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MINISTRY OF AGRICULTURE, NATURAL RESOURCES AND ENVIRONMENT

WATER DEVELOPMENT DEPARTMENT

1413 NICOSIA

TECHNICAL CRITERIA AND METHODS FOR ESTABLISHING RESERVOIR PROTECTION ZONES

Final report V1

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Table of contents

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1. Introduction

1.1. Origin of the mission

In order to comply with the provisions of Articles 4 and 7 of the Water Framework Directive 2000/60, the Water Development Department of the Ministry of Agriculture, Natural Resources and Environment, wished to secure the services of an expert. The aim of this expertise was to provide the necessary technical criteria and methods which will be used for the establishment of Reservoir[1] Protection Zones.

Application was made to the European Commission – TAIEX (Technical Assistance Information Exchange instrument) on march 2006.

This expert mission took place from the 23 to the 27 October 2006.

1.2. Acknowledgements

The expert wishes to thank the Water Development Department and specially :

- **Mr Christodoulos ARTEMIS –** Director, for his welcoming and the attention taken to the good organisation and work conditions of the mission ;

and

- **Mr Sofoclis ALETRARIS -** Head of Nicosia District Office ;
- **Mr. Kyriacos KYROU -** Head of the Division of Construction ;
- **Dr. Stefanos PAPATRIFONOS -** Head of the Division of Hydrology,

for the quality of the explanations and information they brought, the organisation of the reservoirs visits, and the richness of discussions.

1.3. Reservoir context in Cyprus

In Cyprus, the development of the water resources since independence is impressive : dams and ponds (105), large waterworks, conveyors, irrigation projects, integrated rural development project, water treatment plant and desalination plants.

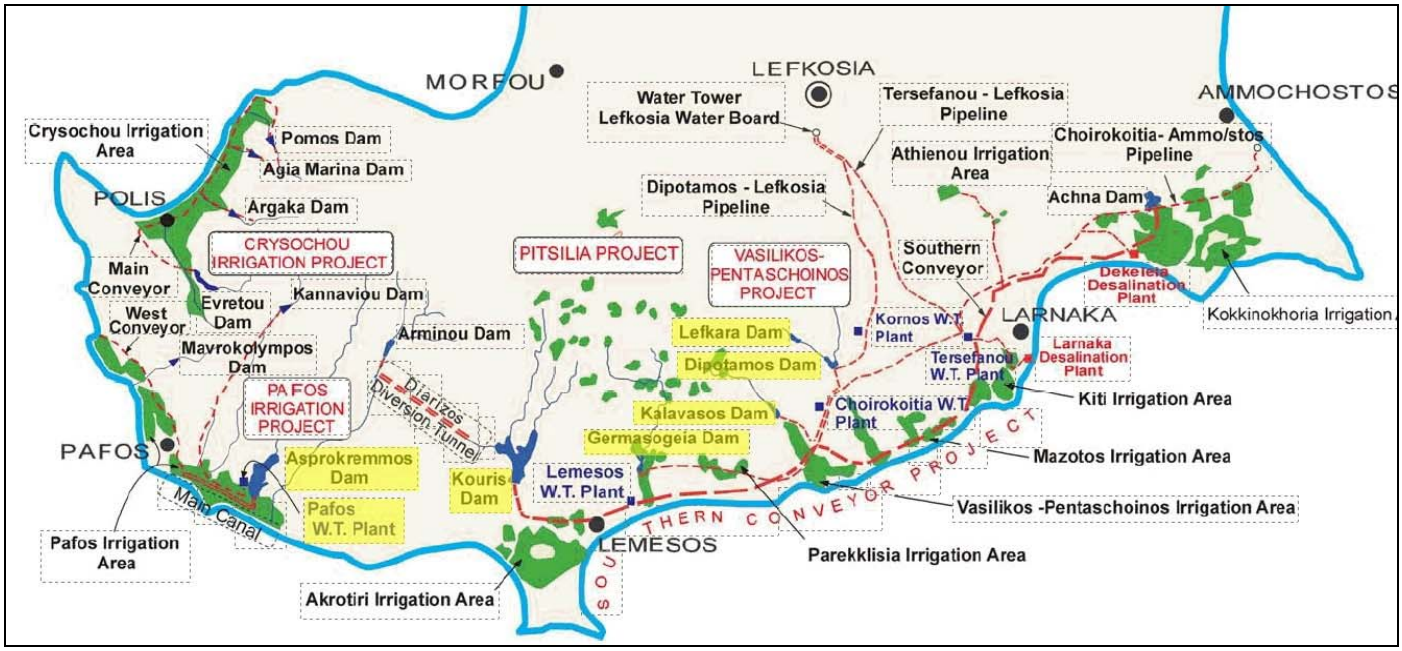
Dams take an important place in water management. With a total capacity of 304 MCM [2], they annually store 54% of the 235 MCM surface water annual flow. This capacity represents 34% of the total usable water supplied by rains and left after evaporation.

Actually, reservoirs provide X% of domestic needs in drinkable water.

[1] Reservoir : Any impoundment of surface waters designed to provide drinking water to the public.
[2] MCM = million cubic meters

1.4. Program of the mission

Monday, 23 October 2006	Introduction meeting Individual work for the expert
Tuesday, 24	Reservoirs visit : Lefkara, Dhipotamos, Kalavassos with Mr.Kyriacos Kyrou
Wednesday, 25	Working meeting Individual work for the expert
Thursday, 26	Reservoirs visit : Yermasogia, Kouris, Asprokremos with Mr. Stephanos Papatryfonos
Friday, 27	Conclusion meeting Delivery of report draft 1 - discussion
Monday, 30	Delivery of report draft 2 (paper and file) which take account of discussion hold on the 27th.



Sites visited during the mission are yellow underlined

2. General principles

The goal of the setting up of protection zones around reservoirs used for drinking water is to ensure the protection of public health and the durability of the resource.

Currently, Cyprus authorities are enforcing an arbitrary zone of 300 meters around the reservoirs. This protection is only effective for direct pollution into the reservoir and must be developed in order to avoid pollution :

- Driven by the slopes into the reservoir and coming from areas distant from more than 300 meters ;
- Brought by the flow of the river which supply the reservoir.

2.1. Integration of "Reservoir protection zones" in Water Framework Directive requirements

This section quickly put reservoir protection into the Water Framework Directive (WFD) context and emphasizes the points which contribute to meet the requirements of the European Acquis.

