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CHANGE DETECTION BY LANDSAT AS A GUIDE TO PLANNING AERIAL PHOTOGRAPHY FOR REVISION MAPPING

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ABSTRACT

It has been demonstrated in a test area that cultural changes in 1:250 000 maps in wilderness areas can be rapidly assessed and often accurately identified and mapped by the use of Landsat MSS imagery. Landsat RBV imagery may provide even more detailed information. On the basis of this change detection, aerial photographic missions can be planned to provide the additional detailed information needed for completing revision and re-validating the map. By being able to direct the aircraft to areas of change only, the efficiency of aerial coverage can be greatly improved, since the need for covering vast blocks with photography, much of which will be found to contain no mappable changes, is eliminated. This increase in efficiency pays double dividends in those northern areas where the photographic season is limited to a few weeks in each year. If block photography is required it may take a number of years to acquire, whereas effectively placed, limited photography can make essential revision information available in one season.

INTRODUCTION

Historically Canada has had to devise straightforward, economical mapping procedures in order to survey and map a very large territory from a relatively small population base. The stage has now been reached where map revision requirements are as heavy a burden to bear as the new mapping requirements. To relieve this burden somewhat, and free resources for other activities, the use of Landsat imagery in a comprehensive revision program has been investigated.

At present the only complete mapping in Canada is at scales of 1:250 000 and smaller. The 1:250 000 map series was completed in 1970 after a compilation period that spanned 23 years and saw many changes in mapping techniques. This series of 918 maps provides only moderately detailed information about relief, drainage, transportation facilities and centres of population. Greater detail is provided by the 1:50 000 scale of mapping, and approximately sixty percent of the 13,150 maps in this series have been published.

Map revision is a never-ending process as cultural and physical changes take place. The larger the number of maps published, the more the resources for mapping must be diverted from new mapping to work on the revision of existing maps. At present 60% of Topographical Survey personnel and resources are engaged in revision.

The normal revision technique for the 1:250 000 series is to couple it with the production of the 1:50 000 series. As blocks of the larger-scale maps become available, the information they contain can be used to strengthen the geometry and update the content of the smaller-scale map. However as long as the 1:50 000 series is incomplete this approach places a constraint on adequate maintenance of the 1:250 000 series.

Since the 1:250 000 series represents the largest scale of mapping available in almost one-half of the country, its increasing obsolescence is causing problems to users. The incompleteness of detailed mapping at 1:50 000, the urgent need for revision of published maps at both scales, and the current climate of economic restraint demands less costly methods be devised than that of obtaining revision information by extensive block aerial photographic coverage. (Moore, 1978; Lapp et al, 1978).

Landsat images have already shown themselves useful in the revision of specific features in Canadian mapping (Fleming, 1976) and it has long been felt that systematic examination of Landsat images would provide a means of detecting areas of change, thereby increasing revision efficiency by concentrating resources in those areas showing most change. A comprehensive test of the technique was initiated in 1979 and a contract was awarded to Gregory Geoscience Ltd. of Ottawa to use Landsat images to detect, and, where possible, map the changes in a block of four 1:250 000 maps. Concurrently, aerial photographic coverage of the area was scheduled. This was to serve as control and as a back-up to the revision information obtained from the Landsat study. The results of this test showed the remarkable extent to which Landsat can be used to monitor changes and provide revision information.

TEST AREA

The area chosen to test the capability of Landsat as a revision tool lies wholly within the sparsely-settled area of Canada to which a map-revision cycle of 30 years has been assigned (figure 1). The sheets are designated 74A, 74B, 74C and 74D in the National Topographic System (N.T.S.). Three of the test sheets (A,B,C) are also mapped at 1:50 000 and the fourth sheet, D, is partially completed at this scale.

Although it was known that many cultural changes would exist on 74D because of the development of the tar sands on the northern edge of the sheet, the extent of any cultural changes in the sheets to the east was unknown.

