# ASSESSMENT OF
# THE UPPER LEVEL LOOP ALTERNATIVE
# FOR THE MANHATTAN PORTION
# OF THE EAST SIDE ACCESS PROJECT

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DELCAN

# Assessment of
# The Upper Level Loop Alternative
# For the Manhattan Portion
# Of the East Side Access Project


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## BACKGROUND

The East Side Access (ESA) is an approved project being developed incrementally by MTA partly as a result of staged funding from FTA and of various stages of approval of some of the project elements. The basic objective of the ESA is to provide a direct route for Long Island Rail Road (LIRR) passengers to the East Side of Manhattan at Grand Central Terminal thereby avoiding the need to travel via Penn Station which is located on the west side of Manhattan. The ESA scheme utilizes the unused lower level of the 63rd Street Tunnel across the East River. This tunnel was built in the 1960s to provide rail transit services from Queens to Manhattan. New facilities are required in Queens to connect the LIRR into this tunnel route and to provide train storage, and in Manhattan to allow trains to run south from 63rd Street to new platforms at Grand Central Terminal (GCT).

One of the most expensive and complex parts of the ESA project is the provision of the terminal facilities at GCT. At the current time, GCT is entirely utilized by Metro-North Railroad (MNR), a commuter rail system that serves areas to the north of Manhattan. Originally, it was proposed that LIRR would run into tracks in the western lower level of GCT that comprise an existing MNR train storage area called the Madison Yard. For the displaced trains that are normally stored during the day in the Madison Yard, the original scheme involved building a new Highbridge yard in the Bronx to accommodate these displaced trainsets. This original scheme also required expensive tunnelling under office towers on the west side of Park Avenue to connect the 63rd Street Tunnel into the Madison Yard.

During preparation of the Final EIS, the MTA ESA project team considered various alternatives and chose a very different scheme that involves constructing four new station platforms in two caverns deep below Park Avenue, to the east of and below the Madison Yard. This preferred scheme is called the “GCT via main line” scheme in the FEIS. The Madison Yard area would be used instead as an intermediate passenger concourse with connections to the surface through buildings along Madison Avenue; the concourse would also contain retail space and offices for LIRR and MNR. Tunnelling under existing office buildings on Park Avenue would not be required. There would be no or minimal effect on MNR operations during construction, although MNR would lose the use of the Madison Yard.

Whereas the earlier cost estimate of the ESA project was about $4 billion, MTA now expects the cost to exceed $6 billion. MTA and other government agencies in the New York region are struggling to fund ESA and other capital projects, including the Second Avenue subway, a single-train service from JFK Airport to lower Manhattan, as well as ongoing renewals and modernization of the existing subway and commuter rail systems. All of these must compete for scarce federal and state funding. Any savings in the cost of one scheme can improve the prospects of it and the other schemes progressing to completion.

In 1996, the Committee for Better Transit (CBT) put forward a scheme to make use of the existing upper level platforms and “loop track” in GCT as the terminal for ESA trains, called the “Apple Corridor” scheme. It also included a proposal to operate direct trains from JFK Airport over the ESA route. The Apple Corridor scheme was one of the alternatives considered by MTA in the preparation of the Final EIS and specific reasons were given in the Final EIS for rejecting it.

In view of the rising costs of the ESA project, the Institute for Rational Urban Mobility (IRUM), a not-for-profit public interest group, revisited the CBT proposals for use of the existing upper level loop platforms. Michael Schabas of London, England and Delcan have assisted IRUM in assessing the Manhattan portion of the Apple Corridor scheme and in reviewing the reasons given by MTA in the Final EIS for rejecting this scheme. More specifically, the objectives of the assessment are to:

- Assess the technical and operational viability of the Manhattan portion of the Apple Corridor scheme;
- Review and assess the disadvantages outlined in the FEIS as they pertain to the Manhattan portion and, if necessary, to determine modifications to the Apple Corridor scheme necessary to eliminate or minimize the extent of such disadvantage;
- Estimate the potential cost implications of adopting the Manhattan portion of the Apple Corridor scheme instead of the preferred “GCT via main line” deep cavern scheme.

This report summarizes the key findings of this assessment. Since only the Manhattan portion of the Apple Corridor scheme was examined, this report refers to that portion as the Upper Level Loop Alternative (ULLA) in order to clearly distinguish it from the total Apple Corridor scheme.

# 1. DESCRIPTION OF THE MTA PREFERRED SCHEME AND THE UPPER LEVEL LOOP ALTERNATIVE

The existing GCT complex and approach tracks are all underground, illustrated in Figures 1 and 2. Proceeding from a north to south direction, there are four MNR mainline approach tracks that transition from 57th Street to about 55th Street into ten throat tracks. By about 51st Street, six of these proceed to the upper level tracks and four to the lower level tracks within the GCT terminal. The throat is considered to extend from 57th Street to about 51st Street. The approach tracks and throat tracks are situated under Park Avenue; essentially Park Avenue is on a deck over this array of tracks. Within the GCT terminal, the underground station tracks are arranged on two levels and extend from the south end of the throat about 51st Street to about mid-way between 44th Street and 43rd Street. The terminal building itself extends from the south end of the terminal tracks to 42nd Street. This configuration is illustrated in Figures 3, 4 and 5.

The preferred scheme for the ESA project as described in the FEIS is called the "GCT via Main Line" scheme in the FEIS. For the purpose of this report, the portion of this scheme into Manhattan is referred to as the Deep Cavern scheme and is illustrated in Figures 6, 7 and 9. It involves the provision of the following elements:

- Two tracks for the LIRR across the East River through the unused lower level of the 63rd Street tunnel which turn toward the south on the west side of the tunnel in Manhattan;
- The two tracks continue south, under Park Avenue in deep tunnel beneath the existing MNR tracks;
- South of 59th Street, the two tracks widen into four tracks on one level, then to eight tracks on two levels;
- LIRR trains terminate on four new platforms on two levels, located in two deep caverns under Park Avenue between 49th and 44th Streets. A mid-level mezzanine is situated between the upper and lower platforms in the caverns together with east-west cross passages. The lower four platforms are155 feet below the surface;
- Escalators and elevators link the Deep Cavern mezzanine to an intermediate concourse in the existing Madison Yard with escalators and elevators continuing to street exits at Madison Avenue similar to the recently constructed Grand Central North exits;
- Tail-track tunnels south of the platforms extending to 38th Street;
- Various other structures including ventilation shafts and emergency exits.

The ULLA follows a different horizontal and vertical alignment compared to the Deep Cavern scheme from the 63rd Street tunnel portal to about 57th Street at park Avenue, although it would involve similar tunnelling construction methods. South of 58th Street, the ULLA differs from the Deep Cavern scheme and is constructed using traditional open cut construction beneath the MNR tracks. The configuration of the ULLA is illustrated in Figures 8 and 9 and is also indicated on Figures 4 and 6, and involves the following elements:

- A twin-track mainline under the MNR tracks under Park Avenue at a shallower elevation than the GCT via Main Line scheme. This is in a mined tunnel north of 55th Street;
- Between 55th and 52nd Street, the LIRR inbound track rises into the existing MNR tunnel, using the track I alignment;

- Track I leads directly into the five existing platforms at tracks 38 to 42 inclusive within the GCT terminal, where LIRR trains would terminate;
- LIRR trains would continue around the existing upper level loop onto track C, which runs north under Park Avenue. Between 51st and 55th Streets, track C would be lowered to form the outbound track and drop into the twin track mainline tunnel, to connect into the 63rd street tunnel;
- LIRR would have exclusive use of tracks I and C, platform tracks 38 - 42, and the upper level loop.

Metro-North would need to make some changes to its operating arrangements, as it would no longer have use of tracks C and I in the throat, tracks 38-42 and the upper level loop. Storage tracks on the east side of the upper level, extending under the Waldorf Astoria Hotel, sometimes call the Waldorf Yard, would be separated from the remainder of the MNR tracks. As with the Deep Cavern scheme, tunnel works for the connection into GCT would be under the MNR tracks under Park Avenue. Unlike the Deep Cavern scheme, MNR would retain use of the Madison Yard area.

Even though the scope of construction work for the ULLA is significantly less than the Deep Cavern scheme, an Environmental Assessment would be required in order to seek final approval for the ULLA.

# 2. TECHNICAL AND OPERATIONAL ASSESSMENT OF THE ULLA

Only the components of the Apple Corridor scheme that involve access to GCT in Manhattan have been assessed from a technical and operational perspective. The ESA plans in Queens have not been reviewed and are assumed to address all major issues on that side of the river regardless of the configuration of the GCT access. The Apple Corridor scheme included a connection to JFK Airport but this is no longer relevant in view of the recent construction of AirTrain. The technical and operational analysis focused on the following categories: track alignment, constructability, train operations and passenger flow. ***It is important to note that the extent of analysis was constrained by the limited information available and by the time available for this assessment and therefore many assumptions and judgments were required based on the experience of the team.***

## 2.1 Track Alignment

### *2.1.1 General*

As noted above, it is proposed to operate LIRR trains on the existing upper level loop of GCT. LIRR trains would enter the station terminal from below the existing tracks on the alignment of existing track I. The trains would use the existing five platform tracks 38 to 42 as well as platforms S, T and U. Trains would operate around the existing loop, which would be isolated from MNR tracks, and exit the terminal via a descending track on the alignment of existing track C. Figures 4, 6, 8 and 9 show the basic elements of this arrangement.

The feasibility analysis from a track point of view has been based on the following documents:

- 1” = 50 ft. plan titled; “New York Central System Grand Central Terminal, Existing Conditions, Express Level”, dated January, 1951
- 1” = 50 ft. plan titled; “New York Central System Grand Central Terminal, Existing Conditions, Suburban Level”, dated January 1, 1951.
- Report dated March 1998; LIRR East Side Access Project Build Alternative Alignment Drawings.
- FEIS Report

In addition, a tour of the publicly accessible areas of GCT was made.

### *2.1.2 Inbound Track Connection*

**Description**

Existing track I would be permanently removed from service from station 26+37 (52nd Street) to 36+50 (56th Street). This would be replaced with a track, on exactly the same horizontal alignment, ascending from north to south, from a point below the existing lower level tracks at the north end, to the upper level loop tracks numbers 38 to 42 at the south end.

## Track Geometry

The track profile is an extension of the track 1 profile shown on drawing No GP-3, Sheet 6 of the report "Major Investment Study for the Long Island Transportation Corridor, Build Alternative Alignment Drawings".

The proposed 3.0% track grade ascending south, changes to a 3.20% grade ascending south at the VPI at station 36+50, elevation -2.5, using a 100 ft. long sag vertical curve (rate of change r = 0.4). The assumption is made that if the track 1, Option 1, profile is acceptable from the 63rd Street tunnel to 56th Street, then the same profile would be equally practical if it were to continue on the alignment of the existing track I, approximately 55 ft east of the Option 1 location. The 3.20% maximum grade is assumed to be permissible as a 3.25% grade is shown in The East Side Access FEIS, page S-10, Table S-2, Option 1, Train Operations.

The track emerges into the existing structure at a portal at approximately station 33+90. This assumes 20'-0" top-of-rail (T/R) to top-of-rail, (Ref. Dwg. GC-5, sheet 15 of above Report), and a vertical clearance of 14'-0" T/R to underside of roof (Ref. Dwg. GC-6, sheet 16 of above Report).

The new track connects to the existing Ladder X and Ladder Z, using a 100 ft long summit vertical curve (rate of change r = 2.4), VPI at station 25+62 approximately, elevation 32.2 approximately. There is a headwall at station 28+10. The new track would remove the top 6 ft (approx.) of this wall. The drawings show a pump house at this location. If it still exists, it may have to be relocated. It is assumed that, in the vicinity of station 26+50, the new ascending inbound track would start to encroach on the clearance envelope of Ladder U on the lower level. At this location the proposed track is approximately 8 inches below the upper level tracks. Consequently, the distance between the underside of the upper track support beams and upper top of rail would have to be reduced 8" in this vicinity. The existing embedded timber tie track support provides ample opportunity for height reduction. Replacement of the timber-style of track support with direct fixation fasteners is suggested as a height reduction method. No problems are foreseen clearing the lower tracks.

## Changes to Existing Tracks-Inbound

At the north end, track I would be permanently removed, between the portal (33+90 approx.), northward, up to and including the turnout at 56th Street which connects tracks I and J.

It may be necessary to temporarily remove the west end of Ladder L connecting track J & I and tracks I & H in order to permit construction of the portal at 33+90, and the shallow part of the tunnel north of the portal.

The intent of removing the following connections would be completely segregate the inbound LIRR track I from all MNRR tracks:

- Permanently remove the existing #8 LH crossover between station 27+07 and 28+70 (53rd Street).

- Permanently remove the north end of Ladder X between tracks H & I to accommodate the summit VC on Track I. Convert the DSS on Track I at 25+20 to a RH turnout. Convert the lap turnout on Track H to a #8 LH turnout.
- Permanently remove the track I connection between Ladder X and Ladder Y (24+00 to 25+00 approx.).
- Permanently remove the connection between Ladder X and Ladder Y (19+30 to 21+30, approx.).
- Permanently remove the track I connection between track 37 and Ladder (17+80 to 19+30 approx.).

**Challenges to Track Construction**

The summit vertical curve at 52nd Street would be immediately south of the turnout connecting Ladder X and Ladder Z. The depth of cover from underside of track-supporting beam to top of rail would have to be reduced by approximately 3-1/2". Existing track construction has the rails secured to timber ties or tie stubs embedded in concrete. This type of construction affords ample opportunity to lower the upper track, probably by substituting direct fixation fasteners for the timber ties.

### *2.1.3 Outbound Track Connection*

**Description**

Existing track C would be permanently removed from service from station 23+00 (51st Street) to 37+50, (north of 56th Street). This would be replaced with a track, on exactly the same horizontal alignment, ascending from north to south, from a point below the existing lower level tracks at the north end, emerging at a portal south of Ladder K at station 33+30, to the upper level immediately north of the north end of Ladder M. This new track connects to the loop track via Ladder M at the south end.

**Track Geometry**

At the south end, the profile of Track C starts to descend northward at a 3.0% grade as close to the north end of Ladder M as practical. The BVC of a 100 ft long vertical curve is located 10 ft north of the PS of the last turnout on Ladder M. Track C would have full access to Ladder M, i.e. the Loop Track.

At the north end, the track would enter a portal at station 33+30 approximately. This assumes 20'-0" vertical separation, top-of-rail (T/R) to top-of-rail, (obtained from Drawing. GC-5, sheet 15 of above March 1998 Report. A vertical clearance of 14'-0" T/R to underside of roof has been assumed, (obtained from Drawing GC-6, sheet 16 of the above Report). The location of this portal permits the retention and continued operation of the existing Ladder K, which connects tracks A, B, and D.

**Changes to Existing Tracks-Outbound**

A section of track C is permanently removed between the portal, station 33+30 and the existing north end of track C, at station 37+50. One #7 slip switch in Ladder K and one #8 turnout north of 56th Street would be permanently removed.

It may be necessary to temporarily remove Ladder K to permit construction of the portal at 33+30 and the shallow part of the tunnel north of the portal.

### *2.1.4 Loop Track Connection*

**Description**

It would be necessary to isolate all LIRR tracks from all MNRR tracks due to incompatible 3rd rail systems. On the east side of the terminal, once the single-track loop is reached, all connecting tracks are permanently removed so that the loop remains a single-track main line with no turnouts, connecting to outbound track C. One operating alternative requires retention of Track #2 as a possible failure-management storage or runaround track.

**Track Geometry**

The horizontal and vertical alignment of all tracks connecting inbound track I with outbound track C remain unchanged from the existing alignment. The loop track has a minimum radius of 335 feet (D = 17º-06'). Where turnouts are removed, some minor track re-alignment is assumed to be practical without encroaching on adjacent columns. Trains could comfortably and safely traverse the loop at 12 mph with "zero" superelevation, and a superelevation unbalance of 1.7 inches, well below the generally accepted 3-inch maximum. As an added safety measure, the existing restraining rail would be extended throughout the site of removed turnouts, so as to be continuous from the last platform turnout, to the Tower U area.

**Negotiability of Loop Track by LIRR Vehicles**

An analysis has been carried out to ensure that coupled LIRR vehicles can physically negotiate the 335 ft radius loop track without mechanical difficulties. The prime concern is the ability of coupled vehicles to negotiate the curve, the critical location being the transition from tangent track to curved track.

The M-7 vehicle has N-2-A type couplers, which have a swing allowance of 25.4 degrees either side of centre. This is more than enough to permit unimpeded travel through a 335 foot radius curve. At the critical location coupled cars would be offset by approximately one foot, and maximum coupler angle would be approximately 19 degrees.

**Changes to Existing Tracks-Loop**

The intent is to remove all the following connections in order to completely segregate the inbound LIRR track I from all MNRR tracks:

- Remove the inner loop track connection to tracks 2 & 3.
- Stub-end tracks 2 & 3. Remove stub-ended tracks 50 through 65 inclusive. (The real estate thus released could be used as an extension of the 47th Street passageway, office and service space related to MNR and/or LIRR operations, with the balance sold for development as required for revenue generation).
- Remove five connecting tracks between Ladder O and Ladder M.

No particular construction challenges are foreseen in carrying out these track removals.

### *2.1.5 Transition to 63rd Street Tunnel*

**Description**

North of the portals the inbound and outbound tracks converge to two parallel main lines up to the 63rd Street tunnel. Track centers are dependent on the method of tunnel construction:

- Fourteen foot centers for drill-and-blast methods;
- Two tunnel diameters for Tunnel Boring Machine construction (with the twin tunnels separated by one tunnel diameter).

As a failure-management option, tracks I and C would converge to a central pocket track immediately north of the proposed portals in the vicinity of 56th Street, accessible from both main lines. This pocket track would be a minimum of one 12-car train long. The pocket track could be used for temporary train storage in off peak hours, and for failure management purposes.

**Track Geometry**

The transition from wide centres (approximately 82 feet between tracks I and C) is accomplished using spiralled, superelevated 4º-22’ curves designed for 30 mph with a superelevation unbalance of 1.6 inches. This is an uncompensated lateral acceleration of 0.03 g’s, well below the 0.08 g’s comfort limit. The central pocket track at 14’-0” centres would be accessed by number 10 turnouts at both ends from both main lines (4 turnouts).

## 2.2 Constructability Analysis

### *2.2.1 Introduction*

The main concerns from the perspective of constructability are to:

- Ensure that the transition from the tunnel to tracks 38-42 is technically and physically feasible;
- Anticipate what would be required in the form of new and/or modified works to achieve this; and,

- Assess what effect this new work would have on all existing facilities structurally, both during and after construction.

Much of the background information regarding the existing layout of the Metro North Railroad approach tunnel along Park Avenue and into GCT (including track elevations, existing support columns and retaining walls, assumed rock elevations, underground subway lines and sewers, and various other data) has been obtained from information included in the Long Island Transportation Corridor Build Alternative undertaken for the MTA. This March 1998 study proposed a similar method for accessing and utilising the GCT but using the lower level tracks in the Madison Yard. Additional information has been obtained from various sources including New York Central System Plan drawings dated January 1, 1951 for the “Street” level, “Express” (upper) level, and “Suburban” (lower) level of Grand Central Terminal, and N.Y.C. & H.R.R.R. Composite Plan drawings dated January 15, 1910. Other information has also been obtained from existing available MTA Capital Construction publications regarding the East Side Access Project, Internet access, and through visual observations.

### *2.2.2 Construction Overview*

The ULLA would require significantly less underground construction activity than in the Deep Cavern scheme. While both schemes enter Manhattan at the existing tunnel portal below 63$^{rd}$ Street and Second Avenue and both follow similar horizontal alignments along Park Avenue to GCT, the Deep Cavern scheme remains at a lower elevation within bedrock. The Deep Cavern scheme requires extensive underground excavation for tracks, platforms, cross passages, mezzanines, escalator/elevator shafts and passages, cross-over caverns and tail-track tunnels, all in bedrock at depths up to 160 feet below street level, from approximately 57$^{th}$ Street south to approximately 38$^{th}$ Street. Conversely, the ULLA rises up from the existing tunnel portal below 63$^{rd}$ Street and Second Avenue, and enters the existing Metro North Railroad Tunnel (MNR track-way) along the existing track C and I alignments between 55$^{th}$ Street and 51$^{st}$ Street, thereby gaining access to the existing tracks and platforms on the upper level of GCT. Both schemes require essentially the same construction methods, in the form of tunnelling in rock from the existing 63$^{rd}$ Street tunnel portal to approximately 55$^{th}$ Street. However, the ULLA requires much less quantity of tunnelling with a short section of open-cut excavation in the throat area of the MNR tracks between 55$^{th}$ Street and 51$^{st}$ Street, but virtually no further excavation south of that point into GCT, or further south to 38$^{th}$ Street.

This constructability analysis focuses on the requirements of the ULLA to transition from the underground tunnels in rock, up through the MNR track-way, and onto the upper level of GCT (see Figure 10)[1], but does not consider in detail the tunnelling work, or any required construction in the platform areas. A comparison of the construction requirements between the ULLA and Deep Cavern schemes is outlined in section 2.2.11.

[1] Cross-section diagrams indicated in Figure 10 and referenced in the following text are in Appendix A.

### 2.2.3 Tunnelling

Tunnelling is required to provide a means of access from the existing 63rd Street tunnel over to Park Avenue, and south along Park to 55th Street, a distance of approximately 3000 feet. The ULLA would have separate or combined tunnels for one inbound and one outbound track from the existing 63rd Street tunnels. If considered necessary for operational considerations, a third train storage track long enough for one complete train length with double crossovers at each end could be included within this rock tunnel section north of 58th Street, requiring a cavern wide enough for three tracks.

A transition of the two inbound and outbound tracks would occur between 57th Street and 55th Street to bring the horizontal alignment underneath the existing C and I tracks within the MNR approach tunnel. The vertical alignment throughout the tunnel section would essentially follow the same alignment as the inbound track #1 of the Build Alternative. As such, clearances with underground obstructions such as the IND 63rd Street Subway Line, the Lexington IRT Subway Line, the 60th Street BMT Subway Line, various sewers and other services can be assumed to be acceptable. In addition, the geotechnical conditions would be the same as those already considered within the Build Alternative. Ground conditions throughout this section of the work are generally in rock which is assumed to be fairly competent.

Excavation would likely be accomplished by means of hand mining using controlled drill and blast techniques. This would accommodate the changing cavern size requirements for the various track layout configurations in single, dual, or triple track mode, plus requirements for switches and turnouts, etc. A Tunnel Boring Machine (TBM) could be used for the main inbound and outbound tunnel drives, but this method would still require some additional hand mining/drill and blast work to open up the caverns required for the various sizes and features as previously noted. Whether the TBM option is economically feasible, would be a consideration of the eventual construction contractor when actually performing the work.

Given the relatively short TBM drives from the 63rd Street access shaft to approximately 55th Street (+/- 3000 feet each), the capital expenditure and set-up costs for a large, hard rock TBM operation may not be justifiable. In either case, special care and procedures would be required when tunnelling near existing structures, and at the southern terminus of the tunnelling operations (between 55th Street and approximately 58th Street), where the cover of rock over head becomes minimal, or even non-existent in places. Special precautions would be required such as pre-grouting the overburden, temporary support for structures, temporary closing off of some tracks during construction, etc. The tunnelling operation would be staged from the 63rd Street site, with all material and equipment access and spoil removal back through the tunnel. This would result in minimal surface access requirements for any of the tunnelling work north of 55th Street.

There is little difference between any of the East Side Access schemes with regard to the anticipated tunnelling requirements and constraints for this section from the portal of the existing 63rd Street tunnel under the East River, to approximately 55th Street at Park Avenue.

#### *2.2.4 Inbound Track Connection*

Open cut excavation methods through the MNR tracks are required to connect the new Inbound track, which emerges from the inbound tunnel at approximately station 33+90, at 55th Street, and rises up to the existing elevation of track I on the upper level of GCT at approximately station 25+87, at 52nd Street. The horizontal alignment directly overlies and replaces the existing track I within the Metro North Railroad Tunnel. This results in a new LIRR Inbound track with differences in top of rail elevations to adjacent track H ranging from 20 feet at the new tunnel portal at station 33+80, to 0 at station 25+87. In order to accomplish this, the new Inbound track must be built between two tapering retaining walls to support the adjacent MNR tracks on either side. This work would involve removal of the existing I track and roadbed, temporary shoring, excavation of overburden and rock, construction of reinforced concrete footings and retaining walls, re-building of the new roadbed, and installation of new track. The two adjacent tracks used by MNR for access to the upper level (track H) and the lower level (track J) may be affected to varying degrees during this phase of construction over at least part, if not all of the time required to build the new structures.

**<u>Station 25+87 to 28+10</u>**

Throughout this initial section, the lowering of the existing track I for the new Inbound track requires the re-work of some facilities on the lower level adjacent to Ladder U underneath 52nd Street. This would allow the re-work of the structural support members for the existing track I, modification of the support wall adjacent to track J, and partial removal of the station end wall at station 28+10. This appears to be readily achievable using a number of methods employing reinforced concrete and/or structural steel components. The effects of this construction on MNR operations on the adjacent tracks J and Ladder U would be minimal.

Figure 10-B.1 shows the typical anticipated cross-section (Section B-B) at approximately station 26+15.

**<u>Station 28+10 to 31+25</u>**

The work within this section requires the removal and/or re-working of an existing retaining wall between track I and J, which tapers from about 12 feet in height at station 28+10, to nothing at its end point at station 31+25, where both tracks I and J are at the same grade. The existing track J increases in elevation from south to north, while the new Inbound track would decrease in elevation over the same distance and direction. The old retaining wall would be replaced by a new wall of varying heights to support the roadbed for the new Inbound track from station 28+10 to approximately station 29+00, and then to support the existing track J from approximately station 29+00 to 31+25. This wall would likely be constructed of reinforced concrete, founded on rock, and would require temporary shoring support for the overburden above the rock, under the adjacent track J during construction. It would be very difficult to avoid encroachment into the operating envelope for MNR operations on track J, and would therefore likely require MNR operations restricted to other lower level access tracks during construction.

The work within this section also requires the installation of a new retaining wall between the new Inbound track, and existing track H over the entire length from station 28+10 to 31+25. This new wall would increase in height form about 8 feet at station 28+10, to about 15 feet at station 31+25, and also likely be constructed of reinforced concrete, founded on rock. This would also require temporary shoring support for the overburden above the rock, under the adjacent track H during construction. Again, it would be very difficult to avoid encroachment into the operating envelope for MNR operations on track H, and would therefore, require MNR operations restricted to other upper level access tracks during construction.

The roadbed and track could be placed upon completion of the excavation to required grade and construction of the new/modified retaining walls. Figure 10-C.1 and Figure 10-D.1 show the typical anticipated cross-sections (Section C-C and Section D-D) at approximately stations 28+40 and 31+00 respectively.

**Station 31+25 to 33+00**

Over this section, the new Inbound track elevation continues to decrease moving from south to north. The requirement for retaining walls on either side of this new track continues, with increasing heights from about 15 feet at station 31+25, to about 20 feet at station 33+00. As the depth of these walls increase, the size and structural design requirements may become substantial, depending on the depth of overburden, and quality of rock encountered. The same operational constraints for MNR use of adjacent tracks would still apply as noted above, restricting operations to other upper and lower access tracks during construction.

On completion of the excavation to required grade, and construction of the new retaining walls, the roadbed and track could be placed. Figure 10-E.1 shows the typical anticipated cross-section (Section E-E) at approximately station 31+30.

**Station 33+00 to 33+80**

At about station 33+00, the depth of the new Inbound track, in relation to the adjacent tracks H and J, provides sufficient vertical clearances (assumed minimum of 14 feet from top of rail to underside of structure roof) to allow the construction of an enclosed reinforced concrete box structure throughout this section. Temporary shoring of the adjacent tracks would likely still be required, but it appears that the structure is now almost entirely in rock. The retaining walls of the previous section would blend into the box structure at station 33+00. The new box structure would also blend into the adjacent tunnel section at approximately station 33+80, depending on the elevation of the top of rock, the quality of the rock, and the actual tunnelling methods used. The operational constraints for MNR operations would remain the same as per the previous section for all construction work in this section, prior to becoming a full tunnelling operation, as well as throughout the initial section of tunnelling with minimal overhead rock cover. It is anticipated that this would occur somewhere between 55$^{th}$ Street and 56$^{th}$ Street, at approximately station 35+00.

The roadbed and track could be placed upon completion of the excavation to required grade and construction of the new reinforced concrete box structure, and any disrupted tracks overhead could be returned to service. Figure 10-F.1 shows the typical anticipated cross-section (Section F-F) at approximately station 33+60.

### *2.2.5 Outbound Track Connection*

Open cut excavation methods are similarly required to connect the new Outbound track, which commences its descent from the existing elevation of track C, on the upper level of GCT, at approximately station 22+90, at 51st Street, and lowers down to a tunnel portal entrance at approximately station 33+30, at 55th Street. The horizontal alignment directly overlies and replaces the existing track C within the Metro North Railroad Tunnel. This results in a new LIRR Outbound track with differences in top of rail elevations to adjacent track D ranging from 0 at station 22+90, to 20 feet at the new tunnel portal at station 33+30. This work would involve the removal of the existing C track and roadbed, temporary shoring, excavation of overburden and rock, construction of reinforced concrete footings and retaining walls, re-building of the new roadbed, and installation of new track. The two adjacent tracks used by MNR for access to the upper level (track D) and the lower level (track B) may be affected to varying degrees during this phase of construction over at least part, if not all of the time required to build the new structures.

**Station 22+90 to 25+50**

Throughout this initial section, the lowering of the existing track C for the new Outbound track requires the closing off of track #180 on the lower level below in this area. This would allow the re-work of the structural support members for the existing track C, modification of the support walls between tracks C and B, and tracks C and D, and partial removal of the station end wall at station 25+50. This appears to be readily achievable using a number of methods employing reinforced concrete and/or structural steel components. The effect of this construction on MNR operations on the adjacent tracks B and D could be minimal. Figure 10-A.1 shows the typical anticipated cross-section (Section A-A) at approximately station 24+50.

**Station 25+50 to 27+50**

The work within this section requires the removal of an existing retaining wall between tracks C and B, which tapers from about 10 feet in height at station 25+50, to nothing at its end point at station 27+50. The existing track B increases in elevation moving south to north, while the adjacent new Outbound track would decrease in elevation in the same direction. The old retaining wall would be replaced by a new wall of varying heights to support the roadbed for the new Outbound track from station 25+50 to approximately station 26+50, and then to support the existing track B from station 26+50 to 27+50. This wall would likely be constructed of reinforced concrete, founded on rock, and would require temporary shoring support for the overburden above the rock, under the adjacent track B during construction. Encroachment into the operating envelope for MNR operations on track B would likely be unavoidable; however, it is anticipated that MNR could temporarily move its operations from track B onto the currently unused track A. Under this scenario, construction could continue with little effect on current MNR operations.

The space between existing track C and D contains a series of structural columns, oriented in a north-south row, to provide overhead support for the east side of Park Avenue. These columns are founded on rock below track level, and are composed of a combination of structural steel members on concrete footing/foundation walls. The lowering of the current track C roadbed for the new Outbound track roadbed is anticipated to undermine these foundations, requiring underpinning in advance to maintain support for the roadway above. This would involve temporary shoring in combination with alternate support systems, while excavating the rock below the existing footings, and replacing with new reinforced concrete support. Depending on actual rock elevations and quality, the depth of the existing as well as the new foundations may vary considerably. The existing column wall provides a natural barrier between track D and the construction for the new Outbound track. Depending on the nature of the existing overburden, depth and quality of the rock, and construction methods used, it may be possible to carry out construction with little impact to MNR operations on track D.

On completion of the excavation to required grade, and construction of the modified/new retaining walls/foundation walls, the roadbed and track could be placed. Figure 10-B.1 shows the typical anticipated cross-section (Section B-B) at approximately station 26+15.

**Station 27+50 to 29+00**

This section is a continuation of the work outlined in the previous section, except that there is no longer an existing retaining wall requiring removal between tracks C and B, and the depth of excavation increases moving northward. A new retaining wall is to be constructed between track B and the new Outbound track, and the structural support columns between track D and new Outbound track require underpinning and foundation re-construction. The same operational constraints for MNR use of tracks B and D would apply as noted above.

On completion of the excavation to required grade, and construction of the new retaining walls/foundation walls, the roadbed and track could be placed. Figure 10-C.1 shows the typical anticipated cross-section (Section C-C) at approximately station 28+40.

**Station 29+00 to 30+80**

This section is again a continuation of the work outlined in the previous two sections, except that the orientation of the structural support columns for the roadway above has been reversed, and the depth of excavation continues to increase moving northward. The underpinning and associated foundation re-construction work is now located between existing track B and new Outbound track, while a new retaining wall is now required between existing track D and new Outbound track. The same operational constraints for MNR use of adjacent tracks would apply as noted above, except that the constraints for tracks B and D would be reversed from that previously indicated.

On completion of the excavation to required grade, and construction of the new retaining walls/foundation walls, the roadbed and track could be placed.

**Station 30+80 to 32+50**

The orientation of the structural support columns for the roadway above again reverts to its previous location between track D and new Outbound track, and the depth of excavation continues to increase moving northward. The new retaining wall construction is now again between existing track B and new Outbound track, while the underpinning and associated foundation re-construction work is between existing tracks D and new Outbound track. The size of the new retaining wall and foundation re-construction may be substantial depending on the depth of overburden and rock quality encountered. The same operational constraints for MNR use of adjacent tracks would still apply as noted above, except that the constraints for tracks B and D would revert to those originally indicated.

On completion of the excavation to required grade, and construction of the new retaining walls/foundation walls, the roadbed and track could be placed. Figure 10-E.1 shows the typical anticipated cross-section (Section E-E) at approximately station 31+30.

**Station 32+50 to 33+30**

North of station 32+50, the depth of the new Outbound track, in relation to the adjacent tracks B and D, provides sufficient vertical clearances (assumed minimum of 14 feet from top of rail to underside of structure roof) to allow the construction of an enclosed reinforced concrete box structure throughout this section. Underpinning of the structural support wall between tracks D and this new structure is still required for construction, but the structure is now almost entirely in rock. The retaining walls and foundation walls of the previous section would blend into the box structure at approximately station 32+50. The new box structure would also blend into the adjacent tunnelled section at approximately station 33+30, or further north, depending on the elevation of the top of the rock, the rock quality, and the tunnelling methods utilised. The operational constraints for MNR operations during construction would be essentially the same for all construction work prior to becoming a full tunnelling operation, as well as during the initial stages of tunnelling with minimal overhead rock cover. It is anticipated that this would occur somewhere between 55$^{th}$ Street and 56$^{th}$ Street, at approximately station 35+00.

On completion of the excavation to required grade, and construction of the new reinforced concrete box structure, the roadbed and track could be placed, and any disrupted tracks overhead could be returned to service. Figure 10-F.1 shows the typical anticipated cross-section (Section F-F) at approximately station 33+60.

### *2.2.6 Outbound Track Connection (Track B Option)*

Consideration has been given to an optional Outbound track connection using the horizontal alignment of track B instead of track C. It is understood that the existing track A leading to the lower level is not currently used for MNR operations, but could be readily placed back into service. By using track B for LIRR outbound trains, there would be 5 tracks connected to the upper level instead of 4 since track C would not be taken out of service. In addition, the requirement for underpinning along the structural foundation wall between track C and track D is reduced and/or eliminated entirely. The vertical alignment would remain the same as for the track C option noted above.

**Station 22+40 to 26+50**

Throughout this section, the new Outbound track begins its decent from a re-aligned Ladder M over top of the existing track B at station 22+40, and does not appear to require major modification to the existing retaining wall between existing track B and track C. The new grade appears to be readily achievable by using a number of methods employing reinforced concrete and/or structural steel components. The effect of this construction on MNR operations on the adjacent track C could be minimal, but would likely require the closure of track A during the period of construction.

Figure 10-A.2 shows Section A-A (Track B Option) and Figure 10-B.2 shows Section B-B (Track B Option), which are the typical anticipated cross-sections at approximately stations 24+50 and 26+15 respectively.

**Station 26+50 to 27+50**

The work within this section requires the removal of an existing retaining wall between tracks B and C, which tapers in height from about 5 feet at station 26+50 to nothing at its end point at station 27+50, and replacement with a new retaining wall over this length. A new retaining wall would also be required on the other side between the new Outbound track, and track A. Encroachment into the operating envelope for MNR operations on both tracks A and C would likely be unavoidable.

**Station 27+50 to 29+00**

New retaining walls are required on both sides of the new Outbound track within this section of work to support the roadbeds of adjacent tracks A and C while the elevation of new Outbound track decreases moving northward. It would be very difficult to avoid disruption to both adjacent tracks during this phase of construction

Figure 10-C.2 shows the typical anticipated cross-section (Section C-C, Track B Option) at approximately station 28+40.

**Station 29+00 to 30+80**

Throughout this section, the new retaining wall between the new Outbound track and existing track A would continue as per the previous section. The space between the new Outbound track and track C appears to have a structural support wall over this length. This would likely require underpinning work as noted previously. MNR operational constraints would therefore be the same as noted in the previous section, with the exception that track C may be minimally disrupted.

**Station 30+80 to 32+50**

This section reverts to the two new retaining wall requirements on both sides of the new Outbound track to support the adjacent tracks A and C while the grade of the new Outbound track continues to decrease moving northward. Complete disruption of both adjacent tracks A and C would be unavoidable.

Figure 10-D.2 shows Section D-D (Track B Option) and Figure 10-E.2 shows Section E-E (Track B Option), which are the typical anticipated cross-sections at approximately stations 31+00 and 31+30 respectively.

**Station 32+50 to 33+30**

The depth of the new Outbound track would again be sufficient to require an enclosed reinforced concrete box structure throughout this section. The operational constraints for MNR operations on adjacent tracks A and C would remain unchanged. Figure 10-F.2 shows the typical anticipated cross-section (Section F-F, Track B Option) at approximately station 33+60.

### *2.2.7 Special Elements of Construction*

#### ***2.2.7.1 Underpinning for Park Avenue Column Supports***

The requirement for Underpinning work has been noted in the above, and applies generally to any requirement to temporarily or permanently provide a means of support for any existing structure. Underpinning work can never be taken lightly, especially in the congested confines of downtown Manhattan, because the integrity of any object overhead is subject to degradation if the support mechanism underneath is disrupted. Obviously, this can have serious consequences on large massive structures such as tall buildings, bridges and/or roadways. In the case of GCT and the Park Avenue track-way, most of the support systems have been in place for decades, and may not withstand any significant movement. The “Build Alternative” proposal contained significant discussion regarding the extensive requirements for underpinning buildings adjacent to Park Avenue.

