



"Recultivation of Jelonek and Winiary lakes in Gniezno by inactivation of phosphorus in bottom sediments".

INFORMATIVE BROCHURE



**Projekt Miasta Gniezna nr LIFE07 ENV/PL/000605
p.n. "Rekultywacja Jezior Jelonek i Winiary
w Gnieźnie metodą inaktywacji fosforu w osadach
dennych" jest współfinansowany przez Wspólnotę
Europejską w ramach Instrumentu Finansowego LIFE +**

Dear readers,

It is with great pleasure and satisfaction that I am delivering this information devoted to the subject of the reclamation of the lakes in the first capital city of Poland to your hands. This is the result of the implementation of a very important project for our city, which, as the only Polish undertaking of this type, has received almost one million PLN for this purpose within the framework of the Life + programme. Owing to the financial support of the European Commission, the city of Gniezno has been able to take up such an important task.

However, cleaner lakes, ordered shores, or repeated fry stocking are not the only effects of this unusual programme. In spite of the fact that a lot of work and effort was put into its execution, it gave our city something much more important. It reminded us that care for the natural environment, especially for reservoirs, results in giving a new brightness and mood to the whole agglomeration. Nothing changes the image of a city so much as the beautiful lakes located in its centre, around which one can walk, ride a bike and rest. These are invaluable opportunities and all inhabitants may derive benefits from them.

I hope that the project entitled "Reclamation of the Jelonek and Winiary lakes in Gniezno by means of the method of phosphorus deactivation in bottom deposits" will be an inspiration for other undertakings of this type in Poland. Owing to them, our country may become even more beautiful and its natural resources may deliver more joy to us.



Mayor of the City of Gniezno

A handwritten signature in blue ink, reading "Jacek Kowalski".
Jacek Kowalski

The problem of the cleanliness of the lakes

Gniezno lies on the Gniezno Lakeland, in an area characterised by the greatest scarcity of rainfall in Poland. The Jelonek and Winiary lakes, which are located within the administrative boundaries of the city, are exposed to the pressure of the city agglomeration.

The Gniezno lakes are small reservoirs with an area of about 12-14 ha. The limited possibility of water exchange in the lakes causes the processes of sedimentation as well as accumulation of suspension matter and disseminated components to prevail in them. The lakes have lost the ability of self-treatment and they would be sentenced to complete degradation without immediate reclamation activities.

The problem of the degradation of water reservoirs became such an important issue on a European scale that in the year 2000, the European Parliament established a framework of actions regarding the water policies on the territory of the European Union. In accordance with the adopted Directive 2000/60/WE of the European Parliament and Council of the European Commission dated October 23rd, 2000 (the so-called Water Directive), establishing a framework of community action in the field of water policy, the member states were obliged to take advantage of and use water resources rationally in accordance with the principle of balanced development. The main objective of the Directive is to achieve a good condition in all surface waters by the year 2015.

The objective indicated, among other things, by the Water Directive, may be achieved by conducting reclamation works resulting in the improvement of the quality of water and condition of the ecosystems degraded by the activity of man.

At a certain point, the unfavourable changes occurring in a given water reservoir assume the character of a chain reaction and, as a consequence, trigger the progressive degradation of the reservoir. A significant characteristic of an over-fertilised water reservoir is their capability of self-maintenance of the high level of trophism, that is, the continuous maintenance of a great number of biogenic compounds (nitrogen and phosphorus) in the water, conditioning in turn the occurrence of algae and blue-green algae. These processes are a consequence of the activity of the mechanism called internal supply, consisting of the release of biogens from bottom deposits and their reintroduction into the circulation (water depth).

In the situation of an occurrence of such unfavourable changes in the water reservoir, it is necessary to start reclamation operations.

Presentation of the applied method

Deciding to choose the main method of reclamation, it is necessary to take into account the degree of its interference in the ecological system of a given reservoir as well as the time needed to conduct the work, and above all the permanence of the expected results which the applied method may bring. A complex approach to the process of the water reservoir reclamation is fundamental. The application of only one type of action usually boils down to the removal or temporary weakening of a single element from a group of unfavourable phenomena occurring in the eutrophic reservoir, and not to the restoration of the ecological balance in the whole ecosystem, which should be the main objective of reclamation activities.