LANDSAT ANALYSIS

For detection of changes the best and most recent Landsat scenes were used, but because the work was done in early summer 1979 the most recent summer scenes were those of the previous year. The location of the Landsat image centres with respect to the test block is shown in figure 2. Forty-two MSS scenes and ten RBV scenes were examined, from which it was established that the minimum number of images required to obtain reliable revision information was five: summer and winter MSS bands 5 and 7, and the best summer colour composite. The amount of RBV data available was very limited but it was regarded as being useful for change detection and mapping at 1:50 000. One disadvantage noted with respect to the RBV was its panchromatic response which could lead to confusion in identifying such features as shallow water, wet ice, or silty water.

The image to be studied was mounted in projection equipment, enlarged to the desired map scale and registered with the map. Once preliminary registration was achieved the interpreter made a quick scan of the image, alternately with and without the map background, to detect any major changes such as new roads or reservoirs. This was followed by a more detailed scan of each 10 000-metre grid square in which smaller changes were noted. Upon completion of the detailed scan for the whole map, an overlay showing the location of all the detectable changes was produced. The final change overlay could thus be the composite of information extracted from several images (Moore, Gregory, 1979).

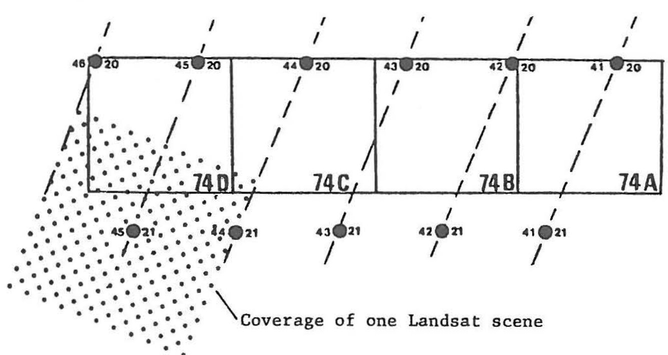

Figure 2
Landsat Image Centres for the Test Block

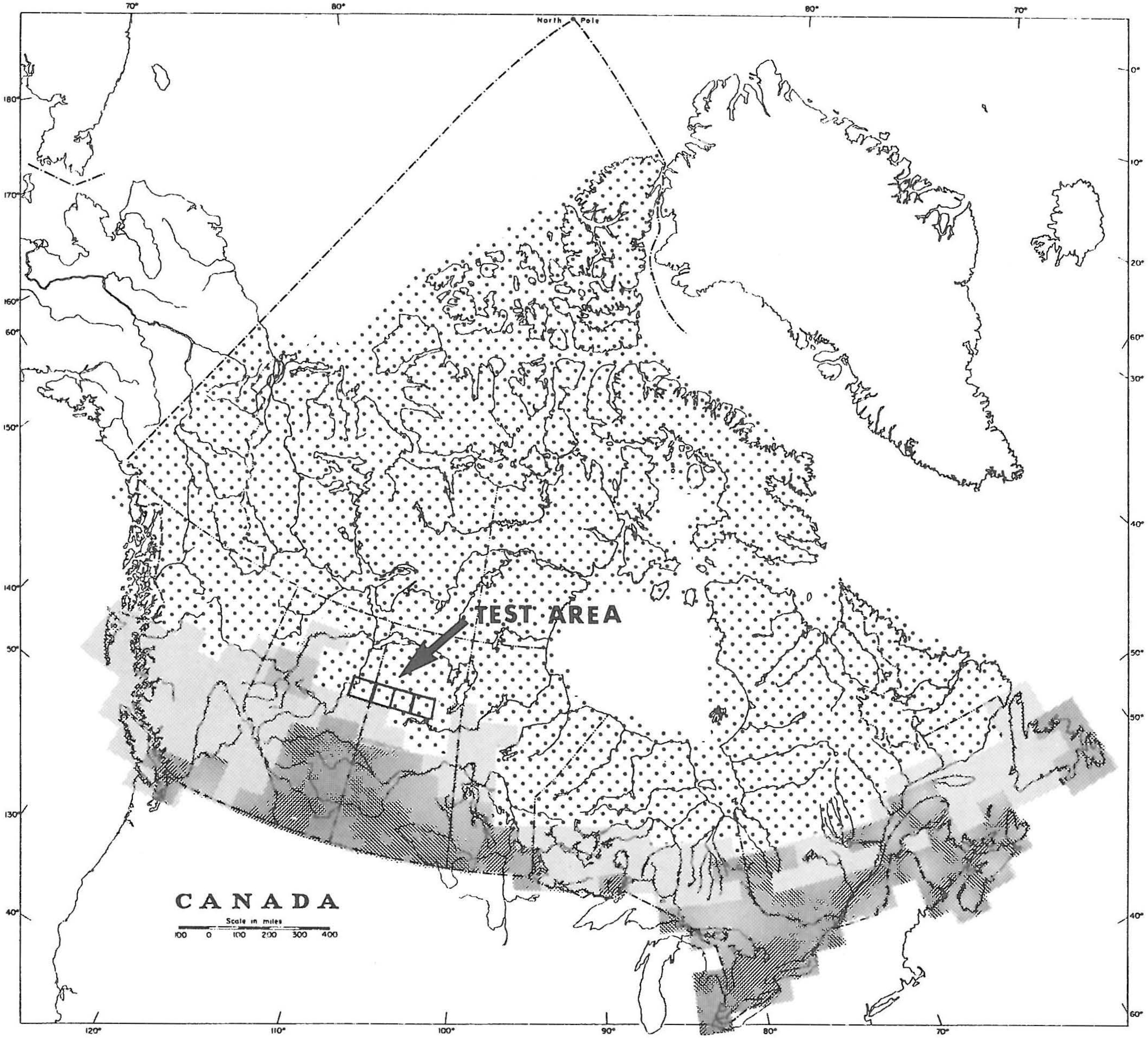

Figure 1

Location of four 1:250 000 maps used as a test block for Landsat change analysis.

NATIONAL TOPOGRAPHIC SERIES

REVISION CYCLES
1:250,000 SCALE MAPS

10 YR. CYCLE	119 Maps
15 YR. CYCLE	111 Maps
30 YR. CYCLE	688 Maps
TOTAL	918 Maps

CHANGES DETECTED

Two categories of change detection were apparent on the map overlays resulting from the Landsat analysis of the test area.

1. Man-made Changes

