr. Bodichon, of Algiers, in a pamphlet just published, deprecates the formation of a vast inland salt water lake till we find out to a certainty whether*

*the salt water thus introduced may not penetrate to the fresh water sources penetrating underground and deprive us of the means of obtaining artesian wells."*

Again from the New York Times, June 20, 1886,

*A few weeks ago M. de Lesseps was again advocating the plan for making lakes in the Algerian Desert. Very little has been said about this enterprise since Commander Landas went to the African coast a year ago to select the site of a new harbor and to sink artesian wells for the use of workmen. The old canal builder has a great task on his hands in the New World, and it may be that he is unwilling that the money of French investors shall be diverted at this critical time from the work on the Panama Isthmus to any other similar undertaking.*

*The African project was broached by Col. Roudaire, and a curious misunderstanding about its features has given rise to many absurd speculations as to the probable effect of its successful completion. Civil engineers have declared that the creation of a great inland sea in the place of the desert of Sahara might lower the temperature of Europe and cause a most formidable current in the Straits of Gibraltar. Upon the assumption that this sea would cover 1,000,000 square miles it has even been said that the withdrawal of so great a body of water from the ocean would lessen the depth of water in the world's great harbors.*

*But the surface of the desert does not lie below the level of the sea. Its average elevation above that level is said to be at least 1,000 feet. Dr. Lenz explored a large area in the western section of the desert and found no point that was not at least 400 feet above the ocean's surface... The great African desert cannot be transformed into an inland sea until water can be made to run up hill or until some great convulsion of nature shall cause its surface to sink.*

*The French Commission that examined Col. Roudaire's plans never thought of drenching the Great Desert, nor did M. de Lesseps and his engineers, who visited Tunis in 1883, submit a report that recognized the possibility of making so great a change in the condition of Africa. But they were convinced that two lakes could be made near the northern coast, and that money spent in making them would be well invested... This area would be about 3,100 square miles, or less than half the area of Lake Ontario.*

*The creation of new lakes in the place of these salt marshes and brackish pools would in all probability transform a large area of barren land around them into land that could be cultivated. Evaporation from this body of water would supply the aqueous vapor without which there can be no vegetation. The climate of the adjacent country would be improved. But the flooding of only 3,100 square miles would not lower the temperature of Southern Europe, nor would it deprive the world's harbors of the water required for the maintenance of ship channels.*

Needless to say, as the Mediterranean couldn't be induced to run uphill, the plans withered, but where money's to be made -- albeit in dollars or in francs -- there will be shady characters. From the New York Times of August 9, 1884,

*A Sahara Swindling Scheme. A parallel to the Port Breton affair was tried today before a Paris court. Two enterprising gentlemen, M. Menier, who seems to be a journalist, and M. Allemand, described as a banker, conceived some time ago the ingenious idea of turning the dry but fertile soil of the Sahara to profitable uses. This was to be done by means of artesian wells and artificial oases. The capital to be subscribed was 400,000f., half of which was to be handed over to the founders in return for the idea and for lands which had been purchased from Arab chiefs. In order to stimulate the co-operation of capitalists two newspapers were founded, the France Populaire, at Paris, and the Sahara, in Africa. The judicial authorities had their attention called to this strange enterprise, and came to the conclusion that MM. Menier and Allemand were swindling the investors who had been inveigled into the business. Allemand at once took flight, and Menier, who was tried today, was condemned to two years imprisonment and a fine of 1,000f.*

The title "A Subterranean Nile," in Bulletin of the American Geographical Society, 33:5 (1901), keeps alive the association discussed in Chapter 14.

*The depression of the Oued-Rhir, in the Algerian Sahara, directly south of the Auras Mountains, may be called a channel in a plateau of limestone and sandstone, running north and south, and bordered by escarpments about twelve miles apart at the edges of the plateau. The depression, about ninety- three miles in length, is fertilized by a subterranean Nile, turning the desert into a garden.*

Might it be that the Saharan Sea is more westerly? "The Phantom Islands," Life, December 6, 1948, quotes an adventurer of 12 years earlier.

*Our stores were rather low so I decided to return to Port Etienne and replenish them before resuming the voyage to Dakar. At Port Etienne I revisited the Foreign Legion officer, whose acquaintance I had made on a previous visit, and told him of our strange experience. He said that the rising and sinking sand islands are well known in that part of Africa. The natives call them the Phantom Islands. The officer said that French scientists attribute the islands to a great river that flows under the Sahara Desert and empties somewhere on the floor of the Atlantic, 60 to 100 miles from the coast. The scientists believe that sand gathers in the outlet of this underground river and, at intervals, the sand clogs the outlet completely. Then the dammed river, increasing its pressure, finally succeeds in belching the tremendous harrier of sand into the ocean. These sudden upheavals of sand from islands that rise to the surface, later settling and sinking below again.*

But in search of a sea below the sands, perhaps we've wandered too far westward. Let's turn to Libya.

The Great Man-Made River

Exploring the Sahara for oilfields in the 1950s, geophysicists found not only petroleum, but also 35,000 cubic kilometers of fresh water underlying the arid landscape. Libya began construction of the Great Man-Made River (GMR) in 1983 to funnel this resource to the populated coastline.

Col. Muammar al Qadhafi deemed the GMR to be the showpiece of the Libyan revolution. "Libya Launches $25 Billion Project to Quench Sahara Nation's Thirst," a feature of the October 3, 1985, Wall Street Journal, began.

> *Unofficially, it's called The Great Madman River by cynics who consider it just another wild venture by Libyan strongman Muammar Qadhafi.*

Contractor for the job, however, was the American firm Halliburton and unlike earlier proposals for Algeria, the Libyan system was aimed downhill.

"The Thirsty Lift a Glass to a River and Qaddafi," New York Times, October 31, 1998, brings us somewhat up to date.

> *It is not that there have not been any problems. Ever since the water began to flow in September 1996, Tripoli's old water mains have burst, one after another, unable to withstand the pressure of water that tumbles into the capital's colonial-era water system from a storage tank here in Sidi Saye, which is about 400 feet above sea level.*
>
> *On countless occasions, local residents say, the flooding has transformed parts of the capital into lakes, with geysers spewing water into the air from corroded Italian-made iron pipes. And though the Tripoli branch of the project is supposed to carry 660 million gallons of water a day, the amount flowing now is still a relative trickle.*
>
> *Still, Libyan engineers said in interviews here that 87 percent of the work on the Tripoli section had now been finished, and they expressed confidence that all of the work would be completed in early 2000.*
>
> *In a country without a single free-flowing river of its own, water flowing at full stream through the pipe, more than 12 feet in diameter, would be enough to irrigate vast new agricultural projects.*
>
> *In the Tripoli section, among the work that remains unfinished is a section of the pipeline that is supposed to end at Tarhuna, about 40 miles southeast of Tripoli, where American officials have said Libya has been building what would be the world's largest underground chemical weapons plant in a hollowed-out mountain.*
>
> *"This project is just to carry water," declared Adel Bakir, the manager of the Tripoli section of the enterprise.*

Phase I of the GMMR, price tag, $5.5 billion, has transported 2,000,000 cubic meters/day since 1991 to the coastal strip between Sirte and Benghazi, 1200 kilometers north.

Phase II, at just over $8 billion, carries 2,500,000 cubic meters/day to the cities between Sirte and Tripoli, Libya's capital, which received its first GMMR water in September 1996.

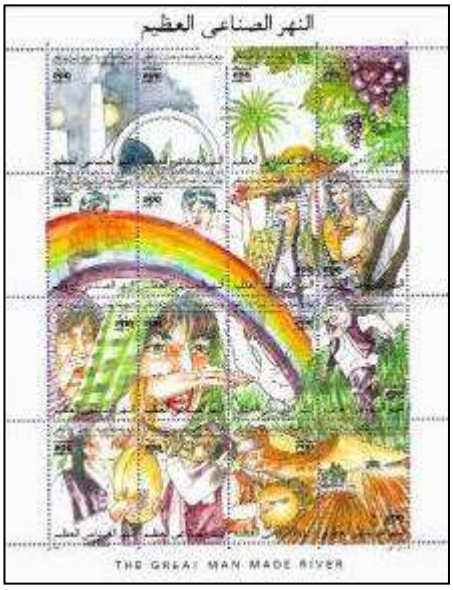
Phase III, estimated to cost $6 billion, connects the two existing networks. Total production comes to 6,430,000 cubic meters/day from 1,149 production wells, most of them more than 500 meters deep.

The cost of GMMR tap water is 28 cents/cubic meter, compared to desalinated water at 85 cents. Adding the cost of pumping inland, the later would be between $2.50 and $3.00/cubic meter.

Seventy percent of GMMR water goes to agriculture, with another 28 percent for municipal use and the remaining 2 percent for industry.

Qadhafi shut the subterranean spigot to Tripoli after he fled to Hasouna, 650 kilometers to the south, but it did him little good.

We could have included the GMR in Chapter 74, a chapter about dangers, by virtue of its weapons-of-mass-destruction plant potential, but we're pretty sure it's just carrying water.

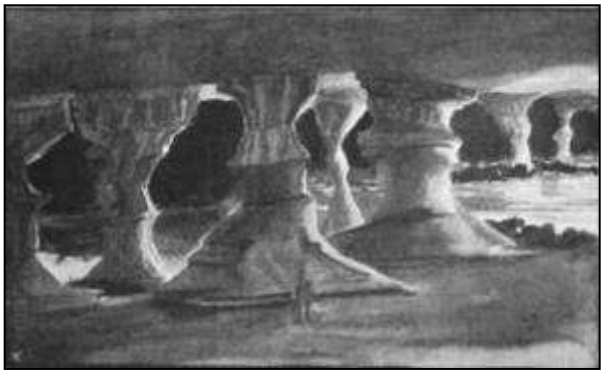



Thus we end our Saharan safari, one in which the waters are indeed underground, but perhaps not exactly riverine.

"Queer Story from Africa"

As we're nearby, however, we'll slip over to the Horn to note how journalism can flavor an explorer's account. The February 17, 1895, Salt Lake Tribune reported a "Queer Story from Africa. Discoveries Made by Donaldson Smith's Party."

> *The Associated Press has received the following letter from Dr. A. Donaldson Smith of Philadelphia, in which the news of the Lake Rudolph East Africa Expedition is given up to December 14, 1894. The letter is dated from the Shebeyll River near Somall Land.*
>
> *A Subterranean Passage*
>
> *"A large tributary of the river Juba had carved a way for itself under a mountain a mile in length. On the other side of the stream were great vaulted chambers from 125 to 150 feet high, and supported on massive columns. The columns were most ornamentally carved by the waters, and many would form long arched passages. The mountain was hollowed out a great distance on the other side of the stream, which I have named the 'Cave of Windlawn.'"*



Written for the popular press, the piece portrays a picture somewhat different than that in which the author reported his findings to his peers. From Smith's "Expedition through Somaliland to Lake Rudolf," Geographical Journal, August 1896,

> *I shall not tire you with details, but before we get back to Somaliland I must mention some wonderful caves we discovered. Hearing that they were some 30 miles to the south of Ginea, Mr. Gillett and I avoided the Abyssinians for a few days on the excuse of elephant hunting, and visited them. We were thunderstruck when we discovered what a superb underground palace the River Web had carved for itself as it dashed through a mountain of quartz. It seemed as if Nature had confined herself to human ideas of the grand and the beautiful in this work, so regular and ornate were her designs. Passing columns and arches and altars of apparently the whitest marble, the clear water disappeared into the dark recesses of a pillared temple. I can give you no idea of how ornate the columns were, with their beautiful capitals and splendid bases, or of the magnitude of the subterranean chambers.*

For the public, we've a river flowing through a great African mountain, a stream we envision the torch-bearing explorer traversing by boat. For the scientific readership, on the other hand, it's a splendid cavern of geologic note, but not an active watercourse.

The latter is the truth. The River Jubba ("Webi" is Somali for river, thus the report's "Web" confusion) is very much above ground, that is, when it flows at all. Wyndlawn Cavern (not "Windlawn," a newspaper's error) indeed exists, but transmits no river.

**The Sarasvati**

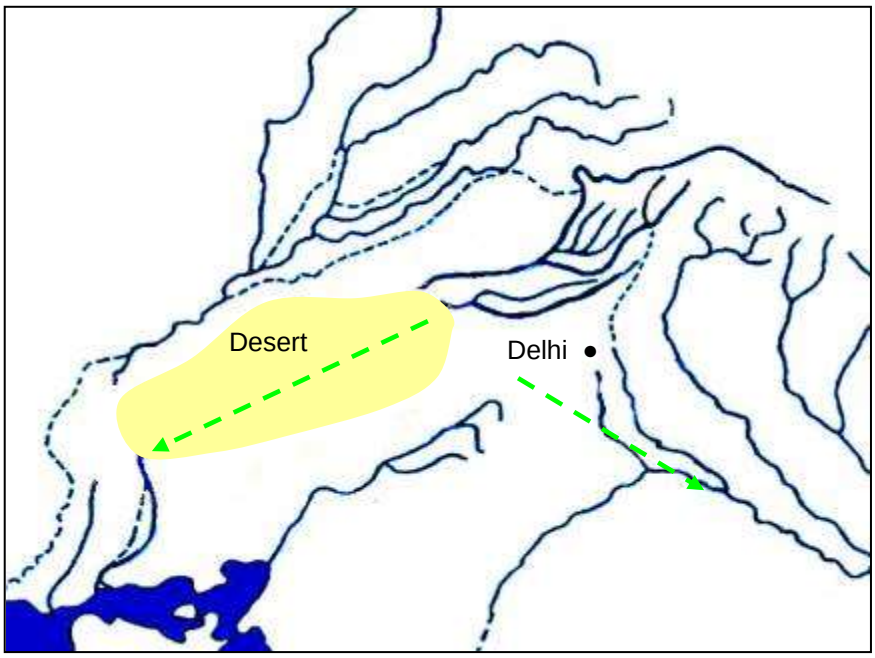
The Sarasvati River is today but a mythical memory from the Rig-Veda. The first modern reference to the river is from the Jaiminiya Brahmana which speaks of it as "diving under."

In Hindu tradition, to bathe in a "triveni sangam," the confluence of three rivers, can free a soul from the cycle of rebirth. One such triveni sangam in Allahabad is said to consist of two physical rivers, the deep, calm and green Yamuna and the shallow, forceful and clear Ganges, and the subterranean Sarasvati.

But is the Sarasvati only a myth, and if not, is this its correct location?

Scientific search for the Sarasvati was sparked in 1893 by C.F. Oldham when riding along the ephemeral Ghaggar riverbed. The river seemed too small for its bed, 3 kilometer wide in places. Perhaps this could be the former course of a much larger river -- the Sarasvati.

Geomorphic evidence indeed suggests that a great river, perhaps as wide as 8 kilometers once flowed not eastward toward Allahabad, but southward, parallel to the modern Indus toward the Arabian Sea. It dried up some 3000 to 5000 years ago.




Solid blue lines indicate modern channels.

Dashed blue lines indicate paleo-channels.

Dashed green lines indicate possible route of the Sarasvati. Tradition claims the south-eastward route. Geological evidence suggests the south-westward route

The possibility of rediscovering the Sarasvati where Oldham suspected was advanced by Landsat photographic evidence of a paleo-channel, 5 meters deep, 3 to 15 kilometers wide and 1500 kilometers long, now buried 60 meters beneath the surface of Rajasthan.

Indian Space Research Organization scientists, notwithstanding, dismissed that the discovery represents a subterranean river, as radioactive tracer studies show that the velocity of water is a sluggish 15 centimeters/year.

Given western India's water shortage, even the hint of a giant underground river created a news-frenzy akin to that of Nevada's alleged Spencer River (Chapter 94, The Rio San Buenaventura). Those who dwell in arid regions beg to believe in hidden water.


"Sarasvati Reappears in Rajasthan,"
TV report on paleo-riverbed.

Why do Indians and Americans and most everybody else, for that matter, believe such things, the quandary of Chapter 99?

It's the Indian Space Research Organization and the Nevada State Engineer who have the onerous duty of informing the public otherwise.

And now let us sail to a land even more distant.

**Shambhala**

The mythical Kingdom of Shambhala predates Tibetan Buddhist, with which it is now generally associated. As noted by the 14th Dalai Lama in 1985, Shambhala is not an ordinary country.

> *Although those with special affiliation may actually be able to go there through their karmic connection, nevertheless it is not a physical place that we can actually find. We can only say*

*that it is a pure land, a pure land in the human realm. And unless one has the merit and the actual karmic association, one cannot actually arrive there.*

Nicholas Roerich's "Song of Shambhala: Thang-La" (1943)

The myth of Shambhala -- a land of enlightenment and longevity -- was central to the Theosophical Society in the latter 1800s and was the basis for the Shangri-La of James Hilton's Lost Horizon (1933).

As with ancient tales of all traditions, however, concepts alter, weave and morph. Thus the Shambhala celebrated by the modern Western occult movement merges with another kingdom, the ominous hollow-earth realm of Aghartha.

The Hindu Vedas speaks of the sacred River Sarasvati, "saras" meaning "pool or water body" and "-vant," a suffix for "having many pools." The Vedas suggest that the Sarasvati originated in the high Himalayas where she "burst with her strong waves the ridges of the hills" and describes the river as flowing to the samudra, usually translated as ocean, as "samudra" means "with waves."

The Sarasvati was said to flow by subterranean channel, joining the Milky Way and the Ganges at Benares -- or Prayag (Allahabad), depending on the source -- as an intersection of waters from three worlds.

