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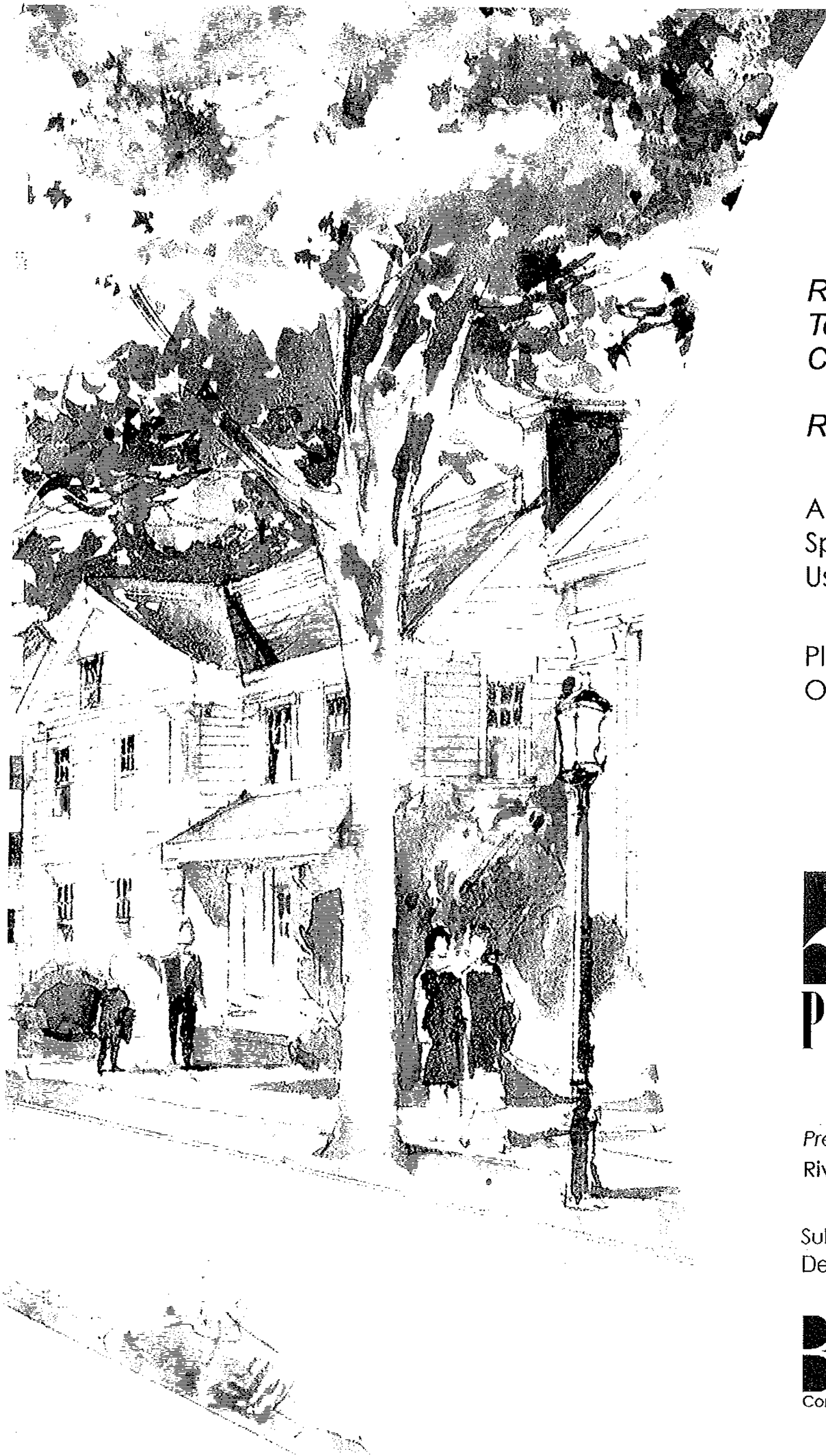

Response to Town Review Comments

Response #3

Application for Special Exception Use

Planning Commission
Old Saybrook, CT

THE PRESERVE

Prepared for:
River Sound Development L

Submitted
December 8, 2004

BL Companies

PLANNING COMMISSION EXHIBIT #103

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I. Executive Summary

The applicant has received numerous comments from town staff and has heard various topics of discussion from the public. The applicant has already submitted responses to some of these comments (November 10 and November 17). This is our third set of responses.

As summarized by the commission's counsel the planning commission must make the following six decisions regarding this Special Exception application proposed by River Sound Development LLC:

1. ***Is the site more conducive to an Open Space Subdivision in general conformance with the plan proposed by the applicant, or is it more conducive to the development as a conventional subdivision?***

2. ***If the site is more conducive to an open space subdivision, what is the proper number of lots to be derived from the yield plan?***

3. ***Once those yield plan numbers are determined, should the proposed Preliminary plan be approved as submitted or should it be modified/conditioned and approved?***

4. ***If conditioned/modified, in what way?***

5. ***Is the open space subdivision as proposed by the applicant (i.e. golf course, road pattern, etc) "reasonably likely to unreasonably impair, pollute, or destroy the public trust in the air, water, or other natural resources of the State" as compared to the conventional subdivision?***

6. ***Are there feasible and prudent alternatives that would reduce or eliminate any unreasonable adverse impacts that are found to exist?***

The contents of this response are organized around these six decisions. The response takes into consideration the testimony presented by the public and questions raised by the commission and town staff up to and including the hearing of November 17. It does not respond to all review comments received after December 1, 2004. The applicant will take into consideration recently received comments. Written responses and any plan changes will be filed in the land use office on or before December 23, 2004.

During the summer of 2002 this commission recognized the need to implement regulations that ensured the conservation of open space in large undeveloped tracts, primarily north of Interstate 95. Ultimately, the Old Saybrook Zoning Commission followed your lead, and modified and approved regulations to meet this goal. The objective of this modification was to provide flexibility in site design to ensure land conservation is attainable. River Sound firmly believes the most amenable, and the appropriate, form of development of the property is a conservation open space subdivision plan (called an 'Open Space Plan' in this report in order to avoid confusion).

The applicant has submitted per the regulations a conceptual standard plan that realistically meets the regulatory mechanisms defined in the regulations. This plan demonstrates that 293 home sites could be developed on this property and that each home site could conform to the requirements of Section 56.3.1 including ALL criteria to meet the minimum area of buildable land. The plan also demonstrates that each house lot could support onsite septic areas - published literature and actual on site testing supports this. Furthermore, the plan takes into consideration typical review criteria employed by the planning and wetland commissions (as evidenced by past deliberations and approvals) as well as the board of selectmen's policy statement for alternative roadway design standards.

The Applicant stands by their determinations. However, the applicant will consider the NLJA memorandum as well as other recently received staff comments in its further response.

Flexible design guidelines are essential to ensure land conservation-- guidelines such as those provided by the new regulations and implemented in the proposed open space plan. This flexibility allows us to respond to the landscape resources within which the development is to be situated. The open space plan proposed by the applicant is the result of more than two years of planning and research ensuring that the landscape is understood and a plan created which responds to the site resources. The applicant has presented information specific to these resources and proposes an open space plan that respects them and meets the purpose of the open space subdivision regulation.

II. Response to Comments

<u>Decision 1</u>: ***Is the site more conducive to an Open Space Subdivision in general conformance with the plan proposed by the applicant, or is it more conducive to the development as a conventional subdivision?***

The conventional subdivision regulations necessarily result in a large-lot sprawling subdivision-- the by-product of existing regulations similar to the Conceptual Standard Plan provided as part of this application. It was strict requirements such as MABL that influenced sprawl and habitat fragmentation. Other than 'no development', the principles of open space plans, and the regulations that guide them, are the strongest means to control sprawling development and to conserve habitat and significant landscapes.

To determine if such an open space plan is the "proper development method for the property" the commission must evaluate the results associated with each development philosophy and consider them in relation to the property's characteristics. Randall Arendt, FRTPI, provides the following remarks on this matter:

> "One does not expect very much at all, in terms of land conservation or the preservation of significant natural and cultural features, when conventional layouts are designed. And the poor results justify those very low expectations, providing no undivided, permanently protected open space. By contrast, however, a Conservation Open Space Plan is deliberately designed around the central organizing principle of conserving the most significant resources on a given property, as the first step in a four-step design process. And it is also designed to help create an inter-connected network of conservation lands, environmental resources, and passive recreational opportunities. If one assumes that the Town would prefer more land to be protected in perpetuity (based on policies in the Plan of Conservation and Development, and also based on its zoning ordinance purpose statement and provisions), there would seem to be little question that the Conservation Open Space Plan approach is very much the most appropriate design methodology on this large tract of land, with its variety of slopes, soil types, wildlife habitats, and historic features."

Michael W. Klemens, Ph. D., offers the following comments on environmental testimony relevant to this question:

> "In response to Dr. Craig's testimony, which discusses the merits of the open space plan vs. the conventional plan, here are my thoughts on this issue, stated once again for the record. The discussion at hand here is not about whether the site be preserved through acquisition and left undeveloped. Members of the team, including myself, have said that complete protection of the site (the no-build alternative) would be the best conservation solution for this site. In the absence of such a solution, conservationists face a very different set of issues here--if the site is to be developed, what methodology is the preferable manner to design the development? Which methodology, the conventional plan or the open space plan, will allow us to incorporate best available science into the decision making process? Much of the public testimony has advocated that the site should be

protected in its totality, and has not focused on the question before the Old Saybrook Planning Commission that if development occurs, how should it be designed? My support of the open space plan, as stated in the following paragraphs, does not mean that I choose this approach over total protection of the site, but that I choose this approach over the conventional development option for this site. I see a gradation of options available on the site, ranging from total protection to conventional development. Of all of the options, the one that will ensure the ecological destruction of the site's biological diversity is the conventional plan, which while protecting wetlands will not protect the wildlife that occur within the wetland and watercourse systems—of which vernal pools are an integral part.

Recent court decisions (see memorandum from Gregory W. McCracken to Michael W. Klemens dated November 30, 2004—contained in the Appendix A) provide the legal justification for my approach to (and support of) the open space subdivision as the best (and legally supported) pathway to conserve vernal pools. Under the conventional plan all wetlands and watercourses have a 100 foot regulated area around them. This is not an area that prohibits intrusion under permitting. In fact RSD has provided information into the record, demonstrating that permitting intrusions into the 100 foot regulated area is frequently part of the approval process in Old Saybrook. Under current law, the regulated area around a vernal pool in a conventional subdivision is 100 feet—the same as with any wetland/ watercourse, which under a conventional subdivision is the status that is granted to a vernal pool, with the same potential for intrusions into this zone as for a wetland/ watercourse. There has been repeated discussion by the public and the Town's consultants that the vernal pool envelopes should be protected in the conventional subdivision. The conventional plan would eliminate the biodiversity of the vernal pools, because a vernal pool envelope without the critical upland habitat zone of 100-750 feet surrounding the envelope reduces the vernal pool to a wetland/watercourse resource without its attendant biodiversity. It would be akin to protecting the heart, but eliminating the arteries, veins, and capillaries. That is why that if development is to occur on this site, the only way the conservation goals that I have consistently espoused in my more than 25 years of research, publication, and practice can be met, is through an open space plan

Finally, I cannot ignore the testimony of Attorney Ranelli of Shipman and Goodwin, LLP and Mr. George Logan of REMA on behalf of the town of Essex requesting extensive upland habitat protection of vernal pools within the context of the conventional subdivision. The Old Saybrook Planning Commission and the public at large should be aware of the *currently* (many individuals and organizations are working to rectify the ecological damage of this decision) defining case of AvalonBay Communities Inc. v Inland Wetlands Commission of Wilton. This is referred to in Mr. McCracken's Memorandum to me dated be ensured through a Conceptual Standard Plan, the intent of the Conservation Open Space Plan is to allow the flexibility for such protection.

We can't emphasize enough that the very significant features sought for protection might not be fully protected in the conventional subdivision plan, and certainly would not be protected to the extent that can be provided in the open space plan.

It has been suggested that the Conceptual Standard Plan should also show a golf course within the layout of the home lots. It is not the intent of the conceptual standard 'yield plan' to duplicate or predict the character of the open space development, but simply to establish a dwelling density. The golf course lot in the Conservation Open Space Plan does take up land area that would be "yards" in a conventional subdivision. But that is the whole point of the combination allowed under the Residence C District regulations; the active recreational golf course use, cluster housing and individual building lots of varying sizes, in an integrated plan. The golf course lot is a stand-alone parcel--privately owned. Some communities (Marlborough, CT for example) allow a golf courses as an allowed active recreation use within open space (private or municipal) and can be included towards meeting the minimum open space calculation. Golf courses are a recognized and accepted use within open space. However, the proposed Preliminary Open Space Plan does not require any of the golf course lot in order to meet its minimum of 50% open space. In fact the minimum requirement is actually exceeded, WITHOUT the use of any land within the golf course property. We could have spread the housing units over the remaining non-required open space portion of the property, but chose instead to cluster them on 20% of the land, leaving the rest of the land available for the golf course/ active open space use

<u>Decision 3</u>: ***Once those yield plan numbers are determined, should the proposed Preliminary plan be approved as submitted or should it be modified/conditioned and approved?***

<u>Decision 4</u>: ***If conditioned/modified, in what way?***

Before making the above determinations, the commission must understand the benefits the Preliminary Open Space Plan has on the environment. These benefits have been discussed by the Applicant in detail and in writing as responses to staff comments. We respectfully request that the commission carefully weigh these factors – which are a culmination of almost twoyears of extensive on site studies and planning.

Decisions on these points 3 and 4 are actually dependent on the results of decisions 5 and 6—all are interrelated.

It should also be noted that the commission and staff does not have the benefit of detailed engineered plans which implement the design and engineering techniques that can address the concerns of the public and issues raised by staff. That level of detail is beyond the requirement of the regulation. The commission should weigh the fact that specific techniques exist and have been identified to address concerns, and respect the fact that detailed engineering plans are not required at this stage.

