# RECOMMENDED WELLHEAD PROTECTION AREA ZONE I DELINEATION METHODOLOGY

COMPLIANCE ASSISTANCE DOCUMENT

COMMONWEALTH OF PENNSYLVANIA
Department of Environmental Protection

BUREAU OF WATERSHED MANAGEMENT
DIVISION OF WATERSHED PROTECTION

May 2004

## Introduction

The purpose of this document is to explain the recommended methodology for delineating the Zone I wellhead protection area (WHPA) for a new ground-water source utilized by a community water system in accordance with Chapter 109.1 and 109.503(a)(1)(iii)(D). Figures 1-4 are graphs that may be used to determine the Zone I area based on site-specific source and aquifer characteristics. Please note that a hydrogeologic report submitted in support of a permit application for a new ground-water source must be prepared by or under the supervision of a licensed professional geologist.

The closer a potential contaminant is to a source of drinking water, the greater the threat to the source. The purpose of delineating a Zone I WHPA is to apply the greatest control of land use activities for the prevention of contamination of the source in the area with the greatest likelihood of impacting source-water quality. It should be noted that this is not the whole area which should be considered to secure water quality for the ground-water source although it is a limited area that can be realistically controlled by the water supplier and concomitantly afford the source a reasonable degree of protection from contamination. This zone of protection allows for adequate time for attenuation or for the supplier to take appropriate steps to protect the source and consumers from potential contamination. Additionally, for a confined aquifer, it is important to prevent breaching of the confining layer that could occur with the drilling of private wells for which there are presently no statutory construction standards and which may not be properly constructed. Consequently, a water supplier should ensure that there are no potential contaminants or avenues for contaminant migration located within the area immediately surrounding a well.

## Theoretical Aspects of the Method

The volumetric flow equation (US EPA, 1987) is a relatively simple WHPA delineation method that involves some site-specific hydrogeologic characteristics but does not require data from an aquifer test. Therefore, the volumetric flow equation (VFE) was used as the basis for constructing the Zone I plots and is the recommended method for directly calculating a Zone I radius for wells.

The VFE is sometimes referred to as the cylinder method (US EPA, 1994) as it essentially defines a cylindrical aquifer volume surrounding a well with a pore volume equal to the volume of water pumped during a given time period. The projection to the land surface of this cylinder is a circle with a radius, r, that can be expressed (in feet) as

$$r = \sqrt{(Qt/\pi nH)} \qquad \text{(Equation 1)}$$

where Q = pumping rate of well ($ft^3$/day)
t = time of pumping (days)
$\pi$ = pi (~3.1415926)
n = porosity (dimensionless; percentage expressed as a decimal)
H = saturated thickness (feet; typically open interval or length of well screen).

As with most hydrogeologic calculations, the following relatively standard set of ***idealistic*** conditions is assumed: confined aquifer or unconfined aquifer with drawdown less than approximately 10% of the saturated thickness, constant aquifer thickness, homogeneous and isotropic aquifer, flat ambient potentiometric surface, fully penetrating well, negligible boundary effects and two-dimensional steady-state flow. A more detailed discussion of the method is given by Risser and Madden (1994, p. 26-31). Given the limited dimension of Zone I (400 feet **maximum**) which would typically be relatively small compared to the saturated thickness and areal extent of most aquifers in Pennsylvania, this method is a reasonable approach for a first-order approximation of the minimum innermost protective zone.

In order to generate the Zone I graphs, four different lines (low effective porosity, short screen/open interval; low effective porosity, long interval; high effective porosity, short interval; high effective porosity, long interval) were derived by calculating distances using the VFE based on a range of pumping rates and a pumping duration of 90 days. The four scenarios were modeled to overcome the difficulty of obtaining one "average" line that would apply to every well in every hydrogeologic setting or a line that would provide a universal solution of the VFE by combining variables into ratios and thus precluding a simple graphical determination of the Zone I radius based on the pumping rate. Assumptions regarding source construction and aquifer lithology were made based on the public water supply (PWS) database and published literature. The saturated thickness values used were derived from well construction statistics for community water system (CWS) wells in the PWS database. The cut-off value between short and long intervals (200 feet) is the difference between mean well depth and mean casing depth for CWS wells in the PWS database. The porosity values used for constructing the plots were taken from published literature (US EPA, 1994; Driscoll, 1986; Freeze and Cherry, 1979). The low effective porosity aquifer setting represents fractured or unfractured crystalline rocks, unfractured carbonate rocks, shales and interbedded sequences comprised predominantly of shales whereas the high effective porosity setting represents unconsolidated sediments, karstic carbonate rocks, sandstones, siltstones and interbedded sequences comprised predominantly of sandstones and/or siltstones. An overlap in ranges of published porosity values allowed the lithologic groupings.