Whatever there may have been, however, has long since dried up and isn't the present-day Sarasvati, which originates in the submontane Ambala district and joins the Ghaggar near Shatrana.

But just as we're relegating another underground river to the folk-tale file, we're informed that the modern Ganges has its own subterranean characteristics. From "Fraser's Journey through the Himalaya Mountains," Edinburgh Magazine, September 1820,

*This mountain, which is considered to be the loftiest and greatest of the snowy range in this quarter, and probably yields to none in the whole Himalaya, obtains the name of Roodroo Himalaya, and is held to be the throne or residence of Mahadeo himself. It is also indiscriminately called Pauch Purbut, from its five peaks... These form a sort of semicircular hollow of very considerable extent, filled with eternal snow, from the gradual dissolution of the lower parts of which the principal part of the stream is generated.*

*About thirty miles west from Bhagirathi* [We'll standardize the spelling in this section] *Uttarakhand, is Gangoutri, a village near the head of the Bhagirathi, considered the main and proper head of the Ganges. A few miles above, it is seen flowing with a moderate current, fifteen or twenty yards broad, and about waist-deep. Higher up, it flows beneath beds of snow, so deep that even its sound is not heard. At length is perceived a wall of rock, from an angle of which, called by the Hindus the Cow's Mouth, on account of its rude resemblance to that orifice, issues the Ganges.*

As Gaumukh (cow's mouth) Cave lies at the base of a 40-kilometer glacier, the outflow is of little mystery, but we're looking at the lore, not the hydrologic science. For some distance the river is called the Bhagirathi, but then becomes the Ganges.

G.T. Vigne, who traveled in Kashmir and Ladakh in the 1830s described how the Bhagirathi dips underground and then resurfaces.

*The Bhagirathi River, after flowing for some distance under the bank, suddenly disappears beneath the ground. It first loses a portion of its water in numerous little whirlpools, that are seen in full play amongst the rounded stones in its bed; and all that escapes absorption in that place pursues its course for a little farther, where it suddenly disappears through the bottom of a large fissure, formed by the almost perpendicular position of the limestone strata, and nearly large enough to allow a man on horseback to sit upright in it. The natives say that the spring of Achibul, or Yechibul, is but the reappearance of the River Bhagirathi. Probability is strongly in favor of this theory. Walnut-shells that have been thrown in the Bhagirathi are said to have reappeared at Achibul; and the direction thus ascribed to the river is much the same, as it would have followed on the surface.*

Walnut shells carried to Achibul poses a problem as Achibul lies in Kashmir to the west, while the Bhagirathi drains to the east as the Ganges, but India is a mysterious land.

As evidenced by the 1888 Encyclopedia Britannica, Ganges whirlpools have attracted the attention of geographers from the early 19th century.

*The Brahmaputra is navigable as far as Dibrugarh, but in the dry season only for steamers of light draught. In the rains it overflows its banks and spreads over the country for hundreds of square miles. At Godlanda, where it joins the Ganges, the current is so strong during the rains, and the eddies and whirlpools formed by the meeting of the waters so numerous, that large and powerful river steamers are often unable to make headway, and have to lie for days until the river subsides.*

To where do such whirlpools whirl?

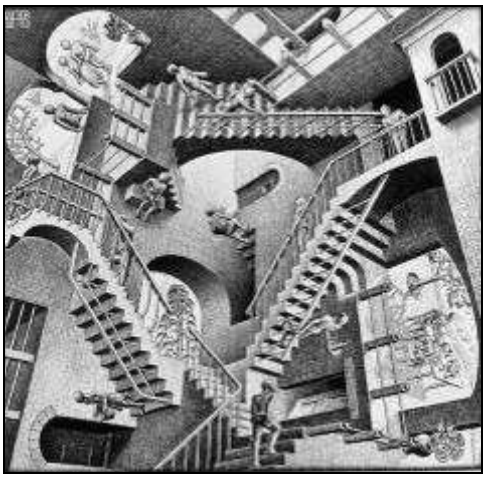
To the intersection of the Serasvati, the Ganges and the Milky Way?
To Aghartha?

C.H. Tawney's translation of the eleventh-century Somadeva's Katha Sarit Sagara (Ocean of Streams of Story) contains the following reference to the Naga underworld Patala, the dimension of hell where wicked souls committing grave sins are punished.

*I perceive those who have written the books and gave information are mostly foreigners and they do not know about this correctly. I suppose the underground dimensions of the Nagas contains priceless diamonds, rubies, etc. This is under the control of Lord Shiva and anyone with intense devotion towards Lord Shiva could enter this portal. But a person devoid of devotion towards the Gods could never make it out if he goes in.*

The well of Patanjali in Sheshna, Benares, India, traditionally where the Yoga Aphorisms of Patanjali was written and said to be the entrance to this underworld, is shown below, along with the remarkable-similar well-known Escher etching.

Well of Patanjali



M.C. Escher's "Relativity"

We depart Hymalayan India without diving into the eutrophic pool, but better understanding how ageless tales remain ageless.

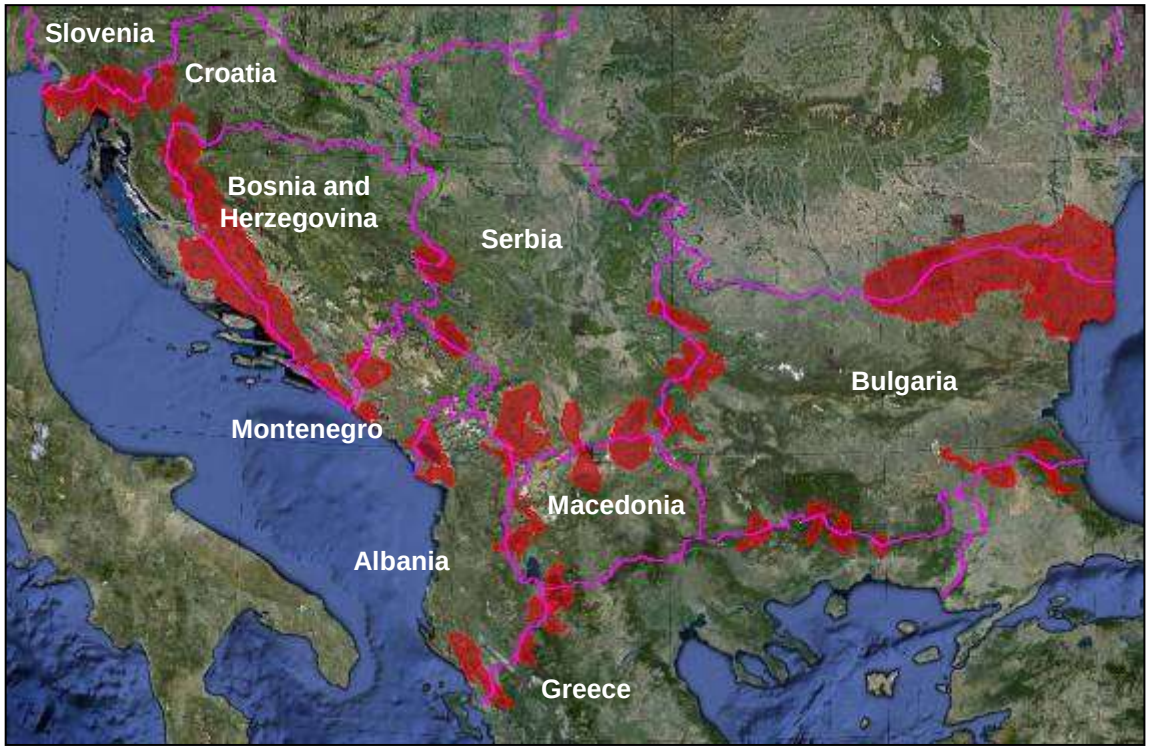
After all, those of us who remember Three Dog Night's, “How does your light shine on the road to Shambhala” should by no means be considered aged.

# CHAPTER 78
# UNDERGROUND AND BALKANIZED

To "balkanize" is to divide into small factions or fragments, term was first used in the 1920s in reference to the political consequence of the dissolution of the Ottoman Empire into small European nations.

In this chapter we will explore the Balkan Peninsula in light of karst piece-wise karst conduits, threads stitched up and down across the map.

The map shows shared karst aquifers, and thus zones of underground transboundary streamflow. Not shown are alluvial aquifers and karst aquifers entirely within a single nation.



Below are border lengths spanning karst aquifers.

| Kilometers of Common Karst Aquifer | Albania | B & H | Bulgaria | Croatia | Greece | Macedonia | Montenegro | Serbia | Slovenia |
|---|---|---|---|---|---|---|---|---|---|
| Albania | | | | | | | | | |
| Bosnia & Herzegovina | | | | | | | | | |
| Bulgaria | | | | | | | | | |
| Croatia | | 496 | | | | | | | |
| Greece | 109 | | 32 | | | | | | |
| Macedonia | 75 | | | | | | | | |
| Montenegro | 35 | 90 | | | | | | | |
| Serbia | 30 | 117 | | | | 65 | | | |
| Slovenia | | | | 148 | | | | | |

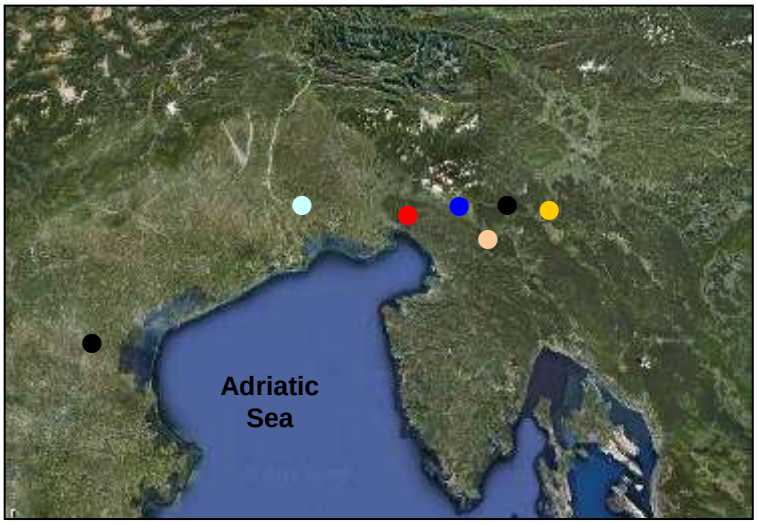
As such karst formations are rife with subterranean channels, what we have above are nearly 10,000 kilometers of transboundary waterways between nations that may or may not be feuding or further subdividing.

Italy, Romania and Turkey are located mostly outside the geographic peninsula, but share some portions of underlying karst with Balkan neighbors and thus are considered Balkan in a geologic sense. The map below shows the Dinaric karst belt wrapping from Italy and Austria in the north-west 700 kilometers to northern Albania in the south-east, the largest single karst expanse in Europe.


With that brief overview -- given the region's political turmoil, it's wise to regularly review what country's what -- we will look at three Balkan river systems noted for fluvial disappearances and reappearances, sometimes not even in the same country.

**The River Timavo**

As with several chapters in our journey, a map's useful for relating rivers speculated to dive down in one place and pop back up in another.




The Italian River Timavo flows from springs 2 kilometers inland from Duino at the head of the Adriatic.

Springs of Timavo

Modern Duino Harbor

The hydro/historical question: What feeds the Springs of Timavo?

The Ancients were amazed that such a short river could be of the Timavo's width and depth and were astounded by the river's flood flows. "According to John Conington in P. Vergili Maronis Opera: The first Six Books of the Aeneid (1863),

> *"Fontem Timavi" is rightly explained by Henry of the fountain or source of the Timavus. Between this and the sea (a distance of about a mile) there are subterranean communications, through which the salt water forces its way, breaking out at the fountain through seven mouths or boles in the limestone rock, and overflowing the channel of the river.*

This theory -- that sea water pushes its way back to the springs -- might fit into Chapter 8, Subterranean Engines, but most speculation more astutely looked inland. From Chapter 3, Roman Encyclopedists,

> Strabo's mention of the disappearance of the River Timavo in a cavern east of Trieste and its reappearance at the coast.
>
> Pliny's mention of a river that goes underground as "does the Timavus in the district of Aquilea."
>
> Virgil's description,

*Fontem superare Timavi*
*Unde per ora novem vasto cum murmure mentis*
*It mare preruptum, et pelago premit arva sonanti.*
*The spring of the Timavo,*
*From which through the nine mouths with a mighty roaring of the mountain*
*The sea goes rushing forth and presses the fields with its resounding flood.*

As noted by Elisee Reclus in The Earth: A Descriptive History of the Phenomena of the Life of the Globe (1872), however,

> [Virgil's count] *no longer applies to the mouths; at present they do not reach the number of nine, because either the extermination of the woods of the Carso has diminished the mass of the water, or the action of the stream and the alluvium of the delta have modified the form of the shore.*

In short, River Timavo, where do you come from? Where do you go?

The Timavo, it was agreed my most, was fed by a mighty underground channel. Many sources were proposed, six of which we'll review.

1. The Danube

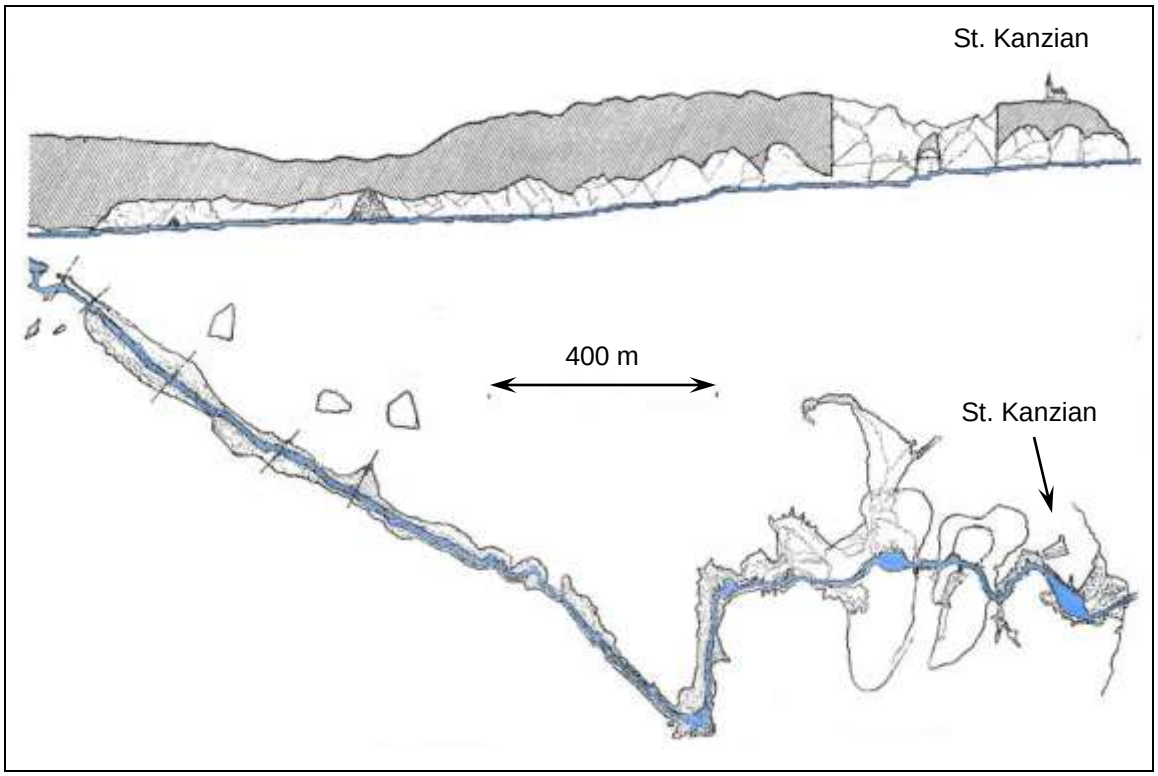
We can dismiss that the Timavo is a subterranean offshoot of the Danube by tracing the idea to an erroneous interpretation of Argo's downriver journey to the Adriatic.

2. The River Reka

As "reka" is Serbo-Croatian for "river," the "River Reka" is a bilingual pleonasm, but that's its usage in English-language geographic references. The linguistic duplicity is akin to the "Rio Grande River."

The Reka drains 442 square kilometers of southwestern Slovenia into a highly-incised canyon flowing in a torrential regime into Skocjanske Cave, surely Strabo's "cavern east of Triste." Discharge into the cave mouth averages 8 cubic meters/second. Discharge in times of drought drops below 1 cubic meters/second and in extremely high water situation it can exceed 400.

Within the cave, the Reka can be navigated for 2.4 kilometers to an inverted siphon. Tourists can explore by foot, but only researchers can travel by boat.




Map of the underground River Reka at Skocjanske Cave, 1905.

The excerpt from the March 20, 1885, Taranaki Herald gives an account of a Skocjanske visit in the days of less-restricted tourism.

> *The exploring party started in two boats, along a channel about 70 yards in length, and bounded by rocky walls more than 100 yards high; then a large cave was reached, where the party lauded and fastened the boats, as waterfalls and rapids prevented their further use. The underground journey was continued on the rocky banks, the river being crossed several times on ladders. Six waterfalls were passed and a seventh was reached. The whole distance traversed was not more than 300 yards, and those who took part in it were sorry that they could do no more.*

But where did the Reka then go?

