The Metro Trolley Overhead Program 1973 to 1981

METRO

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On January 1, 1973, the Municipality of Metropolitan Seattle (Metro) took over operation of the City of Seattle's old 32-mile trolley overhead system. This report is a history of the program which rehabilitated this system and expanded it to 55 route miles. Administration, planning, designing and construction are discussed and final costs are presented.

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PREFACE

The purpose of this report is to provide a document that is useful for planning and executing additional expansions of Metro's trolley system. It is not the purpose of this report to be critical of the many participating divisions within Metro and other local and private agencies. It must be understood that 40 years had gone by since the previous trolley overhead construction took place. There were no design engineers or construction linemen in the work force that had any experience with a comparable project. All previous working agreements with the many City of Seattle departments and private utilities affected had been for purposes of maintaining the previous system. These other support groups were not prepared for the enormous job of reviewing plans for 55 miles of new construction, plus the innumerable interactions during construction. Future projects of comparable size must have written agreements with these agencies in advance of the design phase. City of Seattle elected officials showed strong support for the trolley program by providing the local matching funds for the expansion portion and for the substations. This same level of commitment was not exemplified by city departments directly involved in the program, and they were unprepared and understaffed to provide the level of support needed. Detailed written agreements in advance should clarify roles, budgets and schedules. The same is true between departments in Metro. For example, the impact of changing wire plans by planning and operations after design is devastating to budget and schedule. The roles of operations and maintenance during final inspection, testing and start-up must be agreed in advance in writing to prevent the development of adversary relationships.

It must be recognized that city streets are dynamic arterials where constant change should be expected. Only constant coordination can minimize these impacts.

Relearning the art of overhead trolley design and construction has not come easy. By documenting many of the management problems, it is hoped that future trolley expansions will be accomplished more routinely.

T. W. Mallory
Director
Technical Services Department
May 11, 1981

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I. INTRODUCTION

By September 1939, three years of planning had gone into the proposed modernization of the Seattle Transit System. Progress had been normal and unhurried. Then on Saturday, Sept. 2, 1939, Hitler's Wehrmacht descended upon Poland. War in Europe was imminent. Suddenly, the need for the new transit system became urgent and the newly formed Transportation Commission immediately took steps to accelerate the modernization program. An efficient public transportation system would be vital in time of war. Marvin Anderberg in his paper before the 1948 A.T.A. Northwest Regional Conference, Overhead and Engineering Section in Seattle, wrote:

> "On this particular Saturday morning the new Commission was in the first of many "star chamber" sessions. I had been hurriedly summoned to prepare the specifications and call for bids for 400 miles of trolley wire. Bids were to be opened at 11:50 o'clock that morning. In an ante-room were the representatives of the major wire companies. The specifications were written, the bids received and the awards made on that day all under the pressure of an impending war."(1)

The program was to replace the existing transit system--a mixture of streetcar, cable car and bus lines--with a modern 110 mile trolleybus system. The progress was rapid. Anderberg continued:

> "The first of 235 trolley coaches were delivered in March of 1940 to be first used by the Instruction Division on a special training loop. Trolley coach overhead special work which was ordered the first week in January was delivered within 60 days and the first trolley coach was in regular service on April 28. One year later 351 miles of trolley wire had been erected and the job was 92% completed. The last street car operated on April 12, 1941. In about this same period five new rectifier substations had been installed and placed in service."(1)

Most of the work was done by Seattle Transit System crews, temporarily augmented for the project. This may help explain the remarkable speed with which the program was completed,

especially when compared to Metro's present day construction experience. But equally amazing was the final cost of the program: "$10,000 per street mile for overhead including bridges and terminals, and $4,000 per circuit mile for the feeder distribution system." Today's cost per route mile exceeds $500,000.

The future for the electric trolley system in Seattle seemed bright. Anderberg concluded:

> "It takes energy to accelerate and roll vehicles and electrical energy seems to be the one form that is not suddenly affected by the rising costs of production and distribution. Nor is it in diminishing supply because of the extravagant expenditure of national resources. Therefore unless a better vehicle than we have yet seen is developed and unless there is a radical change in the trend of relative costs of investment, power, fuel, servicing and maintenance, it is probable that the advantages of trolley coach operation will not be equalled."(1)

During World War II, the trolley system continued to expand in small increments until 307 trolleybuses were operating over 110 route miles. But then a slow decline began as the diesel bus began to gain prominence during a period of large and relatively cheap oil supplies. In 1963 the first major trolleybus lines were discontinued in favor of buses powered by internal combustion engines. This pattern of converting trolleybus routes to diesel bus routes continued until 1970. The trolley system had been reduced to 32 route miles with only 57 30-year-old trolleybuses still in operation.

The '70s began with an ever-increasing public sensitivity to the environment and an abrupt realization that energy resources are indeed limited. It was in this atmosphere that the electorate, in September 1972, gave the Municipality of

Metropolitan Seattle (Metro) responsibility to operate a public transit system in the Seattle-King County area. Metro was formed in 1958 to provide water pollution control in King County. It is governed by the Metro Council composed of elected and appointed officials from the county, cities and districts within the service area. (18) On Dec. 1, 1972, the city of Seattle and Metro signed the Transit Transfer Agreement (2), which described how Metro would take over the Seattle Transit System. (According to the agreement, Metro would continue to operate the existing trolleybus system.) Metro began operating the public transportation system Jan. 1, 1973.

The overhead system inherited by Metro was old and, in many areas, worn to the limit of its service life. Therefore, a complete rehabilitation of the system was included in the transit improvement project planned by Metro in 1973. Application for financial assistance was made to the Urban Mass Transit Administration (UMTA) in November 1973.

The Transit Transfer Agreement also provided for expanding the trolley system at the request of the city.

> "The proposal for expansion came about when six of the nine Seattle City Council members proposed to Mayor Wes Uhlman in January 1974, that the City's Capital Improvement Program be amended to include the expansion of the trolleybus system. At the City's request the criteria for expansion and a list of possible routes for electrification were prepared by Metro and submitted to the City."(4)

Thus began Metro's trolley overhead rehabilitation and expansion program. The major events and milestones of the program are charted on Table I-1.

The schedules and costs for planning, designing and constructing this trolley overhead program bear little resemblance to those of Mr. Anderberg's 1940 program. It is the purpose of this report to describe the organization, administrative procedures, technical approaches, problems and successes of Metro's trolley overhead program. In doing so, the differences between this program and the 1940 program will be evident, and a complete history will be available for the planning and implementation of future projects.

Table I-1: CHRONOLOGICAL HISTORY OF MAJOR PROJECT EVENTS

DATE	EVENT			
	ORGANIZATION & ADMINISTRATION	DESIGN	CONSTRUCTION	
			REHABILITATION	EXPANSION
Dec. 1972	Transit Transfer Agreement Between Seattle and Metro			
Jan. 1973	Metro begins operation of transit system			
Nov. 1973	Application to UMTA			
Dec. 1973	Modernization Study completed by Metro Engineers			
Jan. 1974	Letter from City Council Members to Mayor about expanding trolley system			
May 1974	UMTA Grant Approved			
Oct. 1974	Final EIS City requests Metro to Expand Trolley System. Oct. 15			

Table I-1: CHRONOLOGICAL HISTORY OF MAJOR PROJECT EVENTS

DATE	EVENT			
	ORGANIZATION & ADMINISTRATION	DESIGN	CONSTRUCTION	
			REHABILITATION	EXPANSION
Jan. 1975 to Apr. 1975	Metro staff develops scope of work and conducts consultant selection			
Apr. 1975	R. W. Beck & Associates selected as trolley overhead consultant			
June 1975	Report on TB-DC Dist. Syst. by Metro Staff			
July 1975	Seattle City Light appts. technical representative			
Aug. 1975		Design criteria report by Metro staff		
Sept.				
Oct. 1975		Task A NTP to RWB		
Nov. 1975	Plan Refinement Completed			
Feb. 1976	Final EIS of Plan Refinement Council approval			
Apr. 1976	Project Manager Assigned	TASK A Completed TASKS B-F NTP to R.W. Beck		
	UMTA REFUSED TO FUND SED BASE MAPS CONSULTANT TO PROVIDE			
June 1976	OB Hardware recommended			
July 1976	First Project Schedule			

Table I-1: CHRONOLOGICAL HISTORY OF MAJOR PROJECT EVENTS

DATE	EVENT			
	ORGANIZATION & ADMINISTRATION	DESIGN	CONSTRUCTION	
			REHABILITATION	EXPANSION
Jan. 1977	Decision made to shut existing system down for rehab.			
Apr. 1977	Trolleybus delivery dates established			
May 1977			Contract T9A & T12A awarded	Contract T9A & T12A awarded
June 1977	Metro and City agree on expansion plan			
July 1977	Through Routing concept proposed			
Aug. 1977	First Supplement to TTA Establish trolley program (Metro takes over rectifiers) Aug. 1			
Oct. 1977	Transit Trolley project Coordinator appointed at Tech. Serv. Dept. request	Overhead Contracts R1,R2&R5 Design completed		
Nov. 1977		Substation Contract T15A Design completed		

Table I-1: CHRONOLOGICAL HISTORY OF MAJOR PROJECT EVENTS

DATE	EVENT			
	ORGANIZATION & ADMINISTRATION	DESIGN	CONSTRUCTION	
			REHABILITATION	EXPANSION
Jan. 1978	Existing System Shutdown	Overhead Contracts R3&R4 Design complete	Contracts R1,R2&R5 awarded	
Feb. 1978		COB Overhead Design added to contract	Contract T15A awarded	
Mar. 1978	Weekly staff meetings began	Substation Contract T17A Design complete		
May 1978		Substation Contract T19A Design complete	Contracts R3&R4 Contract T17A awarded	
July 1978			Contract T19A awarded	
Oct. 1978	Weekly staff meetings discontinued Trolley Overhead Division formed	Substation Contract T27A Design complete		
Nov. 1978		Overhead Contract T20A(E9) Design complete		
Jan. 1979		Substation Contract T28A Design complete		
Feb. 1979		Outside consultant retained by Metro for third party review of design and construction procedures		
Mar. 1979				Contract T27A awarded

Table I-1: CHRONOLOGICAL HISTORY OF MAJOR PROJECT EVENTS

DATE	EVENT			
	ORGANIZATION & ADMINISTRATION	DESIGN	CONSTRUCTION	
			REHABILITATION	EXPANSION
March Apr. 1979	T.O. Subcommittee formed		T17A Completed	
June 1979	Review Procedures and Schedule revised		T19A Completed	Contract T28A awarded
July 1979		Substation Contract T25A Design Complete (Task E completed)		Contract T20A(E9) awarded
Aug. 1979 Sept. 1979			R1&R2 completed *Routes 2 and 10 begin operation, R5 complete	
Oct. 1979		Overhead contracts T23A(E11) & T24A(E8) Design complete	*Lightning Storm damages system, deficiencies in lightning protection discovered Contract T15A completed	Contract T25A awarded
Nov. 1979 Dec. 1979		Overhead Contracts T21/22A(E7/10)Design Complete (Task F complete)	R4 Completed	T27A Completed Contracts T23A(E11)& T24A(E8) awarded

Table I-1: CHRONOLOGICAL HISTORY OF MAJOR PROJECT EVENTS

DATE	EVENT			
	ORGANIZATION & ADMINISTRATION	DESIGN	CONSTRUCTION	
			REHABILITATION	EXPANSION
Feb. 1980		Design Contract completed, Close out negotiations begin	R3 Completed	Contracts T21A(E7)& T22A(E10) awarded
Mar. 1980	Second Supplement to TPA Increasing Costs Mar. 6		*Two Lightning Storms damage System. System shut down for repairs and addition of lightning protection	
May 1980			Routes 2,10,services return, Route 14 begins service	Route 13 beings service
June 1980				T28A Completed
July 1980			One Lightning Storm, no damage, systems function correctly	T20A(E9) Completed T25A Completed
Aug. 1980				T23A(E11) Completed
Sept. 1980				Routes 1,3&4 begin service

Table I-1: CHRONOLOGICAL HISTORY OF MAJOR PROJECT EVENTS

DATE	EVENT			
	ORGANIZATION & ADMINISTRATION	DESIGN	CONSTRUCTION	
			REHABILITATION	EXPANSION
Jan. 1981			500KW Rectifiers accepted	500KW Rectifiers accepted
April 1981		Design Contract close out still underway		Contract T24A(E8) Complete Contracts T21/22A (E7/10) Complete
May 1981	Trolley Overhead Division disbanded			Routes 7 and 43 begin service

II. ORGANIZATION

A. STRUCTURE AND STAFF ALLOCATION

Metro is administered by an executive director, appointed by the Metro Council. When the transit function was added to Metro in 1973, the number of departments increased to five, each headed by a director who reports to the executive director.

During Metro's first year as a transit agency, the only activity regarding trolley overhead was researching the current state-of-the-art. A division was established in the technical services department--transit technology--which consisted of a manager and three staff members. Only the manager and one staff member were involved in trolley overhead at that time. Approximately one year following the request for trolley system expansion by the city, other departments and divisions within Metro were assigned tasks as the program developed. Route selection was managed by the transit department's transit planning division. The technical planning, predesign criteria and consultant selection was managed by the Technical Services Department. The overall organizational structure during this period is illustrated in figure II-1.

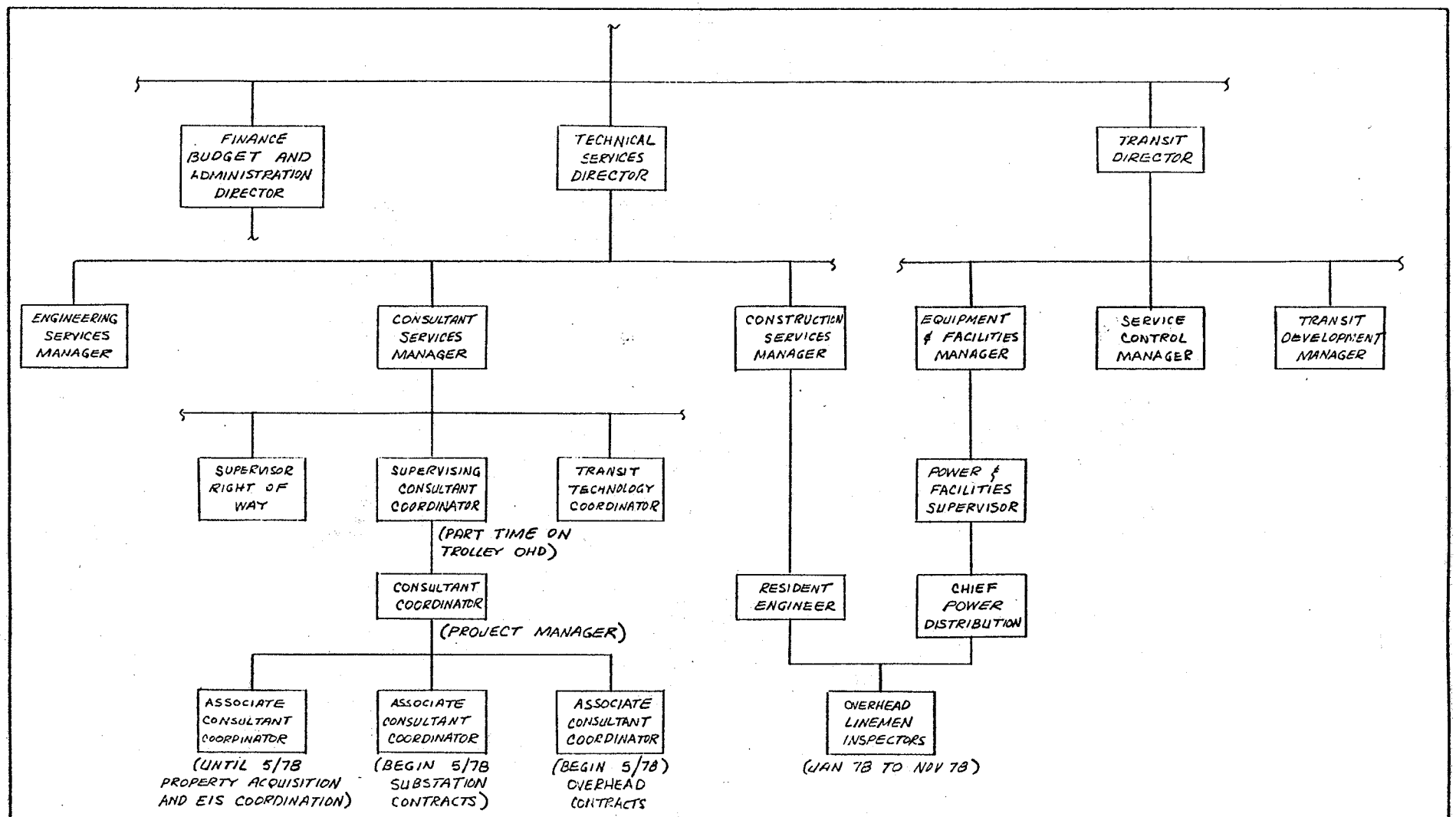
When the preliminary planning for a rehabilitation and expansion program began to change to predesign planning in mid-1975, it became apparent that a manager was needed to direct and coordinate the design phase of the program. The position was assigned to the design electrical engineer who had worked on the scope of work, design criteria and consultant selection tasks during the planning phase. He was already the primary contact between Metro and the design consultant. He was transferred to the consultant

services division where Metro's consultant contracts are normally managed. Gradually the functions of the transit technology division were reduced when much of the equipment and material design and selection was completed. Later the transit technology division became a section within the consultant services division. The organizational structure for this period is illustrated in figure II-2.

This management organization performed adequately until early 1978 when the construction contracts were awarded and work began in the streets. With the very first attempt at setting a support pole, the myriad of unanticipated problems had begun. Schedules and budgets were soon obsolete as the problems mounted. The nature of these problems will be discussed in detail in later sections of this report. What is important here is the background for the rather bold measures taken to reorganize the program management. In a status report to the Metro executive director (16), the director of technical services put it this way:

> "Simply stated, the project is much more complicated in both detail and coordination that originally envisioned. Managing extra work and change orders is lagging weeks behind; coordination with the City needs to be improved; closing the gap between the design team and the construction team is imperative; plus, many more coordination needs. To resolve this management shortcoming I recommend the immediate creation of a separate division for the single purpose of managing all aspects of this one important program."

The new organization is shown in figure II-3. With a few minor adjustments for changes in the amount and type of work load as the program neared completion, this organizational structure remained unchanged.



DESIGN	DRAWN	DIVISION	MUNICIPALITY OF METROPOLITAN SEATTLE	DATE
	LLW		PROGRAM ORGANIZATION 1975-1978 DESIGN AND CONSTRUCTION	2-81
				FILE NO.
				SHEET FIG II-2

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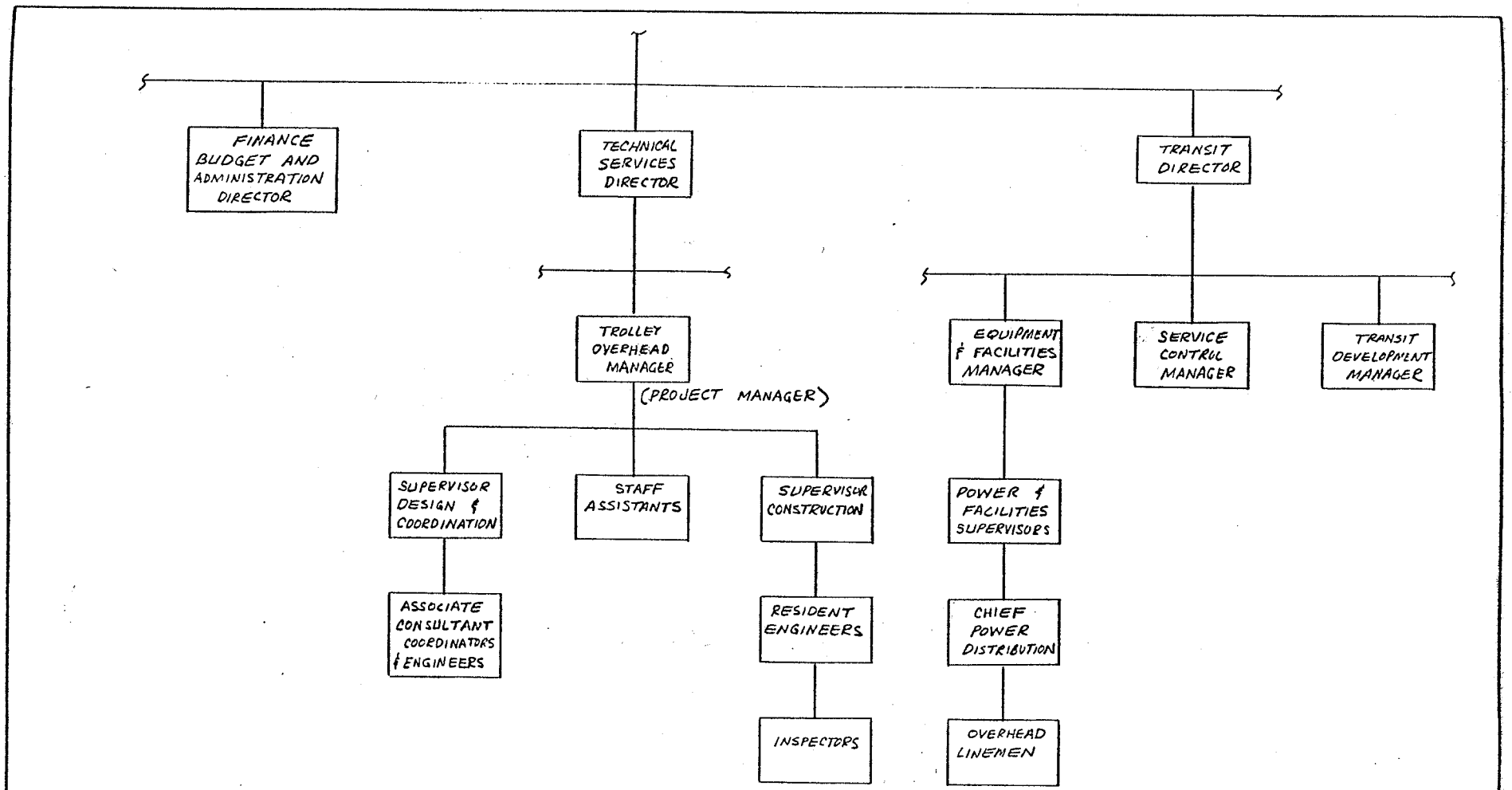


DESIGN	DRAWN	DIVISION	MUNICIPALITY OF METROPOLITAN SEATTLE	DATE
	LLW		PROGRAM ORGANIZATION 1978-1981 DESIGN AND CONSTRUCTION	2-81
				FILE NO.
				SHEET FIG II-3

102077ES

B. PLANNING

Metro first gained the authority to plan for public transportation from the state legislature in 1967. But it wasn't until September 1972--when voters gave Metro the authority to operate a countywide public transit system and approved a public transportation plan which called for extensive improvements to the transit system--that Metro began in earnst to plan the region's transportation system. Rehabilitation of the existing trolley system was a part of that mandate.

1. Concepts

In 1973 the transit technology division was organized under Metro's technical services department to develop information regarding trolley system alternatives. Toward the end of 1973, this division requested a study of power distribution alternatives by the Metropolitan Engineers. A city policy requiring the eventual elimination of overhead wiring--including overhead feeders, but, of course, not including trolley contact wires--significantly affected the scope of the study. The alternatives considered were thus reduced to the following:

1. Place the existing feeders underground.
2. Place reduced size feeders underground and add small rectifier substations.
3. Construct a feederless system utilizing small rectifier substations.

Alternatives 1 and 2 were found to be much more expensive compared to the feederless system, due to the high cost of installing underground feeders. The third alternative, the feederless system, is best described in the technical report:

"To avoid the expense of burying heavy trolley feeder cables it is necessary to eliminate them and let the trolley contact wires carry all the current required. To minimize voltage drop, the trolley contact wires need to have as high a conductance as can be practically attained and the current (i.e. the number of coaches) handled by a feeder circuit needs to be reduced. This requires that distances between power feed points to the trolley contact wire system be made small. It is a purpose of this study to make a preliminary determination of reasonable trolley wire size and distance between the small substations that can provide economical and effective service. Preliminary data have been provided by John Aurelius of Metro Transit along with certain assumptions and limitations. The assumptions and limitations in this study are as follows:

(1.) System operating voltage - 600 volts DC.
(2.) Maximum design load current - 1000 amperes.
(3.) Grooved conductor: 2/0 or 3/0 or 4/0 high conductivity bronze or hard-drawn copper.
(4.) Substation spacing: One mile more or less.
(5.) Regulation: 5 per cent - source to trolley tap; 10 per cent additional along trolley system.
(6.) Two-way trolley system along street with corresponding polarity conductors tied together at frequent intervals.
(7.) Satisfactory operations of trolley coaches to be maintained with any one source along the line out of service. Reduced performance in some degree can be tolerated at an end-of-line situation."(3)

2. Selection Criteria For Trolleybus Routes

Subsequent analysis and engineering reports reaffirmed the use of the feederless system concept for most of the rehabilitation and all future expansion work. This decision was timely because in January 1974 the Seattle City Council indicated its desire to see further electrification beyond the rehabilitation of the existing system. Adding

emphasis to their recommendation, the Council proposed that the proceeds from the sale of the Seattle Transit System be used in part as the local matching funds for the UMTA capital grant funds being sought at that time. Metro, at the city's request, then began to develop the selection criteria and evaluate existing diesel routes for electrification. The basic criteria developed consisted of the following considerations:

> "Because trolley coaches are able to climb hills faster and more effeciently than motor coaches, and are able to descend steep hills more efficiently because of the use of the electric motor as a regenerative or dynamic brake, routes with moderate to severe grades should be considered for electrification.
>
> Service frequency on a route relates to the economic justification for the investment in overhead. As service frequency increases, the capital cost per vehicle mile operated decreases. This criterion is also important from an overhead maintenance viewpoint, since maintenance costs per vehicle mile decline with increasing use of a given stretch of wire.
>
> It a proposed route overlaps an existing trolley coach route, construction costs and cost of maintenance will be reduced from the shared use of overhead. Similar construction and maintenance economies will result if two or more proposed lines share some overhead.
>
> Another criterion for trolley coach extension is the current and future effectiveness of route terminals as they relate to major activity centers and geographic barriers. Trolley coach routes ideally should have high-activity route terminals to minimize the probability that, at some time in the future, a demand will be made to extend trolleys into an area which would not warrant the investment in overhead facilities.

> Because wires are not allowed on freeways with mixed traffic, trolley coaches are generally limited to city streets. This eliminates from consideration lines which have considerable freeway express service, such as the Blue Streak lines, and lines that operate most efficiently to and from the operating base by way of the freeways.
>
> Two additional criteria of a different nature also affect the choice of extensions. One of these is the proposed use of many small, closely spaced, solid-state rectifiers to supply power for the overhead. These are to be used instead of the present system which features a few large substations with many unsightly parallel aerial feeder wires. The proposed system would provide a feederless system with a substantial reduction in visual intrusion.
>
> The final major parameter in developing extensions is coordination with the City's ongoing undergrounding program. Construction economies, such as joint use of poles and minimization of the number of poles, are possible when utilities undergrounding and new trolley overhead equipment are designed and constructed together. (A major factor involved in areas with buried utility wires is the potential visual impact of trolley overhead wires. Each community for which trolley service is proposed would have the opportunity to present its evaluation of this impact for consideration in the final decision-making process by the Seattle City Council and the Metro Council.)"(4)

It should be observed that these were not addressing the question of whether to electrify routes, but rather which routes were the best candidates for electrification. The information then available at the time indicated that the costs of construction and maintaining a trolley system were substantially higher than the costs of a diesel motor coach system. The savings that could be expected in fuel and bus maintenance costs were not large enough to offset

the greater initial capital cost and overhead maintenance costs of a trolley system. Despite the higher costs, expansion of the trolley system was being pursued at the request of the city. The city felt that the indirect benefits of a trolley system--better performance on steep hills, quieter and non-polluting buses--justified expanding the system. The decision was further justified by the fact that diesel fuel was rising faster than the cost of electricity, and that the future stability of diesel supplies was tentative. (For a recent detailed analysis of the economic comparison between trolleybus systems and diesel motor bus systems see reference 19.)

3. Route Selection and Public Involvement

A list of routes was developed using the above criteria. A minimum weekday ridership of about 1,600 became a limiting factor for routes to be considered for electrification. These routes are listed on table II-1 and shown in figure II-4. From this list, suggested new routes for electrification were selected. Table II-2 lists these routes and their corresponding requirements for trolley coaches and overhead wire. Subsequently, these routes were presented to the public in the Aug. 16, 1974, draft environmental impact statement. A public hearing and 10 public information meetings were subsequently held in the communities where the proposed electrification would take place.