<u>Decision 5</u>: ***Is the open space subdivision as proposed by the applicant (i.e. golf course, road pattern, etc) "reasonably likely to unreasonably impair, pollute, or destroy the public trust in the air, water, or other natural resources of the State" as compared to the conventional subdivision?***

<u>Decision 6</u>: ***Are there feasible and prudent alternatives that would reduce or eliminate any unreasonable adverse impacts that are found to exist?***

If the commission's determination under <u>Decision 1</u> is that the site is more conducive to an open space subdivision - the commission has therefore determined that the proposed Preliminary Open Space Plan is not *"reasonably likely to unreasonably impair, pollute, or destroy the public trust in the air, water, or other natural resources of the State" <u>as compared to the conventional subdivision.</u>"* Nevertheless the applicant offers the following responses to comments and testimony that may relate to these particular issues:

The following responses are made by Mr. Klein to comments relevant to his area of expertise - wildlife and plantlife and their relationship to the site's ecology:

<u>Comments by Dexter Chafee-</u>

We appreciate the time and energy that went into the preparation of the list submitted on Mr. Chafee's behalf by Mr. Kryder. We have little doubt that it documents birds that Mr. Chafee observed in the vicinity of the Essex Meadow property. However, it is not useful for evaluating the impact of the proposal on avian resources. With a few minor exceptions (e.g., winter roosting sites for eagles and owls or feeding locations for certain shorebirds), the relevant standard (as per CT DEP and federal permitting requirements) for characterization of avian resources is a breeding bird survey. The survey submitted by Mr. Kryder is NOT a breeding season survey and also does not distinguish "use" (breeding, perching, feeding, singing) from incidental observations (e.g., fly-overs). With regard to the specifics of the list, I would note the following:

- The list includes forty-four (44) species for which no suitable breeding habitat exists on the site, including common forms as well as some state-listed species. Some of these species are present in CT only as migrants and do not breed in the state.

- The list includes forty-three (43) species already confirmed as breeding species at the Preserve site.

- There is no breeding habitat present at The Preserve for the state-listed American Bitterns or King Rails. These species breed in tidal and freshwater marshes.

- The list includes nine (9) species of hawks. The fall migration period typically results in observations of numerous species of hawks throughout

CT. Hawks will continue to pass through CT during migration, regardless of how The Preserve site is developed.

- The list includes three species of gulls, none of which are of conservation concern.

- The list includes Eastern Bluebird, which would not breed at the site in its present state, but which has been documented to thrive on golf courses when appropriate houses are provided and maintained. The final detailed plans for the project will include numerous habitat enhancement measures. Bluebirds are one species that we would expect would benefit substantially from active management (others would include Purple Martins, Tree Swallows, and various bats).

- The list includes eighteen species of common birds, including Cardinals, House Wrens, Mourning Doves, Chickadees, Tufted Titmouse, Blue Jay and Flicker, whose populations would be expected to increase if the project is built.

- The list includes nuisance species like House Sparrow, Canada Goose and Mute Swan, which are not present at the site. Management practices would be instituted at the site to reduce or eliminate the likelihood that these species would become a nuisance on the property.

- The list includes grassland birds such as Savannah Sparrow, Eastern Meadowlark, and Bobolink. The Essex Meadow property includes grassland habitat , but there are no grasslands now on the Preserve site. It should also be noted that grassland birds typically require unbroken grasslands that are tens to hundreds of acres in size (and which are not mowed from April through August) to breed successfully. However, it is possible that some of these species can be "tricked" to breed in small patches of created grassland if they are adjacent to extensive open areas (e.g., fairways and roughs).

Most importantly, there is no question that the Open Space plan has less impact on avian and other biological resources than the conventional subdivision. Furthermore, the portion of the Preserve site that abuts the Essex Meadow property is part of a 100± acre area that will be dedicated for permanent conservation and passive recreation in the open Space subdivision plan.

<u>Comments by Dr. Craig-</u>

Dr. Craig presented initial results from a significant data collection and analysis effort. He provided empirical data to support the theoretical, bio-geographic argument that a system of large, heterogeneous conservation reserves provide habitat for more species than a system of smaller, homogeneous reserves. We agree. Its particular relevance to the Preserve site may be limited, since Dr. Craig's study area includes the entire area east of the Connecticut River, east to Rhode Island and north to Massachusetts. Furthermore, while The Preserve site lies near the coast, it does NOT represent the coastal forest vegetation type (with dense thickets of vines) that Dr. Craig discussed. Most importantly, there can be no doubt that the dedication of 514± acres of the site to permanent, year-round conservation use (as well as the availability of an additional 219± acres at the golf course for winter habitat) is a substantial improvement over a conventional subdivision, in terms of preservation of avian bio-diversity.

Comments by George Logan

With regard to Mr. Logan's comments that the data acquisition effort was insufficient, we would note that the total biological inventory effort at the site was approximately 700 hours of detailed survey work. This does not include field work associated with wetland delineations, functional assessments and impact assessment. In our opinion, the flora and fauna at the site have been thoroughly categorized. The survey team did not identify any CT or US Endangered or Threatened species at the site, during a survey that covered 2 growing seasons. We did identify two reptiles, 3 plants, and one bat species that are classified by the State of Connecticut as Special Concern. The design protects these species via open space set-asides, conservation easements, and special design measures. Furthermore, areas that had historically been identified as supporting state-listed species are also included in open space areas.

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Santiago, M. J. and A. D. Rodewald. Considering Wildlife in Golf Course Management. The Ohio State University Extension. Fact Sheet W-15-04

Terman, M. R. 1997. Natural links: naturalistic golf courses as wildlife habitat. Landscape and Urban Planning. 38:183-197.

Benefits of a Homeowner's Association in Assuring Conservation Goals

Under the Common Interest Ownership Act, Chapter 828 of the General Statutes ("CIOA"), the basic function of a homeowners' association (HOA) is diverse. An HOA can provide maintenance, repair, replacement and blanket insurance of buildings and improvements that lie outside of individually ownable units, which may include individual building lots; to regulate and maintain open space, driveways, parking areas, recreational amenities, and other common elements in the community (including lawns); to administer architectural control provisions; and to operate any recreational amenities. It may own, operate, and maintain a community sewerage system. An association may be unincorporated or incorporated as a non-stock, non-profit corporation under Connecticut law. The association may assess the expenses of its operation against the owners of the units in the common interest community. A common interest community the size of The Preserve would have an incorporated association.

A declaration creating a common interest community may limit activities within individually ownable units that affect other units or the common elements by means of use and occupancy restrictions. The association may enforce such restrictions. The association also may enact and enforce rules and regulations concerning activities in common elements that lie outside of ownable units. Through the application of these use and occupancy restrictions and rules and regulations, an association would have the authority to limit activities by residents of The Preserve that would have an adverse environmental impact, such as the use of lawn chemicals, for example. The Association will have the authority to enforce the rules established by the Declaration of Restrictive Covenants by use of liens, litigation and all other remedies. The Association will charge fees on either a monthly or quarterly basis to the homeowners to fund the budgeted costs of the Association's responsibilities.

The establishment of the Association will not only ensure environmental compliance, but also architectural and maintenance standards and create a harmonious atmosphere which ensures the property will operate at the level intended by the developer.

<u>Control of Lawn Management by the HOA: Comments by Stuart Cohen, ETS</u>

One basic function of the homeowners association at The Preserve will be to administer the maintenance of lawn care on all lawns within the development. This includes not only the village lots but also the estate lots and ¾ acre home sites. Administration and enforcement of this includes the controlling and restricting the application of chemicals (organic or inorganic) to lawns by either the homeowner, private contractor or association owned property management.

No matter the management entity all persons must adhere to the strict guidelines set forth by the association on this matter. The HOA proposes a strict set of guidelines to be followed by ALL such persons. These guidelines include

- the adherence to the Lawn Care Integrated and Turf Management Plan (not to be confused with the Golf Course ITPMP)
- approval of the application of materials including type, quantity, and time
- posting of application
- posting of approval to apply said materials

If an homeowner or hired contractor does not adhere to these guidelines under the Common Interest Ownership Act the association has the authority to enforce the regulations imposed by the HOA. This enforcement may include fines or other means such as remediation at the homeowners expense.

In contrast, conventional subdivisions (such as shown under the Conceptual Standard Plan) will likely have no association for this purpose. Therefore the mechanisms to control such elements typical of a residential development such as chemical applications do not exist. Homeowners will be left to their own free will to place fertilizers and other chemicals on their lawns with no restrictions and certainly no regulatory controls such as currently exists through out Old Saybrook.

If one were to complete a detailed analysis comparing the two types of developments it would be clear that the most beneficial means of application is one under the guides of an HOA whose management documents are also approved by the Zoning Commission under the PRD regulations.

The applicant has completed such an analysis and has determined the following:

Under the Conceptual Standard Plan, 293 houses could be built, with the estimated total lawn areas being 250 acres. Under the Open Space Plan, housing will have an estimated total lawn area of 40 acres and the areas of greens, tees, fairways, and roughs that receive nitrogen application are 4.7, 4.7, 28.7, 52.2 acres, respectively.

Nitrogen use under each plan was calculated based on the areas of the lawn and the golf course that potentially receives nitrogen application. The proposed maximum nitrogen application rate for the lawn is 3 lb per 1000 ft^2 per year (130.68 lb/ac/year). According to the Integrated Turf and Pest Management Plan (pp. 31-24, December, 1999), the maximum nitrogen application rate for greens, tees, fairways, and roughs are 261.36, 261.36, 180, and 90 lb/ac/year. Based on these data, we calculated that the maximum nitrogen load would be:

- 32,670 lb/year under the Conceptual Standard Plan
- 17,548 lb/year under the Open Space Plan

Therefore, the nitrogen use under the Open Space Plan is approximately half of that under the Conceptual Standard Plan.

In addition, the application of nitrogen in the golf course is timed to meet turf growth need only ("Spoon feeding", i.e., more frequent applications but at smaller amounts for each application). Therefore, this reduces the excess nitrogen available for leaching and runoff relative to homeowners who might apply all nitrogen over two or three actions throughout the year. This will significantly reduce any potential environmental impacts for the golf course (the Open Space Plan) relative to the Conceptual Standard Plan. If necessary a detailed calculation processes can be provided.

Control of Sanitary Wastewater

Under a homeowners association a managed wastewater treatment system provides an exceptional means to control harmful pollutants that are associated with unmanaged individual septic systems. A managed system provides exceptional effluent quality and ensures water quality on and offsite is maintained. In contrast to onsite individual septic systems a community system is highly regulated on an ongoing basis. An individual system has limited regulatory monitoring and no mechanism to ensure water quality is not affected and that regular maintenance occurs to ensure its function.

The treated effluent for a community system will meet drinking water criteria for many parameters. The effluent leaching field will serve as the medium to distribute the treated effluent to the ground, not as the primary means of treatment, but to provide final treatment and polishing for even less impact to the environment. This will reduce the amount of nitrogen, phosphorus, and other elements being discharged to the ground water by up to 96% compared to a conventional septic system.

Quarterly monitoring of ground water down gradient of the system and annual reports to the CTDEP are required for compliance with the wastewater discharge permit for the community system. Mechanical components are all redundant and built in two trains, such that the treatment process is rarely interrupted. In addition, because of the high degree of treatment, the discharge to the leaching fields is primarily liquid, such that the potential for the effluent leaching field to clog is also minimal. Conventional systems have no requirement for monitoring other than mandatory pumping every five years and no assurances of treatment and continued operation. The end result is that the community septic system is better for the environment and can be effectively managed and controlled by the homeowners association.

The Golf Course: Turf Management and Potential Environmental Impacts

Several persons raised questions and expressed concerns about turf management techniques at the golf course, and potential offsite impacts on water quality. Although these issues are not directly relevant to the decision that will be made by the Planning Commission, they are indirectly related and may be of interest to the Commissioners. Therefore responses to these concerns follow, in the approximate order in which the issues were raised at the November 17 hearing.

Water Quality Monitoring

As stated in oral testimony provided on November 10, River Sound Development will submit comprehensive water quality monitoring protocols as part of the golf course Special Exception and wetlands commission review phase. Our internal review draft builds on the protocols that were accepted during the previous inland wetlands permitting process. The current protocols update and refine the previous submission based on comments in the record and our own peer review. We concur with the public comment (Mr. Kryder) in this area, i.e., it is important to address sampling frequency, responses to detections, distribution of reports, and all of the other technical factors that constitute a valid protocol. River Sound Development can provide substantive comments to each of these points at the appropriate time. Additionally, these protocols will be reviewed by outside expert consultants hired by the Town .

Potential Water Quality Impacts

Several members of the public expressed concerns about potential impacts on ground water quality and water quality as effects rivers . We respond to this concern several ways. First, we provide a context of actual monitoring results. Then we discuss proactive steps to ensure water quality protection at this site. Finally, we respond to a misleading statement made by a Selectman.

In the late 1990s, ETS conducted a metastudy - - a comprehensive evaluation of the results of other studies - - of ground water and surface water monitoring results from 36 golf courses around the country. We published our work in the scientific peer-reviewed literature (Cohen, S.Z., A.J. Svrjcek, T. Durborow, N.L. Barnes. 1999. "Water Quality Impacts by Golf Courses," J. Environ. Qual., 28(3):798-809 – Appendix B.) We evaluated results for pesticides, nitrates, and solvents. A copy of this study is attached.

Detections of pesticides were infrequent, and detections at concentrations exceeding toxicity guidelines were rare. Most of these courses did not have the benefit of the proactive environmental stewardship program that is being developed for The Preserve. As demonstrated in the risk assessment/risk management pyramid presented on November 10, a strong U.S. EPA scientific and regulatory program underlies state and local regulation. Millions of dollars of multidisciplinary test data are carefully reviewed over a several-year period by EPA scientists before decisions on specific permitted use patterns are made. Then a subset of these products is permitted for use by the Connecticut Department of Environmental Protection (CTDEP).

The comprehensive risk assessment and risk management program that has been developed for The Preserve constitutes a *de facto* third layer of regulation on top of this strong regulatory base. The three-prong program consists of a risk assessment (with a state-of-the-art consideration for amphibians), a turf management program using integrated pest management, and a comprehensive water quality monitoring program.

Finally, it is important to note that the point of compliance for our risk assessment and the resulting risk mitigation measures is the on-site vernal pools for runoff and shallow ground water immediately under the site. If water quality at the site is protected, then there is no threat to offsite water resources such as wells and rivers.