   The cultural changes detected and plotted included such linear features as roads and energy transmission corridors, and areal changes resulting from various types of clearing activity. From the RBV images it was even possible to plot road patterns in a recent subdivision area adjacent to an existing settlement.

2. Changes in the Mapping of Natural Features

   A number of small lakes, visible in the Landsat images and apparently larger than the minimum size of 300 metres used for 1:250 000 mapping were noted as not being mapped. Other mapped lakes lacked evidence of water content, indicating that perhaps they should be mapped as "intermittent lakes". Marsh outlines were also noted as being inconsistent in some areas.

VERIFICATION OF LANDSAT CHANGE DETECTION AND MAPPING

Using the aerial photography obtained during the 1979 season it was possible to check the completeness and accuracy of the Landsat revision overlays. It was found that:

1. All man-made changes significant for 1:250 000 mapping had been detected.
   In addition almost all the significant changes for 1:50 000 mapping had been detected. The only changes not detected were very narrow cut-lines associated with resource exploration surveys.

2. All linear features were plotted with an accuracy suitable for a revision over-print on either the 1:250 000 or the 1:50 000 map.

3. Virtually no errors in change detection occured when MSS imagery was used at 1:250 000.

   The most errors occured in the use of RBV images for 1:50 000 mapping, where a number of linear features were plotted that were not apparent on the aerial photographs.

4. Map compilation errors and omissions were correctly detected with respect to the mapping of minimum size lakes (300 m), the proper categorization of lakes as "intermittent", and lack of uniformity in depiction of marsh outlines.

5. Areal changes, with the possible exception of forestry cutting and housing development adjacent to a settlement, could not be identified as to their nature. These would require aerial photography or field inspection to determine their mapping significance.

