Shortage of fresh water and necessity for storage facilities in the Mekong Delta (M.D)

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Abstract: The Mekong Delta (M.D) is submitted to many important issues that can question its survival. To mitigate severe shortages during the dry season, freshwater storage and decrease in groundwater use are paramount for its survival. The possible types of storage facilities are: tanks and ponds for the individual needs, reservoirs along a River Mekong branch, off-river reservoirs and coastal reservoirs. The two first types of reservoirs have been already constructed in the M.D and should be replicated if possible. The two latter types are relatively new and deserve further studies and commencement of construction as soon as possible. These different types of reservoir are not exclusive but are complementary and depend on the local needs and conditions of the sites.

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The M.D presents several issues concerning its survival as the largest agricultural and aquaculture production hub of Vietnam allowing the living condition for almost 20 million inhabitants. Among all the several issues, indicated namely in [1], only those concerning the shortage of freshwater and the M.D subsidence are dealt in this note which recommends possible mitigated solutions. The other issues such as the floods, the sea level raising, the decrease of sediment supply, the lowering of the water river levels, the saltwater intrusion and the erosion of the river banks are dealt in different other notes.

1. Increase of freshwater demand

The increase in freshwater demands is due to the following factors witch require more or less large volume of water with different quality requirements:

- Growth of population with increase of individual needs: this a high priority for poverty reduction and living conditions improvement as well as environmental protection.
- Development of animal farming: it's necessary to select those requiring low water consumption.
- Development of food industry: this should be increased in the future to develop the regional economy and to absorb the supplement manpower released by agriculture.
- Development of shrimp farming: the necessity to add sometimes fresh water to the seawater to adjust the salt content is to be considered.
- Demand for irrigation: this is the main consumption of fresh water. If it is justified for an extension of the orchards and the vegetable cultivation, it is not judicious to increase the area of ricefields and other crops with low commercial value that require large volume of water. This important last topic is not further developed in this note, but the drawbacks of a future extension of the rice field surfaces and of an annual 3rd crop, with the harmful construction of inappropriate anti-salt levees and overuse of pesticide, have been already pointed out by several other experts.

- Necessity to push back the saltwater intrusion by releasing a sufficient amount of freshwater. It is not the only method of protection, but it can contribute to this issue in some particular sites and circumstances.
- Last but not the least, necessity to replace the large use of groundwater by surface water. This is one of the main reason for freshwater demand in the M.D, as indicated in § 3.

2. Decrease of water supply and droughts

Shortages of freshwater in the M.D were observed these last years with a decrease of the rainfall and of the Mekong River inflows during the dry season.
The decrease of the rainfall on the River Mekong catchment area is due to the climate change and the El Niño phenomenon.
According to many persons, the decrease of the Mekong River inflows these last years is due to the construction of the upstream dams on the Mekong River, in China and on the tributaries in particular, with generally very pessimistic forecasts for this reason. This cause, also widely reported by the media, is not really proved as indicated in §2.2.

2.1 Decrease of the Mekong River discharges in the M.D due to the climate change

With the climate change, it's probable that the global regional rainfalls will not change too much for a future long period, but there is a high probability that low rainfalls and severe droughts - compared with the past situation - would be more frequent and would last during longer periods, as illustrated by these recent years.
The observation of climatic impacts on the flow regimes over the Mekong basin, from 1980 to 2015, was carried out by three precipitation datasets, including the Climate Research Unit (CRU TS 4.03), the Global Precipitation Climatology Center (GPCC), and the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Network–Climate Data Record (PERSIANN–CDR). The pessimistic forecast for droughts is also based on the reports of the Intergovernmental Panel on Climate Change (IPCC) concerning the M.D region.

2.2 Decrease of the Mekong River discharges in the M.D due to human activities

The present and future decrease of the Mekong River inflows in the M.D, due to the following human activities, is probable with:

- The existing and future development of irrigation in Laos, Cambodia and particularly in Thailand with the projects to divert a part of the Mekong River flows.

- The consequences of dams on the Mekong River flows during the dry season .

It is important to evaluate the relative importance of the two main causes indicated above in order to know which we have to take the most efficient action.

For this purpose, it is necessary to take into account objective conclusions deducted from precise measurements and studies such as provided by some recent reports.