The innovative method of reclamation applied at the Jelonek and Winiary Lakes in Gniezno was the method of blocking (deactivation) of phosphorus directly in bottom deposits by means of appropriate chemical substances (coagulants), leading in consequence to a decrease in the quantity of this element available in the water depths e.g. for blue-green algae or phytoplankton algae which could generate

blooms. The innovation consists of triggering intense but controlled disturbance in the deposits and the application of a coagulant directly to bottom deposits.

With regard to feeding the chemical substances intended to block the phosphorus in the reservoir, the site to which they are supplied is of the greatest importance here - these should be, above all, deposits, and possibly as backup it is possible to apply the feeding into the water depth. It must be emphasised that the natural repository of biogens in each water reservoir is the bottom deposits and not the water depth and they mainly have the ability to store biogens, including phosphorus, reaching the reservoir from the reservoir basin, as well as from the phosphorus found in the water depth.

During the reclamation of the lakes in Gniezno performed by the company, which realised the project, an important action was to feed coagulant directly to the bottom deposits and to force out their re-suspension at the same time. This type of actions allows the fed chemical substance to penetrate the external layer of deposits - the one which is most active in the process of internal supply, that is, the one participating in the circulation of biogens (including phosphorus) between the deposits and the water.

As well as the bonding of phosphorus occurring already in the deposits, the operation of feeding chemical substance directly into the bottom deposits allows their condition to be improved. This means that the deposits may regain or improve their ability to store phosphorus, thus leading to a decrease in its concentration in the water depth, and to control the concentration of this element in the long run. The applied method influences the dynamics of phosphorus circulation in the reservoir, decreasing the internal supply, that is, the release of phosphorus accumulated in the bottom deposits into the water depth, being the cause of self-maintenance of the high trophism and occurrence of blooms in the reservoir.

The deactivation of phosphates directly in the bottom deposits was possible owing to the use of a water-craft - the only one in the world - consisting of a unit of two modules: a surface module and an underwater module.



The surface module of the unit of watercrafts moored on the Jelonek Lake in Gniezno.

The surface watercraft is responsible for:

- the movement of the whole unit - this is possible owing to two engines installed on each of the floats of the surface watercrafts (catamaran),
- the transport of chemical substances used in the reclamation process,
- the precise and controlled feeding of the chemical substance - the watercraft is equipped with set of specialist pumps, equipped with meters, with full digital control of the media flow,
- the delivery of air to bottom deposits - there is a compressor located on the watercraft, which could deliver the air oxygenating the bottom deposits to the appropriate depth, forcing out their re-suspension,

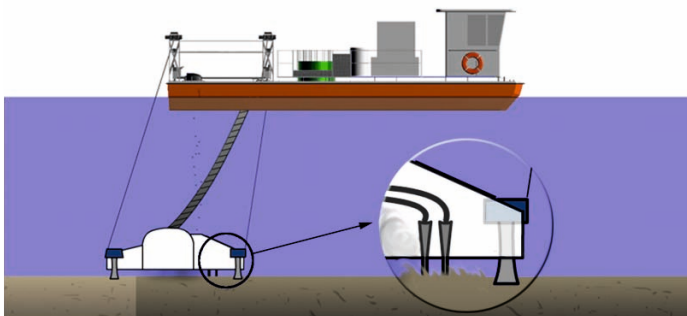
- the precise navigation and control of the underwater module - the installation of two GPS systems on the watercraft, which are compacted with each other, enables navigation on the reservoir, on the other hand, the underwater module is controlled through the creation of a digital map of the bottom of the reservoir and its sonar image,
- the movement and control of the operations of the underwater module - 4 winches programmed and controlled from a PC are installed in the construction of the surface watercraft.

The underwater module is responsible for:

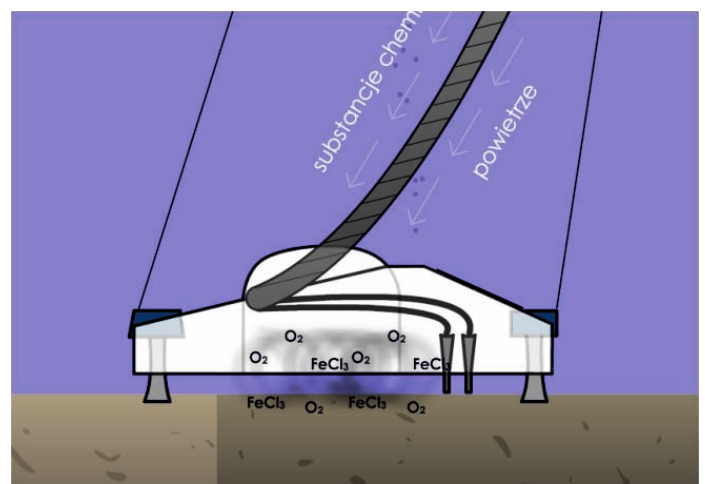
- the provision of information on its location in relation to the deposits through the use of an optical multi-sensor,
- causing controlled re-suspension of deposits within its closed space,
- the oxygenation of bottom deposits,
- feeding the appropriately selected chemical substances for phosphorus bonding by means of a set of nozzles,
- the coagulation and repeated sedimentation of deposits under the influence of the action of chemical substances.