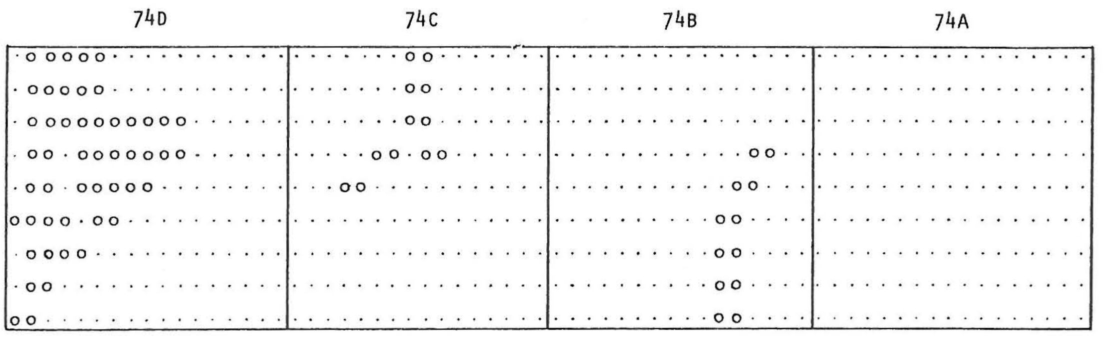

Figure 3. INEFFICENCY OF BLOCK AERIAL PHOTOGRAPHY FOR REVISION PURPOSES

Of the 594 photographs required to cover the test block, each represented by a dot on the diagram, only the 73 circled would show any cultural change from prevous photography. This represents a 12% utilization of new photography.

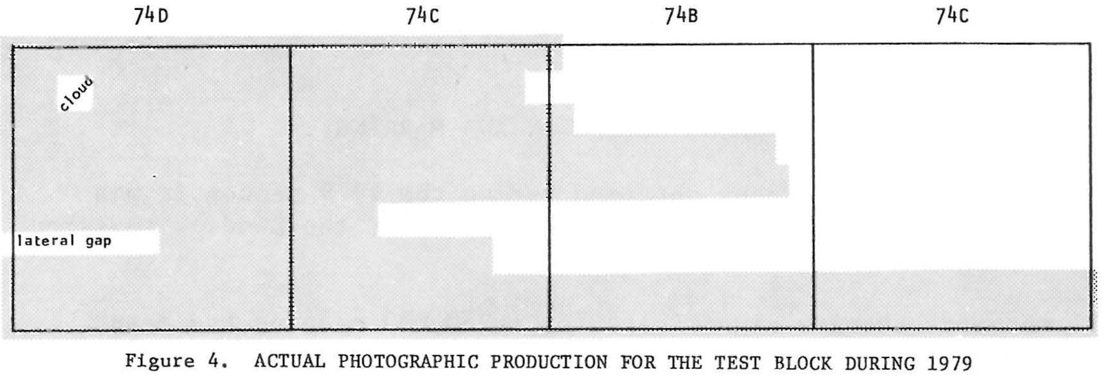

Figure 4. ACTUAL PHOTOGRAPHIC PRODUCTION FOR THE TEST BLOCK DURING 1979

4500 line-kilometres were required to cover the test block. Of these, 2840 km were flown before the season ended (63% completion). None of the map sheets in the block have complete coverage, meaning a delay of another year for full revision information on any sheet.

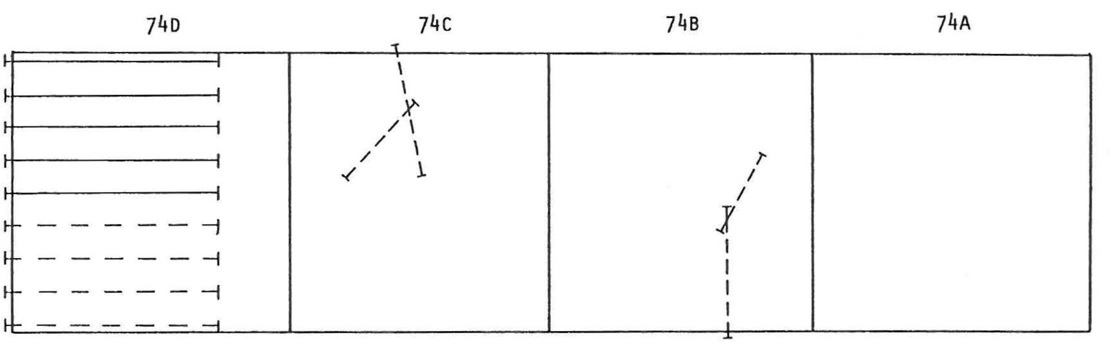

Figure 5. EFFECTIVE PLANNING OF REVISION PHOTOGRAPHY USING LANDSAT

Based on change detection mapping from Landsat images, only those flight lines marked by solid lines (450 line-kilometres) would be required for area revision. An additional 560 kilometres (dashed lines) would cover the remaining linear changes which could equally well be mapped from Landsat.

