EXHIBIT F4

SCENARIO EVALUATION METHODS AND ANALYSES

Lake Maumelle Water Quality Management Plan: Scenario Evaluation Methods and Analyses

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Central Arkansas Water

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1 Introduction

The foundation for the work described here is contained in two prior reports. The Model Calibration Report (Tetra Tech, 2006a) describes the development, calibration, and validation of the numerical models that form the basis of the analysis. The Baseline Modeling Analysis (Tetra Tech, 2006b) describes the development of management objectives, analyzes the potential development within the watershed, and predicts the water quality impacts of such development.

As documented in the Baseline Modeling Analysis, projected development could result in an unacceptable degradation of water quality in Lake Maumelle unless measures are undertaken to mitigate impacts. Tetra Tech thus began a process of working with the project Technical Advisory Committee (TAC) and Policy Advisory Committee (PAC) to develop management strategies to protect the water supply. This report describes the methods and analyses used to evaluate management scenarios, and summarizes the results that have been reported to the TAC and PAC during the process of management plan development.

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2 Setting Allocations

An acceptable management plan for Lake Maumelle is one that will achieve the target values of indicators associated with management objectives, as adopted by the PAC and described in Tetra Tech (2006b). The watershed and lake models were used to establish the amount of loading from the land surface that can be allowed while meeting the targets. These acceptable maximum loadings are referred to as allocations. The allocations provided the basic context for development of management scenarios: a feasible management scenario is one that achieves predicted loading equal to or less than the allocations.

2.1 Approach

Allocations are defined as the *maximum* average annual loading rate that is consistent with meeting the in-lake targets. Once an allocation loading rate (e.g., lb/yr of total phosphorus) is established, management targets at the site scale (e.g., lb/ac/yr of total phosphorus in runoff) can be assigned. The goal of a management plan is to ensure that loading rate remains less than or equal to the allocation load – thus ensuring that targets will be met.

In fact, there is not a single, unique allocation, expressed in terms of mass per time, for pollutants loaded to Lake Maumelle. This is because it is not just the total loading to the lake that determines impact, but also how that load is distributed in both space and time. As a result, there are a variety of possible total allocations. Tetra Tech's strategy was to determine a reasonable allocation based on likely development patterns and use this to evaluate the number of houses that could be built without contravening the targets (a conservation design approach) or performance standards for loading on a per-acre rate that must be maintained to achieve the targets (Performance Standards Approach).

Tetra Tech developed the allocations through an iterative process (Figure 1). First, initial allocations were developed using the lake model by adjusting the existing load until lake management goals were met. These initial allocations determined the approximate range for total allowable loads. From this point, Tetra Tech developed refined allocations that redistribute the allowable increases in lake loading to future disturbed and developed land uses under the assumption that loading rates from undisturbed natural areas will remain unchanged. Fine-tuning of the acceptable loads occurs in this step, because the anticipated loading from development has specific spatial and temporal patterns that affect lake response. Finally, the refined total loading allocations were subdivided into allocations by individual management areas.

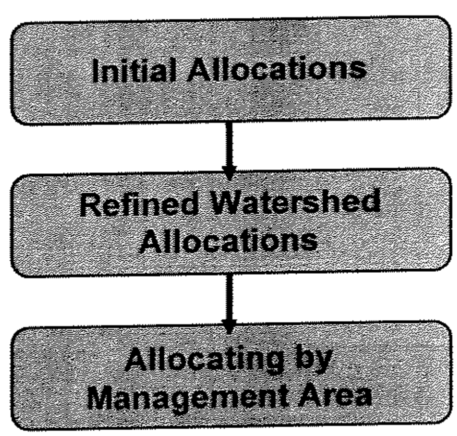

Figure 1. Steps for Setting Allocations

2.1.1 Modeling Framework

2.1.1.1 Modeling Tools

The primary modeling tools employed in the baseline analysis are a linked watershed model (HSPF) and lake response model (CE-QUAL-W2). The watershed model predicts flows and conveyance loads to the lake, while the lake model simulates lake response. Additional tools include a time-of-travel model to evaluate risk of delivery of spills to the lake.

The HSPF watershed model (Bicknell et al., 2001) provides a continuous simulation of flow and pollutant delivery within the watershed and stream network leading to the lake at an hourly time step. Development and calibration of the watershed model is described in detail in the *Lake Maumelle Watershed and Lake Modeling – Model Calibration Report* (Tetra Tech, 2006a). The model was calibrated to observations for 1997-2004 and model performance validated to observations for 1989 to 1996.

The CE-QUAL-W2 lake model (Cole and Wells, 2005) simulates the movement and quality of water within Lake Maumelle on a daily time step. The model operates in two spatial dimensions: longitudinal and vertical. Calibration (1991–1992) and validation (2002–2004) of this model is also described in the *Lake Maumelle Watershed and Lake Modeling – Model Calibration Report* (Tetra Tech, 2006a). The lake model uses input from the HSPF watershed model and predicts variation in management targets, such as algal concentration, within the lakes. Together, the HSPF and CE-QUAL-W2 models provide a comprehensive simulation of loads from the watershed and in-lake impacts.

The time-of-travel model was developed by combining the HSPF watershed model and a separate three-dimensional model of lake hydrology, created using EFDC (Hamrick, 1992). While it was impractical to develop and calibrate a fully three-dimensional model of water quality within the schedule for the project, there are important management concerns that require finer spatial resolution than is provided by CE-QUAL-W2, such as the potential transport of spills of toxic material. This need was satisfied, while maintaining the project schedule, by implementing EFDC in hydrodynamic-only mode parallel to the development of the CE-QUAL-W2 model. Hydrodynamic calibration of EFDC is also described in the *Lake Maumelle Watershed and Lake Modeling – Model Calibration Report* (Tetra Tech, 2006a). Use of EFDC to construct the time-of-travel analysis is described in the Baseline Modeling Analysis (Tetra Tech, 2006b).

2.1.1.2 Model Application for Developing Load Allocations

The allocations were developed using the linked watershed and lake model for the period of January 1998 through September 2004, using a model run starting in January 1997 to allow time for model spin-up. This is the longest continuous period for which linked meteorological and water withdrawal time series are available (the withdrawals are scaled up for the future runs, but need to remain consistent with the meteorological series), and includes both wet and dry years.

2.1.2 Indicators and Targets

As described in Tetra Tech (2006b), the Lake Maumelle Watershed Assessment was undertaken using a structured quality objectives process. At the most general level, Tetra Tech worked with the PAC to define the overarching goals and associated specific objectives for the management plan (see Table 13 in Tetra Tech, 2006b). From this basis, a series of principal study questions was developed. For each study question a measurement endpoint or indicator was proposed as a basis for evaluation of status relative to the management objectives. Finally, Tetra Tech worked with the TAC and PAC to select key indicators and associated target values for the watershed assessment.

2.1.2.1 Adopted Indicators and Targets

Target values of the indicators to guide management were developed in an iterative process with the Technical Advisory Council (TAC) and the PAC. Tetra Tech summarized existing monitoring data on the indicators and presented results of preliminary baseline runs to guide the evaluation process. A list of key indicators and associated targets was then adopted at the PAC meeting on March 16, 2006. The TOC target was expanded to add the condition that the concentration in the intake area should remain less than 3.1 mg/L, consistent with achieving goals for TOC in finished drinking water. The selected indicators and targets are summarized in Table 1.

Specific targets were not adopted for other indicators, such as sediment load and time of travel. However, scenarios can still be compared on a relative basis using these indicators.

2.1.2.2 Additional Information on Phosphorus Loading

Phosphorus itself was not adopted as a key indicator for Lake Maumelle; however, it is clear that phosphorus concentrations in the lake are the key control on expression of the chlorophyll *a* indicator of algal density. In addition to site-specific calibrated models, there are other general guidelines in the literature that indicate the lake has limited additional assimilative capacity for phosphorus. Chlorophyll *a* concentrations observed in Lake Maumelle suggest that the lake is on the border between oligotrophic and mesotrophic status.

Tetra Tech's *Baseline Modeling Analysis* for Lake Maumelle indicates that phosphorus loading to the lake is about 4.5 English tons per year. Based on a surface area of 36 km^2, this equates to an areal loading rate of 0.113 g/m^2-yr of phosphorus.

The 2004 Report of the CAW Task Group for Watershed Management (p. 5) stated the "Permissible and dangerous total phosphorus loadings for Lake Maumelle are 0.085 and 0.166 g/m^2yr…" These numbers are cited as being based on the method in Vollenweider (1976), and the "permissible" load is based on an estimate of the oligotrophic-mesotrophic boundary.

The cited Vollenweider target is less that the current areal loading rate, which has been deemed acceptable in our analysis. What explains the apparent discrepancy?

Vollenweider developed many different varieties of his empirical methods to predict lake trophic status. A little research reveals that the 0.085 g/m^2-yr target is *not* derived from the cited Volleweider (1976) method. Instead, it is from Vollenweider's original (1968) method. The 1968 method is based on phosphorus loading, lake surface area, and lake mean depth only. This simple method had considerable uncertainty, as it did not account for the impact of lake residence time on the phosphorus balance. As noted in Welch and Jacoby (2004), "…such loading-mean depth relationships were unreliable where flushing rate varied greatly…A consideration of residence time…led to refinement of the loading graph…" Vollenweider's 1976 paper included both mean depth (z, m) and hydraulic residence (τ_w, yrs) as predictor variables. Critical loading (L_c, mg/m^2-yr) can be interpreted from critical phosphorus concentration (P_c, µg/L) as

$$L_c = P_c \cdot \left(z / \tau_w \right) \cdot \left(1 + \sqrt{\tau_w} \right)$$

Rast and Lee (1981) showed that the 1976 Vollenweider approach was consistent with classification of U.S. lakes.

Setting the critical phosphorus concentration to 10 µg/L, consistent with Vollenweider's proposed oligotrophic-mesotrophic boundary, and using the reported residence time of 1.51 yrs (Green, 2001), application of the 1976 Vollenweider method yields a critical phosphorus loading rate to the lake of 0.111 g/m^2-yr. This is substantially higher than the estimate from the Vollenweider (1968) method, due to the relatively short residence time in Lake Maumelle, and almost identical to the estimate of current areal loading rates reported in the *Baseline Modeling Analysis*.

Table 1. Key Indicators and Target Values for Lake Maumelle Endorsed by the PAC

<table>
<tr><th colspan="3">INDICATOR: Chlorophyll a</th></tr>
<tr><td>Location: Mid-Lake</td><td>Target: 3.5 µg/L summer median</td><td>Existing: 2.8 µg/L summer median</td></tr>
<tr><td>Location: Lower Lake</td><td>Target: 3.0 µg/L summer median</td><td>Existing: 2.8 µg/L summer median</td></tr>
<tr><td colspan="3">Explanation: Welch and Jacoby, renowned limnologists, indicate that the boundary between oligotrophy and mesotrophy occurs at 3.5 µg/L. To protect the water supply to oligotrophic conditions, it is recommended that a target of 3.5 µg/L chlorophyll a be applied at the mid-lake evaluation point, and that 3.0 µg/L be used as a safety factor at the lower lake evaluation point near the water supply intake. The summer growing season is defined as May through September.</td></tr>
<tr><th colspan="3">INDICATOR: Total Organic Carbon (TOC)</th></tr>
<tr><td>Location: Lower Lake
(Intake area)</td><td>Target: As close to existing concentrations as possible, and < 3.1 mg/L.</td><td>Existing: 2.4 mg/L annual median</td></tr>
<tr><td colspan="3">Explanation: New disinfection byproducts regulations under the Safe Drinking Water Act require that Central Arkansas Water keep its annual running average (calculated quarterly) concentration of TOC under 2 mg/L in the finished drinking water. The CAW treatment system conservatively removes 35 percent of TOC from the raw water intake concentrations. Back-calculating from the finished target to the intake using the 35 percent removal rate produces an approximate target at the intake of 3.1 mg/L. Between August 1999 and January 2006, Arkansas Department of Health quarterly monitoring data indicated raw water concentrations ranged from 1.72 to 3.75 mg/L with median 2.65 mg/L. During that time frame, the highest finished water TOC concentration was 1.93 mg/L. Because the existing levels are close to the 3.1 mg/L boundary, the recommended target is to remain as close to existing levels as possible. The model-predicted annual median for existing conditions is 2.4 mg/L at the lower lake evaluation point (January 1997–September 2004 simulation). Since future evaluations will be done using the model, the 2.4 mg/L value will be used as the desired target for scenario performance comparisons.</td></tr>
<tr><th colspan="3">INDICATOR: Turbidity (use modeled Secchi depth as surrogate)</th></tr>
<tr><td>Location: Lower Lake
(Intake area)</td><td>Target: $\leq$ 0.2 m Secchi depth reduction in annual median</td><td>Existing: 2.8 m annual median (simulated), 2.6 m observed</td></tr>
<tr><td colspan="3">Explanation: The Enhanced Surface Water Treatment Rule requires that turbidity in finished filtered water be $\leq$ 0.3 NTU. The intent of the Enhanced Surface Water Treatment Rule is to reduce the risk of specific microbial pathogens such as Cryptosporidium. Current raw water turbidity ranges from 1 to 5 NTU, with an average of 2.6 NTU over the past 15 years (personal communication, Gary Hum, CAW). Increases in turbidity result in increased treatment cost (e.g., estimated increase in alum dosage = 30 percent to treat water with 9 NTU, per Gary Hum) and increased risk of other contaminants. The lake model does not directly estimate turbidity, but does predict Secchi depth which can be used as a surrogate for turbidity. The empirical relationship between Secchi depth and turbidity for the USGS data is relatively strong (0.77 r^2). Establishing a target of $\leq$ 0.2 m Secchi depth reduction in annual median should maintain turbidity levels within 1 NTU of existing levels. For model analysis, the target is thus 2.6 m.</td></tr>
<tr><th colspan="3">INDICATOR: Fecal Coliform Bacteria</th></tr>
<tr><td>Location: Lower Lake
(Intake area)</td><td>Target: < one order of magnitude increase from existing annual median concentration

(interpreted as < 0.065 #/100ml)</td><td>Existing: 0.0065 #/100ml annual median</td></tr>
<tr><td colspan="3">Explanation: The concentrations of fecal coliform bacteria being predicted for the future are not in and of themselves considered to be a threat. However, fecal coliform is being used as a surrogate indicator for the potential increase of other microbial pathogens such as Cryptosporidium and Giardia. These pathogens are likely present in minute amounts under current conditions, but have not been detected in CAW sampling. Health authorities typically examine risk in terms of the orders of magnitude of reduction in pathogen concentration between sources and water supply lines. By keeping the fecal coliform bacteria indicator concentration changes for future scenarios below one order of magnitude (factor of 10), the increase in risk of other microbial pathogens should also be minimized.</td></tr>
</table>

It should also be noted that Vollenweider's methods have in common that they are attempts to predict the phosphorus mass balance of lakes. The oligotrophic-mesotrophic boundary is assumed to be at 10 µg/L total phosphorus. In fact, algal response to phosphorus concentrations will vary depending on a number of factors including residence time, mixing characteristics, and the fraction of phosphorus contained in organic forms. Vollenweider and Kerekes (1981) found that oligotrophic status occurred in lakes with average total phosphorus concentrations ranging from 3 to 18 µg/L (with mean 8 µg/L), while mesotrophic status occurred in lakes with average total phosphorus concentrations ranging from 11 to 96 µg/L (with mean 27 µg/L) – which suggests that 10 µg/L is a rather conservative boundary for shift to mesotrophic status. For comparison, the average of observed surface concentrations near the intake in Lake Maumelle is 10.9 µg/L.

In sum, it appears clear that the status of Lake Maumelle is indeed near the oligotrophic-mesotrophic boundary. The estimated areal loading rate of phosphorus is consistent with this conclusion using the Vollenweider approach, if the corrected model presented in Vollenweider (1976) is used.

Increased phosphorus loading will lead to increased algal growth. However, the hydraulics of Lake Maumelle result in a situation in which most of the increased growth will occur in the upstream end of the lake, where the majority of flow enters. In addition, changes to hydrology with development (increased runoff and increased withdrawals, both leading to shorter residence time) will lead to higher values of L_C in the Vollenweider equation given above. As the targets for chlorophyll *a* are specified at the mid-lake and near the water intake, application of a dynamic lake model is necessary to determine the amount of additional phosphorus loading that is consistent with achieving management goals.

In conclusion, the Task Force Report was too conservative in its predictions of allowable increase in total phosphorus loading, which would exceed the oligotrophic boundary. Using updated methods, Tetra Tech's analysis yields a more accurate estimate.

2.1.2.3 Additional Information on Secchi Depth Target

The target for Secchi depth is established as an annual median of not less than 2.6 m at the water intake (for model output comparison purposes). This is intended to hold the increase in raw water turbidity to a maximum of 1 NTU.

CAW reports that their treatment system is routinely able to take a 5 NTU source water down to the goal of 0.1 NTU in finished water, but would be concerned if raw water concentrations rose above 5 NTU.

Based on 24 concurrent observations, the natural logarithms of turbidity and Secchi depth exhibit an approximately linear relationship (Figure 2). This may be expressed as a linear regression as

$$\text{LN (Turbidity)} = 1.616 - 1.251 \cdot \text{LN (Secchi Depth)}$$

with an adjusted R^2 of 70.4 percent and a standard error of 0.489. This information may be used to calculate confidence limits about the regression line, using the unbiased back transformation method of Land (1975). Figure 3 shows upper 95 percent (two-sided) confidence limits on the mean regression and upper 95 percent confidence limits on the prediction level for individual observations.

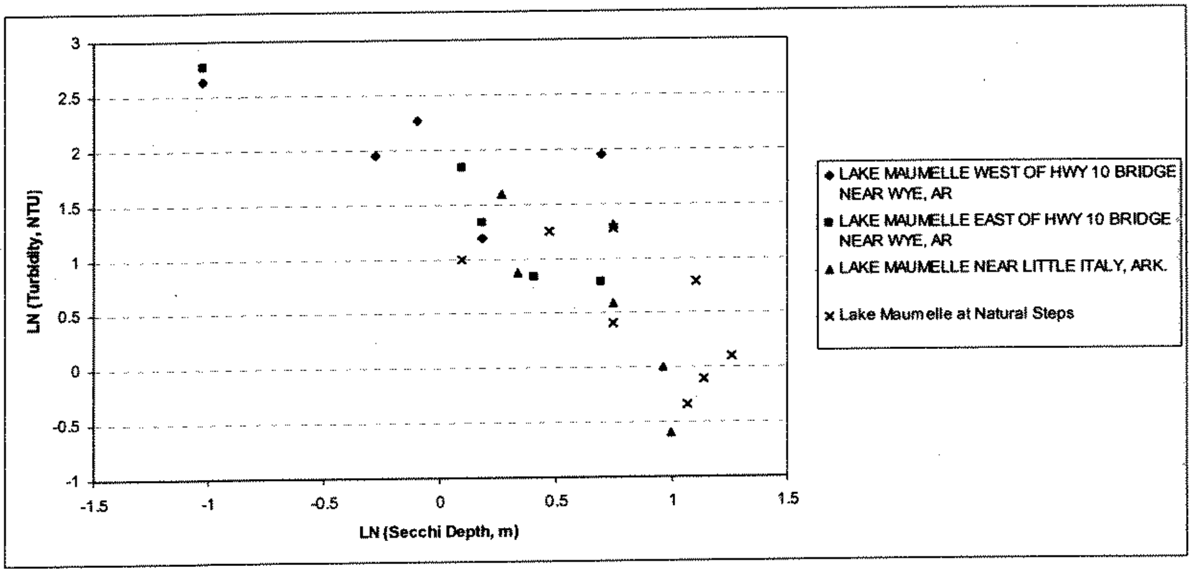

Figure 2. Log-Log Relationship of Turbidity and Secchi Depth, Lake Maumelle

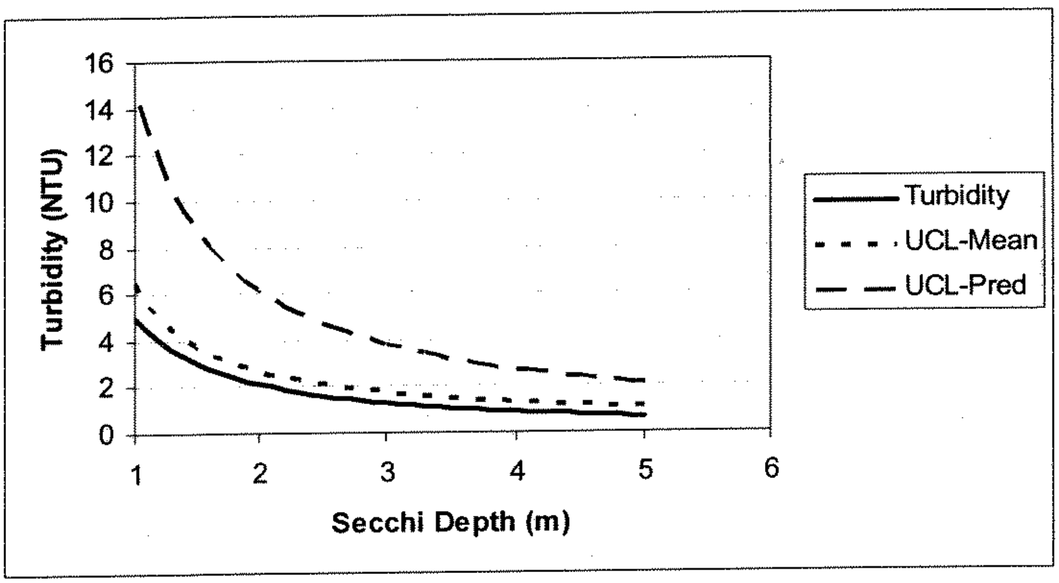

Figure 3. Upper Confidence Limits on the Prediction of Turbidity from Secchi Depth

To be confident that the expected value of turbidity in the raw water remains less than 5 NTU, the Secchi depth in the lower lake near the intake should be greater than about 1.2 m (upper confidence level on the mean); however, to have a high level of confidence that the 5 NTU level is rarely reached in individual observations, the Secchi depth should remain greater than 2.3 m. The relationship of the median Secchi depth (the selected metric) to the range of Secchi depths can be evaluated with the dynamic lake model. The 2.6 m Secchi depth target is thus consistent with meeting operational requirements for turbidity.

