Civil engineering and water conservation

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Civil Engineering and Water Conservation

Génie civil et protection des eaux

Bauingenieurwesen und Wasserschutz

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Thierry Chambolle, born 1939, graduated from the Ecole Polytechnique, the Ecole Nationale des Ponts et Chaussées and the Institut des Sciences Politiques in Paris. Initially Manager of several French ports, subsequently Manager of Water Pollution Prevention and Major Risks Representative at the Ministry of the Environment. In 1988 Thierry Chambolle became a director of the company Lyonnaise des Eaux, and since September 1991, he is Vice-President responsible for Technology, the Environment and General Communication for the group Lyonnaise des Eaux-Dumez.

SUMMARY

The author tackles the problem of the impact of civil engineering structures on rivers and groundwater. Having mentioned the principal characteristics of aquatic areas and of water resources on the earth, he goes on to discuss firstly the case of those structures serving no particular hydraulic purpose, such as transport infrastructures, and then that of hydraulic structures. The effects of these structures as a whole are very diverse and sometimes difficult to foresee. It is important to take these effects into account right from the start at the time when the structures are conceived, in order to avoid ecological obstacles and elevated costs at the time of realisation and subsequently of operation.

RÉSUMÉ

L'auteur aborde le problème de l'impact des ouvrages de génie civil sur les eaux. Après avoir rappelé les principales caractéristiques des milieux aquatiques et des ressources en eau sur cette planète il évoque successivement le cas des ouvrages sans finalité hydraulique particulière, comme les infrastructures de transport et le cas des ouvrages hydrauliques. Les effets de l'ensemble de ces ouvrages sont très divers et parfois difficiles à prévoir. Il importe d'en tenir compte dès la conception des ouvrages pour éviter les blocages d'origine écologique et les surcoûts au moment de la réalisation, puis de l'exploitation.

ZUSAMMENFASSUNG

Der Verfasser behandelt Auswirkungen von Baumassnahmen auf Gewässer. Mit Blick auf die Wesensmerkmale der Wasserumwelt und -vorkommen der Erde stellt sich der Verfasser die Frage von hydraulischen Bauwerken und von jenen ohne bestimmte hydraulische Nutzung, wie zum Beispiel die Transportinfrastruktur. Die Auswirkungen der Gesamtheit dieser Bauwerke sind sehr verschieden und manchmal kaum vorherzusagen. Von der Konzeption an müssen solche Folgen in Betracht gezogen werden, damit Hindernisse aus ökologischen Beweggründen und Zusatzkosten zum Zeitpunkt der Realisierung und des späteren Betriebes vermieden werden können.

THE ROLE OF CIVIL ENGINEERING IN PROTECTING WATER RESOURCES

Mr. President, Ladies and Gentlemen,

Allow me to begin by telling you how honored I am to be speaking for the first time to the AIPC (IABSE, IVBH). Although originally trained as a highway engineer, I have spent a large part of my career working for the environment, and more particularly in the field of water resources. In my company, Lyonnaise des Eaux-Dumez, which includes such well known civil engineering companies as GTM and Dumez, there are several people -- like F. Lemperière and J. P. Teyssandier of GTM and B. Raspaud of Dumez -- that are much more competent than I in the field of civil engineering structures.

But since we're talking about protecting water resources, they preferred that I take the podium. They helped me prepare this presentation, so in fact I'm speaking in their name, and I'd like to thank them publicly for their help.

I hope you don't mind if I take a personal tone with you. I'll be talking more about my experience, rather than my rather limited knowledge of this field.

My first job was building roads and bridges, and I had learned in school that their most important enemy was water. I built my first road, a pretty small affair, in Martinique, over terrain that was very sensitive to water. My first concern was to prevent water -- and there's a lot of it on the island -- from ruining a road that I was very proud of.

A little later, as an engineer in Bayonne on the Atlantic coast of France, I was in charge of monitoring an old bridge, whose pilings had been undermined by the river on both sides, so that they were sort of perched on top of huge piles of sand and gravel.

So you can see that what I had learned in school was true: **water is the civil engineer's greatest enemy.**

After ten years as a highway engineer, I served as Director of Water Resources and Pollution Prevention at the French Ministry of the Environment. This was a complete change of view for me, and I had to admit that **the civil engineer could be water's greatest enemy.**

My position was unique and full of contradictions. As the person in charge of protecting France's water, I had to make sure that the large infrastructure builders, like Electricité de France or Compagnie Nationale du Rhône, did not harm the environment and the quality of water resources. As the person in charge of flood and drought control, I was encouraging the construction of barrages to combat these disasters.