After considering comments from citizens and agencies, the final environmental impact statement was issued

TABLE II-1

MOST HEAVILY PATRONIZED ROUTES AND THEIR POTENTIAL FOR ELECTRIFICATION

Weekday Patronage*	Route		Remarks
6052	7	Rainier	Proposed trolley coach
3424	2	West Queen Anne	Existing trolley coach
3376	9	Broadway	Existing trolley coach
3334	10	Capitol Hill	Existing trolley coach
3274	7	15th NE	Freeway dependent
3118	5	Phinney	Freeway dependent
2784	2	Madrona	Existing trolley coach
2586	3&4	NE Queen Anne	Proposed trolley coach
2518	15	15th NW	Proposed trolley coach
2442	16	Meridian	Freeway dependent
2404	30	Ballard-Laurelhurst	Proposed trolley coach (Ballard-University only)
2314	6	Stoneway	Freeway dependent
2136	4	Montlake	Proposed trolley coach
2070	3	Jefferson Park	Proposed trolley coach
2022	25	Lakeview	Covered by 9-Broadway, 4-Montlake & 7-View Ridge nights & Sundays
1996	28	8th NW	Freeway dependent
1968	12	E Cherry	Existing trolley coach
1968	14	Summit	Existing trolley coach
1914	11	E Madison	Proposed trolley coach
1830	7	15th NE/Blue Streak	Freeway dependent
1782	17	Sunset Hill	Low patronage per route mile
1780	10	Mt. Baker	Existing trolley coach
1778	18	Ballard	Low patronage per route mile
1772	7	View Ridge/Blue Streak	Freeway dependent
1672	13	19th Avenue	Existing trolley coach
1632	41	Park/Ride	Freeway dependent

All other Metro routes have less weekday patronage.

*Random sample conducted May 23, 1973

TABLE II-2

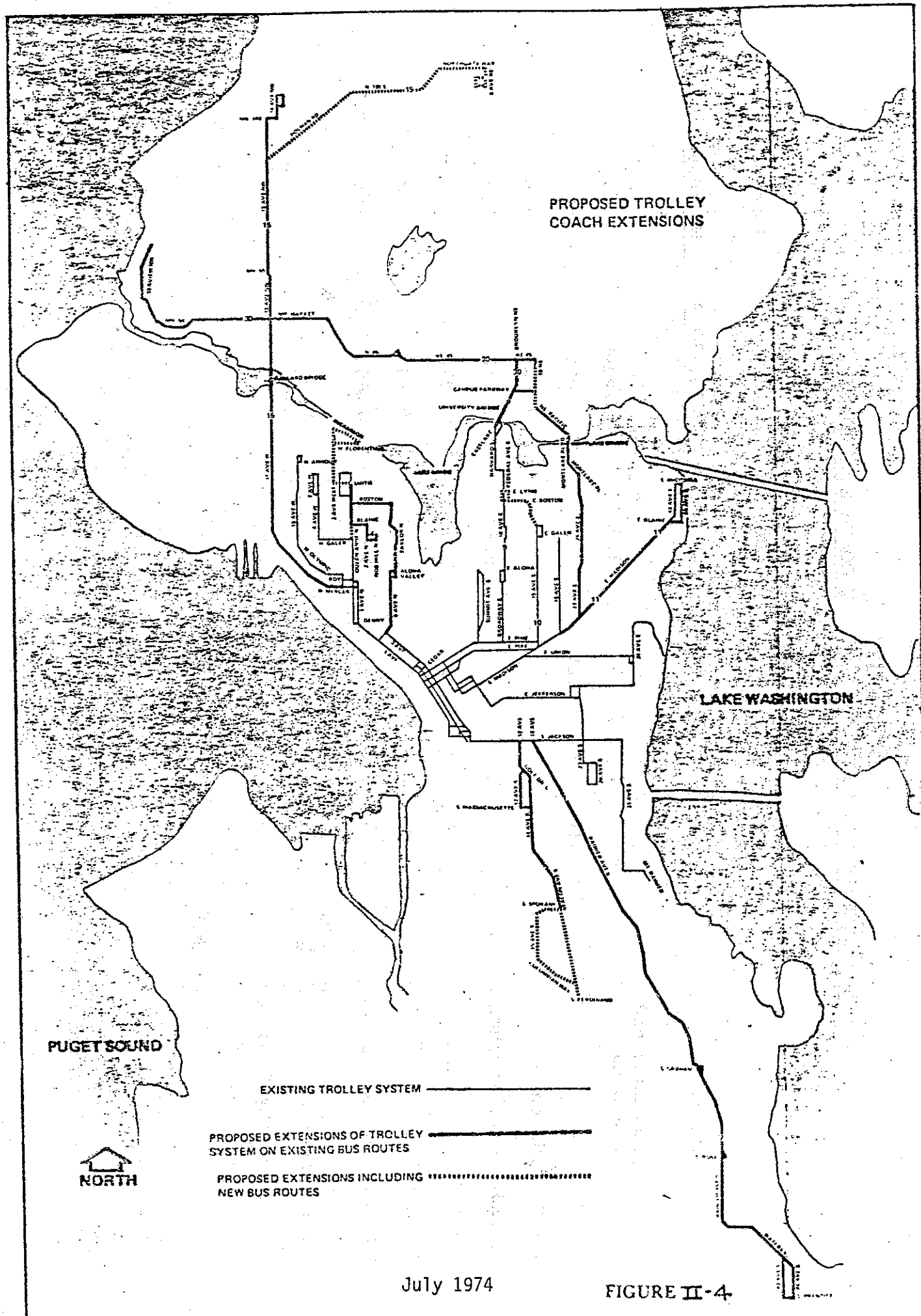
REQUIREMENTS FOR SUGGESTED TROLLEY COACH EXTENSIONS

(As of 1974, see reference 4)

Route	Motor Coaches Presently Assigned	New Trolley Coaches Required	Route Miles of New Wire Required	Weekday Passengers on May 23, 1973	Present Inbound and Outbound Trips Per Weekday
3 N. Queen Anne and 4 E. Queen Anne	8	9	4.5	2,586	167
7 Rainier	18#	12*	8	6,052	203
11 E. Madison	5	5	3	1,914	100
15 15th N.W.-Northgate	7	8*	8.8	2,518	102
3 Jefferson Park	5	5	2.6	2,070	103
4 Montlake	4	4	2.6	2,136	88
30 Ballard-University	9	8	3.9	2,404	158
Extension of 9 Broadway and 10 Capitol Hill to University District	0	2	2.3		
TOTALS - New		53	35.7		

\# - Includes express

* - Excluding express service to be provided by motor coach



July 1974

FIGURE II-4

(4) with the proposed electrification expansion plan shown in figure II-5 and the routes listed in table II-1.

In 1975, the Metro staff developed a scope of work for the project, selected a design consultant, developed more specific design criteria and identified the planning issues which needed to be resolved before the detailed designs could be completed. These issues included:

1. Location of all overhead wire (normal routes plus turnaround loops, parade loops, emergency bypasses, layovers, passing wires, etc.)
2. Frequency of operation of each route.
3. Frequency of operation of routes sharing, in part, common overhead wire.
4. Schedule of vehicles on all routes (headways) both normal and off schedule.
5. Current or planned projects by others (i.e. traffic, LID, street undergrounding projects) which may affect overhead construction.

This effort led to the publication of the Trolley Rehabilitation and Extension Plan Refinement" (5). The refined plan, which was subjected to extensive agency and public scrutiny, differed from the 1974 plan primarily in the location of routes in the central business district (CBD). The revised routes relieved trolleybus traffic on the only east-west street in the existing system, Pike Street, by providing east-west service on other streets in the CBD. These revisions were made to reduce transfers and passenger walking distances. Only minor changes were made in the wire plan outside the CBD. As a result of these proceedings, a final electrification plan was established in November 1975 (see figure II-6). The City Council approved this plan on Jan. 29, 1976.

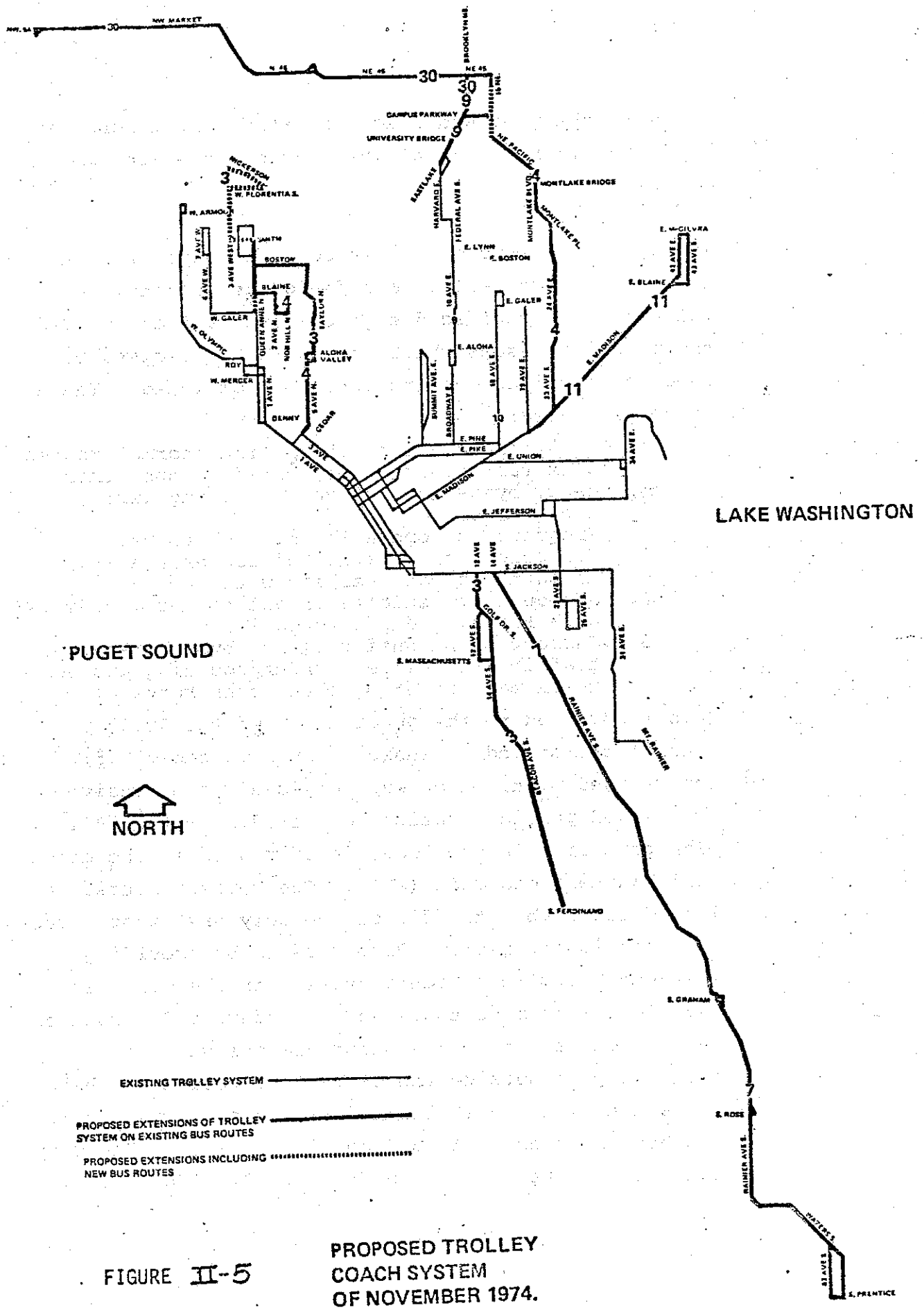
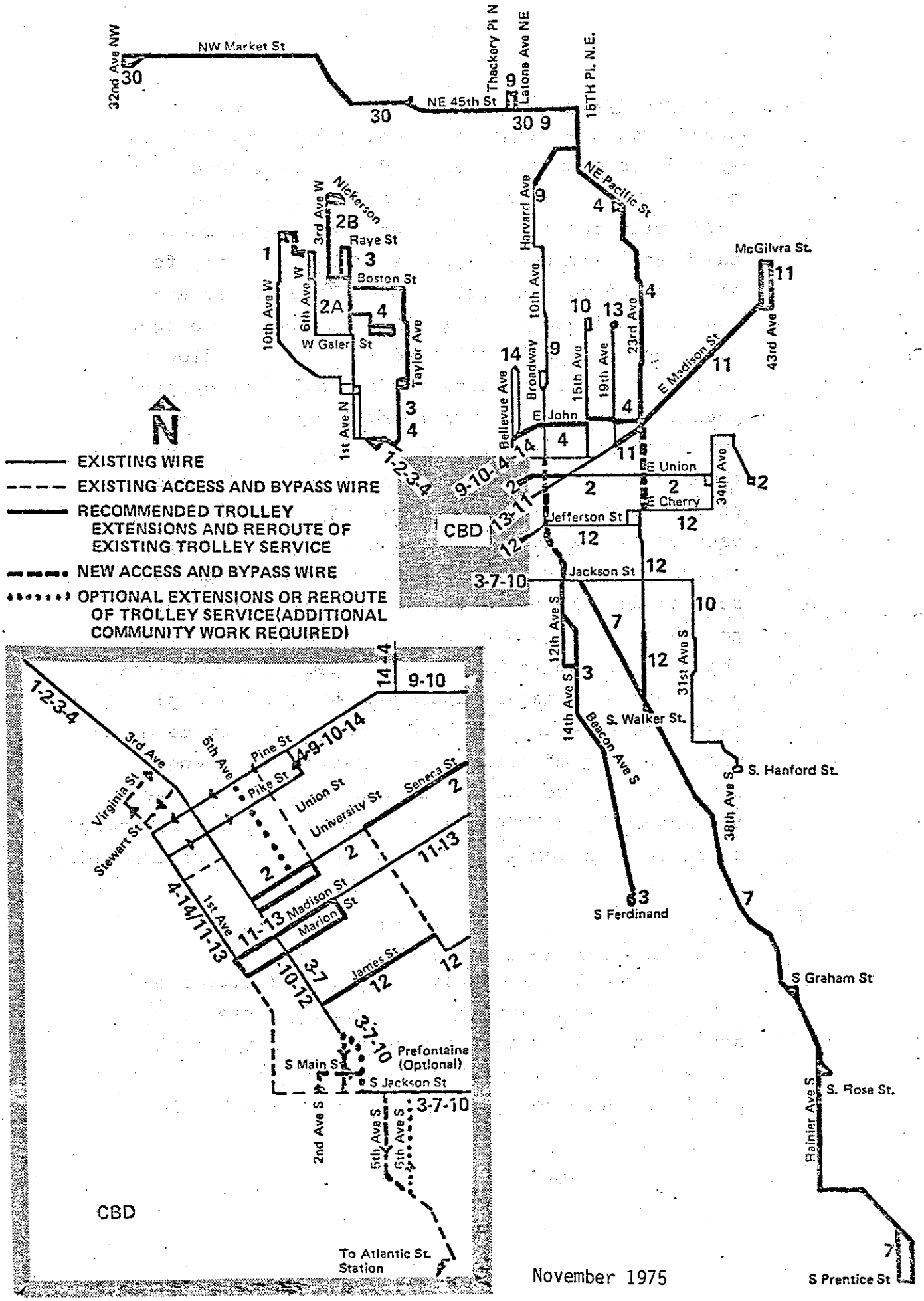


FIGURE II-5

PROPOSED TROLLEY COACH SYSTEM OF NOVEMBER 1974.



November 1975

REFINED PLAN FOR

FIGURE II-6 RECOMMENDED TROLLEY SYSTEM

4. Implementation

Except for the deletion of one route (No. 11) the system was generally designed and built according to this plan. However, it was not until Aug. 1, 1977, with the signing of the first supplement to the Transit Transfer Agreement that the city formally agreed to the routes to be electrified and thus established the "final" wire map for design. But even then there followed a continuous flow of requests for minor route revisions, revised special work intersections, turnaround locations, etc., during the entire duration of the project. Even as the final contracts were being closed out, several revisions were being contemplated. In most every case there was sound reasoning for making these revisions, however the lack of timeliness in the request for these revisions was often detrimental to the schedule and budget of the project. From this experience it has been learned that even after a project wire map is approved, the detailed plan requirements still may need intensive study to minimize "midstream" design and construction changes. However, some revisions will be inevitable. Even Mr. Anderberg's 1940 system underwent "after planning" revisions, primarily after the system was constructed.

C. SCHEDULE

1. Background and Initial Schedule

The trolley overhead program, being multifaceted, required a large variety of carefully prepared schedules. These included schedules for overall planning, design, construction, material procurement and individual contracts. The initial schedule

revealed Metro staff's optimistic hopes and incomplete understanding of the scope of the program. It was initially envisioned during the early planning stage in late 1974 that it would take approximately two years to complete the program from the beginning of design to the end of construction.

The first detailed schedule was to have been included in the Configuration Study (which was otherwise completed in April 1976). However, preparation of the schedule was at first delayed pending final selection of the expansion trolley routes by the city, and the establishment of a trolleybus delivery schedule. When it became apparent that these issues were not going to be resolved soon (see paragraph IIB4 and item 2f below respectively) the consultant was finally permitted to establish the first formal, detailed schedule on July 12, 1976. Assumptions were made regarding the final expansion plan and trolleybus delivery where necessary. This schedule required careful planning for each segment of the work. The interrelationships between work segments, had to be considered so that each would be completed in a timely fashion. The major goal was to minimize the shutdown period of the existing trolley routes and to place the new trolleybuses into service as soon as they arrived and were accepted. With these general goals established and with more complete knowledge of the project details, it was then projected that slightly more than three years would be required to complete the project.

2. Dividing the Work

The project was divided into two major segments called "rehabilitation" and "expansion." The rehabilitation

segment included all work necessary to restore the existing 32-mile trolley system, which was in operation when Metro took over the transit system in January 1973. The 23-mile expansion segment included all work necessary to electrify a selected number of existing diesel routes. The city concurred with the expansion route selections after extensive analysis and public hearings. This division was necessary because the funding arrangement was different for rehabilitation and expansion (see section IIE).

The rehabilitation and expansion segments were further divided separating overhead work and substation work. The construction was then further divided into contracts which were selected based on the following considerations:

a. The shutdown and start-up of each trolley route was to be accomplished in phases to minimize the impact on the existing system. Therefore, each contract was to include all the work necessary for a complete route or routes.

b. The contracts were to be of an optimum size for favorable bidding competition (considered to be about one million dollars).

c. The first contract was to be scheduled well ahead of the others and encompass as great a variety of overhead work as possible. This would be the "learning" contract to provide knowledge and experience for everyone involved.

d. The lead times for some materials items were found to be very long. Therefore, to prevent delays from lack of certain materials--rectifiers, wire and cable, overhead hardware--separate material procurement contracts were planned.

e. Substation contracts had to be apportioned and scheduled to be completed before or at

the same time that the respective overhead sections to which they would provide power were completed.

f. Although trolleybus procurement was handled separately, the routes were to be ready for electrification as soon as the necessary number of buses were delivered and accepted. A general shortage of buses prevailed in 1976. Therefore, it was urgent that new trolleybuses be put into service immediately. (It should be noted here that problems with trolleybus procurement had already caused a slow down in the project. Bids for articulated trolleys had been opened on April 27, 1976. Although the bids were considerably higher than expected, it was not conclusive to the Metro staff that the articulated trolleys would not be cost effective at the prices bid. However, some city officials were also nervous whether articulated trolleys were suitable for the program. As a result, the city refused to concur in the purchase of the articulated trolleys and the bids had to be rejected. It was then determined to call for bids for the manufacture and delivery of standard trolleys with the bid opening scheduled for June 1976. However, before that happened, UMTA required Metro to participate in a joint purchasing contract with the Southeast Pennsylvania Transit Authority (SEPTA). This further delayed the bid opening until March 1977.)

Table II-3 shows the final breakdown of contracts after some adjustments and combinations were made during the course of the program. Table II-4 shows which contracts had to be completed before each route could be started. The construction schedule history is illustrated in figure II-7.

3. Schedule Revisions

a. The first schedule revision occurred in January 1977 when the decision was made to shut down the entire existing system during the rehabilitation

Table II-3: Trolley Overhead Project
Breakdown of Contracts

		Description	Contract Number	Notice to Proceed	Specified Completion Date	Actual Completion Date
MATERIALS		Design	(Task B)	4/76	10/76	12/76
		Manufacture:				
		Rectifiers	T9A	5/77	1/79	1/81 /1
		Overhead Hardware	T12A	7/77	7/78	7/79 /2
		Wire and Cable	Various	4/77	10/77	10/77
REHABILITATION	Sub-stations	Design	(Task C)	4/76	3/78	3/78
		Construction	T15A	3/78	12/78	10/79
		"	T17A	5/78	12/78	4/79
		"	T19A	7/78	3/79	6/79
	Overhead	Design	(Task D)	4/76	10/77	2/78
		Construction	T4A (R1)	1/78	12/78	8/79
		" (Combined)	T5A (R2)	1/78	12/78	8/79
		"	T8A (R5)	1/78	12/78	9/79
		" (Combined)	T6A (R3)	6/78	1/79	2/80
		"	T7A (R4)	6/78	1/79	11/79
EXPANSION	Sub-stations	Design	(Task E)	4/76	10/78	8/79
		Construction	T27A	3/79	9/79	11/79
		"	T28A	7/79	1/80	6/80
		"	T25A	11/79	5/80	7/80
	Overhead	Design	(Task F)	4/76	10/78	12/79
		Construction	T20A (E9)	7/79	7/80	6/80
		" (Combined)	T23A (E11)	1/80	8/80	8/80
		"	T24A (E8)	1/80	12/80	2/81
		" (Combined)	T21A (E7)	2/80	12/80	5/81
		"	T22A (E10)	2/80	12/80	5/81

/1 Extended because of extra work, field testing and field modifications.

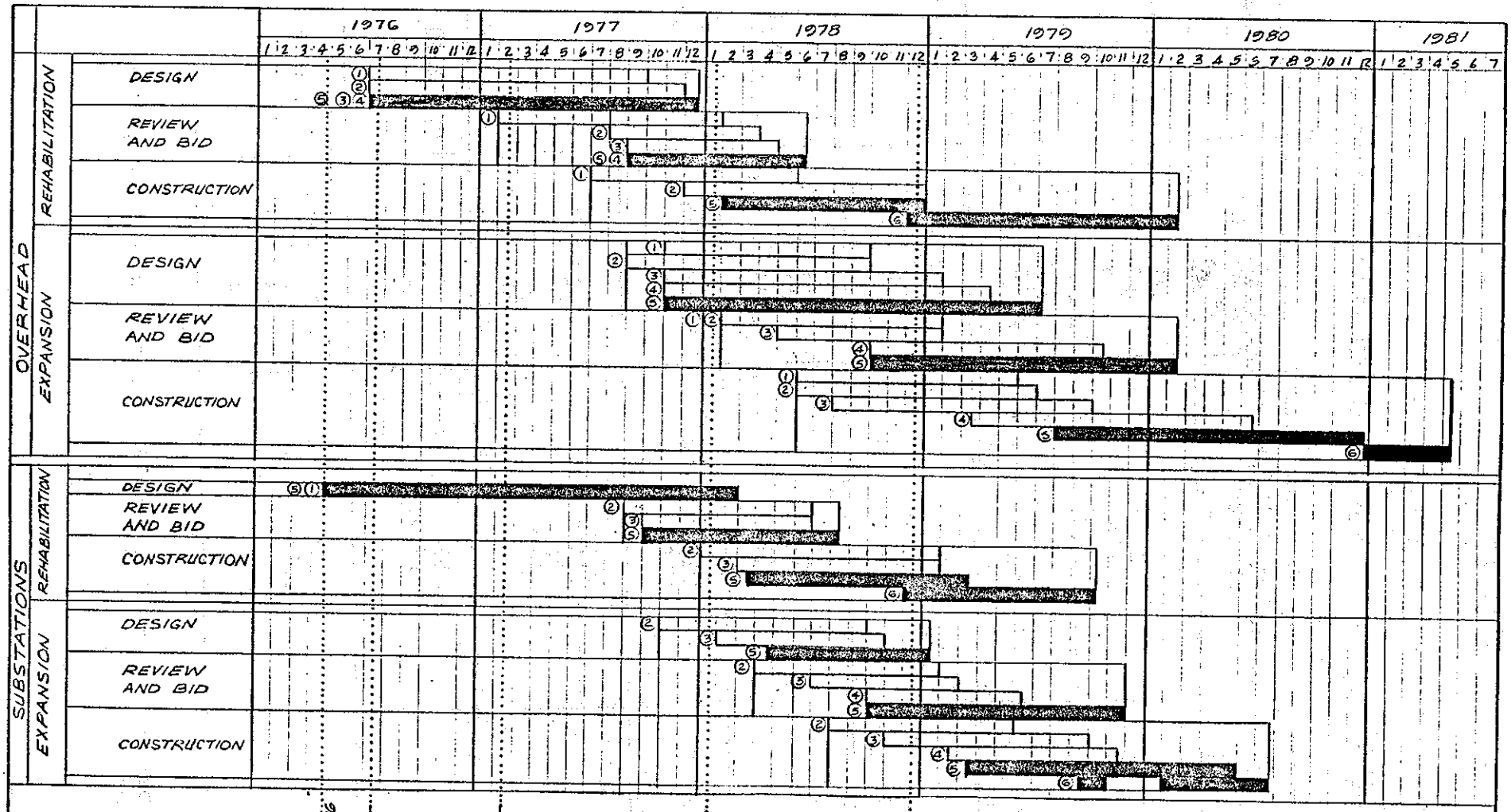
/2 Extended because of increase in quantities after award.

TABLE II-4:

TROLLEYBUS ROUTES AND RESPECTIVE CONSTRUCTION CONTRACTS

Route Number	Related Construction Contracts		Actual Route Start-up Date
	Substation	Overhead	
2	T15A T17A T19A	R1 R2 R5	9/15/79/1
10	T15A T17A	R3 R5	
13	T15A T17A T19A	R1 E9 R2 R5	5/24/80
14	T15A T17A T19A	R3 R4 R5	
1	T15A T28A T19A	R4 E11 R5	9/13/80
3 4	T15A T17A T19A	R1 E9 R2 R4 R5	
7	T15A T27A T17A T19A	R3 E8 R4 R5	2/81
43	T15A T25A T19A T28A	R1 E7 R2 E8 R3 E10 R5	5/81

/1 Shut down between 3/28/80 and 5/24/80 for repair of lightning-caused damage.



DESIGN	DRAWN	DIVISION	MUNICIPALITY OF METROPOLITAN SEATTLE	DATE
LLW	LLW	TROLLEY OVERHEAD	PROGRAM SCHEDULE HISTORY	2-10-81
				FILE NO. 20
				SHEET FIG II-7

1020775

construction. This decision consequently cancelled two basic premises upon which the initial schedule was based. First, the overhead construction contracts had been scheduled in phases to minimize the impact of the shutdown (i.e. keep as much of the system running at any one time and reduce the number of diesel buses required to substitute for the trolleys). Second, the initial contract was to have been awarded well ahead of the others to allow Metro and the consultant time to gain valuable knowledge and experience which could be applied to the remainder of the contracts. As a result the design consultant had to redirect his efforts toward completing all of the five overhead rehabilitation contracts at one time. The decision to change to a total shutdown was made because the complications involved in the phasing out and phasing in of the trolley routes were difficult to overcome, primarily due to the terms of the contract between Metro and the drivers' union. The shutdown period was then scheduled for one year, between January 1978 and January 1979. The start of construction was delayed for five months.

b. The next schedule revision came in January 1978. The selection of the expansion trolley routes had finally been made by the city and the contract for the manufacture and delivery of the trolleybuses had been awarded. With this information finally available, it was felt that a firm program schedule could now be established. The revised schedule showed that the start of

construction had been delayed another two months, attributed largely to last-minute changes in some of the wire configurations at intersections. Of greater importance, however, was the fact that it had been decided in mid-1977 to begin "through routing" of many of the routes. This concept combined two routes into a single route by connecting them in the Central Business District. Thus, a bus on the new route would operate inbound on one of the old routes, "through" downtown and then outbound on the other old route. Unfortunately, several of the route pairs combined a trolley rehabilitation route with a trolley expansion route. As a result, two of the old rehabilitation routes could not be re-started by the scheduled date even if the construction schedule was met. The total delay for these routes was estimated to be six months. In an effort to electrify these routes without further delay, the overhead expansion contractors were required to assign higher priority toward the completion of those portions of the contracts which completed a new "through" route.

