Wake County Field Performance and Operation & Maintenance Survey of Systems Installed 1982-2002

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Executive Summary

On-site wastewater treatment and disposal systems, or septic tank systems, are a widely utilized means of decentralized, wastewater treatment and disposal in Wake County. Such technology has been in use for many years and is accepted as a safe and effective means of treating and disposing of wastewater. Almost one-quarter of Wake County residents utilize septic tank systems to treat and dispose of their wastewater. There are approximately 55,000 septic tank systems in use in the County, and an additional 1,800 septic tank systems are permitted each year. Extension of municipal sewer systems has reduced the overall need for new installations in some areas and has incorporated some developments formerly served by on-site systems into municipal service areas. However, many areas in the County currently served by septic tank systems do not lend themselves to incorporation into urban service systems. Properly functioning and well-maintained septic tank systems provide an effective means of mitigating residential wastes, but when septic tank systems fail they pose public health concern, potentially contaminating surface and groundwater with pathogens and nutrients.

Concerns about the sustainability, functionality, and management of on-site systems were expressed in recommendations of the Wake County "Comprehensive Watershed Management Plan". These recommendations included the development of a pilot study of septic tank systems in a priority area, and based upon study findings, development of conclusions/recommendations with respect to management of septic systems.

In response to the recommendation for a pilot study, staff of the Wake County Department of Environmental Services (WDES) worked together with the North Carolina State University Department of Soil Science and the North Carolina Cooperative Extension to design and conduct a pilot study of septic tank systems in Wake County. The study objectives were to determine the function of systems, the degree and type of maintenance provided to systems, the possible relationship between system function and maintenance, and the need for an expanded wastewater management program.

A protocol under development by Dr. Michael Hoover, Professor of Soil Science at North Carolina State University, was utilized for guidance in designing the study. Considerable time was also devoted to development of the survey instruments, a field data survey and a homeowner interview survey, utilized to record findings from the survey. As the design for the study evolved, it was decided that rather than focusing on a limited, priority area, a better approach would be to evaluate a random sample of systems installed throughout the County. Hence, study results could be more easily extrapolated to a much larger population. Ultimately, the random sample was selected from all systems installed between 1982 and 2001, a population of approximately 33,000 systems (based on a dataset developed by Camp, Dresser & McKee Consulting during the Comprehensive Groundwater Investigation). These years were chosen because soil/site criteria for septic system location were codified in 1982, and WDES Regulations required all systems of this vintage to have access risers over septic tanks to facilitate maintenance/pumping. Systems installed after 2001 were not included to exclude systems that had not matured or that failed quickly due to reasons other than maintenance. A total of 455 systems were randomly selected. The sample was over selected to address loss of sites that proved non-viable for survey purposes. This number was finally reduced to a total of 310 viable sites after the elimination of sites that were found to be served by public/community wastewater disposal systems, sites for which septic tank system permits could not be found, and sites that were excluded on the day of survey (due to inability to locate, occupant refusal, or vacant). This number represented approximately 1% of the total number of systems installed between 1982 and 2001.

Prior to conducting the field survey, the randomly selected sample was geographically grouped into 9 survey districts of relatively equal size utilizing Wake County GIS maps. Survey packets were assembled for each survey district. The packets included copies of the letter of intent (stating the time, purpose and mode of execution of the survey), GIS maps, county road maps and a file folder for each study site in the district. Each file folder was assigned a unique identifier number and included a copy of the survey instruments, a copy of the permit for the septic tank system, and an ortophotograph of the site. Teams comprised of 2 to 3 members surveyed the 9 districts. Each team was constructed to include one Wake County on-site wastewater program staff member and at least one non-staff member to minimize bias. A consistency training session and field practicum was also conducted to help standardize data collection and ensure consistency and quality. In addition to the survey packet, survey teams were also provided with homeowner educational materials and a camera for visual documentation of system failures or other notable conditions.

Additional preparation for the survey included notification of the County's elected officials, the public and those selected for the survey. This was accomplished through memorandum to the Wake County Board of Commissioners, news releases, newspaper articles, a radio interview and letters of intent/cards mailed to the owners of sites selected for the survey.