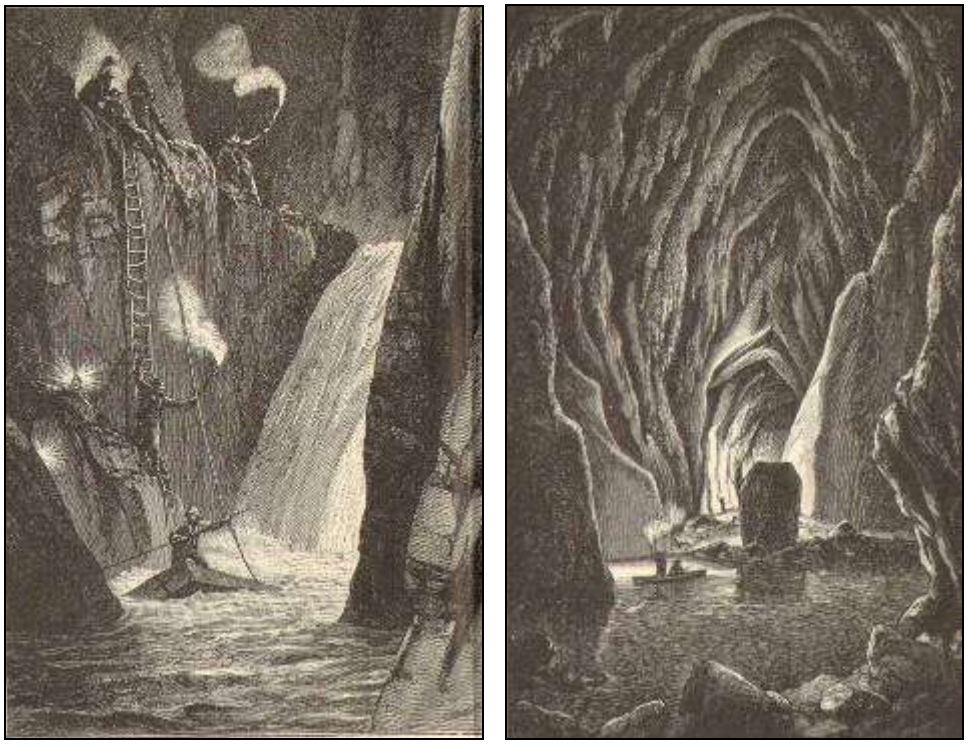
Pietro Imperati (1550-1631) claimed to have proven the continuity of the Rivers Reka and Timavo. From his correspondence to the naturalist Ulisse Aldrovandi,

> *More and more times I went to observe river Timavo to know more about it. You know well that ancient people said the river had seven or nine mouths. I counted more than eighteen of these mouths and certainly there are more. Part of these gush with enormous whirls, others with countless ebullitions.*
>
> *We know the course of the swallowed river till the mouth through three experiments; at first with a dry seaweed, than with the leaves of a type of foreign plant and above all of pine-tree and cypress. At third with broken leaves of grain. But there's more to know about it and about the spring of waters. The mouths, in fact, are larger than springs.*

What isn't clear is where in the river's route Imperati input his tracers. Physical proof of the Reka-Timavo connection would require beginning above Skocjanske Cave, but the reality is that vegetative matter introduced at that point would be impossible to discern by the time it reached the Timavo.

Three centuries later, the Austrians were out to solve the mystery by exploration. From "A Subterranean River," Scientific American, February 14, 1885.

> *Members of the* [Austro-German Alpine Club] *determined, some time ago, to institute a systematic second exploration: of the subterranean course of the river Reka. Rising in the Schneeberg, in Carniola, this mysterious stream suddenly disappears in the so called Karst caverns. At San Giovanni di Duino, twenty miles distant from the spot where the Reka is lost, a river of corresponding magnitude is found issuing from the foot of a hill. This stream is known as the Timavo which takes a westward course, and discharges its waters into the Bay of Montalcone. As to the identity the identity of the Timavo with the Reka, there cannot be a doubt.*
>
> *The expedition, consisting of four persons in two boats, proceeded on their eventful voyage... The river flows for 200 feet through a narrow channel between two perpendicular walls of rock, estimated to be upward of 100 yards in height. At the end of this channel the explorers, whose course throughout was illuminated by the magnesium light, found themselves in a vast cavern where they were able to land. Fastening up their boats, they proceeded for some distance on foot past several cascades and rapids... At length they reached a spot where the river contracts to a width of barely twelve feet... The advance now became more difficult, the explorers being only able to get forward by creeping and climbing. At length they came to the sixth waterfall, which the party was unable to pass. The river here runs between two perpendicular walls of rocks, and suddenly takes a downward leap of over 20 feet.*
>
> *With regard to the Italian Alpine Club, its committee has, during the past summer, done some good service by rendering the splendid cavern of Trebitsch, discovered by Herr Liudner forty years ago, accessible to ordinary tourist.*
>
> *The Trebitsch cavern is 300 feet high, 400 feet in width, and 1,000 feet in length. Through it flows a river, which several authorities believe to be identical with the Reka and Timavo, but the hypothesis is repudiated by many observers. The question can only be settled when the Austro-German Alpine Club shall have accomplished the interesting task it has taken in hand -- that of following the subterranean course of the river Reka from beginning to its termination.*



Skocjanske Cave, Meyers' Konversations-Lexikon (1904)

The Austro-German Alpine Club penetrated no further however, than those before and the answer was still tentative 111 years later. "Timavus and the Supine at Vergil, Aen. 1.246," Classical World 89:5, May 1996, by Robert R. Dyer has this to say about the Reka's fate.

> *Exactly which rivers supplied water in the past to the Timavo is not fully resolved. The accepted source of the modern Timavo, the Recca (or Reka) rises on Mt. Dletvo north of Rijeka (Fiurne)* [near the modern Slovenian-Croatia border] *runs for five miles before disappearing underground in the Karst and then resurfacing for a while, to disappear through the celebrated gorge of Canziano, eleven miles east of Trieste.*

A Skocjanske-to-Timavo underground conduit does in fact exist, and at 40 kilometers, it's the world's longest.

No one's ever traveled it, though.
A health-related warning:

Following "Ought Private Lunatic Asylums to be Abolished?" in Westminster Review, July-December 1894, is an Adriatic travelogue from which the following is extracted.

> *Having obtained candles and a guide, we ascended the stony valley of the Rijeka and penetrated the vast underground cavern, from which that river issues. After we had been climbing for about half an hour over the huge boulders of rock which form the floor of the cavern, we arrived on the shore of an underground lake, similar to that over which visitors to the salt mines near Berchteegaden are ferried by the glare of pine torches. If Montenegro should ever become a haunt of tourists, the grotto at Rijeka with its fine stalactites and its infernal lake will make the fortune of some Montenegrin Charon. It is unfortunate that a place so beautifully situated as Rijeka should, like Antivari, be very unhealthy and malarious.*

3. The River Soca

Robert Dyer, whom we just quoted, informs us of other theories regarding the Timavo's genesis.

*However it has been argued that in earlier days the source of the floods of the Timavo was the ancient Sontius, modern Isonzo, rising eighty-seven miles away as the Soca in the Julian Alps of Slovenia (once part of Carinthia), now entering the Gulf of Panzano through two mouths in its SW extremity, perhaps joined by the Natiso (Natisone), rising a little to the SW of the Isonzo and flowing through Forum Iulii (modern Cividale del Friuli).*

The River Soca to the west of the Timavo is an above-ground channel, but its route has altered several times in past eras.

According to Strabo, the River Aesontius, which in his times flowed past Aquileia to the Adriatic, was once part of the Natisone and Torre river system. A landslide in 585 severed the upper part of the Natisone and caused its subsequent capture by the River Bontius, which in turn lost its subterranean discharge into the Timavo. A subsequent avulsion of the now-larger Bontius returned the watercourse to the lower Natisone. In subsequent centuries the estuary of this new river -- the Soca -- migrated eastward until it captured the costal river Sdobba, through which the Soca now discharges into the Adriatic.

Hydrology can be complex enough without such mobility and we're not even mentioning the Soca's human-made diversions. Even in abbreviated version, it's a convoluted hydrologic chronology, but after all, we're in the Balkans.

Timavo flooding might thus have at times been due to an avulsion of an adjacent channel that would someday be called the Soca. Ensuing legend, however, might have confused the hydrology.

| | | | | |
|---|---|---|---|---|
| "Long ago, my lad, the Timavo plain before you was flooded 5 cubiti deep by the River Bontius." | + | "This, my boy, is the Fontem Timavi, so near the sea." | → | Generations later...<br>"Before our time, kids, the Soca ran underground to Timavo Springs and flooded everything 5 meters deep!" |

And then, of course, there's confused geography.


In the 1571 representation of the Gulf of Trieste, the Timavo appears as a ramification of the River Isonzo, far to the west of its actual location.

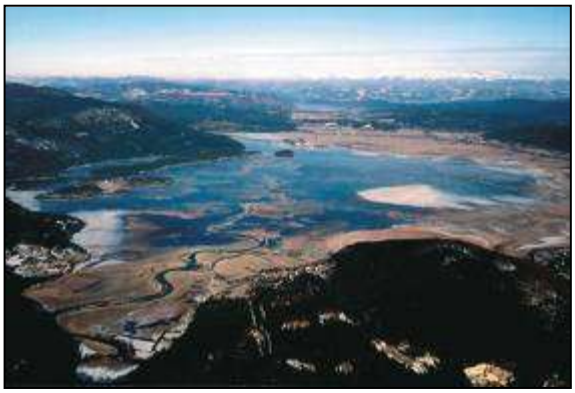
In accordance with ancient writers, Carl von Czornig's L'Isonzo, il Fiume piu Recente d'Italia (1884) described a great lake in the high leg of the River Isonzo and a second great catchment in the middle leg, whose water, through subterranean channels, gives rise to the Timavo.

If the Timavo's location is not agreed upon, it's of little surprise that theories of its source may be literally all over the map.

4. Zirknitzer See (Lake Cerknica)

The Zirknitzer See is a Slovenian lake northeast of Trieste. While its Slovenean name is "Lake Cerknica," we'll use its German form for two reasons: its early reporting took place when the area was part of Austria, and "Cerknica" can be confused with other Balkan geographic features having proper names that look not that much different.

The Zirknitzer See can occupy 40 square kilometers in summer with a depth of 10 meters. In the autumn when rainfall is slight, the lake completely drains into the underlying karst and its bed is covered with foliage. When the rains return, the lake upwells through subterranean inlets. Sometimes the lake does not disappear for several years and in 1834-35, it remained dry for over a year. Its fish disappear and return with the water.



Zirknitzer See, Markus Pernhart (1824-1871)

View today

An early report on the lake is found in "Description of the Zirknitzer Intermittent Lake" by Georg Wernher in his De Admirandis Hungariae Aquis Hypomnemation (1551).

> *It is perhaps only less wonderful, that this* [geological phenomenon] *should be evidence for the existence in the same region of subterranean streams, which flow for great distances below ground, then come to the surface; some of them come to the surface only once, and then are visible no more. And it may also be postulated that from these hidden cavern-reservoirs, certain passages conduct these subterranean waters to the lake; especially since it be known that there are in that locality large mountain caverns, within which the roaring sound of rising or falling waters can be heard; and that the said caverns are as it were lakes, which may overflow as streams or brooks. This I believe to be possible; and testimony thereto is the fact that living ducks come swimming out on them, which nobody can believe to be possible who has ever been in subterranean places to which the atmosphere has no access. But since it is well authenticated that additions to these waters are not fed to them from the mountains by any of river-beds or other hidden water-courses, but come up by some kind of regurgitation process through fissures in the rocks, as though vomited forth, returning by the same channel to be reabsorbed, and all this at regular intervals, who will deny that there is about all this something miraculous?*

We note -- and perhaps by now have to come expect -- Wernher's reference to subterranean streams, but are astonished by the subterranean ducks.

Philip Clover described the lake briefly in Italia Antiqua (1624), confirming the ornithological note: "When the water gushes out to fill the lake there come out with it live ducks"

Johann Weikhard von Valvasor indicated he, too, had seen the same in An Extract of a Letter written to the Royal Society out of Camiola, being a Full and Accurate Description of the Wonderful Lake of Zirknitz in that Country (1687). Ducks are not included in Chapter 50, Wrecks of Ancient Life, but perhaps they should be.

Tobias Gruber's Briefe Hydrographischen und Physikalischen Inhalte aus Krain (1781) postulated an underground riverbed.

> *Below the Zirknitzer See and its surrounding mountains there flows continuous water ... All the caves and passages taken together make an underground river bed, which stretches away invisibly for so many miles, only here and there does it break into daylight a little* [as at the lake] *everywhere it collects water from above ground via abysses and finally leaves the dark regions at Oberlaybach* [Vrhnika] *and other places in the surrounding area.*

Balthazar Hacquet (1739-1815) noted that the mountains surrounding the lake, being of limestone, are filled with caves which give them a cellular structure comparable to a sponge. Even in heavy rain, no streams flow down the mountain side and only after a long delay do the springs at the foot of the hills increase in discharge. The Zirknitzer See, being a completely closed valley, begins to fill up when the underground reservoirs are full.

American Notes and Queries, August 31, 1889,

> *Query -- How do you account for the periodical disappearance of the water of the lake of Czirknitz in Austria? -- R.B.P., Verona, Maine*
>
> *There is very little doubt that the lake of Czirknitz is simply an overflow lake fed by some subterranean river. Very probably that river is the same one which reaches the sea in that wonderful fountain of Timavus, which Virgil so beautifully describes. When the water in the underground river is abundant, the great lake fills, up; when it is low the lake disappears. It is here noteworthy that Mr. Skeat makes the "dry sea" of Chaucer (Book of Duchesse, 1028) to represent this lake.*

We didn't include Chaucer in Chapter 17, Underground Rivers in English Fiction, but it seems that we could have.

5. Predjamski Grad

In the early 1700s, Giovanni Bianchini wondered why the flow of the Timavo near Duino exceeded that of the Reka at Skocjanske Cave. Perhaps the flow was augmented from Zirknitzer See -- every time the latter dried up there was a rising of the Timavo, he'd heard -- or perhaps it was augmented from the cave under the castle Predjamski Grad, not far from Planinska Cave.

Any knight would be pleased to own a castle perched on an underground river, invulnerable from rear assault and assured of water in time of siege. Predjamski Grad is perhaps the most famous of such fortifications, nestled within a 123-meter limestone cliff.

Predjamski Grad €8.00

Below, a 19th-century engraving and modern photograph of Predjamski Grad.

When later informed that the castle cave fed the River Lokva, which in turn joined the River Vipava, Bianchini came to doubt his Predjamski-Timavo hypothesis. He may have been onto something, however, as the Vipava is tributary to the Isonzo/Soca.

6. The Euganean Hills

Dyer also adds this possibility

> *At least by the time of the Elder Pliny and Lucan, the Romans understood that the Timavo was the continuation of a river gone underground much higher up; Lucan* [a Roman Encyclopedist, 39-65 AD] *believed that it rose in "the Euganean hill" to the west near the source of the Aponus.*

Attributing Timavo inflow to the Euganean Hills, far to the west near Venice, stretches the limits of credibility. A conduit circumnavigating the head of the Adriatic would be geologically odd and the Euganean Hills are volcanic, not karst.

We include the Euganean Hills possibility if for no other reason than to illustrate that the Romans were not unimaginative.

"The Euganean Hill from Padua" (c. 1777) by John Robert Cozens

Perhaps Lucian was referring not to the hills' actual location, but instead to their westerly direction. If so, he could have been indicating the Soca.

Modern hydrologic studies indicate that the Timavo draws from multiple subterranean channels which merge before reappearing in the springs. The springs' outflow is roughly

One third from the River Reka via Skocjanske Cave.

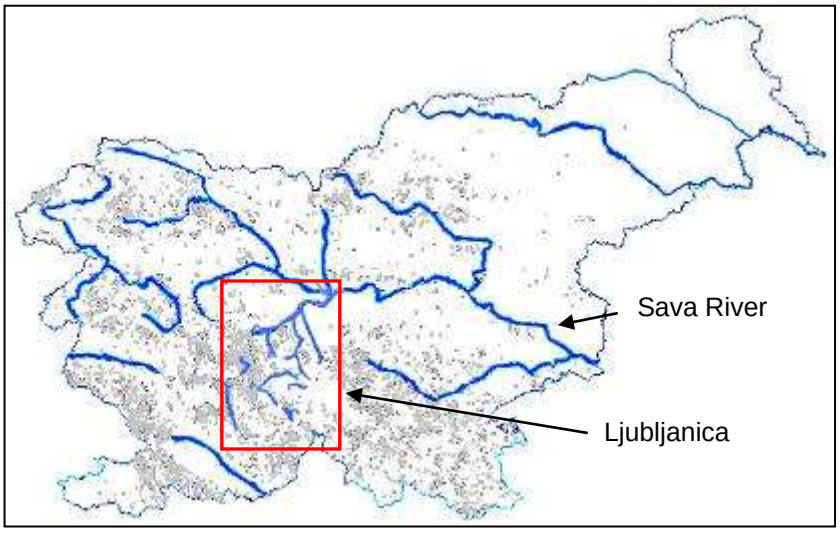
Two thirds from
The River Vipava west of Skocjanske,
The River Soca,
The River Rasa in Croatia, and
Infiltrated precipitation.

Lucan's Euganean Hill theory has never rises to scientific contention and the Trebitsch cavern hypothesis fails because subterranean rivers in the Trebisnjica watershed flow in a south-easterly direction, to be discussed later in this chapter. An Izoso connection, if there ever was one, is obscured by history.