However, as opposed to the extensive underpinning work outlined in the Build Alternative proposal, the relatively small amount of underpinning work required in the ULLA is limited to the upper level support members for the Park Avenue roadway structure only and does not involve any buildings or major structures. In addition, most of the work is in rock and under foundation bearing walls, which should be relatively easily supported using proper construction methods. It is anticipated that this work can be undertaken effectively and without significant risk.

#### ***2.2.7.2 Retaining Wall Construction***

The retaining wall construction anticipated in this proposal is primarily of a conventional nature, and is not significantly different than the retaining wall structures already in place to separate adjacent tracks currently leading to the upper and lower levels of GCT. It is anticipated that all structures would be founded in rock and constructed of reinforced concrete. The general procedure is anticipated to be fairly conventional such as temporary shoring, drilling and blasting and/or hand excavation in rock, formwork, reinforcing placement, concrete placement, stripping, curing, finishing, and backfill. This work can all be accomplished from underground without requirement for surface access. However, the very design of retaining structures (to support elevated grades) requires encroachment into the space on both sides of the wall during construction. It is difficult to provide any positive means of allowing uninterrupted use on either side of a retaining wall under construction.

#### ***2.2.7.3 54th Street Sewer Reconstruction***

An existing sewer crosses the Park Avenue track-way along the centre-line of 54th Street, perpendicular to the approach tracks at station 31+00. Available information indicates that this sewer currently runs just underneath the existing track roadbed on the east and west sides of the track-way, but drops through an existing siphon arrangement to pass under the lower alignment for track F. The current sewer is partially in overburden and partially in rock, with access/drop manholes located in the centre of 54th Street, at the building lines on the east and west sides, as well a sump manhole at the deepest location of the siphon, shown under track G. It is not known when this sewer siphon was installed, but must be assumed to relatively old, possibly of brick construction, and may be near its capacity.

The proposal requires the lowering of the roadbed elevations along the existing track I for the new Inbound track by approximately 12 feet, and also along the existing track C (or B) for the new Outbound track by approximately 15 feet, at the location of this 54th Street sewer, at station 31+00. In both cases, the new vertical alignment would conflict with the elevation of the existing sewer siphon system, and would require the re-construction of the siphon. It appears possible to accomplish this by lowering the entire siphon system below the new track roadbed excavation limits by deepening the two access/drop manholes at each end, on the building lines, as well as the central sump manhole, and installing new pipe below all the new excavation requirements. This work would be almost entirely in rock, and could be done in advance, and/or in conjunction with the other work of lowering the track roadbeds. Some special support and shoring systems, including underpinning of existing structures, would be required to ensure the integrity of the entire track structure, and the Park Avenue overhead structure.

While this item of work is challenging due to the potential conflict with all ten approach tracks in the track-way, as well as the support systems for the track structure itself, it should be considered feasible. It should be noted that re-construction of this sewer siphon was also contemplated, and considered feasible for the “Build Alternative” proposal. Figures 10-D.1 and 10-D.2 show the typical anticipated cross-section (Section D-D) for this location at station 31+00.

#### ***2.2.7.4 53rd Street Independent Subway Line***

The 53rd Street Independent Subway Line passes underneath the ten track Park Avenue track-way within the 53rd Street road allowance at a depth indicated to be approximately 60 to 70 feet below the Park Avenue road surface. At this depth, the subway line is indicated to be entirely in rock, with current clearance to the retaining wall foundation structures for track F of about 20+

feet. The excavation required for placement of the new structures contemplated for lowering existing track I for the new Inbound track, as well as the existing track C (or B) for the new Outbound track, are not as deep as the existing track F structure. Therefore, the clearances between any new construction excavation requirements would be even greater, and it can be assumed that there would be no adverse effect on the 53rd Street Independent Subway Line. Figures 10-C.1 and 10-C.2 (Section C-C) show the approximate elevation of this Line in relation to the proposed and existing track elevations.

#### 2.2.7.5 60th Street BMT Subway Line

The BMT Subway Line is shown to cross directly underneath the foundation for the Park Avenue track-way at 60th Street. At this location, both the new Inbound and Outbound tracks would be constructed in tunnel at a lower depth in the bedrock. Tunnelling operations in the vicinity of 60th Street would be at essentially the same elevations, and of similar sizes for the ULLA as was contemplated for the “Build Alternative” proposal. It has therefore been assumed that the work of this proposal is feasible using similar precautions while excavating in the vicinity of the 60th Street BMT Subway Line.

Figures 10-K.1 and 10-K.2 (Section K-K) show the approximate elevation of this Line in relation to the proposed and existing track elevations.

#### 2.2.7.6 Lexington Avenue IRT Subway Line

The actual depth below grade of the Lexington Avenue IRT Subway Line is not known. However, both the Inbound and Outbound tracks at this location would be constructed in tunnel within the bedrock. As in the previous case, the elevations and sizes of the new tunnels would be essentially the same as those contemplated in the “Build Alternative” proposal. It has therefore been assumed that the work of the Upper Level Loop Alternative in the vicinity of the Lexington IRT Line is feasible using similar precautions and procedures during construction.

### 2.2.8 MNR Operations During Construction

The ULLA requires considerable open cut excavation within the ten track MNR track-way from approximately station 23+00 at 51st Street to station 35+00, between 55th and 56th Streets. Due to the confines between property lines along Park Avenue, the tracks within this train-way appear to have minimal clearances with only approximately 13 feet, centre-to-centre, between adjacent sets of tracks where no interior columns are present, and approximately 15 feet centre-to-centre when separated by columns.

The proposed new Inbound track would follow the alignment of existing track I, and would therefore potentially affect the MNR operations on adjacent tracks H (upper level feed), and J (lower level feed). The proposed new Outbound track would follow the alignment of existing track C, and would therefore potentially affect the MNR operations on adjacent tracks B (lower level feed), and D (upper level feed).

As indicated above, the proposed open cut construction operations would have an impact of varying degrees on ongoing MNR operations during construction. These constraints could range from at the very least “slow movement” orders, to temporary removal from service on tracks adjacent to certain construction activity. Since the proposal removes two tracks from service permanently, this means that up to three of the existing ten approach tracks could be unavailable for MNR use during specific periods during this construction period. On completion of all construction work, MNR would have full use of the remaining eight tracks.

Mitigation of these constraints could be achieved, but not eliminated, by the use of innovative construction methods, off-peak, after hours, or weekend construction operations, accelerated productivity, temporary track/platform re-routing, use of ground pre-stabilization, early strength concrete products, and other similar methods.

Safety would also be of concern when undertaking construction work in close proximity to an operating railway, and special procedures would be required. However, this type of construction is not uncommon, and with proper design and implementation is considered feasible.

## Retaining Wall Construction

In order to lower the grade of one track in relation to the next, the inside face of any retaining wall must be positioned at the mid point between tracks, i.e. in this case, at 6 ½ feet from each track centre-line. To achieve this, the excavation and bulk of the new retaining wall thickness must be positioned entirely on the one side to support the roadbed under the higher of the two tracks. To allow enough room for temporary shoring to support the overburden above the rock, excavation of earth and rock, construction of the wall, and backfill/reinstatement, the encroachment into the upper level track would likely be very close to the rails in most cases. Except in the case of very shallow wall depth requirements, it would be very difficult to provide adequate and safe support to allow operation of any trains on the upper tracks in this situation.

It is anticipated that when lowering the grade to any significant depth between two new retaining walls, the resulting encroachment on the two adjacent tracks would require removal from service of both tracks on a full time basis during construction. However, where the depth of the new track is relatively shallow, it may be possible to construct only one side retaining wall at a time, and therefore only affect one MNR track operation at a time as well.

## Underpinning Construction

In the case of track C, the space between adjacent track D (and in some cases track B), contains a support foundation wall, and structural steel support columns for the Park Avenue roadway above. The foundation wall will require deepening in some places to provide for the lowered track-bed for the new Outbound Track, and therefore, temporary support (underpinning) of these columns would be required, as described earlier. However, since it is assumed that this wall is founded on rock, the work could be accomplished in stages, and the continuous foundation wall would act as a retaining wall and temporary shoring of the overburden may not be required. Under controlled conditions, this construction work may allow continued operation on the adjacent tracks but at reduced speeds.

**GCT Upper Level Support Modifications**

As both new Inbound and Outbound tracks approach GCT, some modification of the existing upper level support system would be required to achieve an initial lowering of the grade. While the operations on the lower level may be affected, this occurs in areas of minimal use by MNR at the present time. It appears that this work may have minimal effect on adjacent MNR operations, and/or could be performed during off-peak hours.

**Inbound Track**

The new Inbound Track requires new retaining walls on both sides of the new track structure, or a new concrete box structure, over most of the length of construction. The total length of track requiring construction operations that may have an effect on adjacent tracks, and thus an effect on MNR operations is just over 900 feet, from station 25+87 to station 35+00. Out of this total length, approximately 25% could be undertaken while operating with slow orders on both adjacent tracks, another 25% could be undertaken while allowing operation on one, or the other, of the adjacent tracks H and J, and the remaining 50% would likely require temporary stoppage of operations on both adjacent tracks.

**Outbound Track**

It is assumed that track A could be placed back into use by MNR with minimal work. The opportunity to use track A in place of track B would have beneficial impact on the potential disruption to MNR operations, by allowing the temporary closure of track B during construction activity on track C, without reducing the current level of MNR service to the lower level of GCT. The total length of track requiring construction that may have an effect on adjacent tracks, and thus an effect on MNR operations, is just over 1200 feet, from station 22+90 to station 35+00. If the track A opportunity noted above is possible, out of this total length, approximately 25% could be undertaken with minimal if any effect on both adjacent tracks, another 25% could be undertaken while operating under slow order conditions on track D, and the remaining 50% would likely require the temporary stoppage of operations on one side, track D only.

### 2.2.9 Construction Methodology

To minimize MNR disruption, construction work could be staged to affect only the inbound or outbound tracks at one time, and taking the above factors into account, the total period of construction could be kept to a minimum. It should be noted that the most expeditious and cost effective approach would be to restrict operations on both adjacent tracks during the complete construction period, to allow the contractor to gain the most efficient use of his labour and equipment, which could reduce the construction time significantly.

It is envisioned that all of the work with respect to the Inbound and Outbound track connections will be undertaken underground at track level, with minimal if any access from surface. It is anticipated that access for equipment, material, and spoil removal could be arranged from an MNR yard to the north during off peak hours. This would allow the work to proceed prior to, or in conjunction with the tunnelling work, rather than waiting for the tunnels to reach the site from the north in advance. All work areas would likely require hoarding off during the construction operations to provide physical barriers with the ongoing MNR operations. Environmental requirements would be necessary to control such things as dust, noise, and other potential pollutants.

Construction could be undertaken using generally conventional methods, with normal labour, equipment and material requirements. It is not anticipated that any specialised or particularly challenging construction methods are necessary.

### *2.2.10 Construction Schedule*

As previously discussed, it is anticipated that construction of the Inbound track open cut excavation (station 25+87 to 33+80 = 793 feet), and the Outbound track open cut excavation (station 22+90 to 33+30 = 1040 feet), should be undertaken in different timeframes, to avoid undue restriction on existing MNR operations. If both adjacent tracks could be removed from service during construction, the work would proceed most efficiently and thus most quickly. Any requirement to maintain adjacent tracks in service, either full or part time, would decrease the efficiency resulting in longer construction periods. It is estimated that this construction period could range from six months to twelve months or more in duration. As previously noted, this work is not weather dependent, can be undertaken at virtually any time, prior to, during, or after tunnelling and/or station platform work, and can be flexible in methodology.

Figure 11 shows a Proposed Bar Chart Schedule of the Manhattan portion of the Upper Level Loop Alternative. This schedule can only be considered a rough estimate at this time and would require refinement after further engineering design. It has been based on the following assumptions:

1. There would be no real action for the remainder of 2004 during which the decision to proceed with the alternative would be made.
2. Due to the major differences between the Upper Level Loop Alternative and the Deep Cavern proposal (which has already undergone considerable design work), a significant period of detailed design for the ULLA is anticipated. This would undoubtedly involve new structural investigations, additional geotechnical investigations and reports, new drawings and documents, costing, scheduling, approvals, etc. An initial period of three months ($1^{st}$ quarter of 2005) has been allocated to progress the design far enough to support the preparation and submission of an Environmental Assessment, while 12-18 months is not unreasonable for completion of 100% final design and preparation of documents for construction.
3. It has been assumed that the process for completing the Environmental Assessment (EA) and securing its approval would take from 6 to 9 months.
4. It has been assumed that some compression of activities would allow re-tendering of the new tunnel contract by early 2006. The contract could not be awarded until the EA is approved.
5. Despite the reduction in actual tunnelling length for the ULLA, a major time component of this type of tunnel construction is consumed by an unavoidable period of mobilization and de-mobilization. This quantity of tunnelling would likely be undertaken by only one

TBM (as opposed to the two planned for the Deep Cavern scheme), and/or by drill-and-blast hand mining techniques. Based on these constraints, a period of only two years for all tunnel construction (complete excavation and finishing) is considered aggressive, but achievable. This period is shown to extend from mid 2006 until mid 2008.

6. Installation of new systems work (track, switches, electrical third rail and components, signals, lighting, and all safety requirements) cannot commence until virtually all of the tunnelling work has been completed. This time period also includes approximately six months of reliability testing and commissioning prior to approval for revenue service. It has been assumed that some work could begin in advance of total tunnel completion, but that at least 12 months are required after tunnel completion resulting in an anticipated revenue service date of mid 2009.
7. The above six points form the critical path of construction activity, which would be difficult to compress any further. All other components of construction work for platforms, open-cut work, new cross passages, concourses, and street entrances should be easily achievable within the intervening time frame from mid 2006 until mid 2009.

### *2.2.11 Construction Comparison*

As discussed previously, all East Side Access options involve the construction of one inbound and one outbound tunnel from the existing 63rd Street tunnel under the East River toward GCT, and are very similar in concept (apart from the quantity of tunnelling required) up to approximately 55th Street. From this point south into GCT, the concepts differ considerably in magnitude of construction activity requirements and subsequent costs. A brief comparison of some of the basic major components of the Deep Cavern scheme with similar components of the ULLA illustrates the order of magnitude difference in the two schemes, particularly relating to costs and time.

The Deep Cavern scheme (see Figures 6 and 7) requires the underground excavation of significant quantities of rock to form the cavities of the two massive caverns in which are built the eight rail tracks and four platforms composing the main station from about 44th Street to 49th Street. Additional extensive tunnel excavation is required for the switches, flyovers, and crossovers required to merge from two tunnels north of 59th Street into the eight separate platforms at the north end of the new station at about 49th Street, as well as to merge back into four tail-tracks south of the station to 38th Street. Additional underground excavation is required for multiple cross passages, mezzanines, ventilation and utility corridors, elevator/escalator corridors and shafts, and other station components. It is conservatively estimated that the rock excavation quantity necessary to achieve all of this could be in the order of 600,000 cubic yards of material. Almost all of this work would be undertaken using access back through the tunnels, a distance of more than a mile, to the 63rd Street access shaft, with limited opportunity to advance any of the station work ahead of completion of all of the tunnel excavation. While the majority of the excavation could be undertaken independent of and without disruption to MNR operations, the upper access points of all required stairs, elevator/escalator shafts, ventilation, utility, and other corridors where they enter the proposed new concourse on the existing lower level of GCT, would likely require significant open cut work with associated shoring, underpinning, and other temporary work.

In contrast, the ULLA (see Figure 8) requires only a relatively small quantity of excavation south of 55th Street to accommodate the open cut excavation between the end of the tunnels and the entrance to the upper level of GCT. It is estimated that this quantity would be in the order of 10,000 cubic yards. While almost all of this excavation requires more costly and slower construction methods than excavation in solid bedrock and potentially has a more direct impact on MNR operations, the time requirements for completion of this work would be significantly less, could be undertaken at any time before, during, or after tunnelling, and is not restricted to access only through the tunnels. This work could be staged/coordinated with MNR for optimum efficiency of construction work vs. train operations. As a result, the difference in underground excavation costs alone between the two schemes could be in the order of $300 to $400 million.

#### *2.2.12 Constructability Conclusions*

Based on the limited information available in the way of specific plans, profiles, cross-sections, and existing structural and geotechnical data, the assumptions and analysis outlined in the foregoing indicate that the ULLA should be viable from a constructability perspective. Obviously, further detailed engineering analysis and review would be required to move from this to a final design.

From a construction perspective, the ULLA has some advantages over the Deep Cavern proposal as follows:

1. Significantly less work in almost all areas of construction including excavation, tunnelling, structural concrete, finishing details, mechanical and electrical components, and related systems installations.
2. Reduction in the time required to complete all construction work, resulting in a shortened schedule, for potentially earlier revenue service to GCT.
3. Ability to undertake major components of the construction work simultaneously reducing the critical path timeline requirements.
4. Reduced costs overall for the construction components of the project.

Some potential disadvantages to be considered are;

1. Some disruption to existing MNR operations into GCT during construction would be unavoidable, but controllable to a minimum.
2. The requirement for re-design and an EA.
3. If desirable in the future, construction of any extension of LIRR service south from GCT would not be readily achievable.

### 2.3 Analysis of Train Operations

#### *2.3.1 Introduction*

The ULLA would require the use of tracks in the GCT currently used by MNR commuter rail services. The following is a summary of physical plant in the GCT required for the ULLA:

- C Track in the throat, referred to as the new Outbound track;
- I Track in the throat, referred to as the new Inbound track;
- Tracks 38, 39, 40, 41, and 42 and platforms S,T,U servicing these tracks;
- Upper Level Loop track;
- Tracks 50 – 65 beneath the Waldorf Astoria Hotel.

(The Madison Yard area in the lower level of the GCT is required for the Deep Cavern scheme concourse but this would not be required for the ULLA.)

An analysis of train operations was undertaken to assess the following:

- Impacts on MNR operations in the 4 track mainline corridor, the 10 track throat leading to the GCT and in the upper and lower levels of the GCT itself;
- Alternative accommodation and any operational modifications for the displaced current MNR operations;
- Accommodation and any operational modifications for future MNR growth;
- Capacity of the ULLA in the GCT from a train operations perspective;
- Impacts on MNR operations and mitigation measures during construction of the Manhattan portion of the ULLA.

### *2.3.2 Metro North Railroad Operations*

MNR operations consist of 3 services: the New Haven, Harlem and Hudson Lines, reaching as far north as Waterbury on the New Haven Line, Wassaic on the Harlem Line and Poughkeepsie on the Hudson Line. These three lines come together into a 4 track mainline corridor at 125$^{th}$ Street in Harlem. Moving from north to south toward GCT, this corridor flares out into a 10 track throat at about 57$^{th}$ Street prior to entering the GCT tracks at about 51$^{st}$ Street. The throat area is approximately 1500 feet in length at it longest point.

Of the10 tracks in the throat, 6 tracks (C,D,E,G,H,I) connect to the Upper Level and 4 tracks (A,B,F,J) connect to the lower level. Track A is currently out of service resulting in 9 tracks in active service. The ULLA would utilize Track C for inbound and Track I for outbound train movements.

Based on the current MNR operating plan, tracks 38 – 42 and the upper level loop track are not used extensively. In the peak hour, 11 trains come into tracks 38 – 42 averaging approximately 1 train every 30 minutes on each track. Of these 11 trains, 2 reverse northward into off-peak scheduled service, 4 reverse northward as equipment movements, and of the remaining 5 trains that use the loop, 4 move to the storage tracks in the Waldorf Yard and 1 train moves to storage track 2.

#### ***2.3.2.1 Four Track Mainline Corridor***

As noted above, the four-track corridor handles three MNR commuter rail services. The current MNR operating plan dated July 19, 2004 shows that in the morning peak, there are 51 trains operating southbound between 0800 and 0900 on 3 tracks, and 25 revenue and non-revenue trains operating northbound in the counter peak direction on the fourth track. The ULLA incorporates a single inbound track and a single outbound track located in a tunnel beneath the existing MNR mainline tracks under Park Avenue, and therefore there would be no impact on the corridor caused by the ULLA.

#### *2.3.2.2 Throat Impacts*

In order to utilize Tracks C and I for the ULLA, it would be necessary to put Track A back into active service. MNR would then have 8 functioning tracks to handle trains in the throat area, four to the upper level and four to the lower level. The net result is that MNR would lose one track in the throat area used for existing operations; (MNR would lose 2 tracks servicing the upper level but gain Track A servicing the lower level). Due to this change, it would be necessary for MNR to modify its operating plan. It is important to note that MNR would have access to all 8 throat tracks from all 4 corridor tracks. All of the ladder tracks in the throat area would be maintained intact.

Of the 8 MNR tracks in the throat, 4 tracks would be required for inbound and outbound corridor trains. The other 4 tracks in the throat area would be available for reverse equipment movements, track maintenance purposes and operating flexibility.

With 51 southbound trains and 25 northbound trains in the AM peak hour, the difference of 26 trains would remain in GCT for midday storage. Of these 26 trains, 16 make reverse movements back into the throat area and then reverse into a storage track for later use. The remaining 10 trains stay on their arrival track and are prepared for outgoing service.

To move a train from the platform to the throat area then reverse into a storage track requires a train to move up to the ladder track, clear the switch then reverse the train back through the ladder into a clear storage track. The total approximate length traveled would be as follows.

Signal to Ladder = average 800ft (varies depending on track routing)
Switch clear length = 150ft
Train to clear point of switch = 680ft (train length 8 car train)
Reverse through point of switch = 680ft
Switch clear length = 150ft
Allowance for operator judgment, say 200ft
Total movement occupying the throat = 2660ft

Assume average operating speed = 10 mph or 14.7 fps
Time for each move = 2660ft./ 14.7 fps = 181 seconds
Plus time for new delays, routing, and reaction time = 20 seconds
Total time equals = 201 seconds

Therefore, it would take approximately 201 seconds to move an eight car train into the throat are and then reverse into a storage track in order to store a train for operation in the next peak period. Since there are 16 such reverse movements in the peak period in the current operating plan, the total time to perform all of these movements is:

Time for Reverse Equipment Moves = 16 X 201 = 3216 sec or 0.9 hours, say 1 hour

From this calculation, it could be concluded that MNR would require one hour of track time in the throat area in the busiest hour of the day for the purpose of shuttling equipment movements. Since there are two levels, this one hour of track time would be divided between two tracks, one that services the upper level and the other that services the lower level.

Track capacity in the throat area is also required for operating flexibility. There are a significant number of parallel movements in the throat area by MNR for purposes other than noted above. These parallel movements take place at the same time inbound and outbound train movements occur. There would be two tracks available for these purposes and based on the above calculation, there also would be spare capacity available on the two tracks assigned for reverse movements. Two additional tracks and other spare track time in the throat should be sufficient to provide MNR with the operational flexibility for parallel movements, congestion requirements and system recoverability in delay situations under current traffic levels.

Although a track could be out of service for track maintenance purposes this should not be the norm. The railroad practice should be that MNR maintains all 8 tracks to revenue operating standards. These tracks could also be used to shuttle equipment into and out of the servicing tracks but this need not occur in the peak hour of the peak period.

Therefore, the allocation of the 8 track throat could be summarized as follows.

- 4 tracks for inbound and outbound service;
- 2 tracks for reverse equipment moves to and from storage facilities within GCT;
- 2 tracks available for all other purposes.

This demonstrates that there is ample capacity in the throat area with the eight remaining tracks to perform all the requirements of today’s operation and includes room for future growth.

#### ***2.3.2.3 Terminal Track Impacts***

To assess the impact to the terminal operation it was necessary to analyze the existing operation using a time and space track occupancy approach. The analysis was performed on the morning peak period from 0700 to 0900 with specific attention given to the peak hour of the peak period being 0800 to 0900. The results of this analysis are shown on two charts in Appendix B (Figures B-1 and B-2), one for the lower level and the other for the upper level.

The objective of this exercise was to determine whether there was existing track capacity that could accommodate the displaced trains currently using tracks 38 – 42 and tracks 50 – 65. From the most up to date MNR operating plan, the following assumptions were made:

- Peak hour 0800 – 0900 would be the worse case scenario.
- All unused platforms could be used as alternate locations as long as track lengths could accommodate the displaced train.

- If tracks were used for purposes other than train operations, such as track maintenance equipment storage, alternate arrangements could be made for the track maintenance department.

The first assumption means that if the alternate accommodation could be arranged for the busiest hour of the day than there should be no problem accommodating operations at all other hours of the day.

There may be reasons why some platforms are not used. It is assumed that changes could be made to existing conditions to re-instate the platform to operations. For example, there may be an existing platform track being used for track maintenance equipment or material storage. It is assumed that changes to this operation or similar operations could be made to free up the platform and platform track for train operations.

From the track occupancy study it was determined that there are a number of under utilized platform tracks. A platform track was considered under utilized when it was used only 30% or less of the peak hour. The following table lists these underutilized tracks, showing track length in number of car lengths, platform, and the possible reason these platforms are under utilized.

**Track Utilization Table**

| Track | Level | Platform | Capacity (cars) | Utilization (%) | Possible Reason |
|---|---|---|---|---|---|
| Track 31 | Upper | O | 7 cars | 0% | Track out of service |
| Track 28 | Upper | M | 15 cars | 0% | Not apparent |
| Track 22 | Upper | J | 7 cars | 0% | Track out of service |
| Track 14 | Upper | F | 9 cars | 0% | Not apparent |
| Track 113 | Lower | J | 5 cars | 0% | Short track |
| Track 106 | Lower | F | 11 cars | 0% | Not apparent |
| Track 116 | Lower | M or N | 5 cars | 7% | Short track |
| Track 113 | Lower | J or K | 5 cars | 17% | Short track |
| Track 111 | Lower | I | 11 cars | 17% | Not apparent |
| Track 114 | Lower | K | 6 cars | 20% | Not apparent |
| Track 32 | Upper | P or O | 10 cars | 28% | Not apparent |

**<u>Trains Displaced from tracks 38 – 42</u>**

The above table shows 5 tracks at 0% utilization that could be utilized for the displaced MNR trains from the upper level tracks 38 – 42. The following changes would accommodate the displaced trains:

- In order to free up track 41, move operations from track 41 to track 106. Track 41 has space to accommodate a 15-car train but the platform would only accommodate up to an 8-car train. Track 106 has space to accommodate an 11-car train. The longest train on track 41 is an eight-car train therefore, track 106 should be suitable.
- In order to free up track 40, move operations from track 40 to track 24. Track 40 has space to accommodate a 15-car train but the platform would only accommodate up to an

8-car train. Track 24 has space to accommodate an 11-car train. The longest train on track 41 is a ten-car train; therefore track 24 should be suitable.

- In order to free up track 38, move operations from track 38 to track 31. Track 38 has space to accommodate a 15-car train but the platform would only accommodate up to a 10-car train. Track 31 has space to accommodate a 7-car train. The longest train on track 38 is a 7-car train therefore track 31 should be suitable.
- In order to free up track 42, inbound trains 724 and 732 could be displaced to track 101 and train 734 could be displaced to track 103. To accommodate this change train 1731 would be moved to track 113.
- In order to free up track 39, inbound train 528 could be displaced to track 28.

**<u>Trains Displaced from tracks 50 – 65 beneath the Waldorf Astoria</u>**

MNR currently uses the storage tracks in the Waldorf Yard to store 4 trains each day following the morning peak in order to be in position for the afternoon peak period. These trains would be displaced from this midday storage location. Provision for platform capacity has been provided in the previous section. Of these 4 trains, there is one 4-car train, two 6 car trains and one 7-car train.

MNR could easily implement double berthing of trains on their many long tracks to accommodate these trains. With the implementation of double berthing, these 4 trains could be handled on the 17 platform tracks available to MNR on the upper level. A train that would normally go to storage at the Waldorf tracks would pull down as far south as possible on one of the 17 long platform tracks and would remain at that location until the end of the midday storage period. A second train could be routed into the same platform track. For a six-car train length, passengers would have to walk up to an additional 520 feet to get into the GCT. There are also other storage tracks on both the upper and lower level that are not being used and which could be used by MNR for the storage facilities in lieu of tracks 50 – 65.

There may be the odd occasion during the day that a train may not be accommodated in the new track location. For example, train 578 shows 8 cars arriving at 18:02 into track 38. The above change would not accommodate an 8-car train. However, track 13 or 14 on the upper level are also available and could be used. It is therefore assumed that these problems could be resolved by utilizing other tracks available in the GCT.

The study time period did not allow for a complete train computer simulation of the above operations. There may be changes required due to unforeseen circumstances. However, given the results of the analysis of track utilization for the peak hour of the peak morning period, it is concluded that the existing tracks and platforms could handle existing traffic levels.

If there are unforeseen reasons the new track assignments are not feasible, then additional platform track space could be provided by modifying track 117. Track 117 could be extended through to the throat area from the east side of the Madison Yard and the platform could be lengthened to accommodate a 12-car train.

### 2.3.3 Accommodation for Future MNR Expansion

In the previous sections it was explained how MNR could operate the current level of traffic using an 8-track throat and the existing terminal tracks. However, the proposed arrangement would leave little room for future MNR traffic growth on existing tracks. Therefore, it was necessary to investigate various ways of accommodating future increases in MNR traffic.

#### 2.3.3.1 Increase Train Length

Before any significant changes to the operation or before any new capital improvements to facilities are made, there are opportunities for increasing train size on some trains that would increase the service capacity without adding new trains. Shorter trains that operate into long platform tracks could be lengthened and still be accommodated by the platform. According to the current MNR operating plan, a large number of train are 6 cars in length. From a sample taken for a 12-hour period on the Monday to Thursday train schedule, 45% of all trains operating are less than 6 cars in length. Trains could be lengthened from 6 car lengths to 8 or 10 cars as the demand increases. Following the implementation of the ULLA, there would be 17 platforms on the upper level and 7 platforms on the Lower Level available to MNR that could accommodate a 10-car train.

There are also opportunities to increase train length to 12 car trains. According to the Monday to Thursday schedule there are only four 12-car trains operating in the entire day. In the GCT there are 14 platforms on the upper level and 3 platforms on the lower level that could accommodate a 12-car train. This demonstrates that there is opportunity to increase train length up to 12 cars with some limitation on the lower level.

To accommodate additional 12 car trains, particularly on the lower level, it may be necessary to provide one or possibly two long platform tracks in the Madison Yard. For example, a platform track could be provided on track 119 by removing track 118 and building a new platform, or by disconnecting track 117 and connecting an extension to 117 through the east side of the Madison Yard and building an extension onto the existing platform. A platform for track 119 could require extensive facility modifications.

#### 2.3.3.2 Maximum Capacity of 4 Track Corridor

The four track mainline corridor would limit the total number of trains that could operate into GCT. As stated earlier, there are 51 trains operating southbound and 25 trains operating northbound in the morning peak hour. Based on the existing schedules and the extent of the MNR system, it was assumed that the maximum number of trains that could be operated in the corridor is probably in the order of 20 trains per hour (i.e., 3-minute headway) per direction on any one track. It is unlikely that trains would operate any closer than 3 minutes apart in the corridor.

Based on this assumption, the 3 southbound tracks in the morning peak could handle 9 more trains. However, the single northbound track is already at capacity, therefore would not allow any additional trains. This means that if the number of trains were increased to 60 trains per hour in the southbound direction, efficiency improvements and/or additional platform and storage facilities would be necessary as these trains would have to move to midday storage following detraining.

#### 2.3.3.3 Efficiency Improvements

To accommodate additional inbound train traffic additional platform track time would be required. As noted on the track occupancy drawings in Appendix B, it is impossible to add additional trains in the 08:30 to 09:00 time slot without providing additional platform track time.

Apart from track changes that could require expensive modifications, there would be opportunities to increase the amount of available platform track time to receive new inbound trains. There are two ways this could be accomplished: double berthing and more efficient service time.

***Double Berthing:***
Double berthing suggests that MNR would continue in the future to operate 6 and 7 car trains. A double berthing opportunity exists when the first train to the platform remains on the platform on hold for a later scheduled departure. This period could be as little as 2 hours to more than 8 hours for some trains that are held waiting for a departure in the afternoon peak period. This is explained in the section above related to the displacement of trains from the Waldorf Yard.

***Efficient Service Time:***
From the MNR operating plan and from field observations it is noted that servicing time to clean coaches on inbound trains in preparation for outbound movements is excessive. On several occasions it was noted that the equipment servicing time was in excess of 30 minutes. If this process could be done in less time by using additional staff or limiting the amount of service, then there may be more opportunity to free up platform track time.

Implementing these operating changes would free up platform track capacity for the arrival of some additional trains.

#### 2.3.3.4 Additional Platform Capacity

When the future ridership demand increases to the level where it would be necessary to increase the number of trains into the GCT and once the efficiency improvements outlined above have been exhausted, it would be necessary to construct new platform facilities on track 117 and 119. It is estimated that these tracks could accommodate another 8 trains. Each of these 8 trains would arrive on either 117 or 119 and detrain. Following detraining, 4 trains could be moved into the Madison Yard for midday storage. Assuming there are at least 4 or 5 six car trains, the remaining trains could be double berthed on tracks 117 and 119 and in other vacant storage tracks on the lower level.

From the above, it is concluded that 8 additional trains could be handled with the addition of new platform facilities on track 117 and 119. At this point, the corridor capacity and the terminal capacity are approaching their limits.

### 2.3.4 ULLA Capacity Simulation

In order to determine whether the same capacity as the Deep Cavern scheme could be achieved with the ULLA (i.e. 24 trains per hour), an analysis was conducted from a train operations perspective. For this analysis, an average speed of 10 mph around the loop and an 8-minute dwell time on each platform was used. The analysis did not consider passenger handling, platform congestion or passenger circulation requirements. Appendix C provides the result of the technical analysis, which demonstrates that from purely a train operations perspective, 24 trains per hour, is possible for the ULLA. However, for this capacity to be sustained, it would be necessary to avoid a delay of any one train in the peak period of no longer than 2 minutes.

The key to operating 24 trains per hour would be the loop track speed. Appendix C contains a detailed description and calculations showing the requirements necessary to attain a maximum speed of 12 mph around the loop and therefore an average speed of 10 mph. An average speed of 10 mph should be attainable based on the geometry and field observations; 10 mph around the Loop would allow headways of 2.5 minutes equating to 24 trains per hour.

### 2.3.5 MNR Operation during the Construction Period

The construction of the tunnels for the ULLA would occur on one side of the corridor at a time. To perform the structural work, there would be up to 3 throat tracks taken out of service during specific but defined periods. MNR currently operates 9 tracks in the throat. With the addition of Track A the result would be a net loss of 2 tracks for MNR. MNR has worked under these kinds of circumstances during the tunnel rehabilitation work beneath Park Avenue. One tunnel was taken out of service and the existing operations had to be performed using only a 3-track corridor. For the ULLA, the worse case scenario would be the reduction to a 6-track throat. This should occur for a short confined period of time. For most of the tunnel construction period there would be 7 tracks available for Metro North operations in the throat.

There are a number of ways to alleviate the impact created by reducing the throat area to 7 tracks:

- Reduce peak hour service;
- Run longer trains;
- Run more outbound trains during the peak period;
- Double berthing.

**<u>Reduce peak hour service</u>**

The construction period would result in impacts to MNR service, thereby requiring service modifications. When the throat area has been reduced down to 6 tracks the service must be curtailed. It should be noted that four tracks would not be out of service for the entire construction period. There would be times when only 2 tracks are out of service and other times when only one track would be out of service during which times the impact on services would not be as severe. A construction plan would be developed with all stakeholders including a service plan covering the entire construction period. These details would be finalized in the construction planning phase.

**Run Longer Trains**

Where 6 car trains were used, running an 8, 9 or 10 car trains would help to mitigate the impact to the schedule. For example, every second or third train on some routes could be cancelled and longer trains could provide the necessary capacity to ensure all passengers could still be accommodated.

**Run more outbound trains during the peak period**

It would likely be necessary to run fewer inbound peak hour trains and more outbound off peak direction service trains in order to alleviate problems on the throat tracks. Longer trains would be of assistance in minimizing the reduction in peak hour capacity. This would provide more of a balance between inbound and outbound mainline traffic. The ratio of tracks used to handle southbound versus tracks used to handle northbound traffic in the morning peak is currently at 3:1. To move toward less trains in the peak hour flow southbound and more trains in the off-peak northbound direction would impact the service but would alleviate pressure on the throat by reducing the number of reverse movements for mid day storage.

**Double Berthing**

As discussed earlier, double berthing smaller trains on long platform tracks would reduce the number of reverse movements in the throat area.

### 2.4 Passenger Handling Analysis

This section includes:

- An analysis of the capacity of the ULLA from a passenger handling perspective, including detailed access and egress requirements;
- A comparison of the location of the platforms and passenger facilities compared to the GCT via Main Line preferred alternative including a comparison of walking distances for the average daily user;
- A qualitative assessment of the impacts of the ULLA passenger flows on the existing concourses and street entrances.

For the purposes of this report, improvements to the Lexington Avenue subway station have not been considered, as they are independent of the option chosen for the East Side Access Project. All options bring a similar number of passengers to the station and distribute them to the street and other transportation facilities in much the same way. The FIES prepared by MTA provided potential solutions to the subway issues, which are also applicable to the ULLA.

### 2.4.1 Capacity of the Upper Level Loop Alternative

#### 2.4.1.1 Introduction

The evaluation of passenger flows is based on two different conditions: normal operating conditions and emergency egress conditions. Normal operations are governed by the design standards adopted by MTA and NYC and provide tools for pedestrian flow analysis based on the level of service concept first applied to pedestrian activity by J.J Fruin in the 1970's. Emergency egress is governed by guidelines set out in the "Standard for Fixed Guideway Transit and Passenger Rail Stations" of the National Fire Protection Association known as NFPA 130. The latter provides specific criteria for the evacuation of the platform and station areas under emergency conditions.

Passenger flow volume depends on the number of trains per peak hour. Therefore, the first step in the analysis was to determine the maximum train capacity of the 5-track and 3-platform configuration based on emergency conditions. Although it was determined from a purely train operations perspective that it would be possible to operate 24 trains per hour (see Section 2.3), the application of NFPA 130 could restrict the train handling capability of the platforms. A key criterion under NFPA 130 is that platform utilization must be arranged to avoid loading two trains on the opposite sides of a centre platform at the same time.

The second part of the analysis then determined the passenger handling capability of the platforms and exit facilities based on normal and emergency egress conditions, as well as improvements required to meet the standards and guidelines referred to above.

#### 2.4.1.2 Track and Platform Capacity

Before track and platform capacity can be calculated, it is important to distinguish between the morning and afternoon passenger activity. In the morning:

- Passenger activity is more concentrated in the peak hour;
- Arriving passengers exit the trains and platform as quickly as possible and move toward the exits to the street;
- Passengers disperse away from the platforms to a variety of exit points.

