Statement of Reasons Pursuant to Connecticut General Statutes Section 4-168d

HEARING REPORT
May, 2005

Amendment of the Regulations of Connecticut State Agencies Concerning Amends to Subsections 22a- 354b-1(e), 22a-354b-1(f) and 22a-354b-1(g) of the Regulations of Connecticut State Agencies: Regulations for Mapping Wells in Stratified Drift Aquifers to Level A Standards

Hearing Officer:

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Water Management Bureau
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Hearing Date:

July 12, 2004

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APPENDICIES

I. INTRODUCTION

On June 8, 2004, the Commissioner of Environmental Protection ("Department") published a notice of intent to amend Subsections 22a- 354b-1(e), 22a-354b-1(f) and 22a-354b-1(g) of the Regulations of Connecticut State Agencies ("RCSA"): Regulations for Mapping Wells in Stratified Drift Aquifers to Level A Standards ("Mapping Regulations"). Pursuant to such notice, a public hearing was held on July 12, 2004 in the Russell Hearing Room at 79 Elm Street, Hartford. Four individuals provided oral comments at the hearing.

The public comment period for the proposed regulations closed on July 16, 2004 at 4:30 p.m. The comment period included a four-day extension of time in response to a verbal request. Ten written comment letters were received. The list of individuals and organizations who submitted comments on the proposed amendments to the regulation is included in Appendix I.

II. ADMINISTRATIVE REQUIREMENTS

As required by the Connecticut General Statutes ("CGS") section 4-168(d), this report describes: the regulation as proposed for hearing; the final wording of the proposed regulation; a statement of the principal reasons in support of the Department's intended action; a statement of the principal reasons in opposition of the Department's intended action and the response to such comments.

III. BACKGROUND

Connecticut citizens have long relied on ground water for drinking water – both from private residential wells and public supply wells. Currently, over one million Connecticut residents use ground water as their source of drinking water. In the late 1970s and early 1980s many public supply wells were found to be contaminated by various pollutants. The Connecticut General Assembly responded by establishing a Legislative Aquifer Protection Task Force to evaluate the need for a regulatory framework to improve the protection of Connecticut's ground-water resources. The Task Force held numerous meetings and public hearings, performed research over a two-year period and prepared two reports to the General Assembly concerning aquifer protection. Legislation passed in 1988 required the Department to develop mapping guidance for Level B (preliminary) mapping and regulations for Level A (final) mapping of aquifer protection areas ("APAs"). The reports recommended that a comprehensive regulatory management framework be enacted to protect Connecticut's largest public supply wells in stratified drift aquifers, including minimum state standards necessary to protect the most sensitive aquifer areas in Connecticut as defined through a scientific mapping process. The outcome was the unanimous passage of the Aquifer Protection Act (CGS sections 22a-354a through 22a-354bb) in 1989.

The Level A mapping regulations were promulgated in 1991, establishing the standards for hydrogeologic mapping of the APAs for large public water supply wells. Once mapped to Level

A standards in accordance with this regulation, the statute requires the municipalities to adopt the mapping as an aquifer protection area and to impose land use restrictions on the area to protect the wells from contamination. These protection measures, the Land Use Regulations, were adopted in February, 2004 pursuant to CGS Section 22a-354i.

The mapping regulations apply to public supply wells which serve more than 1000 people and are located in sand and gravel deposits. There are currently 122 active well fields in Connecticut meeting these criteria (see figure 1 below). All the APAs have been preliminarily mapped using Department guidelines (Level B Mapping Guidelines). These preliminary areas are in the process of being refined through the Level A mapping process. To date, Level A mapping has been submitted for 39 well fields, 20 of which have been approved by the Department.

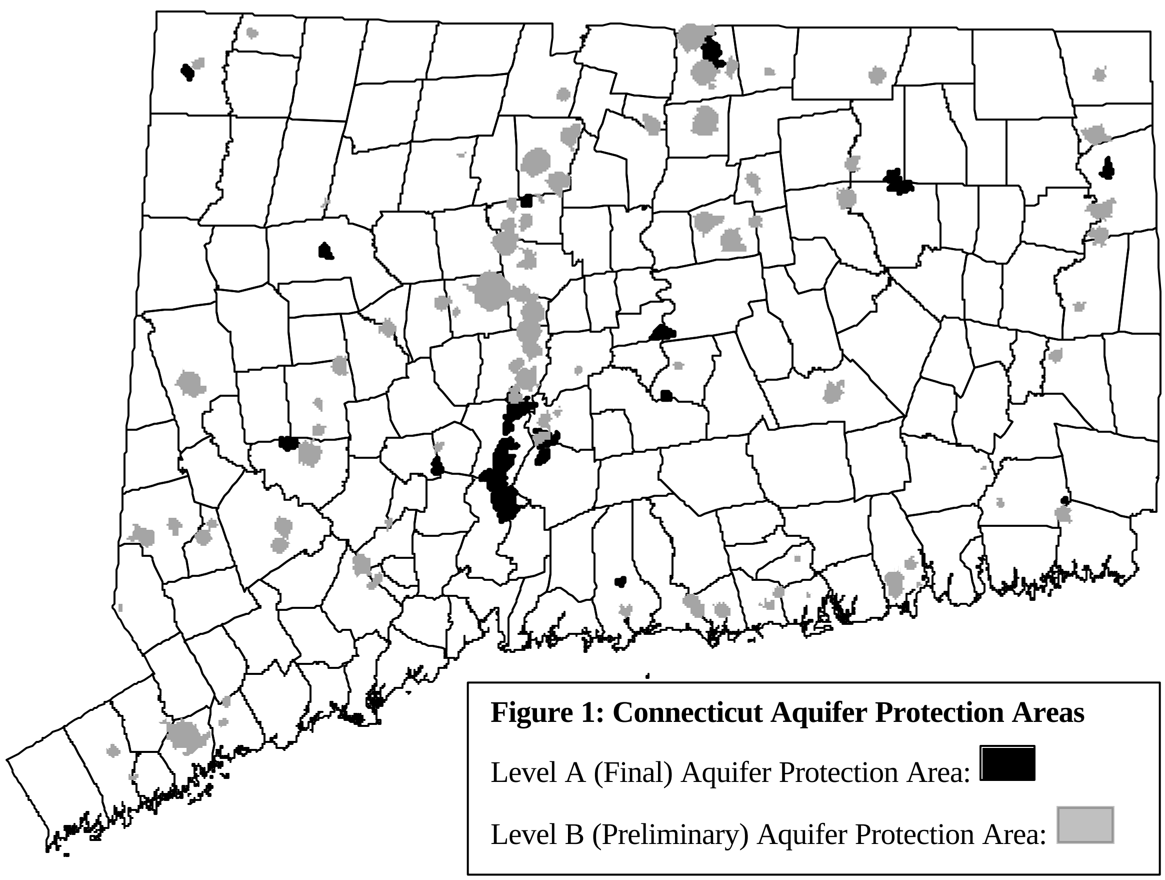

Figure 1: Connecticut Aquifer Protection Areas

The mapping regulations establish the standards and methodologies for conducting Level A mapping. Mapping consists of collecting site specific data about the well field and surrounding aquifer; using this data to create a numerical ground water model of the aquifer system; adjusting, or calibrating, the model against the site data to ensure that the model is a reasonable approximation of the real world aquifer system; and finally, running the calibrated model under a specified set of conditions (the predictive simulation) to predict the land area from which the well field is capturing water under those conditions (the level A area). The mapping regulations spell out the minimum data and modeling standards and the methods to use for the data collection and modeling. The regulations specify that a Plan for Data Collection and Analysis be submitted to the Department for review and approval before the field work and modeling are conducted. Once the plan is approved by the Department, the consultant carries out the work and documents it in a report. The Level A mapping report is then submitted to the Department for review and approval.

The predictive modeling simulation required by the mapping regulations was intended to be conservative – to predict, under a drought condition, what land area contributes water to the well field. The requirements in the existing mapping regulations specify that the predictive simulation begins from a low flow (late summer) condition for stream flow and ground water levels. The simulation is then run for 180 days with no recharge[1] at maximum allowable pumping rates for the well field. The exact same transient[2] model simulation must be run a second time without the wells pumping. The resulting flow fields and water levels (or heads) from the two model runs are then compared to determine the land area affected by the well field under the simulated conditions.

Several water companies have conducted Level A mapping in accordance with the regulations ahead of the statutory deadline. As this mapping progressed, technical questions about the procedure for the predictive simulations were raised by the ground water consultants conducting the mapping. They were concerned that the delineation methodology included areas that would have very little, if any, impact on water quality at the well field, and therefore about defensibility of the delineation if challenged by impacted land owners. The existing methodology requires the predictive simulations to start at late summer low flow conditions, and then to run for an additional 180 days with no recharge. A "snap-shot" of the ground water flow field at the end of the simulation is taken, and all the ground water within the area of contribution for the well field is assumed to reach the well. However, this would be an extreme drought condition, and even if this condition were to actually occur in Connecticut, it would be temporary. Connecticut's precipitation is fairly evenly distributed over the year, and during the winter and spring, when evapotranspiration is low, recharge to the ground water system occurs. Once recharge increases in the winter, flow conditions change, and ground water from fringe areas that was temporarily diverted toward the well field will change direction and flow back to its natural discharge point. Ground water from these fringe areas may never reach the well. Or, if it did reach the well, travel times (on the order of years or tens of years) would be sufficient for considerable dilution and attenuation of contaminants to occur, such that water quality at the well would not be impacted.

In addition, the existing methodology requires two predictive simulations to be run, one with pumping and one without pumping, and then to graphically overlay the flow fields and subtract the water levels from the two runs to determine the area of influence of the well field. The area of contribution is then derived as that portion of the area of influence that flows to the well field. In the time since the regulations were originally developed, improvements in modeling techniques, particularly particle trackers, have eliminated the need for two separate runs and

[1] The term "recharge" incorporates both precipitation and evapotranspiration.

[2] A "transient simulation" is a model simulation that is time-dependant, i.e. run for a specified time period; as opposed to a "steady-state simulation", which is independent of time and is run to equilibrium (where water flowing into each model cell equals that going out).

simplified some aspects of the methodology. Particle trackers allow the modeler to trace ground water movement through the model and provide a more direct methodology for determining the area of contribution to the well field. However, particle tracking methods can not be directly applied to the transient model simulation in the existing regulations.