2.1.1. Articles 4 and 7

According to main provisions of articles 4 and 7 of the Water Framework Directive (WFD) 2000/60, Members states [3] :

- shall implement the necessary measures to prevent deterioration of the status of all bodies of surface water (except in some special conditions) or shall protect and enhance all artificial and heavily modified bodies of water [4], with the aim of achieving good ecological potential and good surface water chemical status in 2015 ;

- shall identify all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m3 a day as an average or serving more than 50 persons, and those bodies of water intended for such future use ;

- shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water.

2.1.2. Article 7, water used for human consumption

Member States must identify :

- all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m3 a day as an average or serving more than 50 persons ;
- and those bodies of water intended for such future use.

Reservoirs actually used for human consumption, and those which are foreseen to be used in the future, fall within this WFD article. This mean that they must be listed in the register of protected areas – see below § 2.1.3

[3] Are only given here the elements concerning reservoirs and drinking water.
[4] Which is the case of most of reservoirs and part of upstream rivers.

2.1.3. Article 6, Register of protected areas

Article 6 request the implementation of a Register of protected areas among which are the areas designated (under article 7) for the abstraction of water intended for human consumption. Logically, the reservoir protection zones should be described or referenced in this register.

The register of protected areas shall be kept under review and up to date.

The actual register for Cyprus, part of the Report establish by the WDD in March 2005, mentions the following water bodies reservoir used for drinking water (general map and list) :

- Asprokremos
- Kouris
- Kalavasos
- Lefkara
- Dipothamos

It appears that this first version of the register needs to be updated :

- by completing the list with all surface water bodies actually used for the abstraction of water for human consumption :
  - by listing all the reservoirs which contribute to this use ;
  - by adding the rivers which deliver water to the reservoirs ;
  - by listing the reservoirs whose water are used for aquifers recharge, when these aquifers are used for abstraction of water intended for human consumption [5].

- by adding the water bodies (reservoirs and rivers) which are intended to be used as mentioned above ;

- by adding the reservoir protection zones when they are established.

According to actual understanding, the WFD doesn't give a rhythm for the revision of the register of protected areas. It's only mentioned that the register lists must be regularly examined and updated. Modifications can be performed in the register before 2009. After that date, it should be logic to update the register at least once per river basin management plan (2015 - 2021 – 2027).

2.1.4. Articles 5 and 7 : Economic analysis and recovery of costs of water services

Surface water from dams is the main water Cyprus resource.

Economic analysis made according to WFD article 5 requirements showed that because of the good environment quality generally observed on reservoirs watershed [6], environmental costs of this resource make a minor contribution to the total water cost.

However, because of the increasing of the demand for urban and tourism uses and the decreasing of rainfall resource, two desalination plants had to be realized since 1997 and two other ones are under discussion.

According to WFD article 9, Cyprus authorities must aim to cost recovery of financial costs including environmental and resource costs. Important pricing efforts allowed to approach this objective : cost recovery target was approximately 73% in 2005.

[5] Moreover, it is assumed that the aquifers used for potable water abstraction are listed in the ad hoc lists of the register of protected areas.
[6] Watershed : Any area lying within the drainage basin of any reservoir.

Reservoirs water quality degradation should handicap this action by forcing :

- the increasing of treatment of water abstracted from reservoirs (or from underground water fed with reservoirs water) ;
- the construction of new desalinization plants.

2.1.5. Conclusion on compliance with Water Framework Directive

The intention of Cyprus government of establishing protection zone for the reservoirs fulfil the WFD for what concerns surface water used or to be used in future for the abstraction of water intended for human consumption (articles 4 and 7)

The register of protected areas needs to be completed with all direct or indirect human consumption usage of reservoirs and will be updated with future usage ; reservoir protection zones are to be included (article 6).

Reservoirs water protection will directly contribute to control water cost increasing and consumers charge, and will finally make easier the water cost recovery (article 9).

2.2. Effective implementation of Protection zones

In all countries, the main weakness of protection zones is their effective implementation and respect.

Naturally, the difficulty increases in densely populated areas.

2.2.1. Socio economic acceptability conditions

In the case of Cyprus dams, watershed generally show the following characteristics :

- population density is low ;
- villages population is in a decreasing phase for main cities development ;
- industrial activities are almost absent.

Realistic analysis drives to consider that these socio-economic conditions are the most favourable ones to protection zones implementation.

Predicable development of the island, partly driven by tourism, will certainly inverse theses trends within next decade with an inland repopulation. Therefore, protection zones implementation should be rapidly driven.

2.2.2. Recreational and tourist activities on reservoir lakes

Cyprus is a tourist destination. The adhesion to Europe, and other causes, bring foreigners to buy land and construct holidays houses ; hotel business has also been highly developed.

Because of the increasing of property demand and high coastal property prices, the tourist pressure will without a doubt go inland. Dam lakes will certainly suffer an high tourist and property pressure : it already starts to be visible with the multiplication of individuals houses in the vicinity of some lakes (Asprokramos, Kouris).

Considering the vital importance of reservoirs for Cyprus, it is strongly recommended that no recreational use should be allowed on dam lakes [7].

It must be focused that any dispensation to these interdictions would generate a hardly controllable situation : multiple extension request for other reservoirs and dam lakes, creation of unauthorized restaurants and campings, use of engine boats for tourists safety, etc.

Furthermore, the satisfaction of water multi-usages on dams (human consumption, agriculture, tourist activities) is technically and politically complex ; because of local economic issues linked with tourism, the keeping of water in the dam if often imposed for recreational purpose.

On an other hand, recreational uses of reservoir would drive to :

- a reduction of the reservoirs water quality ;
- and consequently, to an increasing of the water treatment in order to obtain drinkable water.

These two consequences are contrary to the Water framework directive : articles 4 (non deterioration) and 7 (avoiding deterioration and reducing the level of purification treatment).

2.2.3. Regulation attached to protection zones

It is proposed that every protection zone will be implemented by an ordinance which describes :

- the perimeters of the different protection levels ;
- activity and usage limitations attached to each perimeter.

These ordinances must rely on adapted regulations. Therefore, actual Cypriot regulation must be analysed to identify the necessary changes for the drawing up of the regulation attached to the protection zones.

2.2.4. Public information

Preliminary public information is to be made on the crucial need of protection of reservoirs water quality. This side of the water problem will be brought to public within the scope of public awareness campaigns that are already done by the Cyprus government.