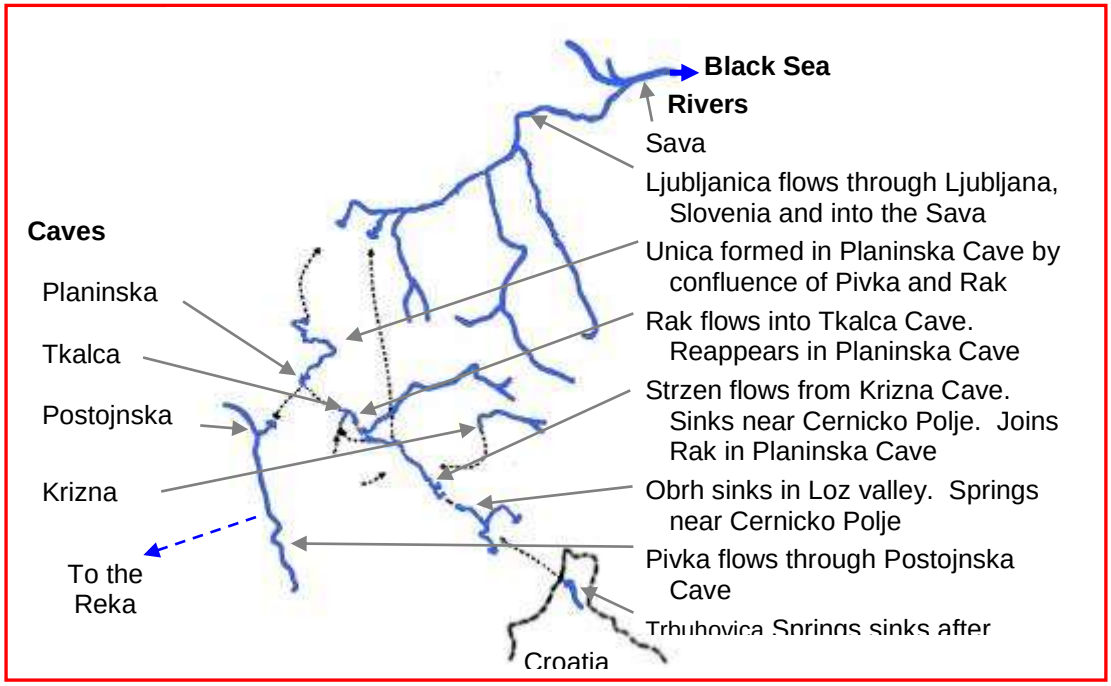
The River Timavo may be but 2 kilometers in length, but it's a civilization's worth of speculation regarding origin.

**The Ljubljanica River**

The River Reka's just a dip and reappearance, not that complex to map. The Ljubljanica, on the other hand, assumes seven names depending on location and cartographer. The basin extends over almost 1800 square kilometers, of which 1100 are karst. Light-grey dots signify caves.



In the cutout below, envision the Ljubljanica flow path as a watch hand sweeping clockwise from 5:00 to 1:00.



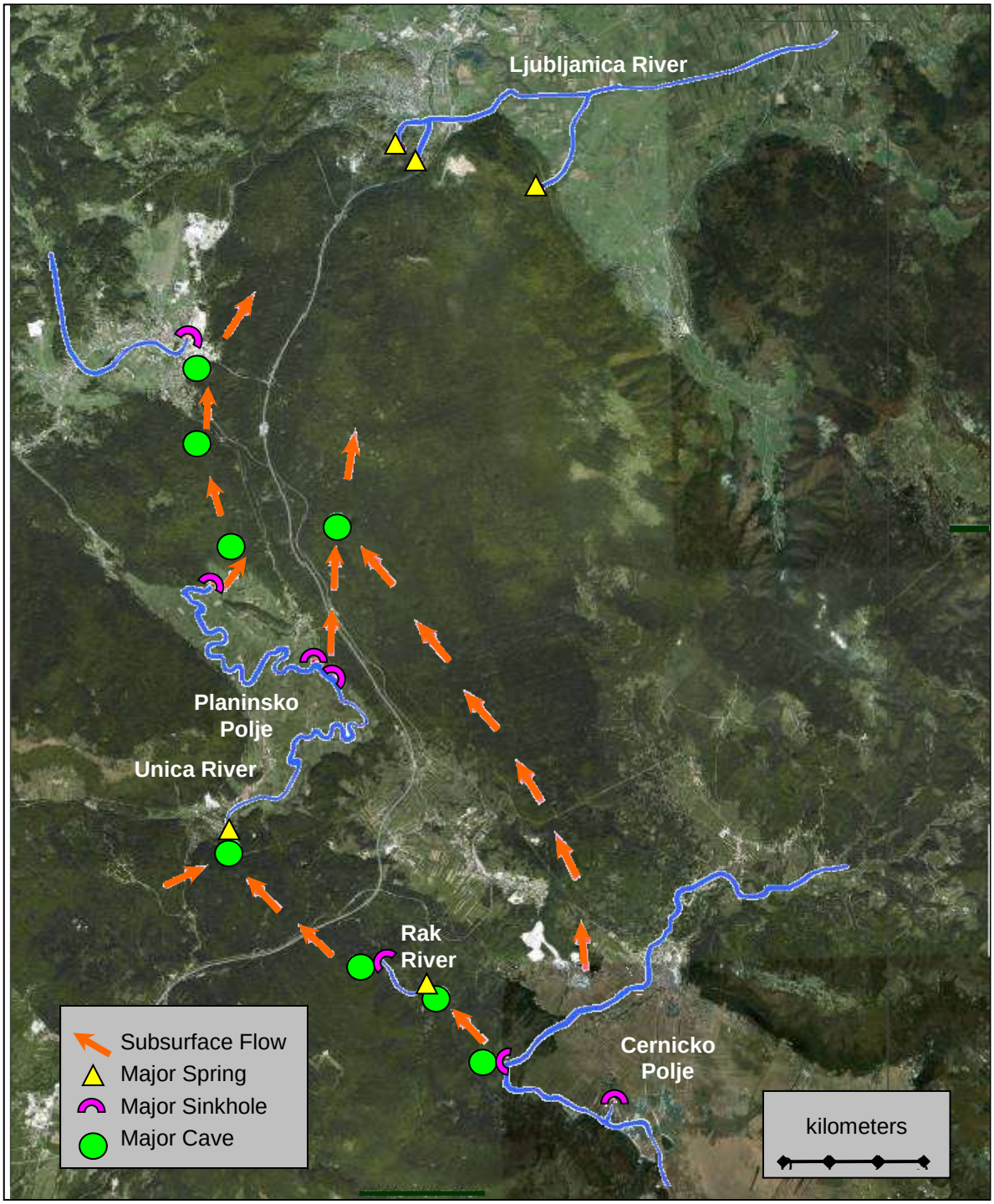


The Ljubljanica is said to be half underground, but that depends upon what's said to be the Ljubljanica. Below is a pair of photos of the headwaters.

Headwaters

The magnitude of the upwellings suggests more than local riparian runoff alone. Something seems to be coming from somewhere, but without a great deal of fieldwork, there are many possible somewheres.

The map below shows a bit more of the system's hydraulic complexity.




Mean discharge of the Trbuhovica reach that's actually called the Trbuhovica is 25 cubic meters/second at it upper end and 44 cubic meters/second at its mouth.

The Sava River, into which the Trbuhovica flows, continues onward through Croatia and Bosnia and Herzegovina and into Serbia, where it joins the Danube and then flows between Romania and Bulgaria to the Black Sea.

But even with the benefit of modern cartography and several centuries of geographic sleuthing, let us admit our confusion regarding this river of sequential names and inebriated directionality.

How much more confounding, then, would the geography have seemed to the early mapmakers whose principal sources were the Greek legends?

The heroic saga of Jason and the Argonauts, recorded by Apollonius of Rhodes in the third century BC, traversed the known world of Greek times.


The voyage involved overcoming obstacles, of course, but where possible, skirting perils, such as the dismal waterways with which we are acquainted from Chapter 1.

> *Thence ye must turn back a little space through the sea and beach your ship on the land of the Mariandyni lying opposite. Here is a downward path to the abode of Hades, and the headland of Acherusia stretches aloft, and eddying Acheron cleaves its way at the bottom, even through the headland, and sends its waters forth from a huge ravine.*

The Argonauts were well aware of the underworld, but as something to avoid. As far as practical sailing, on the other hand, Jason didn't hesitate when told of a remote branch the world-encircling River Ocean of Greek mythology suitable for crossing the Balkans from west to east. The River Istros [the Danube] is "broad and very deep and navigable by a merchant ship... For a long space it cuts its path as a single river through a vast territory."

Istros was said to bubble up in the western mountains, "but when it reaches the boundaries of the Thracians and the Scythians, it splits in two: one stream empties here [the mouth of the Danube]; but behind it the other branch flows through the deep gulf which rises up from the Trinakrian sea [east of Sicily] which lies along your land, if indeed it is true that the Achelous comes forth in your land."

For a branch of the Danube to empty into the Adriatic would be a topographic feat for an otherwise westerly-flowing watercourse, but it's what Jason was promised. He would have been unhappy to find no westerly outlet and thus had to portage the divide. Had had the brave band rowed upstream into one cave and emerged heading downstream from another, Apollonius would have surely informed us.

Unlike the saga of Odysseus, what we're told of Jason's boating is entirely on the surface.


Odysseus

☑ Surface

☑ Underground


Jason

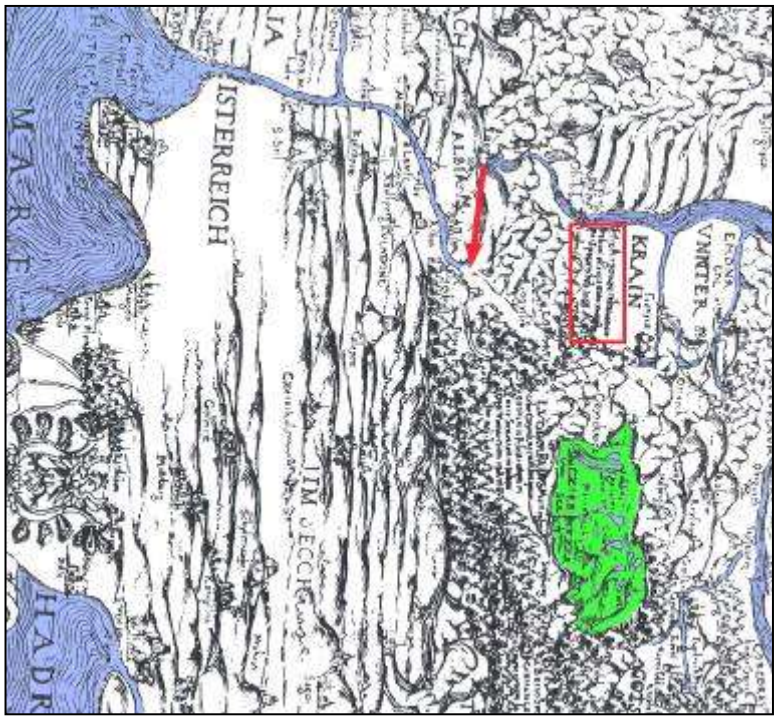
☑ Surface

☐ Underground

Let us now jump to the 1561 maps of the Austrian Empire by Wolfgang Lazius. To the right is a portion of one plate, rotated from the original to make north the top.

The Ljubljanica headwaters flow eastward from the upper center. The Vipava River flows westward. The modern Vipava starts closer to the Adriatic coast, but we're trying to think like Lazius.

Shown in green is Lazius's placement of the Zirknitzer See with blow and suction holes.




According to Lazius -- we've boxed his Latin in red -- this is the region is where the Argonauts dipped underground on their homeward route. We've taken the liberty to mark such a headwater-to-headwater shortcut with the red arrow.

But as a subterranean boat ride wasn't part of the original sage, why did Lazius include reference to a sub-mountain river on his map?

R. Trevor Shaw and G. Macqueen James address the question in "Did the Argonauts of Greek Myth Go Underground in the Slovene Karst?" in Acta Carsologica 27:1, 1998. Their conclusion:

> *The idea seems to have arisen just when maps were showing that hills formed a barrier between the east-flowing Sava and the rivers of the Adriatic basin, and when the existence of caves and underground rivers was becoming more widely known.*

By the 16th century, the Balkan's karst nature was recognized as geographic fact. Quasi-scientific explanation of a classic tale made sense to the mapmaker.

We briefly visited Postojnska Cave (known as Adelsberg Cave in Austrian times) in Chapter 50, Wrecks of Ancient Life, where we met the blind Proteus and the Slovenian 10-tolar coin.

On an August afternoon of 1850 when water in the cave was unusually low, Adolf Schmidl and his son launched their craft into the cavern, paddling upstream for most of the night. Meanwhile, an evening thunderstorm drenched the surrounding area, and at about 1:00 AM, the river rapidly rose 3 meters, stranding the explorers inside the cave. When the river fell, father and son hastily departed.

The government constructed a gate, an illuminated path, a bridge and a stairway. Torches were banned in favor of clean-burning candles and oil lamps. A rail line was built from to the cave mouth in 1857 and 15 years later, 4 kilometers of narrow-gauge tracks were inside, the guides pushing the two-seat cars.

Postojnska, c. 1834

Postojnska Today

From "The Caverns of Adelsberg," The Ladies' Repository 5, 1870, published by the General Conference of the Methodist Episcopal Church,

> *This cavern, in common with others in this district, as at Nabrisina and St. Cangian, is under the control of a company, organized under the direction or sanction of the government. They furnish guides, and all needful conveniences for the traveler. They furnish illuminations of any required extent. We secured what they call the "grand illumination," costing some eight or ten dollars. Men had been sent on in advance to begin lighting our 1,600 candles, which, as we afterward found, were arranged in rows and groups along the sides, or at the distant bottom of chasms, or in glorious crowns far above in the domes of the cavern.*
>
> *Suddenly at your right hand, as you look down far below, you catch the flash of a light on its troubled waters at the bottom of a chasm. This river disappears bodily beneath the hill, in the heart of which the cavern is, entering its west or north-west side, lower down than the cavern's mouth. It recalled vividly to my mind the Xanadu, of Coleridge, in which it is said,*
>
> > *Alph, the sacred river ran*
> > *Through caverns measureless to man,*
> > *Down to a sunless sea.*
>
> *No sooner does the river appear than it disappears in some deeper, and hitherto unexplored, part of the cavern. While we waited the guides run ahead with lamps, and lighted candle after candle, which brought, from time to time, out of the darkness the most unexpected visions.*

The "sunless sea" yet again.

New York Times, March 28, 1881,

> *Just below you the furious river goes tearing and foaming down its dark, narrow channel on its way to the outer world, while above stair after stair of rock-cut steps winds slantwise up the face of the cliff, melting at length into the utter darkness that fills the depths beyond... while the hollow roar of the Stygian stream below, the ghostly glimmer of its half-seen waters, the*

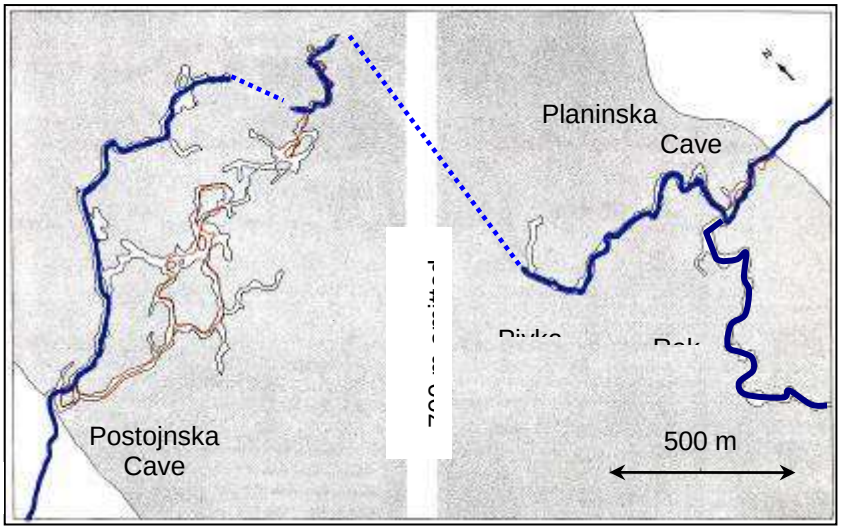
*mighty void of its sunless caverns, which look all the vaster for these tiny specks of light which struggle in vain against the gloom of this shadow of death.*

Postojnska Tourism, Victorian-Era

Today's Train Ride

Postojnska
€20.00

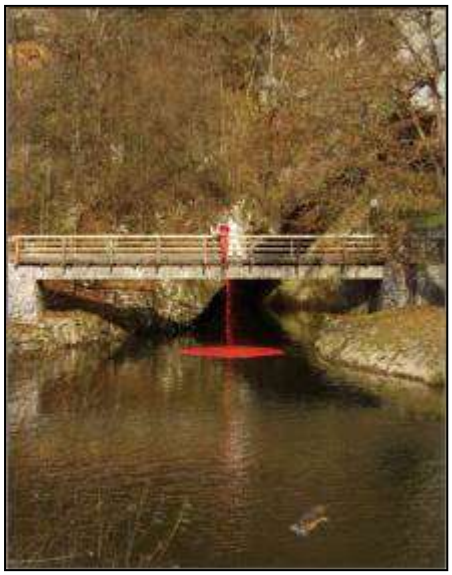
The train loops back to the cave mouth, but the Pivka River, which flows into the cave, makes no such return trip, but continues into what becomes an unexplored route and emerges in nearby Planinska Cave. The price isn't that different than that paid by the Lady Methodists in 1870, but no one today is lighting 1600 candles.