The Department convened a work group of technical experts to evaluate these concerns. The work group included the consultants who raised the concerns, staff of the US Environmental Protection Agency and the US Geological Survey and Department staff (see Appendix II for a complete list of participants.) The Department also funded a comparative modeling study conducted by McDonald Morrissey Associates to evaluate modeling options (see Appendix III for copy of study report.) The study utilized two well fields in the APA program. The two well fields were chosen to cover different aquifer configurations: Aquarian Water Company's Oxford Well Field is in a relatively small aquifer in a narrow valley setting; South Central Connecticut Regional Water Authority's North Cheshire Well Field is in a broad, areally expansive aquifer setting. Three different modeling simulations were run for comparison at each of the well fields. The simulations were as follows: (1) the existing transient Level A mapping simulation of a 180-day drought condition; (2) a steady-state "average" condition simulation (50% duration flow[3] for streamflow, and long-term average annual recharge); and (3) a long-term transient simulation in which a 180-day no-recharge drought occurs every five years, and otherwise average conditions prevail. Of the three modeling scenarios, the long-term transient simulation with periodic drought (#3 above) is the most realistic in terms of identifying the ground water and land area that contribute to the well field. The increased data requirements and the complexities of running such a simulation make requiring this simulation for the regulation infeasible. However, this "realistic" scenario was the benchmark against which the other two simulations were compared for each well field. In both aquifer settings, the steady-state "average" condition simulation (#2 above) provided a very close approximation of the long-term transient simulation, and provided a much better approximation than the 180-day transient simulation (#1 above) (See Appendix III, figures 1 and 2). In contrast, the 180-day transient simulation significantly over-predicted the contributing area for each well field.

The study results were discussed at length by the work group. There was consensus that the 180-day transient drought condition simulation in the existing regulations was overly conservative, i.e., delineated an area larger than necessary to protect the public water supply well field. The recommendation was to change the predictive simulation to a steady-state "average" condition simulation. Further, the work group recommended the addition of particle tracking and the other small changes to the methodology that would contribute to the technical defensibility of the model. The proposed amendments are the result of the work group discussions. They are intended to improve the defensibility of the APAs and simplify the methodology, while still providing adequate protection for these important public water supply wells.

IV. SUMMARY OF REGULATION AS PROPOSED FOR PUBLIC HEARING

The text of the regulations as proposed for public hearing is attached as Appendix IV. The substantive change is proposed to subsection (e) of the regulation. As discussed above, the

[3] 50% duration flow is the streamflow met or exceeded 50% of the time.

amendments are focused on the method specified in the regulation for running the final predictive numerical model simulations. The amendments change the predictive simulation from a transient 180-day drought simulation, to a steady-state simulation under more “average” conditions for stream flow (50% duration flow) and recharge (long-term average annual). This will result in a more accurate, but still conservative, prediction of ground water that is drawn in by the well.

In addition, the amendments add subsection (e)(3), which specifies that particle tracking, or other vector analyses, be utilized to determine the area of contribution to the well field. When the regulations were written in the early 1990’s, particle tracking was cumbersome and not routinely conducted. Improvements in modeling techniques and wide-spread use and availability of particle tracking software will allow improved delineations of the contributing areas, particularly in multi-layer aquifer systems. Many of the consultants are already using particle tracking for Level A mapping.

There is also a minor change to subsection (f)(2) to be consistent with the changes to subsection (e); and minor changes to subsection (g) that (1) reduce the number of copies of the report to be submitted from four copies to two copies; (2) delete requirements for hardcopy submission of all input and output data from the model (this is submitted electronically); (3) allow for the submission of compact disks or other computer storage media as an alternative to floppies; and (4) require electronic submission of the final mapping so that it can more easily be incorporated into the Department’s Geographic Information System.

V. STATEMENT OF PRINCIPAL REASONS IN SUPPORT OF THE REGULATION PROPOSED FOR PUBLIC HEARING

It is important to note that, as discussed above, the proposed amendments are in response to concerns raised by the regulated community, and resulted from discussions of a technical work group. J. Jeffrey Starn, Ground-water Specialist of the U.S. Geological Survey; Elizabeth Gara, Executive Director of the Connecticut Water Works Association; David L. Radka, Chair of the Water Resources Committee of the Connecticut Section American Water Works Association and Richard A. Miller, Director of the Office of Environmental Policy, University of Connecticut, commented in support of the proposed amendments, including the following:

A. The proposed amendments are necessary, and are in response to issues raised by the water utilities and their consultants.

B. The proposed amendments are more realistic instead of overly conservative.

C. The proposed amendments make the regulations stronger technically and more defensible.

VI. STATEMENT OF PRINCIPAL REASONS IN OPPOSITION OF THE REGULATION PROPOSED FOR PUBLIC HEARING AND THE DEPARTMENT’S RESPONSE TO SUCH REASONS

A concern voiced in opposition to the proposed amendments was that the regulations were moving from an overly-conservative simulation to one that is not conservative enough. This concern was raised by Denise Burchstead, P.E., of the Naubesatuck Watershed Council; Margaret Minor, Executive Director of the Rivers Alliance of Connecticut, and Helen Koehn, President of Citizens for Responsible Growth. However, the Department disagrees. Several important conservative factors have been incorporated into the methodology:

A. The simulation is based upon the maximum pumping rate allowable for the well, run 24 hours a day, long-term. Although such a pumping condition may occur for short periods under maximum water use conditions, this is not normal operation for public water supply wells.

B. Connecticut has at least 40 years of precipitation records, collected by the U.S. Geological Survey, upon which the average recharge rates will be calculated. This long-term record includes several periods of severe drought in the state, including periods during the 1960's and 1980's.

C. The statistical long-term average stream flow is approximately 30% duration flow (the flow met or exceeded 30% of the time), which is skewed toward higher flows by flooding. The amendments propose use of the 50% duration flow (the flow met or exceeded 50% of the time), which is a lower stream flow condition than the statistical average.

Therefore, while the proposed amendments are less conservative than the existing methodology, the Department feels they are still conservative enough to provide the necessary protection of the critical areas which supply ground water to the well fields.

VII. SPECIFIC COMMENTS AND RESPONSE THERETO ON THE REGULATION AS PROPOSED FOR HEARING

In addition to the concern in opposition to the proposed amendments discussed above in Section VI, several other changes to the regulations were proposed by those who commented. These proposals are addressed below.

A. **Comment:** Several people recommended deletion of Section 22a-354b-1(f)(3)(B)(ii) from the existing regulation. This section of the regulation specifies that watersheds in till[4] which are drained by perennial streams[5] will be delineated as indirect recharge areas[6]. Indirect recharge areas are not included as part of the APA. It was recommended that these areas be included as recharge areas, which would then be regulated as part of the APA. (Exhibits 1, 5, 6, 8, 10).

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[4] Till is a type of glacial deposit that is an unsorted mixture of clay, silt, sand, gravel and boulders. Because the sediments are unsorted, there is little pore space between the particles and till does therefore not make a productive aquifer. Till blankets the bedrock surface across much of Connecticut, ranging in thickness from 0 to 200 feet.

[5] A perennial stream is one which flows all year.

[6] Indirect recharge area is defined in the mapping regulations as an area from which water by overland flow or ground-water discharge is contributed to a surface watercourse which flows into the area of contribution.

Response: The areas in question are upland areas on the valley sides, outside (uphill from) the main stratified drift aquifer where the subject well field is located. These upland areas are not directly modeled, although surface water and ground water contributions from the valley sides are accounted for in the model. The upland watersheds are bedrock hillslopes covered by relatively thin till (feet or tens of feet thick). Where the upland area is drained by a perennial stream, the stream is the primary discharge point for the ground water in the watershed (the stream is perennial, as opposed to flowing just after a rainstorm, because it is supported by ground-water flow). The stream then flows down into the stratified drift aquifer, where it can contribute to stream flow or ground water flow in the main stratified drift aquifer. Although the till watersheds contribute water to the stratified drift aquifer, and possibly to the well fields, the flow paths between the potential contaminant sources in the till watershed and the supply well are long and indirect. This indirect flow path affords significant opportunity for remediation and natural renovation of contaminants originating in this indirect recharge area, and makes the potential for such contamination to impact the drinking water supply very low and unlikely. This is not as critical an area for protection as the area of contribution and the recharge area that make up the APA. Adding these watershed areas into the APA would therefore provide little additional protection for the well field, but in many cases, would subject large additional land areas to the regulatory program. The Report of the Aquifer Protection Task Force to the General Assembly, March 11, 1988, which is one of the underpinnings of the Aquifer Protection Area program, separates out the indirect recharge area, stating on page 8: "Protection of groundwater quality in the indirect recharge area is still important, but direct contamination of the well from a spillage in that area is less likely and less profound." Finally, these upland areas are not without protection. Other programs, such as the Water Quality Standards and Classifications which govern allowable discharges and clean-up standards for remediation, the National Pollution Discharge Elimination System, State Pollution Discharge Elimination System and the Stormwater Phase II programs which control discharges to the ground, and the Underground Storage Tank program which provides minimum standards and procedures for tank installations and removals, to name a few, are in place to prevent contamination and to clean up should contamination occur.
Recommended Change: None.

B. Comment: Use of U.S. Geological Survey Topographic maps to determine if a stream is perennial or not, as specified under Section 22a-354b-1(f)(3)(B), is inappropriate. The U.S. Geological Survey depiction of a stream on these maps is not based on collected data, but observation from aerial photographs, and the U.S. Geological Survey methodology has changed over the years. Further, many of these streams become losing streams[7] when they move off of the till and onto the stratified drift in the valley, so they can become intermittent[8]. (Exhibit 5)
Response: The Department acknowledges that the U.S. Geological Survey maps were not created for the purpose of making a definitive distinction between perennial and intermittent streams. However, the mapping of perennial streams on the topographic maps is not arbitrary. It is based on the physical characteristics of the stream channel and presence of

[7] A losing stream is a stream or reach of stream with a permeable streambed that is perched above the water table and loses water to the subsurface.
[8] An intermittent stream is a stream or reach of stream that does not flow continuously.

water at the time the aerial photographs were taken, and it is not unreasonable to utilize this published information. The regulations clearly state that in these till areas, we are making an assumption that ground water and surface water divides are coincident. The information the regulations are looking for is whether the stream is ground-water supported, such that the stream is the discharge point for the upland watershed, or if the stream flows only as a result of surface runoff after a precipitation event. If a stream is shown on a topographic map as perennial, it is reasonable to assume that it is ground-water supported, which is the important determination in deciding between recharge areas and indirect recharge areas (see further discussion under comment A above).

The Department is relying on this assumption instead of collecting field data because the cost of conducting the Level A mapping is significant (typically $80,000 to $140,000 per well field), and efforts were made in the regulations to contain costs to the extent possible. Requiring additional data collection to determine flow paths in the less critical upland areas, at costs on the order of thousands of dollars, was not considered warranted, given that a reasonable surrogate is available.

It is often the case that these streams become intermittent or losing streams as the stream moves off the till uplands and into the stratified drift in the valley, because the stratified drift is more permeable and may have a lower water table. However, the delineation of the indirect recharge area ends at the edge of the stratified drift. The portion of the stream in the drift, the portion that may be a losing stream, is part of the area of contribution for the well, and thus part of the aquifer protection area.