2.1.2.4 Additional Information on TOC Target

A TOC target is set to mitigate potential increases in the potential for production of harmful disinfection byproducts (DBPs) in the water treatment process. It is important to note that the impact of TOC on DBP formation depends on the characteristics of individual organic compounds in the water. USGS sponsored a characterization study of DBP sources in Lakes Maumelle and Winona (Pomes et al., 1999). Harmful DBPs arise primarily from the chlorination of aquatic humic substances, particularly fulvic acids. Pomes et al. found that this fraction of DOC in Maumelle and Winona was derived primarily as decay products of terrestrial lignin delivered by oxygenated, surface pathways. In other words, leaf litter and woody biomass are the ultimate source.

In contrast, many simpler organic compounds do not produce DBPs, and so are of less concern to the utility. Development that results in a reduction of woody biomass and substitution of more labile DOC sources is likely to result in a somewhat lower DBP formation potential than a similar amount of loading from terrestrial woody vegetation.

Pomes et al. found that aquatic humic substances (those that have a high potential for formation of DBPs) constituted 51percent of DOC in Lake Winona and 44 percent of DOC in Lake Maumelle, versus a typical value of 40 percent – likely due to the predominance of woody vegetation in watershed cover under existing conditions. It is thus possible that the TOC target may have a built in safety factor, and TOC loads could increase somewhat in Maumelle without increasing DBP formation potential, if the aquatic humic substances fraction went down toward the typical value as woody sources are replaced by more labile sources under future development.

2.2 Initial Allocations

Initial analysis for the January 1998 through September 2004 simulation time period revealed that the Baseline 1 development scenario, with the elimination of any direct discharge of wastewater, was slightly below the targets (Tetra Tech, 2006b). The allocation run was thus developed by scaling up all pollutant load time series in Baseline 1 (leaving flow, dissolved oxygen, and temperature unchanged).

Lake model simulations for a value of *R* equal to 115 percent of Baseline 1, without wastewater discharge, just meet the targets, as shown in Table 2.

Table 2. Comparison of Initial Allocation Run (Jan. 1998 – Sept. 2004) to Management Targets

Indicator	Allocation Run	Target
Chlorophyll *a* Summer Median (Intake Area)	3.0 µg/L	3.0 µg/L
Chlorophyll *a* Summer Median (Mid-Lake)	3.4 µg/L	3.5 µg/L
Total Organic Carbon Annual Median (Intake Area)	3.1 mg/L	3.1 mg/L (as close to 2.4 mg/L as possible)
Secchi Depth (Intake Area)	2.6 m	At least 2.6 m
Fecal Coliform Bacteria Concentration (Intake Area)	0.03 per 100 ml	Less than 0.065 per 100 ml

While the initial allocation run meets management targets, it does lead to some degradation of water quality. For chlorophyll *a*, summer concentrations at the intake change little, but there are larger spring peak concentrations (Figure 4). In the upper lake, minor algal blooms are predicted to occur throughout the year, but have only a small effect near the intake because of the typical long travel time during summer conditions. For Total Organic Carbon (TOC), the initial allocation leads to consistent increases in concentrations at the intake throughout the year (Figure 5).

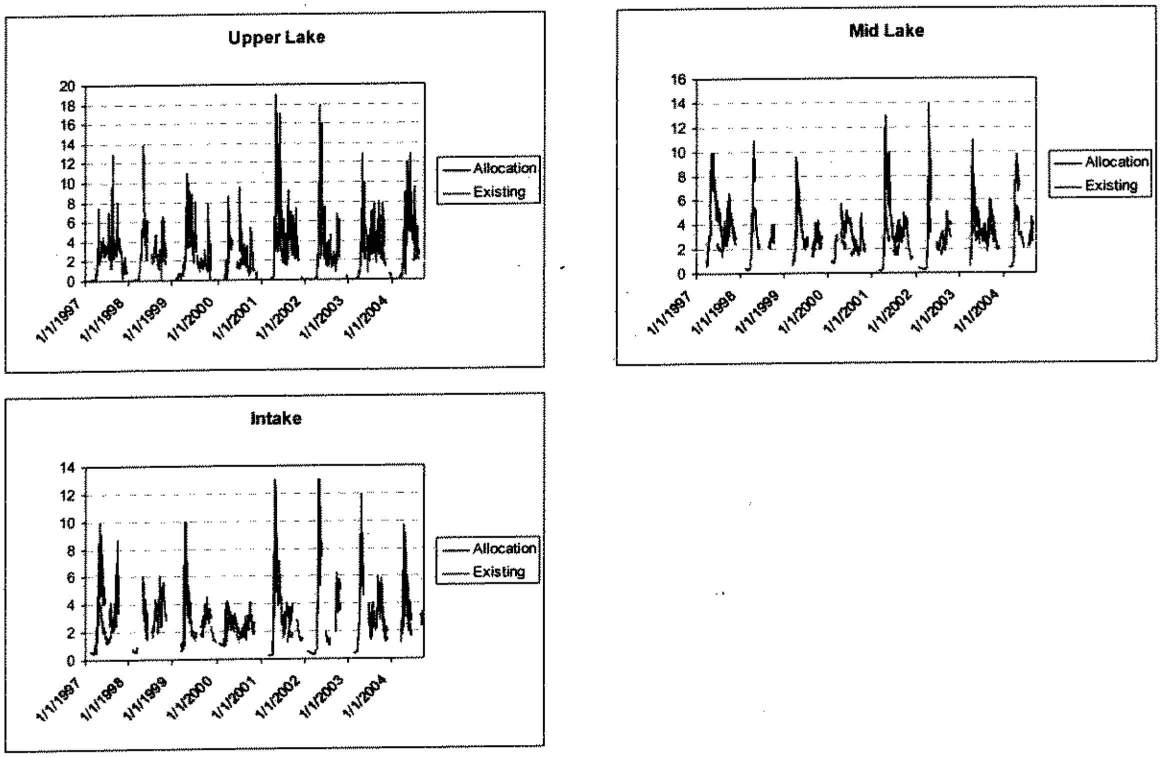

Figure 4. Chlorophyll *a* Results for Initial Allocation Run

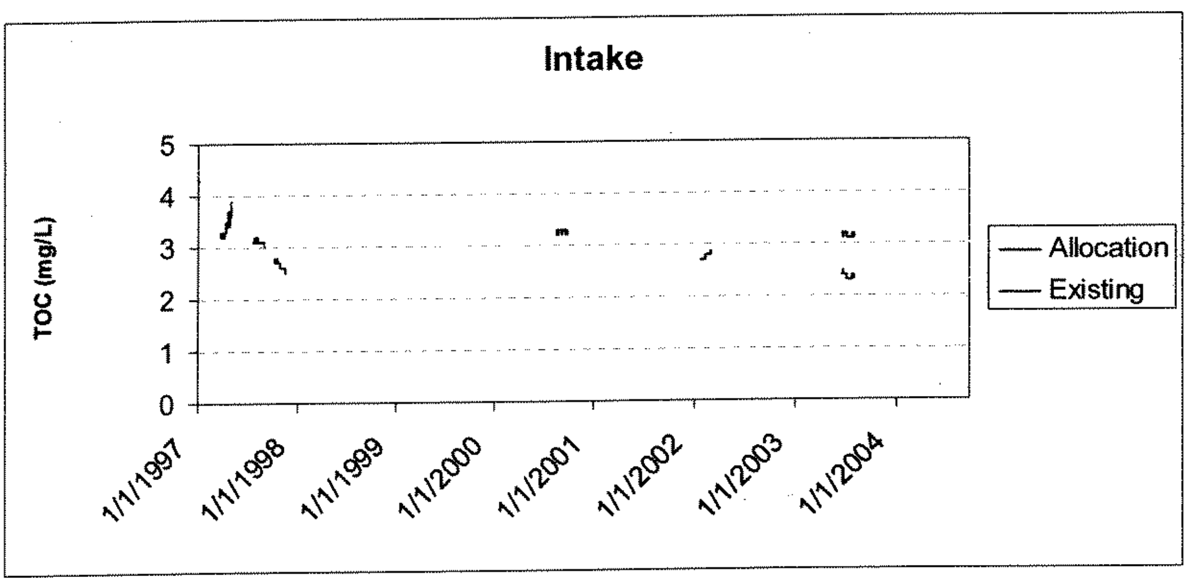

Figure 5. TOC Results for Initial Allocation Run

2.3 Refined Watershed Load Allocations

2.3.1 Developing Refined Allocations

The initial allocations were based on a straight percentage increase of all loads to the lake. The development process will increase loads from disturbed and developed areas, but not from undisturbed areas. Further, development may increase subsurface loads of nitrogen, but is unlikely to result in significant changes in subsurface loads of phosphorus. The initial allocation (using a multiplier on all loads) was refined to better represent the magnitude and timing of loads expected after development.

The overall allocation of loading to the lake represents an increase relative to existing conditions and also an increase relative to Baseline 1 with no wastewater discharge. Loading rates on a per-acre basis are estimated, from the model, for Baseline 1 conditions. If a target can be met by increasing the total loading present in Baseline 1 by a factor *R*, the additional load above Baseline 1 (*BS1*), should be assigned to the developable area (area not already developed) to derive average performance standards for new development. If the post-development load from developable areas can increase by a factor *K*, algebraic manipulation shows that *K* is related to *R* as:

$$K = (R-1)\cdot\frac{Total\ Load\ (BS1)}{Development\ Load\ (BS1)} + 1$$

In the case of inorganic phosphorus, sediment, and organic matter, significant increases in load with development are expected to be associated only with surface washoff, and *Development Load* should be represented solely by the surface washoff fraction. For inorganic nitrogen, development may also increase subsurface loads by a significant amount, due to use of soluble fertilizers and onsite wastewater disposal. Thus, for inorganic nitrogen *Development Load* should include both the surface and subsurface components. This has the effect of assuming that the subsurface loads from development have also increased by the factor *K*.

Additional iterations revealed that achieving targets was most sensitive to inorganic phosphorus loads. Determination of a single scalar *R* to meet targets resulted in a situation in which the reductions in inorganic phosphorus to meet chlorophyll *a* targets would result in highly restrictive limits on organic matter loading that would not be directly needed to meet targets and might not be feasible with available management measures. Therefore, the allocation run was modified to allow a greater increase in surface organic matter loading, which must be compensated by a reduction in inorganic phosphorus loading (because inorganic phosphorus is regenerated in the lake by the decay of organic matter). The final allocation run was constructed by allowing the following changes in loading from developed land relative to the initial simulation of Baseline 1 without direct wastewater discharge:

- Inorganic Phosphorus: 15 percent increase in surface loading from developed land.
- Fecal Coliform Bacteria: 15 percent increase in total loading from developed land.
- Total Suspended Solids: 24.2 percent increase in surface loading from developed land.
- Inorganic Nitrogen: 15 percent increase in total loading (surface and subsurface) from developed land.
- Organic Matter: 50 percent increase in surface loading from developed land due to more washoff and less trapping in natural areas.

2.3.2 Comparison to Targets

Results for the refined allocation run are shown in Table 3 and are nearly identical to those obtained for the initial allocation run in terms of ability to meet targets. The final allocation differs from the initial allocation, however, attributing increases in load relative to existing conditions to new development only.

Table 3. Comparison of Refined Allocation Run (Jan. 1998 – Sept. 2004) to Management Targets

Indicator	Allocation Run	Target
Chlorophyll *a* Summer Median (Intake Area)	3.0 µg/L	3.0 µg/L
Chlorophyll *a* Summer Median (Mid-Lake)	3.4 µg/L	3.5 µg/L
Total Organic Carbon Annual Median (Intake Area)	3.0 mg/L	3.1 mg/L (as close to 2.4 mg/L as possible)
Secchi Depth (Intake Area)	2.6 m	At least 2.6 m
Fecal Coliform Bacteria Concentration (Intake Area)	0.03 per 100 ml	Less than 0.065 per 100 ml

The total pollutant load delivered to the lake under the final allocation run can be obtained directly from the HSPF watershed model output. These are compared to existing conditions in Table 4, based on averages across the simulation period of 1997-2004.

Table 4. Average Annual Load Delivered to Lake Maumelle for Allocation Run

	Total Phosphorus (lb/yr)	Total Organic Carbon (lb/yr)	Total Suspended Solids (tons/yr)	Fecal Coliform Bacteria (#/yr)
Allocation Run	19,000	2,375,665*	5,954	2.16×10^{15}
Existing Conditions	9,414	1,839,521	2,711	6.75×10^{14}

Note: The TOC load target was subsequently reduced from this value to provide an additional safety factor, as described below.

Table 4 shows that substantial increases in existing loads are possible without contravening the specified targets. This is in part a result of the selected targets, but also reflects the fact that existing loads are generally low. It should be kept in mind, however, that the allocation is the maximum permissible loading rate at eventual buildout, and that management planning will endeavor to ensure that loads remain less than the allocation.

2.3.3 Additional Evaluation of TOC

Some special considerations are appropriate for the TOC loading. While the absolute target of 3.1 mg/L is met, the target also contains a provision to further control TOC concentrations at the intake to as close to 2.4 mg/L as possible. In addition, the assumptions for organic matter loading in the allocation run imply no significant increase in the rate of loading by subsurface pathways following development, even where onsite wastewater disposal is used. Septic tank effluent typically contains high concentrations of dissolved organic carbon (DOC), in the range of 30 to 80 mg/L (Wilhelm et al., 1996). However, much of this DOC is metabolized in the leachfield and groundwater system by both aerobic and anaerobic processes. Wilhelm et al. report decreases in DOC concentration to near background by the time effluent reaches the water table in sandy aquifers (from 71.3 to 2.9 mg/L average in one setting, and from 38.2 to 3.3 mg/L in another setting). Anderson et al. (1994) found that total organic carbon decreased from 47.4 mg/L to 8.0 mg/L at a depth of 1.2 m beneath a leachfield. In addition to decay, particulate organic carbon is likely to be strongly retarded in groundwater transport. Therefore, it is believed that onsite wastewater disposal is not likely to result in a large increase in organic matter loading by subsurface pathways; however, some increase may occur.

To account for these uncertainties and introduce a safety factor for TOC, the allocation was revised by assuming that the TOC surface load from developed land would be allowed to increase by only 35 percent, rather than 50 percent, relative to the prediction conditions under Baseline 1 buildout. This reduces the total delivered load of TOC to 2,232,938 lb/yr.

2.3.4 Additional Evaluation of Secchi Depth

The relationship between Secchi depth and turbidity was discussed in Section 2.1.2.3, where it was shown that, to have confidence that the turbidity level in the raw water supply rarely reaches 5 NTU on average, the Secchi depth should remain greater than 1.2 m, while to be confident that it will rarely reach 5 NTU under the range of potential individual events, the Secchi depth should remain greater than 2.3 m. The time series of Secchi depths predicted by the model under the revised allocation scenario is shown in Figure 6. The minimum Secchi depth predicted by the model is 1.82 m, which is within the acceptable range of the confidence limit on the mean of the regression line, but outside the range for prediction of individual events.

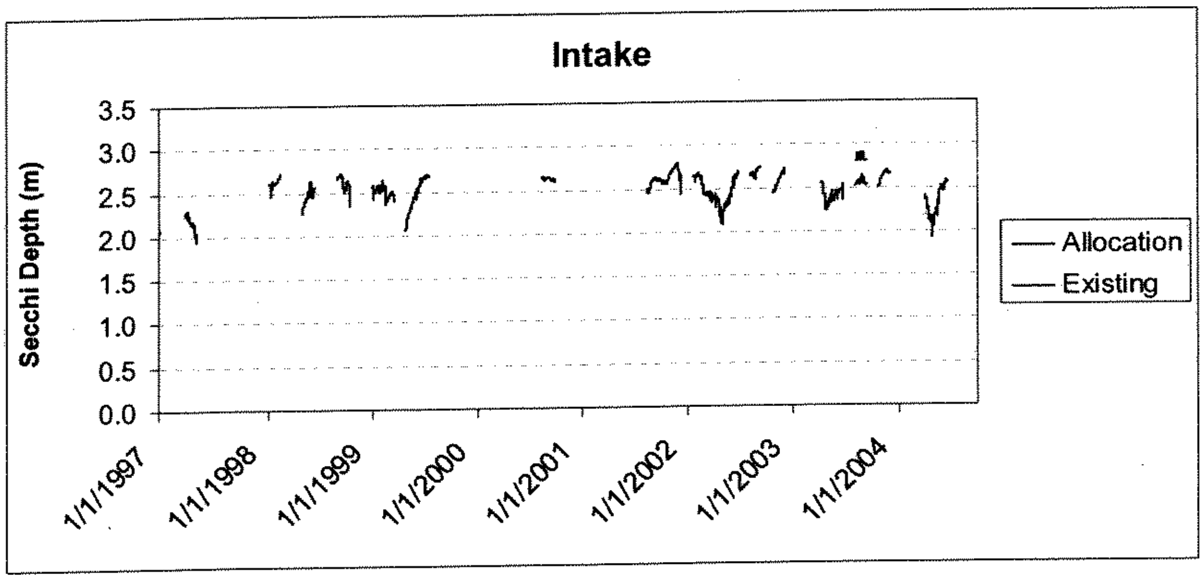

Figure 6. Secchi Depths Predicted at the Water Intake for the Refined Allocation Run

At the minimum predicted Secchi depth of 1.82 m, the expected value of turbidity from the regression would be 2.38 NTU, with an upper confidence limit of 2.96 NTU. However, the upper confidence limit on individual observations would be 6.92 NTU. The actual risk at a Secchi depth of 1.82 m is, however, small: there is only about an 8 percent chance that an individual value would be greater than 5 NTU at this level.

The selected target for Secchi depth thus appears reasonable in light of model results. It should be noted, however, that the model for the allocation focuses on conditions at buildout and does not include representation of fine sediment loading and resulting turbidity that might occur during the construction phase. The final management plan should include measures to avoid the creation of high turbidity spikes during land disturbance, particularly in areas near the water supply intake.

2.4 ALLOCATIONS BY MANAGEMENT ZONE

The allocations presented in Section 2.3 are for total load delivered to the lake. For comparison of management alternatives and the planning of mitigation measures it is necessary to convert these delivered load allocations to allocation load rates, on a per-acre basis, at the site level. Because there is retention and transformation of pollutants in transit from upland areas to the lake, site level loads consistent with the allocation will generally be greater than delivered loads. Further, the rate of pollutant generation and the fraction delivered to the lake will differ according to the location of a land area within the watershed. Different parts of the watershed have different soils, different slopes, different precipitation regimes, and different times of travel to the lake. To convert the general load allocations into management strategies, it is necessary to convert the delivered load allocations to site scale loads and to evaluate the loads by different areas of the watershed.

2.4.1 Development of Management Zones

At the March 16 PAC meeting, Tetra Tech presented three proposed management areas: Critical Area A, Critical Area B, and the Upper Watershed Area (see Figure 7).

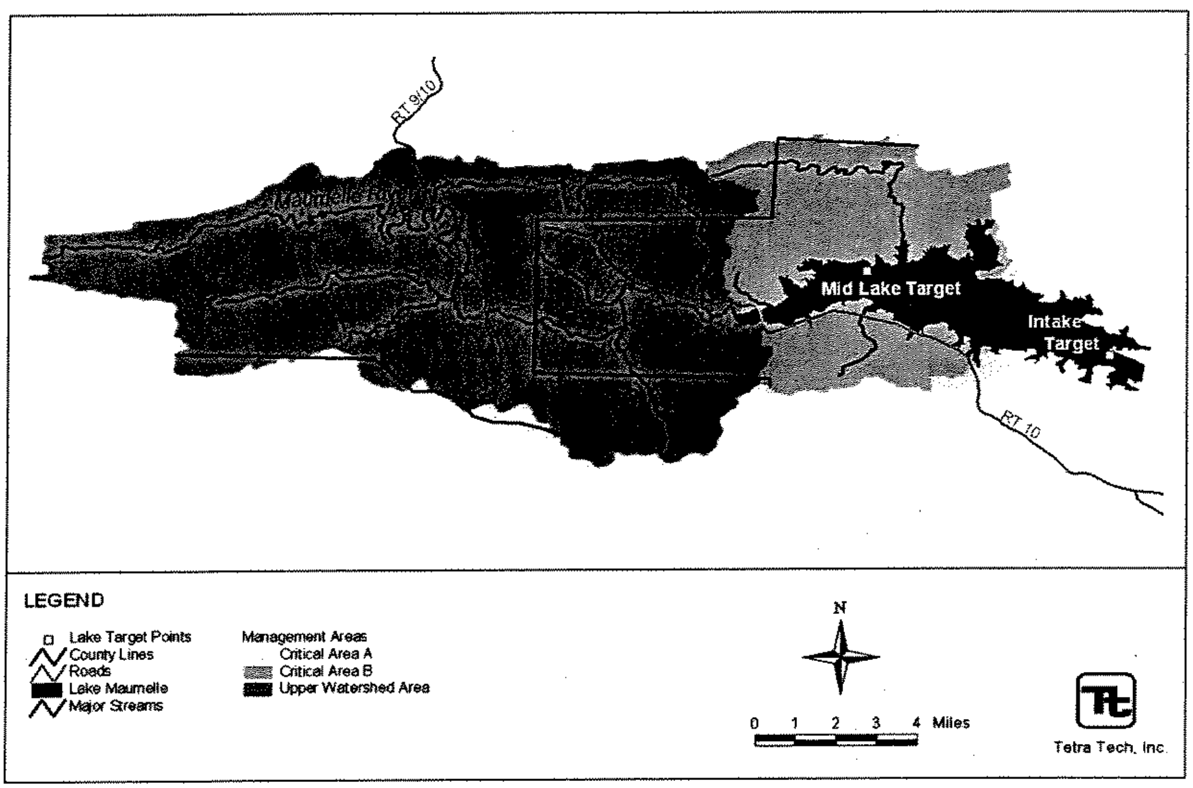

Figure 7. Preliminary Lake Maumelle Management Areas (03-09-06)

Travel time within lake to the intake area shaped the boundaries for these areas, with Critical Area A having a lake travel time of less than 5 days, Critical Area B a travel time of 20-29 days, and the Upper Watershed a 37- day travel time. Tetra Tech noted that travel time *to* the lake was much shorter, a matter of hours rather than days. One of the PAC members raised a concern about the difference between the eastern and western portions of the Upper Watershed Area in terms of the distance to the lake. The question was raised, "How could we justify or explain having the same requirements for both areas when one is much closer to the lake?" Based on this concern, Tetra Tech reevaluated the management area boundaries based on travel time to the lake and within the lake, as well as on watershed and jurisdictional boundaries. The Revised Management Areas are shown in Figure 8, and include a larger Critical Area B. This area includes land up to Williams Junction along the Highway 10 road corridor, which is close to the Big Maumelle River.

