Proceedings of the 12th International Conference on Environmental Science and Technology
Rhodes, Greece, 8 – 10 September 2011

SUSTAINABLE MANAGEMENT OF A LARGE-SCALE TOURIST FACILITY WITH SIGNIFICANT WATER DEMAND

K. HADJIBIROS, A. KATSIRI, A. KOUKOUVINOS, N. MOUTAFIS and G. VILANDOU

Department of Water Resources and Environmental Engineering,
Faculty of Civil Engineering, National Technical University of Athens,
Iroon Polytechniou 5, 15780 Zografou, Athens, Greece
e-mail: k.hadjibiros@hydro.ntua.gr

EXTENDED ABSTRACT

Current technologies create prospects for economic activities with an environmental impact that will approach zero. The zero-waste objective for water resources can be promoted mainly through water saving, as well as through complete reuse of treated liquid waste mainly as irrigation water. Sustainable water resources management can also be achieved through rainwater harvesting in towns and tourist facilities, collection of stormwater runoff or construction of small dams for the enrichment (recharge) of aquifers.

This paper is based on a research project that proposes advanced integrated management measures for a large-scale tourist facility with significant water demand; three hotels, tourist complexes and independent houses, as well as three golf courses, will be part of the whole tourist development. Special emphasis is placed on optimal management of water as a natural resource of paramount importance; a possible misguided use would cause a chain of negative reactions to the environment, the economy and the local society, therefore, the main aim is to minimize negative impacts on the groundwater resources of the area. Rainwater harvesting from the roofs of hotels and houses as well as from the roads and the streams running through the complex, is studied. The principle of reducing water use will be adopted and wastewater will be reused mainly for golf courses and garden irrigation, after tertiary treatment. The solid residue from wastewater treatment (sludge), along with the biodegradable part of the solid waste and green wastes (grass cuttings and plant residues) will lead to energy recovery through anaerobic treatment for production of biogas and compost of good quality. Packaging and other specific solid waste materials will be sorted at source and driven to recycling through alternative management systems. Therefore, the need for landfill is limited to a minimum quantity which will probably not exceed 10-15% of the total solid waste. Water consumption minimization, as well as the feasibility of small dams construction, for water storage or groundwater recharge, are also examined. Hydrological, topographic, geological, site investigation and land use data have been collected, in order to optimize water harvesting potential and to select suitable locations for closed storage water tanks. The proposed scheme of water resources management is expected to eliminate the exploitation of groundwater within the tourist complex, at least during most of the normal hydrological years. Realization of this task will greatly facilitate social acceptance of the tourist facility, because it is expected to minimize local protests related to the agricultural activities and irrigation needs of the area.

Key words: water management, rainwater harvesting, groundwater recharge, wastewater reuse, golf courses irrigation, biogas, compost, recycling.

1. INTRODUCTION

Current technologies create prospects for economic activities with an environmental impact that could approach zero (Hadjibiros and Laspidou 2009). The zero-waste objective for water resources can be promoted through water saving as well as through reuse of treated liquid waste mainly as irrigation water. Sustainable water resources management can also be achieved through desalination of sea or brackish water in order to minimize the use of groundwater reserves. Alternatively, when there is no sea or brackish water available in the area, rainwater harvesting in towns and tourist facilities, collection of stormwater runoff or construction of small dams for aquifer recharge, are activities that can serve the same objective. The aim of this paper is an integrated approach, so as to minimize the water consumption of a tourist facility and reduce its overall environmental footprint. It is worth noting that this tourist investment is addressed to tourists with high income level, for whom the integrated environmental management is an obvious prerequisite. This management model could serve as a promotion on the global tourist market.

