

STEP BY STEP PROCESSING OF ALTIMETER TRAVERSES

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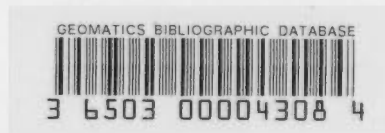
January 1981
Rev. October 1982

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1981
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FORWARD

The altimeter processing instructions were intended for use by staff of the Supplementary Control Section, Geodetic Survey Division, using a HP9830A desk-top computer with 16K memory and the "Basic" program "Altimeter Processing", written by Peter Lawnikanis in 1978. Therefore, it is assumed that the user of these instructions is familiar with this computer and program. For those who are not, the following still provides a wealth of information on field procedures, data processing and accuracy evaluation of altimeter surveys.

1. PREPARATION

1.1 Assembling the Data

Determine the area to be adjusted. Locate and assemble all field data including: field notes (altimeter, spirit levels & other related special surveys); base barometer notes and graphs; field computations; relevant maps, aerial photographs and any other pertinent information (ie. altimeter calibration graphs). Check to ensure that all notes are included and that no information is missing. (This is best done using maps, with pens of different colors to "color in" the altimeter lines on the map according to how they appear in the notes). This method also facilitates easy reference to map or notes later on, while processing.

Field notes must be prepared for input to a cassette storage tape. This usually involves scaling the straight line distance between control points and calculating a "smoothed" gradient correction. This data is then entered in appropriate columns on the field sheets and the data is ready for input.

1.2 Preparing the Program

Begin by placing the program tape in the HP9830. Load the program by keying the sequence: "LOAD X", "EXECUTE" and then "RUN" "EXECUTE" (Where X is the file # where program resides). The program is now in memory. It will flash a reminder for you to set the Line Printer to the top of the page. After doing so, press "END". You will now change the HEADER which is stored in the main program. Note that allowable field length for input of header information is the length of the display. Characters beyond this length will be truncated. Changes must be invoked by lines numbers (each individual change must be terminated by the "END-OF-LINE" key). *When the final header is changed to the appropriate job name press "END-OF-LINE", "END", "INITIALIZE", "CONTINUE 140", "EXECUTE". Now you must write this version of the program on a new tape (especially for this project) by:

- (a) - Marking the file lengths on the new tape.
- (b) - storing the program on tape.

To mark the files simply rewind the blank tape to the beginning. Key in: "MARK 1, 20", "EXECUTE"; "MARK 1, 500", "EXECUTE"; "MARK 1, 3000", "EXECUTE"; "MARK 1, 500", "EXECUTE". Remember to wait between each EXECUTE command for keyboard control.

Rewind the tape to the beginning and key in: "STORE 1", "EXECUTE"; and, when control returns: "STORE KEY 2" "EXECUTE". The altimeter program is successfully stored on the cassette tape (ensure that write-enable tabs are down). Appendix A gives a sample of Header Changes.

*Remember to change the LOAD KEY statement to "LOAD KEY 2", retaining the same line number.

2. ENTERING DATA

2.1 Input

Place the altimeter processing template around the Function Keys and depress the Key marked "INPUT". The display will ask "TEMPERATURE °C or °F". "EXECUTE" the appropriate letter. Next, ENTER the appropriate header information: "DATE", "EXECUTE"; "MAP", "EXECUTE"; "LINE", "EXECUTE"; "OBSERVER", "EXECUTE". Then "EXECUTE" a zero to terminate header input. This input will start over if anything else is entered.

After terminating header input the program will request that you input each line of data in the following order: "POINT, TIME, TEMP, DISTANCE, ALT #1, ALT #2, ALT #3, & GRADIENT CORRECTION".

These can be input in a string, separated by commas, or input individually. After each line of data is entered the display asks for another line, and so on. When all data has been entered, terminate input by entering a string of all zero's. This must be done to exit the input routine.

When entering station identifiers use numeric values only. Station numbers in the range 1000.00 to 9999.99 are used for control stations and values below 1000.00 for altimetric (new) points.

Care must be exercised when entering distances. If there are two consecutive readings at one station the same distance cannot be entered twice in a row. This is a program bug (the program will not accept a zero distance difference between two successive points). This problem can be circumvented by adding +0.01 to the second distance (note: this will cause no change in the results, but it will ensure that you get them).

2.2 Storing the Data on Tape

Verify the input. If all input is correct, then the edit mode can be exited and the "WRITE" mode entered by "EXECUTING" a zero. If you require corrections, then the appropriate line #'s should be executed.

When in the "WRITE" mode, enter the tape # and file # on which you wish to place the data (ie. "1,5", "EXECUTE"). The tape drive will advance to that spot on the tape. The display will show "WRITING TAPE 1, FILE 5?". In order to complete the writing process you must press: "CONTINUE", "EXECUTE".

NOTE: All data must be written on odd numbered files; ie. 5, 7, 9, 11, 13, etc. This is because the file length is variable and the length of each file is recorded (with the header information) in the even numbered file preceding it.

Refer to figure 1 for a description of file storage.

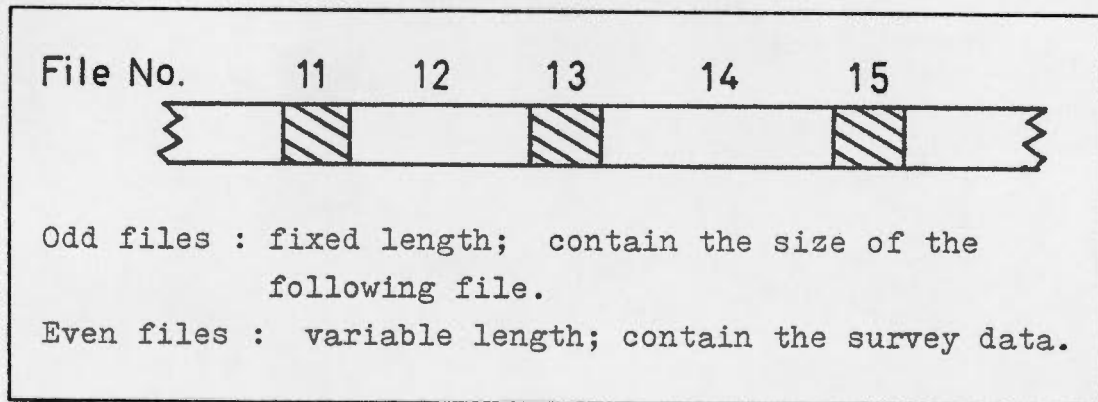


FIGURE 1: Storage Files

2.3 Rewriting Files

Files may be rewritten without destroying those before and after its storage location only if the following instructions are followed.

- a) No more than one line may be added to the original data set. ("n" can only be increased by a maximum of 1).
- b) When writing, a negative sign must be placed in front of the file number. (This prevents the program from marking the next file, since it is already marked and it contains the file length of the data file which it precedes.)

When a command is entered to execute a WRITE (or READ) file 11 (for example) the program will first WRITE (or READ) file 11 with information concerning the amount of data (length) on file 12. In the case of a WRITE statement it will normally then write file 12 and mark a blank file 13. This is useful when you ask it to write file 13. It will then go to file 13 whereupon it will mark the file size of file 14, etc. If file 13 had not been marked at all, further use of the tape for data storage would have been impaired. When you are rewriting an existing file in the middle of a series, the use of the negative sign prevents destruction of information which for example might have been stored in file 13. (REFER to figure 2).

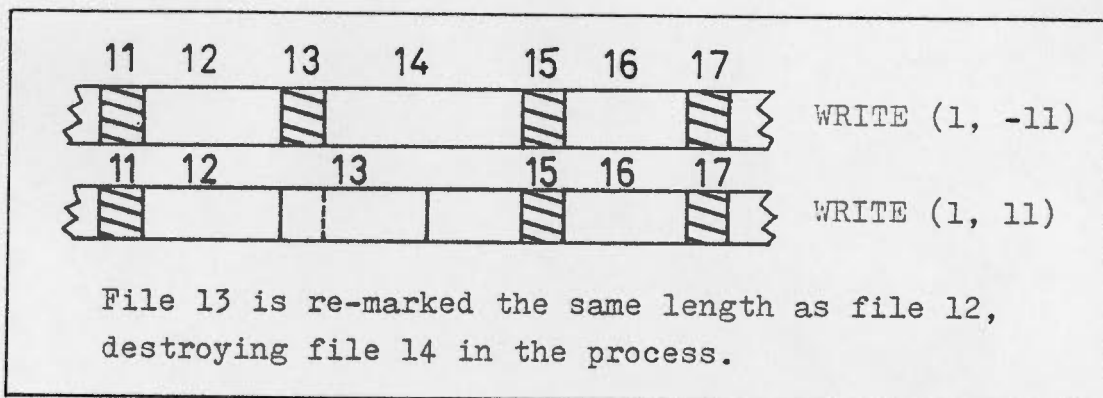


FIGURE 2: Rewriting File 11

2.4 Editing Data

When the EDIT key is accessed, you will be given the options: "CON, REP, OVL, MRG, INS, LST, END". These options are:

- a) CON - this means "CONTINUE" ... it allows the user to continue adding to the file, as many lines at a time as are required without the need of starting over from the beginning. (NOTE: this file cannot be rewritten in the same file space if more than one line is added.)
- b) OVL - this is an "OVERLAP" statement. It allows the user to remove any chosen line without adversely effecting the remaining data. (It is used to negate the effect of large time gaps between readings at a common point.) (i.e., if stopped for gas, the pressure will change. The observed readings at the start and end of the delay can be used to shift all subsequent data as if no delay had occurred. Use of this option is also referred to as "removing overlaps".)
- c) MRG - this is a "MERGE" statement. It permits you to connect two files which were entered separately, but were actually run consecutively in the field.
- d) INS - this is an "INSERT" statement. It enables the user to add one single line to the desired file. The line can be added anywhere it is desired.
- e) LST - "LISTS" the file currently in memory.
- f) END - "EXITS" the EDIT subprogram key.
- g) REP - This allows you to "REPEAT" the entry for any chosen line simply by entering the observation #. This is useful to correct erroneous data already entered.

2.5 Verification of Data

Once the input of a data set has been completed, the operator should list the file on the printer. Further checks will be necessary to ensure detection of any transcription errors. The hard copy will aid in this verification process.

Once an error has been discovered the operator must:

- a) Read the file from the data tape into the HP9830 memory.
- b) Press "EDIT" key to obtain access to the six individual editing subroutines.
- c) Select the appropriate option.

For example, if there is a simple transcription error affecting one line, you can retype the line by following these steps:

- i) select "REP" for repeat and specify temperature used.
 - ii) enter the appropriate line number (refer to hard copy)
 - iii) re-enter the complete, corrected line.
 - iv) repeat steps ii) and iii) as often as required.
 - v) When corrections are complete enter "0" (zero) to end edit "REP" routine. (**NOTE: this step is essential!)
 - vi) Enter "E". This ends the subprogram.
- d) Press "WRITE" key ... (remember that the correction(s) you have made are not yet recorded on the permanent file)
 - e) Enter the same (Tape, File) as was read in step (a), being sure to put a negative sign before the file number

3. DIAGNOSTIC FLAGS

3.1 Checking Altimeter Readings

The altimetry program performs a check on the three readings while computing a mean value. When an inconsistency in reading differences is noted (in excess of ten feet) the program generates a flag. This flag takes the form of a negative sign and is printed immediately to the left of the individual altimeter reading which is suspected to be the outlier.