This comprehensive technical program will be submitted and explained in detail during the future regulatory review process.

There are two related topics that were raised by speakers at the hearing: First, Carolyn Longstreth, on behalf of the Connecticut Fund for the Environment, submitted to the Commission a document on ground water contamination by golf courses. It is six pages from a USGS website visited 11/3/04, and the title is "Pesticides Used on and Detected in Ground Water Beneath Golf Courses" (Appendix C). Unfortunately, the CFE representative only copied the first three columns of the five-column website. A casual review of the exhibit by a busy commissioner might lead him or her to believe that pesticide detections in ground water under golf courses is extensive. We have attached the complete version of this web report, and it is clear by reviewing the previously missing column 4 that pesticides have been detected for only a fraction of the chemicals and states listed in columns 2 and 3.

Second, Essex Selectman Philip Miller stated, "Golf courses are notorious for reliance on petrochemical fertilizers that don't break down into natural things." <u>This is grossly misleading</u>. Turfgrass takes up the natural compounds nitrate and phosphate from soil as nutrients (fertilizers). Therefore any fertilizer applied will not be effective unless it breaks down into these natural molecules. The three fertilizer nitrogen sources that are either *the* most common or *among* the most common are 1) urea, a natural molecule; 2) its precursors in slow-release products - - IBDU and methylene urea; and 3) a wide range of natural "organic" products, such as composted poultry waste.

<u>Mowing Fairways</u>

Finally, during the November 17th hearing, Commissioner Gallicchio inquired about mowing practices. Dr. Cohen answered her question about mowing heights for fairways by stating they are usually ½" to 1". We would like to modify that answer slightly to ½" to ¾", three to four times per week (usually on Mondays, Tuesdays, Thursdays, and Fridays). This frequency is typical to minimize the accumulation of grass clippings on the fairways.

Response to Public Comment – Golf Course Irrigation Demands:
Comments by Sam Haydock LEP, BL Companies, Inc.

This section provides additional response to questions raised by Planning Commission members and the public regarding irrigation water demands for the proposed golf course at The Preserve.

In a submittal to the Planning Commission dated November 17, 2004 " Response to Town Review Comments, Response #2, Application for Special Exception Use, Planning Commission, Old Saybrook, CT", BL Companies stated the following five points regarding irrigation demand:

- Irrigation demand is based on the total number of irrigated acres of fairways, tees, and greens.

- The irrigation season for a typical New England course is April to October (approximately 210 days per year). The irrigation wells will not be used from November to April, and therefore, there is not a continuous withdrawal on the bedrock aquifer.

- Average irrigation demand ranges from 50,000 gallons per day (GPD) in spring and fall to 250,000 GPD in July. During drought conditions in July or August, demand can increase to approximately 300,000 GPD. Average annual use is expected to range from 18-26 million gallons per year (MGY) (50,000 GPD to 70,000 GPD)

- To put these numbers in perspective, a 1,000-acre site in Connecticut, which receives 44" of precipitation per year, will recharge between 300 and 600 MGY to the bedrock aquifer (assuming only 25-50% of the precipitation is available for recharge). The amount of water required for irrigation is less than 5 to 10 % of this annual recharge. This is conservative, because this analysis does not take credit for off-site areas that can also provide recharge to the bedrock aquifer beneath the site.

- Peak irrigation demands will be met from a combination of pumping the wells and withdrawal from storage ponds.

During the public hearing held on November 17, 2004, a member of the public quoted the National Golf Foundation (NGF) when he stated that golf courses can use 220 MGY of water. Reference also was made to a course in Southwick, Massachusetts that reportedly uses over 290 MGY of water for irrigation. Another member of the public stated that the course he plays uses 275,000 GPD of water. These statements grossly overstate the amount of water needed and requested for the proposed golf course at The Preserve.

The National Golf Foundation (NGF) published 1998 water use data in 1999 ("Operating & Financial Performance Profiles of 18-Hole Golf Facilities in the U.S."). The report contains data from 43 private courses in the coastal northeast region. The median of average annual water use for these 43 private facilities is 31.8 MGY. The parallel number for daily fee courses, based on responses from 30 courses, is 18.2 MGY. Both numbers are significantly lower than 220 or 290 MGY. It appears that data from south Florida golf courses during the summer season, with an assumed 365-day summer, using only the upper 95th percentile of water use in that region at that time, was used to generate the 220 MGY figure. (This would be equivalent to applying 90 inches of water to the managed turf, in addition to the 45 inches of rainfall that Connecticut receives annually.) This figure is not relevant to the current application.

With respect to the reference to a golf course in Southwick, Massachusetts, it is unlikely that any course in Massachusetts would use 290 MGY of water for irrigation, even during an extreme drought. During a conversation on November 23, 2004 with Jim Bumgartner of the Massachusetts Department of Environmental Protection, Mr. Bumgartner stated that a private course in Southwick known as The Ranch used approximately 90,000 GPD during 2002 and 2003. The maximum permitted usage for this course is 146,000 GPD.

The NGF data are supported by more recent data from the Golf Course Superintendents Association of America (GCSAA) in Lawrence, KS. Results from "Performance Measurement Survey 1999-2000" (2001) indicate that the national median of golf course water use was 28 MGY (equivalent to applying 13.5 inches of water to irrigated acres (managed turf) per year). A more recent analysis of data from the 39 golf course superintendents who responded from the northeast indicates the median irrigation water use to be 20.9 MGY, and the upper third quartile (50th-75th percentile - - more representative of The Preserve) to be 25.3 MGY (G. Lyman, personal communication, 11/29/04). All three annual ranges derived from the GCSAA data are within the range derived from the NGF data discussed above.

This annual average range of 18.2 MGY – 31.8 MGY is equivalent to 50,000 GPD – 87,000 GPD. This is generally consistent with our site-specific response presented in section VI of our 11/17/04 submission (Response to Town Review Comments Response #2), which was 50,000 GPD – 70,000 GPD. The witness who stated the neighboring golf course uses 275,000 GPD was likely referring to a peak demand average for a short time in the summer. Such peak demand at the

Preserve will be met through a combination of water stored in irrigation ponds and through pumping of irrigation supply wells.

An informal survey of golf course superintendents of courses located along the Connecticut shoreline in the vicinity of The Preserve indicates that the proposed irrigation demands for the Preserve golf course are consistent and reasonable estimates given the amount of irrigated acres. Specifically, Blackhall Country Club in Old Lyme, Clinton Country Club in Clinton, and Misquamicut Club in Watch Hill, Rhode Island responded to BL Companies inquires regarding irrigation water use. Blackhall Country Club reported using between 16-18 MGY to irrigate approximately 45-50 acres. Clinton Country Club used between 9.3 to 23 MGY for the years 2001 to 2004 to irrigate approximately 40-50 acres and Misquamicut Club used between 9.6 and 17.8 MGY between 1994 and 2004 to irrigate approximately 40 acres. These numbers are consistent with the irrigation demands stated above based and that reported by the GCSAA. As stated above, the anticipated irrigation demand for the Preserve is 50,000 to 70,000 GPD (based on 365 day/yr) or 18 MGY to 26 MGY.

Lastly, in the submittal to the Planning Commission on November 17, 2004, BL Companies, Inc. described regulation of the irrigation wells by the Connecticut Department of Environmental Protection through the Diversion Permit process. The Diversion Permit will regulate the maximum daily withdrawal from the irrigation wells and will only be issued and/or renewed if the use of the wells does not have an adverse impact on wetlands, watercourses, habitat, and other existing ground water uses. If water supply problems arise at neighboring properties that are clearly due to the use of the irrigation wells, CTDEP has the authority to stop the withdrawal from the irrigation wells. In addition, the use of the irrigation wells will be subject to CTDEP drought management planning requirements and restrictions. These measures typically require a course operator to institute specific, graduated cut-backs in irrigation in response to drought.

Golf Course as Habitat

The following comments are provided by Randall Arendt in response to comments at the public hearing:

> "Sally Faulkner correctly quoted my statement in "Conservation Design for Subdivisions" (Island Press, 1996) that golf courses do not produce very diverse habitat for wildlife. This is not news, as the applicant has never portrayed the golf course element as habitat-rich.
>
> My remarks in the above-mentioned book are ones I continue to stand by, but should be qualified in several ways.
>
> First, they were based on my Pennsylvania experience, with standard golf courses that had made no attempt whatsoever to maintain or to create wildlife habitat,

unlike newer generations of golf courses, such as those designed under some of Audubon International's awards programs, which have made a concerted effort to be amenable to surrounding habitat in terms of design and maintenance. We have heard testimony that the golf course proposed at The Preserve will exceed all such past criteria, and that it will in fact set a new and higher standard which we understand to be perhaps unparalleled in terms of its ecological sensitivity.

Second, the quoted remarks were expressed in the context of many golf course developers claiming they were creating conservation subdivisions when the ONLY open space they were providing were manicured greens and fairways. At The Preserve, NONE of the golf course acreage has been included in the open space calculations.

Third, at The Preserve, it should be remembered that a substantial proportion (over 50%) of the total golf course acreage is to be maintained as areas of "rough", existing vegetation or planted native grasses, not manicured or treated with fertilizers and herbicides."

Our environmental consultant Michael Klein supplements this reply with additional comments on the habitat potential of the golf course:

"As per the Planning Commission's directive, the issue here is not whether the proposed Open Space Plan will have an impact on wildlife at the site. The development of the site for residential use (conventional or open space), with OR without a golf course, will alter the distribution and abundance of wildlife at the site. This is an unavoidable consequence of the change in land use. The issue for the Planning Commission is whether the Open Space Plan (including the golf course) is preferable to the Conventional Subdivision, with respect to wildlife habitat.

In our judgment, there can be no question that the Open Space Plan including a golf course will have substantially less impact on wetlands, wildlife, and water quality than the conventional subdivision. The flexibility inherent in the Open Space regulations allows the site layout plan to avoid any filling or draining of wetlands, watercourses, or vernal pools. The plan includes structural and non-structural Best Management Practices to maintain existing hydrologic patterns, promote infiltration and renovate runoff from roads and residential areas. The 100' envelopes and the 750' critical terrestrial habitat zones surrounding the high-priority vernal pools will be protected. 514 ± acres of undeveloped, passive open space will be dedicated to the Town for preservation in large blocks ranging in size from 66-245 acres. Counting contiguous undeveloped golf course land, the largest open space block will be 285 acres.

Risk-assessed management plans have been developed for application of turf management products at the golf course and within the residential development. These plans are very conservative and will protect human health, downstream surface water and ground water quality, and amphibian biodiversity. Environmental & Turf Services developed a toxicity assessment scheme, specifically for amphibians, to use on this project (typically fish and aquatic insect data are used as surrogates). A detailed monitoring program will ensure that groundwater and surface water quality are maintained when the golf course moves into operation.

The Open Space Plan also provides the flexibility necessary to design the residential development and the golf course in a manner that preserves ecological connectivity for amphibians and reptiles. One pesticide was eliminated due to its potential to penetrate amphibians' skin as they cross managed turf. These groups were chosen because they are small, generally slow-moving, and/or have permeable skins. Their ability to disperse across the landscape is more limited than birds or mammals, and they are more sensitive to products applied to the turf. Therefore, the site design, which allows for maintenance of genetic interchange between local populations of amphibians and reptiles, will preserve the connectivity between habitat units for other species as well.

The peer-reviewed literature and other research conducted by US Fish and Wildlife Service and university biologists does not support the notion (presented by CFE and others), that all golf courses are sterile landscapes or glorified gardens. Dr. David Gordon of the US Fish and Wildlife Service and his colleagues at Clemson University studied bird communities at 24 golf courses in South Carolina during the breeding seasons of 2000 and 2001 (Jones et al, 2003). They found that woodland birds, including neo-tropical migrants, continued to breed at golf courses with low or moderate levels of habitat alteration. The most significant variable they identified affecting breeding bird use, was the amount of forestland remaining on the site. Forested wetlands were important in maintaining avian bio-diversity in their study. Gordon's co-author, Stephen Jones (pers. comm.) has indicated to me that scrub-shrub is also very important. The open space and golf course plan maximize preservation of forested wetlands.

Ohio State University Extension Service Fact W-15-04 identifies 12 "Steps to increase wildlife habitat (food, water and shelter) and maintain a healthy environment". All 12 steps have been consistent with the conceptual design and will be incorporated into the final course design and operational plans. Max Terman at Tabor College in Kansas compared the bird communities at a championship quality, naturalistic golf course with an adjacent passive recreation area. He found that they "both supported complex bird communities (Terman, 1997). The golf course had similar numbers of species (difference statistically insignificant) and higher bird density, but differences in relative abundance, species diversity, and dominance. Furthermore, Terman reports that his unpublished data demonstrate that naturalistic courses support more diverse, more stable bird communities than conventional golf courses.

Many of the elements of ecologically sensitive landscape design have been identified and applied to The Preserve. These design techniques have been dubbed "naturalistic golf course design". For example, the golf course designed for The Preserve maintains large areas of forested habitat. Carry areas over wetlands will be converted and maintained as scrub-shrub. Forested and scrub-shrub have been documented by Jones et al to be very important for maintaining avian biodiversity. Furthermore, the 510± acres of adjacent conservation set-aside will serve as a critical nearby habitat element that also links the site to other habitat patches to the south and west.

The golf course at The Preserve includes numerous elements that separate it from past "conventional" designs. No wetlands will be filled or drained. No wetlands will be converted to ponds for irrigation, aesthetics, or hazards. Less than 10 acres (or less than one twentieth) of the golf course will be highly managed tees and greens. Approximately 76 acres (or about one third) of the golf course lot will remain undisturbed. This area is mostly forested. In areas where the golf holes play over or parallel to wetlands, native shrubs, grasses and small trees will be established to buffer the wetlands from the golf course. Golf cart paths will pass over wetlands on raised bridges that can be routed around significant trees.

Another important element of the golf course will be active management to promote wildlife habitat. These include:

- use of native plants for course landscaping to provide food and shelter for wildlife
- avoidance of invasive plants to prevent adverse impacts on habitat
- installation of nesting structures for Eastern Bluebird, Tree Swallow, Kestrel, owls, Purple Martins, Wood Ducks, and bats
- design of irrigation ponds to minimize resident Canada Goose attraction
- design of drainage inlets to exclude amphibians
- road and storm drainage design measures to minimize amphibian mortality
- stormwater treatment design that eliminates "decoy" wetlands
- leaving "snags" and creating brush piles.