I think all civil engineers are feeling this contradiction today. They are working to improve water management, but they are often accused of helping to spoil water and destroy nature.

This introduction has already been too long, but I think it was necessary to us to understand each other.

I'd now like to talk to you about water and its role in human society, but also -- and perhaps most of all -- its role in our ecosystems. I'll also mention the many dangers that threaten our water resources.

I'd then like to discuss the problems specific to infrastructure projects, both those that are not involved with water resources, such as bridges and roads, and those that are designed to improve water management, such as dams and dikes.

1. WATER AND WATER PROBLEMS WORLDWIDE

We'd need a whole book -- or maybe several -- to do this subject justice, so for now, I'd like to mention briefly some of the key ideas concerning water and water-related issues.

The Blue Planet

It's not for nothing that Earth is called the Blue Planet. One of our most distinguishing features is an abundance of water -- some 1.4 quintillion cubic meters of it worldwide. Fresh water only amounts to 2.5 percent of this total. The water cycle uses around 500 trillion cubic meters, of which 110 to 120 trillion actually concern the land masses. These figures may not mean much to you, but on a per capita basis, we're talking about an average of 20,000 cubic meters of water a year -- which is a lot.

A wide diversity

The extreme diversity of terrain, weather, seasons and population densities means that water is unequally available worldwide. Per capita resources range from over 100,000 cubic meters a year in very wet, lightly populated countries, like Iceland, Canada and the Congo, to less than 1,000 cubic meters a year in such dry countries as Saudi Arabia, Israel and Libya, or even less than 100 cubic meters a year in a few extreme cases like Malta or the Bahamas.

All water is not available as a resource

Around sixty percent of water evaporates into the atmosphere, while the rest can rarely be found where we need it when we need it. Around 28 trillion cubic meters flow uncontrolled down the world's rivers every year -- although this can decline to as low as 12 trillion. Of this amount, six trillion cubic meters are held behind dams or in reservoirs, and only seven percent, or two trillion, is controlled.

Future imbalances

In the future, the unfair distribution of water resources is going to be further skewed by demographics. By the year 2020, water will inevitably grow increasingly scarce in Africa and Southern Asia.

A major role in the economy

Water is an important economic force in all civilizations. It plays a major role in farming, of course -- you need nearly 1,000 square meters of water a year per irrigated crop to feed one person -- but also in energy, industry and city life. You need 60 to 400 cubic meters to make a ton of cardboard, up to 1,000 cubic meters for a ton of paper, 12 to 50 cubic meters per person per year in the country, 150 in Paris, 500 in New York.

An even greater role in the environment

Water has physically or chemically sculpted the very face of our planet, through erosion, transport and sedimentation; water also washes the planet clean every day. Water makes our landscapes; the level and amount of groundwater determines the type and abundance of vegetation. And naturally water is responsible for biocenosis -- the community of biologically integrated and interdependent plant and animals.

Rivers cannot be separated from the land environment. The ecology of river systems is primarily an ecology of imbalance. On a planetary scale, river-scapes are highly varied, and to understand their dynamics, you need a planetary vision.

Endangered water

In every country, in every region, water can be threatened just as much by excessive use as by pollutants, both concentrated (from industry and cities) and dispersed (from farms and rural communities).

Some countries, where demand has reached or outstripped supply, are in a critical situation. But in many others, where demand doesn't exceed 25 percent of total resources, there are already many local or temporary shortages. Water tables are shrinking, rivers are drying up and wetlands are disappearing.

In all of the industrialized nations, rivers and underground water are suffering serious damage from oxydizable wastes (from cities and industries), nutrients (from cities and farms) and toxic wastes (from industries and farms). Throughout Europe, a good percentage of underground water has been polluted by nitrate and pesticide runoff, making their use as drinking water questionable.

The vast world movement that has formed to protect the ozone layer, prevent changes in the climate, preserve the Antarctic, and limit destruction of the forests cannot ignore fundamental role of water in all its forms, and must make a commitment to protecting this valuable resource -- even as we use it wisely -- for the very future of our planet.