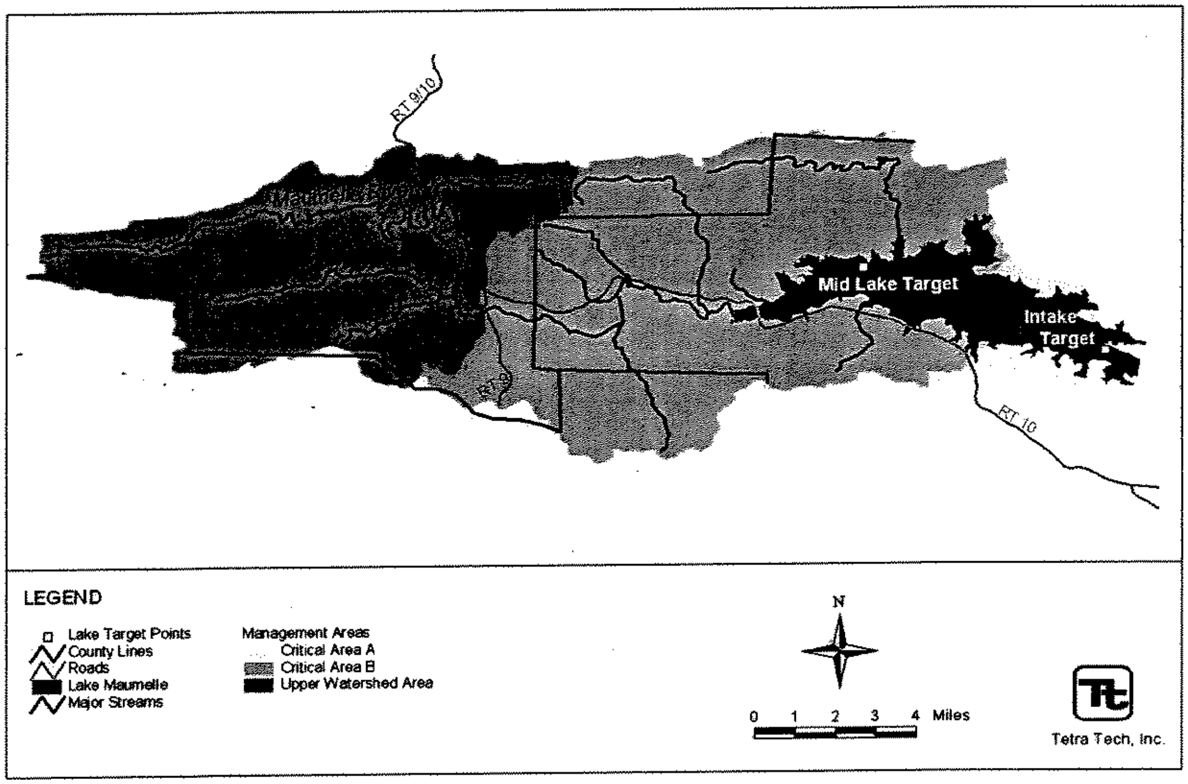

Figure 8. Lake Maumelle Revised Management Areas

2.4.2 Development of Allocations by Management Zone

It is advisable to provide more stringent requirements for those land areas in the portion of the watershed (Zone A) that drain directly to the lower part of the lake near the water intake. Pollutant loads from these areas will have a more direct effect on water quality conditions at the intake. In addition, the short time of travel between uplands and the water intake merits a higher level of protection. On the other hand, the distant upper part of the watershed (UWA) has long travel times to the intake, and a portion (approximately 10 percent) of the phosphorus and sediment load is lost in transit to sedimentation. The selected target of 65 percent of the average allowable loading rate represents a level of additional effort that maximizes protection but is still feasible to achieve. Selection of this target is also consistent with the evaluation of potential transport of microbial pathogens such as *Cryptosporidium*. This analysis (see Section 5.2) showed that the transmission to the water supply intake of *Cryptosporidium* oocysts loaded to the lake in Zone A would be, on average, about 83 percent; transmission of oocysts loaded to Zone B would be, on average, about 21 percent; while transmission from the downstream edge of Zone B would be about 50 percent. These differences are associated with the time of travel over which gradual inactivation of oocysts will occur. Removal of *Cryptosporidium* loads in stormwater runoff will generally involve the same types of BMPs that reduce fine sediment and phosphorus loading. To reduce the risk from Zone A to that associated with the lower portions of Zone B, the targets should be set to approximately 50% / 83% ≈ 60% of the average allocations. Because it is unclear that a reduction to 60 percent of the average load is realistically achievable for total phosphorus and TSS, this target was relaxed to 65 percent of the average load.

Thus, performance standard loading rates for total phosphorus and sediment are set to more restrictive values in Zone A (65 percent of the developable land average), while performance standards differences in UWA are allowed to be approximately 10 percent higher (before rounding) than those in Zone B to account for pollutant loss, while meeting the total developable land load allocation. Total organic carbon (TOC) targets may be more difficult to achieve than phosphorus and sediment targets, so a smaller differential is applied: Performance standards in Zone A for TOC are set at approximately 70 percent of the average, while performance standards in UWA are allowed to be about 15 percent greater than those in Zone B for TOC.

A two-step process was used to estimate the site-scale loads that correspond to the allocations. First, the watershed model was used to output site-scale, per-acre loads for each of the hydrologic response units (HRUs) in the model, with surface and subsurface loading components separated. The HRUs are areas of similar characteristics including land use/cover, soils/slopes, and weather regime. These loading rates can then be combined with the land use distribution to calculate the site-scale or upland loading that corresponds to the delivered-load allocation from each management area.

A summary of site-scale loads and delivered loads by management zone for the allocation run is presented in Table 5. Only TP, TOC, and TSS are shown in this table because the fecal coliform load is predicted to remain well below management targets under allocation buildout conditions, and thus does not require the same level of detailed implementation planning. TOC allocations are based on the revised loading estimate (with safety factor) described in Section 2.3.

Table 5. Allocations by Management Zone

Constituent	Management Zone	Site-Scale Load	Delivered Load	Percent of Total Load
Total Phosphorus (lb/yr)	Critical Zone A	1,017	876	4.6%
	Critical Zone B	13,915	11,997	63.1%
	UWA	7,817	6,126	32.2%
	Entire Watershed	22,749	19,000	100%
Total Organic Carbon (lb/yr)	Critical Zone A	159,397	94,277	4.2%
	Critical Zone B	2,230,024	1,318,967	59.1%
	UWA	1,593,768	819,694	36.7%
	Entire Watershed	3,983,189	2,232,938	100%
Total Suspended Solids (t/yr)	Critical Zone A	348	224	3.8%
	Critical Zone B	5,677	3,664	61.5%
	UWA	3,521	2,066	34.7%
	Entire Watershed	9,546	5,954	100%

3 Evaluating Primary Alternatives

The allocations developed in Section 2 determine the maximum average annual loading in the watershed that is consistent with attaining management objectives. This allowable loading must be distributed to a number of sources:

1. Nonpoint source loading from existing land uses that are not expected to change in the future (including land owned by CAW and the National Forest Service, as well as existing residences and businesses).
2. Nonpoint source loading from new development that replaces existing land uses.
3. Loading from wastewater disposal.

Items 2 and 3 represent new sources of load, while item 1 represents existing sources. Because existing loading rates are low and the land is largely undeveloped, management alternatives focus on limiting loading from new sources.

Once allowable loading was established, Tetra Tech initially envisioned allocating a portion of the loading to wastewater and developing performance standards for wastewater discharges. After determining the maximum extent to which loads from wastewater could be limited, Tetra Tech could then determine the remaining load allocations and performance standards for nonpoint source loading from new development. However, modeling results from the baseline assessment (Tetra Tech, 2006b) made it clear that a strategy that included direct discharges of wastewater would not meet water quality targets. In the baseline scenarios representing current regulations, wastewater discharges were predicted to become the major source of pollutant loading to the lake. Further, uncontrolled development without wastewater discharges was found to meet targets only under assumptions that most of the land in the watershed was developed with 5- and 10-acre lots, and that 76 percent to 88 percent of the lots would be conserved in undisturbed open space. At the March 16, 2006 PAC meeting, members recommended capping the maximum requirement for conservation of open space at 50 percent, and targeting minimum lot size at 5 acres. Thus, a significant amount of load reduction for new development will be needed to meet targets in the absence of any direct wastewater discharges.

Tetra Tech did discuss with ADEQ the possibility of strict effluent limits on wastewater discharges. ADEQ indicated that a "feasible" limit that it might impose is 1 mg/L total phosphorus, which would be considered a very high level of treatment for a package treatment plant. Such a limit, however, would result in a loading rate of 0.95 lb/yr of total phosphorus for a household on a 5-acre lot, which would constitute over 60 percent of the available allocation for new development.

As a result, the primary management alternatives focused on scenarios that included a policy of no direct surface discharges in the watershed. Subsurface discharges of wastewater could be used, as such systems are expected to contribute minimal loads of phosphorus and other targeted indictors, or, in some areas, waste could be pumped out of the watershed. (Further discussion of wastewater alternatives is provided in Section 5).

Another general concern in the Maumelle watershed is the presence of areas with high slopes that may be highly susceptible to erosion and pollutant export. Such lands would also be difficult and expensive to develop. Based on research regarding conservation design guidelines and on consultation with the TAC, it was assumed that vacant land with slopes greater than or equal to 25 percent would not be developable. Land in public ownership or conservation easement, as well as the footprint and immediate surrounding area of existing residential and commercial buildings, was excluded from the total land area potentially developable in the future. The 50-ft buffer around the petroleum pipeline was also considered as "already built" and not available for development. The resulting developable land area (Table 6) represents a refinement of the analysis presented in Tetra Tech (2006b) and was used as a basis for evaluating the primary management alternatives.

Section 3.1 discusses the evaluation methods used for the two primary development design alternatives, performance standards and conservation design. Section 3.2 provides details on the assumptions and requirements for each alternative, as well as the evaluation results. Section 3.3 presents cost estimates for the two primary approaches.

Table 6. Revised Summary of Developable and Undevelopable Land (acres) in the Lake Maumelle Watershed

	Developable			Undevelopable				
	Low Slope (0-15%)	High Slope (15-25%)	Total	Vacant, Slope ≥ 25%	Public Ownership or Already Built	Lake Surface	Total	Total Watershed Area
Critical Area A	580	590	1,170	80	2,370	3,440	5,890	7,060
Critical Area B	14,710	17,740	32,450	4,610	8,270	5,630	18,510	50,960
Upper Watershed Area	6,740	6,190	12,930	570	16,530	0	17,100	30,030
Total	22,030	24,520	46,550	5,260	27,170	9,070	41,500	88,050

3.1 Evaluation Methods for Primary Alternatives

3.1.1 Performance Standards

Performance standards are the loading rates that need to be achieved (on average) by new development to meet lake targets. Performance standards may either be applied directly (by requiring that new development use management measures that reduce expected pollutant loads to meet the performance standards) or indirectly (limiting the amount and density of development to a level that is predicted to be consistent with achieving performance standards).

To determine performance standards for development, the allocations may first be expressed as an average per-acre rate for surface runoff load from all developable land. This is the average loading rate that must be achieved across all developable land to meet the targets. (Note that the average could be achieved if some areas have higher rates and other areas remain undeveloped.) The resulting performance standards (rounded to two significant figures) are shown in Table 7.

Table 7. Performance Standards for Surface Runoff Loading from Developed Land

	Total Phosphorus (lb/ac/yr)	Total Sediment (tons/ac/yr)	Total Organic Carbon (lb/ac/yr)
Developable Land Average	0.31	0.12	45
Zone A Allocation for New Development	0.20	0.08	36
Zone B Allocation for New Development	0.30	0.11	44
UWA Allocation for New Development	0.33	0.13	50

The performance standards in Table 7 represent the site-scale loading rates that need to be achieved to meet the overall loading allocation for the lake. In a performance standards approach, management practices would be adopted for new development to ensure that loads generated by new development are less than or equal to the specified performance standards.

3.1.2 Conservation Design Analysis

The Conservation Design Approach to meeting loading allocations relies on limiting the density of development (for example, by specifying a minimum lot size) and/or the intensity of development (for example, by requiring a certain percentage of undisturbed natural area within a parcel).

Conservation Design scenarios may also be evaluated in relation to the performance standards shown in Table 7, as these are the site-scale loadings that must be achieved, on average, to meet management targets in the lake. However, instead of applying engineered management practices to reduce loads, a land conservation scenario asks a somewhat different question: How much does the density and/or intensity of development need to be reduced in order to bring the net loading rate from new development to meet the performance standards?

3.1.3 Site Evaluation Tool

Evaluation of either a Performance Standards or Conservation Design approach requires comparison of the pollutant load generated by development of a given type (use, lot size, area in natural state, and any engineered management practices) relative to the loading rates specified in the performance standards.

The Site Evaluation Tool (SET) was developed for the assessment of development impacts to water quality at the site level (Tetra Tech, 2005). The SET, a Microsoft Excel spreadsheet-based simulation program, is founded upon sound scientific principles and models, and is capable of evaluating the impact of development on downstream water quality and the influence of Best Management Practices (BMPs) on hydrology and pollutant loads. It can also easily be configured to evaluate the performance of new and existing development against standards and targets for water quality protection. For the Lake Maumelle project, Tetra Tech utilized the annual pollutant loading component of the SET, with several modifications to tailor it to the project needs.

Annual surface runoff in the SET is determined using the Simple Method (Schueler, 1987), which relates runoff depth to annual precipitation and the fraction of the area in impervious cover. The Simple Method can be rearranged to estimate runoff from pervious and impervious areas separately. Loads from surface runoff are calculated from the product of annual runoff depth, pollutant event mean concentration (EMC), and land area, and are determined separately for each type of land surface, including paved and unpaved impervious surfaces, natural, and managed pervious areas. An EMC is the flow-weighted average pollutant concentration across large and small storm events. By separating the pervious and impervious components of runoff and loading, it is possible to estimate total site loads for any combination of percent impervious cover, managed pervious areas (typically grass), and natural land covers such as forest. The SET also estimates the effects of BMPs or trains of BMPs on pollutant yield. BMPs reduce the load based on the fraction of the runoff they treat and their pollutant removal efficiencies.

Typically, EMCs and runoff volume in the SET are calibrated to match loading rates appropriate for the region or locale where they are being used. In the Lake Maumelle project, predicted flows and loads from the SET were set to match loads predicted by the calibrated HSPF model for natural land uses and existing low density development. Loads for more intense development without BMPs were set consistent with predictions of the watershed model for future development scenarios. During the course of the project, adjustments were made to SET EMCs to allow for more impervious land cover classes needed to represent variations in road and driveway surfaces, and also to account for a portion of runoff from impervious surfaces that flows onto adjacent pervious areas, infiltrating into the soil. Six separate versions of the SET were produced, each with unique annual runoff rates and EMCs. Each management zone had two SET versions – one for land with lower slopes (less than 15 percent) and one for land with higher slopes (15 percent to 25 percent). Loading rates for high sloped lands were typically higher than loading rates for low sloped lands within a particular management zone, as reflected in the pervious land covers. The final set of annual runoff rates and EMCs are shown in Table 8 for each management zone and slope class, reflecting the best information for assessing development scenarios.

Table 8. Annual runoff and Event Mean Concentrations used for Maumelle SETs

Critical Area A

Land Cover	Low Slope				High Slope			
	Runoff (in/yr)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)	Runoff (in/yr)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
Forest	9.77	0.0158	8.38	3.00	10.39	0.0639	33.6	12.18
Grassland	11.58	0.0252	13.8	4.77	12.08	0.108	58.9	20.41
Lawn/Developed Pervious	11.58	0.176	13.8	4.77	12.08	0.264	58.9	20.41
Residential-Rooftops	38.45	0.100	5.00	10.0	38.45	0.100	5.00	10.0
Residential-Paved Surfaces	38.45	0.178	96.1	26.04	38.45	0.178	96.1	26.04
Residential-Unpaved Surfaces *	38.45	0.285	336.7	26.04	38.45	0.285	336.7	26.04
Commercial-Rooftops	38.45	0.100	5.00	10.0	38.45	0.100	5.00	10.0
Commercial-Paved Surfaces	38.45	0.260	164	25.33	38.45	0.260	164	25.33
Commercial-Unpaved Surfaces *	38.45	0.285	336.7	26.04	38.45	0.285	336.7	26.04
Paved Roads	38.45	0.137	287	10.21	38.45	0.137	287	10.21
Unpaved Roads	38.45	0.219	1005	10.21	38.45	0.219	1005	10.21

Critical Area B

Land Cover	Low Slope				High Slope			
	Runoff (in/yr)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)	Runoff (in/yr)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
Forest	7.4	0.0461	23.9	8.78	9.21	0.0666	34.9	12.7
Grassland	9.51	0.0504	27.5	9.56	11.43	0.109	59.7	20.72
Lawn/Developed Pervious	9.51	0.214	27.5	9.56	11.43	0.270	59.7	20.72
Residential-Rooftops	38.45	0.100	5.00	10.0	38.45	0.100	5.00	10.0
Residential-Paved Surfaces	38.45	0.178	96.1	26.04	38.45	0.178	96.1	26.04
Residential-Unpaved Surfaces *	38.45	0.285	336.7	26.04	38.45	0.285	336.7	26.04
Commercial-Rooftops	38.45	0.100	5.00	10.0	38.45	0.100	5.00	10.0
Commercial-Paved Surfaces	38.45	0.260	164	25.33	38.45	0.260	164	25.33
Commercial-Unpaved Surfaces *	38.45	0.285	336.7	26.04	38.45	0.285	336.7	26.04
Paved Roads	38.45	0.137	287	10.21	38.45	0.137	287	10.21
Unpaved Roads	38.45	0.219	1005	10.21	38.45	0.219	1005	10.21

Upper Watershed Area								
	Low Slope				High Slope			
Land Cover	Runoff (in/yr)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)	Runoff (in/yr)	TP (mg/L)	TSS (mg/L)	TOC (mg/L)
Forest	7.63	0.0472	25.3	9.00	8.35	0.0879	46.7	16.75
Grassland	10.25	0.0519	28.0	9.85	10.91	0.110	59.5	20.95
Lawn/Developed Pervious	10.25	0.214	28.0	9.85	10.91	0.273	59.5	20.95
Residential-Rooftops	42.97	0.100	5.00	10.0	42.97	0.100	5.00	10.0
Residential-Paved Surfaces	42.97	0.166	102.8	23.54	42.97	0.166	102.8	23.54
Residential-Unpaved Surfaces *	42.97	0.264	365.8	23.42	42.97	0.264	365.8	23.42
Commercial-Rooftops	42.97	0.100	5.00	10.0	42.97	0.100	5.00	10.0
Commercial-Paved Surfaces	42.97	0.250	182	24.34	42.97	0.250	182	24.34
Commercial-Unpaved Surfaces *	42.97	0.264	365.8	23.42	42.97	0.264	365.8	23.42
Paved Roads	42.97	0.128	307	9.61	42.97	0.128	307	9.61
Unpaved Roads	42.97	0.203	1092	9.56	42.97	0.203	1092	9.56

* Reflects earthen surfaces. Reductions for use of gravel are discussed subsequently.

For each development site layout scenario modeled by the SET, detailed assumptions were developed for overall site impervious area, natural and managed pervious land covers, and a breakdown of impervious area into further categories (for instance, roof area, paved driveway area, or unpaved road area). Total land area in each category was input into the SET. Predicted annual average loading rates for various housing density scenarios are shown for Critical Area B (Table 9).

Table 9. Example Loading Rates for Critical Area B

Lot Size	Avg. Lot Slope	TP (lb/ac/yr)	TSS (tons/ac/yr)	TOC (lb/ac/yr)
5	Low	0.258	0.106	27.1
7	Low	0.220	0.089	25.4
10	Low	0.189	0.070	24.2
5	High	0.365	0.133	45.7
7	High	0.328	0.116	44.5
10	High	0.297	0.098	44.0

Note: Reflects paved roads, gravel driveways, and 30 percent forest cover in low sloped areas/50 percent cover in high sloped areas

If BMPs were used in a site layout scenario, the land area was further divided up into drainage areas for each BMP. In most SET applications, fixed removal rates are used for load reduction. However, some Technical Advisory Council members expressed a concern about using fixed removal rates. Research indicates pollutant removal is highly dependent on influent pollutant concentrations (Strecker et al., 2001); when runoff concentrations are low to begin with (frequently the case in rural settings), BMPs tend to show lower removal rates. Furthermore, there is evidence that for a given BMP and pollutant, the effluent concentration cannot be decreased below a certain threshold, often called the "irreducible concentration." This is an over-simplification, of course, since any lower limit on effluent concentration would vary due to many factors – even across different storm events for the same BMP. However, enough research has been conducted and compiled to find lower limit central tendencies for some BMP types and pollutants. GeoSyntec Consultants and Wright Water Engineers (2006) provided the most recent comprehensive statistical summaries of BMP performance focusing on influent and effluent pollutant concentrations. The influence of lower limit concentrations is especially important when considering BMPs connected in series (called "treatment trains"). The first BMP may remove a significant portion of the pollutant, but the fraction that is passed on may have too low a concentration for effective treatment by the second BMP.

To address these aspects of stormwater treatment, Tetra Tech developed a hybrid approach for evaluating BMP performance, combining traditional percent removal under higher loading/concentration conditions, but capping removal at lower concentration limits. When influent was passed to a BMP, the percent load removal calculation was performed using the percent removal rate. If the resulting effluent concentration was greater than the lower limit concentration, the percent removal calculation was used to calculate effluent load and concentration. But if the effluent concentration using percent removal was below the lower limit concentration, the load removed was based on making the effluent concentration equal to the lower limit concentration. The effluent load was then passed either to the next BMP for the same calculation, or to model output. In scenarios with BMP treatment trains evaluated for the Lake Maumelle project, concentrations leaving the second BMP were typically concentration-limited.

For TP and TSS percent removal rates by BMP, Tetra Tech used figures reported in the Watershed Protection Toolbox Primer document prepared for the Policy Advisory Council. A number of data sources were used to develop the removal rates, most notably the National Pollutant Removal Performance Database (Winer, 2000). Other sources include the Chesapeake Bay Program (2003), Wossink and Hunt (2003), Atlanta Regional Commission (2001), and Prince George's County (1999). TOC removal rates were taken either from Winer or were estimated based on best professional judgment, typically as a fraction of TSS removal. Removal rates were rounded to the nearest 5 percent, and are shown in Table 10.