Concerning the influence of dams which depends on numerous parameters, it is to note that so far, an exact correlation between the variations of the inflows versus the hydro-meteorological conditions and mostly the different phases of construction and operation of the upstream dams are often lacking. Enough precise and reliable measured data, detailed critical analysis and feedback are required before having a definitive available conclusion on this topic. Some following studies show that different opinion issued about the influence of dams on the droughts in the M.D are not always correct.

For example, in a recent and comprehensive study [2] based on measured data, it was checked that:
"*In the recent period, minimum and low-flow discharges at all analyzed stations (in the lower Mekong) increased significantly. The duration and frequency of the low-flow season decreased markedly. These are in contrast with significant decreases in the low-flow season precipitation in the upper and entire Mekong basin. Such opposite trends are obvious signals of the effects of dam operations that release water in the dry season… The aforementioned findings imply that existing dams in the Mekong basin in the recent period cumulatively reduced the flood pulses and increased the low-flow discharge along the Mekong through reservoir operations, exceeding climate change effect* ».

It is also indicated in this report that although low-flow discharges in the M.D increased, low-flow water levels decreased. This can be explained through riverbed incision. Riverbed incision is a consequence of reduced sediment supply from the Mekong River due to reservoir sediment trapping and sand mining. The decrease of the low-flow water levels, with the raise of the seawater level, being the main cause of the saltwater intrusion and of the irrigation water shortage, it appears that the reduction of the sediments downstream the dams, aggravated by the sand mining, is better proved than a reduction of the Mekong River inflows due to the dams.

Another interesting observation is provided in the reports of Mr. Nguyễn Minh Quang [3] & [4] on this topic:
"Since mid-February 2016, but not at the peak of the dry season, the national press as well as international radio stations have sounded the alarm over the drought and the saltwater intrusion in the Mekong Delta, causing damage to hundreds of thousands of hectares of rice and causing difficulties in people's daily activities. Vietnamese authorities such as MARD, VKHTL and UBSMC all say that upstream reservoirs are the "dominant cause".

Flow data from hydrological stations released by the MRC show that the water scarcity in the Mekong Delta region is not caused by hydroelectric dams on the main course of the Mekong in China or on tributaries downstream of the Mekong, but mainly due to the increased use of Mekong river water for irrigation during the dry season in Laos, Thailand and Cambodia. Only during the first 2 months of 2016, the average flow used by these countries increased by 2991 m^3/s, or 49% of the flow of the Mekong at Kratié. Not to mention a significant amount of water used in Cambodia for irrigation projects downstream from Kratié, such as the Vaico and Stung Schinit Projects.

But the increase in Mekong water use during the dry season in Laos, Thailand and Cambodia is not the only cause of the current water scarcity in the Mekong Delta. It also stems from the development policy based on the principle of "do what you want" in the basin and the unscientific management of water"…

The MRC drought management strategy should also strive to "restore" the principles of the 1957 International Mekong Commission, including the veto of a member state and its charter. The terms of the 1975 Joint Communique was overturned with the signing of the 1995 MRC agreement and negotiations between the MRC countries and upstream countries, especially China, to reach a fair and equal agreement on the use of the water from the Mekong River.

As the decrease of the low-flow discharges in the M.D due to the dam construction is so far very controversial, it is conservative but realistic to assume in this note a future decrease of freshwater during the dry seasons, whatever the meteo-hydrological and human causes of this decrease, although the risk due to an extension of irrigation seems the most probable.

Severe droughts in the M.D and lack of large storage facilities

3. Groundwater of the M.D

Whereas at the beginning of this century, about 600 000 m^3 groundwater was extracted per day, today it is in excess of 2.5 million m^3 per day. To note that the use of groundwater for household needs is harmful as it is more or less contaminated by organic and chemical matters, by acid sulfate sols (ASS) and by arsenic [1] & [5]. For health reason, the present issue for the inhabitants to use groundwater for domestic use - due to insufficient surface water – must find a solution as soon as possible.

The over exploitation of groundwater is the main cause of the M.D subsidence [6] that is now aggravated by the reduction of the sediment inputs and the sand mining. An over exploitation of groundwater leads also to the contamination of the aquifer by seawater [7], this effect being moreover reinforced by the subsidence of the M.D and the sea level raising.

In order to prevent an acceleration of this phenomenon within a few decades, the groundwater extraction must be considerably restricted in the short-term. This requires to lower the level in the license to exploit the groundwater pumping out to avoid a larger subsidence of the M.D which will accelerate the risks of inundation and of the salt water intrusion in the coastal areas.