The study area is around 12500 acres; it is located west of the village Exarchos, municipality of Atalanti, Greece. According to the Masterplan (WATG 2006), three hotels, tourist complexes and independent houses, as well as three golf courses will be part of the whole tourist development. Particular emphasis is placed on optimal management of water as a natural resource of paramount importance; a possible misguided use would cause a chain of negative reactions to the environment, the economy and the society of the region. The sustainable use of water is therefore a priority, but also is related to the proper management of other environmental systems. The solutions chosen for the water should least affect other parts of the total environment; generally, any burden on the natural resources should tend to zero. Key factor to the success of this approach is to utilize advanced technologies without entailing excessive costs. Technologies for recycling or multiple reuse of water, as well as for sustainable waste management and energy recovery are necessary.

2. METHODOLOGY AND RESULTS

The adapted methodology includes the following components: 1) surface water resources were favored in order to minimize pumping from borehole; an estimation of the mean monthly discharges that can be collected from the streams, the paved and the structured areas was made 2) to achieve best water resources management, the minimum water supply and irrigation demand were calculated and the volumes of water that have to be stored according to management scenarios were estimated 3) reuse of treated wastewater for irrigation and the possible use of grey water were examined 4) regarding solid waste management, sorting at source together with recycling of several materials, energy recovery and production of compost through the anaerobic treatment of biodegradable organics were examined.

2.1. Estimation of water resources and water demand

A hydrological study for the area was performed in order to estimate the mean monthly runoff from watersheds, paved areas and roads. The hydrogeological study (Nikolaou 2007) had estimated that renewable groundwater resources reaching 14.8 hm^3 for the hydrogeological unit within the greater study area are available. Due to lack of flow measurements in the greater area, the mean monthly surface runoff was estimated using the rainfall-runoff model “HYDROGEIOS” (Efstratiadis et al. 2008). The meteorological data that were used as input for the model (rainfall, temperature, sunshine duration, relative humidity, wind velocity) were selected from nearby stations and cover the period 1962–2008, for which a monthly simulation of hydrological procedures in the study area was performed. Geomorphologic data as derived from a digital elevation model (land area, mean elevation, mean slope) and hydrological response units for each one of the five basins in the area were also used. The output of the model was the monthly estimated discharges for each basin. In order to estimate harvested rain water volume from roofs and other impervious surfaces, the mean monthly rainfall in the area and the coverage of built up areas, as derived from the master plan (WATG 2006) for all three construction phases (2014, 2018, 2039), were considered. The mean monthly volume from the impervious areas was then estimated (using a runoff coefficient equal to 0.90). Regarding the road network, the mean monthly rainfall and the estimated area that the main and the secondary road network will cover during each construction phase, were also considered. Therefore, the mean monthly volume from the road network was estimated (using a runoff coefficient equal to 0.90).

Water supply demand was estimated based on the hotel and residential development plan and the expected occupancy per month (WATG 2006). According to the development plan, by the year 2014 one hotel and 400 residences will have been built, by 2018 three hotels and 1200 residences and by the year 2039 a total of three hotels and 5493 residences will be in operation. Assuming that every residence will accommodate on average three persons, it can be assumed that 2175, 5795 and 18674 will be the maximum number of persons accommodated by the years 2014, 2018 and 2039 respectively. Given the occupancy and assuming an average water consumption of 450 litters per person staying in the hotels and 200 litters per person staying in all other units, a mean monthly water supply demand was estimated. For this assumption, willingness of the residents to cooperate for the prevention of water wasting in the tourist facilities was taken for granted.

Minimization of irrigation demand at golf courses and gardens is feasible, so that they will not exceed the amount of 450,000 m^3 per year, mainly through exclusive use of subsurface irrigation and additionally through use of less water demanding varieties for golf courses (Ntzourvas 2007) and other measures of irrigation water saving. The three golf courses will cover an area of 2,160 acres and all other irrigated land areas (hotel gardens, botanical garden, fruit trees, vineyards etc.) will cover an area of 1,250 acres.

