PROTECTING THE AQUATIC ENVIRONMENT FROM THE EFFECTS OF GOLF COURSES

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INTRODUCTION

Do golf courses damage the aquatic environment?

Unfortunately, yes.

Is it possible to construct and operate a golf course without damaging streams, lakes, tidal waters, and other aquatic systems?

Probably.

The answer to the first question is drawn from a study conducted by Community and Environmental Defense Services (Klein, 1989). We examined the impact of 11 golf courses upon aquatic systems. After carefully analyzing the results of the study, we detected a general relationship between the quality of a waterway and the percentage of the drainage area which is in use as a golf course. As the percentage increases, the quality of the waterway declines. When a golf course accounts for more than 50% of the drainage area, then the receiving waters usually exhibit a moderate to severe level of degradation. Such a waterway will be unfit for most human uses.

In comparison to other land uses, our study revealed that the impact of the typical golf course is about twice that of a farm and more like the degradation associated with residential development. For example, the stream draining the Bon Air Golf Course, in southern Pennsylvania, was severely degraded by the time it left the course. But after traveling for a half-mile through extensive cornfields the stream exhibited only a slight degree of degradation.

The results of our study were related to another investigation, which was described in a paper entitled "Urbanization and Stream Quality Impairment" (Klein, 1979). The urbanization study compared the health of fish and aquatic insect communities with various intensities of development. A comparison with the results of the urbanization study shows that the effect of a golf course is similar to a watershed developed in half-acre lots, which equates to 25% of the land surface rendered impervious by asphalt, concrete, and buildings.

The potential causes of the degradation revealed by our study include:

- stream channelization,
- destruction of wetlands,
- lack of a wooded buffer along waterways,
- elevated water temperature due to;
  - a lack of shading vegetation,
  - reduction of groundwater inflow,
  - release of heated water from the surface of ponds, and
  - the entry of heated stormwater runoff from impervious surfaces,
- reduction of base flow due to ground or surface water withdrawals,
- release of toxic substances and oxygen deficient water from ponds,
- intermittent pollution incidents such as spills of pesticides, fertilizers, or fuel,
- loss of pesticides or fertilizers by way of ground or surface water runoff,

- entry of stormwater pollutants washed from parking lots and the other impervious surfaces,
- accelerated channel erosion due to increased stormwater runoff velocity or prolonging the amount of time channels are exposed to erosive velocities,
- elimination of the scouring benefits of flooding by altering the frequency and/or magnitude of flooding,
- poor erosion and sediment control during the construction phase, and
- inadequate treatment of sewage and other wastewaters generated on the golf course.

After compiling a list of the potential causes of degradation, we conducted an extensive search of the scientific literature. The purpose of this search was to assemble what was known about golf courses in general and each potential cause of degradation in particular. We spoke to experts throughout the nation to develop a better understanding of the relationships between a golf course and the aquatic environment. Finally, we analyzed the results of all this research and concluded that yes, it is possible to construct and operate a golf course without damaging the aquatic environment but, as a practical matter, the typical golf course is more prone to be an environmental detriment rather then an asset. But, if the design and management recommendations presented in this publication are closely adhered to, then the likelihood for environmental degradation will be reduced dramatically.

As you may have gathered, the theme of this publication is not "how to design a golf course to maximize the quality of the game", but "how to minimize the impact upon the aquatic environment." It is not that we feel a clean stream is fundamentally more important than a challenging course; in fact it would be foolish to engage in such an argument. No, our purpose in emphasizing environmental protection is to drive home the urgent need to revamp the fundamental approach to golf course siting, layout, construction, and operation. Again, our study revealed that the typical golf course has a substantial negative effect upon the quality of aquatic resources. If this sad state of affairs is to be reversed, then environmental protection must become a primary factor in all aspects of golf course design and management. And the best place to begin is the site selection process.

SCREENING POTENTIAL SITES FOR A GOLF COURSE

When screening a number of tracts as a possible location for a golf course, we suggest giving priority to sites with the following general characteristics.

1. Soils with a medium-texture, high organic matter content, high cation exchange capacity, low erosion and runoff potential, and at least 4-feet of depth to the water table or bedrock.

2. The layout of the course will permit a wooded buffer of at least 100-feet in width along all streams, wetlands, lakes, ponds, or other waterways.

3. Waterway crossings will not be needed, or the site selected would necessitate the fewest number of crossings.

4. Extremely sensitive species of aquatic life, such as trout, shellfish, striped bass, or rare, threatened, or endangered species, are not located downstream or in the area affected by the site.

5. Ponds, if needed at all, can be constructed in upland areas.

6. Sufficient water is available to meet irrigation needs without causing a decrease of more than 5% in the low-flow (7-day, 10-year) of any waterway in the vicinity of the site, nor measurably affecting the yield of existing wells in the area.

7. Parking lots, buildings, and other impervious surfaces can be sited on soils which are suitable for the infiltration of stormwater.

8. Little grading or filling would be needed to construct the course, particularly on slopes steeper than 15%.

9. The number of trees removed during site development would be minimal.

10. During our literature review we encountered a number of references to poisonings of waterfowl, raptors, and other birds due to pesticides applied to turfgrass. Therefore we suggest avoiding sites where waterfowl, raptors, or other birds congregate.

GOLF COURSE LAYOUT & DESIGN

If the protection of aquatic resources were the sole consideration in selecting a site for a golf course, then the criteria listed above would render the choice an easy one. Of course, many other considerations must enter into the site selection process. As these considerations shift the selection in favor of sites which deviate from the criteria listed above, then the potential impact increases. Fortunately mitigation measures are available for reducing some of the impacts associated with golf courses.

Before getting into the mitigation measures, we would like to present a different approach to golf course layout and design. Traditionally, the golf course architect looks at a piece of raw land and lays out each fairway, green, tee, rough, and so forth in a way which will maximize the value of the course to the golfer. Once the site layout is "locked-in" the architect looks for ways of mitigating the resulting impacts upon the environment. In some cases mitigation is successful, but in others, as evidenced by the widespread degradation found in our study, the measures only partially offset the impact upon aquatic resources.

We encourage the architect first to identify all of the sensitive environmental features and avoid sites where a reliable means of mitigating impacts may not be available. Once these features are identified, the course should then be built around the sensitive areas. For example, the architect should identify all steep slopes, highly erodible soils, coarse-textured or shallow soils, and sensitive aquatic resource areas (streams, wetlands, etc.) then layout the course so intrusion upon these features is kept to an absolute minimum. By taking this approach, the dependence upon mitigation measures (particularly those with variable effectiveness) will be reduced. In otherwords, the most likely causes of environmental degradation will be "designed-out" of the course from the beginning.

The following recommendations will aid the architect in avoiding sensitive features and creating impacts which cannot be readily mitigated.

1. An underdrain system should be installed beneath any portion of the fairways, greens, or tees which are sited on coarse-textured soils or where the depth to bedrock or the maximum elevation of the water-table is less than 4-feet. The purpose of the underdrain is to collect fertilizer and pesticide contaminated leachate. The leachate should be treated by applying it to medium-textured soils lying 4-feet or more above bedrock and the water table. Or the leachate may be treated with a system such as a sand-peat filter (Galli, 1989). Either approach will generally lower the concentration of fertilizers and pesticides to an acceptable level.

2. If a waterway crossing must be used, then it should be designed to minimize the removal of trees and other shading vegetation. Cart paths should be constructed of permeable material, no wider than 8-feet, and placed on pilings from edge of floodplain to edge of floodplain. All streams should be bridged, not placed in a culvert.

3. If a site is selected which may affect sensitive species, then a detailed analysis must be made of each impact associated with the golf course to determine if the degree of impact will exceed the species' level of tolerance. Procedures for conducting such an analysis are described later in this publication.

4. A pond should not be located on an intermittent or perennial stream. Upland ponds must not expose stream channels to an increase in either the rate or duration of floodwater velocity. Uplands pond must not reduce flood-scour to a degree that silt and other fine material will accumulate within downstream channels. Ponds should be designed to minimize use by waterfowl, particularly geese.

5. If irrigation withdrawals will reduce the low-flow (7-day, 10-year) by more than 5%, then the Instream Flow Incremental Methodology (Milhous et al. 1984) must be used to determine if the reduction will significantly impact aquatic communities. Options to consider if the impact is deemed significant may include; installing runoff collection

ponds in upland areas, extending an appropriation well to a deeper aquifer, or using several wells located in different groundwater drainage areas to lessen the impact on any single waterway.

6. If impervious surfaces cannot be sited on soils suitable for infiltration, then a wet-pond/sand-filter (Galli, 1989) combination should be used to control stormwater pollutant loadings.

7. If grading or filling must occur on slopes steeper than 15%, then clearance should be timed to occur during that portion of the year when the potential for erosion is lowest (generally late summer and early fall). Work on the steep slopes should be staged so denuded soils can be stabilized within a maximum of 14-days following initial exposure.

8. Another tree should be planted for each tree removed during site development. Replacement trees should be planted within the same watershed where the loss occurs. The survival rate for each tree species should be taken into consideration. If the survival rate averages 25%, then four trees should be planted for each specimen felled.

9. Monitoring should begin one-year prior to the construction of a golf course and continue throughout the life of the course. Ground and surface water should be analyzed quarterly for ammonia, nitrate, and pesticides. Biomonitoring may be substituted for full pesticide analysis beginning in the third year. Initially biological sampling should be performed quarterly, then, beginning in the third year, once annually, in August. Fish tissues should be examined once a year for pesticides used on the course which have a potential to bioaccumulate. A groundwater monitoring program should also be established to detect effects upon existing wells, wetlands, or drawing contaminants in from surface waters. Baseflow and water temperature should be monitored in any streams or rivers in the vicinity of the course.

REDUCING THE IMPACT OF AN EXISTING GOLF COURSE

1. A combination of physical, chemical, and biological monitoring techniques should be employed to assess the current extent of impact and to pin-point probable causes.

2. The maintenance personnel responsible for identifying and controlling pests should become expert in the use of Integrated Pest Management (IPM), but IPM alone will not eliminate the potential for contamination of ground and surface waters with pesticides.

3. If any portion of a fairway, green, or tee is located on coarse-textured soils or the depth to bedrock or the water table is less than 4-feet, then:

a. the area should either be converted to a low-maintenance use (rough),

b. replanted with a grass variety requiring minimal fertilizers, pesticides, and irrigation, or

c. filled with material which will increase the clay and organic matter content, reduce soil permeability, and increase the depth to groundwater, or

d. fitted with an underdrain system to collect leachate so it can be treated through application to suitable soils or with a sand-peat filter.

4. Fertilizers with a low leaching potential should be applied at the lowest acceptable rate and during periods when grass is actively growing.