3.2 Generating Flags

There are two separate ways in which the altimeter reading are checked against each other. In each case, the differences between each altimeter reading are checked for consistency. Figure 3 illustrates how this is done.

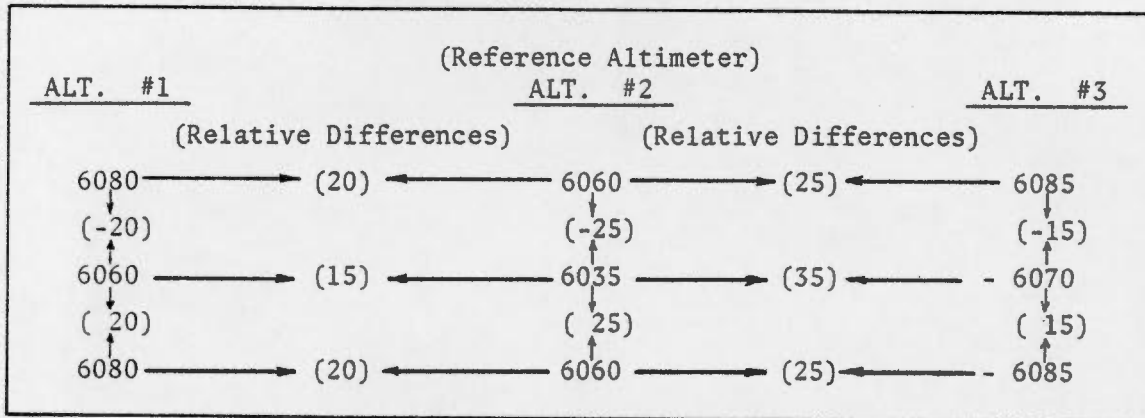


FIGURE 3: Generating Flags

a) Method # 1:

When the first line of information is input, the program compares the three altimeter readings to each other to establish their relative differences. The second altimeter reading is used as a reference for these comparisons. For each successive line of input this comparison is repeated. The relative difference should be consistent (within 10 feet). If there should happen to be an inconsistency greater than or equal to ten feet the suspected reading will be flagged.

b) Method # 2:

Because every altimetric point is normally at a different elevation, the individual altimeter readings will increase or decrease according to the relative shift in elevation. Should one of the shifts differ from the other two by ten feet or more, then a flag will be placed beside that reading.

3.3 Investigating Flags

When a flag appears, the program is simply bringing to our attention those readings which are inconsistent. We immediately know that the discrepancy is ten feet or more. As part of the verification process the operator must check into these flags.

- i) Calculate the spread which generated the flag. (Use "RAW" data ... field notes)

- ii) Determine if the inconsistency is a gross reading error or due to incorrect input.
- iii) If it is a gross error and it cannot be resolved then the point or individual altimeter reading must be omitted and this information must be noted in the final results.
- iv) If it is not a gross error then indicate on the printout that it has been checked and corrected, if necessary. Please note that when altimetry is run with 16 000 foot altimeters the disagreement should be at least 20-25 feet before rejection is considered.

4. PROCESSING THE DATA

4.1 Preparation

Check the comments column of the field sheets for pertinent information. For example, have any control points been observed outside the helicopter?; above or below the station marker?

If the answer to either of these questions is "yes", then the appropriate correction must be calculated and applied to the control elevation.

ie. If reading was taken 3 feet above the survey marker then the known elevation should be increased by 3 feet.

4.2 Adjusting a Traverse

Altimeter points which have known elevations are referred to as control points. When an adjustment is being performed these control points can be assigned elevations (constrained).

The adjustment program recognizes control points as any station number in the range 1000 to 9999. As these numbers are encountered in the adjustment, the program will allow a fixed elevation to be assigned to these points, if desired.

The steps to be followed in adjusting a file are:

- i) Read the file from the data tape into the memory of the HP9830 (if not already in memory).
- ii) Press the f2 adjustment key.
- iii) Enter the fixed elevation which corresponds to the numeric "STATION" name which appears on the screen. If that particular station is not to be held fixed, then enter a "-99" instead of a fixed elevation.
- iv) Repeat Step (iii) as each control point is located and displayed. When the last control point has been dealt with, the adjustment is performed.

As a check, a "free" adjustment should be run. That is, only the start and end control points are held fixed. Any intermediate control stations are allowed to move freely. The resultant altimetric elevation for these control stations can be compared to the known elevations, as a rough check.

A final adjustment is performed by constraining all known control points.

Once a final adjustment has been computed, for each file, all common values for any points should be meaned. Values which were obtained for the same point by using different control stations should be weighted before being meaned. The weights should be based on the proximity to the nearest control point used to derive that value. That is, weights are based on the inverse of the distance to the nearest control point.

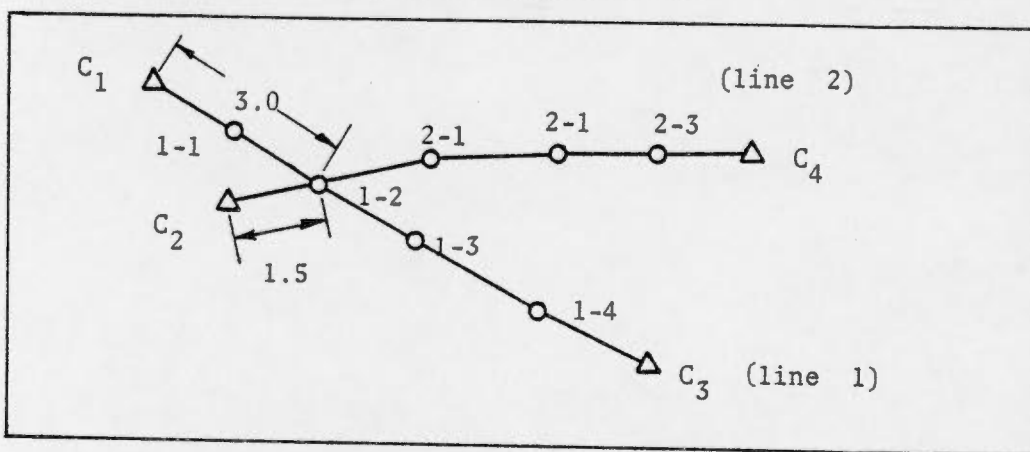


FIGURE 4: Weighted Mean Elevations

Referring to figure 4, point 1-2 is scaled to the nearest control point on line 1 and line 2. The distance along Line 1 is twice the distance along Line 2. The nearer the control point the greater its influence over the computed elevation for point 1-2.

The weighted mean elevation of point 1-2 will normally be given by:

$$\text{Wgtd. Mean Elev.} = \left(\frac{\text{Elev. 1}}{1.5} + \frac{\text{Elev. 2}}{3.0} \right) \bigg/ \left(\frac{1}{1.5} + \frac{1}{3.0} \right)$$

precise. That is, both are observed under similar conditions and residual corrections for each line are about the same. Also, it is assumed that the control points in each case are equally correct.

When there is some evidence as to one line being more precise than another, then this must be reflected in the choice of weights. Often it is necessary for the operator to assign empirical weights, based on his experience of altimeter traversing.

5. ANALYSING THE RESULTS

5.1 Post-Adjustment

Once again, check the comments column to determine if any altimetric points (non-control) have been observed outside the helicopter or above or below the station marker.

If the answer to either question is "yes" then apply the appropriate correction to the final altimetric value.

ie. If a reading was taken above an altimetric point by 3 feet, then the computed elevation is 3 feet too high and must be decreased by 3 feet.

Readings taken outside of the helicopter are corrected on the basis of information supplied by the field observer. Numerous sets of consecutive readings are usually taken inside and outside the helicopter to establish the "venturi" correction. The difference between these is computed and meaned. This mean value will be the standard average correction factor which should be applied in these cases. Remember,, if the reading was taken on a control point, then apply the correction to the known elevation before adjustment. If the reading is taken on an altimetric point (non-control), then apply the correction to the final adjusted elevation.

5.2 Statistical Analysis

An estimate of the quality of the altimetric results is based on a standard deviation computed from the formula:

$$s.d = \sqrt{\frac{\sum (\text{differences}^2)}{(\# \text{ of differences} - 1)}}$$

Every point for which we have two or more altimetrically derived elevations provides a difference.

- a) Two values are subtracted from each other to give one difference.
- b) Three or more values are subtracted from their mean to yield the same number of differences.

APPENDIX A

Header Changes

There are two types of header: one is a program header, the other is a line or traverse header. The first type is written into the program and is printed at the top of each page of output. The second type is entered with the traverse data and is stored on the odd-numbered file associated with each altimeter line. This appendix illustrates how to change the program header.

Appendix F provides a complete program listing. Referring to the first page of that listing, we see line 210 as:

```
210 H$="NORTH BC MAPPING - 339315 - ROY CHEWPA"
```

This shows that the string identified as H\$ contains the name of the project, the CPC number and the field officer in charge. To change this header for a new project headed by John Doe, called Ottawa Mapping and having a CPC number of 333999, then the following steps are performed;

- a) Load the program (refer to section 1.2)
- b) key in:
210 H\$ = "Ottawa Mapping - 333999 - John Doe"
The punctuation is important, but the spaces between characters is arbitrary.
- c) Press the "END OF LINE" key. The revised header is now in memory.
- d) Store the revised program on a new tape prepared for this project.

Note that statement 130 is "LOAD KEY 2". This assumes that the main program is stored on file 1. If, for some reason, it is decided to store the main program on any other file, say file 10, then this statement must be altered to "130 LOAD KEY 11". This change must be made prior to loading the program.

When running the revised program (after storing) it is always a good practice to first execute the sequence.

```
"INIT", "EXECUTE", "CONTINUE 140", "EXECUTE".
```

The program is now ready for processing.

APPENDIX B

Processing Output

Attached are three pages of printer output. These represent the normal processing of an altimeter line. Note that station numbers are strictly numeric. A cross-reference index must also be prepared to relate these numbers to correct station names. Often, the correct name is written over the printer output.

First page: This is a listing of the traverse data

- the first line is the storage tape and file numbers
- the second line is the project header
- the third line is the traverse header
- the traverse data follows; for each station there is an observed time, temperature (in °F and °C), scaled distance from the starting point, scaled gradient correction (taken from base altimeter graphs), the three altimeter readings and the mean altimeter reading. These readings are in feet. On the far right, the known elevation is entered by hand (in metres!). Note that observations 14 and 15 are at the same station. A delay of 9 minutes occurred here, and normally this overlap is removed in processing. The input distance for observation 15 was actually "47.51". (Only one decimal place is printed). Thus, the distance difference between points 14 and 15 is not zero. If it were, an error termination of the program would occur.