Recommended Change: None

C. Comment: Concern was expressed about the limited scope of the aquifer protection area program: The aquifer is much more extensive than that portion proposed for protection; and private wells and bedrock wells are not included in the protection program. (Exhibit 7)

Response: The scope of the aquifer protection area program was defined by the Legislature when the original APA Act was passed. Land use restrictions of the kind to be imposed under this program can not be applied state wide – it is simply not practical nor economically feasible. The legislature weighed the issues and made a decision to focus protection on that portion of the aquifer supplying water to the state's largest, most productive wells - wells in stratified drift serving more than 1000 people. If just one of these wells becomes contaminated, thousands or tens of thousands of Connecticut residents are impacted. In addition, the effort and expense to determine the land area that supplies a particular well field with ground water are significant (typically $80,000 – $140,000 per well field). Smaller water companies and individual citizens (in the case of private wells) could not afford to make such determinations. Finally, as mentioned above, the APA program is just one of Department's many ground water protection programs. Other programs, such as the Water Quality Standards and Classifications which govern allowable discharges and clean-up standards for remediation, the National Pollution Discharge Elimination System, State Pollution Discharge Elimination System and the Stormwater Phase II programs control discharges to the ground, and the Underground Storage Tank program provides minimum standards and procedures for tank installations and removals, to name a few, are in place to prevent contamination and to clean up should contamination occur.

Recommended Change: None

D. Comment: The bedrock supplies a great deal of water to the well fields but bedrock contributing areas are unacknowledged in the mapping. (Exhibits 6 and 7)
Response: Bedrock contributions to the stratified drift system are included in the numerical modeling of the aquifer system. The major flow paths for ground water in these stratified drift systems are through the stratified drift in the valley and typically, induced infiltration from the stream. Although the bedrock contributes water to the aquifer system, it comes in at the edges of the main flow system for these wells. Bedrock contributions are calculated using the watershed area and precipitation records, and the estimated volume of water from the bedrock is distributed into the model along the stratified drift boundaries. Requiring detailed investigation of the bedrock system would add little in terms of protection to the well field, but would add tens of thousands of dollars to the cost of mapping.
Recommended Change: None

E. Comment: There is a need for some type of monitoring to be implemented in aquifer protection areas. (Exhibits 6 and 10)
Response: Under Sections 22a-354i and 22a-354aa of the Connecticut General Statutes, the Department is required to develop regulations for the design and installation of ground water monitoring in the APAs in consultation with the Commissioner of Public Health, water companies, and business and industry. A pilot study to help the Department work through the necessary elements of strategic monitoring has been conducted, and development of strategic monitoring regulations is expected to begin within the next few years.
Recommended Change: None

F. Comment: It was recommended that the mapping regulations explicitly state that (1) water companies have the option of modifying an already approved map to be consistent with the amended regulations and (2) that DEP could modify an already approved map if the water company chose not to, upon consultation with the water company. (Exhibit 4)
Response: The water companies have the ability to re-map in accordance with the amended regulations, under Section 22a-354b-1(i), and the Department will encourage most to do so. Because the modeling (for approved mapping) has already been approved, the cost of running a different predictive simulation will be relatively small, and the submission requirements and Department review time will also be minimal. However, the Department does not have the capability to revise and re-run existing models. Such responsibility must remain with the water companies.
Recommended Change: None

G. Comment: For security-related reasons, certain Level A mapping information should not be made available to the general public, and DEP needs to protect all final maps, reports and data submitted under the regulations. (Exhibits 4, 11)
Response: The Department is aware of the security issues with showing the locations of public water supply wells, and the sensitive nature of the accompanying reports and data. The Department is currently referring inquiries on the mapping to the water utilities so the utility can determine if such information can be released to the requesting party. In addition, exact well locations will not be provided to the general public. However, the public must be able to determine if they are within 500 feet of the well field, because commercial fuel oil tanks within 500 feet of the well field are regulated under the program. A boundary allowing land owners to make such a determination will be placed on the mapping provided to the

towns. The Department will work with the utilities to determine an appropriate designation for the maps.
Recommended Change: None

H. Comment: Requiring the use of particle tracking eliminates the need to separately delineate the area of influence. (Exhibit 3)
Response: The Department agrees. As discussed on pages 3 and 4 of this report, utilization of particle tracking eliminates the need to run two separate predictive simulations to delineate the area of influence and the associated area of contribution. Particle tracking, conducted through modeling programs that allow the modeler to track particles of water from their origination points through the aquifer system, can directly delineate the area of contribution. However, the area of influence methodology is still necessary when analytical modeling[9] is used, since particle tracking is a numerical modeling technique.
Recommended Change: Recommend subsection (e)(2) be re-written as follows:

(2) A steady-state predictive simulation shall be performed to delineate the area of contribution and determine the water budget mass balance. Such predictive simulation shall be performed in accordance with the following:

(a) streamflow and associated stream stage shall be the flow equaled or exceeded fifty percent (50%) of the time (50% duration flow);

(b) mean annual rates shall be specified for precipitation, evapotranspiration, and flux across the boundaries; and

(c) the maximum pumping rate allowable for the well field shall be used, in accordance with the following:

(i) the maximum pumping rate as established by the diversion registration or permit, issued pursuant to sections 22a-368 or 22a-373 of the general statutes; or

(ii) if the maximum diversion registration or permit issued pursuant to sections 22a-368 or 22a-373 of the general statues is not sustainable for the predictive simulation, an alternative pumping rate may be determined by the commissioner, in consultation with the Department of Public Health and the water company; or

(iii) in the case of potential wells that the commissioner may map pursuant to section 22a-354c(b), a pumping rate that does not exceed maximum sustainable yield;

[9] Analytical ground water models are based upon the same hydrogeologic principles as numerical ground water models, but are analyses that incorporate a number of simplifying assumptions. Although typically done using computer software, analytical modeling could be conducted without the aid of a computer. The regulations allow for the use of analytical models only under special circumstances. (For example, analytical modeling may be permitted if the aquifer is of limited extent and pumping will cause water levels to be affected over the entire stratified drift aquifer).

I. Comment: It was suggested that further technical specification be added to the regulations regarding on how weak sinks are handled for particle tracking and use of specific modules in the MODFLOW modeling package. (Exhibits 3 and 6)
Response: These detailed technical specifications will change over time as modeling software continues to evolve and as new modules are developed for MODFLOW. It would be difficult to keep the regulation up to date if further detail is added. However, these details can continue to be handled through the Plan for Data Collection and Analysis. The Plan must be submitted to the Department and approved under section 22a-354b-1(b) of the regulations before the work is conducted. This is the Department's opportunity to comment on the proposed work and evaluate these smaller technical details.
Recommended Change: None

J. Comment: The regulation needs to explicitly state in Section 22a-354b-1(e)(2) that the predictive simulation shall be a steady-state simulation. (Exhibits 4 and 6)
Response: Agreed. Not specifying that it shall be a steady-state simulation was an oversight.
Recommended Change: Modify Section 22a-354b-1(e)(2) to include "steady-state", as shown in Comment H above.

K. Comment: Two typographic errors were noted in the proposed amendments: "weir" is incorrectly spelled in Sec. 22a-354b-1(g)(1)(E); and "prescribed" is incorrectly spelled in Sec. 22a-354b-1(g)(5)(B).
Response: Noted.
Recommended Change: Correct the two typographic errors.

L. Comment: In Sec. 22a-354b-1(g)(5), instead of specifying "Floppy diskettes or compact disks…", the requirement should be generalized to "Computer storage media" to allow for the continued evolution of such media.
Response: Agreed.
Recommended Change: Sec. 22a-354b-1(g)(5) should read as follows: "Computer storage media deemed acceptable by the Commissioner containing the following data:"

VIII. FINAL WORDING OF THE PROPOSED REGULATIONS

SECTION 1 Subsections (e), (f), and (g) of Section 22a-354b-1 of the Regulations of Connecticut State Agencies are amended to read as follows:

(e) Ground-water flow modeling.

Numerical modeling of ground-water flow shall consist of separate but related operations, as set forth in subparagraphs (1), (2), AND (3) of this subsection. The model shall, at a minimum, cover the stratified drift areas.

(1) Initial set-up, calibration, and verification of the model shall be based upon data

collected in accordance with the provisions of subsection (d) of this section, and shall be conducted as follows:

(A) A preliminary model shall be constructed by assembling an initial data set of appropriate hydrogeologic parameters.

(B) Sensitivity analyses shall be performed to assess the adequacy of existing data and as a guide for the collection of new data. The sensitivity analyses shall include, but not be limited to, both reductions and increases of at least fifty percent in specified values describing hydraulic conductivity or transmissivity, storage coefficient or specific yield, evapotranspiration and recharge through hydraulic boundaries.

(C) Model input parameters shall be refined using new hydrogeologic data collected in accordance with subsection (d) of this section after the sensitivity analyses have been completed.

(D) The ground-water flow model shall be calibrated for transient flow conditions in accordance with the following:

(i) simulated pumping rates for all wells in the well field shall be equal to actual pumping rates at the time of the calibration event. Wells within the approximated area of influence, but not included in the well field, that have pumping rates of 50,000 gallons per day or more, shall be included;

(ii) initial conditions of areal recharge, evapotranspiration and fluxes to and from the aquifer shall be representative of actual conditions at the time of the calibration event;

(iii) Calibration has been achieved when the following conditions have been met:

(a) The water budget mass balance difference between sources and discharges is less than 0.5 percent;

(b) the difference between simulated water levels and those measured in fifty percent or more of the observation wells is less than two feet;

(c) the difference between simulated water levels and those measured in seventy percent or more of the observation wells is less than five feet;

(d) the maximum difference between simulated water level and that measured in any observation well is less than ten feet; and

(e) simulated ground-water runoff is as close as possible to ground-water runoff estimated from streamflow records collected from the modeled area.

(E) The calibrated ground-water flow model shall be verified by simulating at least one other transient event for which there is hydrogeologic data. Verification has been achieved when all the conditions of (e)(1)(D)(iii) have been met.

[(2) Predictive simulations shall be performed to delineate the area of influence and determine water budget mass balance in accordance with the following:

(A) Initial conditions for these transient simulations shall consist of data sets derived from the calibrated model.

(B) Water table or potentiometric surface configurations shall be determined for the area of influence based on:

(i) critical drought event for stream flow;

(ii) 180 days with no areal recharge;

(iii) Ground-water elevations representative of long-term drought conditions, if known, or estimated from water utility or U.S. Geological Survey data collected during previous drought periods, for example, during the early- to mid-1960's drought; and

(iv) the maximum pumping rate allowable for the well field as determined from either the water supply plan submitted under Section 25-32 of the general statutes or the diversion registration or permit, issued pursuant to Sections 22a-368 or 22a-373 of the general statutes, whichever is greatest, or in the case of potential wells that the Commissioner may map pursuant to section 22a-354c(b), a pumping rate that does not exceed maximum sustainable yield.]