Table 10. BMP Removal Rates Used When Effluent Concentrations Remain Above Lower-Limit Concentrations

BMP	TP	TSS	TOC
Wet Pond	50%	75%	45%
Extended Dry Detention	20%	45%	25%
Conventional Dry Detention	10%	25%	15%
Bioretention	70%	85%	55%
Grass Swale	20%	35%	25%
WQ Swale (MD Design)	50%	80%	50%
Filter Strip	35%	55%	40%

Results from the GeoSyntec/Wright Water study and other recent research on bioretention (Davis et al, 2006; Tornes, 2005) were used to develop lower limit ("irreducible") concentrations (Table 11). The lower confidence limit reported by GeoSyntec/Wright Water was used, which Tetra Tech interpreted as representing performance typical for lower influent concentrations, which are typical for the low density housing development evaluated in this project. Adjustments were made to the TP lower limit concentrations reflecting information from the other studies and local conditions. No data were available for TOC, so TOC response was scaled to TSS removal when effluent concentrations were controlled by the lower TSS limit.

Table 11. Lower Limit Effluent Concentrations for BMPs

BMP	TP (mg/L)	TSS (mg/L)
Wet Pond	0.086	14.7
Extended Dry Detention	0.105	32.1
Conventional Dry Detention	0.105	32.1
Bioretention	0.080	8.1
Grass Swale	0.185	26.7
WQ Swale (MD Design)	0.080	8.1
Filter Strip	0.185	26.7

During the project, Tetra Tech also evaluated various BMPs designed specifically for reducing loads from road surfaces and their drainage systems. Three levels of practices were investigated – use of gravel instead of native (dirt) surfaces, gravel plus BMPs recommended by the Arkansas Forestry Commission (AFC), and use of a special driving surface aggregate, combined with AFC BMPs and additional BMPs not included in AFC guidance ("Best Available Technology").

Forest road data suggest that an additional 24 percent reduction in sediment delivery could be achieved by using gravel instead of native surfaces. Alan Clingenpeel of the US Forest Service provided Tetra Tech with sediment delivery values for the Maumelle Watershed derived from modeling (personal communication to David Pizzi, Tetra Tech, December 12, 2005). Assuming that traffic level was high, he reported sediment delivery for native forest roads at 20.8 tons/mi/yr and for graveled roads at 15.8 tons/mi/yr. These values suggest that one can achieve a 24 percent reduction in sediment delivery by using gravel instead of native surfaces. However, for the Maumelle project, Tetra Tech assumed the sediment reduction would be 21 percent. In the Lake Maumelle watershed under existing conditions, unpaved roads have both native and gravel surfaces, so the HSPF loading rates for unpaved roads reflected a combination of the two. The majority of the roads had native surfaces though, so the use of gravel does represent a significant reduction in sediment load.

Whitsett (2005) used the Water Erosion Prediction Project (WEPP) model setup for roads (WEPP:Road) to estimate the difference in sediment loading between the current condition of forest roads and full implementation of AFC BMP guidelines. The average reduction estimated was 24 percent. Since the watershed model is calibrated to the average conditions found in forest roads in the Ouachita Mountains, and Whitsett studied a sample of typical road types in this same mountain range, the 24 percent sediment reduction rate represents the difference between an unpaved road of typical construction quality and a road with full implementation of the AFC recommended forest road BMPs in the Lake Maumelle Watershed.

To reduce sediment delivery beyond what is achievable by conventional gravel, Dave Shearer of Pennsylvania State University (personal communication to Heather Fisher, Tetra Tech, April 25, 2006) recommended using an aggregate surface called Driving Surface Aggregate (DSA) developed by Center for Dirt and Gravel Road Studies (CDGRS). Additionally, the AFC guidelines do not include BMPs for diverting subsurface and upland runoff from road surfaces, which could be achieved with underdrains and bank benches. Combining DSA, AFC recommended BMPs, and additional drainage BMPs represents the

"Best Available Technology" (BAT). The performance of this suite of practices is unknown, and difficult to estimate. Tetra Tech made a conservative assumption that BAT would achieve a sediment loading rate midway between use of gravel and AFC BMPs, and fully paved roads.

Combining use of gravel (21 percent reduction) and AFC BMPS (24 percent reduction) results in a net TSS reduction of 40 percent (21 percent, plus 24 percent of the remaining 79 percent). Use of pavement reflects a 78 percent reduction in sediment load over unpaved surfaces. Using the assumption that BAT represents a midpoint between gravel plus AFC BMPs and full pavement, the assumed TSS reduction for BAT was 56 percent.

No data were available for TP load reduction from gravel versus native surface roads. TP removal performance was scaled to the difference between unpaved and paved TP loading rates. The resulting removal rates are reasonable, following a trend of being about half the TSS removal rates, typical for other stormwater BMPs. TOC loading rates do not differ between unpaved and paved roads, so no removal was calculated.

Removal rates for road BMPs are shown in Table 12. It is important to note that, while the use of AFC BMPs and BAT were evaluated for various exploratory analyses, the only road BMP included in the final plan was use of gravel for road surfaces based on input from Policy Advisory Council subcommittee members to keep this aspect of the Plan simple.

Table 12. Road BMP Removal Rates

Technology	TSS	TP
Gravel Only	21%	11%
Gravel + AFC BMPs	40%	21%
BAT	56%	29%

3.1.4 Mitigation Evaluation Approach

One way to reduce total loading of pollutants from a watershed is by acquiring land (or the development rights on land), thereby avoiding the pollutant load that would have been generated by conversion from a natural to a developed condition. Land acquisition to offset a pollutant load is referred to here as mitigation.

Mitigation needs are best summarized in terms of the number of acres required to offset a specified amount of pollutant loading – for example, acres of mitigation land to offset a pound of phosphorus. In general, a mitigation credit may be calculated as

$$M = \frac{L}{R_D - R_N},$$

where M is the amount of mitigation acres required, L is the excess pollutant load requiring mitigation, and R_N and R_D are the loading rates per acre of land for natural and developed conditions, respectively. For the purpose of calculating mitigation credits, R_D is evaluated at the specified performance standard loading rates shown in Table 7.

The mitigation credit depends on whether high slope or low slope land is removed from development because potential loading rates are higher from high slope areas. The mitigation credit also varies according to soil and precipitation variations. We calculated mitigation credits separately for low and high slope lands using values of R_N and R_D that are area-weighted averages for the UWA and Critical

Area B management zones. (Mitigation was not considered as an option in Critical Area A.) Unit mitigation rates are summarized in Table 13.

Table 13. Mitigation Credits per Unit Load

Management Area	Slope	TP (ac/lb/yr)	TSS (ac/ton/yr)	TOC (ac/lb/yr)
Critical Area B	Low	4.48	11.11	0.03
Critical Area B	High	6.21	13.51	0.06
UWA	Low	4.03	9.26	0.03
UWA	High	6.10	11.63	0.05

The mitigation credits shown in Table 13 are used directly in the analysis of offsite mitigation needs under the conservation design approach in Section 3.2. A related analysis presented in Section 4 was used to evaluate the additional phosphorus load relative to performance standards for large lots that would be predicted to occur if exemptions were allowed to create some smaller (2- or 3-acre) lots outside of Critical Area A. The credits shown in Table 13 are then used to evaluate the corresponding amount of mitigation that would be required to offset the impact of the small lot exemptions.

3.1.5 Evaluation of Alternative Lot Size

The basic SET analysis was used to evaluate pollutant loading from residential development at 2, 3, 5, and 10-acre lot sizes. An additional refinement evaluated impacts of minimum lot sizes between 5 and 10 acres. Setting a larger minimum lot size on low slope areas, and thereby reducing the pollutant load per acre, is another approach to meeting mitigation needs.

Evaluation of lot sizes between 5 and 10 acres used the following assumptions:

- Average total imperviousness is 8 percent for 5-acre residential development and 4.5 percent for 10-acre residential development (USDA, 1986; USEPA, 2006; personal communication from Tim Daters regarding local development patterns). Imperviousness for intermediate lot sizes is interpolated log-linearly between these values.
- Building footprint area increases linearly from 3,000 square feet at 5-acre development to 3,500 square feet at 10-acre development. The impervious area at 5-acre development corresponds to the proposed impervious area cap of 8 percent in Critical Area B.
- The amount of new local road area associated with each lot declines from 4.6 percent of the total site area with 5-acre lots to 2 percent of total site area with 10-acre lots, consistent with assumptions in Tetra Tech (2006b). These estimates were approximated from the ratios of road area to development area in existing and future planned developments within Critical Areas A and B. The ratios were extrapolated for 1- and 2-acre lots, since development examples were not available for these lot sizes.
- Area occupied by driveways constitutes the remainder of the total imperviousness, and increases from 4,405 square feet on 5-acre lots to 7,390 square feet on 10-acre lots, consistent with assumptions in Tetra Tech (2006b).

The net result of these assumptions of increasing building and driveway area coupled with decreasing road area per lot as lot size increases is that total imperviousness increases only gradually with lot size (Table 14).

Table 14. Imperviousness Assumptions for Lot Sizes between 5 and 10 Acres

Lot size (ac)	Percent Impervious	Building Footprint (ft^2/lot)	Driveway (ft^2/lot)	Associated Road (ft^2/lot)	Total Impervious Area (ft^2/lot)
5	8.0%	3,000	4,405	10,019	17,424
5.5	7.5%	3,050	4,566	10,398	18,013
6	7.0%	3,100	4,739	10,663	18,503
7	6.3%	3,200	5,158	10,855	19,213
8	5.5%	3,300	5,714	10,594	19,608
9	5.0%	3,400	6,448	9,879	19,727
10	4.5%	3,500	7,390	8,712	19,602

Results differ between the Upper Watershed Area and Critical Zone B due to slightly different precipitation patterns and different soils. SET-predicted loading rates for total phosphorus and total suspended solids for an example set of conditions are summarized in Table 15.

Table 15. Example Average Annual Loading Rates for Lot Sizes between 5 and 10 Acres

Lot size (ac)	Total Phosphorus Load (lb/ac/yr)		Total Suspended Solids Load (t/ac/yr)	
	Upper Watershed Area	Critical Zone B	Upper Watershed Area	Critical Zone B
5	0.281	0.258	0.127	0.106
5.5	0.268	0.245	0.121	0.102
6	0.258	0.236	0.115	0.096
7	0.242	0.220	0.106	0.089
8	0.226	0.205	0.097	0.081
9	0.217	0.197	0.090	0.076
10	0.209	0.189	0.083	0.070

Note: Reflects development on low slopes, with paved roads and gravel driveways, 15 percent forest in the Upper Watershed Area and 30 percent forest in Critical Area B.

3.1.6 Cost Evaluation Methods

The purpose of the cost evaluation was to assist in evaluating the cost impacts of different management requirements on landowners—in terms of development costs—and on local governments in terms of administrative costs.

3.1.6.1 Development Costs (BMPs, Maintenance, and Wastewater)

Best Management Practice (BMP) cost information was gained from national sources, including the US Environmental Protection Agency (EPA) as well as BMP design experts and the Arkansas Forestry BMP Cost-Share Program. Road construction cost information was gathered from local contractors and state and local highway departments. When national or out-of-state costs were used, these costs were converted to Arkansas prices using cost indices from RS Means (2005). Costs were adjusted for inflation using a 3 percent annual inflation rate. Table 16 lists the construction cost data used in the cost estimates. Design and engineering costs were estimated by taking 25 percent of the construction costs. For definitions of the BMPs listed in Table 16 see the Lake Maumelle Watershed Primer (Tetra Tech, 2006c).

When quantifying the required number of gravel road BMPs, Tetra Tech assumed that roads were graded to 10 percent slopes or less so that only broad-based dips would be necessary and no rolling dips would be used, which may be too rugged for residential roads. To estimate the quantity of roadside BMPs, Tetra Tech applied the recommended spacing in AFC (2002) to the estimated road length in the development. Tetra Tech estimated the BMP quantities for the lowest and highest road grades and took the average to determine the average number of dips, wing ditches, and culverts for each development example.

Gravel road construction costs represent the cost of laying aggregate, and paved road costs represent the cost of laying the wearing course (asphalt) and the underlying base course (aggregate). Road grading costs were not included and were assumed to be the same for gravel and paved roads.

Table 16. Little Rock, AR Prices (including materials, labor, and equipment costs)

Component	Unit Cost or Cost Equation	Source
Stormwater BMPs		
Bioretention (V = cubic feet of storage)	$6.5V^{0.99}$	USEPA (2003)
Extended Dry Detention Ponds (V = cubic feet up to the emergency spillway)	$11.1V^{0.76}$	USEPA (2003)
Grass Swale (per square foot)	$0.45	USEPA (2003)
Forested Filter Strip or Buffer (per square foot)	$0.00	Assumed that undisturbed areas would be used as filter strips.
Level Spreader (per linear foot)	$10.00	Hunt et al. (2001)
Gravel Road BMPs		
Broadbased Dip/ Rolling Dip (each)	$60.00	USDA-NRCS (2006)
Roadside Diversion, or Wing Ditch (each)	$25.00	USDA-NRCS (2006)
Culvert (per linear foot)	$24.00	RS Means (2005)
Road Improvements		
Gravel Driveway (per square yard)	$3.60	Personal communication with Jim Barton of Cranford Construction Company, Little Rock, May 2006.
Gravel Road (per square yard)	$5.10	Personal communication with Jim Barton of Cranford Construction Company, Little Rock, May 2006.
Paved Driveway (per square yard)	$7.80	Personal communication with Jim Barton of Cranford Construction Company, Little Rock, May 2006.
Paved Road (per square yard)	$12.60	Personal communication with Jim Barton of Cranford Construction Company, Little Rock, May 2006.

The maintenance costs for roads, BMPs, and wastewater systems were estimated as annual maintenance costs. Table 17 lists the maintenance cost data used in the cost estimates. Tetra Tech assumed that gravel roads and driveways would be maintained annually and that gravel road maintenance typically would involve laying two inches of extra stone on one-half of the road, twice per year. For gravel driveways, Tetra Tech assumed that the same maintenance would be performed only once per year. Maintenance of gravel road BMPs was assumed to be included in the gravel road maintenance cost. Resurfacing was assumed to occur, on average, every 4 years for gravel roads and every 12 years for paved roads. The maintenance and resurfacing costs were summed and averaged over 12 years to arrive at an average annual maintenance cost. The maintenance costs reported in Table 17 have been discounted by 10 percent over the lifetime of a project (i.e., 12 years for roads, 20 years for post-construction BMPs) so that maintenance costs are comparable across different cost frequencies (e.g., annual versus every four years) and reflect the time value of investments.

Table 17. Annual Maintenance Cost Data for BMPs and Infrastructure in 2006 Dollars, Converted to Little Rock, AR Prices

Component	Unit Cost or Cost Equation	Source
Stormwater BMPs		
Bioretention (per cubic foot)	$0.10	Personal communication with W.F. Hunt, NC State University Biological and Agricultural Engineering, January 2006.
Extended Dry Detention Ponds (per cubic foot)	$0.09 to $0.11	Personal communication with W.F. Hunt, NC State University Biological and Agricultural Engineering, January 2006.
Grass Swale (per square foot)	$0.02	Rouge River (2001)
Forested Buffer (per square foot)	$0	Assumed part of level spreader inspection and maintenance.
Level Spreader (per Linear Foot)	$0.32	R.S. Means (2005); professional judgment.
Road Improvements		
Gravel Driveway Maintenance (per Square Foot)	$0.42	Professional judgment.
Gravel Road Maintenance (per Square Foot)	$0.85	Professional judgment.
Driveway and Road Resurfacing	See Table 12	

Offsite mitigation costs were estimated from the range of vacant land sale values in Perry County from 2004 to 2006. Perry County land sales were used to represent watershed-wide offsite mitigation costs because developers are likely to purchase land in the western, more rural parts of the watershed where land is less expensive. The offsite mitigation costs listed represent fee simple acquisition. To reduce costs, developers could have the option of purchasing a conservation easement on the land for less than its fair market value. The conservation easement would protect the land from development and would allow a landowner to use the land for purposes that would not significantly disturb the natural forest cover. From interviews with local government utilities, state property acquisition staff, and land conservancy staff, Tetra Tech found that the price of conservation easements could range from 25 to 80 percent of the fair market value of the land, with a median of 50 percent. For planning purposes in Lake Maumelle, 50 percent of the fee simple acquisition costs would provide a reasonable estimate of the cost for conservation easements.

The offsite mitigation acreage required was estimated for mitigation on low- and high-sloping land separately. The cost estimates reflect the acres required to mitigate on low slopes; more land would be required when mitigating on high slopes, but this increase may be offset by lower land costs because steeper areas tend to have lower land values than less steep areas.

For wastewater systems, different options are available to the developer for the development examples. One cost range across all applicable systems is shown for each development example, and the range for each wastewater option is shown in Table 18.

Table 18. Costs for Wastewater Treatment Options in the Pulaski County Area

System Type	Cost Categories (Average per Residence Served)		
	Planning & Design and Permitting	Installation / Construction	Average Annual Operation/Maintenance
Conventional Septic Tank and Infiltration	$250 – $350	$3,500 – $5,000	$25 – $35
Tank and Capping Fill for Infiltration Area	$300 – $450	$5,500 – $7,000	$25 – $35
Cluster System with Tanks and Drip Irrigation Dispersal of Effluent	$450 – $650	$8,000 – $12,000	$350 – $500

Note: All costs are broad estimates for planning purposes only. Cost ranges reflect averages for typical site conditions in the Lake Maumelle drainage area based upon discussion with local installers and supplemental sources, and do not include expenses for contingencies such as excessive rock, very steep slopes (e.g., > 20 percent), and long distances between homes served by cluster systems (e.g., > 300 ft.). Planning and permitting costs may be somewhat lower if applied to larger (rather than smaller or individual) subdivisions or developments. Operational costs include electricity, periodic inspections and tank pumping (amounts assume tanks pumped every 5-7 years), and replacement of some system components (e.g., float switches, pump motors) as needed.

Sections 3.3.1- 3.3.3 provide development cost comparisons of development options for the Upper Watershed Area, Critical Area B, and Critical Area A.

3.1.6.2 Administrative Costs

Administrative costs were also estimated for local development review and inspection for each management option. This included staff time to review the conceptual plan, final plan, engineering review, site inspection during construction, and final inspection. This represents the staff hours required by both planning staff and engineering staff under each option. The estimates were made based on interviews with local governments who are currently implementing similar watershed protection measures and with local planners in Little Rock and Pulaski County. The estimates for the different management options compared time required to complete development plan review and site inspections currently in Little Rock and Pulaski County. The purpose of this analysis was to show resources needed to implement the plan, and to compare the administrative costs of different management alternatives. Sections 3.3.1-3.3.3 provide comparisons of the administrative costs for the different development options for the Upper Watershed, Critical Area B, and Critical Area A. In addition, the cost of enforcing management requirements – including facilities maintenance and preservation of open space – was also considered. Section 3.3.4 discusses options for enforcement and provides a qualitative comparison of enforcement costs across the management scenarios.

3.2 PRIMARY MANAGEMENT ALTERNATIVES – REQUIREMENTS AND EVALUATION RESULTS

Pursuant to guidance from the PAC, Tetra Tech tested various options for meeting allocations. One set of options focused on land conservation without engineered controls. The other set included engineered controls designed to meet performance standards.

3.2.1 Conservation Design

The Conservation Design Approach is based primarily on limitations on lot size and amount of disturbed area within lots. The PAC set limits on these criteria for Critical Area B and the Upper Watershed Area to reflect political feasibility and equity concerns. Because the initial base case did not meet all performance standards, additional refinements to the base case were evaluated. The following three subsections address requirements, evaluation results, and refinements.

3.2.1.1 Conservation Design Requirements

Critical Area A

More stringent performance standards are required for Critical Area A than for the remainder of the watershed. Development in Critical Area A is required to meet these performance standards under all variants of the Construction Design Approach. To achieve these standards without engineered BMPs, analysis determined that a 20-acre minimum lot size designed with 92 percent undisturbed open space and a 2.2 percent impervious cap would be required.

Critical Area B and Upper Watershed Area – Base Case

The Conservation Design scenarios for Critical Area B and the Upper Watershed Area assume maximum impervious and minimum undisturbed open space requirements. Two scenarios were considered for each management area: 1) Large Lot Development, and 2) Cluster Development. In each scenario, the maximum impervious requirements vary by management area, and the undisturbed open space requirements vary by management area and average slope. "Undisturbed open space" means either undisturbed, forested land *or* land that has previously been disturbed (i.e., logged), yet not graded, and is reforested. No development would be allowed on land with slopes 25 percent or greater.

Large Lot Development

The base case for the Conservation Design large lot scenario limits all residential development to a minimum lot size of 5 acres, based on input from the PAC. A landowner may choose to build on larger lots (e.g., 10 acres, 20 acres, or 100 acres), but the minimum lot size would be 5 acres.

For the large lot development, the maximum imperviousness limits are 8 percent in Critical Area B and 9 percent in the Upper Watershed Area. Where land has less than 15 percent average slopes – the "low" slope category – the minimum undisturbed open space requirements are 30 percent in Critical Area B and 15 percent in the Upper Watershed Area. For land with greater than 15 and less than 25 percent average slopes – the "high" slope category – the minimum undisturbed open space requirements are 50 percent in Critical Area B and 30 percent in the Upper Watershed Area. Land with about 15 percent average slope was divided equally among the two slope categories.

Cluster Development

Under the Conservation Design Cluster Scenario, residential developers can cluster lots that are smaller than 5 acres as long as the overall lot density does not exceed that of a 5-acre lot development. The maximum imperviousness limits are 6 percent in Critical Area B and 7.3 percent in the Upper Watershed Area. For land in the low slope category, the minimum undisturbed open space requirements are

30 percent in Critical Area B and 15 percent in the Upper Watershed Area. For land in the high slope category, the minimum undisturbed open space requirements are 50 percent in Critical Area B and 30 percent in the Upper Watershed Area.

Table 19 summarizes the assumptions for the Conservation Design base case scenarios. A building footprint of 3,500 square feet was assumed for all developments except for the 3-acre cluster and 5-acre large lot developments in Critical Area B; for these developments, the building footprint was reduced to 3,000 square feet to meet the maximum impervious limits. The remaining impervious surface was assumed to be in driveways, sidewalks, and roads. The 5-acre large lot developments were initially assumed to have unpaved (gravel) roads and driveways, and the cluster developments were assumed to have paved roads and driveways. Lawn or managed grassland was assumed to occur on the remaining development area that is not under impervious surfaces or undisturbed open space.

Non-residential land was included as a separate scenario that is exempt from the maximum impervious limits but must comply with the undisturbed open space requirements. A minimum of 5 percent lawn was assumed for non-residential development; therefore, the imperviousness of the non-residential development in Critical Area B was reduced from 70 to 65 percent to accommodate the undisturbed open space requirement of 30 percent and the assumed lawn area. Non-residential land was assumed to occur only under the low slope category.