On the contrary, it is necessary to inject in the aquifer a larger part of the Mekong River inflows to slow down this subsidence.

In conclusion: There is now severe shortage of freshwater in the M.D during the dry season of some years. This shortage will probably increase in the future, whatever the causes. Independently from the program of hydro-electrical and agricultural equipment of the riparian countries and Thailand, for which Vietnam has little power, Vietnam should construct rapidly important water storage facilities in the M.D. These facilities are not temporary solutions to address present issues, as sometimes proposed, but they should be permanent long-term sustainable solutions.
The present and foreseen volumes of groundwater extracted in the M.D have a great consequence on its survival and the solutions to mitigate its over exploitation and to provide enough fresh water to the inhabitants are the drivers of this note.

4. Construction of water storage facilities in the M.D

4.1 General

Taken into account the data indicated above, the only solution to avoid freshwater shortage during the dry season is to store it during the rainy and flood seasons.
To note that some solutions sometimes proposed, such as desalinization of sea water, is insufficient to respond to the demands of hundreds of millions cubic-meters of fresh water in the M.D.
As the collected rainfalls of the wet season cannot be generally sufficient for the needs of the dry season, the only possibility – taking into account the necessity to avoid pumping out large quantity of groundwater – is to store during the flood season a part of the Mekong River inflows.
Only numerous small, medium or some large reservoirs built in the M.D can supply enough freshwater for the dry season.
Except the An Giang and Kien Giang reservoirs in high lands for keeping stream water, the building of large reservoirs in the M.D with a dam, crossing the river with a high water level on the banks, is practically impossible for the following reasons :

- as the topography of the M.D is very flat, the reservoir will inundate large areas of cultivated lands,
- the population, densely settled along the stream banks, is generally poor. They live with fishing and navigation jobs and they are very difficult to move and to relocate,
- the dam will require an important spillway with large gates to evacuate the floods,
- the dam will require the construction of a lock allowing the passage of little boats and eventually the construction of a fish ladder,
- the reservoir can be silted rapidly by the sediments which cannot transit downstream,
- the dam is costly if the river branch is wide with a thick alluvium layer.

In consequence, other alternatives for medium and large reservoirs in the M.D must be researched.

4.2 Construction of very small individual reservoirs (tank and pond)

The construction of numerous very small reservoirs - mainly for each dwelling or family - was proposed, but it is not really a satisfying solution, as observed in the Central Vietnam provinces (Thừa Thiên Huế and Hà Tĩnh), for the following reasons:

- If the freshwater provided by rainfalls, with tanks and containers, may be sufficient for the household use, they cannot respond to the other important demands indicated in §1.
- The tanks and containers are generally empty during the severe droughts due to their small capacities.
- If the small reservoirs are made by digging the soils near the different dwellings (ponds), they become rapidly insufficient because they are often filled with the soils coming from the unstable slopes or from the muddy overflows during the floods.
-These ponds are often polluted by the domestic animals and the lack of a correct sanitation system near the houses. Moreover they can favor the development of harmful mosquito larvae and snails.
These last solutions are often temporary: after some years, the individual small reservoirs must be replaced by pipes carrying water from supply stations equipped with larger reservoirs.

4.3 Construction of large reservoirs in the major bed of a Mekong River branch

An alternative to the traditional large reservoirs is possible if the river includes two branches approximately parallel. One branch can be used for a natural reservoir located solely in the major river bed and the other branch can be used as a diversion channel. The reservoir is blocked by two gated dams at its two extremities. The following figures show the Cai Lon - Cai Be reservoir project under construction.

The Cai Lon - Cai Be reservoir and a view of the gated dam at the extremity

This type of reservoir has been already adopted for the present largest man-made reservoir in the M.D : the Kenh Lap Reservoir in the Ba Tri District, Ben Tre Province, 5km long with a total capacity of about 1 hm^3.