The value of these measures has been documented in many publications, including Bird Conservation on Golf Courses (Gillihan, 1999)."

III. Miscellaneous

The Pianta Parcel

The applicant has provided the commission a schematic plan for the future development of the Pianta parcel as a cluster development of no more than 35 dwelling units, and has confirmed that it will be included within the overall PRD for the entire property. Although the regulations do not require a habitat inventory, an inventory was in fact provided in our environmental consultants' report.

The Golf Course/Club

Commission counsel has asked the applicant to clarify the treatment of the golf course planned for The Preserve in the determination of Total Lots under Section 56.4 of the Zoning Regulations. At this stage of the Application, the golf course can be nothing more than a single lot complying with the specific site requirements for a Private Country Clubs under Section 52.7.16 of the Zoning Regulations. Counsel for the Planning Commission correctly noted that at this stage of the Application, the Planning Commission is not concerned with uses. Under Section 56.6.7 of the Zoning Regulations, each building lot on an approved Open Space Subdivision Plan in a Residence C Conservation District will be used for one or more of the uses listed in Sections 27.1.1 through 27.1.10 and in Sections 27.2.1 through 27.2.14 of the Zoning Regulations. Under Section 27.2.7, golf clubs are permitted by special exception, and under Paragraph 27.2.13, private country clubs are permitted by special exception in accordance with the standards and criteria of Paragraph 52.7.16. Section 52.7.16.A allows at least one golf course with at least 18 holes that is at least 6,200 yards in length, as measured from the furthest back tee areas, as the principal use of a Private Country Club. Section 52.7.16.C requires a Private Country Club to have a minimum contiguous acreage of at least 200 acres, within which the principal and accessory must be located. Compliance with these and other criteria for the granting of the Special Exception is within the purview of the Zoning Commission. For open space subdivisions in the Residence C Conservation District, Section 56.6.4 of the Zoning Regulations requires that the area of open space land shown on the final Open Space Subdivision Plan cover 50 percent or more of the total area of the subdivision. Calculation of the area of open space land excludes areas of a lot, including a PRD lot, that are dedicated to or available for non-municipal active recreational uses, such as golf courses, along with all parking, driveways, and accessory facilities and areas. Although the Zoning Regulations do not count the area of the lot for the Private Country Club as open space, much of this lot will undergo minimal disturbance and development and, as such, it offers a superior alternative to a conventional subdivision from the standpoint of the purposes of an open space subdivision in Section 56.2 of the Zoning Regulations and the standards for an open space subdivision in Section 56.6.

buffer the adjacent road (views) and frame the left side of the hole. As with hole #10, the road and lots are planned along the left side of the hole. Most miss-hit shots will be on the right side of the hole. At hole #18 green there is 130' from the center of the green to the road R.O.W. and 170' from the center of the green to the lot line.

In conclusion, the Central Village is not shoe-horned between two critical fairways, the Pequot Swamp and the community septic system. The relationship between holes #10 and #18 and the roadway and homes of the central village has been designed to protect the health, safety and welfare of both the golfers, adjacent residential lots, roadways and environmental features.

IV. *Appendix A*

MEMORANDUM

To: Michael W. Klemens, Ph.D.

CC: Dwight H. Merriam

From: Gregory W. McCracken

Date: November 30, 2004

Subject: Jurisdiction of an Inland Wetlands and Watercourses Agency over Wetlands-Dependent Wildlife

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You requested that we provide you with a brief overview of the jurisdiction of an inland wetlands and watercourses agency ("IWWA") over wetlands-dependent wildlife in uplands habitat. Until recently, this jurisdictional question was unresolved, and some IWWAs regulated uplands areas based on the presence of wetlands-dependent wildlife. However, the Connecticut Supreme Court definitively resolved the issue in *AvalonBay Communities Inc. v. Inland Wetlands Commission of Wilton*, 266 Conn. 150 (2003) ("AvalonBay"). Concerning the scope of application of the Inland Wetlands and Watercourses Act, Conn. Gen. Stat. §§ 22a-36 through 22a-45 ("Act"), the Court held as follows in AvalonBay, 266 Conn. at 163 & n.19:

> The legislature did not adopt broad definitions of wetlands and watercourses that would protect aspects of the wetlands apart from their physical characteristics, such as, for example, the biodiversity of the wetlands or wildlife species that might be wetland dependent. We conclude, therefore, that the act protects the physical characteristics of wetlands and watercourses and not the wildlife, including wetland obligate species, or biodiversity. There may be an extreme case where a loss of or negative impact on a wildlife species might have a negative consequential effect on the physical characteristics of a wetland or watercourse, but that is not the situation in the present case. Here, the commission claims only that the loss of the salamander will affect the biodiversity of the wetlands.

Timothy S. Hollister, Esq. and Matthew Ranelli, Esq. of Shipman & Goodwin LLP, which represented AvalonBay Communities, Inc., published an article entitled, "The AvalonBay-Wilton Salamander Case: Wildlife Migrate, But Jurisdiction Does Not," in the January-March 2004 issue of *Connecticut Planning*. In their article, they explain the facts of AvalonBay and the significance of the Court's holding. The facts of the case are as follows:

> AvalonBay Communities has a contract to purchase 10 acres adjacent to Route 7 in Wilton. The site (despite what you may have heard) is developed; it contains a large building that was used until 2001 by an advertising agency. The land is bordered by condominiums, single-family homes, Route 7, and industrial and commercial uses. AvalonBay proposed a 113-apartment complex with a 25 percent affordable housing component. In its northwest corner, the site contains one wetland of 0.3 acre which encompasses an intermittent watercourse, and a second wetland, part of an off-site pond, with 0.02 acre on-site. AvalonBay's site plan proposed *no construction* activities in a wetland, watercourse, or the adjacent upland review areas (50 feet from a wetland, 100 feet from a watercourse), and all potential impacts from construction beyond the upland review area were eliminated. The Town's consulting engineers confirmed that the plan would actually improve the quality of stormwater leaving the site.
>
> But the Commission asserted that the plan required a wetlands permit and then denied the permit on this theory: the site contains a small population of spotted salamanders (which are common, not endangered) who breed in Wetland 2 during March-April and then spend the rest of the year in the upland/non-wetland area of the site. Construction in the upland would impact the upland habitat of the spotted salamander, thus reducing the "biodiversity" of Wetland 2. Although there was no impact to the salamanders' wetlands habitat, the Commission claimed that because these salamanders depend on the wetlands for part of their life cycle, they were *legally a part of the wetlands, and thus an impact on a salamander or its habitat, even in an upland, constitutes an impact to a wetland.*

Timothy S. Hollister, Esq. and Matthew Ranelli, Esq., "The AvalonBay-Wilton Salamander Case: Wildlife Migrate, But Jurisdiction Does Not," *Connecticut Planning*, January-March 2004, pp. 1, 11 (emphasis in original).

Explaining the significance of AvalonBay, Attorneys Hollister and Ranelli emphasize that the decision delineates which agencies are responsible for which part of regulating the environment.

> The opinion does not say that wetlands commissions may not regulate or protect wetland and watercourse characteristics—shelter, dissolved oxygen, nutrients, etc.—that benefit wildlife or wetland-dependent species. The holding of the case is simply that wildlife are not part of the resources regulated by the wetlands statute, and as a consequence a wetlands commission may not require a permit for an activity that only impacts wildlife, such as an impact to the upland habitat of wetland-dependent species. In other words (as we argued), spotted salamanders and other species do not "carry the jurisdiction of wetlands commissions on their backs as they roam the landscape." The Court opted to limit commissions' jurisdiction to impacts and areas that can be established by

objective, determinable criteria as stated in the statutory definitions of "wetlands" and "watercourses."

Id. at 11.

To date, only one published decision has applied AvalonBay. In *River Bend Associates, Inc. v. Conservation and Inland Wetlands Commission of the Town of Simsbury*, 269 Conn. 57, 60-61 (2004) ("River Bend"), the Court held that "pursuant to our recent decision in *AvalonBay Communities, Inc. v. Inland Wetlands Commission*, 266 Conn. 150, 156, 832 A.2d 1 (2003), an inland wetlands agency may regulate activities outside of wetlands, watercourses and upland review areas only if those activities are likely to affect adversely the physical characteristics of those wetlands or watercourses and not just the wildlife that uses the wetlands." Indeed, one of the events that Attorney Hollister pursued the appeal on behalf of River Bend Associates "was the decision of the Connecticut Supreme Court in Avalon Bay Communities v. Wilton Wetlands and Watercourses Commission which held that wetlands commissions do not have jurisdiction to regulate wildlife in uplands, invalidating a portion of [the Simsbury] Commission's July 2000 denial resolution." "Griffin Land & Nurseries, Inc. Appeals Simsbury Permit Rejection as 'Illegal, in Violation of Town's Own Regulations,'" ForRelease.com, Feb. 26, 2004, <http://www.forrelease.com/D20040226/nyth100.P1.02262004095441.18981.html>, viewed Nov. 23, 2004.

As with AvalonBay, one or more attorneys from Shipman & Goodwin LLP, which represented River Bend Associates, have published articles on the meaning of AvalonBay and River Bend. In a recent continuing legal education course, another attorney from Shipman & Goodwin LLP offered the following summary of the cases' impact on the jurisdiction of an IWWA:

Wetlands Agency Jurisdiction After the AvalonBay Decision

- Impacts on physical characteristics of wetlands and watercourses AND THEIR FUNCTIONS are regulated
- Activities within "upland review areas" require commission review
- If commission has adopted regulations, it may review activities outside upland review area "likely" to impact
- Commission jurisdiction not defined by wildlife migration, even wetland-dependent species[.]

Christopher J. Smith, "Wetlands Commission Jurisdiction—post *AvalonBay* and *River Bend Associates*, Inc.," *Advanced Zoning and Land Use in Connecticut* (Lorman), Nov. 17, 2004, p. 83.

V. ***Appendix B***

Water Quality Impacts by Golf Courses

Stuart Cohen, Amelia Svrjcek, Tom Durborow, and N. LaJan Barnes

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Water Quality Impacts by Golf Courses

Stuart Cohen,* Amelia Svrjcek, Tom Durborow, and N. LaJan Barnes

ABSTRACT

Interest in water quality impacts by golf courses has grown significantly since the late 1980s due mostly to the local permitting process. Results from permit-driven studies are frequently not published. Seventeen studies (36 golf courses) passed our review criteria and were incorporated into a detailed data review. A total of 16 587 data points from pesticide, metabolite, solvent, and NO_3 analyses of surface water and ground water were reviewed. There were approximately 90 organics analyzed in the surface water database and approximately 115 organics in the ground water database. Widespread and/or repeated water quality impacts by golf courses are not happening at the sites studied. None of the authors of the individual studies concluded that toxicologically significant impacts were observed, although HALs, MCLs, or MACs were occasionally exceeded. The individual pesticide database entries that exceeded HALs/MCLs for ground water and surface water were 0.07 and 0.29%, respectively. The percentages would be somewhat higher if they could be expressed in terms of samples collected rather than chemicals analyzed. The MCL (10 mg/L) for nitrate–nitrogen (NO_3–N) in surface water was not exceeded, and only 31/849 (3.6%) of the samples exceeded the MCL in ground water; however, most of the NO_3 MCL exceedances were apparently due to prior agricultural land use. There was a slight trend for detected pesticides to be more persistent and more mobile than pesticides that were not detected, but the trend was not statistically significant. There are major data gaps in this review, particularly in the midcontinent area.

United States researchers, regulators, and pesticide companies began to focus on pesticides in surface water and ground water in the late 1970s to early 1980s. Wauchope (1978) and Wauchope and Leonard (1980) reviewed surface runoff results from more than 20 studies of agricultural pesticides. More recent work has greatly expanded the knowledge of agricultural pesticides in ground water (e.g., Thurman et al., 1992; Stamer, 1996). Initially, a limited number of studies focused on the nematicides 1,2-dibromo-3-chloropropane (DBCP) and aldicarb as well as certain high volume corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] herbicides in ground water (Peoples et al., 1980; Zaki et al., 1982; Cohen et al., 1984). Since that time, the number of studies, papers, and reports in this field have grown significantly. For example, USEPA (1992a) and Barbash and Resek (1996) collectively summarized the results from more than 300 ground water studies. Most of the studies in both publications were related to agriculture. Part of the motivation of Spalding and Exner's (1993) review of NO_3 in groundwater is the possibility for contaminated ground water to discharge to streams, lakes, and nearshore coastal waters.

Thus there have been many studies on agricultural chemicals in ground water and surface water, but field-scale water quality monitoring studies of nonagricultural pesticides and fertilizers are rare. A ground water monitoring study of four golf courses on Cape Cod found several pesticide and NO_3 detections but no significant impacts (Cohen, 1990; Cohen et al., 1990). The USEPA conducted a stratified random survey of the nation's drinking water wells in the 1987 to 1990 time period (USEPA, 1992b). The most frequently detected organic was the derivative of tetrachlorophthalic acids, metabolites of the herbicide dacthal (DCPA). This herbicide has been used for vegetable crops and turf. The USEPA found a positive relationship between the rate of DCPA use on golf courses and the probability of detecting the metabolites in wells on a regional (multistate) scale. However, a smaller scale analysis was not possible. In addition, it is possible that the presence of managed lawns may be reflected in the correlation.

It is usually not appropriate to extrapolate results from agricultural monitoring studies to golf courses due to the significantly different management practices, plant canopy, surface mat (thatch), and dense root system of turf (Kenna, 1995). The volume of runoff water is usually less, and eroded sediments are significantly reduced in turf compared with row crop agriculture (e.g., Welterlen et al., 1989). Good drainage is promoted in golf course turf, but evapotranspiration is usually higher in turf than most other crops (e.g., Ward and Elliot, 1995). Thus leaching potential is expected to be less in turf, other factors being equal. Limited data indicate that field dissipation rates are significantly greater in turf (shorter DT_{50} values; e.g., Horst et al., 1996).