2. THE IMPACT OF CIVIL ENGINEERING STRUCTURES

In this sensitive environment, civil engineering works have an impact that can remain fairly limited or be very powerful and decisive, depending on their type, use and size.

We'll be talking about three types of works :

- Structures without any particular relationship to water
- Small water-related structures
- Large water-related projects

2.1 Structures without any particular relationship to water

This is mainly transportation infrastructure, such as bridges, roads and railroads.

They can affect water in many ways. Because they cross natural drainage areas, they can have an impact on water flows, especially during peak periods, and on water table levels. Their waterproof surfaces increase the accumulation rate. Washing runoff can spread traffic pollutants to the environment.

In the case of a traffic or railway accident, toxic substances may be spilled into the surrounding environment. Roadway products, such as deicing salts, or maintenance products, such as weed-killers, can contaminate groundwater. Side effects can be observed in quarries, extraction and dump areas.

Let's look at the example of a bridge runoff. Traditionally, floor plate runoff used to be caught in side drainage channels and directly discharged into the environment via gully holes or drainpipes.

Today, large bridges are equipped with special facilities to catch and treat runoff before it is returned to the environment. These facilities include :

- Side drainage channels.
- Screened gully holes across the cantilevering.
- A drainage network composed of a main drainage basin located along the bridge's center axis, generally inside the precast segments, and of side drainpipes crossing the web and connecting the gully hole to the main basin.
- Downspouts located along or inside the river bank abutments, equipped with water tanks that follow plate/abutment shifts.
- A sand-catcher/oil trap located upstream from disposal.

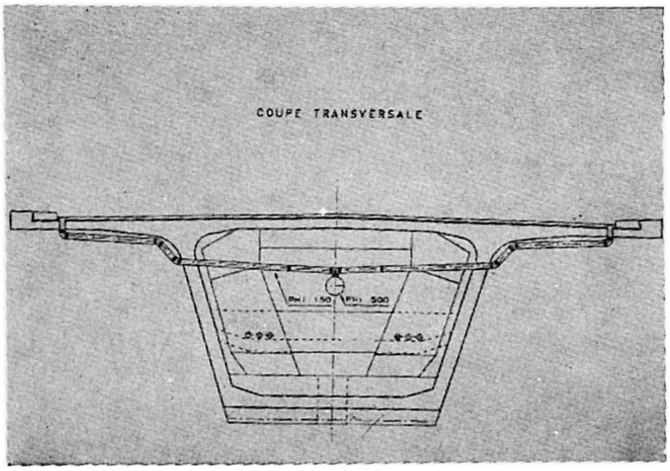

Fig. 1 Cross section

These facilities are being used on both road and rail bridges.
A second example concerns the restoration of groundwater flows. Here I'll be talking about the St-Cyr-Boulevard Périphérique Nord covered drainage channel in Lyon, which cuts across the thalweg of the Rivières brook.