View of the Kenh Lap Reservoir in the M.D

This alternative is interesting where the topographic and hydraulic conditions are favorable. The main inconvenient is a possible sedimentation which reduces the reservoir lifespan and a possible intrusion of saltwater during a severe drought such as in May 2020. It seems that the introduction of saltwater in this reservoir was due to a defective operation of the reservoir and the gates. The reservoir watertightness is necessary with the gates, but also it is necessary to avoid a possible infiltration of saltwater through the foundation (cut-off). These drawbacks can be mitigated by a better conception and operation of the dams and the gates, but it is certain that this operation can be difficult with the necessity to respect some environmental constraints with a reservoir included in a river branch.
This alternative can address some main issues of §1, but cannot be replicated in a great number of sites in the M.D due to the above indicated factors. Consequently, their sole construction cannot respond to the required tens of millions cubic-meters of freshwater for the M.D needs.

4.4 Construction of large off-river reservoirs

To avoid all the drawbacks mentioned in § 3.3, while meeting the needs indicated in § 1, it is possible to create off-river reservoirs built on the ground level, located on some inhabited and cultivated lands, near but not on a Mekong River branch.

According to Mr. Trần Đăng Hồng [8], in Dong Thap Muoi, the lowest area contains many swamps in the area quadrilateral bounded by the Kháng Chiến - Đồng Tiến – Phước Xuyên - Tân Thanh - Lò Gạch with an area of about 700 km^2; of these currently there are over 50 000 ha of desolate swamp land with no inhabitants. It is possible to turn this swamp into freshwater reservoirs with total capacity of 3 km^3. U Minh was originally a swampy lowland area of Kien Giang province (also 50 000 ha of unexploited swamp land), Hau Giang (77 000 ha unused), Bac Lieu (18 893 ha of unused marsh) and Ca Mau. During the rainy season, water floods 3m, but gets dry and salt water intrudes in the drought season.
It is however important to keep in mind that a preservation of the marshy and mangroves in the M.D is also necessary, which will limit in fact the surface of the reservoirs.

The capacity of the reservoirs may be really some millions cubic-meters. The lower limit is due to economic reason and the higher values to the possible required surface for the reservoir.

The reservoir is created by a low (about 10- 15m high) but long ringing earthen dyke built with the top materials extracted from the site (at a depth ≤ 1-1,5m, a reduction of the earthfall volume being possible with a mix of soil-lime). The construction is flexible because the dyke can be easily heightened if an additional capacity is required in the future.

The reservoir water is supplied by pumping out a part of the Mekong River branch inflows during the flood season, that is the main difference with the previous proposals. Given the relative high water levels of the river during this season (1m to 5m) and its duration (3 to 5 months), the filling of the reservoir can be carried out economically using low head (10 to 15m) and low capacity electric pumps (some m^3/s). The electricity for the pumps could be provided by wind turbines and solar panels installed on the dyke crest.

Pumping station in the M.D

A common problem with off-river reservoirs is the inadequate watertightness of the large surface soil and high cost of lining. But in the case of the M.D, the superficial soil is relatively impermeable and the watertightness of the lake bed will gradually improve when the lake is in operation the first years, since SCL flood waters often contain a lot of fine-grained alluvium. It is possible to pump after ths period only the surface water to limit the sedimentation of the reservoir.

The reservoir bottom is almost permanently submerged, that prevents the formation of cracks in the soil and the oxidization of the pyrite horizon into acid sulfate, the store water is in any case less contaminated than the groundwater.
To note that a controlled water infiltration in the aquifer due to the reservoir seepage has a beneficial effect for a water table recovers and for the slow-down of the M.D subsidence. The capacity of the reservoir should be sufficient to take into account the seepage and the evaporation losses.

During the dry season, the store water is released by gravity and distributed to the different users according to their needs and a priority order established by the authorities. The reservoirs can be optimally operated at the local level by the villages or cluster of dwellings which should be associated to the project from its commencement. To increase the profitability of the reservoirs, adding fish farming and tourism activities can be an option.

The off-river reservoirs are similar to the upper basins of the Pumped Energy Transfer Station (STEP in French), but with low head and constraints concerning the watertightness and the rapid cycles of filling-emptying of the reservoir.
The off-river reservoirs are currently built worldwide and the recent ICOLD Meeting and Congress have pointed out their advantages. Technically, it will be possible to benefit from the international feedback.

Off-river reservoirs in Burkina Faso and in USA

In conclusion, the construction of large off-river reservoirs in the M.D - filled by pumping out the Mekong River during the flood season - is a promising solution to address the shortage of freshwater during the dry season. An advantage of this solution is to allow a staged construction of several reservoirs with progressive investment costs. This type of reservoir deserves a comprehensive study and should be built, as soon as possible, with a first example to serve as a reference.