The U.S. Golf Association has funded more than $3 million of environmentally-related research, but this work has ranged from the small-scale size of 1 m^2 or smaller test plots or lysimeters, up to individual greens (Kenna, 1995). In other words, these are not field-scale monitoring studies. Many golf courses built in the USA since the late 1980s have been required to monitor ground water and surface water quality as a result of permit conditions. These studies are rarely published in the peer-reviewed literature, and they are usually not publicized at all. This problem is a frequent target of concern during the state and local approval process. Public accusations in the area of water quality impacts

Environmental & Turf Services, Inc., 11141 Georgia Ave., Suite 208, Wheaton, MD 20902. Received 6 Oct. 1997. *Corresponding author (etscohen@aol.com).

Published in J. Environ. Qual. 28:798–809 (1999).

Abbreviations: ND, not detected; cz, climate zones; gw, ground water; MAC, maximum allowable concentrations; HAL, health advisory level; VOC, volatile organic carbon.

by pesticides can often become highly emotional and speculative. Therefore the purpose of this study was to seek and critically review surface water and ground water quality monitoring results from golf courses around the USA and elsewhere, and to quantitate conclusions about water quality impacts, if possible.

METHODS

Solicitation and Review of Field Studies

Results of surface water and ground water studies conducted on golf courses throughout the USA were solicited through a variety of sources in an effort to gather a broad range of regional coverage and minimize biased conclusions. Initially, press releases were issued requesting information, followed by articles in the golf course press (*Golf Course News and Newsline* [GCSAA]). These are publications read by golf course superintendents and turf researchers. Letters requesting information were sent to all 50 state environmental water quality regulatory agencies and several USEPA regional offices. The response rate was 36% from the state agencies and 100% from the USEPA. In addition, information from 13 studies obtained in a preliminary review of this subject (Cohen and Durborow, 1994) was updated. Finally, the peer network ('word-of-mouth') was used. Thus, it is likely we identified most of the completed golf course water quality studies as of 1996.

There were a total of 19 studies reviewed for this paper. These studies included 40 golf courses. Each study was subjected to a preliminary quality control review. Study directors or laboratory staff were contacted to ensure that adequate quality control measures were followed by the participating laboratories, including proper state certification, and assurance that blank and matrix spike analyses and duplicate analyses were run for appropriate samples. Seventeen of these studies (36 golf courses) passed our review criteria and were included in the statistical analyses; all but one of the 36 golf courses were located in the USA. (One study was done on Prince Edward Island.) All numerical data from the accepted studies were then entered into a database or spreadsheet program, and approximately 10 to 20% of the data (generally closer to 20%) entered for each study was checked for completeness and accuracy in an in-house quality control review. Data from the two other studies in Guam and Japan were reviewed but not added to the database. The locations of the golf courses and media sampled (surface water [sw] and/or ground water [gw]) are shown in Fig. 1.

STUDY DESCRIPTIONS

Locations, sampling sites, objectives, and other key information for all studies used in our analysis are shown in Tables 1 and 2. A supplemental summary of the studies can be requested from the authors. Following is a brief summary of studies from Guam and Japan that could not be included in the critical review due to the extensive amount of data.

Ground Water Quality Monitoring Program Review, Guam

A comprehensive water quality testing program was initiated in 1990 by Guam Municipal Golf, Inc. at Guam International Country Club (Guam EPA, 1992). The purpose of the study was to demonstrate that golf course construction and maintenance, when responsibly managed, are compatible with a quality environment. In this study, more than 86 000 individual analyses for NO_3 and pesticides have been performed on water samples in lakes and wells at the golf course. We have been unable to obtain data more detailed than a four-page summary. No pesticides were detected in this study. The results of this monitoring program are not included in the database.

Water Quality Studies in Japan

Summaries of approximately 250 000 data points were obtained through an American superintendent consulting in Japan (S.L. Carlton, 1996, personal communication) and a poster presented at an international meeting (Minoura et al., 1994). American Cyanamid collected 160 surface water samples from three golf courses in Japan and analyzed them for pendimethalin (Minoura et al., 1994). Both references provided summary results from the Environment Agency of "drain" water analyzed for 30 pesticides over a 3-yr period. The rate of individual

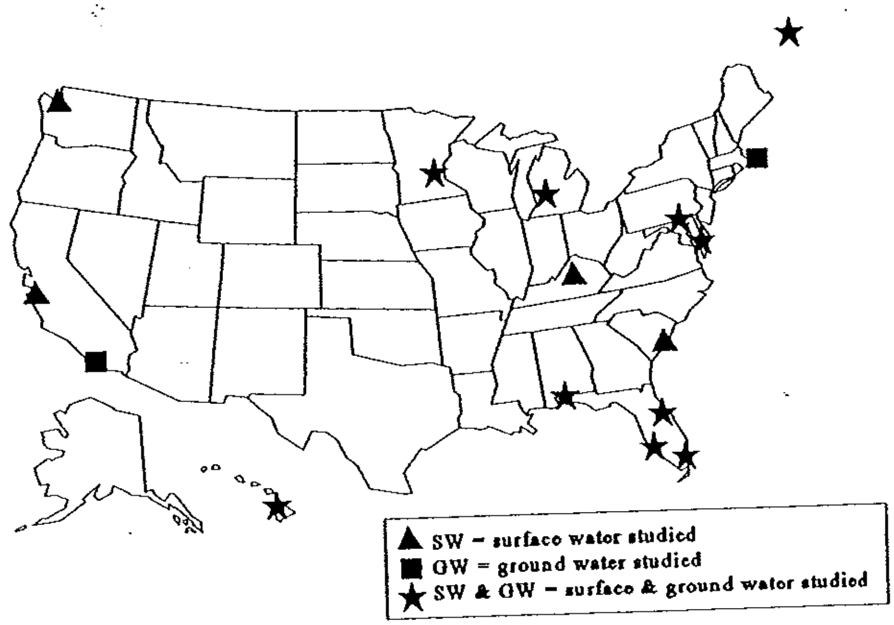

Fig. 1. Golf course study locations.

Table 1. Summary of golf course studies accepted for review.

Study ID	Study title	Golf courses involved	Location	Responsible for study	Reference
CA-1	Singing Hills Country Club and Lodge Water Quality Reports for 1989, 1993, and 1996	Oak Glen Golf Course and Willow Glen Golf Course at the Singing Hills Country Club	El Cajon, San Diego County, CA	Singing Hills Country Club and Lodge, El Cajon, CA	Fern and Nothwanger, 1996
CA-2	Stormwater Monitoring of Watersheds including Golf Courses on the Monterey Peninsula, California	Pebble Beach Golf Links, The Links at Spanish Bay, Spyglass Hill Golf Course, Poppy Hills Golf Course	Pebbles Beach, Monterey County, CA	Pebble Beach Co., Pebble Beach, CA	Carpenter and Toal, 1996
CAN-1	The Links of Crowbush Cove Water Quality Monitoring, Canada	The Links at Crowbush Cove	Morell, Prince Edward Island, Canada	Prince Edward Island Dep. of Economic Development and Tourism, PEI, Canada	Pierce, 1997
FL-1	Water Quality, Pesticide Occurrence, and Effects of Irrigation with Reclaimed Water at Golf Courses in Florida	Hillsborough Co: Buckhorn Springs Golf Course, Pebble Creek Golf Course; Lake County: Skiing Paradise Golf Course; Orange County: Winter Pines Golf Course, Ventura Golf Course; Sarasota County: Groves Golf Course, Highlands Golf Course; Broward County: Bonaventure Golf Course; Escambia County: Pensacola Naval Air Station Golf Course	south Florida (Broward County), central Florida (Hillsborough, Lake, Orange, and Sarasota Counties), and the pan handle (Escambia County)	U.S. Geological Survey, Tampa, FL	Swancar, 1996
FL-2	Palm Beach County Golf Course Study	Boca Lago Country Club and Palm Beach National Golf Course	Palm Beach County, FL	Florida Dep. of Environmental Regulation	Greenhalgh, 1992
FL-3	Water Quality Sampling, Sarasota Bay National Estuary Program and Non-Point Source Loading Assessment	Palm Sola Golf Course	Bradenton Beach, Manatee County, FL	Camp, Dresser, and McKee, Inc., Sarasota, FL	Camp et al., 1992
HI-1	Waikoloa Anchialine Pond Program	Beach Golf Course and Kings Golf Course at the Waikoloa Resort	Waikoloa, Kona Coast on the Island of Hawaii, HI	Univ. of Hawaii, Honolulu, HI	Brock et al., 1994
KY-1	Turfgrass Chemicals Exiting a Well-Managed Golf Course	Champions Golf Course	Jessamine County, KY	Univ. of Kentucky, Kentucky Agric. Exp. Statn., Lexington, KY	Felton and Powell, 1993
MA-1	Bayberry Hills Golf Course	Bayberry Hills Golf Course	West Yarmouth, Barnstable County, MA	Town of Yarmouth Golf Commission	Tessier and Nash, 1996
MA-2	A Ground Water Monitoring Study for Pesticides and Nitrates Associated with Golf Courses on Cape Cod	Bass River Golf Course, Eastward Ho! Golf Course, Hyannisport Golf Course, Falmouth Country Club	Yarmouth, Barnstable, Chatham, Falmouth, Barnstable County, MA	U.S. Environmental Protection Agency, Barnstable County Health and Environmental Dep., Massachusetts Dep. of Food and Agriculture, Cape Cod Commission, formerly Cape Cod Planning and Economic Development Commission	Cohen et al., 1990; Cohen, 1990

continued next page

Table 1. Continued.

Study ID	Study title	Golf courses involved	Location	Responsible for study	Reference
MD-1	Queentown Harbor Golf Links Water Quality Monitoring	Queenstown Harbor Golf Links	Queenstown, Queen Anne's County, MD	Queenstown Harbor Golf Links	Apogee Research, 1996
MD-2	Caves Valley Golf Club Environmental Monitoring Program	Caves Valley Golf Club	Owings Mills, Baltimore County, MD	Caves Valley Golf Club	Kaysak et al., 1990–1995; Chesapeake Environ. Manage., 1996
MI-1	Water Quality Assessment and Recommendations for the Meadows Golf Club	Meadows Golf Club	Allendale, Ottawa County, MI	Grand Valley State University Water Resources Institute	Water Resources, 1995
MN-1	Baker National Golf Course Leachate Study	Baker National Golf Course	Minneapolis, Hennepin County, MN	Minnesota Golf Course Superintendents Assoc.	Barten et al., 1992
MN-2	Quantity and Quality of Runoff from Four Golf Courses in the Twin Cities Metropolitan Area	Baker National Golf Course, Woodhill Country Club, Meadowbrook Golf Course, Minikahda Club	Minneapolis, St. Paul, Hennepin County, MN	Suburban Hennipin Regional Park District	Barten et al., 1994
SC-1	Environmentally Sensitive Techniques in Golf Course Management: A Model Study at the Ocean Course, Kiawah Island, SC	The Ocean Course, Kiawah Island	Kiawah Island, SC	U.S. Golf Association, Clemson University Institute of Wildlife and Environmental Toxicology	Inst. Wildlife, etc., 1993
WA-1	Echo Falls Golf and Country Club Surface Water Quality Monitoring	Echo Falls Golf and Country Club	Snohomish, Snohomish County, WA	Echo Falls Golf and Country Club	Evans-Hamilton, Inc. and Dalton, Olmstead & Fuglesand, Inc., 1990 and Evans-Hamilton, Inc. and Rensel Associates, 1996

analyses that exceeded the government's criteria was 0.013%. The results of this monitoring program are also not included in the database used in this review.

Analytes

A total of 134 pesticides, metabolites, and solvents were analyzed in at least one of the studies in this paper (Table 3). An effort was made to exclude pesticides that were almost certainly never used at a golf course either on turf, in ponds ("lakes"), or in related areas. However, when in doubt, the pesticide was included. This is because pesticide registrations are constantly changing. For example, most people would associate past use of the insecticide chlordane with field crops and termite control in buildings. However, chlordane was used to control mole crickets and crabgrass at golf courses in the early 1970s. Furthermore, when pesticide registrations are canceled, use of existing stocks may continue for several years. Thus only 13 pesticide and volatile organic entries were deleted from the database; that is, we felt confident that these analytes were not likely to be used on golf courses, and therefore might bias our conclusions.

The question remains whether the pesticides used and analyzed in each study are the same. The two lists are probably not identical for most of the studies. Pesticides have been used for which there was no feasible method. Pesticides have been analyzed which may or may not have been used. (Not all states require golf course superintendents to maintain use records of all pesticides.) Therefore, as an aid to the reader, Table 4 lists the pesticides most commonly used in the last 5 to 10 yr in warm- and cool-season turfgrasses.

STATISTICAL ANALYSES

After the preliminary review, data were entered into Borland Paradox Version 5.0 (Borland International, Scotts Valley, CA). All data underwent a quality control check for accuracy, that is., 10 to 20% of data entries (usually close to 20%) in each database were reviewed after entry. Statistical analyses were conducted in Paradox and StatMost (DataMost Corp., Salt Lake City, UT). The various authors used a variety of techniques to report and summarize their data, which were not subject to our initial acceptance criteria. This complicated the selection of appropriate statistical procedures. For example, attempts were made to obtain information for each individual sampling event; however, in three reports, mean values for pesticides or NO_3–N were reported. In those cases, the mean values were used.

There were several limitations in the data. First, golf courses across the country are not selected to conduct studies in a statistically valid manner; that is, with randomization whereby all golf courses in the country and/or in a region had an equal probability of being selected for a monitoring study. The data set is far too limited in terms of geography and climate. Therefore, the number and type of valid statistical analyses and extrapolations that could be done is also limited; that is, it would be inappropriate to conclude that these results provide true national estimates for golf course impacts on water quality.

The second limitation is more of a problem in data interpretation rather than in the data itself. A large fraction of the data entries are "nondetects" (NDs); that is, the substance analyzed was not detected. This is a problem because it is not clear how these data should be entered when calculations are done; for example, should ND equal zero, should it equal the detection limit (which varies significantly), should it equal a value between zero and the detection limit, or is there a sophisticated method of analysis for addressing this issue? As

Table 2. Summary of key information for each study.