Although some time had been lost, it was still considered mandatory that the rehabilitation contracts be completed by the end of the shutdown period in January 1979. The result was that the specified construction periods for the contracts were shortened to meet the scheduled start-up date.

c. Shortly after construction had begun, it became obvious that even the revised schedule was in trouble. The number and variety of problems were large, some of which (such as subsurface interferences and overhead utility conflicts) should probably have been foreseen. Others were unforeseeable, such as shortages of qualified electrical linemen and the refusal of building owners to grant building eyebolt permits. These problems and their impact are discussed in more detail in section IV-C of this report. By the end of 1978, there was no longer a schedule for the rehabilitation contracts other than completing them as soon as possible. The first contracts were completed nine months after the scheduled completion date, permitting the start-up of two routes in Sept. 1979. However, it was not until Feb. 1980 that the final rehabilitation contract was completed--13.5 months behind the revised schedule.

The above discussion focuses solely on overhead construction because it was that portion of the work which delayed the project the most. But, it should be noted that other portions of the project were delayed as well. Delays in the substation contracts would have postponed the completion of the rehabilitation project by at least seven months. The late delivery of the trolleybuses would have delayed start-up at least eight months. There was one noteworthy scheduling success. The early and separate procurement of some of the materials and equipment, including the rectifiers, overhead hardware, guy wire and electrical cables assured that these materials were usually available when needed.

d. Resolving the problems encountered during the rehabilitation project took an enormous amount of unanticipated time away from the Metro staff and the design consultant which should otherwise have been spent on the expansion project. Therefore, the expansion schedule began to slip as well. It was a problem that could not be remedied by increasing staff because of the time required to train them. Also, Metro implemented new review procedures which involved a much more thorough inspection of the design and field conditions. It was hoped that the unexpected field problems could be reduced. Other adjustments and provisions were made in the specifications and construction inspection. The result, as illustrated in figure II-7 was a much longer review and bidding period--six months longer than originally scheduled. However, construction proceeded much more smoothly with no construction time extensions. It is unknown whether any total program time was actually saved by these more extensive review and contract control procedures, since advertising the contracts was delayed. It may have been an equal trade for the construction time extensions that would have been required to resolve unexpected field problems.

4. Results and Analysis

The final result was that it took nearly five years after the predesign report to complete the overhead program which was scheduled to have been completed in slightly more than three years. The explanation, like the program itself, is a sum of many small elements,

all of which are interrelated. But perhaps the primary reason was the lack of modern-day experience with a comparable program. This lead to overly optimistic scheduling and a lack of complete understanding of what problems might be encountered. But, how could a bigger program be completed in slightly more than a year in 1940? Again, the reasons are varied and numerous including: a different type of system; more available experience; a war-time atmosphere with greater urgency and much less sensitivity to public involvement; a transit organization that was part of the city; construction performed by in-house labor rather than by contract; fewer construction rules and regulations; etc. Also, in 1940, by working so quickly there was less time for the route planners to come up with changes. But they did catch up. As a result, in Mr. Anderberg's own words: "the engineering of the project did not stop when the last line was cut over....after the system was in operation it was evident that additional loops, turnbacks and extensions were necessary. The feeder distribution system had to be rebalanced as the routes and headways were changed."(1)

Future scheduling of trolley overhead program should improve with the experience gained from this project. However now, as in 1940 and earlier, scheduling a program with this many bits and pieces, with multiple agency involvement having varying degrees of urgency and commitment, will remain as much an art as it is a science.

D. RELATIONSHIPS AND AGREEMENTS WITH OTHERS

1. Intradepartmental

The organizational charts, figures II-1 through II-3 of section II-A, show the functional relationship of the various divisions within Metro which were involved in the program. No formal agreements were established between the departments regarding the program. Policy, procedures, methods, work requests, etc., were established by memorandum, generally as needed. This lack of formal structure in the beginning of the program did lead to some problems of understanding during the course of the program. Probably the most critical problem arose when the transit department's maintenenace group was requested to take over portions of the system as they were being completed in late 1979 and early 1980. They initially refused, citing numerous objections to some of the construction details, maintenance situations and substation equipment reliability and safety. Gradually these problems were resolved as various modifications were agreed upon and incorporated into the system. But, there were periods when portions of the system were actually placed into service while the trolley overhead construction section still had maintenance responsibility. Even at the time of this writing, with the entire system in operation, the construction section still had the maintenance and repair responsibility for all the rectifiers and switchgear. It is anticipated that the transit department will take over complete responsibility for operating and maintaining the system during the summer of 1981.

This problem clearly illustrates that Metro was becoming too complex an organization to rely on the

"one big, happy family" approach to conducting internal business. Unfortunately, in this case, there was no written agreement between the technical services department and the transit department, establishing in detail the system acceptance criteria.

2. City of Seattle

The organization outside of Metro which had the greatest involvement in the project was the city of Seattle. The formal relationship began in December 1972 with the completion and signing of the Transit Transfer Agreement (2). One provision of this agreement obligated Metro to continue the operation of the existing trolley system and left open the option to expand the system. The city later requested expansion of the trolley system and agreed to provide the funds for the local matching share for this portion of the program being funded by the Urban Mass Transit Administration (UMTA). The grant application was subsequently amended to include the expansion project. On Aug. 1, 1977, the first supplement to the Transit Transfer Agreement was adopted, which defined the expansion program in detail and the terms by which the city's funds were to be provided. This agreement was again amended on March 6, 1980, by the second supplement which increased the project budget to cover unexpected cost increases. When the project moved into the preliminary design stage, there was little involvement at the staff level by the city although the city was asked to participate in developing the scope of work, design criteria and consultant selection. After construction got under way it became apparent that the Seattle Engineering

Department would have to play a very active role. One of the major reasons was that the city was proceeding with several street improvement and utility undergrounding projects, many of which were on streets where the overhead trolley wire was to be installed. To minimize the construction impact and the proliferation of utility poles, detailed coordination was required between the projects which resulted in a series of memoranda of agreement, an example of which is included as appendix A.

Implementing the Transit Transfer Agreement, memoranda of agreement, permits, reviews, and other activities became a complicated task. Metro realized early in the program that a single-person contact in the Seattle Engineering Department was needed to facilitate all of these coordination needs and, in a letter from the executive director to the Mayor, requested that a city coordinator be appointed. Initially the city's coordinator only served on a part-time basis. As the project proceeded and more problems and complications developed, it became apparent that a greater level of involvement by the coordinator was necessary to avoid further delays. A full-time coordinator with expanded authority was appointed by the city on November 1978.

3. Joint Use Poles and Utility Conflicts

Any public works project on an urban street will encounter conflicts with the existing utilities. Installing trolley overhead wire and hardware, in this regard, created particular problems in defining the spatial arrangements of the various utilities which must share the public right-of-way. First, a

large number of support poles had to be located to clear underground utilities and not encroach upon specified areas around fire hydrants, trees, wheelchair ramps, etc. Second, the overhead trolley wire must be a certain height above the roadway, below which no other wires may cross. Other overhead utilities such as power, telephone and cable TV lines often had to be relocated to clear the trolley overhead wires and hardware. Traffic signals also posed particular conflict problems. The existing procedures for resolving these problems were relatively simple and involved only the maintenance and operation personnel of the various utilities. These procedures were soon found to be inadequate for a major project of new construction. Therefore, the following procedures and criteria were developed as the program progressed:

a. The city developed and implemented pole placement criteria in January 1979. Since then, many additions and modifications have been made to the criteria.

b. Poles to be jointly used by Metro and the Seattle Engineering Department required a joint-use pole agreement, consisting of a sketch and construction notes. Initially, the city engineering staff was assigned preparation of these sketches. However, progress was too slow for Metro's needs. Finally, the Metro staff took over the sketch preparation and submitted them to the city for review and concurrence. Example sketches are included as appendix B.

c. Traffic signal interference was a critical problem which was initially handled in the field. Procedures evolved and were later confirmed by letter on April 3, 1978, included as appendix C. Later it was decided to have the consultant provide traffic interference sketches which were forwarded to the city to identify for them the scope of the interferences in advance of construction. Examples of these sketches are included as appendix D.

d. Probably the most strained relationship with another utility was between Metro and the telephone company. Numerous conflicts were encountered in non-undergrounded areas because the telephone company generally occupies an area on the poles or over the streets at about the same height as trolley overhead. A history of this development is included as appendix E. The problems were eventually resolved by the well defined procedures contained in a three-way agreement between Metro, City Light and Pacific Northwest Bell which was finally adopted in January 1980.

4. Miscellaneous

Like any public works project, the trolley overhead program required a number of permits and approvals from a variety of agencies and organizations including the Seattle Design Commission, the Seattle Water Department, Washington State Department of Transportation, University of Washington, and others. None of the transactions were unique as the procedures of these organizations were well established and required only routine compliance by Metro.

E. BUDGET

1. Program Cost Estimates

Metro faced the same dilemma in estimating the cost of the project as it did in trying to establish a project schedule: the lack of experience from a recent comparable project. The project manager in June 1978 described the situation in a file memorandum:

> "There was no body of cost data available for estimating this type of work and no one has ever built a system using the neighborhood rectifier concept.
>
> We found one contract in San Francisco for construction of a small piece of overhead. The only other figures available were the estimating figures used for maintenance work. This data had too limited a base on one hand and it conflicted with itself on the other.
>
> Additionally, there are no 500 KW traction rectifiers available on the market. Different manufacturers quoted us list prices of $50,000, $100,000 and $150,000 per unit for the same units. The Ohio Brass Company gave us a catalog price of $1,175 for a switch and less than a year later bid the switch at $1,922."(20)

The earliest program estimate was made in February 1974, which covered only the rehabilitation of the existing system. Admittedly, it was no better than a guess. The history of the cost estimate increases is shown on table II-5 which includes a discussion on the reasons for the increases.

It is interesting to note that as time went on and the scope of the program became better understood and the estimate was broken down in more detail, the total estimate correspondingly increased.

Table II-5: History of Program Cost Estimates

Date	Description	Estimate	Remarks
Feb. 74	Rehabilitation Construction	$ 3,311,000	Very cursory, no reliable cost data available.
March 74	Rehabilitation Construction Expansion Construction Total	4,115,000 4,700,000 $ 8,815,000	1. Based on Feederless system concept. 2. Cursory field surveys revealed potential problems. Some support poles had been removed.
May 75	Rehabilitation Construction Expansion Construction Total	7,307,300 6,808,700 $ 14,116,000	(Reference 12) 1. More detail in estimate. 2. High cost escalation in steel pole prices. 3. Greater than anticipated inflation. 4. Reliable estimates for rectifiers were unavailable.
May 76	Engineering Materials Rehabilitation Construction Expansion Construction Total	1,500,000 5,067,000 7,170,000 5,983,000 $ 19,720,000	1. Added $1,000,000 for CBD feeders. 2. Added $2,200,000 for inflation. 3. Added $1,600,000 to cost of substations for property, site work, larger rectifiers, etc. 4. Added remainder for miscellaneous items.

Table II-5: History of Program Cost Estimates Continued

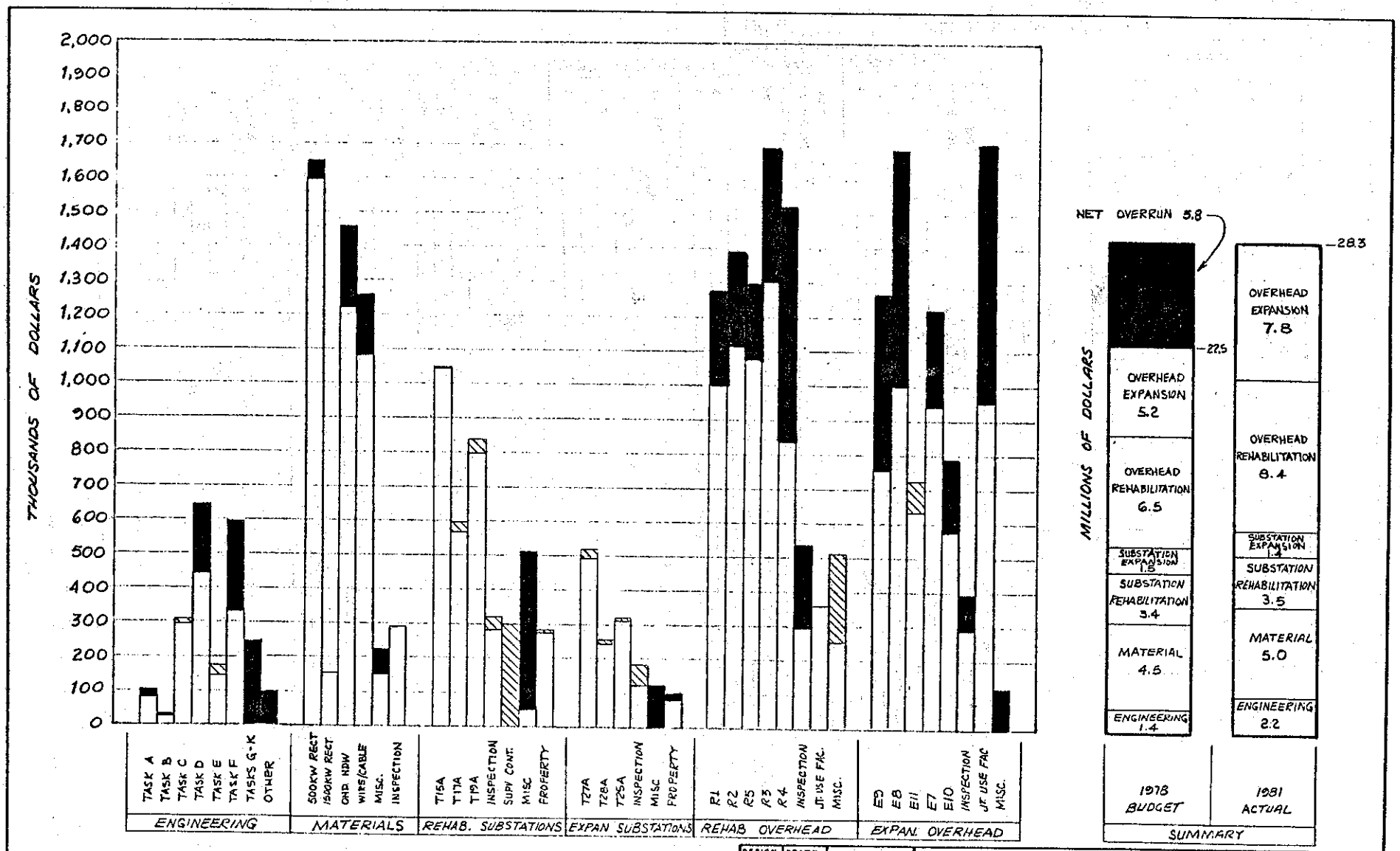
Date	Description	Estimate	Remarks
March 78	Engineering Materials Rehab. Substation Construction Rehab. Overhead Construction Expan. Substation Construction Expan. Overhead Construction Total	1,700,000 4,500,000 3,400,000 6,500,000 1,500,000 5,200,000 $ 22,800,000	1. Higher than anticipated inspection costs (3% expected, 12% actual) 2. Joint use pole costs were found to be a high cost item. Added $1,600,000. 3. Continued inflation at a level higher than expected.
Feb. 79	Engineering Materials Rehab. Substation Construction Rehab. Overhead Construction Expan. Substation Construction Expan. Overhead Construction Total	1,894,000 4,906,000 3,400,000 9,900,000 1,500,000 8,800,000 $ 30,400,000	1. Extensive field problems requiring many expensive change orders. 2. Expansion contract bids were over estimate. 3. Joint Use Pole costs continued to rise. 4. Costs of resolving utility conflicts were higher than expected.
Oct. 80	Engineering Materials Rehab. Substation Construction Rehab. Overhead Construction Expan. Substation Construction Expan. Overhead Construction Total	2,000,000 5,100,000 3,400,000 9,100,000 1,400,000 8,300,000 $ 29,300,000	

The first detailed estimate with some basis came after the rehabilitation contracts were bid in March 1978. Shortly afterward, the field problems began to mount and the contract contingency funds were quickly diminished. These problems, discussed in detail in part IV, were increasing the costs by the same proportion as they were increasing the program time. Figure II-8 graphically shows the breakdown of the cost estimate in March 1978. Also shown are the final program costs.

In late 1978, it became obvious that a critical budget estimate review was necessary. When completed in February 1979, the new estimate revealed that an additional 7.6 million dollars was required--an increase of 33 percent. The increase in overhead construction was actually 49 percent. The Metro Council approved the increase, but charged the staff with the goal of completing the project with only 90 percent of this increase. Figure II-9 shows the same graphic breakdown, with the new budget being compared with the actual costs. The new budget held up and the 90 percent goal was achieved. Unfortunately, the fact remains that the program was nearly constructed before a reliable budget could be established.

2. Program Financing

Funds for the trolley overhead program were provided from a partnership of three sources: the Urban Mass Transit Administration provided grants for 80 percent of eligible project costs; Metro and the city of Seattle providing the 20 percent local share in



DESIGN	DRAWN	DIVISION	MUNICIPALITY OF METROPOLITAN SEATTLE	DATE
LW	LW	TROLLEY OVERHEAD	COST COMPARISON ACTUAL COSTS & 1978 BUDGET	2-17-81
				FILE NO. 20
				SHEET FIG II-8

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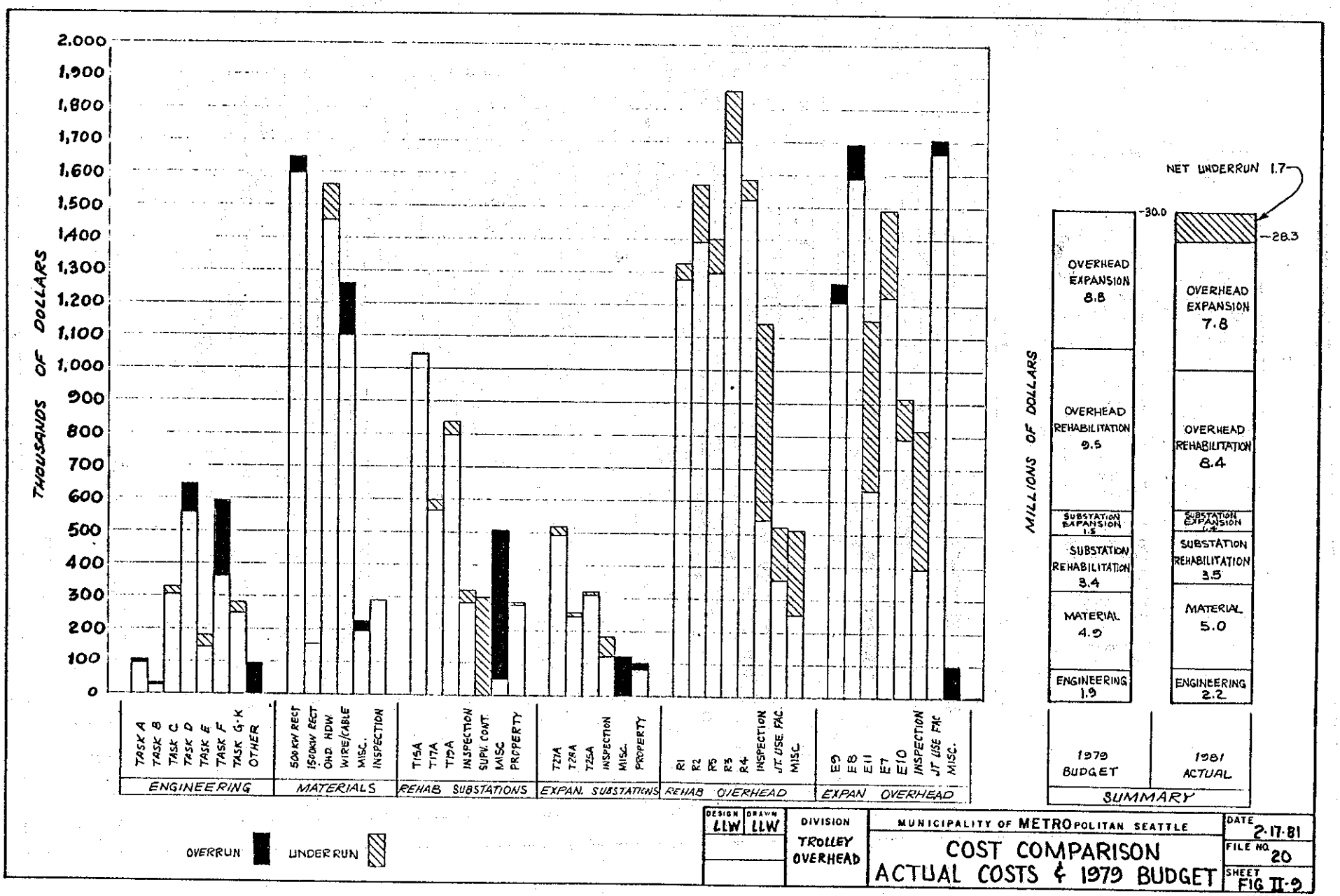

DESIGN	DRAWN	DIVISION	MUNICIPALITY OF METROPOLITAN SEATTLE	DATE
LLW	LLW	TROLLEY OVERHEAD	COST COMPARISON ACTUAL COSTS & 1979 BUDGET	2-17-81
				FILE NO. 20
				SHEET FIG II-9

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accordance with the Transit Transfer Agreement (2). Table II-6 shows the funding sources, a history of the increases and how they were broken down. By comparing tables II-5 and II-6 one may note that there was a considerable lag time between revisions to the program costs and the corresponding revisions to the program's source of funds. Work was able to proceed because UMTA issued letters of no prejudice, which generally assured that grant funds would be available retroactive to UMTA approval of project cost increases.

The funding arrangement was complicated by several factors including the cost sharing agreements with the city, cost accounting differences among the parties and drastic cost increases during crisis situations. All added considerable confusion to the budget history of this program. During the last two years of the program, after a separate division was formed to administer the program, the costs and finances were finally brought into balance.

3. Analysis of Actual Costs

Table II-7 shows the breakdown of actual costs in the categories used during the program for budgets and cost estimates. The costs are separated into three areas: rehabilitation CBD, rehabilitation outlying area, and expansion. The costs per mile for each of these areas were derived by dividing the total cost for each area by the respective number of route miles. Before applying these unit costs to other systems or areas, it is necessary to understand the factors that affected the cost of this program. In summary, some of the major factors were as follows:

TABLE II-6: HISTORY OF PROGRAM FUNDING SOURCES /1

Date	UMTA GRANT (80%) CUMULATIVE		CUMULATIVE LOCAL MATCHING (20%)		CUMULATIVE TOTAL ELIGIBLE AMOUNT
	Number	Amount	City	Metro	
11/73 /2	WA-03-0016 Line hem 10.12.00 (original)	2,578,014	644,504		$3,222,518
9/78	WA-03-0016 Line hem 10.12.00 Amendment 5 (Added $13,501,900)	13,379,534	3,344,884		$16,724,418
4/79	WA-03-0016 Line hem 10.12.00 Transfer of Contingency Funds ($3,813,326)	16,430,195	4,107,549		$20,537,744
3/80	WA-03-0016 Line hem 10.12.00 WA-05-0010 ($4,720,000) WA-03-0031 ($5,080,000)	24,270,195	3,752,000	2,315,549	$30,337,744
10/80	$375,000 for removal of feeder wire deleted from eligible costs.	23,970,195	3,752,000	2,240,549	$29,962,744

TABLE II-6: HISTORY OF PROGRAM FUNDING SOURCES (continued)

Date	UMTA GRANT (80%) CUMULATIVE		CUMULATIVE LOCAL MATCHING (20%)		CUMULATIVE TOTAL ELIGIBLE AMOUNT
	Number	Amount	City	Metro	
Projected as of 3/81	WA-03-0016 Line hem 10.12.00 WA-05-0010 WA-03-0031 (Projected Underrun of $1,685,736)	22,605,604	3,484,997	2,186,407	$28,277,008

/1 Amounts shown are grant eligible costs only. Costs which are not included are Metro's and the City's administrative costs.

/2 Rehabilitation only.

TABLE II-7 TROLLEY OVERHEAD PROGRAM COST SUMMARY
(In Thousands of Dollars)
(as of March 1981)

ITEM	REHABILITATION (32.4MI.) (1978-1979)						EXPANSION (23.4MI.) (1979-1980)		TOTAL (55.8MI.) (1978-1980)	
	CBD FEEDER SYSTEM (7.6MI.)/1		OUTLYING AREA /1 (24.8MI)		TOTAL					
	Amount	$/MI.	Amount	$/MI.	Amount	$/MI.	Amount	$/MI.	Amount	$/MI.
ENGINEERING /2	580	76	756	30	1,336	41	836	36	2,172	39
MATERIALS	1,313	173	1,713	69	3,026	93	2,017	86	5,043	90
SUBSTATION CONSTRUCTION	842	111	2,199	89	3,041	94	1,835	78	4,876	87
OVERHEAD /3 CONSTRUCTION	3,641	479	4,752	192	8,393	259	7,803	333	16,196	290
TOTAL	6,376	839	9,420	380	15,796	488	12,491	534	28,287	507
ADJUSTED 1981 EQUIVALENT COST/MILE		1,000		500		630		630		630

/1 The division of the Rehabilitation Area into the CBD Feeder Area and Outlying Area was not made during the program and, therefore, a cost breakdown for these areas was not readily available. However, from inspection of the various cost items it was determined for illustrative purposes that the costs per mile of engineering, materials and overhead construction in the CBD area were approximately 2.5 times those costs for the outlying area and the substation construction costs were 25% more in the CBD area.

/2 Engineering costs shown include the consultant's maximum claim. These amounts may change upon the final resolution of the consultant's claim (see subsection III-C).

/3 Construction Costs for the overhead wire at the central operating base are not included. The installation of the overhead wire at the base was part of a separate program which constructed Metro's new transit operations and maintenance bases.

a. The rehabilitation portion required work in an area where there was little recent experience to guide the designers, project managers and contractors. Although the construction in the rehabilitation area had the advantage of the prior existence of trolley overhead, many unanticipated problems were encountered. Because of this lack of previous experience there were no quick, inexpensive solutions. (See paragraph IV-C5.)

b. The CBD feeder system used equipment and facilities from the old system. An all new system would have been much more expensive. (See subsection IV-B.)

c. The design and cost of the CBD system is not mutually exclusive from the outlying area. If the outlying area is significantly expanded then some additions and modifications to the CBD system will probably be required.

d. Not all the CBD portion of the program constituted replacement of the existing system. There were some route changes that involved installing overhead on streets where trolleys had not recently operated.

e. A portion of the power from the "rehabilitation" substations provides a significant amount of power to the "expansion" routes. Therefore, the costs shown in table II-7 for substations have been adjusted to reflect this (also see table IV-3).

f. A significant portion of the expansion overhead construction was performed concurrently with several city undergrounding projects. Although some costs were saved in sharing steel poles and other facilities, these costs were still much higher than what would be expected for an outlying area system supported by wood poles.

Other factors are discussed in more detail in Section IV.

III. BASIC SYSTEM DESIGN

A. CONSULTANT SELECTION

1. Scope-of-Work

After the completion of the initial planning and environmental impact proceedings in 1974, Metro staff began work on scopes-of-work for the predesign and design portions of the program. It was decided that the amount of design work required for this program was too great to be efficiently accomplished by Metro staff. Therefore, the services of a design consultant were solicited. The scopes-of-work were prepared on that basis.

The initial scope-of-work described the work in very general terms to ensure that all aspects of the work would be covered. No one at that time knew all the details of this type of program well enough to write a comprehensive description of the work to be done. It was envisioned that the scope-of-work would periodically be revised during the course of the predesign and design portions of the program to specifically identify and define the work as more information was developed (21).

2. Consultant Selection Procedure

In February 1975, upon completion of a draft scope-of-work, Metro advertised for interested consultants. The scope-of-work was made available on request and the responding consultants were asked to submit brochures, statements of qualifications and other information about their firms. The 10 firms that responded were then evaluated using the following criteria:

a. Does the firm/team have qualifications and interest for this type and scope of work?

b. Is the firm/team available to do all phases of this work, including rehabilitation and expansion?

c. Does the firm/team have past performance and experience with similar work with references?

d. Does the firm/team have a depth of professional ability in-house to satisfactorily complete all elements of the work within the time available?

e. Is this a local firm/team?

Concurrently, a consultant selection board was formed to review the applicants. The board consisted of the technical services department director, the transit technology division manager, a representative from the transit department and a representative from Seattle City Light.

The board, except for the City Light representative, met on March 3, 1975, to review the evaluation and the information submitted by the firms. As a result of that review, six firms were selected for further consideration and asked to make an oral presentation. The presentations were made on March 19, 1975. The board met immediately thereafter to deliberate and select the design consultant.