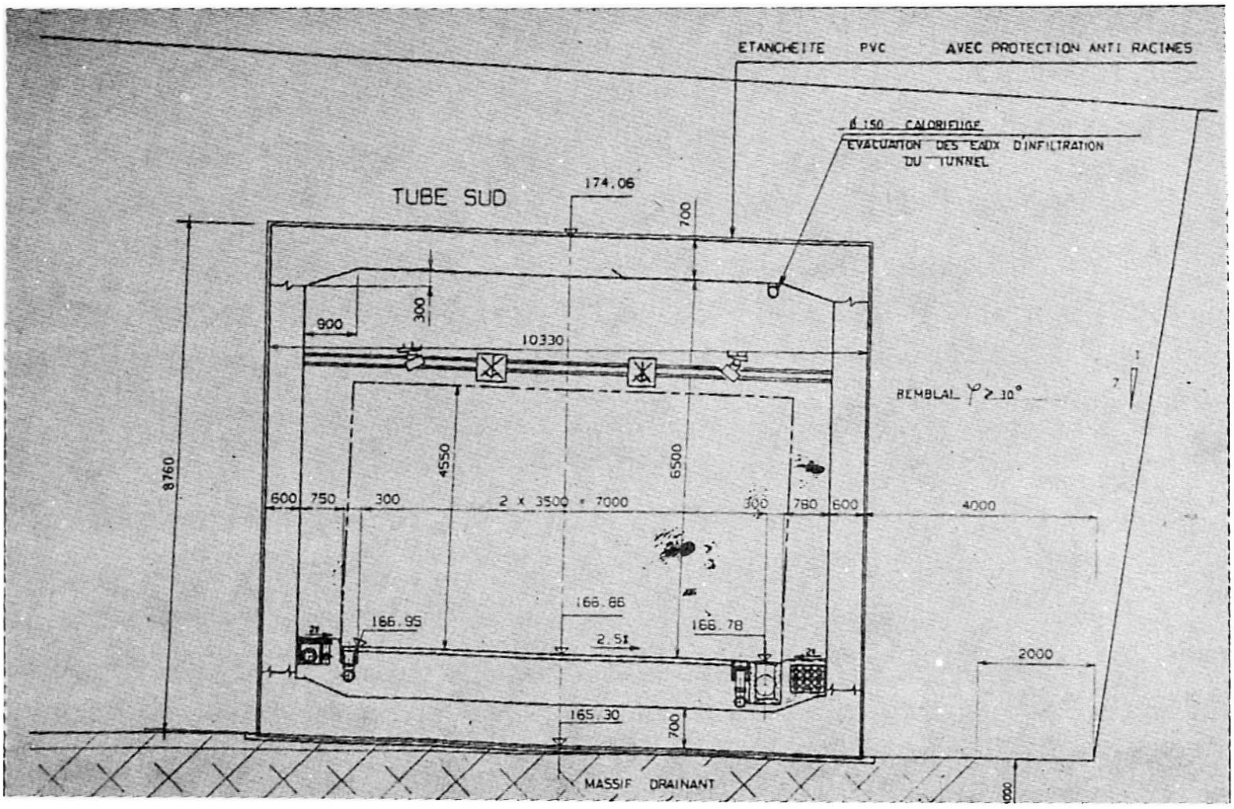

Fig. 2 Special Equipment (for large bridges) to catch and treat run-off before it is returned to the environment

To maintain groundwater flow at all times and prevent blockage by the frames, which descend almost to bedrock and are placed perpendicular to the main groundwater flow, it was decided to build a thick draining layer under the frames. The layer is highly permeable, allowing around 10^2 meters/second flowthrough.

Now let's look at a linear structure like a road. Pollution can come from a number of sources:

- The erosion of unplanted soil and embankments, which can have many negative effects, such as embankment washout or destruction, filling of drainage systems or pollution of receiving watercourses.
- Construction equipment (motor oil or washing runoff).
- Pollution spills.
- Deicing salts.
- Chronic pollutants (dust, lead, zinc, hydrocarbons).

I'd like to use the example of the A-36 Motorway as it crosses Mulhouse. This highway crosses the secure protection zone around the city's catchment fields. This is why it is so highly protected, as shown in the attached drawing. It is built on an embankment, but to prevent any vehicles from exiting accidently, it is protected by high berms on either side. Rainwater is collected by a sewage network and deposited in settling tanks and reservoirs that can store toxic substances as needed. Naturally, rainwater is disposed of upstream and far from the catchment fields. Lastly, a waterproof coating has been applied under the road and the berm embankments to prevent any seepage into the motorway embankment.

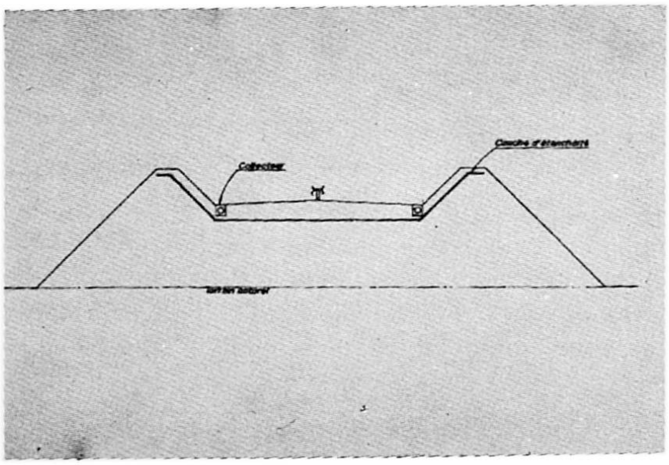

Fig. 3 Protections of the Mulhouse "Catchment fields" (A 36 Mortorway)

J. M. Bernard, who works for SETRA, the French Roads and Highways Technical Engineering Agency, has briefly described the measures to be taken:

"Highway authorities have a number of ways to limit the impact of roads on water resources when they design infrastructure. During the environmental impact study, it is important to prepare a full and accurate initial description. The different types of water resources (groundwater, watercourses, etc.) should be located, their current and future use identified and their exposure to road pollution determined.