## Zone I Determinations For Wells

To determine Zone I graphically for a new well, the applicant will need to know the proposed pumping rate as well as the basic hydrogeology of the area. If the basic hydrogeologic information does not readily exist, it can be estimated from the literature, site characterization work, existing well records, prior knowledge of the area and/or best professional judgment. The basic hydrogeologic information needed is the aquifer lithology in order to assess whether it would be considered low or high effective porosity along with an estimate of the depth to ground water in order to assess whether the length of the screened or open interval will be less than or greater than or equal to 200 feet. Once the appropriate plot has been selected based on lithology and anticipated well construction, the Zone I distance is read directly off the line based on the proposed pumping rate. Questions regarding the use of the graphs should be directed to the drinking water program hydrogeologist in the appropriate DEP regional office.

For those wishing to calculate their own Zone I distance using the VFE, the proposed pumping rate, an appropriate estimate of effective porosity of the aquifer and an estimate of the saturated thickness (generally, this is the screened or open interval of the well) are needed. The time of pumping is 90 days. Equation 1 is then solved for r. If the calculation results in a distance greater than 400 feet, 400 feet is used for Zone I. If the calculation results in a distance less than 100 feet, 100 feet is used for Zone I.

Given the limited methods available for WHPA delineation using a calculated fixed radius, the VFE is the simplest method for a supplier to use to directly calculate Zone I. Another method may be considered, but it will be incumbent upon the applicant to justify its use and to demonstrate that the integrity of the Zone I concept is maintained.

## Zone I Determinations For Springs and Infiltration Galleries

As the hydraulics of ground-water flow to springs and infiltration galleries are different than flow to wells, the VFE is not a viable method for delineating Zone I areas for those sources. Unfortunately, there do not appear to be any simple equations that could be utilized for Zone I determinations for springs and infiltration galleries in an analogous manner to the VFE for wells. Because of the vulnerable nature of these sources, a more stringent approach for Zone I is justified for these sources.

For springs with flows of less than 100,000 gallons per day (gpd), Zone I is a circle extending upgradient from the spring with a 200 feet radius that is arranged such that the spring or spring's outlet is setback 50 feet from the downslope point on the circumference of the circle (Fig. 5a). For springs with flows of 100,000 gpd or more, a circle with a 400 feet radius is used (Fig . 5b). In situations where the spring is located in a flat area and there is no information on the direction of ground-water flow, the circle can be radially centered around the spring.

For infiltration galleries, Zone I will consist of a peripheral 100 feet buffer distance around the outermost extent of the collection field. Given the extent of piping used in these systems, a buffer distance of more than 100 feet could result in a fairly large area which might present difficulties in the administration of control methods.

### Regional Offices:

**Southeast Region (Conshohocken)** 484-250-5980
Counties: Bucks, Chester, Delaware, Montgomery, Philadelphia.

**Northeast Region (Wilkes-Barre)** 570-826-2511
Counties: Carbon, Lackawanna, Lehigh, Luzerne, Monroe, Northampton, Pike, Schuylkill, Susquehanna, Wayne, Wyoming.

**Southcentral Region (Harrisburg)** 717-705-4708
Counties: Adams, Bedford, Berks, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Mifflin, Perry, York.

**Northcentral Region (Williamsport)** 570-327-3675
Counties: Bradford, Cameron, Centre, Clearfield, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, Union.

**Southwest Region (Pittsburgh)** 412-442-4217
Counties: Allegheny, Armstrong, Beaver, Cambria, Fayette, Greene, Indiana, Somerset, Washington, Westmoreland.