At the end of the listing, all pertinent notes are entered by hand, to ensure that appropriate corrections are not neglected.

Second page: This is a "free adjustment" where only the end points are held fixed, and the intermediate computed points are compared to the known. The top of the page shows the observation number, station number and fixed elevation for each point. The output lists each station number, the gradient correction, a temperature correction (T.C.) and the residual correction (R.C.) a linear distribution of the misclosure error. Usually, the known elevations and differences are written in on the page.

Third page: This is the final adjustment, where all known points (whose elevations are considered to be control for altimeter traverses) are held fixed. The stations fixed are noted, as are the corrections due to offsets. Note that the computed elevation is listed in feet (to the nearest foot) and metres (to the nearest 0.1 metre).

READING : ALTIMETER TAPE 1 FILE 13

NORTH B C MAPPING-339315-ROY CHEWPA

DATE-JULY 24 MAP-94 C,F,K LINE-2 OBSVR-G. WALKER

OBS	STATION	TIME	F-TEMP-C	DIST	G.C	ALTIMETERS			MEAN	<i>Mean</i>	
1	1000.00	15.12	46.9	8.3	0.0	0	6634	6660	6642	6645	<i>1816.8</i>
2	2.01	15.25	47.3	8.5	9.0	-2	6560	6584	6558	6571	
3	2.02	15.33	46.6	8.1	14.1	-2	6770	6796	6778	6781	
4	2.03	15.42	47.1	8.4	18.5	-3	6762	6788	6770	6773	
5	100.00	15.46	43.5	6.4	18.7	-3	7732	7752	7738	7741	
6	2000.10	15.56	49.8	9.9	22.7	-4	6390	6418	6400	6403	<i>1739.5</i>
7	2000.00	16.04	47.1	8.4	25.8	-4	7206	7230	7216	7217	<i>1987.7</i>
8	2.05	16.15	47.7	8.7	28.9	-5	6598	6624	6608	6610	
9	2.06	16.20	49.1	9.5	30.6	-5	6560	6588	6574	6574	
10	2.07	16.28	48.6	9.2	33.9	-6	6528	6554	6540	6541	
11	2.08	16.39	47.1	8.4	38.9	-6	6860	6886	6876	6874	
12	2.09	16.47	49.6	9.8	41.1	-7	6744	6770	6752	6755	
13	3000.00	16.58	44.2	6.8	43.6	-7	8140	8168	8150	8153	<i>2271.3</i>
14	3000.10	17.04	50.9	10.5	47.5	-8	7234	7256	7240	7243	<i>1993.0</i>
15	3000.10	17.13	50.9	10.5	47.5	-8	7234	7253	7242	7245	
16	2.10	17.21	50.4	10.2	51.5	-8	7360	7382	7363	7370	
17	2.11	17.31	46.2	7.9	56.2	-9	7164	7186	7176	7175	
18	2.12	17.37	48.9	9.4	57.4	-10	7262	7288	7276	7275	
19	2.13	17.45	47.3	8.5	61.1	-10	7078	7104	7090	7091	
20	2.14	17.54	53.8	12.1	65.2	-11	6978	7008	6992	6993	
21	1002.15	18.06	48.7	9.3	70.2	-12	6916	6942	6924	6927	<i>1896.0</i>
22	2.16	18.15	48.9	9.4	73.7	-12	7322	7346	7334	7334	
23	2.17	18.24	48.0	8.9	78.1	-13	7266	7290	7275	7277	
24	4000.00	18.33	50.9	10.5	80.0	-13	7294	7318	7302	7305	<i>2009.2</i>
25	4000.10	18.40	55.8	13.2	82.1	-14	6268	6296	6278	6281	<i>1695.0</i>

Obs. 5: Read 1 ft. below station; add 0.3 m. to final

obs. 7: Read 4.2 metres below station; control elevation

is $1991.9\text{ m} - 4.2\text{ m} = 1987.7\text{ m}$.

obs. 10: Read 2 ft. below station; add 0.61 m. to final

obs. 13: Read 1 ft. below station; control elevation is:

$2271.6\text{ m} - 0.3\text{ m} = 2271.3\text{ m}$.

obs. 18: Read 2 ft. below pt.; add 0.61 m. to final

"Free Adjustment"

ADJUSTMENT E 2

OBS 1 CONTROL STN 1000 ELEV 1816.8
 OBS 25 CONTROL STN 4000.1 ELEV 1695.1

NORTH B C MAPPING-339315-ROY CHEWPA

DATE-JULY 24 MAP-94 C,F,K LINE-2 OBSVR-G. WALKER

OBS	STATION	G.C	T.C	R.C	ELEVATION		KNOWN	Δ
1	1000.00	0	0.0	0.0	5961	1816.8	FIXED	
2	2.01	-2	0.4	-0.9	5883	1793.3		
3	2.02	-2	-1.3	-1.5	6092	1856.9		
4	2.03	-3	0.1	-1.9	6083	1854.1		
5	100.00	-3	-8.9	-2.0	7041	2146.2		
6	2000.10	-4	8.8	-2.4	5711	1740.6	1739.5	1.1
7	2000.00	-4	-2.5	-2.7	6523	1988.1	1987.7	0.4
8	2.05	-5	3.1	-3.0	5917	1803.5		
9	2.06	-5	0.1	-3.2	5881	1792.5		
10	2.07	-6	0.1	-3.6	5846	1782.0		
11	2.08	-6	-1.4	-4.1	6178	1883.0		
12	2.09	-7	0.4	-4.3	6058	1846.5		
13	3000.00	-7	-8.4	-4.6	7447	2269.8	2271.3	-1.5
14	3000.10	-8	4.4	-5.0	6540	1993.5	1993.0	0.5
15	3000.10	-8	0.0	-5.0	6542	1993.9	1993.0	0.9
16	2.10	-8	0.2	-5.4	6667	2032.1		
17	2.11	-9	0.7	-5.9	6471	1972.5		
18	2.12	-10	-0.5	-6.0	6570	2002.5		
19	2.13	-10	0.7	-6.4	6385	1946.3		
20	2.14	-11	-0.1	-6.8	6286	1915.9		
21	1002.15	-12	-0.2	-7.4	6219	1895.5	1896.0	-0.5
22	2.16	-12	-0.9	-7.7	6624	2019.0		
23	2.17	-13	0.2	-8.2	6566	2001.4		
24	4000.00	-13	-0.0	-8.4	6593	2009.6	2009.2	0.4
25	4000.10	-14	-6.7	-8.6	5561	1695.1	FIXED	

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Final

ADJUSTMENT F 2

OBS 1	CONTROL STN 1000	ELEV 1816.8
OBS 6	CONTROL STN 2000.1	ELEV 1739.5
OBS 7	CONTROL STN 2000	ELEV 1987.7
OBS 13	CONTROL STN 3000	ELEV 2271.3
OBS 14	CONTROL STN 3000.1	ELEV 1993
OBS 15	CONTROL STN 3000.1	ELEV 1993
OBS 21	CONTROL STN 1002.15	ELEV 1896
OBS 24	CONTROL STN 4000	ELEV 2009.2
OBS 25	CONTROL STN 4000.1	ELEV 1695.1

NORTH B C MAPPING-339315-ROY CHEWPA

DATE-JULY 24 MAP-94 C,F,K LINE-2 OBSVR-G. WALKER

OBS	STATION	G.C	T.C	R.C	ELEVATION		
1	1000.00	0	0.0	0.0	5961	1816.8	FIXED
2	2.01	-2	0.4	-2.4	5882	1792.8	
3	2.02	-2	-1.3	-3.7	6090	1856.2	
4	2.03	-3	0.1	-4.9	6080	1853.2	
5	100.00	-3	-8.9	-4.9	7038	2145.3	2145.6
6	2000.10	-4	8.8	-6.0	5707	1739.5	FIXED
7	2000.00	-4	-2.5	2.1	6521	1987.7	FIXED
8	2.05	-5	3.1	0.7	5917	1803.5	
9	2.06	-5	0.1	1.2	5881	1792.6	
10	2.07	-6	0.1	1.9	5848	1782.4	1783.0
11	2.08	-6	-1.4	3.2	6181	1884.0	
12	2.09	-7	0.4	3.7	6062	1847.8	
13	3000.00	-7	-8.4	4.3	7452	2271.3	FIXED
14	3000.10	-8	4.4	-7.1	6539	1993.0	FIXED
15	3000.10	-8	0.0	-1.3	6539	1993.0	FIXED
16	2.10	-8	0.2	0.4	6665	2031.4	
17	2.11	-9	0.7	0.9	6470	1972.1	
18	2.12	-10	-0.5	1.0	6569	2002.1	2002.7
19	2.13	-10	0.7	1.4	6385	1946.2	
20	2.14	-11	-0.1	1.8	6286	1916.1	
21	1002.15	-12	-0.2	2.4	6220	1896.0	FIXED
22	2.16	-12	-0.9	-1.5	6625	2019.2	
23	2.17	-13	0.2	-3.3	6565	2001.1	
24	4000.00	-13	-0.0	-4.1	6592	2009.2	FIXED
25	4000.10	-14	-6.7	1.2	5561	1695.1	FIXED

1	12	obs. 5	Final elevation:	$2145.3 + 0.3 = 2145.6$
2	10	obs. 10	" "	$1782.4 + 0.6 = 1783.0$
3	8	obs. 18	" "	$2002.1 + 0.6 = 2002.7$
4	6			
5	4			
6	3			

APPENDIX C

Weighted Mean Elevations

The following page shows the form used to list computed elevations and scaled weights for a common station, as well as the weighted mean elevation and differences to each computed elevation. Computations are done on the form. Note that the weight is inversely proportional to the distance to the nearest control point. The assumption is that altimeter accuracy decreases with increasing distance from a control point. The differences $(E - X)_i$ are normally less than 3.0 metres. Differences greater than 5 metres are suspect, and the data involved must be thoroughly checked. Normally, differences greater than three times the expected overall accuracy can be considered as outliers. However, care must be taken to ensure that rejections are made for valid reasons and not just to make the results look better.

APPENDIX D

Helicopter/Ground Corrections

Normally, all observations are made from within the helicopter, and the conditions at each observing point are kept as consistent as possible. For example, three altimeters are read in the same place in the helicopter each time, and the helicopter main blade r.p.m.'s are kept consistent. The pitch of the blades is also kept consistently at zero. The idea is to maintain the same helicopter-induced pressure at each observation. When it is not possible to land directly on a station, the usual practice is to land nearby and estimate or measure the offset to the station. Occasionally, it is more practical to read the altimeters outside the helicopter. Before applying any offset correction, it is first necessary to apply a correction due to the helicopter effect. This calibration determined correction will be dependent on the type of helicopter, the blade conditions at observations (r.p.m. and pitch) and the location within the helicopter where the altimeters are read. The following page lists the calibration for a Bell 206B helicopter. Note that readings are taken throughout the project.