5. Irrigation should be performed on an "as-needed" basis, rather then on a set schedule. If irrigation water is drawn from wells of a stream/river, then an analysis of the impact upon low-flows and aquatic organisms should be conducted. An analysis should also be conducted of the effects upon well-yields in the area. If either analysis indicates a problems, then the following options should be considered.

a. constructing a pond(s) to capture stormwater runoff, (If this option is used then the ponds must be designed and sited to avoid either a significant increase or decrease in floodflows.) AND/OR

b. relocating wells to several groundwater drainage basins to reduce the impact upon individual streams or rivers and to lower the impact on other wellwater users, AND/OR

c. relocating a surface water intake to utilize a stream, river, or lake which can meet irrigation needs without an accompanying impact upon aquatic communities, AND/OR

d. reduce or terminate water withdraws during critical periods, AND/OR

e. replant the course with grass varieties having a higher drought-tolerance.

6. The first inch of stormwater runoff from all impervious surfaces should be delivered to an infiltration device (see Schueler, 1987 for details) or a wet-pond/sand-filter combination (Galli, 1989).

7. A 100-foot wooded buffer should be established along all wetlands, streams, rivers, tidal waters, ponds, or lakes on the course.

8. The use of chemical measures for managing ponds and lakes should be reduced or eliminated. Rather than using toxic substances to control algae, techniques with fewer longterm impacts should be used, such as reducing nutrient inputs, dredging, and so forth (see Dunst et al., 1974).

9. Wherever possible, the number of trees and shrubs on the course should be increased.

10. Pesticides, fertilizers, fuels, and other toxic substances should be stored in a location where a spill will not result in rapid, uncontrollable entry into ground or surface waters.

11. If the golf course existed prior to 1980, then soils on greens, tees, and fairways should be analyzed for organochlorine and metallic pesticide residues. If residues are present, then measures should be taken to minimize movement to ground or surface waters, such as increasing the organic matter content of soil.

The basis for all of the recommendations presented above is described at length in the remainder of this publication. The recommendations are discussed according to the various categories of impacts associated with golf courses.

FACTORS ASSOCIATED WITH A GOLF COURSE WHICH MAY AFFECT THE QUALITY OF AQUATIC RESOURCES

Channelization

Through channelization a waterway is straightened and the banks are shaped to a uniform slope. Channelization may be performed for flood-control purposes, lowering the elevation of the water-table, or increasing the amount of land available for fairways, greens, tees, and other features associated with a golf course.

The earth-work involved in channelization causes severe damage to aquatic ecosystems (Duvel et al, 1976; Speir et al., 1976; Tarplee et al., 1971; Whitaker et al., 1971). Aquatic organisms and their habitat is destroyed. Reductions in the number and total biomass of fish is usually on the order of 90% and recovery may take up to 40-years (Bayless and Smith, 1964). Channelization, in the form of agricultural drainage projects, had accounted for 53% of the wetlands lost in Maryland as of 1970 (Metzger, 1973).

Seven of the eleven streams included in our golf course study had been channelized, but the degree of impact was not consistent. The streams flowing through Bon Air Golf Course in York County, Pennsylvania and the Hillendale Country Club, in Baltimore County, Maryland had been channelized and were nearly identical. But the aquatic insect community of the Bon Air stream exhibited only slight degradation, while that of the Hillendale tributary was severely impacted. Although the reason for the difference is unclear, the trend is certainly disturbing. Six of the seven channelized streams were moderately to severely degraded.

Recommendation: Waterways located on the site of a proposed golf course should be left in a natural, unaltered condition. Channelization should not be performed. Other in-stream construction work must be kept to an absolute minimum. Golf cart crossings, foot bridges, or access roads should cross waterways only where absolutely necessary and channel modifications should be avoided.

Buffers

A buffer consists of a strip of natural vegetation abutting waterways or wetlands. Following are the primary benefits associated with a buffer.

1. Buffers provide a barrier between grading, filling, or construction activities, which ensures that the waterway or wetland is not physically altered by heavy equipment.

2. A buffer composed of tall shrubs or trees will protect a waterway from heating due to sunlight.

3. A continuous strip of vegetation adjoining a waterway provides valuable habitat for birds, mammals, and other wildlife species.

4. Buffers have been cited as effective tools in reducing the quantity of pollutants delivered to waterways from upland areas.

5. Leaves, twigs, and other plant parts serve as an extremely important food source for most aquatic ecosystems. Tree trunks and large branches provide vital habitat for fish and other creatures. Streamside forests are the primary contributor of these food and habitat components.

6. Dense, woody vegetation growing upon channel banks and the floodplain retards floodwater velocities, which slows erosion and lessens flood-related damage.

A buffer of natural vegetation extending 50 to 75 feet from each banktop or the outer perimeter of wetlands will usually be sufficient to protect aquatic resources from the physical disturbances wrought by heavy equipment operation (Phillips, 1989). Generally a wooded buffer will continue to intercept solar radiation up to 70-feet from a banktop (SOS, 1980).

A number of studies have found that buffers are effective in reducing the amount of pollution delivered to a waterway (Phillips, 1989; Doyle et al., 1977; Dillaha; Magette et al., 1987; Palfrey and Bradley, 1981; York and Davis, 1972; Schueler, 1987). These studies have found that buffers ranging from 15 to 300 feet in width have reduced pollutant loads by up to 90%.

While it is true that buffers remove significant quantities of pollution from runoff, a buffer should never serve as the only pollution control measure. The effectiveness of buffers declines over time (Magette et al., 1987). Additionally, buffers are most effective when runoff is in sheet flow. Buffers are less effective in controlling the pollutants associated with channel flow. It is difficult to prevent runoff from forming into channel flow.

Sufficient data does not exist to relate long-term buffer effectiveness to the amount of land draining to the buffer. For example, one cannot say how much of a buffer would be needed to adequately reduce the copper contained in runoff from 3-acres of impervious surface to meet EPA's recommended maximum concentration. Until a question such as this can be answered, runoff must be captured by more reliable pollution control measures before it enters a buffer.

For the time being buffers should be viewed as providing substantial, but difficult to quantify water-quality benefits. While it is safe to assume that some pollutant reduction occurs as runoff flows through a buffer, one should not attempt to use these reductions as justification for eliminating more reliable control measures.

Recommendations: A buffer of woody vegetation should extend a minimum of 100-feet from both banktops of a waterway, water body, or the perimeter of wetland areas.

Wetlands

Wetlands, both tidal and nontidal, are extremely important aquatic resource areas. The vegetation and animal life supported by wetlands serves as a vital source of food for aquatic ecosystems. Wetland plants also provide important habitat for fish and wildlife. The dense stands of vegetation found in wetlands may serve to reduce the load of pollutants transported in adjacent waterways and to retard floodwaters. A belt of wetland plants also protects shorelines from wave-induced bank erosion (Goldman-Carter, 1989).

Few wetlands were found on the golf courses we studied. On most of the courses extensive filling had occurred on the floodplain - the same location where wetlands may have once existed. If these golf courses were proposed for construction today, it is doubtful that wetland losses would be as severe. The National Wildlife Federation has developed an excellent publication on wetland safeguards, which is entitled "A Citizen's Guide to Protecting Wetlands". Requests for this publication should be mailed to NWF at 1400 "16th" Street, N.W., Washington, D.C. 20036-2266.

Recommendations: Productive wetlands should be highlighted as sensitive areas and avoided when laying out a golf course. If wetlands do occur on the proposed site of a golf course, then the following safeguards should be taken;

1. Do not allow stormwater runoff from impervious surfaces to enter the wetland unless the concentration of toxic pollutants complies with EPA's Ambient Water Quality Criteria (see the section on stormwater pollution).

2. Identify all wetland areas early in the planning process and establish a buffer of 100-feet along the entire wetland perimeter.

3. Closely examine the effects of proposed ground or surface water withdrawals to ensure that flow patterns, salinities, and other characteristics are not altered within or adjacent to the wetland.

4. Erosion and sediment control is particularly important in areas draining to wetlands. Sediment deposition can severely damage wetlands. Natural wetlands should not be used as part of either the sediment or stormwater controls applied to a site. Pollutants must be captured before entering a wetland.

5. The recommendations provided later in this publication for the control of pesticides should be stringently adhered to whenever a fairway, green, or tee is located within 200 feet of a wetland. The herbicides applied to these areas may severely damage the wetland.

Water Temperature

Most fish species do best when summer water temperature rarely rises above 79 degrees Fahrenheit and mortality may occur when water temperature exceeds 86 degrees (Mihursky et al., 1971; Fay et al., 1983; McCauley and Binkowski, 1982; Brungs and Jones, 1977; EPA, 1976). As water temperature reaches into the mid and upper 80's, dissolved oxygen levels decline and many forms of aquatic life enter into a condition of stress. Trout and other salmonids do best when the maximum temperature does not exceed 68 to 72 degrees (Peterson et al., 1979; Hokanson et al., 1973; McCormick et al., 1972). Several aspects of golf course design may impinge upon the temperature regime of nearby waterways.

The lack of shading vegetation along a narrow waterway has caused water temperature to increase by 20 degrees Fahrenheit (Klein, 1979). The large, exposed surface area of a pond can heat well into the upper 80's. Stormwater management ponds have attained a temperature of 85 degrees and caused downstream waters to heat by an additional 11 degrees (Galli, 1986). Generally a pond must be deeper than 40-feet before bottom waters cool to a "safe" temperature.

If a pond is constructed on a flowing stream, then the constant outflow of heated waters will permanently elevate daytime water temperatures in the summer. Off channel ponds can also contribute excess heat to streams when storm runoff causes heated pond water to spill into the stream.

The rate at which a waterway absorbs heat is related to the ratio of width to depth. A deep, narrow creek will heat less rapidly than a wide, shallow waterway. A reduction in the volume of water transported in the channel can reduce the depth and increase the rate at which a stream heats.

A 27-hole golf course may need as much as 150,000 gallons of irrigation water a day (ETA, 1989). It is generally assumed that all of the water used to irrigate a golf course will evapotranspirate into the atmosphere; little will travel far enough into the earth to rejoin the aquifer. If irrigation water is removed from a channel, or from wells which intercept groundwater flow travelling towards the channel, then a substantial reduction in dry-weather (base) flow may result, which may in turn lead to a decrease in water depth and a subsequent temperature rise.

Pluhowski (1970) found that summertime rainwater runoff from impervious surfaces may cause stream temperature to abruptly increase by 15 degrees Fahrenheit. To appreciate this phenomenon, try walking bare-footed across an asphalt parking lot on a clear August afternoon. Rainwater falling upon the baked asphalt heats just as your feet do and the heat is then transferred to the nearest waterway as the warmed runoff enters the channel. Such a sudden increase in water temperature can be extremely damaging to fish and other aquatic organisms.

Recommendations: The effect of golf courses upon the temperature regime of nearby waterways and wetlands can be minimized through the following measures.

1. Maintain a dense buffer of shading vegetation along all channels. Generally trees will continue to intercept sunlight up to 70-feet from the channel. Therefore, the

100-foot buffer recommended in other portions of this publication will mitigate the effects of sunlight upon water temperature.