(2) A STEADY-STATE PREDICTIVE SIMULATION SHALL BE PERFORMED TO DELINEATE THE AREA OF CONTRIBUTION AND DETERMINE THE WATER BUDGET MASS BALANCE. SUCH PREDICTIVE SIMULATION SHALL BE PERFORMED IN ACCORDANCE WITH THE FOLLOWING:

(A) STREAMFLOW AND ASSOCIATED STREAM STAGE SHALL BE THE FLOW EQUALED OR EXCEEDED FIFTY PERCENT (50%) OF THE TIME (50% DURATION FLOW);

(B) MEAN ANNUAL RATES SHALL BE SPECIFIED FOR PRECIPITATION, EVAPOTRANSPIRATION, AND FLUX ACROSS THE BOUNDARIES; AND

(C) THE MAXIMUM PUMPING RATE ALLOWABLE FOR THE WELL FIELD SHALL BE USED, IN ACCORDANCE WITH THE FOLLOWING:

(i) THE MAXIMUM PUMPING RATE AS ESTABLISHED BY THE DIVERSION REGISTRATION OR PERMIT, ISSUED PURSUANT TO SECTIONS 22a-368 OR 22a-373 OF THE GENERAL STATUTES; OR

(ii) IF THE MAXIMUM DIVERSION REGISTRATION OR PERMIT ISSUED PURSUANT TO SECTIONS 22a-368 OR 22a-373 OF THE GENERAL STATUES IS NOT SUSTAINABLE FOR THE PREDICTIVE SIMULATION, AN ALTERNATIVE PUMPING RATE MAY BE DETERMINED BY THE COMMISSIONER, IN CONSULTATION WITH THE DEPARTMENT OF PUBLIC HEALTH AND THE WATER COMPANY; OR

(iii) IN THE CASE OF POTENTIAL WELLS THAT THE COMMISSIONER MAY MAP PURSUANT TO SECTION 22a-354c(b), A PUMPING RATE THAT DOES NOT EXCEED MAXIMUM SUSTAINABLE YIELD;

(3) PARTICLE TRACKING, OR OTHER VECTOR ANALYSES, SHALL BE APPLIED TO THE PREDICTIVE SIMULATION TO DELINEATE THE AREA OF CONTRIBUTION TO THE WELL FIELD.

(f) Aquifer Mapping.

[(1) The outer limit of the area of influence shall be determined by the model-predicted water-level drawdown of 0.5 feet within the stratified drift aquifer.

(2) The area of contribution shall be mapped using model-generated ground water level contours as that part of the area of influence that drains directly to the pumping well(s).]

(1) THE AREA OF CONTRIBUTION SHALL BE DETERMINED IN ACCORDANCE WITH THE FOLLOWING:

(A) FOR WELL FIELDS FOR WHICH NUMERICAL GROUND-WATER FLOW MODELING HAS BEEN CONDUCTED, THE AREA OF CONTRIBUTION SHALL BE DELINEATED IN ACCORDANCE WITH SUBSECTION (e)(3) OF THIS SECTION.

(B) FOR WELL FIELDS FOR WHICH ANALYTICAL GROUND-WATER MODELING HAS BEEN CONDUCTED, THE AREA OF CONTRIBUTION SHALL BE DETERMINED AS FOLLOWS:

(i) THE AREA OF INFLUENCE SHALL BE DETERMINED AS SPECIFIED IN SUBPARAGRAPH (h)(3).

(ii) THE AREA OF CONTRIBUTION SHALL BE MAPPED USING THE ANALYTICAL MODEL-GENERATED GROUND-WATER LEVEL

CONTOURS AS THAT PART OF THE AREA OF INFLUENCE THAT DRAINS DIRECTLY TO THE PUMPING WELL.

[(3)] (2) The recharge area for the well field shall be determined using the following methods:

(A) For areas of stratified drift adjacent to the area of contribution where model-generated ground-water level contours are available, the recharge area shall be delineated using those contours; and

(B) For areas of stratified drift and till where model-generated ground-water level contours are not available, the recharge area shall be determined by assuming ground water divides are coincident with surface water divides and that ground water flow directions are normal to the land surface contours, unless better data are available, provided:

(i) topographic maps used for the interpretation of drainage divides representing the boundaries of the recharge area shall have a contour interval no greater than ten feet; and

(ii) watersheds in till areas for perennial streams that discharge into the area of contribution shall be assumed not to contribute ground water to the area of contribution by ground-water flow.

[(4)] (3) The indirect recharge area shall be determined within a five-mile radius of the area of contribution using topographic maps with a contour interval no greater than ten feet.

(g) Submission of Final Maps and Reports.

Each water company shall submit [four] TWO copies of the maps, reports and computer data listed in subdivisions (g)(1) through (g)(6) of this subsection to the Commissioner for review and written approval.

(1) A map at a scale no less than 1:4,800 (1 inch = 400 feet), on which the following information shall be shown:

(A) all cultural, surface drainage, and transportation features;

(B) the area of influence, IF DELINEATED UNDER SUBPARAGRAPH (f)(1)(B);

(C) the area of contribution within stratified drift;

(D) location of all pumping wells; and

(E) locations of all observation wells, test borings, geophysical surveys, gaging stations, weirs, and streambed piezometer. Locations map be shown on a separate map at scale of 1 inch = 400 feet.

(2) A map at a scale of 1:24,000 (1 inch = 2,000 feet) of the area of contribution, on which the following are shown:

(A) all geologic contacts between unconsolidated materials;

(B) delineation of the area of contribution within stratified drift;

(C) all existing or proposed pumping wells for which the area of contribution is delineated;

(D) recharge areas; and hydraulic boundaries.

(3) All maps used for constructing the flow model including, but not limited to, the following:

(A) finite difference grid or finite element mesh;

(B) model boundary locations;

(C) contours of aquifer bottom; and

(D) horizontal hydraulic conductivity distribution.

(4) A hydrogeologic investigation report which includes, but is not limited to all of the following:

(A) A description of hydrogeologic setting;

(B) A discussion of geologic and hydraulic boundaries and their treatment in the model.

(C) A discussion of the data used in interpretation of hydraulic characteristics including, but not limited to, hydraulic conductivity and storage coefficient or specific yield.

(D) A discussion of recharge to and discharge from the aquifer system including, but not limited to:

(i) recharge from precipitation;

(ii) recharge from underflow;

(iii) recharge from streamflow losses;

(iv) discharge to evapotranspiration;

(v) discharge to underflow;

(vi) discharge to streamflow; and

(vii) discharge to pumpage.

(E) A discussion of and the data relating to ground water and surface water relationships which takes into consideration the following:

(i) streamflow measurements;

(ii) estimated flow duration of streams;

(iii) elevations of top of surface waterbodies; and

(iv) streambed parameters used in the model.

(F) [A documented listing of all input data used in the model including, but not limited to, input data for the following:

(i) final calibration runs;

(ii) verification run;

(iii) final predictive runs.

(G) A documented listing of model output for:

(i) final calibration runs;

(ii) verification run;

(iii) final predictive runs.

(H)] A discussion of calibration and verification procedures and results. Failure to meet any of the proposed calibration or verification goals shall be explained.

(5) [Floppy diskettes] COMPUTER STORAGE MEDIA DEEMED ACCEPTABLE BY THE COMMISSIONER containing THE FOLLOWING DATA:

(A) All input and output generated under subsection (e) of this section[. The disks shall be formatted for IBM or compatible microcomputers and the required files shall be in ASCII format.] INCLUDING BUT NOT LIMITED TO DATA FOR THE FOLLOWING:

(i) FINAL CALIBRATION RUNS,

(ii) VERIFICATION RUN, AND

(iii) FINAL PREDICTIVE RUNS; AND

(B) ELECTRONIC SUBMISSION OF THE AREA OF CONTRIBUTION AND RECHARGE AREAS, FORMATTED IN A MANNER PRESCRIBED BY THE COMMISSIONER.

(6) Any other information which the Commissioner deems necessary in order to support the delineation of the area of contribution and the areas of recharge to the well field.

Statement of Purpose:

The purpose of this amendment to the Regulations For Mapping Wells In Stratified Drift Aquifers To Level A Standards is to clarify the procedure for running the final predictive ground-water flow model simulations. The simulations are modified from "low flow" conditions to "average flow" conditions to improve the accuracy of the delineation.

IX. ACKNOWLEDGEMENT

I wish to acknowledge the hard work and scientific expertise of Corinne Fitting in the development of this Hearing Report. Ms. Fitting is a hydrogeologist with the Bureau of Water Management, Division of Planning & Standards and I commend Ms. Fitting's dedication to the completion of this report.

X. CONCLUSION

Based upon the comments submitted by interested parties and addressed in this Hearing Report, I recommend the proposed final regulation, as attached hereto, be submitted by the Commissioner of Environmental Protection for approval by the Attorney General and the Legislative Regulations Review Committee.

Robert LaFrance
Hearing Officer

5 · 11 · 05
Date

APPENDIX I
Exhibit List

July 12, 2004
Public Hearing on Proposed Amendments to Regulations for Mapping Wells in Stratified Drift Aquifers to Level A Standards; Russell Hearing Room, 79 Elm Street, Hartford, CT

EXHIBIT	DESCRIPTION
1	Written comments 7/9/04 Matthew W. Hart, Assistant Town Manager, 4 Eagleville Rd, Mansfield CT 06268-2599
2	Written comments 6/22/04 Lori Mathieu, Department of Public Health, 410 Capitol Avenue, PO Box 340308, Hartford, CT 06134
3	Written comments 7/7/04 J. Jeffrey Starn, Ground-water Specialist, U.S. Geological Survey, 101 Pitkin Street, East Hartford, CT 06108
4	Written comments 7/12/04 Elizabeth Gara, Executive Director, CWWA and David L. Radka, Chair, Water Resources Committee, 25 Capitol Avenue, Hartford, CT 06106
5	Written comments 7/12/04 Quentin Kessel, 97 Codfish Falls Road, Storrs, CT 06268
6	Written comments 7/12/04 Denise Burchsted, PE, and Kurt Heidinger, President, Naubesatuck Watershed Council, 19 Chaplin Street, Chaplin, CT 06235
7	Written comments 7/12/04 Geza J. Danyi, 45 Rye Street, Broad Brook, CT 06016
8	Written comments 7/11/04 Margaret Miner, Executive Director, Rivers Alliance of Connecticut, 111 Main Street, Collinsville, CT 06019
9	Written comments 7/15/04 Richard A. Miller, Director, Office of Environmental Policy, University of Connecticut, 31 LeDoyt Road, Unit 3055, Storrs, CT 06269-3055
10	Written comments 7/16/04 Helen Koehn, President, Citizens for Responsible Growth, 83 Separatist Road, Storrs, CT 06268
11	Written comments 6/29/04 John P. Hudak, Environmental Planning Manager, South Central Connecticut Regional Water Authority, 90 Sargent Drive, New Haven, CT 06511-5966
12	Notice of Intent to Adopt Regulations and Notice of Public Hearing
13	Authorization to Hold a Public Hearing
14	Copy of Proposed Aquifer Protection Land Use Regulation
15	Agency Fiscal Estimate of Proposed Regulation
16	Notification Form Small Business Regulatory Impact
17	Notice of Intent to Adopt Regulations and Notice of Public Hearing
18	Speaker's List for Public Hearing 7/12/04
19	Memo from Robert LaFrance, Hearing Officer 7/12/04 extending time period for submitting written testimony into the hearing record to 7/16/04

APPENDIX II
Aquifer Protection Area Mapping Work Group Members

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APPENDIX III

Evaluation of the Effect of the 180-Day Drought Scenario on Wellhead Protection Areas as Specified in Aquifer Mapping Regulations

Mr. Charles P. Spalding and Mr. Daniel J. Morrissey
McDonald Morrissey Associates, Inc., mmacps@aol.com, mmanh@aol.com, Hopkinton, NH, USA

Wellhead protection programs in a number of states require use of numerical ground-water flow modeling to delineate contributing areas for large-producing water supply wells. More specifically, these regulations require that contributing areas be delineated based upon a modeling scenario with low stream-flow conditions, 180-days with no recharge, and the maximum pumping rate allowable for the well field. The ground-water flow field resulting from this 180-day drought condition is held constant and used as the basis for contributing area delineation.