3. Evaluation and Selection

By unanimous agreement the board was able to eliminate two firms from further consideration. An unofficial poll was then taken to develop a ranking of the firms. A general consensus was found immediately. The top three firms were, in order:

a. R. W. Beck and Associates (of Seattle)

b. Steven, Thompson and Runyun (of Seattle) with International Engineering Co.

c. R,B,Q & D, Inc., (of San Francisco) in conjunction with Kramer, Chinn and Mayo (of Seattle)

R. W. Beck and Associates was selected because of their local base, extensive in-house facilities and capabilities, experience in DC electrical design and their association with a consultant with considerable experience in the design, construction and operation of a trolley overhead system. They were formally notified of the selection April 3, 1975, and contract negotiations began shortly thereafter. The negotiations were completed and on June 26, 1975, the Metro Council passed Resolution 2319 authorizing the agreement.

B. CONTRACT

1. Features

The contract between Metro and the consultant (13) contained the normal provisions for an agency/consultant contract for a project funded in part by a federal administration, in this case UMTA. There were some noteworthy provisions, however, which included the following:

a. Scheduling

The work was divided into separate tasks (see table III-2) for which separate notices to proceed could be given. This provided some flexibility for cutting back or revising the scopes of work if necessary (subsection 3A). Twenty days after Metro issued a notice to proceed for a particular task, the consultant was required to "submit a detailed and updated development schedule" for that task (subsection

2A). Once the completion dates were established by these schedules, they could only be extended by mutual agreement and only for "conditions beyond the control of the consultant" (subsection 3B).

b. Payment

The consultant was to be paid "on a cost plus fixed fee basis" not to exceed the maximum amount of $1,305,000. Maximum amounts for each individual task were also established. However, upon completion of all tasks, if the consultant exceeded the maximum for any task, any unused amounts from other tasks could be applied toward the overrun as long as the maximum amount for the total contract was not exceeded (subsection 4A). A maximum payment schedule was also established for the fixed fee with the understanding that adjustments could be made in the fixed fee to correspond with any adjustments made in the project maximum payment schedule (subsection 4C).

c. Provisions for Changes

Additional work or deletions of portions of the work could be directed by Metro. Prerequisite to the final authorization of any addition or deletion would be a written agreement between both parties which established any necessary adjustments to the maximum payment schedules for the design work and the fixed fee (subsection 6B and 6C).

d. Ownership of Documents

Metro was to have ownership of all documents developed and produced as a result of the contract (Section 11).

e. Scopes-of-Work

Scopes-of-work for both the consultant and Metro were attached as Exhibit A to the contract. Both scopes-of-work contained individual scopes-of-work for each task. Because the expansion portion of the program was still contingent upon a plan to be adopted by the city of Seattle and approved by UMTA, it was stressed that the expansion tasks and expansion portions of other tasks were tentative.

The descriptions of the work for each task remained very general. The details were still not well enough known for a detailed, comprehensive scope-of-work to be written. As previously mentioned, Metro had reserved the right to issue separate notices to proceed for each task and to add or delete work if necessary. It was envisioned that the period of time before the issuance of each notice to proceed would be used to evaluate and revise the scopes-of-work for the remaining tasks based on the experience from the previous tasks. It would also provide a convenient time to review the budget, expenditures and cost estimates, and to determine if any portion of the work should be deleted or reduced in scope if necessary without creating complications with the contract (21).

f. Summary Cost Estimate

Exhibit D to the contract was a summary cost estimate that broke down the estimate for each task into salary, overhead fee, expenses, subconsultants and contingency. The contingency was relatively large ($263,768) to provide for expected but not yet identifiable changes and additions.

2. History of Contract Revisions

a. General

Throughout the course of the contract, many revisions were made by a variety of means. Table III-1 summarizes the revisions and shows the corresponding changes in the total contract budget.

b. May 1975 to October 1975

Although the Metro Council had approved the contract on June 26, 1975, further negotiations were necessary to revise the contract to comply with UMTA requirements. This lengthy process resulted in addendums Nos. 1 and 2. In accordance with UMTA requirements addendum No. 2 deleted the large contingency amount established for anticipated changes and additions to the contract. As a result, a statement was added

TABLE III-1: HISTORY OF CONSULTANT CONTRACT REVISIONS AND BUDGET CHANGES

DATE	TYPE OF REVISION	DESCRIPTION	BUDGET	
			CONTRACT AMOUNT	REMAINING CONTINGENCY
6-25-75	-	Original contract, Council Resolution 2319	1,041,232	263,768
7-15-75	Addendum No. 1	Added sections regarding Cost of Living and Minority Business Enterprise	-	-
10-3-75	Addendum No. 2	Deleted contingency from contract to satisfy UMTA requirements but contingency remained in Metro's budget. Added statement regarding the assumptions made to establish the contract amount and the need to reevaluate the scopes-of-work and amounts after the Task A Configuration Study	1,041,232	263,768
1976	5 Change Orders	Additional planning and public meeting support work and extra printing of documents. ($12,815)	1,054,047	250,953
9-1-77	Amendment No. 1 Addendum No. 3	Scopes-of-work revised to more specifically describe the work and to provide for additional work. Budget increased $192,166 for additional work, project delay and increase in consultant's overhead rate. ($319,934 added to Contract and $127,768 deleted from contingency)Council Resolution 2819	1,373,981	123,185

TABLE III-1: HISTORY OF CONSULTANT CONTRACT REVISIONS AND BUDGET CHANGES (cont.)

DATE	TYPE OF REVISION	DESCRIPTION	BUDGET	
			CONTRACT AMOUNT	REMAINING CONTINGENCY
1977	15 Change Orders	Changes in CBD rectifier stations, trolleybus characteristics, wire plan, Central Operating Base overhead design study, extra printing and miscellaneous. ($63,624)	1,437,605	59,561
2-16-78	Change Order	Added Central Operating Base overhead design ($51,800 + $13,200 contingency) Council Resolution 2936	1,489,405	85,761
5-18-78	Amendment No. 2	Added Engineering assistance during construction, tasks G,H,J & K ($128,000 + $13,000 contingency) Council Resolution 2950	1,617,605	85,761
1978	25 Change Orders	Wire plan changes and additions, engineering assistance during construction, extra printing and miscellaneous ($65,000)	1,682,715	20,651
3-1-79	Amendment to Resolution 2950	Increase contingency for engineering assistance during construction ($191,000 contingency) Council Resolution 3125	1,682,715	211,651

TABLE III-1: HISTORY OF CONSULTANT CONTRACT REVISIONS AND BUDGET CHANGES (cont.)

DATE	TYPE OF REVISION	DESCRIPTION	BUDGET	
			CONTRACT AMOUNT	REMAINING CONTINGENCY
1979	14 Change Orders	Wire plan changes and additions, engineering assistance during construction, extra printing and miscellaneous ($166,370)	1,849,085	45,281
1980	3 Change Orders	Miscellaneous ($5,795)	1,854,880	39,486
January 1981	-	Consultant Claim for overruns negotiations in progress (345,419 overruns - 122,239 underruns = 223,180 net overruns)		

that acknowledged the probable need for additional work and corresponding adjustments in the design fee. The consultant was finally given notice to proceed with the first phase of the work--the configuration study, Task A--on October 3, 1975.

c. November 1975 to September 1977

When notice to proceed for the configuration study was issued, the preliminary planning and public hearings for the program plan refinement were still in progress. The extent of the expansion portion of the project had not yet been determined by the city of Seattle. By March 1976, it was recognized that the consultant had been delayed bacause of the delays in completing the route information and design criteria (see subsection IV-A). A change order was issued to increase the maximum allowable payment for task A for the extra work required of the consultant. Task A was compelted and the final report (10) issued on April 16, 1976, 42 days after the scheduled completion date of March 5. However, one item remained incomplete. The critical path method (CPM) schedules required for the remaining tasks could not be completed because a schedule for the delivery of the trolleybuses was not yet established (see paragraph IIC-2f). Also, the city still had not made the final selection of expansion routes (see paragraph IIB-4).

Metro decided to have the consultant proceed as prudently as possible under the circumstances. A blanket notice to proceed for the remainder of the tasks (B through F) was issued on April 20, 1976. This was contrary to the original intent to issue separate notices to proceed.

The work accomplished during this period was in conformance to the configuration study and more specific scopes-of-work, which were being developed as part of the design contract renegotiation. This work included:

(1) A tentative project schedule established July 12, 1976.
(2) An analysis of overhead hardware.

(3) An analysis of the trolley wire for the CBD.
(4) Completion of the contract documents for the manufacture and delivery of rectification equipment and overhead hardware (contracts T9A and T12A, respectively).
(5) Preparation of the standard plans for overhead construction.

Additional work was also required resulting in change orders for:

(1) Adjusting the central substation design to conform with Seattle City Light's space requirements.
(2) Adjusting the system's power design because of the use of chopper controls on the new trolleys (which reduced the power requirements).
(3) Preparing purchase specifications for transformers for the CBD substations (because Seattle City Light would not agree to own and operate the rectifier stations, see paragraph IV-B2a).

The renegotiation of the contract was finally culminated on Sept. 1, 1977, with amendment No. 1 (including addendum No. 3) to the contract. Considerable effort had been made to convince UMTA that (1) there was extra work beyond the original scope-of-work and (2) that the consultant was delayed due to reasons beyond his control. It was apparent in retrospect that it would have been better to have first performed the configuration study as a separate contract before preparing the contract for the actual design work.

d. October 1977 to July 1978

Because of the decision in January 1977 to shut down the trolley system for one year during the rehabilitation construction (see paragraph IIC3), Metro decided to combine the rehabilitation contracts and advertise immediately. Consequently the consultant's design effort during this period was greatly accelerated. Concurrently, several route changes and minor wire map changes

were being requested by Metro's transit department. The consultant was granted an increase in the contract amounts, but the added work somewhat delayed his overall progress and prevented combining all five of the rehabilitation overhead contracts into a single contract document. As a result, the rehabilitation substation and overhead contracts were awarded in five packages between January and July 1978 (see table II-3). In February 1978 the consultant was given a change order to design an overhead system for Metro's Central Operating Base (it had previously been planned to use auxiliary batteries to power the buses at the base).

As construction began on the rehabilitation system it was soon discovered that there were numerous field problems which were going to require the consultant's involvement to resolve. Therefore, the consultant's contract was revised by amendment No. 2 on May 18, 1978, to include engineering assistance during construction and to correspondingly increase the consultant's fee. By July 1978, most of the consultant's time was spent on construction problems and preparing redesigns for the continuing requests for wire plan changes.

e. August 1978 to January 1981

During latter part of 1978 and early 1979, the consultant was primarily occupied with field problems and adjusting the design to accommodate still more requested wire plan changes. One of the overhead expansion contracts (E9) was completed in November 1978 and advertised in December. However, this became a period for "stepping back" and evaluating the status and progress of the program. In October 1978 the Metro staff was reorganized. In February 1979 approval of a budget increase of 7.6 million dollars was requested of the Metro Council. Also in early 1979 Metro hired outside consultants to review technical design, construction procedures, program management, and program control. The resulting changes in the program management produced a more lengthy review process of the consultant's designs and considerable changes

in the provisions in the construction contract documents. This further delayed completion of the expansion contracts. The bid opening of the E9 contract was postponed until June 1979 due to addenda which made major changes and additions to the contract documents.

Although much had been learned from the previous construction contracts, the design work proceeded slowly. Much of the consultant's time was still being taken up by design revisions required in the rehabilitation contracts. Additionally, three of the expansion contracts required considerable coordination with undergrounding and street improvement projects being conducted by the Seattle Engineering Department and Seattle City Light.

As previously mentioned in paragraph IIC-3, little could be done to remedy the situation. An increase in the consultant's staff would only have slowed the progress more because a considerable portion of the existing staff's time would have been required to train new people in the many intricacies of trolley overhead design. Therefore, it was not until the end of 1979 that the last contract package was completed and ready for advertising.

By the spring of 1980 the consultant's work was essentially complete and the closing out of the contract began in May 1980. The contract amount had risen to $1,854,880 by contract additions and sixty-three (63) change orders. However, the consultant at this time presented a final bill which exceeded the maximum contract amount by $223,180. Negotiations between Metro and the consultant over the overrun claim were still in progress at the time of this writing.

C. OTHER ENGINEERING

As operation of the trolley system began, it was determined that other engineering work outside the scope of the consultant's contract would be necessary. Some of this work began in late 1979 and was accomplished at various times during 1980 and early 1981. Some of the work has yet to be initiated as of this writing. This engineering included:

1. Work Completed

   a. Operations and maintenance instructions and manuals for the rectifier stations.

   b. Study of lightning protection devices.

   c. Design of a lightning protection system.

   d. Analysis of telephone interference.

   e. Design of roofs for the 500KW rectifier stations.

2. Work in Progress

   Development and design of improvements to the CBD substations.

3. Future Engineering

   Analysis of the equipment specifications for the rectification equipment.

D. COST SUMMARY

The engineering cost summary is shown in table III-2. The "authorized amount as amended" was the breakdown of engineering costs after completion of the configuration study and the refinement of the scopes-of-work during the summer of 1976 and finally approved by Metro and UMTA on Sept. 1, 1977. This amount then serves as the best projected engineering costs based on planning and pre-engineering but before any design work had begun. The "final authorized amount," which increased the costs by 36 percent, is the final amount authorized for the consultant by contract additions and change orders. This 36 percent increase can be broken down as follows:

1.	Engineering assistance during construction	20%
2.	Engineering of Central Operating Base overhead	5%
3.	Redesigning required by wire plan changes	5%
4.	Extra design work required in the CBD feeder system	2%
5.	Extra costs for printing, planning support and miscellaneous	4%

TABLE III-2: TOTAL COST FOR ENGINEER /1
(As of March 1981)

Item	Authorized Amount as Amended	Final Authorized Amount /2			Final Cost /3				
		Amount	Difference			Difference (from original)		Difference (from revised)	
			Amount	%	Amount	Amount	%	Amount	%
Task A Configuration Study 60R,40E	84,871	96,816	+11,945	+14	103,698	+18,827	+22	+6,882	+7
Task B Rectifiers 60R,40E, Design P,S&E	27,828	28,698	+870	+3	29,347	+1,519	+5	+649	+2
Task C Rehab. Subst.'s Design, P,S&E	295,020	330,220	+35,200	+12	307,834	+12,814	+4	-22,386	-7
Task D Rehab. Overhead Design, P,S&E	444,431	567,772	+123,341	+28	645,778	+201,347	+45	+78,006	+14
Task E Expan. Subst.'s Deisgn P,S&E	174,366	183,116	+8,750	+5	148,036	-26,330	-15	-35,080	-19
Task F Expan. Overhead Deisgn, P,S&E	334,650	367,158	+32,508	+10	595,286	+260,636	+78	+228,128	+62
Task G Const. Services for Task D	-0-	167,200	+167,200	-	195,252	+195,252	-	+28,052	+17
Task H Const. Services for Task C	-0-	40,000	+40,000	-	43,702	+43,702	-	+3,702	+9
Task J Const. Services for Task F	-0-	65,000	+65,000	-	7,784	+7,784	-	-57,216	-88
Task K Const. Services for Task E	-0-	8,900	+8,900	-	1,343	+1,343	-	-7,557	-85
Other Engineering Rehab. (R) & Expan. (E)	-0-	-0-	-0-	-	R 63,558 E 30,736	+94,294	-	+95,893	-0-
Total									
Rehabilitation	807,070	1,180,501	373,431	+46	1,335,951	528,881	+66	155,450	+13
Expansion	554,096	674,379	120,283	+22	836,403	282,307	+51	162,024	+24
TOTAL	1,361,166	1,854,880	493,714	+36	2,172,354	811,188	+60	317,474	+17

/1 See Figure II-8 & II-9 and Table II-7 for program cost summary.
/2 Final Authorized amount per contract.
/3 Final cost for tasks A through K per billings by the consultant, consultant's overrun claim still being negotiated as of 2/81.
NOTE: P,S&E denotes plans, specifications and engineers cost estimate.

The "final costs" include the consultant's overrun claims and the other engineering described above. As shown in the table, the total final cost was 60 percent greater than the original authorized amount, and 17 percent greater than the final authorized amount as revised. The additional 24 percent increase over the original authorized amount includes:

6.	Other engineering	7%
7.	Overruns on tasks A,B,C,D,F,G&H	26%
8.	Underruns on tasks C,E,J&K	-9%

Since no change orders were issued for the overruns, the breakdown of the type of work for the overruns is not yet available. This is part of the previously mentioned negotiations still in progress as of this writing.

IV. COMPONENT DESIGN AND CONSTRUCTION

IV. COMPONENT DESIGN AND CONSTRUCTION

A. PREDESIGN

The predesign portion of the program's design phase was designated as "task A" in the design consultant's scope-of-work. As stated in the scope-of-work, the objective of this task was:

> "To develop a detailed electrical plan for the rehabilitation and expansion of the existing trolley overhead system including substation locations, size and type of rectifier module, type of suspension hardware and system control including telemetry." (9)

Also included was the preparation of network schedules for the design tasks, the corresponding construction contracts for the rehabilitation substations and overhead (tasks C and D), and the expansion substations and overhead (tasks E and F).

Notice to proceed was given October 3, 1975, with a specified completion date of March 5, 1976. The environmental impact proceedings regarding the plan refinement of the expansion portion of the system were proceeding concurrently with the task A work. The slow progress of these proceedings delayed the selection of an expansion plan and thus delayed the design work. The final report, entitled "System Configuration Study - Trolley Overhead System and Substations - Rehabilitation and Expansion," was submitted April 16, 1976. Missing from the report was the overhead hardware evaluation and the project CPM schedules, which were delayed pending additional information. These items were completed on July 12, 1976. The configuration study generally confirmed the feederless system concept favored by Metro staff. However, it was recommended that the feeder system should be retained and rehabilitated in the CBD because of the existing underground duct system.

A preliminary design was presented establishing the required size, number and spacing of substations. The proposed locations of substations and sectionalizers were indicated on the preliminary wire maps included in the report. Also presented were typical layouts, wire diagrams and architectual renderings of the substations (see figures IV-1 through IV-8).

The overhead hardware evaluation, submitted as a supplement to the configuration study, revealed a general superiority of the Ohio Brass hardware over the Kummler and Matter hardware. (These were the only two significant manufacturers of overhead hardware at that time.) Although the K and M material had certain operational advantages and provided for smoother operation, use of the OB material was considered to be more economical because fewer poles would be required and existing attachments--i.e. building eyebolts--could be used. Furthermore, the OB system was considered to be slightly less obtrusive than the K and M system. Finally, Ohio Brass had a local representative available who could provide liaison and technical advise during the course of the program.

B. SUBSTATIONS

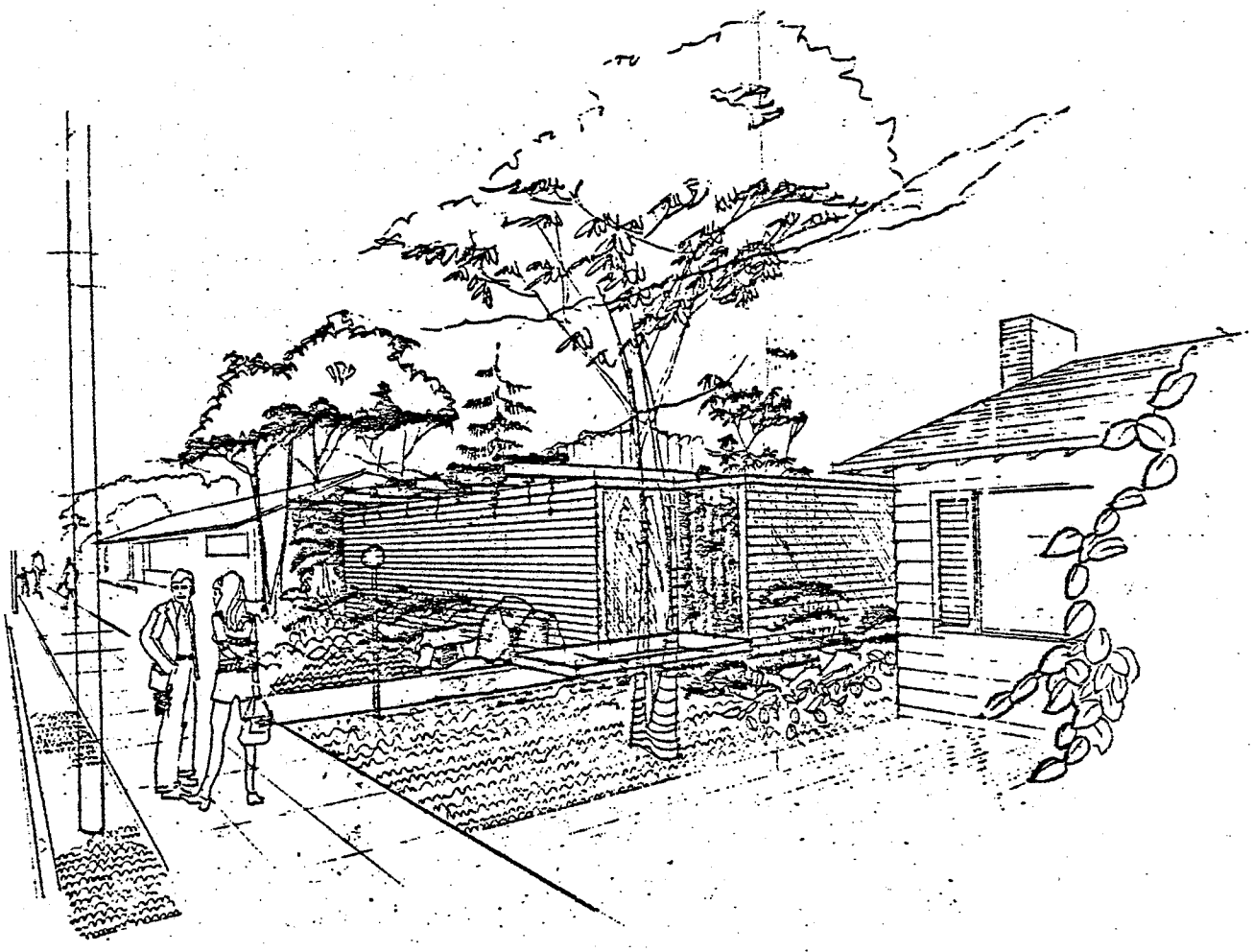
1. Rectifiers and Associated Equipment

a. General

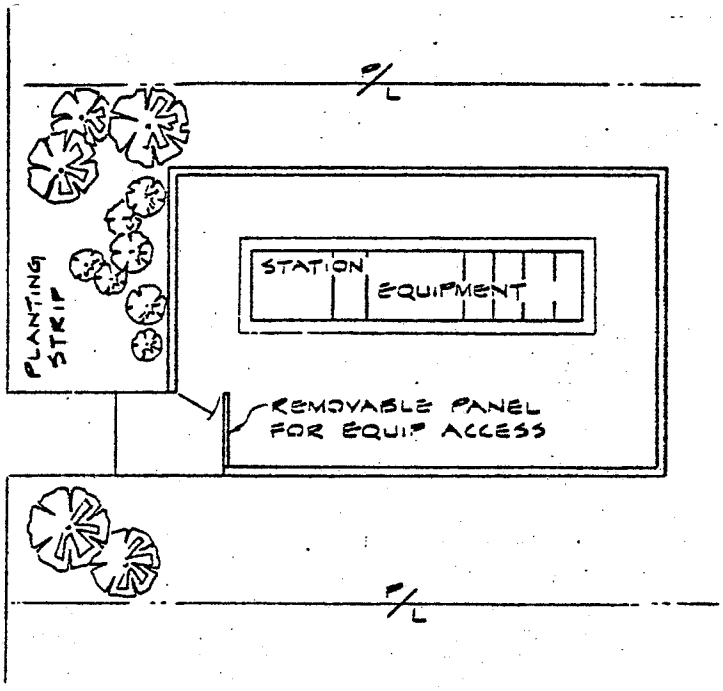
With the basic decision made to use a feederless system in the outlying areas and an underground parallel feeder system in the CBD, rectifier size and performance requirements were set for 500KW and 1500KW rectifiers.

b. Criteria and Specifications

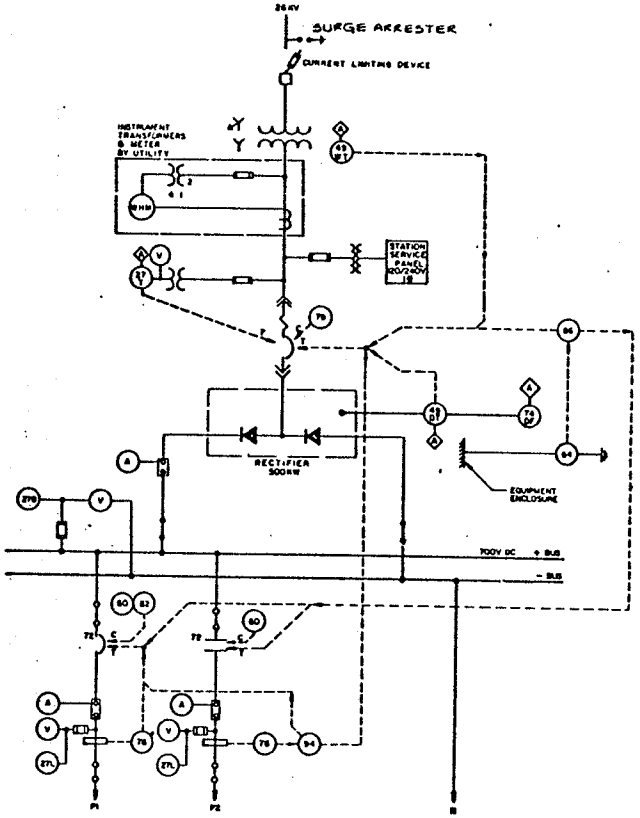
(1) 500KW - for the outlying areas, the feederless system selected was designed as a



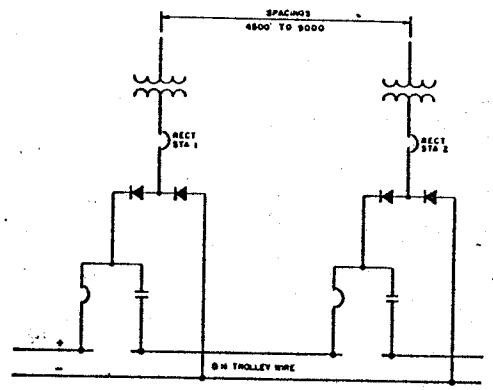
DESIGNED:	METRO Municipality of Metropolitan Seattle	DATE: 4/80
DRAWN: LLW	500 KW RECTIFIER SUBSTATION CONCEPTUAL RENDERING	FILE NO.
RECOMMENDED:		DRAWING NO. FIG IV-1
APPROVED:		SHEET OF



DESIGNED:	METRO Municipality of Metropolitan Seattle		DATE: 4/80
DRAWN: LLW	TYPICAL 500 KW SUBSTATION LAYOUT		FILE NO.
RECOMMENDED:			DRAWING NO. FIG. IV-2
APPROVED:			SHEET OF