2. Ponds should not be constructed on the channel of a flowing waterway (intermittent or perennial). Off-channel ponds should be constructed only when absolutely necessary. The off-channel pond should be used as the source of irrigation water to keep the water level drawn down. By maintaining a reduced water level, a portion of the storage area within the pond will be available for capturing runoff, which will minimize the outflow of heated water.

3. Ground and surface water usage should be managed to avoid reductions in the base flow of streams. If groundwater serves as the source of irrigation water, then, whenever possible, the well(s) should be located in an aquifer which does not contribute to the base flow of a stream. If such an aquifer is not available, then several wells should be used. The wells should intercept several different groundwater basins in order to minimize the base flow reduction in any one waterway. If a reduction in base flow of 5% or more is anticipated, then the "Instream Water Temperature Model" (Theurer et al., 1984) may be used to determine if the reduction will cause water temperature to exceed the optimum range for aquatic communities inhabiting the affected waterway. (CAUTION: The temperature model does not produce accurate results under all conditions.)

4. The first inch of stormwater runoff from all impervious surfaces should be infiltrated to minimize thermal shock.

Base Flow & Freshwater Inflow Reductions

The dry-weather or base flow of a nontidal waterway is composed of water which originates as rain falling upon the surrounding watershed. The rain soaks into the soil and travels through the earth to enter a stream channel by way of the banks, the bed, or by issuing from a nearby spring. A reduction in base flow may cause water temperature to rise excessively come summer and may lead to extensive freezing in winter. A reduction in base flow also lessens the velocity of the stream which can bring about critically low dissolved oxygen levels. The volume of base flow also determines the quantity and quality of habitat in a waterway and the ease with which obstacles can be negotiated by migrating fish.

Base flow is also important to a tidal waterway. The freshwater contributed by base flow mixes with estuarine waters to establish a salinity gradient along the length of the water body. Reducing the inflow of freshwater may cause the salt level to rise throughout the estuary. Such a shift may disrupt aquatic organisms and entire ecosystems which have acclimated to the historic salinity regime of the estuary. Inflow also contributes to the flushing characteristics of an estuary. A reduction of inflow may result in poorer flushing and a build-up of oxygen-demanding materials, fine sediment particles, and other detrimental substances.

There are two aspects of golf course development and operation that affect base flow: a reduction in groundwater recharge resulting from land use changes and the use of groundwater or surface water for irrigation.

The change in land use brought about through the construction of a golf course may also cause base flow/inflow reductions. Using Maryland as an example, an average of 23% of the annual rainfall (43 inches) will soak into the earth and become base flow (Otton, 1972), which is equivalent to 9.9 inches or a quarter-million gallons of recharge per acre each year. If a forest is converted to managed turf, then recharge may decrease by 15% (EPA, 1982). For each acre of forestland replaced with grass, base flow may diminish by 41,000 gallons per year. Converting the same acre to a parking lot or a clubhouse site would prevent the entire quarter-million gallons of rainfall from becoming base flow. Converting an acre of pasture to well-managed turf grass may increase recharge by 14,000 gallons per year, while transforming conventionally tilled cropland would elevate recharge by 8,000 gallons annually.

In Maryland, an 18-hole golf course requires 100,000 to 150,000 gallons of irrigation water per day (Hammond and McKinney 1990). In Hawaii, the same golf course will require 500,000 to 1,000,000 gallons per day (OSP 1992). The actual amount of irrigation required will depend upon a number of factors, including climate, grass species, and soil type. Kentucky bluegrass and Italian ryegrass have very high water requirements while Buffalograss and Zoysiagrass have low to very low irrigation needs (USGA 1990). Up to 90% of the water applied to turfgrass may be lost to the atmosphere via evapotranspiration. In other words, as little as 10% of the water will soak through the root-zone and eventually flow to a nearby waterway.

If irrigation water is obtained from a stream, river, or a pond constructed on a waterway, then the reduction in flow is direct. The use of groundwater as a source of irrigation water can also reduce stream flow, particularly if the water is drawn from an unconfined aquifer. An unconfined aquifer is a water-bearing formation that lacks an impermeabnle barrier, such as a layer of clay. A confined aquifer lies beneath an impermeable barrier.

If an irrigation well taps the same aquifer that provides groundwater inflow to a stream, then the volume of water carried by the stream will be reduced.

Recommendations: The following steps will minimize the negative effects exerted by a golf course upon the base flow or inflow regime of a waterway.

1. Infiltrate the first inch of runoff from all proposed impervious surfaces.

2. Minimize the amount of forest removed to construct the course.

3. Compensate for forest reductions in one area by planting trees in another portion of the same watershed.

4. If a reduction in the 7-day, 10-year low-flow of 5% or more seems unavoidable, then the Instream Flow Incremental Methodology, developed by the U.S. Fish & Wildlife Service (Milhous et al. 1984), should be used to assess the impact upon the affected non-tidal waterway. An appropriate estuarine model should be used to evaluate any reductions in freshwater inflow.

5. If the reduction in inflow is excessive, then consideration should be given to options that will reduce water use. These options may include: the use of drought-resistant grass species, dispersing irrigation supply wells throughout several drainage basins to reduce the impact upon any one stream, recycling treated wastewater onto the course, or collecting stormwater runoff for use as irrigation water.

Release Of Toxics & Oxygen Deficient Water From Ponds
On-channel ponds were present at several of the golf courses we studied. The effect of the ponds on stream quality differed widely. At the Bon Air Golf Course stream quality was slightly degraded above a pond, but declined to a severe level of degradation after passing through the pond. The severely degraded stream at the Hillendale Country Club improved to moderate level of degradation after passing through a pond. And the stream with the best quality of all originated at a pond. This stream was only slightly degraded.

Several explanations may account for the variable effects of on-channel ponds. First, the pond may serve as a water-supply source and the decline in stream quality may therefore be a reflection of a base flow problem. Second, the pond may serve as a "sink" for toxic substances or oxygen-demanding materials. The release of toxics or oxygen-deficient water from the pond may cause a chronic, low-level impact upon downstream waterways. Finally, the pond may release water which exceeds the thermal tolerance of aquatic organisms.

Recommendations: While unavoidable accidents may lead to the accumulation of toxics in ponds, and natural succession will reduce the dissolved oxygen content of pond waters, several steps can be taken to minimize the impact of on-channel impoundments.

1. Avoid siting ponds on the channel of an intermittent or perennial waterway.

2. Off-channel ponds should be designed to minimize the spillage of water during runoff events. The off-channel pond can serve as a source of irrigation water. Withdrawals from the pond can be used to maintain sufficient storage area to capture runoff and lessen the frequency with which pond water spills into nearby waterways.

3. Spill prevention and control measures should be applied to all sites where pesticides, fertilizers, fuels, and other toxics are stored or used. These measures should be designed to prevent the material from flowing onto permeable soils as well as reducing the potential for washoff in stormwater. Storage sites should be located sufficiently far from a waterway or permeable soils to provide ample time to contain and recover spilled materials.

4. Aeration, dredging, or other rehabilitation techniques should be applied to ponds which have become eutrophic (see Dunst et al., 1974 for details).

5. Algicides and other chemicals employed in the control of pond nuisance growths should be used with extreme care.

Intermittent Pollution Incidents
If a large quantity of a pesticide, fertilizer, or fuel is spilled at a golf course, then it may by-pass a pond and enter a stream or tidal creek. The spill control and prevention measures described above, should be designed to minimize the likelihood of such an intermittent pollution incident.

Fertilizers And Pesticides
Pesticide and fertilizer movement has been the focus of much of the research into the impact of golf courses upon the aquatic environment. Fertilizer movement into ground or surface waters may cause nitrate contamination of drinking water supplies. Also, fertilizers may stimulate the growth of aquatic plants to a point where dissolved oxygen levels fall to the lethal threshold. Like fertilizers, pesticides may contaminate water supplies and threaten the welfare of aquatic organisms. A comparison is presented in Table 1, of the amounts of fertilizers and pesticides applied to croplands and golf course. This comparison is drawn from a golf course proposed for construction on a corn and soybean field located on Maryland's eastern shore.

Fertilizers: The quantities of fertilizers applied to the turfgrasses of golf courses is roughly the same as that used on cropfields (see Table 1). Phosphorus tends to be less of a problem when applied to turfgrasses in comparison to cropfields. Of the two nutrients, nitrogen poses the greatest threat to aquatic resources. Nitrogenous fertilizers will primarily enter the aquatic environment by leaching to groundwater.

Up to 84% of the nitrogen fertilizers applied to turfgrass may leach to groundwater, with the average hovering between 5% and 10% (Petrovic, 1990). Nitrate may pose a threat to the health of infants when the concentration in drinking water exceeds 10 mg/l as N. Of the various studies of nitrogen leaching reviewed by Petrovic, 14% reported nitrate concentrations of 10 mg/l N or greater in leachate.

Ideally, the amount of fertilizer applied to a golf course should equal the amount taken up by grass. Unfortunately this ideal is difficult to achieve. The quantity of fertilizer actually applied to turfgrass is always in excess of the projected uptake. It is assumed that a portion of the fertilizer will be lost to plants either because it washes away in surface runoff or leaches below the rooting depth of grass, which averages 18-inches (Frere et al., 1980).

The greatest movement of nitrogen into groundwater occurs when either the water table is located quite close to the treated surface or the soils are very coarse (Petrovic, 1990; Bachman, 1984). These conditions provide a minimum amount of time for the uptake of nitrogen fertilizers by grass. Large portions of the applied fertilizer may pass through the root-zone. Once the fertilizer leaves the

Table 1: Comparison of Fertilizer & Pesticide Use On Cropland & Golf Courses (Source: Welterlen 1988)

Material	Cropland (lb/acre/yr)	Golf Course (lb/acre/yr)		
		Fairway	Green	Tee
FERTILIZER:				
Nitrogen	184	150	213	153
Phosphorus	80	88	44	93
HERBICIDES:				
2,4-D		0.5	0.15	0.5
atrazine	1.5			
bensulide		3.8	7.5	3.8
butylate	2.3			
ethofumesate		1.5		1.5
fenoxaprop-ethyl		0.05		0.6
imazaquin	0.1			
MCPP		0.5	0.5	0.5
oxadiazon		0.5		1.0
pendimethalin		1.5		1.5
trifluralin	0.8			
INSECTICIDES:				
carbofuran	1.1			
chlorpyrifos		2.0	2.0	2.0
FUNGICIDES:				
anilazine			5.5	
benomyl		1.3	2.6	1.3
chlorothalonil		8.2	16.4	8.2
iprodione		1.3	2.6	1.3
maneb		6.5	6.5	6.5
metalaxyl		1.4		1.4
thiram		8.2		8.2
triadimefon			1.3	
TOTAL PESTICIDES	5.8	37.3	45.1	38.3

root-zone, decomposition by soil microbes is the primary mechanism for halting the flow of nitrogen to groundwater.

Again, the shallower the soil, the less time available for microbial action upon nitrogen fertilizers, and the greater the amount reaching groundwater. Once nitrate reaches the water table, dilution is the primary means of reducing the concentration below 10 mg/l.