2.2. Water collection and storage

Field mapping and site investigations revealed high permeability and karstification of the geological formations and reversed the initial assumptions, rendering feasible water storage in reservoirs. Due to the high permeability of the rockmass, the surface runoff is practically limited to flood events. The water from these events can be collected and stored in large capacity water tanks. Water intakes need to be designed at paved areas, at structured but not paved areas and in natural streams. Each one of these water intakes has different requirements in terms of operation and design methodology.

Primary tanks can store water collected from roofs and could be constructed underneath or close to the buildings. Their capacity will, in general, be small. The main volume of water will be stored in central storage tanks. Water abstraction from the streams necessitates the construction of small barriers with appropriate water intakes. Sediment retention should take place at the water intakes, so as to prevent its transport to the storage tanks. Water transport from the water intakes to the storage tanks will be performed by gravity in closed pipes. It is anticipated that a percentage of the floods will overflow the water intakes and flow along the natural galleys. In order to exploit this relatively small volume of water, small technical works should be constructed at proper locations, to retain the flow and direct it underground. It is anticipated that the storage tanks should be fully covered, to reduce water loss due to evaporation, protect the water from exposure to sunlight and allow for a better setting of the structures in the surrounding area.

The amount of rainwater that can be conducted to storage tanks, the water supply demand and the water irrigation demand are presented in Tables 1, 2 and 3.

Table 1: Mean monthly volume (10^3 m^3) that can be collected to storage tanks.

	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Sum
Surface Runoff	2014	77	61	51	17	1	0	0	0	1	13	33	71	325
	2018	74	59	49	17	1	0	0	0	1	13	32	69	316
	2039	65	52	43	15	1	0	0	0	0	12	28	60	277
Impervious areas	2014	7	5	5	3	2	1	1	1	1	5	6	7	43
	2018	18	12	14	7	5	2	2	2	4	12	16	18	113
	2039	47	32	36	19	13	6	6	6	10	33	42	48	298
Roads	2014	7	5	5	3	2	1	1	1	1	5	6	7	55
	2018	7	5	5	3	2	1	1	1	1	5	6	7	55
	2039	17	12	13	7	5	2	2	2	4	12	16	18	145
Total	2014	92	72	62	24	6	2	2	2	4	24	46	87	423
	2018	101	78	69	28	9	3	3	4	6	32	55	96	484
	2039	135	100	96	43	21	9	8	9	16	60	90	132	720

Table 2: Mean monthly water supply demand (10^3 m^3)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Sum
2014	7	6	9	9	12	12	18	18	13	11	9	6	130
2018	15	13	21	21	29	30	45	45	31	28	19	15	309
2039	23	19	35	35	46	58	93	93	54	51	27	23	556

Table 3: Mean monthly irrigation demand (103 m3*)*

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Sum
2014	0	0	4	9	9	64	64	64	43	30	13	0	300
2018	0	0	6	12	12	88	88	88	59	41	18	0	413
2039	0	0	6	13	13	96	96	96	64	45	19	0	450

2.3. Integrated water, wastewater and solid waste management

Resources conservation and water use optimization were primary goals in this development. To achieve these goals four action lines were explored: 1) maximize rain water harvesting, either locally or centrally 2) minimize domestic water use by separating and recycling grey water 3) recycle and reuse of wastewater for irrigation of golf courses and gardens 4) produce energy from organic waste, food residues, grass cuttings and wastewater treatment sludge.

According to the first line of action, central rain water collection as opposed to separate collection in every household or establishment is proposed. Table 4 presents typical characteristics of rainwater (Villarreal and Dixon 2005).