The most important step is determining the route, since routing the road away from recharge areas is the only real way to guarantee water quality. This is because, while some of the pollution will be caught by the sewage system, the rest will be discharged into the surrounding environment and cannot be controlled by the protective or regulatory devices installed in the sewage system.

Lastly, the installation of protective or regulatory devices limits the contamination of the environment by runoff. Some forms of pollution are hard to manage, however. This is the case of salts which dissolve in water and are thus impossible to screen out. These devices should designed to reflect the type of pollution they are expected to treat (suspended solids, hydrocarbons, etc.) and their maintenance and management requirements.

In addition to the problems of water quality mentioned above, roads also have an impact on surface runoff and on groundwater. A road's impact on water resources and water environments should be studied in a comprehensive way. Solutions exist and each case deserves special attention to avoid upsetting the delicate balance of nature."

Let me add that it is possible, in cities and suburbs, to adjust construction methods to allow the use of roads made of thick open-grain asphalt as storm reservoirs. In this case, the road can actually be a solution to a rainwater management problem.

2.2 Small water-related structures

These are the small or medium-sized barrages or diversion cuts that only have limited influence over the entire water basin. Their impact on water is well known. The first examples of this type of structure were built around 5,000 years ago. These were often simple dikes built to create artificial ponds recharged by seasonal rains. Then dams appeared. It seems that the oldest dam still in existence was built by the Mongols in the thirteenth century in Kbar, near Qum, Iran. It is 26 meters high, 55 meters long and five meters thick, and already looks like a road. Since that time, many dams have been built over the centuries, especially in India. In 1990, there were 36,138 dams over fifteen meters high in the seventy-one countries that are members of the International Commission on Large Dams. But the total number of barrages, dikes and dams is much higher, probably over 500,000. These structures are fairly commonplace, and their impact on water is not new. In the earliest times, this impact was the reason why they were built -- to store water for drinking or irrigation, to control floods or to generate electric power. It is only recently that we have begun to study their side or unintended effects.

In the late seventies, the International Commission on Large Dams, fully aware of the importance of environmental issues and public sensitivity to them, created a technical committee to deal specifically with this subject. The commission published a report in 1980, but they realized later that it was too technical for the general public to understand easily. In 1981, therefore, they published a brochure entitled *Dams and the Environment: A Success Story*. The title makes you wonder and even sounds funny when you consider all of the problems encountered by many dam projects in different parts of the world.

The report and the general public brochure deal with the many environmental problems raised by dams:

- Crossing the dam (migrating fish)
- Sediments (accumulation and disposal)
- Discharges (heat, turbidity, water oxygenation)
- Weather effects
- Eutrophication
- Plants and animals
- Changes in groundwater for lowland dams
- Flooding risks due to landslides or earthquakes.

All of these problems and their solutions are well known. The International Committee's bulletins have discussed them many times (notably in 1985). It would be pretentious and time-consuming to talk about them here, before an audience that is well aware of these difficulties and their solutions.

Nevertheless, a dam can profoundly modify the environment, at least locally, and it is becoming harder and harder to get people to accept one "in their backyard", no matter what technical solutions are implemented. In many countries, you need to plan for a compensation program, with not only economic and social measures, but also a whole series of ecological measures, such as reconstituting biotopes, creating reservoirs, and implementing systems to collect and treat wastewater upstream to avoid problems with eutrophication or water quality.

In some densely populated countries, these measures are still not enough to prevent environmentalist opposition, and other solutions have to be found. Examples include creating groundwater reservoirs by artificially recharging the water table, building waterproof underground walls or raising existing dams.

The first solution, already used in France to build drinking water reservoirs, requires very good understanding of groundwater regimes and the use of waterproof underground wall construction techniques, that have been mastered by companies like Bachy and Solétanche.

An innovative technique recently developed to increase the capacity of existing dams is the Hydroplus process, designed and implemented by GTM.