As a point of interest, it has been found that calibrations for the Hughes 500 helicopter are not consistent, and vary unacceptably. Therefore, this machine is not recommended for altimetric traversing.

HELICOPTER TO GROUND CORRECTIONS - Bell 206B - 1979

DATE	TIME	READING, IN FEET		DIFF. TO GROUND, IN FEET
		HELICOPTER	GROUND	
July 26	09:06	3657	3653	-4
July 28	11:18	3649	3646	-3
July 30	08:20	3663	3661	-2
July 30	16:42	3731	3729	-2
Aug. 5	08:06	3682	3677	-5
Aug. 5	11:38	3453	3455	-2
Aug. 5	16:30	3765	3761	-4
Aug. 6	09:36	3681	3679	-2
Aug. 6	10:15	3681	3676	-5
Aug. 7	09:00	3602	3599	-3
Aug. 7	19:02	3625	3625	0
Aug. 9	08:27	3424	3417	-7
Aug. 9	12:53	4785	4785	0
Aug. 9	13:42	4795	4791	-4
Aug. 9	17:04	2828	2827	-1
Aug. 9	17:54	3524	3517	-7
Aug. 10	18:01	3558	3554	-4
Aug. 11	15:20	3595	3591	-4
Aug. 20	12:05	3219	3211	-8
Aug. 20	15:33	3299	3296	-3
Aug. 20	19:54	3306	3301	-5
Aug. 26	16:35	3306	3301	-5
Aug. 26	18:20	3586	3584	-2
Aug. 27	19:20	3728	3725	-3
Aug. 28		5923	5919	-4

n = 25

$\Sigma = -81$

Mean = -3.2 feet
(-1.0 m)

APPENDIX E

Final Results

The final results are submitted to the Data Services Section for appropriate distribution. Attached is an example of a covering memo which indicates the type of information submitted. Note that the memo also specifies the estimated standard deviation of the project. If the project were divided into distinct areas and accuracy estimates computed for each area, then these would be specified. Also attached is an index which indicates the approximate outline of the project in terms of the 1:250,000 NTS map sheets. A rough plot of individual traverses is also added to show the coverage involved. Finally, an example of the final elevation listing is also attached. Note that for each point the correct identifier is used and the information includes the map sheet containing the point, the processing line(s) containing the point, and the final elevation - in metres.



Mr. Lorne Pelton
A/Head
Data Services Section

HOM
DE

Steve Delahunt

SECURITY - CLASSIFICATION - DE SECURITE
OUR FILE/NOTRE REFERENCE A-7 Volume 4
YOUR FILE/VOTRE REFERENCE
DATE 1980-04-02

SUBJECT Adjusted Altimeter Elevations in British Columbia - 339315
OBJET

Please find the following attached:

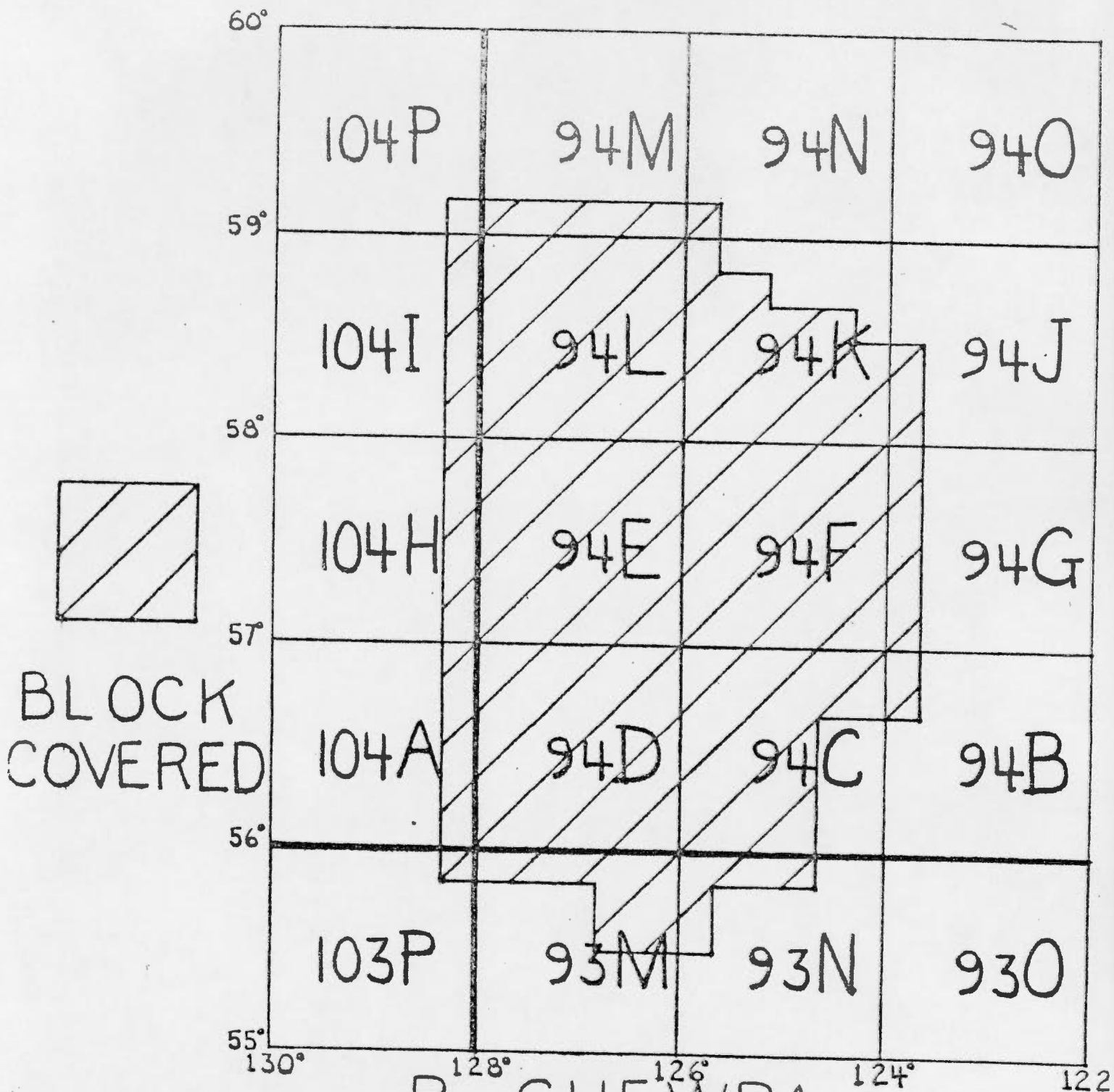
- Block diagram outlining the mapsheets covered by Roy Chewpa's 1979 Altimeter Traverse;
- Block diagram indicating the approximate position of each traverse line in the Block;
- Eighteen (18) pages of listed elevations resulting from this adjustment.

The altimeter points are listed in sequential order. The mapsheet, on which they appear, is given. For our purposes each point is referenced to its data storage location on (Tape,File). Elevations for 346 points are attached. An estimated standard deviation of 2.2 metres was computed, based on 104 elevation comparisons.

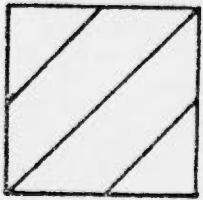
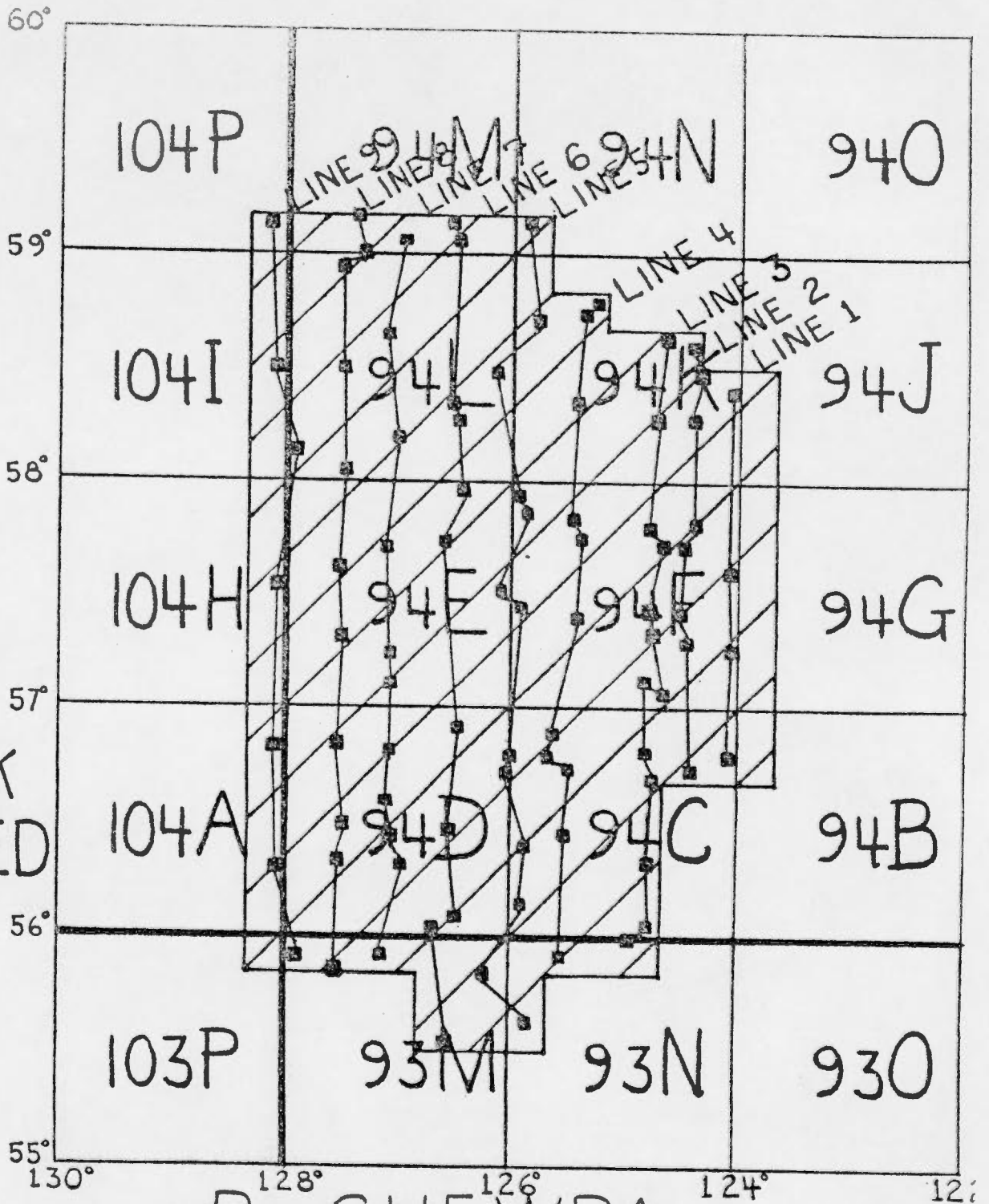
Please ensure that these results are forwarded to Topographical Survey at the earliest possible date. Thank you.