Table 4: Typical characteristics of rainwater collected from roofs or stored in water tanks

	pH	BOD_5 (mg/l)	COD (mg/l)	TOC (mg/l)	Turbidity (NTU)	Total solids, TS (mg/l)	Suspended SS (mg/l)
Roof harvesting	5.2-7.9	7-24	44-120	6.13	10-56	60-379	3-281
Rainwater tanks	6-8.2	3	6-151	-	1-23	33-421	0-19

Rainwater from water intakes, paved areas and structured but not paved areas, will be collected and directed to tanks. Water from paved areas can be stored in underground storage tanks (primary storage), located next to complexes, spatially distributed according to the density and the surface areas of the buildings. Water excess that cannot be stored in the tanks will be conducted to the central storage tanks. The required amount for water supply will be conducted to refineries in order to render it potable and then shall be distributed for domestic use, while the remaining amount will be used for irrigation. Used water or wastewater will be collected, and after suitable treatment (see below) will be stored in irrigation tanks. The recommended management scenario suggests a maximum total required capacity for water supply storage tanks of 281,000 m^3. A volume of about 50,000 m^3 can be stored in primary storage tanks while the rest into two (or more) central tanks at two sites. Similarly, for irrigation the maximum total required capacity of water tanks is about 225,000 m^3. Until the year 2018, when three hotels, three golf courses but only 1200 residences will have been constructed, the water demand for irrigation will be at a maximum. By the time that all residences will have been constructed and the runoff from the paved areas will be at a maximum, the collection of the total amount from the streams will be probably unnecessary.

Stored water will have to be treated by coagulation, sedimentation, filtration and disinfection to become suitable for potable uses. With this treatment suspended matter and any traces of metals and oils will be removed. Any surplus water will be used to supplement irrigation water demand, which is larger than demand for potable water. The water that will be collected from the road network is expected to contain more sediments, but due to the low traffic the concentration of pollutants is expected to be equally low.

The second line of action would involve separate use of “grey water” which is wastewater from sinks, bathtubs, showers, dishwashers and washing machines. Wastewater from toilets is known as “black water”. In a typical household, grey water represents 70-80% of wastewater volume and about 50-60% of its BOD_5 load (Widiastuti et al., 2008). If grey water is collected separately, then it can be recycled back to supply water for toilet flushing. This use does not require any re-treatment and can easily result in a reduction of potable water demand by up to 30%. However, this solution is not recommended, as irrigation demand is higher than water supply demand and given that used water is recycled for irrigation, no reduction of water supply consumption would eventually be achieved. A second disadvantage of this practice is that double water supply and wastewater collection networks must be installed in every house or hotel, thus raising construction costs (Friedler et al 2008).