Public should be informed of the consequences of a degradation of reservoirs water quality :

- cost increasing : new water treatments, need of new desalination plant ;
- risk of water rationing in case of accidental pollution on reservoir in use.

[7] Any kind of boating (row, sail, engine, …), swimming, … Except fishing from the banks which is already allowed.

2.2.5. Monitoring

2.2.5.1. Current monitoring

WDD already carries on site monitoring. Illegal activities (unauthorized farms, non controlled garbage dump, …) are identified and justice actions are driven.

This action is performed by staff of WDD district offices which are in contact with local population and make regular watershed watch over.

2.2.5.2. Reservoir protection zones monitoring

Reinforced monitoring must start immediately after the protection zone ordinance are promulgated. The monitoring has two main purposes :

- insure the respect of ordinance appliance ;
- assess the efficiency of the protection by means of reservoir and river water quality monitoring.

2.3. Strong realistic perimeters

Better is to aim for limited but effective and respected protection zone perimeters instead of large non respected perimeters.

2.3.1. Two steps establishment method

The protection zone perimeters and attached regulations will be technically establish in two steps, taking account of sustainable development considerations :

- Step 1 – determination according to all objective technical criteria : this will drive to establish ideal perimeter and regulation. These technical conclusions will underline the points (perimeter and regulation) that cannot be reduced, even slightly.

- Step 2 - adaptation of the perimeter extension :
  - to inescapable existing socio-economic situations ;
  - to the most important needs of future development which are already reasonably expressed or can be reasonably foreseen (example : village extension) ;
  - to the strategic interest of the reservoir (for example : reservoirs which already have or will have an human consumption purpose.

As a product of Phase 2, perimeters and attached regulations cannot be defined below an efficiency level of reservoir protection to be considered as a minimum.

2.3.2. Inescapable pressures situations

If because of inescapable existing (not foreseen) socio-economic conditions, phase 2 drives to consider that the minimum efficiency level of protection will not be reached, it must be emphasized as a non sustainable situation.

Further studies and actions will be defined.

3. Definition of reservoir protection zones

It is recommended the setting of three protection areas which will compose the reservoir protection zones :

- an ***Immediate Protection Zone***
- a ***Close Protection Zone***
- a ***Distant Protection Zone***

3.1. The Immediate Protection Zone

3.1.1. Goal of the Immediate Protection Zone

The goal of this perimeter is to :

- forbid access to the pumping point and to the treatment or pumping station ;
- prevent damages on structures ;
- prevent direct voluntary or involuntary introduction of pollutant in the water ;
- protect the pumping zone from direct runoff and risk of pollutant spill from the banks.

Essential elements of this immediate protection are operational on the visited dams.

3.1.2. Method for the delineation of the Immediate Protection Zone

Its surface is limited (some hundred square meters to some hectares).

The perimeter include :

- a part on the banks ;
- a part on the lake ;
- and if necessary, a part on the river.

According to the site configuration, the perimeter can be constituted of separates zones.

3.1.3. Means of applying

The land constituting this perimeter must compulsory be the full property of the public authority in charge of the reservoir [8] (for example : inside the fence around the pumping station).

This perimeter understands a physical protection :

- generally a fence on the banks if possible ;
- a buoys line on the lake and/or on the river [9]. This equipment is employed to forbid the approaching of boats or swimmers.

[8] It is already the case for pumping equipment and station, technical building, …

[9] Depending of the configuration :

- the river becomes larger before the beginning of the lake of the reservoir ;
- the length of the lake is little

This figure has not been seen on visited dams and seems nonexistent in Cyprus.

For what concern the pumping place, its position will determine the extension of the part of the Immediate Protection Zone intended to protect it. The bank will be concerned if the pumping zone is close to it ; then a continuity between the fence and the floating buoys will be seek.

If necessary, a guarding of the installation can be done.

Floating dam should be stored on site, ready to be installed around the pumping installation in case accident by floating pollutant as hydrocarbons (petrol, diesel or fuel oil, …).

3.1.4. Uses and activities prohibited within the Immediate Protection Zone

In the Immediate Protection Zone, all activities are prohibited except the ones which are necessary to operate the installation and to maintain the equipment.

3.1.4.1. Vegetation

The vegetation growing within this perimeter will be mechanically managed and no weed killer nor pesticide will be used.

3.1.4.2. Chemicals products

If a storage of chemical products is needed for equipment maintenance purpose, they will be kept within the minimum necessary amounts.

3.1.4.3. Roads in the vicinity of the Immediate Protection Zone

Concerning roads, the ideal access to the reservoir is a non asphalted dead-end road.

The purpose is not to prohibit the access to the dam lake but to limit circulation around the reservoir.

If a road reaches the dam or the reservoir and allows “through traffic” it should be deviated and the access to the dam done by making appropriate road dead end.

Any unavoidable “through traffic” road lining near the dam or the river banks must be equipped with crash barriers.

Example of “through traffic” road running along the bank of a dam lake (Palekhori dam - WDD photo). See also right bank of KOURIS dam at § 3.2.1

If there is a possibility that on a “through traffic” road, an accidental spill (due to a truck accident for example) reaches the pumping zone, ditches shall be dig in order to stop the spill runoff. According to local conditions, the spill might be canalized to a safety basin or at least downstream the dam.

3.2. The Close Protection Zone

3.2.1. Goal of the Close Protection Zone

The goal of this perimeter is to keep the reservoir and the rivers away from punctual and accidental pollutions which can be driven directly in the reservoir by stream or runoff.

By definition, the Cloze Protection Zone should not suffer any non-point nor permanent pollution (see below the list of uses and activities prohibited in the perimeter - § 3.2.4).

3.2.2. Preliminary discussions

Preliminary points must be stated and discussed before broaching the delineation method of the Close protection Zones.

3.2.2.1. Preliminary discussion on the time of transfer of pollutant by the river

In non Mediterranean conditions (for example on the majority of central and north Europe territory), flow and runoff criteria are used to define the Close Protection Zone :

- Flow : criteria are based on a pollutant time transfer of 3 or 4 hours, within a range of flow which is not exceeded 90% of the time [10]. This time limit is determined according to the possibility of having actions after an alert. Keep in mind that this rule is applied :
  - to reservoir fed by rather quiet rivers ;
  - in area with high population density, which gives some chance to an alert to be given.

