SPECIFICATIONS FOR DRILLING AND CASING BOREHOLES FOR P-S SUSPENSION LOGGING

1. Drilling must be done with minimal sidewall disturbance. We strongly recommend the rotary mud or rotary wash method. This method does little damage to the borehole wall, and the drilling fluid coats and seals the borehole wall reducing fluid loss and wall collapse. Drilling borehole diameter should not exceed the outer diameter of the casing by more than 100mm.

2. If the borehole must be cased, the casing must be PVC and properly installed and grouted. Any voids in the grout will cause problems with the data. Likewise, large grout bulbs used to fill cavities will also cause problems.

3. Casing must be about 100mm (4 inches) diameter, Schedule 40 PVC. This thickness and strength is necessary to minimize collapse due to the pressure of the grout. It is usually best to grout the casing while the casing is full of water to help minimize the differential pressure on the outside of the casing. The casing should be inserted with spacers or centralizers to keep the casing centered in the borehole.

4. The best way to grout the casing is through a small PVC pipe inserting through the casing and connected to a one-way ball-check valve in the bottom cap of the casing. Make sure the pump is capable of pumping grout all the way down to the bottom through the small pipe and up to the top of the borehole. Grout is then pumped down through the small pipe and fills up the annulus around the casing from the bottom to the top. Once the grout has filled the annulus around the casing up to the top, pumping is stopped, and the pipe disconnected from the valve and removed. The casing can be rinsed and flushed with water.

Alternatively, a small PVC pipe (1-1/2 inch, or 35mm), called a tremie tube, can be fed down the side of the casing between the casing and the borehole wall. Once the tremie tube reaches the bottom of the borehole, grout can be pumped through the tremie tube and grout filled from the bottom of the borehole.

Alternatively, the borehole can be partially filled with grout, and the capped casing forced down into the grout filled borehole until it reaches the bottom. Ideally the grout volume is calculated so that when the casing is fully inserted the grout is at the top of the borehole. In this method it helps to have the casing full of water.

All of these methods attempt to fill the annular space with grout all the way, top to bottom, with no voids, displacing the mud and debris with minimal sidewall disturbance.

5. The grout mixture should be formulated to approximate closely the density of the surrounding in-situ material after solidification. For rock, use conventional portland cement that will harden to a density about 2.2Mg/m^3 (140lb/cubic ft).

For soils, sands, or gravels, use a mixture with:
- 450g (1lb) bentonite
- 450g (1lb) portland cement
- 2800g (6.25lb) of water.

6. Keep the casing anchored and centered in the borehole until the grout is set. If shrinkage occurs, additional grout should be inserted from the top until the annular space is filled flush with the ground surface.

7. The grout must be set before testing. This means the grouting must take place at least 48 hours before testing.

8. Borehole fluid is required for the logging. The PVC must be filled with water prior to logging. If there is a leak, then water must be available to refill the borehole prior to and/or during logging. Major leaks cannot be allowed because the seismic noise accompanying such rapid water loss will obscure data and prevent data acquisition.
ceeding 6.0 m [20 ft] so that closure can be determined at the mouth of the borehole.

4.2.2 Optional Method—If the scope of a project dictates the use of the optional procedure described in 4.1.2, the following precautions must be undertaken to ensure verticality of the bores.

4.2.2.1 Level the borehole drilling apparatus using a level placed on the drill stem extending into the mouth of the borehole.

4.2.2.2 As drilling progresses, recheck the drill stem at 3.0 m [10 ft] depth intervals and realign as necessary.

4.2.2.3 Limit the maximum depth of investigation to less than 15 m [50 ft]. If the depth of investigation exceeds 15 m [50 ft] a deviation survey such as described in 4.2.1 must be conducted.

4.2.2.4 If casing is used, grout as described in 4.1.1, then evacuate all fluid from the interior and insert a lighted plumb-bob observing its attitude at 3-m [10-ft] intervals. If the plumb-bob strikes the sidewall, note that depth and the direction of deviation.

4.2.2.5 Estimate the distance between borings and provide appropriate caution statements on all data.

4.3 Crosshole Test:

4.3.1 Preferred Method—Begin the crosshole test by placing the energy source in an end hole at a depth no greater than 1.5 m [5 ft] (Fig. 3) into the stratum being investigated. Place the two receivers at the same elevation in each of the designated receiver holes. Clamp the source and receivers firmly into place. Check recording equipment and verify timing. Activate the energy source and display both receivers simultaneously on the recording device. Adjust the signal amplitude and duration such that the P-wave train or S-wave train, or both, are displayed in their entirety.

4.3.1.1 Best results will be obtained by performing two separate tests: one optimized for P-wave recovery (fastest sweep/recorder rate, higher gain settings) and the second for S-wave recovery (slower sweep/recorder rate, lower gain settings). If enhancement equipment is being used, repeatedly activate the energy source until optimum results are displayed. Do not overrange memory circuitry. A clipped signal is unacceptable. Perform the second test by lowering the energy source and receivers to a depth dictated by known stratification, but no greater than 1.5 m [5.0 ft] from the previous test locations in the borings and repeat the above procedure. Perform succeeding tests at intervals determined by stratification, or at intervals of 1.5 m [5 ft] until the maximum borehole depth has been reached. During withdrawal of the energy source and receivers from the boreholes, perform repeat tests at 6.0-m [20-ft] intervals until the ground surface is reached.

4.3.2 Optional Method—Use a minimum of two boreholes. If, however, only two boreholes are used, the importance of true zero time determination as described in 3.1.3 cannot be overemphasized. Place the energy source in one borehole at a depth dictated by test objectives and the receiver at the same elevation in the second borehole. Activate the seismic source and display the trigger mechanism and the receiver simultaneously on the recording device. Adjust the sweep rate so that the P-wave train or S-wave train, or both, are displayed in their entirety. If