**Northwest Region (Meadville)** 814-332-6899
Counties: Butler, Clarion, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Venango, Warren.

Pennsylvania Department of Environmental Protection
Bureau of Watershed Management
May 2004

Figure 1.

# WHPA ZONE I

Long Interval (screen/open borehole >200 feet)
High Porosity (unconsolidated sediments, sandstones, siltstones, karstic carbonate rocks)

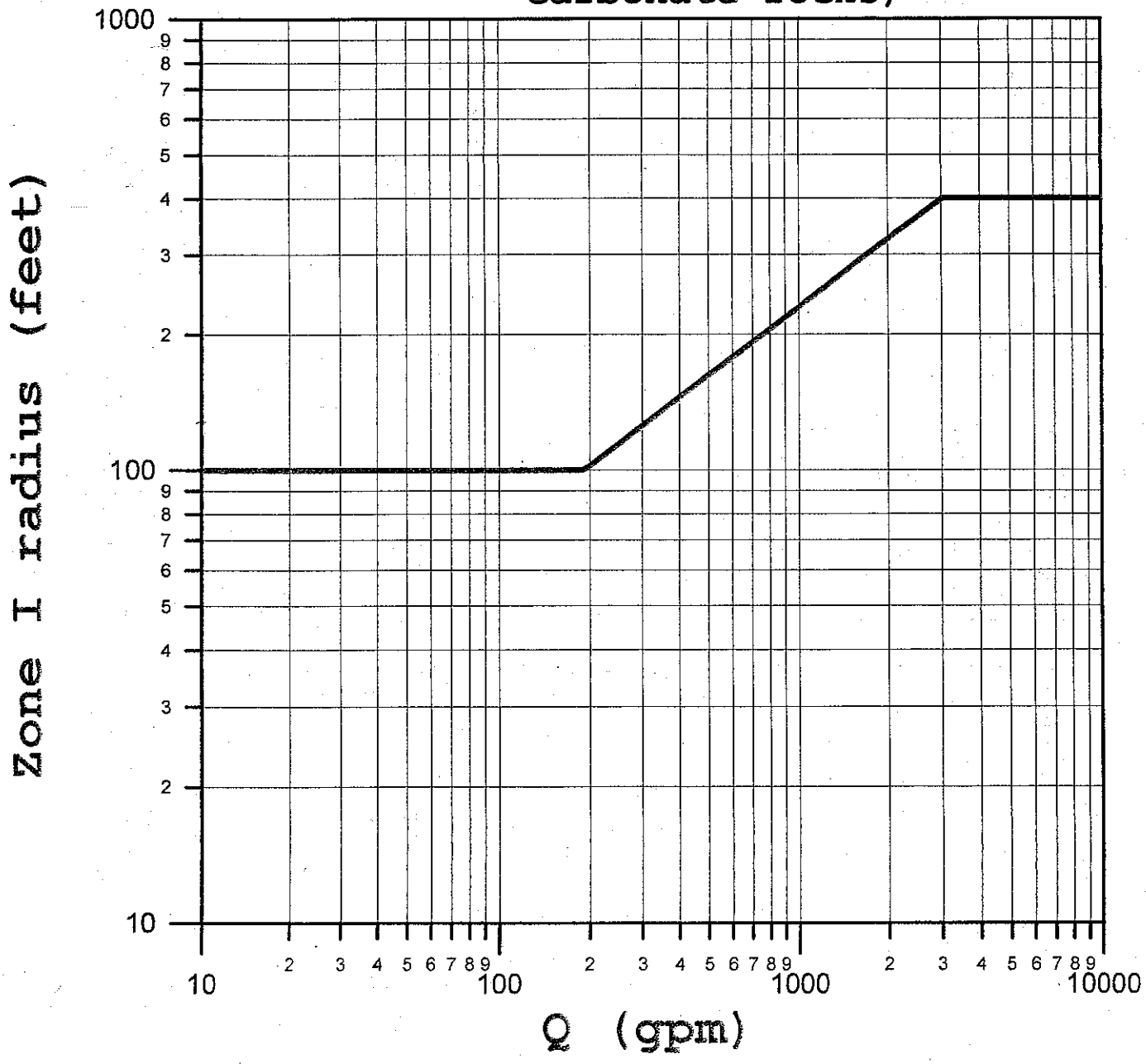


Figure 2.