Golf course studies	No. of: Wells	Surface water sites	No. of L/U†	No. of years sampled	Most recent sampling	Study objective	Analytes‡
CA-1	7			3	1996	Examine environmental conditions; determine if wastes generated were from golf course	P
CA-2		7		<1 Fall/Winter	1996	Storm water runoff; surface water baseflow	P N
CAN-1	4	6		4	1996	Examine water quality of fresh water ponds and ground water	N
FL-1	42	11		4	1996	Reclaimed waste water effects on irrigation	P N
FL-2	4			1	1991	Effects of pesticide use in surficial aquifer	P
FL-3	2	3		1	1992	Determine nutrient loading to Sarasota Bay	N
HI-1	3	19		8	1994	Effects of development on Anchialine Ponds	P N
KY-1	§	§		<1 Apr.–Nov.	1993	Examine water quality to downstream user	P N
MA-1	14		6 U	7	1996	Permitting process	P N
MA-2	19			2	1988	Golf course impacts on ground water	P N
MD-1	13	3		6	1996	Determine nutrient loading to Chesapeake Bay via stream tributaries; water quality effects from agricultural land conversion to golf course	N
MD-2	13	10	3 L	5	1995	Requirement of Special Exception Zoning Agreement	P N
MI-1		2	2 U	4	1995	Golf course operation effects on water quality	P N
MN-1			1 U	2	1992	Determine quantity/quality of subsurface leachate through a green	P N
MN-2		4		1	1994	Quantity/quality of runoff; effects on adjacent water bodies	P N
SC-1		4		<1 Summer	1993	Evaluate golf course impacts to wildlife and water quality	P N
WA-1	3	3	2 L 2 U	6	1996	Address concerns for golf course impacts to wetlands, streams, and sole source aquifer	P N

† L = lysimeters, U = underdrains.
‡ P = pesticides, N = nitrogen.
§ Sampling was from one point in a karst environment. The point sampled was at an exit point from ground water as it flowed into the stream. Authors did not distinguish between ground water and surface water.

a further complication, the specific detection limits vary from study to study and from method to method.

Statisticians often do not agree on the best approaches for tackling these problems. For example, the USEPA (1996) stated that "substitution" methods are suitable for data sets where <15% of the values are ND. In this approach, a specific number is substituted for each ND. The standard practice, which the USEPA endorses, is to substitute ½ × detection limit (dl) for all ND values. Gibbons (1994) stated that this substitution method "... is often adequate for most practical purposes if the detection frequency is 80% or more" (NDs <20%). However, Helsel (1990) has recommended against this approach in favor of more sophisticated techniques (although he focused more on regression analyses and comparisons between data sets, which are less relevant here). We have adopted the USEPA approach for the NO_3–N in the ground water data set, where the ND rate was <15%. It is an easier approach and it has the USEPA's acceptance.

We could find no practical guidance for characterizing a very large data set where more than 90% of the entries are NDs, which is the case for the surface water and ground water database entries for pesticides and related chemicals. Therefore we present a range of means: the lower end of the range assumes ND = 0, and the upper end of the range assumes ND = dl. By doing so, we are implicitly stating that we do not know the true answer, but we know it lies somewhere within the stated range. We also present the 95th percentile values for the data.

Databases that contain between 15 and 50% NDs are more problematic. The NO_3 in the surface water data set fall in this category. The most frequently cited approach for handling data sets such as this, Cohen's method (e.g., USEPA (1996), section 4.7.2.1), cannot be used with our data due to the requirement that all detection limits be the same. We used the winsorized mean approach to analyze this data set, (EPA, 1996, section 4.7.2.3). In this method, the data in the ends (tails) of the data set—the highest and lowest values—are replaced with the next most extreme value. Thus all NO_3 NDs in surface water were replaced at the low concentration end of the distribution by the next highest value. An analogous replacement was made at the high end.

RESULTS

Overview

The database includes 16 587 entries, where one entry is one analysis for a single analyte in one sample (Table 5). Statistical analyses were done for each dataset category in Table 5. Results from ground water studies dominate the database. The database does not include data from Japan and Guam, which total approximately 300 000 entries.

There are approximately 55 possible combinations of climate zones (cz) and ground water (gw) regions, and approximately 48 possible surface runoff/water (sw) and cz combinations (USWRC, 1968; Beard, 1982; Heath, 1982). The studies we evaluated spanned 12 gw/cz combinations and 10 sw/cz combinations. There is a significant data gap in the mid-continent region (Fig. 1). Considering the efforts made to learn of studies throughout the USA, the most likely explanation is that there are far fewer golf course studies in this region than elsewhere. For example, the mountain and west south central regions are ranked six and seven, respectively, out of eight regions in terms of golf facilities.

The specific organics detected are indicated in bold type in Table 3. It is important to note that 13 pesticide

Table 3. Pesticides, metabolites and solvents analyzed in one or more of the studies.†

Analytes analyzed for in one or more samples								
Analyte	GW	SW	Analyte	GW	SW	Analyte	GW	SW
1,1 Dichloroethane	✓		DDD	✓	✓	Malathion	✓	✓
1,1 Dichloroethylene	✓		DDE	✓	✓	Mancozeb		✓
1,1,1 Trichloroethane	✓		DDT	✓	✓	Merphos		✓
1,1,1,2 Tetrachloroethane	✓		Dacthal	✓		Metalaxyl	✓	✓
1,1,2,2 Trichloroethane	✓		Dacthal Diacid	✓		Methamidophos	✓	✓
1,2 Dichloroethylene	✓		Dalapon	✓		Methiocarb	✓	
1,2 Dichlorobromoprop	✓		Delta-BHC	✓	✓	Methomyl	✓	
1,2 Dichlorobenzene	✓		Demeton-O		✓	Methoxychlor	✓	✓
1,2 Dichloroethane	✓		Demeton-S		✓	Methyl bromide	✓	
1,2 Dichloropropane	✓		Diazinon	✓	✓	Methyl isothiocyanate	✓	
1,3 Dichlorobenzene	✓		Dicamba	✓	✓	Methyl parathion	✓	✓
1,3 Dichloropropene	✓		Dichlorvos		✓	Methylene chloride	✓	
1,4 Dichlorobenzene	✓		Dichlorprop	✓	✓	Metribuzin	✓	✓
2,4,5T	✓	•	Dieldrin	✓	✓	Mevinphos	✓	✓
2,4,5 TP	✓		Disulfoton	✓	✓	Naled	✓	✓
2,4-D	✓	✓	Diuron	✓	✓	Norflurazon	✓	
2,4-DB	✓	✓	Endosulfan I	✓	✓	Oryzalin	✓	✓
Acephate	✓	✓	Endosulfan II	✓	✓	Oxamyl	✓	
Acetic Acid	✓		Endosulfan sulfate	✓	✓	PCNB		✓
Aldrin		✓	Endrin	✓	✓	Phorate	✓	✓
Alpha-BHC	✓	✓	Endrin aldehyde	✓	✓	Picloram	✓	✓
Alpha-Chlordane		✓	Endrin ketone	✓	✓	Prodiamine		✓
Ametryn	✓	✓	Ethion	✓		Prometryn	✓	
Anilazine	✓	✓	Ethofumesate		✓	Pronamide	✓	✓
Arsenic	✓	✓	Ethoprop	✓	✓	Propanil		✓
Atrazine	✓	✓	Ethyl parathion	✓		Propiconazole	✓	✓
Azinphos-methyl		✓	Ethylbenzene	✓		Propoxur	✓	
Bendiocarb	✓	✓	Ethylene dibromide	✓		Ronnel		✓
Benomyl	✓		Fenamiphos	✓	✓	Siduron	✓	
Bentazon	✓	✓	Fenamiphos sulfone	✓	✓	Simazine	✓	✓
Benzene	✓		Fenamiphos	✓	✓	Sulprofos		✓
Beta-BHC	✓	✓	Fenarimol	✓	✓	Tetrachlorvinphos		✓
Bromacil	✓	✓	Fensulfothion		✓	TCP	✓	✓
Carbaryl	✓	✓	Fenthion		✓	Terbufos	✓	
Carbofuran	✓	✓	Gamma chlordane		✓	Tetrachloroethylene	✓	
Carbon tetrachloride	✓		Glyphosate	✓	✓	Thiram	✓	✓
Chlordane	✓	✓	Heptachlor	✓	✓	Tokuthion		✓
Chlorobenzene	✓		Heptachlor epoxide	✓	✓	Toluene	✓	
Chloroethane	✓		Hexazinone	✓	✓	Toxaphene	✓	✓
Chloroform	✓		Iprodione	✓	✓	Triadimefon	✓	✓
Chloropicrin	✓		Isofenphos	✓	✓	Trichloroethylene	✓	
Chlorothalonil	✓	✓	Lindane	✓	✓	Trichloronate		✓
Chlorpyrifos	✓	✓	Linuron	✓	✓	Triclopyr		✓
Chlorpyrifos ethyl	✓	✓	MCPA	✓	✓	Xylenes	✓	
Coumaphos		✓	MCPP	✓	✓			

Underline indicates analytes detected in GW and/or SW in one or more samples.
† GW = ground water. SW = surface water. Thirteen pesticides and volatile organics that were not likely used on golf courses were analyzed but are not included in this summary.

and volatile organic entries were deleted from the database due to the fact that they were almost certainly not used in association with golf courses; for example, aldicarb, alachlor, pentachlorophenol, dinoseb, bromoform, and chloromethane. This had the net effect of decreasing the database by well over 100 entries.

Figure 2 summarizes pesticide detection by use class. Some of these pesticides were detected more than once. These detections are 5% of the organics surface water database entries and 1% of the ground water entries.

Surface Water Results

Pesticides

Maximum allowable concentrations (MACs) for aquatic organisms were calculated for all but the three pesticides that had available USEPA ambient water quality criteria (Table 6). Thirteen (including two metabolites) were MACs calculated or estimated by the Vermont Department of Environmental Conservation as part of their Toxic Discharge Control Strategy (July 1991). These MAC values are primarily based on methodologies developed by the USEPA to derive numerical water quality criteria for aquatic species when a large amount of data is not available. The remaining 15 pesticide MACs were calculated using 1/10th the LC_{50} or EC_{50} of the most sensitive freshwater invertebrate or fish species. The toxicity data reviewed were taken from USEPA pesticide fact sheets and the USEPA Pesticide Ecotoxicity database, as well as other resources (e.g., FCH, 1997). These MAC values are not meant to be definitive. They are presented for comparison purposes.

Table 6 presents detailed information describing the database total entries, detections, MACs, maximum contaminant levels/health advisory levels (MCLs/HALs), and exceedances for each of the 31 chemicals detected in surface water. Nine pesticides exceeded MACs for aquatic organisms. The total number of database entries for three selected pesticides are compared to total detections and MAC exceedances in Fig. 3. All nine chlorpyrifos detections (0.1–0.3 μg/L) were from one small-scale study (Michigan) that measured runoff

Table 4. Turf pesticides most commonly used in the last 5 to 10 yr (active ingredient/product).

Cool season (31 pesticides)†	Warm season (36 pesticides)†
Bensulide/Betasan® (H)	Benefin/Balan® (H)
Fenoxaprop-ethyl/Acclaim® (H)	Bensulide/Betasan® (H)
Glyphosate/Roundup® (H)	Dithiopyr/Dimension® (H)
Pendimethalin/Scotts 60® (H)	Fenoxaprop-ethyl/Acclaim® (H)
Siduron/Tupersan® (H)	Glyphosate/Roundup® (H)
2-4-D/Trimec Classic® (H)	Imazaquin/Image® (H)
MCPP/Trimec Classic® (H)	Isoxaben/Gallery® (H)
Dicamba/Trimec Classic®, Banvel® (H)	Metribuzin/Sencor® (H)
Bendiocarb/Turcam® (I)	MSMA/Weedhoe® (H)
Carbaryl/Sevimol® (I)	Oxadiazon/Ronstar® (H)
Clorpyrifos/Dursban® (I)	Pendimethalin/Scotts 60® (H)
Fenamiphos/Nemacur® (I)	Pronamide/Kerb® (H)
Fluvalinate/Mavrik® (I)	Triclopyr/Turflon II Amine® (H)
Isofenphos/Oftanol® (I)	2-4-D/Trimec Classic® (H)
Trichlorfon/Proxol® (I)	MCPP/Trimec Classic® (H) Banvel® (H)
Anilazine/Dyrene® (F)	Bendiocarb/Turcam® (I)
Benomyl/Dupont 1991® (F)	Carbaryl/Sevimol® (I)
Dicarboximide/Captan® (F)	Chlorpyrifos/Dursban® (I)
Chlornoeb/Tersan SP® (F)	Ethoprop/Mocap® (I)
Chlorothalonil/Daconil 2787® (F)	Fenamiphos/NemacurR (I)
Fenarimol/Rubigan® (F)	Fluvalinate/Mavrik® (I)
Fosetyl Al/Aliette® (F)	Isofenphos/Oftanol® (I)
Iprodione/Chipco 26019® (F)	Trichlorofon/Proxol® (I)
Mancozeb/Fore® (F)	Anilazine/Dyrene® (F)
Metalaxyl/Subdue® (F)	Dicarboximide/Captan® (F)
PCNB/Scotts FFII® (F)	Chlorothalonil/Daconil 2787® (F)
Propamocarb/Banol® (F)	Fenarimol/Rubigan® (F)
Thiophanate methyl/Clearys 3336® (F)	Fosetyl al/Aliette® (F)
Thiram/Dupont® (F)	Iprodione/Chipco 26019® (F)
Triadimefon/Bayleton® (F)	Mancozeb/Fore® (F)
Paclobutrazol/Scotts TGR® (GR)	Metalaxyl/Subdue® (F)
	Propamocarb/Banol® (F)
	Thiophanate methyl/Clearys 3336® (F)
	Thiram/Dupont® (F)
	Triadimefon/Bayleton® (F)

† H = herbicide, I = insecticide, F = fungicide, GR = growth regulator.

from the golf course following an application of chlorpyrifos and irrigation. These detections reflect several storm events. Diazinon use on golf courses has been banned since the 1988 to 1990 time period; therefore most of the diazinon detections are probably due to lawn use. This is an overall MAC exceedance rate of 0.9%, or 0.6% if the diazinon results are excluded. Five pesticides and one metabolite exceeded their respective enforceable drinking water standard, that is, MCL, or their lifetime drinking water HAL at least once. The exceedance rate was 0.29%. However, the lifetime HAL/MCL is an overly conservative—albeit convenient—comparison with episodic concentrations.