6. Linear features were not identified specifically as either roads or energy transmission corridors, but in many cases the distinction was apparent. Others would require further investigation by field inspection or correspondence with appropriate authorities.

IMPLICATION OF THE USE OF LANDSAT IN PLANNING A REVISION PROGRAM

The test area consisted of four 1:250 000 maps and fifty-four 1:50 000 maps. If one applied the concept that for each year that passes since the last culture check on a map, one debit revision year exists, then these fifty-eight maps had a total revision debit of 1073 years, or an average "lack of currency" of 18.5 years per map. Although the maps are in an area that has a nominal revision cycle of 30 years and therefore are not technically scheduled for revision, it is known to be an area where resource development is taking place and currency of map information is important if the maps are to fulfil their proper role.

Lacking exact knowledge of where changes may be occuring, block aerial coverage at small scale offers one solution to revision. The inefficiency of this solution can be demonstrated in retrospect for the test area. Almost six hundred aerial photographs at a scale of 1:80 000 are required to cover the test area (figure 3). In this area the number of these pictures that would record any cultural change from previous photographic coverages is seventy-three. For revision purposes this represents an efficiency rate of a mere 12%.

Unnecessary photography is only one of the problems of block coverage. A second and equally serious problem is illustrated by figure 4 which shows the amount of aerial coverage actually achieved in 1979 after 3 sorties into the area by a high-altitude jet aircraft. Of the total 4500 line-kilometres required, only 2480 kilometres were completed (63%) and the season ended without any of the four maps having complete coverage.

What could the Landsat change detection data have done to increase efficiency?

1. It could have precisely identified the locations and the nature of the changes (linear or areal) in these map sheets.

2. Based on this information it would have been necessary to refly only the west portion of 74D for updating 1:50 000 maps.

   To do this would require 450 line-kilometres of 1:80 000 photography or just 10% of the amount of flying required by the 1979 contract (figure 5). In terms of the production achieved in 1979 it would have required only 15% of the actual flight time spent in the area, and besides completing the essential photography, would have freed the jet for 2000 line-kilometres of more essential work elsewhere.

3. The linear features in 74 B,C and D could be added to both the 1:50 000 and 1:250 000 maps from Landsat overlays, and the maps revised by means of a revision overprint on existing stocks.
   If it were felt necessary to record these linear features on aerial photography this could be done in single strips totalling 200 line kilometres, and by increasing the block coverage to 810 km.

TABLE 1

REVISION STATUS OF 1:250 000 TEST MAPS USING LANDSAT

MAP	DATE OF CULTURE CHECK	REVISION	SOURCE	CHANGES
74A	1961 1974 *1978*	Original Overprint *No Change*	 *Landsat*	 Highway *Inspection notes: Hwy not located accurately; 60 small lakes not mapped 16 small lakes to delete or change.*
74B	1954 1977 *1978*	Original No Change *No Change*	 1:50 000 *Landsat*	 *Inspection notes: 44 small lakes not mapped, 3 to change category.*
74C	1952 1977 *1978*	Original Overprint *Overprint*	 1:50 000 *Landsat*	 Highway, Indian Reserve, Airport Roads *Highway continuation* *Inspection Notes; 8 small lakes and marshes not mapped 12 deletions or changes to natural features; check location of 1977 Highway in 3 places.*
74D	1950 1967 *1978*	Original Overprint *Overprint*	 *Landsat*	 Highway, Road *Energy Transmission lines Roads* *Inspection notes: Extensive urban development in 15 km radius of Ft. McMurray extensive forestry cutting extensive marsh changes 9 deletions or changes in small lakes, 4 additions.*

All overprints on the above maps would be to show roads and energy transmission corridors.

4. Maps with no detectable change could have their cultural validation date changed to that of the date of Landsat cultural change check.

Thus from Landsat alone, where this area started with a revision debit rating of 1073 years, the debit rating could be reduced to the 8 debit-years associated with 1:50 000 map 74D/11 where urban development around the townsite of Fort McMurray could only be adequately plotted using aerial photography.