The pilot study involved conducting a wet season, field performance survey of septic tank systems in Wake County to determine whether they were functioning properly and to what extent they were being maintained. For the purposes of this survey, a failed system was defined as (1) one with sewage present on the soil surface on the day of the survey, (2) one where sewage would surface in a moist area when pressure was applied with the surveyor's shoe on the day of the survey, (3) one with a straight pipe from the wastewater system, or (4) one identified as a potential failure on the day of the survey and confirmed as failing during a follow-up visit. The actual field survey of randomly selected systems was conducted during the first week of April 2003 (April 1-4, 2003). Field evaluations were conducted at 310 sites and homeowner interviews were conducted at 199 of these sites. Data were collected for approximately 70 parameters relative to system design/siting, site maintenance, and homeowner (in-house) maintenance. For additional quality assurance and quality control, 27 of the 310 (3 from each team) study sites were randomly selected and revisited for a second "blind survey" by a quality assurance team. Additional survey follow-up work was conducted on 30 sites identified in the initial survey as showing no evidence of current failure on the day of the survey, but showing evidence of recent past, potential failure. This follow-up work identified 5 additional sites that were considered to show evidence of current failure. These additional 5 sites were included with the originally identified 25 sites in the analysis of data relative to system failure.

All data was formatted and entered on an Excel database. Dr. Larry King (Soil Science Consulting, Professor Emeritus of Soil Science, NCSU) and Dr. Larry Nelson (Consulting Statistician, Professor Emeritus of Statistics, NCSU) analyzed the data. Data was analyzed statistically to determine the significance of relationships between approximately 70 parameters and system failure rate. The terms "failure" and "malfunction" are used interchangeably in this report. Therefore, "failure" as used here does not mean that a particular septic system has reached the end of its useful lifespan for the system owner. Many, if not most, of these systems that are in malfunction can be remediated and become functional again. Hence, the failure rates discussed here can be improved as "failing" systems are located and repaired.

The statistical analysis used depended on the type of parameter being studied. For continuous parameters (e.g., age of the systems), regression analysis was used to find the best relationship between the parameter and failure rate. For non-continuous parameters (e.g. types of systems), chi-square (x^2) analysis was used. This procedure allows one to determine the probability that the parameter and the failure rate are related rather than the observed relationship being due to chance. A 10% probability level was used for regression and chi-square analysis (i.e. a 10% probability that the difference observed is due to chance alone).

Failing systems (surface hydraulic failure) were found at a total of 30 of the sites (a failure rate of 9.7%). These included 25 systems (8.06%) identified on the day of the survey and 5 additional systems (1.6%) identified during follow-up assessments of potential failures. These additional 5 sites were included with the originally identified 25 sites that had a surface hydraulic failure in the analysis of data relative to system performance.

Two important parameters that must be considered when selecting a site for a system are landscape position and soil type. Prior to data analysis, landscape positions and soil mapping units (identified as the dominant soil mapping unit on the property utilizing the County GIS layer of the Wake County Soil Survey) were each assigned a numerical score of 0 to 50 (0 being the poorest and 50 being the best landscape position/soil for a drainfield) based on their suitability as a drainfield site. Note that soil assessments were not conducted during the field survey, and actual soil conditions are unknown at the study sites. However, the study teams determined landscape position using standardized terminology and examples. Failure rates were significantly higher at the bottom of slopes and on convex side slopes than on most other landscape positions (mean of 20% vs. 4%). No failing systems were found on head slopes, which is a landscape position commonly regarded as a poor site for on-site systems. Failure rates were significantly higher on soils with suitability scores of 10 or less than on soils with scores of 11 to 50 (24% vs.8%). Site suitability scores were calculated by summing the numerical score for soil and landscape position. Failure rates were not significantly related to site suitability score.

Two major factors considered in system design are selection of the system type and the hydraulic loading rate. Failure rate was not significantly related to the design hydraulic loading rate. Failure rates of conventional gravel trench systems did not differ significantly from those of innovative systems or low-pressure pipe systems. However, rates were significantly higher for low-pressure pipe systems than for innovative systems (28% vs.7%). Within the seven low-pressure pipe systems, those that were operated by a State certified subsurface operator had a 0% failure rate, while those without an operator had a 100% failure rate.

Site maintenance factors were carefully observed and recorded by the survey teams at the study sites. One site maintenance parameter significantly related to failure was shaping or crowning of the drainfield area to shed rainwater. Failure rate was higher where drainfields were not shaped (20% vs. 8%). Failure rate was not significantly related to the system installer, diversion of on-site and/or off-site surface water, or the presence of linear depressions over the drainfield trenches.

Failure rate increased with increasing age of the systems. Combining age and soil suitability score showed that this relationship was significant on soils with scores <20 but was not significant on the more suitable soils. The regression model showed an increase in proportion of failures of 1.6% per year. However, this model explained only 17% of the relationship between age and failure rate. Hence, system age alone was not a strong predictor of failure rate for systems up to 20 yrs of age.