4.5 Large coastal reservoirs

This type of reservoir with large capacity can respond to all the indicated needs - especially for the aquifer recharge and for lowering the saltwater intrusion – with the big advantage to avoid the occupation of large M.D areas.

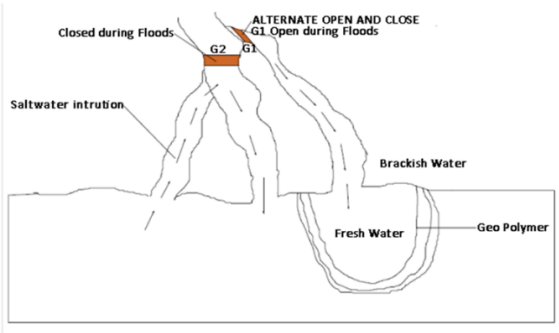
Their general features and advantages are well indicated in the paper [9] and the main conclusions are resumed below:

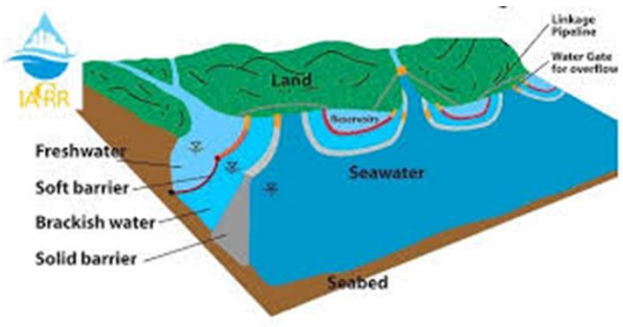
" - *In the next 100 years, the population and water demands may continue to increase significantly; most people in the future will live in coastal and deltaic areas.*

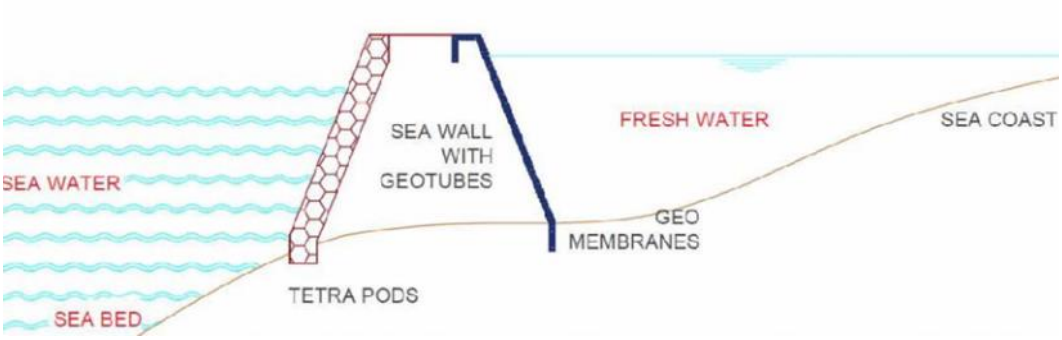
- *The distribution of existing inland reservoirs will not match the population distribution in the future. The majority of the existing inland reservoirs will be out of service due to their structural life span and sedimentation.*

- *The technology of the coastal reservoir is a sustainable, cost-effective and clean way for water supply, and it will dominate future water supply strategies. The water quality at river estuaries can be significantly improved by using agricultural wetlands* ".

The following figures show general features of coastal freshwater reservoirs:







Freshwater coastal reservoirs and ‘gulf embankment dams’ have been already constructed or designed in several countries such as: Netherlands, India, China (Hong Kong and Shanghai), Singapore, South Korea and New Zealand.

View of a dyke separating the sea and the freshwater reservoir in Netherlands

In Vietnam, designs of such coastal reservoirs with capacities varying between 600 hm^3 and 2580 hm^3 in the Rach Gia bay were recently contemplated by the SIWWR/SIWRP.

Different alternatives contemplated for coastal reservoirs in the Rach Gia bay.