Table 19. Impervious Surface and Undisturbed Open Space Assumptions for the Conservation Design Scenarios

Scenario	Lot Size (acres)	Slope Category[1]	Percent Impervious	Percent Undisturbed Open Space Required
Critical Area B				
Non-residential	NA	Low	65%	30%
Large Lot	5.0	Low	8%	30%
	5.0	High	8%	50%
Cluster[2]	1.3	Low	5.5%	30%
	1.3	High	5.5%	50%
	3.0	Low	6%	30%
	3.0	High	6%	50%
Upper Watershed Area				
Non-residential	NA	Low	70%	15%
Large Lot	5.0	Low	9%	15%
	5.0	High	9%	30%
Cluster[2]	1.3	Low	5.5%	15%
	1.3	High	5.5%	30%
	3.0	Low	7.3%	15%
	3.0	High	7.3%	30%

[1] The low slope category includes land with average slopes less than 15 percent, and the high slope category includes land with average slopes greater than 15 percent. Land with about 15 percent slope was divided equally among the two slope categories.

[2] Cluster designs achieve an average yield of 1 house per 5 acres.

The large lot base case for the Conservation Design Approach did not meet all performance standards (see Section 3.2.1.2).

3.2.1.2 Conservation Design Evaluation Results

Conservation Design Base Case Results

Critical Area A

The Conservation Design Approach evaluated use of large lots only (i.e., using no engineered BMPs) to meet performance standards in Critical Area A. Analysis determined that a 20-acre minimum lot size designed with 92 percent undisturbed open space and a 2.2 percent impervious cap would be required to meet the onsite performance standards without engineered BMPs.

The design resulted in the following performance:

Scenario	TP (lb/ac/yr)	TSS (t/ac/yr)	TOC (lb/ac/yr)
Critical Area A	0.200	0.061	32.6

Critical Area B and Upper Watershed Area

Table 20 summarizes the key features of each management option evaluated for this scenario for Critical Area B and the Upper Watershed Area, and the associated loading for key parameters. Blue indicates that the option meets the standard for a particular parameter, green indicates that it does not meet the standard. Sediment loading from unpaved roads is the leading cause of these options not meeting the sediment performance standards. In high slope areas, phosphorus and organic carbon associated with the sediment is a major cause of exceeding the phosphorus performance standards.

Some watershed landowners have expressed a desire to maintain the rural nature of the watershed. Existing rural development and uses in the watershed are assumed to be grandfathered in and exempt from proposed requirements in the watershed plan. However, landowners may choose to propose new development. While some may build on rural 5-acre lots, others may build on larger lots, which in turn would decrease the predicted loading to the lake. As an example, Table 20 shows the loading associated with 10-acre lot developments. This significantly decreases the loading compared to 5-acre lots, but still exceeds the performance standards.

Table 20. Evaluation of Conservation Design Scenario for Critical Area B and Upper Watershed Area, Base Case

Scenario	Lot Size (acres)	Slope Category	Percent Impervious	TN (lb/ac/yr)	TP (lb/ac/yr)	TSS (tons/ac/yr)	TOC (lb/ac/yr)	FC (#/ac/yr)
Critical Area B								
Non-Residential	NA	Low	65.0%	11.5	1.38	0.45	139.0	2.7E+11
Large Lot	5	Low	8.0%	2.7	0.30	0.26	27.1	4.2E+10
	5	High	8.0%	4.1	0.40	0.28	45.7	4.7E+10
	10	Low	4.3%	2.4	0.24	0.14	23.9	3.9E+10
	10	High	4.3%	3.7	0.31	0.16	43.7	3.1E+10
Cluster	1.3	Low	5.5%	2.5	0.22	0.08	25.2	4.2E+10
	1.3	High	5.5%	4.0	0.33	0.09	44.6	4.7E+10
	3	Low	6.0%	2.5	0.22	0.07	25.2	4.1E+10
	3	High	6.0%	4.0	0.33	0.10	44.5	4.6E+10
Upper Watershed Area								
Non-Residential	NA	Low	70.0%	13.4	1.62	0.60	159.3	3.2E+11
Large Lot	5	Low	9.0%	3.1	0.34	0.34	31.3	4.6E+10
	5	High	9.0%	4.7	0.45	0.37	52.7	4.8E+10
	10	Low	4.3%	2.5	0.22	0.16	26.9	3.0E+10
	10	High	4.3%	4.1	0.35	0.20	49.6	3.1E+10
Cluster	1.3	Low	5.5%	2.8	0.24	0.07	28.3	4.5E+10
	1.3	High	5.5%	4.4	0.36	0.10	50.7	4.6E+10
	3	Low	7.3%	3.0	0.26	0.07	29.9	4.5E+10
	3	High	7.3%	4.6	0.38	0.13	51.7	4.7E+10

Legend: [light grey] **Does not meet performance standards** [dark grey] **Meets performance standards**

3.2.1.3 Conservation Design Refinements

The base case for the Conservation Design Approach does not meet all performance standards. One approach to achieving lake targets would be through offsite mitigation that involves purchasing land (or development rights) and maintaining that land in conservation status to restrict the amount of development that could occur. However, meeting the total suspended solids performance standards while allowing 5-acre lots and unpaved roads throughout Critical Area B and the Upper Watershed Area would require mitigation on more than half of the total developable land area. Accordingly, the PAC requested additional evaluation of the Conservation Design Approach, including further variations of lot size for high-slope areas and road and driveway construction requirements.

Table 21 provides an overall summary of how varying lot size for high-sloped land between 5 and 10 acres, and using different combinations of road and driveway material, affects the amount of land that would be required for offsite mitigation (i.e., the permanent dedication of developable land for conservation to offset impacts of newly developed land).

Table 21. Effects of Revising Lot Size and Road/Driveway Requirements on Offsite Mitigation Needs

Lot Size (ac)					
Low Slope	High Slope	Driveway	Road	Offsite Mitigation (ac)	Percent of Developable Land in Offsite Mitigation
5	5	Gravel+BMPs	Gravel+BMPs	24,880	47%
5	10	Gravel+BMPs	Gravel+BMPs	14,560	27%
5	5	Gravel	Paved	7,080	13%
5	5	Gravel+BMPs	Paved	3,830	7%
5	5	Paved	Paved	1,150	2%
5	10	Gravel	Paved	0	0

The results show that even with paving roads and using gravel plus BMPs for driveways, setting minimum lot size requirements to 5 acres on high sloped land would require an estimated 3,830 acres (7 percent of developable land) of offsite mitigation. However, this is down from 24,880 acres (47 percent of developable land) if gravel plus BMPs are used on both roads and driveways on 5-acre lots. If the minimum lot size is increased to 10 acres for high slopes, the offsite mitigation requirements can be reduced to zero, regardless of driveway requirements.

Tetra Tech also analyzed paving roads and driveways on high sloped areas (assuming 10-acre lots) while allowing low sloped roads and driveways (for 5-acre lots) to use gravel with BMPs. This combination would still result in the need for an estimated 7,350 acres of offsite mitigation (14 percent of developable land).

Table 22 and Table 23 provide more detailed results of additional analysis of lot size and road/driveway combinations for low and high sloped land. Table 22 shows options for Critical Area B in their order of effectiveness for meeting performance standards, first for low sloped land and then for high sloped land. Table 23 provides the same information for the Upper Watershed Area. (Note: the first line in each table lists the performance standards for the management area for ease of comparison.) Where an option does not entirely meet performance standards, the estimated loading rates are highlighted in red for the noncompliant parameters. Additionally, for those options not meeting performance standards, the number of acres in offsite mitigation required *per acre of development* is shown depending on whether the mitigation land is located in low or high sloped areas of the management zone. Offsite mitigation acreage was calculated using mitigation credit rates from Table 13 in Section 3.1.4.

Some points to note in Table 22 (for Critical Area B):

- For low sloped land, the performance standards can be achieved with a 5-acre minimum lot size if paved roads are required while allowing driveways to remain in gravel.
- For low sloped land, the standards can be achieved using gravel roads and driveways if the minimum lot size is increased to 10 acres and 60 percent of the site is preserved in undisturbed open space.
- For high sloped land, the performance standards can be achieved with an 8-acre minimum lot size if roads and driveways are paved and 60 percent of the site is preserved in undisturbed open space.
- For high sloped land, the standards can be achieved using gravel roads and driveways if the minimum lot size is increased to 20 acres with preservation of 50 percent of the site in undisturbed open space. Alternatively, the minimum lot size could be decreased to 13 acres with a requirement to maintain 90 percent of the lot in open space.
- For high sloped land, the performance standards can be achieved with a 10-acre minimum lot size and paved roads while allowing driveways to remain in gravel.
- For options that do not meet the performance standards, the rate of required offsite mitigation drops substantially by requiring paved roads.

The results for the Upper Watershed Area are relatively similar (Table 23), but there are some differences worth pointing out:

- Because of slightly different soils and the higher average annual rainfall, performance standards are not met for 5-acre lots until best management practices (BMPs) are added to the gravel driveways.
- Performance standards can also be met for low sloped areas in the Upper Watershed Area by increasing the minimum lot size to 10 acres while leaving roads and driveways in gravel, however the amount of undisturbed open space increases to 70 percent.
- For high sloped land, the standards can be met using gravel roads and driveways if the minimum lot size is increased to 20 acres and 30 percent of the site is preserved in undisturbed open space. Alternatively, the increase in minimum lot size could be limited to 14 acres with a requirement to maintain 83 percent of the lot in open space.
- For high sloped land, the standards can be achieved using a 6-acre minimum lot size if both roads and driveways are paved and 73 percent of the area is maintained in open space.

Table 22. Critical Area B – Evaluation of Compliance with Performance Standards and Offsite Mitigation Options

Slope	Road	Driveway	Undist Area	% Imperv	Lot Size (ac)	TP rate (lb/ac/yr)	TSS rate (ton/ac/yr)	TOC rate (lb/ac/yr)	Overall	Acres Offsite Mitigation per 1 ac of Development: Mitigation on Low Slope	Mitigation on High Slope
Performance Standards						0.300	0.110	43.9			
Results assuming minimum undisturbed area requirement											
Low	Gravel	Gravel	30%	8.0%	5	0.281	0.208	27.1	Does Not Meet	1.09	1.33
Low	Gravel+BMPs	Gravel+BMPs	30%	8.0%	5	0.267	0.164	26.6	Does Not Meet	0.60	0.73
Low	Paved	Gravel	30%	8.0%	5	0.258	0.106	27.1	Meets	n/a	n/a
Minimum lot size meeting all performance standards*											
Low	Gravel	Gravel	60%	4.4%	10	0.188	0.110	22.2	Meets	n/a	n/a
Low	Gravel+BMPs	Gravel+BMPs	30%	5.2%	9	0.204	0.108	23.9	Meets	n/a	n/a
Results assuming minimum undisturbed area requirement											
High	Gravel	Gravel	50%	8.0%	5	0.389	0.234	45.7	Does Not Meet	1.38	1.69
High	Gravel+BMPs	Gravel+BMPs	50%	8.0%	5	0.375	0.190	44.6	Does Not Meet	0.89	1.09
High	Paved	Gravel	50%	8.0%	5	0.365	0.133	45.7	Does Not Meet	0.29	0.41
High	Paved	Gravel+BMPs	50%	8.0%	5	0.360	0.127	45.1	Does Not Meet	0.27	0.37
High	Gravel+BMPs	Gravel+BMPs	50%	4.3%	10	0.297	0.120	43.0	Does Not Meet	0.11	0.13
High	Paved	Gravel	50%	4.3%	10	0.295	0.098	43.7	Meets	n/a	n/a
High	Gravel	Gravel	50%	2.2%	20	0.260	0.101	41.9	Meets	n/a	n/a
Minimum lot size meeting all performance standards*											
High	Gravel	Gravel	91%	3.5%	13	0.228	0.110	31.9	Meets	n/a	n/a
High	Gravel+BMPs	Gravel+BMPs	73%	4.3%	10	0.264	0.110	36.8	Meets	n/a	n/a
High	Paved	Paved	57%	6.0%	8	0.299	0.097	42.8	Meets	n/a	n/a

* Assumes typical impervious areas. Reducing impervious area may allow for a smaller lot size.

Table 23. Upper Watershed Area – Evaluation of Compliance with Performance Standards and Offsite Mitigation Options

Slope	Road	Driveway	Undist Area	% Imperv	Lot Size (ac)	TP rate (lb/ac/yr)	TSS rate (ton/ac/yr)	TOC rate (lb/ac/yr)	Overall	Acres Offsite Mitigation per 1 ac of Development: Mitigation on Low Slope	Acres Offsite Mitigation per 1 ac of Development: Mitigation on High Slope
Performance Standards						0.330	0.130	50.0			
Results assuming minimum undisturbed area requirement											
Low	Gravel	Gravel	15%	8.9%	5	0.318	0.272	31.3	Does Not Meet	1.31	1.65
Low	Gravel+BMPs	Gravel+BMPs	15%	8.9%	5	0.302	0.213	30.0	Does Not Meet	0.77	0.97
Low	Paved	Gravel	15%	8.9%	5	0.292	0.137	31.3	Does Not Meet	0.06	0.08
Low	Paved	Gravel+BMPs	15%	8.9%	5	0.286	0.128	30.6	Meets	n/a	n/a
Minimum lot size meeting all performance standards*											
Low	Gravel	Gravel	70%	4.4%	10	0.196	0.130	23.0	Meets	n/a	n/a
Low	Gravel+BMPs	Gravel+BMPs	15%	5.2%	9	0.224	0.130	26.9	Meets	n/a	n/a
Results assuming minimum undisturbed area requirement											
High	Gravel	Gravel	30%	8.9%	5	0.434	0.302	52.7	Does Not Meet	1.59	2.00
High	Gravel+BMPs	Gravel+BMPs	30%	8.9%	5	0.418	0.243	51.4	Does Not Meet	1.05	1.32
High	Paved	Gravel	30%	8.9%	5	0.408	0.167	52.7	Does Not Meet	0.34	0.48
High	Paved	Gravel+BMPs	30%	8.9%	5	0.402	0.159	52.0	Does Not Meet	0.29	0.44
High	Gravel+BMPs	Gravel+BMPs	30%	4.3%	10	0.329	0.142	49.0	Does Not Meet	0.11	0.14
High	Paved	Gravel	30%	4.3%	10	0.327	0.113	49.8	Meets	n/a	n/a
High	Gravel	Gravel	30%	2.2%	20	0.291	0.119	47.7	Meets	n/a	n/a
Minimum lot size meeting all performance standards*											
High	Gravel	Gravel	83%	3.3%	14	0.257	0.130	38.0	Meets	n/a	n/a
High	Gravel+BMPs	Gravel+BMPs	69%	4.3%	10	0.288	0.130	41.1	Meets	n/a	n/a
High	Paved	Paved	73%	7.9%	6	0.329	0.123	[illegible]	Meets	n/a	n/a

* Assumes typical impervious areas. Reducing impervious area may allow for a smaller lot size.

3.2.2 Performance Standards – Requirements and Evaluation Results

The Performance Standards Approach employs engineered BMPs, along with minimum undisturbed open space requirements, to ensure that loading from new development is predicted to meet the performance standards. The loading to be achieved is fixed, but a review should be undertaken of technical and economic feasibility for attaining these goals.

Critical Area A

Conservation Design with Best Management Practices

Tetra Tech tested a Performance Standards Approach which used site and landscape conservation design and employed engineered BMPs to help meet water quality onsite performance standards and provide for spill risk mitigation. In evaluating the effectiveness of BMPs for sites in the Lake Maumelle watershed, Tetra Tech used national data due to the lack of engineered BMPs in the watershed or on comparable land in the region which could provide more local data. Before engineered BMPs can be employed in Critical Area A, the watershed plan will require that BMP pilot projects be performed on land with comparable topography and soils in areas outside of the watershed (preferably) or, at minimum, outside of Critical Area A. The results of these pilot projects would be used to determine which, if any, BMPs can be used and the degree to which they can be used to meet the onsite performance standards.

Since this area is so close to the intake, in addition to the water quality performance standards, Tetra Tech recommends that a fixed impervious surface cap (6 percent) be used as well as a fixed minimum undisturbed open space requirement (70 percent of the tract). Tetra Tech tested a net density of 5-acre lots, with an average lot size of 3 acres. The Team used a treatment train connecting bioretention cells throughout the development to extended dry detention ponds. The extended dry detention pond has a minimum 48-hour draw-down time. In Tetra Tech's example, bioretention is used for treatment and the extended dry detention is used for flow and spill control only. However, the dry detention could be designed as a water quality and flow/spill control pond. The BMPs and average lot sizes described are for example only. Other BMPs and lots sizes could be used as long as they were shown to meet the performance standards, imperviousness caps, and land conservation requirements. The goal is to meet the performance standards to the extent possible using conservation site design, and to use engineered BMPs to meet only a small fraction of the treatment requirement.

The design resulted in the following performance:

Scenario	TP (lb/ac/yr)	TSS (t/ac/yr)	TOC (lb/ac/yr)
Critical Area A	0.198	0.046	32.8

Critical Area B and Upper Watershed Area

The Performance Standards scenarios for Critical Area B and the Upper Watershed Area have the same undisturbed area requirements as the Conservation Design scenarios, but do not have impervious limits or minimum lot size requirements. Instead, the developments can use stormwater BMPs for water quality treatment so long as the net site-scale loading rates meet the performance standards. The conceptual designs highlighted in Table 24 and Table 25 meet all of the applicable performance standards. The example designs in this section begin with the 3-acre lot cluster, 5-acre overall density scenarios discussed under the Conservation Design scenarios.

Table 24. Upper Watershed Area Performance Standard Designs

Low Sloped Lands

The 3-acre lot cluster, 5-acre overall density design meets the performance standards, so no modifications are needed to the site.

High Sloped Lands

The higher sloped lands have higher pollutant loading rates, so the 3-acre lot cluster, 5-acre overall density design does not meet performance standards. Additional measures are needed to reduce site-scale loading rates. The design had the following elements:

- A development-scale impervious area of 7.3 percent.
- The developed portion of each lot was 1 acre, with a combination of house/driveway impervious surface and maintained lawn. The remainder of each lot had unmanaged native grass cover.
- Forty percent of the site has undisturbed forest area. While this zone (UWA with high slopes) requires 30 percent undisturbed area, it was necessary to leave more of the site in forest cover to meet the performance standards.
- The developed portion of the site (lawns, lot impervious area, and neighborhood roads) was treated by roadside grass swales designed for water quality treatment, all draining to a wet pond providing further pollutant removal.

The design resulted in the following performance:

Scenario	TP (lb/ac/yr)	TSS (t/ac/yr)	TOC (lb/ac/yr)
Upper Watershed Area, high slopes	0.262	0.058	38.3

Table 25. Critical Area B Performance Standard Designs

Low Sloped Lands

The 3-acre lot cluster, 5-acre overall density design meets the performance standards, so no modifications are needed to the site.

High Sloped Lands

The higher sloped lands have higher pollutant loading rates, so the 3-acre lot cluster, 5-acre overall density design does not meet performance standards. Additional measures are needed to reduce site-scale loading rates. The design had the following elements:

- A development-scale impervious area of 7.3 percent.
- The developed portion of each lot was 1 acre, with a combination of house/driveway impervious surface and maintained lawn. The remainder of each lot had unmanaged native grass cover.
- Sixty percent of the site has undisturbed forest area. While this zone (Critical Area B with high slopes) requires 50 percent undisturbed area, it was necessary to leave more of the site in forest cover to meet the performance standards.
- The developed portion of the site (lawns, lot impervious area, and neighborhood roads) was treated by roadside grass swales designed for water quality treatment, all draining to a wet pond providing further pollutant removal.

The design resulted in the following performance:

Scenario	TP (lb/ac/yr)	TSS (t/ac/yr)	TOC (lb/ac/yr)
Critical Area B, high slopes	0.278	0.064	35.3

3.3 Management Scenario Cost Evaluation

This section presents cost estimates for options under the proposed management scenarios, using the approach summarized in Section 3.1.5. For the Conservation Design Approach, this section contains a comparison of management costs across different road surfaces and lot sizes as well as differences in percent undisturbed area. Costs were estimated for road improvements, offsite mitigation, and wastewater systems. The hours required for development review, inspection, and other local government administration were also estimated. For the Performance Standards Approach, the above costs were estimated as well as the cost to construct and maintain BMPs.

The following pages contain the development examples presented to the TAC and the PAC at their May 2006 meetings. Following each development layout, the costs for that development example are listed. All cost estimates represent the costs for a 100-acre development so that they can be easily compared to one another.

3.3.1 Upper Watershed Area Example Costs

The first example is of a development in the Upper Watershed Area on low slopes (i.e., less than 15 percent slope – see Figure 9). It is a 100-acre development with nineteen 5-acre lots. Table 26 shows how the costs vary depending on the type of road improvement:

- Gravel roads and driveways
- Gravel with BMPs on roads and driveways
- Paved roads and gravel driveways
- Paved roads with gravel and BMPs on the driveways

The construction costs for the first two options involving unpaved roads are less than half of the costs of the last two options—a difference of over $600,000. However, the *annual* maintenance for the options with gravel roads is significantly more than those with paved roads. For example, the difference between maintaining gravel roads and driveways in this example development versus paved roads with gravel and BMPs on the driveways is $102,000/year. In a short period, the *overall cost* of constructing and maintaining the gravel roads would exceed that of paved roads. In addition, if a developer were to use gravel roads and driveways or gravel with BMPs on the roads and driveways, the development would not meet the onsite loading allocations. Therefore, the developer would need to buy 130 acres offsite on low slopes (or 165 acres on high slopes) and dedicate it as conservation land at a cost, on average, of about $655,000 (assuming fee simple acquisition). Using $5,000 as the price per acre for offsite mitigation, the upfront cost for gravel plus mitigation was approximately 4 percent less than the upfront cost for paving. When considering annual maintenance costs for paving and gravel surfaces, the long-term costs for gravel are substantially higher.