# WHPA ZONE I

Long Interval (screen/open borehole >200 feet)
Low Porosity (shales, unfractured/fractured crystalline rocks, unfractured carbonate rocks)

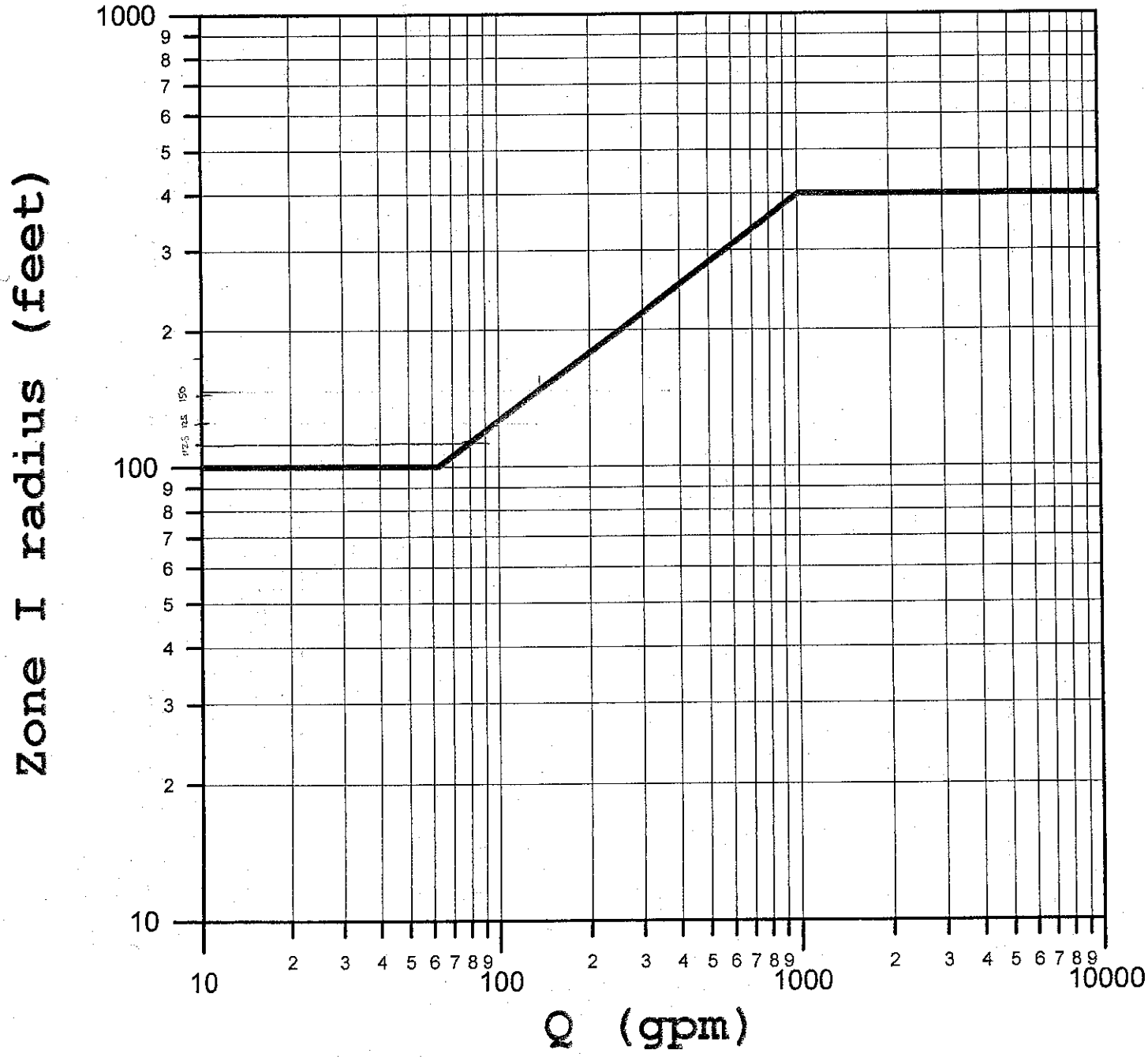


Figure 3.