- Runoff on banks and slopes : the criteria are based on a maximum 20% slope. In order to slow down runoff and keep a part of pollutant, it's recommended that slopes are covered with grass or other dense vegetation [11].

The natural conditions which prevail in Cyprus are different :

- River flow :
  - is very irregular : reservoirs' rivers are dried up 6 to 9 months per year and several rainy days are needed to see flow restarting in the rivers at autumn (cf. river type table below);
  - can be torrential so that a time of transfer of 3 or 4 hours will involve water coming from nearly all the watershed (see below the example on Kouris reservoir) ;
  - furthermore, because of low population density, the possibility to have an alert in case of accidental pollution is slight [12] ;

- Runoff is increased because of :
  - poor vegetation ;
  - high slopes common around dam lakes [13].

[10] The time of transfer is the time needed for water (and pollutant) to be carried from the pollution zone to the reservoir. The time of concentration concerns the same phenomenon applied to the more distant point of the watershed.
[11] cf : Protection of surface water supply point – Study of the French Water Agencies, under the coordination of the Water Directorate of the Environment ministry and of the Health General Directorate of the Health ministry. (Protection des prises d'eau de surface – Quelles stratégies ? Etude des Agences de l'Eau n° 75 – Novembre 1999). http://www.lesagencesdeleau.fr/francais/etudes/modele.php?fiche_id=75&theme=0
[12] On an other hand, low population density reduces accidental pollution hazard.
[13] In hilly or mountainous regions, dam lakes are commonly surrounded by slopes which are not the result of natural erosion and are more abrupt that they should normally be. Runoff is increased by this natural slope equilibrium research.

River type	Number of water bodies	Cover (% of total length)
R1: small rain volume with non-continuous flow	40	15
R2: large rain volume with continuous flow	17	11
R3: large rain volume with non-continuous flow	159	74

Non-continuous flow : 90 % of Cyprus rivers are concerned (expressed in number or length of river)

Time of transfer : Example on Kouris reservoir watershed

The length of the main river upstream the dam is 14.5 km

Under base flow condition (low flow), the average flow speed is 1.8 km/h (0.5 m/s). This means :

- that a pollution that occurred 5.4 km upstream will reach the reservoir within 3 hours ;
- or that a pollution which would even occur at the top of the Kouris river catchments would be in the dam within 8 hours only.

In flood conditions (high flow, stormy conditions), the average flow speed is 7.2 km/h (2 m/s) and the sketch is worse :

- a pollution which would even occur at the top of the Kouris river catchments would be in the dam within 2 hours only.
- A pollution that might occur at the very end of the catchments area (top of Limnatis river, 23.4 km length), will be in the reservoir within 3.5 hours.

Kouris dam (WDD picture)

The fact that the rivers are not permanent changes nothing to the protection problem and to the criteria definition for protection perimeter : the soil pollutions which occurs during dry period will be mobilized during the rainy period and transported by runoff and flow. However, depending on the substance, their pollutant effect will be reduced.

Conclusion on pollutant time of transfer
The usual flow criteria must be adapted and reinforced in order to reach a satisfactory protection.

Taking into consideration the time of concentration [14], protection should concern the whole watershed.

But, in order to reduce restraints on property and land use, it is proposed that strong protections might be limited to the main river and to its direct tributary streams [15].

3.2.2.2. Preliminary discussion on runoff evaluation

The runoff parameter is the most important in the definition of protection zones. Its systematic calculation applied on the watershed might theoretically drive to the definition of appropriate perimeter.

Runoff modelling
Runoff and flow modelling actually in use in other countries are satisfying for global basin calculation because runoff is well computed at large scale and the resulting flow is consequently well estimated.

Unfortunately, these calculation methods are not satisfying for “runoff evaluation” at a local scale. More, data necessary to the calculation are generally not available in the appropriate form :

- soil map (geologic map by default) : available but at large scale ;
- slope : available at the good geographic scale and with an appropriate precision ;
- rainfall : available at very large scale but data can be locally applied ;
- soil moisture content : data is available only locally but can be estimated if soil maps exists and rain chronicle is known ;
- vegetation : not available ;
- etc.

Erosion modelling
An other approach of runoff considered as a pollution vector could be erosion modelling. The bringing closer of these two parameters (runoff and erosion) is based on the assumption that “a runoff able to carry soils (erosion) is able to carry pollutants”.

Erosion models are based on the Revised Universal Soil Loss Equation (RUSLE) whose parameters are rainfall, runoff factor, soil erodability, slope-length, slope-steepness, cover, …

Erosion modelling have already been injected in GIS (Geographical Information System) to produce erosion maps the values for the different RUSLE factors are assigned to their respective mapping units, i.e. a soil unit map, a vegetation class map, and a digital elevation model. The result of such modelling lays in “erosion intensity maps” that adequate threshold might transform in “map of zones submitted to important runoff”.

[14] Time of concentration : Time needed for a drop of water to reach the outlet of a catchment from the most remote location of the catchment
[15] Tributary stream : Any perennial or intermittent stream, including any lake, pond or other body of water formed therefrom, flowing either directly or indirectly into any reservoir.

Unfortunately once more, RUSLE equation application is not yet fully operational and discussions remain on :

- the relative importance of "length of slope" as runoff increasing factor [16] ;
- the multiples coefficients used are linked to specific conditions (soil type, vegetation, erodability, …) and are still rather empiric.

Conclusion on runoff evaluation

Some more years will be necessary before appropriate method and data are available for a correct runoff modelling.

However, remains the main teaching of RUSLE equation : runoff is linked to slope but also to slope length. This means that even on gentle slope, distance must be taken into account.

Meanwhile, it is proposed to combine slope factor with length to characterize runoff risk :

- On what concern slope : A value of 20% is commonly quoted in technical and scientific publications [17]. It's also the value used in French reservoir protection method. Therefore a slope limit of 20% is proposed for the delineation of the Close protection Zone. **It is the best compromise and it will not bring to exaggerate the perimeters ;**
- On what concerns length, the 300 m limit afford a good complementary mean value.

If available in future, new methods and set of data will be used to delineate more precise limits :

- extension of the protection zone when necessary ;
- reducing in some cases if possible.

3.2.3. Method for the delineation of the Close Protection Zone

The whole reservoir, considered at its higher possible water level, is a part of the Close Protection Zone.