S. Delahunt
Supplementary Control Section
Geodetic Survey of Canada

Attach.



R. CHEWPA
 1980-ALTIMETER PROJECT
 BRITISH COLUMBIA MAPPING
 C.P.C. - 339-315



BLOCK
COVERED

R. CHEWPA
1980-ALTIMETER LINES
BRITISH COLUMBIA MAPPING
C.P.C. - 339-315

ADJUSTED ALTIMETER ELEVATIONS - BRITISH COLUMBIA - CHEWPA '79

Compiled April 1980

POINT	MAPSHEET	PROCESS LINE	ELEVATION (metres)
4-13	94F	1,23	1113.0
4-14	94F	1,23	788.9
KWAD CTR	94F	1,23	1620.9
4-15	94F	1,19/1,21	1738.0
4-16	94F	1,19/1,21	1776.3
4-17	94F	1,19/1,21	1746.5
4-18	94F	1,19/1,21	1856.5
DIANE	94F	1,19/1,21	2109.8
4-19	94F	1,19/1,21	1685.8
FRIDGE	94F	1,19/1,21	2134.8
4-20	94F	1,19/1,21	1893.0
4-21	94K	1,19/1,21	1823.9
4-22	94K	1,19/1,21	2059.0
TAGA	94K	1,19/1,21	2251.1
4-23	94K	1,19/1,21	1704.2
ZOOM	94K	1,19/1,21	2226.5
4-24	94K	1,19/1,21	1832.3
4-25	94K	1,19/1,21	2195.8
4-26	94K	1,19/1,21	1815.2
4-27	94K	1,19/1,21	1988.9

APPENDIX F

Program Listing

The following nine pages contain a listing of the processing program (1980 version). This program is written in BASIC for the HP9830. Several versions exist, but the differences between versions are very minor, and usually involve only the I/O. The program consists of a small main routine and twenty sub-routines, referred to as special functions. Function f_1 originally contained an adjustment routine referred to as the "old method". This program version has f_1 replaced by a routine to compute sea level elevations, based on tide predictions.

```

100 COM C1,C2,C3,C4,C5,C9,N,HS[80]
110 DIM AS[100,9],BS[100,9],ES[100],RS[100],TS[100]
120 DIM DS[15],MS[20],RS[15],SS[15],TS[5]
130 LOAD KEY 2
140 C1=0.3048
150 C2=1.8E-03
160 C3=1.967E-03
170 C4=50
180 C5=10
190 C9=100
200 MS="READMERGWRITE TO RCMLF"
210 HS="NORTH B C MAPPING-339315-ROY CHEWPA"
220 DISP "SET TOP-OF-PAGE"
230 WRITE (15,240) 27,84,27,70,16,1056,27,76,15,950
240 FORMAT 108
250 END
260 MAT READ E[9]
270 FOR I=1 TO B[100,8]
280 FOR J=1 TO 9
290 A[I,J]=B[I,J]*E[J]
300 NEXT J
310 NEXT I
320 END
330 DATA 1,0.01,0.1,0.1,1,1,1,1,0.1

```

SPECIAL FUNCTION F0

```

100 Z=FNI1+FNT3
110 END

```

1 12
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2 10
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3 8
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4 6
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5 4
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6 A

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SPECIAL FUNCTION F1

```

100 FIXED 2
110 DISP "DATE ";
120 INPUT D$
130 DISP "ZONE ";
140 INPUT T$
150 DISP "REF PORT ";
160 INPUT R$
170 DISP "HIGHER:MEAN,LRG / LOWER:MEAN,LRG";
180 INPUT A,B,C,D
190 DISP "SEC PORT ";
200 INPUT S$
210 DISP "TIME,MEAN,HIGH/TIME,MEAN,LOW,MWL";
220 INPUT E,F,G,H,I,J,K
230 DISP "REF: FROM-TIME,TIDE/TO-TIME,TIDE";
240 INPUT L,M,N,O
250 P=L
260 Q=M
270 R=N
280 S=O
290 IF M>O THEN 340
300 P=N
310 Q=O
320 R=L
330 S=M
340 T=(F+G)/2*(A=B)+((Q-A)*(G-F)/(B-A)+F)*(A#B)+Q
350 U=(I+J)/2*(C=D)+((S-C)*(J-I)/(D-C)+I)*(C#D)+S
360 V=FNAF+FNAABSE*SGNE
370 W=FNAF+FNAABSH*SGNH
380 IF M>O THEN 450
390 Z=T
400 T=U
410 U=Z
420 Z=V
430 V=W
440 W=Z
450 PRINT
460 PRINT TAB17" TIDE PREDICTION FOR "D$
470 PRINT
480 PRINT "REFERENCE PORT"TAB20"HIGHER MEAN "A"LARGE "B
490 PRINT "- "R$"-"TAB21"LOWER MEAN "C"LARGE "D
500 PRINT TAB20"FROM"L;M"TO"N;O
510 PRINT
520 PRINT "SECONDARY PORT"TAB20"HIGH TIME "E"MEAN "F"LRG "G
530 PRINT "- "S$"-"TAB21"LOW TIME "H"MEAN "I"LRG "J
540 PRINT TAB26"MWL "K
1350 PRINT TAB20"FROM"FNEV;T"TO"FNEW;U
1560 PRINT
1970 DISP "PREDICTION TIME ";
980 INPUT Z
990 IF Z THEN 620
700 STANDARD
610 END
5620 PRINT TAB15;T$" TIME"Z"MSL ELEV "COS(PI*(FNAZ-V)/(W-V))*(T-U)/2+(T+U)/2-K
4630 GOTO 570
3640 DEF FNE(Z)=INTZ+(Z-INTZ)*3/5

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SPECIAL FUNCTION F2

100 Z=FNB2
110 END

SPECIAL FUNCTION F3

100 Z=FNB3
110 END

SPECIAL FUNCTION F4

100 Z=FNB4
110 END

SPECIAL FUNCTION F5

100 Z=FNT1
110 END

SPECIAL FUNCTION F6

100 K=0
110 DISP "OVL,INS,REP,CON,MRC,LST,END ";
120 INPUT S\$
130 GOTO POS(WS[13],S\$(1,1)) OF 140,240,340,380,420,560,680
140 DISP "OVL FROM/TO OBS# ";
150 INPUT K,L
160 N=N-L+K
170 FOR J=1 TO 9
180 X=(A[K,J]-A[L,J])*((J=5)+(J=9))
190 FOR I=K+1 TO N
200 A[I,J]=A[I-K+L,J]+X
210 NEXT I
220 NEXT J
230 GOTO 110
240 DISP "INS OBS# ";

```

250 INPUT K
260 N=N+1
270 READ A[N,9]
280 FOR I=N TO K+1 STEP -1
290 FOR J=1 TO 9
300 A[I,J]=A[I-1,J]
310 NEXT J
320 NEXT I
330 GOTO 360
340 DISP "REP OBS# ";
350 INPUT K
360 J=K
370 GOTO 400
380 J=N+1
390 K=N=C9
400 Z=FNI2
410 GOTO 110
420 IF K THEN 440
430 F=FNT1
440 K=FNDN
450 MAT H=A
460 M=FNT2+N
470 N=N+K
480 A=FND(A[1,4]<B[K,4]-F)
490 F=B[K,4]*A+F*(A=0)
500 G=B[K,5]-A[1,5]
510 L=(A[1,1]=B[K,1])
520 IF A[1,4]#0 OR L=1 THEN 560
530 DISP "DIST" B[K,1] "TO" A[1,1];
540 INPUT D
550 F=F+D
560 FOR J=1 TO 9
570 N=K
580 X=F*(J=4)
590 FOR I=1 TO M
600 N=N+1
610 B[N,J]=A[I,J]+X
620 NEXT I
630 NEXT J
640 MAT A=B
650 GOTO 110
660 A=FNL0
670 GOTO 110
680 END

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SPECIAL FUNCTION F7

1 12
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2 100 Z=FNT3
110 END

3 8
7
4 6
5
5 4
3
6 A

SPECIAL FUNCTION F8

100 WRITE (15,110)11
110 FORMAT B
120 END

SPECIAL FUNCTION F9

100 Z=FNLO
110 END

SPECIAL FUNCTION F10

100 Z=FN13
120 END

SPECIAL FUNCTION F11

100 DEF FNA(W)=INTW+(W-INTW)*5/3

SPECIAL FUNCTION F12

100 DEF FNB(W)
120 I=1
140 PRINT "ADJUSTMENT f"W
160 FOR J=1 TO N
180 E[J]=R[J]=F[J]=0
200 IF ABSA[J,1]<1E+03 THEN 840
220 DISP "OBS"J"STN"A[J,1]"ELEV ";
240 INPUT P
260 IF P<-9 THEN 840
280 PRINT "OBS"J"CONTROL STN"A[J,1]"ELEV"P
300 P=P/C1
320 IF I=1 THEN 800
340 FOR K=1 TO J
360 E[K]=A[K,5]+A[K,9]
380 R[K]=A[K,4]-A[I-1,4]

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6
5
4
3
2
1
6

```

400 NEXT K
420 IF W#2 THEN 580
440 FOR K=1 TO J
460 Y=E[K]-A[K-1,5]-A[K-1,9]
480 T[K]=Z=FNC(A[K-1,3])
500 E[K]=E[K-1]+Y+Z
520 NEXT K
540 X=Y-P-E[J]
560 GOTO 720
580 X=A[I-1,5]+A[I-1,9]
600 FOR K=1 TO J
620 Y=E[K]-X
640 T[K]=FNC((A[K,3]+2*C2*Y)*(W=3)+A[I-1,3]*(W=4))
660 NEXT K
680 X=O-X
700 Y=P-O-Y-T[J]
720 FOR K=1 TO J
740 R[K]=Z=R[K]*Y/R[J]
760 E[K]=E[K]+Z+(T[K]+X)*(W#2)
780 NEXT K
800 I=J+1
820 E[J]=O=P
840 NEXT J
860 RETURN FND0.1

```

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SPECIAL FUNCTION F13

```

100 DEF FNC(X)=C3*((A[K,3]+X)/Z-C4)*Y