TYPICAL STATION ONE LINE



TYPICAL SYSTEM OVERHEAD LINE

NOTE: THIS EQUIPMENT FURNISHED BY MUNICIPALITY FROM RADIO ELEC. CO. UNDER CONTRACT T9A-76

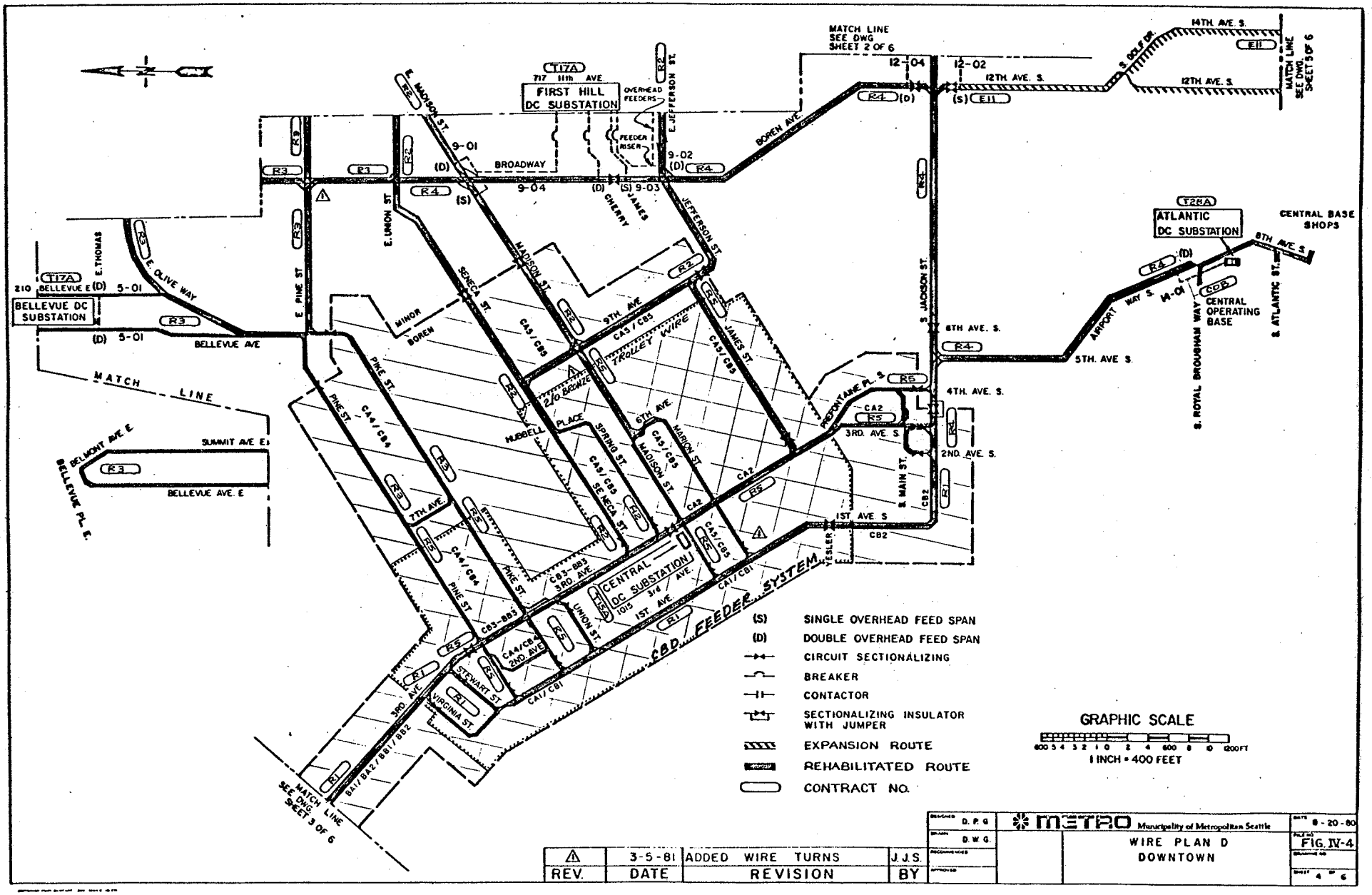
LEGEND

	ALARM
A	AMMETER
V	VOLTMETER
WH/D	WATTHOUR METER WITH DEMAND
	DISCONNECT FUSE
	BREAKER
	POTENTIAL TRANSFORMER
	DIODE
	CURRENT TRANSFORMER
	FUSE
	DC AMMETER SHUNT
	DISCONNECT LINK

49DT	RECTIFIER DIODE TEMPERATURE RELAY
49WT	TRANSFORMER WINDING TEMPERATURE
27	UNDERVOLTAGE RELAY
60	VOLTAGE CHECK
79	AC RECLOSER
64	ENCLOSURE GROUND DETECTION RELAY
72	DC CONTACTOR OR DC BREAKER
76	DIRECTIONAL DC O/C RELAY WITH INSTANTANEOUS UNIT AND RATE OF RISE UNIT
76 DF	DIODE FAILURE ALARM RELAY
82	DC RECLOSING RELAY WITH LOAD TESTING
86	LOCKOUT RELAY
94	AUXILIARY TRIPPING RELAY

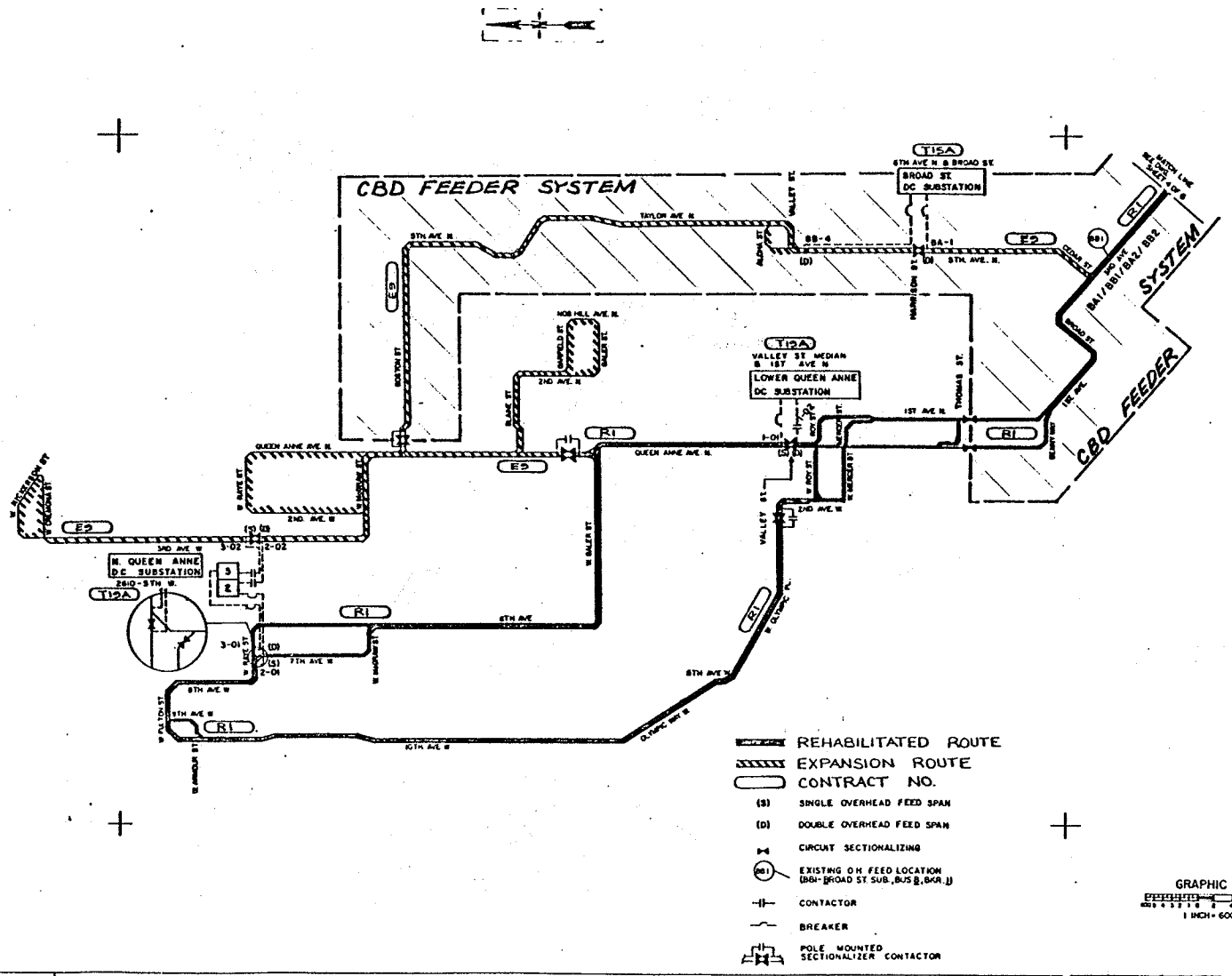
FIGURE IV-3

DESIGNED FH DRAWN RS CHECKED HB	R.W. BECK AND ASSOCIATES ENGINEERS AND CONSULTANTS SEATTLE, WASHINGTON	MUNICIPALITY OF METROPOLITAN SEATTLE	SCALE NONE	FILE — DATE 7/26/79	EXPANSION	ELECTRIC TRANSIT SYSTEM TYPICAL 500KW D C SUBSTATION METER AND RELAY DIAGRAM	DRAWING NUMBER T-25 E3 0 SHEET NUMBER 7 OF 21

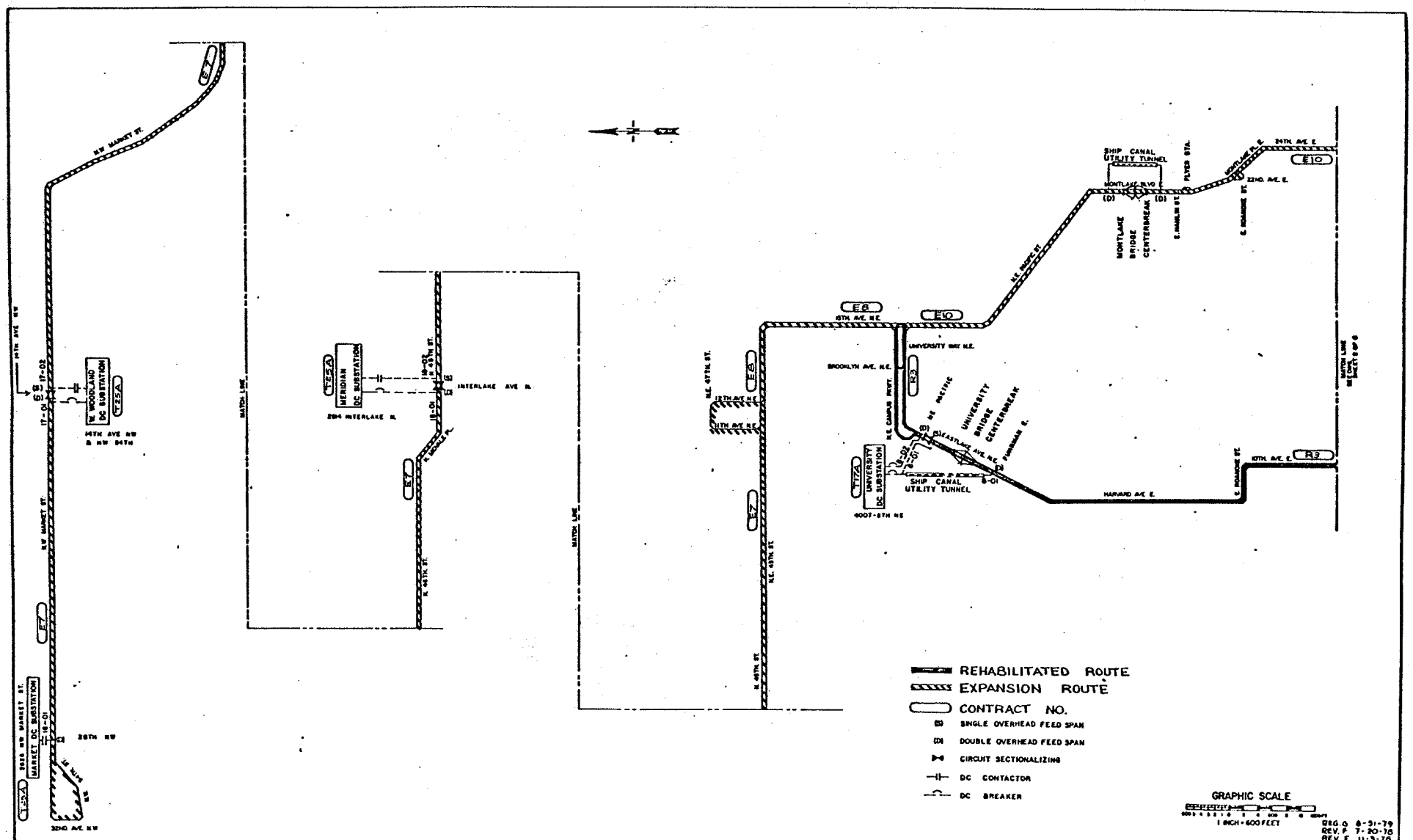


REV.	DATE	REVISION	BY
1	3-5-81	ADDED WIRE TURNS	J.J.S.

DESIGNED D. P. G.	METRO Municipality of Metropolitan Seattle	WIRE PLAN D DOWNTOWN	DATE 8-20-80
DRAWN D. W. G.			PROJECT FIG. IV-4
RECOMMENDED			DRAWING NO.
APPROVED			SHEET 4 OF 6

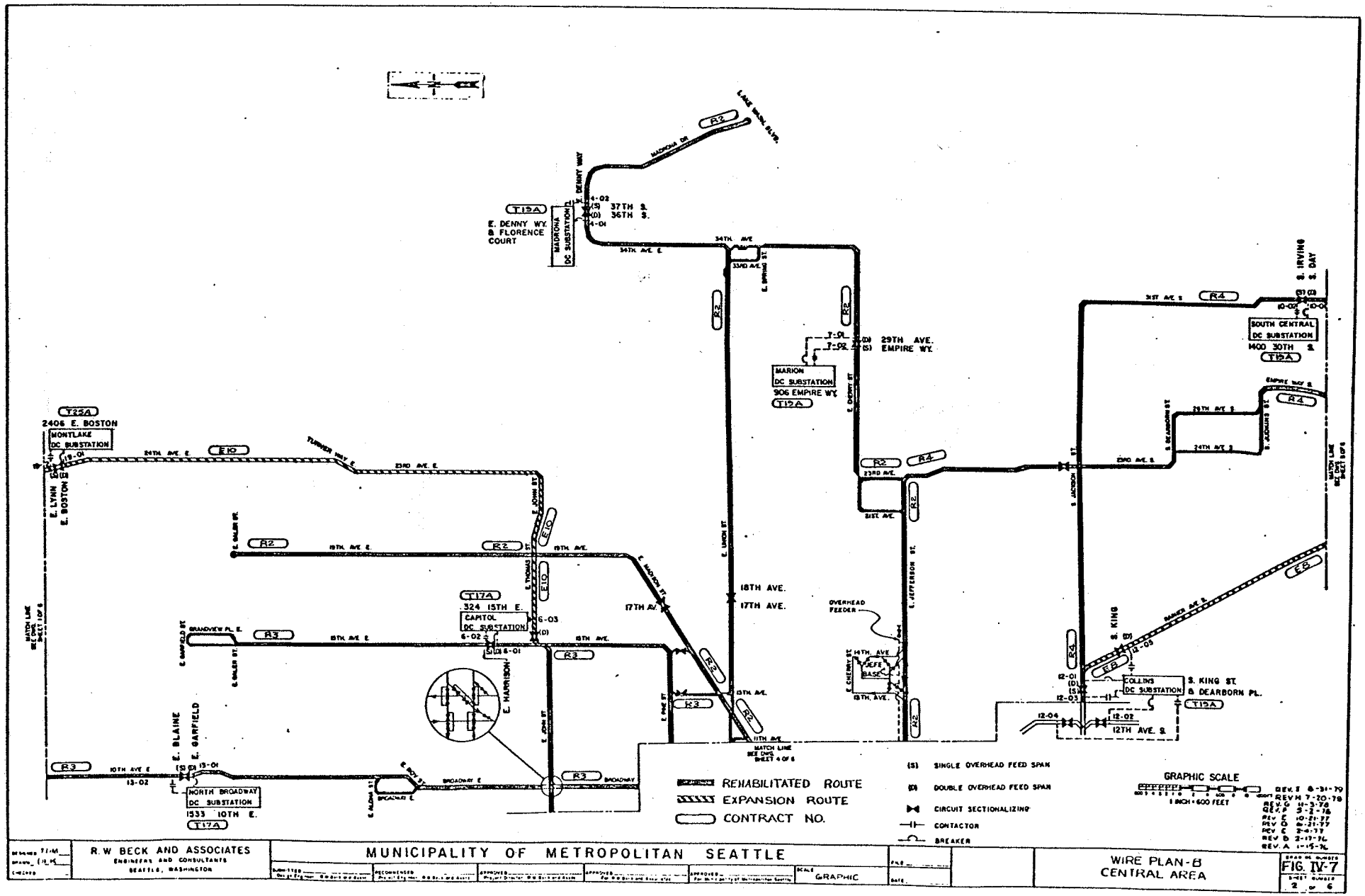


DRAWN TOM TRACED DH	R. W. BECK AND ASSOCIATES ENGINEERS AND CONSULTANTS SEATTLE, WASHINGTON	MUNICIPALITY OF METROPOLITAN SEATTLE	SCALE GRAPHIC		WIRE PLAN-C QUEEN ANNE	DRAWING NUMBER FIG IV-5 SHEET NUMBER 5 - 6



REV. G 8-31-79
REV. F 7-20-78
REV. E 5-2-78
REV. C 10-21-77
REV. B 2-17-76
REV. A 1-16-76

DRAWN TOM TRACED DEK CHECKED	R.W. BECK AND ASSOCIATES ENGINEERS AND CONSULTANTS SEATTLE, WASHINGTON	MUNICIPALITY OF METROPOLITAN SEATTLE SUBMITTED … RECOMMENDED … APPROVED … APPROVED … APPROVED … SCALE GRAPHIC DATE		WIRE PLAN-A BALLARD-UNIVERSITY	DRAWING NUMBER FIG. IV-6 SHEET NUMBER 1 OF 6



R.W BECK AND ASSOCIATES
ENGINEERS AND CONSULTANTS
SEATTLE, WASHINGTON

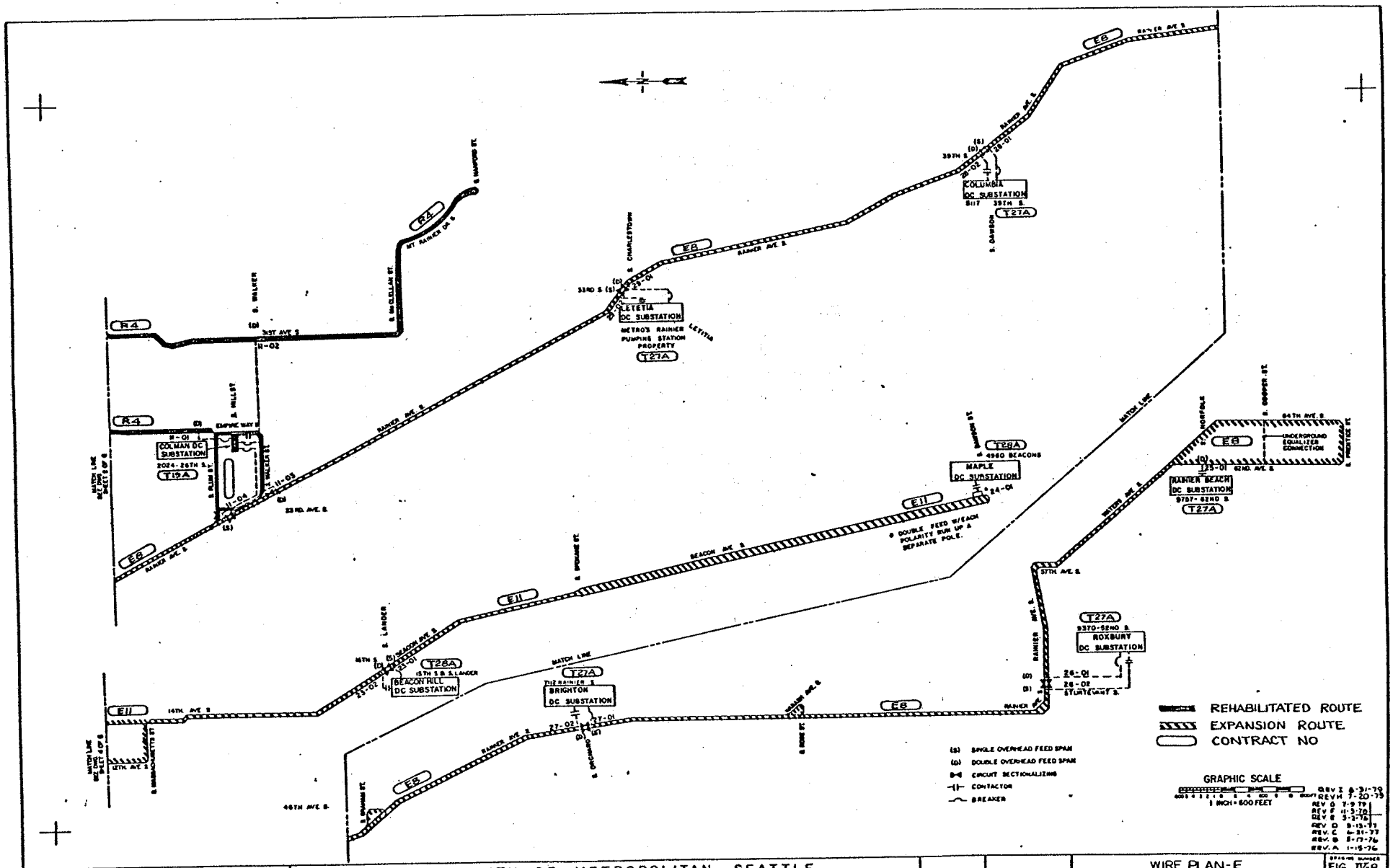
MUNICIPALITY OF METROPOLITAN SEATTLE

SCALE GRAPHIC

WIRE PLAN-B
CENTRAL AREA

FIG. IV-7

SHEET 2 OF 6



DESIGNED TDM DRAWN DEK CHECKED	R. W. BECK AND ASSOCIATES ENGINEERS AND CONSULTANTS SEATTLE, WASHINGTON	MUNICIPALITY OF METROPOLITAN SEATTLE				SCALE: GRAPHIC	WIRE PLAN-E SOUTH AREA	DRAWING NUMBER FIG. IX-8 SHEET NUMBER 9 OF 6

Submitted for ... Design Engineer - R W Beck and Assoc.
Recommended ... Project Engineer - R W Beck and Assoc.
Approved ... Project Director - R W Beck and Assoc.
Approved ... For R W Beck and Associates
Approved ... For Municipality of Metropolitan Seattle
Date

REV I 8-31-79
REV H 7-20-79
REV G 7-9-79
REV F 11-3-78
REV E 3-3-78
REV D 8-13-77
REV C 6-21-77
REV B 8-17-76
REV A 11-15-76

network with discrete sections of wire powered by two substations sharing the load. The system thus provided for continued service in the event of rectifier or primary failure of any one substations. Dependent on the type of substation failure, power would either feed through the DC bus from adjacent substations or feed the wire section up to the DC switch gear in the failed substation. The 500KW capacity was set to provide a balance between substation spacing, forecast loads and voltage regulation. The specifications set by the design consultant called for 26 units consisting of a 26.5Kv primary feed switch, transformer, AC circuit breaker, solid state rectifier and DC switch gear. All associated hardware, buses and wiring were enclosed in dead front cabinets suitable for outdoor installation. Specific performance was set at:

Primary input - 26,400 GRDY/15,242V 3 phase, 60Hz.

Continuous rating - 500KW at 672Vdc.

Overload rating - meet NEMA RI-9 heavy traction requirements.

Voltage regulation - not more than 4% in the 1% to 100% load range; no load voltage not to exceed 700V; at 300% overload not less than 616V.

Efficiency - 96.5% overall at continuous rating.

Power factor - 0.945 or greater from 25% to 100% of rated load.

As many of the rectifiers were located in residential areas, low noise level became a consideration. 56 PNdB at no load was specified.

The specifications as written, were a mix of hardware and performance requirements. Automatic line test and reclosing after fault clearance and provision for later addition of transfer trip equipment were specified. The overhead system wire plans for the expansion area and a rectifier schematic are shown in figures IV-3 through IV-8.

(2) 1500KW - the CBD system was designed to use existing underground feeder ducts and two new 1500KW sold state rectifiers in each of two existing substations with their existing 1500KW transformers and DC switch gear. Ownership, operation and maintenance would be the responsibility of Seattle City Light. Feed redundancy was obtained through multiple feeders on each overhead wire section, and DC bus ties at each substation. Though optimum sizing of the CBD rectifiers was less, the 1500KW size provided cost savings through reuse of existing equipment. Subsequent to award of the rectifier contract, Seattle City Light on whose property the two substations were located refused ownership of the rectifiers, transformers and switch gear and required relocation of the existing transformers within the substation

properties. Given the age of the transformers and the potential for insulation damage during relocation, the decision was made to add new transformers to the rectifier contract. The existing DC switch gear was to be retained and new low side AC circuit breakers would be purchased. With this change order the specifications were set for four 1500KW rectifier units consisting of a dry type transformer, air circuit breaker, solid state rectifier, and associated hardware, buses, and wiring enclosed in dead front cabinets for indoor usage. Specific performance was set at:

Primary input: 26,400VAC for two of the units, 13,750VAC for the other two units; 3.phase 60Hz.

Ratings:

Rectifier - 1500KW, light, traction rating per ANSI 34.2 and medium traction per NEMA RI-9. (These are equivalent ratings.)

Transformer - 1500KW, medium traction service rating.

Voltage Regulation - 4% or less at 100% load; no load voltage of 700VDC.

Again, the specifications were a mix of performance and hardware requirements with several important items omitted, such as the magnitude of the voltage at continuous rated power. Automatic reclosing after fault clearing and provisions for later addition of transfer trip were specified.

It is apparent now that the specifications for both the 500KW and 1500KW were weak to say the least. Test and acceptance procedures were ill-defined, surge protection was ambiguous, coordination of protective devices was not addressed, furnishing as-built drawings or maintenance manuals was not required and the general arrangement of the specification was disjointed.

c. Vendor Selection and Contracts

The 500KW and 1500KW specifications went out as one package for bids in December 1976. Seven bids for the total package were received. Only one bid for the 1500KW units was received. Rapid Electric Company of Brookfield, Connecticut, was awarded a contract April 1976 for 22-500KW units at a low bid of $1,279,127. The Ohio Brass Company of Oak Hill, West Virginia, was awarded the 1500KW contract May 1977 for the low bid of $47,707. In June 1977, a $284,925 change order was added to the Rapid Electric Contract for four additional rectifiers for an added expansion route. In January 1978, a change order for $10,061 was added. In November 1977, the Ohio Brass Contract was increased by $95,292 to add the transformers mentioned earlier. Two, subsequent minor change orders added $3,282 to the Ohio Brass contract.

d. Contract Performance

(1) 500KW - after award of the contract, Rapid Electric was essentially left to perform with no formal technical oversight or

progress reporting requirements. Delivery of the 26 units was to commence July 1978, with the last unit delivered in December 1978. In November 1977, Rapid submitted 16 preliminary electrical and mechanical shop drawings for Metro review. The drawings were rudimentary. With very minor revisions, Metro took no exceptions to the drawings.

In May 1978, the Metro contract coordinator and a consultant design engineer visited the factory. In June the coordinator again visited the factory accompanied by the Metro project manager. The trip reports reveal no significant problems and are optimistic in tone. It was noted in the second report that the contractor did not have the facilities to test the rectifiers as specified.

Deliveries started in July 1978 and were completed in January 1980. The units were given a visual inspection on arrival. The only major problem observed then was peeling paint, apparently due to improper application. As the first units were being installed at substations it became apparent that there were many other quality control problems including: wiring not connected, loose or missing fasteners, misaligned bus bars and wire not marked.

The first rectifiers were installed and put into operation in the summer of 1979. In September 1979, trolleybus revenue service started, and shortly thereafter major problems with the rectifiers began. As the problems were identified, fixes were immediately developed and installed--that process is still ongoing at this writing. Those problems identified after the start-up of operations were:

Latching relays unreliable and erratic in operation - replaced.

Line test voltage for feeder reclosing remained on the line with feeder breaker or contactor in manual open - redesigned.

Feeder contactor of insufficient rating causing contacts to weld together on short circuits - replaced.

No lightning protection for DC switch gear control. Solid state DC overcurrent relay particularly liable to destruction by lightning - designed and installed lightning arrestors for DC bus.

AC supply undervoltage trip operates on very small voltage dips - redesigned.

Rate of rise function in solid state DC overcurrent relay does not function.

Solid state overcurrent relay susceptible to radio and electromagnetic interference.

Relay failure in recloser circuit caused DC circuit breaker to pump - redesigned recloser.

DC cubicle ground fault relay powered by station AC utility circuit. With

station AC supply breaker open and station in DC feed through operation, cubicle ground fault protection is inoperative - redesigned.

Cubicle roofs tack welded to frame allowing water leakage - caulked, designed roofs to be installed by November 1981.

In the process of correcting these deficiencies, other extensive examples of poor quality control were discovered such as: size mismatch of wire terminals and studs, steel studs used on bus bars, wire terminals attached to bus bar studs only (no contact with bus bar), loose, unbundled and untied wiring.

With exception of the transformer, the rectifiers as delivered were of poor quality. The causes may be attributed to weak specifications, poor design and workmanship, and failure to closely monitor and inspect the manufacturer. As of this writing, work to upgrade the units is still in progress.

(2) 1500KW - Almost immediately after contract award negotiations began for an additional purchase of four rectifier transformers and six current transformers. The original specifications for the rectifiers were also changed substantially to those shown earlier in this section. The resulting change order was executed in November 1977, five months after contract award. Delivery was scheduled

for April 1978. Preliminary electrical and mechanical shop drawings were submitted in February 1978. Metro took no significant exceptions to the drawings.

In May 1978, Metro's contract coordinator and a consultant design engineer visited the factory. The trip report is brief and contains no record of equipment inspection or any other useful information. As with the 500KW contract, the contractor built the units with no formal technical oversight or progress reporting requirements.

The two rectifiers with 13.7KV primaries were delivered to Seattle on June 5, 1978--just over a month late. A delivery inspection revealed major discrepancies such as:

- Wiring: incorrect size, terminals and insulation; identification missing; butt splices and some wire to wire soldered taps.
- Interlocks: not installed on access door.
- Grounding lugs: not installed on transformer base.
- High voltage compartment: size and terminals incorrect; metering section incorrectly located.
- Bus bars: inadequately sized, improper fasteners used, joints unplated, disconnect links missing, burrs and sharp edges evident.