In order to correctly take into account the runoff factor, the following rules are established :

- The actual 300 meters zone around the reservoir must be maintained as a minimum safety distance ;

- The 300 m. zone must be extended to the main river which supplies the reservoir and to its direct tributaries (first lever tributary) ;

- If within these 300 meters zone, the slope of the natural terrain remains greater than 20%, the perimeter will be continued as far as the slope do not go below 20% during a minimum of 50 meters [18] ;

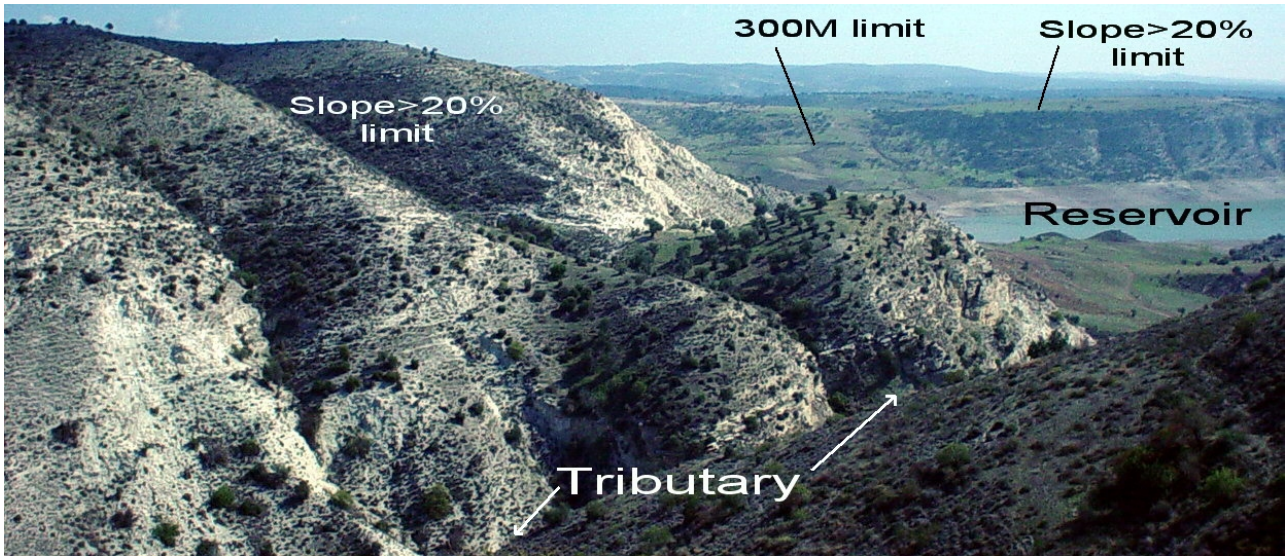
- Care will be taken to stop the extension of the perimeter if changing of watershed : inversion of the slope direction within the 50 meters range [19].

[16] For a constant slope value, it has been observed that erosion is more important on long slopes : rill erosion becoming then the main erosion factor.

[17] For example : Small-scale experiments on herbicides pollutions showed that "Losses dissolved in runoff from plots with 20% slope were ≤1% of the applied herbicide, whereas on plots with 30% slope the maximum recorded loss was 65%." – From "Herbicide loss in runoff: effects of herbicide properties, slope, and rainfall intensity" by MÜLLER K. and al. AgResearch Limited, New Zeland.

[18] This value of 50 m. might be adjusted according to test phase teaching.

[19] Idem.



Example of configuration (Asprokremos dam) and possible protection limit delineation :

- Upper right : cliffs and important slope – the protection zone limit fits with the edge of the plateau where slope becomes < 20% ;
- Upper center : gentle slope – the 300m limit prevails ;
- Left and bottom : important slope on the tributary banks – the 20% slope limit prevails.

3.2.3.1. Determination of the 300 m. limit

Reservoir : the 300 meters zone is to be defined horizontally [20], as a parallel line to the line defined by the higher level of the dam lake.

River : the 300 meters zone is to be measured horizontally, perpendicular to the banks [21] of the river.

3.2.3.2. Determination of the "20% slope" limit

In order to define the 20% slope limit, the use of a data elevation model (DEM) which is available for Cyprus territory is recommended. This DEM has a grid spacing of 25 meters.