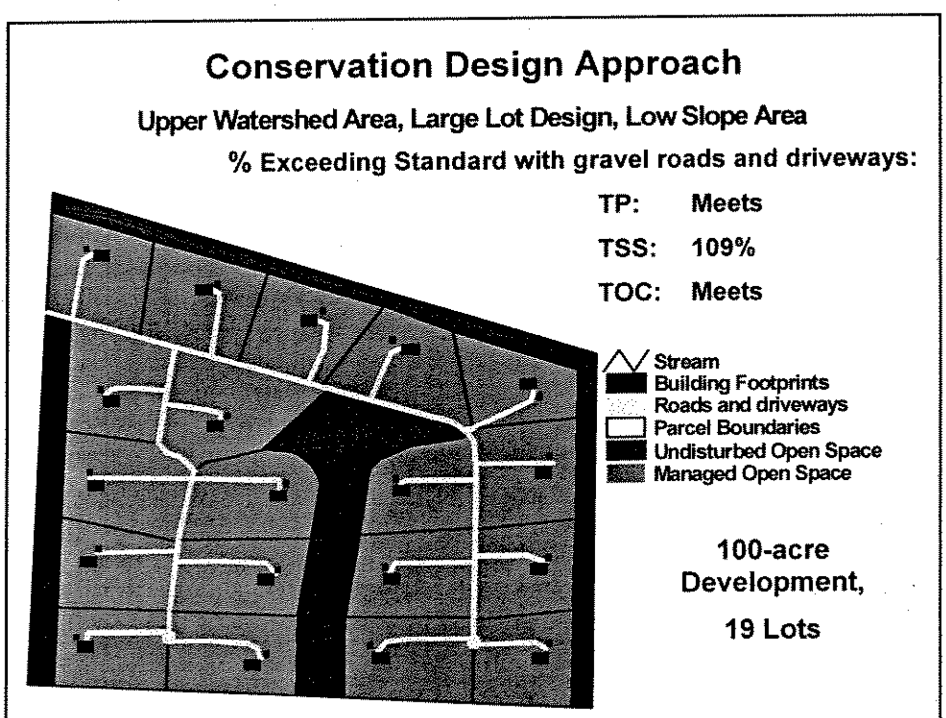

Figure 9. Upper Watershed Area Example Development

Table 26. Cost Estimates for Upper Watershed Area, Large Lot, Low Slope Area

	Assuming Gravel Roads and Driveways	Assuming Gravel with BMPs on Roads and Driveways	Assuming Paved Roads and Gravel Driveways	Assuming Paved Roads and Gravel with BMPs on Driveways
Road Improvements				
Construction, Design, and Engineering:	$557,000	$592,000	$1,201,000	$1,219,000
Annual Maintenance:	$161,000	$161,000	$59,000	$59,000
Offsite Mitigation (cost for mitigating on low slopes; fee simple acquisition)				
Minimum:	$131,000	$77,000	$6,000	$0
Median:	$655,000	$385,000	$30,000	$0
Maximum:	$1,179,000	$692,000	$54,000	$0
Wastewater System Cost				
Construction, Design, and Engineering:	$71,000 - $142,000			
Average Annual Maintenance:	$500 - $700			
Administrative Hours Required (excluding mitigation banking)				
Existing:	45 hours			
Estimated Future:	90-120 hours			

To avoid offsite mitigation, a landowner could develop 10-acre lots using gravel roads and driveways or 9-acre lots using gravel with BMPs (see Table 27). Tetra Tech assumed that this example would have about half the road mileage of the 5-acre lot development, resulting in a proportional decrease in the construction and maintenance of the gravel roads. If the road network is the same as or larger than the 5-acre lot development, the estimated cost would be higher than that shown in Table 27.

Table 26 and Table 27 also show wastewater system costs and administrative costs for the 5-acre, 9-acre, and 10-acre lot developments. For the 5-acre lot development, the wastewater system cost is estimated at $71,000 (for conventional septic system) to $142,000 (for a tank and capping fill system), and the average annual maintenance cost would be approximately $500 to $700. Table 26 shows the cost ranges for the wastewater treatment options. Most areas in the watershed are not suitable for conventional septic systems, and alternatives such as capped systems would therefore be required. Because there would be fewer households in the 100-acre development with 10-acre or 9-acre lots, the wastewater systems would cost less: $38,000 to $82,000 (see Table 27) with annual maintenance costs of approximately $300 to $400.

Finally, the tables show the estimated amount of time (about 45 hours) the staff would likely spend in reviewing the example 100-acre developments under existing regulations (based on conversations with the Pulaski County Planning Department). It then shows the estimated time it would take staff to review development plans in the future under the requirements shown in the example – 90 to 120 hours. This latter estimate is based on interviews with the Pulaski County Planning Department and local governments that are currently implementing similar requirements. The administrative time required per development review would more than double. (Note: This does not include the time required to administer the offsite mitigation.)

Table 27. Alternatives to 5-acre Lot Development in the Upper Watershed Area

	Assuming Gravel Roads and Driveways, 10-acre Lots	Assuming Gravel with BMPs on Roads and Driveways, 9-acre Lots
Road Improvements		
Construction, Design, and Engineering:	$260,000	$337,000
Annual Maintenance:	$74,000	$90,000
Offsite Mitigation (cost for mitigating on low slopes; fee simple acquisition)		
Minimum:	$0	$0
Median:	$0	$0
Maximum:	$0	$0
Wastewater System Cost		
Construction, Design, and Engineering:	$38,000 - $75,000	$41,000 - $82,000
Average Annual Maintenance:	$300 - $400	$300 - $400
Administrative Hours Required (excluding mitigation banking)		
Existing:	45 hours	
Estimated Future:	90-120 hours	
Number of Lots per 100 acres	10	11

3.3.2 Critical Area B Example Costs

The next example is for a 100-acre development with nineteen 5-acre lots in Critical Area B on a low-slope area (see Figure 10). Although the costs change somewhat compared to the Upper Watershed example above, the bottom line is the same: the overall construction and maintenance costs for gravel roads will quickly surpass the costs of paved roads (see Table 28). The gravel roads have an additional—and substantial—offsite mitigation cost. Estimated wastewater system costs vary, with the capped systems (the most likely alternative needed) ranging up to $142,000 in capital costs and up to $700 in average annual maintenance costs for this 100-acre development. Similar to the previous example, administrative hours spent on development review would likely more than double.

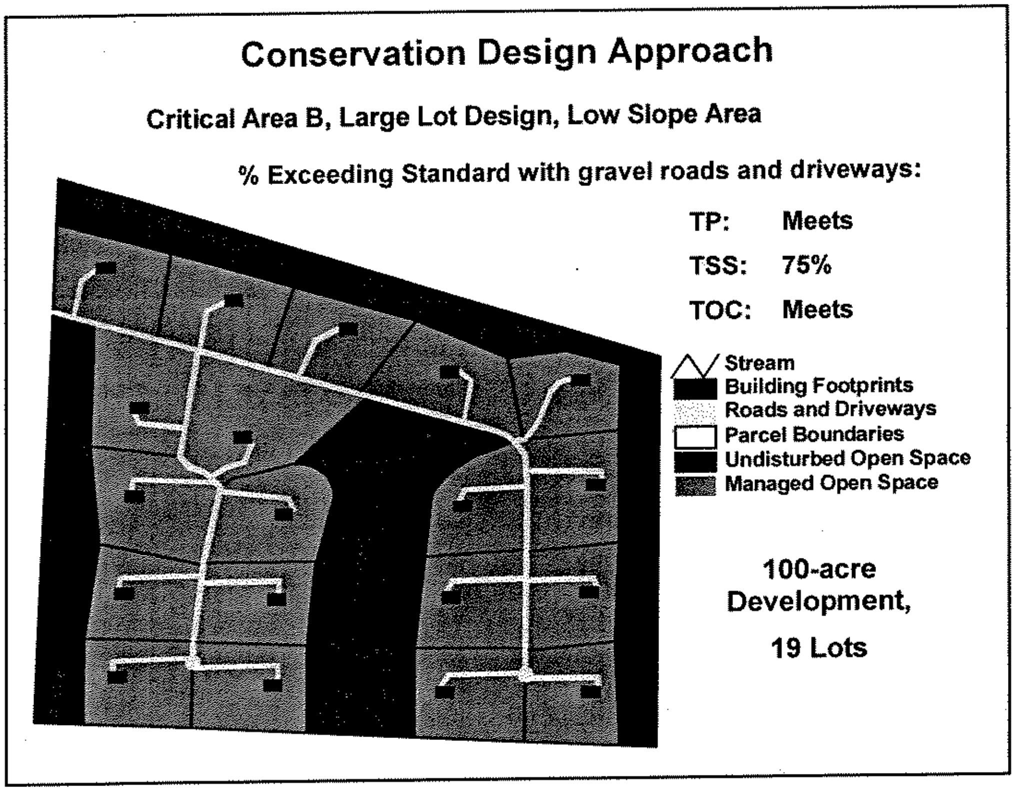

Figure 10. Critical Area B Example Development

Table 28. Cost Estimates for Conservation Design Approach in Critical Area B: Large Lot Design, Low Slope Area

	Assuming Gravel Roads and Driveways	Assuming Gravel with BMPs on Roads and Driveways	Assuming Paved Roads and Gravel Driveways
Road Improvements			
Construction, Design, and Engineering:	$507,000	$538,000	$1,099,000
Annual Maintenance:	$147,000	$147,000	$53,000
Offsite Mitigation (cost for mitigating on low slopes; fee simple acquisition)			
Minimum:	$109,000	$60,000	$0
Median:	$544,000	$299,000	$0
Maximum:	$979,000	$538,000	$0
Wastewater System Cost			
Construction, Design, and Engineering:	$71,000 - $142,000		
Average Annual Maintenance:	$500 - $700		
Administrative Hours Required (excluding mitigation banking)			
Existing:	45 hours		
Estimated Future:	90-120 hours		

To avoid offsite mitigation, a landowner could develop 9- or 10-acre lots with gravel roads (see Table 29).

If pilot projects show that BMPs perform adequately and a Performance Standards option is approved, a landowner could use BMPs to help meet the performance standards. Figure 11 shows this same development—assuming gravel roads and driveways, with the addition of forested filter strips as an engineered BMP. The main differences between this development and the previous 5-acre lot example are:

- No offsite mitigation is required.
- BMP construction costs are estimated at $47,000 with an annual maintenance cost estimate of approximately $1,000.
- Additional staff administrative review time is required for BMP design and construction (approximately 25 additional hours).

This option appears to have the lowest infrastructure and mitigation costs over time for this example development. (See Table 30.)

Table 29. Alternatives to 5-acre Lot Development in Critical Area B

	Assuming Gravel Roads and Driveways, 10-acre Lots	Assuming Gravel with BMPs on Roads and Driveways, 9-acre Lots
Road Improvements		
Construction, Design, and Engineering:	$260,000	$337,000
Annual Maintenance:	$74,000	$90,000
Offsite Mitigation (cost for mitigating on low slopes; fee simple acquisition)		
Minimum:	$0	$0
Median:	$0	$0
Maximum:	$0	$0
Wastewater System Cost		
Construction, Design, and Engineering:	$38,000 - $75,000	$41,000 - $82,000
Average Annual Maintenance:	$300 - $400	$300 - $400
Administrative Hours Required (excluding mitigation banking)		
Existing:	45 hours	
Estimated Future:	90-120 hours	
Number of Lots per 100 acres	10	11

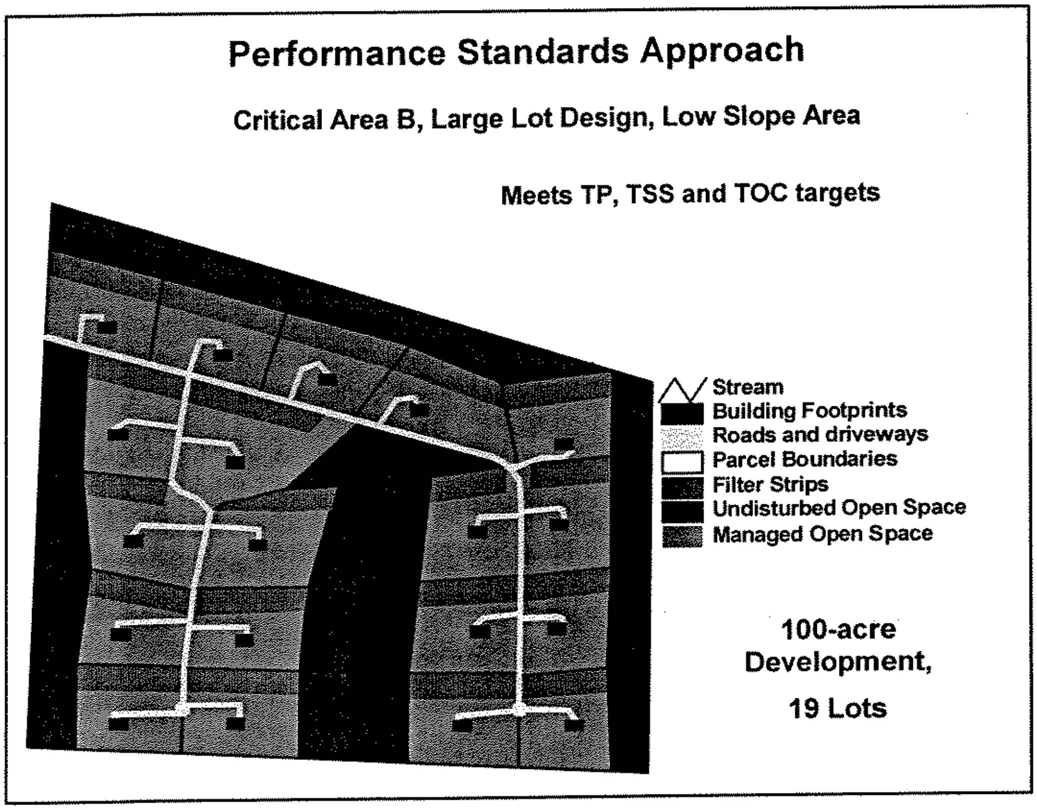

Figure 11. Critical Area B Example Development

Table 30. Cost Estimates for Performance Standards Approach in Critical Area B: Large Lot Design, Low Slope Area

	Assuming Gravel Roads and Driveways
Stormwater Best Management Practices	
Construction, Design, and Engineering:	$47,000
Annual Maintenance:	$1,000
Road Improvements	
Construction, Design, and Engineering:	$451,000
Annual Maintenance:	$122,000
Offsite Mitigation (cost for mitigating on low slopes)	None
Wastewater System Cost	
Construction, Design, and Engineering:	$71,000 - $142,000
Average Annual Maintenance:	$500 - $700
Administrative Hours Required (excluding mitigation banking)	
Existing:	45 hours
Estimated Future:	115-153 hours

Tetra Tech next examined the costs associated with a cluster design development on high slopes in Critical Area B (see Figure 12). This is a 100-acre parcel with nineteen 3-acre lots, and it is assumed that roads and driveways are paved. Table 31 lists the cost estimates for this example. The estimated construction costs for the paved roads and driveways are $831,000, with average annual maintenance estimated at $20,000. Offsite mitigation is required, but substantially less land is needed for offsite mitigation compared to the 5-acre lot example development. The estimated wastewater system cost is $161,000 to $240,000 in capital costs and $7,000 to $10,000 in annual maintenance costs. Administrative hours would more than double from the existing 45 hours to 90-120 hours to review a development.

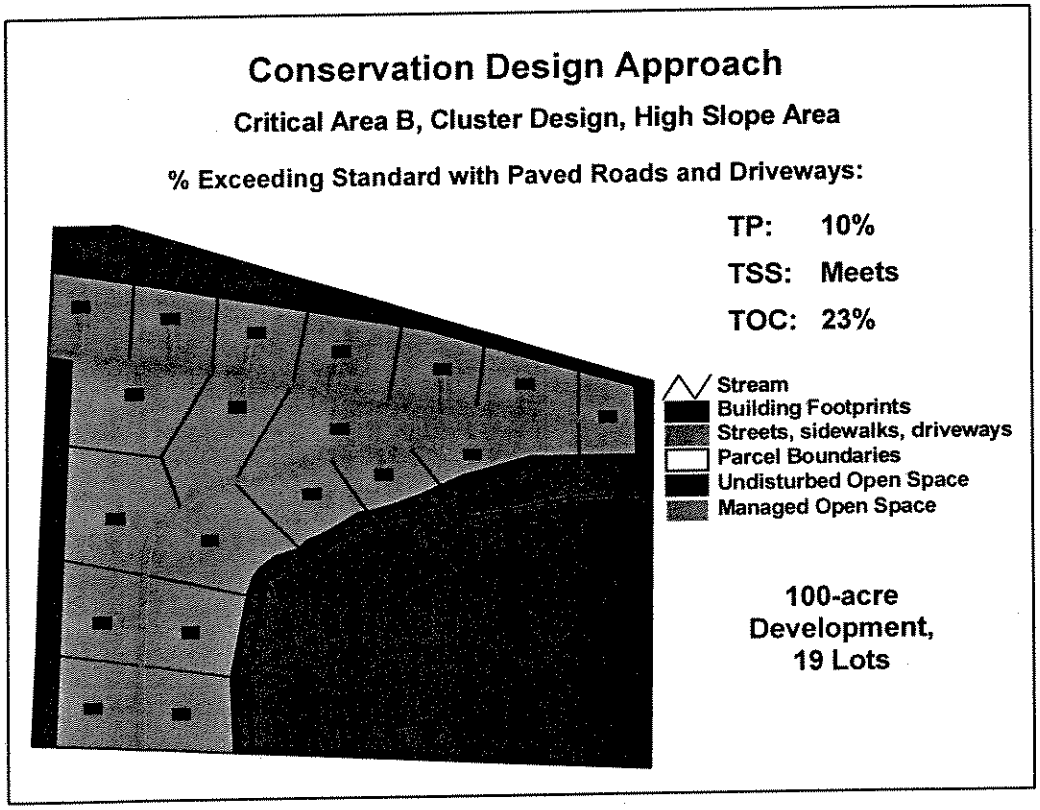

Figure 12. Critical Area B Example Development

Table 31. Cost Estimates for Conservation Design Approach in Critical Area B: Cluster Design, High Slope Area

	Assuming Paved Roads and Driveways
Road Improvements	
Construction, Design, and Engineering:	$831,000
Annual Maintenance:	$20,000
Offsite Mitigation (cost for mitigating on low slopes; fee simple acquisition)	
Minimum:	$15,000
Median:	$75,000
Maximum:	$135,000
Wastewater System Cost	
Construction, Design, and Engineering:	$161,000 - $240,000
Average Annual Maintenance:	$7,000 - $10,000
Administrative Hours Required (excluding mitigation banking)	
Existing:	45 hours
Estimated Future:	90-120 hours

3.3.3 Critical Area A Example Costs

The final example is for a 100-acre development with nineteen 3-acre lots in Critical Area A (Figure 13). It is assumed that roads and driveways are paved. If a pilot project is performed for BMPs and they perform adequately, and local governments adopt a performance standards option, this development design would use 19 bioretention cells (one on each lot) and 3 extended dry detention ponds to meet the performance standards.

Table 32 lists the cost estimates for this example. The estimated construction costs for the paved roads and driveways would be $831,000, with average annual maintenance of $20,000. Stormwater best management practices would cost an estimated $256,000 with an annual maintenance of $3,000. The wastewater system cost would reflect the requirement to pump wastewater out of the watershed and the methods applied. Thus, those costs are to be determined. Administrative hours would be expected to rise substantially, increasing from the existing 45 hours to 300-400 hours to review a development. Many of those hours would be devoted to reviewing BMP design and inspecting BMP construction.

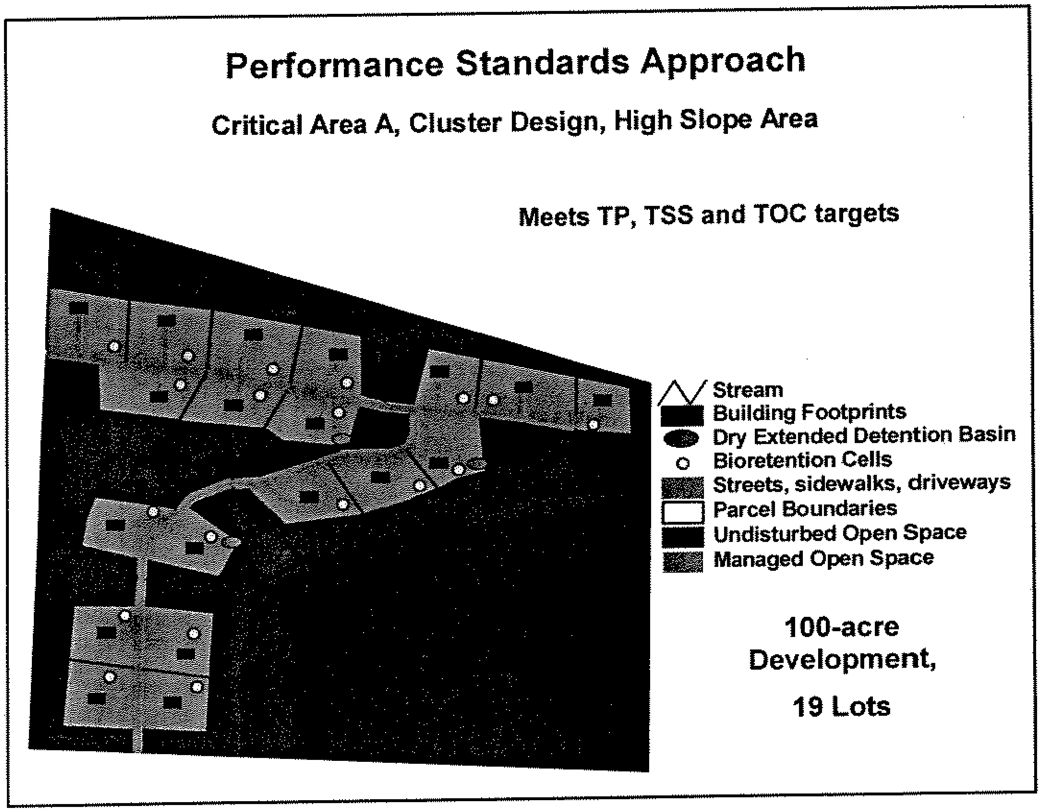

Figure 13. Critical Area A Example Development

Table 32. Cost Estimates for Critical Area A, Cluster Design, High Slope Area

	Assuming Paved Roads and Driveways
Best Management Practices	
Construction, Design, and Engineering:	$256,000
Annual Maintenance:	$1,000
Road Improvements	
Construction, Design, and Engineering:	$831,000
Annual Maintenance:	$20,000
Offsite Mitigation (cost for mitigating on low slopes)	None
Wastewater System Cost	
Construction, Design, and Engineering:	TBD – wastewater is to be pumped out of the watershed
Average Annual Maintenance:	TBD
Administrative Hours Required (excluding mitigation banking)	
Existing:	45 hours
Estimated Future:	300-400 hours

3.3.4 Long-term Enforcement of Management Requirements

Based on this analysis, it was recommended that a watershed administrator be hired to conduct development review and site inspections during construction for all jurisdictions in the watershed. Further, it was recommended that CAW fund this position through ratepayer dollars. Additional staff would be required if the Performance Approach is adopted.