- Rectifier cubicle ground fault detector: incorrect shunt size.
- Rectifier temperature sensor: improperly mounted.
- Cubicle lighting: rectifier diode banks unlighted.
- Fuses: inaccessible without equipment disassembly.
- Test data: not supplied.

The factory sent an engineer to Seattle who also inspected and suggested corrective action. Shipment of the last two units from the factory was delayed. An electrical engineer from Metro then visited the plant in mid-July to negotiate similar corrective action on those units.

The units at the factory were corrected and tested by the end of August. A change order or $1,552 for additional doors and a change order of $1,646 for high-voltage terminals were negotiated. A factory team then went to Seattle and applied the same fixes to the delivered units, completing them in mid-September 1978.

2. Substation Site Selection, Acquisition and Design

a. General

The substation sites have been separated into two categories: those in the CBD feeder system, and those in the outlying area feederless system. Table IV-1 shows all of the substations that are also located on the system wire plans (figures IV-4 through IV-8). Predesign and final design

Table IV-1: List of Substations

Substation			Rectifier Size	Contract	Location	Property Status
CBD-FDR. System		Central	2-1500KW	T15A	Fig.IV-4	Lease from SCL
		Broad	2-1500KW	T15A	Fig.IV-5	Lease from SCL
		Atlantic*	2-500KW	T28A	Fig.IV-4	Metro Property
Outlying Area Feederless System	Rehabilitation	First Hill	1-500KW	T17A	Fig.IV-4	Easement from SCL
		Bellevue	1-500KW	T17A	Fig.IV-4	Easement from SCL
		Lower Queen Anne	1-500KW	T19A	Fig.IV-5	City Permit
		North Queen Anne	2-500KW	T19A	Fig.IV-5	Private purchase
		University	1-500KW	T17A	Fig.IV-6	Metro Property
		Capitol	1-500KW	T17A	Fig.IV-7	Easement from SCL
		North Broadway	1-500KW	T17A	Fig.IV-7	Private Purchase
		Marion	1-500KW	T19A	Fig.IV-7	Easement from SCL
		Madrona	1-500KW	T19A	Fig.IV-7	Private Purchase
		Collins	1-500KW	T19A	Fig.IV-7	Easement from SCL
		South Central	1-500KW	T19A	Fig.IV-7	Lease from State
		Colman	1-500KW	T19A	Fig.IV-8	Easement from SCL
	Expansion	Meridian	1-500KW	T25A	Fig.IV-6	Easement from SCL
		West Woodland	1-500KW	T25A	Fig.IV-6	Condemnation Purchase
		Market	1-500KW	T25A	Fig.IV-6	Easement from SCL
		Montlake	1-500KW	T25A	Fig.IV-6	Easement from SCL
		Beacon Hill	1-500KW	T28A	Fig.IV-8	Private Purchase
		Maple	1-500KW	T28A	Fig.IV-8	Easement and Quit Claim from SCL
		Letitia	1-500KW	T27A	Fig.IV-8	Metro Property
		Columbia	1-500KW	T27A	Fig.IV-8	Easement from SCL
		Brighton	1-500KW	T27A	Fig.IV-8	Easement from SCL
		Roxbury	1-500KW	T27A	Fig.IV-8	Easement from SCL
		Rainier Beach	1-500KW	T27A	Fig.IV-8	Private Purchase

*Constructed under an "Expansion" contract.

locations are shown for those stations where the desired site was not available. The status of site ownership is also indicated.

A significant factor involving all the substations was the question of ownership. Resolving this issue was an extremely complicated process. In very general terms, the sequence of events was as follows:

(1) Between 1939 and 1973 the trolley system belonged to the Seattle Transit System, a city department. Direct current power was provided by five substations that were owned, operated and maintained by Seattle City Light, another city department.

(2) The Transit Transfer Agreement was negotiated and signed by the city and Metro on Dec. 1, 1972. Metro began operating the system on Jan. 1, 1973. Two somewhat conflicting provisions were contained in the agreement. Section 3(a) indicated that the "City shall at its own expense own, operate, maintain, repair and replace such equipment and facilities as may be required to transform electrical energy to direct current and to deliver same at present points of delivery on the trolley system or at additional points of delivery as mutually designated."(2) Seciton 7(e) indicated that the city would provide Metro with the proceeds from the sale of the transit system facilities for financing

new transit facilities within the city. It further states that these facilities would be constructed or acquired by Metro, and said facilities "...shall be owned, operated and maintained by Metro..."(2)

(3) By January 1975, the city was asking Metro to consider taking over the ownership, operation and maintenance of the substations, citing that the D.C. power system would only serve the transit system and therefore the responsibility for the substations would more appropriately be Metro's. Metro's response was to delay the consideration until after the predesign study (configuration study, ref. 10). The study was completed in April 1976.

(4) In August 1976, Metro requested the city to increase its efforts in resolving the issue and indicated that Metro would hold the city to Section 3(a) of the agreement.

(5) The subsequent year involved extensive negotiations between Metro, Seattle Engineering Department and Seattle City Light. The negotiations culminated with the first supplement to the Transfer Transit Agreement on August 1, 1977. In accordance with section 3 of this supplement, Metro agreed to assume the responsibility of the operation and maintenance of the substations. In compensation to Metro for assuming ownership, the city agreed to make an immediate payment of $750,000 in accordance with section 4 of the supplement.

By the time this issue had been resolved the rectification equipment contracts had already been awarded (May 1977) even though the specifications had not been properly reviewed by either Metro or City Light maintenance personnel because neither organization believed it would be ultimately responsible for the maintenance of the equipment. The resulting consequences added unanticipated costs and delays to this portion of the program because Metro then had to obtain additional equipment and acquire rights to the substation sites.

b. Central Business District Feeder System

The CBD feeder system as defined by the configuration study includes three substations:

1. Central-basement of the City Light Building at Third and Madison.
2. Broad Street-City Light substation at 6th Avenue North and Broad Street.
3. Atlantic-Metro Central Operating Base at 1333 Airport Way South.

Because these sites were used for the old system, there were no environmental or site acquisition problems. (25-year leases were obtained from City Light for the Central and Broad Street sites on April 28, 1978.)

The design of the Central and Broad Street substations involved interior remodeling of the areas within the City Light buildings to accommodate two new Metro-furnished 1500 KVA

transformer-rectifier units (see paragraph 1 above). Electrical raceway systems were to be modified and existing DC switch gear units were to be tested, modified and refurbished. At the Central DC substation the existing switch gear was to be relocated. The design of the Atlantic street substation was for a new installation on top of the newly constructed fuel and wash building at Metro's Central Operating Base. Two new Metro furnished 500 KVA recitifers were selected for this site, primarily to provide power to the overhead on the base. The underground DC feeder system was to be substantially replaced with new cable. The cable designated for reuse was to be tested and replaced where necessary.

c. Outlying Area Feederless System

There are 23 substations in the outlying area feederless system as indicated in table IV-1. Acquisition of these sites was accomplished by various means described as follows:

1. 13 sites were acquired as permanent easements on Seattle City Light property (existing power substations).

2. 1 site was acquired from the state Department of Transportation on a 25-year lease.

3. 1 site is located on a City of Seattle right-of-way and was acquired by permit.

4. 2 sites are located adjacent to water quality facilities and were purchased from the Metro's water pollution control department.

5. 6 sites were purchased from private parties, only one of which required condemnation.

There was only one case of site acquisition affecting the system design. The most desirable sites on Queen Anne Hill, as indicated in figure IV-5 and recommended in the predesign configuration study were not obtainable. The sites that were finally acquired are only marginally acceptable because the poor substation spacing hampers the proper performance of the relay system (21).

The outlying-area system was designed as a feederless system as described in section II-B. It was initially envisioned in the predesign that at the two existing substations on Seattle City Light property, the existing switch gear would be tested and revised. However, by the final design these sites were relocated slightly and it was decided to provide all new equipment as was done at all of the outlying substations. Each site presented its own, individual design problems, none of which were peculiar or unique to DC substations.

A small amount of underground feeder was required to connect the substation to the overhead. In a few rare cases, short section of overhead feeder were also used. The cable selected was 2000 volt, XLP insulated of either 350 KCM Class B stranded aluminum or 750 KCM Class C aluminum depending upon voltage drop considerations.

3. Construction Contract Documents

a. Rehabilitation - CBD Feeder System, Awarded February 1978.

The first substation contract document (T15A-77) specified the work for the rehabilitation of the CBD substations, Central and Broad, and the existing feeder system. The bidding schedule broke the contract into four lump sum items: one item each for all work necessary to rehabilitate Central and Broad Street substations, one item for the rehabilitation of the CBD feeder system and one item for the rehabilitation of the Monorail feeder system. A more detailed breakdown of the work was required of the successful bidder. General descriptions of suggested items were given in the contract documents. Other noteworthy features of the contract were:

(1.) Metro furnished the rectifier-transformer equipment and feeder cable.

(2.) The contractor was instructed to test the existing switch gear and a selected portion of the existing feeder system. Based on the results of the tests the contractor was to present a list to Metro of the work required--modifications, additions, replacement--to make the system operable. This work, if accepted by Metro, would then become an extra to the contract.

(3.) The work was under some schedule restrictions imposed by City Light and because of the requirement to maintain power to the Monorail.

(4.) The contractor was responsible for resolving above ground and minor underground conflicts with other utilities. If a major underground utility was first discovered during excavation, then the contractor's work including the initial excavation, repair, backfill and restoration was an extra to the contract.

(5.) The specific locations of cables and raceways were left to the contractor's discretion.

b. Rehabilitation - Outlying Area, May and July 1978. Two contracts, T17A-77 and T19A-77, covered the installation of the rectifier substations in the rehabilitation portion of the outlying area. The contract documents were similar to the T15A document, except additional provisions were necessary to specify the site-development work. Also, the contractor was required to develop as-built drawings during the course of the work.

c. Expansion - March, June and October 1979. The first of three contract documents for the expansion substations--for contract T27A-77--was generally the same as the T17A/T19A documents. The next expansion contract, T28A-77, was similar except that provisions were added for installing an alarm light system to the substations. The final contract, T25A-77, underwent a more extensive review to assure compatibility with the overhead contracts and to add any necessary items to complete all substation work. Other significant changes to the T25A-77 document were:

(1.) A liquidated damages provision was added to the construction scheduling conditions to compensate Metro for damages suffered from the failure of the contractor to timely submit a monthly updated construction schedule.

(2.) The contractor was allowed to restore the sidewalks (this was previously done by city street crews).

(3.) Metro took on greater responsibility for coordinating with the other above ground utilities and for payment of their adjustment costs.

4. Construction History

a. General

Figure II-7 shows how the substation construction period fit into the overall duration of the program and table II-3 shows the construction period for each contract.

b. March 1978 to December 1978

Notice to proceed was given for contract T15A, for the rehabilitation of the CBD feeder system, in March 1978--two months after the one-year trolley system shutdown period had begun. Although there was considerable urgency, progress was hampered immediately because the rectifier installation drawings could not be completed because the manufacturer had not yet delivered the final shop drawings. Then followed a series of field problems, management problems, coordination problems and general squabbles with the contractor. Following is a list of some of the specific problems encountered during this period of contract T15A:

(1.) Poor coordination between Metro, the Contractor, Seattle City Light and other contractors led to a considerable amount of lost time and ill feelings between the parties. The contractor claimed difficulties in obtaining City Light inspections and safety watches at desired times. Feeder poles that were to be installed by other contractors were often not available on time. Some pole installations created problems for pulling in feeder cables. Finally, disputes often occurred between Metro and the contractor regarding the scheduling of the work and the responsibility for the costs of lost or stand-by time.

(2.) The required checkout of the existing switch gear was done in a rather piecemeal fashion. The required summary list of repairs and replacement parts apparently was never developed and submitted for approval. The contractor hired General Electric to provide technical advice but seemingly did little more than transmit General Electric's questions, recommendations, etc., to Metro without developing a coordinated program for rehabilitating the switch gear.

(3.) During a portion of this period there was a shortage of qualified electrical workers.

(4.) Progress was delayed by the late delivery of a variety of materials from batteries, racks and chargers to miscellaneous small items. Much of this delay occurred because the types and quantities of some of the materials was not determined until the contractor could assemble the necessary information from his investigations of the existing facilities.

(5.) Information about the condition of the existing duct system was often incomplete. There were discrepancies in the lengths of ducts and whether the ducts were already occupied. Blockages were often encountered, usually due to old iron pull wires. In two cases where excavation was required, the contractor encountered railroad ties, rails and buried concrete.

(6.) The contractor claimed extra costs and delays to remove the old asbestos fire proofing materials because new regulations governing the handling of asbestos fibers had been instituted.

Notice to proceed for the rehabilitation - outlying area substations, contracts T17A and T19A, was given in May and June 1978, respectively. Progress was slow for these contracts during this period because of the late delivery

of the rectifier units and the shortage of electrical workers. Some site problems also occurred and the usual number of change orders for revisions or additional work were issued. Some hold up was also claimed as a result of a lack of test data for the switch gear and the time City Light was taking to install their current transformers for metering.

c. January 1979 to June 1979

By January 1979, contract T15A had bogged down in disputes over claims for extra-work compensation and time extensions. Work did continue on checking out the switch gear and trouble-shooting the system as it slowly came together. However, the completion date was soon passed and the substations were far from ready for operation. By May, little work was being accomplished as some necessary parts were still on order. The contractor's administrative personnel had changed and some agreements on the claims were made.

The contracts for the construction of 500KW substations in the rehabilitation area were being completed with somewhat less difficulty. The major problems included testing the system and coordinating the efforts of the contractor, rectifier manufacturer and Seattle City Light. By June 1979, both contracts T17A and T19A were completed--five months and three months beyond their respective scheduled completion dates. However, problems still persisted in the rectifier units as described in paragraph IV-B1, but

these problems were not attributable to the 500KW substation contracts.

Notice to proceed was given for the first expansion area 500KW substations in March 1979. By June 1979, some delays had been experienced because of a teamster union strike and a change required at one substation to accommodate the construction of a major water line.

d. June 1979 to July 1980

Between July and September 1979, Metro hired General Electric to troubleshoot the CBD substations and the T15A contractor to perform additional work under the supervision and direction of a Metro staff electrical engineer to make the substations operational. By the end of September, contract T15A was finally completed and the stations were put into operation.

The expansion-area substation contracts were all completed during this period with relatively few major problems, although none of the three were completed by the scheduled date. Contributing to the delays of these contracts were the change in the installation design for a feeder cable located in a watermain tunnel under a ship canal, and the addition of lightning protection materials.

5. Summary

For the most part, the types of problems encountered during the substation construction are not unique to trolley overhead substations construction. These problems could have been encountered in any public

works project involving single site facilities. The serious problems were mostly related to the electrical equipment and therefore not directly related to the construction itself. The summary of costs for purchasing the DC electrical equipment is included in the cost summary table for materials, table IV-4, in subsection IVC-1. The summary of costs in table IV-2 shows that the construction contracts were completed within the budgeted amounts. Table IV-3 shows the total costs for the substation construction portion of the contract, which was accomplished within the original (March 1978) budget--even after the addition of post construction items such as roofs for the 500KW rectifier units, pole mounted lightning arrestors and rectifier relay modifications.

C. OVERHEAD SYSTEM

1. Materials

a. General

A trolley overhead system requires a great variety and large number of materials. After careful analyses by Metro staff and consultation with the various suppliers of overhead hardware, wire and cable, it was obvious that the lead time of ordering, manufacture and delivery of materials could markedly affect the program schedule. Therefore, as in the case of the rectifiers, Metro advertised contracts for these materials separately from the construction contracts. Although this required considerable effort by Metro personnel to receive, store, inventory and distribute these materials, the advance ordering was

TABLE IV-2:
SUBSTATION CONSTRUCTION COST
ORIGINAL BIDS AND FINAL COSTS

Contract		Contract Amount	Contingency		Final Cost	Difference	
			Amount	%		Amount	%
Rehabilitation	T15A	948,640	98,000	10.3	1,045,258	96,618	10.2
	T17A	541,800	55,000	10.2	565,474	23,674	4.4
	T19A	754,050	78,500	10.4	799,088	45,038	6.0
	Sub-Total	2,244,490	231,500	10.3	2,409,820	165,330	7.4
Expansion	T25A	290,865	30,000	10.3	310,322	19,457	6.7
	T27A	467,000	49,000	10.5	491,197	24,197	5.2
	T28A	229,500	25,000	10.9	246,157	16,657	7.3
	Sub-Total	987,365	104,000	10.5	1,047,676	60,311	6.1
TOTAL		3,231,855	335,500	10.4	3,457,496	225,641	7.0

TABLE IV-3: TOTAL COSTS FOR SUBSTATION CONSTRUCTION /1
(as of March 1981)

Item	Original Budget	Revised Budget			Final Cost				
		Amount	Difference			Difference (from original)		Difference (from revised)	
			Amount	%	Amount	Amount	%	Amount	%
Construction:									
Rehabilitation	2,475,990				2,409,820	-66,170	-3		
Expansion	1,198,000				1,047,676	-150,324	-13		
Sub-Total	3,673,990				3,457,496	-216,494	-6		
Inspection:									
Rehabilitation	320,000				280,307	-39,693	-12		
Expansion	180,000				116,138	-63,862	-35		
Sub-Total	500,000				396,445	-103,555	-21		
Supervisory Control: /2	300,000				-0-	-300,000	-100		
Property:									
Rehabilitation	285,000				282,222	-2,778	-1		
Expansion	81,290				101,520	+20,230	+25		
Sub-Total	366,290				383,742	+17,452	+5		
Miscellaneous:									
Rehabilitation	50,000				511,279	461,279	+923		
Expansion	-0-				126,742	126,742	-		
Sub-Total	50,000				638,021	588,021	+1,176		
Total: /3									
Rehabilitation	3,430,990				3,483,628	+52,638	+2		
Expansion	1,459,290				1,392,076	-67,214	-5		
TOTAL	4,890,280				4,875,704	-14,576	0		

/1 See Figure II-8 and II-9 and Table II-7 for program cost summary.
/2 Considered a part of rehabilitation (not implemented).
/3 A significant portion of the power for the expanded system actually comes from "Rehabilitation" substations, estimated to be equivalent to 3 substations, or approximately $443,000.

TABLE IV-4: TOTAL COSTS FOR MATERIALS /1
(as of March 1981)

Item	Original Budget	Revised Budget			Final Cost				
		Amount	Difference		Amount	Difference (from original)		Difference (from revised)	
			Amount	%		Amount	%	Amount	%
500KW Rectifiers	1,597,666	1,597,666	-0-	-0-	1,648,407	+50,741	+3	+50,741	+3
1500KW Rectifiers	154,093	154,093	-0-	-0-	154,090	-3	-0-	-3	-0-
Overhead Hardware	1,224,000	1,567,750	+343,750	+22	1,457,544	+233,544	+19	-110,206	-7
Wire and Cable	1,079,632	1,100,961	+21,329	+2	1,264,846	+185,214	+17	+163,885	+15
Miscellaneous	150,368	195,368	+45,000	+30	227,891	+77,523	+52	+32,523	+17
Inspection	290,000	290,000	-0-	-0-	290,000	-0-	-0-	-0-	-0-
TOTAL:									
Rehabilitation (60%)	2,697,455	2,943,503	+246,047	+9	3,025,667	+328,212	+12	+82,164	+3
Expansion (40%)	1,798,304	1,962,335	+164,032	+9	2,017,111	+218,807	+12	+54,776	+3
TOTAL	4,495,759	4,905,838	+410,079	+9	5,042,778	+547,019	+12	+136,940	+3

/1 See Figure II-8 and II-9 and Table II-7 for program cost summary.

generally considered necessary and the results successful. Later in the project, the lead time for steel poles was determined to be one of the factors delaying construction. Metro then decided to order the poles for the last four expansion contracts and the Central Operating Base separately.

A summary of material costs is shown in table IV-4. The cost of steel poles purchased by Metro are included in the overhead construction cost summary, table IV-6, to be consistent with the original budget categories.

An interesting situation was encountered in ordering materials containing substantial quantities of copper (trolley and guy wire). Because of market fluctuations, the suppliers would not give a firm price at the time of bid. Metro had to accept bids based on the prevailing wire bar price of copper at the time of bid with the provision that the actual price would be based on the copper price at the time of shipment. Fortunately, the copper price actually went down between the bid and shipment dates for the initial large wire orders.

b. Contact Wire

As recommended in the configuration study, it was decided to replace all the contact wire in the existing system. The initial recommendation was to use 4/0 AWG, HDC grooved trolley wire throughout the rehabilitated and expanded system. However, in June 1976, two months after the completion of the study, Metro staff directed

the consultant to investigate and determine whether there would be any cost savings in retaining and using the 2/0 bronze contact wire in the CBD. The consultant's report, completed in November 1976, showed that the existing 2/0 wire should not be reused because of its worn condition and numerous splices. However, it was learned that the better wearing 2/0 bronze wire could be used in the most heavily traveled portion of the CBD without significant changes in the proposed electrical design or material costs. Therefore, 2/0 80 percent conductivity bronze, grooved trolley wire was selected for use in the CBD and later at the Central Operating Base for the same reason of better wearing properties.

The most significant problem was encountered when the first shipment of 2/0 wire arrived with the wire turned to an angle off the specified 90 degrees to the axis of the reel. It also exhibited a tendency to twist when pulled off the reel. These reels of wire were rejected and returned to the factory. The manufacturer was able to correct the problems to Metro's satisfaction and the replacement reels were accepted.

c. Hardware

As recommended by the consultant, Ohio Brass hardware was selected for the project. Quality control appeared to be the major problem at the beginning, but the problems gradually became minor as the project progressed.

Ordering the hardware in advance required a considerable bookkeeping effort to keep track of the large variety of items and where each piece was intended to go in the overhead. Later in the program, the availability of certain items, especially switches and rigid crossovers, would affect the design or limit the options of a desirable field change (21).

d. Guy Wire

Copperweld guy wire was selected primarily because of its better workability and the generally favorable experience Metro overhead maintenance personnel had had with it. However, copperweld is little used by other utilities and, therefore, is not always readily available. When it was realized that the initial guy wire orders would not be adequate to complete construction due to additional pole guying (see paragraph 5b below), additional orders were found to have extremely long lead times. A shortage of copperweld guy wire did occur during two of the expansion contracts but was alleviated somewhat by allowing the use of alumaweld for pole guying.

2. General Design

Some basic overhead design criteria were established during the planning and predesign phases of the program (see references 7,8,10 and 11). From these efforts the type of system, trolley wire and overhead hardware were selected. Then, from mid-1976 until the completion of the first designs in late 1977, the many details of overhead design and construction were

discussed and analyzed in several meetings between the consultant and Metro's engineering staff and overhead maintenance personnel. When completed, the design criteria were essentially contained in the construction standards incorporated into the contract documents for every overhead contract. These standards were revised and new standards were added as the program progressed. The final overhead contract contained 62 construction standards.

With the standards established, the design then becomes a complicated process of balancing forces while maintaining certain special criteria (height, above ground, location from curbs, separation from other utilities, etc.) while conforming to a variety of street configurations. The design methods are generally as described in the Ohio Brass construction manuals (22).

3. Special Design Considerations

a. Central Business District

As previously mentioned, a feeder system which reuses the existing substations and underground duct system was selected for the CBD (see figure IV-4). Also, because of its better wearing properties, 2/0 bronze trolley wire was selected for this high-traffic area. These and other factors contributed to the following special design considerations for the CBD:

(1.) More frequent feeder spans were required.

(2.) Intersections were more complex and more numerous.

(3.) More existing support poles and building eyebolts were reusable.

(4.) Working in the downtown area required certain time restrictions.

(5.) Transitions from 2/0 to 4/0 wire were designed and located.

(6.) Setting new support poles required greater care because of more underground interferences.

b. Outlying Area

As previously mentioned, a feederless system was selected for the outlying areas (see figure IV-4 through IV-8) using 4/0 high-conductivity grooved copper trolley wire, Ohio Brass Hardware and 500KW rectifier substations spaced approximately 5,000 to 8,000 feet apart and interconnected by a feed-through system of circuit breakers. The outlying area was divided into rehabilitation routes (existing prior to shutdown) and expansion routes as described in paragraph II-C2. Generally, the rehabilitation routes had more existing support poles available and required more special work installation. Other special design considerations for the outlying area were as follows:

(1.) Speed curves.

(2.) Two bascule bridge crossings.

(3.) Use of wood poles and guys.

(4.) Use of mast arms for wide and single track streets.

(5.) More coordination with city undergrounding projects.

(6.) Some narrow neighborhood streets.

(7.) More work in residential areas.

4. Construction Contract Documents

a. January 1978

The first overhead contract document combined three contracts: R1,R2, and R5. These contracts covered most of the CBD and a portion of the rehabilitation outlying area (see figures IV-4, IV-5 and IV-7). The bidding schedule was set up so that the contracts could be bid singularly or in combinations. Unit prices were required for specified intersections, selected tangent construction, moving existing wood pole eyebolts and steel pole collars, and dismantling the existing system in the contract area. A more detailed breakdown of the bid price was required of the successful bidder, but the extent or detail required in the breakdown was not specified. Other features of these contract documents were:

(1.) Metro furnished a large amount of the materials including hardware, trolley wire, guy wire and feed span cable. The contractor was required to set up a system for handling and inventory.

(2.) Existing building eyebolts were to be tested. In case of failures, they were to be replaced as an extra to the contract.

(3.) The contractor was responsible for researching pole base sites for underground utility interferences and areaways. If areaways were encountered then the contractor would install wall-type pole foundations under the direction of Metro as an extra to the contract.

(4.) The contractor was responsible for resolving above ground and minor underground conflicts with other utilities. If a major underground utility was first discovered during excavation, then the contractors work including the initial excavation, repair, backfill and restoration was an extra to the contract.

(5.) In an effort to reduce the number of utility poles, many existing poles were selected for use to support trolley overhead. In many cases these existing poles were not strong enough. Therefore, the contract called for replacement of these poles. The replacement of steel poles was a complicated process which required a joint-use agreement for each pole between Metro and the City. These agreements, in the form of sketches, were not available at the time of bidding. Any work required of the contractor by these agreements was to be an extra to the contract.

(6.) Steel poles were to be furnished by the contractor, but many could not be ordered until the joint-use agreement sketches were completed.

b. May 1978

The second overhead contract combined contracts R3 and R4. These contracts covered a small portion of the CBD and the remaining portion of the rehabilitation outlying area (see figures IV-4, IV-6,IV-7, and IV-8). This document was basically the same as the first, with two exceptions: (1) the required breakdown of contract costs was described in more detail; and (2) raking of existing poles was required where necessary.

c. July 1979

The first of the expansion contracts was E9, which completed the overhead system in the Queen Anne Area (see figure IV-5). Although the initial contract document was completed in November 1978 and advertised in December, bid submittal was delayed until June 1979, in order

to prepare an extensive addendum to the document. The addendum resulted from an extensive in-house Metro review, which was conducted to correct problems encountered in the rehabilitation contracts. The addendum incorporated the following changes into the contract documents:

(1.) Extensive scheduling procedures were added including the critical path method of scheduling and more detailed provisions for monitoring the construction progress by Metro.

(2.) The joint-use pole agreements were included in the bid documents.

(3.) The contractor was allowed to restore the sidewalks (this was previously done by city street crews).

(4.) Metro took on greater responsibility for coordinating with the other above ground utilities and for payment of their adjustment costs.

(5.) The contractor was required to first locate all pole and guy anchor sites and get approval of the locations from the engineer before proceeding.

(6.) A list of existing wood poles to be raked and/or keyed was added based on a wood pole survey conducted by Metro maintenance personnel.

(7.) Areas where tree trimming was required were identified.

(8.) A smoothness test of the special work was added in which the overhead is inspected by hand moving a trolley shoe over the track.

(9.) The final inspection and acceptance specification was changed from a "system dressing" criteria to a performance criteria.

(10.) The design was modified to incorporate independent suspension of special work devices.

d. December 1979 and February 1980

The final two overhead contract documents each combined two previously designated contracts: E8 with E11 and E7 with E10. These contract documents differed from the E9 contract documents only by the following additions and modifications:

(1.) Metro took over the responsibility of furnishing the steel poles. This way the order was placed earlier, reducing the lead time for the contractor.

(2.) A list of existing steel poles to be raked was added.

(3.) A list of existing steel poles to be tested was added.

(4.) The design involved coordination requirements between the overhead contracts and several Seattle Engineering undergrounding projects.

5. Construction History

a. General

Figure II-7 shows how the overhead construction period fit into the overall duration of the program. Table II-3 shows the construction periods for each contract. As previously discussed, a variety of external and internal factors had contributed to significant delays in the program during the planning and design phases including:

(1.) The city's delay in making the final selection of expansion routes (see paragraph IIB-4).