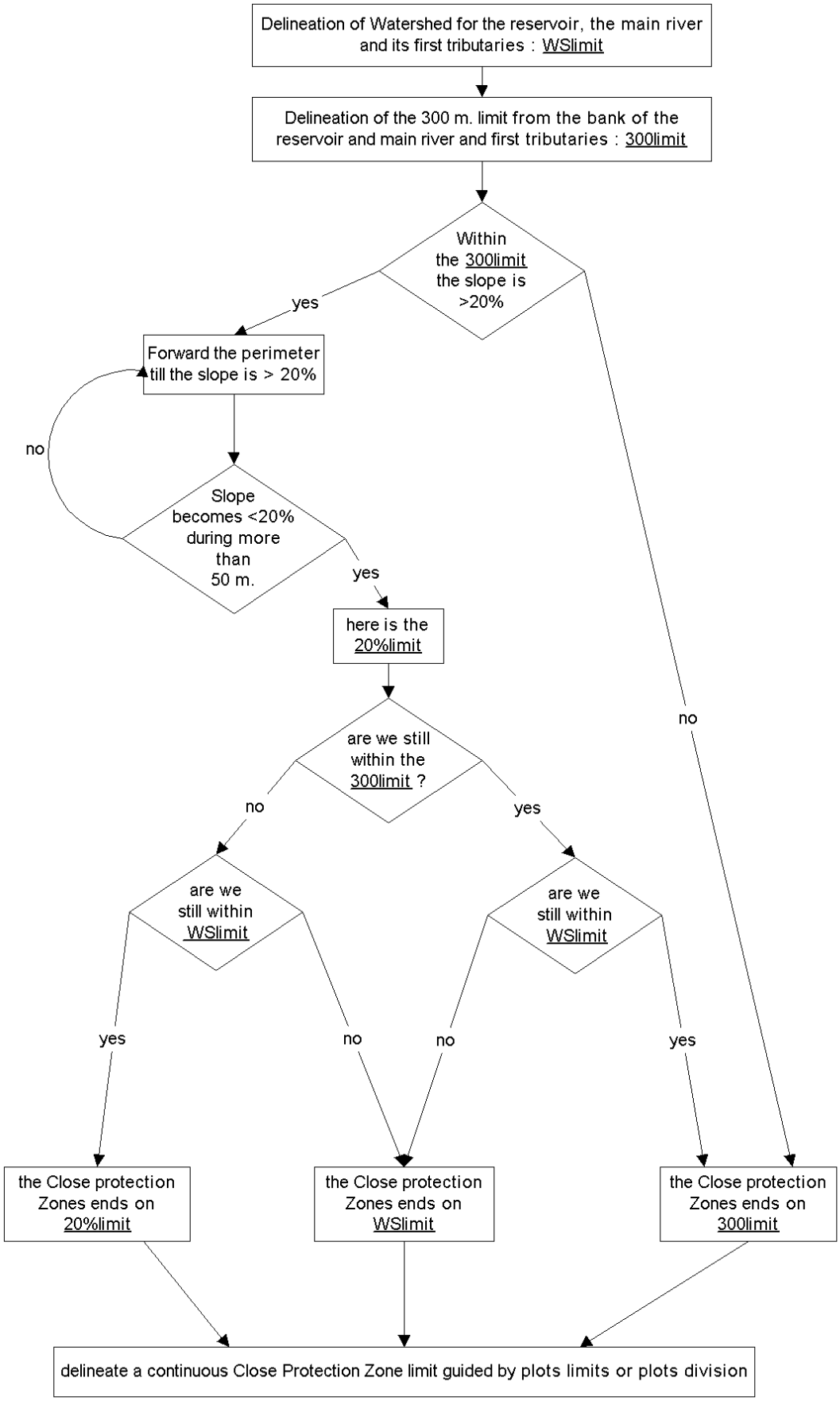
3.2.3.3. Searching for automation

The delineation of the Close protection Zone perimeter will need a lot of cartographic work and the comparison of multiple information.

The use of a Geographical Information System running on the DEM will allows a dramatic efficiency but will not liberate from site control.

The above rules can easily and costless be applied in a GIS.

[20] On an horizontal plan : drawn on a map, not measured on the ground.
[21] Banks delineated by full stream conditions.


Delineation of Watershed for the reservoir, the main river and its first tributaries : WSlimit
Delineation of the 300 m. limit from the bank of the reservoir and main river and first tributaries : 300limit
Within the 300limit the slope is >20%
yes
no
Forward the perimeter till the slope is > 20%
Slope becomes <20% during more than 50 m.
no
yes
here is the 20%limit
are we still within the 300limit ?
no
yes
are we still within WSlimit
are we still within WSlimit
yes
no
no
yes
the Close protection Zones ends on 20%limit
the Close protection Zones ends on WSlimit
the Close protection Zones ends on 300limit
delineate a continuous Close Protection Zone limit guided by plots limits or plots division

3.2.3.4. Application to land registry [22]

The limit of the perimeter will be superposed over the cadastral layer, which is already digitized.

The following examples of rules might be applied after adaptation to local property regulation [23] :

- (a) if a plot of land is covered by the perimeter for more than 80% of its surface, then the plot will be totally considered as being within the perimeter otherwise the plot will be totally considered as being outside the perimeter ;

or

- (b) if a plot of land is covered by the perimeter for less than 80% of its surface, then the plot will be divided in two new plots, one being within the perimeter, the other one outside.

In order to reduce oppositions to the implementation of the perimeter limits, the authority might study the opportunity to adapt these rules to the type of owner : for example, more severe if the plot belongs to public authorities (rule a), less if private owner (rule b).

The division fees will be in charge of the government.

Owners of plots or part of plots designed as being inside the Close Protection Zone will be obliged to respect the restriction of uses and activities attached to the perimeter.

3.2.4. Means of applying

3.2.4.1. Public information

Public information is a major step in reservoir protection. It must be done in the early phases of protection establishing.

As soon as ordinances are established they must be notified to public. The notification must contain :

- clear limits of the protection zones so as everybody will be able to know if he is within or out of the perimeter ;
- clear explanations of what is prohibited ;
- explanation of what to do in case of accidental pollution within the Close protection Zone.

3.2.4.2. Spill response program in case of accidental pollution

Accidental pollution can occur everywhere in the Close protection Zone even if road transport is the most common cause.

People which are responsible or witness of accidental pollution must quickly alert authorities.
Riparian must be informed and encouraged to act this way. It must be explained that the misdeed resides in the fact of “non alert” and not in the “accidental pollution”.

[22] Cadastre

A spill response program must be built to ensure that a communication network associated with spill occurrences is clearly defined, tested and implemented.

The mean of alert must be unique (which is the public authority who must be alerted) and clearly explained to riparian and to local officials.

3.2.4.3. Soil pollutions during dry season

The same spill response program must be in use for any dangerous spilling that might occur during dry season.

Public must be informed that :

- It is in any case a danger for water resource ;
- measures can be taken if necessary before the rainy season (soil removing for example).

3.2.4.4. Vegetation and reforestation

Reforestation advantages are well known. In the case of reservoir protection, some of these advantages are pushed forward :

- the runoff in slowed down ;
- pollutant can be partially blocked by roots and partially or totally neutralized ;
- the stability of the slopes is increased and the erosion is highly reduced. This has a great importance for dams whose capacity is slowly but surely reduced by sediment capture.

Conversely, livestock grazing and drought combine to :

- reduce the vegetation cover ;
- compact the soil,
- increase runoff and erosion.

Topsoil is compacted by livestock trampling causing less rainfall to infiltrate the topsoil leading to greater surface runoff and related erosion.

So the reforestation of the Close Protection Zone - and the reduction of livestock grazing – are reinforcement factors of water protection.

3.2.5. Uses and activities prohibited within the Close Protection Zone

All activity, deposit, installation which are likely to be directly or indirectly the cause of pollutions or pollution vectors must be regulated or forbidden.

3.2.5.1. Forbidden activities within the Close Protection Zone

- Any Potential Contaminating Activity [24], and more precisely :
- New constructions (private houses, farms, industrial building, warehouse, hotels, …) ;
- Extension of existing building more than once and limited to a surface increasing factor of 1.5 [25];
- Boreholes ;
- Sand pit or quarries ;
- Creation and filling of excavation ;
- Garbage dump, even the controlled ones ;
- Spoil heaps ;
- Pipes, tank or storage of liquid or gaseous hydrocarbons, chemical products, domestic or industrial effluents ;
- Transport by road of any chemical, hydrocarbons or dangerous substance ;
- Animal breeding ;
- Livestock grazing (specially goats and sheep) ;
- The use of weed killer, nutrients and pesticides for culture, road maintenance ;
- Spreading or infiltration ;
    - of manure and liquid manure ;
    - domestic or industrial waste waters ;
    - water coming from domestic or industrial water treatment plant ;
    - storm water discharge from impervious areas (urban , industrial, highways, …).