The integrated water management proposed is shown schematically in Figure 1

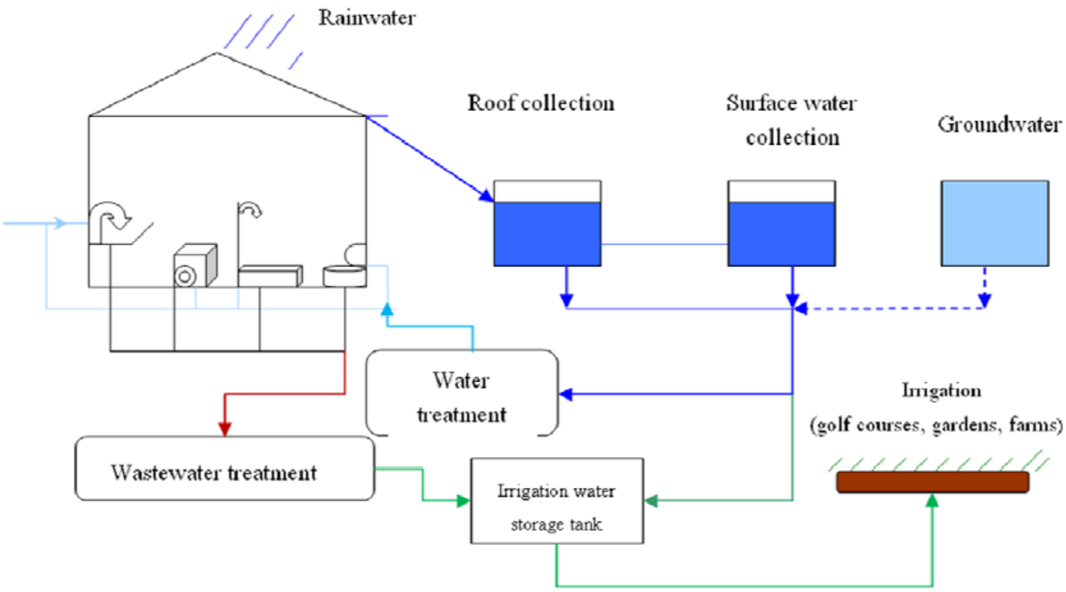

Figure 1: Proposed scenario for integrated water management

The third line of action involves reuse of treated wastewater to satisfy water demand for irrigation of golf courses, gardens and other green areas. Irrigation of golf courses and other recreational areas with direct public access is specifically regulated by a recent decision from the Ministry of Environment and Climate Change. The effluent standards with which treated wastewater must comply are quite strict: 1) total coliforms (TC/100 ml): ≤ 2 for the 80% of samples and ≤ 20 for the 95% of samples 2) BOD_5: ≤ 10 mg/L for the 80% of samples 3) suspended solids: ≤ 2 mg/L for the 80% of samples 4) turbidity ≤ 2 NTU, median value. The required treatment to achieve these standards is biological treatment followed by advanced tertiary treatment by membrane filtration and disinfection by chlorination, ozonation or UV irradiation. The construction of a central treatment unit is recommended, the outflow of which will be collected in the irrigation tank. The unit will have the capacity to receive the highest wastewater discharges that are observed during July and August. It should be noted that the wastewater discharge reaches 80% of water consumption.

The fourth line of action involves sorting of solid waste at source and valorization of all biological waste produced in the development (biodegradable solid waste, agricultural residues, loan and tree cuttings and sludge from wastewater treatment facilities) for energy recovery and compost production. The method for energy conversion proposed is mesophilic anaerobic digestion (Sosnowski et al 2003); it is a well established technology that produces methane gas that can be easily burnt in cogeneration plants (combined heat and energy-CHP) to produce heat and electricity. The anaerobic digestion unit can be installed next to the wastewater treatment plant, restricting by that way the environmental impacts to only one site. Preliminary estimations showed that the readily available biomass for energy production will be 5,6 t/d (2,7 t/d from domestic refuse, 2,3 t/d from green residues and 0.60 t/d (dry matter) from sewage sludge). Conversion by anaerobic digestion yields up to 382 750 m^3/year biogas with an energy content of 2 487 875 kWh/year. After subtracting heat requirements to heat the digester, the produced heat can cover up to 45.3% of the energy requirements for hot water of the entire development. The digeastate is a high quality compost that can be used in the gardens and green areas of the facility. In this way landfilling is avoided and a significant amount of energy is saved. Packaging waste will be separated from domestic refuse and then disposed to the alternative management system of the “blue” bins. The separated materials will be conducted to Recycling Sorting Plants for further sorting and recycling. A separate system of recyclable paper collection bins is recommended. Other recyclable solids (batteries, light bulbs, electrical appliances etc.) will be conducted to the corresponding alternative management systems. Special management should be considered for the rest of solid waste (furniture, mattresses, textiles, leather etc.), as well as for excavation waste and all other construction waste, in accordance with the national and international legislation.

3. CONCLUSIONS AND DISCUSSION

Consideration of the water footprint of the tourist facility is an important issue both for environmental conditions of the region and for local agricultural activities; it requires mainly the assessment of the impact on the underground water potential in the region. The basic conclusion is that high standards tourism can be developed in this area by use of water from local precipitation and that only in exceptionally dry years there will be need for extraction of small quantities of groundwater to supplement the quantities required for drinking water and irrigation. Wastewater will not be disposed to the local recipients but will be completely reused. All quantities of water used by the facility will return to the local aquifer except for water lost by evapotranspiration. Thus the impact on the water resources of the region is limited to the decrease of storm water runoff. These results could be achieved with reasonable cost, by using appropriate technology, carefully designing the facility and avoiding wastage of water.