The changes in revision and validation dates that could be applied to each of the maps of the test area are tabulated in tables 1 and 2.

CONCLUSIONS

Systematic examination of Landsat images for change detection and mapping of linear features can be a powerful tool for those involved in planning revision mapping for developing areas. Aerial photography can be more efficiently directed to areas of change, not only reducing the amount of photography required, but equally importantly, improving the likelihood of completing the essential photography of an area in a single season and freeing survey aircraft and mapping funds for use in higher priority applications.

Linear features, which constitute the only revision features required to up-date the majority of the maps in the non-settled areas of the country can be mapped from Landsat images wherever the land has any type of vegetative cover. Any uncertainties in identification of these features can be resolved without resorting to aerial photography.

Since change detection using Landsat has been found to be complete in these remote areas, it is possible to place a culture check date on a published map on the basis of Landsat data, even when no changes have occured. This effectively extends the revision cycle of the map.

Landsat, like aerial photography, is weather dependent and not all areas have images of the quality or the timing that one would like for revision purposes. It is not expected that this system will be equally effective in all parts of the country; however, over 300 of the 918 maps in the 1:250 000 series are in areas that do not differ radically from the test area.

Landsat 1 and 2 have ceased to function, leaving us with a slightly crippled Landsat 3. Landsat D is scheduled for launch in a year or two. It will carry an MSS, but its primary sensor will be the untried and more elaborate Thematic Mapper. This revision test has shown that even using the more modest capabilities of a satellite system, tremendous dividends can be achieved for revision mapping in remote areas. Increased resolution over that of the MSS offers no great advantage in this application. Eighty-metre pixel size, a red and a near-infrared band on an MSS scanner having cyclic coverage would satisfy our requirements into the foreseeable future. It is hoped that such a relatively simple requirement will not be lost as more complex and specialized satellite sensing systems are developed.

TABLE 2

REVISION STATUS OF 1:50 000 TEST MAPS
USING LANDSAT

MAP	CURRENT DATE AT PUBLICATION	UP-DATE	TYPE OF REVISION	SOURCE
74A1	1953	1978	No Change	Landsat
A2	1975	1978	No Change	"
A3	1975	1977	No Change	"
A4	1975	1978	No Change	"
A5	1952	1978	No Change	"
A6	1971	1978	No Change	"
A7	1971	1978	No Change	"
A8	1974	1978	No Change	"
A9	1975	1978	No Change	"
A10	1975	1978	No Change	"
A11	1971	1978	No Change	"
A12	1954	1978	No Change	"
A13	1954	1978	No Change	"
A14	1954	1978	No Change	"
A15	1954	1978	No Change	"
A16	1975	1978	No Change	"
74B1	1952	1978	No Change	Landsat
B2	1952	1978	Overprint	"
B3	1952	1978	No Change	"
B4	1952	1978	No Change	"
B5	1952	1978	No Change	"
B6	1952	1978	No Change	"
B7	1952	1978	Overprint	"
B8	1952	1978	Overprint	"
B9	1952	1978	Overprint	"
B10	1952	1978	No Change	"
B11	1952	1978	No Change	"
B12	1952	1978	No Change	"
B13	1952	1978	No Change	"
B14	1952	1978	No Change	"
B15	1952	1978	No Change	"
B16	1952	1978	No Change	"
74C1	1952	1978	No Change	Landsat
C2	1952	1978	Overprint	"
C3	1952	1978	Overprint	"
C4	1952	1978	No Change	"
C5	1952	1978	No Change	"
C6	1952	1978	No Change	"
C7	1952	1978	No Change	"
C8	1952	1978	No Change	"
C9	1971	1978	No Change	"
C10	1971	1978	Overprint	"
C11	1971	1978	Overprint	"
C12	1971	1978	No Change	"
C13	1952	1978	No Change	"
C14	1971	1978	No Change	"
C15	1971	1978	Overprint	"
C16	1971	1978	No Change	"
74D5	1974	1978	Overprint	Landsat
D6	1976	1978	Overprint	"
D11	1970	Requires New Photography		"
D12	1970	1978	Overprint	"
D13	1977	1978	Overprint	"
D14	1970	1978	Overprint	"

All overprints on above maps would be to show Roads and Energy Transmission corridors.

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