In addition to soil characteristics, several other factors dictate the quantity of nitrogen which will reach groundwater. These factors are; irrigation practices, grass species, type of nitrogen applied, timing of fertilizer application, and application rates.

Irrigation can increase the leaching of fertilizers (and pesticides) to groundwater. A typical 18-hole golf course may require 100,000 to 150,000 gallons of irrigation water per day (Hammond and McKinney 1990). Morton et al. (1988) found that excessive irrigation of turfgrass increased nitrate-nitrogen leaching to groundwater by six-fold. Snyder et al. (1984) compared the nitrogen losses from grass plots irrigated on a daily basis with plots irrigated only when moisture sensors indicated watering was needed. The amount of nitrogen leached from the daily-irrigated plots was 2 to 28 times greater when compared to the sensor-irrigated plots.

Grass varieties have differing requirements for fertilization, irrigation, and pest control. Zoysiagrass requires the least fertilizer and pesticide treatment. But zoysiagrass cannot survive the occasionally harsh winters of Maryland and more northerly states. As a result, zoysiagrass may not be appropriate for all golf courses. Bluegrass requires the greatest care and, therefore, may create the highest potential for groundwater contamination when extensively planted throughout a golf course. The perennial rye-grasses and the tall fescues require less management than bluegrasses, but more than zoysiagrass.

The characteristics which affect leaching potential vary from fertilizer to fertilizer. Ammonium nitrate and calcium nitrate have a high leaching potential. Fertilizers exhibiting a moderate to low leaching potential include urea, urea solution, and isobutylidene diurea. Materials with the lowest leaching potential are; sulfur coated urea, methylene urea, ureaformaldehyde, and domestic sewage sludge (Gold et al., 1989). But even when slow-release fertilizers are used a significant losses of nitrogen can occur. For example, the nitrate level in groundwater beneath the Falmouth golf course on Cape Cod was 10 to 24-times greater than the background concentration (Cohen et al., 1990). Yet slow-release fertilizers were used on this course.

Fertilizer uptake is at a maximum during the season when grass is actively growing. If fertilizers are applied after growth has slowed or stopped, then nitrogen leaching will increase. For instance, nitrogen uptake by Kentucky bluegrass declines in late summer (Cisar, 1988). High concentrations of nitrate have been observed in soil-water following late summer applications of urea (Morton et al., 1988).

Excessive fertilizer application is most likely to produce high nitrogen leaching rates when turfgrass is subjected to over-application for a period of years (Gold et al., 1989). Overfertilization can double the amount of nitrogen leached from the treated surface (Morton et al., 1988).

Greens may account for up to 10% of the area of a golf course. In order to meet U.S. Golf Association standards, a putting green must consist of a minimum of 93% sand, a maximum of 3% silt and 5% clay, while exhibiting an infiltration rate of at least 2-inches per hour. Additionally, putting greens are frequently fitted with an underdrain system lying 18- to 36-inches below the surface. These conditions would assure rapid passage of leachate through the soil column to an underdrain, and eventually into surface waters. Brown et al. (1982) detected 22% of the nitrogen applied to a green in water issuing from the underdrain. But another study (Snyder et al., 1981) detected only 1% of the applied nitrogen in drainage water from a green. The leachate collected in an underdrain should be treated either by applying it to suitable soils or by discharge to a peat-sand filter (Galli, 1989).

The likelihood of severe contamination is greatest when a golf course is sited on soils which are coarse-textured (sandy loam to sand) and the depth to the seasonally high water table is minimal. The layout of a golf course should be confined to those portions of a site where medium-textured soils (loam) reside at an elevation sufficiently high above the water table to take maximum advantage of uptake in the root zone and microbial action. Nitrogen reductions due to root uptake and microbial action should be at a maximum where the water table lies at least 4-feet below the treated surface of the golf course. Fertilizers with a low leaching potential (sulfur-coated urea, ureaformaldehyde, etc.) should be applied only during periods of active growth, and irrigation should be carefully managed to avoid excessive watering and increased leaching of nitrogen to groundwater.

Pesticides: Can the pesticides used on golf courses adversely affect the aquatic environment? The potential for adverse effects certainly exists, although there is a paucity of information on this question. A recent review of scientific literature on the impact of golf courses concluded that research into this question is just in the initial stages (USGA 1990). However, several studies have shown that under some circumstances pesticides can reach surface waters and groundwater in concentrations that exceed the levels deemed safe by the U.S. Environmental Protection Agency (Cohen et al. 1990 and 1999; Harrison 1989; EPA 1986c and 1986d).

The pesticides used on golf courses fall into three categories; herbicides, fungicides, and insecticides. Golf courses located in southern states may also apply nematicides. A total of 126 different active ingredients are used in the maintenance of golf courses throughout the nation (Kriner, 1985). Studies of the movement of pesticides from managed turfgrass are relatively few in number. Several of these studies are summarized in the following paragraphs.

A wide variety of toxic substances have been used to control pests on turfgrass. Many of the most dangerous compounds, such as DDT, are no longer used. Nevertheless a toxic legacy remains on many lawns and golf courses, particularly those which were in existence in the 1950's and 60's.

Okoniewski studied organochlorine and metal residues on 22 older golf courses. He found that chlordane related compounds were ubiquitous and dieldrin was frequently detected along with DDT and the metals arsenic, cadmium, chromium, copper, lead, mercury, and zinc. The highest levels of pesticide-related residues were found on greens where the total chlordane-related concentration averaged 11.4 ppm (dry-weight), but ranged as high as 40 ppm. The maximum concentration of arsenic, cadmium, lead, and mercury ranged from 69 ppm to 1,860 ppm.

Okoniewski's study was spawned by a concern about wildlife mortalities associated with pesticide treated turfgrass. Birds, particularly waterfowl, are the most frequent victims of turfgrass pesticides.

TABLE 2: Examples of Wildlife Mortalities Associated with Ingestion of Pesticides Applied to Turfgrass (Source: Stone, 1979; Stone, 1980; Anderson and Glowa, 1985; Stone and Gradoni, 1985)

PESTICIDE	WILDLIFE SPECIES	NUMBER KILLED/INCIDENT
Chlordane	Great horned owl	2
Chlorpyrifos	Canada geese	35
Dasanit	Canada geese	25
Diazinon	Ducks	200
	Canada geese	12
	Canada geese	81
	Widgeon	37
	Cowbirds	60
	Widgeon and gadwall	50
	Brant	55
Isofenphos	Red-winged blackbirds	100
	Brant	6

Insecticides are consumed along with insects, worms, and grass. The ponds and large expanses of open turf found on golf courses are attractive to geese and ducks. Several incidents are summarized in Table 2.

Okoniewski stated that the threat of metal contaminated turfgrass soils could be reduced by lowering soil acidity and by maintaining a high organic matter content.

Adding activated carbon to turfgrass soils will serve to inactivate organochlorine pesticides (Kring and Ahrens, 1968, cited in Okoniewski). Innoculating soil with bacteria having the capability of neutralizing pesticides provides another control option.

The most comprehensive review of pesticide releases from golf courses was published by Cohen et al. (1999). The authors reviewed the results of monitoring conducted at 36 golf courses located throughout the United States. The number of pesticides, pesticide metabolites, or solvents monitored at these golf courses totaled 134. Of these 134 materials, 31 were present in surface water at a concentration above the limits of detection and 21 were detected in groundwater. Cohen et al. then compared the maximum concentration detected in ground and surface waters with various water quality protection criteria. Had this analysis shown that maximum pesticide concentrations never exceeded water quality criteria, then there would not be cause for concern. However, this was not the case.

Table 2 presents the maximum pesticide concentrations reported by Cohen et al. Table 2 also includes water quality criteria.

Harrison studied fertilizer and pesticide losses from nine turfgrass plots established at the University Park campus of Penn State University. The plots measured 20-feet in width by a length of 60-feet. The slope of the plots was 9% to 14%. The soil contained within the plots was a Hagerstown with a USDA textural classification of clay. The clay soil exhibited a minimum infiltration rate of 0.02 inches per hour. The plots were planted with bluegrasses, ryegrasses, and fescue.

Harrison monitored both surface runoff from the plots and infiltrated rainfall. Infiltrating water was collected in lysimeters placed 6-inches below the surface. The author found that 1.6% - 2.7% of the pesticides 2,4-D, 2,4-DP, and dicamba applied to well-managed turf was transported from the application site either in surface or groundwater runoff. The range of pesticide concentrations reported by Harrison were; 0 to 312 ug/L for 2,4-D (acid), 0 to 210 ug/L for 2,4-DP (acid), and 0 to 251 ug/L of dicamba. While chlorpyrifos and pendimethalin were both applied to the plots, neither was detected in runoff or infiltrating water.

The federal drinking water limit for 2,4-D and dicamba is 100 ug/l and 210 ug/l, respectively (EPA, 1986c; Watschke and Mumma). The concentration of 2,4-D and dicamba exceeded the drinking water standard on 16% and 4% of the sampling dates, respectively.

. The geology of the area consists of unconsolidated glacial sediments which overlie bedrock. The soils are generally quite coarse in texture, although localized silt and clay layers do occur. The water table occurs at a depth ranging from 5 to 56 feet beneath the surface of the four courses studied. Given the coarse texture of the soil and the deep water table, relatively little surface runoff occurs. Therefore the study was based solely upon analyses of groundwater quality. Wells were placed upslope of each of the courses and within fairways, greens, and tees.

Samples were collected from the monitoring wells on four to six occasions and analyses were performed for 17 different pesticides. Of the 17 pesticides, 10 were detected in groundwater. Pesticides were detected in wells beneath greens and tees twice as frequently when compared to fairways. The range of pesticide concentrations is summarized in Table 3, below.

The authors compared the pesticide concentrations detected in groundwater with health guidance levels (HGL's). Chlordane and heptachlor epoxide exceeded the respective HGL by 240 and 40 times. No other pesticide exceeded its HGL. Neither chlordane nor heptachlor are presently used on golf courses. It was assumed that the residues found in groundwater is a reflection of the extremely persistent nature of both substances.

The U.S. Environmental Protection Agency has published criteria for protecting aquatic life from the effects of chlorpyrifos. EPA's national criteria calls for no more than 0.041 ug/l in freshwater and a maximum of 0.0056 ug/l in saltwater (EPA, 1986d). As illustrated in Table 3, the chlorpyrifos concentration detected in groundwater beneath the Cape Cod golf courses attained 0.10 ug/l, or 2.5 and 18 times higher than that recommended by EPA for fresh and saltwater systems, respectively.

EPA's recommended level for chlordane in freshwater and marine systems is 0.0043 and 0.004 respectively (EPA, 1986c). The maximum chlordane level detected in the Cape Cod study was 7.20 ug/l, or roughly 1,700 times higher than the concentration deemed safe by EPA.