This pattern requires sufficient capacity to clear the platform quickly and in an orderly fashion. Cross flows in the concourse and cross passage areas must be considered to provide sufficient space for efficient passenger flow.

In the afternoon:

- People arrive at the terminal and use all entrances to move towards the platform and concentrate into the areas around the platform access points (primarily the Main Concourse, Dining Concourse and the cross passages);
- Once a train is positioned and the departure track is posted, the waiting passengers move swiftly to their train and board;

- Based on observations, many of the passengers arrive after the train has begun accepting passengers, with a significant percentage arriving in the last 3-5 minutes before departure.

This afternoon pattern requires that adequate waiting space be provided close to the platforms. Space must be provided for passengers to stand and wait and for other passengers to move through the queue area. Placement of signage for announcing train locations and food concessions with seating can be effectively used to manage a portion of this demand.

Train delays in the morning have very little impact on station operations as the passengers disperse quickly after arrival, whereas delays in the afternoon can cause significant queuing. A review of the passenger flows indicates that the overall capacity would be driven by the afternoon peak hour when passengers are waiting for trains leaving Manhattan and therefore the dwell times for trains in the station have to be longer. Today, LIRR service runs from Penn Station with the majority of the trains stopping at Jamaica. This allows some passengers to take the first departing train from Penn Station and make a transfer at Jamaica. When GCT is served by LIRR, the same choice will exist for passengers, with an added incentive. Service east of Jamaica will be served by trains from both GCT and Penn Station. During a delay, passengers may opt to take the first available train to Jamaica and transfer to a Penn-based train. This additional flexibility will reduce the impact of service delays at GCT.

A platform usage analysis was carried out and is represented graphically in Figure 12. The detailed analysis confirms that the afternoon peak hour would be the critical time period, and that during that peak hour the 3-platform and 5-track combination could handle 18 trains based on the NFPA 130 criterion. The analysis is based on a review of the platform and access configuration and takes into account the potential to introduce additional facilities to accommodate passenger flow.

No passenger forecast information is given in the FEIS for the afternoon peak hour. Peak hour factors were derived based on the ratio of scheduled trains operated in the morning and afternoon peak hours. The existing ratio of morning to afternoon peak service currently in place for Metro North is 85.6% and the ratio for LIRR is 92%. Based on the ability to handle 18 LIRR trains in the PM peak hour, the AM peak hour would have to accommodate 21 trains to match the existing peak hour factors. Since there would be less dwell time required in the morning, the analysis determined that the AM peak hour could accommodate the required 21 trains per hour. This would provide a passenger carrying capacity of 30,240, (assuming all trains are 12-car trains with 120 passengers per car) which exceeds the 2020 forecast volume of 29,000.

#### ***2.4.1.3 Platform Access/Egress Requirements***

With the volume of trains established for both the AM and PM peak hours, the requirements for normal and emergency egress passenger handling were determined.

**Design Volume of Passenger Flow**

The analysis required a design year passenger flow. The FEIS indicates that 65,000 LIRR riders would have to be accommodated in the AM 4-hour peak in 2020, or 29,000 in the AM peak hour. This figure is used as the design volume. No volumes are given for the PM peak hour, but can be derived from the AM peak hour to PM peak hour ratio noted above. At the platform level, the number of passengers on a train is the key determinant of platform and access capacity. For this exercise it was assumed that a 12-car train would carry 1,440 people, or 120 passengers per car.

## Existing Platform Dimensions and Access

The three platforms proposed for the ULLA are platforms S, T and U, serving tracks 38, 39 & 40 and 41 & 42 respectively. Each of the platforms is slightly different, and the following table summarizes the platform dimensions and existing access/egress facilities.

| | **Platform S (Track 38)** | **Platform T (Tracks 39 & 40)** | **Platform U (Tracks 41 & 42)** |
|---|---|---|---|
| Length | 1500 feet | 1270 feet | 1215 feet |
| Width | 16 feet | 15.7 feet | 15.7 feet |
| Access | • 6.25-foot wide Ramp at south end<br>• 7-foot wide stair to 47th CP | • 9.5-ffot wide ramp at south end<br>• 7-foot wide stair to 47th CP | • 9.5-foot wide ramp at south end<br>• 7-foot wide stair to 47th CP |
| Notes | • No columns<br>• Wall along the east side<br>• 12-car train can be accommodated without replacing existing ramp | • No columns<br>• Ramp will have to be narrowed or replaced to accommodate 12-car train on Track 40 | • No columns<br>• Ramp will have to be narrowed or replaced to accommodate 12-car train on Track 41 |

The ramps at the south end of Platforms T and U are located approximately 700 feet (or 8 car lengths) from the stairs to the 47th Street Cross Passage (47th CP) near the north end of the platform. There is no circulation space on the platform adjacent to the ramps. In order to accommodate the LIRR 12-car trains for the ULLA, two cars would have to be positioned south of the ramps and therefore the ramps would have to be narrowed to allow for circulation along the platform.

Similarly there is no circulation space on the platforms around the stairs at the 47th CP as they occupy the majority of the platform width. They were built as part of the Grand Central North project and sized to provide maximum passenger flow to and from the platform area south of the stairs in order to accommodate passengers to/from the existing MNR trains. In order to accommodate the LIRR 12-car trains for the ULLA, two cars would have to be positioned north of the 47th CP and therefore the stairs would have to be narrowed to allow for circulation along the platform. These changes have been accounted for in the exiting calculations in the following section.

## Exiting Capacities

In developing an exit system, each element must be viewed as an independent unit and as part of the overall system. Stairs, escalators, ramps and passageways are reviewed based on their normal operating capacities and on their emergency egress capacities. Doorways, narrow sections of passageways and obstructions along the route must also be considered in the analysis. Generally, stairs and escalators govern the overall exit capacity, as they are the most restrictive. As noted above, two of the ramps at the south end will have to be narrowed in order to accommodate the 12-car trains ramps, and to provide sufficient capacity the ramps will have to be replaced with stairs and escalators.

The following table outlines the capacities used to calculate exiting requirements.

| | **Normal Operations** | **Emergency Egress** (2) |
|---|---|---|
| Walking Speed | 200 feet/minute | 200 feet/minute |
| Passageway Capacity | 15 PFM (1) | 2.27 pim (3) or 27 PFM |
| Ramp Capacity | 15 PFM | 2.27 pim or 27 PFM |
| Escalator Capacity (4) | 90 passengers/minute | 1.59 pim – up direction<br>1.82 pim – down direction |
| Stair Capacity | 10 PFM | 1.59 pim – up direction<br>1.82 pim – down direction |

(1) “PFM” means passengers per foot width per minute
(2) Emergency Egress figures taken from NFPA 130-2000
(3) “pim” means passengers per inch per minute
(4) Standard 48”-wide, 2-stream escalators have been assumed. For emergency egress calculations, one of the escalators must be considered out of service

#### ***2.4.1.4 Additional Platform Access/Egress Facilities – Platform S***

To accommodate the passenger volumes, additional platform access would be required. The layout of the platforms and vertical connections is illustrated in Figure 13, and includes:

- Reconstruction of the 47th Street Cross Passage stair to allow for passenger circulation around the stair;
- Construction of an additional stair to the 47th Street cross passage;
- Construction of a new cross passage at 48th Street with a stair and escalator to each of the three platforms and exits to street level at 48th and Madison;
- Connecting to the existing cross passage south of 45th Street leading to the basement of the Roosevelt Hotel, or providing a new cross passage under 45th Street with an access to the street through the hotel basement and main floor; with either option, a stair connection to each of the three platforms would be required. (Note: as explained below, this stair location would be required to meet the 300ft maximum platform exit distance requirement of NFPA 130, but was also necessary to provide adequate capacity to meet the key NFPA 130 criterion of a 4 minute exit requirement);
- Elevator access could be added to either the 47th Street Cross Passage or the Roosevelt Passage (see Section 3.4.4).

In total, platform S would be served by:

- The existing ramp at the south end of the platform
- An escalator at the north end of the platform
- Four stairs (one at the north end, one to 45th/Roosevelt and two to 47$^{th}$ Street cross passage), and
- One elevator (to either the 45th/Roosevelt Passage or the 47$^{th}$ Street cross passage)

**Evaluation of Exiting under Normal Operations**

Fully loaded trains could use any platform in the terminal. As a result the exiting requirements for each platform would be the same. The capacity of the escalators is considered first, and then the effective width of additional stairs is calculated. Side clearances need to be added to the effective width of each stair to account for handrails, the area along the edge of a stair where passengers do not walk and for the enclosure structure. The width of the stair will also be constrained by the clearance required between the edge of a stair enclosure and a platform edge. This clearance distance is set at 4 feet on each side.

The volume of passengers is compared to the capacity of the exit system over a 5-minute period to determine if an appropriate level of service is maintained. The 5-minute standard has been adopted by MTA as the standard analysis timeframe. As the fully loaded train would discharge all passengers at the same time, this level of service would be exceeded for short periods, but this is typical of transportation facilities.

The effective stair width to be provided is based on clearing 1,440 passengers from the platform in 5 minutes:

- Ramp capacity at 94 passengers/minute can handle 470 passengers;
- Escalator at 90 passengers/minute can handle 450 passengers;
- The difference, or 520 passengers must be handled by the stairs;
- Over each minute, the stairs must handle 104 passengers;
- At 10 PFM, the effective stair width needed is 10.4 feet; this could be easily accommodated with the four stairs, which total 15 feet in width.

The combination of ramp, stairs and escalator could accommodate the passenger flows during normal operations.

**Evaluation of Exiting under Emergency Conditions**

Exit requirements are based on the NFPA 130. This standard is more prescriptive than the general level of service calculations provided above. The main differences are:

- Whereas passenger level of service is calculated over a 5-minute time period, NFPA requires that all passengers clear the platform in less than 4 minutes;
- Passengers move more quickly on stairs than under normal operating conditions, increasing the capacity from 10 PFM to approximately 19 PFM;
- One of the escalators must be assumed to be out of service, and the capacity of the remaining escalators is assumed to be the same as a stair;

- Escalators cannot make up more than 50% of the exit capacity;
- The longest walk distance along a platform to a stairway must be less than 300 feet.

The calculation of effective stair width to be provided under emergency conditions is based on clearing 1,440 passengers from the platform in 4 minutes:

- The ramp can process 170 passengers/minute or 680 passengers
- The escalator must be assumed to be inoperable;
- The difference, or 760 passengers must be handled by the 4 stairs;
- Over each minute, the stairs must handle 190 passengers;
- At 19 PFM, the effective stair width needed is 10 feet; this could be accommodated with the four stairs, which total 15 feet in width.

The combination of ramp, stairs and escalator could accommodate the passenger flows during emergency operations.

#### 2.4.1.5 Additional Platform Access/Egress Facilities – Platforms T & U

To accommodate the passenger volumes, additional platform access will be required. The layout of the platforms and vertical connections is illustrated in Figure 13, and includes:

- Replacing the ramp with a stair and escalator at the south end of platforms T and U;
- Reconstruction of the 47th Street Cross Passage stair to allow for passenger circulation around the stair, as described above;
- Construction of an additional stair to the 47th Street cross passage;
- Construction of a new cross passage at 48th Street with a stair and escalator to each of the three platforms and exits to street level at 48th and Madison;
- Connecting to the existing cross passage south of 45th Street leading to the basement of the Roosevelt Hotel, or providing a new cross passage under 45th Street with an access to the street through the hotel basement and main floor; with either option, a stair connection to each of the three platforms would be required. (Note: as explained below, this stair location would be required to meet the 300ft maximum platform exit distance requirement of NFPA 130, but was also necessary to provide adequate capacity to meet the key NFPA 130 criterion of a 4 minute exit requirement);
- Elevator access could be added to either the 47th Street Cross Passage or the Roosevelt Passage (see Section 2.4.4).

In total, both platforms T & U would be served by:

- Two escalators (one at each end of the platform)
- Five stairs (one at each end, one to 45th/Roosevelt and two to 47th Street cross passage), and
- One elevator (to either the 45th/Roosevelt Passage or the 47th Street cross passage)

## Evaluation of Exiting under Normal Operations

Fully loaded trains could use any platform in the terminal. As a result the exiting requirements for each platform would be the same. The capacity of the escalators is considered first, and then the effective width of additional stairs is calculated. Side clearances need to be added to the effective width of each stair to account for handrails, the area along the edge of a stair where passengers do not walk and for the enclosure structure. The width of the stair will also be constrained by the clearance required between the edge of a stair enclosure and a platform edge. This clearance distance is set at 4 feet on each side.

The volume of passengers is compared to the capacity of the exit system over a 5-minute period to determine if an appropriate level of service is maintained. The 5-minute standard has been adopted by MTA as the standard analysis timeframe. As the fully loaded train would discharge all passengers at the same time, this level of service would be exceeded for short periods, but this is typical of transportation facilities.

The effective stair width to be provided is based on clearing 1,440 passengers from the platform in 5 minutes:

- 2 escalators at 90 passengers/minute each could handle 900 passengers;
- The difference, or 540 passengers must be handled by the stairs;
- Over each minute, the stairs must handle 108 passengers;
- At 10 PFM, the effective stair width needed is 10.8 feet; this could be easily accommodated with the five stairs, which total 18 feet in width.

The combination of stairs and escalators could accommodate the passenger flows during normal operations with a good margin of safety.

## Evaluation of Exiting under Emergency Conditions

Exit requirements are based on the NFPA 130, as noted in the previous section.

The calculation of effective stair width to be provided under emergency conditions is based on clearing 1,440 passengers from the platform in 4 minutes:

- 2 escalators are provided, but one must be assumed to be inoperable;
- The remaining escalator can handle 76 passengers per minute or a total of 304 passengers;
- The difference, or 1,136 passengers must be handled by the 5 stairs;
- Over each minute, the stairs must handle 284 passengers;
- At 19 PFM, the effective stair width needed is 15 feet; this could be accommodated with the five stairs, which total 18 feet in width.

The combination of stairs and escalators could accommodate the passenger flows during emergency operations.

#### 2.4.1.6 Additional Potential Stair Locations

There are supplemental locations that could be considered to add additional stair or escalator capacity. The functional elements proposed above only provide for one stair to the 45th Street/Roosevelt Cross Passage, and a second element could be added to this location. This location however, is better suited to the elevator access as it provides access to the main terminal building via the Roosevelt passage.

There is potential to add two sets of stairs on one side of a cross passage as well. Figure 14 indicates how the two sets of stairs would be configured. As they both lead to the same platform signage and wayfinding would not be an issue. Basically, the connection from the cross passage would split, and the first narrower corridor would serve the first stair. The other narrow corridor would run past the first stair and then shift laterally to the center of the platform where the second set of stairs would be developed.

Where the connecting corridor is under the platform, the width would be limited to the available space under the platform. Where the connecting corridor is above the platform, the limitation on width would be less severe and would be related to column and existing basement constraints.

The functional requirements were developed as part of this report, but would have to be refined through further structural analysis to determine if they are feasible.

### 2.4.2 Comparison of Passenger Facilities

#### 2.4.2.1 Introduction

One of the major benefits of the ULLA is the short and direct path created for passengers. There is no reliance on a deep mezzanine level or banks of escalators to move passengers, but rather an enhancement of the existing facilities.

The ULLA would use existing tracks 38-42 on the upper level of GCT to handle LIRR passengers. Passenger handling facilities would include:

- Three platforms (S,T,U) serving five tracks;
- Connections to the Biltmore Room in GCT and the 47th Street Cross Passage;
- Use of existing facilities in GCT connected to the Biltmore Room;
- Connections to new Cross Passages at 48th Street and 45th Street or utilizing the Roosevelt Passage;
- Existing and new street entrances, which would provide connections to the surrounding street network.

The GCT via Main Line preferred scheme creates a new Deep Cavern station under the existing two-level underground GCT terminal and converts a storage track area of the lower level of GCT (Madison Yard) into a new concourse. Passenger handling facilities include:

- Vertical circulation to a mezzanine level between the upper and lower cavern platforms;

- Mezzanine connections to the proposed lower level concourse by means of four escalator banks with a total of 17 escalators;
- A linear concourse in the former Madison Yard area of the lower level of GCT to distribute passengers and provide some amenities (as well as substantial office space); and
- Street connections and a GCT Dining Concourse connection to distribute passengers to the surrounding street network.

#### 2.4.2.2 Comparison of Walking Distances

The walk for the average commuter is significantly longer under the Deep Cavern scheme than under the ULLA. The following two tables summarize an average walk for two passengers to each of two destinations. The passengers are located mid-point of the south half of a train, and mid-point of the north half of a train. The destinations are the entrance to the Lexington Avenue subway station and the corner of Madison and 47$^{th}$ Street. These destinations represent key surface connection points for LIRR customers.

| | **Passenger #1 (Mid-point of the south half of the train)** | | **Passenger #2 (Mid-point of the north half of the train)** | |
|---|---|---|---|---|
| | **Subway** | **Madison & 47th** | **Subway** | **Madison & 47th** |
| **MTA Preferred Alternative** | | | | |
| Walk along platform to nearest stair/escalator | Walk 150’ | Walk 150’ | Walk 180’ | Walk 180’ |
| Transfer to mezzanine | Up or Down 14’-18’ | Up or Down 14’-18’ | Up or Down 14’-18’ | Up or Down 14’-18’ |
| Cross mezzanine to escalators | Walk 80’ | Walk 80’ | Walk 80’ | Walk 80’ |
| Transfer to Lower Concourse | Up 90’ | Up 90’ | Up 90’ | Up 90’ |
| Walk along concourse to appropriate exit | Walk 575’ | Walk 500’ | Walk 1075’ | Walk 50’ |
| Transfer to Subway or Street Level | Up 20’ Walk 500’ | Up 47’ Walk 200’ | Up 20’ Walk 500’ | Up 47’ Walk 200’ |
| **Total Walk Distance** | Walk 1305’ plus Up or Down 124’-128’ | Walk 930’ plus Up or Down 151’-155’ | Walk 1835’ plus Up or down 124’-128’ | Walk 510’ plus Up or Down 151’-155’ |
| | | | | |
| **Upper Level Loop Alternative** | | | | |
| Walk along platform to nearest stair/escalator | Walk 250’ | Walk 250’ | Walk 750’ | Walk 100’ |
| Transfer to Concourse or Cross Passage | Up or Down 5’-10’ | Up or Down 5’-10’ | Up or Down 5’-10’ | Up or Down 5’-10’ |
| Walk along concourse to appropriate exit | Walk 250’ | Walk 150’ Down 10’ | Walk 250’ | Walk 150’ Down 10’ |
| Transfer to Subway or Street Level | Walk 500’ | Up 30’ | Walk 500’ | Up 30’ |
| **Total Walk Distance** | Walk 1000’ plus Up or Down 5’-10’ | Walk 400’ plus Up or Down 45’-50’ | Walk 1500’ plus Up or Down 5’-10’ | Walk 250’ plus Up or Down 45’-50’ |

### 2.4.3 Street Entrance Requirements

During the design of the MTA's Preferred Alternative, options for additional street entrances were developed. The FEIS identifies three new street entrances, a new connection from the south end of the Lower Level Concourse to the Dining Concourse in GCT and a new connection to the 47th Street Cross Passage built as part of the Grand Central North Project. The new entrances are located at:

- 48th Street & Madison
- 45th Street with the street-level entrance in the Roosevelt Hotel
- 44th Street & Madison

Each of these three entrances has been designed with a lower level floor at the same elevation as the Lower Level Concourse. Given the revised elevation of the cross passages under the ULLA, the ability to develop street entrances in the same location as the MTA scheme would have to be reviewed in more detail.

In the ULLA plan, a cross passage would be developed above the upper level tracks in the basement of the Roosevelt Hotel (shown in Figure 13). This would connect to the street level area illustrated in the FEIS.

As a future stage, the Waldorf Yard area could be converted into additional concourse and office space. With an extension of the 47th and 48th Street Cross Passages, this concourse would allow for one or two new street connections in the northeast area of the station, and may permit a direct connection to the 51st Street Lexington Local station and the 53rd Street station for the E and V trains. If a portion of this space were not required for offices or concourse, it may be of interest to the Waldorf-Astoria Hotel, which could help defray the cost of developing the concourse.

### 2.4.4 Accessibility Requirements under The Americans with Disabilities Act

Beyond the facilities required to meet the operational requirements of LIRR, provision should be made for facilities to meet the ADA requirements. The addition of a cross passage at the Roosevelt Hotel, which has a level connection to the Biltmore Room, makes it an ideal candidate for the installation of elevators. Elevators could also be installed at the 47th Street cross passage if the retrofitted stairs are designed in tandem to the south side of the cross passage.

# 3. COST COMPARISON OF THE ULLA AND THE DEEP CAVERN SCHEME

## 3.1 Deep Cavern Scheme Capital Costs

A review of the Metropolitan Transportation Authority (MTA), Capital Construction Company "Capital Program" budget reveals the following:

- Total budget for the East Side Access Project $6,305.7 million
  This is broken down as follows:
  - 1995-1999 Capital Program $ 157.7 million
  - 2000-2004 Capital Program $1,540.5 million
  - 2005-2009 Capital Program $4,607.5 million

- The Capital Program budget for the East Side Access Project apparently includes costs for all aspects of the entire project including all the work required on the east side of the East River in Queens ($800+ million), upgrades to various facilities and interlockings, real estate, engineering, management, purchase of new rolling stock ($460 million), and many other requirements.

- The excavation for the tunnels in Manhattan from the existing 63rd Street tunnel at 2nd Avenue to the new station caverns at GCT has been included in the 2000-2004 Capital Program budget, but not shown as a broken out cost. This cost could be assumed to be in the $300 to $400 million range, depending on what has been included.

- The other construction work in Manhattan has been listed in four (4) main categories included in the 2005-2009 Capital Program budget.
  This has been broken out as follows:
  - Element #60 – GCT Caverns, 63rd St Tunnel Rehab $832.1 million
  - Element #61 – Vent Plant Facilities $101.0 million
  - Element #62 – GCT Concourse/Caverns Finish $373.9 million
  - Element #63 – GCT Surface Entrances $ 64.1 million

- Portions of other elements of the Capital Program budget would be applicable to the Manhattan portion of the overall project such as for Program Management Services, Construction Management, General Conditions, General Engineering Contracts, MTA Management, Procure/Install Track/3rd Rail, Various System Elements, Tunnel Ventilation, etc.

Although many of the components making up the total budget for construction of the Manhattan portion of the Deep Cavern scheme are difficult to allocate, based on the above known factors, the estimated cost is in the $2.0 billion range.

## 3.2 Elements of Work

The cost comparison undertaken for this report looks at the works contemplated in the Manhattan portion of the project only. The planned works in Queens, including the approach tunnels under Yard A and the Sunnyside Yard are assumed to be common to both alternatives. Work on the Manhattan side can be divided into three categories:

- Common elements
- Elements in the Deep Cavern Scheme that are not required for the ULLA, and
- Elements only required for the ULLA

***Common Elements***

These include items that are similar but the scope could be different for the two schemes:

- 63rd Street Tunnel rehabilitation
- Tunnels connecting 63rd Street tunnel to GCT
- Trackwork, signals and systems
- Street entrances

The 63rd Street Tunnel rehabilitation is the same for both alternatives. The ULLA requires less tunnel construction, less trackwork, signals and systems work. The street entrances proposed for the Deep Cavern Scheme would require some modifications for the ULLA.

***Elements in the Deep Cavern scheme that are not required for the ULLA***

The elements currently in the budget that are not required under the ULLA include:

- Construction of the Deep Caverns and tailtracks
- Construction of the long escalator shafts and installation of 17 long escalators
- Retrofitting of the Madison Yard into a 350,000 square foot concourse and office space
- New connection from the Dining Concourse to the new concourse, and
- Construction of ventilation buildings for deep cavern ventilation

The most substantial of these is the deep caverns, which will require significant tunnel boring as well as extensive mining and installation of the structure to support the mezzanine and upper level tracks.

***Elements only required for the ULLA***

The ULLA would require different elements for the project, but these are modest in comparison to the elements included in the Deep Cavern scheme. They include:

- Modification to the throat tracks to incorporate the inbound and outbound tracks for the ULLA;

- New cross passages at 48th Street and 45th Street/Roosevelt Hotel, and concourse space for one of the cross passages;
- Replacement of ramps at the south end of Platforms T & U with a stair/escalator bank;
- Additional stairs and elevators from the platforms to the new cross passages;
- Ventilation and possibly new air conditioning for the new cross passages and concourse space;
- Possible new platforms and tracks in the GCT to accommodate displaced and additional MNR trains;
- Accommodation of some LIRR trains at Yards outside the GCT.

### 3.3 Capital Cost Savings

In order to estimate the potential cost savings of the ULLA compared to the Deep Cavern scheme, specific elements required for the ULLA were accounted for as offsetting costs against the estimated savings associated with differences in scope of common elements and with Deep Cavern items not required.

A comparison of the amount of new construction work required to complete the Deep Cavern scheme, as opposed to the proposed ULLA, reveals that the difference in costs are significant. The estimated difference in excavation quantities is estimated to be in the order of 600,000 cubic yards, while the difference in new reinforced concrete work is estimated to be in the order of 150,000 cubic yards. These two items alone could account for an increased cost for the Deep Cavern scheme of $600 million. Major additional cost would be associated with the extra finishing for the platforms, cross-passages, concourses, escalators, elevators, stairs, lighting, mechanical, electrical, ventilation, and many other components.

The potential cost savings realised by using the ULLA in place of the Deep Cavern scheme can be estimated by comparing the main elements of the Capital Program budget for the Manhattan portion of the work only as follows:

Note: Elements taken from 2005-2009 Capital Program for ESA Project ($ in millions)

| Element # and Description | Budget Allocation | % Savings(*) | $ Savings |
|---|---|---|---|
| 51: Program Management Services | $ 75.0 | 25% | $18.8 |
| 52: Construction Management | $105.5 | 25% | $26.4 |
| 54: General Engineering Contracts | $ 70.6 | 25% | $17.7 |
| 60: GCT Caverns, 63rd St Tunnel Rehab. | $832.1 | 80% | $665.7 |
| 61: Vent Plant Facilities | $101.0 | 75% | $75.8 |
| 62: GCT Concourse/Caverns Finish | $373.9 | 60% | $224.3 |
| 63: GCT Surface Entrances | $ 64.1 | 25% | $16.0 |
| 72: Various System Elements | $450.2 | 25% | $112.6 |
| 73: Tunnel Ventilation | $141.8 | 25% | $ 35.5 |
| Total Estimated Savings (for elements considered only) | | | $1,192.8 |

(*) % Savings are estimated by comparing scale of work involved for each scheme.

**<u>Elements 51,52,54:</u>** Since the value of the construction work within the 2005-2009 budget is approximately 25% less, an equivalent reduction in Program Management Services, Construction Management, and General Engineering Contracts of 25% is considered applicable.

**<u>Element 60:</u>** While the rehabilitation of the 63rd Street tunnel would be required for either scheme, the underground construction and fitting out requirements of the Deep Cavern scheme is entirely eliminated, and offset only by the relatively small amount of open excavation and platform re-fit/upgrades associated with the Upper Level loop Alternative proposal. The reduction in costs has been estimated to be 80%.

**<u>Element 61:</u>** The ventilation requirements of the Upper Level Loop Alternative within GCT are greatly reduced from those of the Deep Cavern scheme. The cost savings have been conservatively estimated to be 75%.

**<u>Element 62:</u>** The amount of construction and fit-out requirements of the new Deep Cavern Mezzanines and Concourses, including elevator/escalator access and platform finishing is greatly reduced with the Upper Level Loop Alternative. However, the work is offset by the requirement for new cross passages, platform access upgrades, and some new Concourse work. The cost savings for this part of the work are estimated to be 60%.

**<u>Element 63:</u>** While the requirement for the size, number, and general location of the various surface entrances can be considered to be similar for both schemes, the access to street from the upper level of the ULLA is considered easier to accomplish than from the concourse of the Deep Cavern scheme, resulting in associated cost reductions. The cost savings here have been estimated to be 25%.

**<u>Element 72:</u>** The various system elements for both schemes are assumed to be similar, but the ULLA requires less new track, switches and control signalling, with the GCT acting as a “through” station operation. The resulting cost savings are conservatively estimated to be 25%.

**<u>Element 73:</u>** Both schemes have significant lengths of tunnel, which require proper tunnel ventilation. However, the ULLA contains much less length of tunnel in the Manhattan section. Therefore, the cost saving for this component has also been estimated to be 25%.

It should be noted that there are many other potential areas of cost saving associated with the reduced amount of new work involved with the proposed ULLA, and there may be some other areas of minor cost increases to be off-set, particularly on the operations side, but a complete comparison of all costs is beyond the scope of this analysis. For purposes of this analysis, only the main construction components in Manhattan have been considered.

In summary, the potential cost saving associated with the ULLA, when compared to the proposed Deep Cavern scheme appears to be in the order of at least $1.2 billion. On this basis of an assumed value of the Manhattan portion of the Deep Cavern scheme at $2 billion, the ULLA cost is therefore estimated at $800 million. It is roughly estimated that of the $800 million, about 50% would be associated with items listed in the bullet points above under “Elements only required for the ULLA.”

## 3.4 Operating Costs

In addition to the above capital costs for the ULLA, there would be additional annual operating costs compared to the Deep Cavern scheme associated with the following:

- LIRR trainset moves to mid-day storage at Yards outside the GCT;
- Some additional reverse moves in the throat;
- Additional train and platform staff at GCT.

Very preliminary estimates suggest that these items would total about $6 million annually. In contrast, the Deep Cavern scheme must include operating costs for:

- 17 long escalators,
- Deeper elevators,
- Larger ventilation and air conditioning systems, and
- Larger mezzanine and concourse areas to maintain and supervise.

It is not possible to assess the associated additional annual operating costs for the Deep Cavern scheme but they would be quite substantial in relation to the $6 million estimate noted above for the ULLA.

# 4. RESPONSE TO FEIS CRITIQUE OF APPLE CORRIDOR SCHEME

The East Side Access FEIS outlines disadvantages of the Apple Corridor scheme in Appendix 1, Pages A.22 and A.23. The following statement from the first paragraph on page A.23 summarizes the key criticisms:
*"Apple Corridor called for the use of the five westernmost tracks (38-42) of the upper level of GCT for both LIRR service and airport access service. This would have had a number of adverse impacts on Metro-North, would not have been sufficient to handle projected LIRR passenger volumes, and would have been more costly to construct than originally envisioned".*
The remainder of the FEIS text on Page 23 expands on these points. The following responds to each of the cited disadvantages.

"***Use of Upper-Level Metro-North Tracks"***

The FEIS states:
*"The use of these five upper level tracks would have provided LIRR and Airport Access service at the expense of existing and future Metro-North service".* The *"upper level tracks…are currently heavily used by Metro-North and accommodate 12-car trainsets".* The *"use of the five westernmost upper level tracks would have completely taken away Metro-North's access to the upper level loop track – severely constraining Metro-North operations".*

First, the ULLA proposal assessed in this report provides for LIRR services but does not involve a connection or service to the JFK International Airport. The ULLA scheme does involve the use of 5 upper level tracks (38-42) that are currently utilized for MNR revenue service. Tracks 38-42 are currently used by 11 trains in the a.m peak hour, which does not constitute heavy use of the tracks at present. The ULLA would preserve the Madison Yard and there would still be approximately 37 platform tracks and 28 storage tracks available for MNR revenue service on the lower and upper levels. Section 2.3 of this report details how these remaining tracks could accommodate the existing MNR service through measures that include changing track utilization, double berthing of short trainsets, shortening service times and adding new facilities in the station if required. Section 2.3 also outlines how the growth of MNR service could be accommodated through measures that include lengthening trains, double berthing to increase platform capacity, more efficient train servicing as well as the addition of new facilities in the station. In this regard, it is acknowledged that some of these operational changes might not normally be considered as conventional practice in relation to GCT, but there are many examples in other major rail terminal operations where such operational measures are employed.

In relation to growth potential, there would be a limit on the number of additional MNR trainsets that could be operated on the four track mainline approach to GCT. Currently, there are 51 inbound trains in the a.m. peak hour operating on 3 tracks and 25 outbound trains during the same peak hour on the fourth track. At a 3-minute headway, the three inbound tracks could handle a maximum of 60 trains. Therefore, the maximum additional number of trains is 9. The analysis outlined in Section 2.3 demonstrates that these 9 additional trains for the most part could be handled in expanded facilities in the Madison Yard and through more efficient use of the existing terminal tracks.

The FEIS reference to the heavy use of upper level tracks for the accommodation of 12-car MNR trainsets does not apply to four of the tracks used for the ULLA. Platform tracks 39 to 42 are currently configured for 8-car trains. The ramp at the south end and the stairs to the 47th St. Cross Passage at the north end define the limits of the 8-car length. A 12-car trainset can only fit on track 38. In this regard, it is interesting to note that at present there are only four MNR 12-car train sets that enter GCT during a weekday.

The ULLA does eliminate the use of the upper level loop for MNR trains but observations of current MNR operations show that the loop track is seldom used. The loop is used only 5 times in the peak period. Again, Section 2.3 outlines how MNR operations could be accommodated without the availability of the loop track and without "severely" constraining Metro-North operations.

***"Creating Capacity for LIRR and Airport Access"***

The FEIS states:
*"The Apple Corridor proposal would not have created sufficient capacity to handle LIRR peak hour service. Track and platform alignments would have accommodated only 18 trains/hour (versus GCT via Main Line's 24 trains/hour), and would have utilized existing platforms of insufficient width to accommodate large LIRR commuter crowds. Moreover, Apple Corridor's proposed simplified track configuration on approach to GCT would not have permitted parallel train moves: just a single track in and a single track out – insufficient to handle LIRR and Airport Access service concurrently The same shortcomings were apparent in the vicinity of Sunnyside Yard in Queen's, where the Apple Corridor proposal did not address the need for midday storage of LIRR trains. Finally, Apple Corridor would require all LIRR passengers heading to or from GCT to transfer at Jamaica."*

This paragraph again refers to Airport Access being part of the Apple Corridor scheme. The ULLA scheme assessed in this report does not involve an airport service. The following responds to each point raised in the above-noted paragraph from the FEIS:

**Only 18 trains/hour can be accommodated**
It is stated in the FEIS that the GCT via Main Line scheme can accommodate 24 trains/hour although the derivation of this number is not explained. Sections 2.3 and 2.4 of this report respectively outline the train operations and passenger flow analysis of the ULLA. From a train operations perspective, 24 trains per hour could be operated with some constraints, namely that the loop track must operate at 10 mph, and that trains will dwell in at the platforms for a maximum of 8 minutes.

Due to emergency passenger egress requirements the practical capacity is limited to 18 trains in the p.m. peak hour and 21 trains in the a.m. peak hour. It is typical that passenger peak hour demand is not as concentrated in the p.m. period as in the a.m. period (in the case of LIRR, about 15% lower than in the a.m. peak hour) and therefore there are fewer trains that operate in the p.m. peak hour. Therefore, a capacity of 18 in the p.m. peak hour is consistent with a capacity of 21 trains in the a.m. peak hour. The average dwell time can be slightly longer at 21 trains/hour.

**Platforms of insufficient width**
While the platform space is limited it is sufficient for the required passenger flow. Actually, it is the vertical access that would require additional capacity, which would be provided with the following:

- The addition of a new 48th St. Cross Passage with an escalator and a stair to each platform;
- The addition of a second stair to the 47th St. Cross Passage;
- Connections to the Roosevelt passage or 45th Street cross passage;
- The required conversion of the ramps at the south end of platforms T and U to an escalator and a stair (the ramp on Platform S could remain)..

These improvements would satisfy the requirements of NFPA 130 and result in acceptable passenger flows.

**Parallel train moves not possible**
The ULLA would not require the same number of parallel movements that a stub end operation would require. The loop track would allow for the free flow of both southbound and northbound traffic. Parallel movements could be performed through the throat in the north end of the yard approaching the platform tracks. The analysis outlined in Section 2.3 confirms that there is adequate throat capacity for such moves.

**Mid-day storage of LIRR trains not addressed**
Since there are 5 tracks used for the ULLA compared to 8 tracks for the preferred alternative, it is estimated that the ULLA would require midday storage for 3 more trains in Queens. With the GCT via Main Line preferred alternative, mid-day storage of some of the LIRR fleet would be required presumably at the Sunnyside Yard in Queens.

In this regard it should again be noted that the ULLA preserves the Madison Yard which could provide storage for MNR trains that otherwise would have to be stored off-site, or used to provide for future MNR growth.

**All LIRR passengers must transfer at Jamaica**
This would not apply to the ULLA since airport access is not part of the scheme.

***"Cost Estimates"***

The FEIS states:

*"Apple Corridor cost estimate …… did not include key elements that would have brought its costs into line with those of GCT via Main Line, including throughput connections at Harold Interlocking; mitigation for loss of Metro-North tracks, platforms and upper loop; design and construction of additional exits and cross passageways at GCT; real estate/easement costs; mitigation of Lexington Avenue subway impacts; and mid-day storage, among others."*

The following responds to each point raised in the above-noted paragraph from the FEIS.

**Throughput connection at Harold Interlocking**
The impact to Harold Interlocking is identical to both Deep Cavern scheme and the ULLA alternative and therefore costs would be the same in both cases.

**No mitigation for loss of MNR tracks, platforms and upper loop**
This is answered in Section 2.3 and Section 3. These sections conclude that existing and future MNR operations could be accommodated within GCT, sufficient platform accommodation could be provided, and the current use of the upper loop by MNR is minor and could be accommodated. Associated costs are accounted for within the overall cost saving ($1.2 billion) of the Manhattan portion of the ULLA compared to the Deep Cavern scheme.

**Construction of additional exits and passageways**
Details of these requirements for the ULLA are included in Section 2.4. Costs for these items have been accounted for in the assessment of capital cost savings for the ULLA compared to the Deep Cavern scheme. Section 3 outlines the assumptions or this assessment and also provides commentary on the annual operating cost comparison of the two schemes.

**Real estate and easement costs**
Real estate and easement costs associated with the entrances/exits for ULLA passenger access to ground level would be in the same order of magnitude as costs for similar access for the GCT via Main Line scheme. Both schemes would require identical easements for the connection from the 63$^{rd}$ Street tunnels, and both schemes would be built under existing MNR tracks under Park Avenue. The Deep Cavern scheme may require additional easements for ventilation shafts and exits and for the overrun tunnels; these would not be required in the ULLA.

There could also be some value to the Waldorf Yard area, which would be released with the ULLA. This space could be used in the future for concourse space, office space or compensation for street level access. The Waldorf-Astoria Hotel might also be interested in additional basement space.

