EXHIBIT B

Effect of Roof Material on Water Quality for Rainwater Harvesting Systems

SCOPE OF WORK

The main objective of the proposed work is to provide recommendations to the rainwater harvesting community in Texas regarding the selection of roofing material for rainwater harvesting and to support these recommendations with scientific data. To achieve this objective, we will first identify roofing materials that are commonly used in Texas in general and roofing materials that are commonly used in Texas for rainwater harvesting. A subset of these commonly used materials will be investigated in the field; these will include traditional roofing materials (e.g., composition shingles, galvanized metal) and alternative roofing materials (e.g., green roofs). In addition, runoff sampling events will be conducted at two existing full-scale roofs. The chemical and biological quality of rainwater harvested from these different roofing materials will be assessed. Tasks 1-4, described in detail below, will be used to accomplish the research objective.

Task 1. Survey of roofing materials commonly used in Texas (3 months).

Other studies have looked at the effect of roofing material on harvested rainwater quality (e.g., Kingett Mitchell (2003) study in New Zealand), but common roofing materials and coatings will vary across the country and the world. We have found only one preliminary study in Texas on the effect of roofing material on harvested rainwater quality (Chang and Crowley, 1993); this study showed that residential roofing materials can negatively impact the water quality in roof runoff, with wooden shingles yielding the worst water quality and terra cotta clay yielding the best water quality. Since roofing materials are key to the water quality of harvested rainwater, the purpose of Task 1 is to undertake a thorough review of the roofing materials used in Texas in general and of the roofing materials used in Texas for rainwater harvesting. Also, it will be noted what products are commonly used to adhere, seal, or coat the roofing materials; this information is important for two reasons: 1. To determine if these products are suitable for use with potable rainwater harvesting systems, and 2. To determine what organic or inorganic contaminants might be released. This task will be guided by Professor Cindy Menches (Construction Engineering Project Management at the University of Texas at Austin), who has experience with a variety of roofing materials and extensive contacts in the construction industry. Information regarding common roofing materials in Texas will be sought from a variety of sources including the National Roofing Contractors Association and from roofers and home builders in Texas. At the end of this task, the results will be shared with the appropriate TWDB staff so that they may have input to the selection of materials for Task 2.

Task 2. Test roofs (9 months).

Based on the results of Task 1, several roofing materials commonly used in Texas will be used for the construction of test roofs (approximately 4 m x 1 m) on plywood frames. Material procurements and test roof construction are estimated to take 3 months. The test roofs will be set up outside at the Lady Bird Johnson Wildflower Center (see attached letter of support), which will allow us to incorporate the effects of dry weather atmospheric deposition, sunlight, moisture changes, and temperature changes. If the graduate student on the project does not have routine access to a car, the test roofs will be set up outside at the Pickle Research Campus of the University of Texas at Austin.

One of each of the following types of roofing materials will be examined: composition shingle, metal, tile, and green. Given the increased attention on energy efficiency and "green engineering", green roofs (i.e., essentially a layer of soil and vegetation in place of traditional roofing materials) are receiving greater attention and will be examined in this study. Six different green roofs are already in place at the Lady Bird Johnson Wildflower Center, and one of these will be chosen for analysis in this study. This choice will be made in conjunction with input from the TWDB staff and based on some of the water quality data that have already been collected for the green roof study.

Each test roof will be mounted on an angled test stand (see Figure 1). The base of each test roof will be equipped with a gutter into which a simple sampling device will be installed. This insert will consist of a clean PVC (potable quality) pipe that has been cut lengthwise in half and fitted with end caps. PVC pipe will be used to direct rainwater collected from the sampling insert to a passive collection system (Figure 1) that consists of a 5- to 10-L container to collect the "first flush" and a 20-L container to collect a representative sample after the first flush. The length of the sampling insert can be adjusted to collect water from approximately 2.5 m^2 area of roof. An experimental set-up similar to this design was successfully utilized in another study that examined water quality from rooftop-harvested rainwater (Kingett Mitchell, 2003).

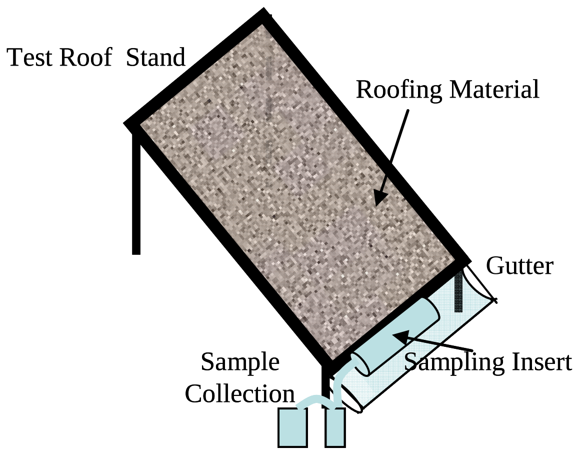

Figure 1. Sampling Apparatus and Test Roof Set Up for Harvesting Rainwater

Natural rain events will be used in this task; over the course of 6 months, samples will be taken during 3 rain events. If insufficient rain occurs during the project period, synthetic rainwater will be utilized. The runoff from all events will be analyzed for pH, conductivity, turbidity, total solids, selected metals, nitrate, and total and fecal coliform. In addition, the runoff from 2 of the rain events will be analyzed for selected synthetic organic contaminants. Thus, these data will allow us to analyze the water quality generated by several roofing materials in the natural environment (i.e., that are exposed to atmospheric deposition, UV radiation, and moisture and temperature changes).

As data is collected for this task, one of the roofs generating the best water quality will be analyzed in a more detailed fashion. Time-course samples will be taken for these roofs to determine concentrations of pollutants over time in the run-off. Therefore, these data will allow us to examine how much "first flush" water should be diverted away from a storage tank.

Task 3. Field sampling (9 months).

This task will examine the water quality of roof runoff from existing roofs in the Austin, Texas area. The two existing roofs that will be sampled are as follows: 1. Metal roof at the home Professor Hillary Hart from the Environmental and Water Resources Engineering Program at the University of Texas at Austin (Aluminum-coated galvanized steel roof <Galvalume>); 2. Composition shingle at the home of Professor Mary Jo Kirisits from the Environmental Water Resources Engineering Program at the University of Texas at Austin.

These roofs will be sampled at two rainfall events, and the same analyses will be conducted as described in previous task: pH, conductivity, turbidity, total solids, metals, nitrate, total and fecal coliform, and selected synthetic organic contaminants. These data will allow us to look at roofs in the environment that are older than the roofs constructed in Task 2.

If time permits, we also will look at the microbial communities that are present in harvested rainwater. To do this, we will take one runoff sample from the 2 existing roofs in the field, extract DNA, and do microbial community fingerprinting analyses to see how the microbial community changes. This analysis will be done with terminal restriction fragment length polymorphism (T-RFLP); it is performed routinely in the PI's lab, so all necessary expertise is in-house. These data will allow us to compare the composition of the microbial communities between different roofing materials. For example, if a roofing material is treated with copper or zinc, we might expect to see a reduced diversity in the microbial community on that roof.

Task 4. Final report (3 months).

This task will include the preparation and submission of the final report for the research. The report will include a summary of the roofing materials, coatings, and guttering that are commonly used in Texas in general and those that are commonly used in Texas for rainwater harvesting. The report also will include a summary of the experimental data that are generated, including the inorganic and organic contaminants present in harvested rainwater from a variety of roofing materials. The data will be analyzed to provide recommendations regarding roofing materials for rainwater harvesting.