Red lines indicate tourist paths and the railway gallery.

Postojnska had about 1,000,000 visitors per year in the 1980s -- twice the tourist traffic of Mammoth Cave -- but the numbers understandably dwindled with the onset of regional warfare.

To the east, the Rak River flows into Tkalca Cave through an arched entrance and disappears into a sump. We discussed tracers in Chapter 49, Finding the Underground Rivers, but here's a photo of Amidorhodamine G injection of into the sink.



The Rak also reappears in Planinska Cave, where it merges with the Pivka to form the Unica, the largest subterranean confluence in Europe.

A Pivka branch tube journey is shown to the right. The Rak branch is considered too dangerous.

Planinska
€7.00

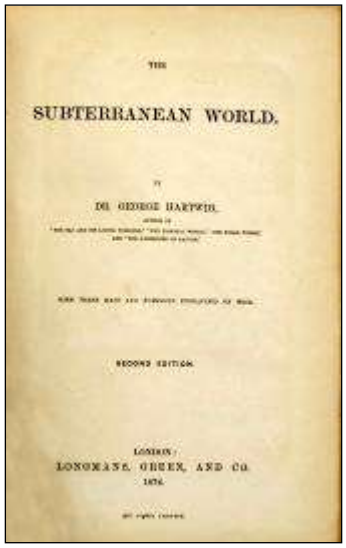
The sparkling waters gushing from the Planinska mouth attracted travelers as early as the 13th century.

It is said that Dante (Chapter 6) visited the region in 1319, where the cave's ambiance inspired the beginning of Inferno.

Postcard copy of an engraving of Dante in the Tolmino cave.

Modern Grotta di Dante

Adolf Schmidl, the explorer who was trapped in Postojnska, was also instrumental in the exploration of Postojnska. The Subterranean World (1872), by Georg Hartwig, gives an account.



THE

SUBTERRANEAN WORLD.

BY

DR. GEORGE HARTWIG.

SECOND EDITION.

LONDON:
LONGMANS, GREEN, AND CO.
1874.

*Among the bold explorers who have launched forth their barques on unknown subterranean rivers, the late Adolph Schmidl, of Vienna, holds a conspicuous rank. In a canoe specially constructed for the purpose he trusted himself to the dark streams of Carniola.*

*To give an idea of the difficulties and of the enjoyments of these subterranean explorations, we will follow the intrepid naturalist on his voyages of discovery through the famous Cave of Planina, through which flows the Poik, a river which is at all times deep enough to carry a boat.*

*The sullen stream, completely filling its whole width, compels the explorer to trust to his canoe. When he has passed a portal about eight fathoms high and half as broad, with proportions as symmetrical as if it had been sculptured by the hand of man, the thundering roar of a distant cataract announces still grander scenes. The portal widens, and the astonished explorer suddenly emerges on a lake 250 feet long and 150 feet broad.*

*In the left or western branch of the cave, into which he penetrated to a distance of more than a mile, his boat had to be unloaded no less than eleven times on account of the reefs that obstructed its passage, while the explorers, wading through the water, dragged it over the shallows. Once even, where the navigation was interrupted by large masses of rock, under which the tumultuous waters disappear with a dreadful roar, they were obliged to take the little shallop to pieces, and to reconstruct it on the opposite side of the mound. The navigable part*

*of this western branch ends in a circular dome, the floor of which is entirely filled with a lake 180 feet long, and from 40 to 45 feet deep.*

*The eastern branch of the cave, through which the main stream flows, is much larger than the branch above described; it is also easily navigated, as it contains but two reefs and a small number of cliffs. On first ascending the stream, the continually increasing roar of waters announces a considerable waterfall. Enormous masses of stone, piled up by the falling in of the roof, have blocked up and narrowed the bed of the river to fifteen feet, and cause the stream to shoot down in a broad sheet ten feet high. The cataract, madly rushing over the jet-black rocks and casting up flakes of milk-white foam, is very beautiful, and, when brightly illuminated, must produce a truly magical effect.*

*Beyond the cataract the river flows for a short space in an invisible channel, as its waters are completely hidden under rocks. It was no easy task to carry the planks of the dismembered boat over these rugged blocks of stone, but after reconstructing it on the opposite side of the mound, and overcoming the minor obstacles of a couple of reefs, the river was found to flow in a deep channel between steep walls, and a free navigation opened to a distance of at least a league and a half.*

*The breathless attention we bestowed on the guidance of our boat and on the wonders that surrounded us sealed our lips, and we glided silently along through the dark waters, that now, for the first time since they began to now, reflected the glare of a torch.'*

*Throughout the whole distance of 1,140 fathoms beyond the second reef, there is but one landing-place; everywhere else the walls rise precipitously from the water. In some parts the roof descends so low that the explorers were obliged to lie down in the boat and to shove it along by holding to the projections of the vault, which finally left but a few inches' space above the water, and thus opposed an invincible obstacle to all further progress.*

By the 18th century, the demand for guides, candles and torches spawned a cottage industry.

Krizna Cave is famous for the cave bear bones unearthed in 1876. The skull is still on display. Only 100 visitors/year are allowed on the boat tour which crosses 13 of the 22 known lakes. The price is for a party of three or four.

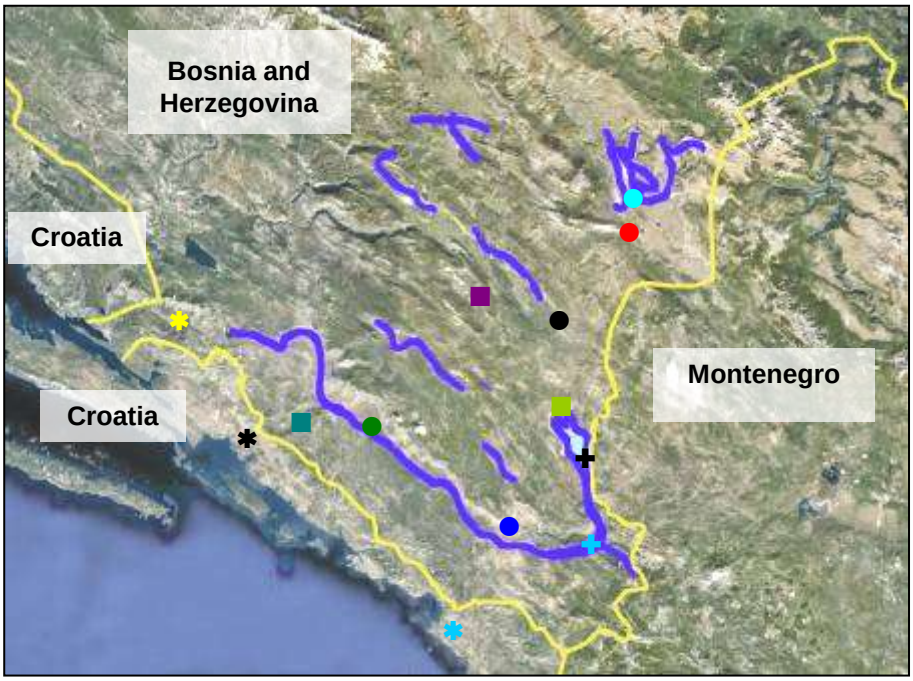
Krizna
€180.00

And now we leave Slovenia, passing through Croatia -- where, had we the time, we could have followed a dozen rivers with subterranean associations -- and into Bosnia and Herzegovina.

**Trebisnjica River**

Bosnia and Herzegovina's Trebisnjica River runs 98 kilometers above ground and 89 below. The watershed drains 5,000 square kilometers, of which 600 are shared with the Neretva drainage to the north, depending on a reservoir elevation to the south. We're dealing with changing geometries, somewhat akin to the regional politics.

The map below is for location reference. Think of a clock hand sweeping the map from 12:00 to 9:00, but be prepared for an occasional counterclockwise 12:00 to 9:00, when it's high water at 6:00.




Poljes
- Gatacko
- Cernicko
- Fatnicko
- Trebinjsko
- Popovo

Caves and Springs
- Dejanova
- Vjetrenica
- Bregava

Reservoirs
- Bileca
- Trebinje

Outlets to the Adriatic
- Neretva
- Slano
- Dubrovnik

We'll employ the Serbo-Croatian term "polje," a flat plain in karst territory, typically having an area measured in tens or perhaps a few hundreds of square kilometers. The scientific literature of karstology routinely employs other Serbo-Croatian improper nouns -- techno-speak for those in the know -- but "polje" is the one term that lacks a satisfactory single-word equivalent in English. "Field," has too many other meanings.

The Trebisnjica River originates from two major mountainous streams characterized by sharp, almost erratic bends and changes of direction. Although we're discussing underground rivers, not politics, we can't help but noting that centuries of Balkan history have likewise been characterized by sharp, almost erratic bends and changes of direction. To study underground rivers is so often to study so much more.

The Musnica River flows from the eastern to the western border of the Gatacko Polje.

The Gracanica River flows also into the Gatacko Polje where it meets the Musnica and together they disappear.

The Devon Karst Research Society, headquartered in the United Kingdom, maintains an extensive database on the region. To remind ourselves of recent history, here is the Society's advice regarding Gatacko Polje.

> Parts of Gatacko Polje remain ethnically sensitive areas and we strongly advise visitors from other countries not to wander around or to travel off-road without specialist local guides

Chapters 70-72 and 74 dealt with dangers associated with underground rivers. In the Balkans, being shot should be included.

The water re-appears in the Fatnicko Polje, only to sink again after a short run in the sunlight. Discharge varies between 0.4 and 14 cubic meters//second, 85 to 90 percent of which until 1967, reappeared in the head of the Trebisnjica River.

**World Record**
**Greatest Insurgence**
**14 cubic meters/second**

In 1967, the springs were inundated by Bileca Reservoir, but we'll get to Bileca shortly.

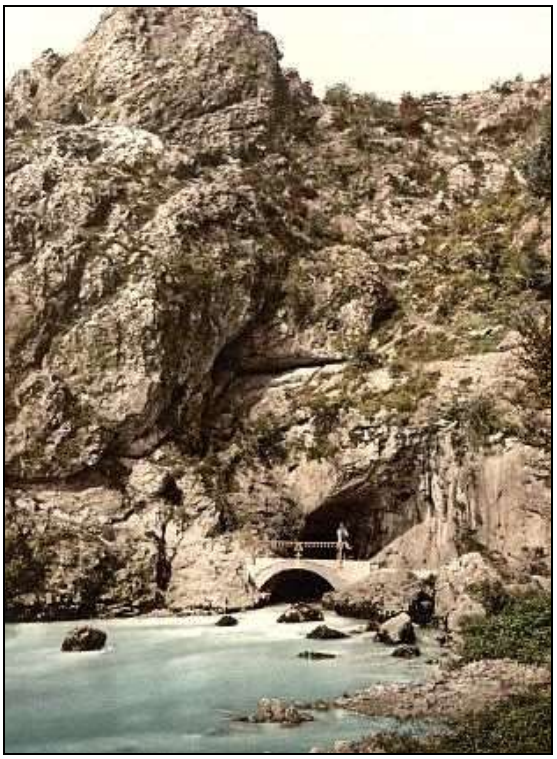
A few facts related to the subterranean journey to the Trebisnjica Spring Group:

| | |
|---|---|
| Straight-line distance from furthest Gatacko Polje | 34 km |
| Difference in elevation from furthest Gatacko Polje | 520 m |
| Difference in elevation from furthest Cernicko Polje | 480 m |
| Difference in elevation from Fatnicko Polje | 130 m |
| Travel time from Gatacko Polje at minimum water table | 35 days |
| Travel time from Gatacko Polje at maximum water table | 5 days |
| Mean discharge | 80 m3/sec |
| Maximum discharge | 864 m3/sec |

The Trebisnjica Springs Group consists of interconnected outlets, the principal ones being,

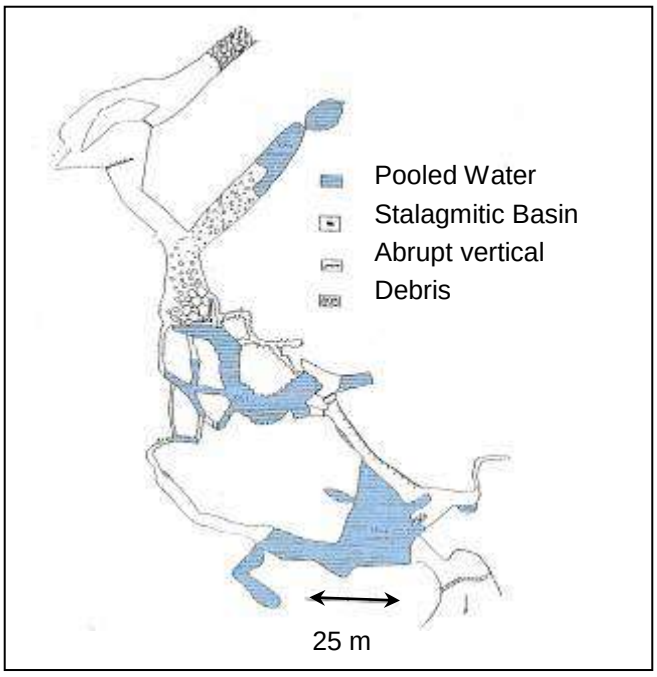
Dejanova Cave,
Oko Springs, and
Niksicko Springs

Below is a pair of historic pictures of Dejanova Cave, its entrance, approximately 4 by 6.5 meters.



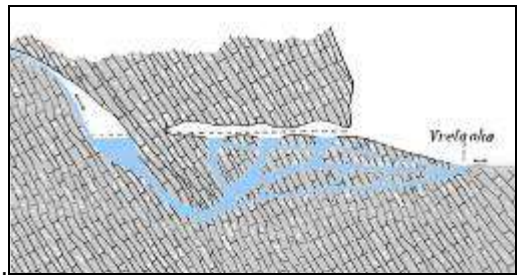
Dejanova Cave,
1890, upper left
1900, upper right
undated, lower left

The natural lake within the cave entrance, usually 1.5 meters below the lip, would rise after periods of heavy rainfall to discharge streamflow under the arched bridge. The depth of the lake was about 1 meter, but increased in the greater part of the chamber.




Cave passages are shown to the left.

The cross-section shows the inverted siphon connections to Oko Springs, five springs in itself, 200 meters downstream.



Local merchants constructed water mills on opposite river banks after World War I, creating an artificial lake which inundated both the arch bridge and the lower portion of the cave entrance.

Thanks are due to Trebisnjica historian Dragan Tabakovic for his contributions to this chapter, this photo-reconstruction of the mill pond being just a small portion.

Dejanova Cave Mills by Zivko Janjic

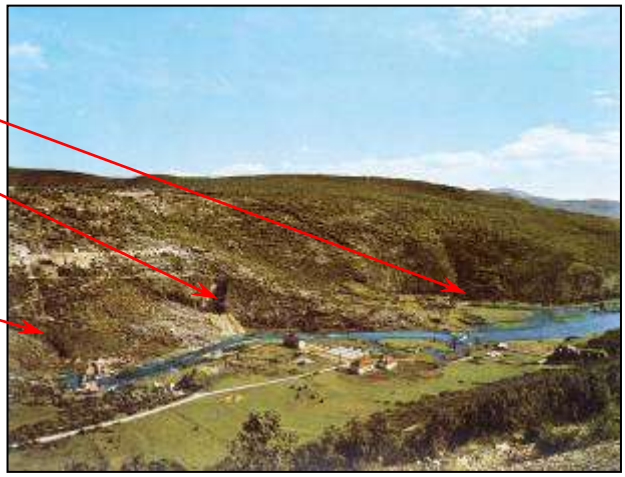
From within Dejanova Cave by local artist Kokolj

Photo, ca. 1960

Niksicko Spring joins the main flow at the second bend

Oko Springs, with its large exit gulley, is opposite the red-roofed Hotel Trebisnjica.

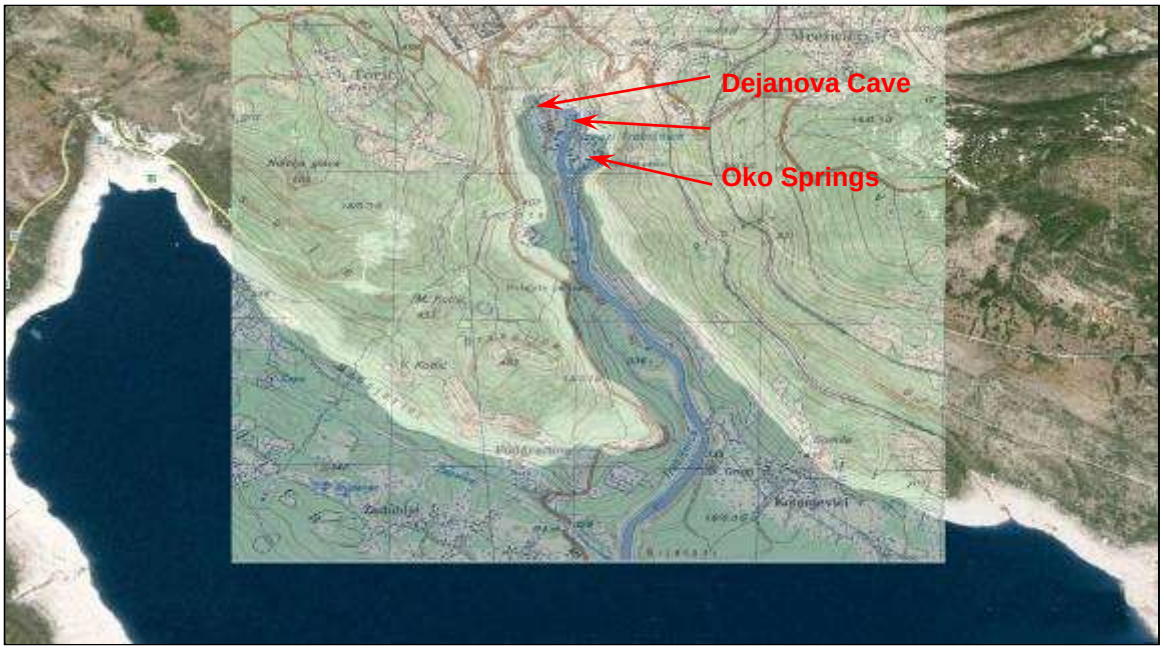
Dejanova Cave



But even that's now history, thanks to 75-meters of inundation by the 1.3 billion cubic-meter Bileca Reservoir. Completed in 1968, the project was the former Yugoslavia's greatest public work. Storage in the karst between the reservoir and Fatnicko Polje is estimated to add another 0.2 billion cubic-meters.