```

SPECIAL FUNCTION F14

```

100 DEF FND(W)
120 REDIM A[N,9],B[N,9]
140 RETURN W

```

↓
1 12
11
2 10
9
3 8
7
4 6
5
5 4
3
6 A

SPECIAL FUNCTION F15

```

100 DEF FNI(W)
105 DISP "TEMP UNITS ";
110 INPUT S$
120 GOTO W OF 140,260,900,320
140 DISP "DATE,MAP,LINE,OBSVR ";
160 INPUT H$(36,45),H$(46,55),H$(56,65),H$(66)
180 L=FNPU
200 GOTO 920
220 J=W
240 K=N=C9
260 Z=FNDN
320 FOR I=J TO K
340 M=I-1
360 DISP "OBS" I "STN,TIM,TEM,DIS,ALT,GRD";
380 INPUT A[I,1],A[I,2],T,A[I,4],X,Y,Z,A[I,5]
400 IF X THEN 460
420 N=M
440 GOTO 880
460 IF S$="F" THEN 500
480 T=T*1.8+32
500 A[I,3]=T
520 IF I=1 THEN 760
540 O=X-ABSA[M,6]
560 P=Y-ABSA[M,7]
580 Q=Z-ABSA[M,8]
600 IF ABS(O-P)<C5 THEN 720
620 IF ABS(O-Q)<C5 THEN 680
640 X=-X
660 GOTO 760
680 Y=-Y
700 GOTO 760
720 IF ABS(P-Q)<C5 THEN 760
740 Z=-Z
760 A[I,6]=X
780 A[I,7]=Y
800 A[I,8]=Z
820 A[I,9]=(ABSX+ABSY+ABSZ)/3
840 L=FNPI
860 NEXT I
880 PRINT
900 W=4
920 DISP "END=0,COR=OBS# ";
940 INPUT J
960 K=J
980 IF J THEN 120
1000 IF W=1 THEN 220
1020 RETURN W

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12
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SPECIAL FUNCTION F16

```

100 DEF FNL(W)
120 FOR L=W TO N+W
140 Z=FNPL
160 NEXT L
180 PRINT
200 RETURN W

```

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SPECIAL FUNCTION F17

```

100 DEF FNP(X)
120 Y=INTX
140 IF Y THEN 300
160 WRITE (15,440)H$(1,35),10,H$(36,45),32,H$(46,55),32,H$(56,65),32,H$(66),10
180 PRINT "OBS STATION ";
200 IF X#Y THEN 260
220 PRINT " TIME F-TEMP-C DIST G.C ALTIMETERS MEAN"
240 RETURN 0
260 PRINT "G.C T.C R.C ELEVATION"
280 RETURN 0
300 WRITE (15,460)Y,A[Y,1];
320 IF X#Y THEN 400
340 Z=A[Y,3]
360 WRITE (15,480)A[Y,2],Z,(Z-32)*5/9,A[Y,4],A[Y,5],A[Y,6],A[Y,7],A[Y,8],A[Y,9]
380 RETURN 0
400 WRITE (15,500)A[Y,5],T[Y],R[Y],E[Y],E[Y]*CI
420 RETURN 0
440 FORMAT Z/,20X,B,/, "DATE-",B," MAP-",B," LINE-",B," OBSVR-",B
460 FORMAT F3.0,F9.2
480 FORMAT F7.2,3F6.1,F5.0,3F6.0,F7.0
500 FORMAT F5.0,2F7.1,F7.0,F8.1

```

SPECIAL FUNCTION F18

```

100 DEF FNT(W)
120 PRINT M$(W*4-3,W*4) "ING : ALTIMETER ";
140 DISP "TAPE,FILE ";
160 INPUT A,B
180 PRINT "TAPE "A"FILE "B
200 IF B=0 THEN 480
220 C=5+5*(A>0)
240 D=ABS B
260 IF D=INT(D/2)*2 THEN 120
280 IF W#3 THEN 440
300 IF B#D THEN 400
320 FIND #C,D

```

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1
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▲

```

340 STOP
360 MARK #C,1,70
380 MARK #C,1,N*18
400 STORE DATA #C,D
420 STORE DATA #C,D+FNDI,A
440 LOAD DATA #C,D
460 LOAD DATA #C,D+FNDI,A
480 PRINT
500 RETURN 0

```

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SPECIAL FUNCTION F19

