The primary and secondary vertical control networks at APS are maintained by traditional double-run differential leveling utilizing invar staffs and a DNA03 digital level from Leica. We also used NA3003 in the past. Each leg in the network (Fig. 1) is measured as a loop with each individual station also measured as a mini-loop (BFBF method). The turn points (TP) are fixed for the primary control network and there is an odd number of TPs between the benchmarks (BM) in each leg. Leica’s digital levels provide firmware for multiple measurements modes, BFBF method, enforcement of tolerances like distance balance, maximum distance, lowest staff height, permitted station differences, maximum difference for double observation (BI-B2, FI-F2), and loop closure [1].

In order to embed certain BM attributes in the data file, we have adopted a naming scheme for all the measured points. The standard ID format is ‘ADDIOD’, where ‘A’ indicates an alphanumerical character, and ‘D’ is a digit (0-9). The first character ‘A’ is an indicator for the BM location as well as the BM type. Since all benchmarks starting with the same character are of the same physical construction, the point’s offset constant (i.e., what the staff is resting on) can be determined from the ID of the point (Table 1). To store supplementary data with the measurements, we utilize the coding feature of Leica instruments. When measuring the level loop, a technician enters the CODE J data block (staff-1 S/N, staff-2 S/N, and data) before starting the level loop (highlighted yellow in Fig. 2). As an administrative policy, we always enter the staff with the lower S/N as staff-1 and start the new loop with staff-1.

The shading column added for backward compatibility.

The leveling data is stored in Leica’s GSI-X format [2] on a Compact Flash card and then uploaded to a PC (Fig. 2) for two-step data reduction. The GSI raw data file is first processed with the DNAGEO program. DNAGEO checks the internal integrity of the data, appends level rods with point-based offsets, and basically translates a GSI file into an IVL file format (Fig. 3). The IVL file is identical to the INLEVEL file that would have been created if a laptop and the old SEAC’s DCM data collection programs had been used [3]. This step is not necessary, but we have used DCMV in the past and wanted to maintain an option of backward compatibility with the proven data processing software.

The preprocessed leveling data from the IVL-type file obtained from step one is further reduced with the LEVRED2 tool. Program LEVRED2 requires access to an auxiliary external file BBD.DAT containing leveling staffs calibration data. LEVRED2 creates two files—a file with extension LEVS and a file with extension LOOPS. The LOOPS file (Fig. 4) contains a summary of the level loops—lists the BMs in the loop, number of stations, loop closure, and reference sigma. A reference sigma is a standard deviation of the vertical difference of the loop based on 50 microseconds per station propagated over a number of stations in the loop. Loops with closures exceeding this value are flagged for closer inspection. The LEVS file (Fig. 5) lists the starting and ending BM for each leg, the vertical difference between these BMs corrected for monument offset, the leveling staff’s calibration offset, a standard deviation for the leg, and the number of stations in the leg. The LEVS file is in a format compatible with the input for a least-squares adjustment program like TIBF or TIBR [3], which we continue to use for vertical control network adjustment.

In addition to the vertical control network, we use digital levels for mapping in APS subsystems. Appropriate methodology, codes, and processing tools were developed to simplify these repeatable tasks. For example, in the APS storage ring, twenty sequential points per sector are measured in forty repeating sectors. This job is accomplished by measuring one station setup with twenty side shots in each sector (Fig. 6). The GEOMATIC tool then translates the GSI measurement file, retrieves the BM elevation and rod calibration data, checks the loop closure, and generates actual fiducial names and their elevations (Fig. 7). The influence of collimation error on sideshots of unequal distances is kept within reasonable limits by the calibration procedure performed daily before the magnet mapping.

The APS Survey and Alignment group wanted to free themselves of laptop data collectors when performing differential leveling. We have developed and implemented a simple solution that we have been using now for several years with positive feedback from our technicians. This could not have been accomplished without great support from APS/SA group leader Horst Friedsam and APS/SA technicians Kim Nisi, Sheel Myers, and Keith Knight who methodically tested the procedure during the development stage.

REFERENCES

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Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

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