Several other parameters associated with site maintenance or system maintenance was included in the survey. Systems on which some type of structure had been built failed at a significantly higher rate than did systems without structures (22% vs. 8%). Failures were also more frequent on systems with no vegetative cover, that were wooded, or that were in weeds and brush than for other types of vegetation (mean of 27% vs. 8%). Failures were more common when the vegetation was not maintained (21% vs. 9%). In some cases these were not clearly cause/effect relationships, but indicated a correlation existed (e.g. lack of maintenance over the system did not necessarily cause a failure).

Failures were significantly higher for systems where the tank had been pumped (18% vs. 7%). This relationship likely results from homeowners having the tank pumped as the first attempt to correct a failing system, rather than pumping being detrimental to system performance.

A significant relationship was found between system failure and indications of past failure or potential failures (48% vs. 0%). One example of this relationship was the fact that failures were significantly higher at sites where fill material had recently been placed over the drainfield, which is a practice homeowners sometime use (often unsuccessfully) in an attempt to correct a failing system (29% vs. 9%).

A very good relationship was found between the number of adults per household and the occurrence of failure. The regression model indicated a 5.4% increase in the proportion of failures with each adult in the household. The model explained 94% of relationship between number of adults and system failures. However, in contrast, the relationship between the total number of occupants in a household and the proportion of failures was not significant.

System failures was not significantly related to the source of water supply (well or public water supply); amount of water used (data available from only 122 sites); number of teenaged children per household; first time living in a house with an on-site system; use of a garbage disposal unit, dishwasher, clothes washer, water softener, toilet bowl sanitizer, septic tank inoculants, whirlpool, hot tub, or irrigation system; and pouring harsh chemicals down the drain.

A relationship between a homeowner's possessing educational material and/or a copy of the system permit versus system maintenance was found. When this information was available, the homeowner was more likely to spread laundry throughout the week than wash all laundry on one day (93% vs.61%), thus reducing hydraulic load on the system. Similarly, homeowners were less likely to pour harsh chemicals, which can impair system function down the drain when they had the information (36% vs.13%).

Scores (weightings) were developed and assigned to parameters associated with site maintenance and system maintenance prior to the field survey. Following data collection, these scores then were totaled to produce an overall maintenance score for each system. No significant relationship was found between the pre-assigned maintenance score and the incidence of failure.

Lessons Learned and Recommendations

The pilot study of septic systems in Wake County revealed that, overall, system performance was quite successful in the county. When viewed in the context of other system performance studies, the observed percentage of system failures (approximately 10%) indicates that the current wastewater disposal program implemented by WDES is working reasonably well. Other studies have detected the occurrence of failures for conventional septic systems to at times exceed 20% (Dr. Michael Hoover, personal communication). The County has maintained a staff of professionals including well-trained environmental health specialists, soil scientists and environmental engineers to provide oversight and technical support of on-site wastewater disposal in the County. The County also regularly conducts operation and maintenance inspections on select systems that employ certain complex technologies (i.e. low-pressure pipe systems, systems employing multiple pumps installed or repaired after 1992, systems designed for disposal of large volumes of wastewater, systems employing pretreatment, etc.). It is notable that the County also inspects discharging and non-discharging systems permitted by the State under Memorandum of Agreement with the North Carolina Department of Environment and Natural Resources, Division of Water Quality.

Although the observed incidence of failure is not excessively high in light of other studies, it is deemed to be higher than that desired or believed achievable. The study was designed to allow for extrapolation of study results to the population of 33,000 systems installed between 1982 and 2001. Viewed in this manner, the observed percentage of failures of approximately 8% on the day of the survey and 10% overall (including the systems classified as failing during the follow-up visits) equates to between 2,600 and 3,300 failing systems during the wet season, spring of 2003. It must also be noted that the study population only accounts for 33,000 of the estimated 55,000 septic systems in the County. Many of these additional 22,000 systems will be older than those studied. If the incidence of failure for these 22,000 additional older systems are similar to the study population, then it is estimated that there are at least 2,600 and perhaps more than 5,500 unrepaired failing septic systems in the county during typical wet seasons.