**No mitigation of Lexington Avenue Subway impacts**
There would be similar impacts with the Deep Cavern scheme and the ULLA as a result of additional passengers transferring to the subway using limited stairway capacity in GCT terminal. The mitigation measured mentioned in the FEIS for the Deep Cavern Scheme would be applicable to the ULLA.

**Mid-day storage not included in cost estimate**
If this refers to mid-day storage for MNR trains, Section 2.3 outlines how this could be accommodated with the ULLA by using existing tracks within GCT plus a number of operational measures.

# 5. CONCLUSIONS

The following conclusions are based on the analysis documented in the foregoing sections. As noted previously, the extent of analysis was constrained by the limited information available and the time available for this assessment and therefore many assumptions and judgments were required based on the experience of the team**.**

## 1. Track Alignment

**From a track alignment perspective, it is feasible to accommodate the ULLA**.

An inbound track can be located on the alignment of the existing Track I. By adjusting track grade and elevation, the inbound track enters the Tower U area with a portal at 55$^{th}$ Street, well clear of Ladder L, which remains unaltered for continued use by MNR. The inbound track climbs southward at a grade of 3.19%, with a summit vertical curve on Ladder Z at 52$^{nd}$ Street. This track grade conservatively assumes a minimum disruption to the trackway floor structure at the south end. A grade of 3.0% is likely achievable with a minor, shallower, reconstruction of the track support structure in the vicinity of 52$^{nd}$ Street.

An outbound track can be located on the alignment of the existing Track C. The track descends northward at a grade of 3.0% with a summit vertical curve immediately north of the north turnout of Ladder M, to a portal at 55$^{th}$ Street. The portal is clear of Ladder K, which remains unaltered for continued use by MNR.

The loop track is converted to a single main line by removing existing connecting tracks and turnouts from the junction turnout of tracks #1 and #2, northward up to and including all turnouts between Ladder M (Loop), and Ladder O, as well as removing the Waldorf Yard tracks, (tracks 50 through 65). In this way the loop track is isolated from other MNR tracks. Trains can proceed from the platform tracks 38 to 42, around the loop to track C without interfering in any way with MNR operations.

Removal of tracks 50 through 65 makes available approximately 3.2 acres of below grade real estate. This property could be used as a concourse for passenger access, for MNR or LIRR office/facility space, as well as for commercial purposes.

## 2. Constructability

**The ULLA would be viable from a constructability perspective**.

This conclusion was reached based on available plans and reports. A further detailed geotechnical and engineering analysis and review would be required to move to a final design. North of 55$^{th}$ Street the ULLA would be constructed in tunnel, and south of 55$^{th}$ Street, the ULLA would be constructed utilizing open cut excavation within the MNR trackway under Park Avenue. From a construction perspective, the ULLA has some advantages over the Deep Cavern proposal, including:

- Significantly less work in almost all areas of construction including excavation, tunnelling, structural concrete, finishing details, mechanical and electrical components, and related systems installations.
- Reduction in the time required to complete all construction work, resulting in a shortened schedule, for potentially earlier revenue service to GCT.
- Ability to undertake major components of the construction work simultaneously reducing the critical path timeline requirements.
- Reduced costs overall for the construction components of the project.

Some potential disadvantages to be considered are;

- Disruption to existing MNR operations into GCT during construction would be unavoidable, but controllable to a minimum.
- The requirement for re-design and an EA.
- If desirable in the future, construction of any extension of LIRR service south from GCT would not be readily achievable.

## 3. <u>Train Capacity</u>

**The passenger flow and train operations analysis determined that the capacity of the 5 track/3 platform configuration in the GCT for the ULLA would be 18 trains per hour in the PM peak and 21 trains per hour in the AM peak.**

The key factor that led to this conclusion was the application of the NFPA 130 guidelines for emergency egress. Platform utilization must be arranged to avoid loading two trains on the opposite sides of a centre platform at the same time. The 21 trains per hour would provide a maximum capacity of 30,240 based on utilizing 12-car trains, which slightly exceeds the 2020 forecast requirement of 29,000.

## 4. <u>Train Operations</u>

**It would be viable to accommodate MNR trains in the throat area and in the terminal for both existing conditions and future growth.**

It was determined that the throat has sufficient capacity even with a reduction from 10 (9 in current operation) to 8 tracks available for MNR trains. Displaced MNR trains in the terminal could be accommodated with a series of measures that would include changing track utilization, double berthing of short trains, shortening servicing times and adding new platform and track facilities. There would be no impact on the 4 track mainline access to GCT similar to the Deep Cavern scheme. There would be service impacts on MNR operations during construction of the inbound and outbound tracks through the throat but these could be mitigated through reductions in the frequency of peak service by employing longer trains, reducing reverse moves through the throat, and double berthing of short trains.

## 5. Passenger Handling

**It was determined that the ULLA 5 track/3 platform configuration would be capable of handling passengers under both normal and emergency conditions on the basis of incorporating a number of new stairs, escalators, elevators, and cross passages.**

Key factors related to passenger handling involved the application of NFPA 130 criteria, particularly the need to evacuate the platform in 4 minutes and the maximum distance between exits of 300 feet. On this basis, plus the train capacity as noted above, the additional access/egress facilities would comprise:

- A stair/escalator unit to replace the ramps at the south end of platforms T and U;
- A stair to a new 45th Street cross passage or reactivate Roosevelt Hotel passage;
- Construction of two sets of stairs to the 47th Street cross passage;
- Construction of a 48th Street cross passage with a stair an escalator to each of the three platforms;
- Elevators to be provided to the 45th Street/Roosevelt Hotel passage or the 47th Street cross passage.

## 6. Schedule

**The Manhattan portion of the ULLA could be implemented by the middle of 2009.**

The critical path of work elements consist of detailed design and EA, construction of the tunnels and the installation of track, signals power and other systems in the tunnels. Based on a review of all required elements, and assuming a decision point to switch to the ULLA of the beginning of 2005, it was estimated that the earliest date for contract award for the ULLA tunnels was mid-2006 and the completion date for the tunnels would be two years later. By overlapping the systems installation work with the tunnels, the earliest date for completion of the work would be the middle of 2009. This would provide an opportunity for an earlier revenue service date compared to the Deep Cavern scheme, subject to completion of other work outside of Manhattan.

## 7. Cost

**It is estimated that the Manhattan portion of the ULLA could be implemented for a capital cost of approximately $800 million, a savings of $1.2 billion of the estimated $2 billion cost of the Manhattan portion of the Deep Cavern scheme.**

The scale of the ULLA is significantly less than the Deep Cavern scheme and therefore substantial capital cost savings could be realized. Costs for elements required specifically for the ULLA were accounted for by offsetting the savings associated with common elements that would be different in scope and elements only required for the Deep Cavern scheme. Of the $800 million estimated for the ULLA, about 50% would be associated with elements only required for the ULLA. (See Section 3.2 for list of elements).

It is estimated that the operating costs associated with the ULLA could be in the order of $6 million per year. The operating costs for the Deep Cavern scheme would be quite substantial in relation to this estimate.

## EXISTING GRAND CENTRAL TERMINAL AND APPROACH TRACKS

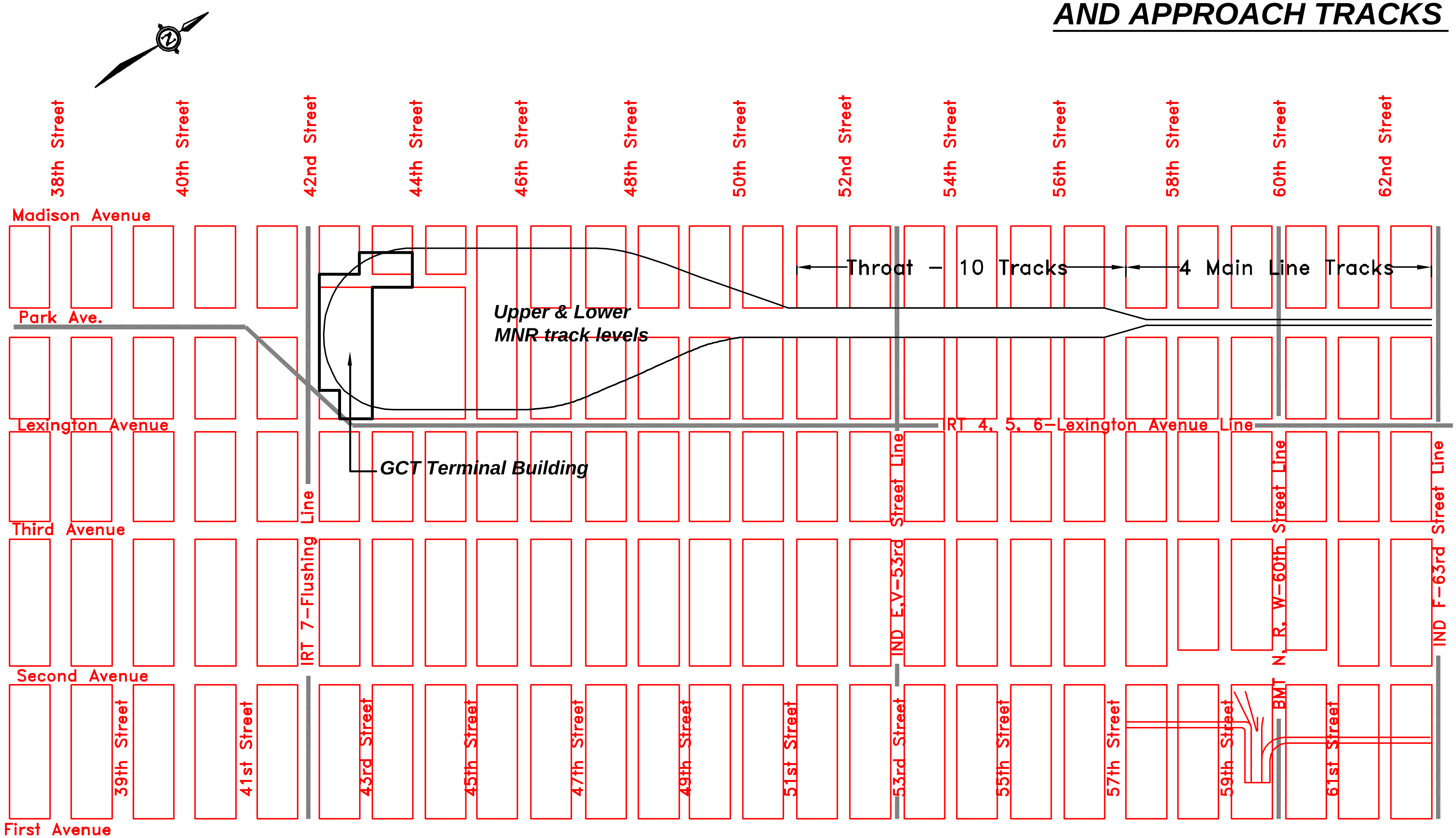


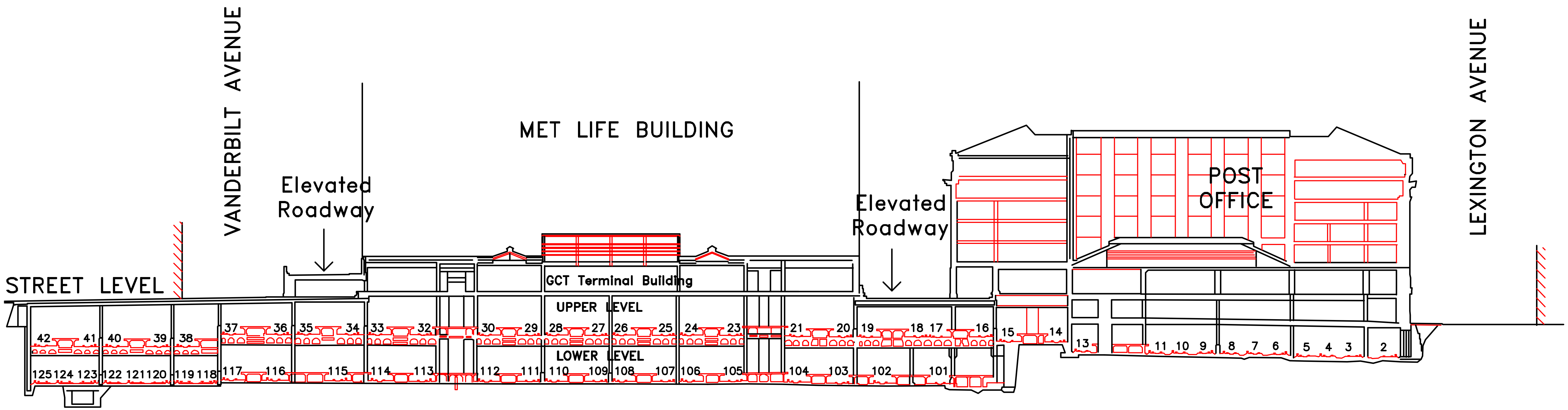

FIGURE 1

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN

NOT TO SCALE

# GRAND CENTRAL TERMINAL
# CROSS-SECTION




**SECTION THROUGH 44th STREET**

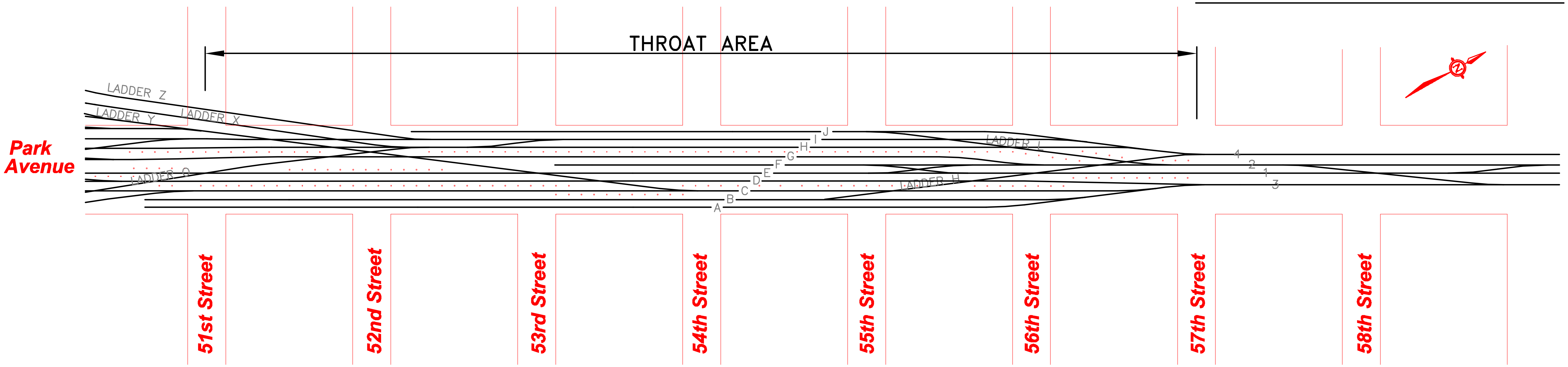
LOOKING NORTH

FIGURE 2

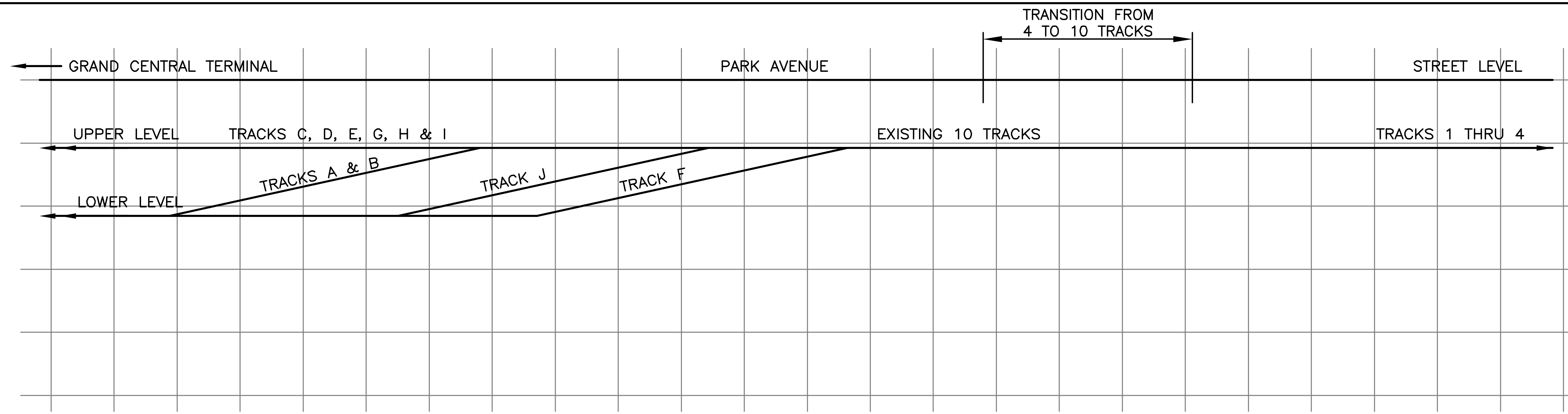
**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

**METRO NORTH RAILROAD THROAT ENTRANCE TO GRAND CENTRAL TERMINAL UNDER PARK AVENUE**




**PLAN**




Legend
—A— Track No.

NOT TO SCALE

**PROFILE**

**FIGURE 3**

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

## GRAND CENTRAL TERMINAL EXISTING UPPER LEVEL TRACKS AND PROPOSED LIRR ACCESS

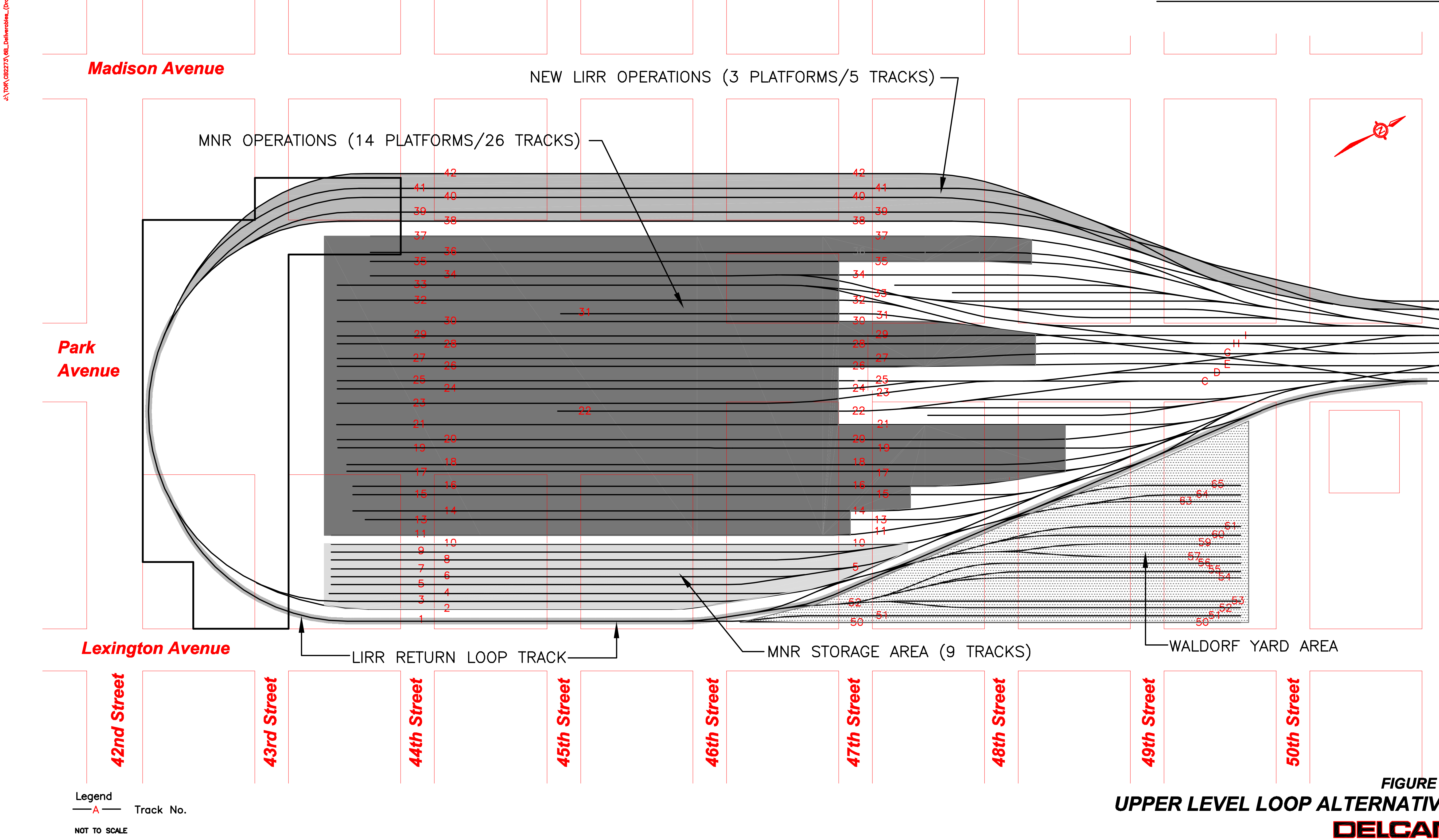
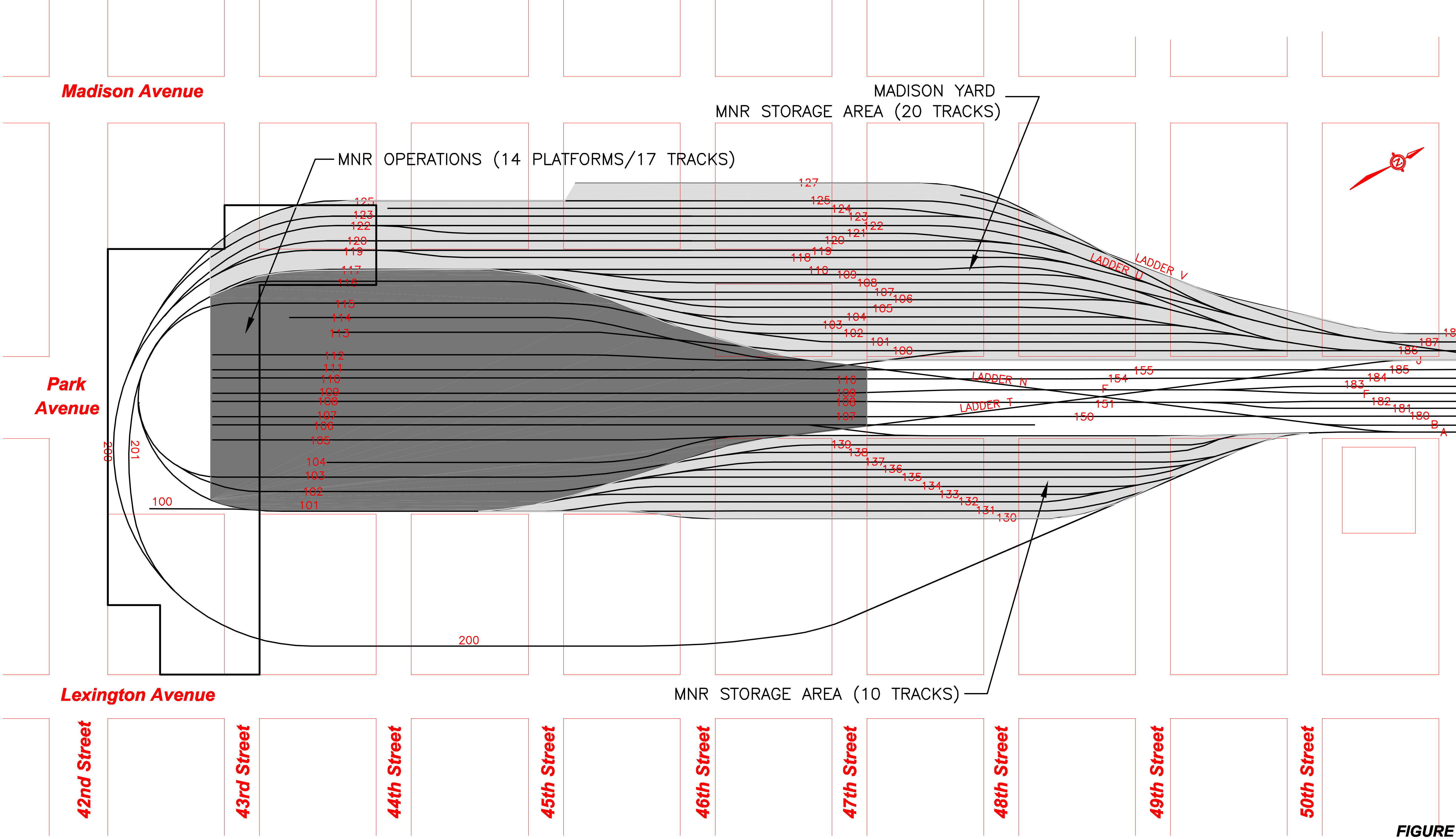



FIGURE 4
UPPER LEVEL LOOP ALTERNATIVE

DELCAN

# GRAND CENTRAL TERMINAL
# EXISTING LOWER LEVEL TRACKS




Legend

—A— Track No.

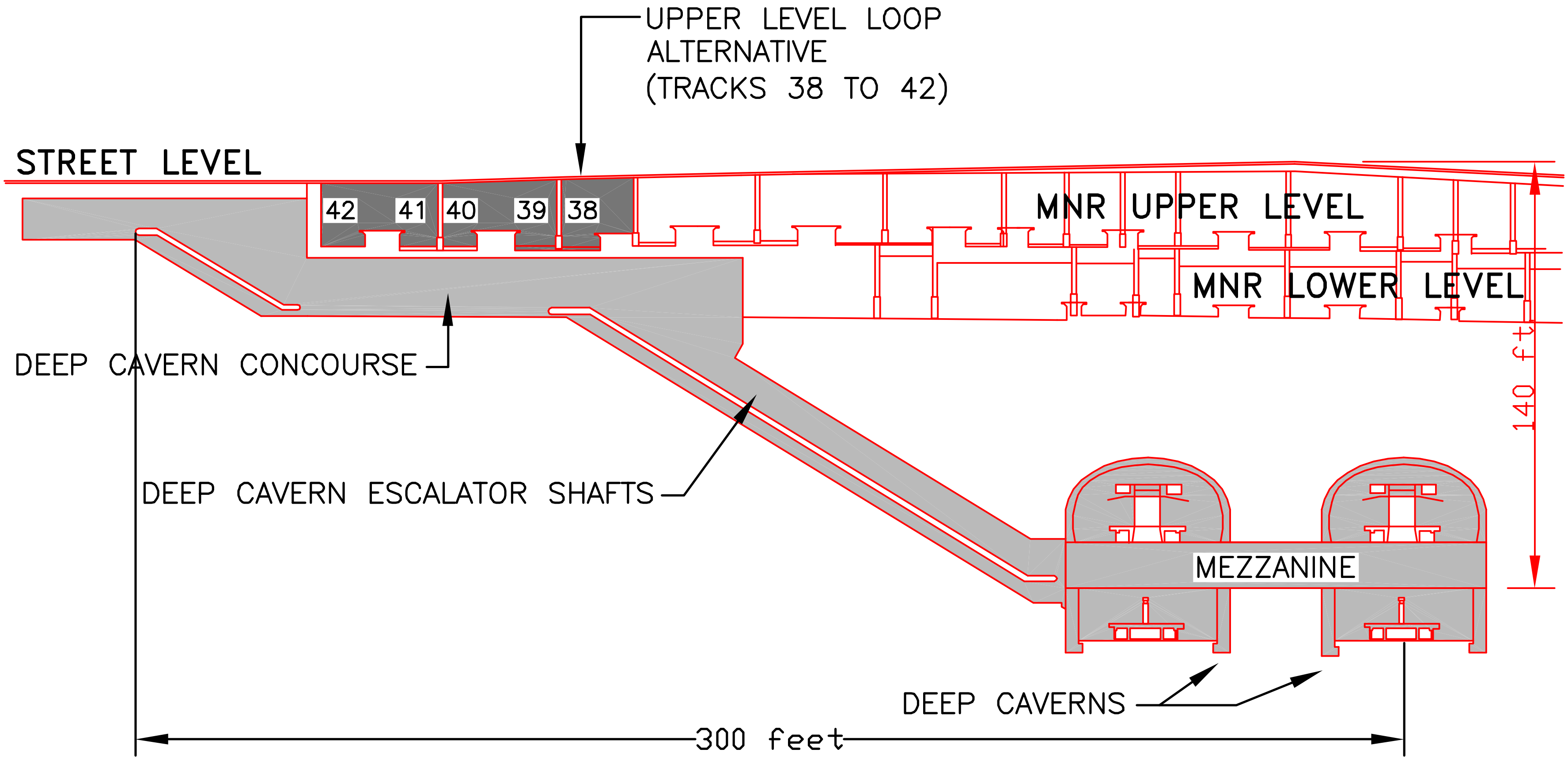
NOT TO SCALE

FIGURE 5

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

## CROSS-SECTIONAL VIEW OF DEEP CAVERN SCHEME AND UPPER LEVEL LOOP ALTERNATIVE




**SECTION LOOKING NORTH**

NOT TO SCALE

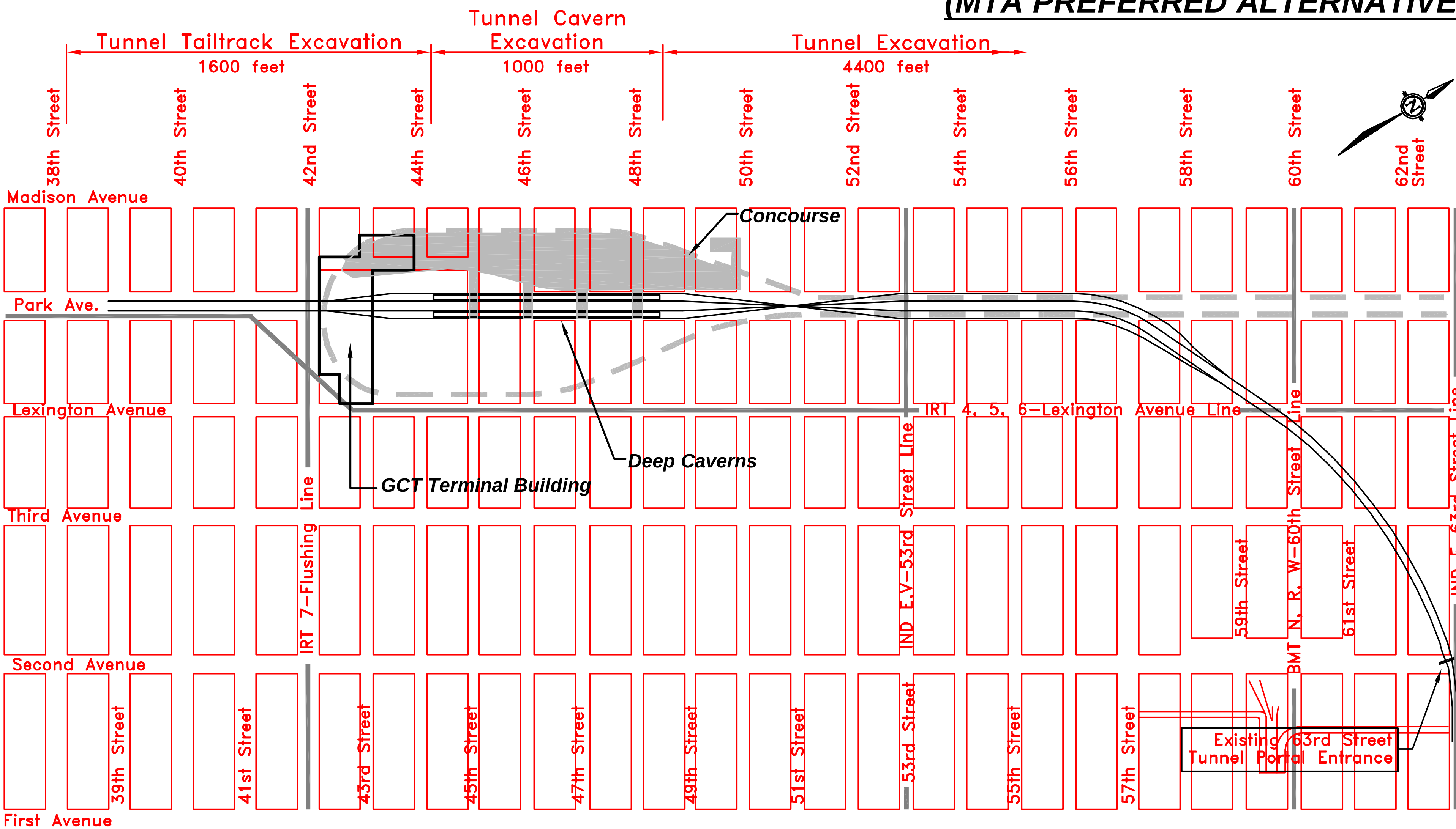
FIGURE 6

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

J:\TOR\CB2273\6B_Deliverables_(Drawings)\Figure7.dwg

# *DEEP CAVERN SCHEME*
# *(MTA PREFERRED ALTERNATIVE)*




NOT TO SCALE

*FIGURE 7*

## *UPPER LEVEL LOOP ALTERNATIVE*

DELCAN

J:\TOR\CB2273\6B_Deliverables_(Drawings)\Figure8.dwg

## LAYOUT OF UPPER LEVEL LOOP ALTERNATIVE

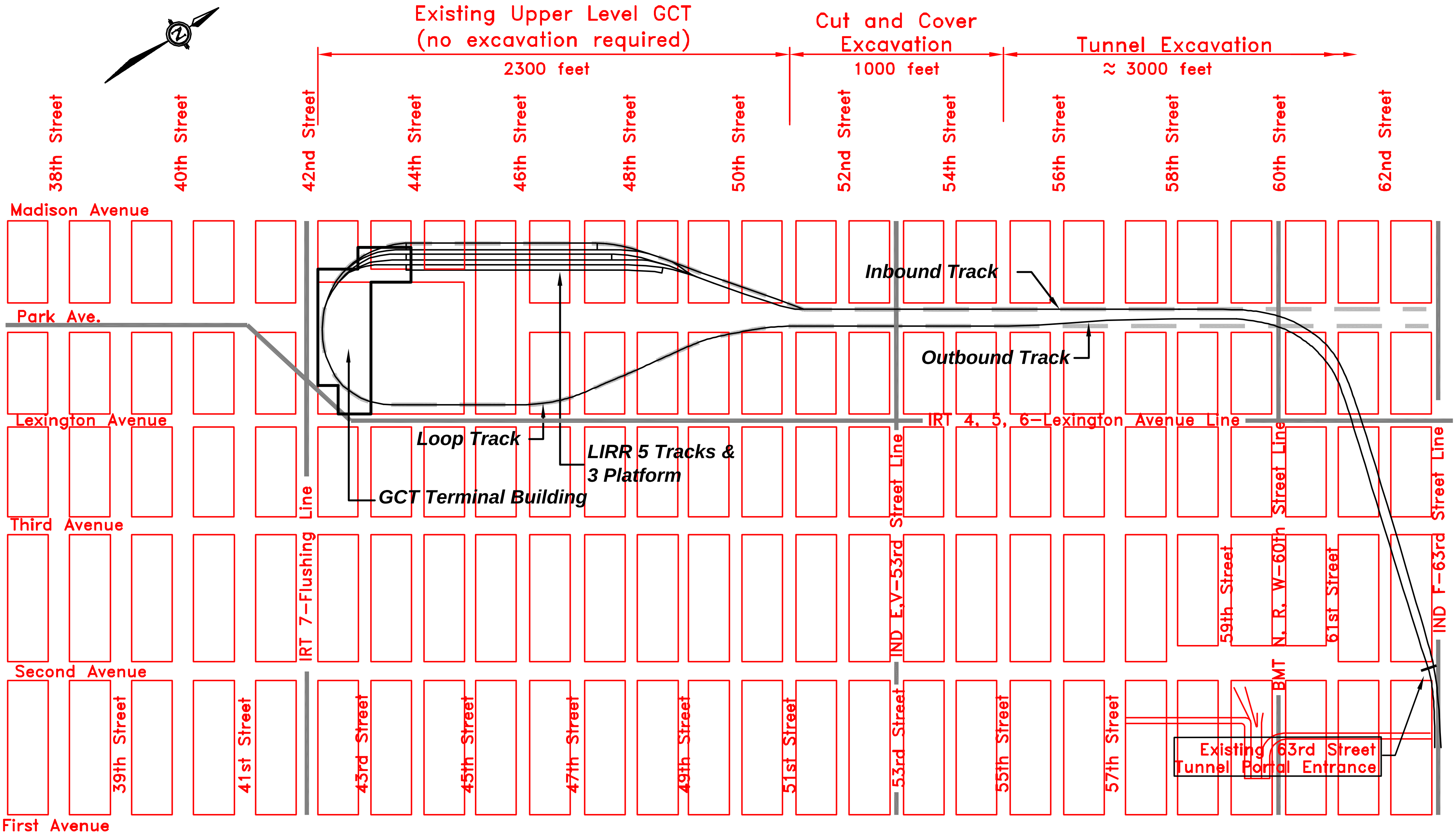


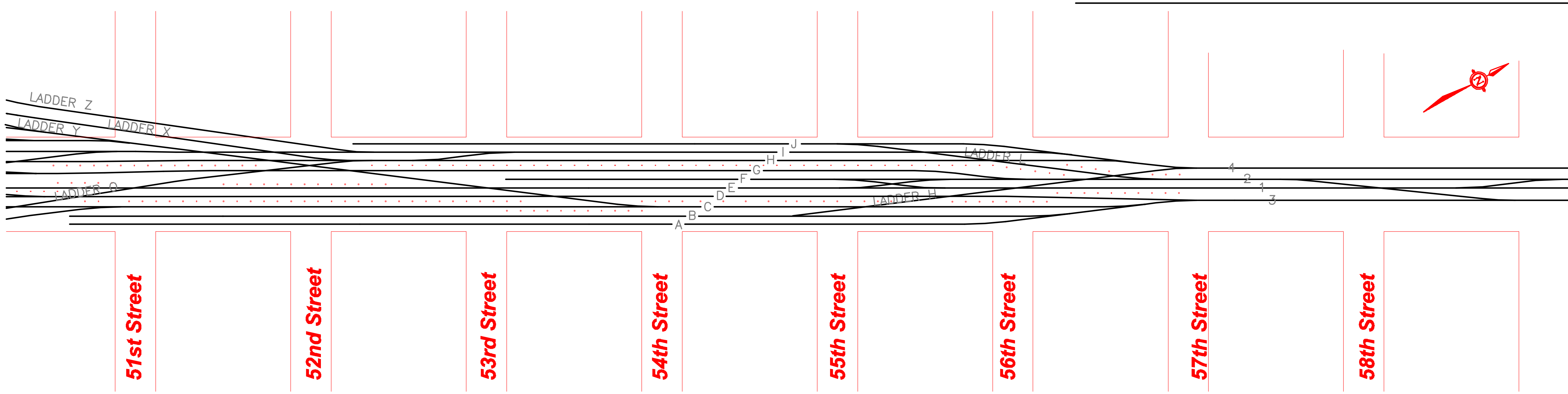

FIGURE 8

## UPPER LEVEL LOOP ALTERNATIVE

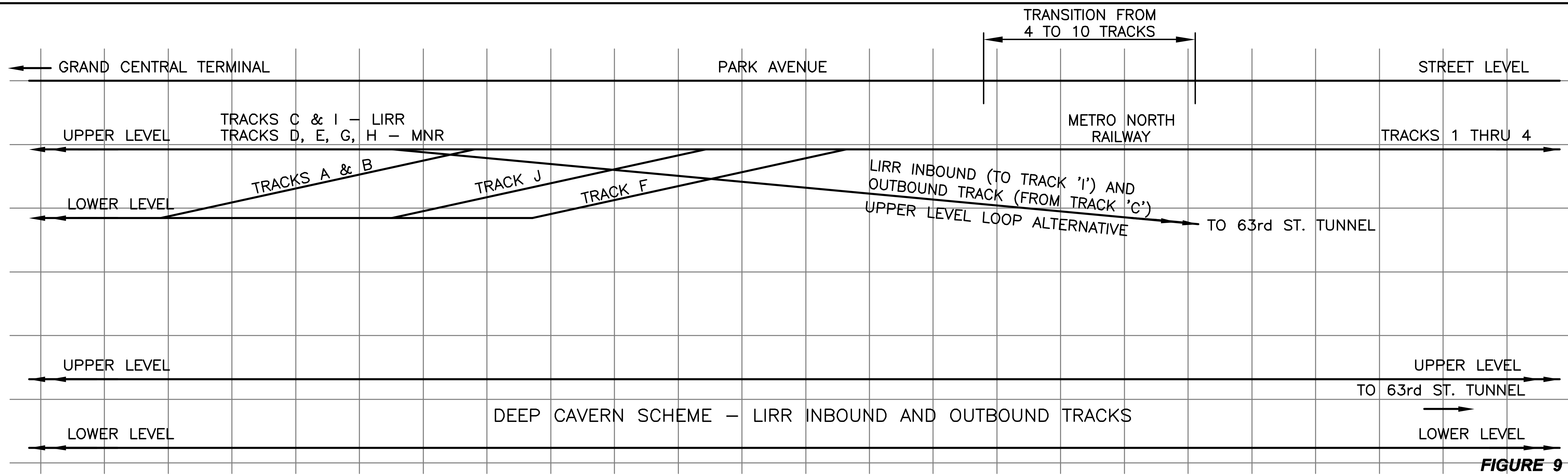
NOT TO SCALE

DELCAN

## UPPER LEVEL LOOP ALTERNATIVE AND MTA DEEP CAVERN SCHEME ENTRANCE TO GRAND CENTRAL TERMINAL




**PLAN**




**PROFILE**

Legend
—A— Track No.