The relative cost of enforcement should be considered for key management elements including stormwater BMPs, roads, wastewater facilities, and open space (undisturbed) area requirements. For stormwater BMPs, enforcement activities vary depending on the BMP, but generally require checks for erosion, sediment accumulation, and the proper functioning of the BMP. The inspection of a facility could be performed by a government inspector or by a private contractor certified by the governing authority. Additional enforcement activities would include processing of inspection reports and administration of non-compliance actions, including fees and other penalties. For road maintenance, enforcement would most likely involve certification of the maintenance activities performed by a contractor. The level of enforcement for open space requirements would depend on whether the open space will be periodically inspected by the governing authority (higher level of enforcement) or whether enforcement will rely on residents to report non-compliance (lower level of enforcement).

Table 33 compares the expected relative level of enforcement needed across the management requirements. Enforcement activities for the maintenance of stormwater BMP facilities and roads are expected to occur about once annually. Enforcement of wastewater facility maintenance varies by type of system, with greater frequency required for community systems than for individual household systems. Enforcement activities are expected to be needed less frequently for open space than for stormwater BMPs, roads, and wastewater facilities. More enforcement will be needed for the Performance Standards scenario compared to the Conservation Design scenario because the Performance Standards scenario involves stormwater BMPs. The level of enforcement for roads and wastewater facilities depends on the number of lots in a development. Developments with lower net densities (large lots greater than 5 acres) will likely require fewer facilities and will require less enforcement than developments with higher net densities.

Table 33. Relative Level of Enforcement Needed for Management Requirements

	Conservation Design Approach, 5-acre Large Lot or 3-acre Cluster	Conservation Design Approach, Large Lots Greater Than 5-acres	Performance Standards Approach
BMPs	NA	NA	✓++
Roads	✓++	✓+	✓++
Wastewater	✓++	✓+	✓++
Open Space	✓	✓	✓

Symbols:

NA = Not applicable to this scenario

✓ = Applicable, relatively low level of enforcement

✓+ = Applicable, medium level of enforcement

✓++ = Applicable, relatively high level of enforcement

The costs of enforcement also depend on how enforcement is administered and funded. The governing authority has several options for administering and funding enforcement efforts, including:

- Private maintenance and inspection: The governing body would require individual homeowners or Homeowner's Associations (HOAs) to hire certified, independent contractors to perform maintenance and inspections and report results. Homeowners or HOAs could choose to perform the maintenance and inspections themselves or to hire a contractor. Enforcement might entail reviewing inspection and maintenance reports, and periodic site inspections by local government staff.
- Public maintenance and inspection funded by district tax program: Establishing a special district in which all residents pay taxes toward the funding of inspections, maintenance, and enforcement. The governing body would perform the maintenance and inspections as well as the enforcement under this option.
- Public maintenance, inspection, and enforcement funded by local governments or their designated agency: The governing body would fund and perform the maintenance and inspections as well as the enforcement under this option.

The first and second options would require homeowners to pay for the majority of maintenance, inspections, and enforcement. The third option would require the governing authority to fund maintenance, inspections and enforcement without passing on the costs directly to the homeowners in the watershed.

3.3.5 Effect of Development Restrictions on Property Values

Restrictions on residential development can have effects, both negative and positive, on property values. Research was conducted on how restrictions – including density, forest preservation, and conservation design requirements – have affected property values in areas across the United States. Tetra Tech found several case studies that illustrate the potential effects of restrictions similar to those proposed for the Lake Maumelle Watershed. While one case of severe development restrictions reduced property values, all of the other case studies demonstrated that development restrictions can be related to an *increase* in property values. Increased open space and other improvements resulting from development restrictions are likely to cause values of restricted properties to increase relative to exempted properties.

In the first case study in the Chesapeake Bay Area, vacant parcels with development restrictions increased by up to 53 percent in value compared to control areas (Jaeger, 2006). Increase in value has also been observed for developed lots. Hardie et al. (2006) studied the effect of the Maryland Forest Conservation Act on developed lot prices Under this act, subdivisions are required to conserve existing forested areas or plant additional forested areas to achieve an overall percentage of forested area in a development. The average price of lots within those subdivisions was observed to increase with the percent of conservation area required.

Conservation subdivision design has been used to maintain full development density while maximizing undisturbed areas, leading to a relative increase in property value compared to conventional designs. A conservation subdivision design in Indiana maintained full development density while adding $20,000 in value to each lot through preservation of undisturbed areas (Arendt, 2001). In Amherst, MA, a comparison of one conservation and one conventional subdivision demonstrated a relative increase in appreciation for the conservation subdivision lots. These developments were nearly identical in density, time of construction, and original sales price. After 20 years, sales prices in the conservation subdivision were 13 percent higher than the conventional development (Arendt, 1999).

Orange County, NC studied the changes in property value that coincided with a change in allowable density within the water supply watershed of Cane Creek Reservoir. The study focused on sales data for vacant land in Bingham Township, whose jurisdiction overlaps the watershed boundary. Figure 14 illustrates the trends in land value before and after the regulation change. During the study period, the density limit on properties outside of the watershed remained constant at a minimum of 1-acre lots. The Cane Creek Watershed density limits changed from a 2-acre to 5-acre lot minimum in 1999. The new regulation allowed an exsiting property owner to subdivide the first 10 acres into 2-acre lots, and conservation design could be used in lieu of the 5-acre lot density limit. Following the regulation, the sales data suggest that the regulation did not negatively impact land values and that the increase in median price for parcels in the Cane Creek watershed was higher than the price increase for parcels outside the watershed (Craig Benedict, Planning Director, Orange County, NC, personal communication and data received from, June, 2006).

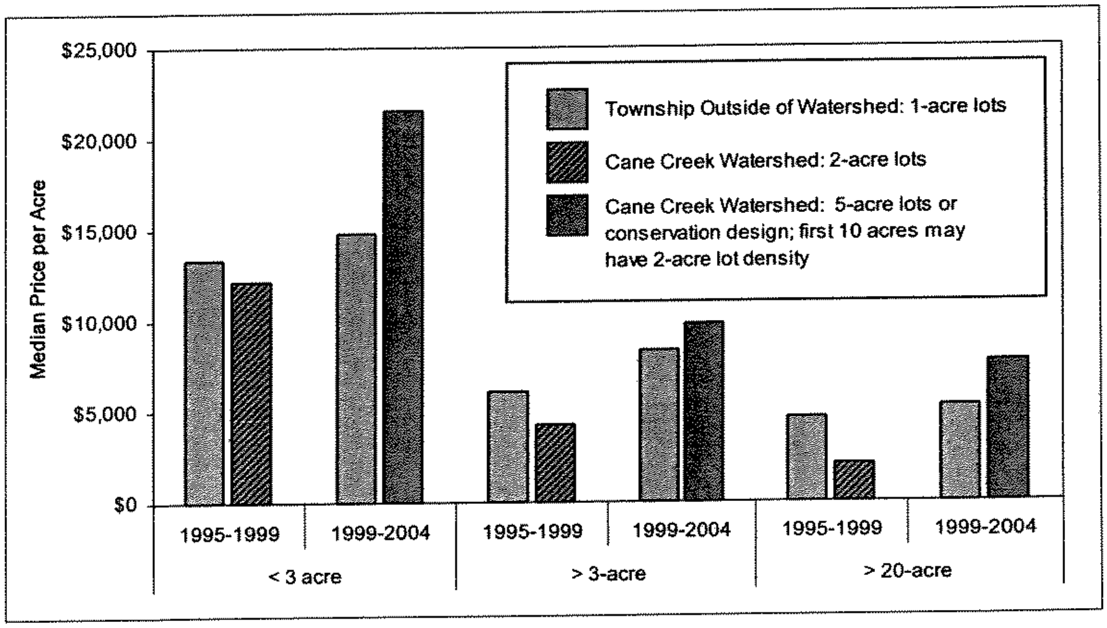

Figure 14. Trends in Land Values by Density Requirement in Bingham Township, NC, 1995-2004

In Northwest Portland, OR, severe development restrictions coincided with a decrease in sales value by eight percent compared to exempt properties. These restrictions apply to an environmental protection overlay zone for riparian areas, wetlands, and upland forest. Under this overlay zone, only publicly beneficial development is allowed and certain additions to existing structures are prohibited. Although a negative effect was observed in Northwest Portland, a positive effect on property values was observed for other parts of the city, and a less severely restricted overlay zone coincided with an increase in sales value relative to exempt properties (Netusil, 2005). Again, the level of restriction in this case study far exceeds the scenarios evaluated for the Lake Maumelle Watershed.

Table 34 summarizes the available studies on the effect of development restrictions on property values. Overall, the studies suggest that development regulations can have a positive effect on property values, both for vacant land and already developed sites. These studies suggest that home buyers are willing to pay a premium for developments with more forested, undisturbed areas as well as the knowledge that the surrounding land is protected from higher density development. Negative effects on property value are possible if the regulations severely restrict the use of the land, as seen in the Portland, OR example.

Table 34. Summary of Studies on the Effect of Development of Property Value

Location	Type	Effect	Regulation
North Carolina	Vacant	+	Minimum Lot Size and Conservation Design
Oregon	Vacant	+/-	Severe Development Restrictions
Chesapeake Bay	Vacant	+	Development Restrictions
Maryland	Developed	+	Forest Conservation and Planting in Subdivisions
Indiana	Developed	+	Conservation Design (voluntary)
Massachusetts	Developed	+	Conservation Design (voluntary)

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4 Flexibility and Exemptions

The methods described in Section 3 allow the big-picture analysis of potential management scenarios at the watershed scale. A variety of finer-scale modifications may need to be considered in an acceptable management plan to address issues of equity, flexibility, and perception (summarized in *Management Scenario Evaluation Memo # 4 – Further Defining "Development" and Landowner Flexibility*, provided to the PAC June 8, 2006). These include potential exemptions, such as allowing expansions to existing homes regardless of any impervious or developed area cap, or allowing private individual landowners of record to establish a limited number of smaller lots from existing parcels. Evaluation of these types of options must be pursued at the parcel level.

4.1 Parcel-level Analysis

Evaluation of the impacts of exemptions requires knowledge of the size, location, and ownership of existing parcels. The Maumelle watershed encompasses parts of Pulaski, Perry, and Saline counties, and different types of parcel information are available electronically for each jurisdiction. For Pulaski and Perry counties, electronic tax parcel information is available that shows ownership, tax class (including whether improvements have been made), and acreage, among other things. For Pulaski only, actual parcel boundaries are available, allowing an exact analysis, while for Perry, only locations of parcel centroids are available. No electronic database of Saline County parcels was available. The small portion of the watershed (about 6 percent) in Saline County appears from aerial photographs to contain very limited, if any, development at this time. Per information later provided by CAW, the majority of the land is owned by Deltic Timber (approximately 5,500 acres), and another 1,080 acres is owned by the U.S. Forest Service. The remaining 265 acres belong to four landowners. The land area in Saline County had to be omitted from the exemptions analysis due to the lack of readily available parcel data at the time of analysis.

For Pulaski and Perry counties, Tetra Tech compiled a database of tax parcel information, including owners and acreage. Owners were attributed to classes, such as private individuals, corporations, family trusts, and government. Parcels containing existing residences or other improvements were identified through a combination of tax class (e.g., "Residential Improved") and improvement value.

Analysis of impacts of allowing a given type of exemption was conducted on a relative basis, by examining the increase in pollutant loading (at the site-scale) with and without the exemption. Use of a relative basis is essential because it was not feasible to identify the extent to which individual parcels in Perry County belonged to high and low slope classes (which have intrinsically different loading rates and may be assigned different minimum lot sizes), due to the lack of a parcel boundary coverage. For a relative analysis, it is sufficient to apply a uniform assumption to "standard" development (e.g., 5-acre single family residential lots) and compare this to the loading that arises when an exemption is allowed.

For analysis of exemptions that allow a limited number of smaller lots, a buildout estimate of "large" and "small" residential lots was created. Here, "large" lots are those areas that are assumed to follow the underlying density assumptions (one lot per 5 acres or greater), while small lots include those created under an exemption allowing smaller lots. Existing residential lots that are buildable, but not further subdividable under a given set of assumptions are assigned to either the large or small lot category. It was assumed that lots already platted could develop regardless of size, as otherwise the owner could be left with no reasonable use. Such lots vary in size, but, because they are a small portion of the total number of small lots that could be created under an exemption, can be assumed to have approximately the same characteristics as the lots created under an exemption.

Using this approach, an exemption can be evaluated by estimating the number and acreage of small and large lots within each of the three watershed management zones. Loading can then be estimated by multiplying by site-scale loading rates that represent an area-weighted average of soil and slope conditions within a management zone. For the purposes of the analysis, large lots were assumed to meet the site-scale performance standards established in Table 7, while loading rates for small lots were based on a lot size of 2 or 3 acres (Table 35). The loading rates for the small lots represent weighted averages over the potential development area in high and low slopes.

Table 35. Area-Weighted Loading Rates for Exemption Analyses

Land Use	Management Zone	TP (lb/ac-yr)	TSS (t/ac-yr)	TOC (lb/ac-yr)
Large Lots at Performance Standard	Critical Areas A and B	0.30	0.11	43.90
Small Lots (2-ac)		0.48	0.11	48.41
Small Lots (3-ac)		0.39	0.09	45.19
Large Lots at Performance Standard	Upper Watershed Area	0.33	0.13	50.00
Small Lots (2-ac)		0.51	0.12	51.77
Small Lots (3-ac)		0.41	0.11	48.48

One complicating factor for the exemptions analysis is the issue of parcels that cross the watershed boundaries. For Pulaski County, parcel boundaries can be clipped to the watershed to provide an accurate estimate of acres within the watershed. This does leave some small fragments of parcels in the watershed, but these would not be considered subdividable if minimum area requirements are not met and so do not substantively affect the analysis for small subdivision exemptions. A larger problem is occasioned in the analysis of additions to existing residences where a parcel that is taxed as residential improved is partially within the watershed. For Critical Area A the problem is particularly acute due to the steep ridgeline and location of a number of residences just outside the watershed. For this area, actual locations of houses were checked against aerial photography to determine the exact number of existing residences located within the watershed. This was not done in Critical Area B or in any part of Perry County, where it was assumed that occasional misattribution of houses into the watershed would be balanced by the potential for residential improvements made under an exemption to extend from an existing house outside the watershed boundary into the watershed.

4.2 Exemption 1: Additions to Existing Residences

Tetra Tech initially recommended that local governments in the watershed exempt expansions to existing development on existing single family lots as follows:

> Additions to existing residential buildings or driveways on single-family residential lots recorded prior to CAW's adoption of the Lake Maumelle Watershed Management Plan shall be exempted if such additions disturb less than 20,000 square feet and the renovation and/or construction costs do not exceed 100 percent of the tax value of the property. Such additions shall be constructed in accordance with local regulations in effect at the time the lot was created.

The ordinance can define "single family lots" in various ways. It is recommended that the definition for single family lot with single family residence include those lots and residences created by:

- Subdivision (division of a lot, tract, or parcel into three or more parcels) as of adoption date of the Watershed Plan.

- Family division – defined as a transaction exempted from subdivision law under the Arkansas Real Property Transfer Act and involving transfers between a father and mother and their descendants and a brother and sister and their descendents as of the adoption date of the Watershed Management Plan.
- Property devised by will as of the adoption date of the Watershed Management Plan.

Tetra Tech reviewed its parcel database for Pulaski and Perry counties and aerial photographs of Saline County. Based on that review, it estimated that there are 12 houses in Critical Area A, 288 houses in Critical Area B, and 49 houses in the Upper Watershed Area for a total of 349 (count revised slightly from numbers reported in June 8, 2006 memorandum). The modeling team included all of these houses in the analysis of the additional pollution loading that would result from allowing this exemption. The analysis included assumptions that the additions, on average, would disturb less than 20,000 sq. ft. and would permanently convert 10,000 sq. ft. of land from undeveloped to developed. Assuming all existing homeowners in the watershed elect to make these additions, this would result in a 0.39 percent increase in Total Suspended Solids, a 0.44 percent increase in Total Organic Carbon, and a 0.60 percent increase in Total Phosphorus loading.

Concerns were raised by the PAC and the public about the wording of the proposed exemptions, specifically the limitations on square footage of land disturbance and link to tax value of the property. For additions to residential property, Tetra Tech indicated that the average house addition would, in reality, disturb less than 20,000 sq. ft. of land area, therefore such a restriction would not be required in the ordinance. The reference to property tax value was also eliminated.

Specific questions were raised about the impact on water quality of applying this additions exemption to houses in Critical Area A. Tetra Tech analysis did include the 12 houses in Critical Area A, and it estimated that the impact on long-term average water quality would not be significant. These houses constitute less than 5 percent of the total number of existing residences. Therefore, Tetra Tech recommended that the exemption be allowed for all existing houses in the watershed, including those in Critical Area A. However, this exemption should be accompanied by a commitment to strict enforcement of erosion and sedimentation guidelines for any associated land disturbing activities.

Tetra Tech was subsequently asked to evaluate the impact of extending the additions exemption for additions to existing residences to include existing businesses, churches, and other existing organizations. Tetra Tech reviewed its parcel database for Pulaski and Perry counties and aerial photographs of Saline County. Based on that review, Tetra Tech estimated that there are 14 businesses and organizations in Critical Area B, and 6 businesses and organizations in the Upper Watershed Area. For businesses, Tetra Tech relied on information that the parcel is being taxed for business purposes and where the parcel appeared to have a structure. The analysis included assumptions that the additions, on average, would disturb less than 20,000 sq. ft. and would permanently convert 10,000 sq. ft. of land from undeveloped to developed status.

If the additions exemption is extended to businesses and organizations, we recommend that the watershed protection plan and ordinance limit the additions exemption to 10,000 square feet of new impervious area. This includes all structures and parking area. If impervious area over this amount is added, the business or organization would need to comply with the watershed protection ordinance.

Assuming all existing homeowners, businesses and organizations in the watershed elect to make these additions, this would result in a 0.41percent increase in Total Suspended Solids, a 0.47 percent increase in Total Organic Carbon, and a 0.64 percent increase in Total Phosphorus loading.

The extent to which this exemption would be utilized is unknown. If all rights created under this exemption were exercised, the total increase in phosphorus load would be about 85 lb/yr. Offsetting this increase would require approximately 455 acres of mitigation land (as a weighted average of high and low slope areas).

4.3 Exemption 2: Grandfathering of Minor Subdivisions

Various scenarios under evaluation include a minimum lot size of 5 acres (on low slope areas). Many private landowners in the watershed have expressed interest in being able to create a limited number of smaller lots. This provision was considered to help address legacy issues, such as the ability of parents to create a homesite for children, as well as to preserve economic interests of existing residents.

The parcel database provides a flexible tool for evaluation of many variations on the minor subdivision exemption, including the types of owners allowed to utilize the exemption, zones in which exemptions are permitted, and the number of small lots that are allowed. Initially, the focus of analyses was on allowing this exemption to private landowners (or family trusts) within Critical Area B and the Upper Watershed Area with rights being created at the parcel level; the exemption would not be allowed in Critical Area A. A subsequent legal opinion indicated that rights must be extended to all landowners equally. At the direction of the TAC and PAC, the allowance for lots that could be created (given sufficient area) was calculated on the basis of current owners of record, rather than by parcel. This allows an owner of several small parcels to combine them to calculate the exemption allowance, but limits the total number of small lots that could be created because an owner of several large tracts would be subject to the exemption cap across all the tracts. Several variations in the date of record for eligibility for the exemption were also examined, although initial analyses focused on the case in which all lots of record through the end of 2005 were eligible.

Relative to pollutant loading allocations, the major impact of creating additional small lots is on increased phosphorus loading, and this provides a basic metric for comparing options. Increased phosphorus loading would in turn increase the number of mitigation acres that might need to be acquired to offset the impact.

The analysis conducted on the parcel database is an upper bound analysis (despite the omission of the small land area in Saline County) because it assumes that all such grandfathered exemptions would be exercised. In fact, many landowners may choose not to subdivide land to the maximum extent allowed, some tracts may not have sufficient capacity for water supply or wastewater disposal to achieve the maximum allotment. Table 36 summarizes results when a 2-acre lot exemption is made at the owner level and is allowed for all owners. It shows that if a landowner is allowed to subdivide one 2-acre lot from his total holdings and exempt that lot from the watershed requirements, then phosphorus loading would be expected to increase by 1.0 percent and up to 633 acres of developable land in the watershed would need to be dedicated as permanent open space if all eligible landowners participated. If up to five 2-acre lots are allowed, then the loading is predicted to increase by 6.1 percent and up to 3,860 acres would need to be dedicated as open space. In contrast, allowing the exemption at the parcel level creates significantly more mitigation needs: If up to five 2-acre lots are allowed at the parcel level it would increase phosphorus loading by 7.4 percent and require up to 5,730 acres of mitigation, or about 11 percent of the developable land in the watershed. Allowing up to 10 lots at the ownership level is approximately equal to allowing up to 5 lots at the parcel level.

Table 36. Maximum Impacts of Small Subdivision Exemption (by number of 2-acre lots allowed)

	Number of Grandfathered 2-acre Lots Allowed per Landowner						
	1	2	3	4	5	7	10
Percent change in TP load	1.0%	3.2%	3.9%	5.1%	6.1%	7.5%	9.2%
Mitigation acres (weighted average high and low slope acres)	384	1,570	1,798	2,474	3,009	3,612	4,233

Similar results are shown for 3-acre small lots in Table 37. In general, the load increases and corresponding mitigation needs associated with allowing 3-acre small lot exemptions are less than those from allowing 2-acre lots, both because the per-acre loading rate is less for 3-acre lots and because somewhat fewer exempt lots can be created under this version. Based on this analysis, Tetra Tech and the PAC Exemptions Subcommittee recommended the 3-acre small lot configuration as the preferred alternative. This recommendation was based on reducing mitigation requirements for the exemption, and on the fact that soils in the watershed would in most cases dictate lots larger than 2 acres in order to meet onsite wastewater requirements.