Recommendation No. 1 – Homeowner-impacted site maintenance, system use and periodic system maintenance were related to the incidence of system failure or to the pattern of use of waste-producing appliances. These include type and maintenance of vegetative cover over system areas, number of adults per house, failed attempts to effect permanent system repair (i.e. pumping of septic tanks and addition of fill to system area), spreading washing of laundry during the week/not pouring harsh chemicals down the drain. These latter two items also were related to possession of educational materials and/or a copy of the system permit. Additionally, evaluation of overall operation and maintenance scores indicated that many system owners were not carrying out site and system maintenance in the preferred manner. It seems apparent that one of the best ways to address these factors is through public education. WDES is currently providing educational materials to applicants for on-site system permits and through cooperative effort with the Raleigh Regional Association of Realtors by supplying educational materials at the time of sale of a property served by an on-site system. North Carolina State University (NCSU) via the Wake County North Carolina Cooperative Extension (NCCE) Center has substantial potential to work with WDES in developing research-based educational programs and materials. The NCCE also maintains a nationally recognized on-site wastewater, training center displaying essentially all septic system technologies here in Wake County. Additional partnerships between NCCE, NCSU and WDES should be developed to bring quality educational materials and programming into the homes of septic system users via public service spots, educational programs, web-based materials and other programs. Consideration may also be given to direct mailing of educational materials to on-site system owners, possibly along with other County mailings such as tax bills. Educational efforts will be coordinated with the Environmental Education & Environmental Information Providers Group, along with exploration of additional educational opportunities.

Recommendation No. 2 – The study indicated several site maintenance parameters that affect the amount of water that must flow through the soil, along with the wastewater, to be related to system performance. The lack of "crowning" or shaping of the drainfield to shed water, which had an even more pronounced effect when combined with soil mapping units with low scores (considered poor), was related to a higher incidence of system failure. A similar relationship was also true of the occurrence of linear depressions over drainfield trenches and lack of diversion of on-site water for systems located on more restrictive landscapes. On the other hand, failure rates can be quite low, even on more restrictive sites, if site maintenance is carefully managed following system installation. Based on these findings, it is recommended that greater consideration be given to requirement and utilization of measures to control surface and shallow groundwater movement on certain landscape positions that tend to collect water. This can be incorporated into the current permitting process. However, this will require inspection of additional structures by WDES staff. Additionally, education of members of the development community along with their cooperation is necessary for success. Water control measures may impose additional setback requirements for on-site systems. Future development will likely be occurring on less suited soils and landscapes than used over the past 20 years. Hence, poor site maintenance could lead to even greater overall failure rates in the future if adequate land is not provided to assure site maintenance. This must be taken into account at the planning stage of subdivision development, and in some cases, may necessitate increased lot size.

Recommendation No. 3 – Many of the site maintenance parameters described in Recommendation No. 2 must be addressed using post-installation inspections of the septic system, since final landscaping occurs subsequent to the installation and construction inspection of the on-site system, and as a result, is not regularly observed by WDES staff. In addition, settling of backfill in proximity to system components and on the drainfield trenches may occur in the first few weeks or months following installation. Addressing these landscaping issues would require an additional inspection by WDES staff, preferably 6 to less than 12 months after installation. Note that the builder/contractor normally retains some responsibility for correction of problems for about 12 months subsequent to facility construction. Such inspection would also allow for review of other features associated with the on-site system (e.g. construction and function of water diversions/interceptors, etc.) and provide an opportunity to interact with the facility owner and provide education to them regarding use and maintenance of their septic system. These activities would require commitment of additional resources.

Recommendation No. 4 – The study showed a clear relationship between system failure rate and certain unauthorized uses (e.g. location of outbuildings, shed, garages, etc.) of the system area. This issue seems most appropriately addressed through the permitting process and education. There has been a trend toward development of lots with reduced available space for location of on-site systems and ancillary structures. This trend appears to be related to the advent of proprietary products that allow for reduction in space required for the on-site system, a shift towards larger homes and market forces that result in maximizing lot yield. WDES has for some time taken the position that proposed additions to a site is reviewed for potential impact on the septic system prior to issuance of building permits. WDES currently conducts reviews for only certain additions to properties that are under

Wake County Building Inspections' jurisdiction. Wake County should expand this process to include all proposed additions to facilities/sites served by on-site systems, and this process should be consistent for any permitting authority issuing building permits in Wake County. This review process also provides an educational opportunity with the permit applicant to discuss the potential impacts to the on-site system of adding appurtenances to their property.