Because average ground-water flow travel times in these aquifer systems are on the order of one to several years, and the simulated drought condition would not be sustained for such a length of time, the resulting contributing area may be conservative. The Connecticut DEP is exploring alternative modeling scenarios that may result in prediction of a smaller contributing area, but that is still protective of the well field. Potential alternative modeling approaches would involve either an average steady-state hydrologic condition or a transient simulation in which the 180-day drought occurs with a reasonable frequency. Previous research has indicated that steady-state simulations of average conditions give reasonable predictions of contributing areas in aquifers with cyclic patterns similar to those found in Connecticut (Reilly and Pollock, 1998). An evaluation of the potential impact that alternative modeling approaches will have on model-predicted contributing areas for wells was made through comparative analysis of three predictive modeling scenarios for two representative Connecticut aquifers using MODFLOW (McDonald and Harbaugh, 1996) and MODPATH (Pollock, 1994).

INTRODUCTION

Wellhead protection programs in a number of states require that methodology used to estimate contributing areas for supply wells incorporate a "drought" condition. The purpose of this requirement is to ensure that contributing areas, and the resulting wellhead protection areas, are protective. Several New England states have defined the "drought" condition to be the water levels that would result after a period of 180 days in which there is no recharge.

The wellhead protection program in the State of Connecticut requires that numerical modeling be used to delineate the contributing areas for most high capacity supply wells. Furthermore, Connecticut requires that the modeling scenario for contributing area delineations be based upon low stream-flow conditions, 180-days with no recharge, and the maximum pumping rate allowable for the well field. The ground-water flow field resulting from this 180-day drought condition is assumed to persist long enough for all of the water within the contributing area to travel to the well field.

Average ground-water flow travel times to wells in typical Connecticut aquifer systems are on the order of one to several years, and because the simulated drought condition would not be sustained for such a length of time, the resulting contributing area may be overly conservative. The Connecticut DEP is exploring alternative modeling scenarios that may result in prediction of a smaller contributing area, but that is still protective of the well field. Potential alternative modeling approaches would involve either an average steady-state hydrologic condition or a transient simulation in which the 180-day drought occurs with a reasonable frequency.

Previous research has indicated that steady-state simulations of average conditions give reasonable predictions of contributing areas in aquifers with cyclic patterns similar to those found in Connecticut (Reilly and Pollock, 1996). An evaluation of the potential impact that alternative modeling approaches will have on model-predicted contributing areas for wells was made through comparative analysis of three predictive modeling scenarios for two representative Connecticut aquifers using MODFLOW (McDonald and Harbaugh, 1988) and MODPATH (Pollock, 1994).

HYDROGEOLOGIC SETTING

High capacity supply wells in Connecticut are generally located in stratified-drift aquifers that lie along major river valleys. The aquifers range in width from less than a mile to several miles wide and saturated thickness may range from several feet to more than 100 feet. The aquifers are composed of highly permeable sand and gravel that lies over less permeable bedrock.

Recharge to stratified-drift aquifers consists of direct infiltration of precipitation, from infiltration of runoff that originates in upland areas adjacent to the aquifers and from induced infiltration of surface water. Annual precipitation ranges from 30 to 65 inches per year and averages about 44 inches. Precipitation is evenly distributed throughout the year.

APPROACH

The Oxford, Connecticut and North Cheshire, Connecticut well fields were selected for consideration in this study. These aquifers were selected because contributing areas have been delineated for both locations with three-dimensional numerical models and submitted to the Connecticut Department of Environmental Protection. The aquifers also represent a reasonable range of hydrogeologic conditions that are found in New England.

At less than one mile wide over much of its length, the Oxford stratified-drift aquifer is relatively small. Average ground water travel times to municipal wells in the Oxford aquifer are slightly less than one-year. The North Cheshire stratified drift aquifer is larger at approximately one mile wide or more over much of its length. Average ground water travel times to municipal wells in the North Cheshire aquifer are approximately three years or greater

For each aquifer system contributing areas were determined using three modeling scenarios as follows: (1) a transient run with low stream flow conditions, 180-days of no recharge and maximum pumping rates; the water level conditions that exist at the end of this 180-day drought simulation are then assumed to exist throughout time as now specified by the Connecticut Level A mapping regulations; (2) a steady-state simulation with average recharge and maximum pumping; and (3) a transient simulation in which a 180-day no-recharge drought occurs every five years (low stream flow, maximum pumping and no recharge) and average conditions prevail otherwise.

The Oxford well field model has two layers and a uniform horizontal grid spacing of 50 feet (Leggette, Brashears & Graham, Inc. and McDonald Morrissey Associates, Inc., 1997). Hydraulic conductivity values vary from 5 to 133 feet per day and specific yield was estimated to be 0.25. The average annual recharge rate from precipitation directly on the stratified drift was estimated to be approximately one-half of annual precipitation. Ground water/surface water interaction was modeled using the STREAM package in MODFLOW. The model was calibrated to average water level conditions with a steady-state simulation and to a 5-day aquifer test with a transient model simulation.

The North Cheshire well field model has two layers and horizontal grid spacing that varies from 100 to 600 feet (Leggette, Brashears & Graham, Inc., 1995). Hydraulic conductivity values vary from 10 to 925 feet per day. Specific yield values vary from 0.02 to 0.1. Average annual recharge rate from precipitation directly on the stratified drift was estimated to be approximately 24 inches per year. Ground water/surface water interaction was modeled using the RIVER package in MODFLOW. The model was calibrated to average water level conditions with a steady-state simulation and to a 5-day aquifer test with a transient model simulation.

For both well fields, the average steady state and transient cyclic condition contributing areas were delineated using Version 3 of the MODPATH particle-tracking program (Pollock, 1994). This version of MODPATH allows particle tracking in either steady state or transient flow fields. The 180-day drought scenario capture zone delineation for the Oxford well field was done for this study using MODPATH. For the same scenario at the North Cheshire well field the particle-tracking program PATH3D (S.S. Papadopolus & Associates, Inc., 1989) was utilized.

RESULTS

Contributing areas for average steady state, transient cyclic-drought and 180-day drought simulations in the Oxford well field are shown in Figure 1 and summarized in Table 1. The average steady state and transient cyclic-drought simulations produce contributing areas that are practically identical, 30 and 32% of the active model area respectively. The average travel time for ground water within each contributing area is slightly less than one year. Previous research has also shown that steady-state simulations of average conditions give similar predictions of contributing areas in aquifers with cyclic patterns of stress (Reilly and Pollock, 1998) in which the length of the cyclic stress is less than the average travel time in the contributing area.

The contributing area calculated for the average steady-state condition and for the transient cyclic drought is smaller the size of the area that is currently specified as the Level A mapping zone contributing area, 38% of the active model area. The existing regulations produce a larger contributing area because the regulations assume that ground water elevations at the end of a 180-day drought will persist indefinitely. When the 180-day drought is simulated as occurring in a cyclic fashion the resulting contributing area is slightly smaller.

The aquifer size and the area impacted by the North Cheshire municipal well are larger than the Oxford well field. Average travel times from the contributing areas in the North Cheshire well field are approximately three years (Table 1). Contributing areas for the North Cheshire well field for average steady state, transient cyclic-drought and 180-day drought simulations are shown in Figure 2 and summarized in Table 1.

The contributing areas determined for transient cyclic drought simulation and the average steady-state simulation are identical at 65% of the total active model area respectively. The contributing area determined under the existing regulation covers 84% of the active model area. The transient cyclic and average steady state scenarios are smaller than the area defined under existing regulations.

EVALUATION OF THE POTENTIAL USE OF SIMULATION SCENARIOS

Based on the three simulation scenarios completed, the method of identifying contributing areas as specified in the existing regulations creates the largest groundwater protection areas. This method, however, calculates an area based on a condition that is less representative of the impacts of droughts that occur under real world conditions. The existing regulations require that the modeling scenario for contributing area delineations be based upon low stream-flow conditions, 180-days with no recharge, and the maximum pumping rate allowable for the well field. The ground-water flow field resulting from this 180-day drought condition is assumed to persist for all time. In reality, based on observations kept to date, these conditions have never occurred and will not likely occur in the future.

Ground water recharge can occur throughout the year but recharge occurs mostly in the spring and fall, before and after the growing season when the ground is not frozen and soil moisture demands are not great. Water level data from U.S. Geological Survey observation well 41461507258160 (U.S. Geological Survey, 1999), which is completed in shallow stratified drift and has of 55 years of continuous record, was examined to determine the length of time in each year in which there is no recharge to ground water (Figure 3). Results of this examination showed that there were only two years, out of 55 years of record, in which there was 180 continuous days of no recharge--1957 and 1980. For both of these events, groundwater was recharged to pre-drought levels within 120 days of the end of the drought period. The median period of no recharge was 3 months (120 days), with a range of 30 to 180 days. The historical record shows that the occurrence of a 180-day drought is a rare and the effects of these events are short lived.

The use of the contributing area delineation method specified in the existing regulations does not add to the data required for the simulations. Each method evaluated requires estimates of low-stream flow conditions; drought impacted upland recharge and maximum pumping rates. Of the three simulation scenarios the existing regulations requires a complicated series of analyses to be performed. This method requires that three analyses be completed. An initial steady-state model using average conditions is used as starting conditions for a transient model simulation of the 180-day drought condition. The resulting water levels are then analyzed assuming steady-state conditions using particle or graphical analyses. In reality, the groundwater system as simulated has not reached steady-state and the use of this technique likely results in some numerical inaccuracies.

Aquifer systems are complex and transient by nature. All modeling efforts require some simplification of both the hydrogeologic framework and the transient nature of stresses imposed on the aquifer system. The transient model evaluated in this study considers the extreme condition where 180-day droughts occur every five years. A simplification of this condition is to ignore drought periods and consider that groundwater conditions time periods greater than a few years are steady enough to be modeled as steady state. The results of this evaluation suggest for the alluvial aquifer systems that typically occur in Connecticut, the calculated contributing areas are virtually identical for both the steady-state and transient drought model scenarios. The strong correlation between these results are representative of the fact that if the stress on the system is shorter than the travel time of a particle of water, the contributing area defined by a transient simulation will closely match the steady-state simulation. This is observation was made and is supported by transient particle analyses performed by Reilly and Pollock (1994). For the alluvial aquifer systems in Connecticut, the maximum travel times, which define the limits of the contributing area, greatly exceed any short-term stresses that have been identified in historic droughts.

Evaluating contributing areas using a steady-state model of average conditions is by far the easiest method of analysis to complete and review. Unlike transient modeling, data identifying the transient stresses are not required. The reduction in model complexity also reduces the potential that errors are made that are not detected by the States review process.