Bileca Reservoir from approximately the same viewpoint as the pre-1967 photo.

The superimposed pre-1967 topographic map and current aerial photo shows the inundation in plan view.



The 16th-century Arslanagic Bridge was dismantled and moved 3 kilometers downstream as a continuation of the second stage of the hydropower system. Although of similar Turkish architectural style, our Dejanova Cave arched footbridge, alas, didn't fare as well. The photo to the right, just prior to inundation, is our adieu to the quaint crossing.

Arslanagic Bridge, Relocated

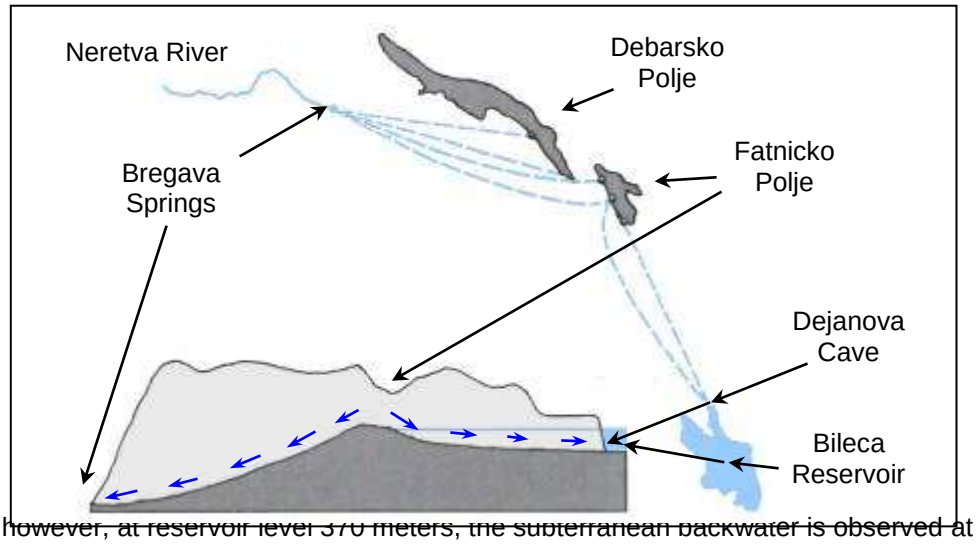
Dejanova Cave Bridge, Submerged

Trebinje Reservoir, a smaller structure, was built downstream. A 90 cubic meter//second tunnel from the reservoir powers a hydroelectric plant near Dubrovnik, Croatia. An additional channel is directed to the Capljina power plant in Herzegovina.

As tabled below, Bileca Reservoir can affect the hydrologic functionality of Fatnicko Polje.

| Elevation (meters above sea level) | |
|---|---|
| 460 | Fatnicko Polje |
| 420 | Bluff above Dejanova Cave |
| 400/402 | Reservoir spillway |
| 400 | Reservoir level at which Fatnicko Polje begins to drain westward |
| 370 | Reservoir level at which Fatnicko groundwater level beings to rise |
| 325 | Dejanova Cave entrance |
| 315 | Riverbed in front of Dejanova Cave |
| 296 | Riverbed at dam |

In pre-reservoir days, Fatnicko Polje spanned the drainage divide between the Trebisnjica watershed to the south and Bregava Springs in the Neretva watershed to the west. What happened on either side didn't affect the other.

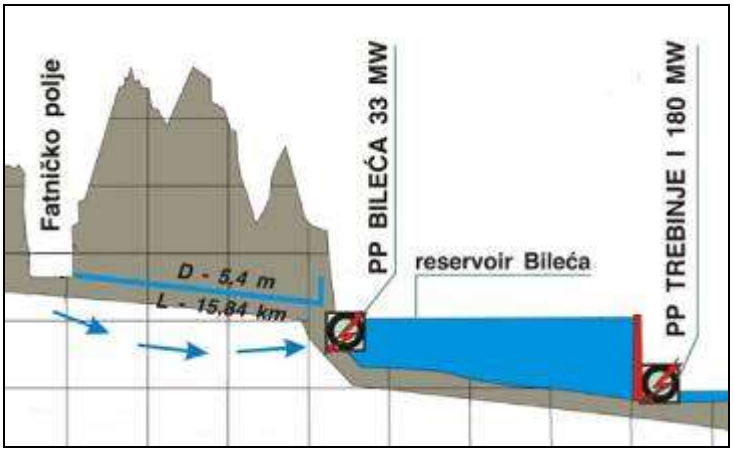



Today, however, at reservoir level 370 meters, the subterranean backwater is observed at Fatnicko Polje. At elevation 400, that of the subterranean ridge, there is no water slope to the south and percolation redirects westward to the Neretva.

As it's beyond our scope to summarize the configuration, complexities and predicted consequences of current and proposed hydroelectric development, we shan't go there. It's just another factional Balkan war, this one waged with consultants. We will, however, note one small component, an underground augmentation, so to speak.

We just saw that Dejanova Cave flow from Fatnicko was good enough for the washer-woman, but the karst channel is insufficient for hydropower. As part of the region's Upper Horizon project, a 5.4-meter tunnel was begun in 1986, suspended for armed conflict, resumed in 2002 and completed in 2009.

Fatnicko Entrance




The power plant itself, however, is still on hold.

The tunnel's local environmental consequences may include

Increased local flooding at Bileca, already documented,
Shrub growth (already observed) due to lack of tunnel lining and/or karst backwater, and
Increased subterranean salinity, predicted but not yet verified

Regional environmental consequences, potentially more severe, may stem from inter-basin transfer. Augmenting a subterranean river without environmental detriment is not easily achieved.

We'll catch up with the Neretva a bit later, so back to Bileca.

Spill from the reservoir turns west into the Trebinjsko Polje, and follows the southern mountain slopes to Popovo Polje, the largest karst field in the Balkans. To reduce loss, the riverbed was blanketed with gunite for 67 kilometers in 1979.

Vjetrenica Cave ("wind cave"), the largest cavern in Bosnia and Herzegovina, runs from the edge of Popovo Polje and has been explored for 6 kilometers, but it could stretch 15 to 20 kilometers to the Adriatic. While the cave conveys some Trebisnjica seepage, however, it's not a major abstraction.

The river then curves north near the Croatian border and again sinks, re-emerging for its finale in three outflows,

1. After some 20 kilometers underground, the Ombla River rises as a cave spring near Dubrovnik, from where it flows 4 kilometers to the sea. Mean discharge is 24 cubic meters/second, with a range of 2.3 to 112.5. The Ombla has been used for Dubrovnik's water supply since 1437


To the right, an 1883 relief map of the Ombla River. Above, Ombla Spring today

2. As submarine springs ("vrulje" or "boiling water") near the harbor of Slano, northwest of Dubrovnik.

3. As springs feeding the lower Neretva River, the watercourse fed by Bregava Springs, which -- as previously noted -- also draws from Fatnicko Polje when Bileca Reservoir is high.

Here's an excerpt from "Herzegovina," a traveler's impression by A.J. Evans in Turkey and the Balkan States, as Described by Great Writers (1908), edited by Esther Singleton.

> *The "polyes," or mountain plateaus, are the most characteristic feature of the country. The smaller towns and villages group themselves on their level and comparatively fertile surface, and the districts, or cantons, thus formed are walled round by a natural rampart of white limestone mountains. These "polyes " may be described as oases in what is otherwise a desert expanse of mountains. The surface of some, as notably the great Mostarsko Blato, is marshy, and in spring forms a lake; others are watered by streams which disappear in swallow-holes of the rock, and make their way by underground channels either to the sea or the Neretva. The most conspicuous example of these is the Trebinjsca, which disappears in two swallow-holes in Popovo Polje, and after making its way by a subterranean passage through a range of mountains, wells up in the mighty source of Ombla, near Ragusa, and hurries in undiminished volume to the Adriatic.*

The intervening century, however, hasn't gone well. The Devon Karst Research Society's notice regarding Popovo Polje today:

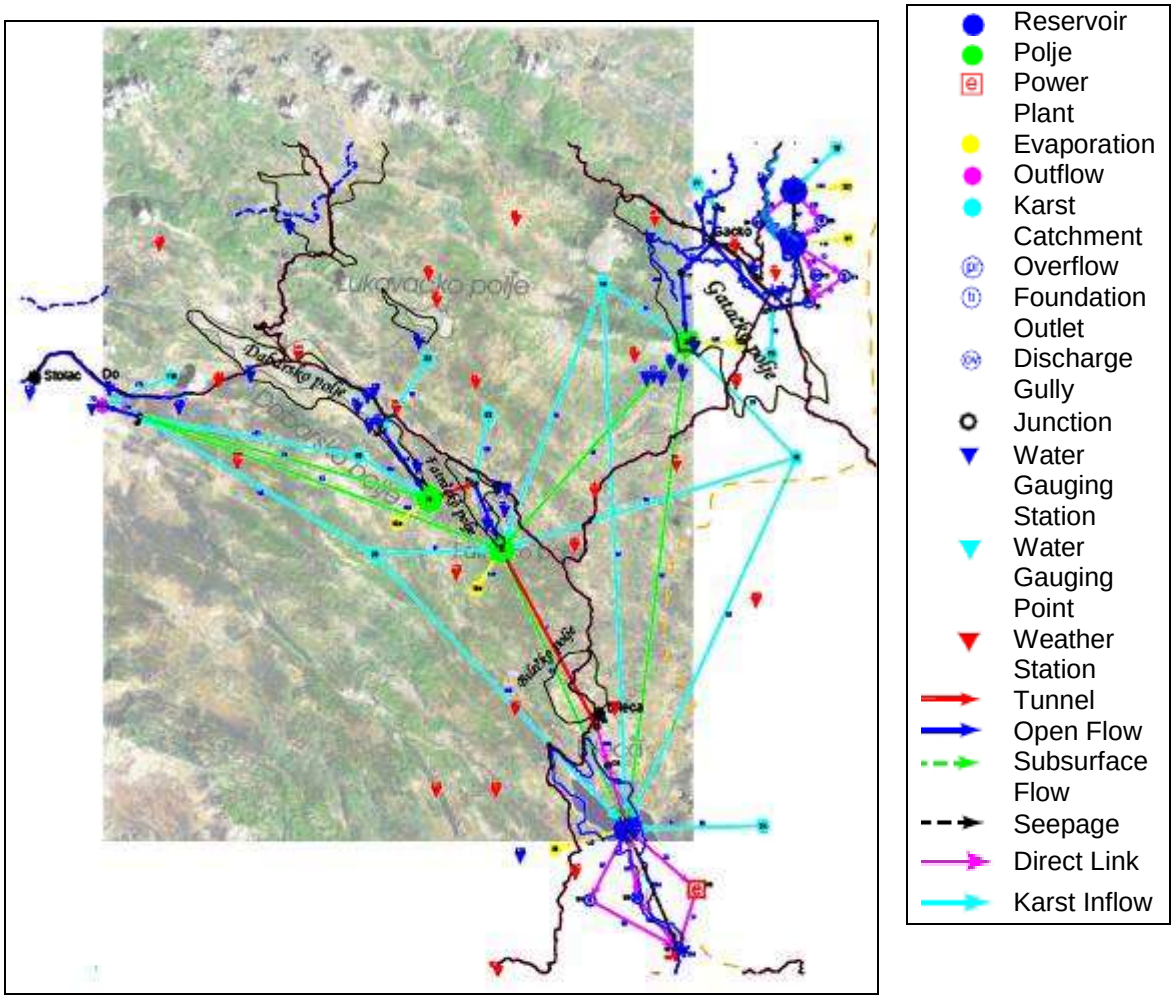
> There are numerous obscured ammunition dumps in the Strujici to Kotezi area and un-cleared minefields and mined buildings in certain parts of the Polje from Zavala to beyond Ravno further west and in Trebinjsko Suma either side of the former front-line areas. Additionally, there is widespread occurrence of sundry unexploded ordnance both on the surface and underground. Concrete bunkers in the former front-line areas invariably contain unexploded munitions and may also be mined. Mine warning signs are not always in evidence.

And speaking of armed men in the Balkans, underground rivers are particularly associated with those from Albania, or at least were so in the past. From The New Student's Reference Work (1914),

> *Albania is the southwestern part of European Turkey. It is about 290 miles long from north to south, and from 40 to 50 miles in width. The country is mountainous, and is noted for its underground rivers and beautiful lakes. The Albanians are mountaineers and many of them brigands.*

We can only wonder how the officials tasked to manage the water resources manage to do so.

To illustrate the level of detail required to scientifically oversee the system, we present a schematic of the Trebisnjica's water balance, each symbol a set of rules and equations.

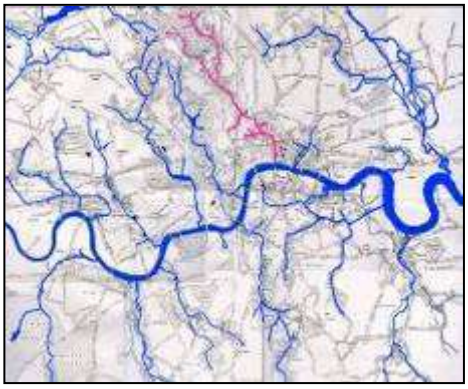



Could the logistics of ethnic conflict involving arbitrary borders and vigilante armed forces be any more difficult to follow?

# CHAPTER 79
# THE SINKING OF THE FLEET

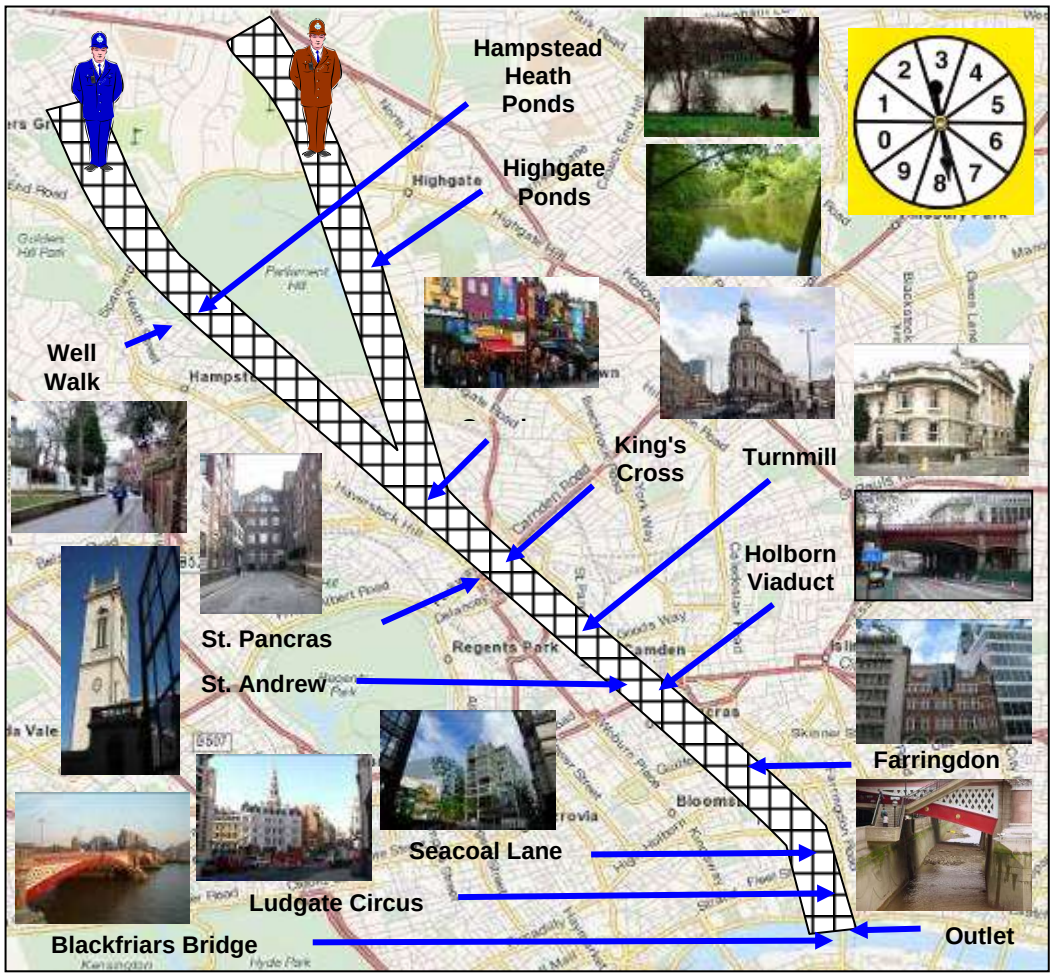
Thirteen rivers have gone missing in London Town:

| | |
|---|---|
| The Westbourne | The Effra |
| The Walbrook | The Tyburn |
| Stamford Brook | Counter's Creek |
| Hackney Brook | The Neckinger |
| The Peak | The Earl's Sluice |
| The Falcon | The Wandel |
| The Fleet | |



We'll investigate just the last, a river last seen flowing toward the Thames in the 1870s. The lost river was said to be of gentile origin, but odiferous and pestilent where it had interacted with the lower classes.