TABLE 3: Pesticides Detected in Groundwater During the Cape Cod Golf Course Study (Source: Cohen et al., 1990)

Pesticide	Detection Limit (µg/l)	Range Of Concentrations (µg/l)
Technical chlordane	0.125	<0.125 - 7.20
Chlorothalonil	0.015	<0.015 - 0.38
Chloropyrifos	0.05	<0.05 - 0.10
2,4-D	0.05	<0.05 - 0.24
Dacthal diacid	0.20	<0.20 - 1.07
Dicamba	0.05	<0.05 - 0.06
2,4-Dichlorobenzoic acid (DCBA)	0.20	<0.20 - 298.00
Heptachlor epoxide	0.03	<0.03 - 0.16
Isofenphos	0.75	<0.75 - 1.17
3,5,6-Trichloro-2-Pyridinol	0.10	<0.10 - 0.76

The concentration of heptachlor considered safe by EPA (1986c) is 0.0038 ug/l and 0.0036 ug/l for freshwater and marine organisms. The maximum heptachlor concentration detected at the Cape Cod golf courses was 0.16, or 44 times the safe level.

Criteria for the protection of aquatic organisms has not been established for the other pesticides detected through the Cape Cod golf course study.

If the chlorpyrifos, chlordane, and heptachlor groundwater concentrations are transmitted to surface waters, then significant damage to aquatic communities could occur. The assumption should be that groundwater beneath the four golf courses will travel to a stream, estuary, or the ocean. One should not depend upon dilution to mitigate the impact upon aquatic organisms. Instead one should strive to keep the concentration of pesticides from reaching the threshold of safety. Pesticides reached groundwater beneath the Cape Cod golf courses even after passing through 35-feet of unsaturated soil. The results of the

Cape Cod study indicate that one should take great care when contemplating a golf course on coarse textured soils, particularly where the depth to groundwater is less than 35-feet.

The characteristics of a pesticide which determine the potential for movement into ground or surface waters are; solubility, half-life (soil and foliar), washoff fraction, and the partitioning coefficient. Other pesticide characteristics of concern are relative toxicity and application rate. Table 4, provides an example of how these characteristics might compare with respect to the pesticides used on a cropfield and a golf course.

Solubility is an expression of the ability of a pesticide to dissolve in water (at 20 degrees C). As the solubility of a pesticide increases, the potential for transport in surface runoff or leaching into soil increases. The U.S. Environmental Protection Agency (EPA) has determined that a pesticide with a solubility in excess of 30 parts per million (ppm) has a potential to contaminate groundwater (EPA, 1986b). As an example, the solubility of the golf course pesticides listed in Table 4, averages 7-times higher in comparison to those used on cropfields.

The half-life of a pesticide is a measure of the amount of time (days) required for 50% of the quantity applied to degrade. Values are given in Table 4, for the half-life of pesticides residing on the surface of plants and in soil. The longer the half-life, the greater the opportunity for pesticide movement into ground or surface waters. The half-life of pesticides applied to cropfields and golf courses is roughly the same.

Washoff fraction is an expression of the degree to which pesticides residing upon plant surfaces will move with rainfall and runoff. As the washoff fraction increases, so does the potential for transport in rainfall and runoff. The average washoff fraction for pesticides applied to golf courses is slightly lower when compared to substances used on cropfields.

The partitioning coefficient is the ratio of the concentration of the pesticide in the soil to the concentration in solution. Pesticides with a low partitioning coefficient will tend to move with rainfall as it soaks into the soil column. A pesticide with a high partitioning coefficient will tend to stay near the surface and, as a result, move in association with eroded soil. The partitioning coefficient of pesticides applied to golf courses averages 6-times higher than the value for cropfields, which may balance out the greater solubility of compounds applied to fairways, greens, and tees.

Acute oral toxicity is the quantity of the active ingredient in the pesticide which must be ingested to produce a 50% mortality among the organisms tested, which are usually rats. As the acute oral toxicity of a pesticide increases, the potential threat to aquatic organisms and humans rises as well. The toxicity of the pesticides applied to golf courses and cropfields is approximately the same.

Generally as the rate of application increases, the potential for movement in runoff increases as well. The pesticide application rate may be 6- to 8-times higher on golf courses when compared to cropfields.

The factors which determine the potential for pesticide movement from a specific site are; the soil erosion rate, soil organic matter content, soil texture, soil permeability, depth to groundwater, plant cover and rooting depth, and rainfall or irrigation rates.

As the soil erosion rate increases, the potential for pesticide movement increases as well. Characteristics affecting the rate of soil erosion include; the steepness and length of slopes, soil erodibility, rainfall intensity, turfgrass quality, and the use of management practices which lessen erosion or sediment movement. The potential would be greatest for those pesticides with a high partitioning coefficient, low solubility, a long half-life, and a high washoff fraction. Soil erosion is generally low on well-managed turfgrass. The primary mechanisms for pesticide movement from turfgrass will normally be solution in runoff waters and leaching into the soil column.

Organic matter has the ability to retain significant quantities of pesticides, particularly those with a high partitioning coefficient. The organic matter content of all the soils on a proposed golf course site should be examined. The course should be designed to take advantage of soils with a high organic matter content while, of course, taking into consideration other characteristics affecting pesticide movement. Management measures which increase the organic matter content should be used on an existing course.

Next to organic matter, clay particles play the greatest role in retarding pesticide movement. Positively charged pesticide molecules will absorb to the negatively charged sites on the surface of clay particles. Generally, as soil texture becomes more coarse (sandy) the amount of clay and organic matter declines. When laying-out a golf course, sandy soils should be avoided in favor of whatever medium-textured loams exist on the site.

A number of computer models have been developed to simulate the movement of pesticides and nitrogen from treated surfaces. Unfortunately none of the models presently available provide an accurate prediction of pesticides losses to groundwater (Shoemaker et al., 1990), and the same appears true for nitrogen. Additionally, the lack of water quality protection criteria for many pesticides hampers the interpretation of model results. If both of these deficiencies can be resolved, then it may be possible to evaluate conditions on an existing or proposed golf course and determine what management practices would be needed to keep pesticide and nitrate concentrations from exceeding the threshold of safety. Until an accurate model and water quality protection criteria are fully developed, the following recommendations will reduce the threat to aquatic resources.

A detailed assessment should be made of soil permeability and the depth to groundwater (during the wettest month) throughout a proposed site for a golf course. Generally the course should be confined to those portions of the site where maximum advantage can be taken of the pesticide and nitrate attenuation occurring in the root-zone and the zone of active microbial decomposition. The treated surfaces of a golf course should be separated from the maximum elevation of the water table and bedrock by a minimum vertical buffer of 4-feet.

A recent review of scientific literature on the environmental effects of intensively managed turfgrass stated that: *Golf courses built on sandy soils over shallow aquifers are* *considered at risk for subsurface transport of frequently and heavily applied nutrients and pesticides* (USGA 1990). Golf courses proposed for such sites should be evaluated with particular care.

In the section on fertilizers, mention was made of the lower fertilizer and pesticide needs of fescue and rye grass in comparison to the Bluegrasses. Again, using these less maintenance intensive grasses on a golf course will lower the potential for pesticide and fertilization movement into ground and surface waters. Judicious use of irrigation will also lessen the quantity of pesticides leached to the water table. Finally, "Integrated Pest Management" (IPM) has the potential to further reduce pesticide use and groundwater contamination at a golf course. But while IPM will help, it is not a panacea.

An effective IPM program for a golf course consists of three parts; prevention, monitoring, and control. Preventing pests from invading a golf course can be achieved through proper selection of turfgrass varieties (fescue vs. bluegrass) which have a high resistance to disease, insects, and so forth. The endophyte content of grass is one of the characteristics which determines susceptibility to pests. The grass selected for a golf course should have a high endophyte content.

Monitoring can reduce the need for pesticides by allowing the golf course manager to detect problems as they develop and before they get out of hand. The current approach used on most golf courses is to regularly apply pesticides to vast areas. The pesticides are applied on a "preventative" rather than "curative" basis. The short mowing heights and vulnerable condition of golf course turfgrass creates an environment in which pests may cause extensive damage in a relatively short period of time. Therefore, a variety of pesticides are applied to broad areas on a routine basis to "play it safe" as opposed to waiting until a pest actually appears.

An effective IPM control strategy would offer a number of pest management tools in addition to conventional pesticides. And these tools would be used on a curative basis, with application occurring only on the specific site where the pest has appeared.

Again, while IPM will definitely reduce the potential for groundwater contamination at a golf course, the threat will not be eliminated. Even with a fully implemented IPM program, turfgrass pest control will remain chemically based. At best IPM may reduce pesticide use on a golf course by 50%, which would still result in pesticide applications 3- to 4-times greater than those made on cropfields. Nevertheless, golf course maintenance personnel should be required to attend a credible training program in IPM.

Recommendations: The potential for contamination of ground and surface waters should be reduced to an acceptable level if the following design criteria and management guidelines are applied to a proposed golf course.

1. All fairways, greens, and tees must be sited on medium-textured soils, which have a high organic matter and clay content, and lie a minimum of 4-feet above the highest elevation of the water table and bedrock.

2. If the conditions described above do not exist naturally throughout a site, then the following alternatives must be used.

a. Suitable fill material may be imported to the site to create soils having a medium texture and a 4-foot vertical buffer separating the treated surfaces from the water table and bedrock. AND/OR

b. An underdrain system may be installed beneath a portion or all of the course. The leachate collected in the underdrain system should either be applied to suitable soils (as described in #1 above) or treated with a system such as a sand-peat filter (Galli, 1989).

3. Once the preceding design criteria have been satisfied, the following management guidelines must be implemented to further reduce the potential for ground and surface water impacts.

a. The course must be planted with a grass variety which is drought and pest resistant, while requiring relatively low fertilizer use.

b. The irrigation system should operate on an "as needed" basis by utilizing some means of assessing the moisture content of the soil.

c. Fertilizers with a low leaching potential should be used whenever possible. Fertilizers must not be applied after active growth has ceased. Applications rates should be kept to the lowest reasonable level.

d. The personnel directly responsible for maintenance must become proficient in the use of Integrated Pest Management.

Stormwater Pollution From Impervious Surfaces

Stormwater runoff transports a wide array of pollutants from impervious surfaces. On a golf course these impervious surfaces may take the form of a parking lot, road, rooftop, sidewalk, patio, cart path, or any other feature which prevents stormwater from soaking into the earth.

The U.S. Environmental Protection Agency funded a massive study of stormwater runoff in 27 areas spread across the nation. The study, which was known as the Nationwide Urban Runoff Program (NURP), documented significant concentrations of nutrients, oxygen-demanding materials, toxics, and carcinogens in runoff from developed areas (EPA, 1982). A comparison is provided in Table 5, of the quantity of pollutants transported in stormwater from developed lands and other land uses.

As illustrated in Table 5, developed areas release 2 to 20 times more nutrients into the aquatic environment than forest and cropland. The quantity of copper, a highly toxic metal, washed from parking lots is nearly 200 times greater than the volume emanating from forest!

EPA has designated 126 substances as priority pollutants. These substances may be highly toxic, carcinogenic, or mutagenic. A number of these pollutants are constituents of pesticides, solvents, or metallic compounds. Of the 126 priority pollutants, 77 have been detected in stormwater runoff (EPA, 1982).