```

100 W=0
120 X=1E+04
140 Z=FNLFNT1
160 FOR J=1 TO N
180 Z=A[J,9]
200 IF Z<W THEN 240
220 W=Z
240 IF Z>X THEN 280
260 X=Z
280 NEXT J
300 O=INT(A[1,2]-0.15)
320 P=INT(A[N,2]+0.92)
340 Z=INT((W-X+49)/50)
360 FOR I=FN1(W+Z*5-1) TO FN1(X-Z) STEP -Z
380 PRINT
400 IF I=FN1 THEN 460
420 WRITE (15,800) I;
440 GOTO 480
460 WRITE (15,800) " .";
480 FOR J=1 TO N
500 IF INT(A[J,9]/Z+0.5)*Z#I THEN 540
520 PRINT TABFN(A[J,2]-O)*4-0.5" *";
540 NEXT J
560 NEXT I
580 FOR I=0 TO P-1
600 PRINT "...+";
620 NEXT I
640 PRINT
660 PRINT " ";
680 FOR I=0 TO P
700 WRITE (15,820) I;
720 NEXT I
740 PRINT
760 END
780 DEF FN1(W)=INT(W/2/5)*5*Z
800 FORMAT F5.0, " +";
820 FORMAT F4.0

```

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SURVEY PROJECT

SOUTHERN YUKON

TECHNICAL REQUIREMENTS

Department of Energy, Mines and Resources
Surveys and Mapping Branch
Geodetic Survey of Canada
Supplementary Control Section

Dated February 3, 1981

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 - 5.3 Photo-identification of control points
 - 5.4 Vertical ties
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6. Materials and information to be provided to contractor
7. Materials and equipment to be provided by contractor
8. Territorial Land Use Regulations
9. Computations
10. Survey returns
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Attached

Notes on Altimeter traversing
Vertical Control-Levelling
Notes on Field Control Placement and Identification

5. General Information

→ 5.1 Altimeter Traversing - The elevations required for the compilation of Topographical Maps will be established by traversing with altimeters, using a helicopter for transportation. The points where elevations are required will be indicated on maps and aerial photographs and have been picked in an effort to satisfy a number of conditions:

- that the point appears suitable for landing a helicopter;
- that the point be located on the common overlap between two lines of aerial photographs;
- that the points be photogrammetrically suitable; (see page 11)
- that the variation in the elevations of the points between control elevations be as small as possible;
- that the points are situated as nearly as possible in a straight line between control elevations.
- The 7000 foot Wallace & Tiernan altimeters should be used on those traverses where the elevation of the points is not expected to exceed 6000 feet. If any traverse points are expected to have elevations higher than 6000 feet, the 16000 foot altimeters must be used on the complete traverse (between control elevations).
- All new vertical control points must be accurately identified on the aerial photography, with a check on this identification to be provided by oblique polaroid pictures.
- All altimeter traverses will be run twice, but the two runs will not be made on the same day. If the standard deviation of elevation differences between the two runs exceeds 2 metres and/or if weather conditions were not good, the project inspector will have the authority to request that the line be run again until the final results are considered to be satisfactory. Past experience has shown that up to 25% of altimeter traverses may have to be rerun - generally due to unstable weather conditions.
- Progress along an altimeter traverse should be at least 50 km per helicopter flying hour.

- Vertical points, to be used as control for the traverse lines, are required at the ends of each line. These control points may be existing trig (of suitable accuracy) or spirit level elevations or new points established by trig. methods from these elevations. If no elevations exist in the general area where a control point is required, a vertical trig. traverse will have to be run.
- Additional control points are required at intervals of 40 to 50 km along the traverse lines. These control points may be similar to those at the ends of the lines or may be established by altimeter tie lines run more or less perpendicular to the traverse lines.
- Within the area where a vertical control point is required, the elevation should be established on flat ground, a low point, a high point, top of hill, saddle, etc. These points are not to be monumented on the ground but a temporary marker is required to be certain that the same point is used on the second or subsequent runs.
- Forms will be supplied (along with sample notes showing the format to be followed) on which to record the traverse data.
- It will be the responsibility of the contractor to compute elevations for each of the altimeter points. Computation forms and sample computations will be supplied.
- See "Notes on Altimeter Traversing".

5.2 Control Elevations for Altimeter Traverses must be located, as nearly as possible, at the average elevation of the points on the traverse. Existing trig or spirit level elevations may sometimes be used directly but it will usually be necessary to transfer these elevations, by trig. methods, to a more suitable location. The determination of the elevation of a new vertical trig control point requires the measurement of simultaneous vertical angles and a slope distance from each end of the line.

5.2.1 Vertical angles must be measured simultaneously from both ends of the line using a Wild T2, Kern DKM2A or equivalent. At least three sets of angles must be measured from each end of the line, a set consisting of one direct and one reverse pointing. If the spread of the means of the three sets, at either end, is greater than 10 seconds, an additional three sets of simultaneous reciprocal vertical angles must be measured.

5.2.2 Slope distance may be measured by a Tellurometer MRA3, CA1000 or equivalent but a complete set of fine readings will not be required. A coarse reading near each end of the frequency scale with a fine reading near the middle of the frequency scale will be sufficient. However, an independent measurement must be made from each end of the line. Distance between stations should not exceed 15 kilometres. Instrument and target heights to be measured and recorded in feet and meters.

5.2.3 Meteorological readings - only one set of met. readings is required at each station (atmospheric pressure, wet and dry bulb temperatures) and can be taken either before or after the distance measurement. The barometer must be calibrated and must have an absolute accuracy of ± 15 metres. Each pair of thermometers (wet and dry bulb) must be matched and temperatures must be recorded to the nearest tenth of a degree.

5.3 Photo Identification of Control Points

Points at which elevations are established by altimetric traversing or by trig. methods must be marked on the aerial photography with the station number and a circle made with a grease pencil along with a brief written description (high point - top of hill - low point-saddle-lake-etc.) and possibly a "pin prick" depending on the terrain. This identification must be substantiated by not less than two oblique polaroid pictures with the location and number of the control point clearly marked on them. These pictures should be taken from the helicopter during the approach to the station or after takeoff and at a distance of 1 to 10 km from the station. They should contain sufficient detail to permit a positive identification of the point.

5.4 Vertical Ties

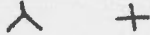
Generally the measurements are similar to those described in Section 5.2 - "Control Elevations for Altimeter Traverses", with the possible addition of some spirit levelling. Because the existing spirit level elevations may be in locations that are difficult to reach by trig. methods, a combination of vertical trig. measurements and spirit levels may be needed to make the required vertical ties.

- There must be sufficient redundant measurements (both trig. and spirit level) to provide a check on the work.
- Spirit levelling must be done to third order specifications, using instruments and procedures as indicated in "Specifications and Recommendations for Control Surveys and Survey Markers", EMR 1978.

5.5 Targets

As the first step in obtaining identification photos of the three required existing trig. stations, suitable targets must be placed at these stations.

- Targets must be placed in one of the following distinctive shapes:



- Each panel of the target is to be 5 metres in length.
- White cotton or white plastic material will be supplied.
- Targets must be firmly anchored and remain in position until identification photos can be taken (one day to a few weeks, depending on weather conditions, etc.)
- The contractor will not be required to take the identification pictures.

5.6 Final altimeter elevations are to have an accuracy of 3 metres or less at the one standard deviation level with respect to the nearest control points.

6. Materials and Information to be Provided to the Contractor Without Charge

Maps: An adequate number of copies of each map of the survey area at a scale of 1:250,000.

Survey notes: The note books or forms on which to record the data obtained from each type of survey - altimeter traverse, vertical angles, and distances.

Aerial Photographs: Coverage of all areas where photographs are required to perform the work.

Coordinates and descriptions (where available) of all existing control that might be used.

Altimeters: Nine Wallace and Tiernan altimeters with calibration graphs (5 - 7000 foot altimeters and 4 - 16,000 foot altimeters). (These altimeters must be returned promptly to Geodetic Survey on completion of the project).

Target material: the required white cotton or white plastic sheets will be provided.

A copy of the current "Territorial Land Use Regulations".

7. Materials, Equipment and Instruments to be Provided by the Contractor

All materials, equipment and instruments, except those included in "6" are to be provided by the Contractor.

8. Territorial Land Use Regulations

An application for a permit under these Regulations must be made by the Contractor.

Contractor is to supply the required details, for a permit, as they become known.

The Contractor and not the Project Authority will be responsible for satisfying all the applicable provisions of the Territorial Land Use Regulations.

9. Computations

The field party must have the knowledge and computer capability to do the following:

- apply meteorological and instrument calibration corrections to the measured slope distances;
- determine the elevations of control stations established by trig.methods;
- determine the elevation difference between trig.elevations and spirit levels that will be tied together vertically.

The Project Inspector will be available, during the period of the field survey work, to evaluate the survey data and computations and to accept or to reject the results.

10. Survey Returns

-All original survey notes and all computations must be sent by registered mail to Geodetic Survey within three weeks of the completion of the field work. As insurance against loss, a copy or abstract of the survey notes must be held by the Contractor.

-Aerial photographs and the polaroid pictures, taken as confirmation of the identification of the vertical points, are to be sent to Geodetic Survey with the Project Report.

11. Project Report by Contractor

A general report must be provided by the Contractor to the Geodetic Project Officer within three weeks of the completion of the field work. The following information is to be included in the report:

- a) a general description of the project, project area, field procedures, personnel (including the names and classifications of the various personnel and the number of calendar man-days each worked on the project);
- b) a daily diary of all significant events that occurred in the execution of the contract;
- c) a list of survey instruments used, including makes, models and serial numbers;
- d) survey instrument maintenance and calibration statements, including photocopies of calibration certificates;
- e) maps of the project area at a scale of 1:1,000,000 showing generally the work that was done;
- f) the paper on which this report is written should be approximately 21.5 x 28 cm. The 1:1,000,000 maps are to be folded to this size also;
- g) a set of maps at a scale of 1:250,000 must also be provided, showing the location of all stations established or used, the traverse lines, trig. measurements and vertical ties.

NOTES ON ALTIMETER TRAVERSING

Supplementary Control Section-Geodetic Survey

General

A helicopter will be used for transportation (Hughes 500 D not acceptable). Suitable control elevations must be available or established before the altimeter traverse is run. It is preferable if the helicopter can land directly on these control points.

Altimeter traverses should be run as rapidly as possible and in as straight a line as possible between points of known elevation, with time, temperature and altimeter readings recorded at each point where an elevation is required. All traverses must be run twice, not on the same day. Care must be taken to be certain that the same points are used on each run.

Traversing in mountainous terrain will be speeded up by having two men in the helicopter - one to read and record altimeters, temperature and time, the other to navigate, photo identify the points and mark the spot for subsequent runs.

General Procedure for Altimeter Traversing

1. Take polaroid pictures of selected point from a distance of 1-10 km.
2. Read and record air temperature before landing (about 15 metres above ground).
3. Land on point where elevation is required.
4. Reduce blade pitch to zero. Rotor RPM to be constant at all points.
5. After a few seconds (10-20) read and record altimeters (3) and time.
6. Identify point on mapping photo and on polaroid pictures.
7. Leave mark on ground to assure recovery of point on subsequent traverse runs.
8. On leaving the station, take additional polaroid pictures if original pictures were not suitable.
9. Proceed to next station.

Altimeters

→ When traversing, always use ~~the average of~~ three altimeters. These altimeters should be selected on the basis of calibration graphs, those with the most linear (and constant correction) graphs being used.

The pointer on some altimeters remains steady under the vibrating conditions in a helicopter. Others oscillate so much that it is difficult to get an accurate reading and these should not be used.

In the helicopter, always take readings under similar conditions, i.e. no pitch on rotor blades and approximately the same rotor r.p.m.

→ Tests should be made to determine the difference between such readings taken in the helicopter and readings taken at ground level with no effect from the helicopter blades. This difference ~~may~~^{will} be needed when reading outside the helicopter on a bench mark or trig. station.

Pressure Gradient

The atmospheric pressure at any point varies as time passes. In order to be able to correct the roving altimeter readings for this variation in pressure, it is necessary to read a "base barometer" (two altimeters should be used) every 15 minutes. A graph can be plotted of base barometer readings against time and the corrections to the roving altimeter readings can be obtained from this graph. If this graph is a straight line (or nearly so) traverse results should be good. If it is too erratic, the traverse should be rerun under more stable weather conditions. The base barometer should be located in the same area as the altimeter traverses being run. (At base camp.)

Weather

→ Make a few general notes on weather conditions. If the wind direction suddenly changes by an appreciable amount, it is quite ~~possible~~^{probable} that atmospheric conditions are unsuitable for altimeter traversing.

Time

The less time that elapses while running between control points on an altimeter traverse, the less chance there will be of serious variations in atmospheric pressure.

→ While traversing, if it is necessary to stop for such things as putting fuel in the helicopter, lunch, etc., ~~always~~ make such stops at a point of known elevation (B.M. or trig. station). Take a reading when landing and another before leaving.

Direction

Because of different atmospheric conditions in different areas, it is quite important to run the traverses as nearly as possible in a straight line between control points. Never run a traverse as a loop, closing on the starting point, unless there is a known elevation at the other extremity.

Temperature

On a sunny day the temperature, as observed close to the ground, is usually unreliable and will give a false correction when computing the traverse. The temperature required is that of the free air without local heating or cooling effects. If a helicopter is used for transportation, read the temperature just before landing (about 15 metres above ground).

Results

→ If altimeter traverses are run to the following specifications, the results should have a standard error of not more than 1.5 ^{to} ~~or~~ two metres and a maximum error of not more than 5 metres:

- not more than 100 km between control points;
- where control is spaced 80 to 100 km apart, additional tie lines should be run to make the control spacing 40 to 50 km. These tie lines should be run twice but both runs should not be made on the same day;
- - not more than 150 m in elevation variation from the starting control point;
- three roving altimeters be used together;
- atmospheric conditions are reasonably stable.

APPENDIX G

Technical Requirements for Altimeter Surveys

The attached represents the technical requirements for a contract mapping project in the Southern Yukon in 1981. The bulk of the work was altimeter traverses to supply elevations for mapping control. This document serves as an excellent description of field procedures for altimeter traverses.

PART 1 — VERTICAL CONTROL

LEVELLING

Specifications

The different orders of vertical control are defined in terms of the allowable discrepancy between independent forward and backward levellings between bench marks as follows:

- Special Order ± 3 mm \sqrt{K} or 0.012 ft. \sqrt{M} .