We've invented a game we'll call "Follow the Fleet." Choose your bobby and spin the spinner.



For those less sporting, the game board may be used as a reference for the remainder of the chapter.

The waters of the Fleet emerge about 100 meters above sea level on the slopes of Hampstead Heath in Northwestern London. The river was known as the "River of Wells" in the Middle Ages when London was more renown than Lourdes for the healing qualities of its springs. Water from Chalybeate Well (on today's Well Walk St.), rich in iron, was sold in London markets.

River Fleet near Hampstead, Illustrated London News, 1854

The top of Hampstead Heath is the only place where the River Fleet now flows on the surface

Today's Heath ponds were formed in the 17th century when the upper reaches of the watershed were dammed to supply drinking water to St. Pancras.

Hampstead Heath

Highgate


Hampstead Heath Bathing £2.00

Hampstead springs have long been spa sites and the City of London Corporation yet operates the pools for year-round bathing, one for men, one for women, and one for mixed swimming

The last sign of the superterranean River Fleet, however, is at the bottom of the lower Highgate pond where the flow drops into a grate.

So thus we must look at history, which being of London, is in no small quantity.

In the Fleet's 7-kilometer descent, the forks originally amalgamated in Camden, then flowed through St Pancras and Kings Cross as a stream up to 20 meters in width, further widening through what would become Farringdon St. with enough flow to turn a mill at what's now Turnmill St. and enough depth to coal a ship at what's now Seacoal Lane. Fleet Bridge was built in about 1180 at what's now Ludgate Circus. The Fleet created an estuarial basin 200 meters wide.

By the 12th century, however, the area was given over to derelict housing and prisons and the stream became choked by filth. Tanneries discharged offal and skin scraps. Butchers added rotten animal parts. The Whitefriars at the mouth of the Fleet complained that the stench overpowered their incense.

As more water was withdrawn during the 13th century, the Fleet became shallower, frequently silting up with rubbish. Well-to-do Londoners yet flocked to the Hampstead spas, but the river further downstream gradually became a conduit for the spread of disease.

In a 1355 inquiry regarding the state of the stream, jurors recommended it be at least 3 meters broad and of sufficient depth to float a vessel freighted with a ton of wine, but the river failed even that test.

In 1598, John Stow wrote in his Survey of London that there were five bridges over the Fleet, and the river was,

> *Impassable for boats, by reason of the many encroachments thereon made, by the throwing of offal and other garbage by butchers, saucemen and others, and by reason of the many houses of office* [toilets] *standing upon it.*

Royal Orders were issued in 1652 for the stream's cleansing and preservation, but it was reconstruction after the Great Fire of London, 1666, that provided Christopher Wren the opportunity to renovate the river's lower reach in the style the Great Canal of Venice.

Alas, however, the 1728 etching of emaciated bathers is a comment on the Royal Orders and Sir Christopher's efficacy regarding sanitation.

It was the rise of real estate prices, coupled with mercantile demand to diminish the noxious odors, that initiated the river's first stage of disappearance in 1737 when Fleet Market, two rows of shops, arched the channel between the Fleet and Holborn Bridges.

Map of 1666

The year of the Great Fire of London

Map of 1705

"New Canal," navigable to Holborn Bridge, constructed in 1669-1673

Map of 1746

Fleet Market, consisting of two rows of shops arching the river, opened in 1737

We can see in the pictures below Wren's architectural influence on the Fleet Bridge and at the same time, gain an appreciation of the Fleet as a viable wharfage.

Fleet River, St. Andrew Church in Background (c. 1700)

The Mouth of the River Fleet as depicted by Samuel Scott (c. 1750)

The feasibility of covering the river spread, however, by the 1810s the Fleet was covered from Kings Cross to Camden.

Out of sight, but as the day's covering wasn't always vapor-proof, now necessarily out of smell. Below is a ditty of 1839.

*Will you go to Bagnigge Wells, Bonnet builder, O!*
*Where the Fleet-ditch fragrant smells, Bonnet builder, O!*
*Where the fishes used to swim, So nice and sleek and trim,*
*But the pond's now covered in, Bonnet builder, O!*

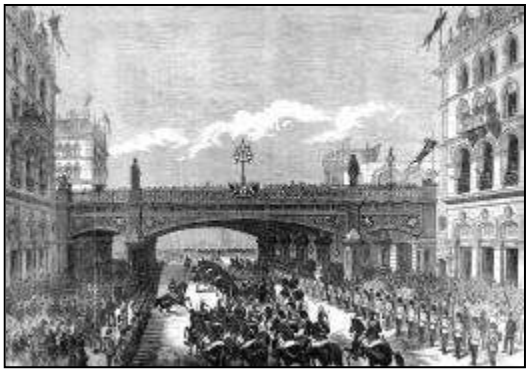
Right: Fleet Sewer, West Street, c. 1844

Or from something more recent,

*Confined underground in phases between the 1730s and 1870s the allure of centuries old brick built tunnels under London still outweighs the thoughts of trudging through a river of detritus. The water flows underground for 4 miles (6.4 kilometers) to join the River Thames.* -- Michael White, Isaac Newton, The Last Sorcerer (1999)

Fleet Market was demolished in 1820, becoming Farringdon St., which in turn was canopied in 1869 by Holborn Viaduct at the former site of Holborn Bridge.

By the 1870s, the entire river, apart from the few hundred meters below the source springs, had been relegated underground.



As lamented by Charles Dickens in "Clock Fast, Five Hundred Years", All the Year Round, April 25, 1863,

*Thames! Why you don't suppose in all these years we have stood still at your old strips and shreds of bridge. It is all bridge now, my boy. Thames is an underground river, at least as far*

*as Gravesend. It runs under that sweep of preen playground. And there is plenty of traffic, be sure, of which in these good days that are come, we no more see the circulation on the face of the town, than we see the circulation of the blood -- otherwise than as a bloom of health upon my sister's face there. All you see on the surface of this lovely London is the bloom."*

"Up the Thames," Lippincott's Magazine of Popular Literature and Science, January 1876, provided another opinion, a bit more erudite.

*The Thames is hereabouts joined from the south by a somewhat exceptional style of river, characterized by Milton* ["At a Vacation Exercise in the College"] *as "the sullen Mole, that runneth underneath," and by Pope* ["Windsor Forest"]*, in dutiful imitation, as "the sullen Mole that hides his diving flood." Both poets play on the word. In our judgment, Milton's line is the better, since moles do not dive and have no flood -- two false figures in one line from the precise and finical Pope! Thomson contributes the epithet of "silent," which will do well enough as far as it goes, though devoid even of the average force of Jamie. But, as we have intimated, it is a queer river. Pouring into the Thames by several mouths that deviate over quite a delta, its channel two or three miles above is destitute in dry seasons of water. Its current disappears under an elevation called White Hill, and does not come again to light for almost two miles, resembling therein several streams in the United States, notably Lost River in North-eastern Virginia, which has a subterranean course of the same character and about the same length, but has not yet found its Milton or Pope, far superior as it is to its English cousin in natural beauty.*

Lost, but not out of power, we might say, as an 1846 sewage gas explosion near King's Cross sent a tidal wave of filth through the streets, demolishing buildings and ramming a boat on the Thames into Blackfriars Bridge.

Map of 1807

New Bridge Street covering the reach to the Thames

Map of 1846

Sewage gas explosion.

Map of 1900

Interceptor sewer system designed by Joseph Bazalgette.

The problem, of course, is that a river sent underground still has a mind to follow the easiest downhill route.

The backbones of Chief Engineer of the Metropolitan Board of Works, Joseph Bazalgette's 318-million-brick sewer system, built between 1859 and 1865, were west-to-east interceptors. These interceptors, shaped like an upside-down horseshoe with a relatively-flat concave floor, carried the flows from smaller round or oval tunnels fed by local flows to pump stations where the waste was stored in reservoirs. At high tide, the reservoir outlets were closed and the sewage accumulated. At low tide -- the difference being as much as 2 meters -- the outlets were opened and the effluent drained to the lower Thames.

Shown to the right is our portion of Bazalgette's system, the original north-to-south course of the Fleet -- shown for orientation, as the river was by now long buried -- transected by three west-to-east interceptors.

Before City-wide sewerage, the River Fleet was still the River Fleet, just underground. Now even that claim couldn't be made, as progressive reaches of the river have been purloined out of the watershed.

Illustrations and reports from the Illustrated London News of 1845 and 1854,

> *One of the oldest Sewers, if not actually the oldest, in the metropolis, is the Fleet; once an open river, which, as Stow tells us, "had been of such breadth and depth, that ten or twelve ships' navies at once, with merchandise, were wont to come to the aforesaid bridge of Fleet" – is still a river, although hidden from sight; the waters of the Highgate and Hampstead hills still run through it; the old Bourne (now also a sewer) still delivers its waters into it; but, in addition to this, from running through a dense population, it probably received and discharges more sewage water than any other sewer in the metropolis.*

As for a vivid sense of the darkened journey, "Through London by Canal," Harper's New Monthly Magazine, May 1885, cites an early traveler of the enclosed waterways.

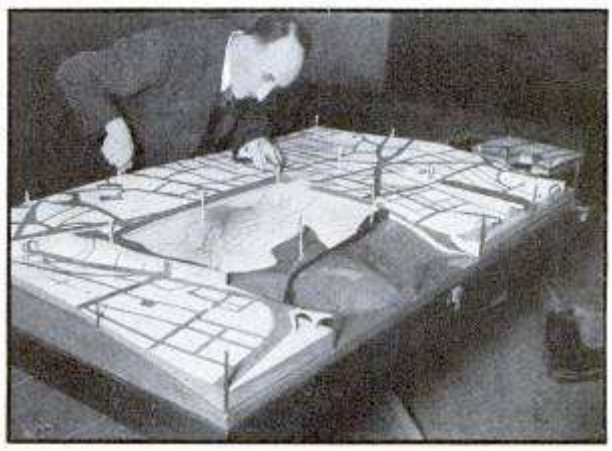
> *The passage by steam-tug has a truly Tartarean aspect: the smoke, fire, noise of the engine, the black gloom of the arch, the blackness of the water, the crashing of the barges against the sides of the tunnel, the lurid light gleaming at each extremity, from an aggregate of infernalia.*

Today, these lost rivers do more than flow to the Thames. From "Underground River to Cool Passengers Sweltering on Tube," Times Online, July 15, 2004,

> *A revolutionary cooling system is to be installed on the London Underground that will draw on the millions of gallons of water pumped out of the deep tunnels each day.*
>
> *The system will be fitted first at Victoria, one of the busiest Tube stations, and is expected to reduce summer rush-hour temperatures on Victoria Line platforms by between 5C and 6C.*
>
> *Tube trains will push the cooler air along the line, bringing relief to the hundreds of thousands of passengers who endure sweltering conditions on the Underground.*
>
> *The cooling system takes advantage of the Underground's existing pumps, which prevent the capital's rising water table from flooding the network. Water will be extracted from boreholes at a temperature of 14C and pumped to heat exchangers located in rooms between platforms. Fans will blow hot air from the stations across water pipes. The water temperature will rise by a few degrees as it extracts heat from the air.*
>
> *The cooler air will then be blown back on to the platforms and the warmer water will be pumped into the Thames. At Victoria, where a trial of the system will begin before next summer, more than 200 liters a second will be drawn from the underground River Tyburn.*

And while we're near Fleet St., the former Central Telegraph Office is just around the corner. From Popular Science, June 1934, "Model Shows London's Buried Lake"

*To aid in planning a restricted building area in London, England, engineers have just completed a five-foot model of one of the city's strangest features. This is a subterranean lake long unsuspected and only recently discovered, twenty-six feet beneath the city's central telegraph office. The lake is estimated to be at least sixteen feet deep. To show how its presence might affect building plans, the scale model was constructed with a removable top.*

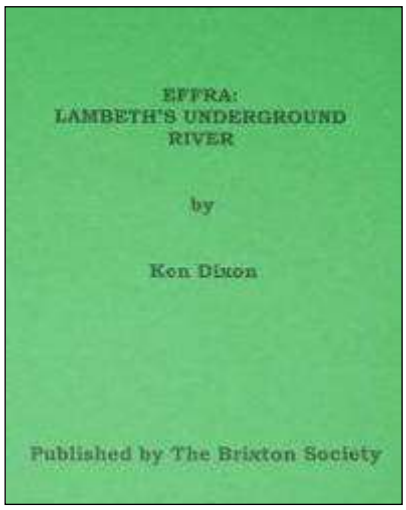


Where there's an underground river, it stands to reason that there might be an underground lake, we expect that the writer meant "aquifer."

Although London's modern sewerage network has been since upgraded, Bazalgette's Fleet diversion can still be inspected.

And at last we've arrived at the Thames, where what minimal remains of the Fleet outflow, emerges beneath Blackfriars Bridge.

The Fleet's not London's only underground river. Take, for example, Effra: Lambeth's Underground River (1993) by Ken Dixon about a district of south London. For more than a century this river has been enclosed, but before urbanization, the Effra ran as an open stream.

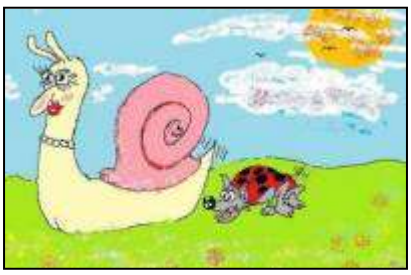



The underground river is woven into British legend. Thomas Learmont, better known as Thomas the Rhymer, was a 13th century Scottish laird and reputed prophet, the hero of "Thomas the Rhymer" in Sir Walter Scott's Minstrelsy of the Scottish Border (1804).

*O they rode on, and farther on,*
*And they waded thru rivers above the knee,*
*And they saw neither sun nor moon,*
*But they heard the roaring of the sea.*

In Paul Andruss' contemporary retelling of the Rhymer tale, a fairy queen weaves her life into a tapestry which when touched, provides passage into the legend and onto on a fairy road running along a river beneath London, emerging in the Thames.

And even as we depart the sub-London waterways, Adventures of Izzy the Snail (undated internet publication) by Fenella Shorty is passing the lore to the next generation.



*"Good afternoon, Sir," a beetle called Ringo emerged from under a leaf. "I am glad to see you, as I was about to make my way to the Police station to report an incident. I heard someone screaming round here earlier. Someone has fallen into one of the hidden holes in this tree."*

*"Oh no!" Sergeant paused for a moment. "Below the tree, there is an underground river that leads to the River Thames..." he said. "The snails are in great danger. We must run to their rescue! Ringo, thanks, you are a star."*

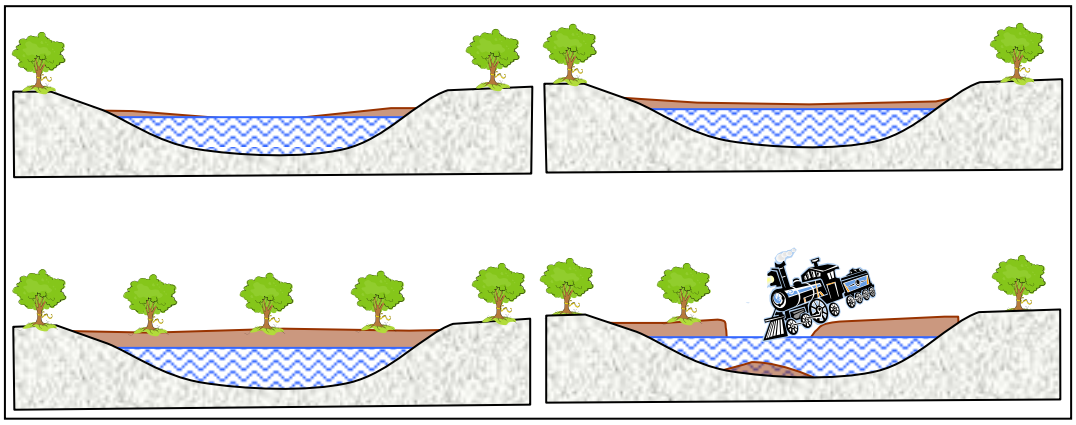
Ringo Starr, of course, sang "Yellow Submarine" and the Beatles' movie was of somewhat similar plot, but we haven't the time to follow every underground channel braid.

Few subterranean streams are so historically complex, but as we've come to recognize, underground rivers follow a myriad of routes, not all of which stem from geology.

# CHAPTER 80
# RAILROADS AND INCRUSTED LAKES

Lake incrustation, a subject with which we may be unacquainted, is the geologic process in which a lake's surface becomes progressively covered with earth, which in turn comes to superficially resemble that surrounding. Such encrustation, however, may not support a locomotive.

Our entire chapter may be reduced, in fact, to the following graphic.



