

floodplain elevation boundary or floodway, as defined in Federal Emergency Management Agency (FEMA) flood hazard maps), to the wellhead. The ground water flow path to a horizontal well is the measured distance from the bed of the river under normal flow conditions to the closest horizontal well lateral.

The floodway is defined by FEMA as the area of the flood plain where the water is likely to be deepest and fastest. The floodway is shown on FEMA digital maps (known as Q3 flood data maps), which are available for 11,990 communities representing 1,293 counties in the United States. Systems may identify the distance to surface water using either the 100 year return period flood elevation boundary or by determining the floodway boundary using methods similar to those used in preparing FEMA flood hazard maps. The 100 year return period flood elevation boundary is expected to be wider than the floodway but that difference may vary depending on local conditions. Approximately 19,200 communities in the United States have flood hazard maps that show the 100 year return period flood elevation boundary. If local FEMA floodway hazard maps are unavailable or do not show the 100 year flood elevation boundary, then the utility must determine either the floodway or 100 year flood elevation boundary.

The separation distance proposed for *Cryptosporidium* removal credit is based, in part, on measured data for the removal of oocyst surrogate biota in full-scale field studies. A variety of surrogate and indicator organisms were analyzed in each study evaluated for today's proposal. However, only two non-pathogenic organisms, anaerobic clostridia spores and aerobic endospores, are resistant to inactivation in the subsurface, approximately similar in size and shape to oocysts, and sufficiently ubiquitous in both surface water and ground water so that log removal can be calculated during passage across the surface water—ground water interface and during transport within the aquifer.

Anaerobic spores are typically estimated at about 0.3–0.4 μm in diameter as compared with 4–6 μm for oocysts. Aerobic spores, such as endospores of the bacterium *Bacillus subtilis*, are slightly larger than anaerobic spores, typically $0.5 \times 1.0 \times 2.0 \mu\text{m}$ in diameter (Rice *et al.* 1996). Experiments conducted by injecting *Bacillus subtilis* spores into a gravel aquifer show that they can be very mobile in the subsurface environment (Pang *et al.* 1998). As presented in the

following discussion, available data indicate similar removal of both aerobic and anaerobic spores, either during passage across the surface water—ground water interface or during ground water flow. These data suggest that anaerobic spores, like aerobic spores, may be suitable surrogate measures of *Cryptosporidium* removal by bank filtration.

Available data establish that during bank filtration, significant removal of anaerobic and aerobic spores can occur during passage across the surface water-ground water interface, with lesser removal occurring during ground water transport within the aquifer away from that interface. The ground water-surface water interface is typically comprised of finer grained material that lines the bottom of the riverbed. Typically, the thickness of the interface is small, typically a few inches to a foot. The proposed design criteria of 25 and 50 feet for 0.5 and 1.0 log *Cryptosporidium* removal credit, respectively, are based on EPA's analysis of pathogen and surrogate monitoring data from bank filtration sites. Most of these data are from studies of aquifers developed in Dutch North Sea margin sand dune fields and, therefore, represent optimal removal conditions consistent with a homogenous, well sorted (by wind), uniform sand filter.

Medema *et al.* (2000) measured 3.3 log removal of anaerobic spores during transport over a 13 m distance from the Meuse River into adjacent ground water. Arora *et al.* (2000) measured greater than 2.0 log removal of anaerobic spores during transport from the Wabash River to a horizontal collector well. Havelaar *et al.* (1995) measured 3.1 log removal of anaerobic spores during transport over a 30 m distance from the Rhine River to a well and 3.6 log removal over a 25 m distance from the Meuse River to a well. Schijven *et al.* (1998) measured 1.9 log removal of anaerobic spores over a 2 m distance from a canal to a monitoring well. Using aerobic spores, Wang *et al.* (2001) measured 1.8 log removal over a 2 foot distance from the Ohio river to a monitoring well beneath the river.

During transport solely within shallow ground water (*i.e.*, not including removal across the surface water-ground water interface), Medema *et al.* (2000) measured approximately 0.6 log removal of anaerobic spores over a distance of 39 feet. Using aerobic spores, Wang *et al.* (2001) measured 1.0 log removal of aerobic spores over a 48 foot distance from a monitoring well beneath a river to a horizontal well lateral.

At distances relatively far from an injection well in a deep, anaerobic aquifer, thereby minimizing the effects of injection, Schijven *et al.* measured negligible removal of anaerobic spores over a 30 m distance. However, few bank filtration systems occur in deeper, anaerobic ground water so these data may not apply to a typical bank filtration system in the United States.

These data demonstrate that during normal and low surface water elevations, the surface water-ground water interface performs effectively to remove microbial contamination. However, there will typically be high water elevation periods during the year, especially on uncontrolled rivers, that alter the nature and performance of the interface due to flood scour, typically for short periods. During these periods, lower removals would be expected to occur.

Averaging *Cryptosporidium* oocyst removal over the period of a year requires consideration of both high and low removal periods. During most of the year, high log removal rates would be expected to predominate (*e.g.*, 3.3 log removal over 42 feet) due to the removal achieved during passage across the surface water-ground water interface. During short periods of flooding, substantially lower removal rates may occur (*e.g.*, 0.5 log removal over 39 feet) due to scouring of the riverbed and removal of the protective, fine-grained material. By considering all time intervals with differing removal rates over the period of a year, EPA is proposing that 0.5 log removal over 25 feet (8 m) and 1.0 log removal over 50 feet (16 m) are reasonable estimates of the average performance of a bank filtration system over a year. This proposal is generally supported by colloidal filtration theory modeling results using data characteristic of the aquifers in Louisville and Cincinnati and column studies of oocyst transport in sand (Harter *et al.* 2000).

Wells must be continuously monitored for turbidity

Under the Surface Water Treatment Rule (40 CFR 141.73(b)(1)) the turbidity level of slow sand filtered water must be 1 NTU or less in 95% of the measurements taken each month. Turbidity sampling is required once every four hours, but may be reduced to once per day under certain conditions. Although slow sand filtration is not bank filtration, similar pathogen removal mechanisms are expected to occur in both processes. Just as turbidity monitoring is used to provide assurance that the removal credit assigned to a slow sand filter is being realized, EPA