EVALUATION OF AVERAGE RECHARGE

If a steady-state model of average conditions is ultimately used to define well field contributing areas, then average recharge conditions will have to be defined. Recharge to the a stratified-drift aquifer occurs by four general mechanisms:

- precipitation directly on the aquifer that seeps through the unsaturated zone to the water table,
- upland runoff from areas not drained by discrete streams that recharges the aquifer along the valley wall contact,
- infiltration through the streambeds of upland streams as they flow onto the aquifer, and
- induced infiltration of surface water caused by pumping that lowers ground water levels beneath the level of nearby surfaces water bodies.

All of these recharge mechanisms are dependent on precipitation as the ultimate source of water. Unless site-specific data indicate otherwise, recharge from infiltration of precipitation that falls directly on the stratified drift aquifer can be assumed to be approximately one-half of the average annual precipitation.

The other half of the total precipitation is lost to evapotranspiration. This estimate is based upon work by MacNish and Randall (1982) in New York State but is reasonable to apply to Connecticut because of the similarity of climates. Average precipitation taken from long periods of record can be obtained from a number of sources for locations around Connecticut. Hunter and Meade (1981) identify 26 locations with recharge records generally existing from 1951 to 1980. More recent data is available from sources such as NOAA.

Runoff from till-covered or bedrock upland areas not drained by tributary streams recharges the stratified drift aquifer near the contact between the valley walls and stratified-drift valley fill deposits. The amount of runoff is dependent on soil type, topography, the rate of evapotranspiration in the uplands and the upland drainage area. Studies have shown that recharge from valley wall runoff can exceed recharge from direct precipitation on stratified-drift river valley aquifers (Caldwell and others, 1987; Morrissey and others, 1988). The average annual runoff (over-land flow, under-flow and ground-water flow) from uplands can be estimated using long-term USGS stream gaging data for local streams and rivers. Average runoff can be assigned by distributing these stresses along the model edges.

Although beyond the scope of this study, final determination of average hydrologic conditions should include careful review of all groundwater studies completed in New England by state and federal agencies.

SUMMARY AND CONCLUSIONS

Numerical simulations represent the best available tool for characterizing groundwater flow in complex hydrogeologic systems such as those found in Connecticut. Critical to appropriate evaluations of the impact of groundwater withdrawals on these hydrogeologic systems is completion of model analyses by competent groundwater modelers and review of these results experienced State personnel. Each model must have appropriate specifications of boundary conditions and hydraulic parameters and must be calibrated to groundwater levels, drawdowns and known streamflows. Input and output must be well documented to facilitate independent review.

Of the scenarios evaluated, a steady-state simulation using average conditions with maximum pumping rates represents the most reasonable approach to evaluating contributing areas. This method is both realistic and relatively straightforward to complete while provided a reasonable degree of protectiveness for the ground water resource.

REFERENCES

Caldwell, D. W., S. Faldetta, and G. Hanson, 1987, Geologic and Hydrologic Effects of a Catastropic Flood in Cold River, South-Western New Hampshire, New England Intercollegiate Geoligcal Conference, Norwich University, Montpelier, Vermont, p. 21-28.

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Reilly, T.E. and Pollock, D.W., 1996, Sources of water to wells for transient cyclic systems: Ground Water, v. 34, no. 6, p. 979-988.

S.S. Papadopolus & Associates, Inc., 1989, PATH 3D a ground-water path and travel-time simulator.

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Table 1. Contributing Areas and Travel Times for Oxford and North Cheshire Simulations.

Simulation Description	Active Model Area (ft^2)	Contributing Area (ft^2)	Percent of Active Area	Average Travel Time (years)[1]
Oxford				
Average Steady-State Condition	8,910,000	2,662,500	30%	0.7
180-Day Drought Held as Steady-State Condition	8,910,000	3,410,000	38%	1.4
Transient 5-year Drought Cycle	8,910,000	2,857,500	32%	0.9
North Cheshire				
Average Steady-State Condition	63,380,700	41,308,800	65%	2.9
180-Day Drought Held as Steady-State Condition	63,380,700	53,414,900	84%	4.5
Transient 5-year Drought Cycle	63,380,700	41,308,800	65%	>2.4

Notes:

[1]Particles released from the beginning of the simulation for the steady-state simulations. For the transient 5-year drought cycle simulation, particles were released every 30 days during drought periods.

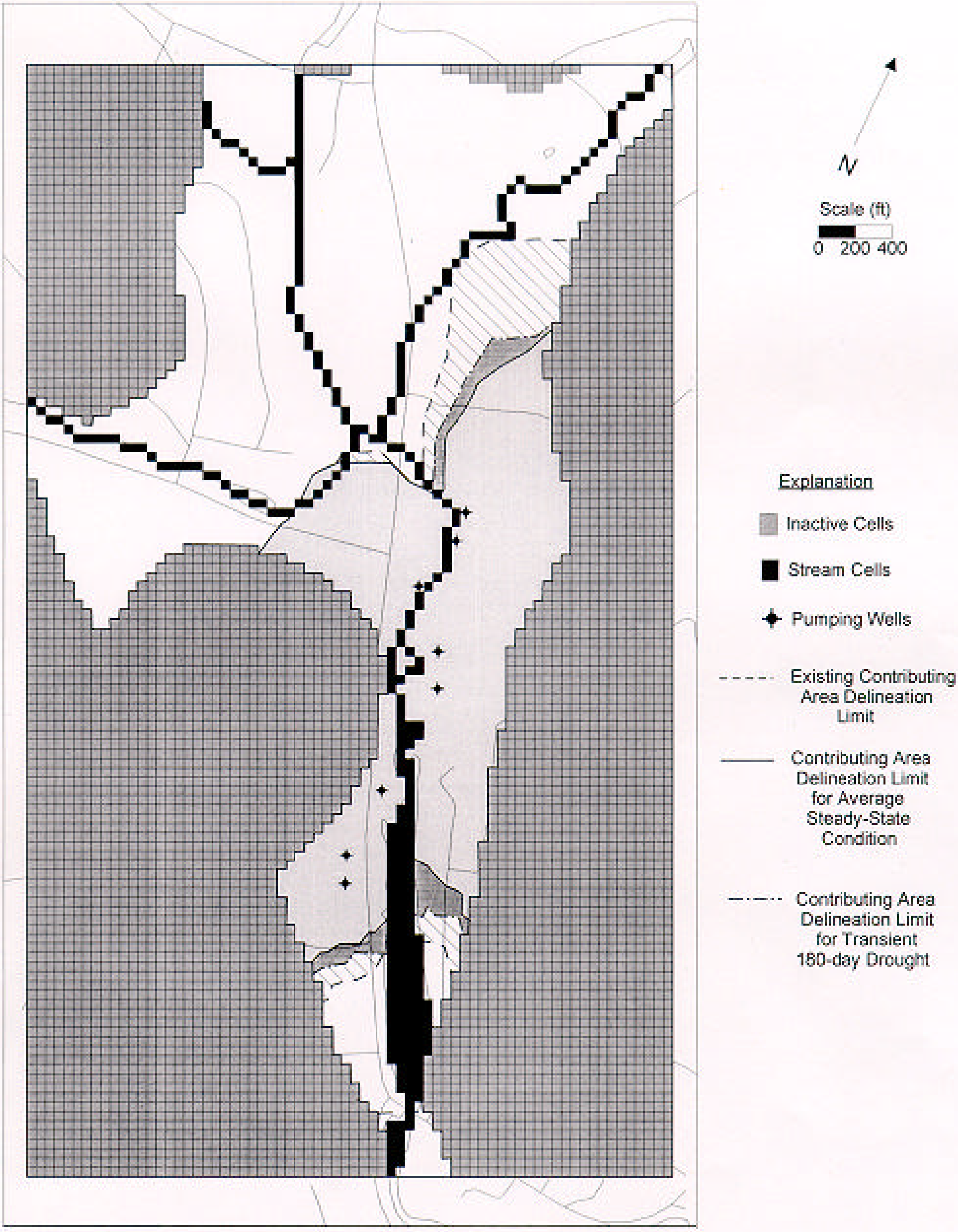

Figure 1. Contributing areas for the Oxford, Connecticut municipal well field for various modeling scenarios.

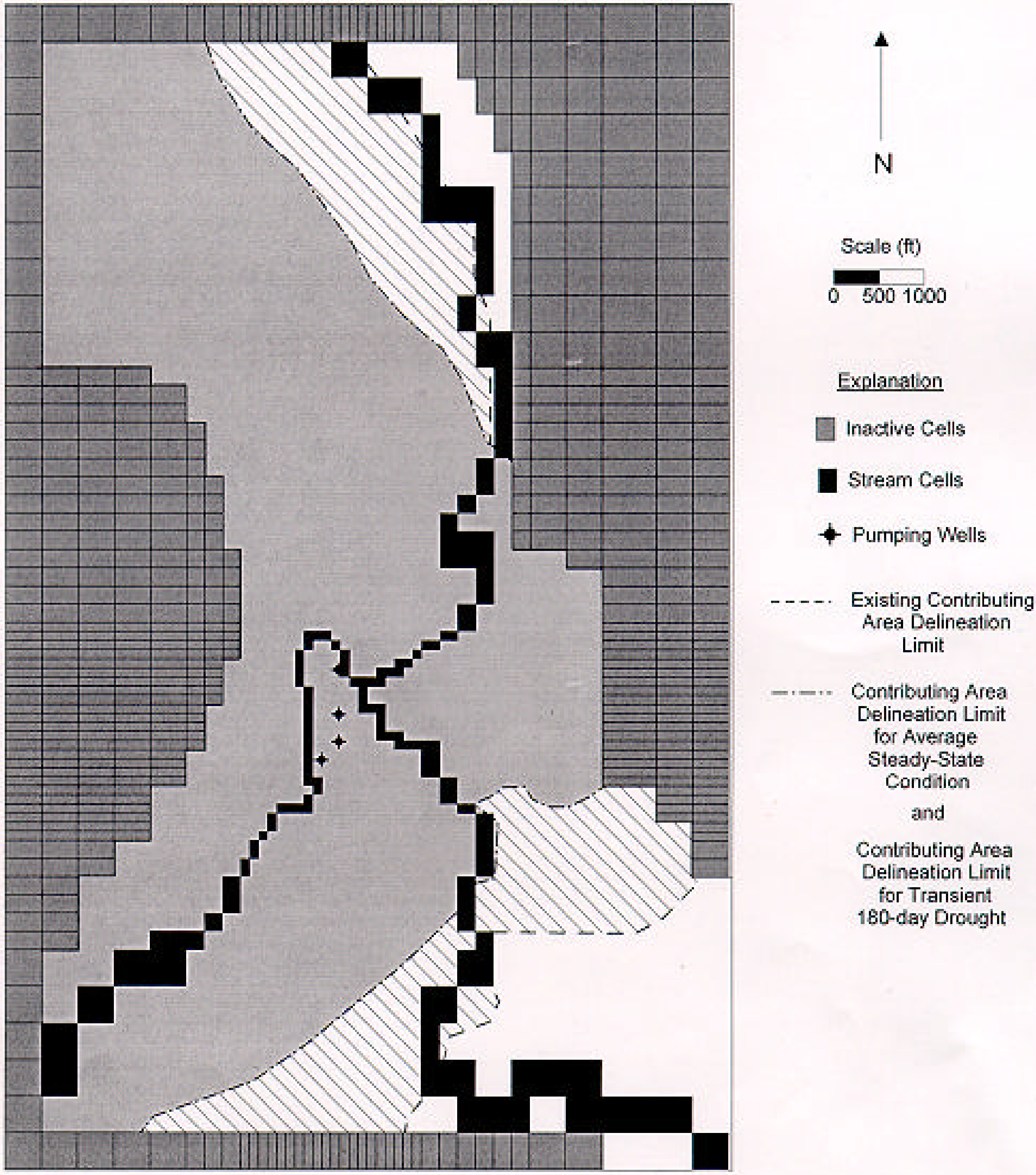

Figure 2. Contributing areas for the North Cheshire, Connecticut municipal well field for the various modeling scenarios.