NOT TO SCALE

**FIGURE 9**

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

## PROPOSED OPEN CUT AND TUNNEL CROSS-SECTIONS

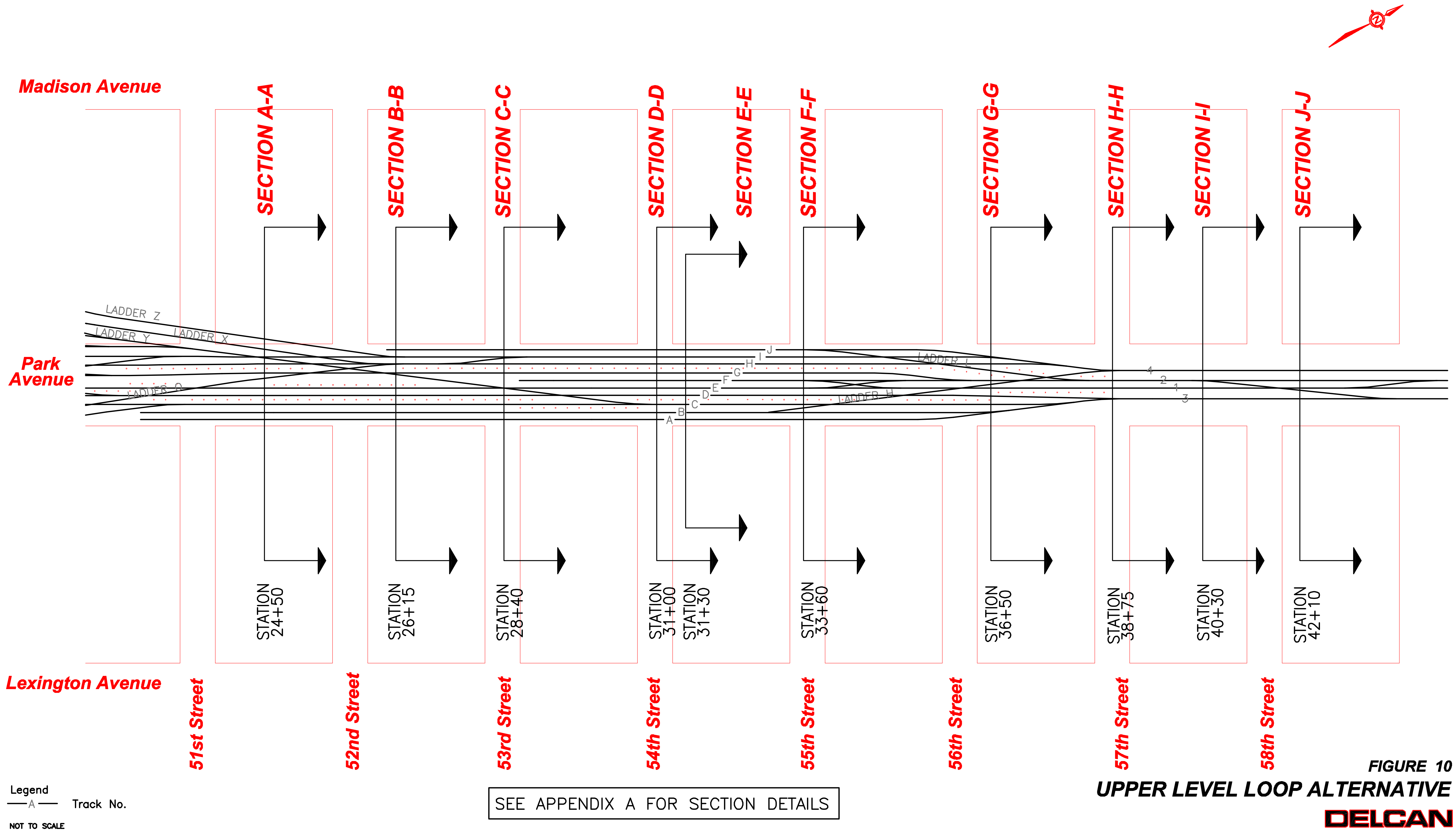



FIGURE 10

UPPER LEVEL LOOP ALTERNATIVE

DELCAN

## *PROPOSED SCHEDULE*

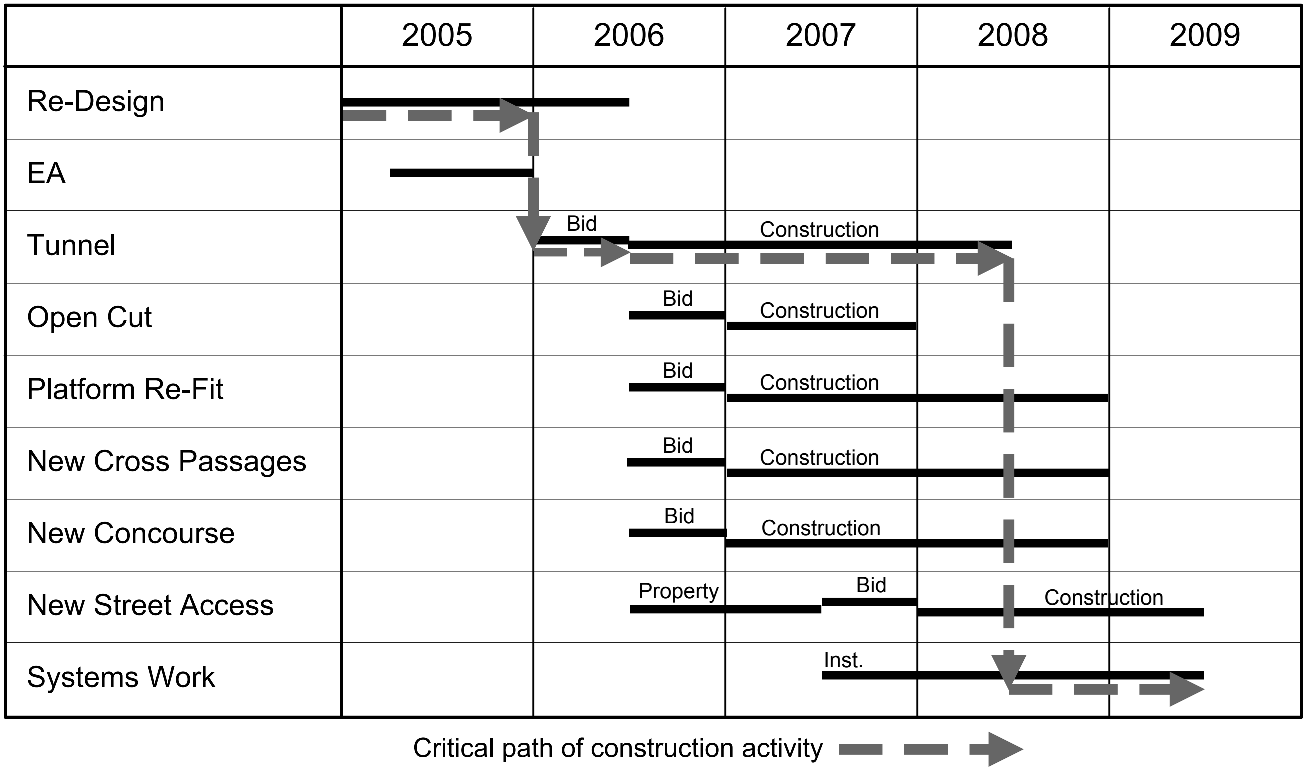



***FIGURE 11***

## *UPPER LEVEL LOOP ALTERNATIVE*

**DELCAN**

## Upper Level Loop Analysis

**Platform Utilitzation at 18 trains per hour (3 trains every 10 minutes)**

**(Full chart prints as three pages)**

**Times shown in bold represent train arrivals**

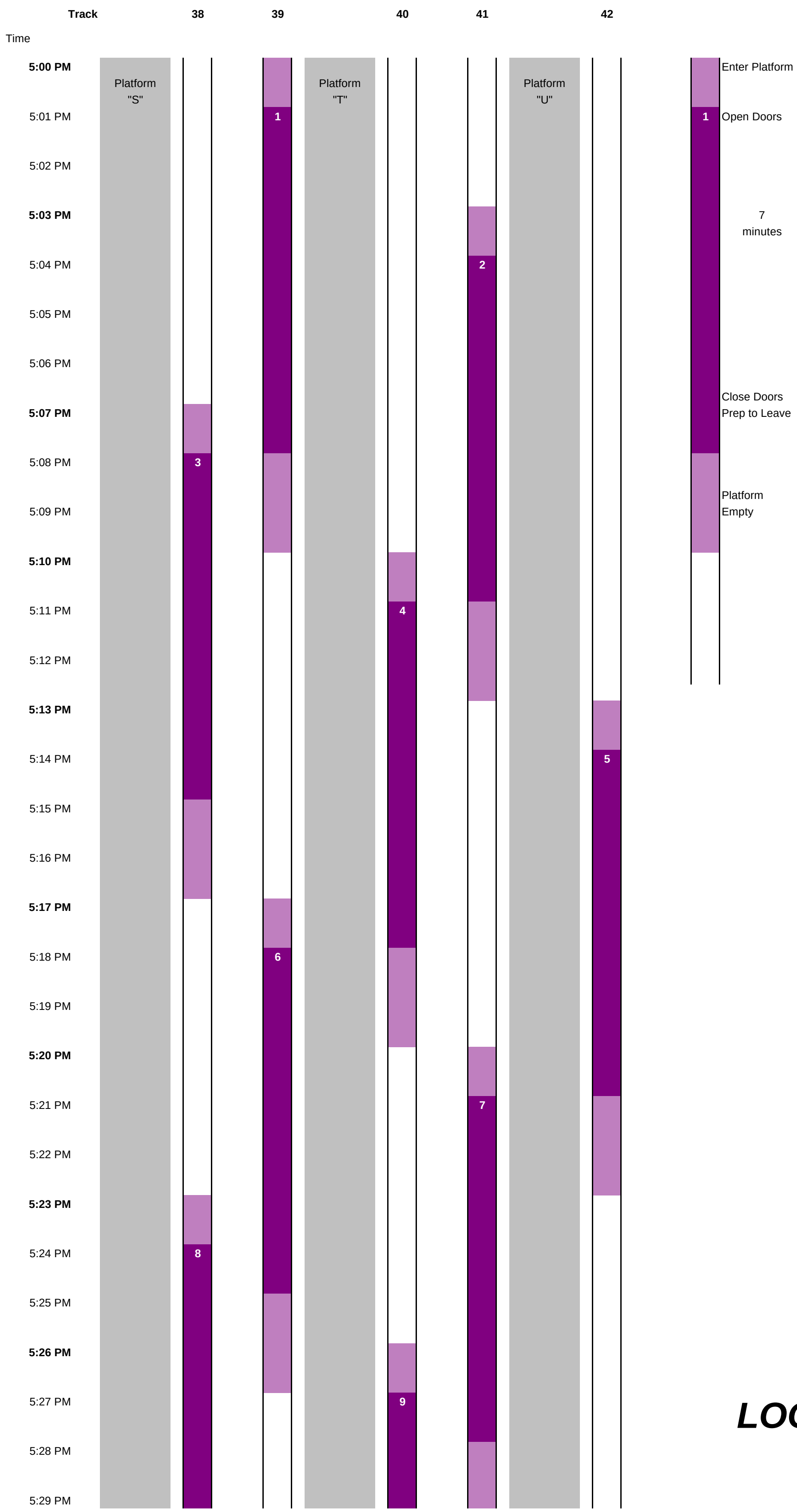



***FIGURE 12***
***UPPER LEVEL LOOP ALTERNATIVE***

DELCAN

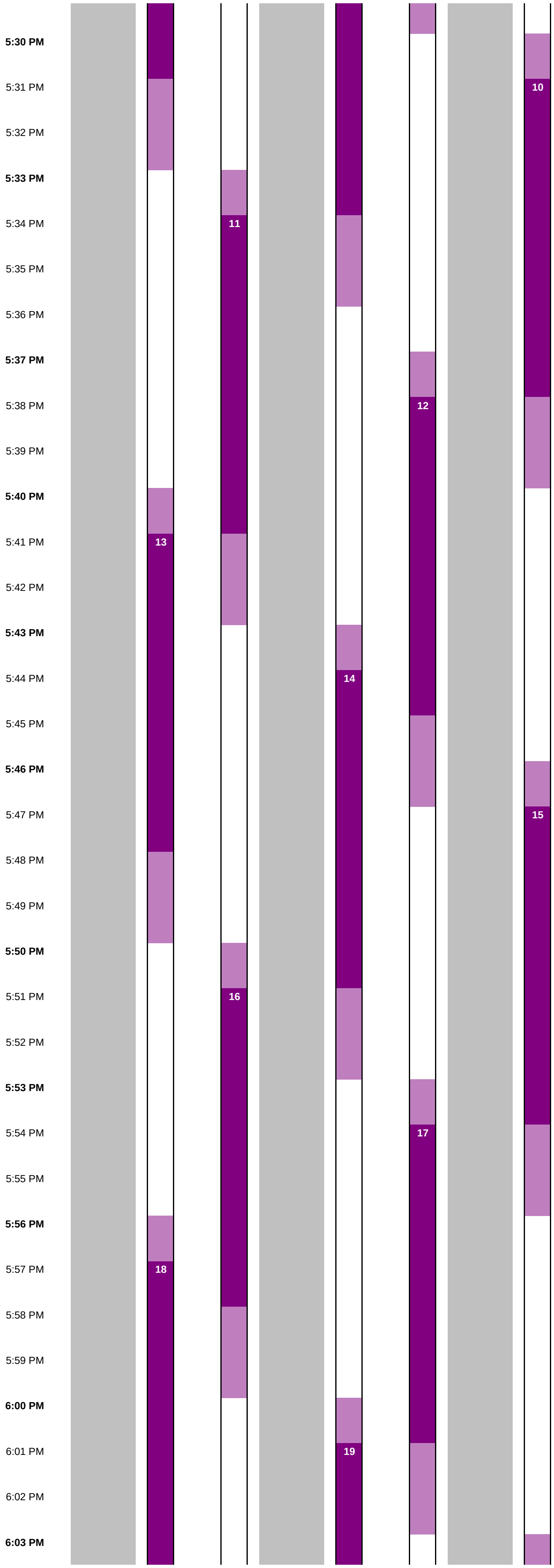



***FIGURE 12***

***UPPER LEVEL***

***LOOP ALTERNATIVE***

DELCAN

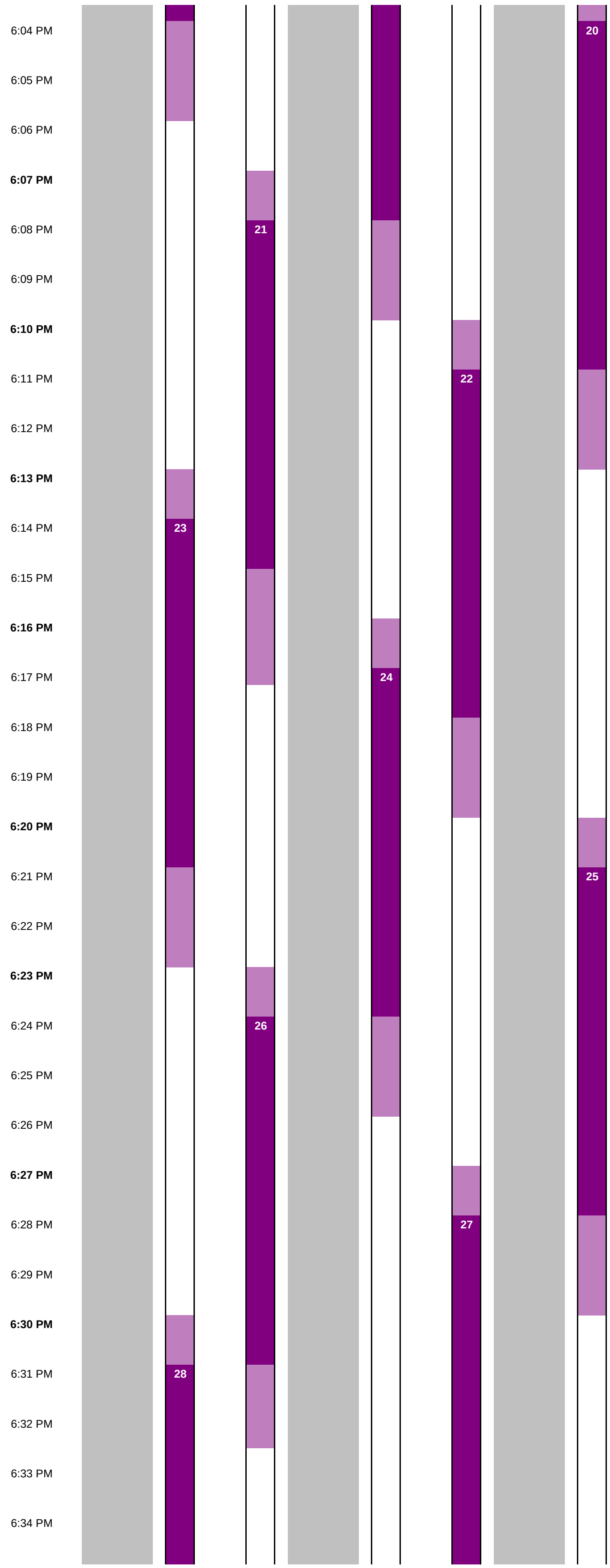



***FIGURE 12***

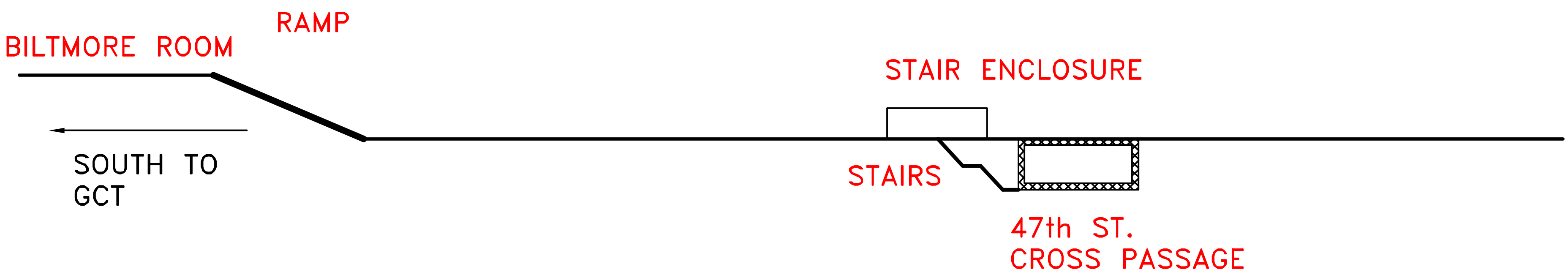
***UPPER LEVEL LOOP ALTERNATIVE***

DELCAN

J:\TOR\CB2273\6B_Deliverables_(Drawings)\Figure13_Passenger Circulation Elements.dwg

## PASSENGER CIRCULATION ELEMENTS

### EXISTING PLATFORM CONFIGURATION




### FUTURE PLATFORM CONFIGURATION

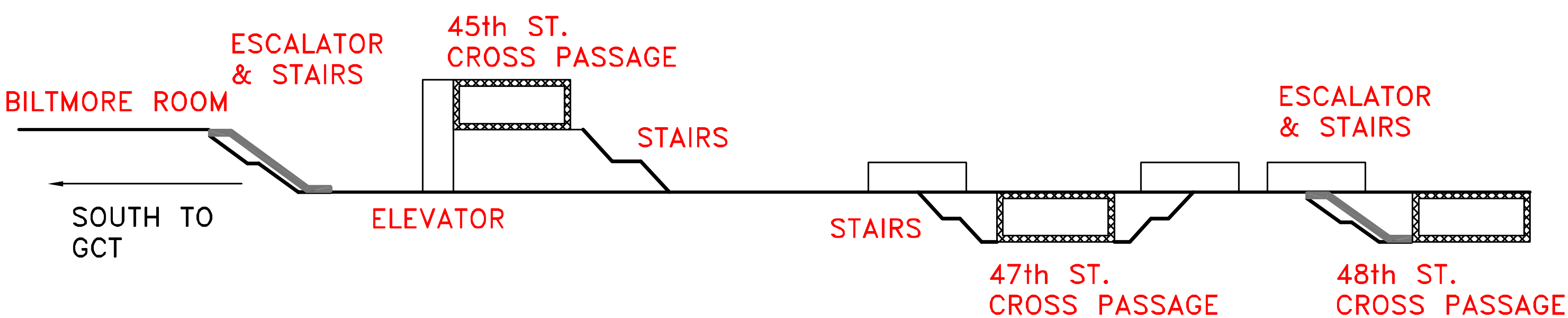



FIGURE 13

UPPER LEVEL LOOP ALTERNATIVE

DELCAN

NOT TO SCALE

# POTENTIAL DOUBLE STAIR ARRANGEMENT

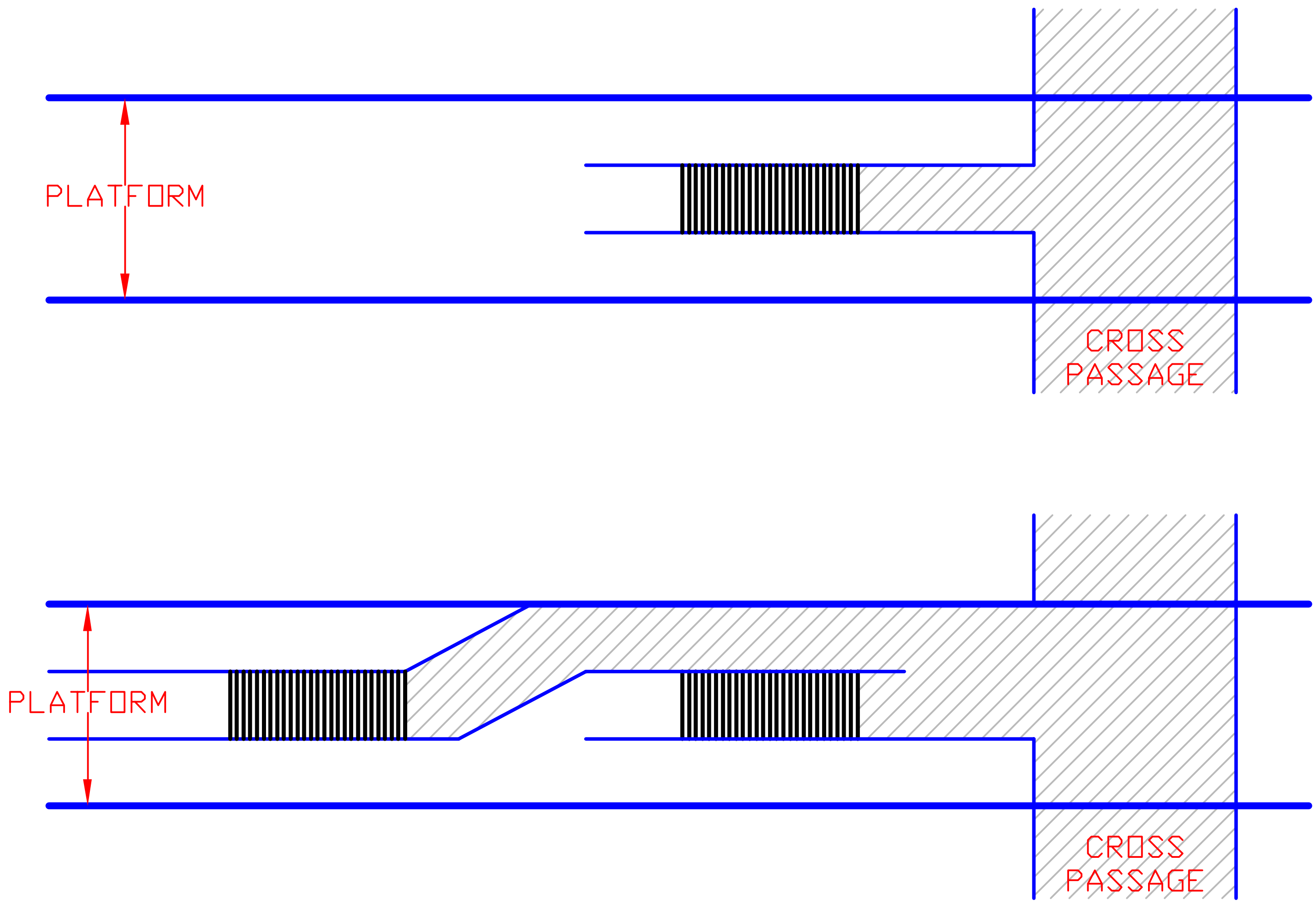



FIGURE 14

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN

NOT TO SCALE

# Appendix A

## Figures 10-A.1 to 10-L.2

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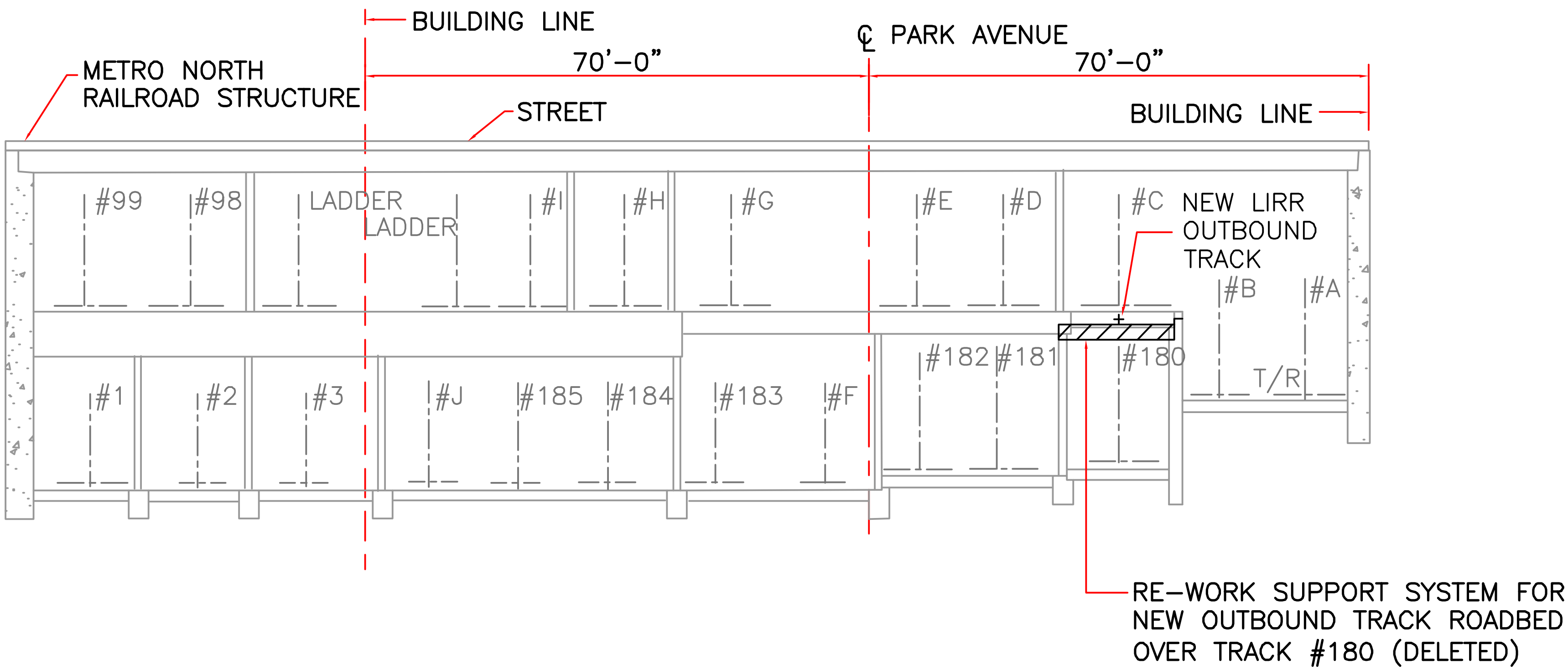


## SECTION A-A

## SECTION BETWEEN 52nd 51st STREET

NOT TO SCALE

FIGURE 10-A.1

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN

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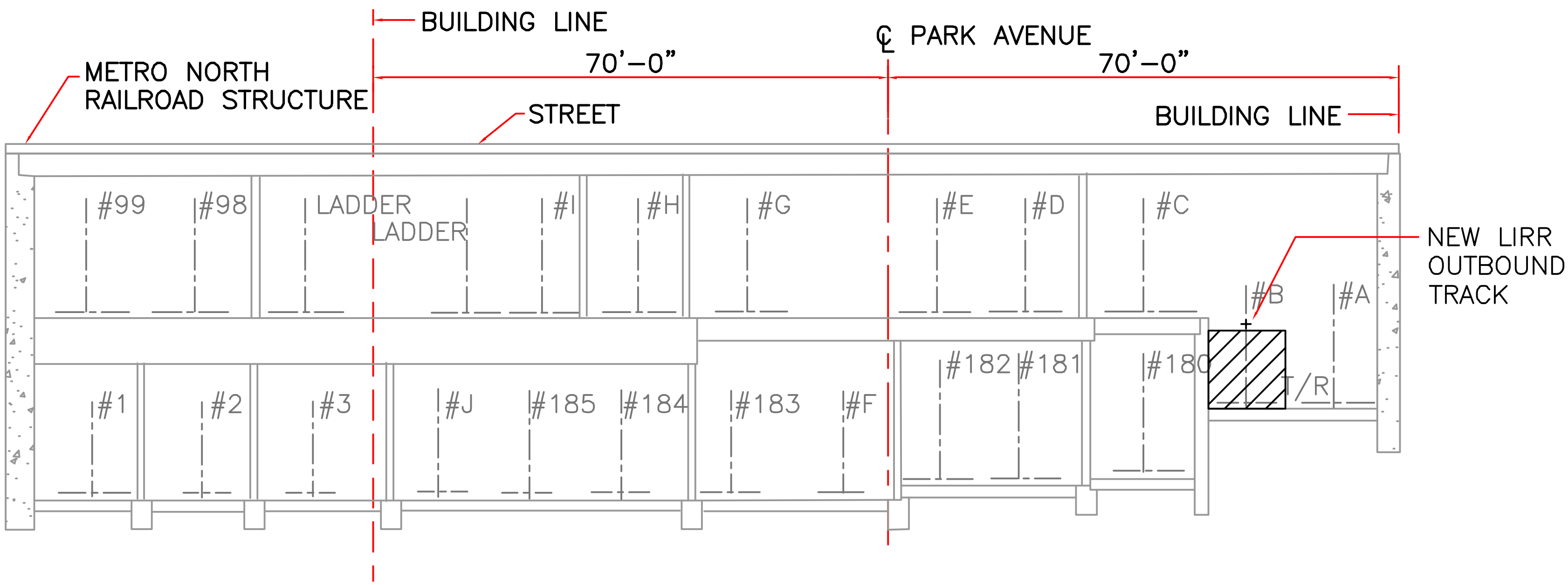



## SECTION A-A

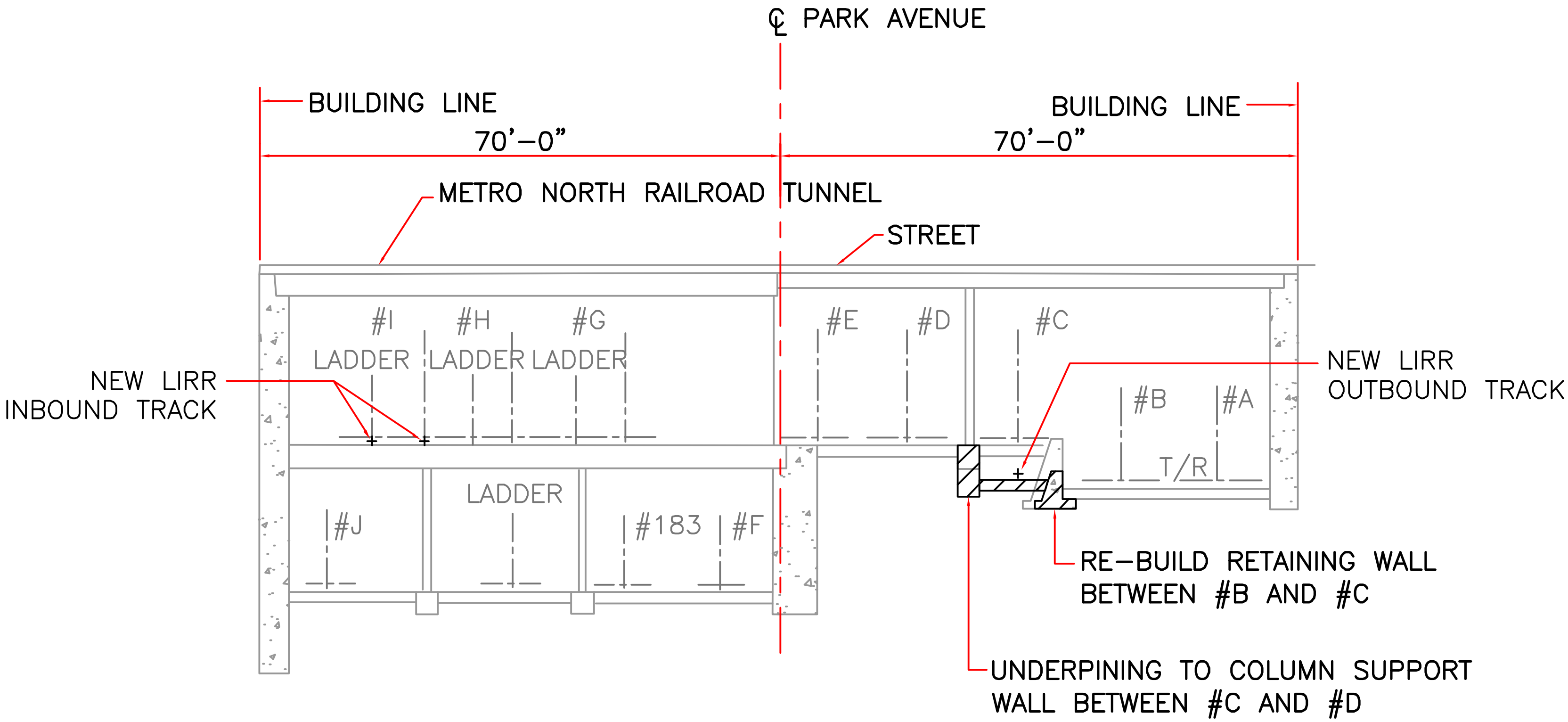
## SECTION BETWEEN 52nd 51st STREET
## TRACK 'B' OPTION