The average concentration of pesticides in surface water was 0.07 to 6.8 μg/L. As explained above, the lower end of the range assumes ND = 0.0, and the upper end of the range assumes ND equals the detection limit, whatever it may be, for the particular pesticide in the particular study. The 90th percentile concentration was between 0 and 4.0 μg/L, depending on whether ND = 0 or ND = dl. The 95th percentile concentration was between 0.015 and 10 μg/L, depending on whether ND = 0 or ND = dl. There were insufficient detections to warrant regional/climate zone analysis.

Table 5. Number of database entries.

	Organics†	Nitrate-N	Total
Ground water	12 101	849	12 950
Surface water	2 731	906	3 637
Total	14 832	1755	16 587

† "Organics" includes pesticides, metabolites, and solvents. Solvents can be included in pesticide formulations.

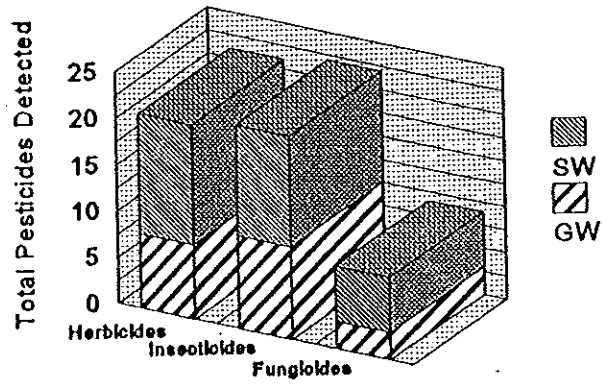

Fig. 2. Pesticides detected in surface water and ground water.

Nitrate–Nitrogen

There were no NO_3–N detections exceeding the 10 mg/L MCL. There were 201 NDs in a surface water database with 906 entries for NO_3–N. The winsorized mean was 0.3 ± 0.3 mg/L (cv = 100%), and the upper 90th percentile was 0.72 mg/L in the winsorized analysis and 1.47 mg/L when all data were used. The median was 0.21 mg/L when the data were winsorized and 0.38 mg/L (very similar) when all data were used.

Ground Water Results

Pesticides

The organics/ground water database included analyses for approximately 115 chemicals, as part of 12 101 database entries in this category. No volatile organics (VOCs) were detected in the studies, which mostly sampled monitoring wells. (VOCs are more likely to be detected in public water systems that chlorinate the water.) There were 21 pesticides/metabolites detected among 160 total detections (1.3% of the ground water organics database entries; Table 7). Only nine detections—0.07%—exceeded an MCL or HAL. Most of the exceedances were in Florida.

The average concentration of pesticides in ground water was 0.09 to 3.6 μg/L, depending on whether ND = 0 or ND = dl. The 95th percentile concentration was between 0 and 10 μg/L, depending on whether ND = 0 or ND = dl. There were insufficient detections to warrant regional/climate zone analysis. There were 103 monitoring points (monitoring wells, lysimeters, and underdrains) in these studies, and 52 of them had at least one pesticide detection. Most monitoring points were sampled more than once, and most studies lasted more than 1 yr.

Nitrate–Nitrogen

Only 81 of 849 database entries were NDs; therefore the substitution approach was used whereby each ND was substituted by one-half of the NO_3–N detection limit for the particular study. The average NO_3–N concentra-

DISCUSSION

Impacts and Trends

None of the reports we reviewed concluded that turf management on golf courses was causing significant impacts on ground water quality. Most researchers concluded that no significant impacts were observed. A few stated that more data are needed before definitive conclusions could be reached. It is worth noting that two of the studies—Waikoloa Anchialine Pond Program and the Ocean Course at Kiawah Island—basically looked at the health of the entire ecosystem.

Insufficient representation of studies in the various regions and climate zones did not allow for valid generalizations to be made. However, data from three studies at 12 golf courses in Florida allow us to make a tentative generalization about the South Atlantic Gulf-Warm Tropical-Southeast Coastal Plain overlap zone: Florida had a disproportionately higher rate of MCL/HAL exceedances than other regions.

A pesticide comparison between surface water results and ground water results produced a conclusion that appeared to be different from what we expected; that is, we expected higher detection frequencies in the surface water database, but detection frequencies were similar. Specifically, the frequencies of monitoring points with at least one detection were 50 and 54% for ground water and surface water studies, respectively. The rates at which HALs/MCLs were exceeded at the monitoring points were 7% for ground water and 6% for surface water; that is, 6 or 7% of all monitoring points had at least one HAL/MCL exceedance for at least one pesticide or metabolite. There were basically no differences within these pairs of numbers. However, there were two departures from this unexpected pattern that are consistent with our original hypothesis. Only 1.3% (160/12 101) of the ground water organics database had detections whereas the detection rate in the surface water organics database was 5.2% (141/2731). Also, the rates of HAL/MCL exceedances for all ground water and surface water entries were 0.07 and 0.29%, respectively. However, the use of chronic HALs or MCLs to evaluate short-term surface water concentrations is an overly conservative risk assessment practice. This is because the HALs/MCLs assume daily exposure to contaminated water for a lifetime, and surface water contamination by pesticides is usually episodic. (The MAC exceedance rate was 0.9% for surface water [0.6% if diazinon is excluded]. A comparison with MACs is generally not appropriate for ground water.)

Our original presumption that there would be more and higher surface water detections was based on extensive computer simulation modeling studies we have done throughout the country, review of test plot data, and basic knowledge of hydrology and solute transport. The ostensibly contradictory results presented in this report may be due to unexplained phenomena, or it may be due to the rather heavy bias in the database of golf courses in coastal plain environments (Fig. 1), that is, settings with flat sandy soils that are generally more conducive to leaching than to runoff. This is a scientific and risk assessment concept that should be explored further.

Impact of Nearby and Prior Land Uses

Some of the chemical detections in the database may be due to nearby or prior land uses. For example, 8 of the 25 MAC exceedances in the surface water organics database were due to diazinon. The use of diazinon on golf courses was phased out during the 1988 to 1990 time period (Federal Register, 28 Mar.1988 and 31 July 1990). Its field dissipation half-life is approximately 1 mo, depending on the site. Most of these studies reviewed herein were done between 1990 and 1996, long after most diazinon residues would have degraded. Therefore the probability is low that most of these results are due to golf course use. However, home lawn use of diazinon is still allowed, and golf courses are frequently part of housing developments. For example, several of the study sites in Florida, Maryland, and probably elsewhere were integrated housing/golf course developments. Thus it is likely that at least some of these results, if not all of them, are due to home lawn use.

Similarly, 2,4-D has been detected at two of the golf courses in this study—Caves Valley and Bayberry Hills—at time periods prior to any application to the golf courses. This herbicide is used widely in agriculture, on home lawns, and in rights-of-way applications. It is also the experience of the first author that labs can sometimes misidentify 2,4-D.

When the Queenstown golf course was constructed, several of the ground water samples exceeded the 10 mg/L NO_3–N MCL. These concentrations have declined over time. The site had been farmland, and nearby land is farmed, so much of the NO_3 probably originated from agriculture.

Observations such as these can be combined with the fact that golf course turf area is <1% of harvested cropland area (Cohen, 1995) to derive a simple lesson: one should not automatically assume that any pesticide or NO_3 detected at golf course sites is due to golf course management. An appropriate analysis should consider prior and adjacent land use and pesticide use, as well as surface and ground water hydrology.

Comparisons with Other Studies

The USEPA has conducted two comprehensive national studies of pesticides in ground water. Their statistically-based National Pesticide Survey is not relevant to this work because it was a true national representation in a coherent study with wells from all 50 states (USEPA, 1992b). Most relevant to this study was the USEPA's compilation of results from 150 studies of pesticides in ground water (USEPA, 1992a). The studies focused mostly on agricultural pesticides. The number of wells with detections were 24% in the USEPA study and 50% in the present (GCSAA) study. The wells with detections exceeding an HAL or MCL were 14% in the USEPA review and 7% in this review. Thus there would appear to be similar impacts of pesticides on ground water from the land uses. However, it should be noted that at least 90%, and possibly 100%, of the wells monitored in the current study were shallow wells or underdrains installed in or immediately adjacent to managed turf areas. The USEPA database contains a significant fraction of deeper drinking water wells that may be more distant from the treatment areas than the 0 to 40 ft distance typically seen in the golf course studies. The additional vertical and lateral distances would tend to attenuate migrating pesticide concentrations.

Spalding and Exner (1993) reviewed approximately 90 papers relevant to ground water contamination by NO_3. The MCL exceedances from 13 large-scale surveys ranged from 3 to 36%, and most exceeded 10%. As reported above, 4% (30/849) of the database entries in this review exceeded the 10 mg/L MCL; 10% (7/72) of the locations sampled had at least one MCL exceedance. However, as noted in the previous section, most of the NO_3–N MCL exceedances may to be due to prior agricultural use. Thus, we hypothesize that NO_3–N impacts on ground water are less from turf than agriculture. The hypothesis could be a more definitive conclusion if both studies were truly representative of the nation's ground water and therefore comparable.

The surface water databases published and herein are sufficiently dissimilar that they make comparisons difficult. Targeted agricultural herbicide monitoring in the Midwest typically has a 50 to 100% detection rate, and lifetime MCL exceedances are often >20% (e.g., Thurman et al., 1992); although, as noted above, the use of chronic HALs or MCLs to evaluate episodic exposure impacts is an overly conservative risk assessment practice. (This is often done because long-term HAL/MCL values are much more readily available and calculable than short-term numbers.) These detection frequencies compare somewhat favorably with the results of the present review which, pointedly, is underrepresented in the Midwest: a 5.2% database entry detection rate, a 54% monitoring point detection rate, and a 0.29% HAL/MCL exceedance rate.

No comparable database on NO_3 in surface water in a readily available format could be found. It is the experience of the first author that the concentrations and detection frequencies seen in this review are similar to results from general surface water quality monitoring at sites with a variety of land uses; for example, as part of state monitoring programs.

Management Practices

Many of these golf courses are high end/high visibility golf courses. Should the results of this study be extrapolated to other golf courses? Statistically, of course, this should not be encouraged due to the lack of randomization in the sample. From a management perspective, the answer is less clear. High-end/high visibility golf courses tend to have a larger pesticide budget, but the superintendents also tend to be more educated about integrated pest management practices. A followup study on this issue is indicated.

Pesticide Degradation and Soil Binding Trends

We computed average environmental fate properties for detected and nondetected pesticides and compared the two groups. Our hypothesis was that pesticides detected in surface water and ground water are more mobile and persistent than pesticides not detected. The measure we used for persistence was field dissipation $t½$ (half-life), and the mobility parameter was K_{oc}, the potential for neutral organics to bind to soil organic C.

We computed the means of the natural logarithms (ln) of $t½$ and K_{oc} for 16 pesticides and one metabolite detected in ground water, nine pesticides frequently analyzed but not detected in ground water, 23 pesticides and one metabolite detected in surface water, and seven pesticides frequently analyzed but not detected in surface water. In three out of four comparisons, the trends supported the hypothesis, but the differences were not statistically significant. The only exception was that the mean ln K_{oc} for the surface water nondetects (5.3) was slightly lower than the mean ln K_{oc} for the detects (5.8). However, the difference was not statistically significant. Further, surface-applied pesticides can run off to surface waters in the dissolved phase or when bound to small particles of eroded sediments. Therefore one would not expect a straightforward trend of K_{oc} data.

The USEPA (1992b) attempted a similar analysis in its National Pesticide Survey and had somewhat better results. They reported trends similar to what we found—higher ln $t½$ and lower ln K_{oc} for those pesticides detected in ground water vs. those not detected—but only the $t½$ comparison was statistically significant.

There may be several reasons for the lack of significant correlations for a hypothesis that appears to be well founded in environmental chemistry. One reason may be simply that more observations are needed, particularly observations from studies where all of the subject chemicals were actually used at each of the study sites. A second possible explanation is that detection is not a strong enough endpoint, that is, some measure of the severity of detection should be used that incorporates frequency of occurrence with, for example, the magnitude of concentrations detected. This is an area that warrants further study.

CONCLUSIONS AND RECOMMENDATIONS

A detailed review of 17 water quality studies of 36 golf courses indicates that widespread and/or repeated water quality impacts by golf courses is not occurring at the study sites. None of the authors of the individual studies concluded that toxicologically significant impacts were observed, although scattered exceedances of HALs, MCLs, or MACs do occur.

There are major data gaps in this review, particularly in the midcontinent area. For example, there are approximately 55 possible combinations of climate zones and ground water regions, and approximately 48 possible surface runoff/water and cz combinations. The study sites we reviewed spanned only 12 ground water combinations and 10 surface water combinations. These data gaps are reflected in the fact that we were not able to make any generalizations about regions or czs, with the exception of Florida.

In addition, the data set selection may have been unintentionally biased. Every effort was made to include all possible relevant studies that met the appropriate QC criteria. However, it is possible that golf courses with contamination problems may have eluded our search.

The percent of individual pesticide database entries[1] that exceeded HALs/MCLs for ground water and surface water were 0.07 and 0.29%, respectively. The percentages would be higher if they could be expressed in terms of samples collected rather than chemicals analyzed, but they would still not indicate significant impacts. There were no MCL (10 mg/L) exceedances of NO_3-N in surface water, and only 31/849 (3.6%) exceedances of the MCL in ground water; however, most of the NO_3-in-ground water MCL exceedances were apparently due to prior agricultural land use.

There was a key finding in the area of contamination prediction that needs further analysis. There was a slight trend for detected pesticides to be more persistent and more mobile than pesticides that were not detected, consistent with our hypothesis, but the trend was not statistically significant.

This database should be updated and reevaluated in 1 or 2 yr. This recommendation reflects the fact that many studies were still in progress as of February 1997, and had not yet produced usable results. In addition, there is an increasing trend by permitting authorities to require new golf courses to conduct water quality monitoring studies.

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[1] One database entry equals one analysis for one chemical.