Table 6, lists several of the most frequently detected priority pollutants associated with stormwater runoff from developed areas. Runoff from developed lands contains sufficient levels of toxic or carcinogenic pollutants to pose a threat to aquatic life and the quality of drinking water every time it rains.

Unfortunately sufficient data is not available to describe how the multitude of stormwater pollutants may interact to pose an even greater threat to aquatic life and people. An example of such an interaction was provided by McKee (1957), who found that a solution containing both copper and zinc killed fish at a concentration 12-times lower than the concentration which killed fish exposed to only one of the two toxic metals. Both copper and zinc were found in virtually all stormwater samples analyzed through NURP.

Ten of the priority pollutants listed in Table 6, pose a significant threat to human health when ingested in drinking waters. Obviously, stormwater must not enter a water supply source unless sufficient treatment has been provided to lower the concentration of these ten priority pollutants to a safe level. Unfortunately, little information is available on the effect of conventional stormwater management measures upon the four non-metal priority pollutants.

The sources of stormwater pollutants are summarized in Table 7. One of the most prevalent sources is the operation of automobiles and other vehicles. A typical golf course may generate 1,230 car trips per day (ITE, 1976). Most of the other sources of stormwater pollutants may also be found on a golf course.

The pollutants entrained in stormwater are washed from impervious surfaces, such as asphalt, concrete, and rooftops. Much of the pollution deposited upon pervious areas - grass and woodland - is carried into the soil by infiltrating rainfall. If soils are medium-textured and the depth to the water table or bedrock exceeds 4-feet, then many of these pollutants will either transform to less noxious substances or become semi-permanently stored within the soil column.

Stormwater runoff from impervious surfaces should never be released directly into ground or surface waters without treatment. As illustrated in Table 6, the pollutants commonly occurring in stormwater will threaten the health of people who consume water from an aquifer receiving untreated runoff from impervious surfaces.

The release of untreated stormwater into the environment may cause a two-fold impact. Aquatic organisms (fish, insects, crustaceans, and plants) exposed to full-strength or partially diluted runoff may die or suffer various forms of sublethal stress. Stormwater pollutants may also accumulate in sediments and bioaccumulate in aquatic organisms. As time goes by, the stormwater pollutants released into the environment will build to higher and higher concentrations in muds and living tissue. Eventually, the concentration may reach a catastrophic threshold.

TABLE 8: Priority Pollutant Concentration, Water Quality Criteria & Reductions Needed to Meet The Criteria (Source: EPA, 1980b, 1984, and 1987; Schueler, 1987)

POLLUTANT	MAXIMUM CONCENTRATION (µg/l)	AQUATIC LIFE PROTECTION CRITERIA (µg/l)	REDUCTION REQUIRED TO MEET CRITERIA
Copper:	114		
Freshwater		9	93%
Saltwater		3	98%
Lead:	149		
Freshwater		74	50%
Saltwater		140	7%
Zinc:	355		
Freshwater		65	82%
Saltwater		95	74%

Criteria relevant to stormwater pollutants must be considered in two different ways; loadings and maximum concentration. Loading refers to the amount of a pollutant delivered to an aquatic system within a specific period of time. Pounds per year or pounds per acre per year are both commonly used to express stormwater pollutant loadings. The loadings for the more common stormwater pollutants are given in Table 5, above. The impact of biochemical oxygen demand and nutrients (nitrogen and phosphorus) upon an aquatic system is primarily a function of the loading rate.

Biochemical oxygen demand (BOD) is a measure of the degree to which a pollutant will reduce the oxygen dissolved in a waterway. For each part of BOD released to a waterway, dissolved oxygen will be depleted by an equal amount. The dissolved oxygen content of trout streams should not fall below 6.0 mg/l and a minimum of 5.0 mg/l must be maintained in other waterways (EPA, 1976). Generally an aquatic system will be adequately protected if the BOD loadings from impervious surfaces is reduced by 80%. If site specific criteria are desired, then an analysis should be performed used a reliable water quality model, such as EPA's WASP model.

Nutrients may cause aquatic plants to proliferate, which may lead to oxygen deficiencies and a variety of nuisance conditions. The nitrogen concentration in stormwater rarely approaches 10 mg/l. But, while stormwater may not directly cause nitrate contamination of a water supply, it can elevate the background concentration and, thereby, increase the vulnerability of an aquifer to nitrate contamination. As with BOD, aquatic systems will generally receive adequate protection if the nutrient loadings associated with stormwater are reduced by 80%. If this level of reduction is deemed unacceptable, then a site specific analysis should be performed using a suitable ground or surface water model.

The effects of toxic substances upon aquatic communities is controlled by the maximum concentration. EPA has established water quality criteria for most of the toxic constituents of stormwater. The criteria for the three most ubiquitous toxics (copper, lead, and zinc) is presented in Table 8. The table also provides the maximum concentration associated with stormwater and the percent reduction required to meet the criteria.

Methods to Control Stormwater Pollution
A number of effective practices have been developed for treating stormwater runoff from impervious surfaces. The two most effective practices are ponds (either extended-detention or wet-ponds) and infiltration. Table 9, illustrates the maximum pollutant removal efficiency associated with the more common practices. Infiltration and the wet-pond/sand-filter are the only methods which will reduce all pollutants sufficiently to protect aquatic resources.

Infiltration cannot be practiced everywhere. For example, the Maryland Department of the Environment allows infiltration only on soils which meet the following conditions (MDE, 1988; DNR, 1984; Code of Maryland Regulation 08.05.05).

1. The depth to the seasonally high water table or bedrock must be 4-feet.

2. Soil permeability must at least be 0.27 inches/hour.

3. The infiltration device must be a minimum of 100-feet downgradient of septic systems and water supply wells.

4. The infiltration device must be a minimum of 10-feet downgradient of building foundations.

5. Porous pavements may not be placed on slopes greater than 5%.

6. All other infiltration devices may not be placed on slopes steeper than 20%.

7. Infiltration shall not be placed on filled areas.

The original land surface is frequently compacted during filling. Runoff percolating through the fill may be retarded at the point of compaction and move laterally to either cause slippage on slopes or the entry of partially neutralized runoff into a water body.

In addition to the siting criteria presented above, the author recommends against locating infiltration measures on coarse textured soils, particularly sand and loamy sand. Approximately half of the copper entrained in stormwater runoff is associated with particles, with the remainder occurring in a dissolved state. While particulate copper may be retained in a coarse textured soil, much of the dissolved metal will pass through to groundwater. As the silt-clay content rises, the ability of a soil to retain dissolved copper increases. Soils assigned to USDA Textural categories sand and loamy sand should not be used for the infiltration of stormwater. If an infiltration device is sited on sand or loamy sand, then it should be assumed that the dissolved copper fractions (50% of the total) will pass through to groundwater.

If a site is not suitable for conventional infiltration practices, then a wet-pond/sand-filter combination should be used.

The wet-pond should be sized to store the first inch of runoff from all impervious surfaces and shaped to maximize the settlement of suspended solids. The wet-pond and runoff collection system must be designed to prevent the movement of stormwater pollutants into the ground unless the depth to the water table and bedrock is at least 4-least, and the soils have a medium- to fine-texture. Additionally, provisions must be made for disposing of stormwater solids when the wet-pond requires cleaning. Ideally, the solids should be incorporated into the surface of medium-textured soils lying at least 4-feet (preferably 4-feet) above the water table and bedrock.

Two basic options are available for the sand filter; 1) a rapid/slow-rate sand filter combination or 2) a sand-peat filter. Of the two, the sand-peat filter provides the greatest benefits.

Storm (1986) designed a system consisting of a rapid-rate sand filter which receives the discharge from the wet-pond. The effluent from the rapid-rate sand filter is released onto a slow-rate sand filter. While this system is highly effective in removing the pollutants associated with suspended solids, it is not as effective in controlling dissolved contaminants. The rapid/slow-rate sand-filter combination is most appropriate for those sites where the discharge from the slow-rate unit can be released onto medium-textured soils. These soils may either exist naturally on the site or may be imported. The water table should not rise within two-feet of the surface where the slow-rate unit effluent is released. As the effluent percolates through the soil column, a significant portion of the dissolved pollutants will be retained, baseflow replenishment will occur, and thermal problems will be resolved.

Mr. John Galli, of the Metropolitan Washington Council of Governments (202)962-3200, has developed a modified version of the sand-peat filter (used extensively for conventional wastewater treatment) which will function as an effective stormwater control practice (Galli, 1989). The filter is contained within an earth-dike and is composed of the following layers (from the bottom to the top):

- a 6-inch deep bed of washed bank-run gravel which is fitted with a perforated underdrain pipe,
- a 24-inch layer of fine-medium sand,
- a 4-inch layer of a 50/50 peat-sand mixture, and
- an 18-inch layer of peat which is planted in grass.

The sand-peat filter should achieve pollutant reductions equalling those associated with infiltration measures. Therefore the filtered runoff issuing from the perforated pipe underdrain should be suitable for release to either ground or surface waters. Ideally the underdrain discharge should be released onto natural soils to recharge the groundwater system and replenish the base flow of nontidal waterways.

Recommendations:

1. The first inch of runoff from all impervious surfaces should be infiltrated. Infiltration should not be practiced on sand or loamy sand.

2. If the first inch of runoff from all impervious surfaces cannot be infiltrated, then runoff should be treated with a wet-pond/sand-filter combination.

3. If the first inch of runoff cannot be infiltrated or treated with a sand-filter, then impervious surfaces should either be reduced, eliminated, or relocated to portions of the site better suited to infiltration.

Erosion Due To Changes In Runoff Velocity & Duration

For the moment the concern is the erosion of channels, not the soil losses associated with the construction phase of golf course development. Converting a tract of land to a golf course may accelerate channel erosion by increasing the velocity at which runoff water travels along a channel. Channel erosion may also be accelerated by prolonging the amount of time the banks and bed are exposed to an erosive velocity (McCuen et al., 1987).

Changes in the maximum rate or duration of velocity may result from increases in the total volume of runoff or by altering channel conditions. An increase in the volume of surface runoff will occur if forest land is converted to grass or impervious surface. Surface runoff will also increase if cropland or pasture is transformed to asphalt, rooftops, or some other impervious surface. Increasing the amount of land draining to a channel will also elevate the volume of runoff delivered to the waterway. The volume of surface runoff may decrease where cropland and pasture is switched to managed turf.

Reducing channel roughness or straightening a channel will increase the velocity at which runoff flows along a channel. A grass-lined channel is less "rough" than one vegetated with dense growing shrubs and trees. The rough channel retards floodwater flow and thereby reduces velocity. Replacing trees with grass allows floodwater velocity to increase along with the potential for channel erosion.

Waterways have a natural tendency to bend and meander. The sinuous nature of waterways has the effect of flattening channel slope. As channel slope decreases so does velocity. Therefore, straightening a channel increases slope and the frequency of erosive velocities (SCS, 1986).