The unit of watercrafts with a visible underwater module suspended in the surface watercraft dock.



Visualisation of the unit of two watercrafts – surface (superior) and underwater directly operating in the deposits.



Visualisation of the underwater module with visible deposit sensors and nozzles delivering the air and selected coagulant.

Treating the lakes in Gniezno as complex organisms, as well as the main method, (deactivation of phosphorus in bottom deposits), other methods supporting the reclamation process were applied in order to make the result of reclamation more permanent.

The following supportive actions were taken on the Jelonek and Winiary in Gniezno lakes:

- biomanipulation - consisting of adjusting and balancing the species composition of fish, which has an impact on the trophic relations in the reservoir. This method consisted of a reduction in the number of benthic - and zooplanktonophagous, in order to restore the sufficient species quantity and composition of zooplankton, so that it could control the quantity of phytoplankton more effectively.
- Macrophyte plantings - macroalgae (charophyceae) as well as submerged and emerged plants (e.g. reed mace), which collect biogens effectively, were planted within the separated areas of water reservoirs. As a consequence, the collection of biogens from the water depth is intensified, bottom deposits become consolidated and habitats for other organisms are formed which causes an increase in the biodiversity.
- Provision of barley straw - The barley straw bales were located at indicated areas of the lakes the decomposition of this straw causes the emission of substances called algaestats limiting the growth of phytoplankton algae and blue-green algae.
- Seasonal mowing of the excess of plants forming reed areas - in this way, it is possible to remove significant quantities of biogens built in the tissues of plants beyond the ecosystem of the reservoir,
- Feeding chemical substances from the surface - (only in combination with feeding into the deposits) speeding up the sedimentation of matter (mineral and organic) suspended in the water depth, and in particular, the fine-particle matter, which settles down very slowly or not at all.
- Pond dredging - in exceptional situations, the deposits from a separated part of the bottom of the given reservoir (e.g. sedimentation zone where a stream flows into the reservoir). may require removal beyond the reservoir basin. In view of the great interference of this method in the ecosystem, it is applied only as a last resort, as it removes one of the most important elements of the lake ecosystem, responsible for the circulation of biogens - bottom deposits.

As a consequence of the application of the method of phosphorus deactivation directly into the bottom deposits, the achievement of the following objectives was assumed:

- bonding of phosphates in bottom deposits (elimination of the so-called internal supply),
- reduction in the concentration of phosphates in water,
- limitation of blue-green algae blooms - the blue-green algae are practically always present in the composition of the phytoplankton, but they stop dominating and generating blooms,
- increase in the water transparency - mainly through the reduction in the quantity of phytoplankton, including blue-green algae, but also through a decrease in the quantity of mineral and organic suspension matter in the water depth,
- occupancy of the bottom by macroalgae and water plants - possible only after an increase in the water transparency. In turn, they provide a protection for deposits, which are more rarely disturbed by the motion of water, also the habitat diversity and oxygen production in the process of photosynthesis increases,
- consolidation of bottom deposits - owing to their bonding by the provided chemical substance,
- improvement of the oxygen balance in the reservoir - owing to aeration of deposits and introduction of macroalgae and water plants,

- increase in biodiversity - owing to the above mentioned data, and in particular, through the improvement of oxygen conditions and the appearance of macroalgae or water plants,
- the habitat diversity is increased which is followed by an increase in the diversity of species inhabiting the ecosystem.