3.2.5.2. Existing usages and activities

- With regard to existing constructions which cannot be connected to public sewage system, they must be equipped with septic tanks or cesspools [26] which have to be monitored by public authority. In karstic areas, only cesspools will be allowed ;
- Concerning existing uncontrolled garbage dump, they should be removed ;
- Private gardening is allowed but weed killer and pesticides should be used as less as possible. In any case the banning of these products is not realistic and will not be applied. Gardeners information and education is more efficient [27].

[24] Activities identified as having the potential to discharge contaminants to surface or groundwaters.

[25] Frequency of building extension (once only, once per decade, …) and surface increasing factor are given as example and are probably to be adjusted according to existing urbanism regulation.

[26] The choice between the two techniques has to be made taking into account local practice :

- When properly set up and used, septic tank is a good private system. The main problem is involuntary (or voluntary) leakages ;
- The main problem with cesspools is that they must periodically be emptied out. This drive some irresponsible users to make a hole (international practice).

All things considered, septic tanks are preferable.

[27] WDD people going regularly on site might have in their car a one sheet information leaflet ready to be distributed at any opportunity. The same leaflet might be distributed in villages by town council.

3.2.5.3. Pre-existing forbidden usages and activities

Forbidden usages and activities which pre-exist within the Close Protection Zone and are listed in the prohibited activities have to be examined in taking account :

- dangerousness ;
- possibility of reducing the risk ;
- possibility to eliminate the activity.

3.2.5.4. Roads in the Close Protection Zone

Transports and specially roads are the major cause of accidental pollutions. Some measures must be taken as a precaution :

- Roads must be equipped with crash barriers ;

- Where there is a possibility that an accidental spill (due to a truck accident for example) runs on the surface of a slope in the direction of the reservoir or the river, ditches shall be dig behind the crash barriers ;

- If there is a possibility or an opportunity to shift dangerous roads outside the Close Protection Zone, it should be done.

These steps will be limited to road sections :

- located within 50 meters from the bank of the reservoir / river ;

- or if the slope is more than 20%.

3.3. The Distant Protection Zone

3.3.1. Goal of the Distant Protection Zone

This zone reinforces the Close Protection Zone.

It has no regulation force but gives to the administration guidelines to bring special attention to the major sources and risks of pollution and drive preventive actions.

3.3.2. Delineation of the Distant Protection Zone

The fact that the whole watershed can be involved under strong flow condition implies that the limits of the Distant Protection Zone are the whole watershed of the reservoir minus the Immediate and Close protection Zones [28].

The delineation will use the existent GIS available data at WFD. If needed, a new delineation will be made from the same DEM that will be used for the Close Protection Zone delineation.

3.3.3. Usages and activities which are to be considered carefully within the Distant Protection Zone

The authority in charge of the protection of the resource shall identify existing and potential new activities within the watershed that generally drive to the following degradations :

- Risk of accidental pollutions of soils and rivers : chemicals and hydrocarbons storage, supply and transport ;
- All wastes used as fertilizer : Livestock wastes (dung, manure), treatment plant and industrial sludge ;
- Intensive agriculture using important quantity of fertilizers and pesticides ;
- Garbage dumps ;
- Acceleration of the flow : Creation of impervious surfaces, deforestation, intensive or semi-intensive sheep and goats pasturage, …

Priority actions will be driven in the direction of theses activities in order to :

- gain full respect of existing regulation ;
- encourage the use of good practices : reasoned agriculture, organic agriculture, …

3.3.4. Roads in the Distant Protection Zone

Attention must be given to transport by road, specially in the vicinity of tributaries.

The reservoir protection ordinances should restrict and/or designate the route of transport for certain kinds of hazardous materials. Recommendations can be made for road design improvements, traffic speed modifications, crash barriers, …

[28] Considering the very short time of concentration on reservoirs watershed, it is the whole watershed that will be considered as the Distant Protection Zone.

4. Reservoir Protection Zones monitoring

As previously expressed, the main weakness of protection zones is their effective appliance. So, the protection zones implementation must be carefully checked by the mean of two main monitoring :

- to insure the respect of the regulation terms of the Reservoir Protection Zones ordinances ;
- to assess the efficiency of the protection : water quality monitoring in the river and in the reservoir.

4.1. Regulation terms monitoring

The control of the respect and good appliance of regulations attached to the Reservoir Protection Zones must be effective and continuous. It has to be carried under the control of WDD district offices, in relation with local authorities.

4.2. Water quality monitoring

Water quality monitoring will concern :

- reservoir water quality as the result of upstream water and soil quality ;
- river water quality as a possible indicator of sub-basins pollutions.

It is considered as a fact that punctual in time river pollutions have no chance to be detected, except finally in the reservoir.

The technical characteristics of water quality monitoring (parameters, frequencies, …) will be those that will be foreseen by the WFD monitoring program :

- for “reservoirs protection zones” and “reservoirs” considered as protected areas for water intended to be uses for human consumption: the monitoring programmes shall be supplemented by the specifications contained in Community legislation under which the protected areas have been established : the Drinking Water Directive (80/778/EEC) amended by Directive (98/83/EC) ;
- for reservoirs and part of river which are classified as Highly Modified or Artificial Water Bodies : because of the human consumption purpose of these waters, the good ecological potential given to these water bodies might not imply a lower monitoring level than the one given to the protected areas for water intended to be used for human consumption.

Therefore, no extra monitoring is requested for Reservoir Protection Zones efficiency assessment. Only few adaptations to the protection context are requested for rivers :

- a part of monitoring stations will be chosen :
  - at the main confluent point of river and tributaries (in order to be able to determine which sub-bassin could be at the origin of a pollution ;
  - downstream of known pollution risk areas.

- monitoring program will be adjusted to the seasonal river flow :
  - one sampling during the first flows in order to detect eventual dry season soil pollutions ;
  - one sampling in high flow conditions in order to detect eventual soils pollutions [29]
  - other sampling in normal or basic flow conditions.

[29] High flows carry fine particles in suspension which are likely to have retain pollutant. This gives better indication than chemical analysis performed on filtered water.