# WHPA ZONE I

Short Interval (screen/open borehole <200 feet)
High Porosity (unconsolidated sediments, sandstones, siltstones, karstic carbonate rocks)

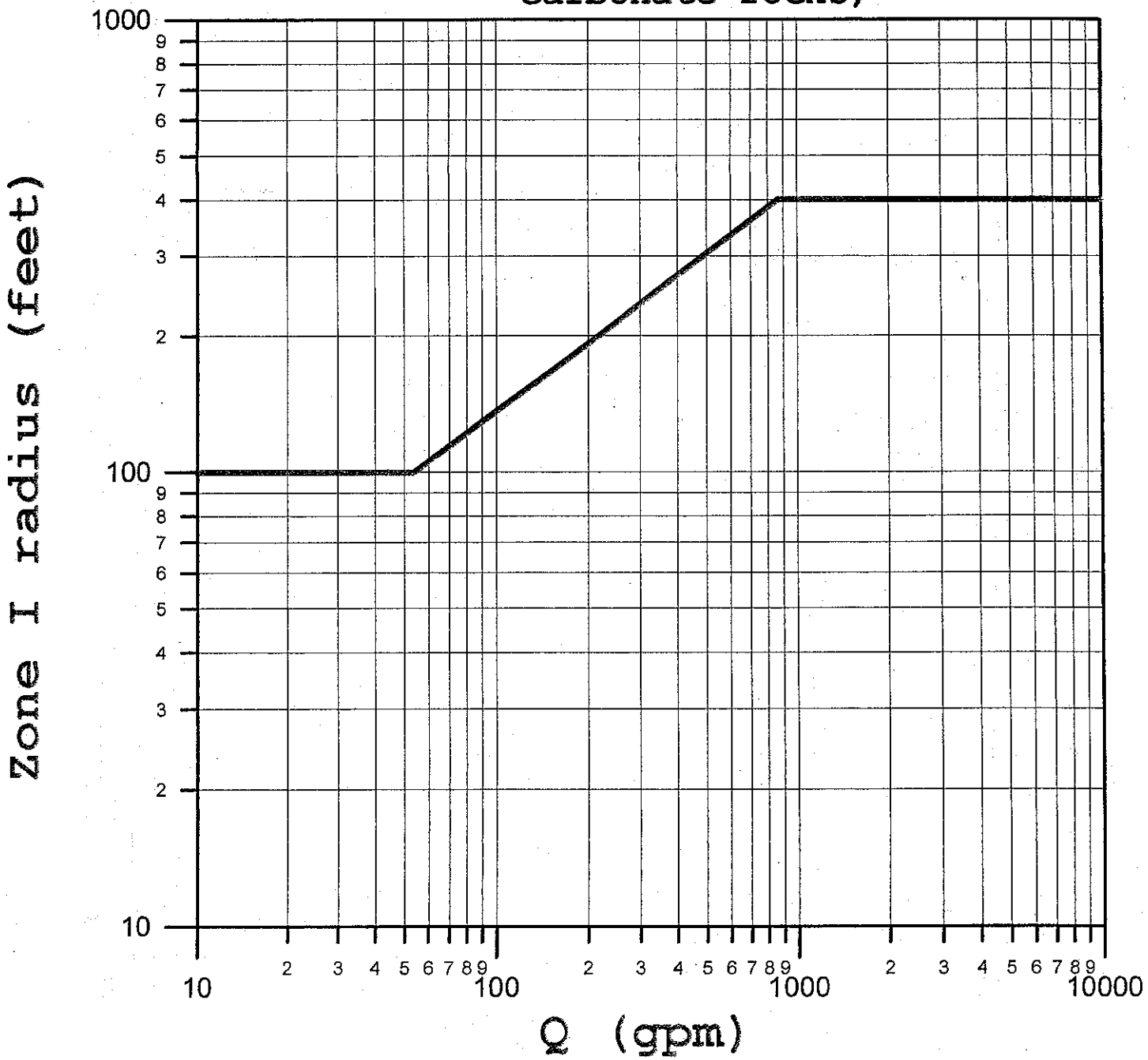
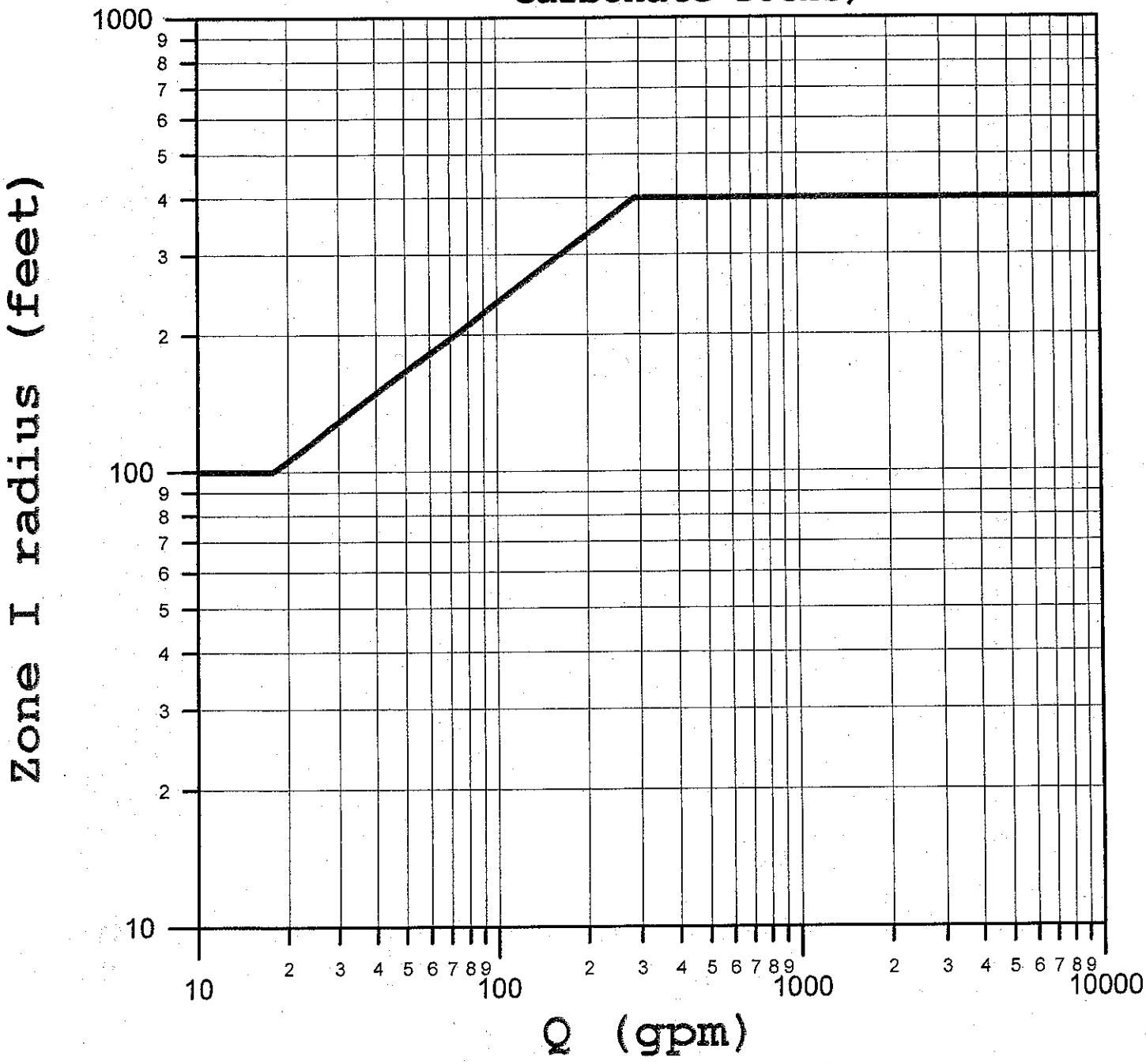


Figure 4.