The method of deactivation of phosphorus in the water depth is a method already applied in various reservoirs, however the method of deactivation of phosphorus in the bottom deposits and the actions supporting the principal reclamation are innovative actions and projects. The application of this method in the case of the reclamation of municipal lakes is a very favourable method. While using the watercraft, there is no need to secure an additional area for the storage of deposits (the problem of odour!). Just as it is in the case of lake dredging, the reclamation works are conducted from the water surface, which does not constitute a risk or hazard for the surroundings and is safe for biological life.

The presented arguments spoke volumes for the fact that this was a method which was practicable with regard to the reclamation of lakes located in the centre and in an area of public buildings in the city.

The total value of the project was estimated up to EUR 431.861,00 and was financed 50% by the LIFE + Program. The implementation of the undertaking covered the years 2009 - 2010.

Actions taken with regard to the lakes in Gniezno

The basis for the commencement of the reclamation works was the execution of the monitoring of the lake catchment. The water inflow sources were controlled. The analyses of collected water samples were carried out.

A retention reservoir, which required regeneration to fulfil the assumed functions, was located at the direct inflow to the lake.

In order to catch the phosphorus from surface flows, a feeder with coagulant was installed at the inflow to the pond (with the possibility of adjustments to the feeding of the coagulant solution), and several partitions made of sacks filled with shingle and iron filings were placed at the estuary to the Jelonek lake. Part of the pond was deepened at the place of the inflow of the Gniezno Stream, which contributed to the enlargement of the sedimentation zone of deposits potentially carried by the stream.

The pond was characterised by a high content of biogenic compounds which caused continuous algi blooms. PIX 111 coagulant was applied to the pond, its task was to precipitate phosphorus in order to limit the intensity of algae development and to aid the improvement in water quality. Submerged plants (spiked water milfoil - *Myriophyllum spicatum*, rigid hornwort - *Ceratophyllum demersum*, water pineapple - *Stratiotes aloides*) and emerged plants (common reed - *Phragmites communis*, broadleaf cattail - *Typha latifolia*) were planted in the pond in order to take advantage of the biogens. These operations contributed to the enhancement of the retention capacity of the pond (in relation to suspension matter and biogens).

During the actions conducted in the pond, a surrounding ditch, which allowed the collision-free flow of Gniezno Stream to the Jelonek Lake to take place, was created.

On top of this, reed fields which overgrew the lakes were removed from an area of 3.500m². Through the elimination of reeds, the quantity of biomass subject to decomposition was minimised.

The scarps of the Jelonek and Winiary lakes were rebuilt. The destroyed scarps were partly covered with sods and sown with grass. At the Winiary lake periphery, basket willow was planted.

The grassy scarps reinforce the Lake shores and collect part of the pollution flowing down from the surface.

The basic action which was taken on Jelonek and Winiary lakes was the blocking of the possibility to secrete phosphorus from bottom deposits and a maximum possible reduction of the quantity of phosphorus in water.

After detailed tests of the bottom deposits, and analysis of the lake waters, the company, which realised the project specified doses, type and sites for application of the coagulant. The substances introduced into the bottom deposits are iron chloride (PIX111) and Phoslock.

The coagulant was fed directly into the bottom deposits at Jelonek and Winiary Lakes, with the use of the "floating device" giving the possibility of precise feeding of the coagulants directly into the bottom deposits during the caused and controlled re-suspension of deposits in the confined volume of the watercraft. The watercraft fed the coagulant uniformly into the strictly specified sites, floating along the indicated routes.

Before the work was started, scuba divers checked the bottom of the lake using a sonar device, and marked any structures located at the bottom which could constitute a hazard for the underwater module of the watercraft. On top of this, a bathymetric plan of the water areas was performed.

The first stage of work was performed in the year 2009, further work was conducted in the second quarter of the year 2010 and The effects of the work monitored. Before each feeding of the coagulant, and after completion of the work, detailed tests of the bottom deposits as well as analyses of the lake water were performed.

In the Jelonek Lake, there were exceptionally favourable conditions for the occurrence of blue-green algi blooms. During the summer period, the partitions made of barley straw bales were exposed. The straw bales were located at the inlet to the pond, in the area of the inflow to the Jelonek Lake and around the Winiary Lake beach.

During the aerobic mineralisation of straw, decomposition products were released into the water, inhibiting the division of blue-green algae cells, which function as natural algaestats. The effects were visible after a period of 3 weeks. No blue-green algi blooms were found.