Particular care must be exercised when siting and designing on-channel ponds or off-channel impoundments intended to collect runoff. It is not sufficient to merely design the spillway to release runoff at the same maximum rate (peak-discharge) which occurred prior to construction of the golf course. If the changes associated with the course will cause the volume of runoff to increase as well, then the pond will expose channels to an erosive velocity for a longer period of time, which will increase channel erosion.

Accelerated channel erosion may produce an unstable environment for aquatic organisms and threaten streamside structures. Through the erosion process sediments enter into suspension and may eventually smother productive bottom-dwelling communities, fill navigation channels, block sunlight from reaching submerged vegetation, and impact aquatic systems in a variety of other ways (Klein, 1984). Increases in velocity - both rate and duration - may prove particularly threatening in estuarine areas where wetlands and tidal creeks are highly vulnerable to erosion.

Recommendations:

1. A buffer of woody vegetation should be maintained along all waterways and wetlands. The buffer should extend a minimum of 100-feet from each banktop, shoreline, or the perimeter of wetlands.

2. All changes in land use, drainage area boundaries, and channel characteristics associated with a proposed golf course should be conducted in a manner which maintains pre-development velocity in terms of maximum rate and duration.

3. Where changes in velocity rate or duration are deemed unavoidable, then an analysis should be performed to determine if the changes will accelerate channel erosion. The procedures described in "Policy Guidelines for Controlling Stream Channel Erosion with Detention Basins" (McCuen, 1987) or "Urban Stormwater Management Needs in North Carolina" (Malcom, 1983) can be used to make this determination.

4. If erosive conditions will be created, then appropriate measures must be taken to protect the threatened aquatic resources.

Loss Of Benefits Associated With Flood-Scour

While increases in the erosion associated with flooding may be harmful, a dramatic reduction in scour can also prove damaging to an aquatic ecosystem. Periodic flood scour flushes waterways of accumulated particles of organic matter and fine-grained sediment. Flood scour is also vital to preventing channels from becoming choked with excessive plant growth (Fox, 1974).

The composition of the sediments forming the bed of a tidal or nontidal waterway plays a major role in determining the overall productivity of the aquatic ecosystem. In nontidal streams particles in the 1 to 10-inch size range support the most productive macroinvertebrate communities (Smith and Moyle, 1944; Cordone and Kelly, 1961; Rabeni and Minshall, 1977; Minshall and Minshall, 1977; Sprules, 1947). Tarzwell (as reported in Cordone and Kelly, 1961) found that a stream bed composed of 1 to 10-inch stones produced 14 to 53 more macroinvertebrates than sand. Sprules (1947) found that macroinvertebrates inhabiting stream beds composed of fine particles suffered far greater damage during flood events when compared to communities occupying coarser sediments. Generally, as the abundance and diversity of macroinvertebrate communities increases, so do the population of important fish species (Needham, 1969; Ersbak and Haase, 1983; Donald et al., 1980).

Similarly, the bottom-dwelling organisms inhabiting tidal waters also show a distinct preference for sediment types. The optimum substrate for the macrobenthos of estuaries is composed of 13% to 25% silt-clay, with the remainder being sand (Saunders, 1956; Kaplan et al., 1974). The poorest communities are found on bottoms where the silt-clay content is 78% or greater (Pfitzenmeyer, 1970; Taylor and Saloman, 1968; Sherk).

A reduction in the frequency and magnitude of flooding can cause bottom substrate composition to shift from the coarser material favored by the benthos to finer sediment fractions. In non-tidal waterways silt may be flushed from a streambed and transported downstream by floods which recur 15 to 20 times a year (Wolman, 1968). Sand is transported discontinuously at flows recurring every two-years or so. And cobble bars are eroded and transported downstream by the floods resulting from storms recurring every four to ten years. Once a bar becomes covered with vegetation, it may resist all but a 50-year flood (Fox, 1974). Thus, a reduction in the flood regime may cause a net build-up of sediment within a channel, with a shift towards finer-grained material. Such a shift would reduce the quality of the substrate for macroinvertebrate and fish communities.

Construction of a golf course may result in a reduction in flooding if;

1. the drainage area contributing runoff to a specific waterway is decreased,

2. ponds are constructed which capture a "significant" portion of the runoff generated during major storm events,

3. channels are modified in a way which redirects the point where floodwaters enter a waterway, or

4. channel modifications cause a large decrease in floodwater velocity.

Recommendations: If the design for a proposed golf course will entail any of the four factors cited above, then an analysis should be performed to determine the effects upon nearby channels. The same references which may be used to assess the effects of increased floodwater discharges can also be used to analyze a reduction in scour (McCuen et al., 1987; Malcom, 1983). Both references express the scouring effects of floods as "impulse intensity". Generally, the substrate composition and channel configuration of a waterway should not be significantly affected if the impulse intensity of a range of floodflows is not changed by more than 10%.

Erosion & Sediment Control

If golf course development will involve extensive grading and filling, then large quantities of sediment may be lost during the construction phase. With other types of construction, the sediment lost from a single site can damage 3-miles of waterway with recovery taking a decade to a century (Fox, 1974). The effects of sediment upon aquatic ecosystems have been discussed previously.

Many states and local jurisdictions require the use of erosion and sediment control measures for all activities which expose soil, except farming. These measures can cut off-site damage by up to 90%. And for each dollar spent keeping mud on a construction site, tax-payers save $83 in damages avoided.

Erosion and sediment control measures function in two ways. Erosion control measures are intended to prevent soil from eroding. The purpose of sediment control is to capture the soil particles after erosion has occurred, but before the sediment leaves the construction site.

The two most commonly used erosion control techniques are straw mulching and the seeding of exposed soils with grass. Frequently these two methods are used jointly. Mulching alone can reduce soil erosion by 75% to 90%. Mulching is most effective when the layer of straw covers the soil so completely that bare earth cannot be seen. If grass seed is applied with straw mulch, then erosion rates may be reduced by 95%.

Perhaps the most familiar sediment trapping method is silt-fence; that black fabric placed along the downslope edge of construction sites. Sediment traps, sediment basins, and straw-bale dikes are other commonly used measures. Trapping devices can retain 30% to 70% of eroded soils on construction sites.

Of these two categories of measures, erosion control is obviously far more effective. In fact, trapping devices alone cannot retain sufficient sediment on a construction site to fully protect aquatic resources. Streams and tidal waters will continue to suffer damage until off-site sediment losses are cut by 90% or more (Klein, 1984).

Before construction of a golf course is allowed to begin, the developer should prepare an erosion and sediment control plan for approval by the local government and/or the soil conservation district. Besides demonstrating that all exposed soils will drain to a sediment trapping device, the plan should call for the application of straw-mulching and/or seeding to any area of exposed soil which will remain idle for 14-days or more.

In Maryland, where erosion and sediment control has been practiced since 1970, plans are usually well-designed. It is in the installation and maintenance phase where control quality frequently falls short. Anywhere from 25% to 75% of the active construction sites may be failing to comply with approved erosion and sediment control plans. Therefore the agency responsible for enforcing erosion and sediment control provisions at a proposed golf site must have a record of achieving a high level of compliance. Otherwise significant harm may be done to downstream waters during the construction phase.

Recommendations: Given the relatively poor track record for compliance with erosion and sediment control requirements, how does one ensure that a golf course will not cause excessive sediment pollution during the construction phase? Minimizing soil exposure is one of the most effective ways of dealing with this problem.

1. Greens, fairways, and tees should be laid-out to minimize the need for mass-grading.

2. Clearing and soil exposure should only occur on those portions of the site where construction activity will immediately begin. Although it is cheaper to clear an entire tract at once, this practice may leave soils exposed to erosive forces for months or years.

3. Initial soil exposure should take place in the summer when off-site sediment movement is least likely (78% of sediment transport from a watershed occurs during the winter-spring season; Klein, 1984). Summer is also the time when many aquatic communities are most resistant to sediment damages.

4. Development of steep slopes (20% or greater) and highly erodible soils should not occur.

5. The enforcement agency responsible for overseeing implementation of the erosion and sediment control plan should have a good track-record.

6. Citizens concerned about the effects of golf course construction should take the erosion and sediment control training course offered by Save Our Streams (301-969-0084). Through the course citizens learn how to monitor control quality as construction proceeds. Save Our Streams can also help in the evaluation of the effectiveness of the erosion and sediment control plan.

Wastewater Treatment

The wastewaters generated on a golf course usually come from restrooms, locker-rooms, the kitchen, and laundry facilities. While these wastewaters do not pose any unusual treatment problems, the impact of the treated sewage should be considered cumulatively with all other pollution sources associated with the golf course.

Treatment facilities do not remove all pollutants from wastewater. Some quantity of nutrients, biochemical oxygen demand, and other substances will remain. The effect of the treated effluent upon ground and surface waters must be combined with the impact of stormwater, golf course leachate, and other potential causes of water-quality degradation associated with the proposal.

If a proposed golf course will adjoin a eutrophic waterway, then all sources of oxygen-demand must be considered when evaluating the impact and setting pollutant reduction goals. The quantity of nitrogen leached from greens, tees, and fairways must be added to the biochemical oxygen demand and nutrients leaving stormwater control devices, then combined with the pollutants released from the wastewater treatment facility to assess the cumulative impact of the course upon the over-enriched waterway.

Similarly, the effect of priority pollutants released from the wastewater treatment facility must be combined with those stemming from stormwater runoff and pesticide use. If the wastewater is disinfected with chlorine, then substances such as trihalomethanes (THM) may occur in the effluent. If THM's, arsenic (commonly found in stormwater), and pesticides are released into an aquifer, then the potential threat to humans may increase considerably.

The physical effects of the treatment facility must be considered in combination with all other physical impacts associated with the golf course. The shear quantity of treated wastewater may disrupt the salinity regime if discharged into a relatively small estuarine system.

Finally, the specific wastewater treatment processes proposed for the course must have a record for producing a consistently high quality effluent. Additionally, the company or agency which will operate and inspect the treatment facility must have a good record of success. The discharge monitoring records (DMR's) for existing plants resembling the proposed facility, in terms of design, operation, and inspection, should be reviewed. The DMR's will reveal how often the treatment system fails to meet effluent limitations and the causes of each violation. As a minimum, the system serving a proposed golf course must be designed and operated in a manner which will preclude the same causes from affecting the new treatment facility.

MONITORING GOLF COURSES FOR EFFECTS UPON AQUATIC RESOURCES

A number of suggestions have been offered in this publication for minimizing the effects of a golf course upon aquatic resources. But will they work? There is only one way to find out. Site, design, construct, and operate a golf course according to these guidelines, then look at ground water, nearby streams, ponds, lakes, and estuaries, as well as wildlife and vegetation to detect any adverse affects. The following procedures can be used to establish a baseline for environmental conditions prior to golf course construction as well as monitoring the effects of the facility once it is built.