Recommendation No. 5 – Currently, operation and maintenance by professional operators is mandated by State rules for only a limited number of systems that utilize more complex technology and/or dispose of large volumes of wastewater. Although the study was not specifically designed to test impacts of different waste disposal technologies, a significantly higher failure rate was observed for the small sample of low-pressure pipe systems that lacked a certified subsurface system operator. These failing systems were installed prior to July 1992 when the operator requirement was mandated by State rules. It is notable that the County has approximately 1,000 systems (low-pressure pipe systems) that were installed prior to 1992 and predate the operator requirement. This information suggests that consideration should be given to expansion of operator requirements for systems employing such complex technology. This would require revisions in State rules and/or Wake County's wastewater regulations and would likely meet with public opposition due to initial increased cost of wastewater system operation/maintenance. However, such requirement would likely result in reduced long-term cost of system operation through improved system performance and avoidance of costly repairs. It is also notable that effluent filters, which require servicing every 2-5 years, have been required for septic tanks installed since February of 1998 in Wake County. For on-site systems without professional operators, this responsibility is left to the system owner.

Recommendation No. 6 – The County should give consideration to meeting the operation and maintenance review criteria (inspected every 5 years) set forth in State rules [15A NCAC 18A .1961 Table V (a)] for all systems installed after July 1, 1992 that include effluent pumps. A much more far-reaching and involved approach would be to require inspection of all systems at some predetermined frequency (e.g. once every 5-7 years). Another possibility would be to refine this approach based upon risk and focus efforts on the areas of the highest public health concern and environmental sensitivity. All of these approaches require extensive commitment of resources and thorough analysis of possible program elements, cost, funding, etc. that goes beyond the scope of this study. Such inspections could be conducted by private entities (i.e. associated with inspection of system components, inspection of residual accumulations in tankage and pumping of tanks, etc.) or by a public agency. Note that a number of possible management models are included in the US Environmental Protection Agency's "Voluntary Guidelines for Management of On-site and Clustered (Decentralized) Wastewater Treatment Systems".

Recommendation No. 7 – As previously indicated, the observed failure rate indicates that there are likely to be between 2,600 and 5,500+ failing systems during any wet season. Approximately 400 repair permits are issued for on-site systems each year. These repairs result largely from citizen complaints, citizen requests for service (oft times associated with sale of a residence) and malfunctions observed by WDES staff in performance of their normal duties. Hence, the number of repair permits issued based upon what is essentially a self-reporting system, does not address the cumulative number of systems in malfunction. Another tool employed by WDES to address areas of higher risk are community surveys of on-site systems. Such surveys are extremely time consuming and of limited application with current resources. It is evident from the number of repairs that a large number of failing systems do not currently come to the attention of the County. One mode of addressing this issue would be the conduct of on-site system inspections by “certified inspectors” at the time a facility was sold. This would possibly require State Legislative action and seems to mesh well with the current effort to establish certification of on-site system inspectors, which has been supported by Wake County’s legislative delegation. However, there are other potential options that can be evaluated and considered. For instance, Wake County could consider establishing requirements for time-of-sale inspection as a part of their local county rules because of the public health significance, the likelihood that self-reporting will not identify malfunctioning systems in a timely fashion and the lack of assurance that a state program will start soon. The county could utilize the efforts of the National Sanitation Foundation (NSF International). NSF is a non-profit public health and safety agency that has established a national, voluntary time-of-sale septic system inspector certification (accreditation) program. Counties throughout the US use this NSF program to set inspection standards and identify appropriately qualified individuals who can conduct them. This offers the opportunity to start an inspection program nearly immediately so that failing systems can be identified via the private sector and brought back into function and compliance via the WDES staff.

Recommendation No. 8 – The importance of having the capability to accurately locate and document the components of on-site systems was made readily apparent by this study. This is also critical for any future management initiatives. The County should proceed as rapidly as possible with the current demonstration project utilizing GPS to locate and catalog location of wells and on-site system components. Based upon the success of this project, sufficient GPS units should be made available to WDES staff to locate all on-site systems and wells. The County should also develop and maintain a layer in GIS to document all on-site system locations. The County could also develop funding proposals (in conjunction with appropriate partners including NCSU and NCCE) for assessment of the potential effects of runoff from failing septic systems into adjacent streams and to establish a loan and grant program to remediate failing septic systems. Similar loan and grant programs have been funded in some local health agencies via NC Clean Water Trust Fund, USEPA and other funding sources. The county should investigate the possibility of obtaining State Revolving Funds (SRF) for repair and remediation. New funding priorities within SRF nationally have identified a specific part of the SRF fund for decentralized wastewater and stormwater remediation technologies in communities.