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VI. Appendix C

USGS

National Water Quality Assessment (NAWQA)

Pesticide National Synthesis Project

PESTICIDES USED ON AND DETECTED IN GROUND WATER BENEATH GOLF COURSES

[Compiled (4/3/97) and updated (11/24/98) by Jack Barbash [jbarbash@usgs.gov]. Where Used on Golf Courses: Years in parentheses, if given, represent those for which use data were compiled; note that the locations given are those for which data are available, but are not necessarily the only areas where the pesticides in question have been applied to golf courses. As, arsenic, presumed to have been derived from MSMA; BS&T, detected in stream bed sediments and tissues of aquatic biota, rather than ground water; CA, California; Disc., year in which use was discontinued, if applicable; NY, New York; Mass., Massachusetts; MCPP, potassium salt of mecoprop; unspec., particular use areas in country not specified.]

USE CLASS	COMPOUND (degradates indented)	WHERE USED ON GOLF COURSES (known sites only)	WHERE DETECTED IN GROUNDWATER (golf courses only)	REFERENCE (citations given below*)
Herbicides	2,4,5-TP (silvex; disc. 1983)	U.S. (unspec.)		Hallberg et al (1996)
	2,4-D	Florida		Swancar (1996)
		Massachusetts	Massachusetts	Cohen et al (1990)
		Massachusetts		Horsley and Moser (1990)
		U.S. (unspec. [1982])		Cox (1991)
		North Carolina		Ryals et al. (1998)
		New Jersey (1993)		NJDEP (1993)
		U.S. (unspec.)		Marquardt (1997)
		New Jersey (1993)		NJDEP (1993)
	amitrol	Japan		Yamamoto et al. (1992)
	asulam	Japan		Suzuki et al. (1998)
		Japan		Suzuki et al. (1998)
	atrazine	North Carolina		Ryals et al. (1998)
		Japan		Suzuki et al. (1998)
	benfluralin (benefin)	New Jersey (1993)		NJDEP (1993)
	bensulide	Japan	Japan	Odanaka et al (1994)
		U.S. (unspec. [1982])		Cox (1991)
		New Jersey (1993)		NJDEP (1993)
	bentazon	Florida	Florida	Swancar (1996)
		New Jersey (1993)		NJDEP (1993)

chlorsulfuron	New Jersey (1993)		NJDEP (1993)
clopyralid	New Jersey (1993)		NJDEP (1993)
dacthal (DCPA)	Massachusetts		Cohen et al (1990)
	Massachusetts		Horsley and Moser (1990)
	U.S. (unspec. [1982])		Cox (1991)
	New Jersey (1993)		NJDEP (1993)
dacthal diacid (TPA)		Massachusetts	Cohen et al (1990)
dicamba	Florida		Swancar (1996)
	Massachusetts	Massachusetts	Cohen et al (1990)
	Massachusetts		Horsley and Moser (1990)
	U.S. (unspec. [1982])		Cox (1991)
	New Jersey (1993)		NJDEP (1993)
dichlobenil	New Jersey (1993)		NJDEP (1993)
diquat	New Jersey (1993)		NJDEP (1993)
dithiopyr	Japan		Suzuki et al. (1998)
	New Jersey (1993)		NJDEP (1993)
DSMA	New Jersey (1993)		NJDEP (1993)
ethofumesate	New Jersey (1993)		NJDEP (1993)
menoxaprop-ethyl	New Jersey (1993)		NJDEP (1993)
glyphosate	Florida		Swancar (1996)
	Massachusetts		Horsley and Moser (1990)
	New Jersey (1993)		NJDEP (1993)
isoxaben	New Jersey (1993)		NJDEP (1993)
MCPA	Japan		Suzuki et al. (1998)
MCPP/mecoprop	Florida		Swancar (1996)
	Japan		Suzuki et al. (1998)
	Massachusetts		Cohen et al (1990)
	U.S. (unspec. [1982])		Cox (1991)
	New Jersey (1993)		NJDEP (1993)
	Massachusetts		Horsley and Moser (1990)
metolachlor	New Jersey (1993)		NJDEP (1993)
metribuzin	Florida		Swancar (1996)
	Hawaii		Miles et al. (1992)
molinate	Japan		Niitsuma and Onishi (1992)
MSMA	Florida	Florida (as As)	Swancar (1996)
	U.S. (unspec. [1982])		Cox (1991)
	New Jersey (1993)		NJDEP (1993)
oryzalin	Florida		Swancar (1996)
	New Jersey (1993)		NJDEP (1993)
oxadiazon	Florida	Florida	Swancar (1996)
	New Jersey (1993)		NJDEP (1993)
	Southern California	(Southern CA, BS&T)	Crane and Younghans-Haug (1992)
	Unspec. (Japan?)		Sudo and Kunimatsu (1992)
pendimethalin	Japan		Odanaka et al (1994)
	New Jersey (1993)		NJDEP (1993)
picloram	New Jersey (1993)		NJDEP (1993)
prodiamine	New Jersey (1993)		NJDEP (1993)

		U.S. (unspec.); MD		Dernoeden (1998)
		Florida		Swancar (1996)
	pronamide	Japan	Japan	Odanaka et al (1994)
		Japan		Suzuki et al. (1998)
	pyributicarb	Massachusetts		Cohen et al (1990)
	siduron	New Jersey (1993)		NJDEP (1993)
		Florida	Florida	Swancar (1996)
	simazine	Japan		Ojima et al (1993)
		Japan		Suzuki et al. (1998)
		Unspec. (Japan?)		Sudo and Kunimatsu (1992)
		Japan		Niitsuma and Onishi (1992)
	thiobencarb (benthiocarb)	Japan		Suzuki et al. (1998)
	triclopyr	New Jersey (1993)		NJDEP (1993)
		New Jersey (1993)		NJDEP (1993)
	trifluralin	Florida	Florida	Swancar (1996)
Insecticides	acephate		Florida	Swancar (1996)
	methamidophos	Florida		Swancar (1996)
	bendiocarb	New Jersey (1993)		NJDEP (1993)
		New Jersey (1993)		NJDEP (1993)
	Bt	Florida		Swancar (1996)
	carbaryl	New Jersey (1993)		NJDEP (1993)
			Florida	Swancar (1996)
	chlordane (disc. in 1987)	Mass. (1950's-1970's)	Massachusetts	Cohen et al (1990)
			Massachusetts	Cohen et al (1990)
	heptachlor epoxide	Florida	Florida	Swancar (1996)
	chlorpyrifos	Hawaii		Miles et al. (1992)
		Massachusetts	Massachusetts	Cohen et al (1990)
		Massachusetts		Horsley and Moser (1990)
		North Carolina		Ryals et al. (1998)
		New Jersey (1993)		NJDEP (1993)
		U.S. (unspec.)		Marquardt (1997)
	trichloropyridinol		Massachusetts	Cohen et al (1990)
	cyfluthrin	New Jersey (1993)		NJDEP (1993)
	diazinon	Japan		Ojima et al (1993)
		Japan		Suzuki et al. (1998)
		Massachusetts		Cohen et al (1990)
		U.S. (unspec. [1982])		Cox (1991)
		NY; other U.S.(unspec.)		Marquardt (1997)
		Japan		Suzuki et al. (1998)
	dichlorvos	New Jersey (1993)		NJDEP (1993)
	dicrotophos	New Jersey (1993)		NJDEP (1993)
	disulfoton	Florida		Swancar (1996)
	ethoprop	New Jersey (1993)		NJDEP (1993)
		U.S. (unspec.)		Marquardt (1997)
		Japan		Murata and Takahashi (1991)
	fenitrothion (MEP)	Japan		Suzuki et al. (1998)

		Unspec. (Japan?)		Sudo and Kunimatsu (1992)
		Japan	Japan	Ojima et al (1993)
		Japan		Odanaka et al (1994)
	fenobucarb (BPMC)	Japan		Niitsuma and Onishi (1992)
	fluvalinate	New Jersey (1993)		NJDEP (1993)
	fonofos	Florida		Swancar (1996)
		New Jersey (1993)		NJDEP (1993)
	isazofos	New Jersey (1993)		NJDEP (1993)
	isofenphos	Japan	Japan	Odanaka et al (1994)
		Massachusetts	Massachusetts	Cohen et al (1990)
		Massachusetts		Horsley and Moser (1990)
		U.S. (unspec. [1982])		Cox (1991)
		New Jersey (1993)		NJDEP (1993)
	isoxathion	Japan		Odanaka et al (1994)
		Japan		Suzuki et al. (1998)
	malathion	Florida		Swancar (1996)
	oil	New Jersey (1993)		NJDEP (1993)
	oxydemeton	New Jersey (1993)		NJDEP (1993)
	prothiophos	Japan		Odanaka et al (1994)
	pyridaphenthion	Japan		Odanaka et al (1994)
	paraffinic oil (also an adjuvant)	U.S. (unspec. [1982])		Cox (1991)
	tetrachlorvinphos	Japan		Odanaka et al (1994)
	trichlorfon	Japan		Odanaka et al (1994)
		U.S. (unspec. [1982])		Cox (1991)
		New Jersey (1993)		NJDEP (1993)
Fungicides	anilazine	Massachusetts		Cohen et al (1990); Horsley and Moser (1990)
		New Jersey (1993)		NJDEP (1993)
	benomyl	Massachusetts		Horsley and Moser (1990)
		U.S. (unspec. [1982])		Cox (1991)
		New Jersey (1993)		NJDEP (1993)
	chloroneb	New Jersey (1993)		NJDEP (1993)
	chlorothalonil	Florida		Swancar (1996)
		Japan		Murata and Takahashi (1991)
		Massachusetts	Massachusetts	Cohen et al (1990)
		Massachusetts		Horsley and Moser (1990)
		U.S. (unspec. [1982])		Cox (1991)
		North Carolina		Ryals et al. (1998)
		New Jersey (1993)		NJDEP (1993)
		U.S. (unspec.)		Marquardt (1997)
	cycloheximide	New Jersey (1993)		NJDEP (1993)
	cyproconazole	New Jersey (1993)		NJDEP (1993)
	etridiazole	New Jersey (1993)		NJDEP (1993)
	fenarimol	Florida		Swancar (1996)
		Japan		Odanaka et al (1994)
		Massachusetts		Horsley and Moser (1990)
		New Jersey (1993)		NJDEP (1993)

	flutolanil	Japan	Japan	Ojima et al (1993); Odanaka et al (1994)
		Japan		Suzuki et al. (1998)
		New Jersey (1993)		NJDEP (1993)
	fosetyl-al	New Jersey (1993)		NJDEP (1993)
	iprobenfos (IBP)	Japan		Niitsuma and Onishi (1992)
	iprodione	Florida		Swancar (1996)
		Japan	Japan	Odanaka et al (1994)
		Japan		Suzuki et al. (1998)
		Massachusetts		Cohen et al (1990); Horsley and Moser (1990)
		U.S. (unspec. [1982])		Cox (1991)
		New Jersey (1993)		NJDEP (1993)
	isoprothiolane	Japan		Odanaka et al (1994)
		Japan		Murata and Takahashi (1991)
		Japan		Suzuki et al. (1998)
	mancozeb	U.S. (unspec. [1982])		Cox (1991)
		New Jersey (1993)		NJDEP (1993)
	maneb	Massachusetts		Horsley and Moser (1990)
		U.S. (unspec. [1982])		Cox (1991)
	mepronil	Japan		Suzuki et al. (1998)
	mercurous chloride	New Jersey (1993)		NJDEP (1993)
	metalaxyl	Florida	Florida	Swancar (1996)
		Japan	Japan	Odanaka et al (1994)
		New Jersey (1993)		NJDEP (1993)
	myclobutanil	New Jersey (1993)		NJDEP (1993)
	oxine-copper	Japan		Odanaka et al (1994)
	PMA	New Jersey (1993)		NJDEP (1993)
	propamocarb HCl	New Jersey (1993)		NJDEP (1993)
	propiconazole	New Jersey (1993)		NJDEP (1993)
	quintozene (PCNB)	New Jersey (1993)		NJDEP (1993)
	sulfur	New Jersey (1993)		NJDEP (1993)
	thiophanate	New Jersey (1993)		NJDEP (1993)
	thiophanate-methyl	New Jersey (1993)		NJDEP (1993)
	thiram	U.S. (unspec. [1982])		Cox (1991)
		New Jersey (1993)		NJDEP (1993)
	toclofos-methyl	Japan		Odanaka et al (1994)
	triadimefon	Florida		Swancar (1996)
		Japan		Suzuki et al. (1998)
		Massachusetts		Horsley and Moser (1990)
		New Jersey (1993)		NJDEP (1993)
	triflumizole	Japan		Odanaka et al (1994)
	vinclozolin	New Jersey (1993)		NJDEP (1993)
Nematicides	ethylene dibromide (EDB)	U.S. (unspec. [1982])		Cox (1991)
	fenamiphos	Florida	Florida	Swancar (1996)
		New Jersey (1993)		NJDEP (1993)
		U.S. (unspec.)		Marquardt (1997)
	fenamiphos sulfoxide		Florida	Swancar (1996)

	fenamiphos sulfone	Florida	Swancar (1996)
Adjuvants (see note below**)	aromatic hydrocarbon solvents	U.S. (unspec. [1982])	Cox (1991)
	pentachlorophenol	Massachusetts	Cohen et al (1990)
	(also a wood preservative)	U.S. (unspec. [1982])	Cox (1991)
	xylenes (mixture of isomers)	U.S. (unspec. [1982])	Cox (1991)
Growth hormones	amidochlor	New Jersey (1993)	NJDEP (1993)
	ammonium chloride	New Jersey (1993)	NJDEP (1993)
	azadirachtin	New Jersey (1993)	NJDEP (1993)
	flurprimidol	New Jersey (1993)	NJDEP (1993)
	mefluidide	New Jersey (1993)	NJDEP (1993)
	paclobutrazol	New Jersey (1993)	NJDEP (1993)
	trinexapac-ethyl	New Jersey (1993)	NJDEP (1993)

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**Adjuvants are chemicals that are added to pesticide formulations to make them easier to handle or apply, or to improve the efficiency with which the pesticide active ingredient reaches its target organism(s). Adjuvant compounds include wetting agents, spreaders, emulsifiers, dispersing agents, foaming enhancers, foam suppressants, penetrants, correctives, surfactants, solvents, solubilizers and buffering agents (Farm Chemicals Handbook, 1995, Meister Publishing Co., Willoughby, Ohio).

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