(2.) The delays in awarding the contract for manufacture and delivery of the trolleybuses (see paragraph IIC-2f).

(3.) The late decision to implement "through routing" (see paragraph IIC-3b).

(4.) The many and varied "last minute" wire map changes requested by the transit department (see paragraph IIC-3b).

(5.) The late decision to shut down the existing system during construction which had disrupted some of the previous planning concepts (see paragraph IIC-3a).

These delays and the need to complete the rehabilitation construction during the one-year shutdown period created an atmosphere of urgency under which the first contracts were awarded.

b. January 1978 to December 1978

It was hoped that all five of the overhead rehabilitation contracts could have been bid and awarded at the same time. However, last minute wire map changes caused the bidding to be conducted in two packages. The results were that R1,R2 and R5 were awarded in January 1978, and R3 and R4 were awarded in June 1978.

Two bidders were successful, with contracts R1 and R2 going to one and contracts R3, R4 and R5 going to the other. The bid prices and contingency funds are shown in table IV-5.

Construction problems began almost immediately. Following is a list of the problems encountered on the rehabilitation overhead contracts:

(1.) Existing support pole strengthening - As existing wood poles were loaded, it was observed that many would lean excessively. (It should be noted that the 2/0 bronze trolley wire of the old system was being replaced in the outlying areas of the new system with 4/0 copper trolley wire, which is 50 percent heavier.) Part of the problem was Metro's maximum loading criteria of 1,500 pounds for unguyed wood poles which the consultant used indiscriminately. A new criteria establishing maximum allowable unguyed loads for wood poles of different length was developed by the consultant and Metro. For many wood poles the allowable unguyed load was reduced which resulted in a large number of added pole guys that were added to the contracts by change orders between September and November 1978.

Other wood poles were leaning but did not require guys. A survey was conducted in April 1978 which produced a list of poles to be raked into the proper position. Again, this was accomplished by change order.

Later in 1978 considerable concern developed over the strength of the existing steel poles, many of which were 40 to 60 years old or more. In November a steel pole failure seriously injured one of the contractor's linemen. This prompted more careful inspection of existing steel poles. A program for strengthening the poles was added to the contracts by change orders during January and February of 1979.

(2.) Building eyebolt permits - Beginning in February 1978 some of the building owners declined Metro permission to install building eyebolts. This unanticipated situation resulted in adding poles or redesigning the support system and then negotiating the subsequent change orders.

In some cases, because of the difficulty of installing a pole, building eyebolt requests were begun well after construction had begun. In other cases, it was simply difficult and time consuming to find the building owner or his representative with the authority to grant permission. As a result, building eyebolt permits were still being sought as late as February 1979, often disrupting the sequence of construction and adding to the unavoidable delays of the contracts.

(3.) Special pole foundations for areaways, bridges and viaducts - The extent of the need for special foundations was not revealed in the plans and specifications. The contractor was indirectly advised in the specifications of the presence of areaways, but the whereabouts and number of these were not shown. The contractor proceeded with the work without apparently conducting a thorough investigation of of these situations. The contractor began

to discover the areaways in March 1978--some of them the hard way by drilling through to basements and underground parking garages. Special pole foundations on viaducts were found to be necessary under contracts R5 and R4 in March and August 1978, respectively. Again, redesigns, delays and added costs resulted.

(4.) Underground interferences - Concurrent with the discovery of the areaways, extensiveness underground interferences were discovered while attempting to install pole foundations. Again the research was not adequately done beforehand by the consultant and the discovery of the problems occurred only after construction began. The solutions were varied including exploratory excavation to find a clear site, requesting a building eyebolt where feasible and redesigning the support system.

(5.) Labor shortage - In June 1978, both contractors informed Metro that a shortage of qualified linemen was threatening their progress. Not only did this slow the existing progress but also prevented adding workers to speed up construction.

Adding to these field construction problems were the previously described problems with late wire map changes (subsection II-B), the rush to award the contracts so that they would be completed during the shutdown period (paragraph II-D-3) and the difficulty with the timely response to interferences by the other utilities (paragraph II-D-3).

The work coordination and processing of change orders to resolve the above problems soon overwhelmed the construction inspection staff. In May 1978, another resident engineer was added to inspect the installation of pole foundations. Toward the end of 1978, after the reorganization (see subsection II-A), a supervising resident engineer position was established and the maintenance linemen who had been serving

as inspectors were replaced with regular construction inspectors. The increase in the construction inspection costs was becoming a major portion of the overall increase in program costs.

c. January 1979 to July 1979

In January 1979, revisions were still being made to the drawings, building eyebolt permits were still being acquired and special pole foundations were still being designed. However, the contractors were beginning to benefit from the experience of the past year and the greatly increased Metro construction staff was beginning to handle field revisions without constantly requesting direction from the design consultant. In February, the Metro staff reported the cost overruns and delays in the trolley overhead program. A budget increase of 6.9 million dollars was requested for the installation of the overhead out of a total budget increase of 7.6 million dollars. This brought more public attention to the program, leading to statements and explanations which appeared to be unfavorable to the contractors. This created a somewhat strained relationship between Metro and contractors.

The work did proceed and by April the special work intersections were being completed. However, progress was still slow with various items still being resolved. By June 1979, the scheduled resumption date of trolley service had long been passed and a majority of the trolleybuses had been received and accepted. As there

was already a shortage of diesel buses, there was considerable interest in getting at least some of the trolleys operating as soon as possible. In an attempt to meet a September start date for two of the routes, overtime and weekend work was authorized by Metro at added costs to the construction contracts.

Also, in July 1979, the first of the expansion contracts (E9) was awarded with an extensively revised contract document (see paragraph D-4c above).

d. August 1979 to February 1981

During the remainder of 1979 the rehabilitation contracts were slowly completed and closed out. Most of the problems encountered in closing out the contracts involved coordination of work to be done by the other utilities. For example, when a pole was replaced the old pole could not be removed until the other utilities transferred their facilities to the new pole.

The first expansion contract proceeded smoothly under the improved and more extensive contract provisions. The experience gained by the contractors and Metro's resident engineers on the previous contracts also began to have a marked affect on the progress of work. Few major or recurring small problems were encountered and when problems did occur Metro and the contractor had the experience to deal with them quickly and efficiently, thus minimizing costs and avoiding delays.

The final pairs of overhead contracts were awarded in December 1979 and February 1980--E8/E11 and E7/E10 respectively. Progress on these projects also went quite well, although major coordination efforts were required with construction projects being conducted by the Seattle Engineering Department. These contracts involved joint-use agreements as described in paragraph IID-2 for four active Seattle Engineering Department projects. Considerable coordination and planning work went into these agreements, but problems did arise during construction from late delivery of steel poles and city contracts being delayed for reasons beyond Metro's control.

In one case, the city was to install all the new steel poles on an 1,800-foot portion of contract E10. This project was continuously delayed until it was obvious that the poles would not be ready during the E10 contract period. Therefore, with the city's approval, Metro negotiated a change order to the E10 contract to perform all the pole installation work which would allow the contractor to complete the overhead.

6. Summary

The rehabilitation contracts were combined and the bidding documents were hastily completed in an attempt to restart the rehabilitation routes by the scheduled date of January 1979. However, problems with strengths of existing poles, eyebolt permits, subsurface interferences, labor shortages, untimely route refinements, coordination with other utilities

and the general lack of experience of most of those involved led to numerous delays and substantial cost overruns. Before the first expansion contract was awarded, the contract documents were extensively modified with the addition of project progress controls and more detailed and extensive description of the work required. Furthermore, the experience gained by Metro and the contractors from the rehabilitation contracts better prepared everyone to anticipate and adjust to the relatively small, but numerous problems encountered in the public rights-of-way. Thus, the expansion contracts, although the original bids were much higher, were completed with only minor delays and within the revised budget. Tables II-2, II-7, IV-6, and Figures II-7, II-8 and II-9 provide a good summary of the schedules, cost estimates and final results of the overhead construction.

TABLE IV-5
OVERHEAD CONSTRUCTION CONTRACTS
ORIGINAL BIDS AND FINAL COSTS
(as of June 1981)

	Contract	Original Contract Amount	Original Contingency		Revised Contingency		Final	Overrun	
			Amount	%	Amount	%	Cost	Amount	%
Rehabilitation	R1	854,842	86,000	10.1	421,000	49.2	1,325,942	471,100	55.1
	R2	954,006	96,000	10.1	616,000	64.6	1,390,968	436,962	45.8
	R3	1,277,588	130,000	10.2	576,000	45.1	1,699,558	421,970	33.0
	R4	1,044,775	120,000	11.5	543,000	52.0	1,522,386	477,611	45.7
	R5	819,877	100,000	12.2	581,000	70.9	1,297,097	477,220	58.2
	Sub. T.	4,951,088	532,000	10.7	2,737,000	55.3	7,235,951	2,284,863	46.1
Expansion	E9	1,264,711	126,500	10.0	-	-	1,269,721	5,010	0.4
	E8/1	1,395,480	209,000	15.0	-	-	1,545,254	149,774	10.7
	E11/1	561,270	84,000	15.0	-	-	599,966	38,696	6.9
	E7/E10/1	1,559,942	234,000	15.0	-	-	1,803,340	243,398	15.6
	Sub. T.*	4,781,403	653,500	13.7	653,500	13.7	5,218,281	436,878	9.1
	Total	9,732,491	1,185,500	12.2	3,390,500	34.8	12,454,232	2,721,741	28.0

/1 Note: does not include furnishing $379,378 worth of steel poles which were provided by Metro.

TABLE IV-6: TOTAL COSTS FOR OVERHEAD CONSTRUCTION /1
(as of March 1981)

Item		Original Budget	Revised Budget			Final Cost				
			Amount	Difference			Difference (from original)		Difference (from revised)	
				Amount	%	Amount	Amount	%	Amount	%
Construction	Rehabilitation	5,333,000	7,688,088	+2,355,088	+44	7,235,951	+1,902,951	+36	-452,137	-6
	Expansion /2	4,000,000	6,359,000	+2,359,000	+59	5,597,659	+1,597,659	+40	-761,341	-12
	Sub-Total	9,333,000	14,047,088	+4,714,088	+51	12,833,610	+3,500,610	+37	-1,213,478	-9
Inspection	Rehabilitation	295,000	1,140,000	+845,000	+286	541,499	+246,499	+84	-598,501	-53
	Expansion	290,000	820,000	+530,000	+183	396,045	+106,045	+37	-423,955	-52
	Sub-Total	585,000	1,960,000	+1,375,000	+235	937,544	+352,544	+60	-1,022,456	-52
Joint-Use Facilities	Rehabilitation	360,000	522,000	+162,000	+45	360,140	+140	0	-161,860	-31
	Expansion	955,000	1,670,000	+715,000	+75	1,710,378	+755,378	+79	+40,378	+2
	Sub-Total	1,315,000	2,192,000	+877,000	+67	2,070,518	+755,518	+57	-121,482	-6
Misc.	Rehabilitation	516,208	516,208	-0-	-	255,055	-261,153	-51	-261,153	-51
	Expansion	-0-	-0-	-0-	-	98,843	+98,843	-	+98,843	-
	Sub-Total	516,208	516,208	-0-	-	353,898	-162,310	-31	-162,310	-31
TOTAL	Rehabilitation	6,504,208	9,866,296	+3,362,088	+52	8,392,645	+1,888,437	+29	-1,473,651	-15
	Expansion	5,245,000	8,849,000	+3,604,000	+69	7,802,925	+2,557,925	+49	-1,046,075	-12
	TOTAL	11,749,208	18,715,296	+6,966,088	+59	16,195,570	+4,446,362	+38	-2,519,726	-13

/1 See Figure II-8 and II-9 and Table II-7 for program cost summary.

/2 Includes $379,378 for steel poles provided by Metro.

APPENDICES

MEMO OF AGREEMENT

APPENDIX A

EXTRA-STRENGTH JOINT USE POLES AND METRO-ONLY POLES

FOR SUPPORT OF TRANSIT TROLLEY LINES

IN COLUMBIA CITY

THIS MEMORANDUM OF AGREEMENT, made and entered into this _____ day of _____, 1981, by and between the Municipality of Metropolitan Seattle, a metropolitan municipal corporation of the State of Washington, acting by and through its Executive Director, hereinafter called "METRO', and The City of Seattle, a municipal corporation of the State of Washington, acting through its Board of Public Works as represented by the Director of Engineering, hereinafter called the "City";

WITNESSETH THAT:

WHEREAS, METRO's Comprehensive Plan for Public Transportation Service, as amended, provides for the rehabilitation and expansion of its trolleybus overhead system (hereinafter called the "Trolley Program"); and

WHEREAS, on August 1, 1977, the City and METRO entered into the First Supplemental Agreement to the Transit Transfer Agreement which established a mutually approved program for the Trolley Program; and

WHEREAS, the City is planning to underground aerial utilities and make street improvements along Rainier Avenue South from South Jackson Street to South Prentice Street (hereinafter called the "Project") which area lies along a portion of one of the Trolley Program expansion routes previously agreed to in said First Supplemental Agreement; and

WHEREAS, the City's design for said Project includes joint use extra-strength steel poles and foundations for City street lighting, City traffic signals and signs, and METRO trolley lines and METRO-only steel poles and foundations for trolley lines; and

WHEREAS, the joint use of extra-strength steel poles in the Project is contingent upon agreement by METRO to share in the cost of such extra-strength poles, subject to reimbursement by the City from the Transit Fund; and

WHEREAS, METRO intends to use funds from the Federal Urban Mass Transportation Administration to pay a portion of the cost of the extra-strength joint use and METRO-only steel poles and foundations; and

WHEREAS, it is in the best interest of METRO to coordinate the implementation of the Trolley Program with City street improvement projects, wherever practicable; and

WHEREAS, the City and METRO agree to apportion the cost and share in the ownership of such joint use extra-strength steel poles and foundations in accordance with the following terms and conditions;

NOW, THEREFORE, in consideration of the mutual covenants contained herein, it is hereby agreed as follows:

Section 1. Responsibility of the City. The City shall: (a) provide right-of-way; (b) complete the design, using METRO Specifications of the poles and foundations; (c) contract for the purchase of, and install fourteen (14) new joint use and eight (8) replacement joint use extra-strength poles for street lighting, traffic signal and sign support, and trolley overhead support; and eight (8) poles and foundations for METRO use only at various locations on and adjacent to the Project area; and (d) provide one (1) bus shelter base.

In addition, the specifications and contract plans of the Project shall be submitted to METRO for review and written approval prior to advertisement for bid of contracts by the City.

The City shall save and hold METRO harmless from any claims, injuries, liability or expense resulting from the City's installation of said poles, foundations, and from the City's installation and/or maintenance of street lighting and traffic control facilities located on joint-use poles and foundations.

Section 2. Responsibility of METRO. METRO will install and maintain at its own expense all trolley overhead and transit-related facilities located on, in, or connected to said poles and conduits and shall have the perpetual right to use said poles and foundations for underground feeder, trolley support facilities, and transit-related purposes.

METRO may furnish an inspector to ensure proper compliance with METRO's trolley facilities needs during the pole installation phase of the Project. Such inspection costs shall be borne by METRO and shall not be considered as a portion of those costs described in Section 10 herein. METRO will give written notice to the City's Director of Engineering if deficiencies are noted and not corrected by the City's construction management personnel.

METRO shall save and hold the City harmless from any claims, injuries, liability or expense resulting from METRO's specifications for poles, foundations, conduit and handholes as well as METRO's installation and/or maintenance of trolley facilities on the same.

METRO and the City reserve the perpetual right to install informational and regulatory signing on all joint use poles and METRO-only poles provided said signing is not detrimental to the structural capacity of the poles and is in conformance with applicable regulations and is reviewed with the other party prior to installation.

METRO will store all new steel Project poles at no cost to the City.

Section 3. Identification of and Cost Sharing for Appurtenances to Joint Use Poles. The City shall pay 100 percent of the cost of new street lighting poles flanges, luminaires and brackets, wire and fusing. The City shall pay 100 percent of the cost of new traffic signal mast arm pole flanges, mast arms, span wires, traffic signals, signs, and associated wiring. METRO will pay 100 percent of the cost of trolley wire support hardware, contact wire system and feeder conduit and cable located on or connected to said poles. METRO will pay 100 percent of the cost of joing use replacement poles and transfer of existing signals, luminaires, associated wiring and signs to the replacement poles.

Section 4 Relocation of Joint Use Poles. In the event either METRO or the City desire to relocate joint use poles installed under this Agreement for transit, street lighting or traffic purposes, the party requesting the relocation shall bear the entire cost thereof, including costs to the other party, of transferring its appurtenances and shall provide a replacement pole approved by the other party at the original location unless otherwise agreed in writing by the parties.

Section 5. Damage Repair or Replacement of Joint Use Poles. In the event a joint use pole and/or foundation must be repaired or replaced dur to damage, each party will bear the costs to repair, remove and replace their own hardware, provided that, in the event such damage was caused by a vehicle or other equipment owned by one of the parties hereto, then the owner of such vehicle or equipment shall be solely responsible for the costs of repairing, removing and replacing all damaged hardware, pole(s) and foundation(s).

In the event of damage, repair or replacement, except due to damage by a vehicle or equipment owned by a party to this agreement, the cost will be apportioned to each party in accordance with Section 14 of this agreement. The parties shall be entitled to a salvage value in the same proportion as ownership for any damaged joint use poles, which value may be offset against the party's share of the replacement cost at said party's discretion. The maintenance supervixors of each party shall agree as to which party shall actually make the repairs or replacement. The party doing said work will include all reasonable costs for such repair or replacement, including current overhead rates, equipment rental and inventory overhead.

Section 6. Maintenance of Records. For a period of not less than three years from the date of final payment to the City, records and accounts pertaining to the original joint use and METRO-only poles, purchase and installation and the accounting therefor shall be kept available by the City for inspection and audit by representatives of METRO and UMTA. Copies of such records and accounts shall be furnished at no cost to METRO and UMTA upon request and shall be maintained in accordance with a work order accounting procedure prescribed by the Division of Municipal Corporations and the State Auditor's Office and such other regulations and procedures as may be required by UMTA.

Section 7. Joint Use Pole Cost Sharing Formula. METRO and the City shall share the purchase and installation cost of the joint use poles, including foundation costs but exclusive of all non-jointly used hardware and appurtenances, as follows:

A = Cost of standard pole and/or foundation, City use only.

B = Cost of standard pole and/or foundation, METRO use only.

C = Cost of basic joint use extra-strength pole and/or foundation.

D = City share of joint use pole and/or foundation.

M = METRO share of joint use pole and/or foundation.

For joint use poles and/or foundations, the following formulae shall apply:

a. City pay its share, $D = (\frac{A}{A+B})C$.

b. METRO pays its share, $M = (\frac{B}{A+B})C$.

The City of Seattle will require the successful bidder to provide cost A. Costs B and C will be taken from successful bidder's bid.

Metro will pay the design costs for siting eight (8) replacement joint use poles for street lighting.

Section 8. METRO-only Pole Costs. METRO shall reimburse the City for contract costs of purchase and installation of METRO-only poles and foundations covered in this agreement.

Section 9. Additional Costs. In addition to the above cost sharing METRO will pay a portion of the total contract mobilization costs determined by the following method:

$$\frac{\text{Total METRO share of construction contract costs}}{\text{Total of City and METRO contract costs}} \times \text{Total mobilization cost}$$

METRO's share of mobilization costs shall not exceed $3,235.00 Payments will be made based on properly documented statements from the City.

Section 10. Contract Management. METRO shall bear the cost of a portion of the City's field and quality control inspection and bid and contract document preparation costs, hereinafter referred to as Contract Management Costs, except for: (a) engineering costs not associated with the trolley bus expansion; (b) administrative and engineering costs associated with the purchase of Project steel poles. The allocation of said costs shall be determined by the following method:

$$\frac{\text{Total METRO share of contract costs}}{\text{Total of City and METRO contract costs}} \times \begin{array}{l}\text{Total of the construction Contract Management costs for both City and METRO contract}\end{array}$$

METRO's share of said costs shall not exceed $12,516.03. Payment will be made based on properly documented statements from the City.

Section 11. Unforeseen Conditions. METRO and the City will share all unforeseen costs related to installation of the joint use poles as set for th in Section 7.

City will pay 100 percent for all unforeseen costs related to City-only items.

METRO will pay 100 percent for all unforeseen costs related to METRO-only items.

Should such unforeseen conditions require an increase in METRO's maximum reimbursement amount shown in Section 13, or if such unforeseen conditions materially change the Project scope, METRO shall obtain METRO Council and UMTA concurrence before approving any increase in maximum reimbursement or a material change in Project scope unless an emergency condition exists.

Section 12. Billing Procedures.

A. Progress Billing. Based on request by the City's contractor for progress payments and after approval by the City for such payments, the City may bill METRO for METRO's share of such payments in accordance with Sections 7, 8, 9, 10 and 11 (above, less any contract retainage withheld by the City). Progress billing may be submitted monthly by the City for reimbursement by METRO.

B. Final Billing. The City's final billing on METRO's share shall occur after final payment to the contractor. Said final bill shall credit all payments made by METRO in response to progress billings. Adjustments under Sections 7, 8, 9, 10 and 11 shall be performed at the time of final billing.

All submitted bills shall be paid to the City within thirty-five (35) days of receipt and approval by METRO of properly documented statements. Billings will be for 100% of the cost of METRO's share.

Section 13. METRO Payment and Reimbursements.

A. METRO Payment. In consideration of the terms and conditions of this Agreement, METRO agrees to pay the City up to a maximum estimated amount of $99,388.18 in response to the billings described in Section 12 above. The estimated cost of the Project, with breakdowns for METRO (including UMTA and City Transit Fund Portions) and the City costs on each bid item based on previous bid openings, is shown on Exhibit A. The METRO payment is subject to and contingent upon City compliance with the provisions for UMTA-assisted contracts as shown on Exhibit B attached hereto and hereby incorporated by reference.

B. City Reimbursement from METRO. METRO shall pay from its UMTA Grant Funds eighty percent (80%) of the METRO expansion work under this Agreement as shown on Exhibit A. The City is authorized and agrees to provide the local match of twenty percent (20%) from the Transit Fund in response to properly documented METRO billing. In addition, the City shall pay 100 percent (100%) of its undergrounding and street improvement costs.

Section 14. Ownership. The proportion of ownership by METRO and the City of the 14 new joint use poles shall be computed on the same basis as the cost sharing formula set forth in Section 7. The proportion of ownership by METRO and the City for the eight (8) replacement joint use poles shall be fifty percent (50%) ownership to each party. METRO shall have sole ownership of METRO-only poles provided under the Agreement.

IN WITNESS WHEREOF, the City and METRO have respectively signed this Memorandum of Agreement as of the day and year first above written.

MUNICIPALITY OF METROPOLITAN SEATTLE

Neil Peterson, Executive Director

ATTEST:

Maureen Varni, Acting Clerk of the Council

CITY OF SEATTLE

Arthur Maronek, Acting P.E.
Director of Engineering

ATTEST:

Assistand Director - Administration

RCP:sk
12-29-80

ESTIMATE FOR COLUMBIA CITY PROJECT

A.	Contract Bid Items	Quantity	Metro Expansion UMTA	Metro Expansion TRNF	City	Total
1.	Mobilization	N/A	$ 2,588.00	$ 647.00	$ 3,999.00	$ 7,234.00
2.	Provide Bus Shelter Base	1	480.00	120.00	-0-	600.00
3.	Provide Joint Use, Foundation, Concrete, Anchor Base	14	5,223.52	1,305.88	5,789.60	12,320.00
4.	Provide 8 Metro Only and 8 Joint Use Replacement Foundations, Concrete, Anchor Base	16	11,616.00	2,904.00	-0-	14,520.00
5.	Install Joint Use Steel Poles, Anchor Base	14	1,305.92	326.48	1,447.60	3,080.00
6.	Install Metro Only Steel Poles, Anchor Base	16	2,816.00	704.00	-0-	3,520.00
7.	Provide Trenching for conduit	2,200'	-0-	-0-	9,680.00	9,680.00
		100'	352.00	88.00	-0-	440.00
8.	Provide Conduit, PVC, 2 inch	2,400'			7,975.00	7,975.00
		200'	440.00	110.00		550.00
9.	Relocate Existing Mast Arm, Signals & Appurtenances	8	11,264.00	2,816.00	-0-	14,080.00
10.	Provide Wiring, Signals Rainier S. & S. Edmunds		1,760.00	440.00	-0-	2,200.00
11.	Wiring, Signals Rainier S & S. Ferdinand		1,760.00	440.00	-0-	2,200.00
12.	Remove Existing Signal Equipment		800.00	200.00	1,000.00	2,000.00
	Contract Total		$40,405.44	$10,101.68	$29,892.20	$80,399.32
B.	Contingencies (5%)		$1,543.66	$385.92	$2,090.37	$4,019.95

		Metro Expension UMTA	Metro Expension TRNF	City	Total
	Pole Purchase				
12.	Purchase 8 Metro Only Anchor Base Poles	$ 5,256.00	$ 1,314.00	$ -0-	$ 6,570.00
13.	Purchase 8 Joint Use Replacement Poles	7,514.40	1,878.60	-0-	9,393.00
14.	Purchase 14 Joint Use Poles	5,794.04	1,448.51	6,685.45	13,928.00
	Pole Sub-Total	18,564.44	4,641.11	6,685.45	29,891.00
	Sales Tax on Poles (5.3%)	983.92	245.98	354.33	1,584.23
	Pole Total	$19,548.36	$ 4,887.09	$7,039.78	$31,475.23
D.	Contract Management	$10,012.82	$ 2,503.21	$15,471.34	$27,987.37
E.	Pre-Construction (For Design of Location of 8 Joint Use Replacement Poles)	$ 8,000.00	$ 2,000.00	$ -0-	$10,000.00
	PROJECT TOTAL	$79,510.28	$19,877.90	$54,493.69	$153,881.87

EXHIBIT B

MUNICIPALITY OF METROPOLITAN SEATTLE
REQUIREMENTS FOR UMTA ASSISTED CONTRACTS

1. Contract Changes. "Any proposed change in this contract shall be submitted to the appropriate Public Body for its prior approval."

2. Interest of Members of or Delegates to Congress. "No member of or delegate to the Congress of the United States shall be admitted to any share or part of this contract or to any benefit arising therefrom."

3. Prohibited Interest. "No member, officer or employee of the Public Body or of a local public body during the tenure or one year thereafter shall have any interest, direct or indirect, in this contract or the proceed thereof."

4. Equal Employment Opportunity. "In connection with the execution of this contract, the Contractor shall not discriminate against any employee or applicant for employment because of race, religion, color, sex or national origin. The Contractor shall take affirmative action to ensure that applicants are employed, and that employees are treated during their employment, without regard to race, religion, color, sex or national origin. Such actions shall include, but not be limited to, the following: employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff, or termination; rates of pay, or other forms of compensation; and selection for training, including apprenticeship."

5. Air Pollution. "The Contractors and suppliers must submit evidence to the project sponsor that the governing air pollution criteria will be met. This evidence and related documents will be retained by the sponsor for on-site examination by UMTA."

6. Motor Vehicle Safety and Pollution:

Motor Vehicle Safety Standards. The motor vehicles will comply with the Motor Vehicle Safety Standards as established by the Department of Transportation.

Motor Vehicle Pollution Requirements. When new motor vehicles are purchased with project funds, the sponsor must obtain from each vendor a certification in writing that:

The horsepower of the vehicle is adequate for the speed range and terrain in which it will be required to operate and also to meet the demands of all auxiliary power equipment. All gases and vapors emanating from the crankcase of a spark-ignition engine are controlled to minimize their escape into the atmosphere.

Visible emission from exhaust will not exceed #1 on the Ringlemann Scale when measured six inches from the tail pipe with the vehicle in steady operation.

When the vehicle has been idled for three minutes and then accelerated to 80 percent of rated speed under load, the capacity of the exhaust will not exceed #2 on the Ringlemann Scale for more than five seconds, and not more than #1 on the Ringlemann Scale thereafter.

7. Minority Business Enterprise. In connection with the performance of this contract, the contractor will cooperate with the project sponsor in meeting his commitments and goals with regard to the maximum utilization of minority business enterprises and shall have the maximum practicable opportunity to compete for subcontract work under this contract.

8. Nonrestrictive Statement. Whenever any material or equipment is specified by patent or proprietary name or by the name of the manufacturer, such specification shall be considered as used for the purpose of describing the material or equipment desired and shall be considered as if followed by the words "or acceptable equal," whether or not such words appear.