- First-Order ± 4 mm \sqrt{K} or 0.017 ft. \sqrt{M} .
- Second-Order ± 8 mm \sqrt{K} or 0.035 ft. \sqrt{M} .
- Third-Order ± 24 mm \sqrt{K} or 0.10 ft. \sqrt{M} .
- Fourth-Order ± 120 mm \sqrt{K} or 0.5 ft. \sqrt{M} .

Note:

K (kilometres) or M (miles) = the distance between bench marks measured along the levelling route. By using equipment and procedures as recommended for a particular order of levelling, it is expected that the discrepancy between the first forward and first backward runnings will not exceed the allowable discrepancy listed above in approximately 84 percent of the sections over the course of a level line. Those sections that exceed the allowable discrepancy must be relevelled and treated as specified under Individual Section Runnings.

Loops and Closures

Loop misclosures should seldom exceed the limits given above for various orders of levelling, taking K as the length in kilometres or M as the length in miles along the level route around the loop. To maintain the specified accuracy, long narrow loops should be avoided. The distance between any two bench marks, measured along the actual level route, should not exceed four times the straightline distance between them.

Branch, spur, or open-ended lines should be avoided because of the possibility of undetected gross errors.

Individual Section Runnings

• Special Order

- a) Level each section once forward and once backward independently, using different instrument men, and if possible, different instruments under different weather conditions and at different times of the day.
- b) Reject and relevel any running with a suspected gross error.

- c) The section is complete if the discrepancy between the original forward and backward runnings is not greater than 3 mm \sqrt{K} or 0.012 ft. \sqrt{M} . The difference of elevation is the mean of the two runnings, where:

$$\text{Mean} = \frac{(F) - (B)}{2}$$

- d) Relevel when the discrepancy between the original forward and backward runnings is greater than 3 mm \sqrt{K} or 0.012 ft. \sqrt{M} .
- e) A relevelled section is complete if the discrepancy is not greater than 3 mm \sqrt{K} or 0.012 ft. \sqrt{M} between at least one forward and one backward running, after the rejection test (item h) is satisfied.
- f) A relevelled section is complete if, after several relevelings, there are at least two forward runnings and two backward runnings surviving the rejection test (item h), even though there is not a check between a forward running and a backward running.
- g) The difference of elevation for a relevelled section is the mean of the separate means of the acceptable forward runnings and the acceptable backward runnings.
- h) **Rejection Test:** where \bar{x} is the mean of the separate means of the forward and backward runnings for a section, a running x is rejected when:
 $|x - \bar{x}| > 3.7 \text{ mm } \sqrt{K} \text{ or } 0.015 \text{ ft. } \sqrt{M}$.

• First -Order

- a) Level each section once forward and once backward, independently, using different instrument men, and, if possible, under different weather conditions and at different times of the day.
- b) Reject and relevel any running with suspected gross errors.
- c) The section is complete if the discrepancy between the original forward and backward runnings is not greater than 4 mm \sqrt{K} or 0.017 ft. \sqrt{M} . The difference of elevation is the mean of the two runnings, where:

$$\text{Mean} = \frac{(F) - (B)}{2}$$

- d) Relevel when the discrepancy between the original forward and backward runnings is greater than 4 mm \sqrt{K} or 0.017 ft. \sqrt{M} .
- e) A relevelled section is complete if the discrepancy is not greater than 4 mm \sqrt{K} or 0.017 ft. \sqrt{M} between at least one forward and one backward running, after the rejection test (item h) is satisfied.
- f) A relevelled section is complete if, after several relevelings, there are at least two forward runnings and two backward runnings surviving the rejection test (item h), even though there is not a check between a forward running and a backward running.

g) The difference in elevation for a relevelled section is the mean of the separate means of the acceptable forward runnings and the acceptable backward runnings.

h) **Rejection Test:** where \bar{x} is the mean of the separate means of the forward and backward runnings for a section, a running x is rejected when:

$$|x - \bar{x}| > 4.7 \text{ mm } \sqrt{K} \text{ or } 0.020 \text{ ft. } \sqrt{M}.$$

• **Second-Order**

a) Level each section once forward and once backward independently, using different instrument men, and, if possible, under different weather conditions and at different times of the day.

b) Reject and relevel any running with suspected gross errors.

c) The section is complete if the discrepancy between the original forward and backward runnings is not greater than $8 \text{ mm } \sqrt{K}$ or $0.035 \text{ ft. } \sqrt{M}$. The difference of elevation is the mean of the two runnings, where:

$$\text{Mean} = \frac{(F) - (B)}{2}$$

d) Relevel when the discrepancy between the original forward and backward runnings is greater than $8 \text{ mm } \sqrt{K}$ or $0.035 \text{ ft. } \sqrt{M}$.

e) A relevelled section is complete if the discrepancy is not greater than $8 \text{ mm } \sqrt{K}$ or $0.035 \text{ ft. } \sqrt{M}$ between at least one forward and backward running, after the rejection test (item h) is satisfied.

f) A relevelled section is complete if, after several relevelings, there are at least two forward runnings and two backward runnings surviving the rejection test (item h), even though there is not a check between a forward running and a backward running.

g) The difference in elevation for a relevelled section is the mean of the separate means of the acceptable forward runnings and the acceptable backward runnings.

h) **Rejection Test:** where \bar{x} is the mean of the separate means of the forward and backward runnings for a section, a running x is rejected when:

$$|x - \bar{x}| > 9.4 \text{ mm } \sqrt{K} \text{ or } 0.040 \text{ ft. } \sqrt{M}.$$

Bench Mark Stability

Before starting a line of levels, the stability of the starting bench mark must be proven by carrying out two-way levelling between the starting and an adjacent bench mark, and comparing the new difference of elevation with the original difference. If this check is within the allowable discrepancy for the order of levelling being carried out, both bench marks are assumed to be stable. If the check is greater than the allowable discrepancy,

then one or both bench marks are considered unstable and additional bench marks must be checked until an agreement is obtained. The bench marks being checked must be located far enough apart so that any disturbing influence is not the same on both marks.

Instruments

To obtain the standards of accuracy set out under "Bench Mark Stability", the following equipment is recommended:

• **Special Order**

a) Self-levelling instrument equipped with parallel-plate micrometer, telescope magnification of at least $40\times$, and a high speed compensator with sensitivity equal to or better than a $10''/2 \text{ mm}$ level vial; or spirit-level instrument equipped with parallel-plate micrometer, telescope magnification of at least $40\times$, and a $10''/2 \text{ mm}$ or better level vial.

b) Invar, double-scale rods with line graduations of width 1 mm to 1.6 mm.

c) Rod supports.

d) Circular levels permanently attached to the rods.

e) Foot plates or steel pins for turning points.

f) Sun shade and instrument cover.

• **First-Order**

a) Self-levelling instrument with parallel-plate micrometer, telescope magnification of at least $32\times$, and a compensator with sensitivity equal to or better than a $10''/2 \text{ mm}$ level vial; or spirit-level instrument with or without parallel-plate micrometer, telescope magnification of at least $32\times$, and a $10''/2 \text{ mm}$ or better level vial.

b) Invar, double-scale rods with line graduations of width 1 mm to 1.6 mm; or invar rods of checker-board design with smallest graduations not less than 1 cm or 0.01 yard and with check graduations on the reverse side.

c) Circular levels permanently attached to the rods.

d) Foot plates for turning points.

e) Sun shade and instrument cover.

Note:

When the parallel-plate method of levelling is employed, for special-order or first-order levelling, double scale line-graduated rods must be used. The spacing of the smallest graduations must be equivalent to the displacement of the parallel-plate micrometer. When the 3-wire method is employed for first or second-order levelling, rods with checker-board design must be used.

• **Second-Order**

It is recommended that the equipment for the first order levelling be used also for second-order levelling. However, instruments with a level vial sensitivity of 20"/2 mm or equivalent compensator, may be used.

• **Lower-Order**

The sensitivity of the level vial or equivalent compensator, should be in the 40" to 50"/2 mm range. Rods with the graduations on wood or metal alloy other than invar are satisfactory, however, it is important that the length graduations be accurate.

Procedures

To obtain the standards of accuracy set out above, the following procedures are recommended:

• **Special Order**

- a) All sections must have an even number of set-ups.
- b) Difference between backsight and foresight distances at each set-up and their total for each section not to exceed 5 metres or 15 feet.
- c) Alternate readings of backsight and foresight at successive set-ups.
- d) Maximum length of sight 50 metres or 165 feet with weather conditions and terrain permitting.
- e) Line of sight not less than 0.5 metre or 1.5 feet above the ground.
- f) Rod reading consists of mean of centre-wire reading on each scale after applying scale constant.

• **First-Order**

- a) All sections must have an even number of set-ups.
- b) Difference between backsight and foresight distances at each set-up and the total for each section not to exceed 10 metres or 33 feet.
- c) Alternate readings of backsight and foresight at successive set-ups.
- d) Maximum length of sight 60 metres or 195 feet with weather and terrain conditions permitting.
- e) Line of sight not less than 0.5 metre or 1.5 feet above the ground.
- f) Rod readings consist of:
 1. Parallel-plate method — mean of the centre wire of each scale after applying scale constant.
 2. 3-wire method — mean of the readings for the three wires.

• **Second-Order**

First-order procedures are recommended. If second-order levelling forms part of a closed loop and the new levelling is less than 40 kilometres or 25 miles, single one-way levelling is acceptable. In this case, first-order procedures are essential. If single, one-way levelling is used, the misclosure must not exceed 8 mm \sqrt{K} or 0.035 ft. \sqrt{M}

• **Lower-Order**

On third and fourth-order work, only one wire need be read. It is preferable that the difference of elevation between successive bench marks be determined twice by two independent levellings.

If the levelling does not form part of a closed loop, or if the length of new levelling exceeds 40 kilometres or 25 miles for third-order work, or 80 kilometres or 50 miles for fourth-order work, some form of double levelling must be employed. Such double levelling may consist of: two independent levellings in opposite directions or in the same direction, levelling with one instrument and two sets of turning points, or simultaneous levellings with two instruments and one set of turning points. In every case, the rod readings must be recorded as two separate levellings, and the two differences of elevation between successive bench marks compared. If two sets of turning points are used with one instrument, two rods graduated in different units should be employed.

In all lower-order levelling, it is extremely desirable to use the two-rod system and to keep balanced foresights and backsights.

OTHER METHODS

Vertical Angles

Elevations of an accuracy equivalent to lower-order spirit levelling may sometimes be obtained by vertical angles in conjunction with traverse, trilateration or triangulation. Highest accuracy can be obtained only on short lines (a few hundred metres). For best accuracy on long lines, the angles at each end must be read simultaneously using one-second or better instruments. To be considered simultaneous, the observations at each end must start within a minute. A minimum of three simultaneous sets is recommended, where a set consists of readings taken in the direct and reverse positions.

The sets should be taken preferably at different times of day, but should not be taken during periods when atmospheric conditions are unstable, such as at dawn or dusk. The order of accuracy which can be achieved depends largely on the care in taking simultaneous

readings and on the stability of the atmosphere. However, results equivalent to fourth order levelling accuracy can seldom be secured if lines are greater than about 15 kilometres (10 miles).

In regions such as mountainous or coastal areas, the effect of the geoid and deflections of the vertical may be significant and should be considered.

Notes on Field Control Placement and Identification
(abstracted from "Manual of Field Control Placement and Identification"
second edition April 1978 S&M Branch)

Vertical Control Placement

Vertical control is best placed in the common overlap between flight lines, for if points are so placed they are ideally situated to level the stereo-model. In block adjustments, vertical control is not needed in every model, thus, chains of vertical control points are generally requested running at right angles to the photographic flight lines and spaced from five to six overlaps apart.

The ideal vertical control point is a level surface of known elevation with suitable image contrast for the precise placing of the floating mark on the ground. There is the obvious requirement that the horizontal position of the level surface can be correctly identified on the compilation photography.

It might appear that the centre of a level grass field would be ideal, but this is not necessarily so. If the texture of the grass is uniform it is difficult to form a stereo image; however, if a foot-path runs across the field or some other pattern exists, this control point can be used to form the stereo image and position the mark on the ground. For the same reason, the centre of a body of water cannot be used as a vertical control point but any point located on the shore which is clear of trees (e.g. a sandy beach) is suitable.

There are two dangers in using water surfaces:

- most Canadian lakes change in water level from year to year and from season to season. Therefore, it is necessary for the field surveyor to determine from local evidence the extent of the seasonal fluctuations of the lake level.
- if the lake is surrounded by trees which come to the water's edge, no suitable stereo image can be obtained at the water level.

The level surface at the centre of a crossroad is easily identifiable and is generally suitable for a vertical control point. In cases where the sun is reflected brightly from the road surface, causing a flare, the photogrammetric operator can usually find a place at the edge of the pavement where the floating mark can be brought to ground level.

It can be deduced that an ideal vertical control point is a level surface containing sufficient detail for good stereoscopic fusion so that the floating mark of the stereoplotter can be placed on the image of the ground. In actual practice, good results are derived from shoreline points, the highest point of bald round-topped hills (i.e., where a helicopter can land at the highest point), level pastureland, parkland and even asphalt parking lots where the white line parking grid forms a suitable pattern for stereoscopic fusion.

Vertical Control Identification in Wilderness Areas

Helicopter altimeter lines are laid out at right angles to the mapping photography flight lines and spaced from five to six overlaps with the proposed vertical control points marked with a circle of about one inch in diameter. These points have been carefully pre-selected by examining the photography with a stereoscope.

The elevation of points along the traverse line should be kept at approximately the same elevation. (The ideal situation is to have all stations at elevations within 75 m of the mean. If the terrain makes this goal impossible, ± 150 m should be considered as the outside limit). Within this overall restraint, the preferred locations for points are in the following order of preference:

- lakes or ponds on which the helicopter can land and with at least part of the shoreline suitable for photogrammetric measurement;
- the highest point of a hill on which the helicopter can land (i.e., clear of boulders or trees and with a reasonably flat top);
- a level clearing with good identification features;
- the lowest point on a saddle ridge between two higher features.

Experience has shown that the most precise way to indicate the elevation of the highest point of a hill is NOT by attempting to pin-prick the position of the highest point, but by circling the part of the hill containing the highest point and letting the plotter operator find this point using the floating mark.

The same system can be used for an elevation on a piece of level ground, by circling the level area so that the plotter operator can drop his mark at any point within the circle. If it is essential to place an elevation point in an area where no hilltops exist and where no level ground can be found, then it is permissible to read an elevation on gently sloping ground beside some point of detail that can be positively identified on the photograph. A pin-prick is used to mark the position on the photo.

Care must be taken to ensure that the helicopter actually rests on the highest point of a feature when this is the station description. A hand level should be used if there is any question of other bumps in the vicinity being higher.