With most high dams and hydroelectric complexes, retained water levels are regulated by sluice gates that let flood waters through. But with the vast majority of lower dams, flood waters flow over a spillway that is a few dozen meters wide and unequipped with any sluicegate control. At flood crest, the spill can rise to around a meter deep, but sometimes exceeds five meters.

The dams are designed for peak flood water levels, but are used only to retain water below the spillway level. This means that there is a great deal of reservoir capacity going to waste. Lost capacity can amount to over twenty percent of the total volume on an average non-sluicegate equipped dam.

One safe, cost-effective way of raising the spillway is to build overspill fusegates that remain submerged for moderate overspill, trigger part of their fuses to rise slightly for the higher waters that come every fifty years or so, and trigger all of the fuse and rise to full height for exceptional flood levels. This solution is very economical.

Every year around the world, the lack of such systems causes us to lose around fifty billion cubic meters of water, much of which could be saved at low cost and relatively quickly through a system of overspill fusegates.

This system can be adapted to most existing free spillways, but can also present major advantages for future dams.

2.3 Large water related projects

The impact of large multi-purpose water-related projects on water regimes and quality is even harder to forecast. And the ways of reducing that impact are even more difficult and unpredictable.

As I said above, the ecology of river systems is an ecology of imbalance. The engineer intervenes in a complex, constantly changing system to substitute a new system that is also in imbalance and will undergo its own process of change.

It is not enough to compare the post-construction state to the initial state. Comparisons have to be made between the different stages of the initial system (without the proposed development) and between these same successive stages in the event the development is carried out. Since it is highly uncertain how each of these stages will evolve, you can imagine how difficult it is to compare them, especially when you have to convince sceptical inhabitants who will not necessarily benefit directly from the project.

All of the major development projects like the Aswan Dam or the reclamation of the Zuider Zee have had unexpected consequences.

The Aswan Dam had many positive effects, but the reduction in silt flows also had a serious negative impact. The river's banks and bed eroded, the delta 1,000 km downstream eroded, fish reproduction declined and salt concentrations rose.

In the Zuider Zee, the improvement in flood control and the development of new polderland also caused the disappearance of biotopes and related species, as well as water eutrophization.

Thus, engineers who prepare large development projects and who analyze their predictable impact on water and the environment have a very difficult task. So do the political authorities who have to take the decision to develop and convince the surrounding population that it is a good idea. If you doubt this, just think about the Bangladesh flood control system. This project offers a number of alternative solutions, such as nearby dikes and distant dikes, but in all cases it means a radical transformation of the local economy and lifestyles, notably in their relationship to water. There is already a great deal of controversy about the future consequences and disadvantages of the different solutions.

I was personally involved in the development of a large French river, the Loire, which is full of history and famous for its beautiful scenery and dramatic floods. The first attempts at flood control date from the twelfth century, when levees were built along its banks.

An initial project prepared in the seventies to develop the water resources needed to cool nuclear power plants and irrigate farmlands proposed the construction of not less than twelve dams. A critical analysis by a blue-ribbon commission of experts reduced the project to five dams -- three for flood control, of which one was already built, and two for low water support, of which one was already partially built.

Environmentalist opposition has caused the number of new dams to be cut to two, with, in addition, the raising of an existing dam and the construction of close set protection dikes.

All of these changes were the subject of major controversy both in France and internationally.

In conclusion, nobody would think of denying the importance of civil engineering works designed to meet new demand for transportation, to enhance the value of our water resources and to protect lives from natural disasters. But these structures cannot be built to the detriment of the environment and of water quality.

We must be aware of the fact that, once a project has aroused environmentalist opposion, it then becomes very difficult to prevent the construction process from grinding to a complete halt : either the project has to be abandoned altogether or those involved must reckon with considerably elevated costs to finance the necessary modifications to the original project. This being the case, it is imperative that we ensure that environmental issues are taken into consideration from the very beginning of each project.

In the past, civil engineers have sometimes underestimated the psychological or factual impact of what they built. As a result, they have sometimes incited feelings of hostility on the part of inhabitants and sometimes of elected officials. They need to act to regain the people's trust.

In closing, I'd like to quote Michel Virlogeux, of the Association Française Pour la Construction:

"Engineers (i.e. all of us) need to learn modesty and should analyze the long-term impact of their actions, particularly on water resources."

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