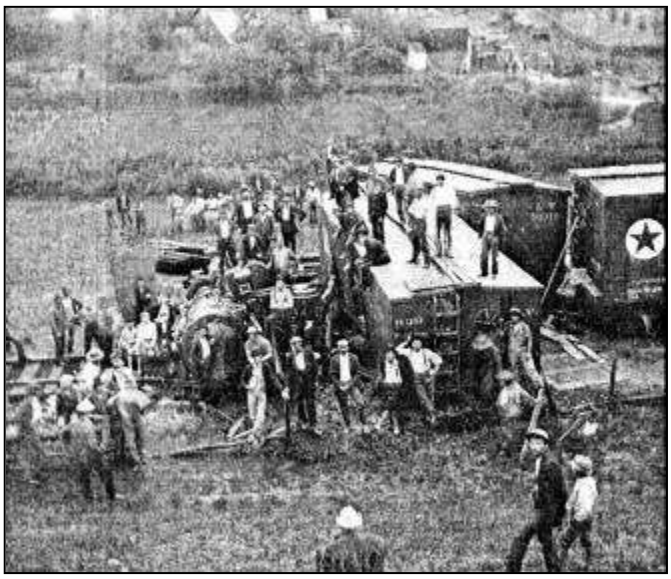
Lake Incrustation and Railroad Derailment

For those who question the premise of land suspended upon water, we have the authority of American railway men on the subject.

**Railroads**

By the mid-1800s, America was on the move, steel rails being king.

Progress wasn't flawless, however, as evidenced by the train wreck caused by an embankment failure on the Maryland and Pennsylvania line. As described in A History of York Township, 1753-2003, an "impressive accident ... creating quite a stir in Ben Roy." Locomotive No. 2 was badly damaged but repaired and returned to service.



The opinions of the railroad men regarding such matters -- we apologize for the gender exclusiveness, but this was the fact -- merit our pursuit.

We'll begin with five news accounts from the late 1840s.

As reported in "Growing over of Lakes," Michigan Farmer of January 1, 1849,

> *There is a small Lake, called Bear Lake, between here and Marshall, which is not far from half a mile across, and which is rapidly growing over. Mr. P. remarked, that during the seventeen years he had been in the country, more than one half of its entire surface had grown over, by means of the gradual accumulation of leaves and other decaying vegetable remains, which floated upon its surface, thus forming a productive marsh. This reminds us of the discovery of an underground lake by the Central Railroad Company, to their cost. A few miles West of Niles, they came to a marsh which needed to be raised to a grade of twenty feet. It is some seventy rods across it in the narrowest place, and here they commenced their grading, but they had not extended it more than forty feet from the bank, when the entire mass of earth, twenty feet in depth, which had been hauled upon the marsh, sank down and disappeared. Upon examination it was found, that the marsh, consisting of common muck, of some ten or twelve feet thickness, rested upon a lake, whose greatest depth is about eighty feet, and whose waters are clear as crystal. The marsh is about two miles long, and averages about a half a mile in width, covering doubtless through its whole extent, the waters of a once open lake. But the company were not to be daunted. They proceeded with their work, filling up where the grade had sunk, and extending it over the unbroken part, until another portion of it gave way, and thus they have gone on, filling up with earth from the bottom of the lake, until they have nearly completed the grade. Eighty men have been employed upon it for fifteen months, and for eight months of the time night and day, one set of hands relieving another. The expense has been enormous. The marsh has yielded the best of wild grass, and a portion of it is said to have been tilled, producing good crops of potatoes, corn, etc.*

The aerial photo to the right shows the location today, Brookwood Golf Course. We can only speculate if in some future era, historians will pursue correspondences between underground rivers and golf courses. See Chapter 88, East Side, West Side, All Around the Town, for further associations.

The Weekly Eagle, December 28, 1848, didn't explain much about the subterranean lake, other than its length, but we like the paper's use of the hand graphic.

*A subterranean lake has been discovered on the line of the Central Railroad of Michigan. It was discovered by the sinking of the embankment built across a marsh plat of ground, and is ascertained to be about two miles in length, and in some parts half a mile wide.*

"Subterranean Lake Recovered," Scientific American, November 18, 1848, offered some speculation.

> *On the Michigan Railway it became necessary to carry a grading or embankment of fifteen feet high across a low piece of ground, containing about 100 acres, nearly dry enough for plowland. When they had progressed with the grading tor some distance, it became too heavy for the soil to support, the crust of the earth broke in, and the embankment sunk dawn into seventy nine feet of water! It appears that the piece of ground had been a lake, but had collected a soil of roots, peat, muck, &c., on its surface, apparently from ten to fifteen feet thick, which had became hardened and dry enough for farm purposes. Mr. Brooks thought it would have supported the road, and the fact might never have been discovered that it had rested on the bosom of a lake.*

"The Subterranean Lake on the Central Railroad, Michigan," Scientific American, December 30, 1848, provided a bit more detail.

> *In reference to this lake, which we noticed some time ago in the Scientific American, the Detroit Free Press says the sudden disappearance of the embankment was accompanied by tremendous convulsions of the ground for some distance around where the casualty occurred, and cracks were caused by the upheaving of the ground, deep and large enough to bury a cart and horse in. From exploration and researches made, it appears that the piece of ground over which the grading was to be made had once been a lake, but was not covered by a soil of roots, muck, &c. to the thickness of from ten to twelve feet. The submerged lake is about two miles long, and is in parts half a mile wide. At the place where this railroad track crosses, it is the narrowest. At one end of the lake is what appears to have been an island, as there are trees of large growth standing. The depth of the lake is ascertained to be about 80 feet in the deepest part.*
>
> *After the sinking of the first grading the work was pushed ahead with increased strength and for eight months, 80 hands were employed continually, day and night, one set retiring as the other came on to the work. As the embankment gradually extended out over the part that sank into the sod and crust, again it would become so heavy that another sinking would take place, and in this manner the work has been going on.*

"Subterranean Lake," Scientific American, April 29, 1848, reported much the same story in nearby Sandusky County, where we'll spend the entire next chapter, Mainlining the Sewage.

> *On the line of railroad between Sandusky and Urbana, and near Bellefontaine, Ohio, is a small "round prairie," containing about 80 acres. The Mud River Railroad was originally laid out and graded across this prairie, but the workmen one morning discovered that a portion of the track had disappeared; large timbers were laid across the "hole," and the superstructure again completed, when about six hundred feet of the road dropped down. Again the company sought to build a foundation -- the timber upon sixty acres was deposited, in this hole, and more than 10,000 dollars expended, and still the hole was not filled. A slight curve around the prairie was then made, at an expense of 1,100 dollars whereon the cars now run.*
>
> *Across this prairie runs a small stream -- the soil is rich, consisting of decayed vegetable matter, some six or eight feet in depth, which is evidently crust over a small lake; the water under this crust is thirty feet deep and fine fish are found in theses subterranean waters. The streams in this cave are not known to rise and fall with the waters of the Green River, in the vicinity, and is supposed to have a water communication with other lakes in the neighborhood, of which there are several, from the fact, among others, that the same species of fish are found in each.*

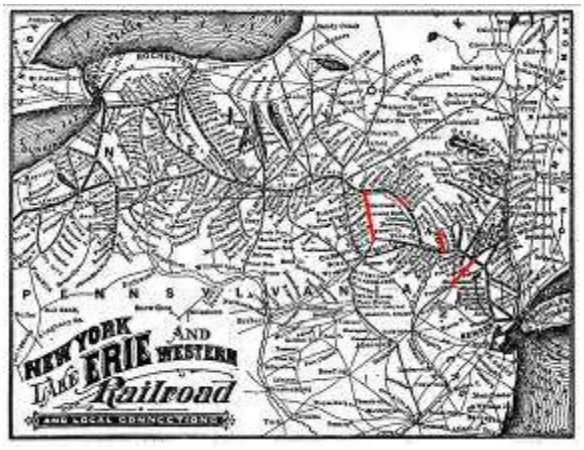
Three Scientific American stories in a single year make encrusted lakes a topic of national interest.

"Phenomenon in Indiana," Scientific American, September 23, 1868, kept the idea in popular circulation.

> *A portion of the track of the Bellefontaine and Indianapolis railroad, about 250 feet long, sank fully sixteen feet and the ground around sank with it. Traffic was interrupted until the track was raised by "cribbing." From twelve to eighteen inches appear where the water has risen out of the crack. A subterranean lake is supposed to exist under the track.*

And then there were the cases of New York, New Jersey and Pennsylvania railways.

The New York Times of September 5, 1871, and June 12, 1880, ("Rails in Unstable Spots, Building over Morasses and Underground Lakes, Instances where Portions of Roads Have Disappeared from Sight -- Driving Piles 160 Feet to Find Solid Ground -- Weeks of labor Made Useless in a Night -- A Train Sinking into the Ground") and the July 1892 Locomotive Engineers Journal chronicle a plethora of disappearing railway beds. Red marking on the 1884 railway map indicates the locations.




As the reports overlap, we'll combine the excerpts.

> *The Jefferson branch of the Erie Railway was built in 1812-8... When it was in course of construction the road-bed for a distance of a quarter of a mile disappeared one night. An apparently bottomless bog appeared in its place. Into this pit 10,000 cart-loads of gravel, and over 500 hundred hemlock trees, branches and all were thrown, without having any visible effect toward forming a bottom. A pile 40 feet long was then driven down its entire length. Upon it another one of the same length was placed and driven down, and still no bottom was found. Four of these long timbers were forced down, one on the other, before solid foundation was reached, proving that the bog, or lake, or sink, was 160 feet in depth. The existence of this*

*curious formation at this spot was the more remarkable because it was on the summit of a ridge 2,000 feet above tide, and all around it were rocky hills and ledges.* -- New York Times, September 5, 1871

*In 1870, when the Monticello and Port Jervis Railroad was being graded near Gilman's, it was noticed that the ground for several rods was moist and "shaky." It required much filling to make a solid road-bed. A year afterward, the road having been in operation several months, the watchman of that section of the track was walking along the railroad just after the passenger train to Monticello had passed the spot. Suddenly he saw the railroad embankment gradually sinking for a long distance ahead of him. He ran to a high bank at the side of the road just as the railroad dropped, with a loud noise, 15 feet below the surface. It required days of labor and the driving of long piles to construct a secure foundation for the rails*. -- New York Times, June 12, 1880

[We must briefly pause at this point to differentiate Monticellos. This one, the one having to sinking terrain, is in New York. The Monticello of the following December 13, 1890, New York Times underground-lake story is from Illinois.

*Monticello -- Frank S. Brooks of Deland, Pratt County, has discovered an underground lake. He was digging a well on the farm of C.H. Moore, west of Deland, when he came to a strata of clay 15 feet thick so hard that he was compelled to use dynamite to remove it. After digging down 65 feet and boring 22 feet he came to a body of water, which burst forth with a rushing current and rose 50 feet in thirty minutes. It then was still rising.*

Following are two more railroad-meets-underground-lake items from the same paper.

*Last fall one of these phenomena occurred near Basket Station, on the Erie Railway, in Sullivan County. About three acres of land, heavily timbered with hemlock occupying an elevated position, suddenly sank below the surface. The tops of the highest trees in the tract could not be seen above tee banks. The sinking was not accompanied by a crash, as in a landslide, but the land appeared to sink gradually and easily. The trees stood, and are still standing in their natural positions, as if nothing had occurred. In close proximity to the scene of this phenomenon there is a lake, which no doubt was once much larger, and over which this plot of ground had formed, as in the other cause.* -- New York Times, September 5, 1871


OFFICIAL POCKET TIME TABLE
OF THE
NEW JERSEY
MIDLAND
RAILWAY.
Issued from the General Ticket Office,
MAY, 1874.
Trains are Run by New York Time.
98 Liberty St., New York.
R. H. CHIPMAN,

*Near a point on the line of the New-Jersey Midland Railroad, known as Port Tuttle, the workmen were greatly surprised one morning a week or two since, to find that several rods of grading that they had left overnight had entirely disappeared, and water and loose mud of unknown depth was all that could be seen. An iron rod fifty feet long was put down, but no bottom was reached, and its real depth hall not yet been ascertained. The general appearance of the surrounding country would seem to indicate that there is here an under-ground lake, which was once a natural sheet of water coveting a large area of country which is now a swamp. By the filling in for ages of earth and rooks from the hillsides, and the growth of vegetation, a crust has been formed over it, which has eventually closed the lake, and its surface is now entirely overgrown... To give foundation to the theory of a subterranean lake, fish have been caught and seen at these springs, from eight to ten inches all without eyes. They are in shape something like our common sucker. A portion of this swamp was once heavily timbered. A team passing over its surface will shake it for yards around, which gives strength to the surmise that it is floating ground.* -- New York Times, September 5, 1871

*Bottom was finally found at a depth of 90 feet. As there was no thoroughfare for the road anywhere else in the vicinity, the gigantic task of making a substantial road-bed in the "Snufftown sink," as the pond was called, had to be accomplished or the railroad project abandoned*. -- Locomotive Engineers Journal, July 1892

*An examination of the spot was made at the time of the sinking or the railroad grading by several scientific men, and they were or the opinion that the lake bad been incrusted by the accumulating vegetable matter of numberless ages until a surface had formed sufficient to sustain forest growth. The boiling springs were regarded as outlets to the subterranean lake.* -- New York Times, June 12, 1880

*The phenomena of the incrustation of sheets of water, which, in the lapse of time, became solid earth apparently forms an interesting subject for scientific investigation. The process of this incrustation may be witnessed at Amber Lake, in the Town of Bethel, Sullivan County. A large of the shores of that delightful little sheet of water is a floating morass, which, near the water's edge, is too thin to sustain the weight of a grown person, but seems firm and solid as the shore is approached.* -- New York Times, June 12, 1880

*The work of bridging over the waters' surface is going slowly on and doubtless continues, hence this entire lake will be encrusted like the ones already mentioned, and only to be detected as they have been.* -- New York Times, September 5, 1871

Today we're more familiar with Bethel, New York's earth-water issue as the muddy field of the 1969 Woodstock Festival.

In summary,

*These singular lakes must prove of interest to scientific men and are worthy of earnest consideration.* -- New York Times, September 5, 1871

A bit to the north-east, the Whitehall and Plattsburg Railroad was having its own problems along Lake Champlain.

*Another curious instance of this kind occurred in 1872 on the Whitehall and Plattsburgh Railroad, near Crown Point. A number of laborers were engaged in repairing the roadbed, gravel being brought to them by a locomotive and two flat cars. These cars had just been unloaded at the spot where the men were working, and, when the engineer started to return to the gravel pit, he noticed something wrong with the rails, and he discovered that they had moved several inches. He ran the train ahead, but had gone but a short distance when the roadbed, locomotive, train and all dropped suddenly 25 feet below the surrounding surface. The engineer and fireman were the only persons on the train, and they managed to clamber up one of the steep sides of the pit into which the train had been precipitated and reach the top in safety, and not a moment too soon, for both sides closed in on the locomotive and train, and they disappeared from view, half a minute later. The earth on all sides opened in fissures from four to eight feet wide and 50 feet deep, and the level surface of the ground for 400 feet around was changed into an area of rounded hummocks and cup-shaped hollows.* -- Locomotive Engineers Journal, July 1892

The New York Times of June 12, 1880, thought the disturbance somewhat longer.

*The earth on all sides opened in large fissures, 4 to 6 feet wide and 50 feet deep, and the surface of the earth for 800 feet was changed into a series of hummocks and gullies*. --

And again to the west. From the Railway Age, November 1, 1901,

*The Chicago, Indianapolis & Louisville has again experienced trouble with the sinking of a portion of its tracks in the vicinity of Cedar Lake, Ind. In the early part of July of the present year a portion of the track about 870 feet in length... was noticed to have settled several inches. A temporary spur was built around the old track and ballast was deposited into the depression on the main line. After being brought to grade a number of times, the track continued to settle until some 7,500 carloads of ballast and earth had been deposited into the depression, when a substantial roadbed was finally obtained.*

*This experience... is a repetition of the difficulties contended with some four years ago, when the company made considerable improvements in the way of eliminating curves and grade on its line in Lake County. At this time, what appeared to be an underground lake developed in the new line of the road, and considerable material, together with a trestle work of piles was used before a substantial roadbed could be obtained.*

Unlike most reports of railways and underground lakes, the lake in Lake County "developed in the new line of the road," almost as if it came as response. One could conjecture that the water was impounded by, say, a the railroad's inadvertent damming of an underground river -- Indiana has such, as we're noted in earlier chapters -- but one could also wonder if the journalist was simply rushing to telegraph the scoop.

In all these cases, however, of sunken railroad beds, piles and fill were sufficient to bridge the obstruction.

Some railroads were more fortunate. From the New York Times, August 18, 1871, "A Subterranean Lake Beneath a Missouri Town,"

*The first five feet of soil passed, the workmen came to a strata of red clay in which were imbedded masses of shattered flint. When this had been penetrated two feet, the pick disclosed a subterranean reservoir or water. The workmen abandoned the wall in alarm... when the sudden "falling out of the bottom" drove them to the surface.*

*Some years ago a similar discovery was made... some few hundred yards* [away]*. Here the roof of the lake, composed of red clay and flint gravel, had fallen until only a thin crust remained. This was broken through by the hoof or a horse or cow, and the vapor arising one frosty morning attracted the attention of a colored man who reported it... White, waterless fish, identical with those found in Mammoth Cave in Kentucky, were seen and caught in buckets let down into the water. From these facts and others unnecessary to be stated, there must be a subterranean lake underlying the town of Newtonia.*