As pointed out by Prof. Pham Hong Giang:

"This proposal, in my opinion, is very promising and should be thoroughly researched for implementation. This lake stores flood water to the West Sea during the rainy season, creates freshwater sources to pump in the dry season into the Mekong Delta and Ca Mau peninsula, supplies water to Rach Gia town in other urban areas in the region. The waters of Rach Gia are not too deep, so construction can be done. The dam also creates a direct traffic route connecting Rach Gia with Ha Tien. The lake in the bay will become a marina, contributing to the development of tourism in the area… There is a question about the environmental impact of the project. This impact must also be carefully studied. Any infrastructure creates a little bit of a change in the environment. There are changes for the better, not necessarily all are bad changes. Environment must be for human life, not just for environment status quo".

It seems however that the Rach Gia project cannot be implemented now because its high cost and it is located in the Kien Giang Biosphere Reserve.

To note that coastal reservoirs, with a sea dyke, has the big advantage to contribute to the protection against the coastal erosion and the saltwater intrusion.

If a coastal reservoir is not possible at Rach Gia, it would be necessary to look for other possible sites in the M.D. These projects deserve surely high consideration as they seem very interesting. However they raise many issues that should be addressed:

- Technical issues : watertightness of the reservoir, pumping station, application of the Separation, Protection and Prevention (SPP) strategy , …
- Socio-economical issues.
- Environmental issues.
- High cost.

The environmental issues should be carefully studied as they are the most sensitive and important topics to appraise before the reservoir construction, since it will be very difficult to return to the initial natural state after this construction.

However, this is an extremely expensive solution (because water is supplied by pumps with extremely large flow), has a large environmental impact and requires strict calculation techniques and design. Since it is related to a dam of high height, solid structure due to the direct impact of waves and coastal currents, special consideration should be given to the feasibility and environmental impact, for the time being, is a research solution for the distant future.

5. Conclusion

The M.D is submitted at present, and surely more in the future, to many important issues that can question its survival as the most important agricultural region of Vietnam allowing the living of about 20 million inhabitants.

Among these several issues, only those concerning the shortage of freshwater and the M.D subsidence, whatever the causes, are dealt in this note.

To mitigate severe shortages during the dry season, an integrated water resource management strategy in the Mekong basin that is collaboratively designed and adopted by all riparian countries would enhance the sustainability of the river ecosystem. But Vietnam cannot really and efficiently influence the riparian countries and Thailand to stop, or at least to

postpone, new dam construction or development of irrigated areas in their own land. Even if discussion and concertation with the riparian countries are always useful, no country has given up on exploiting the hydroelectric or irrigation potential of its rivers when it has the capacity. It is not the systematic opposition to dam construction by some NGOs, such as International Rivers, that has addressed the environmental issues and prevented the construction of any new dams.

Freshwater storage and decrease in groundwater use are paramount for the survival of the M.D. Consequently, Vietnam should take the decision to construct, as soon as possible, important water storage facilities in the M.D.

The possible types of storage facilities, in an increasing order of importance of the projects and their effectiveness and costs, are:

1. Tanks and ponds for the individual needs: they are easy and quick to construct but they are not always reliable for the severe droughts and they don't respond to the other freshwater demands.

2. Reservoirs along a River Mekong branch, such as the reservoir already built at Kenh Lap. They are interesting alternatives but with some possible issues concerning the reservoir sedimentation and the saltwater intrusion. The feasibility of these alternatives depends on favorable topographic and hydraulic conditions that can limit the number. But taking into account the experience of the first reservoir of this type in Vietnam, further improvement can be made.

3. Off-river reservoirs: they are flexible alternatives with many advantages, but these reservoirs may require significant surface of low-value lands every time that important capacities are needed. An advantage of this solution is to allow staged construction of several medium-size reservoirs according to the local demands and the technical, socio-economical, environmental and financial constraints and to take into account the progressive feedback of the first reservoirs. At this stage of needs and development, it seems that this type of reservoirs is the most convenient to mitigate the shortage of fresh water in the M.D.

4. Coastal reservoirs: they offer the possibility to store very large volume of freshwater to respond to all the demands, but they need big concentrated investment, important and long studies to well appraise and address all the different issues concerning the technical, socio-economical and mostly environmental aspects of the project, because it will be difficult after the construction to return to the initial conditions. The high cost of this type of reservoir is probably also a long-term solution for Vietnam.

Scientists believe that freshwater retention structures in the M.D should be built as soon as possible. The two first types of reservoirs have been already constructed in the M.D and should be replicated if possible. The two last types are relatively new and deserve further studies and commencement of construction as soon as possible. These different types of reservoir are not exclusive but are complementary and depend on the local needs and conditions of the sites.

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