NOT TO SCALE

*FIGURE 10-A.2*

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN




## SECTION B-B

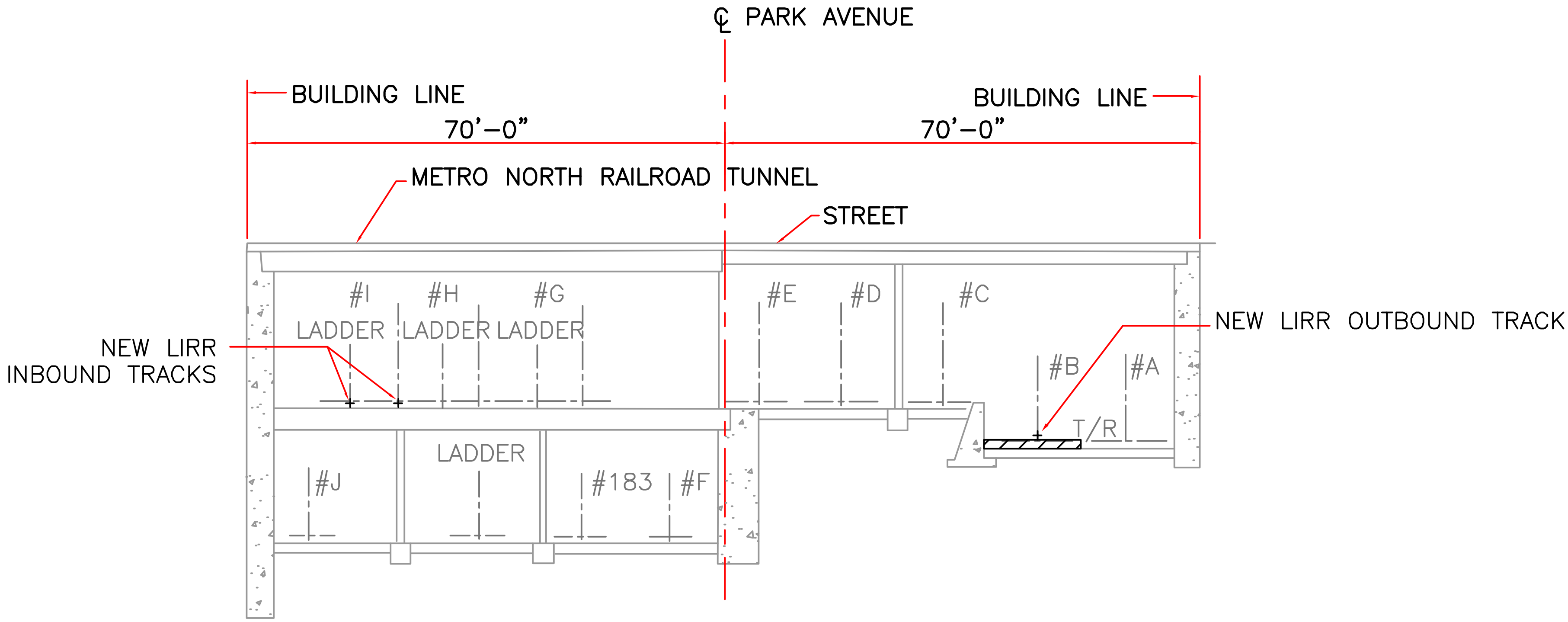
## SECTION NORTH OF 52nd STREET

NOT TO SCALE

FIGURE 10-B.1

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION B-B

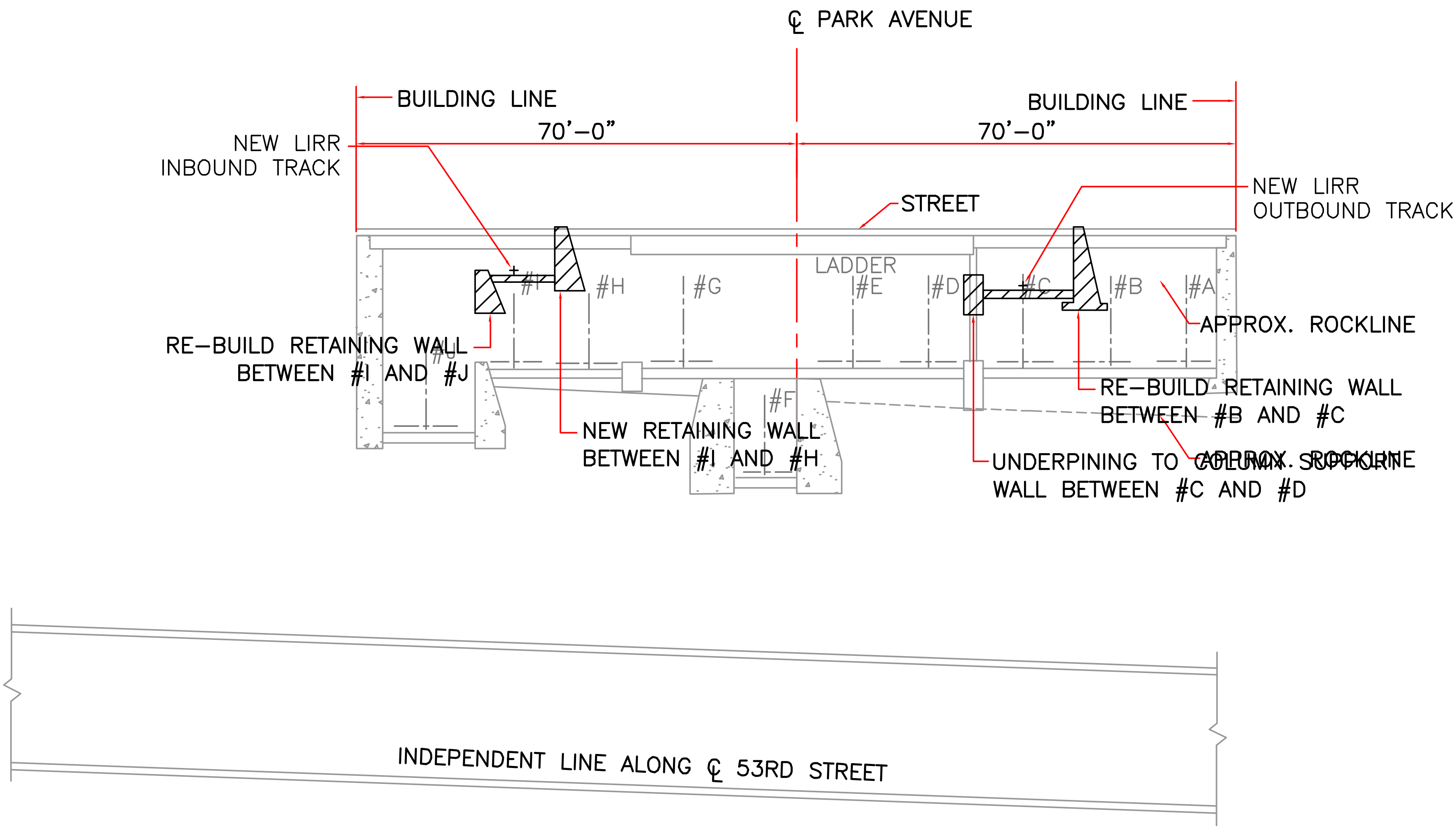
## SECTION NORTH OF 52nd STREET
## TRACK 'B' OPTION

NOT TO SCALE

FIGURE 10-B.2

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION C-C

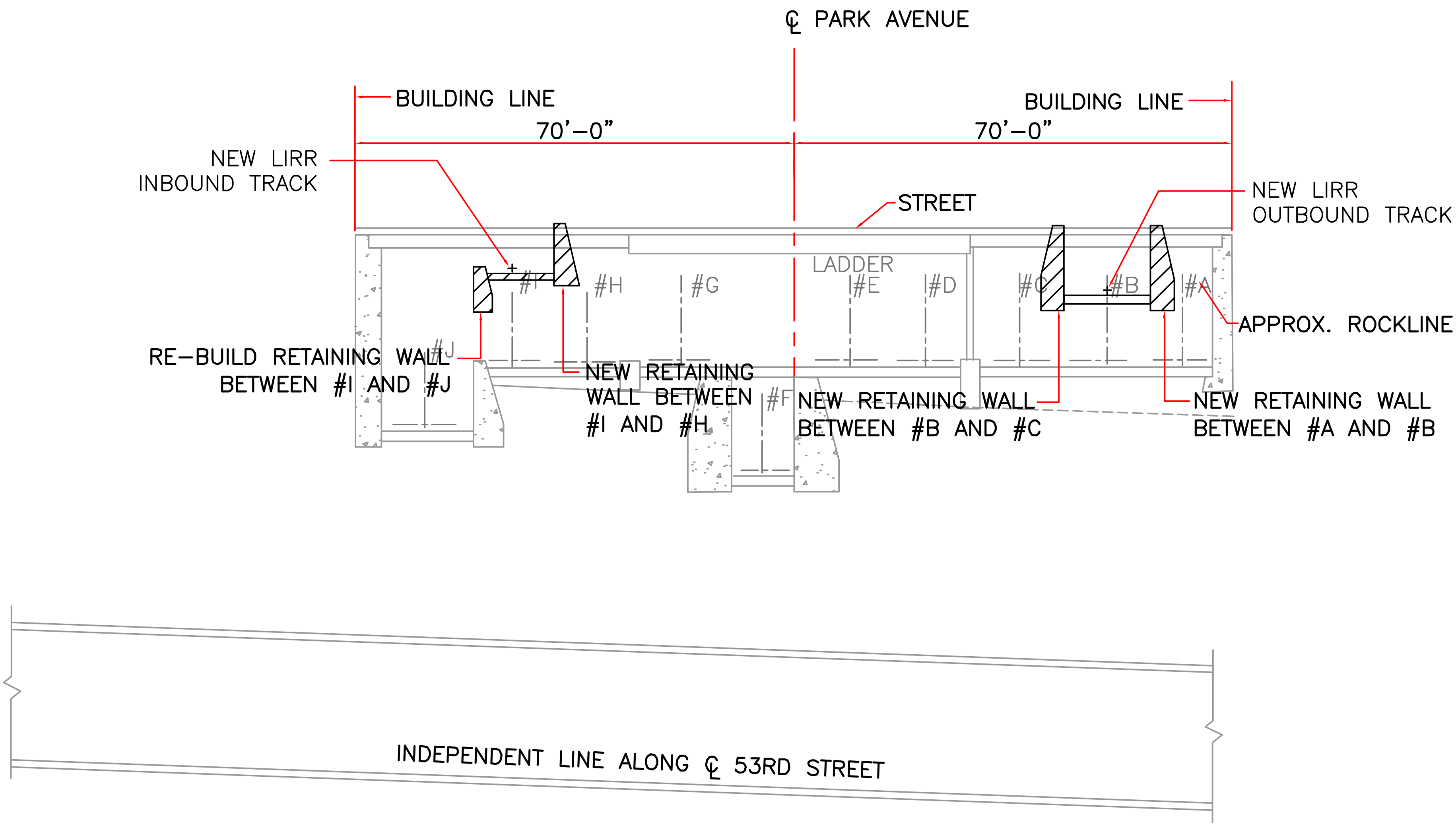
## SECTION AT 53rd STREET

NOT TO SCALE

FIGURE 10-C.1

UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION C-C

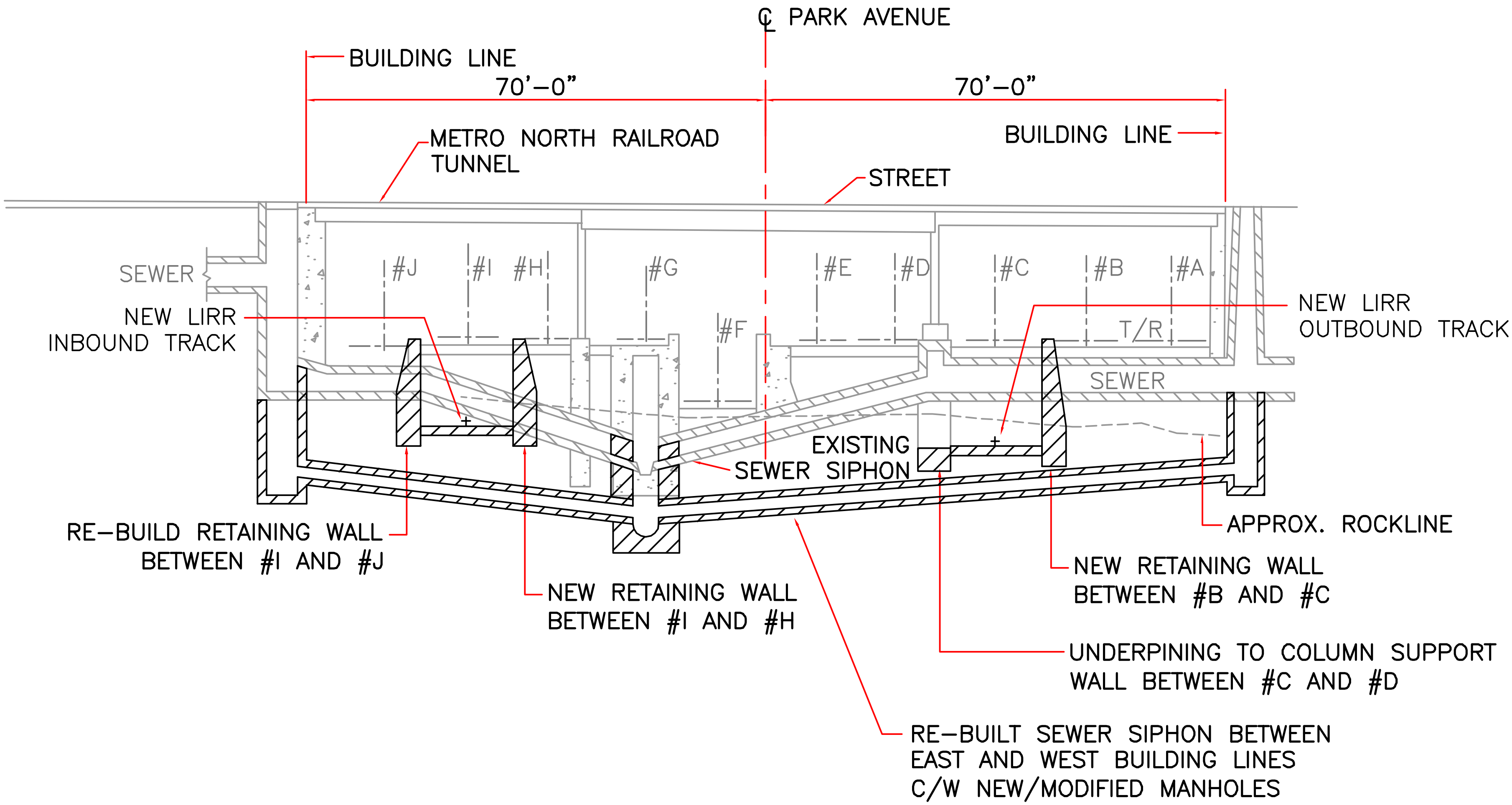
## SECTION AT 53rd STREET
## TRACK 'B' OPTION

NOT TO SCALE

**FIGURE 10-C.2**

**UPPER LEVEL LOOP ALTERNATIVE**

**DELCAN**




## SECTION D-D

## SECTION AT ℄ OF 54th STREET

NOT TO SCALE

**FIGURE 10-D.1**

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN

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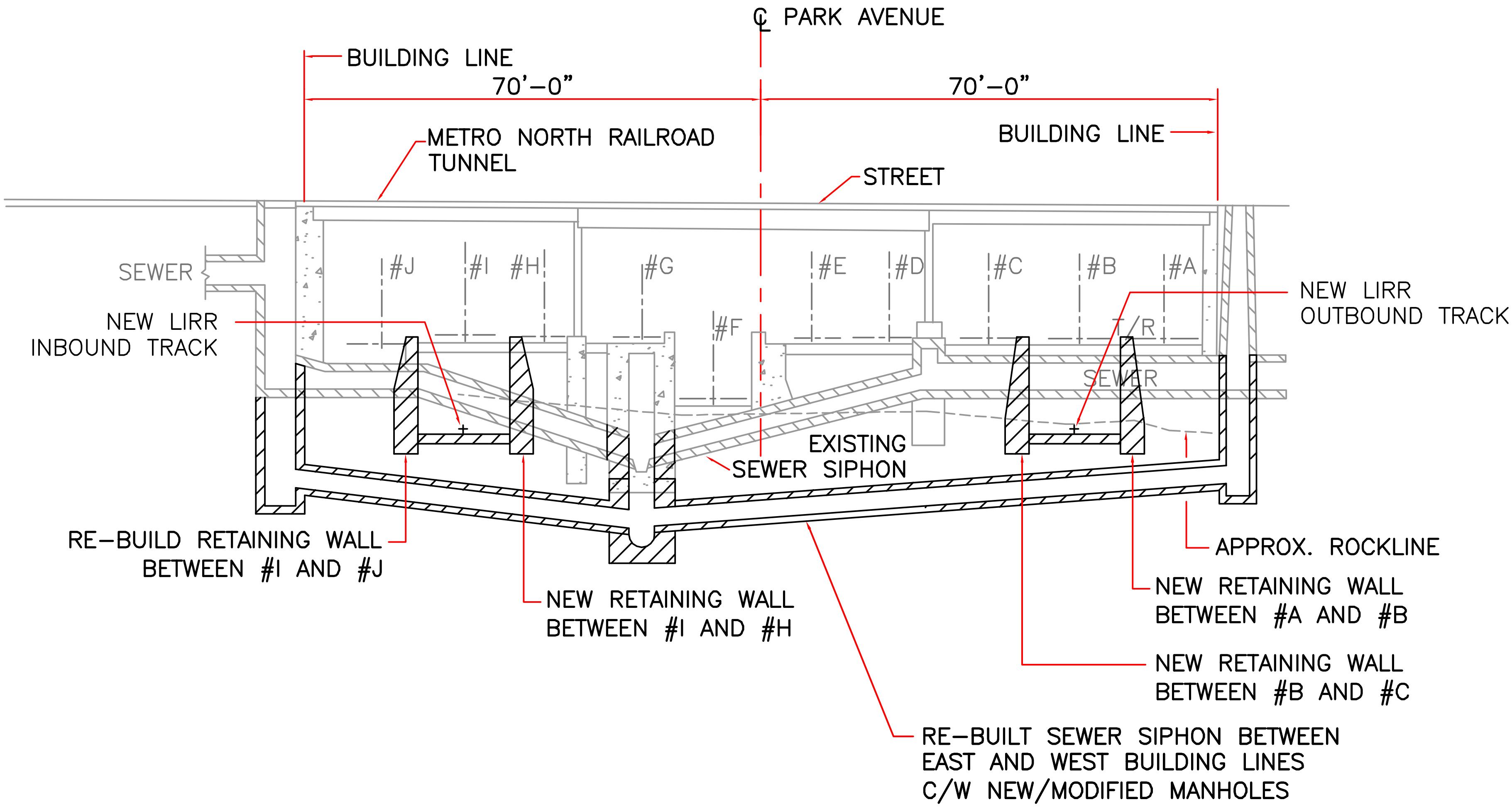



## SECTION D-D

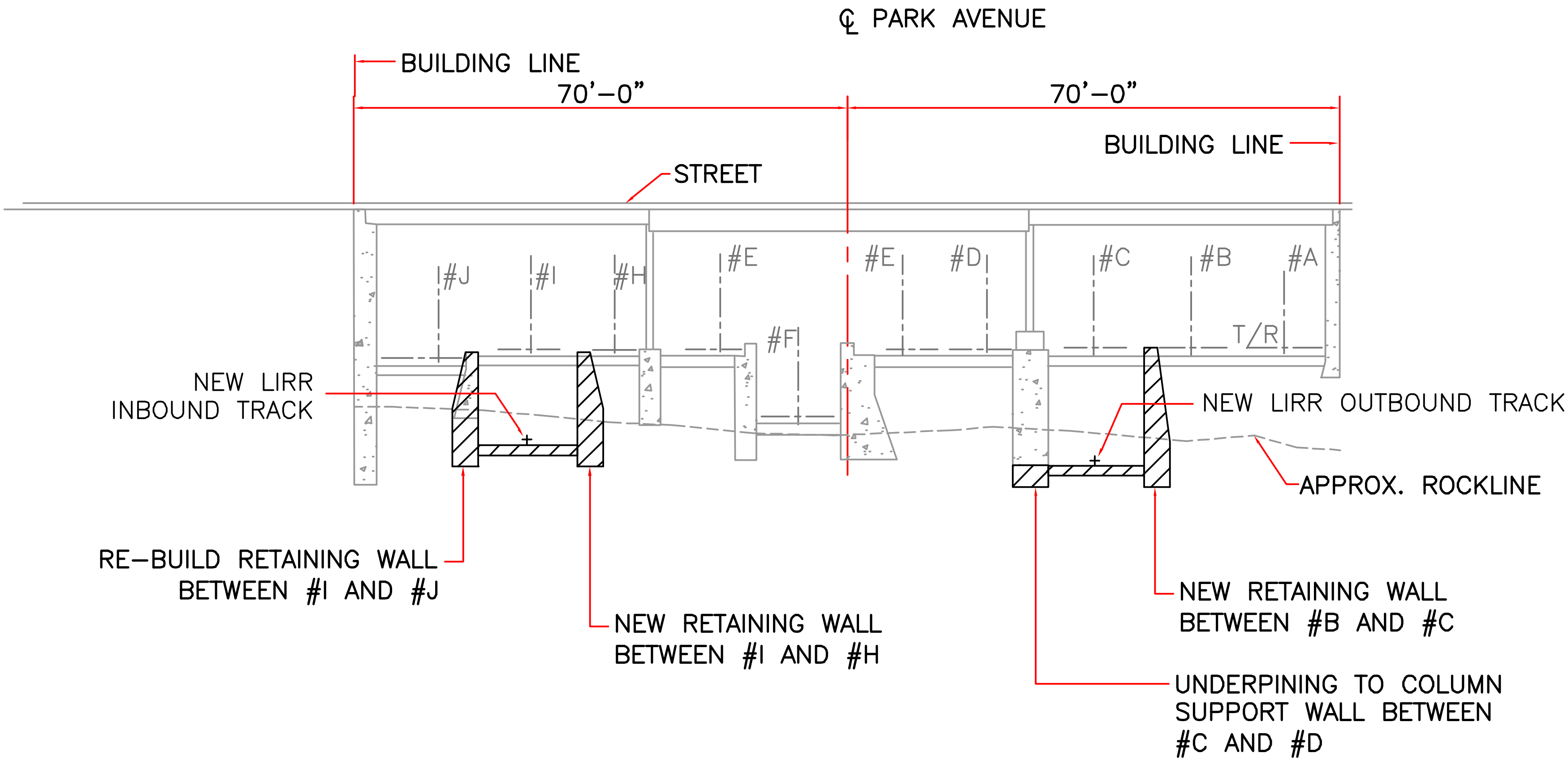
## SECTION AT ℄ OF 54th STREET
## TRACK 'B' OPTION

NOT TO SCALE

**FIGURE 10-D.2**

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN




**SECTION E-E**

**SECTION AT 54th STREET**

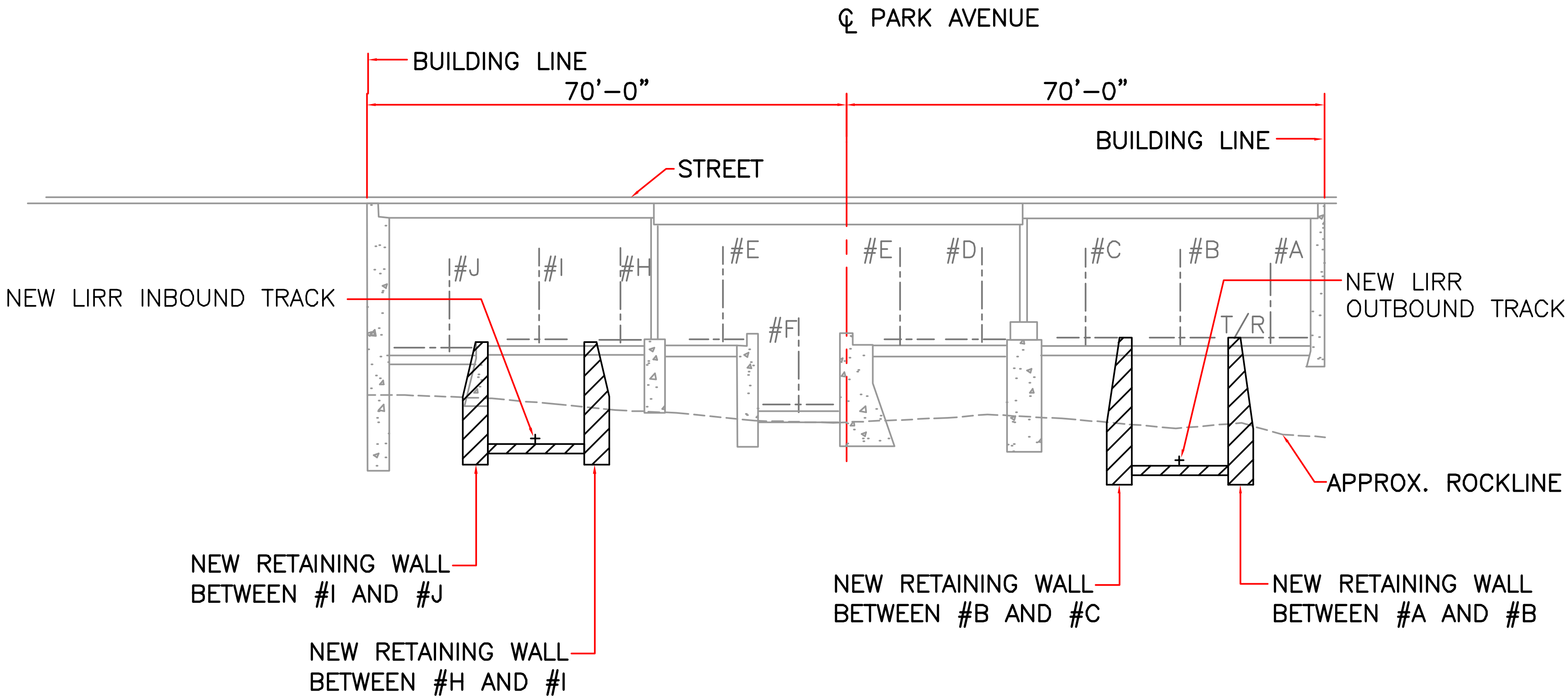
NOT TO SCALE

**FIGURE 10-E.1**

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

J:\TOR\CB2273\6B_Deliverables_(Drawings)\Track-B-Option.dwg




## SECTION E-E

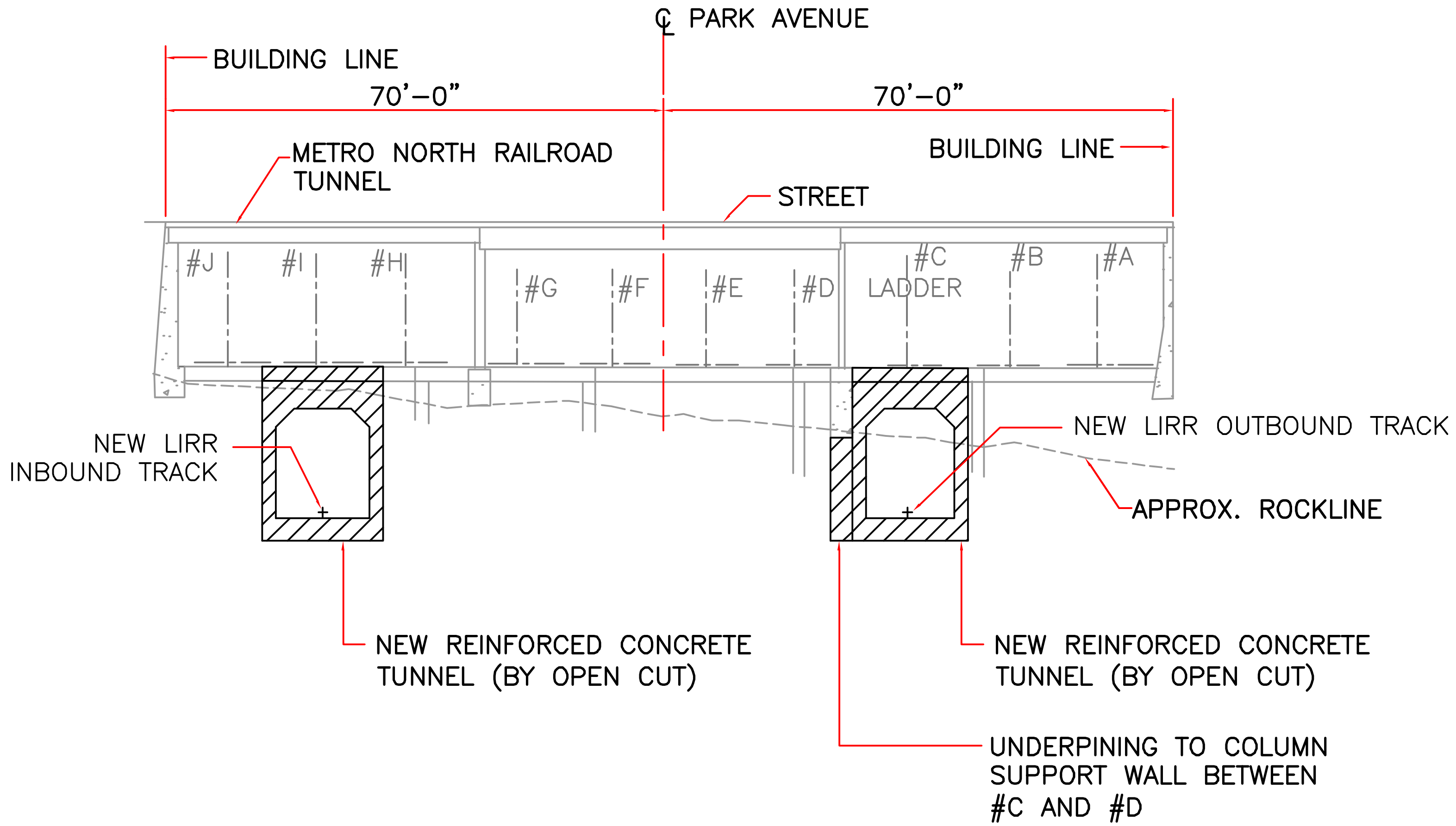
## SECTION AT 54th STREET
## TRACK 'B' OPTION

NOT TO SCALE

FIGURE 10-E.2

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN

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***SECTION F-F***

***SECTION AT 55th STREET***

NOT TO SCALE

***FIGURE 10-F.1***

***UPPER LEVEL LOOP ALTERNATIVE***

DELCAN

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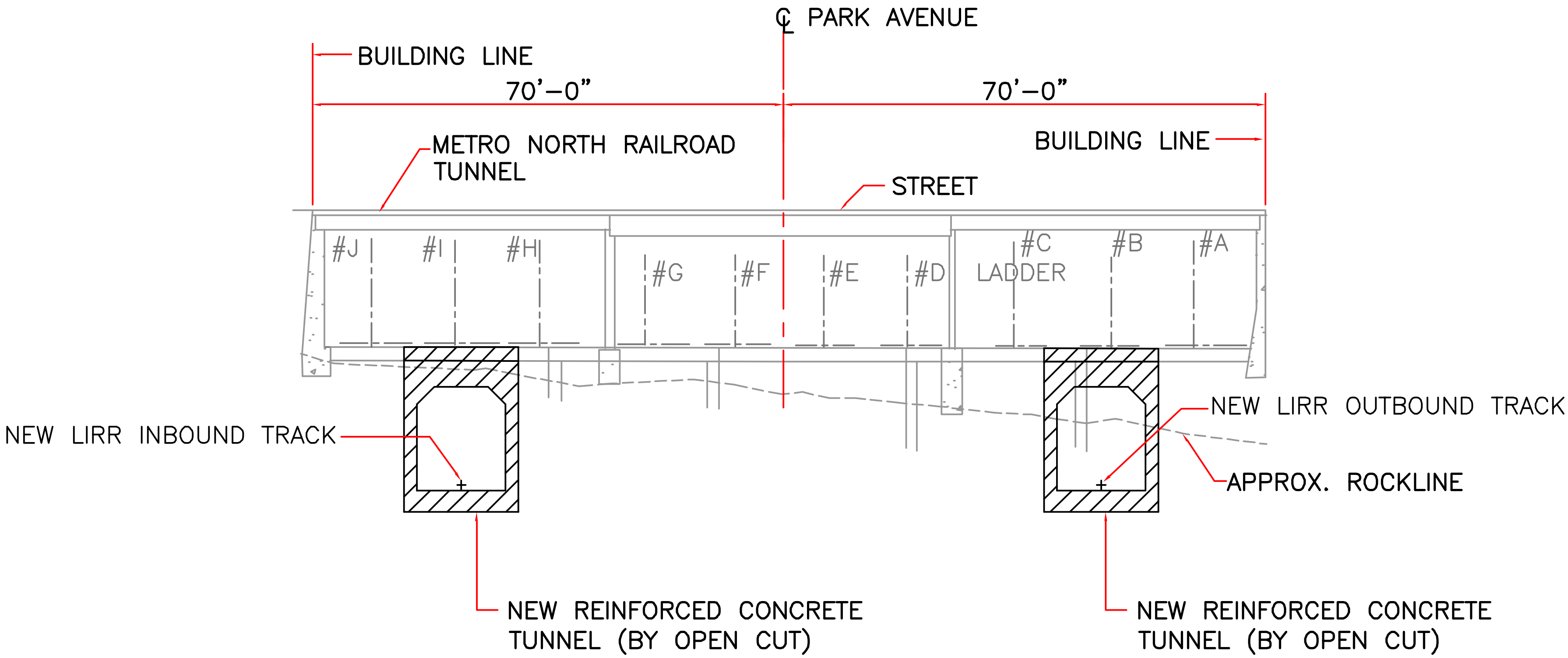



## SECTION F-F

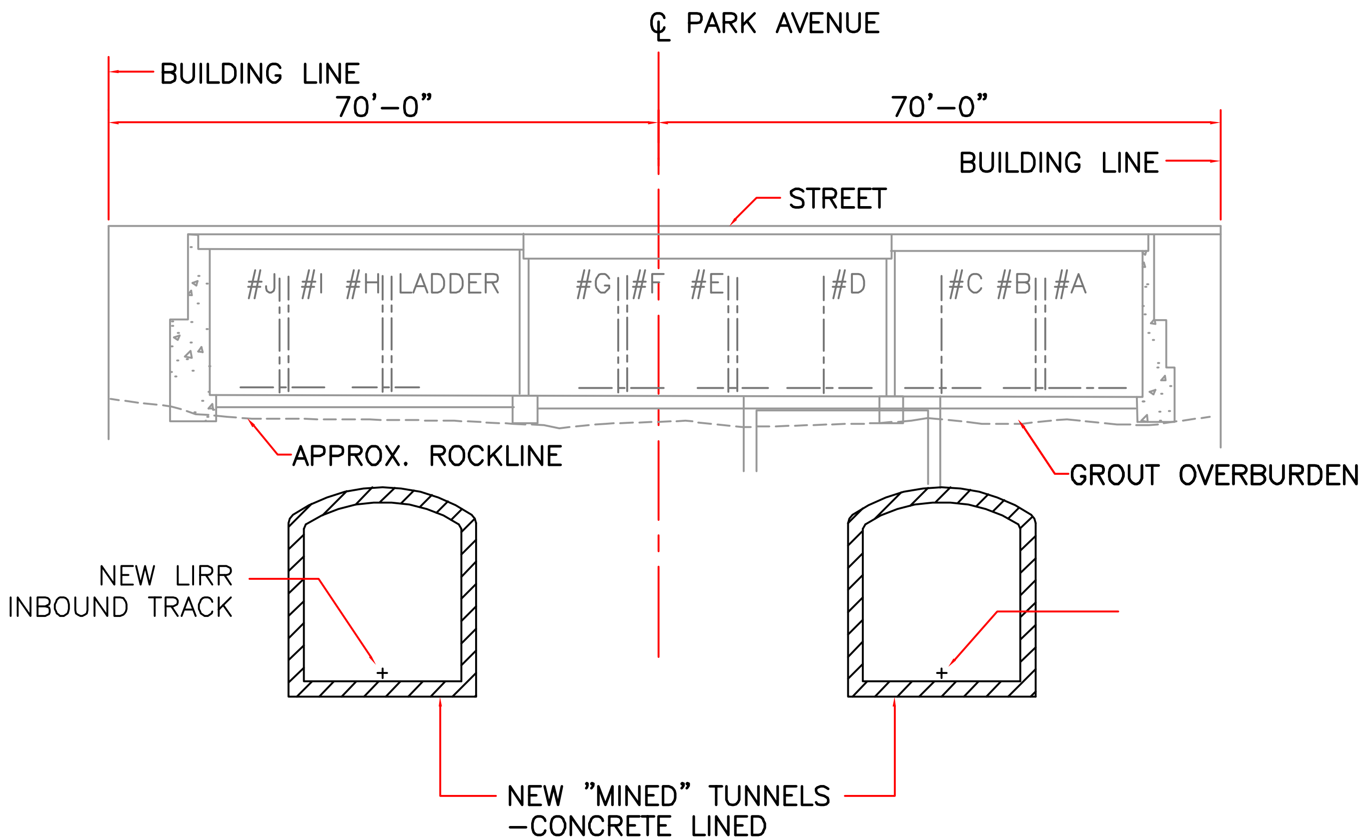
## SECTION AT 55th STREET
## TRACK 'B' OPTION