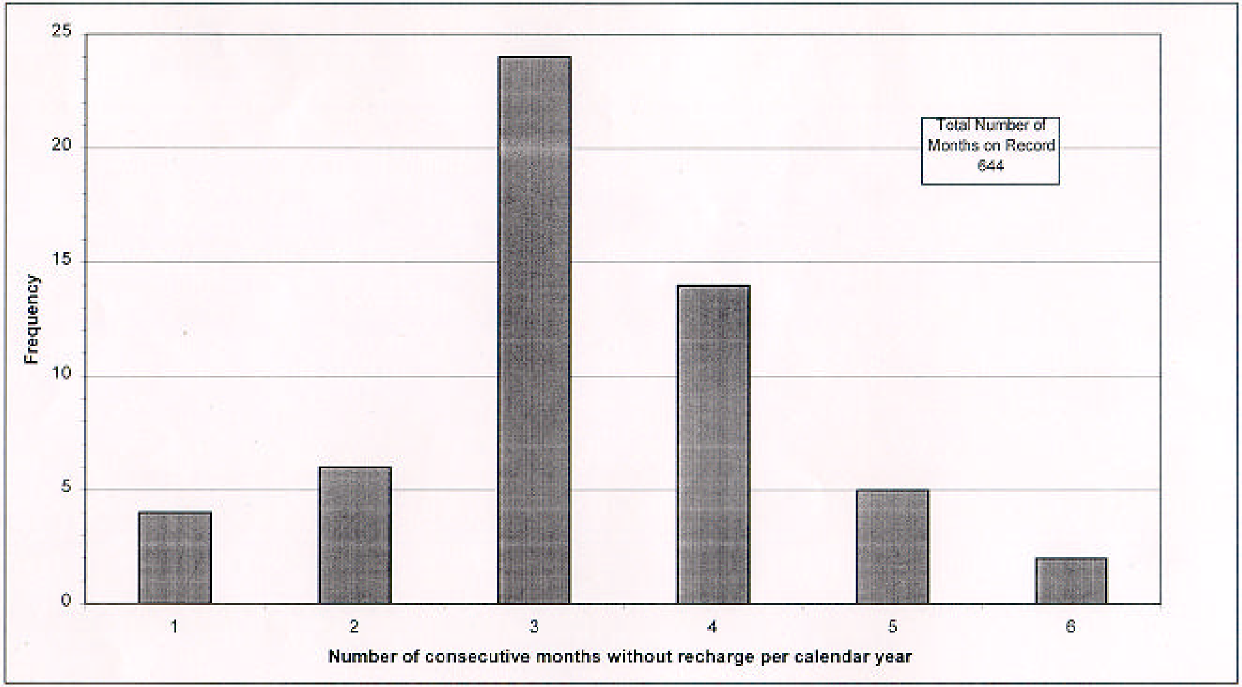

Figure 3. Consecutive months without recharge per calendar year, 1946 to 2000, from long-term hydrograph, Hartford, Connecticut.

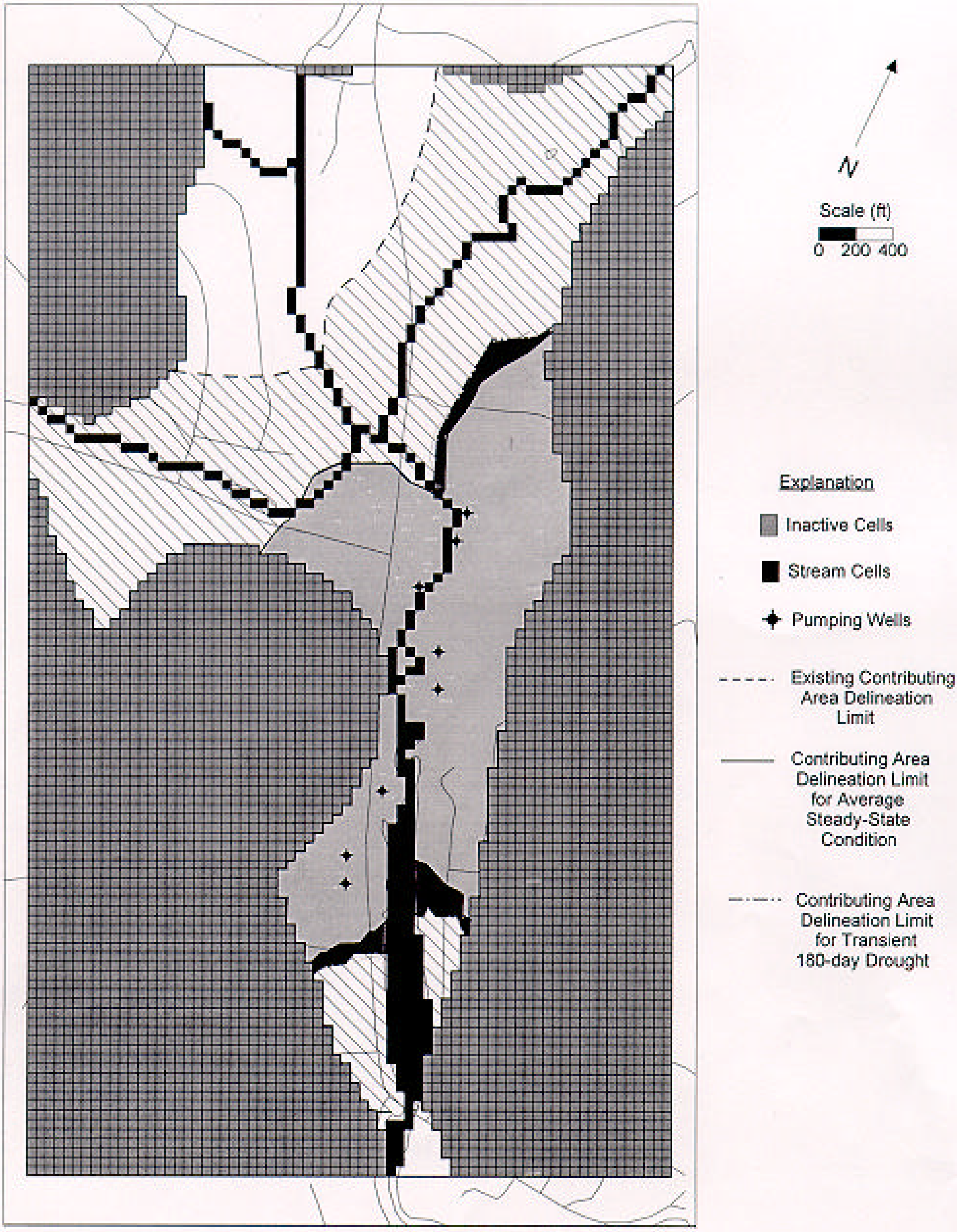

Figure 1. Contributing areas for the Oxford, Connecticut municipal well field for various modeling scenarios.

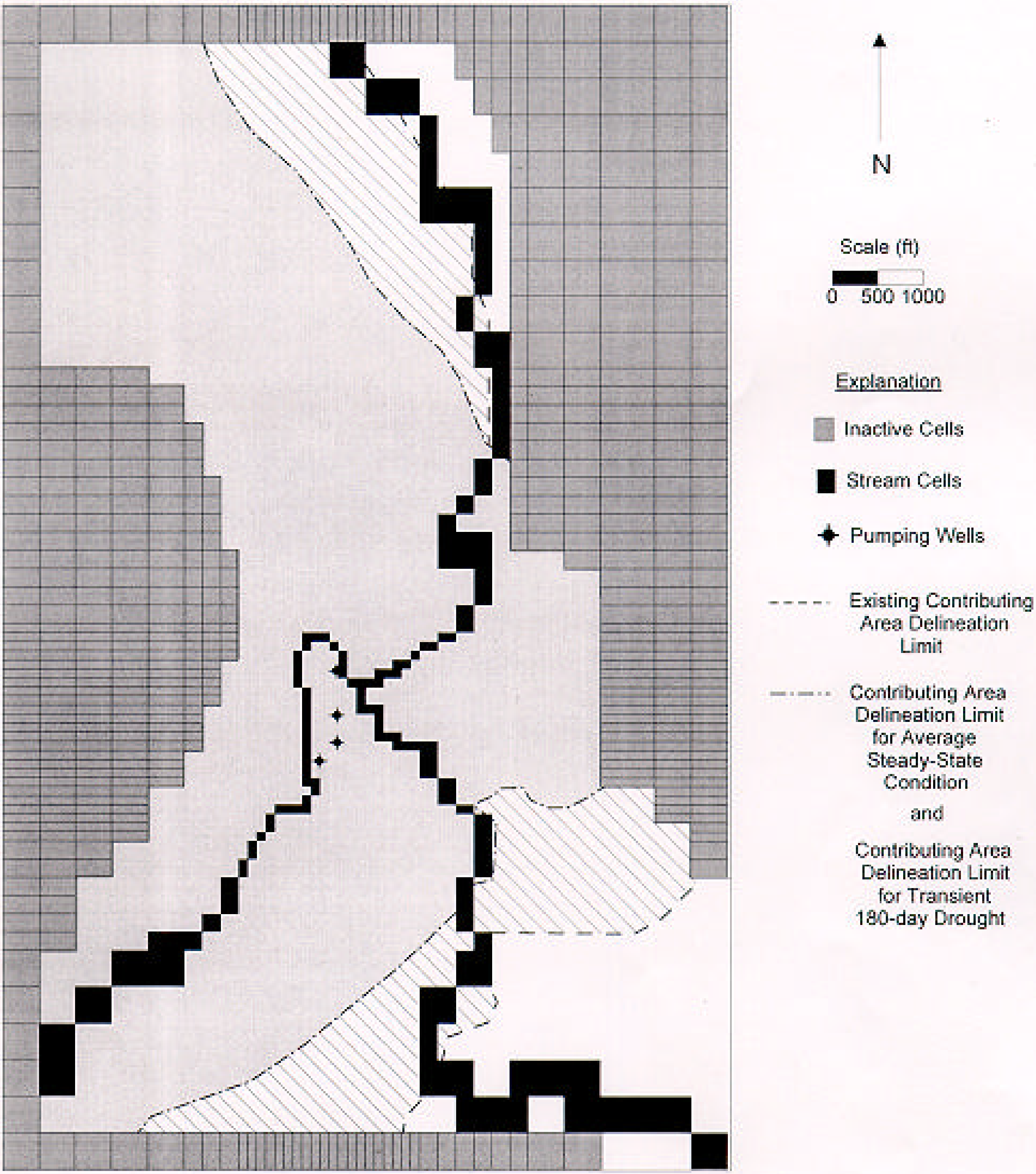

Figure 2. Contributing areas for the North Cheshire, Connecticut municipal well field for the various modeling scenarios.