The present taxonomic structure of fish in the Jelonek and Winiary lakes was typical for reservoirs characterised by high trophism. The significant concentration of Cyprinidae fish and Percidae fish is a factor contributing to the eutrophication and maintenance of bad water quality, therefore, during the Autumn of 2009 and the Spring of 2010, these fish were caught and the pike were introduced.

263 kg of fish were caught in two stages. 10% of fish constituted predatory species (zander, pike) and the remaining 90% constituted the so-called white fish (Crucian carp and Prussian carp, carp bream, tench). On top of this, 290 kg of fish were caught at the Winiary Lake, of which 28% constituted predatory fish (zander, pike, perch) and 72% constituted white fish (Prussian carp, carp, carp bream).

After fishing, the lakes were stocked with Autumn and Spring fry of pike in the quantity of about 1000 pieces/ha. The pike introduced into the ecosystem to eliminate zoo-planktonophagous fish will have an impact on the improvement in the water quality. The manipulation of the fish was carried out by the Polish Angling Association.

In order to ensure the stable, clean-water state of the lakes, in areas containing a large quantity of inactive phosphorus in the deposits, with significant area covered by water plants - macrophytes were reintroduced. The substratum with macrophytes creates an efficient element removing nutrients from the water depth by the creation of barriers and islands. After an increase in water transparency was obtained, work on rebuilding the water plants rooted in the deposits was started. In total, 7050 macrophyte seedlings were planted in both lakes and the pond in the years 2009-2010

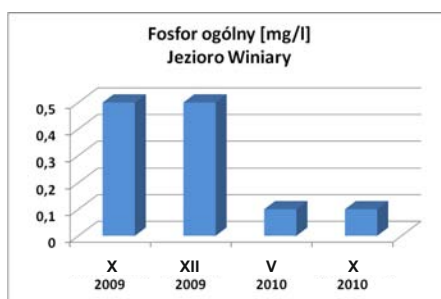
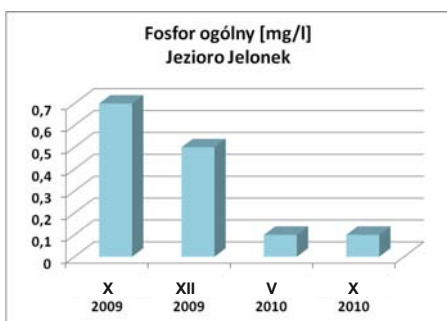
The reclamation work was monitored on a regular basis by an independent entity. At each stage of work, before and after coagulant application, analyses of the water and bottom deposits were performed. A report was prepared for each stage of completed work.

The achieved results were compared with indicators specifying the class of cleanliness of surface waters. Through the whole period, the lakes were monitored with regard to possible changes occurring in the water depth.

Results of the project

The reclamation of the lakes by means of the method of deactivation of phosphorus in the bottom deposits allowed the progressing eutrophication of Jelonek and Winiary lakes in Gniezno to be inhibited, causing:

- a reduction in the content of phosphorus in the water depth. In July 2009 the content of phosphorus in the water depth in the Jelonek decreased and Winiary Lake reached 1,7 - 1,5 mg/l



- a decrease in the production of phytoplankton
- an increase in the visibility of the Secchi disk



- reduction of Chlorophyll a
- growth of underwater plants and fish - which will improve the ecological balance. The white fish were fished out of the lakes and they were restocked with pike in a quantity of about 1000 pieces/ha.
- rebuilding of the complexes of submerged plants and plants with floating leaves. The total quantity of macrophytes planted on the lakes was 7.050
- elimination of blue-algae blooms. In 2010, during the project implementation, in spite of the high temperatures maintained during the summer period, blue-algae blooms were not found.
- an increase in the landscape and recreational value of the lakes. The water in the lakes regained transparency, the water plants along the shores are varied, owing to which the inhabitants regained their favorite recreational places around the reservoirs.

Assessment of the results of the project

During the whole period of implementation of the undertaking, it was important to coordinate the actions and to monitor their effects. The project was implemented by the Municipal Office in Gniezno, and in particular, by the Department of Environmental Protection, Municipal Innovation and Promotion Centre and Finance Management Section.