The overall negative impact of the tourist activity on the underground water potential of the region is expected to be very small. In any case, during prolonged drought periods -and thus use of drillings- only a small percentage of the annual water requirement (556,000 m^3) of the tourist facility will be satisfied with groundwater extraction. Therefore renewable groundwater resources (and thus water uses in the area) will practically not be affected. More specifically, according to the hydrogeological study, current water consumption in the region is 2,790 hm^3 per year; it mainly includes the need for irrigation of cultivated land (2,723 hm^3) which is a small percentage of annual renewable and exploitable groundwater resources of the region (14,8 hm^3). On the other hand, annual water needs (67,525 m^3) of the settlement of Exarchos constitute the use of priority, but they are minimal compared to available resources and will in no way be affected. Moreover, certain quantities of surface runoff will be infiltrated underground through small retention dams. Indeed, the overall impact on the underground water potential may ultimately be even positive despite the possible extraction during dry hydrological years, because the infiltration of surface water to groundwater will increase.

Solid residue from wastewater treatment, along with the biodegradable part of the waste and green waste will lead to energy recovery through production of biogas and compost of good quality. Packaging and other specific solid waste materials will be driven to recycling through alternative management systems. Therefore, the need for landfill is limited to a minimum quantity which will probably not exceed 10-15% of total solid waste; further gradual decline to lower levels can be expected, if the efficiency of sorting at source and of recovery technologies is improved.

It should be noted that the assessments of the research team should hold as far as the order of magnitude of the variables is concerned, but they are not an accurate estimate. The exact design, the dimensioning of the constructions and the avoiding of failures should be based on detailed final studies which are expected to broadly confirm the above conclusions.

REFERENCES

CRES (2010), *Biogas manual*, (in greek).

Efstratiadis, A., Nalbantis I., Koukouvinos A., Rozos E., and Koutsoyiannis D. (2008), HYDROGEIOS: A semi-distributed GIS-based hydrological model for modified river basins, *Hydrology and Earth System Sciences*, 12, 989–1006.

Friedler E. (2008), Chlorination and coagulation as pre-treatment for greywater desalination, *Desalination*, 222, 38-49.

Hadjibiros, K. and Laspidou C. (2009), Zero environmental impact objective as a tool for environmental policy: The case study of an airport built on a wetland, *Proc. 11th Int. Conf. on Environmental Science and Technology*, University of the Aegean, Rhodes, pp.411-418.

Nikolaou L. (2007), *Final hydrologeological design of a tourist facility area, Atalanti hills*, Athens (in greek).

Ntzourvas, P. (2007), *Selecting grass for the construction of golf courses in the Prefecture of Fthiotida and the annual water irrigation needs,* Athens (in greek).

Research Group. (2011) *Investigation of the minimization of environmental impact of tourism development, especially through the best water resources management*. Report of a research program, NTUA, Athens, (in greek).

Scape (2007), *EOS Project, Sustainable design document*.

Sosnowski P., Wieczor A., and Ledakowicz S. (2003), Anaerobic co-digestion of sewage sludge and organic fraction of municipal solid wastes, *Advances in Environmental Research* 7, pp. 609–616,

Villarreal, E.L. and Dixon, A. (2005), Analysis of a rainwater collection system for domestic water supply in Ringdansen, Norrköping, Sweden*. Building and Environment*, 40(9), 1174-1184.

WATG (2006), *EOS Master Plan*.

Widiastuti N., Wu H., Ang M. and Dong-ke Zhang (2008), The potential application of natural zeolite for greywater treatment, *Desalination*, 218, 271–28.