# WHPA ZONE I

Short Interval (screen/open borehole <200 feet)
Low Porosity (shales, unfractured/fractured crystalline rocks, unfractured carbonate rocks)



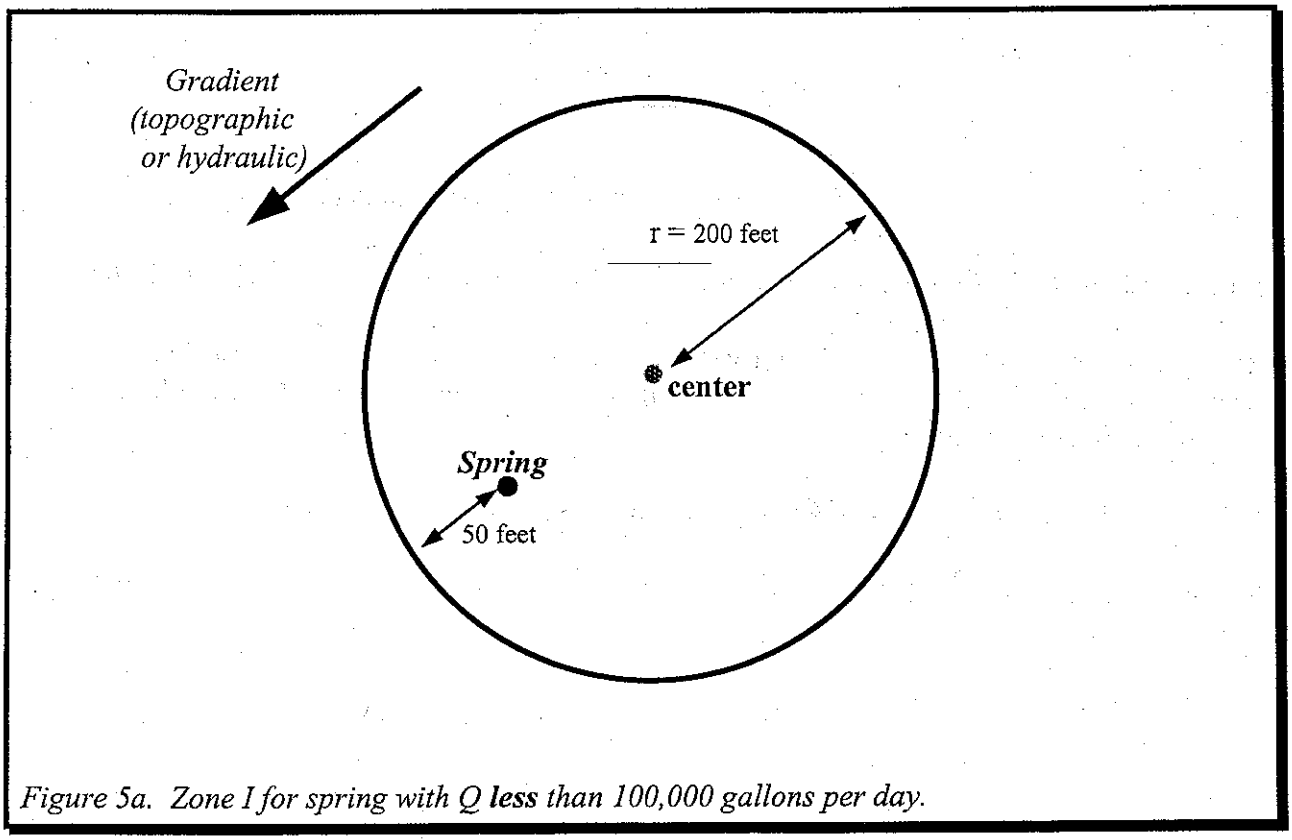



*Figure 5a. Zone I for spring with Q **less** than 100,000 gallons per day.*

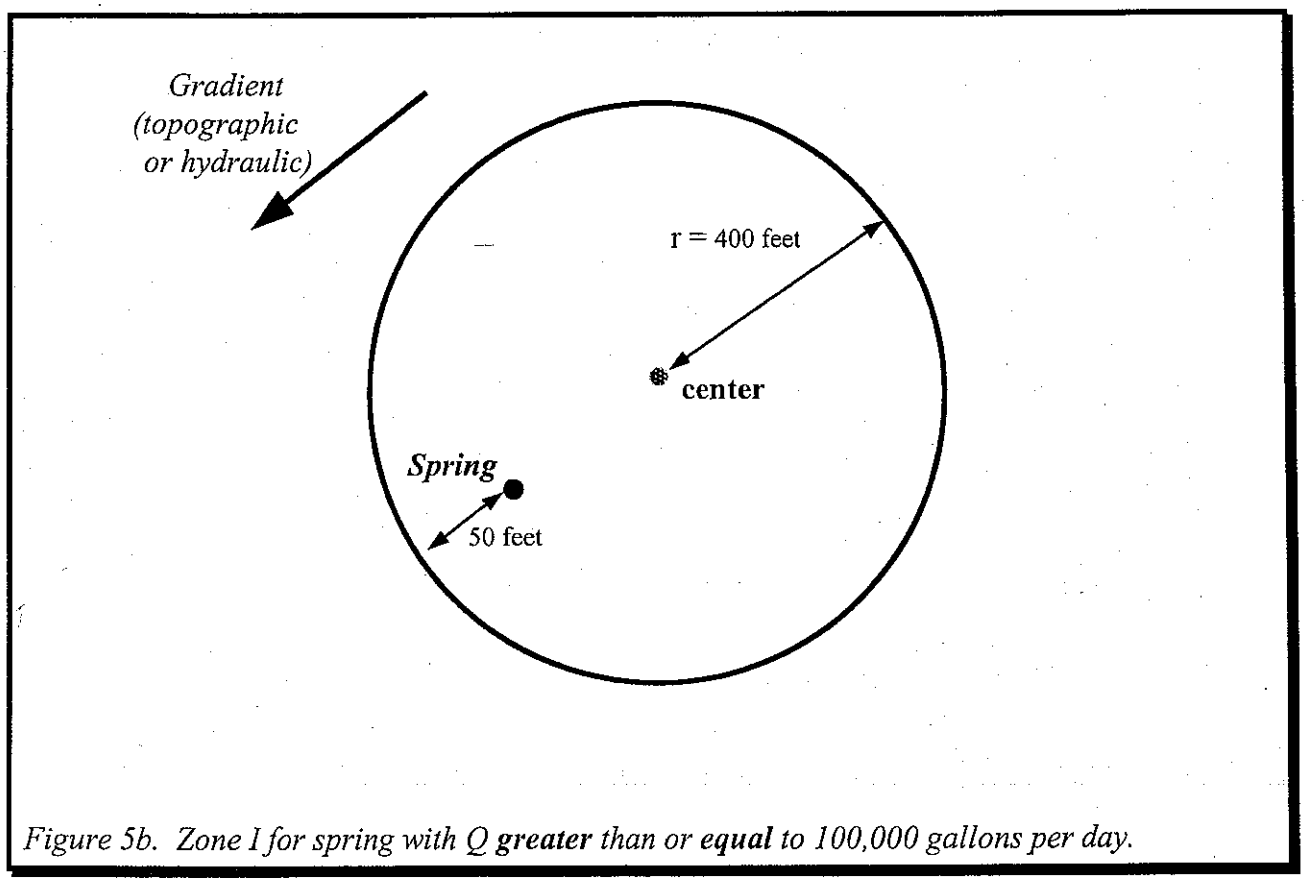



*Figure 5b. Zone I for spring with Q **greater** than or **equal** to 100,000 gallons per day.*

## REFERENCES CITED


Driscoll, F.G., 1986, *Groundwater and Wells*: St. Paul, MN, Johnson Division, 1089 p.

Freeze, R.A. and Cherry, J.A., 1979, *Groundwater*: Englewood Cliffs, NJ, Prentice-Hall, 604 p.

Risser, D.W. and Madden, T.M., 1994, Evaluation of methods for delineating areas that contribute water to wells completed in valley-fill aquifers in Pennsylvania: U.S. Geol. Survey Open-File Report 92-635, 82 p.

US EPA, 1994, Ground water and wellhead protection: EPA/625/R-94/001, 269 p.

US EPA, 1987, Guidelines for delineation of wellhead protection areas: EPA 440/6-87-010.