Table 37. Maximum Impacts of Small Subdivision Exemption (by number of 3-acre lots allowed)

	Number of Grandfathered 3-acre Lots Allowed per Landowner						
	1	2	3	4	5	7	10
Percent change in TP load	0.36%	0.84%	1.75%	1.99%	2.58%	2.82%	3.02%
Mitigation acres (weighted average high and low slope acres)	237	533	1,113	1,260	1,619	1,763	1,882

The PAC Exemptions Subcommittee asked Tetra Tech to evaluate the following question: How much larger would the minimum large lot size need to be to offset the increased total phosphorus load due to the exemption and remove the need for purchase of mitigation acres? Currently, the fixed minimum large lot requirement is 5 acres on the low slope and 10 acres on the high slope areas. Tetra Tech determined that if the minimum lot size on the low slope was increased to 5.5 acres, it would offset the phosphorus load associated with allowing each landowner a subdivision exemption of three 3-acre lots. If the minimum lot size on low slope areas was increased to 6 acres, it would offset the increased phosphorus load associated with allowing a subdivision exemption of ten 3-acre lots (Table 38). In other words, raising the minimum non-exempt lot size would reduce the need for mitigation purchase to offset the impact of the exemption.

Table 38. Increasing Low Slope Lot Size – Mitigation Provided for Subdivision

Low Slope Minimum Lot Size Requirement	Number of 3-acre Lots Exempted per Landowner
5-acre lots (meets target only)	0
5.5-acre lots	Three 3-acre lots per landowner
6-acre lots	Ten 3-acre lots per landowner

Note: Includes private individual landowners, family LLCs, revocable trusts, and other family trusts.

Additional analyses were undertaken to examine different eligibility dates for the exemption and the impact of allowing the exemption for land owned in Critical Area A. First, Tetra Tech analyzed the mitigation needed if the exemption is only allowed in Critical Area B and the Upper Watershed (Table 39). Parts a, b, and c of Table 39 show results based on differing definitions of eligible landowners, with Part a reflecting the subdivision exemption for landowners as of December 2005; Part b for landowners as of December 2002; and Part c for landowners as of December 2000. Tetra Tech was advised by legal counsel to make the exemption available to longstanding watershed landowners only, with the definition of "longstanding" being 5 to 10 years. Therefore, Tetra Tech recommends that the exemption be provided to watershed landowners as of December 2000. This results in a significant reduction in mitigation needs.

Tetra Tech also evaluated the mitigation needed if the exemptions are allowed throughout the watershed (Table 40). In this case, landowners in Critical Area A would receive a subdivision exemption but must transfer or sell the subdivision housing density options for use in other parts of the watershed. Again, results are shown based on differing temporal definitions of landowner eligibility.

Table 39. Allowing Exemptions in UWA and CAB Only

Table 39a. Allowing Exemptions for Lots in Current Ownership by End of 2005

Low Slope Minimum Lot Size Requirement	Acres of Mitigation	Number of Small Lots Exempted per Landowner
5-acre lots (meets target only)	0	0
5-acre lots	1619	5 3-acre lots
5-acre lots	1764	6 3-acre lots
5-acre lots	1882	7 3-acre lots
5.5-acre lots	654	6 3-acre lots
5.5-acre lots	785	7 3-acre lots
6-acre lots	< 0	5 3-acre lots

Table 39b. Allowing Exemptions for Lots in Current Ownership by End of 2002

Low Slope Minimum Lot Size Requirement	Acres of Mitigation	Number of Small Lots Exempted per Landowner
5-acre lots (meets target only)	0	0
5-acre lots	1386	5 3-acre lots
5-acre lots	1510	6 3-acre lots
5-acre lots	1607	7 3-acre lots
5.5-acre lots	546	6 3-acre lots
5.5-acre lots	653	7 3-acre lots
6-acre lots	< 0	5 3-acre lots

Table 39c. Allowing Exemptions for Lots in Current Ownership by End of 2000

Low Slope Minimum Lot Size Requirement	Acres of Mitigation	Number of Small Lots Exempted per Landowner
5-acre lots (meets target only)	0	0
5-acre lots	1251	5 3-acre lots
5-acre lots	1363	6 3-acre lots
5-acre lots	1452	7 3-acre lots
5.5-acre lots	442	6 3-acre lots
5.5-acre lots	540	7 3-acre lots
6-acre lots	< 0	5 3-acre lots

The PAC recommended offsetting the exemptions through CAW purchase of developable land in the watershed.

Table 40. Allowing Exemptions throughout the Watershed (Zone A Exemption Rights Transferred to Zone B)

Table 40a. Allowing Exemptions for Lots in Current Ownership by End of 2005

Low Slope Minimum Lot Size Requirement	Acres of Mitigation	Number of Small Lots Exempted per Landowner	Lots Transferred from Zone A
5-acre lots (meets target only)	0	0	0
5-acre lots	1626	5 3-acre lots	26
5-acre lots	1770	6 3-acre lots	29
5-acre lots	1889	7 3-acre lots	31
5.5-acre lots	661	6 3-acre lots	29
5.5-acre lots	792	7 3-acre lots	31
6-acre lots	< 0	5 3-acre lots	26

Table 40b. Allowing Exemptions for Lots in Current Ownership by End of 2002

Low Slope Minimum Lot Size Requirement	Acres of Mitigation	Number of Small Lots Exempted per Landowner	Lots Transferred from Zone A
5-acre lots (meets target only)	0	0	0
5-acre lots	1390	5 3-acre lots	18
5-acre lots	1513	6 3-acre lots	20
5-acre lots	1610	7 3-acre lots	22
5.5-acre lots	549	6 3-acre lots	20
5.5-acre lots	657	7 3-acre lots	22
6-acre lots	< 0	5 3-acre lots	18

Table 40c. Allowing Exemptions for Lots in Current Ownership by End of 2000

Low Slope Minimum Lot Size Requirement	Acres of Mitigation	Number of Small Lots Exempted per Landowner	Lots Transferred from Zone A
5-acre lots (meets target only)	0	0	0
5-acre lots	1251	5 3-acre lots	15
5-acre lots	1363	6 3-acre lots	17
5-acre lots	1452	7 3-acre lots	19
5.5-acre lots	442	6 3-acre lots	17
5.5-acre lots	540	7 3-acre lots	19
6-acre lots	< 0	5 3-acre lots	15

After deliberation of the numerous options, Tetra Tech and the Exemptions Subcommittee of the PAC recommended providing a five 3-acre lot subdivision exemption for all landowners as of December 2000 in Critical Area B and the Upper Watershed Area. This would require 1,251 acres of mitigation. Next the Subcommittee asked that a mitigation option be developed and applied that reflects full mitigation of the subdivision exemption and partial mitigation of the additions exemption. Partial mitigation was defined as purchasing 250 of the 455 acres needed to fully mitigate the additions exemption for residential and non-residential (e.g., commercial) development. When these 250 acres for mitigating the house and business additions were added to the initial 1,251 mitigation acres, it resulted in a total mitigation need of 1,501 acres (which was rounded off to 1,500 acres). Tetra Tech recommended that CAW set a goal of purchasing this mitigation land over a 10-year period.

If CAW decides to allow development in Critical Area A, Tetra Tech recommended that the subdivision exemption 1) not be allowed in that zone, or 2) establish development credits in Critical Area A that must be applied in Critical Area B or the Upper Watershed Area.

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5 Wastewater Alternatives

5.1 Analysis of Wastewater Disposal Options

As noted in Section 2, Tetra Tech recommended against allowing direct surface discharges of wastewater in the watershed, and the primary management alternatives focused on scenarios that include a policy of no such discharges. Meeting management targets under future development scenarios is simply infeasible if surface water discharge is allowed.

What types of wastewater systems would be allowable? In Critical Area A, if development is allowed by CAW, wastewater could be pumped out of the watershed (see Section 5.2). In Critical Area B and the Upper Watershed Area, conventional septic systems can be used for individual large lot homes where the soil is suitable. However, since soils are not rated as suitable for conventional onsite systems in the majority of the watershed, alternative nondischarge systems will likely be required for most development. Per communication with Arkansas Department of Health (ADH) staff (March 13, 2006), the relatively large lot size and open space requirements being considered would be conducive to identifying alternative nondischarge options. ADH staff indicated that for large individual lots, they prefer using a "capped field" alternative. Particularly with lot sizes of 5 acres or more, ADH staff believed that locating suitable sites for a capped field would be likely. For cluster subdivisions, ADH staff indicated that a "drip irrigation" nondischarge system would be a likely alternative. Maintenance is important for these systems, so strong maintenance requirements for subdivision systems will be essential (Robert Hart, Usman Patel, and Harold Seifert, Arkansas Department of Health, personal communication during conference call, March 13, 2006). Under certain limited conditions wastewater can be pumped out of the watershed for Critical Area B and the Upper Watershed Area.

5.2 Relative Risk Analysis for Critical Zone A Wastewater

An analysis of relative risk was undertaken to help evaluate potential differences between onsite wastewater disposal and pumping wastewater out of the watershed for Critical Area A. While this comparison uses risk assessment methodology, it is not intended to be a quantitative assessment of risk. Specifically, it assumes a worst-case scenario involving an amount of development that is unlikely to occur in this area, given the limited amount of available land. It also makes conservative assumptions about the amount of wastewater that might reach flowing streams following a pipeline break. Despite these conservative assumptions, the relative comparison clearly suggests (1) risk to the water supply from pathogens associated with wastewater disposal is likely to be acceptably low for either option, and (2) pumping out of the watershed is not likely to increase these risks.

5.2.1 Analysis Approach

Potential spills of wastewater from pump stations and force mains is a topic of concern for the management of Lake Maumelle as a drinking water supply. Spills of untreated wastewater may introduce a variety of pathogens into the water supply, including bacteria, viruses, and protozoan pathogens such as *Giardia* and *Cryptosporidium*. Wastewater may also contain toxic household chemicals.

Spills of this nature are expected to be rare, and can be minimized by proper design, siting, and maintenance. Still, the possibility of such spills cannot be entirely eliminated in any area where wastewater is collected and pumped out of the watershed.

The impact of such a spill would depend in part on where the spill occurs. Spills in the down-lake area near the water supply intake are of greater concern than spills that occur far up in the watershed, for two primary reasons:

- Spills occurring near the intake will reach the treatment plant quicker, limiting the response time available to treatment system operators.
- Concentrations of pathogens or toxic chemicals in spills that occur farther away from the intake will be reduced by dilution and degradation during transit.

The two mechanisms that reduce concentrations are dilution and degradation. Both may be investigated through the three-dimensional EFDC model of the lake.

Dilution is an important mechanism because the storage volume of the lake is large. However, model simulations show that the reduction in concentration due to dilution is approximately the same for spills originating anywhere outside of Critical Zone A. That is because a spill from any part of the watershed outside of Zone A will be mixed into approximately the same volume of water by the time it reaches the water supply intake. For the conditions investigated in the time of travel studies, peak concentrations resulting from a spill in subbasin 31 (in Critical Zone A near the intake) would be approximately 3.5 times those from a spill of the same size occurring in Zone B or the UWA. Peak concentrations for a spill in subbasin 32 (also in Zone A) were lower for the conditions tested in the simulation, but still greater than the peak concentrations resulting from a spill outside of Zone A. Results will vary depending on the flow and wind mixing patterns present at a given time.

Concentrations of many pollutants of concern will also be reduced during transit by degradation. For pathogens, die-off or inactivation typically occurs over time, while many organic pollutants may degrade by hydrolysis or photolysis or be lost to the atmosphere. In either case, longer travel times result in reduced concentrations.

The oocysts of the protozoan pathogen *Cryptosporidium parvum* are of particular concern to water supply managers because they are infectious in small doses, difficult to remove by treatment, and have a very slow inactivation rate in the environment. Typical inactivation rates for *Cryptosporidium* in water are in the range of 0.02 log-10 units per day at 15 °C, with strong temperature dependence (Medema et al., 1999). The average travel time from Zone A to the water intake derived in the travel time analysis was about 4 days, while the average travel time from Zone B was 34 days. This suggests that the transmission of *Cryptosporidium* from Zone A is, on average, about 83 percent, while the transmission from Zone B is, on average, about 21 percent. Travel time is shorter from the eastern end of Zone B – about 12 days. This yields about 50 percent transmission, still 2.4 times greater than the average for Zone A.

It is thus clear that spills within Zone A pose a greater relative risk to the safety of the water supply than spills elsewhere in the watershed, but is the resulting level of risk sufficiently great to cause concern? To help answer that question, we have conducted a scoping-level risk assessment.

Properly, the analysis of health risk from a wastewater spill would include integration of the risk from all pathogenic and toxic components – but incorporating all potential components is difficult. Toxic chemicals are unlikely to be a big issue for domestic wastewater and a one time spill. Bacterial pathogens may present some risk; however, these tend to die off in the environment at relatively faster rates and, in most cases, are effectively killed in water treatment. Most viruses also die off in the environment more quickly than *Crytposporidium* and are more readily treated (although treatment may not be completely effective in removing viruses such as hepatitis A). As a result, the major portion of the risk is likely to be due to *Cryptosporidium* – which persists in the environment and is difficult to treat. This assessment thus focuses on *Cryptosporidium.*

While modeling can be used to evaluate concentrations potentially resulting from a spill, it is also necessary to establish target levels of acceptable risk for comparison. Two such targets are available.

First, USEPA's Surface Water Treatment Rule had a goal of ensuring less than an average of 1 in 10,000 microbiologically caused illnesses per capita per year. The 1:10,000 goal translates to a daily risk of infection of $2.7 \cdot 10^{-7}$ per person per day. Alternatively, Englehardt and Swartout (2004) have shown that an equivalent safe dose of *Cryptosporidium* (taking into account variability in susceptibility of exposed individuals and variability in *Cryptosporidium* genotypes) is about $6 \cdot 10^{-6}$ oocysts per exposure.

The assessment of risk begins with assumptions about the nature and volume of a spill. We assume that a failure occurs in a force main or pump station serving an entire subdivision of 300 houses, and that it takes 24 hours to detect and repair the leak. Assuming 2.5 people per household and wastewater generation of 125 gallons per person per day, the wastewater volume is 93,750 gallons. Pump stations and other critical transmission points are anticipated to have some protection against spills, however, and it is assumed that only half of the wastewater (46,875 gallons or 177,441 liters per day) reaches the stream network and is conveyed to the lake.

Oocyst concentrations in untreated human wastewater are typically modeled on the order of 10-100 oocysts/L (Walker and Stedinger, 1999). Assuming the midpoint of this range (55 oocysts/L), the total oocyst load to the stream system is 9,759,262 oocysts/day.

Travel through the stream network in the Maumelle watershed is generally rapid, so inactivation over time is only considered within the lake itself. The EFDC lake model can then be used to calculate the concentration at the water intake resulting from a spill delivered from any of the model subbasins. The model is configured using the inactivation rate of 0.02 log-10 units per day cited above.

5.2.2 Analysis Results

Predicted oocyst concentrations at the water supply intake resulting from a spill on day 200 in Critical Area A (model subbasin 31 are shown in Figure 15. Because travel time is short, the concentration quickly rises to a peak of about $5.4 \cdot 10^{-5}$ per liter. This is followed by a period of rapid decline (through day 215) that is primarily due to dilution of the introduced slug, followed by a slower decline toward zero as the oocysts are inactivated. The raw water concentration is predicted to remain above the daily safe dose level for about 4 weeks.

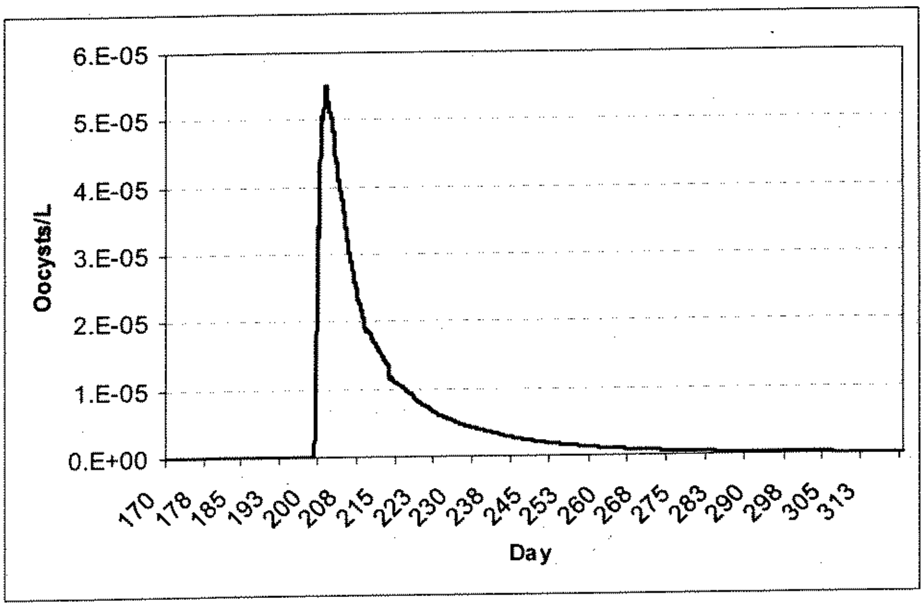

Figure 15. Oocyst Concentrations at Water Supply Intake Predicted to Result from a Spill in Subbasin 31

Dose can be calculated from concentration by assuming an average consumption rate of 1.95 L/d. At the maximum concentration (without any reduction in treatment), the dose is $1.07 \cdot 10^{-4}$ oocysts/d, which is in excess of the safe dose proposed by Englehardt and Swartout (2004) by a factor of 18. The water treatment system, however, is likely to reduce the dose by a factor of 100 or greater (Walker and Stedinger, 1999), resulting in a value less than the safe dose.

Risk can also be evaluated using the exponential dose-response model of Haas et al. (1996), which yields an estimate of the probability of infection by day. Integrating over the course of a year, the risk associated with this spill is estimated at $4.49 \cdot 10^{-6}$ per person per year, without accounting for any additional inactivation in the treatment system – well under the $1 \cdot 10^{-4}$ target.

In both calculations, only the incremental risk due to the spill has been considered. Total risk levels would also need to account for the background concentration of oocysts, which could well increase the total dose above the safe dose level. Background concentrations for Lake Maumelle are unknown, and may change under future development conditions. (Testing by CAW to date has confirmed the presence of *Cryptosporidium* oocysts only once in over 10 years of sampling of Lake Maumelle raw water. However, detection limits have generally been 0.1 per L or greater, far above the levels discussed here.)

For comparison, risk estimates were made for similar spills in the downlake end of Critical Area B (model subbasin 30) and loading through the Maumelle River (Table 41). As expected, the risk declines with spill locations further from the intake. At the downstream end of Critical Area B, the risk is less than one third of that for a spill in subbasin 31 of the Critical Area A. Risk associated with a spill entering through the Maumelle River would be another factor of two lower.

Table 41. Incremental Risk Associated with Individual Wastewater Spills (with no pathogen reduction in treatment system)

	Risk of Infection (per person per year)	Maximum Dose (oocysts/d)
Critical Area A (Subbasin 31)	$4.49 \cdot 10^{-6}$	$2.07 \cdot 10^{-4}$
Lower Critical Area B (Subbasin 30)	$1.43 \cdot 10^{-6}$	$1.27 \cdot 10^{-5}$
Upper Critical Zone B and UWA (via the Maumelle River)	$7.63 \cdot 10^{-7}$	$5.41 \cdot 10^{-6}$
Safe Level	$1.0 \cdot 10^{-4}$	$6.0 \cdot 10^{-6}$

It is important to note that the level of risk calculated above is entirely dependent on assumptions regarding the size and nature of the spill. If the volume of wastewater transported to the lake was larger, or the oocyst concentration in the wastewater higher, then the risk would increase proportionally.

The scoping level assessment suggests that a sewage spill in the watershed would not be a public health disaster, as the impact would likely be small enough that the treatment system (particularly with advance warning) should be able to continue to supply safe drinking water, although it would likely pose a significant public relations concern. On the other hand, a spill would introduce additional risk, with concentrations in the raw water supply likely to exceed the recommended safe dose if the spill occurred in the portions of the watershed nearer to the water supply intake.

In terms of relative risk, the impact of spills in Critical Zone A is much greater than for spills elsewhere. As a result, it is appropriate to place more stringent management controls on activities in Zone A.

5.2.3 Comparison to Onsite Wastewater Disposal

Onsite wastewater disposal also loads pathogens to the water supply, primarily through systems that are failing. Which presents greater risk: a pumped collection system or onsite disposal via septic tanks or subsurface gravity-fed drip irrigation?

Clearly, a pump station failure could provide the largest pulse loading (because it is improbable that all the subsurface systems would fail at the same time). But, as we saw above, even a catastrophic failure of a development pump station is unlikely to exceed target risk levels. Further, such events are expected to be rare. A typical goal for pump station reliability is a 2 percent annual risk of failure – which equals one event in 50 years.

If the peak events do not present an imminent threat to human health, the total annual loading is a better basis for comparison of relative risk. With a 2 percent annual risk of failure and a failure duration of 1 day, the average rate of loading by pump station failure is $125 \cdot 0.02 \cdot 1/365 = 0.0068$ gal/persons/d. At a 10 percent failure rate (10-year life expectancy), the average loading rate would be 0.0342 gal/person/d. These figures could be divided by 2 to account for delivery, as stated above.

In contrast, the Baseline Analysis report assumes that conventional subsurface systems would have a failure rate of 15 percent. In contrast to pump station failures, this load occurs every day, so the loading rate would be $125 \cdot 0.15 = 18.75$ gal/person/d. Even if only 10 percent (for example) of this discharge reaches surface water, the resulting loading rate (1.875 gal/person/d) is 60 times greater than the average loading rate for pump station failure at a low (10 percent) level of reliability. Newer types of nondischarging systems may fail less frequently if properly maintained. However, to achieve the more likely loading rate of 0.0068 gal/persons/d for pump station failure, the product of onsite system failure and delivery would have to be less than 0.006 percent – e.g., a failure rate of 0.6 percent at a delivery rate of 1 percent.

Thus, in terms of cumulative relative loading rates of pollutants to the reservoir, use of onsite wastewater disposal appears to present greater risk than pumping options, assuming the same number of houses present. Short-term pollutant concentrations would be greater for a pump station spill, but unlikely to present an unacceptable public health risk when the water treatment system is functioning properly.

Note that this analysis was conducted for Critical Area A only, which has a recommended density limit of one house per five acres under the Performance Standards Approach. Conclusions would likely be different for Critical Area B and the Upper Watershed Area because there is no recommended density limit for these zones under the Performance Standards Approach. Significantly more houses could be built on a tract where untreated wastewater is pumped out of the watershed as opposed to a tract dependent on soils to treat and dispose the wastewater onsite. The former case (i.e., pumping untreated wastewater out of the watershed) would pose a higher risk to the water supply due to the risk of failure of the lines and/or pump stations and consequent spillage of large volumes of watershed wastewater flowing into Lake Maumelle. There is also risk of a secondary impact from higher density of houses (and people) in the watershed.

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