Biological Monitoring Techniques

The most effective and least expensive way of judging the effect of a golf course upon the environment is biological monitoring. By examining the communities of fish, insects, and algae inhabiting waters associated with a golf course, one can detect the effect of virtually any factor which may degrade the aquatic environment and threaten human uses of these waters. Our study of golf courses in Maryland and Pennsylvania was based solely upon biological indicators (aquatic insect communities). The "bible" for this particular approach to testing the health of fresh, free-flowing waters is "Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish", available from the U.S. Environmental Protection Agency, Assessment & Watershed Protection Division, 401 M Street, S.W., Washington, D.C. 20460 (use order number EPA 444/4-89-01). Unfortunately a similar document does not exist for biological monitoring of ponds, lakes, reservoirs, and estuaries.

The ideal situation for using biological monitoring is one in which a stream originates within the confines of a golf course and the course accounts for most of the watershed land use. In this situation the golf course should be the primary factor determining the health of the stream community. In otherwords should biological monitoring reveal degradation, the golf course would be the most likely source.

If a golf course straddles a stream, which is "nonimpaired" above the course, then one can detect any degradation attributable to the golf course. But, as upstream quality declines, it becomes increasingly difficult to detect any further impact associated with the golf course.

A pond may provide an opportunity to detect any adverse effects associated with a golf course. Obviously both ground and surface runoff should flow to the pond to assess the full effects of the course. Unfortunately procedures for judging the overall health of a pond have not been developed. The best one might do is stock the pond with fish species known to be sensitive to the negative effects associated with a golf course. Sediments and fish tissues from the pond will provide the most reliable medium for detecting pesticide residues. The concentration of a particular pesticide in sediment or fat might be 10, 100, or 1,000 times greater when compared to water.

The effect of groundwater constituents upon aquatic organisms may be assessed using the biomonitoring techniques developed by EPA. In fact, biomonitoring may provide a "relatively" inexpensive means of determining if pesticides are present in water at a level which threatens aquatic life. Furthermore, only biomonitoring can assess the cumulative affects of all of the pesticides present in an aquatic system. It is conceivable that a half-dozen pesticides might be present, yet individually none will exceed EPA's "safe concentration". Yet the combined effects of all six pesticides proves quite lethal to biomonitoring test organisms. Biomonitoring techniques are described in the following publications:

> Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms. EPA 600/4-87/028

> Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. EPA 600/4-87/001

The problem with biological monitoring is that it does not work everywhere. For example, in arid regions one may be hard-pressed to find a stream to sample. If a golf course drains to a tidal system, the sampling techniques are not quite as simple and straight-forward when compared to stream and river settings.

Please give Community & Environmental Defense Services a call (301-329-8194) if you would like to explore the potential for using biological methods for monitoring a golf course. We'll be delighted to help you develop a strategy suitable for your particular situation.

Pesticides & Nitrogen

Both ground and surface waters should be analyzed for nitrogen compounds and all of the pesticides which are presently being used at the golf course. Pesticide analysis should include those substances presently applied to the course and materials formerly used, particularly persistent substances, such as chlordane or metallic compounds (e.g., lead arsenate).

The pesticides of greatest importance are those which are both highly mobile in soil systems and persistent. Table 10, taken from the Cape Cod golf course study, illustrates how pesticides compare in terms of persistence and mobility. A similar assessment can be

TABLE 10: Mobility and Persistence of Pesticides Examined During the Cape Cod Golf Course Study (Source: Cohen et al., 1990)

PESTICIDE	MOBILITY	PERSISTENCE
2,4-D	High	Low
2,4-DCBA	High	High
dicamba	High	Medium
dacthal diacid	High	Medium
MCPP	High	Low
siduron	Medium	High
PCP	Medium	High
iprodione	Medium	Medium
trichloropyridinol	Medium	Medium
diazinon	Medium	Medium
isofenphos	Medium	Medium
chlordane	Low	High
heptachlor epoxide	Low	High
dacthal	Low	Low
chlorothalonil	Low	Medium
chlorpyrifos	Low	Medium
anilazine	Low	Medium

developed using EPA's Pesticide Root Zone Model (PRZM). For further information on the PRZM model contact the Center for Exposure Assessment Modeling, U.S. Environmental Protection Agency, College Station Road, Athens, Georgia 30613-7799, at (404) 546-3549.

As a minimum the nitrogen species nitrate and ammonia should be monitored. Excessive nitrate levels may cause abundant algal growths and can threaten human health at a concentration of 10 mg/l N or greater. Ammonia is extremely toxic to aquatic life (see Quality Criteria for Water, cited as EPA, 1986c in the references section, below). Generally ammonia will pose the greatest threat to aquatic life when transported by stormwater to surface waterways.

Horsley and Moser (1990) described a strategy for monitoring the effects of golf course pesticides and nitrate upon ground water. Clusters of monitoring wells are located "up-ground-water-gradient" of the golf course and within fairways, greens, and tees. Each cluster consists of three, 2-inch wells. Each of the three wells in a cluster is screened at a different depth in the aquifer lying beneath the course; at the top, at mid-depth, and at the bottom of the water-bearing strata. Such a monitoring well arrangement allows one to detect pollutants with varying densities. A single well might sample groundwater above or below a plume of pesticides flowing from a golf course.

Monitoring frequency poses a problem, particularly for pesticides. Periodic well monitoring, say quarterly to once annually, may miss temporary surges of pesticides. These surges are most likely in highly permeable materials, such as sandy soils (USGA 1990). Due to the relatively high cost of pesticide analysis, it is difficult to monitor with sufficient frequency to detect any surges that may occur.

Surface water monitoring should be designed to sample stormwater runoff from treated portions of the course. The base flow of waterways associated with the golf course should also be tested for pesticides and nitrogen compounds. And, as previously mentioned, sediments in ponds or tidal water draining a golf course should be analyzed for toxic compounds to determine if significant off-site movement is occurring.

Other Chemical Characteristics

If groundwater will be used as a source of irrigation water, then contamination may occur by pulling water in from other sources. Pumping may draw pollutants from deeper aquifers or surface water bodies. If a golf courses is located close to tidal waters or a polluted waterway and groundwater will be used for irrigation, then monitoring wells should be installed to detect the movements of contaminants as a result of pumps operated at the golf course.

If unlined ponds are constructed on coarse textured soils, then groundwater beneath the pond should be monitored as well, particularly if the pond receives stormwater runoff from impervious surfaces (roofs, parking lots, or streets) or if fairways, greens, or tees drain to the pond.

Base Flow

The dry weather inflow (base flow) to a stream, lake, or tidal body is composed of groundwater. If irrigation water will be drawn from wells, then dry weather may be diminished. Obviously pumping water directly from a stream or other surface waters may diminish base flow as well. If irrigation water will not come from runoff collection ponds or a municipal supply, then a baseline should be established prior to golf course construction.

The baseline should be created by monitoring base flow volumes. If the course straddles a large waterway, then a monitoring point should be established sufficiently far upstream of the course to avoid the effects of irrigation withdrawals. The downstream monitoring point must be selected to detect the full effects of the water diversion. A year or so of data should be sufficient to establish the normal variation in flow between the two points.

If the golf course is located on a small waterway, then a comparison can be made between the flows in the affected waterway and that of another stream, known as the "control" which must have similar characteristics. By monitoring flows on both waterways a relationship can be established between the two. Once irrigation withdrawals begin the affects can be detected by noting any change in the flow relationship. For example, the affected waterway may consistently carry 85% of the flow of the control, but drops to 70% abruptly following the onset of withdrawals.

But base flow monitoring has little point unless criteria have been established for assessing flow conditions. Ideally one should use a system, such as the Instream Incremental Flow Methodology (see the section on base flow), to establish the minimum amount of water needed to maintain the values associated with the waterway.

Wells

Using groundwater as a source of irrigation water may affect other wells in the vicinity of the golf course. A thorough pump test must be conducted prior to the onset of groundwater use to assess the potential impact upon other well users in the area. The test should be conducted at the maximum projected pumping rate. The results of the test should be used to project the cone-of-depression under drought conditions. If the cone-of-depression for production wells will adversely affect existing wells, then alternative water sources must be provided for irrigation and/or other ground water users.

Stream Temperature

Stream temperature may be elevated as a result of reductions in base flow (irrigation practices), the release of heated water from ponds, stormwater runoff from impervious surfaces heated by the summer sun, and a reduction in the amount of shade along a waterway. The temperature of any streams affected by the golf course should be monitored. Continuous temperature recorders should be used to detect any short-term increases, such as those associated with storm events or brief decreases in base flow. Check with your State fishery biologists or the U.S. Fish & Wildlife Service to learn of temperature standards applicable to waters affected by the golf course. Maximum water temperature normally occurs in July and August, in the afternoon, on cloudless days.

HOW COMMUNITY & ENVIRONMENTAL DEFENSE SERVICES CAN HELP

If you are concerned about a proposed golf course, then we can help you to evaluate the site to determine if it is suitable and what steps must be taken to minimize the potential impact upon your interests and aquatic resources. Ideally our evaluation should include a visit to the site to investigate conditions first-hand, including soils, depth to bedrock and the water-table, and to assess the vulnerability of nearby aquatic resources to golf course related impacts. But we can also conduct a "paper-review" by looking at the plans for the course and other data, such as the county soil survey.

If you live near an existing course, then we can help you to determine if the fairways, greens, and tees presently affect the quality of your well-water, your favorite waterway, or some other feature of importance to you. Specifically we can help you find the quickest, least expensive ways of assessing the impact upon your interests. For example, we would encourage you to use a $50 biological technique to assess the impact upon a stream rather than $5,000 worth of pesticide analyses. If biological analysis indicates degradation, then we'll show you how to get your State pollution control agency, the U.S. EPA, or the golf course owner to run the expensive tests needed to identify the cause of the degradation.

Additionally, Community & Environmental Defense Services is more than just environmental scientists. We're also skilled negotiators, political activists, legal tacticians, and fund-raisers. We would be delighted to assist you in finding a "win-win" solution for your concerns. In otherwords, if there is a way to allow for the construction of a golf course, while fully protecting your interests, we'll know of it. We can then negotiate on your behalf with the golf course developer to gain an iron-clad commitment to the implementation of these solutions. If, on the otherhand, the developer refuses to negotiate in good faith, then we can offer you a variety of tactics for increasing your negotiating leverage. We can also help you raise the funds and develop the political clout crucial to success.

Community & Environmental Defense Services is the only consulting group in the nation which specializes in helping individuals and citizen groups to protect their interests from threats associated with land development and environmental issues. In otherwords, we never work for the folks who build golf courses or shopping centers. We established this policy not because we feel golf courses or development is bad; quite the contrary, we believe that both can be environmental assets. We only work with citizens because that's what we're best at and its where the greatest need exists. You benefit from this policy because it has allowed us to learn what works and what doesn't work when it comes to winning land development and environmental issues, which is just another way of saying that we can help you do all the things that lead to victory and avoid the mistakes which bring defeat.

So please give me a call at 1-800-773-4571 and I'll be delighted to chat with you about your concerns. There will be no charge for our first phone conversation.

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