NOT TO SCALE

**FIGURE 10-F.2**

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN




## SECTION G-G

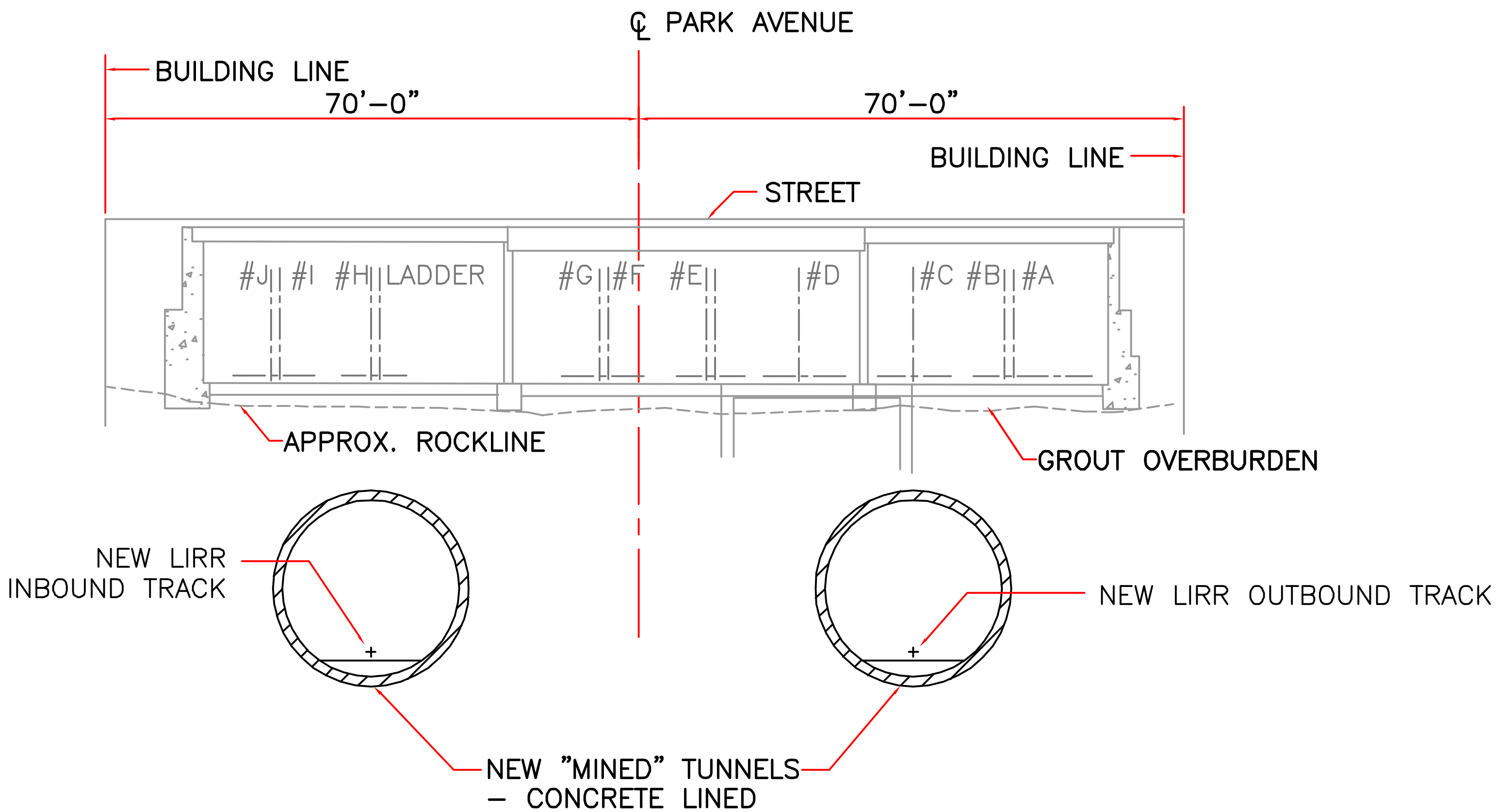
## SECTION AT 56th STREET
## DRILL AND BLAST OPTION

NOT TO SCALE

FIGURE 10-G.1

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION G-G

**SECTION AT 56th STREET**
**TBM TUNNEL OPTION**

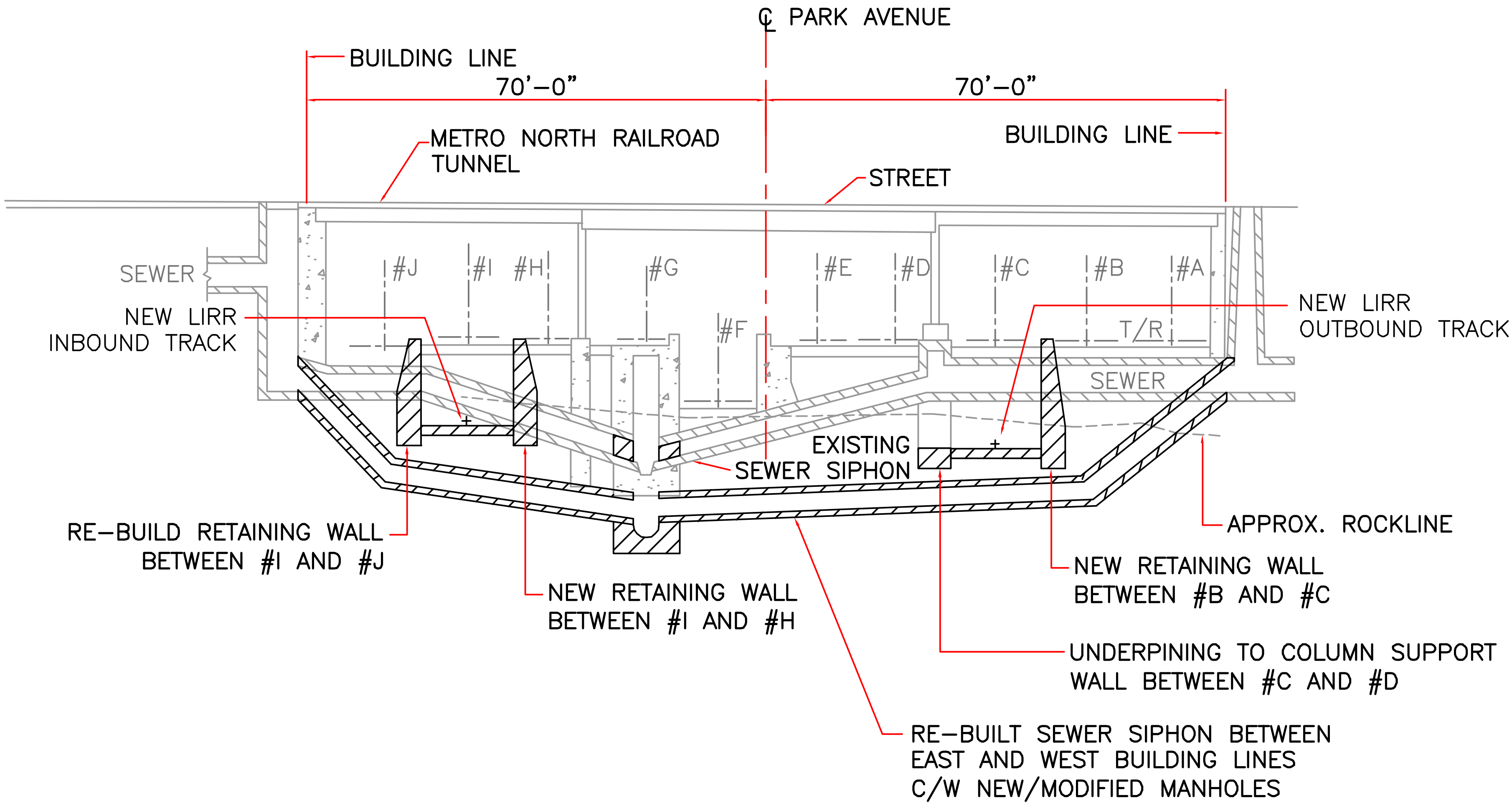
NOT TO SCALE

**FIGURE 10-G.2**

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

J:\TOR\CB2273\6B_Deliverables_(Drawings)\Track-C-Option.dwg




## SECTION D-D

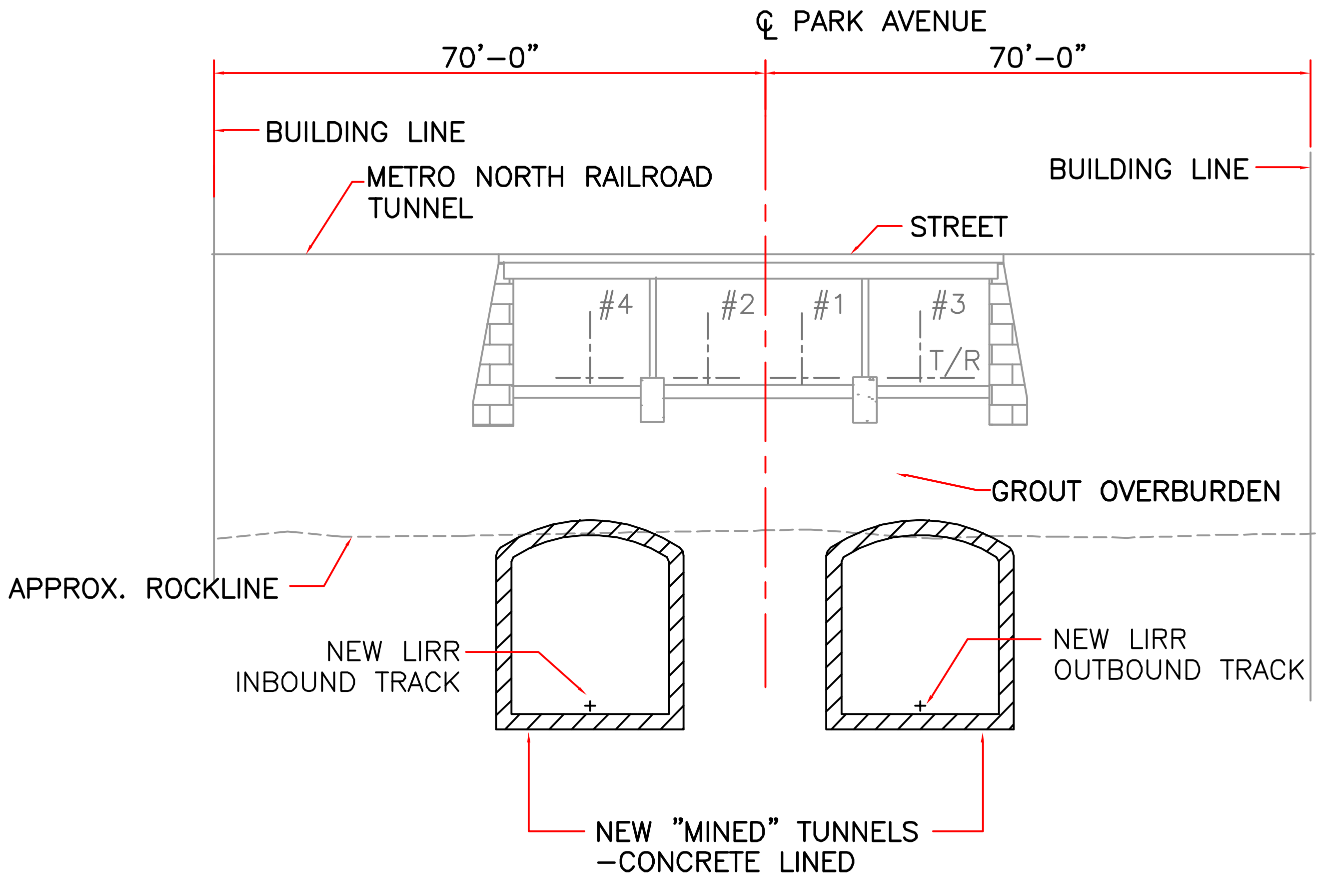
## SECTION AT ℄ OF 54th STREET
## SEWER ALTERNATIVE 'A'

NOT TO SCALE

**FIGURE 10H**

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION H-H

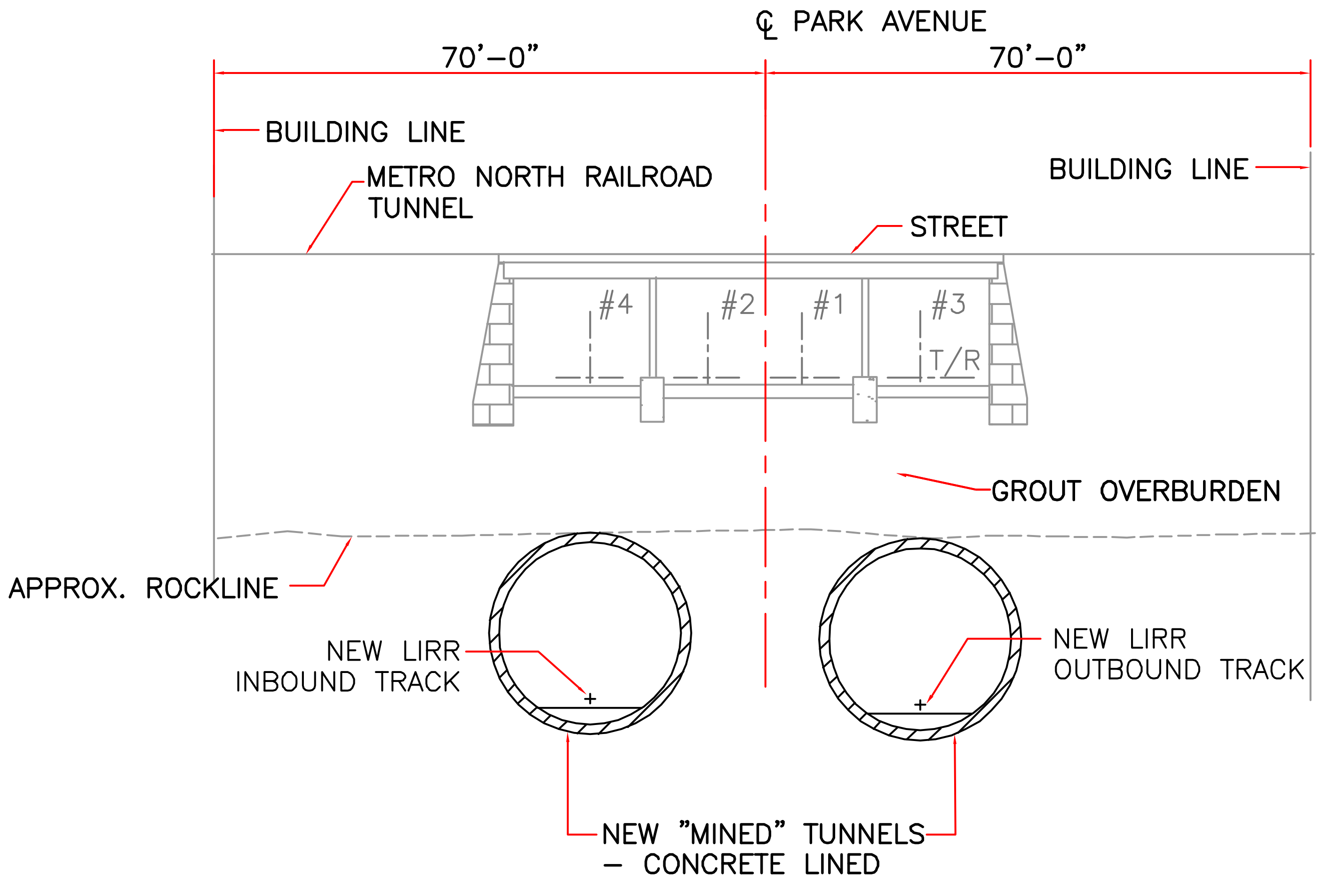
## SECTION AT SOUTH SIDE OF 57th STREET
## DRILL AND BLAST OPTION

NOT TO SCALE

**FIGURE 10-H.1**

**UPPER LEVEL LOOP ALTERNATIVE**

**DELCAN**




## SECTION H-H

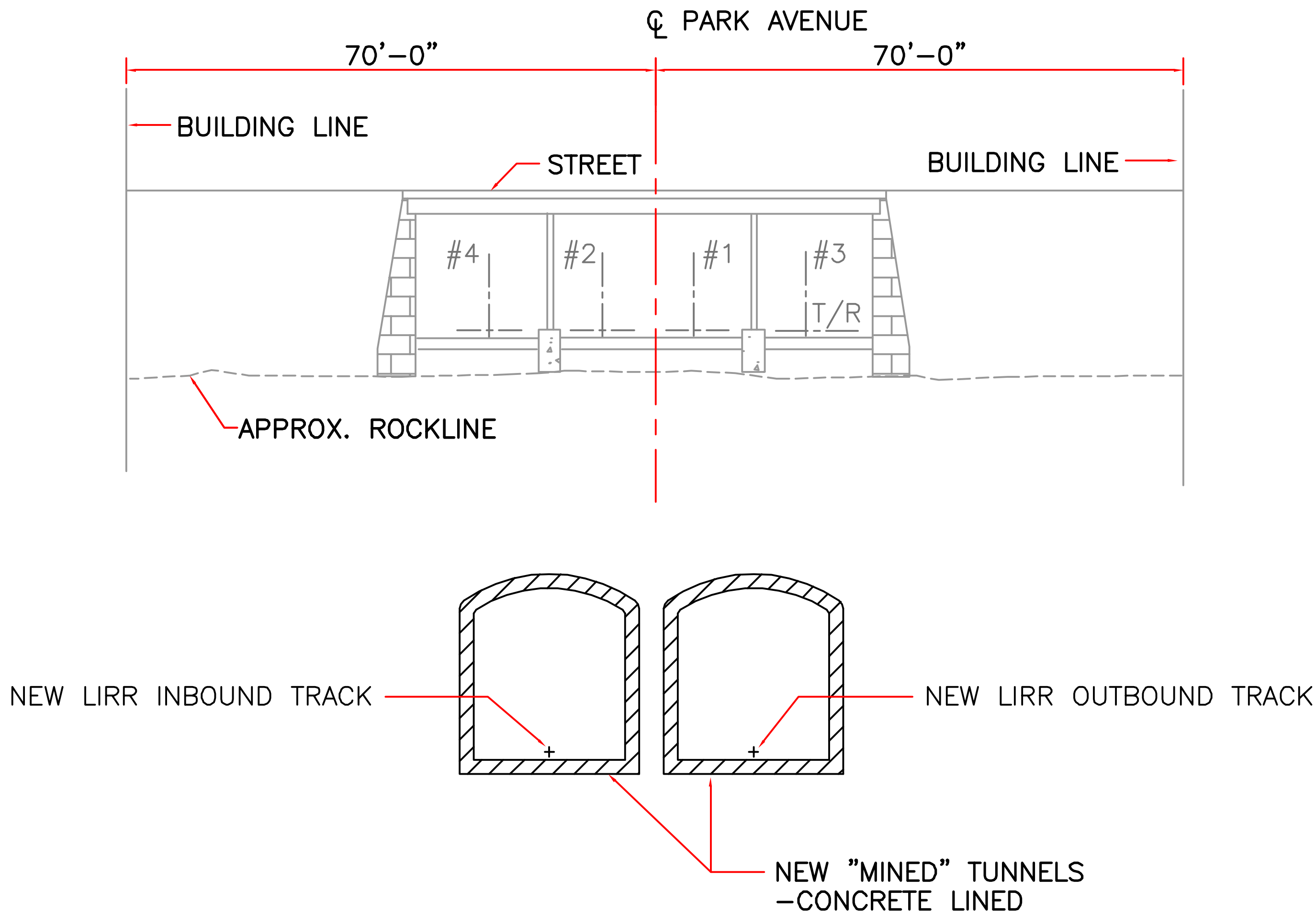
## SECTION AT SOUTH SIDE OF 57th STREET
## TBM TUNNEL OPTION

NOT TO SCALE

FIGURE 10-H.2

UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION I-I

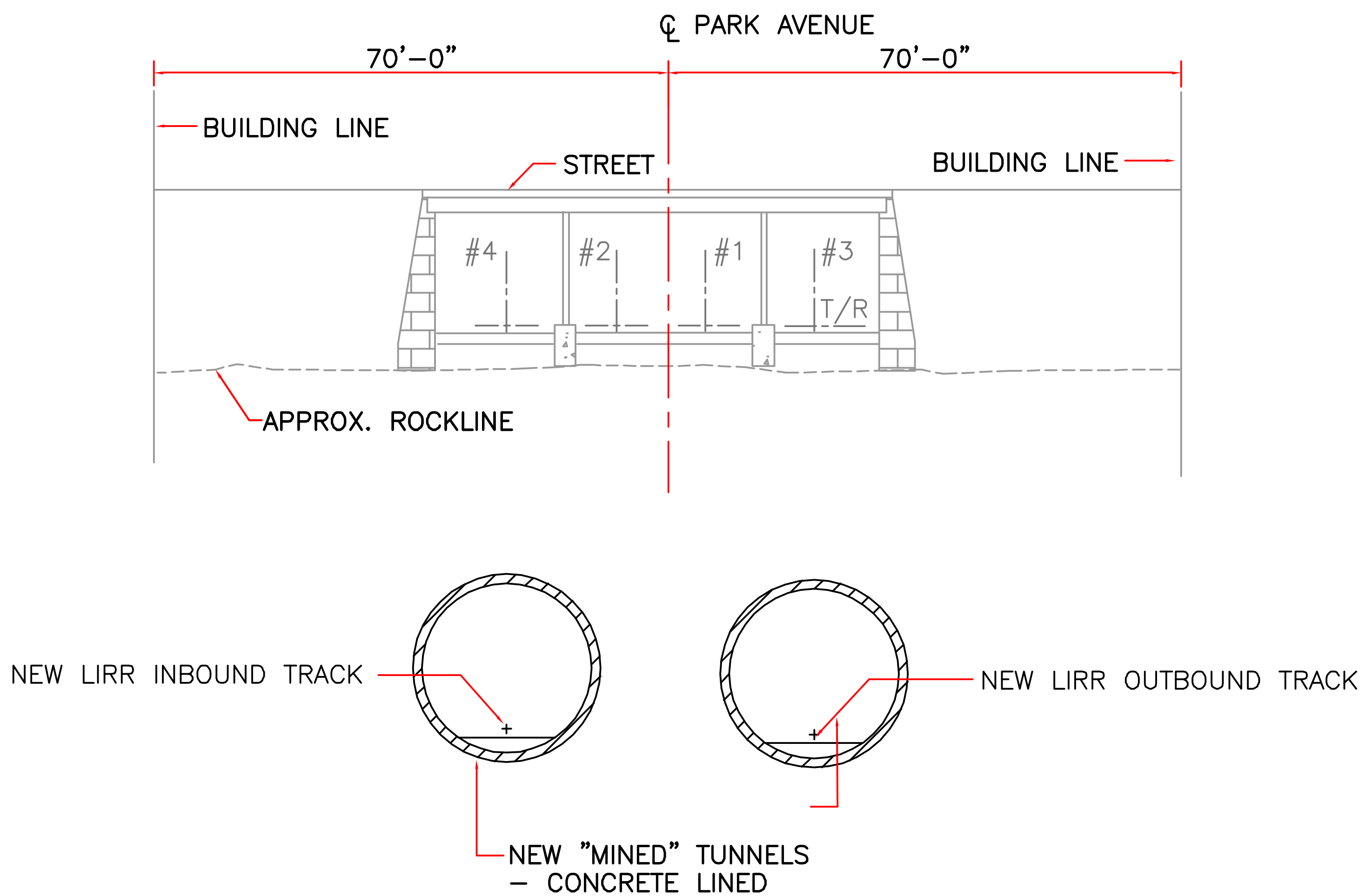
**SECTION BETWEEN 57th AND 58th STREET**
**DRILL AND BLAST OPTION**

NOT TO SCALE

**FIGURE 10-I.1**
**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN

J:\TOR\CB2273\6B_Deliverables_(Drawings)\Track-C-Option.dwg




## SECTION I-I

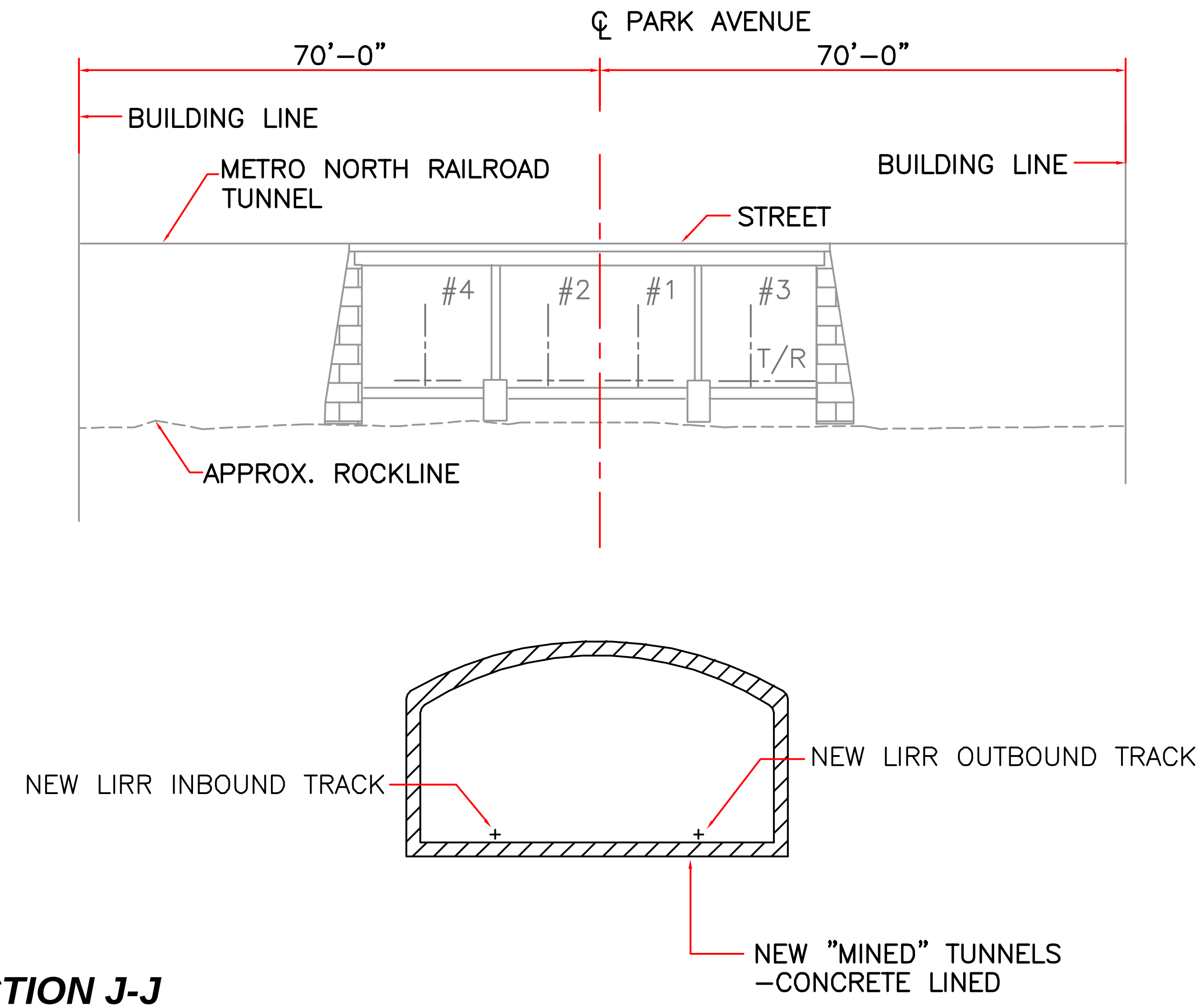
## SECTION BETWEEN 57th AND 58th STREET TBM TUNNEL OPTION

NOT TO SCALE

FIGURE 10-I.2

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN



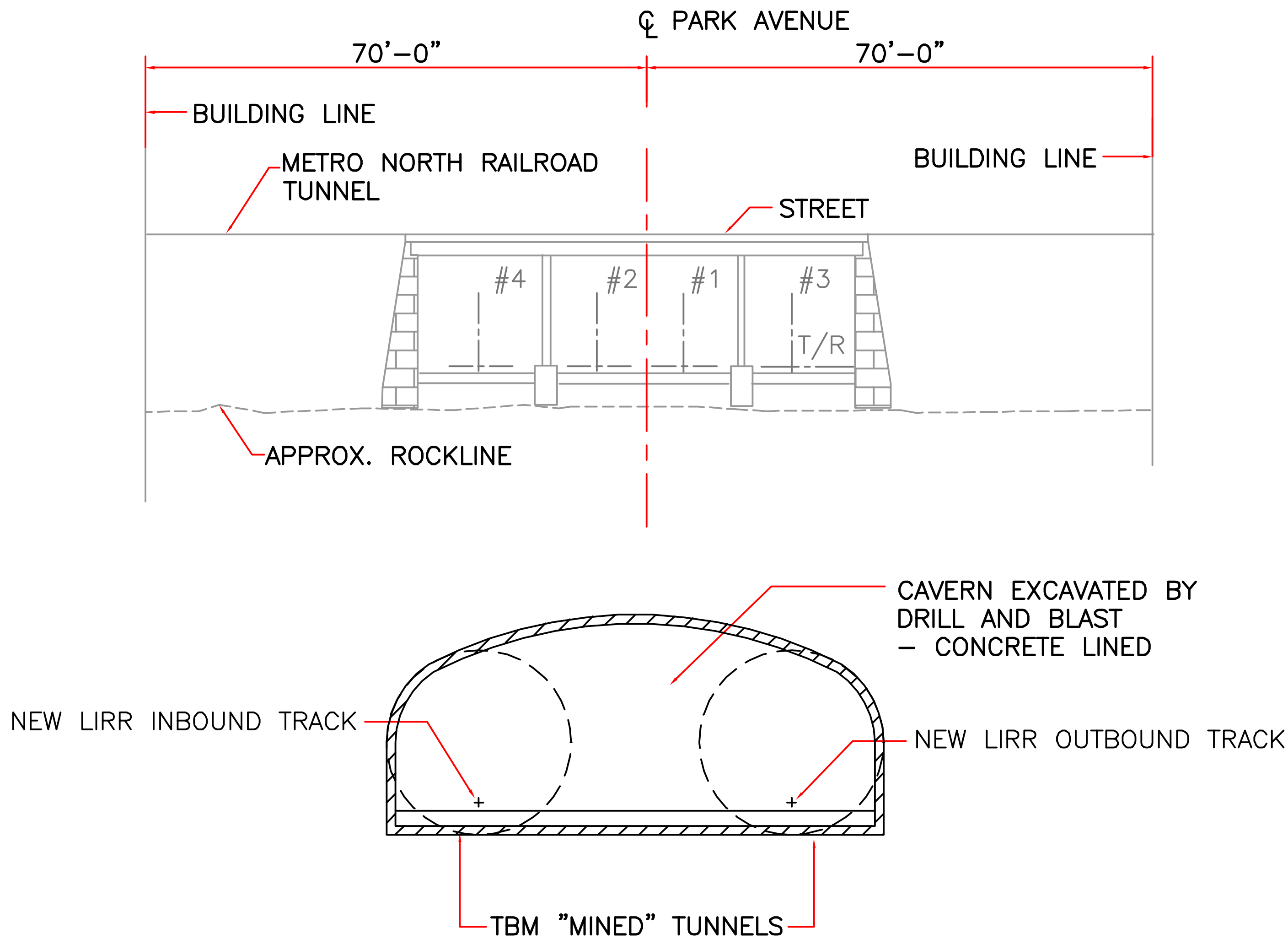

## SECTION J-J

**SECTION BETWEEN 58th AND 59th STREET**
**DRILL AND BLAST OPTION**

NOT TO SCALE

**FIGURE 10-J.1**
**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN




## SECTION J-J

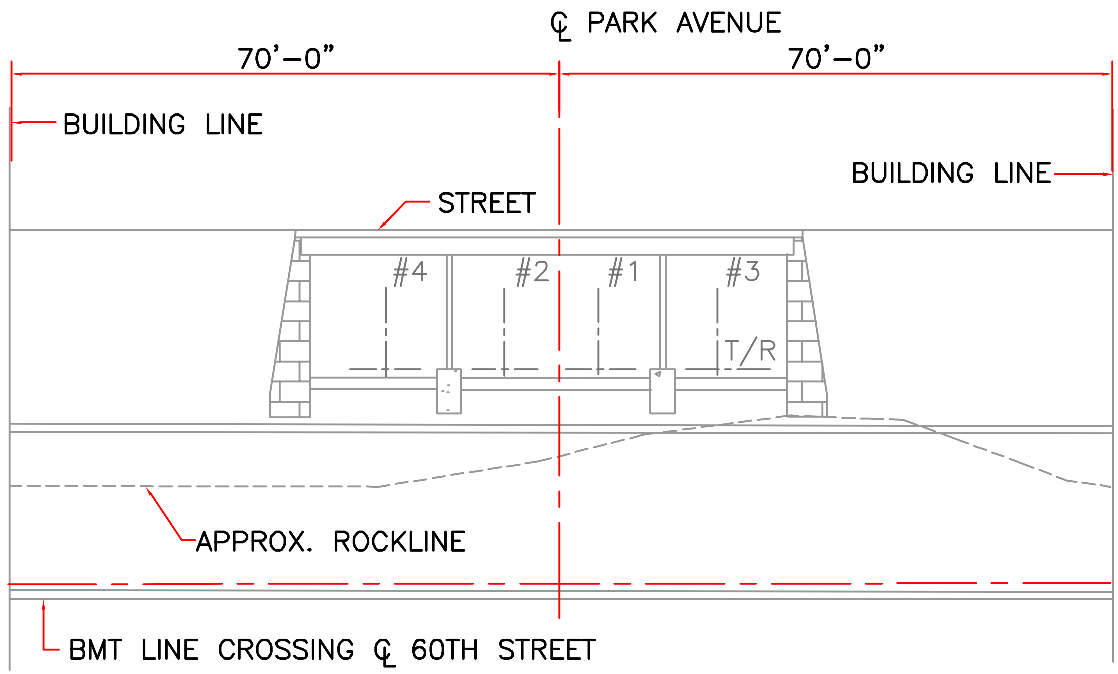
## SECTION BETWEEN 58th AND 59th STREET
## TBM TUNNEL OPTION

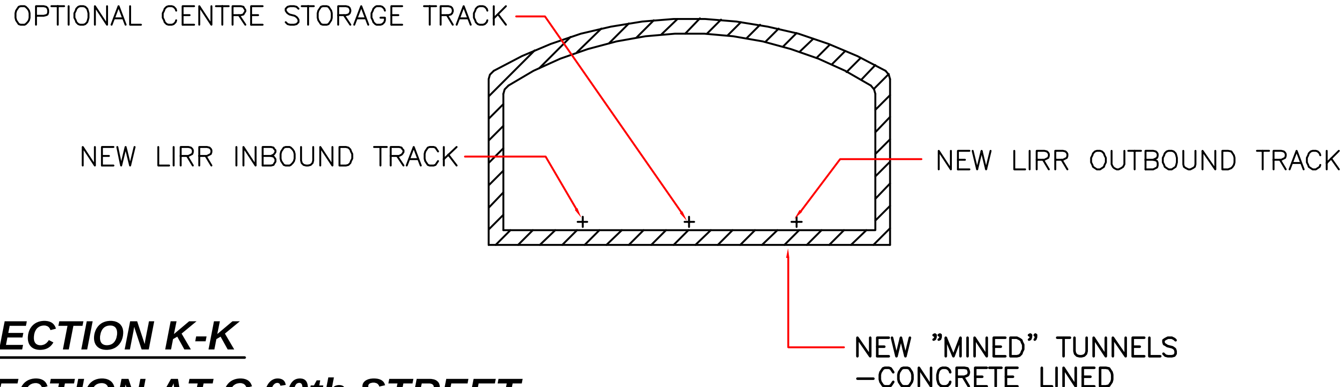
NOT TO SCALE

FIGURE 10-J.2

**UPPER LEVEL LOOP ALTERNATIVE**

DELCAN




## SECTION K-K

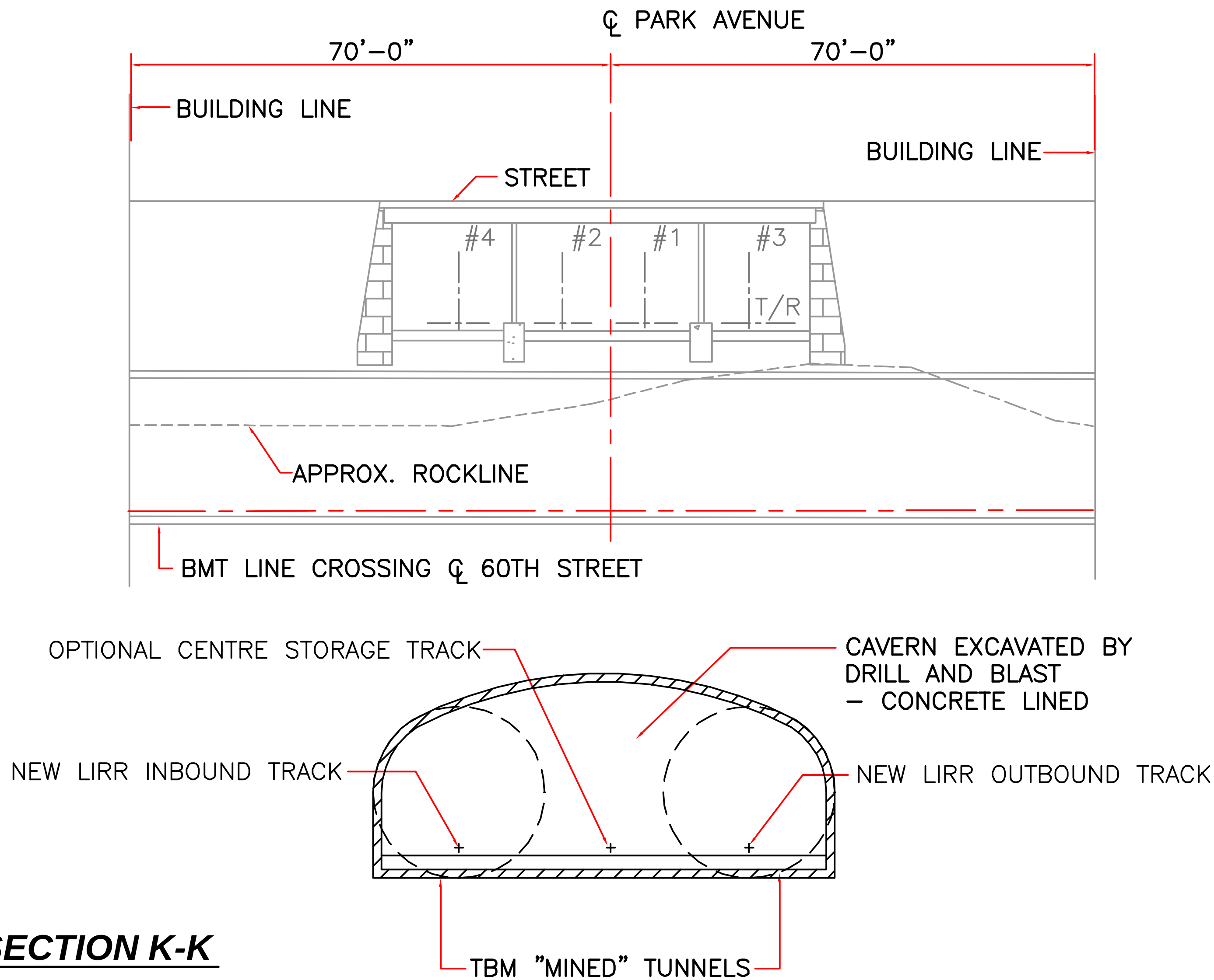
## SECTION AT ℄ 60th STREET
## DRILL AND BLAST OPTION