After the performance of a series of operations at the Jelonek and Winiary Lakes, aimed at their restoration to a good condition, their permanent monitoring will now be necessary. The lake is a system which is complex enough, so the completion of works during both seasons and the accomplishment of positive results is not the last action which will ensure positive effects for years. The lakes will now require permanent care, and necessary further actions will include:

- Seasonal cutting of the reeds from the area of the inflow to the Jelonek Lake which causes the removal of biogens stored in them beyond the lake.
- Control of the species composition of fish - the conducting of controlled fishing, which will allow an assessment of the species structure of fish.
- Controlled mowing of the plants at sites used for recreational purposes is allowed.
- Provision of information to the people on not feeding the water birds.
- Provision of information for anglers about a ban on excessive luring of the fish and reduction of the bait.
- Periodical control of the lake catchment.

Project as an example for other cities

Lakes are very vulnerable to the pressures of man (recreation, rest) and city agglomerations. Many users, both in Poland and all over the world, face the problem of the cleanliness of lake water.

The reclamation method used in Gniezno within the framework of the Life + Programme - consisting of the deactivation of phosphorus in the bottom deposits by means of coagulants fed directly into the bottom deposits, as well as the introduction of macrophytes and the balancing of the fish species - is recommended for lakes in which high fertility is maintained by release of biogenic compounds from bottom deposits. The chemical precipitation of phosphorus by means of coagulants limits the intensity of the development of algae, the result of which is an improvement in the water quality and an increase in its transparency. It is a method which is safe for the biological life of the lake.

The reclamation works were conducted on the water table, without constituting a risk or hazard to the surroundings and biological life.

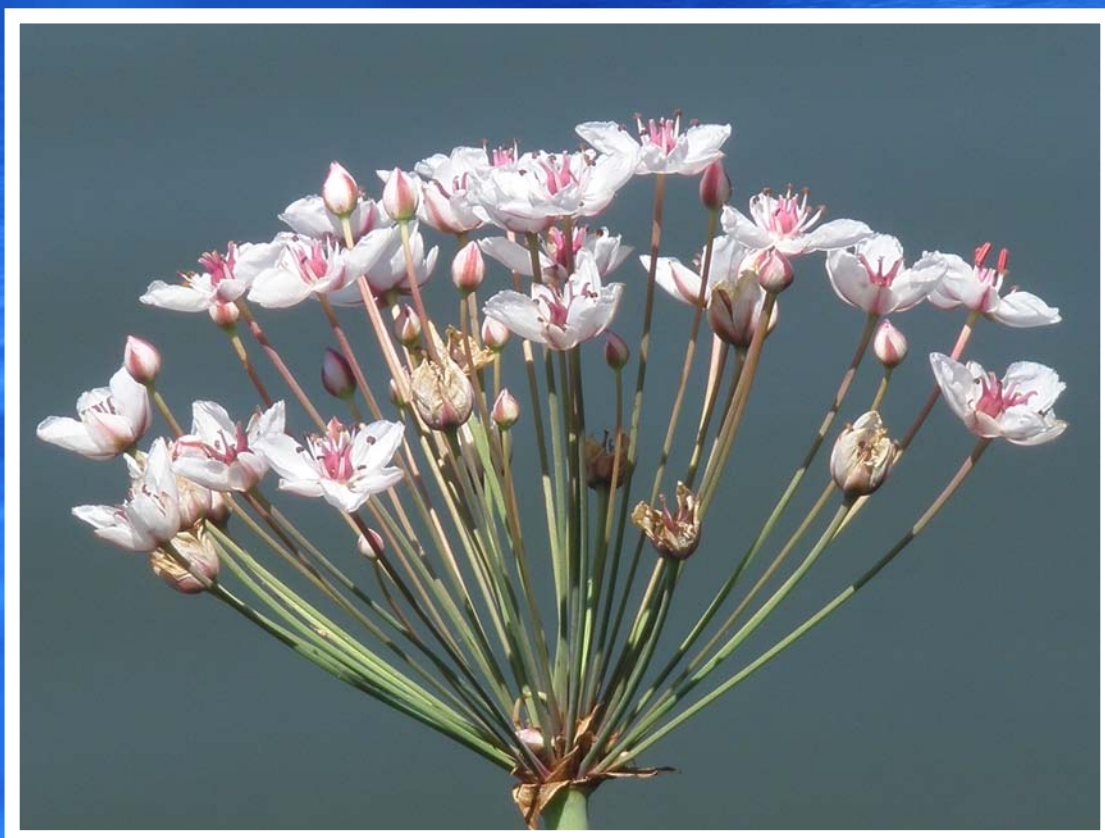
The innovative lake reclamation method which was applied in our project will certainly become applicable in resolving similar problems in other reservoirs.

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