9. Termination of Contract by the Municipality. The Municipality may, at any time, terminate the contract by notice in writing to the Supplier. On the receipt of such notice, the Supplier shall immediately discontinue the work but shall do such extra work as ordered therein to safeguard the work then completed and the materials and equipment then delivered to the site of the work, and do such other extra work as may be ordered by the Purchasing Agent for the purpose of leaving the work in a safe and useful condition. Payment for this extra work shall be made in accordance with the following:

Forthwith upon the Municipality giving such notice of termination, the Purchasing Agent shall estimate all the work done up to the time of the receipt of such notice and the Supplier shall be entitled to and shall receive payment therefor in the manner provided in the contract. In addition thereto, the Municipality will pay to the Supplier, in full and complete satisfaction and settlement for the Supplier's inconvenience, loss of anticipated profits, and all other expenses whatsoever, five (5) percent of the difference between the contract price and the sum of the payments made to the Supplier for work done to the date of receipt of the notice of termination. On completion, to the satisfaction of the Purchasing Agent, of any extra work, the contract shall be deemed to be at an end and of no further force or effect, and, the Supplier shall have no claim against the Municipality for any reason whatsoever by reason of the termination of the contract.

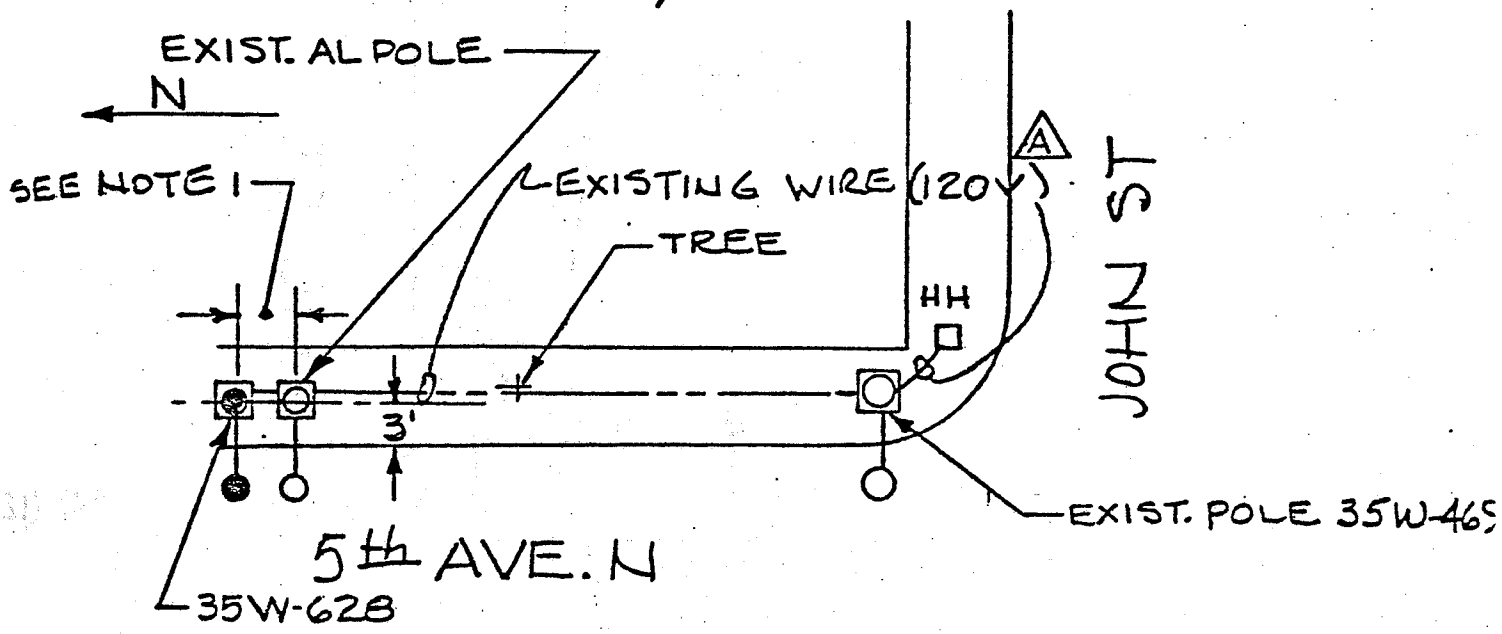
For the purpose of this article, "all of the work done" includes all materials ordered by the Supplier prior to the date of receipt of such notice of termination, whether or not they have been delivered to the site of the work. The amount of payment for all such materials under this article shall be their actual necessary cost to the Supplier up to the date of receipt of such notice of termination. Upon the receipt of such notice of termination, all the Supplier's right, title and interest in and to the materials mentioned in this article shall be vested in the Municipality, and the

Supplier shall, upon demand of the Municipality, execute and deliver to the Municipality all requisite bills of sale, assignments and other documents of transfer that may be necessary to give effect to the intention of this article.

(As used in this exhibit, the Contractor and Supplier refer to the City of Seattle.)

DWG A-1518

POLE 35W-628 SA201NN(LM) Δ
E. SIDE 5th AVE N., 2ND N. OF JOHN ST



Δ 1. INSTALL REPLACEMENT POLE 35W-628 AS SHOWN. PLACE BASE IN CONTACT WITH UNREMOVED PORTION OF EXISTING LIGHT POLE BASE.

Δ 2. NOTIFY CITY LIGHT TO DE-ENERGIZE CCT. INTERCEPT EXIST CONDUIT & EXTEND INTO 35W-628. REMOVE & REPLACE EXISTING WIRE BETWEEN 35W-469 & 35W-628 (DUPL #6AL/SPECS)

3. REMOVE EXISTING POLE, LIGHT & BASE & DELIVER TO CITY PER SPECS. FINISH BASE 6" BELOW GROUND LEVEL.

4. CONTRACTOR TO SUPPLY 6' STANDARD ARM PROVIDED BY POLE MANUFACTURER AT 35' NOMINAL LIGHT PLACEMENT HEIGHT ABOVE GROUND LINE.

5. CITY LIGHT TO INSTALL & CONNECT APPROVED LIGHT PER WORK ORDER.

SED SIG. & HO -12-7-78

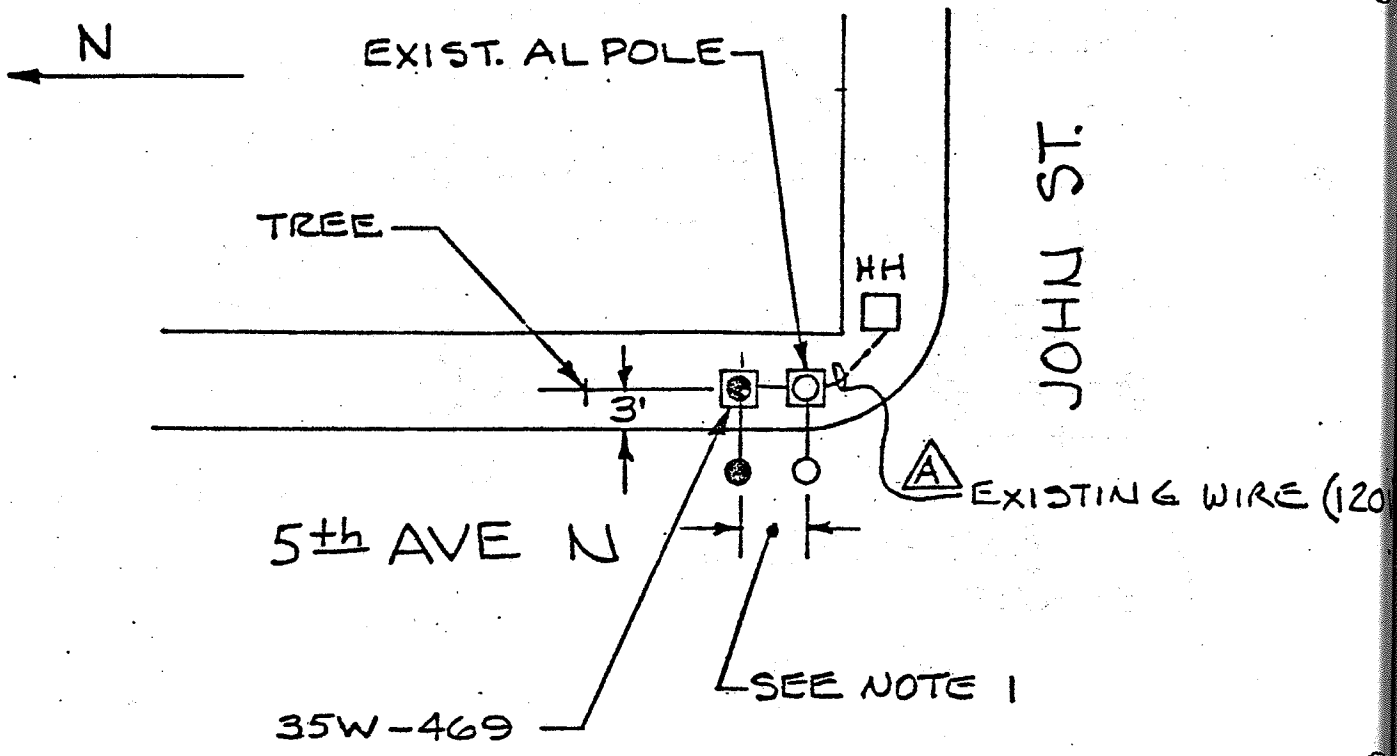
cc GORDON SMITH, CITY LIGHT. 1-10-79

Δ REVISED 1/10/79 AKO 11/30/79

DWG A-1518

APPENDIX B2

POLE 35W-469 SA201 NN(LM) Ⓐ
E. SIDE 5th AVE N., 1ST N OF JOHN ST



1. INSTALL REPLACEMENT POLE 35W-469 AS SHOWN. PLACE BASE IN CONTACT WITH UNREMOVED PORTION OF EXISTING LIGHT POLE BASE.
2. NOTIFY C.L. TO DE-ENERGIZE CCT. INTERCEPT EXIST. CONDUIT & EXTEND INTO 35W-469. REMOVE & REPLACE EXIST. WIRE BETWEEN HH & 35W-469 WITH DUPL #6 AL/SPECS.
3. REMOVE EXIST. POLE, LIGHT & BASE & DELIVER TO CITY PER SPEC FINISH BASE 6" BELOW GROUND LEVEL.
4. CONTRACTOR TO SUPPLY 6' STANDARD ARM PROVIDED BY POLE MANUFACTURER AT 35' NOMINAL LIGHT PLACEMENT HEIGHT ABOVE GROUND LINE.
5. CITY LIGHT TO INSTALL & CONNECT APPROVED LIGHT PER WORK ORDER

cc GORDON SMITH, CITY LIGHT

SED SIG. AD. 12-7-78
KWC 1-16-79

Ⓐ REVISED 1/10/79 AGO 11/21/78

APPENDIX C

METRO
Municipality of Metropolitan Seattle

Exchange Bldg. • 821 Second Ave., Seattle, Washington 98104

April 3, 1978

Mr. Paul Wiatrak
City Engineer
Seattle Municipal Building
Seattle, Washington 98104

Dear Mr. Wiatrak:

Traffic Signal Modifications
for Trolley Program

This will confirm the procedures to be used to enable the City to perform necessary traffic signal modifications for Metro's trolley overhead rehabilitation and expansion contracts.

The City will establish one work order account for this work. City personnel will meet in the field with Metro inspectors and Metro's contractors personnel. Field sketches will be made denoting the work required at each pole location. Metro will prepare a purchase order for all the work to be done at an intersection with the appropriate field sketches attached. One such purchase order will be given to the City for each intersection to authorize the required work. The City should bill Metro monthly for work performed under authority of each purchase order.

The total estimated cost for the work required for contracts T4A, T5A and T8A-77 (R1, R2 and R5) is $60,200. When cost estimates are available for the remainder of the rehabilitation contracts and for the expansion contracts, those estimates will be forwarded to the City, and this same procedure will then be followed to accomplish the necessary work.

If you concur in the procedure outlined above, please sign and return two copies of this letter.

Very truly yours,

Theodore W. Mallory
Director of Technical Services

TWM:rpl

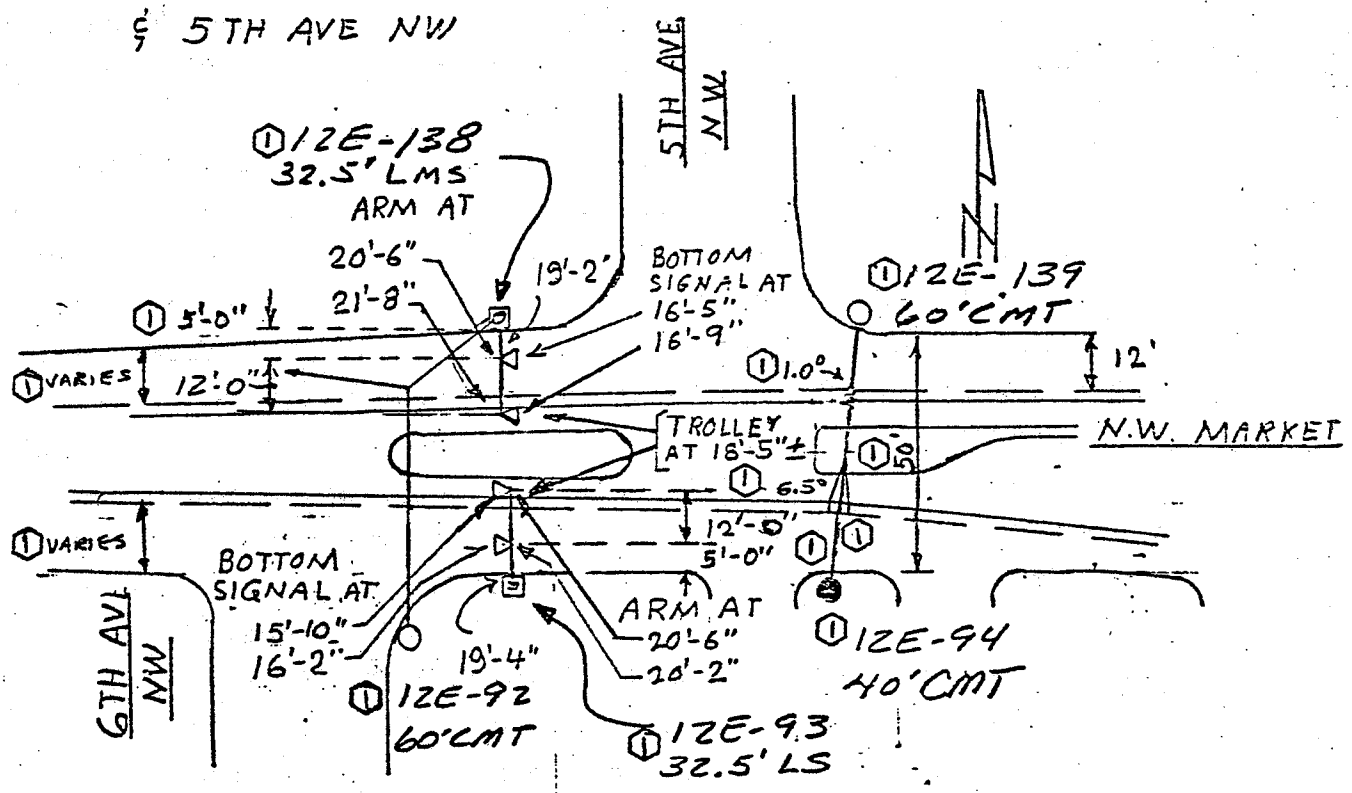
Enclosures

APPROVED Paul W Wiatrak Date 4-10-78
City Engineer

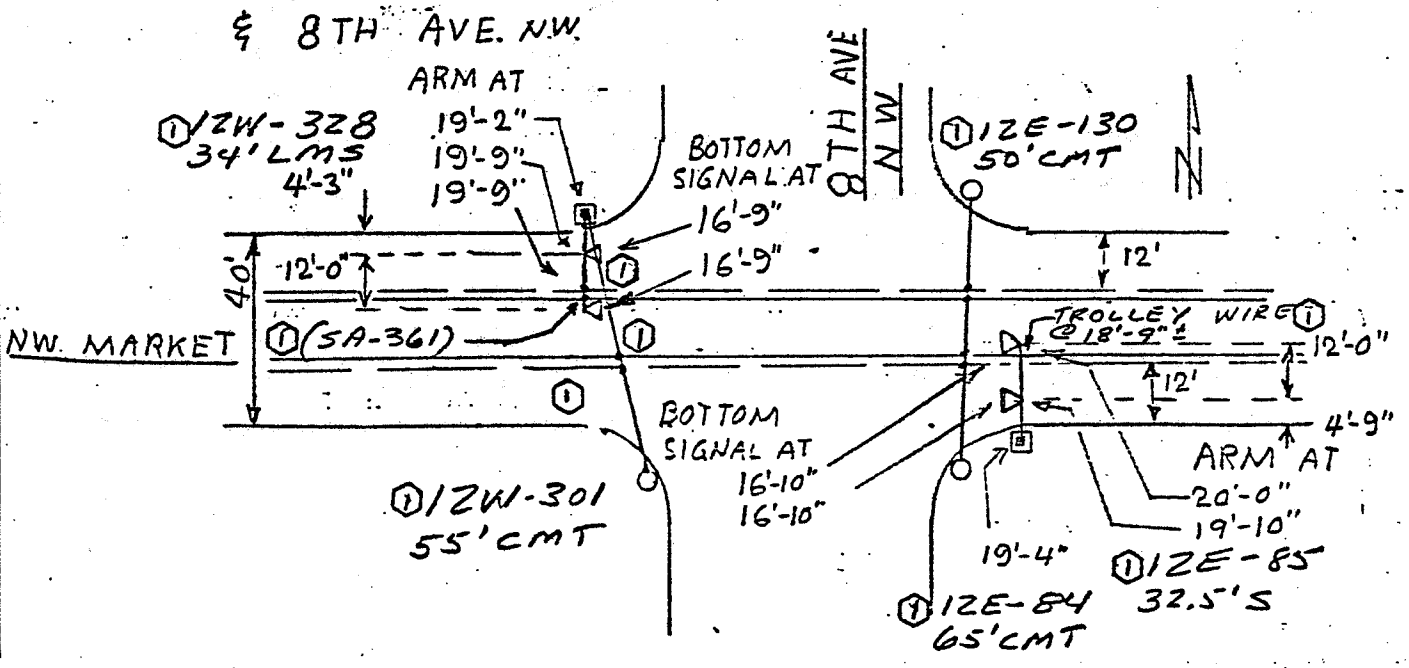
① REV. 11-9-79 CLS

R. W. BECK AND ASSOCIATES	METRO TRANSIT OVERHEAD SYSTEM SUPPLEMENTAL INTERFERENCE DATA	PROJECT WW 1421 ETI TF
	COMP. GARDINER CHK. ____ REV. ____	FILE NO. 3023
	DATE 6-21-79 DATE ____ DATE ____	PAGE 7 OF 14 PAGES

REF DWG	CONFLICTING SPAN LOCATION	NATURE OF INTERFERENCE
A-1812	N.W. MARKET ST. & 5TH AVE NW	MAST ARM SIGNAL HEADS



REF DWG	CONFLICTING SPAN LOCATION	NATURE OF INTERFERENCE
A-1812	NW MARKET ST & 8TH AVE. NW.	MAST ARM SIGNAL HEADS



BACKGROUND: JOINT POLE USE AGREEMENT

The joint use of utility poles within the City of Seattle is directed by Section 30.D. of Ordinance No. 90047. The intent of the ordinance is to enhance the urban environment by keeping the number of utility poles at a minimum through avoiding any duplication of pole setting by the various utilities.

Rehabilitation of the trolley overhead system was beset with problems from the start due to the ramifications of compliance with the street use ordinance and with two additional legal requirements. Chapter 296-44, WAC, Electrical Construction Code of the State of Washington, prescribes the minimum clearances for wiring above a traveled roadway. It also prescribes minimum clearances between various attachments on any specific pole and between suspended wires of various types. All Metro rehabilitation construction was required to conform to the minimum permissible height of 18 feet above public streets. There were areas, however, where the trolley overhead wiring had originally been at a height of between 16 and 17 feet above the street and where clearance from telephone wires was minimal. In raising the height of the trolley overhead as required, many "clearance conflicts" were caused with equipment and wiring of Pacific Northwest Bell Telephone Company (PNB) since the Electrical Construction Code specifies clearances between various conductors and other wires and attachments. Locations at which clearances between trolley and PNB wires and equipment had previously been marginally adequate became problem areas when trolley wire was raised by as much as two feet.

Solution of the clearance problem with PNB was hampered by lack of a working agreement governing the joint use of utility poles. Positions were taken by various representatives of PNB

and Metro but no process for negotiation evolved. By April 1979, Metro personnel involved in trolley overhead rehabilitation had taken a position that any conflicts existing were due to the previous illegal height of PNB equipment and therefore PNB should, at PNB expense, raise in height to obtain the required legal clearances. PNB asserted that the conflicts were solely attributable to Metro construction since PNB had, in good faith, been at the same heights for 39 years with no previous problems. PNB concluded that Metro should pay for any required adjustments. There were many cases where the physical proximity of Metro and PNB wires precluded completion of trolley overhead construction unless corrective action was first taken.

An additional problem existed in that all work performed coorperatively by PNB, Seattle City Light and Metro had, in the past, been performed following negotiations by representatives of the utilities involved and formalized in a format known as a joint pole notification (JPN). The JPN was initiated by the utility requesting action and which stated pertinent details of construction and expenses. Metro, by April 1979, had fallen behind in the processing of JPN due to lack of personnel, and PNB declined to take action on work requests which were not formalized by a completed JPN. Trolley overhead construction could not progress without some assistance from PNB, such as the raising of service drops which occupied space required for trolley overhead.

In May 1979, a staff assistant position in the trolley overhead division was established and filled, and the staff assistant was charged with the timely processing of JPN. The backlog of JPN was quickly eliminated, but it became apparent that the lack of an interutility agreement on joint-pole use was the basic and enduring cause of real problems. PNB negotiators, not being bound by any agreement, were refusing to

cooperate almost entirely except when Metro agreed to pay all expenses. Previous informal working arrangements such as those dealing with the replacement of bad order poles were unilaterally repudiated. Metro construction personnel countered by setting duplicate poles and abandoning old poles to PNB and by tying up PNB wires which obstructed trolley overhead. Relationships at negotiating level became acrimonious.

With the negotiation situation at JPN level approaching a terminal breakdown, Metro initiated a recommendation that Metro and PNB negotiate a two-way agreement on joint-pole use so that standards and procedures could be stabilized. PNB expressed interest and the invitation was extended also to Seattle City Light. Negotiations started in June 1979 and a final draft agreement was produced in July 1979. The draft was furnished to attorneys for the three utilities on Aug. 1, 1979, and received final approval in December. It was signed by representatives of the three utilities in January 1980, and was effective from Jan. 1, 1980. Previous verbal instructions had been issued that JPN negotiators were to abide by the draft agreement starting in September 1979.

Any agreement is subject to the goodwill of the persons implementing it and no agreement can be all-inclusive. With those thoughts in mind it can be said that the three-way agreement has been a success. It has tempered the severe problems which existed previously and has furnished a "common meeting ground" on which future problems can be worked out on an amicable basis. It additionally provides a tool for planning and enables the solving of joint-pole problems well in advance of suspense dates.

REFERENCES

REFERENCES

1. "The Engineering of the Seattle Transit System Trolley Coach Installation," Marvin O. Anderberg, January 1948.

2. "Transit Transfer Agreement" between the City of Seattle and Metro, December 1, 1972; 1st Supplement August 1, 1977; 2nd Supplement March 6, 1980.

3. "Metro Transit Trolley Line and D-C Power Supply Modernization Study," Metropolitan Engineers, December 1973.

4. "Final Environmental Impact Statement for the Electric Trolley Bus System Expansion in the City of Seattle," Metro and the City of Seattle, October 1974.

5. "Trolley Rehabilitation and Extension Plan Refinement," Metro and the City of Seattle, November 1975.

6. "Final Environmental Assessment for the Electric Trolley Plan Refinement in the City of Seattle," Metro and the City of Seattle, February 1976.

7. "Trolleybus D-C Distribution Systems, A Report on the Rehabilitation and Expansion of the System in Seattle," S. Cavit (Metro Staff), June 1975.

8. "Trolleybus D-C Distribution Systems, A Criteria for the Rehabilitation and Expansion of the System in Seattle," S. Cavit (Metro Staff), September 1975.

9. "Scope of Work for Trolley Overhead System and Substations Rehabilitation and Expansion Final Design, Contract Drawings and Specifications - Consultant and Metro," Metro April 1975.

10. "System Configuration Study Trolley Overhead System and Substations Rehabilitation and Expansion," R. W. Beck and Associates, April 1976.

11. "Overhead Hardware Evaluation" (supplement to ref. 10), R. W. Beck and Associates, July 1976.

12. "Evaluation of Metro Transit Trolley Expansion and Rehabilitation," Metropolitan Engineers, May 1975.

13. "Agreement for Professional Consulting Services Trolley Overhead System and Substations Rehabilitation and Expansion," between Metro and R. W. Beck and Associates, October 3, 1975.

14. "First Supplement to Transit Transfer Agreement," Between Metro and City of Seattle, August 1, 1977.

15. "Second Supplement to Transit Transfer Agreement," Between Metro and City of Seattle, March 6, 1980.

16. "Position Paper on the Trolley Program," A Memo from Ted Mallory (Technical Services Department Director) to Neil Peterson (Executive Director), September 27, 1978.

17. "Status Report Trolley Program," February 1979.

18. "20-Year Report 1959-1979," Metro, 1979.

19. "Trolley-vs.-Diesel study by Metro TRANSITTION Division."

20. "Cost Estimate-City Cost Summary," A Memo from Steve Cavit to file, June 9, 1978.

21. Interviews with Mr. Stephen Cavit, August 1980.

22. Trolley Coach Overhead Construction, L. W. Birch, Ohio Brass Company (undated).

CONSTRUCTION CONTRACT DOCUMENTS

Materials

T9A	"Manufacture and Delivery of Rectifier Stations and Equipment," September 1976, Schedules B & E awarded to the Ohio Brass Company and Schedules A, portion of C, and D awarded to Rapid Electric Company, May 19, 1977.
T12A	"Manufacture and Delivery of Overhead Hardward," December 1976, Awarded to the Ohio Brass Company May 19, 1977.
T13A	"Manufacture and Delivery of Power Cable and Contact Wire," January 1977, Bids rejected April 21, 1977 (Later purchased by various purchase orders).

Rehabilitation

T15A	"Rehabilitation of Central and Broad Street D.C. Substations and CBD Feeder System," November 1977, Awarded to Amelco Electric Company February 16, 1978.
T16A	"Construction of Lower Queen Anne, North Queen Anne, Madrona and Marion D.C. Substations," January 1978, Bids rejected April 6, 1978 (Combined with T19A for rebid).
T17A	"Construction of Belleuve, Capitol, First Hill, North Broadway and University D.C. Substations," February 1978, Awarded to Holert Electric Company, May 4, 1978.
T18A	(not used)
T19A	"Construction of Lower Queen Anne, North Queen Anne, Madrona, Marion, South Central, Colman and Collins D.C. Substations and North Queen Anne and Broad Street Feeders," May 1978, Awarded to Tyee Construction Company, July 6, 1978.
T4A-76(R1) T5A-76(R2) T8A-76(R5)	"Overhead System Rehabilitation," October 1977, R1 and R2 (Routes 2,3,4,13 & 43) Awarded to Westcoast Electric Company and R5 (CBD-all routes) Awarded to Tyee Construction Company January 5, 1978.
T6A-76(R3) T7A-76(R4)	"Overhead System Rehabilitation," February 1978, R3 (Routes 7,10,14 & 43) and R4 (Routes 1,3,4, & 14) Awarded to Tyee Construction Company, May 18, 1978.
R6	(not used)

Expansion

T25A-77	"Construction of Market, West Woodland, Meridian, and Montlake D.C. Substations and Feeders; Capitol Feeder and Alarm Light System," August 1979, Awarded to Amelco Electric Company, October 4, 1979.
T26A-77	(not used)
T27A-77	"Construction of Rainier Beach, Roxbury, Brighton, Columbia, and Letitia D.C. Substations and Feeders and Colman and Collins Feeders," October 1978, Awarded to Amelco Electric Company, March 1, 1979.
T28A-77	"Construction of Atlantic, Beacon Hill and Maple D.C. Substations and Feeders, University Feeder and Alarm Light System," January 1979, Awarded to Amelco Electric Company, June 21, 1979.
T20A-77(E9)	"Overhead System Expansion," December 1978, (Routes 3,4 and 13) Awarded to Tyee Construction Company, July 5, 1979.
T21A-77(E7) T22A-77(E10)	"Overhead System Expansion," December 1979, (Route 43) Awarded to Signal Electric, Inc., February 7, 1980.
T23A-77(E11) T24A-77(E8)	"Overhead System Expansion," October 1979, E11 (Route 1) and E8 (Route 7) Awarded to Westcoast Electric Company, December 6, 1979.