NOT TO SCALE

**FIGURE 10-K.1**

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION K-K

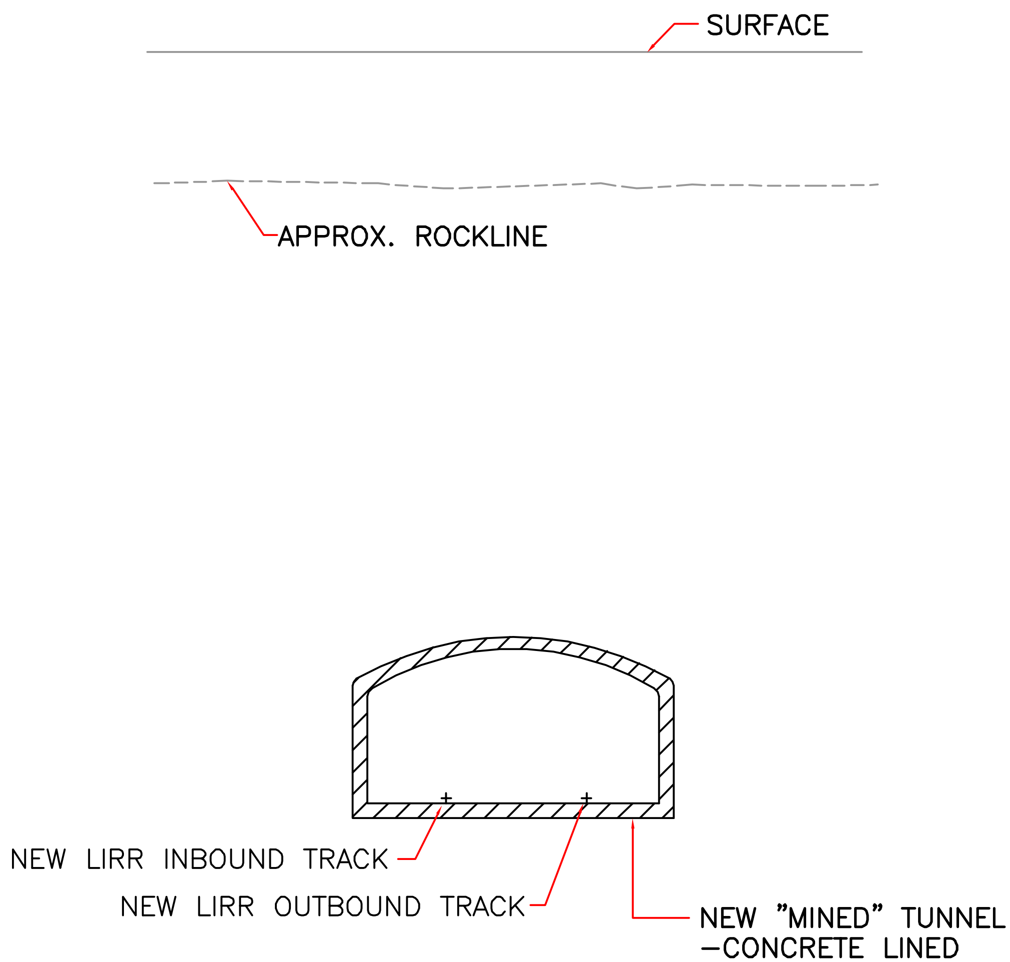
## SECTION AT ℄ 60th STREET
## TBM TUNNEL OPTION

NOT TO SCALE

**FIGURE 10-K.2**

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION L-L

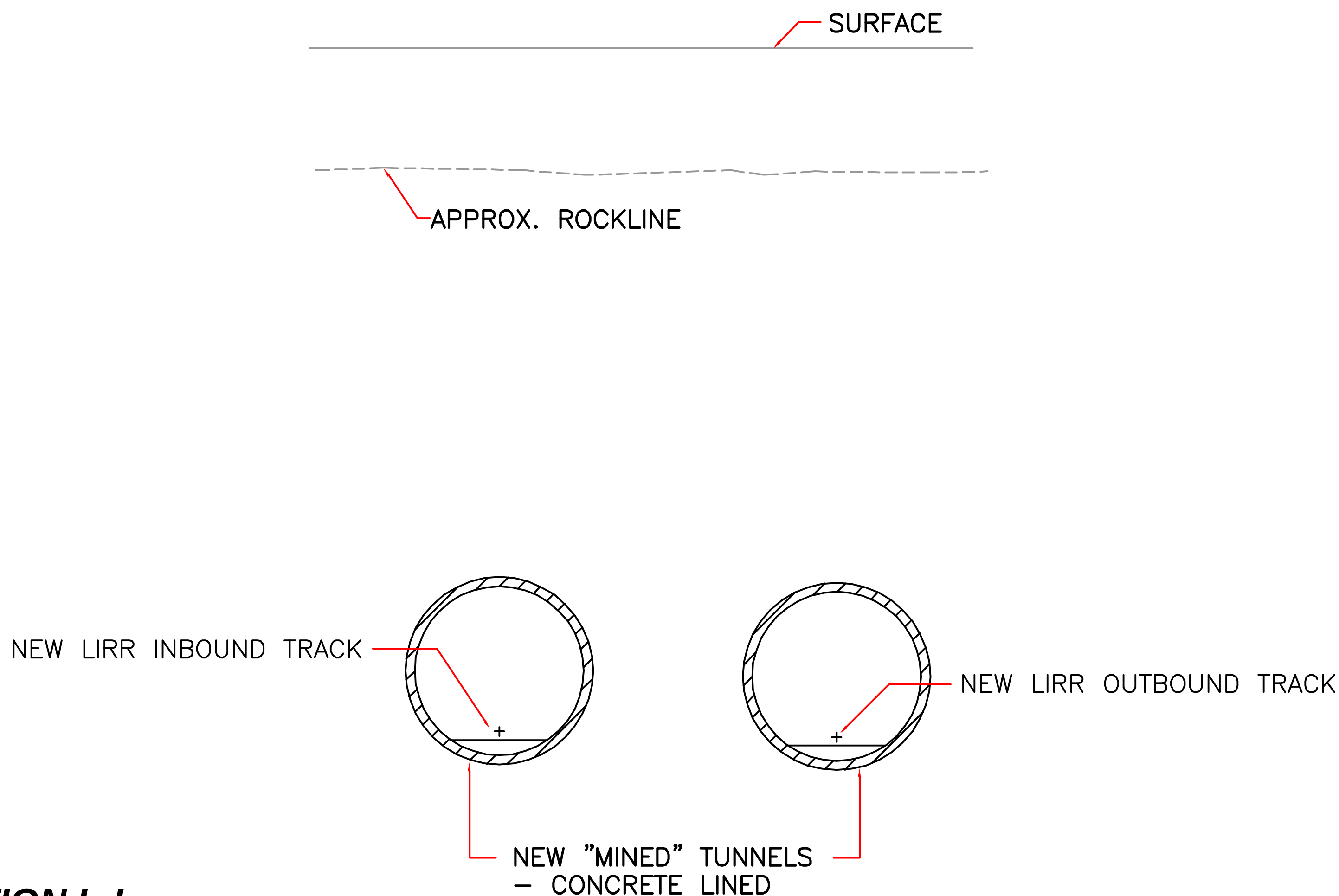
## SECTION AT 62nd STREET
## DRILL AND BLAST OPTION

NOT TO SCALE

FIGURE 10-L.1

UPPER LEVEL LOOP ALTERNATIVE

DELCAN




## SECTION L-L

## SECTION AT 62nd STREET
## TBM TUNNEL OPTION

NOT TO SCALE

FIGURE 10-L.2

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN

# Appendix B

## Track Utilization Charts

## Upper and Lower Level

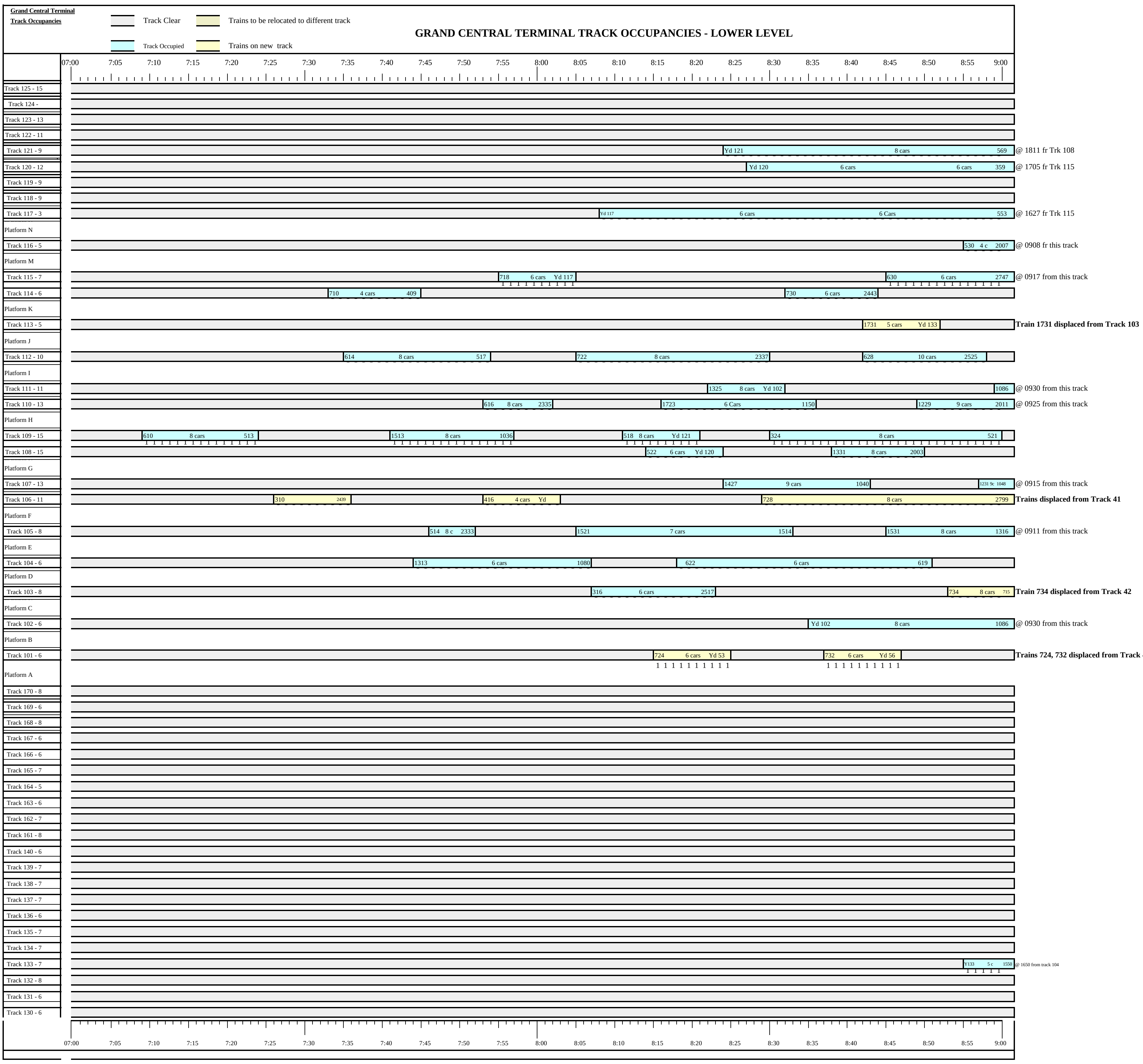



FIGURE B - 1

## UPPER LEVEL LOOP ALTERNATIVE

DELCAN

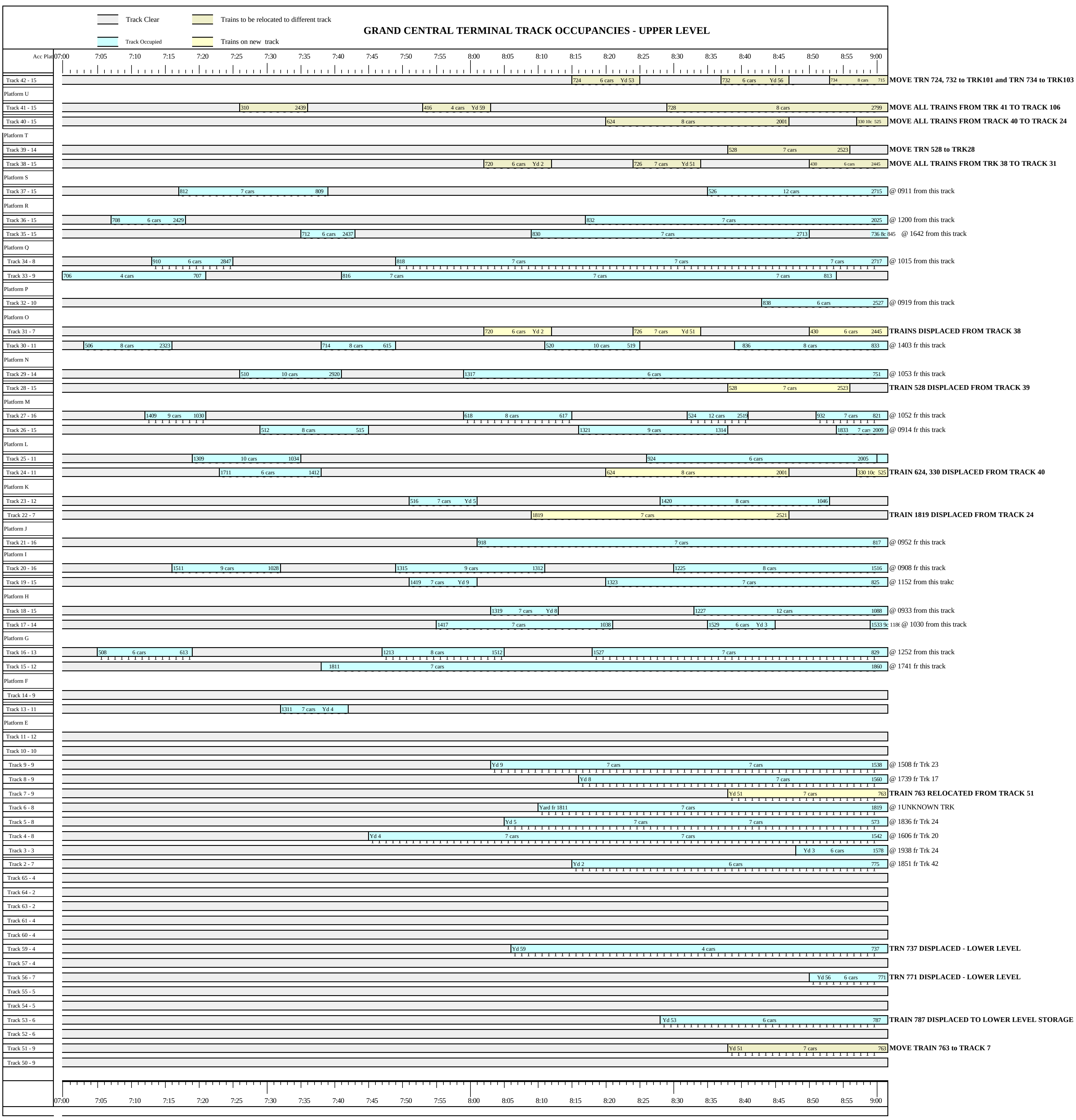



*FIGURE B - 2*

***UPPER LEVEL LOOP ALTERNATIVE***

DELCAN

# Appendix C

# Train Simulation

## 1. Train Simulation

The ULLA was tested using a simulation technique for both 20 trains per hour and 24 trains per hour in the afternoon peak period. The afternoon peak period is the more critical period since arriving trains must stop, detrain inbound passengers, and entrain a trainload of commuters before departing. It was assumed that all trains could be scheduled with between a 7 to 8 minute dwell time similar to the situation at Penn Station for this purpose. In the morning peak, it was assumed that every second train spent only 2 minutes at the terminal to off load passengers then depart immediately for midday storage. For this reason, the peak hour of the peak period in the afternoon would be more constraining than the morning.

The results of the simulation revealed that in the afternoon peak period, up to 24 trains per hour would be possible using an average loop track speed of 10 mph and a dwell time of 8 minutes. All 5 tracks in the terminal would be required for arriving trains. Each departing train would operate around the loop then continue northward maintaining a right hand running operation. The limiting condition would be the time a train remained stopped at the platform. If a train were delayed at the platform when all five platforms were in use, following trains entering the terminal from the mainline would also be delayed. It is estimated that following trains would be stopped while approaching the terminal when there would be more than 2 minutes delay at the platform. To provide some room for operating flexibility, two enhancements are proposed. The first is a passing track situated on the east side of the loop track; this track would be utilized if there were delay to trains on the line exiting the loop. The second is a pocket track situated between both mainline tracks in the area of the tunnel portal. This track could be used to assist in system recovery following a delay situation and would be accessible for trains in both directions.

To accommodate 24 trains per hour, the ULLA scheme requires that the maximum speed around the Upper Loop Track be increased from 6 mph to 12 mph. Using an average speed around the loop of 10 mph, trains could be maintained at 2.5-minute headways allowing 24 trains to operate in the peak hour of the peak period. Based on the existing track geometry an increase to a maximum speed of 12 mph around the loop track could be accomplished without any changes to the existing track.

The following operating parameters were used for analysis of the new LIRR service.

- Loop Track Maximum Speed = 12 mph
- Number of Trains per hour = 24
- Number of coaches per Train = 12
- Train Length = 1020 feet
- Entry Headway to GCT = 2.5 minutes
- Exit Headway from GCT = 2.5 minutes
- Dwell Time for all Afternoon Peak Period Trains = 8 minutes

Figure C-1 is the simulation output that confirms that 24 trains per hour would work on the basis of the above parameters. For this frequency to be sustainable, the LIRR would need to ensure high reliability in the areas of equipment, track, signals and operating practices. Excessive delays to following trains would result when preceding trains are more than 2 minutes at the platforms.

Partly for this reason, and more particularly due to the requirements of the NFPA 130 as outlined in Section 2.4, it was concluded that the maximum practical capacity would be 18 trains per hour in the afternoon peak and 21 trains per hour in the morning peak.

## 2. Simulation Parameters

### 2.1 Dwell Time

The simulations noted above revealed that the dwell time at the station and more specifically the passenger handling capability of the system are key to ensuring a highly reliable system. Even with the conclusion of a maximum practical capacity of 18 trains per hour in the PM peak and 21 per hour in the AM peak, these capacities are based on the same dwell times that were used for the train simulations above.

A train's dwell time is the entire time the train sits stationary at a platform. It is normally the sum of the time required to detrain passengers, service equipment, entrain outgoing passengers plus any delays that occur that cause the train to be held at the terminal. For example, congestion at the terminal could cause the outgoing train to be held waiting a clear signal to proceed. This delay would be included in the dwell time.

The dwell time of MNR trains at GCT was assessed for inbound trains that would be used in outbound revenue service. Typically, these trains sit at GCT for 30 – 45 minutes to detrain passengers, service equipment, entrain passengers and wait for scheduled departure. Trains that were routed to other tracks at GCT for midday storage would also sit on the platform track for approximately 30 minutes.

The dwell time for the new LIRR service would have to be kept to the minimum and be maintained at that level. The dwell time for inbound trains that would not be used in outbound revenue service would have to be restricted to approximately 2 minutes. The dwell time for inbound trains used in outbound revenue service would have to be maintained at 8 minutes.

A fundamental change would have to be made to the equipment servicing operation in GCT to accomplish these dwell times. Trains that are not used in outbound revenue service could be serviced at the staging facility in the Sunnyside Yard. Trains that are cycled back into revenue service would have to be serviced quickly by on-board and platform personnel. Outgoing passengers must wait in the concourse for the indication from the passenger information system with respect to the track from which their train departs. Once this information is received, passengers would move to the platform track and board the train in preparation for departure. Based on terminals with similar operating conditions such as Penn Station, 8 minutes dwell is considered reasonable for the trains that would be cycled back into revenue service and 2 minutes dwell for trains that would not entrain passengers and proceed to mid-day storage. It may be necessary to increase operating staff on platforms and trains to assist with the entraining and detraining of passengers. Passenger Service Attendants have been added to some transit services where the dwell time is tight and passengers have to move quickly in both directions.

### 2.2. Exit Headways

The time between trains is known as the headway. The constraint at GCT is the headway between trains exiting the five tracks (38 – 42) onto the Upper Loop Track.

There are a number of physical constraints associated with the train equipment that limit headways. These constraints directly affect the time the end of the train takes to clear the track to the rear of the train. They are as follows;

- Acceleration rate – limits the rate of increasing change in speed;
- Maximum Allowable Loop Track Speed – limits the time the movement takes to travel distance;
- Deceleration rate – limits the length of the control block;
- Train Length – limits the time to clear the track to the rear.

***Acceleration Rate***
The rate of acceleration is the rate of changing speed in time either measured in feet per second per second or miles per hour per second. The information provided on the M-7 equipment is close to 1 mph per second depending on the power source conditions at the time of acceleration.

In 6 seconds the M-7 equipment would travel 165 feet when accelerating from 0 to 15 mph. In the case of the loop track it is intended to operate to a maximum of 12 mph. From this information it is noted that the M-7 equipment picks up speed quickly and in less than 2 car lengths it would have reached the maximum allowable speed around the Loop of 12 mph.

***Maximum Allowable Loop Track Speed***
The key issue is whether the existing loop track geometry would permit speeds greater than the current MNR speed restriction on this curve of 5 mph.
The maximum allowable speed on the loop track that the track geometry would permit could be calculated using industry-accepted methods that have been in use for many years. From engineering drawings, the loop track was constructed using a 335-foot radius curve or expressed in degrees, a 17 degree 6 minute curve.

The superelevation is the difference in elevation between the outer and inner rails in a curve. This difference in elevation is designed in curves to balance the forces placed on the rails from the movement of rail traffic.

Using the formula for superelevation; $E = 0.0007DS^2$ where,

E – the superelevation (inches)
D – degree of curvature
S – speed of the train (mph)

For 12 mph:

$E_{bal} = 0.0007 \text{ X } 17.1 \text{ X } (12)^2$
$E_{bal} = 1.7”$ or 1 ¾ inches

Typically in passenger train operations, an imbalance of 3” in superelevation is permitted. This would allow the superelevation in the curve to be maintained at zero or level track and still be acceptable for operations. However, the LIRR uses more restrictive alignment design criteria for their operations. The maximum allowable imbalance on the LIRR is 1-½ inches. This restriction is for passenger comfort and not because of engineering design principles. Therefore the LIRR would limit the speeds on the curve to what ever 1.5” of imbalance would allow.

Using an E value of 1.5 inches for the maximum superelevation, the following maximum speed in the Loop Track could be calculated.

$$1.5 \text{ inches} = 0.0007 \text{ X } 17.1 \text{ X } (S)^2$$
$$S = \sqrt{1.5/(0.0007 X 17.1)}$$
$$S = 11.2 \text{ mph}$$

Since the balance superelevation for 12 mph is only slightly higher than 1.5 inches it is safe to conclude that the LIRR should allow a maximum speed of 12 mph around the Loop.

***Deceleration Rate:***
To maximize the number of trains the system could handle, hardwired track circuits must be installed along the length of track in order for the trains to operate as close as possible. The minimum length of block could be calculated from the deceleration rate of the equipment. Changes will be necessary to the signaling system to accommodate this requirement.

The deceleration rate is the braking rate of the M-7 equipment. The rate of deceleration from a maximum of 12 mph to 0 mph is used in the calculation of the minimum control block length.

***Train Length:***
The simulations were based on 12 M-7 units, each at 85 feet in length. The total length of train therefore is 1020 feet.

## 2.3 Other Constraints

***Track Plant***
In addition to the physical constraints of the equipment there is also the physical constraint of the track plant on which the trains operate. There are two other segments that must be traveled as follows;

- From Platform to Point of Switch where all tracks converge = 500 feet measured from Engineering drawings
- Minimum Control Block Length = 250 feet calculated using the deceleration rate. (Below is the calculation for minimum block length)

***Minimum Control Block Length:***
To operate trains as close as possible to maximize the number of trains the system could handle, hardwired track circuits must be installed in the shortest possible segments of track. The minimum block length could be calculated from the deceleration rate of the equipment.

When considering the minimum block length the ability of the train to stop in the block must be calculated. Based on information received, the following deceleration rate is used for calculation purposes.

Safe Braking Rate for the M7 = 1.713 feet per second per second

From this data the following could be approximated,

Deceleration distance from 12 mph – 0 mph = approx. 100 feet to stop

To determine the minimum block length the assumption is made that the operator has accepted an indication to proceed. If a stop is required in the block the reaction time of the operator to respond to an obstruction that causes the initiation of train brakes must also be considered. A reaction time of 5 seconds is assumed for this operation.

Safe Braking Distance at 12 mph + distance traveled in reaction time.

Minimum Block (12mph) = 100 feet + (17.6 X 5 sec) = 100 + 88 = 188 feet

Due to differences in equipment performance and operator judgment a safety factor of 30% must be added.

Minimum Block (including safety factor) = 188 feet X 1.30 = 244 feet, say 250 feet.

The Minimum Block length could be finalized in the detailed design but for the purpose of this study 250 feet was assumed for the minimum block length.

## 3. Minimum Headway around the Loop:

A simulation of train operations into and out of the five platform tracks 38 – 42 was performed for the peak hour of the peak period on a typical weekday for commuter travelers.

The simulations were performed using an average speed around the Loop of 10 mph or 14.7 feet per second. The Loop Track was then divided up into various segments as follows.

- 500 feet from the platform to point of switch (POS) connecting tracks (38 – 42).
- 1020 feet from the POS plus 1 Train Length.
- 500 feet to clear two 250-foot blocks to the rear.

When the train ahead travels the full distance above the next train following could commence. This distance would allow a safe operating distance between trains. The initial 500 feet, is the distance the first train must travel to reach the point of switch where all tracks 38 to 42 converge. The next segment is the distance the entire train must travel to clear the point of switch for a 12-car train, 1020 feet. Lastly, based on the minimum block length of 250 feet and the requirement to maintain at least 2 blocks to the rear the train must travel another 500 feet to clear the two blocks from the point of switch. Two blocks are maintained to the rear to comply with standard railroad practice that signal systems should be designed to allow following trains to follow on a permissive signal indication.

Using an average Loop speed of 10 mph or 14.7 feet per sec the following minimum headway could be calculated.

- 500' / 14.7 fps = 34 secs
- 1020' / 14.7 fps = 69 secs
- 500'/14.7 fps = 34 secs
- Plus reaction time to set up next route and reaction time for the operator to respond, assume 10 seconds.
- Total for T42 – T41 = 147 seconds = 2.45 minutes say 2.5"

From the above, using an average speed of 10 mph through the Loop Track, 2.5-minute headways or 24 trains per hour, are attainable. Figure C-2 is a time distance graph that shows two trains operating on the Loop Track at 2.5-minute headways.

To maintain an average speed of 10 mph from the platform and clear of the Loop on the east side means that the Loop Track must be maintained for the absolute maximum speed of 12 mph. It is important to employ track maintenance activity in such a way to ensure the maximum speed around the Loop is always attainable.

## 4. Conditions that would adversely affect the Exit Headway:

For the transit system to maintain 24 trains per hour, trains must not experience more than a 2-minute delay on the platform at GCT before delaying following trains. There are numerous ways to delay a train. The following are some of the key areas that must be monitored constantly and where failures occur, new measures should be implemented to keep the performance of the system high.

***Equipment failures – Rolling Stock***
The M-7 equipment reliability is known to be good by industry standards. Information provided from Bombardier (the manufacturer) suggests that the M-7's Mean Distance Before Failure is on average 200,000 miles. This figure is monitored regularly by rail operators to track the performance of the rolling stock. Each failure of the equipment that results in a delay to the operations is charged against that equipment. This specific equipment is operating well at an average of 200,000 miles before a delay is charged. It is important to keep the equipment well maintained to ensure the Mean Distance Before Failure remains high.

***Control System or routing problems***
The signaling and control system was not reviewed in detail. It is important to minimize the delay time required in routing trains, selection of new routes, changes to routes selected, and signaling through GCT.

***Door problems:***
Transit systems historically have been burdened down with delays at stations due to door problems on the transit cars. The manufacturers have given this problem a lot of attention so the issues should be manageable.

***Entraining and Detraining passenger problems:***
As stated under Dwell Times, additional operating staff may be required to assist with passengers entraining and detraining trains. It is common in many transit services where dwell times are tight to employ Passenger Service Attendants. These employees would be responsible for the passenger assistance on the platforms, assisting them to ensure quick movement to and from the train and on and off the platforms. These employees would require special people skills and safety training. One of these employees would ride with the train and assist the conductor and a second employee would be present on the platform directing and assisting passengers.

***Train Servicing Problems:***
As stated in the text above, trains would not be fully serviced in GCT. Incoming trains that are cycled back into revenue off-peak service must be quickly swept through by operating staff. Problems could occur when something is found onboard left by passengers that have just detrained. It may be necessary to call security in certain instances. However, with good communications in this regard with the passengers, these delays should be kept to a minimum. This operation should be no more than a quick walk through of the train from both ends following which outgoing passengers should be allowed to board. Regular servicing and cleaning of the equipment would be performed at Sunnyside Yard.

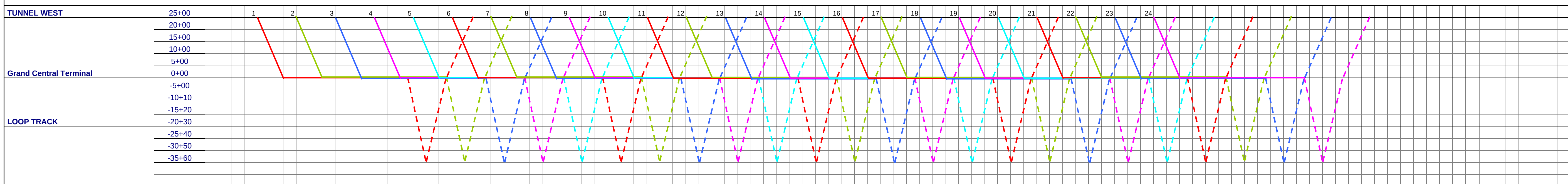
***Employee problems:***
Problems could occur at crew change locations which typically occur at the larger terminals. Proper management of the employees to correct the frequency of these incidences must be done to ensure crews are ready and available for work when they are scheduled. It would not be advisable to have crew changes scheduled for the peak period to minimize any problems during this time.

***Track and Power Infrastructure problems:***
The infrastructure could cause delays if the track and or the power supply system is not well maintained. The maintenance of the track and power system should take place at night when there are no trains operating. Metro North is very familiar with performing this function under extremely tight schedules. Based on current schedules there are only 3.5 hours between 01:30 and 05:00 where there are no trains operating into or out of GCT. It would be necessary to have all preparatory work including track maintenance vehicles and equipment at track side ready to go when planned maintenance is scheduled. This is critical to ensure the high performance of the track system minimizing any delay account track or power failure.

**LOOP TRACK SPEED = average 10 MPH**

**24 Trains per hour each direction**
**Trainsets 12 cars = 1020' in Length**
**Entry Headway = 2.5 minutes**
**Exit Headway = 2.5 minutes**
**Dwell Time = 8 minutes for all trains**

**AFTERNOON PEAK**




| Time in 50 second intervals | 5:00 PM | 5:05 PM | 5:10 PM | 5:15 PM | 5:20 PM | 5:25 PM | 5:30 PM | 5:35 PM | 5:40 PM | 5:45 PM | 5:50 PM | 5:55 PM | 6:00 PM | 6:05 PM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| Track Utilization | Occupancy | |
|---|---|---|
| Track 38 | 1 1 1 1 1 1 1 1 1 1 1 1 1 | If train 1 delayed 2 mins terminal needs 6 tracks |
| Track 41 | 2 2 2 2 2 2 2 2 2 2 2 2 2 | If train 2 delayed 2 mins terminal needs 6 tracks |
| Track 39 | 3 3 3 3 3 3 3 3 3 3 3 3 3 | If train 3 delayed 2 mins terminal needs 6 tracks |
| Track 40 | 4 4 4 4 4 4 4 4 4 4 4 4 4 | If train 4 delayed 2 mins terminal needs 6 tracks |
| Track 42 | 5 5 5 5 5 5 5 5 5 5 5 5 5 | If train 5 delayed 2 mins terminal needs 6 tracks |
| Track 38 | 6 6 6 6 6 6 6 6 6 6 6 6 6 | If train 6 delayed 2 mins terminal needs 6 tracks |
| Track 41 | 7 7 7 7 7 7 7 7 7 7 7 7 7 | If train 7 delayed 2 mins terminal needs 6 tracks |
| Track 39 | 8 8 8 8 8 8 8 8 8 8 8 8 8 | If train 8 delayed 2 mins terminal needs 6 tracks |
| Track 40 | 9 9 9 9 9 9 9 9 9 9 9 9 9 | If train 9 delayed 2 mins terminal needs 6 tracks |
| Track 42 | 10 10 10 10 10 10 10 10 10 10 10 10 10 | If train 10 delayed 2 mins terminal needs 6 tracks |
| Track 38 | 11 11 11 11 11 11 11 11 11 11 11 11 11 | If train 11 delayed 2 mins terminal needs 6 tracks |
| Track 41 | 12 12 12 12 12 12 12 12 12 12 12 12 12 | If train 12 delayed 2 mins terminal needs 6 tracks |
| Track 39 | 13 13 13 13 13 13 13 13 13 13 13 13 13 | If train 13 delayed 2 mins terminal needs 6 tracks |
| Track 40 | 14 14 14 14 14 14 14 14 14 14 14 14 14 | If train 14 delayed 2 mins terminal needs 6 tracks |
| Track 42 | 15 15 15 15 15 15 15 15 15 15 15 15 15 | If train 15 delayed 2 mins terminal needs 6 tracks |
| Track 38 | 16 16 16 16 16 16 16 16 16 16 16 16 16 | If train 16 delayed 2 mins terminal needs 6 tracks |
| Track 41 | 17 17 17 17 17 17 17 17 17 17 17 17 17 | If train 17 delayed 2 mins terminal needs 6 tracks |
| Track 39 | 18 18 18 18 18 18 18 18 18 18 18 18 18 | If train 18 delayed 2 mins terminal needs 6 tracks |
| Track 40 | 19 19 19 19 19 19 19 19 19 19 19 19 19 | If train 19 delayed 2 mins terminal needs 6 tracks |
| Track 42 | 20 20 20 20 20 20 20 20 20 20 20 20 20 | If train 20 delayed 2 mins terminal needs 6 tracks |
| | 21 21 21 21 21 21 21 21 21 21 21 21 21 | If train 21 delayed 2 mins terminal needs 6 tracks |
| | 22 22 22 22 22 22 22 22 22 22 22 22 22 | If train 22 delayed 2 mins terminal needs 6 tracks |
| | 23 23 23 23 23 23 23 23 23 23 23 23 23 | If train 23 delayed 2 mins terminal needs 6 tracks |
| | 24 24 24 24 24 24 24 24 24 24 24 24 24 | |

**Note:** This scenario uses a Loop Track Speed of 10 mph.

***FIGURE C-1***

## *UPPER LEVEL LOOP ALTERNATIVE*

DELCAN

## *TIME DISTANCE CHART FOR UPPER LOOP*

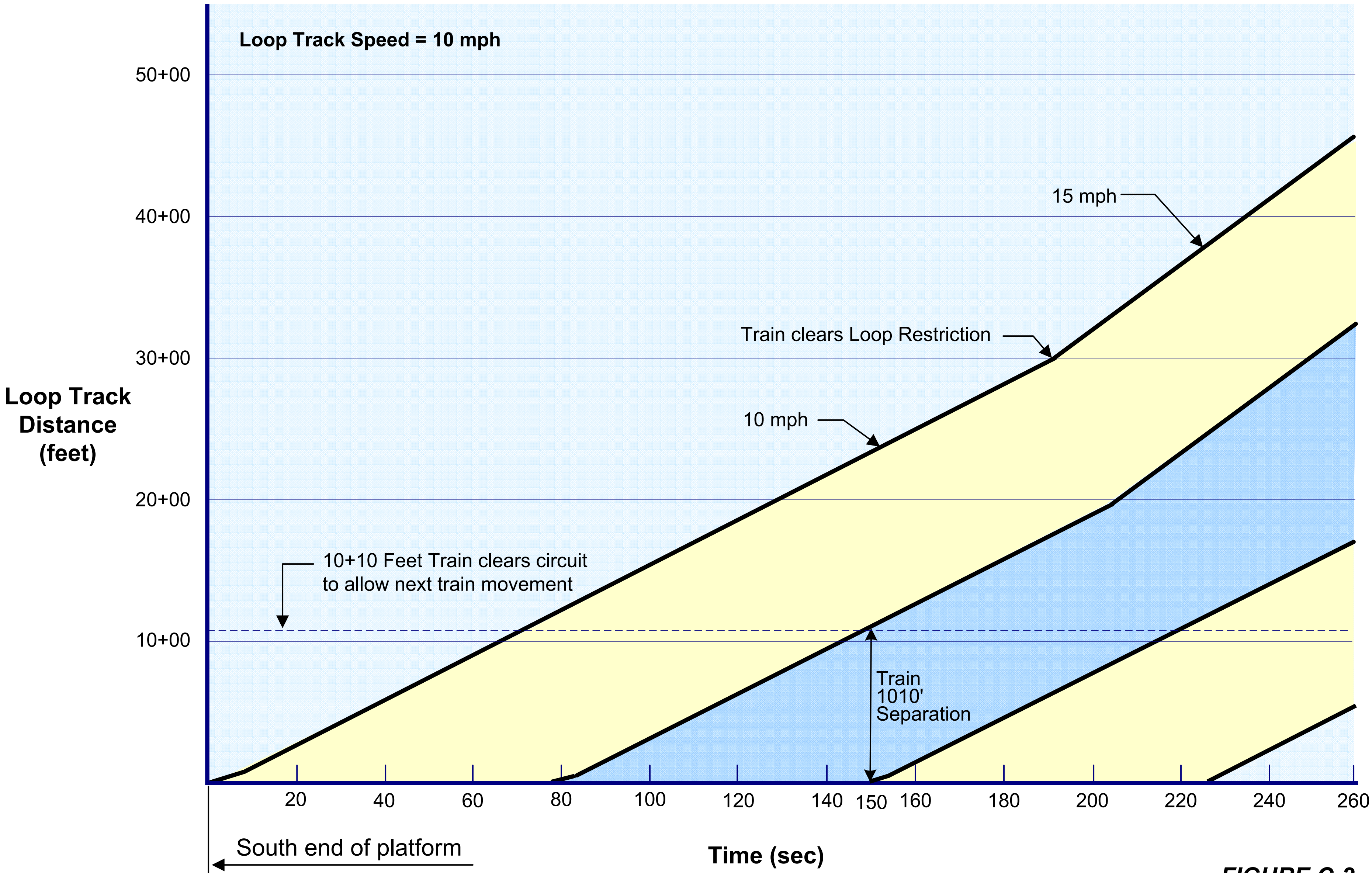



***FIGURE C-2***

## ***UPPER LEVEL LOOP ALTERNATIVE***

**DELCAN**