APPENDIX IV
Text of Amendments to Level A Mapping Regulations
as proposed for Hearing
May, 2004

<u>SECTION 1</u> Subsection (e) to subsection (g) of Section 22a-354b-1 of the Regulations of Connecticut State Agencies are amended to read as follows:

(e) Ground-water flow modeling.

Numerical modeling of ground-water flow shall consist of separate but related operations, as set forth in subparagraphs (1) and (2) of this subsection. The model shall, at a minimum, cover the stratified drift areas.

(1) Initial set-up, calibration, and verification of the model shall be based upon data collected in accordance with the provisions of subsection (d) of this section, and shall be conducted as follows:

(A) A preliminary model shall be constructed by assembling an initial data set of appropriate hydrogeologic parameters.

(B) Sensitivity analyses shall be performed to assess the adequacy of existing data and as a guide for the collection of new data. The sensitivity analyses shall include, but not be limited to, both reductions and increases of at least fifty percent in specified values describing hydraulic conductivity or transmissivity, storage coefficient or specific yield, evapotranspiration and recharge through hydraulic boundaries.

(C) Model input parameters shall be refined using new hydrogeologic data collected in accordance with subsection (d) of this section after the sensitivity analyses have been completed.

(D) The ground-water flow model shall be calibrated for transient flow conditions in accordance with the following:

(i) simulated pumping rates for all wells in the well field shall be equal to actual pumping rates at the time of the calibration event. Wells within the approximated area of influence, but not included in the well field, that have pumping rates of 50,000 gallons per day or more, shall be included;

(ii) initial conditions of areal recharge, evapotranspiration and fluxes to and from the aquifer shall be representative of actual conditions at the time of the calibration event;

(iii) Calibration has been achieved when the following conditions have been met:

(a) The water budget mass balance difference between sources and discharges is less than 0.5 percent;

(b) the difference between simulated water levels and those measured in fifty percent or more of the observation wells is less than two feet;

(c) the difference between simulated water levels and those measured in seventy percent or more of the observation wells is less than five feet;

(d) the maximum difference between simulated water level and that measured in any observation well is less than ten feet; and

(e) simulated ground-water runoff is as close as possible to ground-water runoff estimated from streamflow records collected from the modeled area.

(E) The calibrated ground-water flow model shall be verified by simulating at least one other transient event for which there is hydrogeologic data. Verification has been achieved when all the conditions of (e)(1)(D)(iii) have been met.

[(2) Predictive simulations shall be performed to delineate the area of influence and determine water budget mass balance in accordance with the following:

(F) Initial conditions for these transient simulations shall consist of data sets derived from the calibrated model.

(G) Water table or potentiometric surface configurations shall be determined for the area of influence based on:

(i) critical drought event for stream flow;

(ii) 180 days with no areal recharge;

(iii) Ground-water elevations representative of long-term drought conditions, if known, or estimated from water utility or U.S. Geological Survey data collected during previous drought periods, for example, during the early- to mid-1960's drought; and

(iv) the maximum pumping rate allowable for the well field as determined from either the water supply plan submitted under Section 25-32 of the general statutes or the diversion registration or permit, issued pursuant to Sections 22a-368 or 22a-373 of the general statutes, whichever is greatest, or in the case of potential wells that the Commissioner may map pursuant to section 22a-354c(b), a pumping rate that does not exceed maximum sustainable yield.]

(2) PREDICTIVE SIMULATIONS SHALL BE PERFORMED TO DELINEATE THE AREA OF INFLUENCE AND DETERMINE THE WATER BUDGET MASS BALANCE. TWO PREDICTIVE SIMULATIONS SHALL BE RUN: ONE SIMULATION IN WHICH THE WELLS IN THE WELL FIELD ARE NOT PUMPING; AND A SECOND SIMULATION TO ESTABLISH THE EFFECTS OF PUMPING. SUCH PREDICTIVE SIMULATIONS SHALL BE PERFORMED IN ACCORDANCE WITH THE FOLLOWING:

(A) STREAMFLOW AND ASSOCIATED STREAM STAGE SHALL BE THE FLOW EQUALED OR EXCEEDED FIFTY PERCENT (50%) OF THE TIME (50% DURATION FLOW);

(B) MEAN ANNUAL RATES SHALL BE SPECIFIED FOR PRECIPITATION, EVAPOTRANSPIRATION, AND FLUX ACROSS THE BOUNDARIES;

(C) FOR THE PUMPING SIMULATION, THE MAXIMUM PUMPING RATE ALLOWABLE FOR THE WELL FIELD SHALL BE USED, AS FOLLOWS:

(i) THE DIVERSION REGISTRATION OR PERMIT, ISSUED PURSUANT TO SECTIONS 22a-368 OR 22a-373 OF THE GENERAL STATUTES; IF THE MAXIMUM DIVERSION REGISTRATION OR PERMIT ISSUED PURSUANT TO SECTIONS 22a-368 OR 22a-373 OF THE GENERAL STATUES IS NOT SUSTAINABLE FOR THE PREDICTIVE SIMULATION,

(ii) AN ALTERNATIVE PUMPING RATE MAY BE DETERMINED BY THE COMMISSIONER, IN CONSULTATION WITH THE DEPARTMENT OF PUBLIC HEALTH AND THE WATER COMPANY; OR

(iii) IN THE CASE OF POTENTIAL WELLS THAT THE COMMISSIONER MAY MAP PURSUANT TO SECTION 22a-354c(b), A PUMPING RATE THAT DOES NOT EXCEED MAXIMUM SUSTAINABLE YIELD; AND

(D) FOR THE PUMPING SIMULATION, THE STARTING HEADS SHALL BE THE RESULTANT HEADS FROM THE NON-PUMPING SIMULATION.

(3) PARTICLE TRACKING, OR OTHER VECTOR ANALYSES, SHALL BE USED TO DELINEATE THE AREA OF CONTRIBUTION.

(f) Aquifer Mapping.

(1) The outer limit of the area of influence shall be determined by the model-predicted water-level drawdown of 0.5 feet within the stratified drift aquifer.

(2) The area of contribution shall be mapped [using model-generated ground water level contours] as that part of the area of influence that drains directly to the pumping well(s).

(3) The recharge area for the well field shall be determined using the following methods:

(A) for areas of stratified drift adjacent to the area of contribution where model-generated ground-water level contours are available, the recharge area shall be delineated using those contours; and

(B) for areas of stratified drift and till where model-generated ground-water level contours are not available, the recharge area shall be determined by assuming ground water divides are coincident with surface water divides and that ground water flow directions are normal to the land surface contours, unless better data are available, provided:

(i) topographic maps used for the interpretation of drainage divides representing the boundaries of the recharge area shall have a contour interval no greater than ten feet; and

(ii) watersheds in till areas for perennial streams that discharge into the area of contribution shall be assumed not to contribute ground water to the area of contribution by ground-water flow.

(4) The indirect recharge area shall be determined within a five-mile radius of the area of contribution using topographic maps with a contour interval no greater than ten feet.

(g) Submission of Final Maps and Reports.

Each water company shall submit [four] TWO copies of the maps, reports and computer data listed in subdivisions (g)(1) through (g)(6) of this subsection to the Commissioner for review and written approval.

(1) A map at a scale no less than 1:4,800 (1 inch = 400 feet), on which the following information shall be shown:

(A) all cultural, surface drainage, and transportation features;

(B) the area of influence;

(C) the area of contribution within stratified drift;

(D) location of all pumping wells; and

(E) locations of all observation wells, test borings, geophysical surveys, gaging stations, weirs, and streambed piezometer. Locations map be shown on a separate map at scale of 1 inch = 400 feet.

(2) A map at a scale of 1:24,000 (1 inch = 2,000 feet) of the area of contribution, on which

the following are shown:

(A) all geologic contacts between unconsolidated materials;

(B) delineation of the area of contribution within stratified drift;

(C) all existing or proposed pumping wells for which the area of contribution is delineated;

(D) recharge areas; and hydraulic boundaries.

(3) All maps used for constructing the flow model including, but not limited to, the following:

(A) finite difference grid or finite element mesh;

(B) model boundary locations;

(C) contours of aquifer bottom; and

(D) horizontal hydraulic conductivity distribution.

(4) A hydrogeologic investigation report which includes, but is not limited to all of the following:

(A) A description of hydrogeologic setting;

(B) A discussion of geologic and hydraulic boundaries and their treatment in the model.

(C) A discussion of the data used in interpretation of hydraulic characteristics including, but not limited to, hydraulic conductivity and storage coefficient or specific yield.

(D) A discussion of recharge to and discharge from the aquifer system including, but not limited to:

(i) recharge from precipitation;

(ii) recharge from underflow;

(iii) recharge from streamflow losses;

(iv) discharge to evapotranspiration;

(v) discharge to underflow;

(vi) discharge to streamflow; and

(vii) discharge to pumpage.

(E) A discussion of and the data relating to ground water and surface water relationships which takes into consideration the following:

(i) streamflow measurements;

(ii) estimated flow duration of streams;

(iii) elevations of top of surface waterbodies; and

(iv) streambed parameters used in the model.

(F) [A documented listing of all input data used in the model including, but not limited to, input data for the following:

(i) final calibration runs;

(ii) verification run;

(iii) final predictive runs.

(G) A documented listing of model output for:

(i) final calibration runs;

(ii) verification run;

(iii) final predictive runs.

(H)] A discussion of calibration and verification procedures and results. Failure to meet any of the proposed calibration or verification goals shall be explained.

(5) Floppy diskettes OR COMPACT DISKS FORMATTED FOR IBM OR COMPATIBLE MICROCOMPUTERS, containing THE FOLLOWING DATA:

(A) All input and output generated under subsection (e) of this section[. The disks shall be formatted for IBM or compatible microcomputers and the required files shall be in ASCII format.] INCLUDING BUT NOT LIMITED TO DATA FOR THE FOLLOWING:

(i) FINAL CALIBRATION RUNS,

(ii) VERIFICATION RUN, AND

(iii) FINAL PREDICTIVE RUNS; AND

(B) ELECTRONIC SUBMISSION OF THE AREA OF CONTRIBUTION AND RECHARGE AREAS, FORMATTED IN A MANNER PERSCRIBED BY THE COMMISSIONER.

(6) Any other information which the Commissioner deems necessary in order to support the delineation of the area of contribution and the areas of recharge to the well field.

Statement of Purpose:

The purpose of this amendment to the Regulations For Mapping Wells In Stratified Drift Aquifers To Level A Standards is to clarify the procedure for running the final predictive ground-water flow model simulations. The simulations are modified from “low flow” conditions to “average flow” conditions to improve the accuracy of the delineation.