5. Testing and adjusting the Reservoir Protection Zones method

The methods proposed above for reservoir protection (Immediate, Close and Distant protection Zones), must be tested on real case before appliance to all concerned reservoirs.

5.1. A preliminary phase test

A test phase is necessary to assess :

- If the proposed criteria fit to Cyprus environment and water bodies ;
- If adjustments or corrections are necessary to make the methods easier to apply and more efficient ;
- The means that will be necessary when applying to all concerned reservoirs : personnel working charge, set of data, technical resources ;
- The technical and regulation stages that must be introduced.

It is proposed to perform exercise:

- On one reservoir whose watershed gather multiple types of human pressures : cities or villages, agricultural activities, …. We propose to choose between :
    - KOURIS dam which is interesting because it combines the above pressures on a large watershed ;
    - ASPROKREMOS dam has the same kind of interest but its size and strategic importance are lower.

- And optionally on one reservoir whose medium size watershed is subject to low pressures.

The purpose of a possible two-headed test (one on a complex case, one on a simple one) is to be able to distinguish difficulties :

- that are due to the method itself (delineation uncertainty, parasitic data, method weakness under specific conditions, …) ;
- from the ones raising from its appliance to complex environment : scattered pressures, zone on the point of view of

Whatever the number of tested reservoirs, a register of “difficulties / solutions” will be kept during test phases. It will be useful when adjusting the methods and when writing the manual.

5.2. A step by step test

All the steps leading to the complete Reservoir Protection Zones (RPZ) delineation and ordinance will be realized on the test zone(s).

A. Choice of the test reservoir(s)

Data collection

Here starts step 1 of protection zones establishment method (see 2.3.1).

B. Collection of data on pressures (data are described and have GIS coordinates) :
   a. Villages : sewage system, waste water treatment plant, disposal of domestic or industrial sewage effluent, zone with individual sewage
   b. Representative traffic roads, traffic statistics, safety equipment (crash barriers)
   c. … all activities and usage listed in § 3.2.5.1
   d. Known or foreseen future development needs

C. Collection of hydrologic data
   a. Maximum dam water level
   b. Identification of main river and its first tributaries
   c. Delineation of river banks under full stream conditions
   d. Identification of existing or to create water quality monitoring sites

D. GIS data collection
   a. DEM and derived data
      i. Slope map
      ii. Watershed
         1. whole basin watershed (for Distant PZ)
         2. watershed of main river and first tributaries (for Close PZ)
      iii. The 300 m. limit from reservoir and river banks
      iv. Identification of topographic singularities :
         - Isolated hills or mounds
         - Peninsulas
         - Hanging valleys
   b. Administrative limits
   c. Roads
      i. Identification of non safe road sections (see B.b.)
         1. road close to the reservoir or river banks
         2. presence or absence of crash barriers
      ii. High traffic roads [30]
   d. Geology [31]**
   e. Cadastre - At this stage is it necessary to identify public and private plots ?

E. CORINE LAND COVER and derived layers
      i. Agriculture areas
      ii. Built areas
      iii. Forest **
      iv. Nude soil or poor vegetation **

[30] If no traffic counting are available for all concerned roads, roads will be classified into two categories : High traffic and Low traffic.
[31] ** = information which are not yet included in the RPZ method but can be useful while testing.

Outwork phase

F. "GIS delineation" of the Close PZ using the delineation method given above in § 3.2.3.3

G. Superposition of the Close PZ and Cadastre. Identification of problems when transforming the "GIS delineation" into "plot delineation"

Here start step 2 of protection zones establishment method (see 2.3.1).

H. Superposition of pressures to identify :
   a. Pressures within the Close PZ which are listed in the prohibited usages and activities in § 3.2.5.1. Pressures which need action : treatment, deletion (see 3.2.5.3) or create an un-sustainable situation (see 2.3.2)
   b. Pressures within the Distant PZ which are listed in the prohibited usages and activities in § 3.3.3 and need attention.

Site Control

I. Checking if the existing installations protections (dam, buildings, installation for pumping in the reservoir, …) are compatible with the Immediate Protection Zone requirements (see 3.1).

J. Semi exhaustive visit [32] on site to check :
   a. The Close PZ delineation results from a geomorphologic point of view up to plot scale
      i. Efficiency of the 300 M. and 20% limits
      ii. Managing of topographic singularities
         1. To be removed from delineation maps
         2. Which imply handmade corrections
   b. Pressures
      i. Reality of pre-identified pressures
      ii. Eventually ignored or badly known pressures
      iii. Make list of unauthorized activities and usages within the Close Protection Zone (see 3.2.5)
      iv. Evaluation of future development needs
      v. Identification of inescapable existing socio-economic situations
         1. Identification of cases where a minimum protection efficiency level will not be reached (non sustainable situation)
         2. List of possible further studies and actions to solve the problem

Ordinance writing on test zone(s)

K. A full ordinance for the test reservoir(s) must be written. This writing will be very useful to identify the case when the ordinance can rely on existing national regulation or when national regulation should be adapted.

[32] It is proposed that 30 to 50% of the total Close Protection Zone delineation be checked out on site : followed on foot or visually on a distance. The check being roughly divided : 25% for zone without delineation problem, 75% for zones with problems or singularities.

Corrections and adaptations of the RPZ method
L. All previous steps will give matter for adjustments and corrections of the method proposed in the present document.
Instruction manual writing
M. Once method is stabilized and regulation adapted, a RPZ instruction manual must be written as a support for real cases. Its writing can start earlier for what concerns steps B to J.

5.3. Test organization

5.3.1. Phases A to H (data collection and outwork)

These phases might be time consuming because of various profile of staff to involve (engineers, WDD site staff, GIS technician) and because data collection and GIS tools preparation.

So it is preferable that these phases start as soon as possible since many phases can be simultaneously started.

5.3.2. Phases I to L (site control, ordinance writing and RPZ method corrections)

Theses phases depend on the previous ones completion.

They will bring WDD site staff and engineers in charge of the setting of the RPZ method working together on practical and theoretical stage.

Site control and method corrections are important and need full attention.

On practical consideration, because important out in the field presence, phase I and J (Site control) should be planned in spring or at autumn.

5.3.3. RPZ Instruction manual

Version 1 of this manual will be produced at the end of tests. It will be enriched with experience on next reservoir protection work and will be accordingly modified.